LNAPL Remediation via Horizontal Biosparging Wells Facilitates Property Redevelopment

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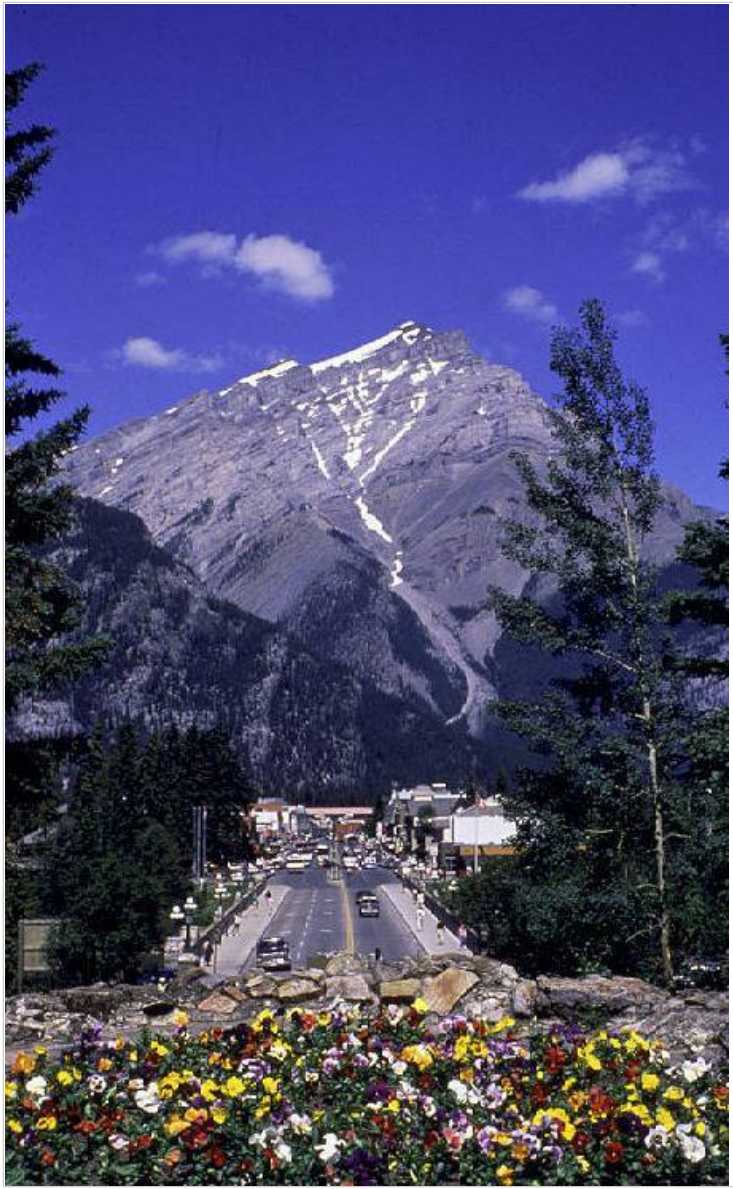


Outline

- **Site History and Background Information**
- **Horizontal well design and installation**
- **Air delivery system design and installation**
- **Performance monitoring results**
- **Summary**

