Delivery Approaches for Groundwater Amendments

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Background

- Increasing number of applications of *in situ* bioremediation for CVOCs (PCE, TCE)
- Improved understanding of the microbiology but challenges with implementation (delivery and mixing)
- Biobarriers, biocurtains, biologically active zones … zones in the subsurface where GW is treated as it flows
- How do you make a PRB with soluble and semi-soluble amendments?

Outline

- Groundwater Amendments
- Delivery Approaches
- Advantages and Disadvantages of Different Approaches
- Case Studies / Field Experience

Groundwater Amendments

- Electron donors:
  - to create reducing conditions and promote biodegradation of CVOCs
- Microorganisms:
  - to provide appropriate organisms for biodegradation
- Nano-scale iron:
  - to promote abiotic degradation

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Groundwater Amendments

- Soluble, mobile
  - alcohols, sugars, lactate, acetate, citrate
- Semi-soluble or emulsions, less mobile
  - oleate, sterate, emulsified vegetable oil
- Solid, slow release compounds
  - Chitin, HRC
- Microorganisms (bioaugmentation)
  - Dehalococcoides (DHE)
- Nano-scale particles

Delivery Approaches

- Temporary probes
- Injection wells
- Injection/extraction wells
- Gravel trench
- Slow release solids in trench

Delivery Approaches

- Passive
- Semi-Passive
- Active

- Discrete Point Injections
- Intermittent Recirculation
- Continuous Recirculation

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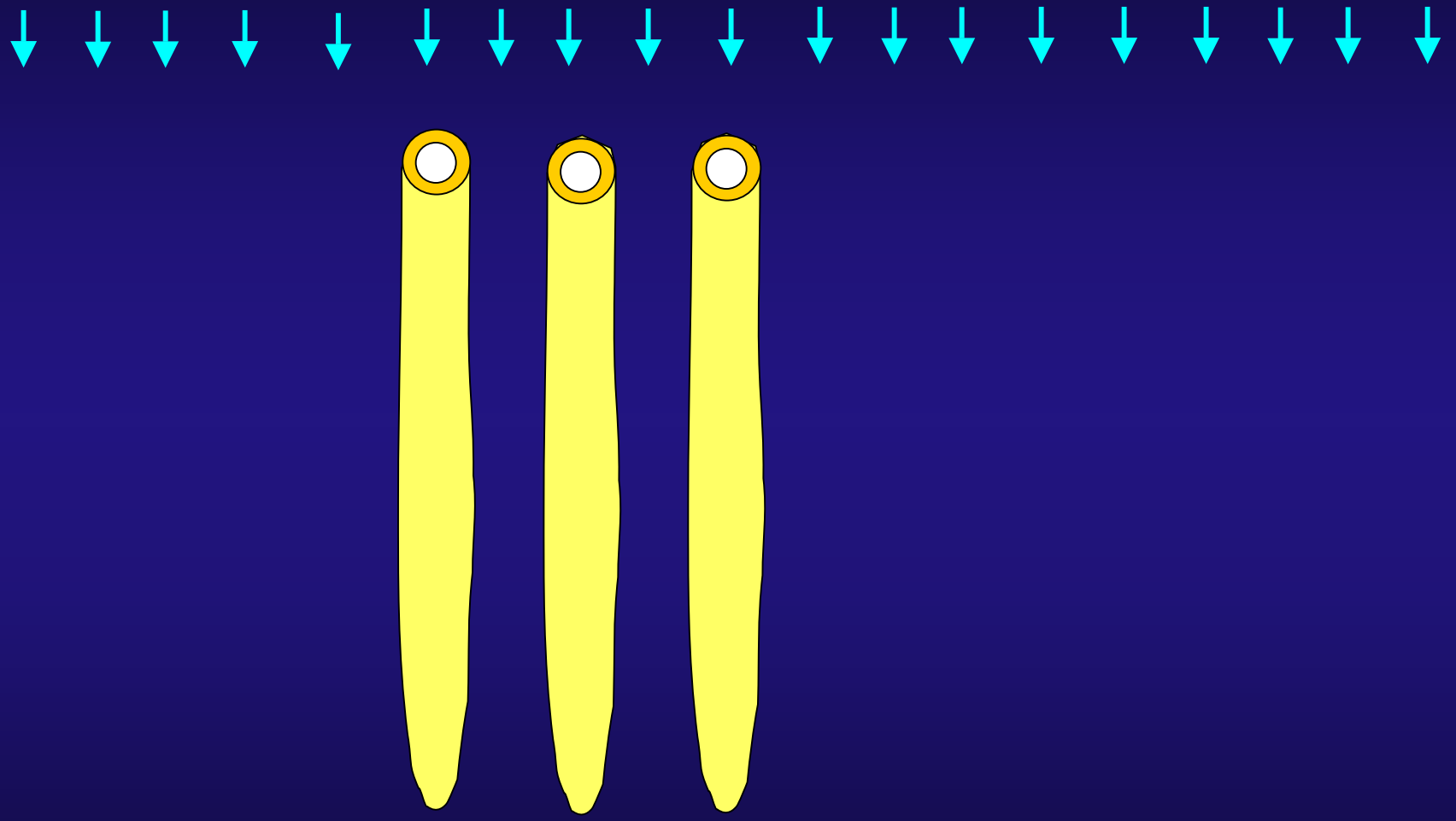
Injection Points or Wells



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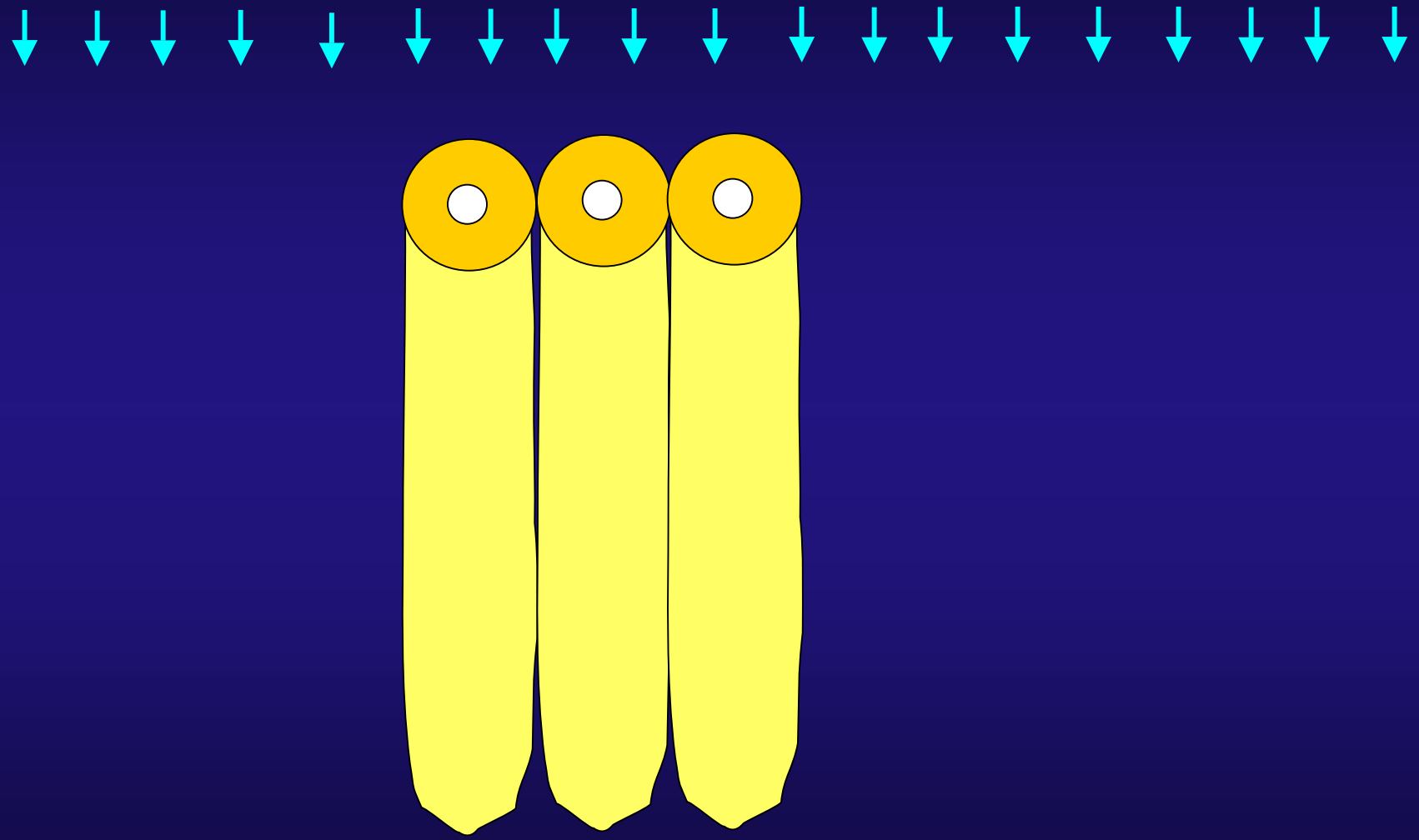
Injection Wells with Water Flush



