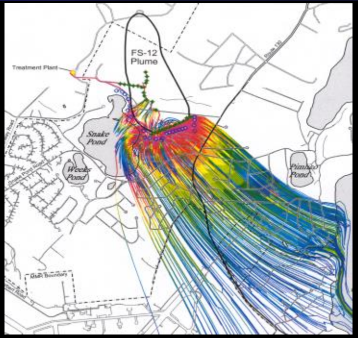
The Use of Monitoring and Modeling to Optimize Remedial Systems and Reduce Site Uncertainties at the Massachusetts Military Reservation (MMR)



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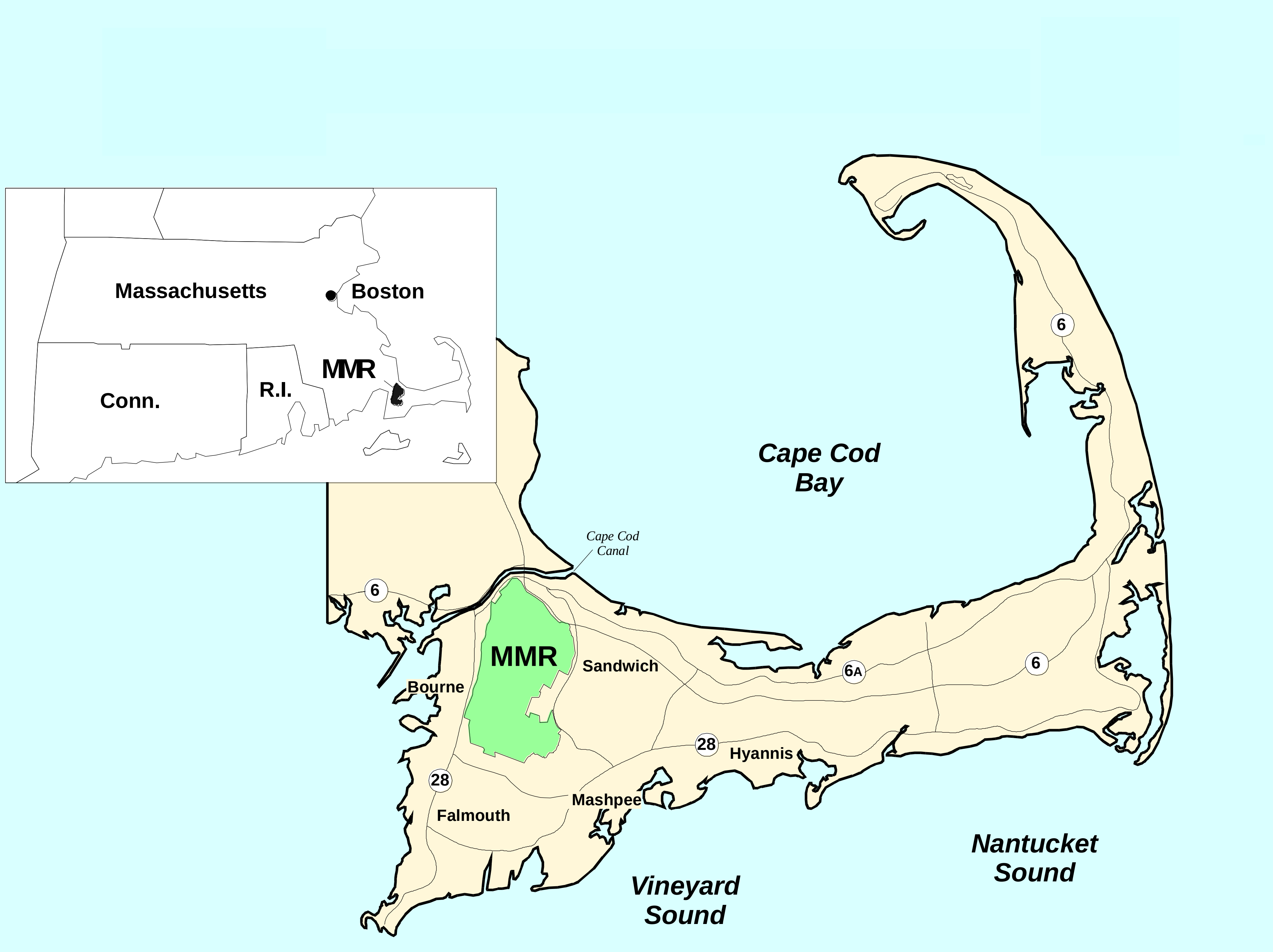


Massachusetts
Boston
MMR
Conn.
R.I.
Cape Cod Bay
Cape Cod Canal
6
6A
28
MMR
Sandwich
Bourne
Hyannis
Mashpee
Falmouth
Vineyard Sound
Nantucket Sound

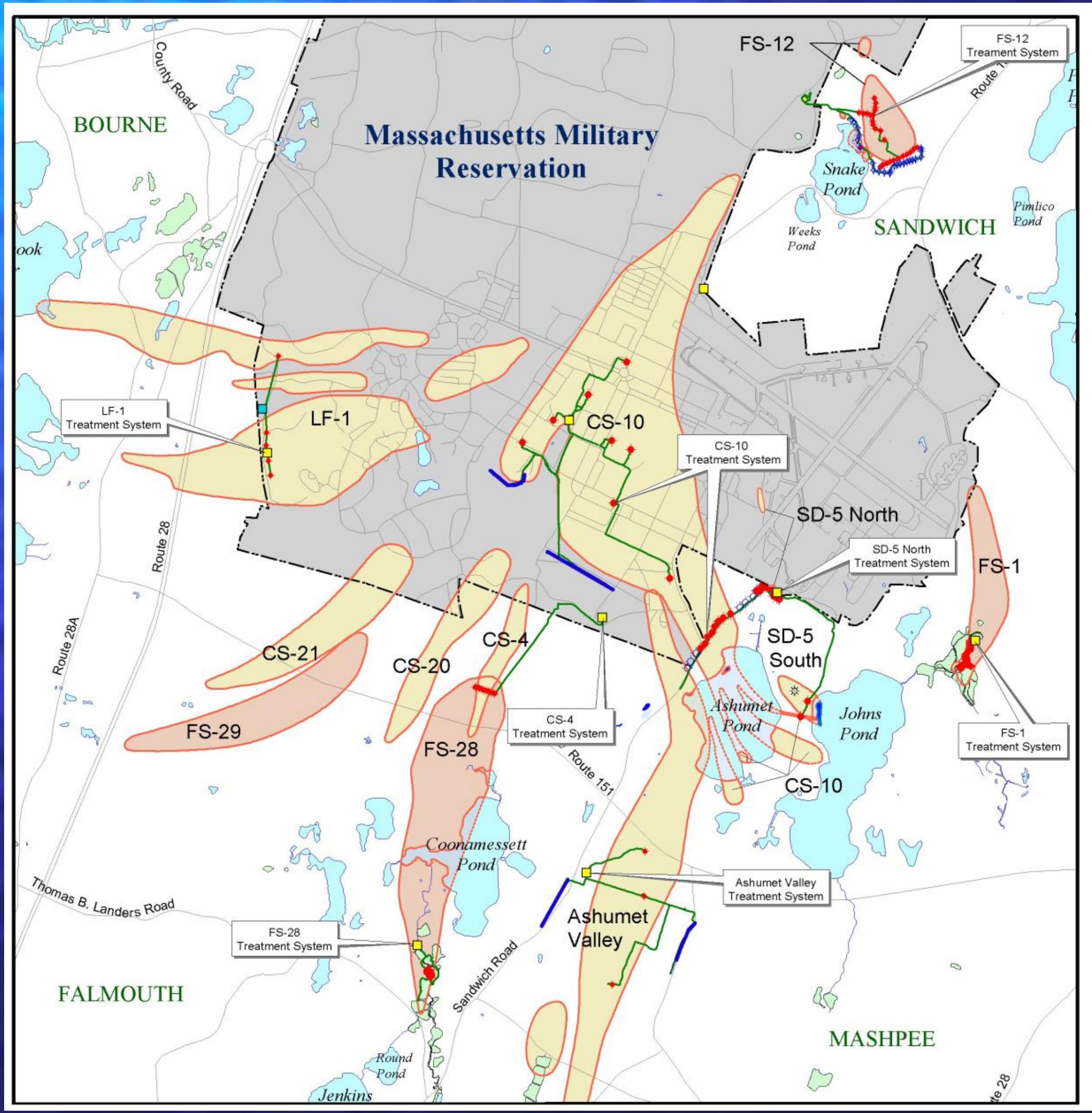
Introduction

Jacobs has designed, constructed, operated, and analyzed the performance of seven groundwater remediation systems at the Massachusetts Military Reservation (MMR) over the past 6 years.

Four new remediation systems are currently being designed and will be operational by mid 2005.

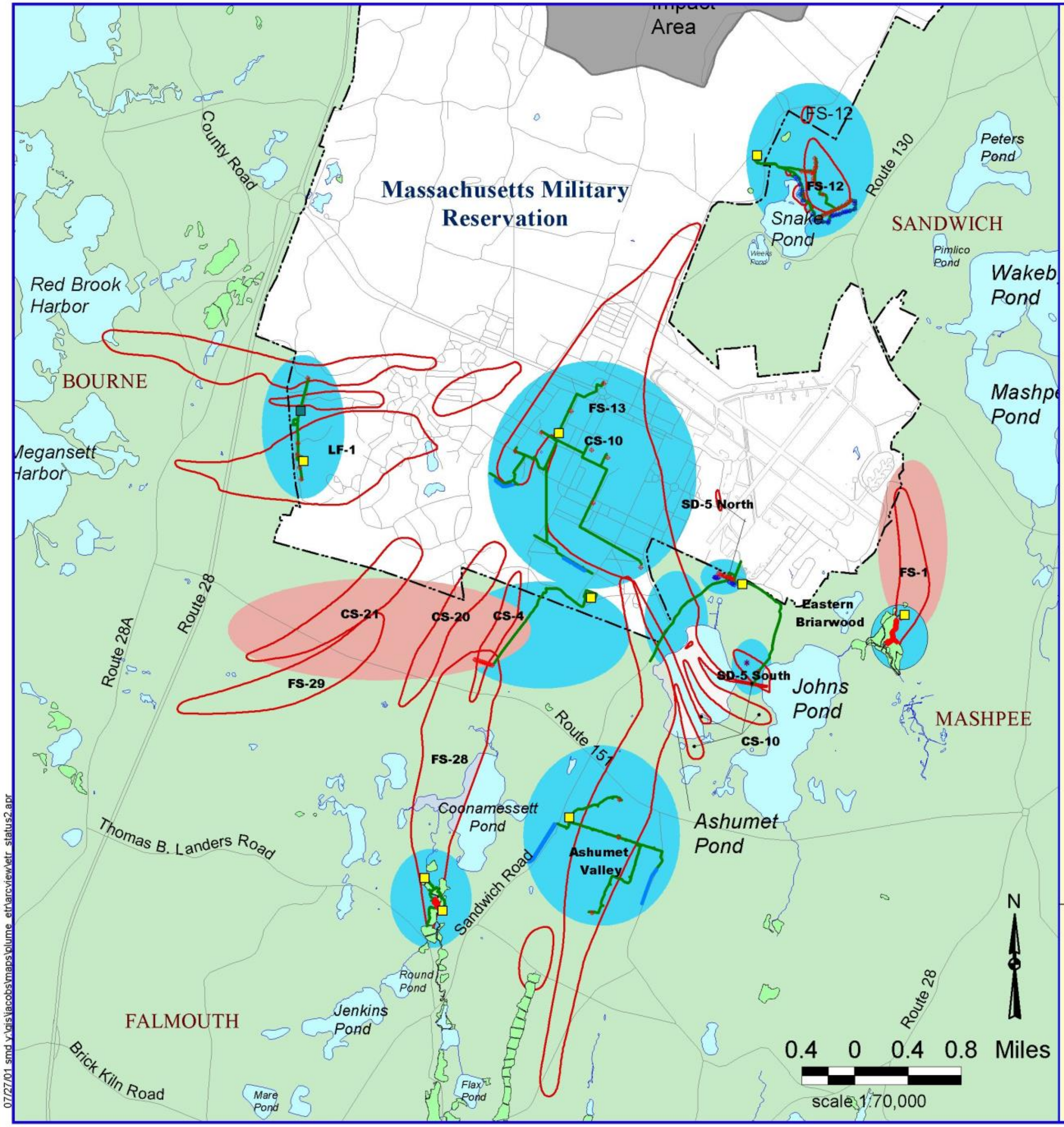
This presentation will use data from the CS-10 plume to show how groundwater hydraulic and chemical monitoring and flow and transport modeling is used to:

- Optimize the pump and treat systems, monitoring networks, and the treatment systems
- Reduce uncertainties in hydraulic conductivities and concentration distributions present in large plumes
- Maximize contaminant mass removal by using observed data and making strategic changes to the operational conditions of the remedial systems



Overview

- Remedial Process Optimization (RPO) Overview and Approach
- MMR Model Overview
- CS-10 Optimization Example
- Monitoring Network Optimization Example



Legend

Treatment System Status

Treatment Systems In Operation

Future Treatment Systems

END OF CY	NUMBER SYSTEMS	TREATMENT RATE GPM	MGD
98	5	2335	3.35
99	10	6565	9.45
00	13	8200	12.00
03	16	10835	15.60

Air Force Center For Environmental Excellence

Why System Performance Validation and Optimization Are Important

February 2002

JE JACOBS

Remedial Process Optimization Sequence

Periodic Review of Remediation Goals and System Performance (System Performance Validation)

Screening to Identify Optimization Opportunities (System Efficiency Assessment)

Existing System Adequate-Continue Operation and Monitoring

Optimize Existing Systems and/or Explore New Regulatory/Technology Options?

Implement Optimization and Continue Operations and Monitoring

Implement New Technical and/or Regulatory Approach and Resume Operation and Monitoring

Optimization Definitions

At MMR, three forms of optimization are routinely addressed. These include:

1. Pump and Treat System Optimization
   - Adjustments can be made to extraction and injection flow rates and screened intervals to improve mass removal

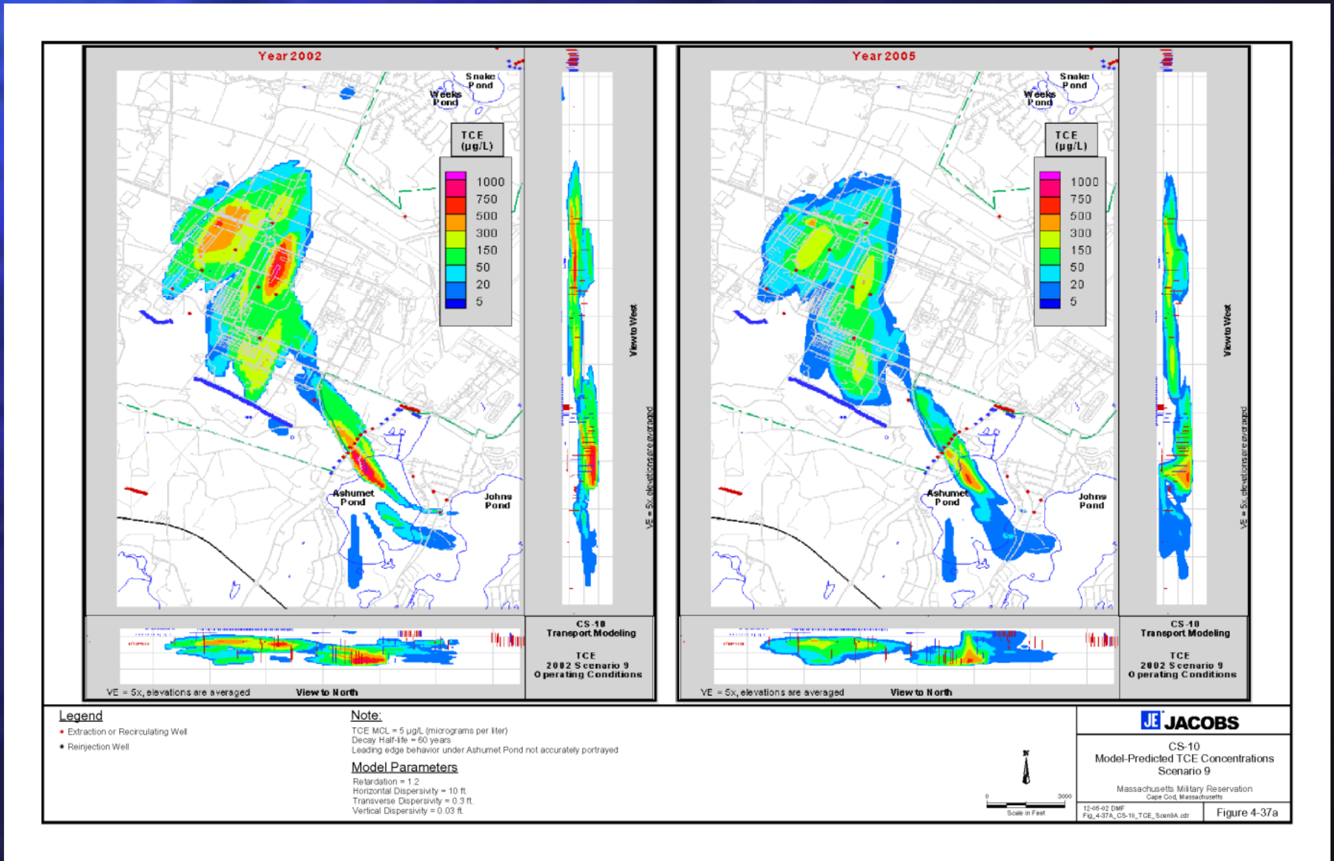
2. Monitoring System Optimization
   - Reduction in the number of monitoring wells and the sampling frequency used to monitor remedial system performance and to delineate plumes

3. Treatment System Optimization
   - Changes can be made to the water treatment systems to reduce cost and eliminate problems that emerge over time

Results of the Optimization Studies

- The optimization studies identify ways to improve the operational efficiency of these systems and to reduce ongoing O&M costs.

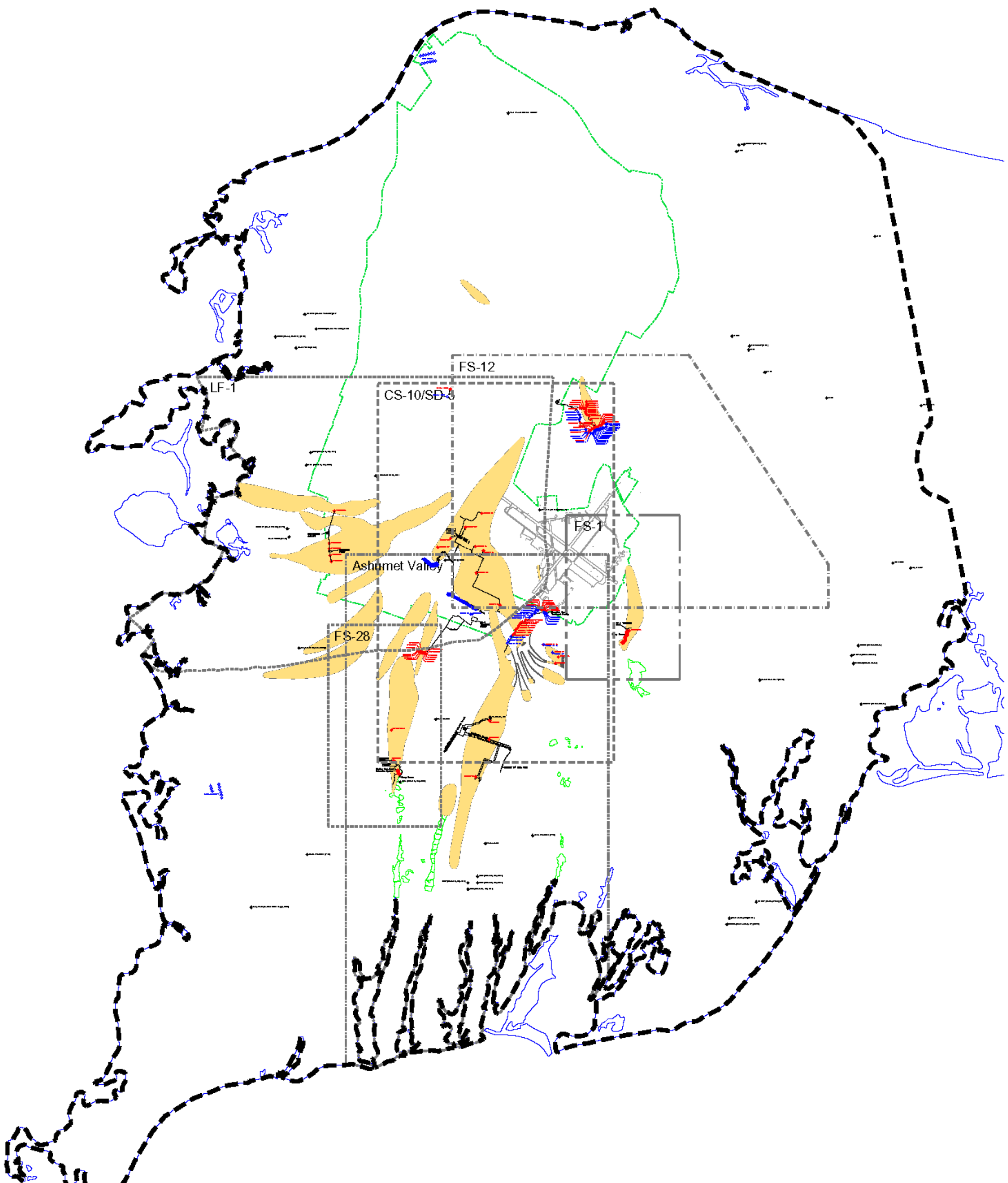
- The results provide the technical justification needed to convince regulators that changes to the remedial system will help get the site to closure sooner.