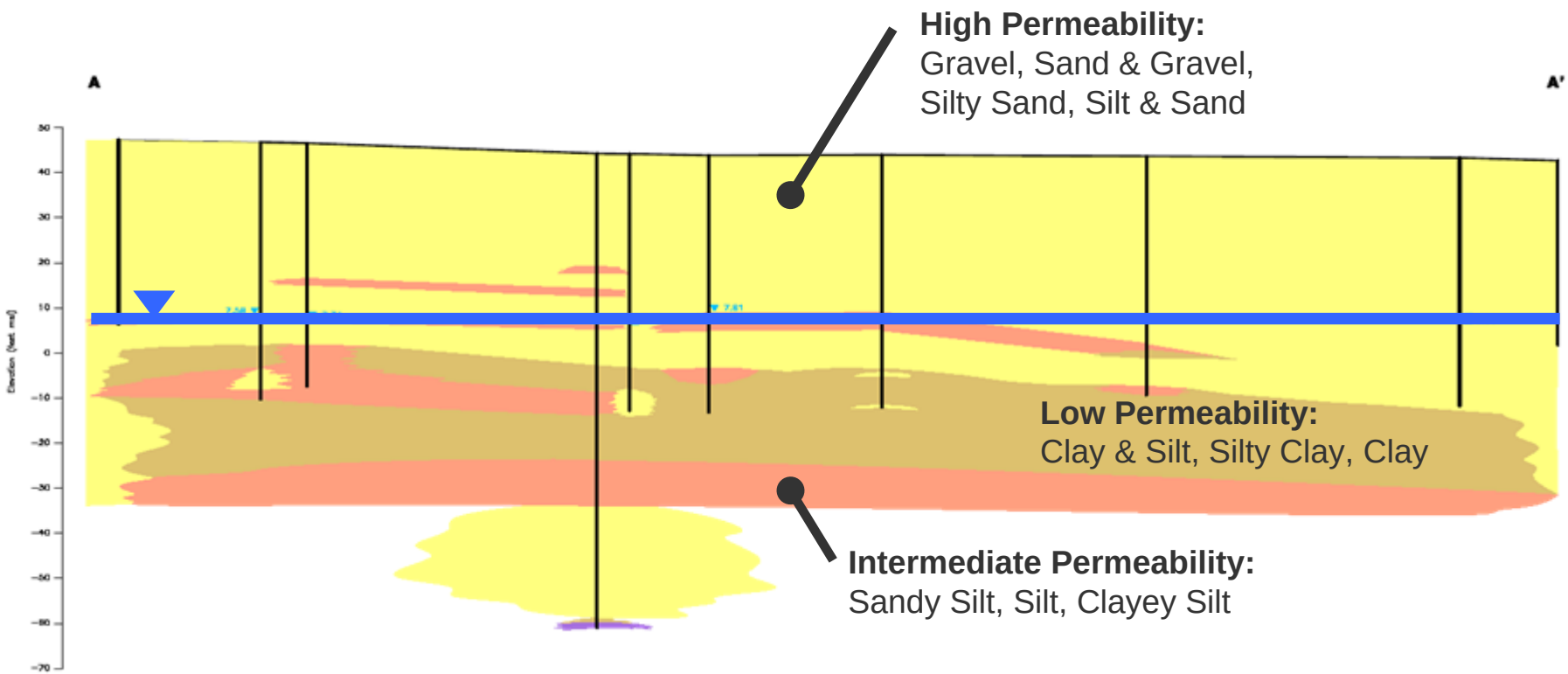
Background

- **Former 55 acre manufacturing facility**
- **Facility demolished and property redeveloped into commercial warehouses**
- **Groundwater impacted by LNAPL and dissolved-phase VOCs (toluene and derivatives) exceeding groundwater standards**
- **Residual LNAPL in smear zone soil serving as source of dissolved-phase VOCs in groundwater**

Pre-Redevelopment

Redeveloped Property

Geologic Cross-Section



Remediation Issues

- **Soil and groundwater impact delineated prior to sale**
- **Two Areas of Concern (AOCs) with residual and free LNAPL**
  - Toluene and other aromatics
  - Source of dissolved-phase volatile organic compounds (VOCs) in groundwater
- **Minimal impact on redevelopment**

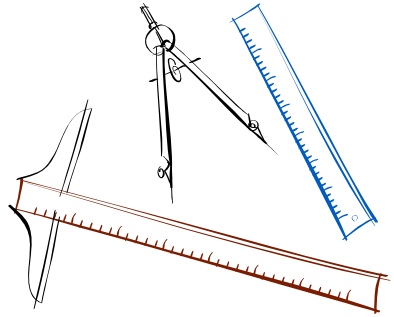
Why Horizontal Well Biosparging?

- **VOCs are aerobically biodegradable**
- **Sandy soil conducive to air sparging**
- **35 to 40-foot depth to water table provides sufficient soil column for VOC vapors to diffuse and biodegrade before reaching ground surface**
- **Construction and operation of horizontal wells would have low impact on property redevelopment compared to vertical wells**
- **Larger area of influence compare to vertical wells**

Approved Remediation Program

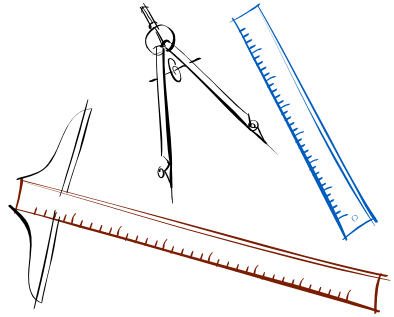
- **Horizontal Biosparging to remediate the two LNAPL AOCs**
- **Redevelopment of the site to prevent direct contact**