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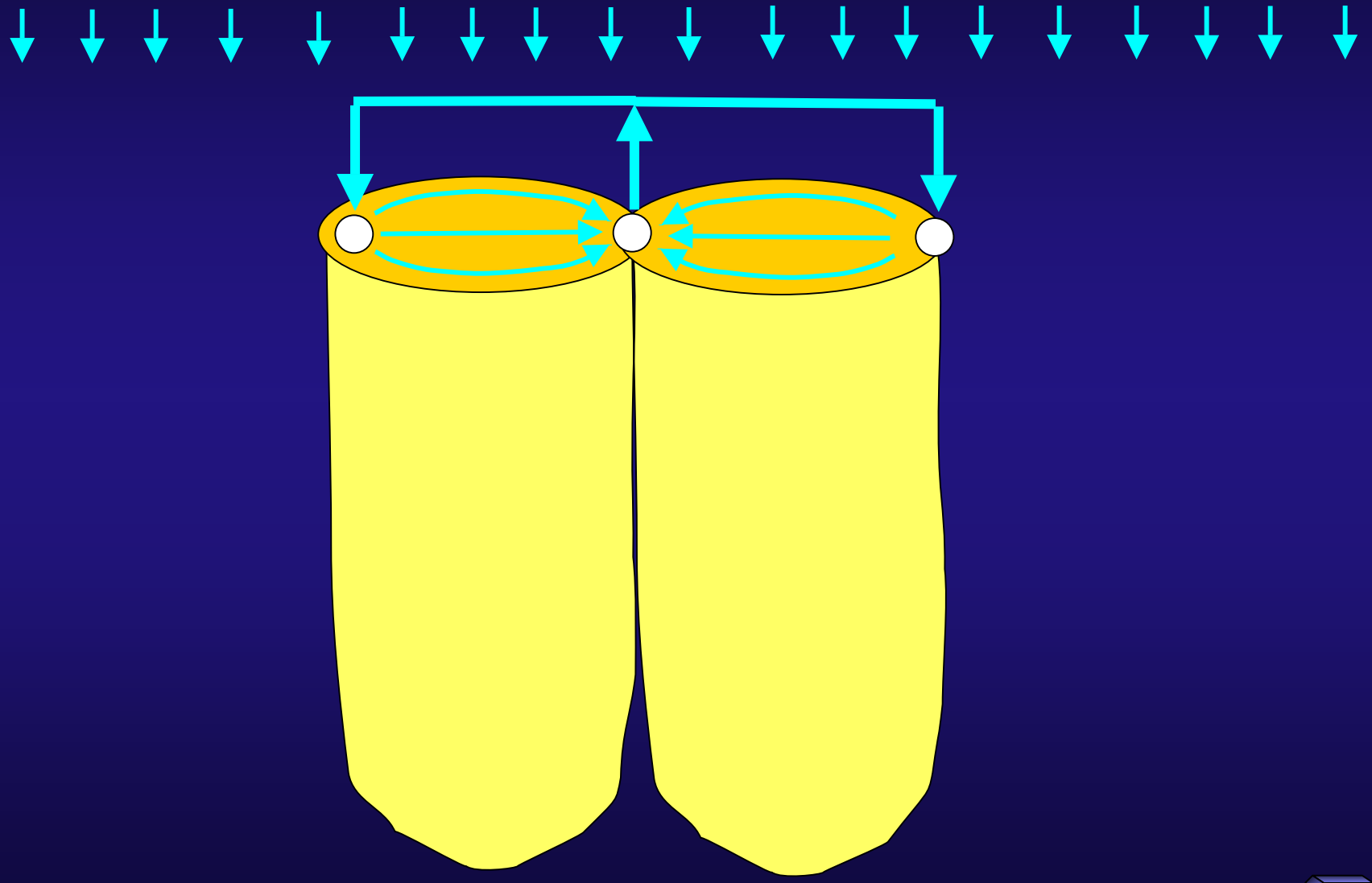
Injection Wells with Intermittent Circulation



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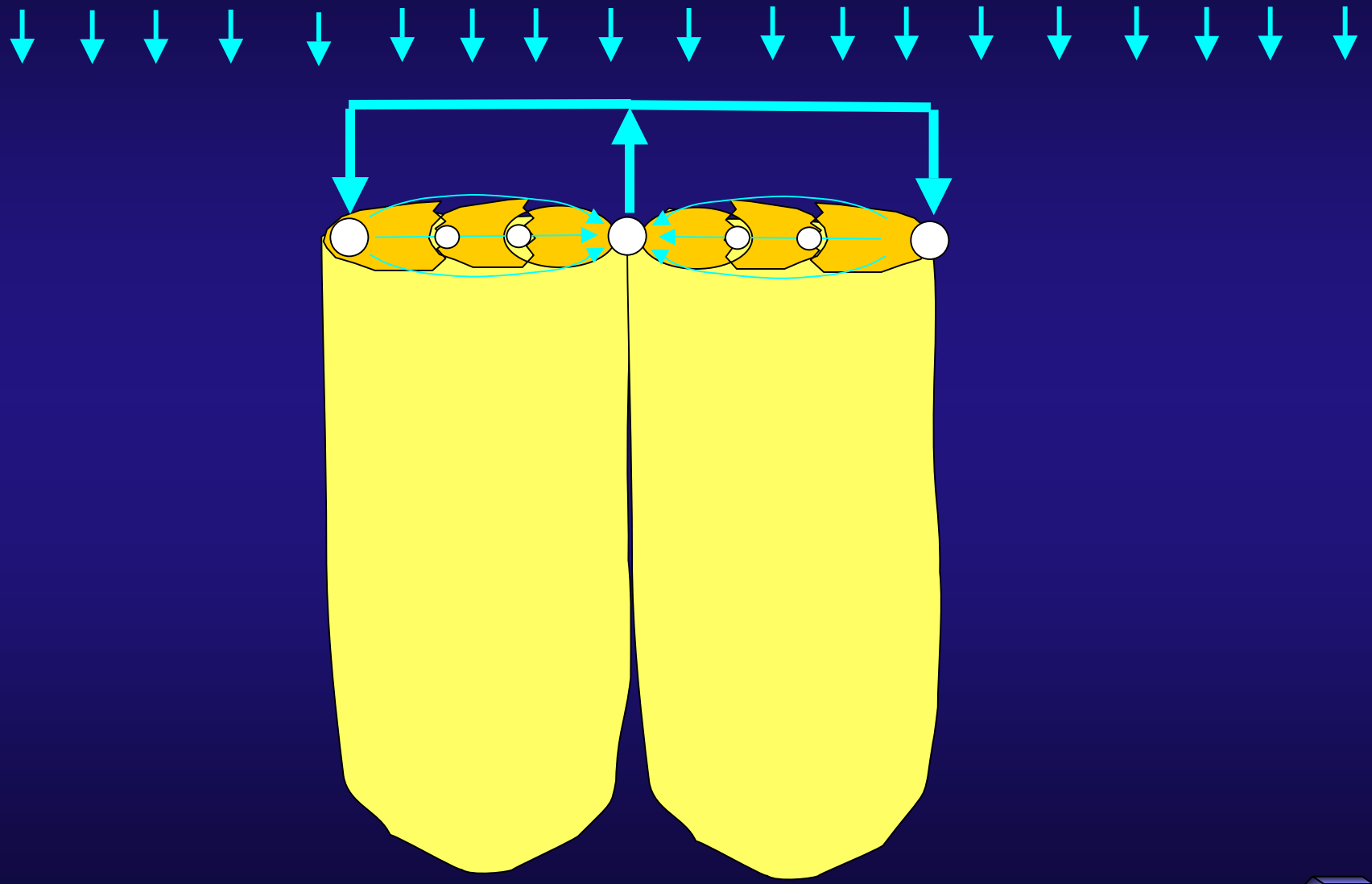
Row of Injection Wells with Intermittent Circulation and Intermediate Wells



