NAVFAC
Naval Facilities Engineering Command
SOUTHWEST

Use of Steam to Enhance VOC-TPH NAPL Mixture Dissolution at a Major Source Area through Volatilization, Recovery, and Biodegradation

Naval Air Station North Island, San Diego, CA

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Project Team

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**** Presenting***

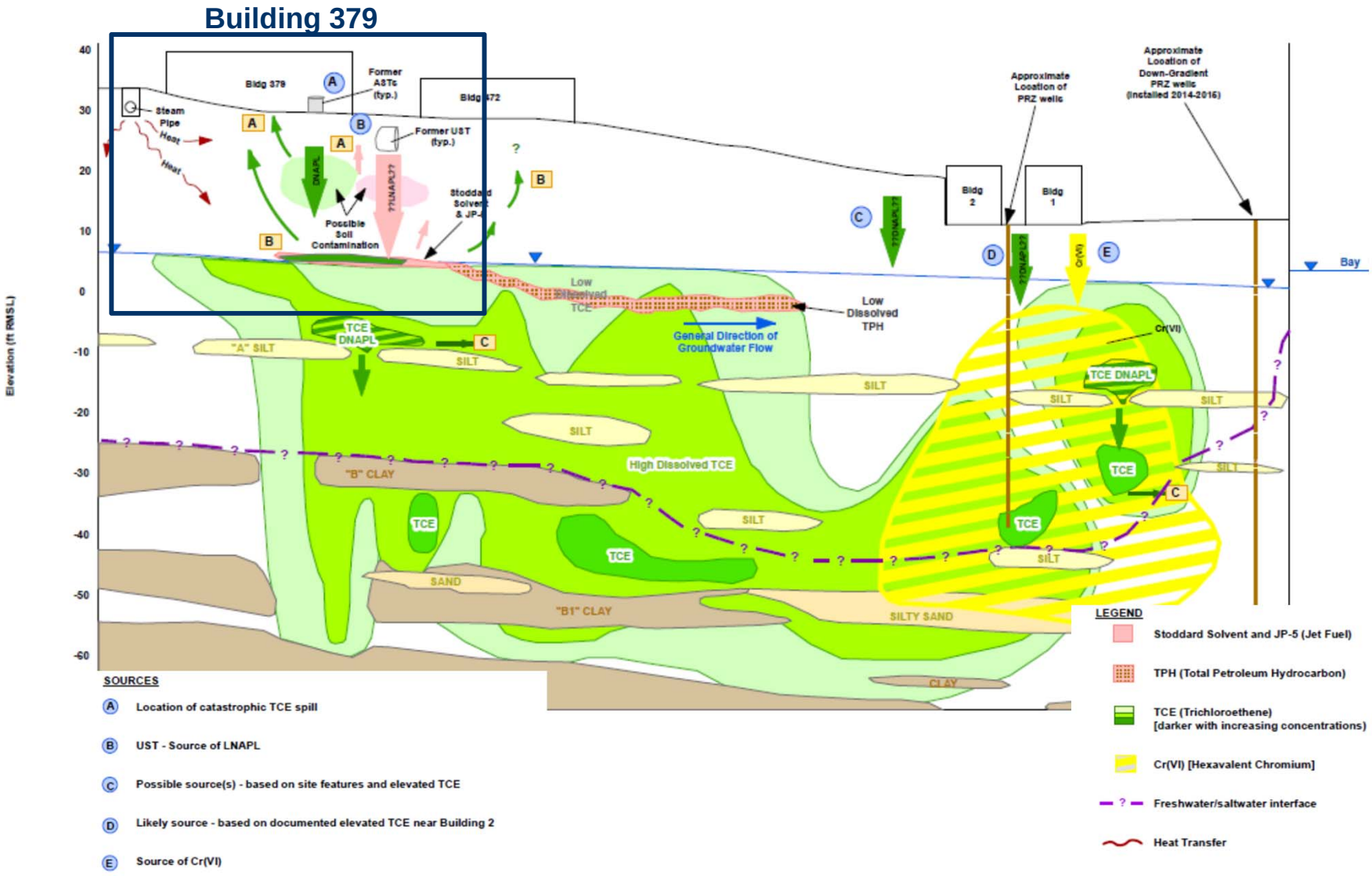
Presentation Overview

1. **Background**
2. **Site Conditions**
3. **Objectives**
4. **Results**
5. **Key Findings (To Date)**

