Remediation of Perchlorate Impacted Vadose Zone Hydraulically Upgradient of an Industrial Site – A Regulatory Perspective

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Palm Springs, California

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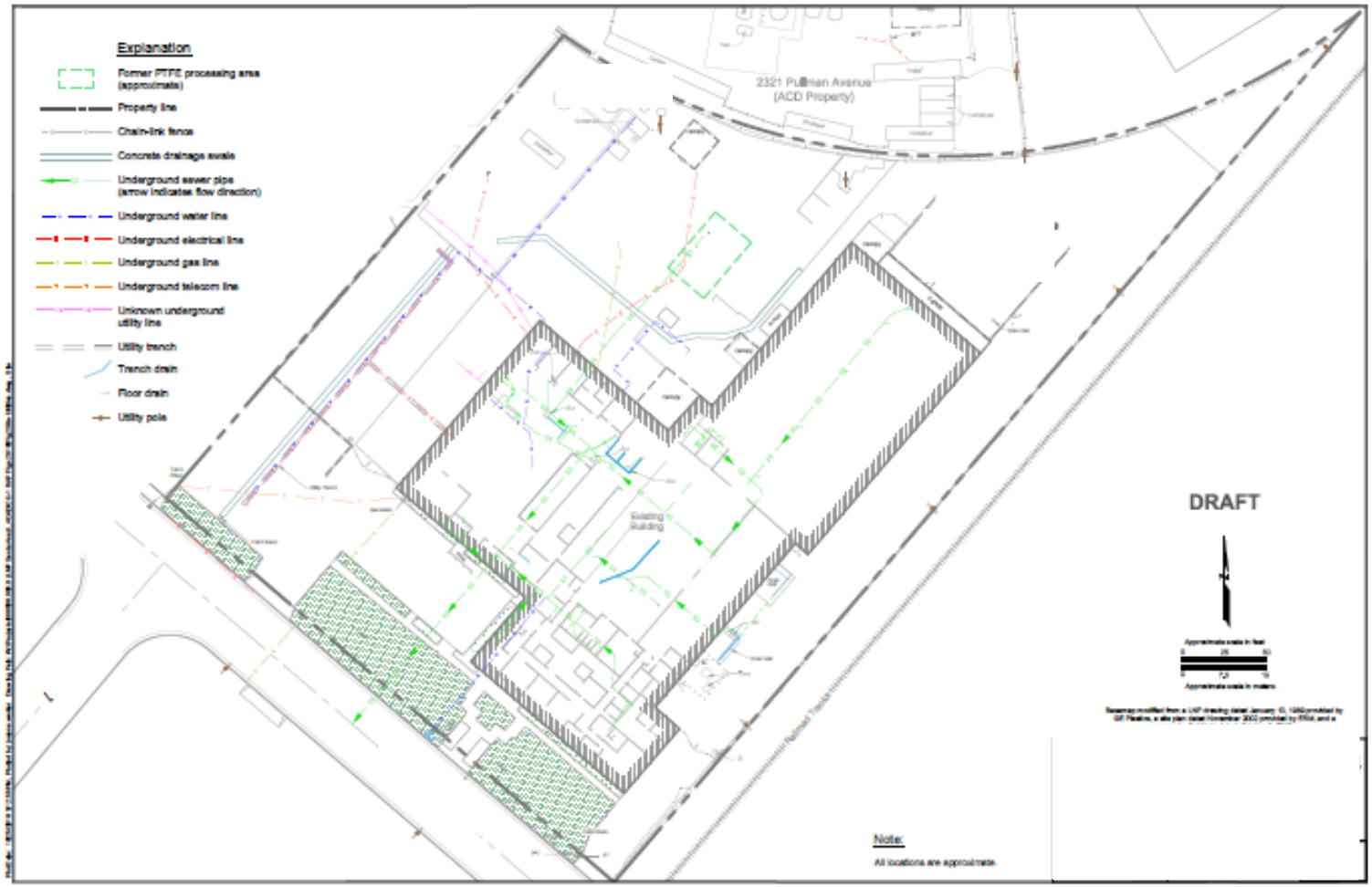
Presentation Outline

Understanding the problem and the regulatory questions:

- Have we developed a reasonable conceptual site model
  - Where is the source?
  - What was the mechanism of transport?
  - What is the extent of the impact?
- What are the risks and can the risks be managed by an interim action?
- What is the interim action objective?
- What is the selected remedy?
- Was the remedy successful and can the case be closed?

WHERE IS THE SOURCE?



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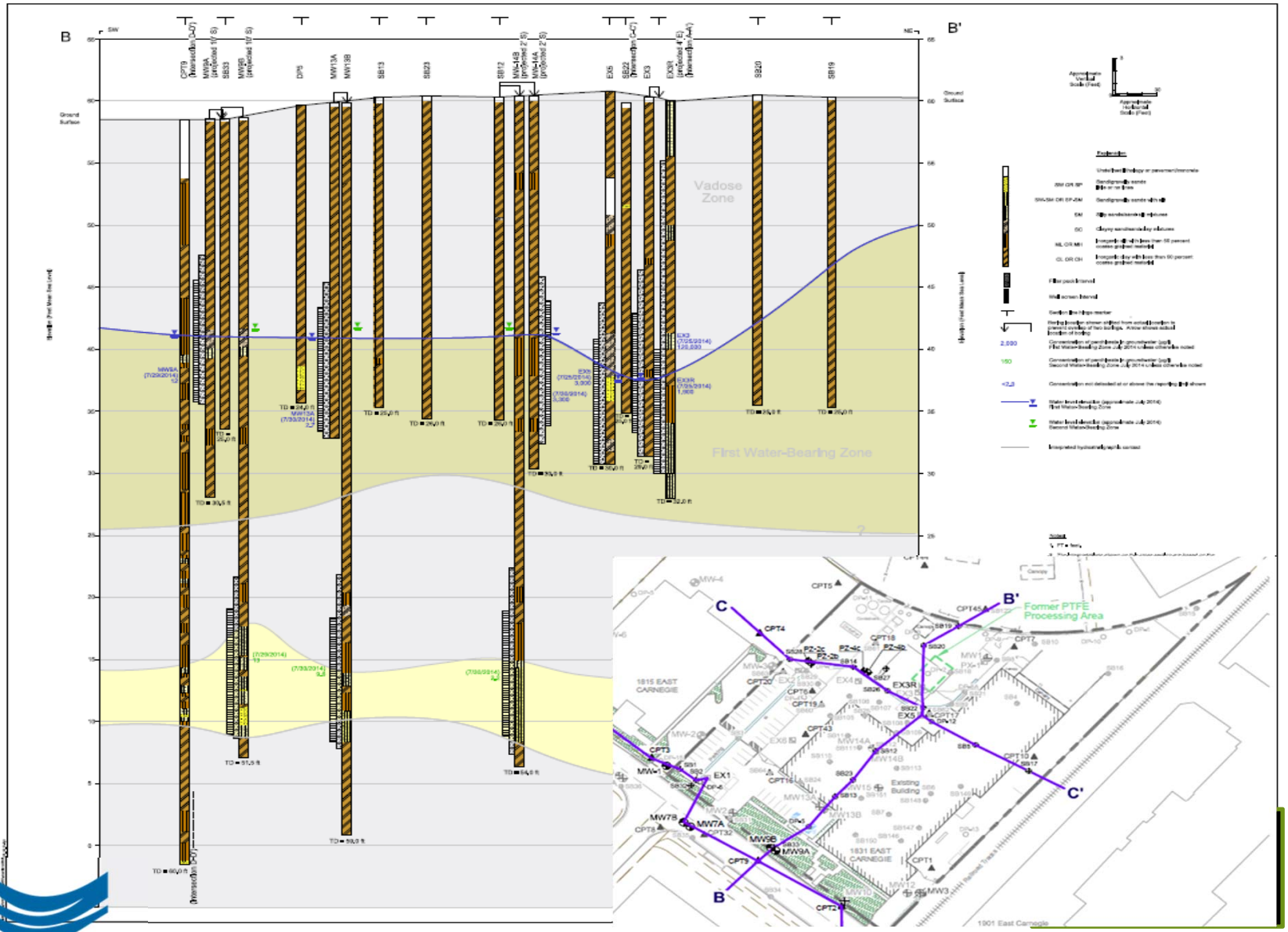
DEVELOPING CSM – GEOLOGY AND HYDROGEOLOGY

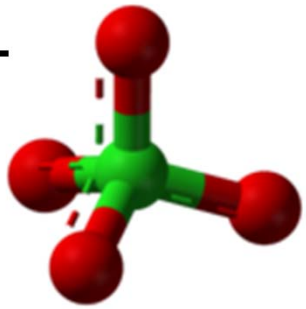


DEVELOPING CSM – GEOLOGY AND HYDROGEOLOGY

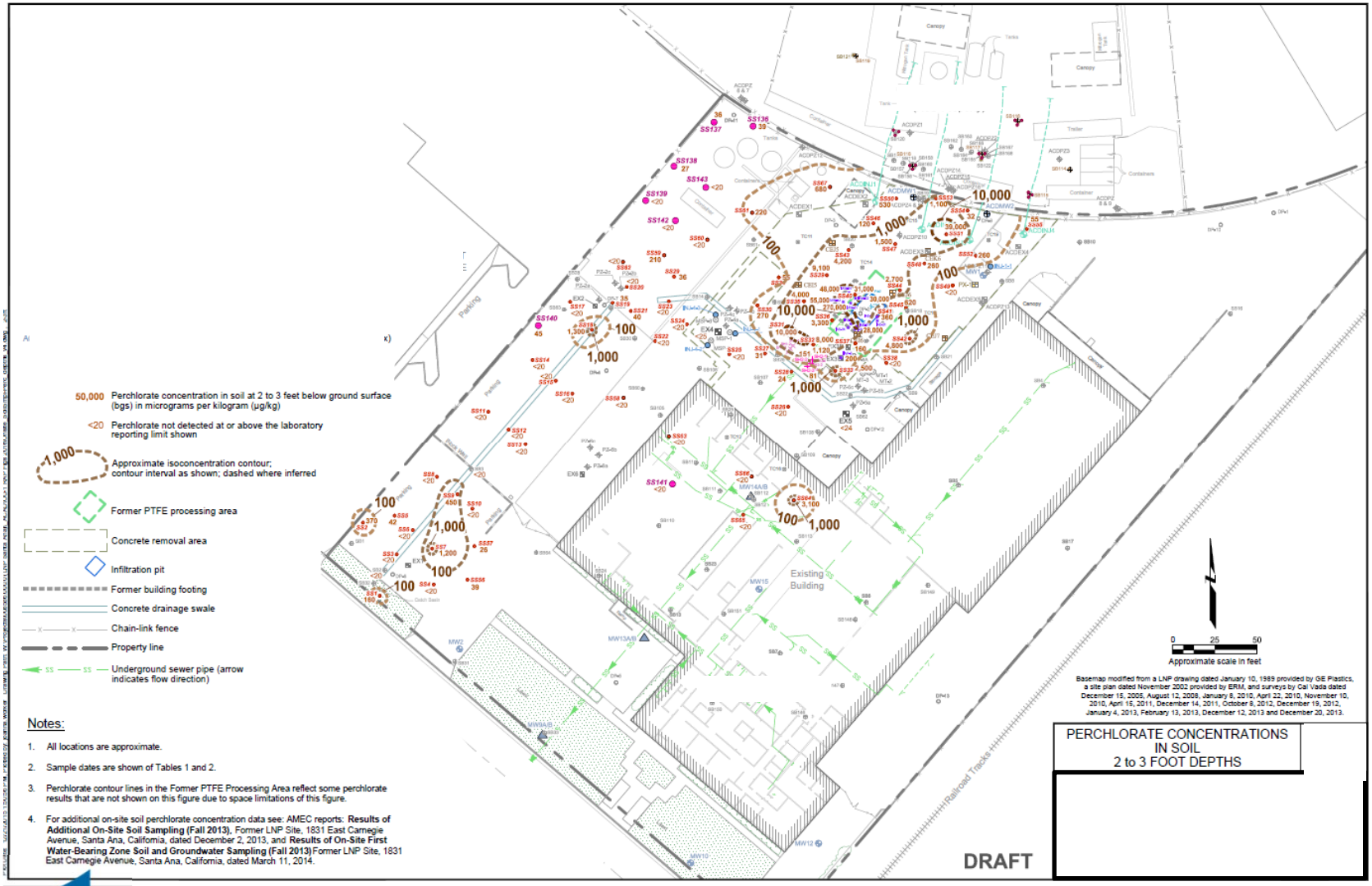
- Depth to the water: 15 to 20 feet bgs
- Direction of flow: southwest and south-southwest
- Two water-bearing zones to approximately 60 feet bgs
- The first water-bearing zone: from the water table to a depth of approximately 26 to 36 feet
- The second water-bearing zone: 40 and 58 feet bgs
- The first and second water-bearing zones separated by a sequence of predominantly low permeability clayey and silty sediments