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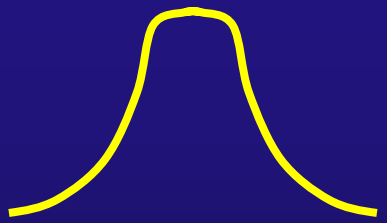
Intermittent Amendment Addition

- Are Fluctuations in Amendment Concentrations an Issue?
  - Longitudinal dispersion results in significant mixing (Devlin & Barker, 1996)
  - Semi-soluble & slow release amendments have greater dispersion than soluble amendments
  - Trap & Treat – treatment of dissolved & adsorbed contaminants when amendment concentration is high, followed by adsorption onto soil matrix (Dybas, et. al., 2002)
  - Growth of biomass followed by decay provids continuing carbon source

Pulse Dispersion

T1

T2



T3

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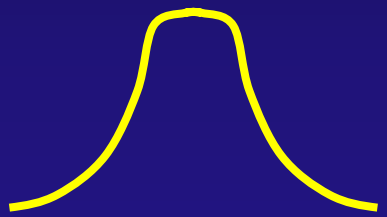
Overlapping of Pulses

T1



T2

T3

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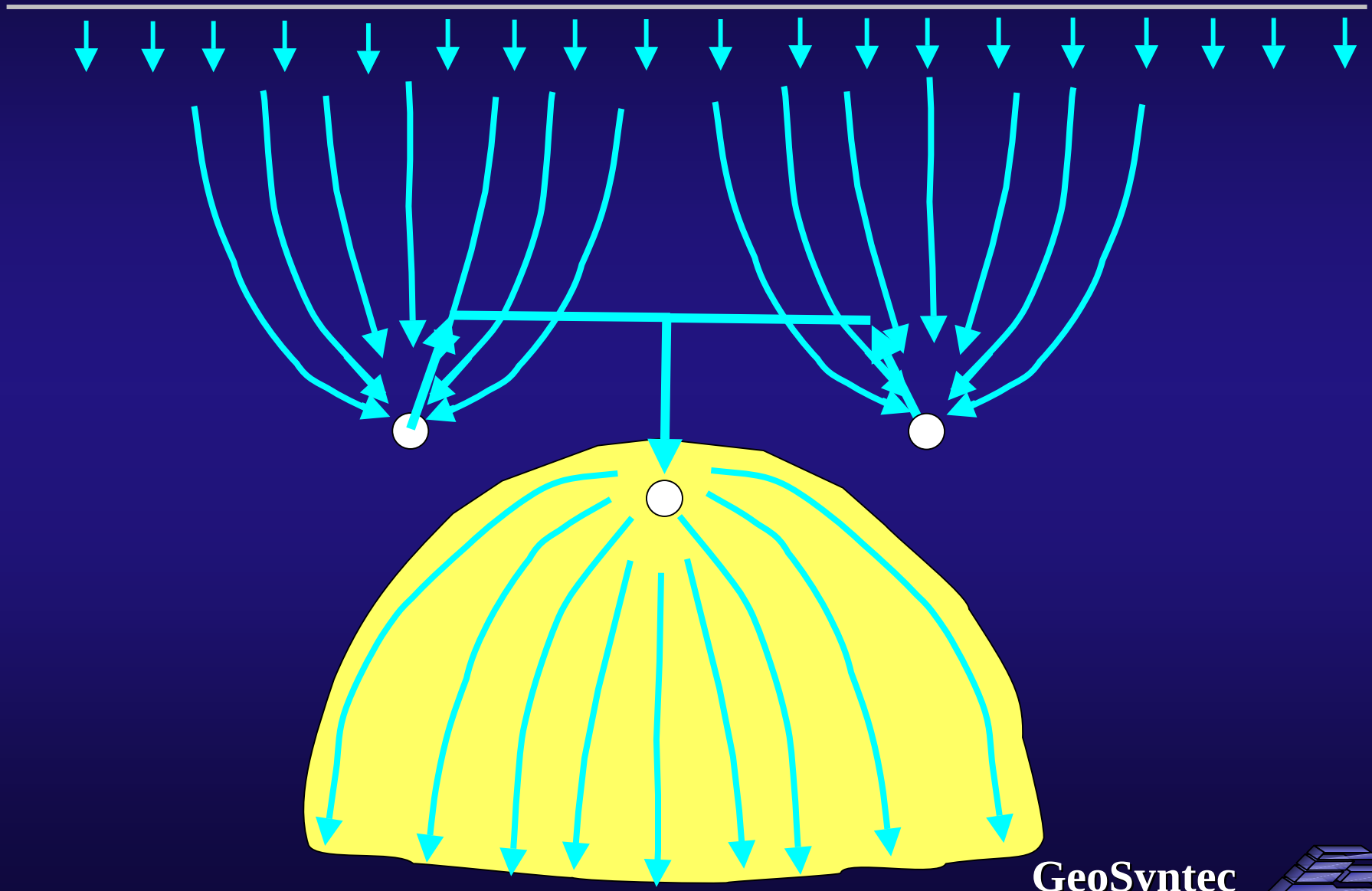
Extraction, Amendment & Reinjection



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Relative Advantages

	Passive	Semi-Passive	Active
# Well Required (Cap $)	high	med	low
Infrastructure (Cap $)	low	med	high
Operation (O&M $)	low	med	high
Fouling of Wells (O&M $)	low	med	high
Distribution in GW	poor	better	best
Control of Dose	poor	better	best
Maintains Water Quality	poor	better	best

Case Study #1 Passive Injection

- Industrial Site in California
- TCE in low-permeability shallow groundwater (15 - 35 ft bgs)
- Injecting lactate, soybean oil, food grade emulsifiers & DHE to promote biodegradation of TCE
- Injection wells 15 ft apart
- Adding water to push amendments out from injection wells (10,000 gal per point)

