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Starting Soon: Groundwater Statistics for Environmental Project Managers

- Technical and Regulatory Web-based Guidance on Groundwater Statistics and Monitoring Compliance (GSMC-1, 2013) at http://www.itrcweb.org/gsmc-1/
- Download PowerPoint file
  - Clu-in training page at http://www.clu-in.org/conf/itrc/gsmc/
  - Under "Download Training Materials"
- Using Adobe Connect
  - Related Links (on right)
    - Select name of link
    - Click "Browse To"
  - Full Screen button near top of page
- Follow ITRC

No associated notes.

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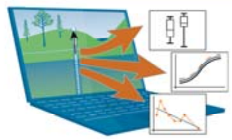
Welcome – Thanks for joining this ITRC Training Class

Groundwater Statistics for Environmental Project Managers



Groundwater Statistics and Monitoring Compliance (GSMC) Technical and Regulatory Guidance Web-Based Document (GSMC-1)

Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)
Hosted by: US EPA Clean Up Information Network (www.cluin.org)

Statistical techniques may be used throughout the process of cleaning up contaminated groundwater. It is challenging for practitioners, who are not experts in statistics to interpret and use statistical techniques. ITRC developed the Technical and Regulatory Web-based Guidance Document on Groundwater Statistics and Monitoring Compliance (GMSC-1, 2013) and this associated training specifically for environmental project managers who review or use statistical calculations for reports, who make recommendations or decisions based on statistics, or who need to demonstrate compliance for groundwater projects. The training class will encourage and support project managers and others who are not statisticians to:
-- Use the ITRC Technical and Regulatory Web-based Guidance Document on Groundwater Statistics and Monitoring Compliance (GMSC-1, 2013) to make better decisions for projects
-- Apply key aspects of the statistical approach to groundwater data
-- Answer common questions on background, compliance, trend analysis, and monitoring optimization

ITRC's Technical and Regulatory Web-based Guidance Document on Groundwater Statistics and Monitoring Compliance (GMSC-1, 2013) and this associated training bring clarity to the planning, implementation, and communication of groundwater statistical methods and should lead to greater confidence and transparency in the use of groundwater statistics for site management.

ITRC (Interstate Technology and Regulatory Council) www.itrcweb.org

Training Co-Sponsored by: US EPA Technology Innovation and Field Services Division (TIFSD) (www.clu-in.org)

ITRC Training Program: training@itrcweb.org; Phone: 402-201-2419

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Housekeeping

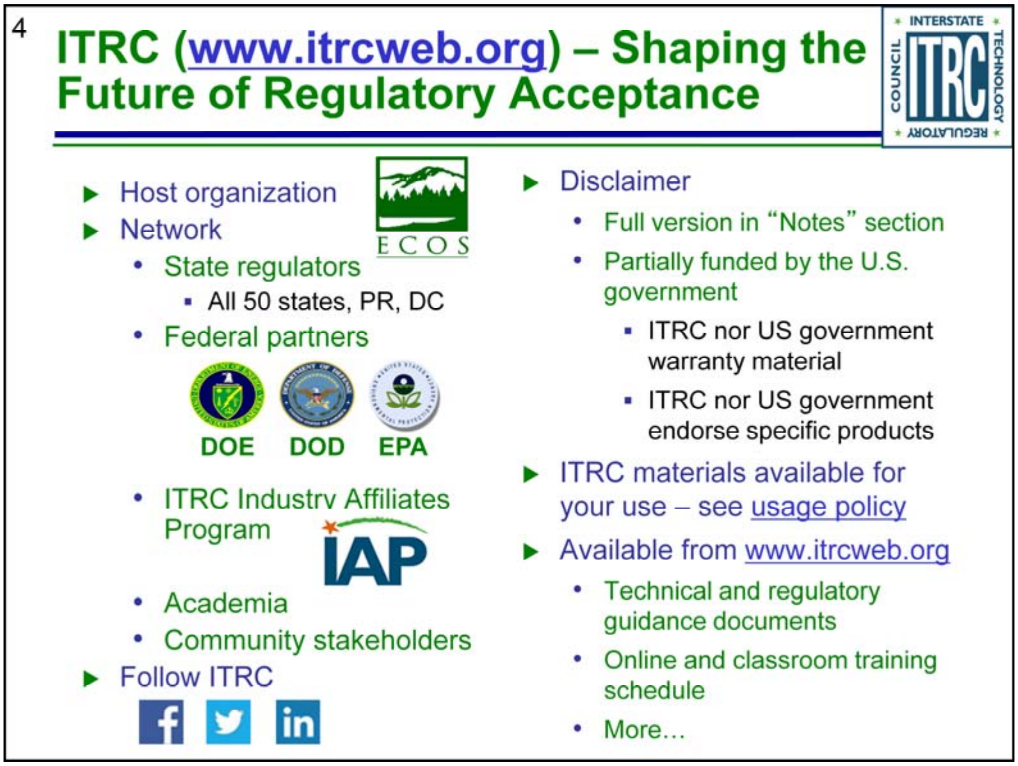
- Course time is 2¼ hours
- This event is being recorded
- Trainers control slides
  - **Want to control your own slides?** You can download presentation file on Clu-in training page
- Questions and feedback
  - **Throughout training:** type in the "Q & A" box
  - **At Q&A breaks:** unmute your phone with #6 to ask out loud
  - **At end of class:** Feedback form available from last slide
    - **Need confirmation of your participation today?** Fill out the feedback form and check box for confirmation email and certificate

Although I'm sure that some of you are familiar with these rules from previous CLU-IN events, let's run through them quickly for our new participants.

We have started the seminar with all phone lines muted to prevent background noise. Please keep your phone lines muted during the seminar to minimize disruption and background noise. During the question and answer break, press #6 to unmute your lines to ask a question (note: *6 to mute again). Also, please do NOT put this call on hold as this may bring unwanted background music over the lines and interrupt the seminar.

Use the "Q&A" box to ask questions, make comments, or report technical problems any time. For questions and comments provided out loud, please hold until the designated Q&A breaks.

Everyone – please complete the feedback form before you leave the training website. Link to feedback form is available on last slide.



The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of all 50 states (and Puerto Rico and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

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Harold Templin is a Senior Geologist at the Office of Land Quality of the Indiana Department of Environmental Management (IDEM). Since 1985, Harold has worked as a geologist with compliance and permitting of hazardous waste facilities and solid waste landfills. In that role, Harold has designed or approved ground water monitoring systems, sampling and analysis plans, and statistical evaluation plans. While working at IDEM Harold has set on numerous panels setting policy and guidance for closure of land disposal facilities, and risk assessment of corrective action sites. Since 1977, Harold has worked with land use regulations and with efforts to encourage the best use of our natural resources. This is Harold's first effort of working on an ITRC team. Harold earned a BS degree in geology from Indiana State University in 1972. Additionally, Harold has taken additional graduate level courses in hydrogeology and groundwater modeling at Indiana University. Harold is a licensed professional geologist in the State of Indiana.

Chris Stubbs is a principal consultant with Ramboll in Emeryville, California. Since 2000, he has worked in environmental science and engineering, with special emphasis on groundwater hydrology and chemical fate and transport in the environment. Specific areas of expertise include groundwater modeling, statistical analysis, risk-based site assessment and remediation, exposure analysis and human health risk assessment. He has prepared evaluations of the risk from vapor intrusion into indoor air at numerous sites, including preparing expert reports and giving deposition testimony as an expert witness. He has developed regional groundwater flow and transport models to evaluate remedial alternatives and to estimate cleanup times. Chris is a member of the ITRC Groundwater Statistics and Monitoring Compliance project team. Chris earned a bachelor's degree in 1988 in physics from the University of California at Berkeley, CA. He earned a master's degree in 1996 in technology and policy, a master's degree in 1996 in environmental engineering, and a PhD in 2000 in hydrology and water resource engineering all from the Massachusetts Institute of Technology in Cambridge, MA. He is a professional civil engineer in California.

Liz Simmons is a Senior Principal Geologist and Senior Fellow over the Environmental Site Characterization Practice for Kleinfelder in the San Diego, California office. Liz has worked for Kleinfelder since 1998, and in the environmental field since 1984. Her extensive technical background includes numerous groundwater assessments, risk assessments, modeling, groundwater optimization, and litigation support for sites encompassing industrial facilities, landfills and surface impoundments, oil refinery and underground fuel storage sites, and superfund sites, both in the United States and abroad. As Technical Practice Leader, she is also responsible for providing on-going technical training to Kleinfelder personnel. Liz has been active in the ITRC since 2008, and has been involved with the Contaminated Sediments, Groundwater Statistics and Monitoring Compliance, and Geophysical Classification for Munitions Response workgroups. She earned a bachelor's degree in geology from Brigham Young University in Provo, Utah in 1979, and underwent graduate studies in petroleum geology and geophysics at California State University in Long Beach from 1981-1984. Liz is a registered PG with the California Board for Professional Engineers, Land Surveyors and Geologists.

Randall Ryti is a Senior Scientist with Neptune and Company, Inc. in Los Alamos, New Mexico. Randall was one of the founding partners of Neptune in 1992 and has worked on basic and applied environmental problems, including ecological and human health risk assessment support to the Los Alamos National Laboratory, the Hanford Site, and other clients. These risk assessment projects have addressed environmental contamination including groundwater over large spatial scales with multiple stressors, large and complex databases, and significant involvement of regulators, natural resource trustees, and the public. Randall has also assisted in the planning, decision logic, and statistical design of environmental data collection activities for Environmental Restoration sites at Department of Energy facilities (Hanford, Los Alamos, and Savannah River), Department of Navy Base Realignment and Closure facilities in California, and EPA-lead Superfund sites. Randall has been a member of ITRC teams since 2009 and has been active in the Groundwater Statistics and Monitoring Compliance team starting in 2011. Randall received the Industry Recognition Award from the ITRC in October 2012. Randall earned a bachelor's degree in biology from University of California Los Angeles in 1979 and a PhD in biology from University of California San Diego in 1986. Randall is certified as a Senior Ecologist by the Ecological Society of America.

Are You Drowning in Groundwater Data From Your Sites?

- What data should you use?
- Where do you start?
- What are the data telling you?
- How do you make the best use of your data?

No associated notes.

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Can a Statistical Approach Help to Manage My Groundwater Data?

- If you are not a statistician
  - More informed consumer of statistics
  - Confidence to spot misapplications and mistakes
  - Review selection of tests
  - Understand language of statistics

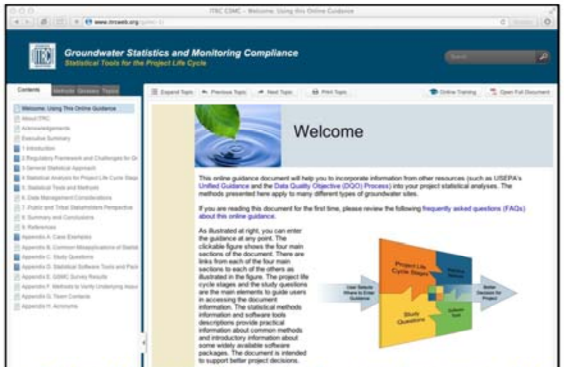
- If you are a statistician
  - Help make your work and conclusions understandable to a general audience

No associated notes.

ITRC Solution

Groundwater Statistics and Monitoring Compliance, Statistical Tools for the Project Life Cycle

- Ask the right questions to apply statistics
- Direct you to an appropriate statistical method
- Maximize the value of the data



http://www.itrcweb.org/gsmc-1/

No associated notes.

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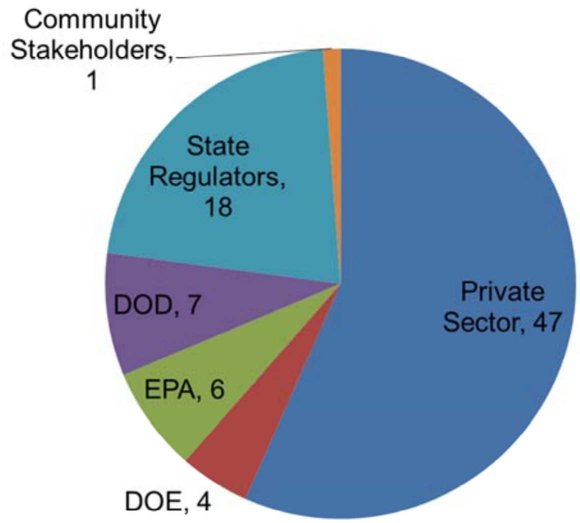
Groundwater Statistics and Monitoring Compliance Team

- Team formed in 2011
- Experts from DOD, EPA, DOE, industry, states, consulting

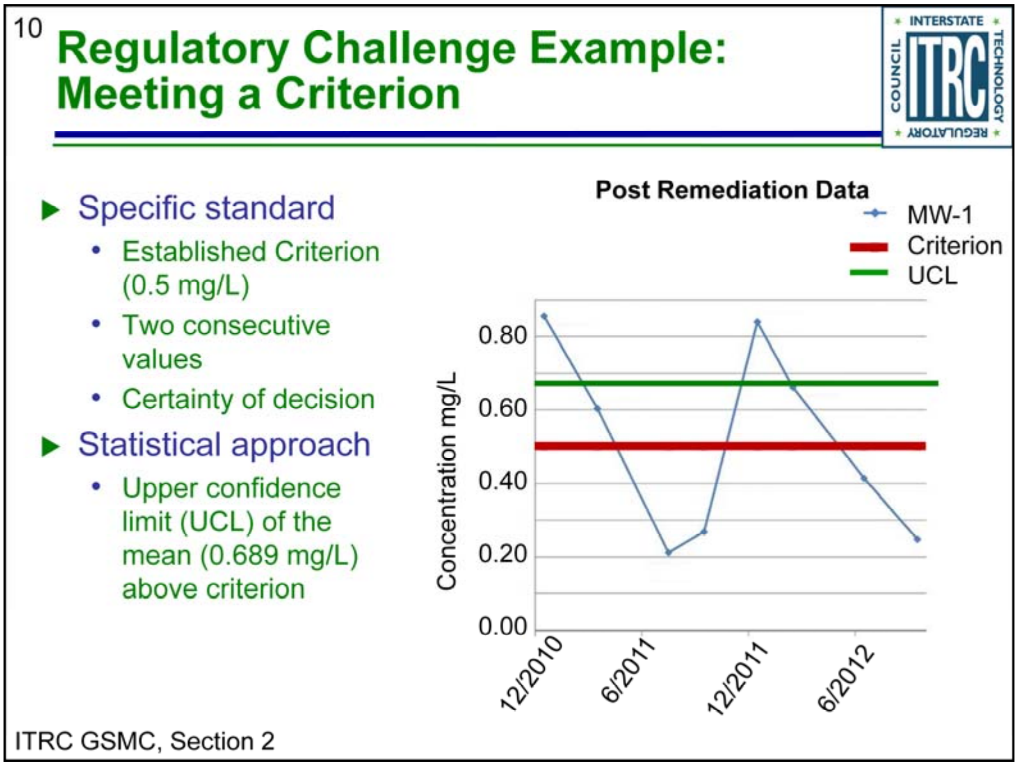


ITRC GSMC-1, Acknowledgements, Appendix G

ITRC formed this team in 2011 to develop the ITRC Groundwater Statistics and Monitoring Compliance document and training.

The team of experts includes

1. State regulators
2. Federal partner experts from DOD, DOE and EPA
3. Consulting community and from industry



Statistically, the upper confidence limit (UCL) is 0.689 mg/L more remediation is needed to be confident the groundwater concentration is below the criterion.

Additional reference for information about groundwater variability: McHugh, T., L. M. Beckley, et al. (2011). "Factors influencing variability in groundwater monitoring data sets." Ground Water Monitoring & Remediation 31(2): 92-101.

Definition of upper confidence limit (UCL): The upper value on a range of values around the statistic (for example, mean) where the population statistic (for example, mean) is expected to be located with a given level of certainty, such as 95% (science-dictionary.org 2013).