DEVELOPING CSM – GEOLOGY AND HYDROGEOLOGY

- Low-permeability soil beneath the Site
- Vertical hydraulic conductivity <<< horizontal hydraulic conductivity → significant retardation of vertical groundwater flow
- Concentrations of perchlorate ~ 190,000 µg/kg in vadose zone near the source area
- Historic concentrations of perchlorate > 1,000,000 µg/L in groundwater samples from the first water-bearing zone



EXTENT OF THE IMPACT IN SOIL (2 to 3 feet)



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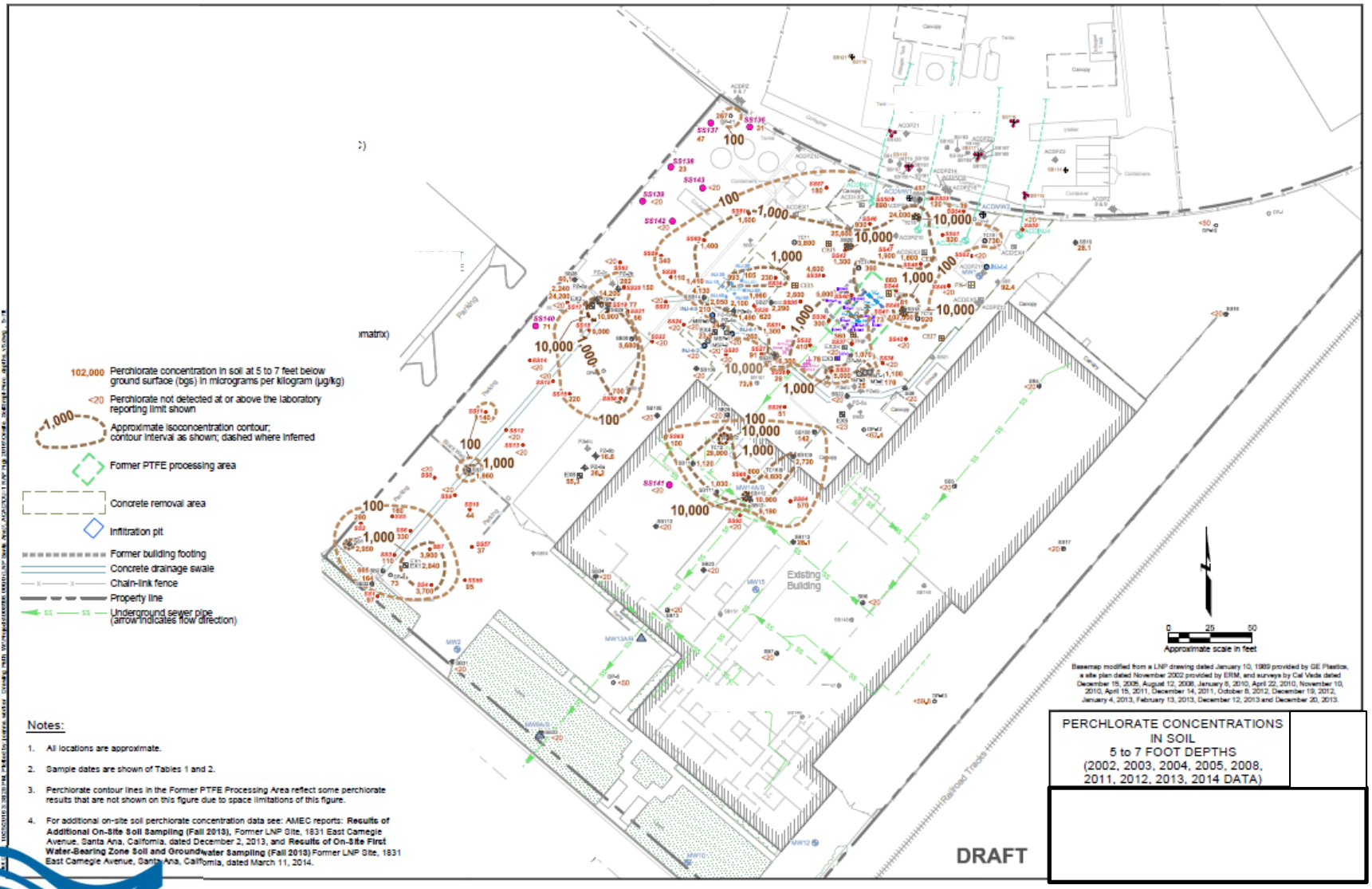
EXTENT OF THE IMPACT IN SOIL (5 to 7 feet)



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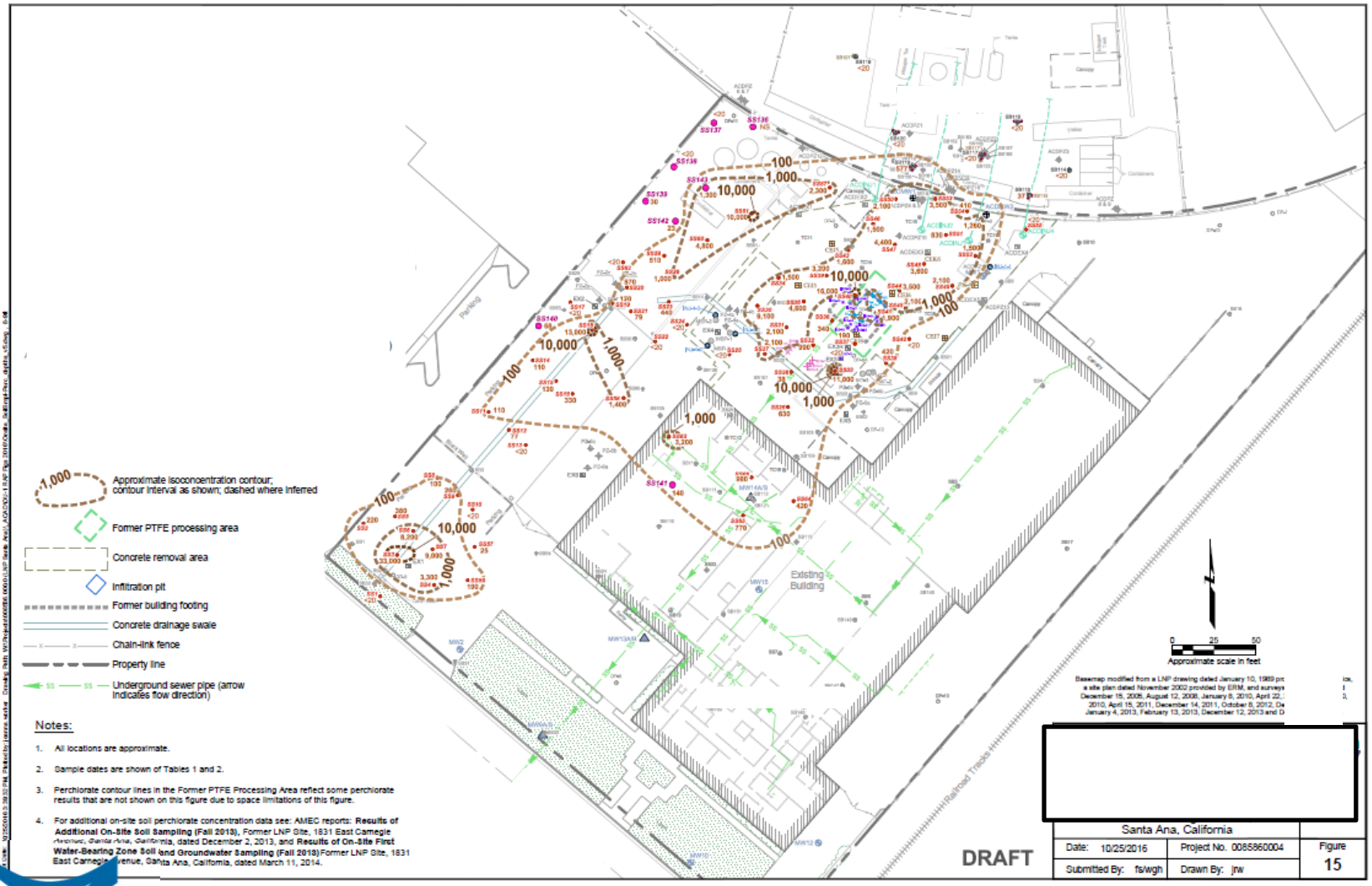
EXTENT OF THE IMPACT IN SOIL (8 to 9 feet)



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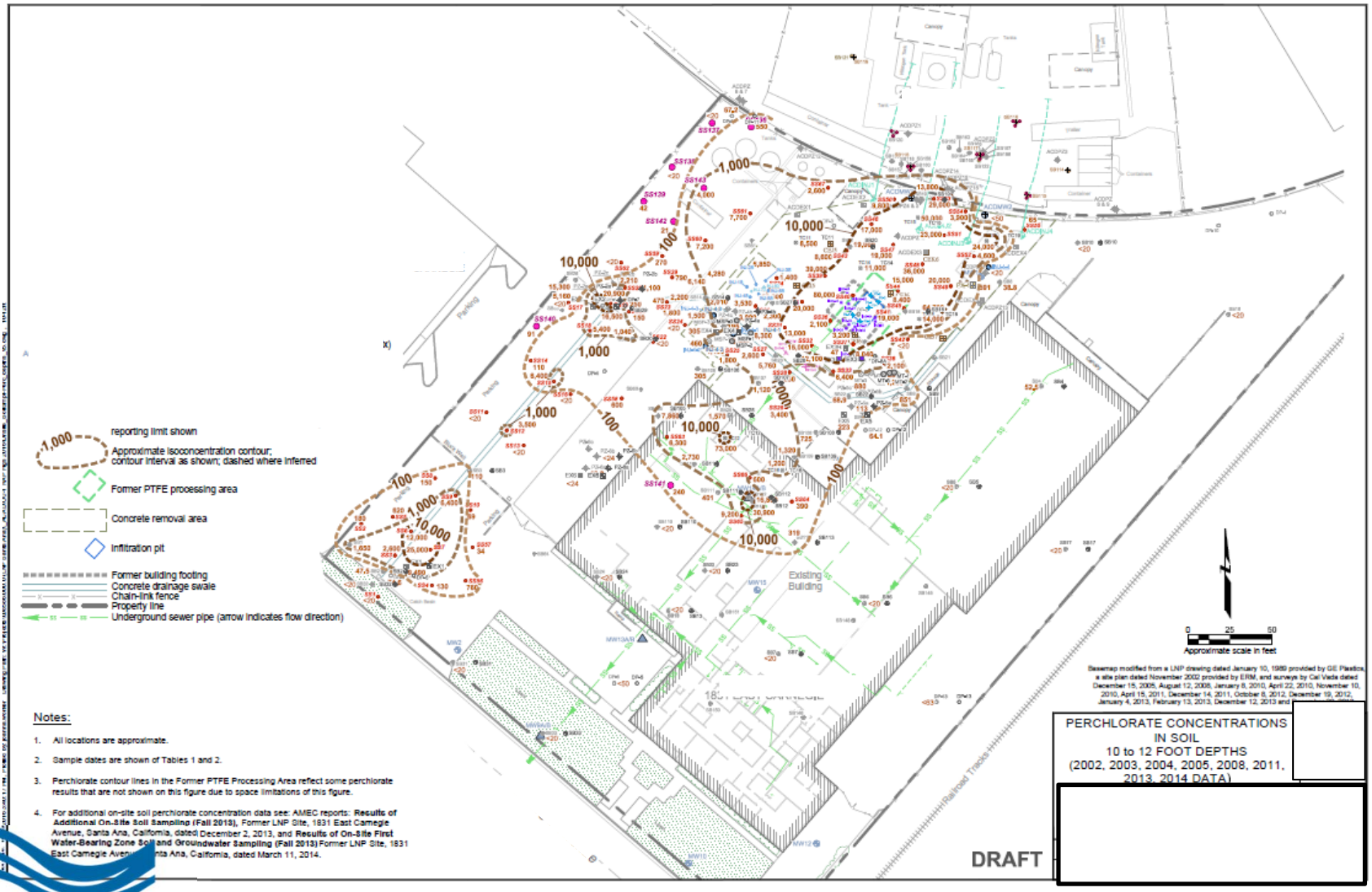
EXTENT OF THE IMPACT IN SOIL (10 to 12 feet)



