LTMO Case Studies

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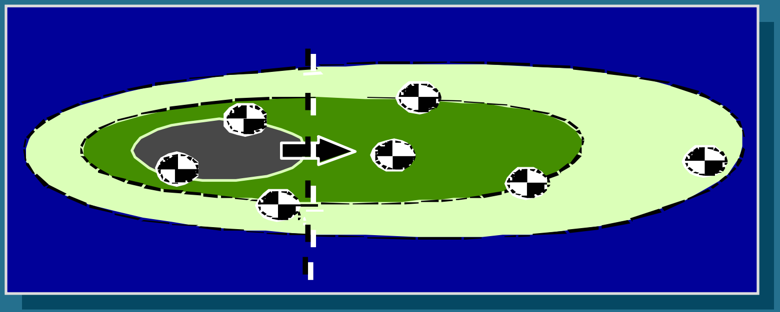
Monitoring & Remediation Optimization Software

- Conceptual Model
  - Site characterization, remedial decision complete
  - Distinct source & tail
  - 2-Dimensional
  - GW flow in one direction
  - At least 4-6 sample events



MAROS

- General Objectives
  - Determine overall plume stability
  - Evaluate concentration trends
  - Remove redundant wells w/o information loss
  - Add new wells where uncertainty is high
  - Sampling frequency recommendations
  - Compare with current monitoring status

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Case Study

- Wurtsmith AFB
  - Landfill source (many sources)
  - Short plume discharging to a lake
  - YMCA campground
  - Many new wells
  - Aesthetic issues
  - Stakeholder issues
  - Extensive Remediation

Approach

- Wurtsmith AFB
  - Rank COCs
    - Benzene for toxicity and prevalence
    - VC for mobility, TCE just because
  - Source is a line
  - Evaluate geochemically similar compounds
  - 65 ft Saturated thickness treated as one unit

MAROS COC Assessment

Project: Wurtsmith AFB **User Name:** MV

Location: Oscoda **State:** Michigan

Toxicity:

Contaminant of Concern	Representative Concentration (mg/L)	PRG (mg/L)	Percent Above PRG
BENZENE	2.7E-02	3.9E-04	6784.4%
TRICHLOROETHYLENE (TCE)	2.3E-02	5.0E-03	356.6%
VINYL CHLORIDE	3.4E-03	2.0E-03	71.2%

Note: Top COCs by toxicity were determined by examining a representative concentration for each compound over the entire site. The compound representative concentrations are then compared with the chosen PRG for that compound, with the percentage excedence from the PRG determining the compound's toxicity. All compounds above exceed the PRG.

Prevalence:

Contaminant of Concern	Class	Total Wells	Total Excedences	Percent Excedences	Total detects
BENZENE	ORG	51	30	58.8%	35
VINYL CHLORIDE	ORG	51	18	35.3%	35
TRICHLOROETHYLENE (TCE)	ORG	51	6	11.8%	21

Note: Top COCs by prevalence were determined by examining a representative concentration for each well location at the site. The total excedences (values above the chosen PRGs) are compared to the total number of wells to determine the prevalence of the compound.

Mobility:

Contaminant of Concern	Kd
VINYL CHLORIDE	0.042
BENZENE	0.0984
TRICHLOROETHYLENE (TCE)	0.297

Note: Top COCs by mobility were determined by examining each detected compound in the dataset and comparing their mobilities (Koc's for organics, assume foc = 0.001, and Kd's for metals).

Contaminants of Concern (COC's)

BENZENE

TRICHLOROETHYLENE (TCE)

VINYL CHLORIDE

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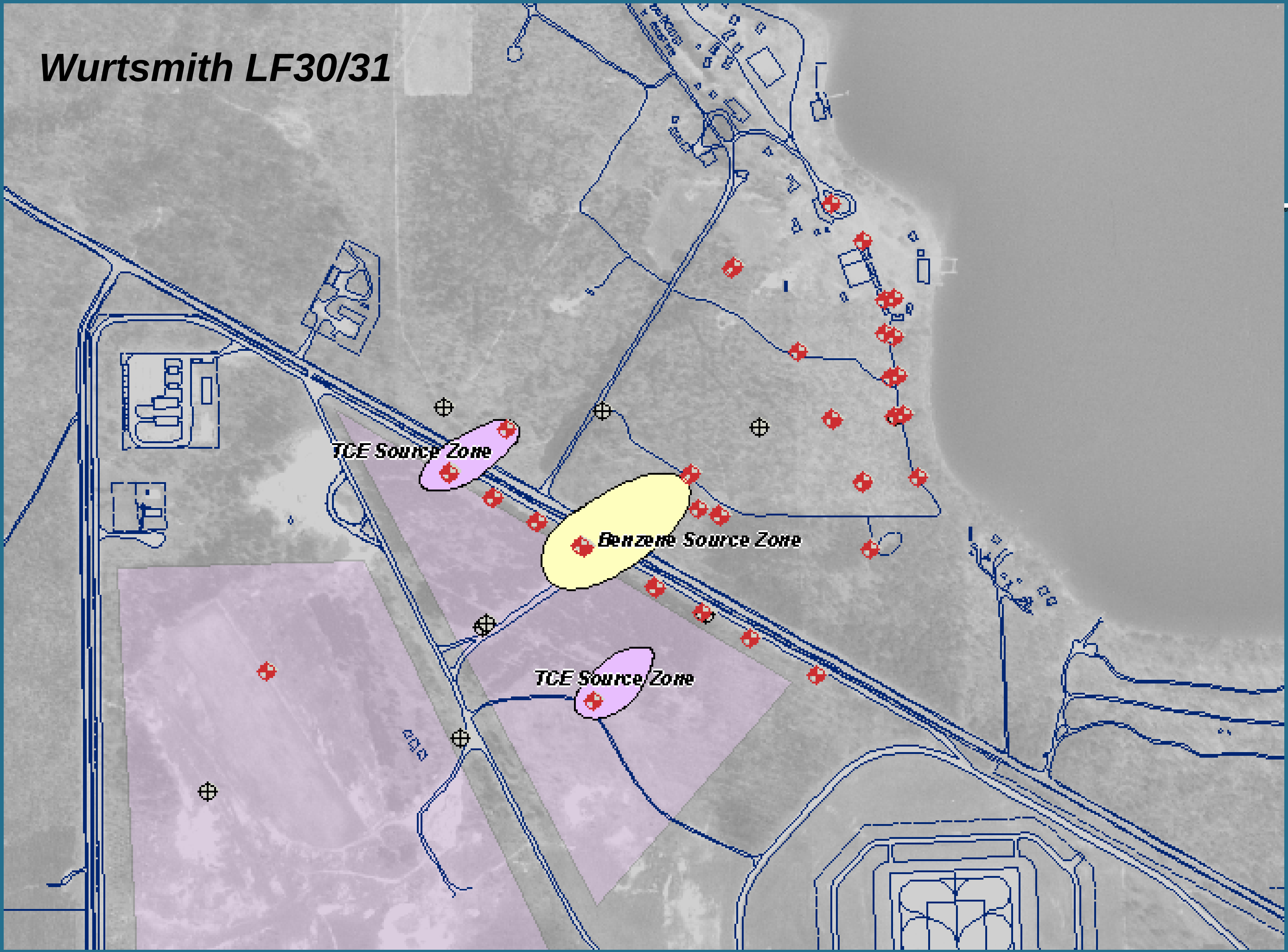
Wurtsmith LF30/31



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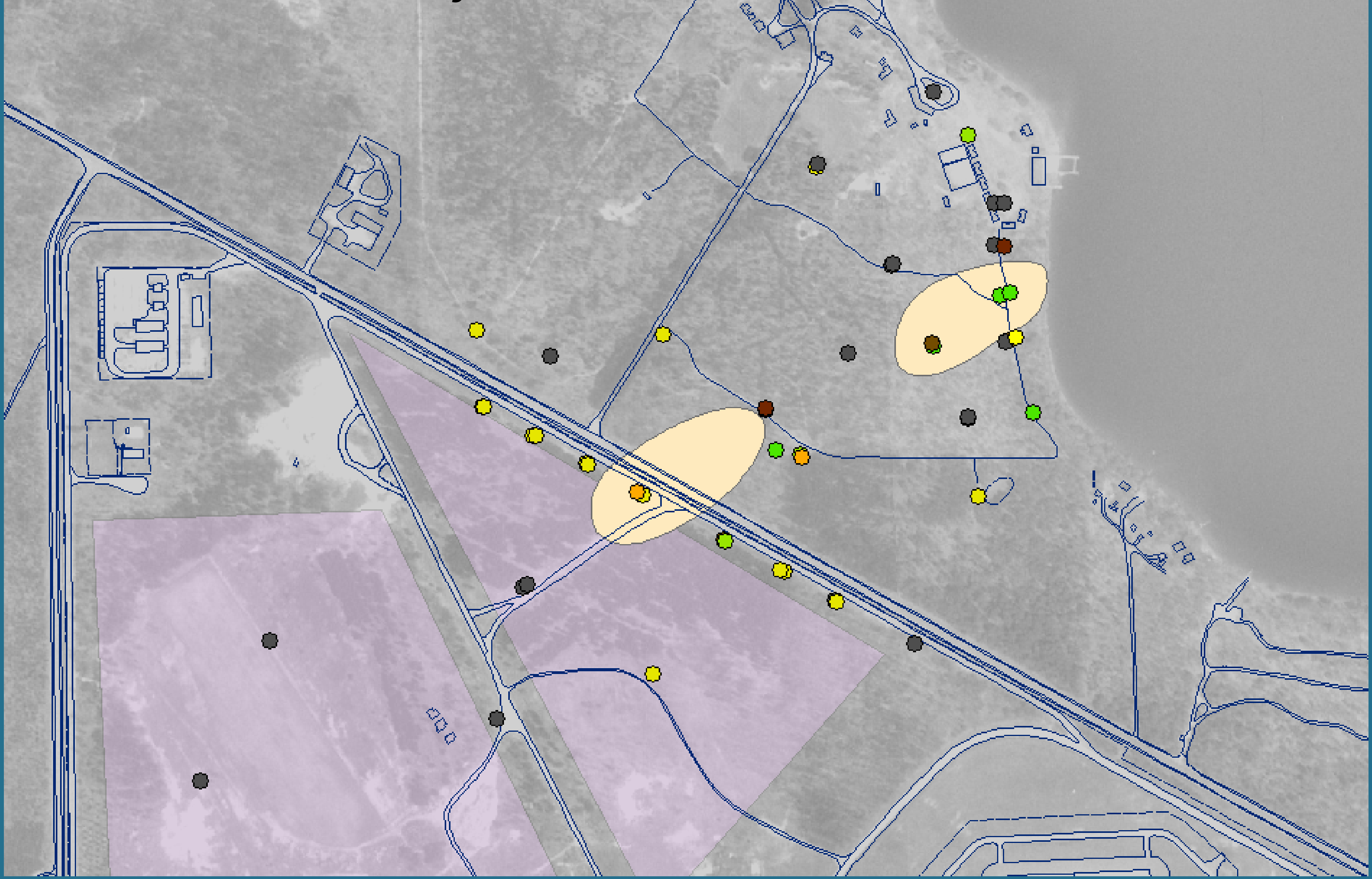
Benzene Trend Analysis



