DESIGN AND PERFORMANCE OF A BIOBARRIER FOR PERCHLORATE TREATMENT

Symposium on Bioremediation and Sustainable Environmental Technologies

April 18, 2019

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Setting and Background

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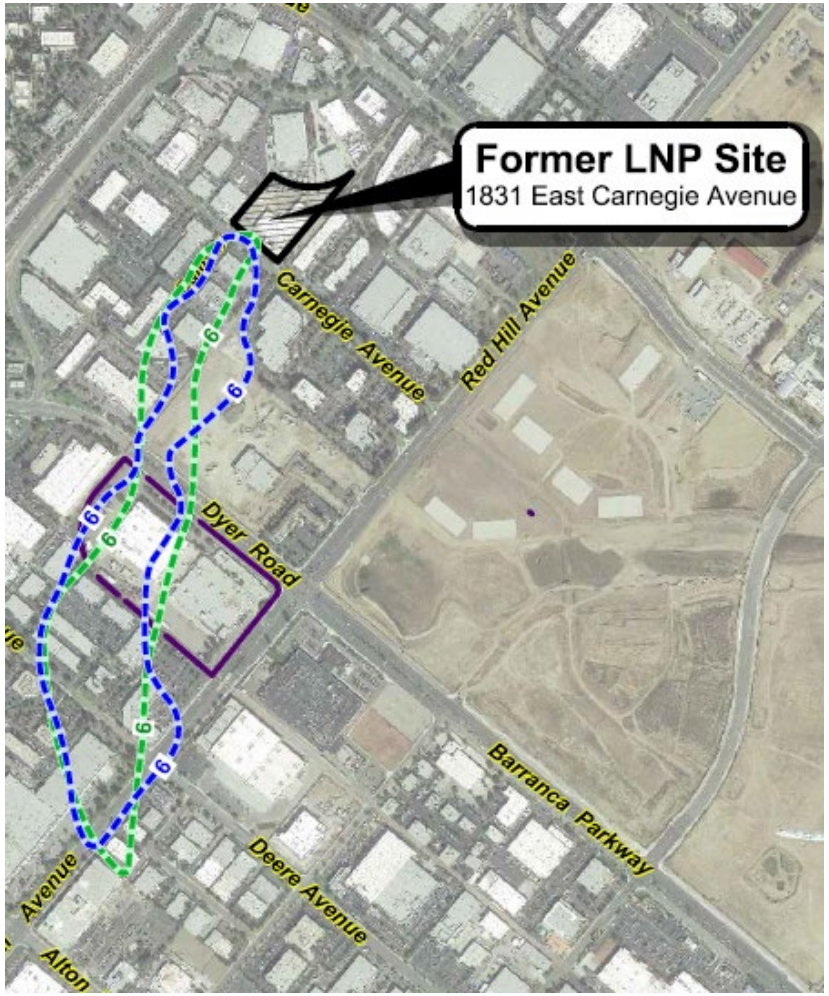

Overseen by Santa Ana Regional Water Quality Control Board (RWQCB)

On Site:

- Perchloric acid used 1973-1992
- Perchlorate in soil and groundwater (GW)
- GW hydraulically controlled since 2003
- GW extraction and treatment ongoing

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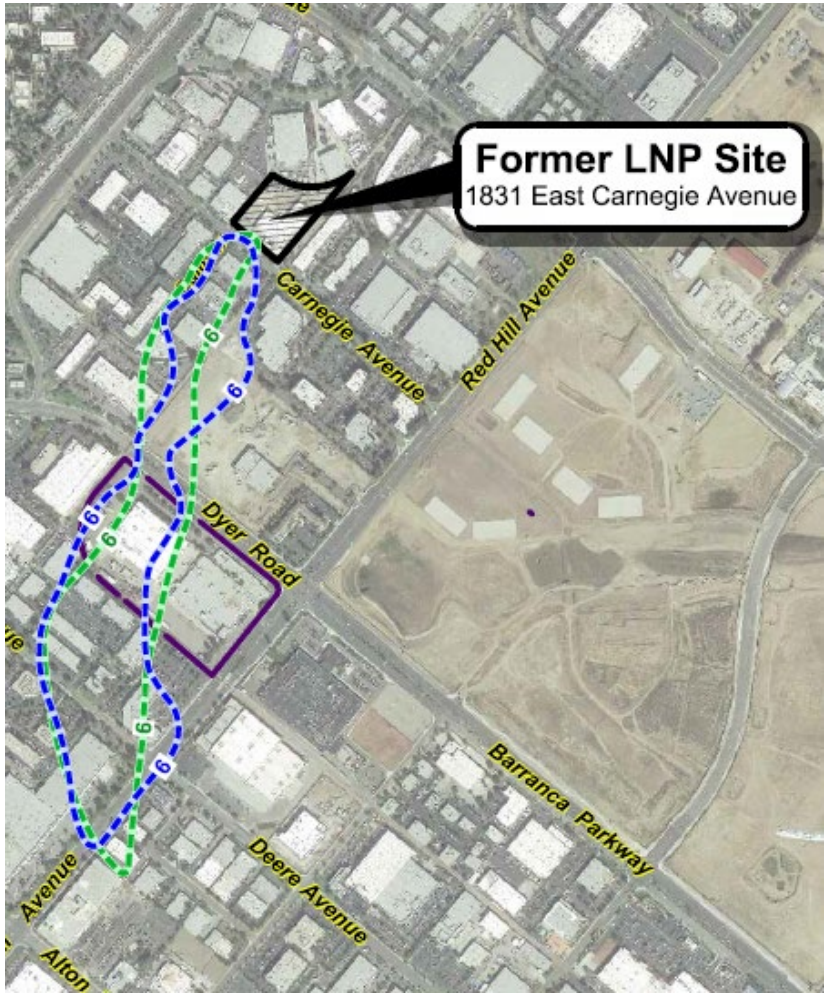
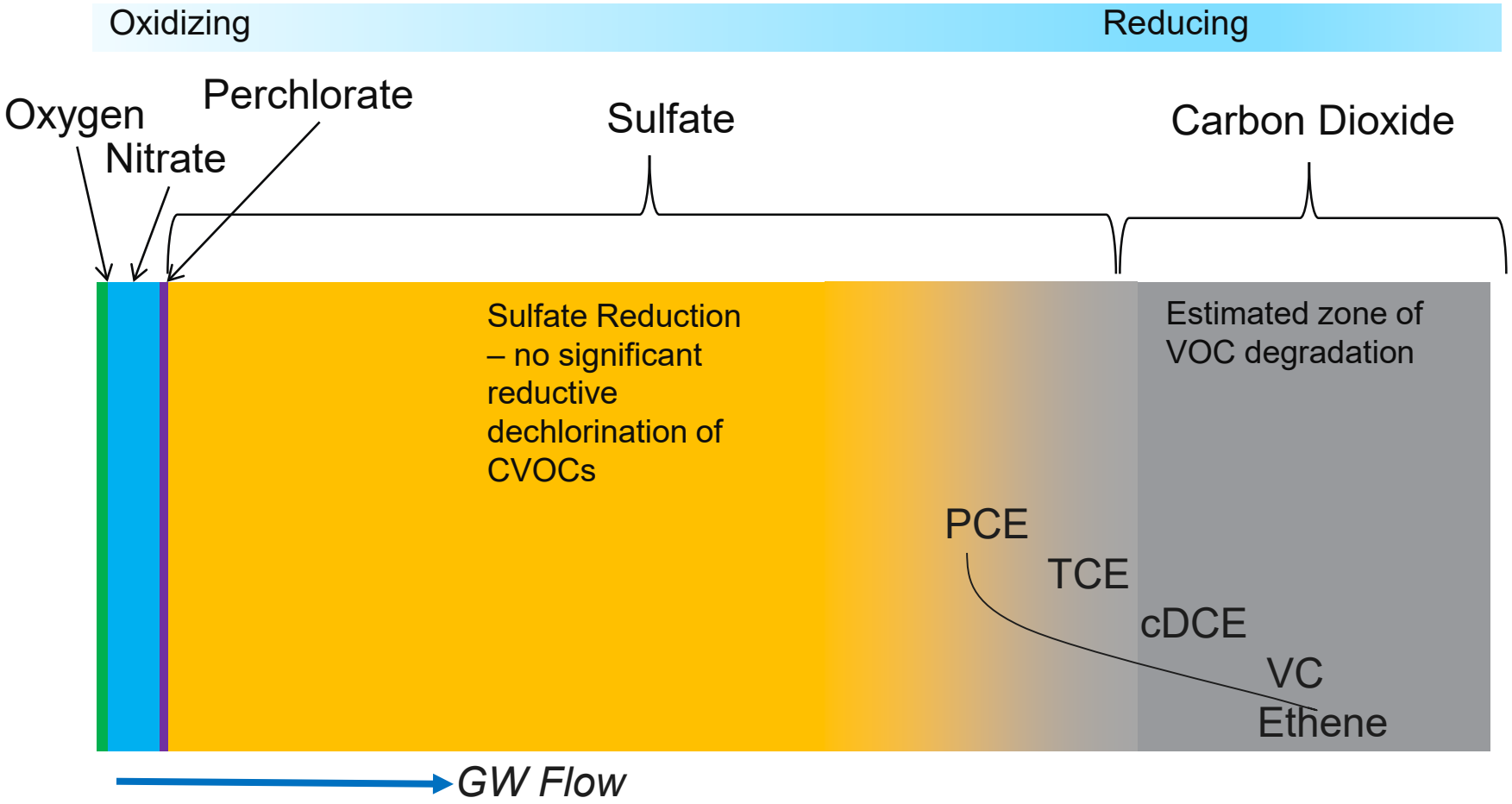


