Characterization, instrumentation and performance of managed aquifer recharge sites

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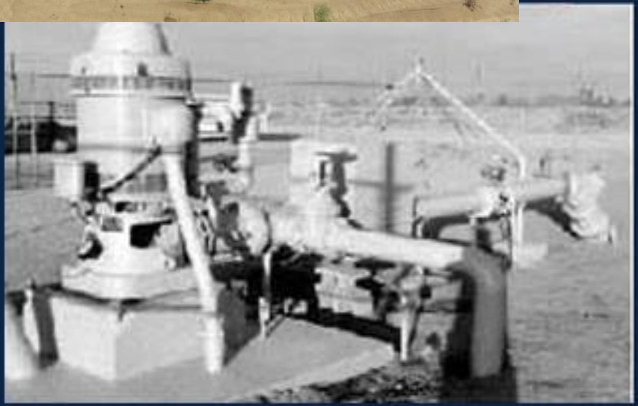
Scope of Presentation

- Overview of Recharge and Study Locations
- Selection of Recharge Sites
- Characterization of Recharge Sites
- Instrumentation of Monitoring Sites
  - Monitoring Wells
  - Unsaturated-Zone Monitoring Sites
- Performance of Sites / Monitoring
- Sampling and Geochemical Considerations
- Importance of Understanding Heterogeneity
- Conclusions