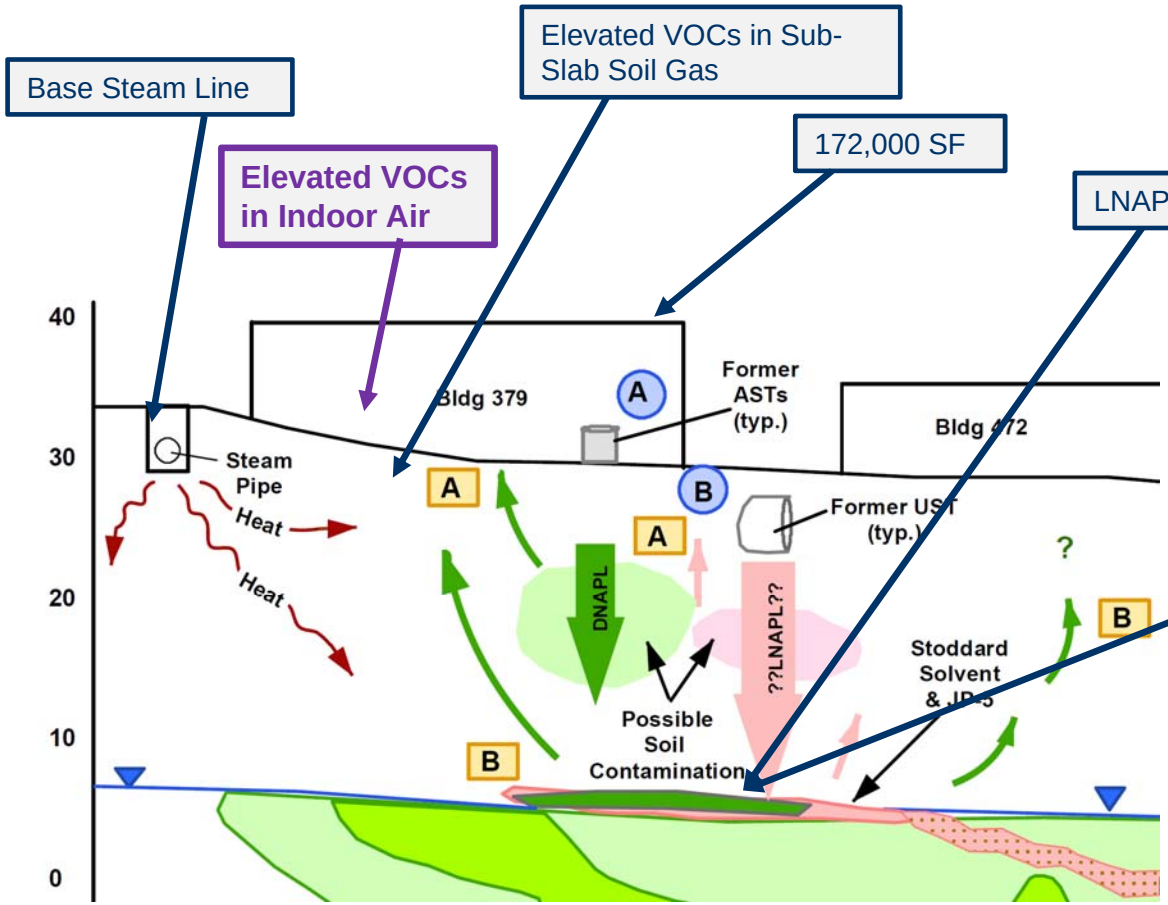
1. Background

- Building 379 has a footprint of 172,000 square feet and partially overlies a LNAPL plume
- Groundwater is at 23 feet bgs
- LNAPL is present below the building
- Elevated levels of cVOCs and TPH are present in sub-slab soil gas
- Indoor air was above screening levels
- A Time Critical Removal Action was implemented to mitigate indoor air