Horizontal Well Design

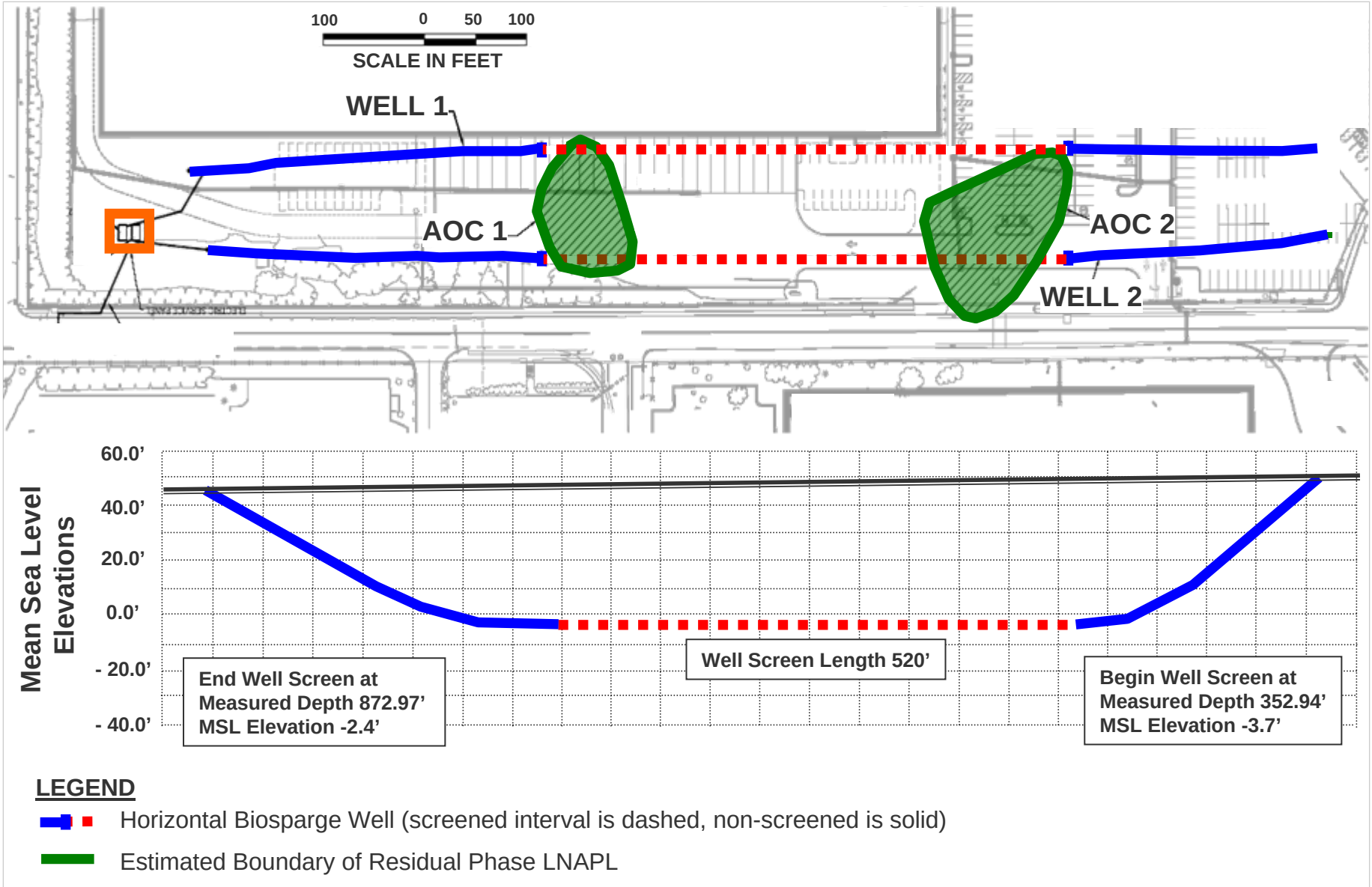


- **Complex well screen design**
  - Well screen slot sizing
  - Injection pressure for uniform airflow distribution
  - Well screen resistance to aid in uniform airflow distribution
- **Specifications**
  - Two parallel horizontal wells at ~50 feet bgs
  - ~1,200 linear feet total length
  - ~520 linear feet of custom slotted well screen
  - 100 - 120 scfm air flow (260 capacity) at 9.7 psi
  - 6 inch well casing and screen diameter
  - Material of construction is SDR-11 HDPE

