Federal Remediation Technologies Roundtable

OPTIMIZATION

Accelerating Site Closeout, Improving Performance, and Reducing Costs

Concepts and Practice in Optimization of Long-Term Monitoring Programs

presented by

John W. Anthony

MTS™ Mitretek Systems

Innovative Technology in the Public Interest™

ESTCP

SERDP DoD EPA DOE Strategic Environmental Research and Development Program

INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

Current Guidance for Monitoring Programs

OSWER Directive No. 9355.4-28

GUIDANCE FOR MONITORING AT HAZARDOUS WASTE SITES

FRAMEWORK FOR MONITORING PLAN DEVELOPMENT AND IMPLEMENTATION

U.S. Environmental Protection Agency
Office of Superfund Remediation and Technology Innovation

January 2004

What is Monitoring?

"… the collection and analysis of repeated observations or measurements to evaluate changes in conditions and progress toward meeting a management objective."

"[Environmental] monitoring is the collection and analysis of data (chemical, physical, and/or biological) over a sufficient period of time and frequency to determine the status and/or trend in one or more environmental parameters or characteristics."

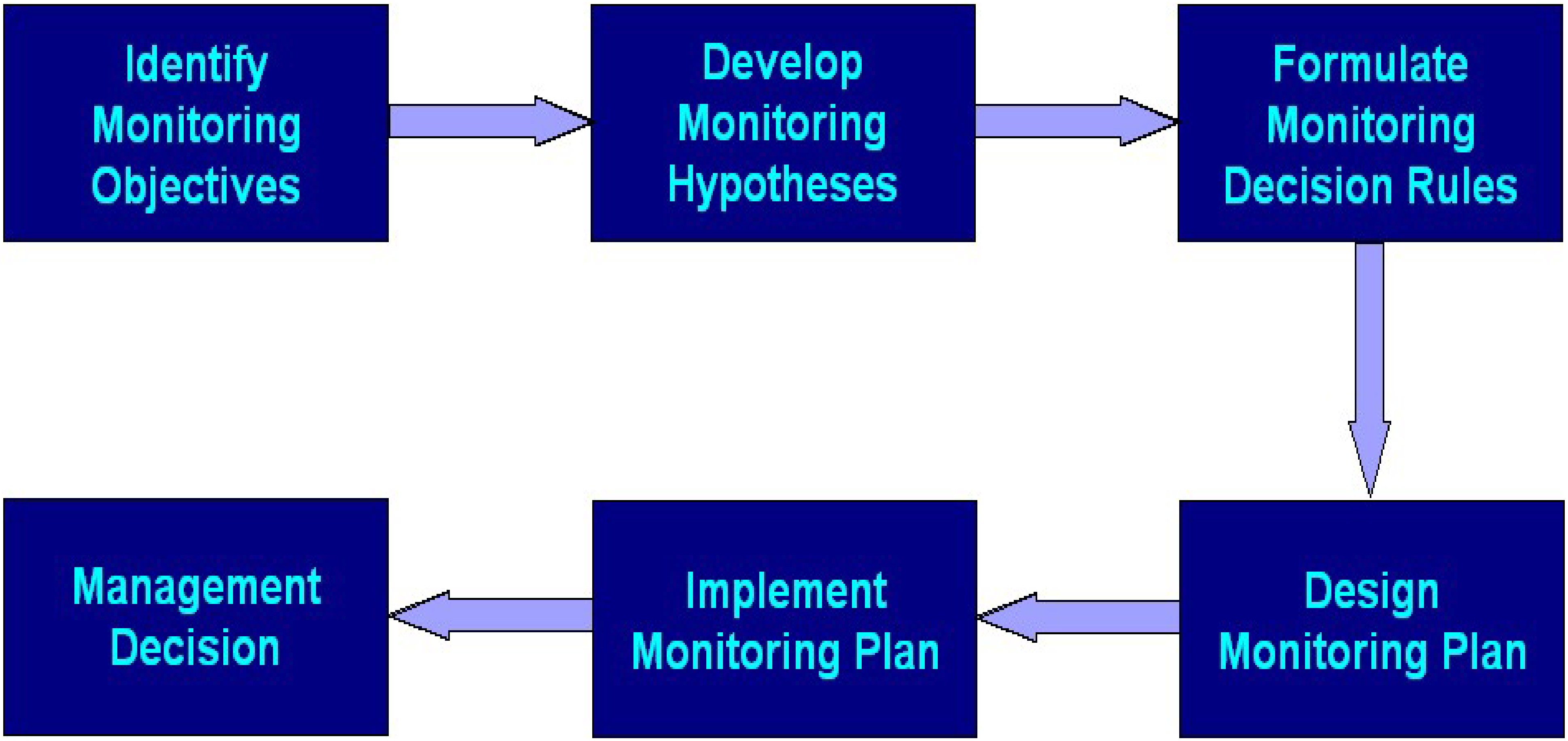
Why Monitor?

- **RCRA and CERCLA Statutory Requirements**
  - **Identify potential threats to human health and the environment**
  - **Evaluate remedy performance**

Types of Monitoring Programs

- **Characterization Monitoring**
  - **Site characterization**
- **Detection Monitoring**
  - **Detect releases from RCRA facilities**
- **Compliance Monitoring**
  - **Assess movement of contaminants to designated compliance points**
- **Long-term Monitoring**
  - **Evaluate remedy performance after a response action has been put in place**

