Data Management, Visualization, and Predictive Analytics Tools to Streamline Decision-Making and Optimize Performance on Steam-Enhanced Extraction Sites

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Sustainability is our business

Agenda

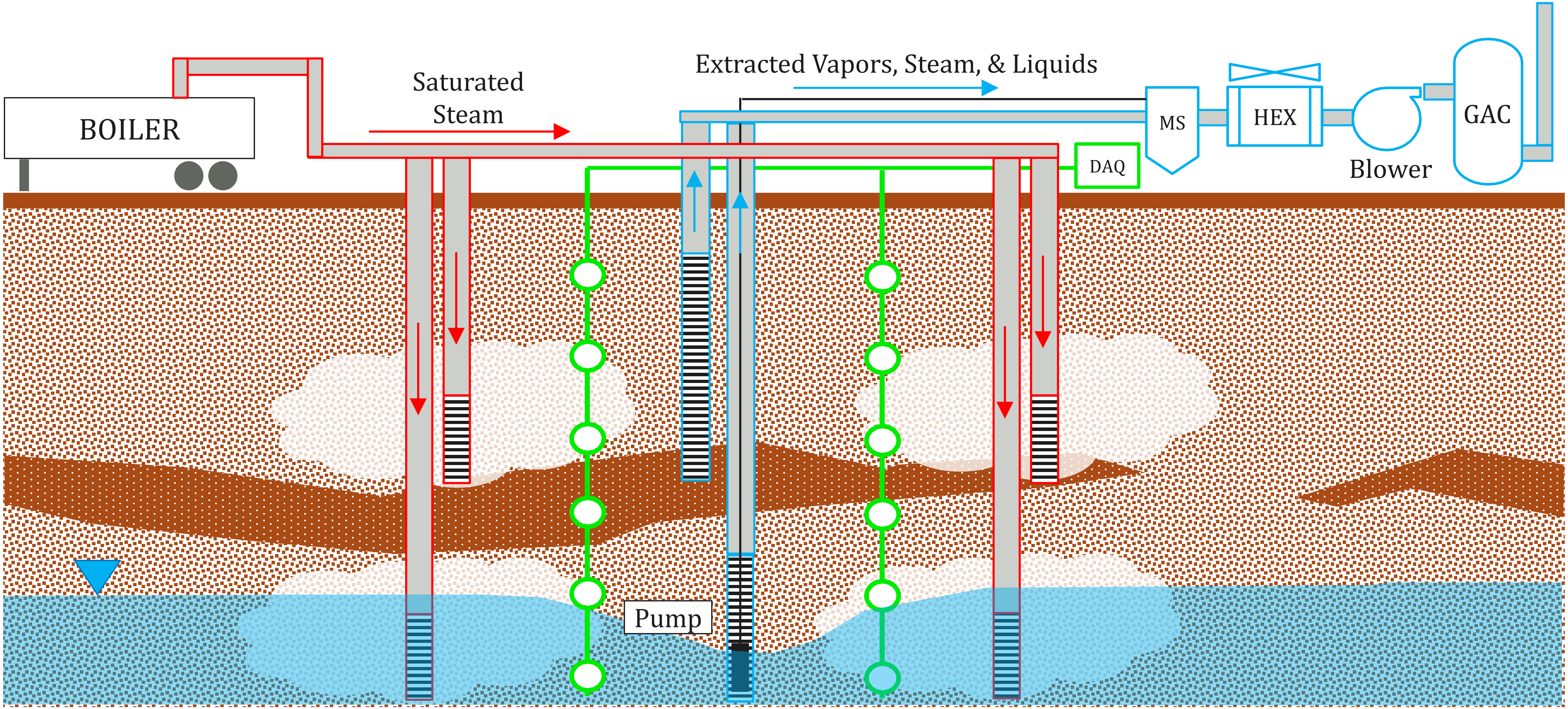
- **Introduction**
- **Background**
- **Approach**
- **Results**

Introduction

Introduction to Steam-Enhanced Extraction

- SEE is an in situ thermal remediation technique (ISTR) used to **accelerate the removal of contaminants** from the subsurface.
- It involves **injecting steam** into the ground to heat soil and groundwater, **mobilizing**, **volatilizing**, and **vaporizing** contaminants for extraction.
- Steam-laden vapors are **extracted, conditioned, and treated** above-grade using a **complex system** of mechanical equipment.
- Its used predominantly in **higher permeability** formations.
- ISTR techniques, including SEE, are frequently chosen for site remediation because they are **rapid** and **effective** techniques.

Introduction to Steam-Enhanced Extraction



Data Inputs and Outputs on SEE Sites

Investigation Phase

- Soil and groundwater contaminant concentrations
- Physiochemical properties of contaminants
- Geologic properties
- Permeability/conductivity
- Hydrogeology
- Geophysics
- NAPL presence/type/saturation

Design Phase

- Conceptual Site Model (geology, hydrogeology, mass distribution, receptors and exposure routes)
- Contaminant mass estimate
- Heater and extraction well layout
- Heatup models & scenario analysis
- Target injection intervals
- Injection and extraction rates
- Treatment system criteria

Operations Phase

- Subsurface temperature distribution
- Injection and extraction rates
- NAPL recovery
- Mass removal
- Boiler operational data
- Energy useage
- Operational uptime/alarm history
- Compliance data

Improving Decision-Making and System Performance

Better Decisions

Improved Stakeholder Communication

Enhanced data management and effective visualizations **streamlines the communication of complex ideas**, leading to **better alignment** on key decisions (e.g. design decisions, shutdown evaluations).

