Considerations Related to Post-Closure Monitoring of Uranium In-Situ Leach/Recovery Sites

An Advisory

Presented by
U.S. Environmental Protection Agency
Office of Radiation and Indoor Air
Radiation Protection Division

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Presented to
EPA Science Advisory Board
Radiation Advisory Committee

Overview of Presentation

- Draft Technical Report
- Elements of the Charge (Statement)
- Regulatory Context and Framework
- ISL/ISR Operations
- Elements of the Charge (Detail)

Content of Draft Technical Report

Available at: http://www.epa.gov/radiation/docs/tenorm/post-closure-monitoring.pdf

Part 1

- Background information
  - UMTRCA
  - RCRA
  - ISL/ISR operations
  - Purpose of groundwater monitoring systems
- Discussion
  - Factors affecting the timeframe and ability to restore an ISL/ISR wellfield to baseline conditions
  - Statistical techniques and approaches to measure achievement of post-operational restoration goals

Part 2

- Case studies
- Key issues associated with post-closure monitoring
- Summary of performance issues regarding groundwater monitoring

Elements of the Charge

1. Comment on the technical areas described in this report and their relative importance for designing and implementing a monitoring network. Identify any technical considerations that have been omitted or mischaracterized.

2. Comment on the proposed approaches for characterizing baseline groundwater chemical conditions in the pre-mining phase and proposed approaches for determining the duration of such monitoring to establish baseline conditions.

3. Comment on the approaches considered for monitoring in the post-mining/restoration phase and the approaches considered for determining when groundwater chemistry has reached a "stable" level.

4. Comment on statistical techniques about which you are aware that have been used in other applications (particularly for the areas in items 2 and 3 above).

Regulatory Context

- The goal of baseline definition/restoration stability is to ensure that future users of groundwater are protected
  - Within the ore zone (water quality is not degraded)
  - Outside of the ore zone (i.e., no migration)
- Your advice will help us develop technical options to address
  - Technical analyses that best demonstrate that these goals are achieved
  - How much analysis/data is necessary

Regulatory Framework

- UMTRCA requires EPA's standards to be consistent with requirements for non-radiological hazardous constituents under the Resource Conservation and Recovery Act (RCRA)
- 40 CFR Part 192 incorporates RCRA groundwater protection requirements for units managing hazardous waste, e.g.,
  - Landfills
  - Surface impoundments
  - Waste piles
- Separate permit for injection well(s) by EPA
  - Aquifer exempted for injection, but there is no exemption under UMTRCA

RCRA Monitoring Requirements

- RCRA requirements in 40 CFR Part 264 address:
  - Groundwater protection standard
  - Hazardous constituents
  - Concentration limits
  - Point of compliance
  - Compliance period
  - General monitoring requirements
  - Detection and compliance monitoring
  - Corrective action
- Flexibility in use of statistical methods
  - Focus on applicability of existing methods

Applying RCRA to ISL/ISR Sites

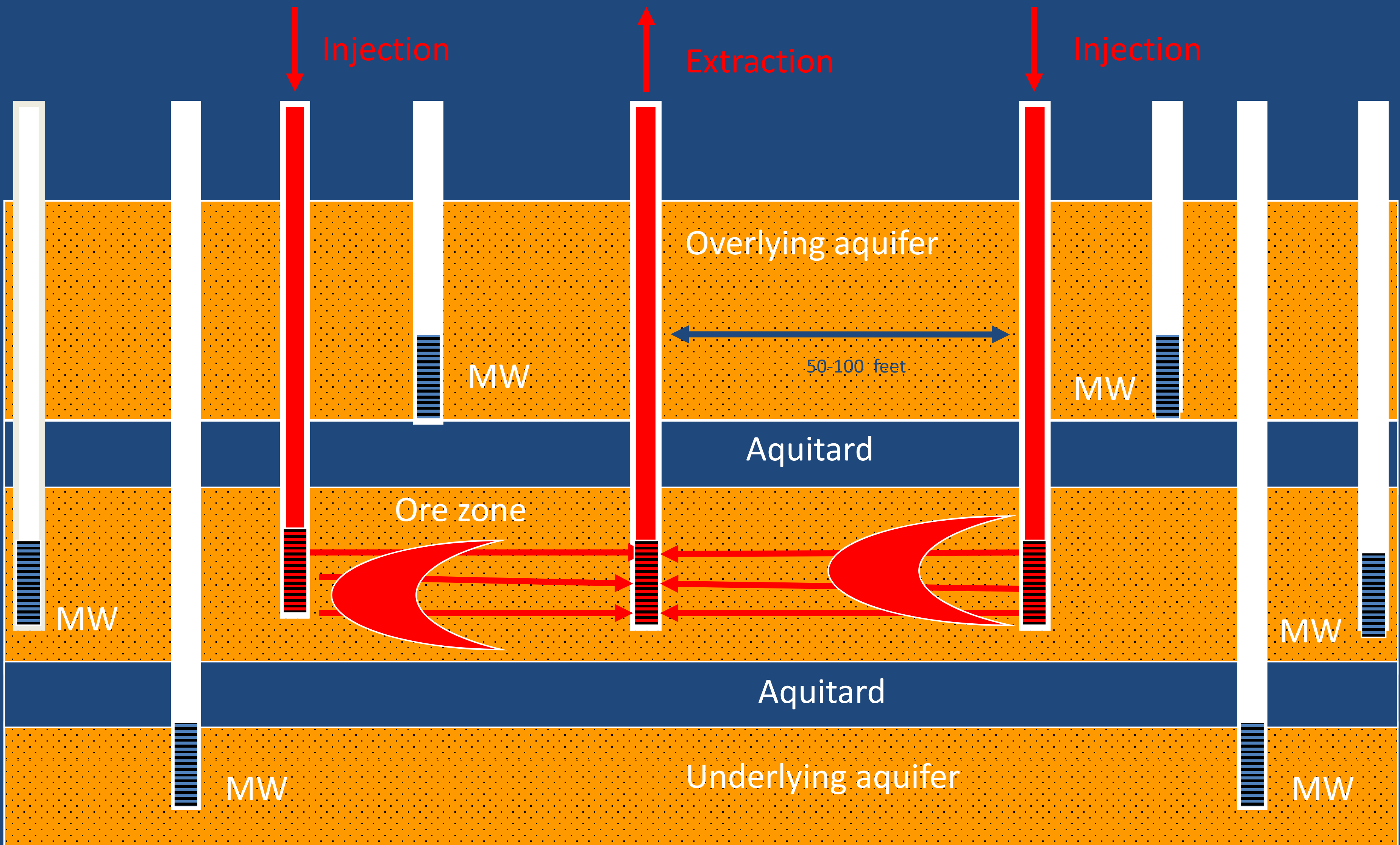
- RCRA applies well to conventional mills
  - Engineered surface impoundments
  - Processed material placed into impoundments
  - Intent to avoid releases to uppermost aquifer
- Why specific provisions for ISL/ISR facilities?
  - “Unit” is a natural feature not defined by engineered boundaries, likely not homogeneous
    - More complex to determine “background” conditions
  - May extend for tens of square miles
  - ISL/ISR process creates intentional “releases” of “contaminants” to groundwater
    - Potential to affect multiple water-bearing units

