



## Steam Enhanced Remediation In Fractured Rock

(and a little about the other sites)

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# Visalia Pole Yard



Creosote DNAPL to +140 ft depth

160,000 gallons removed from subsurface

Alluvial sands and gravels with clays

In-situ destruction significant

Both LNAPL and DNAPL

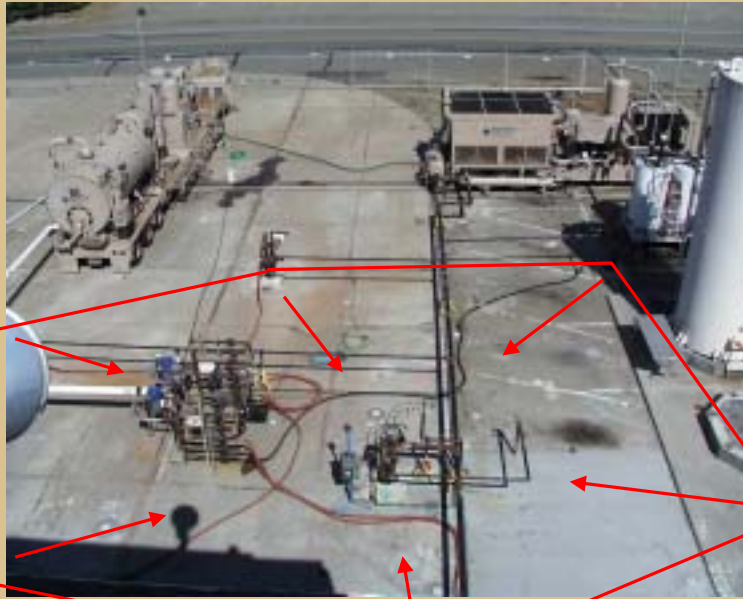
Approaching MCLs in 2002

UC Berkeley – LLNL - SCE

Craig Eaker, SCE



Alameda Point (Berkeley Environmental Restoration Center)



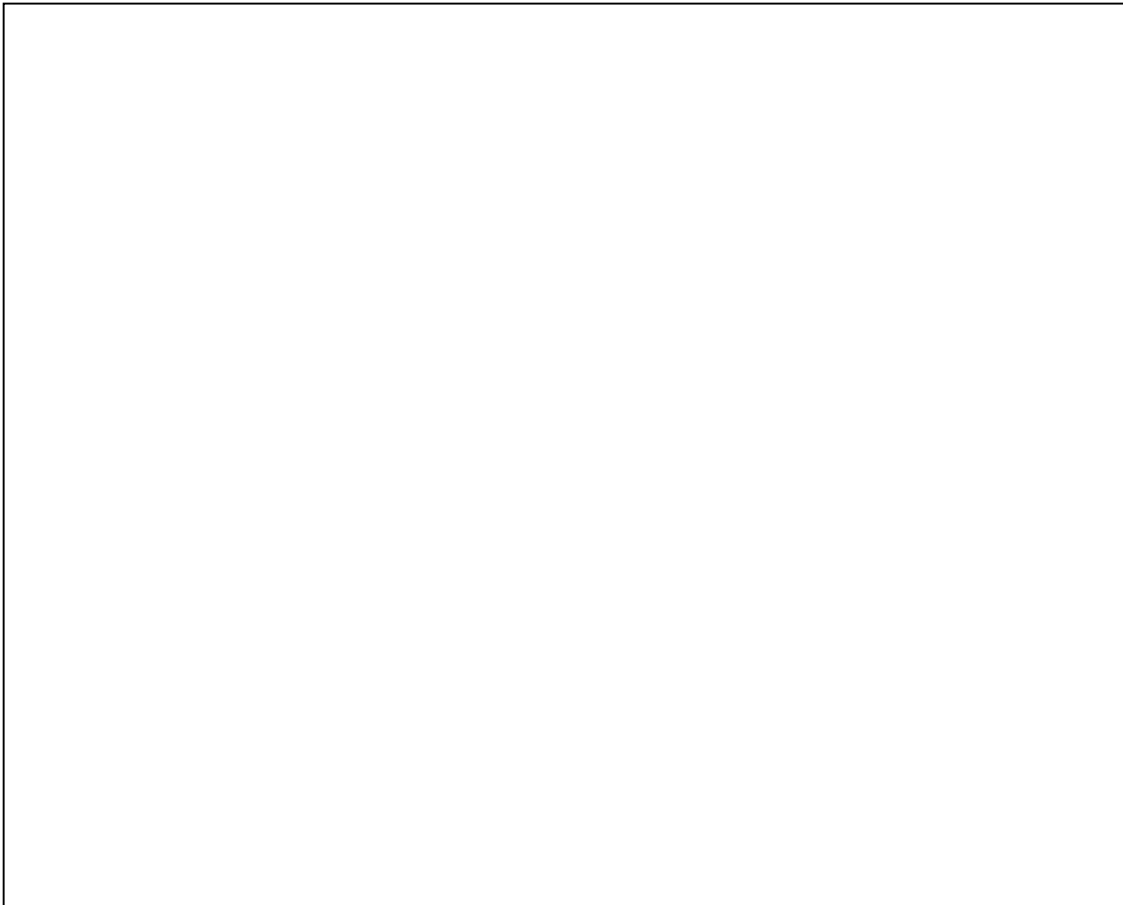
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# Edwards AFB Site 61



