

Headquarters U.S. Air Force

Integrity - Service - Excellence

Air Force Long-Term Monitoring Optimization Tools



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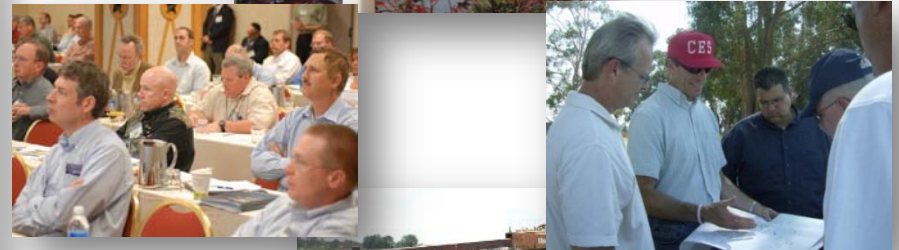
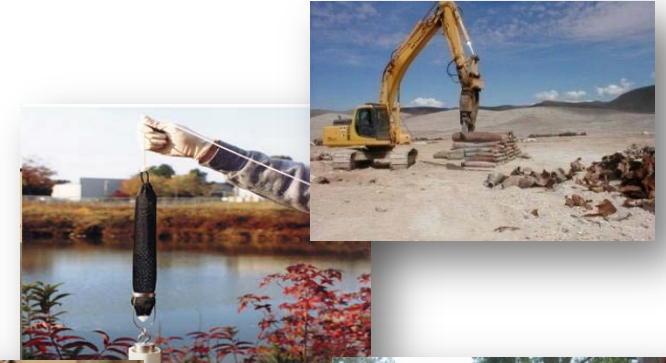
**AFCEE/TDV
Phil Hunter, P.G.
2011 May**



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Overview

- ✓ Process & Opportunity
- ✓ Tool Inventory
- ✓ Status & Availability
- ✓ Application & Management
- ✓ Summary





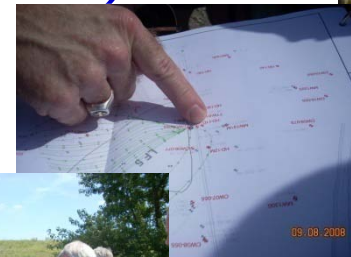
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Products and Services

AFCEE Restoration Branch

- ✓ Organization
- ✓ Staff
- ✓ Mission
- ✓ Goals
- ✓ Products and Services
- ✓ Funding
- ✓ Issues

- Peer Review Support
- Decision Support & Analysis
- Rapid Site Characterization
- Innovative Technologies
- **Performance Based Remediation (PBR)**
- Consulting Services
- Exit Strategy Development
- ROD Reviews
- 5-Year Review Support
- LTM Optimization
- Emerging Issues



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Performance Based Remediation (PBR)

Role of LTMO Tools

- **Fence-to-fence approach**
- **Contracts are fixed price and regionalized**
- **AF Provides a preferred inventory of tools without fee**
- **Contractors should be familiar with tools and have relevant experience & training**
- **AF needs standardized approach to negotiate with regulators and validate PBR proposals**
- **Some orphan sites & installations are optimized out-of-cycle from PBR contracts**

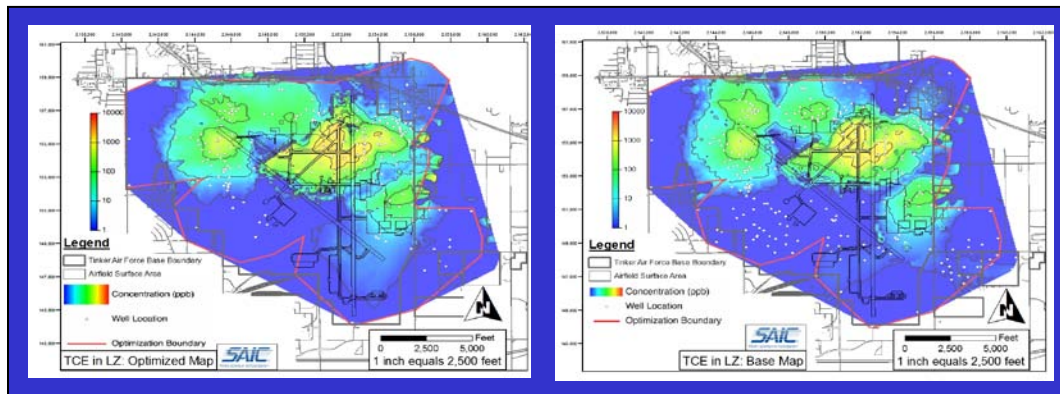
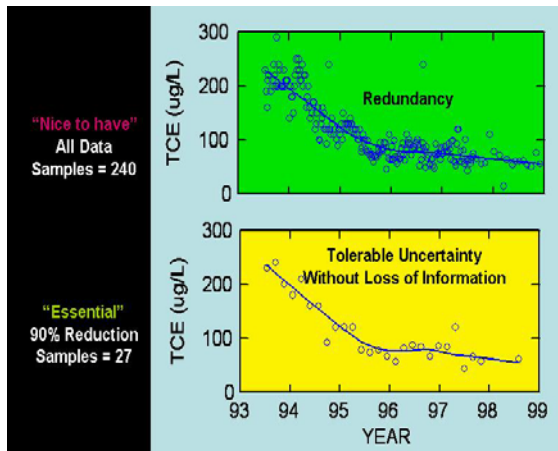
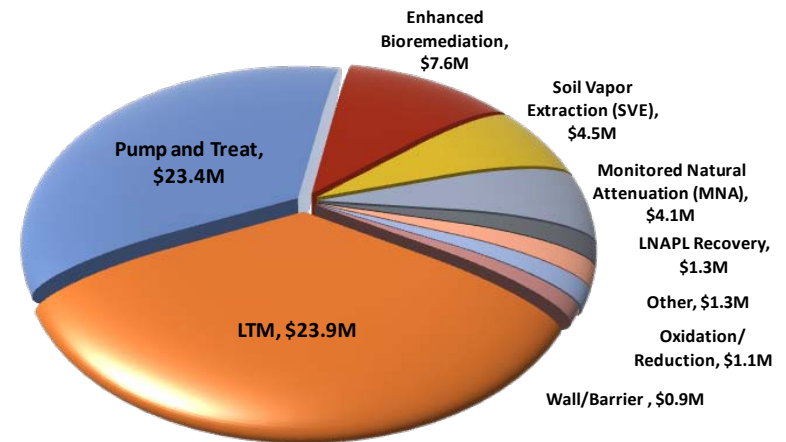


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Why Optimize?

Data Redundancy & Resource Considerations

FY08 System Inventory Cost by Technology



- Most data is below env stds
- Target is essential data
- "Smart monitoring" & sustainable
- Resource effective & green



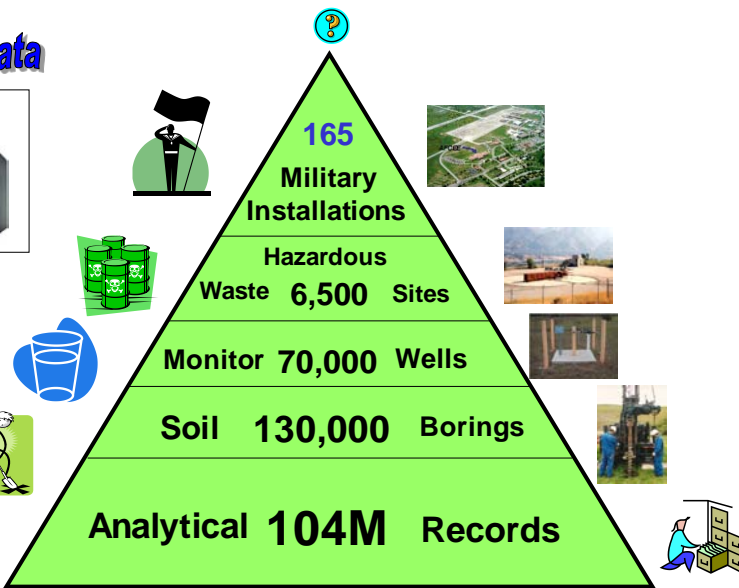
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What are We Monitoring?