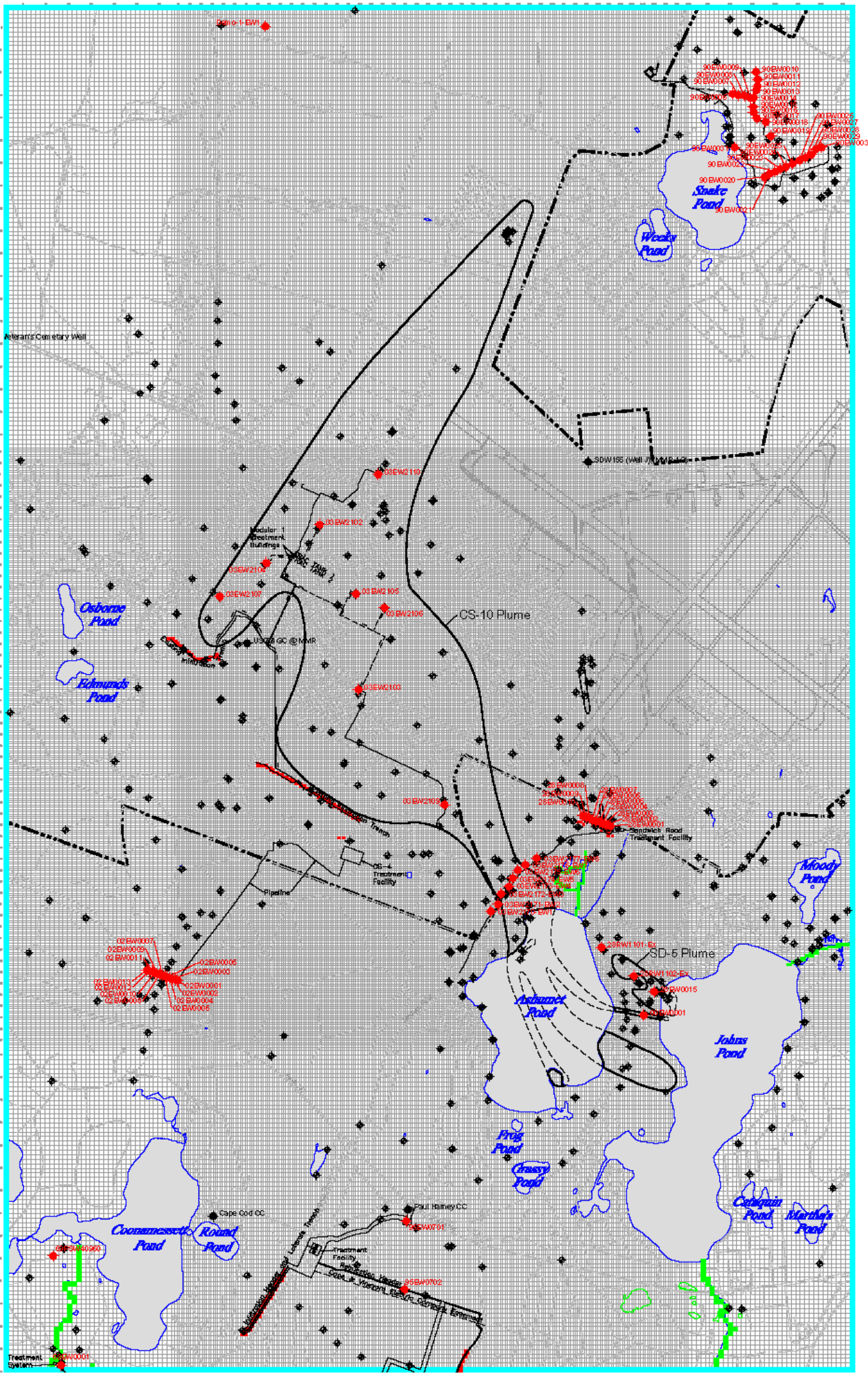
MMR Groundwater Modeling

- A regional model of Western Cape Cod has been formulated and updated over time based on observed lithologic, hydraulic and chemical data
- The regional model is the basis for several site-specific (zoom) models that are used to quantify remedial system performance
- The flow and transport models are all solved using MODFLOW-SURFACT and are post-processed with Jacobs codes and commercial software
- Model sizes range up to 4 million cells

MMR Model Domains

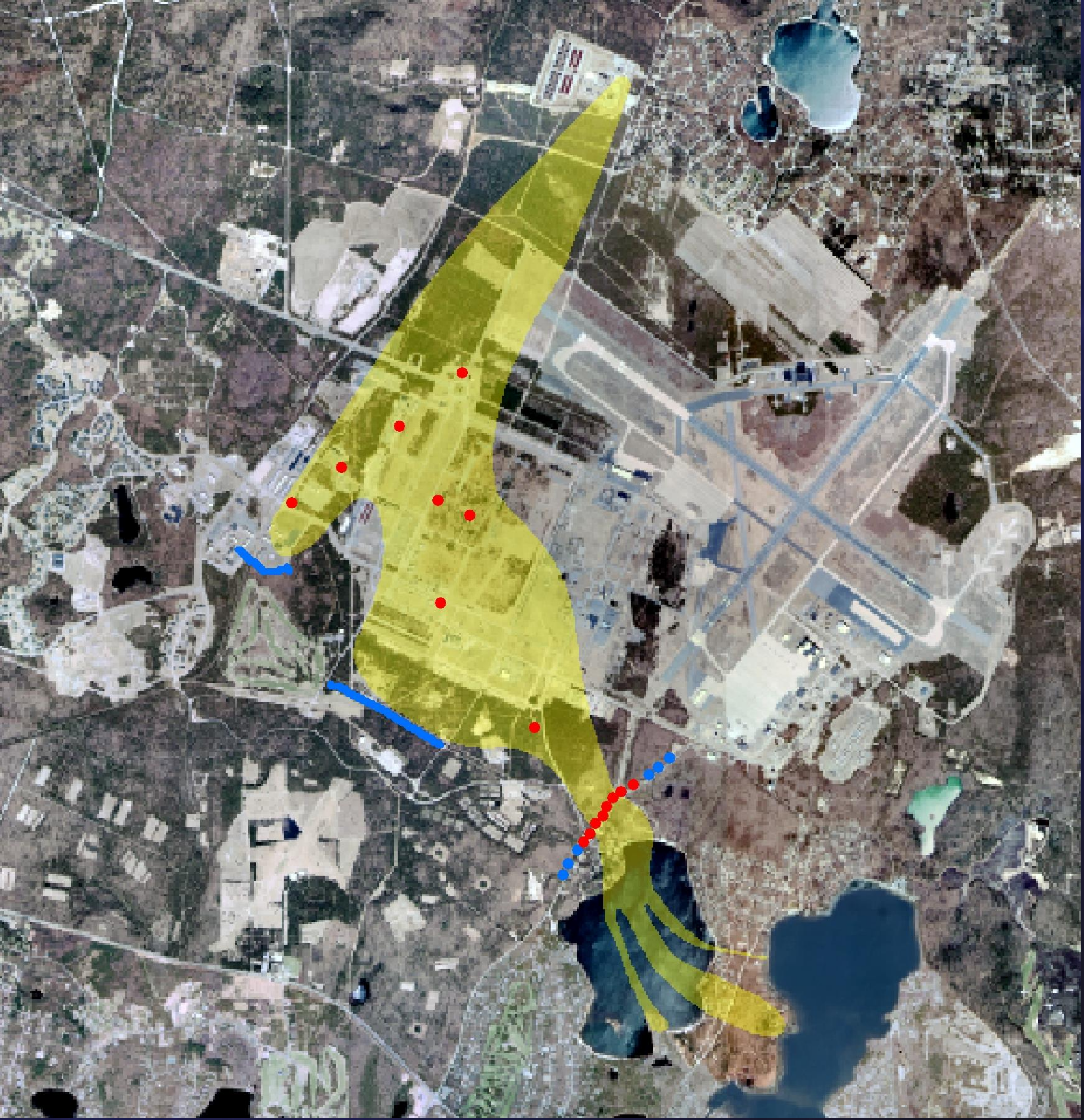


Regional model shown in heavy black dashed line along the coast, zoom models in grey



CS-10 Model Domain

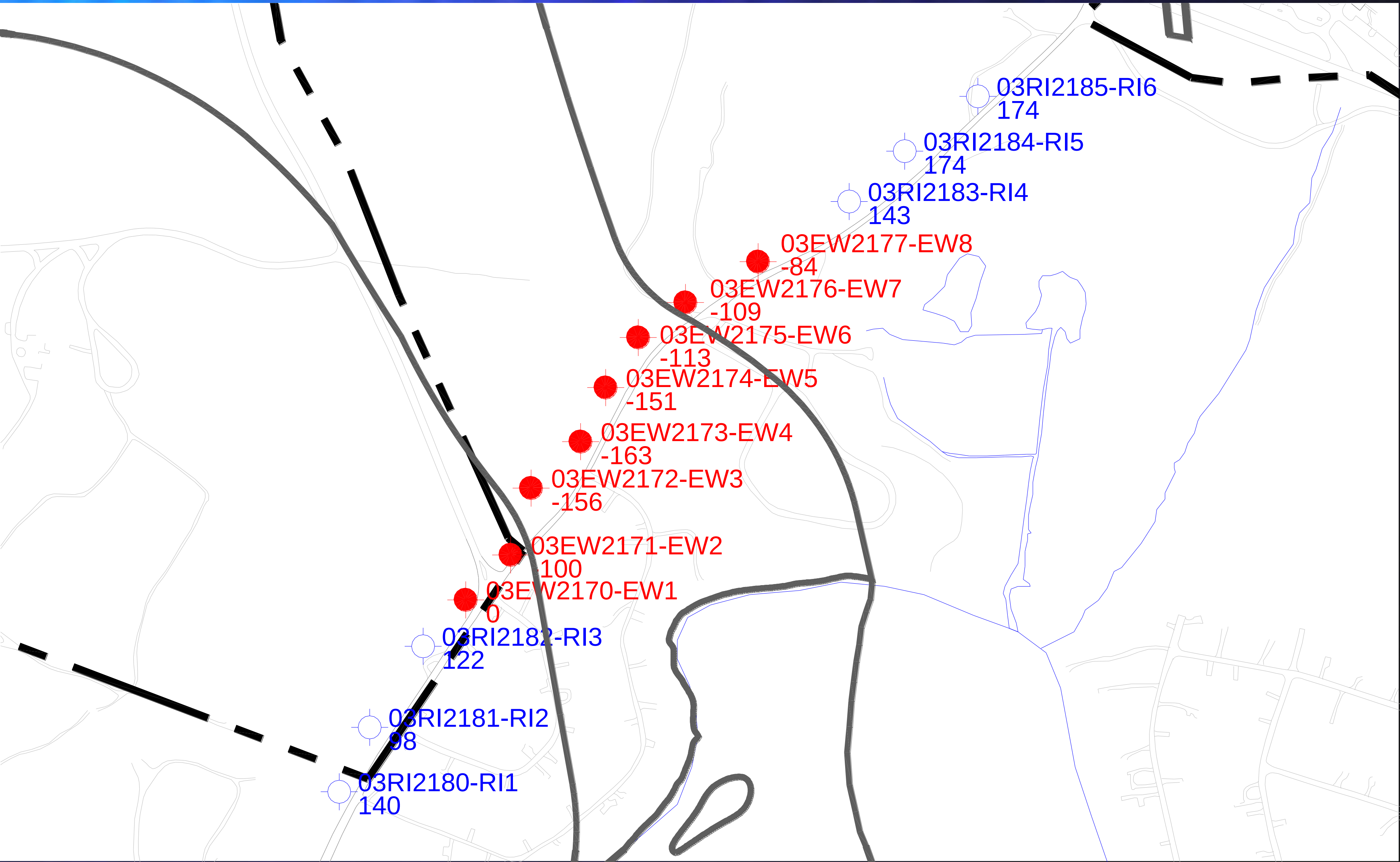
- 3,152,880 finite-difference cells
- 24 layers
- 50 by 50 foot minimum grid spacing
- 100 by 100 ft grid maximum grid spacing