Project Execution Team Empowerment

Dashboards, visuals, and predictive analytics tools can help eliminate “analysis paralysis”, **empowering** the “boots on the ground” to make **effective data-based decisions** in real-time.

Enhancing Performance

Optimized System Operations

Real-time dashboards, predictive analytics, and visualization tools help operators **quickly identify inefficiencies** and **adjust steam injection rates** and extraction processes for optimal performance.

Continuous Improvement

Real-time data and predictive analytics enable **ongoing performance reviews**, trend identification, and strategy implementation for **continuous enhancement** of SEE operations.

Background

Defense Fuel Support Point (DFSP) San Pedro

Ownership and Operations:

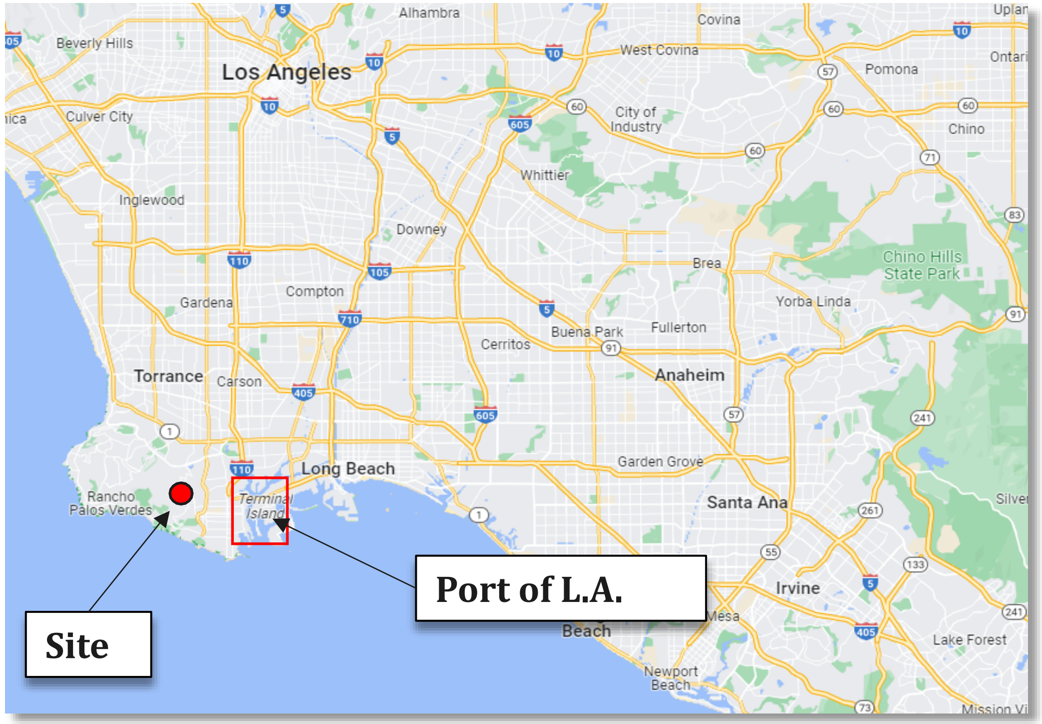
- Owned and operated by U.S. Department of Navy (1942-1980)
- Leased to Defense Logistics Agency (DLA) in 1980

Site Details:

- 480-acre property in Los Angeles, California
- Used for receiving, storing, and distributing diesel and jet fuels
- Heavier oils, including Bunker C and Navy Special Fuel Oil, also stored

Storage Infrastructure:

- 27 bulk, field-constructed underground storage tanks (BFCUSTs) of 50,000 barrels each
- 3 aboveground storage tanks (ASTs)
- Operations ceased in 2014