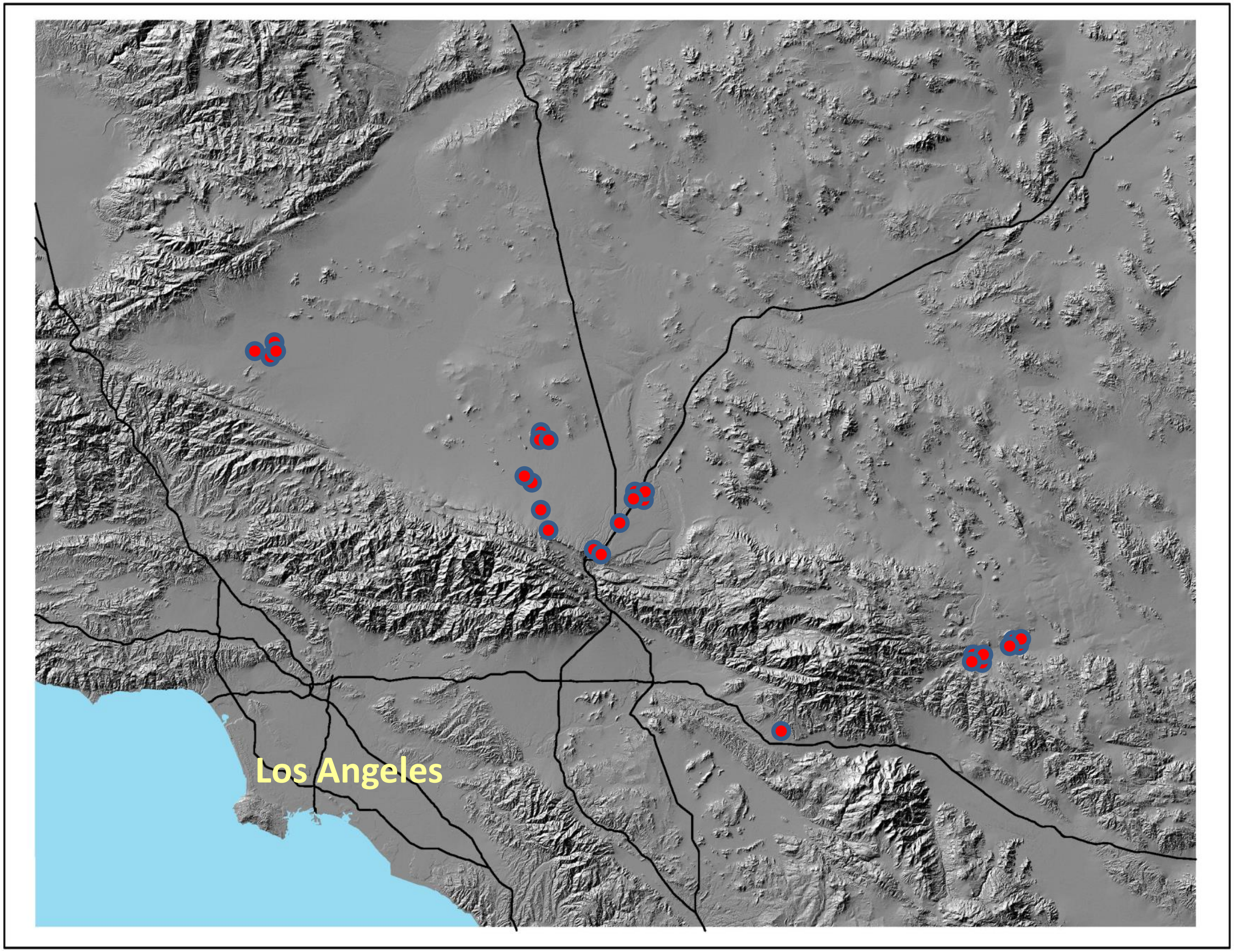
Enhanced natural recharge

Infiltration from ponds

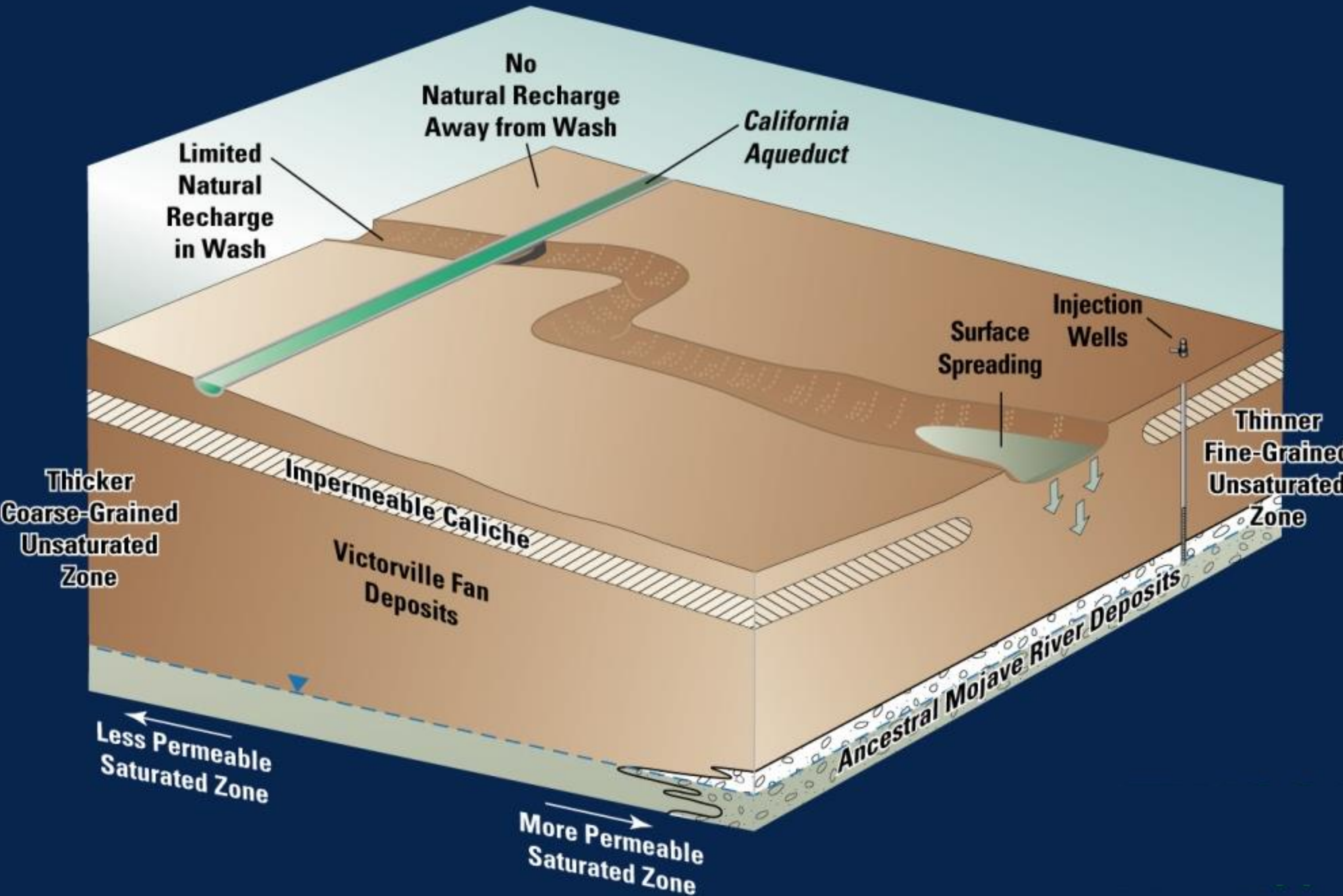


Aquifer storage recovery (ASR)
Injection / Recovery

LOCATION



Selection of Sites



Availability of water for recharge

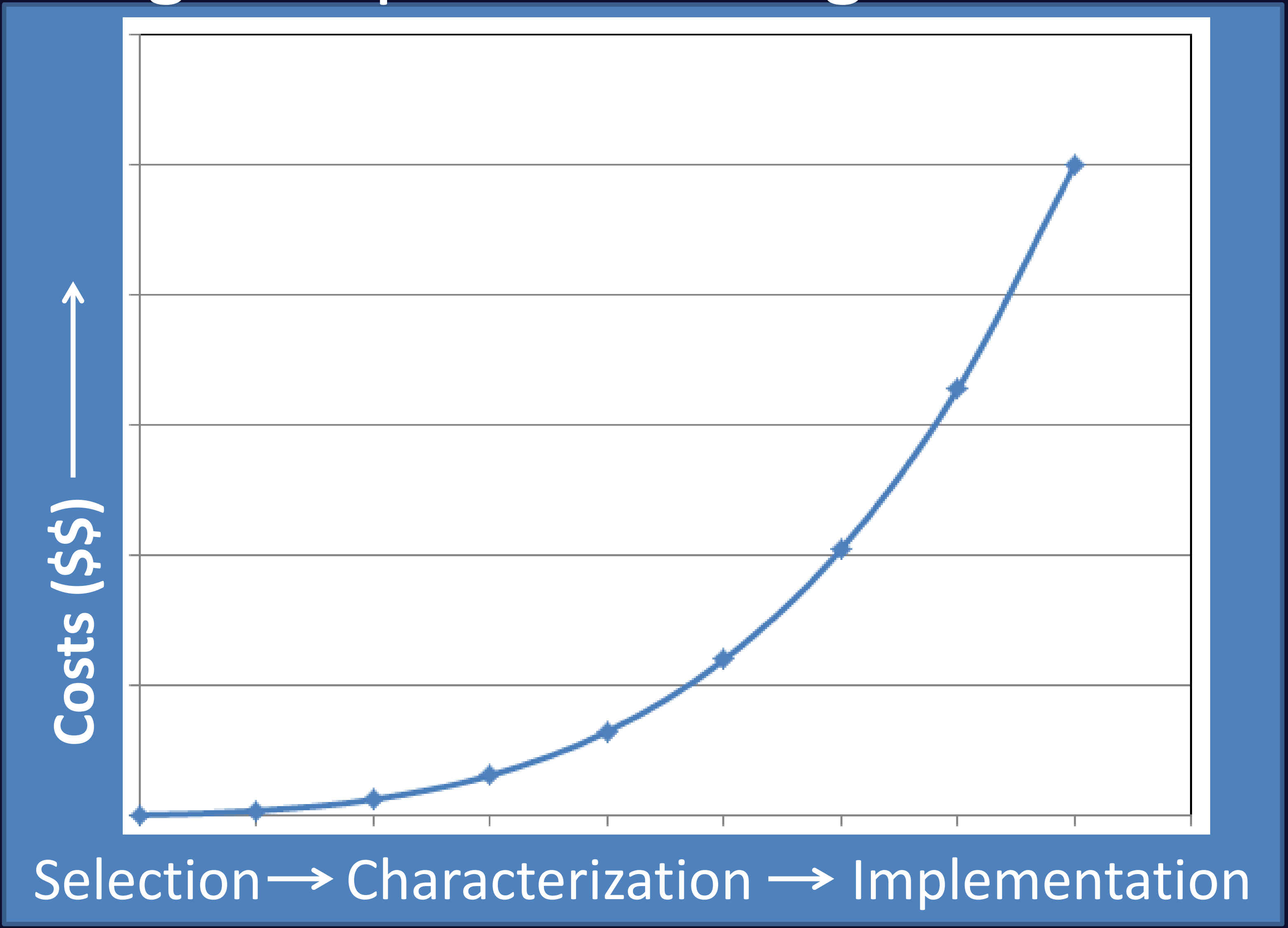
Caliche/impeding layers

Faults

Septic systems or other potential sources of contamination

Recovery of water/ location of extraction wells

Managed Aquifer Recharge Costs



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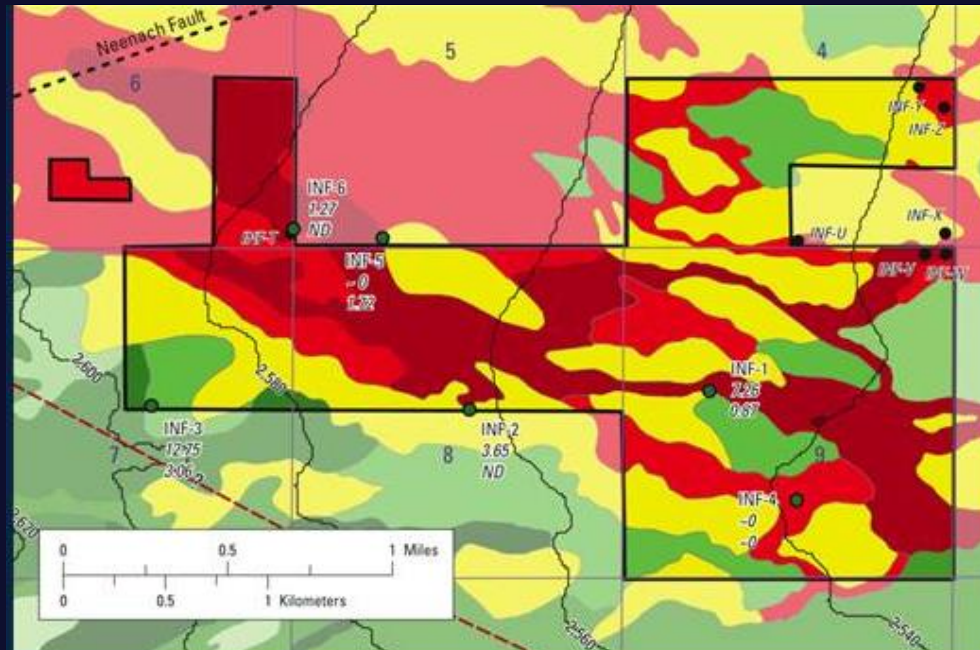
Selection of Sites

Double-ring infiltrometer experiments

Surficial geology / soil surveys

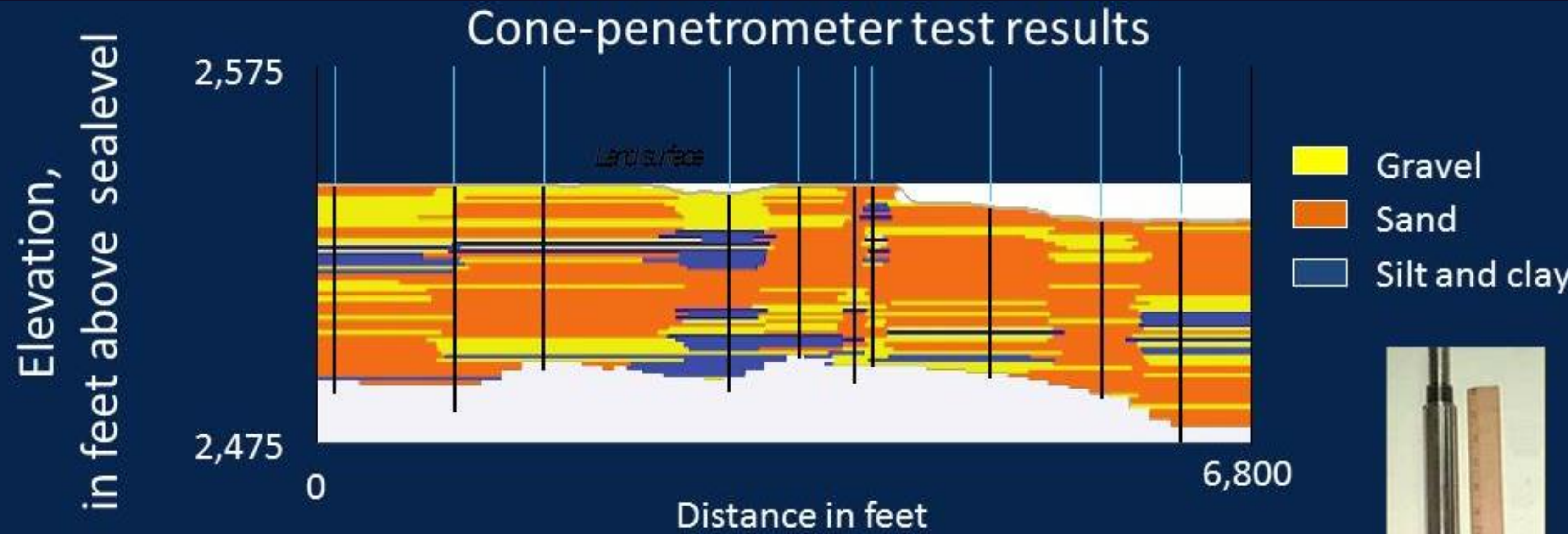


1	Ro	7.26	0.87
2	Ro	3.65	ND
3	HkA	12.75	3.06
4	Rp	~0	~0
5	Rt	~0	1.72
6	Rt	1.72	ND

ND is no data

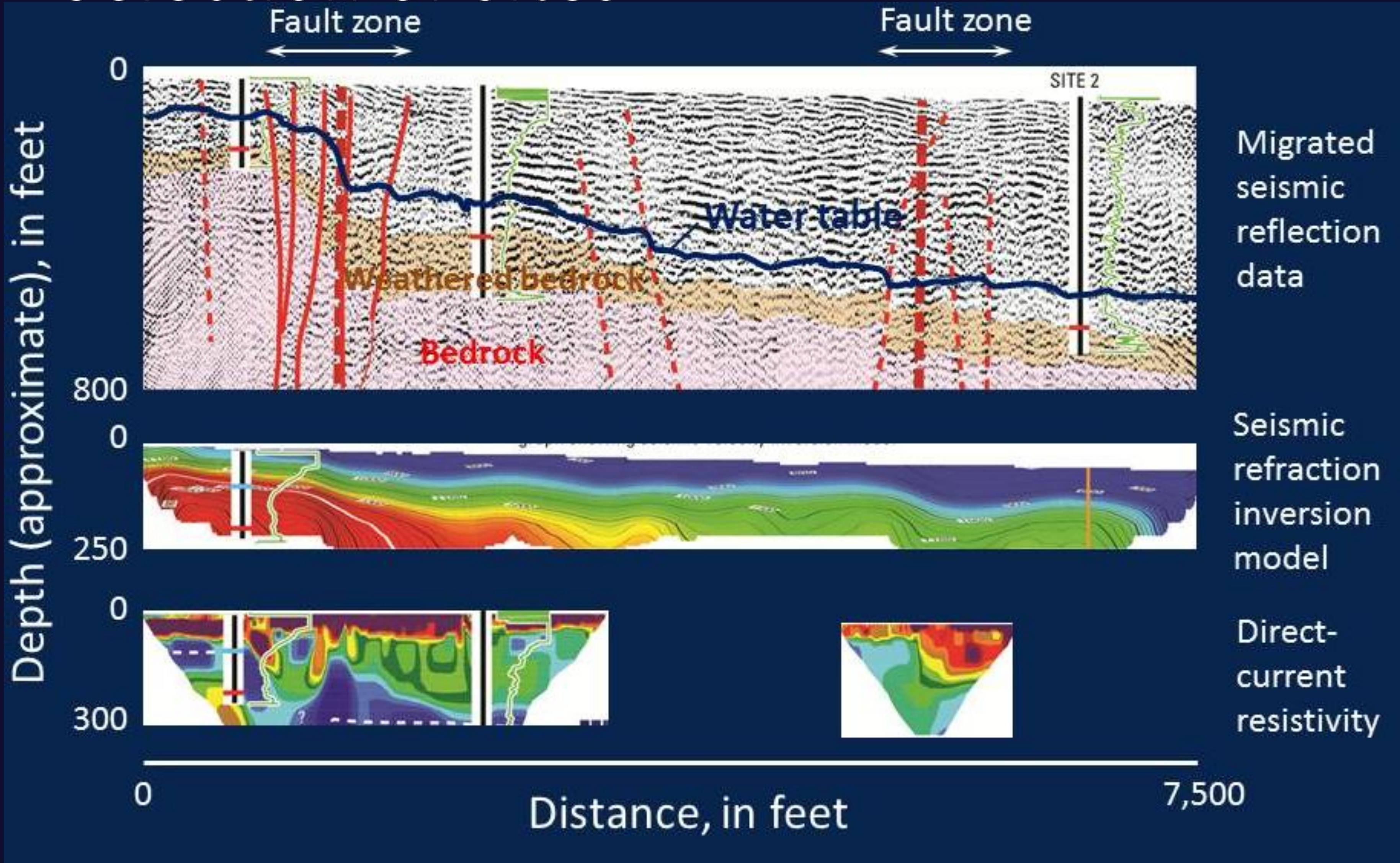
Simple and inexpensive!

