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Managing Water in the West

Regulating Wetlands Pilot Study for Concentrate Management

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Reverse osmosis facilities in the greater Phoenix area are predicted to produce 80 million gallons per day (mgd) of potable water, which will generate 12 mgd of concentrate as a reject stream. Disposal of this concentrate is particularly challenging for an inland community, such as Arizona, where oceanic discharges are not available. While thermal processes, deep well injection, and evaporation ponds are common methods for concentrate management, the water industry continues to seek innovative approaches that are more cost effective, provide beneficial use of the water, and sustain the environment. The use of treatment wetlands is one such approach with a proven capacity to remove pollutants such as nutrients and metals, while creating and restoring wetland habitat.

This regulating wetlands approach is being piloted by the U.S. Bureau of Reclamation and the City of Goodyear. In this concept, the wetland-treated concentrate, with contaminants reduced to levels safe for discharge, would be blended with treated reclaimed water and used as a source of water to restore a local reach of the Gila River. First-year results indicate that organic media-based subsurface flow wetlands can reduce concentrations of metals within water quality standards and provides a preliminary basis for estimating media life, wetlands size, and costs.

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by

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Tempe, Arizona

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Abbreviations and Acronyms

ADEQ	Arizona Department of Environmental Quality
AWWA	American Water Works Association
CASS	Central Arizona Salinity Study
City	City of Goodyear
COD	chemical oxygen demand
DO	dissolved oxygen
ea	each
ET	evapotranspiration
ft^2	square feet
GBWC	Goodyear Bullard Water Campus
gpd	gallons per day
gpm	gallons per minute
HLR	hydraulic loading rate
HRT	hydraulic retention time
ICP-MS	inductively coupled plasma mass spectrometry
LS	lump sum
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mgd	million gallons per day
mm	millimeters
mV	millivolts
ORP	oxidation reduction potential
PVC	polyvinyl chloride
Q	flow
Reclamation	United Stated Bureau of Reclamation
RO	reverse osmosis
SF	surface flow
SOP	standard operating procedure
TDS	total dissolved solids
VF	vertical flow
WET	whole effluent toxicity
WRF	water reclamation facility
yd^3	cubic yard
µg/L	micrograms per liter

1. Executive Summary

Management of the concentrate produced by reverse osmosis (RO) membrane treatment is a significant challenge to water suppliers in central Arizona. RO concentrate includes elevated concentrations of contaminants removed to make, in this case, brackish ground water potable. Contaminants include salts, metals, and nutrients at concentrations that typically exceed water quality standards and must be removed or diluted before discharge to surface waters. In coastal settings, a common solution for disposal of concentrate is ocean discharge. In inland areas, such as central Arizona, few pragmatic alternatives exist. Thermal driven evaporation processes are commonly used at industrial facilities, but have high energy and carbon footprint. Deep well injection has been used in some states such as Florida but has never been successfully permitted in Arizona. Solar evaporation ponds, though proven, have large land requirements and not always practical when dealing with high concentrate volumes.

The water industry continues to seek innovative methods for concentrate disposal that are cost effective, provide a beneficial use of the water, and are environmentally sustainable. One approach, that may have significant advantages, is utilizing vertical flow (VF) wetlands to treat RO concentrate. Recent projects have demonstrated the potential for constructed brackish water marshes to treat the concentrate by natural processes yielding brackish water that meets applicable water quality criteria for most metals (CH2M HILL, 2004 and 2005) while creating and restoring wetland habitat. This “regulating wetlands” approach is being piloted by the U.S. Bureau of Reclamation (Reclamation) in a joint effort with the City of Goodyear, City of Phoenix, and CH2M HILL. In this project, the wetland-treated concentrate, with contaminants reduced to levels safe for discharge, would be blended with treated reclaimed water and used as a source of water to restore a local reach of the Gila River at existing concentrations of total dissolved solids. Regulating wetlands can be used in a variety of concentrate management scenarios besides this particular project.

To test this approach, a pilot-scale facility has been constructed at the City of Goodyear’s Bullard Water Campus (GBWC). The City currently produces 3.5 million gallons per day (mgd) of drinking water from brackish groundwater using RO at the GBWC. Approximately 0.5 mgd of RO concentrate is generated from this process. Currently, the City discharges the concentrate to the 157th Avenue Water Reclamation Facility (WRF), and plans to increase their RO treatment capacity in coming years. However, the saline input of the RO concentrate degrades the effluent quality from the WRF such that the total dissolved solids (TDS) of the effluent is approximately 2,000 mg/L. The salinity of the effluent is too high for irrigation at parks, schools, and local baseball fields in Goodyear. If successful, the regulating wetlands alternative approach would not only help restore the habitat in the Gila River but also allow the City to use the reclaimed water from the WRF for local irrigation. For these reasons, the GBWC was selected as the site for piloting this concept.

The pilot system was constructed during 2010 and consists of seven treatment bins arranged as four separate series, or trains. Each tank is 8 feet wide and 24 feet long (192-ft^2 surface area) and contains various media, plant types, and hydraulic configurations. The majority of the bins were planted in September 2010 and did not fully establish until early 2011. The pilot system is used to determine the relative importance of hydraulic and mass loading rates, type of media beds, and plant species to performance. The pilot system is also being used to establish preliminary engineering criteria for a full-scale system. Six of the treatment bins are VF wetlands for biologically mediated anaerobic reduction, precipitation of metals, and denitrification. A final bin is operated and planted as a surface flow (SF) marsh for final polishing, excess maintenance period treatment capacity, and wetland habitat. All bins were planted with a variety of wetland plant species native to central Arizona and the southwestern U.S.

First-year results are based on data collected from January 2011 to December 2011 and indicate that organic media-based subsurface flow wetlands can reduce concentrations of arsenic (greater than 30 to less than micrograms per liter [10 µg/L]), selenium (greater than 20 to less than 1 µg/L) and chromium (greater than 45 to less than 5 µg/L)—all well within water quality standards, consistent with conceptual expectations. Nitrate-nitrogen concentrations were reduced from approximately 55 milligrams per liter (mg/L) to less than 1 mg/L.

Seasonal water volume reduction through evapotranspiration was found to be significant, leading to a typical increase from 8,000 mg/L in TDS during the summer to 11,000 mg/L through a sequence of three treatment bins. Peat and wood waste based treatment wetlands showed differences in performance thought to be related to different proportions of processes such as adsorption, biological reduction, and precipitation. Metals and salts all showed accumulation within the media bed and to a lesser extent in the vegetation, leading to a preliminary basis for estimating media life and replacement frequency, and a basis for quantifying ecological exposure pathways.

The first year of operations of the Goodyear Wetlands project has shown that it is feasible to reduce contaminants in RO concentrate using wetlands. Initial results indicate that the concentrate regulating wetlands concept warrants continued investigation based on the expected benefits. Treating the RO concentrate with a wetlands system and blending with wastewater effluent for surface water discharge will benefit the City's reclaimed water quality as well as provide a source of water appropriate to restore riparian habitats in the Gila and Salt Rivers.

Based on the results and conclusions from the first year of operations, the following recommendations and objectives are planned for the second year:

- Continue the study and modify the bins to test specific improvements, to optimize the pilot wetlands to establish the best configuration and design criteria for a larger scale wetland system.

- Develop a permitting approach to obtain approval from the Arizona Department of Environmental Quality (ADEQ) for surface water discharge of treated wetland concentrate.

- Identify funding pathways and opportunities available to implement a demonstration scale wetland system.

- Sustain and focus industry outreach to key organizations to deepen technical support. Continued presentations at local conference and targeting peer-reviewed publications will the focus of outreach efforts.

- Identify stakeholders that will be involved or affected by implementation of a full or demonstration scale system.

2. Background

The Central Arizona Salinity Study (CASS) has predicted that by 2025, RO facilities in the greater Phoenix area will produce 80 mgd of potable water from the treatment of brackish ground water and domestic wastewater effluent. While this increased use of RO membranes will provide effective treatment, it will also generate approximately 12 mgd of concentrate as a reject stream. The planned RO facilities will treat brackish groundwater and secondary effluent with TDS levels exceeding 1,200 mg/L, and will produce concentrate with TDS ranging from 4,500 mg/L to more than 10,000 mg/L depending on source water quality and recovery of the process. CASS also predicts that by 2035, the concentrate generated from RO facilities will approach 28 mgd.

Disposal of concentrate is particularly challenging for an inland community, such as those in Arizona, where ocean discharge is not available. While thermally driven evaporation processes, deep well injection, and evaporation ponds are common concentrate management methods, the water industry continues to seek innovative methods for concentrate disposal that are cost effective, provide a beneficial use of the water, and are environmentally sustainable. The use of treatment wetlands is one such approach with a capacity to remove pollutants such as nutrients and metals and to reduce the volume of RO concentrate, while creating an opportunity for wetland habitat creation and restoration (CH2M HILL, 2004).

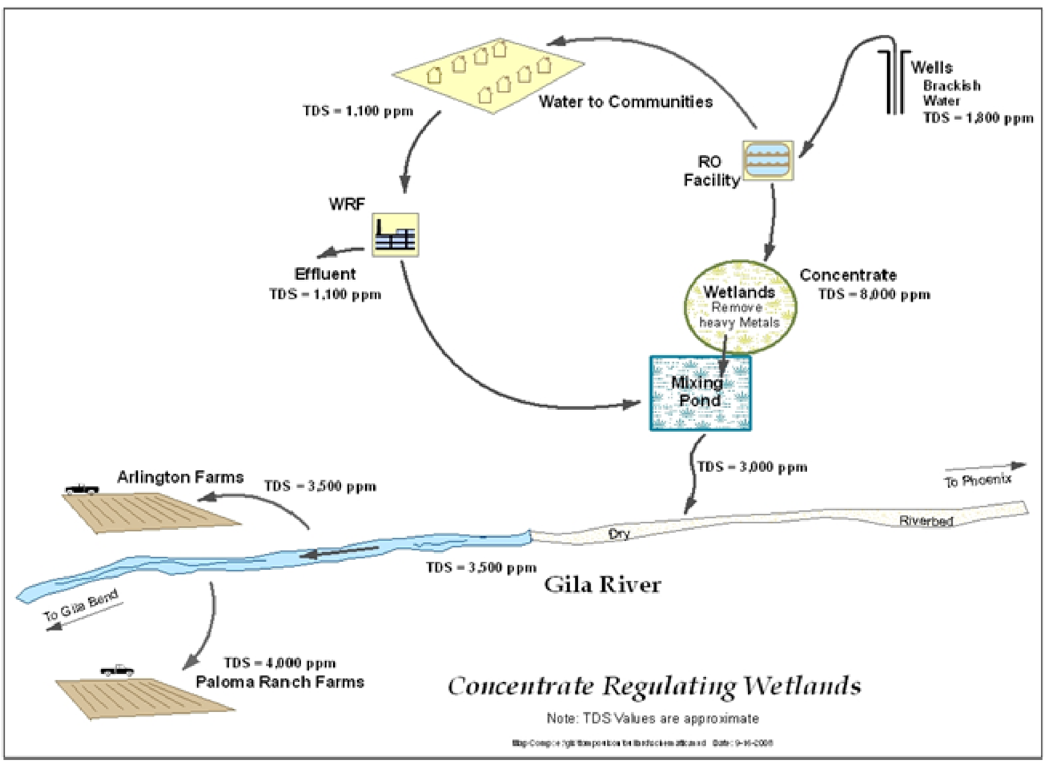
This project was initiated by Reclamation to evaluate the use of engineered wetlands to treat RO concentrate to a quality that can be used beneficially for the restoration of habitat in the Gila River in Arizona. This report describes the project history, pilot scale-system and results, recommendations for further piloting, and economics.

2.1 Project History

The City of Goodyear, Arizona (City) currently operates a RO facility treating brackish groundwater at the GBWC. The treatment facility is comprised of seven 0.5-mgd RO skids that produce 3.5 mgd of permeate that is blended with groundwater for potable water use within the City. These systems produce approximately 0.5 mgd of concentrate that is currently discharged to the sewer for conveyance to the City's 157th Avenue Water Reclamation Facility (WRF). The concentrate contributes 10 percent of the hydraulic load and 40 percent of the salt load to the WRF, which has a significant effect on the quality of the reclaimed water. The TDS of the WRF effluent is approximately 2,000 mg/L, which is considered too high for the City to irrigate park grounds, schools, or for the Cactus League professional ball fields located nearby the WRF. Like other inland communities in the southwest, the City is thus challenged to develop more sustainable concentrate management methods that will reduce or eliminate the impact of the concentrate on water resources and the environment.

In 2007, Reclamation developed a conceptual approach for the beneficial reuse of RO concentrate by blending wetland-treated RO concentrate with treated wastewater effluent to create a water source for habitat creation and maintenance of river flow (Poulson, 2007). This concept, termed the regulating wetlands project, calls for the use of engineered wetlands to remove contaminants of concern such as arsenic, selenium, and nitrate–nitrogen from the concentrate. The treated concentrate would then be blended with municipal wastewater effluent or groundwater, then surface discharged to the Gila River. A preliminary modeling study conducted in early 2008 for Reclamation determined that the proposed combined process of wetland treatment and dilution could reduce contaminants to concentrations consistent with Arizona water quality standards. These initial results established a rationale for piloting the system to confirm wetland performance and planning requirements. Figure 1 shows the overall treatment and blending scheme.

FIGURE 1
Treatment Trains Plan View



Later in 2008, CH2M HILL designed a pilot RO concentrate regulating wetlands treatment system that was subsequently constructed by Reclamation at the GBWC. The pilot system has been in operation for approximately 1 year, since fall 2010.

2.2 Pilot System

2.2.1 Objectives

The objective of pilot wetlands system is to achieve the following:

- Evaluate the feasibility of the concentrate regulating wetlands concept and demonstrate that constructed brackish wetlands can remove contaminants from RO concentrate.
- Optimize system configuration (media type and depth) and measure plant species growth and suitability
- Develop sizing coefficients and operating parameters, which will help in the implementation of future, larger phases of this project
- Demonstrate that treated RO concentrate can be blended with local wastewater effluent to achieve receiving-water quality

2.2.2 Planning and Design

The original concept pilot RO concentrate regulating wetlands treatment system developed by CH2M HILL included two main components: a treatment system and blending system. The treatment system was to be built at GBWC, composed of seven tanks connected in various configurations and surrounded by a network of visitor access boardwalks that would also be used by operations staff to access the tanks and serve to cover the piping network from sight. A blending facility was to be built at the Goodyear WRF, and comprised of two tanks in series and used test blending schemes for the treated RO concentrate and wastewater effluent. However, because of funding limitations, Reclamation only proceeded with the construction of the treatment system which is described herein. Not all of the original components were included. The original design is described in a technical memorandum submitted to Reclamation in 2008 (CH2M HILL, 2008).

The treatment system at the GBWC is located in an open area south of the RO building and uses concentrate from the RO facility as its influent. Concentrate is collected from the RO plant concentrate discharge line located on the south side of the building and pumped into a static head tank. The pilot wetlands system is made up of seven treatment bins connected by PVC piping. The treatment bins are arranged in four different train configurations and designed to receive stored concentrate flows by gravity from the static head tank. Each bin is 8 feet wide and 24 feet long (192-ft^2 surface area) and contains various media, plant types, and hydraulic configurations. The leading treatment bin in each train is equipped with a flow meter to control RO concentrate flows into the trains. Treated effluent is then collected in a small tank from which it is pumped into a sewer collection box or into an effluent storage tank. To allow for water quality monitoring, sample points were installed on the effluent side of each bin as well as upstream of the static head tank to sample the influent. Figure 2 shows the configuration the treatment trains. A photo of the pilot system in 2011 is shown in Figure 3.

FIGURE 2
Treatment Trains Plan View

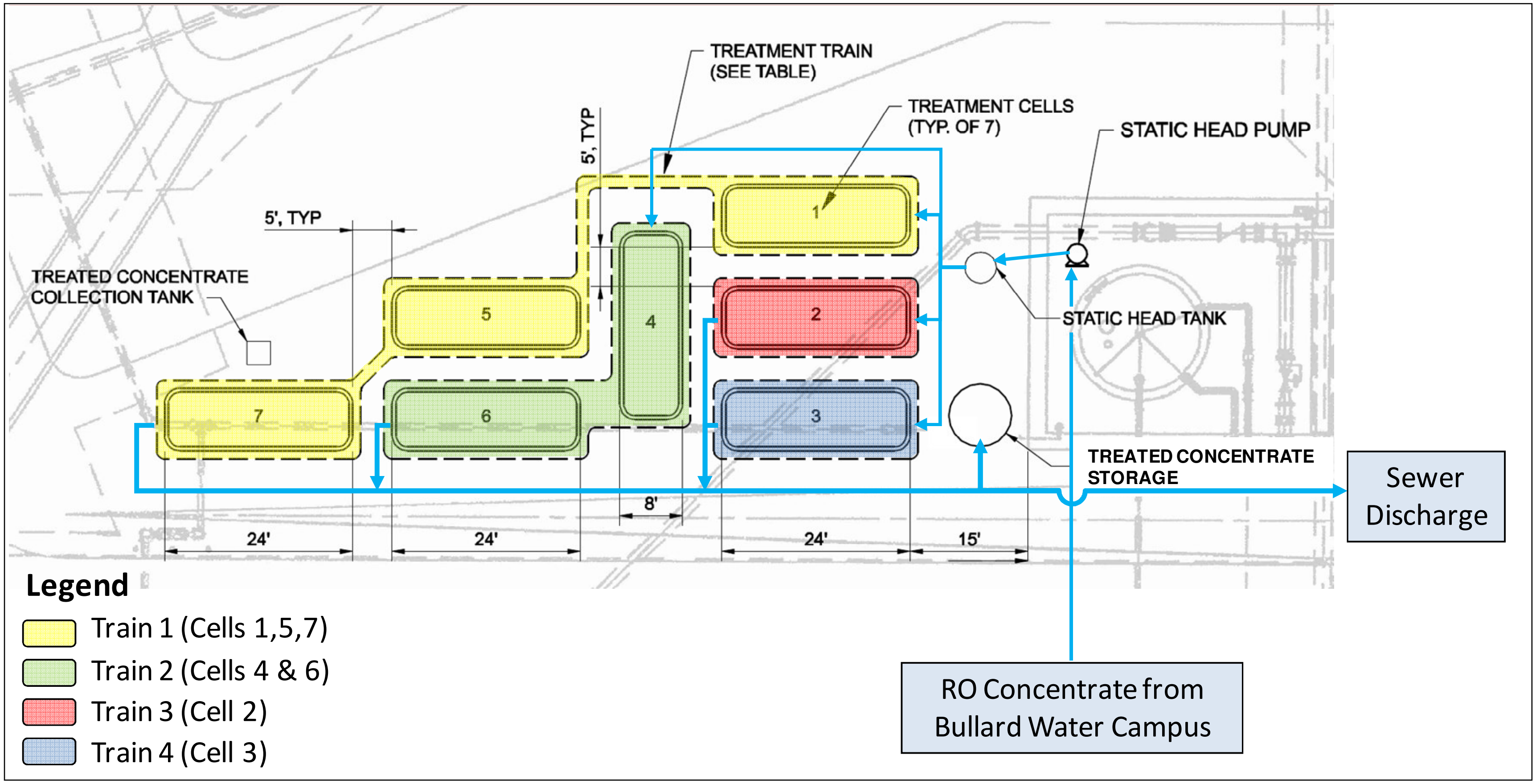
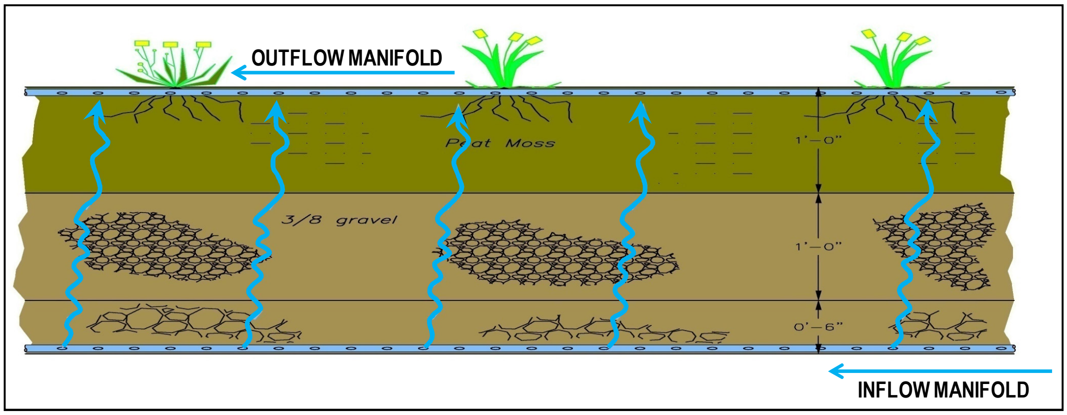


FIGURE 3
Concentrate Regulating Wetlands Pilot Photo (Fall 2011)

Train 1 is comprised of Bins 1, 5, and 7, configured in series. Bins 1 and 5 contain the same plants and are designed for vertical flow while Bin 7 was planted differently and designed as a surface flow wetland for additional residence time prior to sewer discharge. Train 2 is a two-bin train that includes Bins 4 and 6 in series. Both bins are identically planted and are vertical flow. Trains 3 and 4 are single-bin trains made up of Bins 2 and 3.

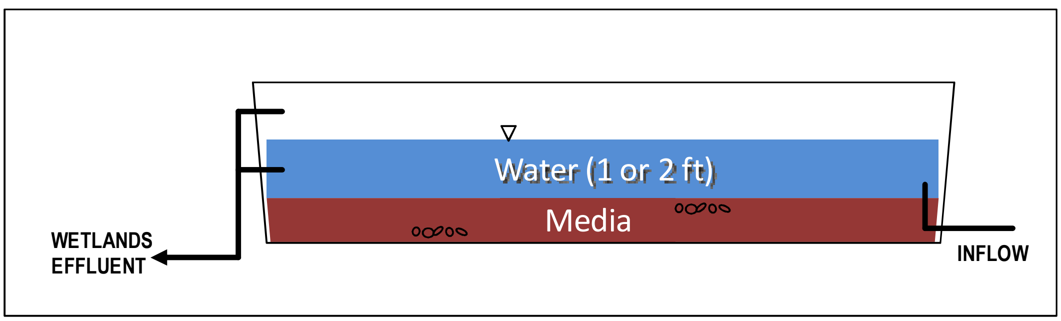
Bins 1 to 6 are configured for VF while Bin 7 is configured for SF. In the VF configuration (Bins 1-6), flow enters into the wetland through a horizontal inlet pipe into a perforated PVC manifold pipe at the bottom of the bin. Water trickles out of the perforations, where it slowly flows upwards, first through a 6-inch layer of 3/4-inch rock, then through a 12-inch layer of gravel and finally through a layer of media. As it moves upwards, the plants extract nutrients necessary for their growth. Microbial communities (biofilms) that are attached to plant and gravel surfaces assimilate and transform nutrients and other pollutants, and the media binds certain metals and nutrients before water reaches the collection manifold. Just below the surface, water is collected by the perforated PVC collection manifold and piped to the next treatment bin by gravity, or into a PVC pipe that directs flow to the sewer. All flow is subsurface in the VF configuration and both the distribution and collection manifolds are buried. Figure 4 shows a typical cross-section of a VF wetland.

FIGURE 4
Vertical Flow Wetlands



In the SF configuration (Bin 7), water is delivered to the wetland through a vertical inlet pipe then flows horizontally across the wetland through a matrix of emergent vegetation. As the water flows across the wetland, the plants extract nutrients necessary for their growth. Microbial communities (biofilms) that are attached to plant and soil surfaces assimilate and transform nutrients and other pollutants before the water exits through an outlet pipe at the end of the treatment bin. Two outlet pipes were installed to set the water level at 1 or 2 feet. Figure 5 shows a typical cross-section of a SF wetland.

FIGURE 5
Surface Flow Wetlands



2.2.3 Construction

The treatment bins were manufactured by D&T Fiberglass of Sacramento, California. The tanks were shipped to Goodyear in May 2009. Between July 2010 and October 2010, the tanks were leak tested, and where necessary, repairs made prior to adding media and plantings. The tanks were also reinforced at three locations to provide structural stability.

A variety of media and vegetation planting types was used for each of the seven bins and is presented in Table 1. With the exception of Bin 7, each bin is layered with 3/4-inch rock, 3/8-inch pea gravel and a layer of media. Peat moss was purchased from a local supplier, Western Organics, and used as the media in each VF bin except Bins 4 and 2. Peat moss was selected for its long history as an effective media for metals removal, mine drainage treatment, and filtration of municipal wastewater. Furthermore, peat moss is the media that was successfully used at similar project conducted by the City of Oxnard, California between 2003 and 2005 to treat RO concentrate. Local “green waste” (yard clippings, cut plant materials, etc.), also purchased from Western Organics, was used as the media type in Bin 4 as an alternative source of organic matter. These two media types were initially chosen to establish contaminant removal characteristics for different types of soil, gravel, and organic substrates.

Because of excessive leaks, Bin 2 was not filled, planted or connected along with the other bins and remained out of operation for the initial stages of the pilot. Repairs and recoating of Bin 2 began in March 2011 and was completed in June 2011. The media used for Bin 2 contained a mix that included woodchips, sawdust, peat, limestone, hay and manure. The media was be mixed and applied on top of a bottom layer of gravel as a 12-inch layer. To control odors, a 6-inch layer of peat was used to cover the media layer.

TABLE 1
Wetland Cell Characteristics

Parameter	Units	Bin 1	Bin 2[a]	Bin 3	Bin 4	Bin 5	Bin 6	Bin 7
Wetland Configuration[b]		VF	VF	VF	VF	VF	VF	SF
Media Substrate[c]		PM	MOM	PM	GW	PM	PM	Soil
Depth		4	4	4	4	4	4	4
Hydraulic Depth		4.4	3.3	3.4	3.8	3.9	3.3	3.3
Tank Volume		768	768	768	768	768	768	768
Rock Elevation		0.5	0.5	0.5	0.5	0.5	0.5	0.0
Gravel Thickness		1.0	1.0	1.0	1.0	1.0	1.0	0.0
Media Thickness		1.0		2	1.5	1.0	1.0	1.0
Water Elevation		2.8		2.8	2.8	2.8	2.8	2.8
Water Volume		264		427	346	264	264	417

[a] Bin 2 was nonoperational for the initial stages of the pilot because of leaks and was not planted until after the bin was repaired.
[b] The wetland bins were configured for vertical flow (VF) or surface flow (SF).
[c] Three types of substrate were used to plant the wetlands: green waste (GW), peat moss (PM) and a mixed organic media (MOM) containing woodchips, sawdust peat, limestone, hay and manure.

The plant species used for the treatment bins span a variety of characteristics. Different types of vegetation were selected to help determine which species grow best in this concentrate and to what degree their growth characteristics support treatment performance. Table 2 shows the list of species selected and the initial plant coverage assessment based plant density. A species planting plan is also presented in

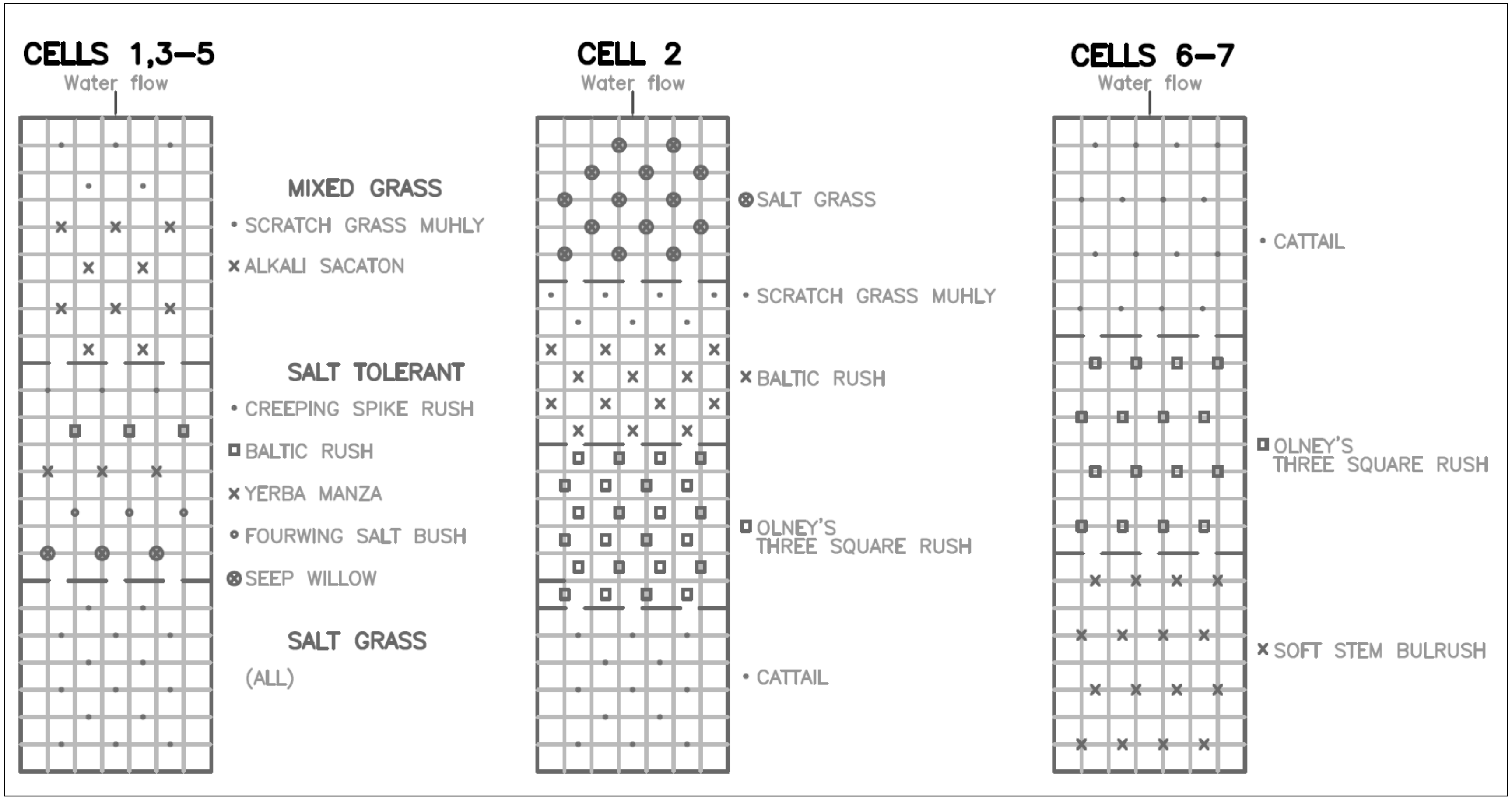
Figure 6. All of the plants were purchased by Reclamation from Hydra Aquatic Inc., a wetland plant nursery located in New Mexico, except for the Cattails which were transplanted from the Gila River. All species are native to the arid southwest and commonly found in the wetlands of this region. The wetland bins (with the exception of Bin 2) were planted in September 2010. RO concentrate was used to hydrate the VF wetland bins. Untreated, brackish groundwater was initially used to hydrate Bin 7 (SF wetland bin) until plants matured. Upon maturation, Bin 7 received treated RO concentrate from Bin 5. After 6 weeks, plants were observed to be generally healthy, consistent with their early growth stage. Some dead or dying plants were removed and replaced. Planting of Bin 2 was conducted in July 2011 using transplants of the best performing plant species from other wetland bins.

TABLE 2
Plant Species List and Initial Coverage by Bin

	Plant Coverage by Bin (%)						
Plant Species	**Bin 1**	**Bin 2***	**Bin 3**	**Bin 4**	**Bin 5**	**Bin 6**	**Bin 7**
Scratch grass muhly	11.1	8.3	11.1	11.1	11.1	-	-
Alkali sacaton	22.2	-	22.2	22.2	22.2	-	-
Creeping spike rush	6.7	-	6.7	6.7	6.7	-	-
Baltic rush	6.7	16.7	6.7	6.7	6.7	-	-
Yerba manza	6.7	-	6.7	6.7	6.7	-	-
Fourwing salt bush	6.7	-	6.7	6.7	6.7	-	-
Seep willow	6.7	-	6.7	6.7	6.7	-	-
Salt grass	33.3	25.0	33.3	33.3	33.3	-	-
Cattail	-	25.0	-	-	-	33.3	33.3
Olney's three square rush	-	25.0	-	-	-	33.3	33.3
Soft stem bulrush	-	-	-	-	-	33.3	33.3

*Bin 2 was nonoperational for the initial stages of the pilot because of leaks and was not planted until after the bin was repaired. Best performing plant species in other bins were transplanted to Bin 2 in July 2011.

FIGURE 6
Planting Plan



2.2.4 Operations

The pilot wetlands system was designed to operate continuously because of the pump and head tank configuration. An operations and monitoring guidance manual was developed by CH2M HILL to guide pilot activities and serve as a resource for troubleshooting (Appendix A). The manual included a Standard Operating Procedures (SOP) Checklist used to facilitate daily inspections by GBWC staff confirm operation of the pilot equipment, record inflows, measure outflows, document field conditions (temperature, humidity, soil conditions etc.) and monitor plant health. In addition to the daily inspection, a more thorough inspection was conducted weekly by Reclamation. These weekly inspections included monitoring items on the daily SOP checklist as well as a detailed assessment of plant heath and the onsite water quality measurements. Weekly water quality measurements were taken of the RO concentrate and effluent from each bin for the following parameters:

- Dissolved oxygen (DO)
- Electrical conductivity
- Oxidation-reduction potential (ORP)
- pH
- Temperature

Water quality samples were taken by Reclamation one to two times a month and analyzed by the City of Phoenix Water Services Lab for the following parameters:

- Arsenic
- Chloride
- Chromium
- Chemical oxygen demand (COD)
- Nitrate –N
- Selenium
- Sulfate
- Total dissolved solids (TDS)
- Total phosphorus

Because of limited budget, only one of the monthly samples was analyzed for all the listed parameters. The second monthly sample was only analyzed for arsenic, selenium and nitrate.

To document nutrient and metal accumulation, samples of the media, plant roots and shoots were taken at the start of pilot and after one year of operations.

2.2.5 Cost

Table 3 provides a summary of the costs for the pilot as of December 31, 2011. Costs include all piloting facilities, installation costs, maintenance, consulting services, monitoring equipment, and laboratory analysis. Cost of labor by Reclamation staff is not included in this summary.

TABLE 3
Regulating Wetlands Pilot Cost Summary

Description	Quantity	Unit	Cost ($)
Pilot Facilities, Installation and Maintenance			
Bins[a]	7	ea	39,700
Piping[b]	1,000	LF	8,200
Tanks	2	ea	5,500
Pumps	1	ea	900
Flow Meters	4	ea	750
Plants	228	ea	3,400
Media	90	yd^3	4,000
Sitework	3,000	ft^2	6,400
Electrical	1	LS	7,800
Signage	1	LS	1,600
Miscellaneous			450
		Subtotal	**$97,400**
Technical and Analytical Support			
Operations and Monitoring Support and Consulting Services[c]	1	LS	60,000
Monitoring Equipment	1	LS	2,000
Water Quality Analysis[d]	11	Sample Events	45,100
Plant and Soil Analysis	2	Sample Events	5,100
		Subtotal	**112,200**
		Total	**209,600**

Notes:
[a] Bin costs include leak testing for all bins and the relining and repair of Bin 2
[b] Piping includes PVC manifold, inlet/outlet piping, elbows, valves and fittings
[c] Operations and Monitoring support and Consulting Services was provided by CH2M HILL
[d] Water quality analysis was provided as in-kind services by the City of Phoenix Water Services Lab

2.3 Stakeholders and Contributions

The project is based on the cooperation of four different entities: City of Goodyear, City of Phoenix Water Services Department, Reclamation, and CH2M HILL.

The City of Goodyear hosts the site and provides power to operate the influent pump for the pilot wetlands system. Jerry Postama serves as the Deputy Director of Water Resources for the City of Goodyear. GBWC personnel managed by Ruben Valoz (Operations Supervisor) and Keith Edwards (Facility Supervisor) provided daily inspections of the pilot and assists with some maintenance activities.

The City of Phoenix Water Services Department performed regular water quality analysis for the pilot as in kind services. Brandy Kelso and Erich Lais serve as project representatives for the City of Phoenix. Laboratory services were scheduled and coordinated through Jennifer Calles.

Reclamation was primarily responsible for the installation, operation and maintenance of the pilot system. The Phoenix Area Office Program Management Division Chief is Leslie Meyers. Tom Poulson served as the main contact and field director for the project.

CH2M HILL provided operational and monitoring support as well as consulting services to Reclamation. Primary activities included water quality sampling and data analysis. Ryan Rhoades managed the project and coordinated support activities with Reclamation. Michael Hwang served as field engineer under the direction of senior technical consultant James Bays.

In addition to these four entities, CASS is considered a stakeholder and partner in this project as the regulating wetland concept is an innovative approach to concentrate management.

2.4 Project Relevance to Desalination and Water Purification Research Objectives

The management of concentrate produced through membrane separation processes remains a significant challenge to inland desalination implementation. The Goodyear wetland concept outlines an approach to reduce contaminants in RO concentrate to a level allowing the safe discharge of water to brackish surface waters. A successful demonstration of this approach will provide a useful precedent for projects considering similar solutions elsewhere in the arid West and even coastal settings.

To support this type of demonstration, the Goodyear Wetland project has been designed to provide information to meet the following objectives:

- Demonstrate reduction of contaminant concentrations to levels equal or below state water quality standards.
- Establish allowable hydraulic and mass loading rates for each parameter.
- Determine feasibility of establishing wetland vegetation using membrane concentrate as the water source.

- Establish baseline accumulation rates for metals and salts in the media and plants.

- Confirm the blending ratio needed and final water quality suitable for discharge to the Gila River.

- Confirm the aesthetic acceptability of wetland-treated water.

3. Pilot Results

3.1 Overview

Over the first year of operations the water quality in the concentrate and wetland treated effluent from each bin was sampled consistently. Field conditions were recorded and solids analysis was conducted on both media and plant tissue samples. The results from the first year of piloting indicate that the Train 2 (Bins 4 and 6) and Train 3 (Bin 2) configurations have been the most effective in removing arsenic and selenium from the RO concentrate while Trains 1 and 4 achieved a lesser reduction. For this reason, the data presented herein are focused on the results from Trains 2 and 3, as it best represents the configuration that would be carried forward to full or demonstration scale design. A summary of the data for all bins are included in the Appendix B.

