MAROS Decision Support System for Optimizing LTM Programs:

Application to Fort Lewis Logistics Center

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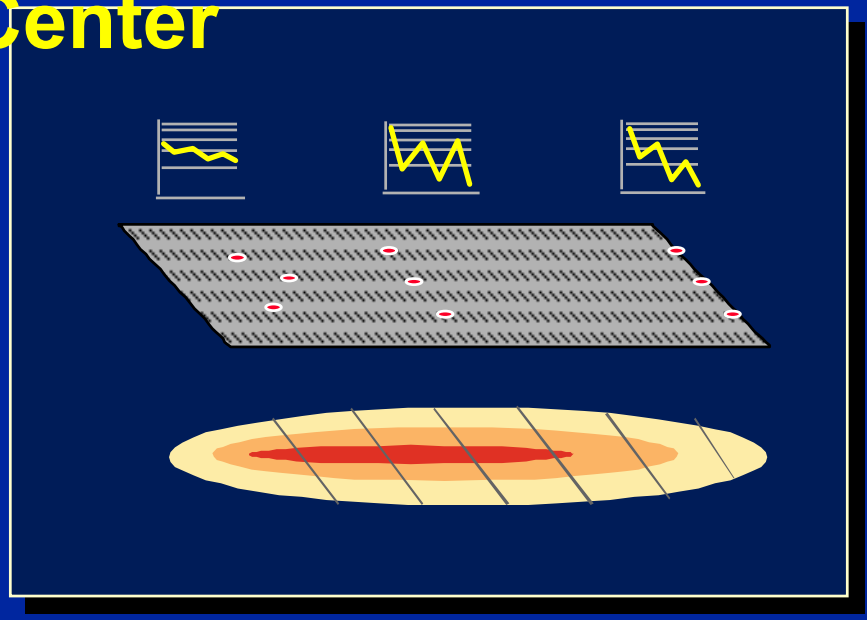
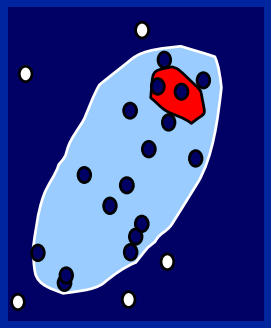


Long-Term Monitoring Calculus

		Number of Sites		*Cost Per Well*		*Number of Wells*		*Frequency, Duration of Sampling*		Data management & reporting	
LTM Cost ($)	=		X		X		X		X		
Addressed By This Tool?		*NO*		*NO*		*YES*		*YES*		*YES*	

TWO LONG-TERM MONITORING PLANS

	$	NPV $
A. CONVENTIONAL PLAN: *10 Wells Quarterly for 30 Years*	**$ 1,200 K**	**$ 615 K**
B. OPTIMIZED PLAN: *Six Wells Twice/Yr for 30 Years*	**$ 360 K**	**$ 185 K**

COST SAVINGS: 70%

Current LTMP Negotiation Process

Owner Collect, Analyzes Site Data

What are conditions at site?

Owner Submits Multiple Reports Over Several Years

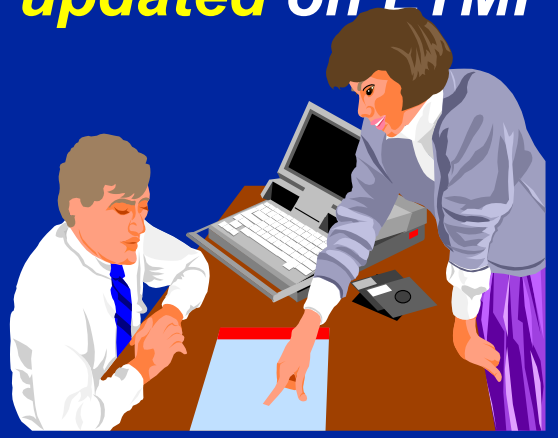
What are the data saying?

Owner, Regulators Negotiate Long Term Monitoring Plan

What is the bottom line on this plume?

Obstacles to Effective Negotiations

- *Historical data not all in one place - it is difficult to get "birds-eye view" of plume over time.*
- *Trends are not always clear due to data scatter.*
- *No formal mechanism to say which wells aren't needed.*
- *No mechanism to keep regulators updated on LTMP results.*



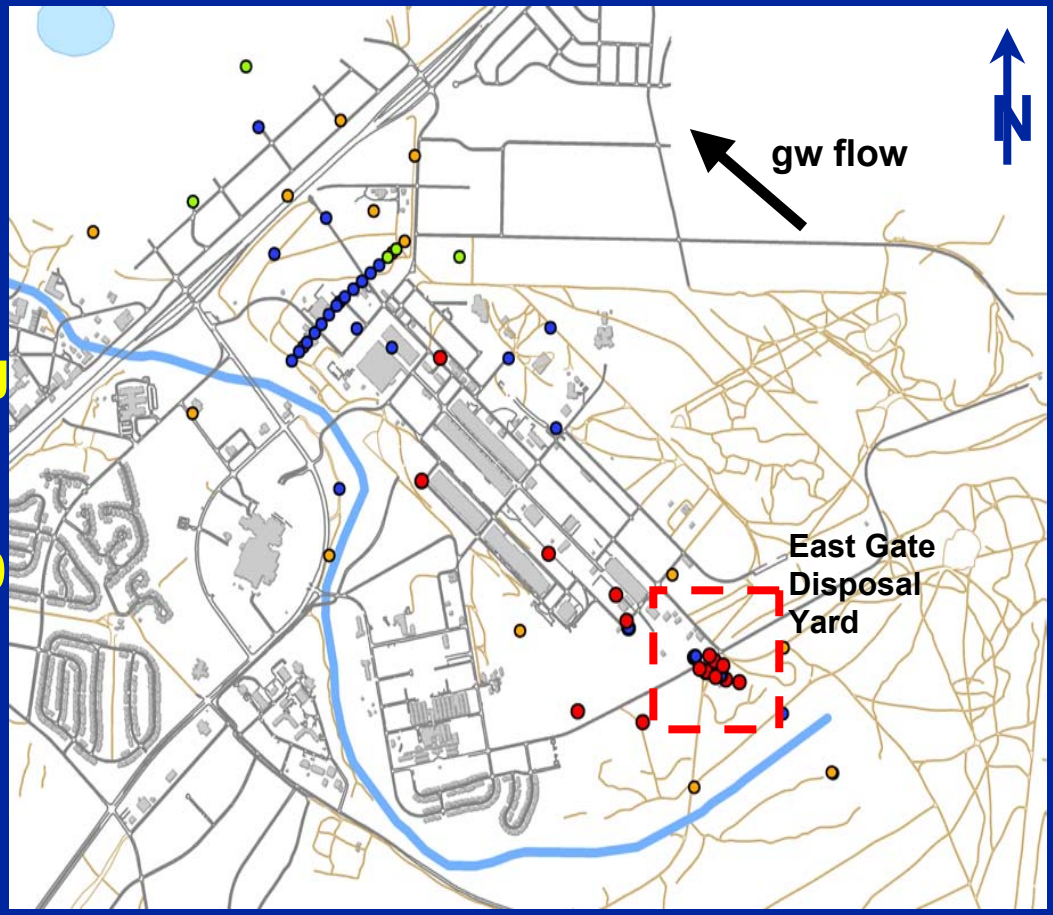
MAROS Database Software

- *Storehouse/presentation tool for site historical data .*
- *Provides statistical information on trends.*
- *Tool for identifying "redundant" wells.*
- *Help "optimize" sampling frequency, number of wells.*
- *New data goes in, updated report automatically comes out.*

- **Geostats Tool:** **Keep it simple & free**

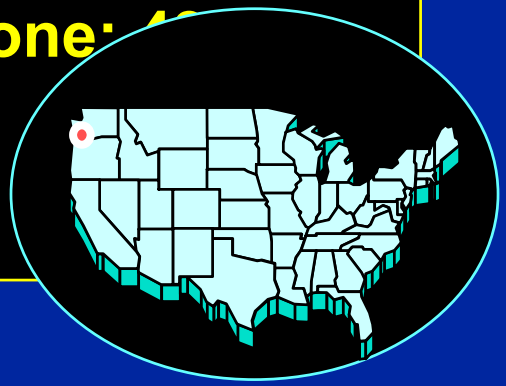
Site Description

- MAROS Analysis performed on a TCE plume monitoring network, Fort Lewis Logistics Center, Pierce County, Washington
- TCE used as a degreasing agent until 1970's
- Chlorinated solvents: historically TCE up to 250 mg/L, NAPL present
- Plume Length: 10,000 ft
  Plume Depth: 60 – 80 ft
- Under Active Remediation: pump and treat system in since 1995