Selection of Sites



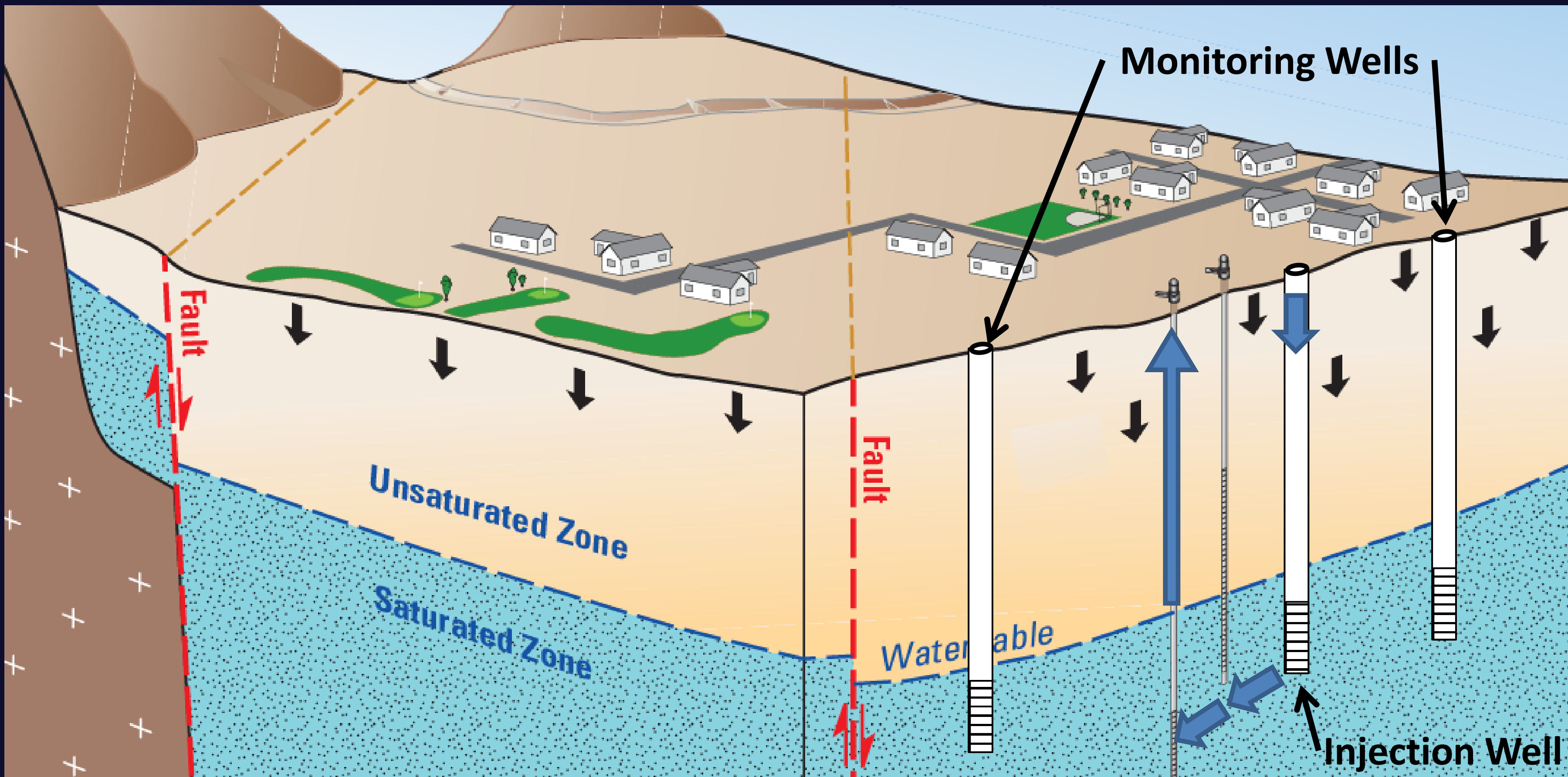
From Izbicki and others, unpublished data

Selection of Sites



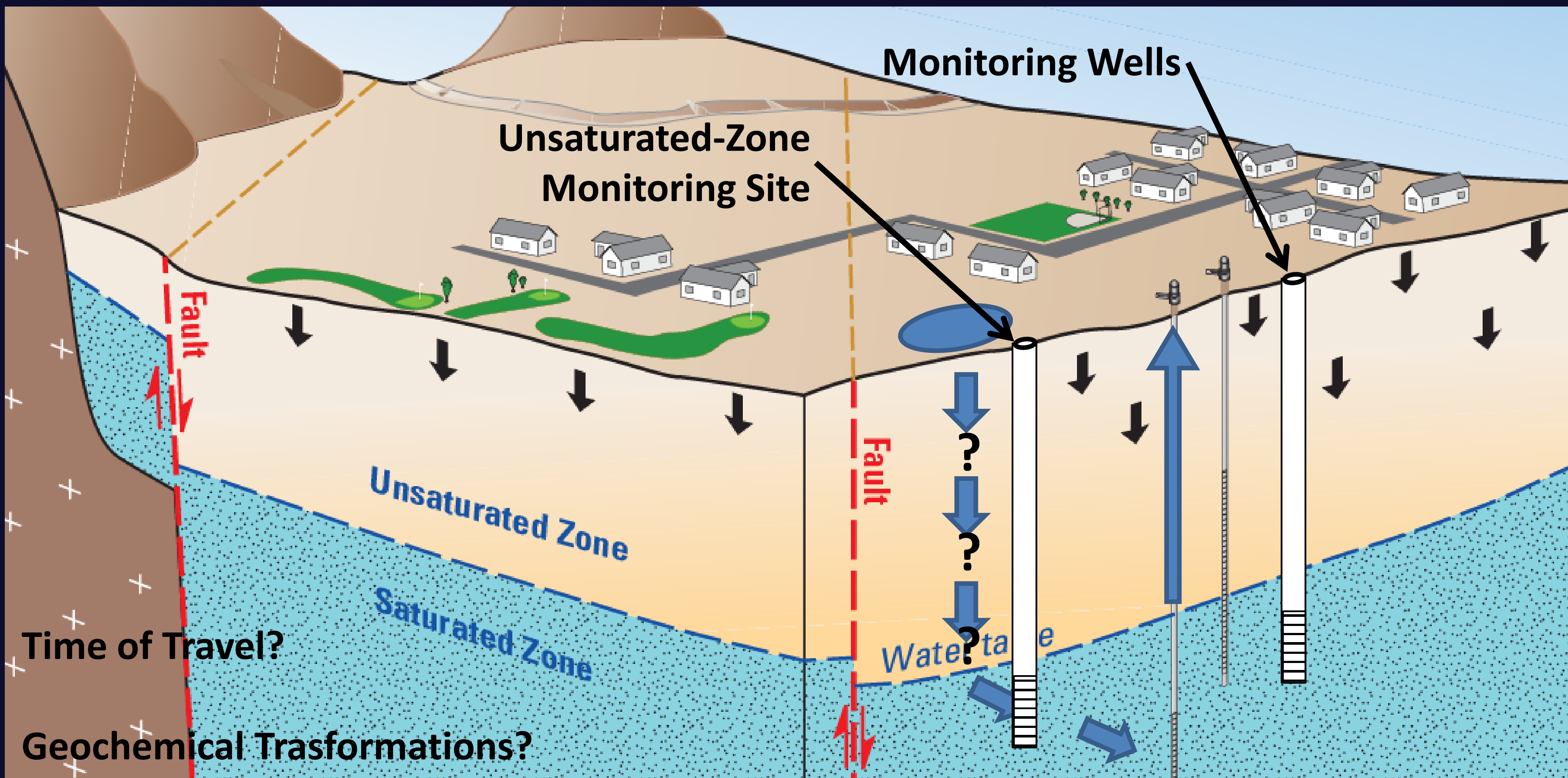
Monitoring Recharge Operations

-Aquifer Storage and Recovery (ASR) / Injection



Monitoring Recharge Operations

-Surface Ponds and Unsaturated-Zone Monitoring



Characterization of Recharge Sites (Unsaturated-Zone Monitoring Sites)

- Monitor recharge through "thick" unsaturated-zones (>20 m)
- Drilling techniques (ODEX Drilling)
- Detailed Lithologic/Geophysical Logs
- Cores
- Construction and Instrumentation
- Data collection and sampling