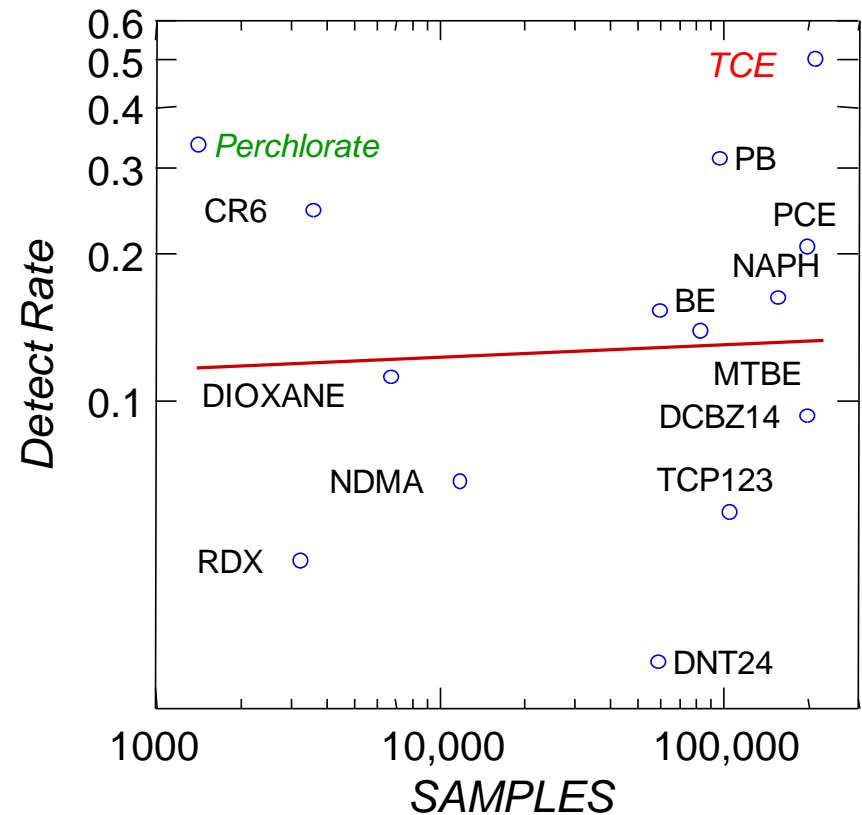
90% of Data are Below MCLs/PRGs

Air-Force Wide Data ERPIMS Database

ERPIMS Data



Less than 10% Exceeds Env Criteria





➤ Describe existing monitoring program

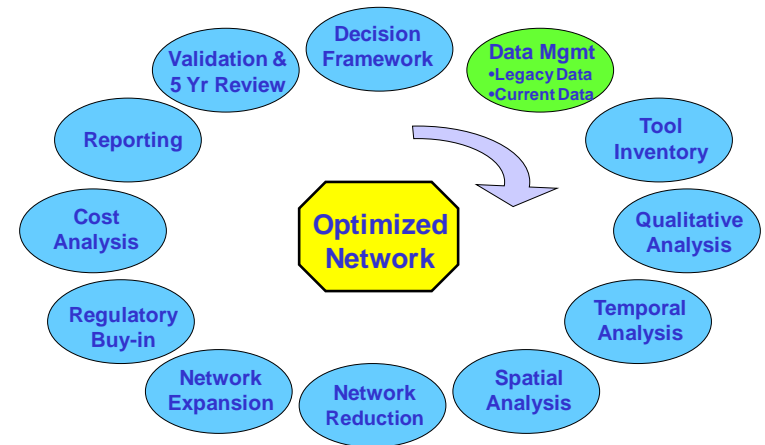
- Wells, coordinates, events, & analytes
- CSM and aquifer zones

➤ Tool selection & optimization scope

➤ Create & edit dataset

➤ Analysis

- Reduce redundancy
- Propose new monitoring plan
- Expand coverage with new wells
- Cost benefit analysis





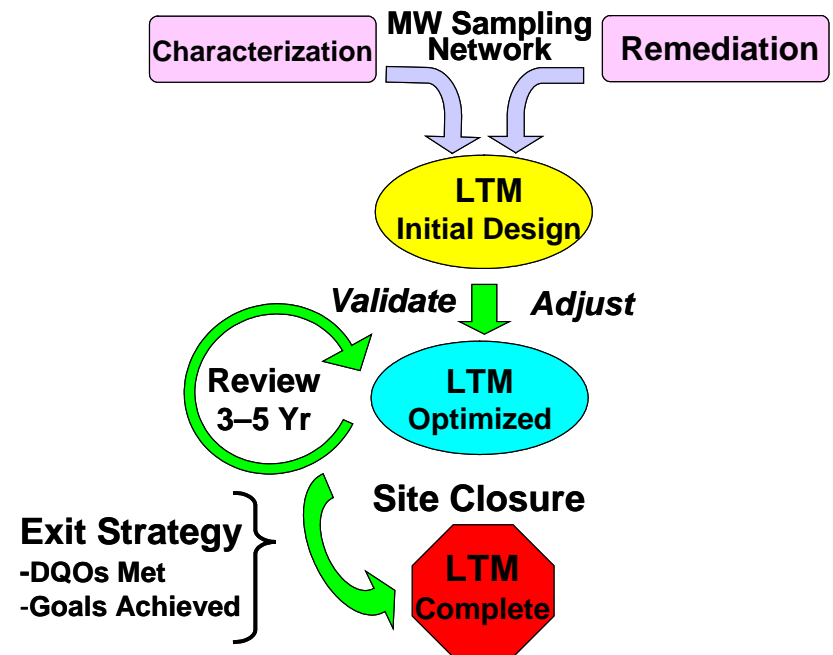
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Opportunity

What they do...

- Determines **essential** / redundant **wells** and placement of new wells
- Calculates optimal sampling frequency
- Typical LTM cost savings: **20-40% per site**, up to **\$1M** per installation; **savings are cumulative**
- Formal test for trend
- Essential to PBRs & 5 Yr Review
- Standard reports

-Costs to perform optimization is about **10%** of O&M budget
-Return on Investment = **1-2 yrs**



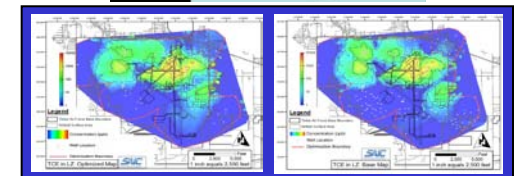
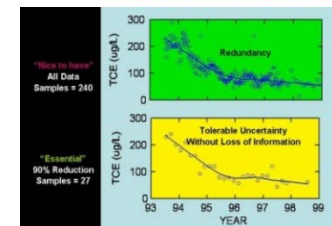


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Opportunity

What you get...

