Session 4

Paving the path to success: Data driven solutions

Erik Gaiser, PG
Wildermuth Environmental

Treatment technologies for removing contaminants of emerging concern: 1,4-dioxane, 1,2,3-TCP, PFOA/PFOS, perchlorate, and Cr6

Nicole Blute, PhD, PE
Orange County Water District

PFAS: How we got here and legal options going forward

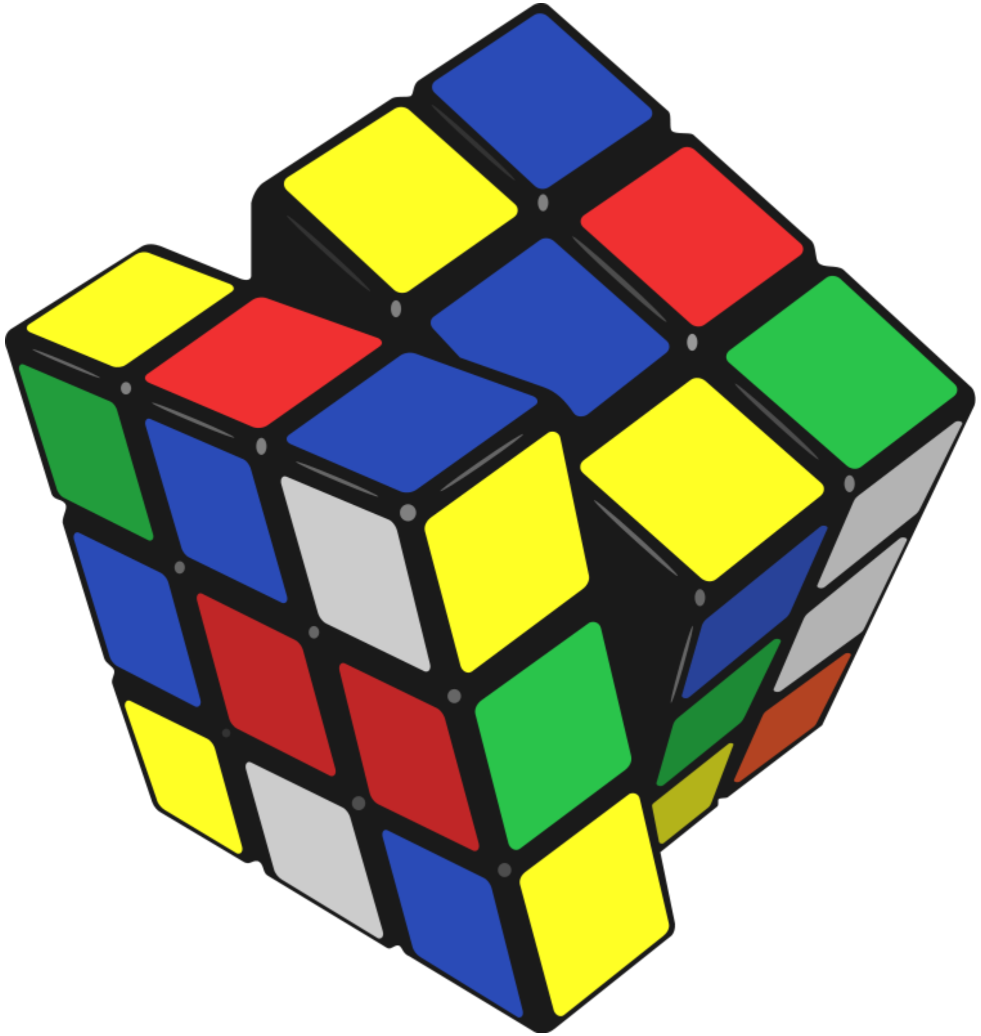
Richard Head
SL Environmental Law Group PC

Paving the path to success: Data driven solutions

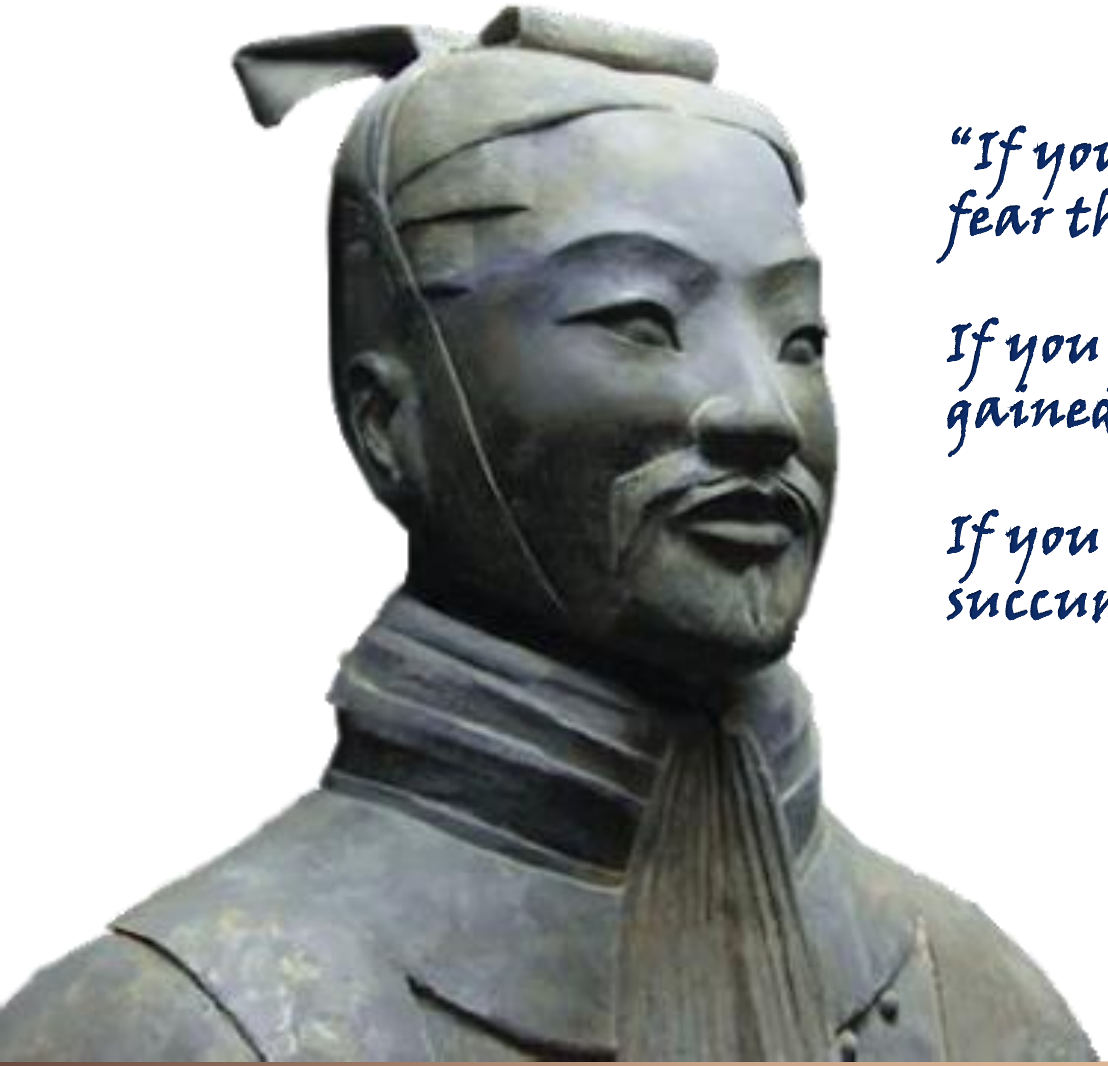
Chino Basin Water Quality Colloquium

May 2, 2019

Houston…We Have a Problem



Where to Start



"If you know yourself and know your enemy, you need not fear the results of a hundred battles.

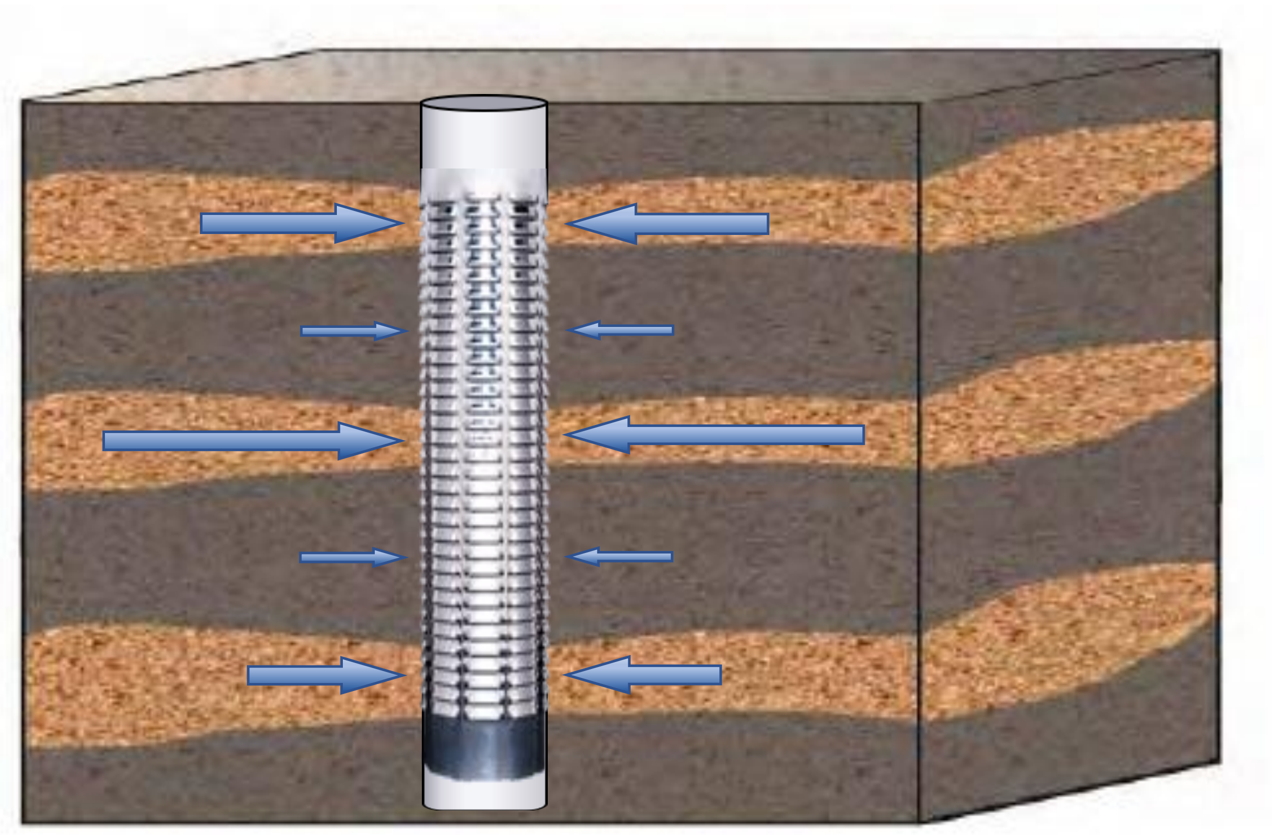
If you know yourself but not the enemy, for every victory gained you will also suffer a defeat.

