## Arundo Donax Removal in the Santa Ana River Watershed

***Jenny Glasser*** *– Orange County Water District*

On June 6, 2003, Orange County Water District (OCWD) was awarded the Ruth Anderson Wilson Award by the Santa Ana Watershed Project Authority for its collaborative efforts in a program to remove Arundo donax (arundo) from the Santa Ana River watershed. The arundo removal program is also one reason the U.S. Environmental Protection Agency selected OCWD as a Clean Water Partner for 2003.

*Arundo donax. Photo by Orange County Water District.*

Arundo donax, or the giant cane, is a non-native, abundant bamboo-like grass that invades the habitats of native flora and fauna, all the while consuming enormous amounts of water. In addition, it is extremely flammable, it clutters beaches, and it clogs up streams and waterways, causing flooding and even bridge damage. Eight thousand acres of arundo use 20,000 to 30,000 acre-feet (about 10 billion gallons) of water per year more than does native habitat, enough water for 100,000 people.

Arundo, nicknamed "the plant from hell," was introduced into Orange County from Europe in the late 1800s as a means of preventing erosion of irrigation ditches. It is a member of the grass family, although it looks more like bamboo. It is primarily found along the Santa Ana River and its tributaries, but can also be found in neighborhoods throughout Orange County and all the way down to the beach. Given sufficient sunlight and water, it can grow up to 10 inches per day in the summer and reach a height of more than 25 feet. Arundo grows so densely in pure stands that it is virtually impenetrable.

An estimated 8,000 to 10,000 acres of arundo inhabit the Santa Ana River watershed. To date, about 1,500 acres have been removed. Initial removal of one acre of arundo costs $5,000 to $9,500, but removing the plant by cutting it off above ground only stimulates additional growth from its massive root system. Full control requires decades of follow-up treatment of the regrowth by additional manual cutting and treatment with herbicides. Removal of the root systems is impractical. Furthermore, arundo removal must be initiated at the top of each watershed because the persistent plant has the ability to break off and transplant itself downstream. However, after the long battle against arundo is waged, native willows, sycamores, and cottonwoods can be replanted or regenerate

*see Arundo, page 33*

*Arundo, continued from page 6*

on their own. Restoration of the natural habitat supports local flora and fauna and saves water.

OCWD has not tackled arundo removal alone; the agency has partnered with several others, including the Santa Ana Watershed Association, which consists of the Riverside-Corona, East Valley, San Jacinto Basin, and Inland Empire West Resource Conservation Districts; the U.S. Fish and Wildlife Service; the Santa Ana Regional Water Quality Control Board; the U.S. Army Corps of Engineers; the California Department of Fish and Game; and area counties, cities, and private landowners abutting the Santa Ana River and its tributaries. To date, more than $17 million has been raised for arundo removal. The resource conservation districts either perform or oversee most of the work on the ground.

Compounding problems in removing arundo is the fact that some commercial nurseries sell it for use as a privacy screen because of its dense growth. It is hoped that soon the California Department of Food and Agriculture will ban the sale of arundo in the state.

The Ruth Anderson Wilson Award is named after a co-founder of the Tri-County Conservation League. The group aims to keep a "soft bottom" to the river for recreational use when it is not in flood conditions, let the natural effects of flooding be accommodated so that new soil and seeds can create young forage for wildlife, and retain water in the Santa Ana River to refill the local groundwater reservoirs. The Santa Ana Watershed Project Authority, which sponsors the award, is a group of water agencies that collaborate to protect and improve the environment and water in the land drained by the Santa Ana River. The Authority includes the Inland Empire Utilities Agency, Eastern Municipal Water District, Orange County Water District, San Bernardino Valley Municipal Water District, and Western Municipal Water District.

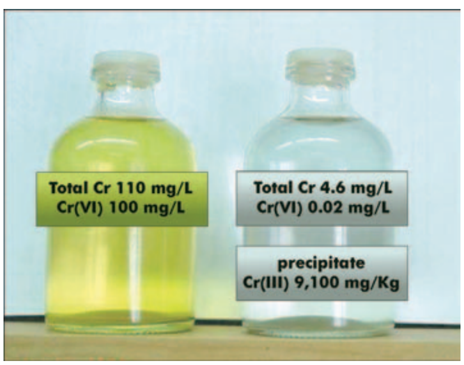
*Visit www.ocwd.com for more information.*

## *In-Situ Remediation of a Chromium-Contaminated Site Using Calcium Polysulfide*

***Andrew Messer, Peter Storch,*** *and* ***David Palmer***
*– URS Corporation*

URS Corporation is using calcium polysulfide (CPS) for in-situ geochemical fixation of hexavalent chromium, Cr(VI), in soil and groundwater in alluvial fan sediments at a former metal plating facility in western Arizona. Concentrations of Cr(VI) in groundwater at the site exceed 200 milligrams per liter (mg/L) compared to the maximum contaminant level of 0.1 mg/L for dissolved chromium in drinking water set by the U.S. Environmental Protection Agency. URS has completed vadose zone and groundwater pilot tests using CPS and has begun full-scale vadose zone application in the source area.

