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Adaptive Site Management While Implementing DNAPL Source Zone Containment

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(Tetra Tech, Pittsburgh, Pennsylvania, USA)

Background/Objectives. Multiple releases of trichloroethene (TCE) occurred at Launch Complex 34 (LC34), Cape Canaveral Air Force Station, Florida, between the late 1950s and 1968. The overall mass remaining nearly 40 years after termination of launch activities is estimated at 90,000 pounds. The associated groundwater plume has TCE and daughter products at concentrations exceeding Florida Department of Environmental Protection Groundwater Cleanup Target Levels over an area of 330 acres and extending to a depth of approximately 80 feet below land surface. A robust groundwater model and corrective measure study was completed for the site. However, additional investigations expanded the overall treatment footprint and an interim measure approach was developed to offer flexibility in site dynamics. Retroactive modifications to the interim measure design were conducted as the fidelity of site conditions increased from ongoing investigations. Hydraulic containment was implemented as an interim measure to contain the TCE high-concentration plume and dense nonaqueous-phase liquid (DNAPL) source zone and to reduce site contaminant mass. The interim measure was implemented to mitigate further migration while future treatment options are evaluated. The objective of this presentation is to describe the flexible treatment train approach applied to a large DNAPL site, anticipated milestone decision points, and potential operational modifications to enhance plume containment while reducing operational intensity.

Approach/Activities. Operation of a groundwater extraction and treatment system was initiated in January 2009 for hydraulic capture of the TCE high-concentration plume and DNAPL source zone. Key components of the system include a network of extraction and injection wells, infiltration gallery, and treatment system consisting of filtration units, an air stripper, liquid-phase carbon vessels, and catalytic oxidation unit. Within 18 months of operation, approximately 18 million gallons of groundwater and 18,000 pounds of CVOC mass have been removed and destroyed. The intense mass loading on the treatment system, particularly affecting the lifecycle of oxidizer components, requires significant consideration towards site objectives and operation and maintenance (O&M) efforts. Various analyses were conducted to evaluate optimization scenarios to adapt to changing site conditions. Examples of optimization scenarios considered as part of the treatment train approach to the interim measure include vapor-phase carbon versus catalytic oxidizer transition cost/benefit analysis, integration of biostimulation within the treatment area via a large-scale recirculation system, adjusting mass recovery dynamics to reduce future O&M efforts and accelerate vapor-phase treatment transition, and source zone treatment.

Results/Lessons Learned. Adaptive site management of a DNAPL site provides a flexible approach to remediation management, as changing site conditions dictate operations.

Although the objective of the interim measure was for containment of a TCE high-concentration CVOC plume and DNAPL source zone, additional concepts outside the primary objectives may further optimize the interim measure. For example, a transition point of approximately 25 milligrams per liter of TCE was modeled to be an effective target concentration for optimal transition from catalytic oxidation to vapor-phase carbon treatment. The cost evaluation considered many treatment technologies elements including capital, O&M, repair, media, and disposal. The model will be used to track site conditions and progress to support offgas treatment decisions. To expedite the transition, DNAPL flux, extraction approaches, and source depletion are being evaluated. Beyond the treatment process, the site is undergoing evaluation for supplementary technologies to complement hydraulic containment via groundwater extraction. Injection of biostimulants in the existing periphery groundwater injection wells is one such technology under evaluation to provide treatment of the high-concentration plume and potentially within the DNAPL dissolution interface.

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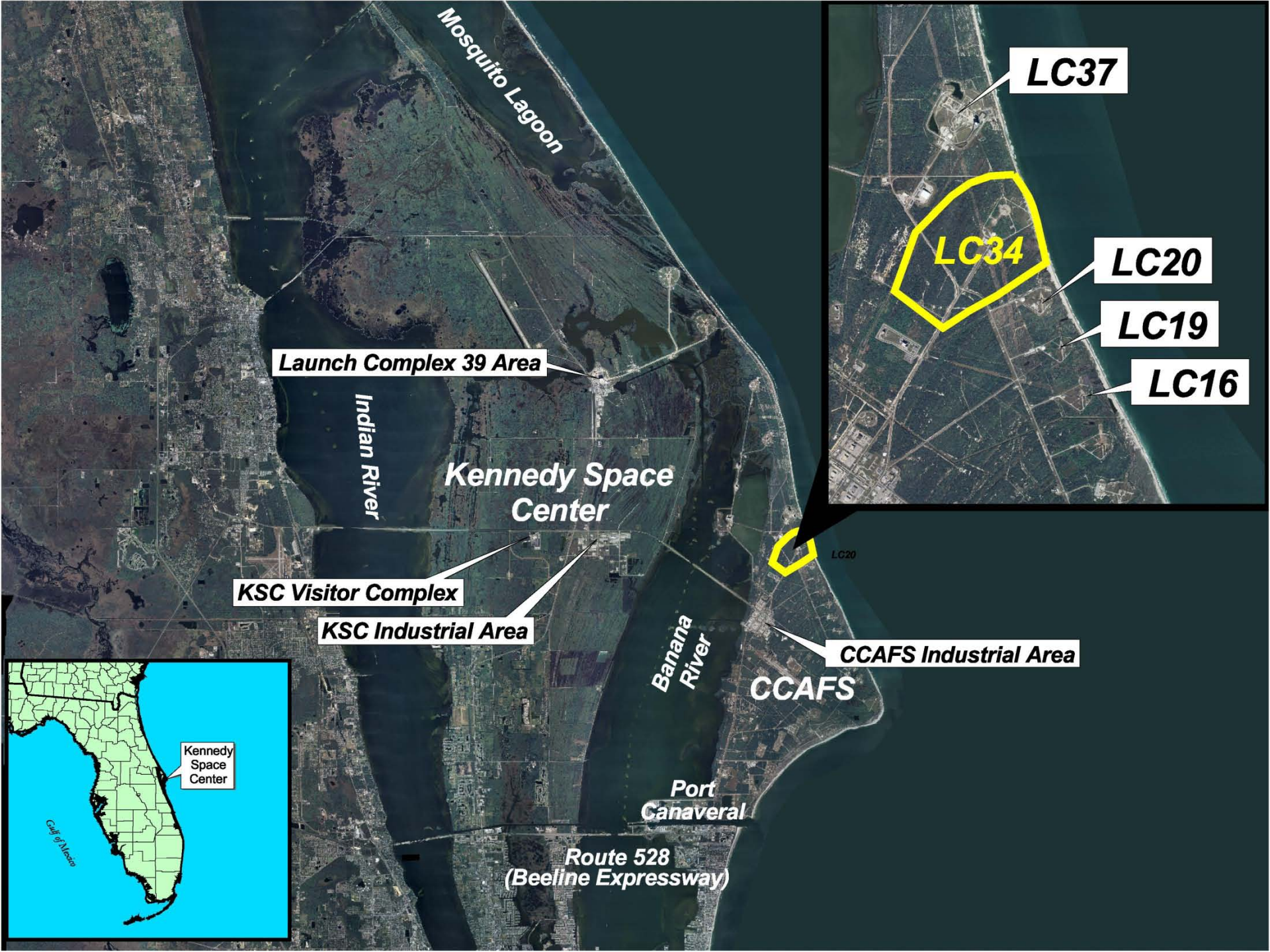
Goals / Overview