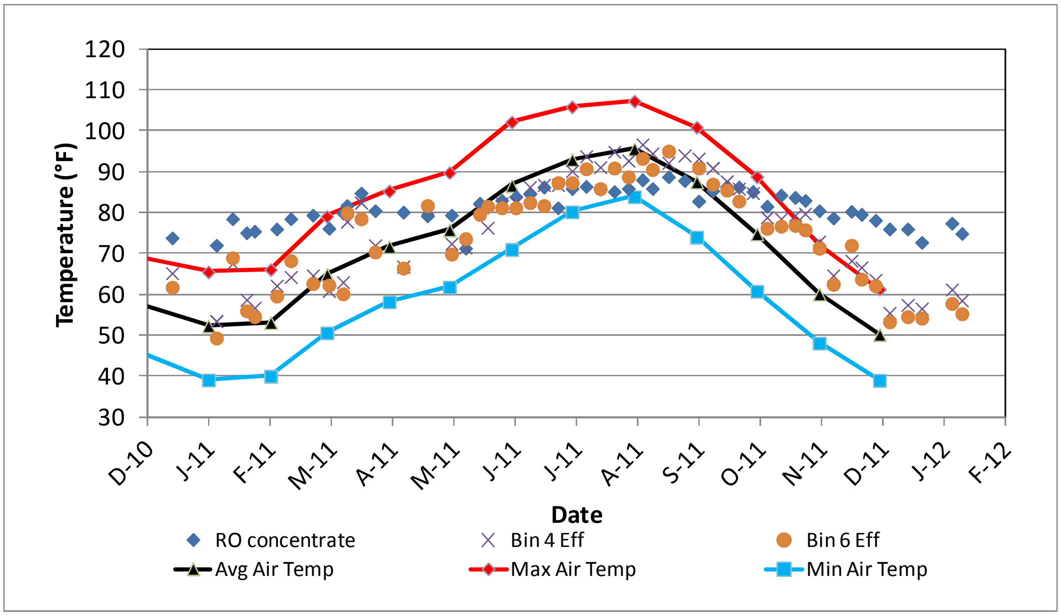
3.2 Field Conditions

A portable water quality multi-meter (Ultrameter II) was used to monitor temperature, conductivity, ORP and pH in the RO concentrate and effluent from each wetland bin. DO measurements we also recorded using a DO data meter. Field measurement data for all bins are presented in Appendix B. This section summarizes the results.

3.2.1 Temperature

Figure 7 presents the temperature data during the first year of operations. The water temperature of the concentrate and wetland effluent ranged between 47° and 100° F, with the peak temperatures being observed in the summer. In comparison with the RO concentrate, the temperature of the wetland effluent was lower than the RO concentrate in the winter and higher than the RO concentrate in the summer. This is because the wetland bins are above ground allowing the flow through the system to be heated or cooled by the outside temperature. The RO concentrate samples, on the other hand, are collected as they are discharged into the sewer just outside the GBWC building. Because the temperature control of the GBWC, the temperature variability in the RO concentrate was less than the other samples. A comparison with the monthly average air temperature in Goodyear shows that the wetland effluent closely tracks the ambient temperature during the operating period, and retains heat through the fall.

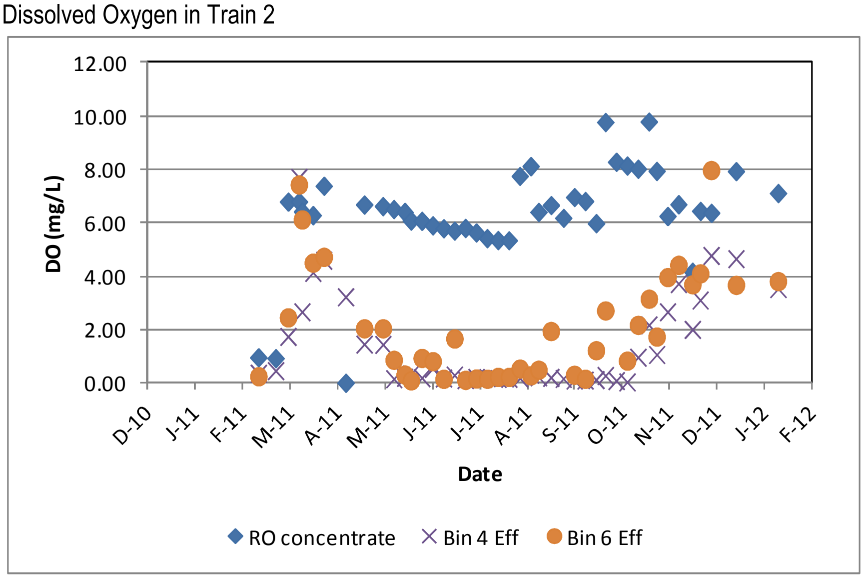
FIGURE 7
Water and Ambient Air Temperature



3.2.2 Dissolved Oxygen (DO)

Dissolved oxygen measurements varied throughout the year for each bin and assumed to be directly related to microbial activity. Figure 8 presents the DO for Train 2 (Bins 4 and 6), and shows DO in the wetland effluent from each bin was initially the same as the RO concentrate but sharply decreased starting in March 2011 from 4 mg/L to less than 1 mg/L, consistent with the expectation of anaerobic and reducing wetland environment. The DO remained low throughout the summer until September when DO began to increase until it stabilized at approximately 4 mg/L. Small spikes in DO during the summer are most likely related to mid-year precipitation from monsoon events.

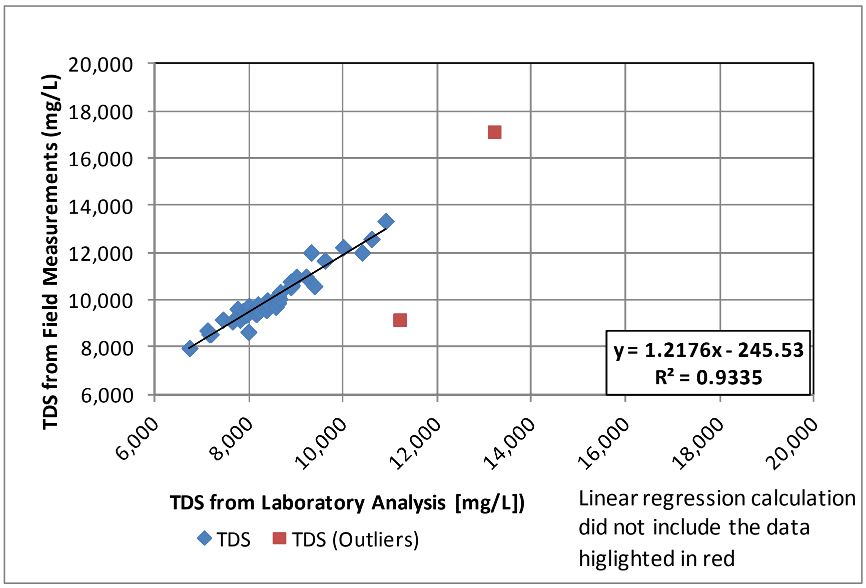
FIGURE 8
Dissolved Oxygen in Train 2



3.2.3 Conductivity

Conductivity was sampled as part of the routine field measurements using the multimeter and recorded as estimated mg/L TDS. Conductivity increased through each successive bin. The highest readings were recorded during the summer months, confirming the expected correlation with peak evaporation, and related evapoconcentration. The field measurements for conductivity serve as a relative indicator of evapotranspiration, but are not typically as accurate as laboratory analysis. Figure 9 regresses the results from the laboratory analysis and corresponding field measurements taken on the sample day using the multimeter. The graph shows that the field readings overestimate the actual TDS as analyzed in the laboratory by approximately 19 percent.

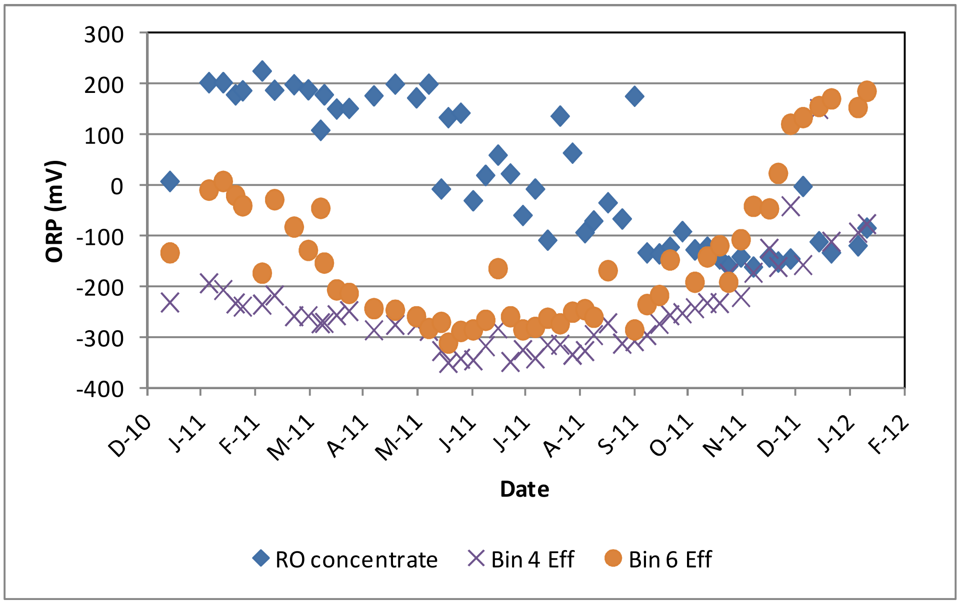
FIGURE 9
Conductivity Measurements in the Laboratory versus Field



3.2.4 Oxidation-Reduction Potential (ORP)

Similar to the DO levels, the ORP varied throughout the year for each bin and changes were assumed to be directly related to microbial activity. Figure 10 presents the results for ORP for Train 2. Inflow values during the year were predominantly positive in the range of 110 to 227 millivolts (mV), but declined to -150 mV during the latter half of the year. Redox potential of the bins varied from -100 to -350 mV in Bin 4 and -300 to 200 mV in Bin 6. Bin 4 showed a negative ORP throughout the entire operating period of the first year and a negative ORP developing for Bin 6 from January 2011 to November 2011. The steady decline in the early months of 2011 in Bin 6 is indicative of a maturation period required for microbial communities to establish. This occurred as ambient temperatures were increasing which enhances microbial activity. The increased ORP starting in September is correlated more closely with the decrease in temperature during these same months shown in Figure 8.

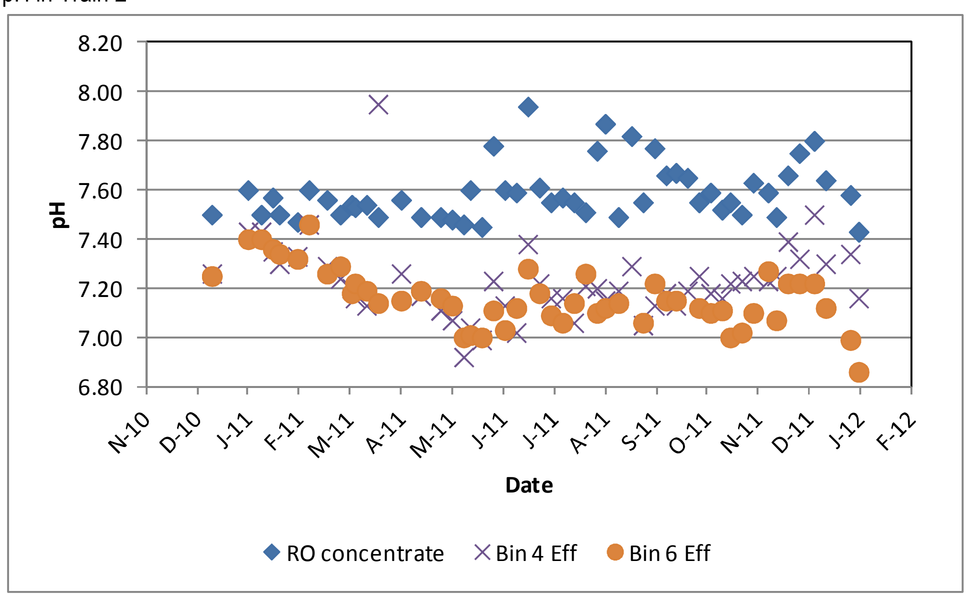
FIGURE 10
Oxidation Reduction Potential in Train 2



3.2.5 pH

The pH of the RO concentrate influent was relatively constant at pH 7.4 to 7.6; however, peaks were observed occasionally and were not considered significant in terms of the impact to the wetlands system. The pH in Bins 4 and 6 was slightly less, generally remained in the range of 7.0 to 7.4. The pH of all bins remained within a range of 6.8 to 8.0 during the first year of operations. Figure 11 presents a summary of the pH in Train 2 for first year operations.

FIGURE 11
pH in Train 2



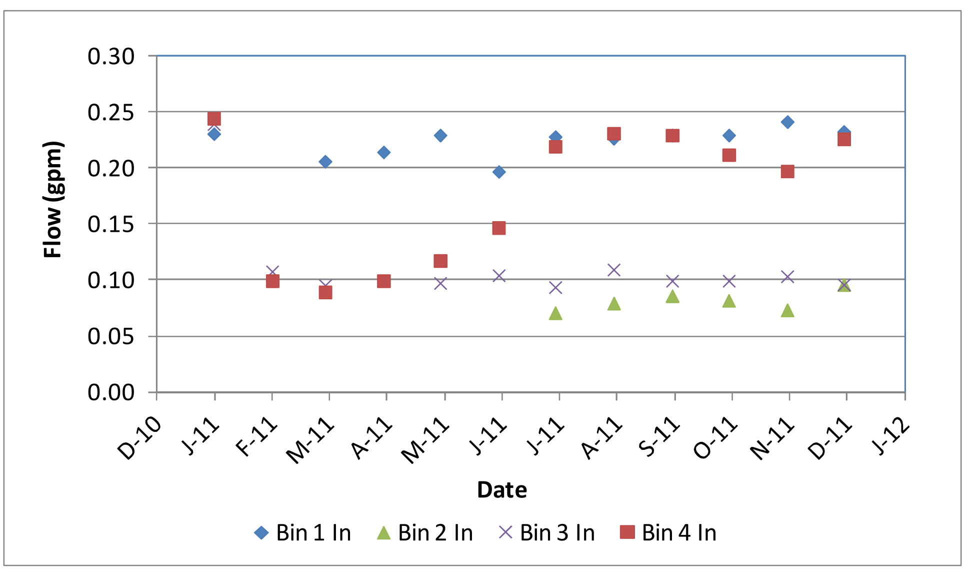
3.3 Hydraulics and Evapotranspiration

The original hydraulic design criteria for the wetland bins called for an inflow of 0.25 gpm into each wetland train. This was calculated based on the surface area of the bins (192 ft^2), and a design hydraulic loading rate (HLR) of 3 inches per day (76.2 millimeters per day). This corresponds to hydraulic retention time (HRT) of between 5 to 9 days, depending on the porosity of the media. These HLR and HRT design values are consistent with the general literature on constructed wetlands (e.g., Kadlec and Wallace, 2009). Consequently, all flow meters were initially set to feed 0.25 gpm into the trains at the start of the pilot in October 2010.

At the end of January 2011, the inflows were reduced to 0.10 gpm to feed less flow into the bins, thereby extending the hydraulic retention time (HRT) in the bins. The intent of increasing the HRT was to help facilitate the establishment of microbial communities within the media. As temperatures increased and the plant communities began to flourish, the flows into the multi-bin Trains 1 and 2 were steadily increased. Flows into Train 4 (Bin 3) were kept at 0.1 gpm. Similarly, the flow into Train 3 (Bin 2) was kept low when it was put in operation. Figure 12 shows the monthly average inflows during the first year of operations. Flow measurements out of each bin were taken and averaged. As expected, the outflows for each treatment bin were less than inflows because of evapotranspiration (ET). ET rates were calculated based on flow measurements at the inlet and outlets using the principle of mass balance (leakage was negligible):

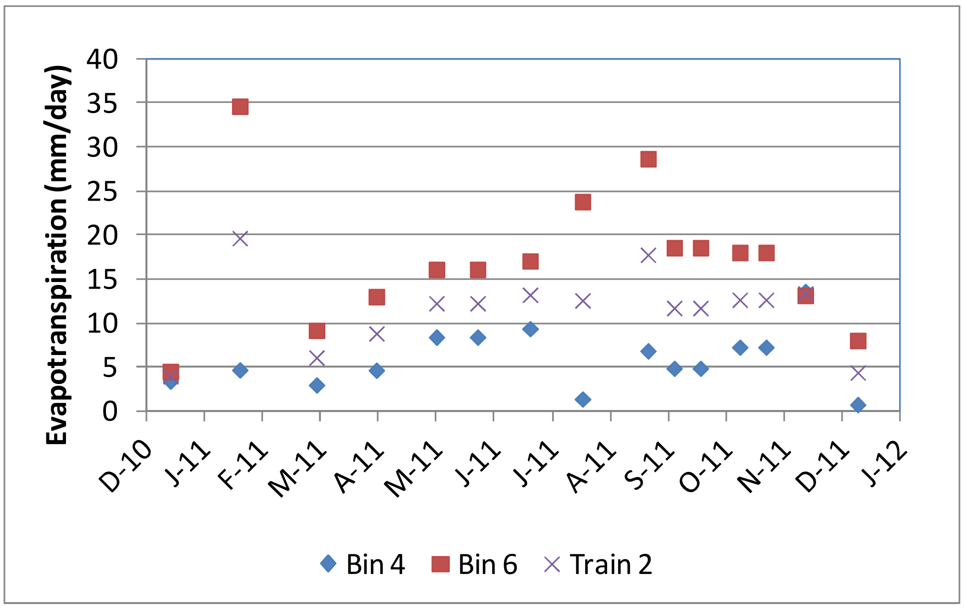
$$Q_{inflow} - Q_{evapotranspiration} = Q_{outflow}$$

FIGURE 12
Inflows to Each Treatment Train



Based on the initial leak testing, it is assumed that the tanks are leak proof and that losses other than to ET are not likely since none were identified through visual inspection. Flows from precipitation, while important during the day of the storm event, are negligible when compared to the average hydraulic loading, and are not specifically included in the water balance. ET rates were calculated for each bin as flow, then normalized by dividing by the surface area of the wetland bins to yield in inches or millimeters per day. For multiple-bin trains, ET was estimated for the entire train based on inflow into the leading bin and outflow from the final bin and normalized using the total area for the bins in the train. Figure 13 presents the estimated monthly averages for ET for Train 2 over the course of first year operations. The increases in ET during summer months are consistent with the temperature changes shown in Figure 7. The occasional spikes in ET for Bin 6 are attributable to flushing activities required to unclog the connecting pipe between Bin 4 and Bin 6.

FIGURE 13
Estimated Evapotranspiration Rates in Train 2



3.4 Water Quality

Samples were taken regularly (once or twice a month depending on parameter) to monitor concentrations of salts, metals and nutrients in the water. A complete list of the parameters is listed in Section 2.2.4. A brief summary of the general trends are included in this section and is focused mainly on Trains 2 and 3 which have consistently yielded contaminant reductions superior to the other trains. Parameters selected to characterize changes in salt, metals and nutrient concentrations include TDS, arsenic, selenium, and nitrate and are discussed in this section. A full summary of all the water quality data is included in Appendix B.

3.4.1 Water Quality Targets

Water quality targets for the pilot were established based on the surface water quality standards used by ADEQ. These standards are presented in Table 4 and based on the unofficial copy of the 2009 Surface Water Quality Standards for Surface Waters (18 A.A.C., Chap 11, Article. 1).

TABLE 4
Water Quality Targets

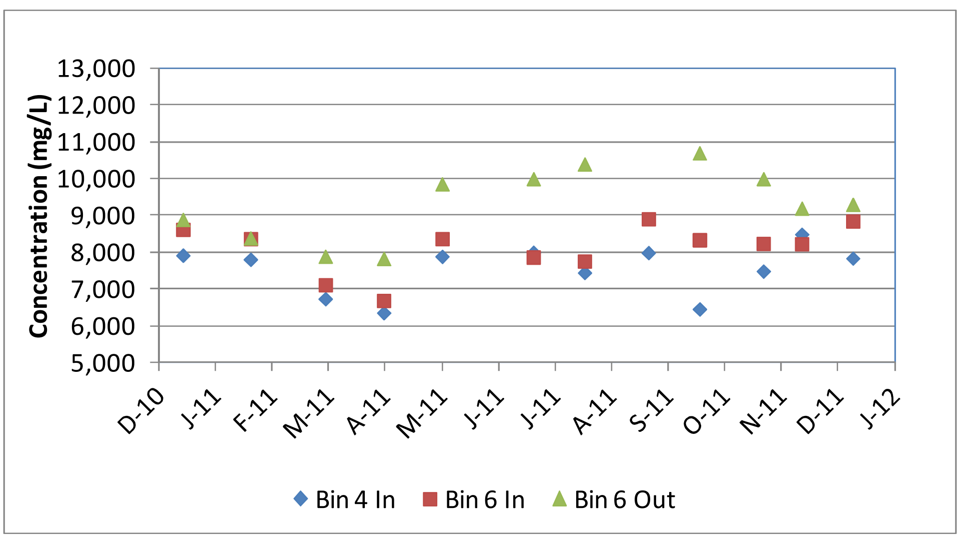
Parameter	Unit	Limit	Standard*
Arsenic	µg/L	10	Domestic Water Source
Chromium (Total)	µg/L	100	Domestic Water Source
Selenium	µg/L	2	Aquatic and Wildlife Effluent Dependent Water
Nitrate	mg/L	10.0	Domestic Water Source

Notes:
*The standard with the lowest limit was selected for target values

3.4.2 Salts

Total dissolved solids, sulfate, and chloride are being monitored for this project through monthly sampling. Figure 14 presents the laboratory results for TDS in Train 2 over the testing period. The average influent TDS was approximately 7,500 mg/L, ranging between 6,400 and 8,500 mg/L over the course of the first year. At the start of the pilot, when the temperatures were colder and the plants had not yet reached maturation, the effluent TDS out of Bins 4 and 6 was only slightly greater than the influent TDS. As temperatures began increasing in March, the increase in TDS across the flow path in all trains indicates a proportional increase in evaporation. The outflow concentrations from Bins 4 and 6 were measured above 10,000 mg/L during June through September, the warmest months of the year. A similar trend was observed with Train 1, which was also a multi-bin train. When the temperatures began to drop (October 2010), the decrease in ET resulted in lower TDS in the wetland outflow. Sulfate and chloride concentrations tracked TDS trends throughout the year. Water quality data for the other trains and also for sulfate and chloride are included in Appendix B.

FIGURE 14
TDS Concentrations in Train 2



3.4.3 Metals

The primary metals that are being monitored for the pilot include arsenic, selenium, and chromium. Results indicate that the wetland bins are reducing these metals. Figure 15 and Figure 16 present the results for selenium levels across Train 2 and Train 3. The average selenium in the influent was approximately 0.024 mg/L, ranging between 0.016 and 0.042 mg/L over the course of the first year. As shown in Figure 15, Train 2 has been consistently reducing the selenium levels, specifically during the period between August and November of 2011, when the effluent levels were frequently measured as non-detect (less than 0.0017 mg/L). Near the end of 2011, the data shows a steady increase in selenium levels in the effluent of both bins in Train 2. This is likely related to the decrease in temperature in the winter and a reduction in microbial activity during this period. If in the second year selenium is once again reduced upon reaching the spring and summer months, this will confirm the seasonal variability in selenium reduction that can be expected as a result of temperature.

Similarly, Train 3 (Bin 2) has also been consistently reducing the selenium levels from August to December 2011, when effluent levels were frequently measured as non-detect (less than 0.0017 mg/L or less than 0.00085 mg/L). Unlike Train 2, the reduction in selenium remained steady during the winter months, suggesting that the mixed organic media provides a more favorable environment for anaerobic activity, and is not affected by the seasonal change in temperature.

FIGURE 15
Selenium Concentrations in Train 2

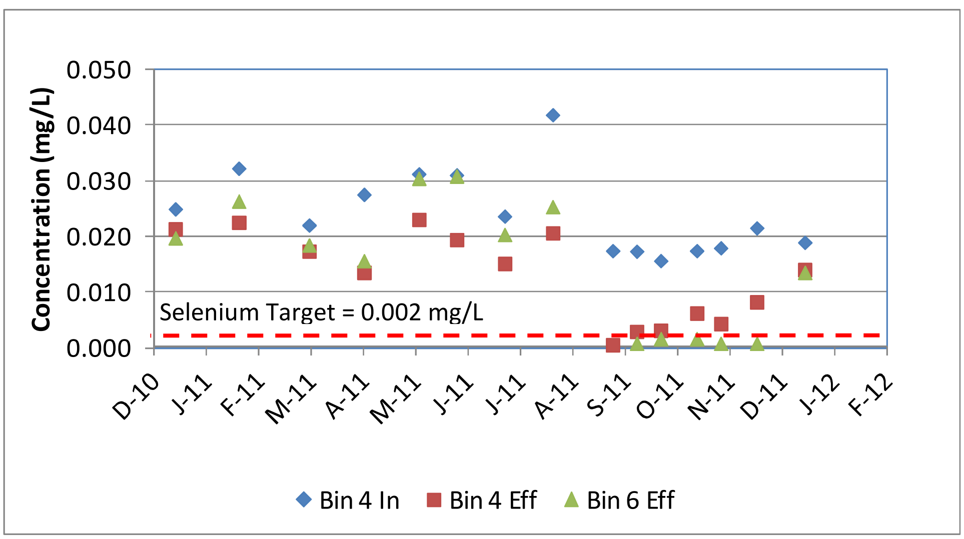
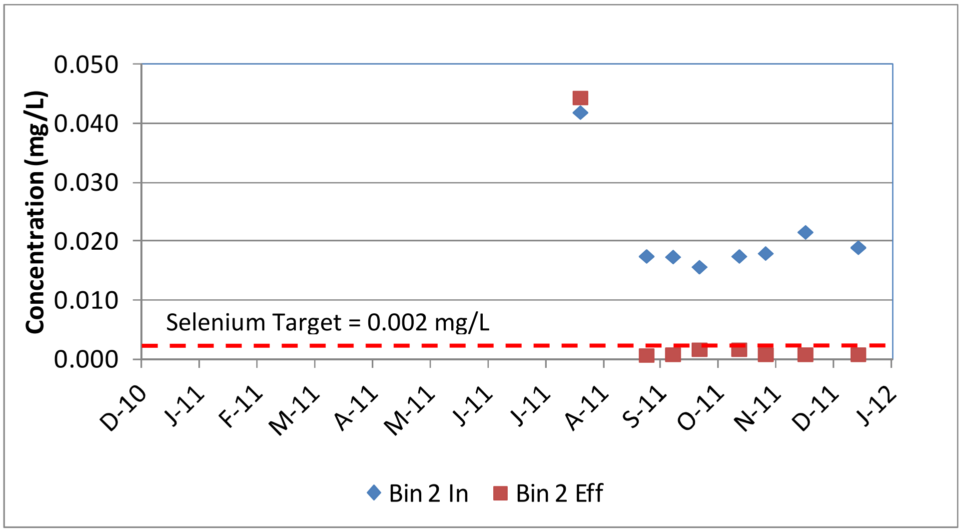


FIGURE 16
Selenium Concentrations in Train 3



Trends for arsenic reduction in train 2 are presented in Figure 17 and show the arsenic being reduced from 0.025 mg/L (average inflow) to non-detect (less than 0.010 mg/L) in the wetland effluent in the fall months of the year (September to December 2011). Initially, the reduction or arsenic was only observed across Bin 4 and not across Bin 6. The arsenic levels in the effluent from Bin 6 were initially lower than the influent levels. However, an apparent spike was measured in April when the arsenic averaged 0.057 mg/L until June when the levels began to decrease. One possible explanation for the increased arsenic in the Bin 6 effluent is related to the release of sulfur and carbon-based byproducts from Bin 4 from the increased bioactivity. The decrease of arsenic levels in Bin 6 that followed this spike along with the continued low ORP levels in Bin 6 suggest that arsenic reducing organisms established themselves in this period. By the end of September, the arsenic in Bin 6 had decreased to levels less than Bin 4.

FIGURE 17
Arsenic Concentrations in Train 2

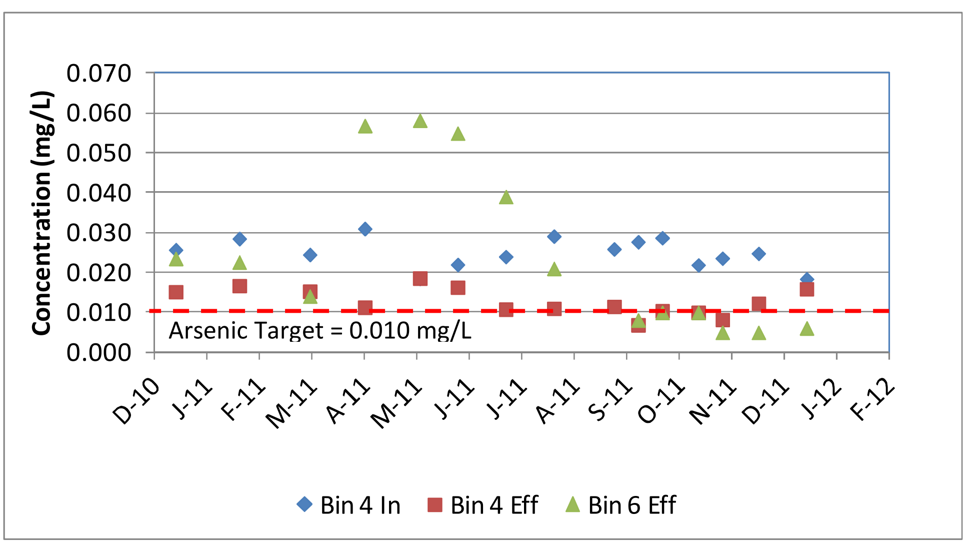
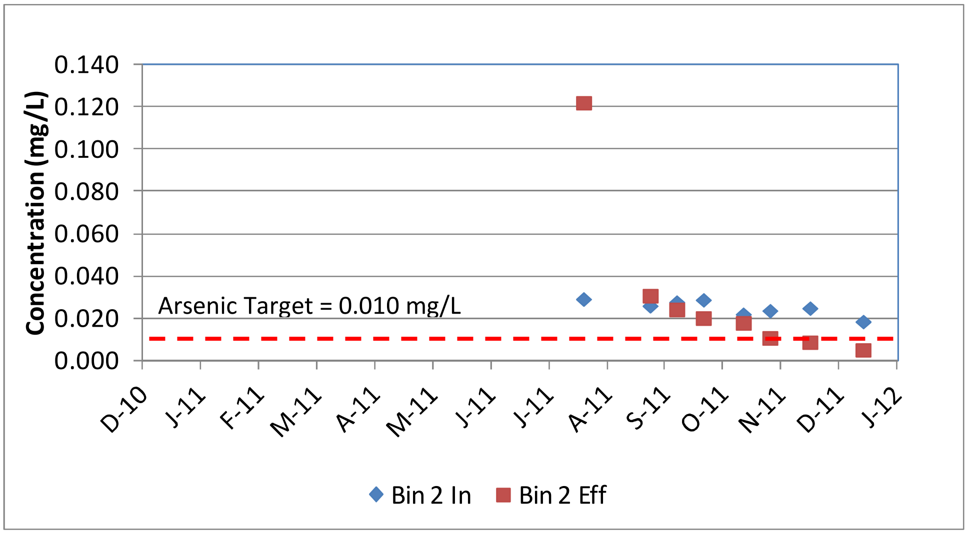


FIGURE 18
Arsenic Concentrations in Train 3



Reductions in arsenic were also observed in Train 3 (Bin 2) when it was put into operation (Figure 18). A downward trend was observed in the Bin 2 effluent showing the arsenic levels in December 2011 were less than 0.005 mg/L whish is below the surface water quality limit of 0.010 mg/L. However arsenic levels were not reduced in Train 1 or Train 4. These results suggest the formation of an anaerobic zone unique to train 2 which utilizes the green waste as the media for the leading bin (Bin 4) and explains the different results observed in Trains 1 and 4. Conversely, a different mechanism is assumed to be at work to remove chromium as wetland train effluent levels are being removed to non-detect levels in all of the vertical flows. A complete summary of the water quality for the metals is included in Appendix B.

Copper and zinc were monitored initially, but were dropped from the water quality analysis after initial results showed that levels were non-detect (less than 0.01 mg/L) in both the RO concentrate and the wetland effluent from all bins.

3.4.4 Nutrients

Nitrate, total phosphorus and COD are being monitored to characterize nutrient levels in the water. The nitrate-nitrogen level in the inflow concentrate averaged approximately 57 mg/L within a relatively narrow range between 51 and 61 mg/L. Similar to the trend observed for the metals, the nitrate levels were being reduced in train 2 and 3. Figure 19 presents the nitrate concentrations for Train 2 and shows that nitrate levels were reduced by over 90 percent to concentrations less than 5 mg/L from March to October. The upward trend of nitrate in the wetland effluent in Train 2 at the end of 2011 is attributable to the seasonal change in temperature and helps explain the upward trend observed in selenium levels, which is thought to respond to seasonal temperatures.

FIGURE 19
Nitrate-N Concentrations in Train 2

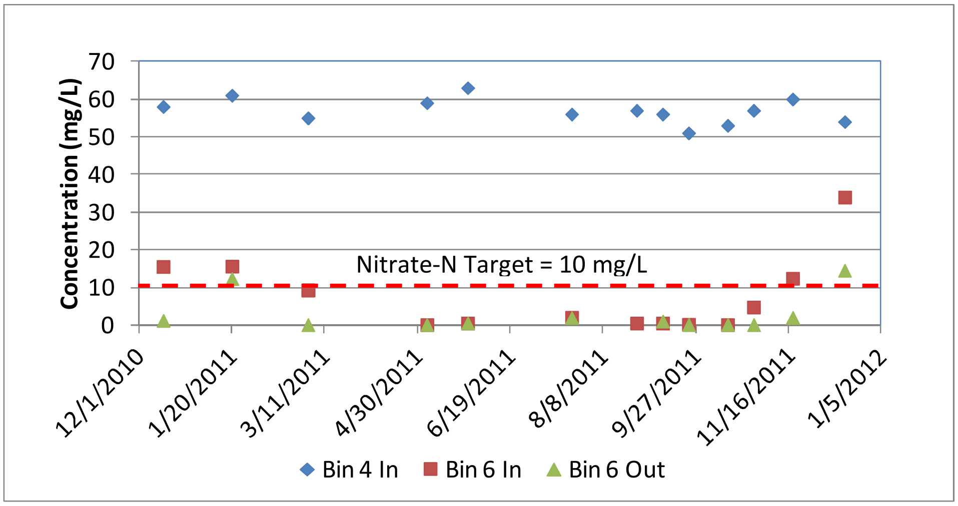
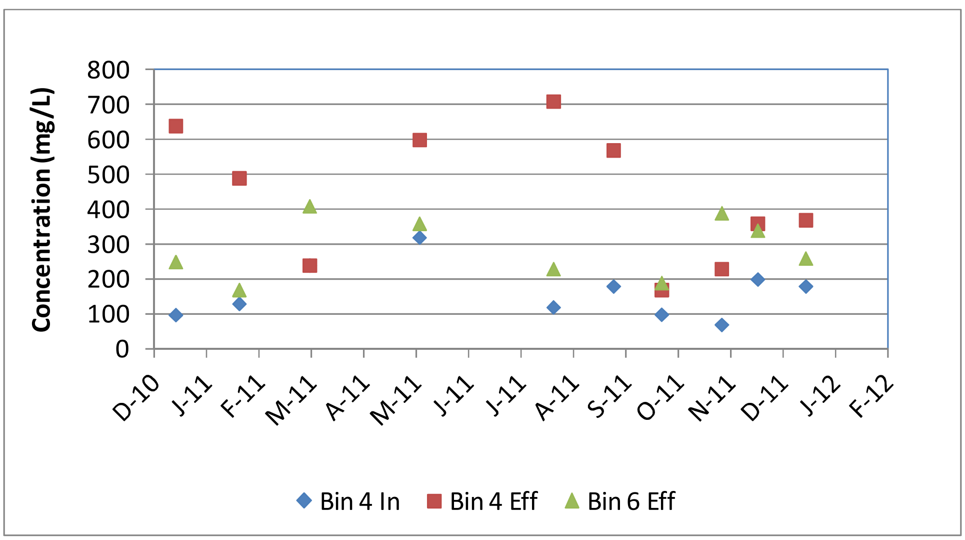


Figure 20 presents the COD levels in Train 2 and shows an increase in COD through Bin 4. This suggests that carbon is being leached from the green waste media into the water as it flows through the wetland system. This is evidenced by both the color and odor in the Bin 4 outflow. The COD data also suggests that the carbon is being consumed in Bin 6 and also observed by the clearer color in the Bin 6 outflow.

FIGURE 20
COD Levels in Train 2



3.4.5 Summary

The results show that though the wetland effluent will be higher in TDS because of evapotranspiration, the wetlands are able to reduce the concentrations of heavy metals and simultaneously remove the nitrate. Not every configuration achieved an equal reduction in concentrations, and Train 2 proved to be the most effective. In the subsequent section, the differences in media used and impact on performance will be described.

3.5 Media Quality

The media substrate was sampled to determine nutrient and metal accumulation. Prior to placing substrates in the wetland tanks, ten samples were collected in September 2010, to document the baseline conditions for the 3/8-inch rock, dirt, green waste, and peat. Analysis was conducted using ICP-MS to measure thirty different parameters including arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. A year later, in October 2011, substrate samples were collected from Bins 1 and 6 (peat based), as well as Bin 4 (green waste). Samples were taken from the top surface (top 2 inches) and also from both the deep (9 to 12 inches) and shallow zones (6 inches) in each bin. Analysis was conducted on the same set parameters. Figures 21, 22, and 23 present the data. Full results are included in Appendix C.