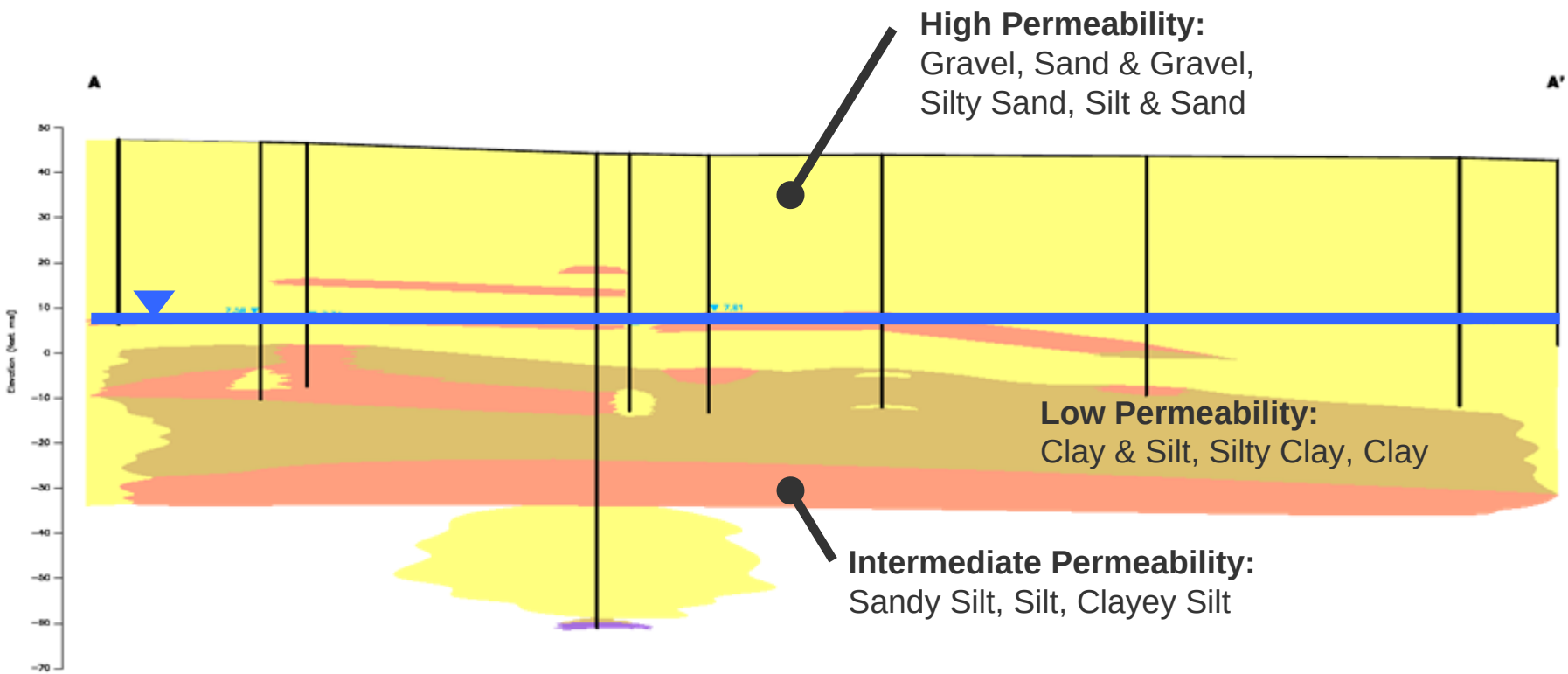
Horizontal Well Design



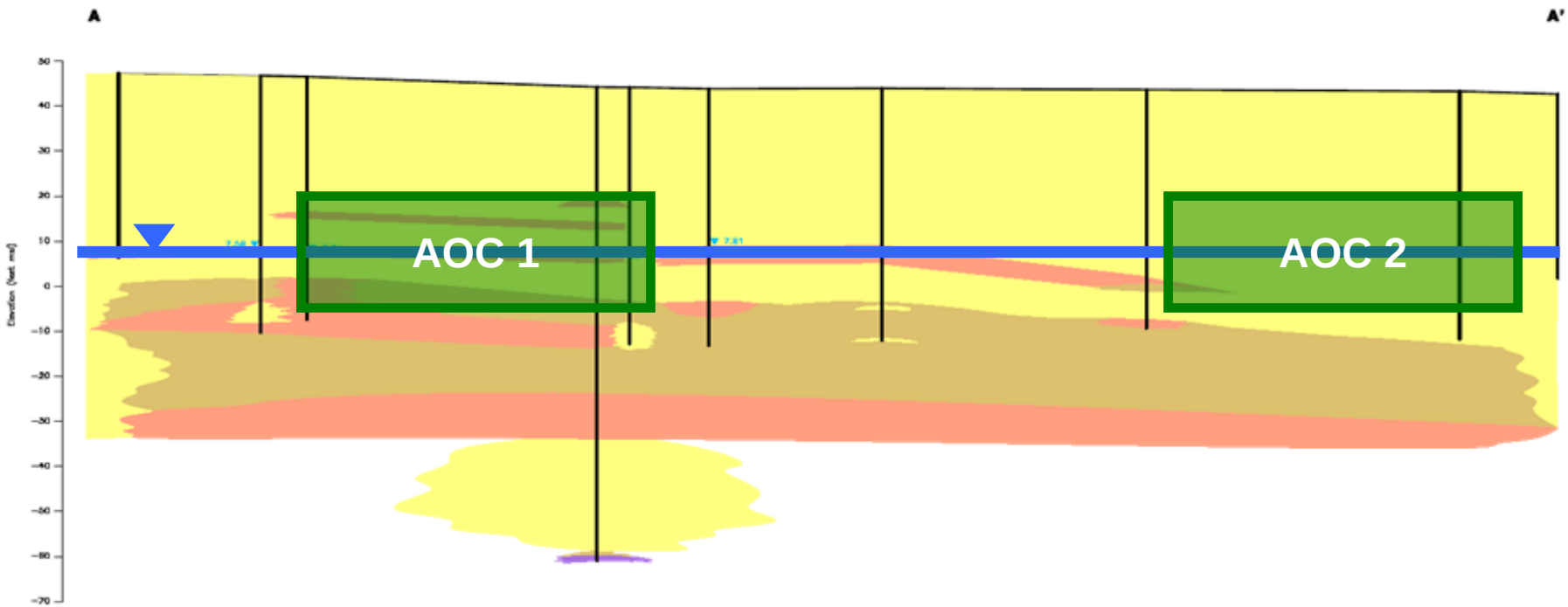
- **Well Screen Slot Size:**
  - Two sections of custom slotted well screen
  - 2 rows of lateral slots for each section
  - First section: 26 slots/foot, 0.02-in wide by 0.625-in long (measured on inside of pipe)
  - Second section: 22 slots/foot, 0.02-in wide by 0.75-in long (measured on inside of pipe)
- **Injection Pressure: 9.1 psi @ 260 cfm**


100 0 50 100
SCALE IN FEET
WELL 1
AOC 1
AOC 2
WELL 2
Mean Sea Level Elevations
60.0'
40.0'
20.0'
0.0'
- 20.0'
- 40.0'
End Well Screen at Measured Depth 872.97' MSL Elevation -2.4'
Well Screen Length 520'
Begin Well Screen at Measured Depth 352.94' MSL Elevation -3.7'
LEGEND
Horizontal Biosparge Well (screened interval is dashed, non-screened is solid)
Estimated Boundary of Residual Phase LNAPL