Drilling Techniques - ODEX

Odex drilling technology – air, not water, is the drilling fluid

High-quality cuttings at 1 foot intervals

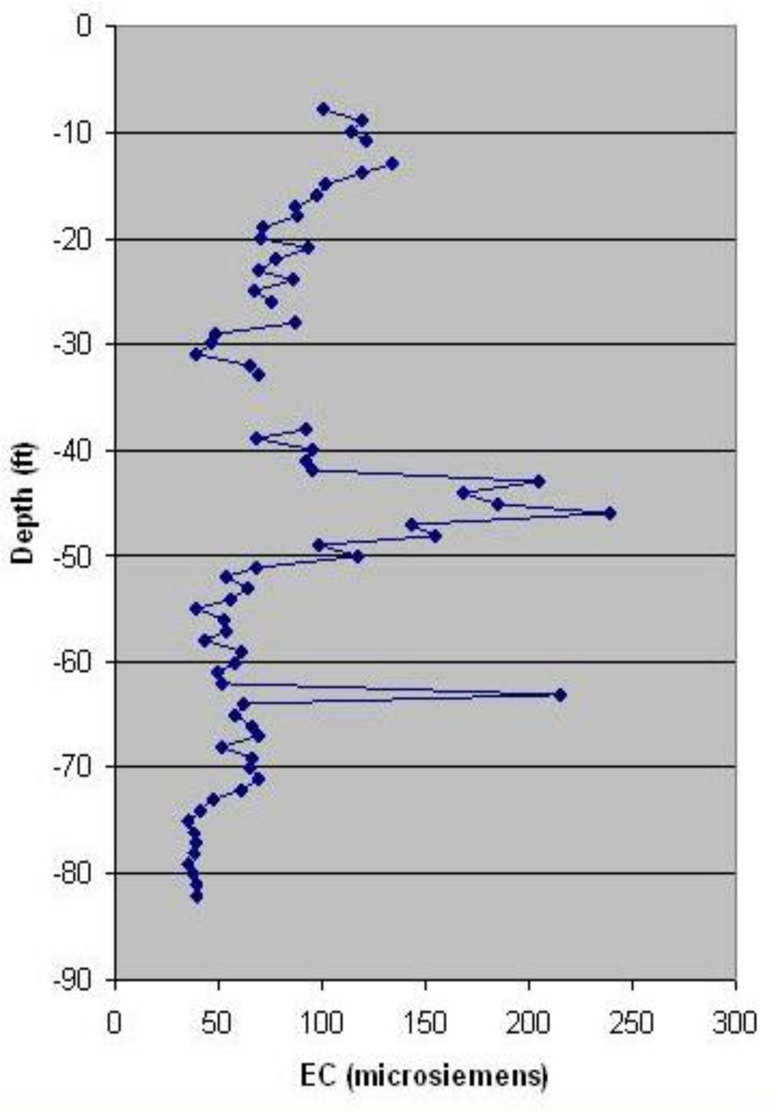
Core material collected at selected intervals for analysis of hydraulic properties

Sampling Techniques

Lithology

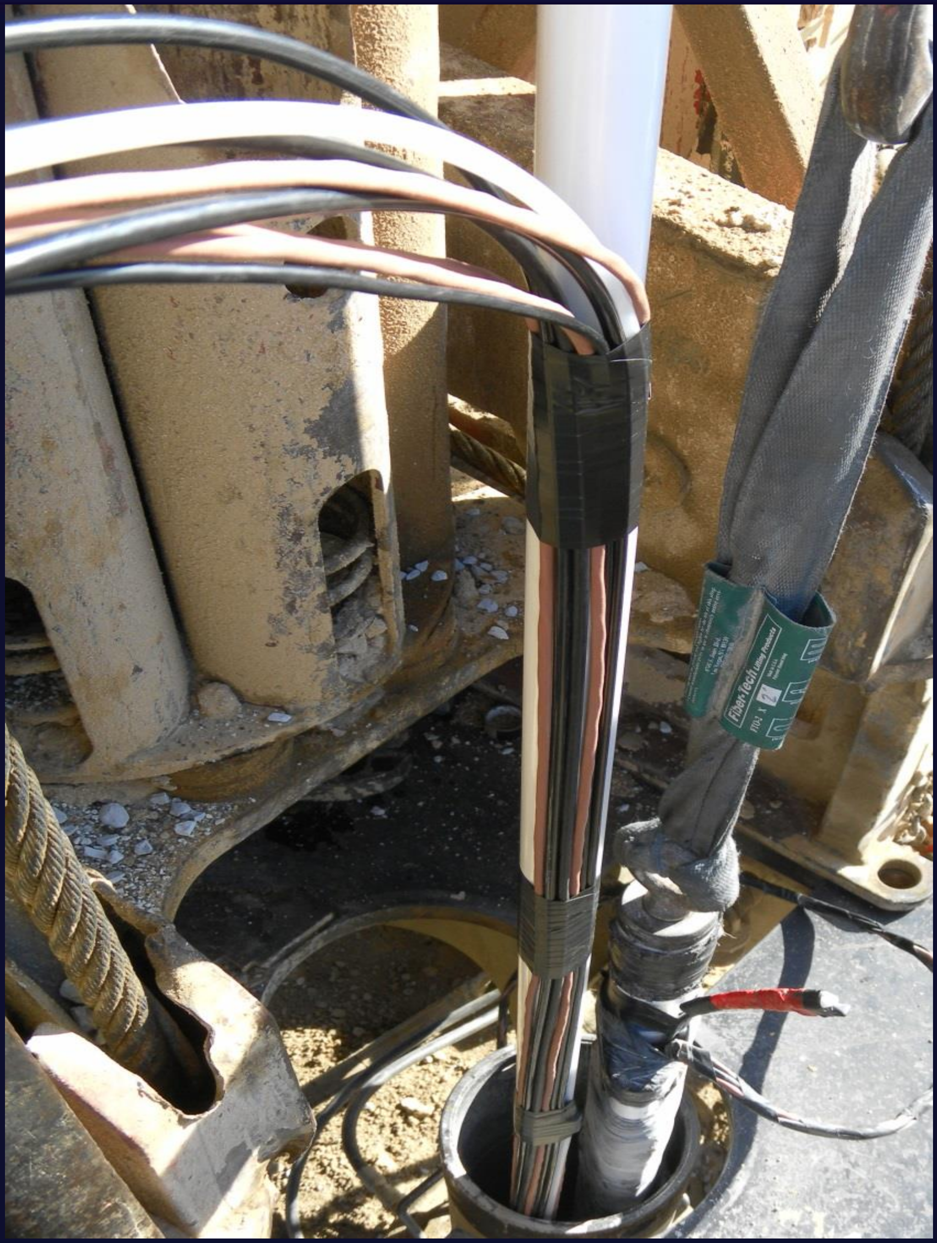
- Finely discretized
- Very thin fine-grained units can dominate rates of recharge through the UZ
- Ample material available for column/batch geochemical experiments