ISL/ISR OPERATIONS

Lifecycle of an ISL/ISR Facility

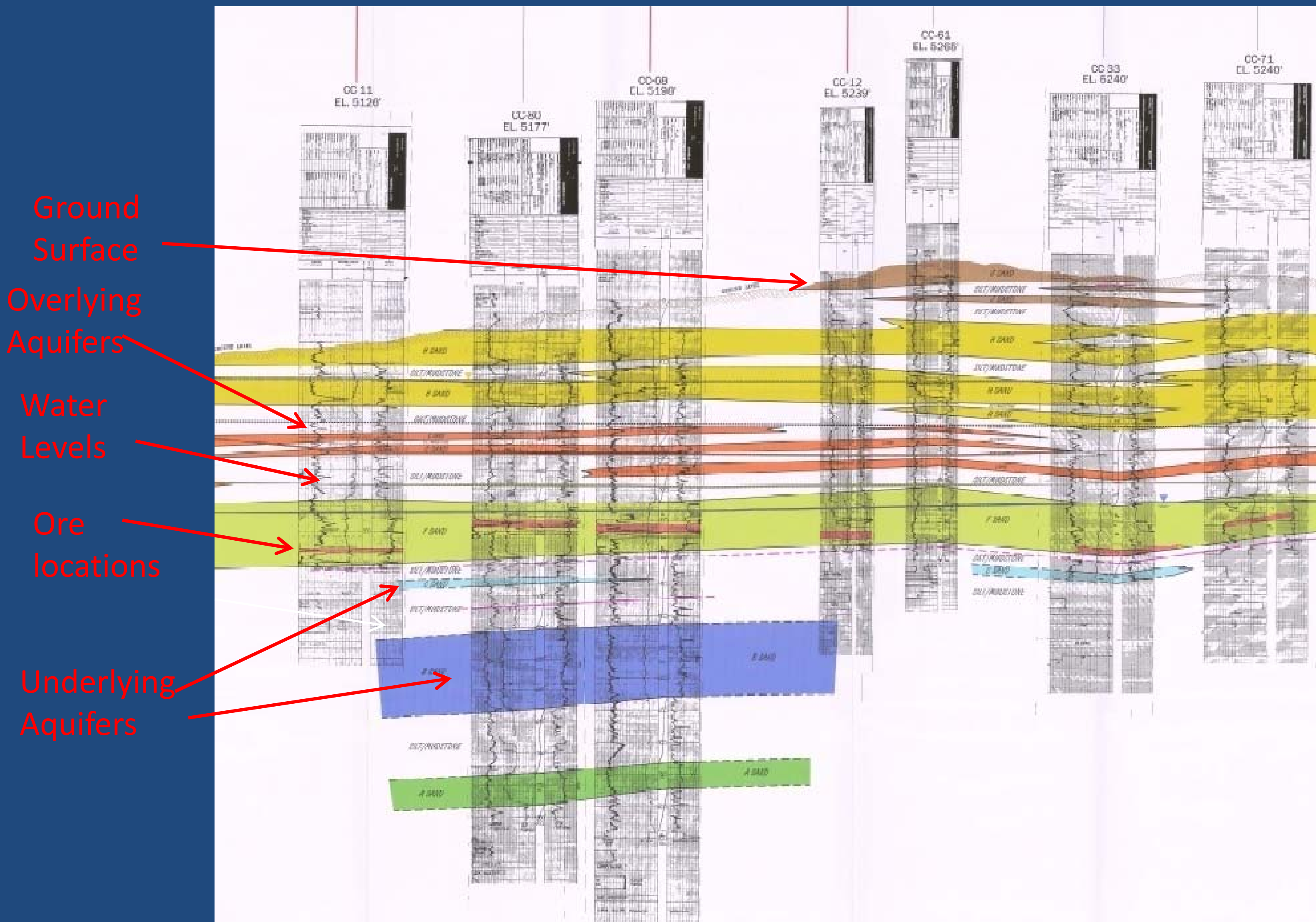
- Exploration and site characterization
- Establish baseline conditions
- Recover uranium from ore body
- Restore groundwater to predetermined conditions
- Demonstrate that restored groundwater has reached steady state
- Post-restoration stability monitoring of groundwater
- Decommission mined area and surface facilities