Development and Application of Monitoring Program



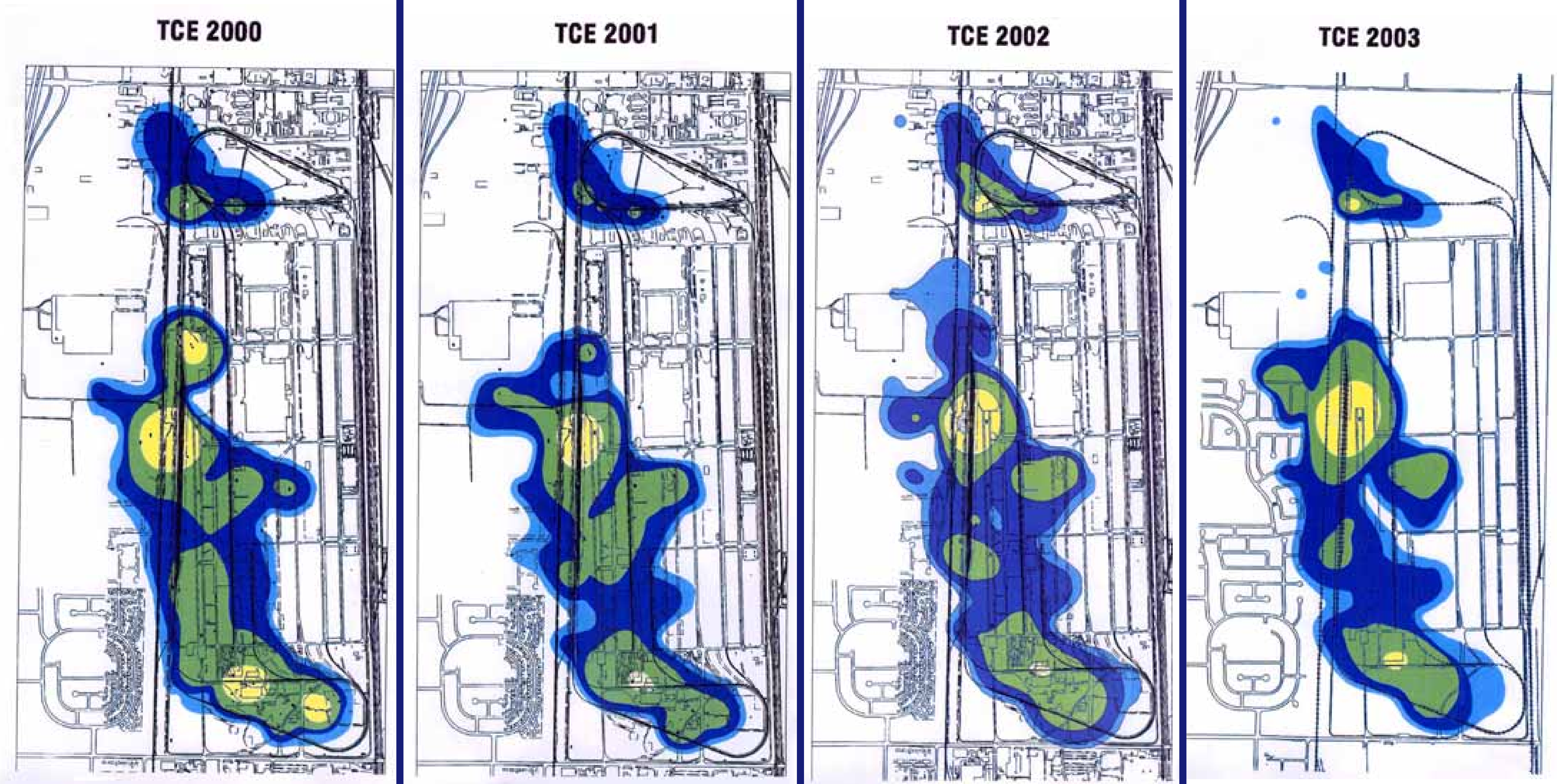
Components of Monitoring Program

- **Program Objectives**
- **Monitoring Program Hypotheses (Conceptual Site Model)**
- **Decision Rules**
- **Monitoring Plan**
  - **Sampling Locations (Network)**
  - **Sampling Schedule (Frequency)**
  - **Data Collection and Analysis Methods**
  - **Data Quality Objectives and QA/QC**
  - **Reporting**
- **Management Decision**

Characteristics of Long-Term Monitoring Data

- **Constituent Concentrations Detected in Samples Collected at One or More Locations at Several Different Periods of Time**
- **Variable in Space and Through Time**

Concentration Data – Spatial and Temporal Variability



Variability – Implications for Monitoring

Because Environmental Data are Variable in Space and Through Time, an Effective Monitoring Program Must Recognize the Dynamic Nature of System and Account for Natural and Anthropogenic Variability

