The Apache Nitrogen Wetland

Groundwater Denitrification Using Constructed Wetlands

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Despite contrary efforts of Mother Nature, the Apache Nitrogen Products Wetland is alive and well and treating nitrate-contaminated groundwater in southeastern Arizona. The wetland project is part of a groundwater remediation effort undertaken by Apache Nitrogen Products Inc. (ANPI) to denitrify groundwater in an alluvial aquifer. The wetland is located on ANPI property across the San Pedro River from St. David in Cochise County. The innovative design of the wetland led the National Ground Water Association to present its inaugural Outstanding Ground Water Remediation Project award to the Apache Wetland Project in 1998.

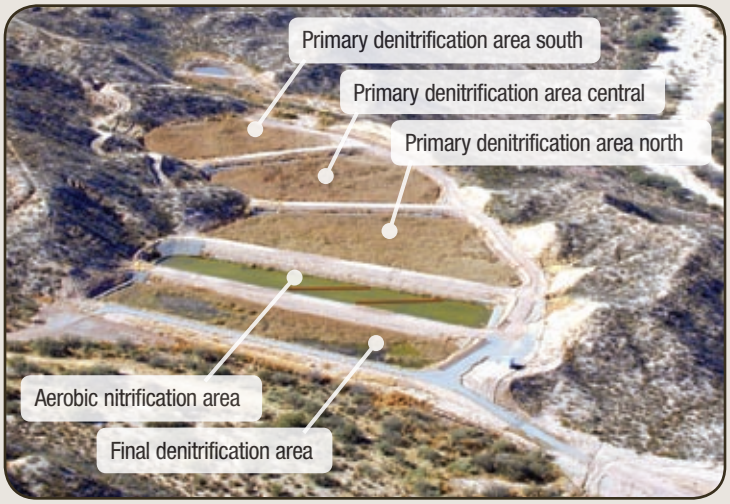
The remediation system includes an extraction well, delivery pipeline, five treatment ponds, and discharge piping. The system currently treats groundwater with nitrate as nitrogen (nitrate-N) concentrations of approximately 200 milligrams per liter (mg/l) at a rate of approximately 180 gallons per minute (gpm). After treatment, the system effluent meets the federal 10 mg/l nitrate-N drinking water standard.

ANPI (formerly the Apache Powder Company) has manufactured industrial chemicals and explosive products continuously since 1922. Wastewater from the manufacturing processes typically was laden with dissolved nitrogen in the form of ammonia-N and nitrate-N. Originally, wastewaters were discharged to unlined ditches that emptied into existing washes. During times of sufficient flow, the washes discharged into the San Pedro River. In 1971, ANPI constructed evaporation ponds, thereby eliminating discharges to the washes. However, because both the ponds and the delivery ditches were unlined, much wastewater infiltrated into underlying soils, creating a mound of groundwater perched on the St. David clay, some 20 to 30 feet below land surface. As this mound grew in volume and areal extent, it began to flow laterally, eventually seeping nitrate solutes into the alluvial aquifer.

The Arizona Department of Health Services first identified potential groundwater contamination problems at the site in 1979. In the early 1980s, the U.S. Environmental Protection Agency and the State of Arizona conducted soil, groundwater, and surface water sampling within the area. Elevated nitrate-N concentrations were detected in some shallow aquifer wells downgradient from the site. In 1989, the EPA directed ANPI to perform remedial investigations at the site and in 1990 designated the area as a Superfund site.

By September, the wetland had … removed approximately 300,000 pounds of nitrate-N from the shallow aquifer.

In October 1994, EPA issued a Record of Decision based on the agency's feasibility study and selected constructed wetlands as its preferred remedial alternative. The wetland project was subsequently designed by Hargis + Associates Inc. in consultation with Robert A. Gearheart of Humboldt State University. After review and approval of the proposed design by EPA and the Arizona Department of Environmental Quality, construction of the wetland began in June 1997 and was completed that September.



Aerial view of the ANPI wetland.

