ABSTRACT & POWERPOINT PRESENTATION

In-Situ Arsenic Removal during Groundwater Recharge through Unsaturated Alluvium

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Symposium Organizers:

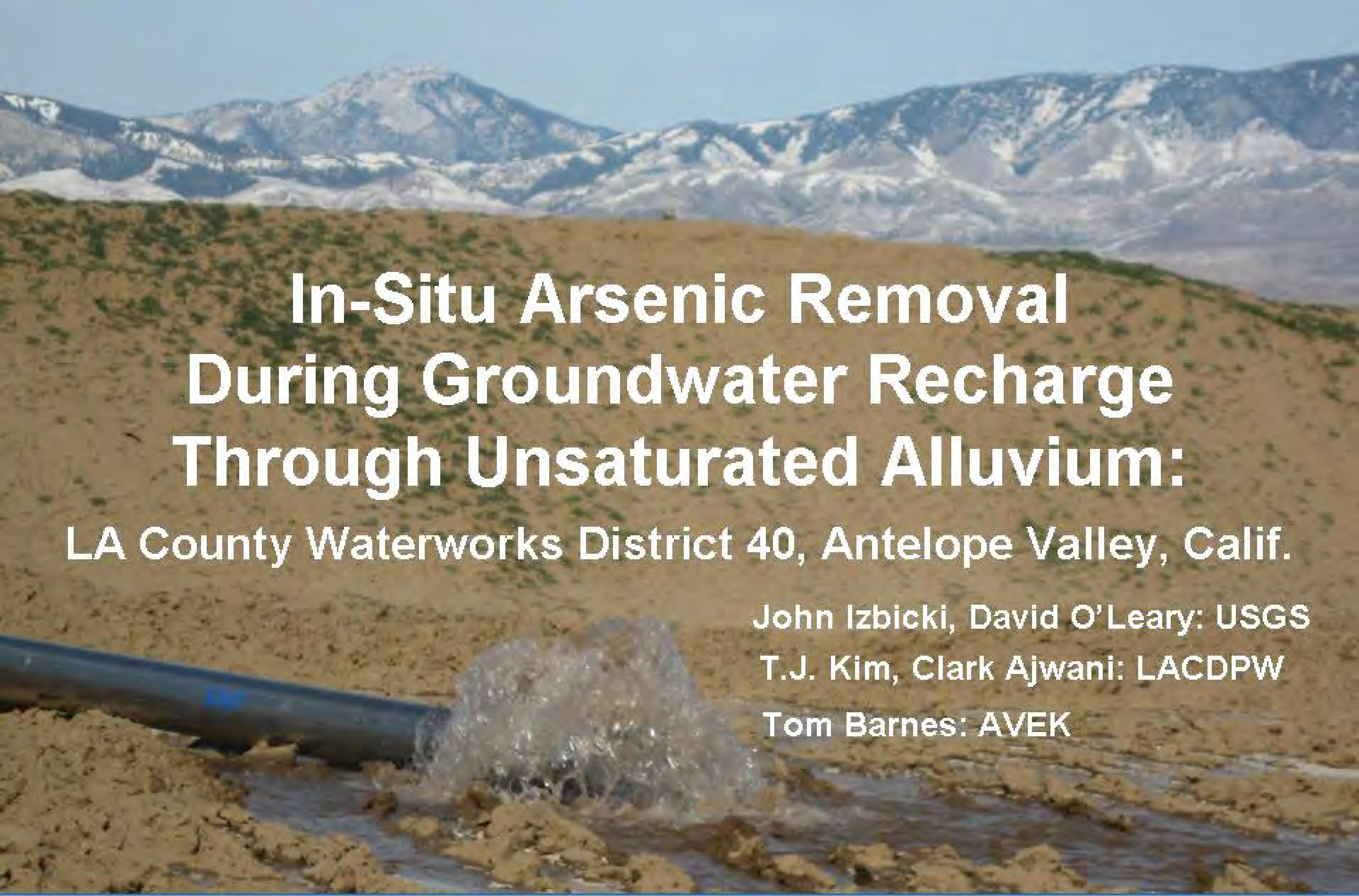
- National Water Research Institute
- Orange County Water District
- Water Research Foundation