See the GSMC-1 document for more glossary items: www.itrcweb.org/gsmc-1

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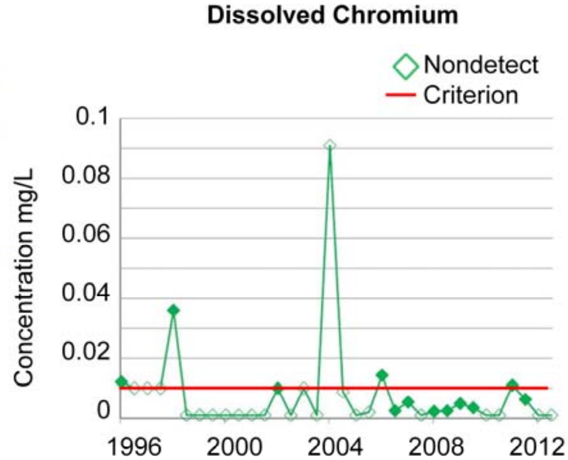
Regulatory Challenge Example: Managing Nondetects/Censored Data

- Multiple values
- Simple substitution
  - Mean = 0.0078 mg/L
  - UCL = 0.0125 mg/L
- Kaplan-Meier
  - Mean = 0.0022 mg/L
  - UCL = 0.0055 mg/L

Upper confidence limit (UCL)



ITRC GSMC, Section 2, Section 5.7

Definition of nondetects: Laboratory analytical result known only to be below the method detection limit (MDL), or reporting limit (RL); see "censored data" (Unified Guidance).

Definition of censored data: Values that are reported as nondetect. Values known only to be below a threshold value such as the method detection limit or analytical reporting limit (Helsel, D.R. 2012)

Helsel, D.R. 2005. Nondetects and Data Analysis. Hoboken, NJ: John Wiley & Sons.

Helsel D.R. 2012. Statistics for Censored Environmental Data Using Minitab and R. 2nd ed. Hoboken, New Jersey: John Wiley & Sons.

USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities." Unified Guidance EPA 530/R-09-007. Washington DC: United States Environmental Protection Agency. http://www.epa.gov/osw/hazard/correctiveaction/resources/guidance/sitechar/gwstats/unified-guid.pdf.

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ITRC Document is for Environmental Project Managers

- You can use the document for a number of project management activities
  - Reviewing or using statistical calculations for reports
  - Making recommendations or decisions based on statistics
  - Demonstrating compliance for groundwater projects

No associated notes.

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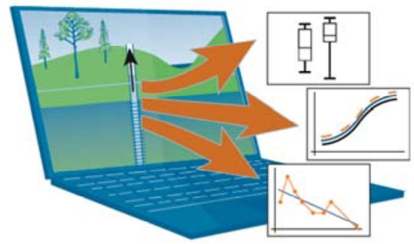
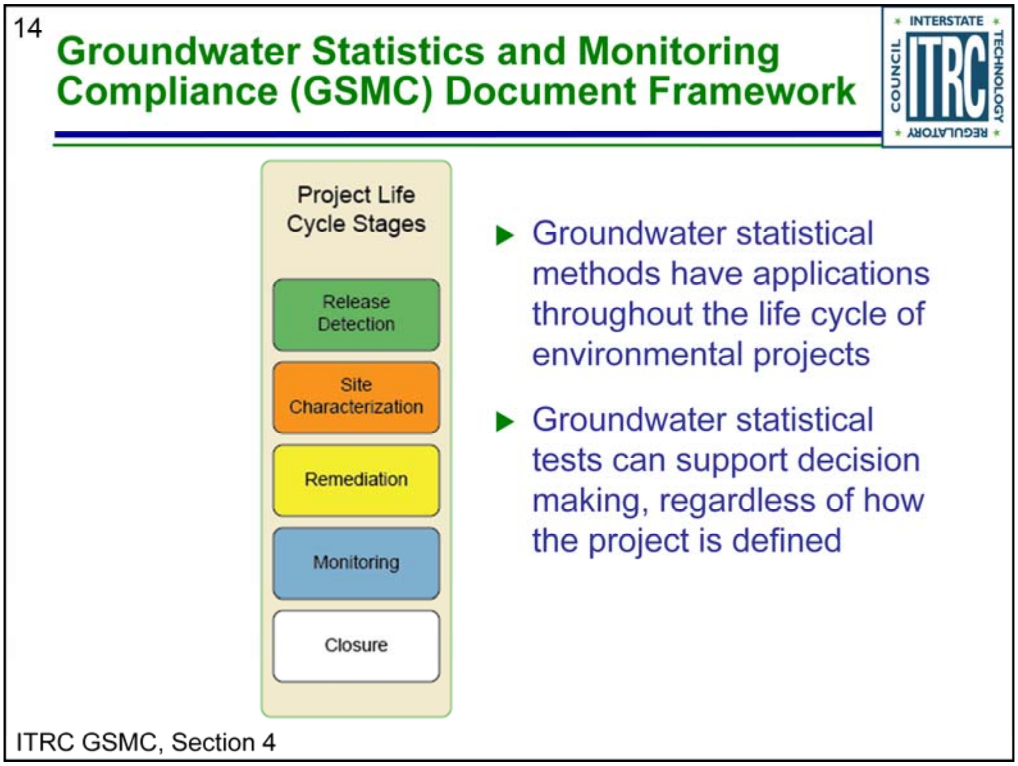
Training Roadmap
What You Will Learn

- How to use the GSMC Document
- Getting Ready to Apply Statistics
- Question & Answer Break
- How to Apply Study Questions for
  - Background
  - Compliance
  - Trend Analysis
  - Monitoring Optimization
- Summary
- Question & Answer Break



No associated notes.



The terminology and framework for the project life cycle stages may vary under different regulatory programs. To simplify the organization of the document the team chose these 5 project life cycle stages.

Groundwater Statistics and Monitoring Compliance (GSMC) Document (GSMC-1)

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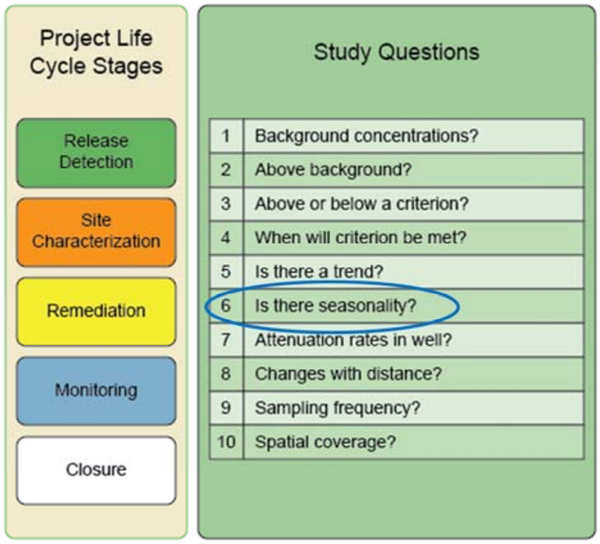
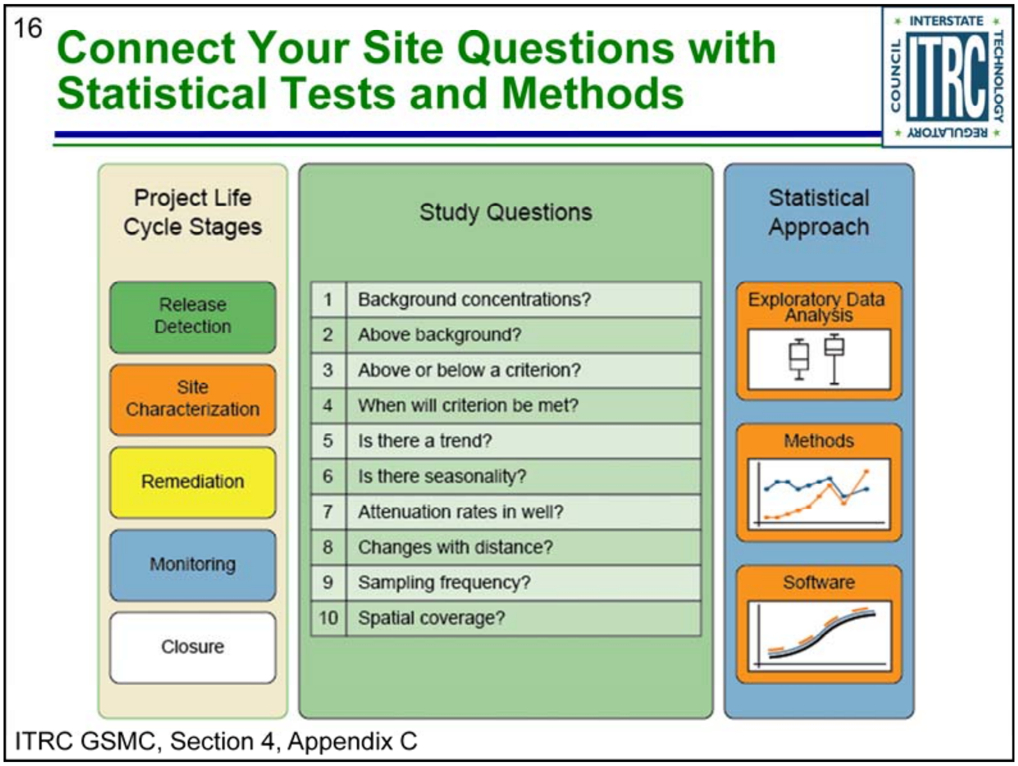
Site Problem Statements Take the Form of Study Questions



- This document explores some of the common problem statements **(Study Questions)** that guide decision making throughout environmental projects

ITRC GSMC, Section 4, Appendix C

No associated notes.



The study questions serve as a bridge to connect life cycle-based activities on your sites with relevant statistical approach (exploratory data analysis, tests, and software) that may assist you with site decisions using groundwater data.

Definition of exploratory data analysis (EDA): An approach for initial data evaluation using graphical methods to open-mindedly explore the underlying structure and model of a dataset to aid in selection of the best statistical methods. Typical techniques are box plots, time series plots, histograms, and scatter plots (Tukey 1977; NIST/SEMATECH 2012; Unified Guidance).

NIST/SEMATECH. 2012. "e-Handbook of Statistical Methods." In. http://www.itl.nist.gov/div898/handbook/ (accessed August 2013).

Tukey, J.W. 1977. Exploratory Data Analysis. Reading, MA: Addison-Wesley.

USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities." Unified Guidance EPA 530/R-09-007. Washington DC: United States Environmental Protection Agency. http://www.epa.gov/osw/hazard/correctiveaction/resources/guidance/sitechar/gwstats/unified-guid.pdf.

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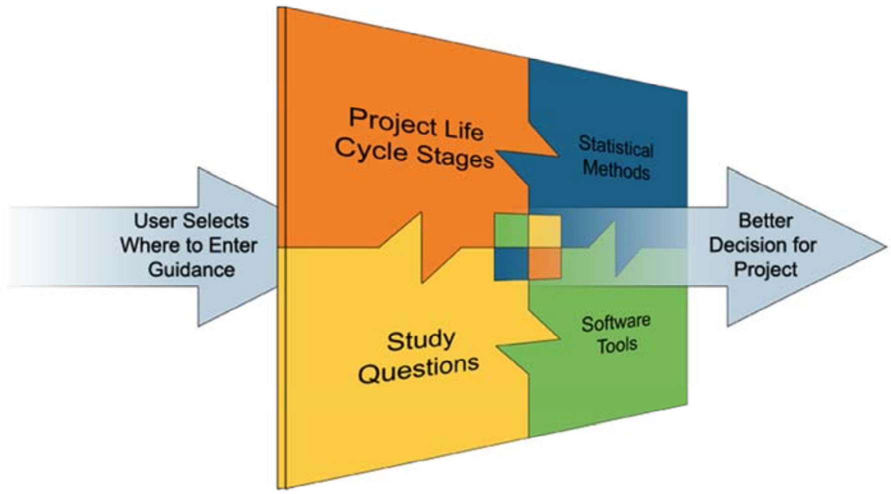
Use the Document To Support Your Site Decisions at any Project Life Cycle Stage

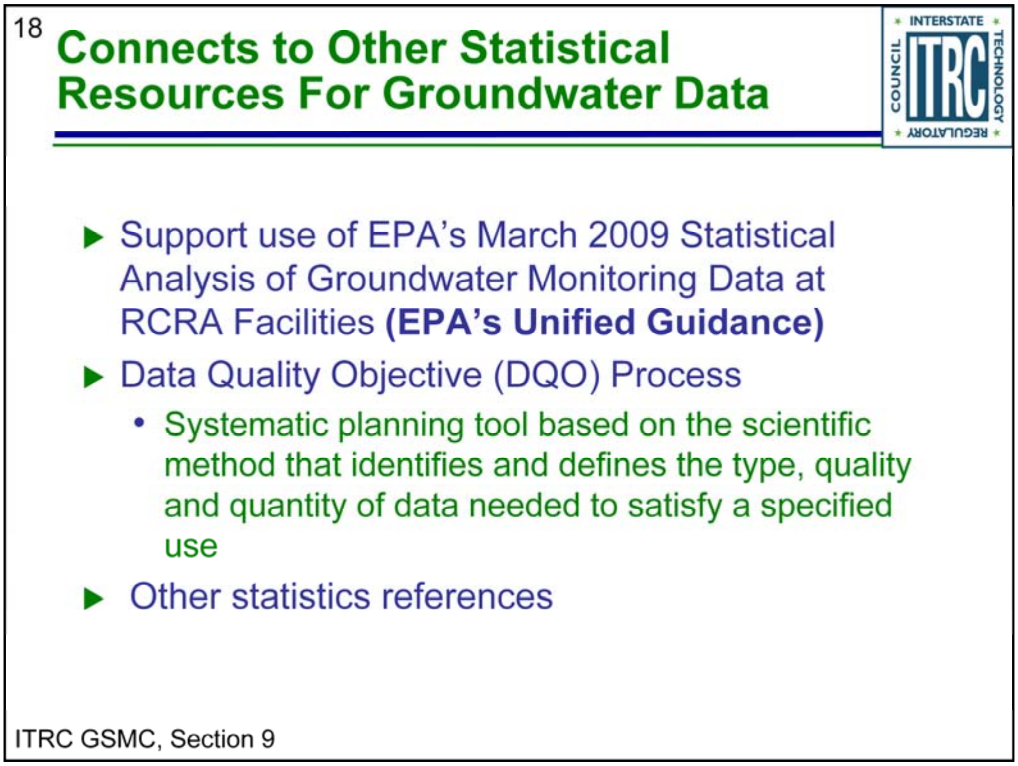


Project Life Cycle Stages (Section 4) Study Questions (Appendix C)
Statistical Methods (Section 5) Software Tools (Appendix D)

The web-based document was designed to be accessed from many different perspectives or sections

All of the sections of the document are interconnected and can be accessed from any other section.

This figure is located on the Welcome screen of the web-based tech-reg document and by clicking on the named parts of the document, you will go to that section of the document.



The team has tried to make this document user friendly for the Project Manager with its cross references and links to the study questions methods, and tools.

This web-based guidance document will help you to incorporate information from other resources

1.Unified Guidance (USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities." In Unified Guidance EPA 530/R-09-007. Washington DC: Unites States Environmental Protection Agency. www.epa.gov)

2.Guidance on Systematic Planning Using the Data Quality Objective Process (USEPA. 2006a. "Guidance on Systematic Planning Using the Data Quality Objectives Process." In EPA QA/G-4. Washington D.C.: United States Environmental Protection Agency. http://www.epa.gov/QUALITY/qs-docs/g4-final.pdf)

3.ASTM documents (for example, ASTM. 2012. Standard Guide for Developing Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs. West Conshohocken, PA: ASTM International)

4.Textbooks on groundwater statistics (for example, Gibbons, R.D. 1994. *Statistical Methods for Groundwater Monitoring*. New York: John Wiley & Sons)

5.Other guidance documents on the DQO process (for example, United States Army Corp of Engineers (USACE). 1998. "Environmental Quality, Technical Project Planning (TPP) Process." EM 200-1-2. Washington, D.C.: Department of the Army. www.usace.army.mil/missions/environmental/technicalprojectplanning.aspx.)

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Training Roadmap

- How to use the GSMC Document
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- How to Apply Study Questions for
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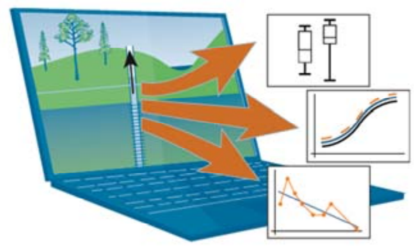
  - Compliance
  - Trend Analysis
  - Monitoring Optimization
- Summary
- Question & Answer Break



This next section reviews the major elements of the statistical approach applied to groundwater data.

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What Use Is Statistics?