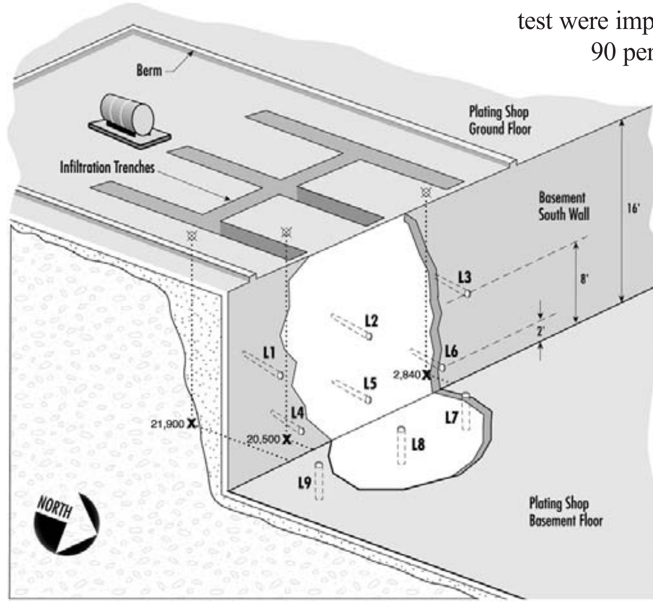
CPS is used extensively as an agricultural soil amendment and for removal of metals in water treatment systems, and has recently been approved for in-situ remediation at several sites in the United States. CPS is more stable and persistent in subsurface environments than other reductants such as sodium dithionite, does not form insoluble precipitates such as ferrous sulfate, and is relatively safe to handle in the field. CPS reduces Cr(VI), commonly in the form of chromate, $CrO_4^{2-}$, to the relatively insoluble form of trivalent chromium, Cr(III), which is less toxic and tends to fall out of solution and adhere to soil. One example of the reaction is:




*Groundwater samples from an observation well: pretreatment (left) and day 9 of treatment (right).*

$$2CrO_4^{2-} + 3CaS_5 + 10H^+ \rightleftarrows 2Cr(OH)_{3\,(s)} + 15S_{(s)} + 3Ca^{2+} + 2H_2O$$

The fixation of Cr(VI) by CPS is considered to be a permanent remediation technique under most groundwater conditions. The reaction is theoretically reversible; however, under natural groundwater conditions the equilibrium condition is dominated by the right side of this reaction. Furthermore, the only mechanism identified in the literature for the re-oxidation of Cr(III) under natural groundwater conditions is by a grain surface reaction that occurs when dissolved Cr(III) is exposed to aquifer sediments coated with manganese dioxide ($MnO_2$). Since $Cr(OH)_3$ is a solid precipitate, reaction with $MnO_2$ is limited by the extremely low solubility of this compound.




*Vadose zone pilot test infiltration trenches and lysimeters.*

Prior to vadose zone treatment, Cr(VI) concentrations in the 20 square-foot test zone were as high as 2,190 mg/kg in soil and 3,600 mg/L in the vadose zone pore water. Over a period of about 24 hours, approximately 660 gallons of 29 percent CPS were applied to infiltration trenches, followed by 2,500 gallons of water to disperse the chemical through the test zone. The wetting front was monitored and sampled with soil lysimeters installed in a basement wall (see figure above). Results during the first 30 days indicated that eight of the nine lysimeters used to monitor the test were impacted and demonstrated a 90 percent reduction in Cr(VI) concentrations.