www.nwri-usa.org/rechargesymposium2011.htm

In-situ arsenic removal during groundwater recharge through unsaturated alluvium

By: John A. Izbicki, T.J. Kim, Clark Ajwani, and Thomas Barnes

Arsenic in excess of the U.S. Environmental Protection Agency Maximum Contaminant Level (MCL) of 10 micrograms per liter (μg/L) is common in aquifers throughout much of the southwestern United States. A field-scale experiment is being done in Antelope Valley, Calif., in cooperation with Los Angeles County Department of Public Works and Antelope Valley East Kern Water Agency, to determine if naturally occurring iron, manganese, and alumina oxides present on the surfaces of mineral grains in the unsaturated zone can be used to remove arsenic in applied water that contains high concentrations of arsenic. In the study area, a shallow unconfined aquifer with arsenic concentrations less than the MCL overlies a deeper aquifer that has an average arsenic concentration of about 30 μg/L. High-arsenic groundwater will be pumped from the deeper aquifer into a half-acre pond and then infiltrated through a 300-foot thick unsaturated zone to recharge the shallow aquifer, where it later could be pumped and delivered for public supply. An unsaturated-zone monitoring site consisting of multiple tensiometers, heat-dissipation probes, and suction-cup lysimeters will be constructed adjacent to the pond to monitor the movement and quality of the applied water as it infiltrates to the underlying water table. Cores and cuttings collected during the construction of the site will be used in column experiments to determine the physical and chemical factors that control sorption of arsenic under different geochemical conditions, thereby facilitating transfer of the technique to other areas having similar geologic conditions. In addition, batch experiments will be done using radiolabled arsenic-73 (a man-made isotope, having a half-life of 80.3 days) to determine partitioning of arsenic on mineral grains and its potential incorporation from sorbed into increasingly mineral phases. These factors are believed to control the long-term fate of sorbed arsenic, and its potential mobility if overlying land use changes. The experiment is designed to recharge 1,600 acre-feet of water from a half-acre pond over a two-year period. Preliminary estimates suggest that the unsaturated zone underlying the pond may contain enough naturally-occurring oxides to treat as much as 50,000 acre-feet of high-arsenic water. The cost of arsenic treatment and recharging the shallow aquifer in this way is the cost of pumping the water.



In-Situ Arsenic Removal During Groundwater Recharge Through Unsaturated Alluvium:

LA County Waterworks District 40, Antelope Valley, Calif.

John Izbicki, David O'Leary: USGS

T.J. Kim, Clark Ajwani: LACDPW

Tom Barnes: AVEK

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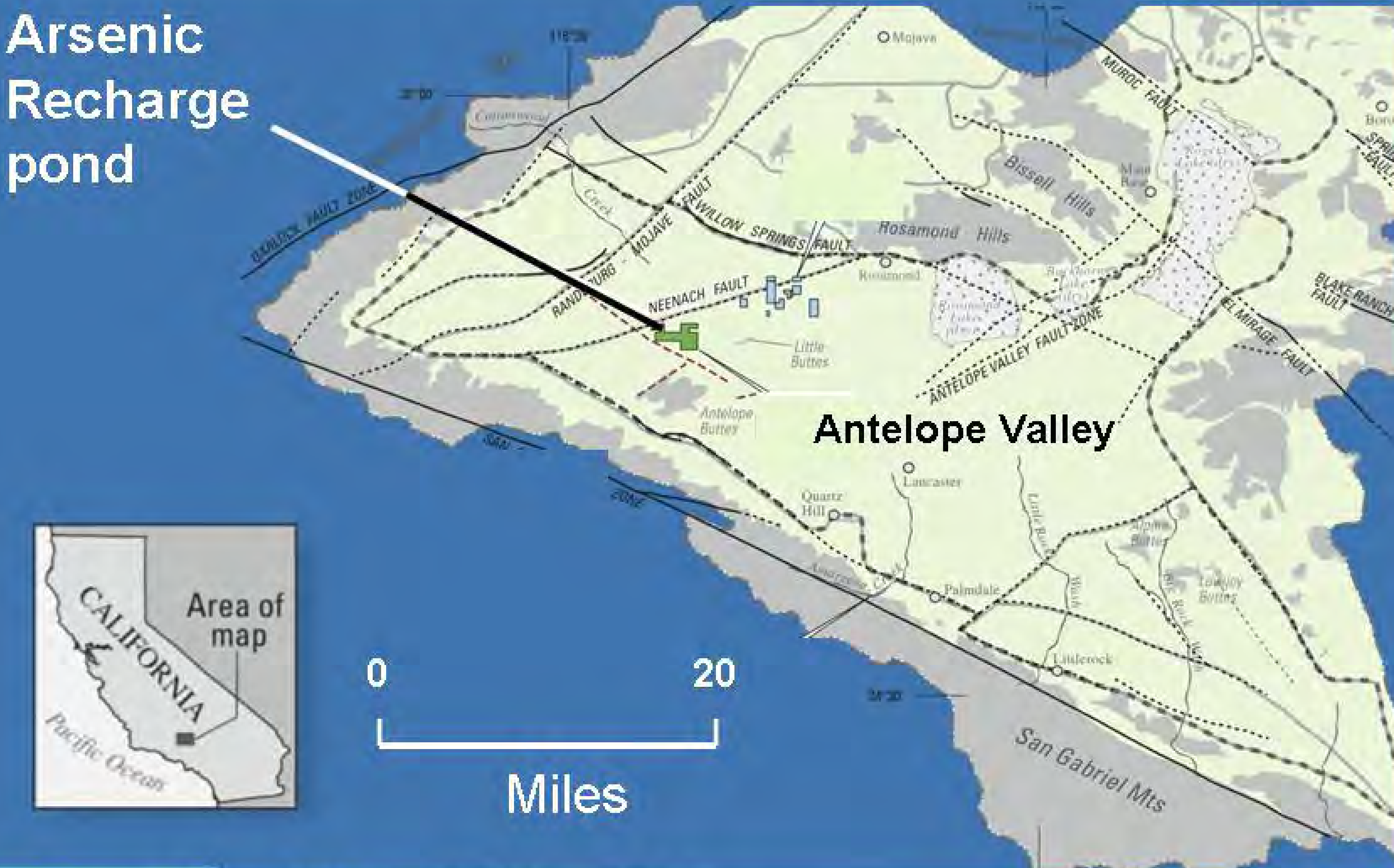
In cooperation with: LA County Department of Public Works, Antelope Valley East Kern Water District and additional funding from the Water Research Foundation