- Site History
- RCRA Corrective Actions
- Interim Measure Selection
- Hydraulic Containment Implementation & Optimization
- Performance Data

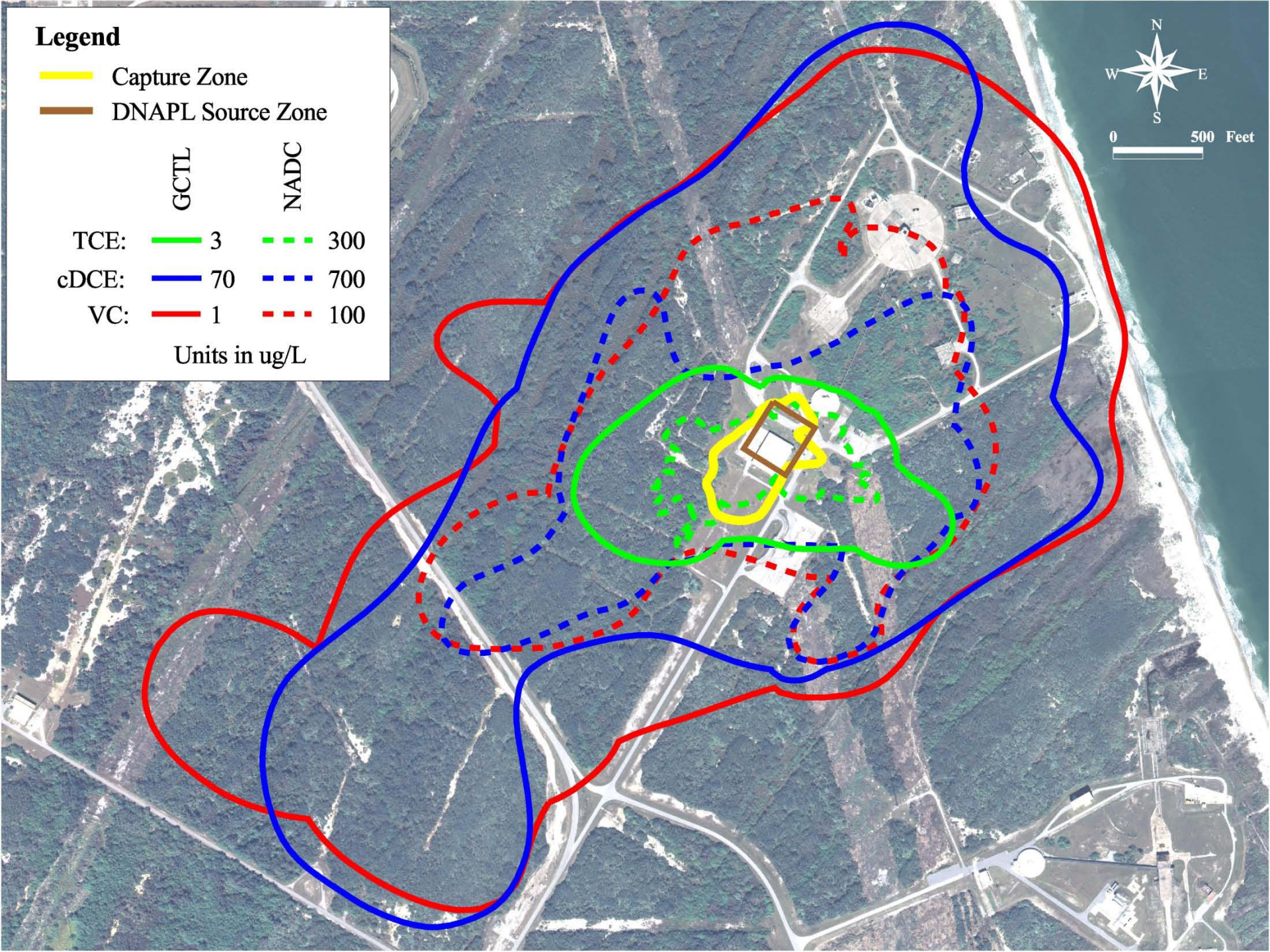

Mosquito Lagoon
Launch Complex 39 Area
Indian River
Kennedy Space Center
KSC Visitor Complex
KSC Industrial Area
Banana River
CCAFS Industrial Area
CCAFS
Port Canaveral
Route 528 (Beeline Expressway)
LC37
LC34
LC20
LC19
LC16
Kennedy Space Center
Gulf of Mexico

Site History

- Constructed between 1959 and 1961 for the Saturn 1 and 1B rocket programs
  - Seven Saturn 1 and 1B launches from 1961-1968
  - Location of the Apollo 1 mishap
- Extensive cleaning of spaceflight components with trichloroethene (TCE)
- Launch structures dismantled and facilities abandoned in place following the launch of Apollo 7

RCRA Corrective Action History

- 1994
  - Chlorinated solvent contamination discovered in groundwater
- 1996 - 2007
  - RCRA Facility Investigation & Corrective Measures Study
  - Investigation Results
    - ~330 acres impacted groundwater by CVOCs (1 mi. x ½ mi. plume)
    - Source area groundwater contamination present to 118 ft bls
    - Sand aquifer with inter-bedded silt, clay, and shell layers (8 Layers)
    - DNAPL (TCE) present between 18 ft & 80 ft bls
      - 74,000 lbs TCE (saturated soil > 300 mg/kg)
      - Additional 12,000 lbs of TCE mass in “shell” of soil surrounding DNAPL (TCE sat. soil concentrations 100 - 300 mg/kg)


Legend
Capture Zone
DNAPL Source Zone
GCTL
NADC
TCE: 3 300
cDCE: 70 700
VC: 1 100
Units in ug/L
N
W
E
S
0
500 Feet