FIGURE 21
Arsenic Levels in Peat and Green Waste After First Year of Operations (2011)

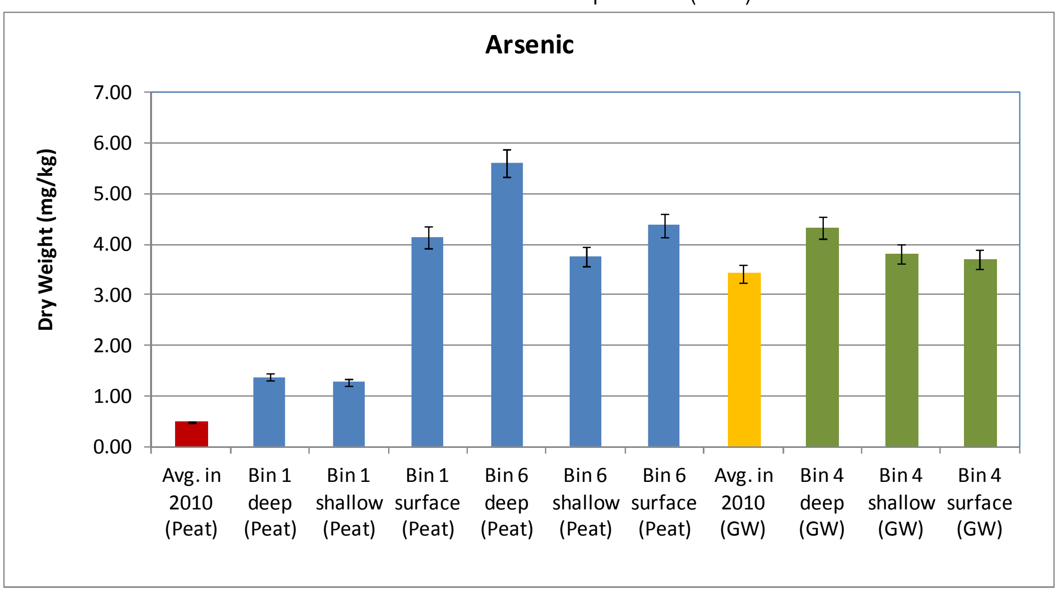


FIGURE 22
Selenium Levels in Peat and Green Waste After First Year of Operations (2011)

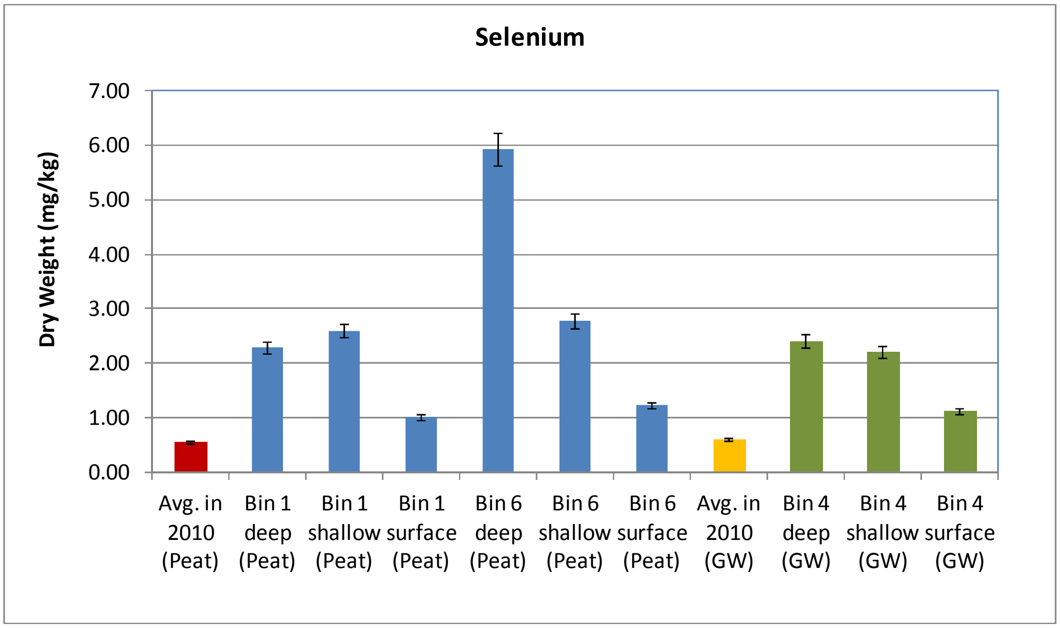
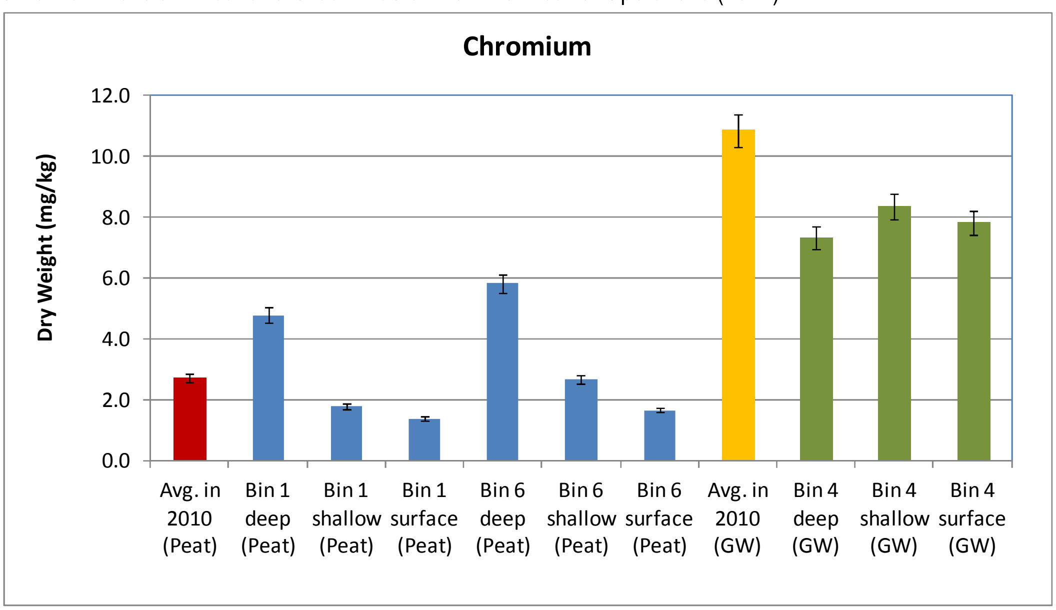


FIGURE 23
Chromium Levels in Peat and Green Waste After First Year of Operations (2011)



3.6 Vegetation

Plant establishment was monitored monthly during the testing period. Plant species, diversity, density, cover, growth, and vigor will be recorded during each monitoring event by Reclamation. Plant coverage was estimated based on the cover-class method presented in Table 5. Figure 24 and Figure 25 present the plant coverage for Bins 4 and 6 at the start and end of the first year of operations. Digital photos were also taken monthly to document plant health and growth in each wetland bin. Photos of Bins 4 and 6 in December 2010 and November 2011 are shown in Figure 26 and Figure 27.

Within Bin 4, the alkali sacaton and saltgrass showed a clear dominance by the end of the first year. The yerba manza persisted but showed little growth, and the scratchgrass muhly decreased in cover. Within Bin 6, cattails and Olney's three-square rush dominated by the end of the first year. Few living shoots of bulrush were located. In general, it was commonly observed that the green waste media was denser and as a result was less hospitable to plant growth. The more fine-textured peat was a supportive growth medium for all species installed. By the end of the year, in general, the tallest plant species or those species with a dense growth habit attained the greatest coverage.

TABLE 5
Plant Cover Classification System

Cover Class	Range of Coverage
Class 6	95 -100% cover
Class 5	75 - 95% cover
Class 4	50 - 75% cover
Class 3	25 - 50% cover
Class 2	5 - 25% cover
Class 1	1 - 5% cover
Present[a]	< 1% cover

[a] Present is identified graphically by a value of 0.5 to differentiate between <1% cover and no plants

FIGURE 24
Plant Coverage in Bin 4

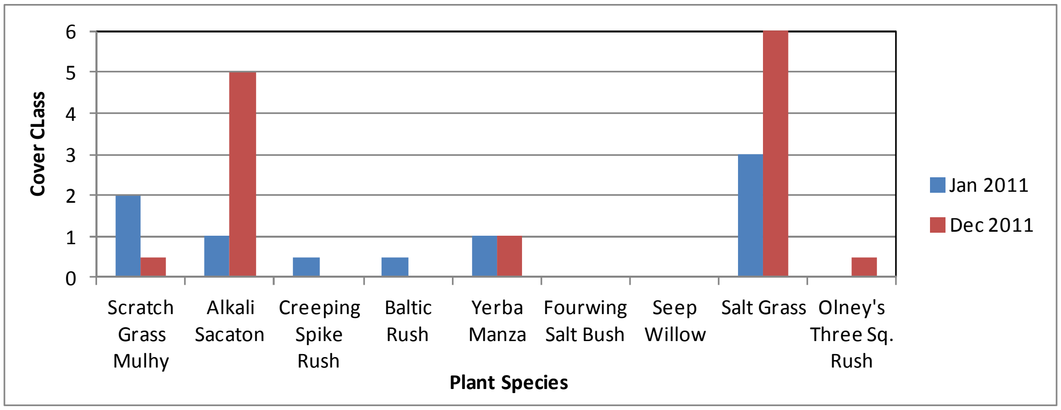


FIGURE 25
Plant Coverage in Bin 6

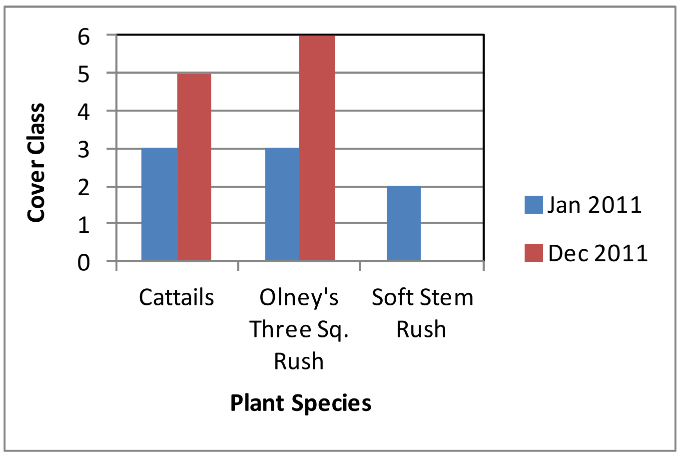
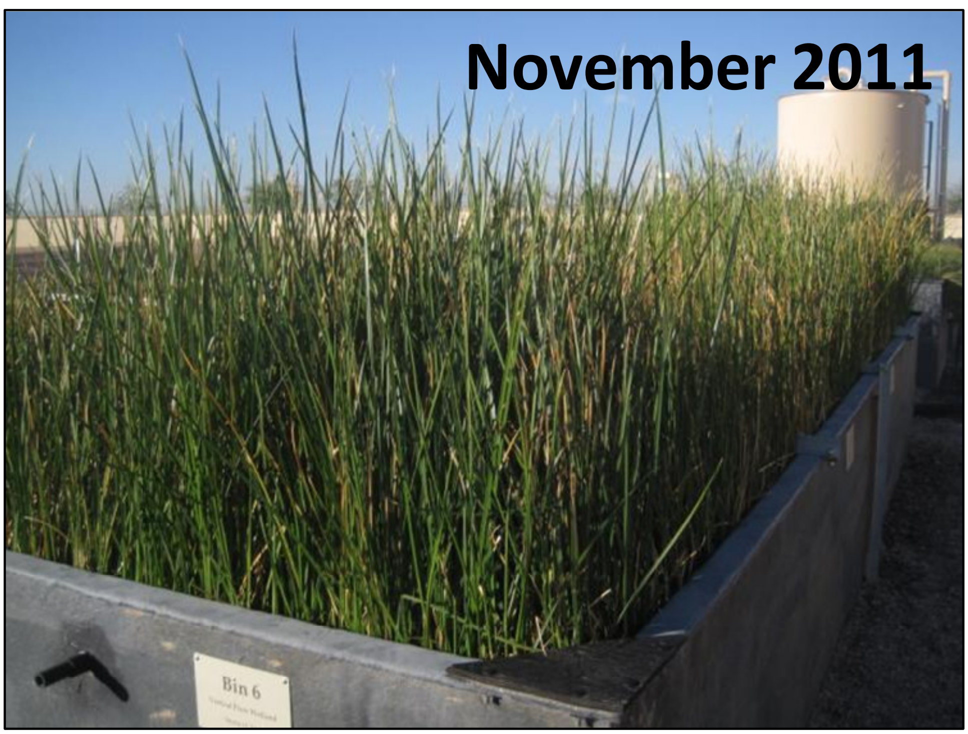


FIGURE 26
Bin 4 Plant Cover in December 2010 and November 2011

FIGURE 27
Bin 6 Plant Cover in December 2010 and November 2011



Plant root and shoot materials were sampled and analyzed to determine nutrient and metals concentrations. Prior to installing plants in the wetland bins, a sample of each was collected to establish baseline ion concentrations. Plant samples were analyzed for thirty different parameters including arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. Figure 28 shows some photos of the plant sampling conducted at the beginning of 2012. The full set of plant data including a photo summary documenting plant growth can be found in Appendix D. A second set of plant sampling and analysis is planned for February 2012 to document the metals accumulation after the first year.

FIGURE 28
Plant Sample Collection for Analysis

3.7 Aesthetics

Aesthetic considerations that often emerge with natural treatment systems include odors and vectors. Although the some of the bins that have formed anaerobic communities (Bins 2, 4, 6) during the first year of operations, odors have been well controlled by the top of layers of peat and densely packed green waste. Odors in the wetland effluent associated with sulfate reduction have only been detected when the effluent sample ports are opened. During regular field visits, vectors were rarely detected during the first year of operations. The vertical flow design for Bins 1 to 6 prevent the buildup of standing water in the bins which often foster the growth of mosquito communities. On a few occasions after rain events standing water has been observed; however, it usually subsided after a few days. Although Bin 7 is a surface flow wetland, the constant flow through the system and also elevated salt levels has kept vectors from establishing in this bin.

4. Conclusions and Recommendations

4.1 Overview

The first year of operations of the Goodyear Wetlands project has shown that it is feasible to reduce contaminants in RO concentrate using wetlands. Initial results indicate that the concentrate regulating wetlands concept warrants continued investigation based on the expected benefits. Treating the RO concentrate with a wetlands system and blending with wastewater effluent for surface water discharge will benefit the City's reclaimed water quality, thus freeing up potable water replaced by the reclaimed water used for urban irrigation, as well as providing a source of water appropriate to restore riparian habitats in the Gila River. The treated RO concentrate blended with effluent will also be slightly better quality water than the existing water in the Gila River at this location.

4.1.1 Summary of Conclusions

The following conclusions can be drawn from the project work to date:

- A wetlands system is capable of providing effective treatment of RO concentrate. Results show that arsenic, selenium and chromium are being removed to state standards for aquatic and wildlife designated uses. A candidate configuration is Train 2, which employs a green waste based VF wetland followed by a peat-based VF wetland. Bin 2, consisting of a mixed organic media bed, may be a more effective media system, if continued trends are sustained through a second year of data collection.

- Plant establishment can be achieved in a wetland system that is supplied by RO concentrate over a season of maturation. Given relatively cold winters and hot summers, planting should be completed in the early spring for best plant survival and growth.

- The regulating wetlands concept has gained local and industry support through effective outreach by Reclamation and other team partners. Continued testing of the system for an additional year will strengthen industry understanding and acceptance of the concept.

4.1.2 Summary of Recommendations and Objectives

Based on the results and conclusions from the first year of operations, the following recommendations and objectives are planned for the second year:

- Continue the study, as a minimum, of the most effective systems, including Bins 2, 4 and 6. Modify the bins to test specific improvements, to optimize the pilot wetlands to establish the best configuration and design criteria for a larger scale wetland system. This will be accomplished by increasing flows to determine the potential capacity of these systems. In addition, blending tests will be performed to determine sizing criteria for a blending wetland and wastewater flows required to achieve sufficient dilution prior to surface water discharge.

- Develop a permitting approach to obtain approval from ADEQ for surface water discharge of treated wetland concentrate. The approach is anticipated to support the potential of a full-scale wetland system to provide a net ecological benefit to the Salt and Gila River. Whole Effluent Toxicity (WET) testing will be conducted and results incorporated in discussions with ADEQ

- Identify funding pathways and opportunities available to implement a demonstration scale wetland system.

- Sustain and focus industry outreach to key organizations to deepen technical support. Continued presentations at local conference and targeting peer-reviewed publications will the focus of outreach efforts

- Identify stakeholders that will be involved or affected by implementation of a full or demonstration scale system,

The recommendations and objectives listed are further described in the subsequent sections.

4.2 Optimization of Operations

For the second year of operations, all bins should remain in operation. Some potential changes in operation may be implemented to develop engineering design criteria. For example, to test the limits of performance, the flow rates into the most successful train (Train 2) may be increased to determine the minimum wetland area required to achieve water quality objectives. The water quality results will refine the understanding of microbial process rates and plant community development. Another recommended change is the replanting of Bin 1. Given the limited success of these bins to remove heavy metals, Bin 1 should be partially excavated, relayered with a finer textured green waste or mixed organic media and replanted with plants that have shown greatest growth during the first year. Finally, it is likely that Bin 7 could be isolated from Train 1 and used to facilitate blending tests that are described in the next section. Table 6 summarizes the changes in configuration and operation by bin that are planned for the second year.

TABLE 6
Configuration and Operational Changes for Second Year Piloting

Bin	Change in Configuration or Operation	Rationale
Train 1		
1	Top layer (12 inches) will be excavated and replaced with 3/8" green waste or mixed organic media. Planting plan will be established based on best performers from 1st year operations.	Determine the impact of using finer green waste media and serve as a basis of comparison with performance of Bin 4 (¾" green waste). Determine impact of partial media replacement on the startup period will be documented.
5	Bin 5 will remain planted as is and continue to receive flow from Bin 1.	Determine Impact of changing upstream wetland bin media will be assessed.
7	Bin will remain in service as is and continue receiving flow from Bin 5. Upon implementation of pilot scale blending test, Bin 7 will be converted into a blending bin. Piping may be reworked to accommodate for flows from train 2.	Onsite blending will provide a tangible representation of hydraulics, smell, aesthetics, vector population and evapotranspiration that can be expected when blending is implemented on a full or demonstration scale level.
Train 2		
4	Flows will be increased steadily at controlled increments.	Evaluate the hydraulic loading threshold of the wetland bins and ability of inhabiting microorganisms to continue removing heavy metals and other contaminants.
6	Increasing inflows to Bin 4 will result in greater inflows to Bin 6.	Same as Bin 4.
Train 3 (Bin 2)	No operational changes are planned for Bin 2. Depending on plant establishment, flows may be increased in the summer.	Any increases in flow to Bin 2 will be to evaluate the hydraulic loading threshold of the wetland bins and ability of inhabiting microorganisms to continue removing heavy metals and other contaminants.
Train 4 (Bin 3)	No operational changes.	Bin 3 will remain in operation as in the first year and serve as a baseline for comparison.

Maintenance and monitoring activities will continue as performed during the first year. The pilot team will conduct daily and weekly inspections of the facility and record both flows and field conditions during each visit. Water quality sampling and analysis will be completed biweekly assuming availability of lab services from the City of Phoenix. A plant analysis will be scheduled and completed in early 2012 to characterize the accumulation in the plants. A third plant analysis and media substrate analysis will be conducted at the end of 2012 to document changes after the second year.

The changes in operation and continued maintenance and monitoring will be used to establish the design criteria for a full scale system

4.3 Blending and WET Testing

The blending operation will be conducted during the second year to test the effects of salt (and metals) dilution on water quality and WET. This will be accomplished by blending a variety of treated waters with wetlands effluent in both the lab and in the field.

For bench scale testing, wastewater effluent and wetland treated concentrate will be collected in 55-gallon barrels and sent to a laboratory. Initial water quality analysis of each sample will be used to calculate the volumes of each needed to produce a select blend. The wastewater and treated concentrate will then be blended, sampled and analyzed for contaminants of concern listed in the monthly sampling (e.g. arsenic, selenium, TDS, and nitrate,). Upon confirmation of the correct water quality, WET testing will be conducted using the blend. Performing blending on the bench scale will allow greater control and opportunity to repeatability. Although the mixing conducted in the lab will not fully simulate the actual conditions in the field, the results will provide a basis for conducting blending on the pilot scale at the site. The final protocol for blending will be decided early in the second year so that multiple tests can be run.

4.4 Permitting and Regulatory Considerations

The regulating wetlands approach for managing concentrate will require permitting from ADEQ to advance the project from pilot to demonstration/full scale. Discharging the wetland treated concentrate or even a blend of the concentrate and wastewater effluent into the Gila River will require a surface water discharge permit which is subject to approval by the ADEQ. Concern has been expressed that the concentrate/effluent blend will not be able to pass a WET test because chloride levels will be elevated relative to known effects thresholds. Chlorides above 300 mg/L have been known to cause failure of the WET test because one of the test animals, the water flea (*Ceriodaphnia*), is unable to tolerate high chloride levels. The concentrate/effluent blend is expected to contain approximately 1,220 mg/L of chloride.

Given this potential concern, a discharge permit may still be issued consistent with the requirements of Rule R-18-11-106, which allows exceptions to the regulations in effluent-dominated waters if it can be demonstrated that the regulating wetland system creates a net ecological benefit. The code establishes multiple criteria that must be met to achieve a net ecological benefit when the discharge of effluent creates or supports an ecologically valuable aquatic, wetland, or riparian ecosystem. This rule has been applied before in Arizona to approve the construction and implementation of the East Yuma Wetlands Project, a riparian restoration project utilizing treated effluent for irrigation. Rule R-18-11-106 is thus expected to be applicable to the regulating wetland concept.

Given the elevated chloride concentrations in the Gila River (1,240 mg/L), the potential impact of a blended, wetland-treated concentrate discharge to freshwater invertebrates (as measured by toxicity to water fleas, which do not inhabit the Gila River) is negligible. Conversely the positive effects of the wetland-treated concentrate discharge are numerous and include:

- Improving the wastewater effluent quality from the Goodyear WRF to be more suitable for irrigation and other reclaimed water uses

- Providing additional water supply to the Gila River habitat that will improve the water quality and also foster habitat development from new wetlands

- Reducing greenhouse gas emissions by reducing energy consumption on concentrate management.

Reclamation and the City of Goodyear discussed the concept with ADEQ initially in October 2008 and August 2009. The pilot wetlands project was initiated to establish concept environmental safety, determine feasibility of permitting, and to test the ability of the wetlands to remove regulated ions. The existing data gathered, ongoing data collection, and planned blending and WET testing activities provide a basis for Reclamation to develop a permitting approach that will be subject to discussion with ADEQ. The permitting approach will include pilot results, preliminary concepts for larger scale implementation to facilitate discussions with ADEQ to identify application requirements for regulatory approval of the wetlands concept.

Because a full-scale wetland system may likely be sited near Gila River near the existing Water Reclamation Facility, the proximity to the Goodyear Airport requires that the project comply with the Federal Aviation Administration's separation criteria for hazardous wildlife attractants on or near airports. The site for a demonstration/full scale wetland system will need to be outside the 10,000-foot limit of the Goodyear Airport and not be located in the direct path of the approach to the airport. Coordination with FAA is anticipated if and when a demonstration/fill scale project is implemented.

4.5 Identifying Funding Pathways

The completion of the second year activities for the pilot wetlands will mark the completion of the study phase for this concept. As described, advancing into full or demonstration scale will not depend upon the outcome of the permitting process but also on obtaining adequate funding support from local partners. If regulatory issues are addressed and a permit can be successfully issued, implementation will need to be undertaken by the City of Goodyear. Continued partnership with City of Phoenix for analytical support will be beneficial. It would also be advantageous for the City to invite other agencies such as the Central Arizona Project to collaborate as a partner.

Because of the relevance of this project to Reclamation's long standing objectives for reuse, Reclamation is recommended to continue as an active partner during implementation. One possibility for Reclamation to stay involved would be through the agency's WaterSMART (Sustain and Manage America's Resources for Tomorrow) Program which is funding opportunity for Title XVI Water Reclamation and Reuse Feasibility Studies. Under the WaterSMART program, the regulating wetlands concept is eligible for an Advanced Water Treatment and Pilot and Demonstration Project Grant. Reclamation will fund up to $150,000 per applicant. Applicants must provide at least 50 percent non-federal cost-shared funding for the feasibility study. Studies must be completed by March 2014. The collaborative agreements associated with the WaterSMART program would lend itself to continued involvement by Reclamation, if the regulating wetlands were awarded a grant.

4.6 Industry and Grassroots Outreach

Continued industry outreach to promote and confirm the value of the regulating wetlands concept is also key activity for the second year of operations. Since its inception, this concept has been presented to the water treatment industry at a number of professional society meetings, conferences and also in a white paper. Locally, the pilot wetlands are regularly discussed at quarterly CASS meetings. These meeting are typically attended by engineering professionals from the private and public sector in the greater Phoenix area. Continuing to present the results from first year operations at these same events will help gauge acceptance and obtain feedback from the industry. Other avenues that can help gain industry approval would be to update of the original white paper and/or submission of an article to a peer-reviewed journal such as Water Environment Federation or Water Research Foundation. Table 7 lists the previous and expected presentations and publications to date that have focused on the concentrate regulating wetlands pilot.

TABLE 7
Previous and Planned Presentations and Publications

Title	Type	Event/Publication
A Salt Marsh: An Innovative Method of Managing Concentrate in the Greater Phoenix Area	White Paper	Reclamation (2007)
The Goodyear Regulating Wetlands Concept	Paper/ Presentation	Water Environment Federation (2009)
Pilot Study of the Regulating Wetlands for Concentrate Treatment	Presentation	Southwest Membrane Operators Association (SWMOA, February 2010)
Concentrate Management Wetlands Pilot Project	Paper/ Presentation	WateReuse Annual Symposium (September 2011)
Pilot Study of the Regulating Wetlands for Concentrate Treatment: Water Supply and Sustainability in the Arid Southwest	Paper/ Presentation	AWWA Annual Conference and Exposition (June 2011)
Pilot Study for Regulated Wetlands for Concentrate Treatment: First Year Results	Paper/ Presentation	Arizona Water Annual Conference (June 2012 Planned)
Progress in the Use of Brackish Wetlands for Concentrate Treatment: Overview of First-year Results of the Goodyear Regulating Wetlands Pilot Study	Paper/ Presentation	WateReuse Annual Symposium (September 2012 Pending Acceptance)
Brackish Wetlands For Concentrate Treatment: Overview Of Pilot Results Of The Goodyear Regulating Wetlands	Paper/ Presentation	AWWA Water Quality Technology Conference (November 2012 Pending Acceptance)

4.7 Stakeholders

Identifying stakeholders and gaining their support will be a critical success factor for implementation. An organized effort to connect with stakeholders is recommended in parallel to permitting and industry outreach activities. Stakeholder outreach should be coordinated and coordinated with the agreement of active project partners. Some of stakeholders that will be engaged include the Maricopa County Flood Control District, Central Arizona Project, Gila River Indian Community, Arlington Farms, and Paloma Farms.

4.8 Implementation for Full Scale

A model was developed by CH2M HILL to develop some preliminary design criteria and costs for a full scale system. The model was used to assess a wetland system designed to treat a concentrate flow from the GBWC of 0.5 mgd. Removal rates using in the model were calibrated based on the data collected from the first year of pilot operations, specifically from July to December 2011.

This period was selected because the performance is most representative of an established wetland system. It is assumed that the plant and microbial communities were still becoming established during prior months.

The full scale scenario was modeled based on a combination of the configurations in Bins 2, 4, and 6. It is assumed that the system would be composed of green-waste based wetlands (similar to Bin 4) followed by mixed organic media based wetlands (similar to Bin 2) and lastly, peat based wetlands similar to Bin 6. Because results from the pilot show that the mixed organic media based systems achieve the majority of the metals removal, the model assumed mixed organic media for 60 percent of the wetland area. Green waste to peat based wetlands were assumed to be 20 percent of the entire system During the modeling exercise, sizing targets of 5, 10, and 5 µg/L were selected for selenium, arsenic and chromium, respectively, in the system effluent based on water quality standards established by ADEQ shown in Table 4. Selenium was determined to the contaminant driving the wetland sizing. The estimated wetland surface area was approximately 15 acres to provide the required treatment. Table 8 shows the projected performance based on the preliminary modeling.

TABLE 8
Projected Wetland Performance

Parameter (units)	Summer			Winter		
	Concentrate	Effluent	Removal	Concentrate	Effluent	Removal
Selenium (µg/L)	41.9	0.6	98.5%	19.0	2.0	89.4%
Arsenic (µg/L)	29.1	8.4	71.1%	18.4	9.2	50.1%
Chromium (µg/L)	43.0	6.0	86.0%	33.0	4.4	86.7%
Nitrate (mg/L)	56.0	0.5	99.2%	54.0	1.3	97.6%
TDS (mg/L)	7,450	14,534	N/A	7,840	9,629	N/A
Flow (mgd)	0.50	0.26	48.7%	0.50	0.41	18.6%

Preliminary costs were prepared for the design and construction of this treatment alternative based on the following standard equations for subsurface flow and surface flow wetlands (Kadlec and Wallace, 2009).

$$Cost\ (\$thousands) = 652 \times Area\ (ha)^{\ 0.704}$$ [Subsurface Flow Wetland]

$$Cost\ (\$thousands) = 163.44 \times Area\ (ha)^{\ 0.76}$$ [Surface Flow Wetland]

The costs assume multiple one hectare (ha) systems will be constructed to make up the 15 acre wetland plus an additional one hectare backup system. A two acre surface flow wetland was assumed to accommodate for blending purposes. The costs are summarized in Table 9 and assume 15 percent for engineering and permitting services as well as a contingency of 30 percent. The costs were adjusted from 2009 to 2012 based on a factor of 1.056.

TABLE 9
Preliminary Cost Estimate

Description	Cost ($)
Media Bed Subsurface Flow Wetlands a	$4,200,000
Surface Flow Wetlands b	$150,000
Sub-Total	**$4,350,000**
Engineering and Permitting (15%)	$700,000
Contingency (30%)	$1,300,000
Total [c]	**$6,350,000**

[a] The subsurface flow wetlands assume multiple one ha wetland systems plus one ha back up wetland system for a total of 17.5 acres
[b] An area of two acres of surface flow wetlands was assumed for blending purposes.
[c] Total cost estimate does not include costs for siting or land acquisition.

This estimate has been prepared for the guidance in project evaluation and implementation from the information available at the time of the estimate. Costs were prepared in a fashion consistent with Association for the Advancement of Cost Engineering International Class 5 standards, for which the estimated accuracy range is from -30 to +50 percent. Actual costs will be dependent on the final site selection. Siting and land acquisition will be critical steps that will need to be considered when implementing the full scale design.

5. Reference List

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Appendix A
Technical Memorandum: "Regulating Wetlands Pilot Facility: Operations and Monitoring Guidance Summary"

Regulating Wetlands Pilot Facility: Operations and Monitoring Guidance Summary

PREPARED FOR: Tom Poulson, P.E./U.S. Bureau of Reclamation, Phoenix Office

PREPARED BY: CH2M HILL

DATE: April 11, 2012

1. Introduction

In 2007, the US Bureau of Reclamation (Reclamation) developed a conceptual approach to the beneficial reuse of membrane concentrate by blending wetland-treated reverse osmosis (RO) concentrate with treated wastewater effluent to create a water source for habitat creation and maintenance of river flow (Poulson 2007). This concept, termed the Regulating Wetlands project, calls for the use of specially-designed wetland cells to remove contaminants of concern from RO concentrate ('treatment cells') combined with separate cells that reduce TDS in the RO concentrate through blending with treated effluent ('blending cells'). In 2008, CH2M HILL designed a pilot RO concentrate regulating wetlands treatment system that was subsequently constructed by Reclamation at the City of Goodyear's Bullard Water Campus (Bullard Site), which houses a RO plant.

The objective of pilot wetlands construction and operation is to evaluate the feasibility of the Regulating Wetlands concept, optimize system configuration (media type and depth), measure plant species growth and suitability, and operating parameters. The purpose of this technical memorandum is to provide an operations and monitoring guidance summary of the pilot facility.

2. Process Overview and System Hydraulics

2.1 Process Overview

The pilot Regulating Wetland at the Bullard Site is located in an open area south of the RO building and uses concentrate from the RO facility as its influent. The triangular-shaped parcel covers approximately 3,000 square feet and is shown in Figures 1 to 7 of Appendix A. Concentrate is collected from the RO plant concentrate discharge line located on the south side of the building, and pumped into a static head tank. Seven tanks, or treatment cells, connected by PVC piping, make up the treatment component of the pilot wetlands. Each tank, or treatment cell, is 8 ft wide and 24 ft long (192 ft^2 surface area) and contains various media, plant types, and hydraulic configurations. The stored concentrate flows by gravity through four different wetland trains for treatment. Cells 1 to 6 are configured for vertical upward flow while Cell 7 is configured for surface flow. Treated effluent is then collected in a small tank from which it is pumped into a sewer collection box or into an effluent storage tank.

2.1.1 Treatment Cell Media and Plants

The treatment cells were constructed from prefabricated aquaculture tanks manufactured by D&T Fiberglass of Sacramento, California. The tanks were leak tested, and where necessary, repairs made prior to adding media and plantings. A variety of media and vegetation planting types was used for each of the seven cells. With the exception of cell 7, each cell is layered with 6 inches of ¾ inch rock, 1 foot of 3/8 inch pea gravel and a layer of media. Peat moss was purchased from a local supplier, Western Organics, and used as the media in each vertical upflow cell except cell 4. Peat moss was selected for its long history as an effective media for metals removal, mine drainage treatment, and filtration of municipal wastewater. Furthermore, peat moss is the media that was successfully used at similar project conducted by the City of Oxnard, California between 2003 and 2005 to treat RO concentrate. Local "green waste" (i.e., yard clippings, cut plant materials, etc.), also purchased from Western Organics, was used as the media type in cell 4 as an alternative source of organic matter. These two media types were chosen to establish contaminant removal characteristics for different types of soil, gravel, and organic substrates. If the "green waste" proves to provide similar levels of treatment, it may be used as an economical substitute for peat moss during full demonstration.

The plant species used for the treatment cells span a variety of characteristics and are shown in Table 1. The species planting plan is presented in Figure 1. Use of different types of vegetation will help determine which species grow best with the constituents present in the concentrate and to what degree their growth characteristics support treatment performance. All of the plants were purchased by Reclamation from Hydra Aquatic Inc., a wetland plant nursery located in New Mexico. All plants are native species to the arid regions of the southwest and commonly found in the wetlands of this region. As the project progresses, plant selections will be re-evaluated based upon success in growth/dominance and observed treatment performance benefits. Re-evaluation will be conducted if needed on a quarterly basis as part of the monthly pilot performance summaries.

TABLE 1
Planting Summary

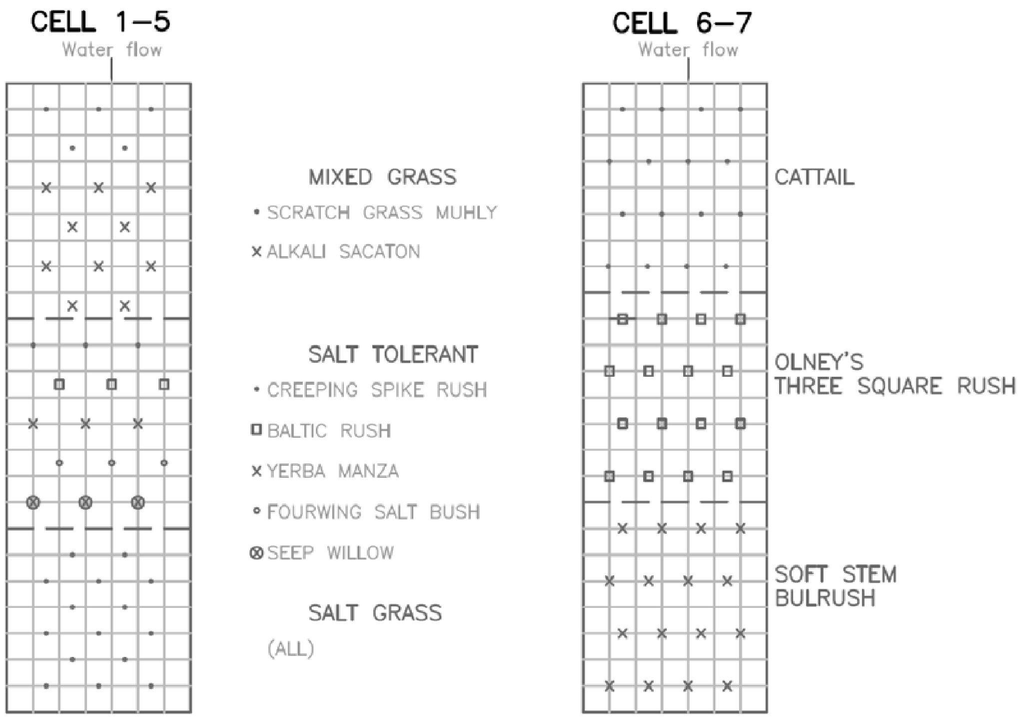
Plant Species	Plant Coverage by Cell						
	Cell 1	Cell 2[a]	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7
Scratch Grass Muhly	11.1%	TBD	11.1%	11.1%	11.1%	-	-
Alkali Sacoton	22.2%	TBD	22.2%	22.2%	22.2%	-	-
Creeping Spike Rush	6.7%	TBD	6.7%	6.7%	6.7%	-	-
Baltic Rush	6.7%	TBD	6.7%	6.7%	6.7%	-	-
Yerba Manza	6.7%	TBD	6.7%	6.7%	6.7%	-	-
Fourwing Salt Brush	6.7%	TBD	6.7%	6.7%	6.7%	-	-
Seep Willow	6.7%	TBD	6.7%	6.7%	6.7%	-	-
Salt Grass	33.3%	TBD	33.3%	33.3%	33.3%	-	-
Cattail	-	TBD	-	-	-	33.3%	33.3%
Olney's Three Square Rush	-	TBD	-	-	-	33.3%	33.3%

TABLE 1
Planting Summary

Plant Species	Plant Coverage by Cell						
	Cell 1	Cell 2[a]	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7
Soft Stem Bulrush	-	TBD	-	-	-	33.3%	33.3%

[a] Cell 2 is currently not operational due to leakage in the tank. Cell characteristics will be updated once the cell is repaired.

FIGURE 2
Planting Plan



Plants were initially installed on September 3, 2010. RO concentrate is used to irrigate cells 1 through 6. Untreated groundwater is being used to irrigate cell 7 until plants mature, at which time this cell will be irrigated with concentrate as well. During a site inspection performed on October 15, 2010 (after 6 weeks of growth), plants were observed to be generally healthy in a fledgling state. Some dead or dying plants were removed and replaced. Plants are expected to reach maturity at 12-18 weeks. Plants should be closely and continuously monitored on a weekly basis until they are mature and then throughout the operation of the pilot.

2.1.2 Treatment Trains

Four process trains were designed as part of this pilot to facilitate testing of different system configurations and operating parameters. For cells 1 through 6, the concentrate first flows through a PVC piping manifold that passes through the bottom of the initial treatment cell. The PVC piping is perforated, allowing vertical flow upwards through the media filled wetland cell. PVC piping at the surface of the cell collects and conveys the rising concentrate to the next cell or to the sewer. Figure 2 shows the physical configuration of the four treatment trains.

