

U.S. EPA Groundwater Statistics Tool



EPA

United States
Environmental Protection
Agency

Introduction

◆ Purpose of the U.S. EPA Groundwater Statistics Tool:

- » To provide guidance on when a groundwater site cleanup is complete
- » To address both attainment and site cleanup situations

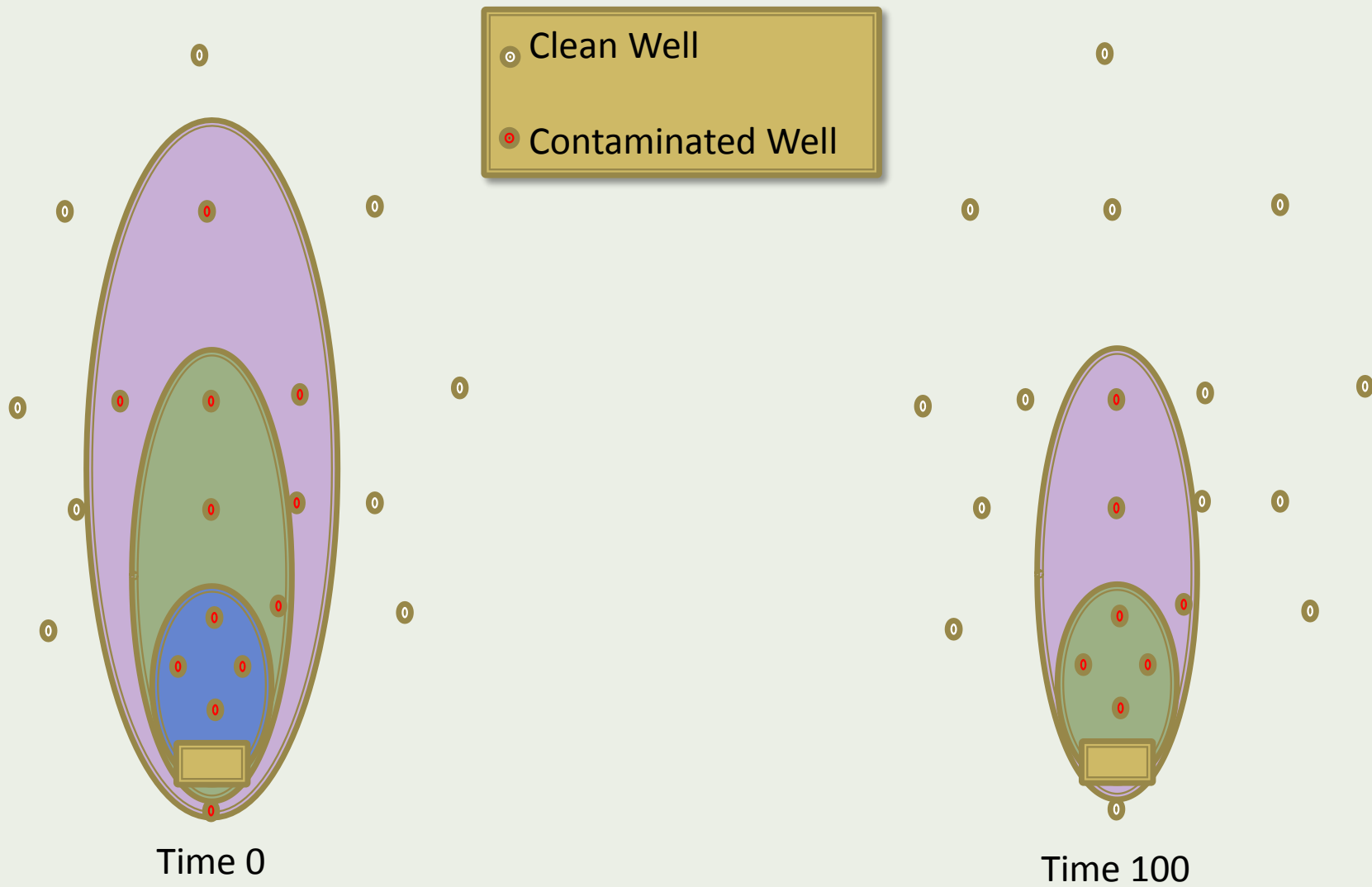
◆ Reason for Development:

- » Other tools can do similar functions (MAROS or ProUCL), but require more intensive training and software installation
- » A simple spreadsheet tool to handle most common cases

Well-by-Well Analysis - Why?