Real-Time Analysis

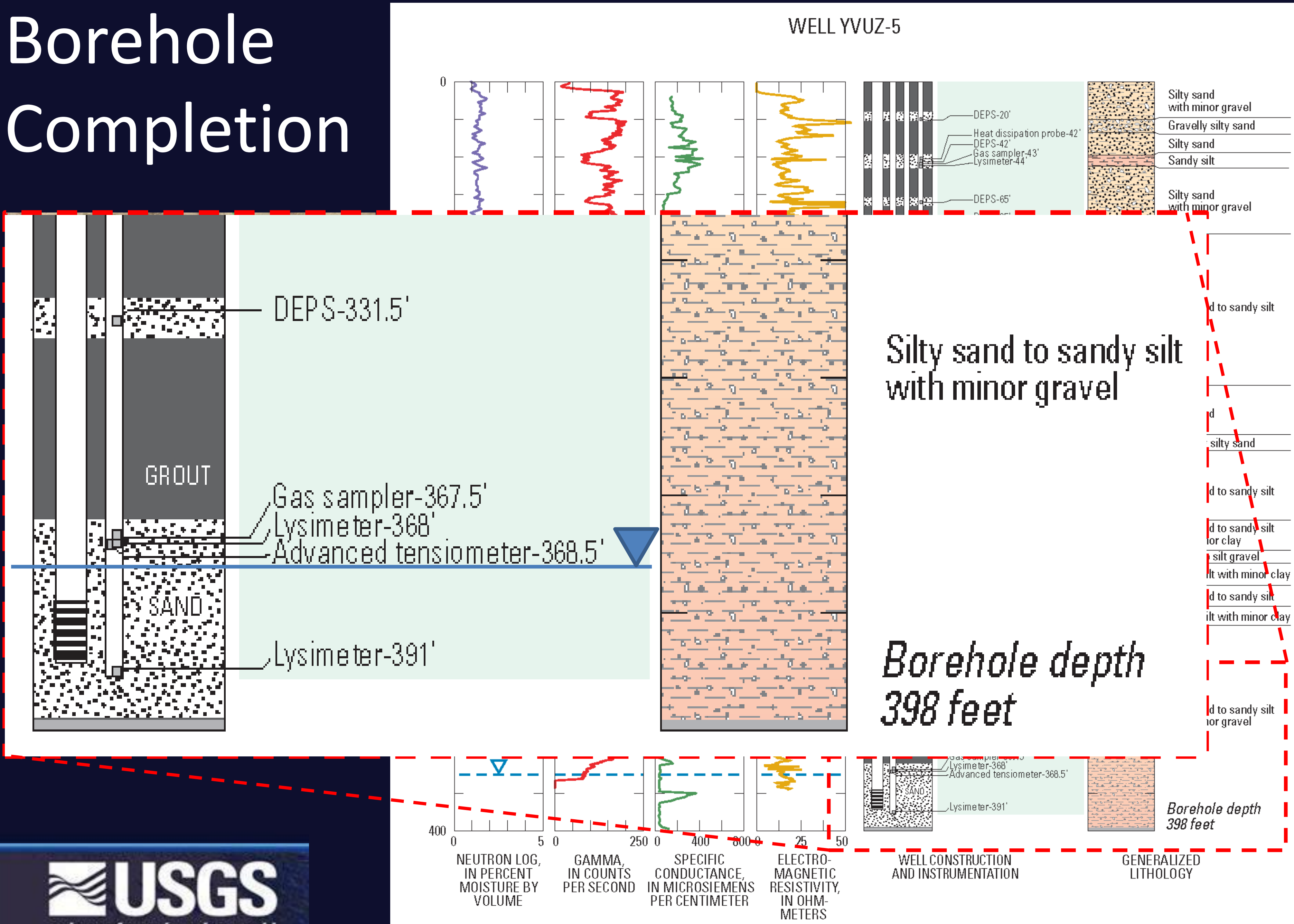


Monitoring / Site Performance

- Instrumentation (design and construction of borehole)
- Monitoring
- Sampling



Borehole Completion



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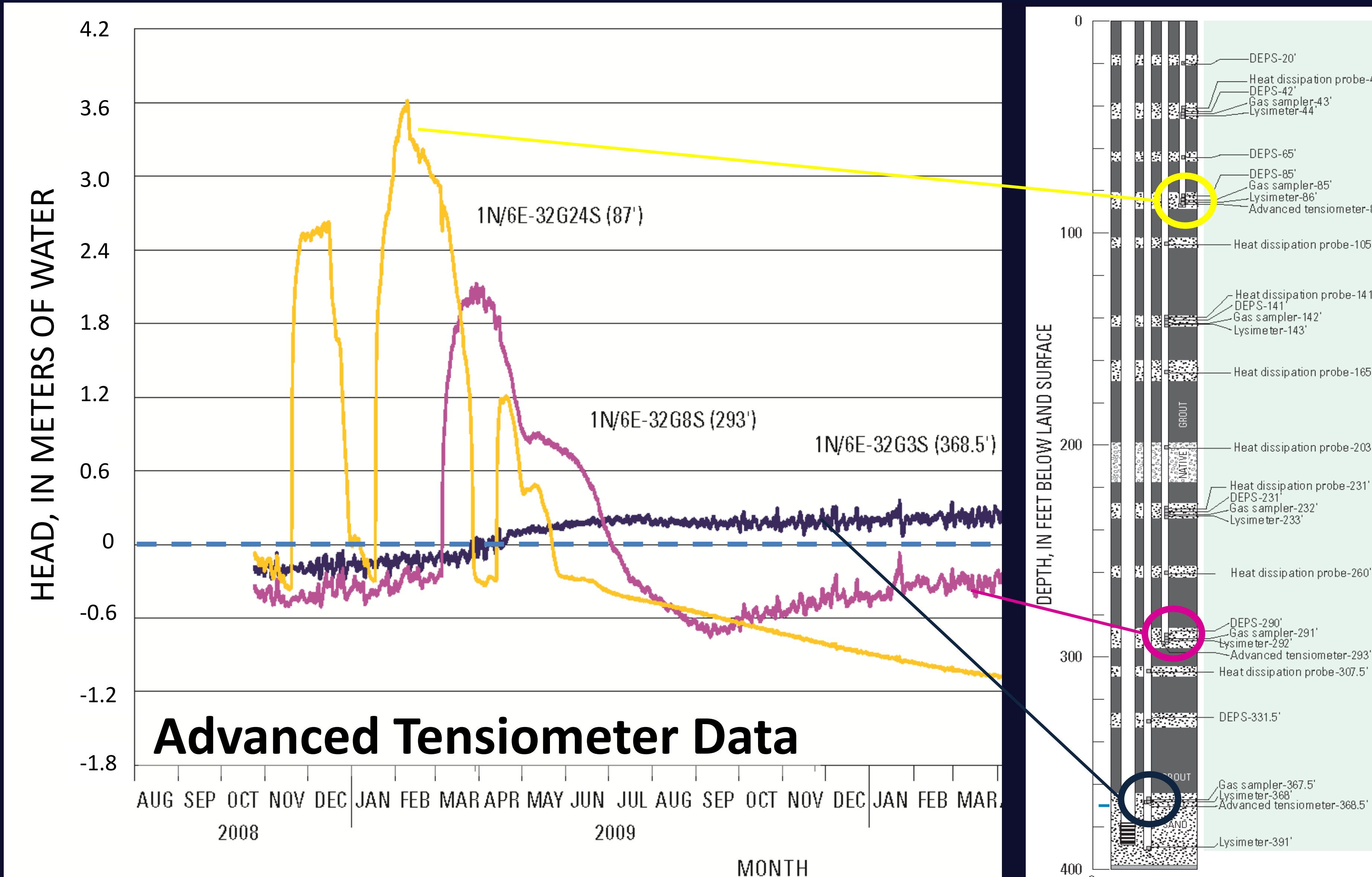
Unsaturated-Zone Instrumentation

- **Advanced Tensiometers** – measure matric potential and saturated pressures between **-800 to 800 cm** (-0.8 to 0.8 bars) and are usually installed near the water-table or above clay layers or other materials where water may accumulate.
- **Heat-dissipation Probes –** measure matric potential less than **-70 cm** (-0.07 bars) and are typically installed in drier materials.
- **Dielectric Permittivity Sensors –** measure matric potential less than **-100 cm** (-1 bar) and are able to monitor wetter materials than heat-dissipation probes.
- **Suction-cup Lysimeters –** used to collect **samples** of unsaturated-zone water.

Advanced Tensiometer Data



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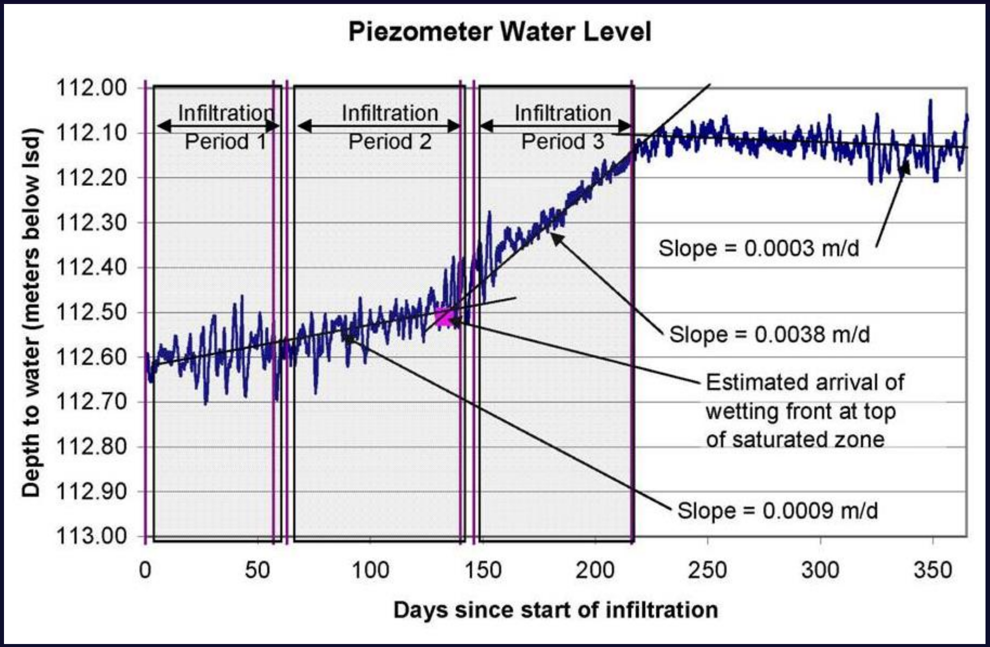
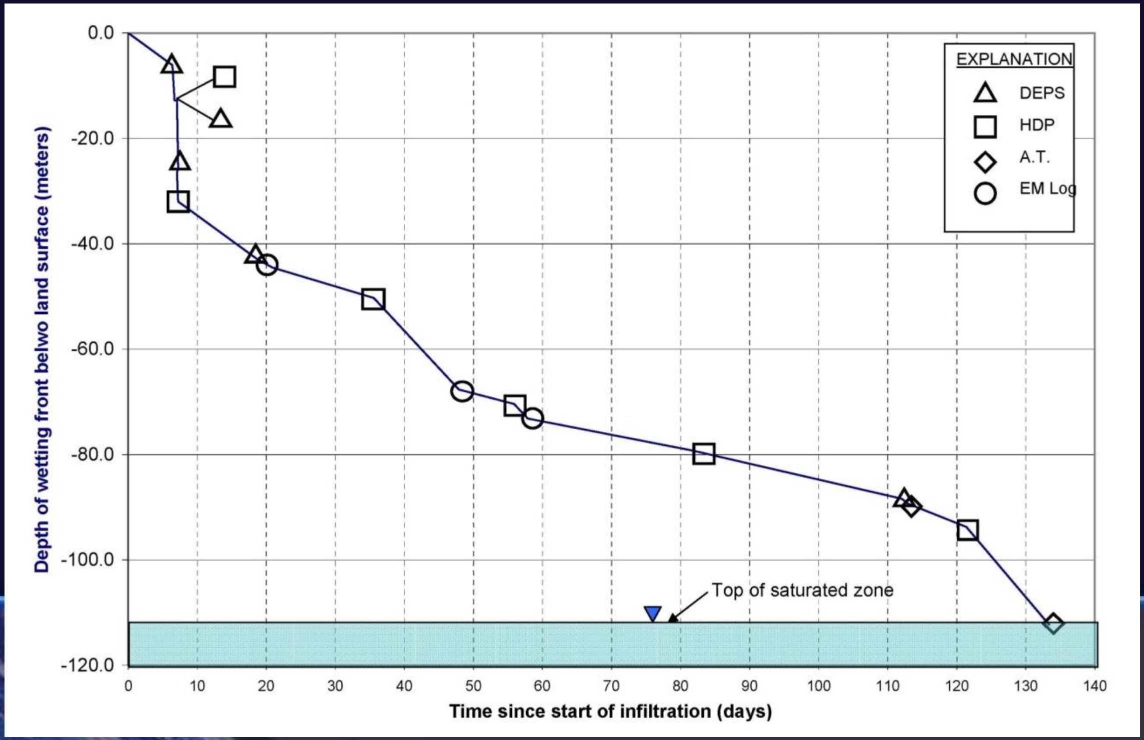