Off Site:

- ~4000’ long plume of perchlorate-impacted GW
- Average GW velocity ~0.45 feet / day
- Perchlorate occurs in 1st and 2nd water bearing zones (WBZs), to a depth of ~60’ bgs – focus today on 1st WBZ or “A zone” from ~15’ to 30’ bgs
- Geology: primarily fine-grained material with irregularly occurring, laterally discontinuous silt and sand interbeds
- GW high in TDS: sulfate ranges 1000-6000 mg/L
- Bioremediation identified as preferred remedy and approved by RWQCB
- Emulsified vegetable oil (EVO) is the amendment for bioremediation

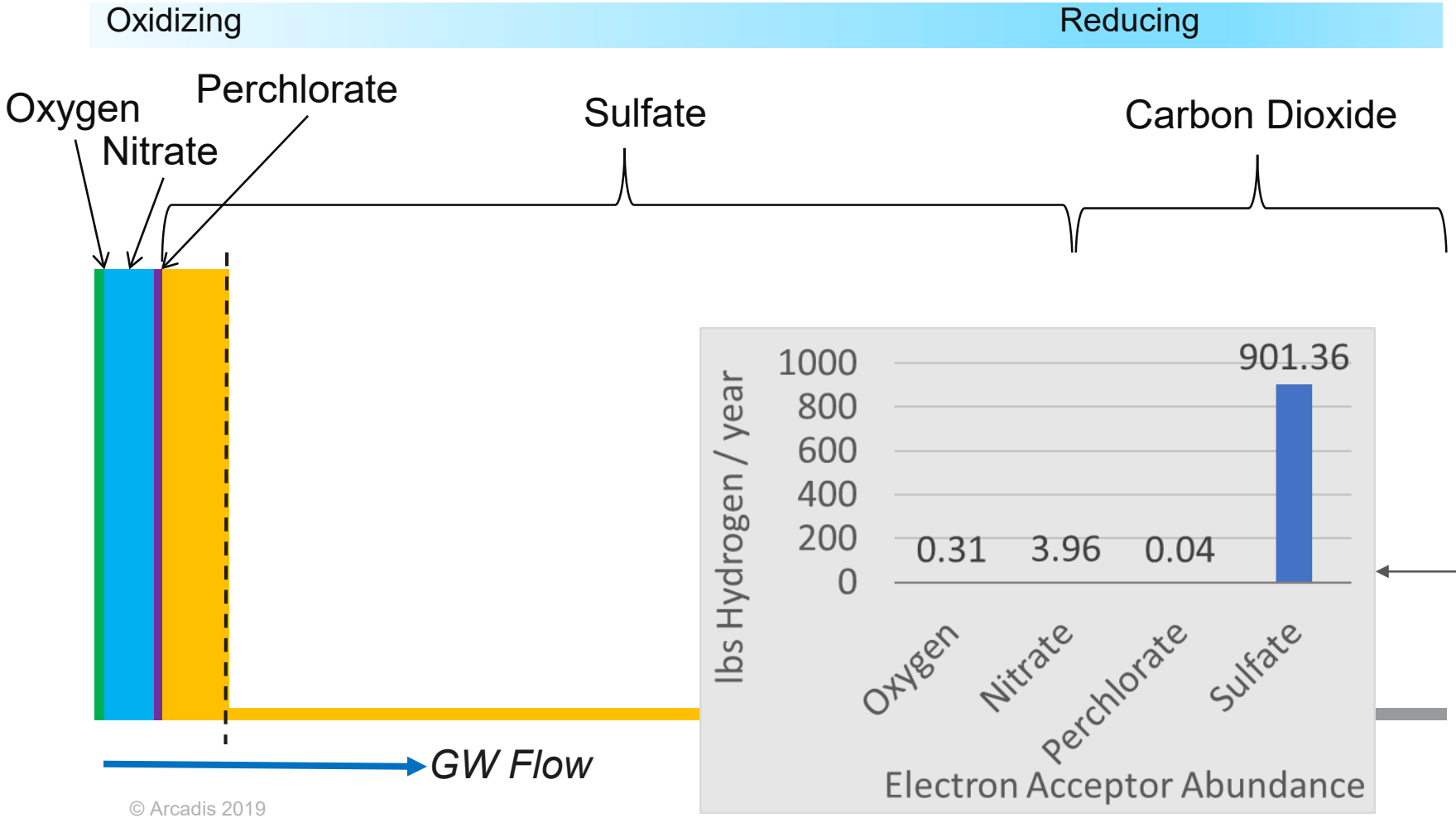
Theory and Design

CVOC-Biobarrier in High Sulfate Environment



- Reactive zone ~100+ days residence
- Need to “get through” all the sulfate
- Frequently use permanent wells to deliver amendment
- Nutrient and microbe addition often employed

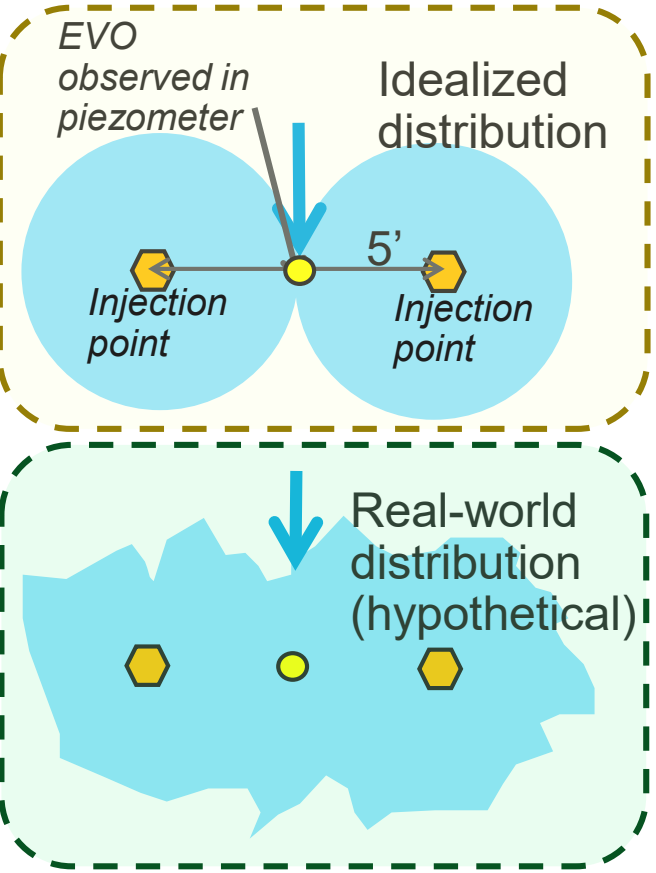
Perchlorate Biobarrier



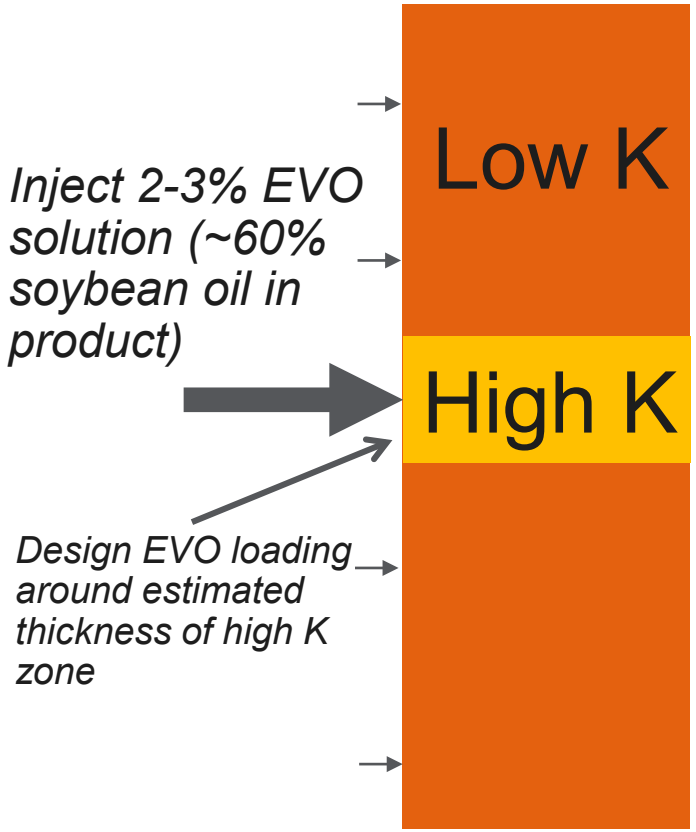
- Reactive zone ~2-4 days
- Need to “get through” nitrate but sulfate reduction is not necessary
- “Small” reactive zone is most efficient
- Limited microbial growth preferable to limit influence of abundant sulfate

Design Concepts

1-Small Reactive Zone



2-Design primarily for high K zones



3-Keep the conditions nutritionally sparse

Amend with carbon only – no additional nutrients – to minimize growth of sulfate reducing bacteria