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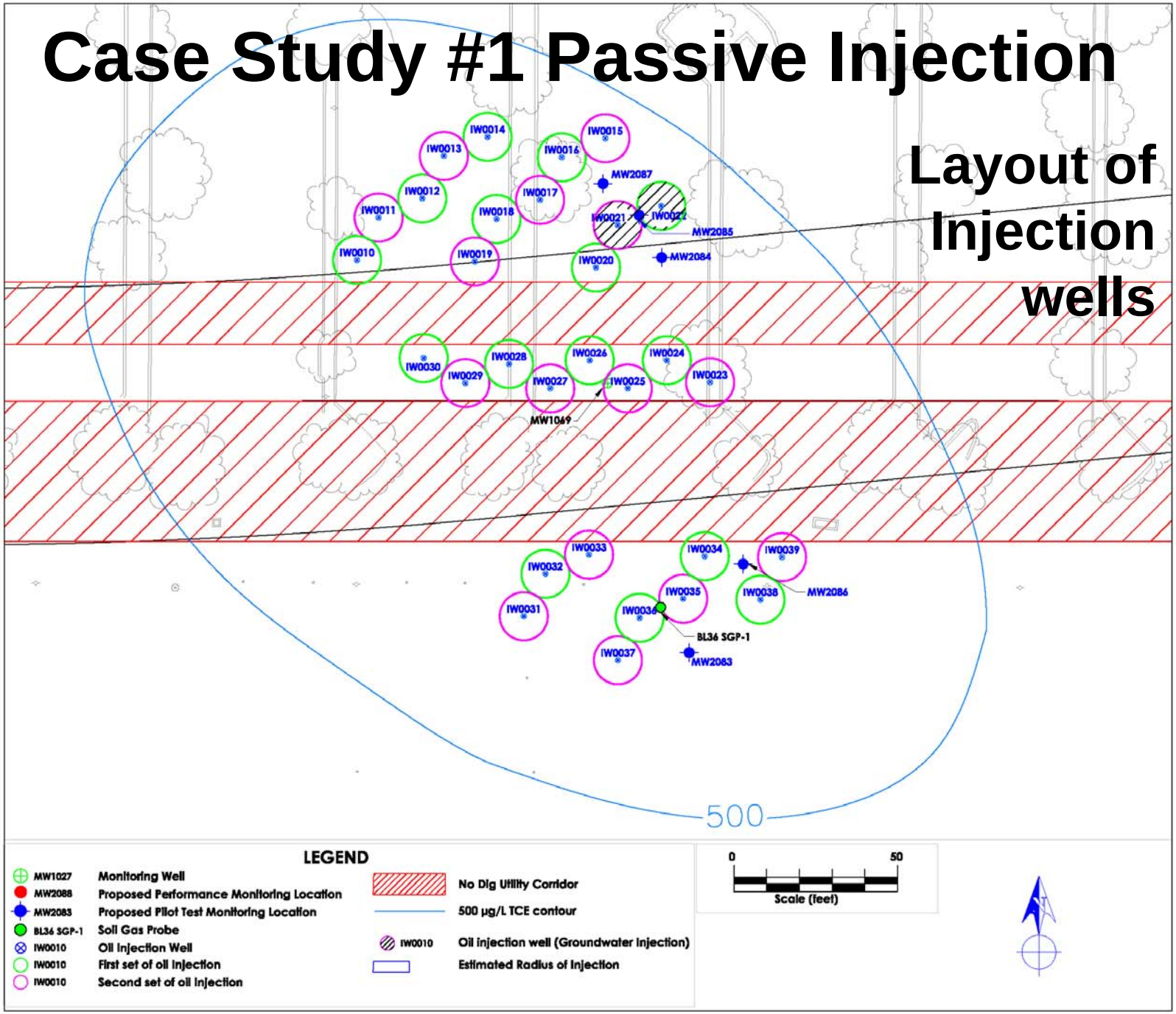
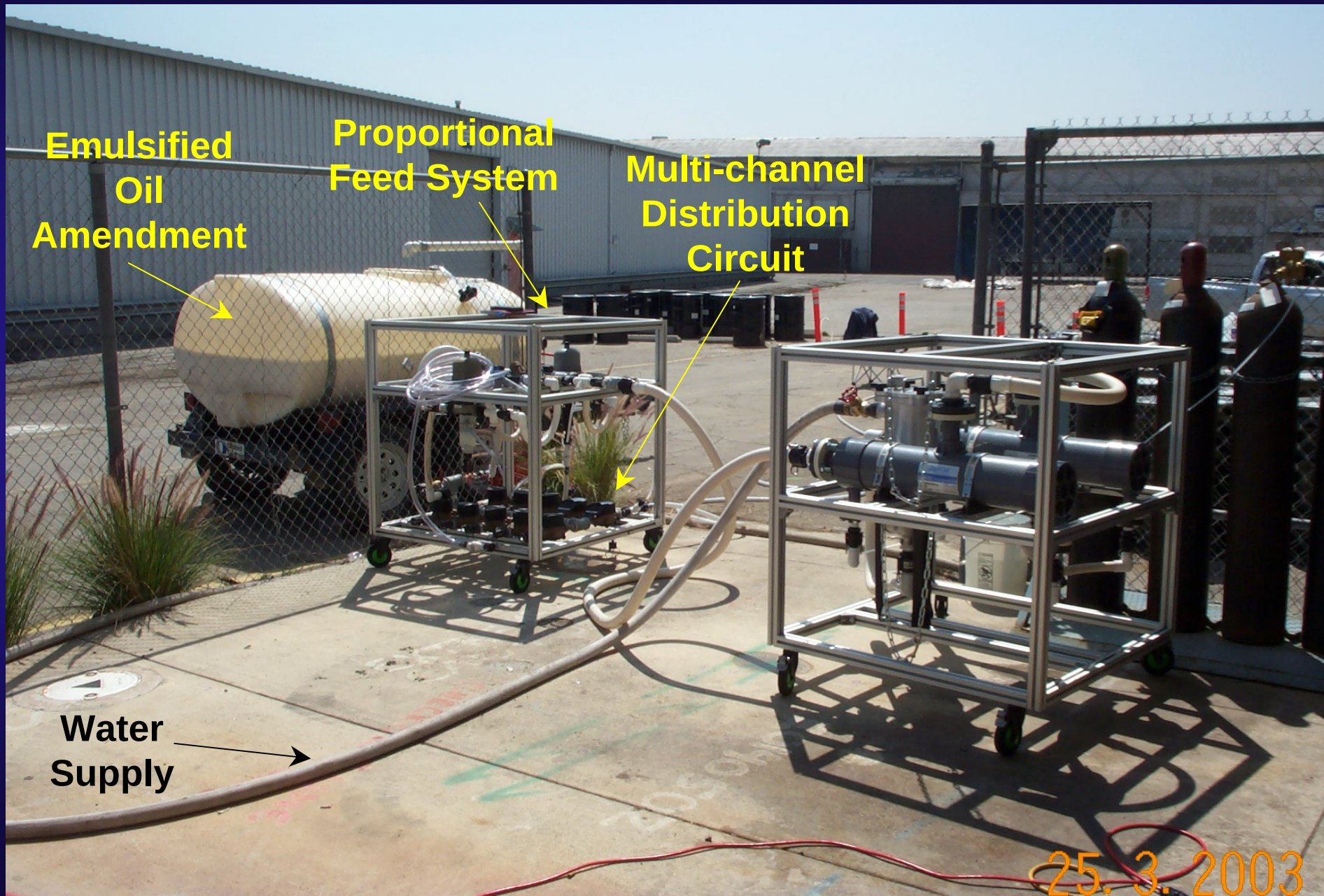
Case Study #1 Passive Injection