Train 1 is comprised of cells 1, 5 and 7, configured in series. Cells 1 and 5 contain the same plants and are designed for vertical flow while Cell 7 is designed as a surface flow wetland for additional residence time prior to sewer discharge. Train 2 is a two-cell train that includes Cells 4 and 6 in series. Both cells are identically planted. Trains 3 and 4 are single cell trains made up of Cells 2 and 3, however, only Cell 3 is currently operational. Effluent from each train is discharged through a 1-inch line, with the four lines combining into a 4-inch discharge line. Tables 2 to 4 present the characteristics of each train by cell. A piping plan of the site and hydraulic profile of each train are shown in Figures 4 and 5 of Appendix A.

FIGURE 2
Treatment Trains Plan View

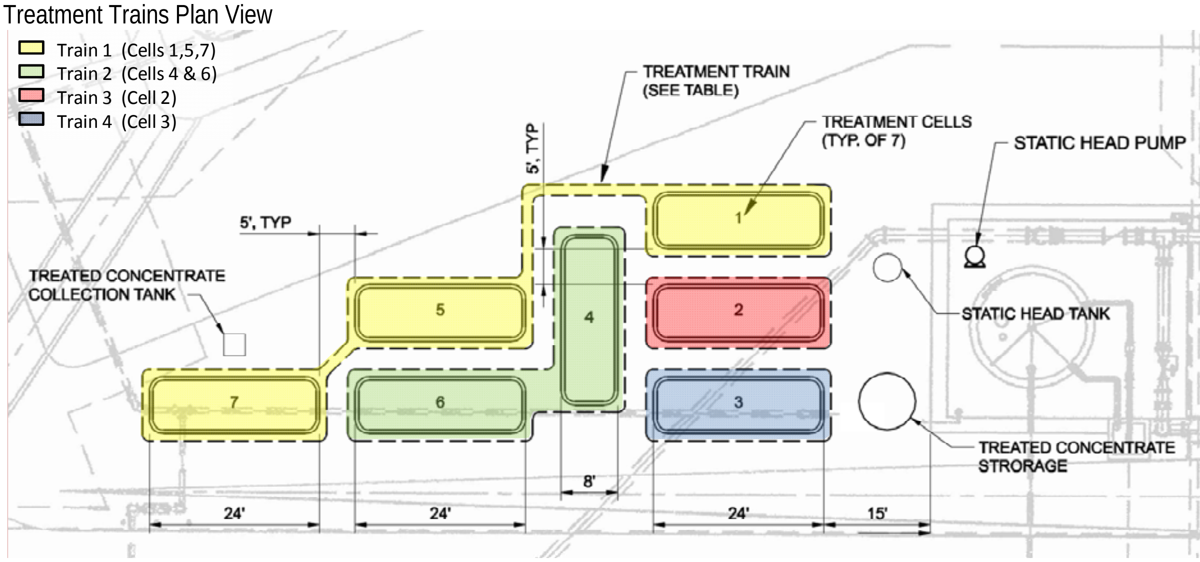


TABLE 2
Train 1 - Characteristics by Cell

Parameter	Units	Cell 1	Cell 5	Cell 7
Type		VUF	VUF	SF
Substrate		PM	PM	Soil
Depth	ft	4	4	4
Hydraulic Depth	ft	4.4	3.87	3.33
Tank Volume	ft^3	768	768	768
Rock Elevation	ft	0.5	0.5	0.0
Gravel Thickness	ft	1.0	1.0	0.0
Media Thickness	ft	1.0	1.0	1.0
Water Elevation	ft	2.8	2.8	2.8
Water Volume	ft^3	264	264	417

VUF = Vertical Upflow
SF = Surface Flow
PM = Peat Moss

TABLE 3
Train 2 Characteristics by Cell

Parameter	Units	Cell 4	Cell 6
Type		VUF	VUF
Substrate		GW	PM
Depth	ft	4	4
Hydraulic Depth	ft	3.82	3.3
Tank Volume	ft^3	768	768
Rock Elevation	ft	0.5	0.5
Gravel Thickness	ft	1	1
Media Thickness	ft	1.5	1
Water Elevation	ft	2.82	2.82
Water Volume	ft^3	346	264

VUF = Vertical Upflow
PM = Peat Moss
GW = Green Waste

TABLE 4
Independent Cells 2 & 3 Characteristics

Parameter	Units	Cell 2	Cell 3
Type		VUF	VUF
Substrate		TBD	PM
Depth	ft	4	4
Hydraulic Depth	ft	3.32	3.37
Tank Volume	ft^3	768	768
Rock Elevation	ft	0.5	0.5
Gravel Thickness	ft	1	1
Media Thickness	ft	TBD	2
Water Elevation	ft	TBD	2.82
Water Volume	ft^3	TBD	427

VUF = Vertical Upflow
PM = Peat Moss
TBD = To be determined

2.2 System Hydraulics

2.2.1 Influent

The source water for this pilot is from the RO concentrate discharge line located on the south side of the RO building through a 3-inch valve and pumped into a 300 gallon static head tank by a 12 gpm constant rate static head pump. The pump should be operated and maintained according to the manufacturer's instructions. The pump can be operated on continuous duty to keep the static head tank filled at all times. A 4-inch overflow line on the tank will drain excess concentrate to sewer when the water level in the tank exceeds 75.5 inches. If the pump is stopped, the tank will continue to flow by gravity to the treatment cells for approximately 5 hours at 1 gpm. If the concentrate flow to the pump is interrupted, the pump should also be turned off to avoid overheating and failure. If needed, a switch will be added to shut off the pump on low discharge or suction pressure. The treatment cells receive water by gravity from the static head tank through a main valve that splits flow to the inlet of four initial stage treatment cells (cells 1, 2, 3, and 4). Flows should be continuous to each cell so plants are sufficiently hydrated. Inlet pipes to the initial stage treatment cells have been equipped with flow meters that should be read daily. In addition, the media soil surface should be monitored to be moist at all times. If the inflow is too low, the plants in each cell will begin to dehydrate and eventually die. If the inflow is too high the cells will begin to overflow which will be evidenced by a rise in water surface height. Flow should be increased or decreased to allow for steady flow through the trains by adjusting the valve on the downstream end of the static head tank or the inlet to the initial cell of the treatment train.

Flow monitoring can be accomplished at the following locations:

- Inlet to initial cell of the treatment train (cells 1, 2, 3 and 4) – Flow meters
- Outlet of any treatment cell – time and volume method

The outlet flows for a treatment cell are expected to be less than inlet flows due to evapotranspiration (ET). ET rates will be calculated based on flow measurements at the inlet and outlets using the principle of mass balance:

$Q_{Inflow} - Q_{evapotranspiration} = Q_{outflow}$

Based on the initial leak testing, it is assumed that the tanks are leak proof (once cell 2 is repaired) and that losses other than to ET will not be considered unless identified through visual inspection. Flows from precipitation are negligible and will not be considered. These will be collectively defined as water losses and will be theoretically calculated if necessary.

2.2.2 Effluent Control

All wetland system effluent will be collected in a 525-gallon treated concentrate collection tank. The effluent from the treatment cells is designed to be gravity fed into down a 4-inch PVC line into the treated concentrate collection tank then either discharged into the sewer or pumped into the effluent storage tank. As part of the original concept based on blending wetlands effluent with tertiary wastewater effluent for discharge to the Gila River, water from the effluent storage tank is to be trucked to the 157^{th} Avenue Goodyear Water Reclamation Facility where it will be blended with tertiary effluent to approximate future blended effluent quality. However, because the WRF is not currently ready to receive treated RO effluent water from Bullard Water Campus, the effluent storage tank will not be operated and water will be bypassed into the sewer box for discharge.

2.2.3 Hydraulic Summary

Table 5 provides a summary of the hydraulic design criteria for each cell. Flow parameters are based on initial operating conditions and are expected to change. All changes will be recorded and discussed as part of the monthly pilot performance summaries.

TABLE 5
Hydraulic Design Criteria

Parameter	Units	Cell 1	Cell 2[a]	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7
Width	ft	8	8	8	8	8	8	8
Length	ft	24	24	24	24	24	24	24
Area	ft^2	192	192	192	192	192	192	192
Depth	ft	4	4	4	4	4	4	4
Tank Volume (Empty)	ft^3	768	768	768	768	768	768	768
Target Inflow [b]	gpm	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Outflow [c]	gpm	-	-	-	-	-	-	-
Evapotranspiration [d]	gpm	-	-	-	-	-	-	-
HLR [e]	in/d	3	TBD	3	3	3	3	3
nHRT [f]	days	5.5	TBD	8.9	7.2	5.5	5.5	8.7

[a] Cell 2 is currently not operational due to leakage of the tank. Cell characteristics will be updated once the cell is repaired.

[b] Inflow values are based on current flows through the pilot and will be adjusted based on performance

[c] Outflow will be measured through the time and volume method

[d] ET rates will be estimated based on inflow and outflow

[e] Hydraulic Loading Rate (HLR) may vary during pilot operation

[e] Effective Hydraulic Residence Time (nHRT) are based on current inflows and media layering in each cell. nHRT will change as these parameters are adjusted during the pilot

3. Standard Operating Procedures (SOP) Checklist

To ensure that the pilot is operating properly, a standard operating procedure (SOP) checklist was developed to guide daily and weekly inspections of the pilot. Daily inspections will be conducted every morning by City of Goodyear Staff using the daily SOP form included in Appendix B. The main goal of these inspections is to verify that flow is being delivered to each treatment train by checking pump operation, flow meter settings, outflow from each cell and soil moisture content. Execution of the daily SOP also provides opportunity to check for any signs of cracks or leaks in the tanks or piping. Completed SOP forms should be sent via email to Reclamation and CH2M HILL at the end of each business week. All signs of malfunction or damage in the pilot equipment should be reported to Reclamation and CH2M HILL immediately. Contact information for Reclamation and CH2M HILL personnel are included on the inspection forms and in Table 6 of this report.

A more thorough inspection will be conducted by Reclamation on a weekly basis and to document plant health and any evidence of invasive species in each cell. Any plant death, signs of pestilence or invasive species should be recorded during these inspections. Inflows and outflows will be measured as part of this inspection and used to calculate key hydraulic parameters. All tanks and bins will be assessed as part of the weekly inspection once a month to check for cracks and sedimentation in the tanks. The weekly SOP form is included in Appendix B.

4. Water Quality Sampling, Testing and Analysis

4.1 Procedure

Onsite water quality measurements will be conducted by Reclamation on a weekly basis as part of the weekly inspection . Samples will be collected on a bi-weekly basis for laboratory (off-site) testing. All measurements and samples will be collected for the train influent (RO Concentrate) and the effluent from each cell (eight sample points). The influent sample should be collected from the RO concentrate discharge line located on the south side of the main building. Effluent samples can be collected by opening the valve installed on the outlet line of each cell.

The bi-weekly water quality testing will be conducted by the City of Phoenix Water Quality Laboratory. Prior to the sampling, Reclamation will need to contact the City of Phoenix to schedule the water quality analysis and also to obtain sample bottles, chain of custody forms and any preservatives required to be added following sample collection. Sample containers will be labeled clearly with the sample date and cell number by Reclamation prior to collection. Samples should be kept on ice and delivery to the City of Phoenix should be completed within 4 hours of collection.

4.2 Parameters

During each weekly visit, the following parameters shall be measured for the water at each sampling point by Reclamation and recorded on the Water Quality Data form located in Appendix B:

- DO [mg/L]
- Temperature [°C]
- Electrical Conductivity [µSiemens/cm
- pH
- ORP (oxidation-reduction potential)

Water quality parameters to be measured by the City of Phoenix on a bi-weekly basis include:

- TDS [mg/L]
- Selenium [mg/L]
- Chromium [mg/L]
- Copper [mg/L]
- Chloride [mg/L]
- Arsenic [mg/L]
- Nitrate + Nitrite-N [mg/L]
- Sulfate [mg/L]
- Zinc [mg/L]
- Total phosphorus [mg/L]
- Color [color units]
- COD [mg/L]

4.3 Results

Samples will be analyzed by the City of Phoenix within the appropriate holding time following receipt from Reclamation. Results from the water quality testing will be delivered to Reclamation after 30 days or less via email. Water quality data measured by Reclamation in the field shall also be recorded on the water quality form in Appendix C and sent to CH2M HILL for review.

4.4 Wetland Operation and Performance Analysis

CH2M HILL will analyze water quality and operations data and document results and recommendations in a pilot performance summary of 2 pages or less that will be distributed within 10 days of receiving monthly operation and testing data. Reclamation will lead 1 hour monthly operations review calls to review operations results, analysis, and look-ahead activities.

At the end of 6 months operation, CH2M HILL will provide an interim pilot testing report of 20 pages or less. This report will document, through text, photos, and charts, trends in inflow and outflow rates and cell hydrology, influent and treated water quality for each treatment cell and train, sediment and vegetation constituent concentrations, lessons learned, and general recommendations for next steps in pilot testing. The monthly summaries will serve as the appendices to the report. This report will not estimate costs nor will it evaluate future pilot or demonstration phases of this project.

5. Vegetation and Substrate Analysis

Plant establishment will be monitored monthly during the testing period. Plant species, diversity, density, cover, growth and vigor will be recorded during each monitoring event by Reclamation. Digital photos will be taken by CH2M HILL to visually document plant health and growth at every cell on a monthly basis. Plant root and shoot materials will be sampled and analyzed to determine nutrient and metals concentrations. Prior to installing plants in the wetland cells, a sample of each was collected to establish baseline conditions. Every six months during the test period, root and shoot samples will be collected from a section of each cell. Two samples will be collected by excavating two 12 by 12 inch square plots to a depth of 1 foot. Each sample location will be refilled with media and marked to avoid resampling the same site. Roots will be separated from shoots and media and placed in weighed paper bags and air dried. Plant roots and shoots will be analyzed for bulk density, selenium, chloride, arsenic, chromium, copper, zinc, sulfur, nitrogen, and phosphorus. Planting analysis will be conducted by IAS Laboratories at a rate of $85 per sample and coordinated by Reclamation. IAS Laboratories is located on 2525 E. University Drive, Phoenix, AZ 85034.

Media substrate will be sampled to determine nutrient and metal accumulation. Prior to placing substrates in the wetland tanks, two samples each for native soils and peat were collected to establish baseline conditions. Every 6 months, two surface substrate samples will be collected from each of the plots sampled for vegetation analysis. Media will be analyzed by IAS Laboratories for bulk density, selenium, chloride, arsenic, chromium, copper, zinc, sulfur, nitrogen, and phosphorus.

6. SOP Inspection, Data Collection and Analysis Forms

Forms for SOP Inspections, Data Collection and Analysis are included in the Appendices of this report.

7. Communication

All communications, including transfer of data, between Reclamation, City of Phoenix, City of Goodyear and CH2M HILL shall be via email. Monthly calls will be conducted between Reclamation and CH2M HILL to review operational results, water quality analyses, and look-ahead activities. These calls will also be used to make decisions on replanting if necessary.

The key contacts for this project and stakeholders involved are included in Table 6.

TABLE 6
Key Contacts

Name	Role	Entity	Phone	Email/Website
Thomas Poulson	Project Manager	Reclamation	(623) 773-6278 [o] (602) 578-2510 [c]	tpoulson@usbr.gov
Darlene Tuel	Staff Engineer	Reclamation	(623) 773-6268	dtuel@usbr.gov
Jim Bays	Senior Technologist	CH2M HILL	(813) 874-0777 [o] (813) 765-9286 [c]	jim.bays@ch2m.com
Michael Hwang	Project Engineer	CH2M HILL	(480) 377-6296 [o] (626) 823-6444 [c]	michael.hwang@ch2m.com
Ryan Rhoades	Project Manager	CH2M HILL	(480) 377-6212 [o] (602) 392-7214 (c)	ryan.rhoades@ch2m.com
Jerry Postama	Deputy Director of Water Resources	City of Goodyear	(623) 882-7517	jerry.postema@goodyearaz.gov
Keith Edwards	Bullard RO Facility Supervisor	City of Goodyear	(623) 693-0168	keith.edwards@goodyearaz.gov
Ruben Valoz	Operations Supervisor	City of Goodyear	(623) 932-3010	rveloz@goodyearaz.gov
Brandy Kelso	Project Representative	City of Phoenix	(602) 495-7676	brandy.kelso@phoenix.gov
Erich Lais	Project Representative	City of Phoenix	(602) 495-5938	erich.lais@phoenix.gov
Jennifer Calles	Water Quality Analysis	City of Phoenix Water Services Lab	(602) 256-5658	jennifer.calles@phoenix.gov
IAS Laboratories	Plant Analysis	IAS Laboratories	(602) 273-7248	caw@iaslabs.com www.iaslabs.com
Ross Coleman	Wetland Plant Nursery	Hydra Aquatic Inc.	(505) 249-9139	rcoleman7@gmail.com www.hydraaquatic.com

8. Troubleshooting Guidance

There are two types for issues that can be anticipated with the operation of the wetlands pilot. The first type is hydraulic related malfunctions in pilot equipment. Some examples of this include a broken flow meter, a burned out pump, cracks and leaks in the piping manifold, damage to storage tanks and clogged outlet pipes. In the case that any of these (or other hydraulic malfunctions) is observed, Reclamation should be contacted immediately so that damaged or malfunctioning equipment can be repaired or replaced if needed. CH2M HILL is also available to provide operations support and should be contacted when hydraulic issues are encountered.

The second type of issue that can be anticipated is biological issues observed in the wetland cells. Decline in plant health can evidence itself as the drying of leaves or stems, lack of growth or plant death. These effects should be investigated to determine if the root cause is related to hydration, soil conditions, or inherent to the plant. Lack of hydration may be a result of a hydraulic malfunction (e.g. damaged equipment reduces flow into a cell). In these cases, equipment should be repaired and replaced immediately. A second biological issue relates to soil conditions that may warrant evaluation and possibly replacement of the media in a cell. If a specific plant species is overtaken or consistently declining in multiple cells, it may be an indicator that the plant is not suitable for treatment of the RO concentrate or the cell configuration (media, flow, etc) may not be suitable for plant growth. In these cases, a re-evaluation of the planting schemes will be conducted between Reclamation and CH2M HILL. Any changes in planting will be documented and conducted by Reclamation.

The daily and weekly SOP inspections are designed to help monitor and identify signs of these two types of issues before they cause major problems in the pilot testing. This section will be updated by Reclamation and CH2M HILL as the pilot is performed to document all encountered issues and included in the interim pilot testing report after 6 months of operation.

9. References

CH2M HILL. 2008a. Technical Memorandum: “Preliminary Analysis of a Conceptual Wetland System for Managing Membrane Concentrate.” Prepared for U.S. Bureau of Reclamation. Phoenix Ariz.

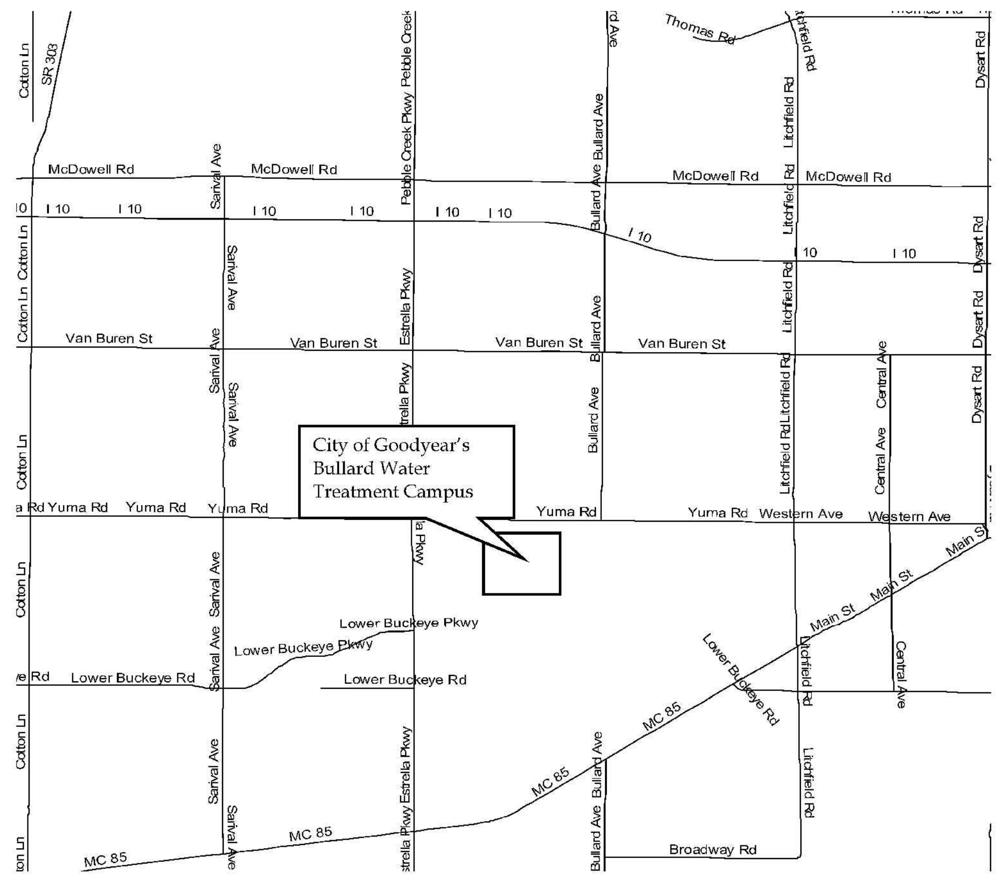
CH2M HILL. 2008b. Technical Memorandum: “Goodyear RO Concentrate Regulating Wetlands: Demonstration Facility Scale Analysis.” Prepared for U.S. Bureau of Reclamation. Phoenix, Ariz.

Poulson, T. 2007. White Paper: “A Salt Marsh: An Innovative Method of Managing Concentrate in the Greater Phoenix Area.” Prepared for U.S. Bureau of Reclamation. Phoenix, Ariz.

Appendix A
Pilot System Design Plans

USBR / GOODYEAR RO CONCENTRATE TREATMENT WETLANDS PILOT SYSTEM
JUNE 2009

LIST OF FIGURES



VICINITY MAP
NTS

CH2MHILL 2625 SOUTH PLAZA DR TEMPE, AZ 85282

TREATMENT WETLANDS PILOT SYSTEM

COVER SHEET, VICINITY MAP, & DRAWING INDEX

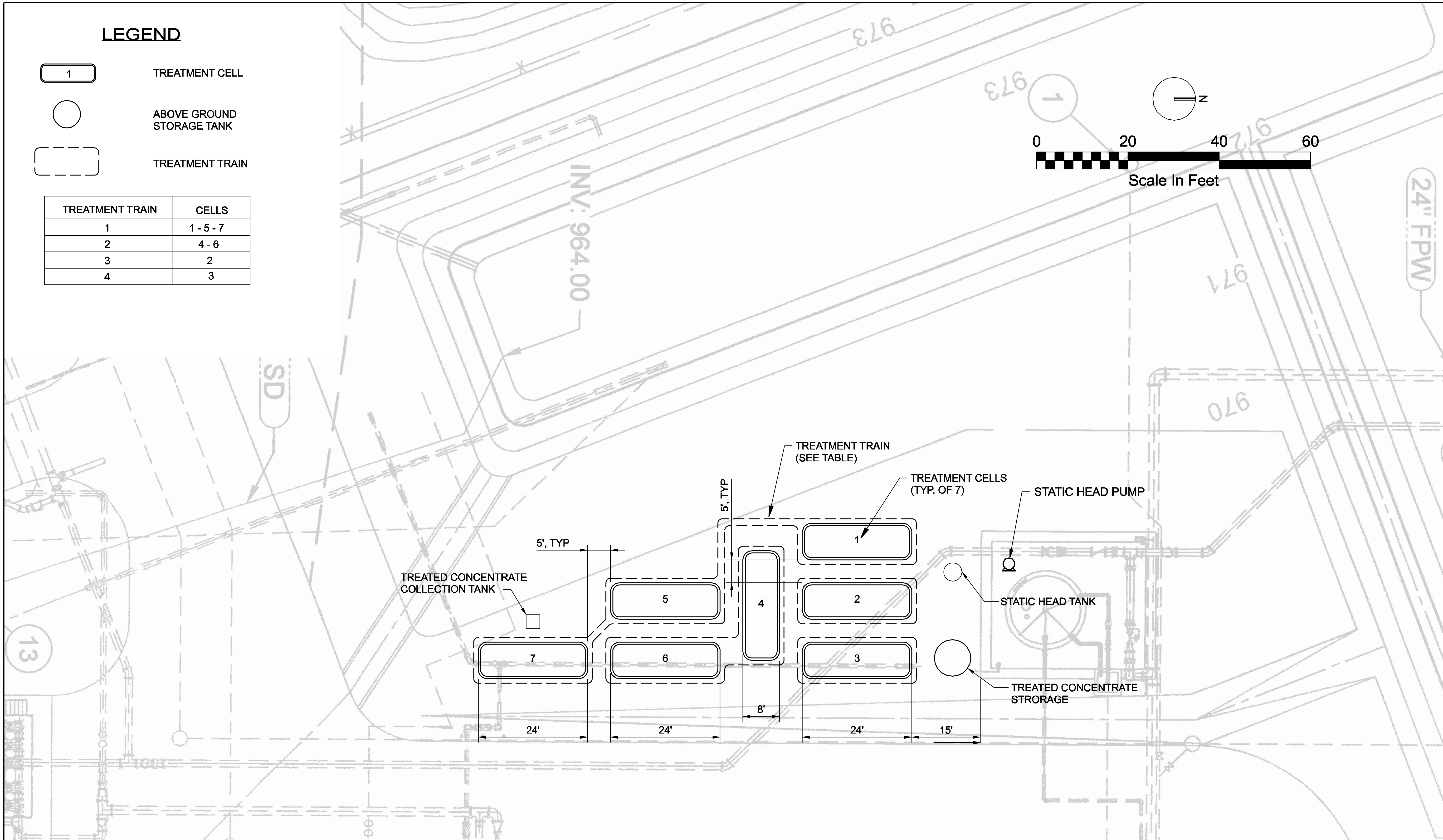
UNITED STATES BUREAU OF RECLAMATION

FIGURE 1

FILENAME: USBR-PS_FIG-01_COVER.dgn PLOT DATE: 06/03/2009 PLOT TIME: 9:32:44 PM

LEGEND

TREATMENT TRAIN	CELLS
1	1 - 5 - 7
2	4 - 6
3	2
4	3



CH2MHILL 2625 SOUTH PLAZA DR TEMPE, AZ 85282

TREATMENT WETLANDS PILOT SYSTEM

LAYOUT PLAN

UNITED STATES BUREAU OF RECLAMATION

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

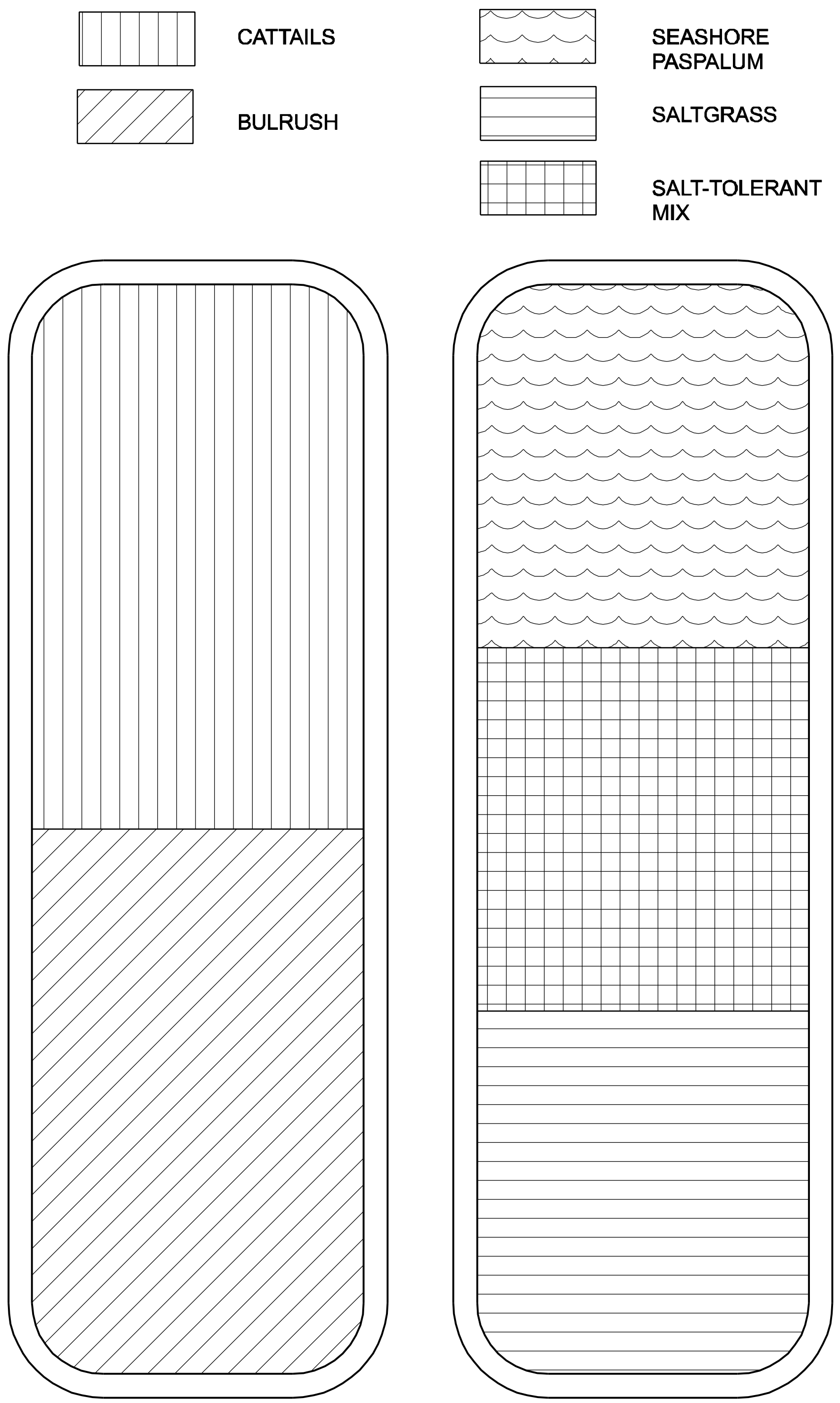
FIGURE 2

FILENAME: USBR-PS_FIG-02_PLAN.dgn PLOT DATE: 6/4/2009 PLOT TIME: 1:42:16 PM

	CELL 1		CELL 2		CELL 3		CELL 4		CELL 5		CELL 6		CELL 7	
	BOT	TOP	BOT	TOP	BOT	TOP	BOT	TOP	BOT	TOP	BOT	TOP	BOT	TOP
OUTLET MANIFOLD	LOWER		LOWER		LOWER		UPPER		LOWER		LOWER		LOWER	
LAYER THICKNESS (FT)	1	1	1	1	1	1	1	2	1	1	1	1	1	1
SOIL MEDIA TYPE	GRAVEL	PEAT MOSS	GRAVEL	GREEN WASTE	GRAVEL	PEAT MOSS	GRAVEL	GREEN WASTE	GRAVEL	PEAT MOSS	GRAVEL	PEAT MOSS	NATIVE SOIL	WATER
Flow Type	VERTICAL UPFLOW		VERTICAL UPFLOW		VERTICAL UPFLOW		VERTICAL UPFLOW		VERTICAL UPFLOW		VERTICAL UPFLOW		SURFACE FLOW	
VEGETATION	SALT TOLERANT MIX, SEASHORE PASPALUM, SALTGRASS		SALT TOLERANT MIX, SEASHORE PASPALUM, SALTGRASS		SALT TOLERANT MIX, SEASHORE PASPALUM, SALTGRASS		SALT TOLERANT MIX, SEASHORE PASPALUM, SALTGRASS		SALT TOLERANT MIX, SEASHORE PASPALUM, SALTGRASS		WETLAND MIX		WETLAND MIX	

MEDIA	GENERAL SPECIFICATIONS	QUANTITY (CY) 1	2	3	4	5	6	7
PEA GRAVEL	# 6 PEA GRAVEL (3/8 INCH DIAMETER), WASHED, LOCAL SOURCE	7	7	7	7	7	7	7
UNDERDRAIN GRAVEL	#57 CRUSHED GRAVEL (3/4-INCH DIAMETER), WASHED, LOCAL SOURCE	1	1	1	1	1		1
PEAT MOSS	FINE-TEXTURED SPHAGNUM, ASH CONTENT <15%, pH RANGE 4.9-5.2, LOOSE BULK DENSITY 0.12-0.15 G/CC, SHREDDED, UNCOMPACTED, UNIFORM, CLEAN HEMIC PEAT, NO FERTILIZER ADDED	7		7		7		7
GREEN WASTE	LOCAL MUNICIPAL COMPOSTED YARD WASTE/GRASS CLIPPINGS, AGED, FRIABLE, NO ODOR, FREE OF DEBRIS, NO FERTILIZER ADDED		7		14			
NATIVE SOIL	LOCAL LOAMY SAND OR SANDY LOAM, SAND 35-60%, SILT 30-55%, CLAY 10-25%, FREE OF DEBRIS, CLEAN FILL						7	

PLANT SPECIES			QUANTITY (NUMBER OF PLANTS) ON 2-FOOT CENTERS						
			1	2	3	4	5	6	7
COMMON NAME	Scientific Name	PROPAGULE							
SALT TOLERANT MIX									
FOURWING SALTBUSH	*Atriplex canescens*	BARE-ROOT OR NURSERY PLUG	40	40	40	40	40		
DESERT SEEPWEED	*Sueada suffrutescens*	BARE-ROOT OR NURSERY PLUG	40	40	40	40	40		
YERBA MANSA	*Anemopsis californica*	BARE-ROOT OR NURSERY PLUG	40	40	40	40	40		
ALKALI CORDGRASS	*Spartina gracilis*	BARE-ROOT OR NURSERY PLUG	40	40	40	40	40		
IODINEBUSH	*Allenrolfea occidentalis*	BARE-ROOT OR NURSERY PLUG	40	40	40	40	40		
BALTIC RUSH	*Juncus balticus*	BARE-ROOT OR NURSERY PLUG	40	40	40	40	40		
SEASHORE PASPALUM									
SEASHORE PASPALUM	*Paspalum vaginitum*	BARE-ROOT OR NURSERY PLUG	250	250	250	250	250		
SALTGRASS									
SALTGRASS	*Distichlis spicata*	BARE-ROOT OR NURSERY PLUG	260	260	260	260	260		
WETLAND MIX									
CATTAIL	*Typha domingensis*	FIELD-HARVEST						250	250
BULRUSH	*Schoenoplectus maritimus*	FIELD-HARVEST OR BARE-ROOT						250	250
BULRUSH	*Schoenoplectus pungens*	FIELD-HARVEST OR BARE-ROOT						250	250



BULLARD SITE
SURFACE FLOW SYSTEM
(CELL 7)

BULLARD SITE
VERTICAL FLOW SYSTEM
(CELLS 1-6)

VALVE IDENTIFICATION	SIZE (INCHES)	VALVE TYPE	VENDOR	PART #	QUANTITY
TYPE V301	<2	BALL VALVE TYPE	ASAHI/AMERICA	1601010/1601020	50
TYPE V304	4	BALL VALVE TYPE	ASAHI/AMERICA	1603040	10

CH2MHILL
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TEMPE, AZ 85282

TREATMENT WETLANDS PILOT SYSTEM

PLANTING PLAN

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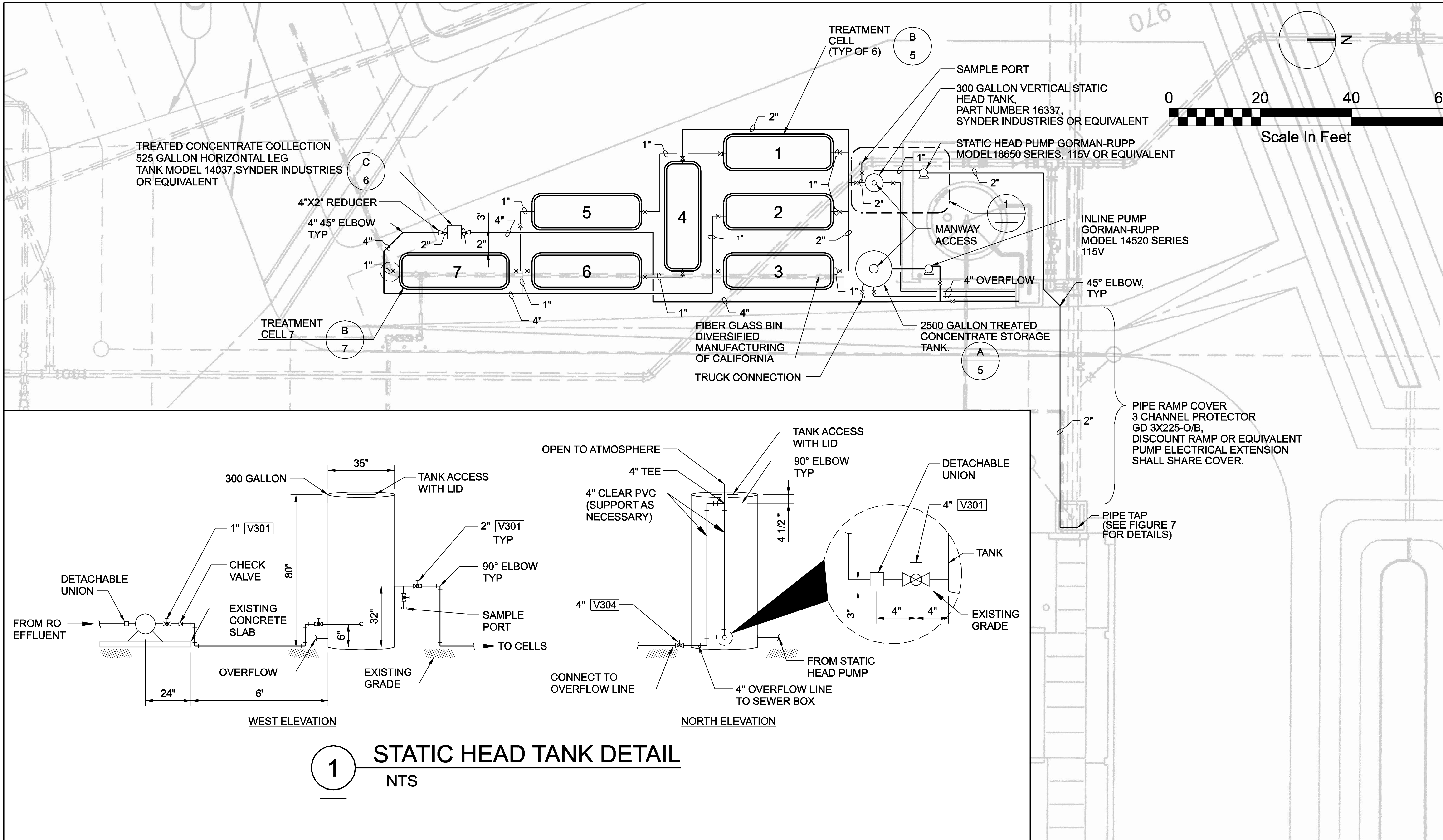
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