Effective Groundwater Monitoring Program

- **Program is "Effective" if it Achieves the Stated Objectives**
- **"Optimal" Site-Specific Monitoring Strategy Will Maximize the Amount of Relevant Information Obtained While Minimizing Incremental Costs**
  - **"Relevant" information effectively addresses the temporal and spatial objectives of monitoring**

Important Question

- **What are the Objectives of Monitoring?**
  - **Evaluate temporal trends in contaminant concentrations within or outside of remediation zone as a means of monitoring the progress of remediation (Temporal Objective)**
  - **Evaluate the extent to which continued contaminant migration is occurring, particularly if a potential exposure point for a susceptible receptor exists (Spatial Objective)**

ESTCP

SERDP Strategic Environmental Research and Development Program

ITRC Interstate Technology Regulatory Council

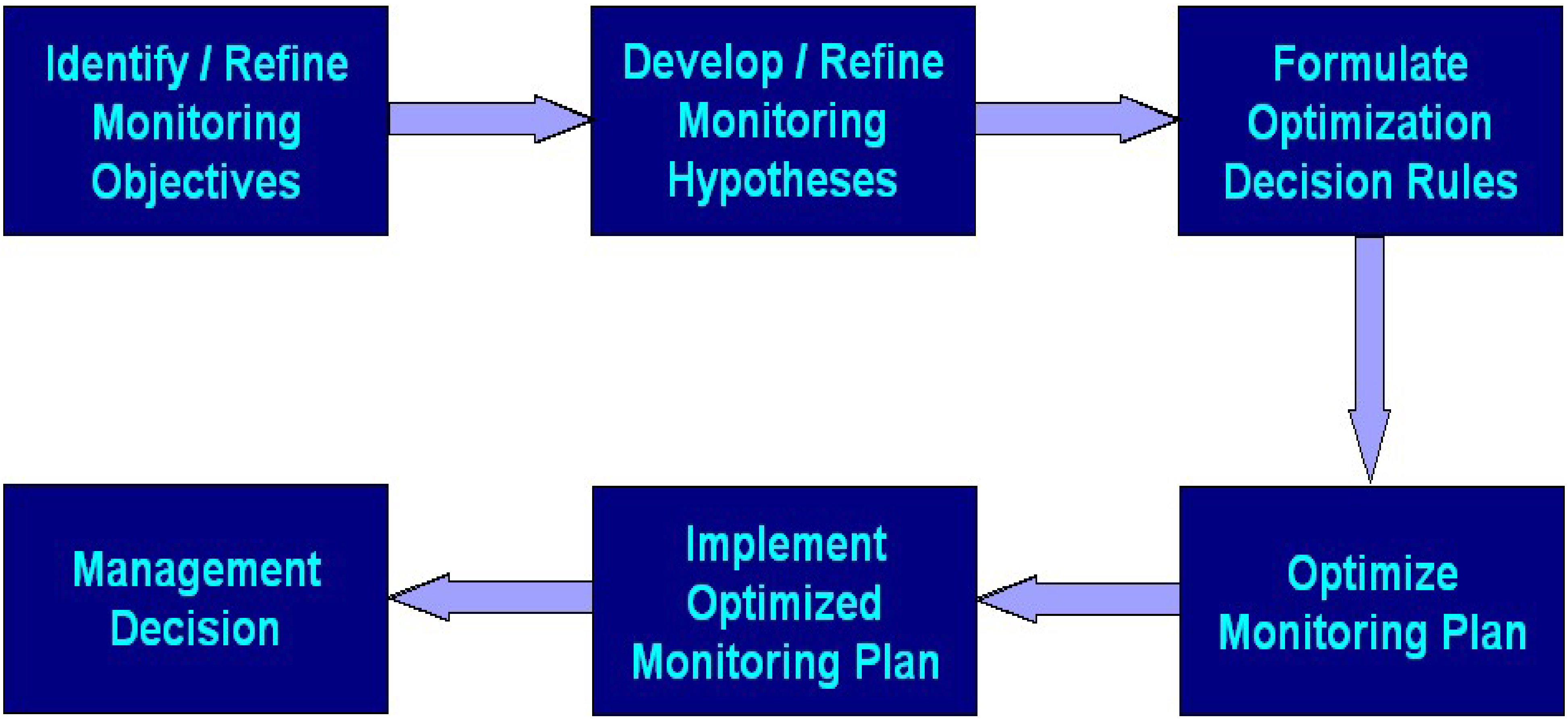
What is Optimization?