- Statistics is the science of drawing conclusions from data
  - Visualize and understand data
  - Separate signal from noise
  - Summarize large-scale behavior
  - Quantify uncertainty
  - Make better and more defensible decisions
- This section reviews the major elements of the statistical approach applied to groundwater data

No associated notes.

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Hypothesis Testing: Guilty or Not Guilty?

- Crime: Burglary (laptop)
- Defendant: Mr. Ivan M. Shifty
- Assume defendant is not guilty (null hypothesis)
- Present evidence (fingerprints, stolen goods)
- Prove guilt beyond a reasonable doubt?
- We want to avoid errors
  1. Shifty is innocent but goes to jail (false positive)
  2. Shifty is guilty but goes free (false negative)

No associated notes.

Decision Errors

Site characterization phase of life cycle

Null hypothesis H_0: Site groundwater is NOT contaminated

True State of Site	Decision based on statistical sample: H_0: Site Not Contaminated	Decision based on statistical sample: H_A: Site Is Contaminated
Not Contaminated	**Correct Conclusion** (Probability = 1-α)	**False Positive** (Probability = α) Significance Level
Contaminated	**False Negative** (Probability = β)	**Correct Conclusion** (Probability = 1-β) Power

ITRC GSMC-1, Section 3.6.1

See also USEPA. 2006a. "Guidance on Systematic Planning Using the Data Quality Objectives Process." In EPA QA/G-4. Washington D.C.: United States Environmental Protection Agency. http://www.epa.gov/QUALITY/qs-docs/g4-final.pdf. for more information (Table 7)

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Statistical Decision-Making

- When making statistical decisions, we should consider both types of errors
  - One error type may be more important to avoid
- "Statistical significance"
  - Small chance that result is a false positive
- Selecting significance level (α)
  - Medicine: 1 in 20 (5%) Physics: 1 in 3.5 million
- False negative error (β) / Power ($1-\beta$)
  - Depends on variability, sample size, effect size
  - Remember to check power if null is not rejected

No associated notes.

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Key Aspects

- What are the key aspects of a statistical approach?
  - Develop a conceptual site model
  - Conduct exploratory data analysis
  - Design statistical sampling plan
  - Evaluate statistical evidence and uncertainty
  - Check statistical assumptions

ITRC GSMC-1, Section 3

All of these concepts are discussed in Section 3 of the web-based guidance document www.itrcweb.org/gsmc-1

Purpose of using a statistical approach is to make better, more defensible decisions (for example, has the site impacted groundwater?).

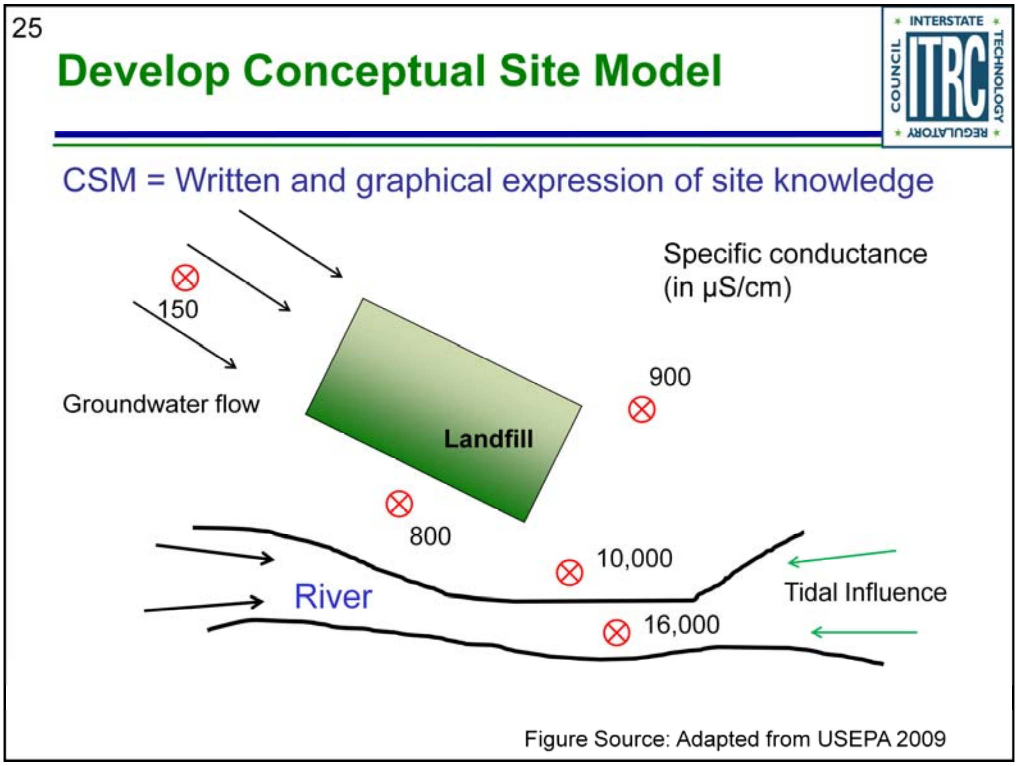


Figure Source: USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities." In Unified Guidance EPA 530/R-09-007. Washington DC: United States Environmental Protection Agency. www.epa.gov

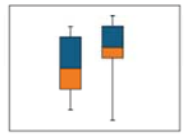
A CSM summarizes the potential contaminant sources and transport pathways through the subsurface. For example, here is a landfill situated near a stream. Groundwater flows under the landfill toward the stream. We want to look at specific conductance to see whether the landfill is leaking. But in this case, there is another potential source of chloride to groundwater—the stream is tidally influenced. Importance of getting the CSM right is crucial to doing good statistics.

CSM: Example

- Was there a release from the landfill?
- To answer, we statistically evaluate specific conductance (along with other parameters)
- Two possible approaches:
  - Interwell testing (compare **multiple site wells**, potentially affected vs. background wells)
  - Intrawell testing (compare results in **one well** over time)
- Based on CSM, one approach might be better

No associated notes.

Conduct Exploratory Data Analysis



- All data should be plotted!
- The top 5 plots to use:
  - Time series plot – trends, inconsistencies
  - Box plot – comparing groups, distributions, outliers
  - Scatter plot – association between variables
  - Histogram – distribution
  - Probability plot –distribution, outliers

No associated notes.

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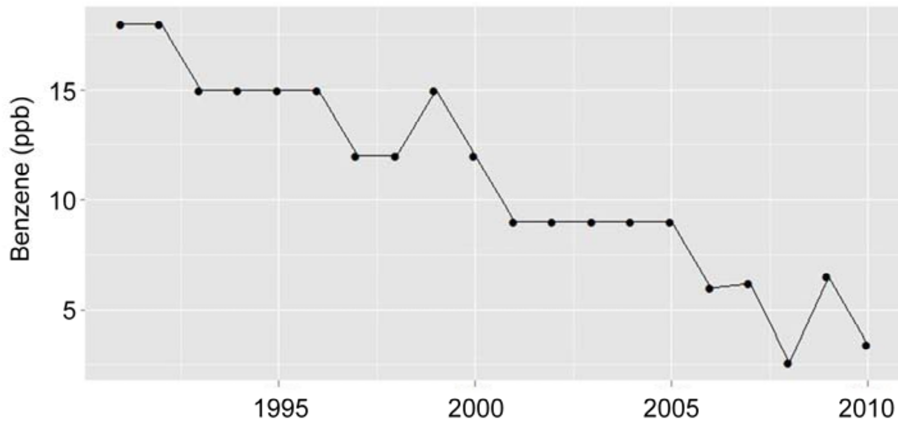
Time Series Plots

- Plot time series to look for possible trends and outliers



ITRC GSMC-1, Section 3

Another important aspect of conducting a good statistical evaluation is exploratory data analysis (EDA). This is nothing more than taking a good hard look at the data, particularly using graphs that show clearly what’s going on.

For example, we often want to look at trends. According to this plot, benzene concentrations at a well appear to be going down over time.

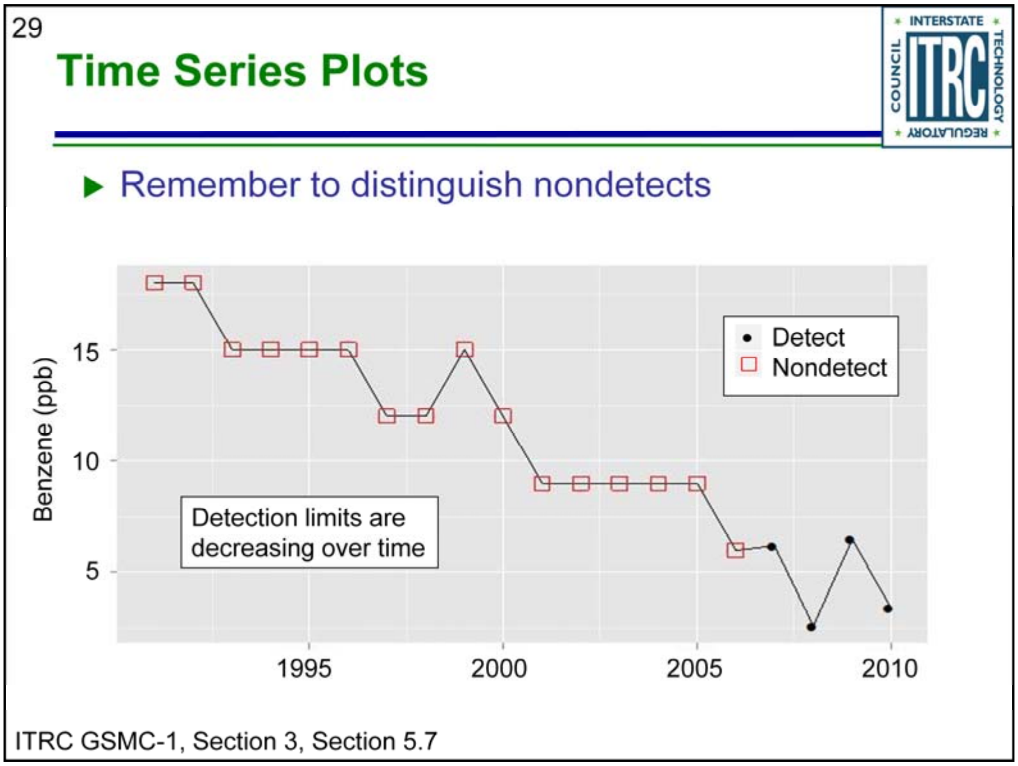
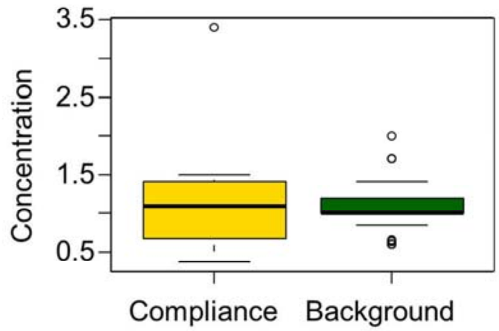


Figure 5-14 Example time series plot of benzene data with nondetects.

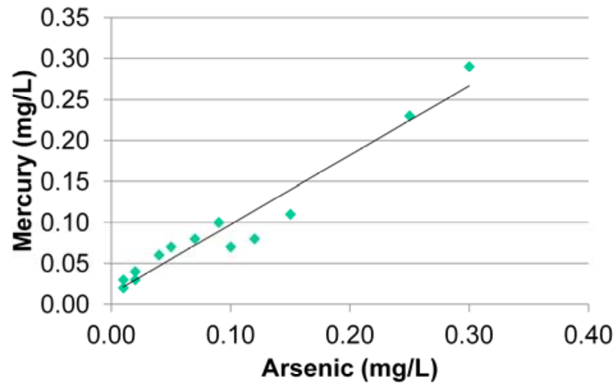
Box Plots Compare Groups

- Box plot components:
  - Line - median
  - Box - (75%-25%)
  - Whiskers
  - Circles - extreme values
- Shows central tendency, spread, and outliers



Understand your data; see what your data set is telling you. The side-by-side box plots show that the data sets have similar buy not equal variances. It is fairly common that data from a compliance well will have a larger variance than data from a background well.

Scatter Plot



Scatter plots show the relationship between two variables, such as concentrations measured in a single well.

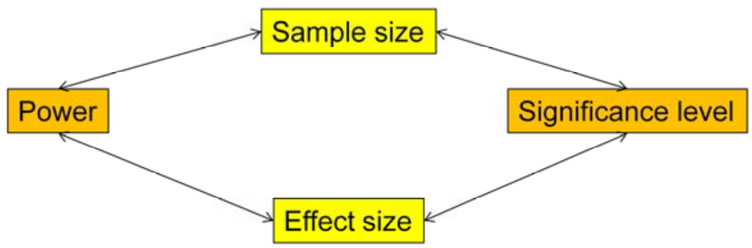
ITRC GSMC, Section 5.1

Figure Source: Adapted from USEPA 2009

Figure Source: USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities." In Unified Guidance EPA 530/R-09-007. Washington DC: United States Environmental Protection Agency. www.epa.gov

Design Statistical Sampling Plan

- Planning for statistical decisions
  - Select sampling plan to control decision errors (prior to sampling)
  - Understand statistical power achieved (after sampling)
- Understand design tradeoffs



ITRC GSMC-1, Section 3

Every decision using real data involves uncertainty. Did we conclude the site was impacting groundwater when it really wasn't (false positive)? Or perhaps the site was a source of groundwater contamination and we didn't see it because there wasn't enough data (false negative). The best way to control these potential errors is through up front planning through a quality assurance project plan or something similar.

Sometimes we can't plan ahead. We can still use the same statistical tools to help us understand the level of uncertainty.

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Evaluate Statistical Evidence

- Hypothesis testing
  - Null hypothesis (e.g., not guilty) versus alternative hypothesis (e.g., guilty)
  - Is there sufficient evidence to reject the null hypothesis (burden of proof)?

- Choice of null hypothesis depends on purpose
  - Do site concentrations exceed background?
  - Have cleanup goals been achieved?
  - Is there a trend in concentrations?

ITRC GSMC-1, Section 3, 5

No associated notes.

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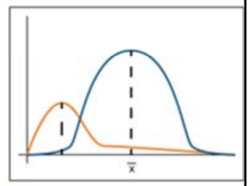
Hypothesis Testing



The Steps:

1. Define your hypotheses (null, alternative)
2. Compute the test statistic from the data under the assumption that the null is true
3. Calculate the probability (p-value) of what was observed if null were true
4. Make a decision
   - Reject null hypothesis if p-value is less than significance level of test (α)
   - Fail to reject the null and verify power of test

No associated notes.

Value of p-values

- All test statistics (and p-values) measure the discrepancy between what you actually observe and what you'd expect to see if the null is true
- Could these data have arisen solely due to natural variability?
  - P-value measures the strength of the evidence against the null hypothesis
  - Lower p-values represent stronger evidence (it's less likely null is true)

No associated notes.

Describing Uncertainty

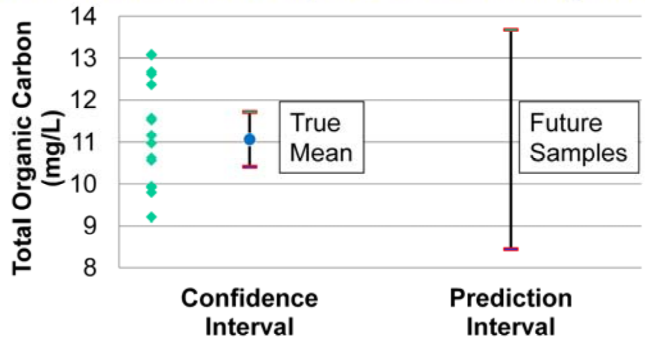
"The mean concentration is 5.1 mg/L."

- How reliable is this estimate?
- Statistical Intervals
  - Use an interval ("error bars") to show reliability
  - Types: confidence, prediction, tolerance
- Confidence level (1-α) of the interval (e.g., 95%)
  - Probability that interval will include the value of interest
  - Hypothesis tests can be formulated using intervals

No associated notes.

Confidence and Prediction Intervals

- Confidence intervals show uncertainty in statistics calculated from existing data (means, medians, slopes)
- Prediction intervals are used to evaluate how consistent future samples are to existing data



ITRC GSMC-1, Section 5

Confidence intervals are often used when comparing mean groundwater concentrations to fixed standards such as maximum contaminant levels (MCLs). Prediction intervals are often used for detection monitoring at RCRA facilities to determine whether future samples are consistent with background concentrations.