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# Beale AFB



# Loring: Fractured limestone



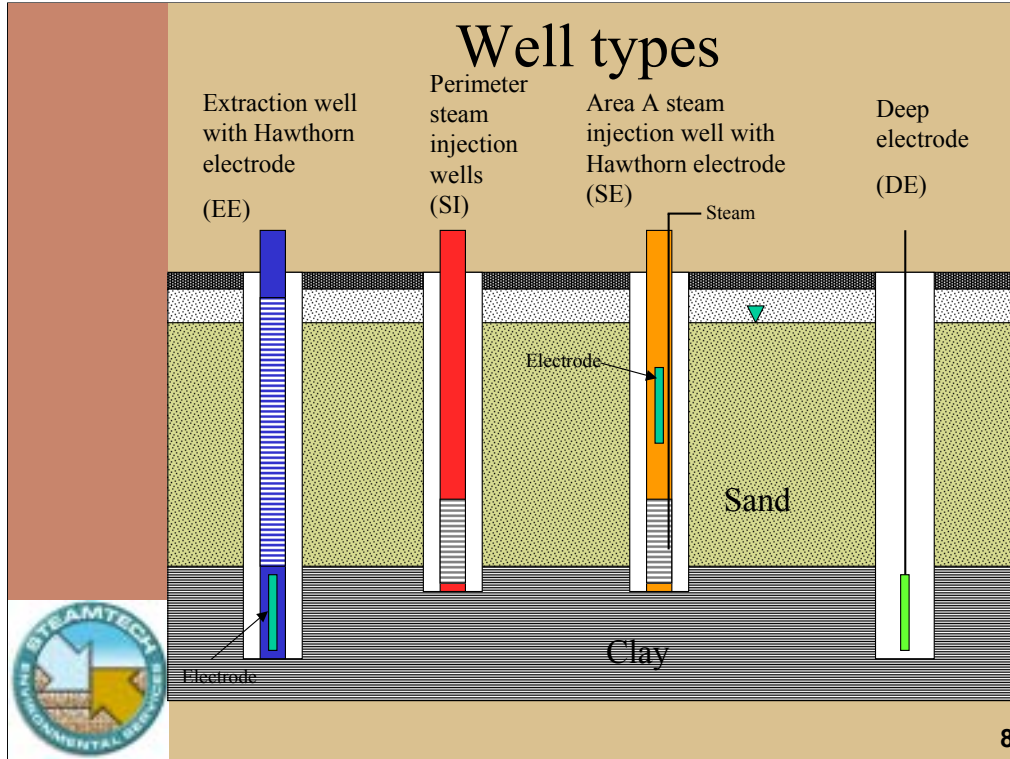
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## Florida site

- Full-scale clean-up with performance guarantee
- Steam enhanced remediation and electrical heating
- Tight pneumatic and hydraulic control
- Stimulated oxidation reactions for reduction of TPH concentrations in oily areas
- Detailed subsurface monitoring (temperature and electrical resistance tomography)







# Preliminary results, Edwards AFB

Acknowledgments to:

- Stephen Watts, Edwards AFB project manager
- Dave Leeson, AFCEE
- Scott Palmer, Earth Tech project manager
- Gregg Crisp, site manager and operator
- Layi Oyelowo, Edwards AFB



Results are preliminary, conclusions have not been published or confirmed by the above persons



## Fractured granite (quartz monzonite)



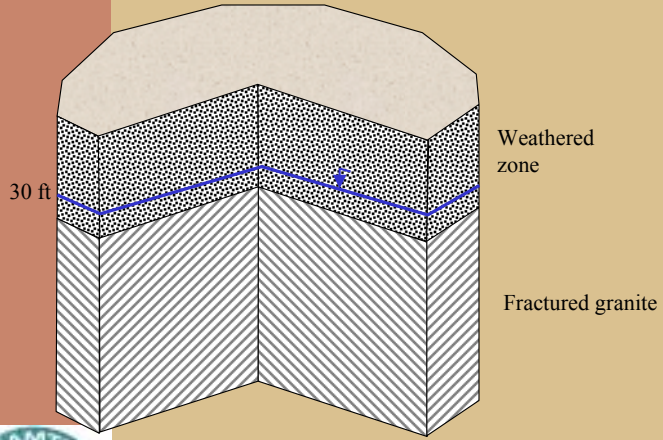
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## Objectives/questions