FIGURE 3

FILENAME: USBR-PS_FIG-03_PLANTING PLOT DATE: 6/4/2009 PLOT TIME: 1:43:56 PM



LEGEND

1	TREATMENT CELL		ABOVE GROUND STORAGE TANK		MANUAL BALL VALVE		REDUCER
1"	PIPING WITH SIZE		PUMP		CHECK VALVE		DETACHABLE UNION

CH2MHILL
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TEMPE, AZ 85282

TREATMENT WETLANDS PILOT SYSTEM

CONCEPTUAL PIPING PLAN

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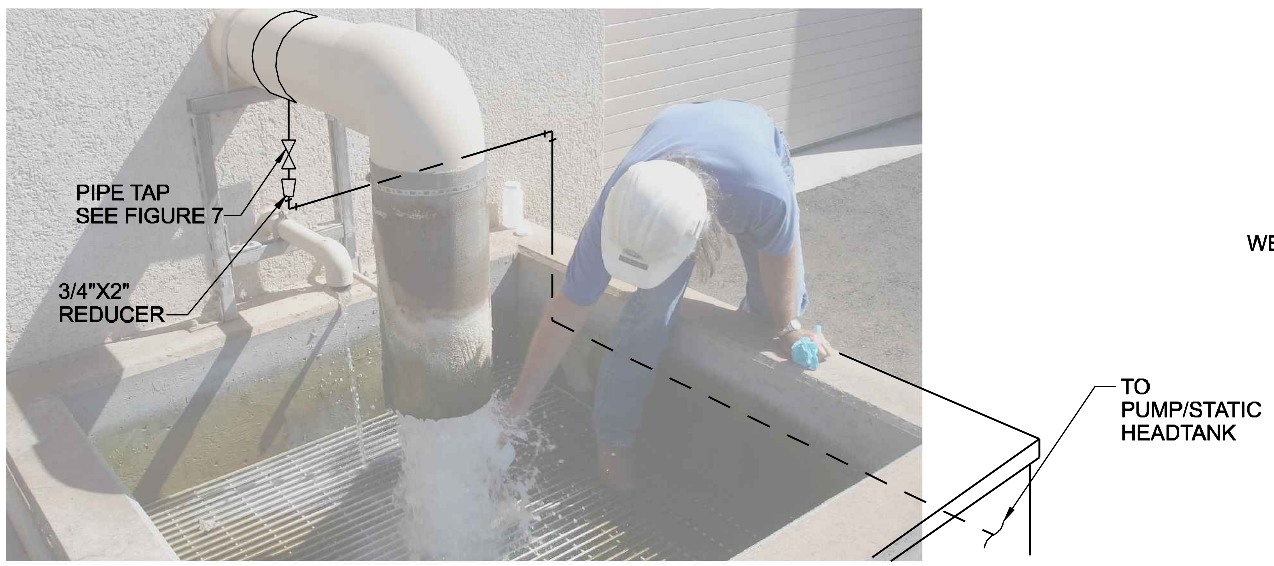
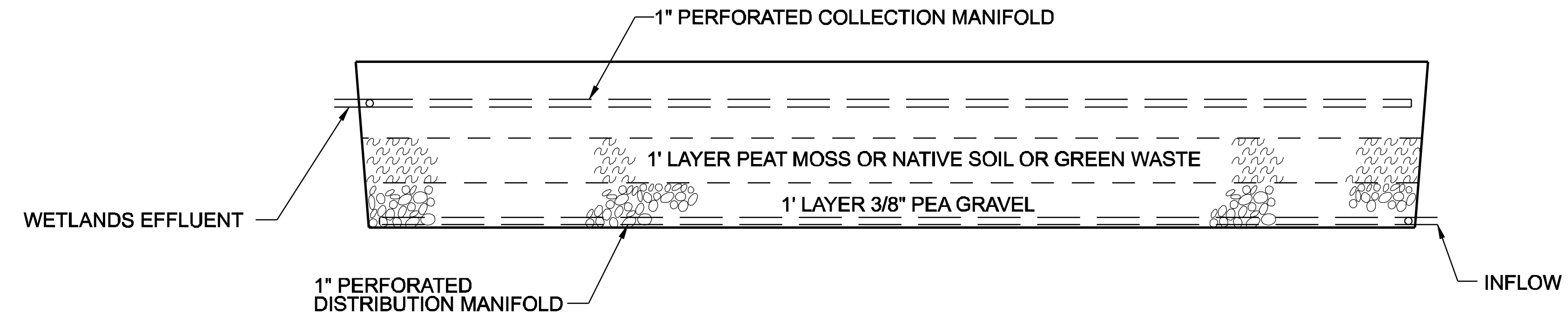
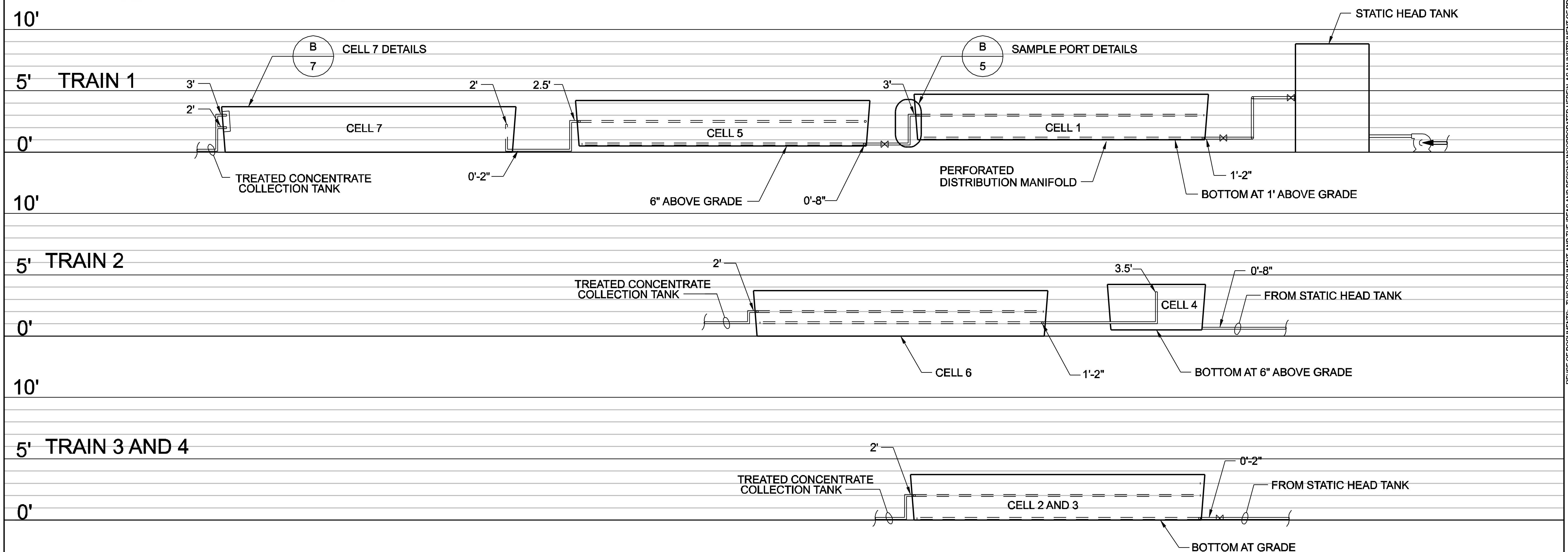
FIGURE 4

FILENAME: USBR-PS_FIG-04_PIPING.dgn PLOT DATE: 6/4/2009 PLOT TIME: 3:15:00 PM





TYPICAL TREATMENT CELL SECTION



0 8 16 24

Scale In Feet

CH2MHILL 2625 SOUTH PLAZA DR TEMPE, AZ 85282

TREATMENT WETLANDS PILOT SYSTEM

CONCEPTUAL CROSS SECTION
HYDRAULIC PLAN

UNITED STATES
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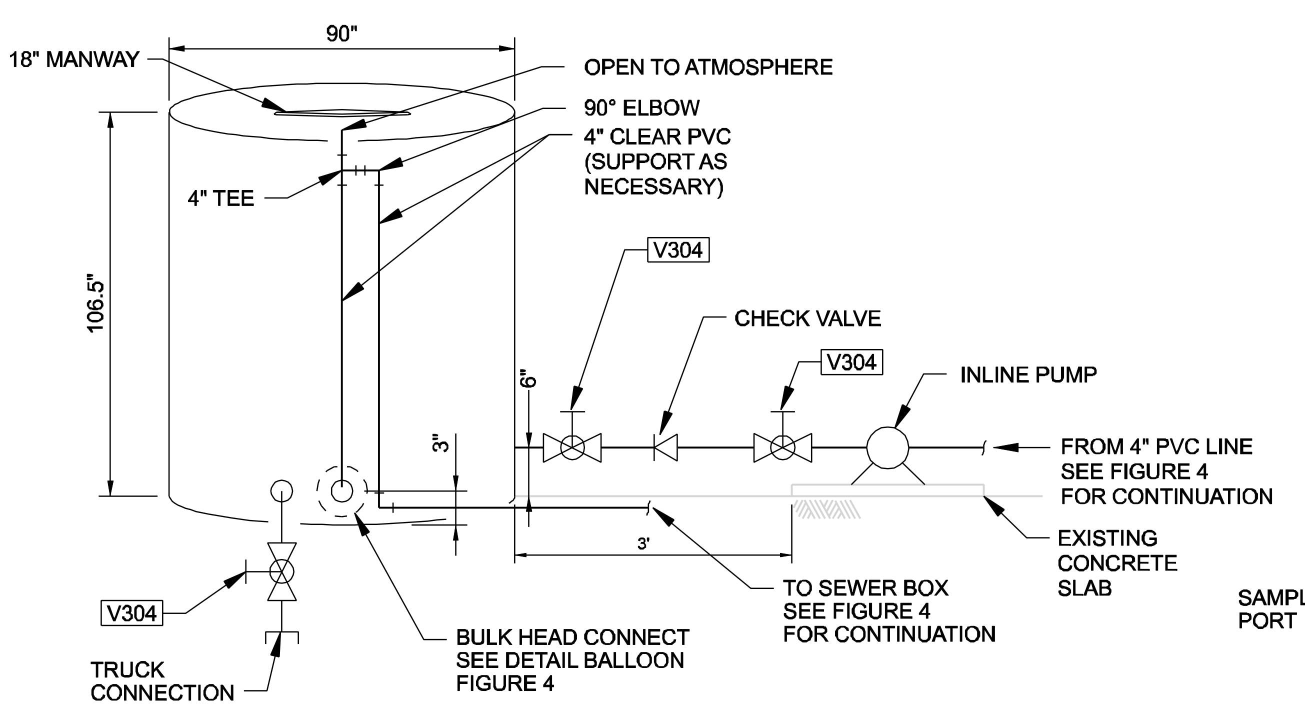
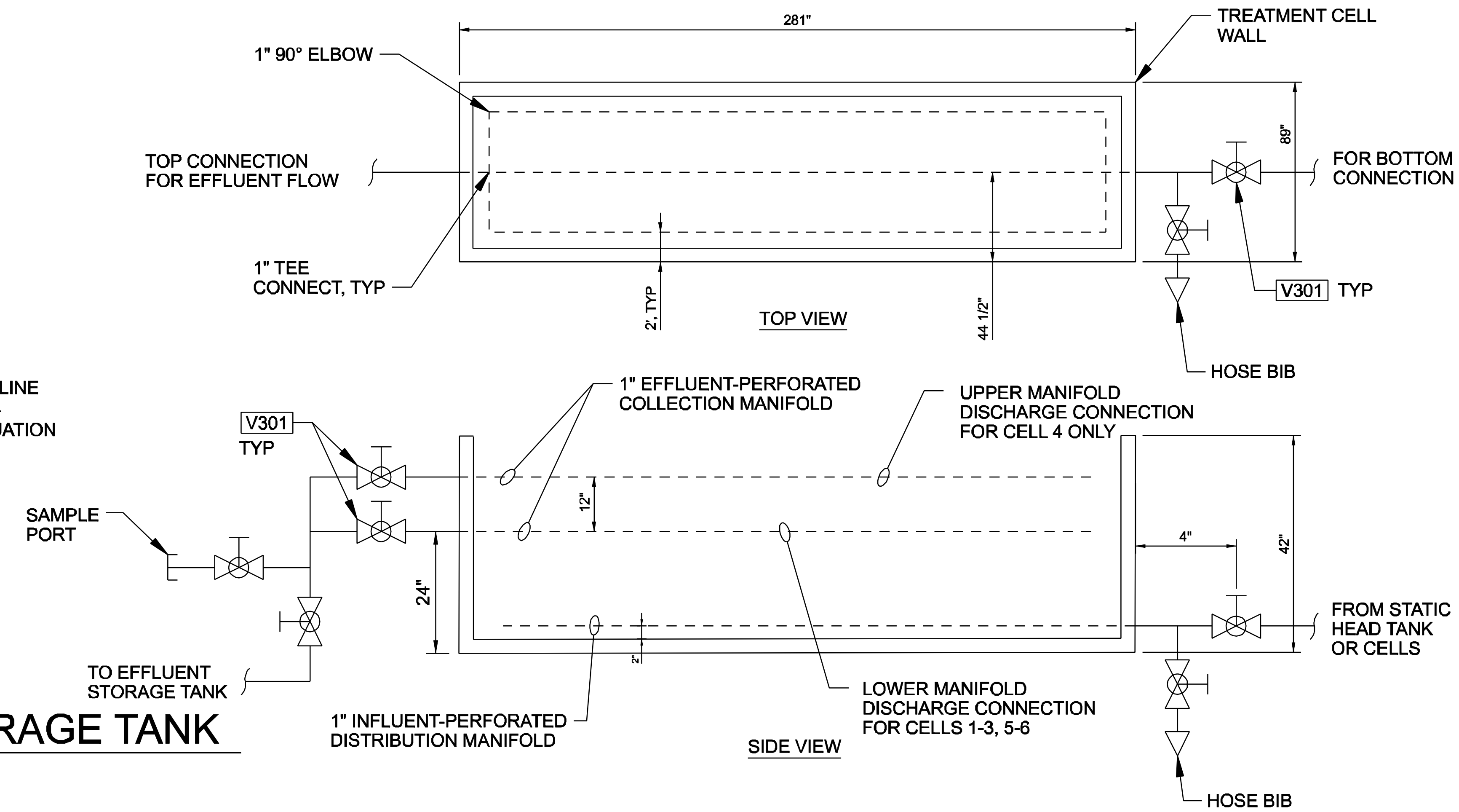
FIGURE 5

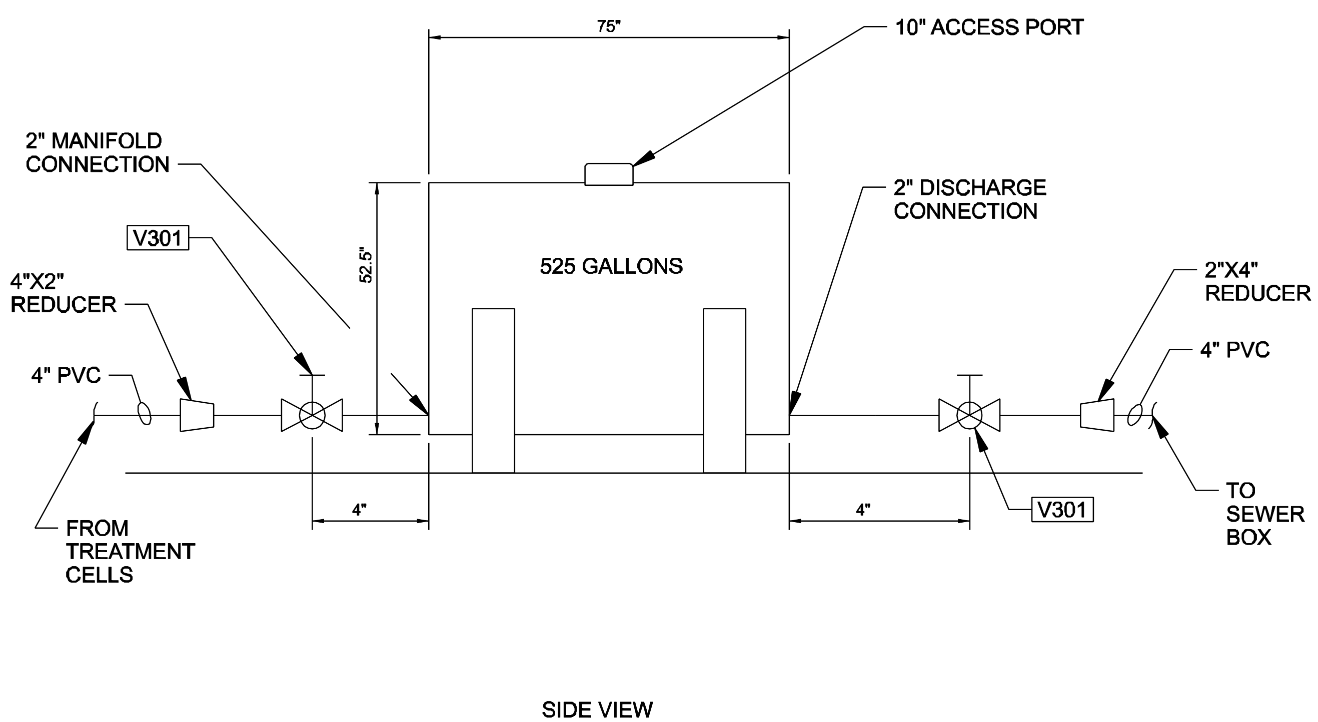
FILENAME: USBR-PS_FIG-05_XSECTS.ai PLOT DATE: 06/04/2009 PLOT TIME: 9:55:35 AM



A
2500 GALLON TREATED CONCENTRATET STORAGE TANK
NTS



B
TREATMENT CELL 1-6 DETAIL
NTS



C
TREATED CONCENTRATE COLLECTION DETAIL
NTS

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TEMPE, AZ 85282

TREATMENT WETLANDS PILOT SYSTEM
DETAILS - 1

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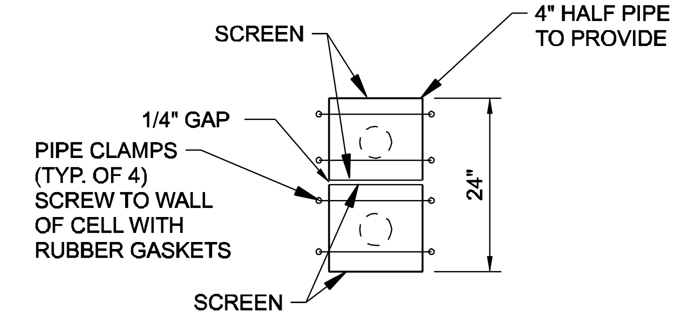
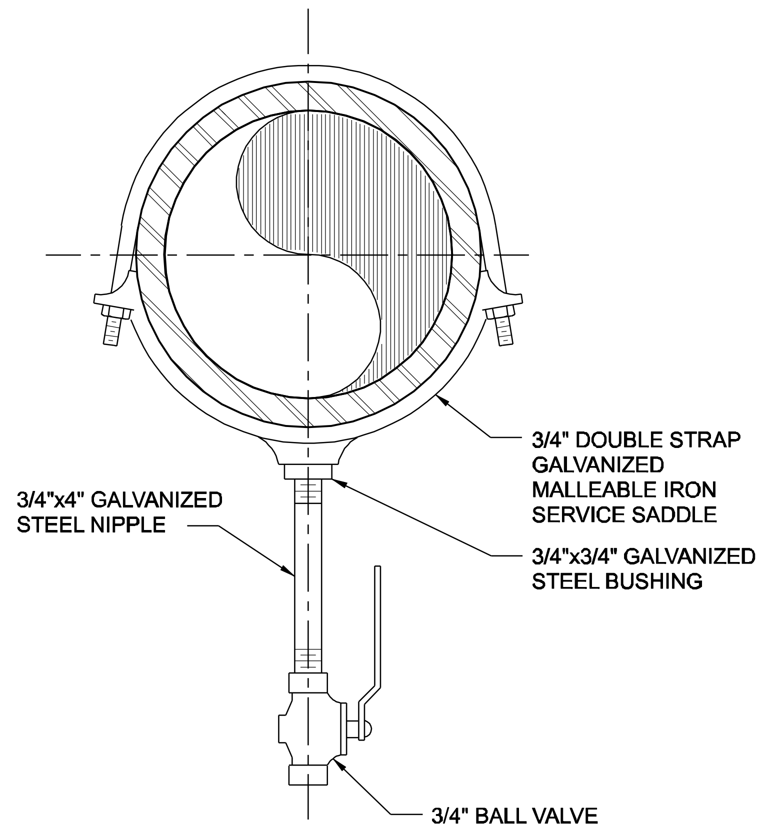
FIGURE 6

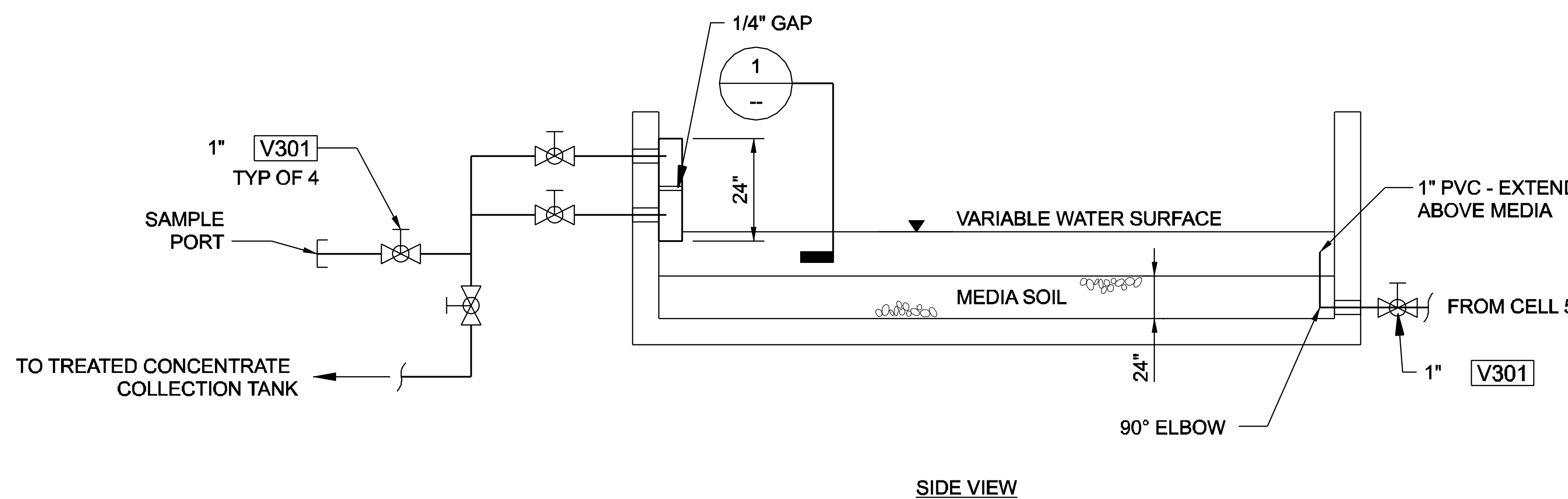
FILENAME: USBR-PS_FIG-06_DETAILS PLOT DATE: 6/4/2009 PLOT TIME: 3:38:33 PM



1 DETAIL
NTS



A PIPE TAPPING SLEEVE
NTS



B CELL 7 DETAIL
NTS

CH2MHILL
2625 SOUTH PLAZA DR
TEMPE, AZ 85282

TREATMENT WETLANDS PILOT SYSTEM

DETAILS - 2

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FIGURE 7

FILENAME: USBR-PS_FIG-07_DETAILS2.dgn PLOT DATE: 6/4/2009 PLOT TIME: 3:17:26 PM

Appendix B
Daily and Weekly Standard Operating Procedures (SOP) Checklist

Morning Daily Standard Operating Procedures (SOP) Checklist

USBR/Goodyear RO Concentrate Treatment Wetlands Pilot

Name: ________________________
Date/Time: ________________________
Temperature: ________________________
Humidity: ________________________
Weather: Cloudy / Partly Cloudy / Clear (Circle one)

Which well is serving the RO plant today?

Check Influent Flow

Is there RO Concentrate flowing from the RO Plant? Y/N
Is the influent pump operating? Y/N
Record Flow Meter readings for each Train below

Cell 1	*Cell 2*	*Cell 3*	*Cell 4*

Wetland Cell Inspection

Record outflows readings for each cell by using time volume (stopwatch bucket) method for 30 seconds.

Cell 1	*Cell 2*	*Cell 3*	*Cell 4*	*Cell 5*	*Cell 6*	*Cell 7*

Is the soil in each cell moist? If not, please describe below. Y/N
Are there any significant changes in plants since the last visit (e.g. sudden death or frost kill)? If yes, describe. Y/N

Additional Inspection Notes

Use space below to document any irregularities observed in the pilot facility. Some examples of irregularities include cracks and leaks in piping or tanks, flow meter malfunction, flooding or damage of wetland cells, pump shut down and plant death. Reclamation and CH2M HILL should be notified immediately if any irregularities are observed.

All forms should be filled out on a daily basis and emailed to Reclamation and CH2M HILL at the end of each week. For questions or to report irregularities please call Reclamation or CH2M HILL.

Tom Poulson/Reclamation	*(602) 578-2510*	*tpoulson@usbr.gov*
Darlene Tuel/Reclamation	*(623) 773-6268*	*dtuel@usbr.gov*
Michael Hwang/CH2M HILL	*(480) 377-6296*	*mhwang@ch2m.com*

Last Revised on 6/20/2011

Weekly Standard Operating Procedures (SOP) Checklist

USBR/Goodyear RO Concentrate Treatment Wetlands Pilot

Name: ______________________
Date/Time: ______________________
Temperature: ______________________
Humidity: ______________________
Weather: Cloudy / Partly Cloudy / Clear (Circle one)

Which well is serving the RO plant today?

Check Influent Flow

Is there RO Concentrate Flowing from the RO Discharge Line? Y/N
Is the influent pump operating? Y/N
Record Flow Meter readings for each Train below

Cell 1	*Cell 2*	*Cell 3*	*Cell 4*

Wetland Cell Inspection

Record outflows readings for each cell by using time volume method

Cell 1	*Cell 2*	*Cell 3*	*Cell 4*	*Cell 5*	*Cell 6*	*Cell 7*

Is the soil in each cell moist? If not, please describe below. Y/N
Are there any significant changes in plants since the last visit (e.g. sudden death or frost kill)? If yes, describe below. Y/N

____
____
____

Pump and Pipeline Cracks and Leaks

Are there cracks or leaks in the pipeline or in the pump? If yes, describe below. Y/N

____
____
____

Tank Inspection

Check Vertical Static Tank, Effluent Storage Tank and Effluent Connection Tank for leaks, cracks and sediment buildup.
Please describe observations in space below.

____
____
____

Plant Health Assessment

Use space below to estimate plant cover in each cell.

Species	*Cell 1*	*Cell 2*	*Cell 3*	*Cell 4*	*Cell 5*	*Cell 6*	*Cell 7*
Scratch Grass Muhly							
Alkali Saction							
Creeping Spike Rush							
Baltic Rush							
Yerba Manza							
Fourwing Salt Brush							
Seep Willow							
Salt Grass							
Cattail							
Olney's Three Square Rush							
Soft Stem Bulrush							

Weekly Standard Operating Procedures (SOP) Checklist

USBR/Goodyear RO Concentrate Treatment Wetlands Pilot

(Plant Health Assessment continued...)

Use Space below to provide a written description of the plants at each cell

Cell 1

Cell 2

Cell 3

Cell 4

Cell 5

Cell 6

Cell 7

Water Quality Parameters (Onsite Measurements)

Sampling Point	Influent	Effluent						
		Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7
DO mg/L								
Temperature °C								
Conductivity S/m								
pH								
ORP								

Additional Inspection Notes

Appendix B
Flow and Water Quality Data

Appendix B-1
Monthly Average Flows
Regulating Wetlands Pilot Study for Concentrate Management

Month	Train 1 Flows (gpm)					
	Bin 1 In	Bin 1 Eff	Bin 5 In	Bin 5 Eff	Bin 7 In	Bin 7 Eff
Dec-2010	0.244	0.178	0.178	0.130	0.130	0.167
Jan-2011	0.231	0.193	0.193	0.145	0.145	0.195
Feb-2011	0.100	0.069	0.069	0.028	0.028	0.096
Mar-2011	0.207	0.139	0.139	0.098	0.098	0.129
Apr-2011	0.215	0.180	0.180	0.110	0.110	0.295
May-2011	0.230	0.181	0.181	0.120	0.096	0.150
Jun-2011	0.198	0.149	0.149	0.097	0.097	0.105
Jul-2011	0.229	0.199	0.199	0.132	0.132	0.142
Aug-2011	0.227	0.208	0.208	0.144	0.144	0.150
Sep-2011	0.230	0.208	0.208	0.164	0.164	0.149
Oct-2011	0.230	0.218	0.218	0.182	0.182	0.174
Nov-2011	0.242	0.236	0.236	0.203	0.203	0.211
Dec-2011	0.233	0.237	0.230	0.225	0.225	0.230

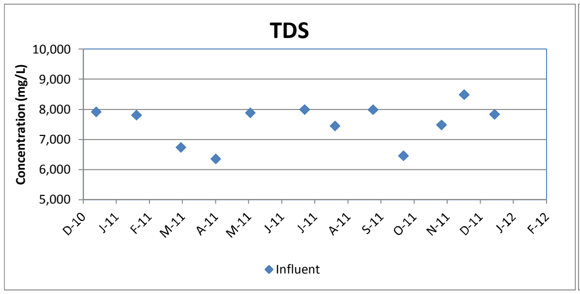
Appendix B-1

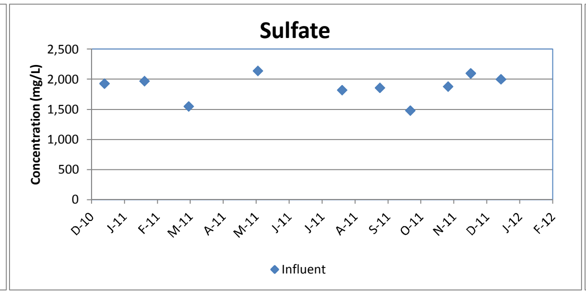
Monthly Average Flows

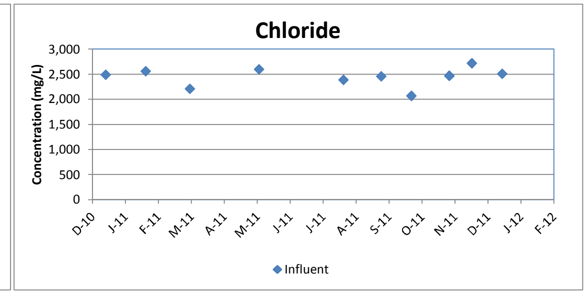
Regulating Wetlands Pilot Study for Concentrate Management

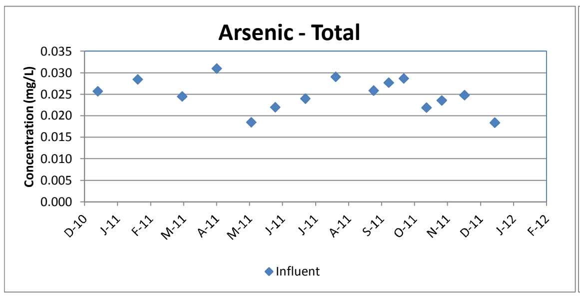
Month	Train 2 Flows (gpm)				Train 3 Flows (gpm)		Train 4 Flows (gpm)	
	Bin 4 In	Bin 4 Eff	Bin 6 In	Bin 6 Eff	Bin 2 In	Bin 2 Eff	Bin 3 In	Bin 3 Eff
Dec-2010	0.251	0.240	0.240	0.225			0.269	0.245
Jan-2011	0.245	0.230	0.230	0.116			0.240	0.178
Feb-2011	0.100	0.142	0.142	0.074			0.108	0.101
Mar-2011	0.090	0.080	0.080	0.050			0.096	0.078
Apr-2011	0.100	0.085	0.085	0.042			0.100	0.071
May-2011	0.118	0.090	0.090	0.038			0.098	0.071
Jun-2011	0.148	0.117	0.117	0.061			0.105	0.068
Jul-2011	0.220	0.216	0.216	0.138	0.071	0.049	0.094	0.070
Aug-2011	0.232	0.209	0.209	0.115	0.080	0.066	0.110	0.096
Sep-2011	0.230	0.214	0.214	0.153	0.087	0.073	0.100	0.090
Oct-2011	0.213	0.189	0.189	0.130	0.083	0.081	0.100	0.093
Nov-2011	0.198	0.154	0.154	0.110	0.074	0.079	0.104	0.096
Dec-2011	0.227	0.224	0.224	0.198	0.097	0.088	0.097	0.093

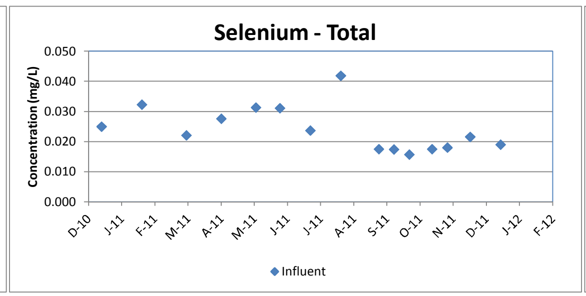
Appendix B-2
RO Concentratate (Influent) Water Quality Summary
Regulating Wetlands Pilot Study for Concentrate Management

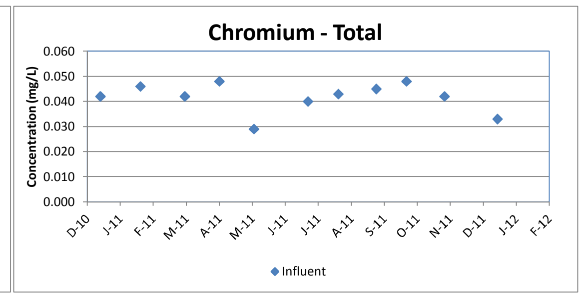


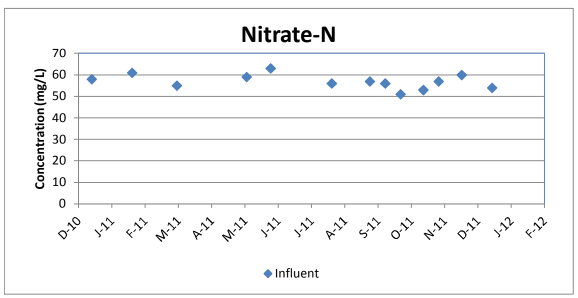


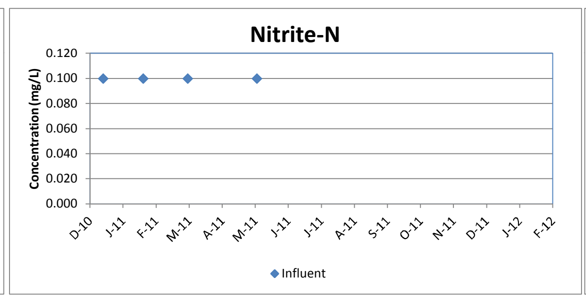


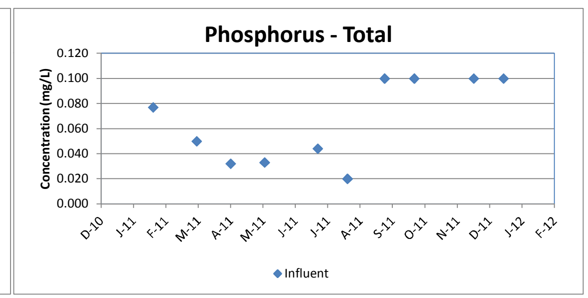




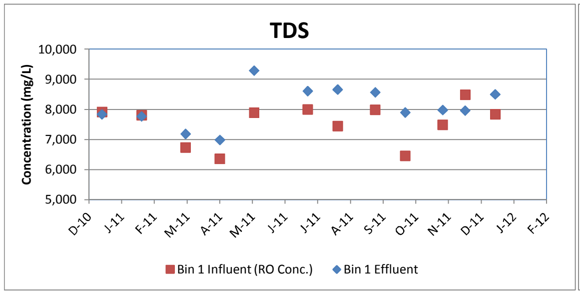


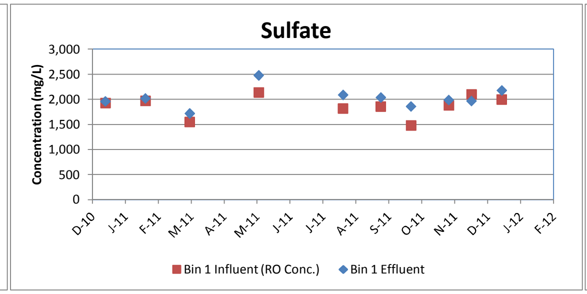


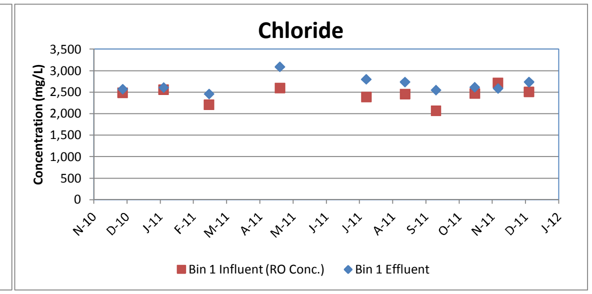


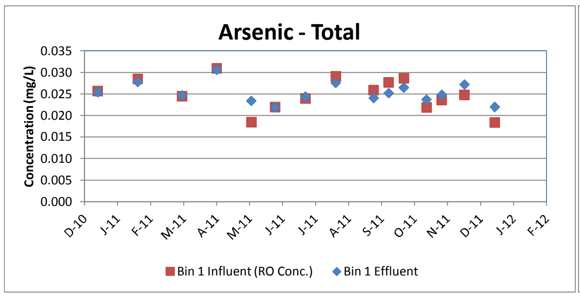


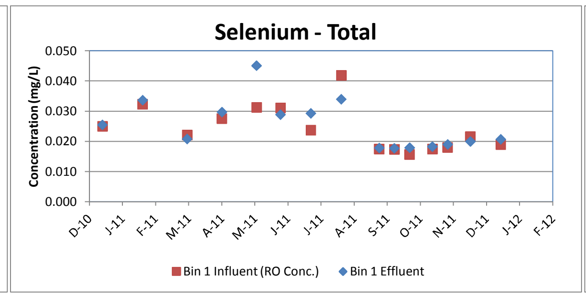
Appendix B-3
Bin 1 Water Quality Data Summary
Regulating Wetlands Pilot Study for Concentrate Management