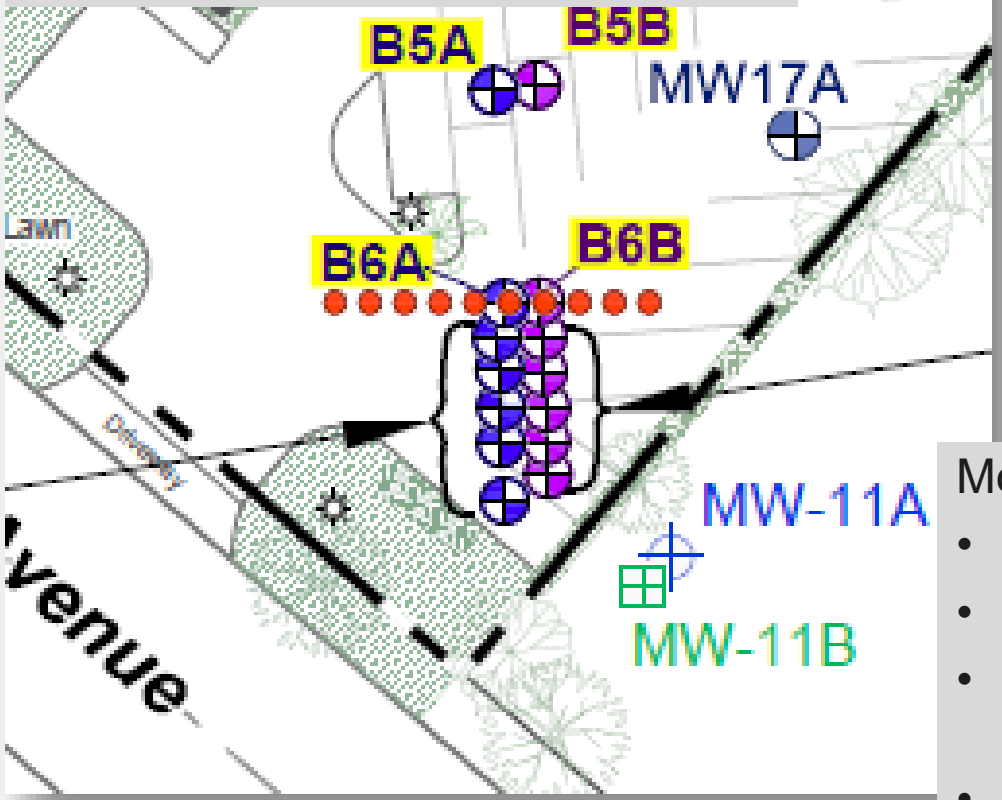
Don't allow "undesirable" bacteria to dominate

$$\frac{dC}{dt} = V = XkC$$

$$\frac{dC}{dt} = V = X\frac{V_{max}C}{K_{\frac{1}{2}} + C}$$

Pilot and Full Scale Biobarrier

Pilot Barrier: 10 direct push points covering 1st and 2nd water bearing zones to prove concept