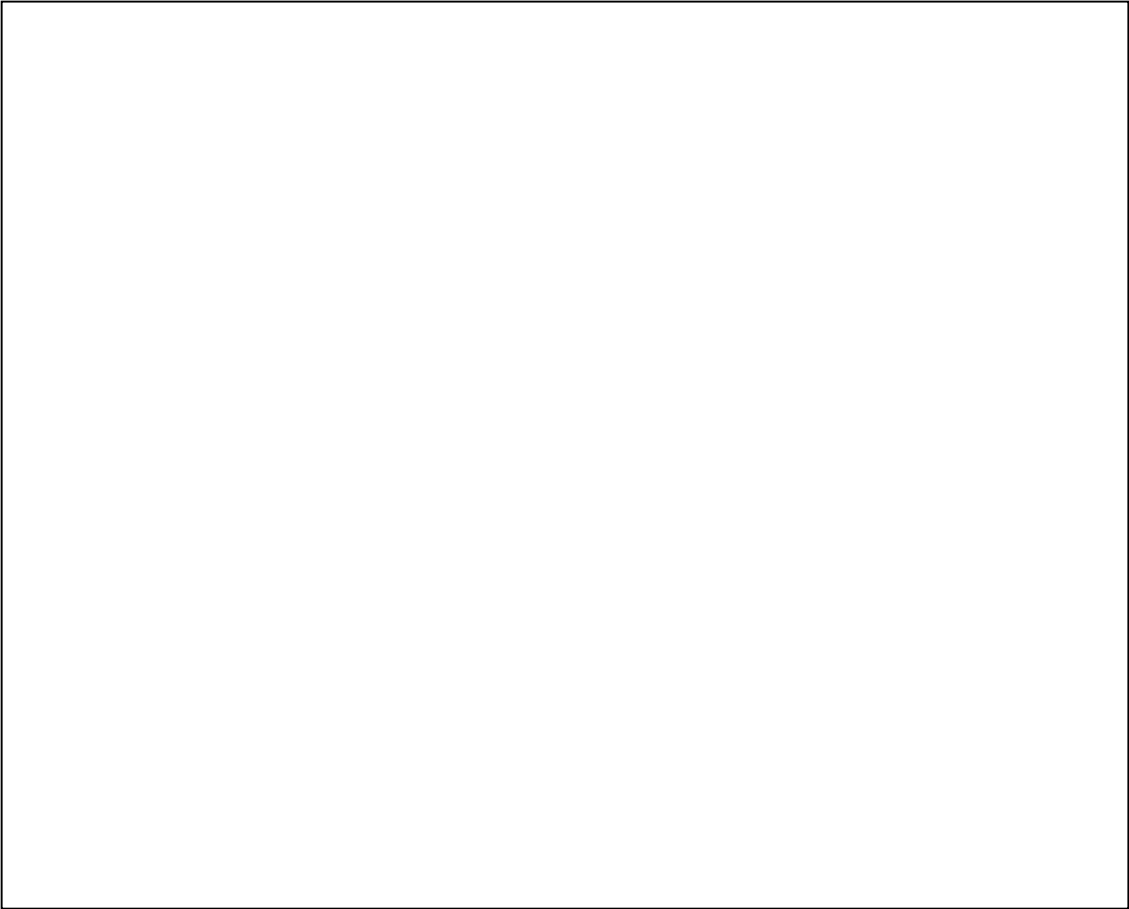
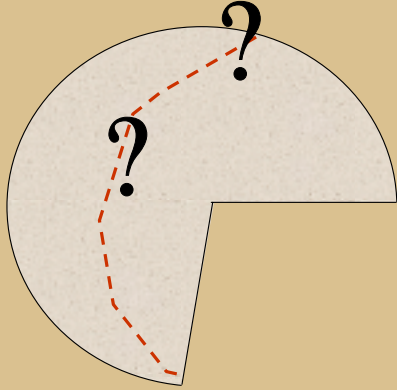
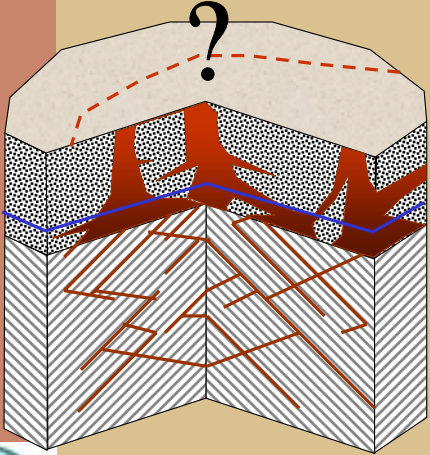
- Will SER be effective for removal of VOCs from fractured rock at Edwards AFB?
- How is the DNAPL mobilized and extracted?
- What are the ultimate VOC cleanup levels that can be expected at Edwards AFB using SER?
- How rapidly will the steam heat Site 61 at Edwards AFB?
- How should steam injection and extraction well-fields be designed for optimum performance at Edwards AFB?
- What is the optimal steam injection and extraction strategy for DNAPL in fractured rock at Edwards AFB?
- How long will the site stay hot after completion of the steaming?



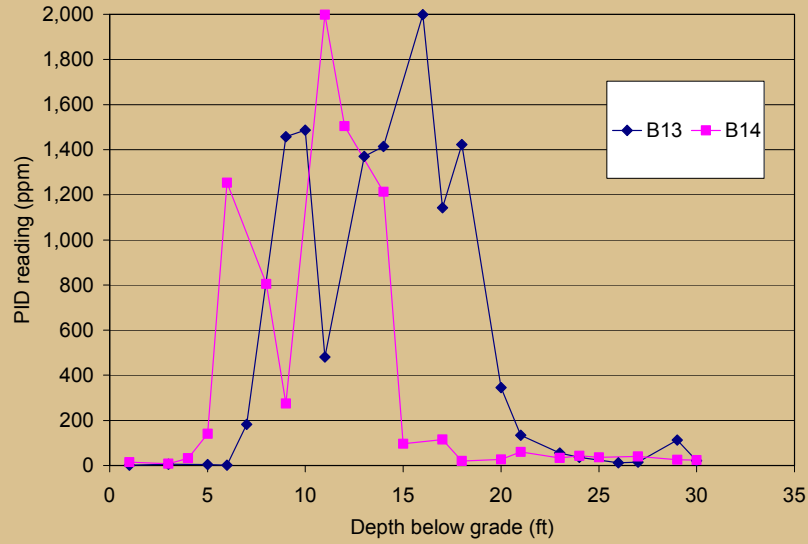
# Hydrogeology



# TCE distribution

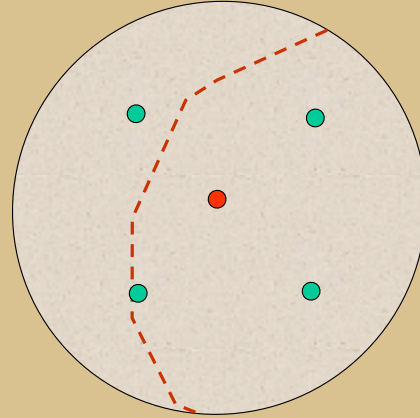
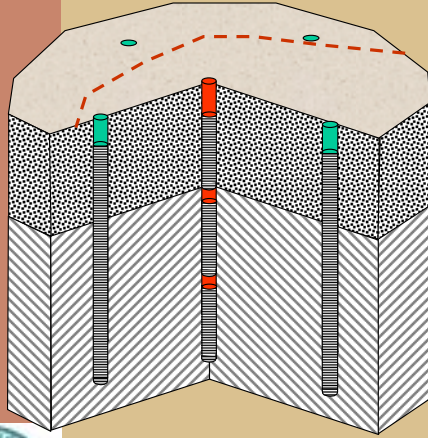