Injection, Extraction, and Monitoring Wells



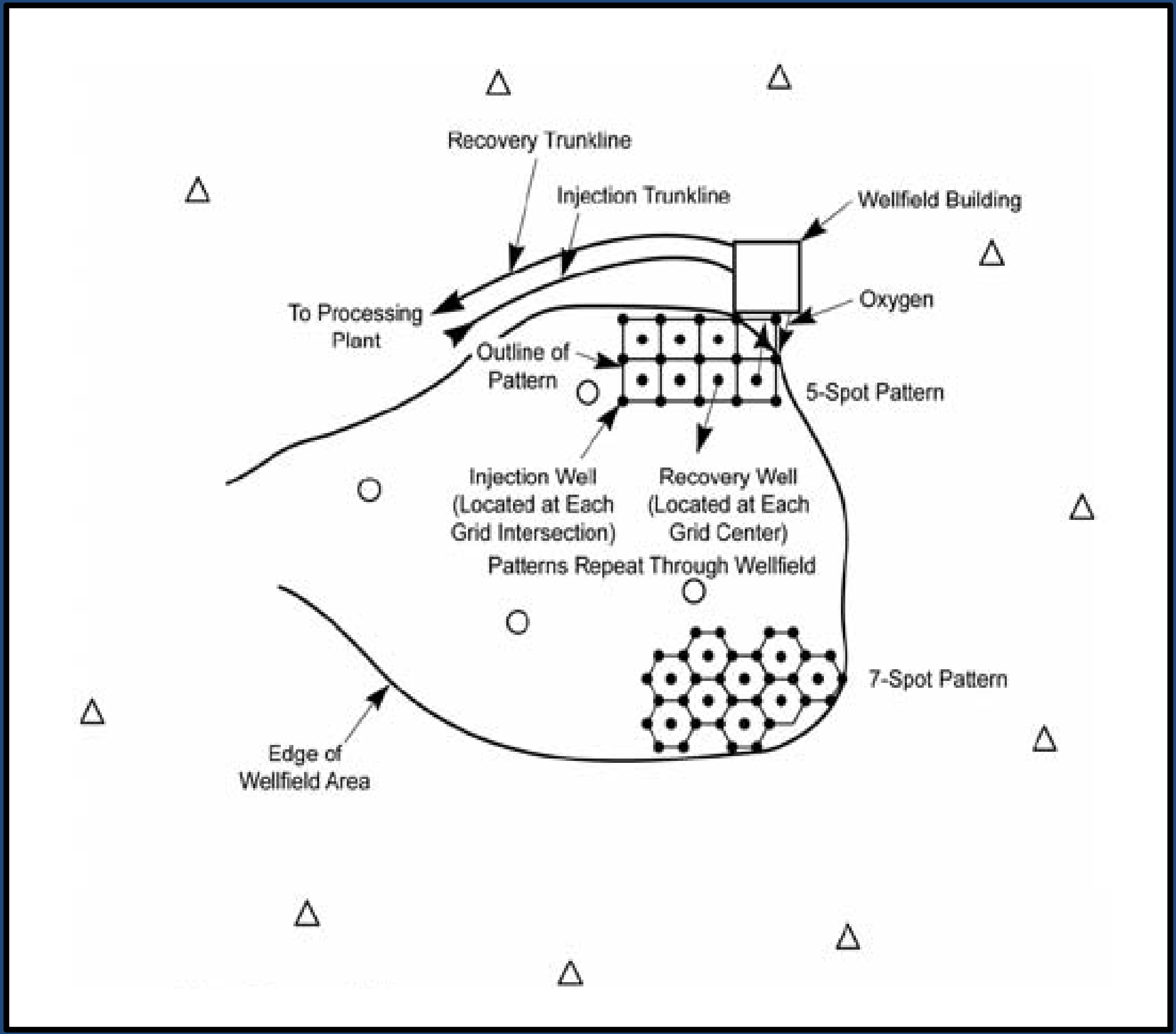
From NRC presentation (January 2011)

