The Tres Rios Wetlands: From Demonstration Project to Full-Scale Facilities

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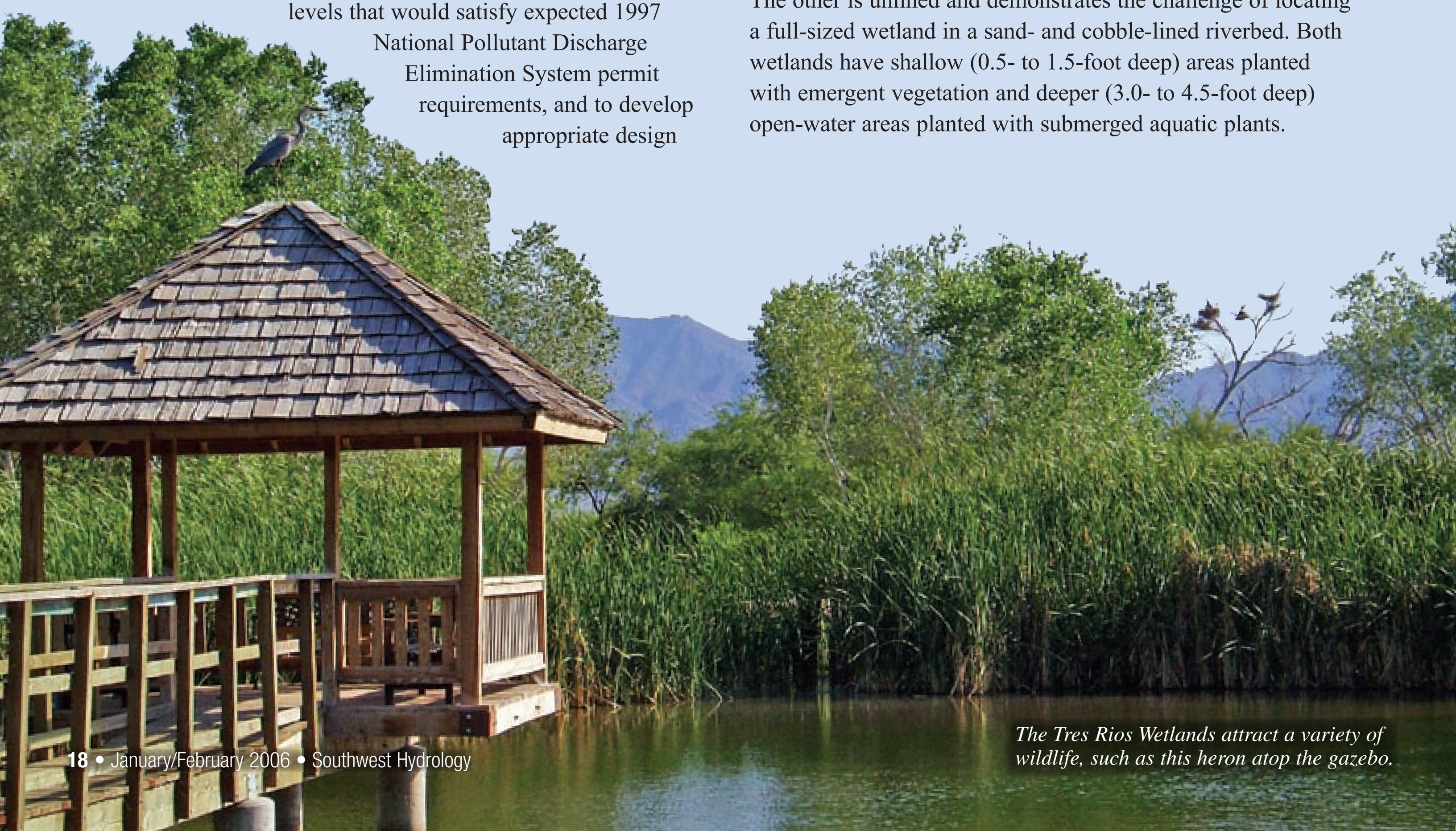
In the mid-1990s, the city of Phoenix and the Subregional Operating Group (SROG), which includes the municipalities of Glendale, Mesa, Scottsdale, and Tempe, partnered with the U.S. Bureau of Reclamation to develop the Tres Rios Constructed Wetlands Demonstration Project. The project was designed to assess the efficacy of using full-scale treatment wetlands to polish the majority of effluent from Phoenix's 91st Avenue Wastewater Treatment Plant (WWTP), the city's largest such facility. The wetlands were to be established along the north bank of the Salt River in southwestern Phoenix. The project would also supply in-channel improvements along the Gila River, ending at the confluence of the Gila and Agua Fria rivers, thus incorporating three major rivers – "Tres Rios."

