LONG-TERM SOIL VAPOR EXTRACTION MONITORING AND EFFECTIVENESS IN TWO ADJOINING LOW PERMEABILITY ZONES

CONFERENCE ON REMEDIATION OF CHLORINATED AND RECALCITRANT COMPOUNDS

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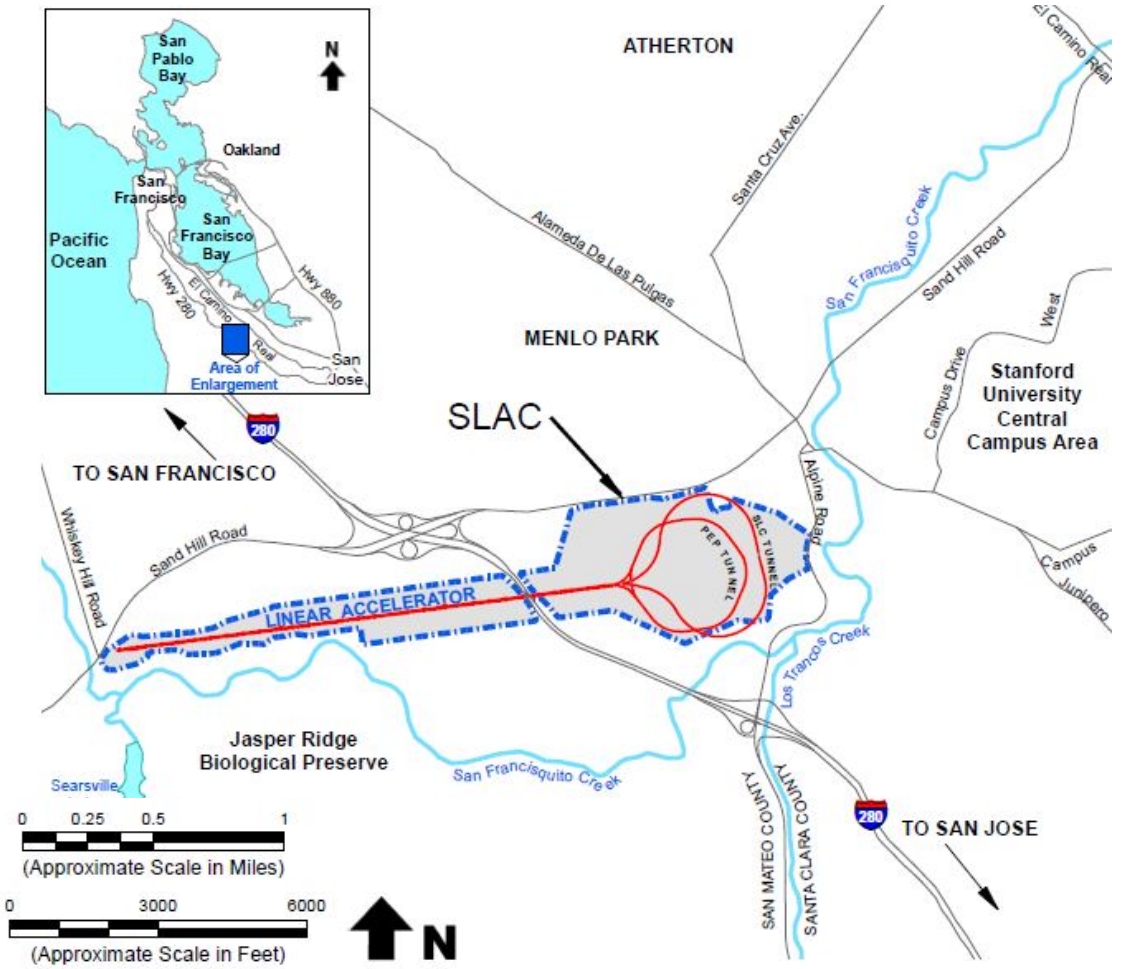
SLAC NATIONAL ACCELERATOR LABORATORY