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How to Select and Test the Null Hypothesis

Release Detection/ Site Characterization

- Site is assumed to be clean unless proven otherwise
- Hypothesis:
  - Null: Mean ≤ MCL
  - Alt: Mean > MCL
- Confidence interval test:
  - Reject if lower confidence limit on mean > MCL

Corrective Action/ Remediation

- Site is assumed to be contaminated unless proven otherwise
- Hypothesis:
  - Null: Mean ≥ MCL
  - Alt: Mean < MCL
- Confidence interval test
  - Reject if upper confidence limit on mean < MCL

No associated notes.

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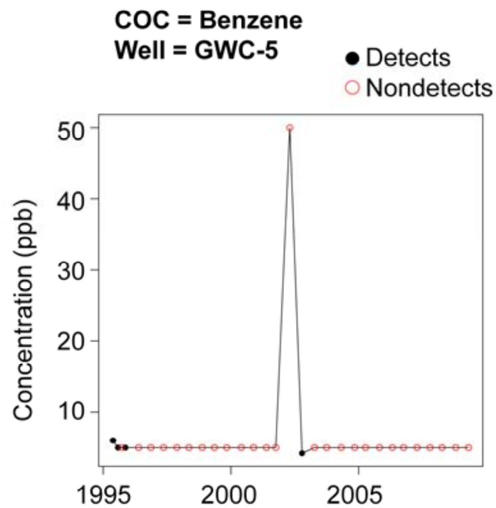
Test Assumptions

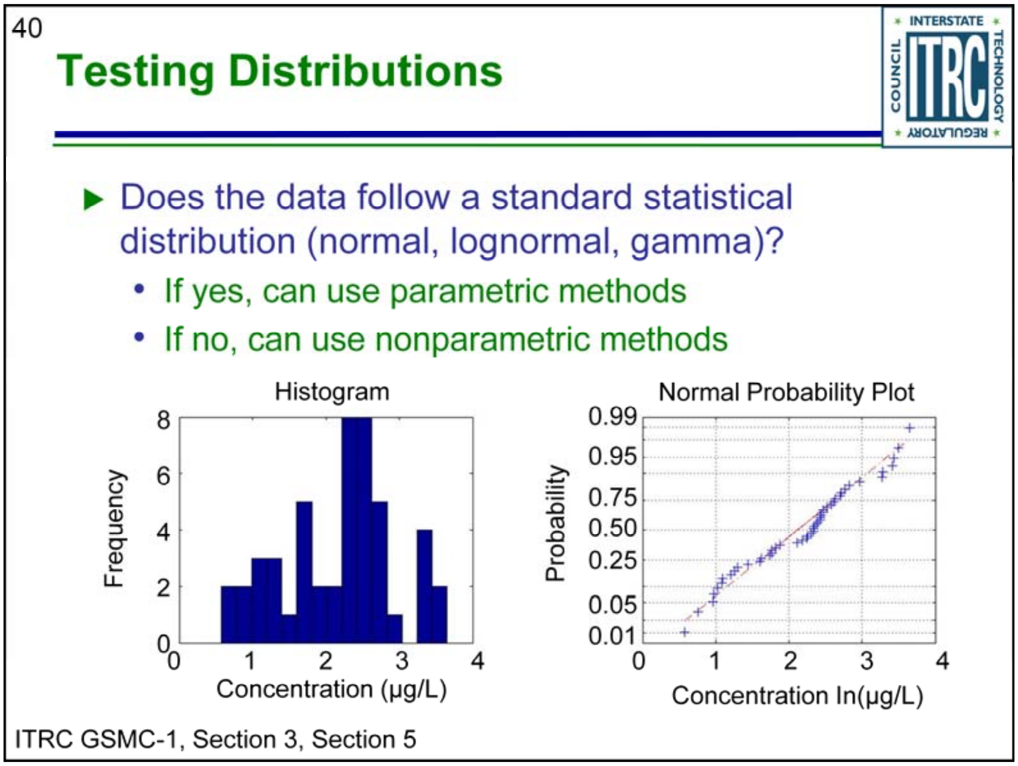
- Testing for outliers
  - Outliers can dramatically skew statistical limits



ITRC GSMC-1, Section 3, Section 5

Figure Source: Kirk Cameron, Ph.D.

All statistical tests are based on some sort of simple model of reality. The statistical model never matches reality exactly, but we need to check that the assumptions of the model are more or less satisfied. For example, the presence of outliers can wreck havoc with statistical tests. These extreme values should be identified and investigated – just a typo, lab error, or maybe real.



Another common assumption is that of normality. Do the data follow a bell curve? If not, then non-parametric approaches should be favored.

Figure A.5 from the web-based document.

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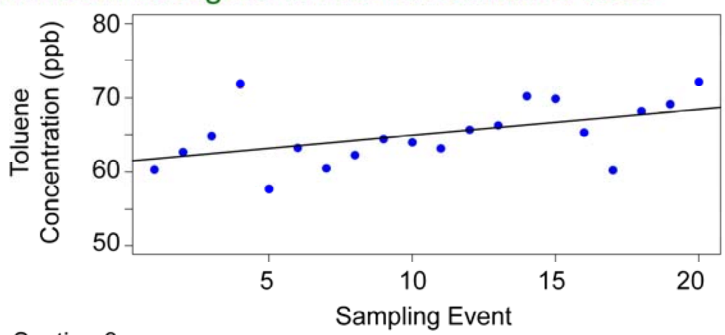
Other Assumptions

- Spatial/temporal independence
  - Don't sample too often!
  - Replicates/duplicates not independent
- Background stability
  - Trends in background rule out standard tests



ITRC GSMC-1, Section 3

Figure Source: Kirk Cameron, Ph.D.

Temporal independence– standard tests assume independence; positively correlated data tend to underestimate true variance; can lead to wrong decisions

Advice– don't sample too often; quarterly sampling just a rule of thumb; run a pilot study to get site-specific sampling frequency

Background stability/stationarity– standard tests assume a stationary mean in background; variance will be overestimated and significant changes missed if trends are not accounted for

Advice– switch to trend test or remove effect of trend first

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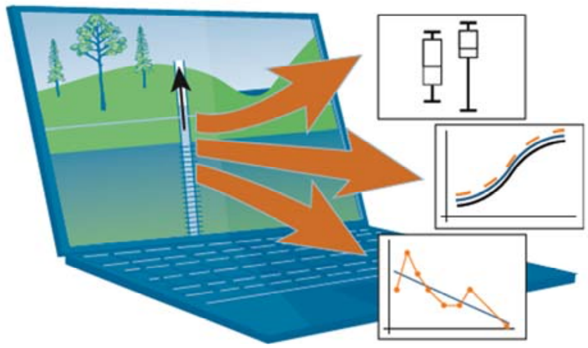
Closing Thoughts on Getting Ready to Apply Statistics

- Plot the data
- Are there sufficient data to make a good decision with appropriate error rates?
- Confirm regulatory requirements
- Use results of statistical analyses with other lines of evidence
- "If you torture the data long enough, it will confess to anything."

No associated notes.

Question & Answer Break

Follow ITRC



No associated notes.

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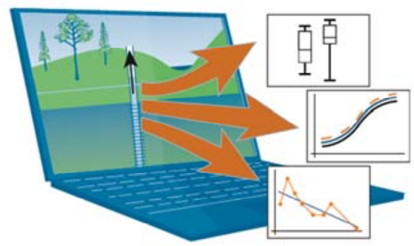
Training Roadmap

- How to use the GSMC Document
- Getting Ready to Apply Statistics
- Question & Answer Break
- How to Apply Study Questions for
  - Background
  - Compliance
  - Trend Analysis
  - Monitoring Optimization
- Summary
- Question & Answer Break



No associated notes.

45

Connecting Life Cycle Stages and Study Questions

Release Detection	Site Characterization	Remediation	Monitoring	Closure		Study Questions
X	X			X	1	Background concentrations?
X	X		X	X	2	Above background?
X	X	X	X	X	3	Above or below a criterion?
		X	X	X	4	When will criterion be met?
		X	X	X	5	Is there a trend?
		X	X	X	6	Is there seasonality?
		X	X	X	7	Attenuation rates in wells?
		X	X	X	8	Changes with distance?
		X	X	X	9	Sampling frequency?
X	X	X	X	X	10	Spatial coverage?

Project Life Cycle Stages

ITRC GSMC-1, Section 4, Appendix C

We use the project life cycle stages and the study questions to illustrate the connections to the example information for the hypothetical sites.

Project life cycle stages are shown as columns. The study questions are listed on the right. The study questions that generally apply to each of the life cycle stages are noted with the X's in the table on the left. In the web-based document this connection between life cycle stages and study questions is used to help the reader find information that is relevant for their particular site.

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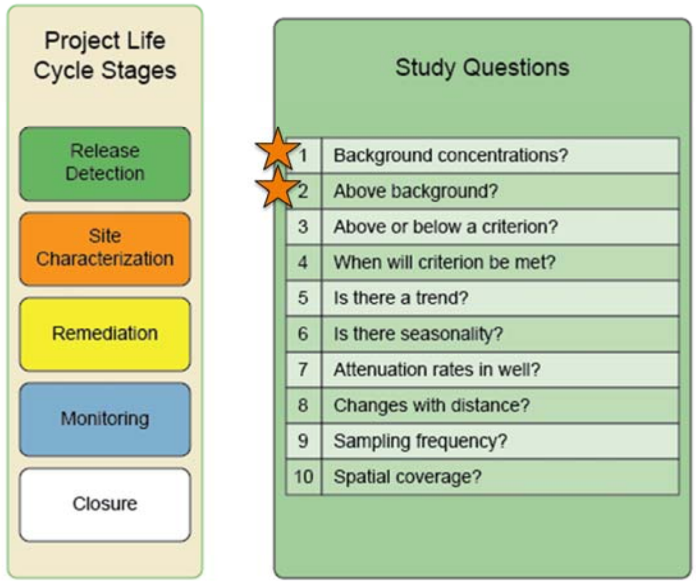
Background

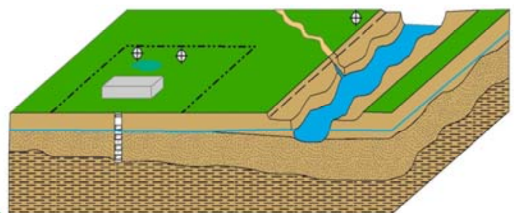


ITRC GSMC-1,
Section 4,
Appendix C

Two of the 10 questions are directly related to background.

Background

- What is background?
  - Groundwater not influenced by site
- Basis of background
  - Site related vs. not site related
  - Regulatory threshold
  - Published literature
- Wells
  - One well many times - Intrawell
  - Many wells - Interwell

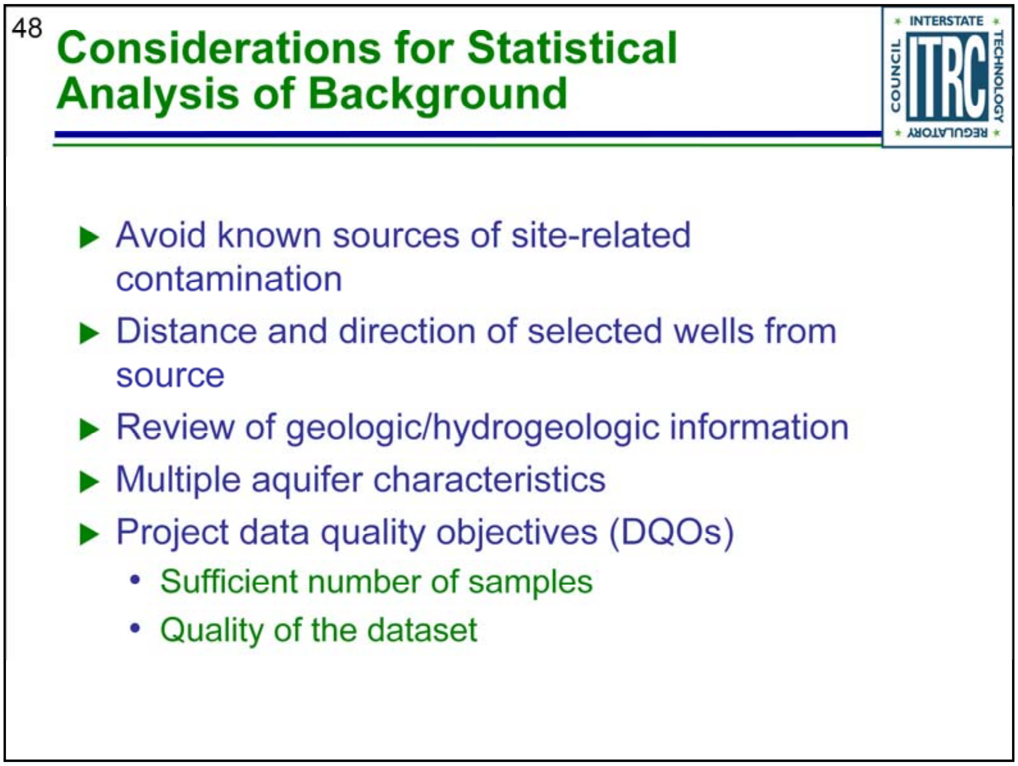


Site related vs. not site related: In general, both native and man-made sources need to be taken into account; however, a baseline must be established, because groundwater may already be tainted with concentrations of a contaminant from either native or man-made sources that would make it difficult, if not impossible, to clean up to a "pristine" standard. The web-based guidance document addresses this in more detail.

Intrawell vs. Interwell (see Slide 31)

Intrawell – Sample one well many times and compare

Interwell – Sample many wells many times and compare



DQOs – should be developed up front

Sufficient samples to provide reliable results

Quality of dataset (multiple detection limits)

A good CSM model should be developed to maximize the validity of your assumptions.

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EDA for Background

- Use of EDA (Exploratory Data Analysis) in selection of background wells (section 3.3.3, section 3.5)
  - Inspecting sample data – assess dataset quality
    - Multiple detection limits
    - Analytical methods (e.g., EPA methods 8020, 8021, 8260)
  - Graphical plots of sample data – assess shape of the dataset (section 5.1)
  - Determine the distribution of the sample data
    - Parametric or non-parametric (section 5.6)
    - Outliers (section 5.10)

ITRC GSMC-1, Section 3, 5

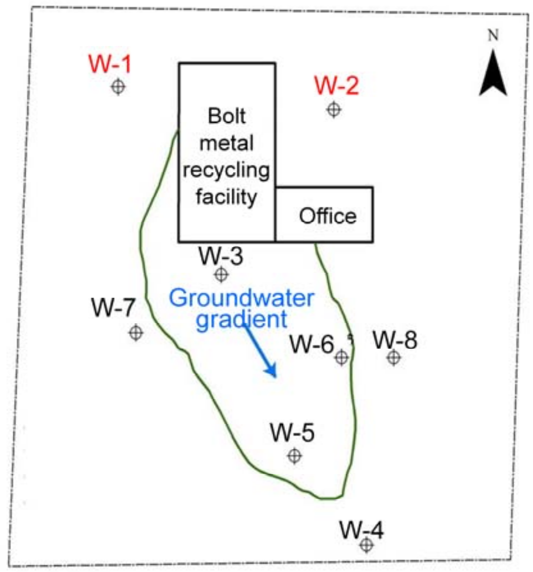
Use Exploratory Data Analysis methods to help evaluate a potential background dataset.

To get a quick visual, use graphical methods such as histograms, quartile plots, box plots or scatter plots to plot the dataset and evaluate the shape of the dataset to provide insight into the overall spread and potential distribution of the data.

Distribution of the dataset will help you determine whether parametric or non-parametric (doesn't fit normal distribution) statistical methods will be needed in your evaluation of background. For example, t-test (parametric) is sensitive to outliers.

Background Example

- Study Question 1: What are background concentrations?
- Study Question 2: Are concentrations greater than background concentrations?
- Metal recycling facility
  - Arsenic
  - Determine preliminary background wells for evaluation based on CSM



Property boundary
Shallow groundwater plume
Monitoring well

This example site shows a site with a groundwater plume and wells located upgradient (W-1 and W-2), side-gradient (W-7 and W-8) and down-gradient (W-3, W-4, W-5 and W-6) from the plume. It will be used to show how potential background well data can be evaluated to determine whether the dataset can be used to characterize background.