- ◆ **Groundwater restoration is a long term and dynamic process**
- ◆ **Monitoring well network**
 - » Well network should be designed to adequately characterize and evaluate the contaminated aquifer
 - » Number of wells and frequency of sampling changes as lateral and vertical extent of contaminated aquifer change during remediation
- ◆ **Well-specific conclusions should be made throughout the lifetime of the remedial action**

Well-by-Well Analysis



Well-by-Well Analysis: An Overview

◆ Two “Phases”

- » Remediation Monitoring Phase
- » Attainment Monitoring Phase

Remediation Monitoring Phase

- ◆ Phase of the remedy where either active or passive remedial activities are being implemented to reach groundwater cleanup levels selected in a remedy decision document
- ◆ The completion of this phase provides stakeholders a decision point for determining that the groundwater in a well has reached cleanup levels for all contaminants of concern
- ◆ Decision point to start evaluating attainment

Attainment Monitoring Phase

- ◆ **Phase of the remedy and monitoring conducted after cleanup levels have been reached**
- ◆ **Considerations of active versus passive systems**
- ◆ **Evaluations done on a contaminant by contaminant-specific basis**
- ◆ **The completion of this phase when monitoring data analysis provides conclusions that:**
 - » The contaminant cleanup level has been met; and
 - » Groundwater will continue to meet the contaminant cleanup level in the future

Remedial Action Completion Determination

- ◆ **Based on well-specific conclusions**
- ◆ **Guidance does not recommend:**
 - » Aggregating conclusions between well
 - » Aggregating conclusion between intervals for wells with multiple discrete screening depths
- ◆ **Well-specific conclusions should be evaluated in conjunction with the conceptual site model to ensure well network sufficient to characterize lateral and vertical extent of contaminated aquifer**