- Decision logic and formalized approach
- Optimal sampling plan proposal
- New well locations to expand coverage & reduce uncertainty
- Living dataset
 - GIS capability
 - Time series graphics
 - Ability to flag anomalous data
- Excellent tools for *risk communication*
- Free-public domain software

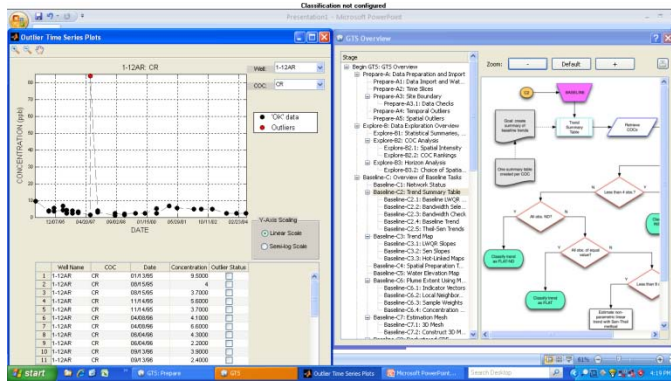




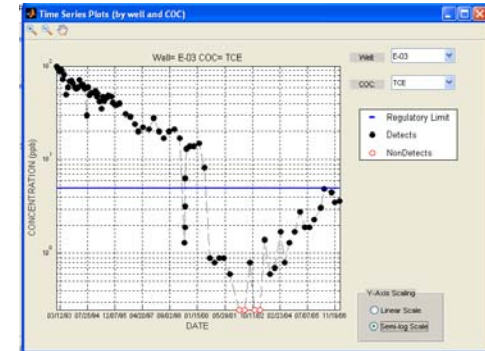
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Tool Features

Transparent Decision Logic



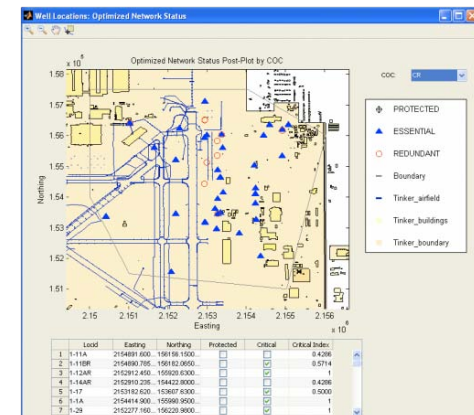
Time Series Plots



Formal Test for Trend

GTS Well ID	Loc ID	Trend Type	Par Label	Easting	Northing	Slope (ppb/day)	Slope Significant (p<0.1)	Lower 90% Confidence Bound (ppb)	Upper 90% Confidence Bound (ppb)	Regulatory Limit (ppb)	Trend Direction	Regulatory Exceedance
9	E-04	LWQR	CR	796273.1	404182.4	-0.0042	Yes	9.269	11.424	100	DECR	NO
10	E-04M	INSUFFIC	CR	796268.2	404169.5		No			100	FLAT	NA
29	EL-01	LWQR	CR	803442	400602	-0.00396	Yes	9.686	12.686	100	DECR	NO
30	EL-02	LWQR	CR	801093.2	403219	0.00599	Yes	14.849	24.023	100	INCR	NO
31	EL-03	LWQR	CR	799307.6	403114.9	-0.00746	Yes	2.471	4.491	100	DECR	NO
32	EL-04	LWQR	CR	796985.4	403395.4	-0.00249	Yes	10.791	12.525	100	DECR	NO
33	EPA-01	LWQR	CR	795412.1	403906.3	-0.00674	Yes	-2.435	11.378	100	DECR	NO
35	EPA-02A	LWQR	CR	796647.6	404489.8	-0.00448	Yes	11.002	14.105	100	DECR	NO
36	EPA-03	INSUFFIC	CR	798228.5	405950.5		No			100	FLAT	NA
37	EPA-04	LWQR	CR	794893.5	405309.3	0.003	Yes	6.164	14.187	100	INCR	NO

Essential Wells

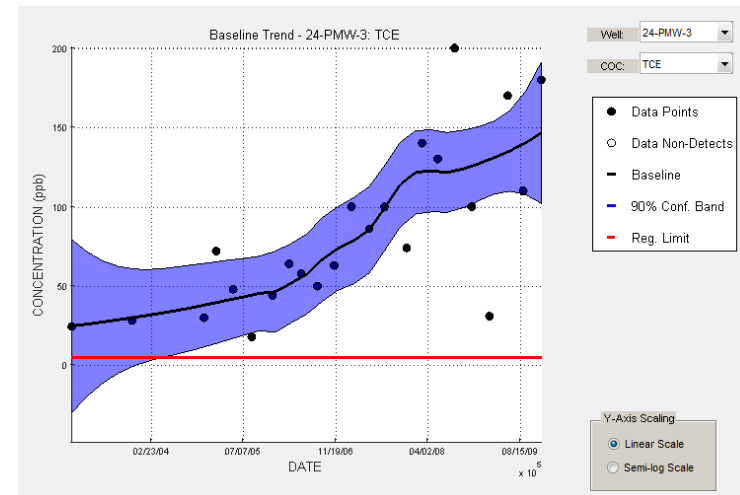
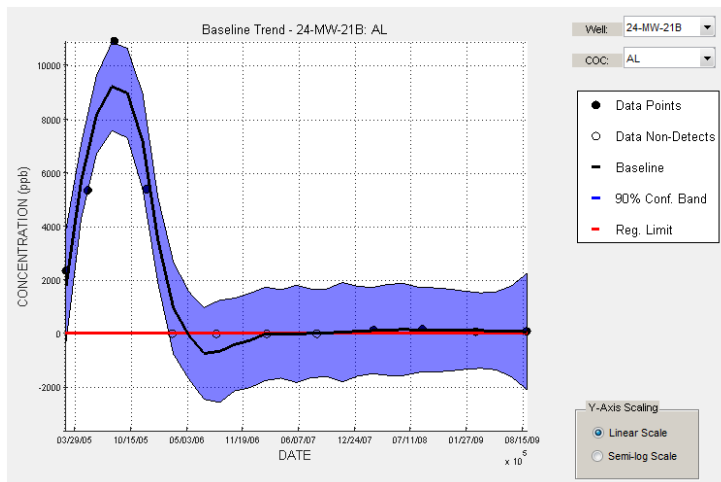
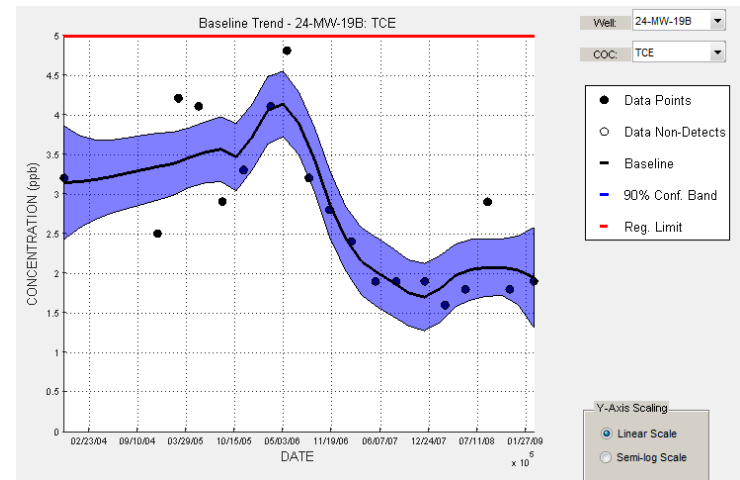
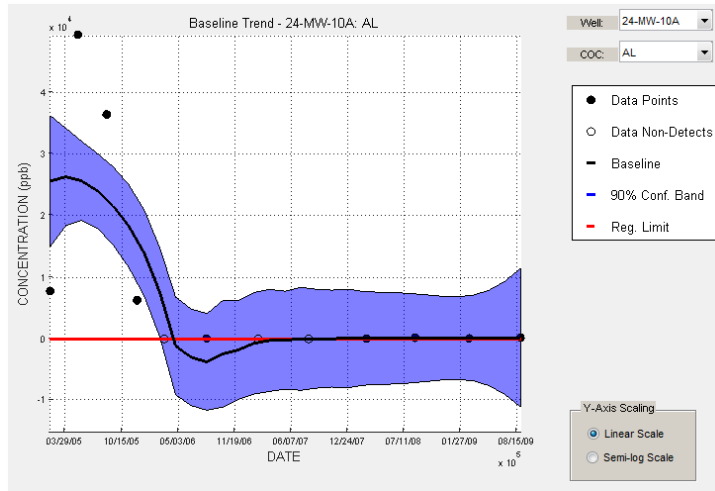




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Creating a Monitoring Knowledge Base

Centralized, Comprehensive, Dynamic





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LTMO Tool Inventory

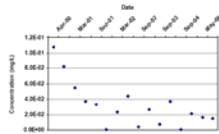
- Geostatistical Temporal-Spatial (GTS) optimization software
- Monitoring and Remediation Optimization System (MAROS) software
- **3TMO (3-Tiered Monitoring Optimization tool)**