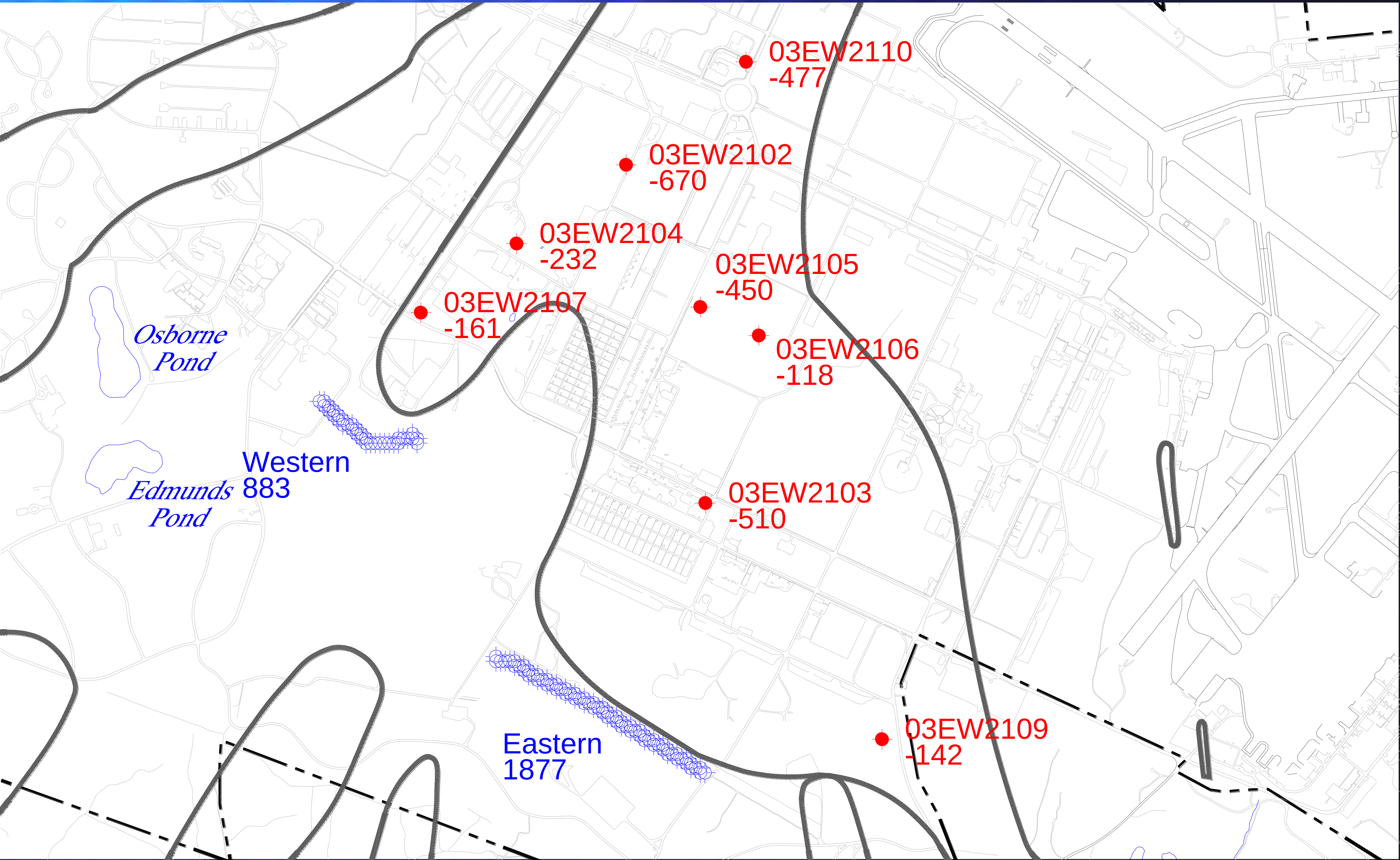
CS-10 Area

- Plume in yellow
- Extraction (red)
- Injection (blue)
- 4 miles long
- 1 mile wide (max)

Sandwich Road Extraction and Injection Wells and Current Flow Rates (gpm)



In-Plume Extraction Wells, Infiltration Trenches and Current Flow Rates (gpm)



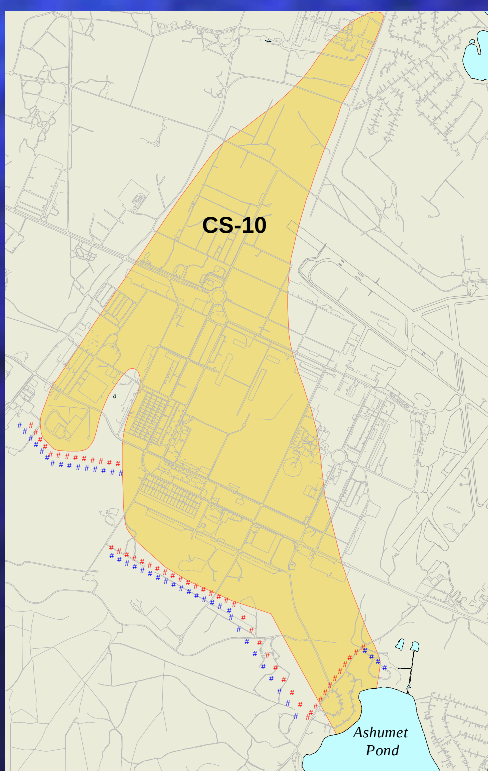
Examples of Optimizations Already Conducted at MMR

- Three rounds of pump and treat optimizations for the CS-10 plume:
  - Design optimization
  - Sandwich Road optimization
  - In-Plume optimization
- Monitoring system optimization for FS-12
- One treatment system optimization briefly mentioned in this presentation

Results CS-10 Design Optimization

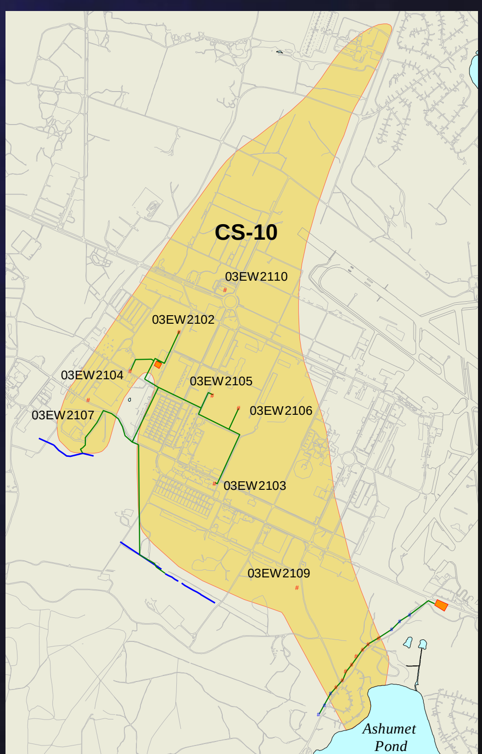
- 50% reduction in total pumping requirement
- 60% reduction in number of extraction wells
- Improved mass removal

60 Percent Design



60% Design		Final Design	Adaptive Pumping (Final Design)
✓	Plume Stabilization	✓	✓
6,954	Pumping Rate	3,520	3520-250
39	Number of Extraction Wells	16	16-1
84.2%	Initial Mass Extracted	95.0%	76.0%
-1741	Change in Plume Volume from Initial (million gallons) 12 Years 26 Years	-5456	-5770