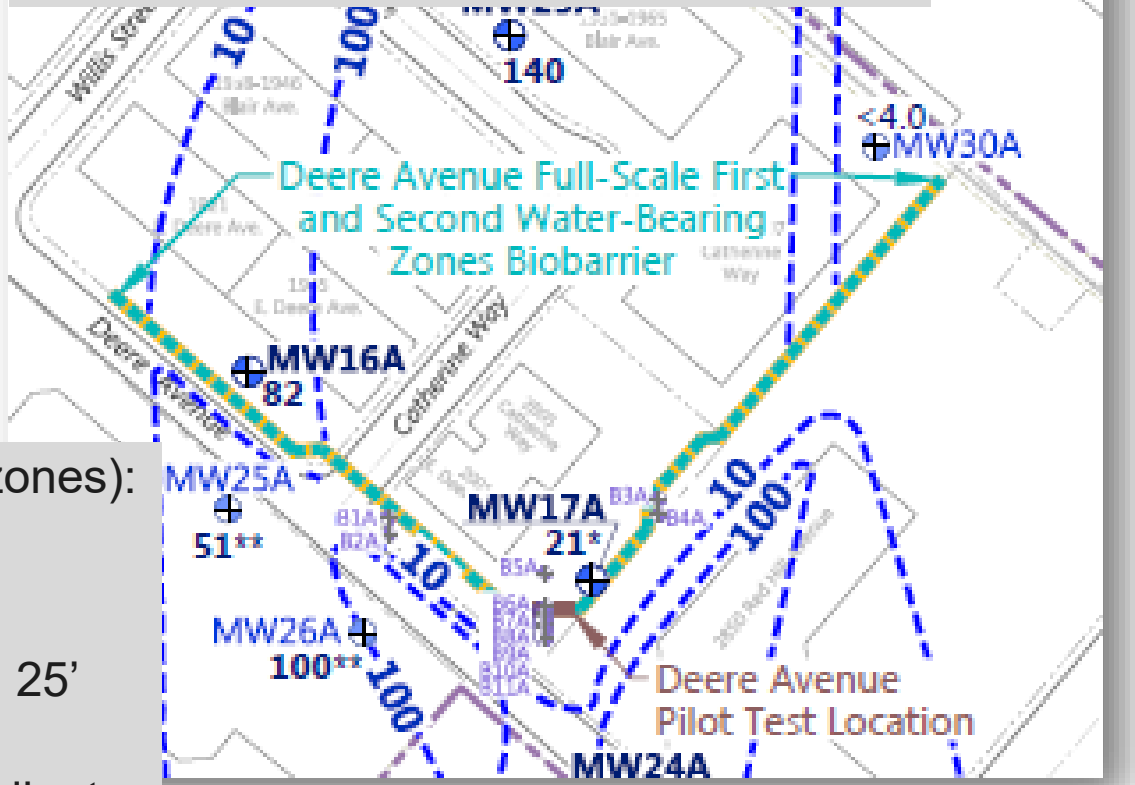


General GW Flow Direction

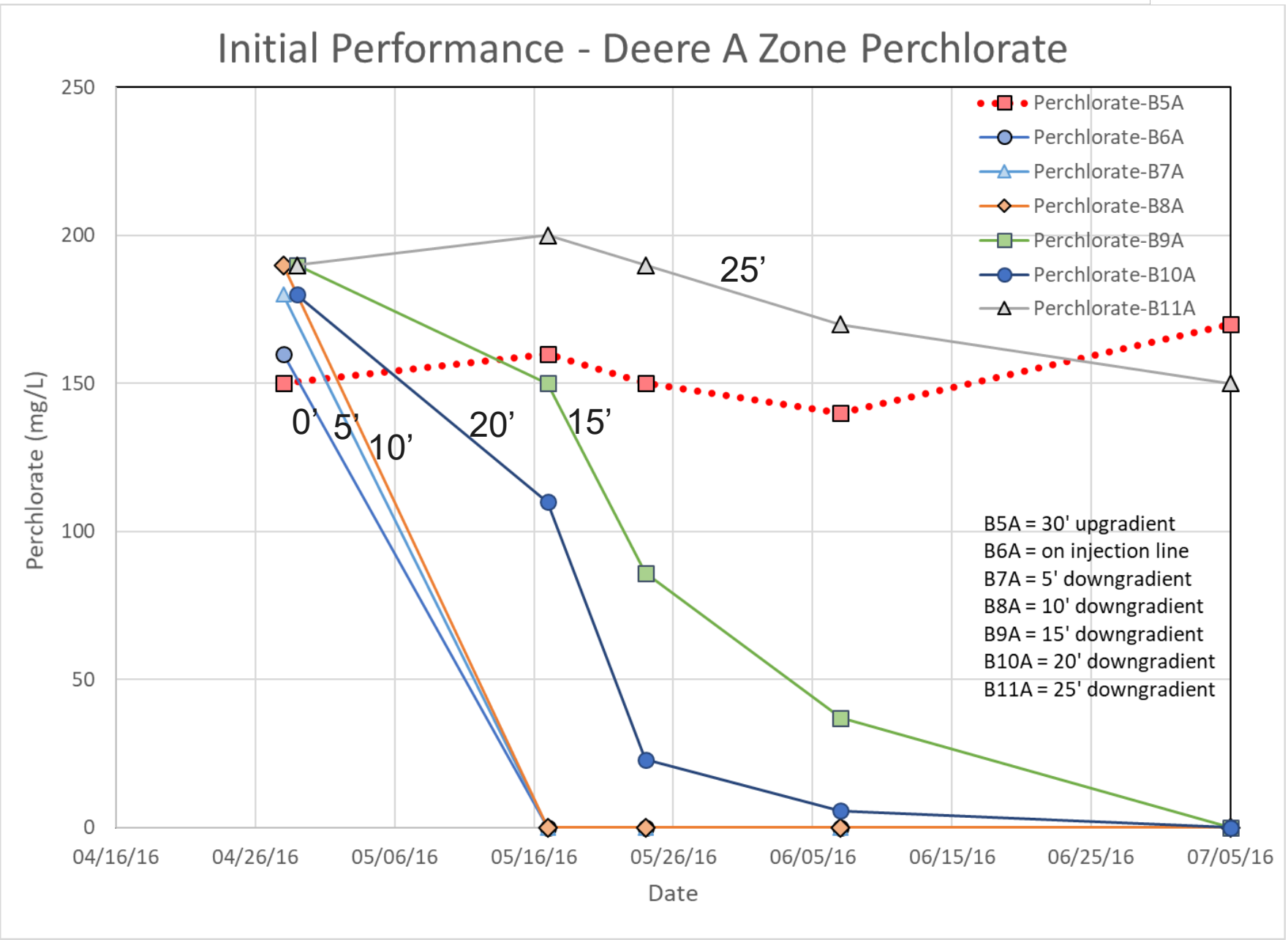
Monitoring (both zones):

- Upgradient
- In-barrier
- 5', 10', 15', 20', 25' downgradient
- Distal downgradient

Full Scale Biobarrier: 214 direct push points covering 1st and 2nd water bearing zones to control full width of plume