"… the procedure or procedures used to make a system or design as effective or functional as possible."

Why Optimize?

- NRC (1999) Estimates that Groundwater Has Been Contaminated at 300,000 to 400,000 Sites in the US
- Projected Total Costs for Remediating Groundwater -- $500B to $1T
- Costs of Monitoring May Reach ~40% of Total Costs of Groundwater Remedy; Annual Costs at Individual Sites May Be $1,000s to More than $1M

Optimization and Application of Refined Monitoring Program



Monitoring Program Optimization

Process:

- **Monitoring Program Optimization**
  - **Qualitative Review**
  - **Temporal Statistical Analysis**
  - **Spatial Statistical Analysis**

Qualitative Review

- **Hydrogeology**
- **Contaminants of Concern (COCs)**
- **Contaminant Distribution**
- **Remedial System Operation**
- **Regulatory Compliance**
- **Proximity to Other Wells**
- **Sampling Frequency**

Qualitative Review (Temporal Questions)

- **Comparison of Groundwater Flow Velocity With Sampling Frequency?**
- **Do Contaminant Concentrations Display Significant Temporal Changes?**
- **Would a Rapid Change in Contaminant Concentrations Alter a Course of Action?**
- **Is Well Important for Monitoring Remedial System Operation?**

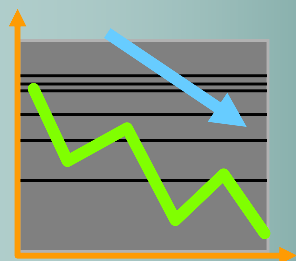
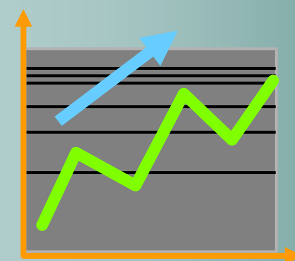
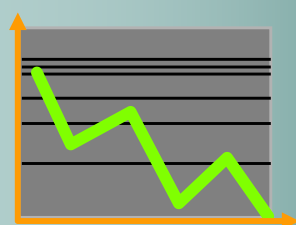
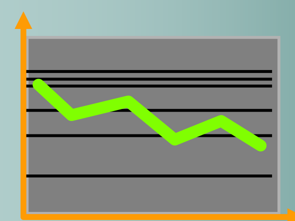
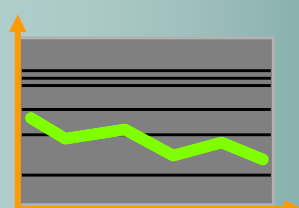
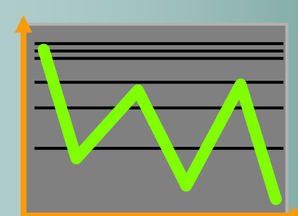
Qualitative Review (Spatial Questions)

- Is Well Needed to Monitor "Background" Conditions?
- Is Well Important for Defining Contaminant Extent (Lateral or Vertical)?
- Is Well Important for Monitoring Remedial System Operation?
- Does Well Monitor Potential Exposure Point or Point of Compliance?
- Is Spatial Proximity to Other Wells such that Well is Redundant?
- Is Well Often Dry?
- Are Concentrations Consistently Below Targets?

Temporal Statistical Analysis

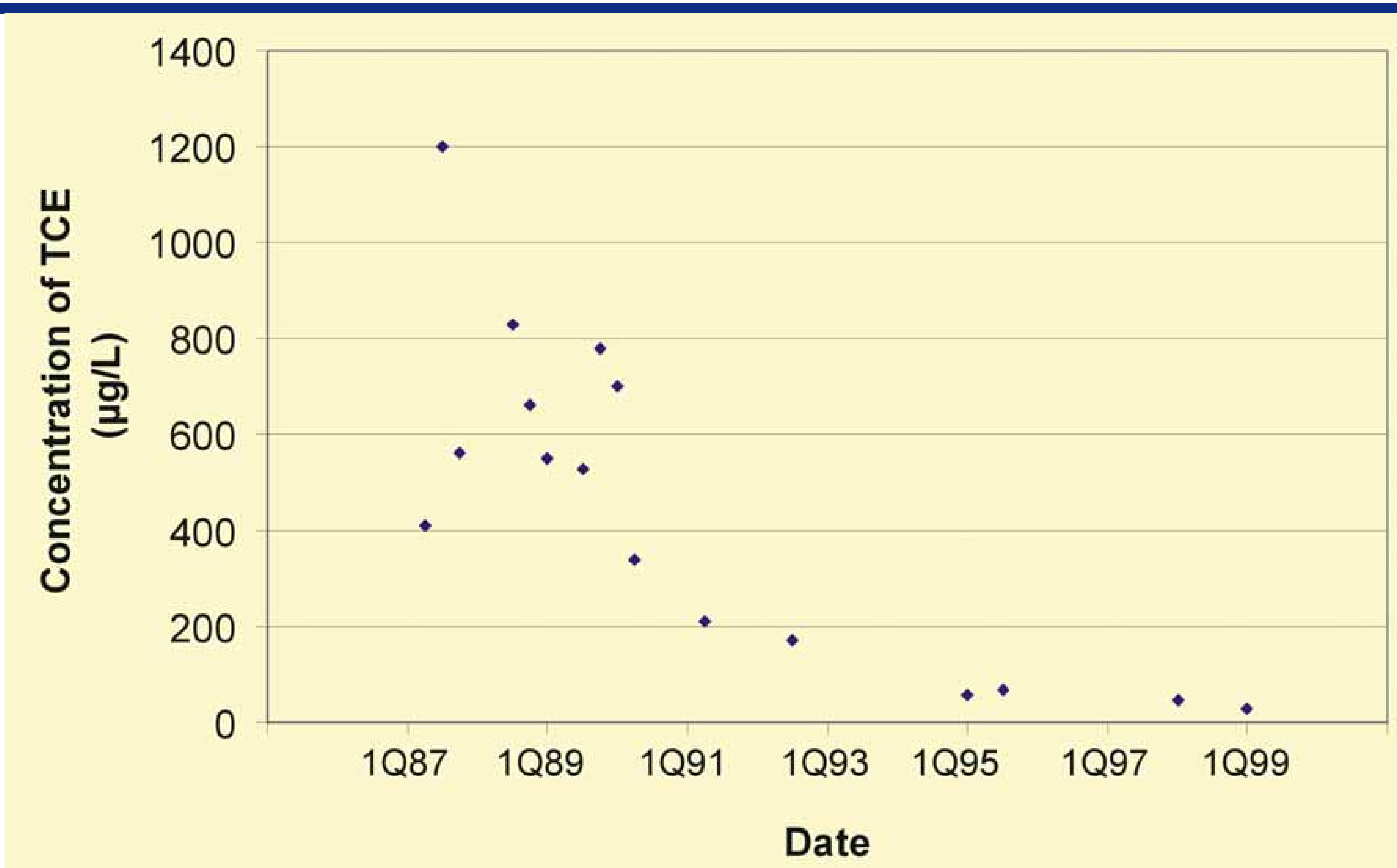
- **Mann-Kendall Test**
  - **Evaluate contaminant concentration trends**
  - **Iterative process -- well by well, constituent by constituent evaluation**