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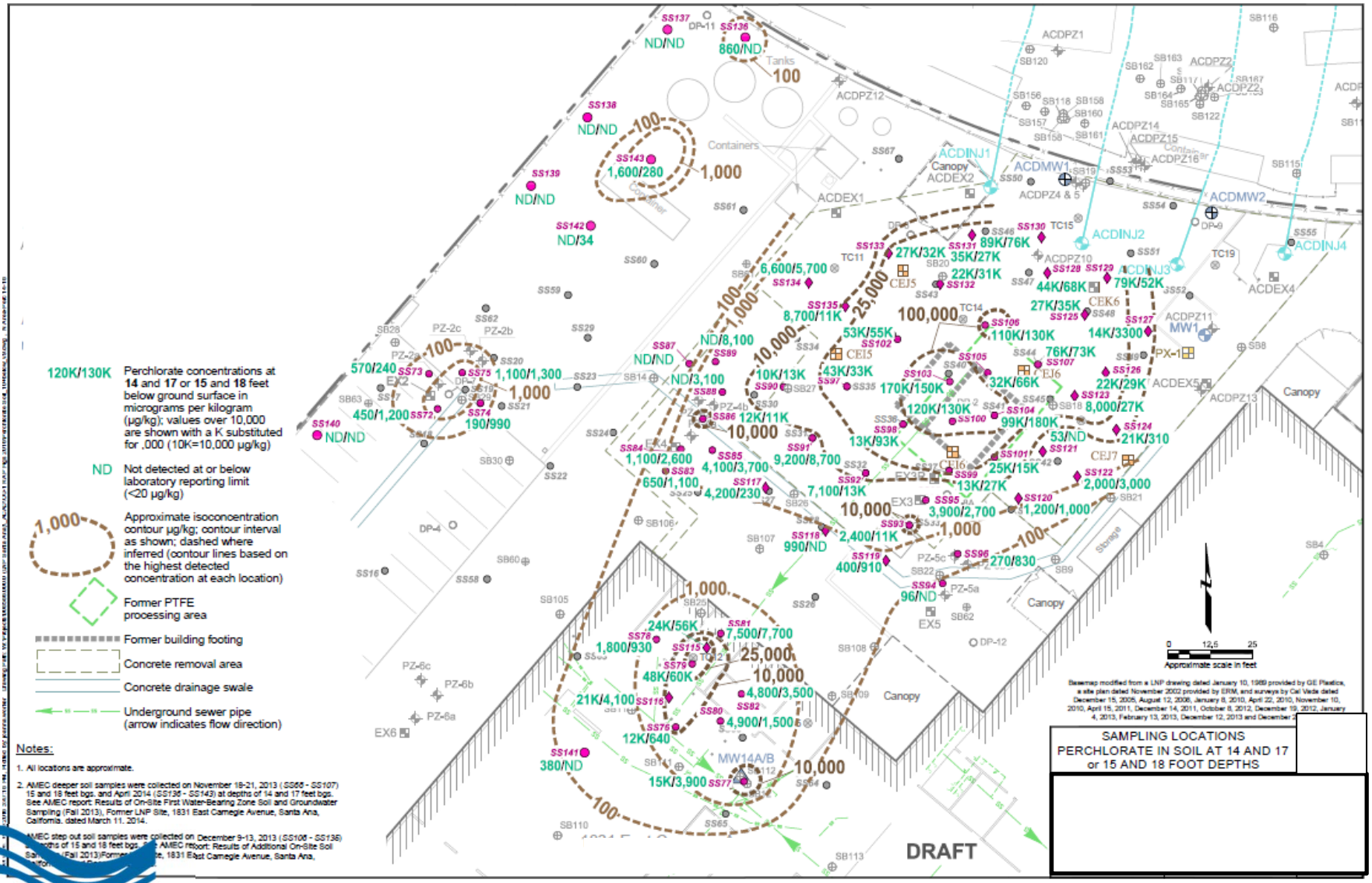
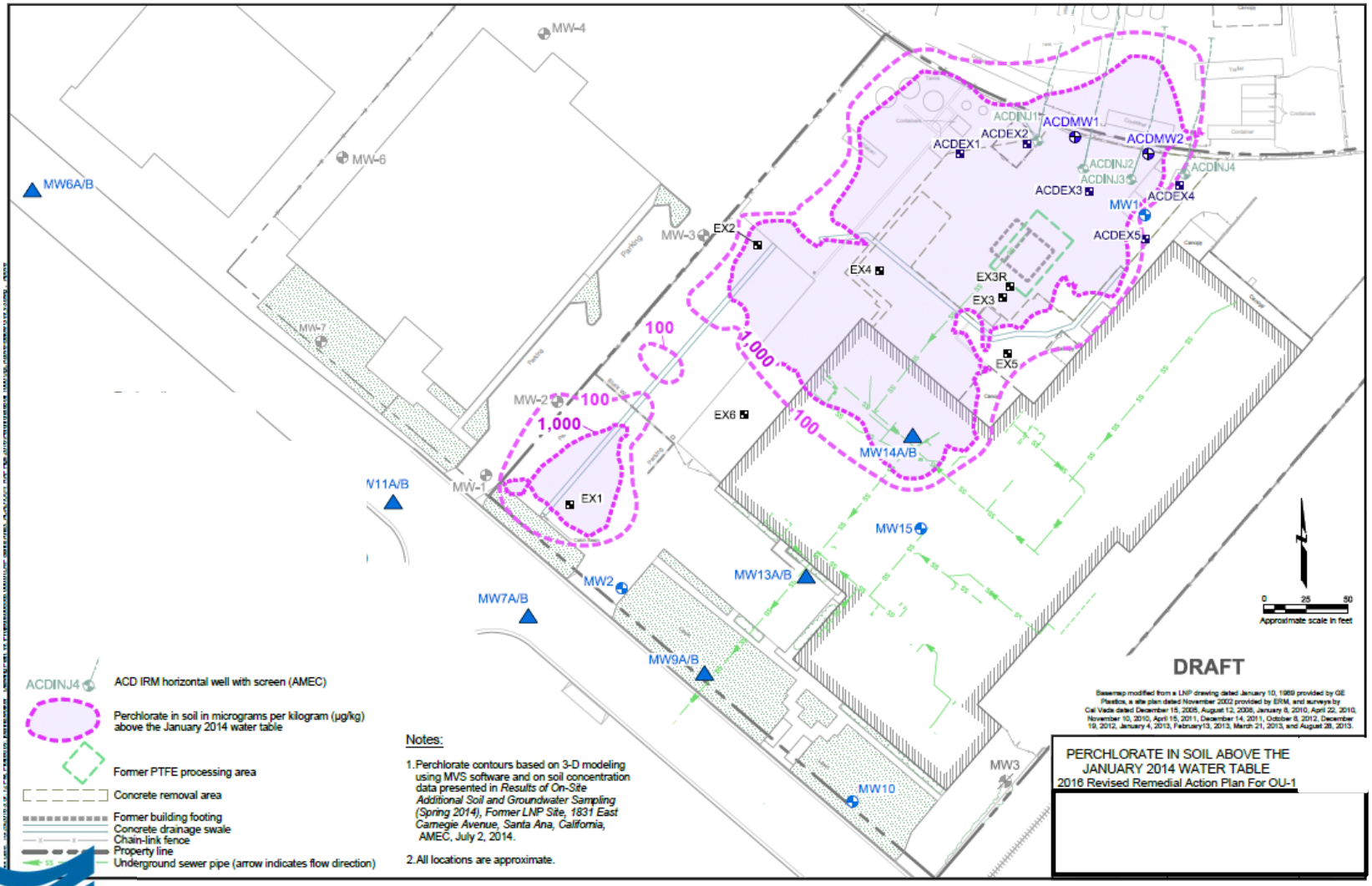
EXTENT OF THE IMPACT IN SOIL (14 to 17 feet)



OVERALL EXTENT OF THE IMPACT IN SOIL



WHAT IS THE MECHANISM OF TRANSPORT?

- Elevation of the upgradient property is 4 feet higher than the Site
- Migration of perchlorate within the vadose zone to the upgradient property through sandy layers within predominantly clayey deposits
- Perchlorate concentrations exceeding 6,100 µg/kg in soil samples collected from the upgradient property
- No perchlorate detected in groundwater samples collected beneath the upgradient property

WHAT ARE THE RISKS?

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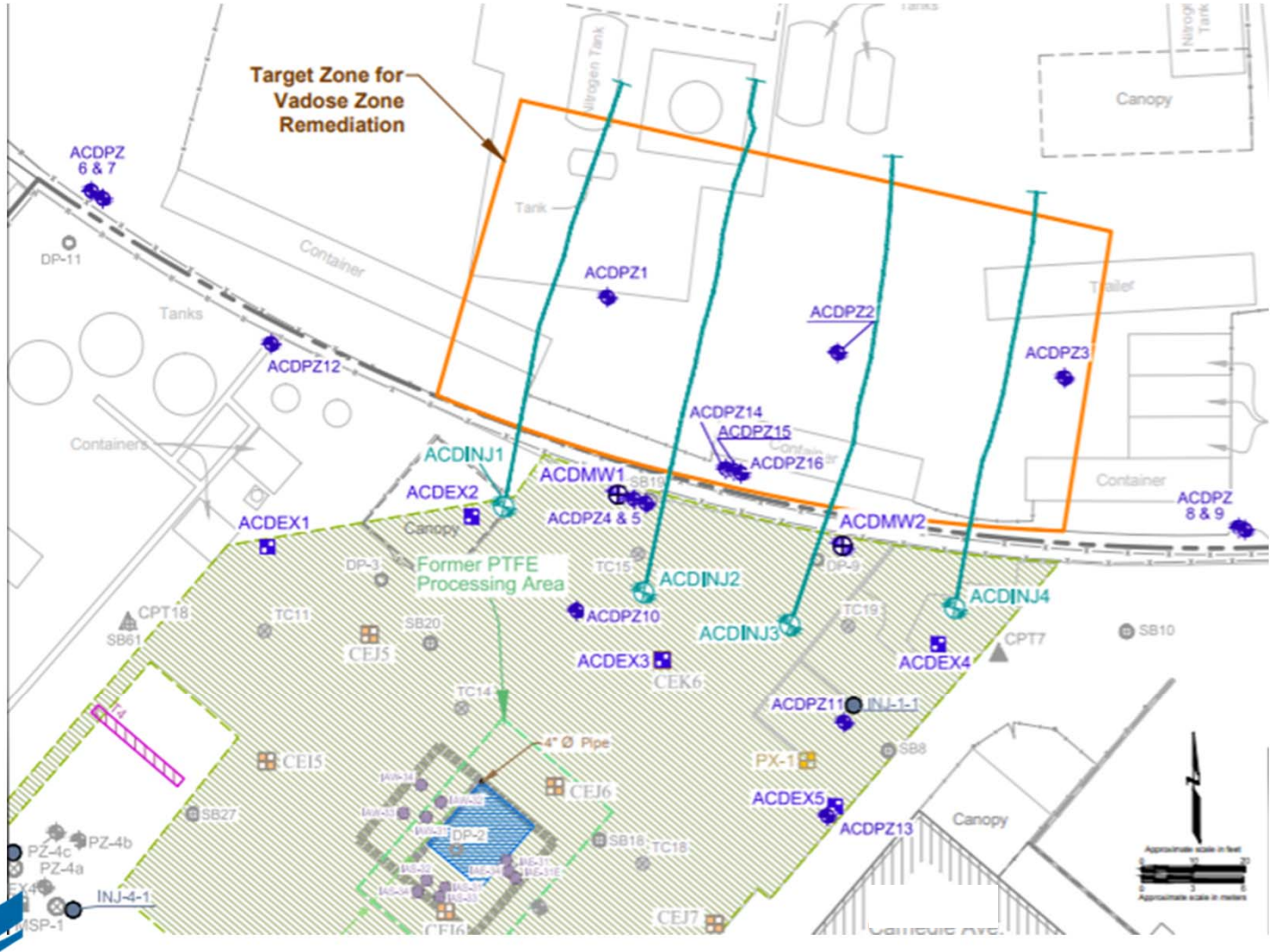
CAN THE RISK BE MANAGED BY AN INTERIM ACTION?