The Demonstration Wetlands

The primary objectives of the demonstration project were to test the capability of constructed wetlands to treat effluent to levels that would satisfy expected 1997 National Pollutant Discharge Elimination System permit requirements, and to develop appropriate design criteria for a full-scale wetland development capable of accommodating a peak flow of 450 million gallons per day (mgd), while providing flow attenuation and conveying sufficient effluent to meet downstream contractual obligations. Secondary objectives were to enhance wildlife benefits and serve as a community resource for education and passive recreation.

Construction of wetland cells began in the spring of 1995. Now complete, the systems receive approximately 2 mgd of nitrified wastewater effluent from the 91st Avenue WWTP. The demonstration wetlands consist of two 2.1-acre in-stream wetland cells (the Cobble Site), two 3.0-acre upland cells (the Hayfield Site), and 12 0.3-acre pilot cells.

The Cobble Site contains two parallel basins within the Salt River channel. One basin was lined with topsoil to facilitate vegetation establishment and reduce water losses to infiltration. The other is unlined and demonstrates the challenge of locating a full-sized wetland in a sand- and cobble-lined riverbed. Both wetlands have shallow (0.5- to 1.5-foot deep) areas planted with emergent vegetation and deeper (3.0- to 4.5-foot deep) open-water areas planted with submerged aquatic plants.



The Tres Rios Wetlands attract a variety of wildlife, such as this heron atop the gazebo.

The Hayfield Site contains two wetland cells in a riparian/upland area on the north bank of the Salt River. Although they have equal amounts of open water and emergent areas, the northern cell has five interior open-water zones while the southern basin has only two. These deep zones allow water to be remixed after it transitions the shallow emergent areas.

The final wetland system is a series of 12 small (1,200-m^2) research cells located within an abandoned sludge-drying basin, divided into four sets of three cells each, with different amounts of open-water deep areas.

Water Quality Effects

After collecting data for nearly 10 years, much was learned about how the wetlands affect water quality.

cBOD and COD: When operated with at least 60 percent vegetative cover, the wetland cells reduced both the carbonaceous biological oxygen demand (cBOD) and chemical oxygen demand (COD). Incoming cBOD is typically around 3.0 milligrams per liter (mg/L), while effluent varies from 1.9 to 2.2 mg/L. While operating with around 50 percent vegetation, COD slightly increases (on average less than 10 percent) as water travels through the wetland, and is likely an artifact of biomass decay.

Total dissolved solids (TDS): TDS increased 1 to 3 percent in the wetland cells from inlet to outlet, correlating to increases in chloride concentration, attributed to evaporative concentration of salts. The full-scale facilities will be designed to operate at short hydraulic retention times (less than one day) to mitigate evaporative concentration.

Nitrogen: Total nitrogen was removed in all wetland cells. Inflow averaged 2.7 to 3.0 mg/L of nitrate-N, while outflow ranged from 1.7 to 2.0 mg/L nitrate-N. The average incoming ammonia concentration of less than 2.0 mg/L was reduced to 0.4 to 0.5 mg/L at the outlet. Total Kjeldahl nitrogen (organic plus ammonia) was reduced from 3.2 mg/L to 1.4 to 1.5 mg/L. Overall, long-term total nitrogen removal in the wetland basins has been around 35 to 45 percent.

Chlorine: A total residual chlorine study by WASS Gerke + Associates (2004) found that the time required for 2.5 mg/L residual chlorine to decay to 0.011 mg/L (the regulatory limit) in the demonstration wetland was about 12 to 29 hours at normal water temperature (20˚C), slightly longer under colder temperatures (10˚C) and higher hydraulic loading rate. This is within the modeled retention time for the full-scale facilities during normal operating conditions. Based on typical chemical loading rates, the full-scale wetlands could potentially remove 0.75 to 1 ton of chlorine per day.

A mixture of open water and emergent marsh areas in the ratio of 50:50 to 40:60 was found to optimize management and water quality benefits.

Vegetation Lessons

The emergent wetland fringe and deep open-water areas of all wetlands were originally planted with similar vegetation. In 2003, plant stress and plant failure in some basins prompted an evaluation of plant species, depth regimes, and bottom topography. Depth was found to contribute most to wetland plant sustainability. Only a few emergent macrophytic species can withstand years of continuous inundation at depths greater than eight inches, but considerably more can grow at a depth of six inches or less. Thus, the full-scale facilities are being designed with two emergent marsh depth regimes. Further, the bottom of the wetland was reconfigured with hummocks, submerged mounds that provide a gradient of water depths from 0.0 to 1.5 feet.