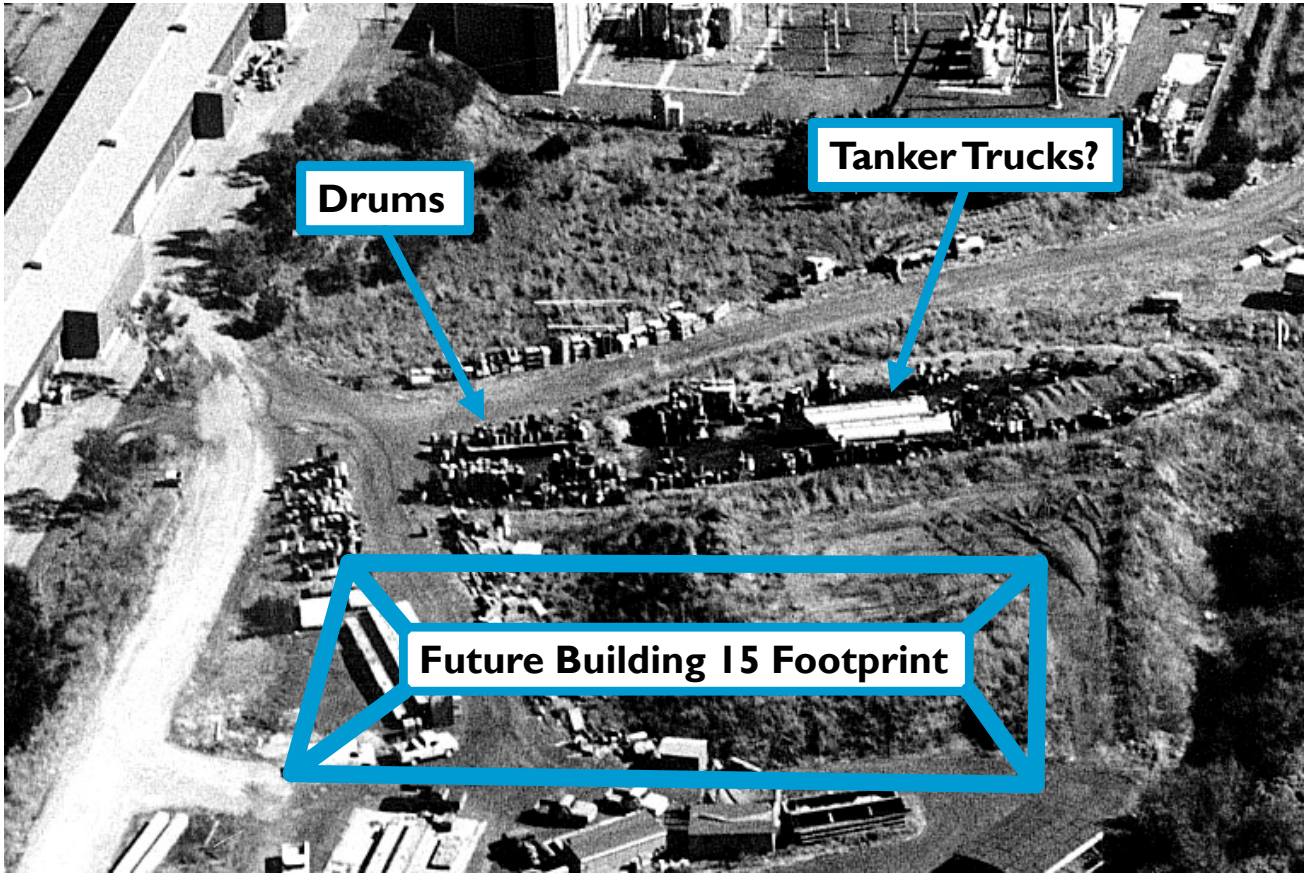
INTRODUCTION

- SLAC = SLAC National Accelerator Laboratory
  - A U.S. Department of Energy (DOE) laboratory operated by Stanford University
- FHWSA = Former Hazardous Waste Storage Area



FHWSA HISTORY

- Used for storage of hazardous materials from late 1960s to early 1980s
- VOCs found in both groundwater and soil vapor
- Dual-Phase Extraction (DPE) has been primary element of remedy at FHWSA since 2006.



FHWSA CURRENT USE

Aerial photograph provided by Google Earth

LOW PERMEABILITY SOIL

- Ladera and Santa Clara Formations covered by thin clay/import fill
  - Micro-fractured silty-sandstone, behaves as low permeability media
  - Intrinsic permeability ~10^{-9} cm^2
  - Saturated hydraulic conductivity ~10^{-5} - 10^{-4} cm/s
- Soil vapor monitoring was implemented to:
  - Determine risk-based area of concern (for remediation)
  - Monitor remediation progress

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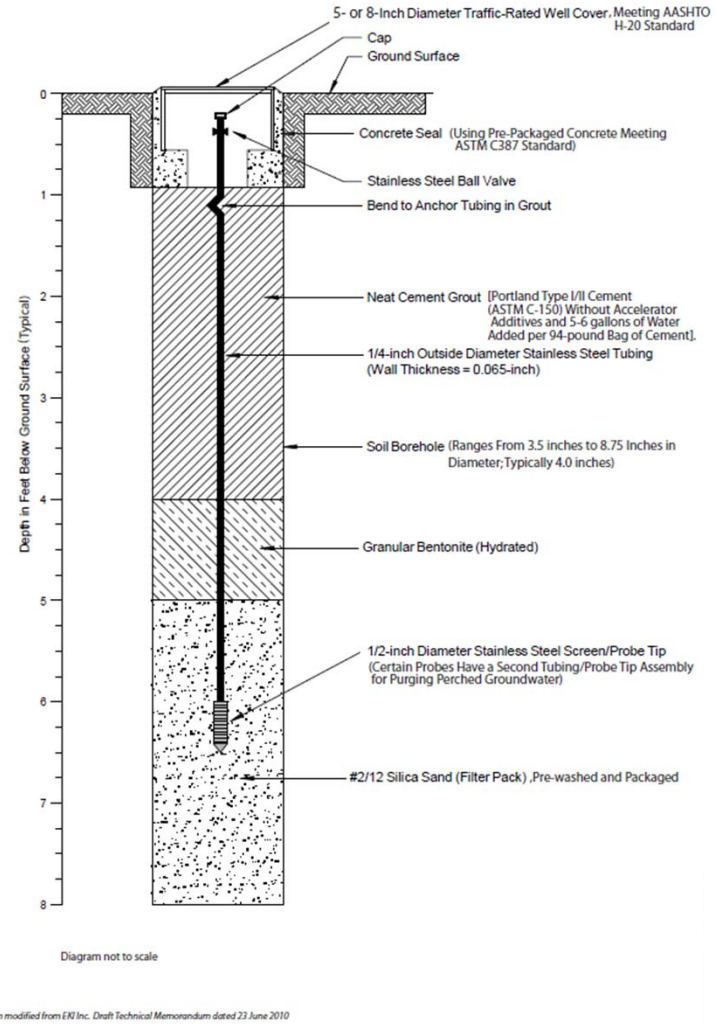
SOIL VAPOR PROBES