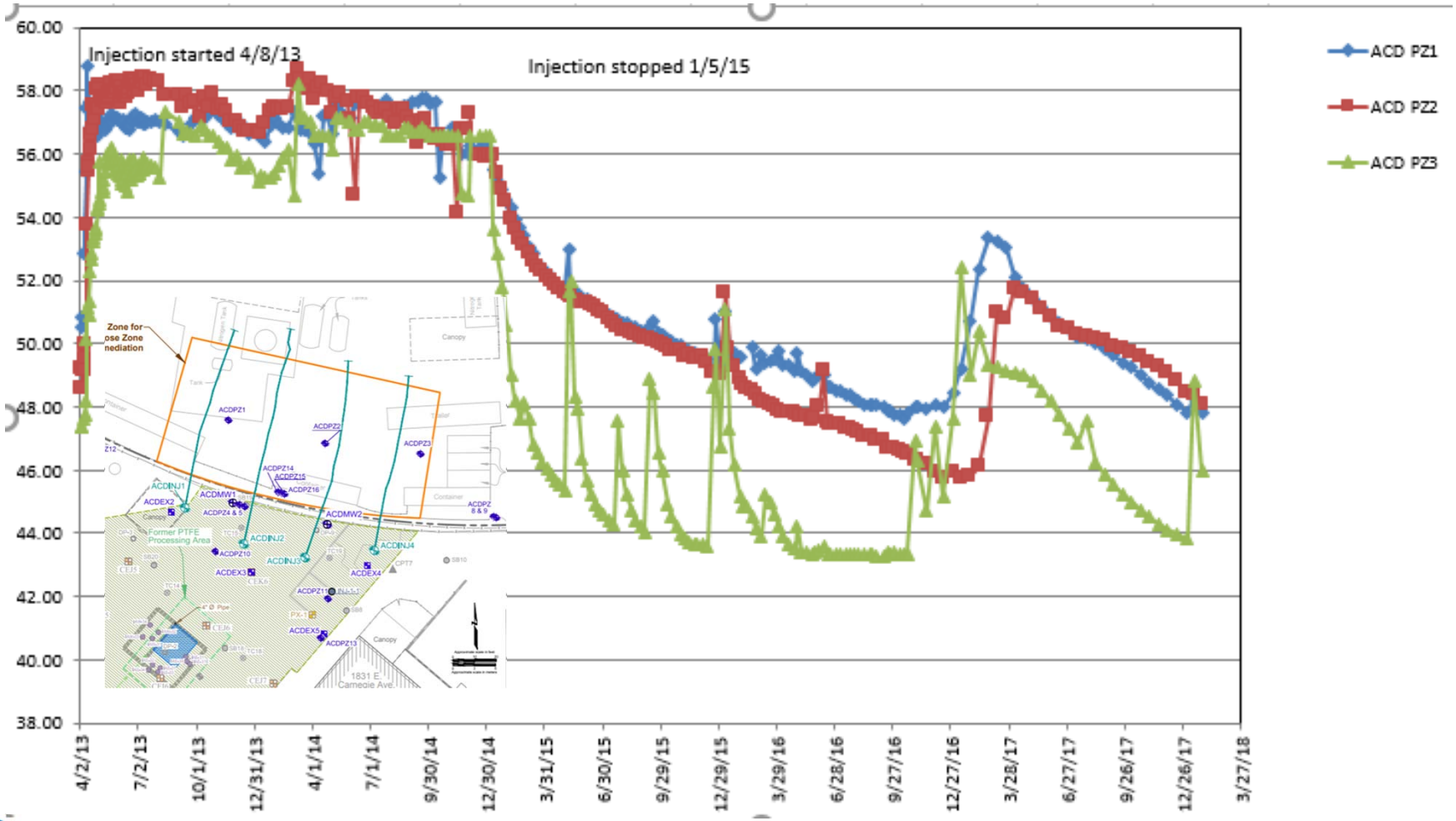
WHAT ARE THE OBJECTIVES AND LIMITATIONS?

- Interim action objective: Reduce perchlorate mass in vadose zone at the upgradient property
- Limitations
  - Highly utilized surface area of upgradient property
  - Limited access to conduct remedy
  - Highly heterogeneous subsurface condition
  - LUC not acceptable to the property owner

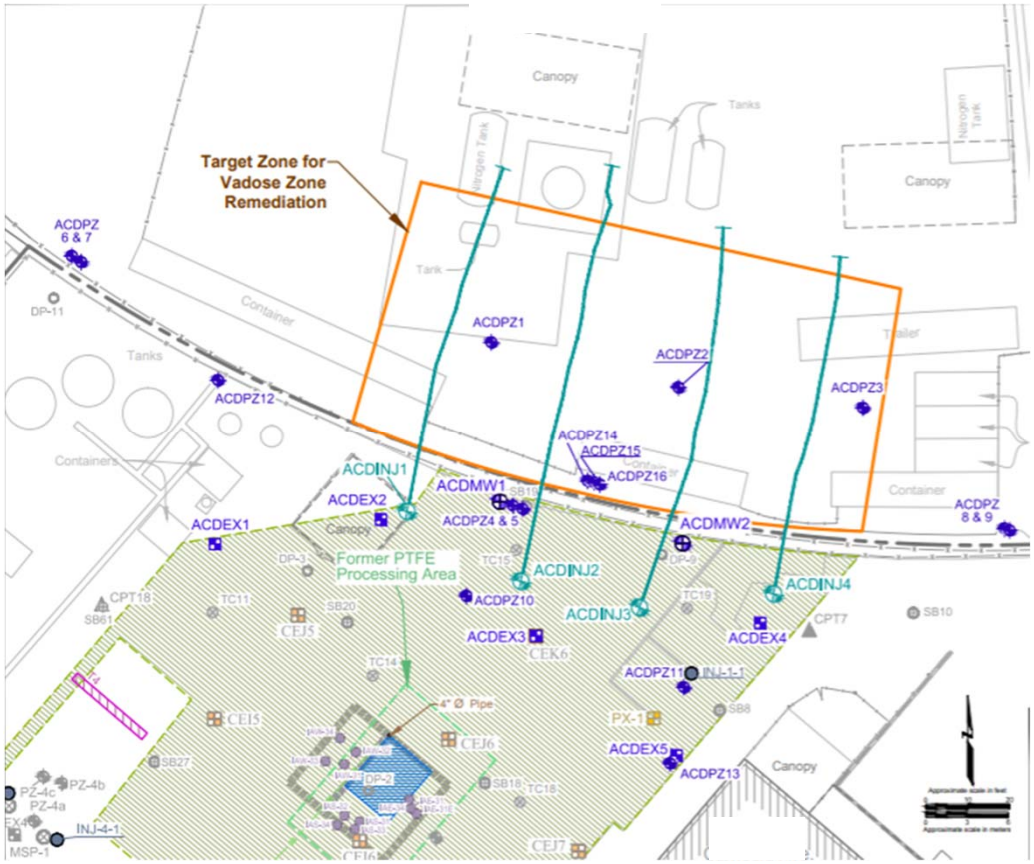
WHAT IS THE INTERIM REMEDIAL ACTION?

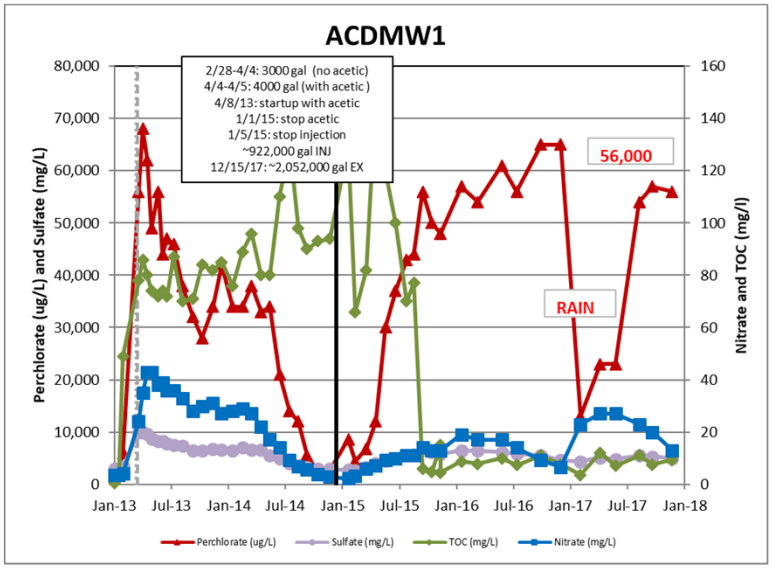
- The interim remedial action for soil at the upgradient property included:
  - Injecting water amended with carbon substrate (acetic acid) through four horizontal injection wells to promote –
    - Flushing of the impacted vadose zone
    - In-situ destruction of perchlorate
  - Hydraulic containment using on-site groundwater extraction wells