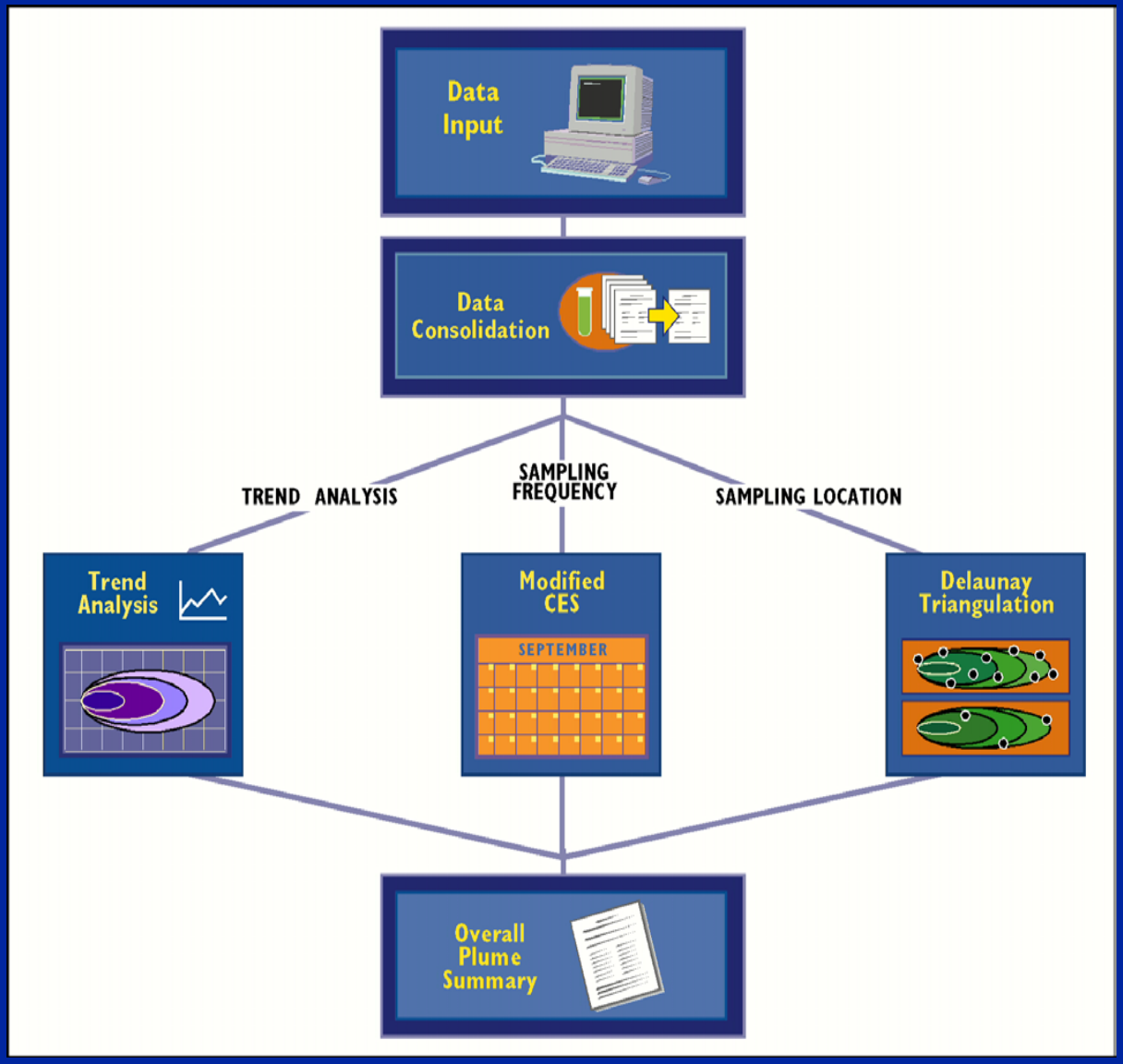


Hydrogeologic/Well Network Parameters

PARAMETER	
Representative Media Type	Outwash Sand and Gravel
Depth to Water (ft, BGS)	10 – 30
Saturated Thickness (ft)	Upper Zone: 60
GW Seepage Velocity (ft/yr)	550
Extraction Wells	Upper Zone: 21
Monitoring Wells	Upper Zone:
Quarterly monitoring	
7 years of sampling data	



MAROS Road Map



- **Database Input:** Excel or Access Files, Archive files, simple updates
- **Automated Data Consolidation:** Dups, ND's, and J Flag Values
- **Optimization Tools:**
  - ***Plume Stability and Individual Well Trend Analysis:*** *Simple Stats, Moment Analysis*
  - ***Sampling Frequency:*** *Individual Well Recommendations*
  - ***Sampling Location:*** *Well Redundancy*
  - ***Sampling***

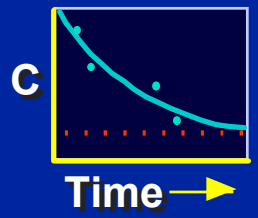
MAROS Data Input:
Data Requirements and Analysis Methods

Data Requirements

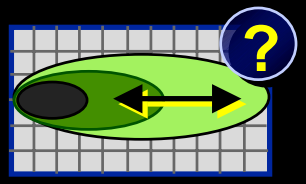
Historical measurements of plume concentrations: multiple sampling events (including upgradient, downgradient, and 2 or more plume wells.)

Data Consolidation

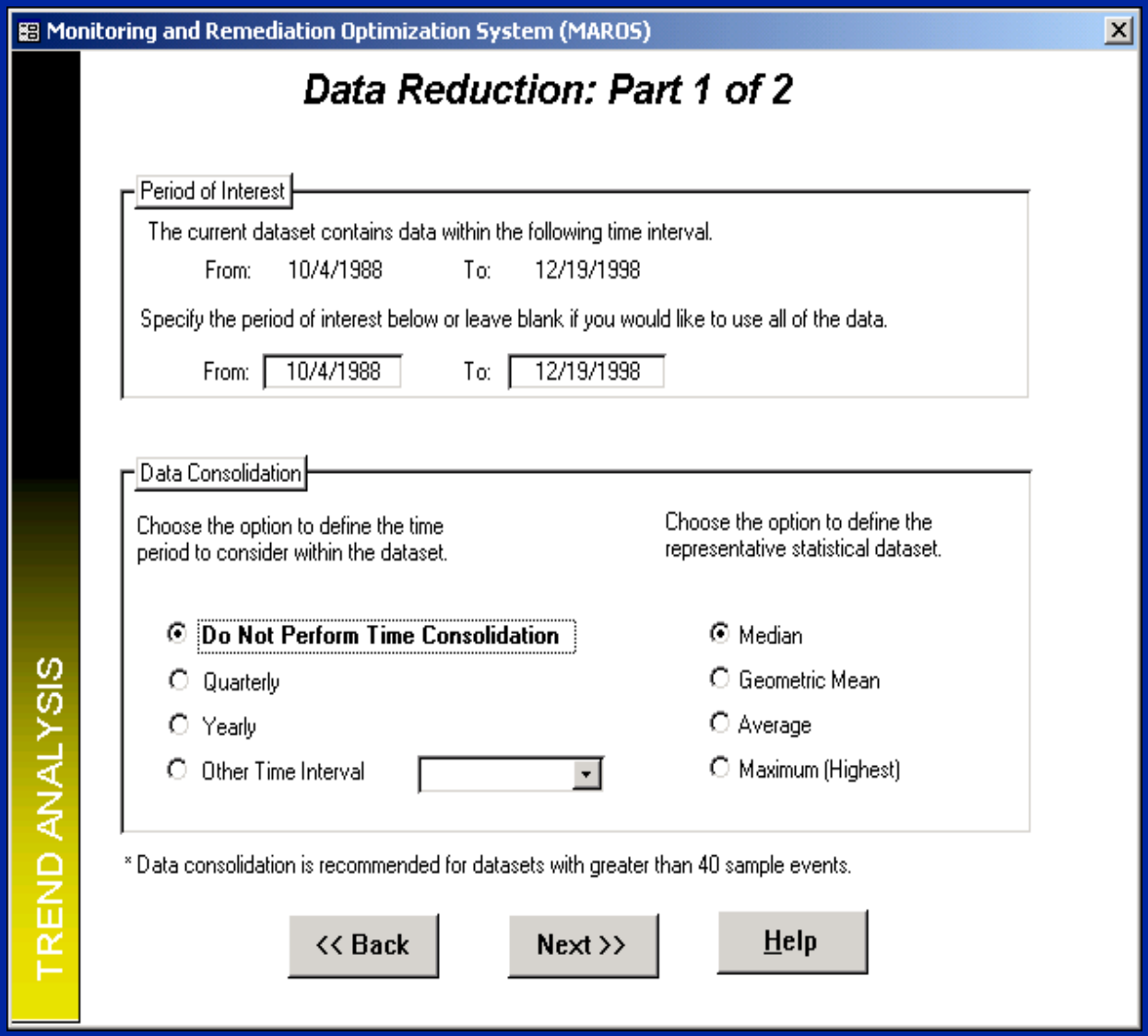
Assign representative results for sample events: non-detects, duplicates, trace levels, and irregularly sampled wells.