TCE Distribution

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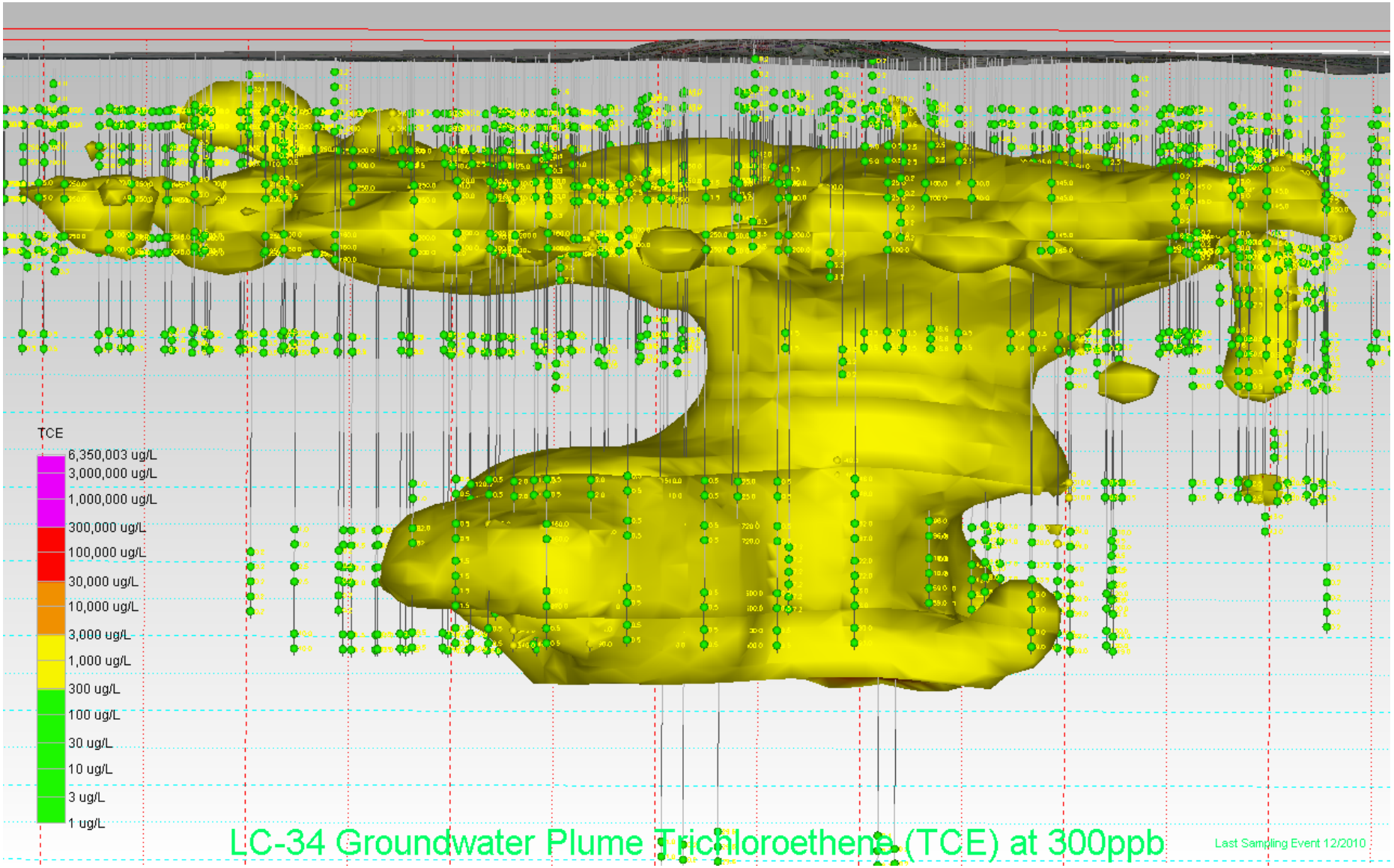

Technology Demonstration History

- 1997 – 2002
  - Interagency DNAPL Consortium
    - $KMNO_4$
    - Six Phase Heating
    - Steam Injection

- 2002
  - NASA Small Business Innovative Research Program
    - Emulsified Zero-Valent Iron
- 2002 - 2003
  - NASA Small Business Technology Transfer Research Program
    - Bioaugmentation Demonstration – KB-1
- 2003 - 2004
  - ESCTP Demonstration
    - Sequential Application of In Situ Chemical Oxidation and Enhanced Bioremediation

RCRA Corrective Action History

- 2008
  - Presented Corrective Measures costs at the *6th International Conference on Remediation of Chlorinated and Recalcitrant Compounds*
    - DNAPL Source Zone (DSZ) capital costs ranged from $1M to $70M
    - Hydraulic containment was presented as the preferred alternative

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Geosyntec consultants

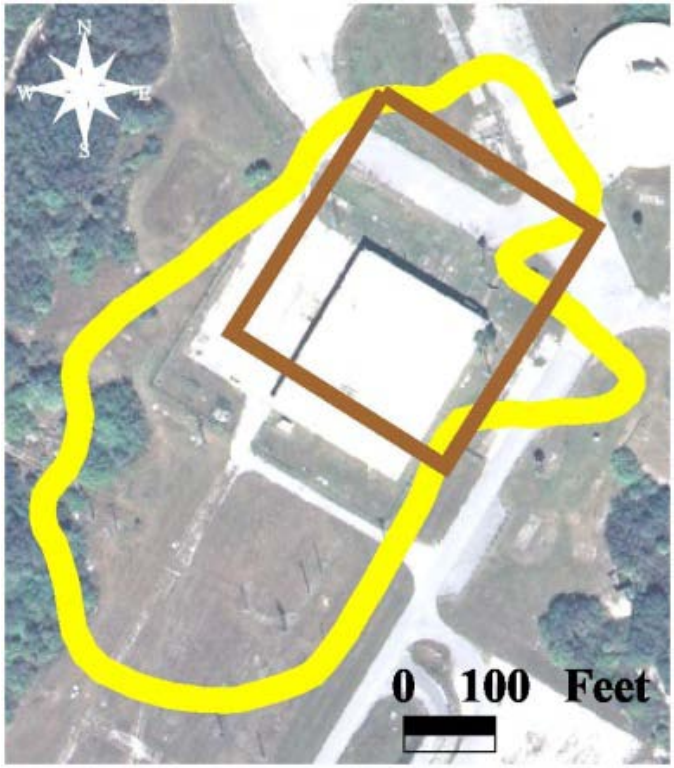
LC34 DNAPL Source Zone Costs

Treatment Zones and Alternatives	First Year Cost (Capital Cost + First Year O&M&M Cost)	Total "Pay As You Go" Cost (First Year Cost + Total Non-Discounted O&M&M)	Total NPV (First Year Cost + Total O&M&M NPV)
DNAPL Source Zone			
Hydraulic Containment via Pump and Treat	$1M	$100M	$4M
Permeable Reactive Barrier	$12M	$60M	$15M
Enhanced Bioremediation	$5M	$45M	$10M
Conventional Excavation to 55 feet bls, Enhanced Bioremediation 55-85 feet bls.	$40 - $50M	$54M	$42 - $50M
LDA/Steam/Iron to 55 feet bls, Enhanced Bioremediation 55-85 feet bls	$50 - $70M	$100M	$55 – 75$M
ZVI Clay or Slurry Wall Barrier to 85 ft bls (Containment - No Treatment Provided)	$5 - $6M	$5 - $7M (based upon 30 yrs)	$5 - $6M (based upon 30 yrs)

2

RCRA Corrective Action History

- 2008 – 2009
  - Reached a regulatory agreement to:
    - Implement hydraulic containment of the DSZ **and** the TCE dissolved plume in Layer 6 as an Interim Measure
    - Conduct supplemental assessments of "Hot Spots" outside of the DSZ
  - Adaptive Site Management
    - KSC decided that a preferred approach would be to implement a series of Interim Measures (IMs) with the final remedy ultimately being Long Term Monitoring
    - Process allows for adaptive site management and site conditions (following IM implementation) to dictate future remedial actions.
    - Development of program-wide multi-step Engineering Evaluation Process