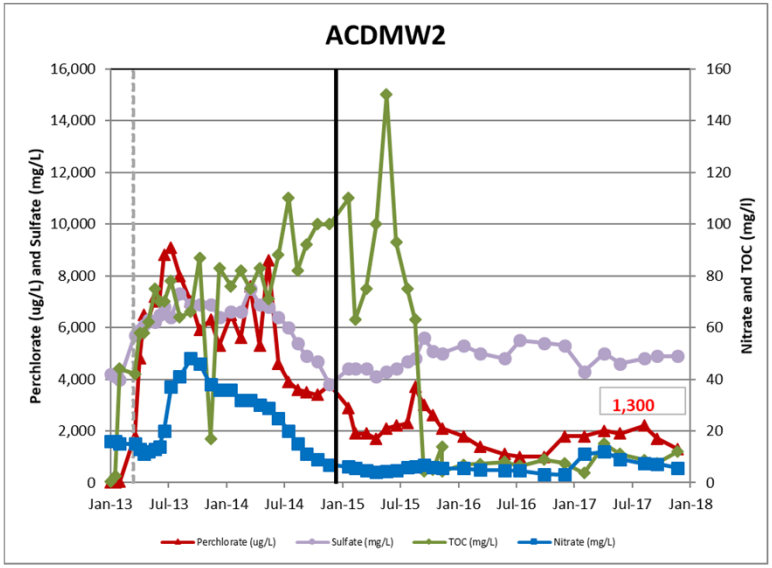
WATER LEVEL RESPONSE TO INJECTION



GEOCHEMICAL RESPONSE TO AMENDMENT INJECTION







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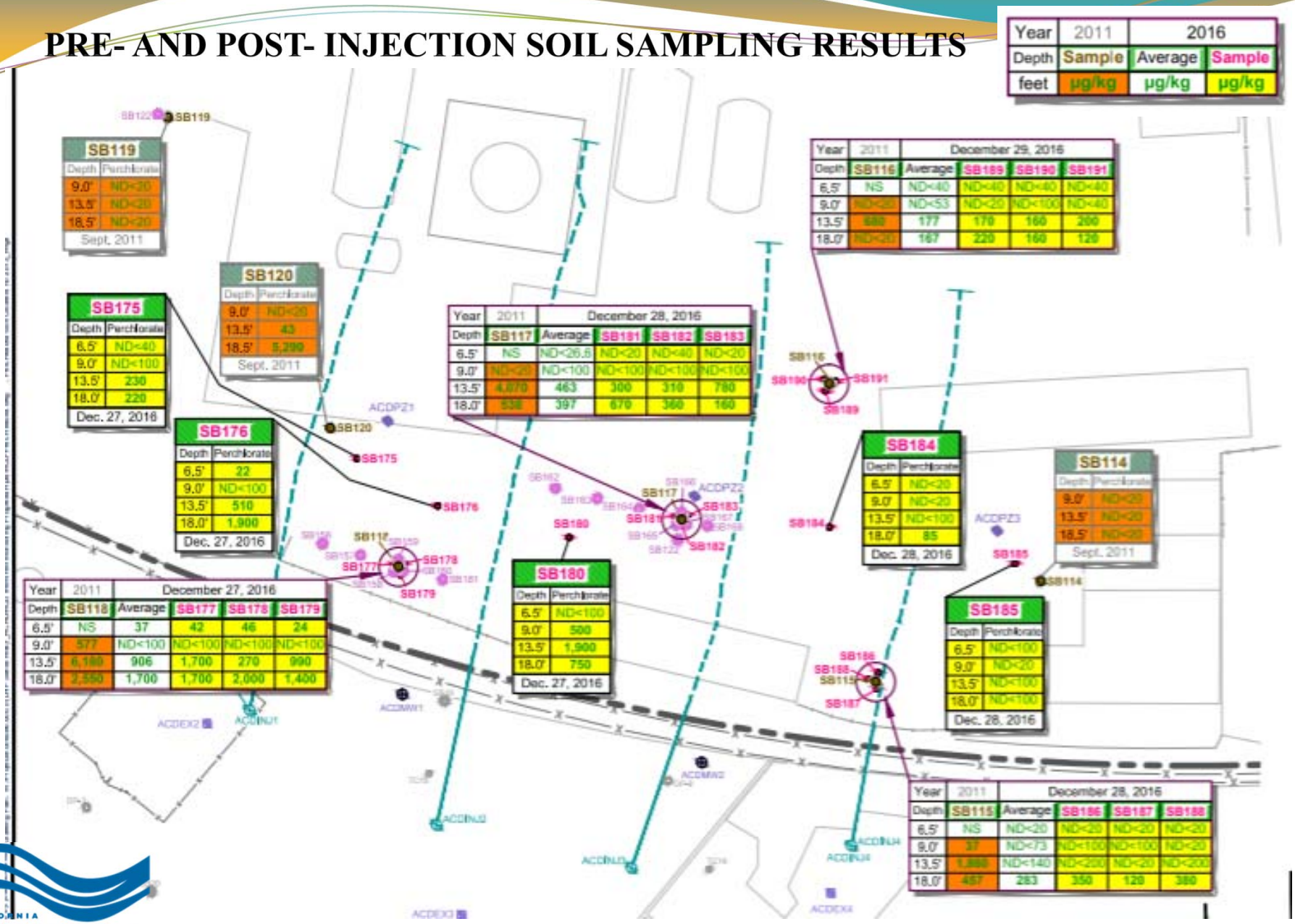
PRE- AND POST- INJECTION SOIL SAMPLING RESULTS



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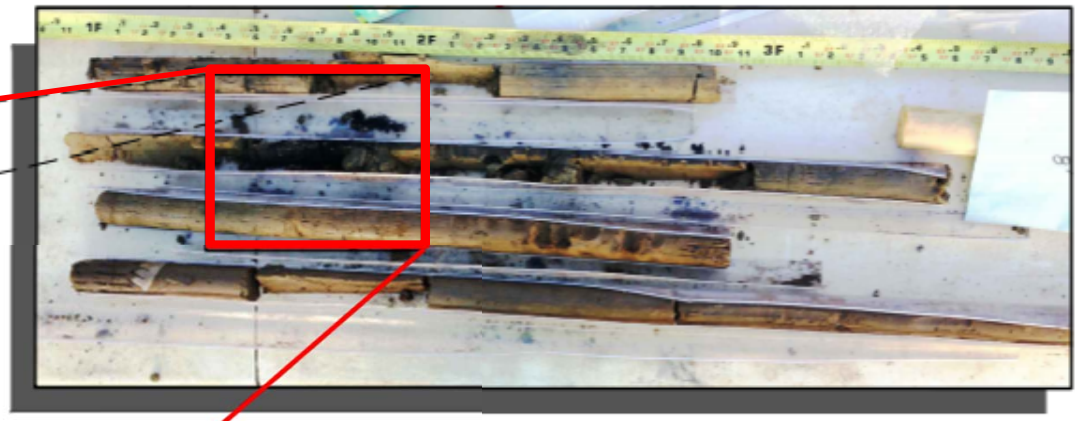
VISUAL EVIDENCE OF REACTION

Soil Core From Boring SB186



Soil Core Close Up From Boring SB186

Soil Core From Boring SB187

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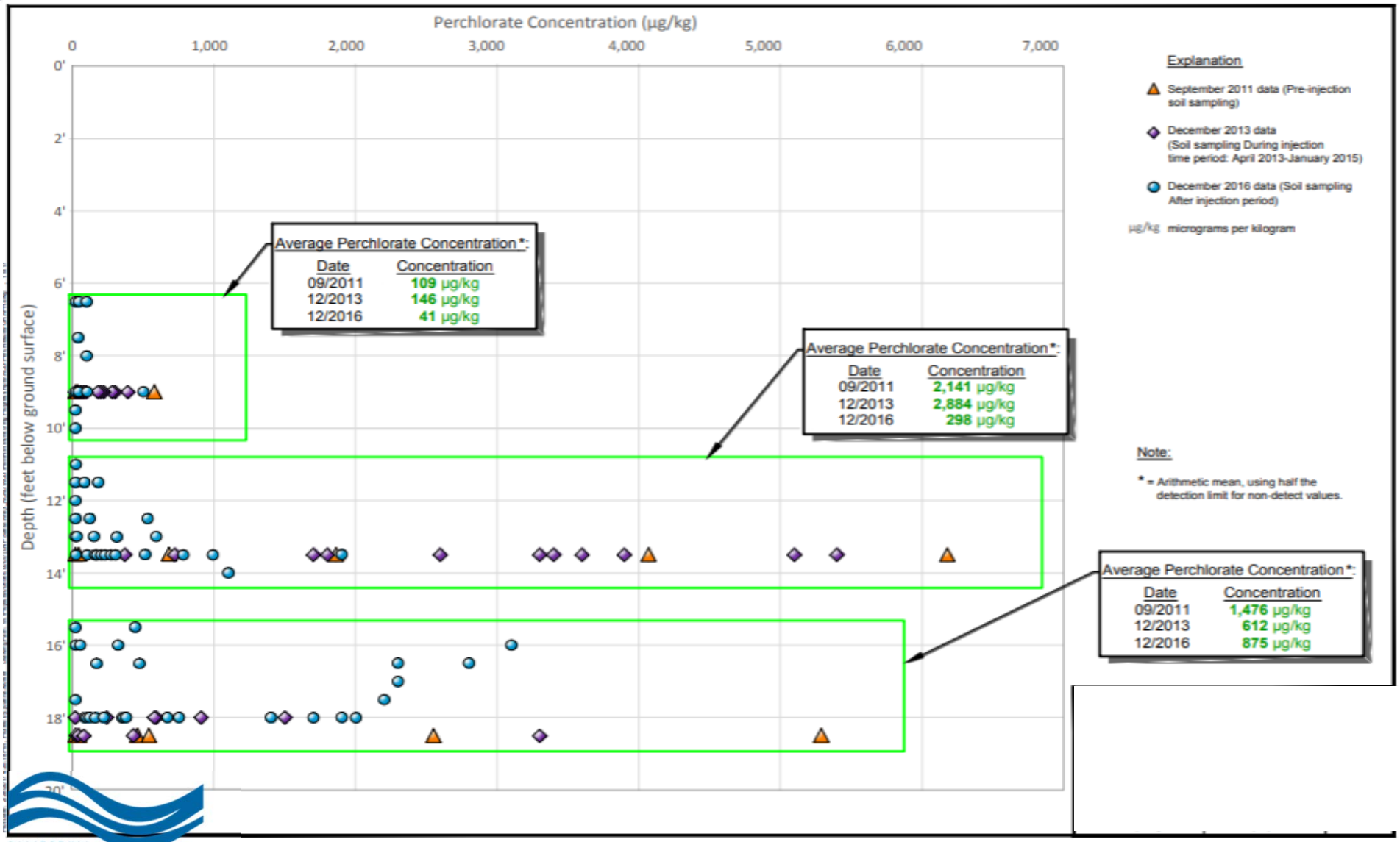
DISTRIBUTION OF PERCHLORATE CONCENTRATIONS IN VADOSE ZONE



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CONCLUSIONS

- There has been a significant contaminant transport in vadose zone upgradient of the source area.
- Concentrations of perchlorate generally decreased in the vadose zone.
- Significant destruction of perchlorate in higher conductivity layers and lenses was observed.
- Transport of noticeable perchlorate mass from vadose zone to groundwater resulted in an order of magnitude increase in perchlorate concentrations in groundwater.
- The residual perchlorate continues to exist in the vadose zone and can still pose a threat to groundwater.
- Further remediation of the vadose zone soil is necessary.

Thank you!

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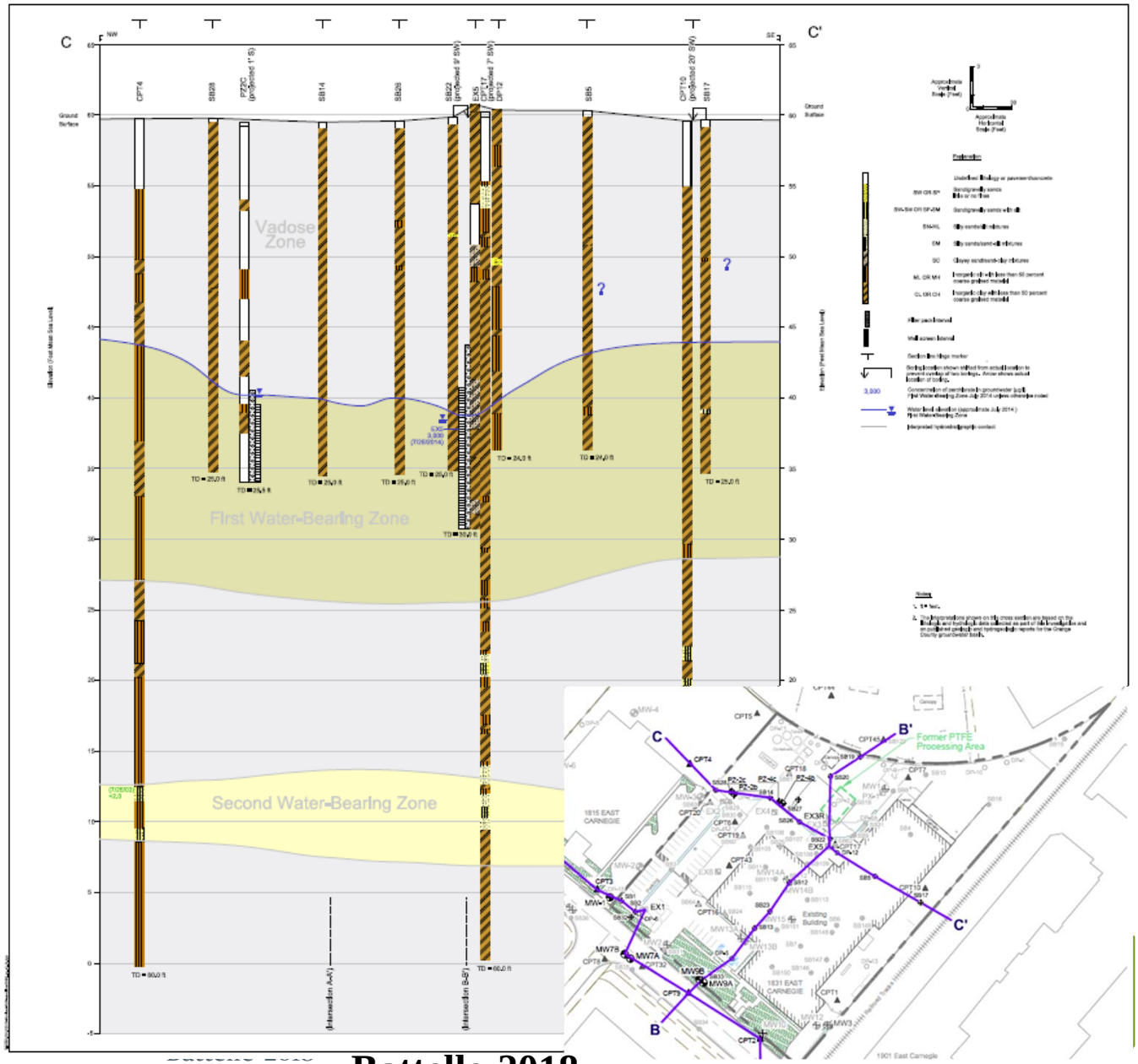