Study area location



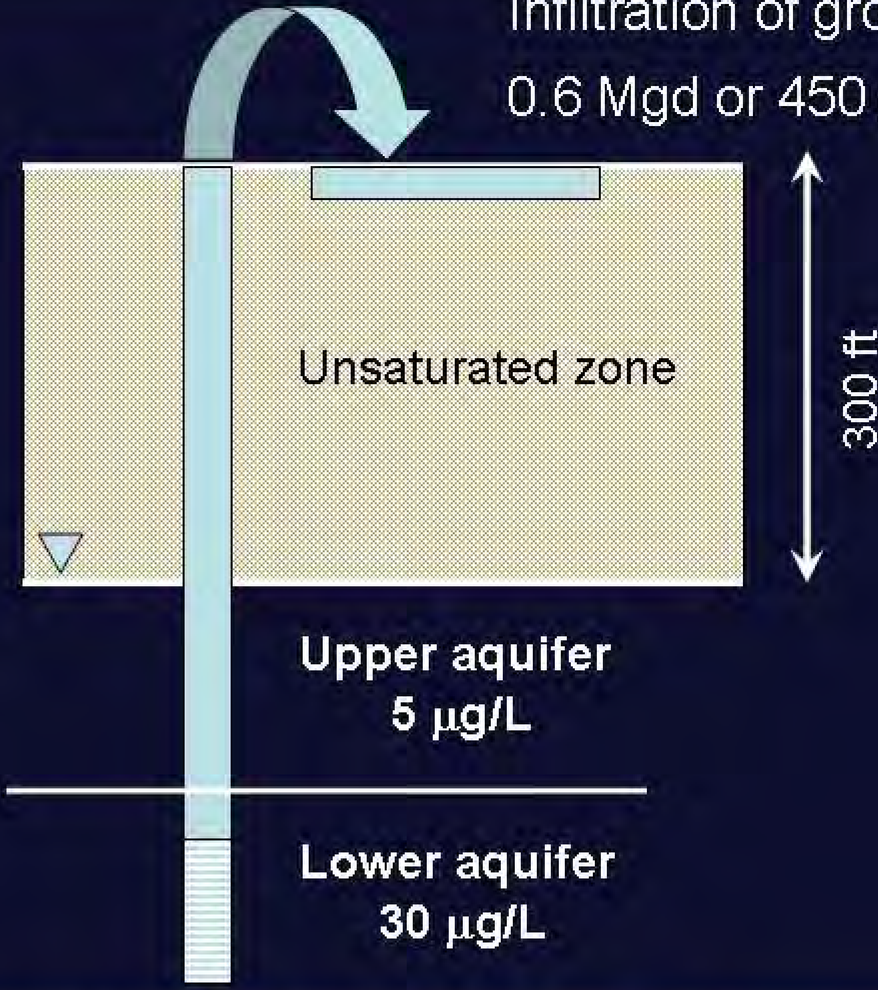
Scope of presentation

- Theory
- Site construction and instrumentation
- Preliminary results
- Transferability of results and site closure
- Benefits, concerns, and limitations