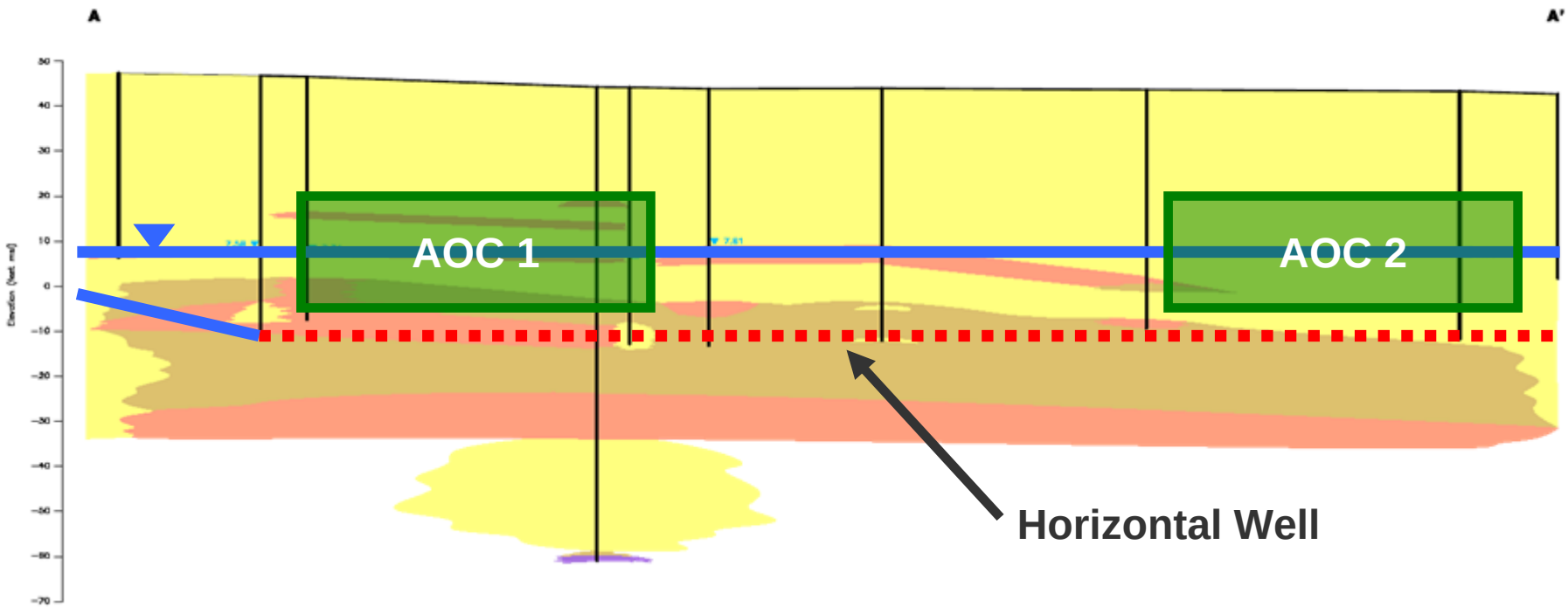
Geologic Cross-Section



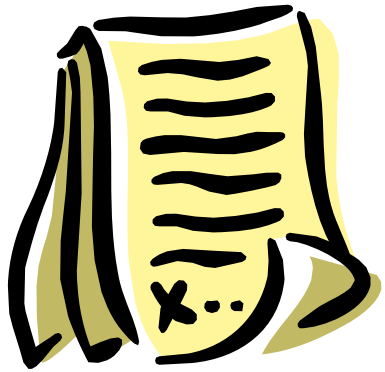
Geologic Cross-Section



Geologic Cross-Section



Permitting/Regulatory Approvals



- **Well Installation Permit**
  - Default well installation regulations are based on vertical wells; therefore needed State approval
  - Proposed alternate grouting procedure to protect the well screen while satisfying intent of regulations
    - intent = *not creating preferred pathway for surface discharge to impact groundwater*
    - *Note: >>$$ to reinstall well screen if grout impacted*
- **Air Permit**
  - State indicated that no permit is required since no air emissions expected (no SVE)





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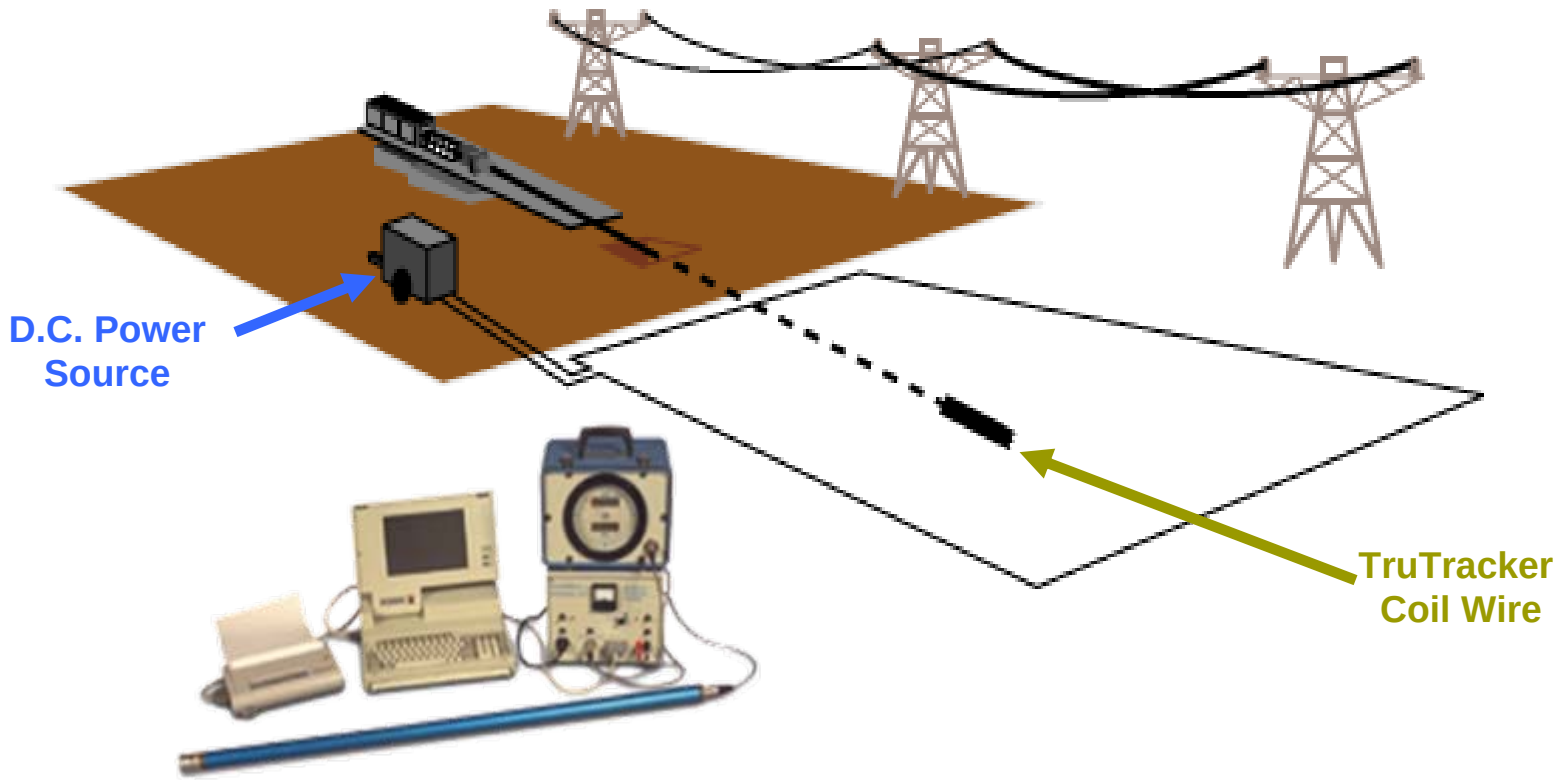
TruTracker Navigation