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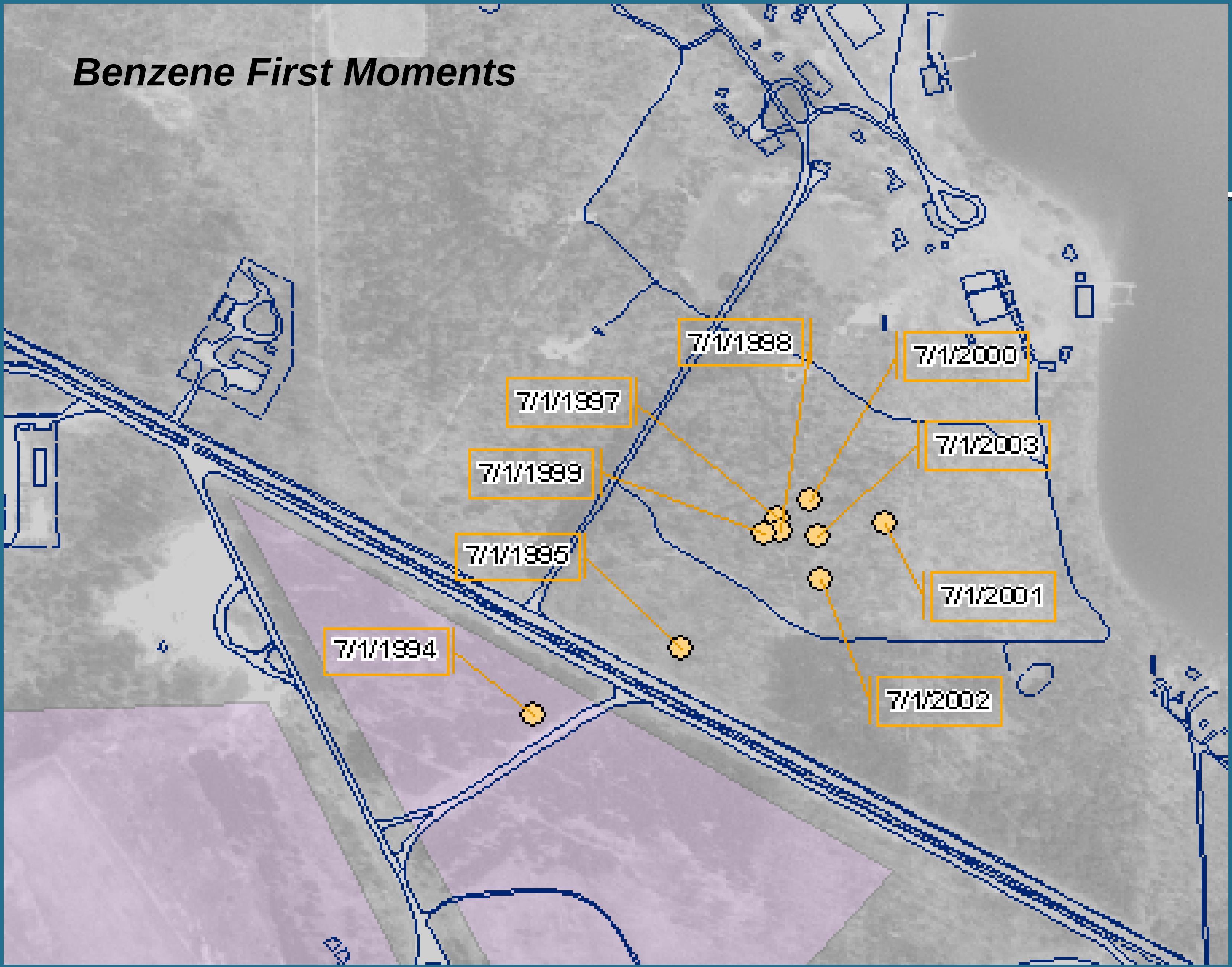
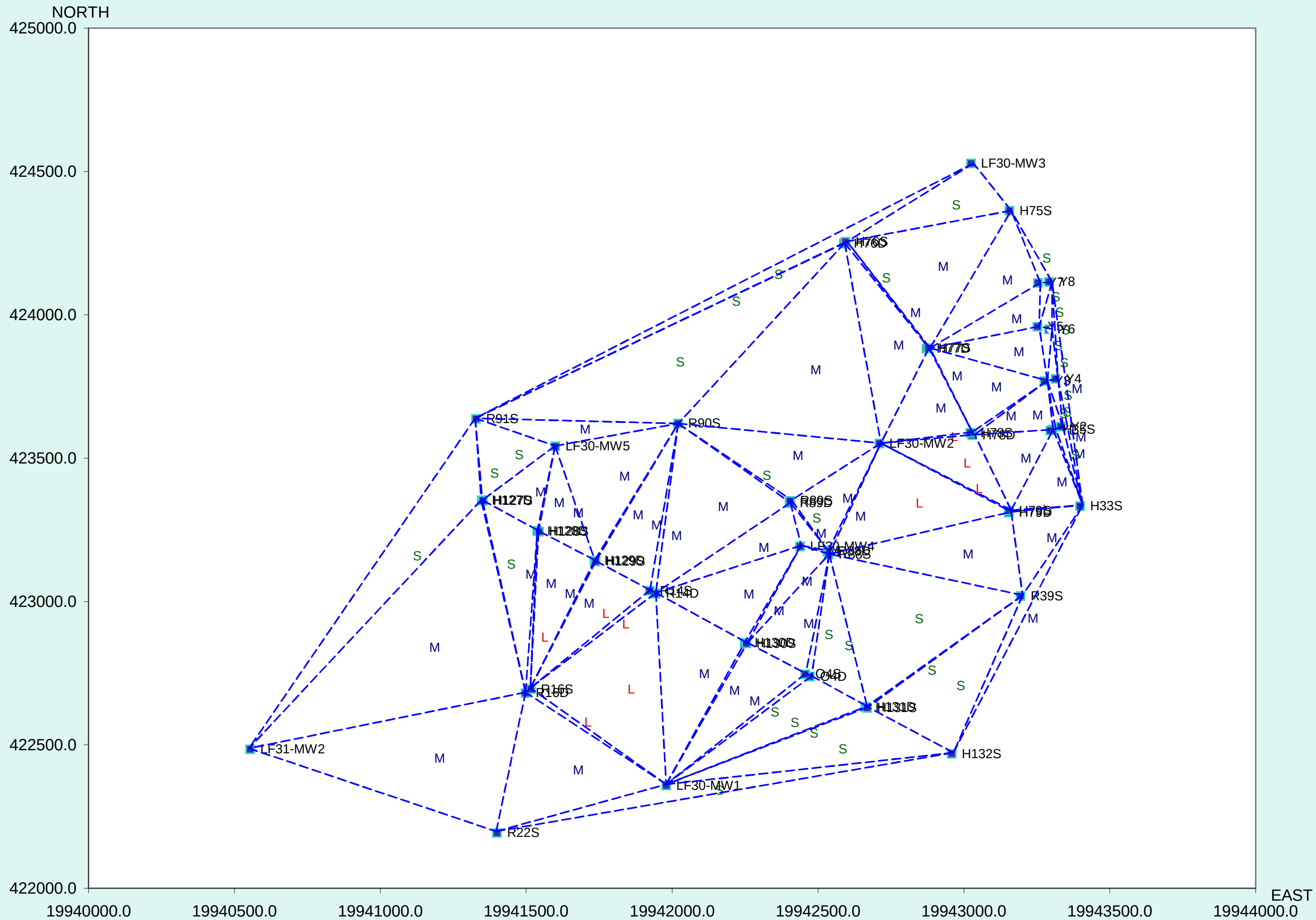
Benzene First Moments



Well Name	Benzene Recommended Frequency Result[(3)]	Vinyl Chloride Recommended Frequency Result[(3)]	TCE Recommended Frequency Result[(3)]	Final Interpreted Result	Comment
H127D	Annual*	Annual*	Annual	**Annual**	TCE source area
H127S	Annual	Annual*	Annual	**Annual**	TCE source area
H128D	Biennial	Annual	Biennial	**Biennial**	
H128S	Biennial	Annual	Biennial	**Biennial**	
H129D	Biennial	Annual	Biennial	**Biennial**	
H129S	Annual	Annual	Biennial	**Annual**	
H130D	Biennial	Annual	Biennial	**Biennial**	
H130S	Annual	Annual	Biennial*	**Annual**	
H131D	*	*		**Eliminate**	
H131S	*	*	*	**Eliminate**	
H132S	*	*	*	**Eliminate**	
H33S	Biennial	Annual	Biennial	**Annual**	Monitoring for vinyl chloride
H35S	Annual	Quarterly	Annual	**Annual**	Decreasing trend for vinyl chloride
H75S	Annual	Annual	SemiAnnual	**Annual**	
H76D	Annual	SemiAnnual*	Annual*	**Annual**	Recommended for removal, kept as compliance point with reduce frequency
H76S	Annual*	SemiAnnual*	Annual*	**Annual**	Recommended for removal, kept as compliance point with reduce frequency
H77D	Annual	SemiAnnual	Annual*	**Annual**	Limited history, no TCE detections, benzene and vinyl chloride below MCLs
H77S	Annual	SemiAnnual	Annual*	**Annual**	Limited history, no TCE detections, benzene and vinyl chloride below MCLs