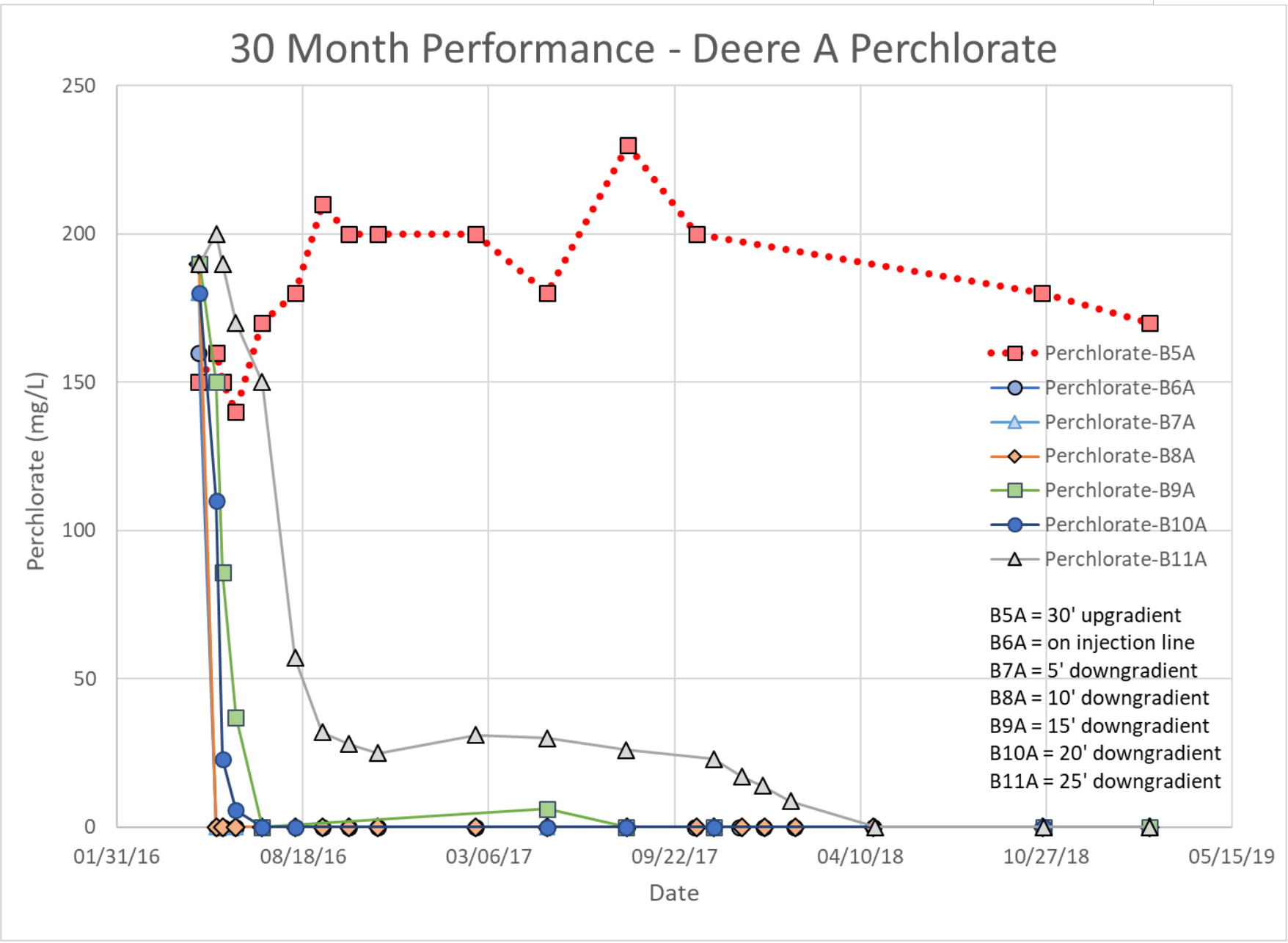
Biobarrier Performance



Rapid onset of perchlorate reduction

Perchlorate-free GW observed downgradient

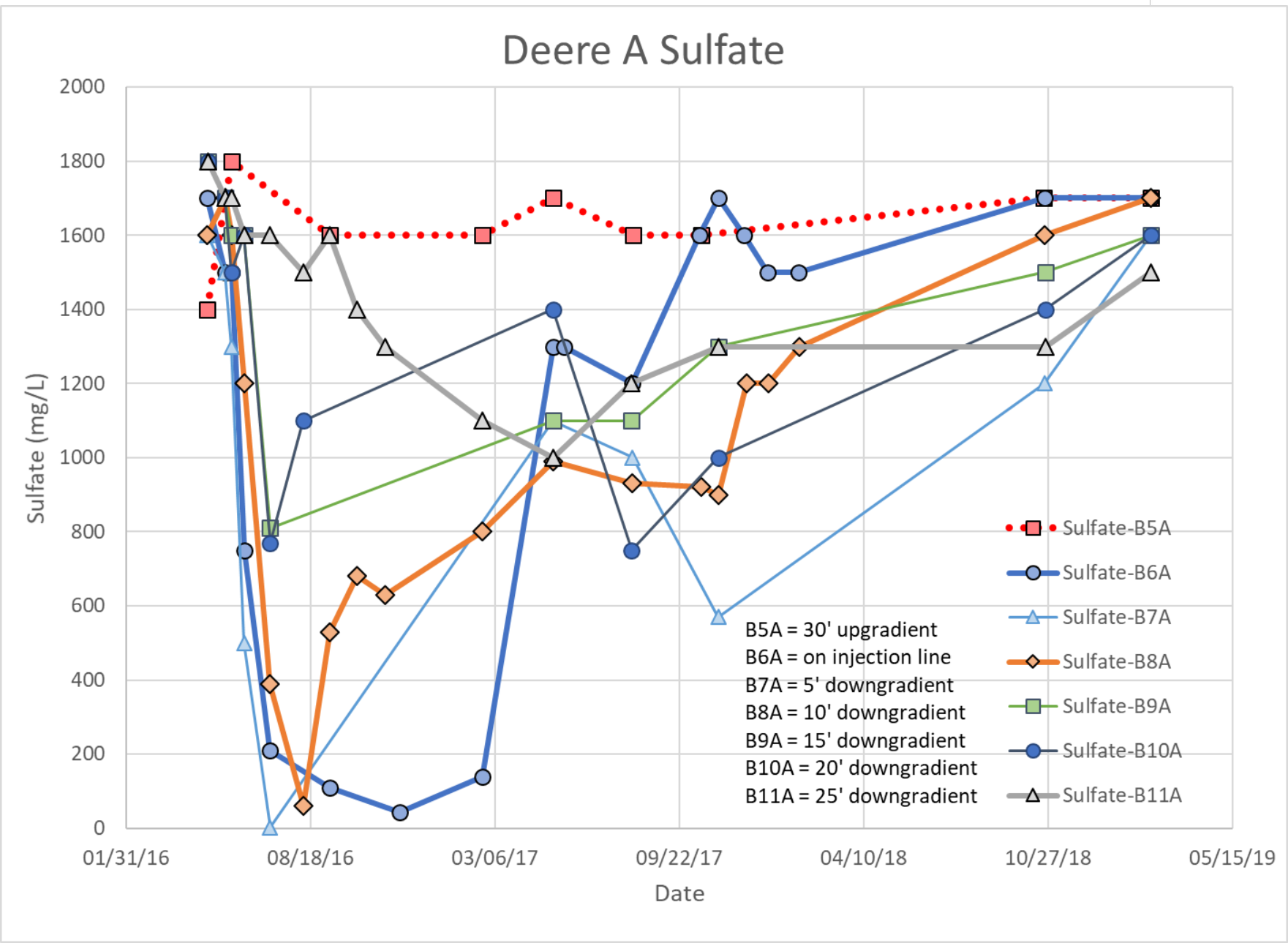
Progress of observed perchlorate concentration reduction further downgradient over time