In the groundwater pilot test area, the aquifer at 165 feet below surface was impacted by Cr(VI) concentrations of 240 mg/L, nitrates exceeding 400 mg/L, and trichloroethene and other VOCs. Approximately 9,000 gallons of 29 percent CPS were injected through an existing monitor well, followed by 79,000 gallons of water, at an average rate of 31 gallons per minute, to flush the well and push the reductant to an observation well at a distance of 30 feet across the regional hydraulic gradient. Downhole monitoring was conducted in the observation well using a multiparameter probe and depth-specific sampler. After 35 hours, breakthrough of CPS was indicated by a decrease in oxidation/reduction potential (ORP) and an increase in pH and total dissolved solids. Concentrations of Cr(VI) in the observation well dropped from 240 mg/L to less than 1 mg/L shortly after ORP became negative. Mobilization of arsenic, iron, and manganese from aquifer solids due to the reducing conditions was not observed. In the observation well at the edge of the injected CPS footprint, rebound of Cr(VI) concentrations occurred after 115 days. In the injection well at the center of the injected reductant, ORP has remained negative and Cr(VI) concentrations were below detection after 419 days. URS is proceeding with full-scale vadose zone application in the source area and plans a full-scale groundwater remediation.

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## Siphon-Infiltration Trench Field-Tested in Albuquerque

***James A. Kelsey**, Senior Scientist and **John T. Kay**, Hydrogeologist – Daniel B. Stephens & Associates*

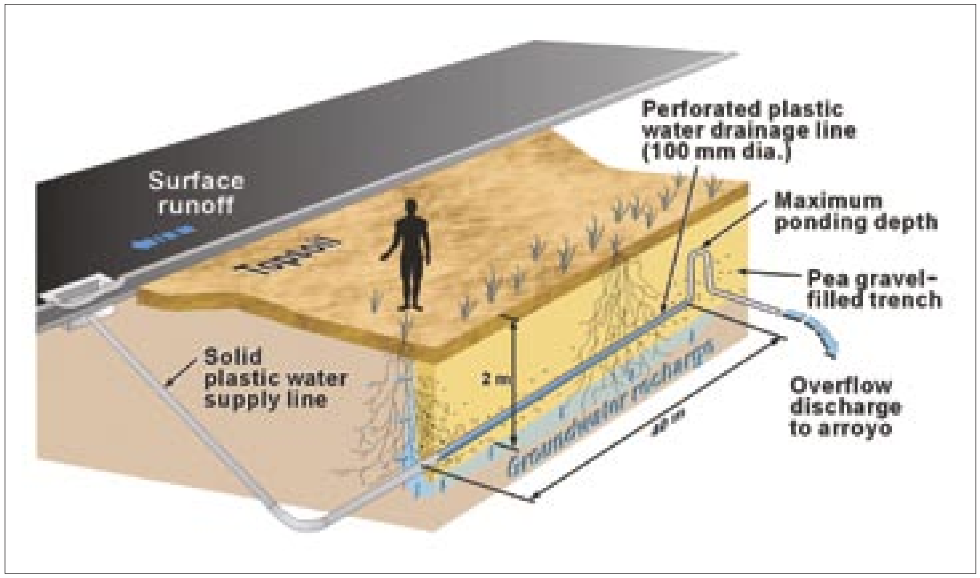
Daniel B. Stephens & Associates (DBS&A) recently designed and field-tested a self-cleaning infiltration trench. DBS&A's siphon-infiltration trench offers a low-cost, low-maintenance solution to the sedimentation and performance problems associated with traditional agricultural drains and other infiltration trenches. The trench intercepts surface runoff and diverts it to the subsurface, and, depending on the location, can result in increased groundwater recharge, decreased erosion, improved water quality, and improved riparian habitat. A siphon creates periodic, rapid-flow conditions that flush sediment out of the infiltration system, thus providing a self-cleaning function.

*AMAFCA assists with construction of the trench*

With the assistance of the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA), DBS&A installed a 50-meter-long siphon-infiltration trench adjacent to an unlined arroyo in Albuquerque, New Mexico. The trench was outfitted with multiple flow meters and pressure transducers to monitor flow rates and water levels at different locations along the trench. Self-cleaning ability and infiltration potential are currently being monitored and assessed.

### How It Works

As far as DBS&A has been able to ascertain, siphons have not previously been used in a similar infiltration application. Almost no relevant literature exists on this subject. The design and installation of this system were determined from bench-scale results obtained in the DBS&A laboratory.