New Location Analysis for

BENZENE

Existing Locations

Potential areas fo new locations are indicated by triangle with a high SF leve

Estimated SF Level:

- S - Small
- M - Moderate
- L - Large
- E - Extremely large

High SF -> high estimation error -> possible need for new locations

Low SF -> low estimation error -> no need for new locations

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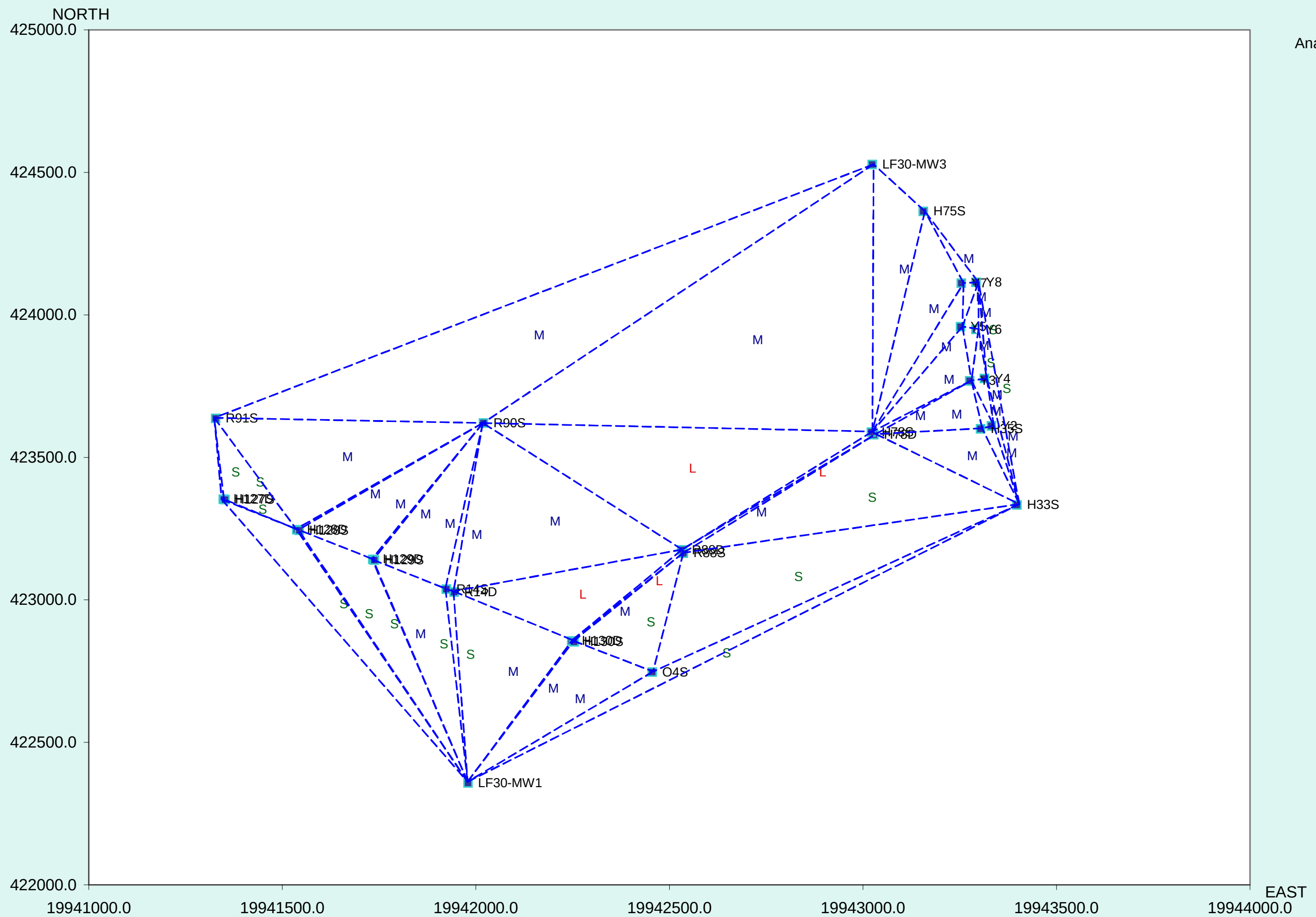

New Location
Analysis for Optimized Netwo

BENZENE

Existing Locations

Potential areas fc new locations are indicated by triangle w ith a high SF leve

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Results

- Wurtsmith AFB
  - 3 distinct COC plumes
  - Trends mainly stable to decreasing
  - First Moments increasing before remediation, stable to decreasing after
  - Increasing second moments (wider, more dilute)
  - Remove 8 wells from the program

Results

- Wurtsmith AFB
  - Average of 41 samples annually
    - 7 Semi-annual
    - 24 Annual
    - 6 Biennial
  - Original recommendation 94 samples annually
  - Savings of $53,000/yr

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GTS Basics

- Statistical & geostatistical algorithm
  - Not meant to supplant hydrogeological expertise
  - Decision-logic framework
- Optimization algorithm looks at two areas:
  - Monitoring network locations
  - Sampling frequencies in network
- Focus on statistical redundancy

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GTS Philosophy

- Must balance cost-accuracy tradeoff
  - **Optimal system** = minor information loss but large gain in resource savings
  - Remove redundancy in practical, statistically defensible ways
    - Redundancy: what happens when data removed from current system?
    - Can trends be re-constructed?
    - Can base maps be 'preserved'?

Case Studies

- 3 AF sites with varied geology
  - Pease AFB, New Hampshire
    - Site 49, TCE plume from underground storage tank
    - Fractured bedrock; varied overlying geology
    - 67 wells used as baseline

Case Studies (cont.)

- Loring AFB, Maine
  - Site OU-12, 30 contaminant sources, including BTEX, TCE
  - Lightly to heavily-fractured bedrock; 3 distinct overburden units
  - 115 wells used as baseline

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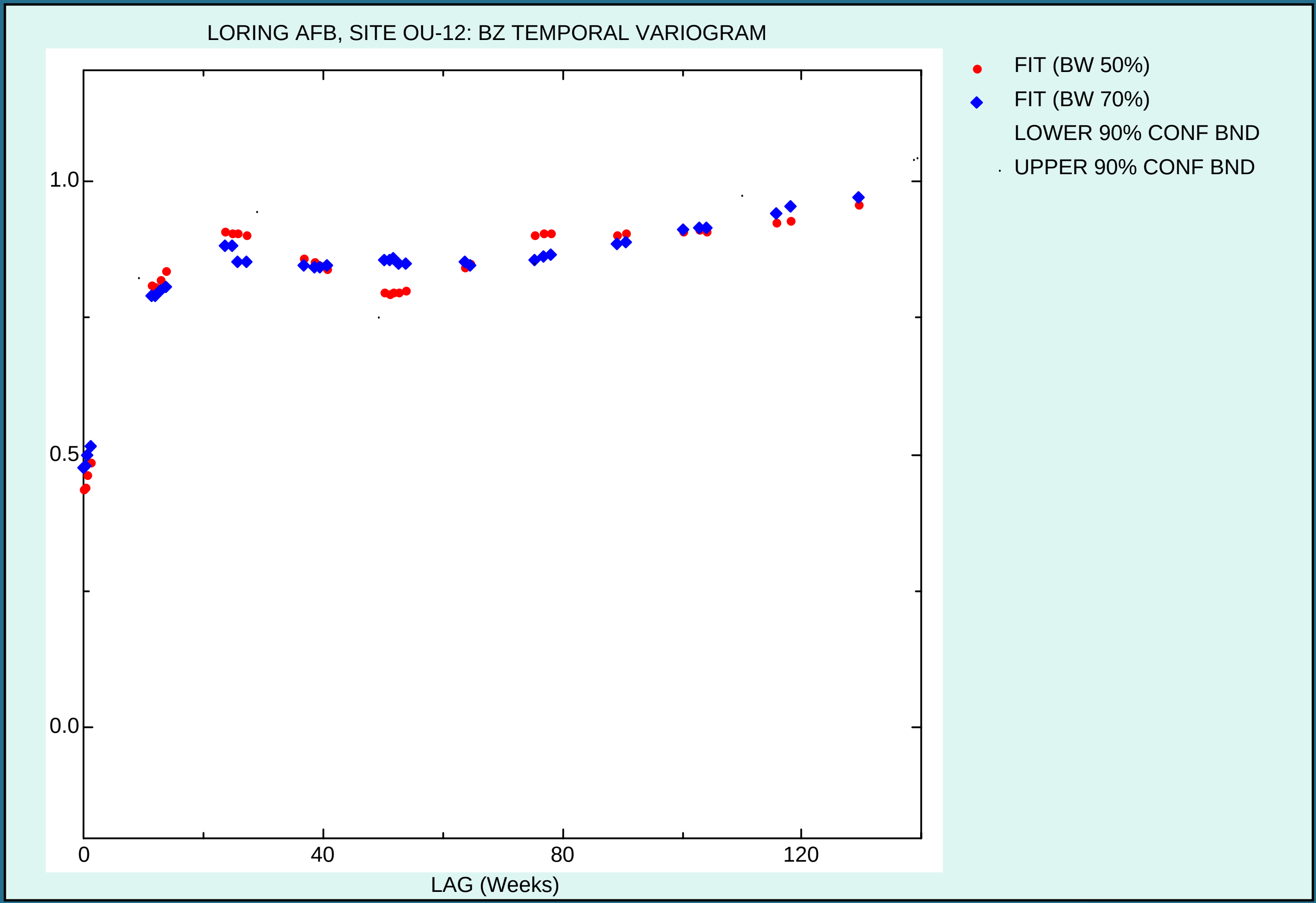
Case Studies (cont.)