Sustained perchlorate destruction over 30 months

Perchlorate below detection (ND) at all 1st WBZ wells

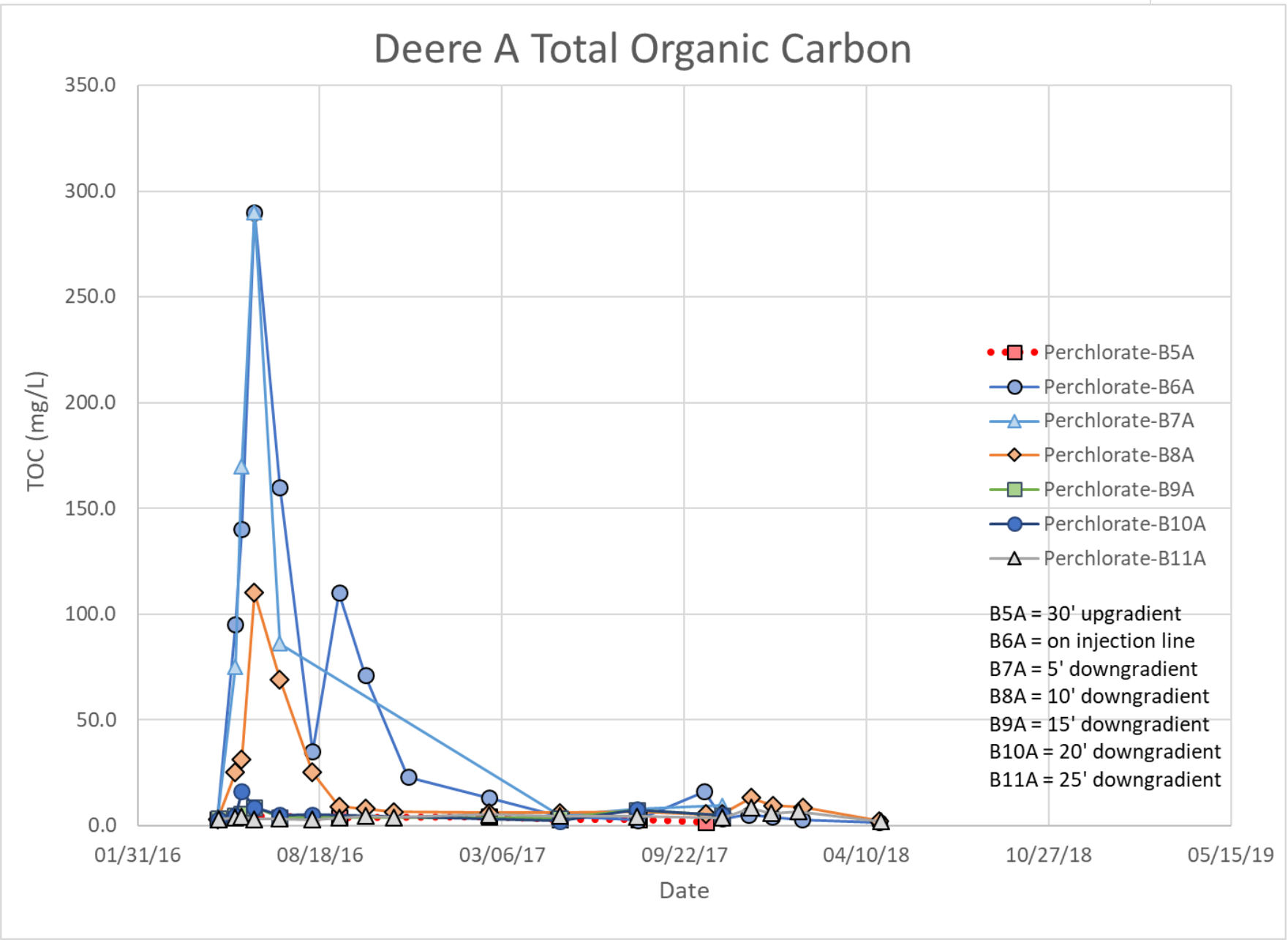
Nitrate was almost always ND except in the baseline event (data not shown)