## Vertical distribution of contaminants before operations: PID readings on cores

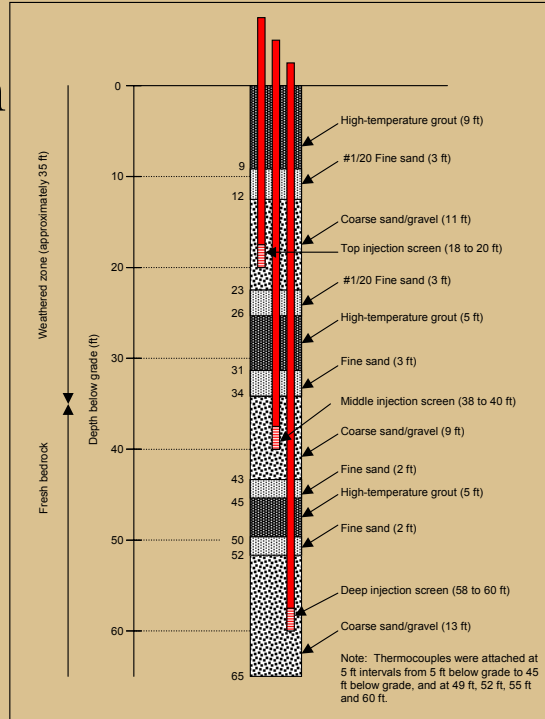


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# Extraction and steam injection wells



# Injection well design









# Strategy

Vacuum test: Vapor capture radius ~ 80 ft

Initially steam injection deep only, extraction shallow

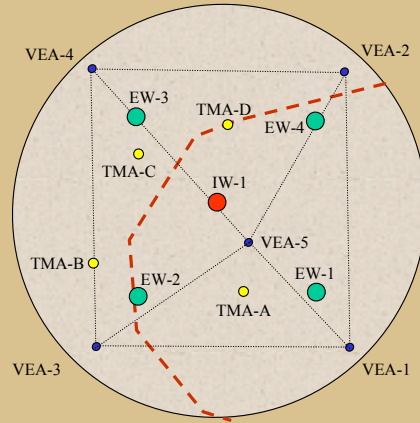
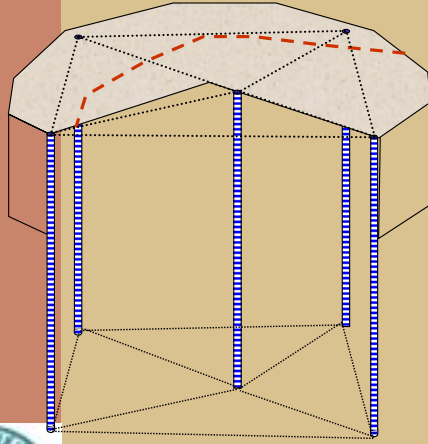
Air co-injection

Extract 25 to 50 % more than injected

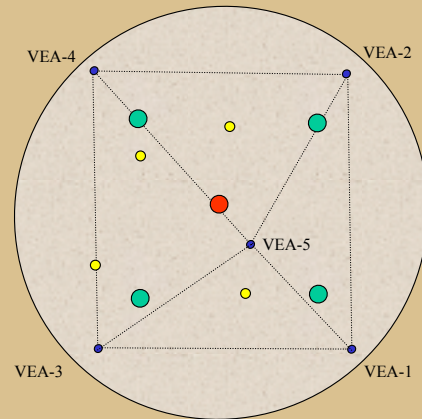
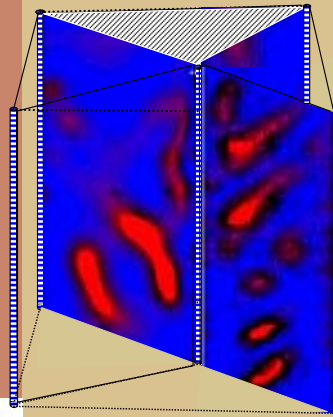
Monitor carefully and adjust strategy