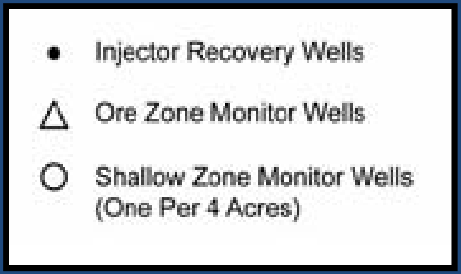
Comprehensive Cross-Section

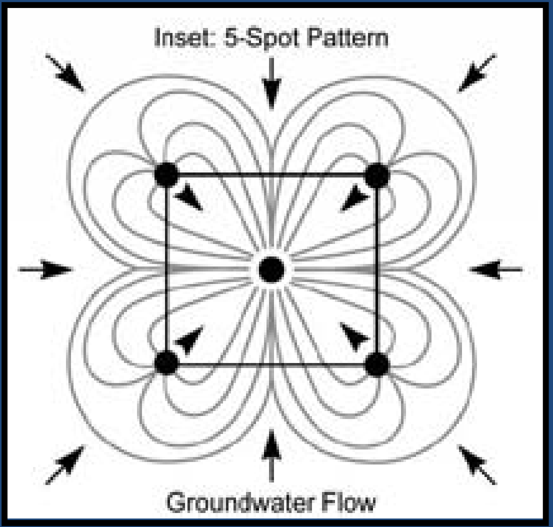


Source: Nuclear Regulatory Commission

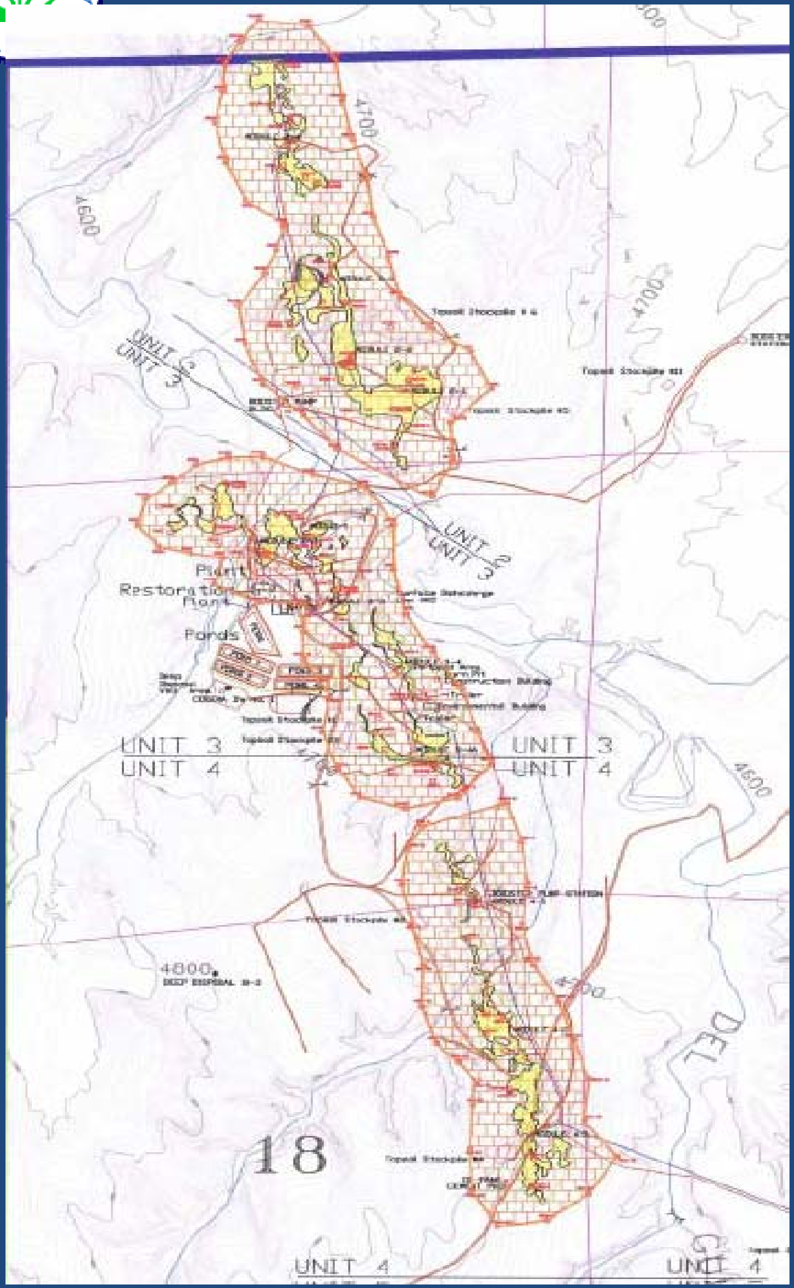
Injection/Production Well Patterns







Ore Body



- Variability possible in
  - Shape
  - Thickness
  - Depth
  - Proximity to recharge zones
  - Degree of confinement
  - Flow properties