Interpretation of Mann-Kendall Test

MK Statistic (S)	 **MK < 1** **Decreasing Trend**	 **MK > 1** **Increasing Trend**
Confidence Factor (CF)	 **CF > 90%** **Strong Trend**	 **CF < 90%** **Weak Trend**
Coefficient of Variation (COV)	 **COV < 1** **Stable Trend**	 **COV > 1** **Fluctuating Trend**

Source: GSI, 1998

Temporal Trend in TCE Concentrations

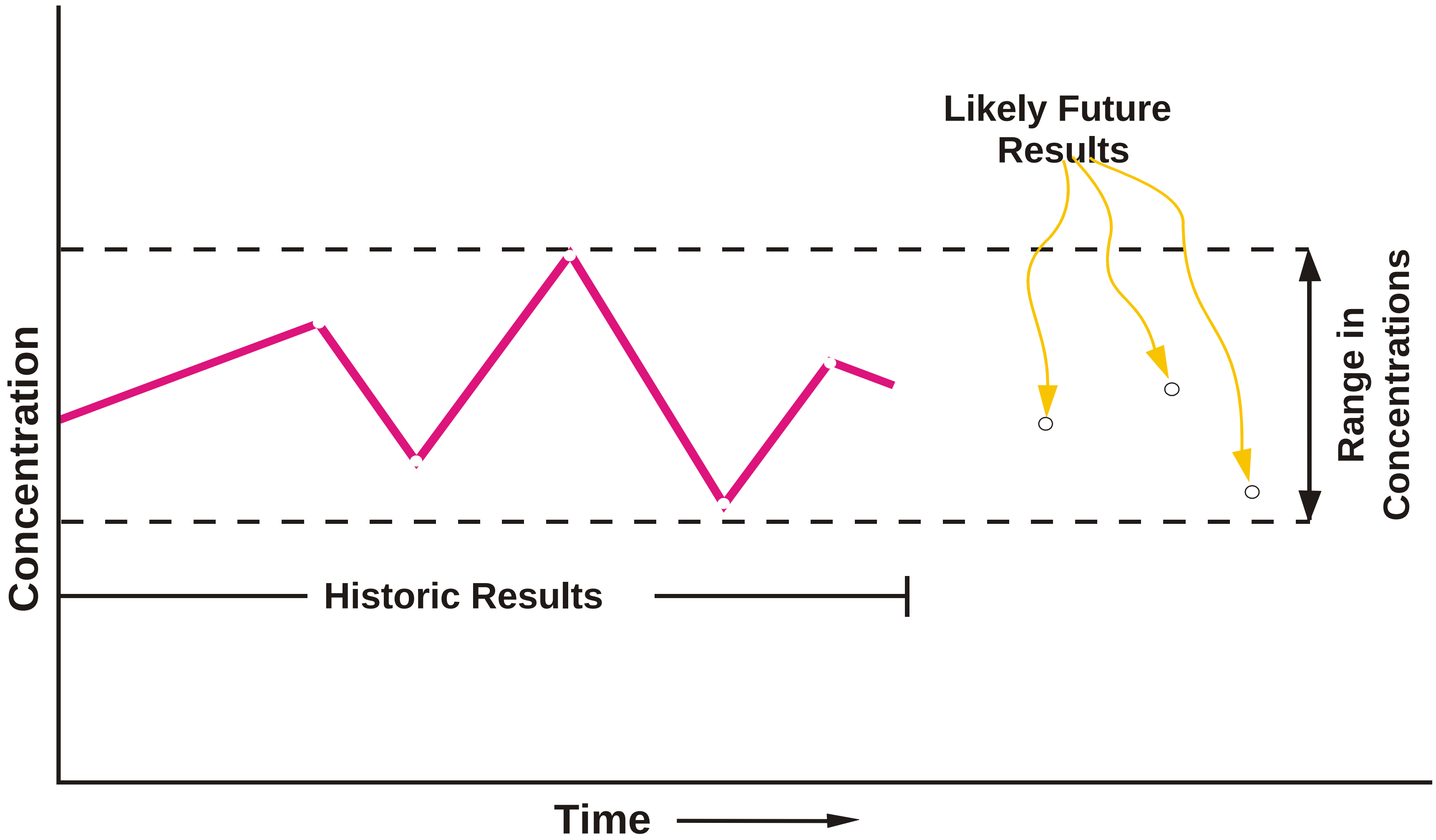


ESTCP

SERDP
DoD EPA DOE
Strategic Environmental Research and Development Program

INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

Continued Monitoring at Well With No Temporal Trend



Temporal Trends and Relative Worth of Information

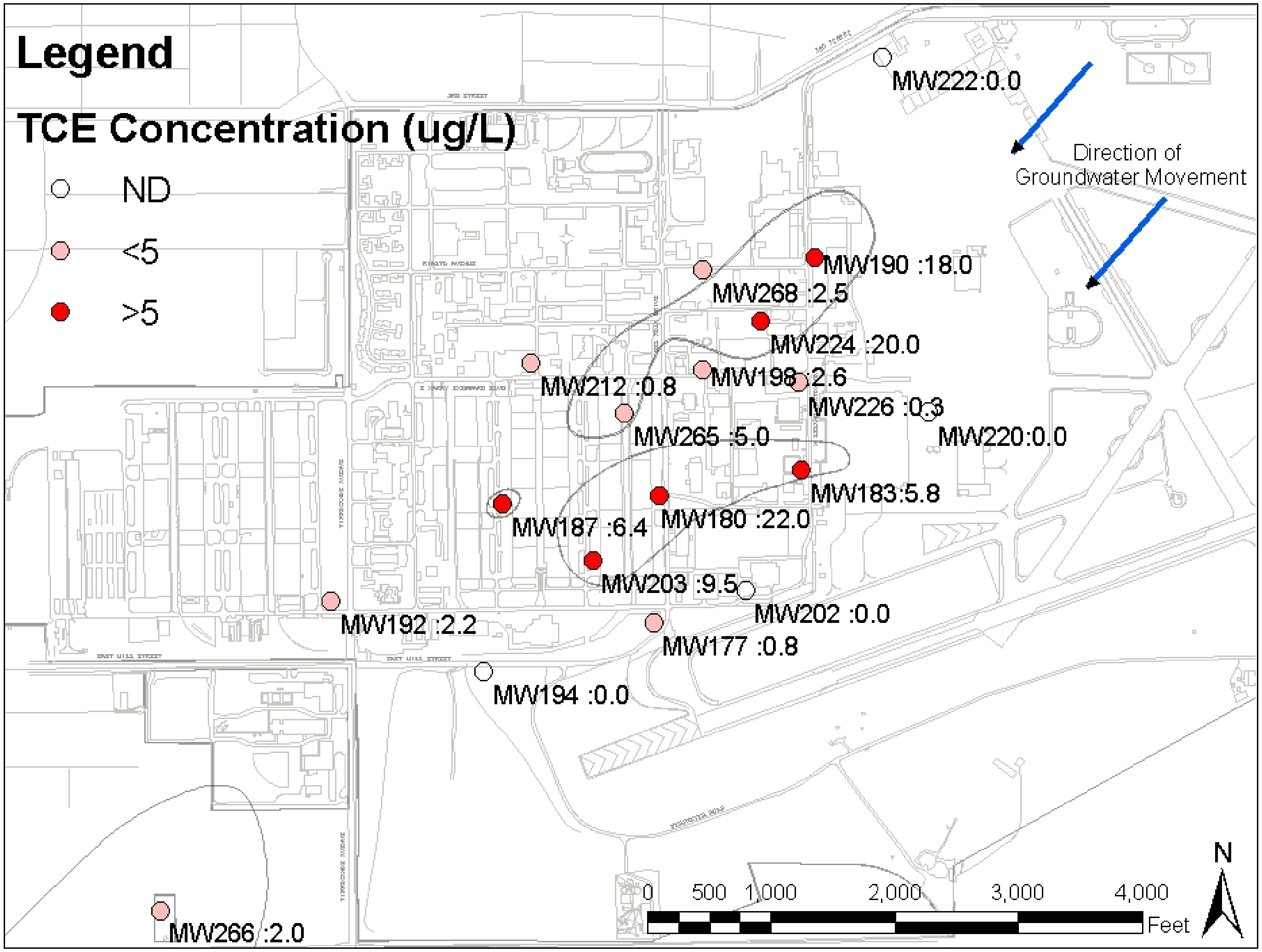
J.P. Morgan on trends:

"The market will fluctuate … "

Temporal Statistical Analysis -- Decision Rules

- **Monitoring Point Near Contaminant Source**
- **Monitoring Point Upgradient From Contaminant Source**
- **Monitoring Point Downgradient From Contaminant Source**
- **Sampling Frequency Considerations**