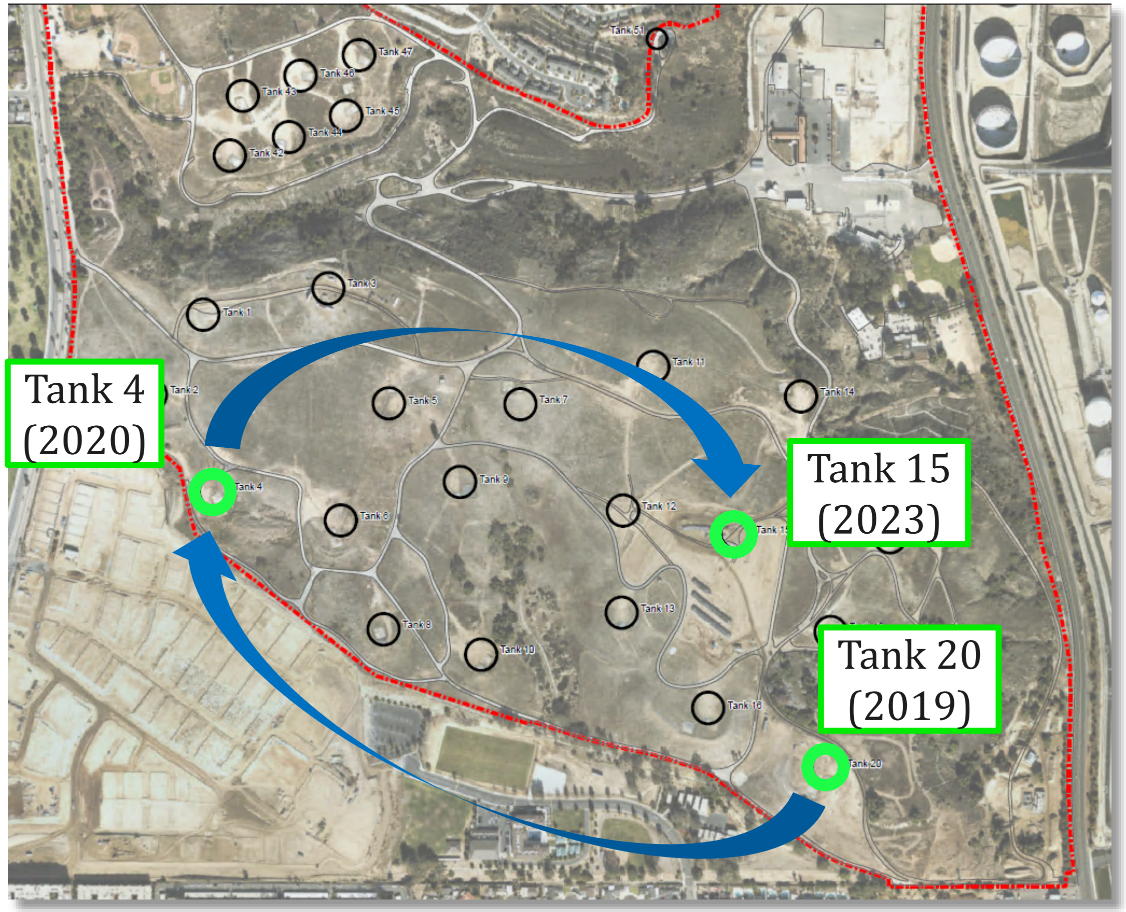
Defense Fuel Support Point (DFSP) San Pedro

Closure and Contamination:

- Closure of tanks and pipelines began in 2017 under Los Angeles Fire Department oversight
- Investigations revealed petroleum hydrocarbons and free-phase product (LNAPL) in soil and groundwater.
- Nine (9) BFCUSTs indicated sufficient mass to warrant in-situ thermal remediation.

Remedial Actions:

- **Objective**: Implement interim RAs to achieve closure under the California Water Board's low-threat closure policy for UST sites.
- Of the nine tanks identified for ISTR, three were identified as suitable for SEE (Tanks 20, 4, and 15), while the remaining six were chosen to be heated via ERH (Tanks 1, 3, 5, 7, 11, and 12).
- The first two tanks, Tanks 3 (ERH) and 20 (SEE) were successfully remediated as full-scale pilots between 2018 and 2019.
- The remaining two SEE tanks, Tanks 4 and 15, were remediated between 2020 and 2023.