Layout of Injection wells



Case Study #1 Passive Injection

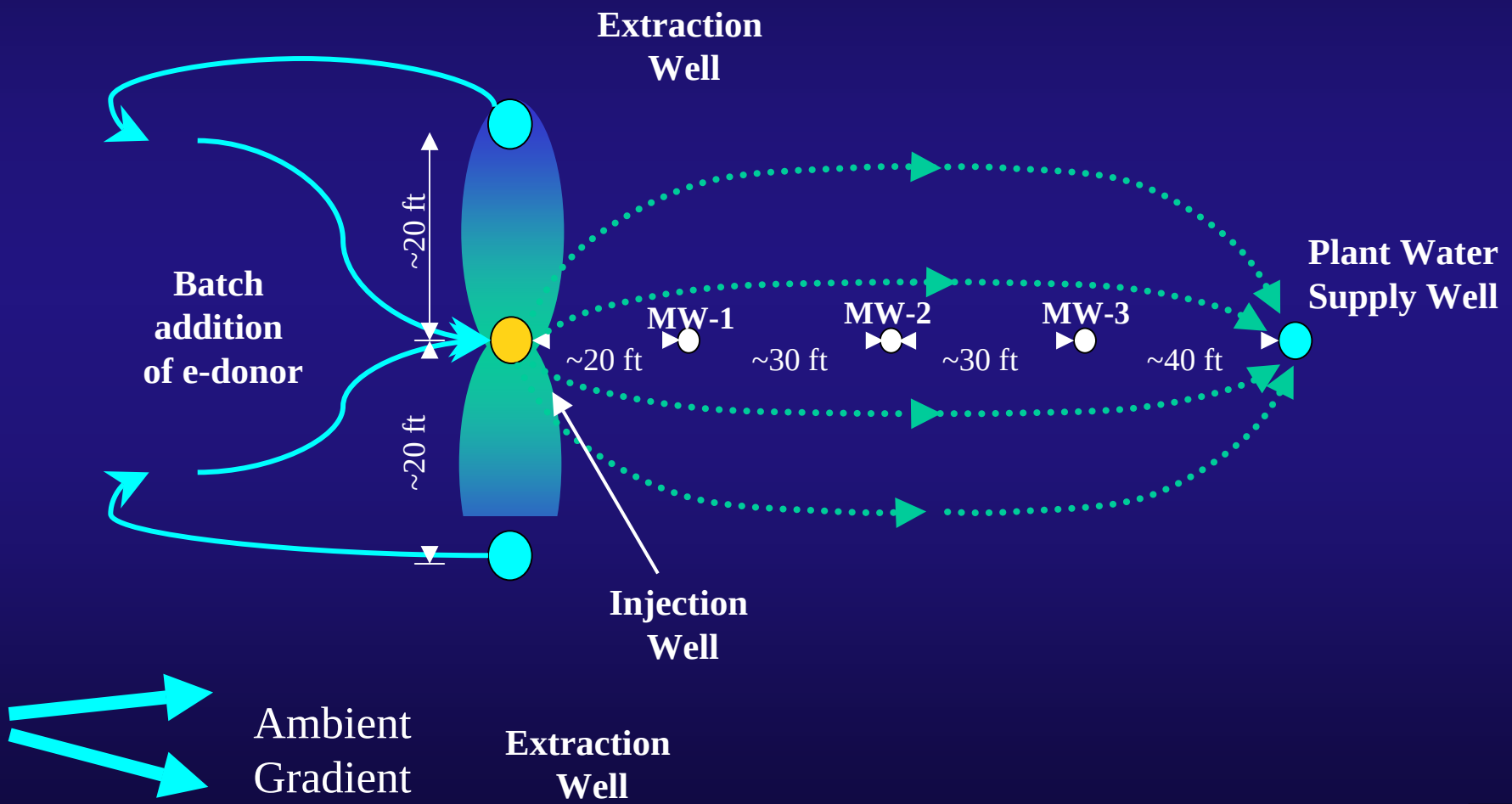


Case Study #1 Passive Injection

Case Study #2 Semi-Passive Injection

- Industrial Site Massachusetts
- TCA in groundwater (25-35 ft bgs)
- Adding methanol and sodium lactate to promote biodeg. of TCA
- Injection well with extraction wells 20 ft on either side
- Intermittent pumping following batch lactate addition (8 hours once per week at 4 gpm)
- Very simple operation

Case Study #2 Semi-Passive Injection



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Case Study #2 Semi-Passive Injection

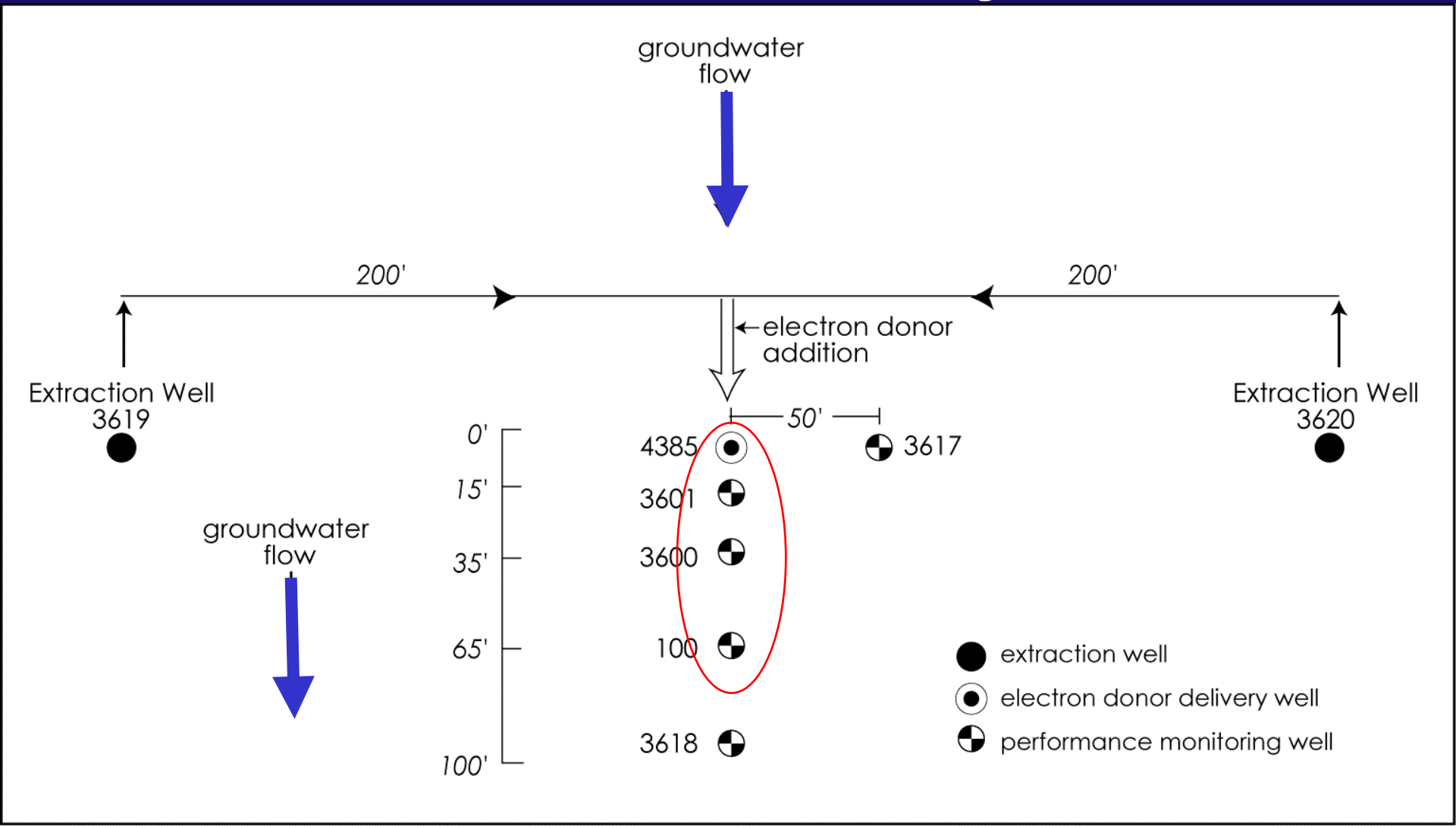
- Methanol detected in extraction well after circulation
- Lactate not detected
- TCA degradation observed in groundwater