MAROS Mann-Kendall Statistics Summary

Well: M1-C
Well Type: T
COC: 1,1-DICHLOROETHENE

Time Period: 4/1/2002 to 5/5/2010
Consultation Period: No Time Consultation
Correlation Type: Serial
Duplicate Correlation: Average
ND Status: 12 Detection Limit
J Flag Values: Actual Value

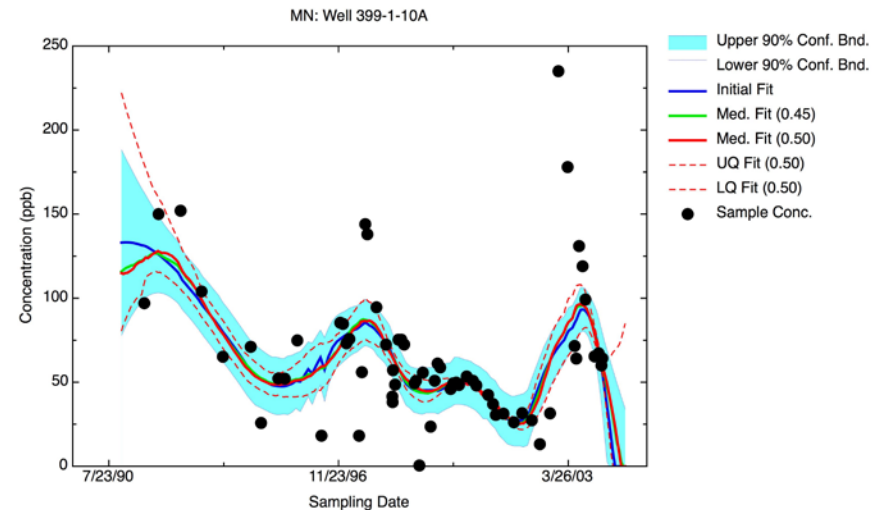


Mann-Kendall S Statistic:
Confidence In Trend:
Coefficient of Variation:
Mann-Kendall Concentration Trend (See Note):

Data Table:

Well	Well Type	Effective Date	Concentration	Result (mg/L)	Flag	Number of Samples	Number of Detects
M1-C	T	4/1/2002	1.10000	1.1000		2	2
M1-C	T	5/1/2002	1.10000	2.2000		2	2
M1-C	T	7/1/2002	1.10000	0.5000		1	1
M1-C	T	9/1/2002	1.10000	0.5000		1	1
M1-C	T	11/1/2002	1.10000	0.5000	ND	2	0
M1-C	T	1/1/2003	1.10000	0.5000		2	2
M1-C	T	3/1/2003	1.10000	4.0000		2	2
M1-C	T	5/1/2003	1.10000	4.0000		2	2
M1-C	T	7/1/2003	1.10000	7.0000		2	2
M1-C	T	9/1/2003	1.10000	2.0000		2	2
M1-C	T	11/1/2003	1.10000	2.0000		2	2
M1-C	T	1/1/2004	1.10000	2.0000		2	2
M1-C	T	3/1/2004	1.10000	1.0000		2	2
M1-C	T	5/1/2004	1.10000	1.0000		2	2
M1-C	T	7/1/2004	1.10000	1.0000		2	2
M1-C	T	9/1/2004	1.10000	1.0000		2	2
M1-C	T	11/1/2004	1.10000	1.0000		2	2
M1-C	T	1/1/2005	1.10000	1.0000		2	2
M1-C	T	3/1/2005	1.10000	1.0000		2	2
M1-C	T	5/1/2005	1.10000	1.0000		2	2
M1-C	T	7/1/2005	1.10000	1.0000		2	2
M1-C	T	9/1/2005	1.10000	1.0000		2	2
M1-C	T	11/1/2005	1.10000	1.0000		2	2
M1-C	T	1/1/2006	1.10000	1.0000		2	2
M1-C	T	3/1/2006	1.10000	1.0000		2	2
M1-C	T	5/1/2006	1.10000	1.0000		2	2
M1-C	T	7/1/2006	1.10000	1.0000		2	2
M1-C	T	9/1/2006	1.10000	1.0000		2	2
M1-C	T	11/1/2006	1.10000	1.0000		2	2
M1-C	T	1/1/2007	1.10000	1.0000		2	2
M1-C	T	3/1/2007	1.10000	1.0000		2	2
M1-C	T	5/1/2007	1.10000	1.0000		2	2
M1-C	T	7/1/2007	1.10000	1.0000		2	2
M1-C	T	9/1/2007	1.10000	1.0000		2	2
M1-C	T	11/1/2007	1.10000	1.0000		2	2
M1-C	T	1/1/2008	1.10000	1.0000		2	2
M1-C	T	3/1/2008	1.10000	1.0000		2	2
M1-C	T	5/1/2008	1.10000	1.0000		2	2
M1-C	T	7/1/2008	1.10000	1.0000		2	2
M1-C	T	9/1/2008	1.10000	1.0000		2	2
M1-C	T	11/1/2008	1.10000	1.0000		2	2
M1-C	T	1/1/2009	1.10000	1.0000		2	2
M1-C	T	3/1/2009	1.10000	1.0000		2	2
M1-C	T	5/1/2009	1.10000	1.0000		2	2
M1-C	T	7/1/2009	1.10000	1.0000		2	2
M1-C	T	9/1/2009	1.10000	1.0000		2	2
M1-C	T	11/1/2009	1.10000	1.0000		2	2
M1-C	T	1/1/2010	1.10000	1.0000		2	2
M1-C	T	3/1/2010	1.10000	1.0000		2	2
M1-C	T	5/1/2010	1.10000	1.0000		2	2

Note: Increasing (I) Probably Increasing (PI) Stable (S) Probably Decreasing (PD) Decreasing (D) No Trend (NT) Not Applicable (NA) - Due to insufficient Data or 4 sampling events; ND = Non-detect





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LTMO Tools

How They Compare...

**Quantitative/Statistical
Calculative**

**Balanced
Approach**

**Qualitative/Judgmental
Heuristics**

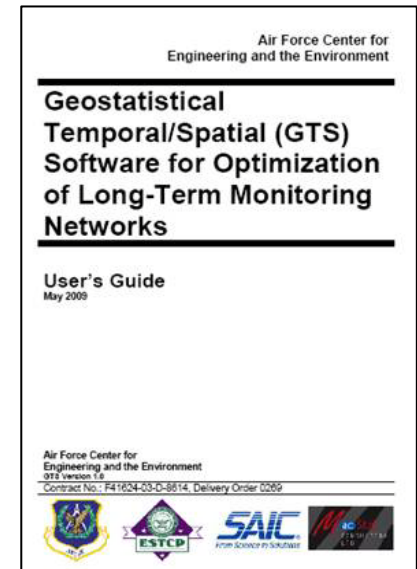
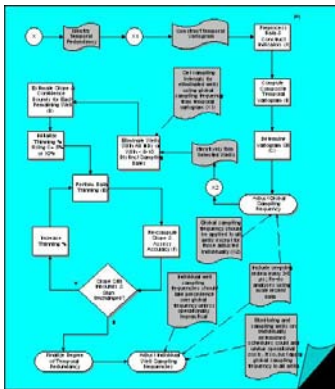