Approach

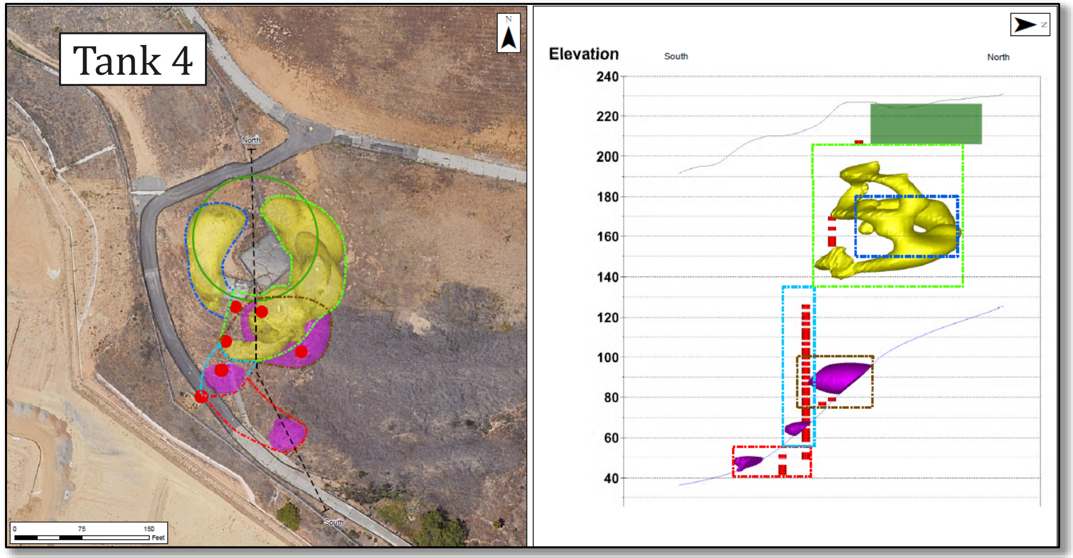
Pre-Design Investigation and CSM Update

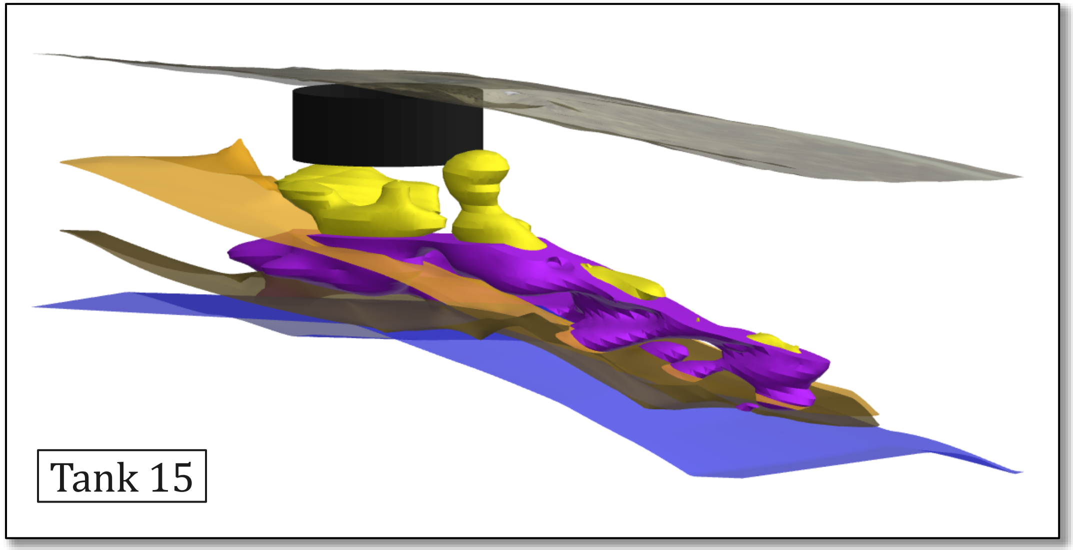
Tank 4:

- 29 soil borings were installed to depths up to ~140 feet bgs.
- Shallow soils underlaying tank were predominantly medium sands, Malaga mudstone at deeper.
- Some LNAPL present at the water table and a “column” of product from the shallow sands was found.
- EVS estimated TPH mass to be **100,000 pounds.**

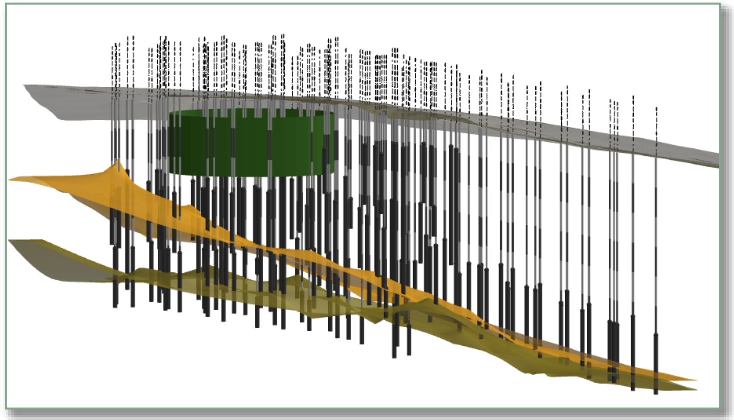
Tank 15

- 62 borings were required to characterize the site, depths generally no deeper than 80 feet.
- Silty clay underlaying sand, which was itself underlain by Malaga mudstone.
- LNAPL found in limestone fractures within the deep Malaga mudstone.
- Approximately **143,000 pounds** of TPH mass was estimated by EVS.



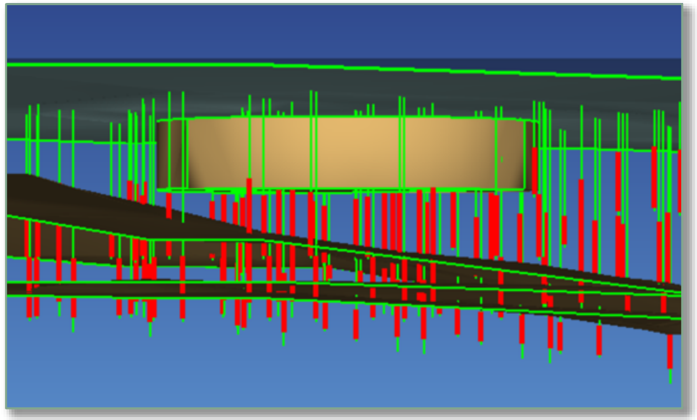


Design and Heating Models



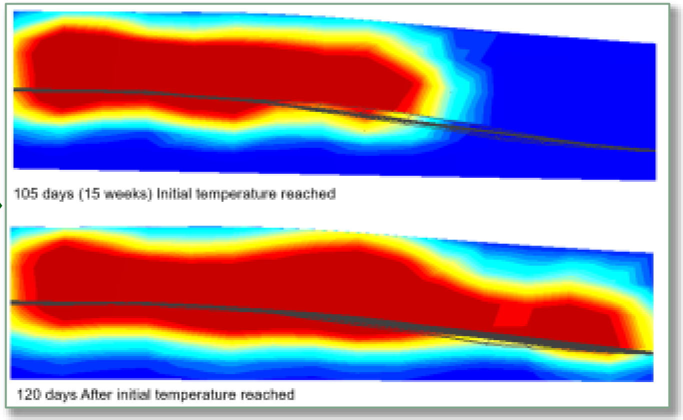
Design Model

- Initial well layout and spacing determined by spreadsheet model.
- Injection and extraction intervals determined by EVS geologic interface query.
- 3d Model allowed for visual "tweaks".