GOAL: Establish plume status as stable, shrinking, or expanding based on historical data.



Data Input & Data Reduction



Well Network Input Data:

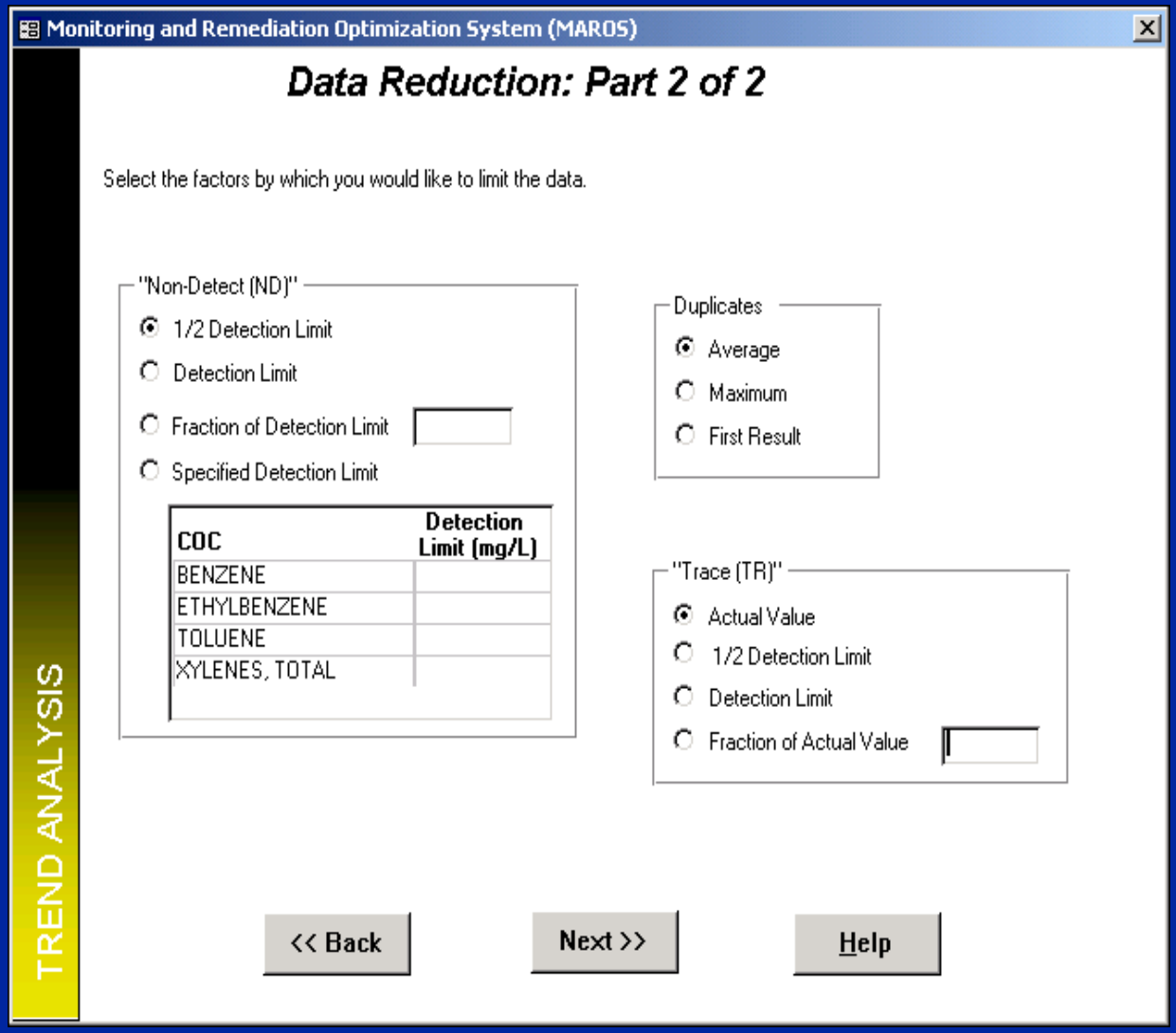
- 10 Source Wells
- 33 Tail Wells
- 21 Extraction Wells

Data Consolidation:

- Post-remediation start-up data:

  1995 – 2001
- One COC for site: TCE
- No Time Consolidation

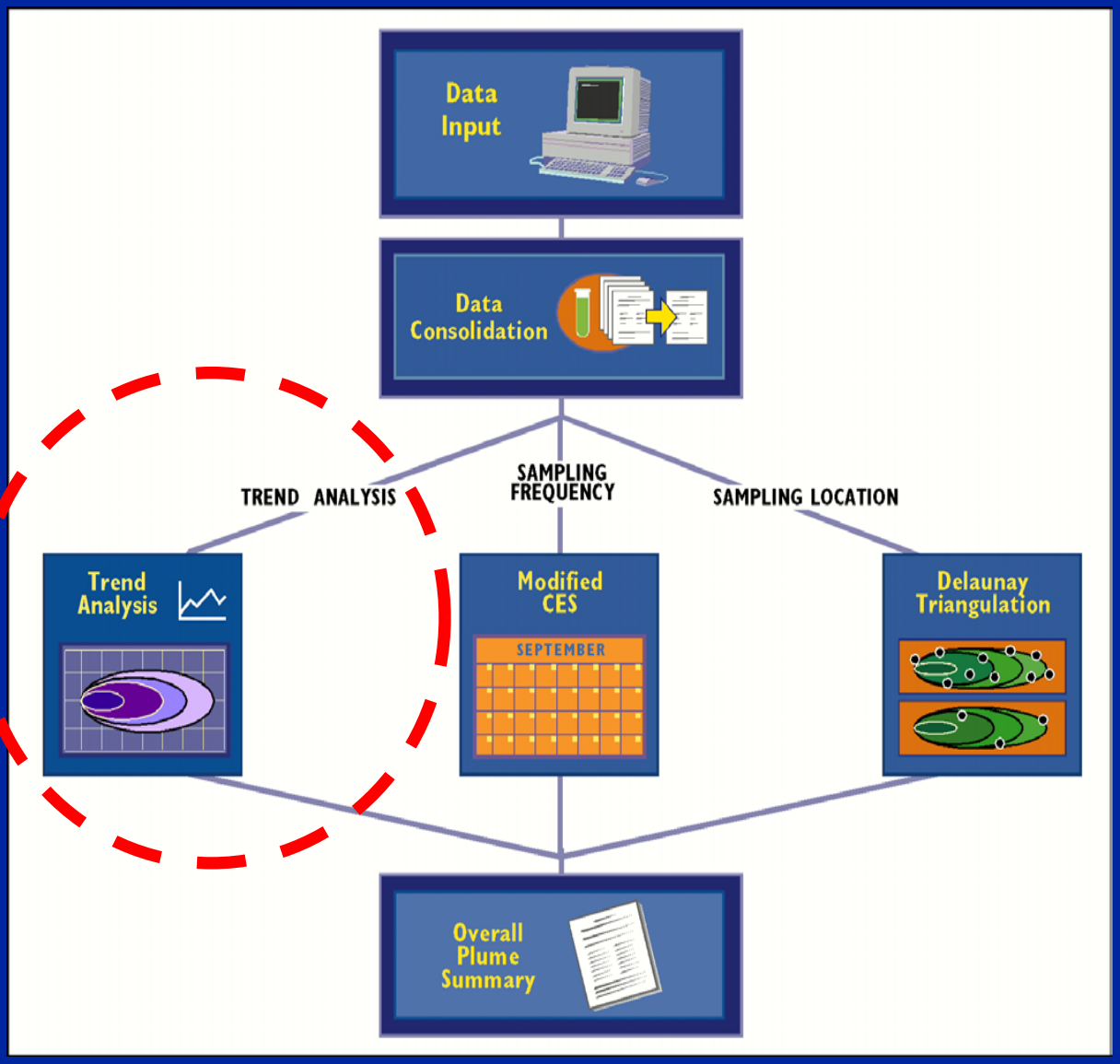
Data Reduction



Data Consolidation:

- Non-detect values set to minimum detection limit.
- Average Duplicates
- Trace Values set to actual values

MAROS Road Map

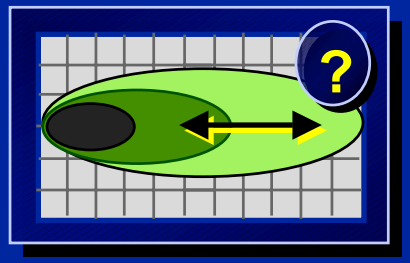


- **Optimization Tool:**
  - ***Plume Stability and Individual Well Trend Analysis:*** *Conc. vs. Time Data, Simple Stats, Moment Analysis*

MAROS Temporal Trend Analysis

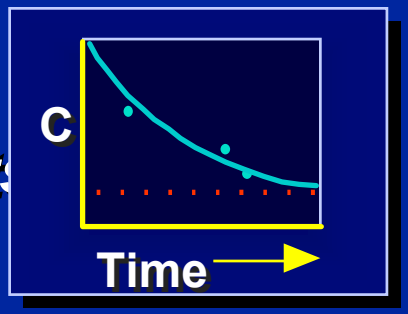
WHAT

Define ground water plume status as stable, shrinking, or expanding.



HOW

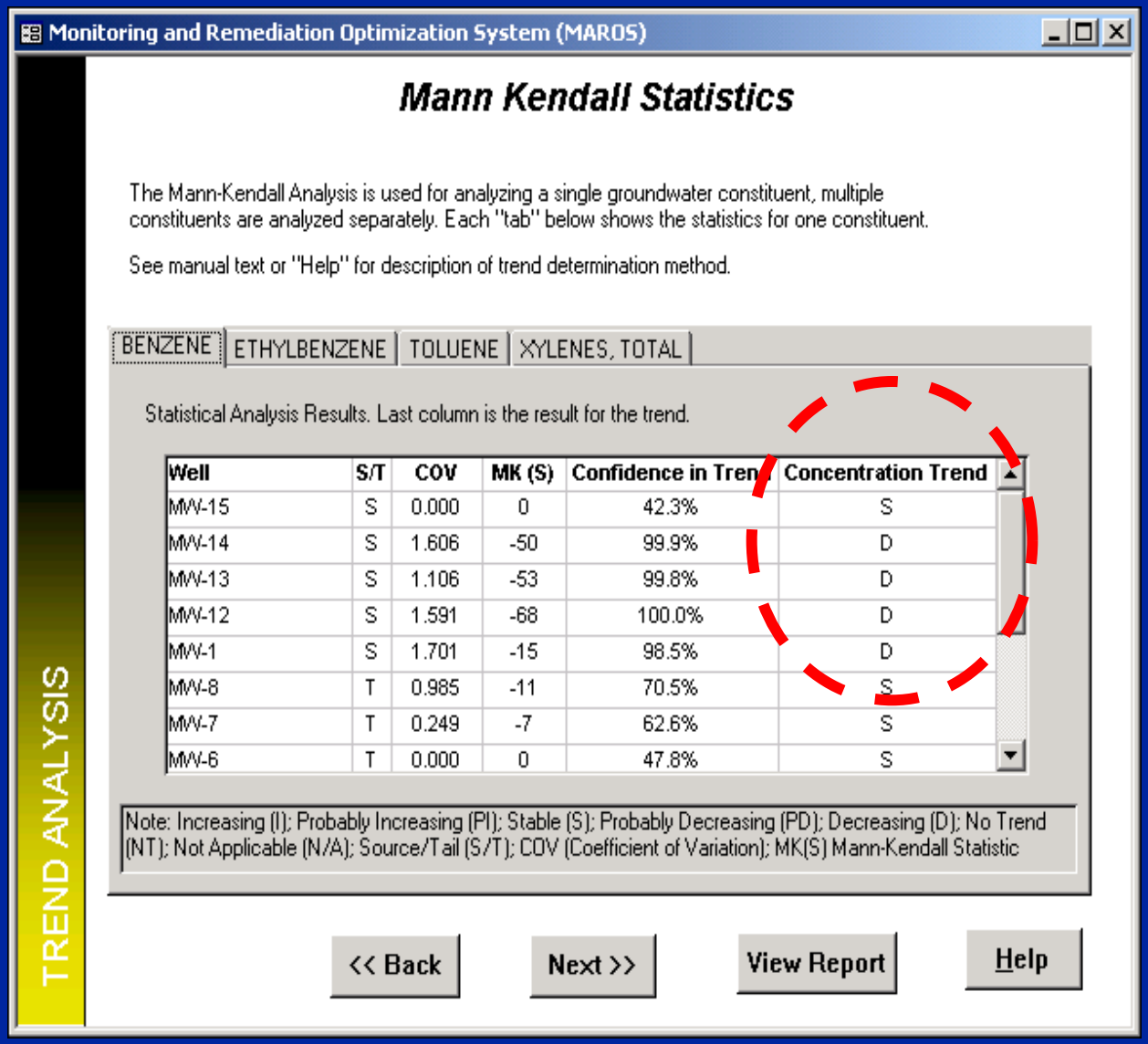
Evaluate historical concentration measurements in ground water.