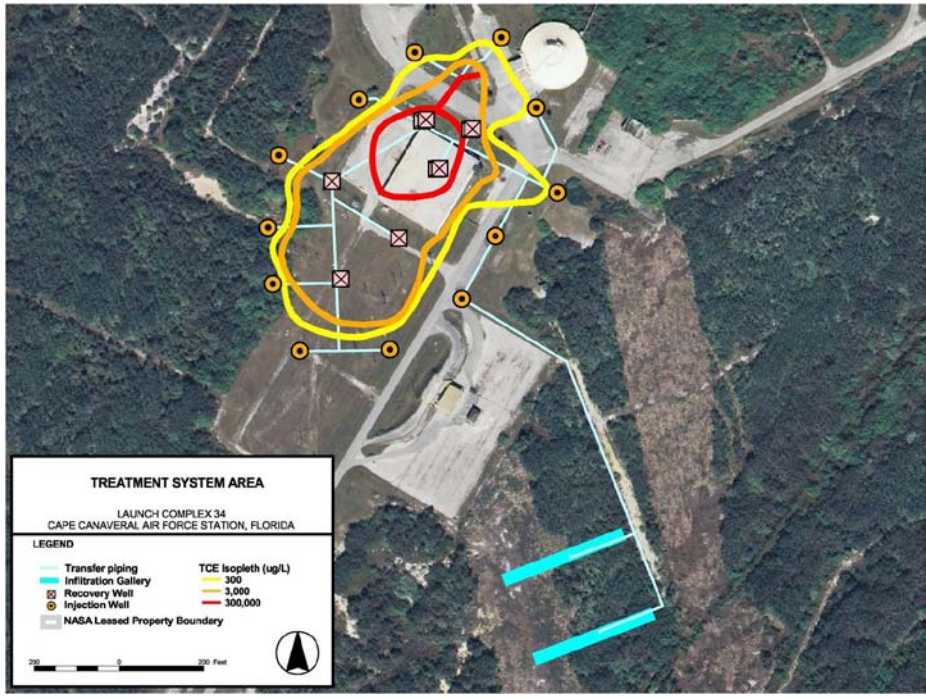


RCRA Corrective Action History

- 2009
  - Interim Measure Work Plan development
  - Supplemental assessment
  - Dynamic pumping test conducted in source area
    - Estimate influent mass loading
    - Basis of design conditions
  - Contract awarded for implementation of the hydraulic containment
  - Objective of the Interim Measure
    - Achieve hydraulic containment of TCE in Layer 6 and control flux of the DNAPL Source Zone

RCRA Corrective Action History

- 2009 Continued:
  - IM Design - Hydraulic containment system consisting of:
    - 6 DNAPL source zone pumping wells
    - 3 high dissolved TCE plume pumping wells
    - Air stripping (contaminants to vapor phase)
    - Vapor-phase GAC
    - Shallow and deep well injection of treated groundwater
  - System modifications
  - IM Installation
  - System start-up
- 2010 - 2012
  - Containment system OM&M



Design Modifications

- Despite high fidelity of investigation, overall contaminant mass and flux was a large variable (unknown mass flux dynamics)
- Vapor-phase GAC changed to catalytic oxidation:
  - Screened vs. alternate technologies (HiPOx, RayOx, etc.)
  - Substantial and unknown vapor-phase GAC loading
  - Sustained high mass loading/costs
  - CatOx costs independent of loading
  - Cost effective utilize treatment train approach (site conditions/treatment)
  - Permitting/Haz. waste management implications
  - CatOx flexibility (system expansions)
- Shallow injection replaced with infiltration gallery
  - Additional shallow contamination identified

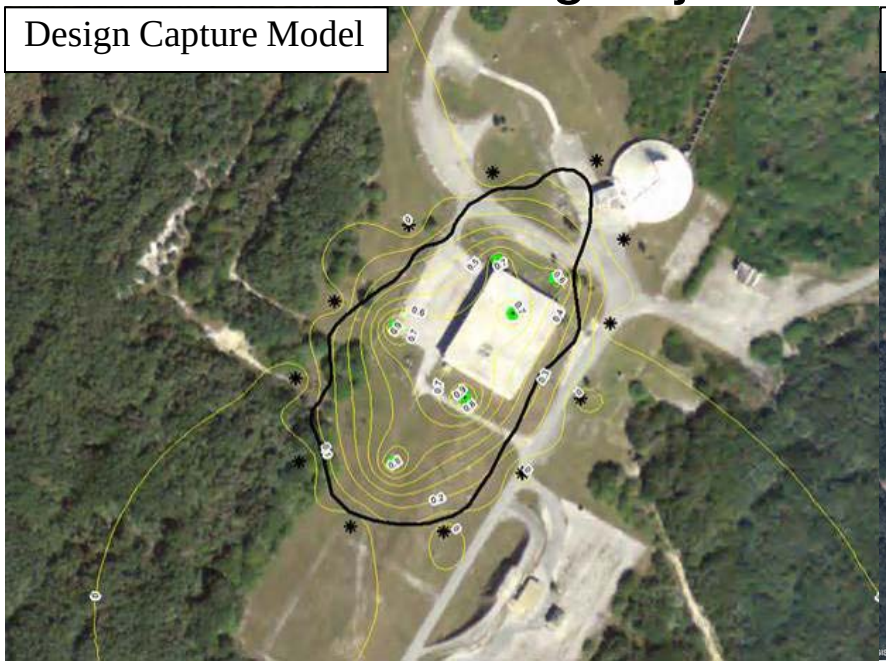
IM Optimization

- System Startup (2009)
  - Utilized mobile lab
  - Air stripper redesigned
  - Liquid-phase GAC polishing added
  - Biodispersent program added
- Full Scale O&M (2010 and ongoing)
  - Predictive maintenance program
  - IM objective verification
  - Capture study in January 2011 confirmed containment objective
- Source zone pumping optimization (2011)

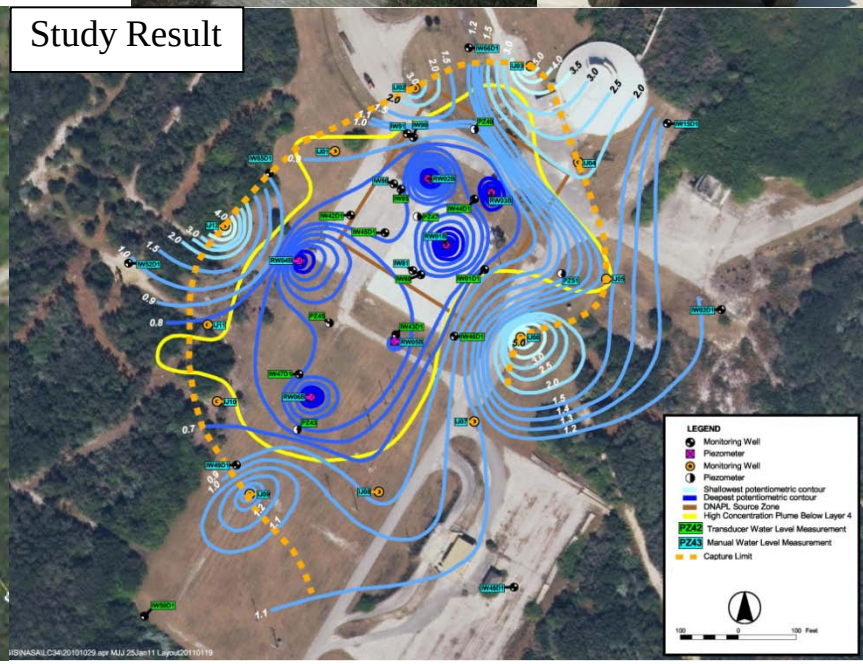
IM Objective Verification

- Capture study conducted to evaluate:
  - Verify IM objective
  - Containment performance/boundaries
- Independent and combined pumping zone testing
- Real time monitoring/adjustments