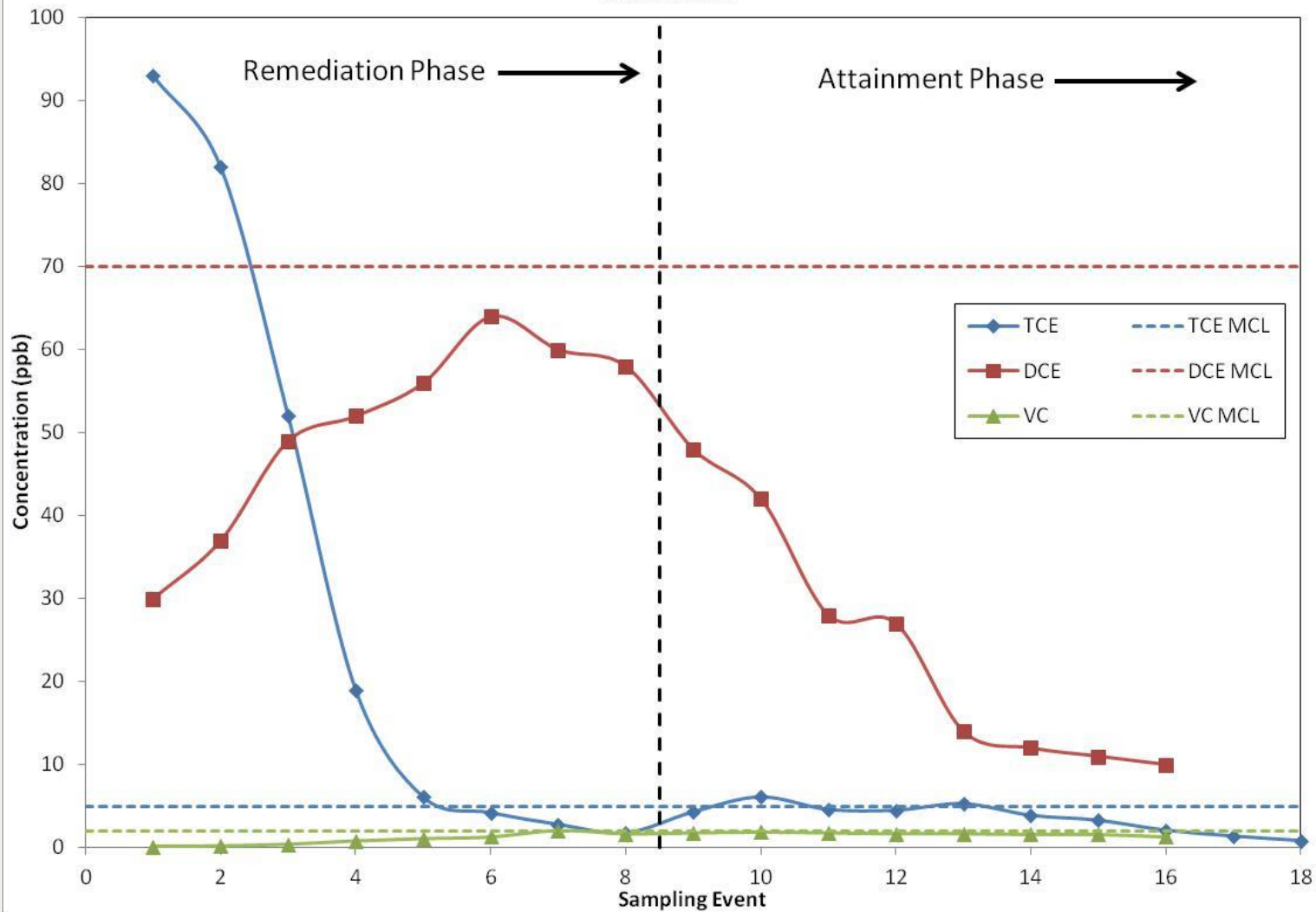
Recommended Approach

- ◆ **Provides a methodology for conducting a well-specific analysis**
- ◆ **Document contains recommendations on:**
 - » Data set considerations
 - » Remediation Monitoring Phase statistical evaluation (if needed)
 - » Attainment Monitoring Phase statistical evaluation (if needed)

Groundwater Statistical Tool

- ◆ Microsoft Excel-based tool, available for download at http://www2.epa.gov/sites/production/files/2015-11/gw_stats_tool_08112014.final_xlsm
- ◆ Comports with the Recommended Approach
- ◆ Tool to use statistics to evaluate completion of a groundwater remediation action at a specific well (for a specific contaminant)
- ◆ Other potential uses

Overview



Remediation Monitoring Phase Completion Determination

- ◆ **Done for ALL contaminants in a well**

- ◆ **Goal(s):**

- » Provide a decision point to start attainment monitoring phase data collection and analysis
- » Terminate active systems if they are being employed

- ◆ **Methodology:**

- » Nonstatistical or visual evaluation
- » Statistical tools (2 types)
 - › Mean test
 - › Trend test

- ◆ **Minimum four data points**

Attainment Monitoring Phase Completion Determination

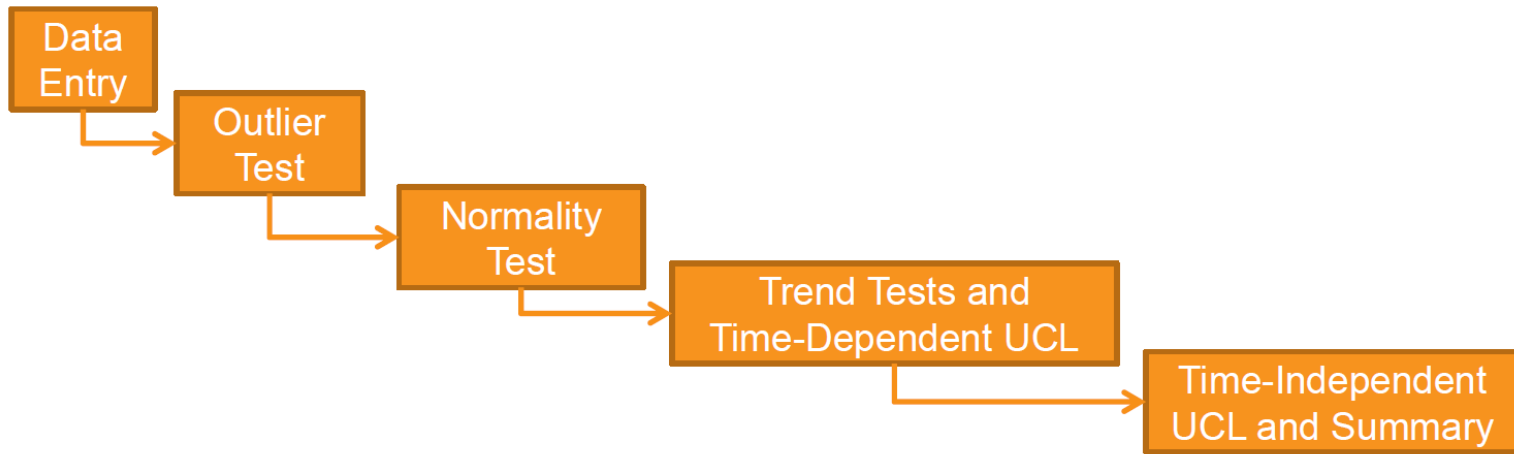
- ◆ **Performed for each contaminant separately**
- ◆ **Goal(s):**
 - » Provide assurance that the cleanup level for each contaminant in the well has been met; and
 - » Provide assurance that the groundwater in the well will remain below contaminant cleanup level(s) in the future
- ◆ **Steady State Considerations**
 - » Active systems versus passive systems
 - » Data set considerations
- ◆ **Minimum eight data points**