If you know neither the enemy nor yourself, you will succumb in every battle."

The Art of War
Sun Tzu, 500 B.C.

How Much is Enough to Solve the Problem?

What Bulk Sample Results Mean



- High volume groundwater samples are not an average concentration
- Stratification of water quality can occur due to variations in aquifer structure and materials
- Flow is concentrated in high permeability zones ($K > 10^{-4}$)
- Mass is stored in low permeability zones ($K < 10^{-4}$)
- Provides conductivity proportional result
  - Results are biased toward water quality in higher K zones

When is a Bulk Sample is Enough?

Blending

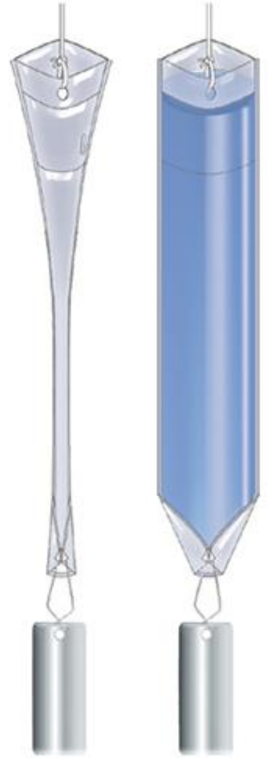
Wellhead Treatment

When You Need Something More

Bomb Samplers

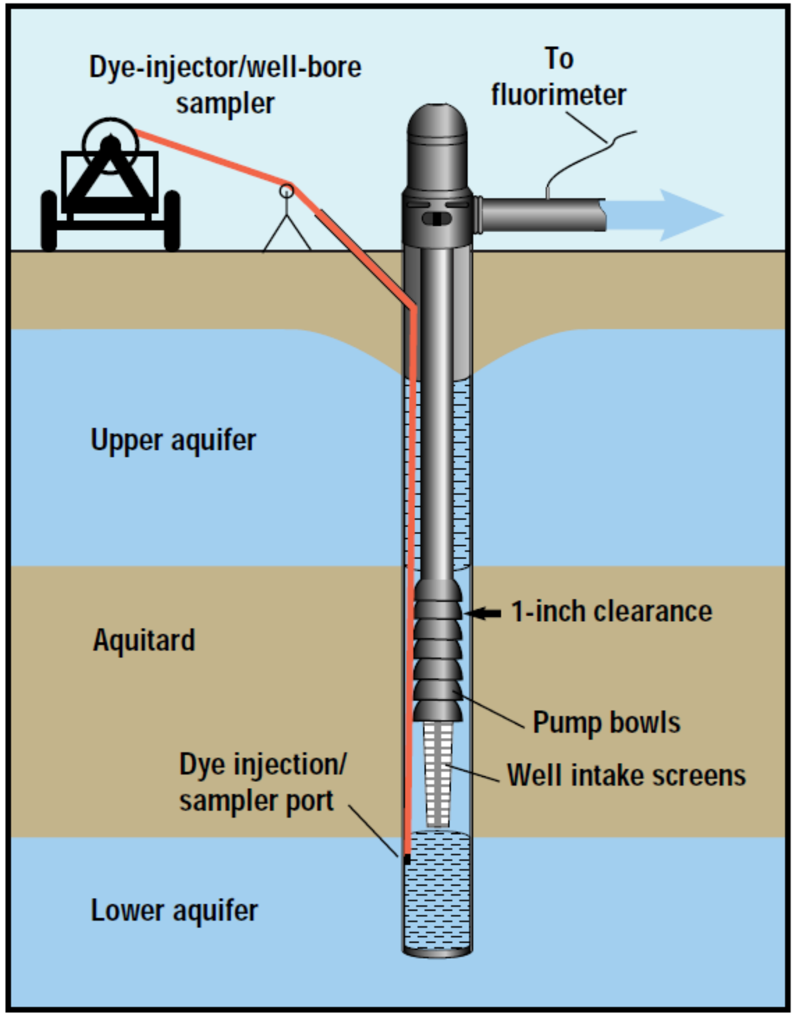
Low-Flow Bladder and Piston Pumps

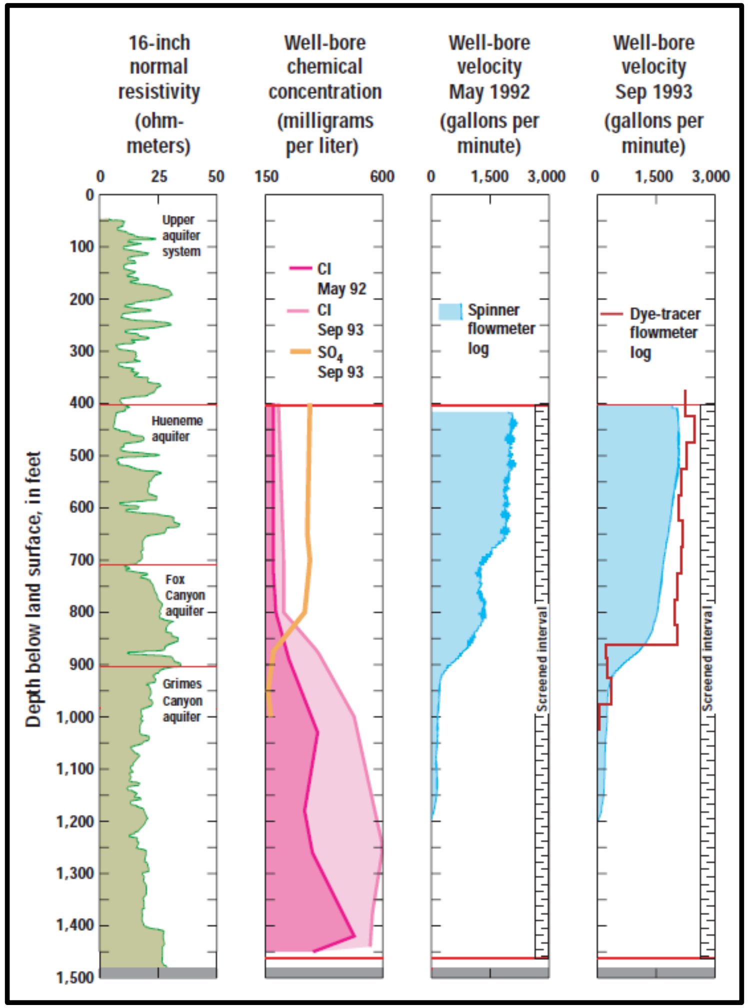
Passive Diffusion Bags



HydraSleeve

Best Available Technology





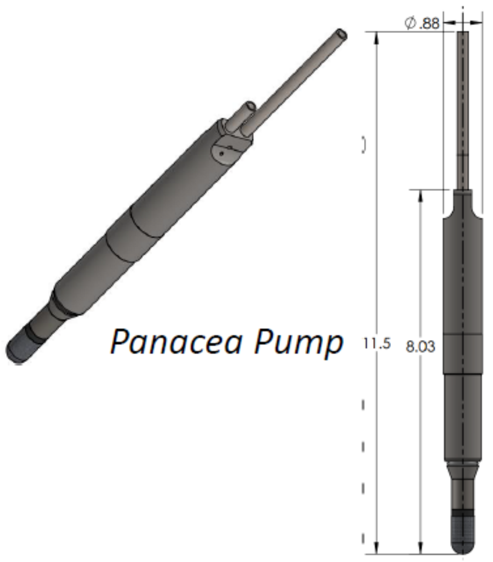
Combined Well-Bore Flow and Depth-Dependent Water Sampler