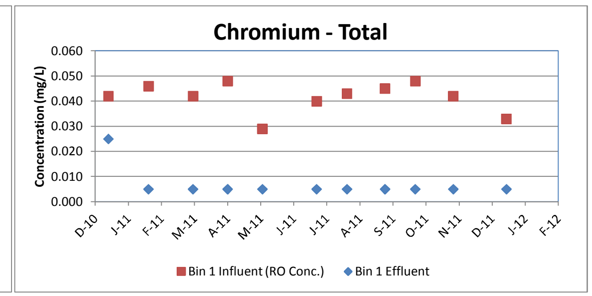


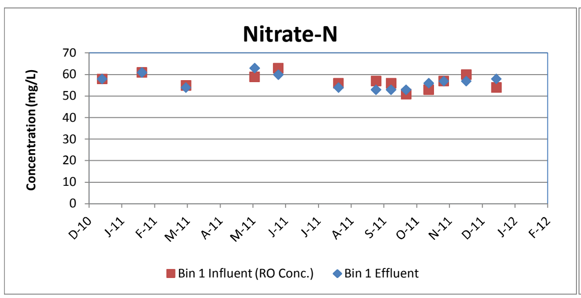


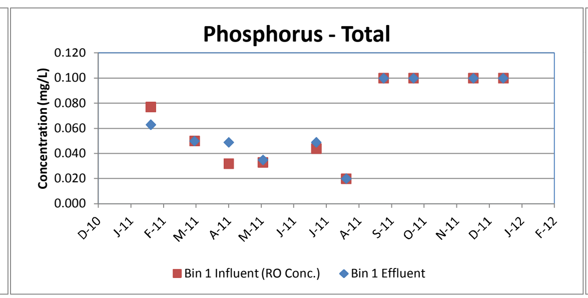


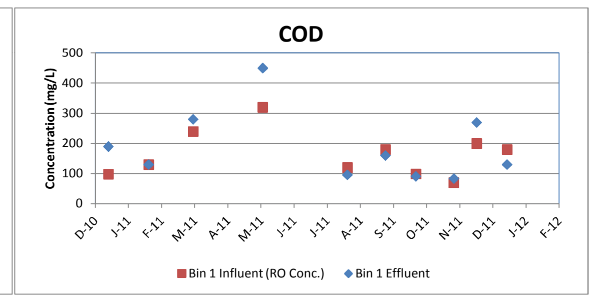




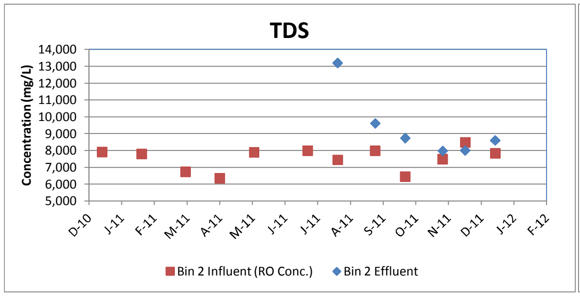


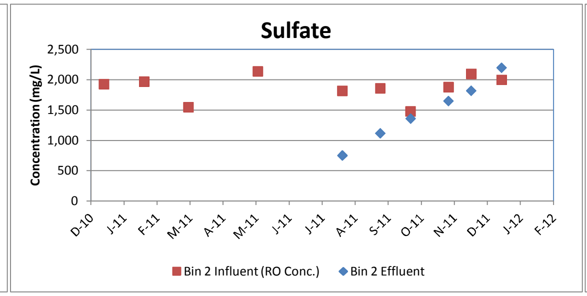


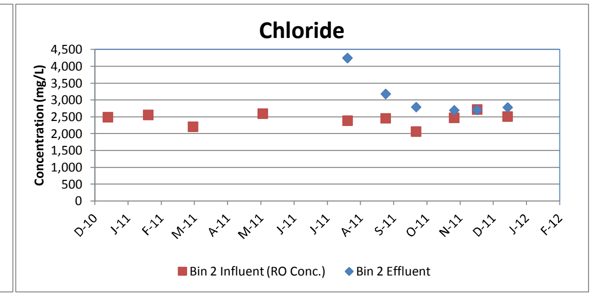


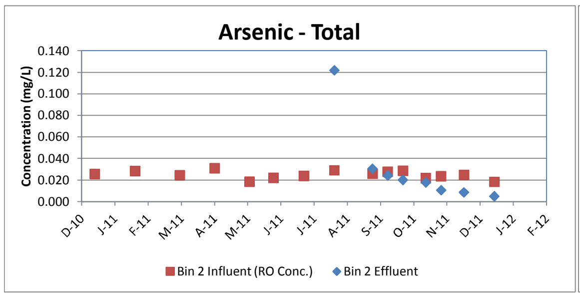


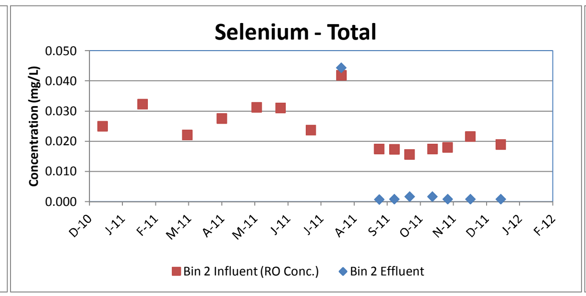
Appendix B-4
Bin 2 Water Quality Data Summary
Regulating Wetlands Pilot Study for Concentrate Management

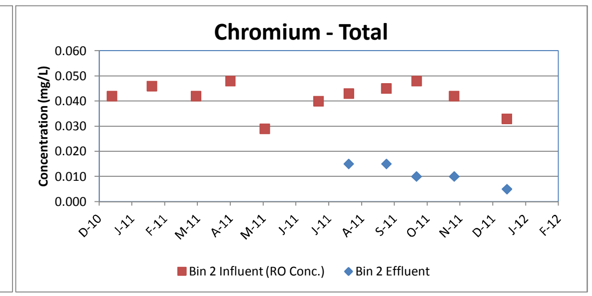


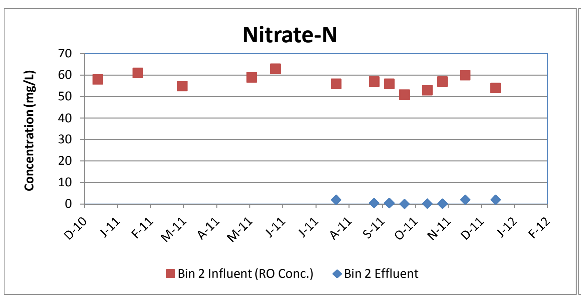


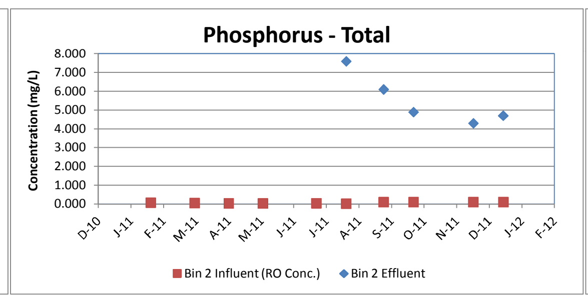


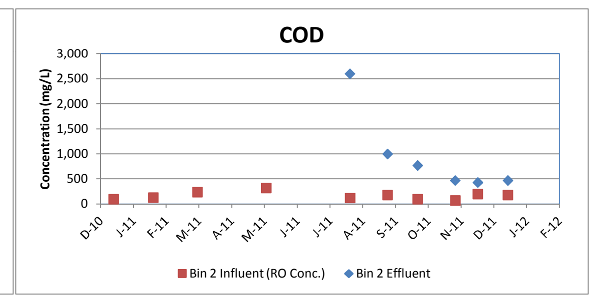




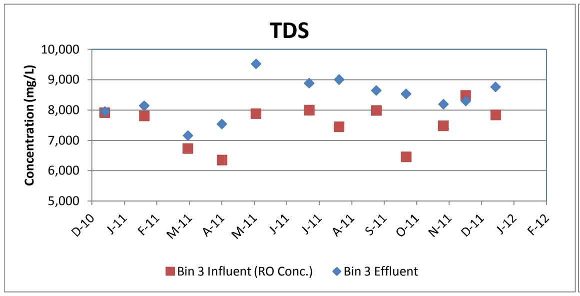


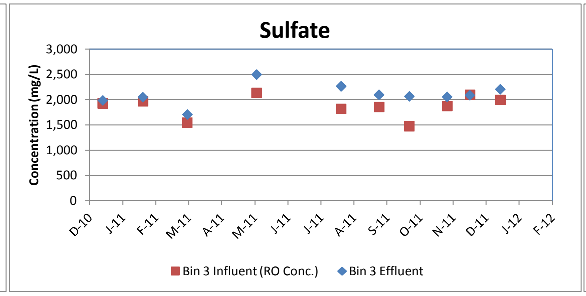


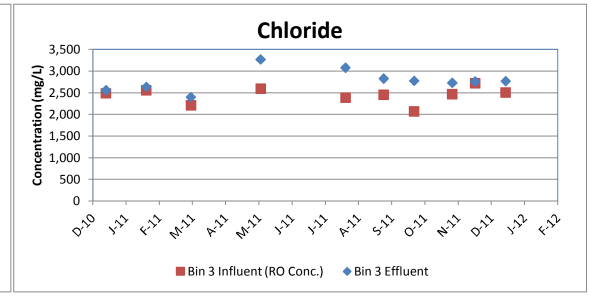


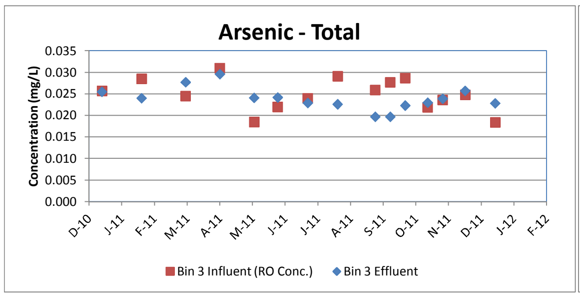


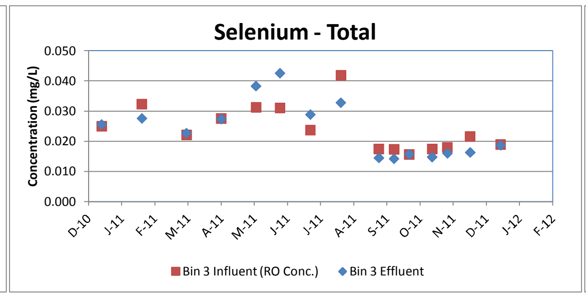
Appendix B-5
Bin 3 Water Quality Data Summary
Regulating Wetlands Pilot Study for Concentrate Management

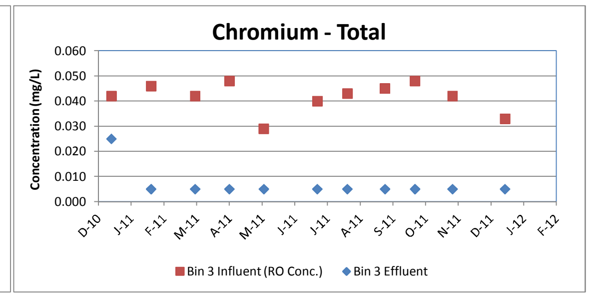


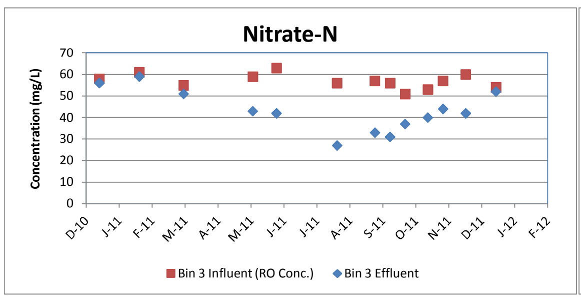


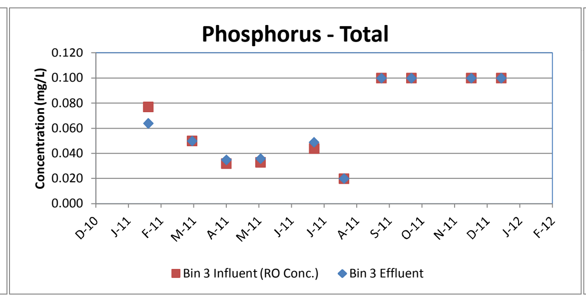


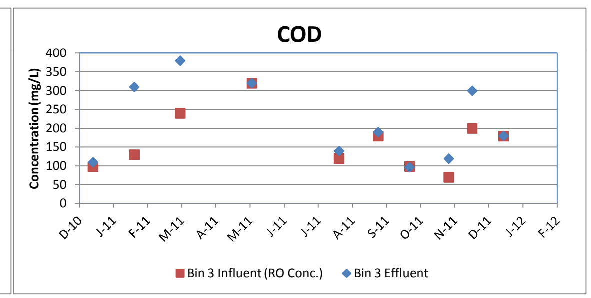




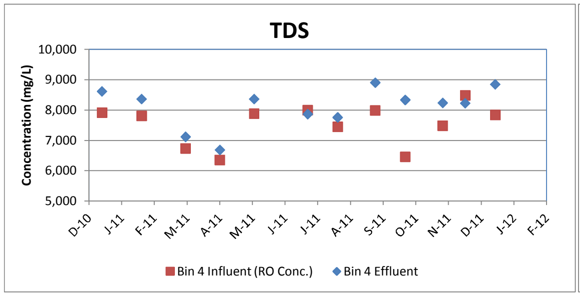


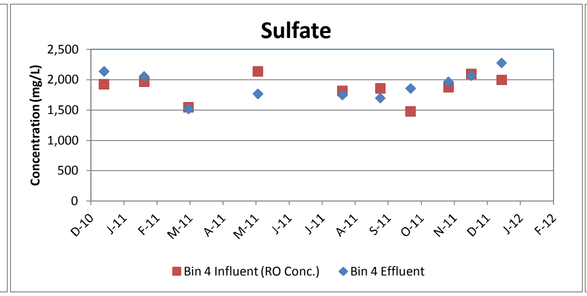


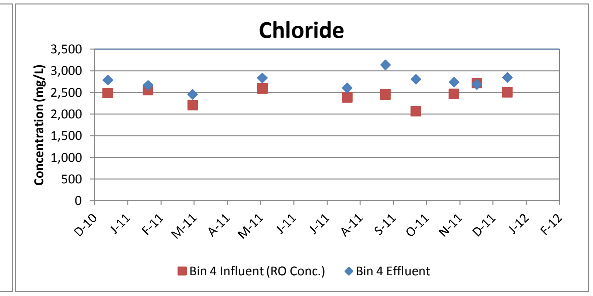


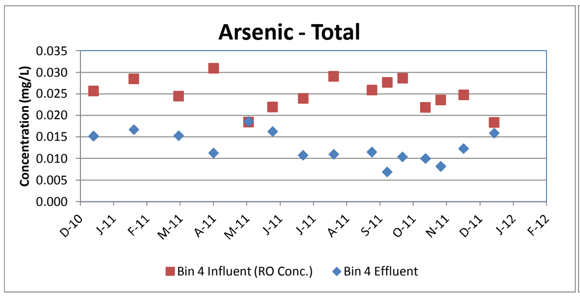


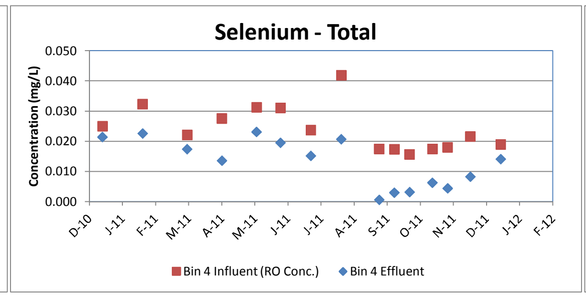
Appendix B-6
Bin 4 Water Quality Data Summary
Regulating Wetlands Pilot Study for Concentrate Management

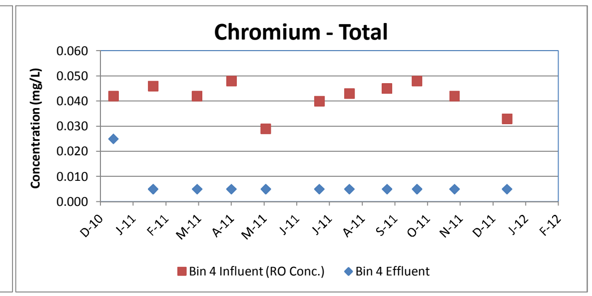


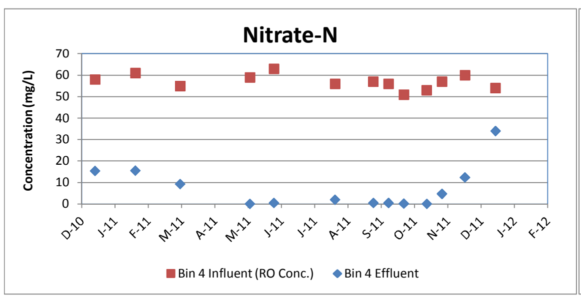


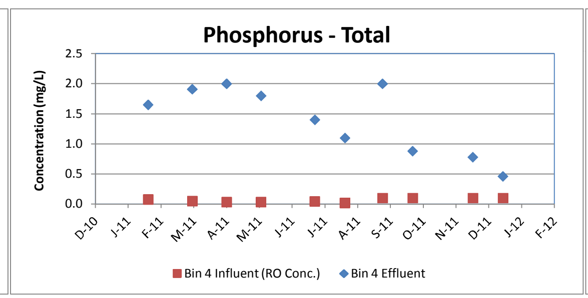


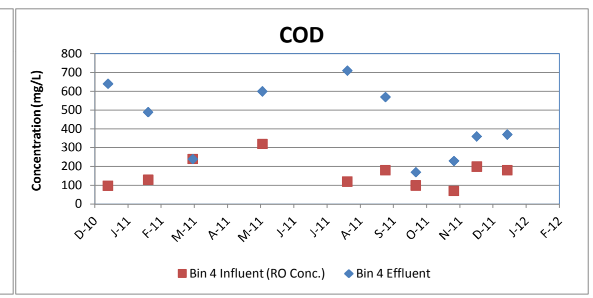




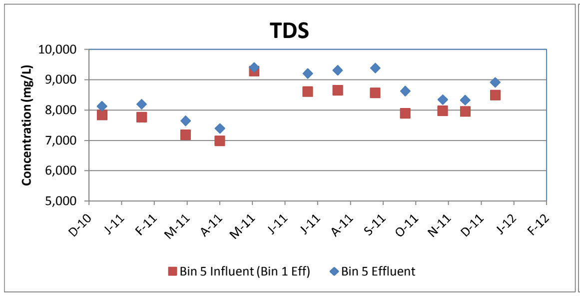


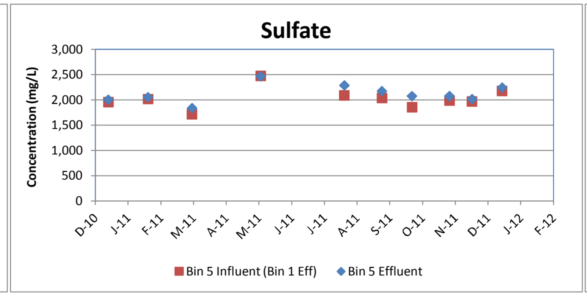


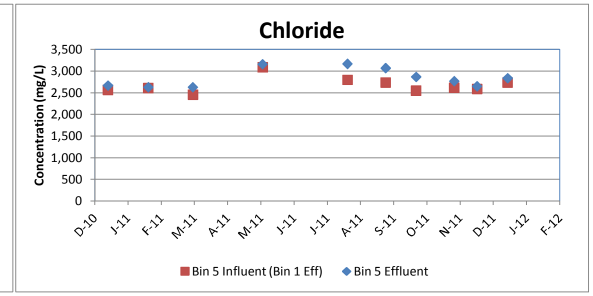


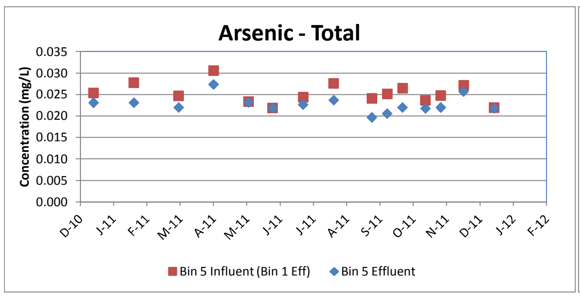


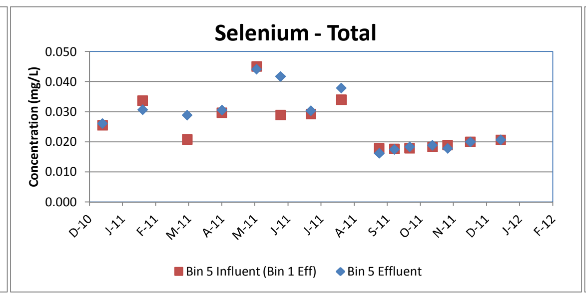
Appendix B-7
Bin 5 Water Quality Data Summary
Regulating Wetlands Pilot Study for Concentrate Management

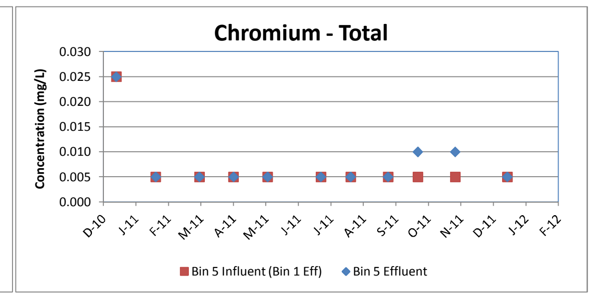


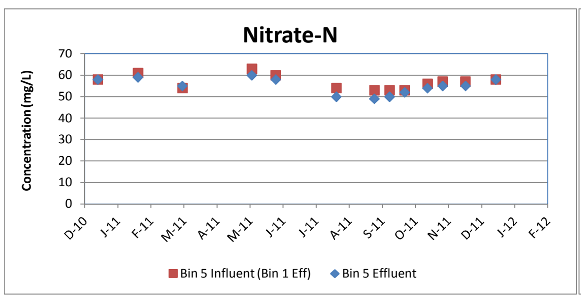


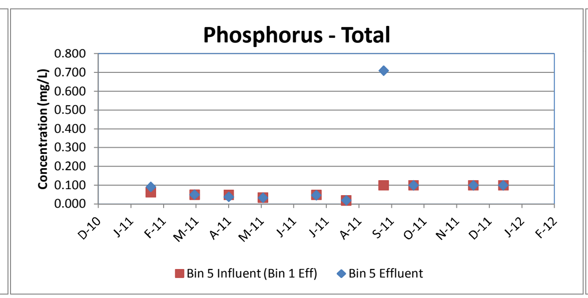


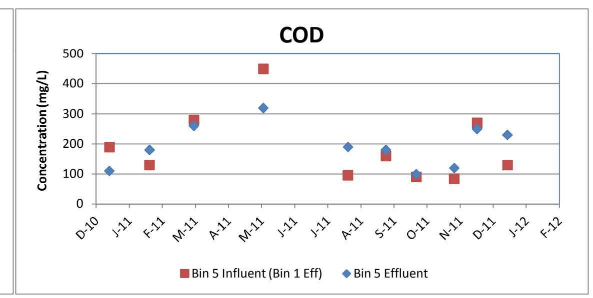




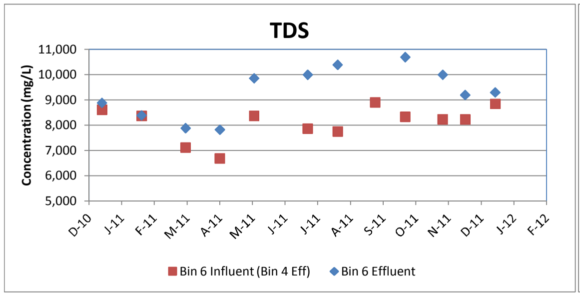


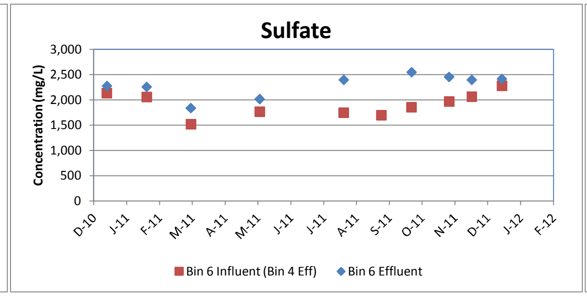


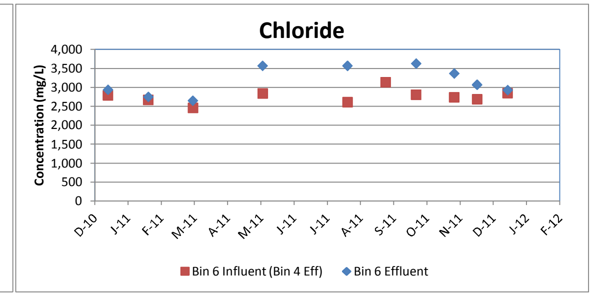


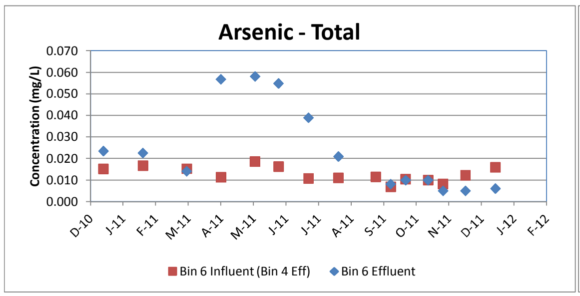


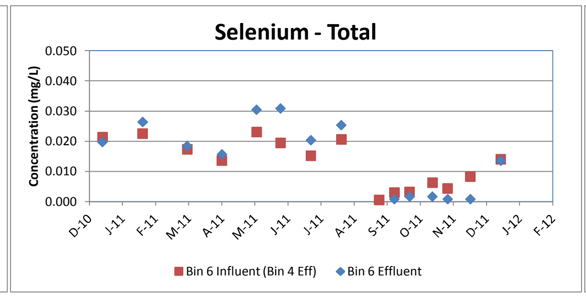
Appendix B-8
Bin 6 Water Quality Data Summary
Regulating Wetlands Pilot Study for Concentrate Management

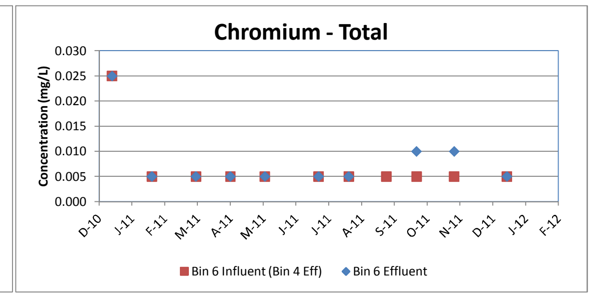


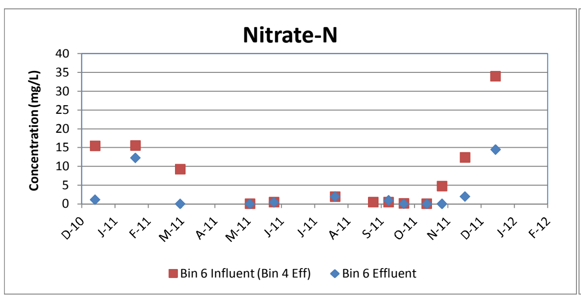


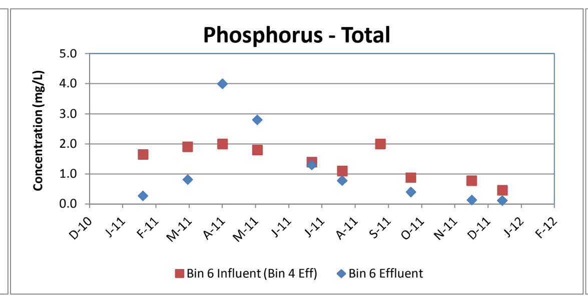


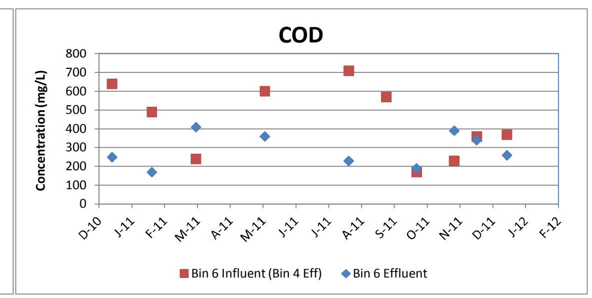




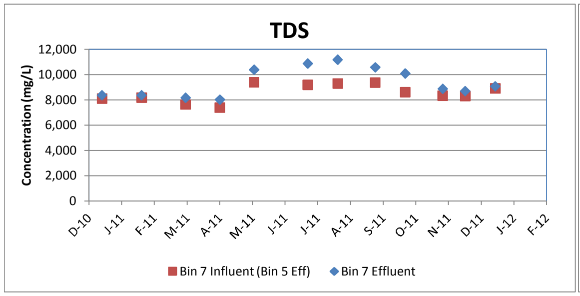


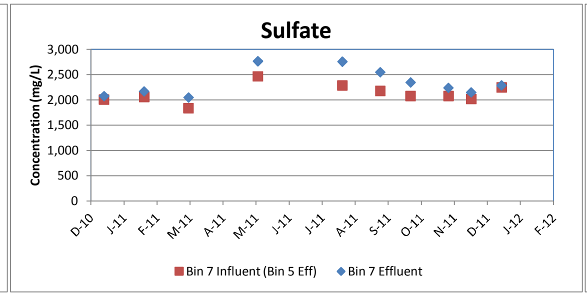


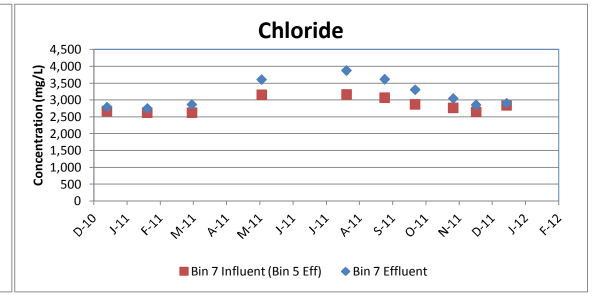


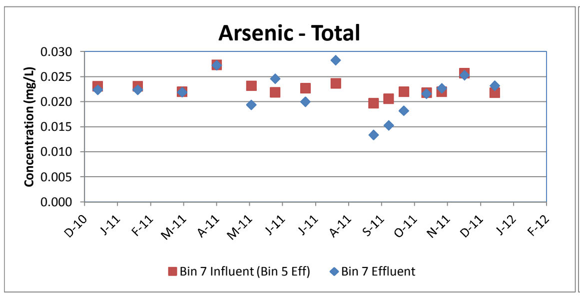


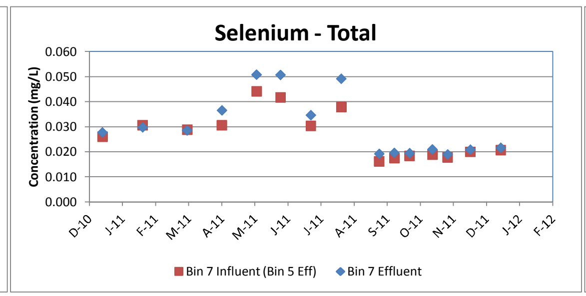
Appendix B-9
Bin 7 Water Quality Data Summary
Regulating Wetlands Pilot Study for Concentrate Management

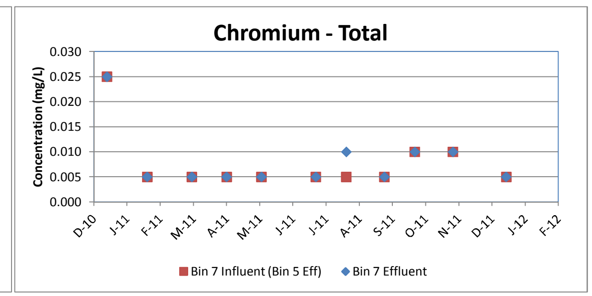


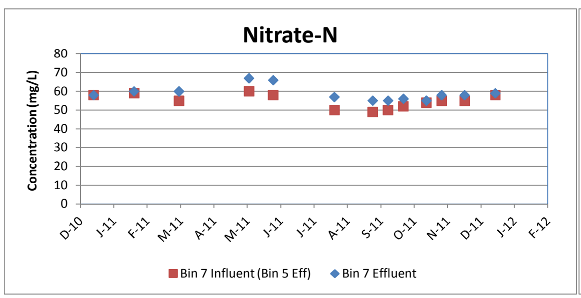


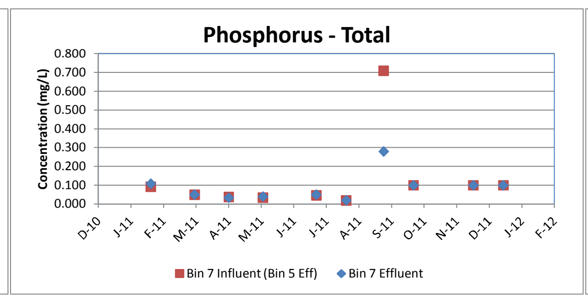


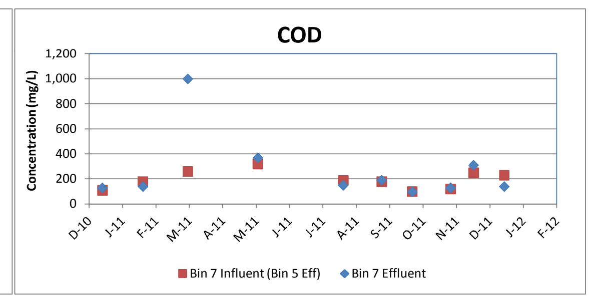




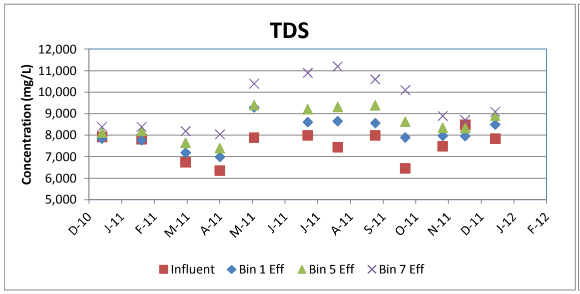


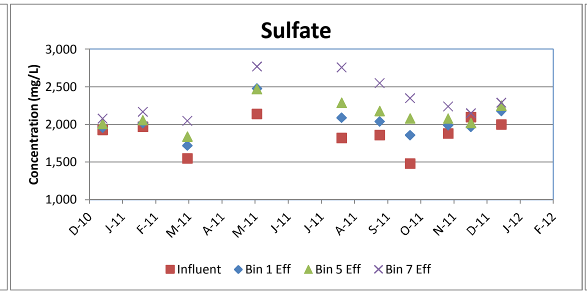


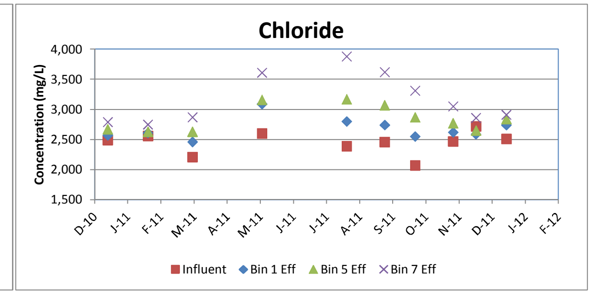


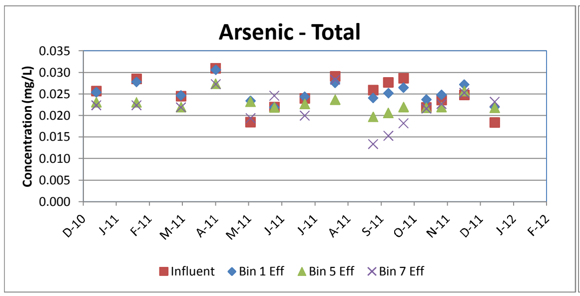


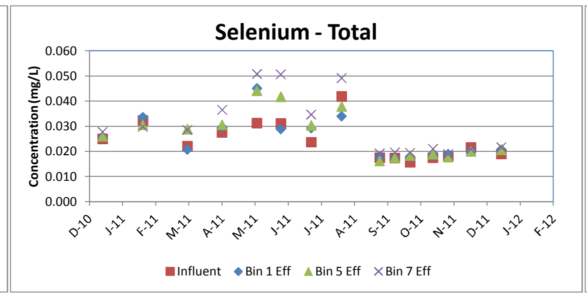
Appendix B-10
Train 1 (Bins 1, 5 and 7) Water Quality Summary
Regulating Wetlands Pilot Study for Concentrate Management