Proposed *insitu* treatment of arsenic

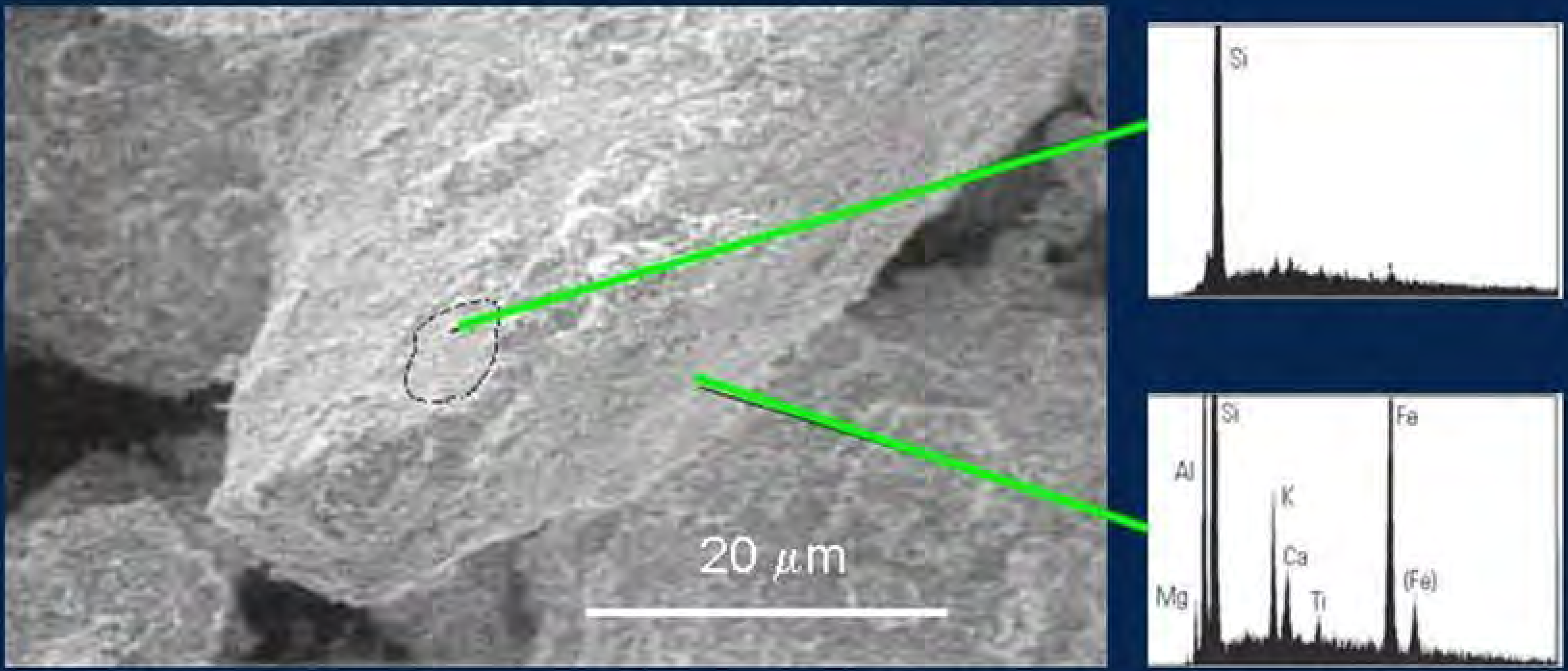
Infiltration of ground water from a 1-acre pond at 2 ft/d

0.6 Mgd or 450 gal/min



- 10^7 ft^3 of material beneath pond
- Assuming a porosity of 0.33 and a grain density of 2.65 g/cm^3
  5.3 x 10^7 kg of alluvium

Why will this approach work



- Abundant alumina, iron, and manganese oxides present as surface coatings on mineral grains
- The same chemistry that forms the basis for absorptive media sold commercially for arsenic removal

Infiltration, clays, and surface area

- Extensive paleosol development within the Victorville fan – initial infiltration to the water table required 3 years

- Limited paleosol development in Warren basin at the mouth of Water Canyon – infiltration to the water table occurred in 4 months