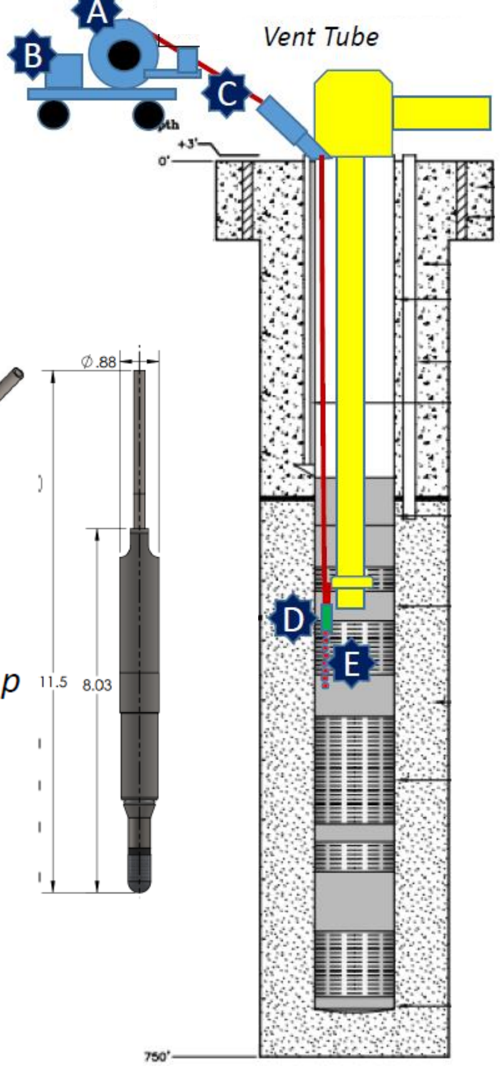
Commercially Licensed to BESST

Improvements to the USGS Tooling

- **Horizontal dye injection to compensate for wells that are off from vertical**
- **Smaller diameter gas piston pump**
  - **Capable of sampling at depths up to 1200 ft**
  - **Can fit in vent tubes or other ports with 1"-diameter ID or larger**
- **Capable of being run under ambient or operating conditions**

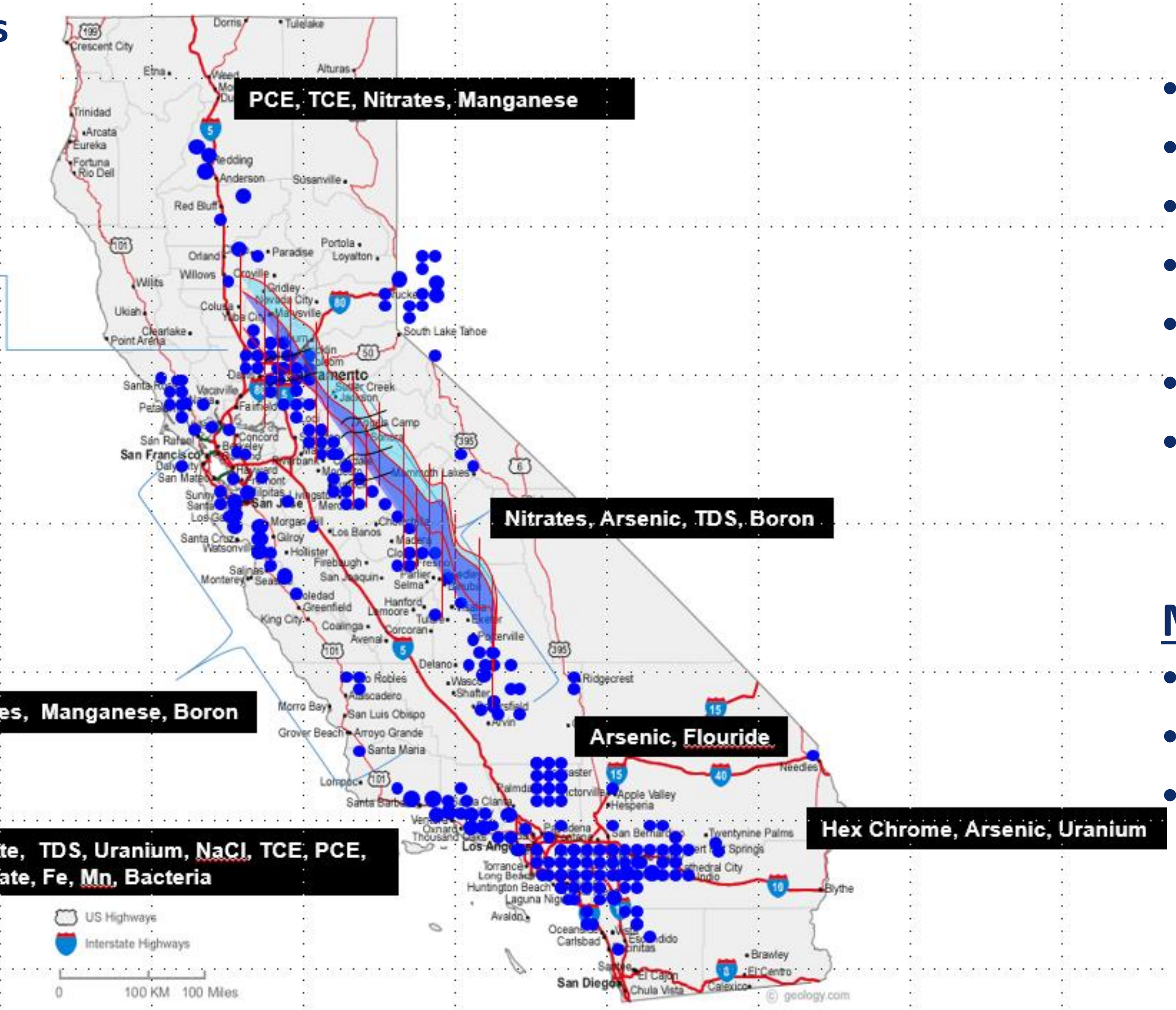
- **Concentration is $C_a=(C_iQ_i-C_{i+1}Q_{i+1})/Q_a$**
- **Flow is $Q=(V\pi r^2)$**
  - **Where $V=(d_2-d_1)/(t_2-t_1)$**





A Growing Compendium of Data

~800 Production Wells profiled in California



Highly to Moderately Stratified

- Arsenic
- Iron
- Fluoride
- Hydrogen sulfide
- Uranium
- Color
- Many anthropogenic contaminants

Moderately Stratified

- Boron
- Manganese
- Chrome VI

Case Study – Naturally Occurring Contaminants

Flow Profiling

1860 GPM

Average Well Head Concentrations (initial)

As = 12.5 µgl **Fe = 145 µgl** **Mn = 64 µgl**

% of Flow

15%

0%

12%

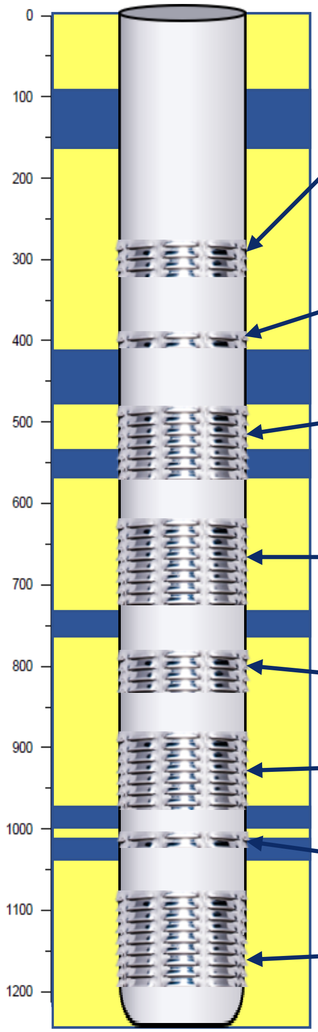
29%

10%

16%

2%

16%



282-310 ft – 12%
310-330 ft – 3%

390-400 ft – 0%
400-410 ft – 0%

480-500 ft – 3%
500-520 ft – 2%
520-540 ft – 2%
540-570 ft – 5%

620-640 ft – 12%
640-660 ft – 0%
660-680 ft – 0%
680-700 ft – 15%
700-720 ft – 2%