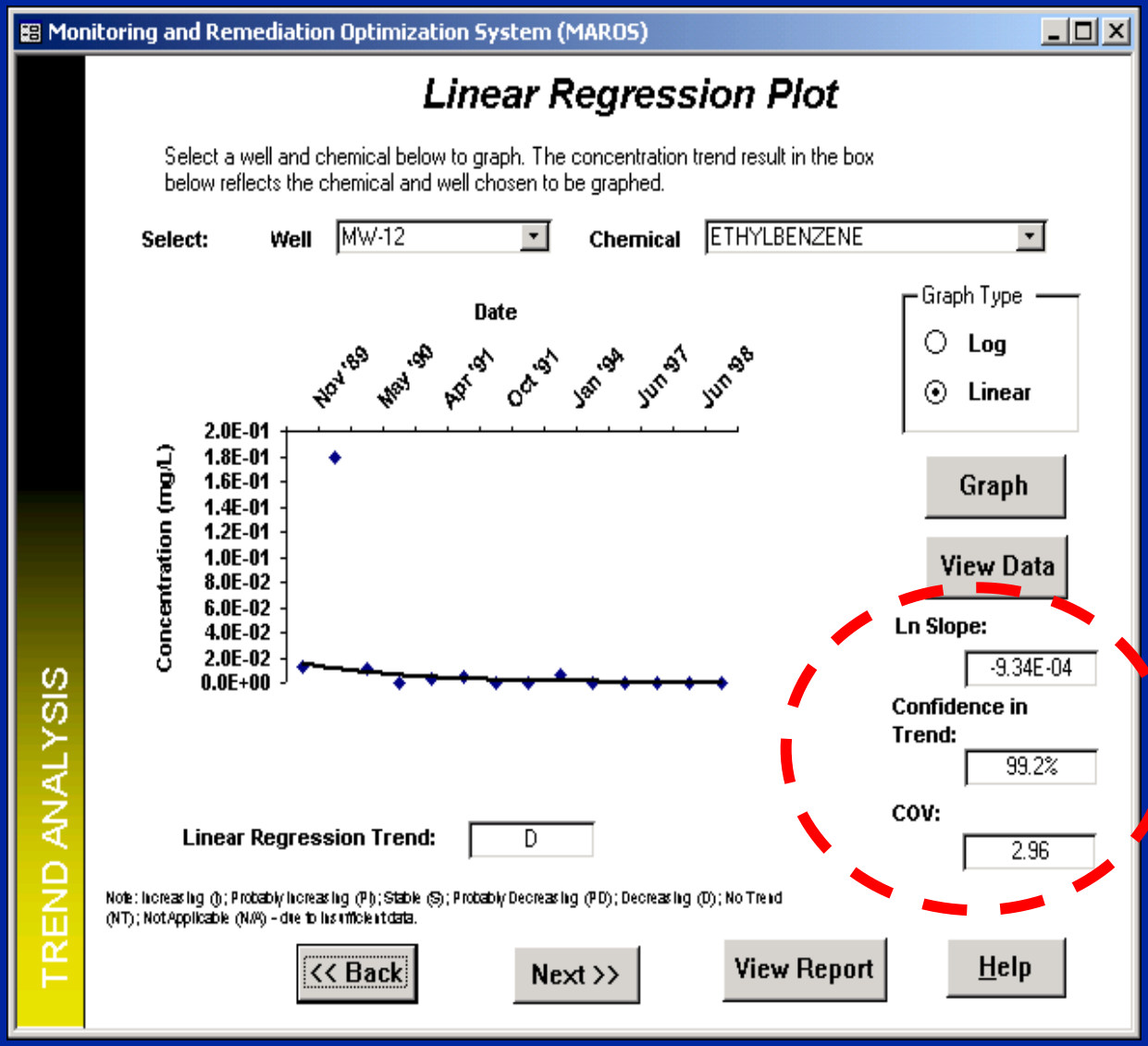
WHEN

Always apply based on sufficient historical data.

Mann-Kendall Analysis



Linear Regression Analysis



Mann-Kendall and Linear Regression Analysis Results

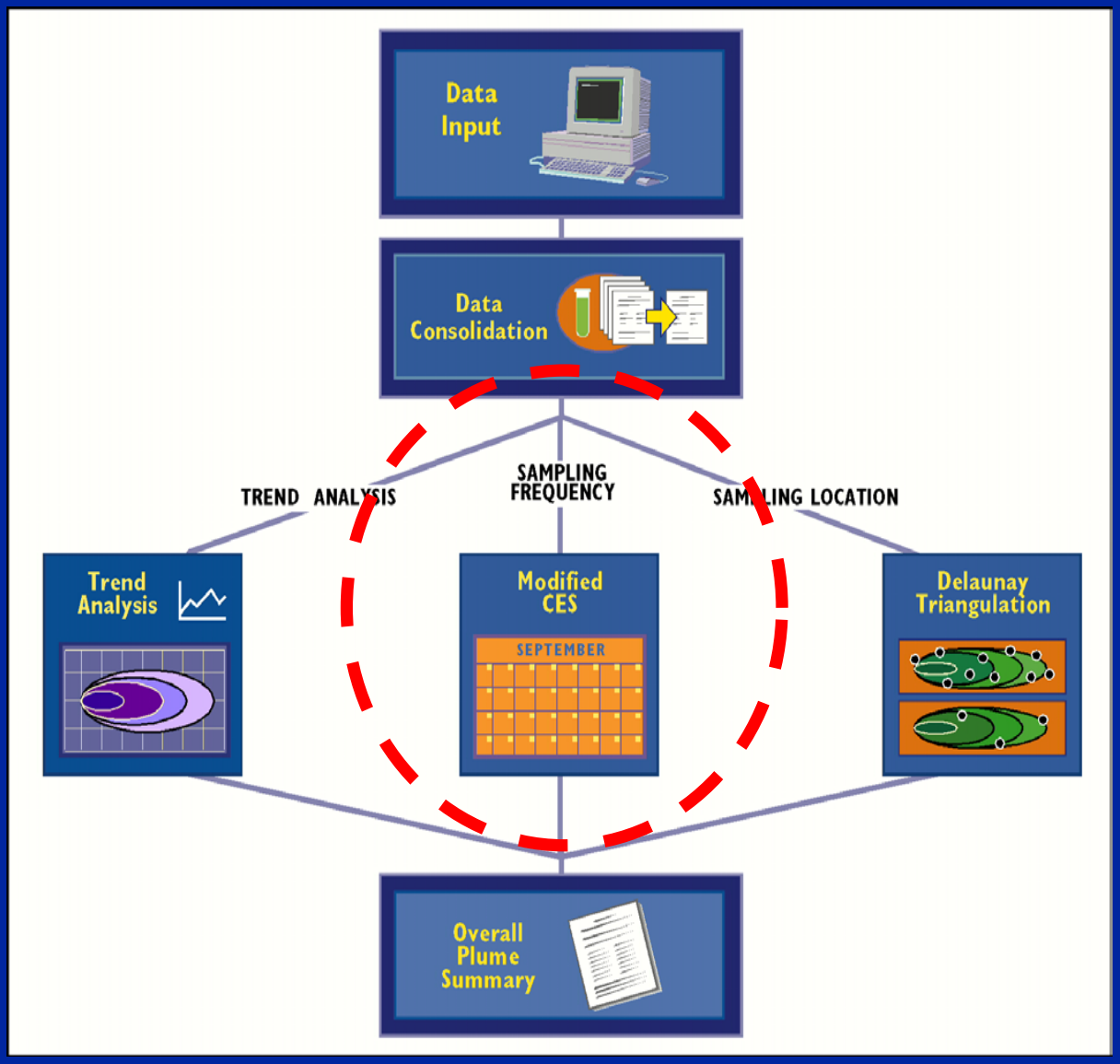
MAROS Trend Analysis		
Well Type	PD, D, S	I, PI
Source	6 of 10 (60%)	4 of 10 (40%)
Tail	15 of 33 (45%)	11 of 33 (33%)
Extraction	18 of 21 (85%)	2 of 21 (9%)

- Increasing (I)
- Probably Increasing (PI)
- No Trend (NT)
- Stable (S)
- Probably Decreasing (PD)
- Decreasing (D)

Moment Analysis Results

Mann-Kendall Trend Analysis		
Moment Type	Trend	Comment
0th: Mass Estimate	Increasing	• Extraction system moving high concentration groundwater from source zones to nearby monitoring wells OR •Change in monitoring wells sampled
1st: Center of Mass	Stable	Only slight movement forward or backward along the direction of groundwater flow.
2nd: Plume Spread	Decreasing	Indicates that wells representing very large areas both on the tip and the sides of the plume show decreasing concentrations.

MAROS Road Map



- **Optimization Tool:**
  - ***Sampling Frequency:*** ***Individual Well Recommendations***

Cost Effective Sampling (Ridley, 1998)