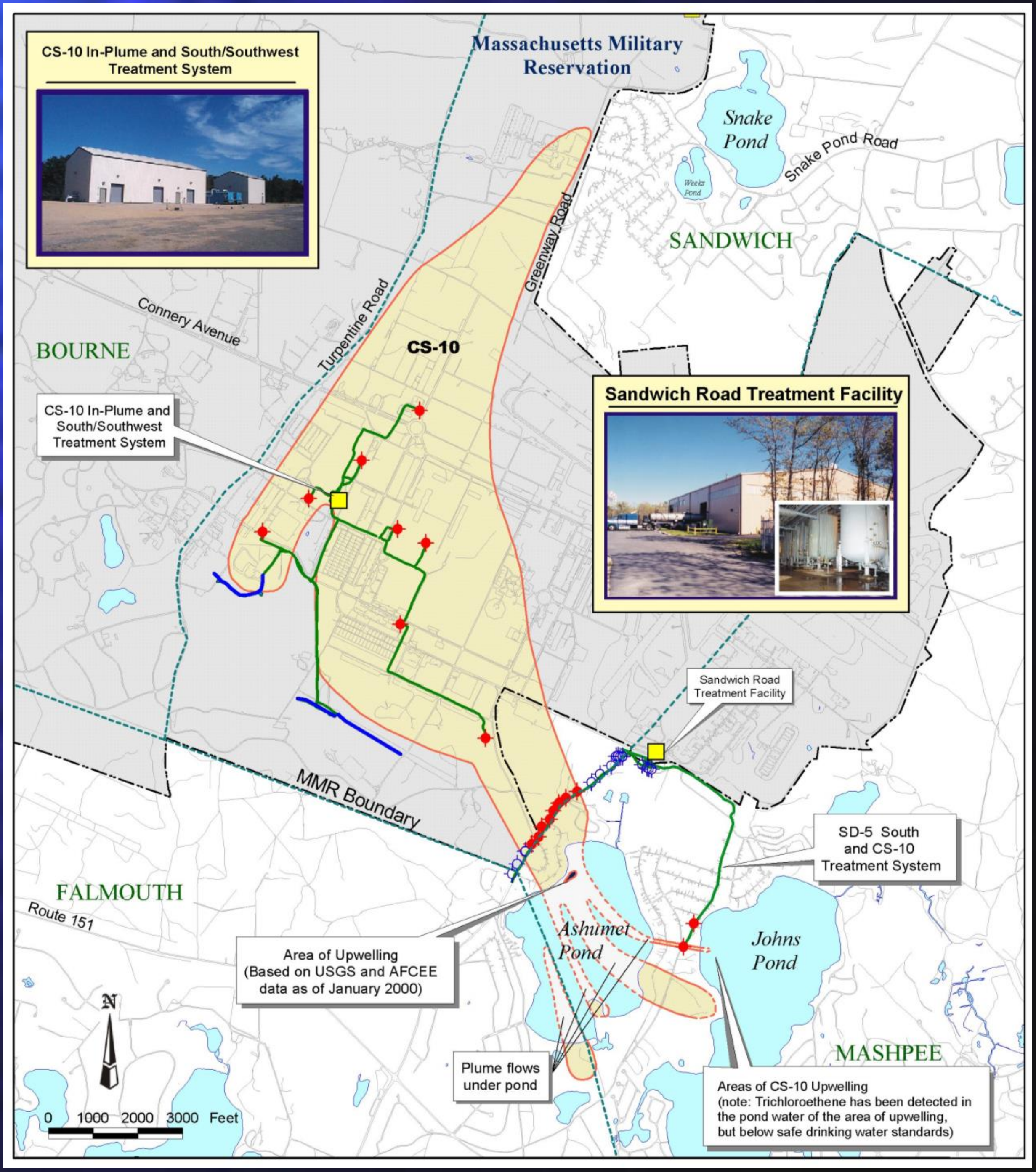
Final Design



CS-10 Optimization Examples

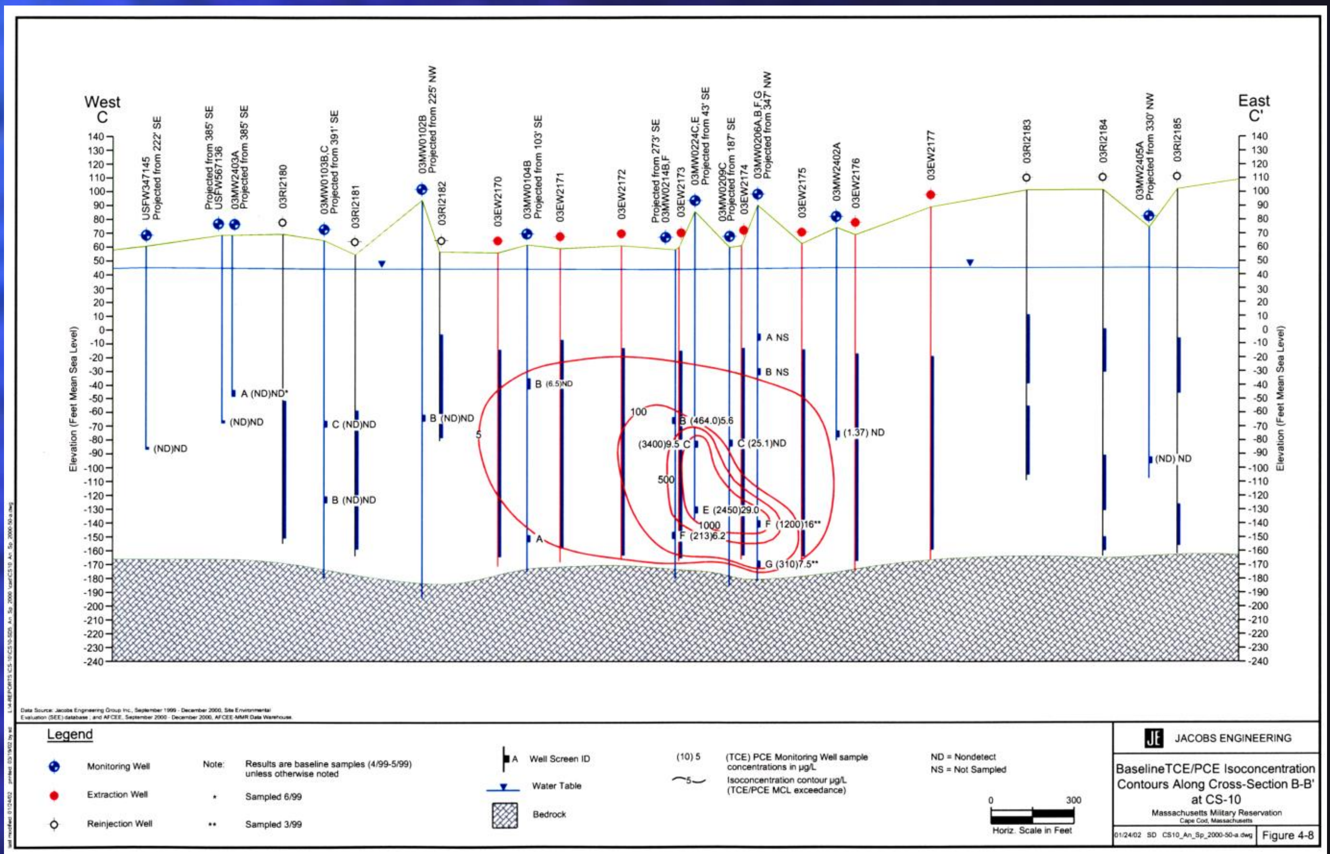
Overview

- Three remedial systems employed – a cutoff fence and In-Plume removal
- Extraction wells and injection wells and infiltration trenches used
- Total extraction over 3500 gpm (5 mgd)

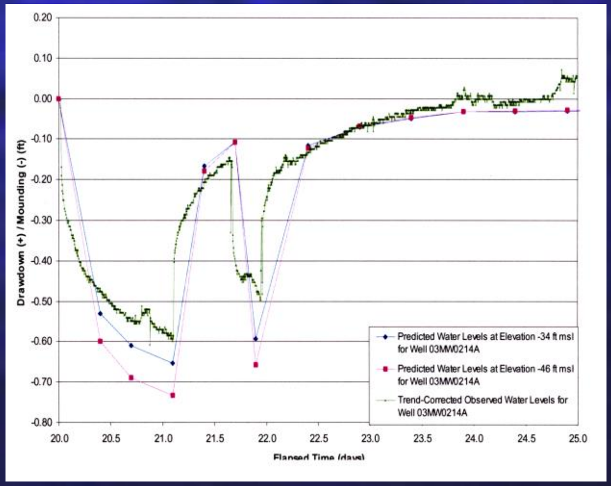


Sandwich Road

Conceptual Model Observations

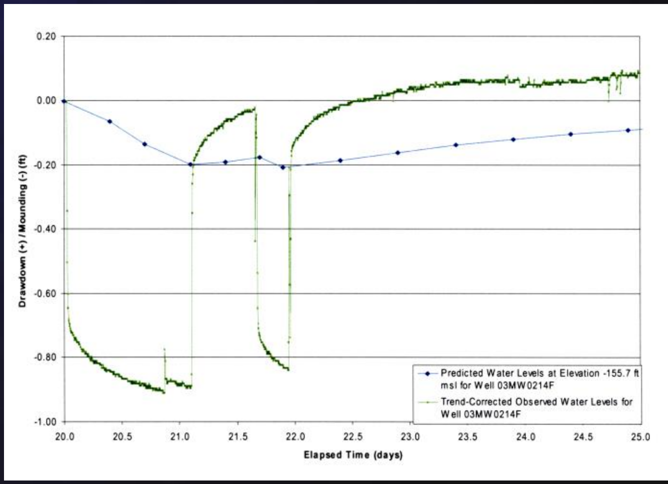


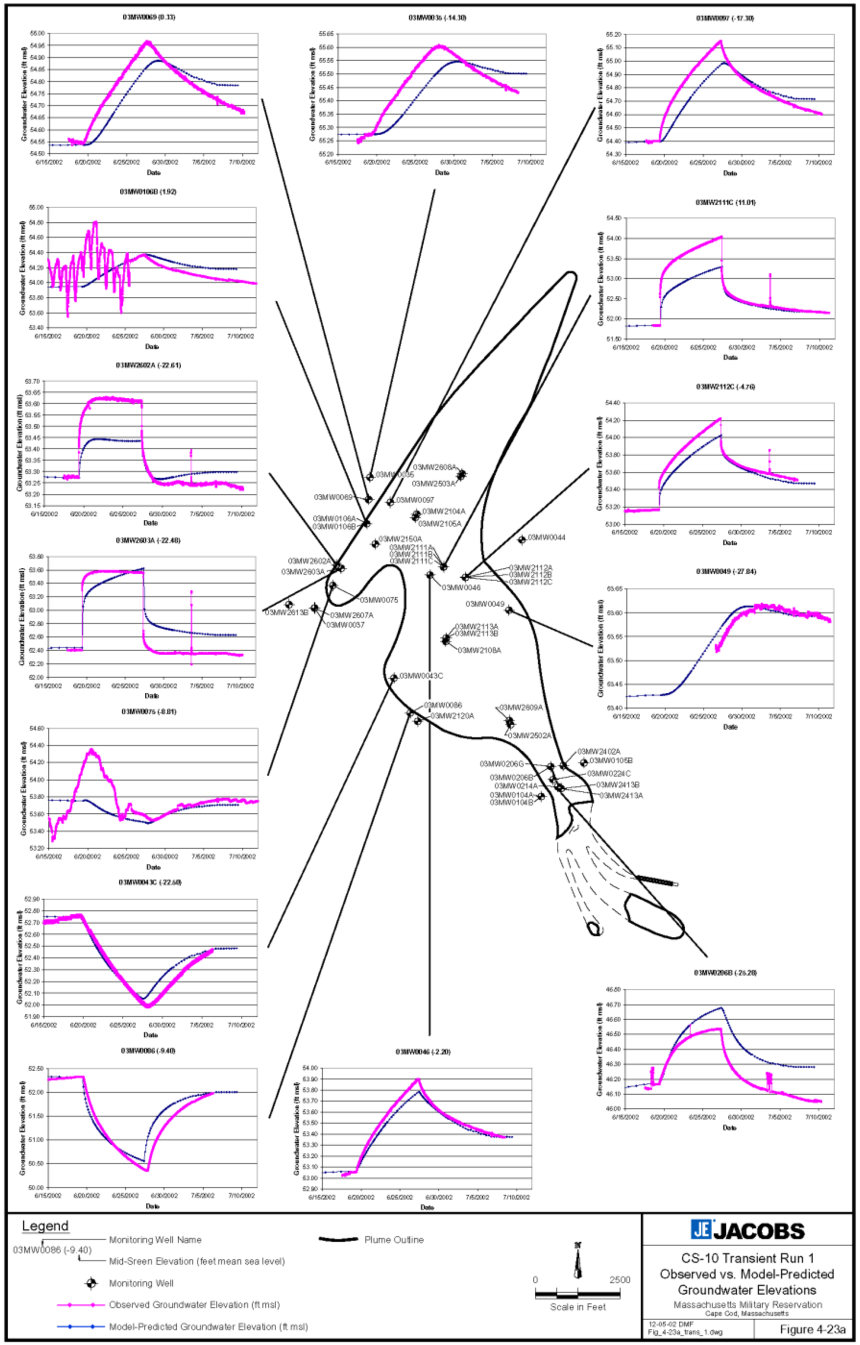
Shallow Hydraulic Response



K-field revision needed at depth

Deep Hydraulic Response



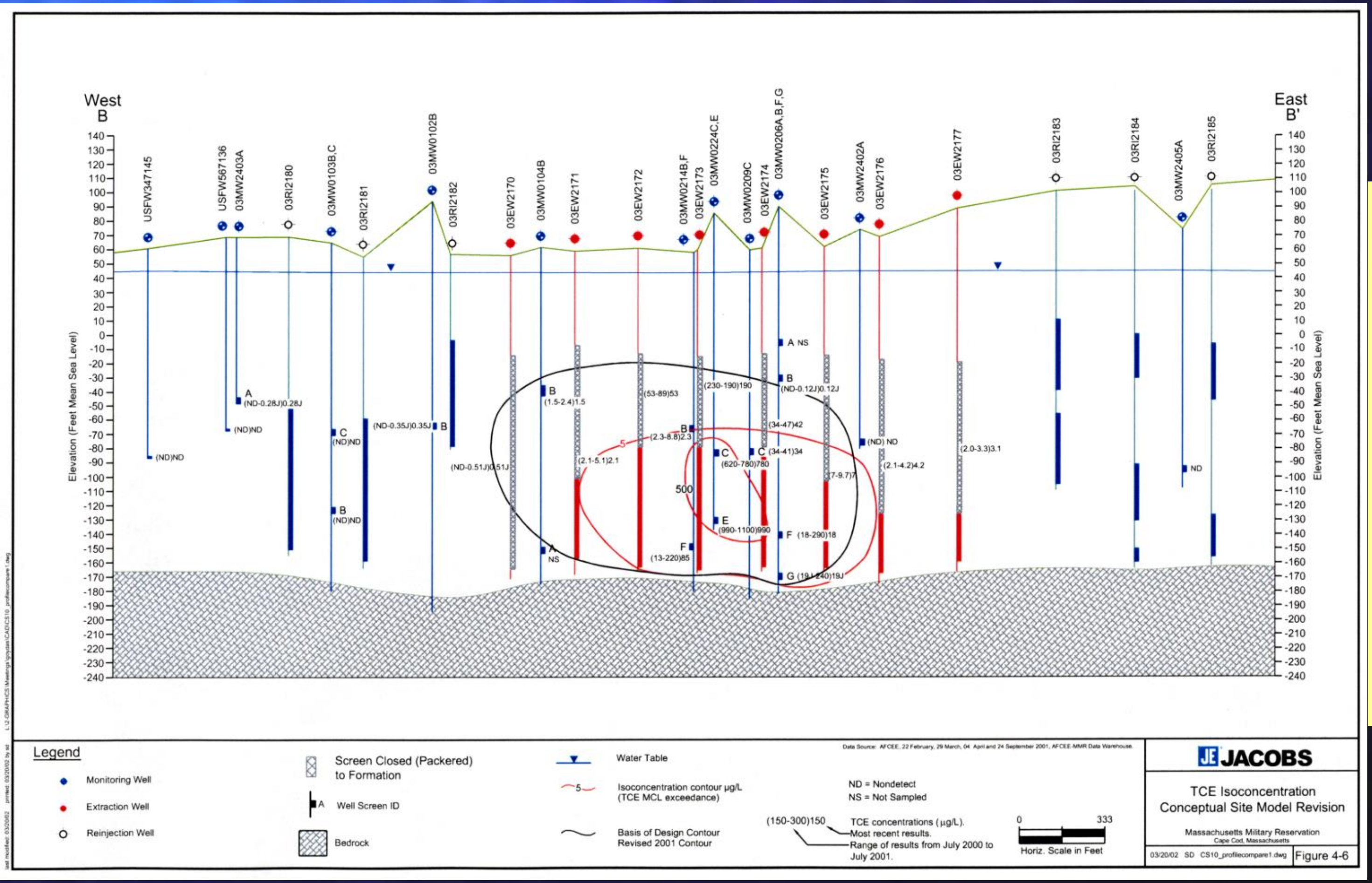


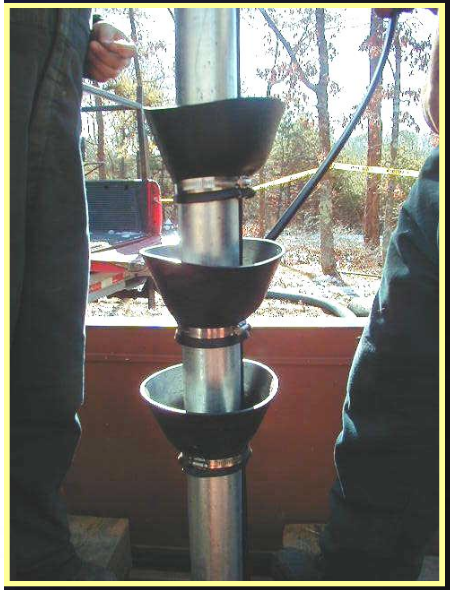
Transient Model Comparisons To Evaluate Accuracy of Model

- The remedial system is shut-down and restarted to evaluate drawdown and mounding
- Data loggers used to capture transient hydraulic responses
- Model comparisons used to evaluate and update the 3D K-field distributions

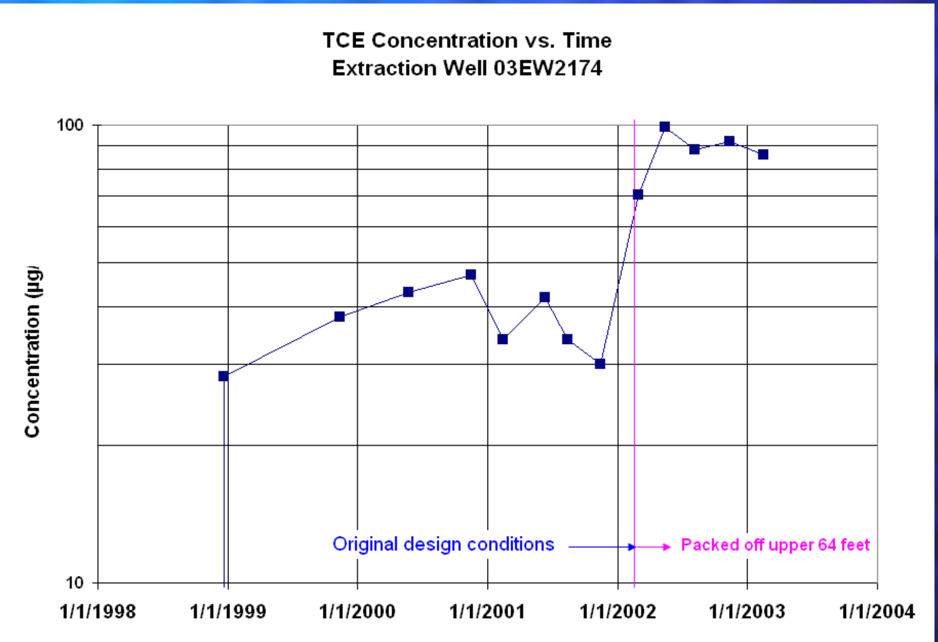
Sandwich Road Optimization

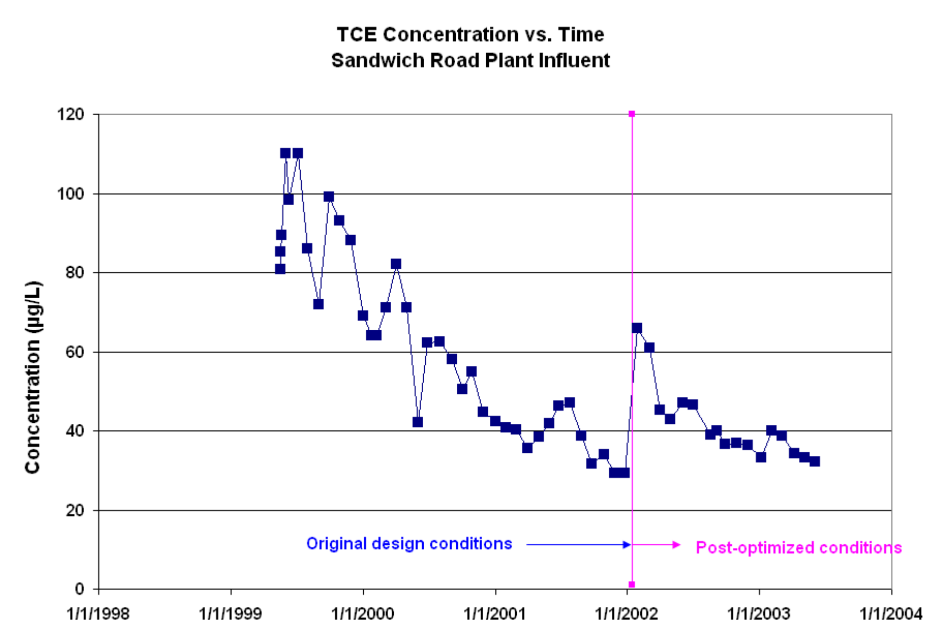
Pack the screened intervals, modify deep hydraulic conductivities and modify flow rates to improve mass removal





Sandwich Road Optimization Results

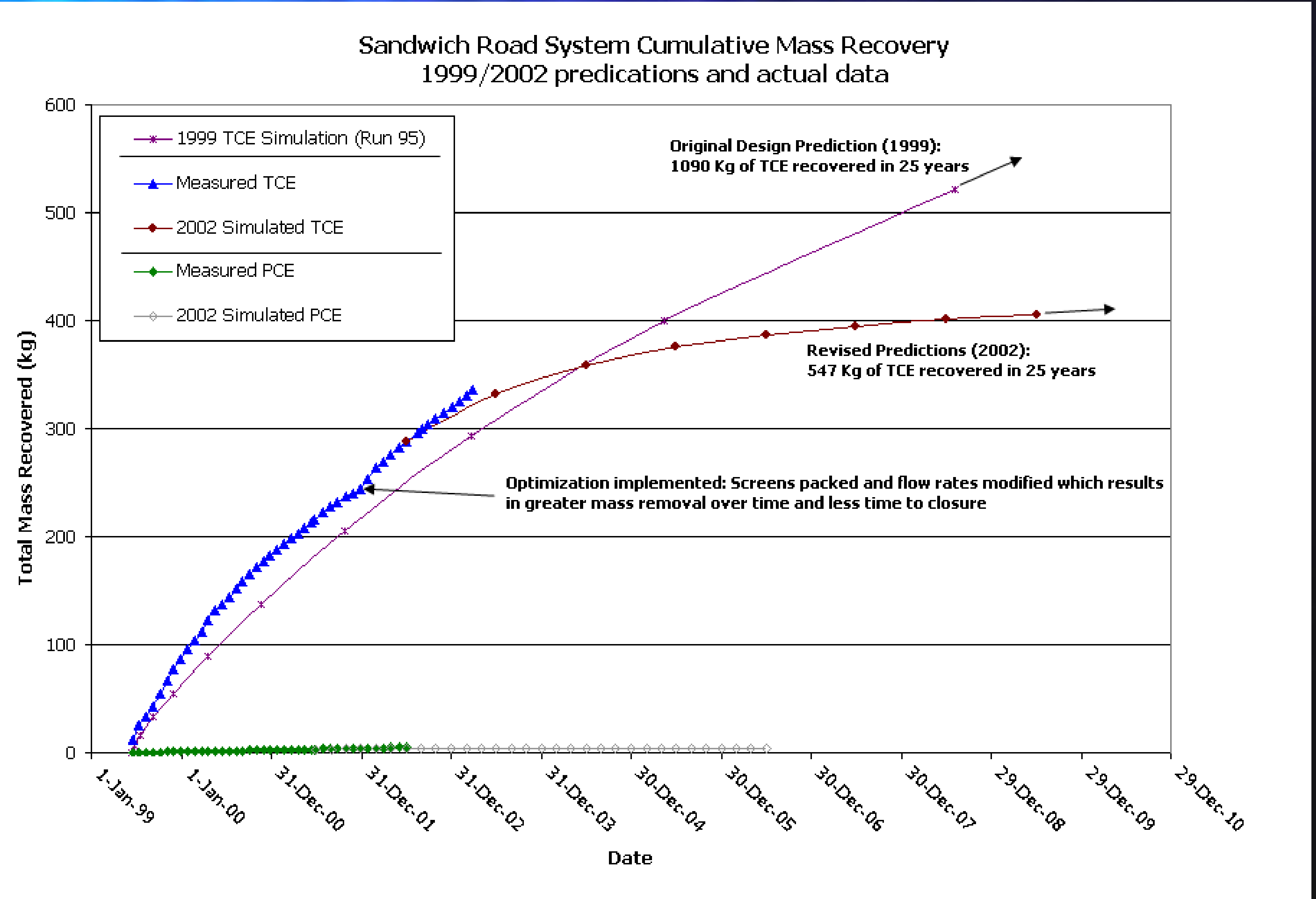




- More efficient mass removal
- More robust capture zones
- Greater carbon utilization
- More effective monitoring

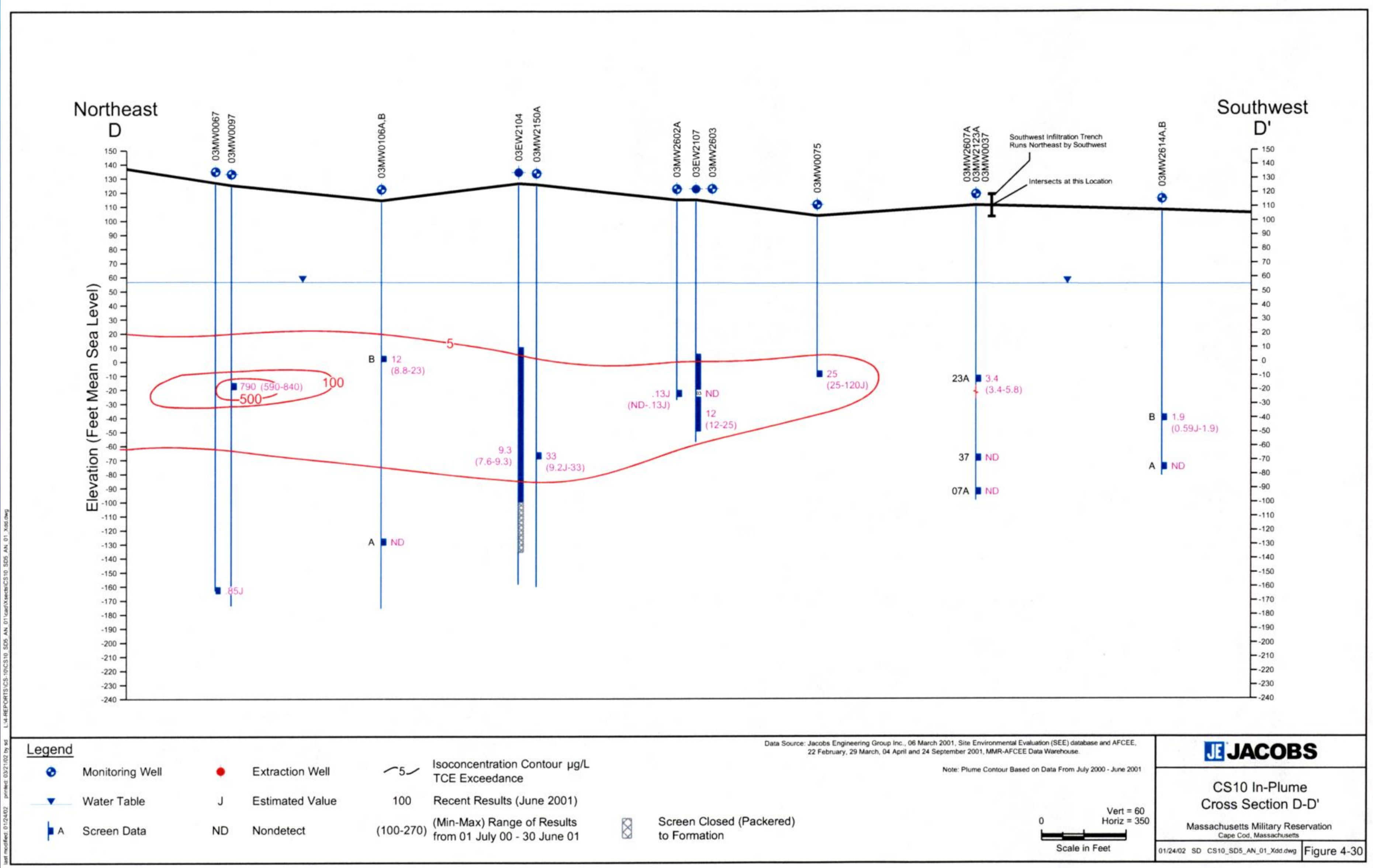
More Effective and Efficient Operations !

Sandwich Road Mass Recovery

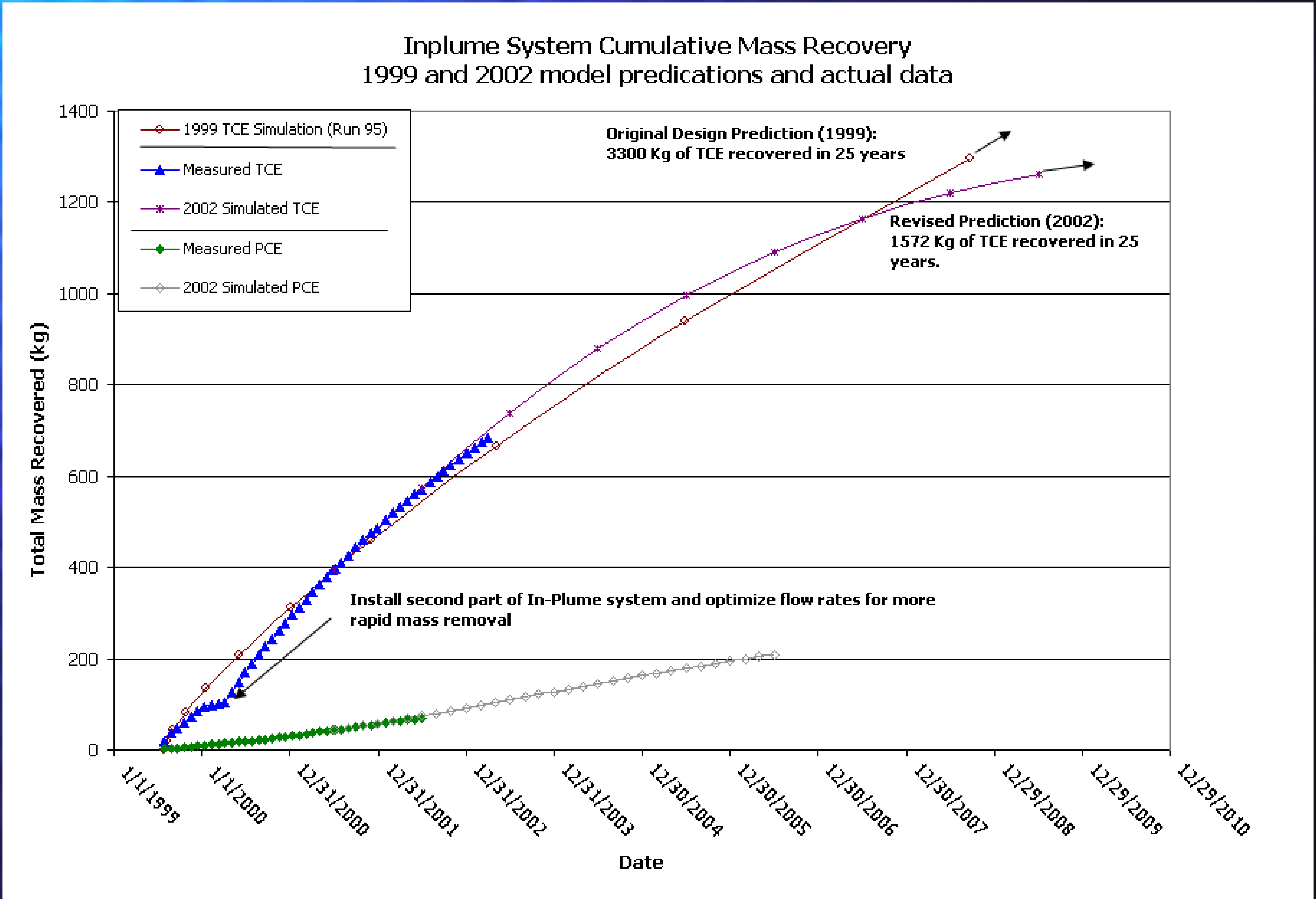


In-Plume Optimization

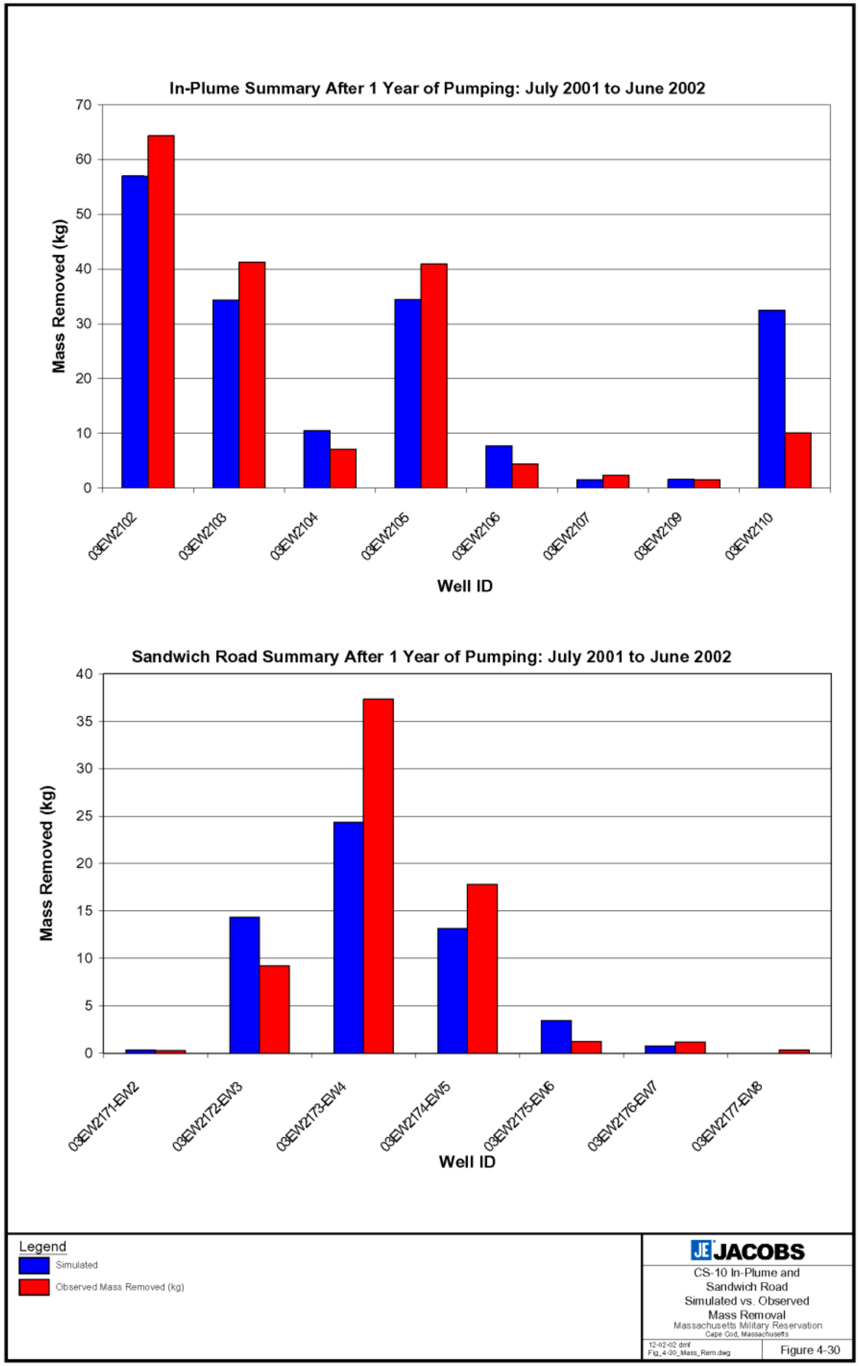
Pack the screened intervals and modify flow rates to improve mass removal