Initially much of sulfate consumed

Over 30 months sulfate returns to baseline or near baseline conditions

Even a “thin” barrier constructed using 5’ centers and a modest EVO dose reduced sulfate

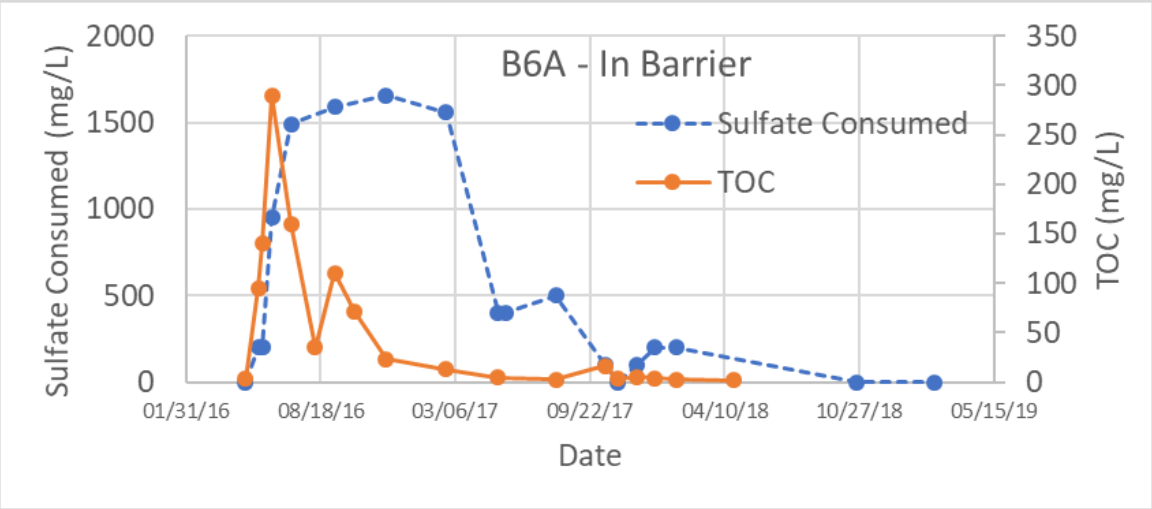


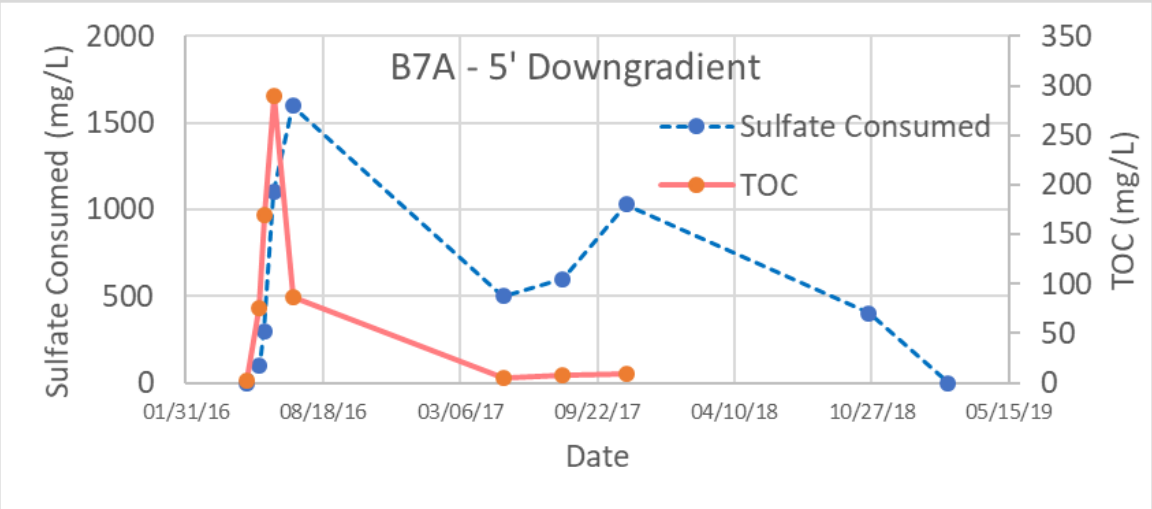
Initial soluble TOC increase observed in wells nearest the injection