Design Capture Model

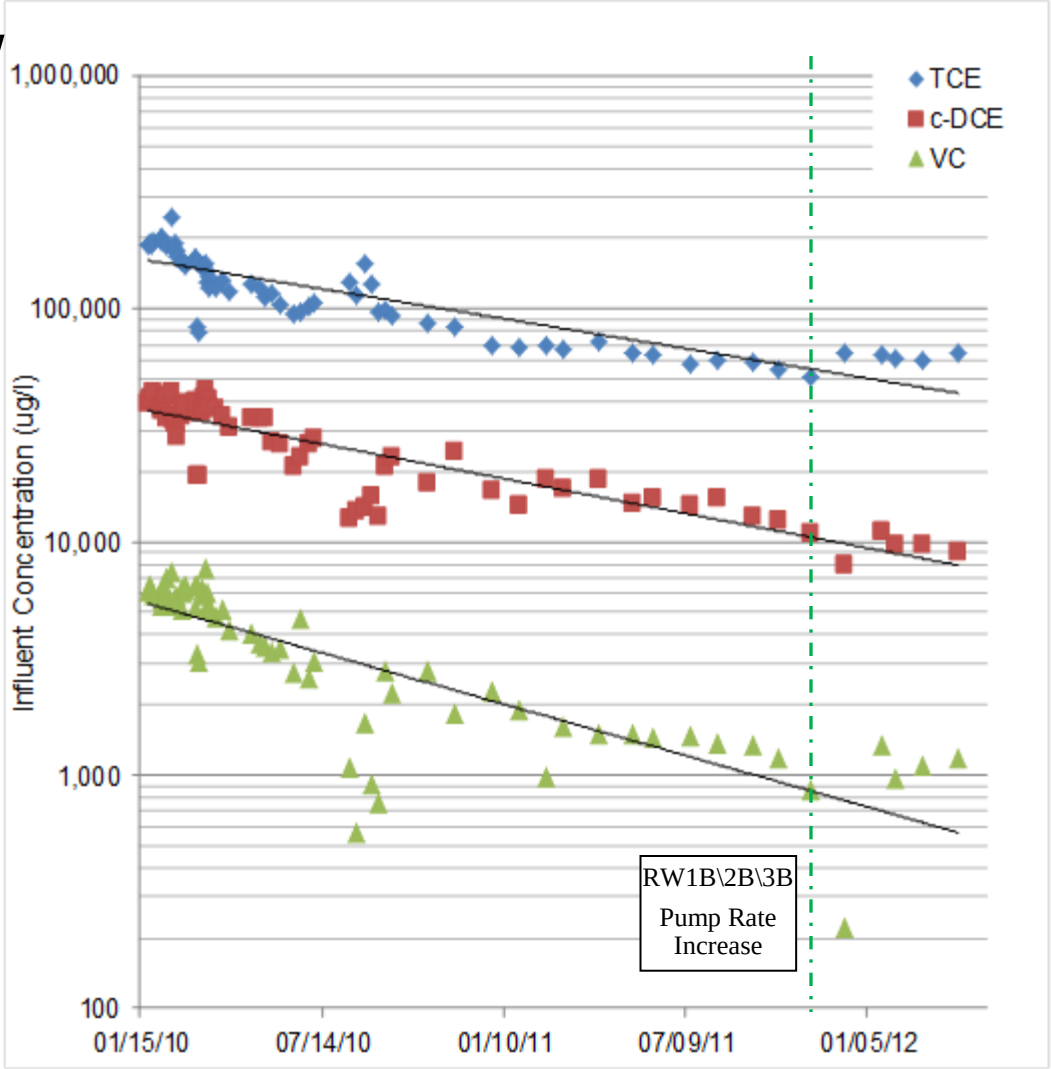


Study Result



System Influent

- TCE data indicates slow source depletion
- Daughter compounds behaving similar to TCE
- Pumping optimization offset influent +10 mg/L