- Designed for sampling in low permeability soil
  - Installed with long sand filter pack
  - Minimum 4-liter pore space in sand pack, guaranteeing 1-liter sample
- 56 soil vapor probes (SVPs) installed between 2003 to 2016



SVP SAMPLING METHODOLOGY

- Equilibration method – designed for low permeability
  - Fixed probes are long term, allowing VOC concentration in sand pack void space to equilibrate with soil gas before sampling
  - Purging limited to 3x tubing volume (not sand pack volume), ~50 mL
- 1-liter sample collected (summa canister)
  - 1 liter = ~25% of sand pack void space (4 liters)
  - Vacuum during sampling does not exceed 100 in-WC limit, even if no soil gas flows from soil into sand pack during sample collection
- Has provided representative results (over 14 years of monitoring), key to risk assessment and remediation monitoring

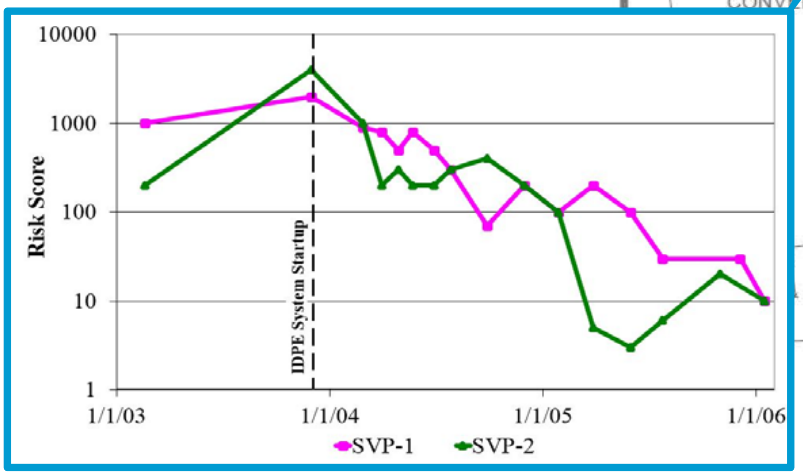
SVP MONITORING AND RISK SCORE CALCULATION

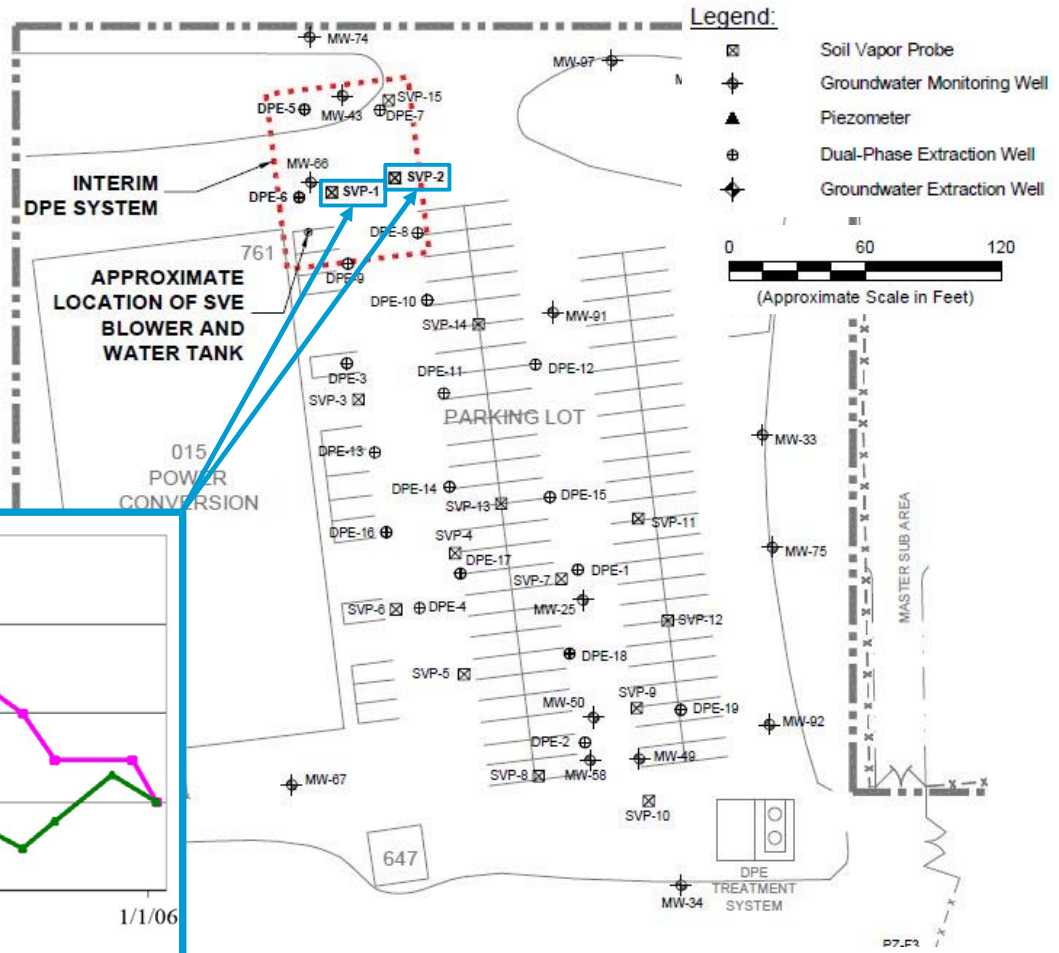
- Analytical results for VOCs in each SVP sample used to calculate cumulative "risk scores"
  - Calculated using risk-based Human Health Preliminary Remediation Goals (HH-PRGs) based on vapor intrusion pathway for unrestricted future land use
  - Risk score of 1 = cancer risk of 1 x 10^{-6}
  - Plotted for 'spatial risk characterization'
- Risk scores are primary method of evaluating risk and remediation effectiveness