Attainment Monitoring Phase Completion Determination

- ◆ **Guidance recommends two lines of evidence to support completion of this phase**
- ◆ **Methodology:**
 - » Nonstatistical or visual evaluation
 - » Meeting contaminant cleanup level?
 - › Mean test
 - » Groundwater anticipated to continue to meet contaminant cleanup levels in the future?
 - › Trend test (slope)

Groundwater Statistical Tool

Situation	Decision	Criteria
Attainment	Has action level been attained?	Time-dependent UCL < Action level AND Trend is not increasing AND Time-independent UCL < Action level
Site Cleanup	Is site cleaned up?	Time-independent UCL < Action level



Groundwater Statistical Tool Tests

Type of Test	Normal	Nonparametric	Nondetects present
Outlier Test	Dixon's test		
Normality Test	Shapiro-Wilk test		
Trend Test and Time-Dependent UCL	Linear Regression	Mann-Kendall test with Theil-Sen line	Kendall's Tau test with Akritas-Theil-Sen line
Time-Independent UCL	Student's t	Student's t with KM	Chebyshev with KM

Note on Non-Detects in Dataset

- ◆ **Simple substitution method**
- ◆ **Each non-detect result is substituted with a randomly generated real number**
 - » Generated off internal computer clock
 - » Between zero and the reported detection limit
 - » This substitution prevents the introduction of artificially low variability from multiple identical (or similar) detection limits

Outlier Testing Worksheet

Groundwater Statistics Tool		
Outlier Testing Worksheet		
Dixon's Outlier Test Results		
Risk of false rejection	1%	
Critical value	0.597	
Outlier type	Low	High
Test statistic	0.2567	0.2228
Potential Outlier?	No	No
Validity of Dixon's Test	Valid	

Box and Whiskers Plot - Detected Data Only

Legend:

- Detected Values Outside 3 IQR
- Detected Values Outside 1.5 IQR
- ◆ Detected Values Within 1.5 IQR