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GTS Features

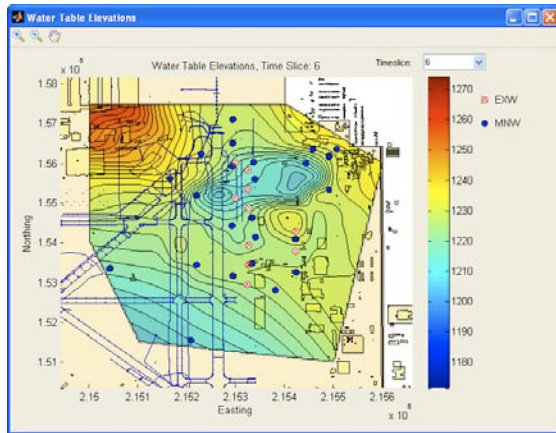
➤ Algorithm-based



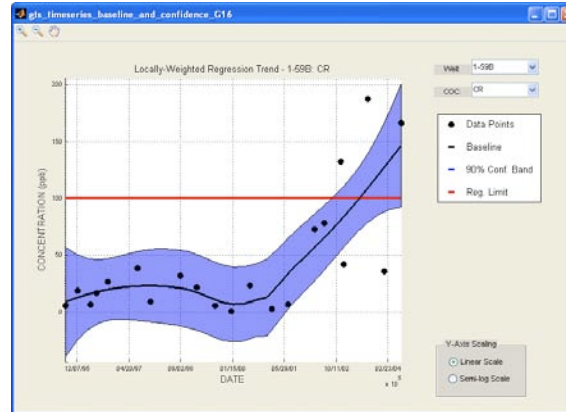
➤ Unique Features

- Highly quantitative; focus on geostats
- Balance between full-scale expert system & heuristic model
- Designed for midlevel & expert analysts; numerous defaults
- Geospatial analysis uses quasi-genetic algorithm
- Installation-wide or individual site analysis

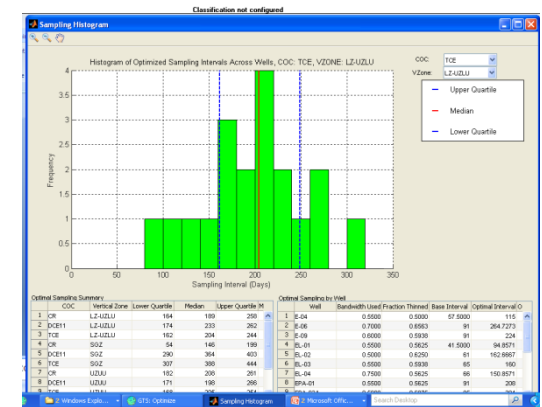
Water Table Maps



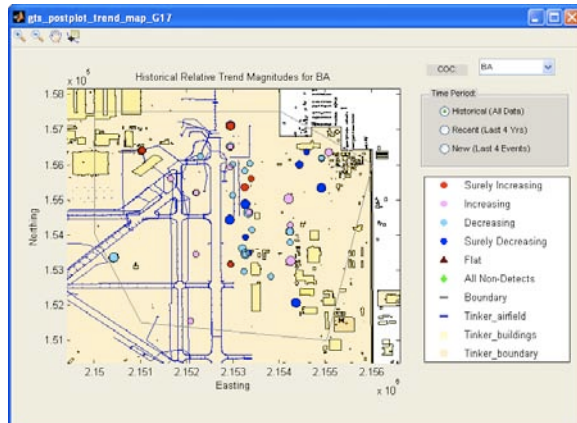
Non-Linear Trend Analysis



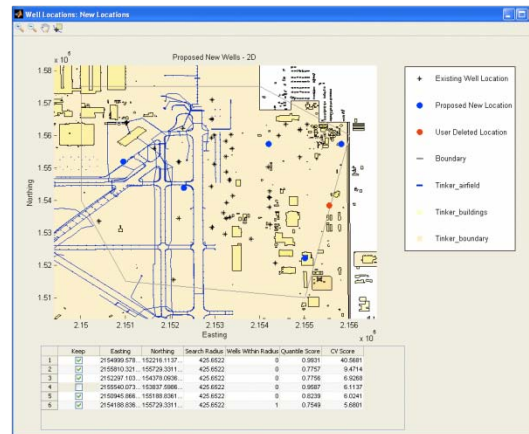
Optimal Sampling Histogram



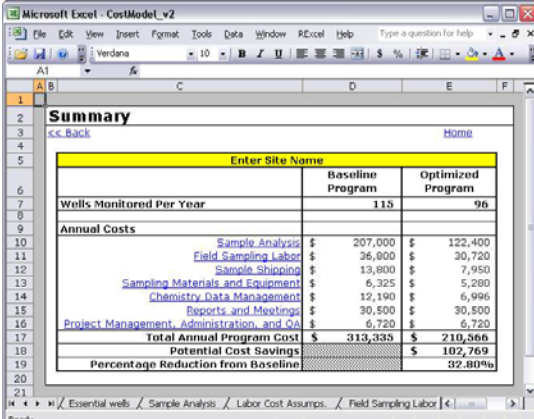
“Bubble” Trend Maps



Proposed New Wells



Cost Benefit Analysis



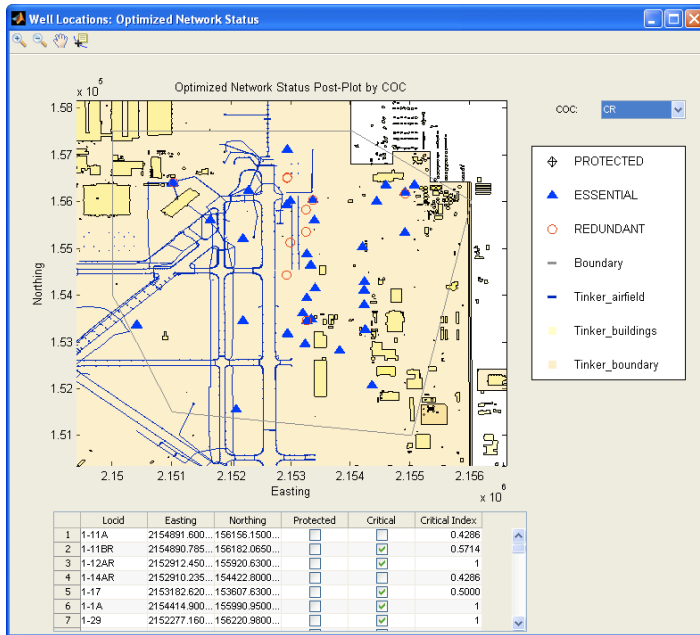
Enter Site Name		Baseline Program	Optimized Program
Wells Monitored Per Year		115	96
Annual Costs			
Sample Analysis	\$	207,000	122,400
Field Sampling Labor	\$	36,600	30,720
Sample Shipping	\$	13,900	7,950
Sampling Materials and Equipment	\$	6,325	5,280
Chemistry Data Management	\$	12,190	6,996
Reports and Meetings	\$	30,500	30,500
Project Management, Administration, and QA	\$	6,720	6,720
Total Annual Program Cost	\$	313,335	210,566
Potential Cost Savings	\$	102,769	
Percentage Reduction from Baseline			32.80%



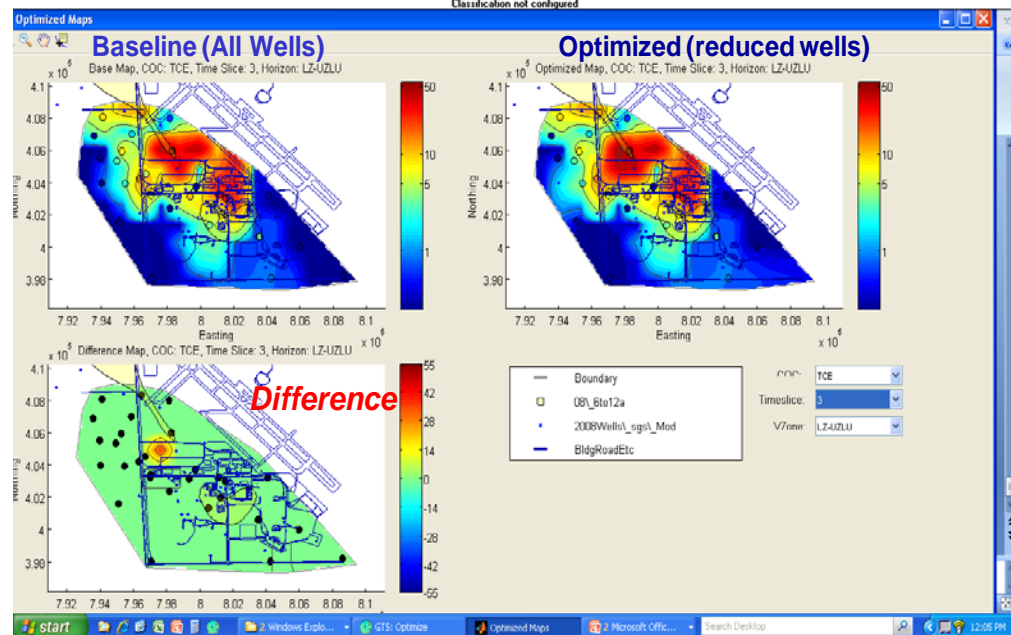
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GTS Features