Maximum Soil Vapor Risk, pre-2006

DPE PILOT TEST AND INTERIM DPE SUCCESSFUL

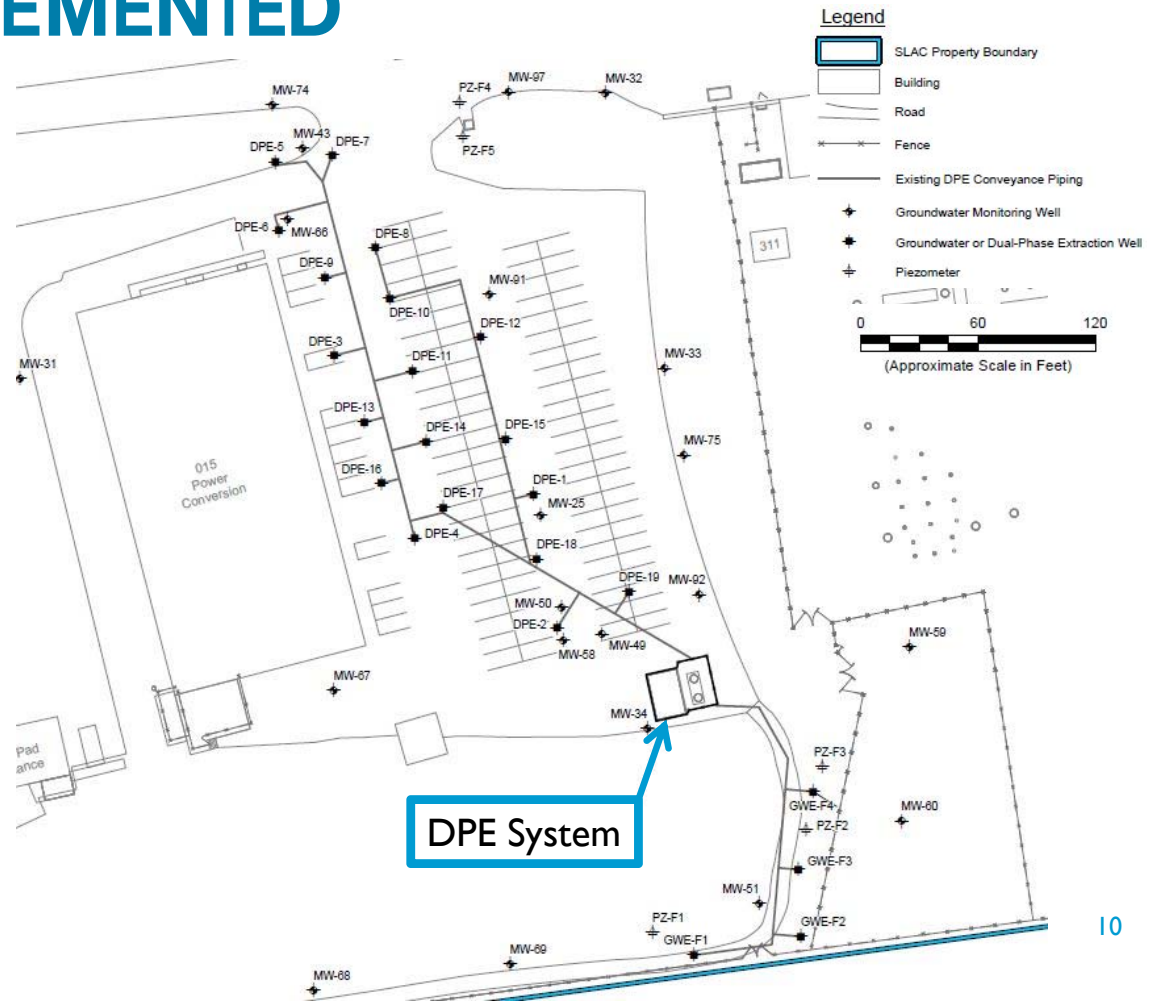
- 2003: DPE Pilot Test
  - SVE shown to be potentially feasible (low air flow attainable)
- 2004-2005: Interim DPE
  - >99% risk reductions shown at SVP-1 and SVP-2