Provides physical and geochemical data during infiltration of water through the unsaturated-zone



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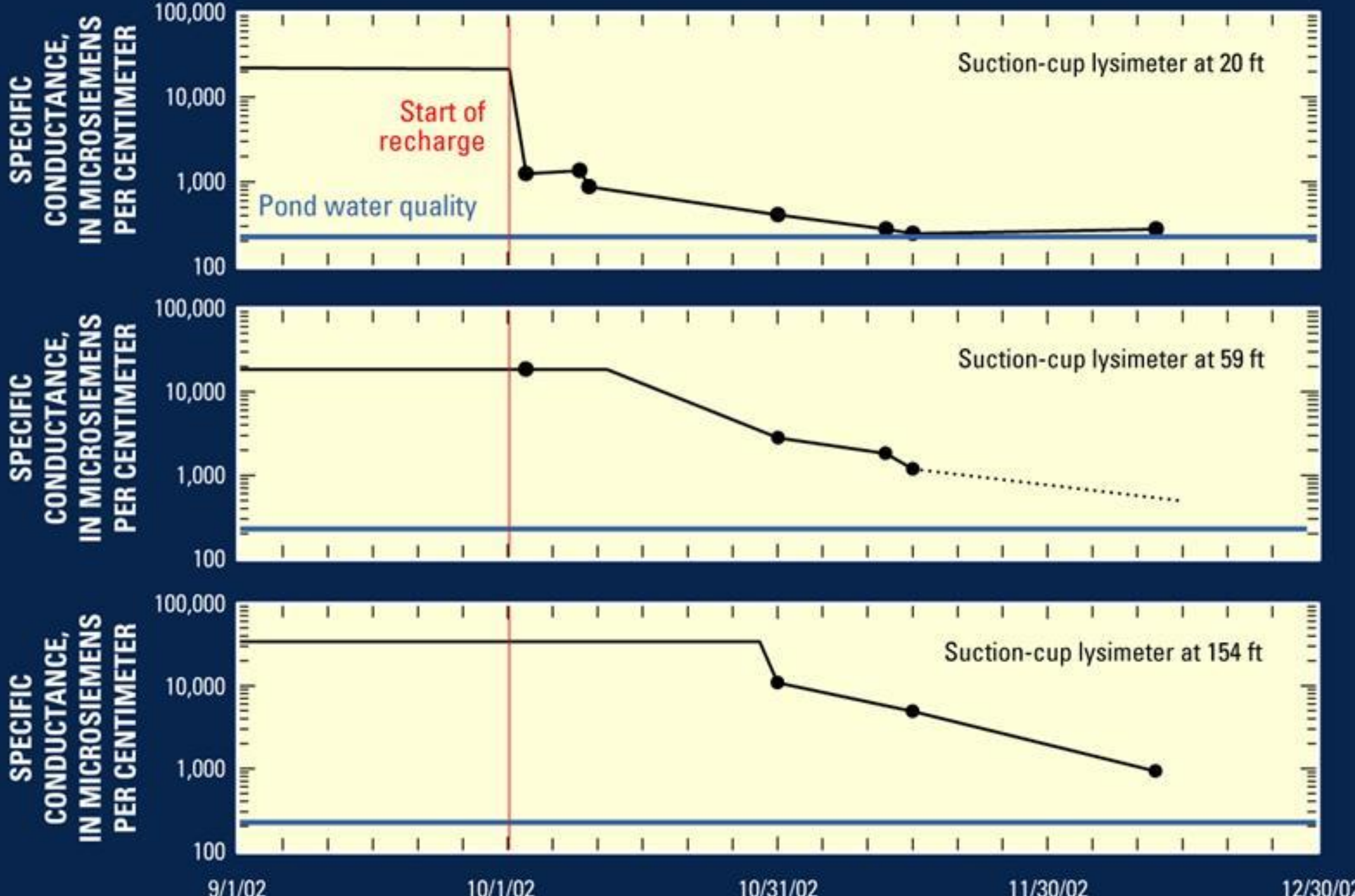
Water Quality Data - Recharge Site



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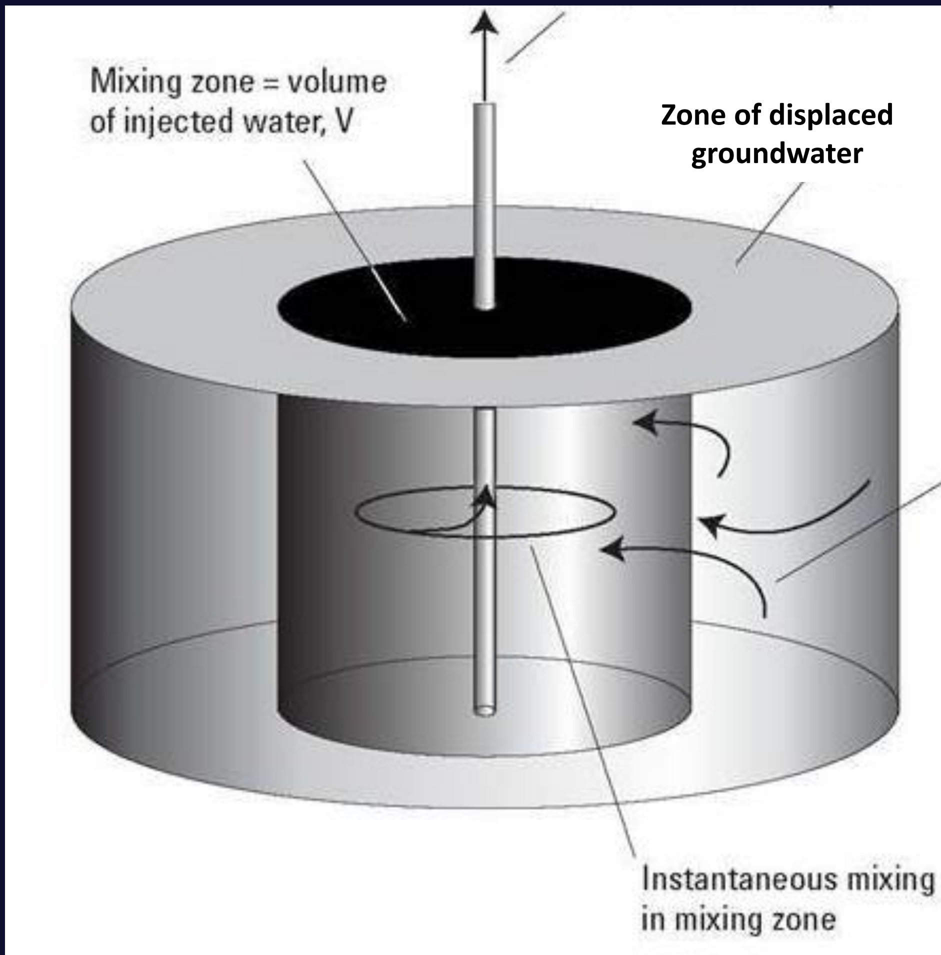
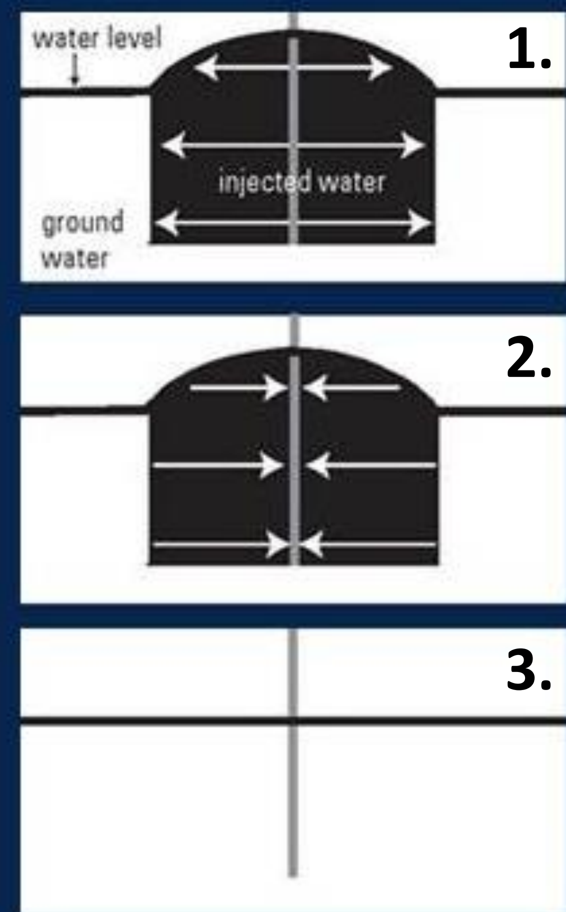
Injection/Extraction and Geochemical Considerations

- Source of water
  - High Quality / Highly-treated water
  - Water of impaired quality (treated waste-water)
  - Stormwater capture
  - "Natural" sources (rivers, streams, aqueducts)
- Interactions between recharge water and aquifer matrix
  - (i.e., As, U, F, B, Pb, Cr, Ba, TDS etc. – good and bad)
- Interactions between recharge and native groundwater
  - (redox chemistry, disinfection byproducts, etc.)
- Interactions between recharge and constructed well
  - (physical clogging, precipitation of minerals)