Norton AFB -- CBA

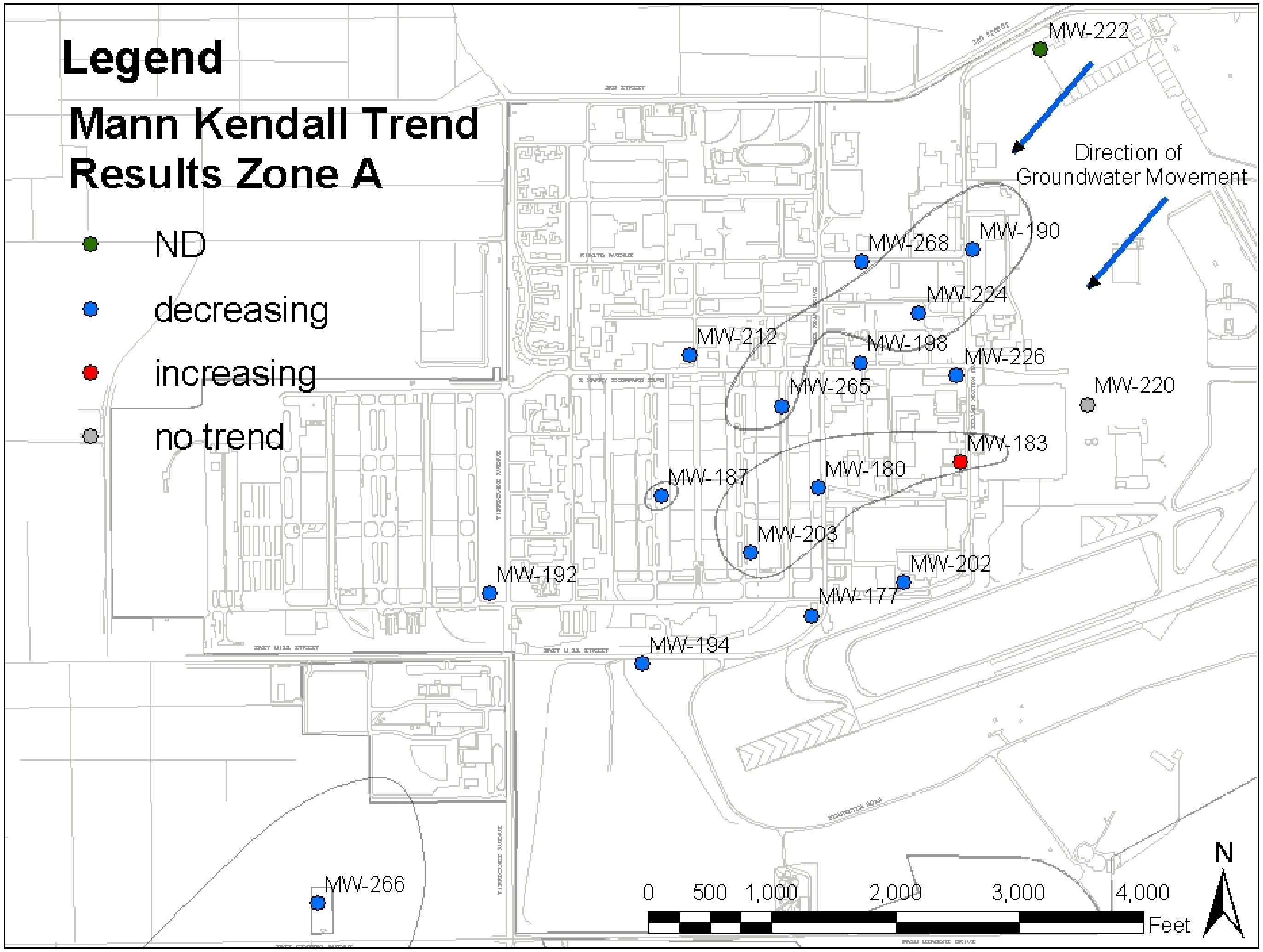


ESTCP

SERDP
DoD EPA DOE
Strategic Environmental Research and Development Program

INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

Norton AFB -- CBA
Results of Temporal Trend Analysis



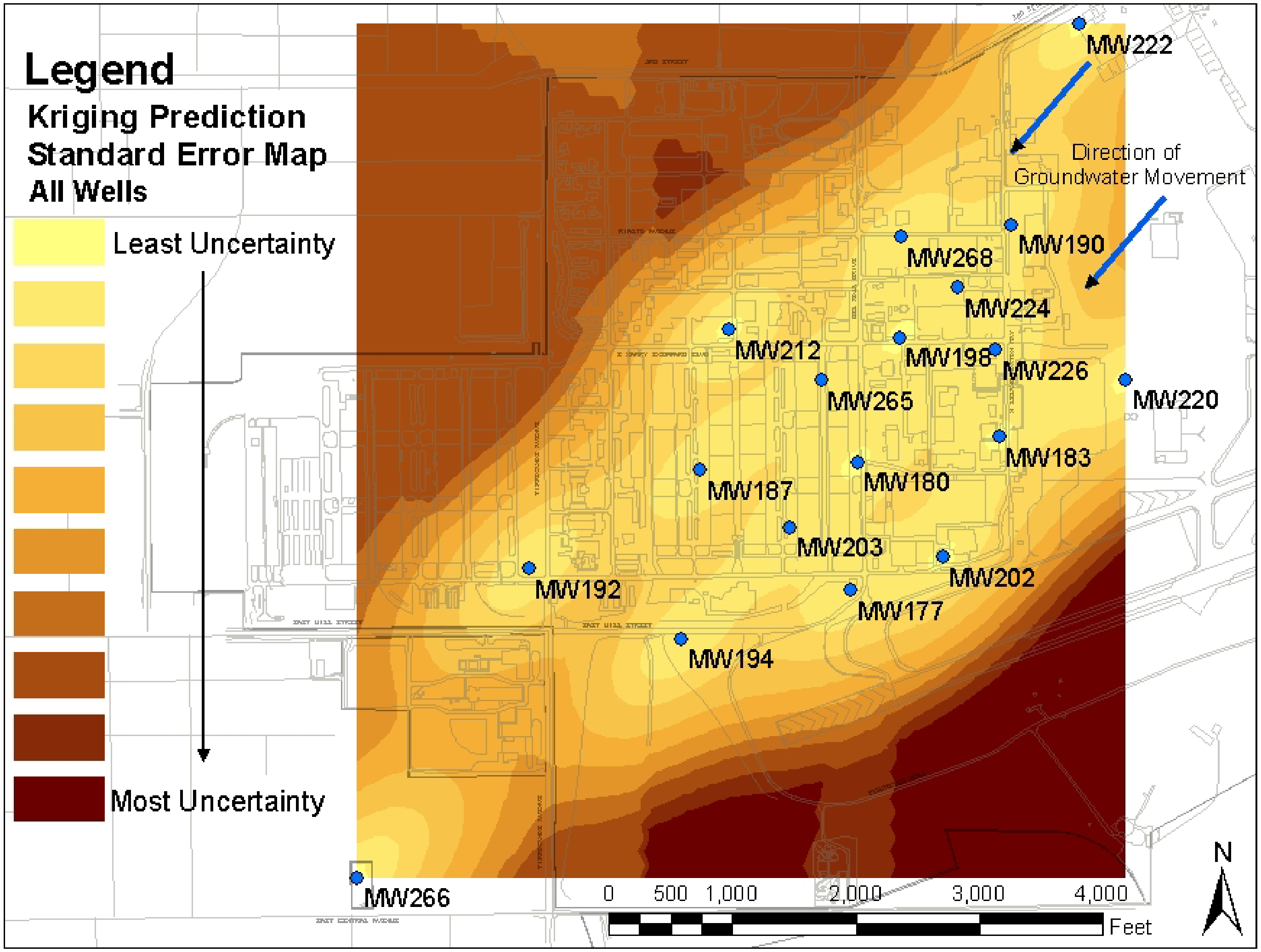
Spatial Statistical Analysis

- **Uses Geostatistics or Other Techniques to Evaluate Relative Importance of Monitoring Wells in Evaluating Spatial Distribution of Network**
  - **Iterative process -- well by well, constituent by constituent evaluation**