Case Study #3 Active Recirculation

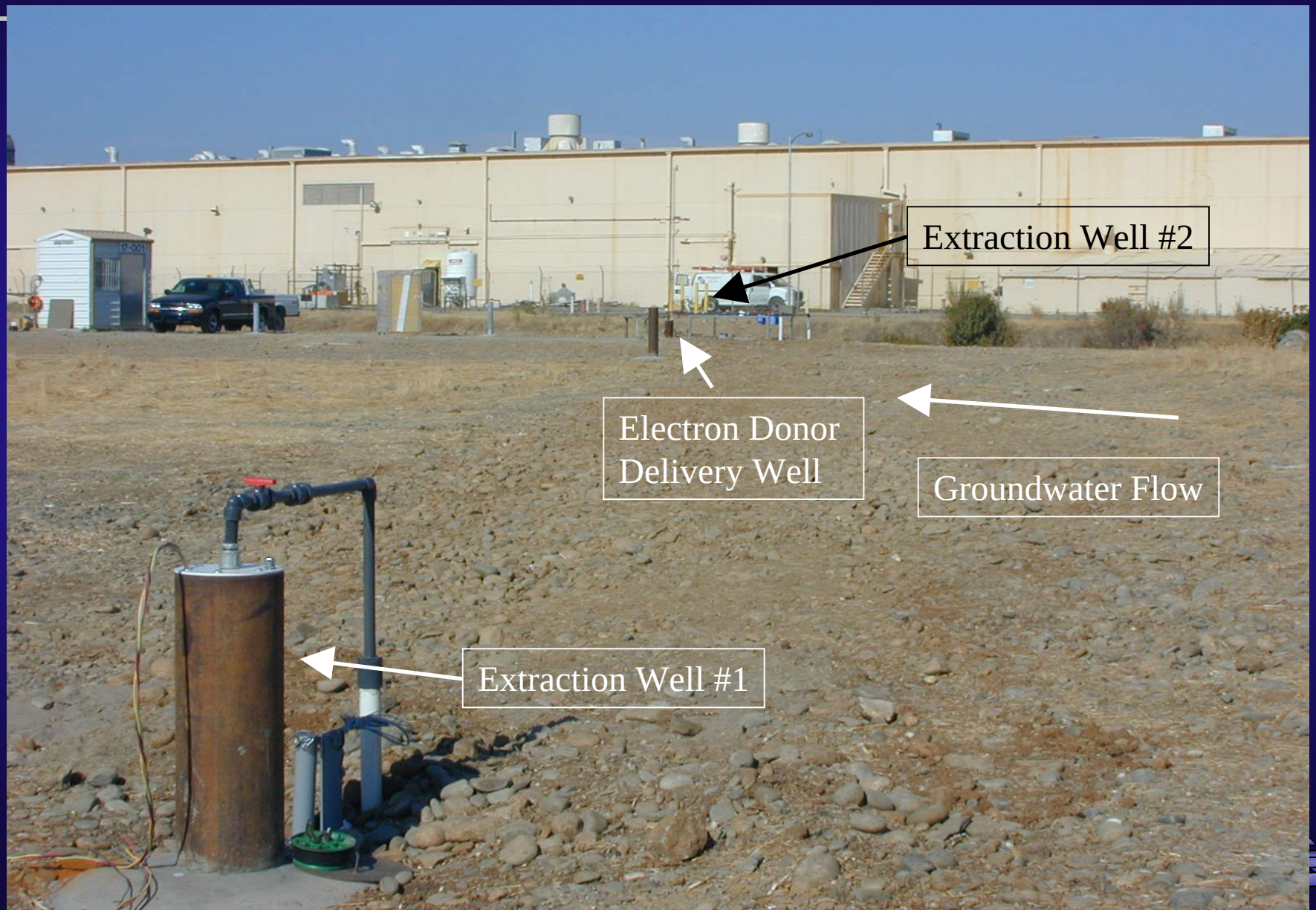
- Rocket Mfg in California
- TCE in sand aquifer (100 ft bgs)
- Adding ethanol to promote biodeg. of perchlorate and TCE
- Injection well with extraction wells 200 ft on either side
- Active recirculation (10 gpm from each of 2 wells) and amendment with ethanol