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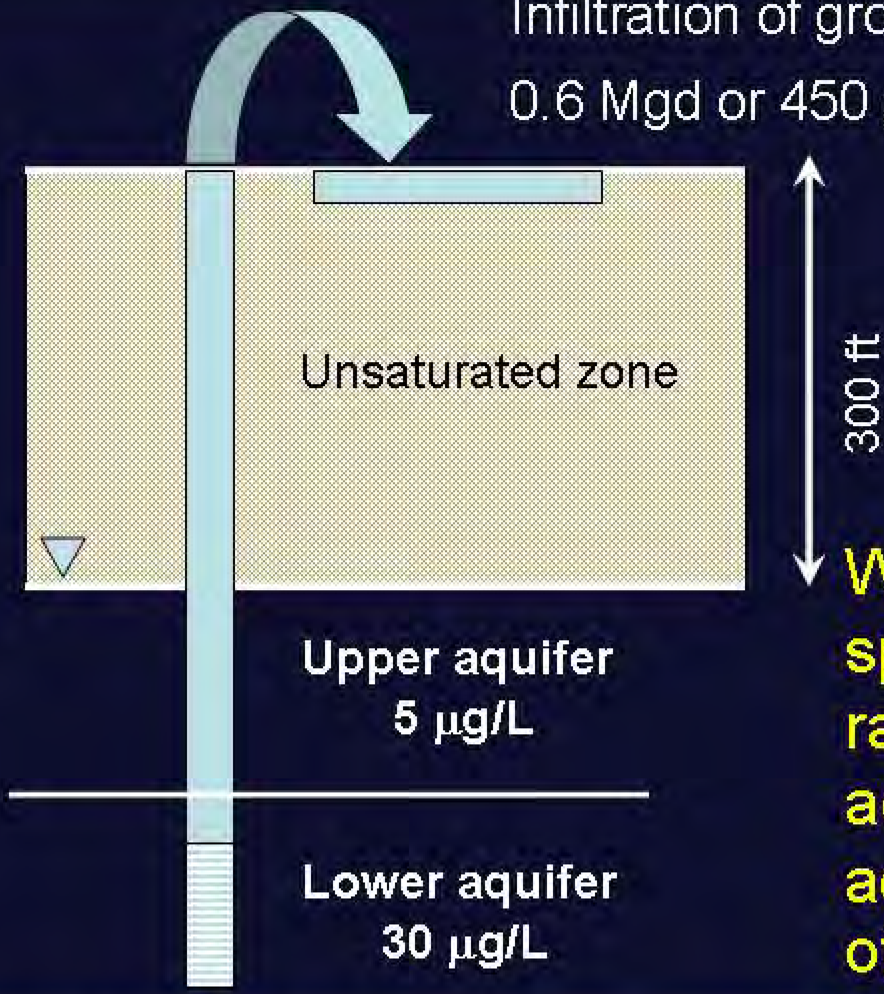
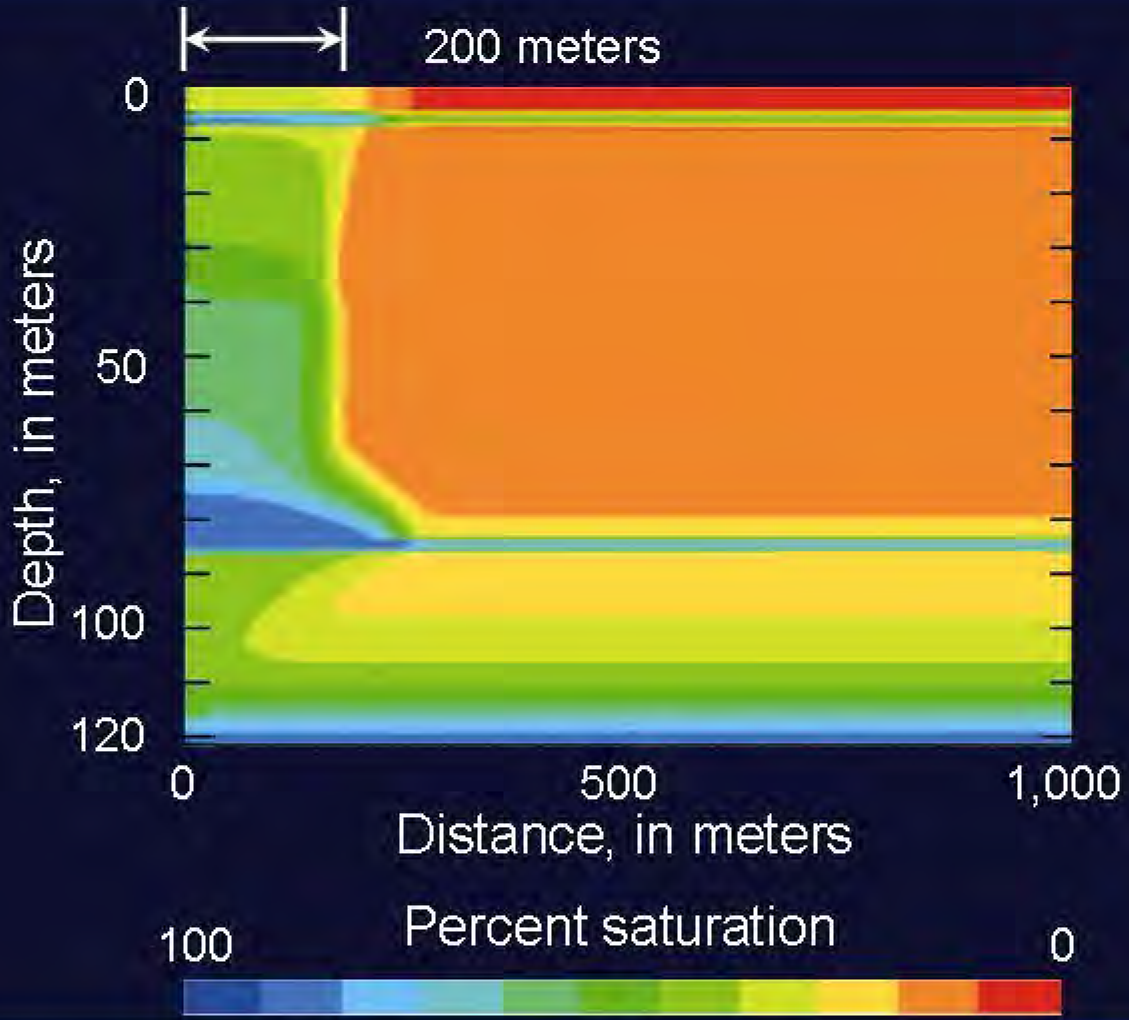


- 10^7 ft^3 of material beneath pond
- Assuming a porosity of 0.33 and a grain density of 2.65 g/cm^3
  5.3 x 10^7 kg of alluvium

Without accounting for lateral spreading and given an infiltration rate of 450 gal/min, 300 ft of aquifer material can treat 6,700 acre-feet of water having 30 µg/L of arsenic to <1 µg/L for 4.4 years

Effect of lateral spreading



- Average footprint of wetted area from 1 acre pond is 30 acres
- Accounting for lateral spreading and given an infiltration rate of 450 gal/min, 300 ft of aquifer material can treat more than 200,000 acre-feet of water having 30 μg/L of arsenic to <1 μg/L over 130 years