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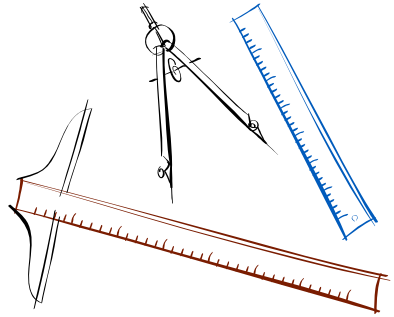
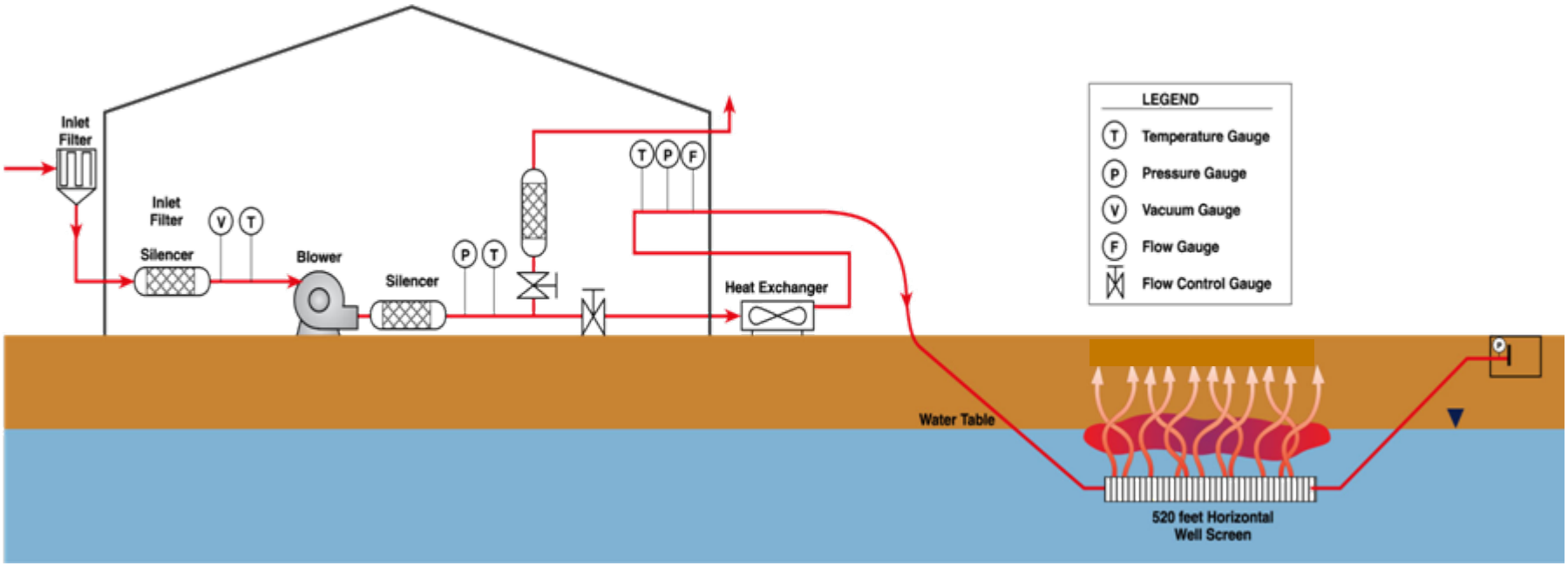
HBW-2

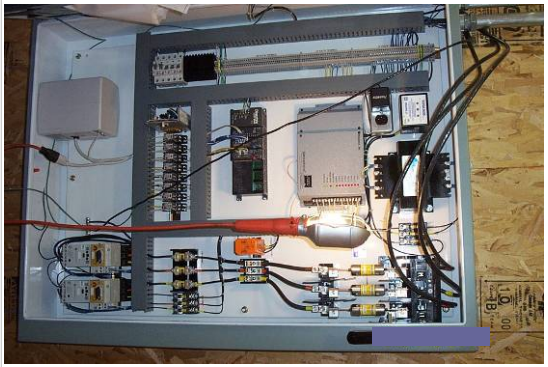
Air Delivery System Design



- **Separate air delivery system for each well**
- **Each system consisted of the following:**
  - 30-HP positive-displacement blower
  - Air-to-air heat exchanger (outside of shed)
  - Flow control valve and meter
  - Air bleed line with flow control valve
  - Pressure and temperature instrumentation
  - PLC and autodialer
- **Blower capable of delivering 260 cfm at a pressure of 9.7 psi (9.1 psi injection pressure plus 0.6 psi of head losses in system before entering the well)**