Heating Model

- Design model parameters (geology and hydrogeology, and well parameters) were exported from EVS to PetraSim for modelling heating performance.



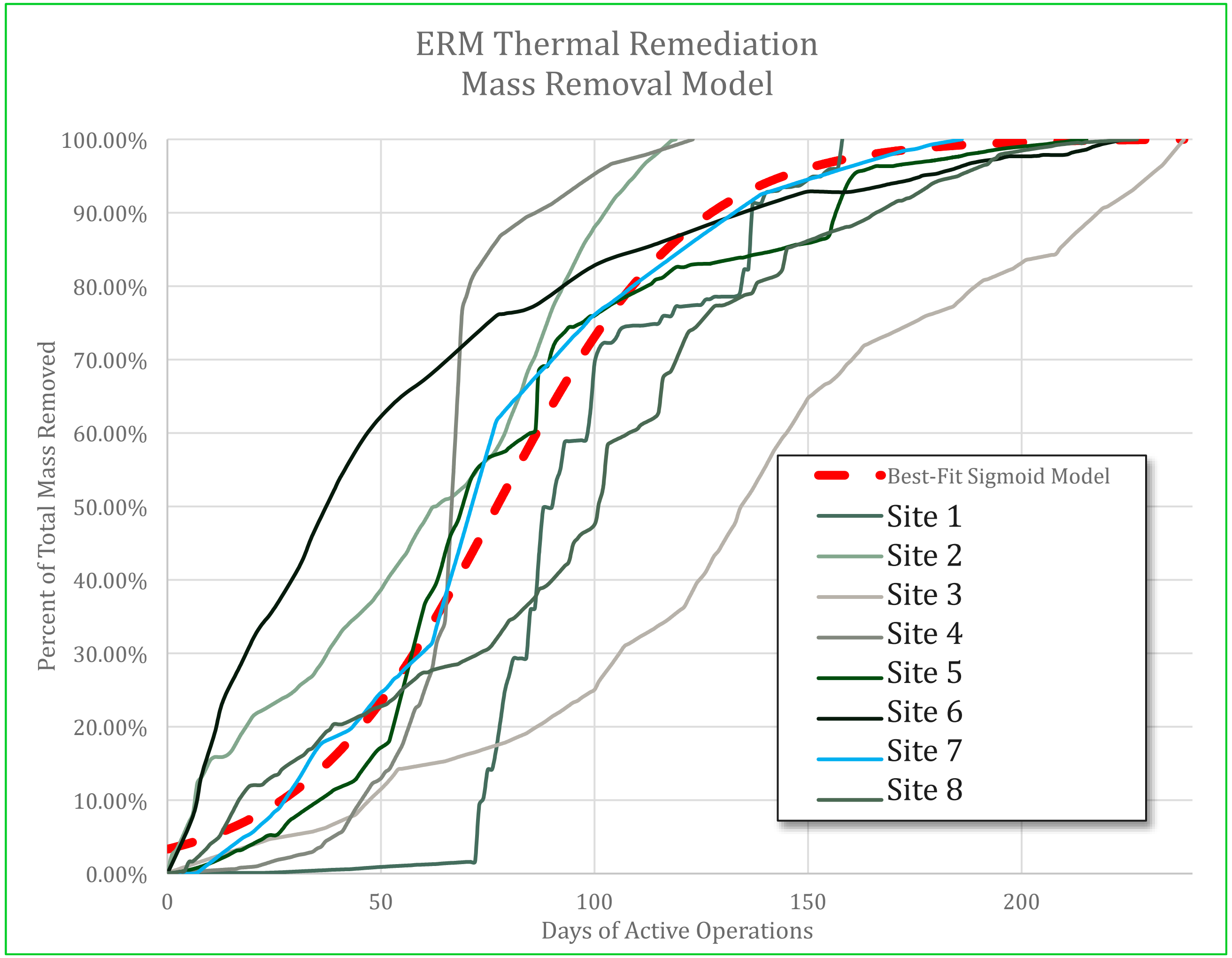
Heating Simulations

- Injection rates and durations were varied across multiple simulations.
- The design model was updated to reflect changes in injection intervals or spacing. Heating model was then updated and was re-simulated.

