ECF-200UP1-19-0013
Revision 0

Calculation of the 95th Percentile Upper Confidence Limit on Plume Monitoring Data for the 200-UP-1 Groundwater Operable Unit Through Calendar Year 2018

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

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APPROVED
By Lynn M. Ayers at 12:30 pm, May 13, 2019

Release Approval Date

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ENVIRONMENTAL CALCULATION COVER PAGE

SECTION 1 - Completed by the Responsible Manager

Project:
200-UP-1 Groundwater Operable Unit

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Calculation Title and Description:
Calculation of the 95 Percent Upper Confidence Limit on Plume Monitoring Data for the 200-UP-1 Groundwater Operable Unit through Calendar Year 2018

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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SECTION 2 - Completed by Preparer

Calculation Number: ECF-200UP1-19-0013 | **Revision Number:** 0

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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SECTION 5 - Applicable if Calculation is a Risk Assessment or Uses an Environmental Model

Prior to Initiating Modeling:

Required training for modelers completed:
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Safety Software Approved:
Integration Lead:

Print First and Last Name	Signature	Date
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Calculation Approved:
Risk/Modeling Integration Manager:

Print First and Last Name	Signature	Date
N/A		

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Terms

95% UCL	95 percent upper confidence limit
CY	calendar year
ECF	environmental calculation file
HEIS	Hanford Environmental Information System
MNA	monitored natural attenuation
OU	operable unit
WMA	waste management area

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1 Purpose

This environmental calculation file (ECF) documents the calculation of the upper one-sided 95 percent confidence limit (95% UCL) on mean concentrations of contaminants for cleanup remedies in the 200-UP-1 groundwater operable unit (OU). The 95% UCL is a plume-wide statistic used to track remediation progress, as described in DOE/RL-2015-14, *Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action*. The calculations in this ECF support annual reporting for Calendar Year (CY) 2018.

2 Background

The following active, groundwater-restoration remedies were operating in 200-UP-1 during CY 2018:

1. Groundwater extraction at Waste Management Area (WMA) S-SX primarily for technetium-99; chromium and nitrate also are recovered
2. Groundwater extraction in the U Plant area downgradient from the 216-U-1 and 216-U-2 Cribs primarily for uranium; technetium-99 and nitrate also are recovered

The following passive, groundwater-restoration remedies were operating in 200-UP-1 during CY 2018:

1. Monitored natural attenuation (MNA) for the regional nitrate plume
2. MNA for the regional tritium plume

The extraction wells near WMA S-SX and U Plant also remove carbon tetrachloride from the aquifer, but remediation of this plume is being implemented as part of remedial actions for the 200-ZP-1 OU. Thus, plume monitoring and evaluations of remediation progress for carbon tetrachloride are overseen as part of 200-ZP-1 OU activities.

Use of the 95% UCL statistic is recommended for calculating groundwater plume exposure point concentrations in superfund risk assessment guidance (OSWER 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*), and it is calculated using sample results at monitoring wells. The advantage of the 95% UCL is that it provides a comprehensive evaluation of plume concentrations in a single metric. It is used in the 200-UP-1 OU to track remediation progress by evaluating the trend of the 95% UCL values over time and by comparing the 95% UCL values from monitoring data to values calculated from fate and transport modeling results.

Previous calculation of 95% UCL values for the 200-UP-1 OU were documented in:

- ECF-200UP1-16-0073, *Calculated Timeframes for Attainment of Cleanup Levels in the 200-UP-1 Operable Unit for Remedial Action based on 95th Percent Upper Confidence Limit Calculation for Groundwater Monitoring Data and Updated Simulated Future Groundwater Fate and Transport*
- ECF-200UP1-18-0017, 2018, *Calculation of the 95th Percentile Upper Confidence Limit on Plume Monitoring Data for the 200-UP-1 Groundwater Operable Unit through Calendar Year 2017*

The 200-UP-1 performance monitoring plan, DOE/RL-2015-14, is undergoing revision and two changes are being made to the methodology for calculating 95% UCL values. First, the calculations will use only a single sample result for each well within a single year (the last sample of the year), rather than using all sample events within the year. This will prevent the 95% UCL values from being biased toward those

wells that are sampled more frequently, thus providing more uniform spatial representations of mean plume concentrations. Second, to keep the statistical sample sizes relatively large, 95% UCL values will be calculated using 3 years of sample results for each constituent. These changes were implemented in ECF-200UP1-18-0017 and will result in more compatibility with the 95% UCL values calculated from fate and transport modeling, which also used 3 years of results in each calculation and only a single result per well per year. Fate and transport modeling of 95% UCL values are documented in:

- ECF-200UP1-17-0093, *Fate and Transport Analysis for U Plant Groundwater Plumes in the 200-UP-1 Operable Unit*, for uranium and technetium-99 at U Plant
- ECF-200UP1-17-0094, *Fate and Transport Analysis for WMA S-SX Groundwater Plumes in the 200-UP-1 Operable Unit*, for technetium-99, chromium, and nitrate at WMA S-SX
- ECF-200ZP1-17-0095, *Fate and Transport Analysis for the Groundwater Plume Remedies in the 200-ZP-1 and 200-UP-1 Operable Units Using the Central Plateau Groundwater Model*, for the regional tritium and nitrate plumes.

3 Methodology

The one-sided 95% UCL was calculated using Student's *t* distribution (OSWER 9285.6-10):

$$UCL_{95} = \bar{x} + t_{\alpha,n-1}\frac{s}{\sqrt{n}} \quad \textbf{(Eq. 1)}$$

where

$\bar{x}$ = arithmetic mean of the sample results

$t_{\alpha,n-1}$ = the 1-α^{th} quantile of Student's *t* distribution with *n*-1 degrees of freedom; for the 95th percentile, $\alpha = 0.95$ (one-tailed)

s = standard deviation of the sample results

n = number of samples.

The calculations were performed using the following procedure:

1. Identify the well networks for each constituent as specified in DOE/RL-2015-14.
2. Obtain sample results for the monitoring wells from the Hanford Environmental Information System (HEIS) database and export into a Microsoft Access® database for the period from 1/1/2016 through 12/31/2018. The fields extracted from the HEIS database are listed in Table 1. For chromium, obtain available sample results for both filtered total chromium and hexavalent chromium (filtered or unfiltered).
3. Remove all sample results flagged as suspect (REVIEW_QUALIFIER = 'Y') or reject (REVIEW_QUALIFIER = 'R').
4. Remove all characterization sample results (COLLECTION_PURPOSE = 'C'). These denote non-standard samples, such as those collected during well drilling for characterization purposes.

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5. For non-detect results (LAB_QUALIFIER = 'U'), use the method detection limit as the sample result.
6. In accordance with DOE/RL-2015-14, when concentrations in a well decline below 1/10th the cleanup level for three consecutive years, the well is removed from the 95% UCL calculation. The 200-UP-1 cleanup levels are 900 pCi/L for technetium-99, 45 mg/L for nitrate, 48 µg/L for hexavalent chromium, 30 µg/L for uranium, and 20,000 pCi/L for tritium. Chromium concentrations at well 299-W22-113 were less than 4.8 µg/L in 2016, 2017, and 2018, so these data were excluded from the 95% UCL calculation for chromium.
7. For duplicate analytical results obtained from a well on the same sample day, use the average of those results. For chromium, where both filtered total chromium and hexavalent chromium results were obtained from a well on the same sample day, use the average of those results.
8. For each well, select the last sample result in 2018, 2017, and 2016, respectively (three results total). For a newer well without sample results in previous years, use 2017 or 2016 data from the dry well that was replaced (if available) or use additional 2018 results (as needed) to provide up to three sample results for the newer well.
9. Calculate a 95% UCL value using Equation 1 for the following:

- Technetium-99 at WMA S-SX
- Chromium at WMA S-SX
- Nitrate at WMA S-SX
- Uranium at U Plant
- Tritium, regional plume
- Nitrate, regional plume

Table 1. HEIS Database Fields

Field Extracted*	Definition
SAMP_SITE_NAME	Location Identification
SAMP_DATE_TIME	Sampling Date and Time
STD_CON_LONG_NAME	Analyte Name
STD_VALUE_RPTD	Reported Concentration
STD_ANAL_UNITS_RPTD	Units for Concentration Measurement
FILTERED_FLAG	Sample Filter Status, Yes or No
LAB_QUALIFIER	Laboratory Data Qualifier
REVIEW_QUALIFIER	Review Data Qualifier
COLLECTION_PURPOSE	Primary Reason for Sample Collection

Table 1. HEIS Database Fields

Field Extracted*	Definition

*Field codes are defined in HNF-38155, *HEIS Sample, Result, and Sampling Site Data Dictionary*.

HEIS = Hanford Environmental Information System

4 Assumptions and Inputs

Input data to the 95% UCL calculations consisted of the well networks specified in DOE/RL-2015-14 (Step 1 in Section 3) and sample results obtained from HEIS (Step 2 in Section 3). The well networks are listed in Table 2. The sample data used for these calculations are shown in Appendix A.

There were two main assumptions associated with these calculations. First, it was assumed that sample results for filtered total chromium are compatible with results for filtered or unfiltered hexavalent chromium in that all of these represent the dissolved (and therefore mobile) chromium concentration in the aquifer. This is consistent with plume mapping conventions used for Hanford Site annual groundwater monitoring reports. As stated in DOE/RL-2016-67, *Hanford Site Groundwater Monitoring Report for 2016*, "Dissolved chromium in Hanford Site groundwater is nearly all hexavalent (Chapter 7 of WHC-SD-EN-TI-302, *Speciation and Transport Characteristics of Chromium in the 100D/H Areas of the Hanford Site*; Appendix C of DOE/RL-2008-01, *Hanford Site Groundwater Monitoring for Fiscal Year 2007*), so filtered total chromium data effectively represent [hexavalent chromium] concentrations."

Second, use of Student's *t* distribution involves the assumption that the data are normally distributed. Normality was not tested, but there is no substantial consequence if this assumption is violated because the 95% UCL statistic will not be used for risk assessment purposes. Use of Student's *t* distribution for these calculations will allow for consistent assessment of remedial progress through time.

Table 2. Well Networks for the 200-UP-1 95% UCL Calculations

Well	Status	Contaminant of Concern				
		Chromium (Hexavalent)	Nitrate	Technetium-99	Tritium	Uranium
299-W15-37	O	—	Regional	—	—	—
299-W18-15	O	—	Regional	—	—	—
299-W18-21	O	—	Regional	—	—	—
299-W18-40	O	—	Regional	—	—	—
299-W19-4	O	—	Regional	—	—	—
299-W19-36	O	—	—	—	—	U Plant
299-W19-39	O	—	Regional	—	—	U Plant

Table 2. Well Networks for the 200-UP-1 95% UCL Calculations

Well	Status	Contaminant of Concern				
		Chromium (Hexavalent)	Nitrate	Technetium-99	Tritium	Uranium
299-W19-43	O	—	Regional	—	—	U Plant
299-W19-44	O	—	Regional	—	—	—
299-W19-45	O	—	Regional	—	—	—
299-W19-46	O	—	—	—	—	U Plant
299-W19-47	O	—	Regional	—	—	—
299-W19-48	O	—	Regional	—	—	U Plant
299-W19-49	O	—	—	—	—	U Plant
299-W19-101	O	—	Regional	—	—	U Plant
299-W19-105	O	—	—	—	—	U Plant
299-W19-107	O	—	Regional	—	—	—
299-W19-115	N,R,O	—	Regional	—	—	U Plant
299-W19-18	D	—	Regional	—	—	U Plant
299-W19-116	N,R,O	—	Regional	—	—	—
299-W19-123	N,R,O	—	—	—	—	U Plant
299-W21-3	N,R,O	—	—	—	Regional	—
699-35-70	D	—	—	—	Regional	—
299-W22-47	O	S-SX	—	—	—	—
299-W22-72	O	—	—	—	Regional	—
299-W22-82	O	S-SX	—	S-SX	—	—
299-W22-83	O	S-SX	S-SX	S-SX	—	—
299-W22-86	O	S-SX	S-SX	S-SX	—	—
299-W22-93	N,R,O	S-SX	S-SX	S-SX	—	—
299-W22-44	D	S-SX	S-SX	S-SX	—	—
299-W22-95	O	S-SX	S-SX	—	—	—
299-W22-96	O	—	—	S-SX	Regional	—
299-W22-113	R,O	S-SX	S-SX	S-SX	Regional	—
299-W22-49	D	S-SX	S-SX	S-SX	Regional	—

Table 2. Well Networks for the 200-UP-1 95% UCL Calculations

Well	Status	Contaminant of Concern				
		Chromium (Hexavalent)	Nitrate	Technetium-99	Tritium	Uranium
299-W22-114	N,R,O	—	—	—	Regional	—
299-W22-9	D	—	—	—	Regional	—
299-W22-115	N,R,O	—	S-SX	S-SX	Regional	—
299-W22-45	D	—	S-SX	S-SX	Regional	—
299-W22-116	N,R,O	S-SX	S-SX	S-SX	—	—
299-W22-50	D	S-SX	S-SX	S-SX	—	—
299-W23-4	O	—	—	—	Regional	—
299-W23-19	O	S-SX	S-SX	S-SX	Regional	—
299-W23-21	O	—	S-SX	—	Regional	—
699-31-68	N,O	—	—	—	Regional	—
699-32-72A	O	—	—	—	Regional	—
699-34-72	O	—	—	—	Regional	—
699-35-66A	O	—	—	—	Regional	—
699-36-61A	O	—	—	—	Regional	—
699-36-63B	N,O	—	—	—	Regional	—
699-36-66B	O	—	Regional	—	Regional	—
699-36-70A	O	—	—	—	Regional	—
699-36-70B	O	—	Regional	—	—	—
699-37-66	O	—	Regional	—	Regional	—
699-38-61	O	—	—	—	Regional	—
699-38-64B	N,O	—	Regional	—	—	—
699-38-65	O	—	Regional	—	Regional	—
699-38-68A	O	—	Regional	—	—	—
699-38-70B	O	—	Regional	—	—	—
699-38-70C	O	—	Regional	—	—	—
699-39-68	N,O	—	Regional	—	—	—
699-40-62	O	—	Regional	—	—	—

Table 2. Well Networks for the 200-UP-1 95% UCL Calculations

Well	Status	Contaminant of Concern				
		Chromium (Hexavalent)	Nitrate	Technetium-99	Tritium	Uranium
699-40-65	O	—	Regional	—	—	—

References:

DOE/RL-2015-14, *Performance Monitoring Plan for the 200-UP-1 Groundwater Operable Unit Remedial Action*.

ECF-200UP1-18-0017, *Calculation of the 95th Percentile Upper Confidence Limit on Plume Monitoring Data for the 200-UP-1 Groundwater Operable Unit through Calendar Year 2017*.

Status Codes

D = well yields insufficient water for sampling (dry) or is nearly dry; dry wells are shown with grey text and are listed beneath their associated replacement wells if previously used for 95% UCL calculation

N = new well installed since Revision 0 of DOE/RL-2015-14 (the 200-UP-1 OU PMP)

O = operational well (currently sampled)

R = replacement well for dry well

S-SX designates well used for 95% UCL calculation in the WMA S-SX vicinity for chromium, nitrate, or technetium-99.

Regional designates well used for 95% UCL calculation in the regional plume areas for nitrate or tritium.

U Plant designates well used for 95% UCL calculation in the U Plant vicinity for uranium

Additions to the 95% UCL well network since Revision 0 of DOE/RL-2015-14 are the replacement wells shown above and the following:

299-W22-95 for chromium

299-W19-4, 299-W19-116, 299-W22-95, 699-38-64B, 699-38-70B, and 699-39-68 for nitrate

699-31-68 and 699-36-63B for tritium

299-W19-123 for uranium

Deletions to the 95% UCL well network since Revision 0 of DOE/RL-2015-14 are the dry wells shown above.

For technetium-99 near WMA-SX, the 95% UCL was recalculated for 2015, 2016, and 2017 using available concentration data through 2015 for well 299-W22-45 (which is now dry) and data from 2016 and 2017 for well 299-W22-115 (the replacement for well 299-W22-45). The initial routine sample collected from well 299-W22-115 on 12/29/2015 was not used to avoid spatial redundancy and given its relatively-low concentration of 954 pCi/L compared to later results at this well and previous results at well 299-W22-45. These recalculations increased the 95% UCL values from those calculated in ECF-200UP1-18-0017 by approximately 2% for 2015, 2016, and 2017.

95% UCL = 95% upper confidence limit

OU = operable unit

PMP = performance monitoring plan

WMA = waste management area

5 Software Applications

All software used for this calculation was used in accordance with PRC-PRO-IRM-309, *Controlled Software Management*.

5.1 Exempt Software

Microsoft Excel® is site-licensed software used as "flat file" spreadsheets that are wholly incorporated into this calculation and verified during the technical review of this report and is therefore rated as exempt software (PRC-PRO-IRM-309, Section 1.3, Exemptions). Spreadsheets were used to tabulate the groundwater data obtained from HEIS and to calculate the 95% UCL statistic using the methodology described in Section 3.

5.2 Approved Software

No utility calculation software, as defined in PRC-PRO-IRM-309, were used in these calculations

6 Calculation and Results

Calculations of the 95% UCL values were performed in spreadsheets, which are archived as part of this ECF. The calculation results for 2018 are provided in Appendix A. These results are summarized in Table 3 along with results for 2008 through 2017. Calculations for years prior to 2018 are documented in ECF-200UP1-18-0017. Time-series charts for the 95% UCL calculation results for 2008 through 2018 are provided in Figures 1 through 6.

Table 3. 95% UCL Calculation Results

Area	Constituent	Year	95% UCL
WMA S-SX	Technetium-99 (pCi/L)	2008	21,771
WMA S-SX	Technetium-99 (pCi/L)	2009	21,964
WMA S-SX	Technetium-99 (pCi/L)	2010	19,968
WMA S-SX	Technetium-99 (pCi/L)	2011	19,768
WMA S-SX	Technetium-99 (pCi/L)	2012	21,301
WMA S-SX	Technetium-99 (pCi/L)	2013	15,060
WMA S-SX	Technetium-99 (pCi/L)	2014	12,296
WMA S-SX	Technetium-99 (pCi/L)	2015	8,368
WMA S-SX	Technetium-99 (pCi/L)	2016	6,841
WMA S-SX	Technetium-99 (pCi/L)	2017	6,123
WMA S-SX	Technetium-99 (pCi/L)	2018	7,188
WMA S-SX	Nitrate (mg/L)	2008	190.0
WMA S-SX	Nitrate (mg/L)	2009	199.6
WMA S-SX	Nitrate (mg/L)	2010	188.4

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Table 3. 95% UCL Calculation Results

Area	Constituent	Year	95% UCL
WMA S-SX	Nitrate (mg/L)	2011	192.7
WMA S-SX	Nitrate (mg/L)	2012	208.5
WMA S-SX	Nitrate (mg/L)	2013	156.4
WMA S-SX	Nitrate (mg/L)	2014	130.5
WMA S-SX	Nitrate (mg/L)	2015	94.8
WMA S-SX	Nitrate (mg/L)	2016	78.8
WMA S-SX	Nitrate (mg/L)	2017	73.3
WMA S-SX	Nitrate (mg/L)	2018	70.7
WMA S-SX	Chromium (µg/L)	2008	420.2
WMA S-SX	Chromium (µg/L)	2009	409.6
WMA S-SX	Chromium (µg/L)	2010	404.8
WMA S-SX	Chromium (µg/L)	2011	419.0
WMA S-SX	Chromium (µg/L)	2012	545.6
WMA S-SX	Chromium (µg/L)	2013	381.4
WMA S-SX	Chromium (µg/L)	2014	288.4
WMA S-SX	Chromium (µg/L)	2015	179.4
WMA S-SX	Chromium (µg/L)	2016	130.4
WMA S-SX	Chromium (µg/L)	2017	107.8
WMA S-SX	Chromium (µg/L)	2018	101.4
U Plant	Uranium (µg/L)	2008	263.5
U Plant	Uranium (µg/L)	2009	234.2
U Plant	Uranium (µg/L)	2010	223.1
U Plant	Uranium (µg/L)	2011	220.0
U Plant	Uranium (µg/L)	2012	191.9
U Plant	Uranium (µg/L)	2013	182.7
U Plant	Uranium (µg/L)	2014	215.0
U Plant	Uranium (µg/L)	2015	317.5
U Plant	Uranium (µg/L)	2016	464.1
U Plant	Uranium (µg/L)	2017	844.3
U Plant	Uranium (µg/L)	2018	777.3
Regional	Nitrate (mg/L)	2008	216.5
Regional	Nitrate (mg/L)	2009	174.3

Table 3. 95% UCL Calculation Results

Area	Constituent	Year	95% UCL
Regional	Nitrate (mg/L)	2010	179.1
Regional	Nitrate (mg/L)	2011	160.1
Regional	Nitrate (mg/L)	2012	544.1
Regional	Nitrate (mg/L)	2013	451.2
Regional	Nitrate (mg/L)	2014	367.8
Regional	Nitrate (mg/L)	2015	353.0
Regional	Nitrate (mg/L)	2016	267.9
Regional	Nitrate (mg/L)	2017	226.3
Regional	Nitrate (mg/L)	2018	105.7
Regional	Tritium (pCi/L)	2008	101,127
Regional	Tritium (pCi/L)	2009	75,501
Regional	Tritium (pCi/L)	2010	64,677
Regional	Tritium (pCi/L)	2011	55,060
Regional	Tritium (pCi/L)	2012	111,057
Regional	Tritium (pCi/L)	2013	95,053
Regional	Tritium (pCi/L)	2014	87,013
Regional	Tritium (pCi/L)	2015	78,604
Regional	Tritium (pCi/L)	2016	70,633
Regional	Tritium (pCi/L)	2017	62,602
Regional	Tritium (pCi/L)	2018	57,939

95% UCL = 95% upper confidence limit
WMA = waste management area

Figure 1. 95% UCL Values for Technetium-99 in the WMA S-SX Vicinity

Figure 2. 95% UCL Values for Nitrate in the WMA S-SX Vicinity

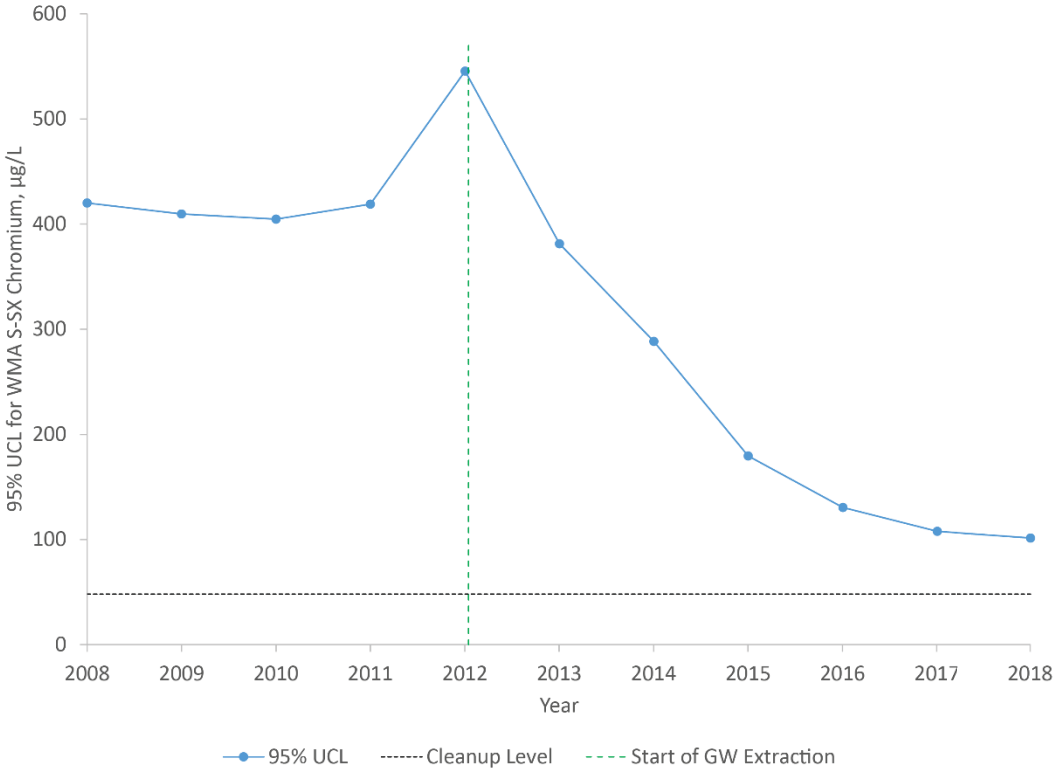

Figure 3. 95% UCL Values for Chromium in the WMA S-SX Vicinity

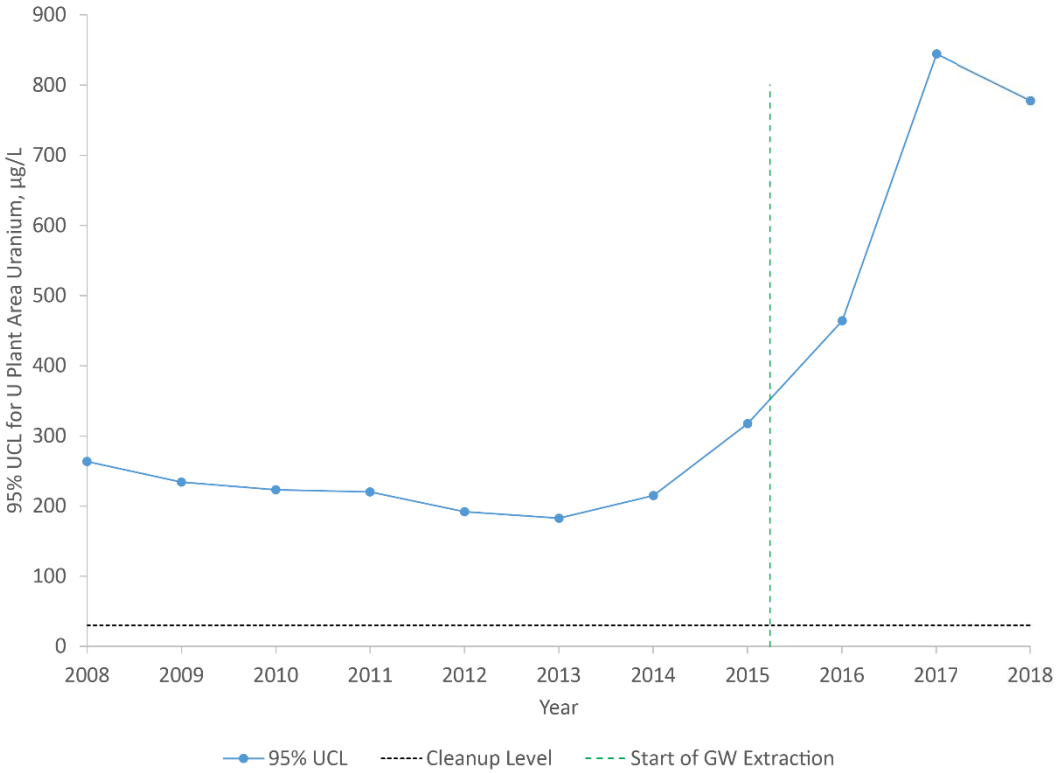

Figure 4. 95% UCL Values for Uranium in the U Plant Area

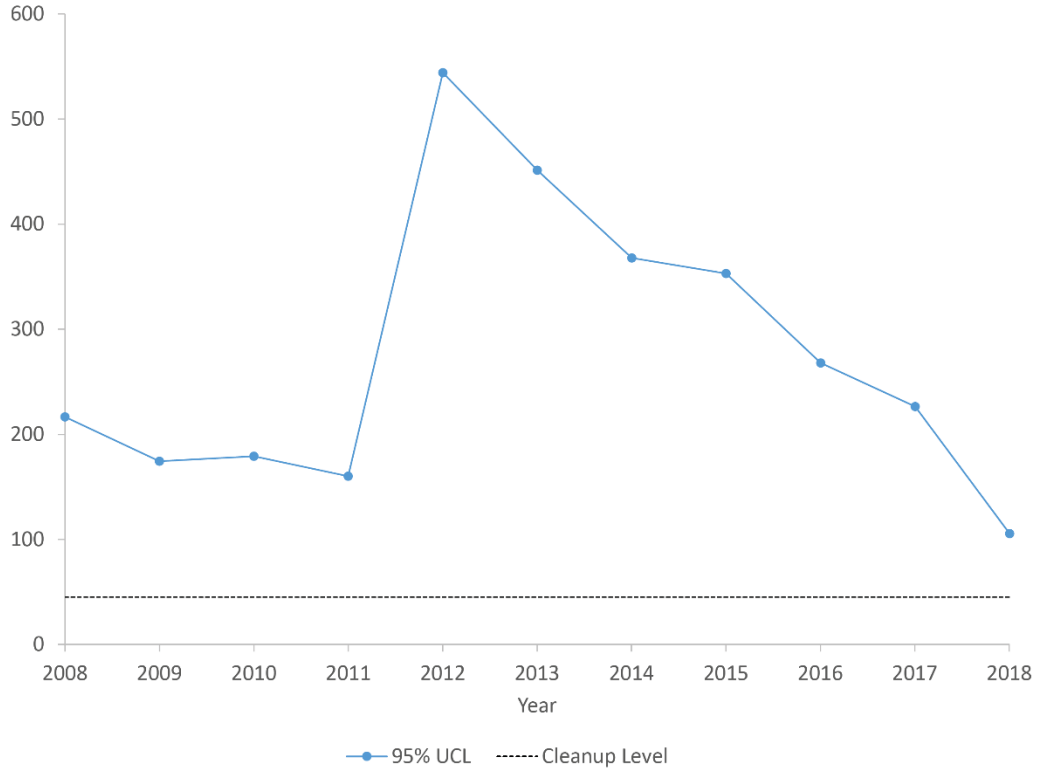

Figure 5. 95% UCL Values for Regional Nitrate in 200-UP-1

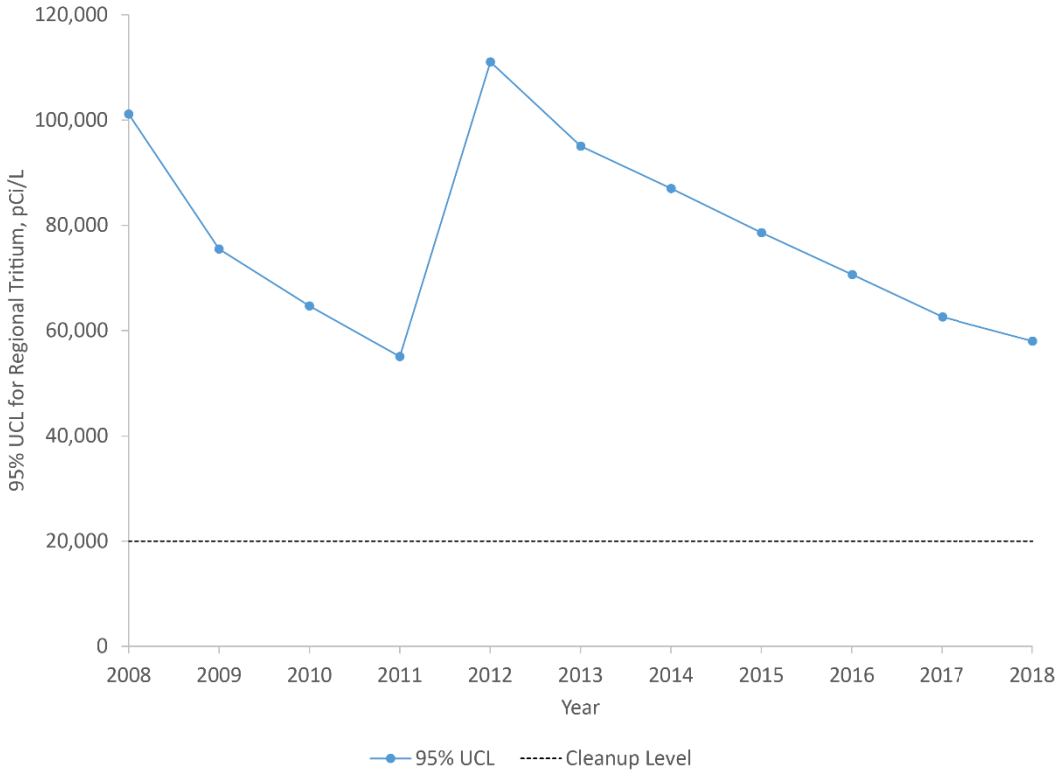

Figure 6. 95% UCL Values for Regional Tritium in 200-UP-1

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Appendix A

95% UCL Data and Calculations

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95% UCL (Student's t) Calculation for the 200-UP-1 OU - WMA S-SX Technetium-99

mean:	4996.648148
SD:	6675.970575
SE:	1284.791136
n:	27
UCL:	95%
t26*	1.70561792
95% UCL:	**7188.010933**

Notes:
n = number of values in data set
SD = standard deviation
SE = standard error
UCL = upper confidence limit
$t_{(n-1)}$* = t-critical (left-tailed inverse of Student's t-distribution)

WMA S-SX Technetium-99 Data

Well Name	Sample Date	Reported Value	Units
299-W22-113	12/21/2016	386	pCi/L
299-W22-113	12/14/2017	805	pCi/L
299-W22-113	12/10/2018	744	pCi/L
299-W22-115	12/21/2016	2390	pCi/L
299-W22-115	12/13/2017	2680	pCi/L
299-W22-115	12/7/2018	3390	pCi/L
299-W22-116	12/21/2016	11200	pCi/L
299-W22-116	12/14/2017	11200	pCi/L
299-W22-116	12/10/2018	12950	pCi/L
299-W22-82	12/2/2016	2140	pCi/L
299-W22-82	6/12/2017	2230	pCi/L
299-W22-82	6/11/2018	1260	pCi/L
299-W22-83	12/2/2016	4650	pCi/L
299-W22-83	12/13/2017	757	pCi/L
299-W22-83	12/7/2018	913.5	pCi/L
299-W22-86	6/2/2016	2400	pCi/L
299-W22-86	6/9/2017	1630	pCi/L
299-W22-86	6/8/2018	1790	pCi/L
299-W22-93	9/13/2016	1490	pCi/L
299-W22-93	12/13/2017	2020	pCi/L
299-W22-93	12/10/2018	924	pCi/L
299-W22-96	12/2/2016	2580	pCi/L
299-W22-96	6/16/2017	2610	pCi/L
299-W22-96	7/2/2018	4570	pCi/L
299-W23-19	9/21/2016	12600	pCi/L
299-W23-19	6/12/2017	13700	pCi/L
299-W23-19	6/8/2018	30900	pCi/L

95% UCL (Student's t) Calculation for the 200-UP-1 OU - WMA S-SX Nitrate

mean:	58.49814815
SD:	37.05410411
SE:	7.13106566
n:	27
UCL:	95%
t26*	1.70561792
95% UCL:	**70.66102152**

Notes:
n = number of values in data set
SD = standard deviation
SE = standard error
UCL = upper confidence limit
$t_{(n-1)}$* = t-critical (left-tailed inverse of Student's t-distribution)

WMA S-SX Nitrate Data

Well Name	Sample Date	Reported Value	Units
299-W22-83	12/2/2016	37.2	mg/L
299-W22-83	12/13/2017	13.4	mg/L
299-W22-83	12/7/2018	17.3	mg/L
299-W22-86	6/2/2016	25.2	mg/L
299-W22-86	12/13/2017	13.55	mg/L
299-W22-86	12/7/2018	14.2	mg/L
299-W22-93	12/19/2016	102	mg/L
299-W22-93	12/13/2017	47.8	mg/L
299-W22-93	12/10/2018	48.7	mg/L
299-W22-95	12/21/2016	62	mg/L
299-W22-95	12/13/2017	41.7	mg/L
299-W22-95	12/7/2018	40.7	mg/L
299-W22-113	12/21/2016	48.7	mg/L
299-W22-113	12/14/2017	40.1	mg/L
299-W22-113	1/30/2018	44.3	mg/L
299-W22-115	12/21/2016	84.1	mg/L
299-W22-115	12/13/2017	65.1	mg/L
299-W22-115	12/7/2018	84.1	mg/L
299-W22-116	12/21/2016	70.8	mg/L
299-W22-116	12/14/2017	65.5	mg/L
299-W22-116	12/10/2018	81.9	mg/L
299-W23-19	12/19/2016	104	mg/L
299-W23-19	12/15/2017	149	mg/L
299-W23-19	12/7/2018	155	mg/L
299-W23-21	6/3/2016	40.7	mg/L
299-W23-21	12/20/2017	56.7	mg/L
299-W23-21	12/7/2018	25.7	mg/L

95% UCL (Student's t) Calculation for the 200-UP-1 OU - WMA S-SX Chromium

mean:	73.79402778
SD:	78.95205003
SE:	16.11601973
n:	24
UCL:	95%
t23*	1.713871528
95% UCL:	**101.4148151**

Notes:
n = number of values in data set
SD = standard deviation
SE = standard error
UCL = upper confidence limit
$t_{(n-1)}$* = t-critical (left-tailed inverse of Student's t-distribution)

WMA S-SX Chromium Data [a]

Well Name	Sample Date	Reported Value	Units
299-W22-47	12/19/2016	4.34	µg/L
299-W22-47	12/12/2017	5.5	µg/L
299-W22-47	12/6/2018	4.7	µg/L
299-W22-82	12/2/2016	26.75	µg/L
299-W22-82	12/12/2017	18.8	µg/L
299-W22-82	12/6/2018	12	µg/L
299-W22-83	12/2/2016	69	µg/L
299-W22-83	12/13/2017	14	µg/L
299-W22-83	12/7/2018	24.05	µg/L
299-W22-86	6/2/2016	24.4	µg/L
299-W22-86	12/13/2017	18.1	µg/L
299-W22-86	12/7/2018	21	µg/L
299-W22-93	9/13/2016	128.5	µg/L
299-W22-93	12/13/2017	138.67	µg/L
299-W22-93	12/10/2018	114.6	µg/L
299-W22-95	12/21/2016	55.5	µg/L
299-W22-95	12/13/2017	42.8	µg/L
299-W22-95	12/7/2018	41.7	µg/L
299-W22-113	12/21/2016	— [b]	µg/L
299-W22-113	12/14/2017	— [b]	µg/L
299-W22-113	12/10/2018	— [b]	µg/L
299-W22-116	12/21/2016	119.5	µg/L
299-W22-116	12/14/2017	93.5	µg/L
299-W22-116	12/10/2018	103.65	µg/L
299-W23-19	12/19/2016	162	µg/L
299-W23-19	12/15/2017	190	µg/L
299-W23-19	12/7/2018	338	µg/L

[a] Hexavalent or filtered total chromium result or average of these if both analyses conducted

[b] Concentration < 1/10th the cleanup level for 3 consecutive years - removed for 95% UCL calculation

95% UCL (Student's t) Calculation for the 200-UP-1 OU - U Plant Area Uranium

mean:	440.0333333
SD:	1087.07607
SE:	198.4720285
n:	30
UCL:	95%
t29*	1.699127027
95% UCL:	**777.262521**

Notes:
n = number of values in data set
SD = standard deviation
SE = standard error
UCL = upper confidence limit
$t_{(n-1)}$* = t-critical (left-tailed inverse of Student's t-distribution)

U Plant Area Uranium Data

Well Name	Sample Date	Reported Value	Units
299-W19-36	8/2/2016	2350	µg/L
299-W19-36	8/15/2017	5000	µg/L
299-W19-36	8/2/2018	2980	µg/L
299-W19-39	8/2/2016	44.6	µg/L
299-W19-39	8/3/2017	37.7	µg/L
299-W19-39	8/2/2018	39.3	µg/L
299-W19-43	8/10/2016	133	µg/L
299-W19-43	8/3/2017	108	µg/L
299-W19-43	12/27/2018	70.9	µg/L
299-W19-46	8/30/2016	37	µg/L
299-W19-46	8/3/2017	26	µg/L
299-W19-46	12/20/2018	19.4	µg/L
299-W19-48	8/5/2016	41	µg/L
299-W19-48	8/3/2017	32	µg/L
299-W19-48	8/2/2018	31.7	µg/L
299-W19-49	8/5/2016	147	µg/L
299-W19-49	3/27/2018	105	µg/L
299-W19-49	8/2/2018	102	µg/L
299-W19-101	8/10/2016	100	µg/L
299-W19-101	8/3/2017	78	µg/L
299-W19-101	12/20/2018	58.6	µg/L
299-W19-105	2/5/2016	23.6	µg/L
299-W19-105	2/26/2017	18.1	µg/L
299-W19-105	2/21/2018	15.6	µg/L
299-W19-115	10/31/2017	410	µg/L
299-W19-115	8/3/2018	430	µg/L
299-W19-115	11/8/2018	417.5	µg/L
299-W19-123	5/8/2018	107	µg/L
299-W19-123	8/2/2018	114	µg/L
299-W19-123	11/2/2018	124	µg/L

95% UCL (Student's t) Calculation for the 200-UP-1 OU - Regional Nitrate

mean:	94.30746269
SD:	55.77951811
SE:	6.814552734
n:	67
UCL:	95%
t66*	1.668270514
95% UCL:	**105.6759801**

Notes:
n = number of values in data set
SD = standard deviation
SE = standard error
UCL = upper confidence limit
$t_{(n-1)}$* = t-critical (left-tailed inverse of Student's t-distribution)

Regional Nitrate Data

Well Name	Sample Date	Reported Value	Units
299-W15-37	8/2/2016	84.1	mg/L
299-W18-15	2/22/2017	53.1	mg/L
299-W18-15	2/21/2018	29.7	mg/L
299-W18-21	1/19/2016	31.9	mg/L
299-W18-21	1/24/2017	35.9	mg/L
299-W18-21	3/5/2018	44.3	mg/L
299-W18-40	1/15/2016	79.7	mg/L
299-W18-40	10/15/2017	81.9	mg/L
299-W18-40	10/22/2018	77.5	mg/L
299-W19-4	8/3/2017	93	mg/L
299-W19-4	8/2/2018	97.4	mg/L
299-W19-39	8/2/2016	33.6	mg/L
299-W19-39	8/3/2017	31.4	mg/L
299-W19-39	8/2/2018	31	mg/L
299-W19-43	8/10/2016	133	mg/L
299-W19-43	8/3/2017	53.1	mg/L
299-W19-43	12/27/2018	57.5	mg/L
299-W19-44	7/10/2016	48.7	mg/L
299-W19-44	10/15/2017	53.1	mg/L
299-W19-44	10/19/2018	102	mg/L
299-W19-45	7/10/2016	128	mg/L
299-W19-45	10/16/2017	183.5	mg/L
299-W19-45	10/19/2018	142	mg/L
299-W19-47	7/10/2016	70.8	mg/L
299-W19-47	10/15/2017	93	mg/L
299-W19-47	10/19/2018	111	mg/L
299-W19-48	8/5/2016	27.4	mg/L
299-W19-48	8/3/2017	18.6	mg/L
299-W19-48	8/2/2018	17.7	mg/L

Regional Nitrate Data

Well Name	Sample Date	Reported Value	Units
299-W19-101	8/10/2016	93	mg/L
299-W19-101	8/3/2017	70.8	mg/L
299-W19-101	12/20/2018	48.7	mg/L
299-W19-107	8/22/2016	48.7	mg/L
299-W19-107	2/27/2017	29.2	mg/L
299-W19-107	2/21/2018	79.7	mg/L
299-W19-115	10/31/2017	48.7	mg/L
299-W19-115	8/3/2018	28.8	mg/L
299-W19-115	11/8/2018	24.8	mg/L
299-W19-116	10/31/2017	106	mg/L
299-W19-116	8/15/2018	102	mg/L
299-W19-116	11/2/2018	106	mg/L
699-36-66B	9/22/2016	53.1	mg/L
699-36-66B	9/27/2017	29.8	mg/L
699-36-66B	9/18/2018	53.1	mg/L
699-36-70B	4/11/2016	88.5	mg/L
699-36-70B	4/5/2017	81.5	mg/L
699-36-70B	12/20/2018	84.1	mg/L
699-37-66	9/22/2016	146	mg/L
699-37-66	9/27/2017	133.5	mg/L
699-37-66	9/18/2018	155	mg/L
699-38-64B	9/13/2018	217	mg/L
699-38-64B	12/17/2018	181	mg/L
699-38-65	6/17/2016	164	mg/L
699-38-65	6/26/2017	189	mg/L
699-38-68A	2/4/2016	159	mg/L
699-38-68A	1/29/2018	164	mg/L
699-38-70B	7/5/2016	48.7	mg/L
699-38-70C	5/6/2016	124	mg/L
699-38-70C	5/8/2017	113	mg/L
699-38-70C	5/18/2018	133	mg/L
699-39-68	12/19/2018	93	mg/L
699-40-62	1/29/2016	115	mg/L
699-40-62	2/26/2017	142	mg/L
699-40-62	1/4/2018	168	mg/L
699-40-65	5/22/2016	212	mg/L
699-40-65	5/2/2017	215	mg/L
699-40-65	5/1/2018	226	mg/L

95% UCL (Student's t) Calculation for the 200-UP-1 OU - Regional Tritium

mean:	47656.86441
SD:	47249.01976
SE:	6151.298427
n:	59
UCL:	95%
t58*	1.671552762
95% UCL:	**57939.08429**

Notes:
n = number of values in data set
SD = standard deviation
SE = standard error
UCL = upper confidence limit
$t_{(n-1)}$* = t-critical (left-tailed inverse of Student's t-distribution)

Regional Tritium Data

Well Name	Sample Date	Reported Value	Units
299-W21-3	12/27/2016	82900	pCi/L
299-W21-3	12/5/2017	52500	pCi/L
299-W21-3	9/24/2018	49200	pCi/L
299-W22-113	12/21/2016	39700	pCi/L
299-W22-113	12/14/2017	28800	pCi/L
299-W22-113	12/10/2018	23200	pCi/L
299-W22-114	12/7/2017	26400	pCi/L
299-W22-114	7/2/2018	20700	pCi/L
299-W22-114	9/24/2018	23600	pCi/L
299-W22-115	12/21/2016	62300	pCi/L
299-W22-115	12/13/2017	51400	pCi/L
299-W22-115	12/7/2018	51700	pCi/L
299-W22-72	6/3/2016	15600	pCi/L
299-W22-72	6/8/2017	9540	pCi/L
299-W22-72	6/11/2018	12900	pCi/L
299-W22-96	6/7/2016	12600	pCi/L
299-W22-96	6/16/2017	4210	pCi/L
299-W22-96	7/2/2018	6100	pCi/L
299-W23-19	6/3/2016	10500	pCi/L
299-W23-19	6/12/2017	9520	pCi/L
299-W23-19	6/8/2018	12100	pCi/L
299-W23-21	6/3/2016	16500	pCi/L
299-W23-21	6/13/2017	8020	pCi/L
299-W23-21	6/11/2018	4805	pCi/L
299-W23-4	2/9/2016	50550	pCi/L
299-W23-4	2/26/2017	57100	pCi/L
299-W23-4	2/21/2018	84250	pCi/L
699-31-68	12/21/2016	22000	pCi/L
699-31-68	10/19/2017	21000	pCi/L

Regional Tritium Data

Well Name	Sample Date	Reported Value	Units
699-31-68	10/15/2018	20300	pCi/L
699-32-72A	4/13/2016	38100	pCi/L
699-32-72A	4/5/2017	37900	pCi/L
699-32-72A	4/4/2018	29300	pCi/L
699-34-72	2/22/2016	9610	pCi/L
699-34-72	2/24/2017	9950	pCi/L
699-34-72	2/14/2018	11850	pCi/L
699-35-66A	3/11/2016	69000	pCi/L
699-35-66A	3/9/2017	60600	pCi/L
699-35-66A	3/7/2018	56000	pCi/L
699-36-61A	6/19/2016	41200	pCi/L
699-36-61A	6/19/2017	53600	pCi/L
699-36-61A	7/6/2018	48500	pCi/L
699-36-63B	12/5/2017	95000	pCi/L
699-36-63B	9/14/2018	101000	pCi/L
699-36-63B	12/7/2018	97300	pCi/L
699-36-66B	3/11/2016	250000	pCi/L
699-36-66B	3/9/2017	218000	pCi/L
699-36-66B	3/7/2018	187000	pCi/L
699-36-70A	9/22/2016	42400	pCi/L
699-36-70A	9/27/2017	42200	pCi/L
699-36-70A	9/18/2018	47000	pCi/L
699-37-66	3/11/2016	53450	pCi/L
699-37-66	3/8/2017	46100	pCi/L
699-37-66	3/7/2018	38300	pCi/L
699-38-61	2/18/2016	71000	pCi/L
699-38-61	2/24/2017	61700	pCi/L
699-38-61	2/14/2018	41200	pCi/L
699-38-65	6/17/2016	52500	pCi/L
699-38-65	6/26/2017	12000	pCi/L