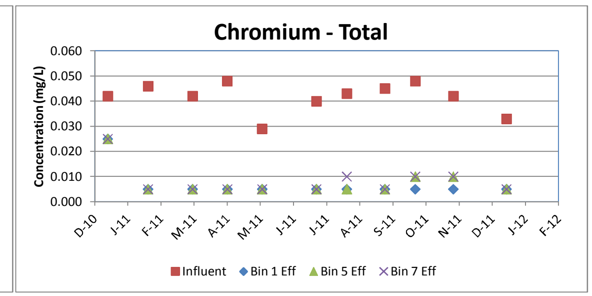


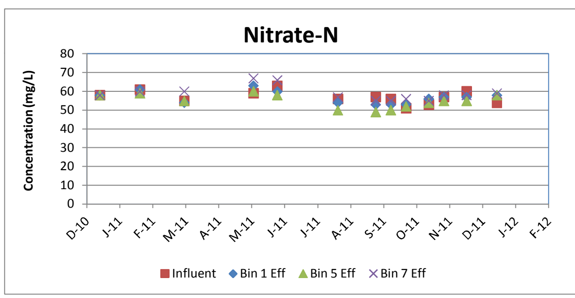


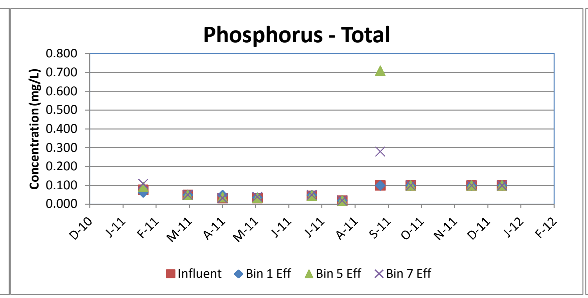


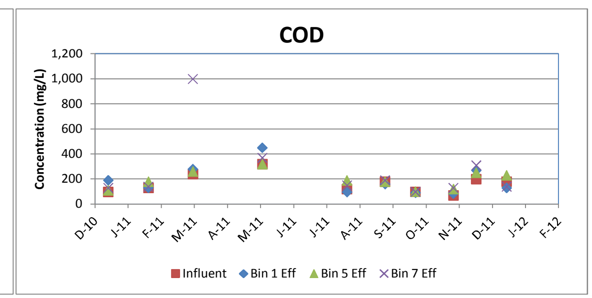




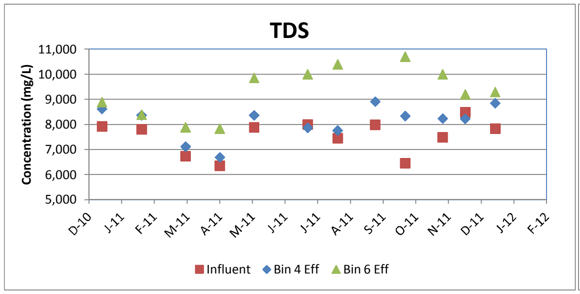


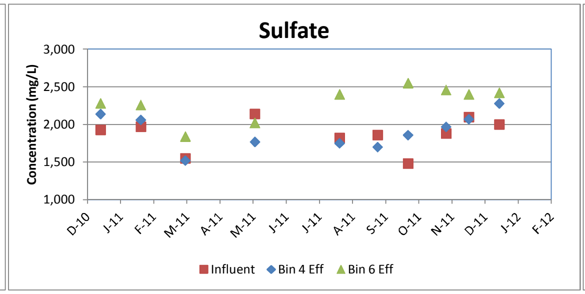


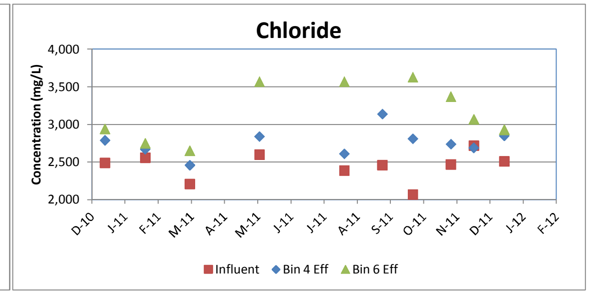


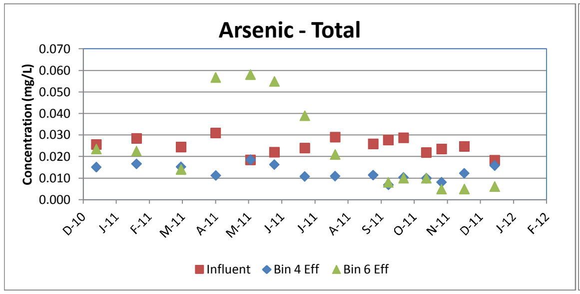


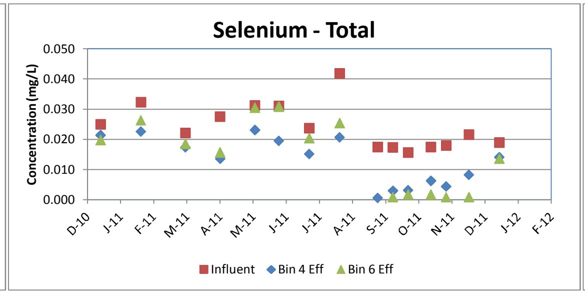
Appendix B-11
Train 2 (Bins 4 and 6) Water Quality Summary
Regulating Wetlands Pilot Study for Concentrate Management

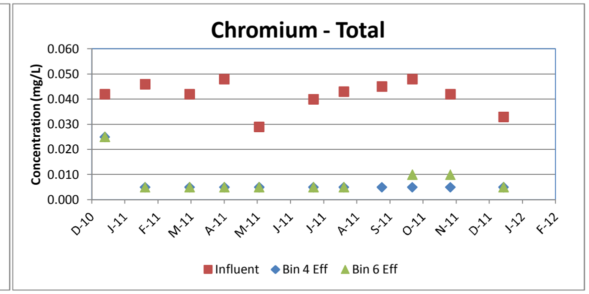


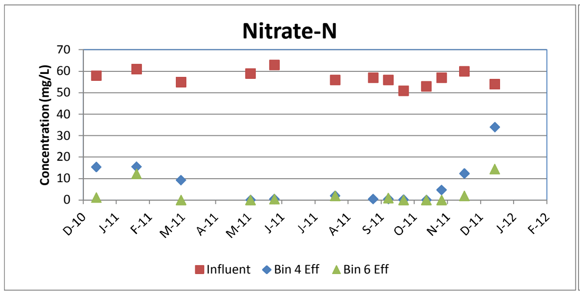


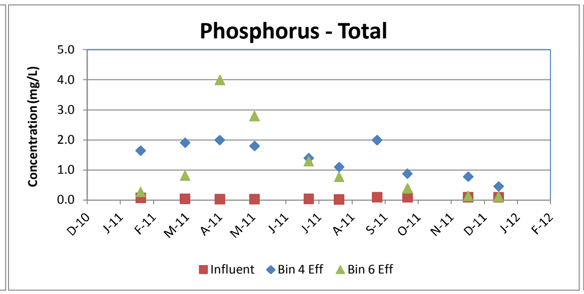


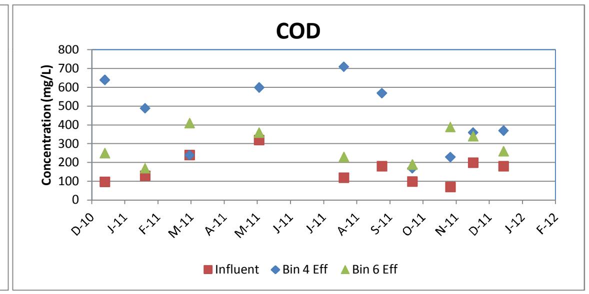






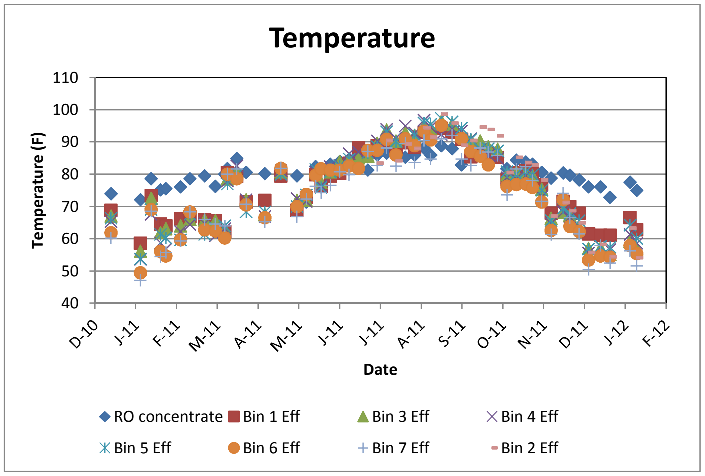


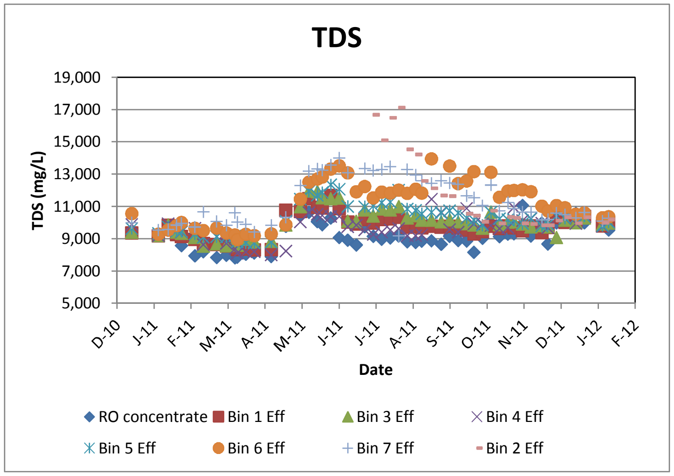




Appendix B-12
Field Parameters Summary
Temperature and TDS
Regulating Wetlands Pilot Study for Concentrate Management

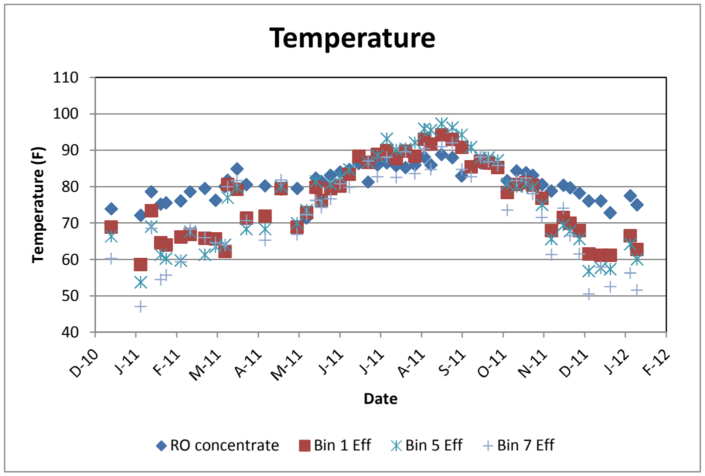
Pilot System

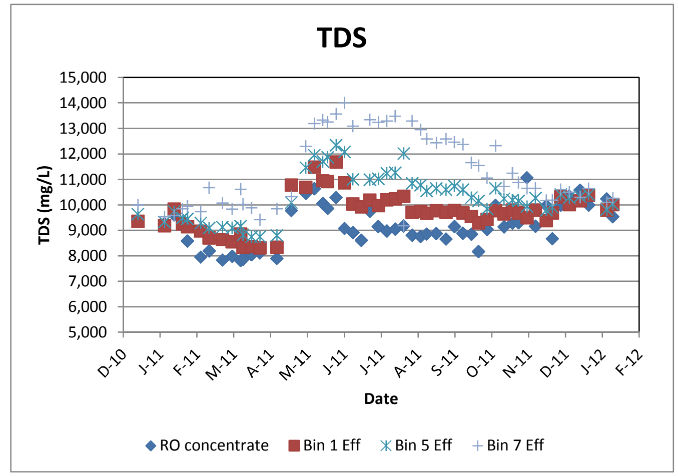




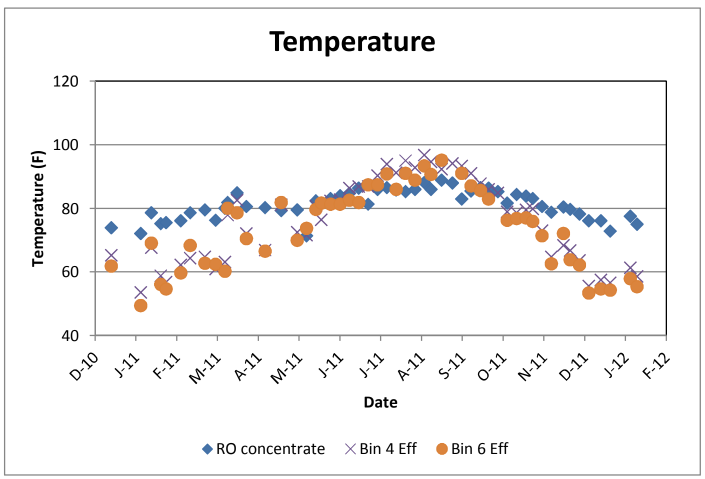
Appendix B-12
Field Parameters Summary
Temperature and TDS
Regulating Wetlands Pilot Study for Concentrate Management

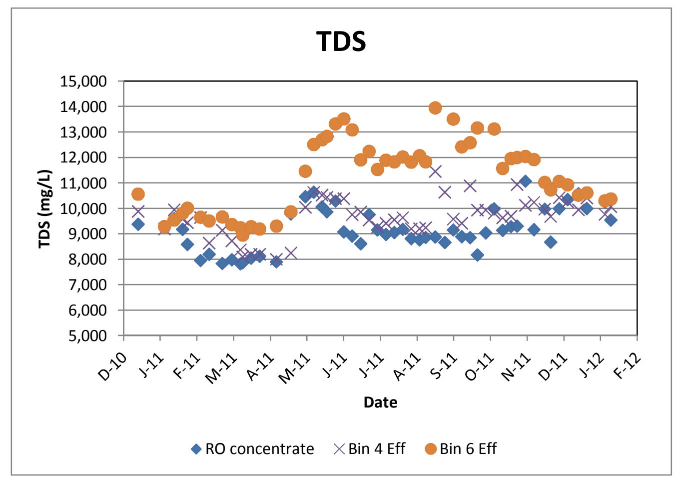
Train 1
Bin 1, 5, 7





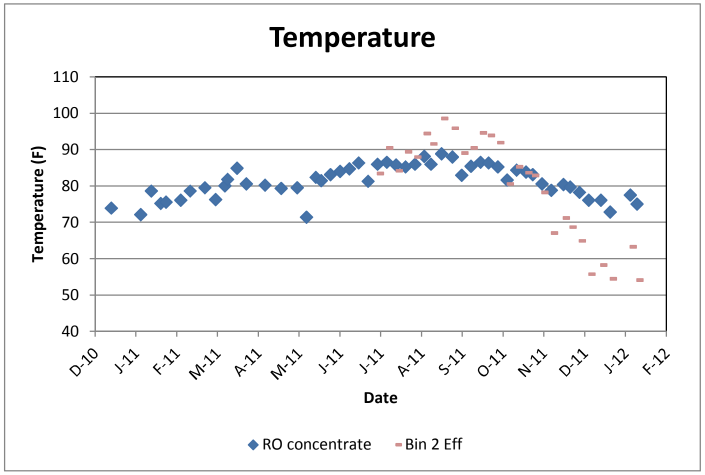
Train 2
Bins 4 & 6

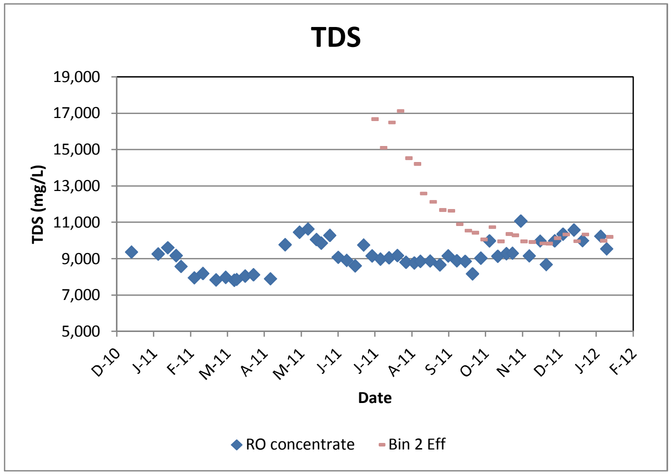




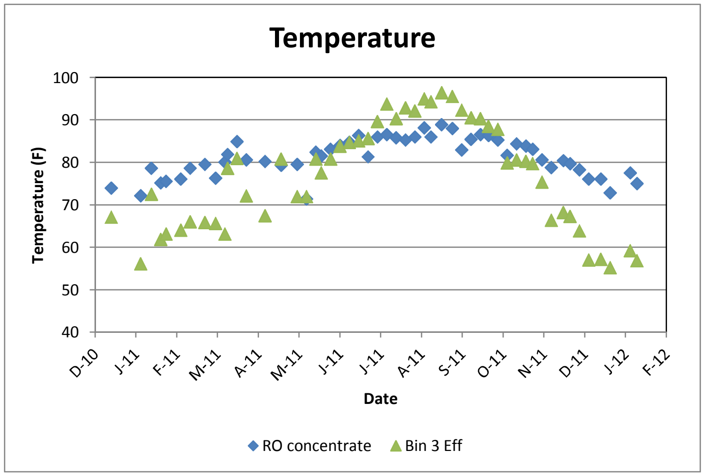
Appendix B-12
Field Parameters Summary
Temperature and TDS
Regulating Wetlands Pilot Study for Concentrate Management

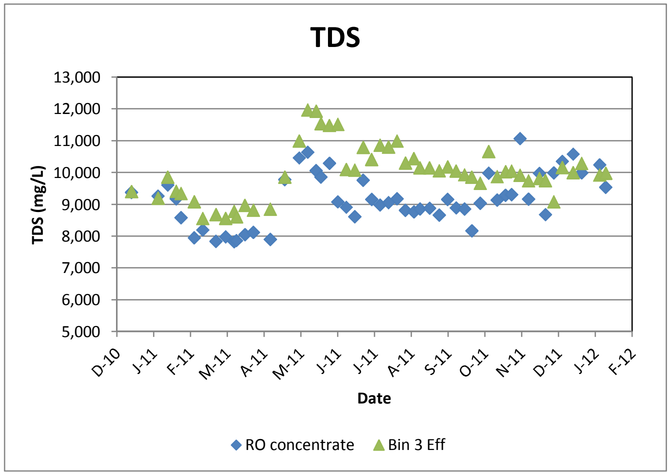
Train 3/Bin 2
Bin 2





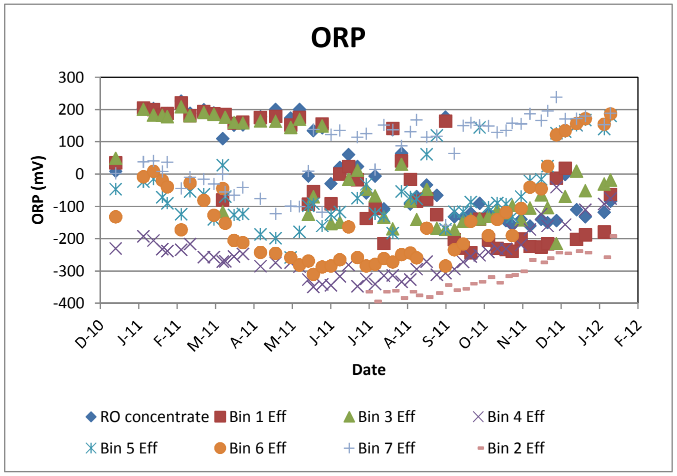
Train 4
Bin 3

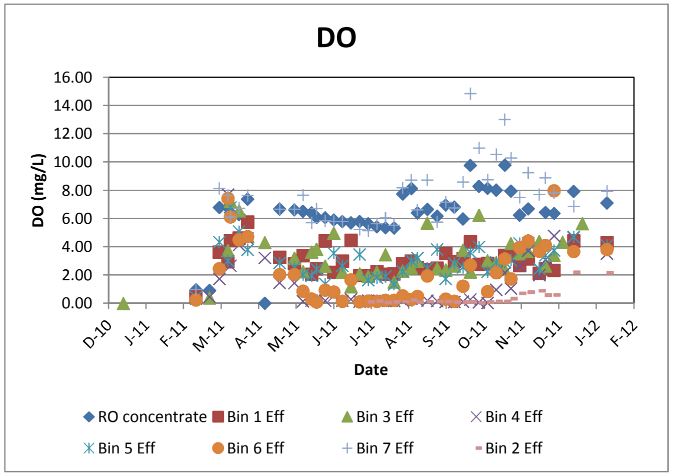




Appendix B-12
Field Parameters Summary
ORP and DO
Regulating Wetlands Pilot Study for Concentrate Management

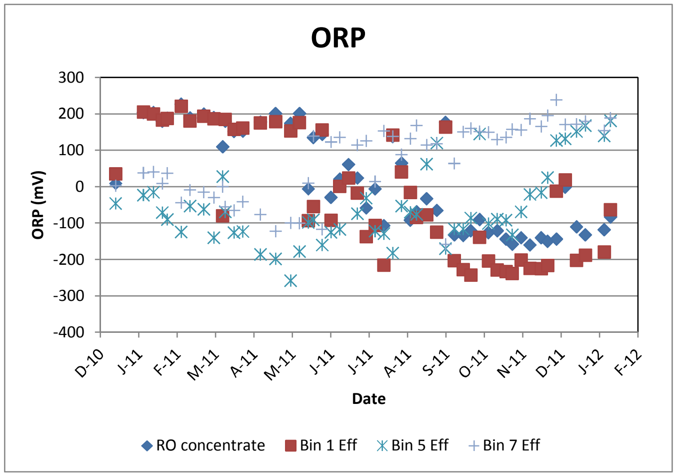
Pilot System

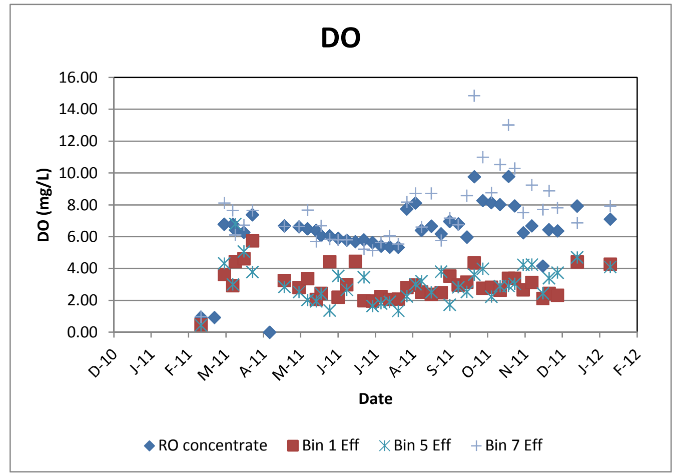




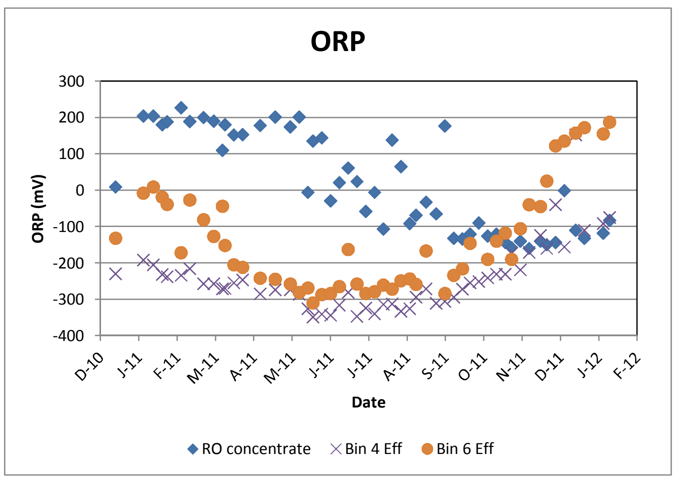
Appendix B-12
Field Parameters Summary
ORP and DO
Regulating Wetlands Pilot Study for Concentrate Management

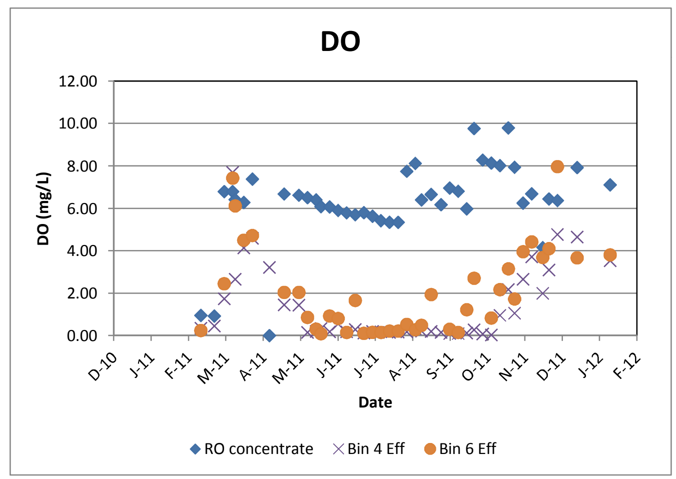
Train 1
Bin 1, 5, 7





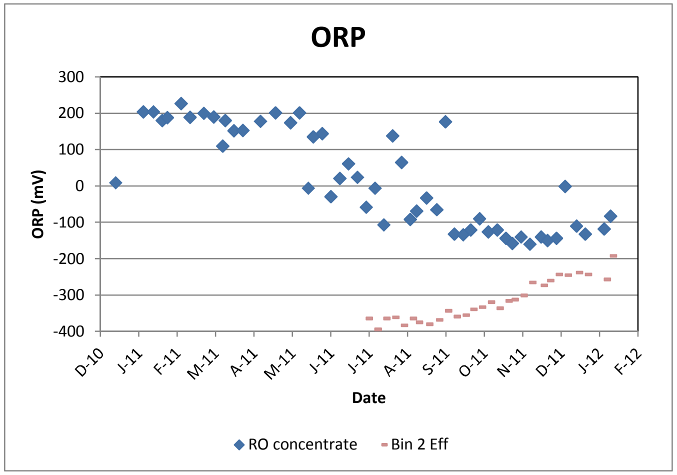
Train 2
Bins 4 & 6

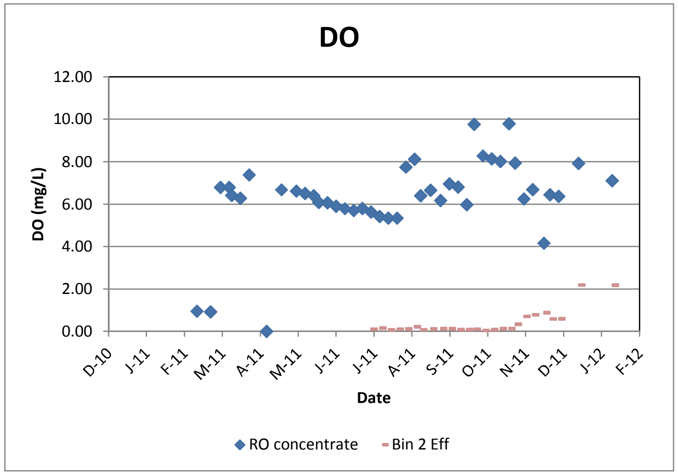




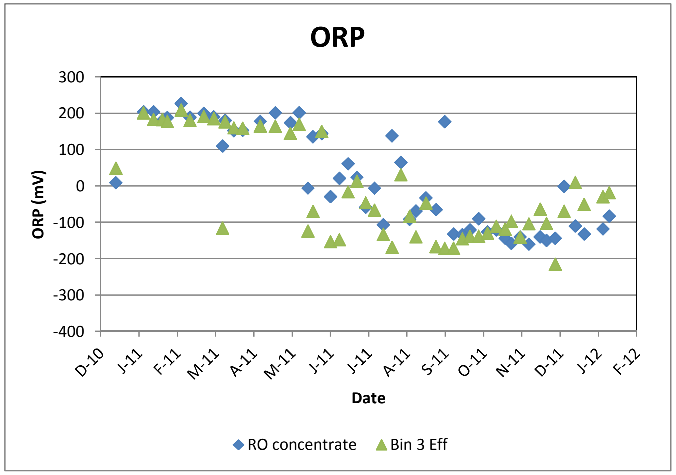
Appendix B-12
Field Parameters Summary
ORP and DO
Regulating Wetlands Pilot Study for Concentrate Management

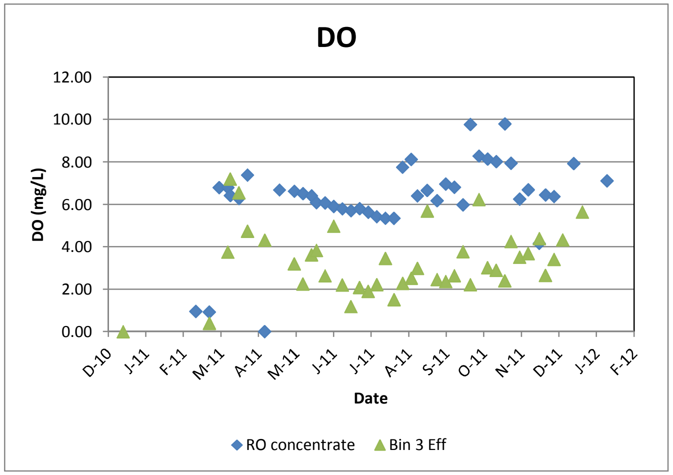
Train 3/Bin 2
Bin 2





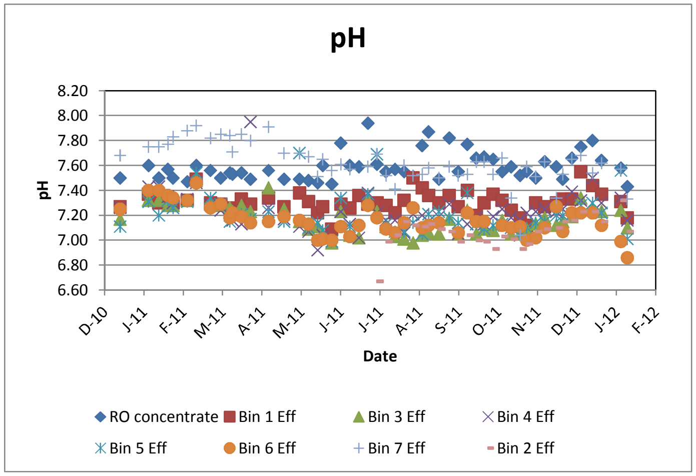
Train 4
Bin 3





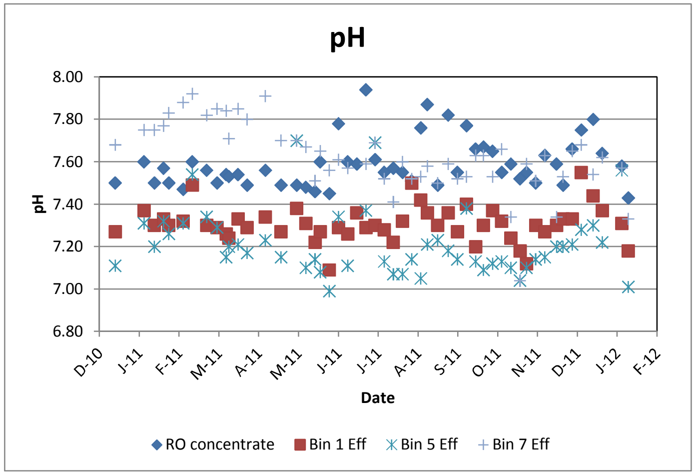
Appendix B-12
Field Parameters Summary
pH
Regulating Wetlands Pilot Study for Concentrate Management

Pilot System

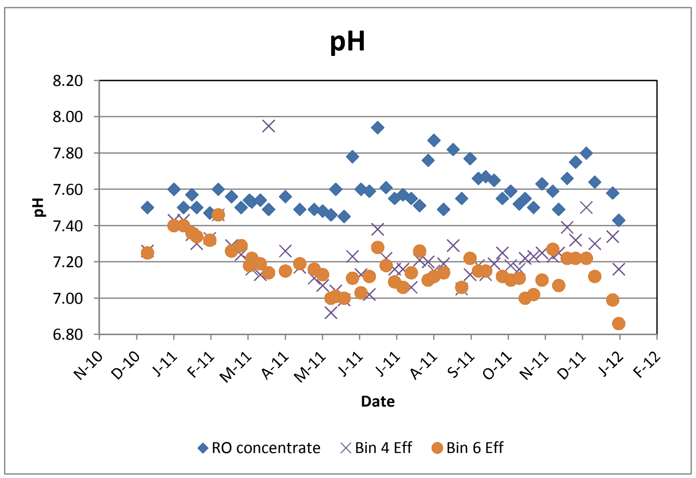


Appendix B-12
Field Parameters Summary
pH
Regulating Wetlands Pilot Study for Concentrate Management

Train 1
Bin 1, 5, 7

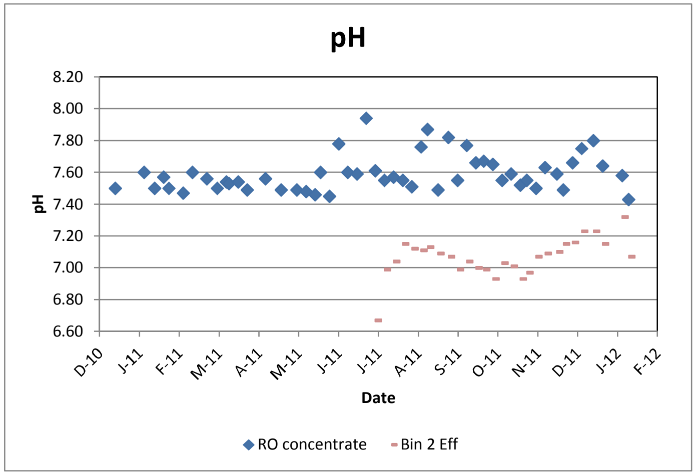


Train 2
Bins 4 & 6

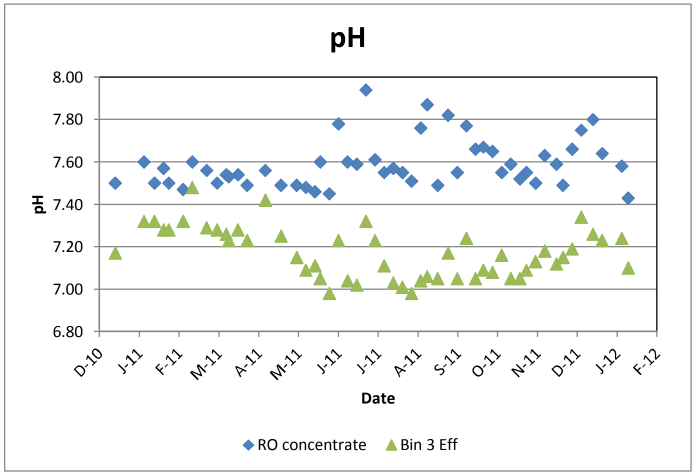


Appendix B-12
Field Parameters Summary
pH
Regulating Wetlands Pilot Study for Concentrate Management

Train 3/Bin 2
Bin 2



Train 4
Bin 3



Appendix C
Soil Analysis Data

Appendix C-1
Soil Analysis Summary
Regulating Wetlands Pilot Study for Concentrate Management

Soil Data (Baseline - Sept 2010)

					Concentration (ppm)													
SOIL	**Sample #**	**Zone**	**Date**	**TKN %**	**Ag**	**Al**	**As**	**B**	**Ba**	**Be**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Li**
3/8 inch rock	1A	Bin 1 sec A	10-Sep-10	<0.001	0.07	1377.72	0.54	0.34	18.39	0.12	2032.11	0.04	2.02	0.61	9.24	2703.86	176.43	3.16
3/8 inch rock	6C	Bin 6 sec C	10-Sep-10	<0.001	<0.01	1270.93	0.76	0.23	15.74	0.06	2277.35	0.02	1.27	0.97	9.45	3121.32	189.44	3.00
Dirt	7A	Bin 7 sec A	10-Sep-10	<0.001	0.31	3852.10	1.84	0.53	56.60	0.23	14358.84	0.04	3.21	5.73	6.83	6037.48	859.69	7.11
Dirt	7C	Bin 7 sec C	10-Sep-10	<0.001	<.01	3553.22	1.95	0.60	57.21	0.22	14344.08	0.04	3.17	5.61	7.06	5317.11	823.60	6.57
Green waste	1G	pile	10-Sep-10	0.97	0.44	2088.08	3.42	40.41	67.16	0.17	31070.95	0.36	2.82	11.03	38.84	5133.79	7583.52	9.75
Green waste	2G	pile	10-Sep-10	1.22	0.34	1412.32	3.64	38.39	53.23	0.12	29608.32	0.28	2.26	10.82	40.14	4311.20	7204.72	8.11
Green waste	3G	pile	10-Sep-10	0.79	0.41	1378.72	3.22	42.55	62.87	0.13	28770.48	0.31	2.53	10.72	36.65	4160.24	7099.30	8.72
Peat	1P	stack	10-Sep-10	1.26	<0.01	419.50	0.54	20.95	35.48	0.03	20504.94	0.10	0.59	2.92	3.46	1298.52	285.80	0.61
Peat	2P	stack	10-Sep-10	2.25	<0.01	317.46	0.48	20.71	32.68	0.03	21306.83	0.09	0.50	2.65	1.64	1062.59	126.56	0.45
Peat	3P	stack	10-Sep-10	0.63	<0.01	348.82	0.44	21.40	33.40	0.03	20341.37	0.09	0.49	2.66	1.72	980.69	117.51	0.44

SOIL		**TKN %**	**Ag**	**Al**	**As**	**B**	**Ba**	**Be**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Li**
Peat	Avg. in 2010	<0.01	<0.01	361.927	0.487	21.020	33.853	0.030	20,717.713	0.093	0.527	2.743	2.273	1,113.933	176.623	0.500
	95th Percentile	2.151	N/A	412.432	0.534	21.355	35.272	0.030	21,226.641	0.099	0.581	2.894	3.286	1,274.927	269.876	0.594
	5th Percentile	0.693	N/A	320.596	0.444	20.734	32.752	0.030	20,357.727	0.090	0.491	2.651	1.648	988.880	118.415	0.441
	Standard Deviation	0.817	N/A	52.267	0.050	0.350	1.454	0.000	516.704	0.006	0.055	0.153	1.028	165.018	94.658	0.095
Green Waste	Avg. in 2010	0.993	0.397	1,626.373	3.427	40.450	61.087	0.140	29,816.583	0.317	2.537	10.857	38.543	4,535.077	7,295.847	8.860
	95th Percentile	1.195	0.437	2,020.504	3.618	42.336	66.731	0.166	30,924.687	0.355	2.791	11.009	40.010	5,051.531	7,545.640	9.647
	5th Percentile	0.808	0.347	1,382.080	3.240	38.592	54.194	0.121	28,854.264	0.283	2.287	10.730	36.869	4,175.336	7,109.842	8.171
	Standard Deviation	0.216	0.051	400.202	0.210	2.080	7.134	0.026	1,164.290	0.040	0.280	0.158	1.764	523.966	254.647	0.829

Soil Data (Year 1 Update)