Typical Wellfield

Some Wellfields Close to Public

ELEMENTS OF THE CHARGE

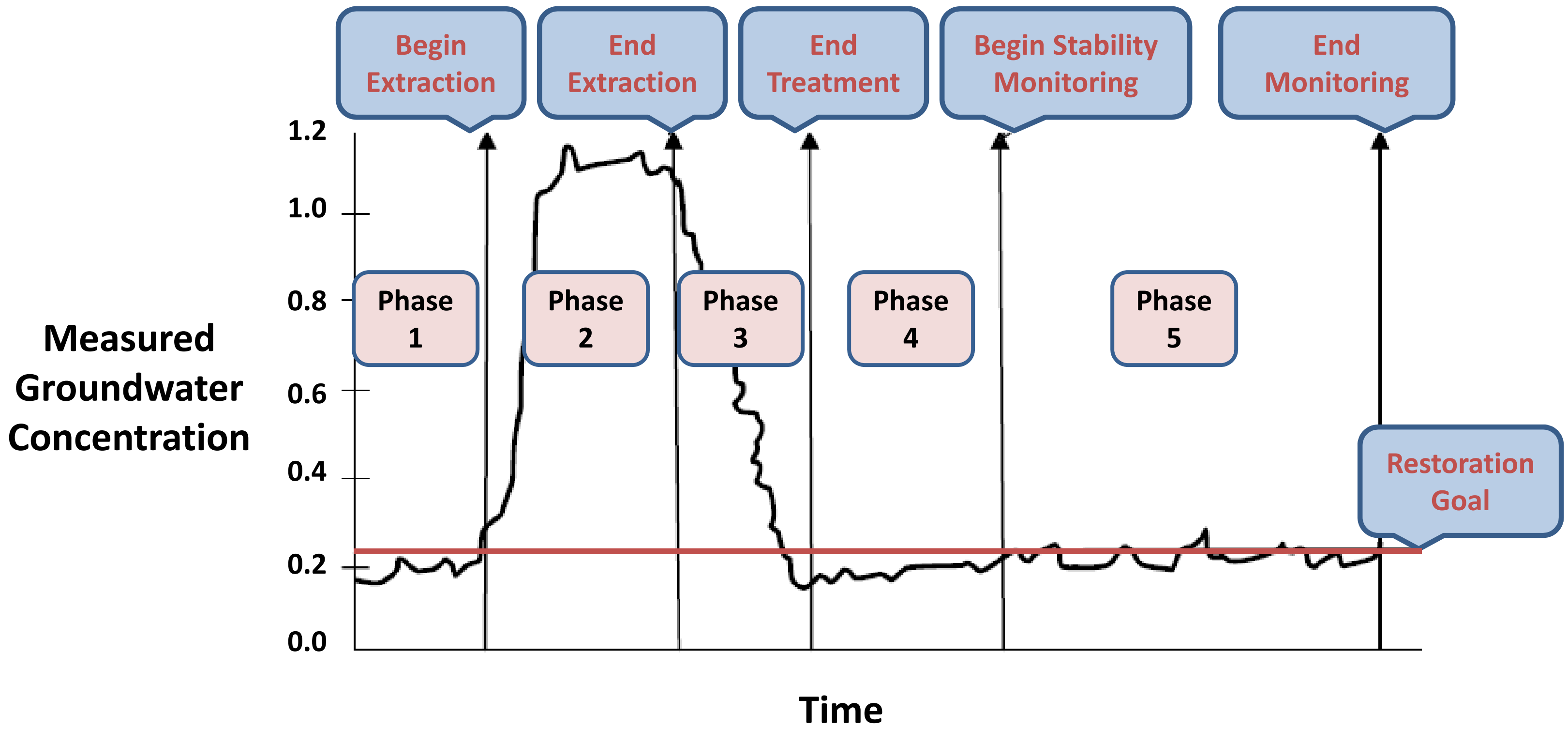
Charge Element 1.

Comment on the technical areas described in this report and their relative importance for designing and implementing a monitoring network. Identify any technical considerations that have been omitted or mischaracterized.

- *There are three main technical issues for consideration:*
  - *Defining pre-operational baseline levels of constituents and chemical conditions*
  - *Defining post-operational stability of constituents and chemical conditions*
  - *Comparing post-operational monitoring results to a pre-determined level*

Groundwater Monitoring Phases

Phase 1	Measure baseline groundwater concentrations
Phase 2	Conduct in-situ operations
Phase 3	Conduct wellfield restoration
Phase 4	Establish wellfield steady state
Phase 5	Conduct long-term stability monitoring



Purpose of Statistical Testing

- Statistical testing is applied for two purposes
  - Determining trends within monitoring data
  - Determining compliance with restoration goals
- Tests used for these purposes may have different characteristics and data needs, depending on how the test is applied

Issues Associated with Statistical Tests

- Parametric vs. non-parametric
  - Relative performance depends on data distribution
  - How to manage non-detects?
- Outliers in data set
  - Discard outliers or include all data (as in WRS test)
  - Identifying outliers should be done with caution
- Level of confidence
  - Number of samples determined by desired level
  - Greater confidence calls for greater sampling

Example Statistical Tests

Mann-Kendall Trend Test

- Used to show whether data are stable or trending upwards/downwards
  - Applied to test the post-restoration data from each well for trends
    - Samples are analyzed for trends well by well
  - Applied after seasonal adjustment of the data and before post-restoration conditions are compared with baseline conditions

Wilcoxon Rank Sum (WRS) Test

- Used for comparing post-restoration data with baseline conditions to determine when pre-ISL/ISR conditions are achieved
  - Applied to determine if post-restoration values have achieved targeted remediation goals
  - Applied once conditions are stable

Statistical Analyses
Examples in the Draft Report

- Parametric and non-parametric statistical tests can be used
- Data demands differ between approaches
- Parametric tests generally more data demanding
  - Need to prove data distributions first
- We used non-parametric tests because of limited data
  - No preference at this point
- See Attachment D of draft technical report

Comparing Before and After

- The goal of baseline definition/restoration stability is to ensure that future users of groundwater are protected
  - Within the ore zone (water quality is not degraded)
  - Outside of the ore zone (i.e., no migration)
- Technical approaches can be bounded by:
  - Comparison of individual wells
  - Comparison of the wellfield as a whole (average)

Well Comparison – Before and After

- Comparing individual wells prior to operation and after restoration provides the most detail
  - Identification of anomalies and "hot spots"
  - Identification of problematic zones within the field
  - May allow definition of "regions" for trending
- There may also be drawbacks
  - Likely to be much more data-intensive
  - Need to account for each well's zone of influence
  - Many wells may be required
  - Groundwater chemistry has deliberately been altered

Wellfield Average

- It may be simpler to average over the entire wellfield as a baseline/restoration measure
  - Comparable to natural conditions as the goal
  - Requires less intensive data analysis
- This approach also has drawbacks
  - No accounting for residual “hot spots”
    - May be “hotter” than “natural hot spots”
  - No accounting for trending within the field

Technical Challenges

- In considering the technical application of these approaches
  - What are the strengths and weaknesses of each?
  - What are the impediments or demands of each?
  - How can the best of each be kept ("hybridized")?
  - What would be lost by sampling only a subset of wells?
  - What would be defensible approaches to dividing up the wellfield into different zones? (e.g., geology)
  - What technical analyses do you recommend?

Potential Hybrid Approach?