Recovery Well Influent Data

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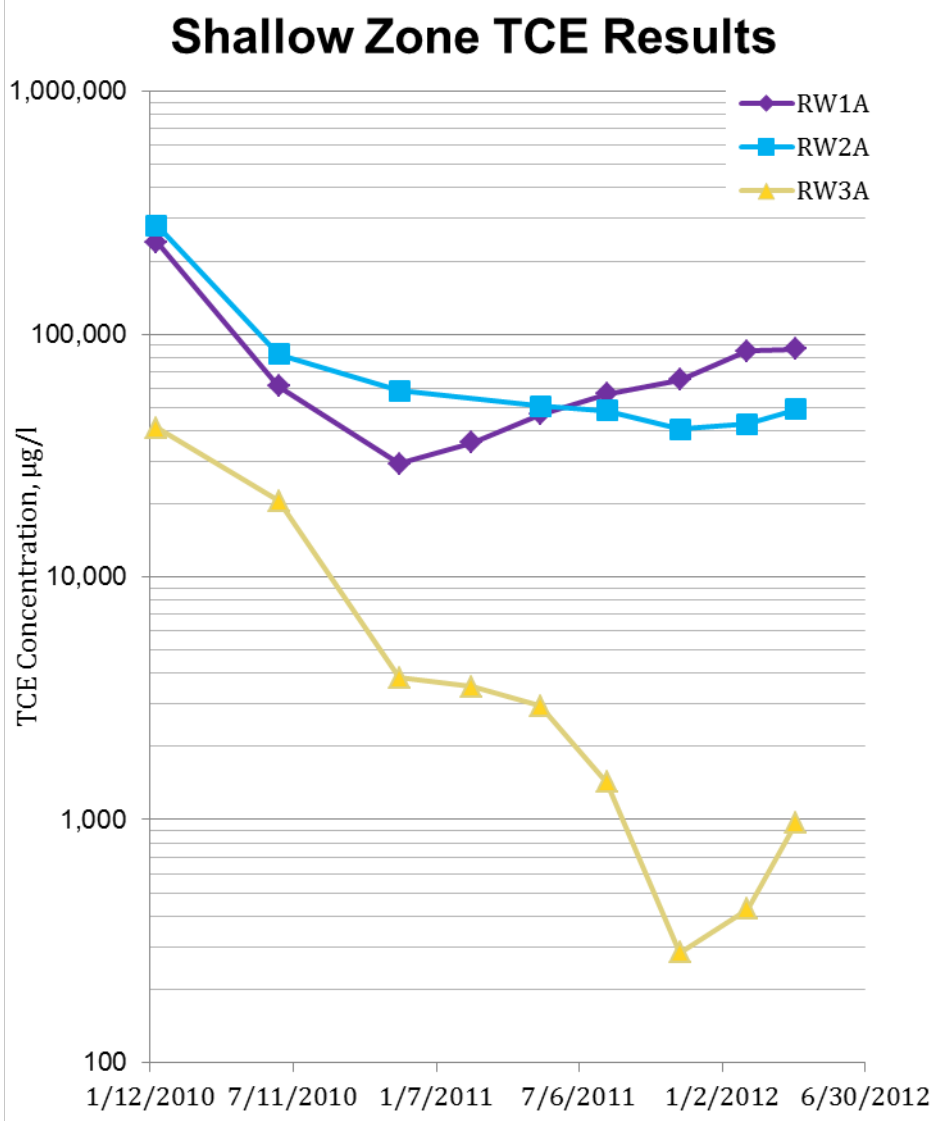
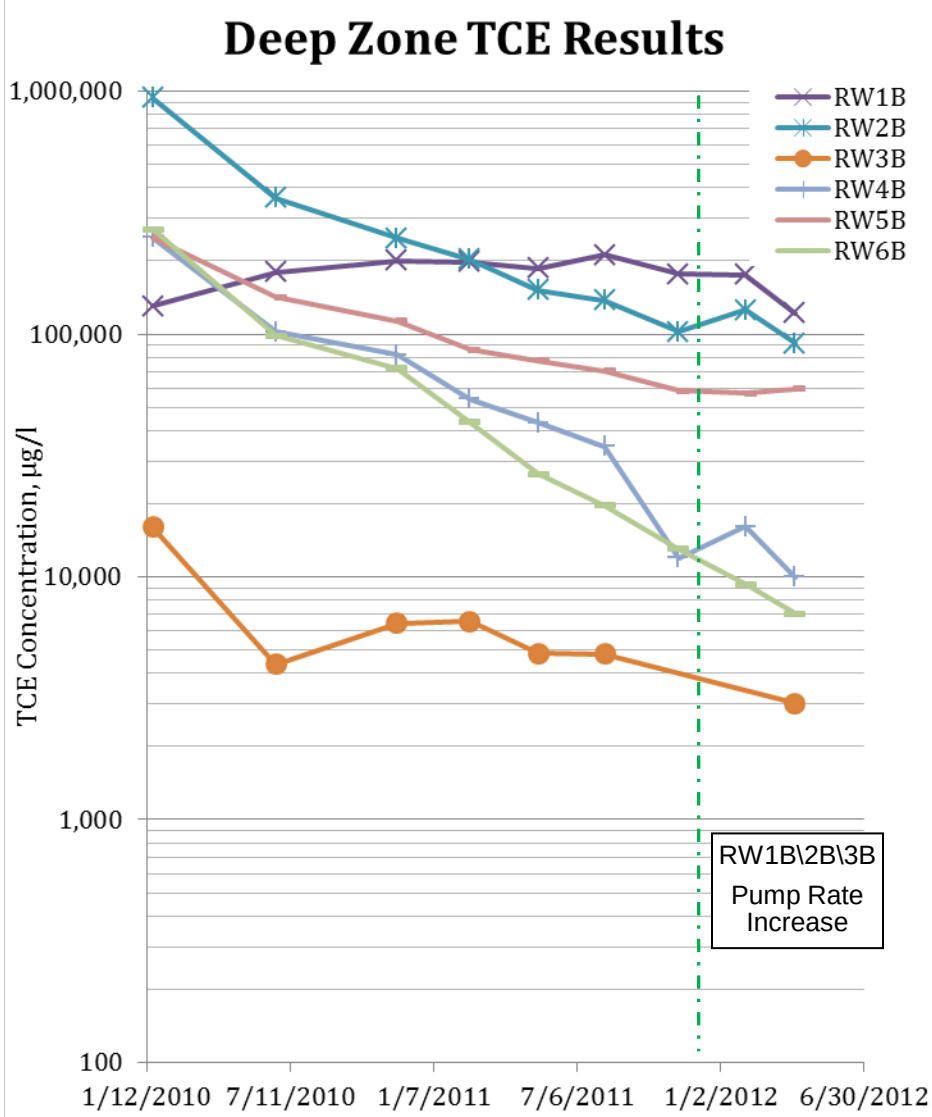
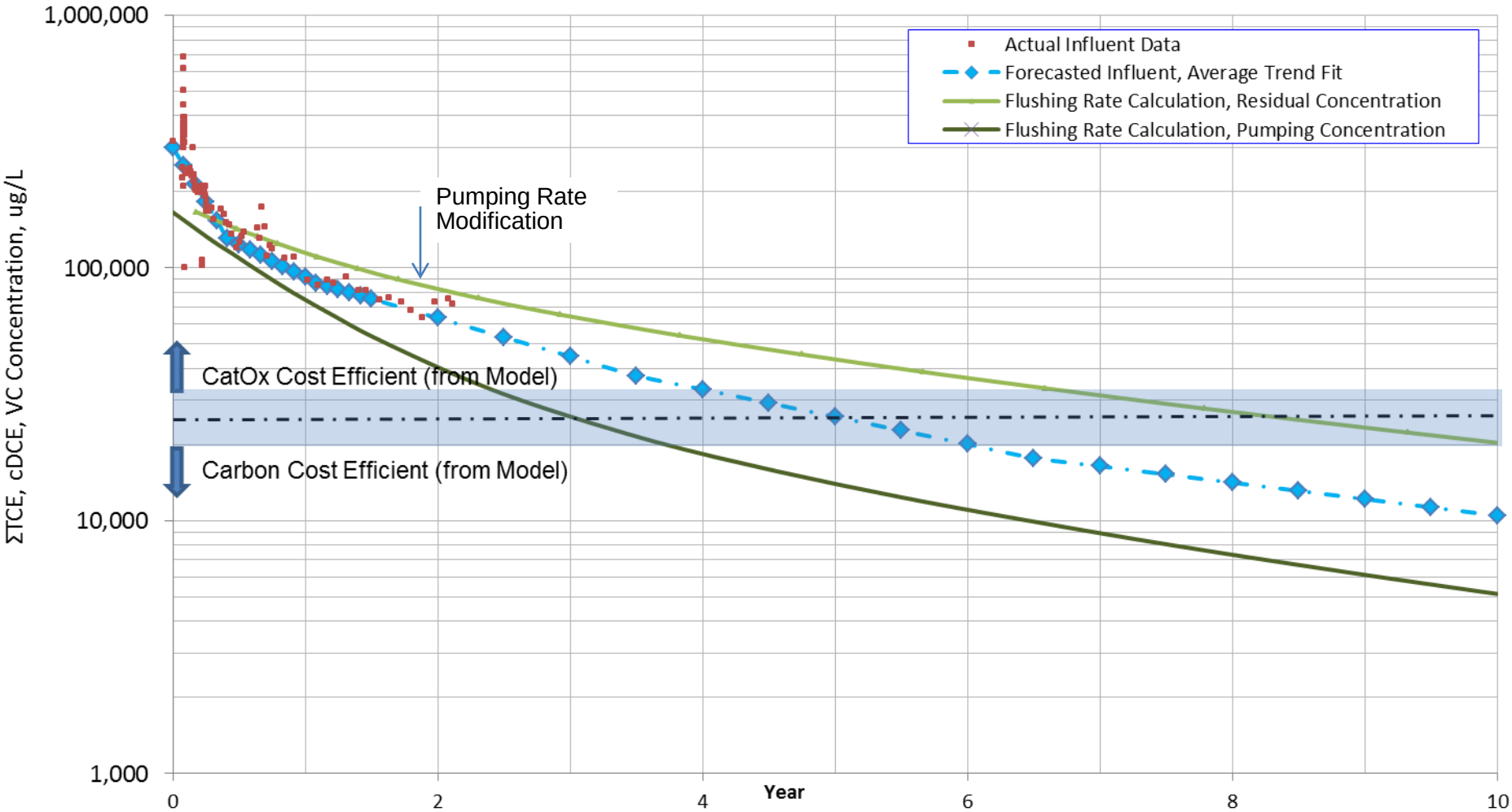