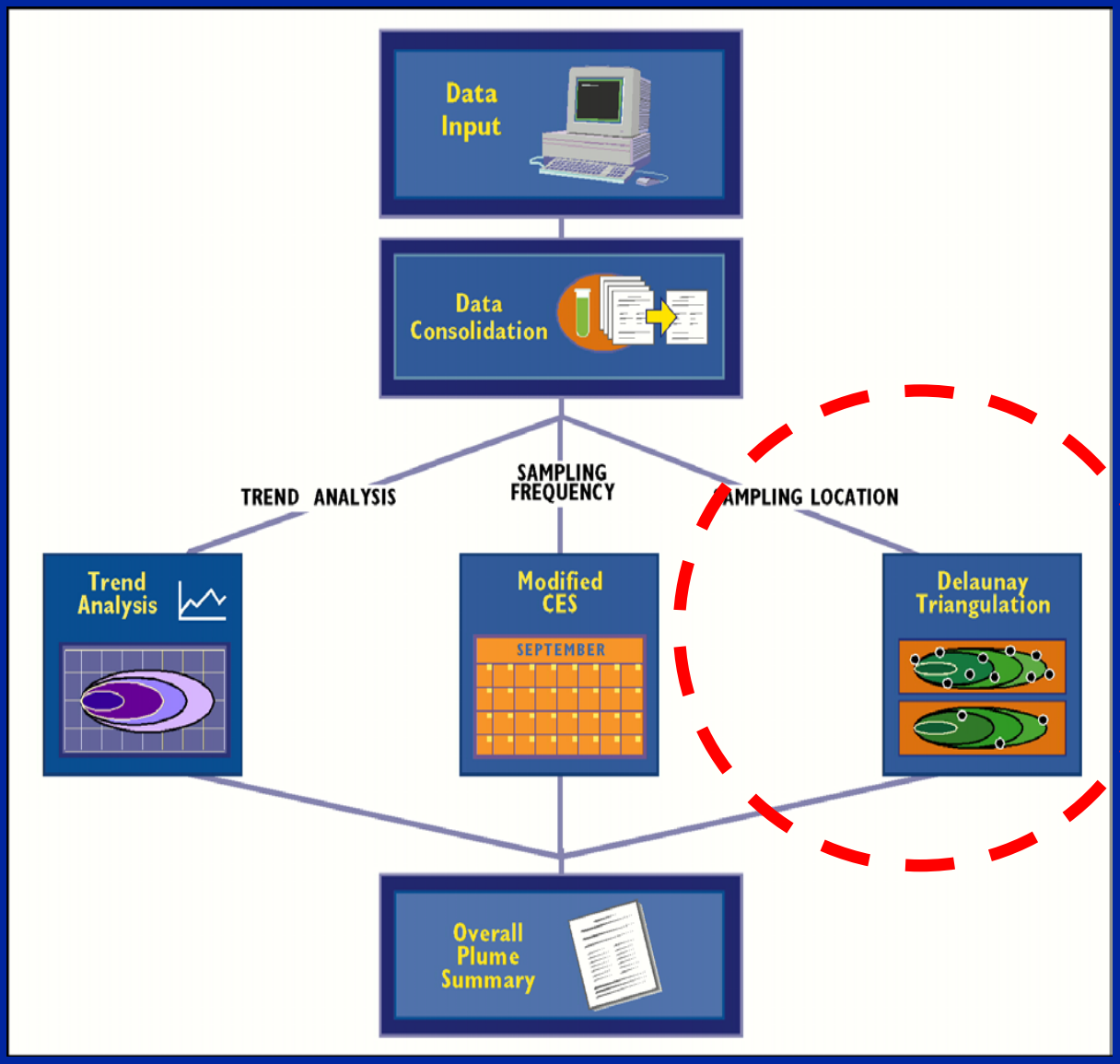
Overview: Estimate lowest frequency of sampling for a monitoring location but still provide enough information for regulatory and remedial decision making.

Sampling Frequency Results

Frequency Analysis: Modified CES			
Monitoring Wells	Current Sampling Frequency	Recommended Sampling Frequency	Number of Wells
Group 1	Quarterly	Annual	14
Group 2	Quarterly	Semiannual	2
Group 3	Quarterly	Quaterly	8 (No Change)

Note: Cost Effective Sampling (CES)

MAROS Road Map



- **Optimization Tools:**
  - ***Sampling Location:*** ***Well Redundancy***

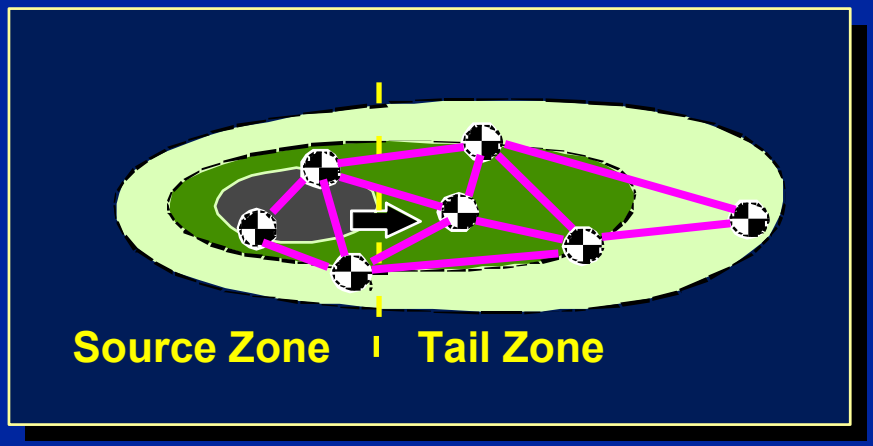
Sampling Location Optimization

Delaunay Method:

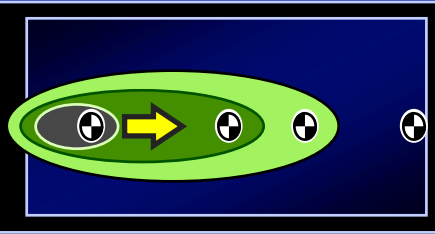
- **Evaluate significance of current sampling locations in monitoring network (eliminate "redundant" wells)**

OR

- **Add wells in areas of the well network with high level of plume concentration uncertainty.**

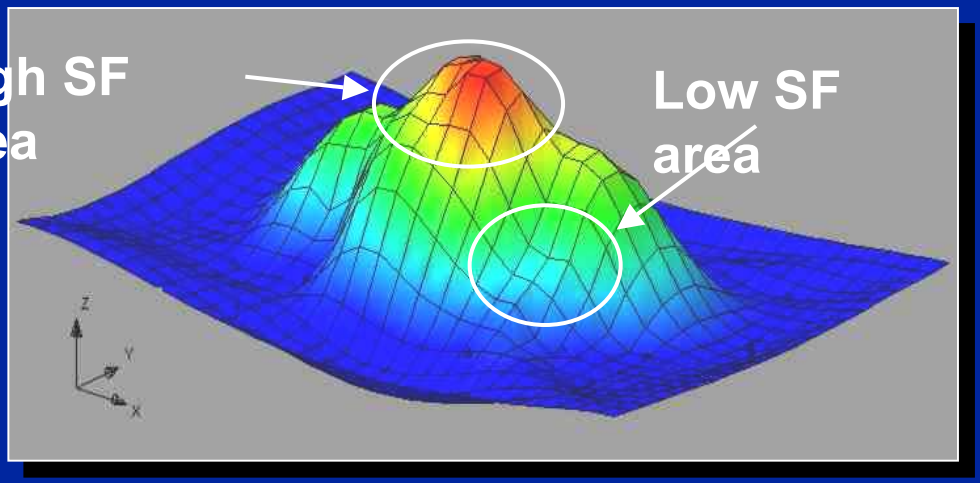


Key Point: **Does estimated concentration change if well is removed?**



Recommendation for New Sampling Locations

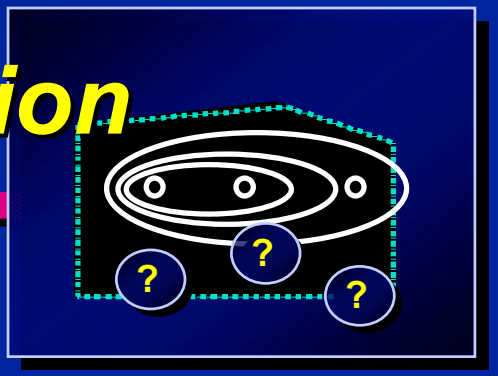
Generate **estimation uncertainty plot** based on SF values