- Keeping the protection goals in mind, a simple conceptual approach might involve:
  - Comparing the wellfield average to pre-determined restoration goals
  - Using individual wells to identify anomalies or "hot spots" that may need further attention
  - Conducting trend analysis to ensure that there is no unacceptable migration of constituents downgradient within the field

Case Study
Irigaray Site, Wyoming

- Restoration goal is baseline water quality, by constituent, on production-unit average
- 27 of 29 constituents met restoration goal
  – 13 measured constituents exceeded baseline min-max range and baseline mean
  – 6 others exceeded baseline mean without exceeding baseline min-max range
  – Modeling to demonstrate no further degradation

Charge Element 2.

Comment on the approaches considered for establishing baseline groundwater chemical conditions in the pre-mining phase and the proposed approaches for determining the duration of such monitoring to establish baseline conditions.

- *Characterizing the baseline groundwater conditions prior to operations is important since baseline levels may be the level to which an ISL/ISR wellfield is to be restored*
- *Issues such as seasonality of the measurements can be important influences that need to be considered*

Characterizing Baseline

- The key to baseline monitoring is to adequately characterize groundwater *temporal* and *spatial* variability before ISL/ISR operations begin
  - What technical information is necessary to determine that variability has been <u>adequately</u> captured, i.e., to say that baseline conditions have been established with some level of confidence?

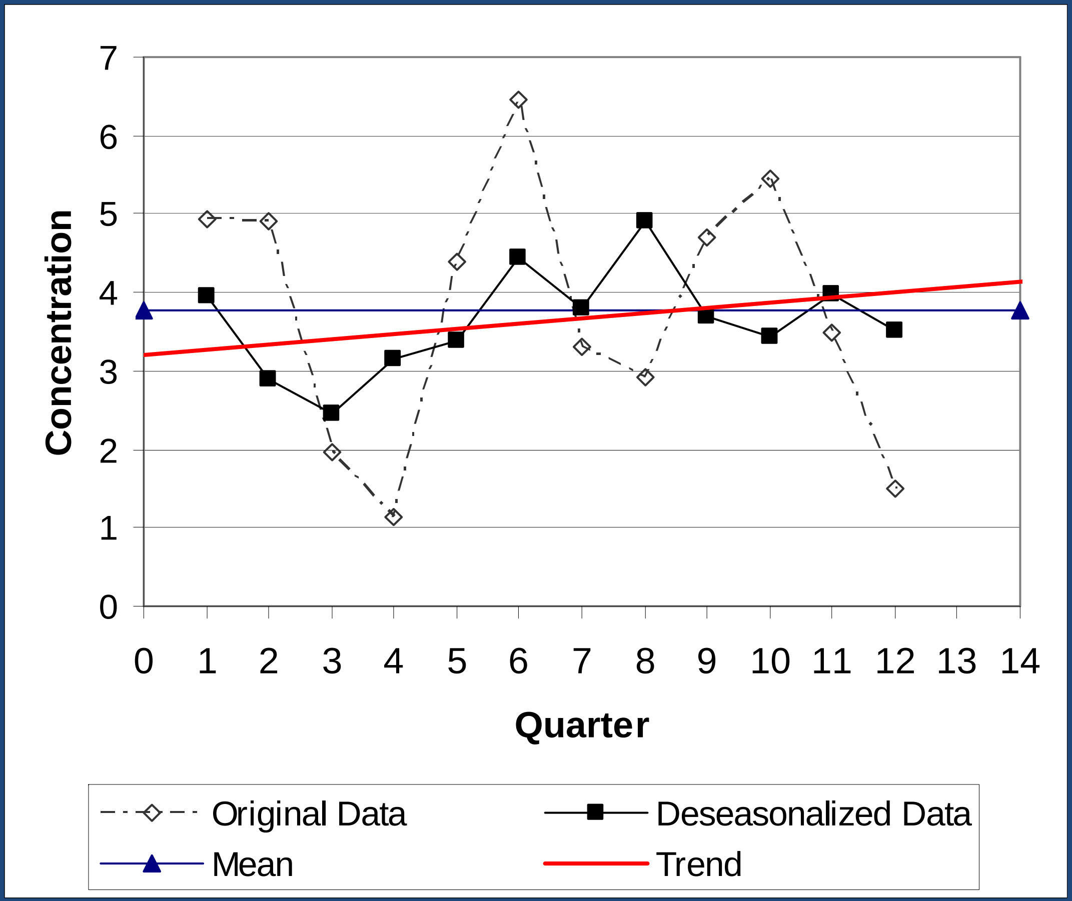
Establishing Baseline Conditions

- Need to consider the following components and parameters:
  - Hydrogeologic setting
  - Hydrogeochemical conditions
  - Concentrations of constituents listed in 40 CFR Part 192 (e.g., arsenic, barium, cadmium, …)
  - Uranium ore deposit types and oxidation states
    - How might characterization activities affect conditions?

Baseline Development Issues

- Basic decisions on the number and spacing of wells, frequency and duration of sampling will depend on the size of the wellfield and
  - Aquifer properties
  - Connectivity with overlying and underlying aquifers
  - Sampling effects
  - Seasonal variation

Seasonal Adjustment



How important is it to seasonally-adjust data set?

Case Study

Dewey-Burdock Site, South Dakota

- Proposed action area of 10,520 acres
  - ~16.4 square miles
- Operator proposed to characterize baseline
  - 19 wells (14 existing, 5 newly drilled)
  - Multiple water-bearing units
  - Quarterly sampling over one year (July – June)
  - State required 12 additional wells be sampled
    - Monthly sampling for one year
    - Upgradient, downgradient, and within production zone

Statistical Approach for Baseline Sampling

- Estimate required number of wells
- Estimate required number of samples
- Adjust measured data for seasonality
- Use Mann-Kendall test, or other similar statistical test, to check for unexpected trends

Charge Element 3.