Background Example Dataset

- Identify a dataset
- Number of samples
- Address nondetects

Arsenic (μg/l)		
Date	W-1	W-2
1/2009	2.9	3.1
4/2009	3.1	4.9
7/2009	2.6	2.6
10/2009	2.4	2.5
1/2010	2.7	3.2
4/2010	3.0	7.5
7/2010	2.6	2.8
10/2010	2.5	2.8
1/2011	2.7	3.5
EPA Drinking Water MCL = 10 μg/l		

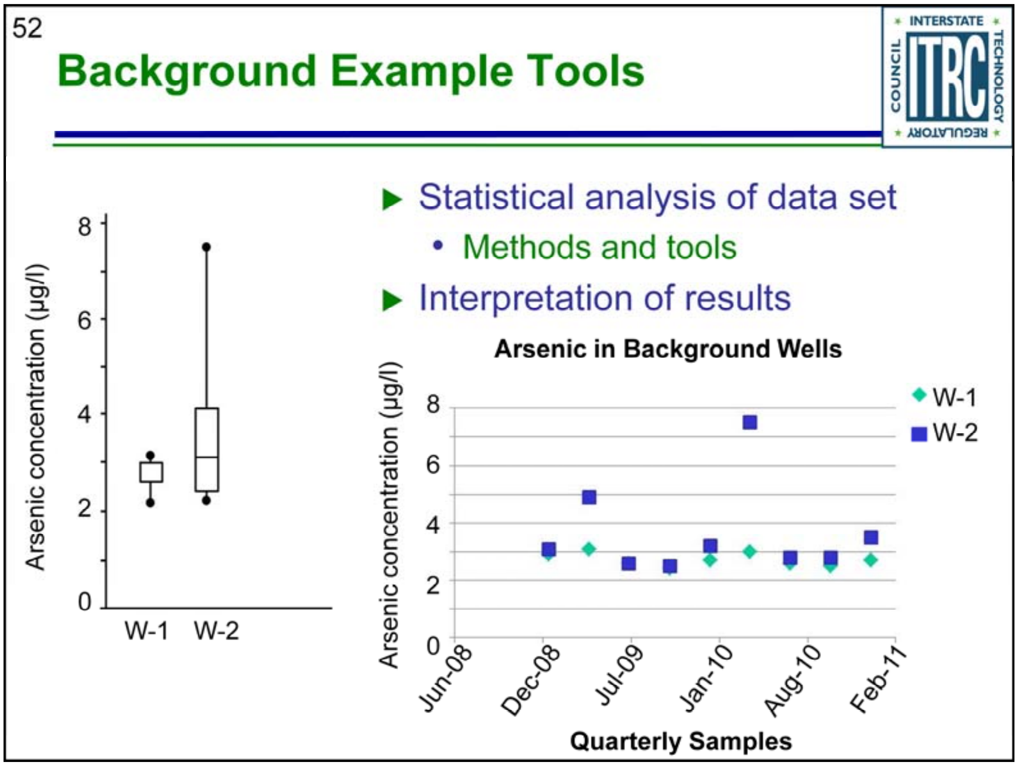
To identify whether a dataset that would be consistent with background:

Select a potential dataset - evaluate quality, shape and distribution. Outliers?

What are the DQOs - how do they apply to number of samples?

Are there non-detects (in this case, no)?

Both upgradient wells are below the MCL.



Methods and tools to do preliminary statistical analysis:

Probability Plots (Section 5.1.5), Time Series Plots (Section 5.1.1), Outlier Identification (Section 5.10)

Interpretation of Results:

Understanding the source of variation (natural or man made, site related or not site related)

Temporal changes

Presence of outliers

Does your CSM need to be revised?

Training Roadmap

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  - Compliance
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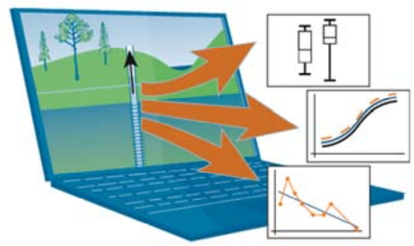
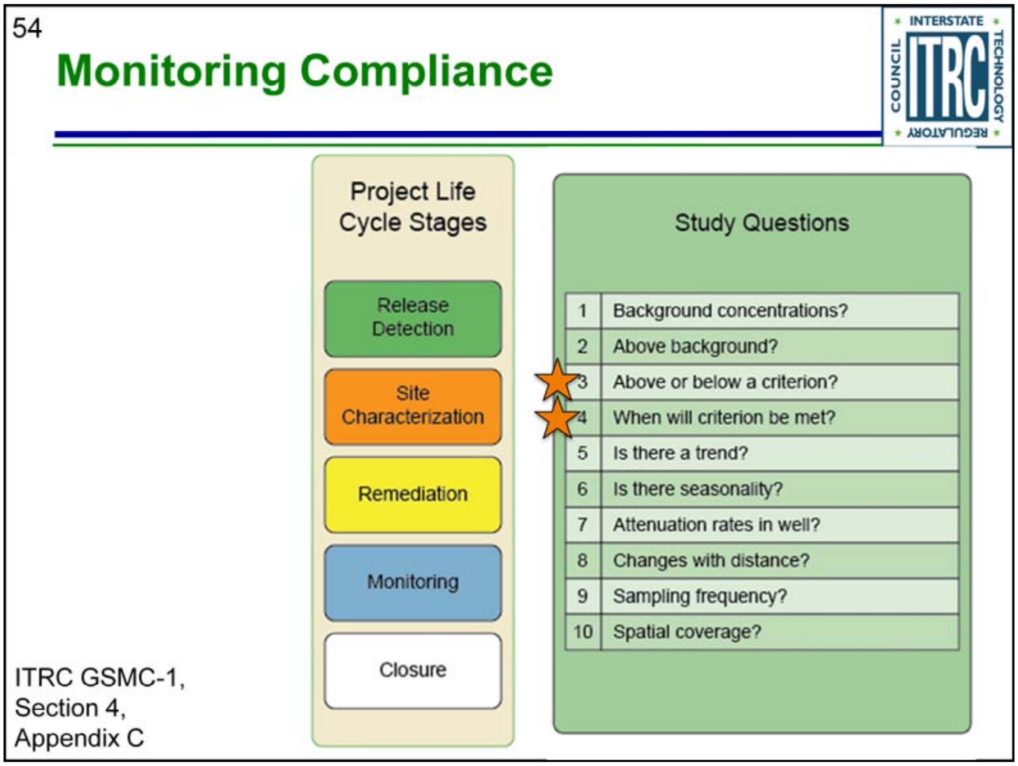
- Summary
- Question & Answer Break



No associated notes.



Two of the 10 questions are directly related to compliance.

Question 4 deals with when a particular criterion will be met, which is not considered in the IBT. Please refer to the web-based document for more information on Question 4.

Why Monitoring Compliance?

- Why monitoring?
  - Evaluate site characteristics
  - Evaluate chemical concentrations for compliance with groundwater protection criteria
- Monitoring design
  - Evaluate chemicals present over time
  - Identifying a release
  - Develop conceptual site model
  - Compliance with regulatory requirements

No associated notes.

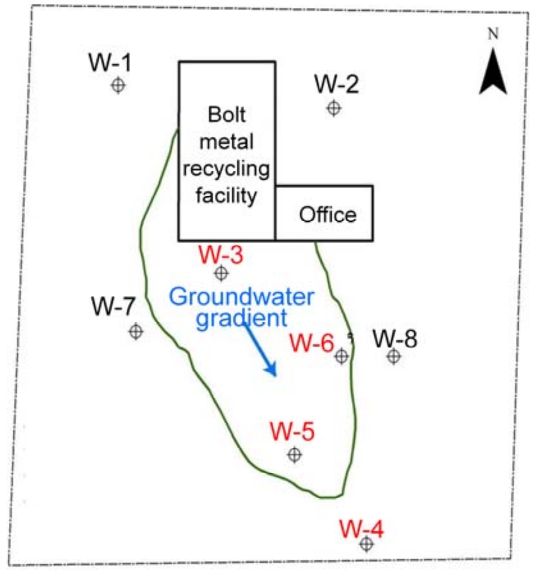
Basis of Monitoring Compliance

- Groundwater criteria compliance
  - MCL
  - Background
  - Risk-based value
  - Ecological protection value
- Basis of compliance
  - Number of samples
  - Distribution
  - Regulatory threshold
  - What is the compliance point?

No associated notes.

Monitoring Compliance Example

- Study Question 3: Are concentrations above or below a criterion?



Property boundary
Shallow groundwater plume
Monitoring well

Determined that wells W-1 and W-2 are background wells. Based on our CSM, wells W-7 and W-8 are side gradient.

For this question, focusing on wells W-3, W-4, W-5 and W-6, within the plume and/or downgradient of the suspected source.

Monitoring Compliance Dataset

- Is the site in compliance? Are chemical concentrations less than or greater than a criterion?
  - Selection of data set
  - Statistical analysis of data set
    - Methods and tools
  - Interpretation of results
  - Uncertainty

Arsenic (μg/l)				
Date	W-3	W-6	W-5	W-4
1/2009	78	23	11.9	2.9
4/2009	79	28	10.9	3.0
7/2009	66	22	9.1	2.7
10/2009	67	21	8.5	2.6
1/2010	90	26	11.1	2.7
4/2010	89	27	11.4	2.8
7/2010	73	25	9.4	2.4
10/2010	70	24	9.2	2.3
1/2011	72	26	10.8	2.6
EPA Drinking Water MCL = 10 μg/l				

Although W-3 and W-6 are several times the MCL and W-4 is below the MCL, you may think you might not need statistics. Misconception. There is always uncertainty in the results.

Monitoring Compliance Dataset

- Is the site in compliance? Are chemical concentrations less than or greater than a criterion?
  - Selection of data set
  - Statistical analysis of data set
    - Methods and tools
  - Interpretation of results
  - Uncertainty

Arsenic (μg/l)				
Date	W-3	W-6	W-5	W-4
1/2009	78	23	11.9	2.9
4/2009	79	28	10.9	3.0
7/2009	66	22	9.1	2.7
10/2009	67	21	8.5	2.6
1/2010	90	26	11.1	2.7
4/2010	89	27	11.4	2.8
7/2010	73	25	9.4	2.4
10/2010	70	24	9.2	2.3
1/2011	72	26	10.8	2.6
EPA Drinking Water MCL = 10 μg/l Data are measured values				

No associated notes.

Monitoring Compliance Dataset

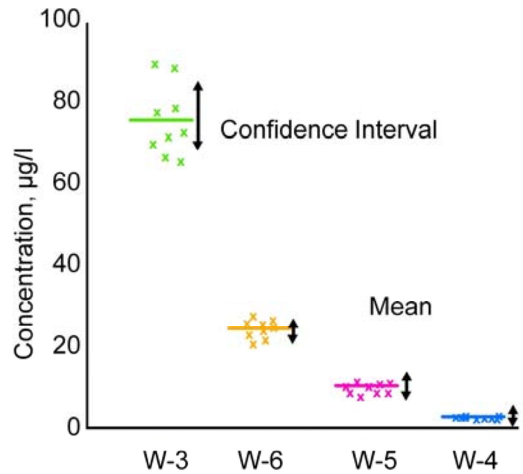
- Is the site in compliance? Are chemical concentrations less than or greater than a criterion?
  - Selection of data set
  - Statistical analysis of data set
    - Methods and tools
  - Interpretation of results
  - Uncertainty

Arsenic (μg/l)				
Date	W-3	W-6	W-5	W-4
1/2009	78	23	11.9	2.9
4/2009	79	28	10.9	3.0
7/2009	66	22	9.1	2.7
10/2009	67	21	8.5	2.6
1/2010	90	26	11.1	2.7
4/2010	89	27	11.4	2.8
7/2010	73	25	9.4	2.4
10/2010	70	24	9.2	2.3
1/2011	72	26	10.8	2.6
EPA Drinking Water MCL = 10 μg/l				

No associated notes.

Confidence Intervals in Compliance

- Important concept – confidence intervals
  - Mean
  - Percentile
  - Variability
  - Parametric vs. Nonparametric



Many kinds of confidence intervals

Mean (average) is a typical confidence measure.

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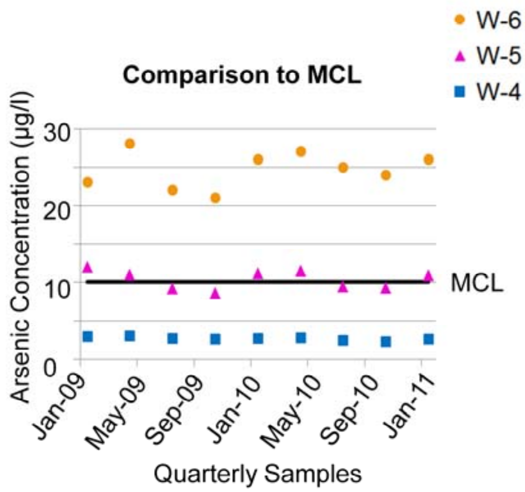
Monitoring Compliance State Guidance Example

- What is clean?
  - 95UCL W-6 = 25.4
  - 95UCL W-5 = 12.7
  - 95UCL W-4 = 3.1
- The consequence of the limit
- The consequence of the distribution



This site is in the State of Washington, and we must use guidance that has been designed by the state. This is one method, and it doesn't match up with what is in the Unified Guidance. In the web-based document we identify the topic areas where programs are likely to have guidance (see Section 2.2.1)

What is considered clean is most-often determined by the regulatory program (under law, regulation or guidance). Those requirements may not have a statistical basis.

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Monitoring Compliance State Guidance Example

State of WA Guidance

- 95UCL of mean < MCL?
- Max data value < 2X MCL
- Are 10% of the data > MCL?

Arsenic (μg/l)	W-3	W-6	W-5	W-4
SD	8.8	2.4	1.2	0.2
Mean	76.0	24.7	10.3	2.7
Confidence (0.05)	5.8	1.5	0.8	0.2
UCL	83.8	25.4	12.7	3.1
Max Data Value	90	28	11.9	3.0
10% Data >MCL	Yes	Yes	Yes	No
	OUT	OUT	OUT	*IN*

MCL 10 μg/l

In = In Compliance
Out = Out of Compliance

Data from wells W-3, W-6, W-5 and W-4 were evaluated using the State of Washington compliance test:

- Is the upper 95% CI on mean less than the cleanup standard?
- Is the maximum data point value less than 2x the cleanup standard?
- Are 10 Percent of the data above the cleanup standard?

1. For W-3, that would be no, no and yes, so not clean
2. For W-6, that would be no, no and yes, so not clean
3. For W-5, that would be no, yes, and yes, so not clean
4. For W-4, that would be yes, yes, and no, so clean

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Monitoring Compliance RCRA Example

- 40 CFR 264.99 evaluation using USEPA's *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance* (2009)

Arsenic (μg/l)	W-3	W-6	W-5	W-4
SD	8.8	2.4	1.2	0.2
Mean	76.0	24.7	10.3	2.7
Confidence (0.05)	5.8	1.5	0.8	0.2
UCL	83.8	25.4	12.7	3.1
LCL	70.2	23.1	9.5	2.5
	OUT	OUT	*IN*	*IN*

MCL 10 μg/l

In = In Compliance
Out = Out of Compliance

As referenced in the web-based document, when looking at a RCRA situation (based on 40 CFR 264.99), the US EPA's Unified Guidance document is typically used.