High SF areas → High estimation error → Possible need for new locations

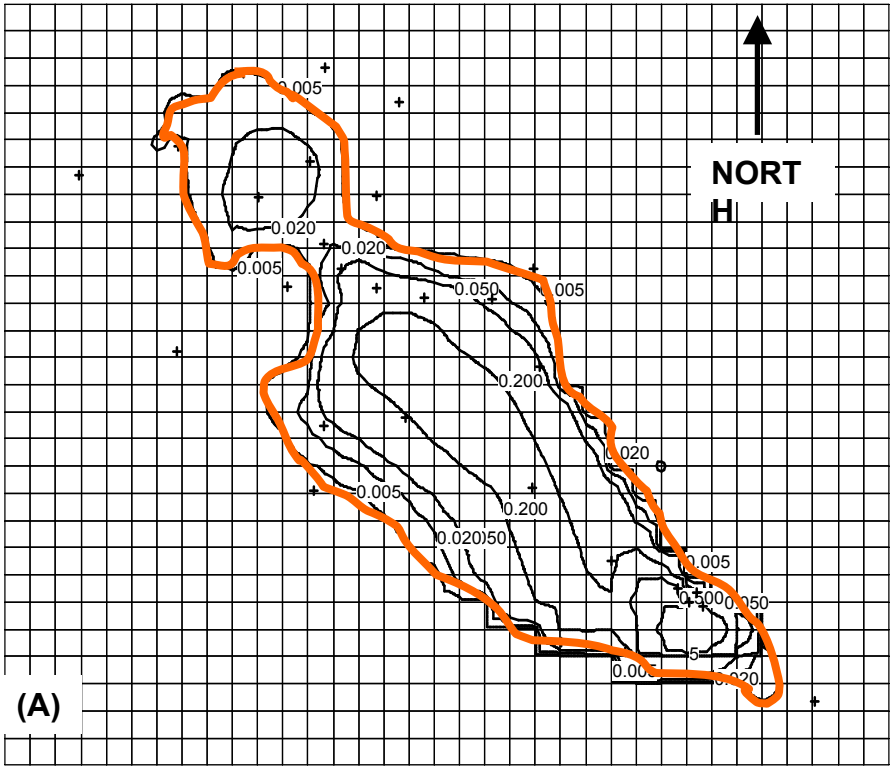
Low SF areas → Low estimation error → No need for new locations

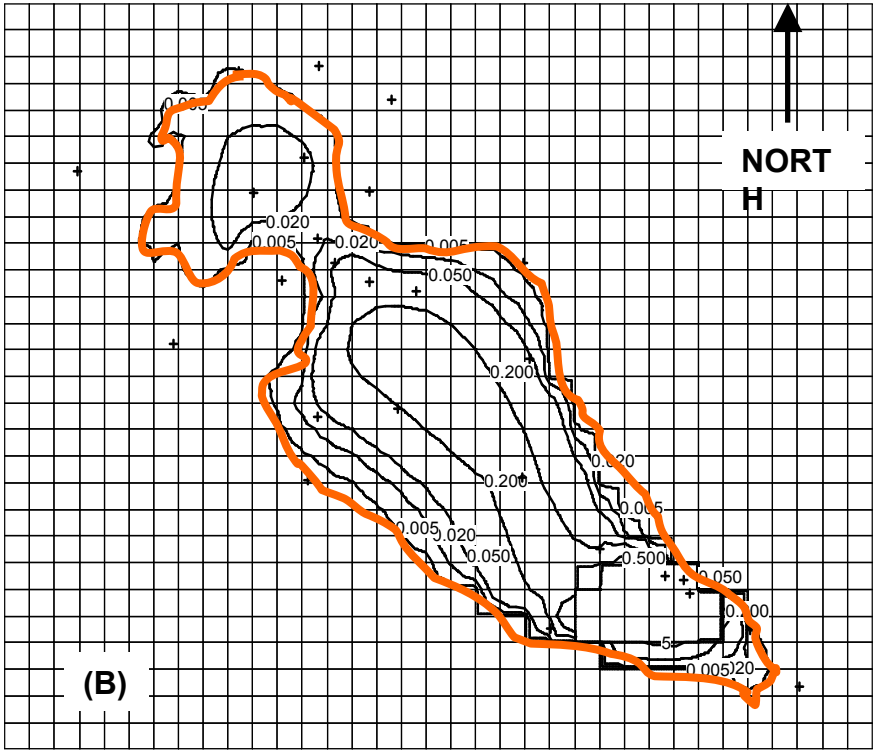
Sampling Location Optimization



Summary	Before Optimization	After Optimization
Redundancy reduction	38 wells	8 candidates for removal
New locations	6 new wells are proposed inside the well network	