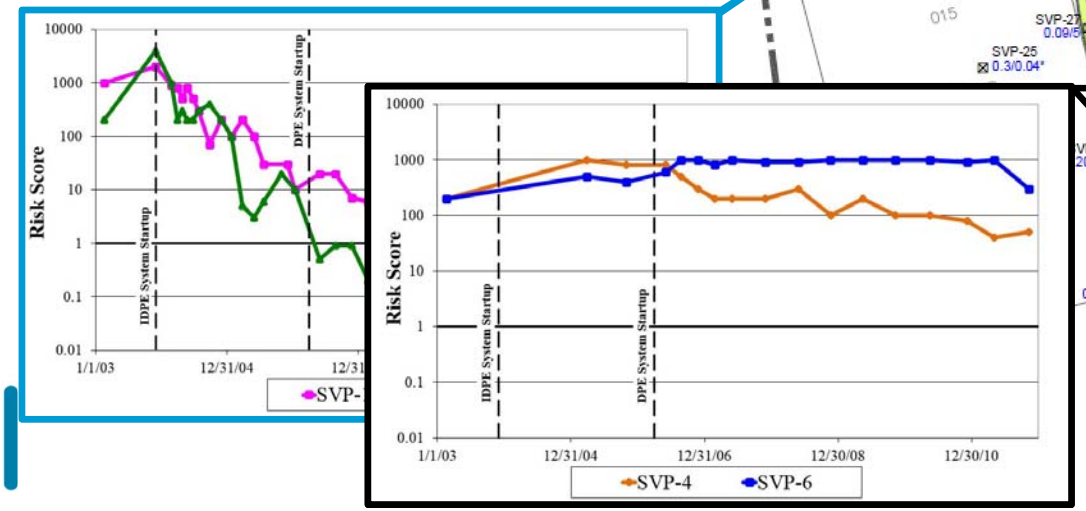
FULL SCALE DPE IMPLEMENTED

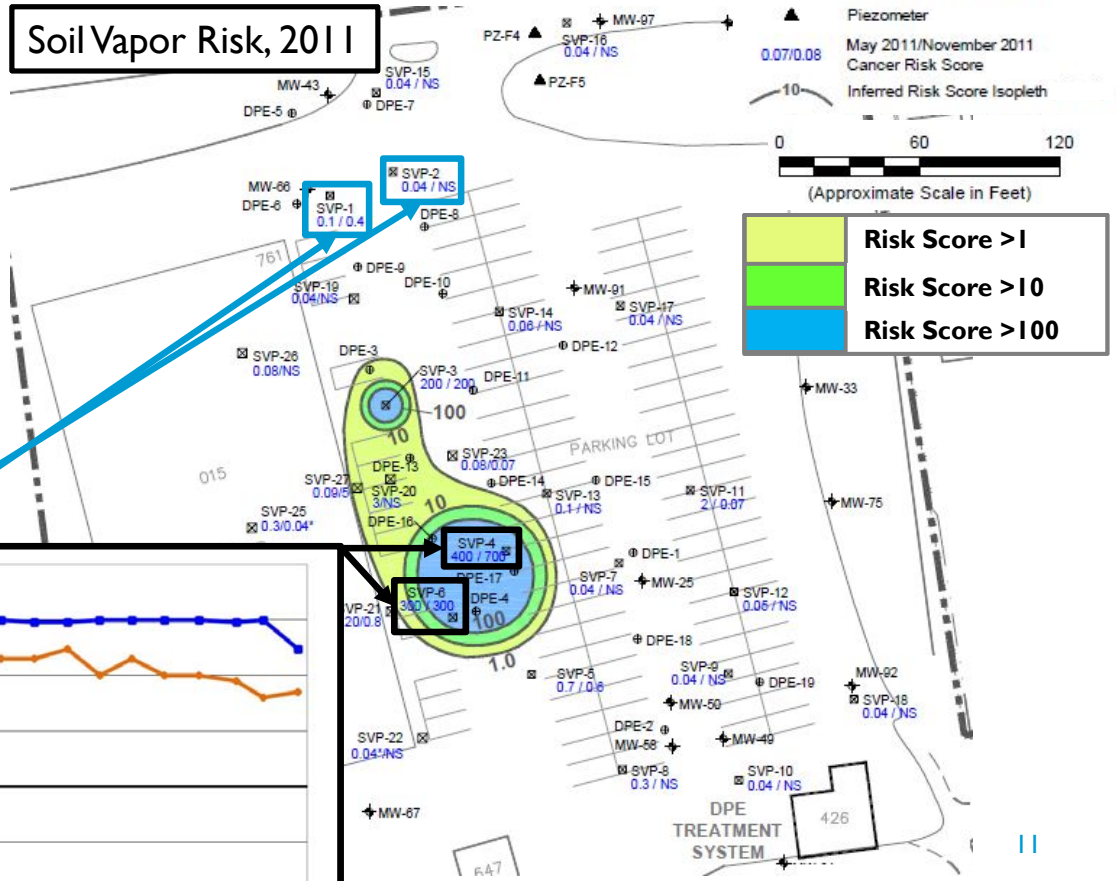
- 2006: Full scale DPE system began operation
  - 23 DPE wells
  - Total SVE flow rate between 50 to 90 scfm
- 15 SVPs to monitor progress
  - filter packs 5 – 8 feet bgs