Wetland Treatment Process

Five wetland treatment ponds, covering approximately 4.3 acres, include four anaerobic denitrification ponds and one aerobic nitrification pond. The ponds range from two to five feet in depth. Nitrate-laden groundwater is pumped to the wetland from a "hot spot" in the shallow aquifer using a 10-inch diameter, 110-foot deep extraction well. The groundwater is routed nearly a mile to the wetland via an above- and below-ground delivery system, comprising four-inch diameter polyvinyl chloride (PVC) and high-density polyethylene (HDPE) piping.

Once at the wetland, water flows by gravity through three primary anaerobic denitrification ponds populated with cattails (*Typha latifolia*). The cattails form a carbon-rich detritus for the metabolic processes of denitrifying bacteria. In the absence of dissolved oxygen, certain bacteria utilize alternate sources of oxygen, such as that bound into the nitrate radical. Through this process, nitrate is reduced to free nitrogen, which is liberated to the atmosphere. Additional nitrate-N removal is realized via utilization by cattails and other green flora. The three primary denitrification ponds reduce the influent nitrate concentration more than 90 percent.

Following treatment in the three primary denitrification ponds, the water flows by gravity into an aerobic nitrification pond. This pond contains pondweed (*Potamogeton pectinatus*) and periphyton algae, which oxygenate the water through photosynthesis. Under such aerobic conditions, any ammonia that was either generated in the denitrification ponds or originally dissolved in the groundwater is converted back to nitrate. Upon exiting the aerobic pond, the water passes through a final denitrification pond where remaining nitrate-N is reduced to a concentration of less than 10 mg/L.

The wetland effluent is discharged by gravity flow through about one-half mile of six-inch HDPE pipe prior to discharging to a wash located approximately one-third mile from the San Pedro River. Depending on flow rates and other conditions, the effluent either recharges into the shallow aquifer or flows on to the river.

Full-Scale Operation

The process of bringing the Apache Wetland into full-scale operation proceeded in three phases: establishment, start-up, and full-scale operation. The establishment period began upon completion of construction and planting. During the establishment period, cattail growth and senescence resulted in the accumulation of sufficient detrital biomass and carbon to support denitrification. However, recurrent caterpillar infestations consumed significant quantities of the cattails, thereby delaying the rate of detrital accumulation. *Bacillus thuringiensis* var. Berliner/kurstake (Btbk) was periodically applied aerially from 1998 through 2002. By 2003, aerial spraying of Btbk became unnecessary, presumably due to the habitation of natural predators.

Start-up activities were performed on a limited scale from 2002 through 2004. During this time, the rate of carbon accumulation from cattail senescence could not support the requisite denitrification rate. Additionally, it was determined that a phosphate deficiency was a potentially limiting factor to cattail vitality. Initially, sodium acetate and super triple phosphate were added to the denitrification ponds. Later, molasses was added to overcome solubility limitations and the overall ineffectiveness of sodium acetate. Molasses enhanced denitrification but also generated offensive hydrogen sulfide odors. Sucrose and triple sodium phosphate (TSP) were subsequently added to the wetland to enhance denitrification while minimizing the odors. However, mixing and distribution problems resulted in limited denitrification. Finally, sucrose and TSP were replaced with molasses and sodium tripolyphosphate. The molasses dosage was monitored carefully to avoid generation of hydrogen sulfide odors. By 2004, it was evident that carefully dosed molasses and sodium tripolyphosphate were the most effective amendments for the purpose of enhancing denitrification.

In June 2005, the wetland began full-scale operation. By September, the wetland had treated approximately 200 million gallons of groundwater and removed approximately 300,000 pounds of nitrate-N from the shallow aquifer.

Bonuses

The wetland is an oasis in otherwise dry chaparral. A variety of wildlife frequents its banks: deer, javelina, Gila monsters, bobcats, snakes, lizards, and amphibians, and numerous bird species. Wildlife-friendly fencing allows both near-to-ground fauna and deer to enter and leave the wetland safely, while denying entry to cattle that graze on or otherwise damage sensitive flora. Bats visit the wetland at dusk and control populations of mosquitoes and other insects. Once water is delivered to the wetland via the electrical pump, no other supplied energy is necessary, although solar panels were recently installed to provide electricity for field equipment. The wetland is an environmentally friendly, innovative remedy for groundwater contamination. Through ANPI's community outreach program and Earth Day activities, the wetland also offers an educational experience for students of all ages.

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