740-776 ft – 9%
810-830 ft – 1%

880-900 ft – 1%
900-920 ft – 0%
920-940 ft – 2%
940-960 ft – 10%
960-970 ft – 3%

1000-1010 ft – 1%
1010-1020 ft – 1%

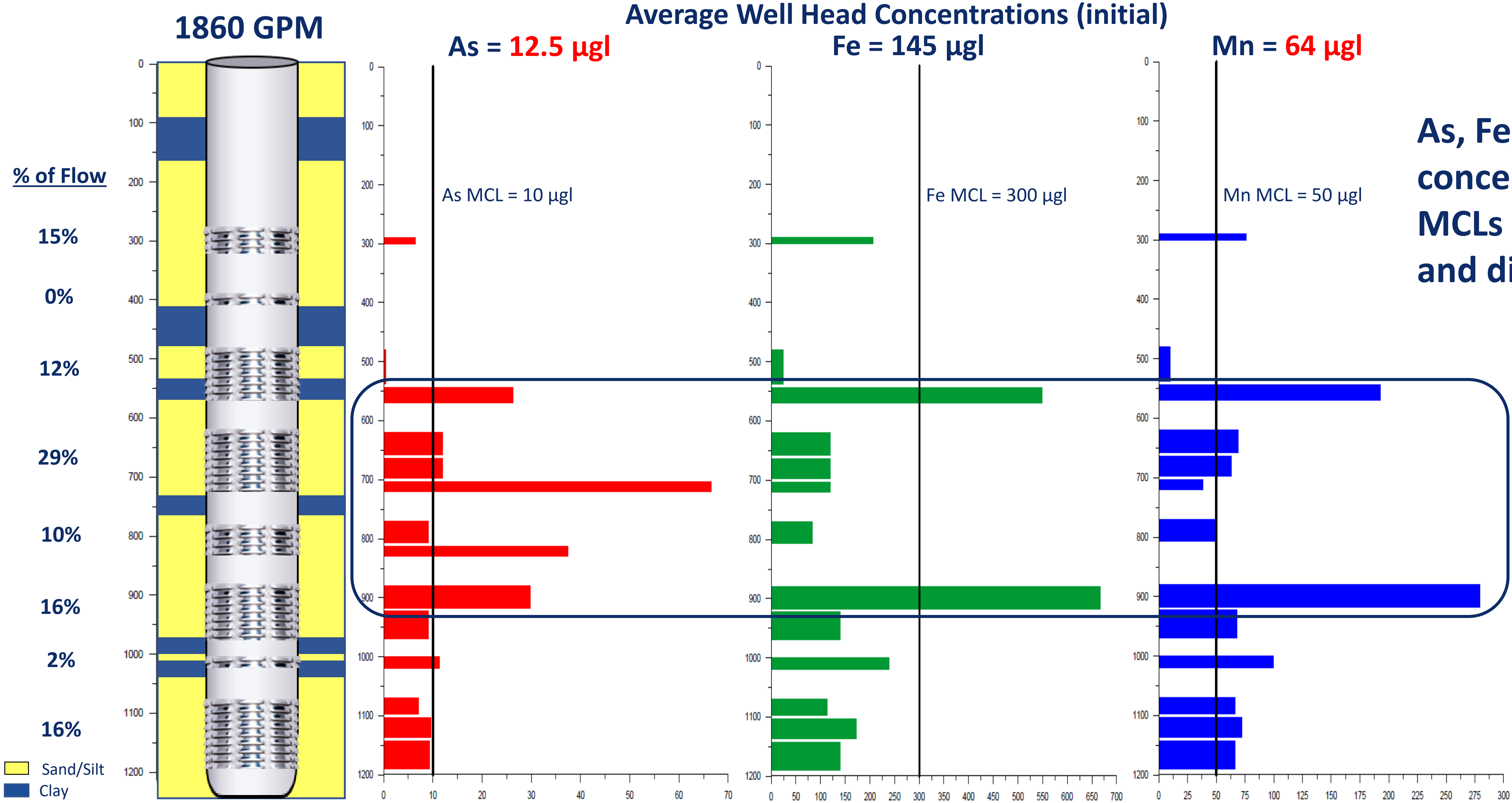
1070-1090 ft – 5%
1090-1110 ft – 3%
1110-1130 ft – 2%
1130-1140 ft – 1%
1140-1160 ft – 2%
1160-1180 ft – 3%

- **As and Mn above MCLs**
- **1950's well log with basic lithology**
- **Operating Mn wellhead treatment system**
- **Well profiling completed in 2 days**
- **Performed under operating conditions with no modification to the well**
- **Flow profiling done first**
- **Profiling costs = $22,000**

Data courtesy of BESST INC. GLOBAL SUBSURFACE TECHNOLOGIES

Case Study

Contaminant Profiling



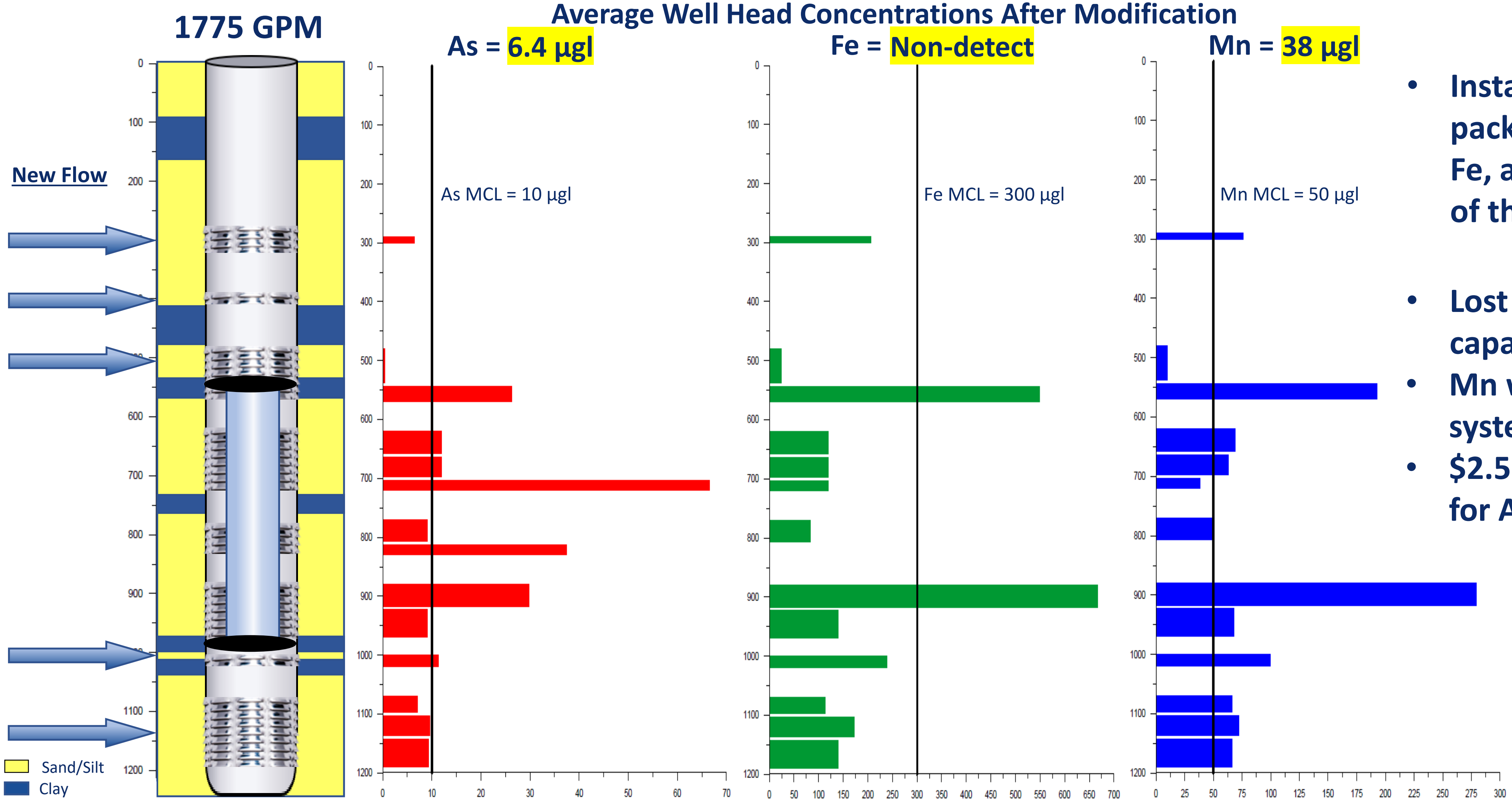
As, Fe, and Mn at concentrations above the MCLs occur in isolated and discrete intervals

Data courtesy of BESST INC. GLOBAL SUBSURFACE TECHNOLOGIES

Case Study

Remedy and Results

Average Well Head Concentrations After Modification



Remedy

- Install sleeve with packers to isolate high As, Fe, and Mn from the rest of the well

Results

- Lost ~5% of production capacity
- Mn wellhead treatment system taken offline
- $2.5M treatment system for As no longer required

Data courtesy of BESST Inc. Global Subsurface Technologies

Another Success Story

WRD
WATER REPLENISHMENT DISTRICT OF SOUTHERN CALIFORNIA

Technical Bulletin
Volume 23 ~ Summer 2010

WRD's Safe Drinking Water Program and Well Profiling Program: Improving Water Quality

By: Ted Johnson, Chief Hydrogeologist, tjohnson@wrd.org

There are currently over 500 groundwater production wells in the Central and West Coast Basins operated by 110 entities delivering water for municipal, industrial, and agricultural use to the nearly 4 million people in 43 cities overlying the basins. The groundwater is extracted from sand and gravel Pleistocene aquifers ranging in depth from 50 feet (ft) to over 2,000 ft. The aquifers are separated by clay and silt aquitards creating both unconfined and confined conditions. Most of the wells are screened across multiple aquifers to maximize groundwater production (Figure 1).

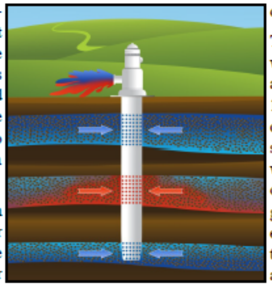


Figure 1: Water well screened across multiple aquifers. The water quality at the wellhead is a blend of the aquifers tapped.

Although many of the production wells extract high quality groundwater that needs little to no treatment before serving, some wells do face water quality issues that require action before the water can be used. Both natural and anthropogenic contamination can occur from a variety of sources, including the inherent aquifer characteristics and human-related activities such as leaking underground storage tanks, dry cleaners, metal shops, junk yards and others. WRD Technical Bulletin, Volume 15, provides details of the groundwater quality in the Central and West Coast Basins and identifies the most prevalent natural contaminants (arsenic, total dissolved solids, manganese, and odor) and human-caused contaminants (perchloroethylene and trichloroethylene) found in water wells throughout the basins.

Safe Drinking Water Program: One common solution to removing contaminants from groundwater is through wellhead treatment. In this process, the water from the well is run through filtering and cleaning devices to remove the contaminants before being sent into the distribution system. Granular activated carbon (GAC) is a common water treatment technology to remove volatile organic contaminants (**Figure 2**). For iron and manganese removal, the simplest process is through direct filtration using an oxidizing media such as manganese greensand.

Figure 2: GAC Water Treatment System

To assist water purveyors with their wellhead treatment projects, WRD has a Safe Drinking Water Program. Since 1991, this Program has provided financial assistance (grants or loans) to construct wellhead treatment projects at 19 wells throughout the District, restoring over 30,000 acre-feet per year of groundwater to beneficial use. However, because wellhead treatment systems can be very expensive in capital and long-term operational and maintenance costs, WRD has been exploring alternatives.