DPE HAS PARTIAL SUCCESS

- 2011: Risk-based AOC reduced by 85%
  - Successful for most SVPs
    - 1-year rebound test in 2012 proves sustainability of risk score reductions
  - Still ineffective in some SVPs

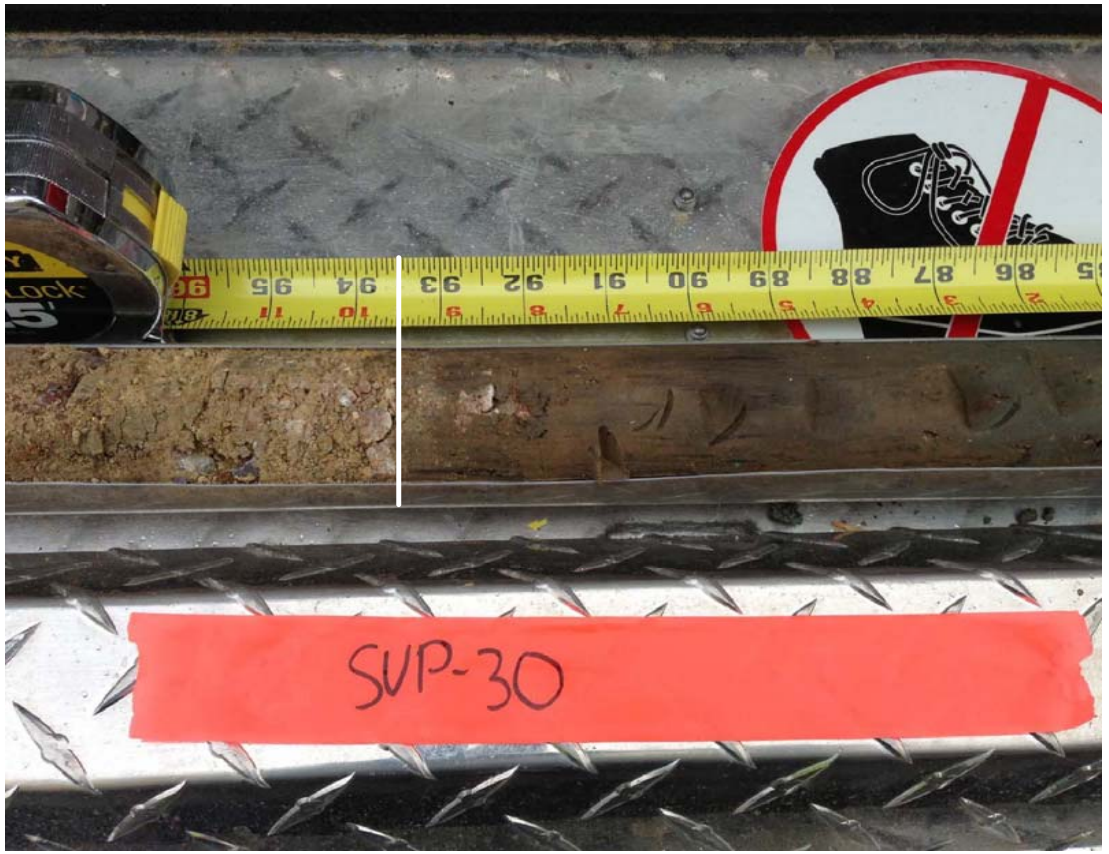




NEW SVPs INSTALLED TO INVESTIGATE SITE MODEL

- Focused on thin shallow clay above Santa Clara Formation and Ladera Sandstone
- 2014: SVP-29 and SVP-30 installed