← Return to Data Input Screen

Proceed to Normality Screen →

Normality Testing Worksheet

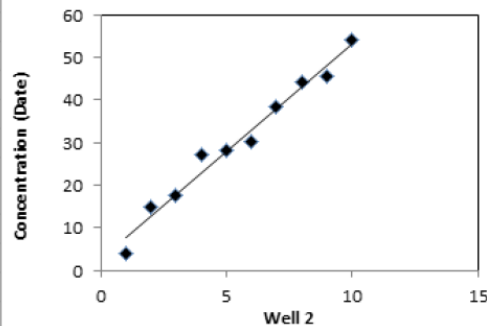
Groundwater Statistics Tool

Normality Testing Worksheet

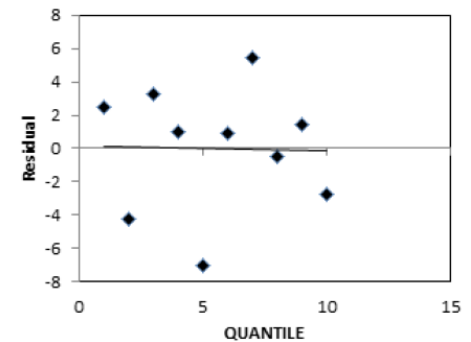
Normality Test Results

Parameter	All Data	Minus Outliers	Residuals
Shapiro-Wilk alpha value	5%	N/A	5%
Slope	18.50716923	N/A	-0.267842037
Intercept	30.42	N/A	2.6348E-15
Correlation, R	0.991832269	N/A	0.059779147
Exact Test Value	0.978435291	N/A	0.978435291
Critical Value	0.842	N/A	0.842
Approximate Test Value	May add later	May add later	May add later
p-Value	May add later	May add later	May add later
Conclude sample distribution:	Appears normal	N/A	Appears normal

Normal Q-Q Plot, Detected Data Only



Residuals



← Return to Outliers Screen

Proceed to Trend Screen →

Proceed to UCL Screen →→

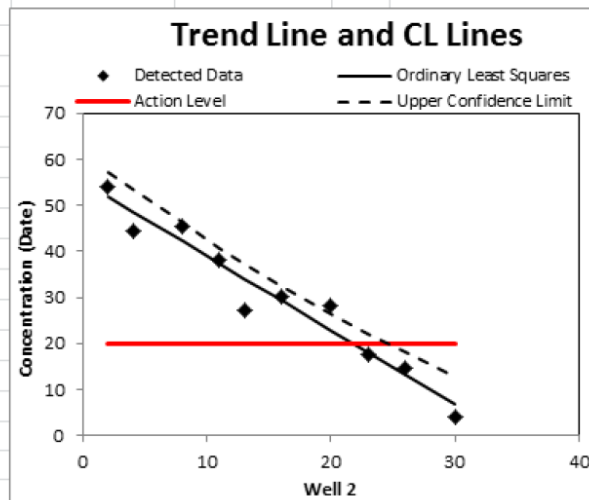
Trend Test Results for Normal Datasets with Only Detects

Groundwater Statistics Tool

Trend Test Results for Normal Datasets with Only Detects

i	t (Days)	C (ppb)	(t-tmean)	Slope term	C Predicted	95 UCL Line	Regression residual
1	2	54.2	-13.3	-720.86	51.73517189	57.33406409	2.464828107
2	4	44.3	-11.3	-500.59	48.52988289	53.56277767	-4.229882886
3	8	45.4	-7.3	-331.42	42.11930487	46.14798943	3.280695127
4	11	38.3	-4.3	-164.69	37.31137136	40.77171435	0.988628636
5	13	27.1	-2.3	-62.33	34.10608236	37.32470089	-7.006082357
6	16	30.2	0.7	21.14	29.29814885	32.42423679	0.901851152
7	20	28.3	4.7	133.01	22.88757083	26.41096169	5.412429165
8	23	17.6	7.7	135.52	18.07963733	22.19839302	-0.479637325
9	26	14.7	10.7	157.29	13.27170382	18.1415664	1.428296184
10	30	4.1	14.7	60.27	6.861125803	12.87295377	-2.761125803
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

Ordinary Least Squares	
Slope	-1.602644503
Intercept	54.9404609
Test Result	Decreasing
Test Statistic	-11.435
Critical Value	1.860
Tabulated p-value	May be added



← Return to Normality Screen

Proceed to UCL Screen →

UCL Calculations and Summary

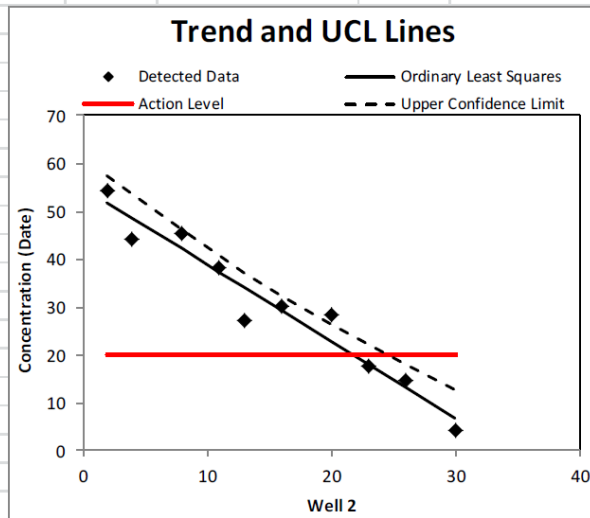
Groundwater Termination Tool

Upper Confidence Limit (UCL) Calculations and Summary

Site Name	Test
Operating Unit (OU)	Test
Type of Evaluation	Attainment
Date of Evaluation	10/31/2012
Person performing analysis	R. Tisdale