Well Profiling is one technology that shows promise as an alternative or beneficial supplement to wellhead treatment. This technology has been around for years but advances in equipment miniaturization are making it more available and reducing overall costs. As **Figure 1** shows, wells can tap multiple aquifers that may have different water qualities. The quality of the water produced at the wellhead will be a blend of the various water qualities tapped by the well.

The water entering a well may not be distributed equally across the screened intervals, but instead be highly variable based on the transmissivity of the aquifers, the depth of the pump intake, the pumping rate, and whether any perforations are sealed off due to physical, chemical, or biological plugging. It cannot be assumed, for example, that a well pumping 1,000 gallons per minute (gpm) with 100 feet of screen is producing 10 gpm from each foot of screen. More likely, one-third to two-thirds of the screen length is providing most of the water with the remaining screen relatively stagnant.

Well profiling is a method to determine where the water entering the well is coming from and what the water qualities are. This is done by raising and lowering measurement tools inside the well during pumping and non-pumping conditions to determine flow characteristics across the screen intervals and by collecting numerous depth-specific water quality samples. After analyzing the data, a profile can be completed to show the flow contributions and water quality information in the well (**Figure 3**). If a poor water quality zone is identified, it can possibly be sealed off so that the well produces higher quality water from the other zones. Conversely, in a remediation project, the contaminated zone(s) can be isolated for extraction without pulling out the cleaner groundwater.

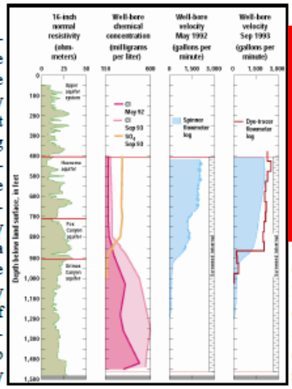


Figure 3: Well Profiling including Water Quality and Flow measurements (USGS, 1999)

A Case Study: WRD has a Well Profiling Program to assist pumpers with investigating the source and quality of groundwater entering their wells. To date, 6 wells have been successfully profiled and two have been retrofitted to improve water quality.

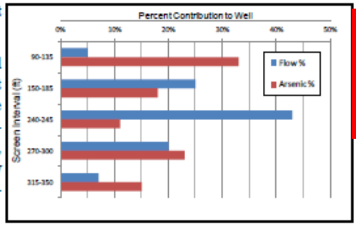


Figure 4: Arsenic and Flow Contributions to a local well

For example, one well in the District was producing arsenic at concentrations between 8 and 24 parts per billion (ppb). In January 2006, the Federal maximum contaminant level (MCL) for arsenic was reduced from 50 ppb to 10 ppb, rendering this well in potential violation of the standard. Well profiling was performed and determined the following: 1) The pumping rate was 1,200 gpm and the pump intake was set at 190 ft; 2) there are 5 screened intervals in the well; 3) profiling showed the highest arsenic contribution was coming from the shallowest screened interval, (90 ft—135 ft), but this interval was not contributing much water to the well (**Figure 4**). The lowest arsenic contribution and the highest flow rate was coming from the screened interval from 240 ft to 245 ft.

Based on the results, the well was equipped with a rubber inflatable packer lowered to 200 feet to seal off the upper two screen intervals and eliminate their flow and arsenic contributions to the well. A pump suction was extended through the packer to a depth of 260 feet so that the well only produced water from the lower three intervals. When the well was turned back on, arsenic concentrations steadily decreased to less than 5 ppb. The well is now in compliance with the arsenic MCL and no wellhead treatment is required. And, pumping capacity was not lost from the well as the high transmissivity of the lower aquifers made up for the loss of the shallower screen intervals.

Total cost for the well profiling and screen sealing were about 10% of the cost for an full arsenic treatment system, proving the value of the upfront work. For more information on WRD's Safe Drinking Water Program and Well Profiling Program, please contact Ted Johnson.

References:

Izbicki, J.A., Christensen, A.H., and Hanson, R.T., 1999, U.S. Geological Survey Combined Well-Bore Flow and Depth-Dependent Water Sampler; U.S. Geological Survey Fact Sheet FS 196-99.

Izbicki, J.A., 2004, A Small-Diameter Sample Pump for Collection of Depth-Dependent Samples from Production Wells under Pumping Conditions", U.S. Geological Survey Fact Sheet 2004-3096.

WRD, 2008, Groundwater Quality in the Central and West Coast Basins; Volume 15, Spring 2008.

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Copies of this and previous Technical Bulletins are available on our web site www.wrd.org

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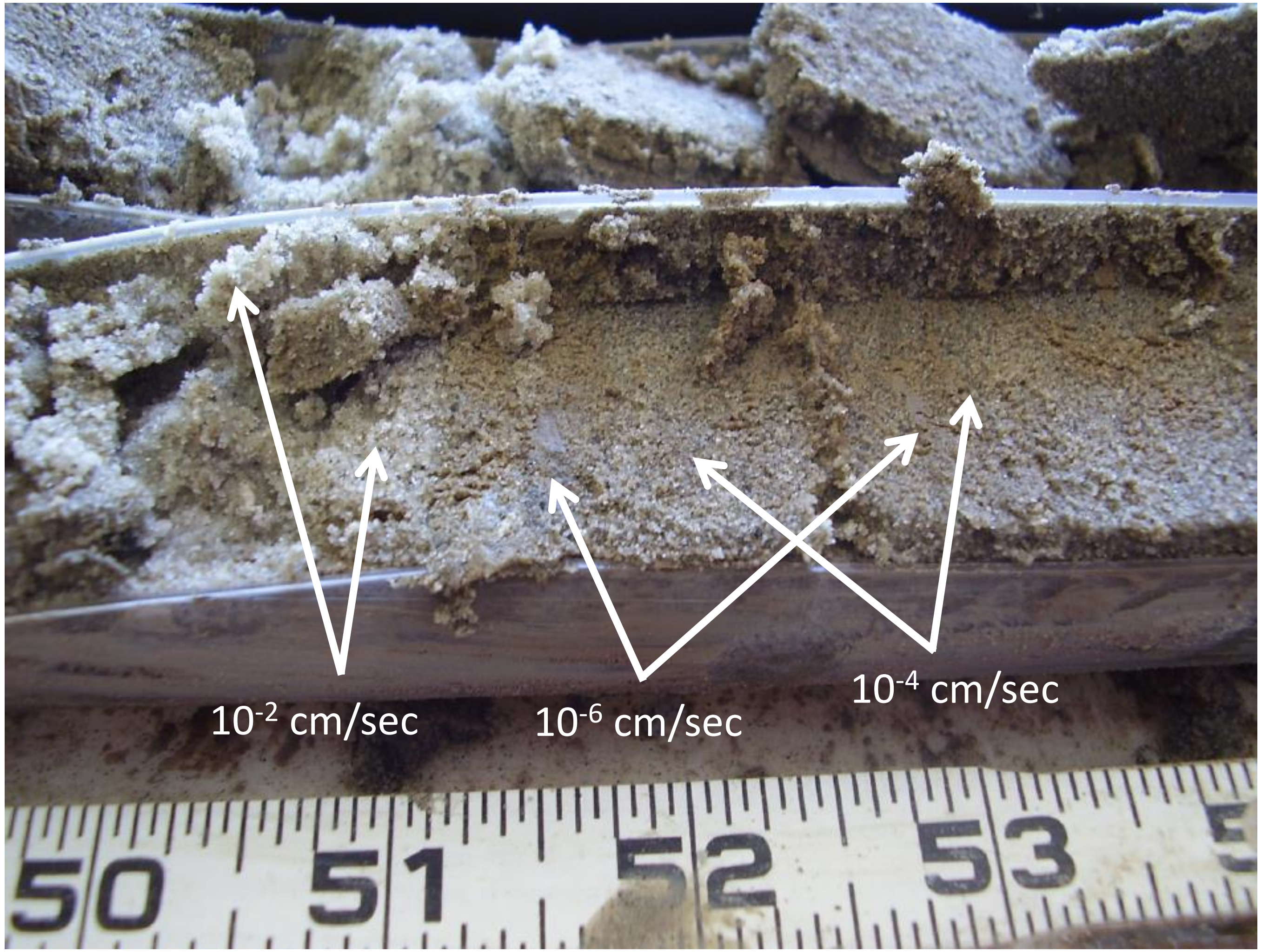
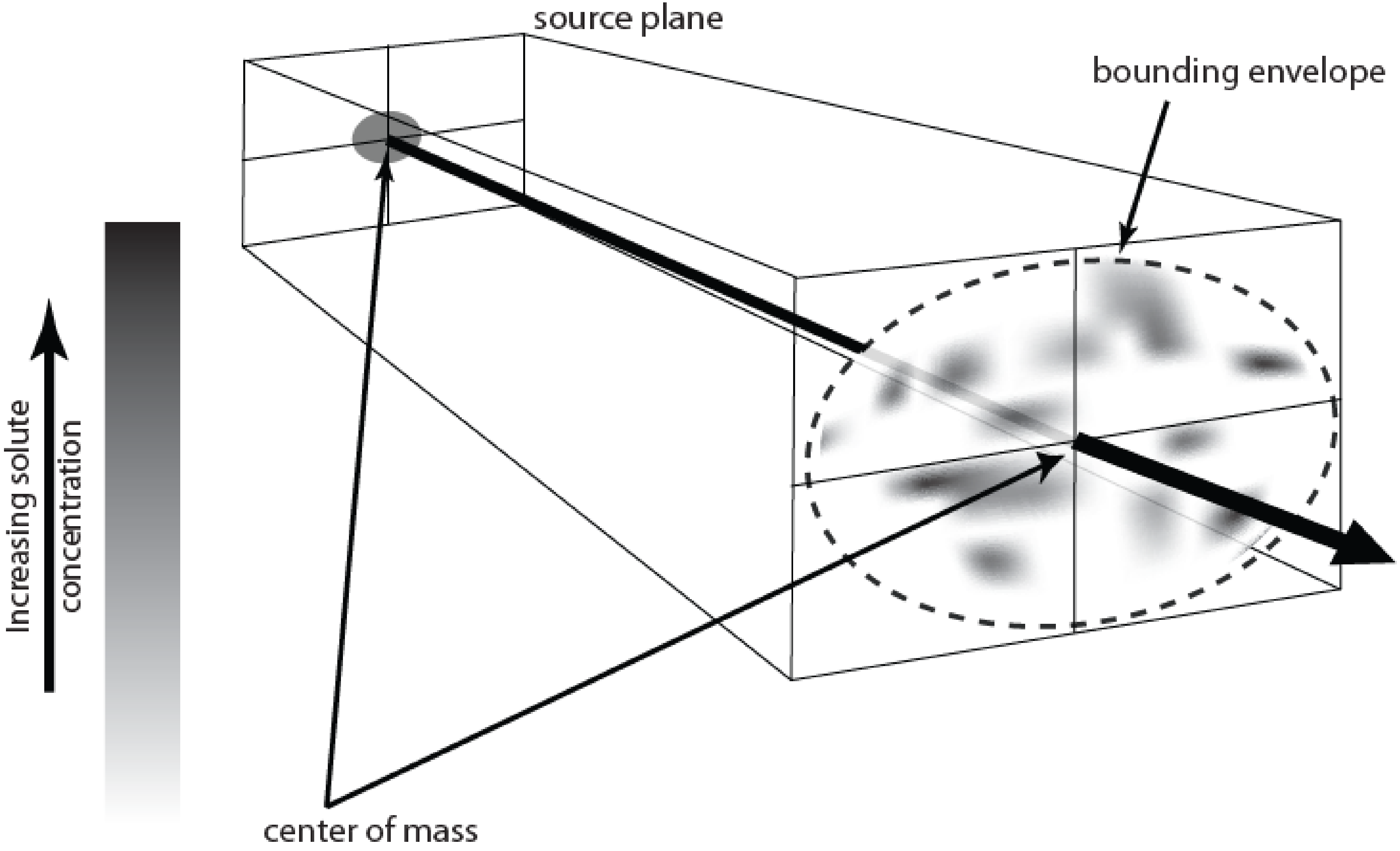
A Closer Look at Heterogeneity