- Edwards AFB, California
  - Sites 133, 37; Contamination due to storage & waste disposal practices
  - Fractured crystalline bedrock; weathered bedrock overlay
  - 140 wells used as baseline

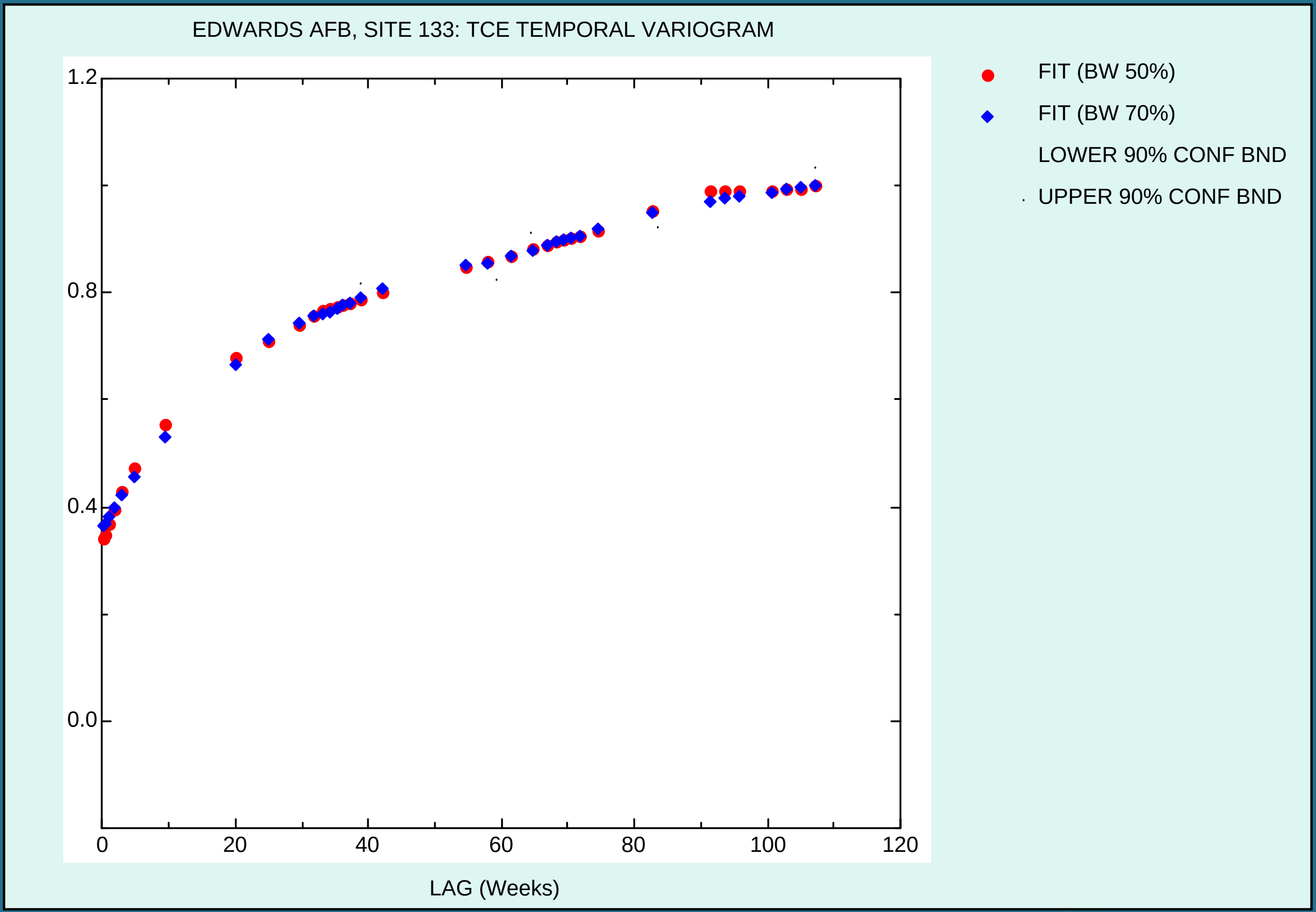
Temporal Optimization

- Two approaches
  - Temporal variogram to estimate average correlation between sampling events
  - Iterative “thinning” of individual wells to adjust well-specific sampling frequencies