Case Study #3 Active Recirculation

Plan View of Well Layout

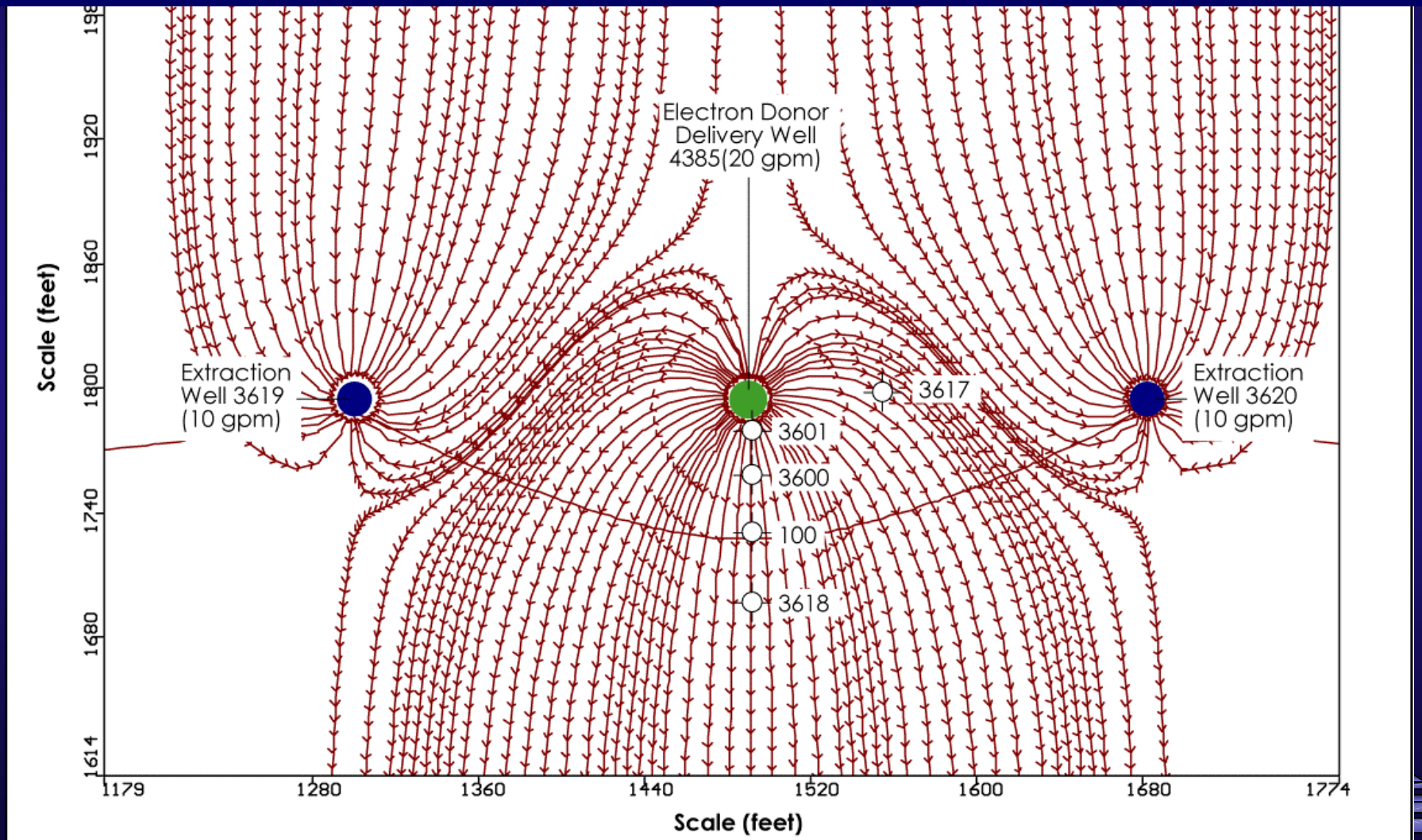


Case Study #3 Active Recirculation



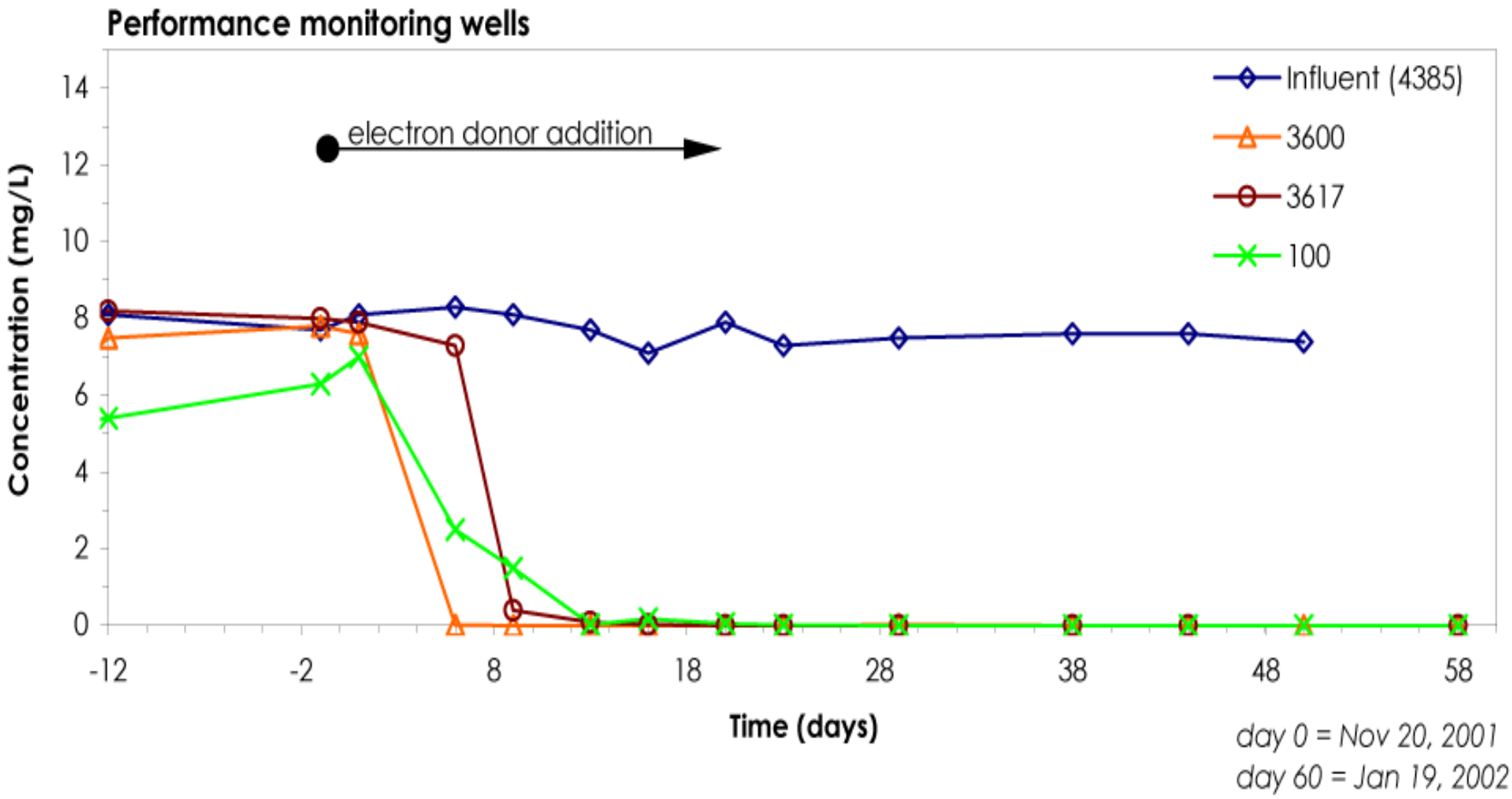
Case Study #3 Active Recirculation

Groundwater Flow Modeling



Case Study #3 Active Recirculation

Degradation of Perchlorate



Case Study #3 Active Recirculation

Bioaugmentation to enhance TCE degradation

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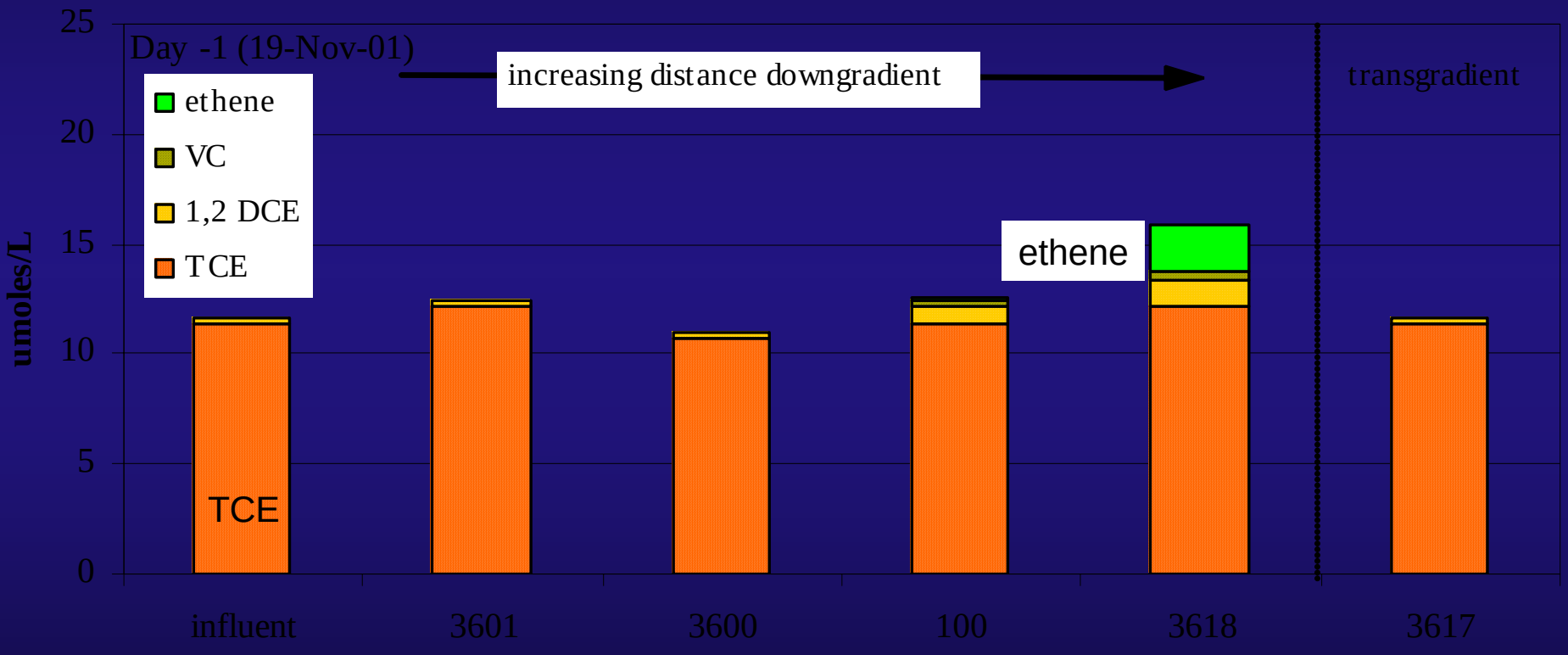
Case Study #3 Active Recirculation

Baseline Concentrations of TCE (day 1)