Process Flow Diagram





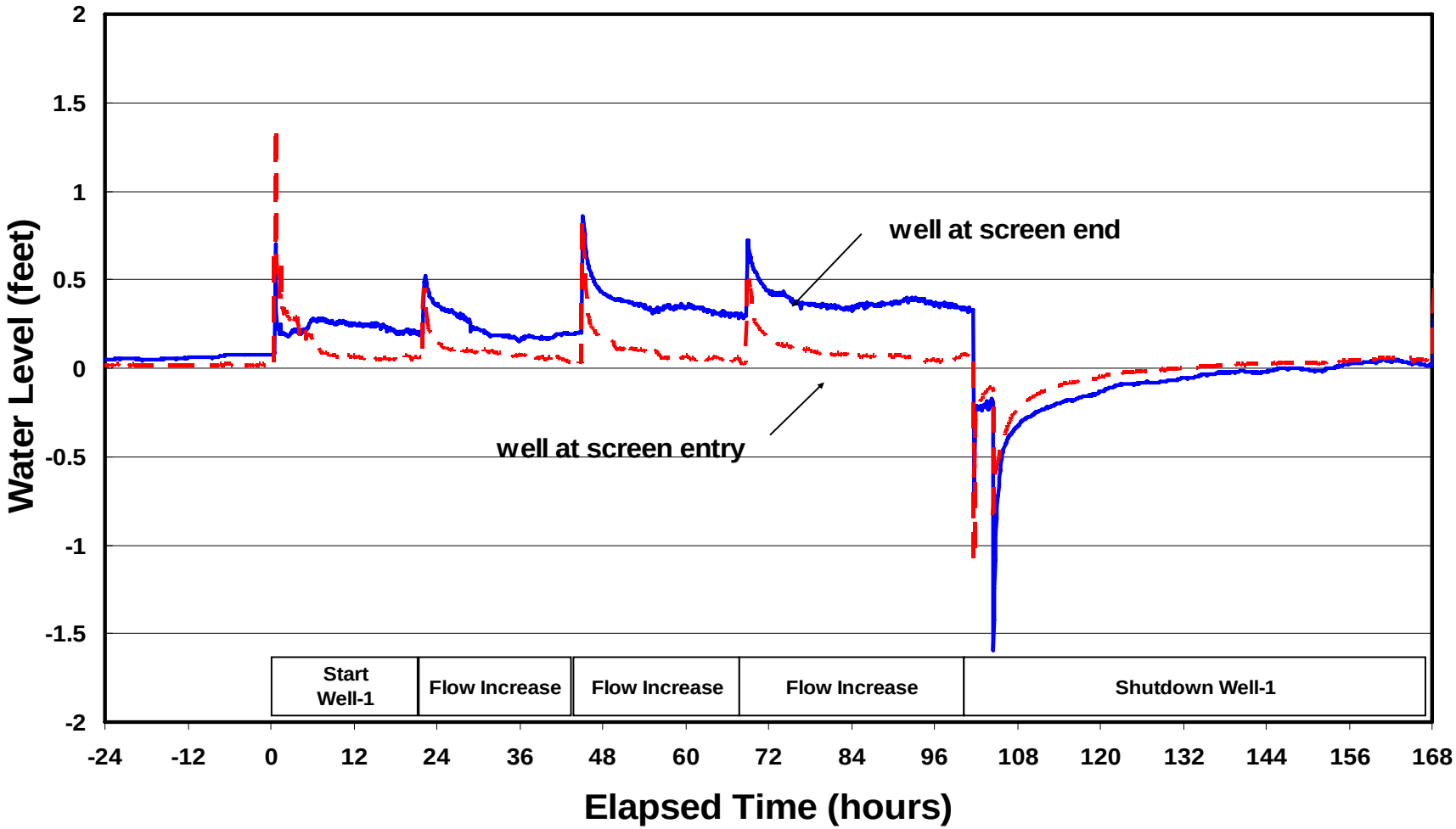
Performance Monitoring

- **Zone of influence measurements**
- **Soil gas sampling**
- **Groundwater sampling**
- **Soil sampling**

Zone of Influence

- Pressure transducers were used to monitor the influence of the system on ground water levels during both startup and again during shutdown
- The influence of the injection of air on the aquifer was evident along the length of both horizontal wells
- Air release within wells also used to confirm zone of influence (i.e., radius of influence)

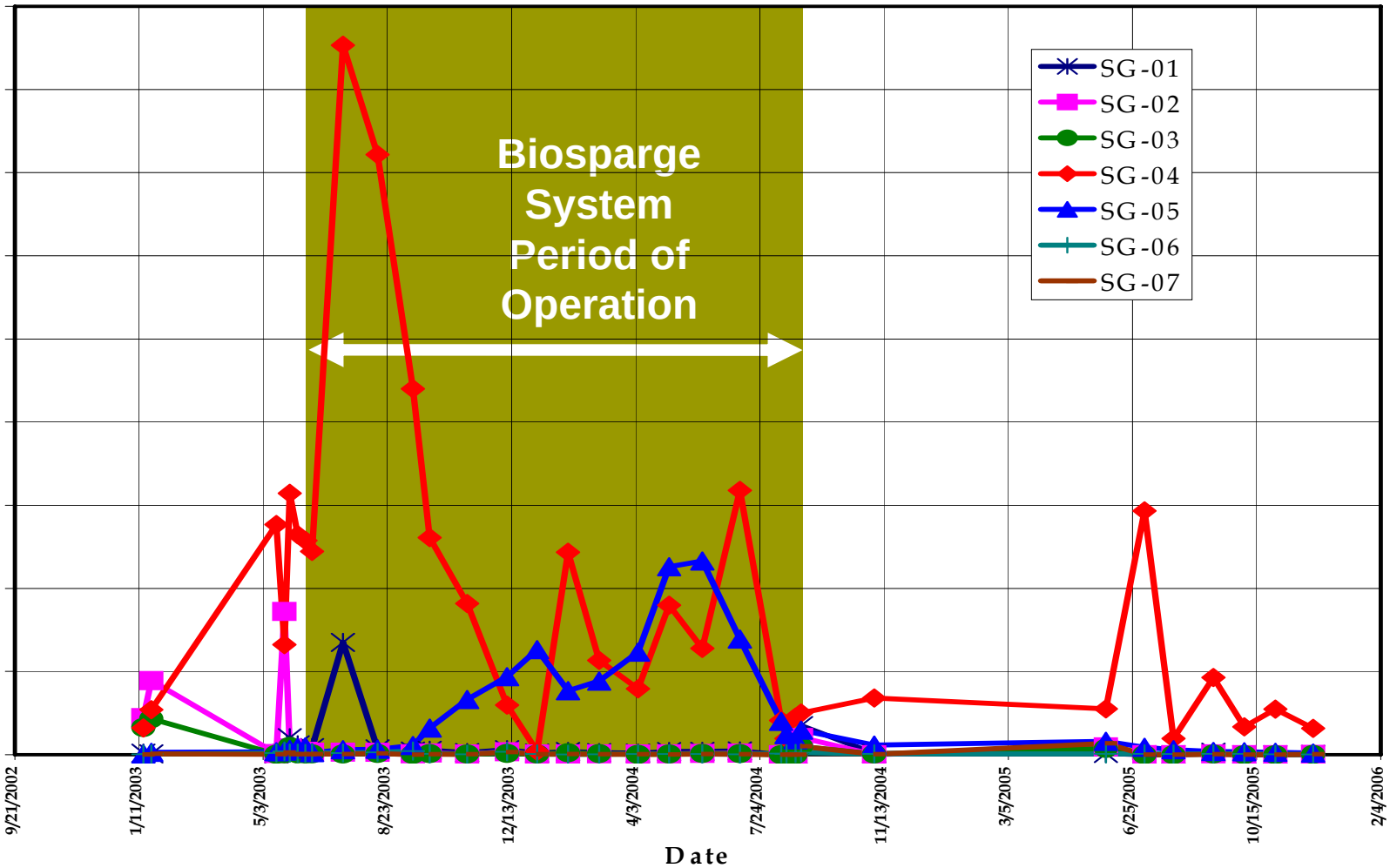
Water Level Response



Soil Gas Sampling

- **Collected weekly from 7 locations**
- **Tedlar bags from 3 feet bgs from 1 inch probes**
- **Off-site analysis during operating period**
  - Prior to start-up- weekly for 1 month
  - Weekly for 1st month
  - Monthly until October 2005
- **On-site screening – daily for 1st week of operation**