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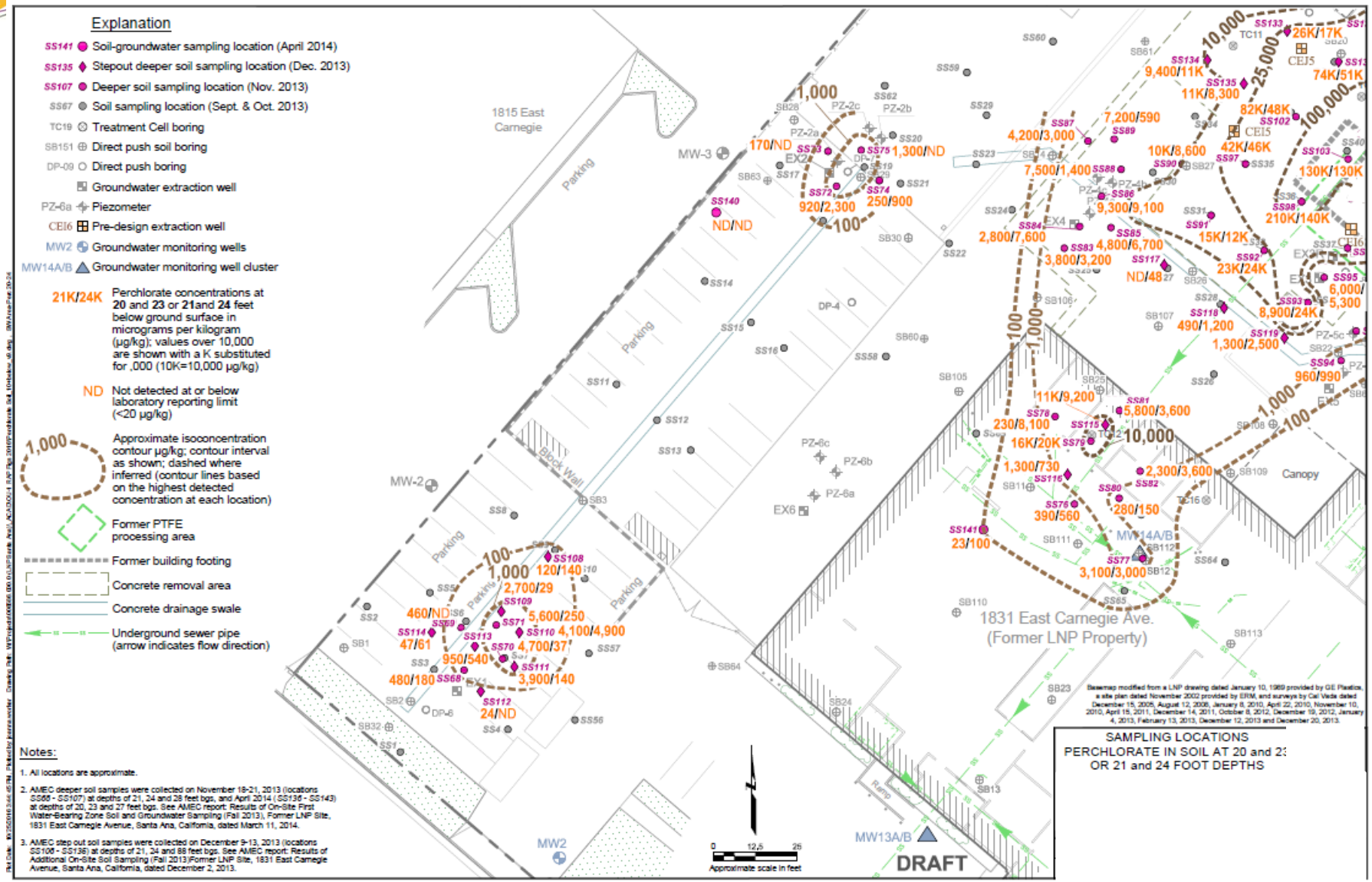

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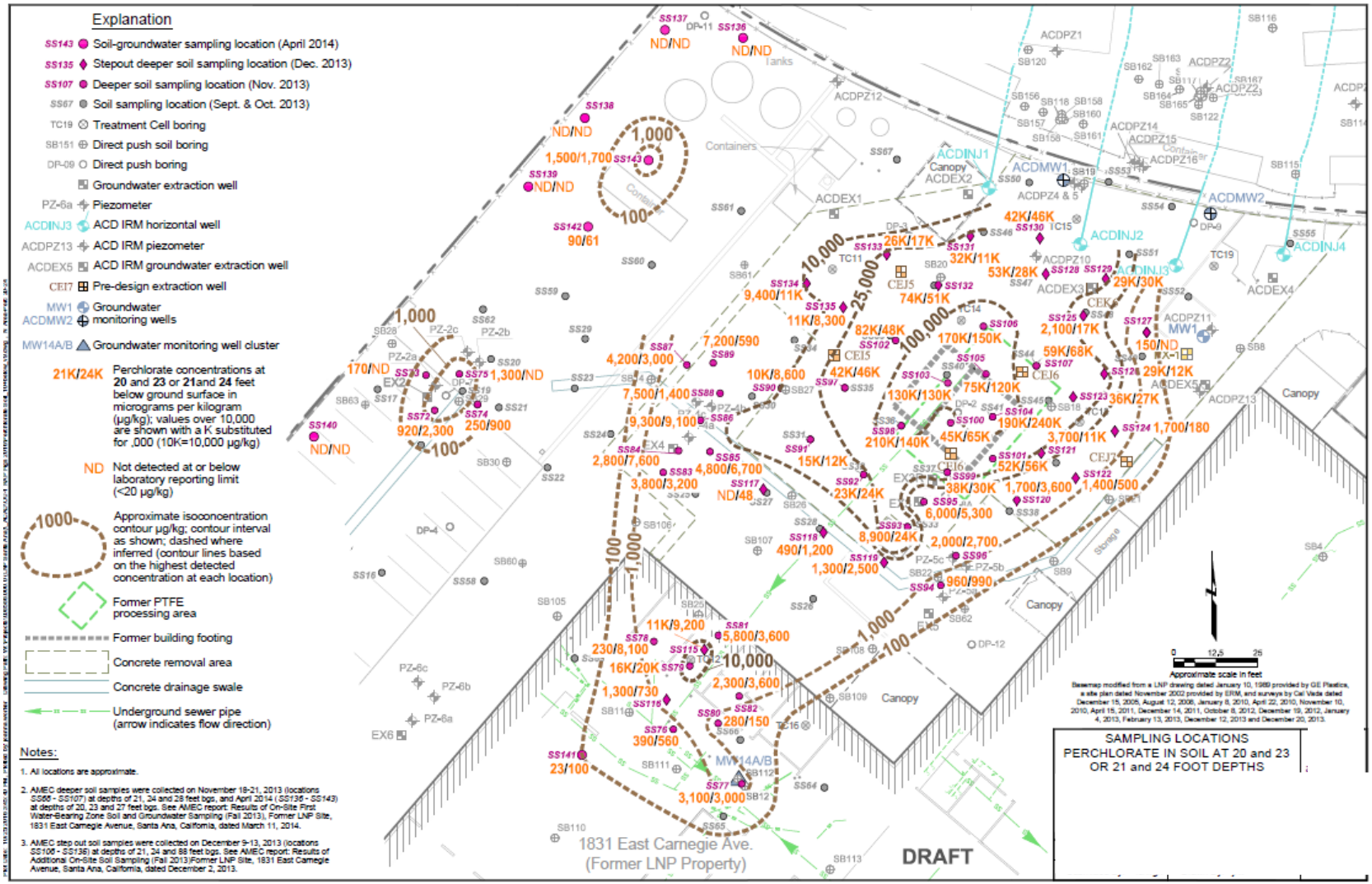

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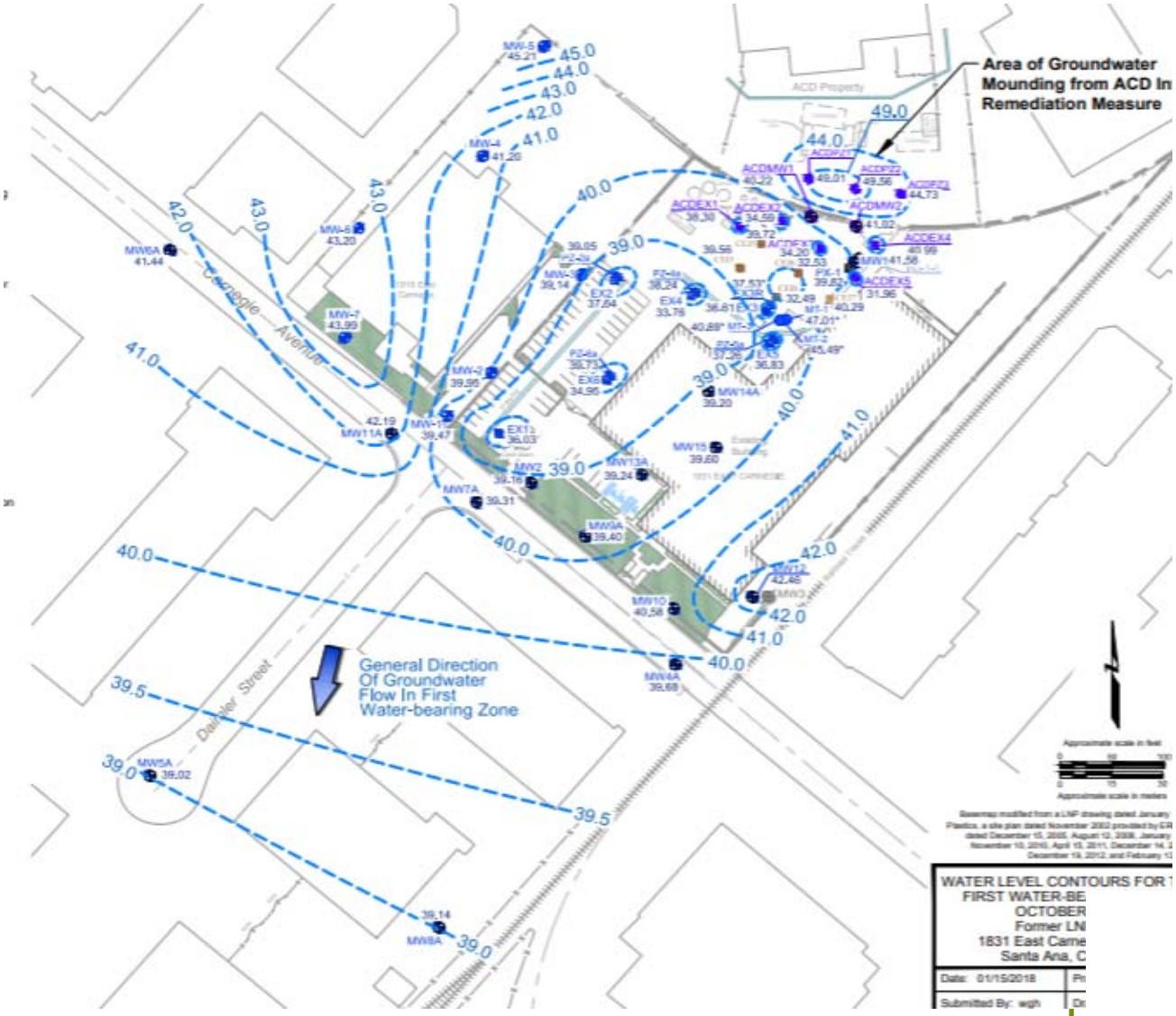