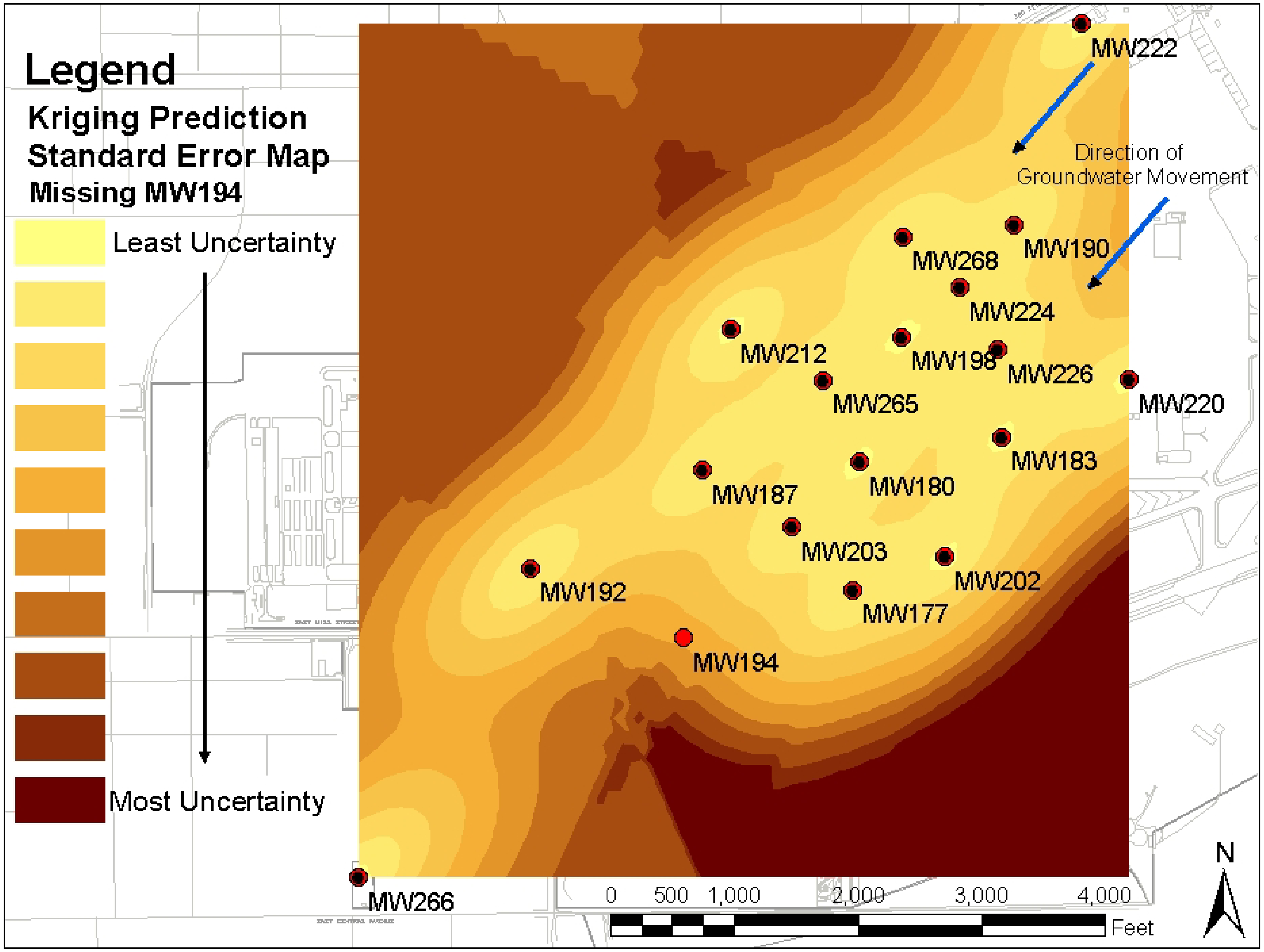
Spatial Statistical Analysis

- **Develop Expression of Spatial Relationship Among Sampling Results at Different Locations**
- **Apply Spatial Relationship to Evaluation of Monitoring Network**
  - **Generate estimates of values (e.g., chemical concentrations) at every point in spatial area**
  - **Generate estimates of error (standard deviation) associated with each estimated value**
  - **Generate estimates of global error associated with realization**
- **Iteratively Remove Individual Wells and Re-Calculate Realization to Evaluate Relative Importance of Each Well**

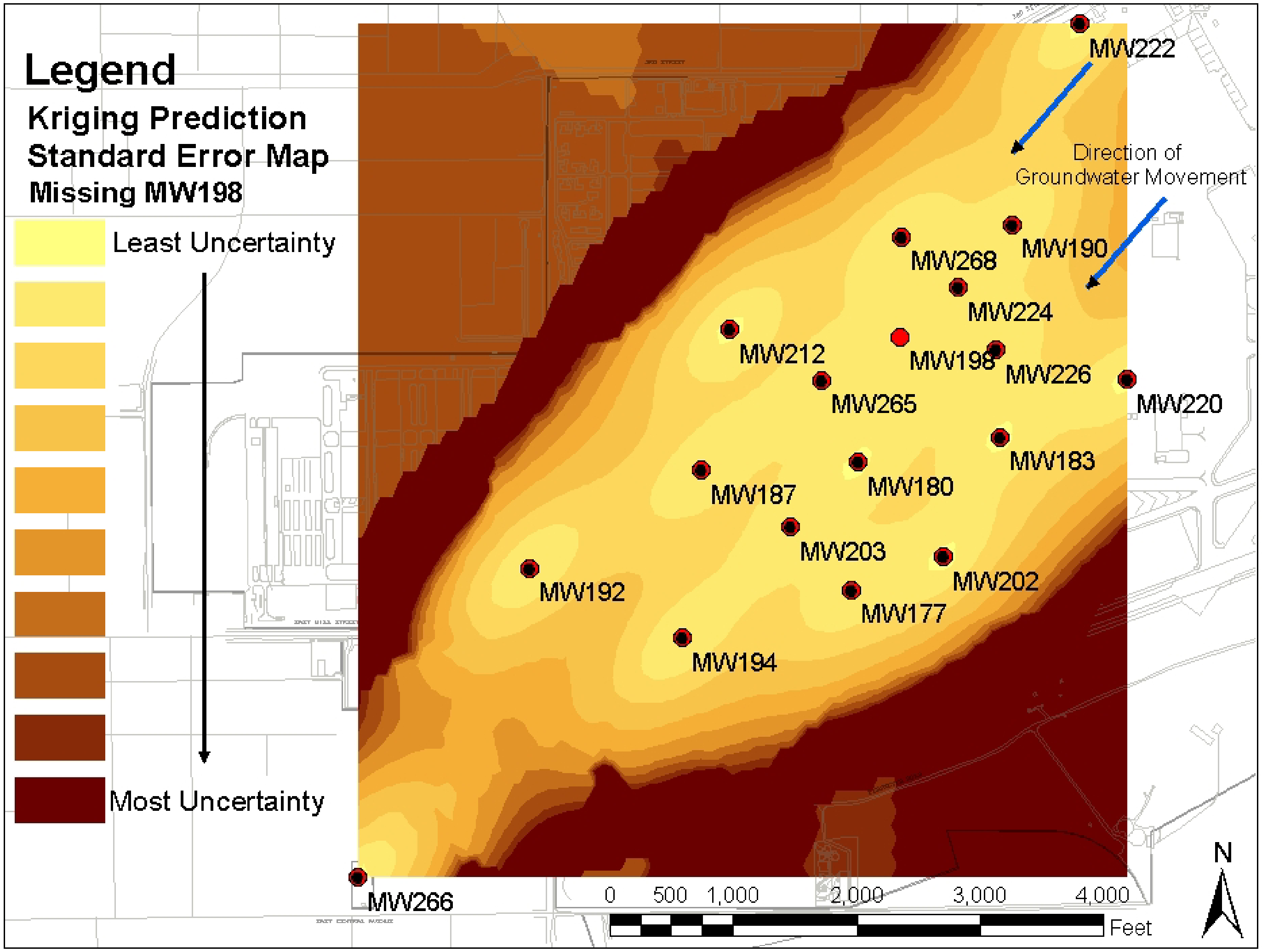
Norton AFB -- CBA Kriging Standard Error (Current)