- Variations in permeability occur on a very small scale
- Studies of the Borden Aquifer have shown that simple changes in the packing arrangement can result in orders of magnitude change in permeability
- How does this impact the transport of anthropogenic compounds?
  - Transport concentrated in high permeability soils ($K > 10^{-4}$)
  - Short term storage in soils with permeability ~10-4
  - Storage concentrated in low permeability soils (K < 10-4)

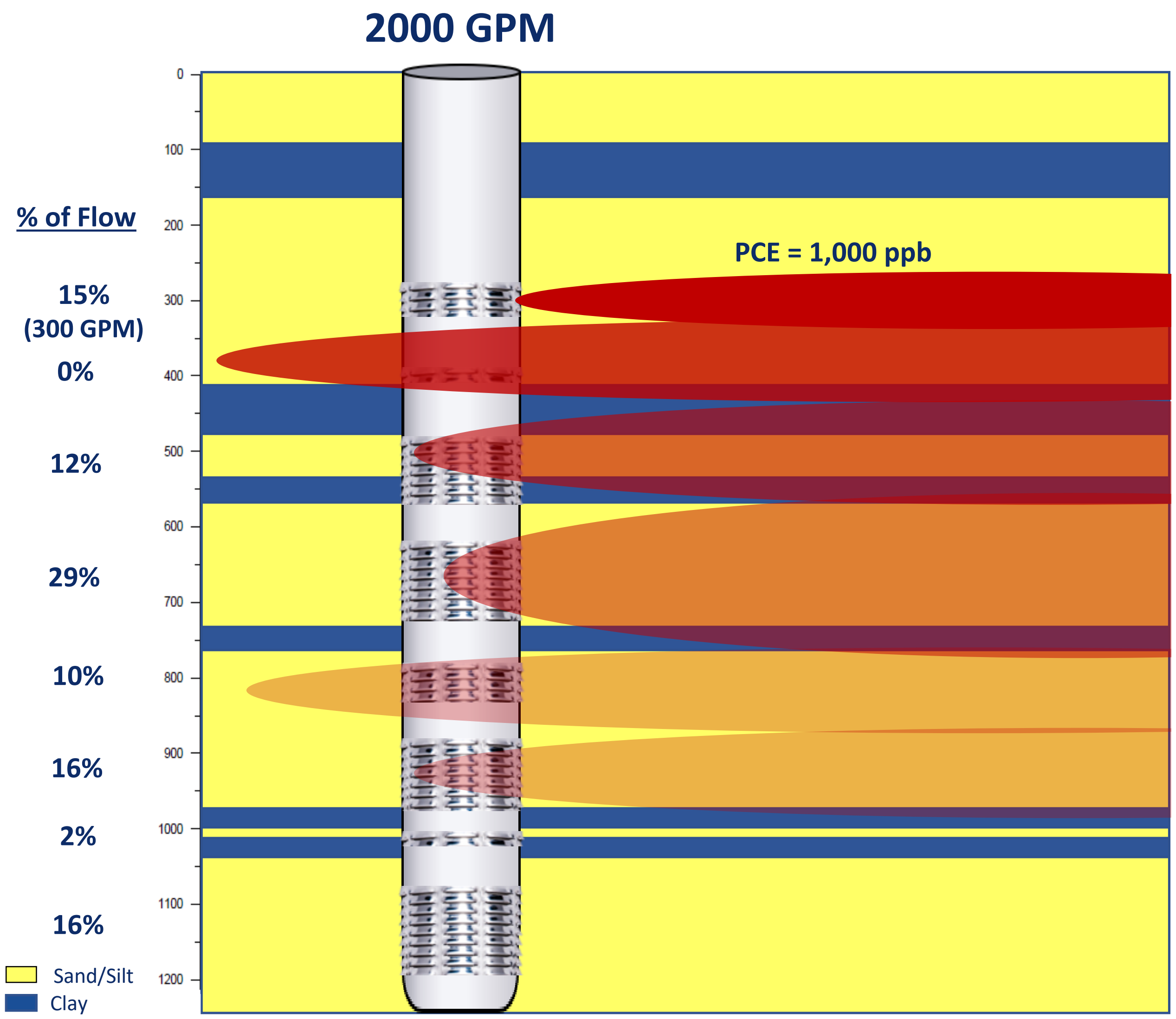


Permeability Dominates Anthropogenic Contaminant Transport



- Near zero dispersivity
- Contaminant concentrations can change by orders of magnitude over small intervals (think foot scale)
- Results in 90% of mass moving in ~10% of the aquifer
- Extremely inefficient to treat the whole aquifer

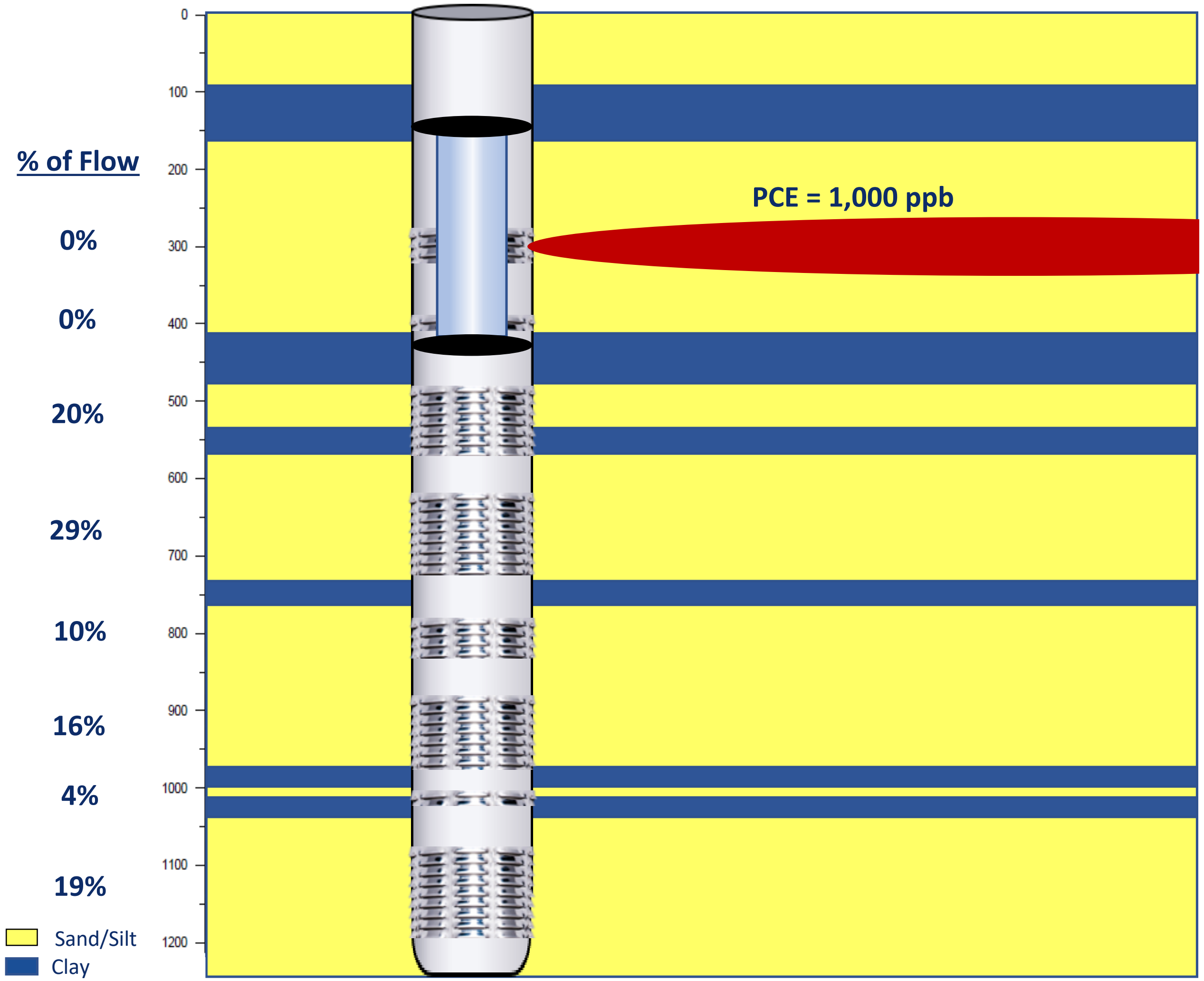
Predominant Approach to Anthropogenic Contaminants