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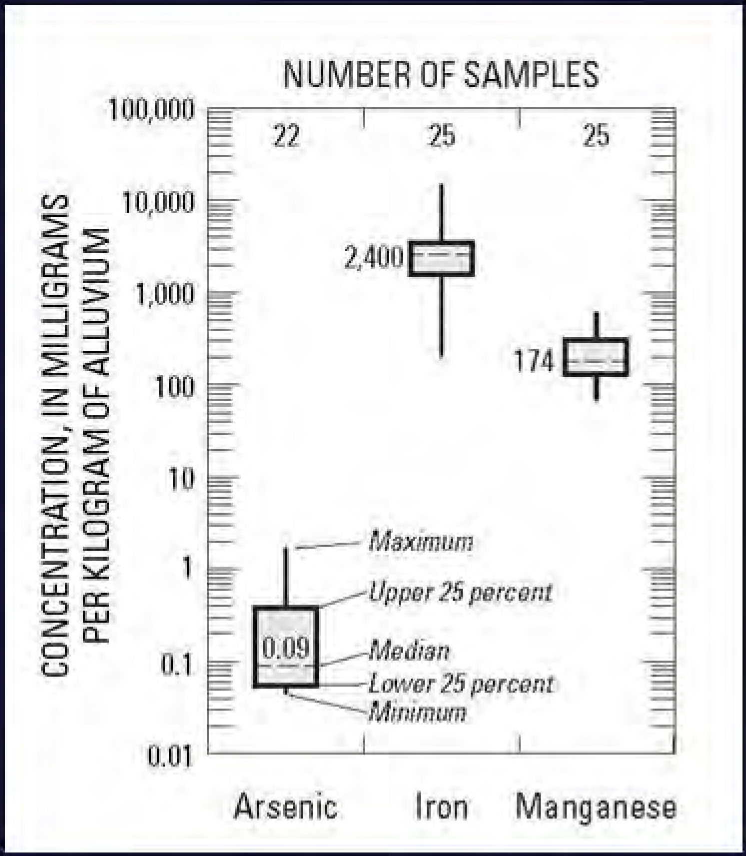
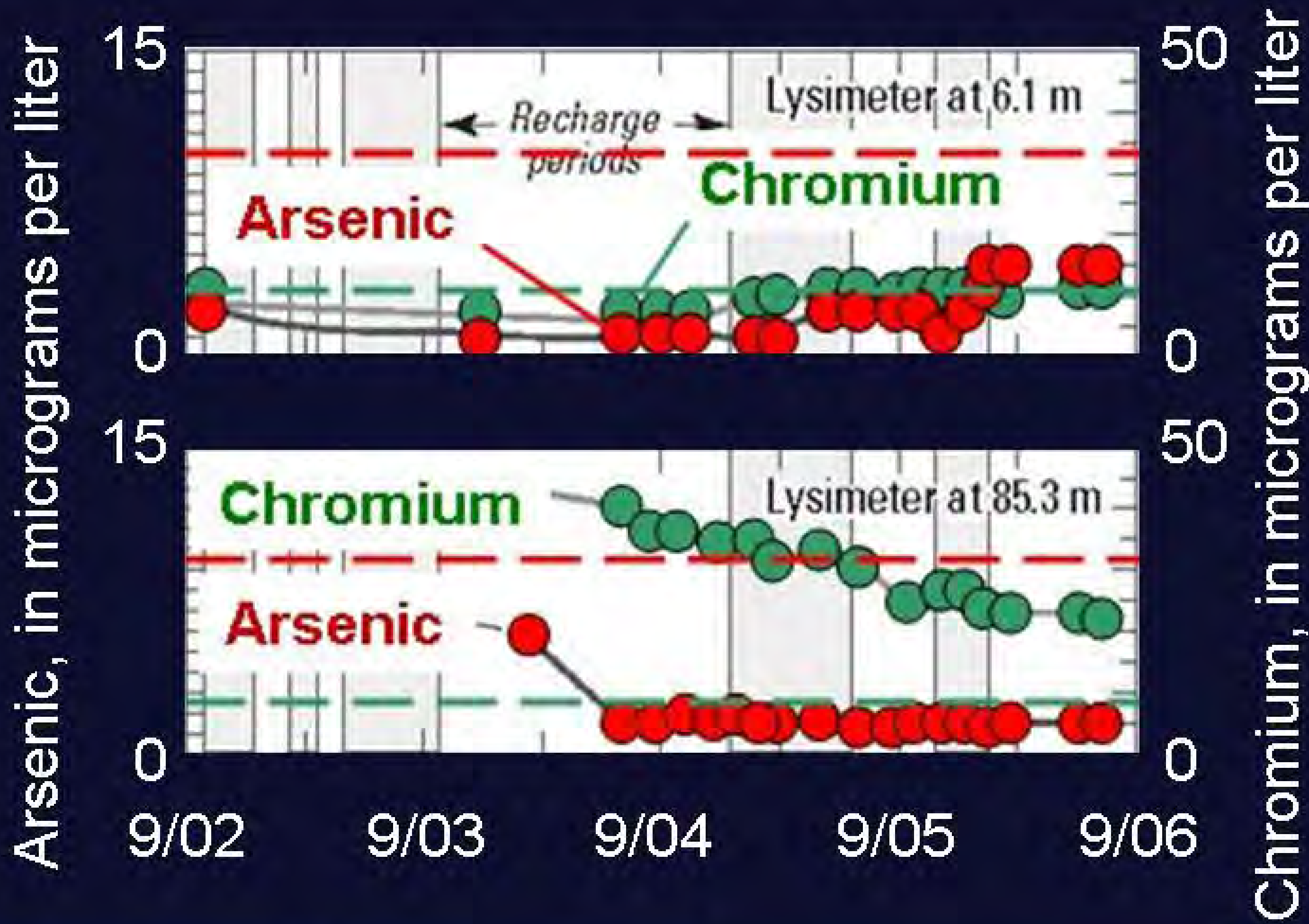
Arsenic concentrations on sorption sites