Minimal dissolved TOC detected for majority of 30 month performance period

Biobarrier Longevity

TOC and Sulfate Consumption



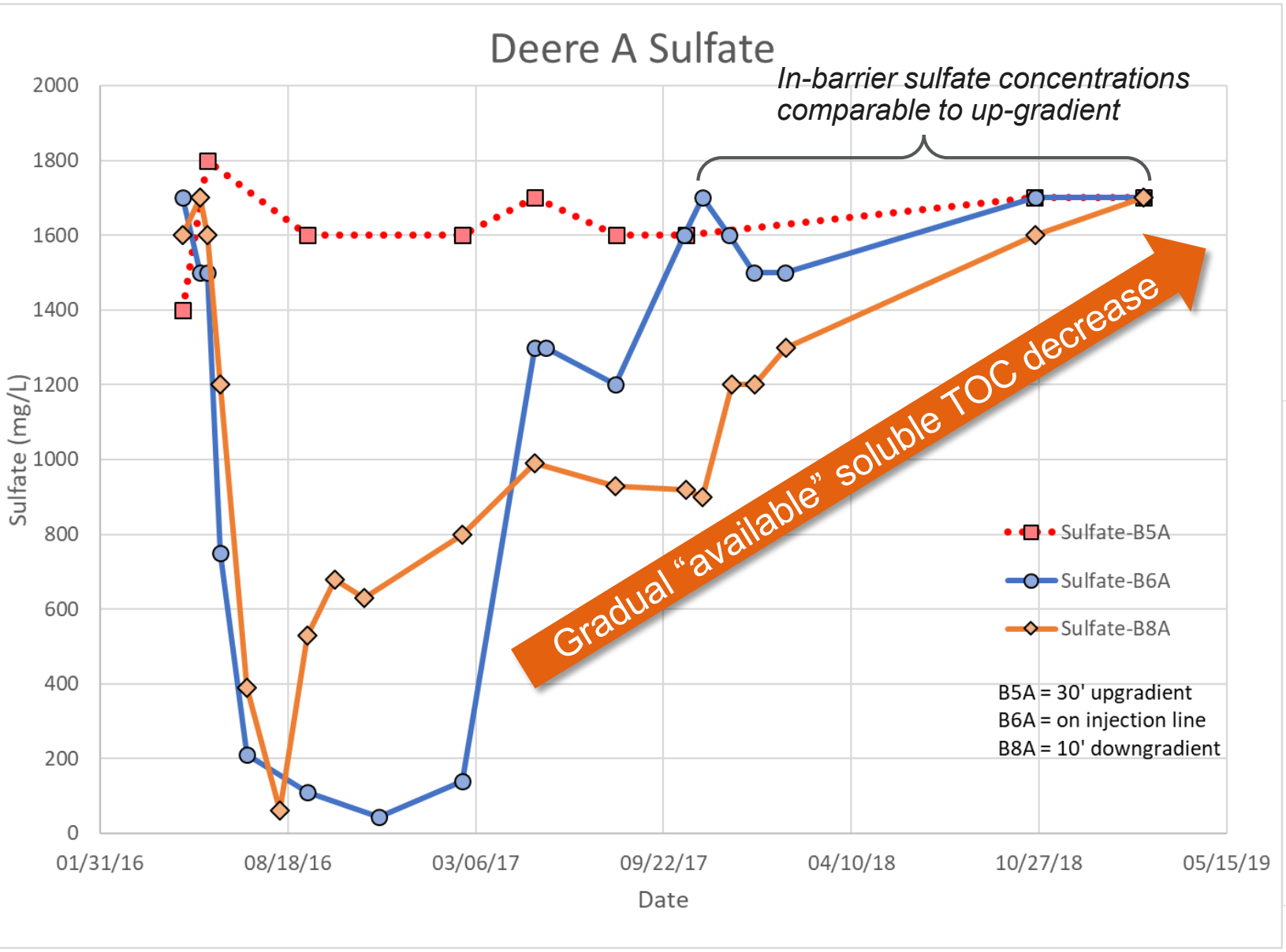


In-barrier perchlorate was ND in all but baseline samples

Perchlorate, nitrate, and sulfate consumption outlasted measurable elevated TOC even in barrier

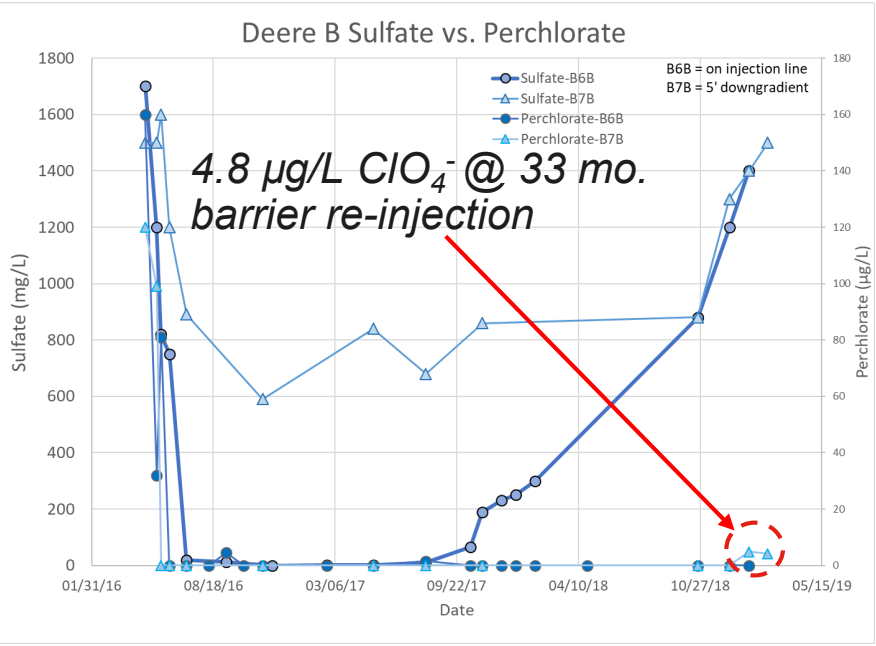
Soluble TOC was likely consumed as fast as it was produced, yielding no net TOC measured in wells during the majority of the performance period

Bulk water measurements do not reflect conditions within a biofilm – biological activity continues in biofilm on soil/sediment particles



Over time, decreased sulfate reduction is best indicator of available TOC and predictor of EVO longevity

Perchlorate reduction as an indicator is unlikely to give much warning before exceeding target performance concentration (<6 µg/L)



Conclusions

Perchlorate reduction can be reliably achieved in a “short”-residence time biobarrier

In high sulfate groundwater, biobarrier can reduce perchlorate without reducing all sulfate

The conditions, and therefore the design, for sustained perchlorate reduction have some key differences from a typical CVOC biobarrier

Soluble TOC concentration was not a reliable predictor of biobarrier performance

Sulfate was a good indicator of longevity of the perchlorate reducing biobarrier

Questions