Chemical of Concern	TCE
Well Name/Number	Well 2
Date Units	Date
Concentration Units	umho

Confidence Level	95%
Number of results	10
Number < action level	3
Are any potential outliers present?	No
Mean of concentration	30.42
Standard deviation of concentration	15.5077615
t-value for UCL calculation	1.833



Time-independent UCL	39.40955791
Method for calculating UCL	Student's t UCL
Does the UCL method match ProUCL guidance?	Yes
Time-dependent UCL value at final measurement	12.87295377
Trend indicated at specified confidence level?	Decreasing
Action level	20
Source of action level	MCL
Can the remedy be considered complete at this well for this analyte?	Inconclusive

- ←←← Return to Data Input Screen
- ←← Return to Normality Screen
- ← Return to Trend Screen

N/A

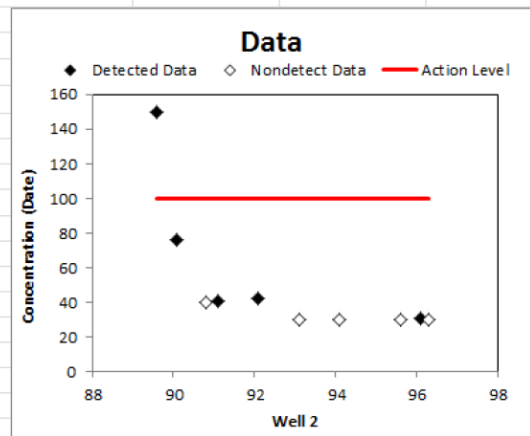
Data Input Worksheet

Groundwater Statistics Tool

Data Input Worksheet

Site Name	Test
Operating Unit (OU)	Test
Type of Evaluation	Attainment
Date of Evaluation	10/31/2012
Person performing analysis	R. Tisdale
Chemical of Concern	Copper
Well Name/Number	Well 2
Date Units	Year
Concentration Units	ppb
Confidence Level Desired	95%
Action Level	100
Source of action level (MCL, risk-based concentration, etc.)	MCL
Risk of False Outlier Rejection	1%

Time (Year)	Copper Concentration (ppb)	Data Qualifier	Detected? (Yes or No)
89.6	150		Yes
90.1	76		Yes
90.8	40	U	No
91.1	41		Yes
92.1	42		Yes
93.1	30	U	No
94.1	30	U	No
95.6	30	U	No
96.1	31		Yes
96.3	30	U	No



Minimum Value for Concentration Axis
0

Reset Concentration Axis

Data Review	
Are all necessary data fields entered?	Yes
Are sufficient data points (>4) present for statistical analysis?	Yes
Are detection limits for nondetects ≤ maximum detected value?	Yes
Is the detection frequency greater than 20%?	Yes

Recommendations	
Are all necessary data fields entered?	None
Are sufficient data points (>4) present for statistical analysis?	None
Are detection limits for nondetects ≤ maximum detected value?	None
Is the detection frequency greater than 20%?	None

Pressing the "Check for Outliers" button to the right will open a worksheet that shows the results of a Dixon's test for outliers.

Check for Outliers →

Outlier Testing Worksheet

Groundwater Statistics Tool		
Outlier Testing Worksheet		
Dixon's Outlier Test Results		
Risk of false rejection	1%	
Critical value	0.780	
Outlier type	Low	High
Test statistic	0.0840	0.6218
Potential Outlier?	No	No
Validity of Dixon's Test	Valid	