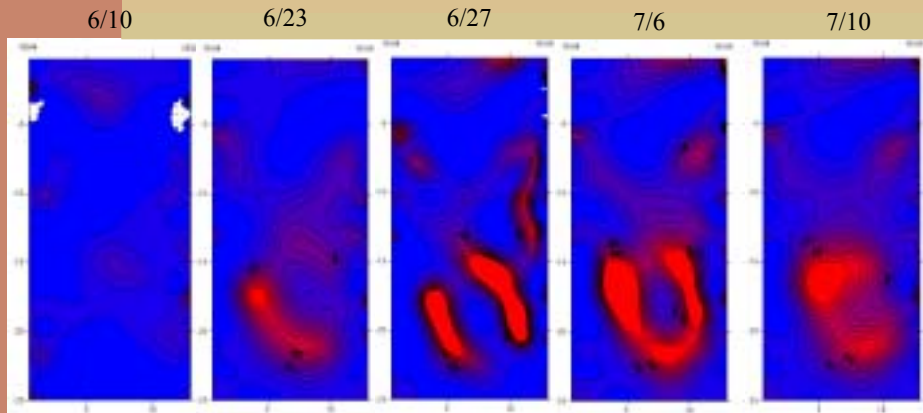
# Subsurface monitoring network



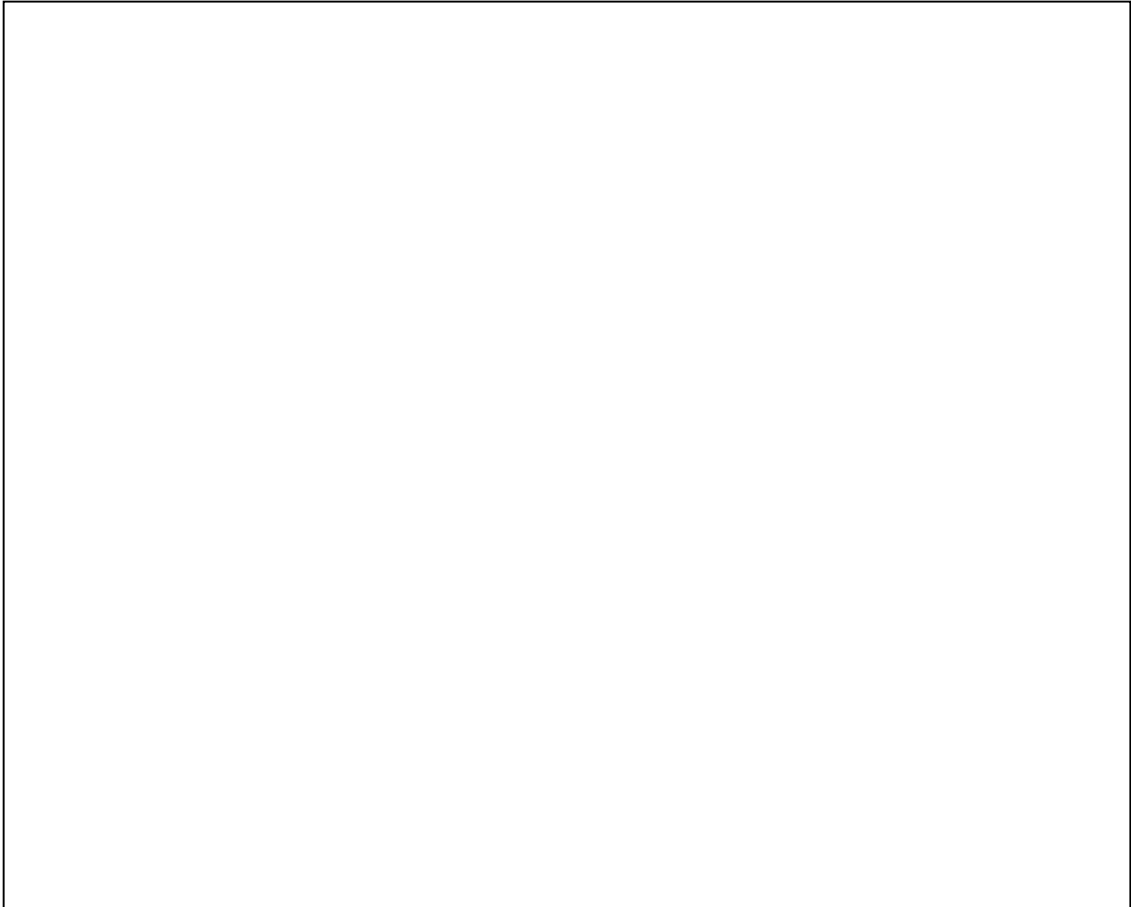
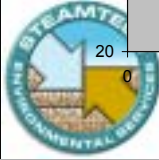
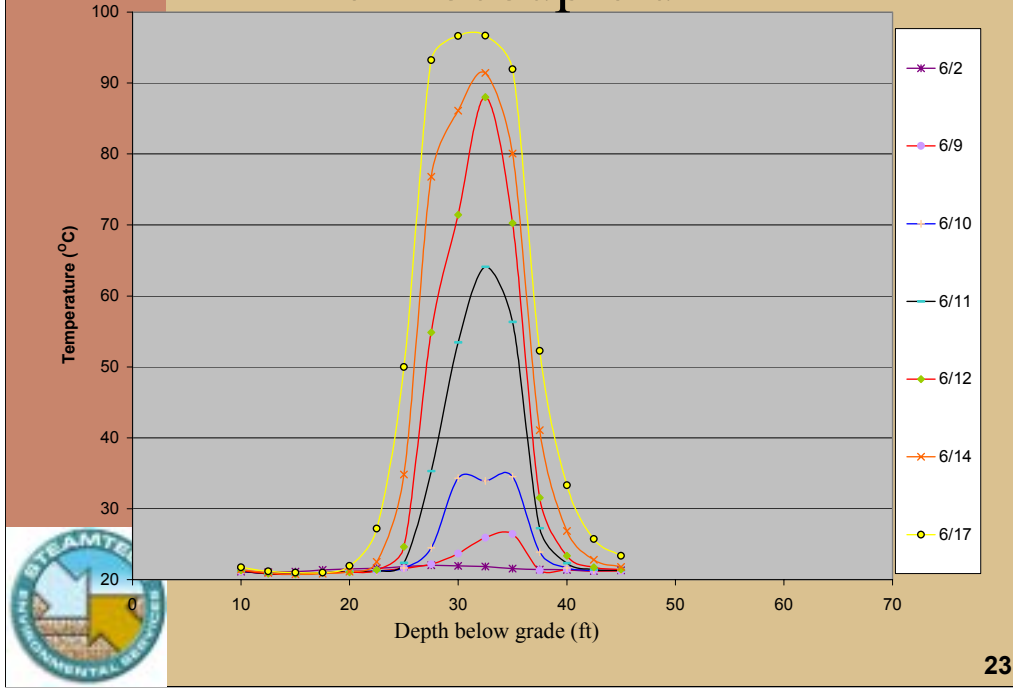
# ERT data planes