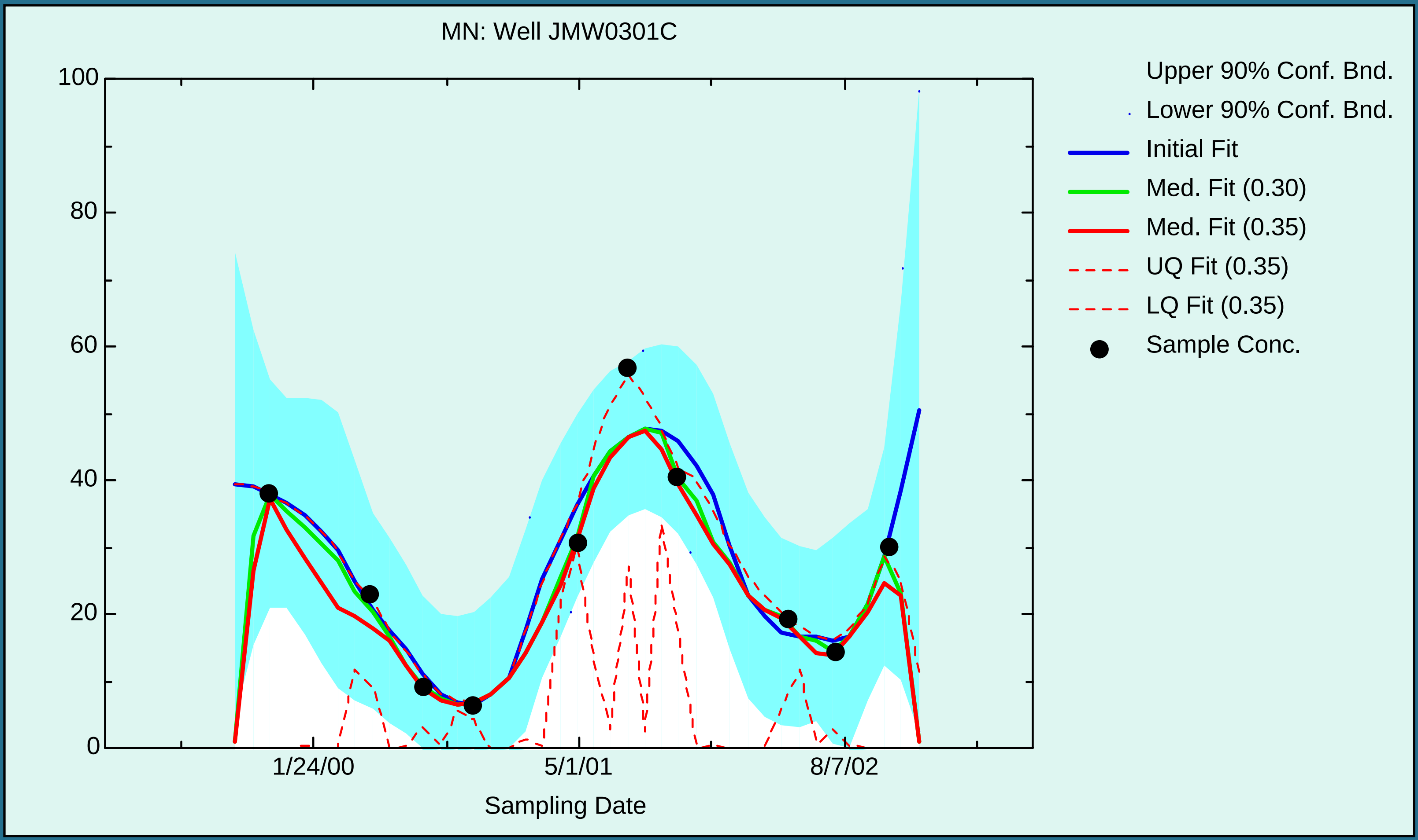
BZ Temporal Variogram



TCE Temporal Variogram



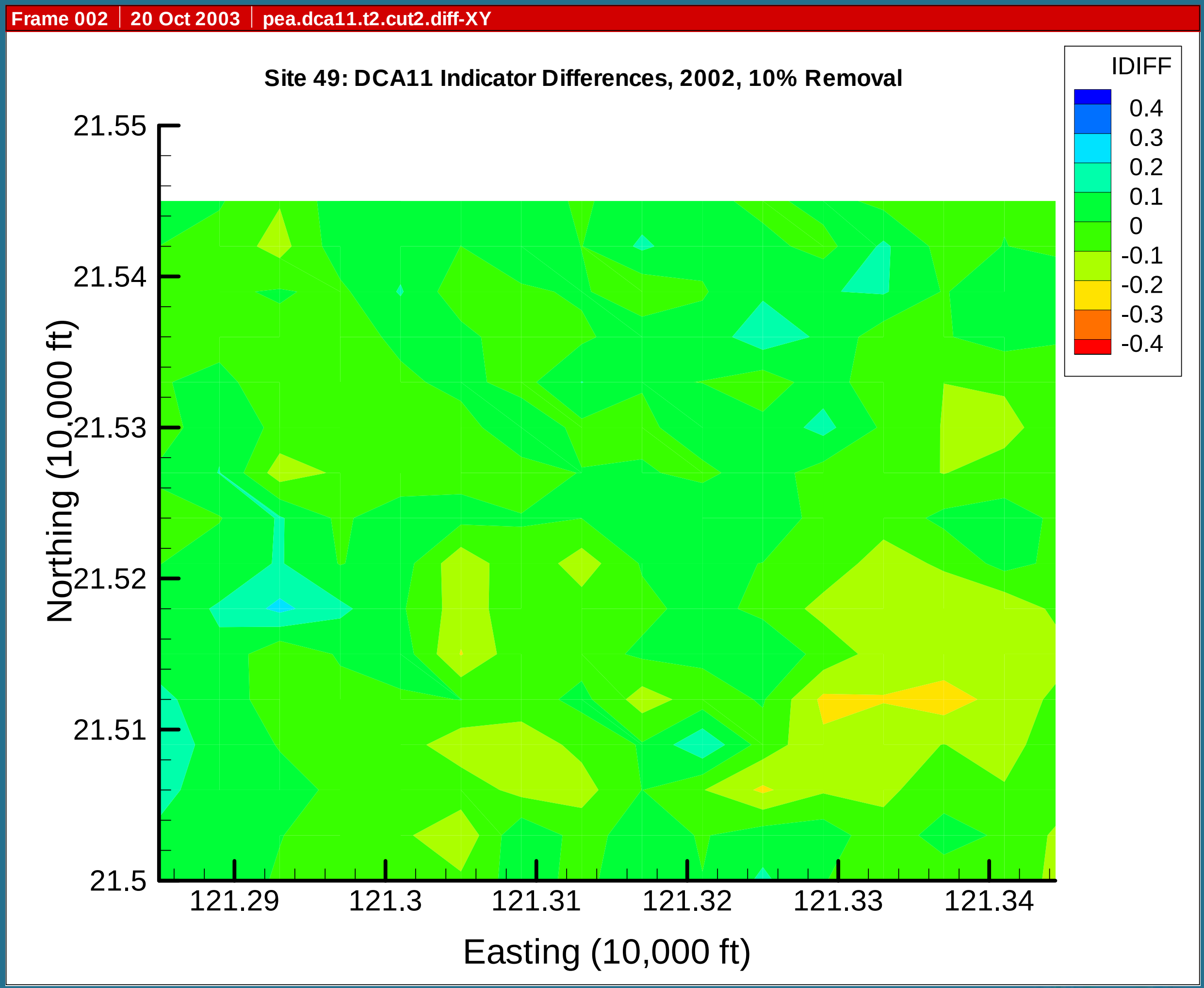
Iterative Thinning: Loring



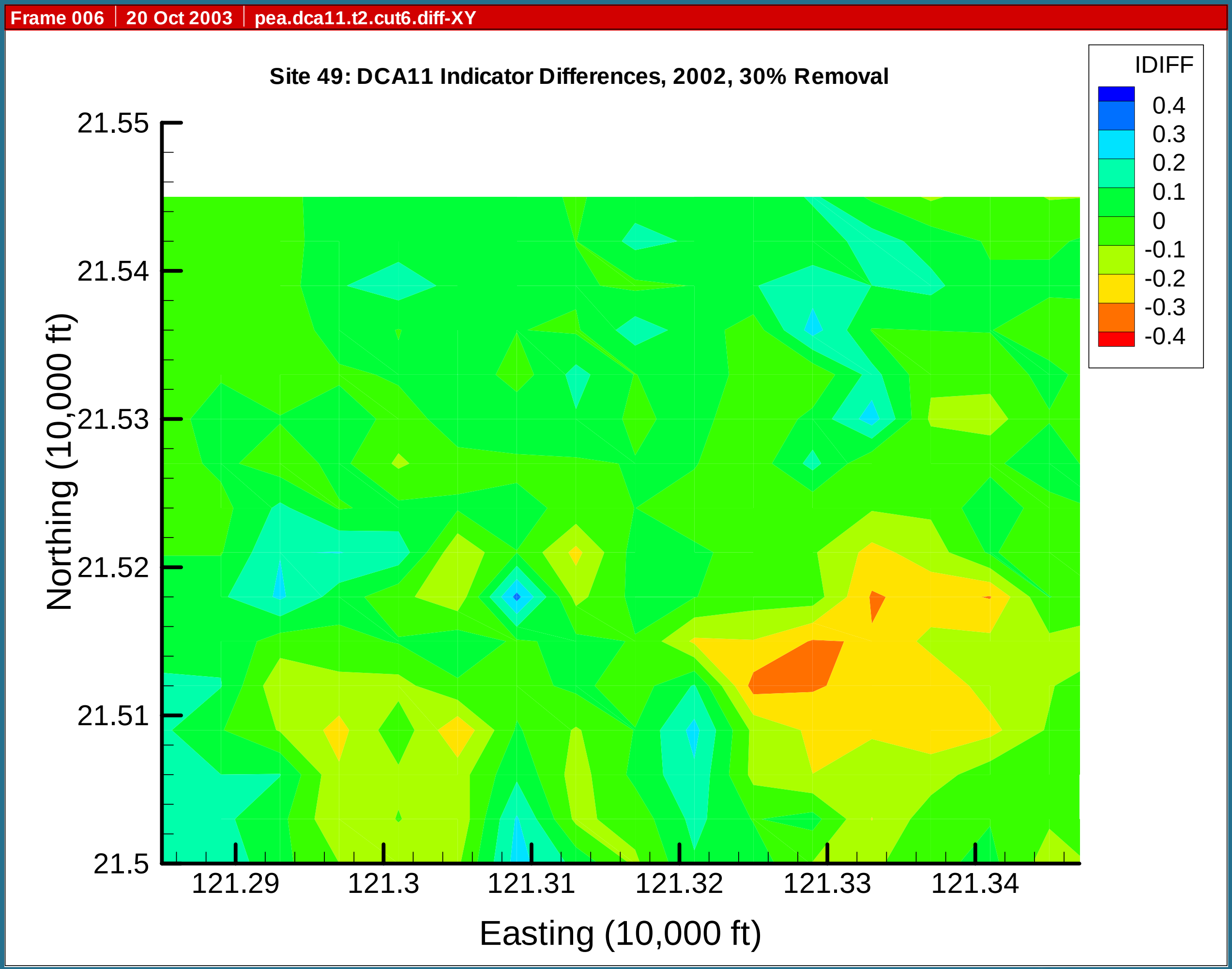
Basic Spatial Approach

- Create base map using all available data
- Iteratively remove least influential wells; re-estimate map
  - Influence measured by loss of map quality/accuracy compared to baseline
- Create cost/accuracy tradeoff curves
  - Pick off optimal degree of data removal

