ECF-200E-19-0108
Revision 0

Groundwater Elevation Mapping for 200 East Area - Quarter 2 Calendar Year 2019

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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By Sarah Harrison at 12:18 pm, Nov 05, 2020

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ENVIRONMENTAL CALCULATION COVER PAGE

SECTION 1 - Completed by the Responsible Manager

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Professional Licenses:

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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SECTION 2 - Completed by Preparer

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ENVIRONMENTAL CALCULATION COVER PAGE (Continued)

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

Prior to Initiating Modeling:

Required training for modelers completed:
Integration Lead:

Print First and Last Name	*Signature*	*Date*

Safety Software Approved:
Integration Lead:

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Calculation Approved:
Risk/Modeling Integration Manager:

Print First and Last Name	*Signature*	*Date*

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Terms

CCU	Cold Creek unit
CHPRC	CH2M HILL Plateau Remediation Company
CPGWM	Central Plateau Groundwater Model
CY	calendar year
DWMU	dangerous waste management unit
ECF	environmental calculation file
HISI	Hanford Information Systems Inventory
HSU	hydrostratigraphic unit
OU	operable unit
SME	subject matter expert
TRIM	Tikhonov Regularized Inverse Method

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1 Purpose

This environmental calculation file (ECF) describes calculations made to generate water-level maps for the second quarter of calendar year (CY) 2019 in the 200 East Area at the Hanford Site Central Plateau (Figure 1). This ECF provides the conceptual and methodological basis for the calculations performed, details the specific methods and codes used to undertake the calculations, and presents results of the calculations. These water-level maps are used in a variety of calculations and reports for the different *Resource Conservation and Recovery Act of 1976* dangerous waste management units (DWMUs) and *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* groundwater operable units (OUs) located within the 200 East Area. A separate ECF is being prepared to present calculations of groundwater hydraulic gradients and average linear velocities at the individual DWMUs.

2 Background

Historically, groundwater elevations in the 200 East Area varied greatly in response to discharges of water from Hanford Site operations to many large wastewater receiving features such as the 216-B-3 Pond and the 216-A-25 Pond. The 200 East Area groundwater elevations also responded to historical discharges in the 200 West Area. Most of those discharges ceased by the mid-1990s, after which groundwater elevations in the 200 East Area fell steadily in areas where discharges formerly occurred. In recent years, changes in groundwater elevations and in corresponding hydraulic gradients and flow directions have been less evident from year-to-year, as groundwater elevations asymptotically approach a quasi-steady-state condition.

As described in ECF-200E-19-0081, *Groundwater Elevation Mapping for 200 East Area - Quarter 1 Calendar Year 2019*, the majority of the unconfined aquifer beneath the 200 East Area of the Central Plateau occurs in a buried paleochannel consisting of highly permeable sediments of the Hanford formation and Cold Creek unit (CCU) overlying basalt. The high permeabilities cause the water table to exhibit a very low-magnitude hydraulic gradient (i.e., the water table is flat). Local variations in water-level measurements in such a low-gradient setting obscure differences in the true water table and resulting estimates of hydraulic gradients are subject to uncertainty from a low signal-to-noise ratio. To improve the accuracy of depth to groundwater measurements and corresponding groundwater elevation (i.e., water table) maps in the 200 East Area, a network of wells was established for which steps were taken to reduce water-level measurement error. The collection of monthly water-level measurements from this network began in May 2013. Over time, the well network was expanded so that eventually a single low-gradient well network was established encompassing much of the 200 East Area.

Two groundwater extraction wells (Figure 1) are operating within the main unconfined aquifer in the 200 East Area to address groundwater contamination at the 200-BP-5 Groundwater OU. Due to the high transmissivity of the gravel of the CCU, the effects of groundwater extraction at the well only influences hydraulic gradients and corresponding groundwater flow directions and rates measurably in the immediate vicinity of extraction wells.

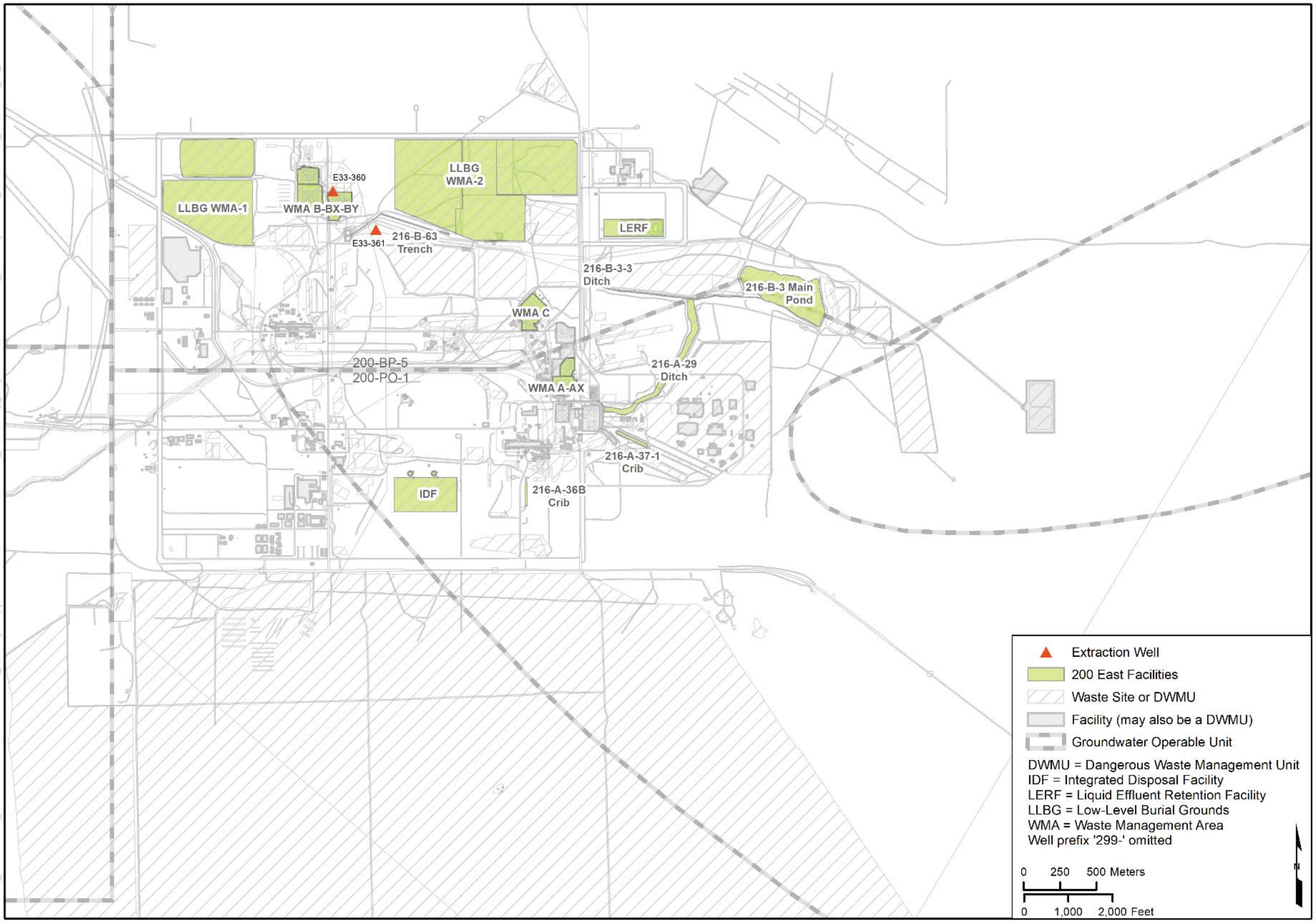

Figure 1. Hanford Site 200 East Area and Associated Waste Sites

3 Calculation Methods

Calculations were completed to develop groundwater elevation maps for the 200 East Area. The calculation approach and tools developed for ECF-200E-19-0081 were used to meet the objectives of this ECF. The method detailed in ECF-200E-19-0081 combined a simplified groundwater flow simulator with statistical methods to obtain a best estimate of groundwater flow patterns in the vicinity of each facility. The parameters of the underlying flow simulator were determined through a regularized inverse interpolation technique referred to as the Tikhonov Regularized Inverse Method (TRIM).

Using the data and methods described in the following sections, regularized inverse water-level mapping was performed to produce continuous gridded depictions of groundwater elevations that conserve flow throughout the 200 East Area and are consistent with measured groundwater levels.

3.1 Data Used

Maps of groundwater levels in the 200 East Area rely on measurements obtained primarily from the wells of the low-gradient network. Groundwater elevations for each well in the low-gradient network were acquired when available from the Hanford Environmental Information System database for April, May, and June 2019. The data were corrected for borehole deviation from vertical and were used to prepare piecewise, continuous grids of groundwater elevations for each month of the second quarter of CY 2019. From these data, a set of averaged groundwater elevations were also calculated and used to prepare a groundwater elevation grid for the second quarter of CY 2019. Groundwater elevations from wells outside the low-gradient network are used when necessary to control contours at the boundaries or in the vicinity of the DWMUs. When used, these measurements are assigned lower weights during the calibration process due to lower confidence in the accuracy of the measurements. The process of assigning weights during calibration allows these measurements to be included where needed but to have less influence on the overall results than the data from the low-gradient network wells.

3.2 Method Description

TRIM was used to obtain a piecewise, continuous grid of groundwater elevations using a simplified groundwater flow simulator as the mechanism to interpolate between measured water levels. TRIM is a formal mathematical technique that is used to trade the complexity of a method or parameterization that is being used to analyze measured data against the "fit" obtained to those data. When used with a deterministic model, Tikhonov regularization is used to constrain the parameters of the model while attempting to attain a satisfactory fit to the measured data that comports with independent subject matter expert (SME) knowledge and information.

As described in ECF-200E-19-0081, this was accomplished by developing a single-layer (i.e., two dimensional) steady-state simulation approximating dominant groundwater flow characteristics over an area encompassing the 200 East Area Facilities, and then using the Tikhonov regularization (Tikhonov and Arsenin, 1977, *Solutions of Ill-Posed Problems*) to constrain parameter complexity and prevent over-fitting to the measured water-level data. The advantage of using a simplified groundwater flow simulator as the mechanism to interpolate between the measured water levels is that the resulting groundwater elevation grids conserve flow and are suitable for tracking particles to evaluate likely paths of groundwater movement.