In-Plume Mass Recovery



Comparison of Mass Removals From Extraction Wells



In-Plume Wells

Sandwich Road Wells

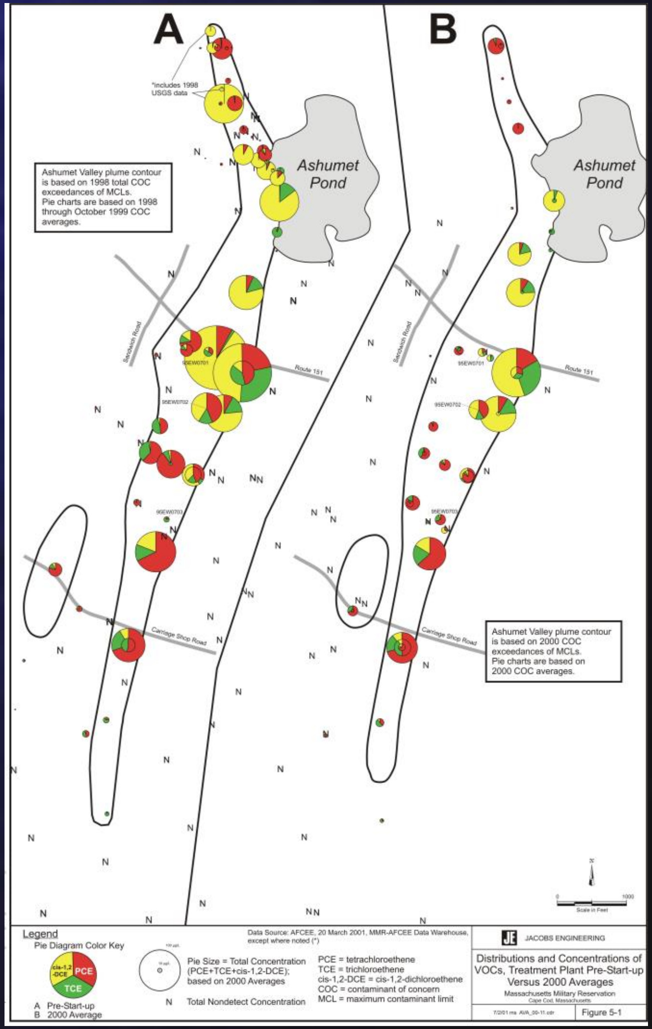
Goal of Monitoring Optimization

- Maximize the amount of relevant information while minimizing cost

- Relevant information addresses temporal and spatial
  objectives of monitoring

Monitoring Network Refinement/Optimization

- Intuitive Refinement
  - Trend analysis
  - Spatial and temporal redundancy/weaknesses
  - Field and modeled flow analysis
  - Focus on weak links in design (based on design sensitivity testing) and key components of system
- Design Plume Shell Kriging Tools
  - Spatial thinning
  - Identify weaknesses in network (error or uncertainty mapping)
  - Support of annual remapping of plumes
- Statistical Analysis of Data Sets/Monitoring Network
  - 2D and 3D assessment of network appropriateness
    - Well-by-well basis
    - Groups of wells based on monitoring objectives



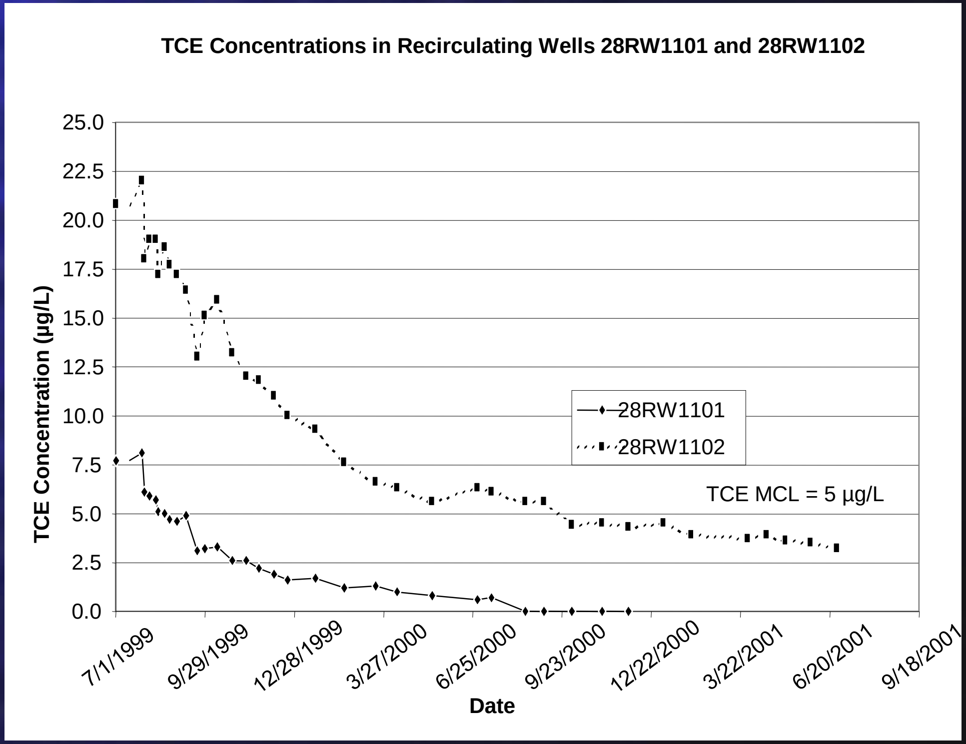
Geostatistical Optimization

Spatial Redundancy

- Variogram modeling to estimate spatial correlation between wells
- Indicator kriging to estimate typical contribution from each well to plume mapping results

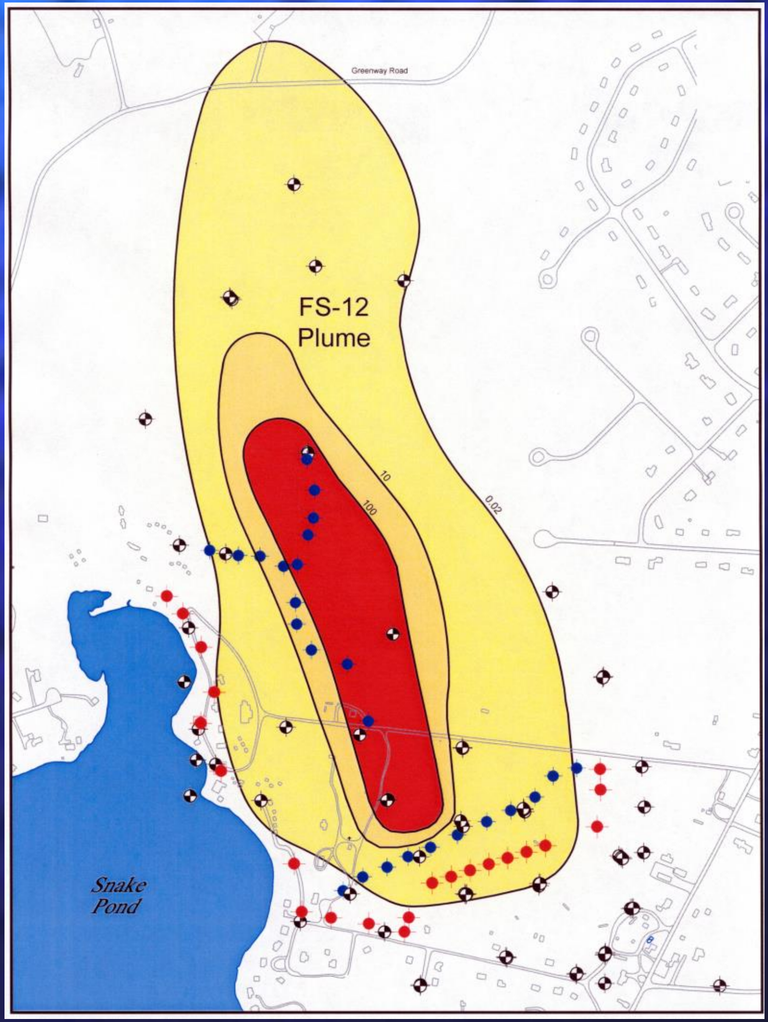
Temporal Redundancy

- Temporal variogram to estimate average correlation between sampling events
- Iterative "thinning" of individual wells to adjust well-specific sampling frequencies

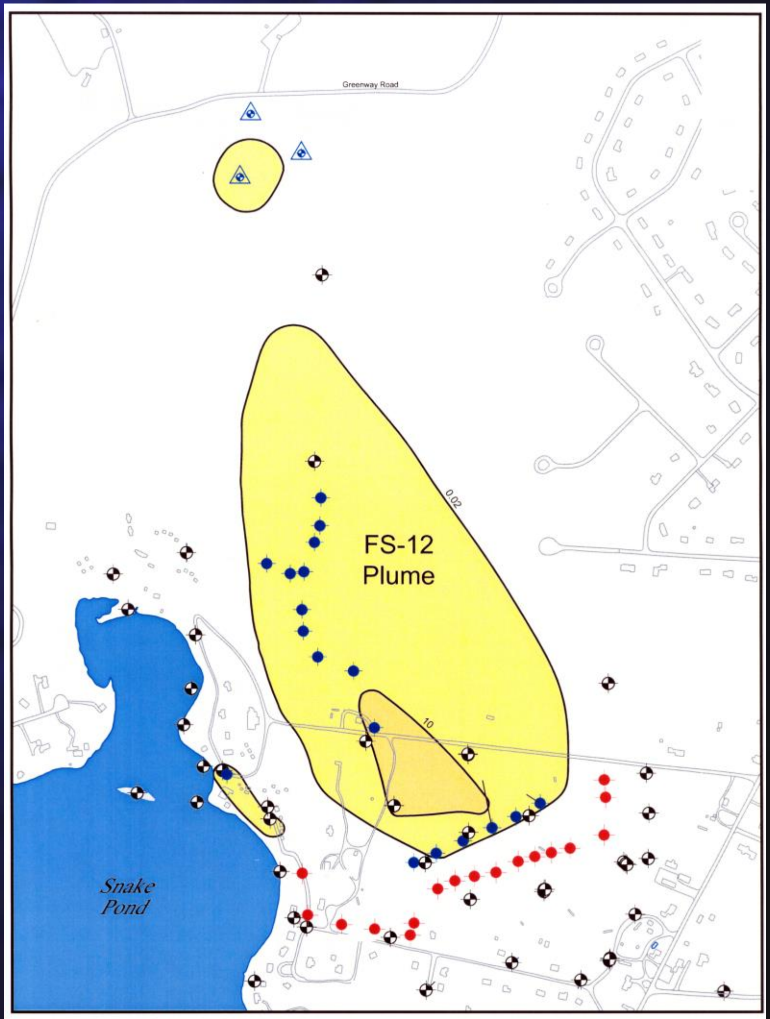


Results of Optimizing FS-12 Monitoring Network

FS-12 Monitoring Network



Optimized Monitoring Network



LTM Optimization Results for FS-12

- Spatial winnowing eliminated 49 of 135 locations, a savings of 36%
- Temporal thinning indicates that annual rather than quarterly sampling is sufficient to detect long-term trends
- Overall, these optimizations produce an 84% reduction in sampling costs

Optimization through mid-2002 has lead to the following changes at MMR

- Shut down of 16 extraction wells in three plumes
- Shut down of 1 remedial system (recirculating well)
- Modified flow rates for 6 remedial systems
- Extraction screens packered to:
    - increase mass removal and efficiency and increase capture zone width
- Monitoring program reductions (locations, frequencies, analytes) resulting in $3.5 million in cost avoidance
- Data gaps and operating uncertainties reduced
- Treatment optimization improved carbon lifetime at FS-12 from 40 to 170 days, saving over 115K per year

Summary

- Groundwater modeling is used at MMR to help manage the operations of all remedial systems and to design future systems
- Periodic optimizations are completed to shorten the operational lifetime of the remedial systems
- The optimizations and continuing site characterizations are leading to more efficient systems and less uncertainty

The End