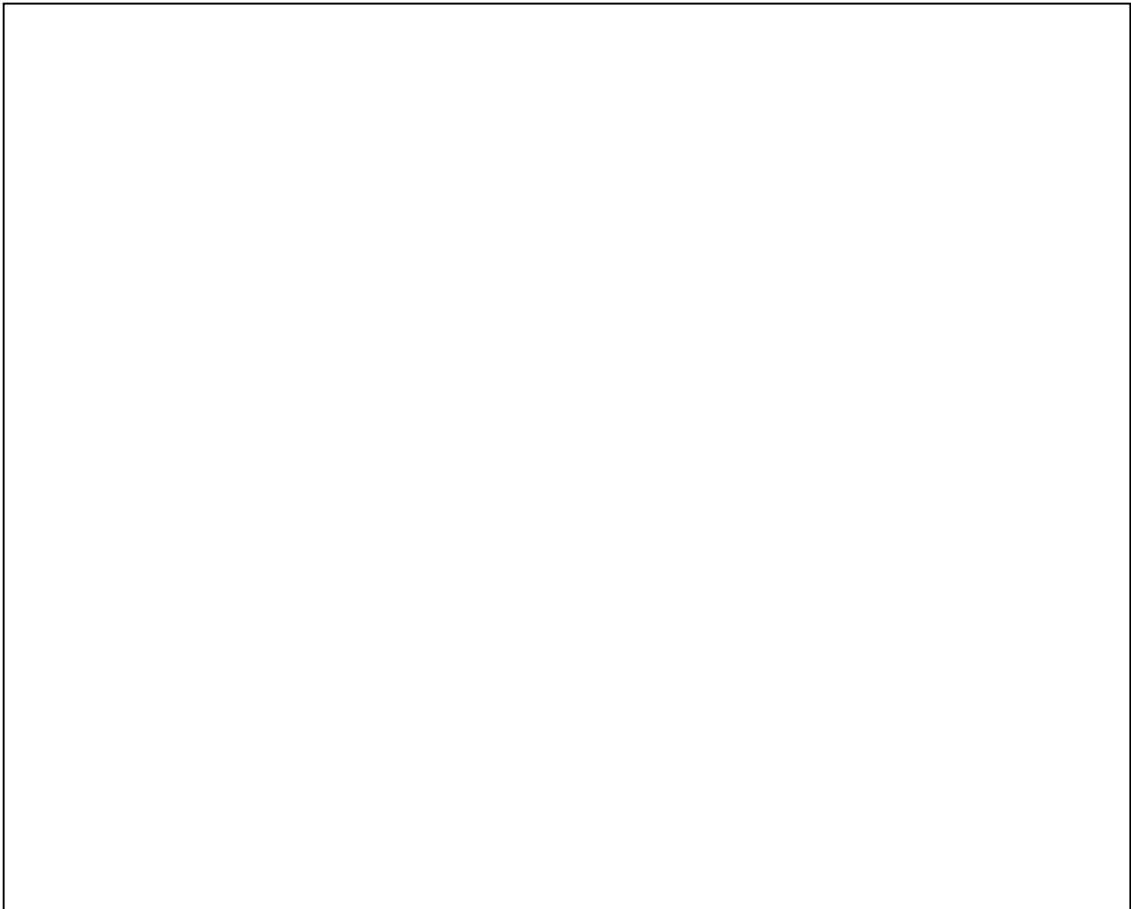
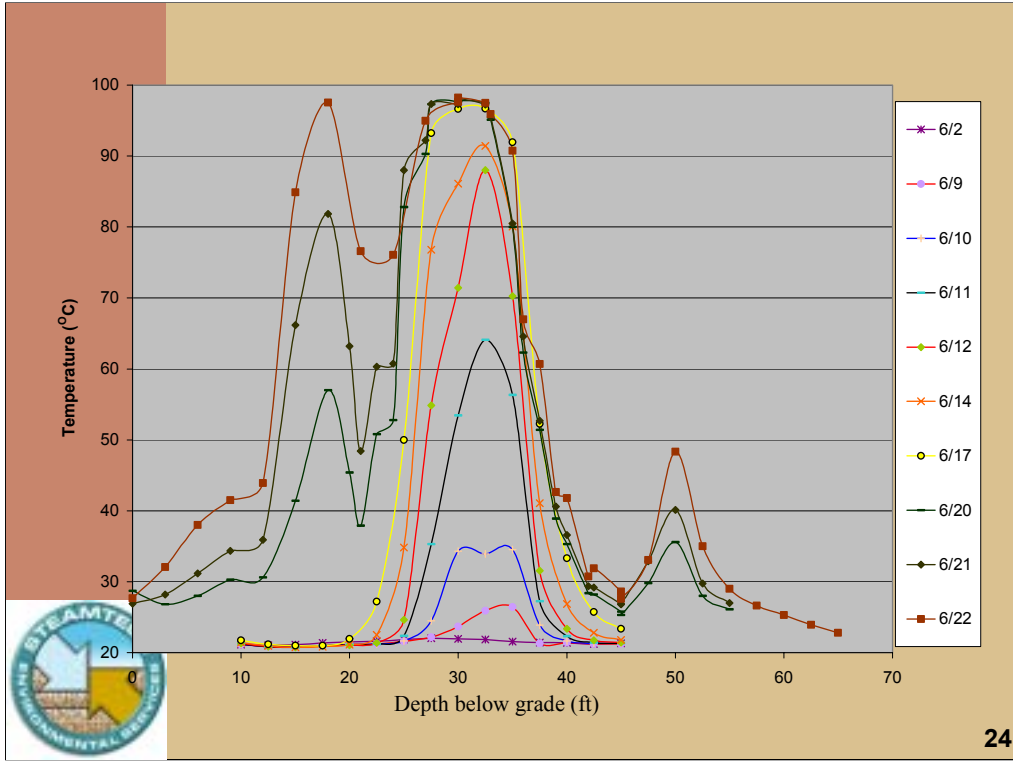