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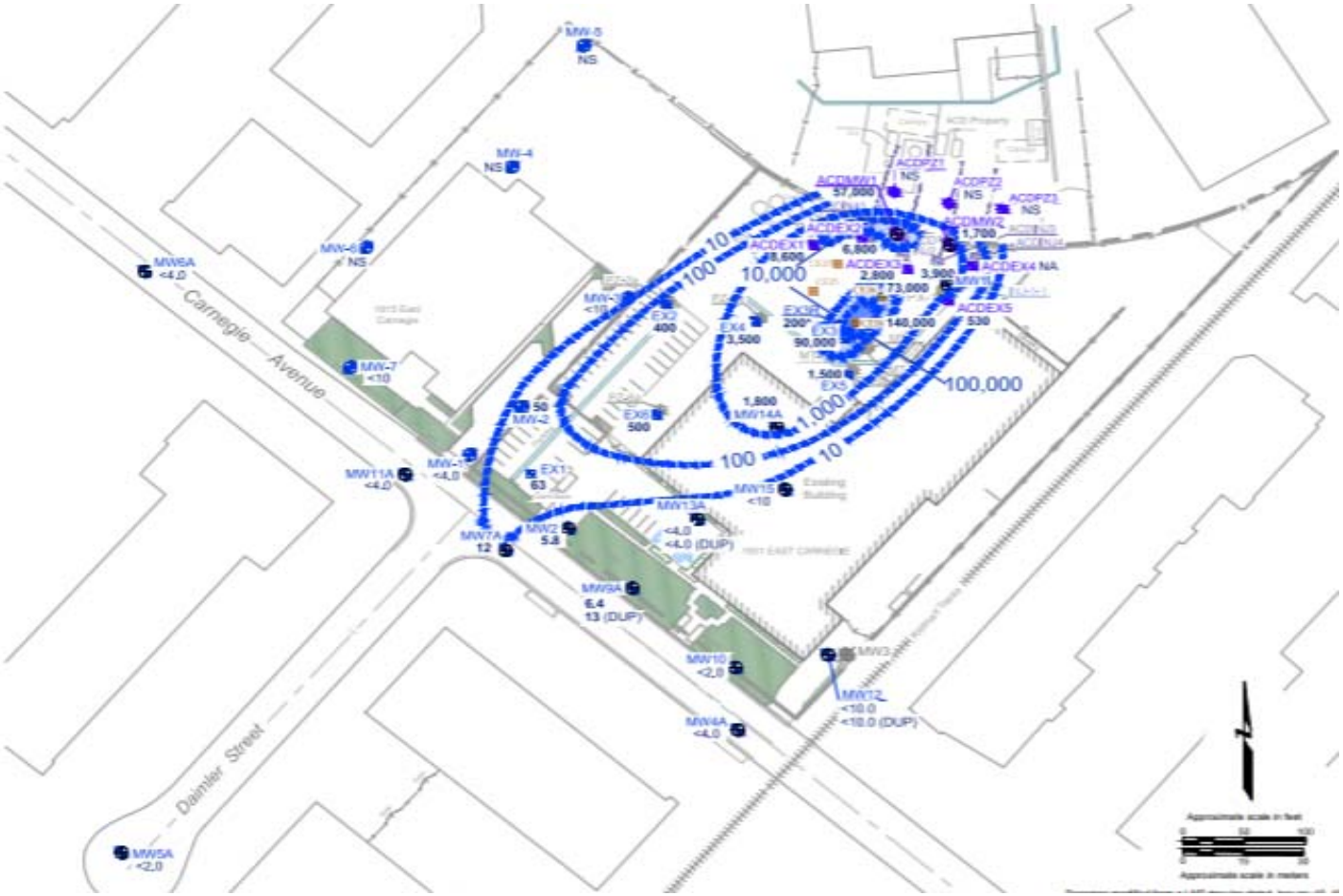

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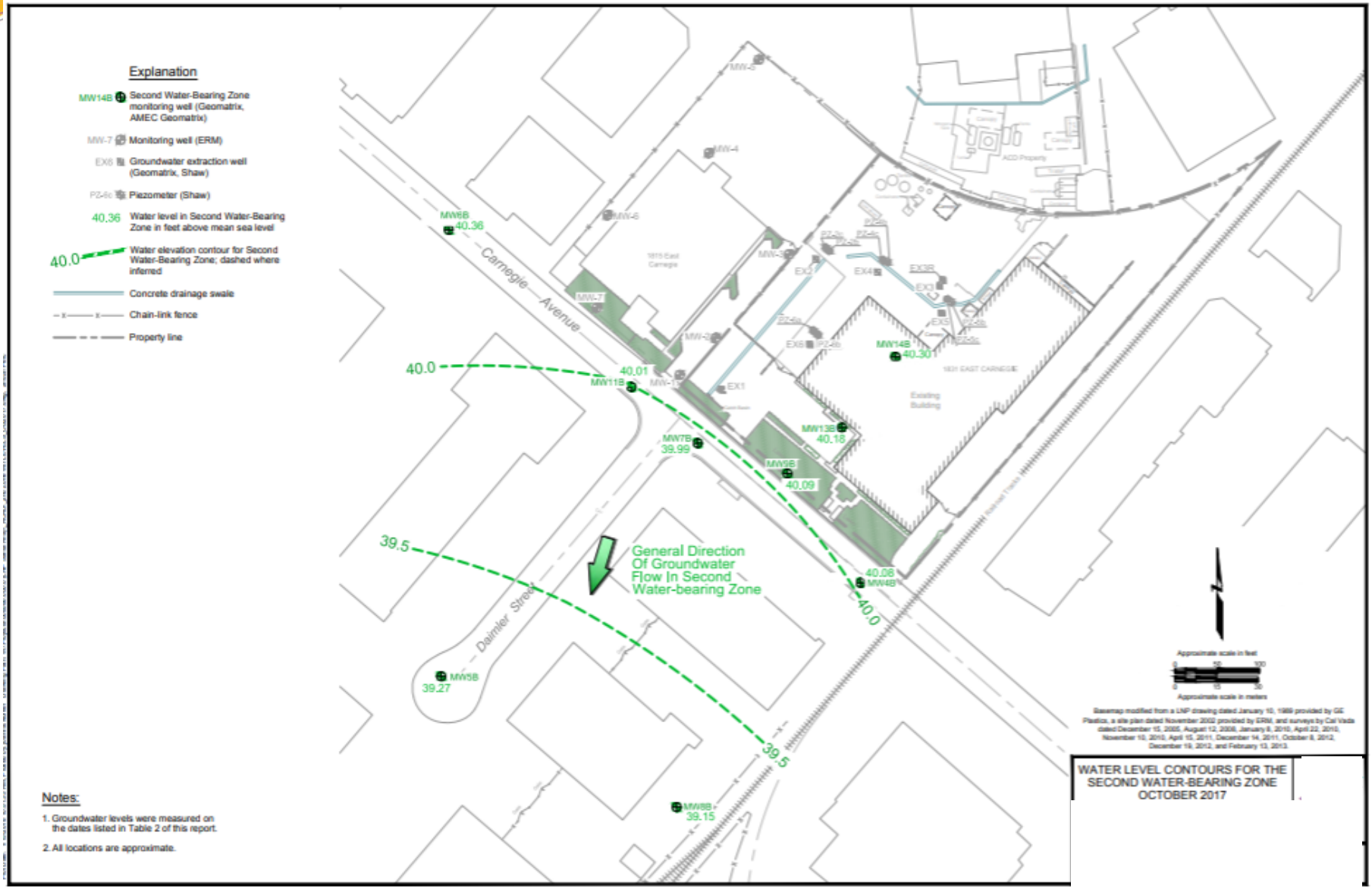

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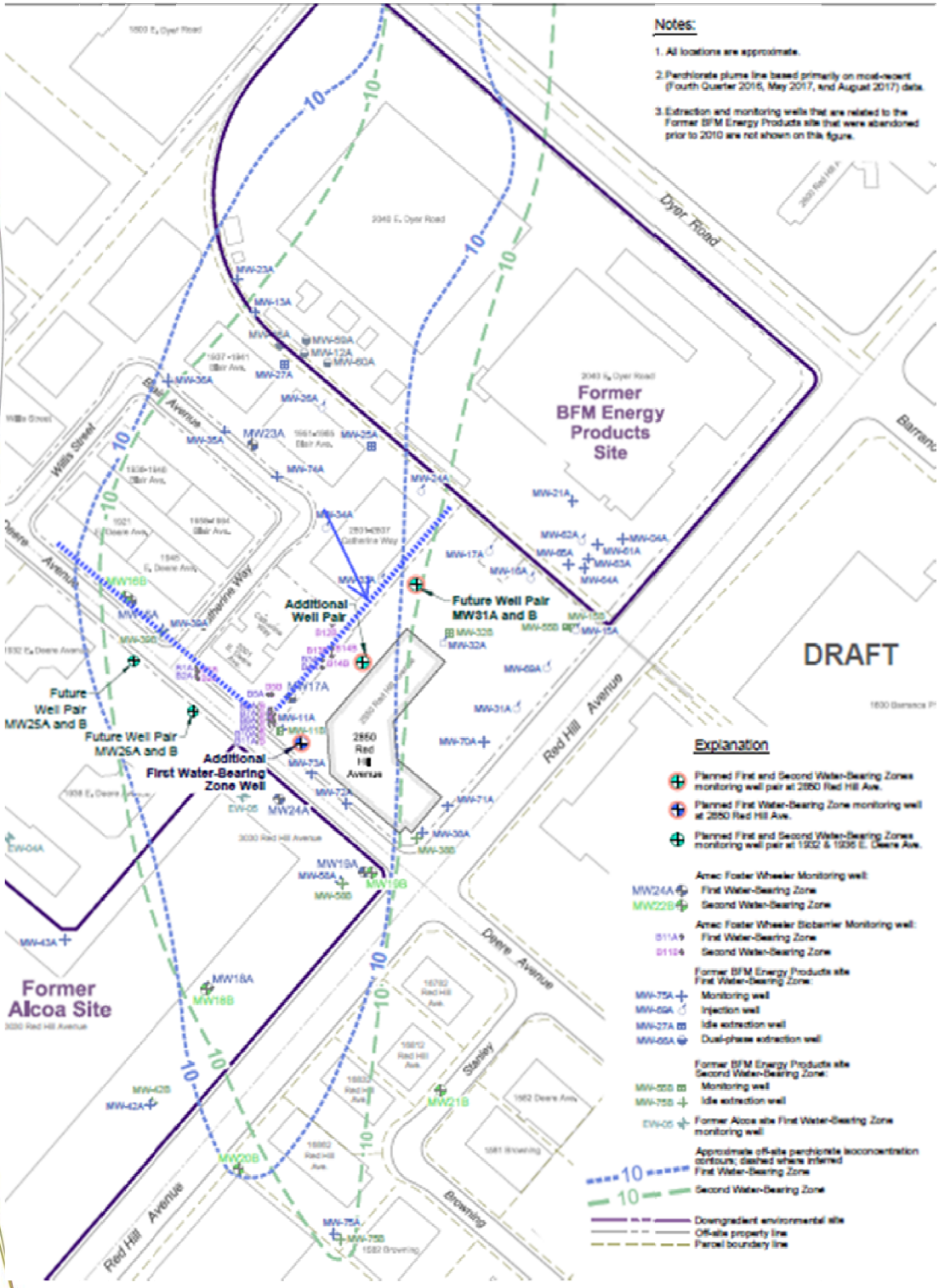

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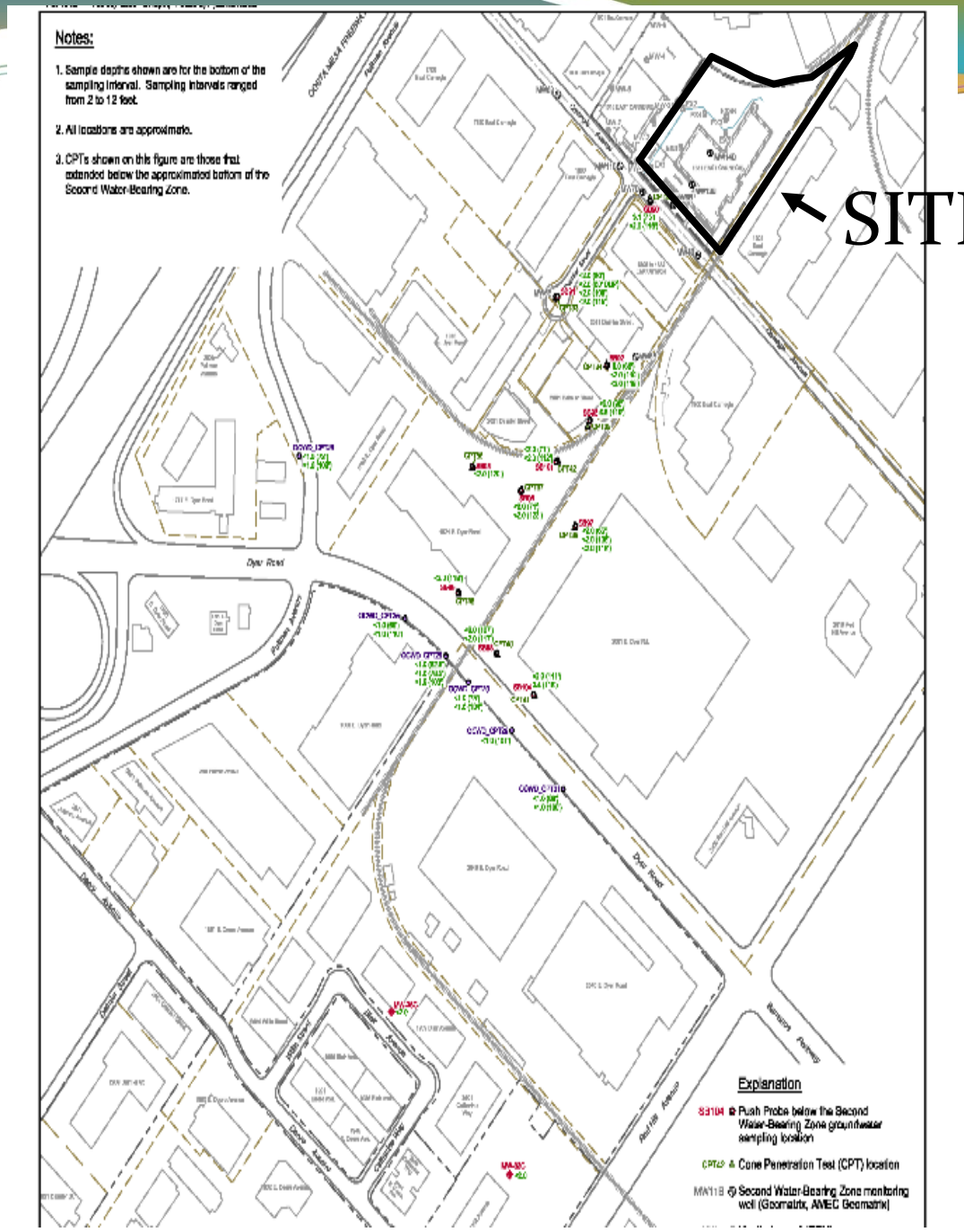