Norton AFB -- CBA
Kriging Standard Error (-MW194)



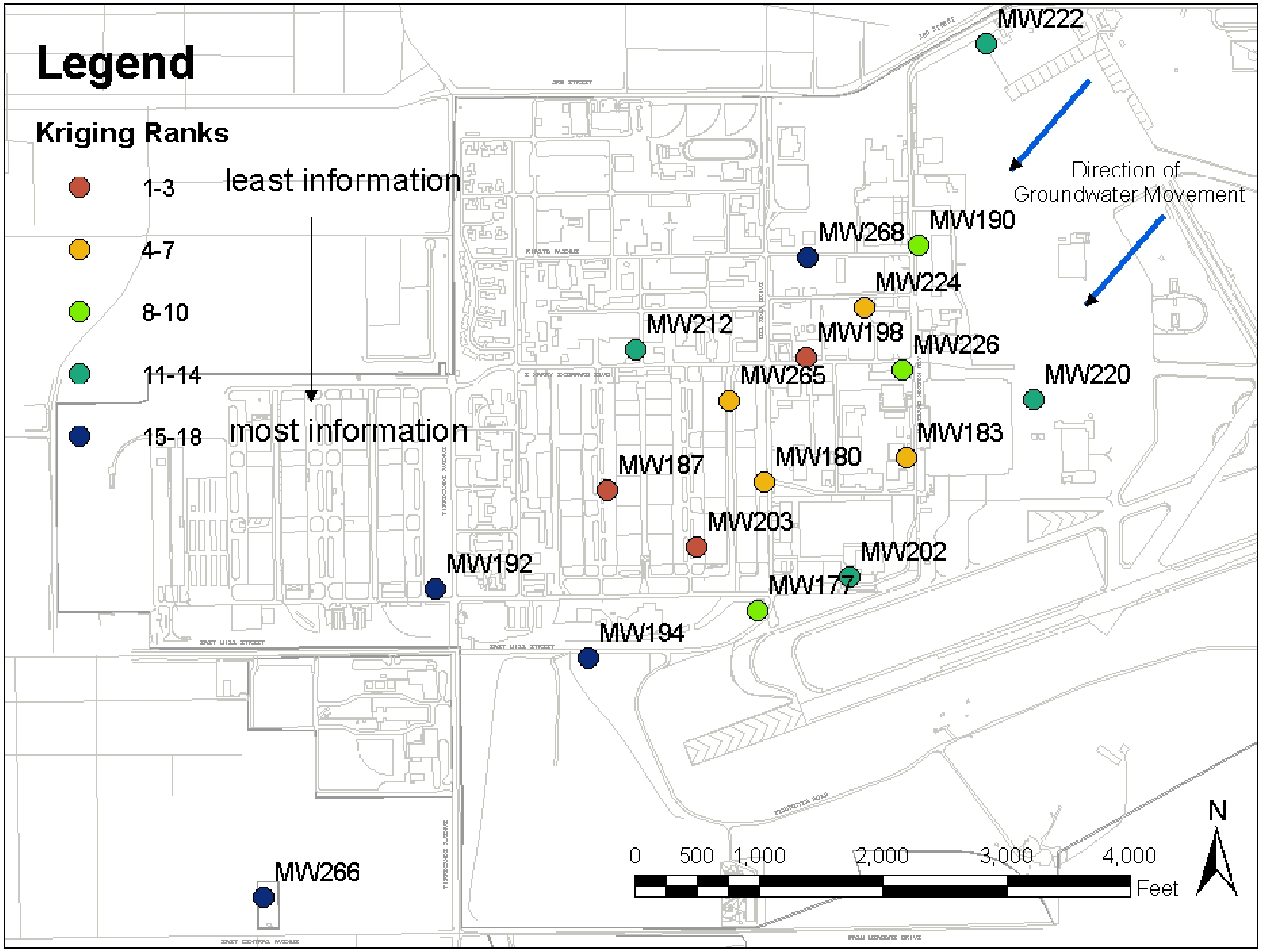
Norton AFB -- CBA
Kriging Standard Error (-MW198)



Spatial Statistical Analysis -- Decision Rules

- **Relative Worth of Information from Each Monitoring Point**
- **Incremental Amount of Information to be Considered “Redundant”**
- **Other Considerations**

Norton AFB -- CBA
Results of Geostatistical Analysis



Apply Results of Qualitative, Temporal, Spatial Analyses

- **Do Monitoring Results Continue to Support Monitoring Hypotheses?**
  - **Yes – proceed**
  - **No – examine/refine hypotheses (CSM)**
- **Develop/Apply Defensible Decision Rules**
- **Transparent Metrics**
  - **Can optimized program continue to achieve monitoring objectives?**
- **Management Decision**

ESTCP

SERDP DoD EPA DOE Strategic Environmental Research and Development Program

INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

Components of Optimized Monitoring Program

- Refined Program Objectives
- Refined Monitoring Program Hypotheses (CSM)
- Optimized Decision Rules
- Optimized Monitoring Plan
  - Sampling Locations (Network)
  - Sampling Schedule (Frequency)
  - Data Collection and Analysis Methods
  - Data Quality Objectives and QA/QC
  - Reporting
- Better-Defined Management Decision

Thank You!

Concepts and Practice in Optimization of Long-Term Monitoring Programs

For more information, contact

John W. Anthony — MTS Mitretek Systems — Innovative Technology in the Public Interest™ — **john.anthony@mitretek.org**

Dr. Carolyn Nobel — **carolyn.nobel@parsons.com**

Kathy Yager — **kathy.yager@epa.gov**

ESTCP

SERDP — DoD EPA DOE — Strategic Environmental Research and Development Program

ITRC — Interstate Technology Regulatory Council