CatOx/GAC Transition Evaluation

Concentration Decay Curve (Treatment Model Mass Loading Basis)



CatOx/GAC Transition & Cost Analysis

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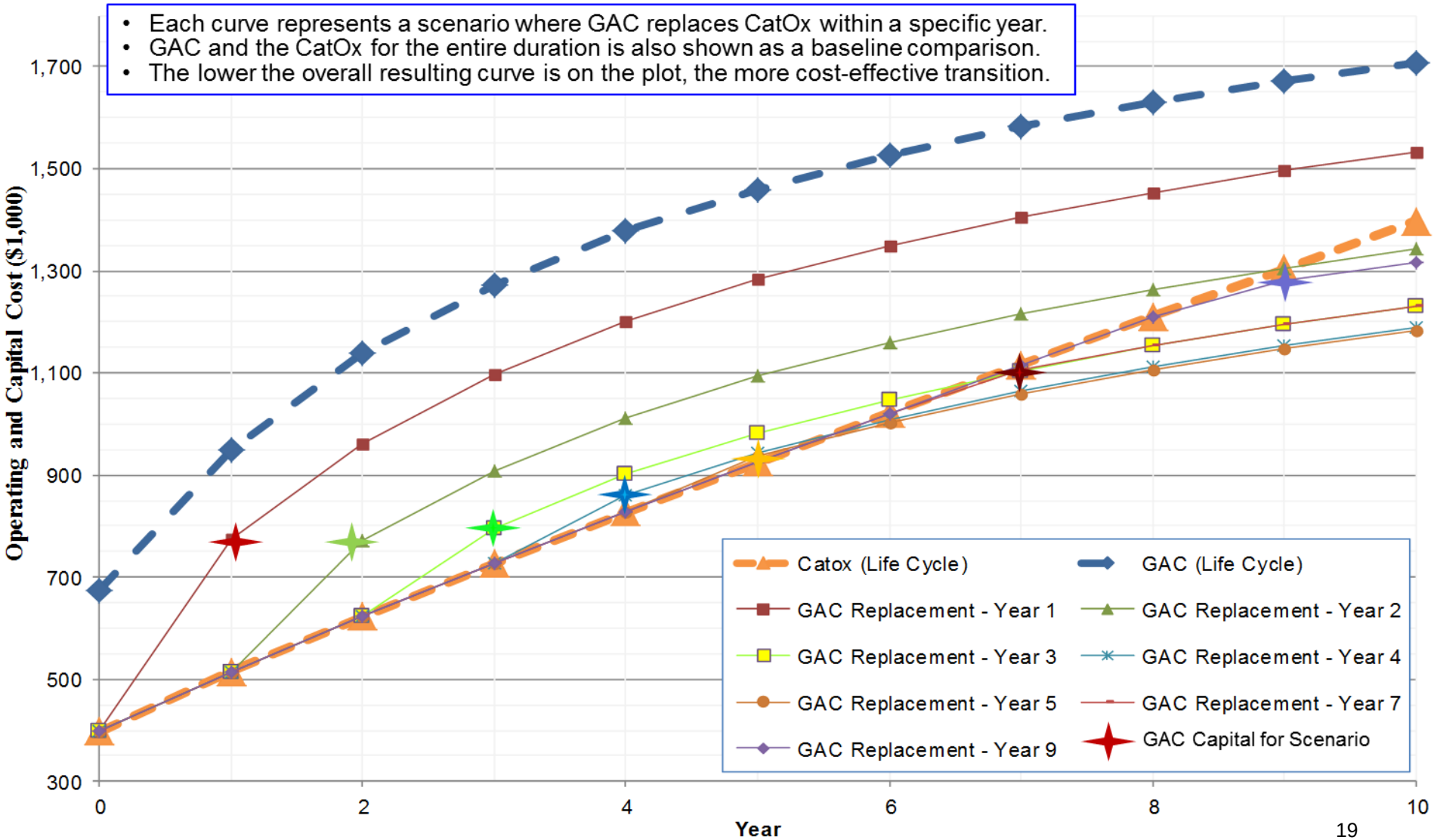
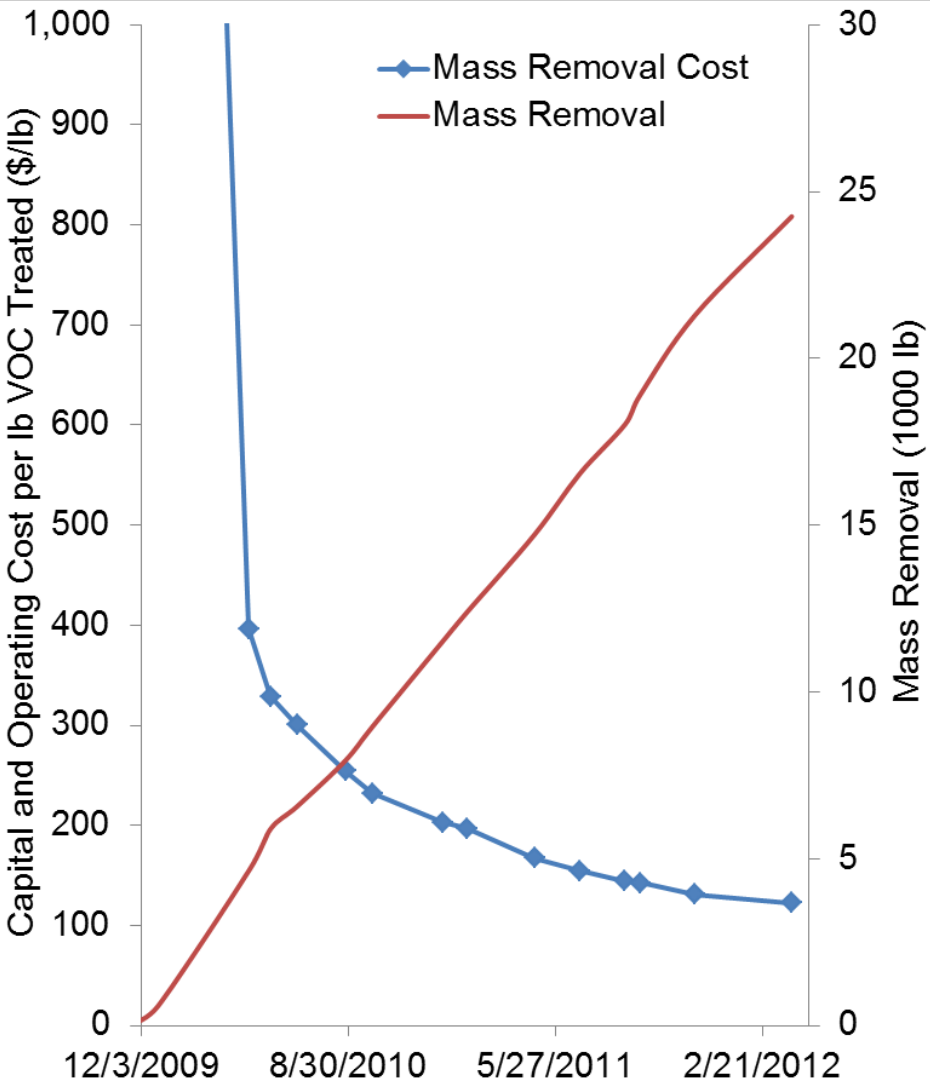