- The objectives of production and the new generation of remediation are at odds with each other
- Long screens on production wells are problematic
  - High probability of drawing contaminants down through the aquifer
  - High probability of not capturing all the mass
- One recent case study of two production wells
  - Well screens 150 - 200 feet in length
  - 1st well pumping at 2,000 GPM
    - Only 80 GPM of which had contaminants
  - 2nd well pumping at 1,000 GPM
    - Only 35 GPM of which had contaminants

Don’t Treat it Like Naturally Occurring Contaminants

2000 GPM



Don't Treat it Like Naturally Occurring Contaminants

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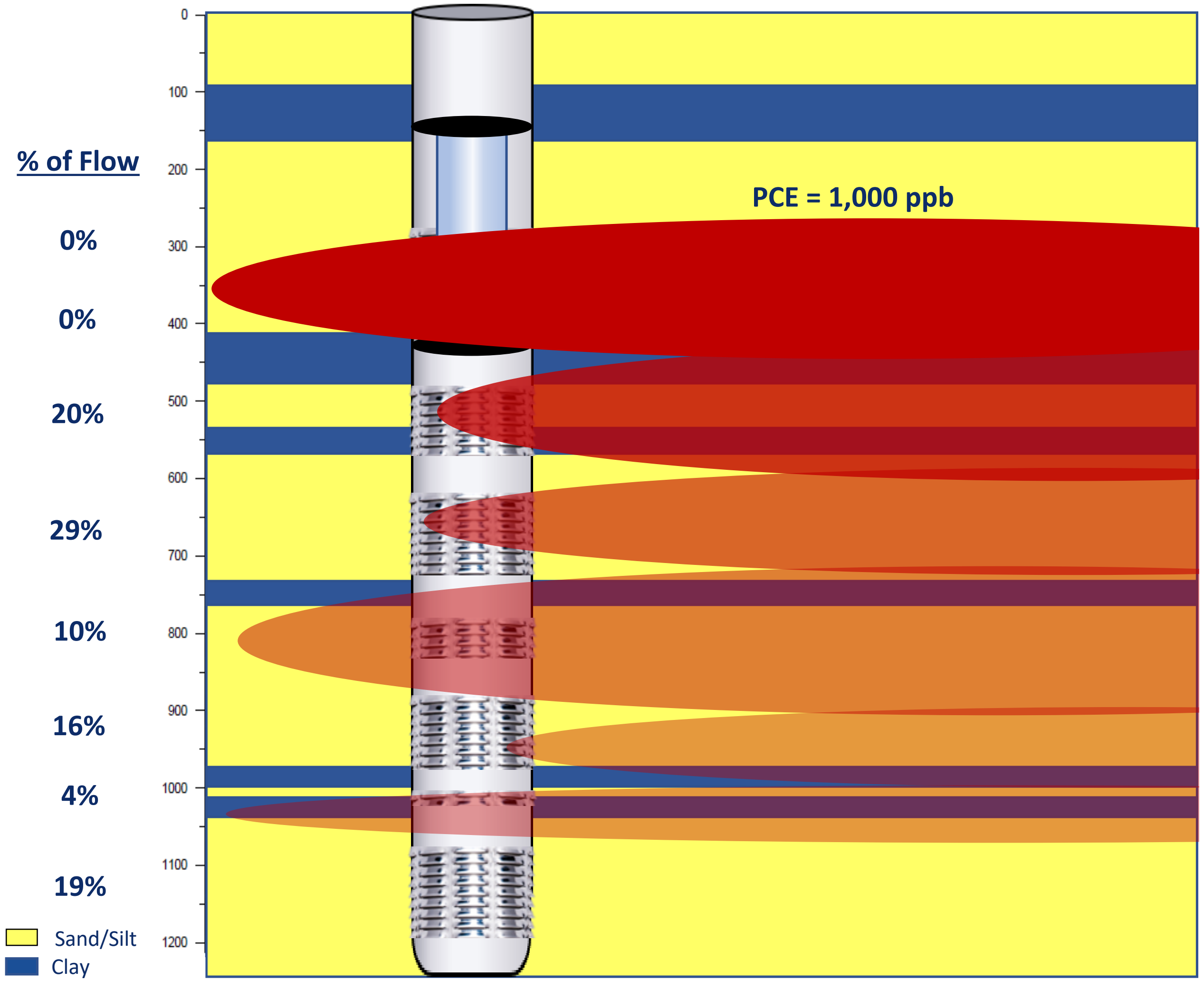
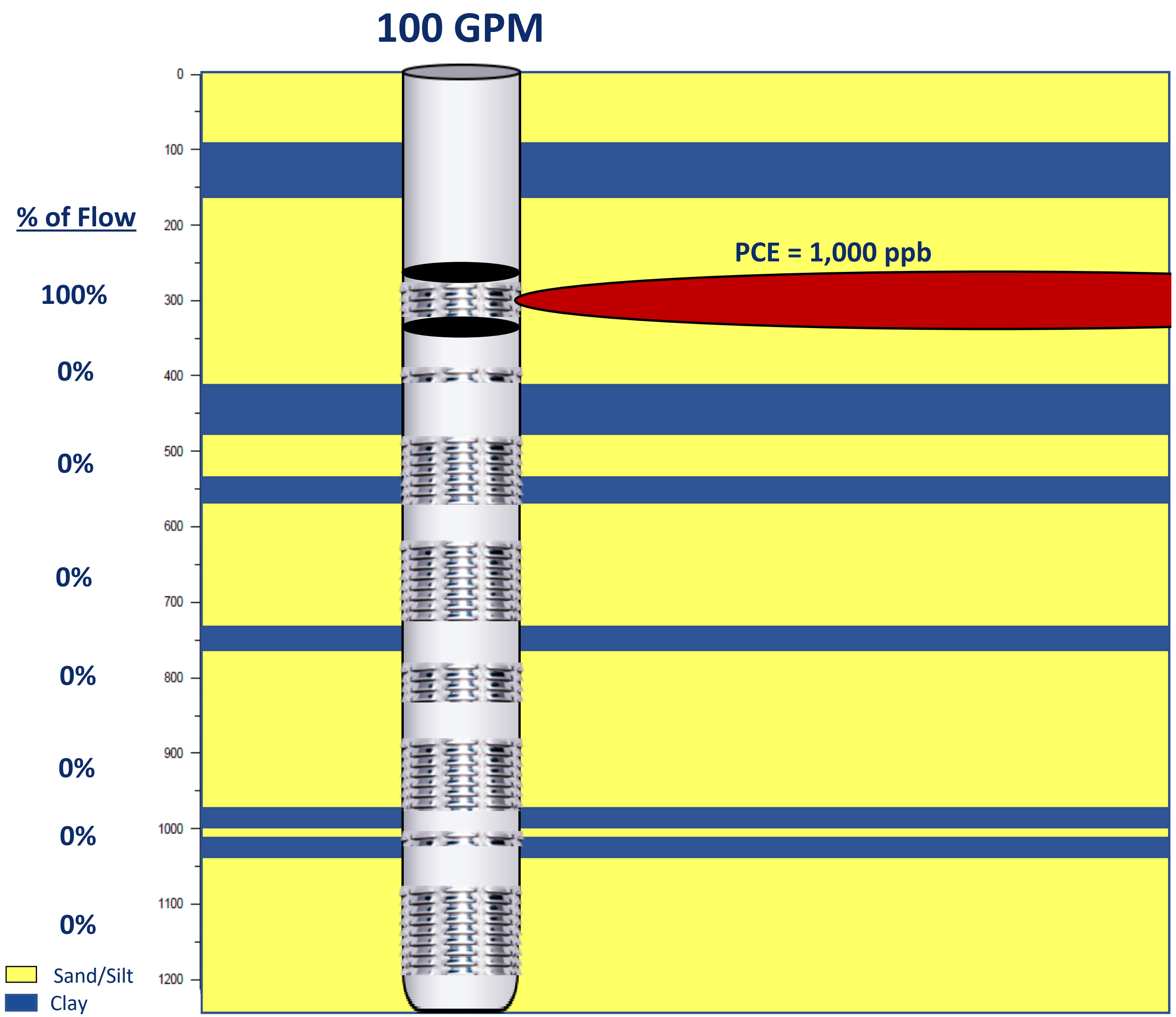


It's Time to Rethink

Taking a Page From the Environmental Community



- If you can afford to lose the production capacity…isolate the zone(s) with contaminants
- Focus extraction on that zone(s) but at substantially reduced flow rate
- Potential benefits include:
  - Significantly smaller treatment system
  - No probability of drawing contaminants down through the aquifer