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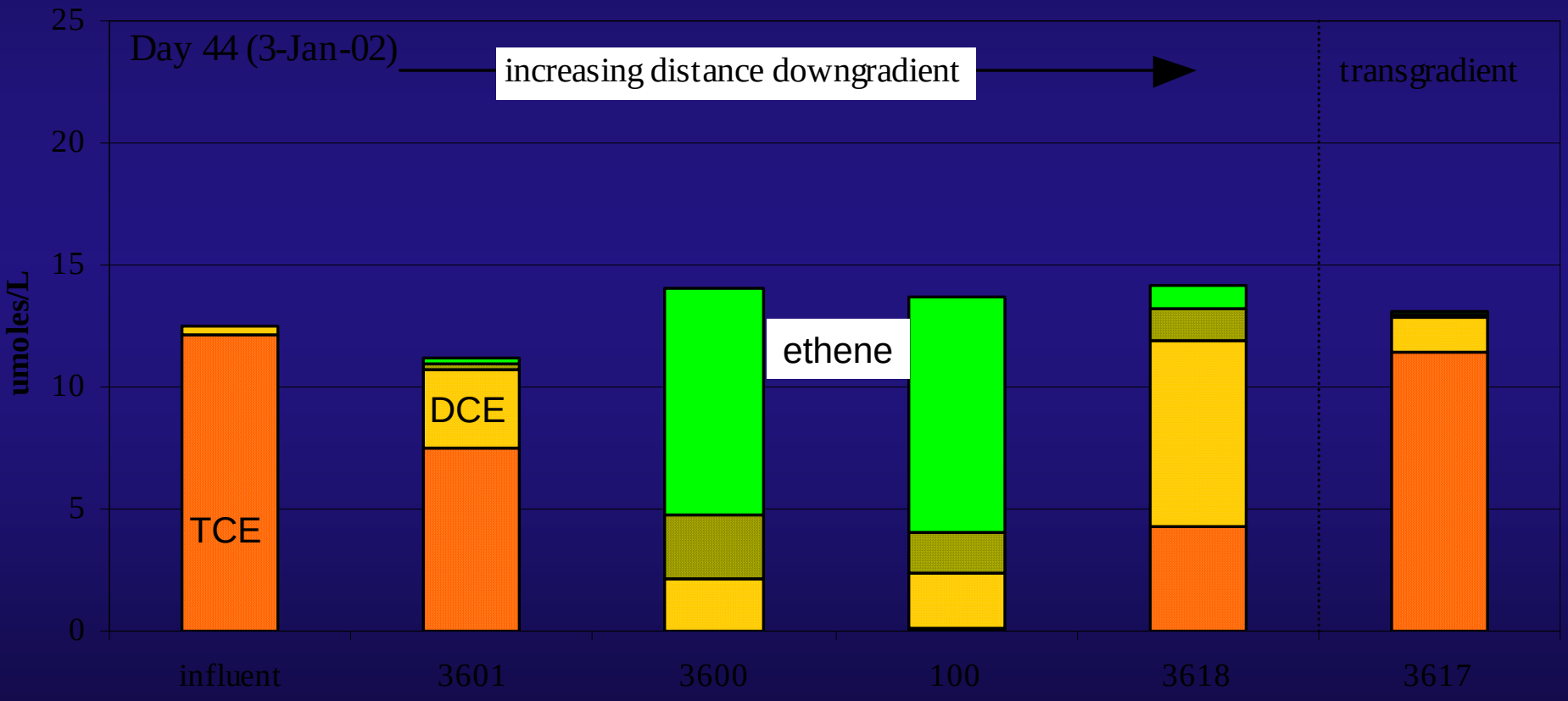
Case Study #3 Active Recirculation

Degradation of TCE (day 44)



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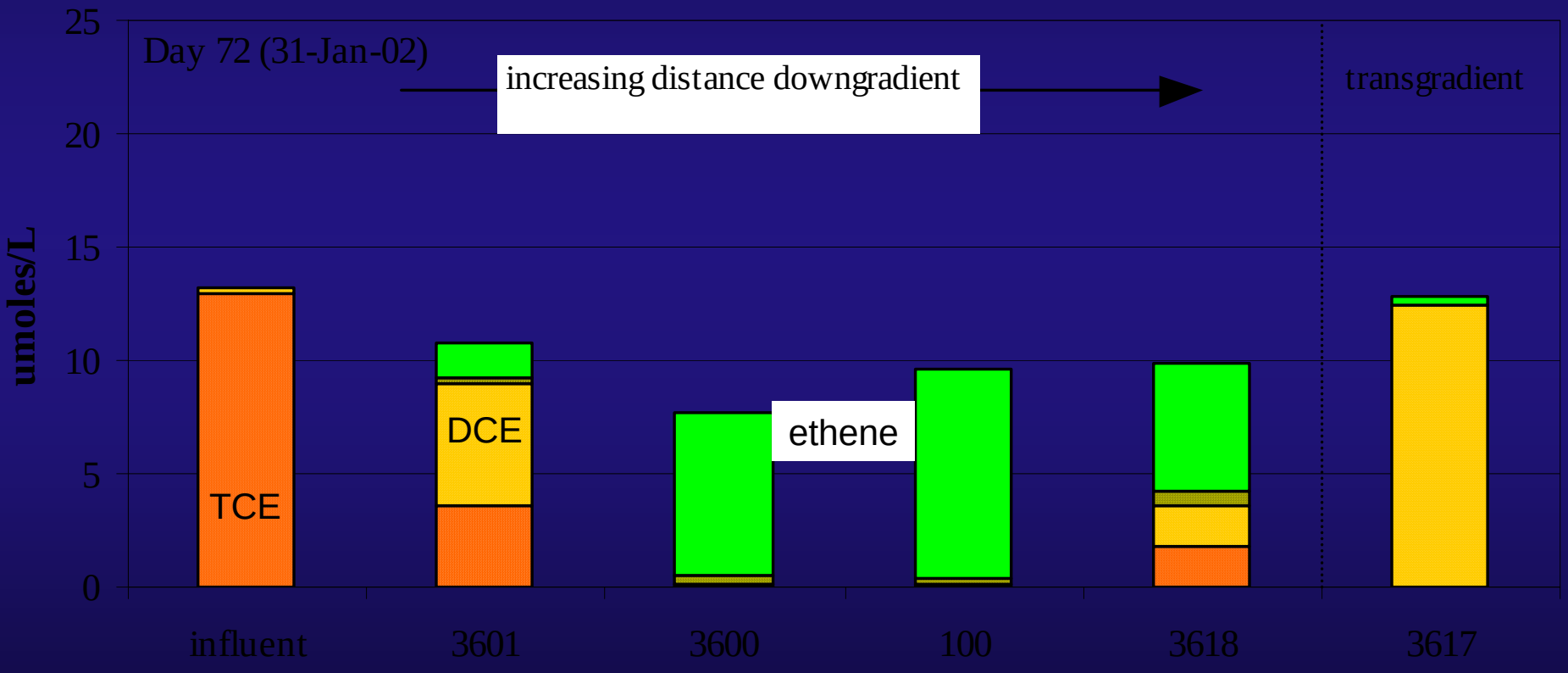
Case Study #3 Active Recirculation

Degradation of TCE (day 72)



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ESTCP Demo

Comparison of Active & Semi-Passive In Situ Bioremediation Approaches for Perchlorate-Impacted Groundwater

- Comparison of 2 *in situ* bio approaches:
  - Active Biobarrier
    - Site: Navy Industrial Reserve Ordnance Plant (NIROP) (ATK)
    - Location: Salt Lake City, Utah
  - Semi-Passive Biobarrier
    - Site: Longhorn Army Ammunition Plant (LHAAP)
    - Location: Karnack, Texas
- Development of a Guidance Manual / Protocol

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Conclusions

- Variety of approaches for addition of amendments to GW to create flow through treatment zones (PRBs)
- Best method for particular site based on depth, plume dimensions, water quality issues & other site characteristics
- Passive system often suitable for shallow GW
- Semi-passive or active for deeper GW & sites where control of amendments is critical

References

- Dybas et al., Development, Operation, and Long-Term Performance of a Full-Scale Biocurtain Utilizing Bioaugmentation. *Env. Sci. & Technol.* 2002.
- Devlin & Barker, Field investigation of nutrient pulse mixing in an in situ biostimulation experiment, *Water Resources Research*, Vol. 32, No. 9, pp. 2869-2877, 1996.
- Cox et al., Successful Demonstration of Bioaugmentation to Remediate Trichloroethene in Groundwater, *Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds*, May 2002.