Visual Comparison of TCE Plumes

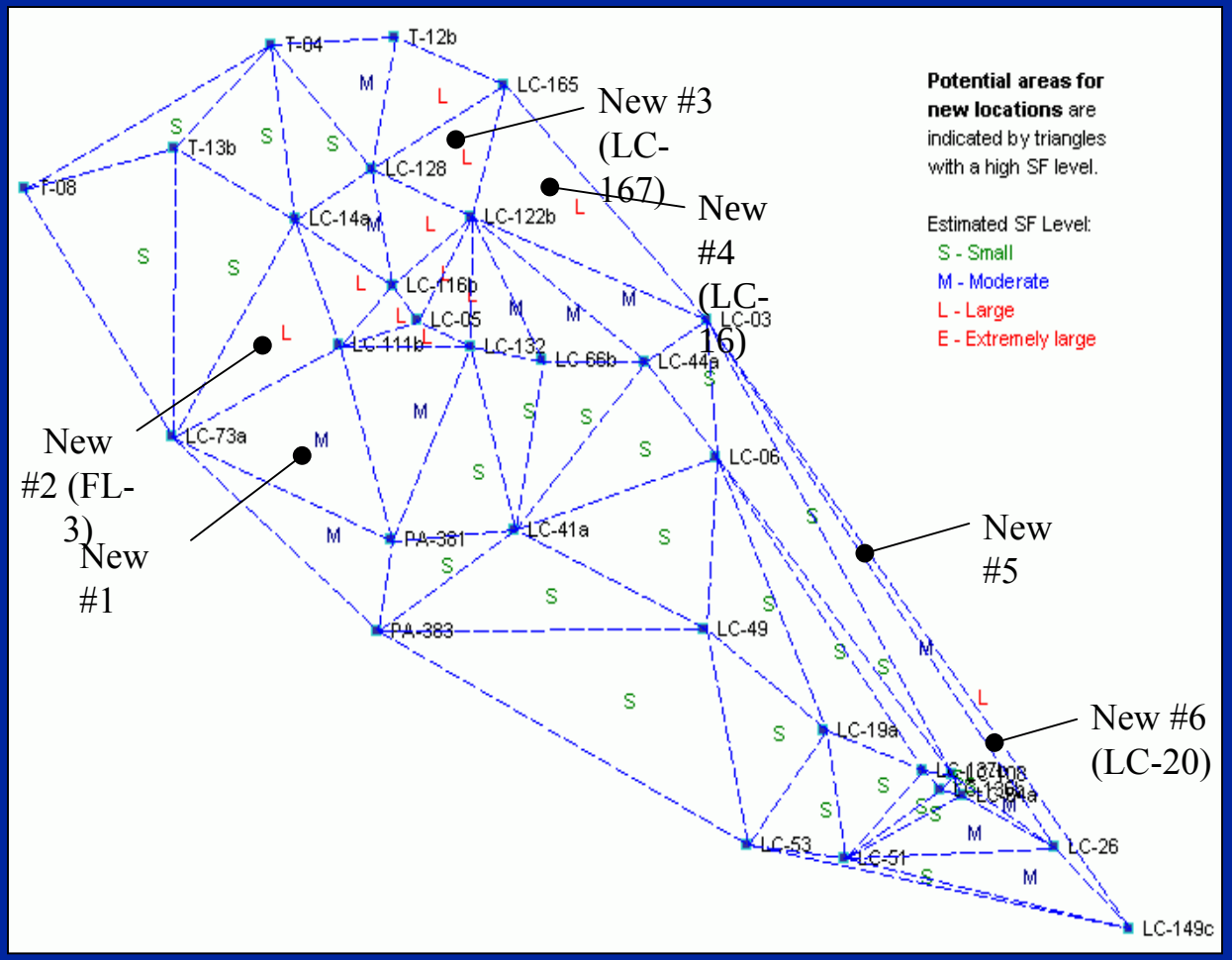




(A) September 2001
Before
Optimization

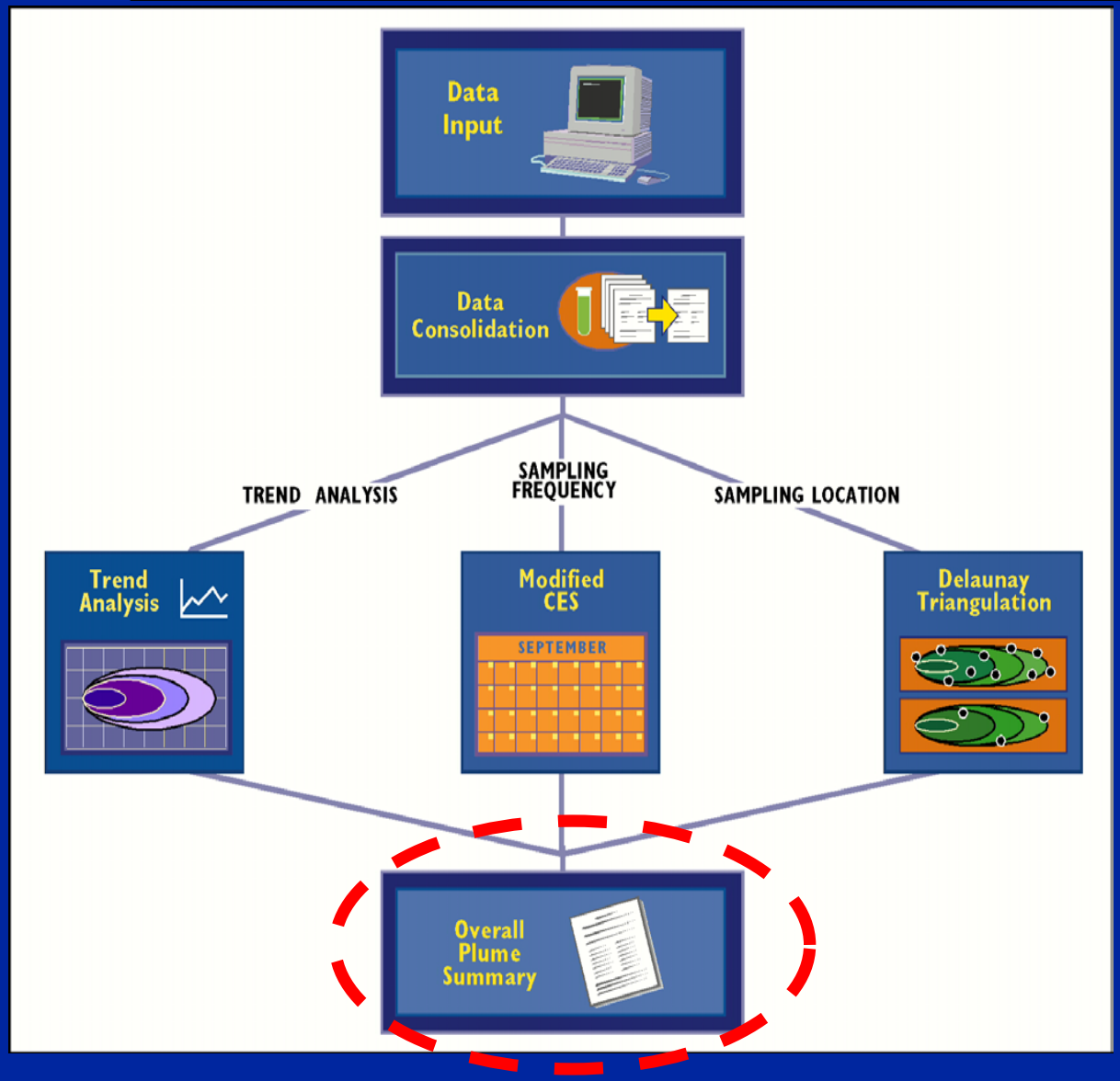
(B) September 2001
After Optimization

Proposed New Sampling Locations



Note: Only applicable for areas inside the well network

MAROS Road Map

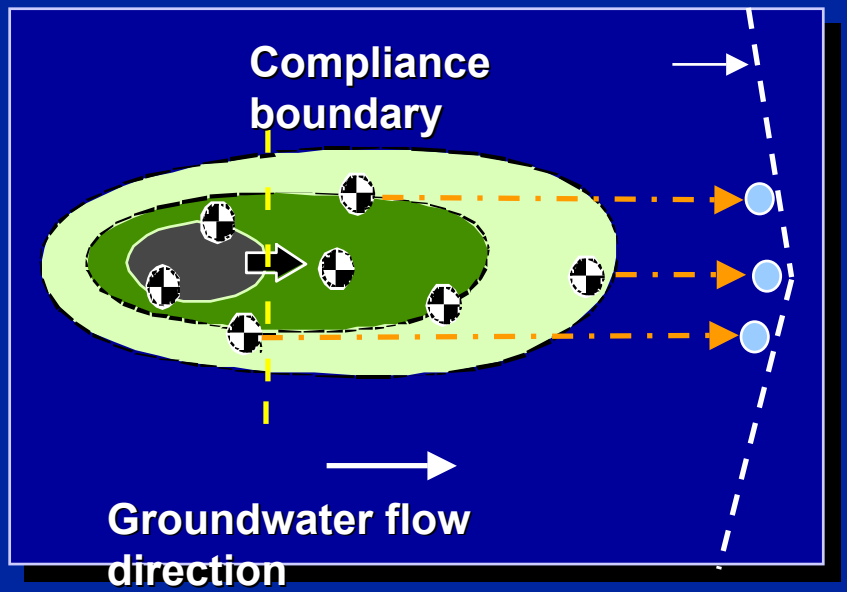


- **Optimization Tools:**
  - ***Data Sufficiency:*** ***Power Analysis***

Data Sufficiency: Power Analysis

Risk-based goals require cleanup standards be met at the compliance boundary

1. Establish "virtual" wells at the compliance boundary
2. Project concentrations at these "virtual" wells
3. Perform statistical power analysis with these projected concentrations

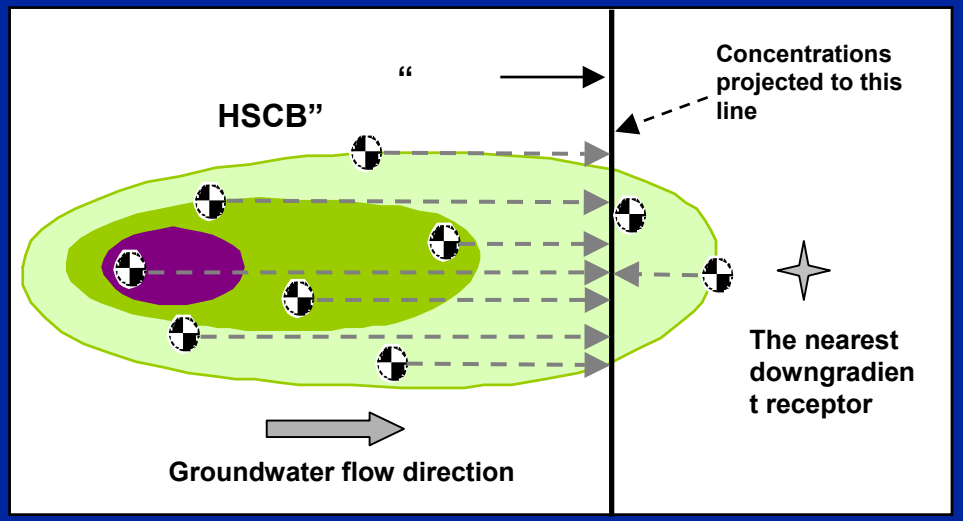


Data Sufficiency Analysis – Results

Risk-based site cleanup status

1000 ft down-gradient	*2000 ft down-gradient*
Close to Statistically protected	Statistically Protected

Conclusion: The site remedial system is effective in containing the plume and reducing the TCE concentration



HSCB: Hypothetical Statistical Compliance Boundary

MAROS Application Conclusions

1 Plume Stability

- Plume Stable to Decreasing

2 Frequency Analysis

- Majority of wells can be sampled Annually

3 Well Location Analysis

- Remove 8 monitoring wells
- Add 6 new monitoring wells

4 Data Sufficiency

- Currently Statistically Protected 2000 ft downgradient

Conclusions and Future Work

- MAROS 2.0 software has been applied to optimize the Upper Aquifer groundwater long-term monitoring plan at the Fort Lewis Logistic Center, approximate Cost Savings: $58 K per year.
- EPA Geostatistical Study: To compare MAROS 2.0 with other optimization methods to find out its merits and shortcomings.
- MAROS Version 2.0 (release 2/02)

AFCEE Tool - download at www.gsi-net.com