Box and Whiskers Plot - Detected Data Only

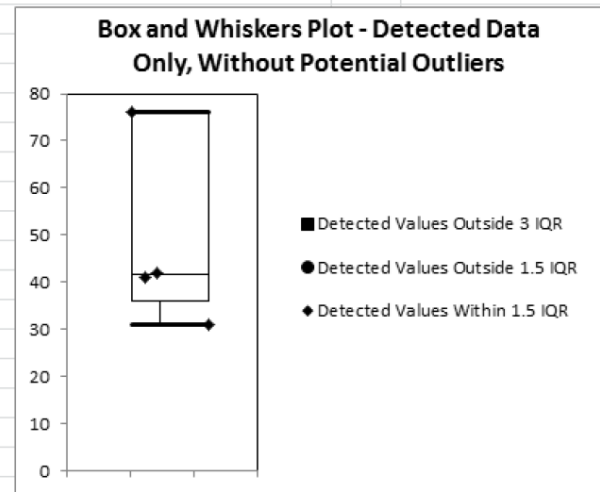
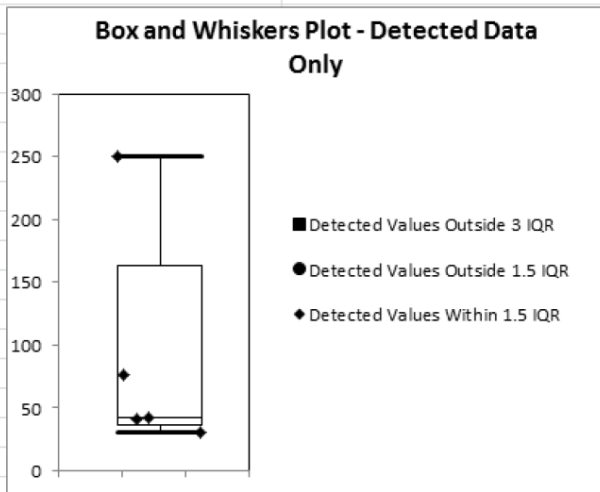
■ Detected Values Outside 3 IQR
● Detected Values Outside 1.5 IQR
◆ Detected Values Within 1.5 IQR

← Return to Data Input ScreenProceed to Normality Screen →

Groundwater Statistics Tool

Outlier Testing Worksheet

Dixon's Outlier Test Results		
Risk of false rejection	1%	
Critical value	0.780	
Outlier type	Low	High
Test statistic	0.0457	0.7945
Potential Outlier?	No	Yes
Validity of Dixon's Test	Not Valid - data do not appear normal after removal of outlier.	



← Return to Data Input Screen

Proceed to Normality Screen →

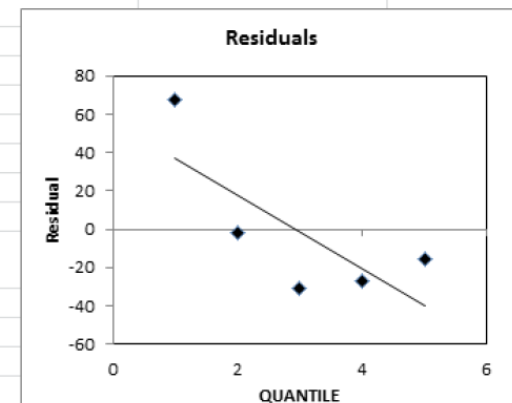
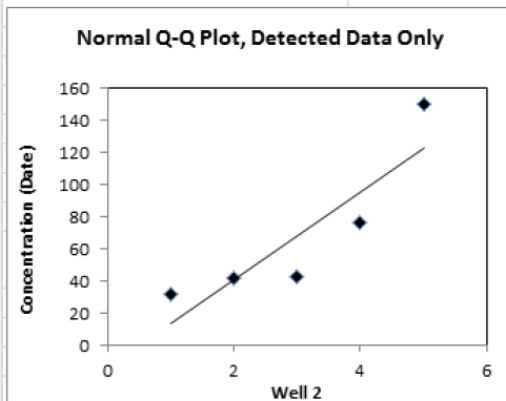
Normality Testing Worksheet

Groundwater Statistics Tool

Normality Testing Worksheet

Normality Test Results

Parameter	All Data	Minus Outliers	Residuals
Shapiro-Wilk alpha value	10%	N/A	10%
Slope	58.05024148	N/A	-40.73172055
Intercept	68	N/A	-1.480105576
Correlation, R	0.889059525	N/A	0.759839362
Exact Test Value	0.801297697	N/A	0.801297697
Critical Value	0.806	N/A	0.806
Approximate Test Value	May add later	May add later	May add later
p-Value	May add later	May add later	May add later
Conclude sample distribution:	Does not appear normal	N/A	Does not appear normal



← Return to Outliers Screen

Proceed to Trend Screen →

Proceed to UCL Screen →→

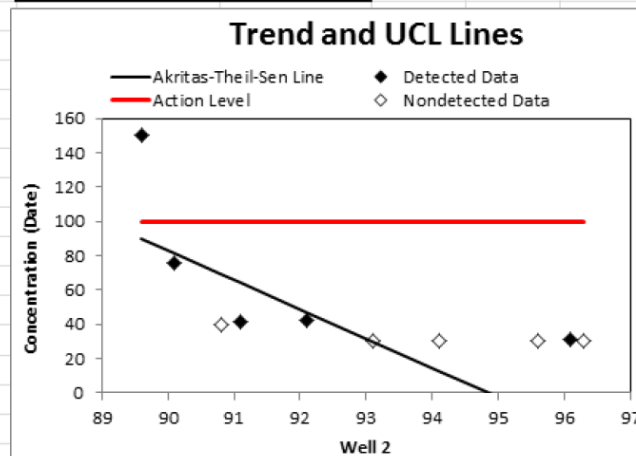
Trend Test Results for Normal Datasets with Only Detects

Groundwater Statistics Tool

Trend Test Results for Datasets with Nondetect Results

i	t (Days)	C (ppb)	C Predicted	95 UCL Line
1	89.6	150	89.5	
2	90.1	76	81	
3	90.8	20	69.1	
4	91.1	41	64	
5	92.1	42	47	
6	93.1	15	30	
7	94.1	15	13	
8	95.6	15	-12.5	
9	96.1	31	-21	
10	96.3	15	-24.4	
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Kendall's Tau	
Test Result	Decreasing
Test Statistic (S)	-22
Normalized S	-2.411
Critical Value	1.645
Approximate p-value	May be added
Akritas-Theil-Sen	
Slope	-17
Intercept	1612.7



← Return to Normality Screen

Proceed to UCL Screen →

UCL Calculations and Summary

Groundwater Statistics Tool

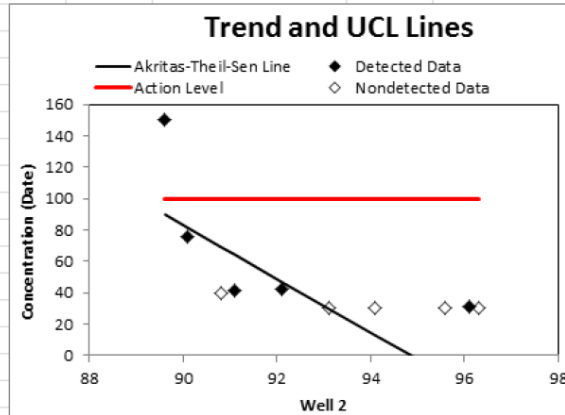
Upper Confidence Limit (UCL) Calculations and Summary

Site Name	Test
Operating Unit (OU)	Test
Type of Evaluation	Attainment
Date of Evaluation	10/31/2012
Person performing analysis	R. Tisdale

Chemical of Concern	Copper
Well Name/Number	Well 2
Date Units	Year
Concentration Units	ppb

Confidence Level	95%
Number of results	10
Number of detected results	5
Number of non-detected results	5
Detection frequency	50%
Number < action level	9
Are any potential outliers present?	No
Mean of concentration	6
Standard deviation of concentration	9.132360045

UCL	18.58808961
Method for calculating UCL	KM Chebyshev UCL
Does the UCL recommended match ProUCL guidance?	To be programmed later, Yes or No
Time-dependent UCL value at final measurement	57.4953991
Trend indicated at specified confidence level?	Decreasing
Action level	100
Source of action level	MCL
Can the remedy be considered complete at this well for this analyte?	Yes



←←← Return to Data Input Screen

←← Return to Normality Screen

← Return to Trend Screen

Questions?



Disclaimer

- ◆ Information presented in this presentation represents the views of the author(s)/presenter(s) and has not received formal U.S. EPA peer review.
- ◆ This information does not necessarily reflect the views of U.S. EPA, and no official endorsement should be inferred.
- ◆ The information is not intended, nor can it be relied upon, to create any rights enforceable by any party in litigation with the United States or any other party.
- ◆ Use or mention of trade names does not constitute an endorsement or recommendation for use.