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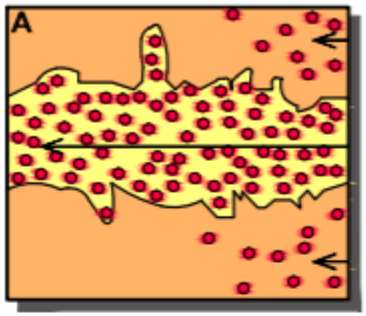
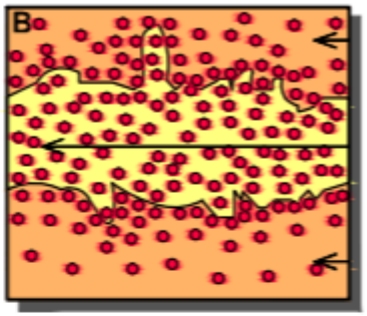
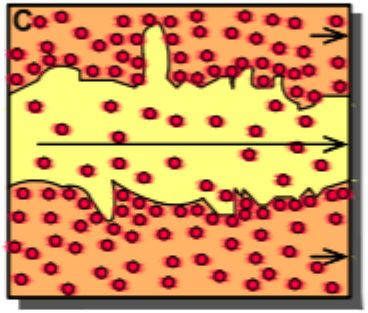


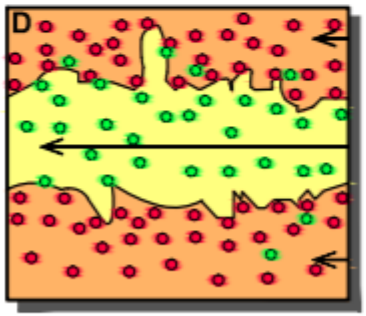
Initial conditions: perchlorate-impacted groundwater migrates to beneath the Pullman Street property. It moves primarily through the pores in the more-permeable soil layers.



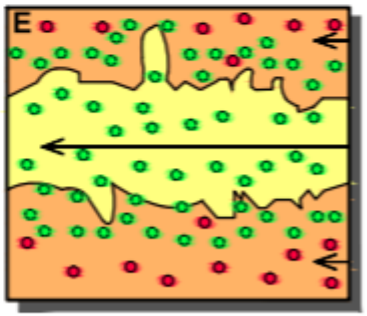
Over a period of time (many years), perchlorate diffuses into the pore water in the lower-permeability soils. This pore water is relatively immobile. This is a relatively very slow process.



With groundwater extraction on the former LNP site, the concentration of perchlorate in groundwater in the more-permeable layers is reduced some, as non-impacted groundwater is drawn into the area.



Initial injection of amended water: Amended water, introduced via the horizontal wells, flows out (and down), primarily through the more-permeable layers. Perchlorate in the pore water in the more-permeable layers is destroyed or flushed out. Slow diffusion into lower permeability soils begins.



After flushing multiple pore volumes through the soil, the majority of the perchlorate in the pore water in the more permeable layers is destroyed or flushed out. In the lower permeability soils, some perchlorate-impacted immobile pore water remains .

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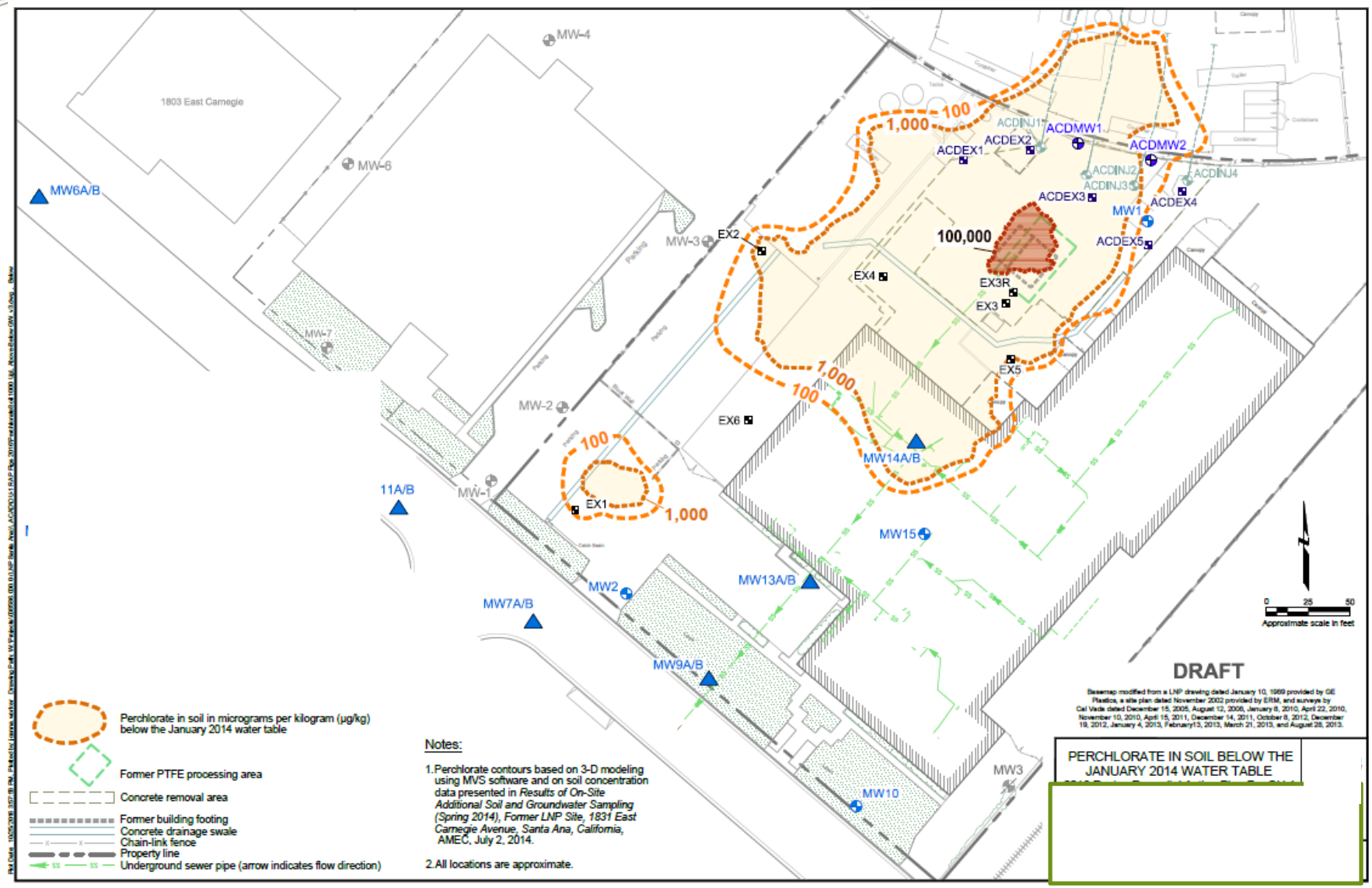

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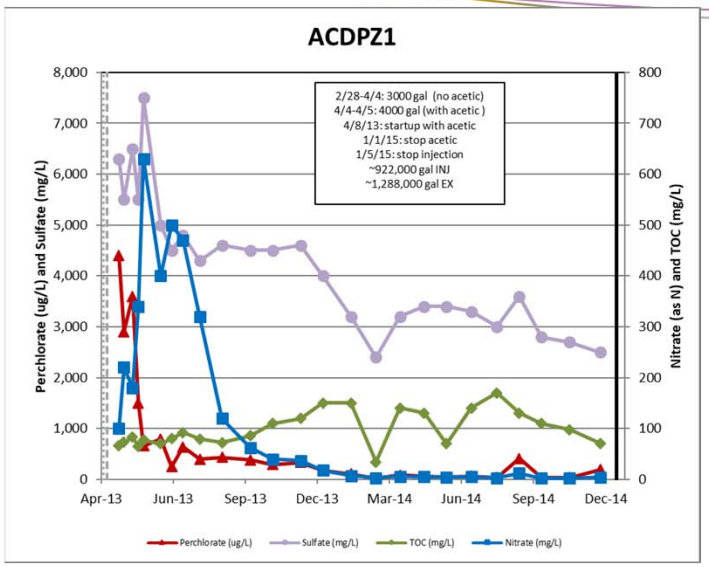

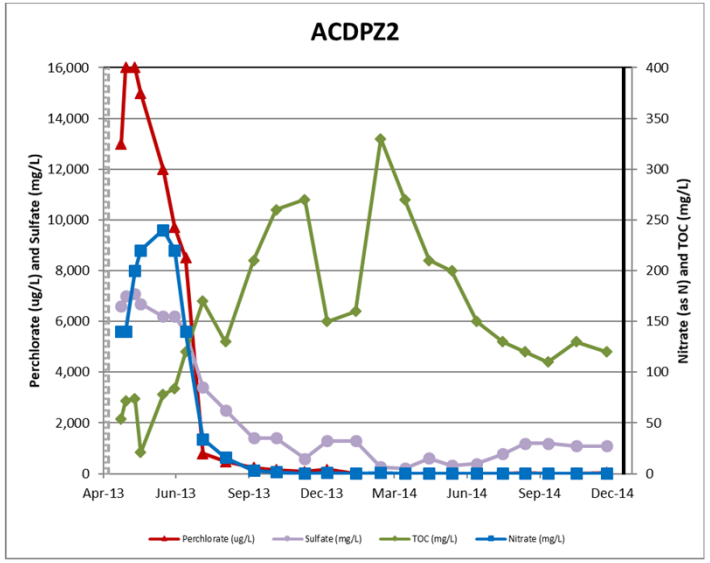

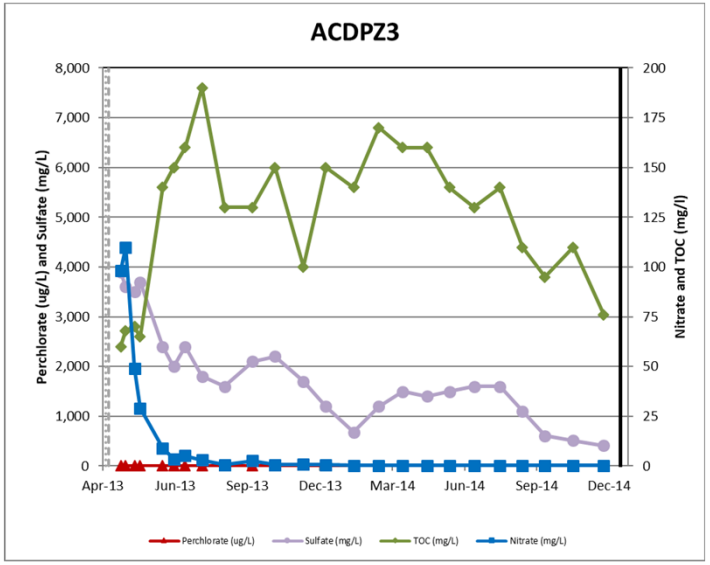

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