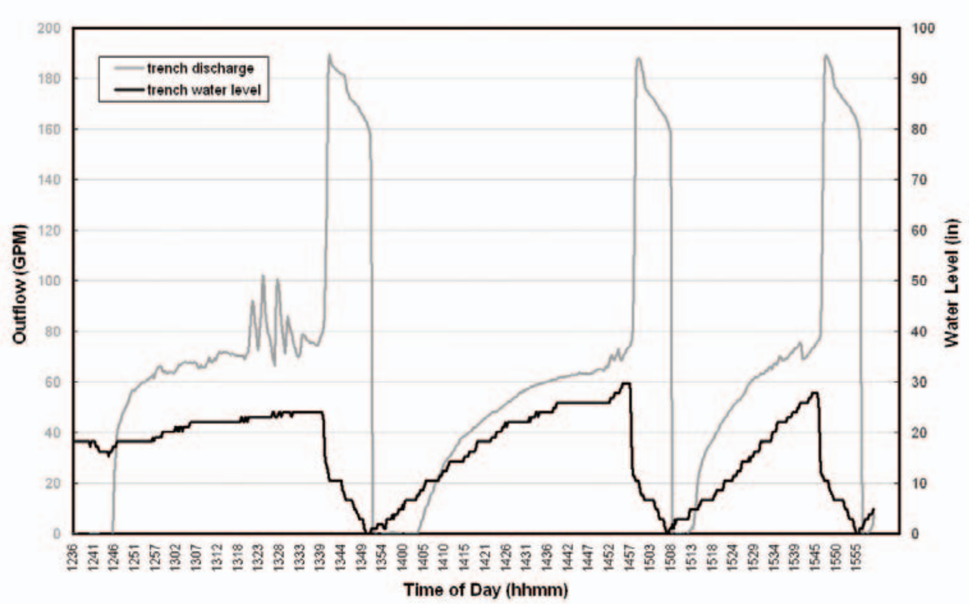

*Schematic diagram of a typical siphon-infiltration trench. The infiltration trench can be applied to most locations where diversion of surface water to the subsurface is desirable.*

The siphon-infiltration trench is essentially an infiltration trench connected to a siphon at the outlet, and consists of a perforated water supply line, gravel backfill, the surrounding soil, and the siphon mechanisms, as shown in the illustration above. As the infiltration trench fills, water replaces the air at the top of the siphon mechanism, activating the siphon. Once activated, the siphon flushes water from the trench under high velocities until the trench empties, at which point air enters the system and breaks the siphon. When the siphon breaks, the trench begins to refill, thus repeating the cycle. Infiltration of water into the surrounding vadose zone occurs continuously during each phase of the cycle.

### Self-Cleaning Ability

For a trench to be self-cleaning, discharge velocities must be greater than the velocity of flow into the trench. The maximum observed inflow rate in DBS&A's trench was approximately 0.62 meters per second (m/s). According to Stokes' Law and the Impact Law (Gibbs and others, 1971), this velocity will entrain a particle approximately 5 millimeters (mm) in diameter. During siphoning, observed velocities ranging from 1.33 m/s to 1.92 m/s were observed (see chart on page 9). These velocities can be expected to flush particles larger than 16 mm in diameter.

During a controlled experiment conducted on Aug. 29, 2002, substantial amounts of sediment previously deposited in the trench were discharged from the siphon during the first cycle. It is estimated that approximately 1,300 kilograms (kg) (0.5 cubic meters) of sand and small




*Flow rates under siphoning and non-siphoning conditions. When water levels rise to an engineered height, the siphon is actuated. The three peaks in flow rate correspond to three separate siphoning events. After the trench drains, the siphon is broken, and water levels begin to rise again. Infiltration into the surrounding soil occurs continuously.*

gravel were flushed during this one cycle. To quantify the siphon's capability to entrain particles further, known masses of different-sized particles were introduced to the trench during a controlled experiment conducted on Oct. 29, 2002. All sediment with a diameter less than 9.5 mm (40 kg) was discharged during one siphon cycle. Approximately 70 percent of the sediment with a diameter ranging from 9.5 to 19 mm (20 kg) was discharged, and the remaining sediment was near the upper end of this range.

### Conclusions

The design of the siphon-infiltration trench is very flexible, making it suitable for a wide range of applications and site locations. Trench design must consider local flow regimes and potential sediment loads, and allow a period and magnitude of siphon discharge sufficient to prevent clogging. The design goal is to discharge only as much water as necessary to prevent the buildup of sediments, thus maximizing infiltration while maintaining long-term performance. A few of the applications for which siphon-infiltration trenches can be used are (1) increasing groundwater recharge, (2) vadose zone filtering and treatment of coliforms, pesticides, or other compounds, and (3) promoting plant growth to reduce erosion near unlined ephemeral waterways.

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### Reference

Gibbs, R.J., M.D. Mathews, and D.A. Link. 1971. The relationship between sphere size and settling velocity. J. of Sed. Petr. 41:7-18.