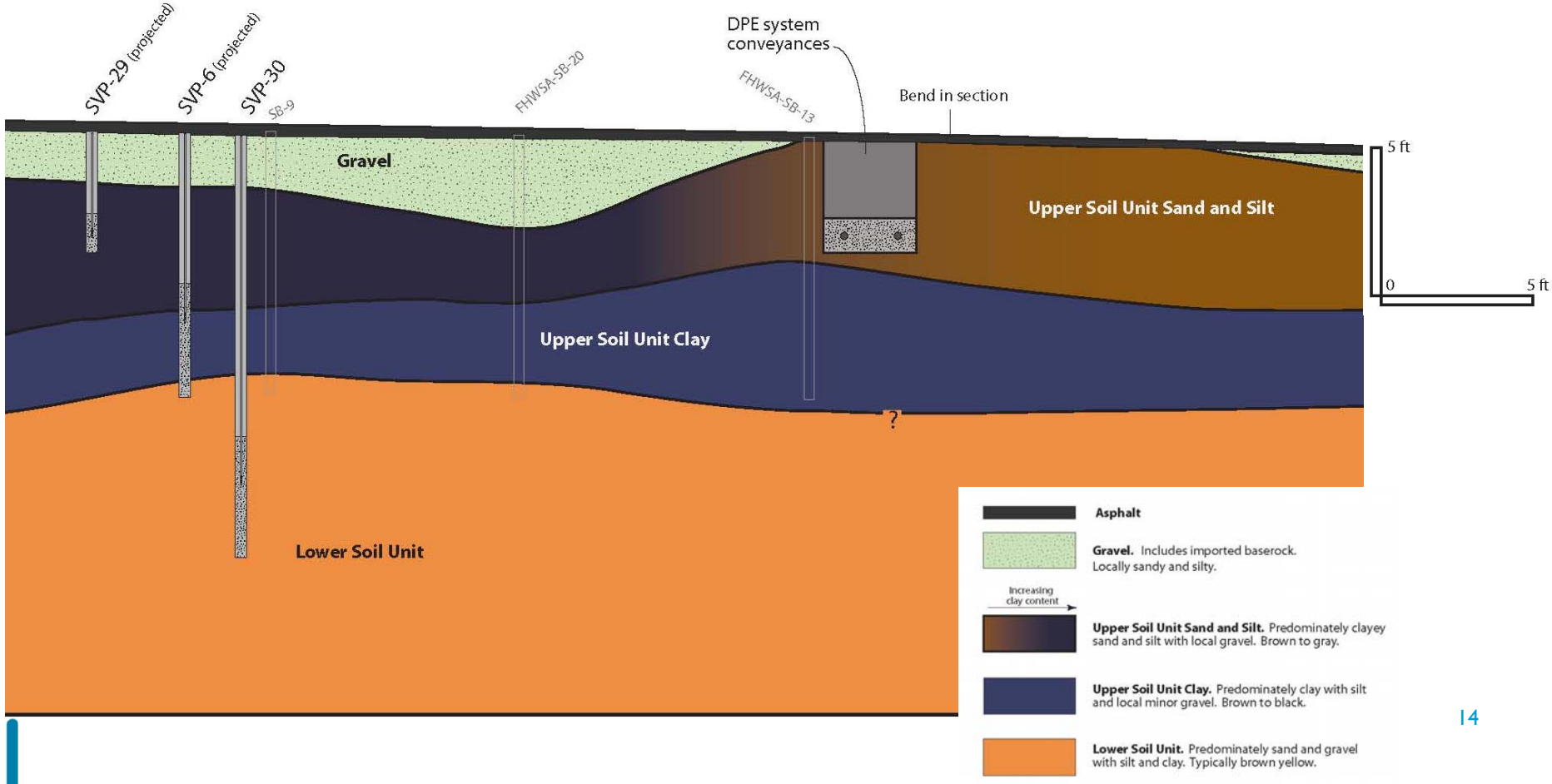
SVP	Filter Pack Interval (feet)	Risk Score (May 2015)
SVP-6	5 – 8.9	200
SVP-29	3.0 – 4.2	900
SVP-30	11.0 – 14.0	0.02



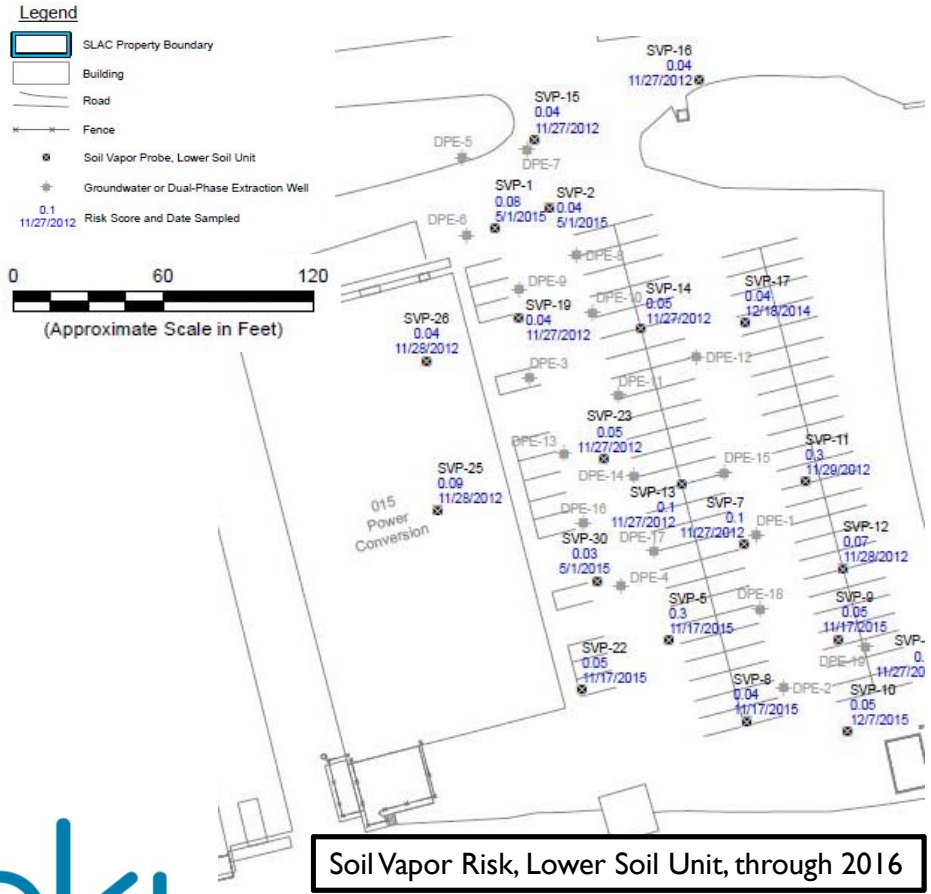
EXPANDED CHARACTERIZATION OF SHALLOW SOIL