- The bulk of the alluvial material is Inert silicate minerals
- Granitic alluvium
  0.09 milligrams per kilogram
  After breakthrough
  9.5 milligrams per kilogram
- Spent activated iron media
  5.5 grams per kilograms
  Spent activated alumina media
  4 grams per kilograms

Empirical data from Victorville fan



800 acre-feet of water having an arsenic concentration of 10 μg/L treated to <1 μg/L

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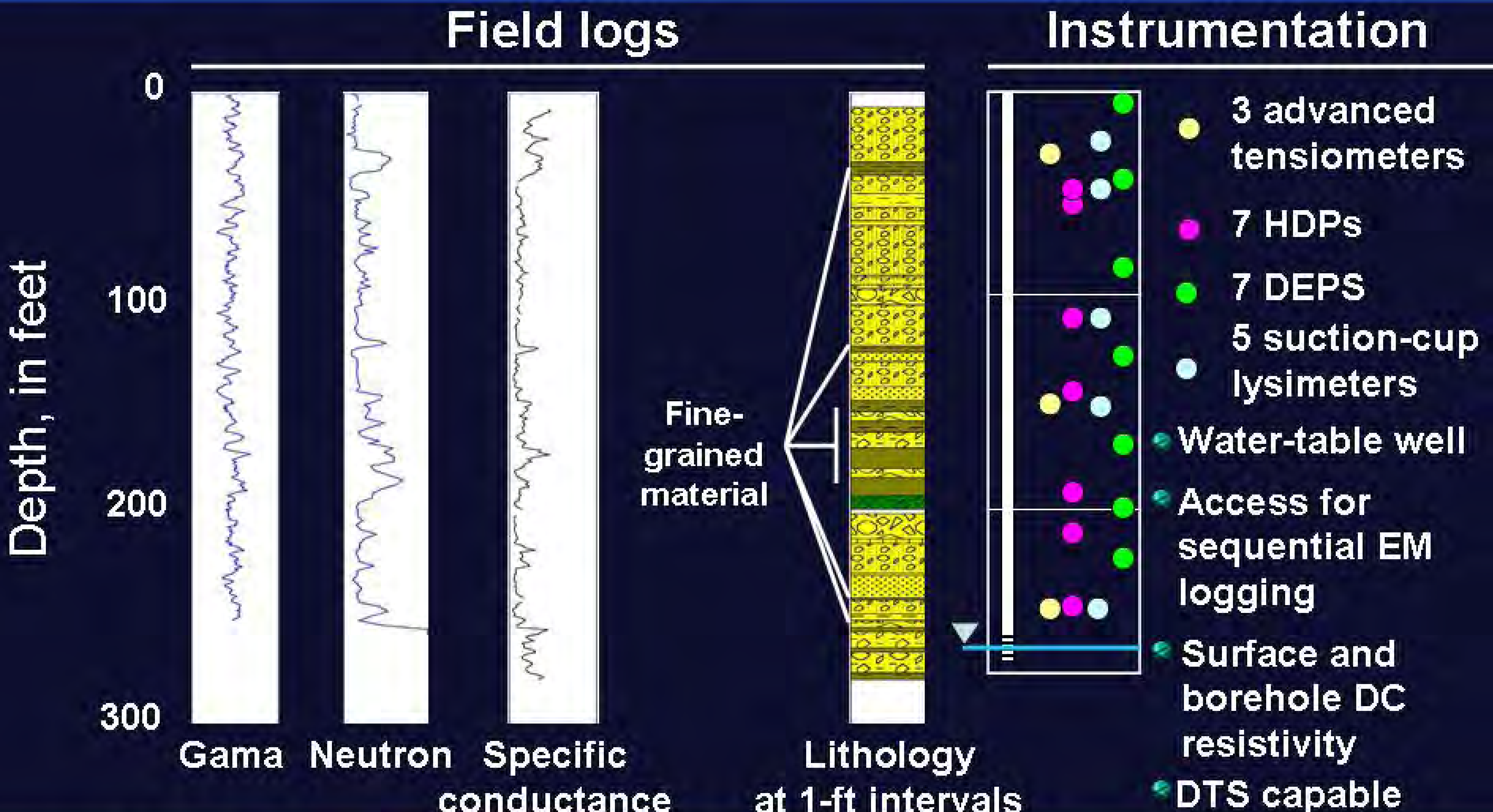
Drilling

- ODEX drilling technology
- Air is the drilling fluid
- Sample collection at 1 foot intervals

Site construction and instrumentation



Project timeline and preliminary results

- Water infiltrated in early December had an arsenic concentration of 30 μg/L
- Water that reached the lysimeter at 27 ft (above the first paleosol) by Jan 19th had an arsenic concentration of 8 μg/L