Comment on the approaches considered for monitoring in the post-operational (post-mining) / restoration phase and the approaches considered for determining when groundwater chemistry has reached a "stable" level.

- *One technical option the Agency is considering (for addressing the post-operational phase issue of whether the chemistry has reached a stable level):*
  - *Establish a performance standard with a requirement that the constituent levels attain a specified confidence level in wells within the wellfield*

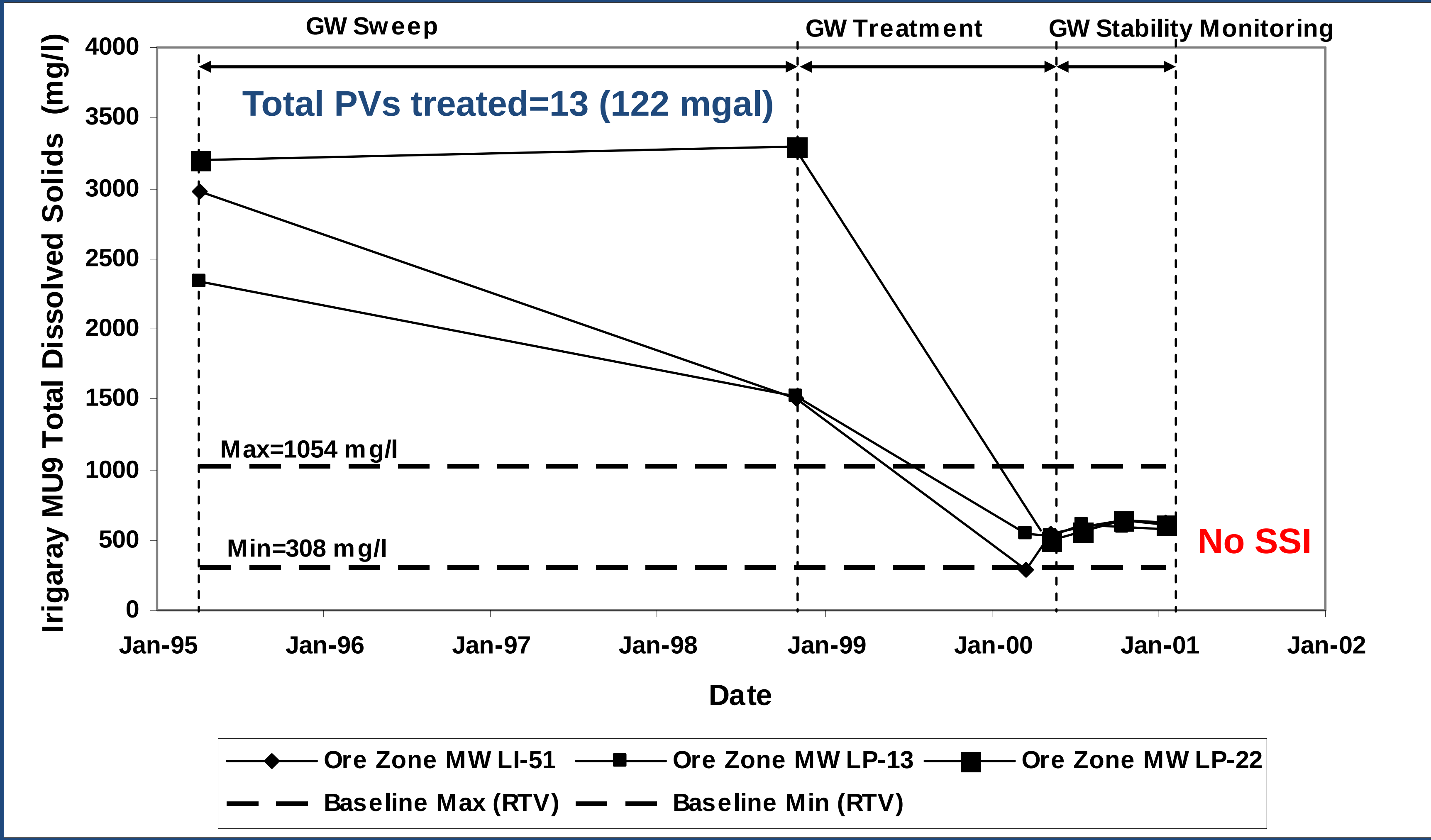
Post-Operational Monitoring

- Demonstrate when the groundwater chemistry has reached "stable" levels
  - Distinction between "steady state" and "stability" is largely a regulatory decision – greater level of demonstration for stability
- Determine if post-operation restoration levels for groundwater constituents have been met