1.1 Site Conceptual Model



1.2 B379 Conceptual Site Model



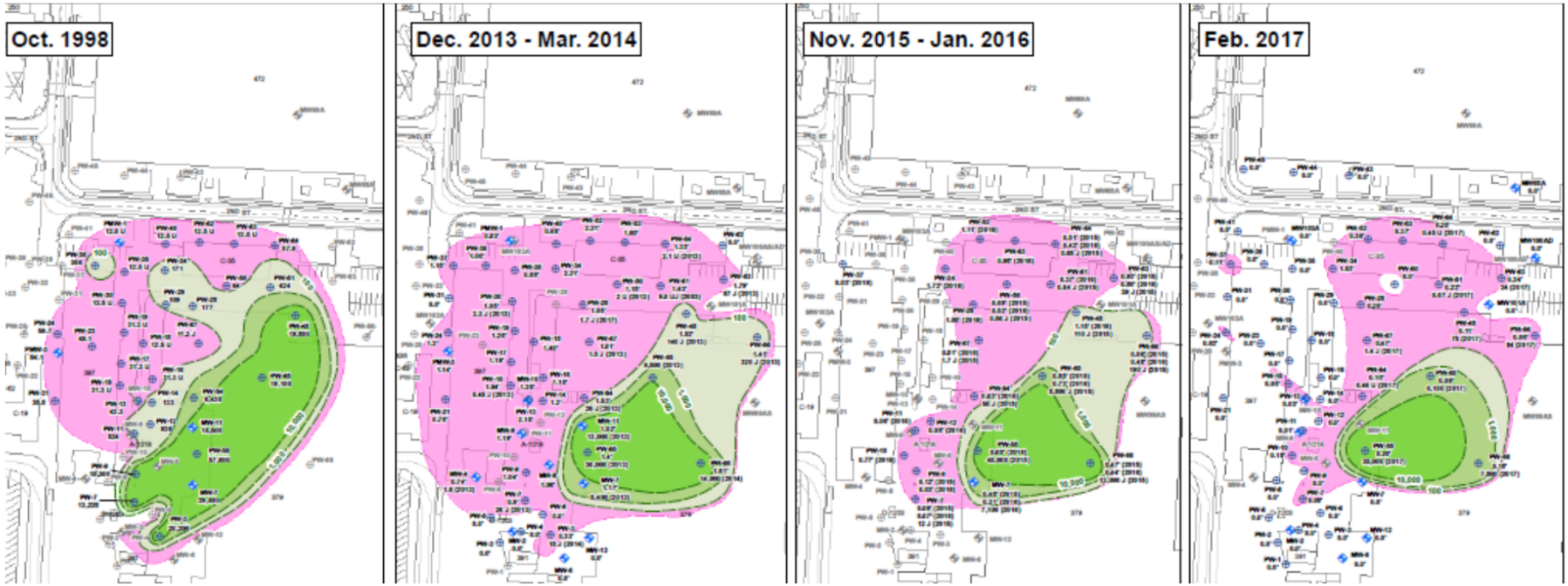
LNAPL includes:
98% TPH : JP-5, Stoddard Solvent
2%: cVOCs - TCE, 1,1,1-TCA

- The heat from the steam pipe has radiated through the soil (~20 feet vertically)
- Laterally, increased temperatures are observed at least 30 feet away from the steam pipe

2.0 Site Conditions

- Volatilization of the LNAPL has resulted in soil vapor concentrations >10,000,000 µg/m^3 (likely exacerbated by the elevated LNAPL temperatures)
- cVOCs represent approximately 50% of the soil vapor concentrations (although < 2% of LNAPL is cVOCs)
- cVOCs are the main risk driver (specifically TCE) and are present in sub-slab soil vapor at several orders of magnitude above project screening levels
- Elevated TCE concentrations in sub-slab soil gas caused TCE concentrations in indoor air to exceed action levels, resulting in relocation being offered to some personnel

2.1 Site Conditions - LNAPL Extent over Time



TCE Isoconcentration in LNAPL (mg/kg)