Conceptual Model of Injection/Extraction

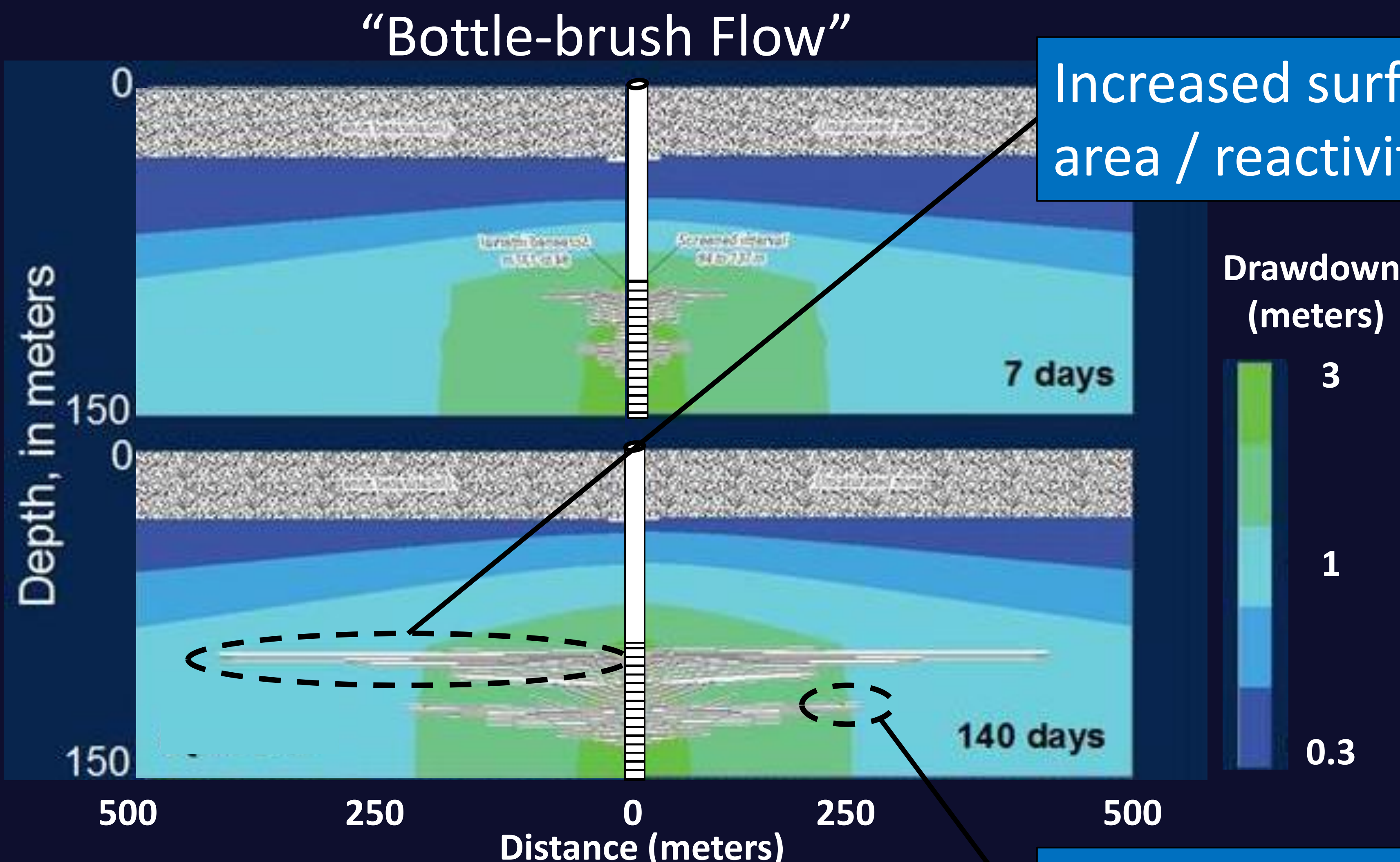
"Piston Flow"





Does not account for heterogeneity!

Conceptual Model of Injection/Extraction



Increased surface area / reactivity

Implications for recovery of water

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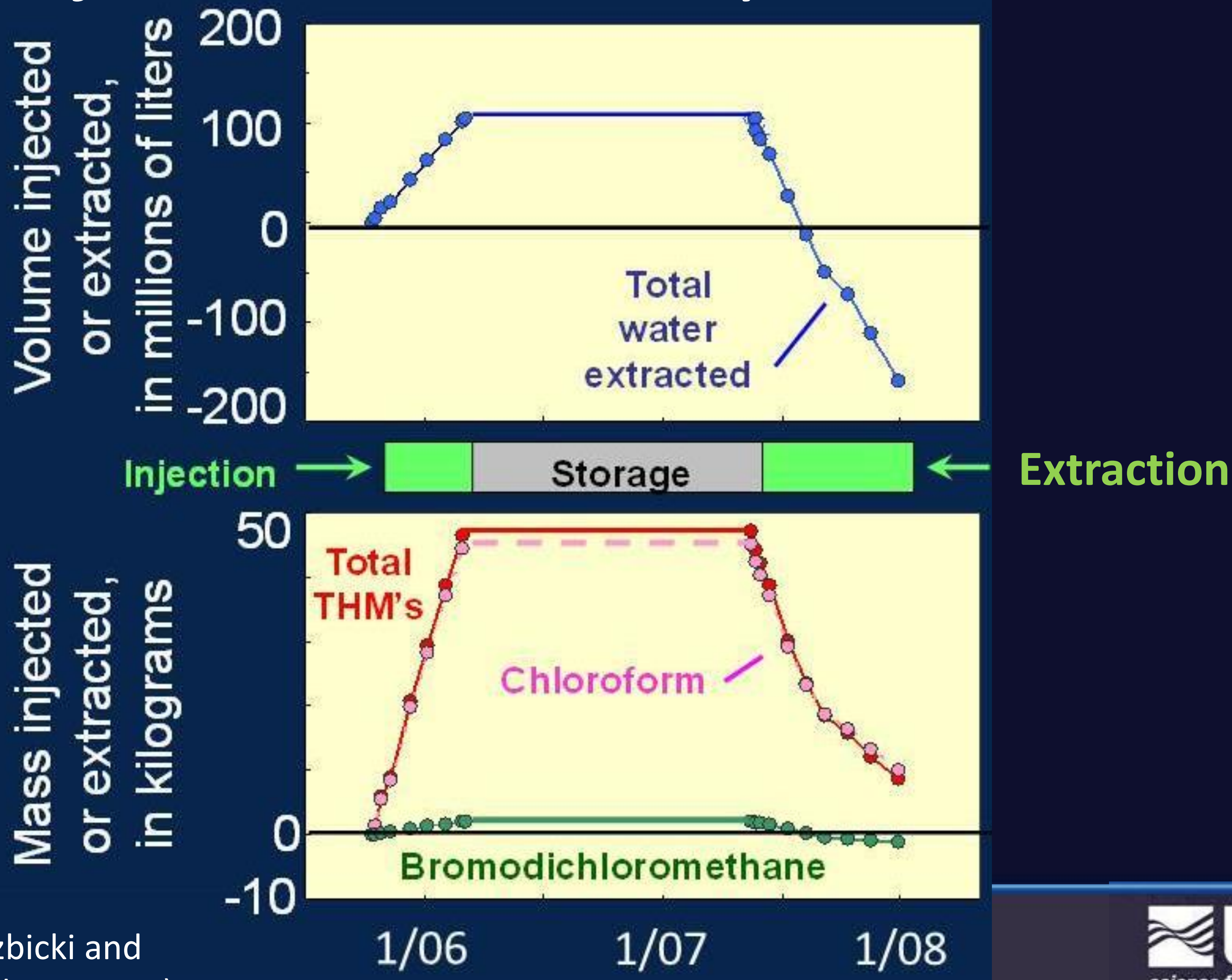
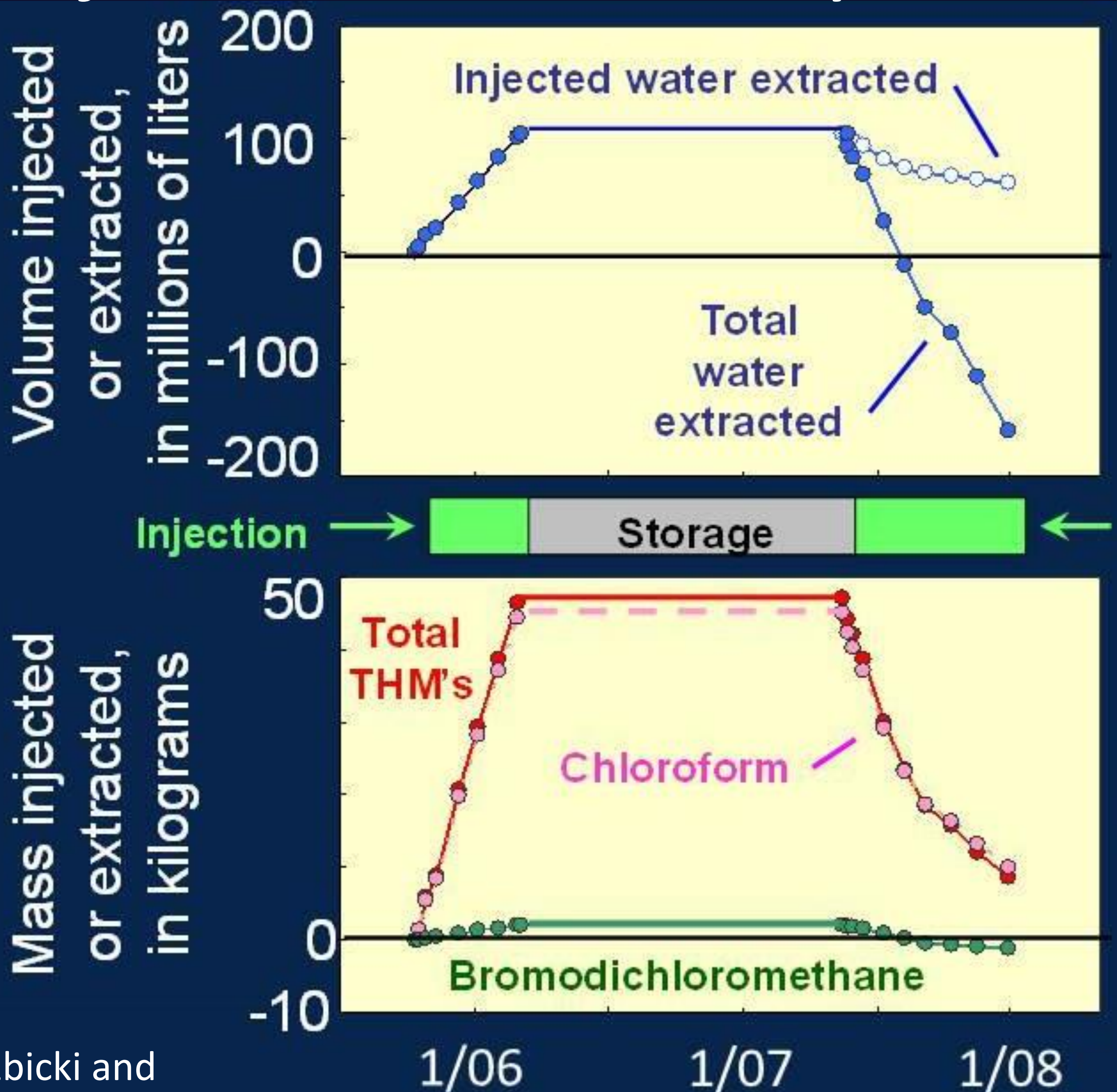
Injection and recovery of water an DBPs