Statistical Approach for Steady State and Stability Monitoring

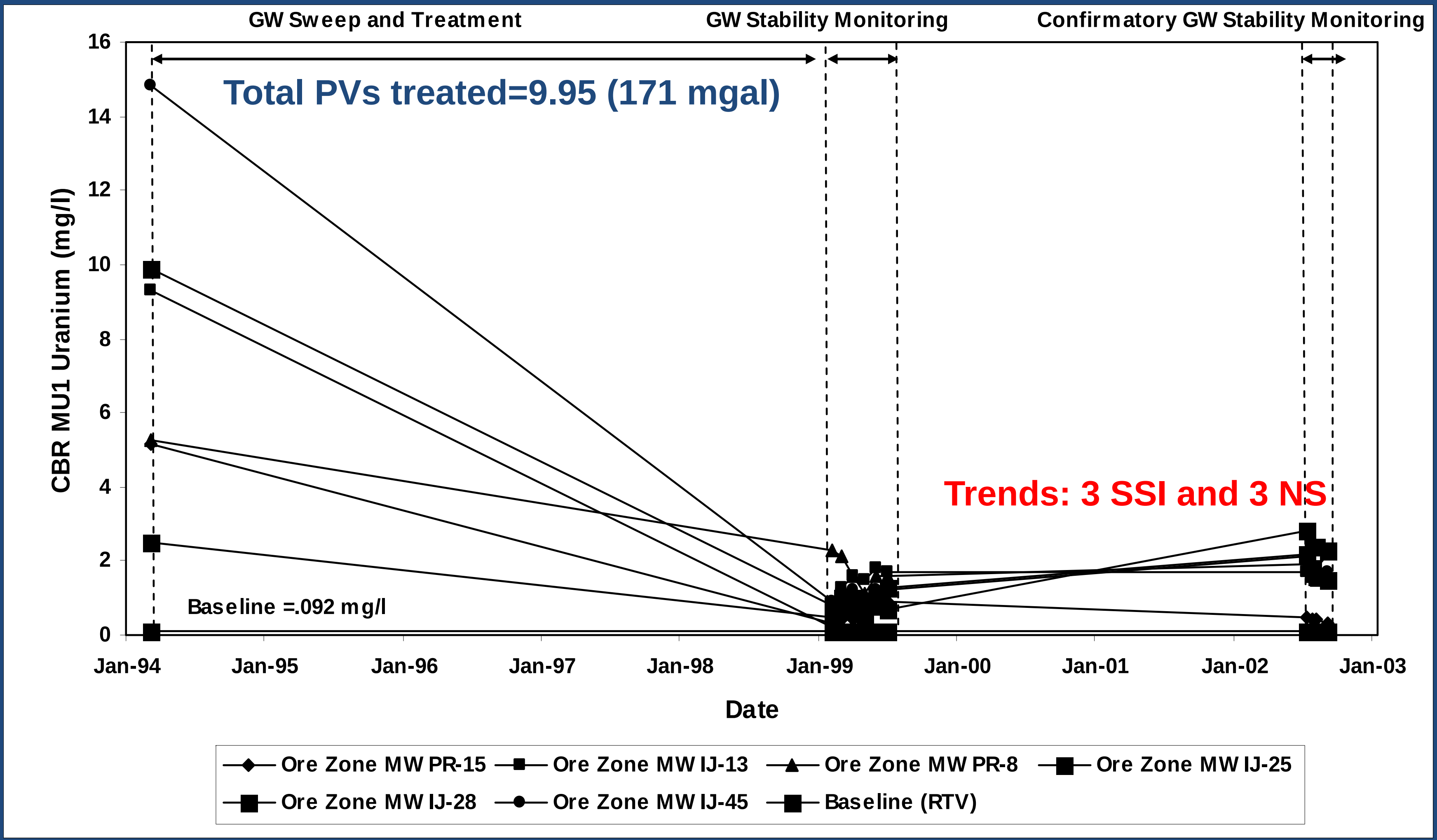
- Adjust measured data for each well for seasonality
- Use Mann-Kendall test for trends of each well
- If trend is detected, assess trend magnitude
  - Use linear regression or Theil-Sen test
  - If trend is not detected, compare baseline to stability monitoring results for a single well
    - Use WRS
    - Repeat for each well
- If the before/after comparison is made between multiple wells, first test all wells for homogeneity
  - Use chi-squared approach
- Test to confirm compliance of all wells with restoration goals
- If post-restoration data are from different wells than baseline data and trends are not detected, compare baseline to stability monitoring results for the pooled data of all wells combined
  - Use Wilcoxon Rank Sum (WRS) test
- Summary of approach from Section 8.5 of draft technical report

ISL/ISR Restoration: Short-Term Stability Monitoring Trend Analysis



Source: Nuclear Regulatory Commission

ISL/ISR Restoration: Stability and Long-Term Monitoring Trend Analysis



Source: Nuclear Regulatory Commission

Charge Element 4.

Comment on the statistical techniques about which you are aware that have been used in other applications (particularly for the areas in elements 2 and 3 above).

- *The Agency has examined different statistical techniques for use in different environmental programs*
  - *Reviewed statistics used in the RCRA and CERCLA programs for applicability to ISL/ISR issues*
  - *Conducted some analyses to provide a basis for discussion (see Attachment D in draft technical report)*

Hypothesis Testing

- Hypothesis testing can be a useful means of framing the purpose of a given test
  - In considering restoration, the *null hypothesis* can be framed as an assumption that compliance with restoration goals <u>has not been achieved</u> and must be proven
  - In considering stability, the *null hypothesis* can be framed as an assumption that no trends are present, i.e., stability has been achieved
  - The *null hypothesis* also defines Type I and Type II errors for the situation (false positive/false negative)

Summary of Monitoring/Statistical Issues

- We are seeking SAB advice on two key issues related to the application of statistical methods for ISL/ISR groundwater monitoring:
  - Appropriate use of statistical approaches/methods to assess baseline and post-restoration stability questions
  - Data demands and requirements for statistical tests and their field implementation implications

Purpose of Advisory

- EPA requests SAB advice on technical issues related to groundwater monitoring at ISL/ISR facilities
  – Establishing representative baseline site conditions
  – Post-operational stability issues
  – Application of statistical methods to compare pre- and post-operational conditions
  – Identification of additional technical analyses and information that would be useful in developing site-specific, performance-based standards

- We also request comments on the draft technical report providing background information on these groundwater monitoring issues for uranium ISL/ISR operations