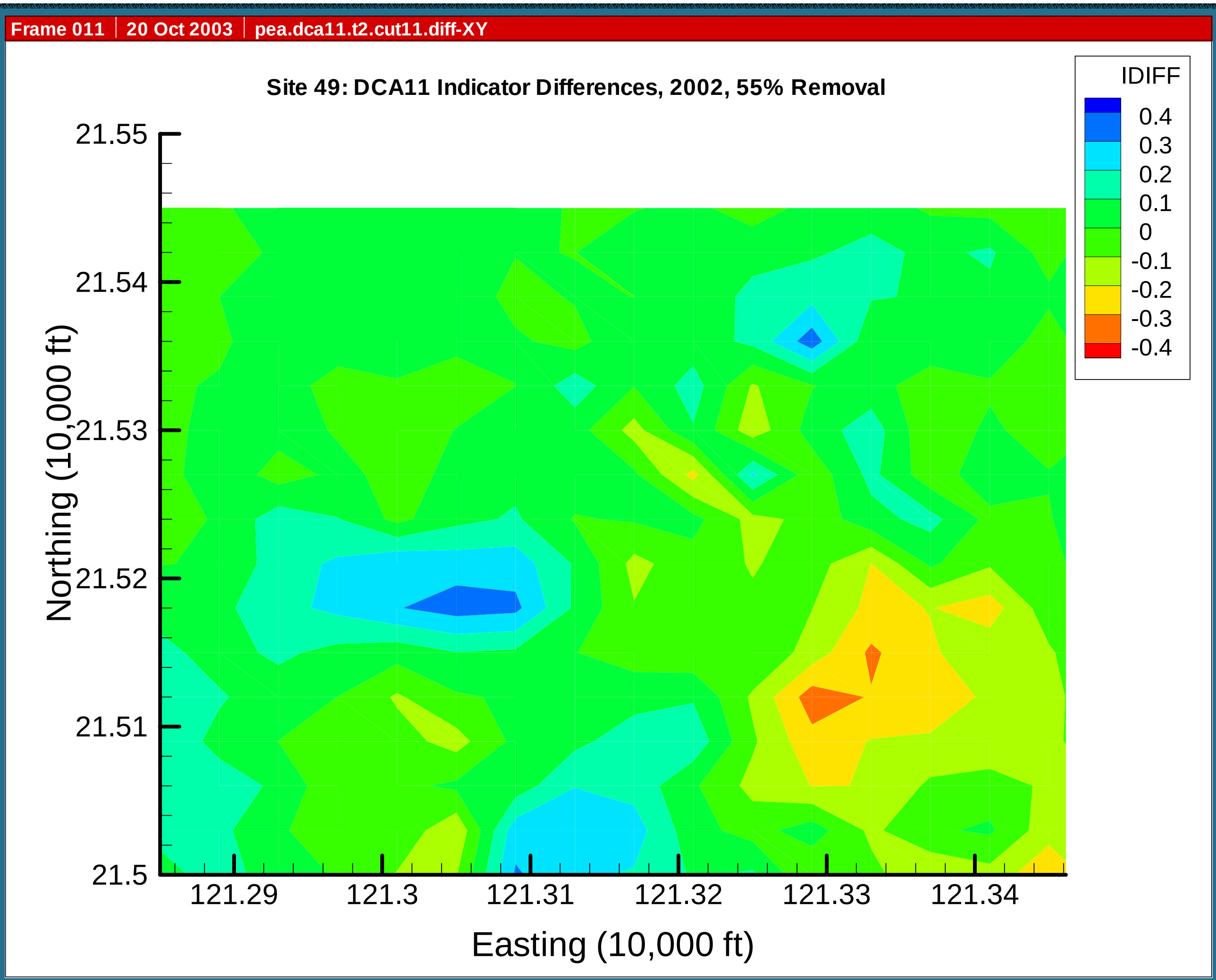
Pease: 10% Removal



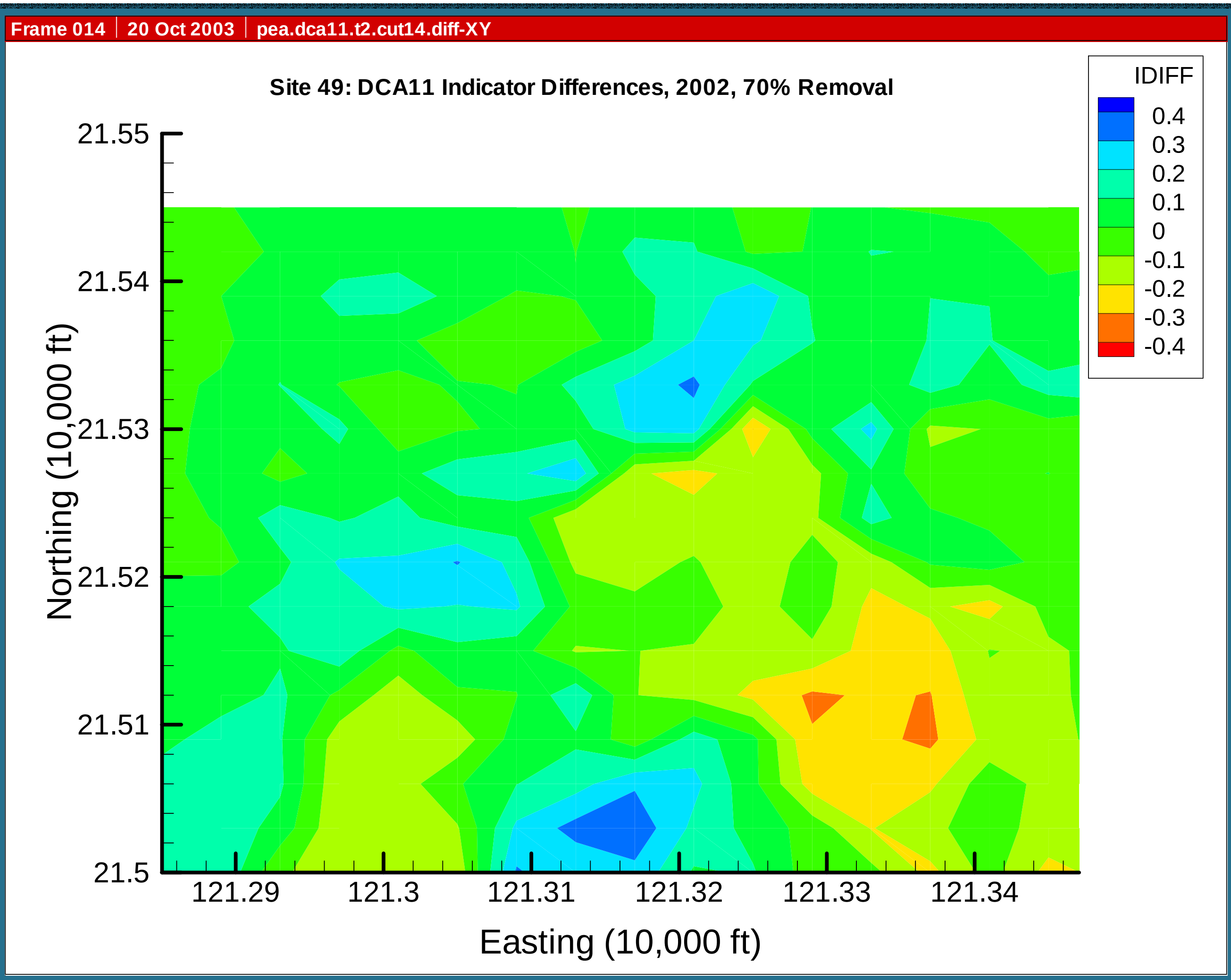
Pease: 30% Removal



Pease: 55% Removal



Pease: 70% Removal



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Case Study Results

	Edwards	Loring	Pease
Original Interval	Annual	Qtrly	Annual
Optimized Interval	Every 7 Qtrs	Every 2-3 Qtrs	Biennial
Redundant Wells	20-34%	20-30%	10-36%
Cost Reduction	54-62%	33-39%	49-52%
Annual Cost Savings	$230 K-$266 K	$306 K-$358 K	$85 K-$89 K

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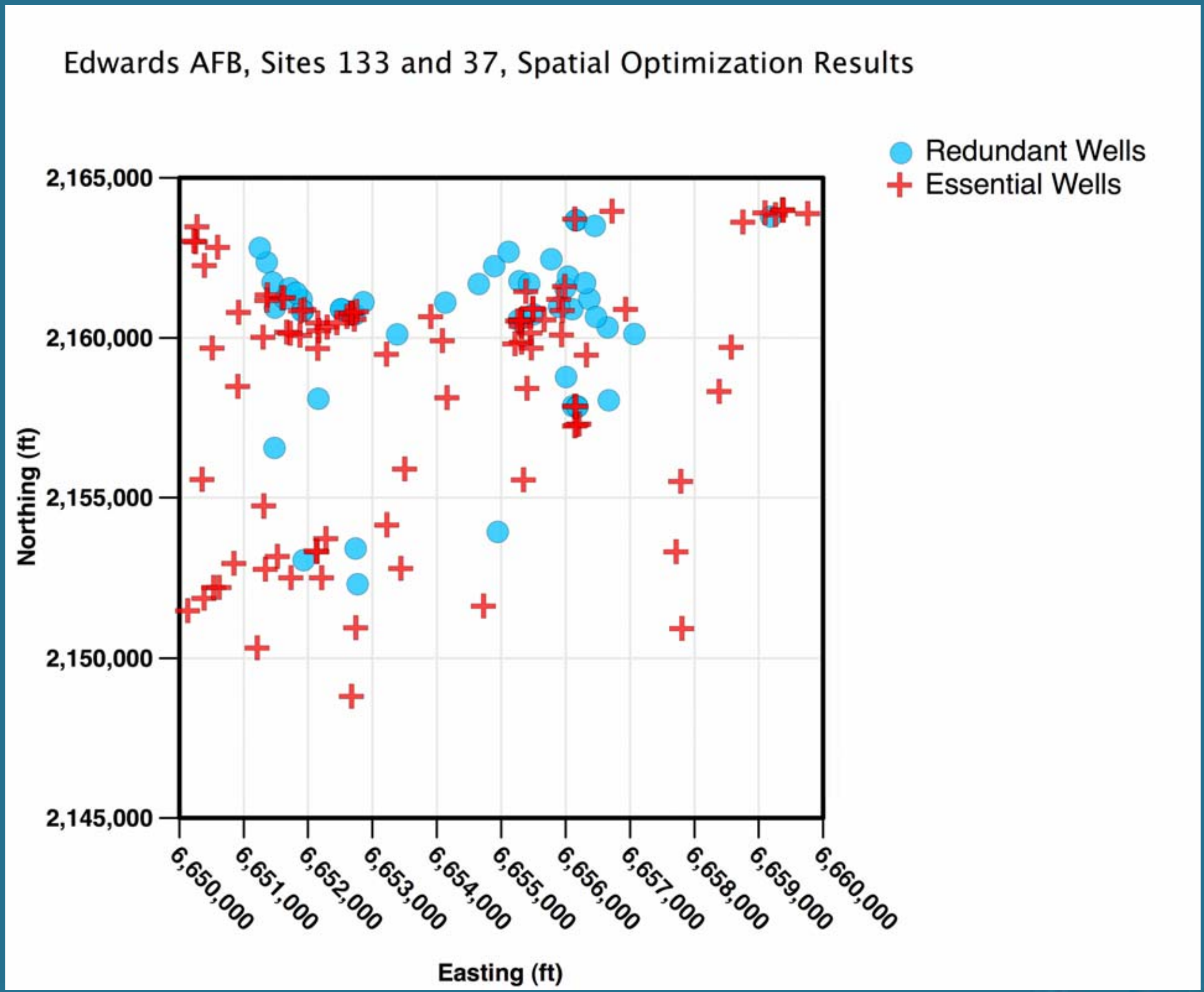
Edwards: Optimized Wells