A mixture of open water and emergent marsh areas in the ratio of 50:50 to 40:60 was found to optimize management and water quality benefits. When the basins were operated with 80 to 90 percent emergent zones, water quality was highest, with TSS typically less than 5.0 mg/L, nutrients removed, and no toxicity. However, the wetlands bred excessive mosquitoes and were dominated by marsh birds such as yellow-headed blackbirds and marsh wrens. When the emergent zone was reduced to 50 to 60 percent, mosquito management was achieved and more classes of wildlife utilized the basin. But water quality fell: more basin surface area was exposed to sunlight, so algal dynamics dominated in the open water areas, resulting in high dissolved oxygen levels during daylight hours and higher concentrations of TSS and nutrients.

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Photo: Joan Gable

new growth will be unable to compete with the native riparian vegetation that is maturing in the area. The SRPMIC now plans to extend similar efforts to remove salt cedar and plant native vegetation upstream of the demonstration site.

Fluctuating Water Levels

SRPMIC's demonstration wetland is a true wetland in the sense that it experiences variable flows and fluctuating water levels, primarily due to seasonal agricultural activities and summer monsoons. This variability did not impact the construction of the wetland, but did impact vegetation diversity. By planting a variety of floating and emergent plant species, the plants will adjust to the availability of water. Some may not survive, but those that do are finding the appropriate location and water depth for successful growth. The wetland is thriving with a diverse vegetative community.

The wetland has also provided an opportunity to educate visitors about non-point source flows, pollution reduction, and native vegetation. Signs provide common English and botanical/scientific names of the riparian plants as well as their names in two of the tribes' native languages, O'Odham and Piipaash. This project has not only improved the water quality of the NPS flows, but restored a riparian ecosystem to what it was before population increases, climate changes, and water resources management practices changed the landscape, and has helped to remind visitors of the unique history of the area.

On a typical morning from this wetland, one can see the gridlock on Highways 202 and 101, while airplanes fly overhead to Sky Harbor. And yet, here one can also see raccoon prints in the mud, flocks of egrets and herons, stands of cottonwood and willows, and hear the trickle of water making its way to the Salt River channel.

In May 2005, the EPA awarded the SRPMIC the 2005 Environmental Achievement Award for its efforts to preserve and protect the environment, of which this demonstration wetland project was a significant part.

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Full-Scale Project

The full-scale project will consist of two primary wetland sites. The Flow Regulating site is expected to remove total residual chlorine, mitigate the occurrence of transient toxicity associated with the effluent, and remove up to 1.25 tons of nitrogen per day.

Another goal of the full-scale facilities will be to regulate flows to the Salt River. Due to long travel times in the collection system and contractual obligations for the effluent, discharge to the Salt River currently fluctuates diurnally, ranging from nearly zero to 200 mgd on a typical summer day. The full-scale facilities will attenuate the flow so that a constant average daily discharge is achieved, stabilizing Salt River water levels and providing enhanced aquatic habitat.

Design of the full-scale facilities is scheduled for completion in August 2006. Construction is expected to cost about $18 million and take 18 to 24 months to complete once funding is secured.

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Reference

WASS Gerke + Associates, 2004. Residual Chlorine Study for the Tres Rios Demonstration Constructed Wetland Project. Prepared for U.S. Bureau of Reclamation, Phoenix.

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How do passive systems compare to conventional treatment performance? Properly designed and sized passive treatment systems can equal or surpass the performance of active systems under similar operating conditions; hybrid active/passive systems are now being considered.

How much do they cost compared to conventional treatment? Economic studies have shown that life cycle costs (combined capital and operating costs) of passive systems are about half those of active systems treating similar flows and ARD chemistry.

Southwest Design Challenges

ARD flow variation in response to wet weather is probably the most significant design challenge in the climate of the Southwest. This challenge would exist for any treatment system sized for the "design" event. What should happen to flow or loading that exceeds the design condition? Experience has shown that routing overloading events through biologically derived passive treatment systems can have consequences that extend beyond the event itself. Some passive systems have been observed to withstand temporary overloading by a factor of three for several weeks and merely sustain temporary minor metal removal efficiency decreases. Longer-term overloading can actually remobilize metals that had previously been precipitated. Thus, it is important to route extreme overloading flow (either increased flow or more aggressive ARD chemistry) around the primary passive treatment unit, which is typically a sulfate-reducing bioreactor. This measure can protect the sensitive biogeochemistry of the bioreactor so that its long-term performance is not compromised. Fortunately, the excessive alkalinity typically found in a sulfate-reducing bioreactor effluent will neutralize some of the acidity in the bypassed ARD. Also, most passive systems can be designed to accommodate low- or no-flow conditions during dry seasons.

Summary

Passive treatment systems should be considered a key component in solving ARD problems if adequate land area is available. Significant capital and operating cost savings may be accrued compared to the costs of conventional water treatment techniques for ARD. Additionally, depleted organic substrate may become a valuable resource if precipitated metals can be economically recovered using hydrometallurgical techniques common to the mineral industry. The passive treatment of ARD holds much promise, especially for the chronic, low-flow mine and mill site drainages that impede the closure and reclamation processes.

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