IM Cost Data

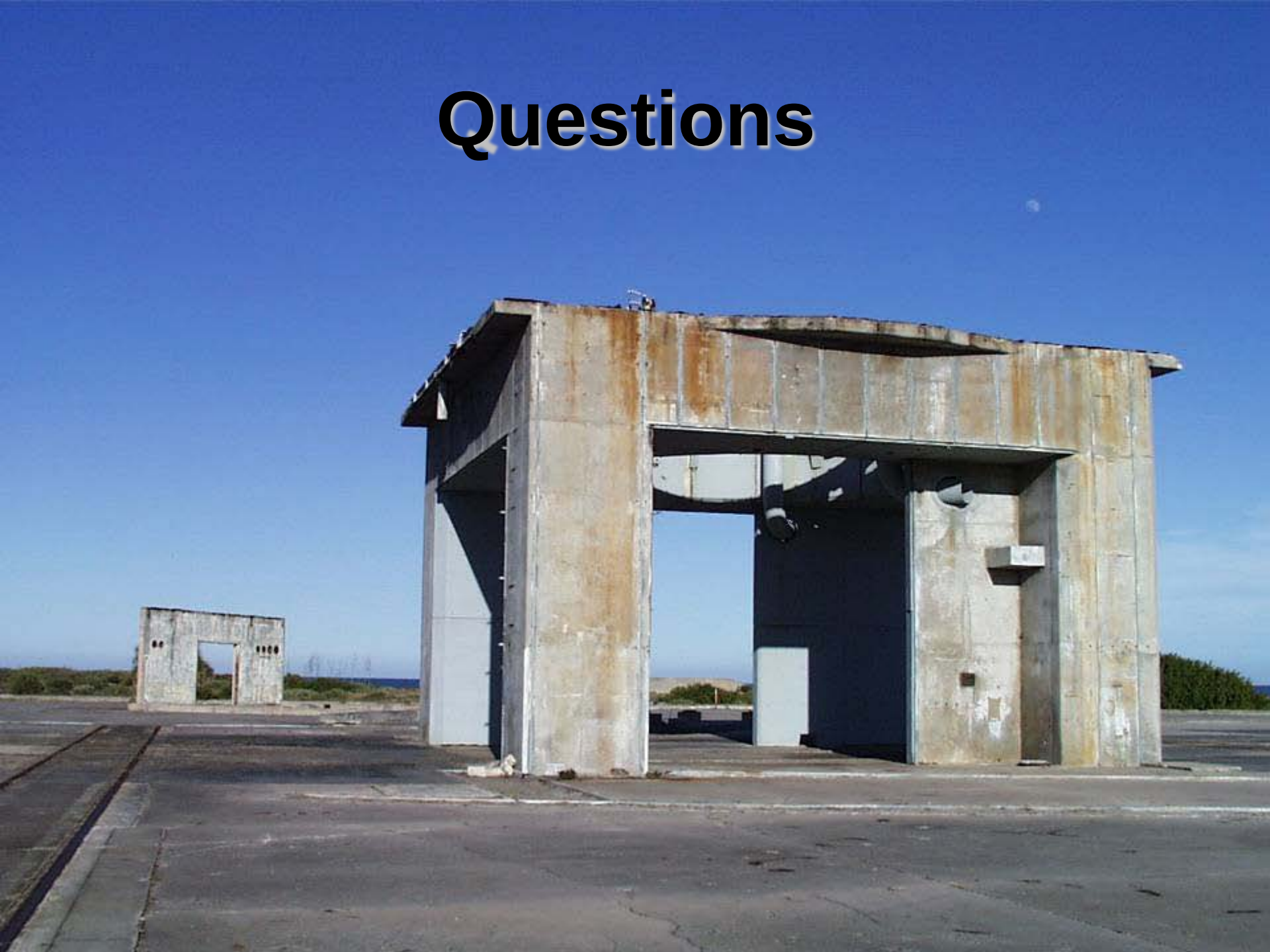
- Mass removal/treatment costs approaching asymptote minimum
- Figure used to evaluate if major operational adjustments are warranted
- Inflection points could indicate treatment or IM technology transition warranted on an efficiency basis
- Example: integrating biorecirculation into the containment system to enhance in situ activity



Ongoing Activities

- Supplemental assessments conducted (2008 to present)
  - 271 direct push technology locations
  - 1,225 water samples collected
  - Refinement of contaminant distribution at Hot Spots 1 through 6
  - Delineated an additional 650 pounds of TCE mass at Hot Spot 3/4
  - Resulted in upcoming design for containment system expansion
- Partitioning electron donor ESTCP pilot (NAVFAC funded)
  - Evaluation of bioremediation in fine-grained unit
  - Potential application for residual mass
- Continue Hydraulic Containment IM and optimization

Adaptive Management Perspective

- Adaptive site management practices of LC34 Team:
  - Assessment (*DOES NOT END WITH DESIGN*)
    - Hot spot areas prioritized
    - Data density based on plume conditions (concentrations, heterogeneity, etc.)
    - Well developed and up-to-date CSM critical
    - Performed supplemental assessments
  - Design (*DOES NOT END WITH IMPLEMENTATION*)
    - Utilize pilot testing, technology screening, and costing evaluations
    - Work plan modifications based on site conditions/supplemental assessments
    - Adaptation of process design (equipment, treatment trains, etc.)
  - Optimization evaluations (*THROUGHOUT*)
    - Does IM meet expectations/objectives (temporal, spatial, performance)?
    - Have site conditions changed (source flux, constituents, etc.)?
    - Can efficiencies be gained?
    - Are supplemental or different technologies applicable?

Questions