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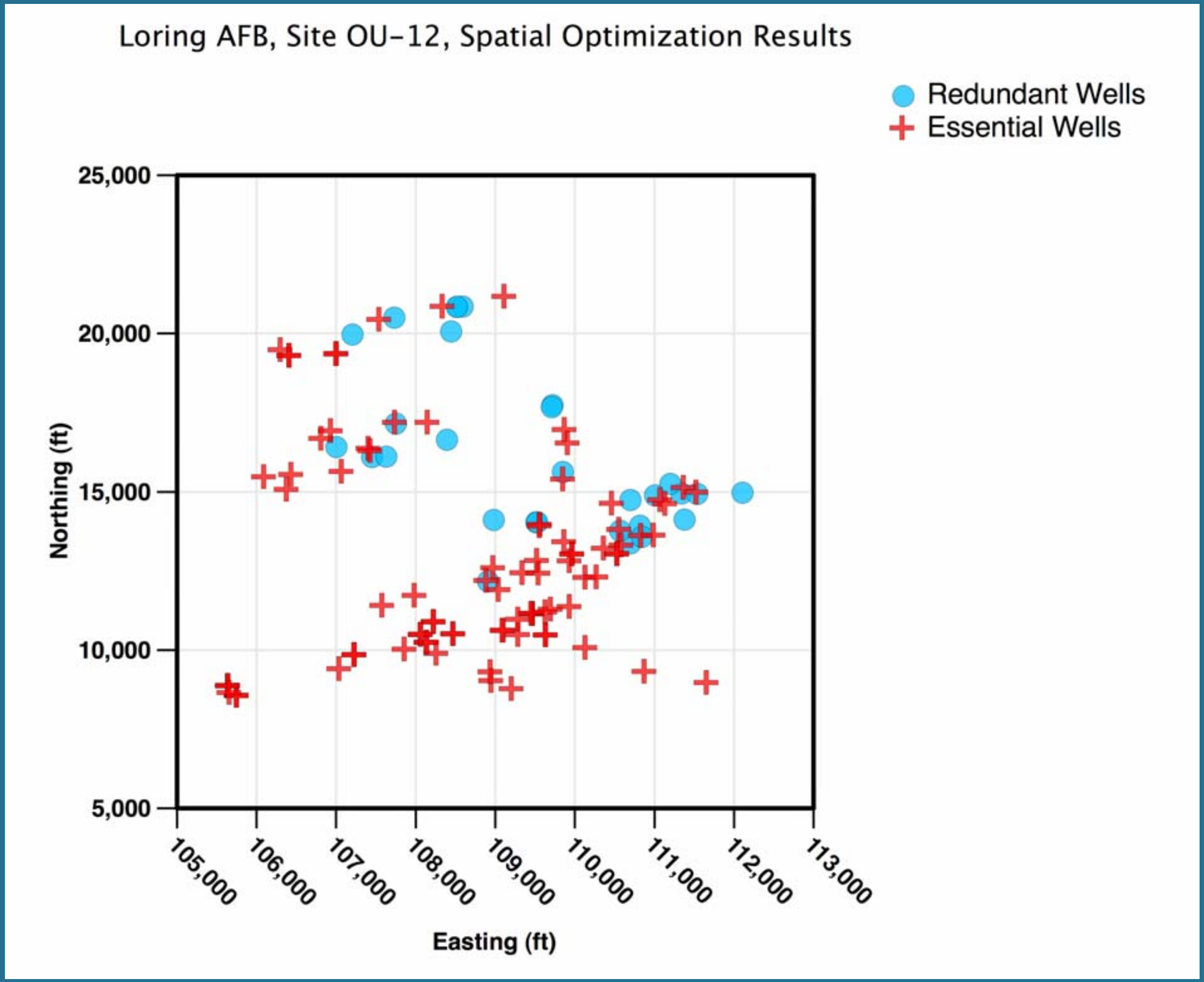
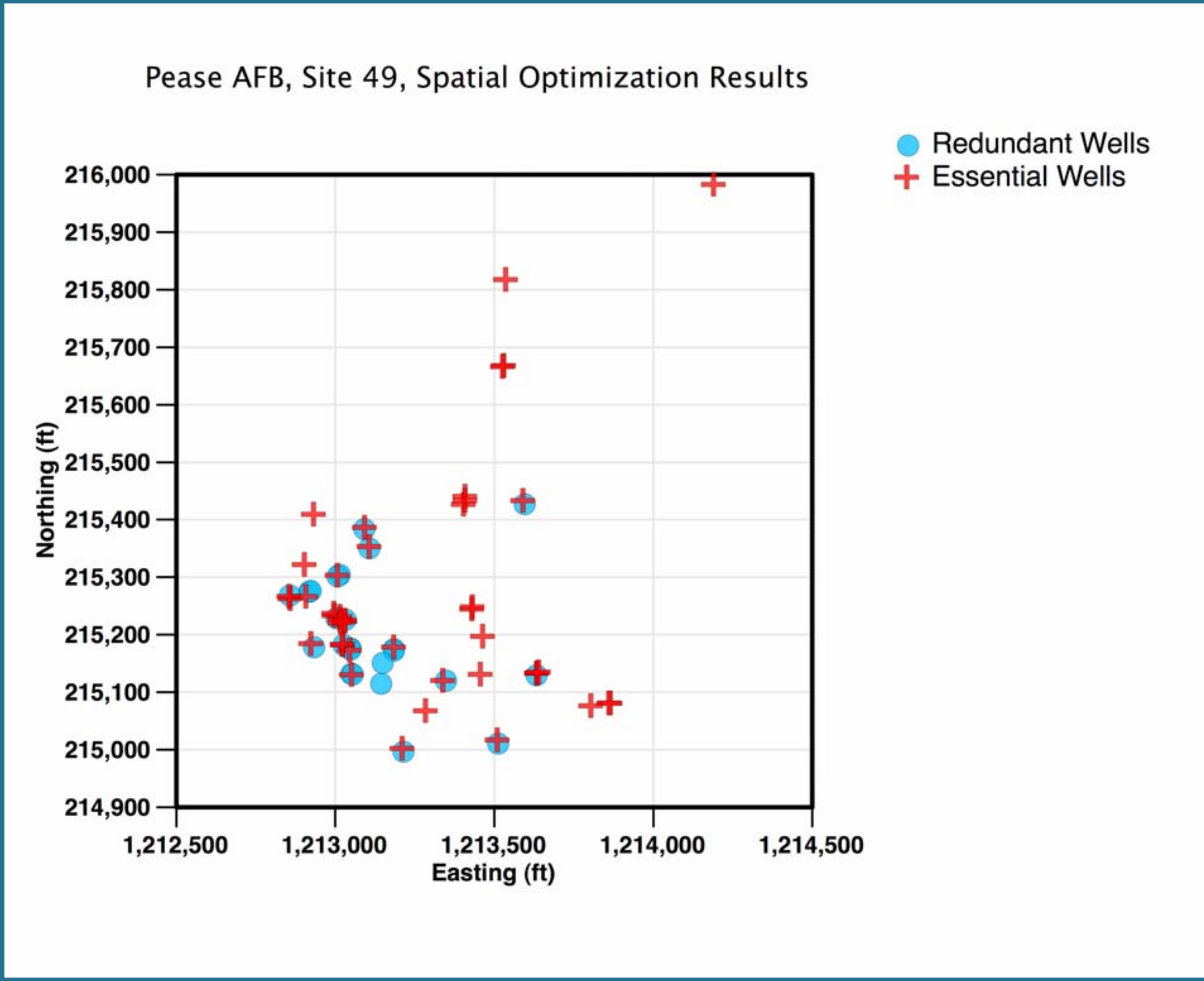
Loring: Optimized Wells



Pease: Optimized Wells



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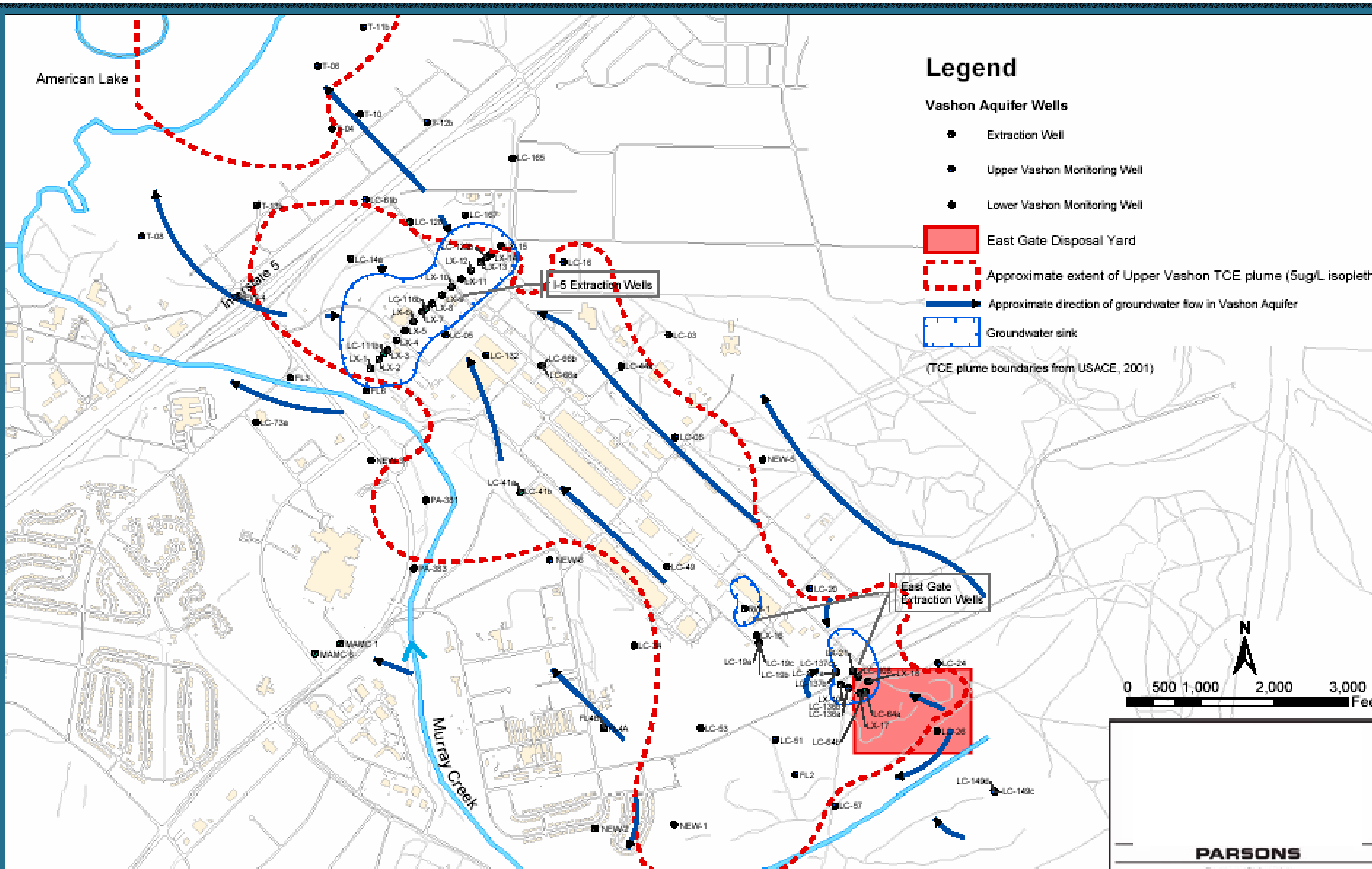
Parsons 3-Tiered: Background

- Large pump & treat system, army installation, USACE project
  - 2-mile-long TCE plume from dump area (DNAPL)
  - Containment system at boundary
  - Additional wells near source
  - Hydrogeology – outwash sands, gravels, tills, non-glacial deposits; plume in outwash
- ~ 40 wells had been sampled quarterly
  - Some background, some in source, some in middle of plume, some near boundary/downgradient
  - Some wells at different depths

Site Layout



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Previous Analyses of Monitoring Program