3.2.1 Development of Single-Layer Simulator

The simplified two-dimensional groundwater flow simulator was inherited from the TRIM analysis work completed for and described in ECF-200E-18-0085, *Water Level Mapping and Hydraulic Gradient Calculations for 200 East Area RCRA Sites, 2018*. Throughout the 200 East Area, the predominant factors that affect areawide groundwater flow patterns are (1) the high-hydraulic conductivity sediments that comprise the Hanford formation and the CCU, (2) the location of lower hydraulic conductivity sediments and basalts that are lateral to or a subcrop within the high-conductivity sediments, and (3) lateral sources and sinks (inflows and outflows) of water particularly along the northwest and southeast extents of the 200 East Area.

These predominant factors were represented in the simplified single-layer (two-dimensional) steady-state simulator of groundwater flow using the unstructured grid release of the MODFLOW[1] (Panday et al., 2013, *MODFLOW-USG Version 1: An Unstructured Grid Version of MODFLOW for Simulating Groundwater Flow and Tightly Coupled Processes Using a Control Volume Finite-Difference Formulation*) program, MODFLOW-USG. The MODFLOW-USG simulation code is a control-volume finite-difference formulation of the commonly used finite-difference U.S. Geological Survey MODFLOW groundwater flow simulator. MODFLOW-USG can support a Voronoi grid, which is well suited to the purpose of these calculations because a much smaller number of cells is needed to discretize the area encompassing the 200 East Area Facilities, and a correspondingly smaller number of regularization equations is needed to specify relations between the parameter value in each cell and that of its neighbors. The simplified two-dimensional simulator of groundwater flow conditions was constructed with the resolution of the mesh refined in areas of particular interest, such as near groups of monitoring wells.

Based on SME knowledge, the hydraulic conductivity of the sediments within which the water table resides was discretized into three hydrostratigraphic unit (HSU) zones, representing the Hanford formation, CCU gravel, and Ringold Formation member of Wooded Island – unit E. Delineation of HSUs at the elevation of the water table was prepared by intersecting the Central Plateau Groundwater Model (CPGWM) water-table grid with a three-dimensional geological model (ECF-HANFORD-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*). Within each of these delineated HSU zones, the hydraulic conductivity was defined as homogeneous for purposes of defining initial parameter values (this represents the “preferred system condition” at the commencement of the Tikhonov regularization that followed). The resulting grid, boundaries, and hydraulic conductivity zones are shown in Figure 2.

3.2.2 Tikhonov Regularization

The program PEST (Doherty, 2015, *Calibration and Uncertainty Analysis for Complex Environmental Models; PEST: complete theory and what it means for modelling the real world*), was used for the implementation of Tikhonov regularization. The PEST software can implement Tikhonov regularization in two modes of operation, the regularization and pareto modes. When operating in the regularization mode, the PEST program calculates updates to the initial values of the parameters that provide an improved fit to the measured values and also determines a global regularization weight parameter. The weight parameter enables the regularization to meet a target value ascribed by the user as representing an “acceptable” fit (Doherty, 2015). When operating in the pareto mode, the PEST program calculates updates to the values of the parameters that explores the relationship between the regularization objective function, the global regularization weight parameter, and measurement objective function. These two modes allow for the tradeoff between the complexity of the simulator or its parameterization versus the fit obtained to the measured data.

[1] MODFLOW is a product of the U.S. Geological Survey, Reston, Virginia.

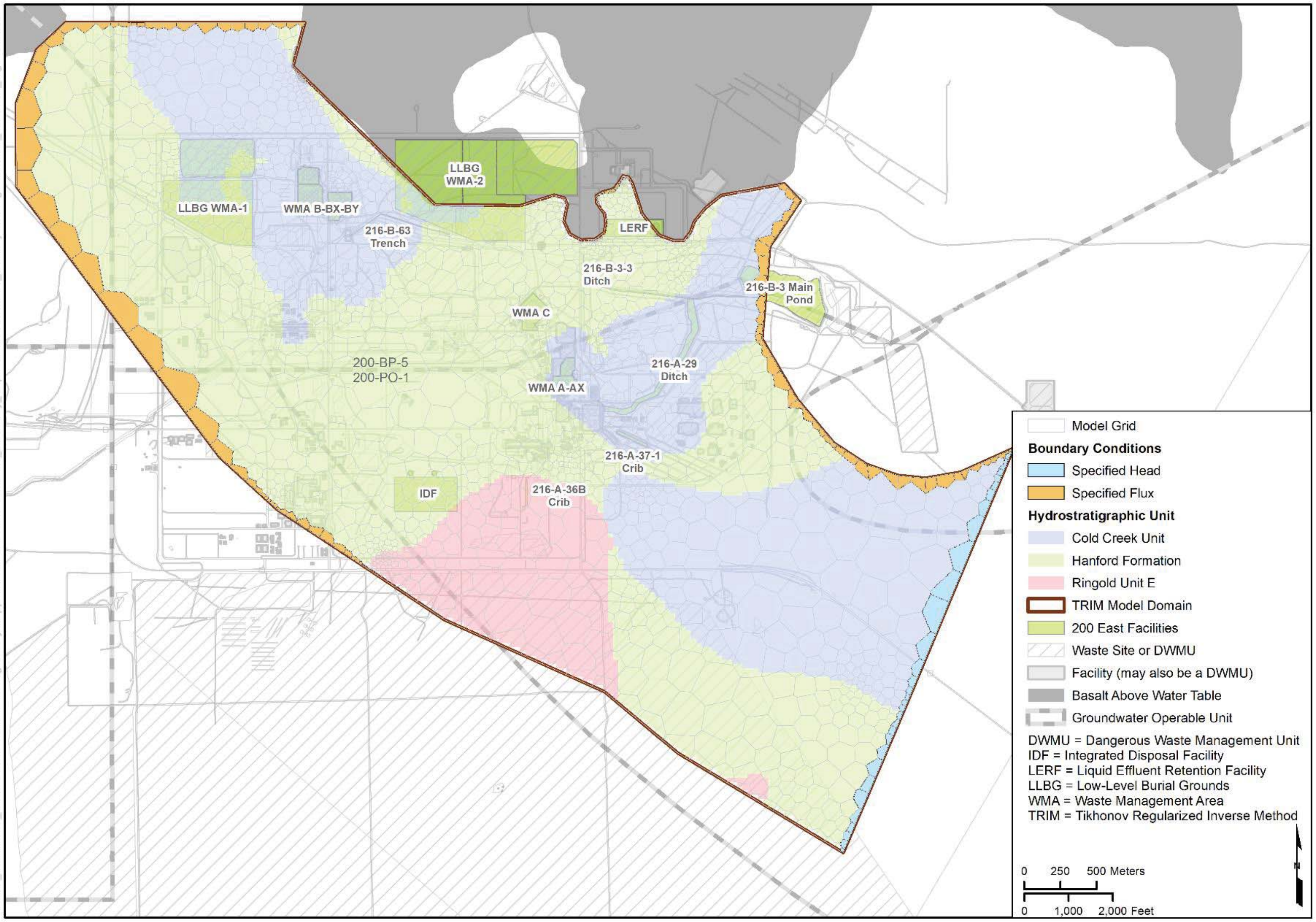

Figure 2. Two-Dimensional Simulator Boundary Conditions and HSU Zones

3.2.3 Limitations

The simplified two-dimensional groundwater flow simulator that underlies TRIM, developed using the MODFLOW-USG code for purposes of this ECF, was implemented specifically for the purpose of providing a mechanism to interpret groundwater level data and obtain groundwater elevation contours depicting directions of groundwater flow and potential migration pathways based upon those measured data. The groundwater elevation contours are obtained by trading-off the complexity of the parameterization of the groundwater simulator versus the fit that is obtained to the measured groundwater elevation data, effectively using the groundwater simulator as an alternative to distance-weighted interpolation (such as kriging) to interpolate between the measured groundwater level data. Because the resulting piecewise, continuous groundwater elevation grids depict hydraulic gradients that comport with independent SME knowledge of subsurface conditions, they are suitable for particle-tracking analyses to depict approximate rates and directions of groundwater flow and potential contaminant migration in the vicinity of the 200 East Area Facilities.

The simplified two-dimensional groundwater flow simulator that underlies TRIM is not a substitute for existing three-dimensional groundwater flow and contaminant transport models at the Hanford Site, such as the CPGWM and the Plateau to River model. There are many simplifications in the underlying groundwater flow simulator developed for purposes of this ECF that include use of a single layer representing only water-table conditions, the regularization objective sought in TRIM of homogeneity without specific regard for the values or physical meaning of the resulting parameters, and the simplified representation of the lateral boundaries of the area of interest. Because of these and other simplifications and limitations, the MODFLOW-USG simulator underlying TRIM should not be used as an alternative to the existing three-dimensional groundwater flow and contaminant transport models (i.e., the CPGWM and Plateau to River model) for mass-conserved simulations of contaminant transport.

4 Assumptions and Inputs

This chapter outlines the assumptions and inputs that underlie the calculations presented in this ECF.

4.1 Assumptions

Assumptions used for the groundwater flow analysis and groundwater elevation mapping are discussed in this section. Water-level contour maps were constructed using the simplified simulator of groundwater flow together with the use of PEST for model calibration and implementation of Tikhonov regularization. The resulting groundwater elevation contour maps provide plausible interpretations of groundwater levels and hydraulic gradients between measured locations. The accuracy of the contours is influenced by several factors contributing uncertainty to the analysis, including the following:

- The accuracy of the measured or recorded water levels (i.e., in some instances, the measurement error may be of similar magnitude to the elevation difference between separate measurement locations at the observed low gradient)
- The number, distribution, and location of monitoring wells (i.e., wells have been installed for other purposes than determining regional groundwater elevation and resulting in unmeasured segments of the aquifer may be quite large)
- The relationship between the vertical open intervals of the monitoring wells and those of any extraction and injection wells (i.e., operation of extraction or injection wells can directly influence groundwater elevations in nearby wells)

These potential sources of error mean that the maps are interpreted as reasonable approximations that provide useful inference in the interpretation of likely directions and rates of groundwater movement, particularly in regions of low hydraulic gradients. The water-level analysis presented in this ECF incorporates the working assumption that the potential errors imposed by these conditions are understood and the resulting effects are acceptable to the overall interpretation of groundwater elevation. Based on SME knowledge and understanding of the groundwater system in the 200 East Area, these estimates are assumed to be representative of observed conditions.