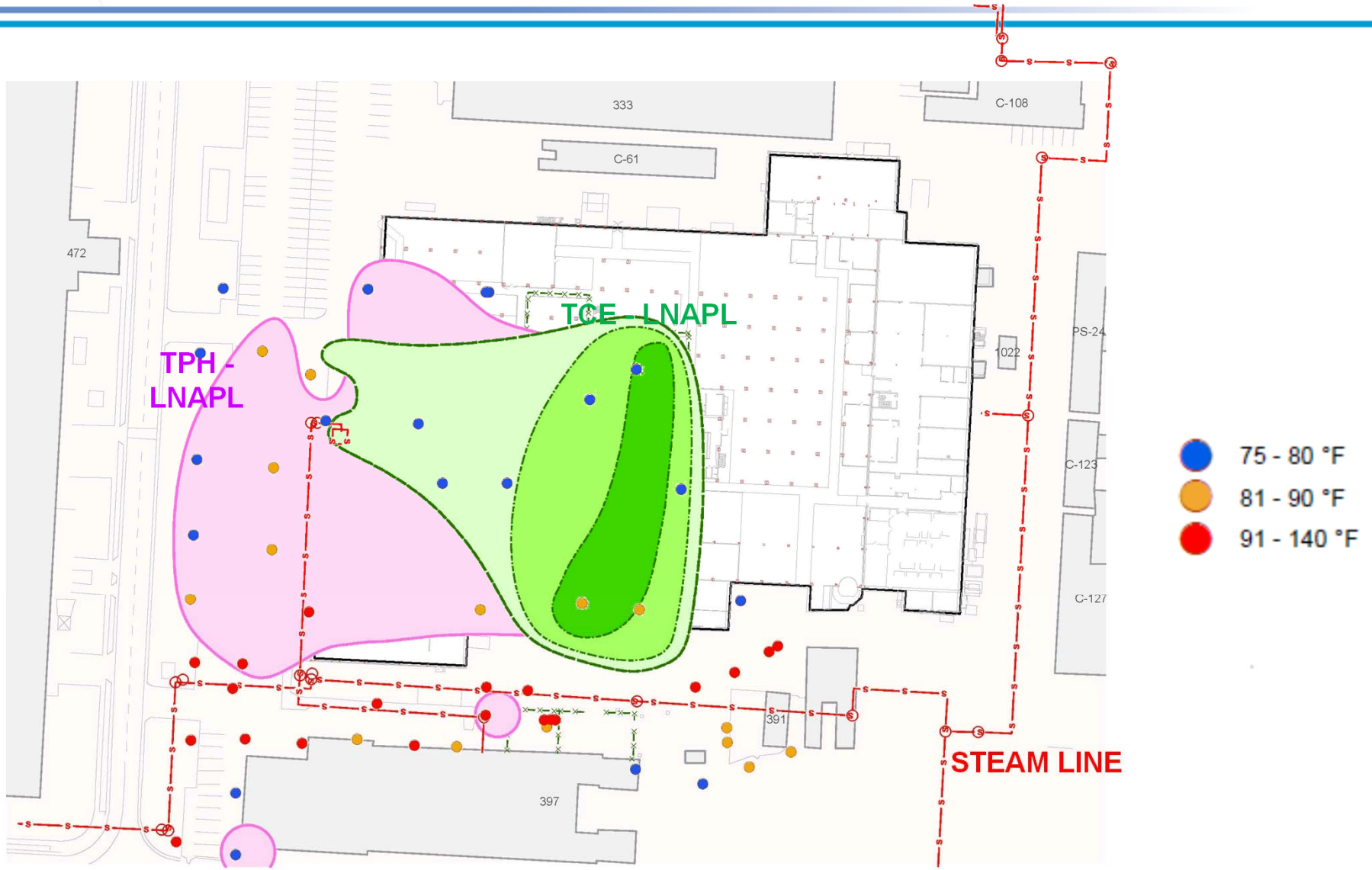
100 mg/kg

1,000 mg/kg

10,000 mg/kg

Extent of LNAPL

2.2 Site Conditions - LNAPL/GW Temperatures (2018)



2.3 Site Condition - Remedial Activities 2016

- A soil vapor extraction (SVE) system has been in operation since May 2016, consisting of:
  - Two horizontal SVE wells under the northern portion of the building at 10 feet bgs
  - A vapor extraction and treatment system that uses compression and refrigeration to condense the TPH/cVOCs in extracted vapor to liquid product
- The SVE system was installed as a VI mitigation measure, coupled with sealing 15,000 feet of cracks and joints in the floor

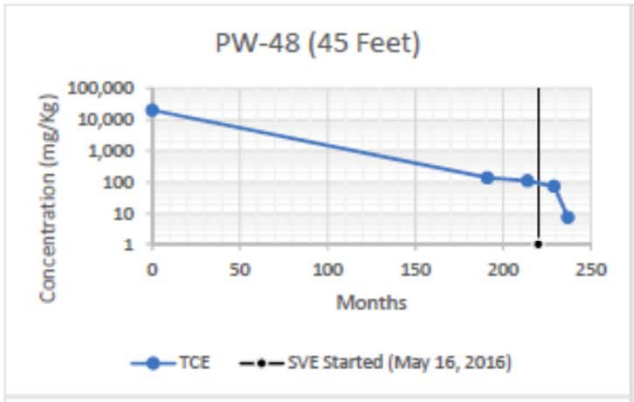
3.0 Objective

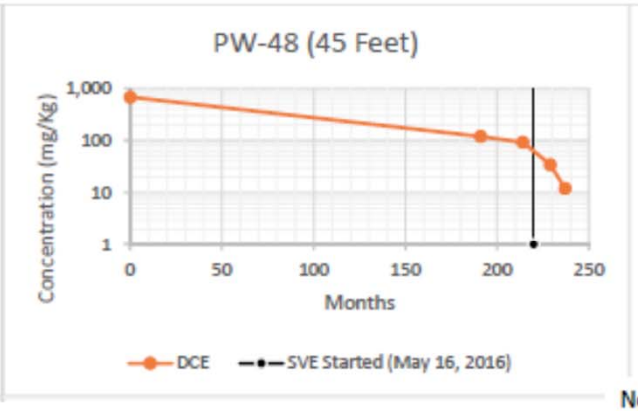
Present an overview of a complex remedial approach at Building 379, Naval Air Station North Island (NASNI) in San Diego, CA, including:

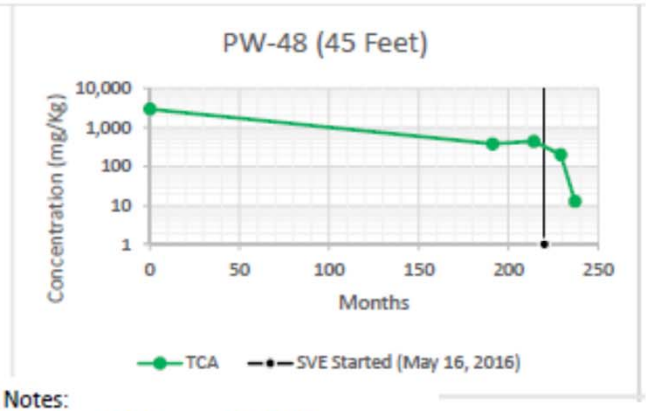
- SVE using horizontal wells under Building 379 to extract soil vapor with elevated levels of total petroleum hydrocarbons (TPH) and chlorinated volatile organic compounds (cVOCs)
- Volatilization of light non-aqueous phase liquid (LNAPL) with SVE
- Biodegradation of TCE in LNAPL
- Enhancement of volatilization and biodegradation by injecting steam under LNAPL

4.1 Effect of SVE on cVOCs in LNAPL

- SVE operation has removed 17,000 lbs (2,100 gallons) of TPH/cVOCs from soil gas between May 2016 and April 2018
- Significant decrease in cVOCs in LNAPL due to SVE (Note – the SVE wells are ~ 13 feet above the top of LNAPL)
- Decreases in LNAPL thickness were also observed
- cVOCs in extracted vapor at 50% (same as TPH), vs. 2% within LNAPL (vs. 98% TPH)





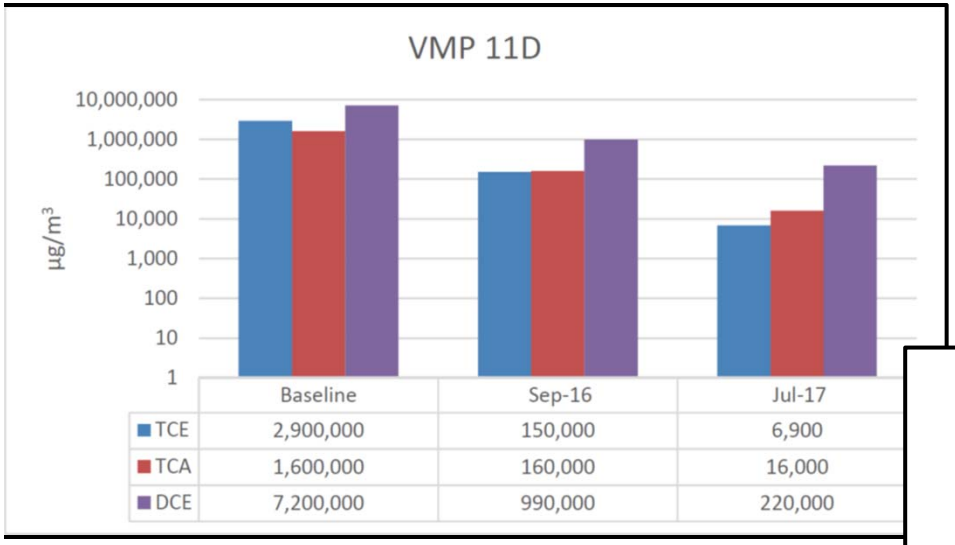


Notes:
Months = 0 is January 20, 1998
Distance from Nearest Steam Line in Title

4.2 Degradation of TCE in LNAPL

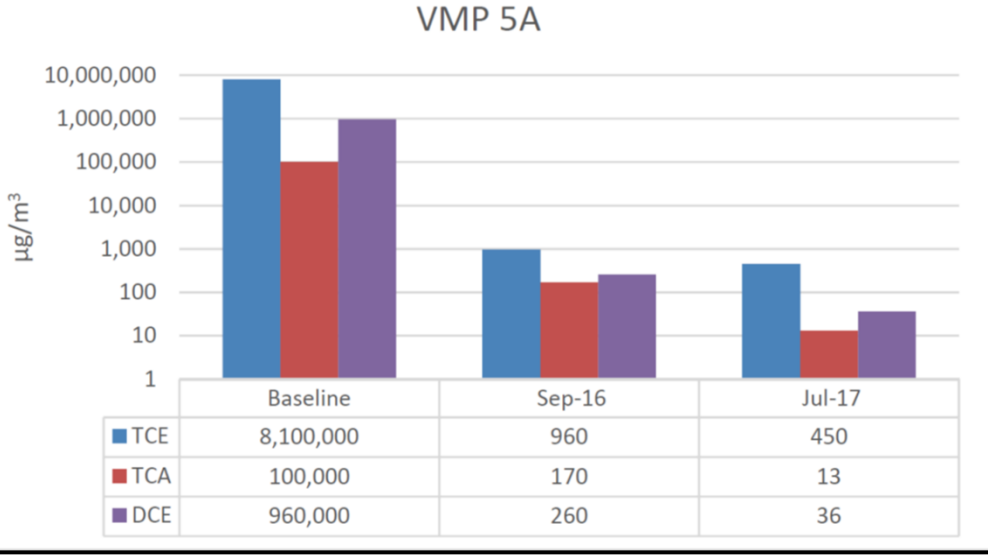
- Significant levels of cDCE were detected in soil vapor, both in sub-slab and at depth – this is most likely due to biodegradation of TCE
- There is ample electron donor (TPH in the jet fuel and Stoddard Solvent)
- Biodegradation of TCE in LNAPL was confirmed in bench-scale treatability tests (unamended controls showed a decrease in TCE coupled with an increase in cDCE)
- Currently, levels of cDCE>TCE in soil vapor probes that are close to the Base steam line, whereas TCE>cDCE away from steam line