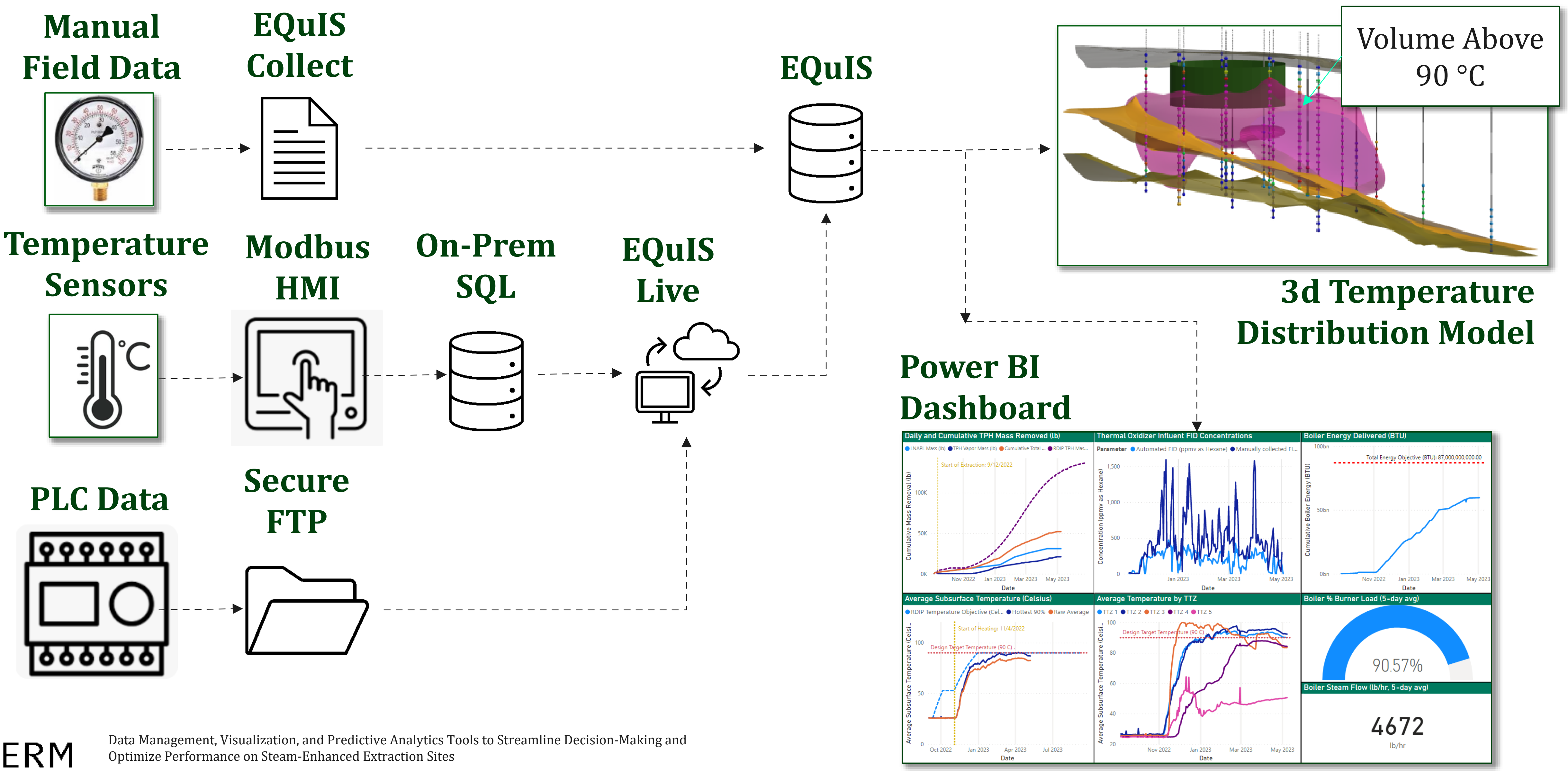
Predictive Analytics for Mass Removal Performance

- The contract required establishing a mass estimate (modelled by EVS) and a performance curve by which operational performance would be measured.
- ERM used the historical performance at eight recent and similar SEE sites to model expected performance at the DFSP tanks.
- Mass removal performance was normalized to the maximum mass that was removed over the course of those projects.
- Modelling included a regression analysis using the least squares method fitting to the logistic function:

$$f(x) = \frac{L}{1 + e^{-k(x - x_0)}}$$

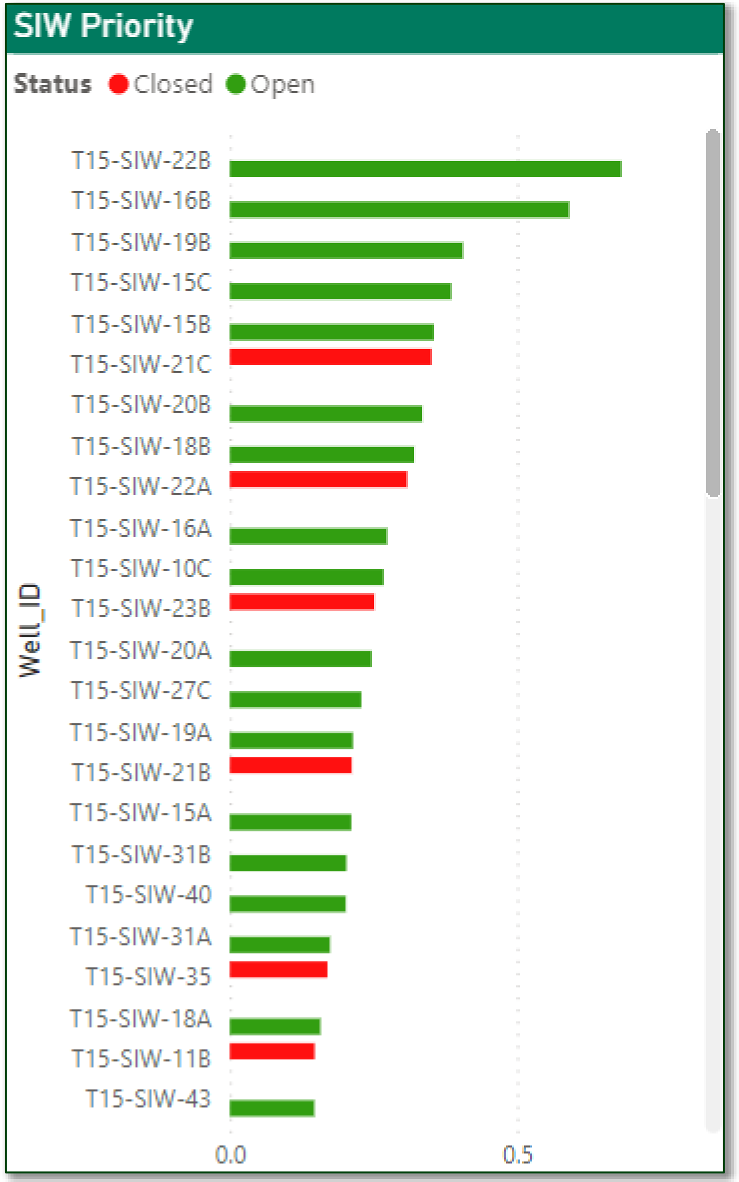


O&M Data Flows



Predictive Analytics Tool for Optimizing Steam Injection

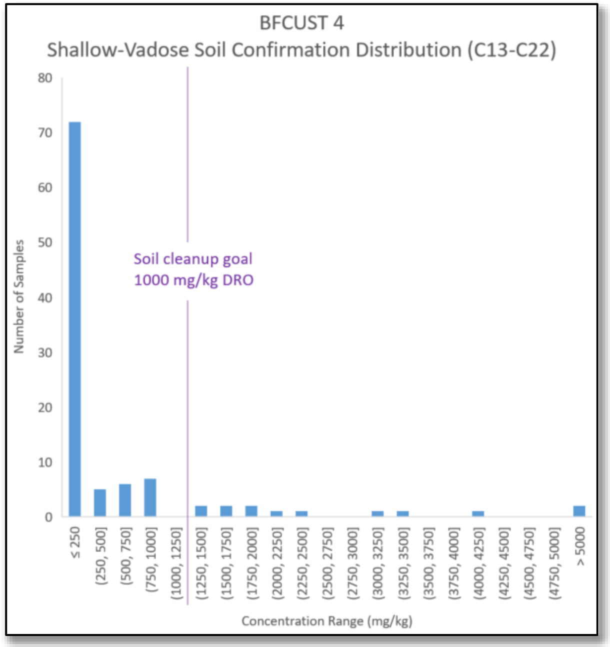
- A 324 x 89 array including data of three-dimensional proximal distances from 324 temperature sensors to 89 steam injection wells (SIWs) was created.
- For each of the ~29,000 nodes, a daily temperature value from each sensor was assigned.
- A “score” was assigned to each node using an algorithm that corresponded to the ratio of difference in temperature value from the target temperature, divided by the 3d-distance from the sensor to the SIW.
- For each steam injection well, the score was automatically summed for the 324 temperature sensor combinations on a daily basis.
- The resultant output was a daily priority list, with the highest priority SIWs being the “closest” wells to the “coldest” sensors.
- The priority list automatically updated daily with the previous day’s algorithm output, allowing field operators to make incremental changes to steam injection rates in order to maximize heating performance in trouble areas.