Essential & Redundant Well Map



Plume Comparisons Baseline vs Optimized

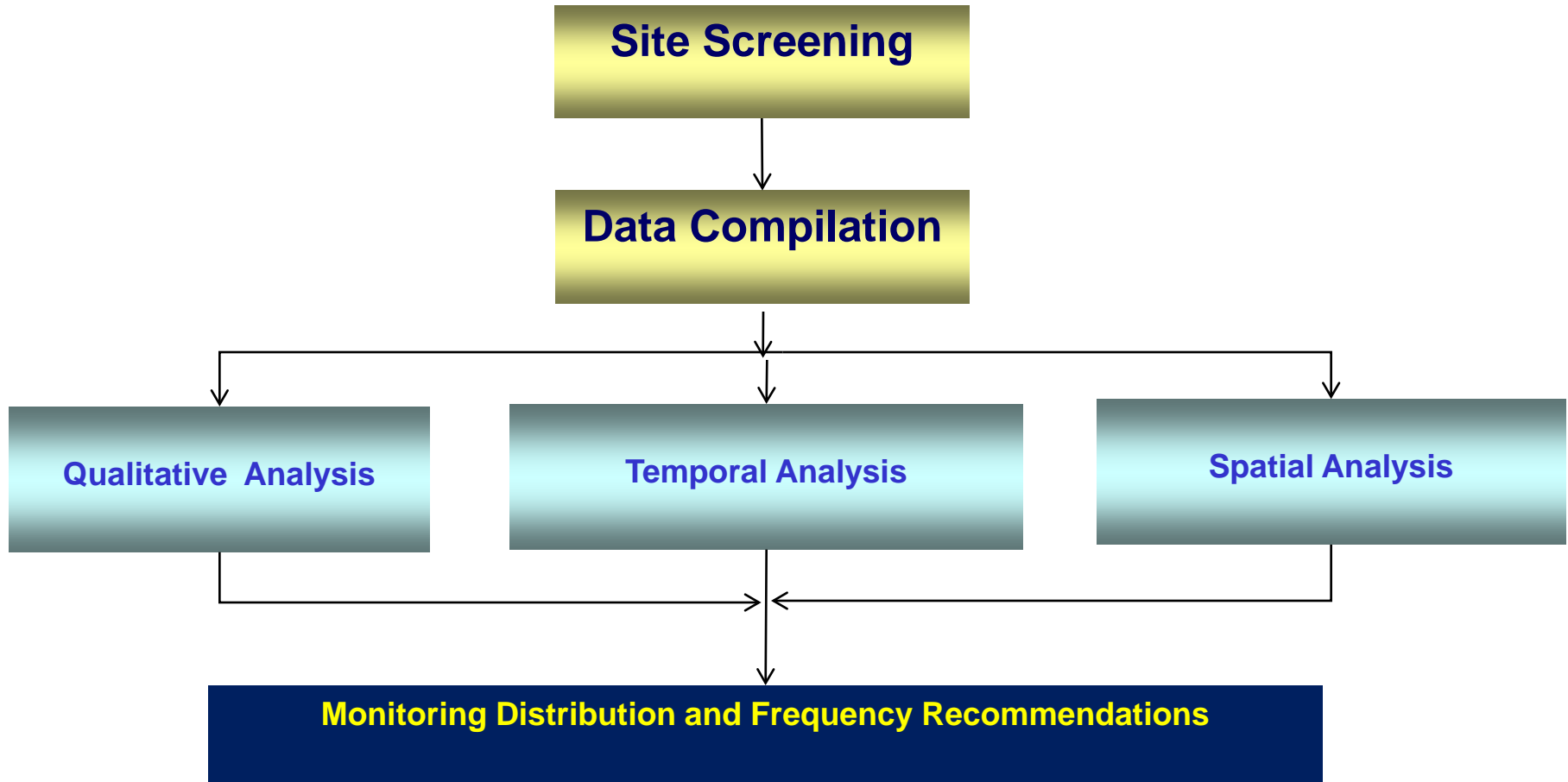




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3TMO

3-Tiered Approach





Long Term Monitoring Optimization Tool (LTMO) Project: C:\LTMO\Sprint3Demo\Sprint3Demo.Itmo

Project LTMO Framework Tools Reports Help v1.0.0.71

LTMO Framework > Well Retention > Qualitative Evaluation

A1 Current Question
Is the well needed to monitor water quality at a compliance point (e.g., Base or site boundary) or receptor exposure point (e.g., sentinel well for municipal wells)?

Well Selector
Display: All Yes No Unassigned
Grouping: None Zone User Function

- Well1
- Well2
- Well3
- Well4
- Well5
- Well6
- Well7
- Well8
- Well9
- Well10
- Well11
- Well12
- Well13
- Well14

Your Answer:

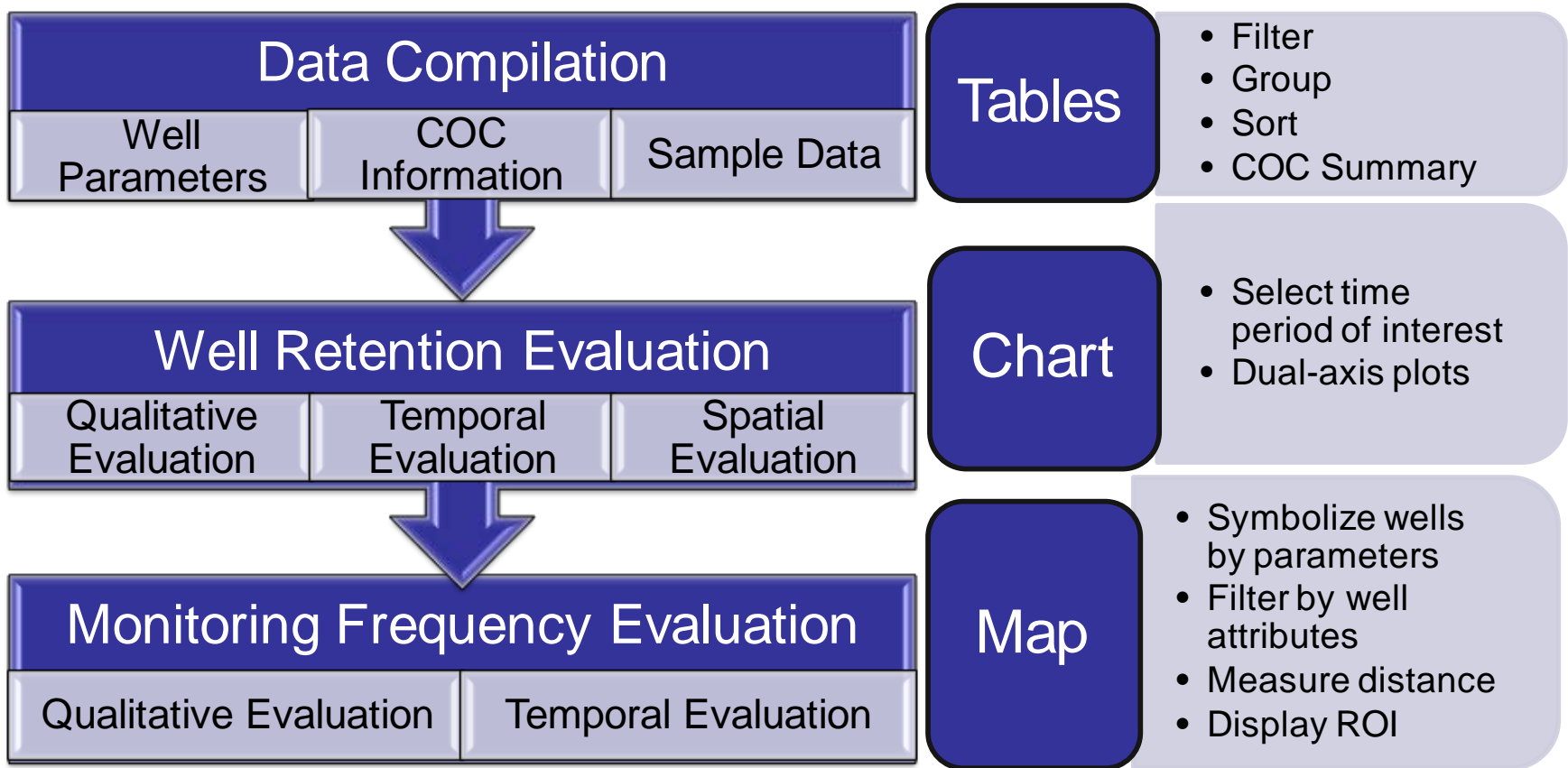
Following Questions

A6
Is the well a potential conduit for vertical contaminant migration to another hydrostratigraphic zone or for surface water intrusion?

A2
Is the well needed for defining background or upgradient groundwater quality and/or biogeochemistry?

Show Supplemental Information

```
graph TD
    A1["A1: Y: 11, N: 2, U: 1"] -- Y --> A6["A6: Y: 11, N: 0, U: 0"]
    A1 -- N --> A2["A2: Y: 0, N: 2, U: 0"]
    A2 -- Y --> A3["A3: Y: 0, N: 2, U: 0"]
    A2 -- N --> A7["A7: Y: 0, N: 2, U: 0"]
    A3 -- Y --> A4["A4: Y: 0, N: 2, U: 0"]
    A3 -- N --> A5["A5: Y: 0, N: 2, U: 0"]
    A4 -- Y --> A5
    A4 -- N --> AR1["AR1: T: 2"]
    A5 -- Y --> A9["A9: Y: 0, N: 2, U: 0"]
    A5 -- N --> AR2["AR2: T: 2"]
    A6 -- Y --> A7
    A6 -- N --> A8["A8: Y: 0, N: 2, U: 0"]
    A7 -- Y --> AR3["AR3: T: 11"]
    A7 -- N --> A8
    A8 -- Y --> AR3
    A8 -- N --> A9
    A9 -- Y --> A10["A10: Y: 0, N: 2, U: 0"]
    A9 -- N --> AR2
    A10 -- Y --> A11["A11: Y: 0, N: 2, U: 0"]
    A10 -- N --> AR3
    A11 -- Y --> AR3
    A11 -- N --> AR2
```



Well Analysis

Qualitative Evaluation

- Decision Diagram (yes/no questions)

Temporal Evaluation

- Mann-Kendall Trend Calculations
- Chart Tool

Spatial Proximity Evaluation

- Map Tool

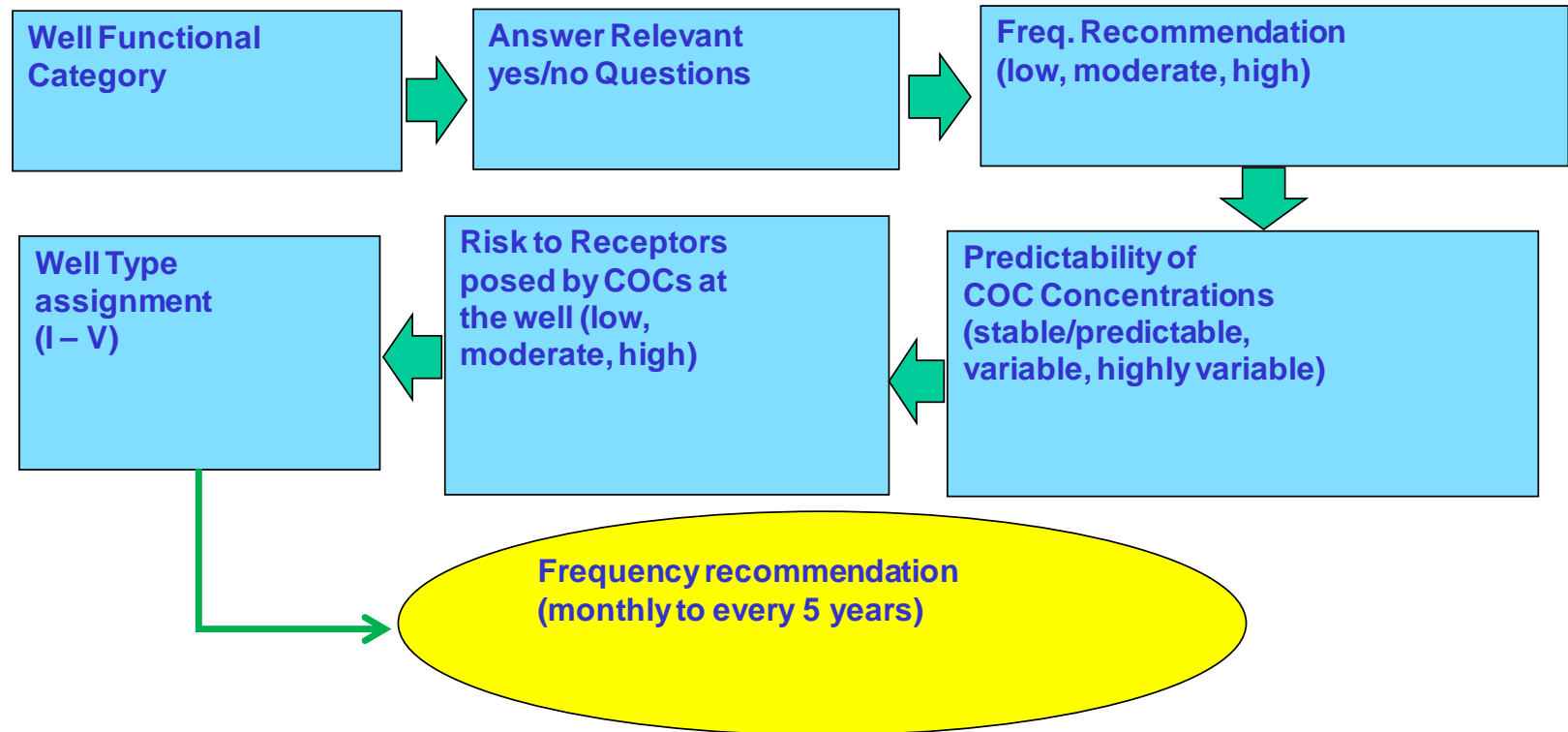
Combined Evaluation Summary

- 3 sets of results
- Determine final retain/exclude recommendations
- Enter rationale (optional)

Well Type & Frequency

		Risk to Receptors		
		Low	Moderate	High
Predictability of COC Concentrations	Predictable	Type I	Type II	Type III
	Variable	Type II	Type III	Type IV
	Highly Variable	Type III	Type IV	Type V

	Type I	Type II	Type III	Type IV	Type V
High Frequency	Biennial	Annual	Semi-annual	Quarterly	Monthly
Moderate Frequency	Every 3 Years	Biennial	Annual	Semi-annual	Quarterly
Low Frequency	Every 5 Years	Every 3 Years	Biennial	Annual	Semi-annual