It's Time to Rethink

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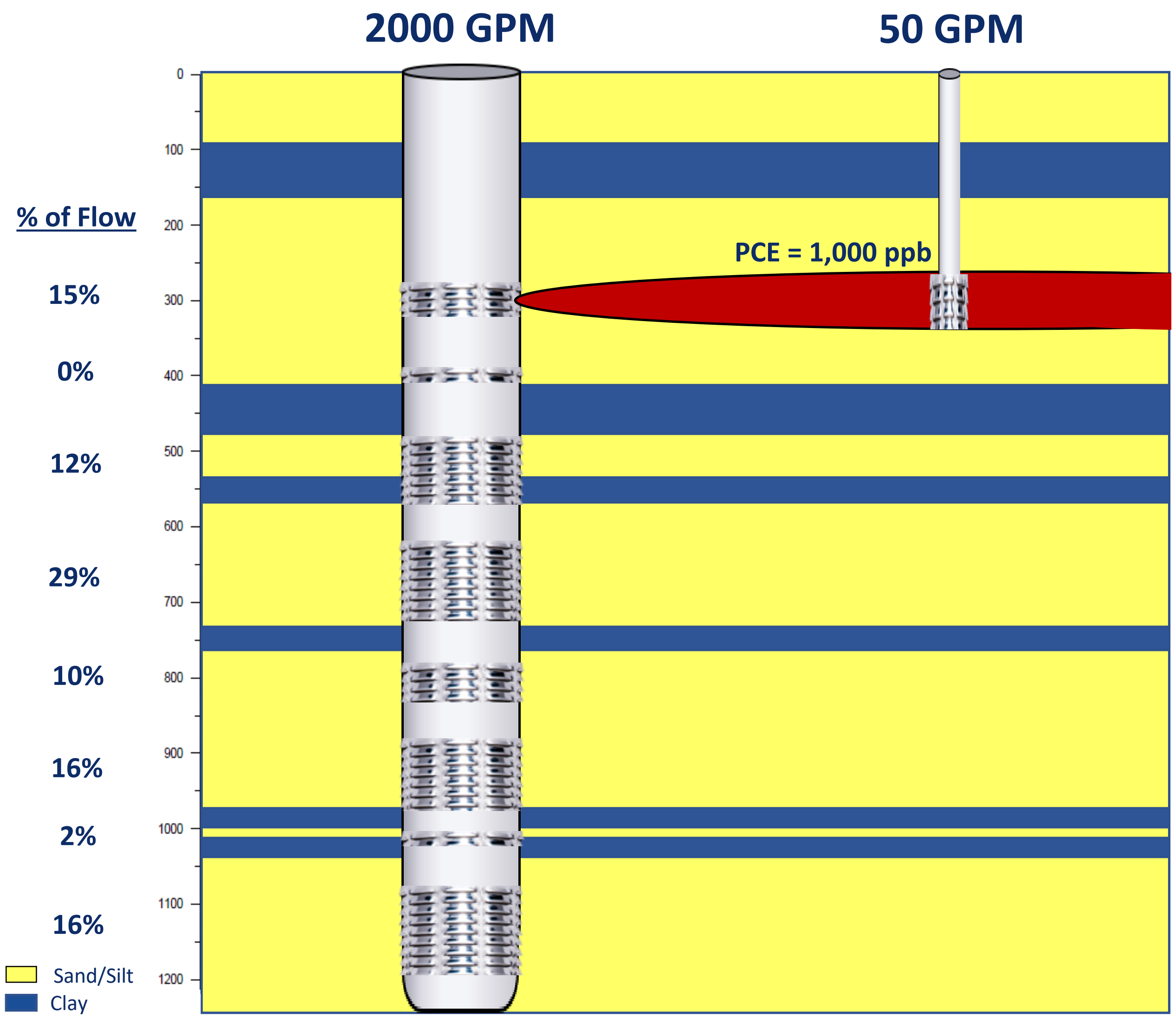


- If you can't afford to lose the production capacity…consider an intercept well(s)
- Focus extraction on the 10% of the system carrying 90% of the mass
- Pump at a substantially reduced flow rate
- Potential benefits include:
  - Significantly smaller treatment system
  - Minimized probability of drawing contaminants down through the aquifer

Key Takeaways

- Know yourself – what is your timeframe for implementation, what are your cost constraints, and what are your most likely treatment options

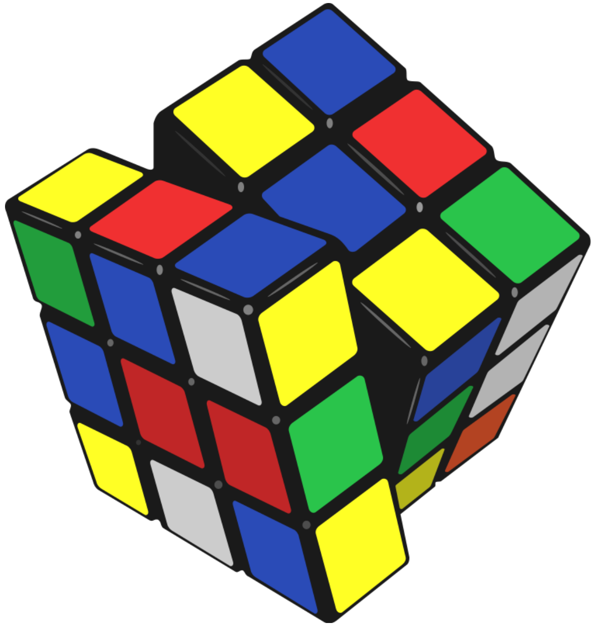
- Know your enemy – what is the contaminant, how does it behave in the environment, and where exactly is it entering the well

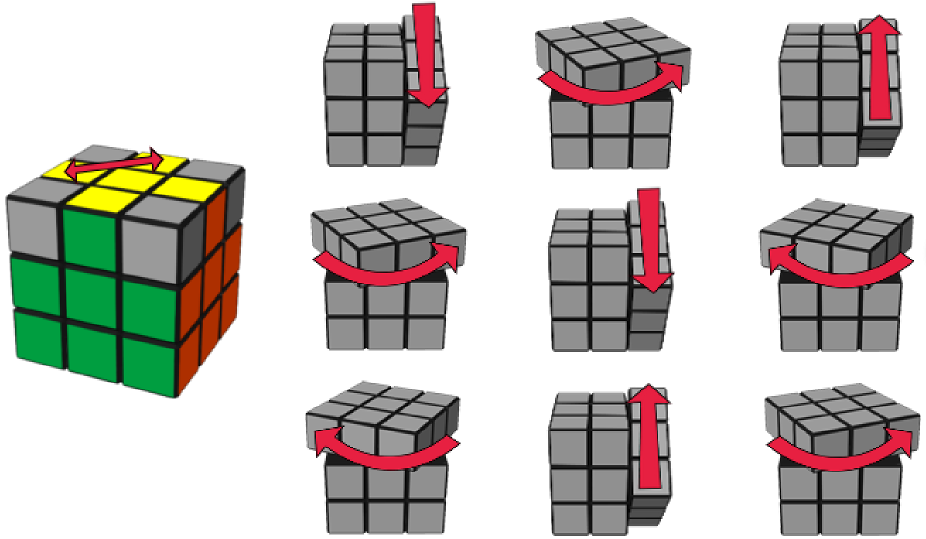
- Naturally occurring contaminants typically occur in very discrete intervals
  - There is often the opportunity to isolate these zones using a sleeve-packer system
  - Pump from <u>above/below</u> the packered interval
  - Doing so can result in cost savings up to 90% in comparison to wellhead treatment systems

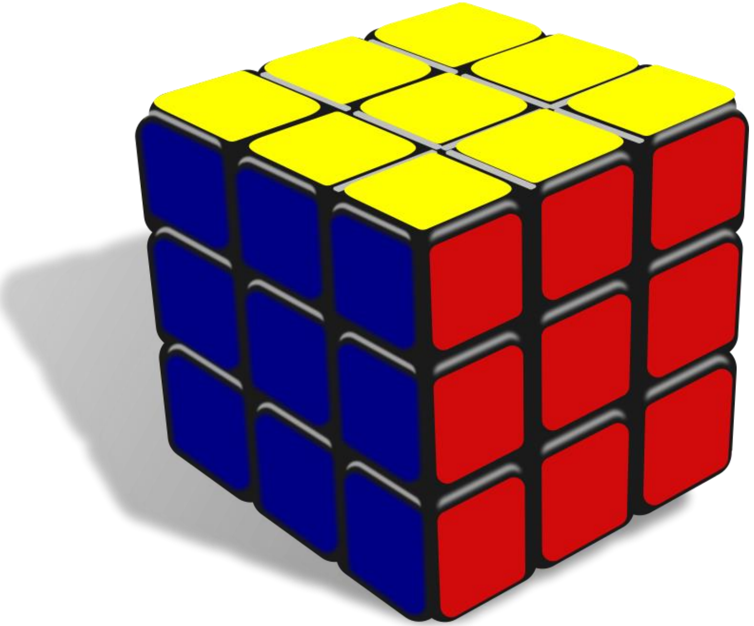
- Think/do the opposite for anthropogenic contaminants
  - There is often the opportunity to isolate contaminated zones using a sleeve-packer system
  - Pump from <u>within</u> the packered interval or install an intercept well(s) upgradient
  - Focused extraction can be done at substantially lower rates
  - Potential cost savings in smaller, more effective treatment systems

- We need to re-evaluate using productions wells for contaminant remediation

With the Right Data We Have a Path to Success







Thank you

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