- Program: quarterly sampling of ~40 wells
- Optimization recommended in 1999 remediation system evaluation
  - Professional judgment only
  - Recommended removal of 3 wells
  - Trend assessment – lower frequency suggested
  - RSE recommended more rigorous analysis
- USACE district used MAROS to optimize
  - Removed some wells, added others in 2001
- Demonstration project also applied 3-Tiered approach

Results of Demonstration – Qualitative Evaluation

- Recommended removal of 15 wells
- Reduced frequency of 11 other wells
- Recommended reduced frequency for sampling extraction wells to annually
- Recommended change in analytical method
- Revisit monitoring if change in extraction system

Results of Demonstration – Trend Analysis

- Plot Concentrations over Time for Monitoring Points
- Perform Statistical Tests for Trend
  – Mann-Kendall Test (non-parametric)
  – Specified Level of Confidence in Trend
  – Quantify Trend Line
- Different Recommendations Based on Trend & Location
  – Increasing Trend: Retain if Not in Source Area
  – Decreasing Trend: Retain if in Source Area or Sentinel Well
  – No Trend: Retain if Sentinel Well or if Variability High
  – Non-Detect: Retain if Sentinel Well Only
- Recommended Removal of 20 Wells

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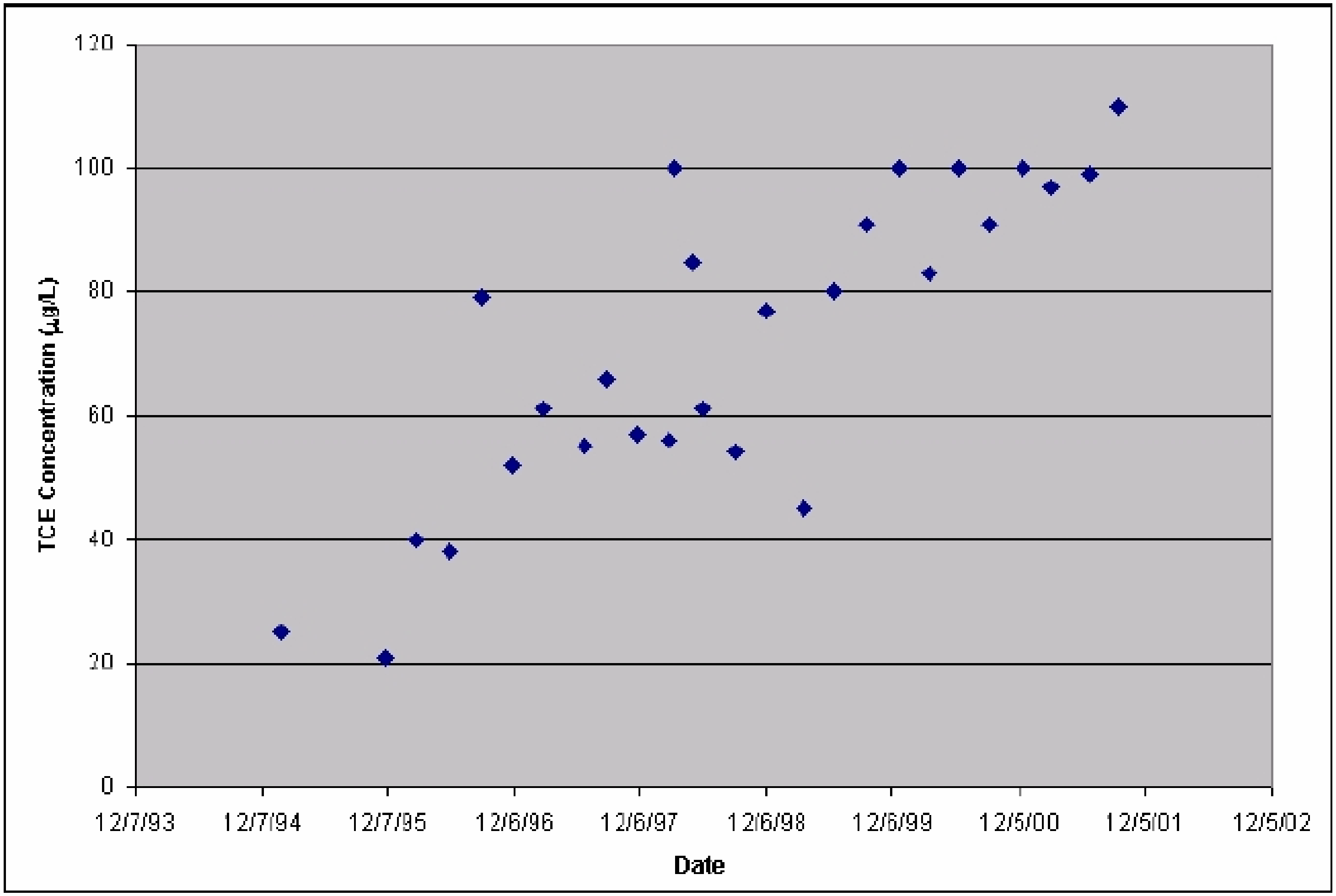
Trend for One Monitoring Well



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Results of Demonstration – Spatial Network Analysis

- Evaluate monitoring network using geostatistics
  - Develop variograms, model
  - Iterative kriging: drop one well at a time
  - Look at median prediction errors vs. Base case (with all wells)
  - Rank wells based on error increase if excluded
- Recommended removal of 21 wells
- Recommended adjustment of some proposed new wells in areas of high error

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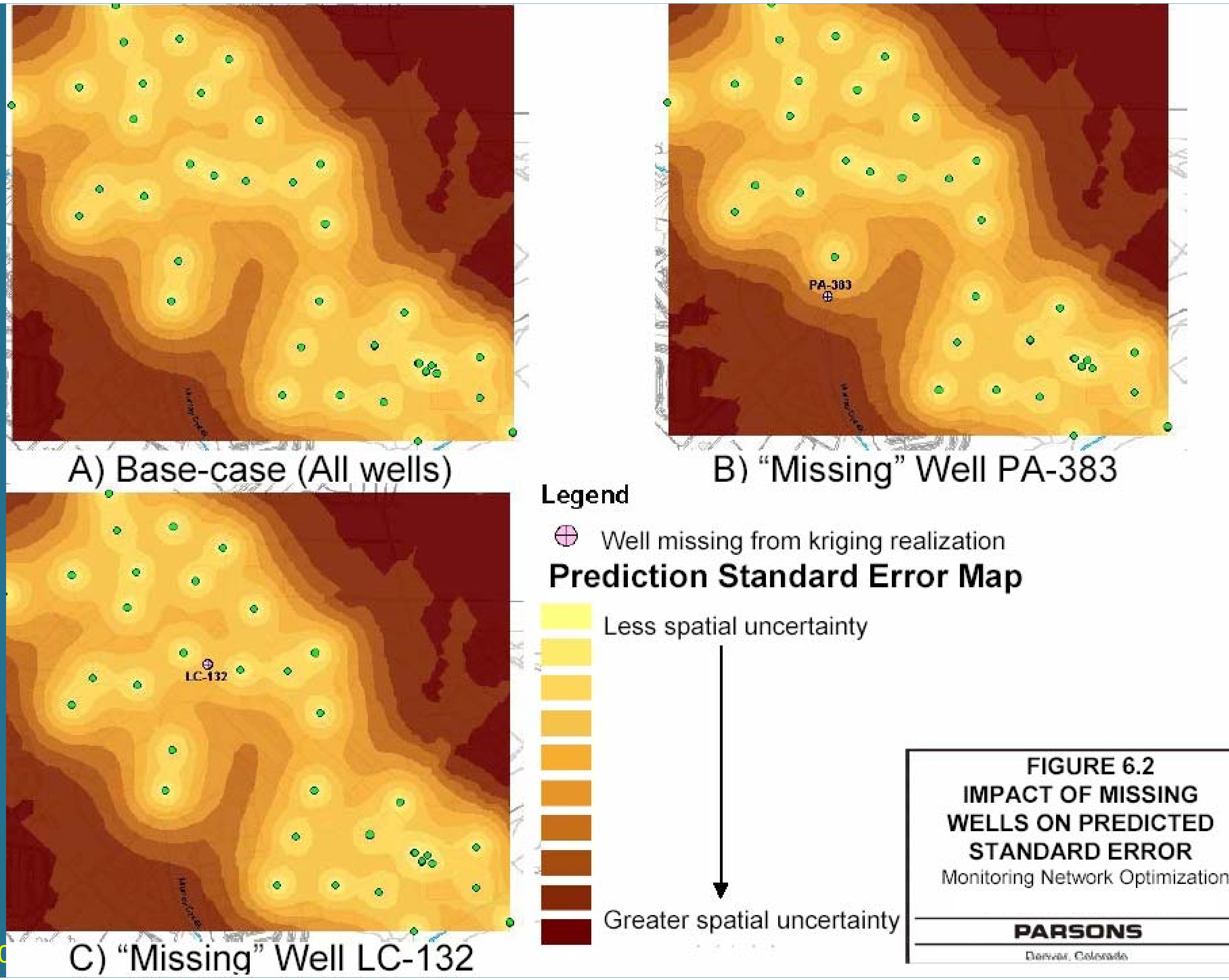
A) Base-case (All wells)
B) "Missing" Well PA-383
PA-383
C) "Missing" Well LC-132
LC-132
Legend
Well missing from kriging realization
Prediction Standard Error Map
Less spatial uncertainty
Greater spatial uncertainty
FIGURE 6.2
IMPACT OF MISSING
WELLS ON PREDICTED
STANDARD ERROR
Monitoring Network Optimization
PARSONS
Denver, Colorado

Results of Demonstration – Overall Analysis

- Professionals reviewed results of three analyses
- Synthesized overall recommendation:
  – Remove 13 wells, add one
  – Relative to original quarterly sampling – reduce frequency:
    - 7 semi-annually, 17 annually, 14 biennially (16 to stay quarterly); reduce sampling of extraction wells
    - Many of these changes made in 2001 evaluation
  – Net reduction in number of samples from 180 to 107/year compared to current (revised 2001) program
- Net savings: ~$35K per year

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