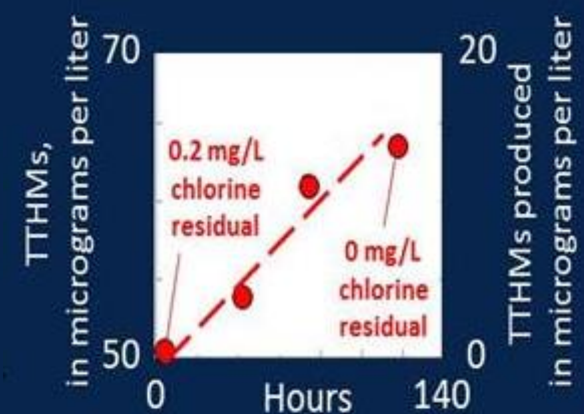


(Izbicki and others, 2010)

Injection and recovery of water an DBPs

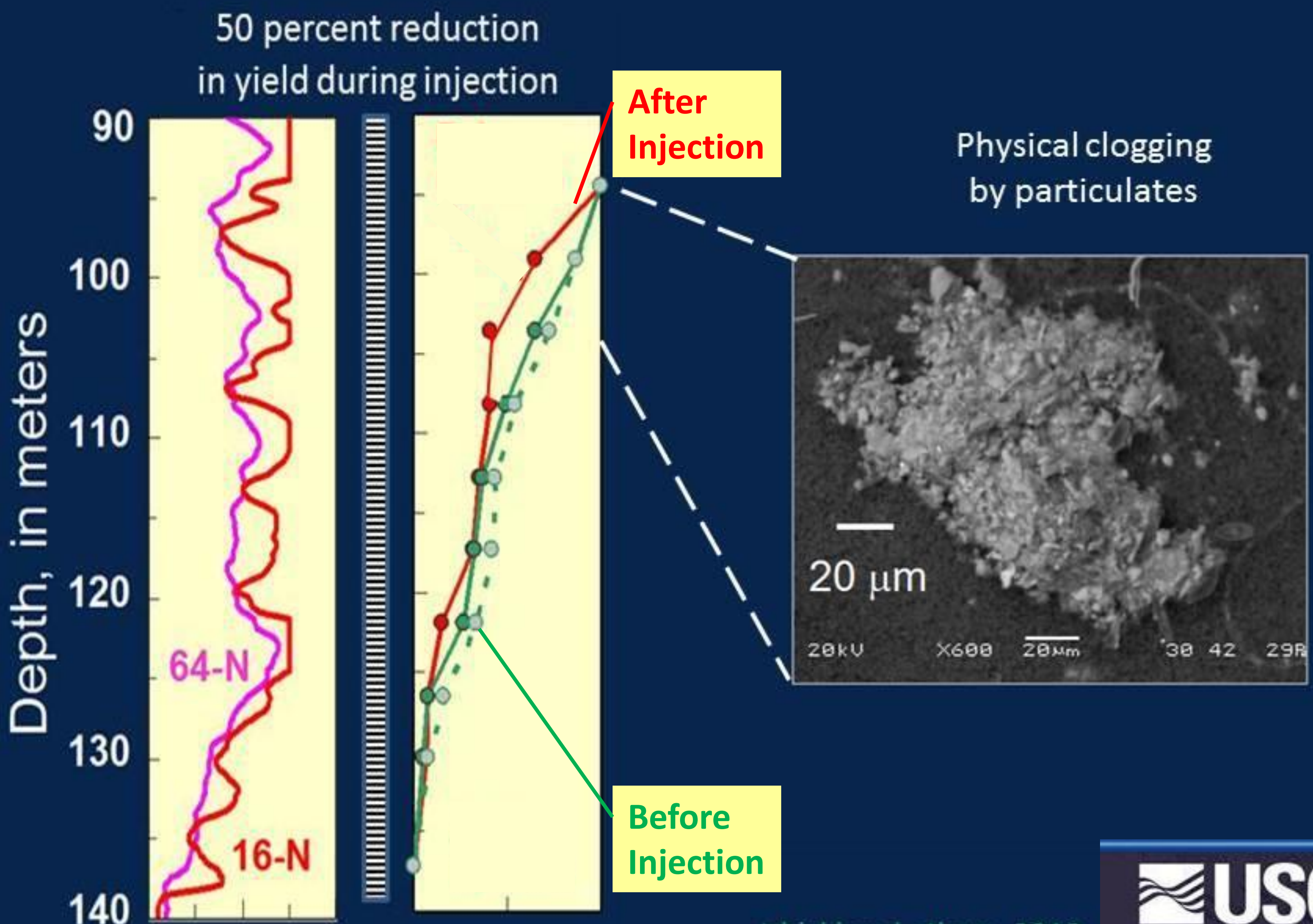


Use of tracers to track recovery of injected water



(Izbicki and others, 2010)

Aquifer Storage Recovery, 1N/6E-17F1: well clogging



Izbicki and others, 2010

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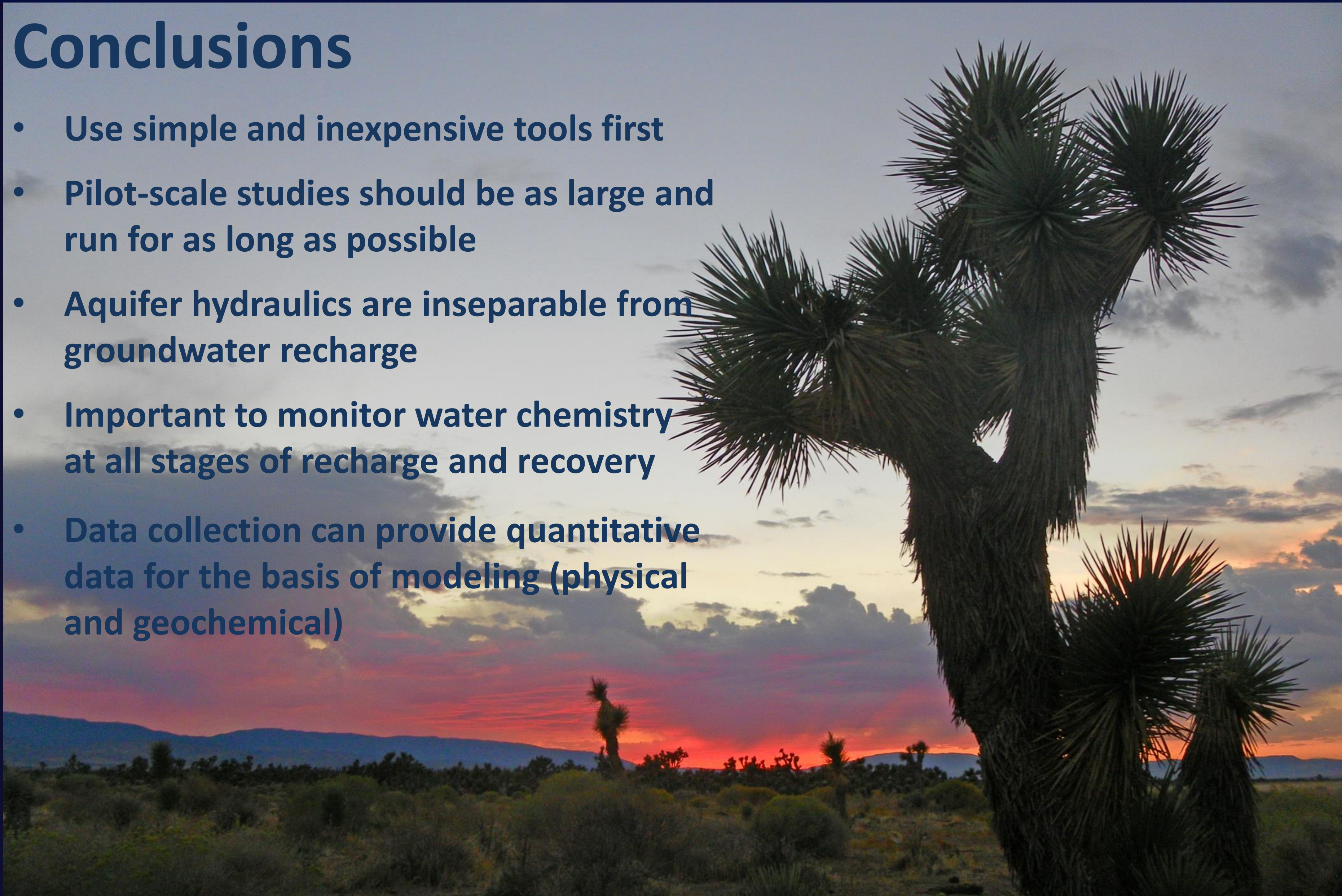
Conclusions

- Use simple and inexpensive tools first
- Pilot-scale studies should be as large and run for as long as possible
- Aquifer hydraulics are inseparable from groundwater recharge
- Important to monitor water chemistry at all stages of recharge and recovery
- Data collection can provide quantitative data for the basis of modeling (physical and geochemical)



Conclusions

- **Quantitative understanding of the effects of aquifer heterogeneity on injection, storage, and recovery is one of the most effective tools available to understand the physical movement of recharge water and the mixing sorption and degradation reactions that occur within aquifers and the unsaturated-zone that control the movement, quality, and quantity of recovered water.**

¿Preguntas?

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