4.2 Input Data

This section summarizes the general input requirements for the calculations described in this ECF.

Water-level data were retrieved from the Hanford Environmental Information System database for 63 low-gradient network monitoring wells and one additional well, 299-E26-10. Data were limited to those used specifically for water-table mapping. Table 1 lists data for the second quarter of CY 2019 and the calculated average water-level elevations for that period.

Table 1. Water-Level Measurements

Well Name	Average Measured Water Levels (NAVD88 meters)			Average Apr-to-Jun-2019
	Apr-2019	May-2019	Jun-2019	
299-E17-18	121.616	121.605	121.607	121.609
299-E17-21	121.652	121.641	NM	121.647
299-E17-22	121.632	121.627	121.620	121.626
299-E17-23	121.633	121.616	NM	121.625
299-E17-25	121.646	121.627	NM	121.637
299-E18-2	121.681	121.673	121.663	121.672
299-E23-1	121.630	121.607	121.602	121.613
299-E24-16	121.647	121.635	121.633	121.638
299-E24-18	121.623	121.608	NM	121.616
299-E24-21	121.637	121.613	121.625	121.625
299-E24-22	121.649	121.625	121.617	121.630
299-E24-24	121.639	121.625	121.624	121.629
299-E24-25	121.611	121.601	121.599	121.604
299-E24-33	121.647	121.620	121.624	121.630
299-E25-19	121.660	121.628	121.641	121.643
299-E25-24	121.663	121.621	121.648	121.644
299-E25-25	NM	NM	NM	--
299-E25-32P	NM	NM	NM	--

Table 1. Water-Level Measurements

Well Name	Average Measured Water Levels (NAVD88 meters)			Average Apr-to-Jun-2019
	Apr-2019	May-2019	Jun-2019	
299-E25-34	121.635	121.659	121.637	121.644
299-E25-35	121.651	NM	121.634	121.643
299-E25-36	NM	NM	121.610	121.610
299-E25-93	121.640	121.621	121.617	121.626
299-E26-10	NM	NM	NM	--
299-E26-13	121.637	121.617	NM	121.627
299-E26-14*	NM (121.750)	NM (121.781)	121.791	(121.774)
299-E26-15	121.738	121.602	NM	121.670
299-E26-4	121.639	121.619	NM	121.629
299-E26-79	NM	NM	121.758	121.758
299-E27-12	121.649	121.627	121.625	121.634
299-E27-14	121.648	121.621	121.628	121.632
299-E27-15	121.648	121.622	121.626	121.632
299-E27-17	121.641	121.622	121.632	121.632
299-E27-18	NM	121.626	121.629	121.628
299-E27-21	121.641	121.613	121.619	121.624
299-E27-22	121.669	121.648	121.662	121.660
299-E27-23	121.644	121.622	121.622	121.629
299-E27-7	121.646	121.624	121.629	121.633
299-E27-8	121.647	121.624	121.632	121.634
299-E27-9	121.649	121.625	121.645	121.640
299-E28-1	121.636	121.625	121.624	121.628
299-E28-17	121.635	121.606	121.624	121.622
299-E28-18	121.648	121.631	121.638	121.639
299-E28-27	121.641	121.626	121.627	121.631
299-E32-5	121.652	121.632	121.633	121.639
299-E32-6	121.650	121.633	121.631	121.638
299-E32-8	121.657	121.639	121.636	121.644

Table 1. Water-Level Measurements

Well Name	Average Measured Water Levels (NAVD88 meters)			Average Apr-to-Jun-2019
	Apr-2019	May-2019	Jun-2019	
299-E33-14	121.638	121.629	121.630	121.632
299-E33-28	121.640	121.629	121.629	121.633
299-E33-31	NM	NM	121.624	121.624
299-E33-32	NM	NM	121.632	121.632
299-E33-339	121.640	121.627	121.625	121.631
299-E33-34	121.645	121.630	121.635	121.637
299-E33-342	NM	NM	121.626	121.626
299-E33-37	121.653	121.633	121.635	121.640
299-E33-38	121.642	121.632	121.626	121.633
299-E33-41	NM	NM	121.625	121.625
299-E33-42	NM	NM	121.625	121.625
299-E33-44	NM	NM	121.630	121.630
299-E34-10	121.650	121.629	121.632	121.637
299-E34-9	121.650	121.620	121.630	121.633
699-37-43	121.611	121.569	121.588	121.589
699-37-47A	121.617	121.598	121.601	121.605
699-49-55A*	NM	121.665	121.665 (121.660)	(121.662)
699-49-57A*	121.662	121.637 (121.652)	121.642	(121.652)

Reference: NAVD88, *North American Vertical Datum of 1988*.

*Wells for which water-levels were obtained via separate calculations. The actual measurement, where available, is reported as normal, and the calculated water-level used as data input is reported in parenthesis. The average for these wells is based on the calculated water-levels, not the actual measurements, and hence reported in parenthesis.

NM = not measured

Separate calculations had to be made for the following three boundary wells:

- 299-E26-14: This well serves as an important measurement at the basalt subcrop to the north. However, there were no water-level measurements for April and May 2019. As such, the measured water-level for March was applied for April and the water-level for May was obtained by linearly interpolating between the March and June water-level measurements.

- 699-49-55A: This well serves as an important measurement at the north-west boundary of the model domain. The measured water-level for June 2019 was generating high residuals during the calibration process and, as such, the water-level for June was obtained by linearly interpolating between the May and July water-level measurements.
- 699-49-57A: This well serves as an important measurement at the north-west boundary of the model domain. The measured water-level for May 2019 was generating high residuals during the calibration process and, as such, the water-level for May was obtained by linearly interpolating between the April and June water-level measurements.

A full set of data for the second quarter of CY 2019 is included in Appendix A.

5 Software Applications, Descriptions, Installation and Checkout, and Statements of Validity

Software used to perform the calculations for this ECF was in accordance with CH2M HILL Plateau Remediation Company's (CHPRC's) controlled software management procedure, which implements DOE O 414.1D Chg 1 (Admin Chg), *Quality Assurance*.

5.1 Approved Software

The software used for this ECF is approved, managed, and used consistent with CHPRC's controlled software management procedure under the following software lifecycle documentation:

- CHPRC-00257, *MODFLOW and Related Codes Functional Requirements Document*
- CHPRC-00258, *MODFLOW and Related Codes Software Management Plan*
- CHPRC-00259, *MODFLOW and Related Codes Software Test Plan*
- CHPRC-00260, *MODFLOW and Related Codes Requirements Traceability Matrix*
- CHPRC-00261, *MODFLOW and Related Codes Acceptance Test Report*

CHPRC-00258 distinguishes between safety software and support software based on whether the software calculates reportable results or provides run support, visualization, or similar functions. Brief descriptions of the software are provided in Section 5.2.

5.2 Software Description

A controlled calculation software, MODFLOW-USG, was used for the calculations that support this ECF as follows:

- Software title: *MODFLOW-USG Version 1: An Unstructured Grid Version of MODFLOW for Simulating Groundwater Flow and Tightly Coupled Processes Using a Control Volume Finite-Difference Formulation*
- Software version: 1.2.00; approved as CHPRC Build 8 compiled to default single precision
- Executable name: mfusg-chprc08spv.exe
- Hanford Information Systems Inventory (HISI) identification number: 2517
- Workstation type and property number (from which software is run): SSP&A and FE616

5.3 Support Software

The following software programs are classified as support software by CHPRC-00258:

- PEST: (Doherty, 2015) Estimates parameter values that minimize the objective function(s) to calibrate models using inverse theory.
- Groundwater Vistas™: Rumbaugh and Rumbaugh, 2017, *Groundwater Vistas Version 7*. Provided graphical tools used for model quality assurance and model input/output review.
- ArcGIS®: Visualization and post-processing tool for assessing simulated plume distributions, identifying extraction/injection well coordinates and mapping auxiliary data (Mitchell, 1999, *The ESRI Guide to GIS Analysis, Volume 1: Geographic Patterns & Relationships*).
- Surfer®: Data interpolation for visualization, model implementation, and quality assurance.
- AlgoMesh®: A mesh-generating software used for creating unstructured triangular and Voronoi grids for MODFLOW-USG: AlgoMesh Version 1.2.0.37827 (64 bit) (HydroAlgorithmics, 2016).

5.4 Software Installation and Checkout

Safety software installations are checked and tested in accordance with CHPRC-00258 using the installation tests provided in CHPRC-00259. Executables are obtained from the CHPRC software owner (who maintains the configuration-managed copies in MKS Integrity®). Software installation and checkout forms are required and must be approved for installations used to perform model runs. Approved users are registered in the HISI authorized users list for safety software.

5.4.1 Statement of Valid Software Application

The software identified above was used consistent with intended uses, as identified in CHPRC-00257, and is a valid use of this software for this application. The software was used within its limitations, as identified in CHPRC-00257.

6 Calculations

This chapter describes the calculations and steps performed to develop the necessary input files, perform the calculations, and post-process the outputs to produce the results presented in this ECF.

Groundwater elevation maps presented in this ECF were produced in a two-step process as follows:

- **Data Compilation**: Input data were compiled from retrieved database sources. Outliers were flagged from constructing trend plots of all measured data and excluded from calculations. Average groundwater elevations were then calculated for the second quarter of CY 2019 based on the filtered monthly measurements and used to define the targets for the calibration process.
- **Calibration**: The boundary conditions of the simplified two-dimensional groundwater flow simulator described in Chapter 3 were then used as parameters for PEST in estimation mode to approximate

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measured groundwater levels for the second quarter of CY 2019. Targets corresponding to the north-west, north, south-east, and south of the model domain boundaries were assigned higher weights during the calibration process such that the overall average measured gradient across the 200 East Area is respected.

The calibration targets and their associated weights are listed in Table 2. During the calibration process, wells that were repeatedly registering high residuals were flagged and compared to adjacent measurements. Based on understandings of any nearby stresses, surrounding geology, and inferred flow directions (i.e., upgradient versus downgradient), these wells or surrounding wells were assigned lower weights due to lower confidence in the accuracy of their measurements.

Table 2 also lists the final residuals obtained for the calibration targets. A residual, or estimated error, value for each measured point was calculated as the difference between the measured value and the value interpolated by the calculation. The target residual, that which would indicate acceptable calibration, is an absolute value of less than 0.03 m. Figure 3 illustrates the cumulative frequency plot of the absolute residuals obtained from the calibration for all nonzero weighted targets. One hundred percent of the residuals are within 0.03 m of average measured groundwater levels for the second quarter of CY 2019. Thus, the calibration of this interpolation is deemed acceptable and the results are usable for the purposes of this evaluation.

Table 2. Calibration Targets for Second Quarter CY 2019

Well Name	Average Measured Water-Level (NAVD88 meters)	Grid Interpolated Water-Level (NAVD88 meters)	Residual (Estimated Error) (meters)	Calibration Weight
299-E17-18	121.609	121.618	-0.009	7
299-E17-21	121.647	121.638	0.008	10
299-E17-22	121.626	121.623	0.003	9
299-E17-23	121.625	121.622	0.002	8
299-E17-25	121.637	121.626	0.010	8
299-E18-2	121.672	121.670	0.002	10
299-E23-1*	121.613	121.632	-0.019	0
299-E24-16*	121.638	121.623	0.015	4
299-E24-18	121.616	121.626	-0.010	7
299-E24-21	121.625	121.627	-0.001	8
299-E24-22	121.630	121.625	0.005	10
299-E24-24	121.629	121.632	-0.002	10
299-E24-25*	121.604	121.630	-0.026	0
299-E24-33	121.630	121.626	0.004	10
299-E25-19*	121.643	121.616	0.027	0

Table 2. Calibration Targets for Second Quarter CY 2019

Well Name	Average Measured Water-Level (NAVD88 meters)	Grid Interpolated Water-Level (NAVD88 meters)	Residual (Estimated Error) (meters)	Calibration Weight
299-E25-24*	121.644	121.611	0.034	0
299-E25-34*	121.644	121.621	0.023	0
299-E25-35*	121.643	121.620	0.023	0
299-E25-36	121.610	121.620	-0.010	10
299-E25-93	121.626	121.623	0.003	10
299-E26-13	121.627	121.628	-0.001	10
299-E26-14	121.774	121.771	0.003	20
299-E26-15	121.670	121.677	-0.007	9
299-E26-4	121.629	121.626	0.003	10
299-E26-79*	121.758	121.690	0.068	0
299-E27-12	121.634	121.631	0.003	10
299-E27-14	121.632	121.630	0.003	10
299-E27-15	121.632	121.631	0.001	10
299-E27-17	121.632	121.634	-0.002	10
299-E27-18	121.628	121.634	-0.007	10
299-E27-21	121.624	121.628	-0.004	10
299-E27-22*	121.660	121.632	0.028	0
299-E27-23	121.629	121.629	0.000	10
299-E27-7	121.633	121.631	0.002	10
299-E27-8	121.634	121.634	0.001	10
299-E27-9	121.640	121.634	0.006	7
299-E28-1	121.628	121.635	-0.006	10
299-E28-17*	121.622	121.637	-0.015	4
299-E28-18	121.639	121.638	0.001	10
299-E28-27	121.631	121.636	-0.005	10
299-E32-5	121.639	121.643	-0.004	10
299-E32-6	121.638	121.644	-0.006	10
299-E32-8	121.644	121.645	-0.001	10

Table 2. Calibration Targets for Second Quarter CY 2019

Well Name	Average Measured Water-Level (NAVD88 meters)	Grid Interpolated Water-Level (NAVD88 meters)	Residual (Estimated Error) (meters)	Calibration Weight
299-E33-14	121.632	121.635	-0.003	10
299-E33-28	121.633	121.637	-0.004	10
299-E33-31	121.624	121.636	-0.012	10
299-E33-32	121.632	121.636	-0.004	10
299-E33-339	121.631	121.635	-0.004	10
299-E33-34	121.637	121.641	-0.005	10
299-E33-342	121.626	121.636	-0.010	10
299-E33-37	121.640	121.635	0.006	10
299-E33-38	121.633	121.636	-0.003	10
299-E33-41	121.625	121.635	-0.010	10
299-E33-42	121.625	121.636	-0.010	10
299-E33-44	121.630	121.636	-0.005	10
299-E34-10	121.637	121.635	0.002	10
299-E34-9	121.633	121.635	-0.002	10
699-37-43	121.589	121.588	0.001	20
699-37-47A	121.605	121.606	-0.001	10
699-49-55A	121.662	121.652	0.010	20
699-49-57A	121.652	121.657	-0.004	10

Reference: NAVD88, *North American Vertical Datum of 1988*.

*Well assigned a low weight for PEST software calibration.

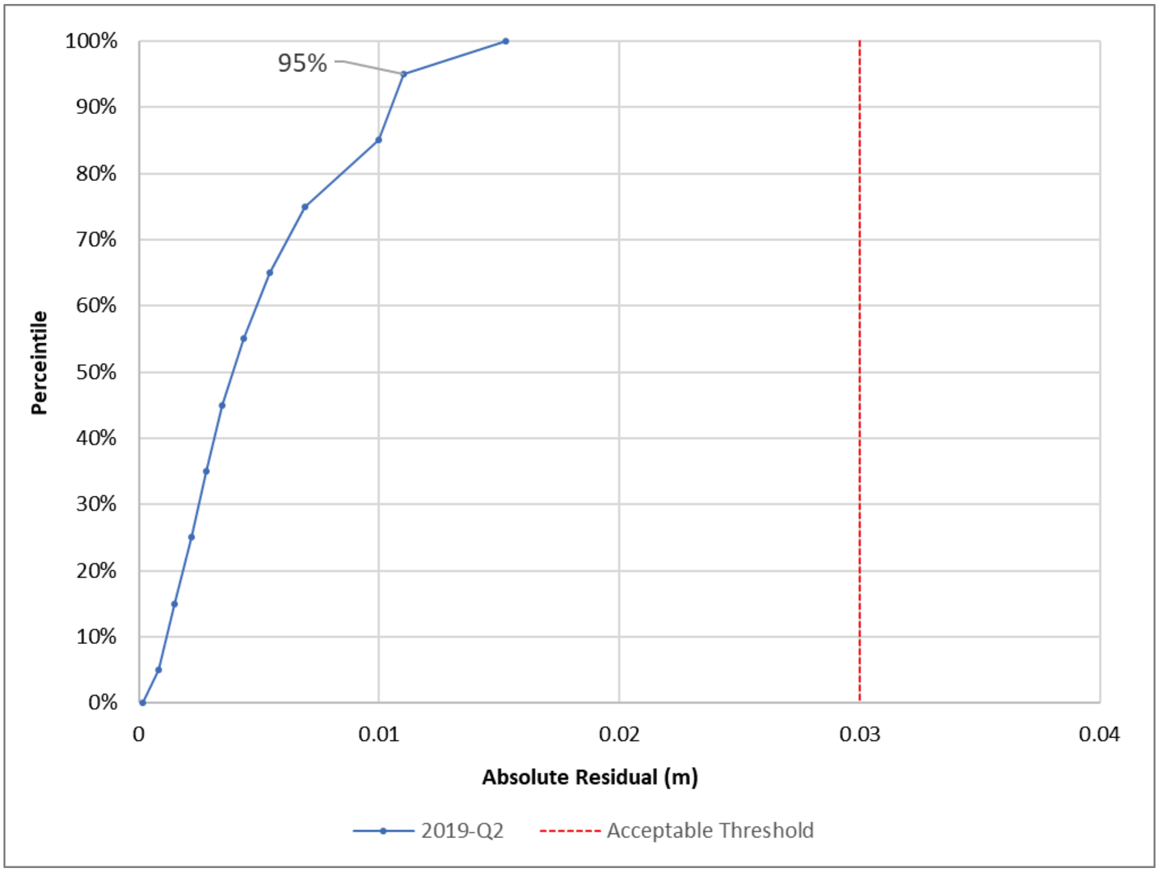

Figure 3. Cumulative Relative Frequency of Absolute Residuals

7 Results

This chapter presents outputs from the described calculations. These include the following:

- The 200 East Area water-level mapping results for each month in the second quarter of CY 2019
- A 200 East Area water-level map for average water levels for the second quarter of CY 2019

After the calibration steps described in Chapter 6, scatter plots that compare the calculated groundwater elevations with the measured groundwater elevations were prepared. Figures 4 through 6 depict the monthly calibration results for April, May, and June 2019, and Figure 7 shows the simulated versus the measured groundwater elevations for the second quarter of CY 2019. Note, the squared Pearson product-moment correlation coefficient, or R^2 value, indicated on these plots only correspond to the high-weighted targets.

Figures 8 through 10 depict the groundwater elevation contours throughout the 200 East Area for April through June and were prepared using the methods and inputs described previously. Figure 11 depicts the groundwater elevation contours throughout the 200 East Area that were generated using average water levels for the second quarter of CY 2019. All water-level map figures also illustrate calibration weights and calibration residuals for monitoring wells included in the calibration process.

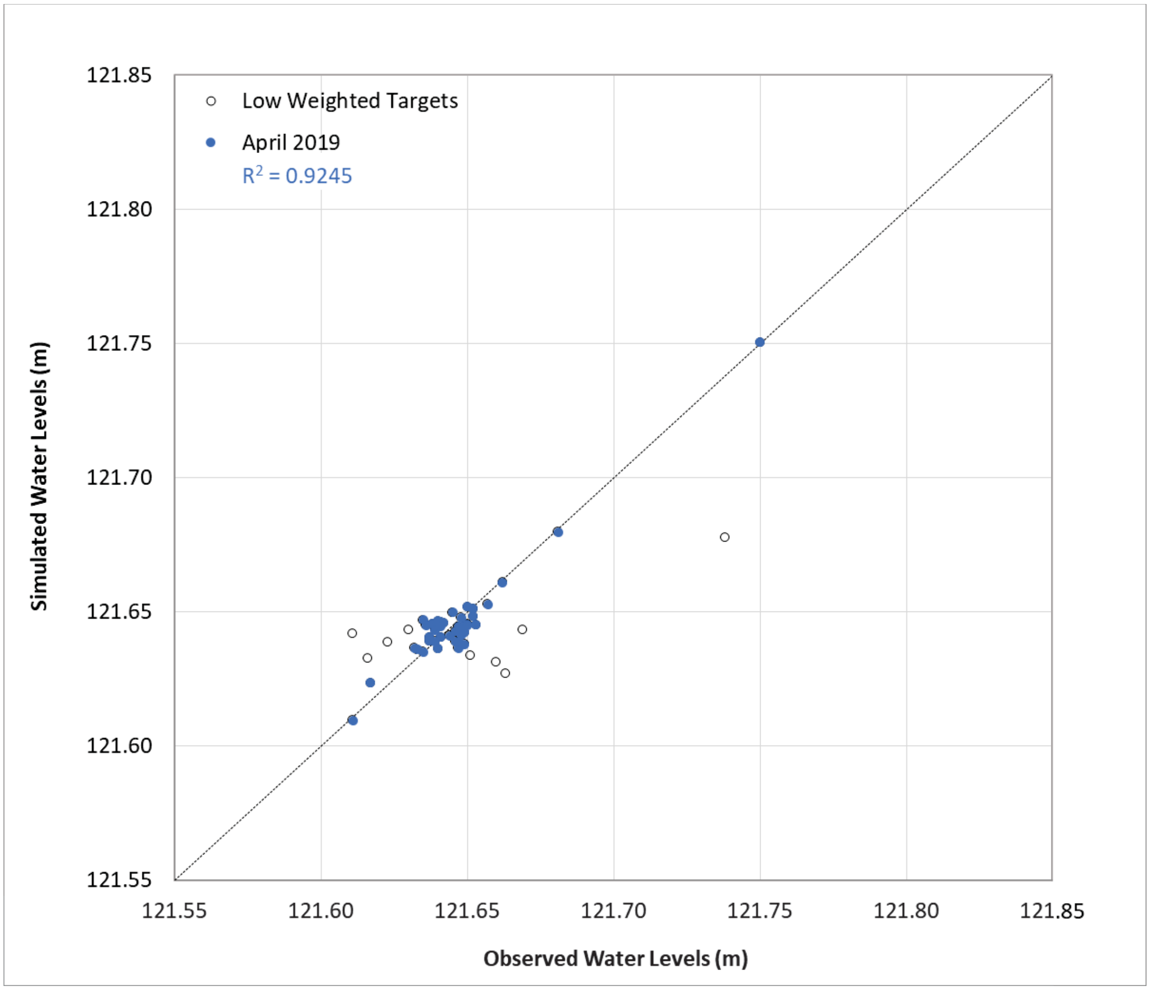

Figure 4. Monthly Observed vs. Simulated Calibration Plots – April 2019

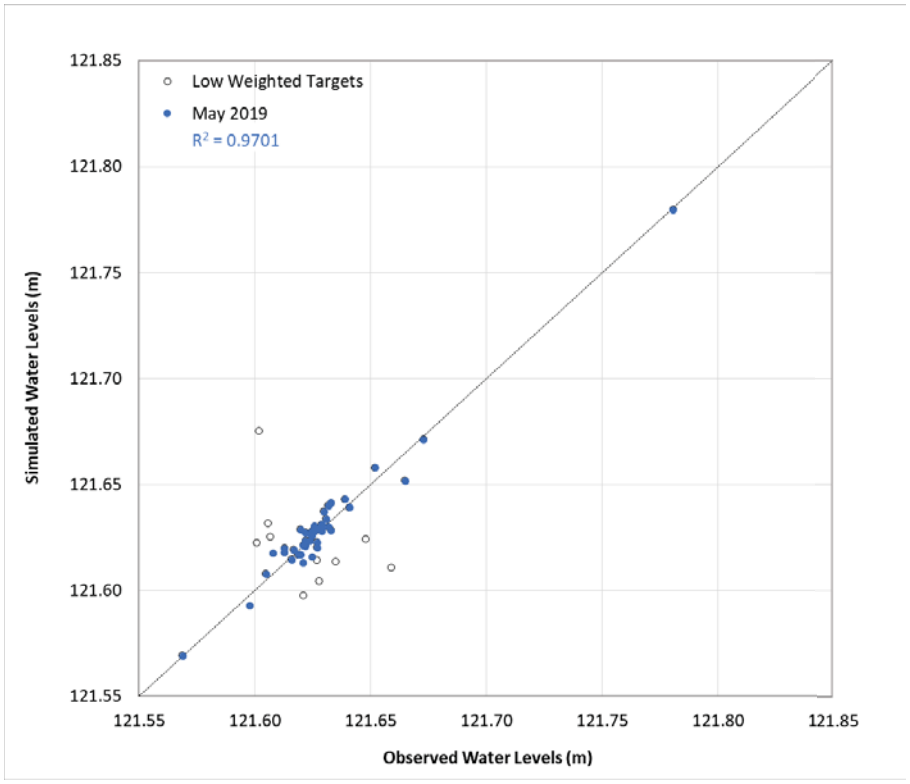

Figure 5. Monthly Observed vs. Simulated Calibration Plots – May 2019

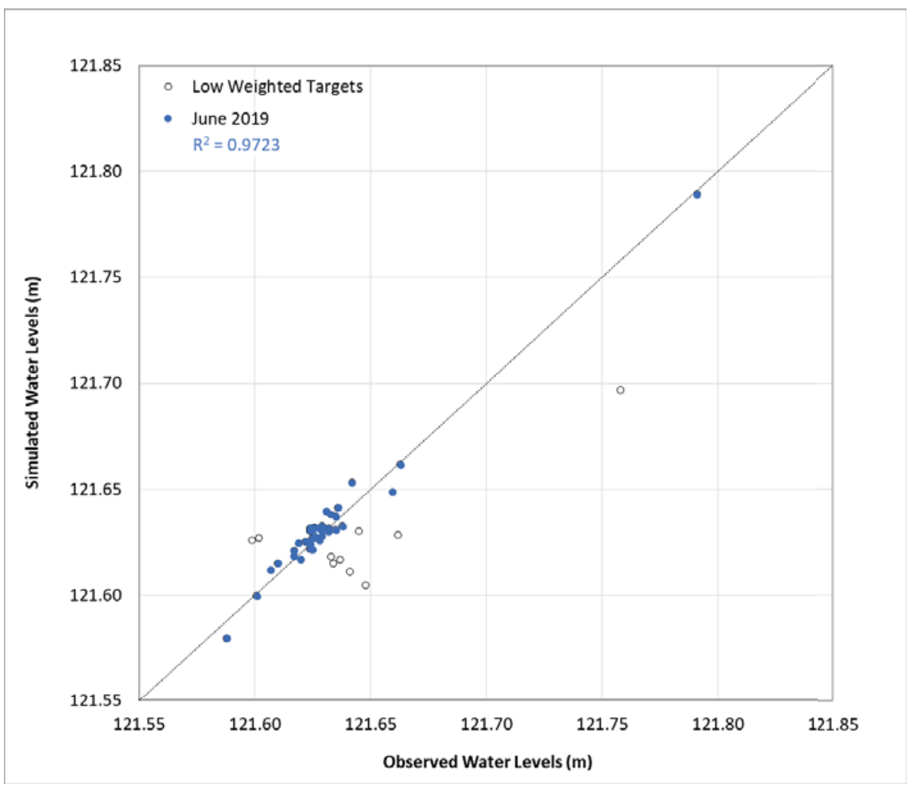

Figure 6. Monthly Observed vs. Simulated Calibration Plots – June 2019

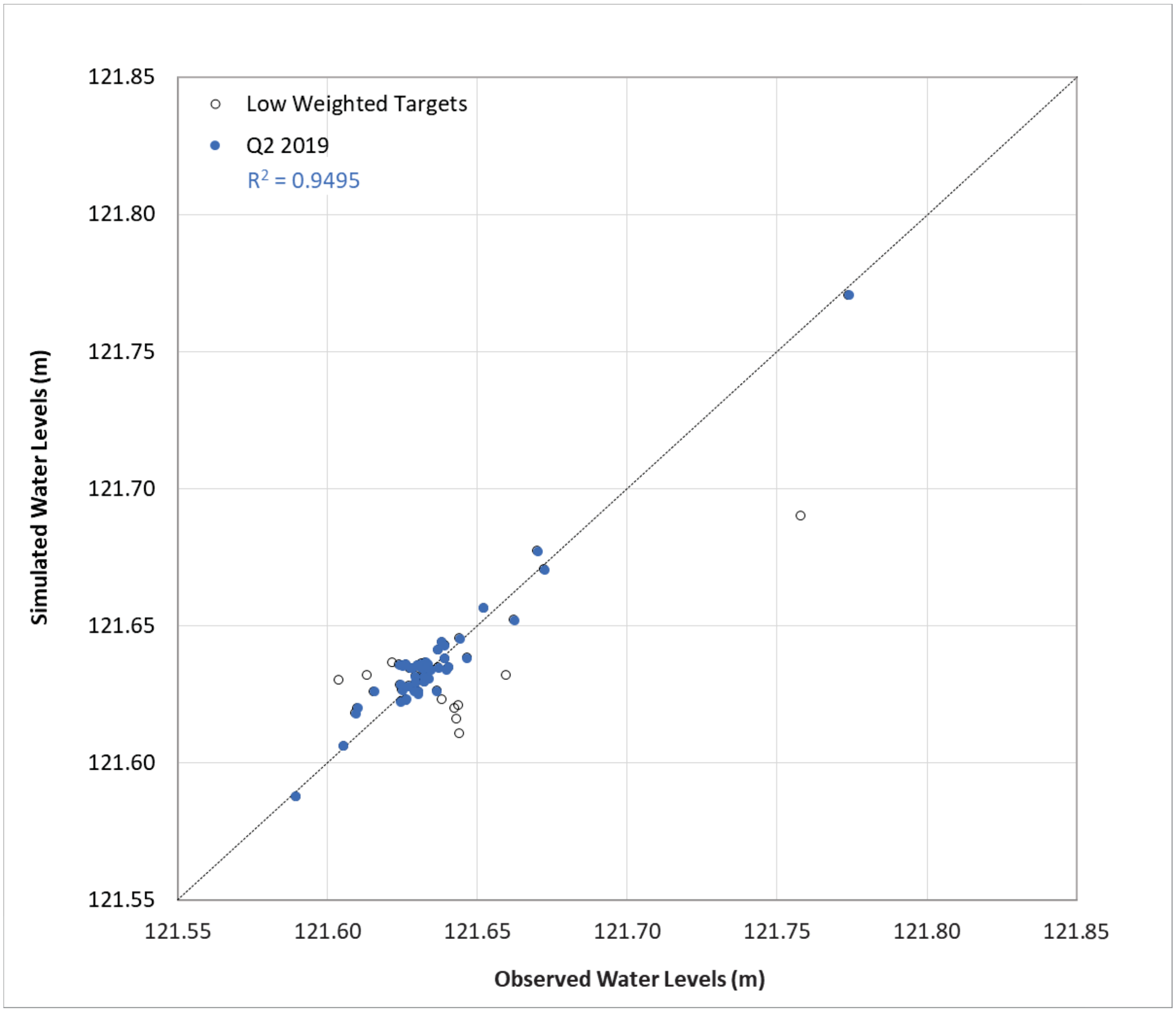

Figure 7. Comparison of Observed vs. Simulated Water-Levels – April Through June 2019

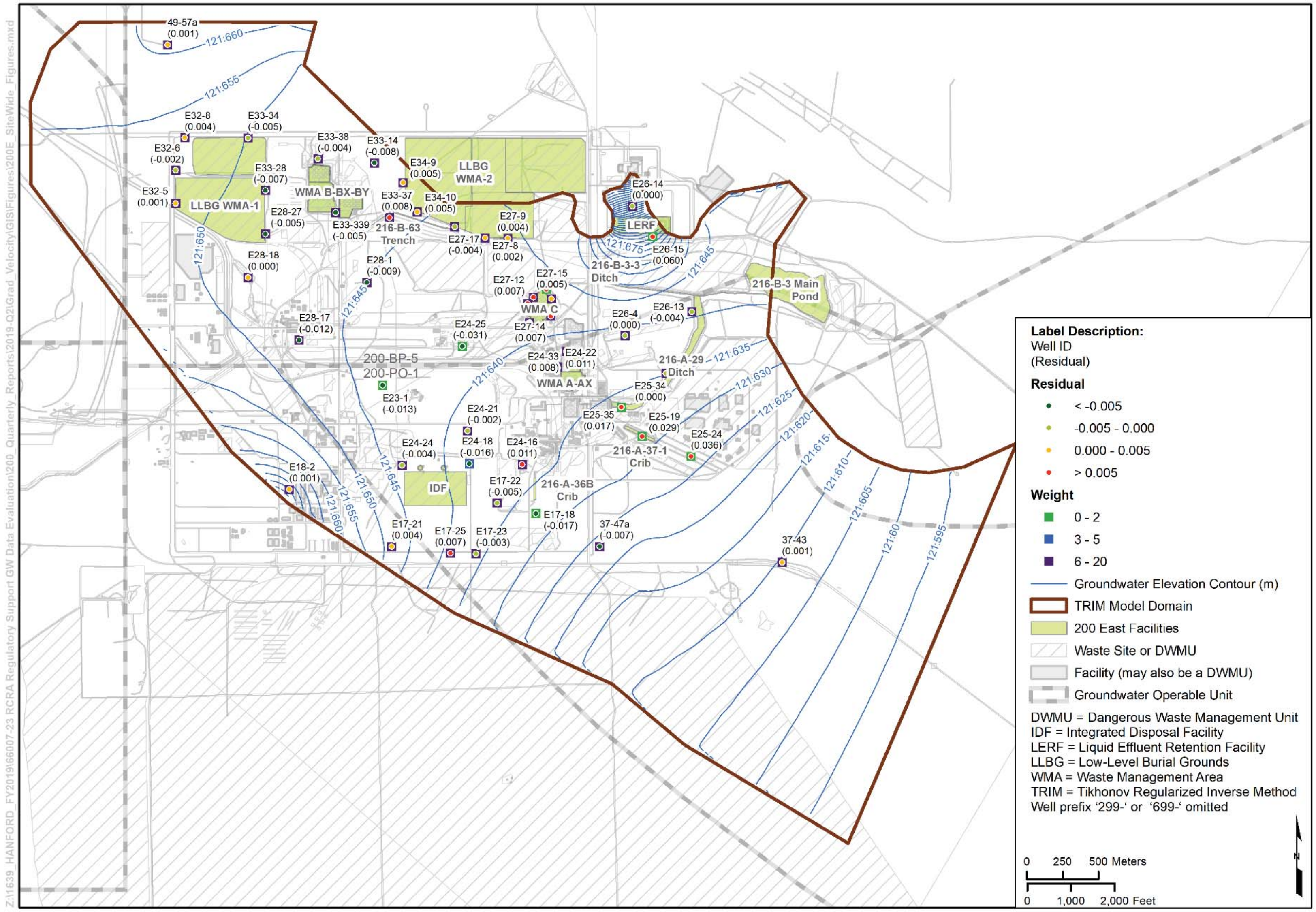

Figure 8. Mapped Groundwater Elevations and Calibration Residuals – April 2019

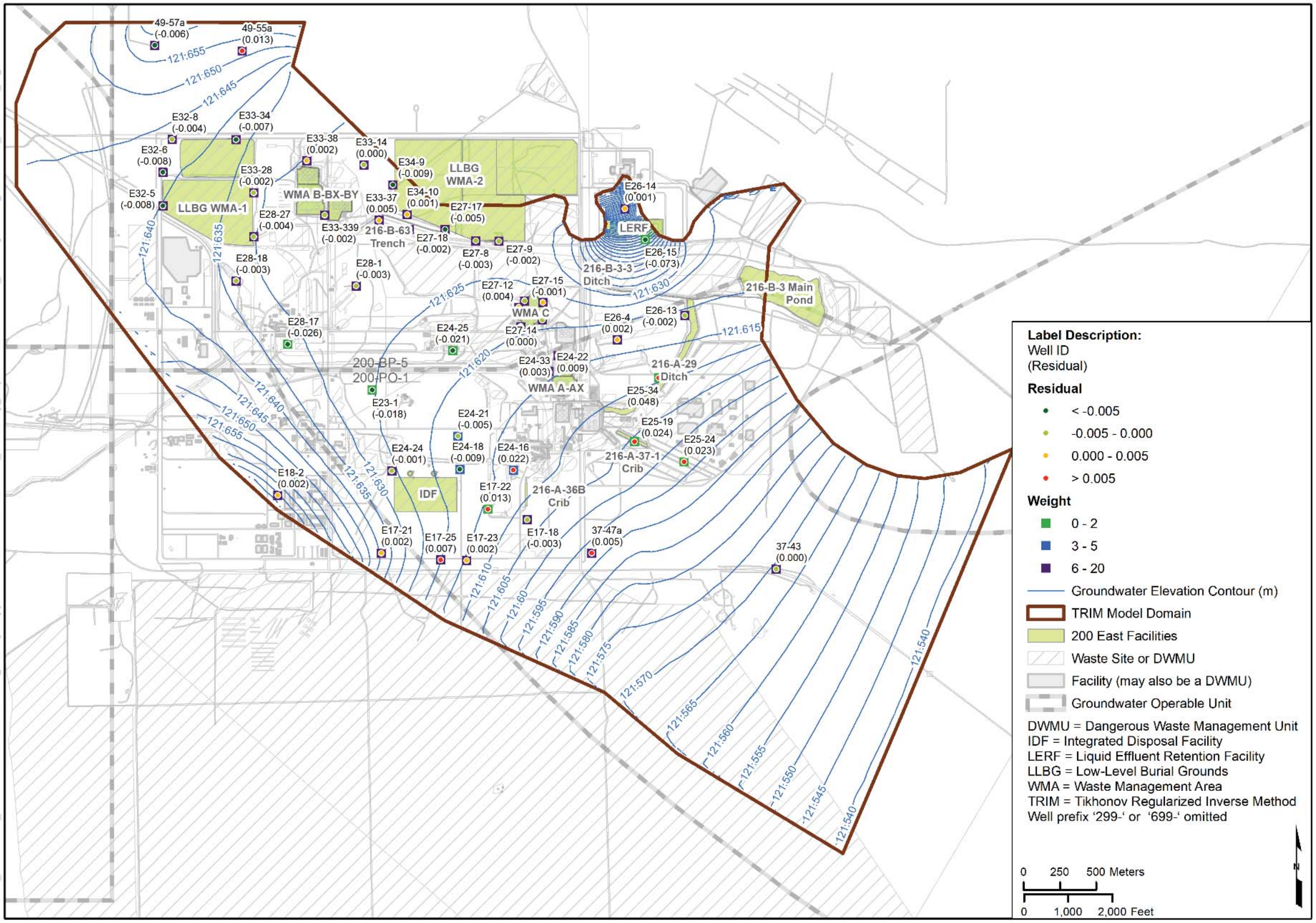

Figure 9. Mapped Groundwater Elevations and Calibration Residuals – May 2019

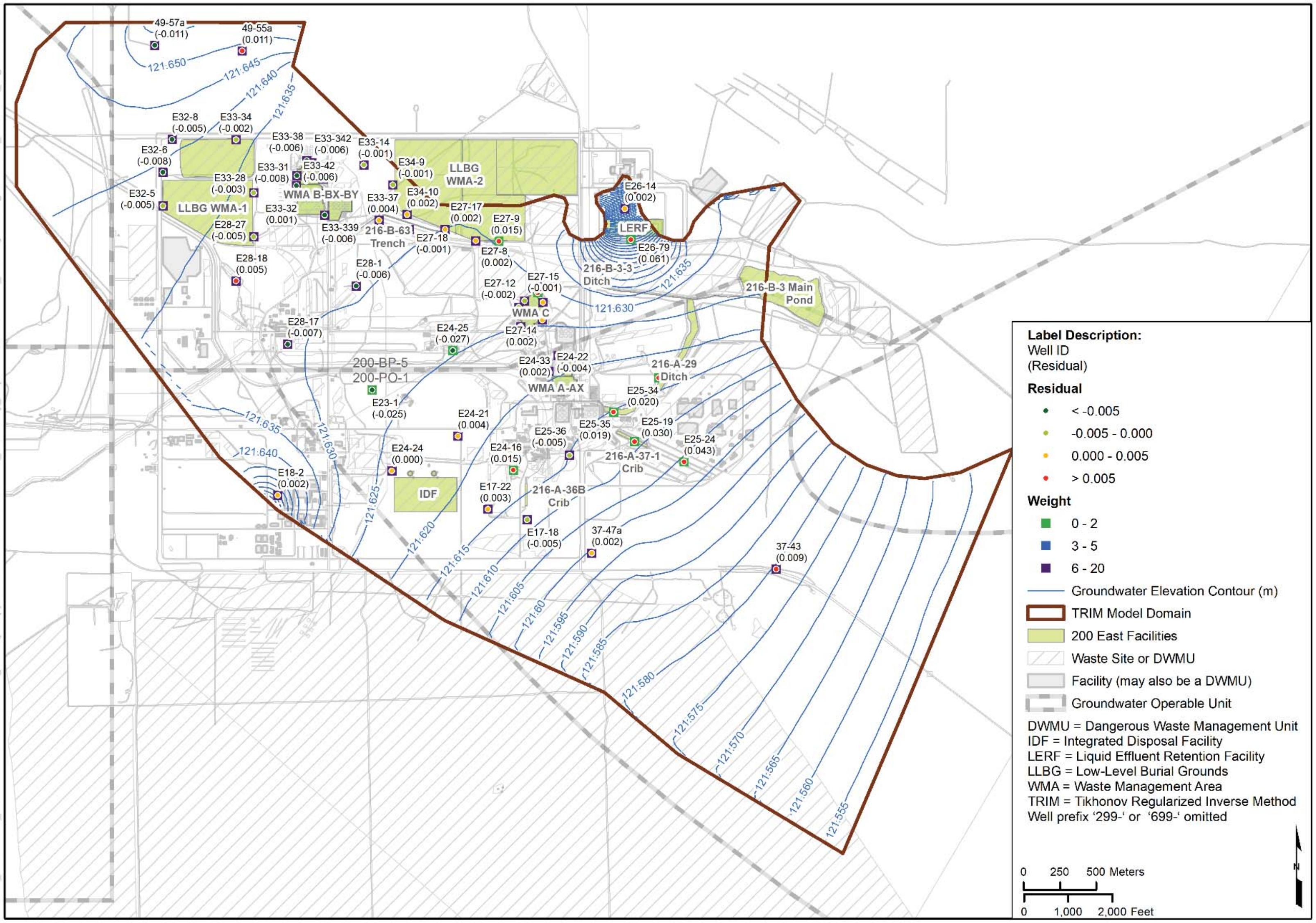

Figure 10. Mapped Groundwater Elevations and Calibration Residuals – June 2019

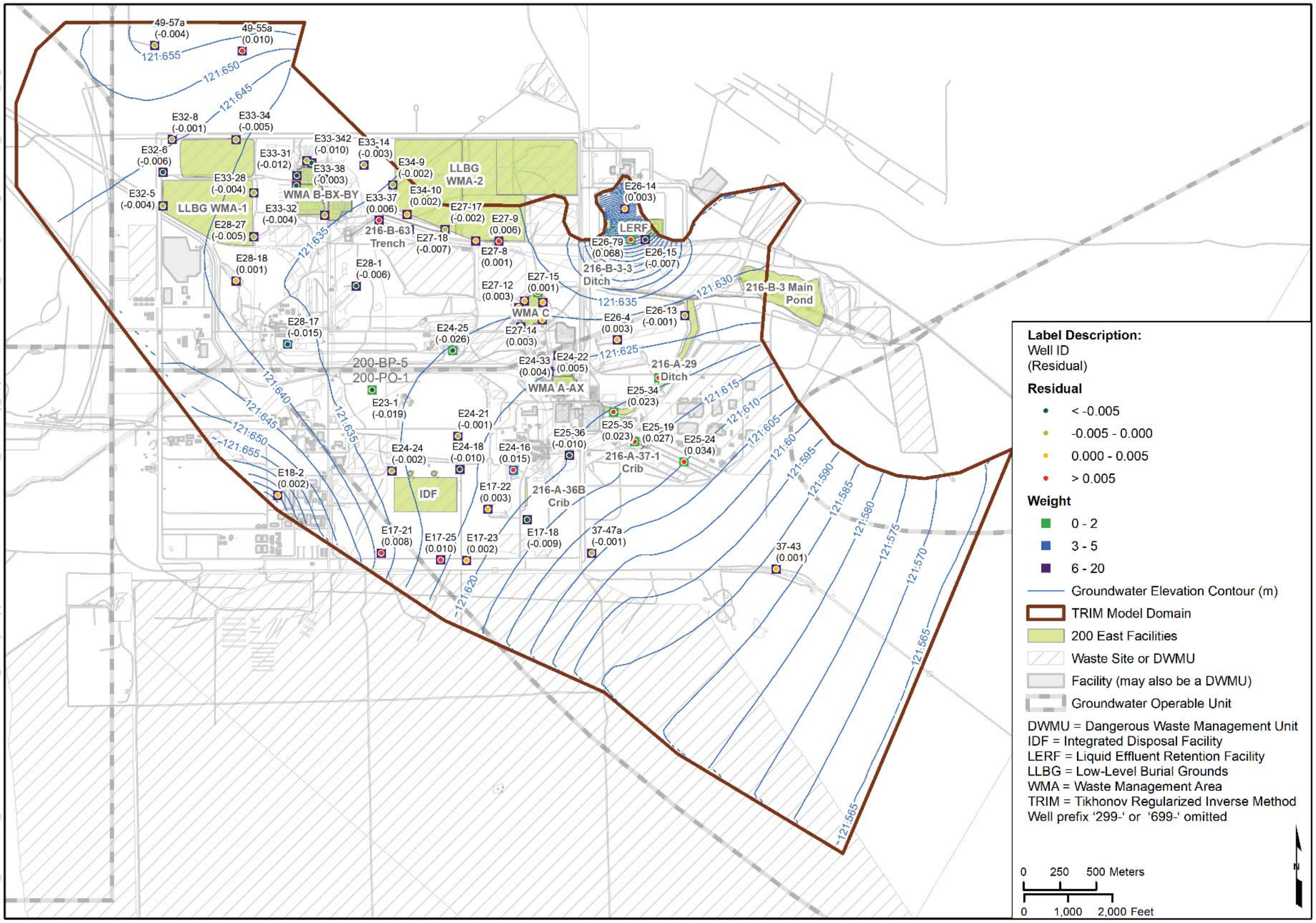

Figure 11. Mapped Groundwater Elevations and Calibration Residuals – Average April Through June 2019

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Appendix A

Groundwater Elevations in Monitoring Wells

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Contents

Tables

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A1 Introduction

The tables in this appendix present the data used in the calculations. The data were retrieved from the Hanford Environmental Information System database on September 17, 2019.

Measured water levels presented in this appendix are based on the *North American Vertical Datum of 1988* (NAVD88). Spatial coordinates of well locations are presented in the *North America Datum of 1983* (NAD83) State Plane, Washington South FIPS 4602 coordinate system.

Table A-1. Water-Level Data Used for Water-Level Mapping: April 2019

Well Name	Easting (m)	Northing (m)	Date-Time	Measured Water Level (m)
299-E17-18	575112	135124	4/22/19 10:36 AM	121.616
299-E17-21	574107	134893	4/22/19 9:56 AM	121.652
299-E17-22	574841	135196	4/22/19 10:28 AM	121.632
299-E17-23	574694	134842	4/22/19 10:20 AM	121.633
299-E17-25	574515	134846	4/22/19 10:14 AM	121.646
299-E18-2	573392	135291	4/22/19 9:47 AM	121.681
299-E23-1	574043	136017	4/22/19 11:44 AM	121.630
299-E24-16	575018	135464	4/22/19 11:10 AM	121.647
299-E24-18	574647	135470	4/22/19 8:34 AM	121.623
299-E24-21	574636	135698	4/22/19 11:23 AM	121.637
299-E24-22	575263	136143	4/23/19 9:34 AM	121.649
299-E24-24	574180	135459	4/22/19 10:06 AM	121.639
299-E24-25	574599	136287	4/23/19 12:38 PM	121.611
299-E24-33	575325	136251	4/23/19 9:44 AM	121.647
299-E25-19	575852	135659	4/23/19 10:28 AM	121.660
299-E25-24	576194	135521	4/23/19 10:36 AM	121.663
299-E25-34	576019	136100	4/23/19 11:14 AM	121.635
299-E25-35	575708	135865	4/23/19 10:46 AM	121.651
299-E25-93	575472	136022	4/23/19 9:57 AM	121.640
299-E26-13	576199	136529	4/23/19 11:21 AM	121.637
299-E26-15	575926	137051	4/23/19 12:19 PM	121.738
299-E26-4	575734	136361	4/23/19 11:01 AM	121.639
299-E27-12	575054	136584	4/23/19 8:34 AM	121.649
299-E27-14	575217	136498	4/23/19 9:24 AM	121.648

Table A-1. Water-Level Data Used for Water-Level Mapping: April 2019

Well Name	Easting (m)	Northing (m)	Date-Time	Measured Water Level (m)
299-E27-15	575095	136630	4/23/19 8:45 AM	121.648
299-E27-17	574547	137122	4/23/19 7:16 AM	121.641
299-E27-18*	574300	137119	4/23/19 7:39 AM	121.754
299-E27-21	575145	136407	4/23/19 8:16 AM	121.641
299-E27-22	575185	136685	4/23/19 8:54 AM	121.669
299-E27-23	575069	136452	4/23/19 8:26 AM	121.644
299-E27-7	575221	136619	4/23/19 9:06 AM	121.646
299-E27-8	574759	137044	4/23/19 7:23 AM	121.647
299-E27-9	574918	137041	4/23/19 7:29 AM	121.649
299-E28-1	573933	136733	4/22/19 9:35 AM	121.636
299-E28-17	573461	136332	4/22/19 11:55 AM	121.635
299-E28-18	573104	136768	4/22/19 9:25 AM	121.648
299-E28-27	573227	137070	4/22/19 9:18 AM	121.641
299-E32-5	572600	137285	4/22/19 12:24 PM	121.652
299-E32-6	572600	137515	4/22/19 12:17 PM	121.650
299-E32-8	572663	137741	4/22/19 12:11 PM	121.657
299-E33-14	573986	137567	4/22/19 8:52 AM	121.638
299-E33-28	573226	137375	4/22/19 9:01 AM	121.640
299-E33-339	573717	137222	4/22/19 8:01 AM	121.640
299-E33-34	573104	137740	4/22/19 9:10 AM	121.645
299-E33-37	574091	137185	4/23/19 8:01 AM	121.653
299-E33-38	573591	137594	4/22/19 8:11 AM	121.642
299-E34-10	574284	137225	4/23/19 7:07 AM	121.650
299-E34-9	574186	137430	4/23/19 6:57 AM	121.650
699-37-43	576829	134783	4/23/19 10:16 AM	121.611
699-37-47A	575557	134893	4/22/19 10:43 AM	121.617
699-49-55A*	573146	138352	4/22/19 12:47 PM	121.562
699-49-57A	572544	138389	4/22/19 12:41 PM	121.662

Note: Water levels shown with an asterisk (*) represent outliers and were not included in the water-level mapping dataset.

Table A-2. Water-Level Data Used for Water-Level Mapping: May 2019

Well Name	Easting (m)	Northing (m)	Date-Time	Measured Water Level (m)
299-E17-18	575112	135124	5/28/19 10:23 AM	121.605
299-E17-21	574107	134893	5/28/19 11:04 AM	121.641
299-E17-22	574841	135196	5/28/19 10:40 AM	121.627
299-E17-23	574694	134842	5/28/19 10:47 AM	121.616
299-E17-25	574515	134846	5/28/19 10:59 AM	121.627
299-E18-2	573392	135291	5/28/19 11:13 AM	121.673
299-E23-1	574043	136017	5/28/19 9:15 AM	121.607
299-E24-16	575018	135464	5/28/19 10:34 AM	121.635
299-E24-18	574647	135470	5/29/19 10:11 AM	121.608
299-E24-21	574636	135698	5/29/19 10:20 AM	121.613
299-E24-22	575263	136143	5/29/19 10:45 AM	121.625
299-E24-24	574180	135459	5/29/19 10:28 AM	121.625
299-E24-25	574599	136287	5/28/19 9:05 AM	121.601
299-E24-33	575325	136251	5/29/19 10:53 AM	121.620
299-E25-19	575852	135659	5/28/19 10:12 AM	121.628
299-E25-24	576194	135521	5/28/19 10:06 AM	121.621
299-E25-34	576019	136100	5/28/19 9:45 AM	121.659
299-E25-35*	575708	135865	5/28/19 9:58 AM	121.734
299-E25-93	575472	136022	5/29/19 10:38 AM	121.621
299-E26-13	576199	136529	5/28/19 9:38 AM	121.617
299-E26-15	575926	137051	5/29/19 11:40 AM	121.602
299-E26-4	575734	136361	5/28/19 9:29 AM	121.619
299-E27-12	575054	136584	5/29/19 11:11 AM	121.627
299-E27-14	575217	136498	5/29/19 10:59 AM	121.621
299-E27-15	575095	136630	5/29/19 11:16 AM	121.622
299-E27-17	574547	137122	5/29/19 9:37 AM	121.622
299-E27-18	574300	137119	5/29/19 9:31 AM	121.626
299-E27-21	575145	136407	5/29/19 10:00 AM	121.613
299-E27-22	575185	136685	5/29/19 11:21 AM	121.648
299-E27-23	575069	136452	5/29/19 11:06 AM	121.622

Table A-2. Water-Level Data Used for Water-Level Mapping: May 2019

Well Name	Easting (m)	Northing (m)	Date-Time	Measured Water Level (m)
299-E27-7	575221	136619	5/29/19 11:26 AM	121.624
299-E27-8	574759	137044	5/29/19 9:45 AM	121.624
299-E27-9	574918	137041	5/29/19 9:50 AM	121.625
299-E28-1	573933	136733	5/28/19 8:45 AM	121.625
299-E28-17	573461	136332	5/28/19 8:55 AM	121.606
299-E28-18	573104	136768	5/28/19 8:24 AM	121.631
299-E28-27	573227	137070	5/28/19 8:17 AM	121.626
299-E32-5	572600	137285	5/28/19 11:38 AM	121.632
299-E32-6	572600	137515	5/28/19 8:06 AM	121.633
299-E32-8	572663	137741	5/28/19 8:01 AM	121.639
299-E33-14	573986	137567	5/29/19 9:13 AM	121.629
299-E33-28	573226	137375	5/29/19 8:13 AM	121.629
299-E33-339	573717	137222	5/29/19 8:55 AM	121.627
299-E33-34	573104	137740	5/28/19 8:11 AM	121.630
299-E33-37	574091	137185	5/29/19 9:24 AM	121.633
299-E33-38	573591	137594	5/29/19 9:02 AM	121.632
299-E34-10	574284	137225	5/28/19 8:39 AM	121.629
299-E34-9	574186	137430	5/28/19 8:35 AM	121.620
699-37-43	576829	134783	5/22/19 9:18 AM	121.569
699-37-47A	575557	134893	5/22/19 9:26 AM	121.598
699-49-55A	573146	138352	5/22/19 9:45 AM	121.665
699-49-57A	572544	138389	5/22/19 9:51 AM	121.637

Note: Water levels shown with an asterisk (*) represent outliers and were not included in the water-level mapping dataset.

Table A-3. Water-Level Data Used for Water-Level Mapping: June 2019

Well Name	Easting (m)	Northing (m)	Date-Time	Measured Water Level (m)
299-E17-18	575112	135124	6/28/19 6:56 AM	121.607
299-E17-22	574841	135196	6/28/19 6:49 AM	121.620
299-E18-2	573392	135291	6/28/19 6:16 AM	121.663
299-E23-1	574043	136017	6/28/19 7:10 AM	121.602
299-E24-16	575018	135464	6/28/19 6:43 AM	121.633
299-E24-21	574636	135698	6/28/19 6:33 AM	121.625
299-E24-22	575263	136143	6/28/19 7:46 AM	121.617
299-E24-24	574180	135459	6/28/19 6:25 AM	121.624
299-E24-25	574599	136287	6/26/19 8:34 AM	121.599
299-E24-33	575325	136251	6/28/19 7:52 AM	121.624
299-E25-19	575852	135659	6/26/19 8:50 AM	121.641
299-E25-24	576194	135521	6/26/19 8:55 AM	121.648
299-E25-34	576019	136100	6/26/19 9:09 AM	121.637
299-E25-35	575708	135865	6/26/19 9:03 AM	121.634
299-E25-36	575404	135566	6/26/19 8:44 AM	121.610
299-E25-93	575472	136022	6/28/19 7:36 AM	121.617
299-E26-13*	576199	136529	6/26/19 9:13 AM	121.698
299-E26-14	575786	137265	6/26/19 9:35 AM	121.791
299-E26-4*	575734	136361	6/26/19 9:20 AM	121.687
299-E26-79	575828	137052	6/26/19 9:29 AM	121.758
299-E27-12	575054	136584	6/28/19 8:16 AM	121.625
299-E27-14	575217	136498	6/28/19 8:00 AM	121.628
299-E27-15	575095	136630	6/28/19 8:22 AM	121.626
299-E27-17	574547	137122	6/26/19 10:01 AM	121.632
299-E27-18	574300	137119	6/26/19 10:24 AM	121.629
299-E27-21	575145	136407	6/28/19 8:48 AM	121.619
299-E27-22	575185	136685	6/28/19 8:37 AM	121.662
299-E27-23	575069	136452	6/28/19 8:09 AM	121.622
299-E27-7	575221	136619	6/28/19 8:29 AM	121.629
299-E27-8	574759	137044	6/26/19 9:57 AM	121.632

Table A-3. Water-Level Data Used for Water-Level Mapping: June 2019

Well Name	Easting (m)	Northing (m)	Date-Time	Measured Water Level (m)
299-E27-9	574918	137041	6/26/19 9:52 AM	121.645
299-E28-1	573933	136733	6/28/19 8:56 AM	121.624
299-E28-17	573461	136332	6/28/19 7:19 AM	121.624
299-E28-18	573104	136768	6/28/19 9:59 AM	121.638
299-E28-27	573227	137070	6/28/19 9:55 AM	121.627
299-E32-5	572600	137285	6/28/19 10:14 AM	121.633
299-E32-6	572600	137515	6/28/19 10:07 AM	121.631
299-E32-8	572663	137741	6/28/19 10:10 AM	121.636
299-E33-14	573986	137567	6/26/19 10:30 AM	121.630
299-E33-28	573226	137375	6/26/19 10:37 AM	121.629
299-E33-31	573525	137491	6/28/19 9:48 AM	121.624
299-E33-32	573525	137354	6/28/19 9:36 AM	121.632
299-E33-339	573717	137222	6/28/19 9:31 AM	121.625
299-E33-34	573104	137740	6/26/19 10:41 AM	121.635
299-E33-342	573626	137580	6/28/19 9:11 AM	121.626
299-E33-37	574091	137185	6/26/19 10:18 AM	121.635
299-E33-38	573591	137594	6/28/19 9:05 AM	121.626
299-E33-41	573707	137370	6/28/19 9:24 AM	121.625
299-E33-42	573521	137424	6/28/19 9:42 AM	121.625
299-E33-44	573706	137469	6/28/19 9:18 AM	121.630
299-E34-10	574284	137225	6/26/19 10:04 AM	121.632
299-E34-9	574186	137430	6/26/19 10:10 AM	121.630
699-37-43	576829	134783	6/26/19 8:04 AM	121.588
699-37-47A	575557	134893	6/26/19 8:09 AM	121.601
699-49-55A	573146	138352	6/26/19 11:15 AM	121.665
699-49-57A	572544	138389	6/26/19 10:50 AM	121.642

Note: Water levels shown with an asterisk (*) represent outliers and were not included in the water-level mapping dataset.

A2 References

NAD83, 1991, *North American Datum of 1983*, as revised, National Geodetic Survey, Federal Geodetic Control Committee, Silver Spring, Maryland. Available at: https://www.ngs.noaa.gov/datums/horizontal/north-american-datum-1983.shtml.

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