Column experiments

- Testing materials to minimize sorption
- Range of geologic materials and textures to assess the effect of particle-size and oxide abundance
- Range of pH's to evaluate pH dependence of sorption

- Use of "synthetic water" to control for competition for sorption sites by other oxyanions

Don Suarez
U.S. Soil Salinity Laboratory

Radiolabeled Arsenic-73 experiments

- Samples spiked with As-73 and incubated for up to 1 year
- Replicates periodically harvested and arsenic sequentially extracted
- As-73 mobilized by each extraction step analyzed by gamma spectroscopy

Sequential Extraction

Chao and Sanzolone (1989) and Wenzel et al. (2001)

0.25 M KCl

↓

0.1 M KH_2PO_4

↓

0.2 M NH_4-oxalate buffer

↓

0.2 M NH_4-oxalate buffer + ascorbic acid

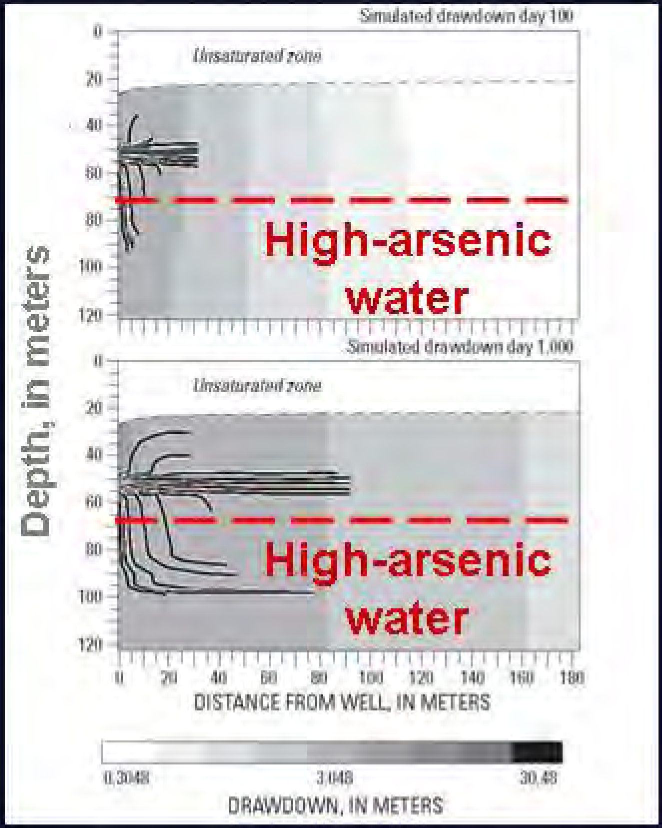
↓

Measure remaining radioactivity

Tom Kulp
USGS, NRP

Benefits

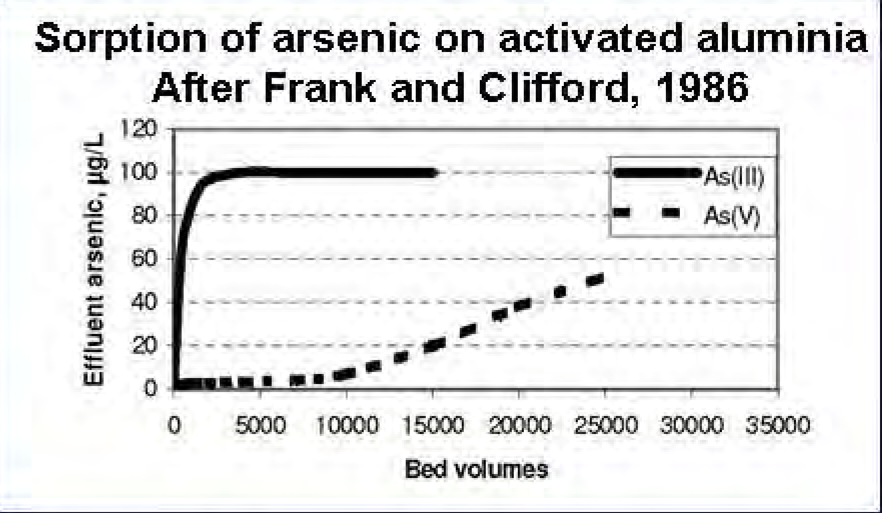
- Pumping from deep aquifer controls pressure induced upward movement of high-arsenic water
- Restores a source of water supply lost as a result of regulatory changes
- Minimal costs and infrastructure without generation and disposal of waste
- Treated arsenic remains *insitu* and never leaves the site



Induced movement of water from deeper aquifers by pumping

Concerns and limitations

- Arsenic III is less readily sorbed than Arsenic V
- Potential concerns about mobility of trace elements such as chromium and vanadium
- Preferential flow and rapid transport of arsenic to the water table



- Optimize pumping rates and pond size to ensure adequate depressurization of underlying aquifer at minimal cost

Caution: do not infiltrate water having a high organic carbon load such as aqueduct water, treated municipal wastewater, or stormflow runoff to ensure maintenance of oxic conditions. Similarly, frequent cleaning of the pond may be required to minimize development of algal mats

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Questions and answers

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