- Most existing SVPs below thin clay layer (Lower Soil Unit)
- Some existing SVPs partially within thin clay layer (Upper Soil Unit)
- Between 2014 and 2016, added 26 new SVPs within Upper Soil Unit

HIGH RESOLUTION CROSS SECTIONS DEVELOPED

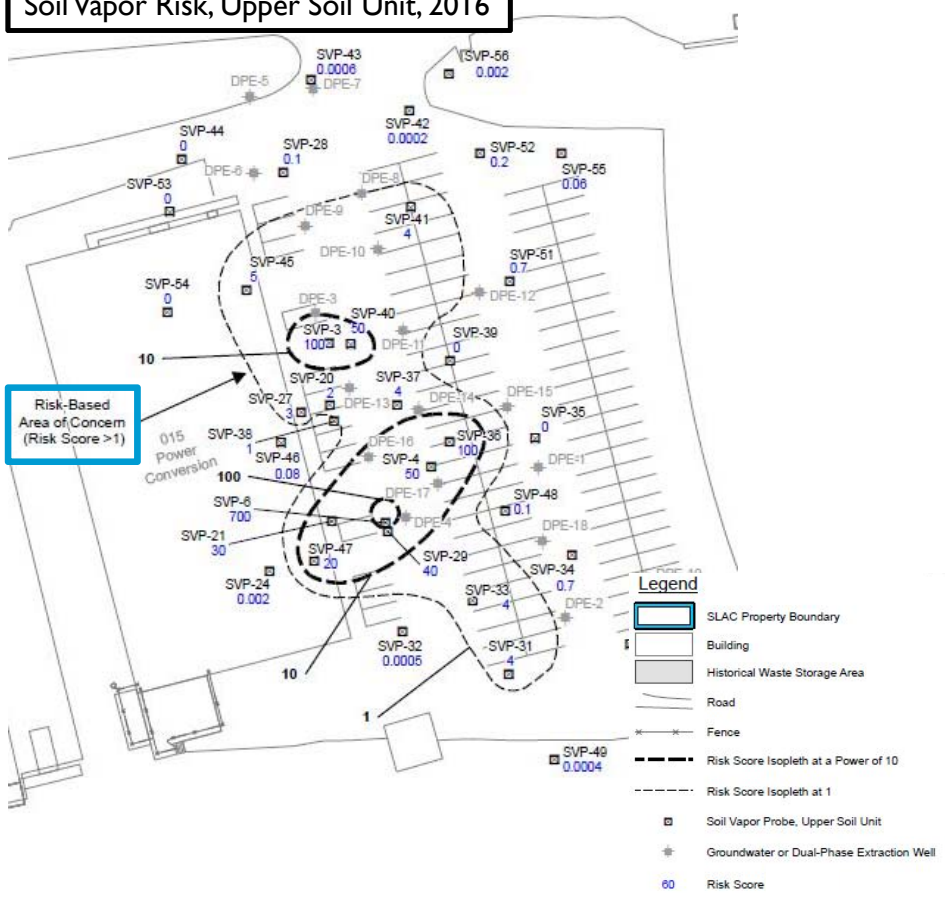


SVPs IN LOWER SOIL UNIT & UPPER SOIL UNIT



Soil Vapor Risk, Lower Soil Unit, through 2016

Soil Vapor Risk, Upper Soil Unit, 2016



ALTERNATIVE REMEDY FOR UPPER SOIL UNIT

- Soil vapor monitoring indicated SVE was not effective in Upper Soil Unit and delineated the area of concern
- Performed evaluation of alternative remedies
- Excavation of shallow clayey soil in upper soil unit AOC planned for Summer 2018

CONCLUSION: SVP MONITORING EFFECTIVE

- Monitoring fixed SVPs using low-purge equilibration method in low-permeability soil delivered consistent results
- Reliable soil vapor data successfully informed:
  - Risk characterization
    - Where to apply DPE
  - Remediation progress evaluation
    - Success in deeper soil
    - Lack of progress in shallow soil
  - Remediation decisions
    - Where an alternative remedy was required for shallow soil

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