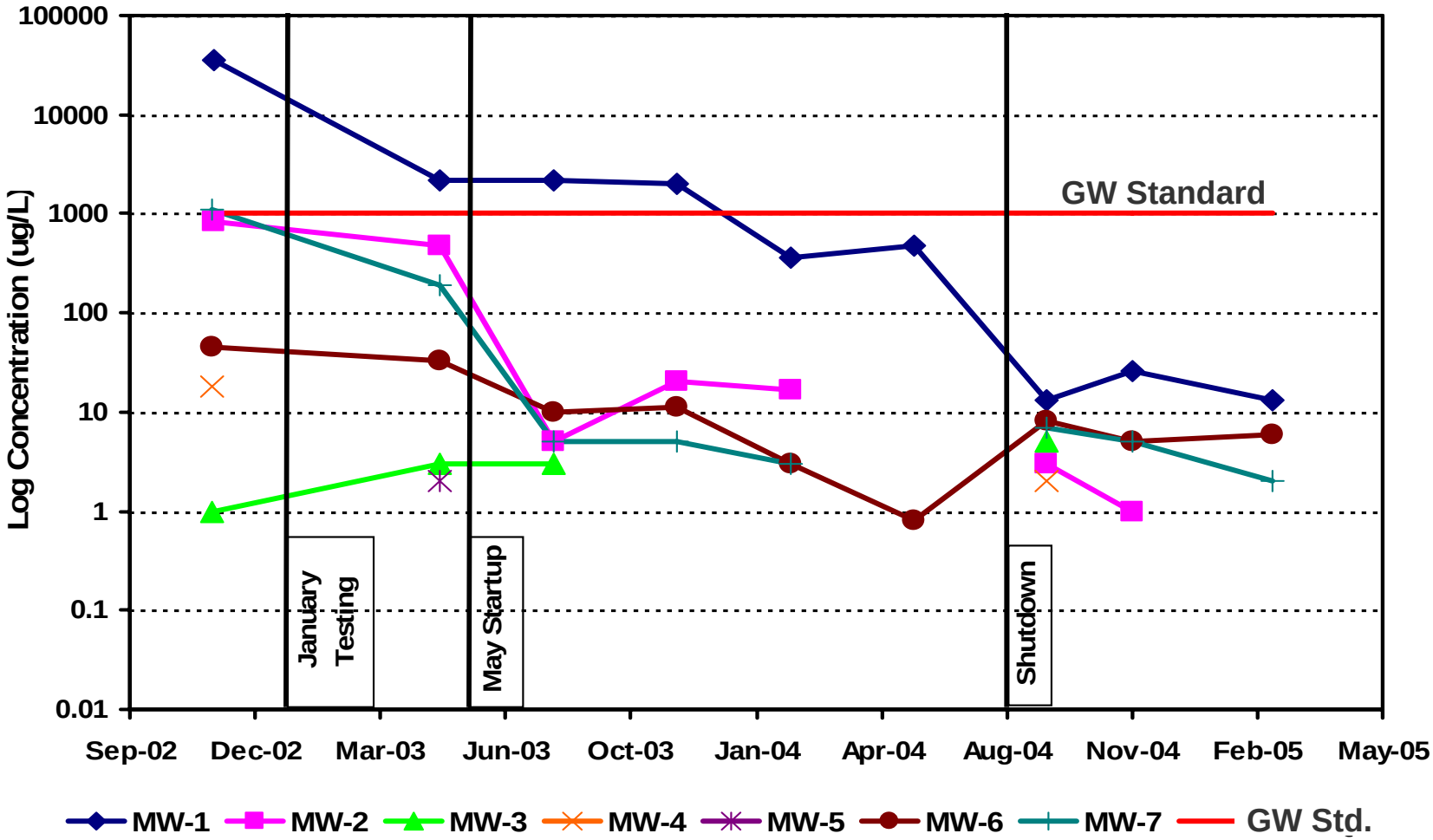
Soil Gas Concentrations



Ground Water Sampling

- **Monitored quarterly from 7 locations**
- **Monitored before, during, and after operation**
- **Low flow sampling method**

Groundwater Concentrations



Soil Sampling Results

- **Continuous sampling within vadose zone and across water table**
- **Visual observations indicated a decrease in free and residual LNAPL**
- **One boring with indications of residual LNAPL**

Summary

- Zone of influence of ~50 to 100 feet laterally (the targeted treatment area) with a constant pressure maintained.
- Toluene levels within groundwater (a direct measure of LNAPL presence) decreased and maintained after shutdown below the applicable State groundwater standards.
- Free phase LNAPL not observed within monitoring wells after four months of system operation. Additionally, no free phase LNAPL has been observed within onsite monitoring wells since shutdown.

Summary

- No free phase LNAPL and only slight indication of residual LNAPL was observed within the soil borings completed after the system was shutdown.
- Soil gas concentrations indicated that the system was able to contact the contaminants of concern within the formation and that some volatilization occurred, but stabilized once biomass built up.

Acknowledgements

- **My coworkers and coauthors**
  - William Butler, P.E., BCEE
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Questions?

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