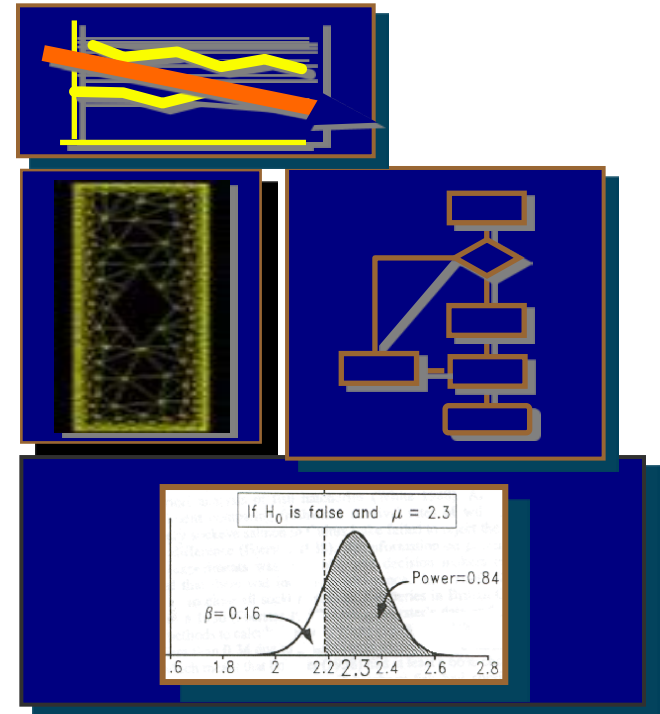




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MAROS Fundamentals

- Built on MS Access Platform – full database analyses
- Modular
- Simple statistical and heuristic tools;
 - Trend Analysis
 - Summary Statistics
 - Plume Stability Analysis
 - Sampling Frequency
 - Well Redundancy/Sufficiency
 - Data sufficiency/attainment





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MAROS

Temporal Analysis

Qualitative 'Lines of Evidence'

➤ Individual Well and Plume-Wide

■ Individual Well Analyses

- ❖ Rate of change – well concentration, linear regression slope (+ or -)
- ❖ Trend of concentration change
- ❖ Decision logic – sample size, [C] vs. MCLs

■ Plume-Wide – all wells

- ❖ Rate of change – total mass (zeroth moment), linear regression slope (+ or -) and R^2
- ❖ Coefficient of variation
- ❖ Decision logic – GW flow velocity





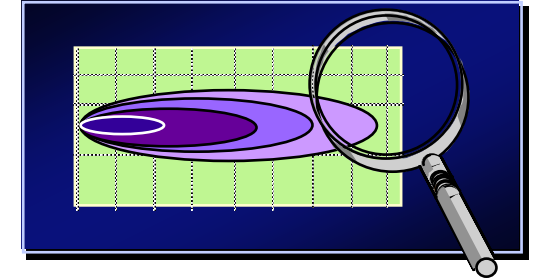
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MAROS

Spatial Optimization

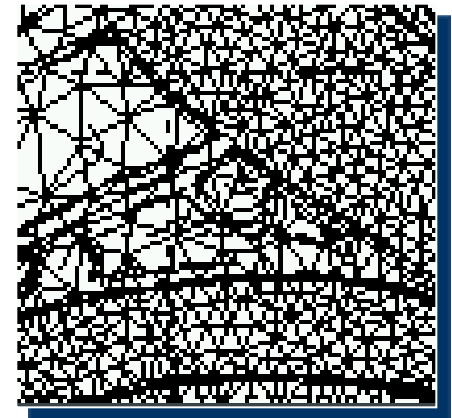
Redundancy

- **Delaunay Triangulation**
 - **Automated optimization**
 - **Manual removal of low-rank wells**
 - ❖ *Plume mass* impact
 - ❖ *Plume area* impact
 - ❖ Compare to 'reasonable' error limits



Sufficiency

- **Identify areas of high uncertainty**
- **Identify monitoring objectives**





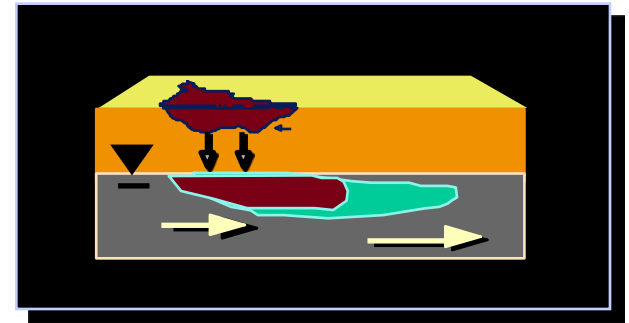
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MAROS

Plume Analysis

➤ Moment analysis

- Well choice (wells sampled routinely over time)
- Sample Event choice
- Estimates and trends
 - ❖ Total dissolved
 - ❖ Center of mass
 - ❖ Spread over time
- Which wells contribute most to mass estimate → contributes to well ranking
- Plume stability by monitoring objective





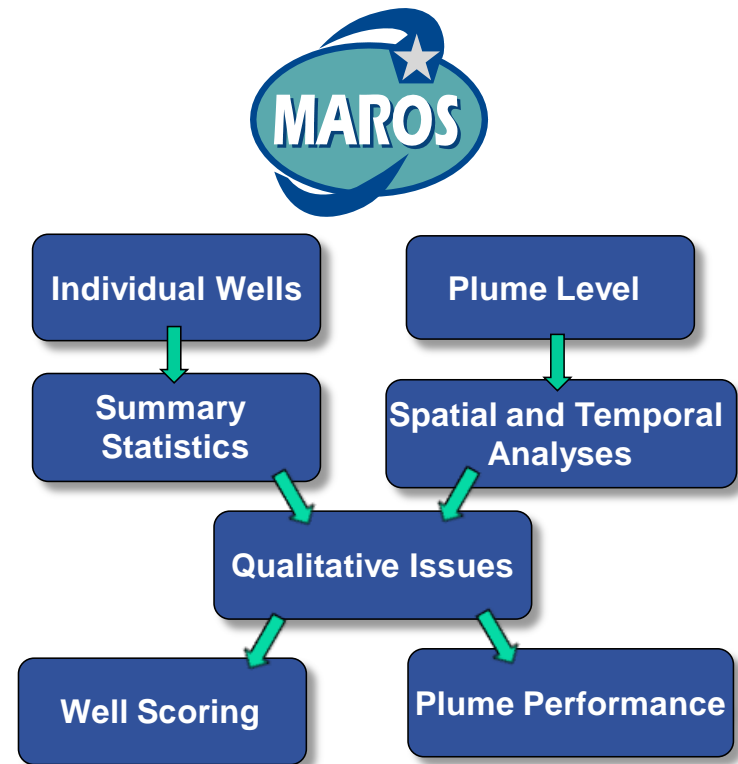
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MAROS

Upgrade Version 3.0

➤ MAROS Updates

- Data Input
- Summary Statistics
- Monitoring Objectives
- Qualitative issues
- Moment Analyses
- Redundancy/Sufficiency
- Sampling frequency
- More User Options
- Compatibility





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Status of Tools

Availability

➤ ***GTS***

- Publically available as Vers 1.0
- AF approved software 2011 Summer

➤ ***MAROS***

- Upgrade in process; new version out 2011 Sept
- New features & compatibility with MS Office 2007

➤ ***3TMO***

- New software development
- Publically available 2011 Summer



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Tool Resources

More Information

➤ **GTS**

- <http://www.afcee.af.mil/resources/restoration/ltm/index.asp>
- Philip.hunter@us.af.mil; kmacstat@qwest.net
- <http://www.estcp.org/Technology/ER-0714-FS.cfm>

➤ **MAROS** - <http://www.gsi-net.com/software/free-software/maros.html>

➤ **3TMO**- John.Hicks@parsons.com



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Summary

- **LTM is a major life-cycle enterprise for the corporate AF and DoD**
- **Tools are robust and offer a wide range of capabilities for a diverse technical audience**
- **Tool output is important for risk communication and negotiation**
- **Tools are an essential component of PBRs, 5 Year Reviews, remedy effectiveness, and ultimately site closure**
- **Tools offer a green and sustainable approach to “smart” monitoring**



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Thanks



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