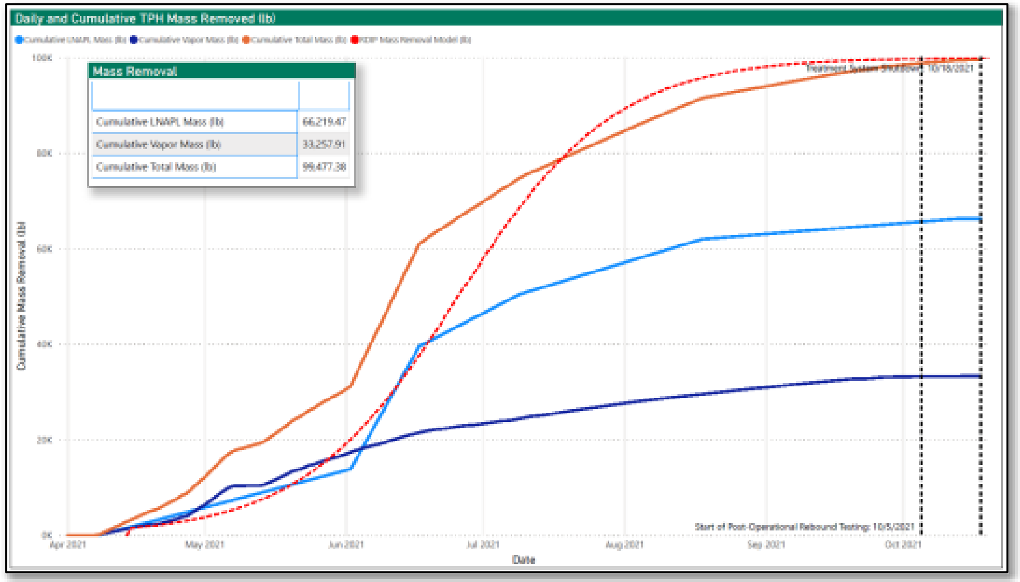


Results

Tank 4 Results

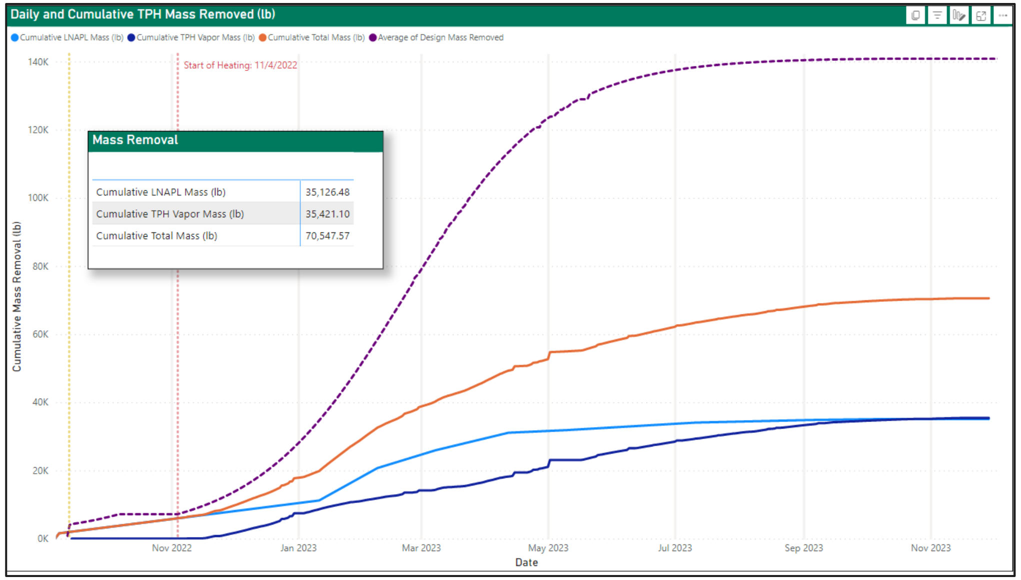
- System operated for 6 months.
- Temperature targets were achieved.
- 99,500 lbs of mass removed (vs. initial estimate of 100,000 lbs)
- 9,900 gallons of LNAPL removed.
- 12 confirmation soil borings advanced in February and March 2022.
- 183 total samples collected.
- 18 samples exceeded SCGs, but 95% UCL indicated remedial goals had been met.
- No measureable LNAPL in any wells.
- “No further remedial action” in soil achieved.

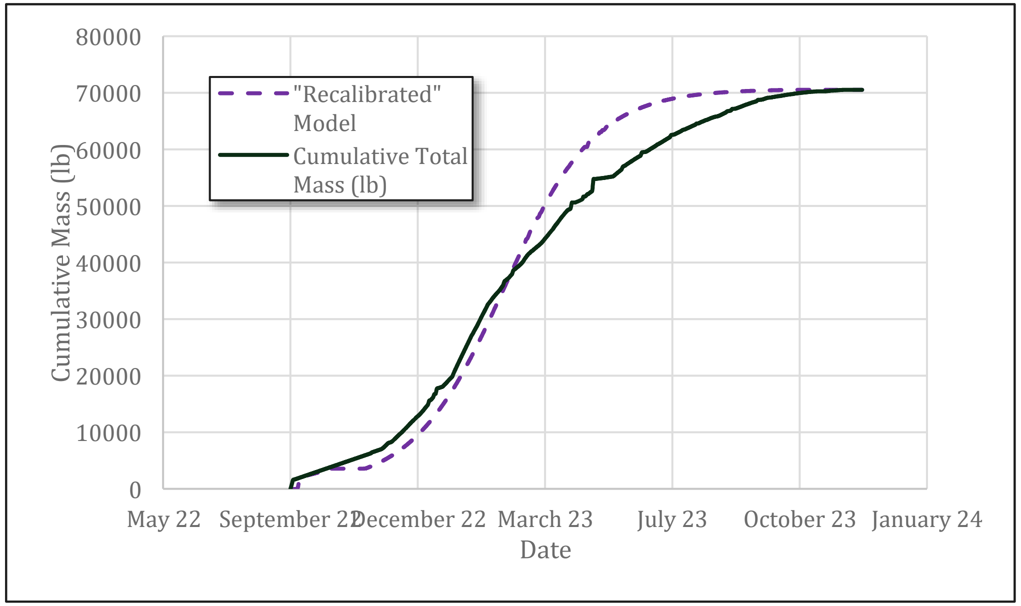




Tank 15 Results

- Temperature targets were achieved but were difficult to sustain.
- No LNAPL present in any of the monitoring or MPE wells.
- Wellhead vapor concentrations decreased by over 98%
- Mass removal was below the predicted model - 70,000 pounds removed vs 143,000 predicted.
- However, when recalibrating the model to the actual mass recovered, the shape of the curve is a close fit. This indicates that the initial mass may have been over-estimated.
- Overall, the agency agreed that the soil source to groundwater had been removed and that no further remedial actions in soil would be needed.
- Groundwater to be managed via forthcoming RAP.





Thank you

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