# Example ERT data plane

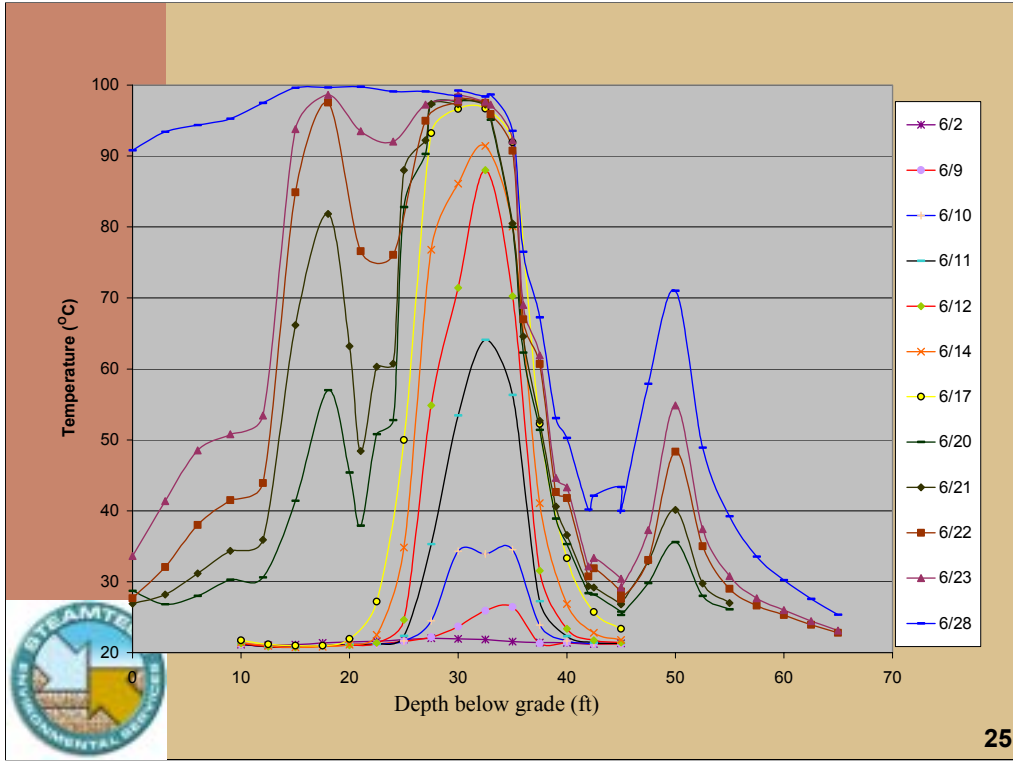


# Thermocouple data

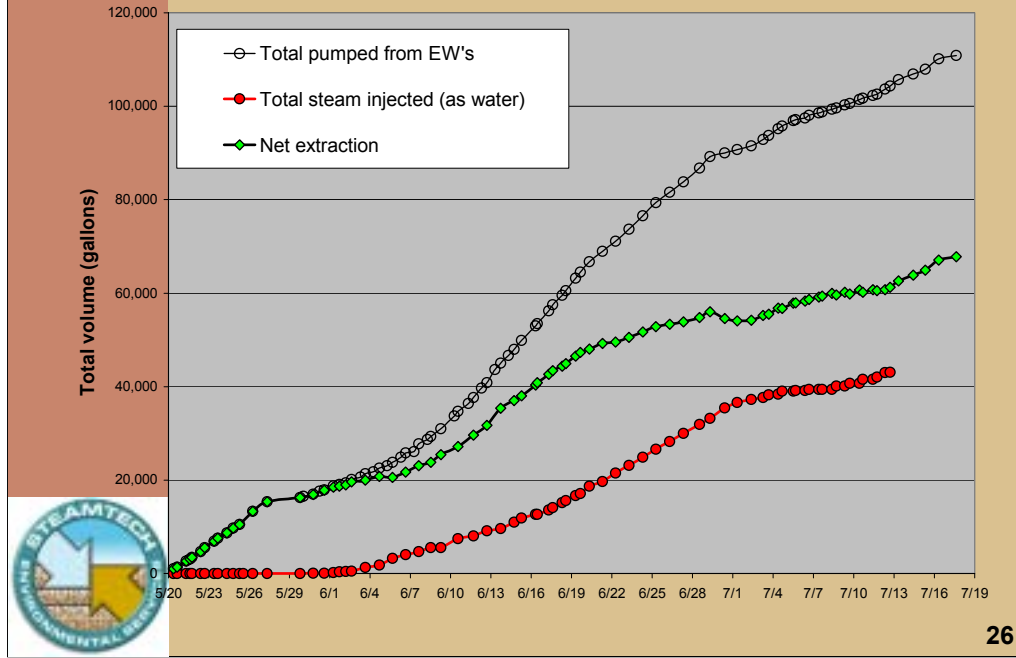




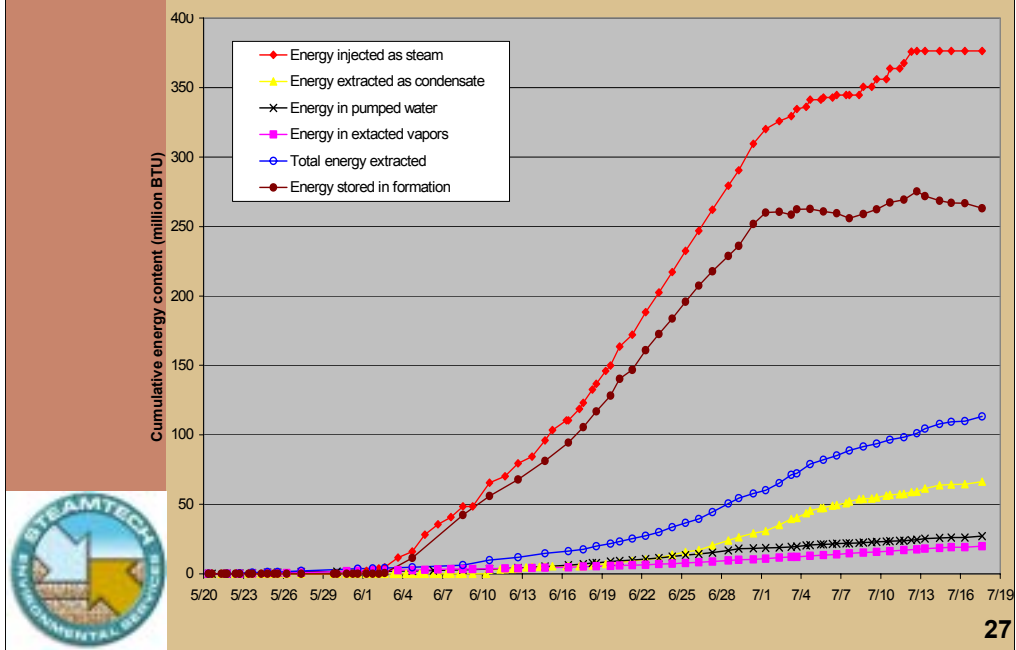


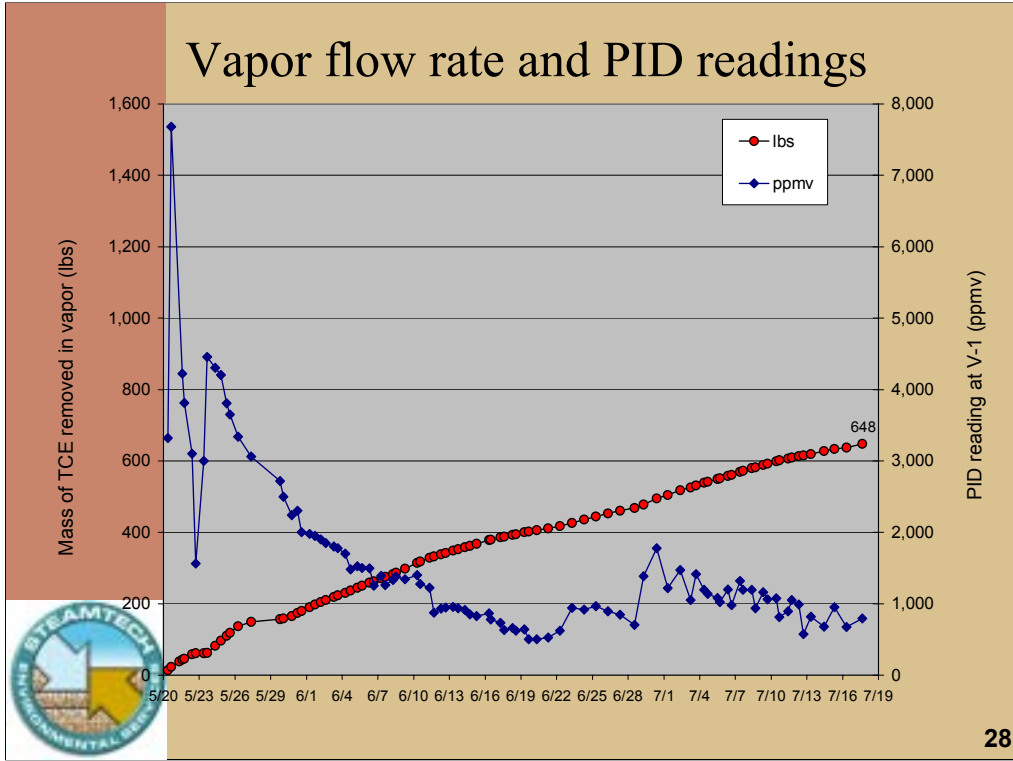


# Water balance

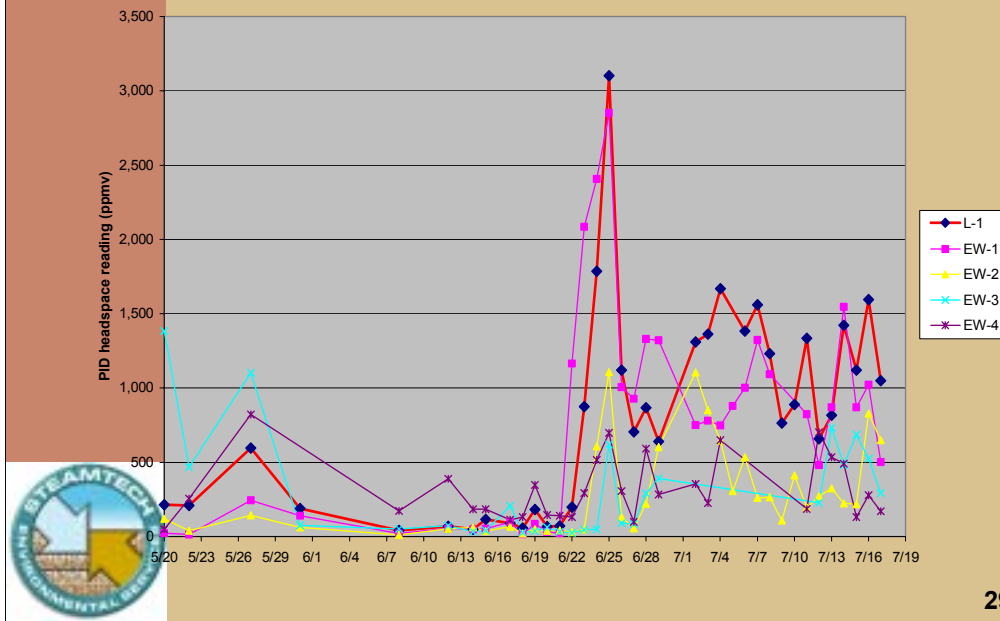


# Energy balance

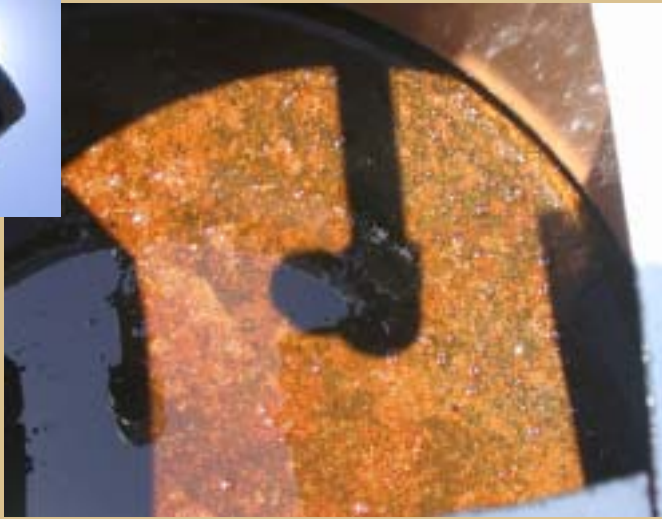




# Headspace PID data



# Recovery of NAPL



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## Results

- Successful treatability study - great data
- Steam heated site partially, and accelerated mass removal
- More than 700 lbs of VOCs removed
- NAPL recovered where no NAPL was expected
- Air injection promising for opening fractures to steam flow, and potentially for reducing risk of NAPL condensation
- ERT apparently valuable at Edwards: Heated zones showed large changes in electrical resistivity
- Very uneven steam distribution: Increased focus on temperature monitoring, also in extraction wells