						Concentration (ppm)													
SOIL (1 year update)		**Sample #**	**zone**	**Date**	**TKN %**	**Ag**	**Al**	**As**	**B**	**Ba**	**Be**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Li**
Peat	Bin 1 deep (Peat)	1 deep	Bin 1 sec B	9-Oct-11		<0.01	467.08	1.37	107.91	57.98	0.02	48,924.34	0.09	0.76	48.79	3.42	1,401.74	509.63	5.08
Peat	Bin 1 shallow (Peat)	1 shallow	Bin 1 sec B	9-Oct-11		<0.01	356.64	1.28	110.55	53.98	0.02	42,535.36	0.09	0.51	1.81	2.41	1,176.00	438.39	4.63
Peat	Bin 1 surface (Peat)	1 surface	Bin 1 sec B	9-Oct-11		<0.01	370.45	4.14	85.56	72.60	0.01	86,444.26	0.05	0.47	1.39	2.75	972.30	409.76	7.18
GW	Bin 4 deep (GW)	4 deep	Bin 4 sec B	9-Oct-11		0.07	1,252.62	4.34	49.56	52.90	0.08	41,456.63	0.24	2.38	7.33	30.40	4,327.73	704.42	6.91
GW	Bin 4 shallow (GW)	4 shallow	Bin 4 sec B	9-Oct-11		0.07	1,185.45	3.80	34.22	45.07	0.12	29,820.71	0.24	2.10	8.36	75.02	4,538.47	646.55	5.62
GW	Bin 4 surface (GW)	4 surface	Bin 4 sec B	9-Oct-11		0.02	1,314.87	3.71	75.62	96.19	0.07	103,894.76	0.18	1.59	7.84	24.57	3,533.66	784.25	11.16
Peat	Bin 6 deep (Peat)	6 deep	Bin 6 sec B	9-Oct-11		<0.01	609.11	5.61	152.96	52.64	0.08	31,087.46	0.11	4.11	5.83	3.65	4,247.93	620.88	4.46
Peat	Bin 6 shallow (Peat)	6 shallow	Bin 6 sec B	9-Oct-11		<0.01	456.95	3.77	147.96	128.50	0.04	95,364.86	0.07	1.33	2.69	2.41	1,828.71	769.71	7.04
Peat	Bin 6 surface (Peat)	6 surface	Bin 6 sec B	9-Oct-11		<0.01	455.02	4.37	83.13	204.03	0.02	194,128.19	0.04	0.68	1.67	2.11	1,470.92	840.39	7.93

Appendix C-1
Soil Analysis Summary
Regulating Wetlands Pilot Study for Concentrate Management

Soil Data (Baseline - Sept 2010)

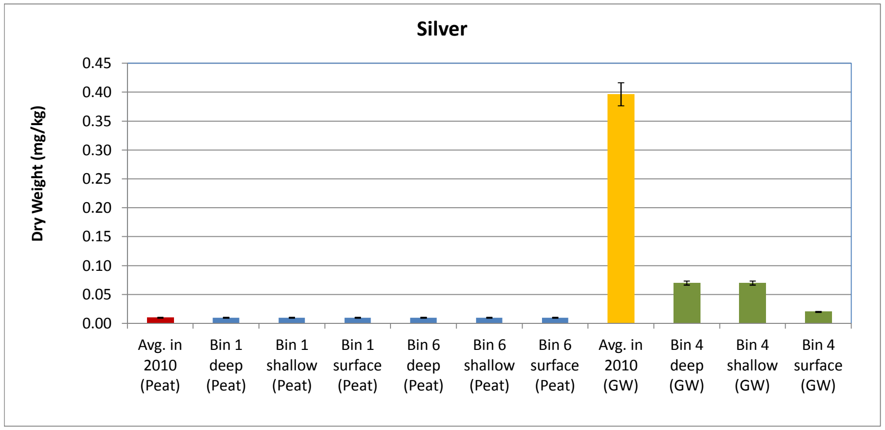
SOIL	Sample #	Zone	Date	Concentration (ppm) Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Se	Si	Sn	Sr	Ti	V	Zn
3/8 inch rock	1A	Bin 1 sec A	10-Sep-10	1094.32	69.24	0.05	74.77	5.34	459.46	2.41	<0.01	0.10	14.91	0.02	16.32	0.01	2.21	11.45
3/8 inch rock	6C	Bin 6 sec C	10-Sep-10	889.84	57.55	0.03	34.74	2.43	284.12	1.60	<.01	0.05	22.91	0.02	9.84	0.01	3.50	8.23
Dirt	7A	Bin 7 sec A	10-Sep-10	3324.50	160.12	0.07	84.52	7.10	475.46	4.78	<.01	0.12	65.40	0.01	52.97	28.30	9.95	28.32
Dirt	7C	Bin 7 sec C	10-Sep-10	2833.21	131.41	0.04	84.12	6.91	334.24	4.22	<.01	0.13	69.97	0.01	46.84	0.05	9.68	15.64
Green waste	1G	pile	10-Sep-10	4037.89	176.19	3.21	1539.08	9.28	2278.53	10.03	0.18	0.60	64.30	0.47	335.43	0.04	8.49	88.31
Green waste	2G	pile	10-Sep-10	3107.16	134.22	4.04	1539.18	7.94	1796.50	7.01	0.22	0.59	80.95	0.39	257.49	0.03	7.25	87.21
Green waste	3G	pile	10-Sep-10	3221.32	134.12	3.89	1515.86	8.90	1913.13	9.37	0.21	0.62	60.36	0.62	272.12	0.03	7.73	87.16
Peat	1P	stack	10-Sep-10	2620.37	177.26	0.23	94.67	2.91	374.98	0.79	0.04	0.56	113.43	0.05	122.58	0.01	1.13	19.86
Peat	2P	stack	10-Sep-10	2634.16	179.08	0.18	69.08	2.50	323.53	0.31	0.03	0.51	129.63	0.02	125.02	0.01	0.81	17.81
Peat	3P	stack	10-Sep-10	2401.26	162.64	0.19	64.46	2.66	353.66	0.29	0.04	0.59	112.07	0.02	122.41	0.01	0.83	18.55

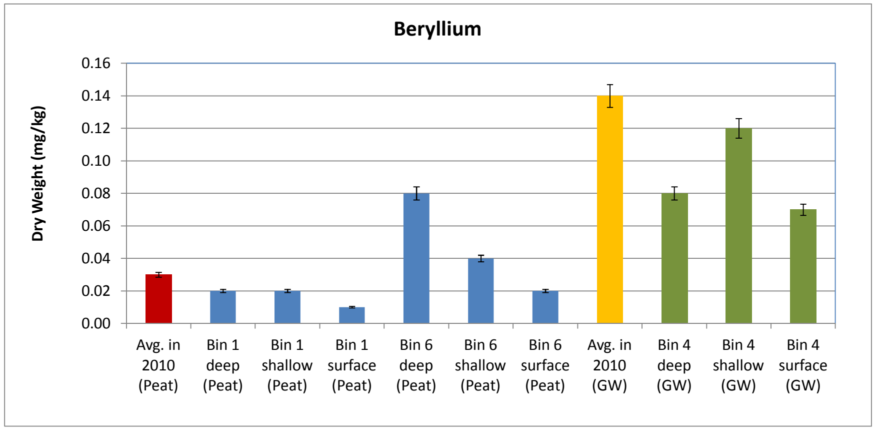
SOIL		Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Se	Si	Sn	Sr	Ti	V	Zn
Peat	Avg. in 2010	2,551.930	172.993	0.200	76.070	2.690	350.723	0.463	0.037	0.553	118.377	0.030	123.337	0.010	0.923	18.740
	95th Percentile	2,632.781	178.898	0.226	92.111	2.885	372.848	0.742	0.040	0.587	128.010	0.047	124.776	0.010	1.100	19.729
	5th Percentile	2,423.171	164.102	0.181	64.922	2.516	326.543	0.292	0.031	0.515	112.206	0.020	122.427	0.010	0.812	17.884
	Standard Deviation	130.666	9.012	0.026	16.273	0.207	25.850	0.283	0.006	0.040	9.769	0.017	1.460	0.000	0.179	1.038
Green Waste	Avg. in 2010	3,455.457	148.177	3.713	1,531.373	8.707	1,996.053	8.803	0.203	0.603	68.537	0.493	288.347	0.033	7.823	87.560
	95th Percentile	3,956.233	171.993	4.025	1,539.170	9.242	2,241.990	9.964	0.219	0.618	79.285	0.605	329.099	0.039	8.414	88.200
	5th Percentile	3,118.576	134.130	3.278	1,518.182	8.036	1,808.163	7.246	0.183	0.591	60.754	0.398	258.953	0.030	7.298	87.165
	Standard Deviation	507.621	24.260	0.442	13.435	0.691	251.486	1.588	0.021	0.015	10.929	0.117	41.426	0.006	0.625	0.650

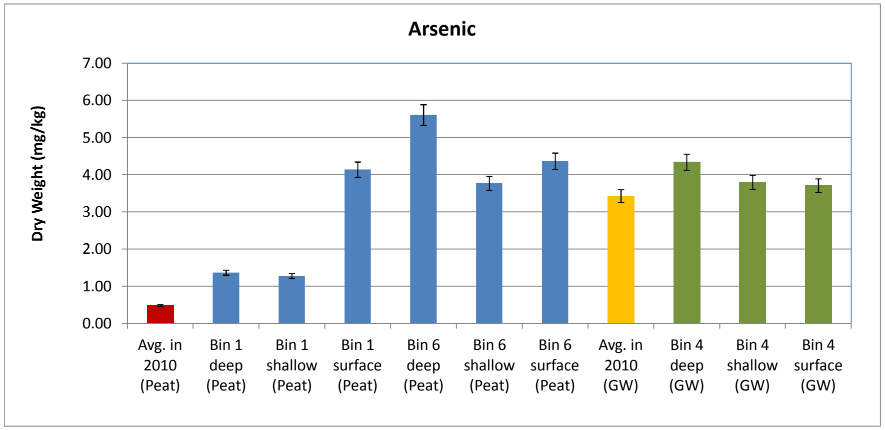
Soil Data (Year 1 Update)

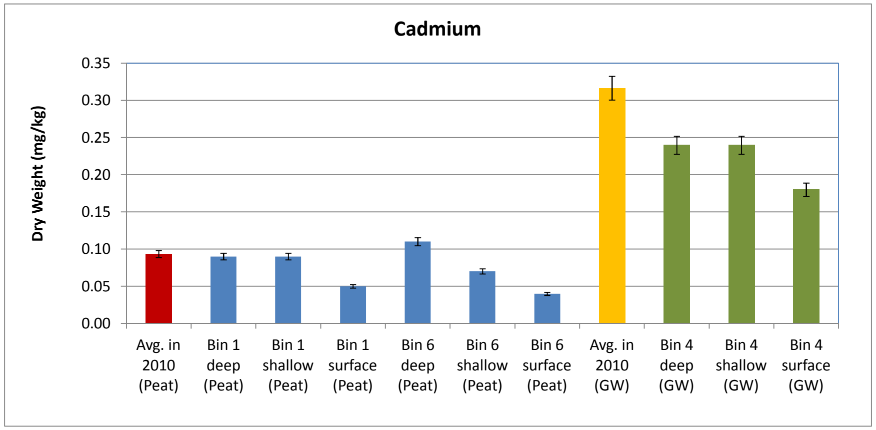
SOIL (1 year update)		Sample #	zone	Date	Concentration (ppm) Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Se	Si	Sn	Sr	Ti	V	Zn
Peat	Bin 1 deep (Peat)	1 deep	Bin 1 sec B	9-Oct-11	8,498.37	40.90	2.94	12,719.51	5.30	285.23	0.37	0.07	2.29	130.29	0.05	864.89	0.01	304.34	13.90
Peat	Bin 1 shallow (Peat)	1 shallow	Bin 1 sec B	9-Oct-11	8,281.03	33.12	4.80	10,780.88	3.50	268.56	0.37	0.09	2.60	276.20	0.07	806.08	0.02	3.02	13.78
Peat	Bin 1 surface (Peat)	1 surface	Bin 1 sec B	9-Oct-11	12,444.17	189.32	0.43	8,310.44	1.93	193.06	0.47	0.03	1.02	398.55	0.06	1,372.18	0.01	1.29	14.86
GW	Bin 4 deep (GW)	4 deep	Bin 4 sec B	9-Oct-11	6,533.69	138.21	4.12	6,554.32	8.94	1,404.28	5.95	0.16	2.41	125.59	0.66	631.64	0.04	8.22	67.43
GW	Bin 4 shallow (GW)	4 shallow	Bin 4 sec B	9-Oct-11	4,322.14	133.17	4.64	5,029.51	7.50	1,263.26	5.95	0.16	2.21	101.38	0.61	380.50	0.04	8.27	64.09
GW	Bin 4 surface (GW)	4 surface	Bin 4 sec B	9-Oct-11	13,595.83	183.08	1.15	7,089.86	5.60	1,676.14	5.23	0.09	1.12	259.35	0.50	1,797.92	0.03	6.19	69.83
Peat	Bin 6 deep (Peat)	6 deep	Bin 6 sec B	9-Oct-11	6,980.40	94.92	7.84	10,341.44	8.19	331.69	2.07	0.27	5.93	196.72	0.95	564.87	0.03	39.66	21.63
Peat	Bin 6 shallow (Peat)	6 shallow	Bin 6 sec B	9-Oct-11	9,560.69	330.90	2.64	16,303.69	5.00	447.39	0.67	0.18	2.77	218.64	0.28	1,394.44	0.01	9.25	12.82
Peat	Bin 6 surface (Peat)	6 surface	Bin 6 sec B	9-Oct-11	10,005.82	739.98	0.43	13,857.24	3.54	707.45	0.46	0.17	1.23	242.79	0.11	2,687.88	0.01	1.46	10.01

Appendix C-2
Soil Analysis Summary
Regulating Wetlands Pilot Study for Concentrate Management

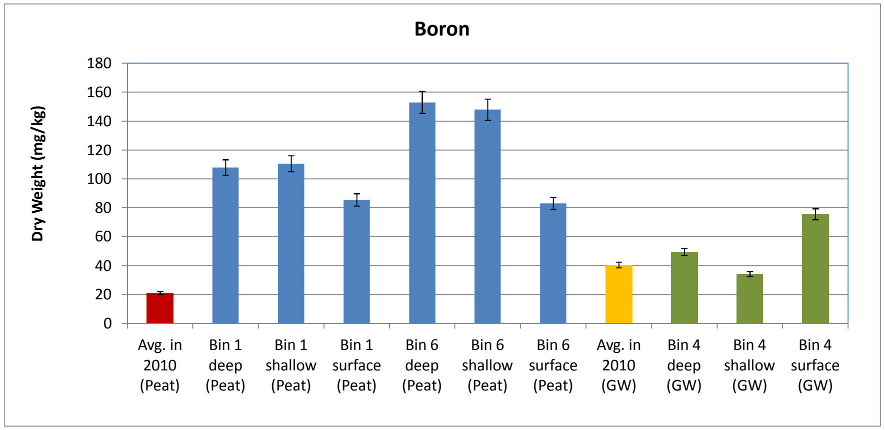


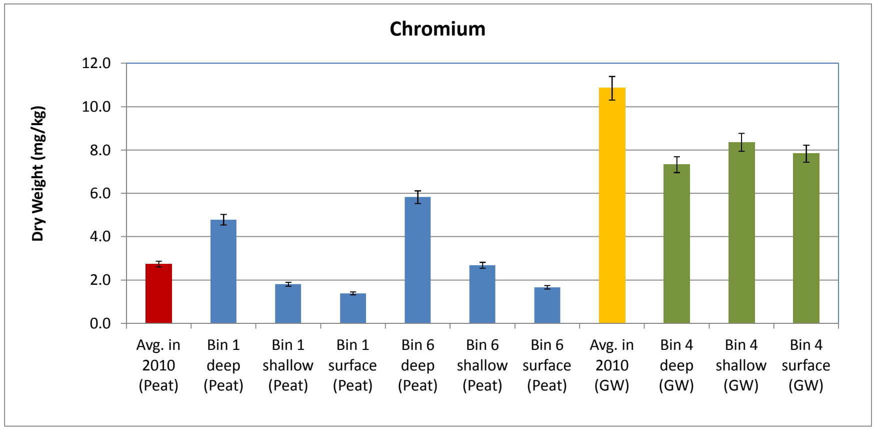


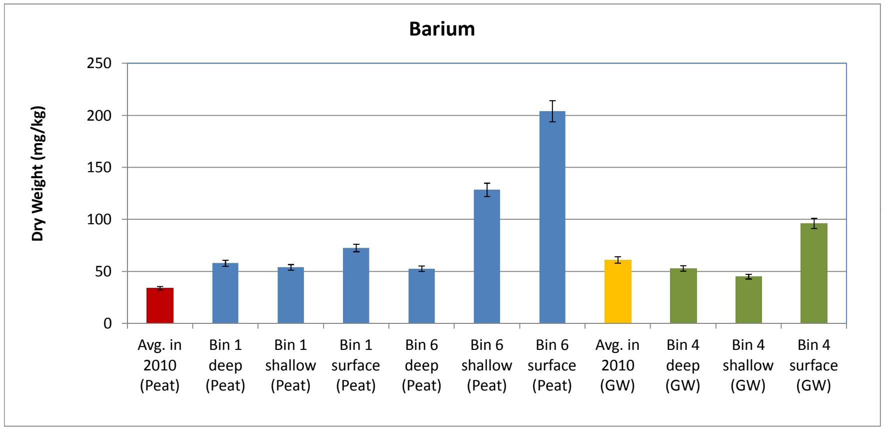


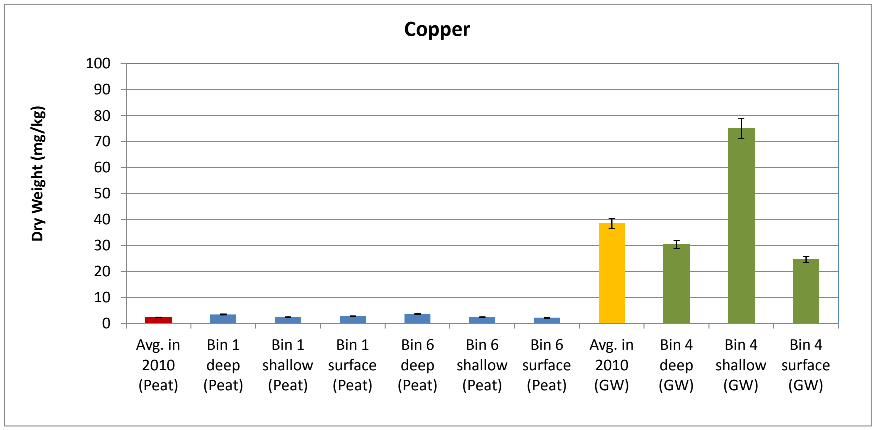


Appendix C-2
Soil Analysis Summary
Regulating Wetlands Pilot Study for Concentrate Management

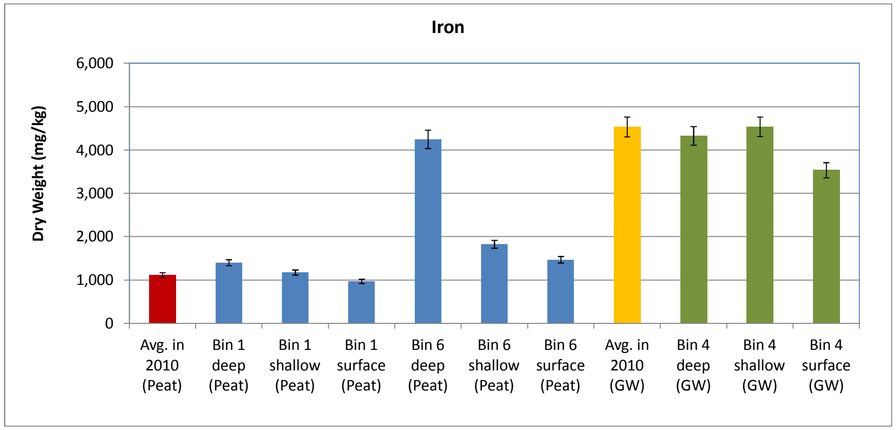


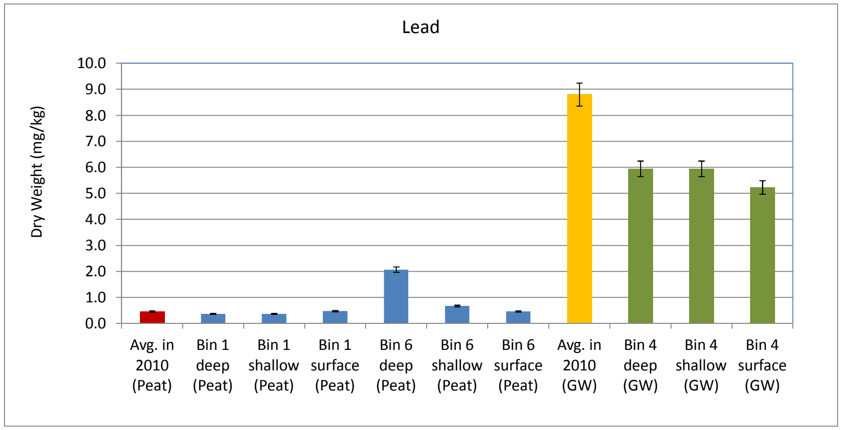


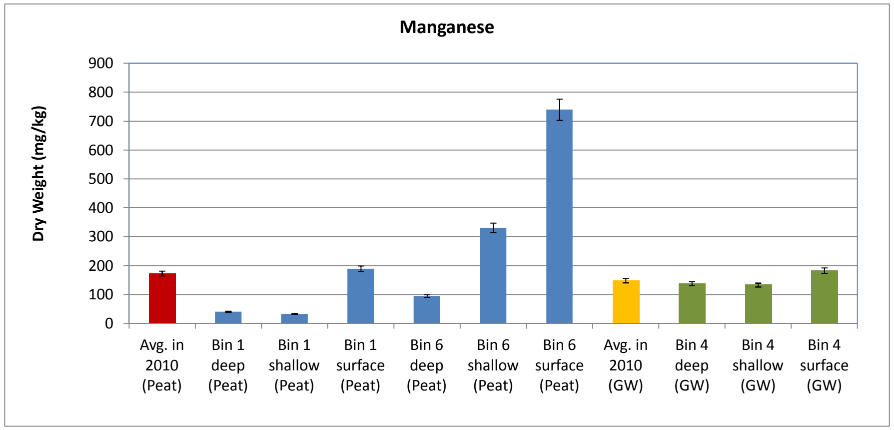


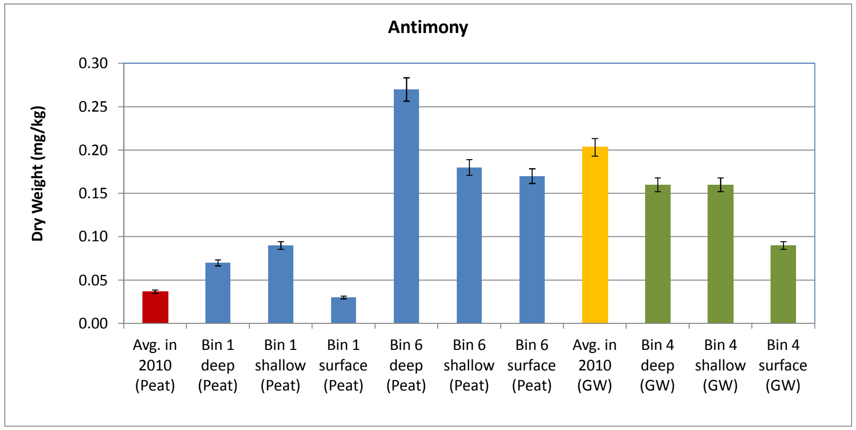


Appendix C-2
Soil Analysis Summary
Regulating Wetlands Pilot Study for Concentrate Management

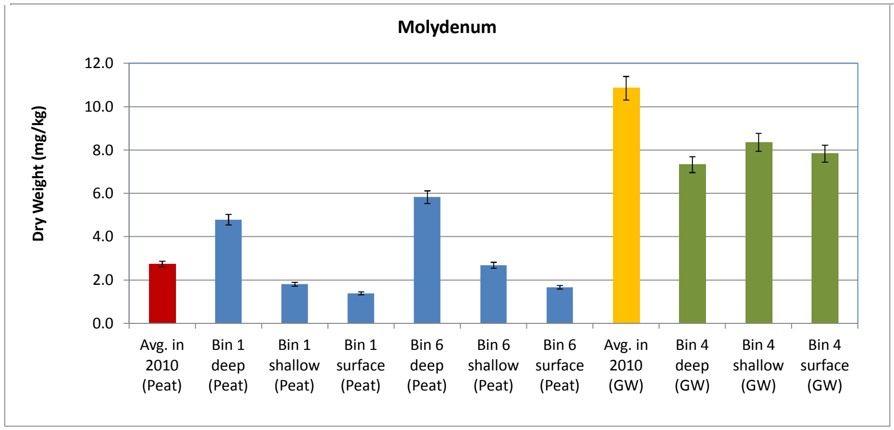


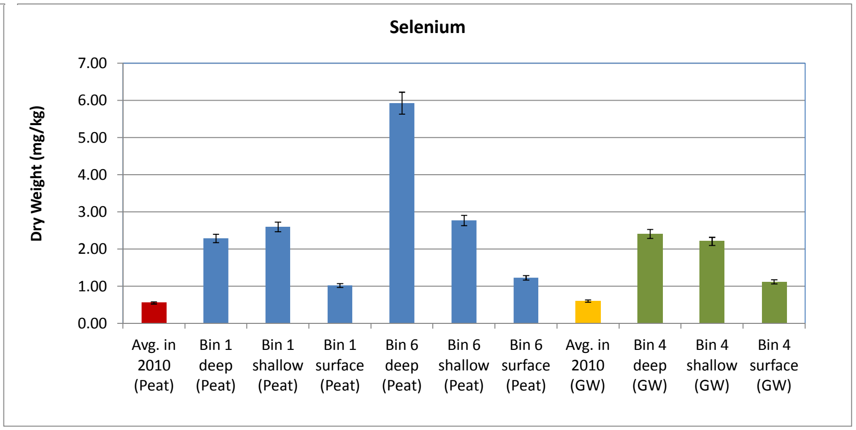


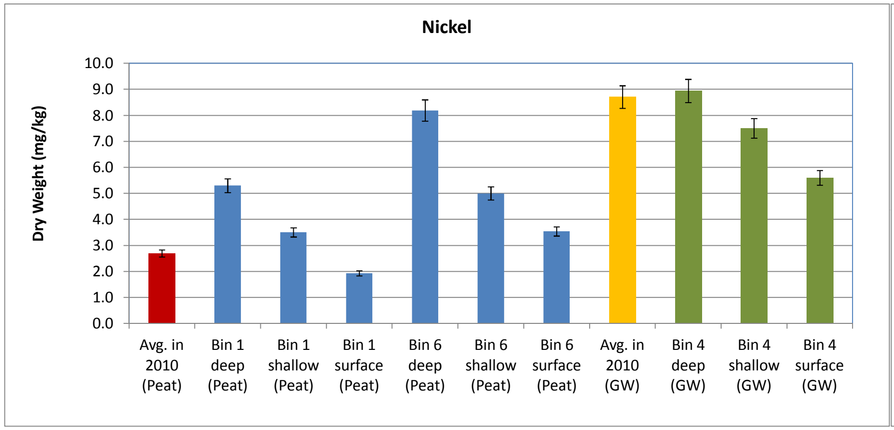


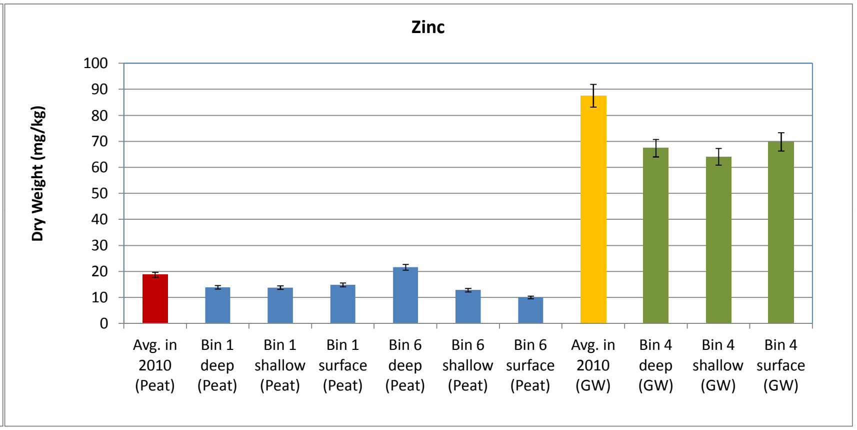


Appendix C-2
Soil Analysis Summary
Regulating Wetlands Pilot Study for Concentrate Management









Appendix D
Plant Analysis Data and Photo Log

Appendix D-1
Plant Analysis (Baseline - September 2010)
Regulating Wetlands Pilot Study for Concentrate Management

					Concentration (ppm)													
Plant	**Sample #**	**zone**	**Date**	**TKN %**	**Ag**	**Al**	**As**	**B**	**Ba**	**Be**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Li**
Scratchgrass Muly	1R	Root	2-Sep-10	0.83	0.01	114.86	4.54	13.77	17.96	0.03	4192.22	0.25	0.83	3.63	14.51	663.62	4197.15	1.80
Scratchgrass Muly	1S	Stem	2-Sep-10	0.39	<.01	132.79	1.12	23.48	18.83	0.01	4185.65	0.04	0.20	3.70	4.41	208.38	3750.47	4.90
Alkali Sacaton	2R	Root	2-Sep-10	0.50	<.01	48.62	5.04	13.67	13.78	0.01	3480.92	0.19	0.41	3.89	8.86	305.68	2264.20	1.30
Alkali Sacaton	2S	Stem	2-Sep-10	0.59	<.01	386.15	1.05	26.95	17.96	0.02	3418.33	0.06	0.23	3.22	3.81	272.94	5097.05	2.23
Saltgrass	3R	Root	2-Sep-10	0.53	<.01	71.55	3.33	6.37	21.73	0.01	3006.09	0.19	0.65	2.72	17.84	343.50	4882.50	0.73
Saltgrass	3S	Stem	2-Sep-10	0.54	<.01	76.54	0.80	14.41	50.17	0.01	3866.02	0.02	0.11	2.64	5.21	136.17	4925.68	0.97
Saltgrass	4R	Root	2-Sep-10	0.61	<.01	163.53	5.88	10.96	25.33	0.02	3943.79	0.19	0.64	3.69	19.57	717.68	5211.93	1.22
Saltgrass	4S	Stem	2-Sep-10	0.68	<.01	126.94	1.01	20.86	38.34	0.01	5367.75	0.03	0.19	4.12	6.45	217.75	5007.28	1.27
Creeping Spike Rush	5R	Root	2-Sep-10	0.84	<.01	401.60	4.96	20.97	47.95	0.05	6558.92	0.14	0.87	5.14	15.82	1317.49	4366.90	1.62
Creeping Spike Rush	5S	Stem	2-Sep-10	1.05	<.01	46.14	1.39	41.99	60.93	0.01	8773.94	0.01	0.10	2.42	7.04	119.40	13249.34	5.39
Baltic Rush	6R	Root	2-Sep-10	0.58	<.01	75.81	1.84	17.39	21.63	0.02	4055.80	0.07	0.24	2.34	5.74	578.98	5589.78	1.57
Baltic Rush	6S	Stem	2-Sep-10	0.41	<.01	22.63	0.98	35.59	29.44	<0.01	8597.36	0.04	0.06	2.24	2.26	69.22	8835.24	4.45
Yerba Manza	7R	Root	2-Sep-10	0.61	<.01	73.22	2.82	19.91	24.28	0.01	3124.58	0.10	0.30	2.47	26.87	98.81	11196.17	1.82
Yerba Manza	7S	Stem	2-Sep-10	0.70	<.01	34.84	0.51	77.57	71.33	<0.01	17703.97	0.01	0.06	2.15	4.49	95.07	18129.96	8.58
Fourwing Saltbush	8R	Root	2-Sep-10	2.39	<.01	179.65	1.03	17.16	29.33	0.01	6545.80	0.06	0.21	2.32	6.75	154.83	8119.44	1.48
Fourwing Saltbush	8S	Stem	2-Sep-10	1.58	<.01	293.54	0.61	55.11	41.57	0.02	9710.05	0.04	0.27	2.79	5.17	426.29	29664.88	3.04
Seepwillow	9R	Root	2-Sep-10	0.44	<.01	133.60	2.39	23.61	13.42	0.01	3883.32	0.17	0.33	2.76	16.52	176.39	16407.31	1.20
Seepwillow	9S	Stem	2-Sep-10	0.67	<.01	8.19	0.25	32.72	6.84	<0.01	5585.65	0.08	0.12	2.41	7.19	39.96	14513.65	2.64
Olney's Threesquare Rush	11R	Root	2-Sep-10	0.59	<.01	137.41	3.31	23.39	29.81	0.02	4657.14	0.18	0.64	2.63	13.46	834.91	5482.76	1.73
Olney's Threesquare Rush	11S	Stem	2-Sep-10	0.73	<.01	81.62	1.24	39.12	67.95	0.01	9695.28	0.02	0.14	2.38	4.04	171.60	10713.93	5.85
Softstem Bulrush	13R	Root	2-Sep-10	0.40	<.01	236.36	2.07	34.94	31.59	0.04	6328.22	0.09	1.25	3.06	11.99	1135.38	3330.52	2.27
Softstem Bulrush	13S	Stem	2-Sep-10	0.74	<.01	27.15	0.76	55.07	61.52	<0.01	7124.85	0.01	0.15	2.21	2.28	93.22	15017.23	9.62
Cat tail	15S	Stem	10-Sep-10	2.49	<.01	14.70	0.60	103.63	4.38	<0.01	18147.90	0.04	0.06	2.10	4.36	146.07	32924.73	24.46
Cat tail	15R	Root	10-Sep-10	0.56	<.01	2358.46	3.12	13.95	46.11	0.21	39592.07	0.43	2.82	6.17	12.65	3691.18	7093.72	7.80

Appendix D-1
Plant Analysis (Baseline - September 2010)
Regulating Wetlands Pilot Study for Concentrate Management

				Concentration (ppm)														
Plant	Sample #	zone	Date	Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Se	Si	Sn	Sr	Ti	V	Zn
Scratchgrass Muly	1R	Root	2-Sep-10	907.40	165.86	3.64	2340.70	1.70	1403.99	2.76	0.10	0.57	260.45	0.36	40.84	0.03	4.76	79.42
Scratchgrass Muly	1S	Stem	2-Sep-10	796.07	106.58	6.06	2937.57	2.04	1128.62	2.09	0.05	0.23	749.55	0.48	34.90	<.01	2.66	33.64
Alkali Sacaton	2R	Root	2-Sep-10	718.65	115.50	1.00	2873.10	1.02	801.84	1.16	0.05	0.63	131.72	0.16	37.01	0.01	3.35	45.32
Alkali Sacaton	2S	Stem	2-Sep-10	1227.64	40.71	0.77	3900.86	2.56	1123.84	2.90	0.07	0.22	664.71	0.73	25.48	<.01	2.53	19.74
Saltgrass	3R	Root	2-Sep-10	859.69	104.81	0.55	2366.34	1.95	1561.30	3.88	0.14	1.16	127.14	1.20	29.73	0.06	2.31	75.59
Saltgrass	3S	Stem	2-Sep-10	862.77	132.71	2.02	3121.38	1.71	1036.04	3.08	0.05	0.48	575.67	1.63	32.15	<.01	0.99	24.69
Saltgrass	4R	Root	2-Sep-10	1114.79	109.10	0.66	3477.06	1.72	1944.78	4.71	0.13	1.29	190.78	1.33	38.55	0.05	3.86	58.12
Saltgrass	4S	Stem	2-Sep-10	995.49	132.17	2.26	3554.45	2.01	1119.67	6.04	0.06	0.57	519.73	2.98	41.66	<0.01	1.36	25.51
Creeping Spike Rush	5R	Root	2-Sep-10	1612.57	155.76	2.24	2488.81	4.53	1950.83	4.89	16.09	0.33	385.15	0.78	71.56	0.07	7.83	49.36
Creeping Spike Rush	5S	Stem	2-Sep-10	1910.95	221.40	2.57	4787.49	0.46	2724.05	0.76	0.03	0.28	1715.07	0.40	90.77	0.01	1.78	43.10
Baltic Rush	6R	Root	2-Sep-10	1474.46	104.68	1.69	5297.12	0.75	1651.29	2.02	0.05	0.38	148.68	0.27	48.76	0.05	3.10	34.03
Baltic Rush	6S	Stem	2-Sep-10	2671.25	138.83	1.40	5743.29	0.28	873.48	0.57	0.02	0.32	347.78	0.30	124.12	0.01	1.23	12.93
Yerba Manza	7R	Root	2-Sep-10	2380.94	93.90	0.90	9925.18	0.43	2183.81	0.98	0.03	0.25	166.36	0.04	59.56	0.08	3.26	37.61
Yerba Manza	7S	Stem	2-Sep-10	4141.65	30.57	1.18	19881.74	0.20	1848.73	0.34	0.02	0.57	121.45	0.02	204.37	0.02	0.65	16.40
Fourwing Saltbush	8R	Root	2-Sep-10	3054.29	47.65	0.65	4736.21	0.72	8475.21	1.60	0.07	0.09	102.07	0.06	68.45	0.01	4.11	87.87
Fourwing Saltbush	8S	Stem	2-Sep-10	4829.82	46.73	0.66	3457.20	0.82	2079.53	1.25	0.03	0.13	144.15	0.14	85.84	0.01	1.55	30.02
Seepwillow	9R	Root	2-Sep-10	623.20	28.89	1.19	5528.78	1.18	2475.11	5.03	0.06	0.18	80.25	0.34	42.59	0.02	3.33	21.21
Seepwillow	9S	Stem	2-Sep-10	1340.29	21.67	0.45	4171.48	0.32	1534.02	1.15	0.01	0.13	87.44	0.61	36.07	<0.01	0.35	39.57
Olney's Threesquare Rush	11R	Root	2-Sep-10	1533.04	163.88	1.40	6604.04	1.49	2065.74	3.24	0.11	0.39	295.34	0.37	58.40	0.08	4.59	95.65
Olney's Threesquare Rush	11S	Stem	2-Sep-10	3207.61	755.84	0.78	11314.11	0.60	1613.63	0.74	0.03	0.34	544.47	0.07	136.19	0.01	1.29	25.27
Softstem Bulrush	13R	Root	2-Sep-10	1615.97	156.71	1.47	4893.36	2.50	1123.21	2.31	0.10	0.32	287.24	0.17	81.39	0.04	3.79	36.27
Softstem Bulrush	13S	Stem	2-Sep-10	2031.50	407.08	0.52	6047.29	0.49	1313.32	0.55	0.02	0.32	535.43	0.17	109.94	<0.01	0.72	11.60
Cat tail	15S	Stem	10-Sep-10	3328.88	326.33	1.47	13647.15	4.16	1515.41	0.71	0.01	2.76	80.52	0.59	190.88	0.01	0.31	21.30
Cat tail	15R	Root	10-Sep-10	4688.94	222.14	1.42	25430.34	8.01	1130.81	4.38	0.06	4.17	115.25	0.92	316.70	0.08	14.65	32.36

Train 1 (Bins 1, 5 & 7)

Bin 1

Bin 5

Bin 7

Train 2 (Bins 4 & 6)

Bin 4

Bin 6

Train 3 (Bin 2)

Train 4 (Bin 3)