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Training Roadmap

- How to use the GSMC Document
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- Question & Answer Break
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  - Compliance
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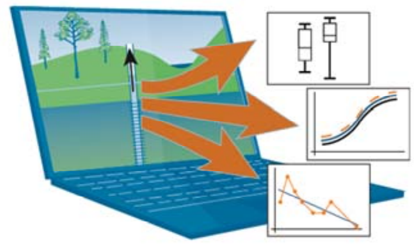
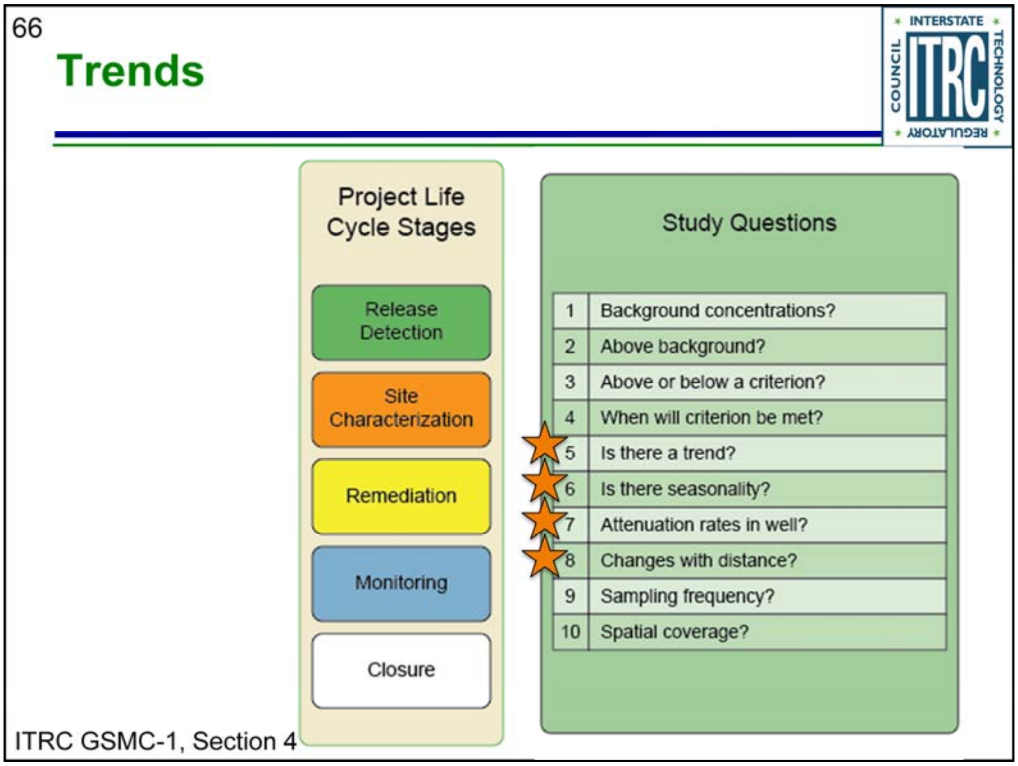


No associated notes.



Four of the 10 questions are directly related to trends. Trend analyses are indirectly related to all questions. For example, trend analyses are a component of exploratory data analysis. In addition, one also just consider when trends when establishing or comparing to background or how to optimize monitoring networks. Although trend analyses can be relevant to any of the project life cycle phases, they are most important to remediation, monitoring, and closure.

Question 8 deals with spatial trends, which are not considered in the IBT. Please refer to section 5.15 of the web-based guidance document for more information on spatial statistical methods.

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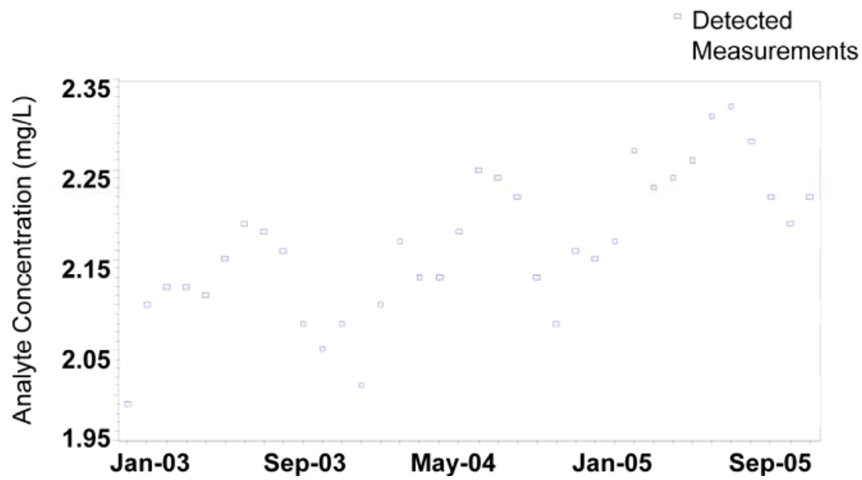
Trend Basics: A Picture Is Worth a Thousand Words…



ITRC GSMC-1, Study Question 5

Figure Source: Adapted from USEPA 2009

Figure Source: USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities." In Unified Guidance EPA 530/R-09-007. Washington DC: United States Environmental Protection Agency. www.epa.gov

Start with a scatter plot of your data … three years of data from a single well

scatter plots

Graphical representation of multiple observations from a single point used to illustrate the relationship between two or more variables. An example would be concentrations of one chemical on the x-axis and a second chemical on the y-axis. They are a typical exploratory data analysis tool to identify linear versus nonlinear relationships between variables (Unified Guidance).

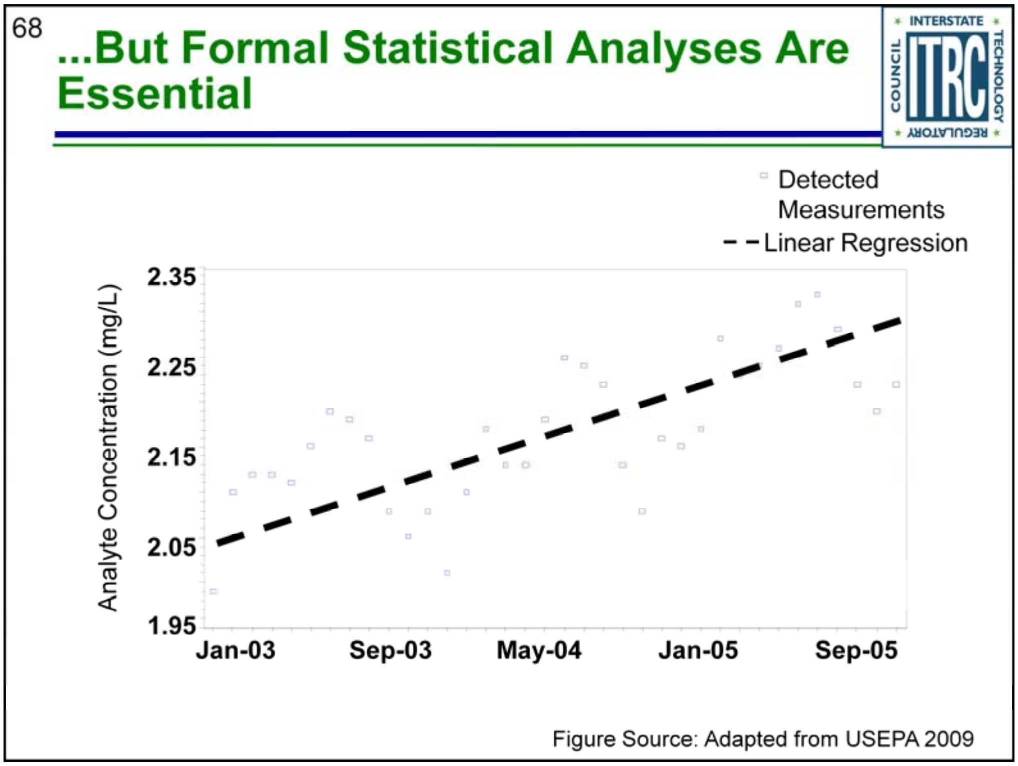


Figure Source: USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities." In Unified Guidance EPA 530/R-09-007. Washington DC: United States Environmental Protection Agency. www.epa.gov

Formal statistical tests answer:

1) is there a trend (cyclical, increasing, decreasing)? and/or 2) what is the slope (or rate of change)?

linear regression analysis

A parametric statistical method to measure the linear trend of a data set using data point regression residuals that are based on assumptions of normality, homoscedasticity, and independence (Unified Guidance).

parametric

A statistical test that depends upon or assumes observations from a particular probability distribution or distributions (Unified Guidance).

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Trend Applications

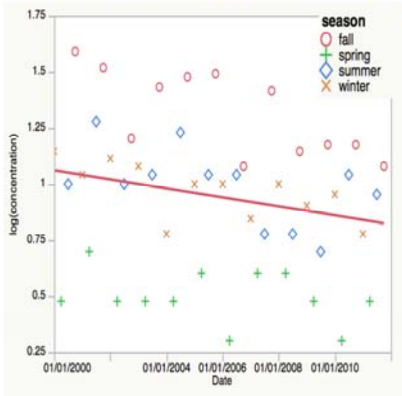
- All project life cycle phases
  - Exploratory Data Analysis (EDA Section 3.3.3) — are background levels stable?
- Specific project life cycle phases
  - Release detection (Section 4.2) — are concentrations steadily increasing?
  - Assessing compliance (Section 4.6) — is monitored natural attenuation feasible/realistic?
  - Optimization (Section 4.5) — is the sampling effort appropriate?

Exploratory data analysis applies to all project life cycle phases. Several statistical tests assume that concentrations are stable. For example, the background statistics assume there is no trend in the background well.

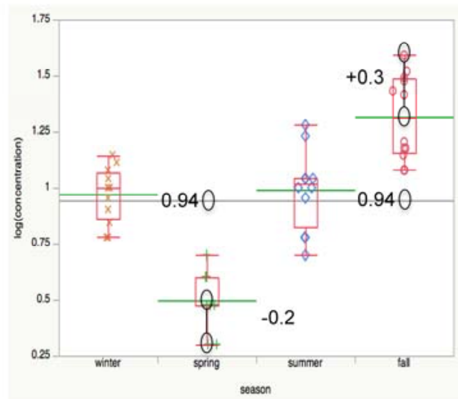
Seasonal or cyclical changes in concentrations can appear consistent with transient changes in concentrations. For documenting a release it is important to show changes are steadily increasing by using trend analyses and documenting statistical significance. Trend analyses can support assessment of monitored natural attenuation by estimating a rate of change or a date that a target concentration might be attained.

70 # Trend Example Seasonality

Study Q6 (Appendix C) – Is there seasonality?



To adjust for seasonality, take the value minus the season mean plus the overall mean.



Data from Appendix A, Table A-2

log(concentration) = 2.99 - 6.37e-10*Date, r^2=0.045

Grand mean 0.94

Winter mean 0.97

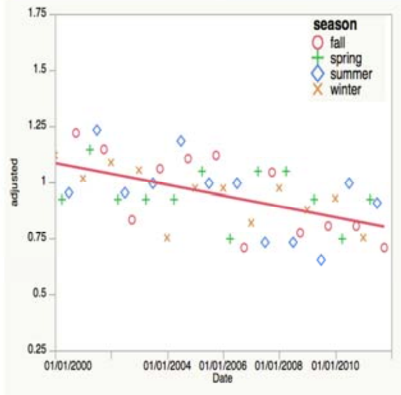
Spring mean 0.50

Summer mean 0.99

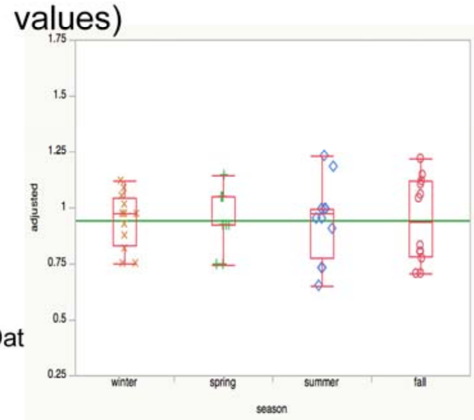
Fall mean 1.32

Trend Example Seasonality - Adjusted Data

Study Q6 (Appendix C) – Is there seasonality?



Adjusted data have similar slope but substantially more significant trend (compare r^2 values)

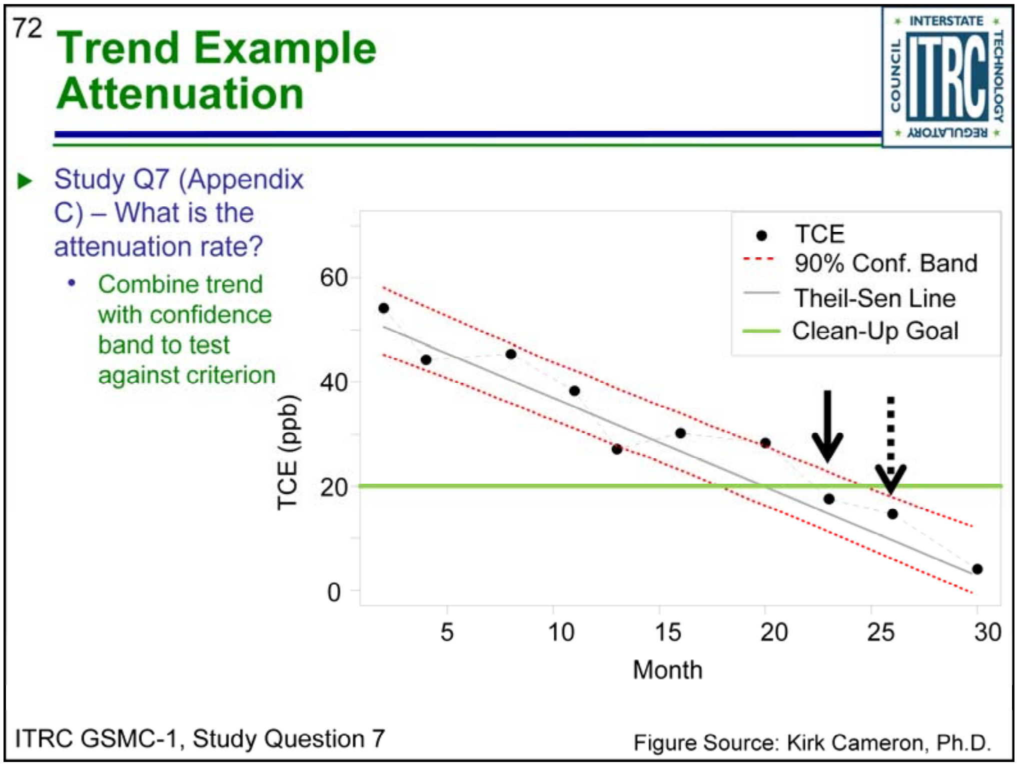


Data from Appendix A, Table A-2

log(concentration) = 3.40 – 7.63e-10*Dat

r^2=0.323

Recall that the unadjusted r^2=0.045



Data used to generate the figure are from the EPA’s Unified Guidance, Example 21-7. USEPA. 2009. "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities." In Unified Guidance EPA 530/R-09-007. Washington DC: United States Environmental Protection Agency. www.epa.gov

Statistical confidence bands on observed trends can help to establish compliance. The scatterplot graph displays TCE concentrations over time at a monitoring well. Note that first sample result less than the criterion has an upper confidence band on the individual concentrations greater than the criterion. The upper confidence bound for the next result is less than the criterion. The confidence bands are calculated for the predicted values (y-axis, dependent variable, TCE concentration in the well).

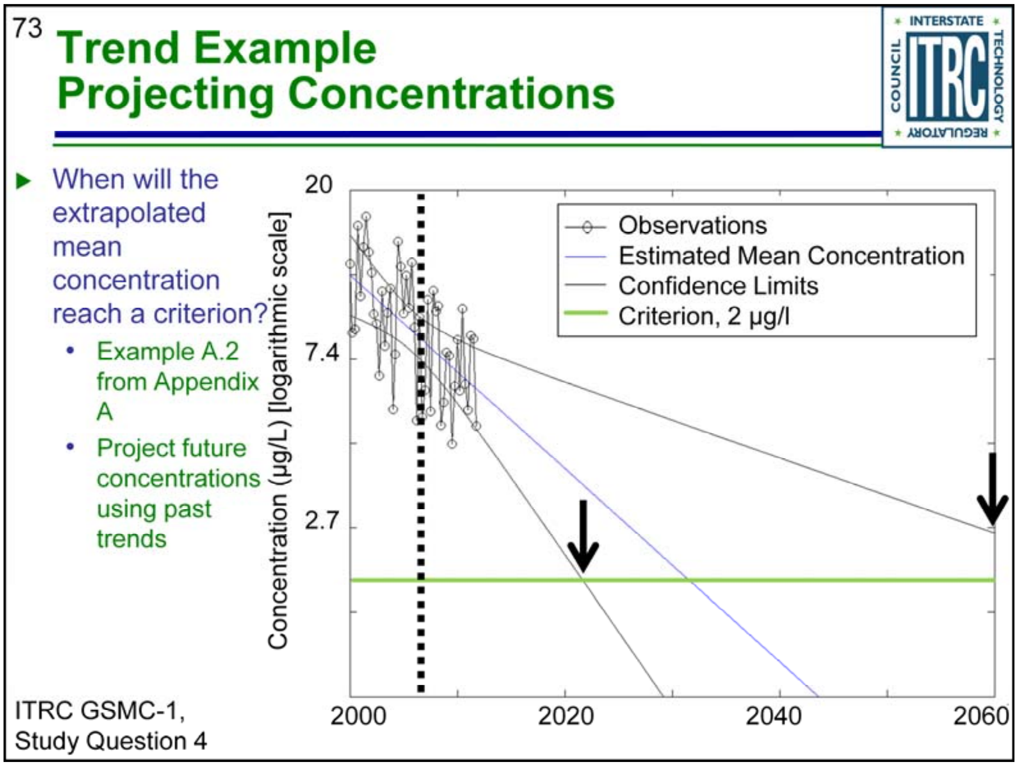
The Theil-Sen test is a nonparametric (no statistical distribution assumed) test that can be used with or without seasonality.

confidence interval

Statistical interval designed to bound the true value of a population parameter such as the mean or an upper percentile (Unified Guidance).

nonparametric

Statistical test that does not depend on knowledge of the distribution of the sampled population (Unified Guidance).