4.3 Effect of Steam on Degradation of TCE in LNAPL



	Baseline	Sep-16	Jul-17
TCE	2,900,000	150,000	6,900
TCA	1,600,000	160,000	16,000
DCE	7,200,000	990,000	220,000

VMP-11D is ~15 feet from Steam Line: **DCE>TCE**



	Baseline	Sep-16	Jul-17
TCE	8,100,000	960	450
TCA	100,000	170	13
DCE	960,000	260	36

VMP-5A is ~100 feet from Steam Line: **TCE>DCE**

4.4 Steam: Friend or Foe?

Initially, steam was considered to be a foe:

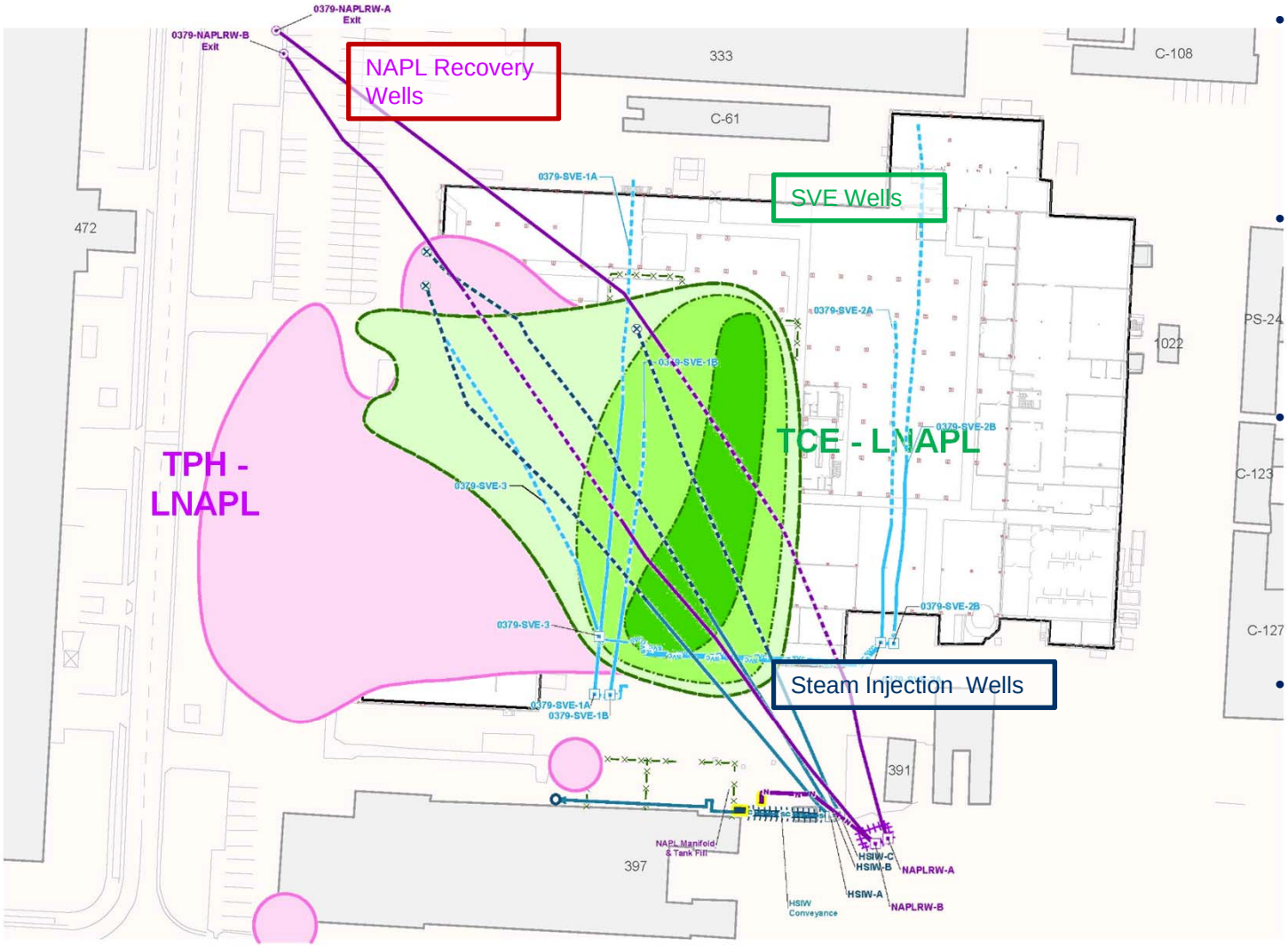
- Increased temperatures of LNAPL – likely exacerbated levels of VOCs in sub-slab soil vapor
- Response was to consider engineering measures to mitigate

But then, the following were considered:

- The LNAPL footprint has shrunk in past few years, concurrent with increase in LNAPL temperatures
- cDCE within LNAPL has increased significantly, coupled with a decrease in TCE – likely due to biodegradation of TCE, which may have been caused or enhanced by the elevated temperatures
- The SVE wells are effectively capturing cVOCs/TPH from sub-slab soil gas and decreasing LNAPL mass

Based on this, instead of mitigating the effects of steam, it was decided to add more steam to the subsurface!

4.5 Remedial Activities 2017



- Two horizontal SVE wells in the southern portion of the building at 10 feet bgs
- One horizontal SVE well in the northern portion of the building at 20 feet bgs
- Three steam injection wells (screened 5 feet below LNAPL) to enhance LNAPL volatilization and biodegradation
- Two horizontal LNAPL recovery wells (screened just below the LNAPL) to recover mobilized LNAPL (due to steam injection)

4.6 Remedial Activities 2017

Steam Injection Manifold

The Project Team – Some of them are here today

Horizontal Well – The Beginning.....

…..The End (A few days later)

4.7 Steam Injection

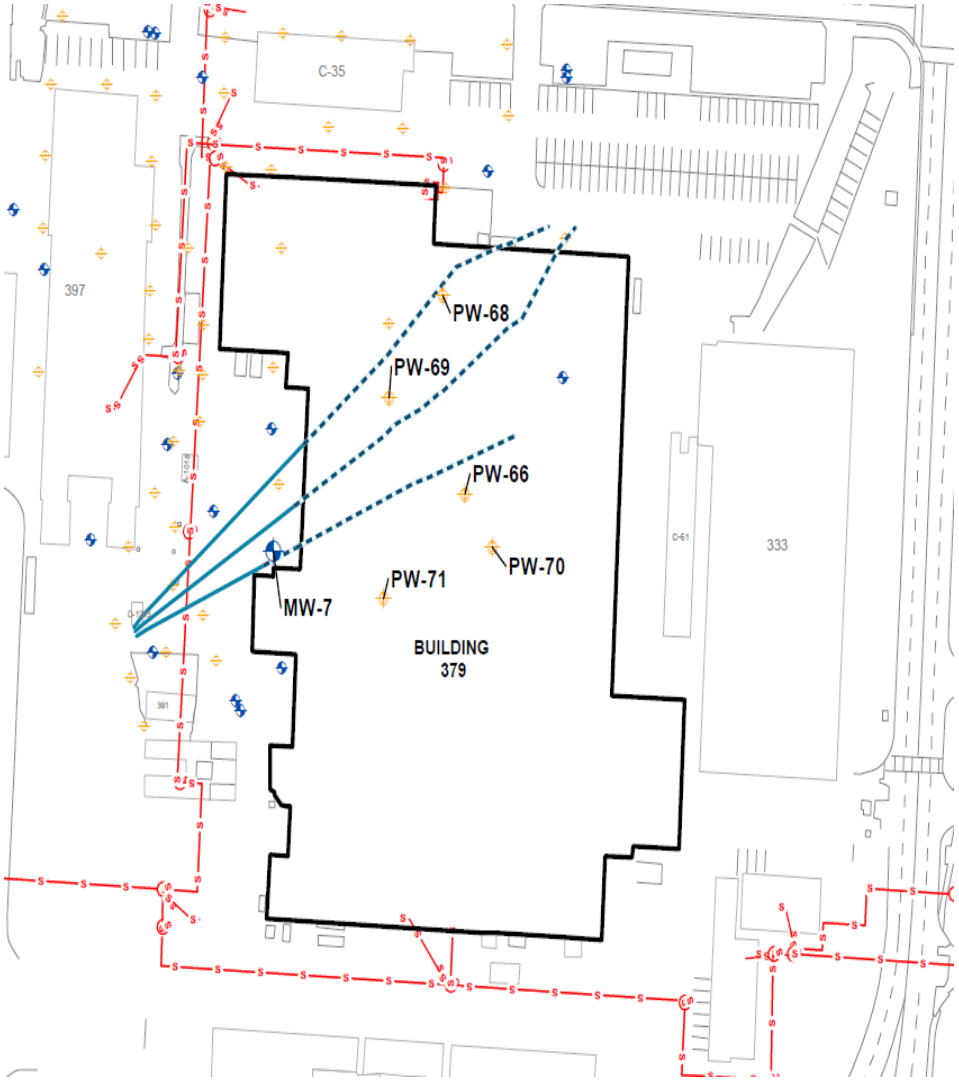
- Steam is being injected into the aquifer through the steam injection wells to further heat up the groundwater and the LNAPL above it (injection started 06 February 2018)
- Steam injection testing ongoing
  - ❖ Approximately 3,000 lbs/hr at 15 psig
  - ❖ Started with few hours/day, followed by 3 days continuous
  - ❖ Temperature increases of up to 30 ^{o}F were observed in product after 50 hours of injection
- Evaluation of effect of steam injection on concentrations in extracted vapor is ongoing
- Steam injection is expected to decrease the viscosity of the LNAPL and facilitate extraction via the LNAPL recovery wells

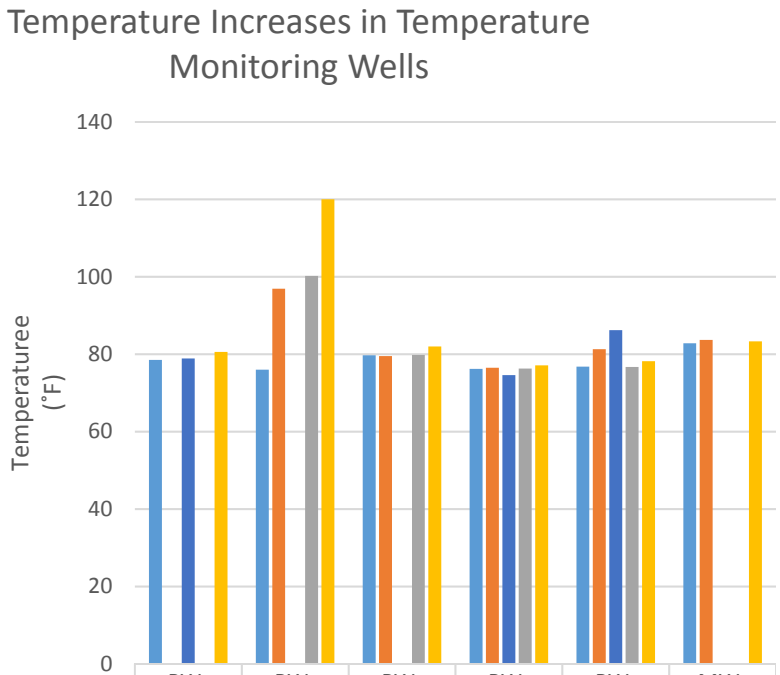
4.8 Effect of Steam Injection

No.	Parameter	Before Steam Injection	After Steam Injection
1	VOC Reading (PID): SVE-1B Influent	1,500 ppm	4,200 ppm
2	VOC Reading (PID): SVE-3 Influent	130 ppm	520 ppm
3	Temperature of Extracted Vapor	70 ºF	85 ºF
4	Volume of Effluent of C3 System	20 gallons	40 gallons

Steam injection has significantly increased the rate of recovery of contaminants from the subsurface

4.9 Temperature Increases in LNAPL with Steam Injection





	PW-66	PW-68	PW-69	PW-70	PW-71	MW-07
AMBIENT	78.5	76	79.7	76.2	76.8	82.8
INJECTING		96.9	79.5	76.5	81.3	83.7
INJECTING- DAY 2 NON-CONTINUOUS	78.9			74.6	86.2	
OFF- 2 WEEKS POST INJECTION		100.2	79.8	76.3	76.7	
AFTER 3 DAY INJECTION	80.6	120	82	77.1	78.2	83.3

5.0 Key Findings (To Date)

- SVE coupled with sealing of cracks/joints has caused indoor air TCE to be < IASL
- Levels of cVOCs in sub-slab soil gas (while SVE is on) are orders of magnitude below baseline; operation of 2 wells in the northern portion was adequate to decrease indoor air cVOCs to acceptable levels
- SVE is remediating LNAPL:
  - ❖ Over 2,100 gallons of TPH/cVOCs have been recovered as of April 2018
  - ❖ Levels of cVOCs in LNAPL have decreased significantly since SVE was started, even though the SVE wells are screened 13 feet above the top of LNAPL
  - ❖ Levels of cVOCs in LNAPL are decreasing about 50 times faster than TPH
- The Base steam line (6 feet bgs) is heating up the LNAPL (23 feet bgs) to over 100 ºF, TCE in the LNAPL is biodegrading to cDCE, either caused or enhanced by the steam
- Steam injection (to date) has resulted in tripling of SVE influent levels, and doubling of liquid volumes in effluent of the C3 system

QUESTIONS?