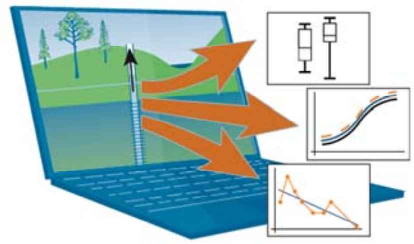
Statistical confidence bands on observed trend models can help to establish compliance. Note that the confidence bands on the model are quite different from those calculated for individual points shown on the previous slide. For this example the projected dates of compliance run from about 2020 to 2075 (off the x-axis scale).

Extrapolating from current conditions to future mean concentrations leads to wider and wider confidence limits. This is due to extrapolating from the mean x or mean of dates sampled to future conditions. The mean data of the measured data (mean x) is marked by the dashed line. Confidence is greatest at the mean x-value (date) and expands with greater lags. Consider that when one extrapolates to possible future outcomes that there is a mean slope but also a range of possible slopes. We are also familiar with increasing bounds on model predictions based on predicted future storm tracks.

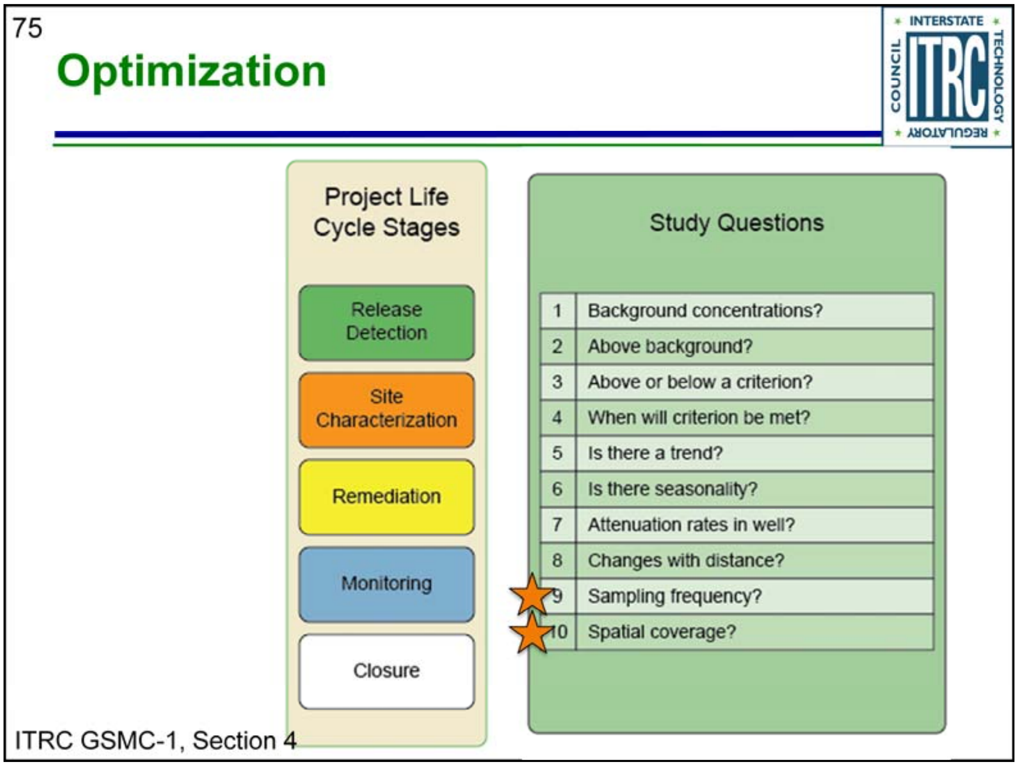
Figure A-11. How long until the compliance goal is met?

Training Roadmap

- How to use the GSMC Document
- Getting Ready to Apply Statistics
- Question & Answer Break
- How to Apply Study Questions for
  - Background
  - Compliance
  - Trend Analysis
  - Monitoring Optimization
- Summary
- Question & Answer Break



No associated notes.



There are two study questions that deal specifically with optimization or determining the appropriate sampling frequency or well selection.

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Optimization

- Optimization entails efficient data collection – collecting the right amount of data for the decisions (Section 4.5.3)
- Sampling design optimized for any site when
  - Little statistical correlation or redundancy in sample results, AND
  - Adequate data collected for accurate decisions

ITRC GSMC-1, Study Questions 9, 10

Similar results collected from nearby locations or closely-spaced times may indicate correlation or redundancy

Optimization can lead to either a larger or smaller number of wells, number of samples, or analytical suites

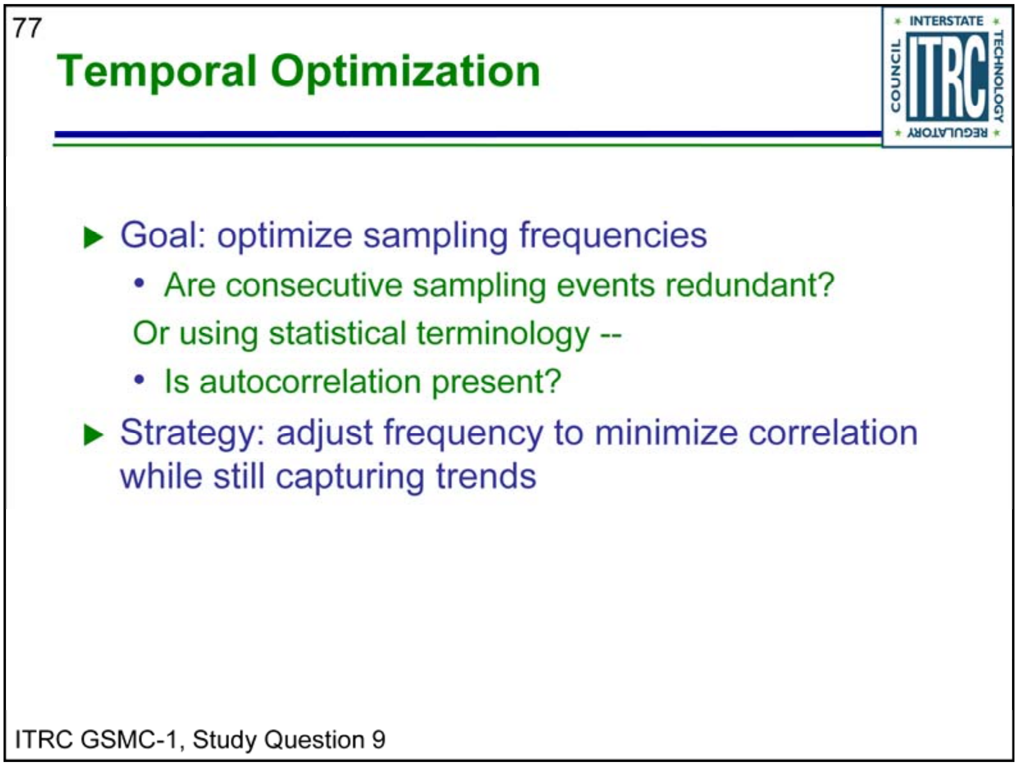
Sites at later stages in the project life cycle are more likely to have redundant data and the information necessary to conduct optimization

Optimization, like any statistical sampling procedure, should be completed with adequate site knowledge based on the conceptual site model.

Also, note there is a related ITRC team and guidance document http://gro-1.itrcweb.org

Geostatistics for Remediation Optimization
Leads: Ning-Wu Chang (nchang@dtsc.ca.gov) and Harold Templin (htemplin@idem.in.gov)

Project: Remediation optimization can improve performance, increase monitoring efficiency, and justify contaminated site decisions. For complex groundwater cleanup projects, however, optimizing the remediation performance monitoring system is challenging. A simple, deterministic decision flow chart may not adequately account for complex site conditions. Geostatistical approaches can be used as tools to evaluate optimization opportunities to improve groundwater remediation performance and monitoring. Geostatistical approaches for remediation optimization typically use spatial and temporal statistics to estimate correlations and redundancy between sampling locations and events. These approaches also identify areas and periods of high statistical uncertainty in a groundwater monitoring network over time. This project will develop a web-based guidance document and Internet-based training course to help state regulators and project managers understand how to use geostatistical approaches for remediation optimization and make better decisions regarding site cleanup.



Phased sampling approach typical of many sites—

Generally sample more frequently in initial project phases

Reduce frequency once temporal relationships can be established

Common tests to identify temporal correlation (autocorrelation) include sample autocorrelation function (ACF) and rank von Neumann. The web-based document has information on methods to assess autocorrelation, including the example in Appendix A-2 that was discussed in the last section of this training.

autocorrelation

Correlation of values of a single variable data set over successive time intervals (Unified Guidance).

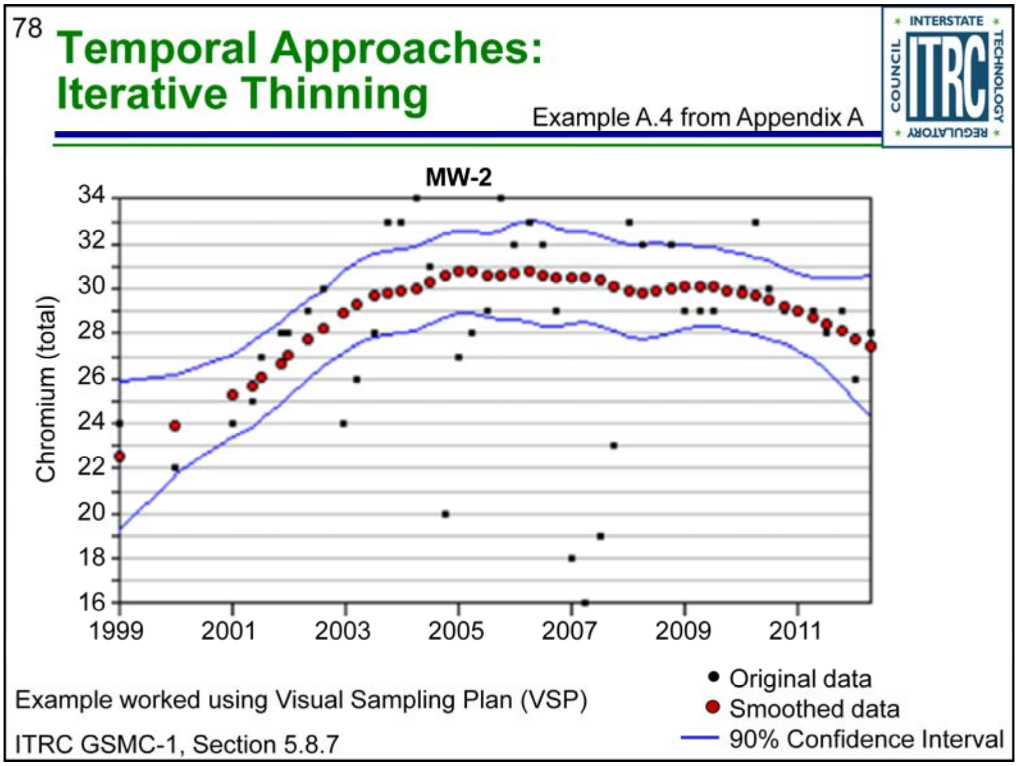


Figure A-15. Visual Sampling Plan (VSP) results for concentration (mg/l) from MW-2.

Iterative thinning method. Iterative thinning examines whether sampling frequencies can be reduced due to temporal redundancy in the sampling events. This approach identifies redundancy by first estimating a baseline trend using the full data set, after which the trend is repeatedly re-estimated using subsets of the full data to identify the average number of data points needed to accurately reconstruct the baseline. The computations in iterative thinning create a series of 'what if' scenarios estimating the nature of the trend that would have been identified if only some of the existing data had been sampled. The overriding principle in iterative thinning is that if a trend can be accurately reconstructed using fewer sampling events, the optimal sampling frequency should be based on this smaller number.

This example is from Appendix A, A-4 and used the VSP software (see Appendix D.23). The black symbols represent the original quarterly well sample data and the red symbols are the smoothed trend using all data. The blue band is the 90% confidence interval on the trend. According to the VSP output, the optimal sampling frequency for MW-2 would be 227 days. If a semi-annual frequency (180 days) were proposed for future sampling in this well, there would be a 50% reduction in sampling costs with no significant difference in the ability to monitor trends in this well.

The user selects the following **Simulation Parameters** in VSP:

Smoothing bandwidth: for example 0.3

Number of simulations: for example 500

Confidence interval (CI) confidence level: 90% [for the smoothed line]

Percent of simulated trend required to be within the CI: for example 75%

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Temporal Approaches: Cost Effective Sampling (CES)

Sampling Frequency

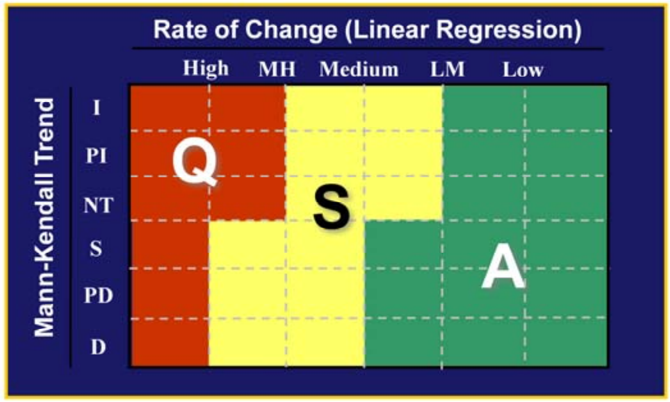
Q: Quarterly

S: Semiannual

A: Annual

I = Increasing
PI = Probably Increasing
NT = No Trend
S = Stable
PD = Probably Decreasing
D = Decreasing

MH = Medium High
LM = Medium Low



Rate of change relative to cleanup goal vs. trend.

ITRC GSMC-1, Section 5.8.7, Appendix C.9

Figure Source: AFCEC 2012

Figure Source: Air Force Civil Engineer Center (AFCEC). 2012. "Monitoring and Remediation Optimization System (MAROS) Software, User's Guide and Technical Manual." In: Air Force Center for Environmental Excellence. http://www.gsi-net.com/en/software/free-software/maros-30.html.

See Also Ridley, M.N., V.M. Johnson, and R.C. Tuckfield. 1995. Cost-Effective Sampling of Groundwater Monitoring Wells. Vol. UCRL-JC-118909. Livermore, CA: Lawrence Livermore National Laboratory

Cost-effective sampling method (CES). In CES, a linear trend is estimated for each chemical-well pair and then classified according to the slope of the apparent trend as well as how much variation exists around the trend. Trends with relatively ‘flat’ slopes (small rates of change) and low variation are recommended for less frequent sampling, while trends with higher slopes or higher degrees of variation are targeted for more frequent sampling. The overriding principle is to (1) sample more frequently at locations where the apparent changes are more dynamic and associated with the greatest statistical uncertainty, and (2) sample less frequently when the trend is changing little and is statistically more certain (that is, less variable). A high rate is change is 2 times the cleanup goal, medium is equal to the cleanup goal, and low is 50% of the cleanup goal.

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Spatial Optimization

- Goal: optimize number and/or placement of well locations
  - Are any wells redundant?
  - Should new wells be added and where?
- Strategy: assess spatial uncertainty either by
  - Removing specific wells or groups of wells
  - Locating areas with highly uncertain concentrations and few or no wells

ITRC GSMC-1, Study Question 10

Spatial optimization is a challenging objective and an active area for research

Requires lots of data; broad spatial coverage

Optimization software results should be checked against what is known or hypothesized about contamination via the CSM (see section 3.2 of the web-based document), and other lines of evidence.

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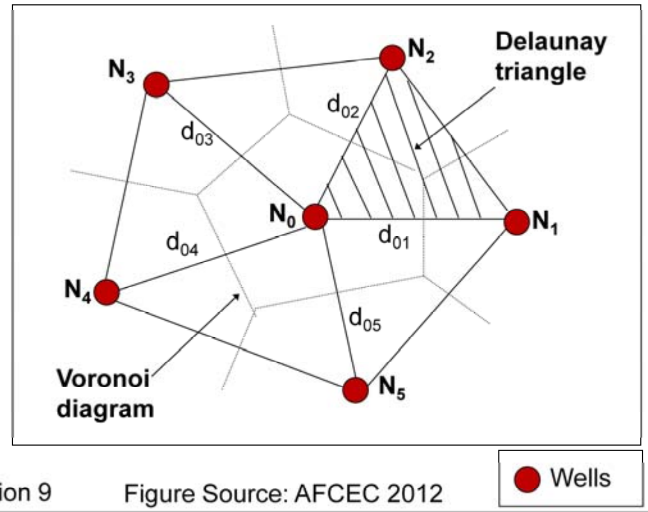
Spatial Approaches

- Identify spatial redundancy (well removal)
  - Tools
    - Genetic algorithms
    - GTSmart
    - Slope factors/ relative errors
    - Kriging uncertainty
    - Qualitative evaluation



ITRC GSMC-1, Study Question 9 Figure Source: AFCEC 2012

Figure Source: Air Force Civil Engineer Center (AFCEC). 2012. "Monitoring and Remediation Optimization System (MAROS) Software, User's Guide and Technical Manual." In: Air Force Center for Environmental Excellence. http://www.gsi-net.com/en/software/free-software/maros-30.html.

Spatial redundancies in a monitoring network can be identified, leading to fewer sampling points and more cost-effective monitoring. In this case, multiple tools and approaches exist to answer the question. For instance, nearest neighbor estimation can be combined with leave-one-out cross-validation to generate the slope factors in MAROS. Some approaches remove one well at a time or groups of wells, then try to either reproduce plume maps using the reduced network or minimize the statistical uncertainty of the resulting network

3TMO uses qualitative evaluation (see Appendix D.1);

GTS uses quasi-genetic algorithm called GTSmart (see Appendix D.6);

Summit Tools uses genetic algorithm (see Appendix D.21);

MAROS uses slope factors (see Appendix D.11);

VSP uses kriging uncertainty (see Appendix D.23)

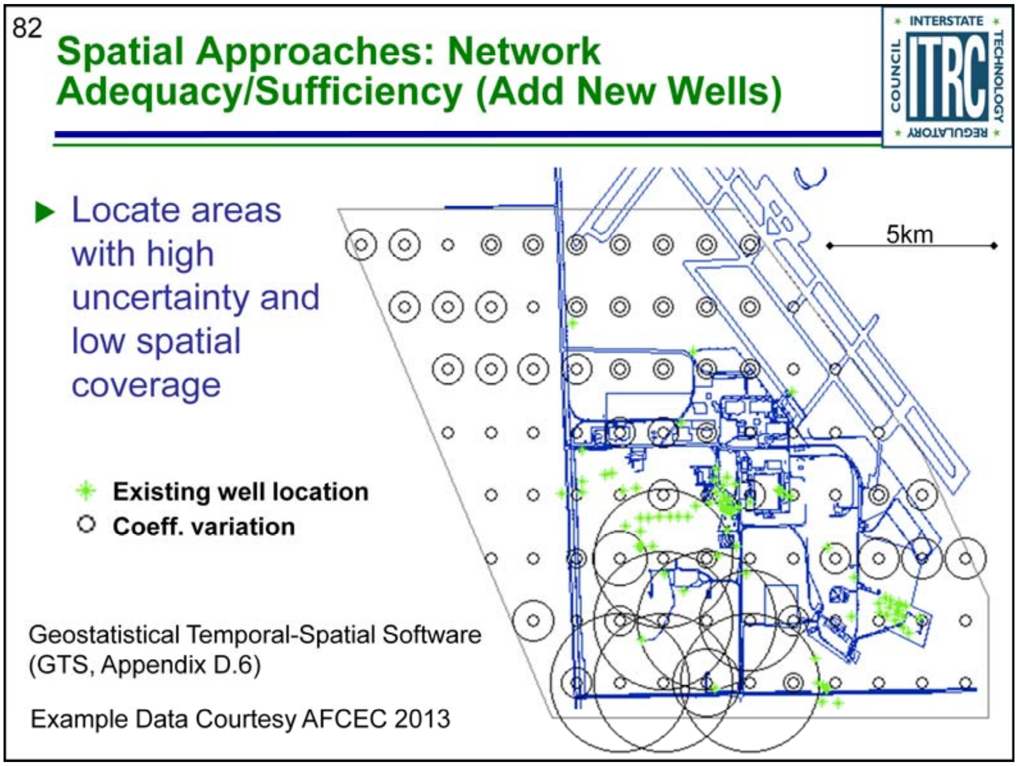
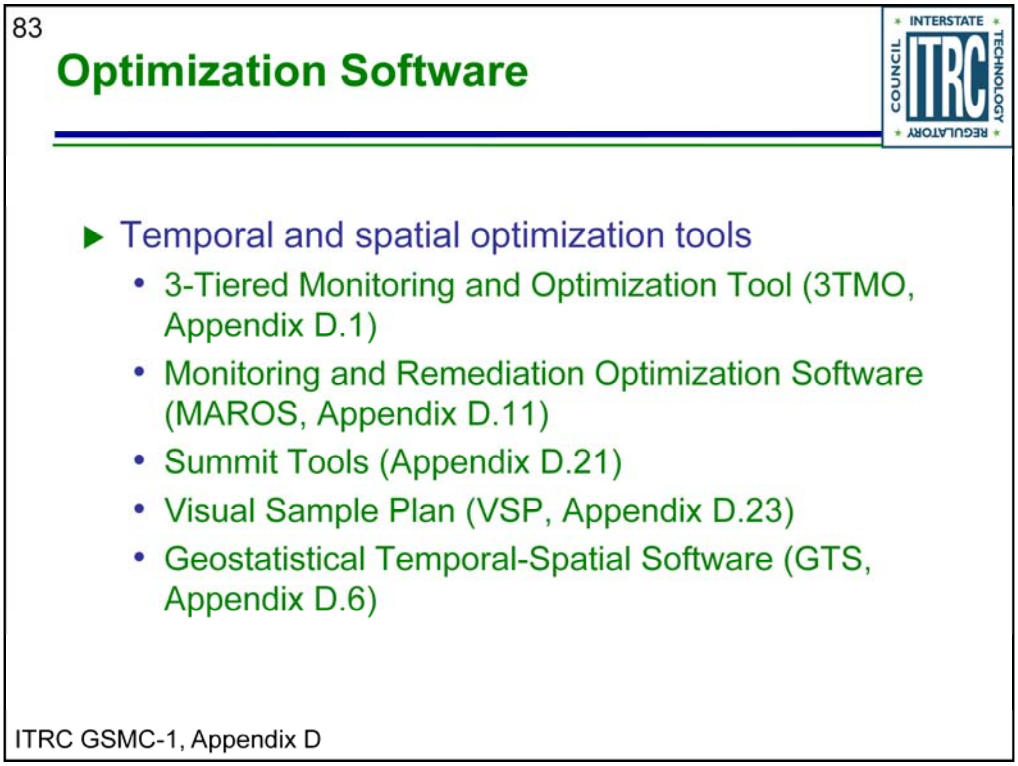


Figure Source: Map of network adequacy evaluation results developed in GTS using example data from the software. Example data courtesy AFCEC 2013.

The plus symbols locate existing wells. The circles represent current estimates of uncertainty in concentrations. Add wells where uncertainty is high and coverage of existing wells is low. Remove wells is coverage is high and uncertainty is low. The CSM should be considered when making decisions to either add or remove wells from the monitoring network.



Spatial optimization generally relies on geostatistical methods to understand the distance over which sample results are correlated and the strength of such relationships. Temporal optimization relies on estimating trends and the uncertainty associated with those trends.

3TMO

The 3-Tiered approach to LTMO is unique when compared to existing LTMO statistical applications because it focuses on qualitative factors that are supported by quantitative statistical analysis. The spatial analysis included in 3TMO is a qualitative evaluation facilitated by the Map Tool; the spatial importance of each well is not quantitatively determined using geostatistics.

MAROS

Uses simple statistics and decision frameworks to prioritize data collection efforts and link data to defensible site management decisions. Can use results from this software to develop lines of evidence, which combined with professional judgment, can be used to inform site management decisions for safe and economical long-term monitoring of groundwater plumes. Can use MAROS to help design and calculate remediation performance metrics and as a tool to evaluate progress toward site remedial goals.

GTS

GTS has five modular components linked together in a user-friendly interface: Prepare, Explore, Baseline, Optimize, and Predict. The Optimize component runs two distinct types of temporal optimization—iterative thinning and temporal variograms—as well as spatial optimization involving both a search for statistical redundancy and an assessment as to whether and where new wells should be added. Finally, the Predict module focuses on flagging newly imported data that are inconsistent with projected trends and maps.

Summit Tools

SampleOptimizer and SampleTracker are tools for both spatial and spatio-temporal analysis for monitoring network optimization. SampleOptimizer applies mathematical optimization to monitoring networks in an easy-to-use desktop software tool. SampleTracker reviews new monitoring data against historical data.

VSP

VSP has a module to evaluate redundancy of wells. The well redundancy modules in VSP can identify redundant wells and identify a technically defensible temporal spacing of observations for wells. The redundant well module uses a geospatial analysis based on kriging. VSP also has a module to help with new well placement to reduce estimation uncertainty. The sampling frequency well evaluation is applied on a well-by-well basis and is based on iterative thinning methods.

Training Roadmap

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- How to Apply Study Questions for
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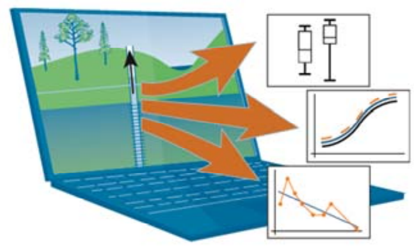
  - Compliance
  - Trend Analysis
  - Monitoring Optimization
- Summary
- Question & Answer Break



No associated notes.

Statistical Methods/Tests

- 14 groups of methods
  - Grouped based type and application
  - Examples
    - 5.1 Graphical methods
    - 5.2 Confidence limits
    - 5.5 Trends
    - 5.7 Nondetects
- References provided, including references to EPA's Unified Guidance
- Details for each
  - Applications and relevant study questions are linked
  - Assumptions
  - Requirements and tips
  - Strengths and weaknesses
  - Further information
  - Not intended as a "how to," but a resource

In Section 5 of the web-based document the statistical methods are grouped by their application.

There are references provided for the methods.

A lot of practical information about the methods is provided in Section 5.

Appendix D: Software Tools and Packages

- Brief summaries included for widely available software packages – 23 included
- Based on survey results and team input
- Information included
  - Approximate cost
  - Operating system requirements
  - Ease of use
  - Data Import
  - Capabilities
  - Benefits and Limitations
  - References

Software Packages	
D.1 3TMO	D.13 PAM
D.2 CARStat	D.14 Pro-UCL
D.3 ChemStat	D.15 R for Statistics
D.4 DUMPStat	D.16 Sanitas
D.5 Excel	D.17 SAS
D.6 GTS	D.18 Scout
D.7 GWSDAT	D.19 SPSS
D.8 JMP	D.20 Statistica
D.9 MATLAB	D.21 Summit Tools
D.10 MINITAB	D.22 SYSTAT
D.11 MAROS	D.23 VSP
D.12 NCSS	

Appendix D includes summaries of 23 statistical software packages. Table D-1.

Each summary includes some practical information such as the approximate cost and capabilities.

You should be sure to carefully review any software to be sure that it is applicable to your needs.

Appendix D: Software Packages Capabilities Table

Statistical Method	Capability As Is	Capability with Scripts/Add-Ins
Handling of NDs		
Simple Substitution	●	N/A
Kaplan-Meier		N/A
ROS		N/A
Cohen/MLE	◒	N/A
Exploratory/Diagnostic Tools		
Summary Statistics	●	N/A
Distributional tests	◒	N/A
Outlier tests	●	N/A
Data Transformations		N/A

Ratings are none, some capability and full capability. These can be used to determine which software can implement the functions that you are looking for.

The Big Challenge
Groundwater Data Management

- Based on data quality objective (DQO) procedures
- Large site databases
  - Environmental Restoration Information System (ERIS)
  - Navy Installation Restoration Information Solution (NIRIS)
  - Staged Electronic Data Deliverable (SEDD)
- Good practices
  - Streamline data analysis
  - Provide a basic structure

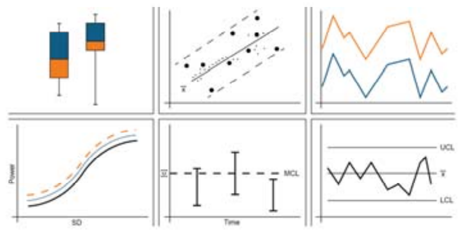
No associated notes.

Overall Course Summary Statistical Information

What You Have Learned

- More confident with statistical concepts
- Better able to select appropriate statistical methods for your project
- Appropriate software tools for your project

Statistics…



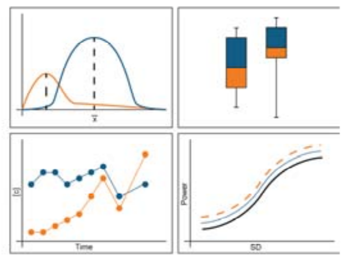
Statistical concepts

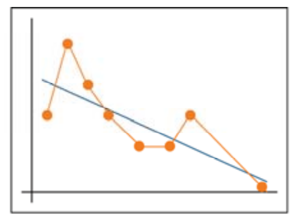
Select appropriate methods and software tools

Avoid misapplications of statistics at your groundwater sites.

Overall Course Summary
Practical Applications

- Ready for practical application of statistics in four key areas:
  - Background
  - Compliance
  - Trend analysis
  - Monitoring optimization





ITRC GSMC, Appendix C

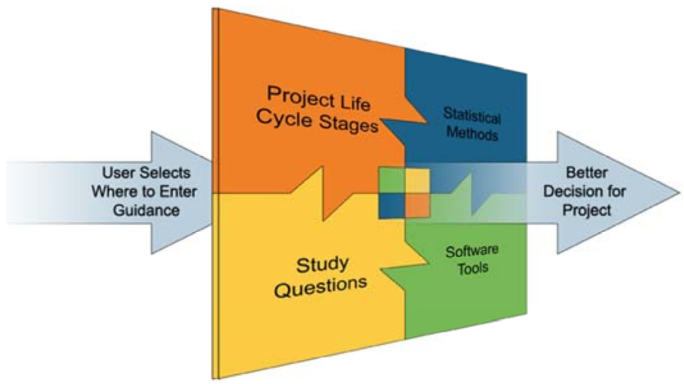
No associated notes.

Overall Course Summary

Navigating the ITRC GSMC Guidance Document

ITRC GSMC Guidance Document
http://www.itrcweb.org/gsmc-1/

Access to meet your needs



ITRC GSMC, Section 1

You learned how the Web-based guidance document fits together to give you a resource in evaluating or designing a statistical approach.

This document guides the project manager in using appropriate statistical methods to address common project tasks (such as evaluating whether a groundwater remedy is functioning effectively or whether there is a downward trend which supports a natural attenuation remedy selection) and make better decisions for their projects.

You may also find the GSMC Team as a resource for more information (Appendix G).

Thank You

Follow ITRC

- 2nd question and answer break
- Links to additional resources
  - http://www.clu-in.org/conf/itrc/gsmc/resource.cfm
- Feedback form – *please* complete
  - http://www.clu-in.org/conf/itrc/gsmc/feedback.cfm
- Register for "Geospatial Analysis for Optimization at Environmental Sites" training at https://clu-in.org/conf/itrc/GRO/

View Your Participation Certificate (PDF)

Need confirmation of your participation today?

Fill out the feedback form and check box for confirmation email and certificate.

Links to additional resources:
http://www.clu-in.org/conf/itrc/gsmc/resource.cfm

Your feedback is important – please fill out the form at:
http://www.clu-in.org/conf/itrc/gsmc/feedback.cfm

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

How you can get involved with ITRC:

✓Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

✓Sponsor ITRC's technical team and other activities

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects