ECF-HANFORD-20-0049
Revision 0

DESCRIPTION OF GROUNDWATER CALCULATIONS TO SUPPORT PERFORMANCE ASSESSMENT FOR THE CALENDAR YEAR 2019 (CY 2019) 200 AREAS PUMP-AND-TREAT REPORT

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

Approved for Public Release;
Further Dissemination Unlimited

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Terms

2D	two-dimensional
3D	three-dimensional
AWLN	automated water-level network
CHPRC	CH2M HILL Plateau Remediation Company
COC	contaminant of concern
CPGWM	Central Plateau Groundwater Model
CTS	contaminant treatment system
CY	calendar year
ECF	environmental calculation file
F&T	fate and transport
FY	fiscal year
gpm	gallons per minute
HISI	Hanford Information Systems Inventory
ICFM	interpolated capture frequency map
MEUK	multi-event universal kriging
MNA	monitored natural attenuation
MODFLOW	Modular Ground-Water Flow Model
MODPATH	Particle-tracking post-processing program
MT3DMS	Modular 3-D Transport Multi-Species
OU	operable unit
P2R Model	Plateau to River Groundwater Model
P&T	pump and treat
RD/RAWP	Remedial Design/Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act of 1976
RK4	Runge-Kutta numerical integration scheme
Rlm	Ringold Formation, member of Wooded Island – lower mud unit
ROD	Record of Decision
SCFM	simulated capture frequency map

SGSIM	Sequential Gaussian simulation program
SSP&A	S.S. Papadopulos and Associates, Inc.
USGS	U.S. Geological Survey

1 Purpose

This environmental calculation file (ECF) describes calculations that were performed to assist in evaluating the performance of the groundwater pump and treat (P&T) remedies in place at the Hanford Site 200-ZP-1 and 200-UP-1 Groundwater Operable Units (OUs) as one basis for results presented in DOE/RL-2019-68, *Calendar Year 2019 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump and Treat Operations*. This ECF describes:

1. The use of groundwater elevation mapping and groundwater modeling to estimate the extent of hydraulic containment that is developed by both the 200-ZP-1 and the 200-UP-1 P&T remedies.
2. The use of groundwater elevation mapping and groundwater modeling to evaluate the status of flowpath control in the downgradient areas of both the 200-ZP-1 and the 200-UP-1 P&T remedies.
3. Calculations of actual mass recovered to-date by the 200-ZP-1 P&T system, comparisons of the actual and the simulated historical mass recovery, and projections of anticipated future mass recovery under assumed future extraction and injection rates.
4. The methods and tools used to make the foregoing calculations.

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2 Background

Groundwater P&T is an element of the selected final remedy for the 200-ZP-1 OU, the interim groundwater remedy for the S-SX Tank Farms (located in the 200-UP-1 OU), and the remedy for uranium associated with the U Plant (located in the 200-UP-1 OU) on the Hanford Site Central Plateau, located near Richland, Washington (Figure 2-1).

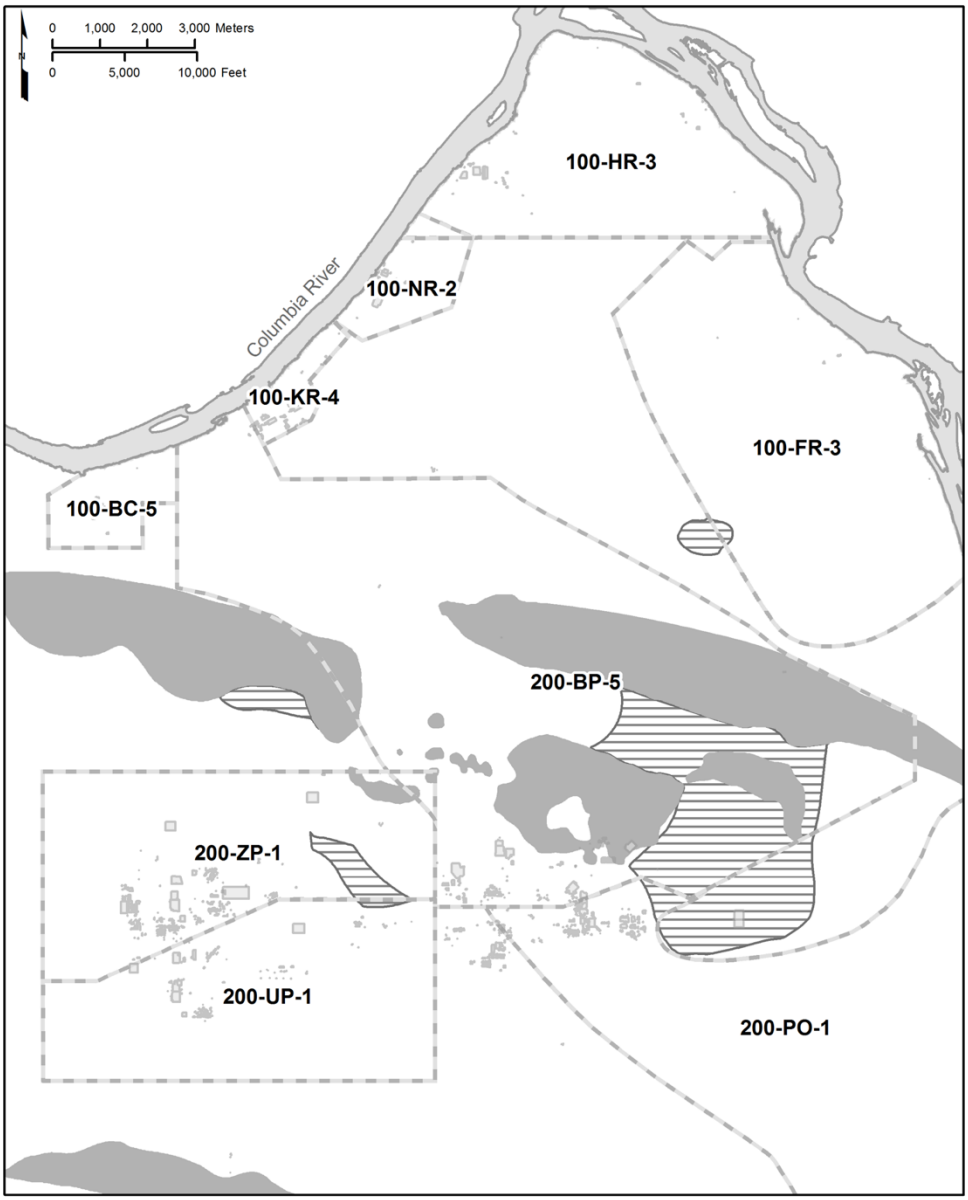

Figure 2-1. Location of the Groundwater OUs on the Hanford Site

2.1 Groundwater Operable Units and Associated Remedies

This section describes the 200-ZP-1 and 200-UP-1 OUs and their associated remedies.

2.1.1 200-ZP-1 Operable Unit

For remediation of the 200-ZP-1 OU, DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*, and DOE/RL-2007-33, *Proposed Plan for the Remediation of the 200-ZP-1 Groundwater Operable Unit*, describe groundwater P&T as an element of the final remedy, as set forth in EPA et al., 2008, *Record of Decision, Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington* (hereinafter referred to as the 200-ZP-1 OU Record of Decision [ROD]). The selected remedy combines P&T, monitored natural attenuation (MNA), flow-path control, and institutional controls with the goal of recovering 95% of the mass of each contaminant of concern (COC) within the 200-ZP-1 OU within 25 years (which corresponds with the year 2037; the active P&T remedy period commenced in 2012) as a measure of progress toward ultimately achieving remedial action objectives defined by published groundwater cleanup levels within a time frame of 125 years (which corresponds with the year 2137). Calculations of hydraulic containment, contaminant fate and transport (F&T), and mass recovery presented in previous 200-ZP-1 OU reports provide one basis for the calculations presented in this ECF.

2.1.2 200-UP-1 Operable Unit — S-SX Tank Farms

Groundwater in the 200-UP-1 OU is contaminated by releases that occurred near the S-SX Tank Farms, as well as other locations (Figure 2-2). A P&T interim remedial action has been implemented including three extraction wells located adjacent to the S-SX Tank Farms. The interim remedial action goal for contaminants for the S-SX Tank Farms P&T is to capture or contain technetium-99 contamination where it exceeds the maximum contaminant level by a factor of 10 or greater. The interim action is not intended to address any potential continuing sources (except to the extent that it contains groundwater contamination around the source area) until it can be determined if additional remedial actions are required under a final ROD.

2.1.3 200-UP-1 Operable Unit — Reduction-Oxidation Plant and U Plant

Uranium in groundwater near U Plant (Figure 2-2) originated from the 216-U-1 and 216-U-2 Cribs, which were also a source of technetium-99 and nitrate to groundwater. The uranium plume is interpreted to extend 1.5 km (0.9 mi) to the east of the cribs above the 30 μg/L cleanup level. The selected active remedy for plumes in the U Plant area is groundwater extraction and treatment (EPA et al., 2012, *Record of Decision for Interim Remedial Action Hanford 200 Area Superfund Site 200-UP-1 Operable Unit*). During 2015, construction of the uranium remedy was completed, including two extraction wells (299-W19-113 and 299-W19-114) and pipelines to convey extracted groundwater to the 200 West P&T radiological building for treatment. The U Plant P&T system began operating in September 2015. In calendar year (CY) 2017 one more extraction well was completed (299-W19-125) that began operating in September 2017.

The Reduction-Oxidation Plant (REDOX; Figure 2-2) cribs were the primary sources of iodine-129 that occurs in a region extending east from the southeastern 200 West Area. The selected remedy for this plume is hydraulic containment while other potential treatment technologies are evaluated (EPA et al., 2012). Hydraulic containment will be achieved by operating injection wells for the 200 West P&T located to the east of the iodine-129 plume to create a hydraulic barrier to further eastward migration. Three hydraulic control injection wells (299-E11-1, 299-E20-1, and 299-E20-2) were drilled during 2015 and began operating on October 28, 2015.

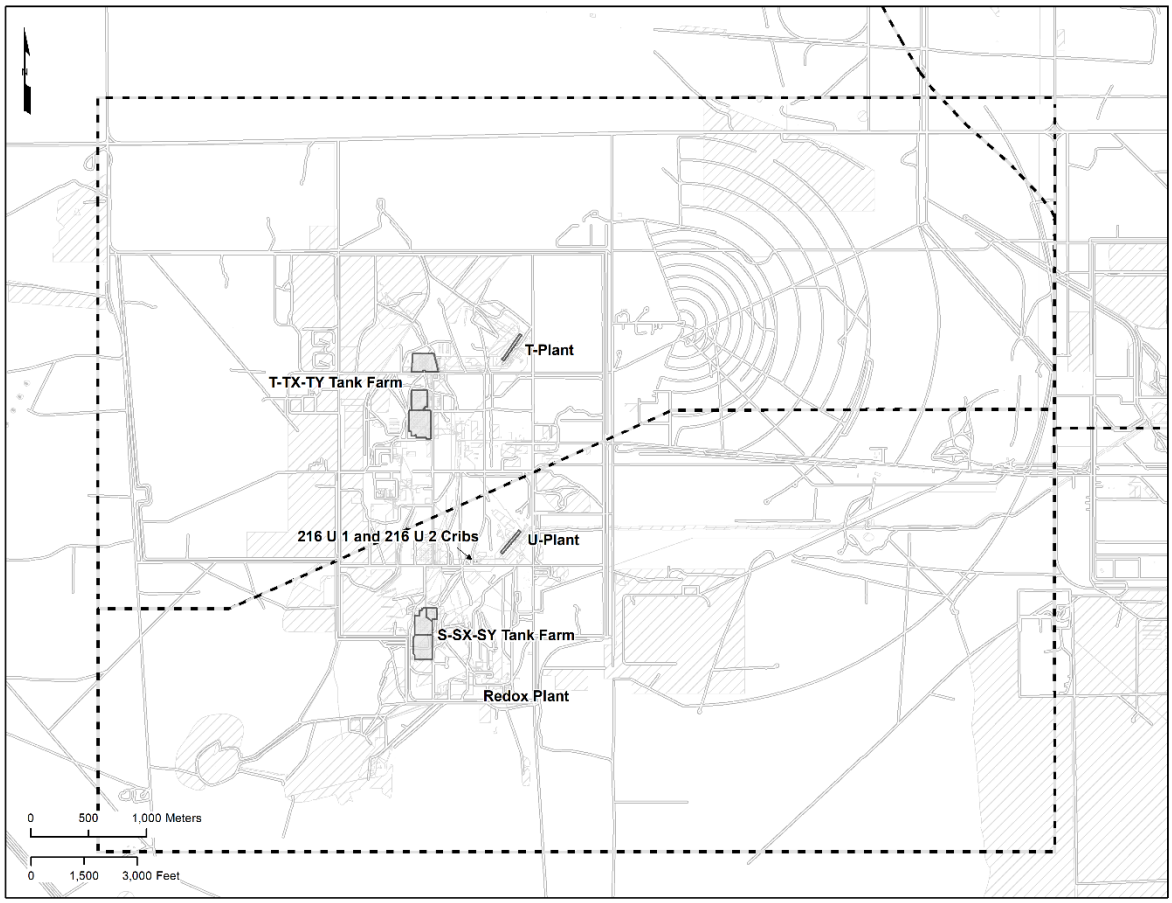

Figure 2-2. Location of Major Facilities within the Groundwater OUs

2.2 Use of Multiple Lines of Evidence

The variety of calculation methods used to support the CY 2019 annual P&T report (DOE/RL-2019-68) is summarized in the following subsections, and each calculation is discussed in further detail in Chapter 3. The various calculation methods comprise a multiple-lines-of-evidence approach used to evaluate groundwater P&T remedy performance. Because the requirements of the remedies in each groundwater OU differ, there are some differences in the methods or calculations used within each OU. Chapter 4 discusses the assumptions and inputs for each calculation, and Chapter 5 describes the software used to complete the calculations. Specific calculations are detailed in Chapter 6, and the results are presented in Chapter 7.

2.2.1 200-ZP-1 Operable Unit

To assess the current performance of the 200-ZP-1 P&T remedy and projected future performance in achieving the remedial action objectives (RAOs) set forth in the 200-ZP1-OU ROD, the following lines of evidence are used:

- Assessment of hydraulic containment and assessment of flow-path control:
  - Groundwater sample result spatial interpolation (i.e., plume mapping)

  - Historical groundwater flow modeling and pathline calculation to estimate the modeled extent of hydraulic containment
  - Historical groundwater elevation mapping and pathline calculation to estimate the mapped extent of hydraulic containment
  - Historical groundwater flow modeling and groundwater elevation mapping to identify areas of reduced or reversed hydraulic gradients
- Assessment of contaminant mass recovery:
  - Historical and projected groundwater flow and contaminant transport modeling
  - Calculation of historical modeled and measured, and future (model-projected), P&T system influent concentrations and mass recovery

In addition to the foregoing evaluations that are presented in this ECF, other calculations are presented in companion ECFs to evaluate concentration changes for the COCs in groundwater over time.

2.2.2 200-UP-1 Operable Unit — S-SX Tank Farm and U-Plant

To assess the current status of 200-UP-1 S-SX Tank Farm and U Plant P&T remedy performance in achieving the interim remedy objective of hydraulically containing or reducing the rate of migration of targeted constituents in groundwater, the following lines of evidence are used:

- Historical groundwater flow modeling and pathline calculation to estimate the mapped extent of hydraulic containment, and identify areas of reduced or reversed hydraulic gradients
- Historical groundwater elevation mapping and pathline calculation to estimate the mapped extent of hydraulic containment, and identify areas of reduced or reversed hydraulic gradients

Historical modeled influent concentrations are also calculated for 200-UP-1 extraction wells simultaneously with the calculations made for the 200-ZP-1 wells. However, these calculations are not used directly at this time to infer the performance of the 200-UP-1 extraction wells.

2.3 Groundwater Models

The Central Plateau Groundwater Model (CPGWM) (CP-47631, Rev. 4, *Model Package Report: Central Plateau Groundwater Model, Version 8.4.5*) has been the principal computational tool used to design and evaluate the performance of the 200-ZP-1 and 200-UP-1 groundwater remedies until fiscal year (FY) 2019 when it was replaced by the Plateau to River Groundwater Model (P2R Model) (CP-57037, Rev. 2, *Model Package Report: Plateau to River Groundwater Model Version 8.3*). Groundwater modeling, previously conducted using the CPGWM and for CY 2019 onward conducted using the P2R Model, is used as one line of evidence to assess the performance of the P&T remedies and is supplemented by direct interpretations of water-level and pumping data, as well as other calculations and lines of evidence presented in companion ECFs.

2.3.1 Model History

2.3.1.1 CPGWM

In 2008, a groundwater flow and contaminant transport model was developed to support 200-ZP-1 remedy decisions by estimating the extent of hydraulic containment developed by pumping and predicting COC influent concentrations and mass removal. That version of the model is described in DOE/RL-2008-56, *200 West Area Pre-Conceptual Design for Final Extraction/Injection Well Network:*

Modeling Analyses, and in DOE/RL-2008-78, *200 West Area 200-ZP-1 Pump-and-Treat Remedial Design/Remedial Action Work Plan* (hereinafter referred to as the RD/RAWP). DOE/RL-2008-78 discusses the plan for the design, installation, and operation of the remedy set forth in the 200-ZP-1 OU ROD (EPA et al., 2008). DOE/RL-2009-38, *Description of Modeling Analyses in Support of the 200-ZP-1 Remedial Design/Remedial Action Work Plan*, presents modeling results supporting the RD/RAWP, including estimated concentrations over time at extraction wells and for the combined treatment system for 200-ZP-1 OU COCs - carbon tetrachloride, total chromium, hexavalent chromium, nitrate, trichloroethene, iodine-129, technetium-99, and tritium - plus uranium, which is not a 200-ZP-1 COC but a COC for the 200-UP-1 OU that is treated at the 200 West P&T. During 2009 and 2010, the model underwent development and recalibration and was issued as the CPGWM. Version 3.3 (CP-47631, Rev. 0, *Model Package Report: Central Plateau Groundwater Model, Version 3.3*) of the CPGWM was used to project the mass recovery of carbon tetrachloride across a range of pumping strategies (SGW-47651, *Final 200-ZP-1 Pump-and-Treat Remedy: Results of FY 2010 Groundwater Flow and Contaminant Transport Simulations*) and concluded that operating the P&T remedy at rates proposed in the 200-ZP-1 Feasibility Study (DOE/RL-2007-28) or RD/RAWP (DOE/RL-2008-78) would likely not achieve 95% mass recovery. Further evaluation in SGW-50390, *FY 2011 Simulation-Optimization of the 200-ZP-1 Remedy Using the Central Plateau Model*, suggested that dynamic P&T remedy operation consistent with U.S. Environmental Protection Agency guidance on P&T optimization (e.g., EPA et al., 2008) could increase mass recovery so it could approach (though not attain) 95% mass recovery.

In 2014, Version 6.3.3 of the CPGWM was released to coincide with Build 6 of the CH2M HILL Plateau Remediation Company (CHPRC) Modular Ground-Water Flow Model (MODFLOW), update the simulation period to 2014, and accommodate monthly pumping stresses from the year 2007. Version 8.3.4 of the CPGWM was released in 2016 to coincide with Build 8 of CHPRC MODFLOW and extend the simulation period through August 2016. The most recent model package report describing the CPGWM was released in 2017 as CP-47631, Rev. 4. CPGWM Version 8.4.5 was a major update of the CPGWM, which included defining layers based directly on the hydrostratigraphic geological formation rather than by the surface data analyzed as part of the model development. The model used the same build of MODFLOW as Version 8.3.4. The name "Version 8.4.5," reflects the use of Build 8 of the CHPRC MODFLOW code, Version 4 of the model grid, and Version 5 of the boundary conditions.

2.3.1.2 P2R Model

In FY 2019, the CPGWM was retired in favor of the P2R Model (CP-57037, Rev. 2) to provide far-field simulation capability integrated between 200-West and 200-East. Figure 2-3 shows the current P2R Model domain and boundary conditions. The P2R Model Version 7.1 (CP-57037, Rev. 0, *Model Package Report: Plateau to River Groundwater Transport Model Version 7.1*) was developed in response to comments received as part of 11-NWP-001, "Department of Ecology Comments on the Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit, DOE/RL-2009-83, Draft A." Comments received encouraged extending the eastern boundary of the CPGWM Version 3.3 to the Columbia River. In response, the initial model was developed using similar methods and identical codes as those used to develop the CPGWM but with an extended model extent.

In Version 8.2, (CP-57037, Rev. 1, *Model Package Report: Plateau to River Groundwater Model, Version 8.2*) the P2R Model was updated with a new grid structure, a longer calibration period, and spatially varying hydraulic properties. The calibration period was extended to represent conditions from 1944 through 2016 to evaluate the performance of the model against the historical hydraulic head data.

In the current version of the P2R Model (Version 8.3) the grid structure has been updated to reduce discontinuities in simulated contours, such as produced by the extension of the western edge of the model to basalt subcrops to the west of the 200 West Area. In addition, recharge was updated to account for

varying recharge spatially and temporally at the Hanford Site, and simulation of monthly stress periods from 2012 to 2018. These model enhancements resulted in improved calibration metrics and reduced transport artifacts. Version 8.3 simulates groundwater flow using the U.S. Geological Survey (USGS) three-dimensional (3D) groundwater flow model, MODFLOW, discussed in the following documents:

- McDonald and Harbaugh, 1988, "A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model"
- Harbaugh and McDonald, 1996, *User's Documentation for MODFLOW-96, an update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model*
- Harbaugh et al., 2000, MODFLOW-2000, t*he U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process*
- Harbaugh, 2005, *MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model – The Ground-Water Flow Process*

Contaminant transport is simulated using Modular 3-D Transport Multi-Species (MT3DMS) (Zheng and Wang, 1999, *A Modular Three-Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide*; Zheng, 2010, *MT3DMS V5.3 Supplemental User's Guide*). MT3DMS is a 3D, multi-species transport model developed for use with MODFLOW to simulate contaminant advection, dispersion, and chemical reactions in groundwater and on soils. MT3DMS was used to calculate the approximate directions and rates of migration of 200-ZP-1 and 200-UP-1 COCs, as well as the approximate time-varying influent concentrations and masses of these contaminants at individual extraction wells and at the combined system influent. The particle-tracking post-processor (MODPATH) (Pollock, 1994, *User's Guide for MODPATH/MODPATH-PLOT, Version 3; a particle tracking post-processing package for MODFLOW, the U.S. Geological Survey finite-difference ground-water flow model*) is used to compute pathlines based upon results obtained from groundwater flow simulations.

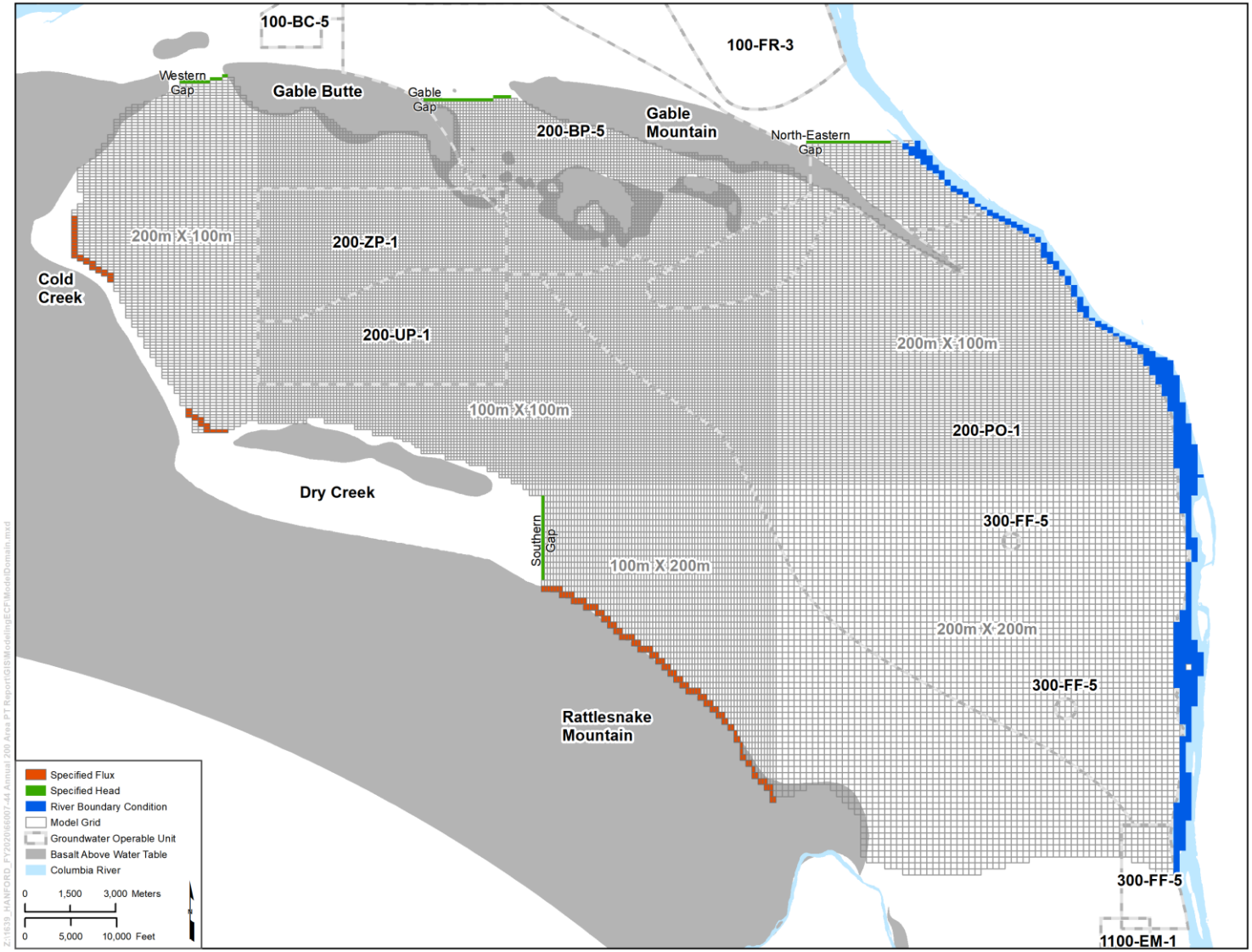

Figure 2-3. P2R Model – Model Domain and Model Boundary Conditions

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3 Calculation Methods

This chapter describes the calculation methods used. Assumptions underlying the methods and inputs for the calculations are presented in Chapter 4.

3.1 Water-Level Mapping

Groundwater flow directions and rates in the 200 West Area are affected by extraction and injection from the P&T systems. In addition to the use of groundwater modeling, groundwater elevation data are interpreted by evaluating measured water-level data hydrographs and by preparing maps of groundwater levels that depict patterns of groundwater flow and likely contaminant migration. These groundwater-level maps are also used in a variety of calculations and reports associated with various *Resource Conservation and Recovery Act of 1976* (RCRA) Dangerous Waste Management Units (DWMUs) and *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) groundwater OUs located within the 200 West Area. Previously, 200 West monthly water-level maps were prepared and documented at the end of the CY. In CY 2019, because of RCRA requirements, monthly water-level maps were prepared at the end of each quarter and documented in four ECFs: ECF-200W-19-0082, *Groundwater Elevation Mapping for 200 West Area - Quarter 1 Calendar Year 2019;* ECF-200W-19-0109, *Groundwater Elevation Mapping for 200 West Area - Quarter 2 Calendar Year 2019*; ECF-200W-19-0131, *Groundwater Elevation Mapping for 200 West Area - Quarter 3 Calendar Year 2019;* and ECF-200W-20-0015, *Groundwater Elevation Mapping for 200 West Area - Quarter 4 Calendar Year 2019*.

3.1.1 Universal Kriging with Analytic Elements

Groundwater-level mapping is used to estimate the extent of hydraulic containment through a step-wise data interpolation and pathline calculation process. For this purpose, the multi-event universal kriging (MEUK) technique (Tonkin et al., 2016, "Multi-Event Universal Kriging [MEUK]") was used to obtain a piecewise, continuous grid of groundwater elevations. Groundwater levels were mapped using the MEUK technique. MEUK is an extension of the hybrid mapping technique combining universal kriging and the analytic element method that is implemented in the program KT3D-H2O described in the technical report SGW-42305, *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance*, and further described by Karanovic et al., 2009, "KT3D_H20: A Program for Kriging Water Level Data Using Hydrologic Drift Terms."

For this analysis, the water-level maps for each month of CY 2019 were used to track particles on the mapped water-level surface to estimate the extent of hydraulic containment resulting from operation of the 200-ZP-1 and 200-UP-1 groundwater P&T systems.

3.1.2 Particle Tracking

The particle tracking program "Transient Tracker" is used to estimate the extent of hydraulic containment that would develop under conditions represented by a single groundwater-level map, providing an instantaneous depiction of hydraulic containment corresponding to the water levels and pumping rates used to prepare the map. Particle tracking is accomplished using the fourth-order Runge-Kutta numerical integration scheme (RK4) (Press et al., 1996, *Fortran Numerical Recipes, Volume 2 (Fortran 90): The Art of Parallel Scientific Computing*). Particle tracking using the RK4 approach indicates the approximate path of migrating groundwater and dissolved contaminants, as well as the relative timing of contaminant arrival at points of interest. The RK4 approach is based on that implemented in both mod-Path3DU (SSP&A, 2020, *User's Guide for mod-PATH3DU, a Groundwater Path and Travel-Time Simulator*, retrieved from and documented at mp3du.sspa.com/man) and PATH3D (Zheng, 1992, PATH3D: *A Groundwater Path and Travel-Time Simulator, Version 3.0*) – both also particle-tracking post-processing

programs – that provide similar results to the USGS particle-tracking program, MODPATH (Pollock, 1994), which is used with the P2R Model for similar purposes. The Transient Tracker program can be used as standalone program executed from command line or executed from KT3D_H20 (described in the technical report SGW-42305) or GroundWater Desktop (SSP&A, 2019, *GroundWater Desktop User Manual, Version 4*).

3.1.3 Interpolated Capture Frequency Map

If concurrent water-level and pumping rate data are available, maps depicting water levels and capture can be produced on any frequency. A best estimate of overall capture using numerous maps can be discerned by calculating an interpolated capture frequency map (ICFM). An ICFM depicts capture that is estimated on the basis of numerous water-level maps. An ICFM depicts the frequency that each particle terminates at an extraction well, calculated over all water-level maps. A frequency of 1.0 indicates that the particle is captured on every map, a frequency of zero indicates that a particle is not captured on any map, and intermediate frequencies indicate that the particle is captured using some maps and not on others. Frequencies below 1.0 may be due to variations in pumping rates; temporary well shut-off for scheduled and unscheduled maintenance; or the degree of adherence to, or violation of, assumptions that underlie the mapping method. An ICFM is most appropriately interpreted as a collective estimate for the monitoring period. Only frequencies of 0.5 and higher are depicted in figures in this ECF.

3.2 Groundwater Modeling

The P2R Model is used to aid in understanding performance of the in-place remedies and to project the likely future performance of the remedies under assumed operating conditions.

3.2.1 Model Updates

No changes were made to the fundamental structure (i.e., the grid discretization, layering, and the representation of the site hydro-stratigraphy) of the P2R Model Version 8.3 (CP-57037, Rev. 2) before performing the simulations described in this ECF. Limited changes that were made to the time discretization, boundary conditions and other inputs, are described in the following subsections.

3.2.1.1 Time Discretization

For the calculations in this ECF, the time discretization was updated to simulate current and future P&T operations. Because the P2R Model Version 8.3 ends in December 2018, the time discretization of the P2R Model was updated for CY 2019 through 2137 to simulate future operations of remedies for the 200-ZP-1 and the 200-UP-1 S-SX Tank Farms and U Plant and the period during which MNA is the operating remedy. Model time is discretized into stress periods and time steps, and changes in external forcing functions (e.g., recharge or pumping) typically occur by changing stress periods. Stress periods are further divided into time steps, which allows for a more accurate discretization of the time derivative of the partial differential groundwater flow equation.

For purposes of predictive simulations described in this ECF, two models were developed with different model start times and transport initial conditions. The purpose of making calculations with two time discretizations is to transition from previously prepared initial conditions (contaminant plumes, as discussed in ECF-200ZP1-13-0006, *Description of Groundwater Modeling Calculations for the Calendar Year 2012 (CY2012) 200 Areas Pump-and-Treat Report*) to more recently prepared initial conditions, as presented in the following discussion (preparation of the updated initial conditions [contaminant plumes] as detailed in ECF-200W-20-0052, *Updates to the 200-West Three-Dimensional Groundwater Concentration Plumes for Calendar Year 2015 for use as Initial Conditions in the Plateau to River (P2R) Groundwater Model*).

The time discretization for the model application that simulates the period from 2012 through 2019 using initial conditions (contaminant plumes) that approximately represent conditions during CY 2011 is represented by 96 monthly stress periods as summarized in Table 3-1.

The time discretization for the model application that simulates the period from 2015 through 2137 using initial conditions (contaminant plumes) representing approximate conditions in early CY 2015 is summarized in Table 3-1 and is outlined below:

- The first 93 stress periods are monthly, representing the current remedy operations and connection of future wells to the P&T system.
- Stress periods 94 through 108 are yearly, representing the simulation of the final phase of the 200-ZP-1 P&T system operation.
- Stress period 109 is 100 years long, used to simulate the period during which MNA is the operating remedy.

Table 3-1. P2R Model Temporal Discretization

Original P2R Model Version 8.3 Model		
Stress Period	**Duration**	**This Application**
1 through 69	1943 through 2011	Yearly stress periods
70 through 153	2012 through 2018	Monthly stress periods
Predictive Model Starting in 2012		
Stress Period	**Duration**	**This Application**
1 through 96	01/01/2012 to 12/31/2019	Monthly stress periods representing end of interim and startup of 200W P&T system operation (200W P&T system commences October 1, 2012)
Predictive Model Starting in 2015		
Stress Period	**Duration**	**This Application**
1 through 93	01/01/2015 to 09/30/2022	Monthly stress periods representing 200W P&T system operation and system increase in capacity.
94 through 108	10/01/2022 to 09/30/2037	1-year stress periods
109	10/01/2037 to 9/30/2137	100-year stress period

P&T = pump and treat
P2R Model = Plateau to River Groundwater Model

3.2.1.2 Boundary Conditions and Other Inputs

The following updates were made to input files to the P2R Model to reflect recent data. Since these updates comprise inputs to the P2R Model, the details of these inputs are described in Section 4.2:

- Updated well flow rates to actual rates recorded for extraction and injection wells through the end of CY 2019

- Updated the constant head, river and recharge boundary conditions for the P2R Model
- Updated initial heads:
  - For the predictive model starting in 2012, initial heads were obtained from the calibrated historical P2R Model.
  - For the predictive model starting in 2015, initial heads were obtained from the model starting in 2012.
- Updated contaminant treatment system (CTS) package to reflect P&T system efficiencies through the end of 2019 and to include mass recovery from BP-5 OU extraction wells.
- Updated 3D initial conditions (contaminant plumes). The 3D plume depictions and transport initial conditions could not be easily translated from CPGWM to the P2R Model because of substantial differences in their vertical discretization (i.e., model layering). ECF-200W-20-0052 describes in detail the methods and calculations used to generate the initial conditions for the P2R Model to make F&T predictions for the COCs in the 200 ZP-1 and UP-1 OUs.
- Inclusion of a continuing source. A simulated continuing source was included in technetium-99 F&T simulations in order to match the stable concentrations measured at well 200-W11-50 and a recent increasing trend in well 200-W14-20. The true location, character and persistence of any potential continuing source(s) in this area are unknown at this time.

In addition to the above, the P2R Model groundwater level calibration/validation data set was updated through the end of CY 2019, although no model parameters were adjusted and re-calibration was not performed. Summary statistics for the validation/calibration residuals presented in Section 4.2.2 were similar to those presented for the calibrated model in CP-57037, Rev. 2, which suggests that over the extended validation period (from 2012 through 2019), the model performs as well (in terms of statistical correspondence with measured water levels) as during the calibration period.

3.2.2 Flow Modeling and Simulated Capture Frequency Map

Groundwater simulations performed for CY 2019 assume transient-state (i.e., time-varying) conditions in the aquifer that reflect water-level changes due to operation of the P&T extraction and injection wells. The stress periods correspond to calendar monthly average conditions. The approximate extent of hydraulic containment was calculated with the P2R Model using an approach similar to that described in Festger and Walter, 2002, “The Capture Efficiency Map: The Capture Zone Under Time-Varying Flow”; and Reilly and Pollock, 1996, “Sources of Water to Wells for Transient Cyclic Systems,” focusing on the evaluation of the regions of the subsurface that are consistently contained despite temporal variations due to changing flow patterns and hydraulic gradients. This process is similar to the process used to calculate an ICFM and is implemented using the P2R Model as follows:

- Release particles near the end of each of the 12 monthly stress periods and simulate their migration using a very low effective porosity, approximating “instantaneous” particle travel
- Record the instantaneous fate of each particle for each stress period
- Calculate a capture zone for each stress period based on the “snapshot” of aquifer conditions at the time of the particle release, producing 12 instantaneous snapshots of the extent of capture

- Construct a simulated capture frequency map (SCFM) by counting the number of times that a particle originating from a location was captured by a well, and then divide this count by the total number of releases (i.e., by 12)

3.2.3 Transport Modeling and Mass Recovery Calculations

Contaminant transport simulations were conducted to approximate the recent and likely future movement and fate of the 200-ZP-1 and 200-UP-1 COCs. For purposes of the 200-ZP-1 OU, the objectives of these simulations are as follows:

- Historical simulations:
  - Calculate influent concentrations and mass recovery at each individual extraction well and for the treatment system in its entirety since startup of the 200-ZP-1 P&T system
  - Compare these values with recorded influent concentrations and mass recovery rates
- Future projections:
  - Calculate influent concentrations and mass recovery at each individual extraction well for the remaining years of operation, providing an indication of the relative concentrations and mass recovery between different extraction wells over the life of the remedy
  - Calculate the movement and fate of COCs in groundwater and estimate the likely disposition and concentration of the COCs over the life of the remedy

Inputs used for contaminant F&T simulations are detailed in Section 4.2.

3.3 Flow-Path Control

As stated in Section 4.3.3 of the 200-ZP-1 OU ROD (EPA et al., 2008):

> "Flow-path control is also required and shall be achieved by injecting the treated groundwater into the aquifer to the northeast and east of the groundwater contamination such that the treated injected water in these locations will slow the natural eastward flow of most of the groundwater and, as a result, keep COCs within the capture zone, as well as increase the time available for natural attenuation processes to reduce the contaminant concentrations not captured by the extraction wells."

The locations and rates of extraction and injection wells were designed to encompass and recover the majority of contaminant mass and to slow the migration of contaminants present at lower concentrations. Evaluating the development of flow-path control relies upon assessing (1) the extent of contamination (emphasizing carbon tetrachloride), (2) the extent of hydraulic containment determined using both water-level mapping and groundwater modeling (i.e., the ICFM and SCFM, respectively), and (3) the region over which hydraulic gradients are affected by the operation of the P&T system, as determined using both water-level mapping and groundwater modeling. The control line for evaluating flow-path control has currently been established as a line that (1) is located a short distance upgradient of the eastern series of injection wells, (2) is generally perpendicular to the prevailing groundwater flow direction prior to when the 200 West P&T started operating, and (3) extends to the north and south of the eastern (downgradient) line of injection wells until such time as a perpendicular to this line of control extends outside the 100 µg/L carbon tetrachloride isoconcentration line. Calculation details for flowpath control are provided in this ECF.

3.4 Transport Modeling – Initial Conditions from Sequential Gaussian Simulation

As detailed in ECF-200W-20-0052, application of quantile kriging results in a single depiction of the 3D extent of contamination, whereas the application of sequential Gaussian simulation (as detailed in ECF-200W-18-0028, *Evaluation of Three-Dimensional Extent of Carbon Tetrachloride and Nitrate in Groundwater for 200-West for Calendar Years (CYS) 2015 and 2017*) results in multiple "realizations" of the 3D extent of contamination. Each of these realizations, or any combination derived from multiple realizations, can be used for F&T modeling. In support of the 200-ZP-1 RD/RAWP, completed in 2008, depictions of the extent of carbon tetrachloride and other COCs were prepared using sequential gaussian simulation (SGSIM) (DOE/RL-2009-38; DOE/RL-2008-78). At that time, it was found that the estimated extent and mass of contamination within groundwater generated using the ensemble average (E-Type) of 100 SGSIM realizations was substantially larger than that generated using the ordinary kriging (quantile) technique and that it might over-state the mass of dissolved carbon tetrachloride present within the convex hull of the sampling data. This arose, in part, due to the difficulty encountered at that time constraining realizations. As the 200 West P&T system has operated, a record of mass recovered by the P&T system has been compiled together with data obtained from multiple groundwater sampling events throughout a network of monitoring wells. These data have been used to help constrain estimates of mass and distribution for both carbon tetrachloride and nitrate derived from SGSIM realizations.

For CY 2017, constrained realizations were obtained by executing 100 transport model simulations, each using one of 100 SGSIM initial realizations as the initial plume, and comparing the simulated mass recovery at the P&T system and simulated concentrations at monitoring wells with reported values and developing a "weighted-average" plume from the SGSIM realizations to compare with that generated using quantile kriging. A detailed description, and calculations, of the SGSIM E-Type and "weighted-average" plumes is provided in ECF-HANFORD-18-0030, *Description of Groundwater Calculations and Assessments for the Calendar Year 2017 (CY2017) 200 Areas Pump-And-Treat Report*. This procedure for developing initial conditions was undertaken for carbon tetrachloride and nitrate for purposes of the CY2017 annual P&T report.

4 Assumptions and Inputs

This chapter outlines the assumptions and the inputs for the calculations in this ECF.

4.1 Assumptions

This section discusses the calculation assumptions.

4.1.1 Water-Level Mapping and Interpolated Hydraulic Containment

Water-level contour maps are constructed using a technique that incorporates the effects of drawdown and mounding due to groundwater extraction and reinjection, respectively (SGW-42305). The resulting contour maps respect the values of water levels measured at each well and provide a plausible interpretation of groundwater levels and hydraulic gradients between measured locations. However, the accuracy of the contours is influenced by the following, as well as other factors:

- Degree of adherence to, or violation of, assumptions that underlie the mapping method (as outlined in SGW-42305):
  - The aquifer is homogeneous, isotropic, and of infinite areal extent.
  - The aquifer is confined so the transmissivity is uniform and unchanging. If the aquifer is unconfined, drawdowns should be a reasonably small fraction of the aquifer saturated thickness.
  - The pumping well penetrates and receives water from the entire saturated thickness of the aquifer (i.e., the well is not partially penetrating).
  - The drawdown and/or mounding has/have reached a (quasi-state) steady-state condition. If this is not the case, the rate of change in hydraulic gradients should approach zero.
- Accuracy of the measured (or recorded) water levels
- Number, distribution, and location of monitoring wells
- Relationship between the vertical open intervals of the monitoring wells and those of the extraction and injection wells
- Presence, continuity, and hydraulic properties of the Ringold Formation, member of Wooded Island – lower mud unit (Rlm).

These factors mean that the maps only approximate actual conditions. The water-level and hydraulic-containment maps are approximations that help interpret likely directions and rates of groundwater movement and the likely extent of convergent hydraulic gradients that is consistent with hydraulic containment. An ICFM typically provides a reasonable estimate of remedy-wide capture within the footprint of the measured water-level data. However, distinguishing the capture zones of individual wells within a multi-well remedy can be difficult because the steady-state (or transient) balance of groundwater flows is not guaranteed using water-level mapping. In addition, the water-level mapping method assumes that vertical flow is negligible compared to horizontal flow, which is usually a reasonable assumption at some distance from pumping wells in regions of relatively low recharge.

4.1.2 Groundwater Flow Modeling and Simulated Hydraulic Containment

Simulated groundwater elevations are computed using the P2R Model, which is a calibrated and flow-conserved numerical simulator of groundwater in the Central Plateau. Because previous efforts were completed to calibrate flow model parameters, flow model outputs (i.e., heads) in general correspond with

measured water levels throughout the area. However, the accuracy of the simulated groundwater elevations (and of inferences from those elevations, such as hydraulic containment) is influenced by (1) the structural accuracy of the P2R Model (i.e., how well the model represents actual physical conditions), (2) the accuracy of the water-level data used for calibration, (3) the magnitude and distribution of validation/calibration residuals, and other factors. These factors and resulting approximations in the simulated groundwater contours, drawdown and mounding, and extent of hydraulic containment result in the simulated depictions only approximating actual conditions. As such, the simulated water-level and hydraulic-containment maps are interpreted as approximations that help interpret likely directions and rates of groundwater movement, and extents of convergent hydraulic gradients that are consistent with hydraulic containment. Comparison of groundwater-level maps and extents of hydraulic containment (simulated using the P2R Model) with the depictions obtained using the water-level mapping technique provides confidence in the combined evaluation as follows:

- In areas where the estimated extent of hydraulic containment is similar between the methods, confidence is relatively high that containment is achieved (if both methods suggest containment is achieved) or is not achieved (where both methods suggest containment is not achieved).
- In areas where the estimated extent of hydraulic containment differs substantially between the methods, confidence is lower in the interpretation of containment because one method suggests containment is being achieved, while the other suggests it is not achieved.

4.1.3 Transport Modeling and Mass Recovery Calculations

Contaminant transport modeling and projected fate calculations (including simulated recovery of contaminant mass at extraction wells) rely upon the accuracy of the outputs of the groundwater flow simulations (because the groundwater flow model forms the basis of the contaminant transport model) and also the accuracy of the parameters and other assumptions and inputs to the contaminant transport model. Assumptions and limitations underlying the groundwater flow model were summarized above. The following are key assumptions and limitations underlying the contaminant transport model, for purposes of the calculations presented in this ECF. These assumptions and limitations are fundamental to the use of contaminant F&T models at any site:

- The initial conditions (plume shells) are reasonable representations of the extent of contamination in groundwater under current conditions at the beginning of the simulations.
- The instantaneous equilibrium assumption that is used to partition dissolved contamination (plume shell concentrations) to the aquifer material provides a reasonable representation of the distribution of sorbed contamination at the commencement of the simulations.
- The transport parameters (i.e., porosity, dispersion, distribution coefficient, and degradation/decay rates) reasonably describe the processes that each COC undergoes in groundwater and on aquifer sediments.

4.2 Input Data

This section summarizes the inputs that are specific to the calculations presented in this ECF. Features and inputs to the P2R Model that do not change for these calculations (e.g., the structure of the P2R Model) are not discussed here. The principal inputs to the calculations completed for the CY 2019 annual groundwater P&T report (DOE/RL-2019-68) are as follows:

- Current and future estimated extraction and injection rates at wells
- Specified head boundary conditions
- Groundwater elevations measured at monitoring wells that are used to validate simulated groundwater levels
- Parameters for contaminant transport simulations
- Updated CTS package for transport simulations
- Updated initial conditions for contaminant transport simulations (i.e., plumes)
- Added continuing technetium-99 source to represent persistent concentrations in the vicinity of some tank farms.

These inputs are described in the following subsections.

4.2.1 Extraction and Injection Rates

Historical groundwater extraction and injection flow rates for the 200 West P&T wells are provided in Table A-1 (for CY 2012/2013), Table A-2 (for CY 2014/2015), Table A-3 (for CY 2016/2017), and Table A-4 (for CY 2018/2019) in Appendix A. During the CY 2019, extraction pumping rates for the 200 West P&T varied between 6,869 and 9,369 L/min (1,815 and 2,475 gallons per minute [gpm]). The system pumped a combined total average of 8,054 L/min (2,128 gpm). Figure 4-1 depicts rates in December 2019 for the 200 West P&T treatment system.

It is anticipated that suspending biological treatment, which occurred in October 2019, together with other treatment system upgrades including installation of a third air stripper and the additional extraction and injection wells will enable the 200 West P&T treatment capacity to increase up to a maximum of approximately 14,200 L/min (3,750 gpm) in throughput. This expansion of capacity is being undertaken as part of planned optimization activities. The actual, individual future operating rates of extraction and injection wells across both 200 West and 200 East are, at this time, not known. However, to accommodate potential future operating conditions with this increased 200 West P&T system capacity, a predictive simulation was prepared that assumed a total operating rate of 13,173 L/min (3,480 gpm), which included an increased rate of extraction and injection within the 200-ZP-1 OU to about 11,621 L/min (3,070 gpm) facilitated by the addition of 10 hypothetical extraction wells. The remaining 2580 L/min (270 gpm) was reserved for future operation of 200 East WMA-A and WMA-C P&T treatment. The estimated future groundwater extraction and injection flow rates for the 200 West P&T wells are provided in Table A-5 (for CY 2020/2021) and Table A-6 (for CY 2022 through 2037) in Appendix A.

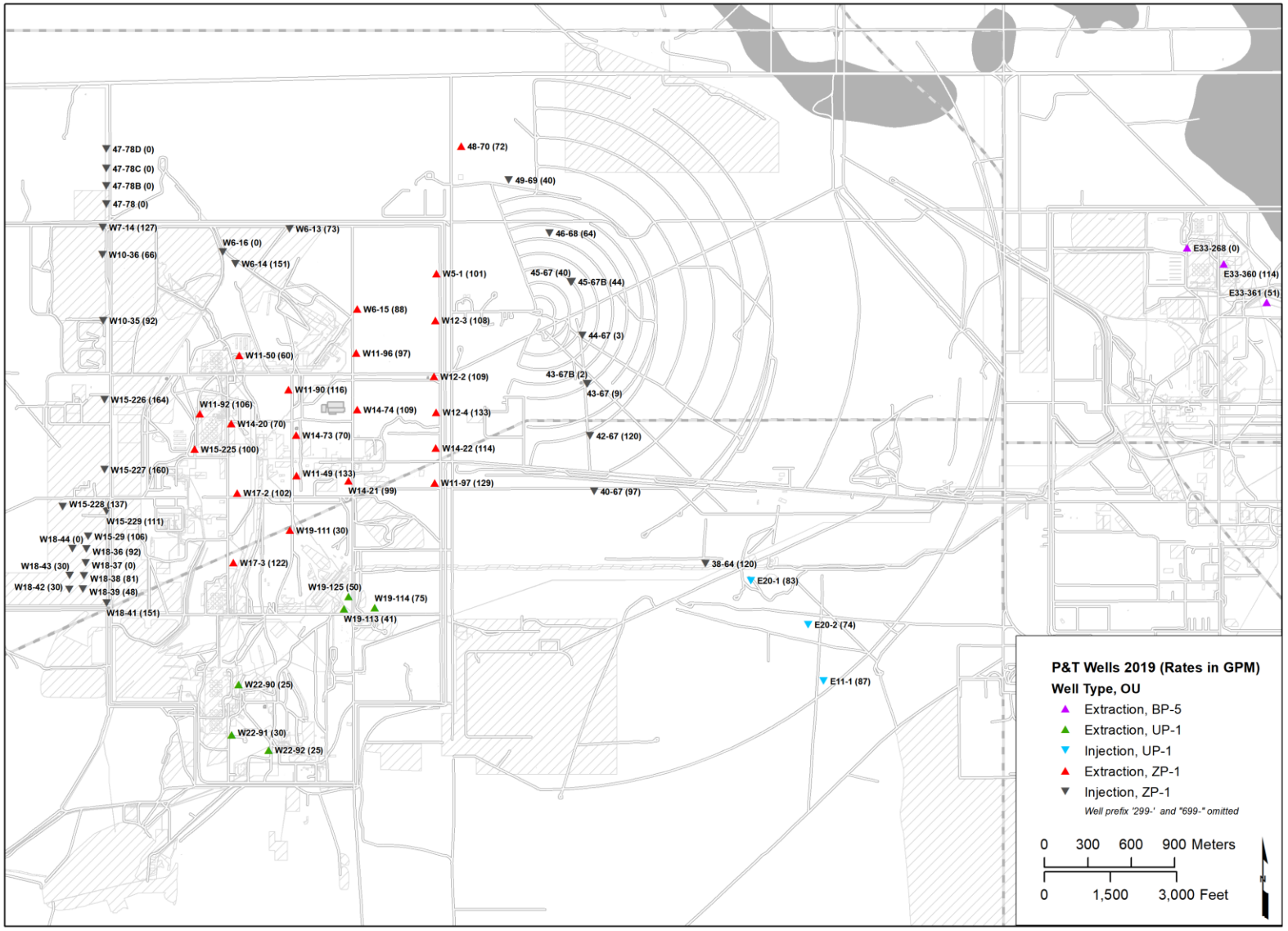

Figure 4-1. Pumping Rates in December 2019 for the 200 West Pump and Treat

4.2.2 Specified Head Boundary Condition

Four locations where the water table is above the top of the basalt are defined by specified head boundaries (CP-57037, Rev. 2) shown as green shading in Figure 2-3. During the calibration process (i.e., the historical period), for each of the 4 boundary locations (Southern, Gable Gap, Western Gap, and North-Eastern) the hydraulic head values assigned to the boundary were taken as the annual average observed head at observation wells near the boundary location. For the predictive simulation described in this ECF, specified heads were extended through to the year 2037. For each boundary location, an exponential function was fit to the recent period of hydraulic heads, and then the fitted function was used to project approximate future hydraulic heads over time at those locations for use in the corresponding boundary. Historical and predicted hydraulic heads are shown in Figures 4-2 through 4-5.

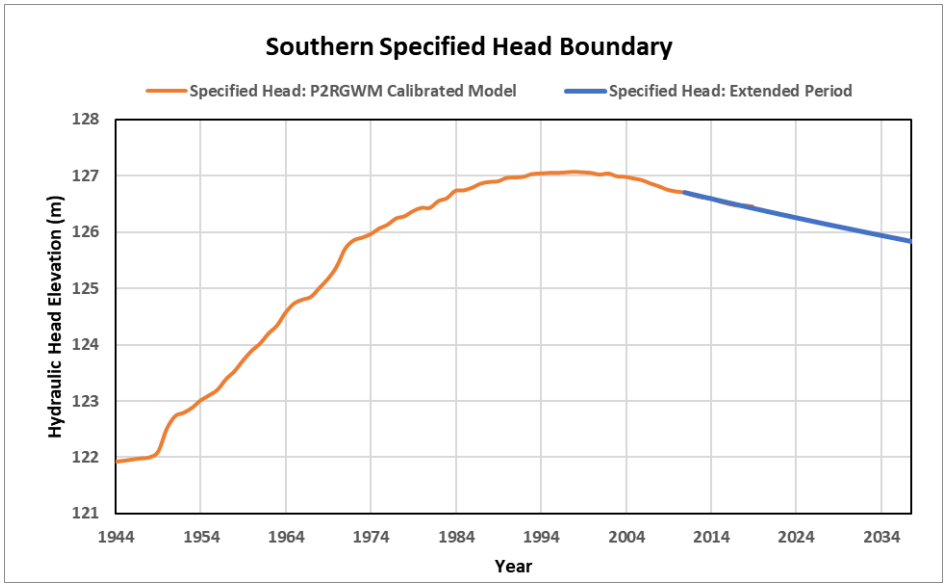

Figure 4-2. Specified Head at Southern Boundary

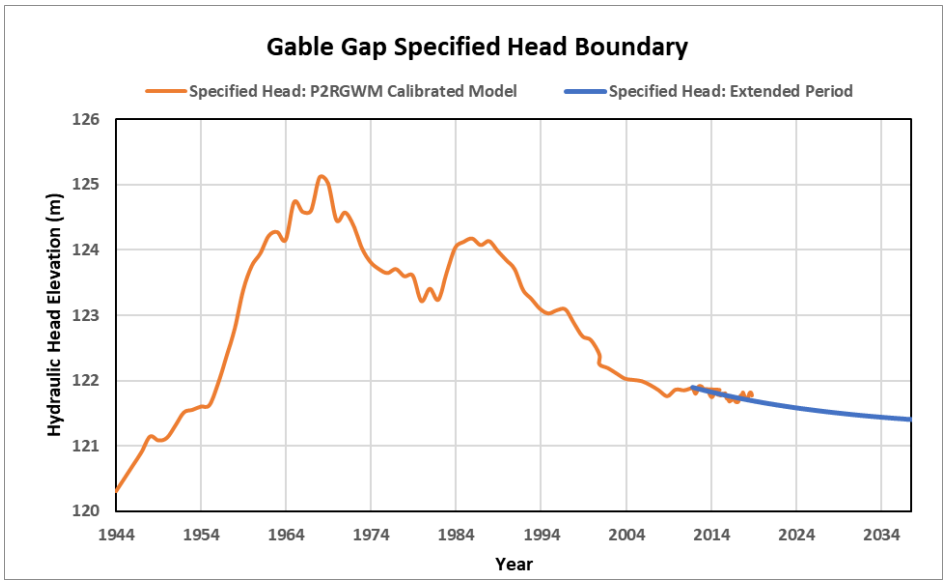

Figure 4-3. Specified Head at Gable Gap Boundary

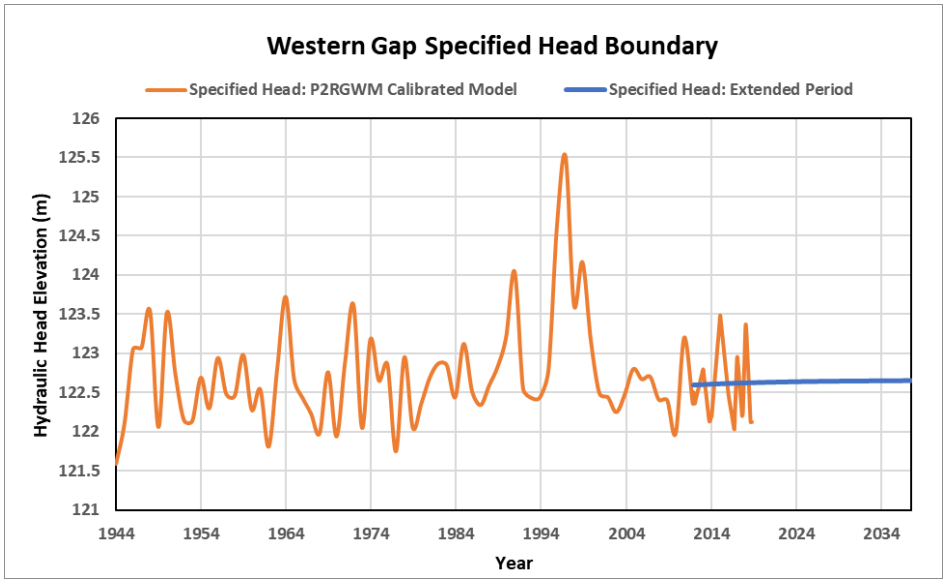

Figure 4-4. Specified Head at Western Gap Boundary

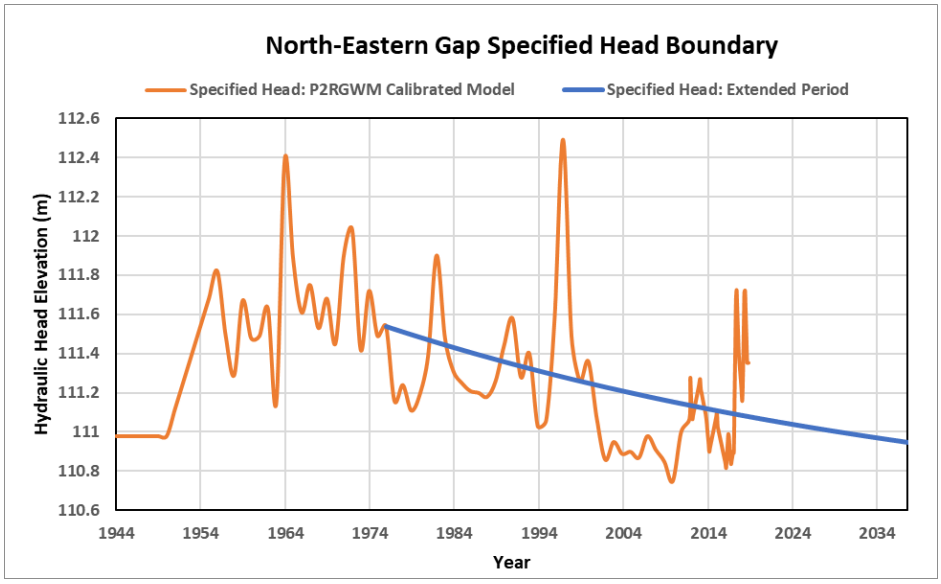

Figure 4-5. Specified Head at North-Eastern Boundary

4.2.3 River package

The eastern side of the P2R Model domain is bounded by the Columbia River. Aquifer interaction with the Columbia River is simulated using the Modflow River (RIV) Package. To extend the RIV package beyond 2018 for predictions, the following steps were followed:

- For years 2015 through 2018, the river package is the same as in the calibrated P2R Model.
- For years 2019 through 2028, the river package is represented as a repetition of last 10 years simulated in calibrated P2R Model (i.e., the years 2009 through 2018).
- Stress periods for years after 2028 were kept constant and simulated using the values from year 2028.

4.2.4 Recharge

Recharge to the water table throughout the P2R Model domain comprises the following contributions:

- Natural recharge estimated using the surface soil type.
- Mountain-front discharge representing an influx to the aquifer from Dry Creek and Cold Creek watersheds and Rattlesnake Mountain.
- Anthropogenic discharges representing two components: operational discharges at the waste sites and ancillary discharges due to other human activities.

A MODFLOW recharge package (RCH) for recent and predictive stress periods was generated using the same set of tools and the data used to generate historical recharge during the P2R Model calibration.

4.2.5 Groundwater Elevations Measured at Monitoring Wells Used to Validate Simulated Groundwater Levels

Groundwater-level data obtained during CY 2019 included water levels obtained during or concurrent with synoptic water-level surveys, and water levels obtained at various locations on a continuous basis from wells equipped with transducers and data loggers. The latter, collectively referred to as part of the Hanford Site automated water-level network (AWLN), comprises a smaller number of wells than is measured during synoptic surveys.

The synoptic water-level event for the 200-ZP-1 OU occurred during March 2019 when water levels were obtained from over 200 monitoring wells. Throughout 2019, water levels were recorded using data loggers and transducers installed in approximately 30 monitoring wells throughout the 200-ZP-1 OU. In addition to the monitoring well data, water levels were recorded with data loggers in the extraction and injection wells that were actively operating during 2019. The number of wells monitored varied throughout the year. Figure 4-6 presents selected water-level hydrographs illustrating the correspondence between simulated and measured groundwater elevations.

The calibration target data set for the P2R Model was augmented with available continuous and manually measured water-level data through December 2019. Data that have been added to this data set in recent years (following the most recently conducted formal calibration) are used to compute statistics similar to those used in the calibration, to compare with calibration statistics in a model calibration/validation procedure. Daily average water-level values were calculated and incorporated into the validation/calibration data set. Figure 4-6 provides comparisons of simulated and measured water levels at selected wells, including the extended simulation time frame through CY 2019. Since the flow parameters of the P2R Model were not recalibrated, this ECF does not present a rigorous evaluation of validation/calibration residuals; however, summary statistics for the validation/calibration residuals are provided in Table 4-1. The statistics listed are similar to those presented in the previously calibrated P2R Model Version 8.3 (CP-57037, Rev. 2), as updated through December 2019 using water-level data obtained both manually and from the AWLN. The values for these statistics are similar to those presented for the calibration that is documented in CP-57037, Rev. 2, which suggests that over the extended validation period (from 2009 through 2019), the model performs similarly (in terms of statistical correspondence with measured water levels) as during the calibration period. This is also supported by the correspondence between simulated and mapped water levels, between simulated and mapped drawdowns, and between simulated and mapped estimates of the extent of hydraulic containment, as presented in this ECF.

Table 4-1. Residual Summary Statistics from P2R Model Version 8.3 Validation, as Updated through December 2019

Correlation	0.99
Average Residual (m)	0.06
Maximum Residual(m)	2.35
Minimum Residual(m)	-3.38
Sum of Squares for Errors	6674.62
Mean Square Error	0.22
Root Mean Square Error	0.467
Observation Range(m)	15.59
Root Mean Square Error/Observation Range	0.030
Coefficient of Determination (R^2)	0.98

P2R Model = Plateau to River Groundwater Model

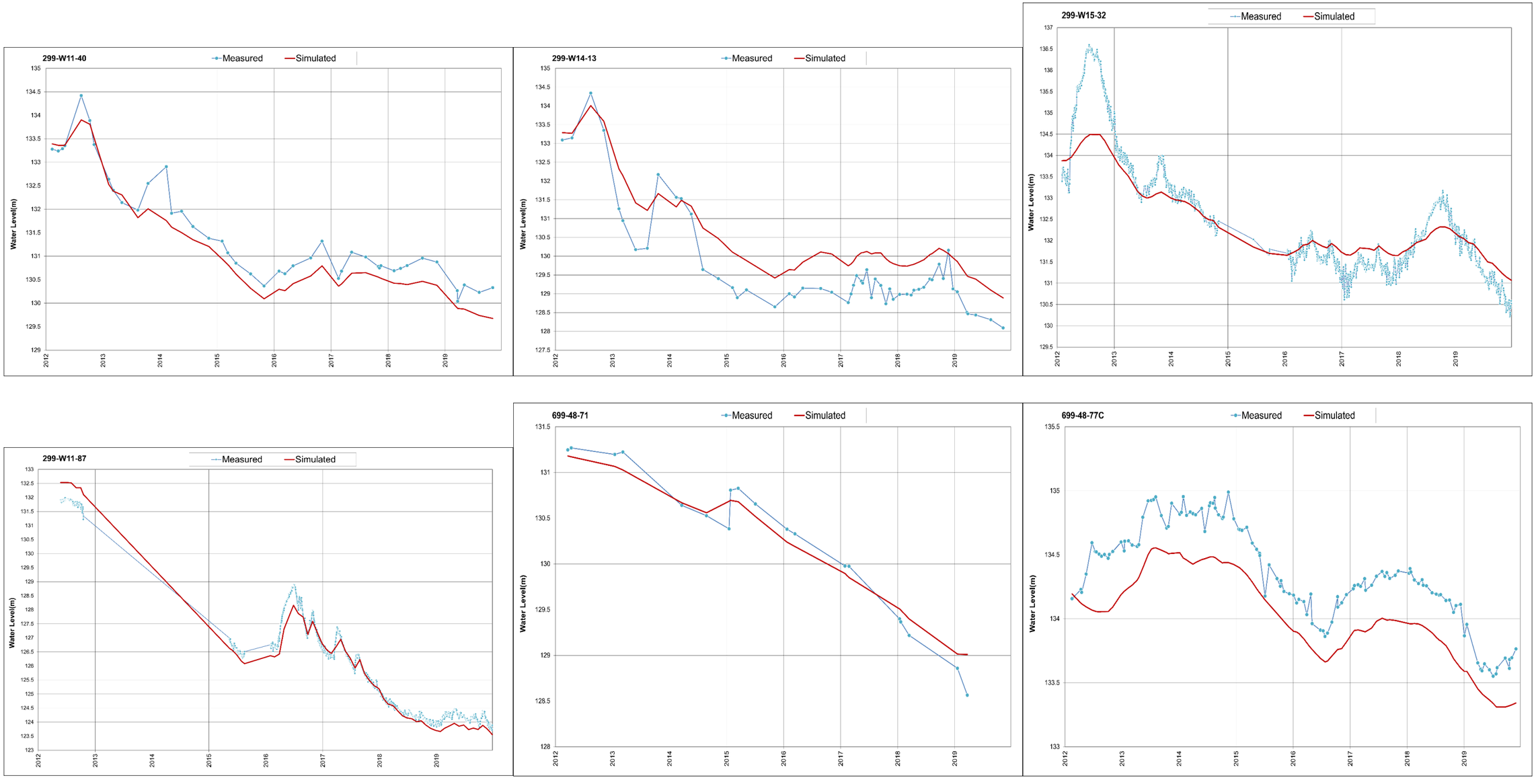

Figure 4-6. Selected Water-Level Hydrographs throughout the Study Area Illustrating the Correspondence between Simulated and Measured Groundwater Elevations

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4.2.6 Contaminant Transport Properties

Contaminant transport parameters used in the calculations presented in this ECF are unchanged from those used in the basic P2R Model as documented in CP-57037, Rev. 2. However, these parameters are listed in Table 4-2 for completeness.

4.2.7 Updated Initial Conditions for Contaminant Transport Simulations (Plumes)

3D depictions of the extent of contamination used for transport initial conditions were prepared using data obtained through CY 2019 as described in ECF-200W-20-0052. Two-dimensional (2D) depictions of the maximum extent of the previously prepared CY 2012 initial conditions and the maximum extent of the recently updated for CY 2015 initial conditions (ECF-200W-20-0052) are also shown in Figures 4-7 through 4-14 for comparison purposes. 2D depictions of the maximum extent were calculated as the maximum concentration from all model layers at each model row-column location (i.e., the highest concentration, regardless of model layer) and then bilinearly interpolated from the model grid to a finer grid size for visualization and other calculations. Simulation results obtained using the CY 2015 3D depictions for each COC are presented later in this ECF for comparison with measured quantities.

Table 4-2. Contaminant Transport Properties Assumed for F&T Analyses Using the CP Model

Constituent-Specific Parameter Values for the Central Plateau Model for the CY-2019 P&T Report						
COC	**K_d (mL/g)**	**Half-Life (yr)**	**Half-Life (day)**	**1st Oder Decay Rate (one/day)**	**Reference for K_d**	**Reference for Degradation Rate**
Nitrate	0	None assumed	None assumed	None assumed	PNNL-18564, Table 6.9, sandy-gravel sediment type	No Hanford Site relevant reference
Iodine-129	0.10	15,700,000	5,730,000,000	1.21×10^{-10}	PNNL-18564, Table 6.9, sandy-gravel sediment type	—
Technetium-99	0	211,000	77,100,000	8.99×10^{-9}	—	—
Tritium	0	12.3	4,500.0	0.000154	—	—
Carbon Tetrachloride	0.011	300; 630 [a]	109,575; 230,107	6.3258×10^{-6}; 3.012×10^{-6}	Compilation for Feasibility Study (DOE/RL-2007-28, Table D-58) and modeling undertaken for Rev. 0. of the RD/RAWP.	PNNL-22062
Trichloroethene	0.0250	None assumed	None assumed	None assumed	Empirical calculation [b]	No Hanford Site relevant reference
Chromium	0	None assumed	None assumed	None assumed	Same as for hexavalent chromium	—
Uranium	0.4000	4,470,000,000	1,630,000,000,000	4.25×10^{-13}	PNNL-18564, Table 6.9, sandy-gravel sediment type	—

Table 4-2. Contaminant Transport Properties Assumed for F&T Analyses Using the CP Model

Aquifer Dependent Transport Parameter Values for the Central Plateau Model for the CY-2019 P&T Report		
Property	**Value**	**Comments**
Effective Porosity	0.15	Approximate central value (Table D-2 of DOE/RL-2007-28)
Longitudinal Dispersivity	3.5-6.2 m	Based on grid cell size according to Schulze-Makuch (2005)
Transverse Dispersivity	0.7-1.24 m	20% of longitudinal (consistent with the ratio specified in DOE/RL-2008-56)
Vertical Dispersivity	0.35 – 0.62 m	20% of longitudinal (consistent with the ratio specified in DOE/RL-2008-56)
Molecular Diffusion Constant	0.0 m^2/day	Negligible term
Bulk Density, Hanford Sandy Gravel, Cold Creek	1.93 g/cm^3	PNNL-18564, Table 6.2 (sitewide average values for this formation)
Bulk Density, Ringold Taylor Flat, unit E, lower mud, unit A	1.90 g/cm^3	PNNL-18564, Table 6.2 (sitewide average values for this formation)
Particle Tracking Parameters		
Effective Porosity	0.15	Approximate central value (Table D-2 of DOE/RL-2007-28)
Hydraulic Conductivity	5	Approximate Value for Ringold E

References: DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit*.

DOE/RL-2008-56, *200-West Area Pre-Conceptual Design for Final Extraction/Injection Well Network: Modeling Analyses*.

PNNL-13560, *Assessment of Carbon Tetrachloride Groundwater Transport in Support of the Hanford Carbon Tetrachloride Innovative Technology Demonstration Program.*

PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report*.

PNNL-22062, *Abiotic Degradation Rates for Carbon Tetrachloride and Chloroform: Final Report.*

Schulze-Makuch, 2005, "Longitudinal Dispersivity Data and Implication for Scaling Behavior."

a. The values used for carbon tetrachloride are based upon studies completed by PNNL during the development of the Remedial Investigation and Feasibility Study (DOE/RL-2007-28, Rev. 0) in particular and analyses completed for Rev. 0 of the RD/RAWP. Subsequent analyses as reported in PNNL-22062 estimated the half-life of carbon tetrachloride in aqueous systems at 16°C to be about 630 years, and noted that this rate is highly temperature dependent, with increasing temperatures resulting in a decreased half-life. This information will be integrated into future simulations of the 200-West remedies.

b. The empirical calculation is based on PNNL-13560 Equations 1 and 2 (p. C.16), assuming foc = 0.00027, solubility of PCE at 150 mg/L, and solubility of trichloroethene at 1,100 mg/L.

COC = contaminant of concern
CP = Central Plateau
CY = calendar year
F&T = fate and transport
P&T = pump and treat
PCE = perchloroethene
K_d = distribution coefficient
PNNL = Pacific Northwest National Laboratory
RD/RAWP = Remedial Design/Remedial Action Work Plan

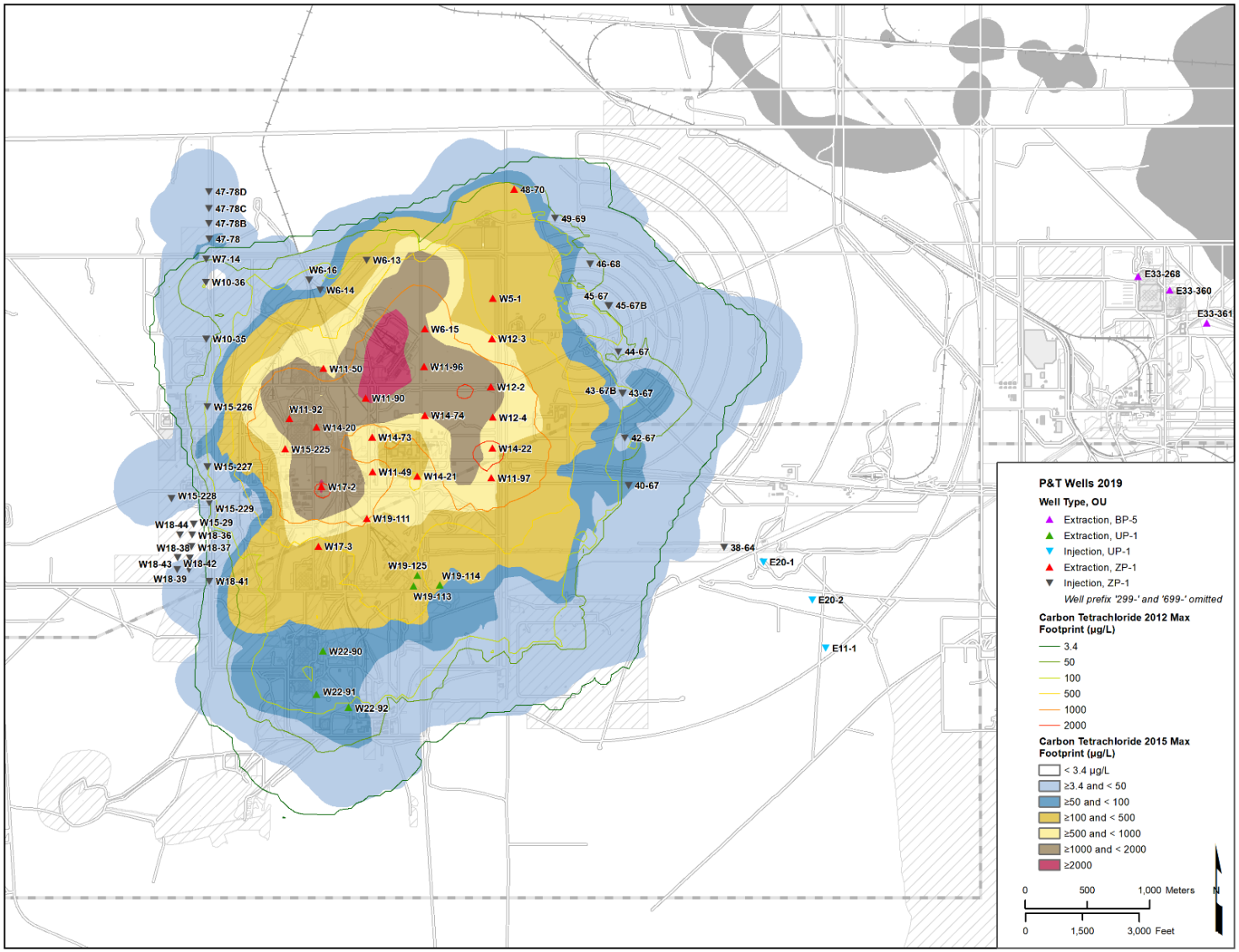

Figure 4-7. Maximum Footprint – CY 2015 Initial Conditions Compared to CY 2012 Initial Conditions for Carbon Tetrachloride

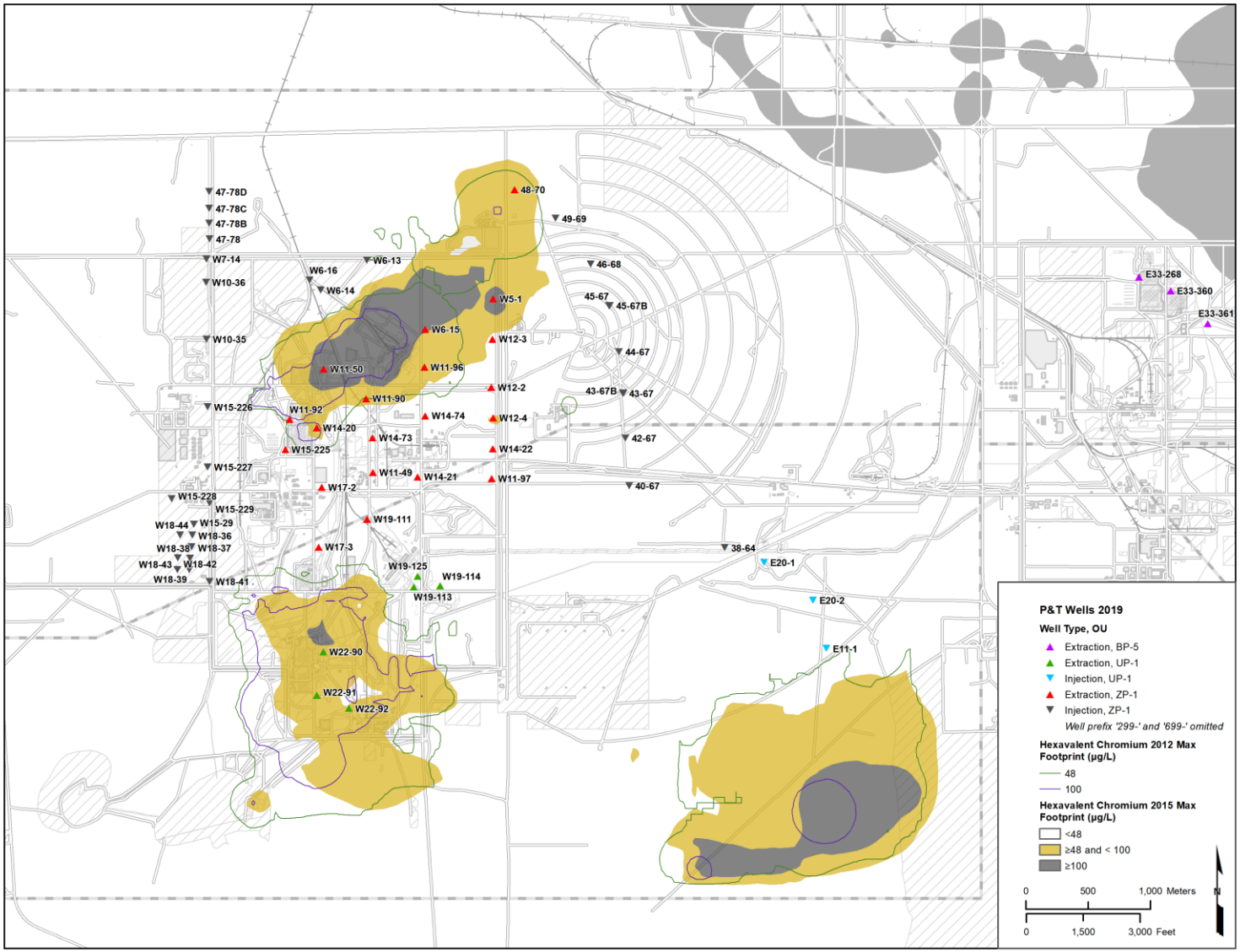

Figure 4-8. Maximum Footprint – CY 2015 Initial Conditions Compared to CY 2012 Initial Conditions for Hexavalent Chromium

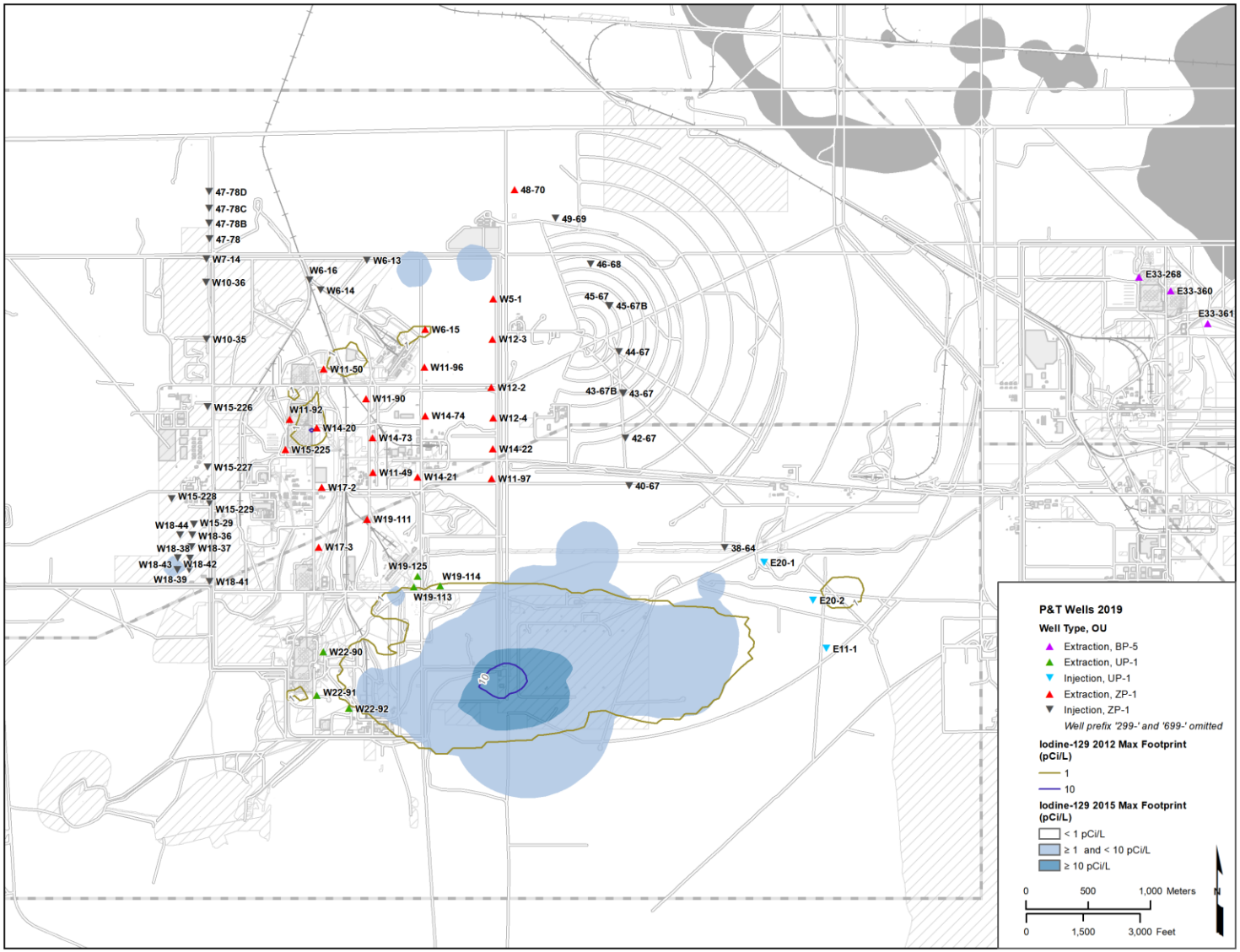

Figure 4-9. Maximum Footprint – CY 2015 Initial Conditions Compared to CY 2012 Initial Conditions for Iodine-129

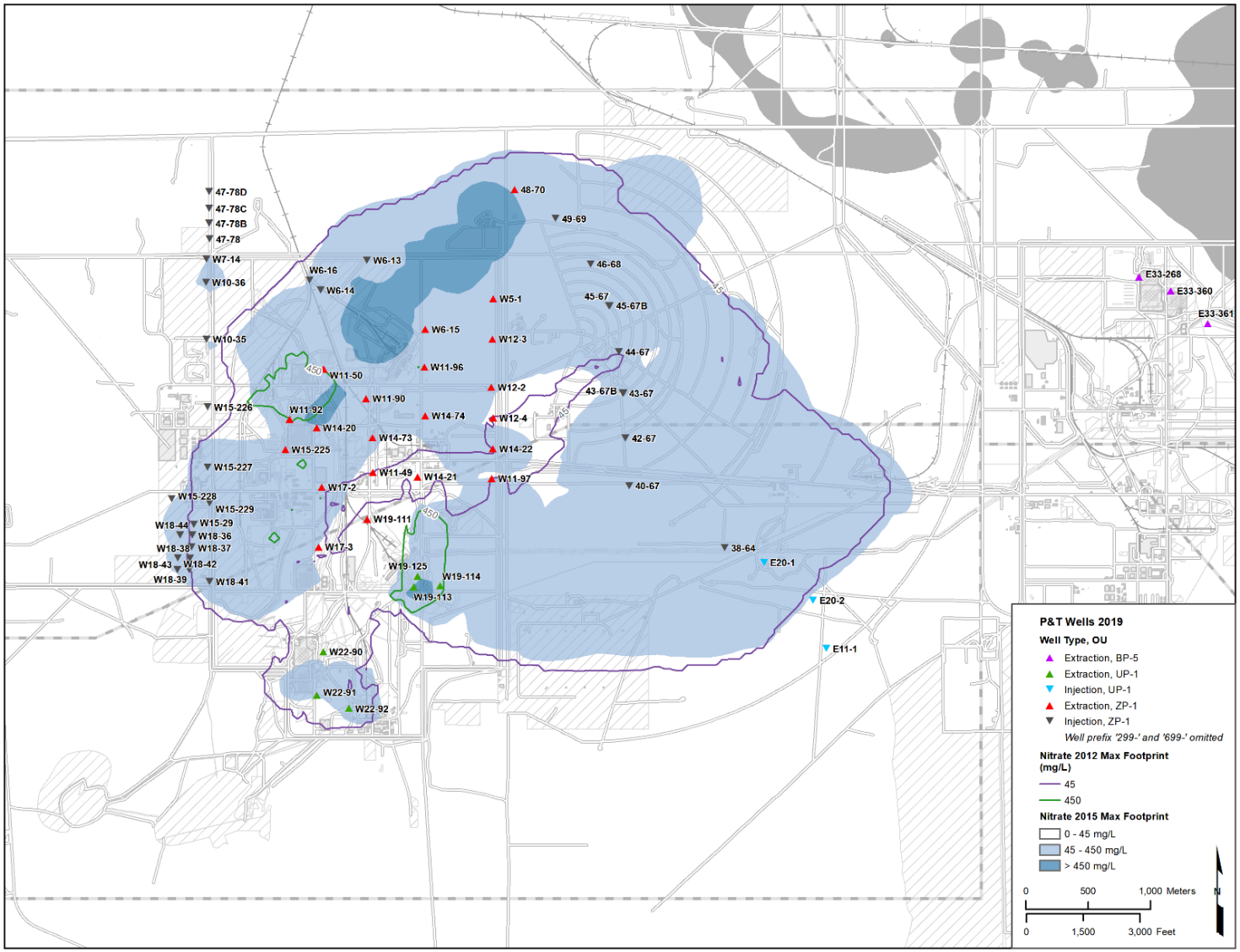

Figure 4-10. Maximum Footprint – CY 2015 Initial Conditions Compared to CY 2012 Initial Conditions for Nitrate

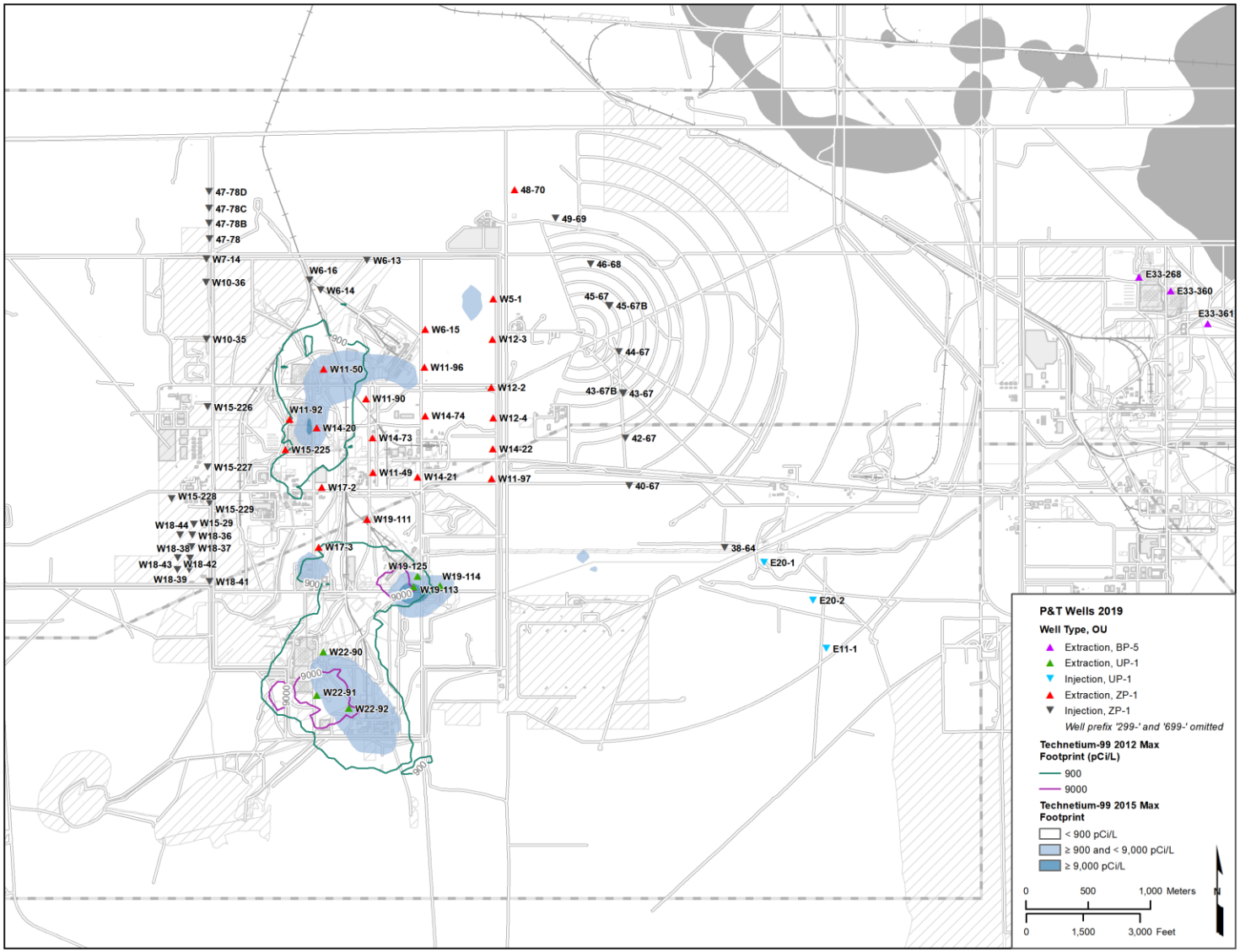

Figure 4-11. Maximum Footprint – CY 2015 Initial Conditions Compared to CY 2012 Initial Conditions for Technetium-99

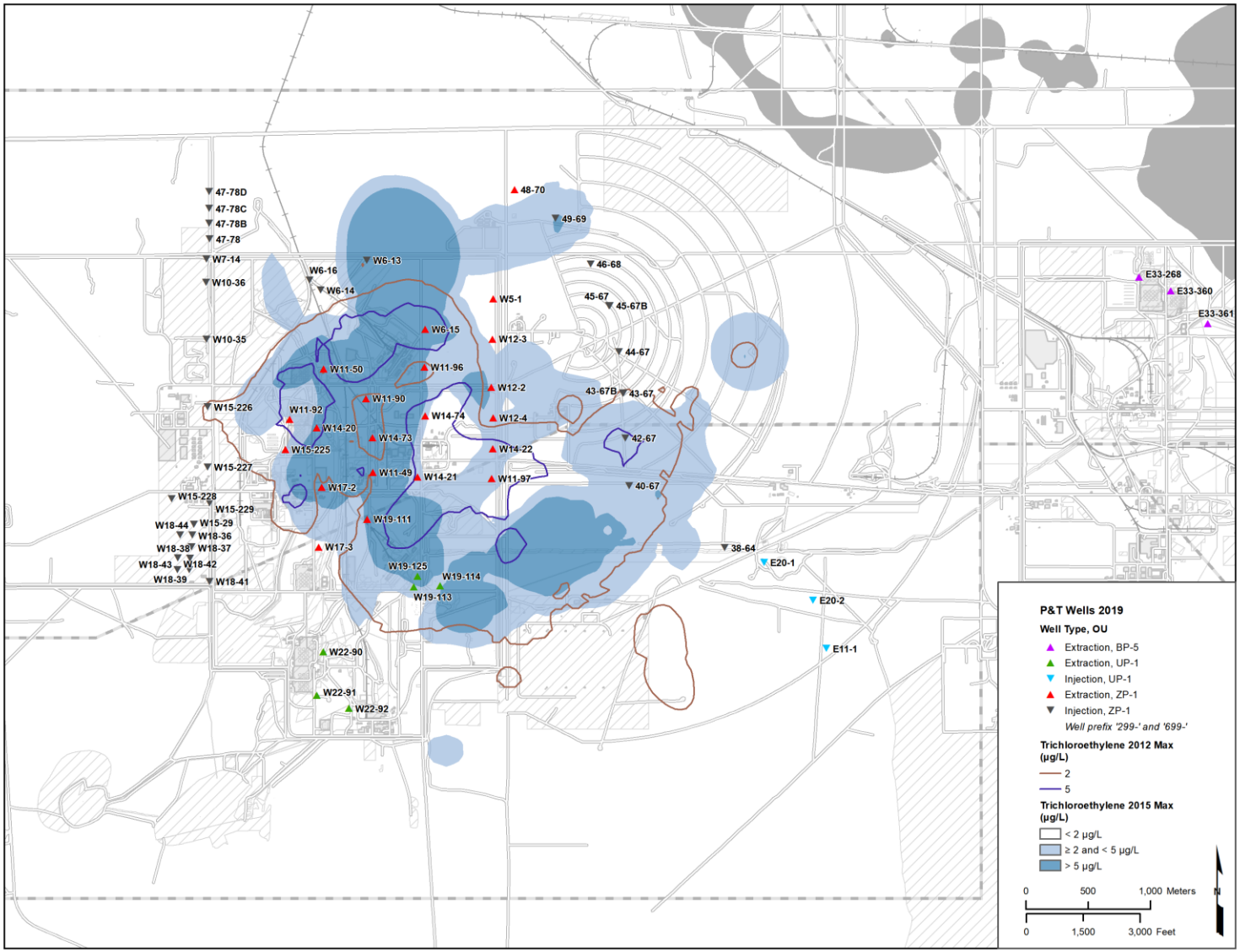

Figure 4-12. Maximum Footprint – CY 2015 Initial Conditions Compared to CY 2012 Initial Conditions for Trichloroethene

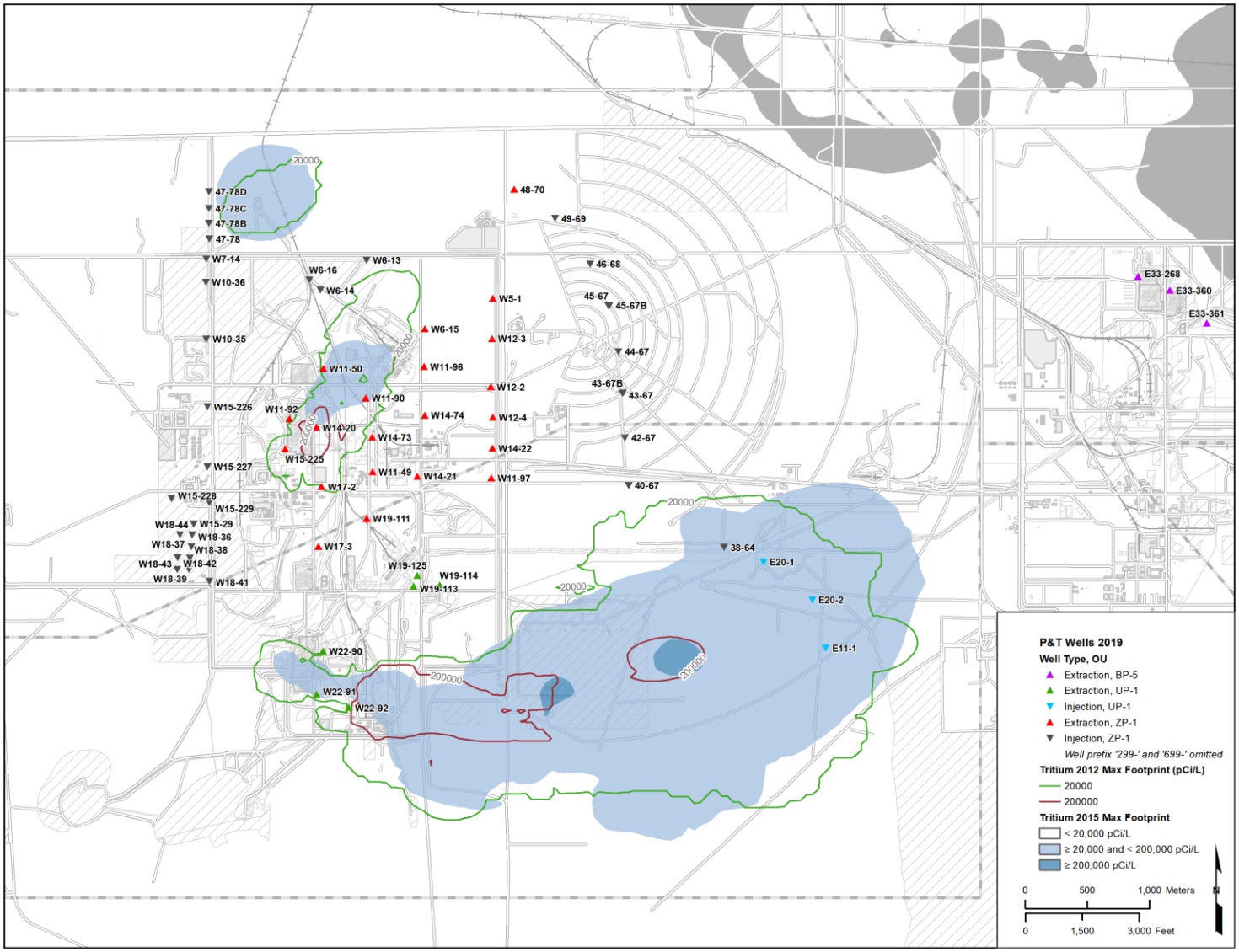

Figure 4-13. Maximum Footprint – CY 2015 Initial Conditions Compared to CY 2012 Initial Conditions for Tritium

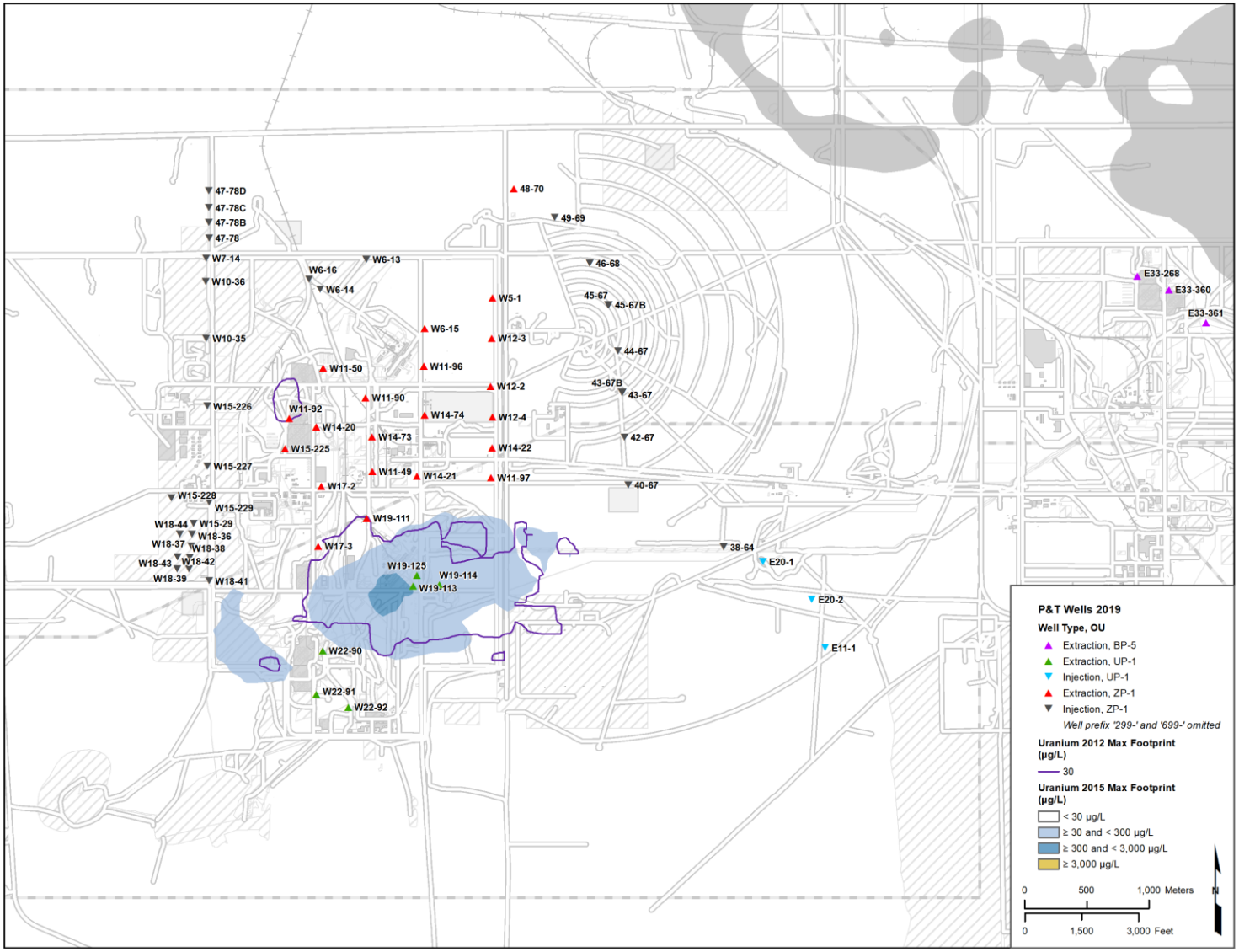

Figure 4-14. Maximum Footprint – CY 2015 Initial Conditions Compared to CY 2012 Initial Conditions for Uranium

4.2.8 Technetium-99 Continuing Source

Simulations completed using the P2R Model with an initial dissolved plume of technetium-99 are generally unable to reproduce the persistence of elevated concentrations in nearby monitoring and extraction wells. For this reason, use of the interpreted 3D technetium-99 initial plume, to match reported concentrations and mass recoveries in extraction well 299-W11-50 located near T tank farm and well 299-W14 (located downgradient of TX-TY tank farm) was facilitated by the inclusion of hypothetical continuing sources in the technetium-99 transport simulation. The hypothetical continuing sources were simulated using two locations: the first, simulated as occurring near extraction well 299-W11-50 with a constant concentration value of 4,000 pCi/L, and the second simulated as occurring near extraction well 299-W14-20 using a constant concentration of 3,000 pCi/L. The locations of the model cells used to simulate the hypothetical continuing sources are shown on Figure 4-15. The correspondence between the measured concentrations and the simulated concentrations at proximal wells when executing the P2R Model both with and without these hypothetical continuing sources is presented in Figures 4-16 and 4-17. For purposes of these calculations in this ECF, both hypothetical continuing sources were assumed to be active until the end of the model simulation period.

The location and characteristics of the hypothetical continuing sources were estimated based upon F&T simulations alone, and as such these do not at this time represent a best-estimate of a potential continuing source but rather a potentially plausible scenario that provides improved correspondence between F&T model outputs and measured data. The model simulations using these hypothetical continuing sources rely upon assumptions - including estimates of the source location, concentration, duration, and persistence over time – that are uncertain and unverified in the field. As a result, the predictions of future plume conditions and mass recovery for technetium-99 should be regarded only as one plausible indication of potential future conditions. Further evaluation of the potential for, and character of, any continuing sources of technetium-99 in this area is strongly recommended.

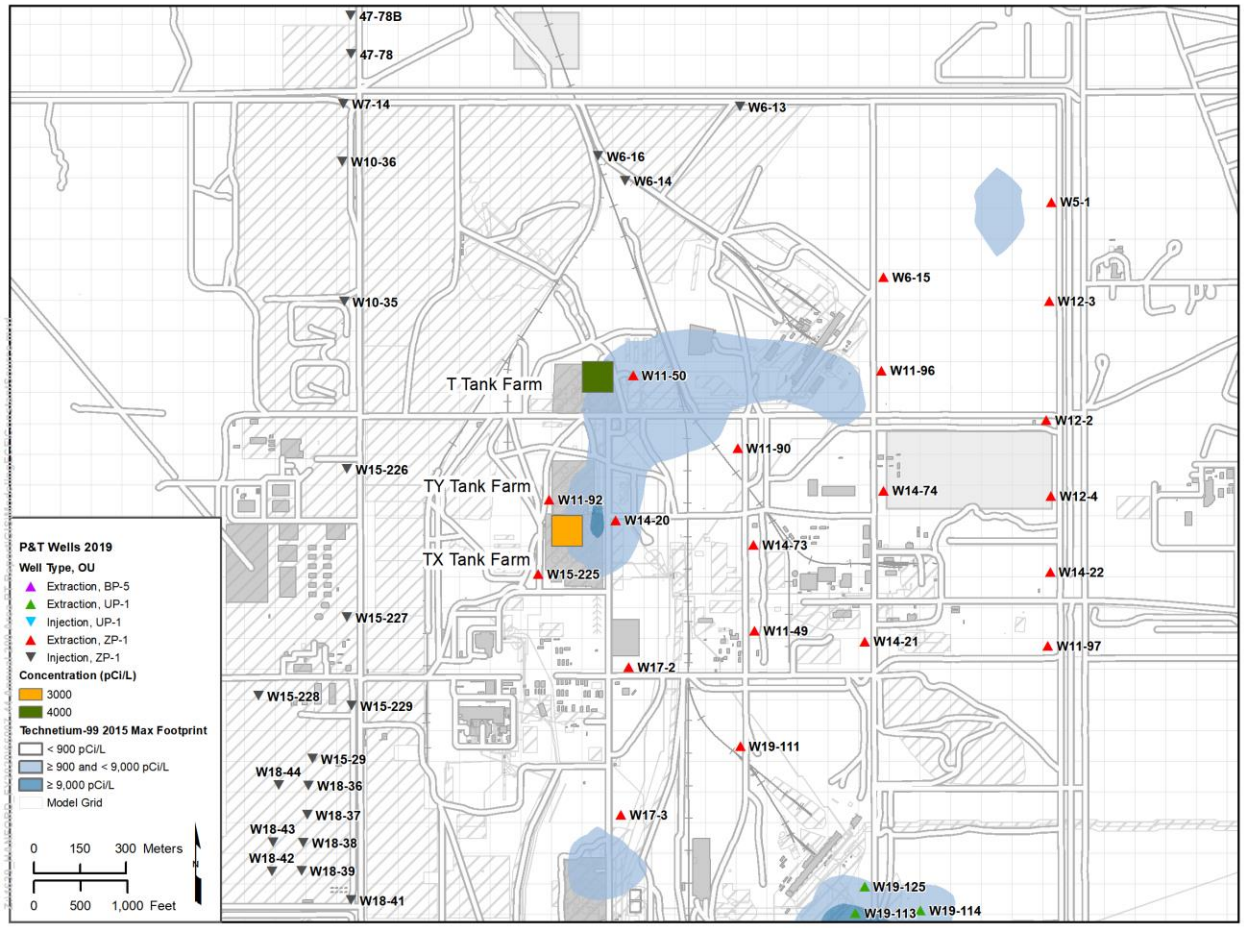

Figure 4-15. Location of Technetium-99 Continuous Sources

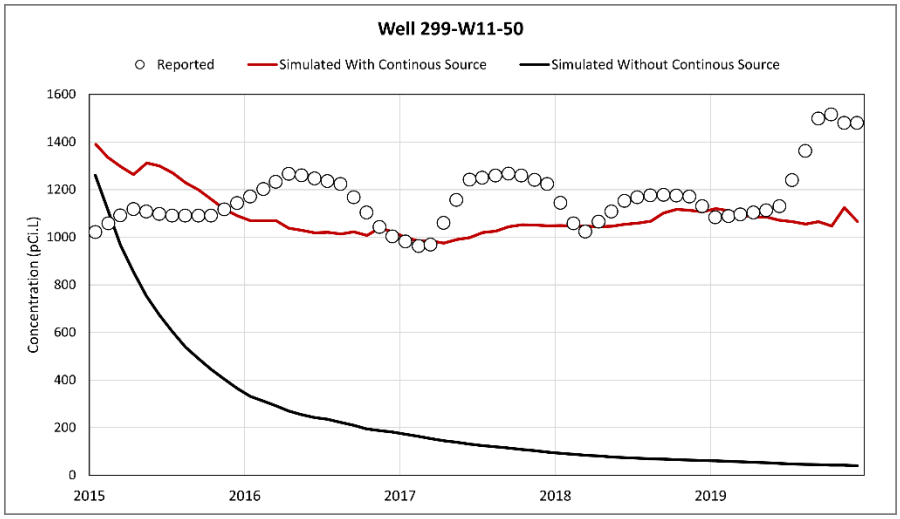

Figure 4-16. Reported vs. Simulated Technetium-99 Concentration for Well 299-W11-50

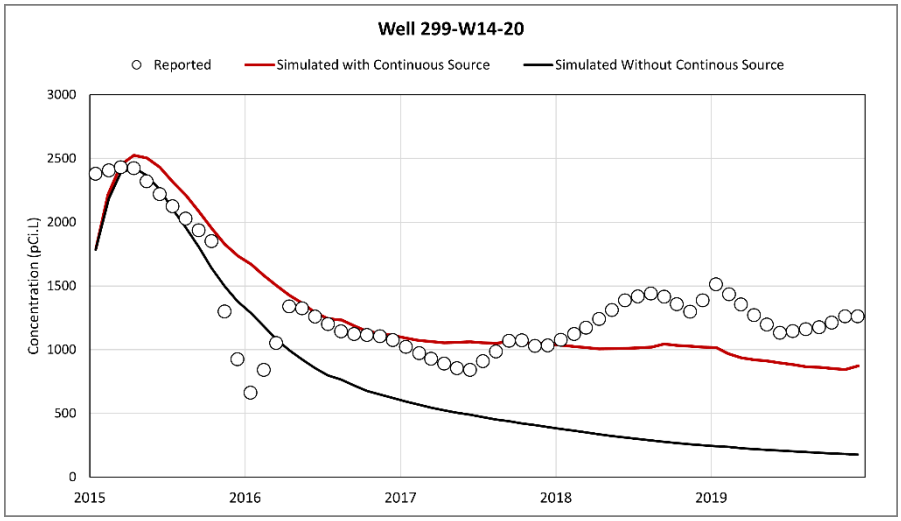

Figure 4-17. Reported vs. Simulated Technetium-99 Concentration for Well 299-W14-20

4.2.9 200 West P&T System – Implementation of MT3D Contaminant Treatment System (CTS) Package

The 200 West P&T system exhibits varying COC-specific efficiencies in removing constituents from the extracted groundwater prior to reinjection. The effect of this varying treatment efficiency is simulated using the previously developed MT3DMS CTS package, which enables flow and transport simulations using the Hanford Site-specific versions of MODFLOW-MT3DMS to represent the removal of COCs from extracted water prior to reinjection. The CTS package specifically simulates the mixing and removal of contaminant mass via a treatment system. The CTS package incorporates extraction wells, mixing, treatment, and injection wells as part of an integrated P&T system. Using the CTS package, the removal efficiency can be specified in a variety of ways, although the most suitable method is often deriving the efficiency empirically from actual treatment plant data. Use of the CTS package is particularly important where some contaminants (e.g., tritium) are essentially recirculated without treatment; where some contaminants (e.g., iodine) are greatly affected by mixing within the treatment system; and where some contaminants (e.g., nitrate), despite treatments to below applicable standards, are still reinjected at concentrations that represent a considerable mass.

Figure 4-18 illustrates the reported removal efficiency calculated on the basis of influent and effluent concentrations measured at the 200 West P&T. Based upon the efficiencies presented in Figure 4-18 and listed in Table 4-3, the CTS treatment option to set the percentage of mass that is typically removed by the treatment system was implemented with the P2R Model simulations.

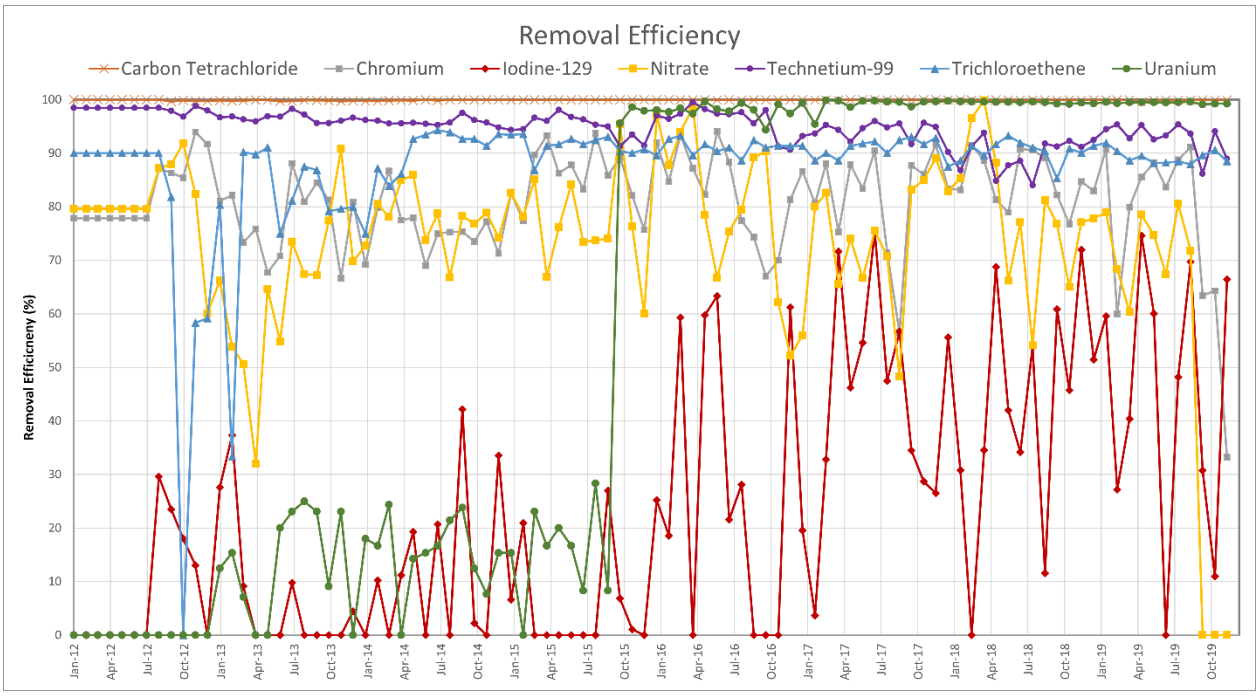

Figure 4-18. Reported Contaminant of Concern Removal Efficiency

The CTS package also has an option to include the mixing and treatment of additional contaminant mass that enters the system from external sources (i.e., not from the simulated extraction wells). This enables the CTS package to properly account for the mass treated in a P&T system, and to properly project the effluent concentration that will go to injection wells over time. Because the 200-BP-5 OU COC plumes were not included in the P2R Model transport simulations described in this ECF (but in reality, contaminated groundwater is transported to and treated by the 200 West P&T system from the 200-BP-5 OU), this CTS package external source option was used to simulate mass removal from 200-BP-5 OU extraction wells. Three COCs were simulated using this option: nitrate, technetium-99 and uranium. Other COCs were not included because their mass removal is very small compared to the mass removed by the 200 West extraction wells. The total mass removed by the 200-BP-5 OU extraction wells was calculated on a monthly basis by multiplying their average reported pumping rates and measured concentrations. Their future combined mass removal was projected using an exponential decay function presented in Figures 4-19 through 4-21.

Consistent with recent changes at the 200 West P&T treatment system, active biological treatment of nitrate was suspended on October 9, 2019 and the remedy was transitioned to MNA for nitrate. Calculations described in this ECF were made to help evaluate the potential effects of the suspension of biological treatment on effluent water quality and to support long-term groundwater monitoring strategy for the 200-ZP-1 OU optimization study (DOE-RL-2019-76, *200-ZP-1 Operable Unit Optimization Study Sampling and Analysis Plan*). To accomplish this, inputs for the CTS package were adjusted to reflect the cessation of the active treatment of nitrate. The nitrate effluent concentrations computed by the CTS package both before (i.e., during active treatment) and following (i.e., after cessation of biological treatment) are compared to reported concentrations in Figure 4-22.

Table 4-3. CTS Efficiency Percent Values Used for Transport Simulations (Percent)

Month/Year	Carbon Tetrachloride	Chromium	Iodine-129	Nitrate	Technetium-99	Trichloroethene	Uranium	Tritium
Jan-12	100.0	77.9	0.0	79.6	98.5	90.0	0.0	0.0
Feb-12	100.0	77.9	0.0	79.6	98.5	90.0	0.0	0.0
Mar-12	100.0	77.9	0.0	79.6	98.5	90.0	0.0	0.0
Apr-12	100.0	77.9	0.0	79.6	98.5	90.0	0.0	0.0
May-12	100.0	77.9	0.0	79.6	98.5	90.0	0.0	0.0
Jun-12	100.0	77.9	0.0	79.6	98.5	90.0	0.0	0.0
Jul-12	100.0	77.9	0.0	79.6	98.5	90.0	0.0	0.0
Aug-12	100.0	87.1	29.6	87.2	98.5	90.0	0.0	0.0
Sep-12	99.6	86.3	23.5	87.9	97.9	81.8	0.0	0.0
Oct-12	99.9	85.4	18.1	91.9	96.8	0.0	0.0	0.0
Nov-12	99.7	93.9	13.0	82.4	98.8	58.3	0.0	0.0
Dec-12	99.7	91.7	0.0	60.1	98.0	59.2	0.0	0.0
Jan-13	99.9	81.1	27.6	66.3	96.7	80.4	12.5	0.0
Feb-13	99.7	82.2	37.3	53.8	96.9	33.3	15.4	0.0
Mar-13	99.8	73.3	9.1	50.6	96.3	90.2	7.1	0.0
Apr-13	99.9	75.8	0.0	32.0	95.9	89.8	0.0	0.0
May-13	99.9	67.7	0.0	64.7	96.9	91.1	0.0	0.0
Jun-13	99.7	70.8	0.0	54.9	96.8	75.0	20.0	0.0
Jul-13	99.7	88.1	9.8	73.5	98.3	81.1	23.1	0.0
Aug-13	99.9	80.9	0.0	67.4	97.2	87.5	25.0	0.0
Sep-13	99.9	84.5	0.0	67.3	95.6	86.8	23.1	0.0
Oct-13	99.8	81.3	0.0	77.4	95.6	79.2	9.1	0.0
Nov-13	99.7	66.7	0.0	90.8	96.1	79.6	23.1	0.0
Dec-13	99.8	80.9	4.5	69.8	96.6	80.0	0.0	0.0
Jan-14	99.7	69.2	0.0	72.7	96.2	75.0	18.0	0.0
Feb-14	99.8	79.9	10.2	80.5	96.1	87.2	16.7	0.0
Mar-14	99.8	86.7	0.0	78.1	95.5	83.9	24.4	0.0
Apr-14	99.9	77.5	11.2	85.0	95.6	86.1	0.0	0.0
May-14	99.8	77.9	19.3	86.0	95.7	92.6	14.3	0.0
Jun-14	100.0	69.0	0.0	73.8	95.5	93.4	15.4	0.0
Jul-14	99.8	75.0	20.7	78.7	95.3	94.3	16.7	0.0

Table 4-3. CTS Efficiency Percent Values Used for Transport Simulations (Percent)

Month/Year	Carbon Tetrachloride	Chromium	Iodine-129	Nitrate	Technetium-99	Trichloroethene	Uranium	Tritium
Aug-14	100.0	75.3	0.0	66.8	95.7	93.9	21.4	0.0
Sep-14	100.0	75.4	42.2	78.3	97.6	92.6	23.8	0.0
Oct-14	100.0	73.5	2.2	76.8	96.2	92.6	12.5	0.0
Nov-14	100.0	77.2	0.0	78.9	95.7	91.4	7.7	0.0
Dec-14	99.9	71.3	33.6	74.2	94.8	93.6	15.4	0.0
Jan-15	100.0	82.6	6.6	82.6	94.8	93.4	15.4	0.0
Feb-15	100.0	77.3	20.9	78.2	94.3	93.6	0.0	0.0
Mar-15	100.0	89.7	0.0	85.1	94.5	86.8	23.1	0.0
Apr-15	100.0	93.3	0.0	66.9	96.6	91.4	16.7	0.0
May-15	100.0	86.3	0.0	76.2	96.0	91.7	20.0	0.0
Jun-15	100.0	87.8	0.0	84.2	98.1	92.6	16.7	0.0
Jul-15	100.0	83.3	0.0	73.4	96.8	91.7	8.3	0.0
Aug-15	100.0	93.7	0.0	73.8	96.3	92.4	28.3	0.0
Sep-15	100.0	85.9	27.0	74.0	95.3	93.1	8.3	0.0
Oct-15	100.0	89.2	6.9	95.5	95.0	90.4	95.6	0.0
Nov-15	100.0	82.1	1.1	76.3	91.3	90.0	98.6	0.0
Dec-15	100.0	75.7	0.0	60.0	93.5	90.7	97.9	0.0
Jan-16	100.0	91.9	25.2	97.0	91.4	89.6	98.0	0.0
Feb-16	100.0	84.7	18.6	87.8	97.0	92.6	97.7	0.0
Mar-16	100.0	93.4	59.3	94.0	96.4	93.2	98.4	0.0
Apr-16	100.0	87.2	0.0	98.6	97.4	89.6	97.4	0.0
May-16	100.0	82.3	59.8	78.4	99.5	91.7	99.6	0.0
Jun-16	99.9	94.1	63.3	66.7	98.2	90.4	98.2	0.0
Jul-16	100.0	88.4	21.6	75.4	97.4	91.1	97.8	0.0
Aug-16	99.9	77.4	28.1	79.4	97.3	88.6	99.4	0.0
Sep-16	100.0	74.3	0.0	89.2	97.6	92.4	98.1	0.0
Oct-16	100.0	67.0	0.0	90.4	95.5	91.1	94.4	0.0
Nov-16	100.0	70.0	0.0	62.1	98.0	91.4	99.1	0.0
Dec-16	100.0	81.3	61.2	52.2	91.3	91.4	97.4	0.0
Jan-17	100.0	86.6	19.5	56.0	90.6	91.4	99.4	0.0
Feb-17	99.9	80.7	3.7	80.0	93.2	88.6	95.5	0.0

Table 4-3. CTS Efficiency Percent Values Used for Transport Simulations (Percent)

Month/Year	Carbon Tetrachloride	Chromium	Iodine-129	Nitrate	Technetium-99	Trichloroethene	Uranium	Tritium
Mar-17	99.9	88.0	32.8	82.6	93.7	90.0	99.9	0.0
Apr-17	99.9	75.3	71.7	65.6	95.3	88.6	99.8	0.0
May-17	100.0	87.9	46.2	74.0	94.4	91.4	98.6	0.0
Jun-17	100.0	83.4	54.6	66.7	92.2	91.8	99.7	0.0
Jul-17	100.0	90.5	75.4	75.5	94.7	92.2	99.8	0.0
Aug-17	99.9	71.5	47.5	70.7	96.0	90.0	99.6	0.0
Sep-17	100.0	56.5	56.7	48.3	94.8	92.4	99.6	0.0
Oct-17	100.0	87.7	34.5	83.2	95.6	93.1	98.7	0.0
Nov-17	100.0	86.0	28.7	85.0	91.7	91.7	99.6	0.0
Dec-17	100.0	91.6	26.5	89.0	95.7	92.9	99.6	0.0
Jan-18	99.9	83.4	55.6	82.9	94.9	87.5	99.7	0.0
Feb-18	100.0	83.2	30.8	85.4	90.2	88.6	99.7	0.0
Mar-18	99.9	91.5	0.0	96.6	86.8	91.4	99.6	0.0
Apr-18	99.9	88.6	34.6	99.9	91.3	89.6	99.6	0.0
May-18	100.0	81.3	68.8	88.2	93.8	91.7	99.6	0.0
Jun-18	99.9	79.0	42.0	66.2	84.8	93.3	99.6	0.0
Jul-18	99.9	90.8	34.2	77.1	87.7	92.0	99.5	0.0
Aug-18	99.9	90.6	53.8	54.1	88.6	91.1	99.6	0.0
Sep-18	99.9	89.1	11.6	81.3	84.0	90.4	99.5	0.0
Oct-18	99.9	82.2	60.9	76.8	91.8	85.3	99.3	0.0
Nov-18	99.9	76.8	45.7	65.0	91.2	90.8	99.2	0.0
Dec-18	99.9	84.7	72.0	77.1	92.3	90.1	99.4	0.0
Jan-19	100.0	83.0	51.4	77.9	91.2	91.4	99.3	0.0
Feb-19	99.9	90.8	59.6	78.9	92.5	91.9	99.6	0.0
Mar-19	100.0	60.0	27.2	68.4	94.5	90.4	99.3	0.0
Apr-19	99.9	79.9	40.4	60.3	95.4	88.6	99.5	0.0
May-19	99.6	85.6	74.6	78.5	92.7	89.5	99.5	0.0
Jun-19	99.9	88.2	60.0	74.7	95.2	88.2	99.5	0.0
Jul-19	99.9	83.7	0.0	67.4	92.6	88.2	99.5	0.0
Aug-19	99.9	88.8	48.2	80.6	93.3	88.5	99.5	0.0
Sep-19	99.9	91.2	69.7	71.8	95.4	88.0	99.6	0.0

Table 4-3. CTS Efficiency Percent Values Used for Transport Simulations (Percent)

Month/Year	Carbon Tetrachloride	Chromium	Iodine-129	Nitrate	Technetium-99	Trichloroethene	Uranium	Tritium
Oct-19	99.9	63.4	30.8	0.0	93.7	89.7	99.1	0.0
Nov-19	99.9	64.3	11.0	0.0	86.2	90.6	99.3	0.0
Dec-19	99.9	33.2	66.5	0.0	94.1	88.5	99.2	0.0
2019-2037	99.9	76.0	45.0	0.0	92.9	88.5	99.4	0.0

CTS = contaminant treatment system

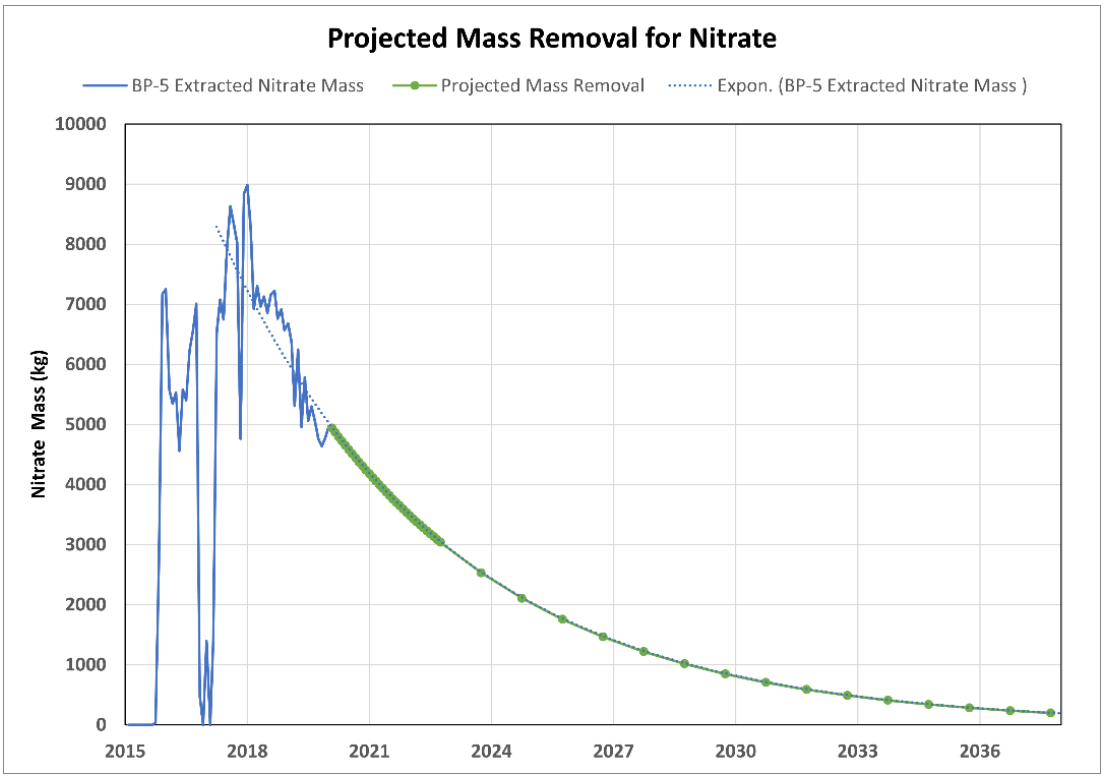

Figure 4-19. Historical and Projected Nitrate Mass Removal for BP-5 OU

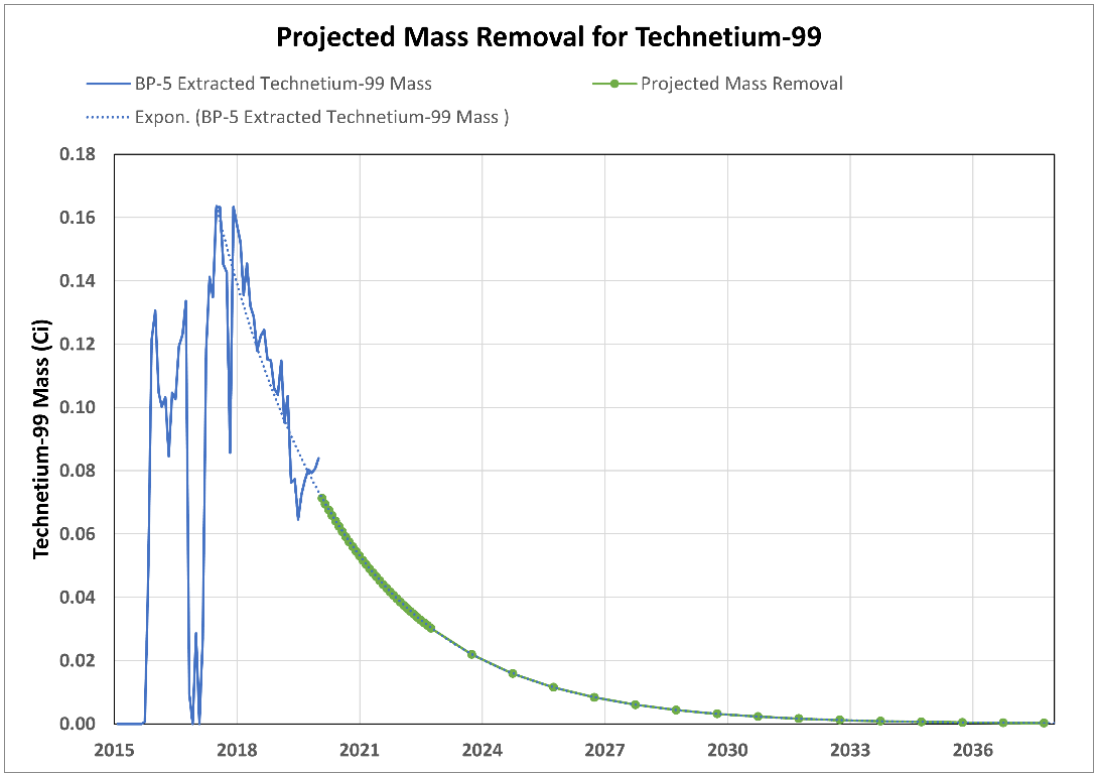

Figure 4-20. Historical and Projected Technetium-99 Mass Removal for BP-5 OU

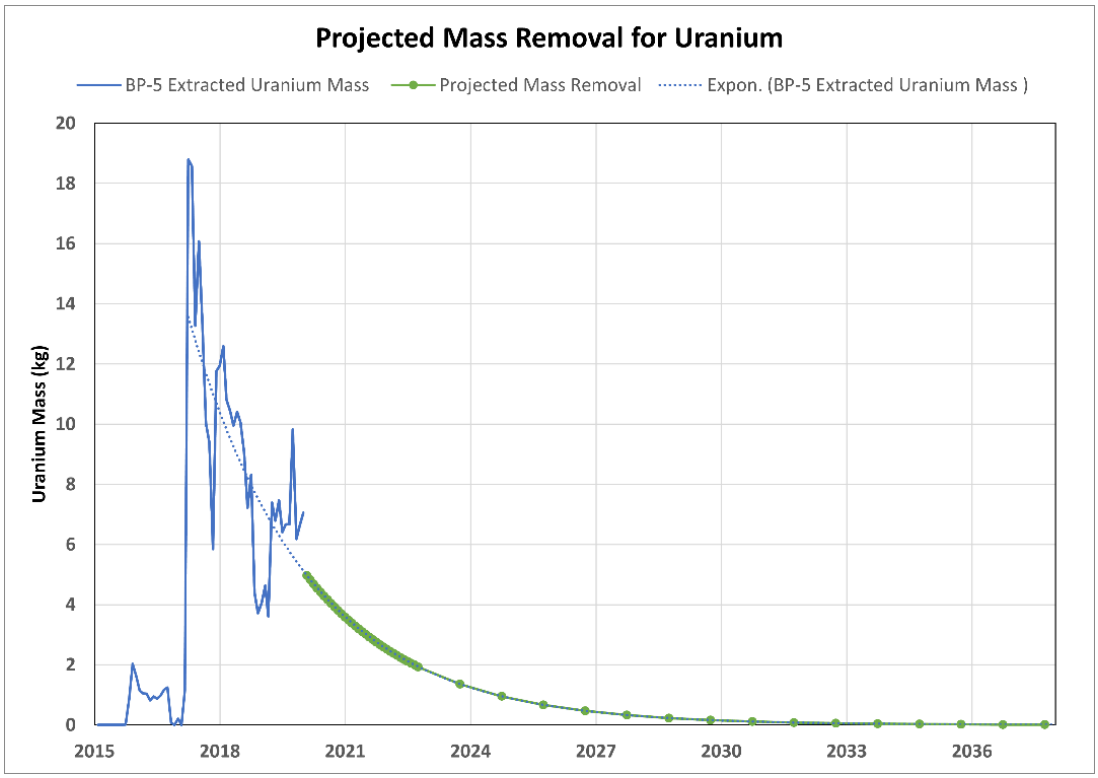

Figure 4-21. Historical and Projected Uranium Mass Removal for BP-5 OU

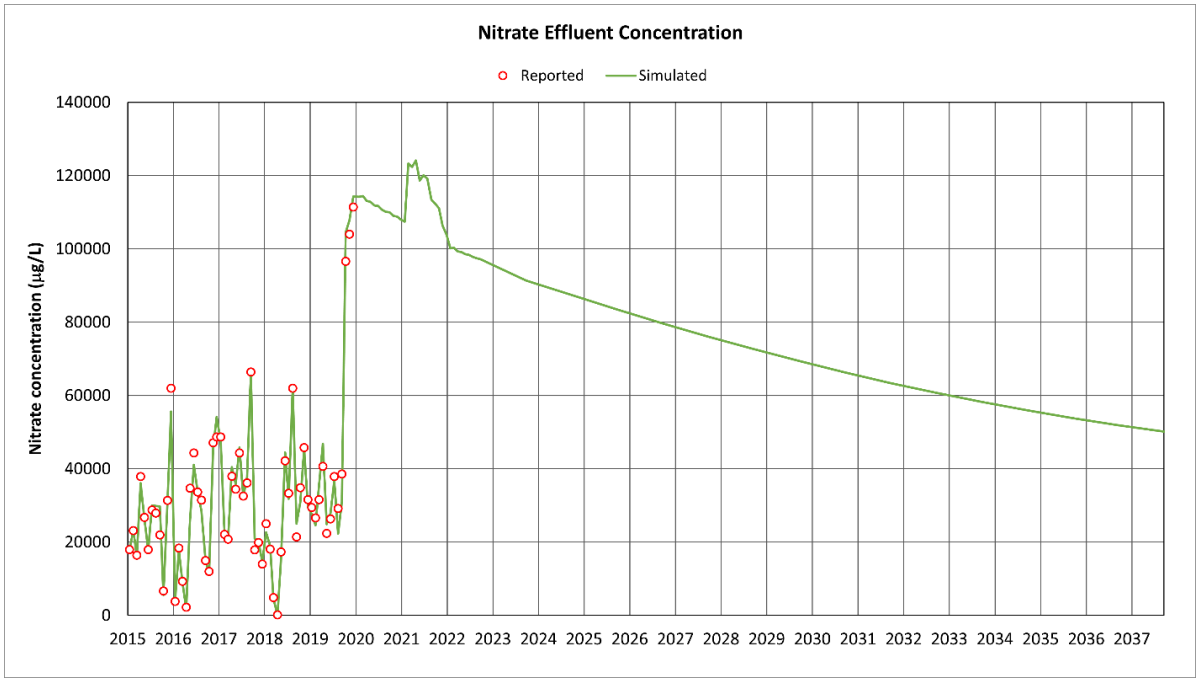

Figure 4-22. Simulated vs. Reported Nitrate Effluent Concentration

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

Software used for this calculation was in accordance with applicable Project internally controlled software management requirements.

5.1 Approved Software

The following software was used to perform calculations and was approved under Project internally controlled software management procedures:

- CHPRC-00257, Rev. 1, *MODFLOW and Related Codes Functional Requirements Document*
- CHPRC-00258, Rev. 4, *MODFLOW and Related Codes Software Management Plan*
- CHPRC-00259, Rev. 3, *MODFLOW and Related Codes Software Test Plan*
- CHPRC-00260, Rev. 8, *MODFLOW and Related Codes Requirements Traceability Matrix*
- CHPRC-00261, Rev. 8, *MODFLOW and Related Codes Acceptance Test Report*

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

5.1.1 MODFLOW (Controlled Calculation Software)

- **Software title:** MODFLOW-2000 (Harbaugh et al., 2000); solves transient groundwater flow equations using the finite-difference discretization technique.
- **Software version:** Version 1.19.01, modified by S.S. Papadopulos and Associates, Inc. (SSP&A) to address dry cell issues and to use the Orthomin solver (Vinsome, 1976, *Orthomin, an Iterative Method for Solving Sparse Sets of Simultaneous Linear Equations*); approved as CHPRC Build 8 using a version of the executable “mf2k-mst-chprc08dpv.exe” compiled to default double precision for real variables and optimized for speed.
- **Hanford Information Systems Inventory (HISI) identification number:** 2517 (safety software, graded Level C).
- **Workstation type and property number (from which software is run):** SSP&A, FE449.

5.1.2 MT3DMS (Controlled Calculation Software)

- **Software title:** MT3DMS (Zheng and Wang, 1999; Zheng, 2010).
- **Software version:** Version 5.3, modified by SSP&A to address dry cell issues; approved as CHPRC Build 8 using a version of the executable “mt3d-mst-chprc08dpv.exe” compiled to default double precision for real variables and optimized for speed.
- **HISI identification number:** 2518 (safety software, graded Level C).
- **Workstation type and property number (from which software is run):** SSP&A, FE449.

5.1.3 MODPATH

- **Software title:** MODPATH (Pollock, 1994). A particle-tracking, post-processor developed for use with the MODFLOW codes was used to evaluate the approximate directions and rates of groundwater flow and the approximate extent of hydraulic capture developed by proposed P&T well configurations.
- **Software version:** Version 5 modified by SSP&A to address dry cell issues; approved as CHPRC Build 6 using executable "modpath-chprc06.exe."
- **Workstation type and property number (from which software is run):** SSPA, FE449.

5.1.4 MEUK

MEUK was used to perform groundwater-elevation mapping using measured groundwater levels. MEUK is classified as safety software and graded level C. Use of this software at the Hanford Site is managed under the integrated software management plan (CHPRC-02839, *KT3D_H2O and MEUK Integrated Software Management Plan*):

- **Software title:** MEUK (S.S. Papadopulos and Associates, Inc., 2016, Version 0.2.2).
- **Software version**: CHPRC Build 2 (Version 0.2.2).
- **HISI identification number:** 2517 (safety software, graded level C).
- **Workstation type and property number (from which software is run):** SSPA, FE449.

MEUK is programmed in the R language (R Development Core Team, 2013, *R: A Language and Environment for Statistical Computing*) and uses the gstat package (Pebesma, 2004, "Multivariable Geostatistics in S: the gstat Package"). MEUK can be supplemented or validated using KT3D_H2O (Karanovic et al., 2009).

5.1.5 KT3D_H2O

Although KT3D_H2O was not used to perform any calculation, it is listed here because the particle tracking program "Transient Tracker" which is part of KT3D_H2O is used to compute extent of hydraulic containment using mapped water levels.

Use of this software at the Hanford Site is managed under an integrated software management plan (CHPRC-02839):

- **Software title:** KT3D_H20 (SSP&A, 2011, *User's Guide to KT3D_H2O, Version 2*).
- **Software version**: CHPRC Build 2 (Version 3.5.1).
- **HISI identification number:** 2517 (safety software, graded Level C).
- **Workstation type and property number (from which software is run):** SSPA, FE449.

5.2 Support Software

The following programs are classified as support software.

5.2.1 MODFLOW Suite Support Software

- **Groundwater Vistas™:** Rumbaugh and Rumbaugh, 2015, *Groundwater Vistas Version 6*. Provided graphical tools used for model quality assurance and model input/output review.
- **Groundwater Desktop™:** SSPA, 2019. Provided graphical tools used for model quality assurance and model input/output review and run particle tracking using "Transient Tracker" program.
- **ArcGIS®:** Mitchell, 1999, *The ESRI Guide to GIS Analysis, Volume 1: Geographic Patterns and Relationships*. Provided visualization tool for assessing simulated plume distributions, identifying extraction/injection well coordinates, and mapping auxiliary data.

5.2.2 R and Surfer®

- **R:** The R programming environment, a language and environment for statistical computing and graphics (The R Development Core Team, 2012, *The R Project for Statistical Computing*; Ihaka and Gentleman, 1996, "R: A Language for Data Analysis and Graphics"), was used to perform a variety of data processing including post-processing of model results and generating plots of aggregate data time series. The following R packages were also used as follows:
  - Package GSTAT provided the kriging engine for water levels.
  - Package SSPAMEUK provided functions for the generation of water-level kriging drifts.
  - Package raster for the generation of water-level ASCII grids and raster calculations.
- **Surfer:** Data interpolation for visualization, model implementation, and quality assurance purposes.

5.2.3 Particle Tracking support software

- **GetCaptureFreqFromGrids.exe:** Reads monthly capture maps generated by Transient Tracker and calculates the capture frequency map.

5.3 Software Installation and Checkout

Safety software is checked out in accordance with procedures specified in CHPRC-00258. Executables are obtained from the CHPRC software owner, who maintains the configuration-managed copies in MKS Integrity, ensures that installation tests identified in CHPRC-00259 are performed and that successful installation is confirmed. Checkout forms are required and must be approved for installations used to perform model runs. Approved users for safety software are registered in HISI.

5.3.1 Statement of Valid Software Application

- The software identified in this ECF was used consistent with intended use for CHPRC (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.

™ Groundwater Vistas is a trademark of Environmental Simulations, Inc., Reinholds, Pennsylvania.
™ Groundwater Desktop is a trademark of Environmental Simulations, Inc., Reinholds, Pennsylvania.
® ArcGIS is a registered trademark of Environmental Systems Research Institute, Inc., Redlands, California.
® Surfer is a registered trademark of Golden Software, LLC, Golden, Colorado.

- The R programming environment has not been identified in CHPRC-00258 but is scheduled by the software owner to be included as support software in the next revision of that document. It is a publicly available, open-source freeware.

6 Calculations

This section presents the calculations performed.

6.1 200-ZP-1 Operable Unit

This section explains the calculations used for the 200-ZP-1 OU.

6.1.1 Water-Level Mapping, Particle Tracking, and ICFM

This section discusses the procedure used to develop the capture zone maps as a post-processing step using the water-level maps produced as output for the 200 West area as presented and described further in ECF-200W-19-0082, ECF-200W-19-0109, ECF-200W-19-0131, and ECF-200W-20-0015. The development of the input files to the calculations required to prepare the water-level maps are detailed in ECF-200W-19-0082, ECF-200W-19-0109, ECF-200W-19-0131, and ECF-200W-20-0015.

First, the 12 (monthly) groundwater-level maps that were constructed through the kriging interpolation process (that is described in detail in ECF-200W-19-0109) were compiled together, so that each of these groundwater-level maps could be used together with the particle-tracking program Transient Tracker to trace particles and delineate the approximate extent of hydraulic containment. As detailed earlier, Transient Tracker implements the fourth-order RK4 (Press et al., 1996) numerical integration (particle-tracking) scheme, calculated upon hydraulic head surfaces.

Second, input files for the Transient Tracker particle-tracking analyses were constructed, including particle starting locations encompassing an area equivalent to and extending beyond the extent of groundwater contamination by the COCs. To run capture-zone analysis, the input file requires entering coordinates for a grid encompassing the expected capture area extent together with the cell size. Using entered values, Transient Tracker releases particles at the center of each cell, tracks their path, and generates a capture grid.

Third, the Transient Tracker program was executed within the Microsoft® Windows Command Line, once independently for each of the 12 groundwater-level maps, resulting in the generation of 12 capture gird output files recording the path and fate of every simulated particle. The resulting 2D capture grid contains integer numbers representing the capture ID where values larger than 10 represent particles that terminated at the extraction well.

Fourth, each of these 12 individual output files was used to produce an individual (monthly) capture-zone map depicting the extent of hydraulic containment corresponding to that month's groundwater-level map.

Finally, an ICFM was developed from the resulting 12 individual monthly capture-zone grid files by executing the post-processing utility "GetCaptureFreqFromGrids.exe," which calculates the frequency with which each particle terminates at an extraction well, calculated over all (monthly) capture-zone maps each corresponding to an individual (monthly) groundwater-level map.

6.1.2 Groundwater Flow Modeling, Particle Tracking, and SCFM

The following steps were followed to develop the necessary input files, perform the calculations, and post-process the outputs to develop an SCFM using the P2R Model:

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1. An input file for the MODFLOW Multi-Node Well (MNW) package was constructed to reflect the spatial and temporal configuration of the extraction and injection well operations. The historical (prior to CY 2012) groundwater extraction rates used to generate this input file are reported in the EMMA data archive and accompanying documentation (Appendix H of CP-57037, Rev. 1). Historical and predicted groundwater extraction and injection flow rates for the 200 West P&T wells are also provided in Appendix A,
2. The P2R Model flow component was executed, and the simulated hydraulic head distributions, as well as accessory outputs, were obtained.
3. Input files for particle-tracking analyses were constructed, including particle starting locations encompassing an area equivalent to and extending beyond the extent of groundwater contamination by the COCs.
4. The particle tracking program MODPATH was executed independently for each of 12 (monthly) simulated head distributions for CY 2019, and the results were post-processed to identify particles that, if given sufficient time, would be captured by the extraction wells under each of the 12 conditions. To estimate hydraulic capture above and below Rlm, particles were released in the middle of the model layers 4 and 7 respectively.
5. An SCFM was developed from the resulting 12 individual monthly capture-zone maps by executing the post-processing utility program "GetCaptureFreqFromGrids.exe," which calculates the frequency with which each particle terminates at an extraction well.

6.1.3 Transport Modeling and Mass Recovery Calculations

The following steps were followed to develop the necessary input files, perform the calculations, and post-process the outputs to develop the historical (recent time) and future (projected) contaminant extent and migration over time, as well as to compute historical and projected future influent concentrations and mass recovery, using the P2R Model:

1. Each initial condition plume described earlier in Section 4.2.7 was converted to the required MT3DMS initial concentration input file format.
2. Each COC-specific contaminant transport simulation was executed to calculate concentrations over time and produce the required MT3DMS concentration and mass output files.
3. Post-processing scripts were used to produce figures presented in this ECF, including the following:
    a. Concentration versus time for each individual extraction well for each COC presented in Section 7.1.3 and 7.3.3 of this document.
    b. Concentration versus time for monitoring wells for each COC presented in Appendix B.
    c. Extracted mass versus time for each individual extraction well for each COC.
    d. Projected and cumulative mass recovery plots for the 200 Area P&T remedies.
    e. A table summary of transport results at year 2037.

6.1.4 Flow-Path Control Calculations

The locations and rates of extraction and injection wells were designed to encompass and recover the majority of the contaminant mass, and to slow the migration of contaminants present at lower concentrations. Flow-path control considers the extent of hydraulic containment and presence of reduced hydraulic gradients. A line of control for evaluating flow-path control has been established (Figure 6-1)

that includes the approximate lateral extent of groundwater contaminated by carbon tetrachloride, as derived from 3D interpolation completed in CY 2012 and more recently as depicted in ECF-Hanford-20-0018, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2019 Hanford Site Groundwater Monitoring Report*. The following steps were followed to develop the necessary input files, perform the calculations, and post-process the outputs to develop figures to assist with the evaluation of Flow-Path Control:

1. Mapped and simulated water table grids which represent "Baseline" and "Current" conditions were obtained using methods described in Chapter 3. Baseline conditions represent hydraulic conditions of the flow field in June 2012 as described in ECF-200ZP1-13-0006 and current conditions represent December 2019 as described in ECF-200W-20-0015.
2. The following steps we used to calculate Flow Path Vectors:
    a. Water table grids were imported into the program Surfer, then using the Surfer Calculus First derivative and Terrain Aspect tools, new grids were calculated representing the hydraulic gradient magnitude and direction respectively. Gradient direction was calculated using a threshold value of 1E-30 and magnitude using angle of 180 degrees.
    b. Points representing the flow-path control line were then intersected with the flow gradient direction and magnitude grids to extract grid values at point locations representing the gradient direction and magnitude at the location of the flow-path control line. These points were then used to create the hydraulic gradients arrows depicted in presented figures.
3. Grids representing the change in hydraulic gradient throughout the area were calculated by subtracting the Current and Baseline water-level grids then gradient magnitude change was calculated using calculated grid and the Surfer Calculus First derivative tool with 180 degrees for direction angle.

6.2 200-UP-1 Operable Unit — S-SX Tank Farms and U Plant

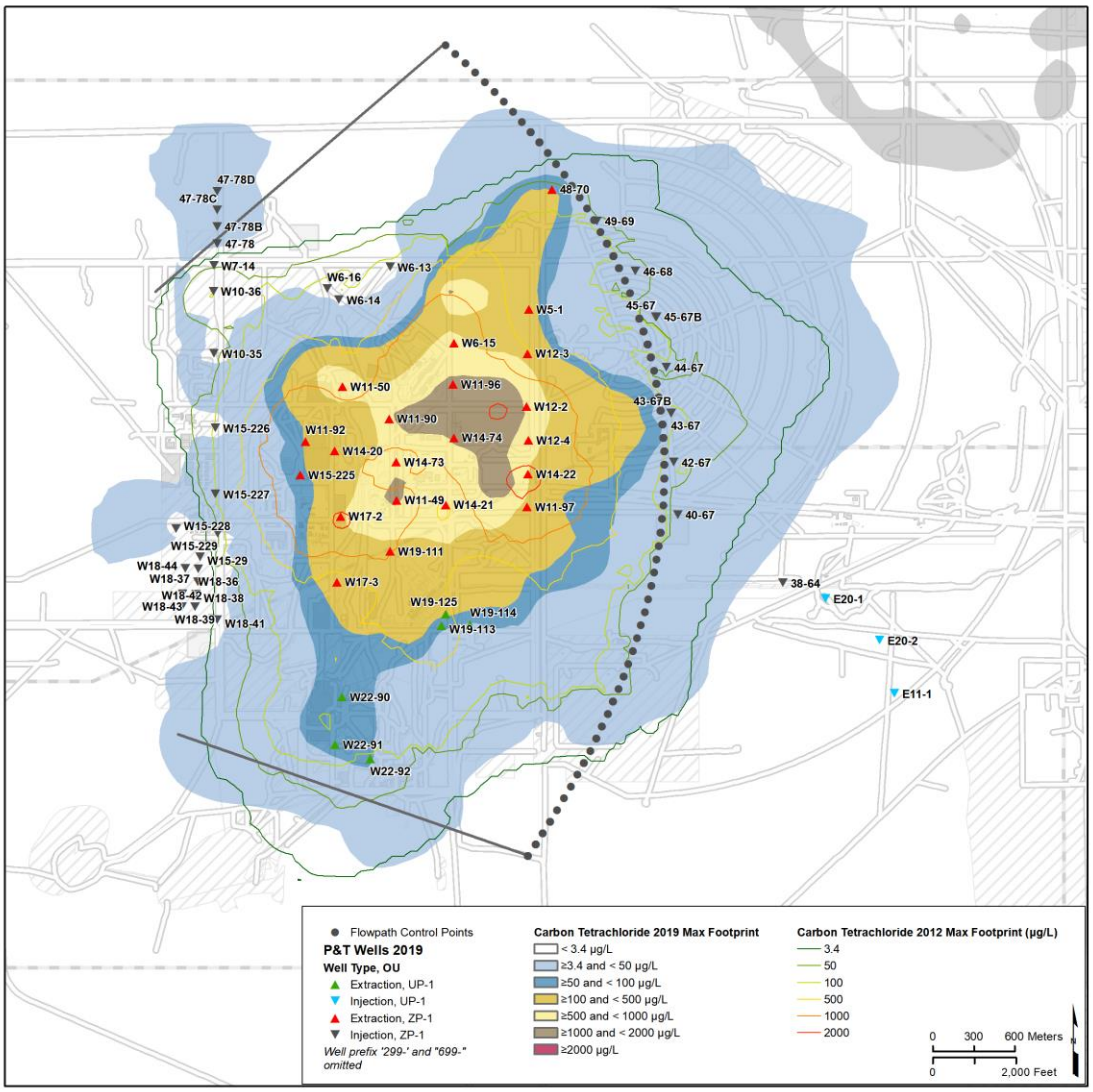
6.2.1 Water-Level Mapping and Particle Tracking

The pathline calculations completed for the 200-UP-1 OU differ from those prepared for 200-ZP-1, however, the groundwater levels and extraction data used to develop the 200-UP-1 OU water-level maps were the same as the maps used for the broader 200-ZP-1 OU (details presented in ECF-200W-20-0015). The following procedure was used to develop the necessary input files, perform the calculations, and post-process the outputs to develop the capture-zone maps using the "Transient Tracker" program for the two areas within the 200-UP-1 OU. Particles were tracked on the groundwater elevation surfaces obtained only for the single month of December 2019 using the Transient Tracker program executed via the GroundWater Desktop (GWD) Graphical User Interface (GUI) rather than via the Command Line, in order to simplify the definition of particle starting locations. Particle starting locations were set at the perimeter of a 10 m diameter circle around extraction wells 299-W22-90, 299-W22-91 and 299-W22-92 in S-SX and extraction wells 299-W19-113, 299-W19-114 and 299-W19-125 in U-Plant area. Capture analysis for the S-SX Tank Farms particles were tracked for the equivalent of 10 years assuming a mobile porosity of 0.15 and a hydraulic conductivity of 5 m/d (16.4 ft/d).

6.2.2 Transport Modeling and Mass Recovery Calculations

Since the 200-UP-1 S-SX Tank Farms and U Plant extraction wells are within the domain of the P2R Model and are adjacent to the larger 200-ZP-1 OU P&T system, simulated concentrations of COCs are obtained for the S-SX Tank Farms and U Plant wells when the P2R Model is executed (as described in

Section 7.3.3). The simulated influent concentrations are presented in this ECF; however, these concentrations are not currently used to draw inferences about the performance of the S-SX Tank Farms remedy.



Note: The CY 2019 2D map of carbon tetrachloride (ECF-Hanford-20-0018, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2019 Hanford Site Groundwater Monitoring Report*) and the mapped extent of carbon tetrachloride are derived from three dimensions (ECF-200ZP1-13-0006, *Description of Groundwater Modeling Calculations for the Calendar Year 2012 (CY2012) 200 Areas Pump-and-Treat Report*).

Figure 6-1. Schematic of the Flow-Path Control Line-of-Control Used for Calculations in Chapter 7

7 Results

7.1 200-ZP-1 Operable Unit

The figures and tables produced as output from the calculations described in this ECF for the 200-ZP-1 OU are provided in this chapter.

7.1.1 Hydraulic Containment

The results of the hydraulic containment calculations are presented in the following series of figures that depict groundwater-level contours and the extent of hydraulic containment, as estimated using both the water-level mapping method and the groundwater modeling method:

- Figure 7-1 depicts the ICFM for the 200-ZP-1 P&T system, as well as the approximate extent of carbon tetrachloride that is dissolved in groundwater above the Rlm (as represented by the 2D maximum extent derived from 3D interpolation completed in CY 2019), with groundwater levels calculated using the water-level mapping method.
- Figure 7-2 depicts the SCFM for the 200-ZP-1, as well as the approximate extent of carbon tetrachloride that is dissolved in groundwater above the Rlm (as represented by the 2D maximum extent derived from 3D interpolation completed in CY 2019), with groundwater levels calculated using the P2R Model.
- Figure 7-3 depicts the SCFM for the 200-ZP-1, as well as the approximate extent of carbon tetrachloride that is dissolved in groundwater below the Rlm (as represented by the 2D maximum extent derived from 3D interpolation completed in CY 2019), with groundwater levels calculated using the P2R Model.

For CY 2019, the differences between the simulated and mapped capture frequencies are most evident in the southern part of the maps and to the southeast, beyond the region of carbon tetrachloride contamination at both 100 µg/L and at 3.4 µg/L, where the water-level monitoring network has limited coverage.

These figures depict the extent of hydraulic containment using methods that integrate a series of quasi-steady-state calculations. In actuality, conditions in the Central Plateau vary over time due to P&T operations, and also as a result of historical activities. In particular, the water table in the Central Plateau is decreasing in many areas as a result of the cessation of historical operational discharges of water within ponds and other surface features that infiltrated to the subsurface; the rate of decline was estimated to be on the order of 0.22 to 0.27 m/yr in 2014, the most recent evaluation that was completed of this underlying decline. To depict the approximate extent and magnitude of the drawdown and mounding resulting from operation of the P&T remedies, this underlying trend in water levels should be incorporated. The following figures present unadjusted and adjusted estimates of drawdown and mounding. The unadjusted estimates are based on computing the difference between the June 2012 and December 2019 water-level contours. The adjusted estimates, however, are based upon computing the difference between the June 2012 and December 2019 water-level contours, and this difference is then added to the estimated area-wide head change of about 1.858 m (6.09 ft) from June 2012 to December 2019 due to the cessation of historical operational discharges.

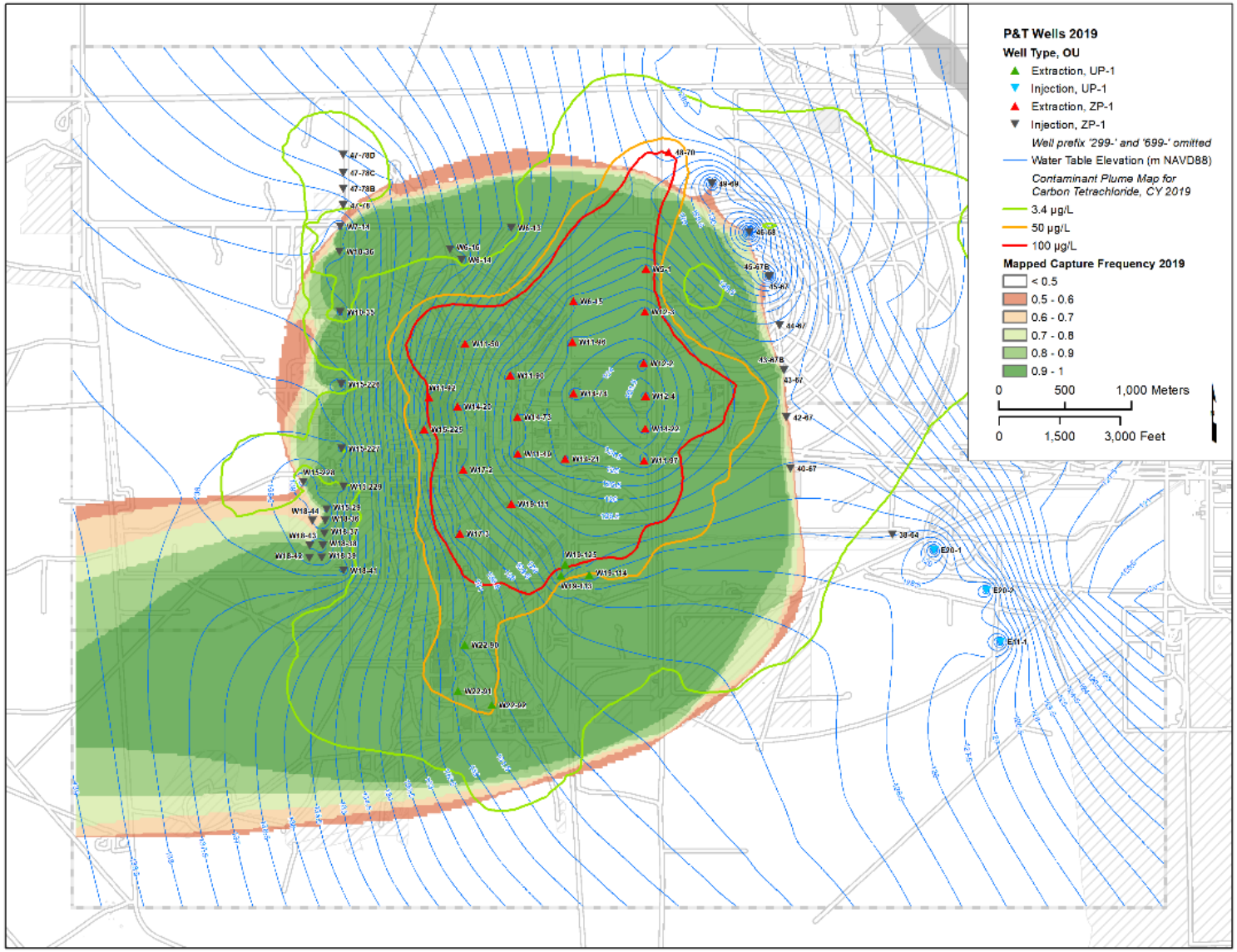


Figure 7-1. Mapped Groundwater Levels, Extent of Carbon Tetrachloride and ICFM for 200-ZP-1 above the Rlm

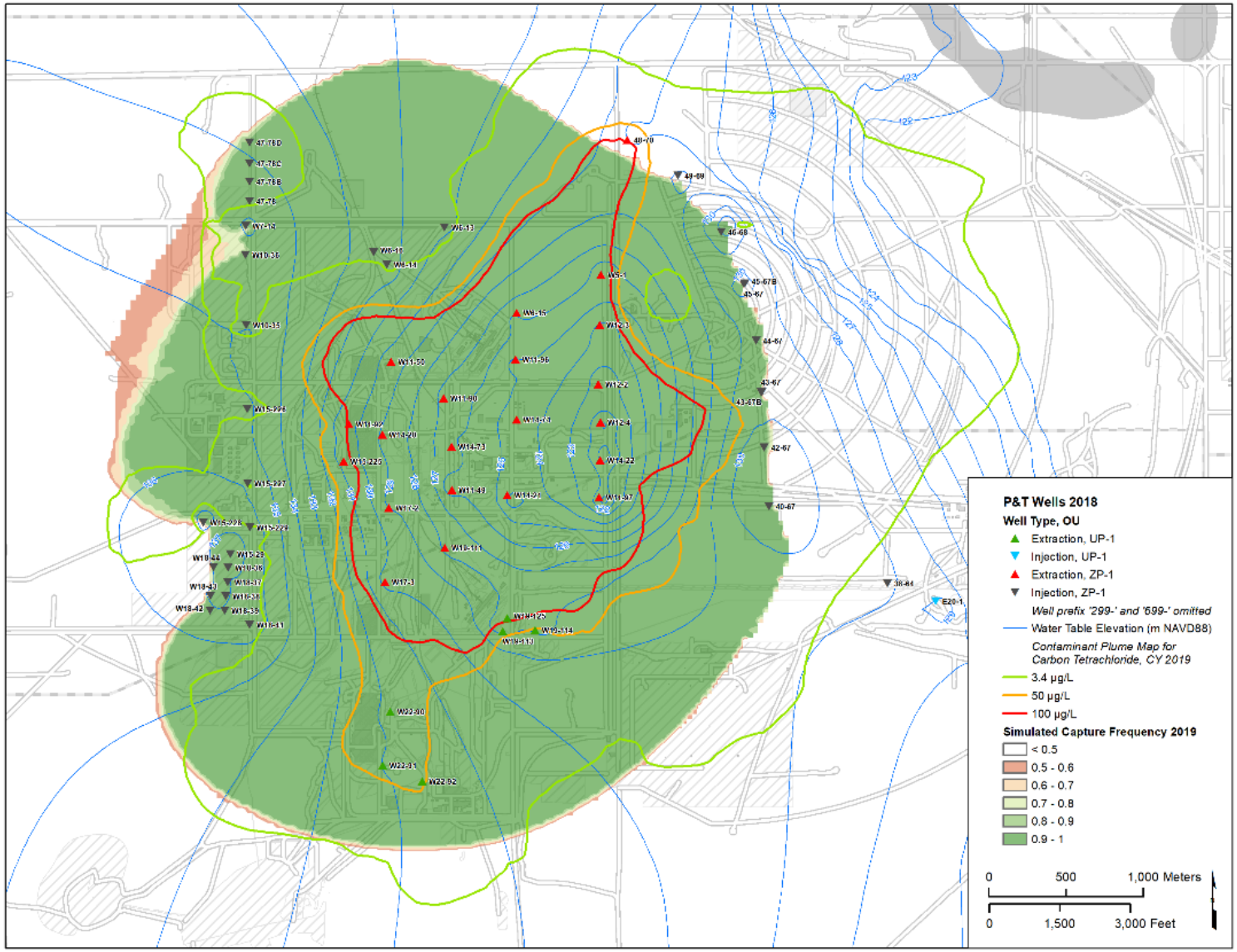


Figure 7-2. Simulated Groundwater Levels, Extent of Carbon Tetrachloride and SCFM for 200-ZP-1 above the Rlm

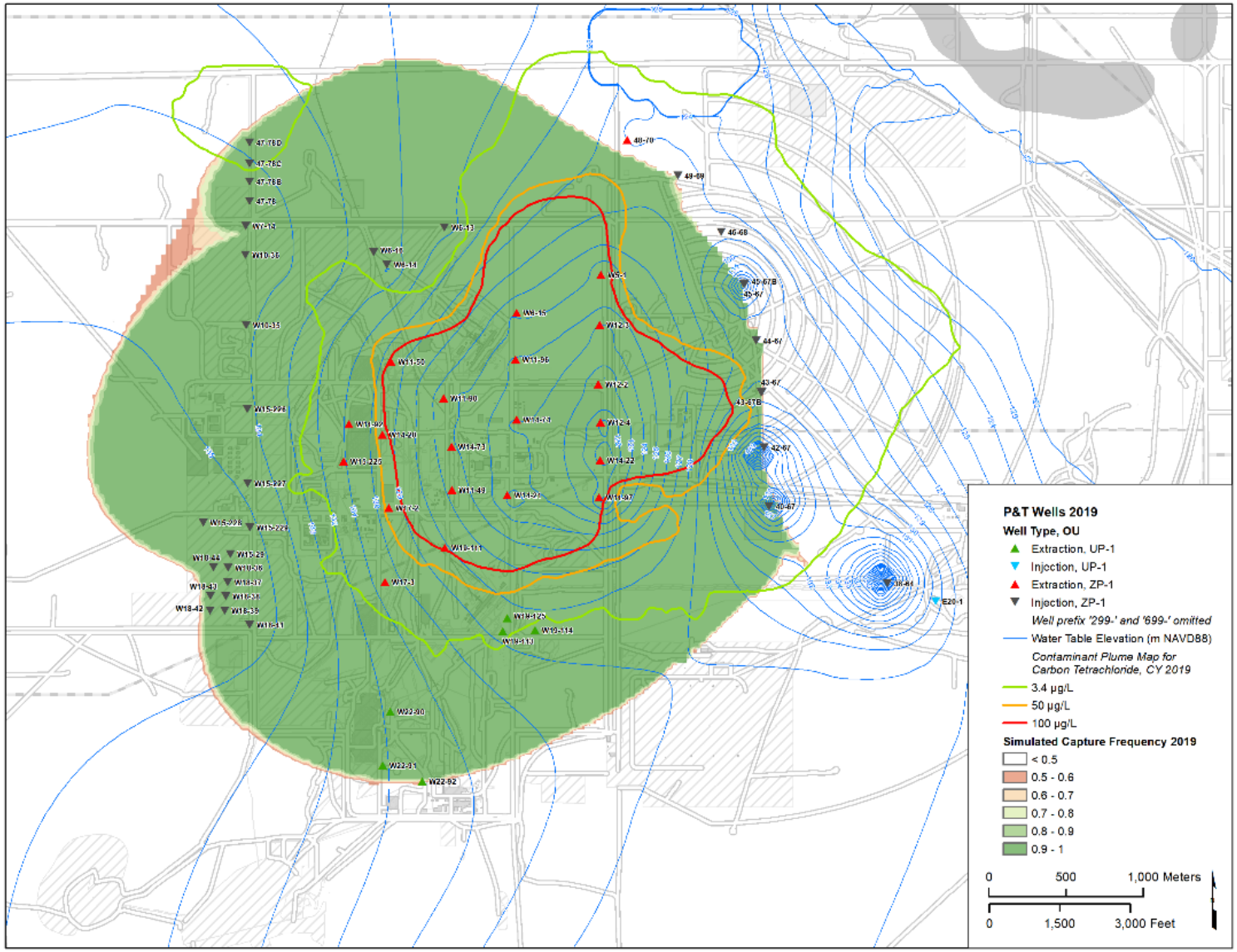


Figure 7-3. Simulated Groundwater Levels, Extent of Carbon Tetrachloride and SCFM for 200-ZP-1 below the Rlm

Figures 7-4 through 7-6 depict the estimated extent and magnitude of drawdown resulting from operation of the 200-ZP-1 and 200-UP-1 groundwater P&T systems as follows:

- Figure 7-4 depicts the approximate extent of drawdown and mounding calculated using the water-level mapping method above the Rlm. Two panels are shown:
  - Unadjusted: No correction is made for the background decline (recession) in water levels due to cessation of historical wastewater discharges to the subsurface.
  - Adjusted: A correction of 1.858 m is made for the background decline (recession) in water levels due to cessation of historical wastewater discharges to the subsurface.
- Figure 7-5 depicts the unadjusted approximate extent of drawdown and mounding calculated using the P2R groundwater model. Two panels are shown:
  - Above the Rlm, represented by model layer 4
  - Below the Rlm, represented by model layer 7
- Figure 7-6 depicts the adjusted approximate extent of drawdown and mounding calculated using the P2R groundwater model, incorporating a correction of 1.858 m for the background decline (recession) in water levels due to cessation of historical wastewater discharges to the subsurface. Two panels are shown:
  - Above the Rlm, represented by model layer 4
  - Below the Rlm, represented by model layer 7

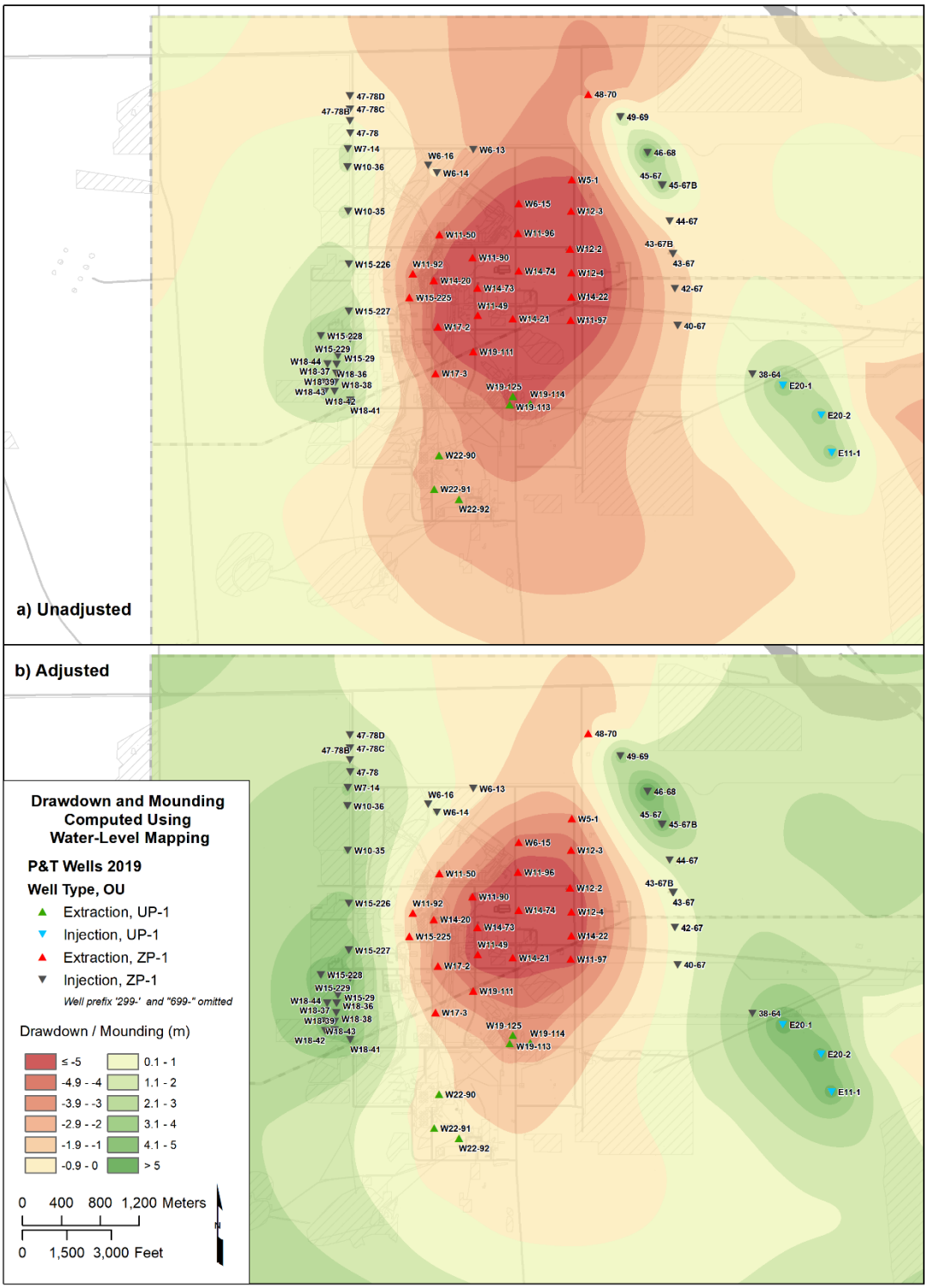


Figure 7-4. Drawdown and Mounding (Mapping Method) above the Rlm: (a) Unadjusted and (b) Adjusted

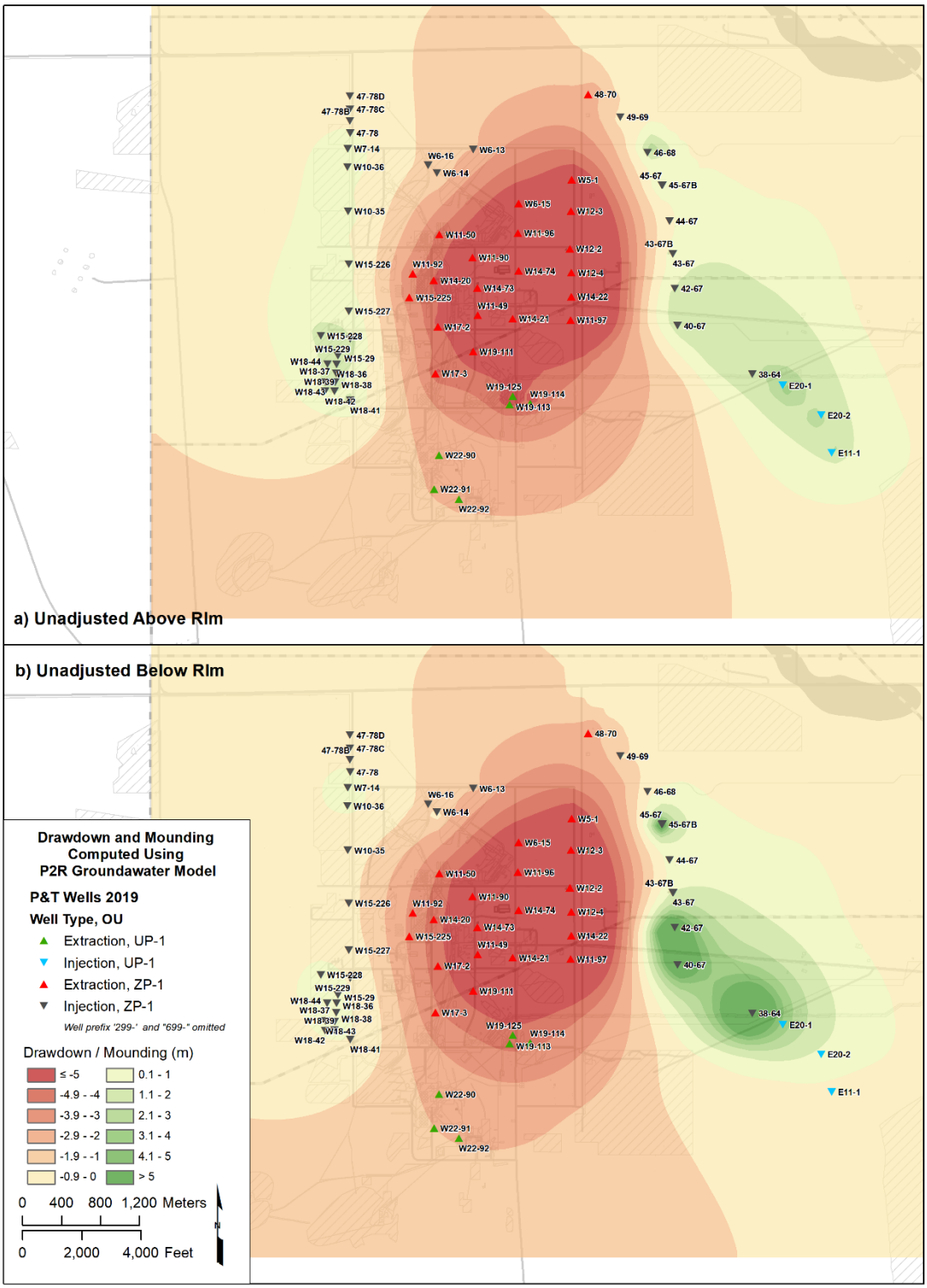


Figure 7-5. Unadjusted Drawdown and Mounding Estimated using the P2R Model: (a) Unadjusted Drawdown above the Rlm at the End of 2019 and (b) Unadjusted Drawdown below the Rlm at the End of 2019

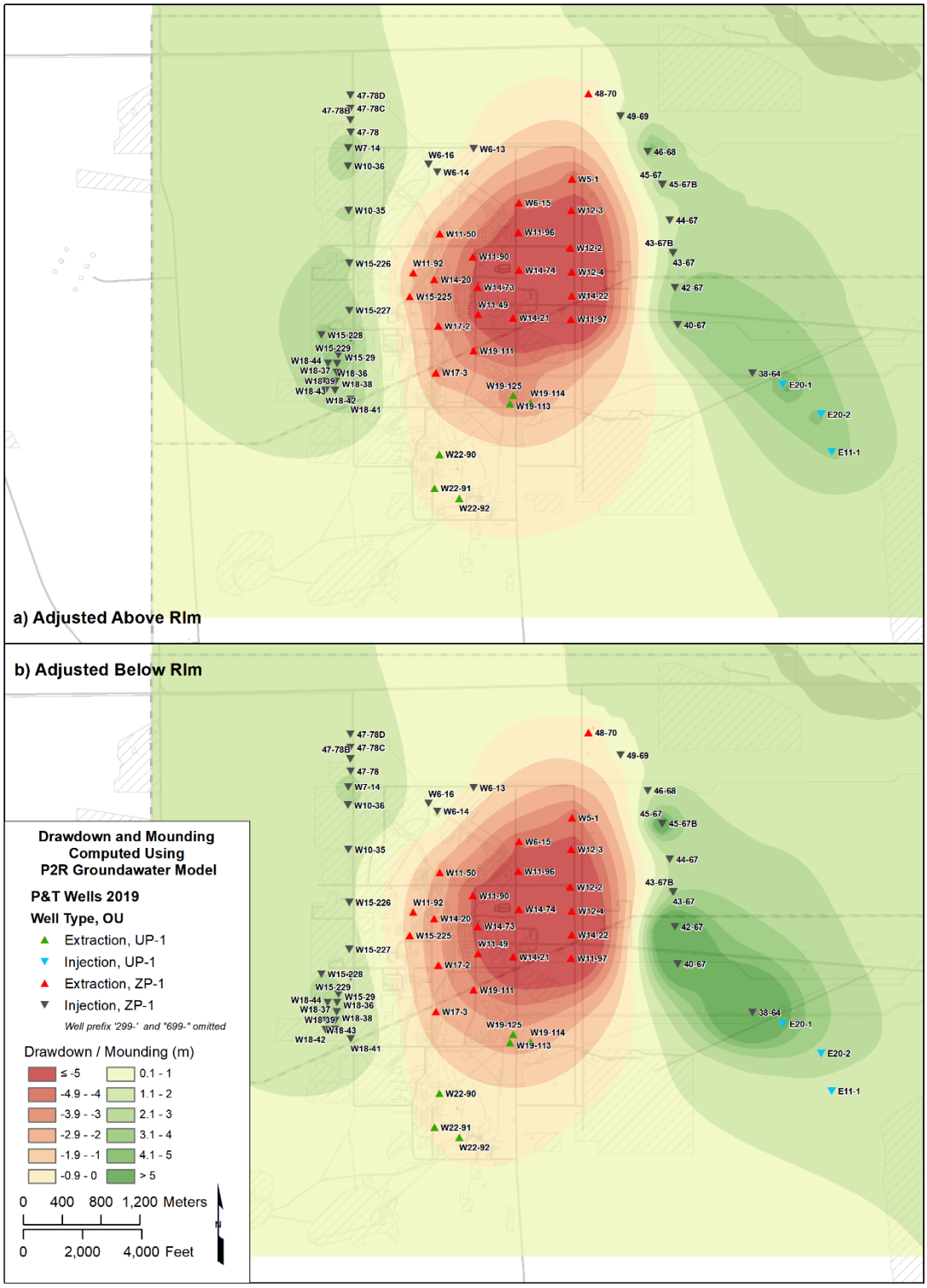


Figure 7-6. Adjusted Drawdown and Mounding Estimated using the P2R Groundwater model: (a) Adjusted Drawdown above the RIm at the End of 2019 and (b) Adjusted Drawdown below the RIm at the End of 2019

7.1.2 Flow-Path Control

Figures 7-7 to 7-9 depicts areas along the flow-path control line above the Rlm, where hydraulic gradients are reduced or reversed by the combined operations of extraction and injection. In each case, the direction and length of the arrows posted along the control line indicate the direction and relative magnitude of the hydraulic gradient at that location:

- Inset “a” depicts the “Baseline” hydraulic conditions of the flow field in June 2012 (ECF-200ZP1-13-0006). Posted arrows represent the flow direction and arrow length represents the hydraulic gradients.
- Inset “b” depicts “Current” hydraulic conditions of the flow field in December 2019. Posted arrows represent the flow direction and arrow length represent the hydraulic gradients. Colored map depicts the change in hydraulic gradients, which is calculated as the difference between hydraulic gradients between current conditions in December 2019 and baseline conditions in June 2012.

Figure 7-7 depicts areas along the control line above the Rlm, where gradients are reduced or reversed by the combined operation of extraction and injection, as calculated using the water-level mapping method.

Figure 7-8 depicts areas along the control line above the Rlm, where gradients are reduced or reversed by the combined operation of extraction and injection, as calculated using the P2R Model.

Figure 7-9 depicts areas along the control line below the Rlm, where gradients are reduced or reversed by the combined operation of extraction and injection, as calculated using the P2R Model.

Figures 7-7 to 7-9 depict reductions in hydraulic gradients (indicated by negative change in hydraulic gradient shaded in red color) between concentrated areas of extraction and injection wells to the northeast and southeast of the 200-ZP-1 OU. To the north and to the south of the eastern (downgradient) line of injection wells, the gradient change is smaller. Inset “b” in Figures 7-7 to 7-9 also depicts the approximate extent of groundwater contaminated by carbon tetrachloride represented by the most recent (CY 2019) 2D extent as described in ECF-Hanford-19-0010, *Calculation and Depiction of Groundwater Contamination for the Calendar Year 2018 Hanford Site Groundwater Monitoring Report*.

The flow-path control assessment indicates that during CY 2019, flow-path control had developed along much of the control line, through the reduction in gradients by groundwater extraction and reinjection at the 200 West P&T. With the installation of the new extraction well in the small region of contamination extending to the northeast which was identified in CY 2017 (well 699-48-70) flow-path control (and indeed, hydraulic containment) have greatly improved in this area.

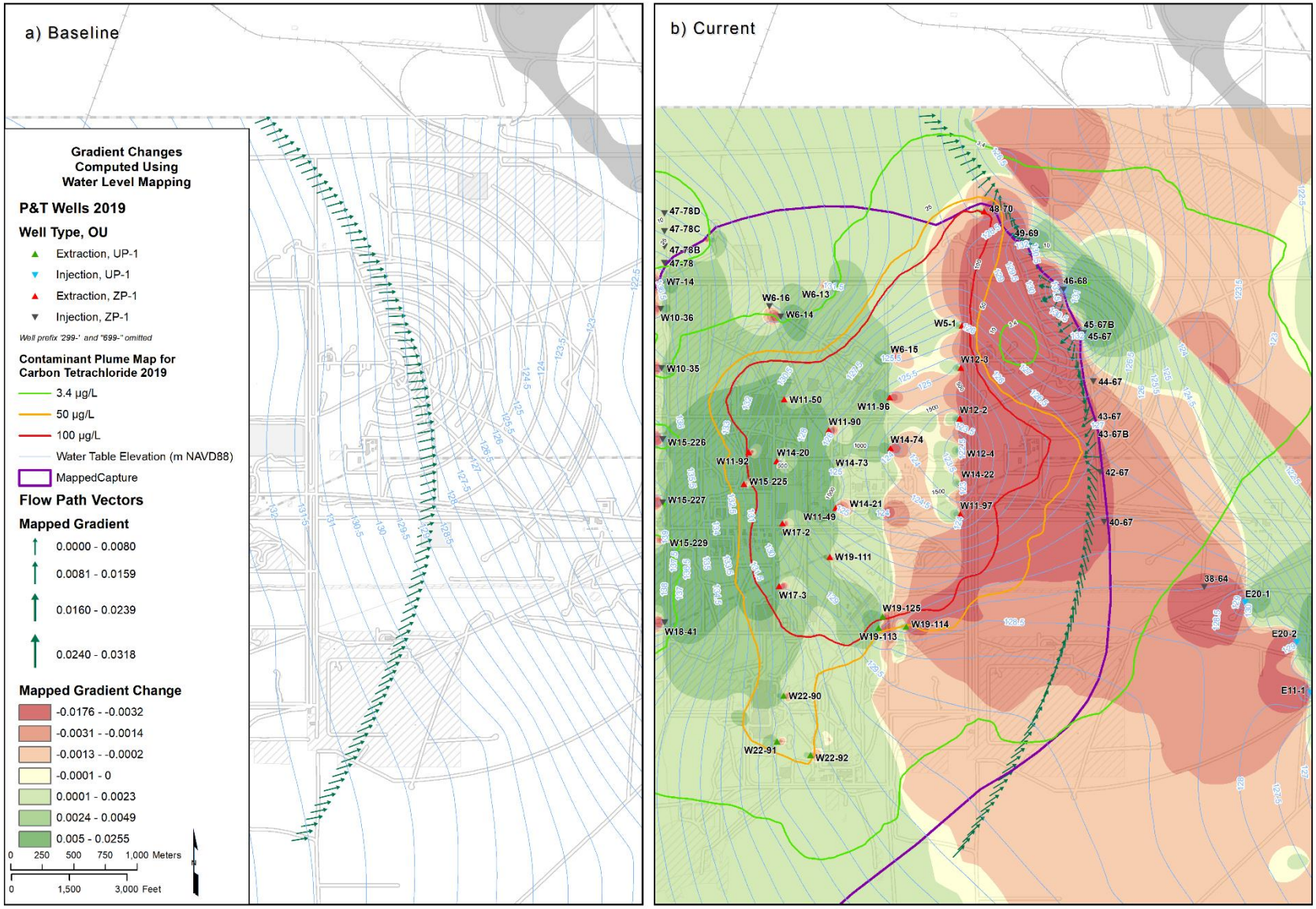


Figure 7-7. Mapped Gradient Changes Along Line of Control above the Rlm: (a) Baseline and (b) Current

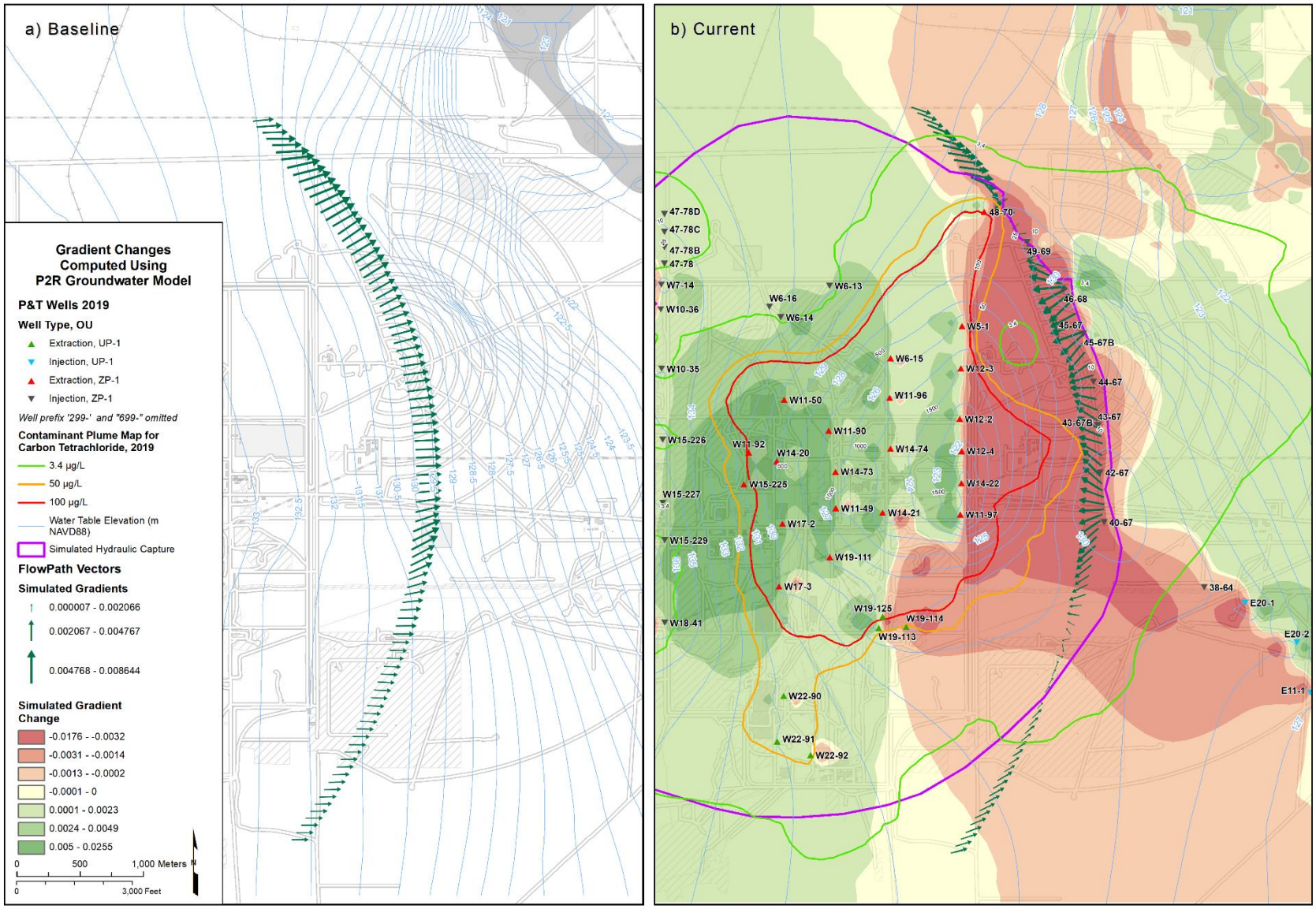


Figure 7-8. Simulated Gradient Changes Along Line of Control above the Rlm: (a) Baseline and (b) Current

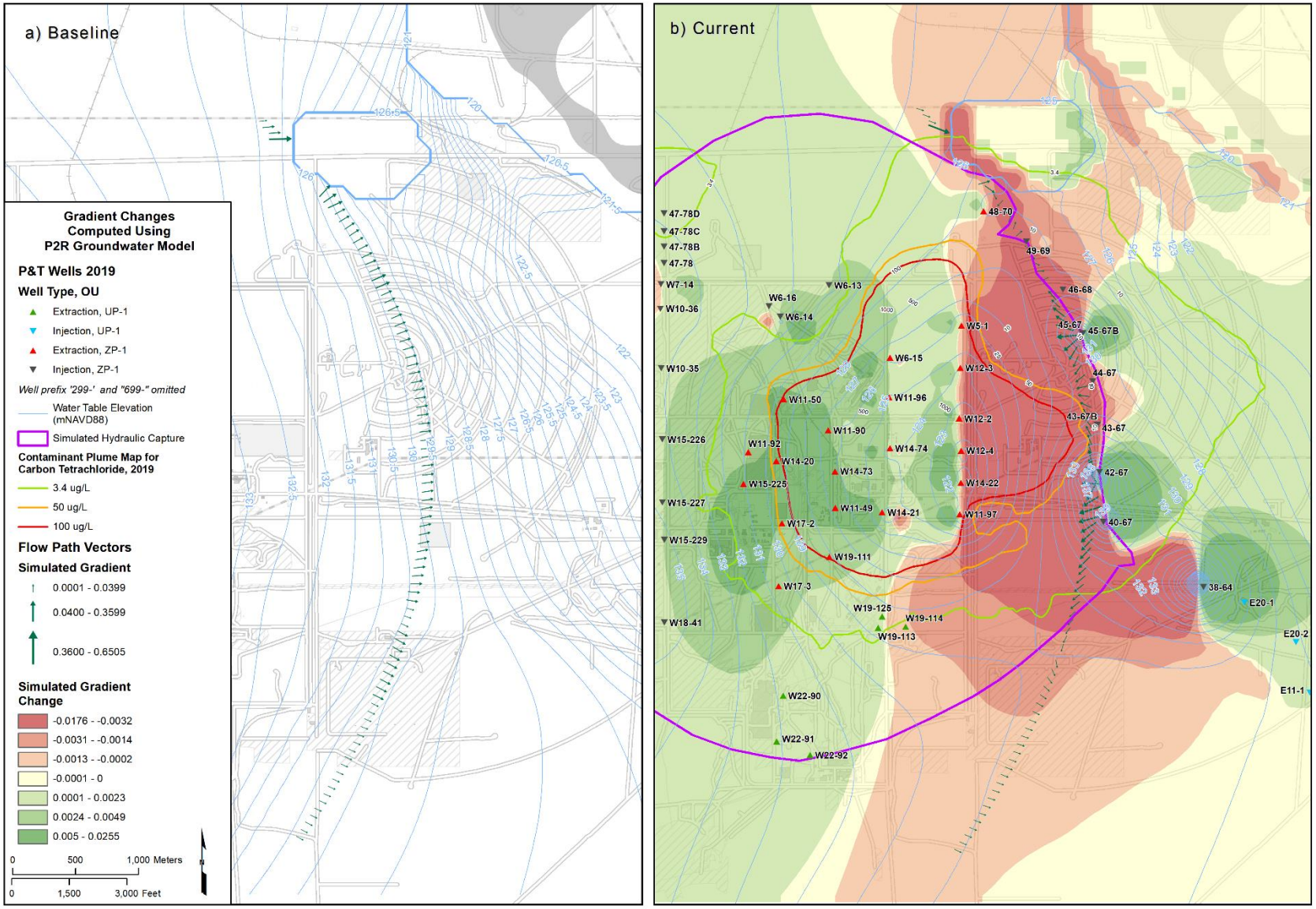


Figure 7-9. Simulated Gradient Changes Along Line of Control below the Rlm: (a) Baseline and (b) Current

7.1.3 Simulated and Observed Extraction Well Concentrations and Mass Removal

Figures 7-10 through 7-18 depict a comparison of the simulated and observed (measured) historical influent concentrations for each COC at the 200 West P&T extraction wells. These figures include extraction well concentration information as follows:

- Figure 7-10: carbon tetrachloride (assuming a 300-year half-life)
- Figure 7-11: carbon tetrachloride (assuming a 630-year half-life)
- Figure 7-12: hexavalent chromium
- Figure 7-13: iodine-129
- Figure 7-14: nitrate
- Figure 7-15: technetium-99
- Figure 7-16: trichloroethene
- Figure 7-17: tritium
- Figure 7-18: uranium

Comparison of the simulated and observed (measured) historical influent concentrations at the monitoring wells is presented in Appendix B.

Figures 7-19 through 7-27 depict a comparison of the simulated and observed (measured) historical contaminant cumulative mass recovery for each COC at the 200 West P&T system extraction wells based upon the documented (and simulated) flow rates and the simulated and observed (measured) sample concentrations. These figures include extraction well and mass removal information for simulations using initial plumes generated by the ordinary quantile kriging method (ECF-200W-20-0052):

- Figure 7-19: carbon tetrachloride (assuming a 300-year half-life)
- Figure 7-20: carbon tetrachloride (assuming a 630-year half-life)
- Figure 7-21: hexavalent chromium
- Figure 7-22: nitrate
- Figure 7-23: iodine-129
- Figure 7-24: technetium-99
- Figure 7-25: trichloroethene
- Figure 7-26: tritium (note: tritium is not effectively removed from the recovered water by the 200 West treatment system. However, to reflect the activity of tritium that was recovered via extraction wells, the result of calculations is reported using tritium concentrations and flow rates at individual extraction wells).
- Figure 7-27: uranium

Figures 7-28 through 7-29 depict a comparison of the simulated and observed (measured) historical contaminant cumulative mass recovery for carbon tetrachloride for which initial plumes were generated using the SGSIM “weighted-average” method derived from the 100 SGSIM realizations described in ECF-200W-18-0028.

- Figure 7-28: carbon tetrachloride (assuming a 300-year half-life)
- Figure 7-29: carbon tetrachloride (assuming a 630-year half-life)

The terms that are depicted in these figures are defined as follows:

- **Simulated Extracted:** The cumulative mass recovery at pumping wells, as read directly from the standard transport model output file
- **Simulated Extracted 200W**: The cumulative mass recovery at pumping wells, as read directly from the standard transport model output file representing simulated mass extracted by pumping wells located in 200W area
- **Simulated Extracted BP5**: The cumulative mass simulated as an external source from BP-5 OU extraction wells
- **Simulated Injected:** The cumulative mass reinjected by injection wells due to partial (i.e., less than 100%) treatment efficiency for that constituent
- **Total Removed:** The simulated cumulative mass removed, calculated as a difference between extracted and injected simulated mass
- **Calculated:** Mass calculated using reported pumping rates and concentration values at the extraction wells

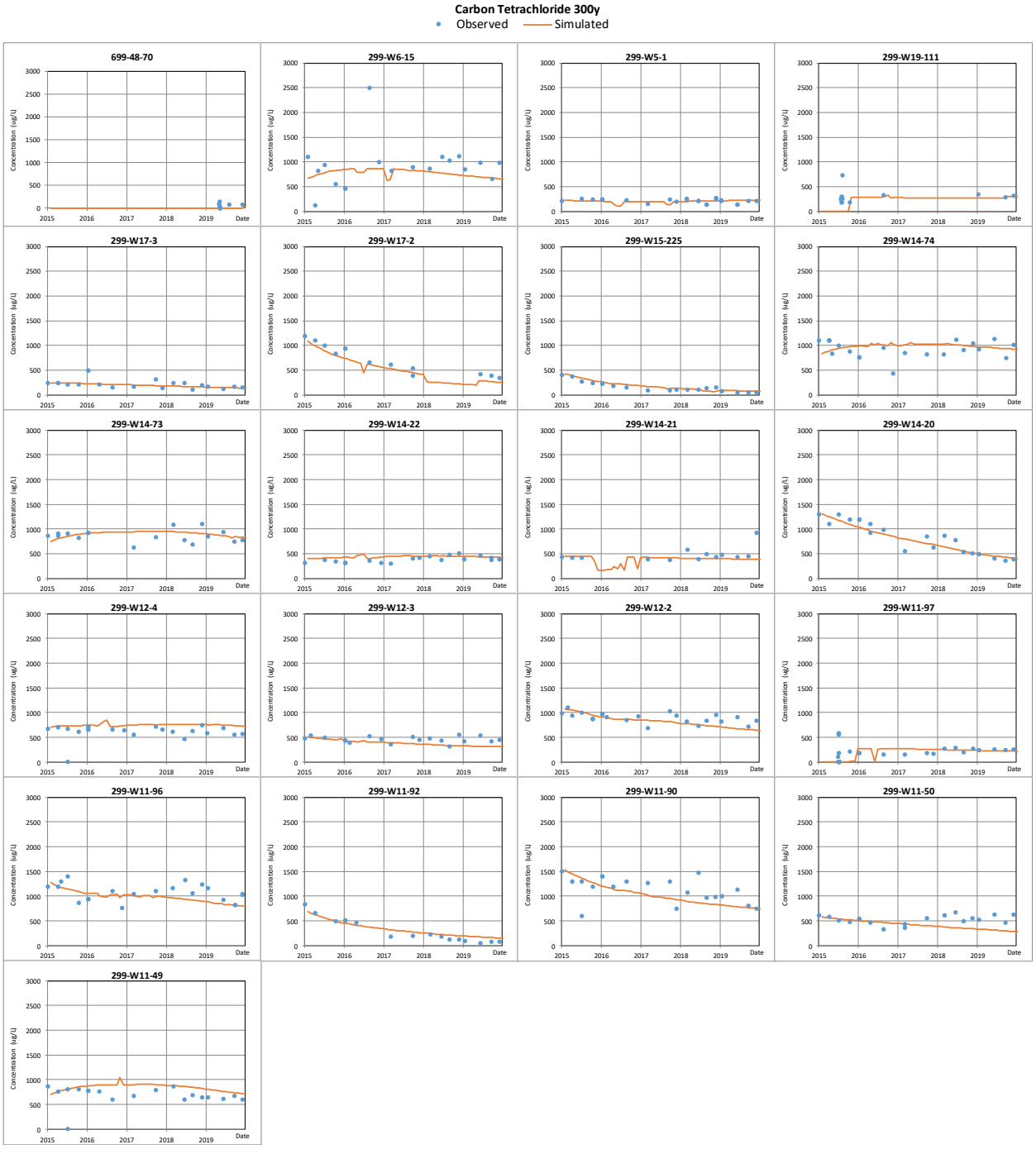


Figure 7-10. Comparison of Simulated and Observed Historical Influent Concentrations at 200-ZP-1 for Carbon Tetrachloride (300-Year Half-Life)

Figure 7-11. Comparison of Simulated and Observed Historical Influent Concentrations at 200-ZP-1 for Carbon Tetrachloride (630-Year Half-Life)

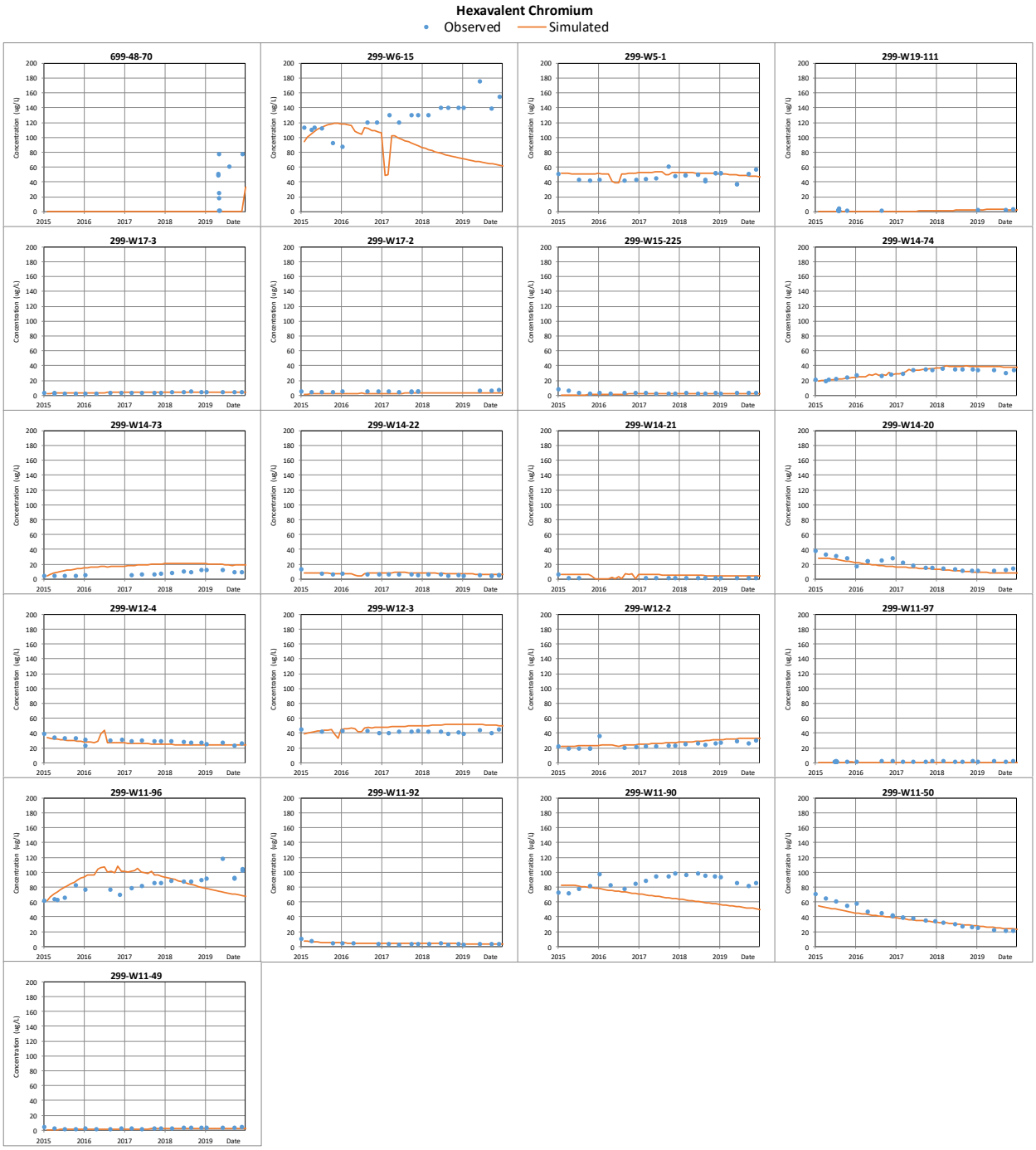


Figure 7-12. Comparison of Simulated and Observed Historical Influent Concentrations at 200-ZP-1 for Hexavalent Chromium

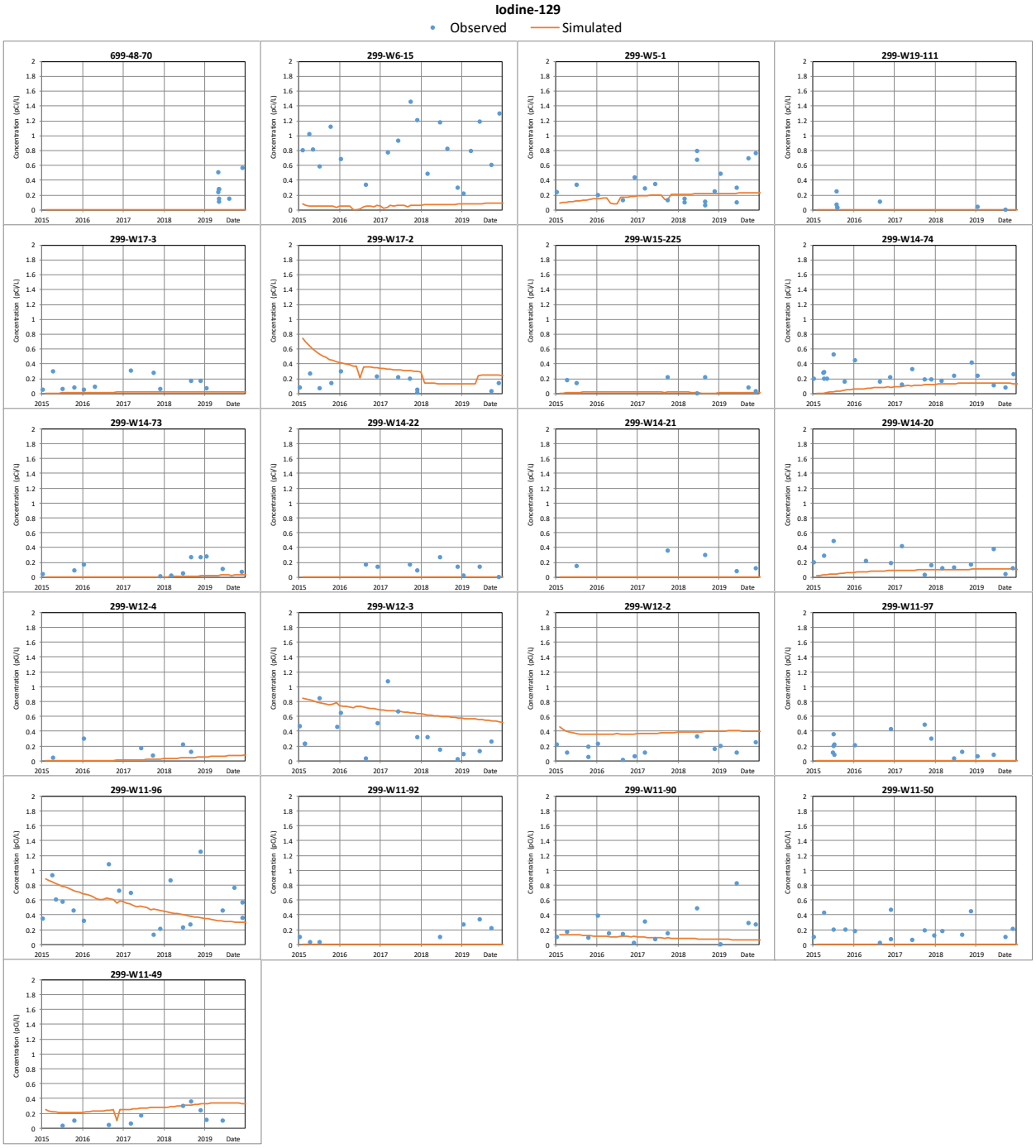


Figure 7-13. Comparison of Simulated and Observed Historical Influent Concentrations at 200-ZP-1 for Iodine-129

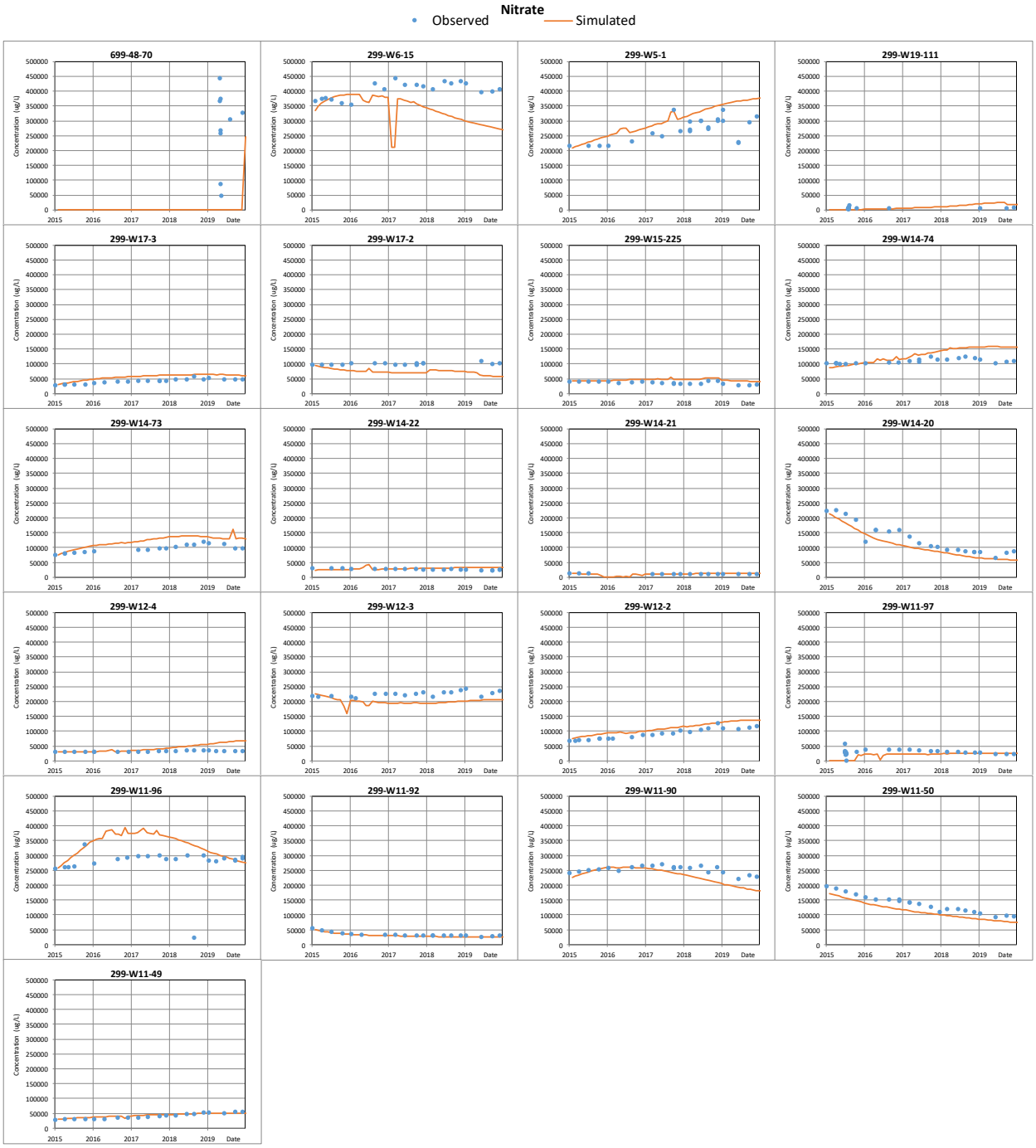


Figure 7-14. Comparison of Simulated and Observed Historical Influent Concentrations at 200-ZP-1 for Nitrate

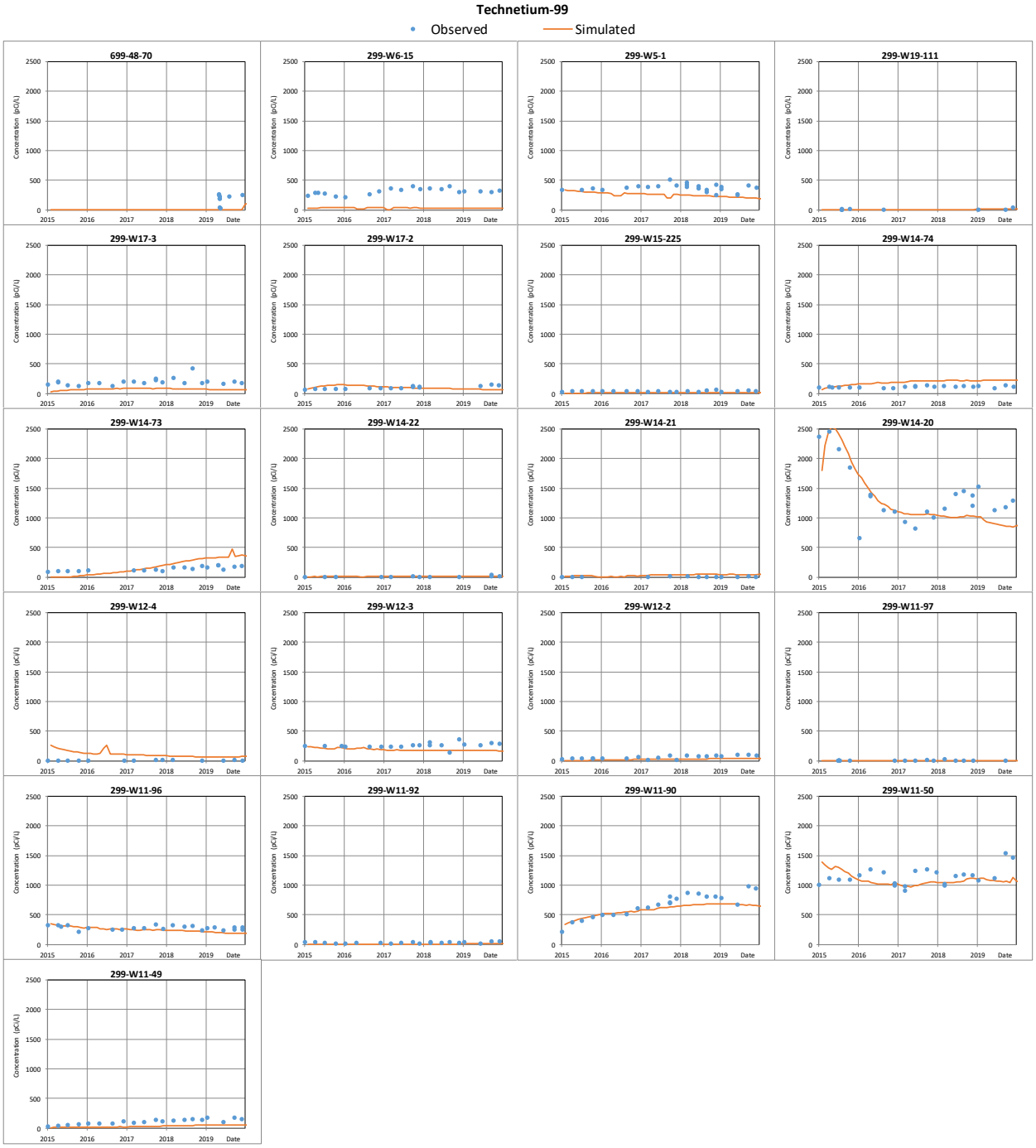


Figure 7-15. Comparison of Simulated and Observed Historical Influent Concentrations at 200-ZP-1 for Technetium-99

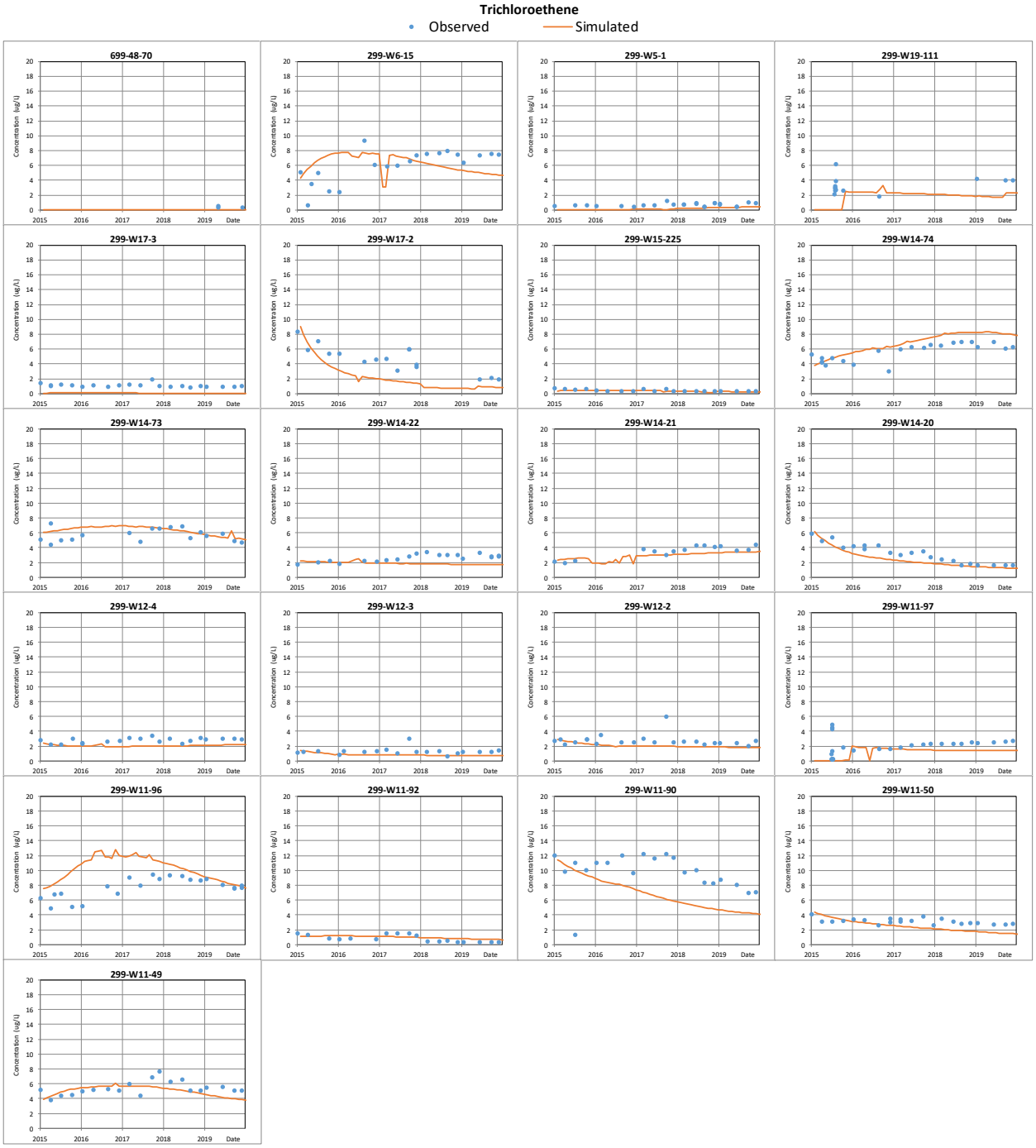


Figure 7-16. Comparison of Simulated and Observed Historical Influent Concentrations at 200-ZP-1 for Trichloroethene

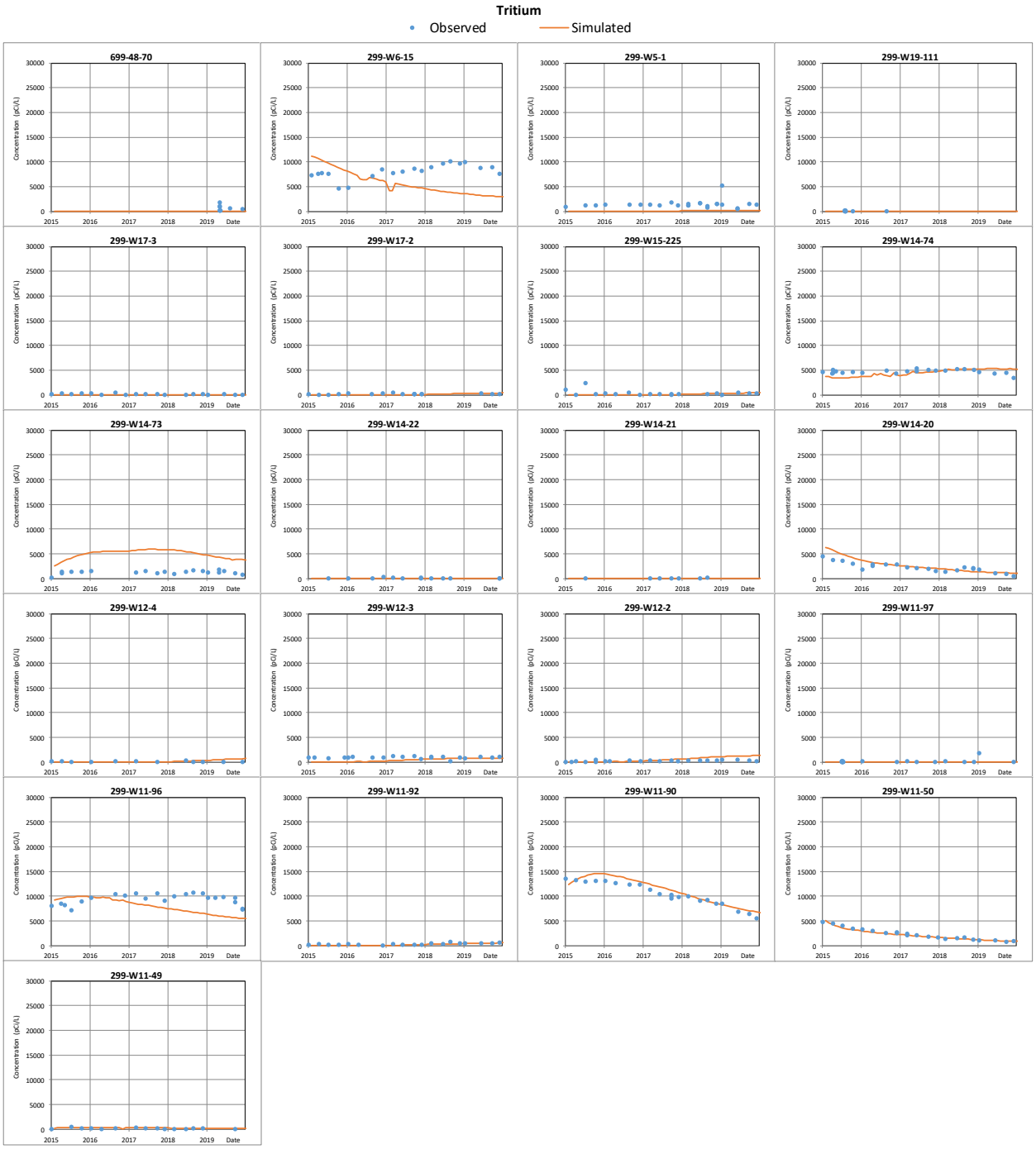


Figure 7-17. Comparison of Simulated and Observed Historical Influent Concentrations at 200-ZP-1 for Tritium

Figure 7-18. Comparison of Simulated and Observed Historical Influent Concentrations at 200-ZP-1 for Uranium

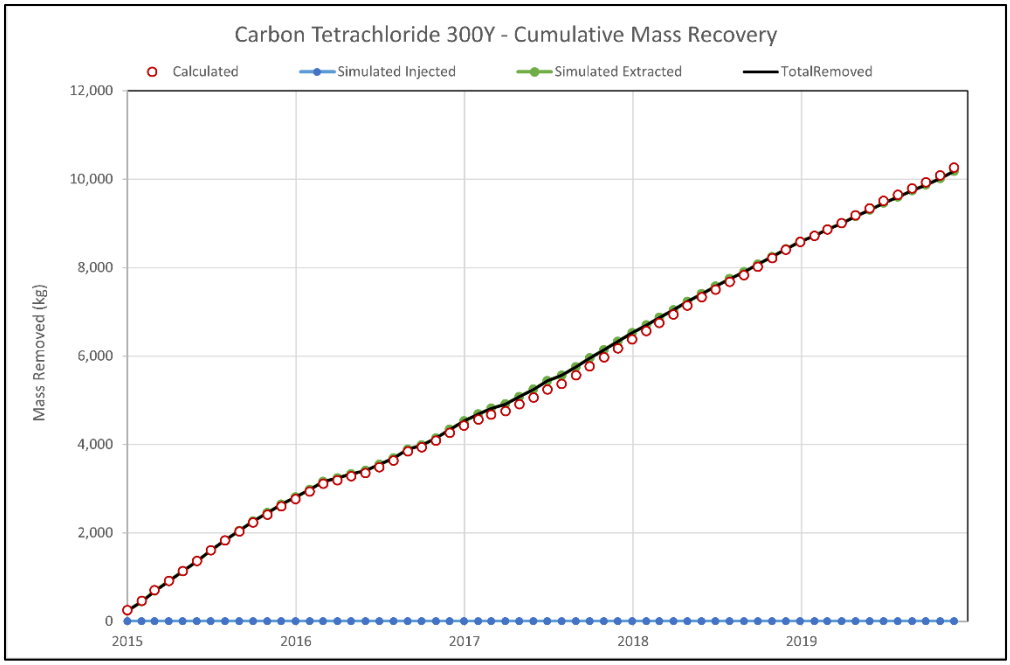


Figure 7-19. Cumulative Mass Removal for Carbon Tetrachloride 300Y Half Life

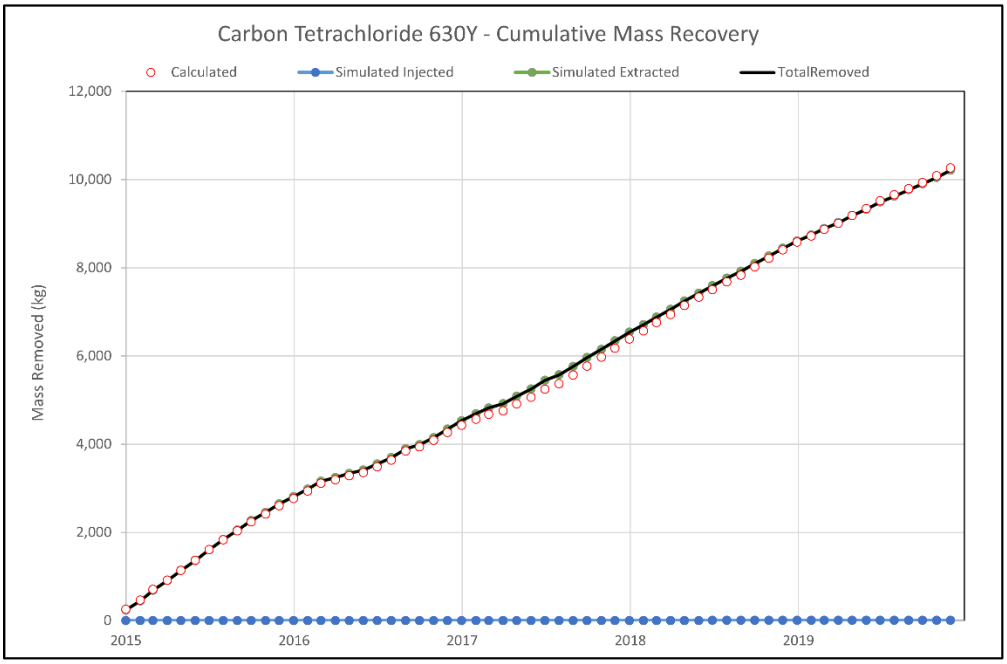


Figure 7-20. Cumulative Mass Removal for Carbon Tetrachloride 630Y Half Life

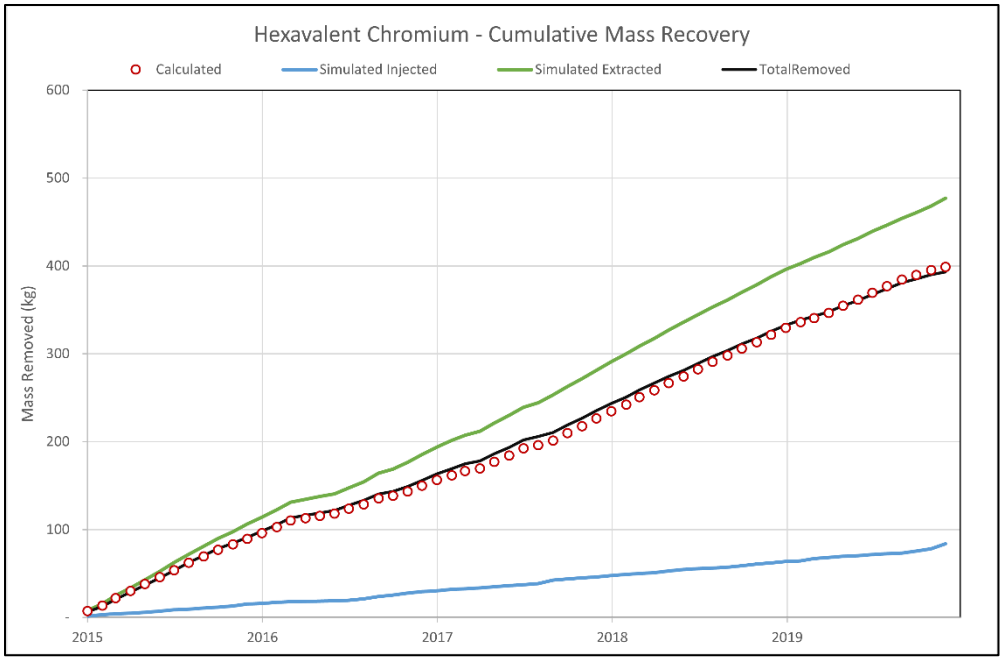


Figure 7-21. Cumulative Mass Removal for Hexavalent Chromium

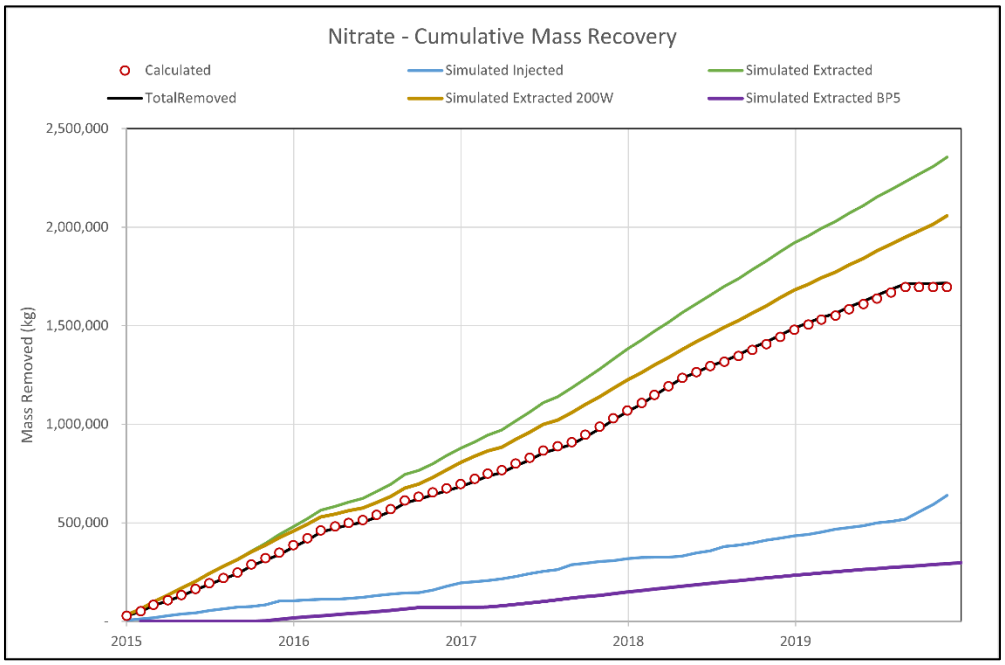


Figure 7-22. Cumulative Mass Removal for Nitrate

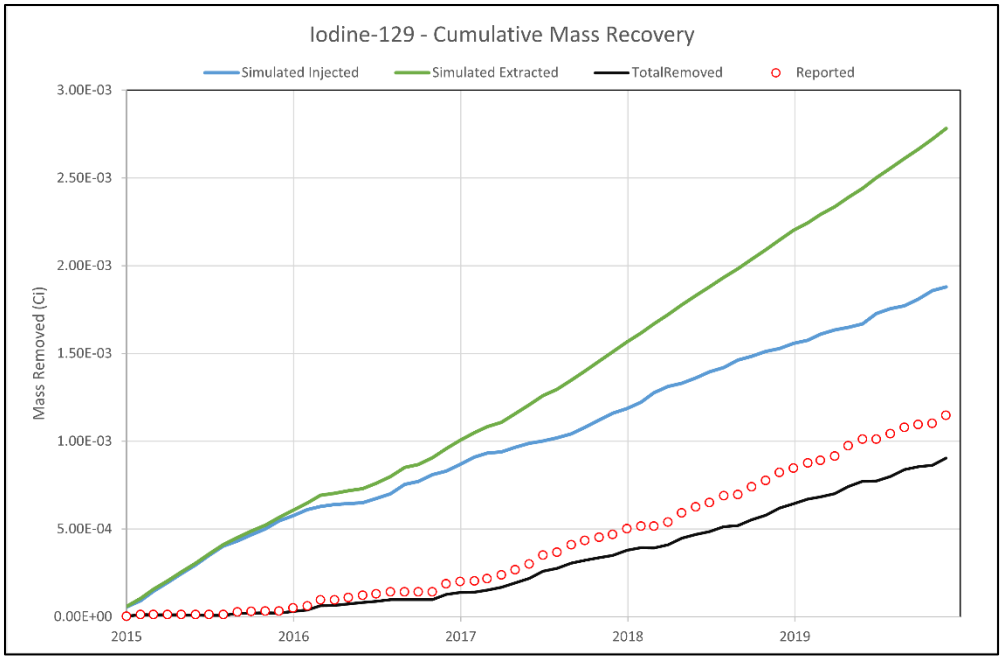


Figure 7-23. Cumulative Mass Removal for Iodine-129

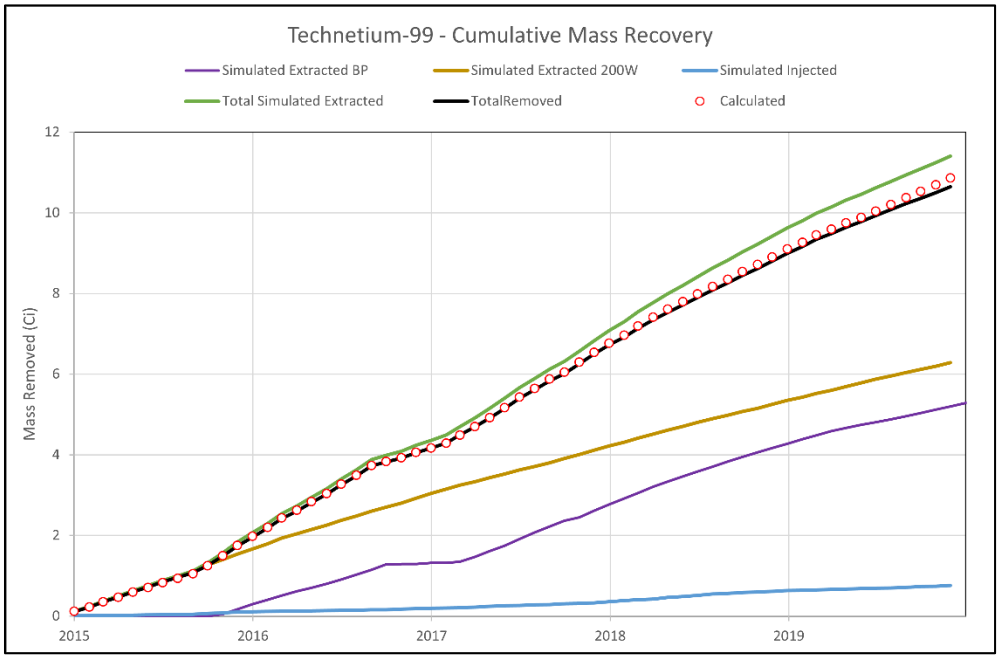


Figure 7-24. Cumulative Mass Removal for Technetium-99

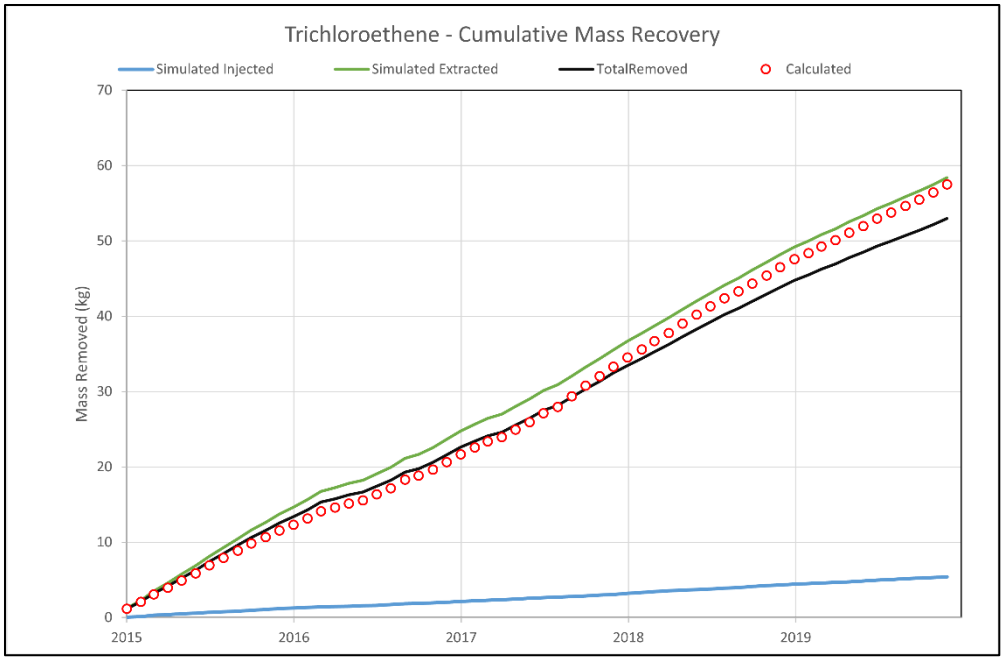


Figure 7-25. Cumulative Mass Removal for Trichloroethene

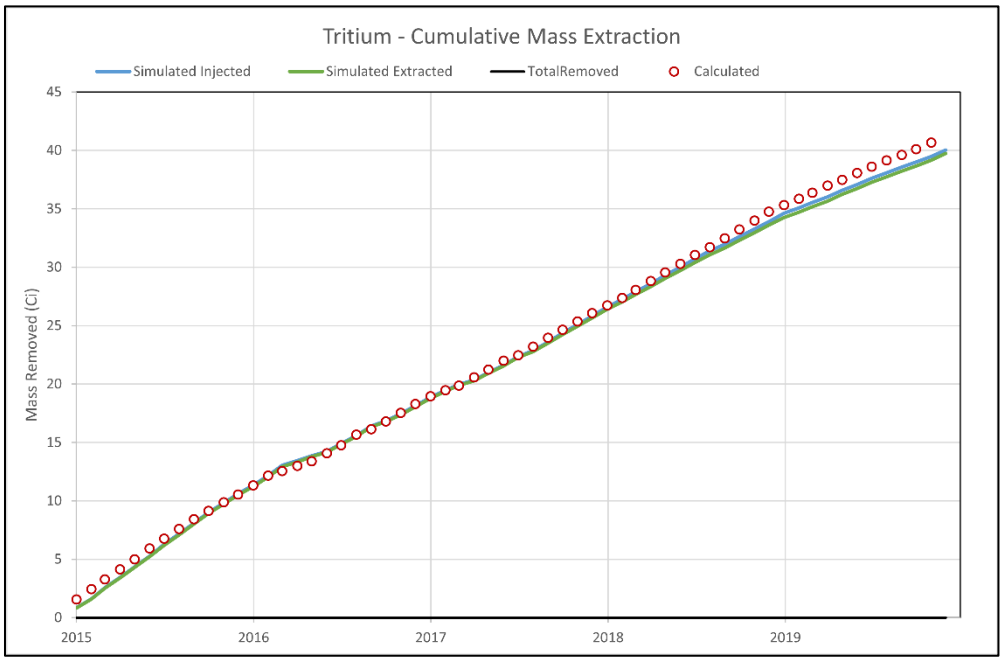


Figure 7-26. Cumulative Mass Removal for Tritium

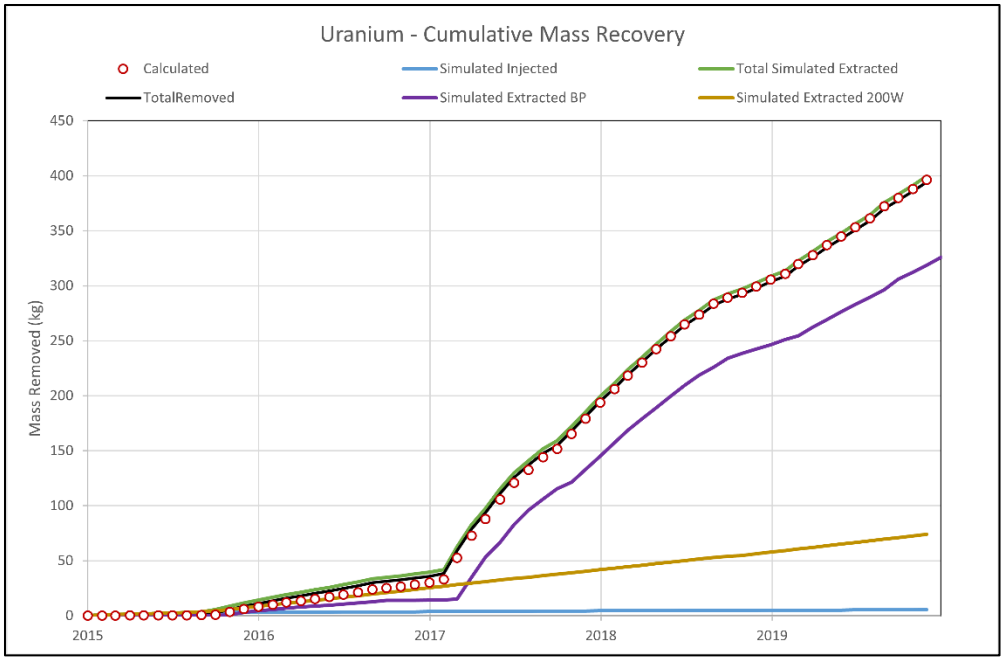


Figure 7-27. Cumulative Mass Removal for Uranium

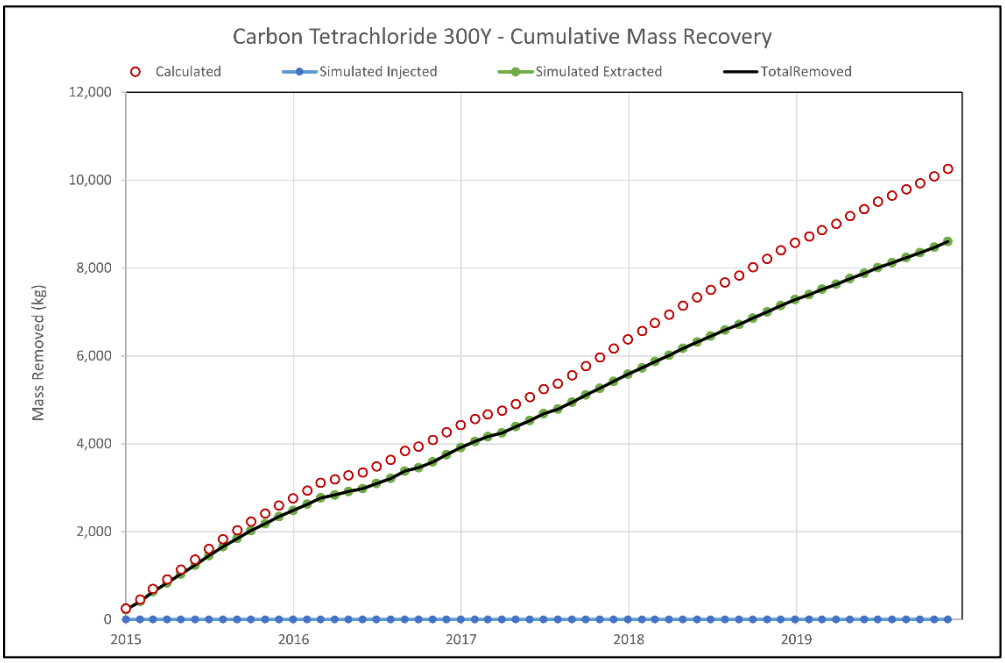


Figure 7-28. Cumulative Mass Removal for Carbon Tetrachloride 300Y Half Life - SGSIM Weighted Average Method

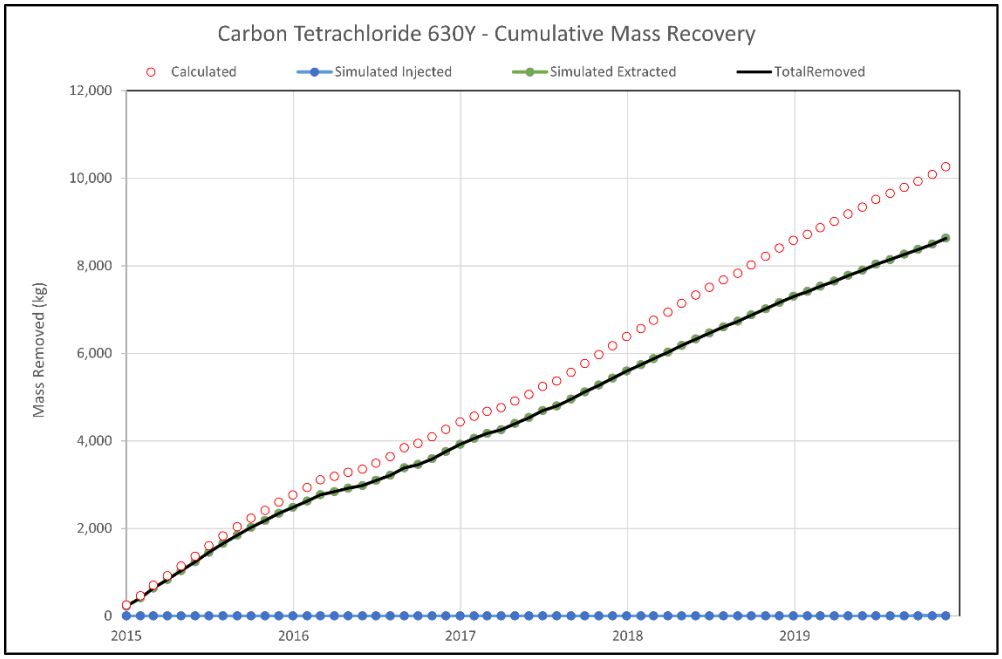


Figure 7-29. Cumulative Mass Removal for Carbon Tetrachloride 630Y Half Life - SGSIM Weighted Average Method

7.1.4 Projected Remedial System Mass Removal

The results of the predictive simulations of contaminant transport simulated using the P2R groundwater model, based upon data obtained through CY 2015, are presented in Figures 7-30 through 7-40. The terms that are depicted in these figures are defined as follows:

- **Wells:** The cumulative mass recovery at pumping wells, as read directly from the standard transport model output file
- **Reactions:** The cumulative mass destruction via reactions (e.g., radioactive decay and degradation), as read directly from the standard transport model output file
- **Simulated Mass Extracted + Decay:** The cumulative mass removed by wells and reactions
- **Mass Remaining:** Cumulative mass remained in aquifer calculated as initial mass in the aquifer minus mass removed by wells and reactions
- **Actual Mass Removed**: Reported cumulative mass recovered by P&T system

Figures 7-30 through 7-38 depict the projected cumulative mass recovery and the cumulative mass recovered as a fraction of initial mass (percentage) for simulations using initial plumes generated by ordinary quantile kriging method (ECF-200W-20-0052) as follows:

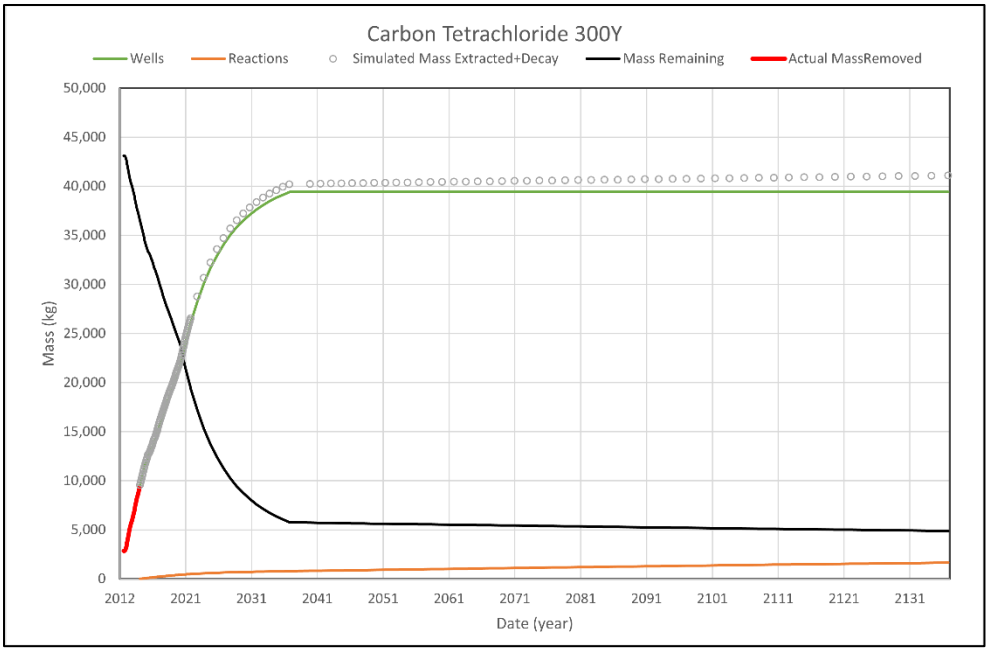
- Figure 7-30: carbon tetrachloride (assuming a 300-year half-life)
- Figure 7-31 carbon tetrachloride (assuming a 630-year half-life)
- Figure 7-32: chromium

- Figure 7-33: iodine-129
- Figure 7-34: nitrate
- Figure 7-35: technetium-99
- Figure 7-36: trichloroethene
- Figure 7-37: tritium
- Figure 7-38: uranium

Figures 7-39 and 7-40 depict the projected cumulative mass recovery and the cumulative mass recovered as a fraction of initial mass (percentage) for carbon tetrachloride which initial plumes were generated using SGSIM "weighted-average" method derived from the 100 SGSIM realizations described in ECF-200W-18-0028:

- Figure 7-39: carbon tetrachloride (assuming a 300-year half-life)
- Figure 7-40 carbon tetrachloride (assuming a 630-year half-life)

Inflections in the "wells" and "sinks" curves are seen to occur around 2037 and result from the simulated cessation of pumping at the 200-ZP-1 OU at that time.



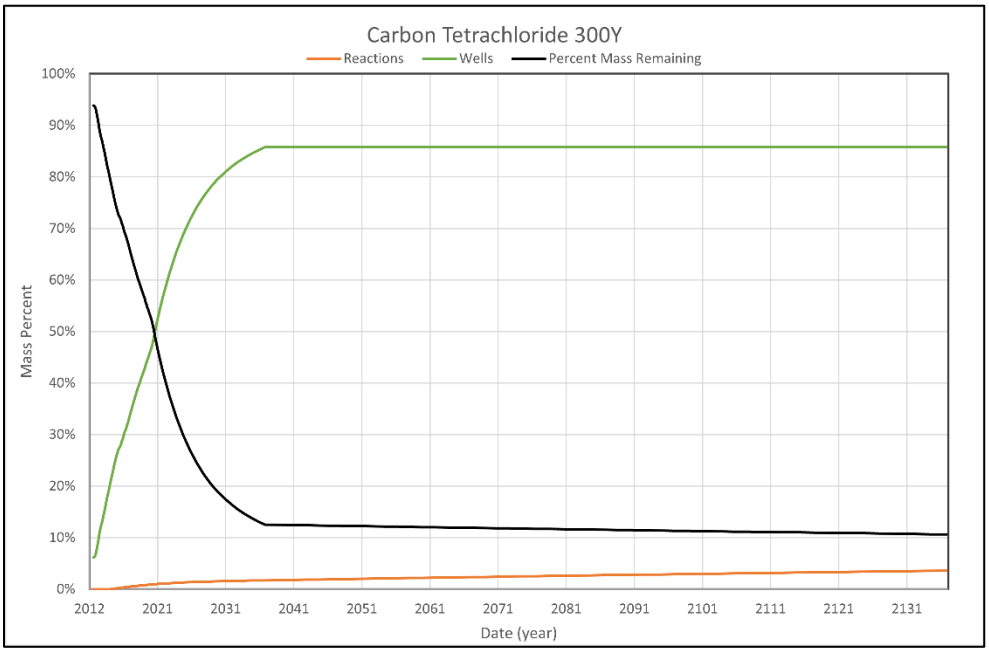
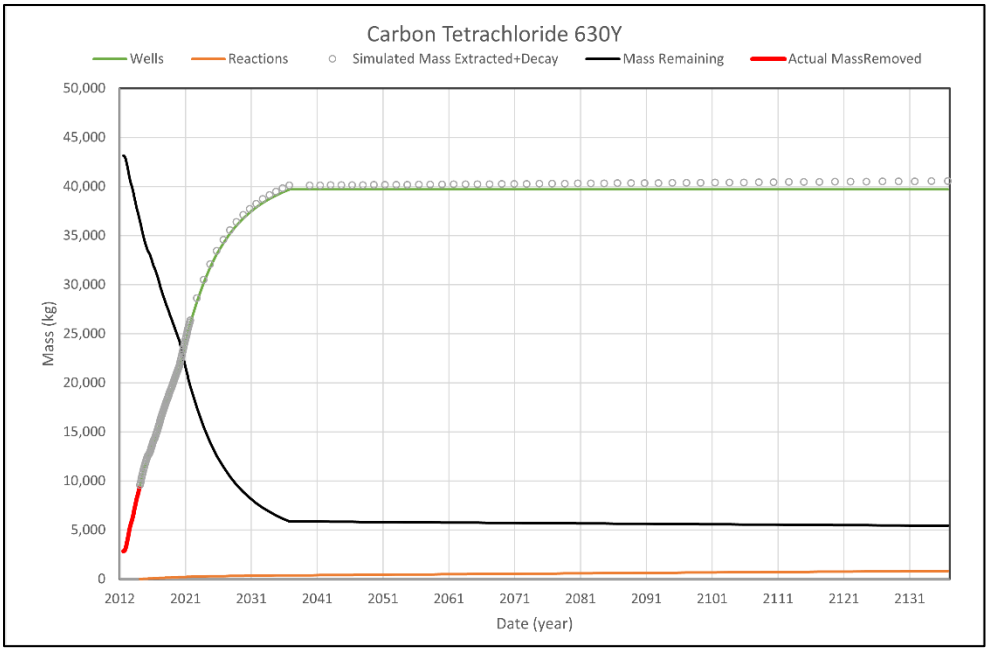


Figure 7-30. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Carbon Tetrachloride (Assuming 300-Year Half-Life)



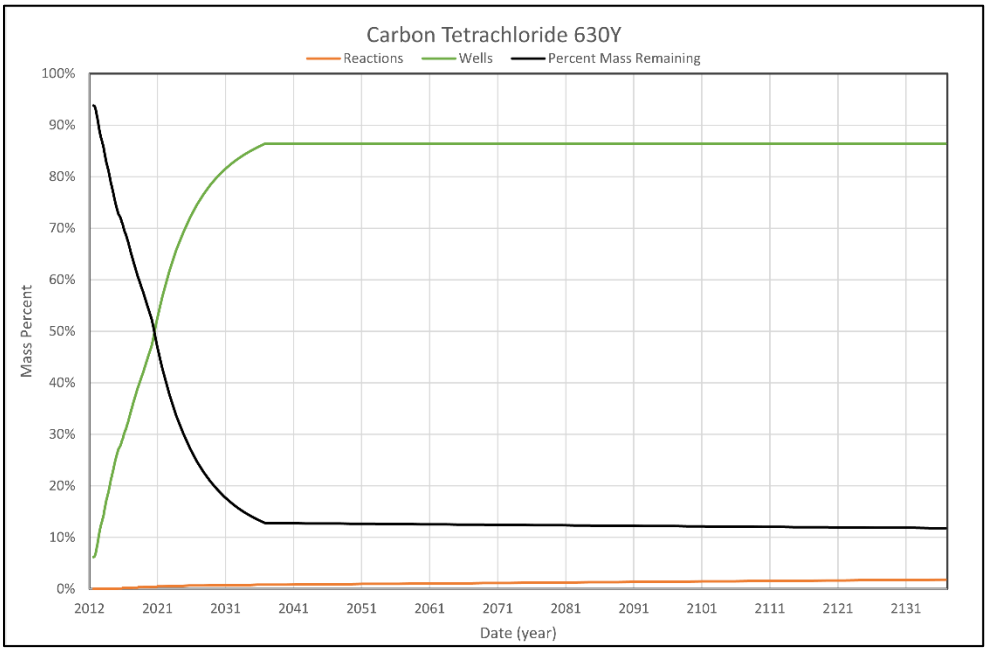
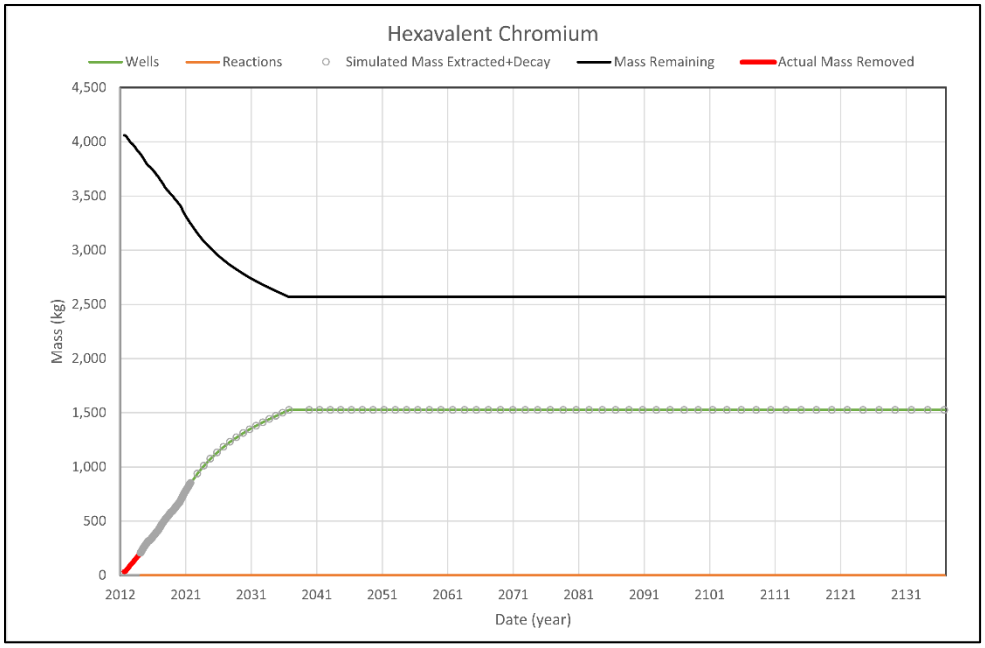


Figure 7-31. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Carbon Tetrachloride (Assuming 630-Year Half-Life)



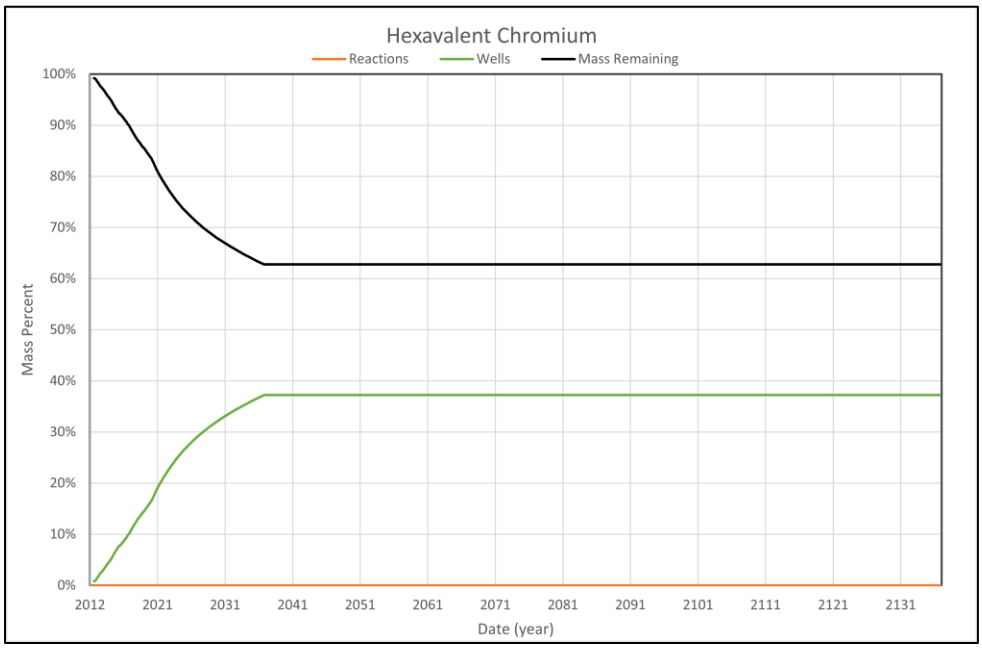
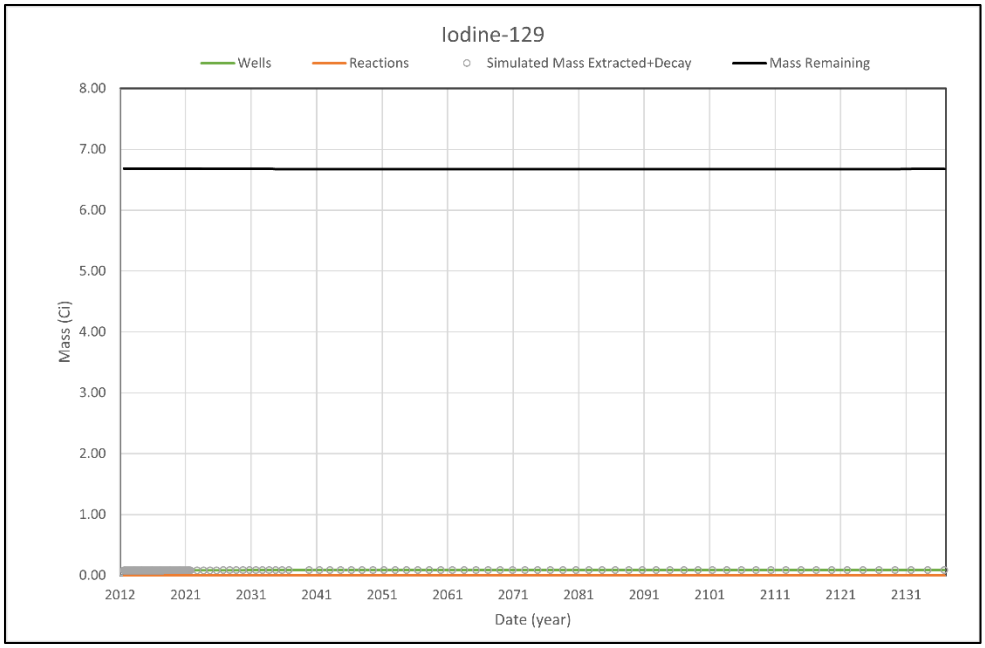


Figure 7-32. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Chromium



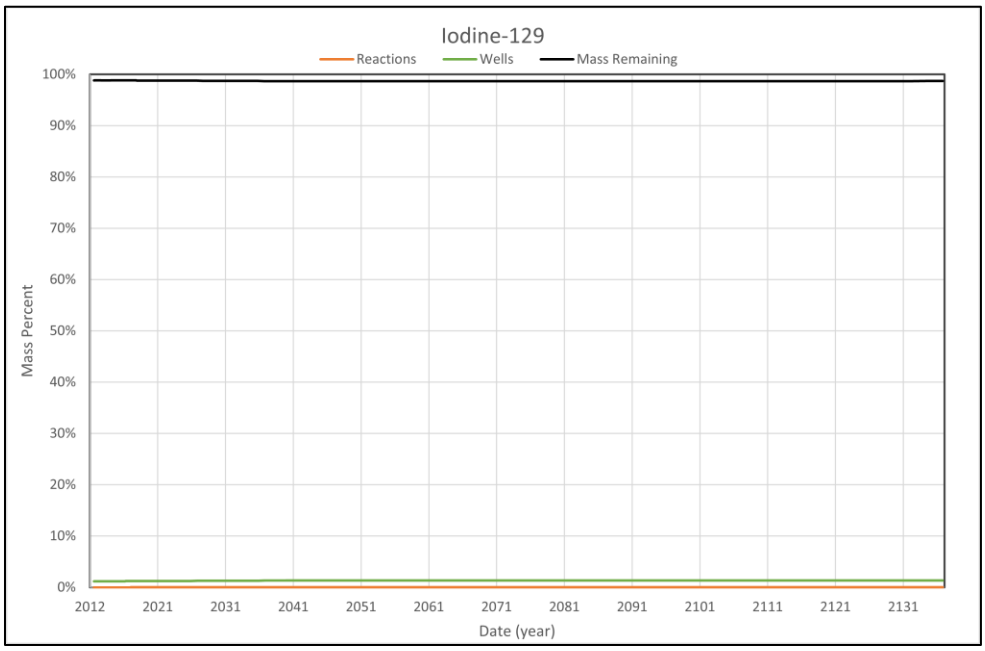
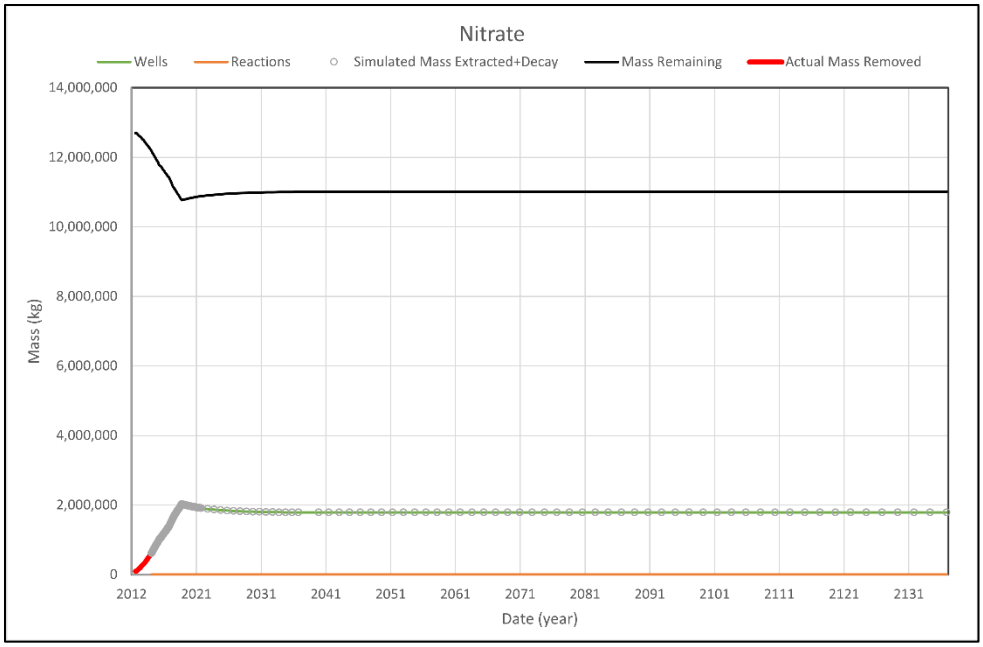


Figure 7-33. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Iodine-129



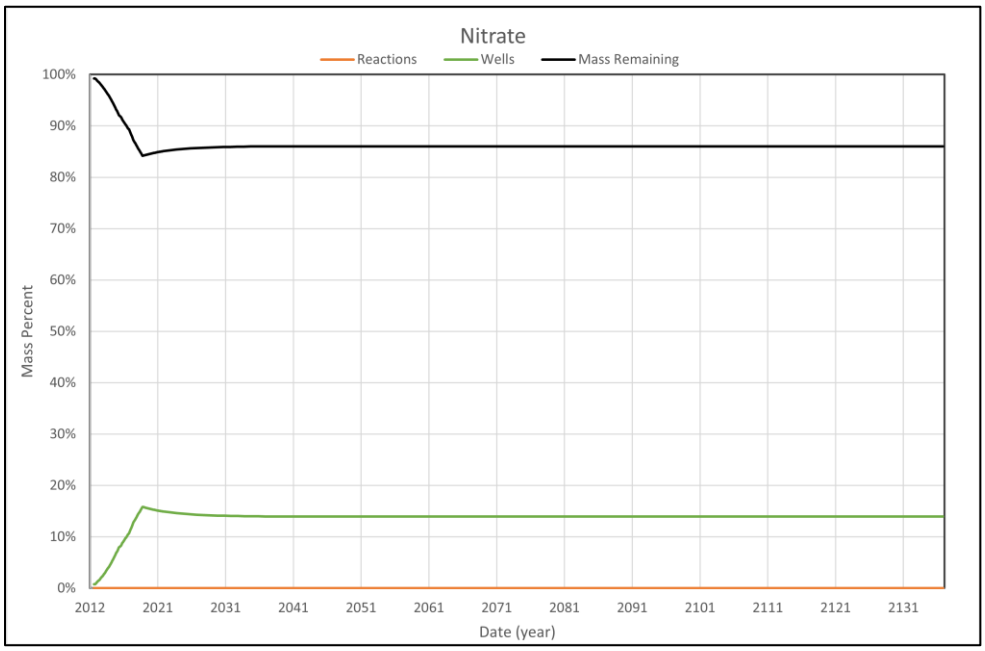


Figure 7-34. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Nitrate

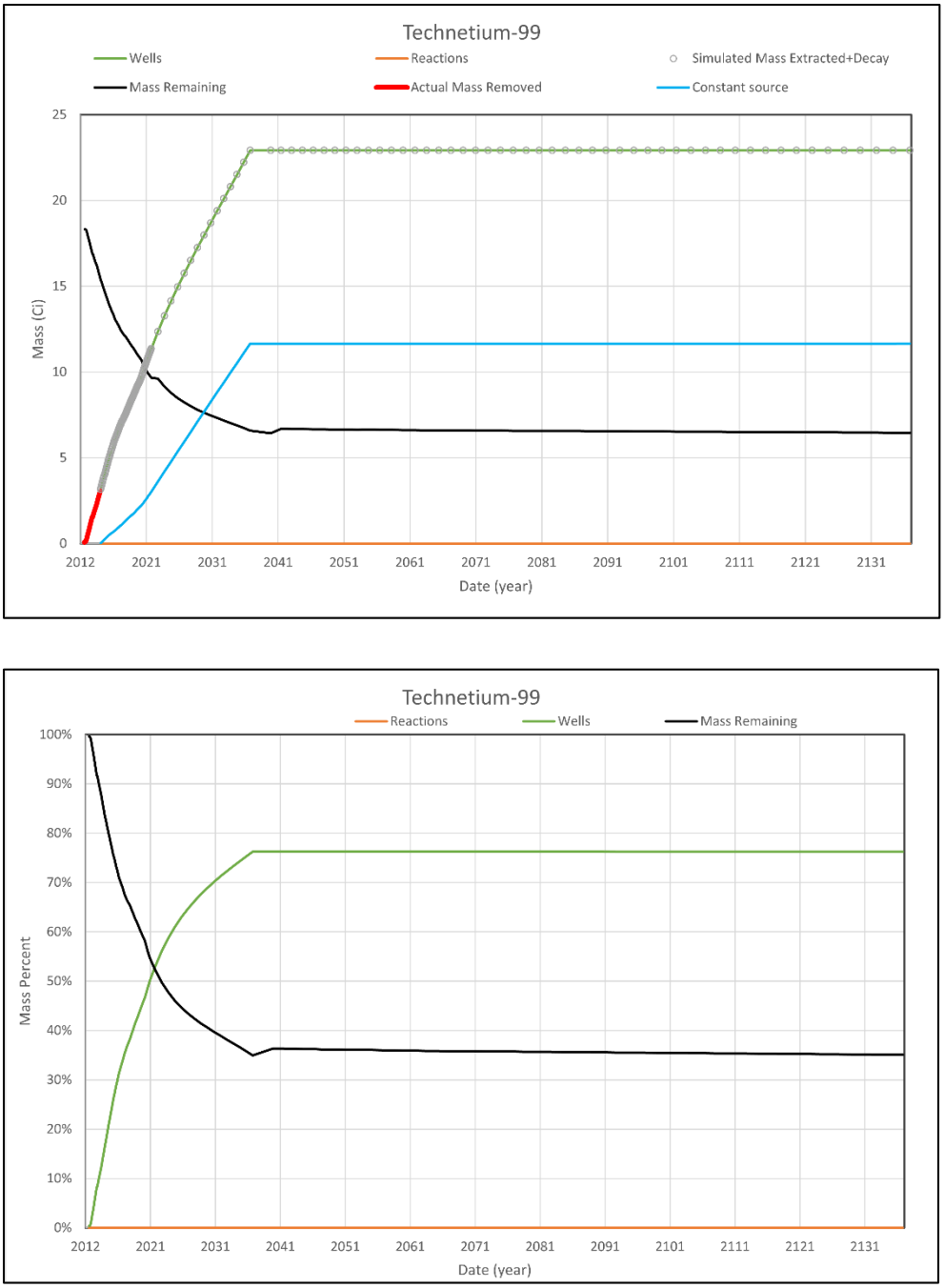
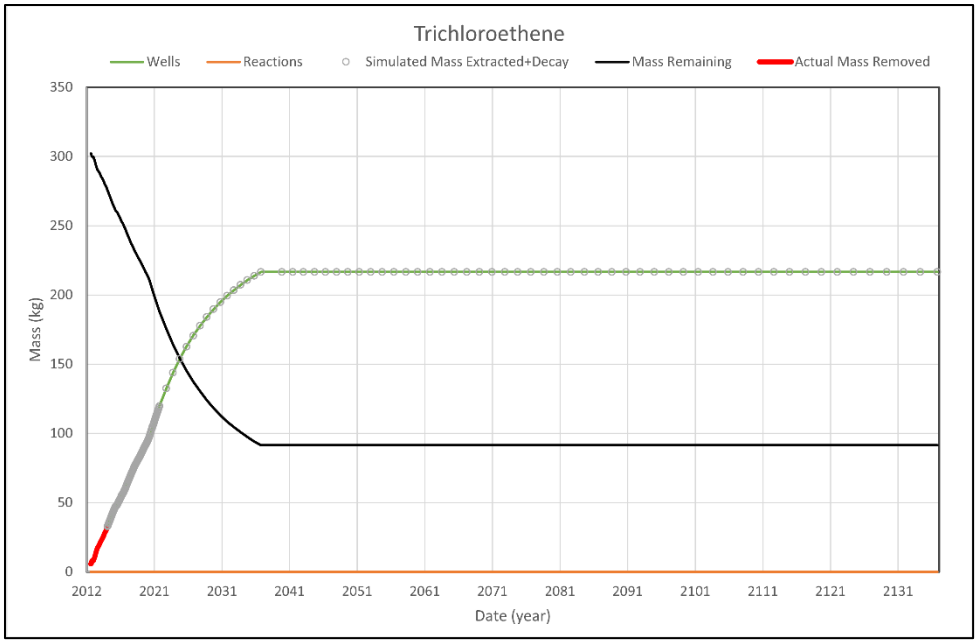


Figure 7-35. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Technetium-99



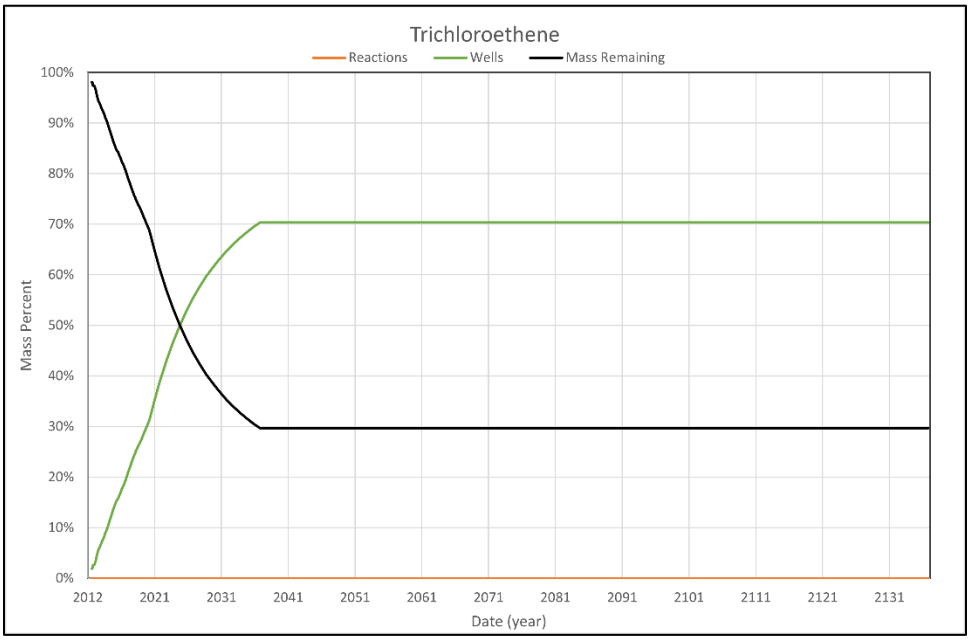
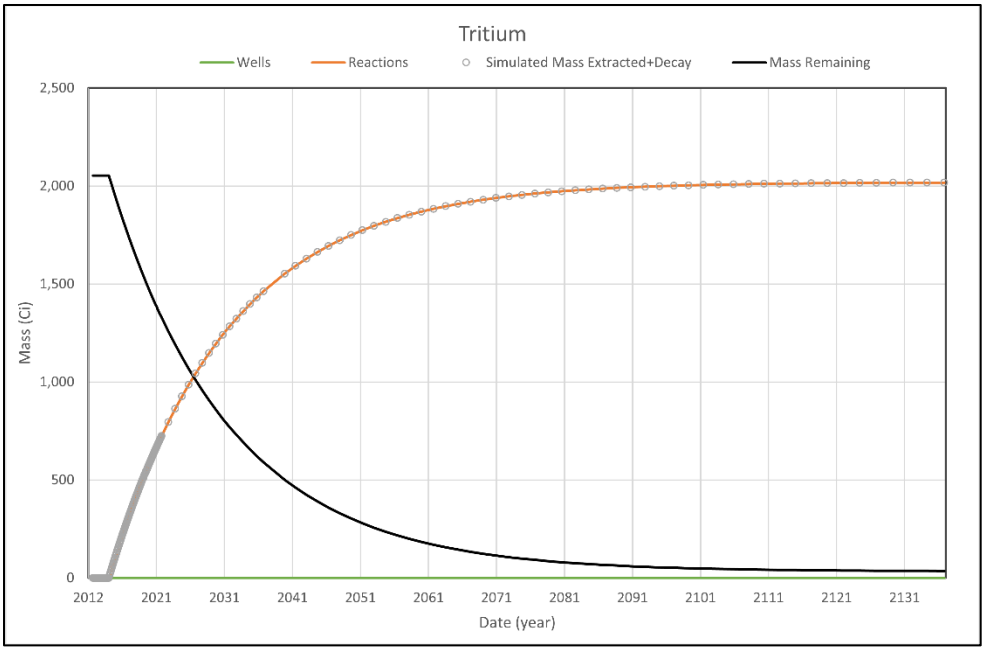


Figure 7-36. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Trichloroethene



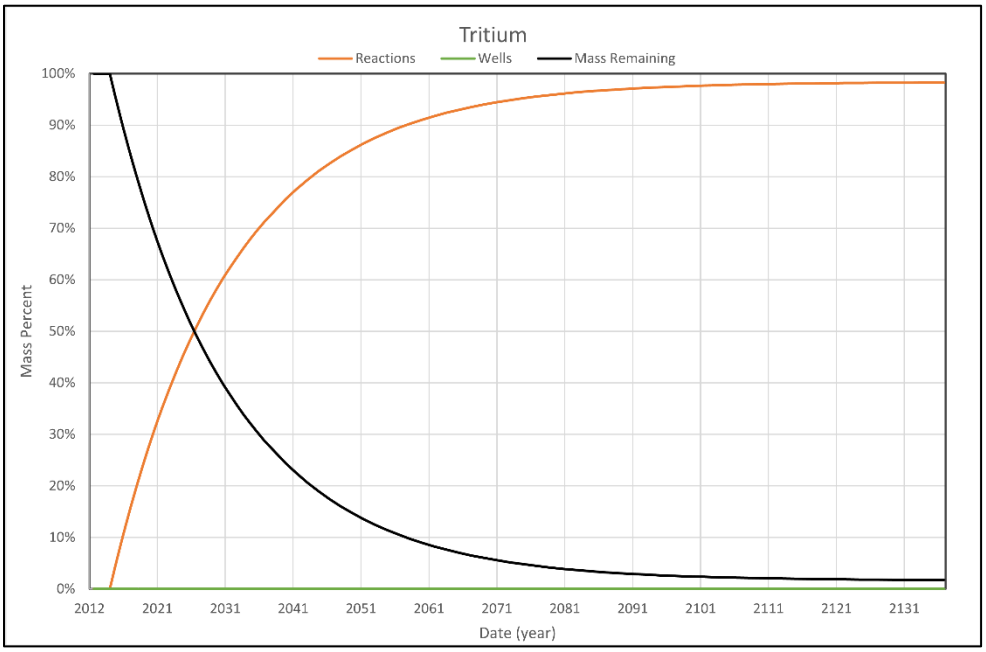


Figure 7-37. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Tritium

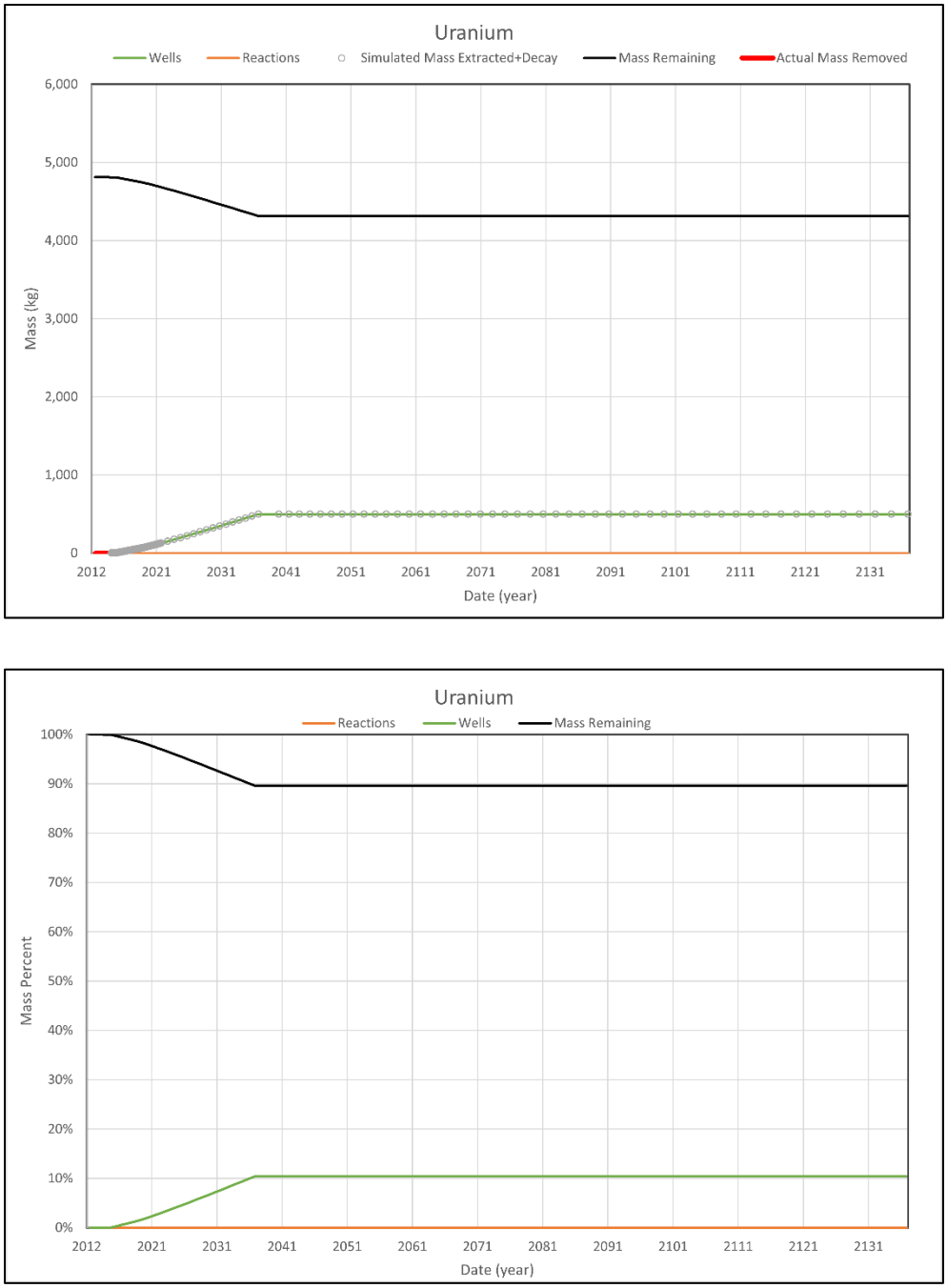
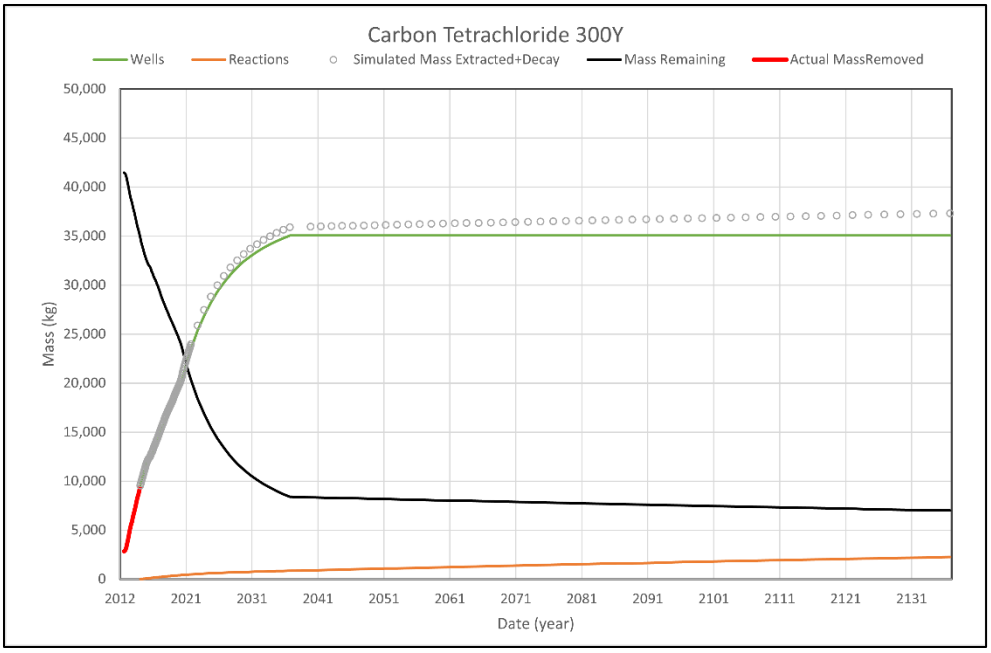


Figure 7-38. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Uranium



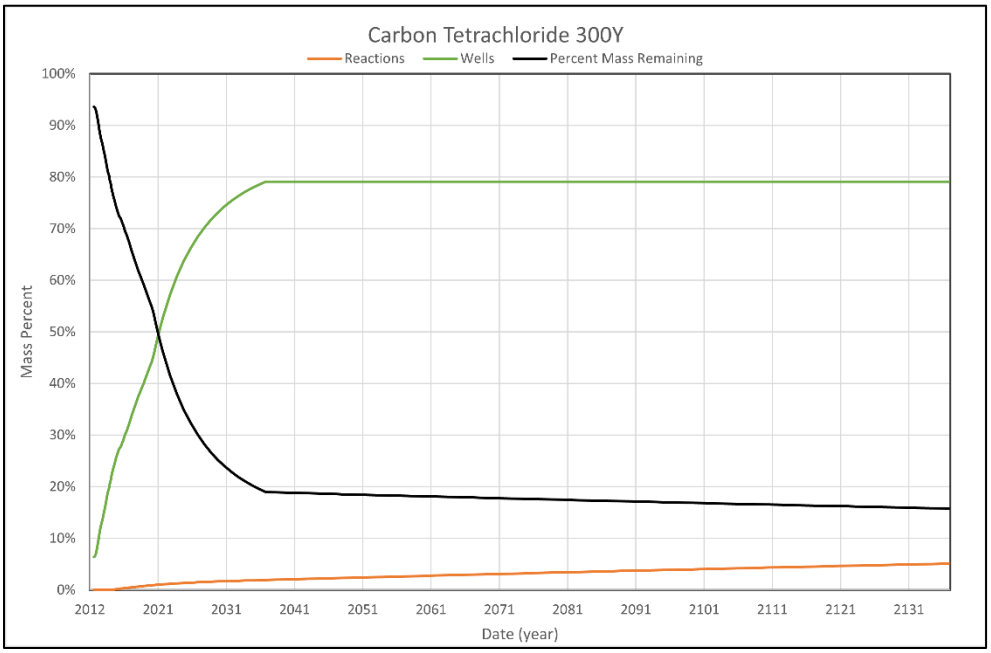
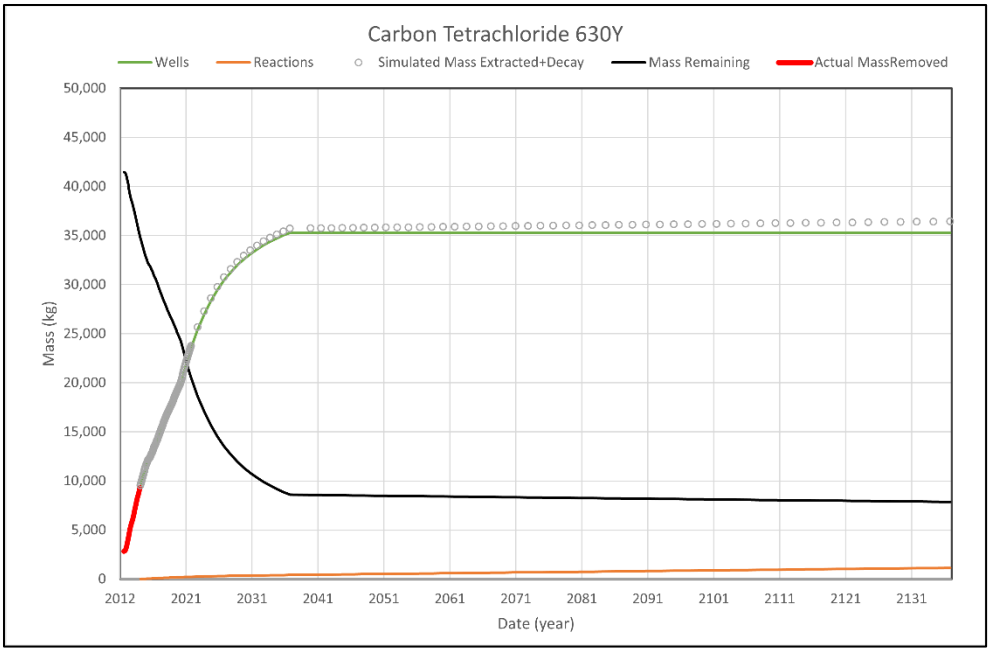


Figure 7-39. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Carbon Tetrachloride (Assuming 300-Year Half-Life) – SGSIM Method



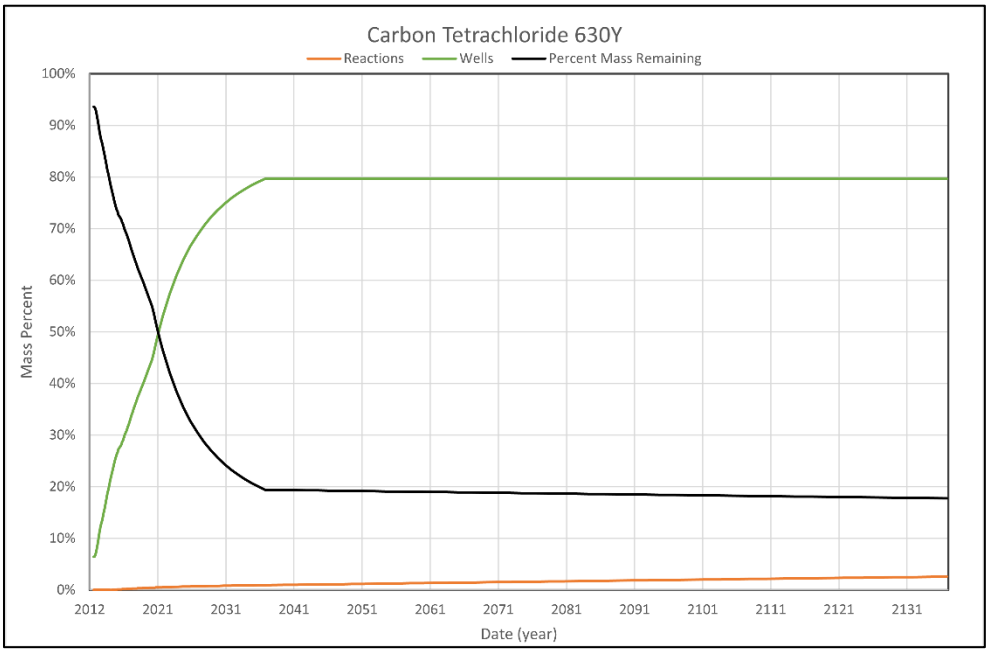


Figure 7-40. Projected (top) Cumulative Mass Recovery, and (bottom) Cumulative Mass Recovered as a Fraction of Initial Mass (%) for Carbon Tetrachloride (Assuming 630-Year Half-Life) – SGSIM Method

Table 7-1 presents a summary of the projected carbon tetrachloride mass that will be recovered by the 200 West P&T remedy at the end of active pumping (CY 2037) and the fraction of the initial mass that this represents, for alternate SGSIM realizations compared to the quantile-kriging and SGSIM weighted-average.

Table 7-2 presents a summary of the projected contaminant mass that will be recovered by the 200 West P&T remedy, the fraction of the initial mass that this represents, and selected concentration statistics

(i.e., the median, average, and 90th percentile) for each COC remaining in groundwater at the end of active pumping (CY 2037).

Figures 7-41 through 7-44 depict the projected cumulative carbon tetrachloride plume extents for years 2022, 2027, 2032, and 2037 compared to the initial mass in 2015 as generated using the quantile method assuming 630-Year Half-Life.

Table 7-1. Mass Recovered, Fraction of Initial Mass Recovered for Carbon Tetrachloride at End of Active Pumping (2037)

Run	Initial Condition	Half Life (years)	K_d	Porosity	Calculated R	Initial Mass 2015 (kg)			Mass Extracted (kg)	Mass Decayed (kg)	Mass Remediated (kg)	Mass removed prior CY 2015	% Total Mass Remediated in 2037	% Dissolved Mass Remediated in 2037
						Dissolved	Sorbed	Total						
1	Quantile Kriging	300	0.011	0.15	1.1404	32,141	4,514	36,655	30,110	789	30,899	8,783	87%	97%
2	Stochastic Average Weighted					30,676	4,308	34,985	25,730	856	26,586		81%	90%
3	Stochastic E-Type					45,310	6,363	51,673	30,178	1,583	31,761		67%	75%
1	Quantile Kriging	630				32,141	4,514	36,655	30,396	379	30,775	8,783	87%	97%
2	Stochastic Average Weighted					30,676	4,308	34,985	25,978	411	26,389		80%	89%
3	Stochastic E-Type					45,310	6,363	51,673	30,487	762	31,249		66%	74%

CY = calendar year

K_d = distribution coefficient

Table 7-2. Mass Recovered, Fraction of Initial Mass Recovered, and Concentration Statistics (Median, Average, and 90th Percentile) for Each COC at End of Active Pumping (2037)

Contaminant of Concern	Half Life (years)	K_d	Porosity	Calculated R	Initial Mass 2015 (kg)			Mass Remediated by P&T (kg)	Mass Decayed (kg)	Total Mass Removed (kg)	Reported Mass removed prior CY 2015	% Total Mass Remediated in 2037	% Dissolved Mass Remediated in 2037	Projected 2037 Concentrations		
					Dissolved	Sorbed	Total							Median	Average	90th Percentile
Carbon Tetrachloride 300y Half life (kg | µg/L)	300	0.011	0.15	1.1404	32,141	4,514	36,655	30,110	789	30,899	8,783	87%	97%	0.011	0.15	1.1404
Carbon Tetrachloride 630y Half life (kg | µg/L)	630	0.011	0.15	1.1404	32,141	4,514	36,655	30,396	379	30,775	8,783	87%	97%	0.011	0.15	1.1404
Chromium (kg | µg/L)	NA	0	0.15	1.0000	3,893	-	3,893	1,325	-	1,325	181	37%	37%	0	0.15	1.0000
Iodine-129 (Ci | pCi/L)	1.57E+07	0.1000	0.15	2.2767	3	4	6.7	0.01	6.63E-06	0.01	0	0%	0%	0.1000	0.15	2.2767
Nitrate (as NO3) (kg | µg/L)	NA	0	0.15	1.0000	12,201,500	-	12,201,500	1,275,850	-	1,275,850	580,375	15%	15%	0	0.15	1.0000
Technetium (Ci | pCi/L)	211000	0	0.15	1.0000	15	-	15	20	0	20	3	125%	125%	0	0.15	1.0000
Trichloroethene (kg | µg/L)	NA	0.025	0.15	1.3192	210	67	276	185	-	185	32	70%	90%	0.025	0.15	1.3192
Uranium (kg | µg/L)	4.47E+09	0.40000	0.15	6.1067	788	4,024	4,812	497	0	497	-	10%	63%	0.40000	0.15	6.1067
Tritium (Ci | pCi/L)	12.3	0	0.15	1.0000	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	0.15	1.0000

COC = contaminant of concern K_d = distribution coefficient P&T = pump and treat
CY = calendar year NA = not applicable

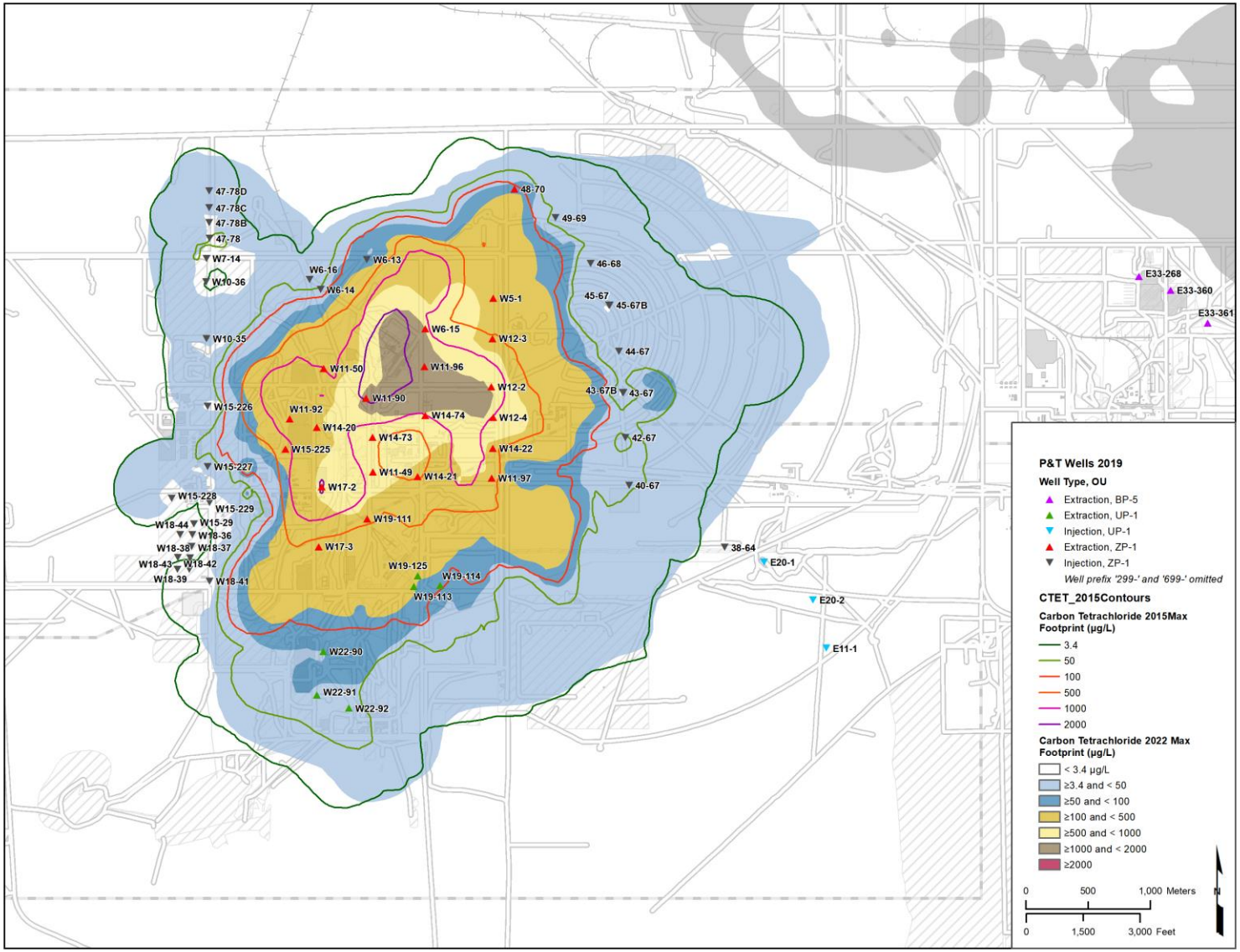


Figure 7-41. Projected Carbon Tetrachloride Plume Extent in CY 2022 using a Half-Life of 630 Years

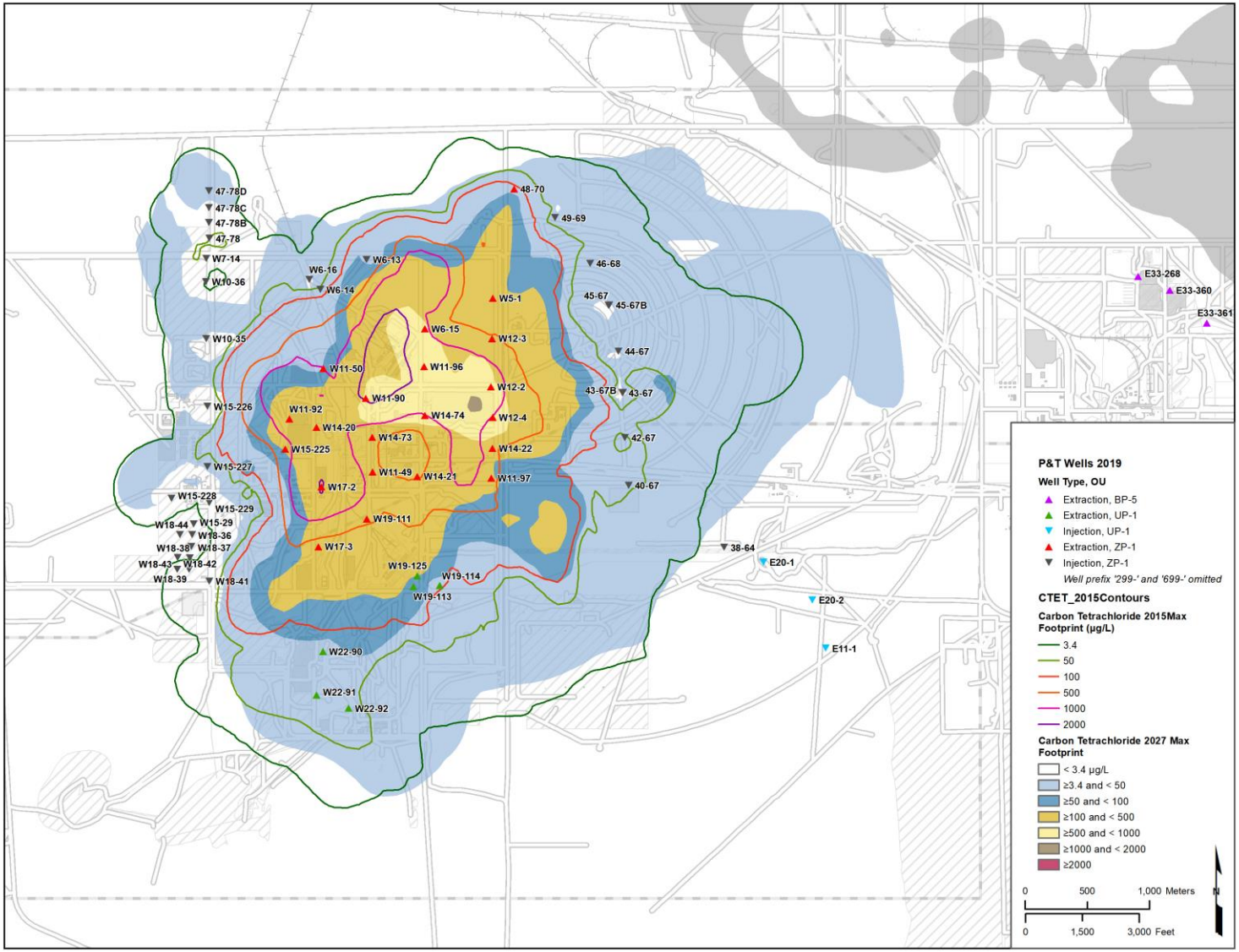


Figure 7-42. Projected Carbon Tetrachloride Plume Extent in CY 2027 using a Half-Life of 630 Years

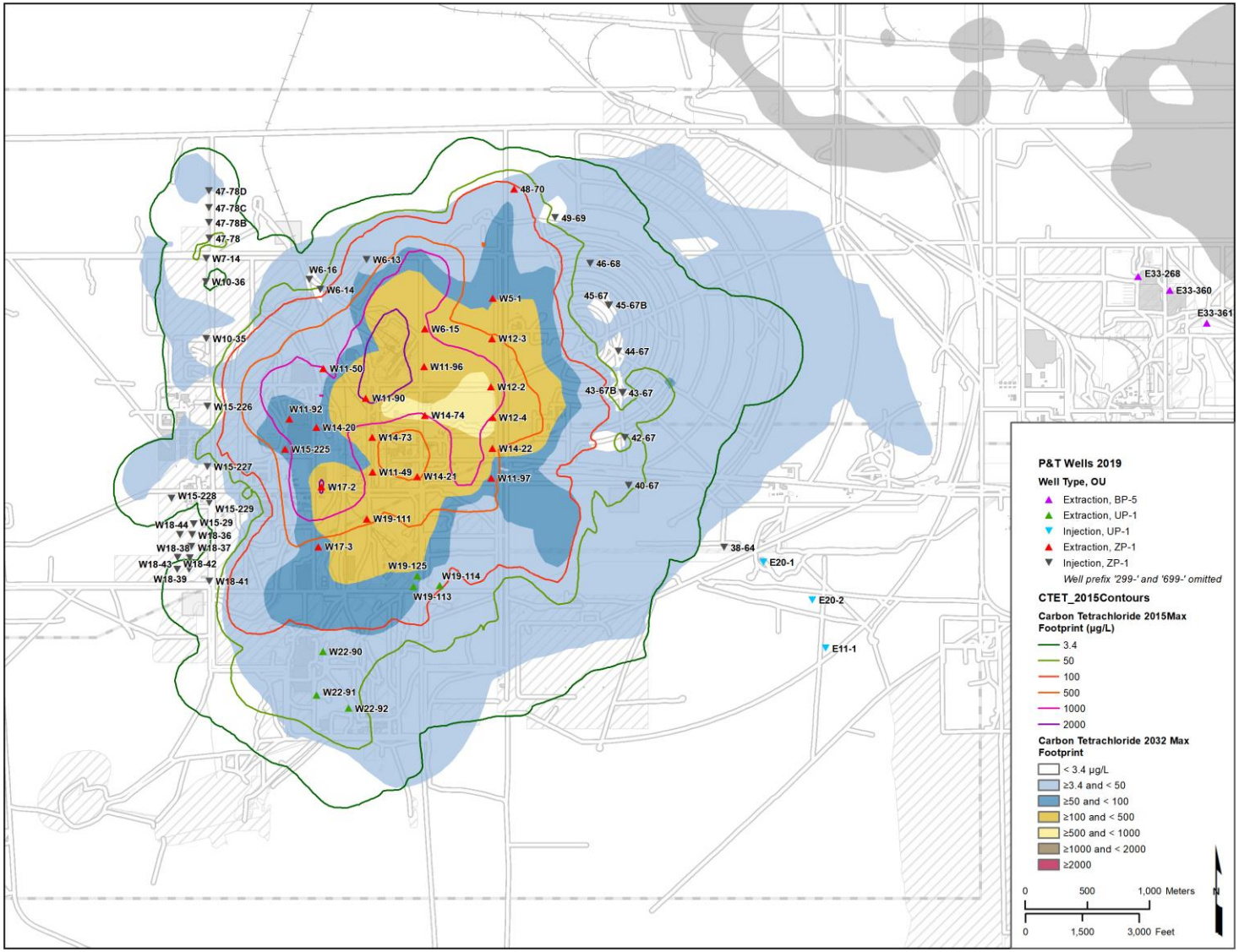


Figure 7-43. Projected Carbon Tetrachloride Plume Extent in CY 2032 using a Half-Life of 630 Years

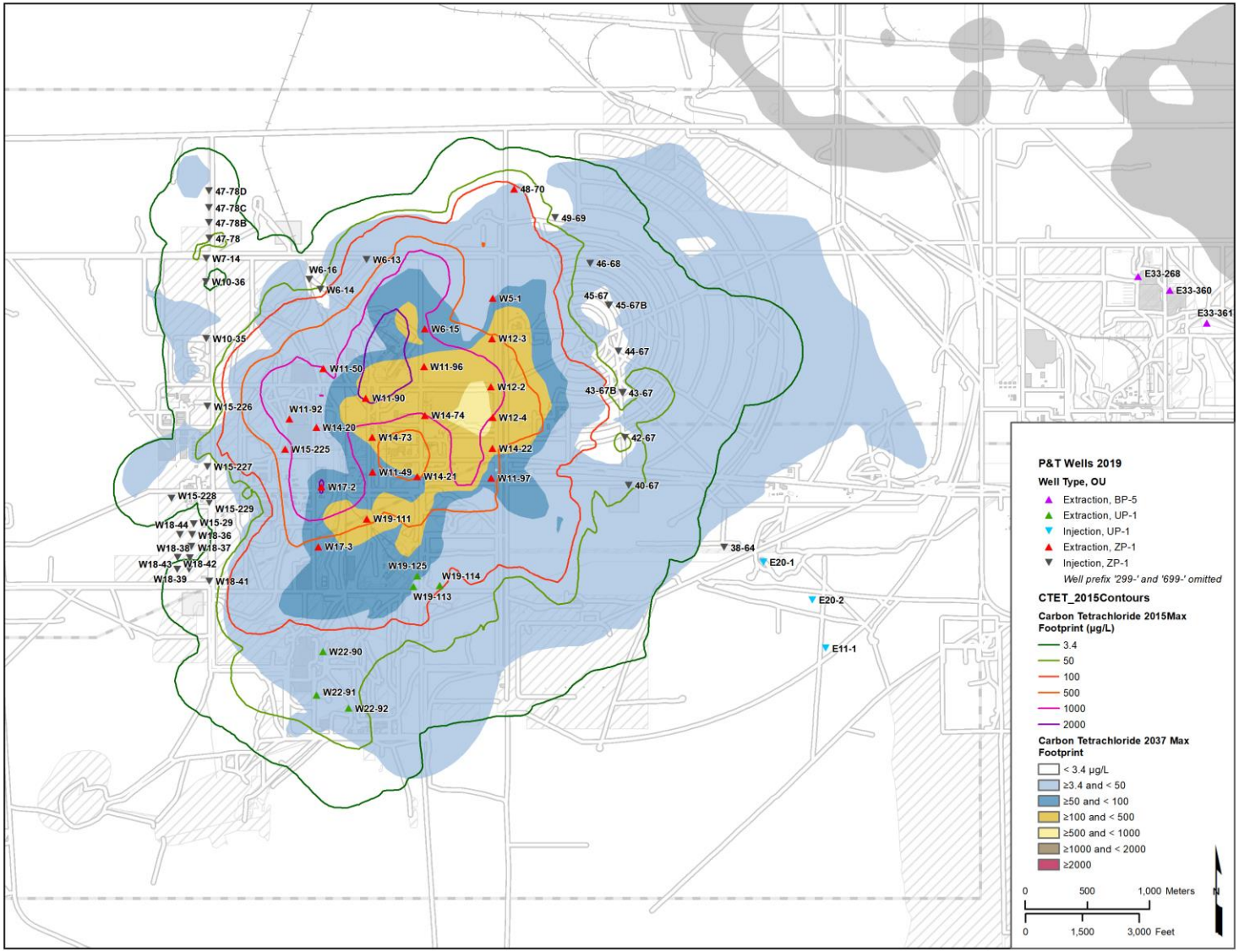


Figure 7-44. Projected Carbon Tetrachloride Plume Extent in CY 2037 using a Half-Life of 630 Years

7.2 200-UP-1 Operable Unit - S-SX Tank Farms

This section presents figures and tables produced as output from the calculations contained in this ECF for the 200-UP-1 S-SX Tank Farms P&T remedy. These calculations and figures are produced as an accessory to the calculations undertaken to evaluate the performance of the 200-ZP-1 remedy, and are provided here to assist with inferring the performance of the 200-UP-1 remedies. Other calculations, analyses and figures in addition to those presented here are produced and documented in ECF-200UP1-17-0094, *Fate and Transport Analysis for WMA S-SX Groundwater Plumes in the 200-UP-1 Operable Unit*, to support evaluations of the 200-UP-1 remedies.

7.2.1 Hydraulic Containment and Flowpaths

Figure 7-45 depicts mapped water levels together with estimated particle paths computed using reverse tracking from each extraction well as described in Section 6.2.1. Annual time-stamps are depicted on the particle paths, which were estimated based upon the groundwater levels and hydraulic gradients, and the pumping rates during December 2019. Figures 7-46 through 7-48 depict the same water-level map and particle paths, as well as the mapped extent of technetium-99, chromium, and nitrate, respectively, as depicted in ECF-Hanford-20-0018. When operating, the hydraulic capture zones developed by the S-SX extraction wells effectively cover most of the technetium-99 plumes at concentrations above 9,000 pCi/L.

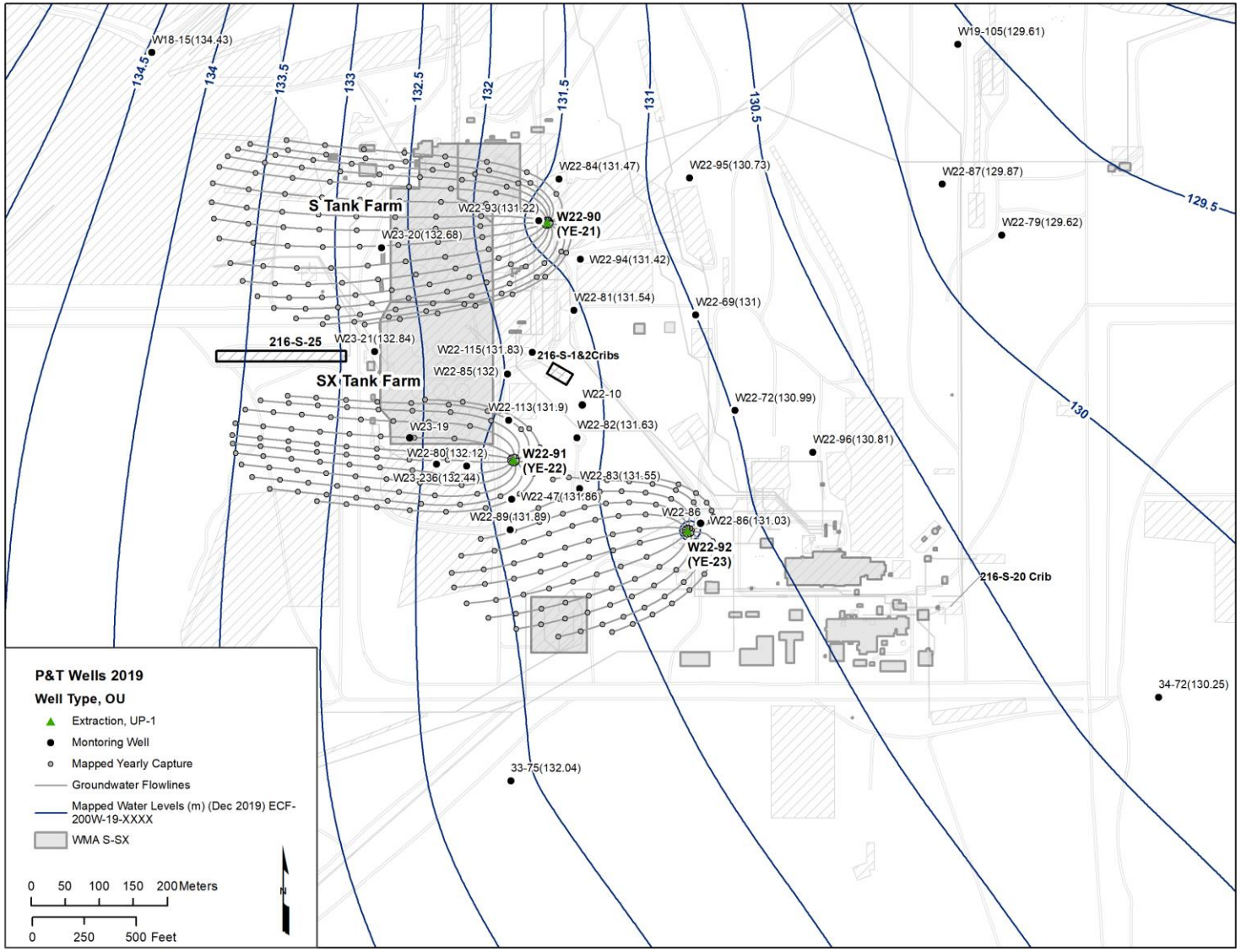


Figure 7-45. Groundwater Levels (Mapping Method) and Calculated Pathlines for 200-UP-1 OU - S-SX Tank Farms

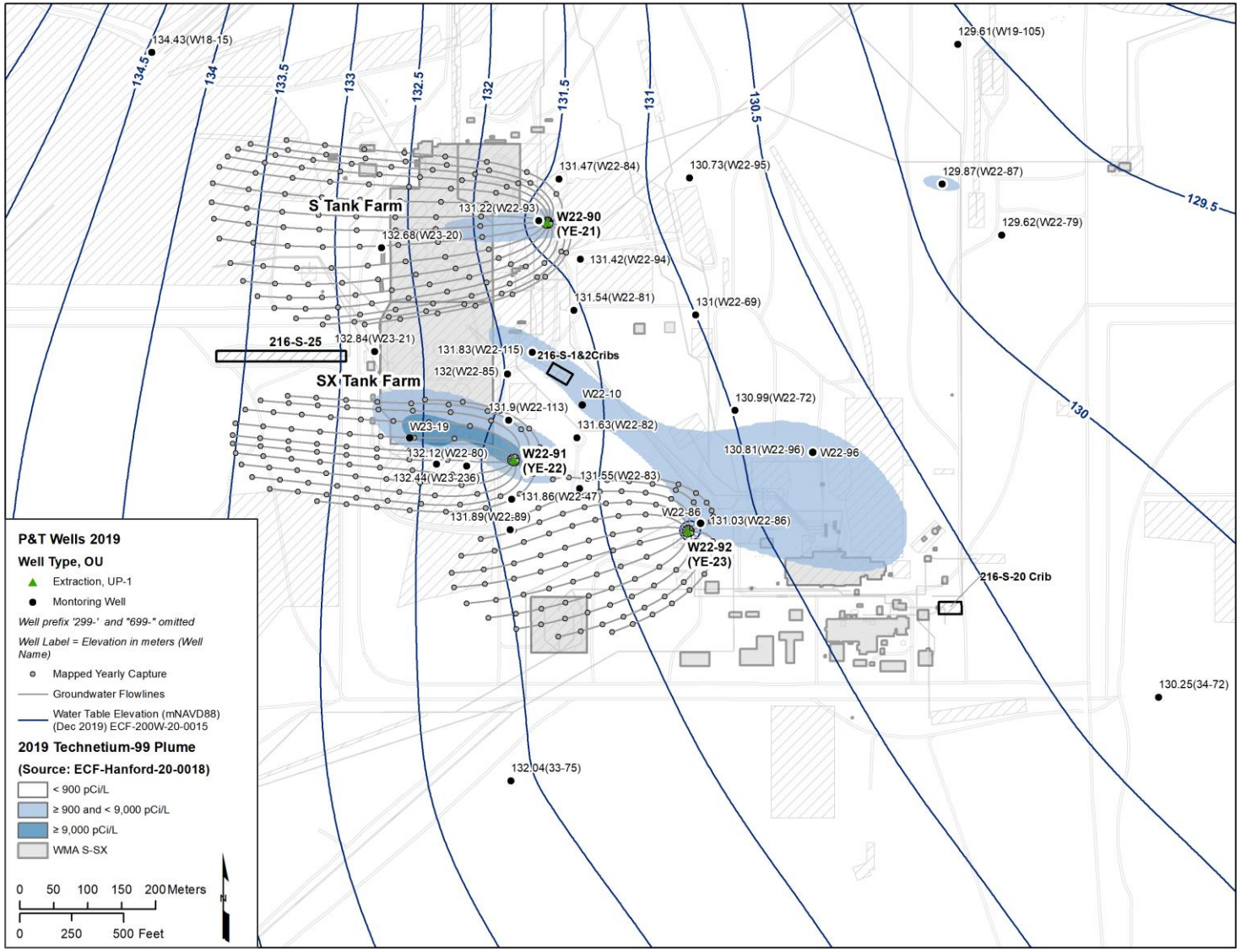


Figure 7-46. Calculated Pathlines and Extent of Technetium-99 for 200-UP-1 OU - S-SX Tank Farms

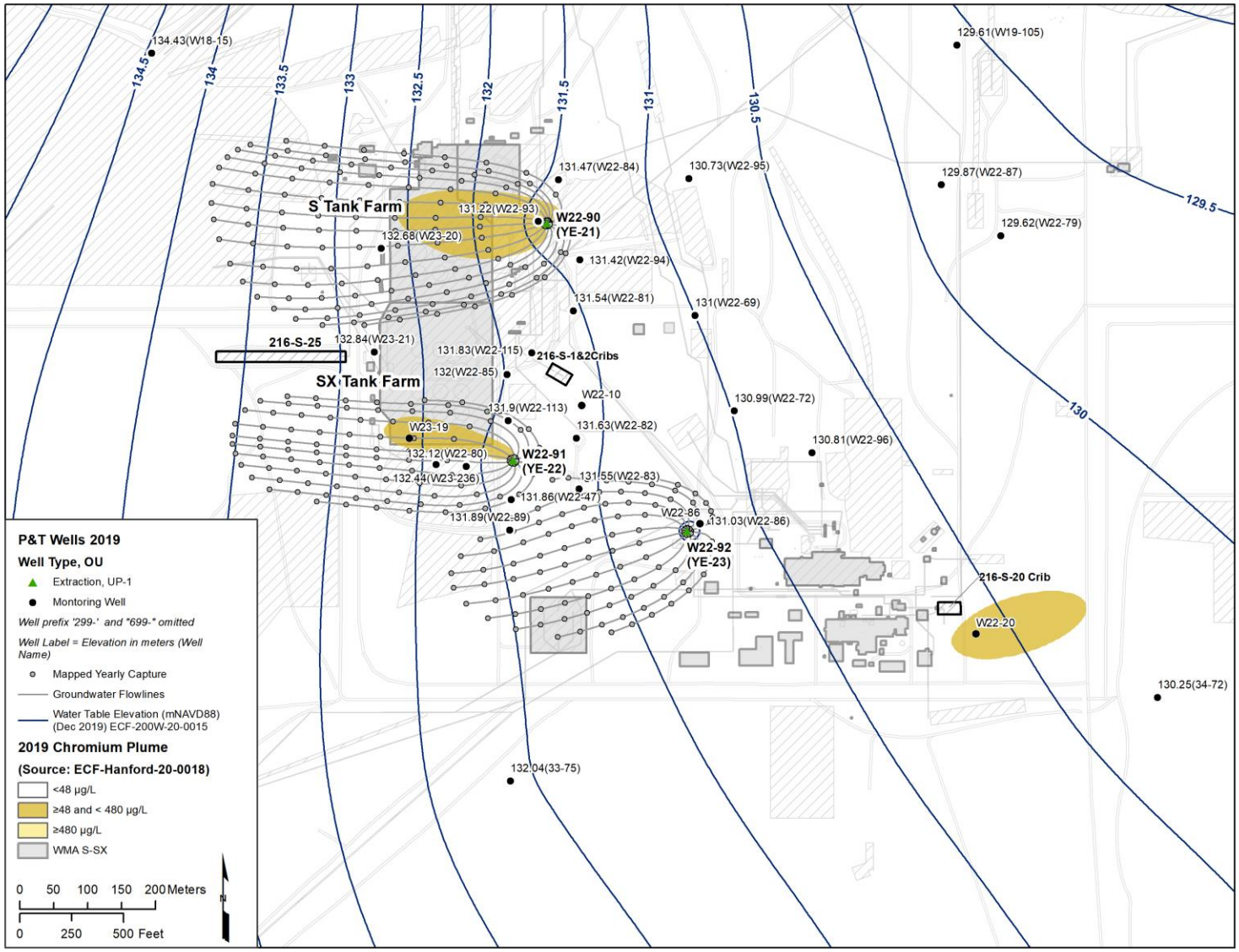


Figure 7-47. Calculated Pathlines and Extent of Chromium for 200-UP-1 OU - S-SX Tank Farms

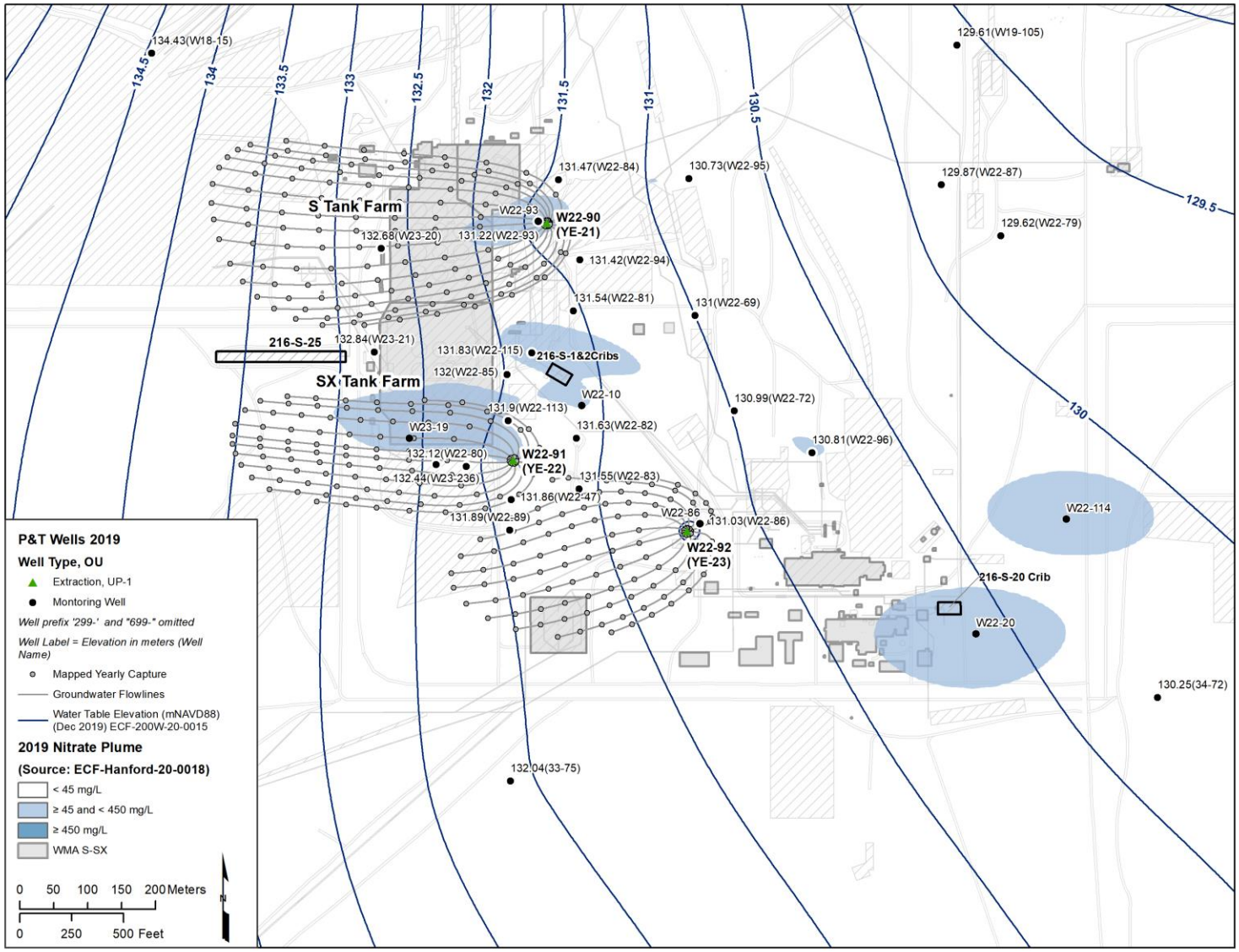


Figure 7-48. Calculated Pathlines and Extent of Nitrate for 200-UP-1 OU - S-SX Tank Farms

7.3 200-UP-1 - U Plant

This section presents figures and tables produced as output from the calculations described in this ECF for the 200-UP-1 OU U Plant extraction and injection remedy components. These calculations and figures are produced as an accessory to the calculations undertaken to evaluate the performance of the 200-ZP-1 remedy, and are provided here to assist with inferring the performance of the 200-UP-1 remedies. Other calculations, analyses and figures in addition to those presented here are produced and documented in ECF-200UP1-17-0093, *Fate and Transport Analysis for U Plant Groundwater Plumes in the 200-UP-1 Operable Unit*, and ECF-200UP1-18-0018, *200-UP-1 U Plant 2017 Uranium Plume Pump and Treat System Analysis*, to support evaluations of the 200-UP-1 remedies.

7.3.1 Hydraulic Containment and Flowpaths

Figure 7-49 depicts mapped water levels and estimated particle paths computed using reverse tracking from each extraction well. The figure also depicts approximate annual time stamps based upon groundwater levels, hydraulic gradients and pumping rates during December 2019. Figures 7-50 through 7-52 depict the same water-level map and particle paths, together with the mapped extent of uranium, technetium-99, and nitrate, respectively, as depicted in ECF-Hanford-19-0010.

Figures 7-51 and 7-52 show the December 2019 capture zones with the technetium-99 and nitrate plumes, respectively. The technetium-99 plume south of the U Plant is completely enveloped by the capture zones. For nitrate, all concentrations in the U Plant area are now below the high-concentration level (i.e., greater than 450 mg/L). The selected remedies for nitrate were P&T for the high-concentration area at U Plant and MNA for the remainder of the plume.

7.3.2 Hydraulic Containment and Flow Path Control for Iodine-129

Injection wells installed close to the leading edge of the iodine-129 plume on the east side of the 200-UP-1 OU are designed to slow the migration of the iodine-129 plume while attenuation processes take place to reduce concentrations in groundwater. Figure 7-53 depicts the mapped groundwater elevations for December 2019 near the injection well line of control established to contain and slow the migration of the iodine-129 plume. Figures 7-54 and 7-55 depict outputs from the flow-path control assessment that was developed with specific application for 200-ZP-1, as applied to the injection wells of the 200-UP-1 iodine-129 remedy. These figures depict areas where hydraulic gradients are reduced or reversed by the injection. In each case, the direction and length of the arrows posted along a control line indicate the direction and relative magnitude of the hydraulic gradient at that location: inset “a” depicts the “Baseline” hydraulic conditions of the flow field under baseline conditions represented by March 2015 water levels, whereas inset “b” depicts “Current” December 2019 hydraulic conditions of the flow field. In each case, posted arrows represent the flow direction and arrow length represent the hydraulic gradients. The colored map depicts the change in hydraulic gradients, which is calculated as the difference between hydraulic gradients in current conditions and baseline conditions. Figure 7-54 depicts results as calculated using the water-level mapping method, whereas Figure 7-55 depicts results as calculated using the P2R Model. Together, Figures 7-54 and 7-55 depict reductions in hydraulic gradients (indicated by negative change in hydraulic gradient shaded in red color). These results are consistent with expectations, as gradients have been reduced, and in some places reversed, in the region between the iodine-129 plume and injection wells.

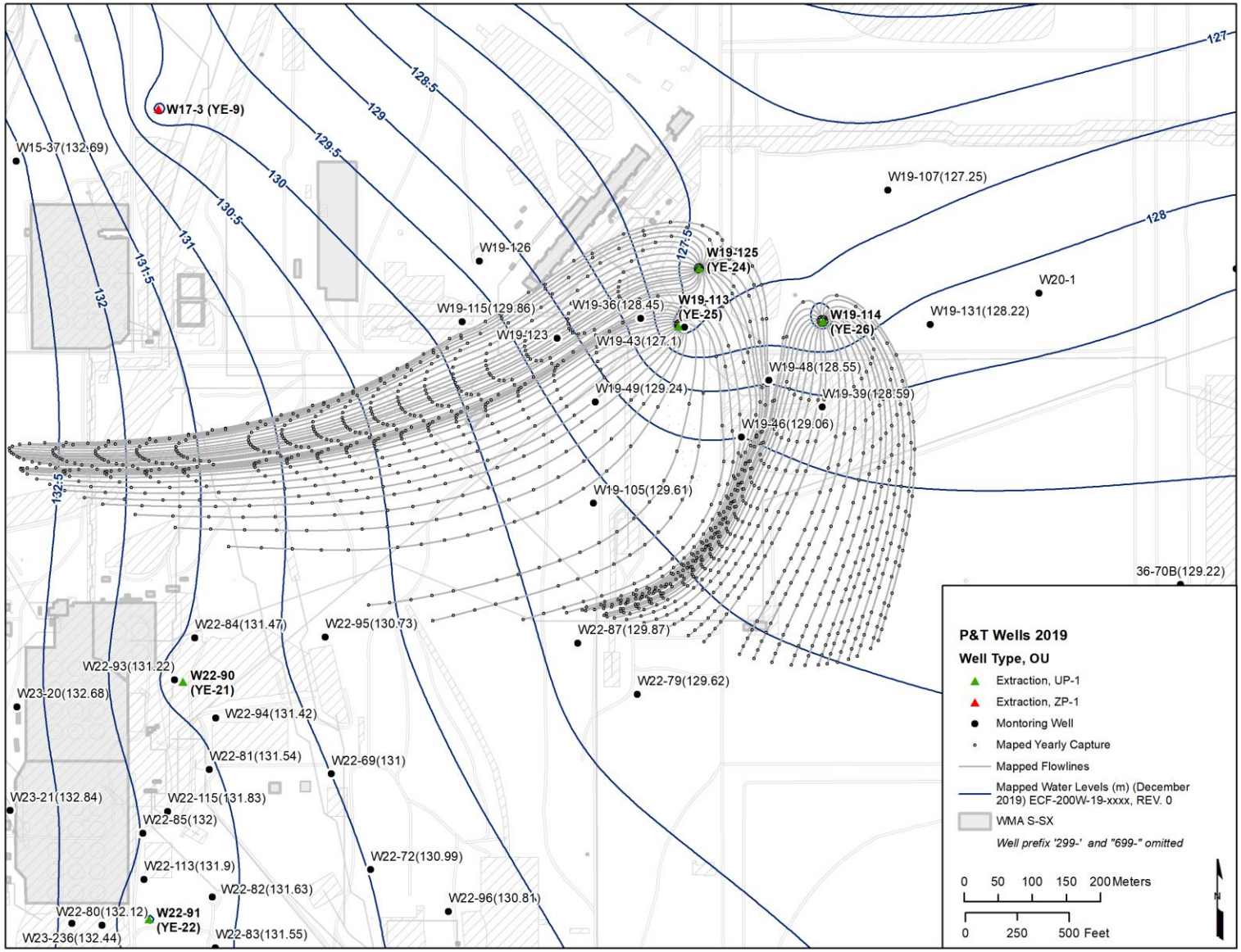


Figure 7-49. Groundwater Levels (Mapping Method) and Calculated Pathlines for 200-UP-1 OU - U Plant

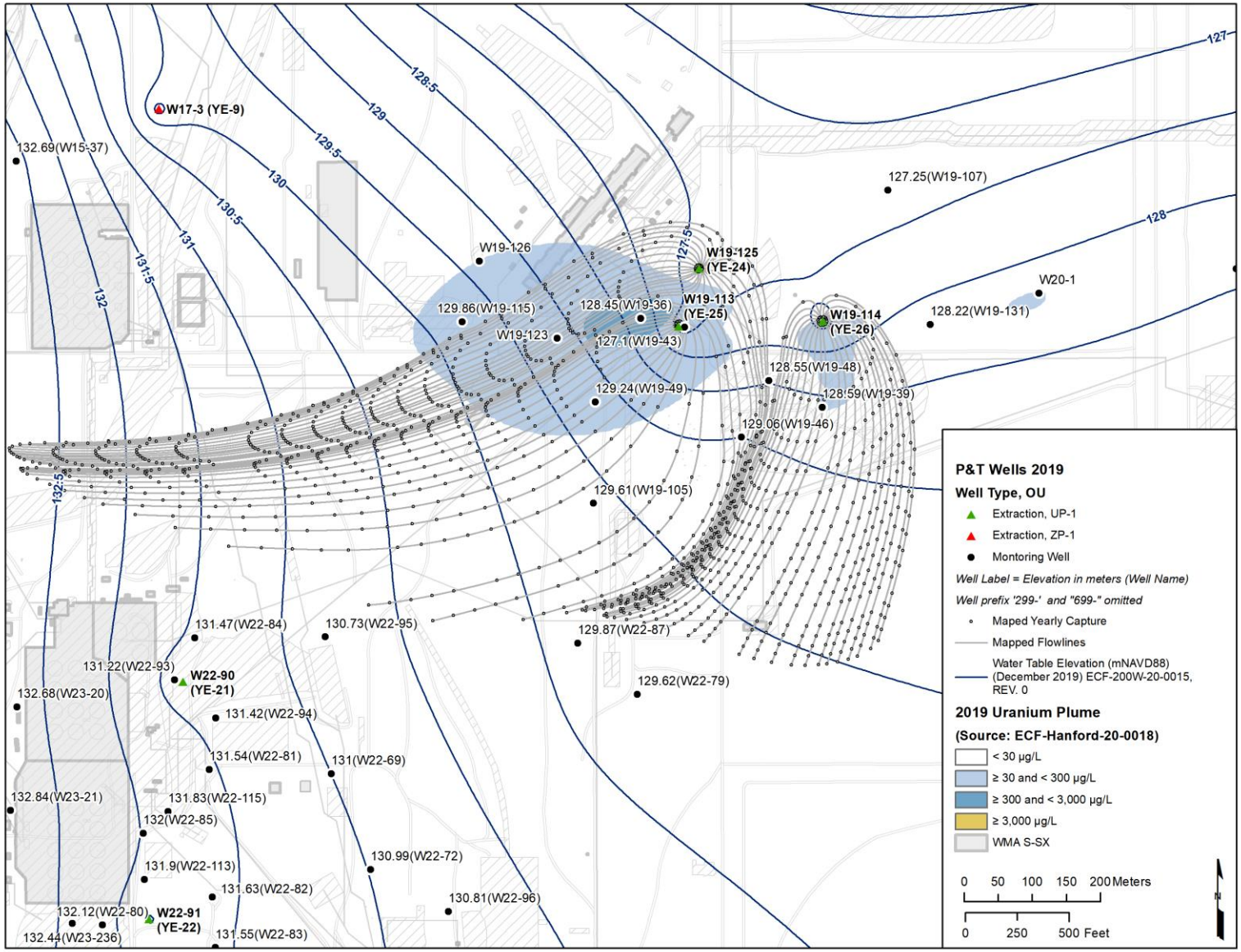


Figure 7-50. Calculated Pathlines and Extent of Uranium for 200-UP-1 OU - U Plant

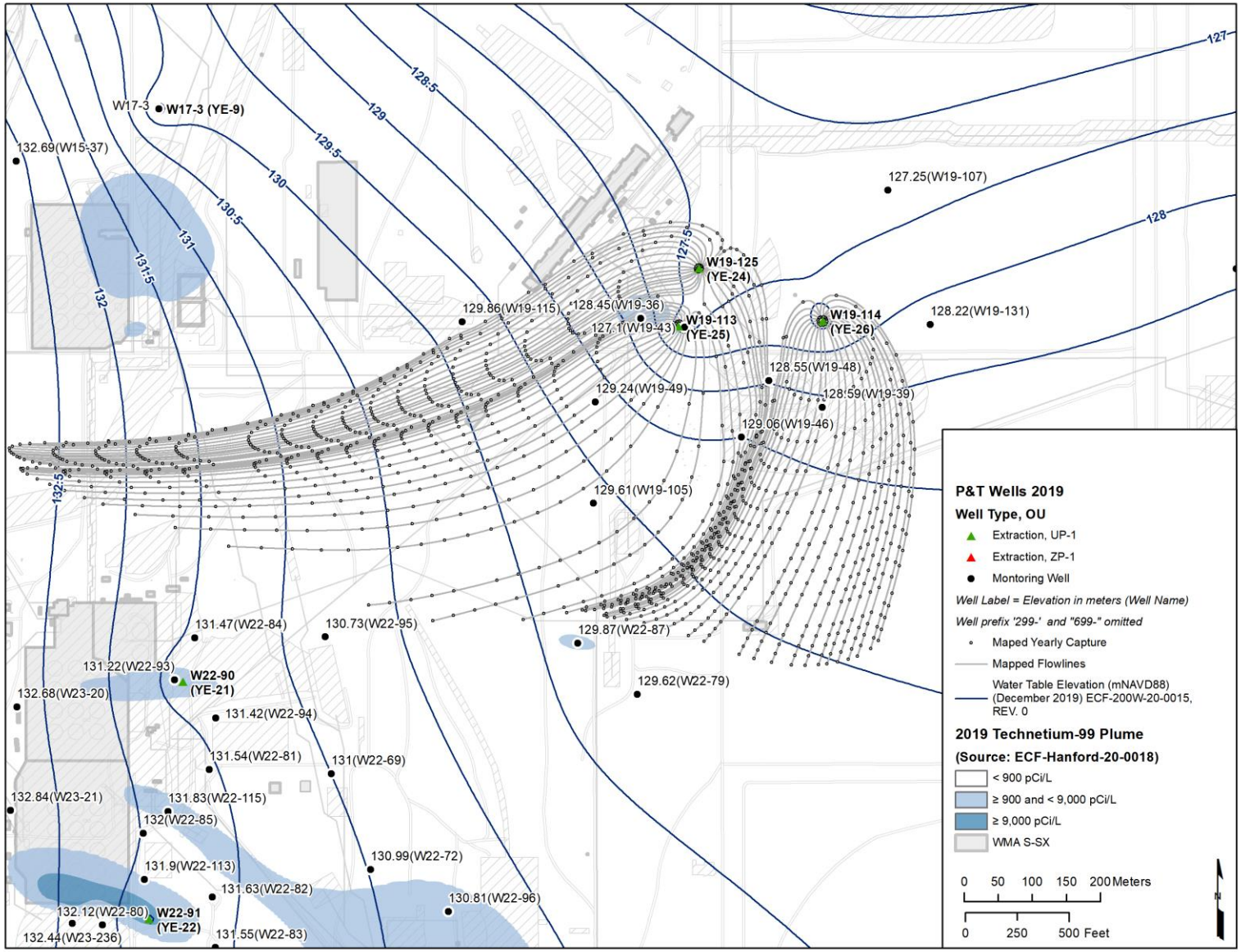


Figure 7-51. Calculated Pathlines and Extent of Technetium-99 for 200-UP-1 OU - U Plant

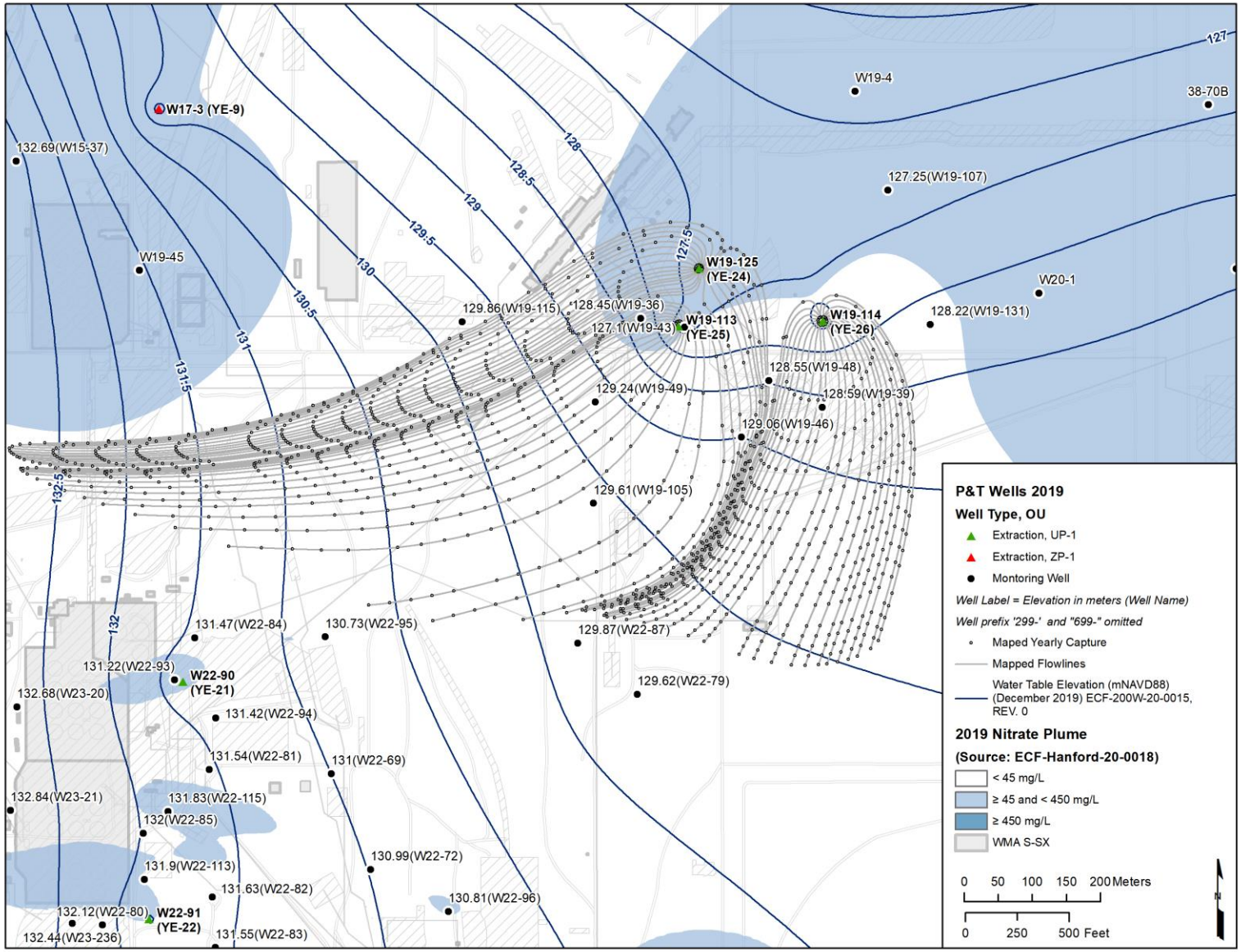


Figure 7-52. Calculated Pathlines and Extent of Nitrate for 200-UP-1 OU - U Plant

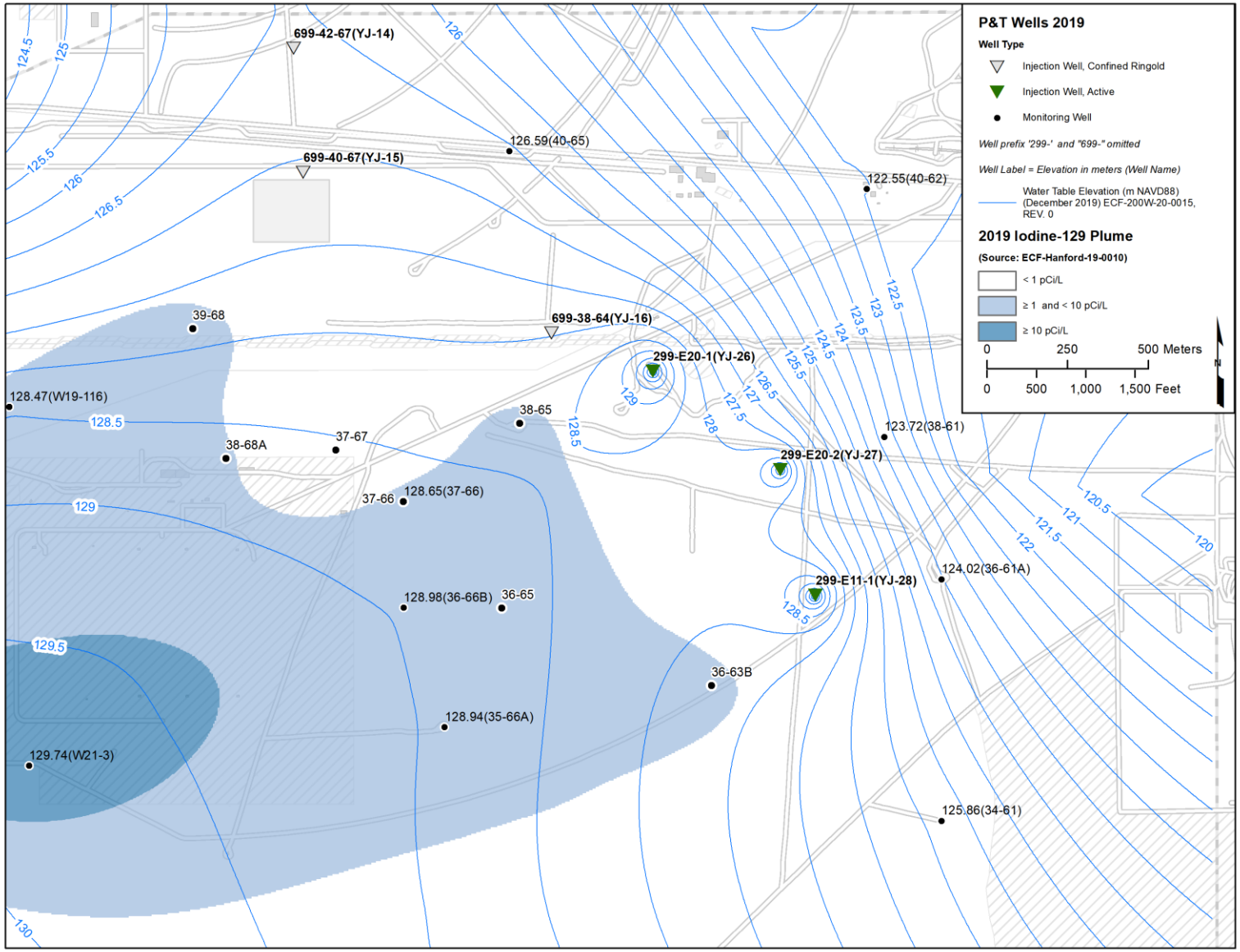


Figure 7-53. Mapped Groundwater Elevations along Iodine-129 Injection Well Line of Control, December 2019

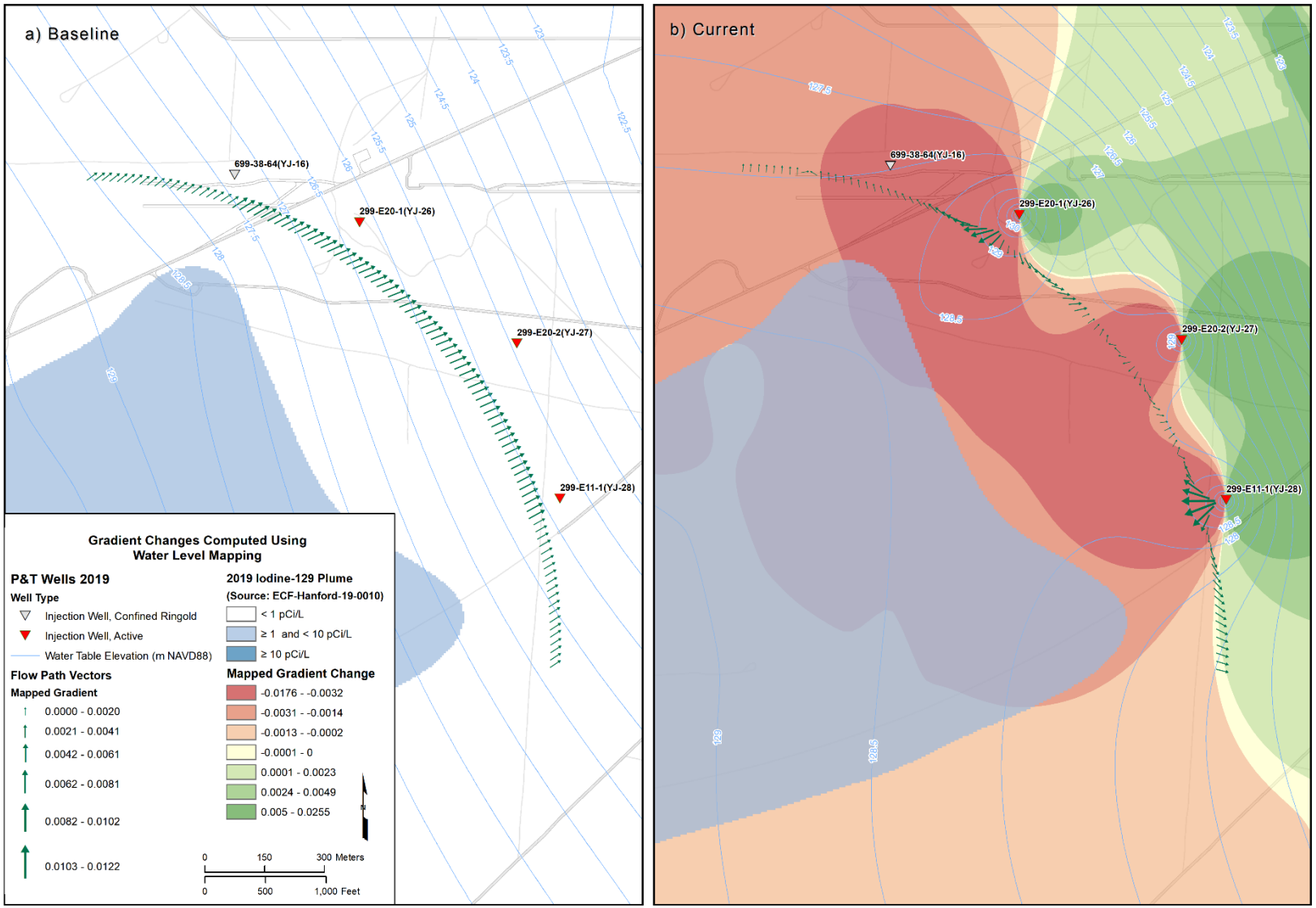


Figure 7-54. Mapped Gradient Changes Along Line of Control above the Rlm: (a) Baseline and (b) Current

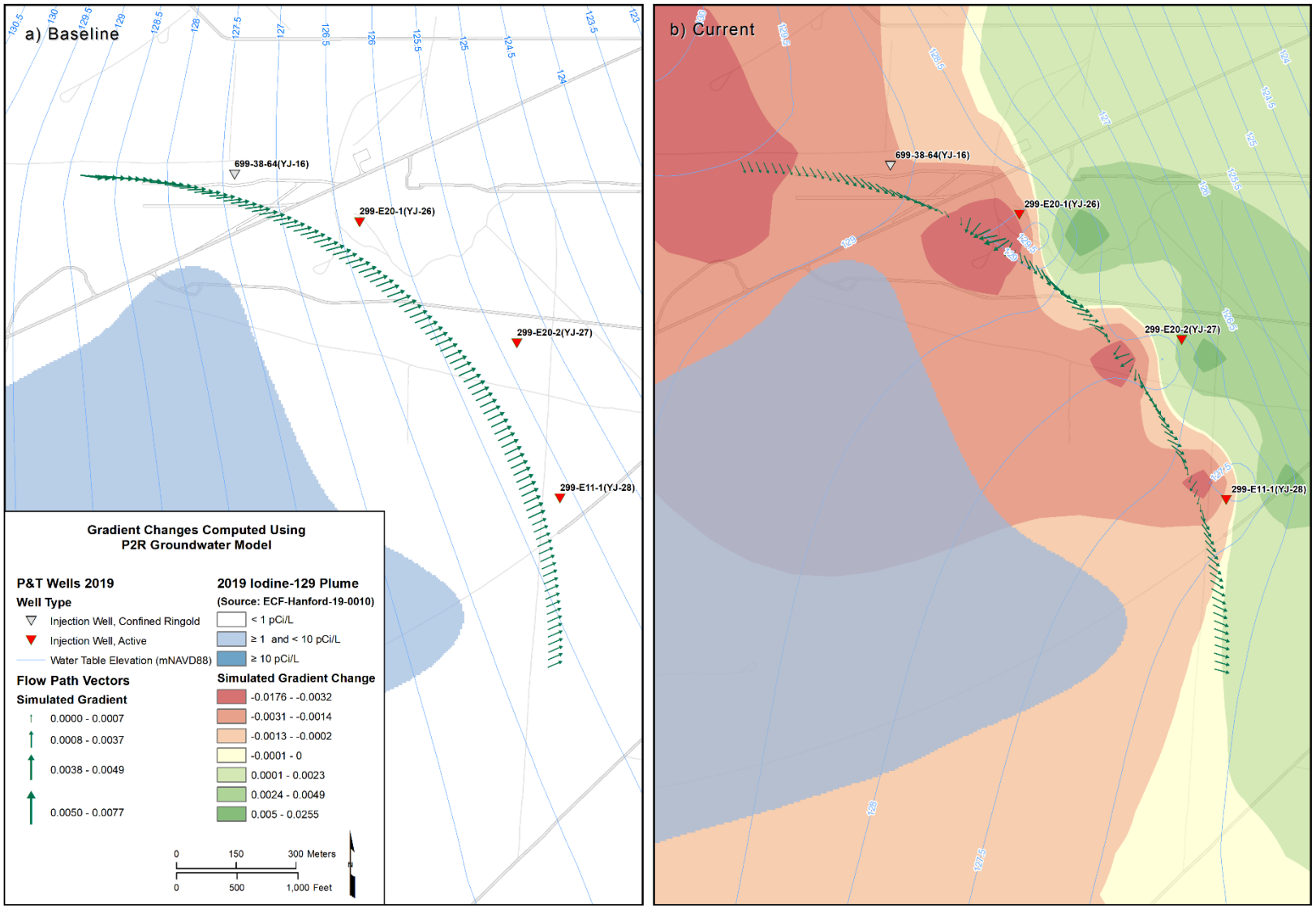
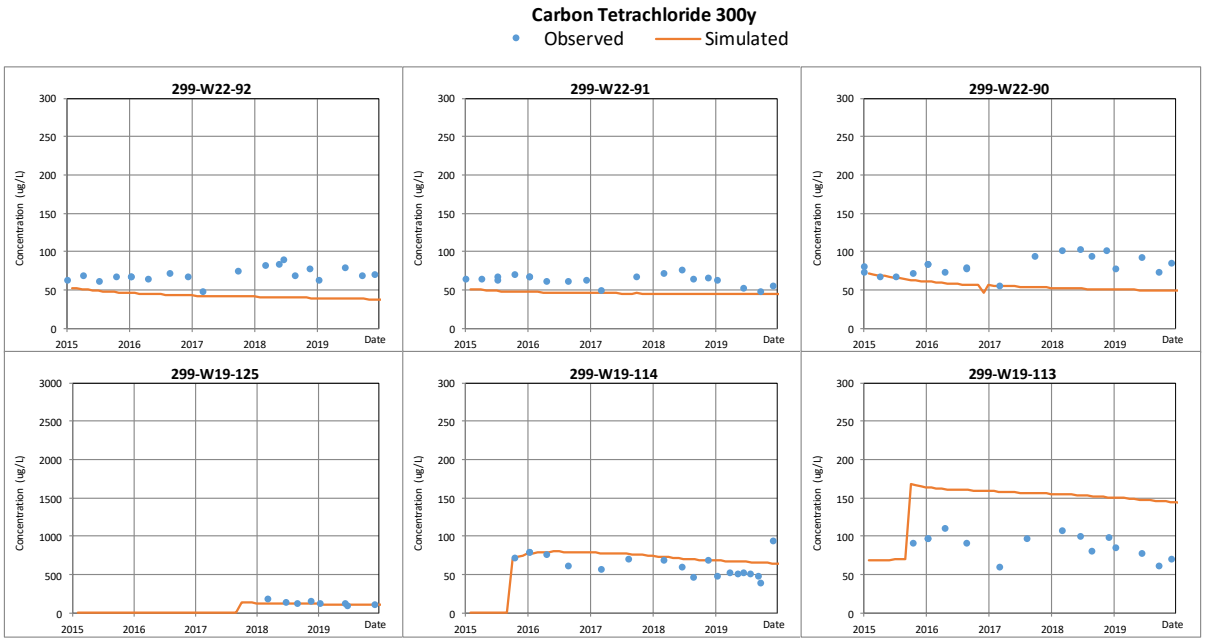


Figure 7-55. Simulated Gradient Changes Along Line of Control above the Rlm: (a) Baseline and (b) Current

7.3.3 Simulated and Observed Extraction Well Concentrations

Figures 7-56 through 7-60 depict a comparison of the simulated and observed (measured) historical influent concentrations for the 200-UP-1 S-SX Tank Farms and U-Plant system extraction wells for each of the chemical constituents that was simulated using the P2R Model contaminant F&T model. Not all of these chemical constituents are COCs for the 200-UP-1 OU. However, since the water extracted at these wells is conveyed to the 200 West P&T above ground treatment system (as well as water extracted by the 200-ZP-1 P&T wells), all chemical constituents are plotted.



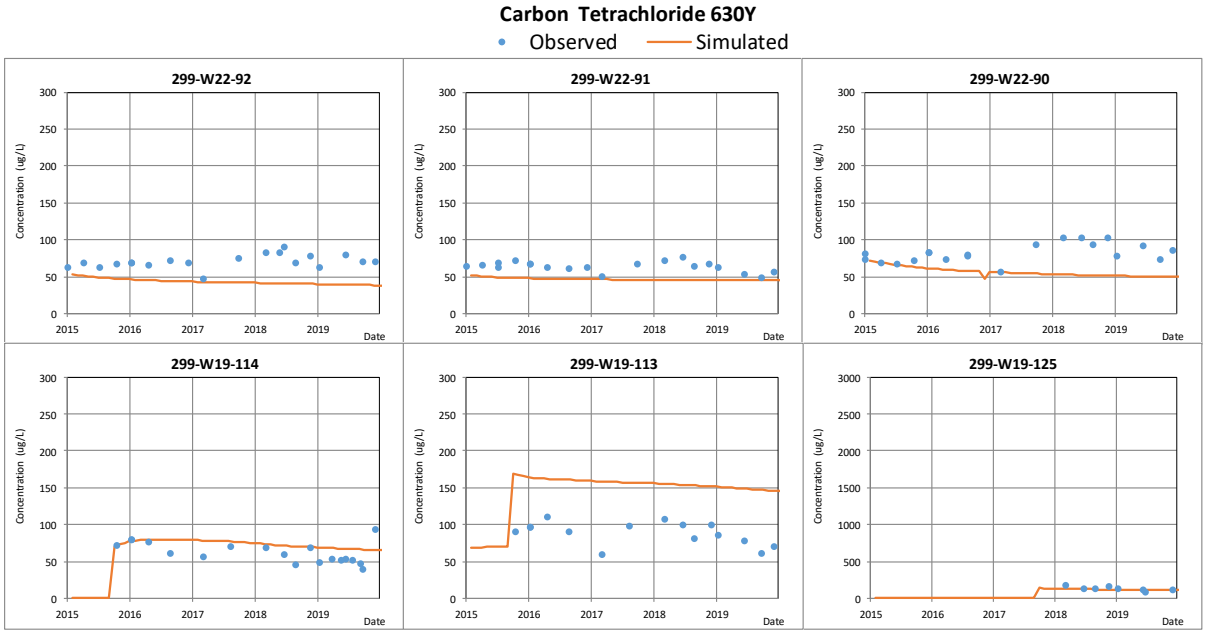
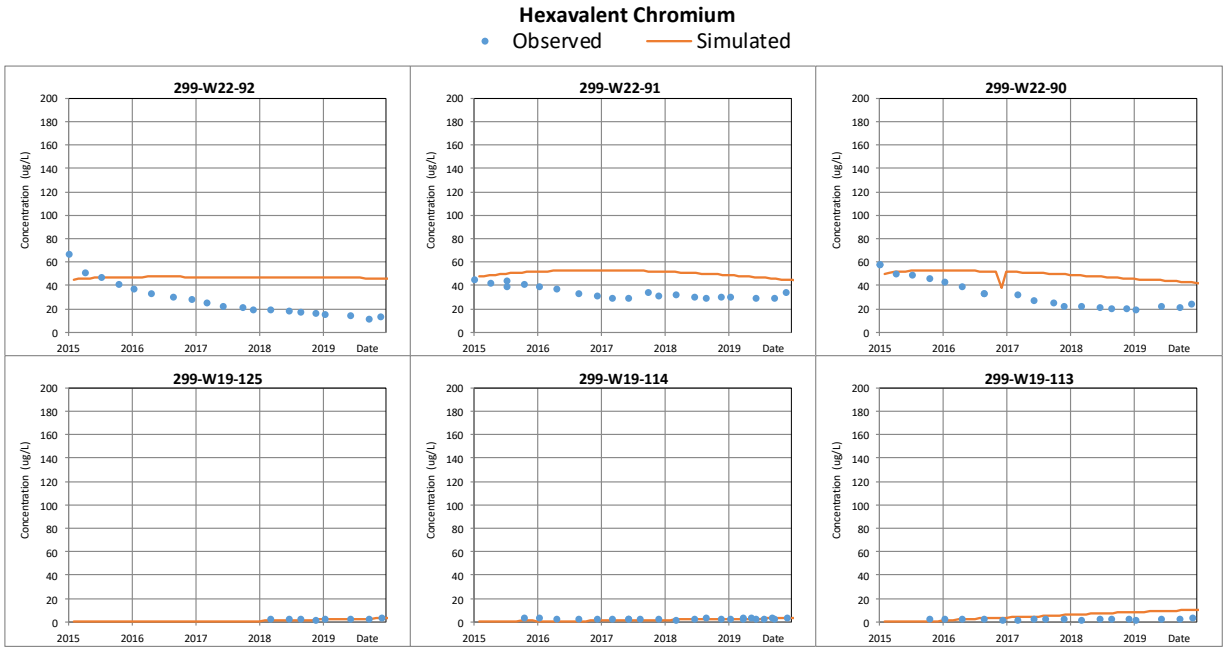


Figure 7-56. Comparison of Simulated and Observed Influent Concentrations at 200-UP-1 OU — S-SX Tank Farms and U Plant (Carbon Tetrachloride 300y and Carbon Tetrachloride 630Y)



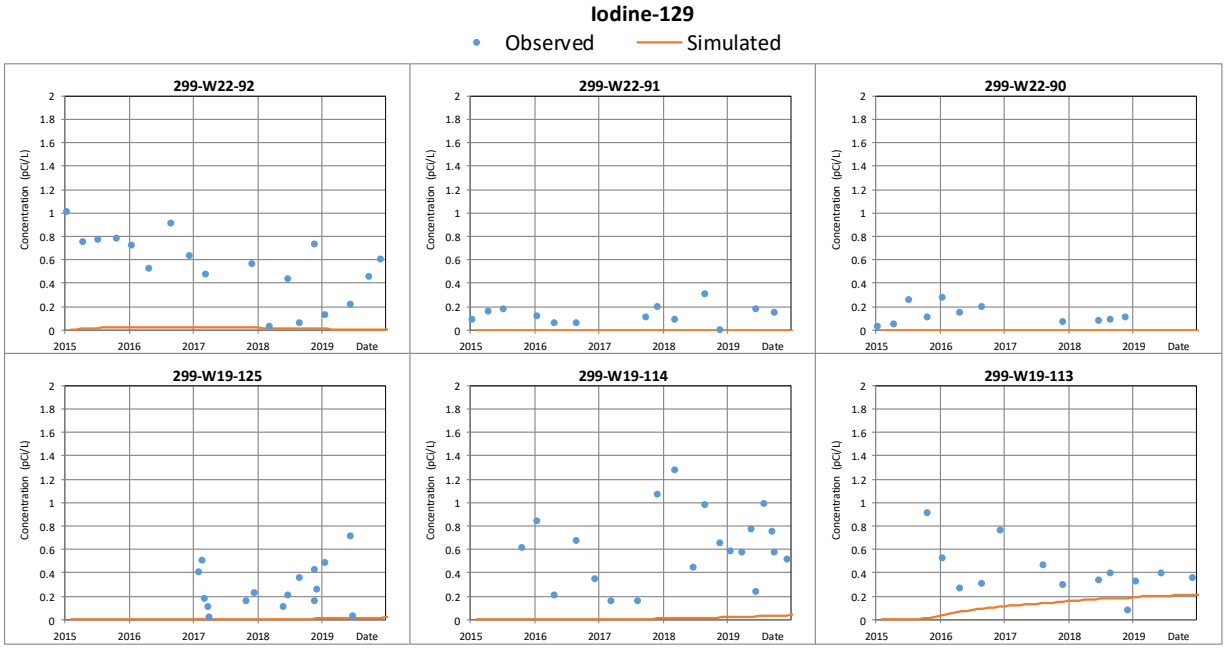


Figure 7-57. Comparison of Simulated and Observed Influent Concentrations at 200-UP-1 OU — S-SX Tank Farms and U Plant (Hexavalent Chromium and Iodine-129)

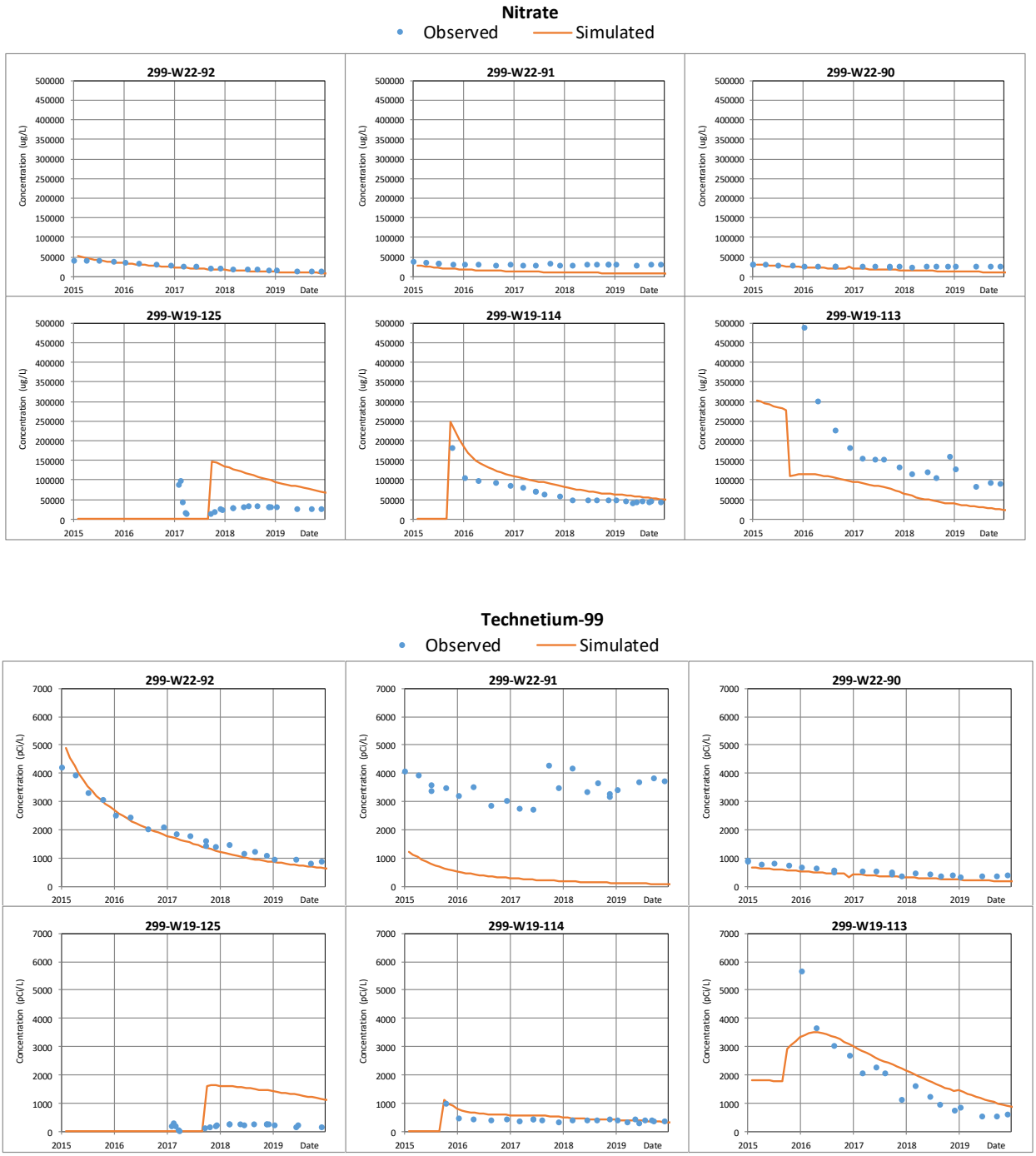


Figure 7-58. Comparison of Simulated and Observed Influent Concentrations at 200-UP-1 OU — S-SX Tank Farms and U Plant (Nitrate and Technetium-99)

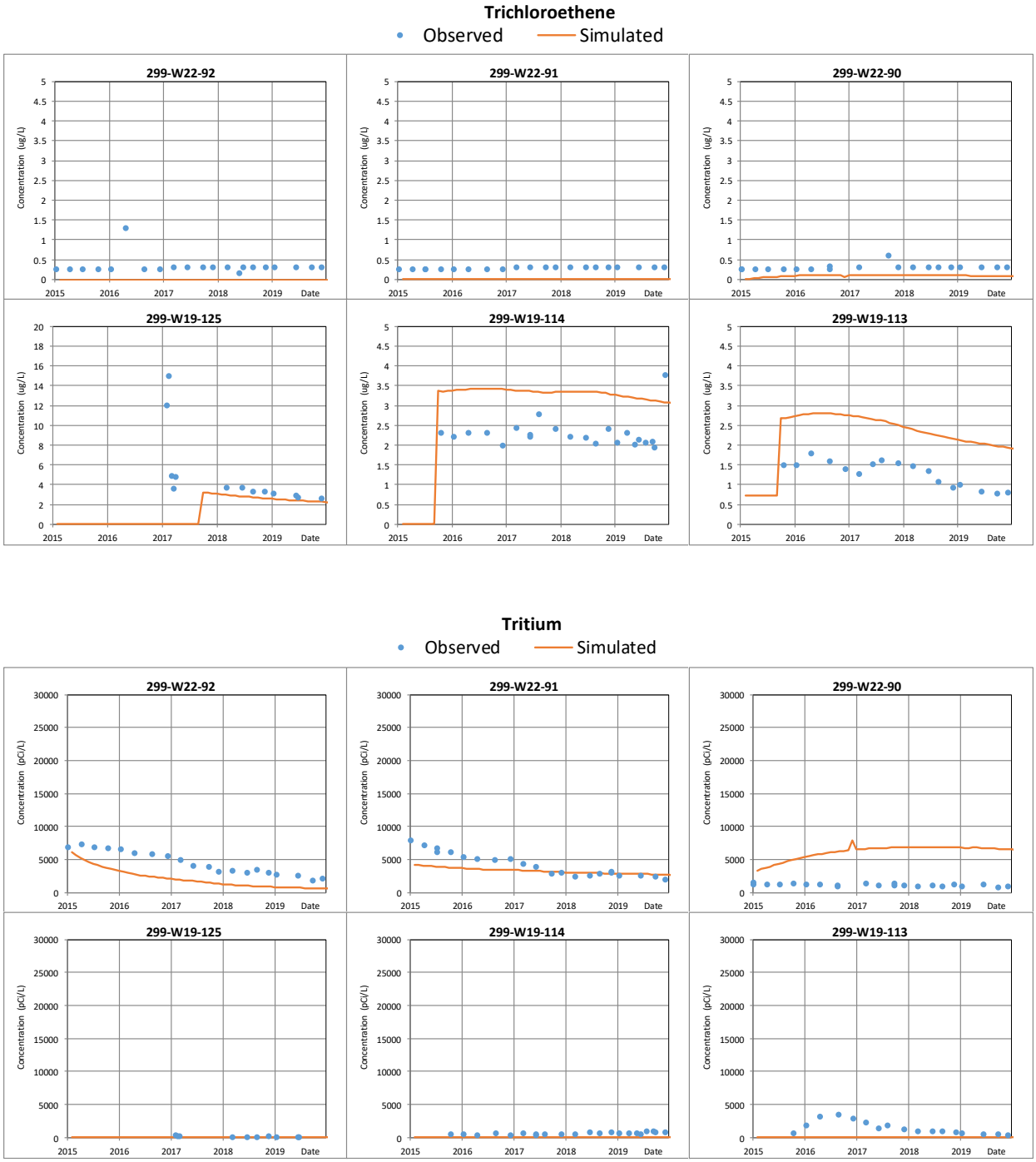


Figure 7-59. Comparison of Simulated and Observed Influent Concentrations at 200-UP-1 OU — S-SX Tank Farms and U Plant (Trichloroethene and Tritium)

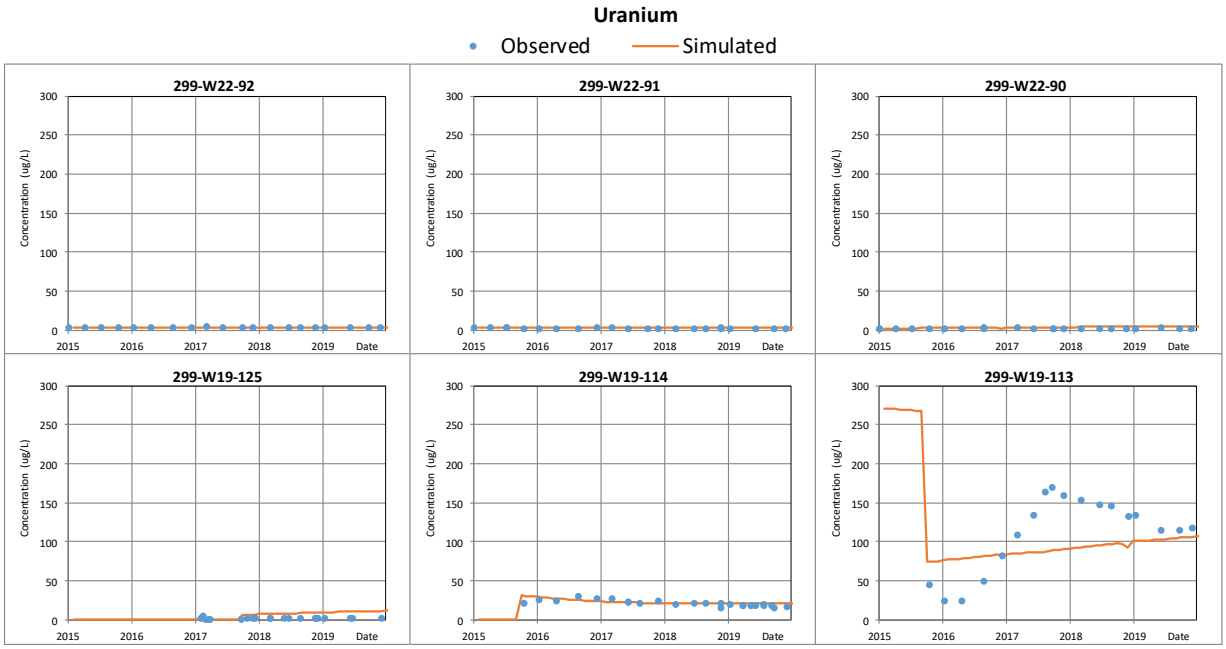


Figure 7-60. Comparison of Simulated and Observed Influent Concentrations at 200-UP-1 OU — S-SX Tank Farms and U Plant (Uranium)

7.4 Summary

7.4.1 200-ZP-1 Operable Unit

Figures of mapped capture and modeled hydraulic containment (ICFMs and SCFMs) presented in this ECF indicate that groundwater contaminated by carbon tetrachloride at concentrations greater than 100 µg/L is almost entirely hydraulically contained by the 200 West P&T system. The flow-path control assessment indicates that during CY 2019, flow-path control had developed along much of the control line, through the reduction in hydraulic gradients by groundwater extraction and reinjection at the 200 West P&T.

Section 7.1.4 provides the calculations based upon groundwater flow modeling and contaminant transport modeling in order to compare observed and predictive containment and mass removal and make future projections of the likely progress toward achieving the mass recovery goal. These calculation methods will be applied in future annual reports, when the 200 West P&T has been running at full capacity for a long enough period of time for hydraulic gradients to stabilize and for the parameters and assumptions of the contaminant transport model to be validated, recalibrated and revised, where necessary.

7.4.2 200-UP-1 Operable Unit

The system at the 200-UP-1 OU for the S-SX Tank Farms is able to operate at its design capacity. When operating, the combined pumping rate from the three extraction wells is about 300 L/min (80 gpm) (note that the system may not operate 100% of the time due to scheduled and unscheduled periods of maintenance and shutdown). When operating, the hydraulic capture zones developed by the extraction wells effectively cover most of the technetium-99 plumes at concentrations above 9,000 pCi/L.

The U Plant area groundwater extraction system came online in September 2015 with two extraction wells, 299-W19-113 and 299-W19-114, and removes uranium, technetium-99, and nitrate from the groundwater downgradient from the 216-U-1 and 216-U-2 Cribs. In 2017, a third extraction well,

299-W19-125, was added to the system. In CY 2019, the extraction wells operated at a combined average rate of 627 L/min (166 gpm), which is 110% of the nominal design rate of 568 L/min (150 gpm).

The iodine-129 plume hydraulic containment injection wells were designed to operate at nominal flow rates of 189 to 379 L/min (50 to 100 gpm) per well. During 2019, 299-E20-1 operated at an average rate of 270 L/min (71.4 gpm), 299-E20-2 operated at an average rate of 251 L/min (66.4 gpm), and 299-E11-1 operated at an average rate of 276 L/min (72.9 gpm). Water-level data indicate the magnitude of the hydraulic gradient between the plume boundary and the injection wells has decreased, which has slowed the eastward migration of the plume.

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Appendix A

Historical and Predicted Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies

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Tables

Table A-1. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2012 and CY 2013 ..... A-1
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Table A-1. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2012 and CY 2013

Stress Period of Model Commences in 2012		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Well ID	Well Name	Jan. 2012	Feb. 2012	Mar. 2012	Apr. 2012	May 2012	June 2012	July 2012	Aug. 2012	Sept. 2012	Oct. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Feb. 2013	Mar. 2013	Apr. 2013	May 2013	June 2013	July 2013	Aug. 2013	Sept. 13	Oct. 2013	Nov. 2013	Dec. 2013
YE-01	299-W15-225	-249	-250	-247	-242	-11	0	0	0	-3	-28	-50	-69	-68	-68	-68	-83	-99	-94	-84	-68	-91	-86	-79	-81
YE-02	299-W14-20	0	0	0	0	0	0	0	-5	-14	-54	-87	-96	-101	-91	-96	-119	-111	-109	-107	-97	-87	0	-100	-103
YE-03	299-W14-73	0	0	0	0	0	0	-2	-23	-12	-46	-55	-67	-79	-75	-77	-104	-133	-113	-99	-73	-1	-69	-80	-81
YE-04	299-W14-74	0	0	0	0	0	0	0	0	0	0	-55	-91	-95	-90	-83	-110	-110	-104	-94	-97	-110	-111	-86	-95
YE-05	299-W12-2	0	0	0	0	0	0	0	-18	-8	-52	-65	-81	-97	-94	-97	-117	-137	-95	-62	-57	-23	-80	-88	-86
YE-06	299-W11-50	0	0	0	0	0	0	0	0	-12	-50	-83	-96	-101	-91	-97	-45	-112	-109	-108	-85	-105	-43	-103	-90
YE-07	299-W11-90	0	0	0	0	0	0	0	-4	-15	-56	-89	-95	-98	-92	-98	-132	-113	-111	-109	-97	-114	-56	-103	-110
YE-08	299-W11-96	0	0	0	0	0	0	0	-7	-22	-41	-58	-68	-95	-90	-82	-109	-128	-95	-62	-57	-64	-109	-83	-81
YE-09	299-W17-3	0	0	0	0	0	0	-3	-20	-10	-45	-68	-78	-83	-75	-78	-102	-124	-112	-97	-87	-96	-44	-75	-80
YE-10	299-W17-2	0	0	0	0	0	0	-2	-17	-9	-38	-57	-66	-84	-77	-79	-91	-93	-91	-87	-51	0	-62	-81	-81
YE-11	299-W19-111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-12	299-W11-49	0	0	0	0	0	0	-4	-23	-11	-48	-67	-77	-81	-75	-77	-101	-127	-111	-95	-95	-96	-87	-79	-79
YE-13	299-W11-97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-14	299-W6-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-15	299-W14-21	0	0	0	0	0	0	-3	-20	-10	-44	-60	-62	-82	-74	-78	-101	-108	-102	-95	-89	-95	-34	-79	-100
YE-16	299-W11-92	0	0	0	0	0	0	0	-2	-9	-53	-81	-94	-102	-93	-101	-126	-113	-110	-109	-101	-90	0	-102	-129
YE-17	299-W5-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-18	299-W12-3	0	0	0	0	0	0	-3	-21	-8	-44	-60	-92	-98	-94	-97	-119	-135	-95	-72	-64	-100	-109	-87	-85
YE-19	299-W12-4	0	0	0	0	0	0	-4	-23	-8	-49	-69	-94	-99	-95	-97	-112	-131	-95	-61	-102	-88	-79	-87	-124
YE-20	299-W14-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-21	299-W22-90	0	0	0	0	0	0	0	-1	-3	-10	-17	-23	-22	-23	-23	-22	-23	-23	-23	-22	-14	-3	-23	-23
YE-22	299-W22-91	0	0	0	0	0	0	0	-1	-3	-11	-20	-23	-33	-20	-27	-34	-35	-35	-35	-34	-21	-3	-25	-24
YE-23	299-W22-92	0	0	0	0	0	0	0	-1	-3	-10	-19	-14	-23	-23	-24	-23	-24	-24	-24	-23	-14	-3	-24	-24
YE-24	299-W19-125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-25	299-W19-113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-26	299-W19-114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-27	299-E33-268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-1. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2012 and CY 2013

Stress Period of Model Commences in 2012		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Well ID	Well Name	Jan. 2012	Feb. 2012	Mar. 2012	Apr. 2012	May 2012	June 2012	July 2012	Aug. 2012	Sept. 2012	Oct. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Feb. 2013	Mar. 2013	Apr. 2013	May 2013	June 2013	July 2013	Aug. 2013	Sept. 13	Oct. 2013	Nov. 2013	Dec. 2013
YE-31	299-E33-360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-01	299-W6-13	0	0	0	0	0	0	5	25	7	82	125	118	133	120	127	221	296	277	49	90	119	51	97	82
YJ-02	299-W6-14	0	0	0	0	0	0	4	18	6	55	88	89	97	90	93	143	178	177	147	82	145	111	163	173
YJ-03	299-W10-36	0	0	0	0	0	0	4	16	5	49	79	82	89	83	86	126	160	158	135	74	84	90	148	127
YJ-04	299-W10-35	0	0	0	0	0	0	4	19	6	56	92	92	101	93	97	152	196	205	169	148	56	135	138	128
YJ-05	299-W15-226	0	0	0	0	0	0	5	19	7	69	105	102	114	104	109	176	228	234	201	186	72	85	282	159
YJ-06	299-W15-227	0	0	0	0	0	0	4	15	4	50	80	83	90	84	87	127	158	158	130	135	141	84	211	221
YJ-07	299-W15-228	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-08	299-W18-41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-09	699-49-69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-10	699-45-67B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
YJ-11	699-45-67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	145
YJ-12	699-44-67	0	0	0	0	0	0	0	5	51	80	71	113	147	144	153	122	109	20	75	78	107	79	60	49
YJ-13	699-43-67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-14	699-42-67	0	0	0	0	0	0	0	8	51	87	69	114	150	144	138	111	112	21	101	109	115	81	74	50
YJ-15	699-40-67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-16	699-38-64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-17	699-43-67B	0	0	0	0	0	0	0	11	50	93	72	117	145	139	138	118	85	14	72	67	52	47	56	23
YJ-18	299-W15-29	135	129	118	91	4	0	0	0	0	1	12	131	77	75	78	108	133	122	135	136	140	78	23	1
YJ-19	299-W18-36	84	81	76	64	3	0	0	0	0	21	69	72	77	75	77	86	92	103	93	87	85	70	36	80
YJ-20	299-W18-37	1	1	1	1	0	0	0	0	0	16	67	71	75	45	74	66	70	80	72	66	54	31	54	74
YJ-21	299-W18-38	68	66	62	53	3	0	0	0	0	13	59	65	71	76	62	29	38	66	43	21	8	24	64	91
YJ-22	299-W18-39	69	67	63	54	4	0	0	0	0	6	56	63	69	72	64	49	62	66	46	35	10	17	49	68
YJ-23	699-46-68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-24	299-W15-229	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-25	299-W7-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-26	299-E20-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-1. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2012 and CY 2013

Stress Period of Model Commences in 2012		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Well ID	Well Name	Jan. 2012	Feb. 2012	Mar. 2012	Apr. 2012	May 2012	June 2012	July 2012	Aug. 2012	Sept. 2012	Oct. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Feb. 2013	Mar. 2013	Apr. 2013	May 2013	June 2013	July 2013	Aug. 2013	Sept. 13	Oct. 2013	Nov. 2013	Dec. 2013
YJ-27	299-E20-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-28	299-E11-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-29	299-W6-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-30	299-W18-44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-31	299-W18-43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-32	299-W18-42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W11-45	-6	-8	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W11-46	-9	-13	-18	-18	-15	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-1	-10	-11	-9	-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-11	-10	-10	-10	-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-34	-11	-11	-10	-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-35	-13	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-43	-12	-12	-12	-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-45	-14	-14	-14	-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-46	-43	-43	-26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-7	-5	-5	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W15-765	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W18-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
N/A	299-W18-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-1. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2012 and CY 2013

Stress Period of Model Commences in 2012		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Well ID	**Well Name**	**Jan. 2012**	**Feb. 2012**	**Mar. 2012**	**Apr. 2012**	**May 2012**	**June 2012**	**July 2012**	**Aug. 2012**	**Sept. 2012**	**Oct. 2012**	**Nov. 2012**	**Dec. 2012**	**Jan. 2013**	**Feb. 2013**	**Mar. 2013**	**Apr. 2013**	**May 2013**	**June 2013**	**July 2013**	**Aug. 2013**	**Sept. 13**	**Oct. 2013**	**Nov. 2013**	**Dec. 2013**
N/A	299-W19-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: Extraction and injection rates are shown in gallons per minute (gpm).

CY = calendar year

ID = identification

N/A = not available

P&T = pump and treat

Table A-2. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2014 and CY 2015

Stress Period of Model Commences in 2012		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Stress Period of Model Commences in 2015														1	2	3	4	5	6	7	8	9	10	11	12
Well ID	Well Name	Jan. 2014	Feb. 2014	Mar. 2014	Apr. 2014	May 2014	June 2014	July 2014	Aug. 2014	Sept. 2014	Oct. 2014	Nov. 2014	Dec. 2014	Jan. 2015	Feb. 2015	Mar. 2015	Apr. 2015	May 2015	June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015
YE-01	299-W15-225	-81	-80	-87	-90	-90	-93	-98	-90	-80	-99	-99	-97	-98	-96	-98	-97	-95	-96	-98	-86	-94	-96	-96	-96
YE-02	299-W14-20	-104	0	0	0	-65	-99	-119	-112	-110	-111	-109	-107	-110	-105	-113	-108	-110	-110	-115	-99	-111	-116	-114	-100
YE-03	299-W14-73	-80	-79	-86	-90	-84	-93	-89	-82	-79	-127	-144	-138	-147	-130	-125	-117	-118	-116	-130	-127	-129	-127	-123	-108
YE-04	299-W14-74	-90	-79	-107	-127	-99	-111	-94	-93	-76	-123	-129	-130	-139	-107	-143	-123	-121	-135	-144	-140	-140	-128	-106	-91
YE-05	299-W12-2	-79	-85	-93	-112	-93	-100	-102	-93	-5	-129	-118	-106	-113	-105	-115	-106	-105	-106	-112	-110	-96	-98	-97	-89
YE-06	299-W11-50	-81	-115	-116	-119	-108	-115	-119	-112	-110	-112	-110	-110	-110	-106	-113	-109	-109	-110	-114	-99	-110	-113	-112	-94
YE-07	299-W11-90	-111	-138	-137	-149	-109	-111	-100	-99	-95	-105	-106	-104	-110	-102	-113	-107	-109	-113	-115	-99	-113	-119	-109	-94
YE-08	299-W11-96	-78	-70	-88	-101	-84	-91	-96	-38	0	-100	-101	-86	-98	-78	-92	-90	-92	-105	-111	-110	-112	-90	-75	-92
YE-09	299-W17-3	-77	-96	-90	-96	-92	-82	-100	-86	-71	-109	-114	-117	-124	-117	-125	-122	-117	-123	-131	-128	-119	-130	-121	-109
YE-10	299-W17-2	-80	-79	-86	-90	-85	-91	-99	-89	-78	-95	-95	-93	-95	-92	-85	-85	-86	-86	-91	-88	-89	-85	-73	-91
YE-11	299-W19-111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-12	299-W11-49	-78	-79	-86	-89	-105	-111	-126	-106	-78	-117	-117	-122	-133	-121	-131	-126	-120	-128	-131	-125	-127	-131	-117	-109
YE-13	299-W11-97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-48
YE-14	299-W6-15	0	0	0	0	0	0	0	0	0	0	0	0	-7	-56	-59	-57	-52	-64	-58	-59	-55	-46	-16	-60
YE-15	299-W14-21	-109	-107	-107	-109	-96	-97	-99	-89	-79	-99	-100	-104	-108	-107	-109	-108	-104	-106	-108	-102	-75	0	0	0
YE-16	299-W11-92	-137	-137	-137	-139	-116	-112	-100	-92	-88	-109	-110	-107	-120	-93	-108	-113	-111	-112	-117	-108	-108	-117	-120	-101
YE-17	299-W5-1	0	0	0	0	0	0	0	0	0	-1	-41	-58	-57	-58	-65	-58	-62	-55	-65	-68	-65	-72	-84	-84
YE-18	299-W12-3	-79	-80	-95	-98	-88	-89	-86	-86	-57	-103	-93	-83	-84	-76	-84	-80	-86	-85	-104	-101	-29	0	0	-64
YE-19	299-W12-4	-136	-86	-120	-135	-97	-121	-114	-103	-97	-144	-123	-108	-126	-109	-127	-118	-114	-117	-125	-121	-125	-121	-108	-98
YE-20	299-W14-22	0	0	0	0	0	0	0	0	0	-1	-41	-58	-63	-66	-82	-61	-71	-80	-88	-85	-84	-94	-96	-90
YE-21	299-W22-90	-22	-23	-22	-23	-24	-20	-17	-16	-16	-17	-17	-17	-19	-24	-25	-25	-25	-24	-25	-21	-23	-24	-24	-24
YE-22	299-W22-91	-35	-35	-35	-35	-35	-36	-35	-33	-33	-35	-35	-33	-35	-35	-35	-35	-35	-34	-35	-30	-33	-35	-35	-35
YE-23	299-W22-92	-24	-24	-24	-24	-24	-29	-35	-33	-33	-35	-35	-33	-35	-35	-35	-35	-35	-34	-34	-30	-33	-34	-34	-34
YE-24	299-W19-125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-25	299-W19-113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-9	-34	-34	-44
YE-26	299-W19-114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-16	-81	-81	-97

Table A-2. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2014 and CY 2015

Stress Period of Model Commences in 2012		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Stress Period of Model Commences in 2015														1	2	3	4	5	6	7	8	9	10	11	12
Well ID	Well Name	Jan. 2014	Feb. 2014	Mar. 2014	Apr. 2014	May 2014	June 2014	July 2014	Aug. 2014	Sept. 2014	Oct. 2014	Nov. 2014	Dec. 2014	Jan. 2015	Feb. 2015	Mar. 2015	Apr. 2015	May 2015	June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015
YE-27	299-E33-268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-44	-94	-95
YE-31	299-E33-360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-01	299-W6-13	46	102	102	99	73	103	111	87	94	63	10	47	87	31	82	81	53	58	51	64	50	33	35	46
YJ-02	299-W6-14	207	204	131	182	243	241	276	211	103	318	298	251	276	218	210	129	178	187	183	175	182	179	220	215
YJ-03	299-W10-36	150	90	87	204	124	117	121	102	116	110	116	108	85	117	106	76	94	76	104	96	104	90	85	76
YJ-04	299-W10-35	146	138	169	187	177	159	96	140	122	133	156	164	160	120	99	104	110	100	120	114	116	96	63	74
YJ-05	299-W15-226	176	172	186	123	197	216	223	217	191	220	238	231	239	192	234	282	229	248	217	226	251	260	171	163
YJ-06	299-W15-227	262	251	255	239	155	167	136	103	90	105	107	58	102	76	108	92	115	125	123	117	109	71	75	119
YJ-07	299-W15-228	0	0	0	0	0	0	0	0	0	0	0	0	144	174	176	178	128	135	138	99	137	120	121	123
YJ-08	299-W18-41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	97	94	94	75	91	85	83
YJ-09	699-49-69	0	0	0	0	0	0	0	0	26	81	83	93	103	62	89	67	49	28	50	32	17	53	58	66
YJ-10	699-45-67B	50	20	16	36	21	0	35	8	0	3	8	5	2	2	4	1	0	3	0	0	0	0	0	0
YJ-11	699-45-67	110	85	99	116	113	84	80	94	57	120	107	90	72	109	102	81	57	80	90	81	81	66	48	50
YJ-12	699-44-67	33	27	43	59	43	43	84	61	47	36	45	44	28	18	46	41	43	30	43	32	13	17	14	15
YJ-13	699-43-67	0	0	0	0	0	0	0	0	0	0	0	0	0	70	83	94	101	93	85	55	52	63	48	67
YJ-14	699-42-67	42	16	105	80	96	95	90	128	116	107	117	120	114	106	120	104	110	83	121	115	79	81	106	105
YJ-15	699-40-67	0	0	0	0	0	0	0	0	0	101	134	131	131	117	110	102	110	109	107	70	90	90	58	29
YJ-16	699-38-64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	136	133	126	77	70
YJ-17	699-43-67B	3	48	50	53	41	59	54	47	42	4	40	31	10	47	55	63	67	62	57	37	35	42	32	44
YJ-18	299-W15-29	49	42	57	33	40	60	55	44	42	45	46	45	30	43	43	31	38	16	28	13	26	55	53	52
YJ-19	299-W18-36	88	94	96	100	65	90	101	89	79	81	88	85	70	56	67	42	60	72	60	69	70	66	68	68
YJ-20	299-W18-37	42	17	22	0	20	28	30	22	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-21	299-W18-38	97	100	98	73	60	87	84	69	55	58	57	54	59	58	57	58	36	45	42	51	45	39	40	41
YJ-22	299-W18-39	73	66	48	64	51	77	73	62	38	56	55	53	25	4	34	29	13	39	30	39	41	38	9	5
YJ-23	699-46-68	0	0	0	0	0	0	0	0	0	117	136	136	101	97	30	83	103	114	152	75	91	118	63	87
YJ-24	299-W15-229	0	0	0	0	0	0	0	0	0	0	17	98	145	112	152	166	158	158	158	143	83	159	157	149

Table A-2. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2014 and CY 2015

Stress Period of Model Commences in 2012		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Stress Period of Model Commences in 2015														1	2	3	4	5	6	7	8	9	10	11	12
Well ID	Well Name	Jan. 2014	Feb. 2014	Mar. 2014	Apr. 2014	May 2014	June 2014	July 2014	Aug. 2014	Sept. 2014	Oct. 2014	Nov. 2014	Dec. 2014	Jan. 2015	Feb. 2015	Mar. 2015	Apr. 2015	May 2015	June 2015	July 2015	Aug. 2015	Sept. 2015	Oct. 2015	Nov. 2015	Dec. 2015
YJ-25	299-W7-14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-26	299-E20-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	58	79
YJ-27	299-E20-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	53	59
YJ-28	299-E11-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	75	87

Note: Extraction and injection rates are shown in gallons per minute (gpm).

CY = calendar year

ID = identification

P&T = pump and treat

Table A-3. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2016 and 2017

Stress Period of Model Commences in 2012		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
Stress Period of Model Commences in 2015		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Well ID	Well Name	Jan. 2016	Feb. 2016	Mar. 2016	Apr. 2016	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016	Dec. 2016	Jan. 2017	Feb. 2017	Mar. 2017	Apr. 2017	May 2017	June 2017	July 2017	Aug. 2017	Sept. 2017	Oct. 2017	Nov. 2017	Dec. 2017
YE-01	299-W15-225	-86	-49	-33	-60	-74	-96	-55	-76	-79	-73	-92	-99	-99	-92	-90	-45	-84	-83	-86	-11	-92	-87	-88	-79
YE-02	299-W14-20	-82	-116	-116	-106	-108	-110	-114	-76	-120	-101	-99	-100	-100	-98	-76	-72	-79	-67	-84	-71	-70	-81	-71	-76
YE-03	299-W14-73	-87	-89	-95	-63	-47	-29	-99	-91	-97	-69	-105	-118	-113	-102	-69	-48	-90	-94	-108	-54	-119	-116	-120	-129
YE-04	299-W14-74	-83	-97	-102	-5	-68	-24	-82	-85	-119	-10	-72	-104	-109	-104	-58	-17	-87	-88	-103	-113	-114	-114	-113	-113
YE-05	299-W12-2	-77	-87	-71	-1	0	0	-52	-55	-110	-59	-88	-93	-99	-95	-52	-50	-82	-89	-101	-79	-107	-93	-80	-58
YE-06	299-W11-50	-80	-87	-82	-77	-80	-81	-92	-74	-75	-45	-38	-98	-100	-96	-75	-71	-77	-66	-81	-70	-69	-60	-61	-63
YE-07	299-W11-90	-80	-127	-133	-80	-81	-82	-117	-95	-119	-100	-95	-85	-100	-98	-76	-72	-78	-66	-95	-106	-104	-99	-87	-87
YE-08	299-W11-96	-75	-93	-107	0	0	0	-59	-67	-109	-2	-48	-99	-108	-97	-51	-19	-94	-96	-99	-20	-106	-105	-106	-108
YE-09	299-W17-3	-87	-86	-78	-67	-32	-8	-89	-84	-82	-21	-103	-128	-118	-101	-89	-74	-86	-93	-99	-10	-97	-102	-108	-120
YE-10	299-W17-2	-84	-88	-86	-28	-54	0	-59	-91	-96	-66	-99	-110	-108	-99	-68	-48	-91	-94	-104	-88	-110	-109	-109	-75
YE-11	299-W19-111	0	0	0	0	0	0	0	-2	-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-12	299-W11-49	-85	-89	-95	-94	-101	-93	-35	-80	-92	0	-79	-121	-117	-91	-85	-71	-85	-92	-113	-96	-131	-135	-136	-135
YE-13	299-W11-97	-85	-42	-13	-29	0	-5	-55	-36	-80	-24	-79	-99	-95	-86	-78	-74	-88	-93	-91	-9	-77	-93	-91	-92
YE-14	299-W6-15	-66	-63	-59	0	0	0	-16	-49	-92	-30	-88	-26	0	0	-23	-22	-95	-97	-95	-18	-97	-95	-97	-98
YE-15	299-W14-21	0	0	0	0	0	0	0	-22	-74	0	0	-33	-91	-77	-82	-73	-74	-76	-95	-81	-98	-94	-88	-97
YE-16	299-W11-92	-87	-86	-78	-83	-98	-99	-63	-67	-93	-51	-99	-119	-113	-100	-88	-75	-83	-91	-101	-69	-97	-92	-97	-100
YE-17	299-W5-1	-42	-53	-43	-1	0	0	-39	-47	-94	-59	-81	-96	-99	-92	-44	-45	-97	-98	-56	0	0	-56	-81	-90
YE-18	299-W12-3	-72	-69	-56	-1	0	0	-46	-52	-91	-11	-88	-104	-96	-86	-56	-19	-97	-98	-99	-54	-99	-105	-104	-81
YE-19	299-W12-4	-72	-85	-64	-1	0	0	-52	-54	-93	-62	-91	-112	-80	-81	-62	-55	-79	-85	-118	-66	-136	-134	-135	-134
YE-20	299-W14-22	-43	-56	-44	-1	0	0	-39	-46	-82	-45	-83	-100	-89	-78	-59	-53	-78	-88	-97	-16	-97	-97	-109	-115
YE-21	299-W22-90	-25	-25	-22	-24	-25	-25	-24	-18	-9	-5	0	-8	-25	-25	-25	-25	-24	-24	-23	-20	-20	-25	-25	-25
YE-22	299-W22-91	-35	-35	-31	-34	-35	-35	-35	-34	-30	-31	-32	-34	-35	-35	-35	-35	-34	-35	-29	-20	-21	-30	-30	-30
YE-23	299-W22-92	-34	-34	-30	-33	-34	-33	-34	-33	-33	-33	-32	-30	-34	-33	-33	-32	-32	-32	-26	-20	-20	-25	-13	-25
YE-24	299-W19-125	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-18	-49	-50	-50
YE-25	299-W19-113	-54	-54	-54	-53	-54	-55	-55	-46	-55	-53	-55	-55	-55	-55	-55	-55	-54	-54	-39	-46	-50	-49	-50	-50
YE-26	299-W19-114	-99	-99	-99	-97	-99	-100	-99	-95	-100	-96	-86	-100	-100	-99	-100	-99	-97	-96	-73	-93	-82	-50	-50	-50

Table A-3. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2016 and 2017

Stress Period of Model Commences in 2012		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
Stress Period of Model Commences in 2015		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Well ID	Well Name	Jan. 2016	Feb. 2016	Mar. 2016	Apr. 2016	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016	Dec. 2016	Jan. 2017	Feb. 2017	Mar. 2017	Apr. 2017	May 2017	June 2017	July 2017	Aug. 2017	Sept. 2017	Oct. 2017	Nov. 2017	Dec. 2017
YE-27	299-E33-268	-79	-81	-78	-66	-79	-80	-90	-95	-108	-7	0	-23	0	-26	-89	-86	-77	-24	0	0	0	0	0	0
YE-31	299-E33-360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-8	-30	-35	-110	-141	-139	-141	-82	-162	-167
YE-32	299-E33-361	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-01	299-W6-13	57	55	35	51	54	54	10	16	66	20	52	50	50	45	12	12	72	62	67	47	47	7	45	56
YJ-02	299-W6-14	163	194	105	78	124	101	154	128	190	74	152	193	208	193	54	140	201	205	210	94	182	182	189	212
YJ-03	299-W10-36	72	62	80	83	62	68	67	38	55	43	54	58	57	40	78	62	62	91	64	69	72	58	82	95
YJ-04	299-W10-35	73	85	107	61	22	27	110	78	110	40	74	126	146	132	95	91	134	142	142	58	105	102	105	121
YJ-05	299-W15-226	159	175	134	184	239	205	177	124	176	71	109	185	193	197	175	49	189	195	203	170	93	180	185	200
YJ-06	299-W15-227	91	108	145	90	53	70	123	102	145	52	116	147	150	145	124	83	112	148	162	142	96	125	139	131
YJ-07	299-W15-228	124	119	122	110	0	0	81	151	156	73	154	182	179	172	174	163	178	151	186	39	176	171	186	121
YJ-08	299-W18-41	77	97	96	43	0	1	35	71	110	44	102	120	122	114	80	42	130	105	157	30	134	130	134	123
YJ-09	699-49-69	56	40	45	0	8	26	43	35	43	22	21	12	8	27	22	10	9	34	28	26	33	24	24	24
YJ-10	699-45-67B	0	3	2	0	0	0	2	1	0	0	0	0	0	0	1	0	1	2	6	5	1	10	8	5
YJ-11	699-45-67	34	56	41	11	29	24	41	32	8	10	32	13	8	3	0	5	9	3	22	29	18	21	27	24
YJ-12	699-44-67	11	8	14	1	3	0	0	0	0	0	2	31	11	10	3	2	3	2	2	6	3	25	24	20
YJ-13	699-43-67	60	37	31	10	23	20	34	30	39	25	12	25	24	23	19	17	15	0	33	30	32	26	21	15
YJ-14	699-42-67	59	49	108	39	90	78	110	90	93	69	72	89	78	76	72	64	75	65	57	83	82	57	83	82
YJ-15	699-40-67	30	49	40	9	14	23	51	35	54	32	26	16	61	41	19	17	19	15	30	21	21	36	22	52
YJ-16	699-38-64	53	53	47	14	21	22	57	46	78	41	51	45	1	61	47	43	68	56	77	41	82	99	86	92
YJ-17	699-43-67B	40	25	20	7	15	14	22	20	26	17	8	17	16	15	13	11	10	0	22	20	21	18	14	10
YJ-18	299-W15-29	51	57	56	41	20	17	20	41	56	25	58	65	67	69	63	54	73	71	64	12	25	64	64	54
YJ-19	299-W18-36	68	71	70	54	61	34	63	65	77	33	76	85	87	84	78	27	61	74	80	10	86	48	0	0
YJ-20	299-W18-37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-21	299-W18-38	44	42	27	29	69	44	45	55	57	29	57	67	65	63	64	59	15	65	94	10	103	97	159	114
YJ-22	299-W18-39	1	1	12	19	20	12	20	21	21	11	19	20	20	20	21	11	17	12	0	0	0	0	0	0
YJ-23	699-46-68	66	69	53	17	41	15	63	51	56	42	42	25	0	1	2	1	11	39	45	23	25	46	45	45

Table A-3. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2016 and 2017

Stress Period of Model Commences in 2012		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
Stress Period of Model Commences in 2015		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Well ID	Well Name	Jan. 2016	Feb. 2016	Mar. 2016	Apr. 2016	May 2016	June 2016	July 2016	Aug. 2016	Sept. 2016	Oct. 2016	Nov. 2016	Dec. 2016	Jan. 2017	Feb. 2017	Mar. 2017	Apr. 2017	May 2017	June 2017	July 2017	Aug. 2017	Sept. 2017	Oct. 2017	Nov. 2017	Dec. 2017
YJ-24	299-W15-229	140	148	119	18	0	0	36	114	148	55	102	110	114	48	55	78	111	81	71	24	126	61	119	89
YJ-25	299-W7-14	0	0	0	0	0	0	0	133	205	114	184	223	189	137	166	162	185	211	136	157	175	160	157	100
YJ-26	299-E20-1	63	70	59	3	7	9	12	66	91	43	61	66	70	78	66	47	71	61	74	69	56	78	74	77
YJ-27	299-E20-2	48	51	42	3	1	3	44	6	44	30	76	63	64	70	59	40	61	54	64	60	64	82	85	88
YJ-28	299-E11-1	73	77	65	13	36	29	62	52	74	48	42	73	75	83	60	34	77	70	81	79	82	54	66	72
YJ-29	299-W6-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-30	299-W18-44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-31	299-W18-43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	165	175	106	173
YJ-32	299-W18-42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	113	138	77	118

Note: Extraction and injection rates are shown in gallons per minute (gpm).

CY = calendar year

ID = identification

P&T = pump and treat

Table A-4. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2018 and 2019

Stress Period of Model Commences in 2012		73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
Stress Period of Model Commences in 2015		37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Well ID	Well Name	Jan. 2018	Feb. 2018	Mar. 2018	Apr. 2018	May 2018	Jun 2018	Jul 2018	Aug. 2018	Sept. 2018	Oct. 2018	Nov. 2018	Dec. 2018	Jan. 2019	Feb. 2019	Mar. 2019	Apr. 2019	May 2019	Jun 2019	Jul 2019	Aug. 2019	Sept. 2019	Oct. 2019	Nov. 2019	Dec. 2019
YE-01	299-W15-225	-83	-96	-77	-52	-46	-33	0	0	0	0	-11	-70	-75	-70	-100	-62	-75	-88	-97	-71	-93	-81	-47	-100
YE-02	299-W14-20	-76	-76	-76	-83	-75	-75	-76	-76	-55	-78	-77	-75	-72	-107	-104	-99	-101	-105	-108	-108	-107	-103	-112	-70
YE-03	299-W14-73	-136	-119	-137	-137	-139	-139	-140	-136	-132	-140	-134	-135	-136	-128	-90	-116	-127	-122	-88	0	-64	-21	-31	-70
YE-04	299-W14-74	-109	-108	-18	-99	-110	-111	-107	-108	-106	-112	-111	-111	-105	-104	-75	-84	-99	-105	-108	-99	-97	-67	-97	-109
YE-05	299-W12-2	-114	-102	-116	-109	-109	-109	-109	-106	-99	-106	-105	-104	-104	-90	-80	-81	-93	-96	-106	-96	-104	-88	-104	-109
YE-06	299-W11-50	-61	-60	-60	-65	-60	-60	-60	-59	-42	-56	-54	-60	-60	-60	-61	-55	-60	-59	-60	-60	-58	-59	-18	-60
YE-07	299-W11-90	-91	-90	-90	-75	-90	-90	-91	-91	-65	-97	-93	-96	-98	-73	-62	-76	-92	-84	-85	-86	-85	-83	-110	-116
YE-08	299-W11-96	-108	-107	-107	-107	-107	-106	-106	-106	-102	-108	-107	-107	-98	-70	-72	-67	-85	-51	-85	-80	-78	-76	-81	-97
YE-09	299-W17-3	-121	-123	-87	-65	-103	-95	-10	-9	-30	-55	-78	-101	-108	-87	-106	-67	-86	-95	-112	-79	-105	-108	-118	-122
YE-10	299-W17-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-52	-86	-97	-70	-90	-99	-103	-102
YE-11	299-W19-111	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	0	-12	-18	-30	-30
YE-12	299-W11-49	-136	-137	-134	-136	-137	-137	-126	-131	-128	-133	-134	-129	-118	-85	-103	-104	-122	-105	-120	-97	-119	-133	-137	-133
YE-13	299-W11-97	-101	-119	-82	-80	-104	-113	-64	-100	-90	-75	-87	-100	-106	-86	-105	-70	-86	-94	-114	-86	-112	-124	-129	-129
YE-14	299-W6-15	-98	-97	-96	-94	-97	-97	-96	-95	-88	-98	-97	-97	-91	-71	-72	-67	-81	-49	-78	-77	-78	-74	-76	-88
YE-15	299-W14-21	-100	-100	-86	-93	-100	-100	-76	-95	-86	-97	-96	-90	-96	-92	-99	-88	-86	-76	-82	-77	-88	-95	-98	-99
YE-16	299-W11-92	-111	-108	-93	-86	-78	-77	-32	-55	-64	-70	-90	-75	-86	-91	-110	-68	-85	-90	-96	-84	-105	-107	-125	-106
YE-17	299-W5-1	-96	-98	-75	-81	-88	-85	-46	-75	-66	-62	-73	-90	-90	-70	-74	-70	-79	-87	-100	-93	-97	-82	-95	-101
YE-18	299-W12-3	-106	-111	-97	-102	-103	-104	-67	-94	-82	-103	-108	-104	-95	-70	-74	-78	-85	-88	-103	-94	-98	-87	-100	-108
YE-19	299-W12-4	-134	-136	-120	-135	-137	-102	-134	-133	-115	-135	-137	-132	-128	-118	-130	-117	-128	-119	-132	-121	-119	-97	-118	-133
YE-20	299-W14-22	-114	-117	-100	-101	-115	-116	-68	-102	-94	-103	-115	-91	-90	-107	-118	-91	-105	-95	-114	-97	-100	-91	-107	-114
YE-21	299-W22-90	-24	-25	-25	-25	-25	-25	-25	-25	-24	-25	-25	-24	-25	-5	-3	-16	-25	-24	-25	-25	-25	-23	-25	-25
YE-22	299-W22-91	-29	-27	-29	-29	-30	-30	-30	-30	-29	-30	-30	-29	-30	-30	-30	-27	-30	-29	-30	-30	-30	-28	-30	-30
YE-23	299-W22-92	-24	-25	-25	-25	-25	-25	-25	-25	-24	-25	-25	-25	-25	-25	-25	-23	-25	-24	-25	-23	-24	-24	-24	-25
YE-24	299-W19-125	-50	-50	-50	-50	-45	-49	-50	-50	-49	-50	-50	-50	-50	-43	-45	-42	-47	-46	-53	-50	-50	-47	-50	-50
YE-25	299-W19-113	-50	-50	-50	-50	-50	-50	-50	-50	-49	-23	-1	-49	-50	-51	-50	-45	-50	-49	-46	-45	-45	-42	-45	-41
YE-26	299-W19-114	-50	-50	-50	-50	-51	-50	-50	-50	-49	-59	-93	-50	-51	-80	-75	-71	-69	-70	-75	-73	-74	-72	-74	-75

Table A-4. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2018 and 2019

Stress Period of Model Commences in 2012		73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
Stress Period of Model Commences in 2015		37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Well ID	Well Name	Jan. 2018	Feb. 2018	Mar. 2018	Apr. 2018	May 2018	Jun 2018	Jul 2018	Aug. 2018	Sept. 2018	Oct. 2018	Nov. 2018	Dec. 2018	Jan. 2019	Feb. 2019	Mar. 2019	Apr. 2019	May 2019	Jun 2019	Jul 2019	Aug. 2019	Sept. 2019	Oct. 2019	Nov. 2019	Dec. 2019
YE-27	299-E33-268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YE-31	299-E33-360	-163	-163	-163	-163	-162	-163	-164	-163	-159	-163	-164	-163	-162	-155	-160	-131	-114	-111	-114	-114	-113	-109	-113	-114
YE-32	299-E33-361	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-70	-50	-51	-51	-51	-49	-51	-51
YE-33	699-48-70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-72
YJ-01	299-W6-13	63	63	58	61	62	59	53	60	55	54	57	49	40	40	42	32	24	63	69	75	70	59	65	73
YJ-02	299-W6-14	204	207	190	201	223	214	188	195	106	86	132	140	7	0	43	122	140	152	161	97	77	126	137	151
YJ-03	299-W10-36	91	91	67	46	82	78	66	73	52	36	38	9	0	0	0	0	0	0	0	0	35	54	59	66
YJ-04	299-W10-35	118	115	106	62	137	130	108	122	96	90	107	109	114	87	102	118	140	150	151	150	84	112	126	92
YJ-05	299-W15-226	195	197	183	187	202	196	121	175	140	137	145	146	159	123	119	132	151	165	174	169	90	120	147	164
YJ-06	299-W15-227	152	163	149	158	165	153	125	93	138	124	125	133	172	200	177	117	134	142	154	100	75	131	144	160
YJ-07	299-W15-228	108	88	72	154	154	135	99	80	80	114	105	128	148	43	42	110	132	147	154	59	132	109	120	137
YJ-08	299-W18-41	156	158	149	118	159	143	121	122	131	121	113	110	116	122	115	99	115	148	163	64	32	124	137	151
YJ-09	699-49-69	26	7	37	28	22	3	5	16	23	26	27	26	63	60	70	5	72	71	86	43	71	15	6	40
YJ-10	699-45-67B	5	5	4	3	1	3	0	0	0	5	6	14	37	35	31	30	25	39	44	37	43	8	26	44
YJ-11	699-45-67	30	30	28	20	19	29	30	30	28	30	31	39	48	49	51	38	22	42	38	37	38	8	13	40
YJ-12	699-44-67	18	11	8	15	6	11	13	7	14	27	31	39	46	48	51	38	23	41	38	36	37	39	40	3
YJ-13	699-43-67	12	27	16	27	18	22	22	21	20	21	25	30	218	28	33	33	24	33	40	42	29	42	41	9
YJ-14	699-42-67	83	64	0	15	64	46	21	27	59	91	101	116	121	121	107	0	56	119	115	108	110	115	120	120
YJ-15	699-40-67	48	25	32	31	24	36	37	37	14	52	64	70	88	85	89	67	74	44	85	71	94	73	72	97
YJ-16	699-38-64	90	96	75	82	94	104	89	96	80	86	97	97	117	113	117	92	107	49	113	96	118	89	89	120
YJ-17	699-43-67B	8	18	10	18	12	15	15	14	13	14	16	20	11	20	22	22	13	26	27	25	23	27	28	2
YJ-18	299-W15-29	32	66	59	63	66	61	46	47	59	62	82	81	80	80	82	80	93	78	116	116	106	59	98	106
YJ-19	299-W18-36	0	0	0	0	0	0	0	0	24	61	61	47	50	61	60	53	51	48	33	63	101	79	85	92
YJ-20	299-W18-37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-21	299-W18-38	114	71	57	54	55	91	76	74	51	55	44	53	27	0	0	38	69	54	16	47	68	53	86	81
YJ-22	299-W18-39	0	0	13	5	6	0	0	0	0	0	0	0	6	15	9	14	1	2	68	63	13	5	56	48

Table A-4. Historical Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2018 and 2019

Stress Period of Model Commences in 2012		73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
Stress Period of Model Commences in 2015		37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Well ID	Well Name	Jan. 2018	Feb. 2018	Mar. 2018	Apr. 2018	May 2018	Jun 2018	Jul 2018	Aug. 2018	Sept. 2018	Oct. 2018	Nov. 2018	Dec. 2018	Jan. 2019	Feb. 2019	Mar. 2019	Apr. 2019	May 2019	Jun 2019	Jul 2019	Aug. 2019	Sept. 2019	Oct. 2019	Nov. 2019	Dec. 2019
YJ-23	699-46-68	40	37	24	38	52	46	0	40	49	55	59	58	67	66	70	56	40	55	68	58	63	52	53	64
YJ-24	299-W15-229	88	78	77	44	92	79	75	67	75	61	87	76	75	75	80	77	89	89	98	43	116	54	84	111
YJ-25	299-W7-14	150	157	152	139	100	49	86	92	79	74	83	96	87	61	63	65	72	47	6	94	139	119	123	127
YJ-26	299-E20-1	77	77	63	77	76	80	66	69	23	73	97	84	86	82	84	73	82	45	71	62	76	64	49	83
YJ-27	299-E20-2	87	87	74	88	87	91	83	86	84	72	9	55	75	76	71	60	67	26	75	59	75	67	71	74
YJ-28	299-E11-1	74	75	63	75	74	79	80	80	76	81	81	79	81	81	81	74	81	13	77	64	81	71	84	87
YJ-29	299-W6-16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-30	299-W18-44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-31	299-W18-43	159	226	206	214	95	107	137	134	90	128	92	86	108	113	104	47	72	88	29	49	98	75	19	30
YJ-32	299-W18-42	147	141	129	123	104	149	98	146	140	167	131	140	118	106	105	103	132	111	0	46	138	118	19	30

Note: Extraction and injection rates are shown in gallons per minute (gpm).

CY = calendar year

ID = identification

P&T = pump and treat

Table A-5. Predicted Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2020 and 2021

Stress Period of Model Commences in 2015		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Well ID	Well Name	Jan. 2020	Feb. 2020	Mar. 2020	Apr. 2020	May 2020	June 2020	July 2020	Aug. 2020	Sept. 2020	Oct. 2020	Nov. 2020	Dec. 2020	Jan. 2021	Feb. 2021	Mar. 2021	Apr. 2021	May 2021	June 2021	July 2021	Aug. 2021	Sept. 2021	Oct. 2021	Nov. 2021	Dec. 2021
YE-01	299-W15-225	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-80	-70	-75	-75	-75	-75	-60
YE-02	299-W14-20	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-100	-100	-100	-100	-100
YE-03	299-W14-73	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-120	-120	-120	-120	-110
YE-04	299-W14-74	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-100	-100
YE-05	299-W12-2	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-105	-100	-100
YE-06	299-W11-50	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-60	-100	-100	-100	-100	-100	-100	-100
YE-07	299-W11-90	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-130	-130	-130	-130	-130	-100	-120
YE-08	299-W11-96	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-130	-130	-120	-120	-120	-120	-120
YE-09	299-W17-3	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-100	-90	-80	-80	-80	-80	-60
YE-10	299-W17-2	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-95	-110	-110	-110	-110	-110	-80
YE-11	299-W19-111	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10
YE-12	299-W11-49	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-120	-120	-120	-120	-120
YE-13	299-W11-97	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-120	-120	-120	-110	-80
YE-14	299-W6-15	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-110	-110	-110	-110	-110	-110	-110
YE-15	299-W14-21	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90	-90
YE-16	299-W11-92	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-100	-80	-70	-70	-70	-70	-60
YE-17	299-W5-1	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-90	-80	-80	-80	-80	-80	-60
YE-18	299-W12-3	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100	-100
YE-19	299-W12-4	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-130	-120	-120	-120	-120	-110
YE-20	299-W14-22	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-115	-110
YE-21	299-W22-90	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25
YE-22	299-W22-91	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30
YE-23	299-W22-92	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25
YE-24	299-W19-125	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40
YE-25	299-W19-113	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50
YE-26	299-W19-114	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80	-80
YE-27	299-E33-268	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-5. Predicted Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2020 and 2021

Stress Period of Model Commences in 2015		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Well ID	Well Name	Jan. 2020	Feb. 2020	Mar. 2020	Apr. 2020	May 2020	June 2020	July 2020	Aug. 2020	Sept. 2020	Oct. 2020	Nov. 2020	Dec. 2020	Jan. 2021	Feb. 2021	Mar. 2021	Apr. 2021	May 2021	June 2021	July 2021	Aug. 2021	Sept. 2021	Oct. 2021	Nov. 2021	Dec. 2021
YE-31	299-E33-360	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110	-110
YE-32	299-E33-361	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50
YE-33	699-48-70	-75	-75	-75	-75	-75	-75	-75	-75	-75	-75	-75	-75	-75	-75	-75	-75	-75	-80	-100	-100	-100	-100	-100	-100
YE-34	299-W11-103	0	0	0	0	0	0	0	0	0	0	0	0	0	-125	-125	-155	-150	-160	-155	-140	-140	-140	-130	-130
YE-35	299-W12-5	0	0	0	0	0	0	0	0	0	0	0	0	0	-125	-125	-155	-150	-160	-160	-140	-140	-140	-130	-130
YE-36	299-W11-104	0	0	0	0	0	0	0	0	0	0	0	0	0	-125	-125	-155	-150	-165	-160	-150	-150	-150	-130	-130
YE-37	299-W14-28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-125	-160	-150	-160	-160	-140	-140	-140	-130	-130
YE-38	299-W14-27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-150	-160	-160	-140	-140	-140	-130	-130
YE-39	299-W14-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-150	-140	-140	-140	-130	-130
YE-40	299-W14-31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-140	-140	-140	-130	-130
YE-41	299-W14-32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-130	-130
YE-42	299-W14-33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-130
YE-43	699-40-70A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-01	299-W6-13	130	130	130	130	130	130	130	130	130	130	130	130	130	110	120	120	140	140	140	130	130	130	130	130
YJ-02	299-W6-14	140	140	140	140	140	140	140	140	140	140	140	140	140	110	120	120	140	140	140	130	130	130	130	130
YJ-03	299-W10-36	130	130	130	130	130	130	130	130	130	130	130	130	130	110	120	120	130	140	140	130	130	130	130	130
YJ-04	299-W10-35	130	130	130	130	130	130	130	130	130	130	130	130	130	110	120	120	130	140	140	130	130	130	130	130
YJ-05	299-W15-226	130	130	130	130	130	130	130	130	130	130	130	130	130	110	120	120	130	140	140	130	130	130	130	130
YJ-06	299-W15-227	140	140	140	140	140	140	140	140	140	140	140	140	140	110	120	130	130	140	140	130	130	130	130	130
YJ-07	299-W15-228	130	130	130	130	130	130	130	130	130	130	130	130	130	120	120	130	130	140	140	130	130	130	130	130
YJ-08	299-W18-41	130	130	130	130	130	130	130	130	130	130	130	130	130	120	120	120	130	140	140	130	130	130	130	130
YJ-09	699-49-69	50	50	50	50	50	50	50	50	50	50	50	50	50	30	30	30	30	30	60	60	60	60	60	60
YJ-10	699-45-67B	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	25	25	25	25	25	25	25	25
YJ-11	699-45-67	50	50	50	50	50	50	50	50	50	50	50	50	50	35	40	30	30	30	60	60	60	60	60	60
YJ-12	699-44-67	50	50	50	50	50	50	50	50	50	50	50	50	50	40	50	45	45	45	60	60	60	60	60	60
YJ-13	699-43-67	50	50	50	50	50	50	50	50	50	50	50	50	50	40	60	60	60	60	70	70	70	70	70	70
YJ-14	699-42-67	50	50	50	50	50	50	50	50	50	50	50	50	50	120	120	120	130	130	130	140	140	140	140	140

Table A-5. Predicted Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies during CY 2020 and 2021

Stress Period of Model Commences in 2015		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Well ID	Well Name	Jan. 2020	Feb. 2020	Mar. 2020	Apr. 2020	May 2020	June 2020	July 2020	Aug. 2020	Sept. 2020	Oct. 2020	Nov. 2020	Dec. 2020	Jan. 2021	Feb. 2021	Mar. 2021	Apr. 2021	May 2021	June 2021	July 2021	Aug. 2021	Sept. 2021	Oct. 2021	Nov. 2021	Dec. 2021
YJ-15	699-40-67	50	50	50	50	50	50	50	50	50	50	50	50	50	40	50	50	50	50	50	60	60	60	60	60
YJ-16	699-38-64	50	50	50	50	50	50	50	50	50	50	50	50	50	40	50	50	50	50	50	50	50	50	50	50
YJ-17	699-43-67B	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	25	30	30	30	30	30	30
YJ-18	299-W15-29	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
YJ-19	299-W18-36	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
YJ-20	299-W18-37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
YJ-21	299-W18-38	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	110	110	110	110	110	110
YJ-22	299-W18-39	15	15	15	15	15	15	15	15	15	15	15	15	15	5	5	5	15	15	25	25	25	25	25	25
YJ-23	699-46-68	90	90	90	90	90	90	90	90	90	90	90	90	90	50	50	100	100	100	100	100	100	100	100	100
YJ-24	299-W15-229	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	130	140	140	150	150	150	150	150
YJ-25	299-W7-14	120	120	120	120	120	120	120	120	120	120	120	120	120	110	120	120	130	140	140	135	135	135	135	135
YJ-26	299-E20-1	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
YJ-27	299-E20-2	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
YJ-28	299-E11-1	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
YJ-29	299-W6-16	0	0	0	0	0	0	0	0	0	0	0	0	0	120	120	130	130	140	140	130	130	130	130	130
YJ-30	299-W18-44	0	0	0	0	0	0	0	0	0	0	0	0	0	120	120	130	130	140	140	130	130	130	130	130
YJ-31	299-W18-43	110	110	110	110	110	110	110	110	110	110	110	110	110	120	120	130	130	140	140	135	135	135	135	135
YJ-32	299-W18-42	130	130	130	130	130	130	130	130	130	130	130	130	130	120	120	130	130	140	140	150	150	150	150	150
YJ-33	699-47-78	0	0	0	0	0	0	0	0	0	0	0	0	0	120	120	130	130	130	140	150	150	150	150	150
YJ-34	699-47-78C	0	0	0	0	0	0	0	0	0	0	0	0	0	120	120	130	130	130	130	150	150	150	150	150
YJ-35	699-47-78B	0	0	0	0	0	0	0	0	0	0	0	0	0	120	120	130	130	130	130	150	150	150	150	150

Note: Extraction and injection rates are shown in gallons per minute (gpm).

CY = calendar year

ID = identification

P&T = pump and treat

Table A-6. Predicted Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies from CY 2022 through 2137

Stress Period of Model Commences in 2015		85 -108	109
Well ID	Well Name	Jan. 2022 – Sep. 2037	Sep 2037 - Sep. 2137
YE-01	299-W15-225	-50	0
YE-02	299-W14-20	-100	0
YE-03	299-W14-73	-110	0
YE-04	299-W14-74	-100	0
YE-05	299-W12-2	-100	0
YE-06	299-W11-50	-100	0
YE-07	299-W11-90	-100	0
YE-08	299-W11-96	-120	0
YE-09	299-W17-3	-50	0
YE-10	299-W17-2	-50	0
YE-11	299-W19-111	-10	0
YE-12	299-W11-49	-120	0
YE-13	299-W11-97	-60	0
YE-14	299-W6-15	-100	0
YE-15	299-W14-21	-90	0
YE-16	299-W11-92	-50	0
YE-17	299-W5-1	-50	0
YE-18	299-W12-3	-80	0
YE-19	299-W12-4	-110	0
YE-20	299-W14-22	-100	0
YE-21	299-W22-90	-25	0
YE-22	299-W22-91	-30	0
YE-23	299-W22-92	-25	0
YE-24	299-W19-125	-40	0
YE-25	299-W19-113	-50	0
YE-26	299-W19-114	-80	0
YE-27	299-E33-268	0	0
YE-31	299-E33-360	-110	0
YE-32	299-E33-361	-50	0
YE-33	699-48-70	-100	0
YE-34	299-W11-103	-130	0
YE-35	299-W12-5	-130	0
YE-36	299-W11-104	-130	0
YE-37	299-W14-28	-130	0
YE-38	299-W14-27	-150	0
YE-39	299-W14-30	-130	0
YE-40	299-W14-31	-130	0
YE-41	299-W14-32	-130	0
YE-42	299-W14-33	-130	0
YE-43	699-40-70A	-130	0
YJ-01	299-W6-13	130	0
YJ-02	299-W6-14	130	0
YJ-03	299-W10-36	130	0
YJ-04	299-W10-35	130	0
YJ-05	299-W15-226	130	0
YJ-06	299-W15-227	130	0
YJ-07	299-W15-228	130	0
YJ-08	299-W18-41	130	0

Table A-6. Predicted Groundwater Extraction and Injection Rates for 200-ZP-1 and 200-UP-1 P&T Remedies from CY 2022 through 2137

Stress Period of Model Commences in 2015		85 -108	109
Well ID	Well Name	Jan. 2022 – Sep. 2037	Sep 2037 - Sep. 2137
YJ-09	699-49-69	60	0
YJ-10	699-45-67B	25	0
YJ-11	699-45-67	60	0
YJ-12	699-44-67	60	0
YJ-13	699-43-67	70	0
YJ-14	699-42-67	140	0
YJ-15	699-40-67	60	0
YJ-16	699-38-64	50	0
YJ-17	699-43-67B	30	0
YJ-18	299-W15-29	120	0
YJ-19	299-W18-36	100	0
YJ-20	299-W18-37	0	0
YJ-21	299-W18-38	110	0
YJ-22	299-W18-39	25	0
YJ-23	699-46-68	100	0
YJ-24	299-W15-229	150	0
YJ-25	299-W7-14	135	0
YJ-26	299-E20-1	50	0
YJ-27	299-E20-2	50	0
YJ-28	299-E11-1	50	0
YJ-29	299-W6-16	130	0
YJ-30	299-W18-44	130	0
YJ-31	299-W18-43	135	0
YJ-32	299-W18-42	150	0
YJ-33	699-47-78	150	0
YJ-34	699-47-78C	150	0
YJ-35	699-47-78B	150	0

Note: Extraction and injection rates are shown in gallons per minute (gpm).

CY = calendar year

ID = identification

P&T = pump and treat

Appendix B

Simulated Versus Observed Concentrations in Monitoring Wells

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Figure B-124. Comparison of Simulated and Observed Concentrations for Uranium (Page 15 of 16)..... B-124
Figure B-125. Comparison of Simulated and Observed Concentrations for Uranium (Page 16 of 16)..... B-125

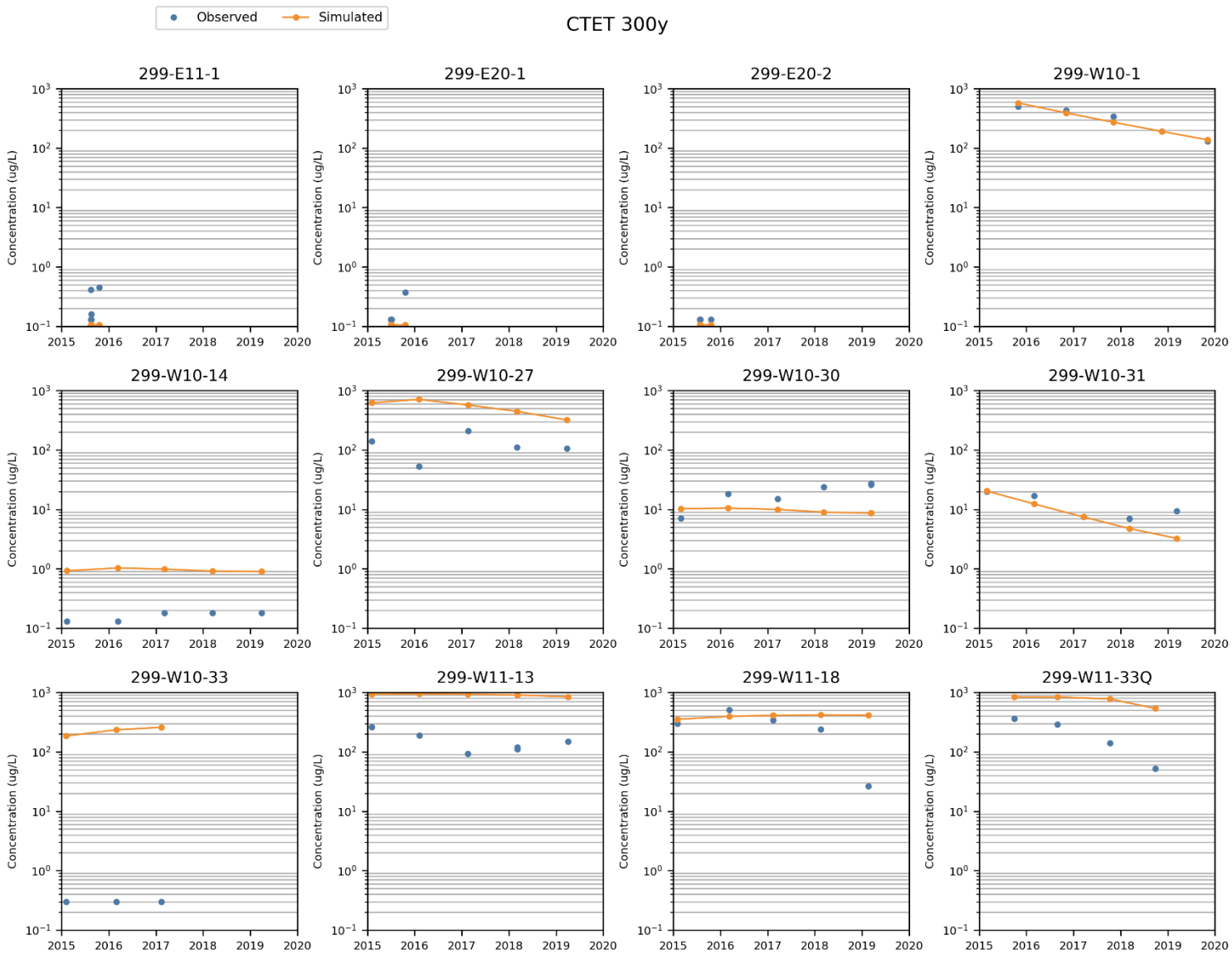

Figure B-1. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 1 of 12)

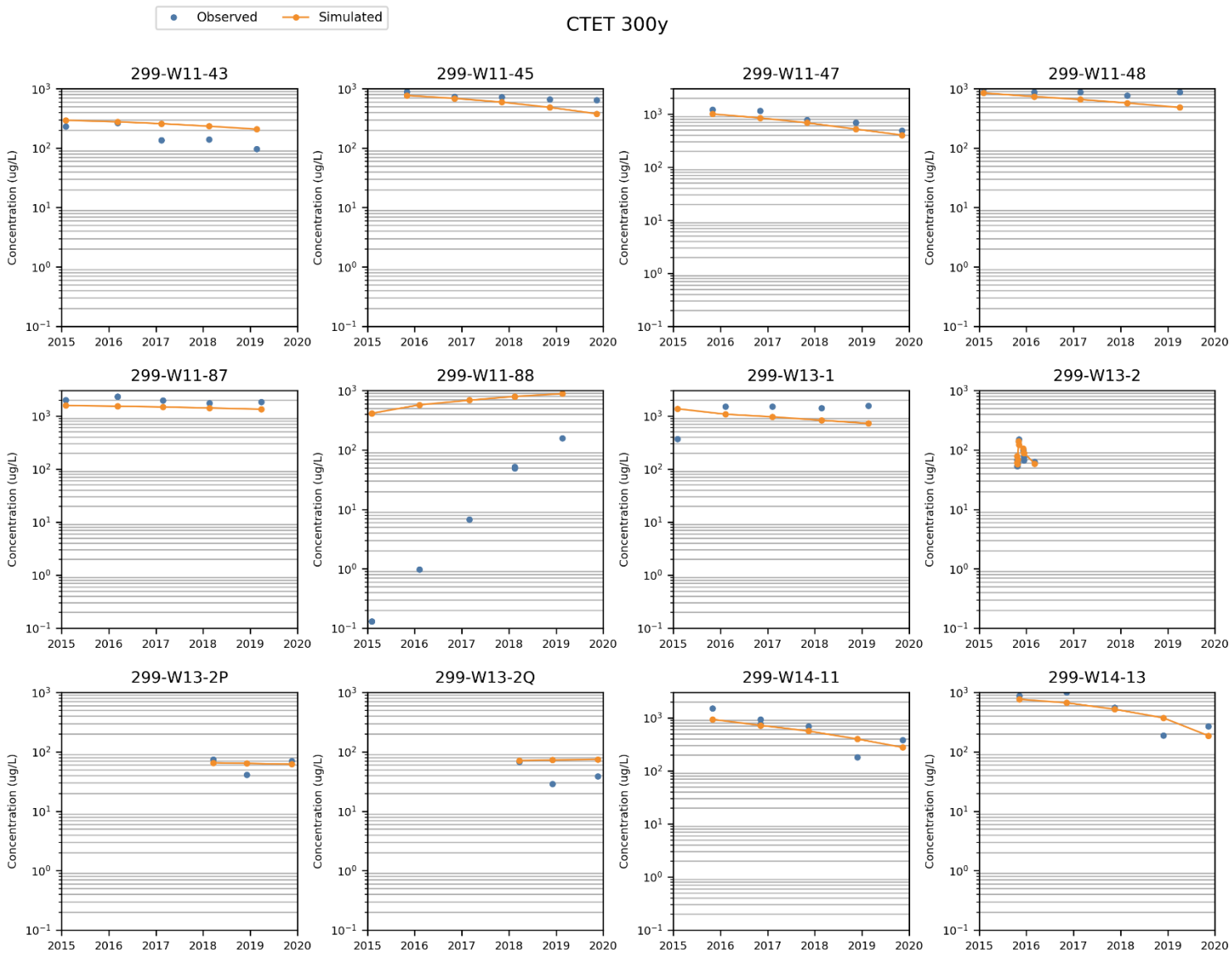

Figure B-2. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 2 of 12)

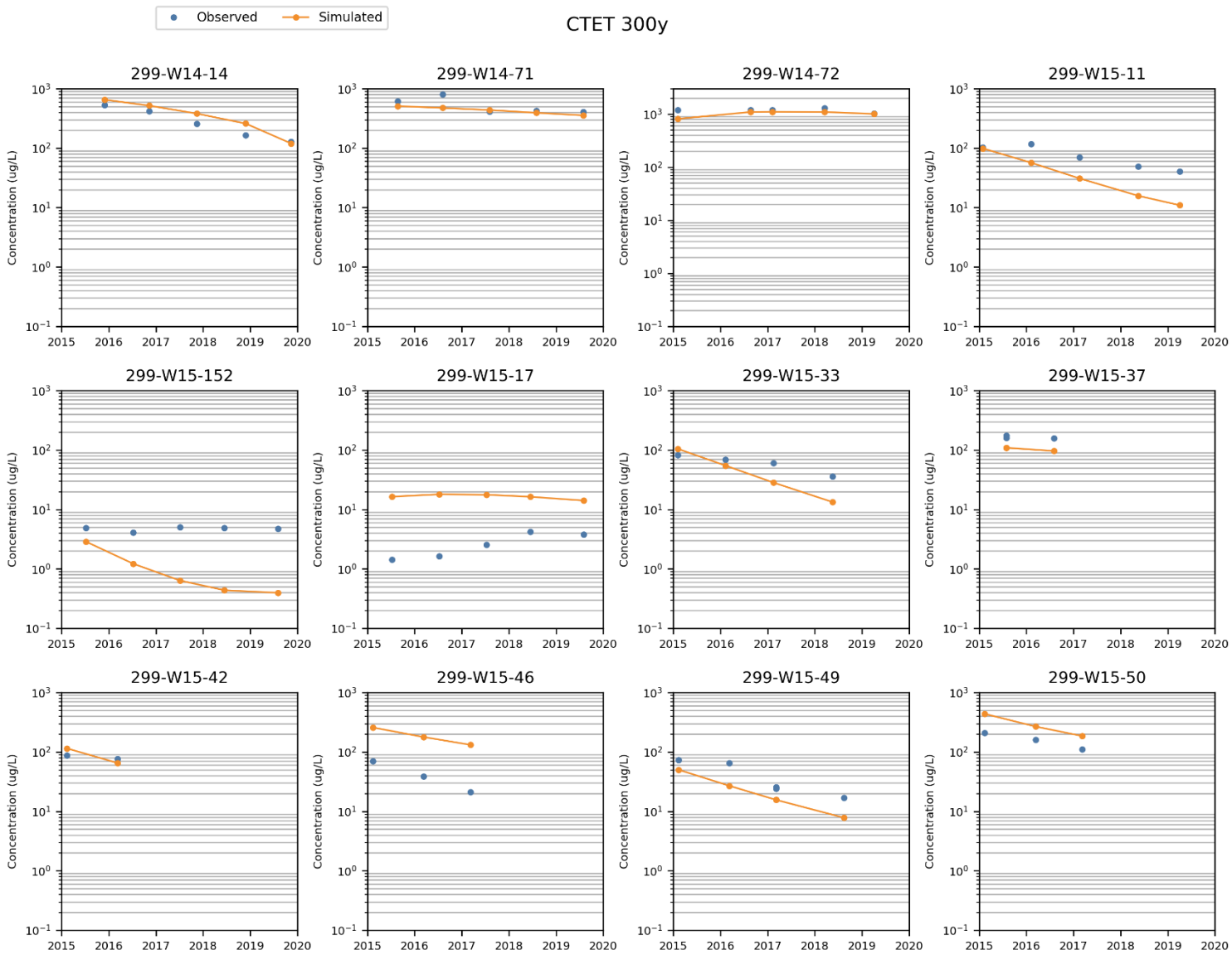

Figure B-3. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 3 of 12)

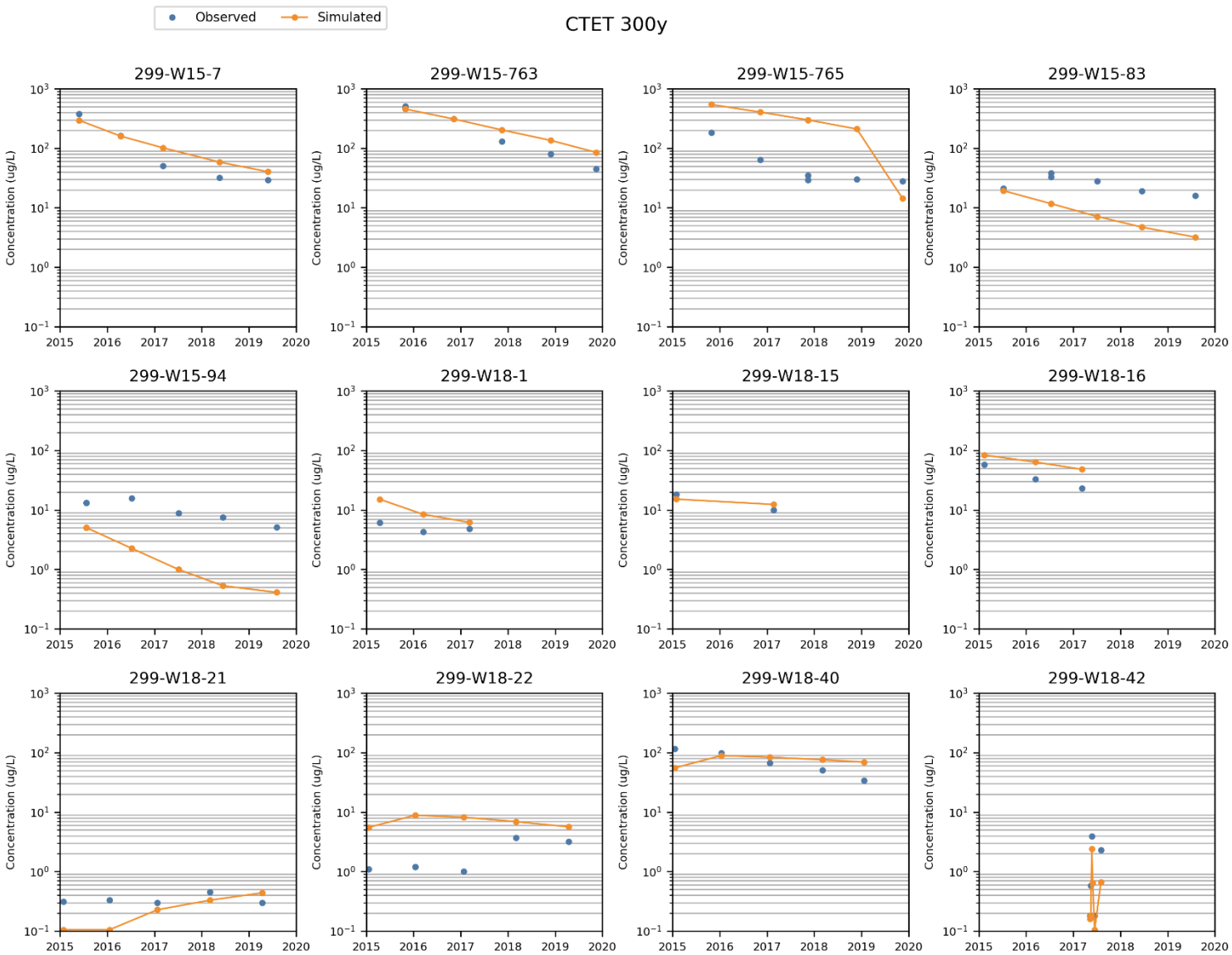

Figure B-4. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 4 of 12)

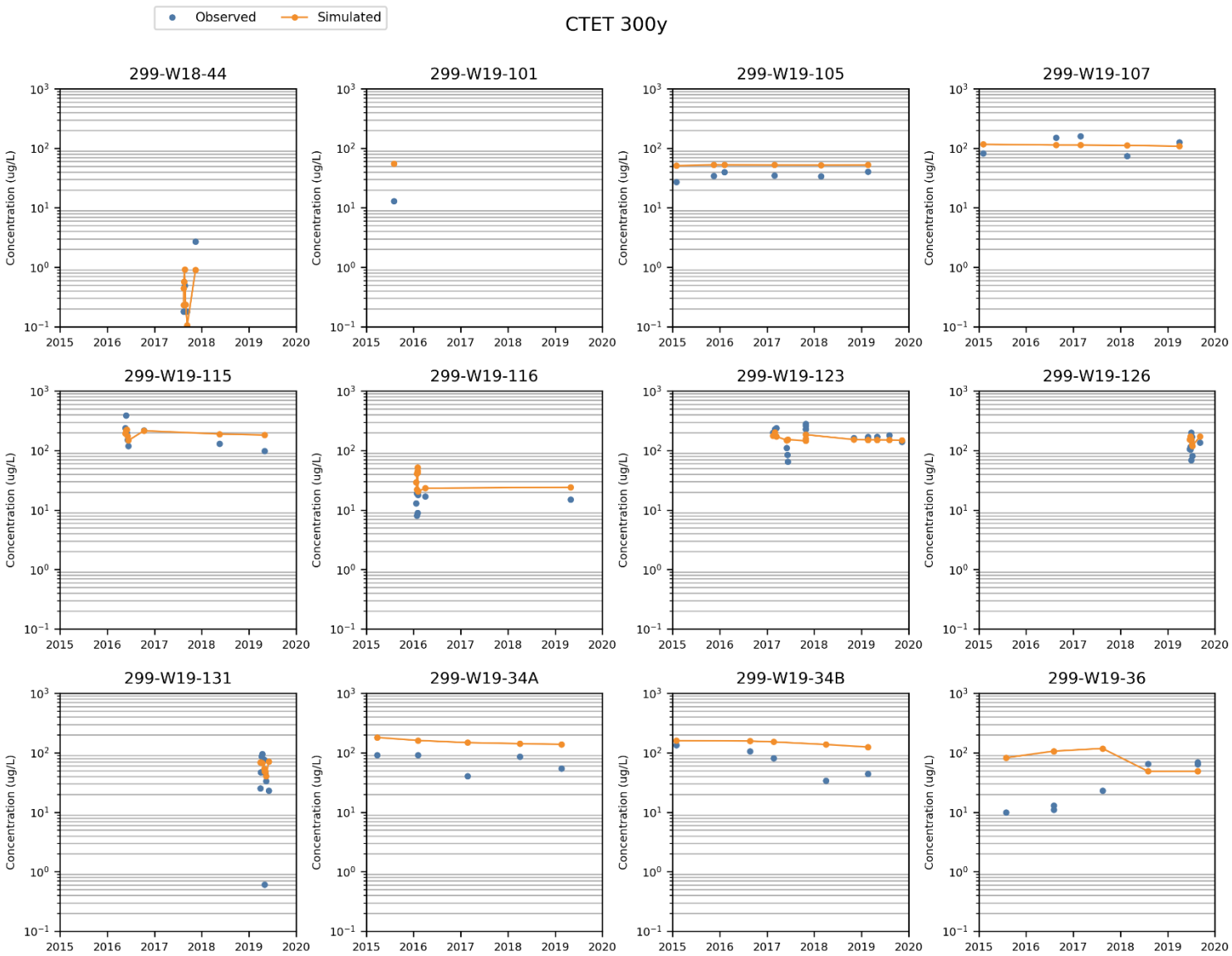

Figure B-5. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 5 of 12)

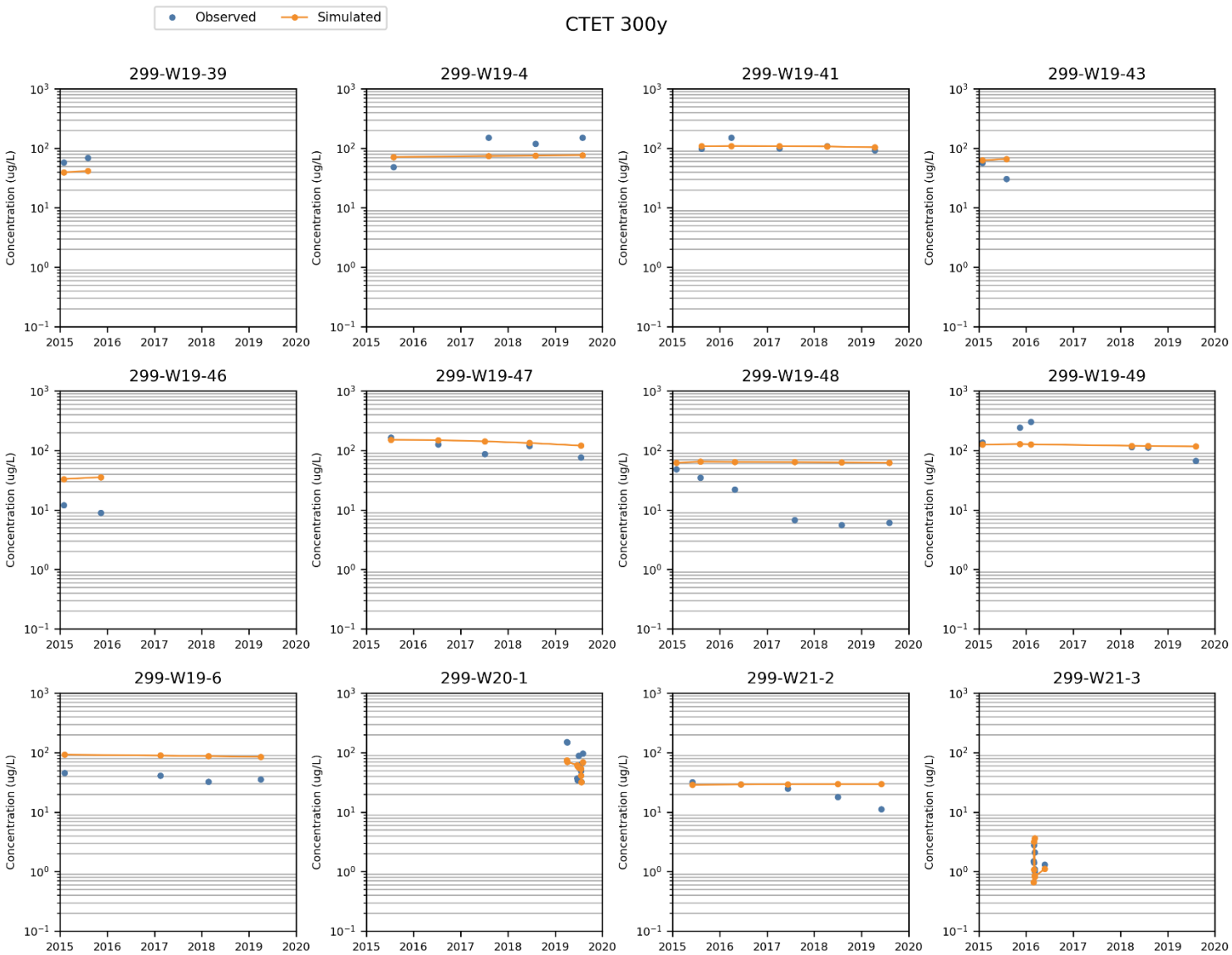

Figure B-6. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 6 of 12)

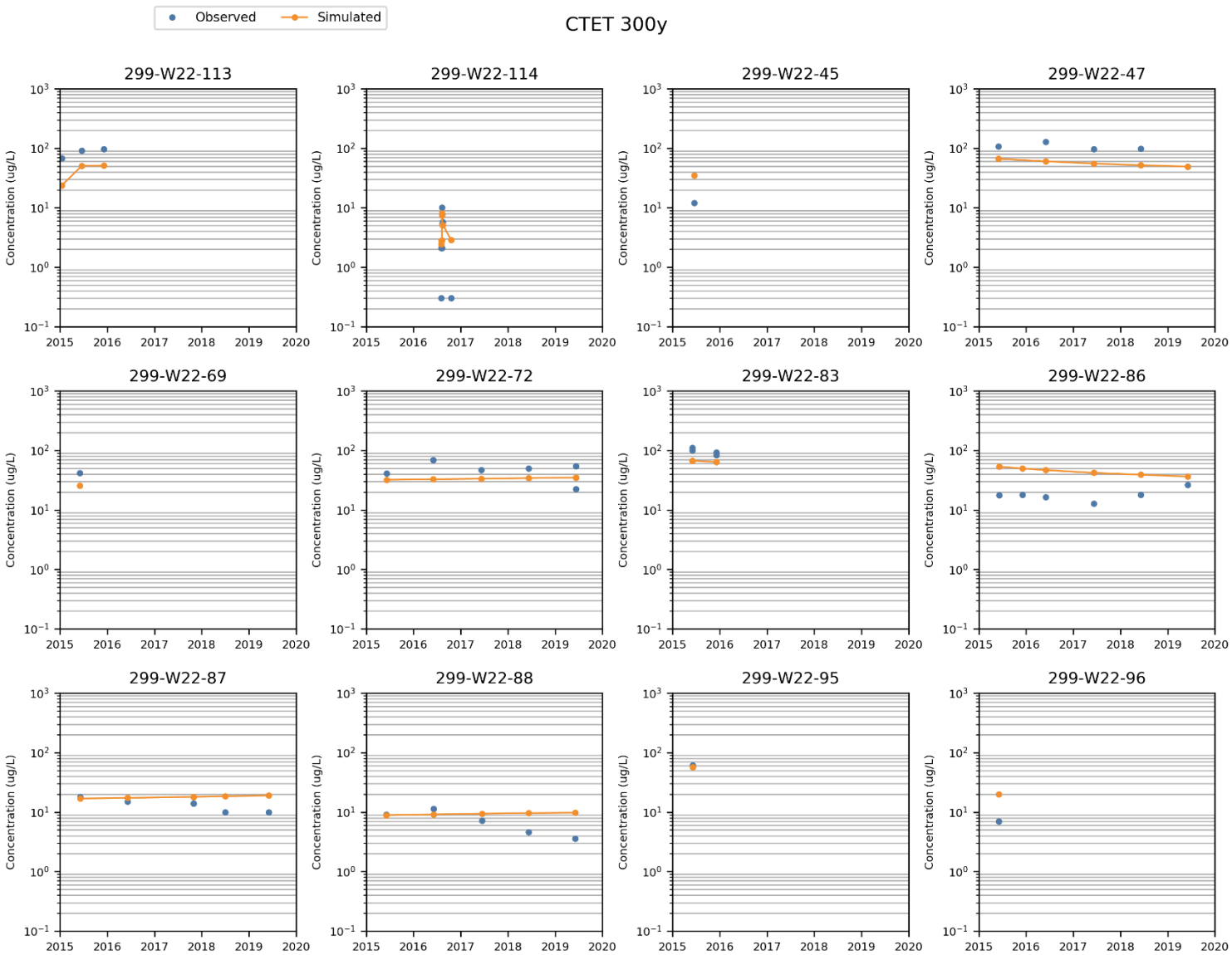

Figure B-7. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 7 of 12)

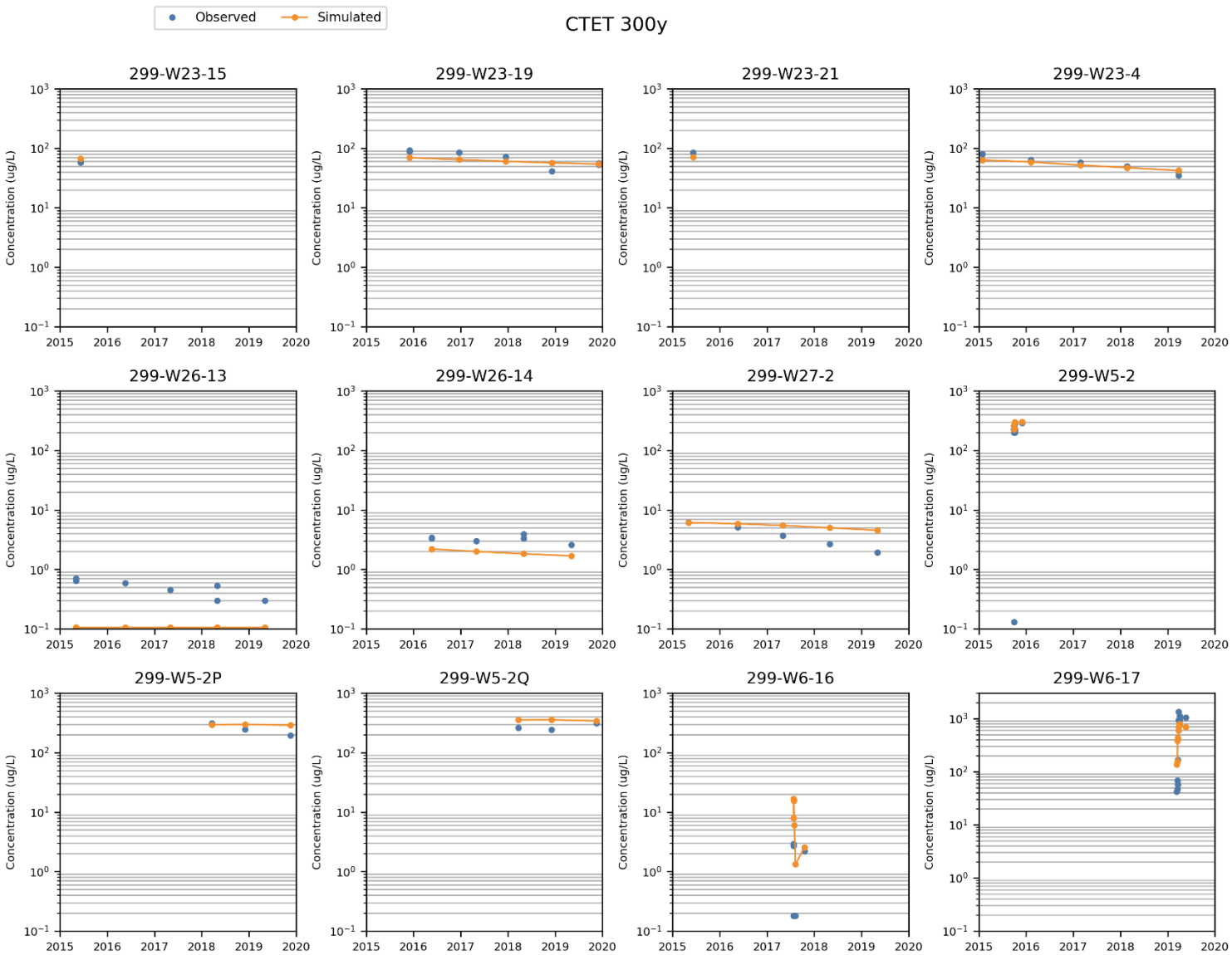

Figure B-8. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 8 of 12)

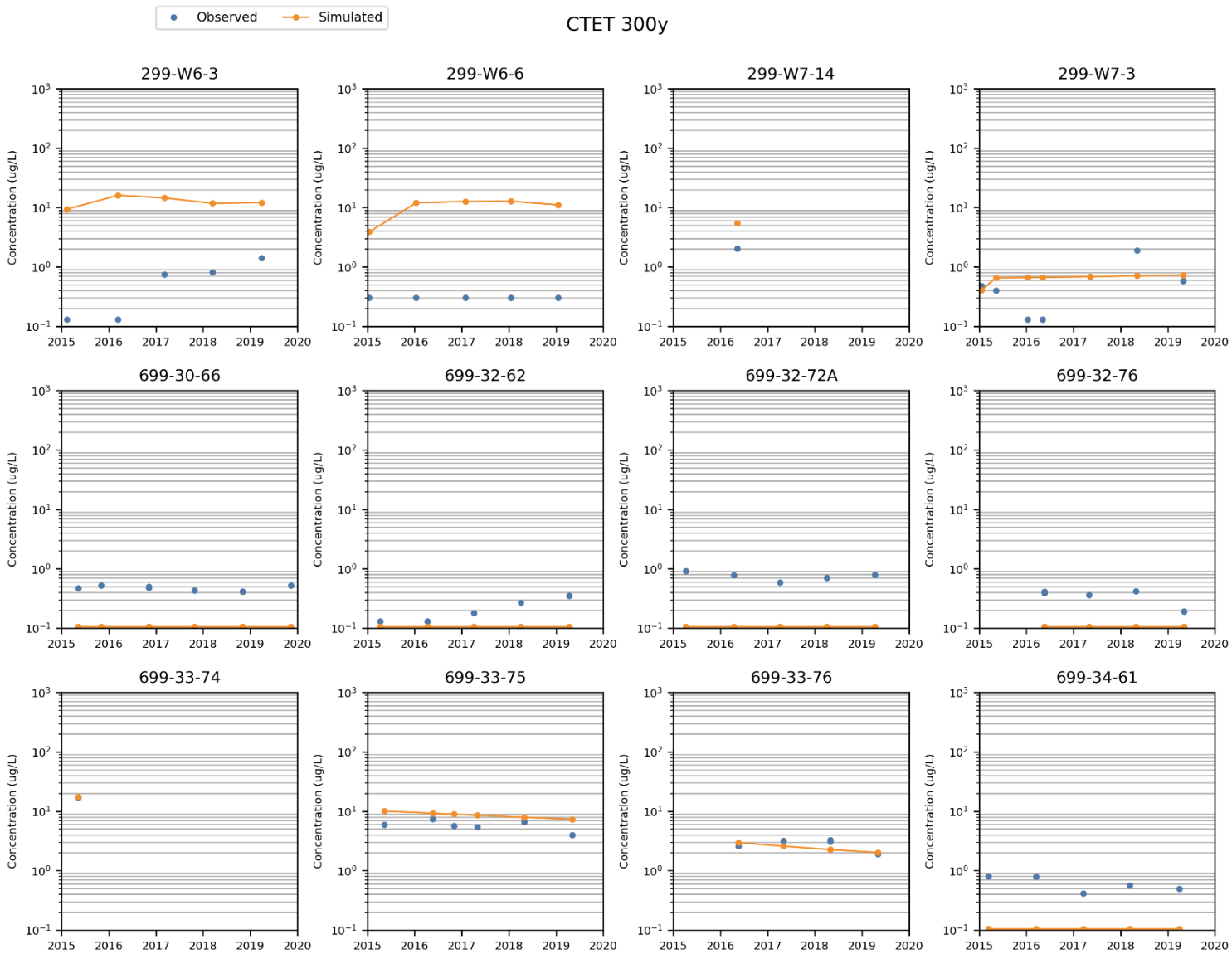

Figure B-9. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 9 of 12)

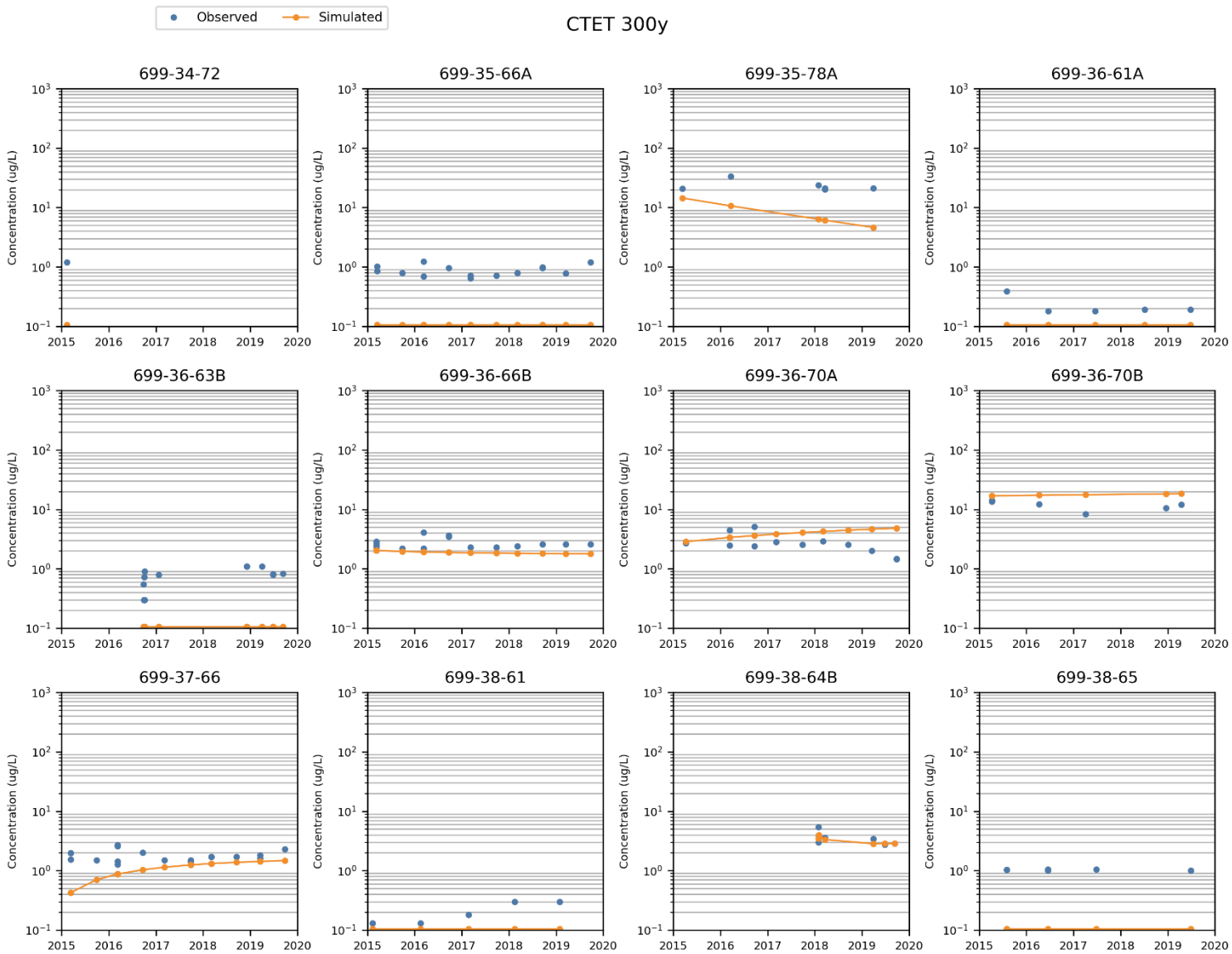

Figure B-10. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 10 of 12)

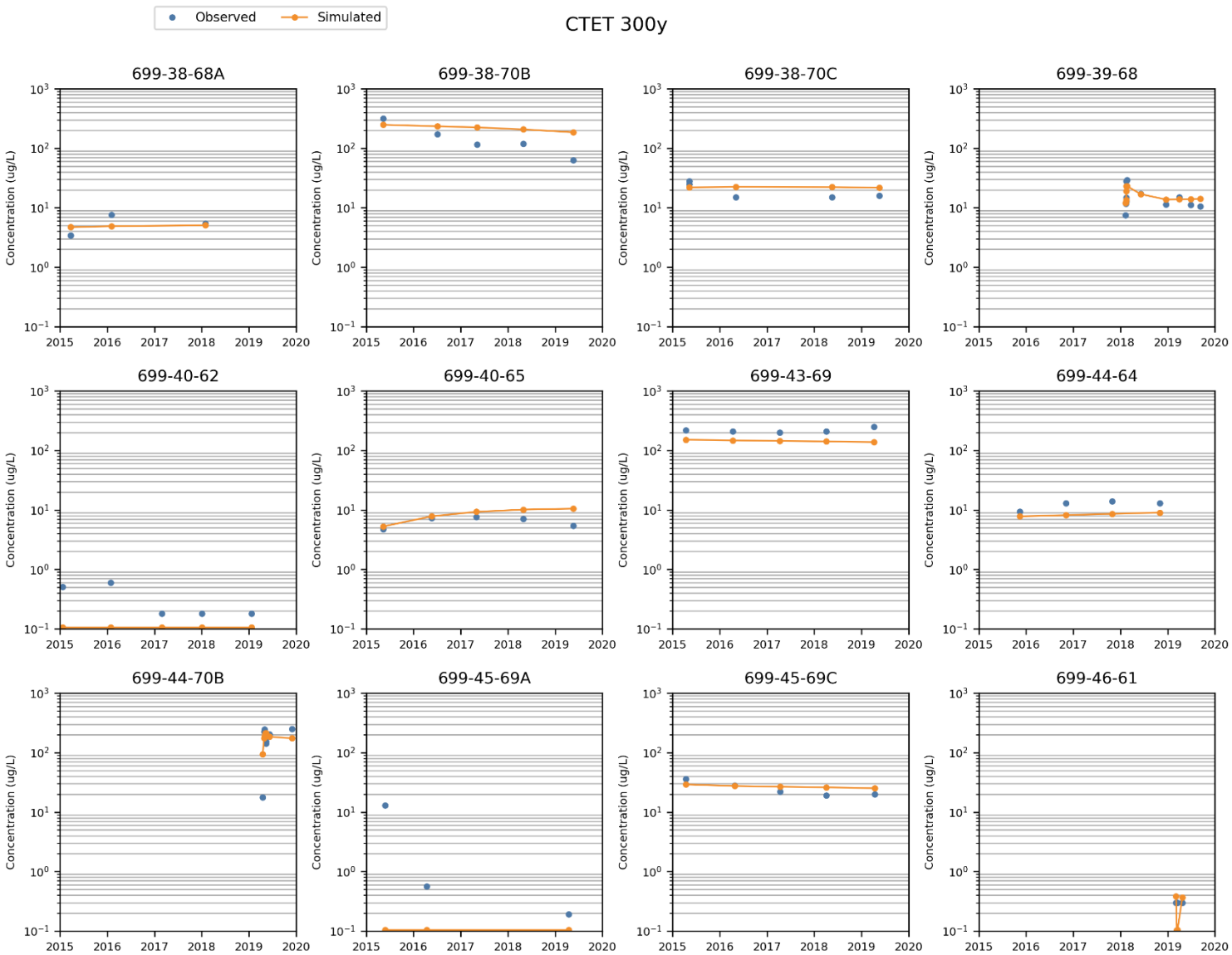

Figure B-11. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 11 of 12)

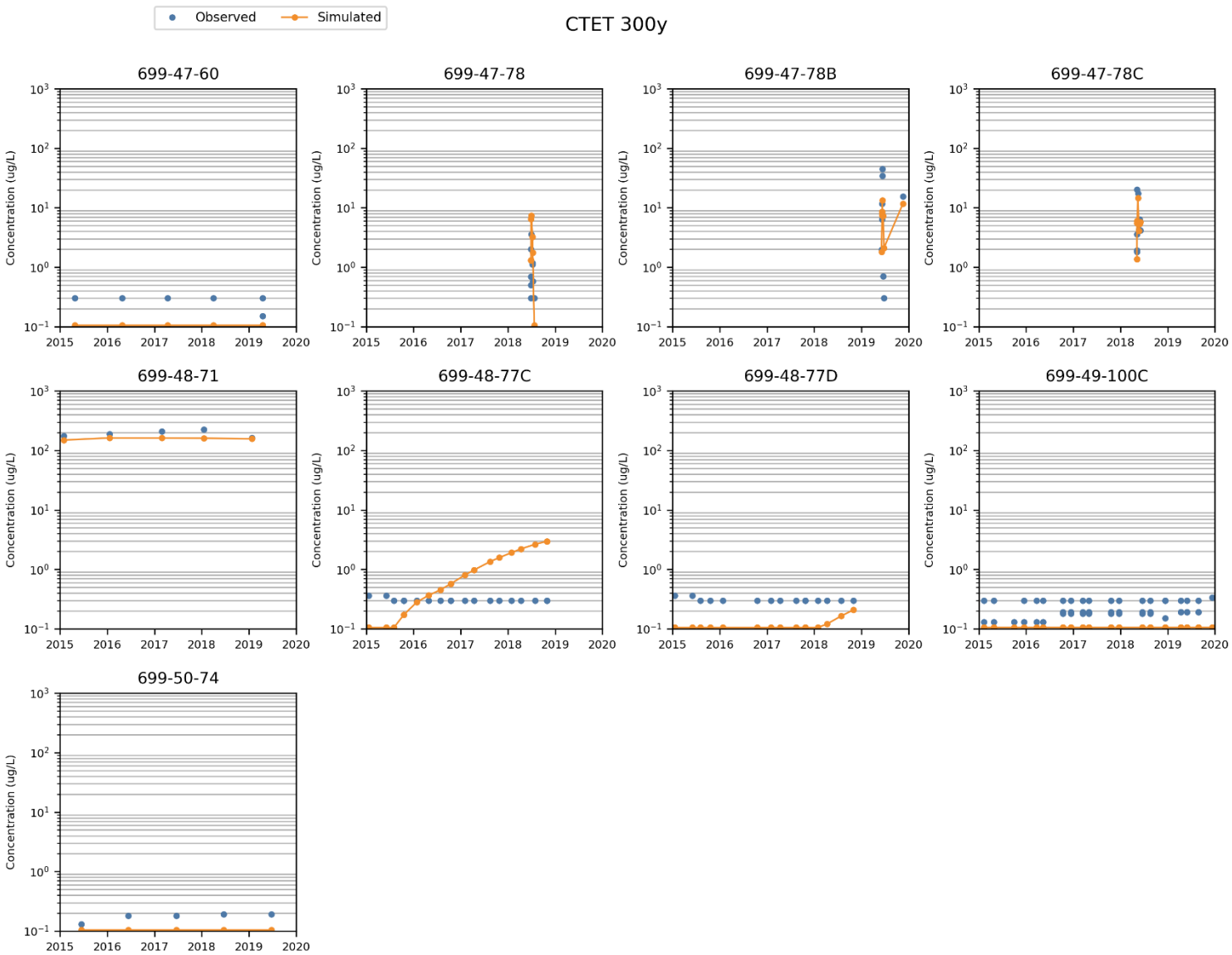

Figure B-12. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 300-Year Half-Life (Page 12 of 12)

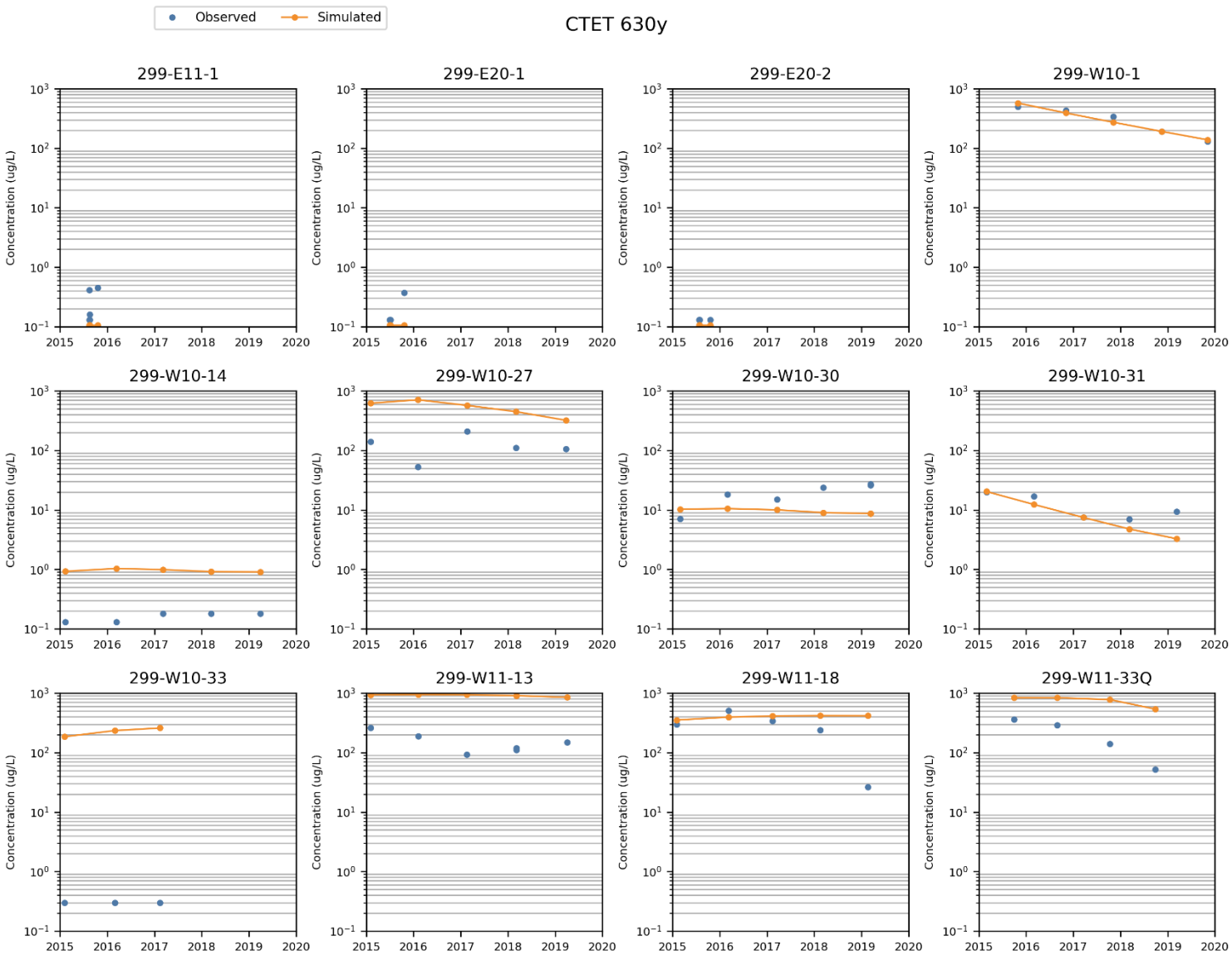

Figure B-13. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 1 of 12)

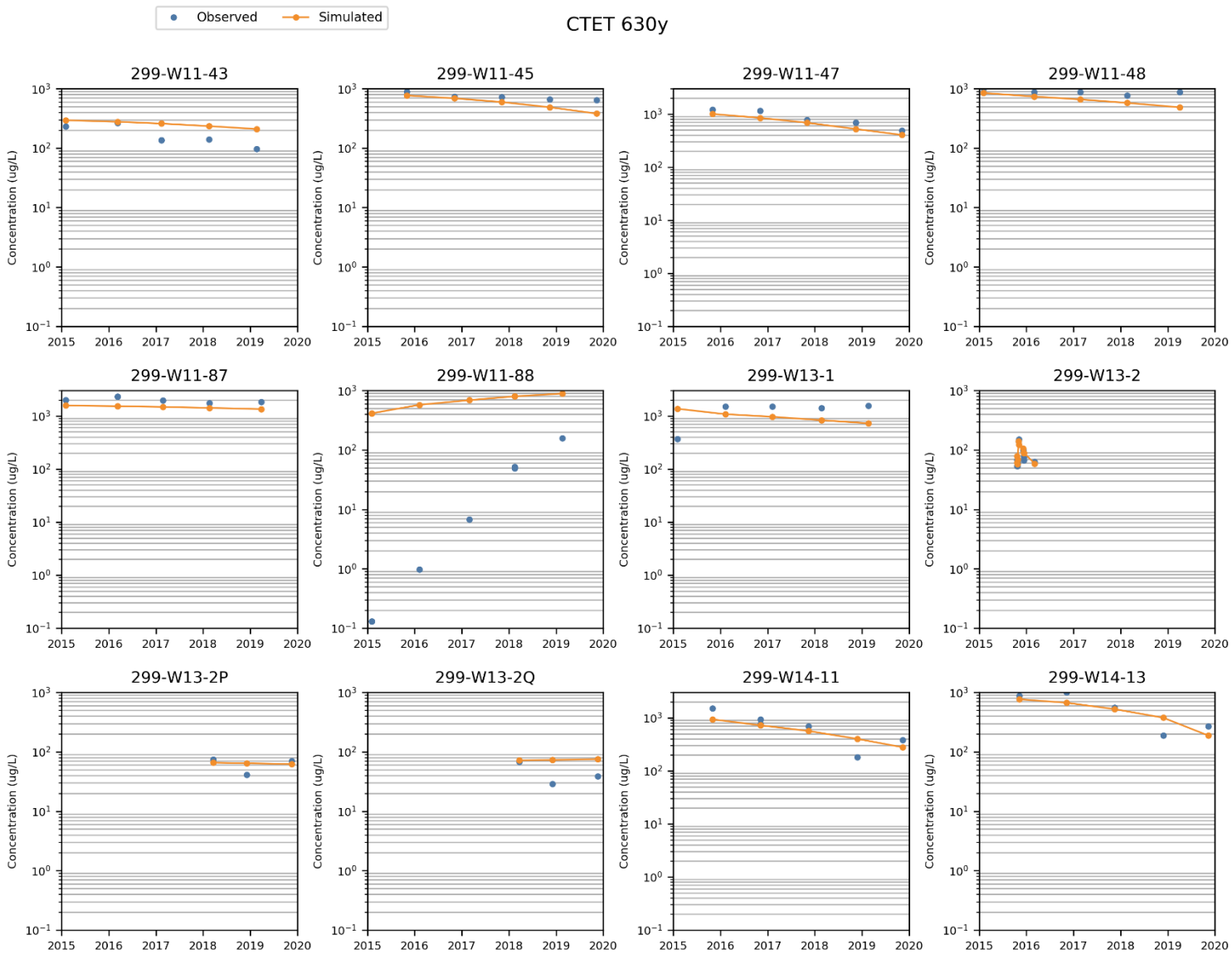

Figure B-14. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 2 of 12)

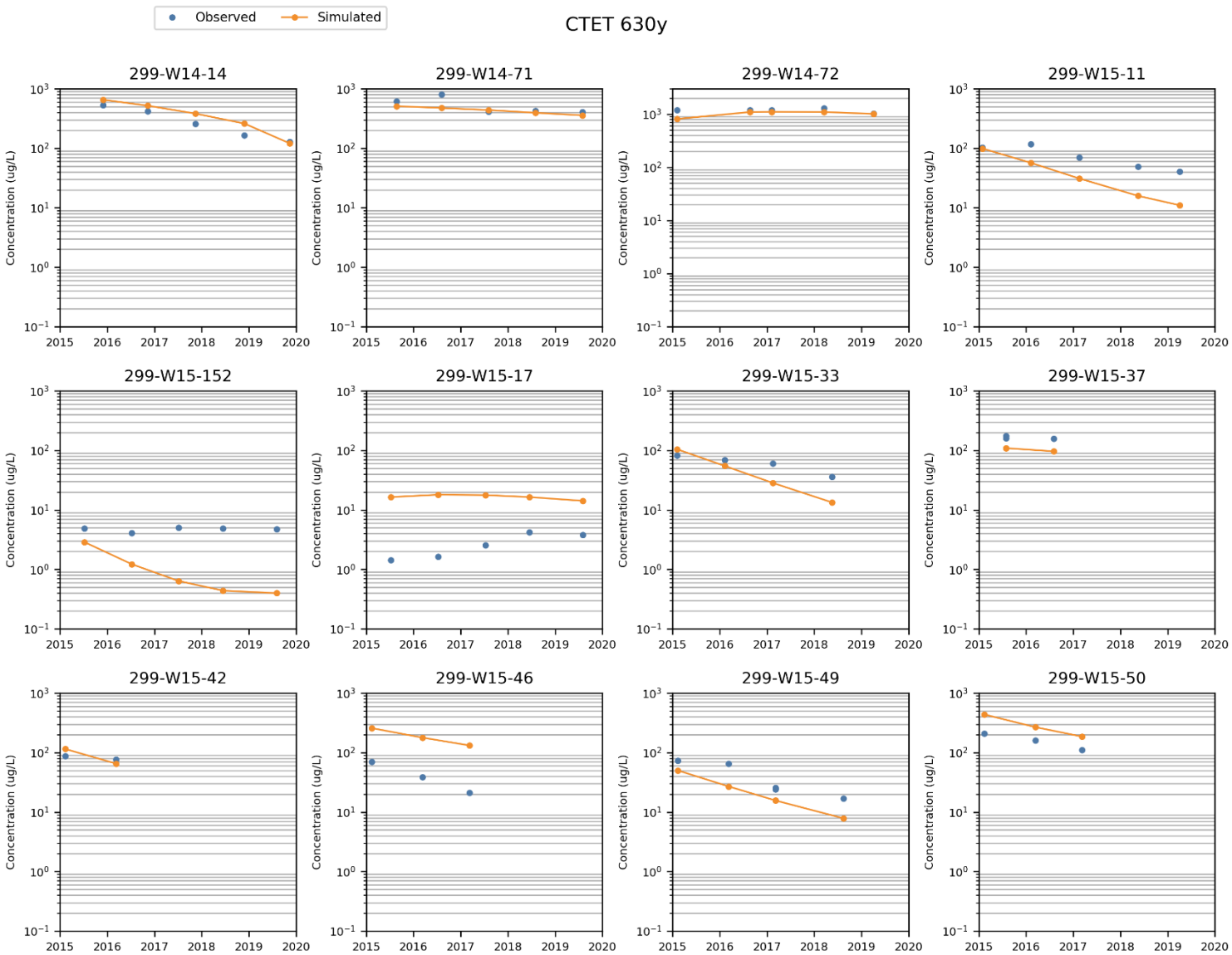

Figure B-15. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 3 of 12)

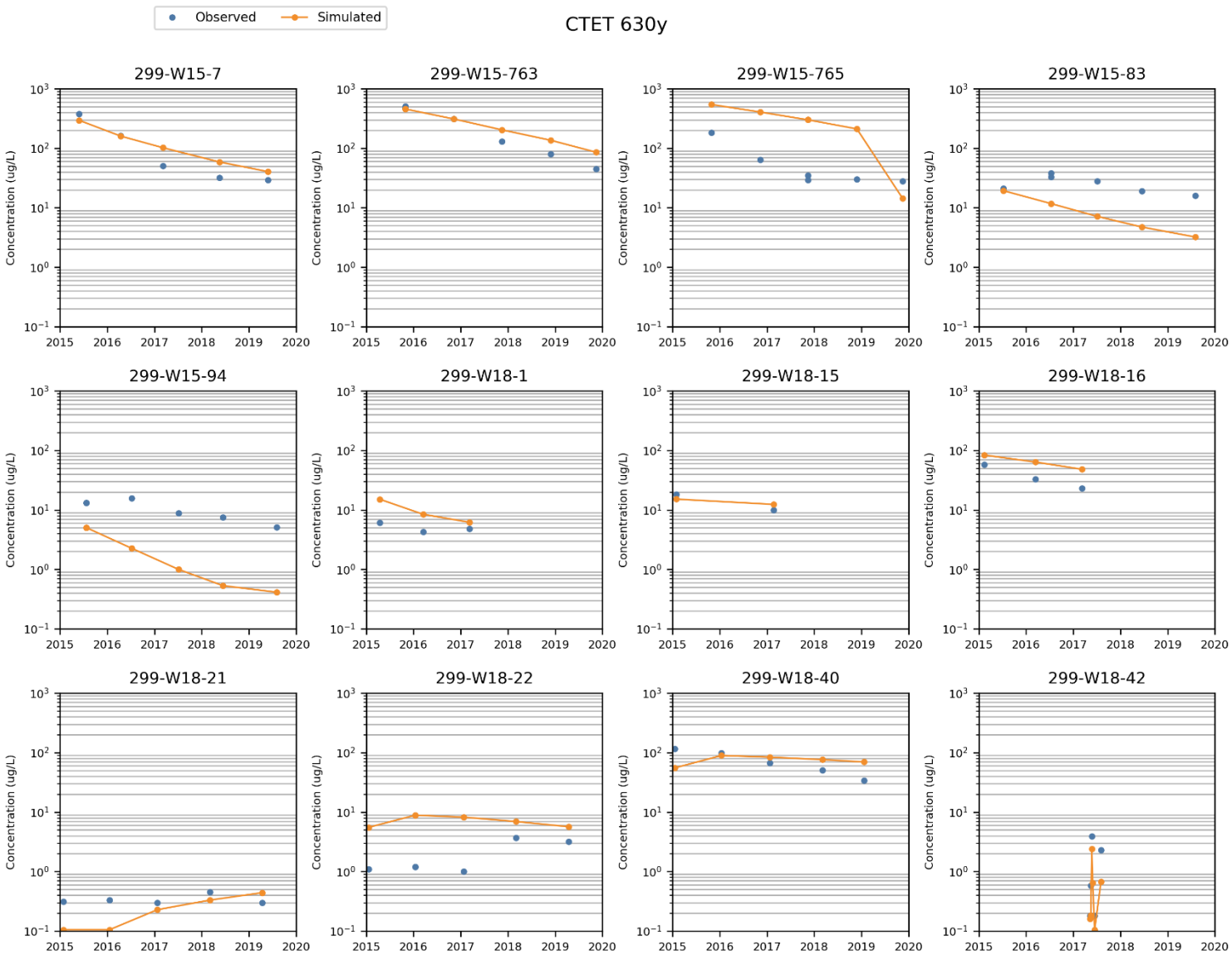

Figure B-16. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 4 of 12)

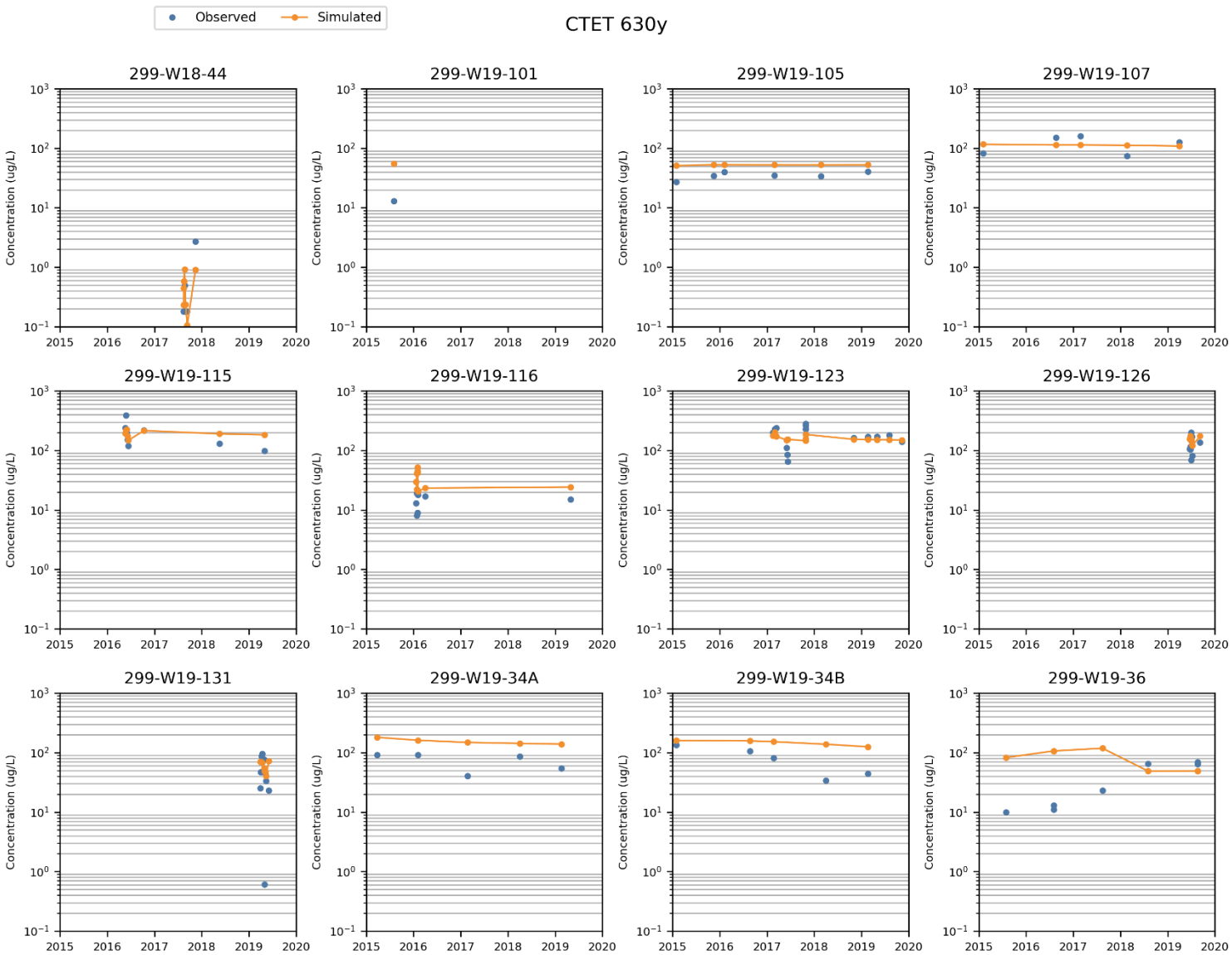

Figure B-17. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 5 of 12)

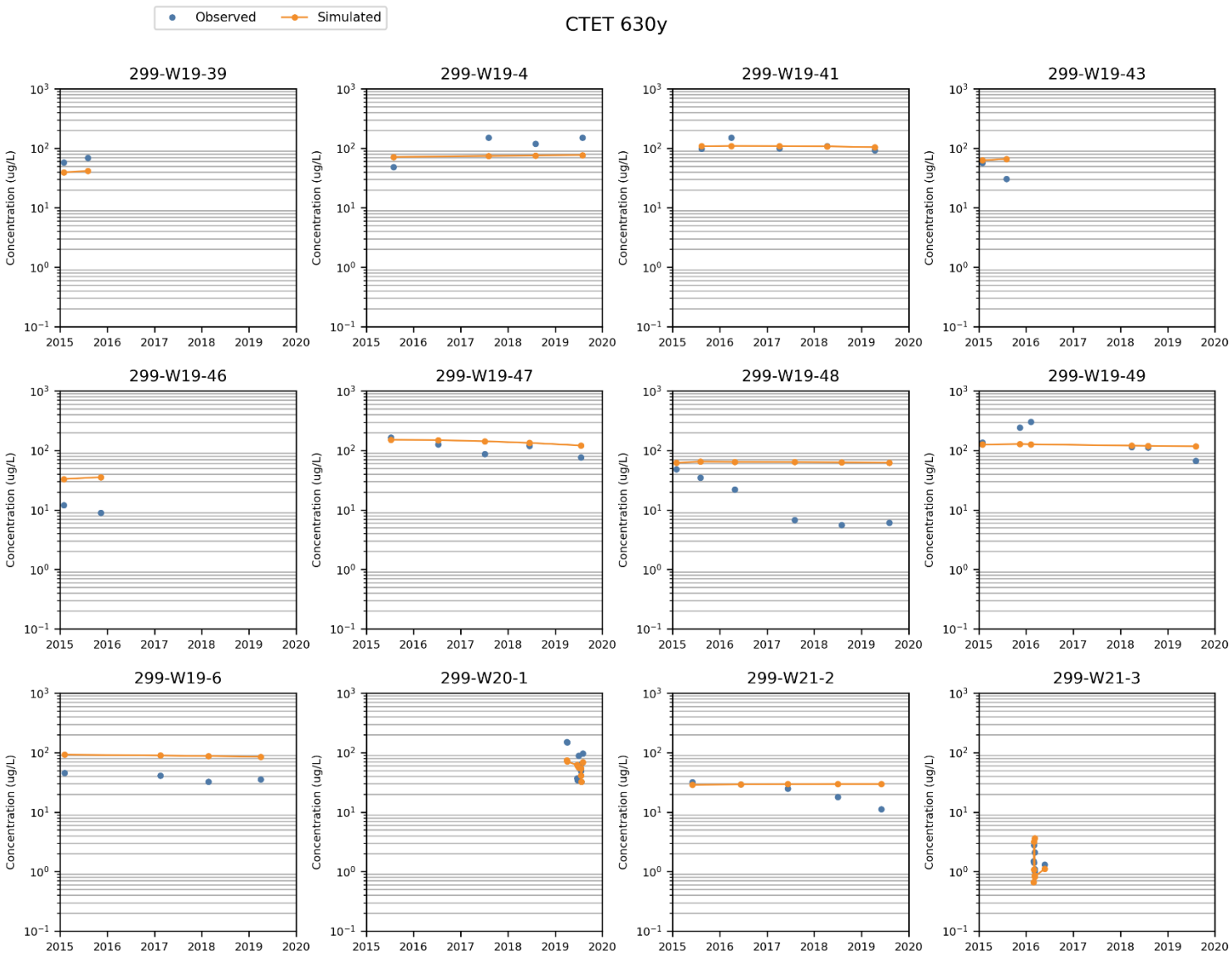

Figure B-18. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 6 of 12)

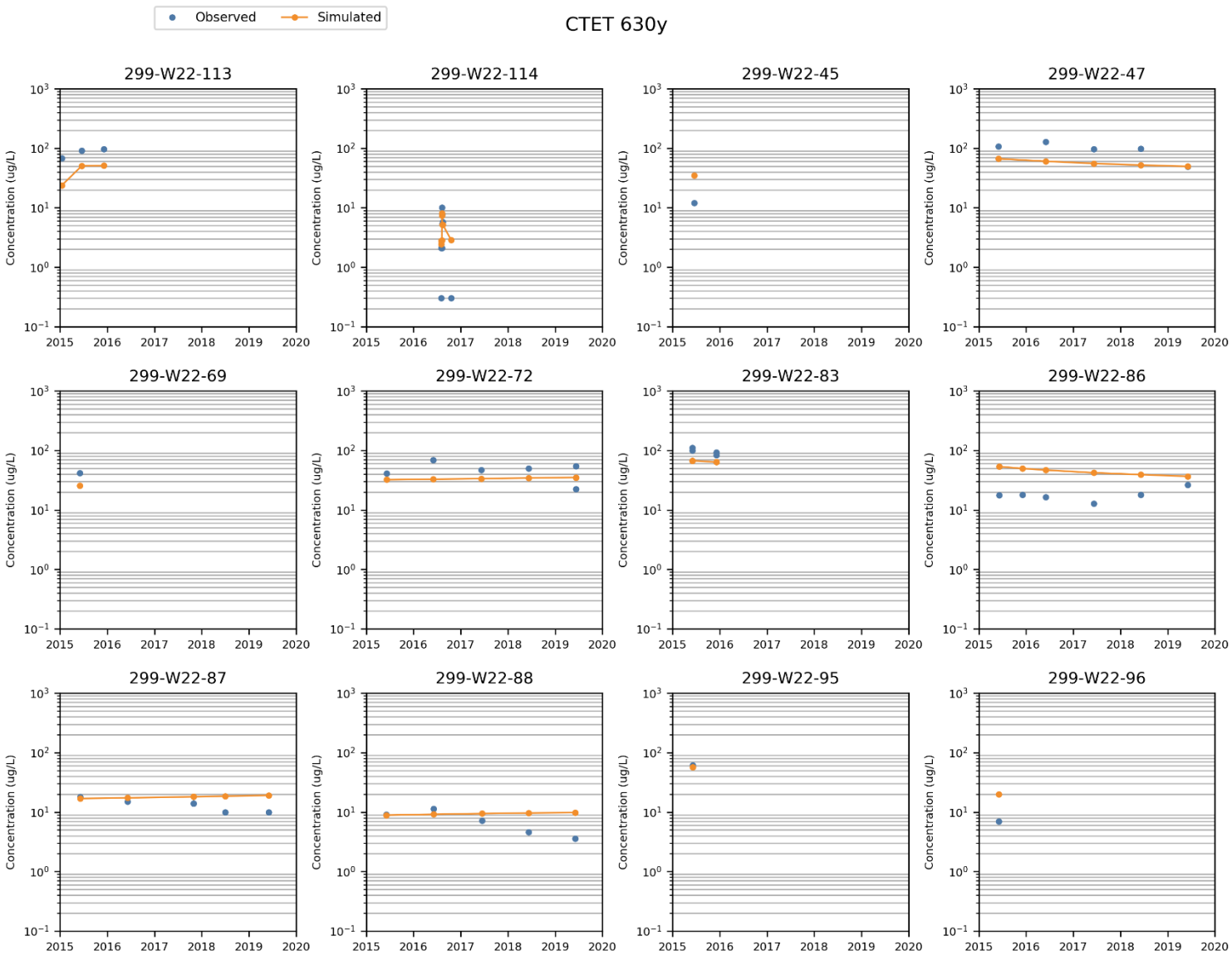

Figure B-19. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 7 of 12)

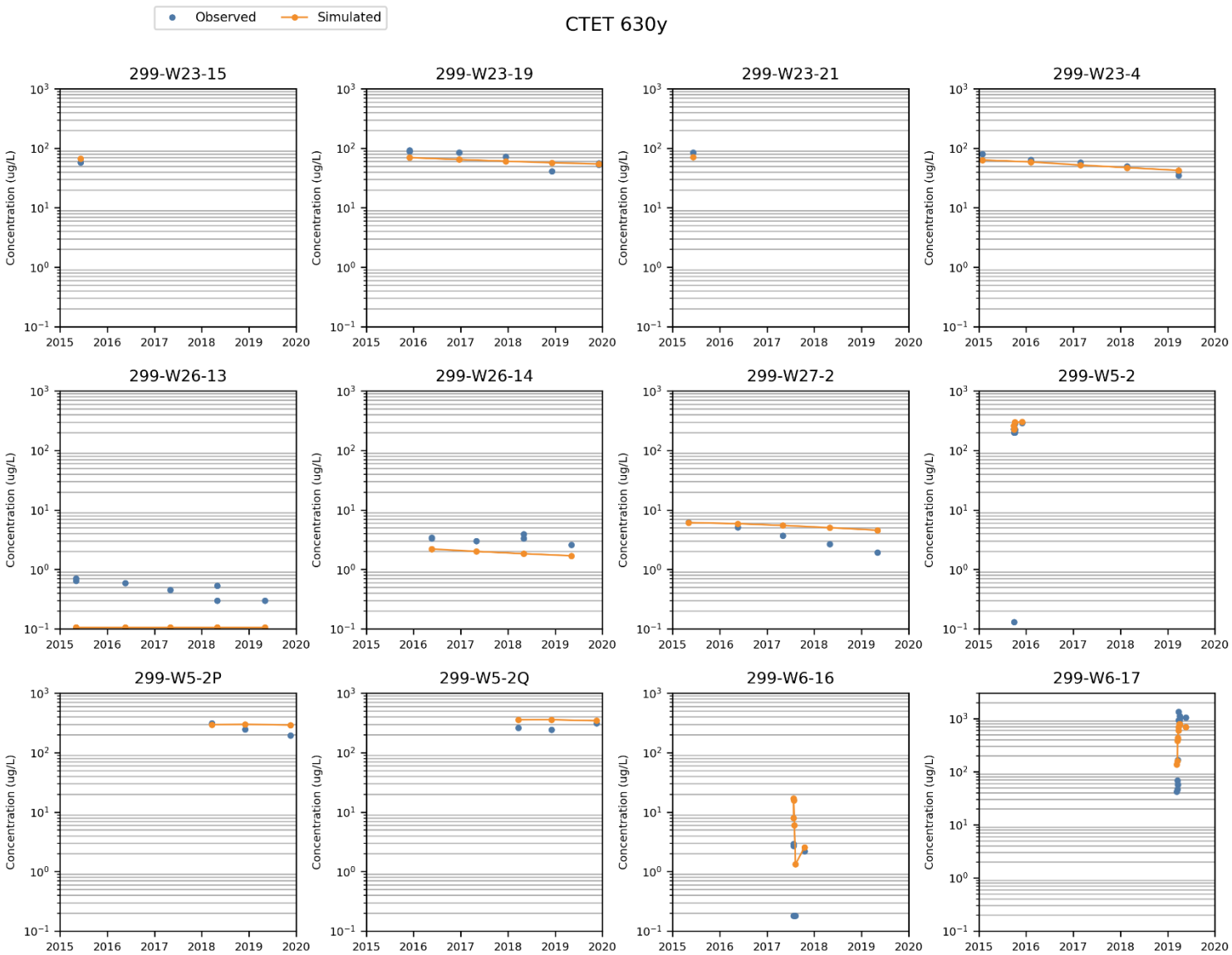

Figure B-20. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 8 of 12)

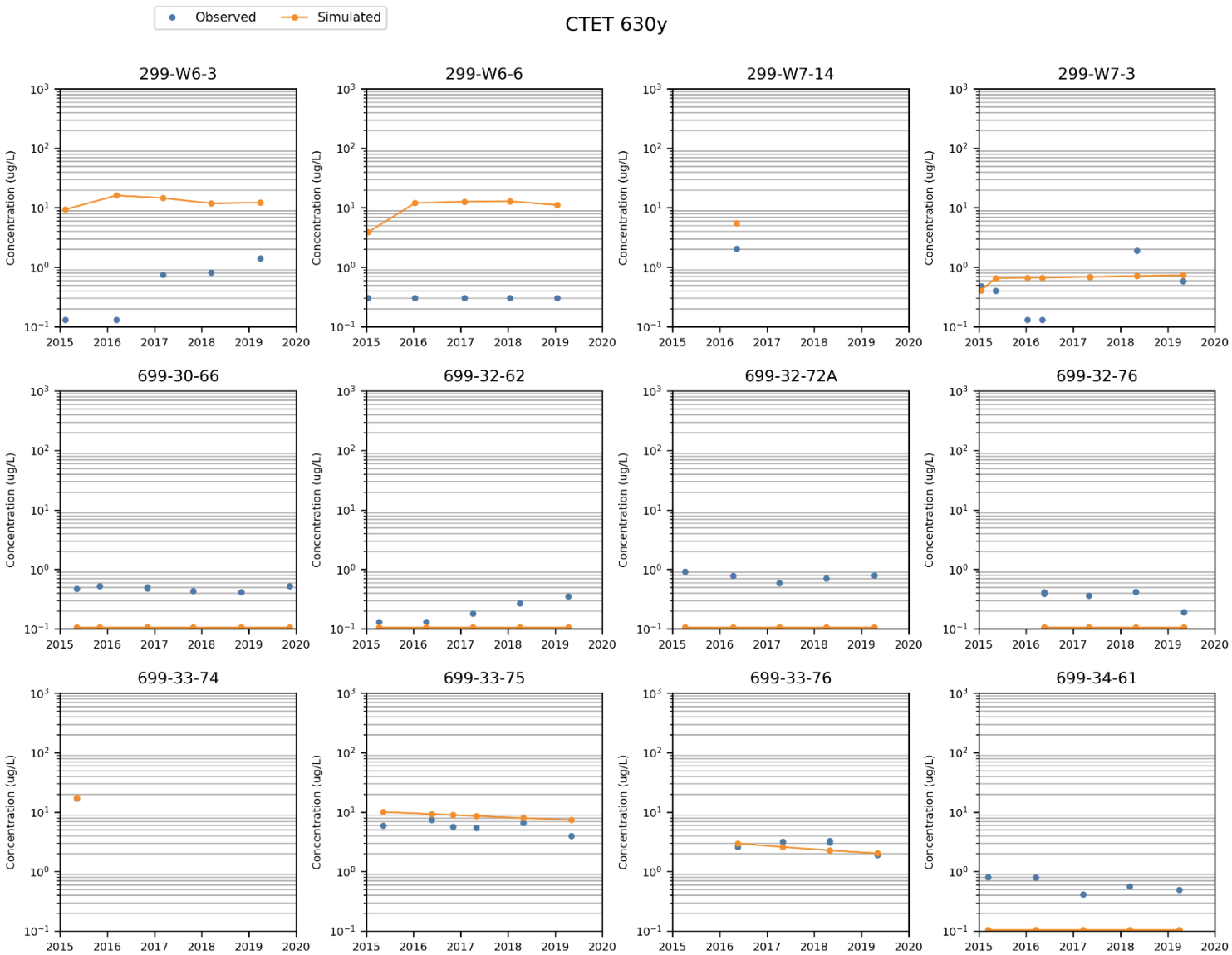

Figure B-21. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 9 of 12)

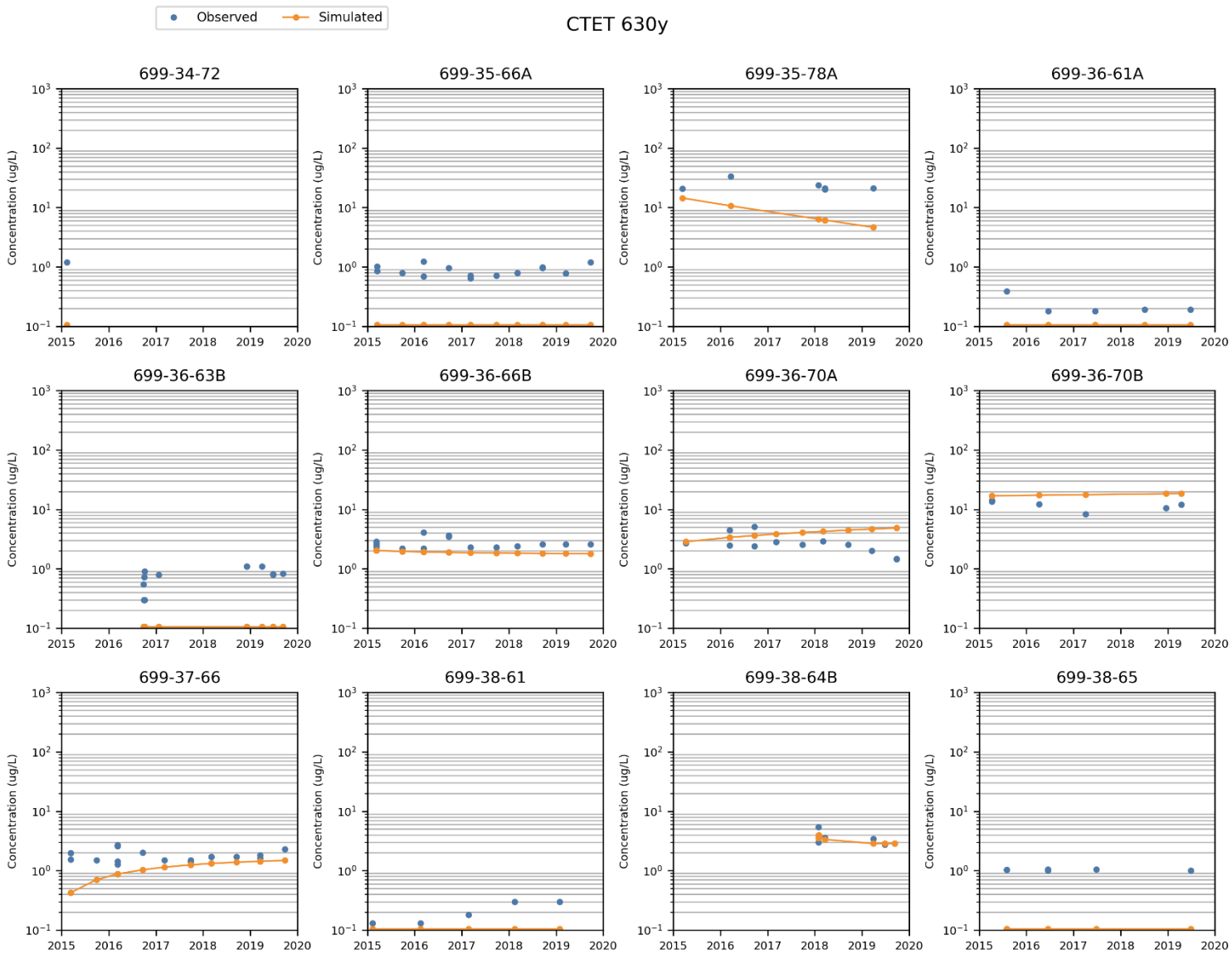

Figure B-22. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 10 of 12)

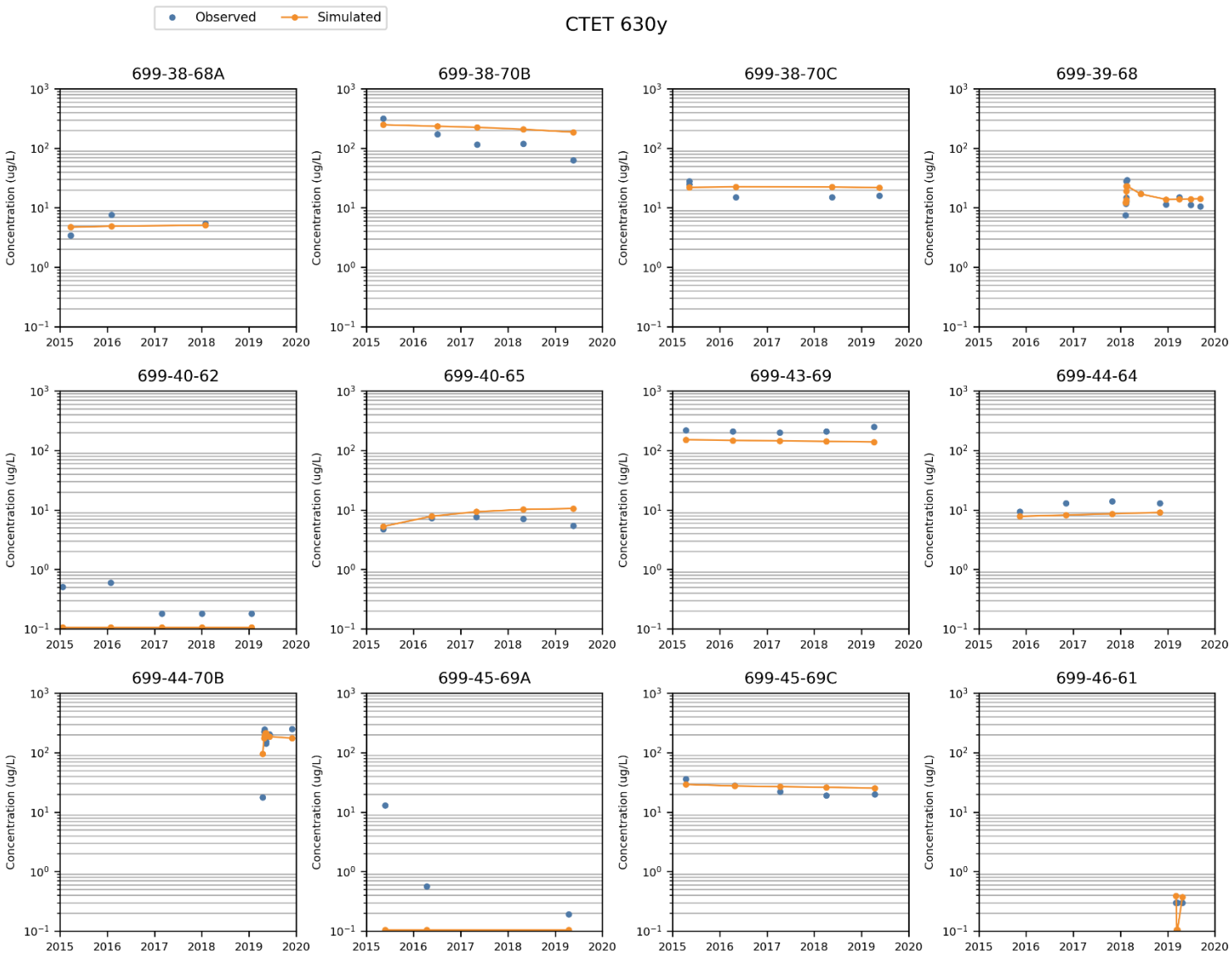

Figure B-23. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 11 of 12)

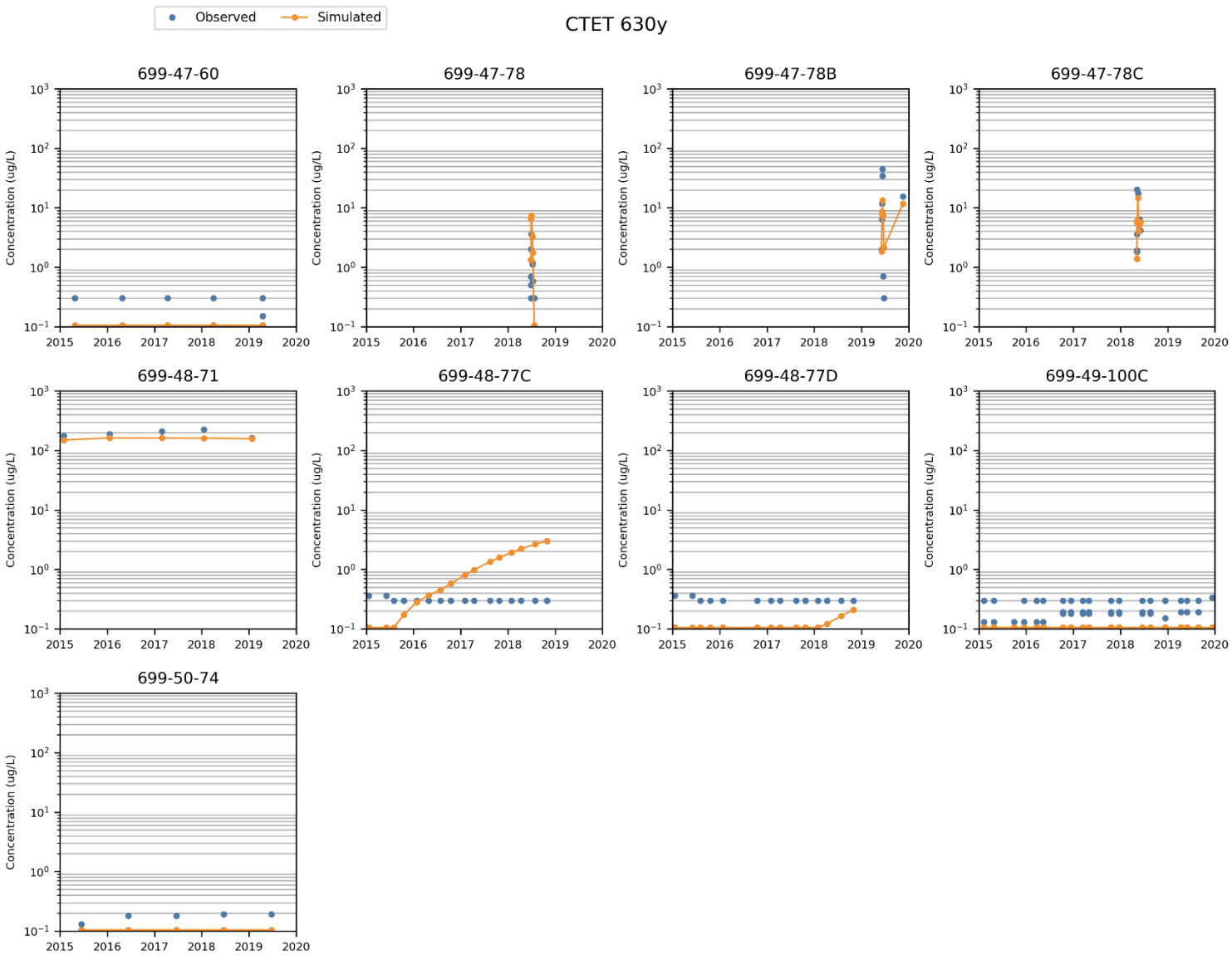

Figure B-24. Comparison of Simulated and Observed Concentrations for Carbon Tetrachloride 630-Year Half-Life (Page 12 of 12)

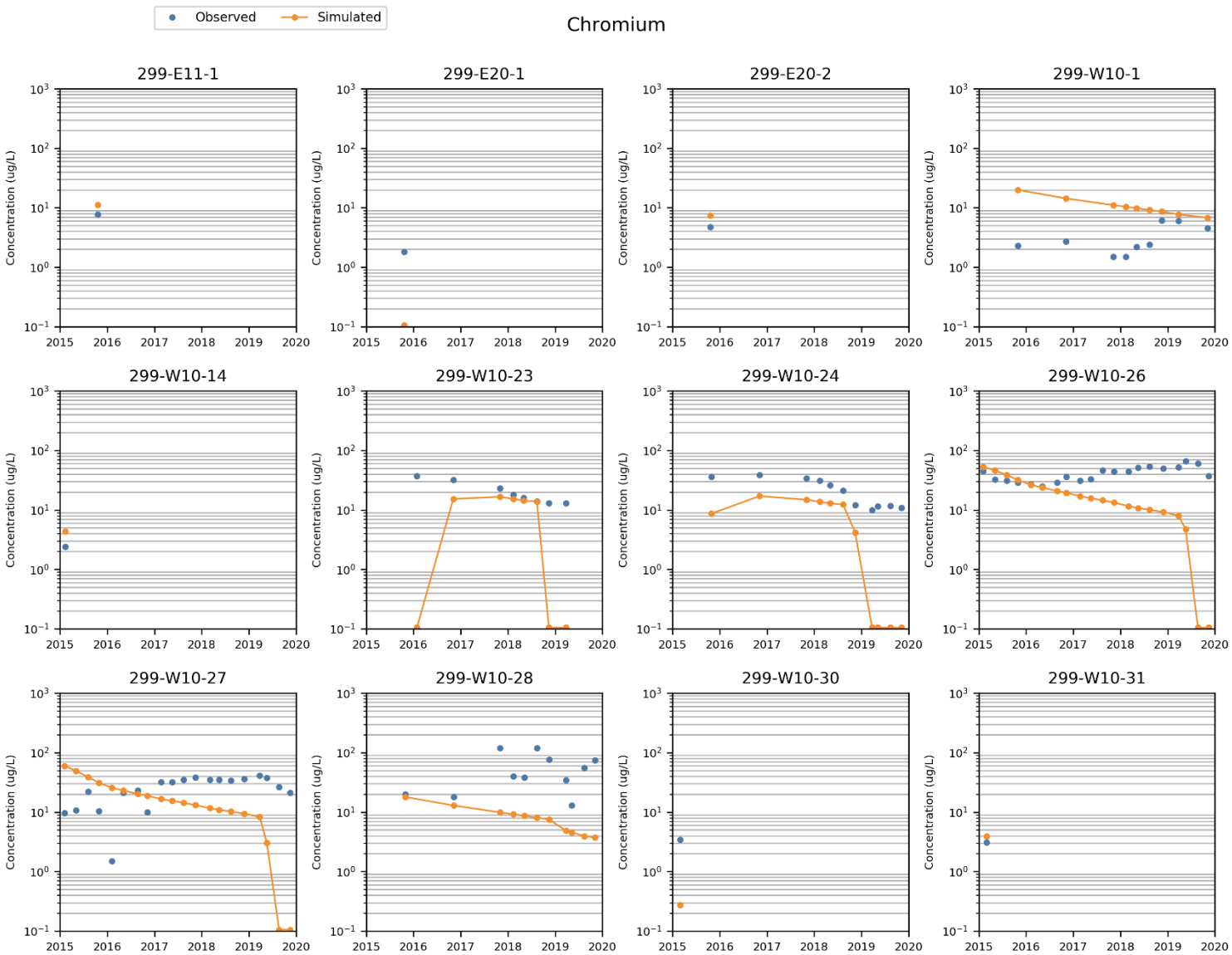

Figure B-25. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 1 of 13)

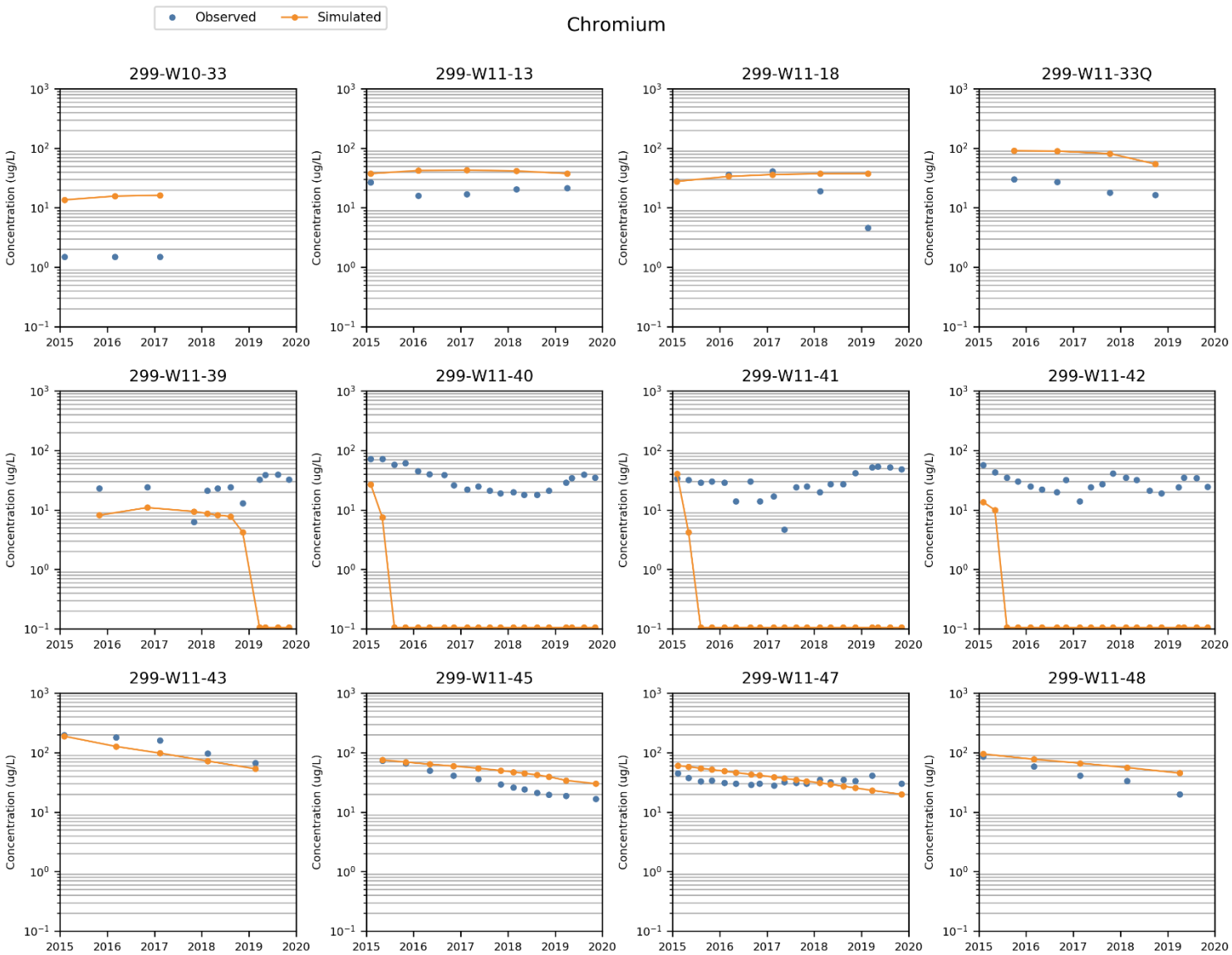

Figure B-26. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 2 of 13)

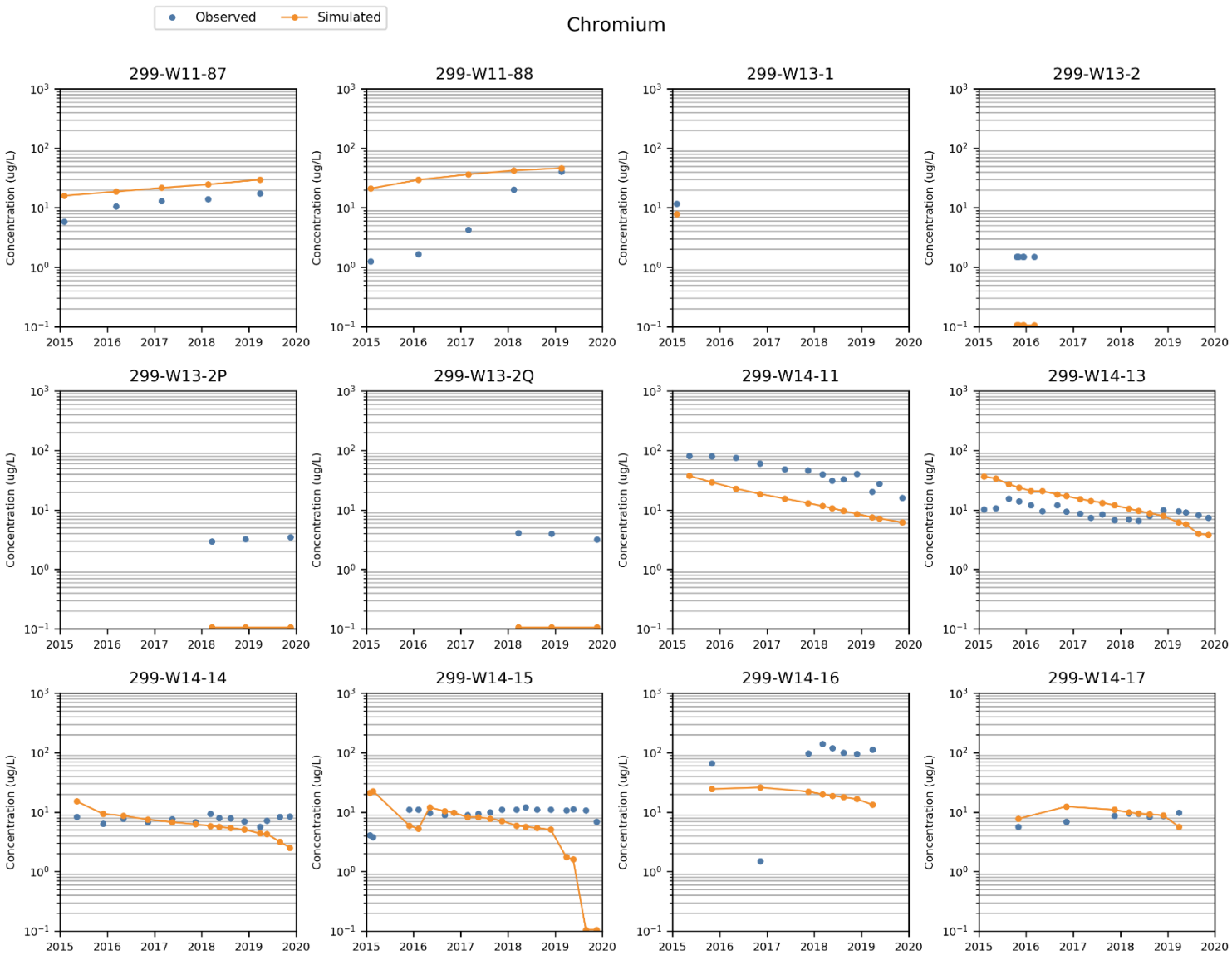

Figure B-27. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 3 of 13)

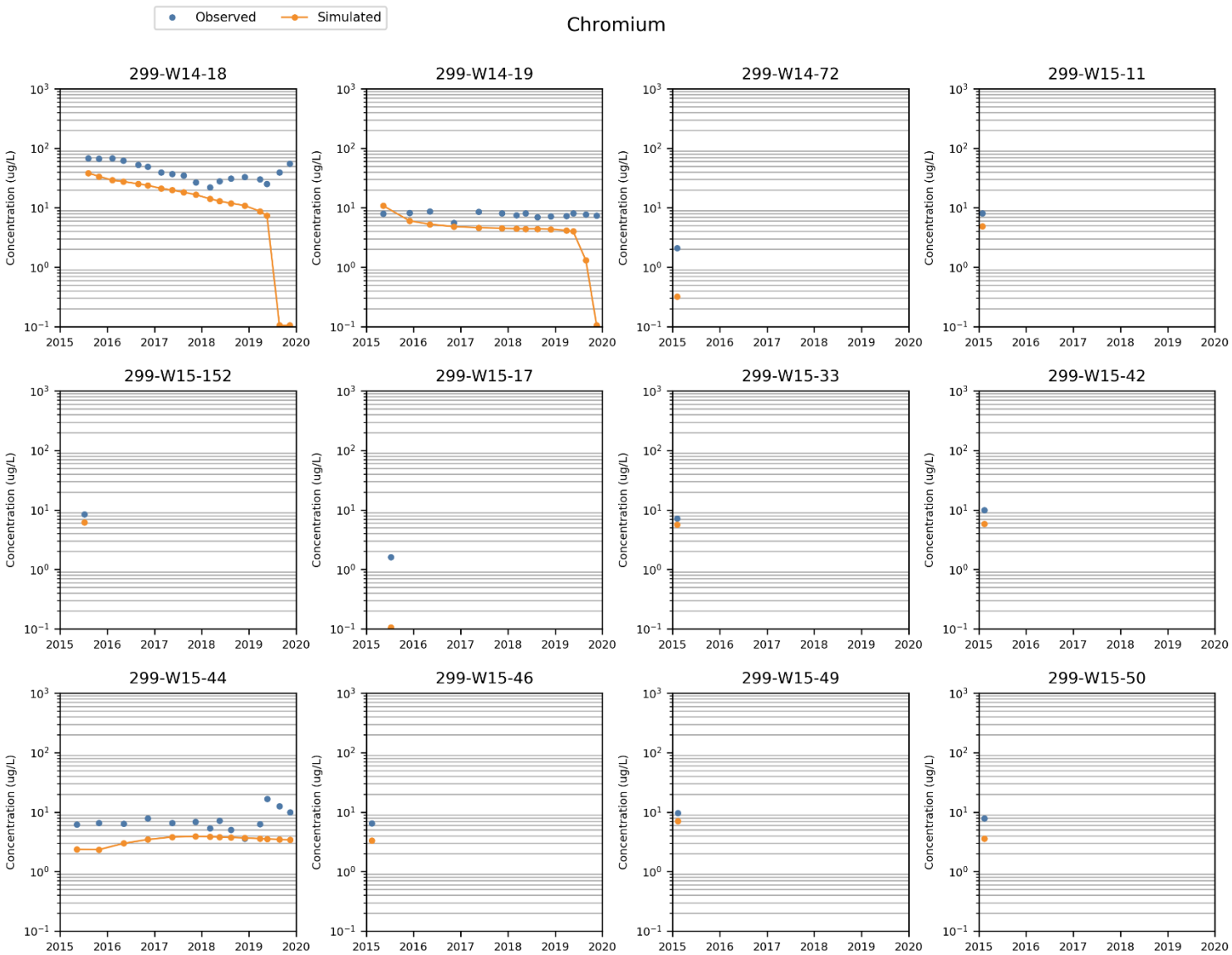

Figure B-28. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 4 of 13)

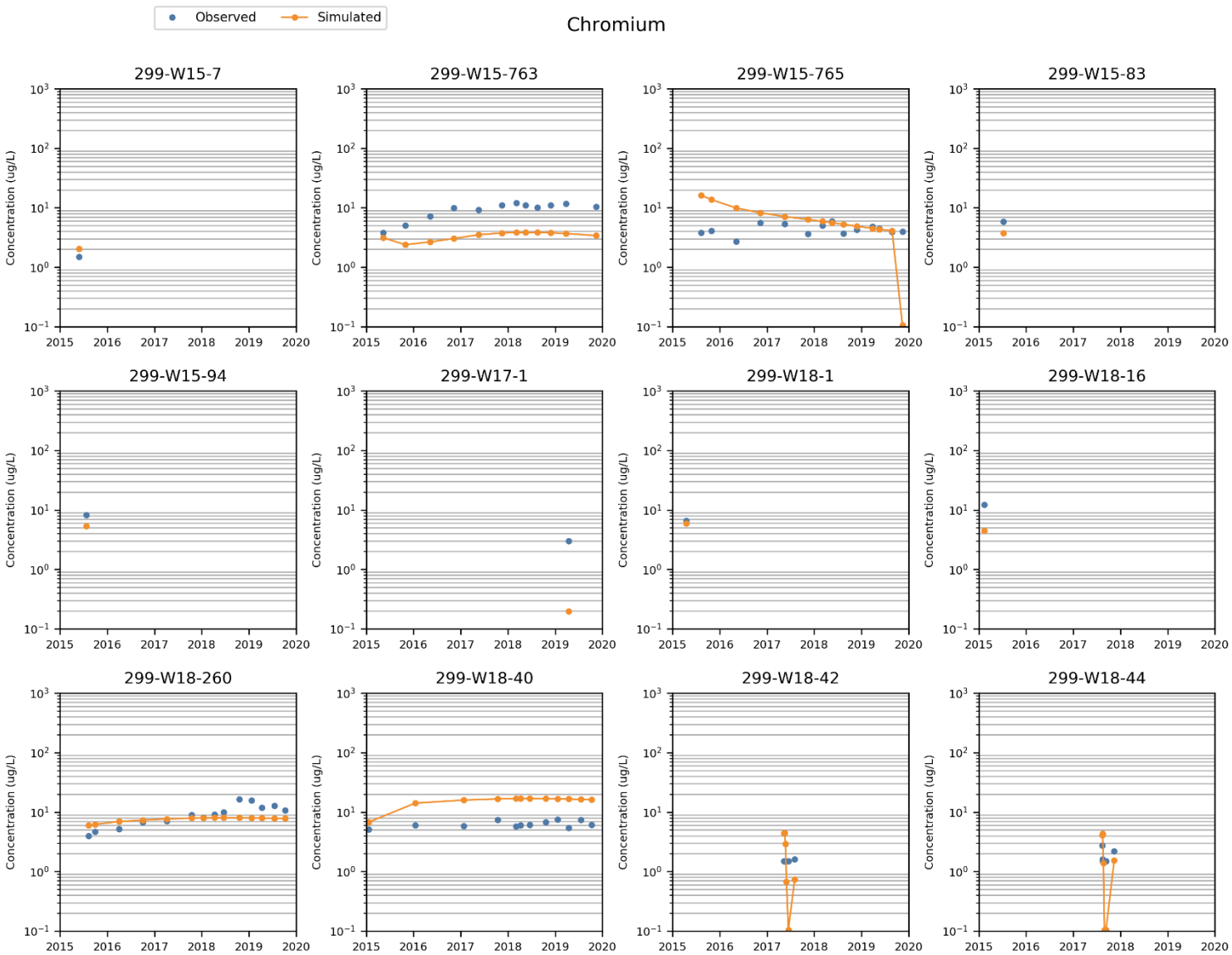

Figure B-29. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 5 of 13)

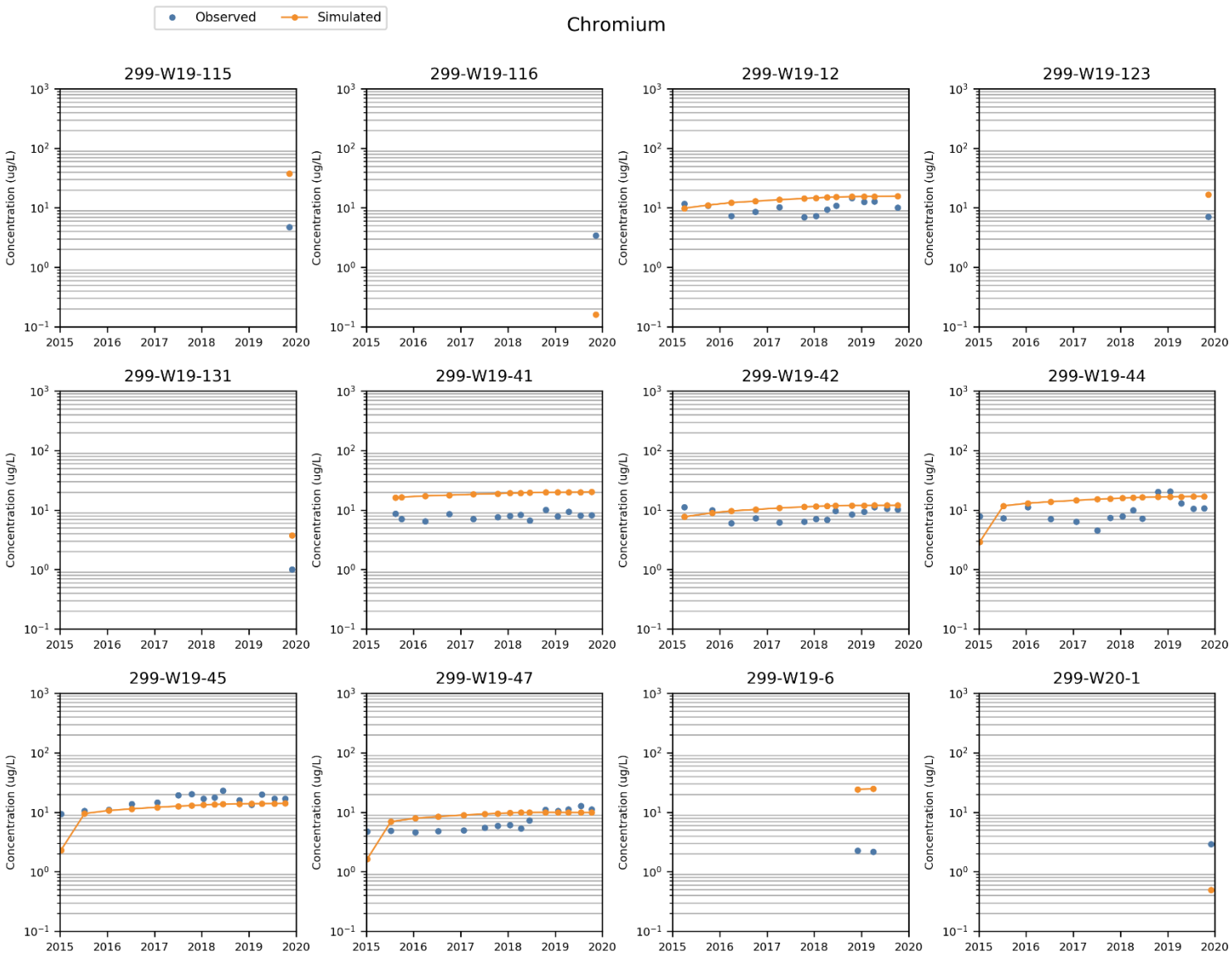

Figure B-30. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 6 of 13)

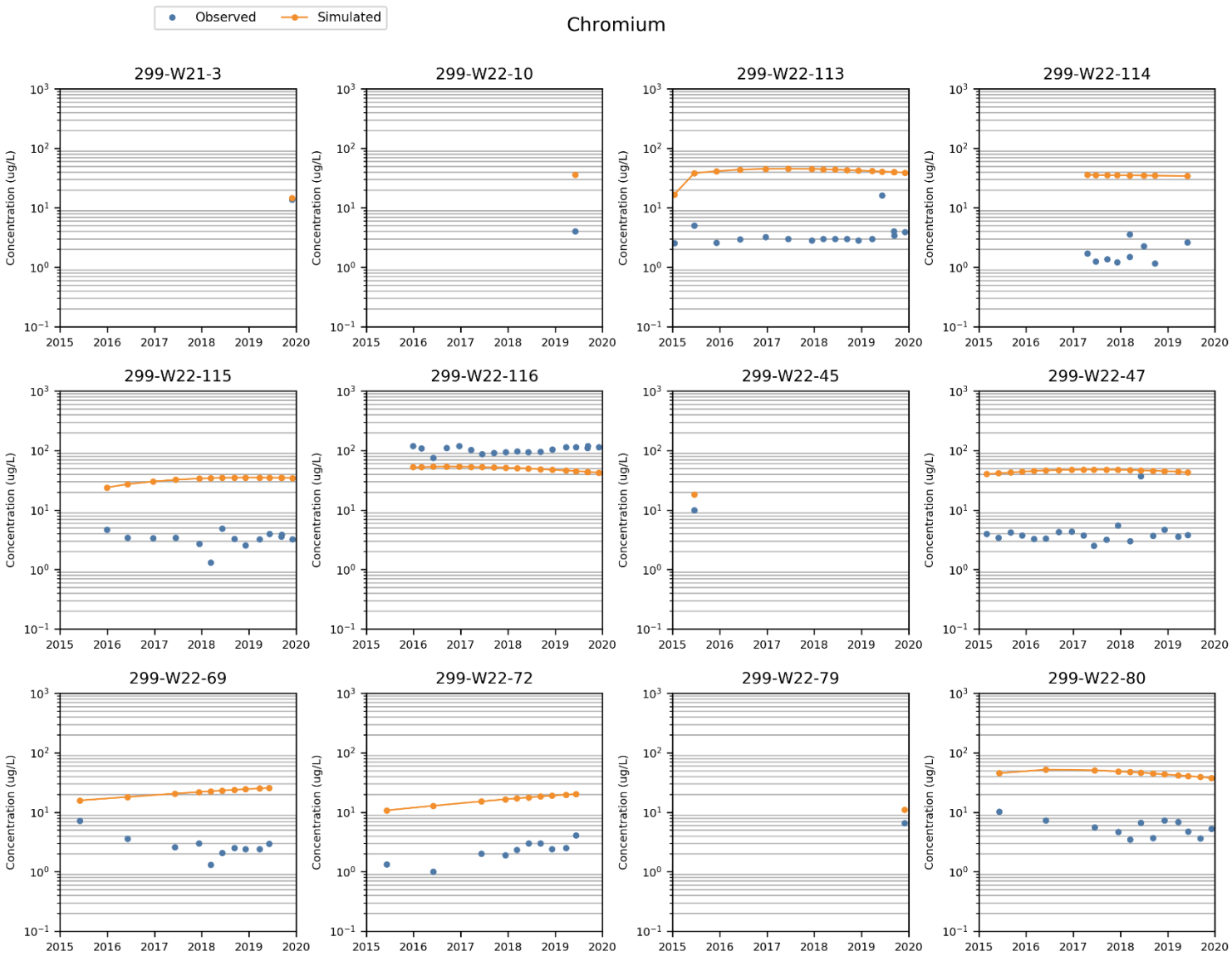

Figure B-31. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 7 of 13)

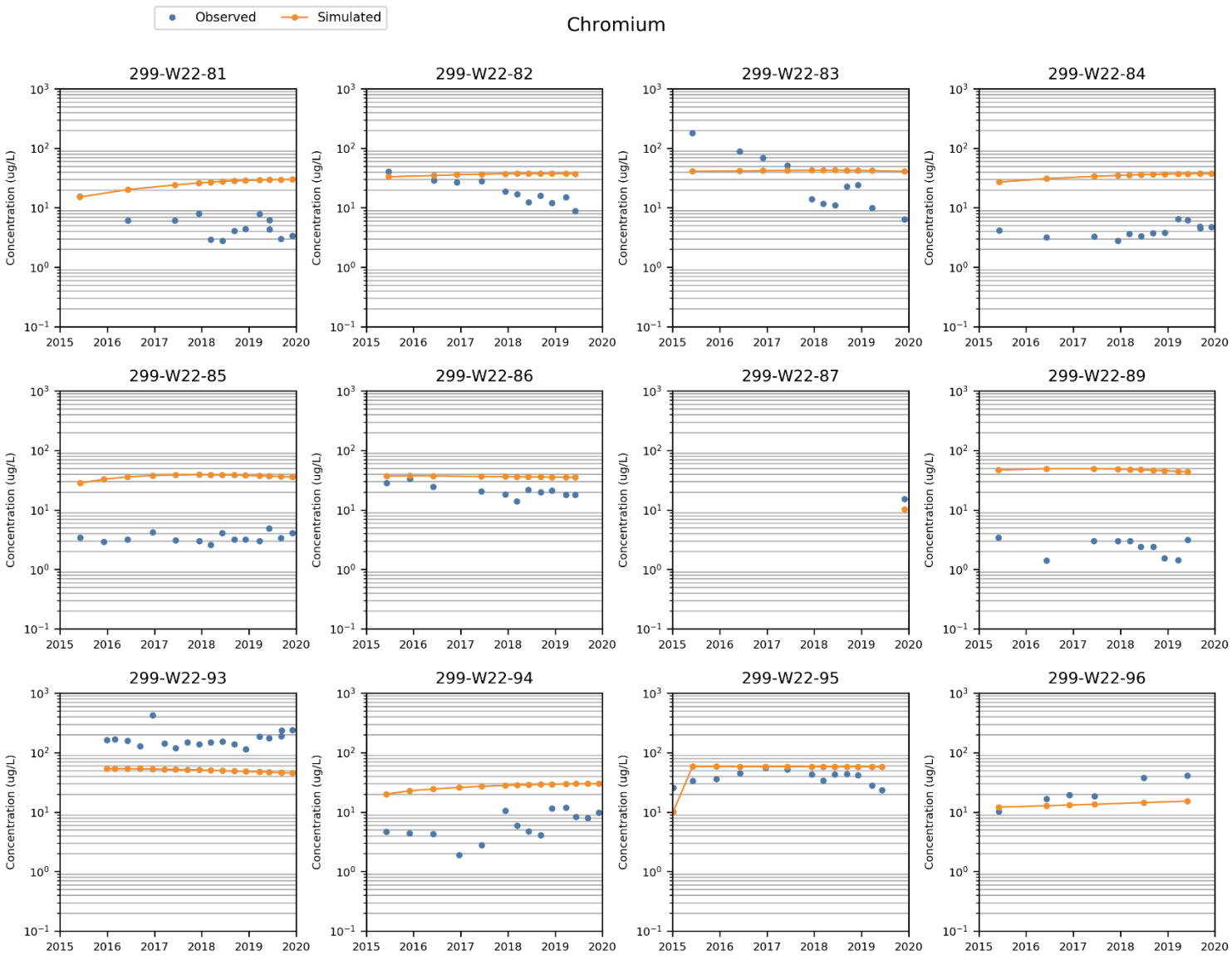

Figure B-32. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 8 of 13)

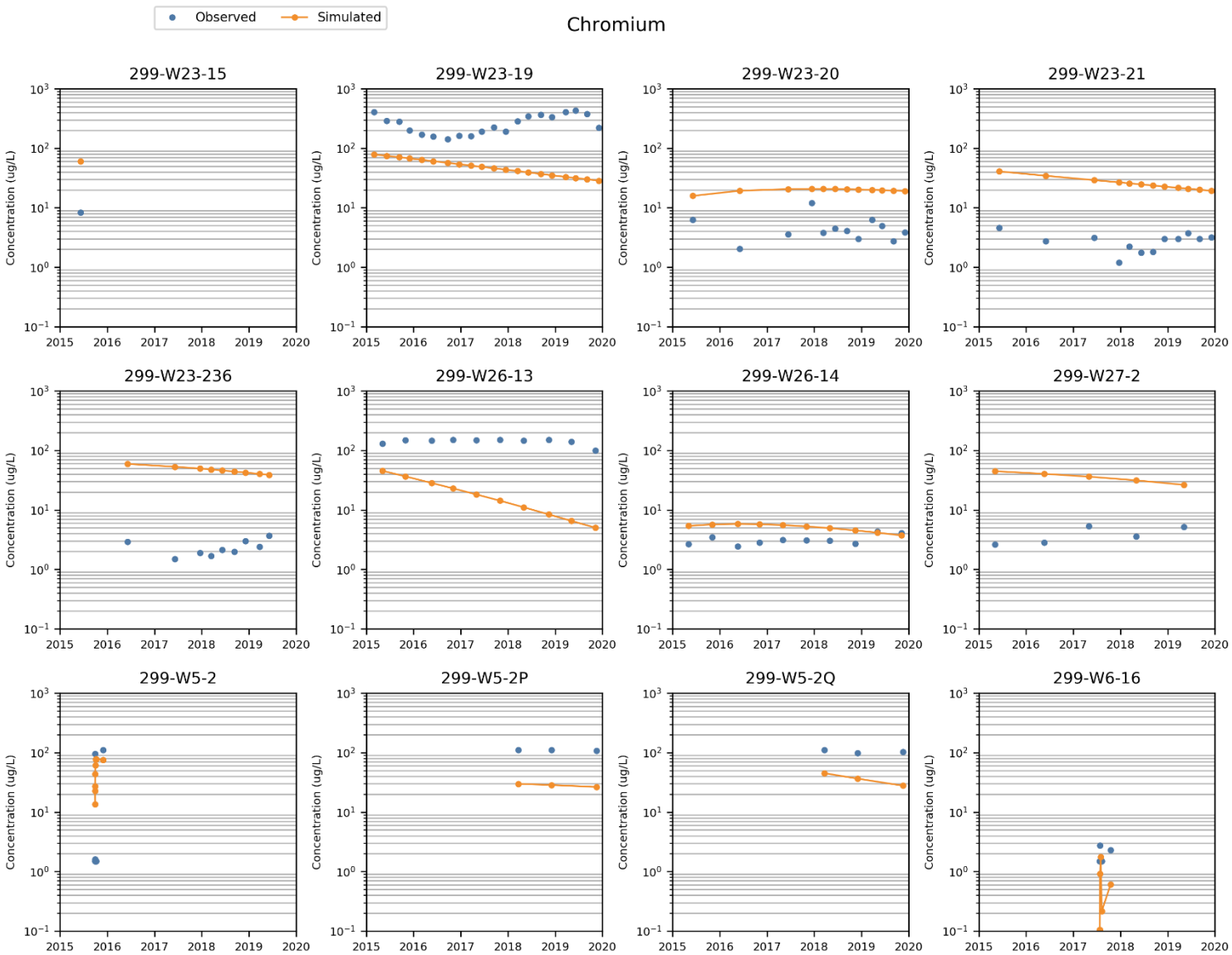

Figure B-33. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 9 of 13)

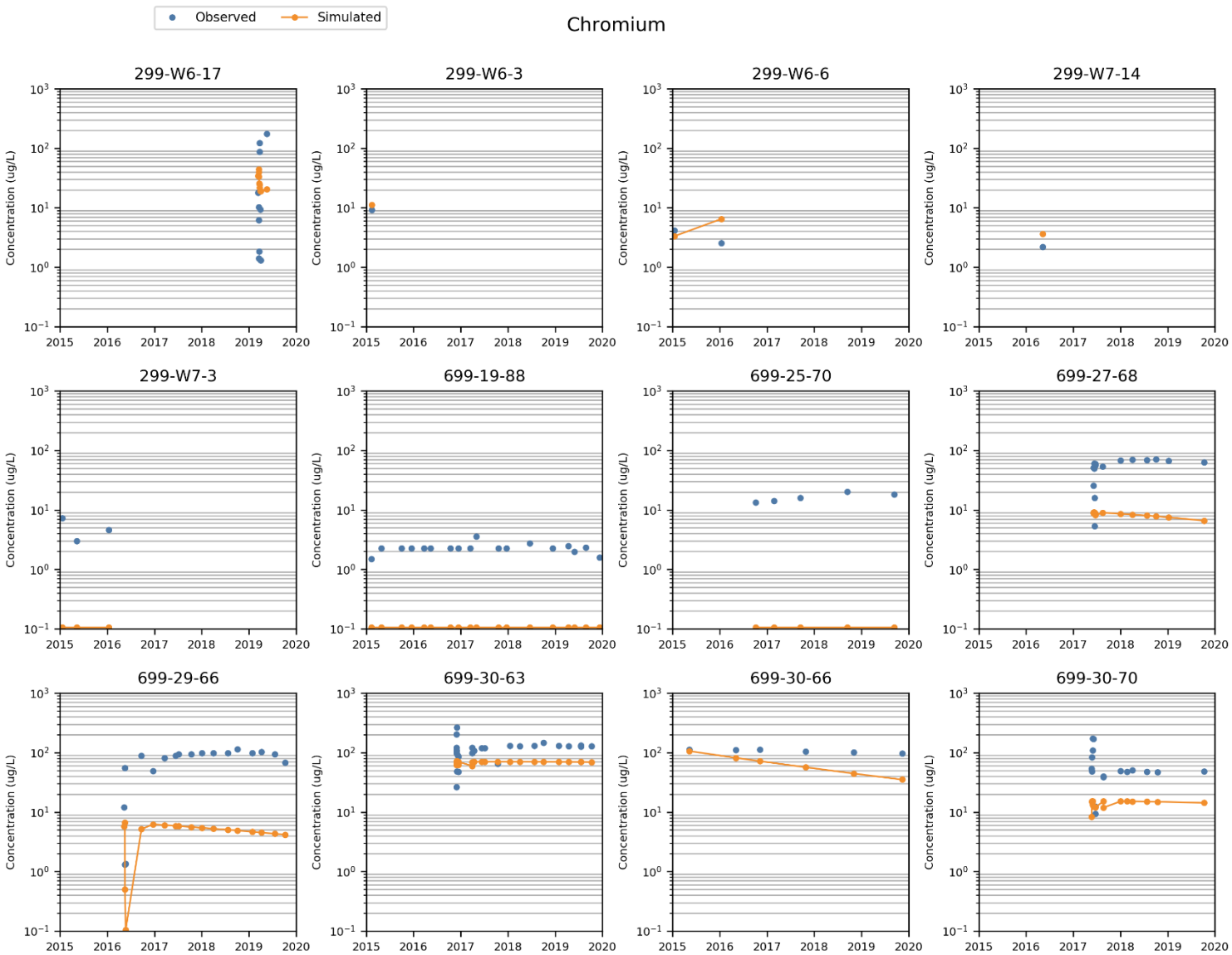

Figure B-34. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 10 of 13)

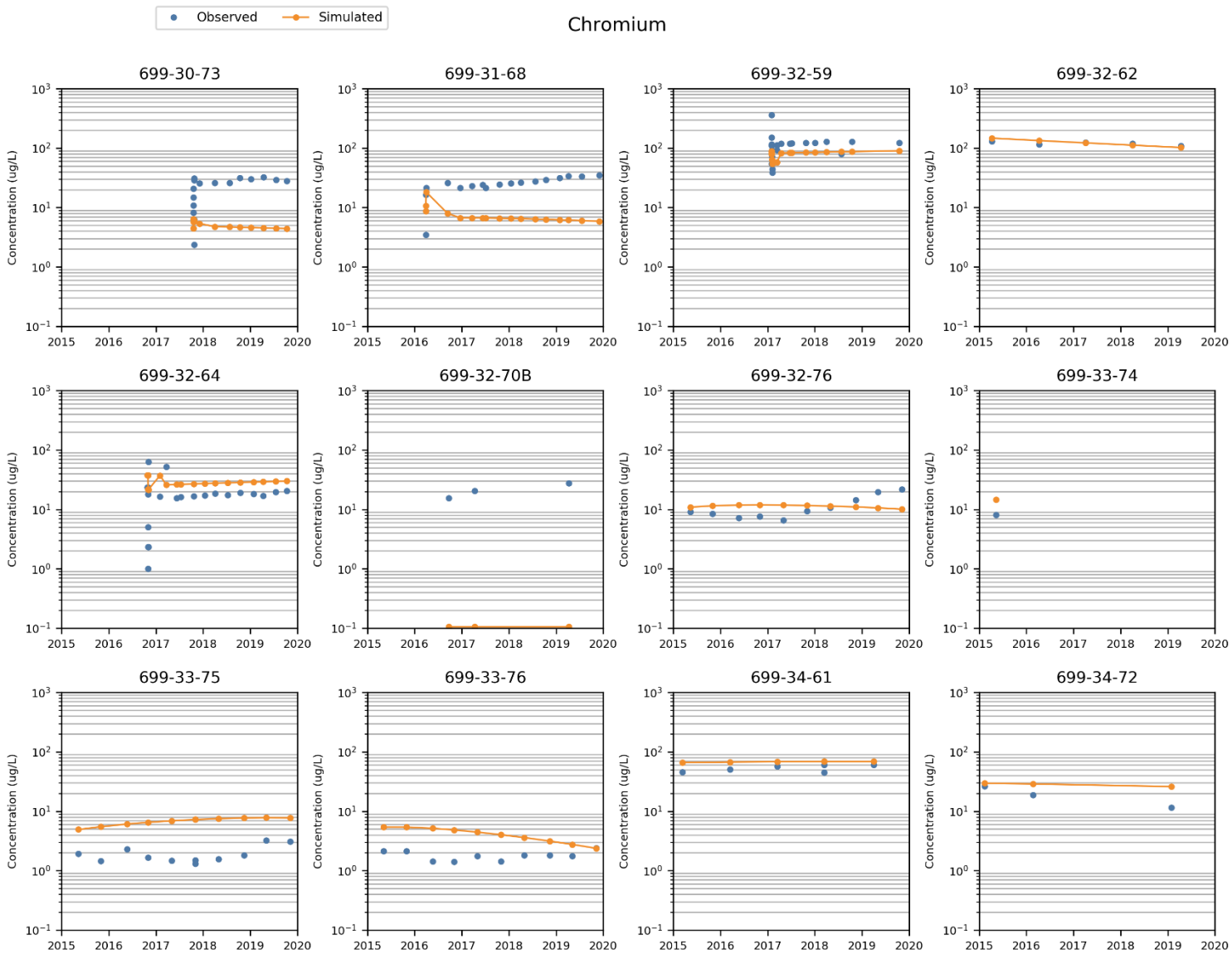

Figure B-35. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 11 of 13)

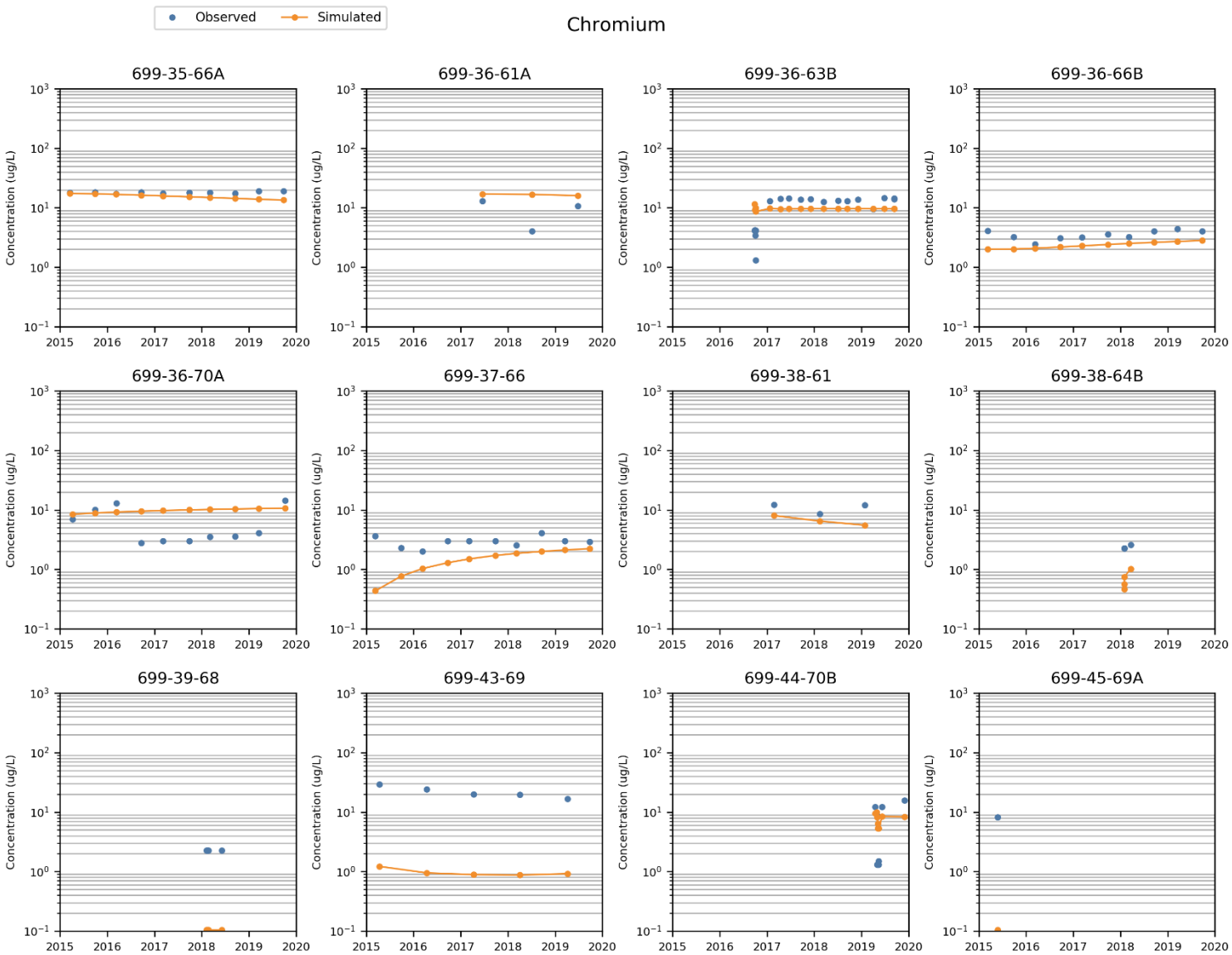

Figure B-36. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 12 of 13)

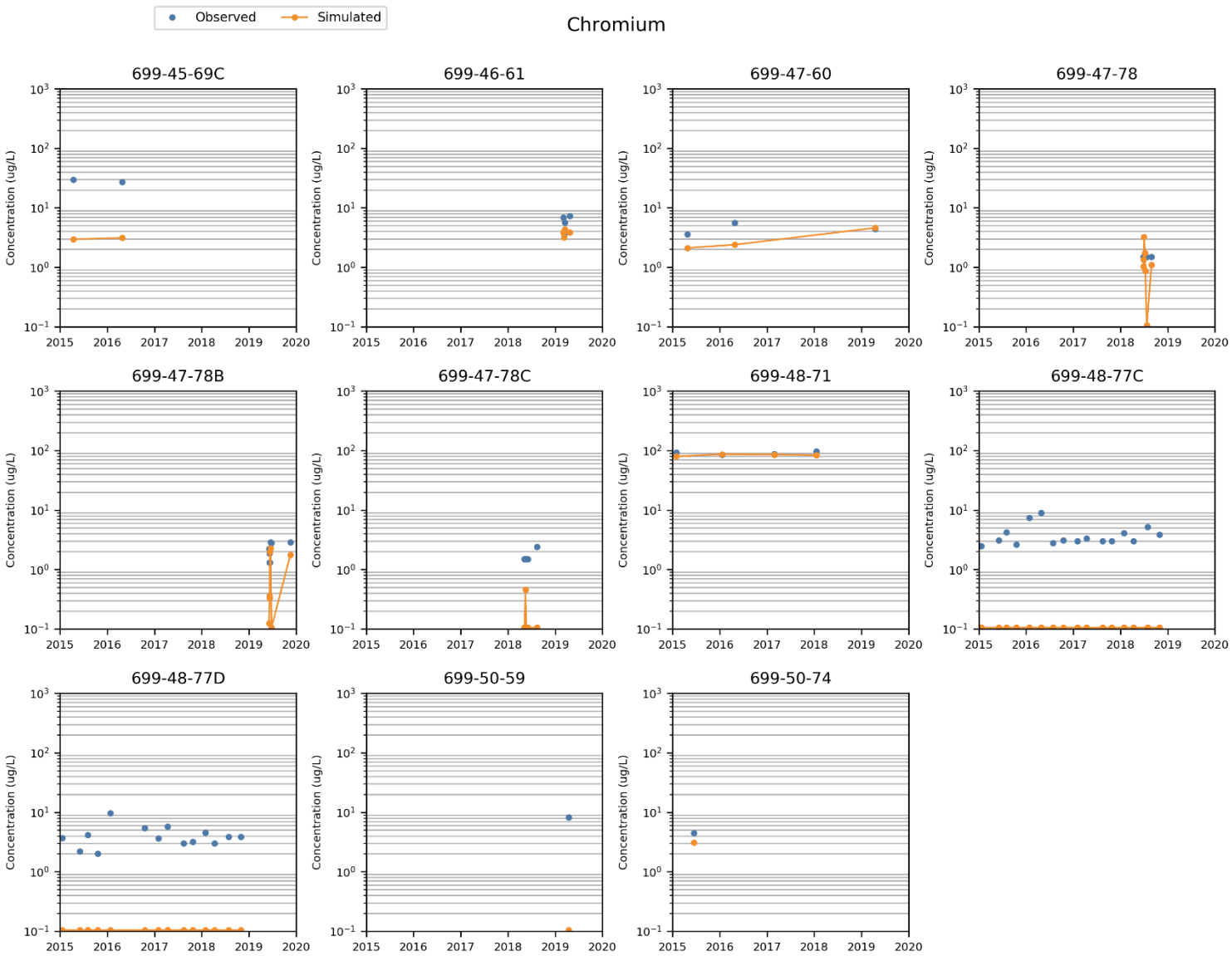

Figure B-37. Comparison of Simulated and Observed Concentrations for Hexavalent Chromium (Page 13 of 13)

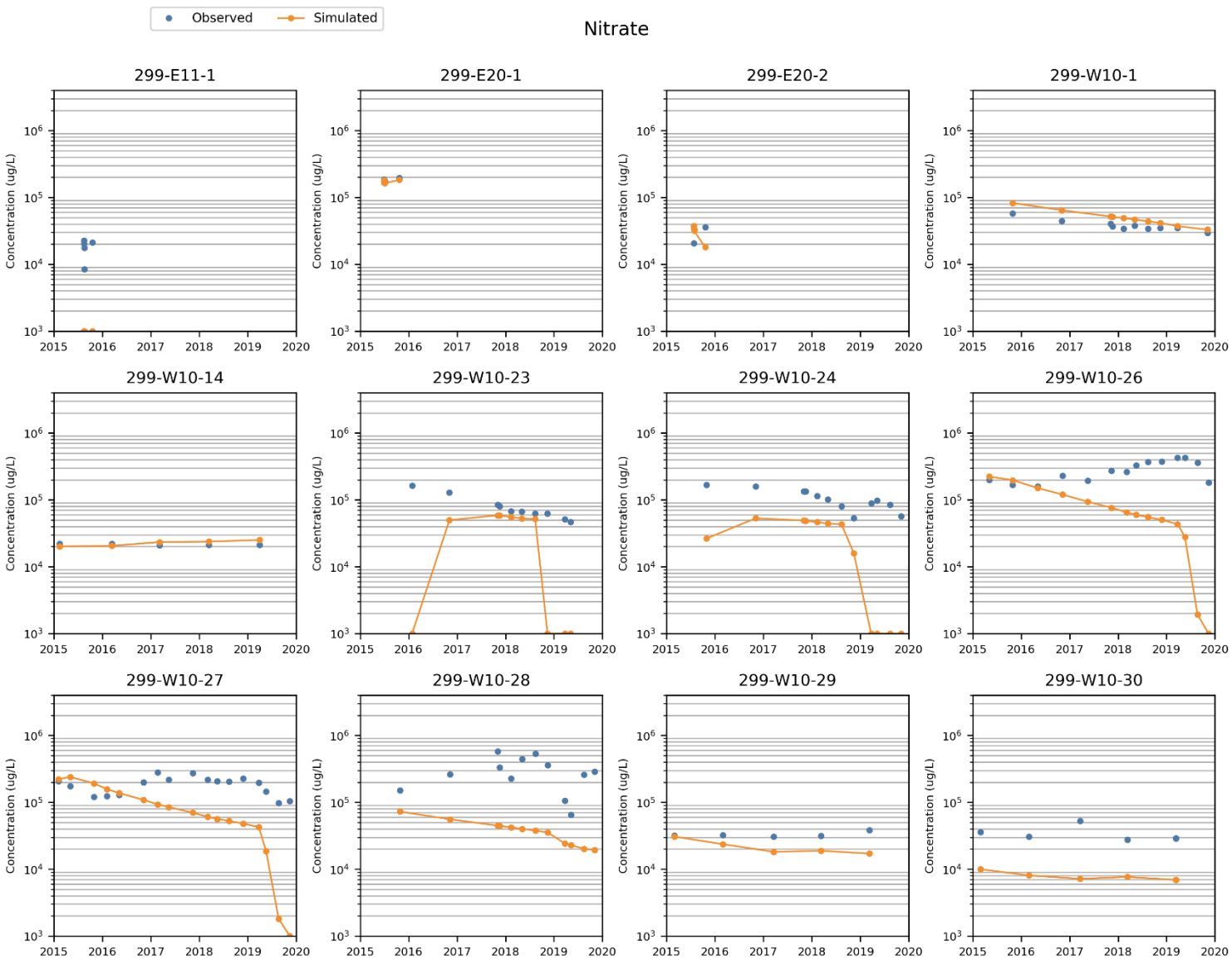

Figure B-38. Comparison of Simulated and Observed Concentrations for Nitrate (Page 1 of 17)

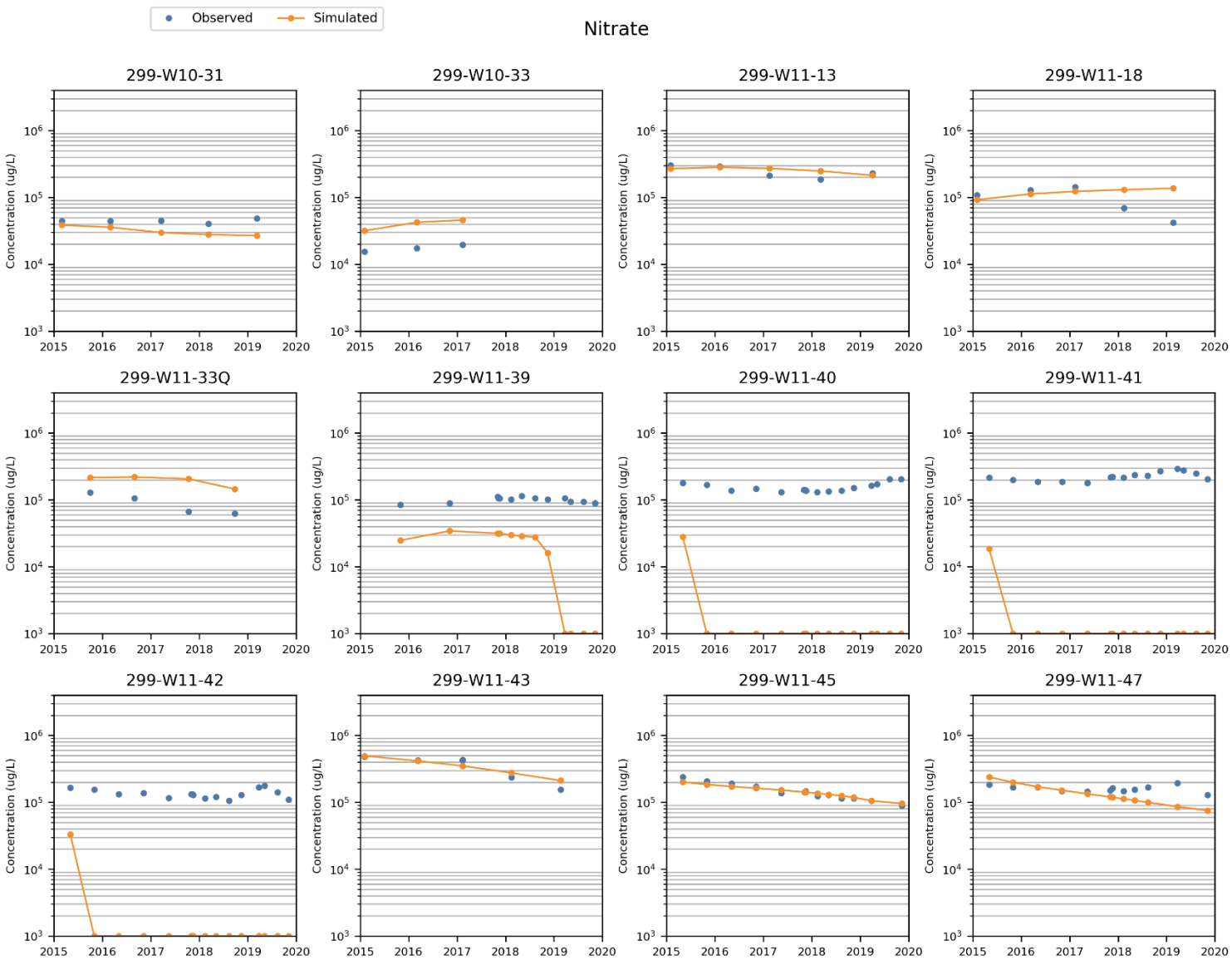

Figure B-39. Comparison of Simulated and Observed Concentrations for Nitrate (Page 2 of 17)

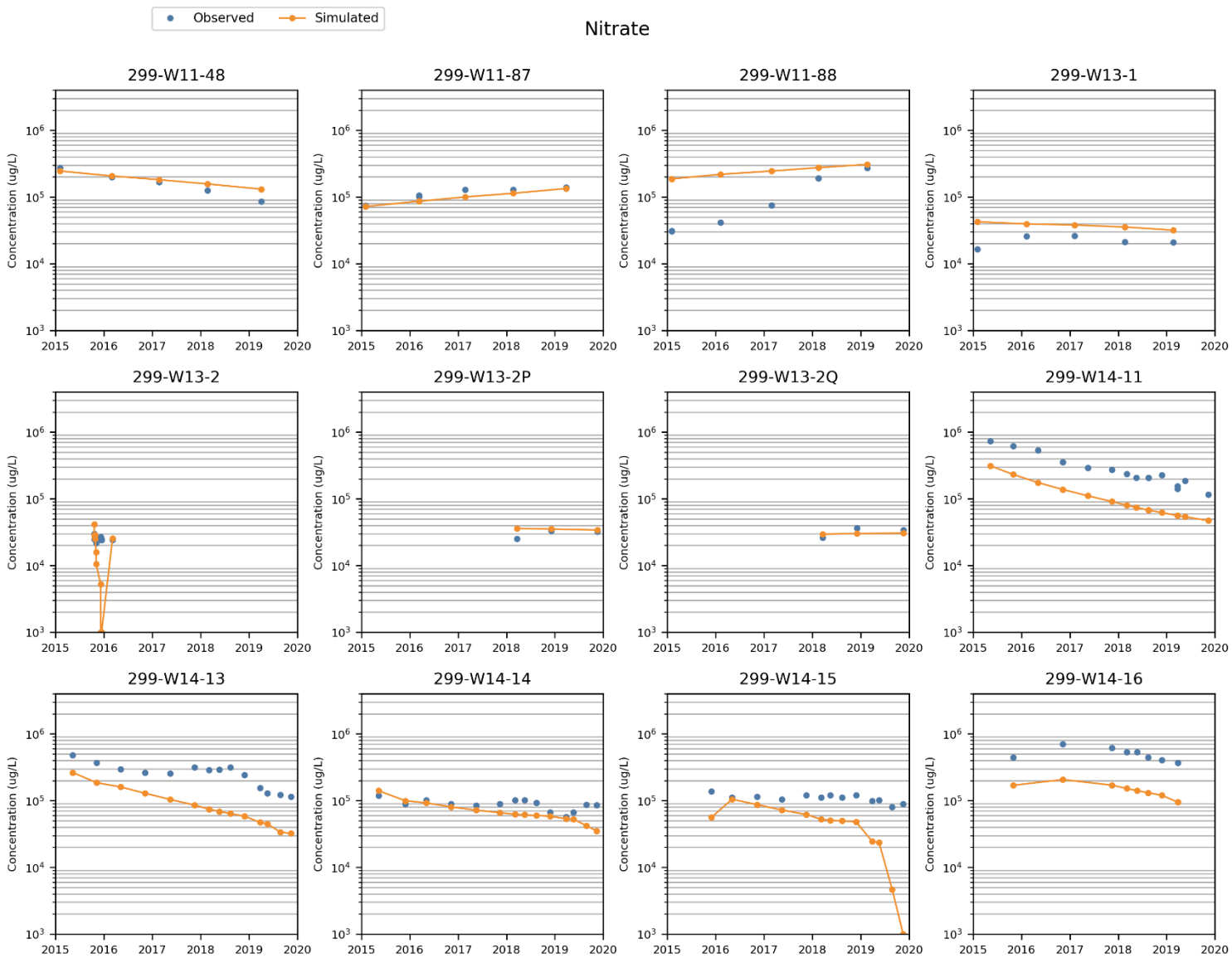

Figure B-40. Comparison of Simulated and Observed Concentrations for Nitrate (Page 3 of 17)

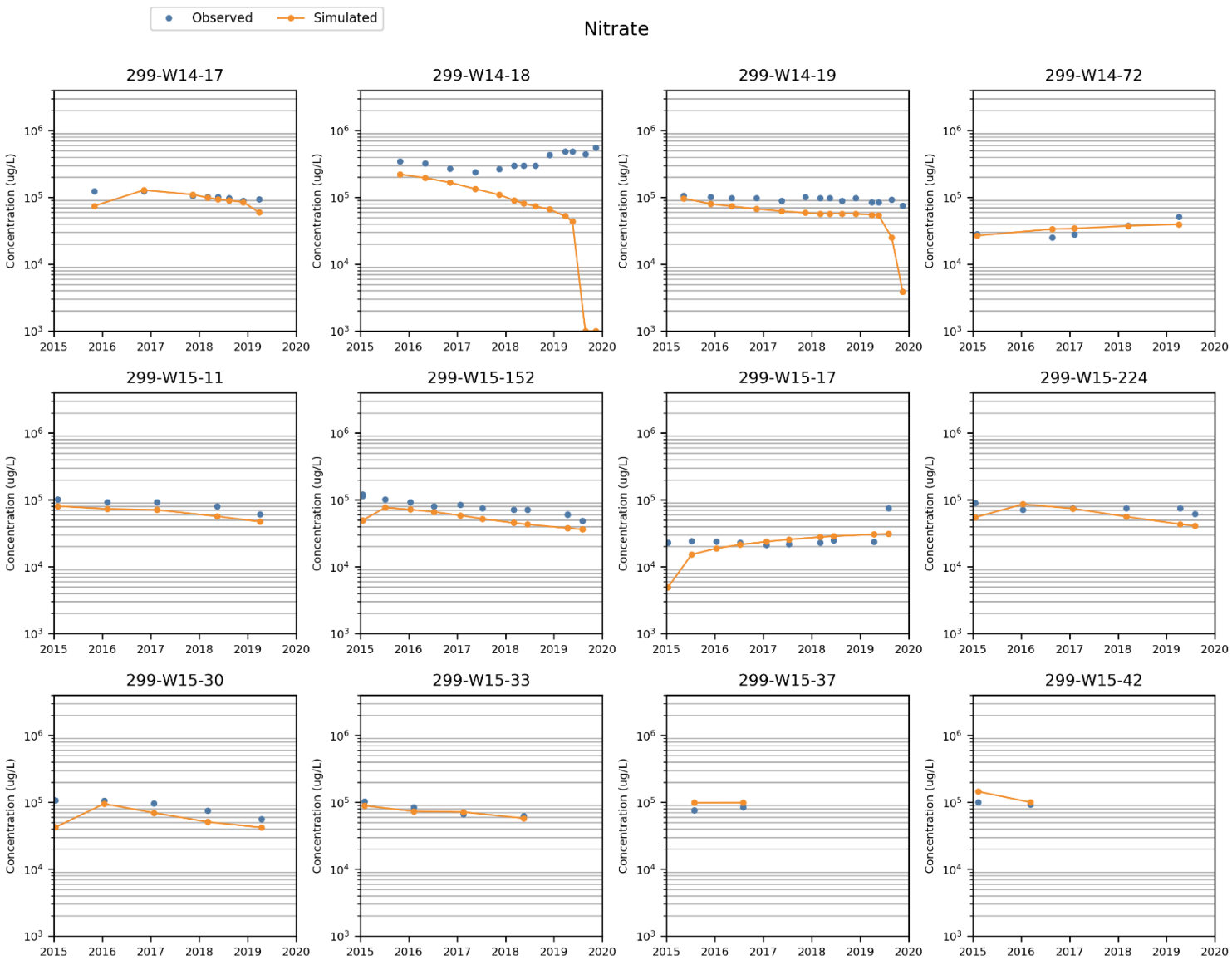

Figure B-41. Comparison of Simulated and Observed Concentrations for Nitrate (Page 4 of 17)

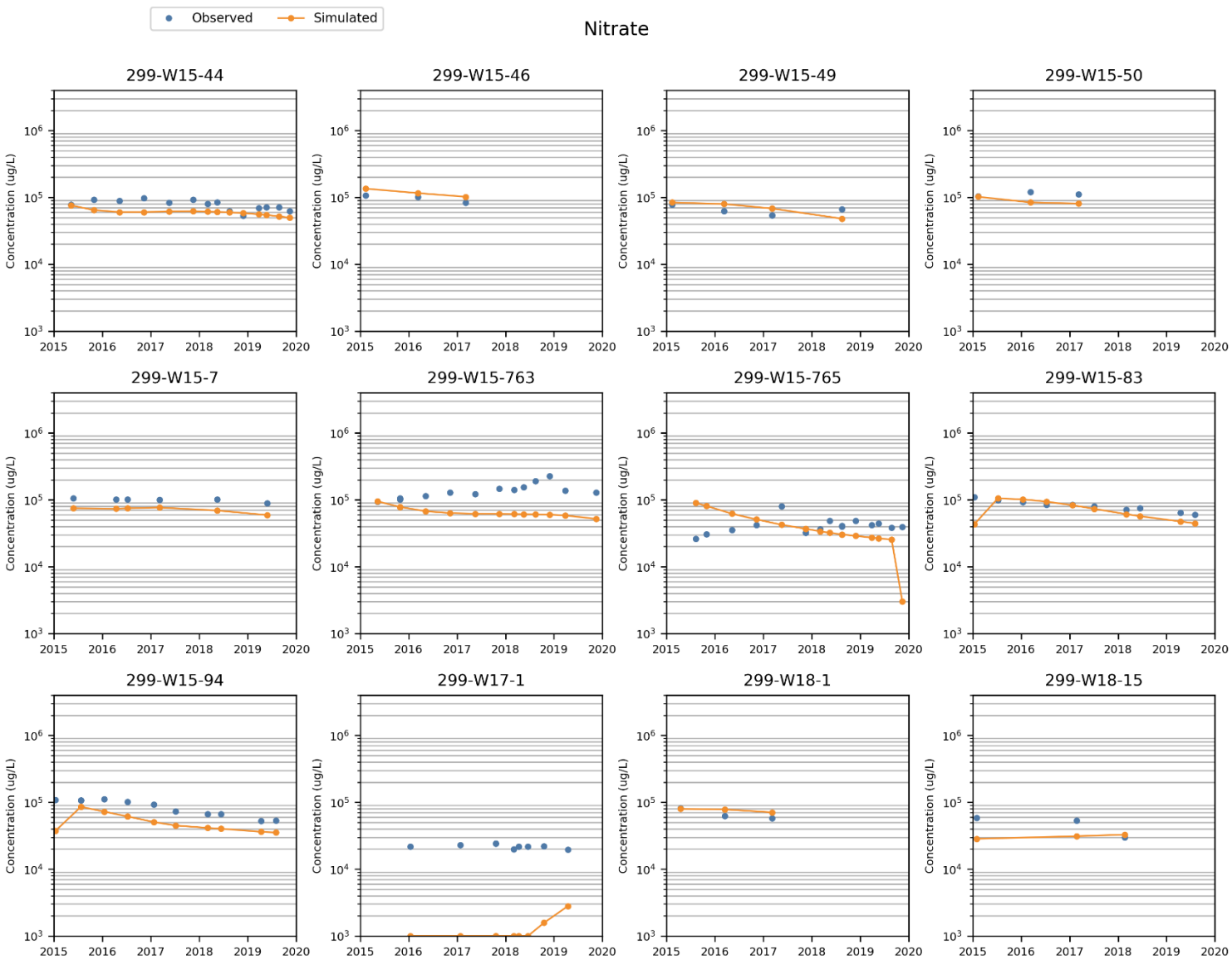

Figure B-42. Comparison of Simulated and Observed Concentrations for Nitrate (Page 5 of 17)

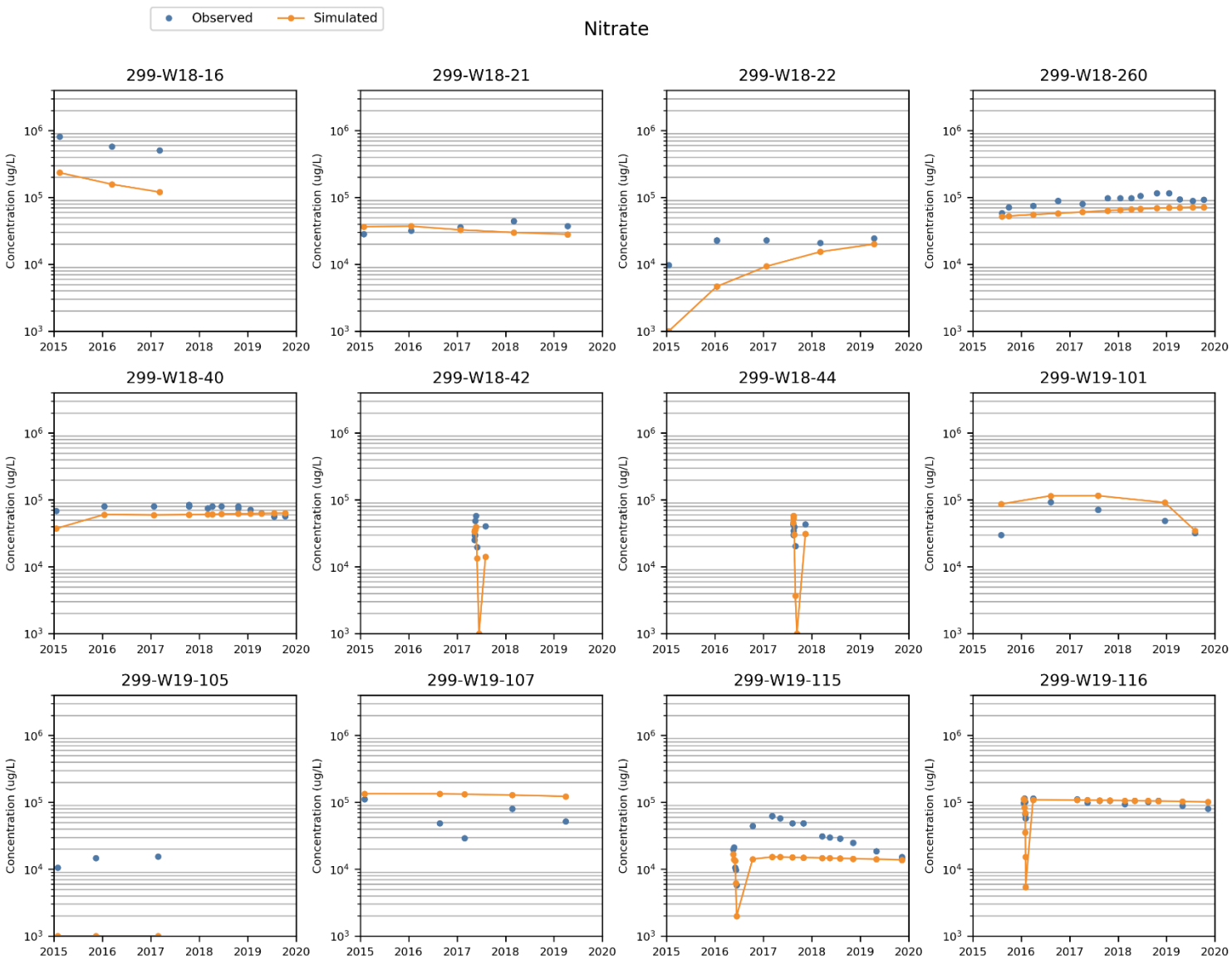

Figure B-43. Comparison of Simulated and Observed Concentrations for Nitrate (Page 6 of 17)

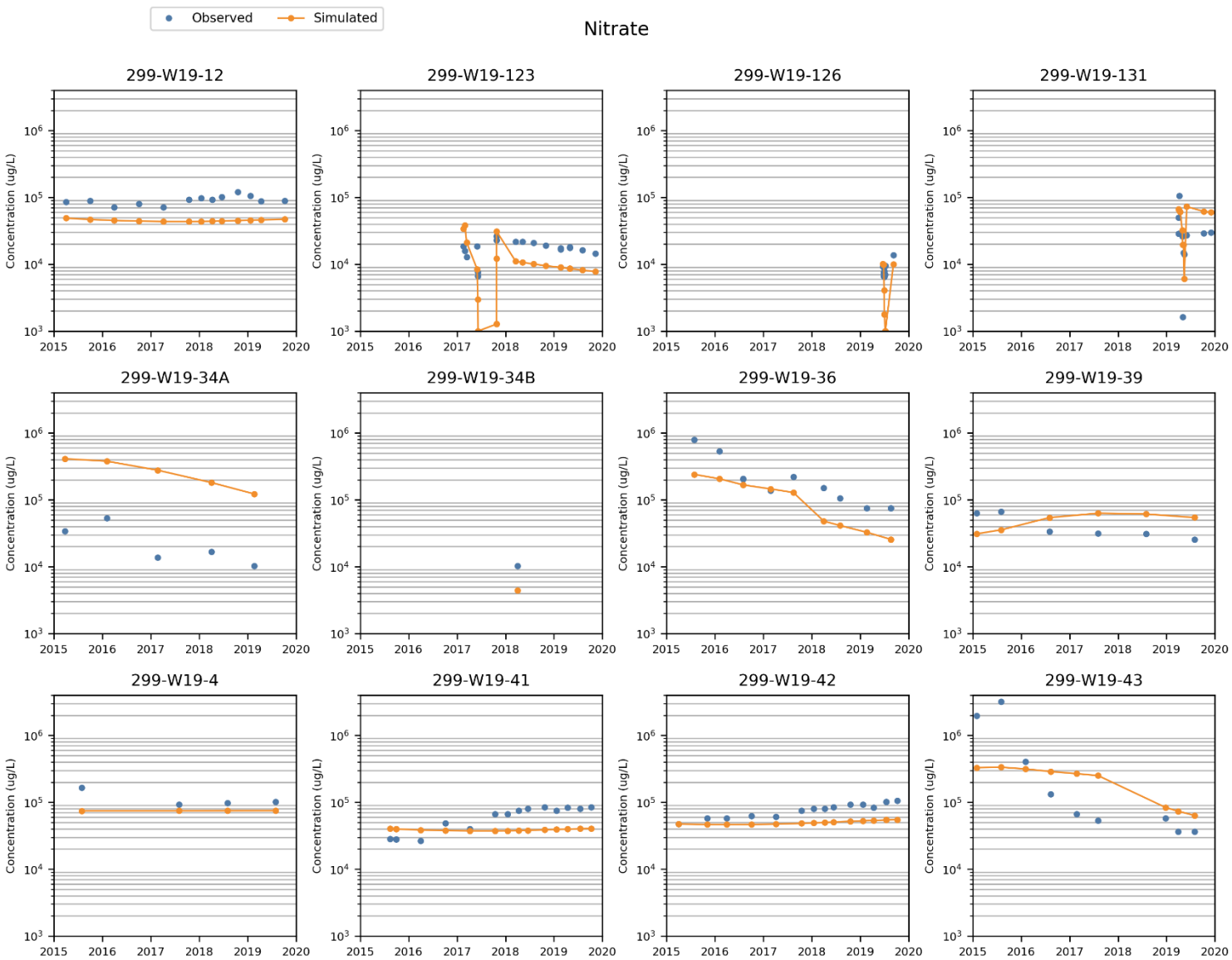

Figure B-44. Comparison of Simulated and Observed Concentrations for Nitrate (Page 7 of 17)

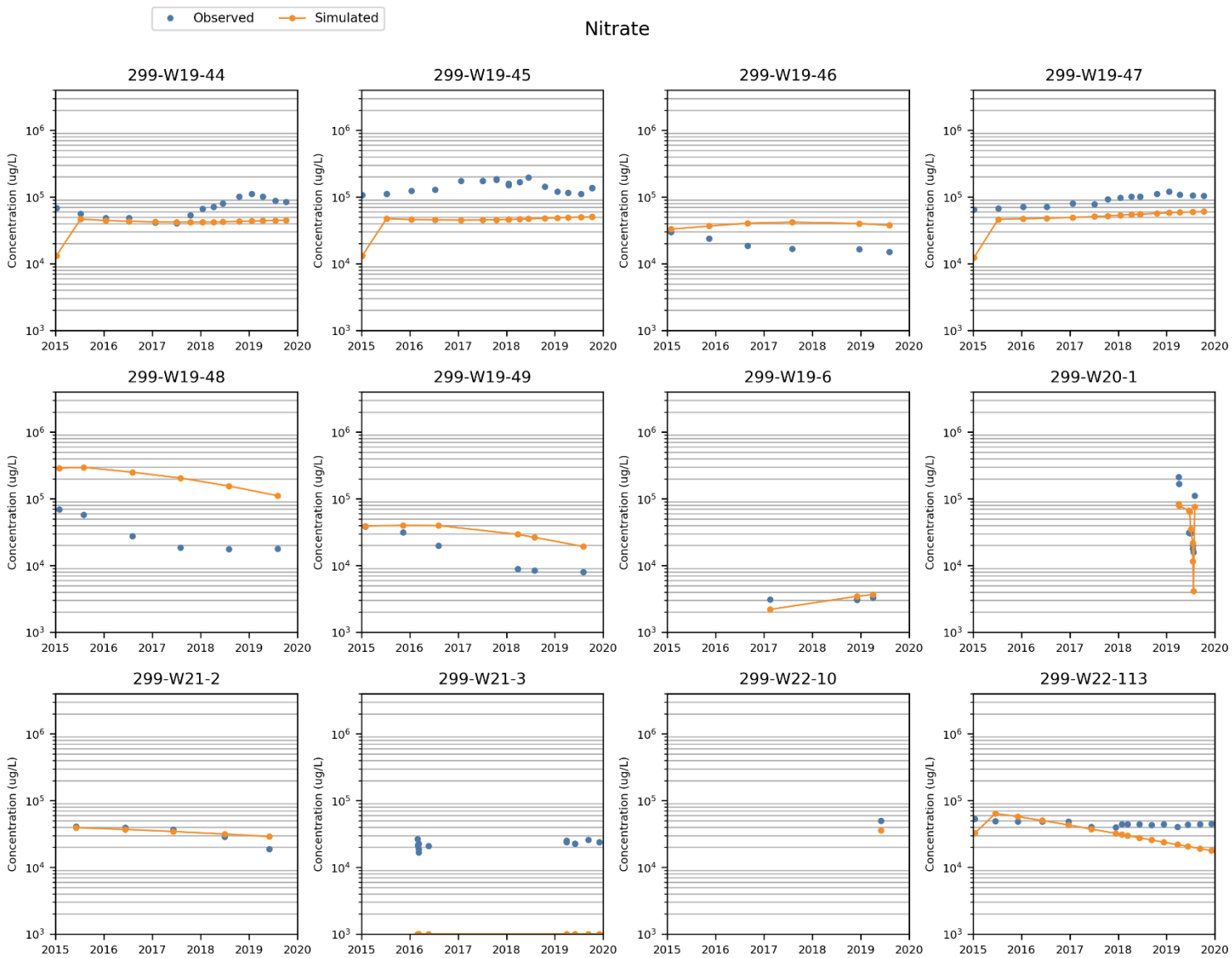

Figure B-45. Comparison of Simulated and Observed Concentrations for Nitrate (Page 8 of 17)

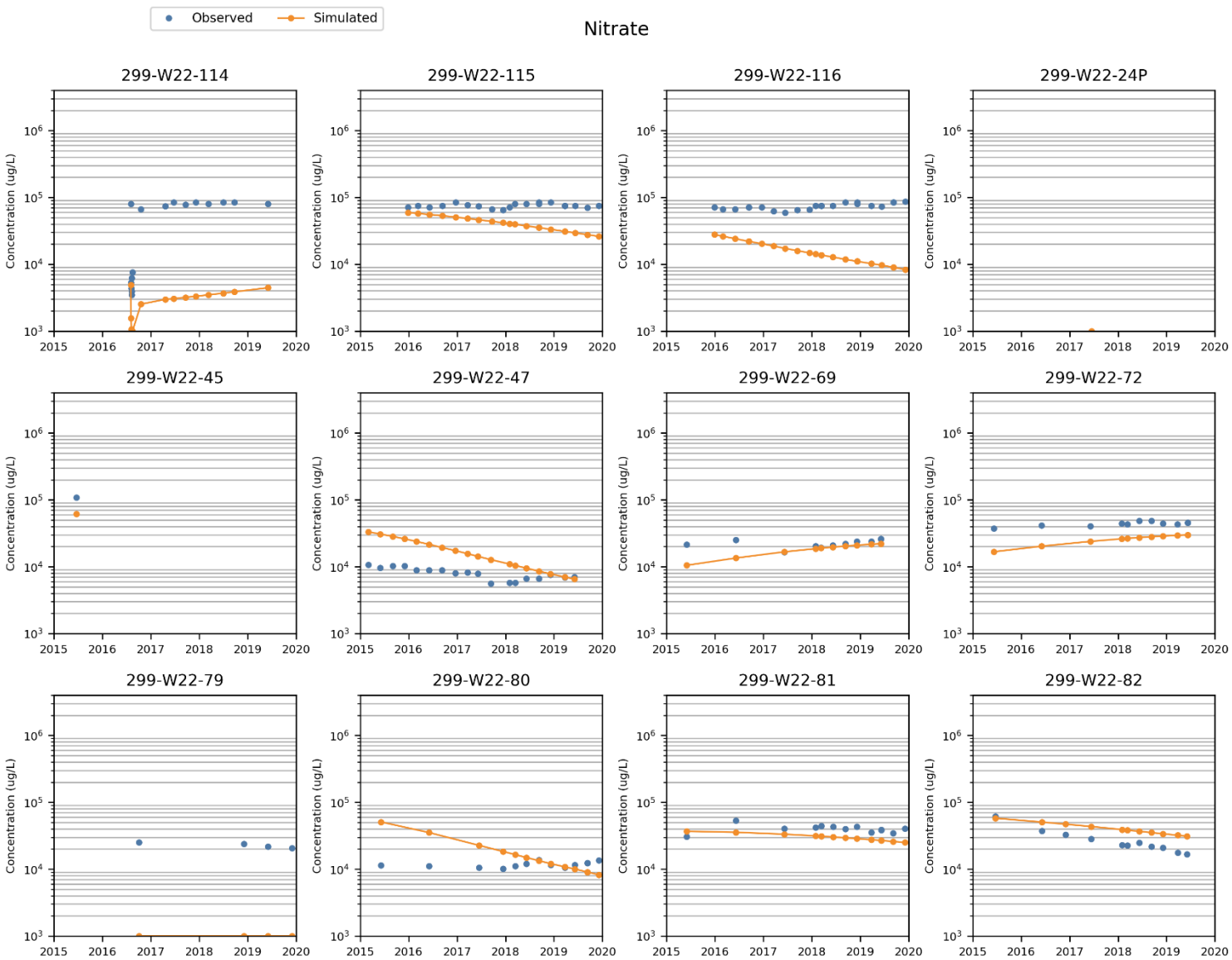

Figure B-46. Comparison of Simulated and Observed Concentrations for Nitrate (Page 9 of 17)

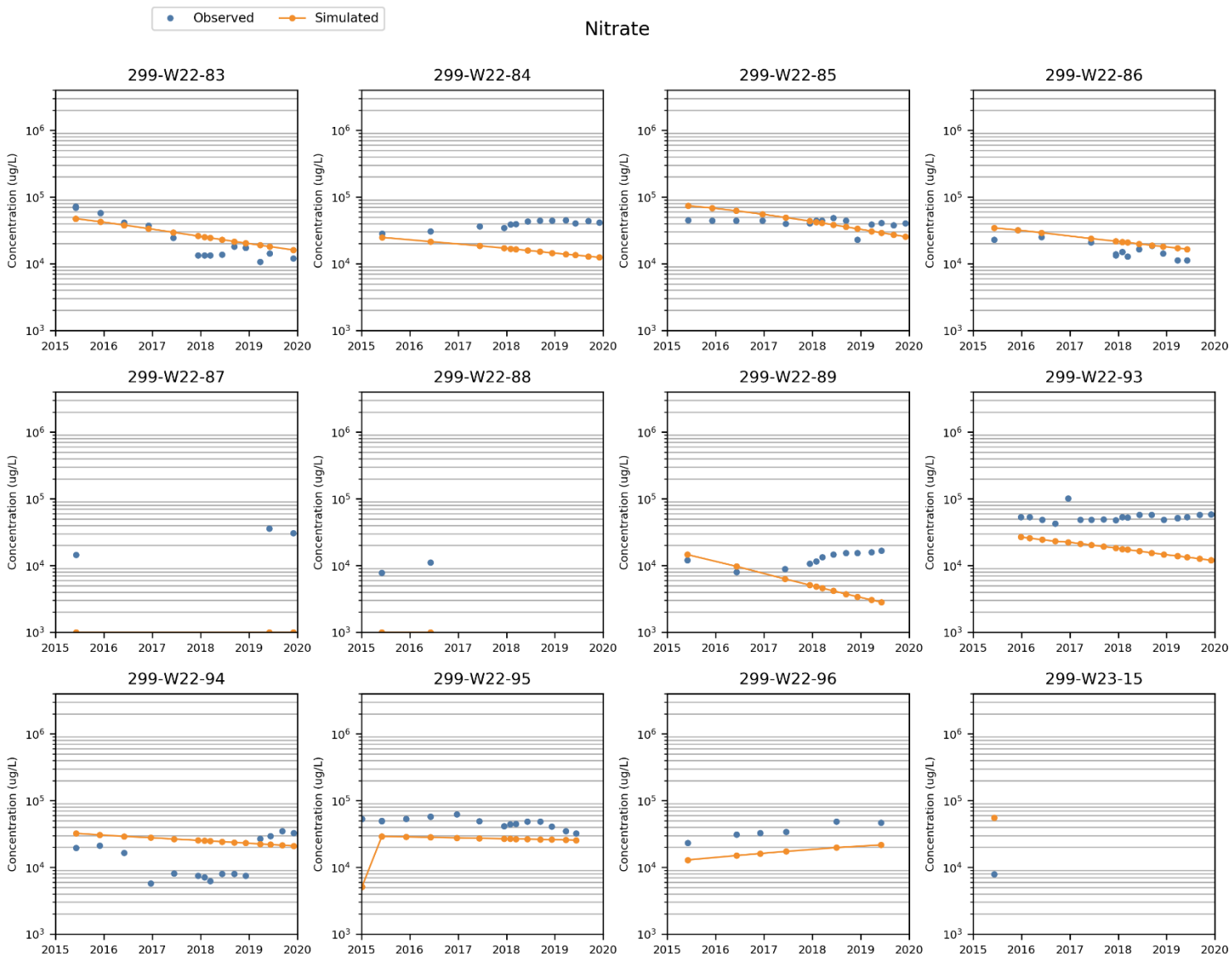

Figure B-47. Comparison of Simulated and Observed Concentrations for Nitrate (Page 10 of 17)

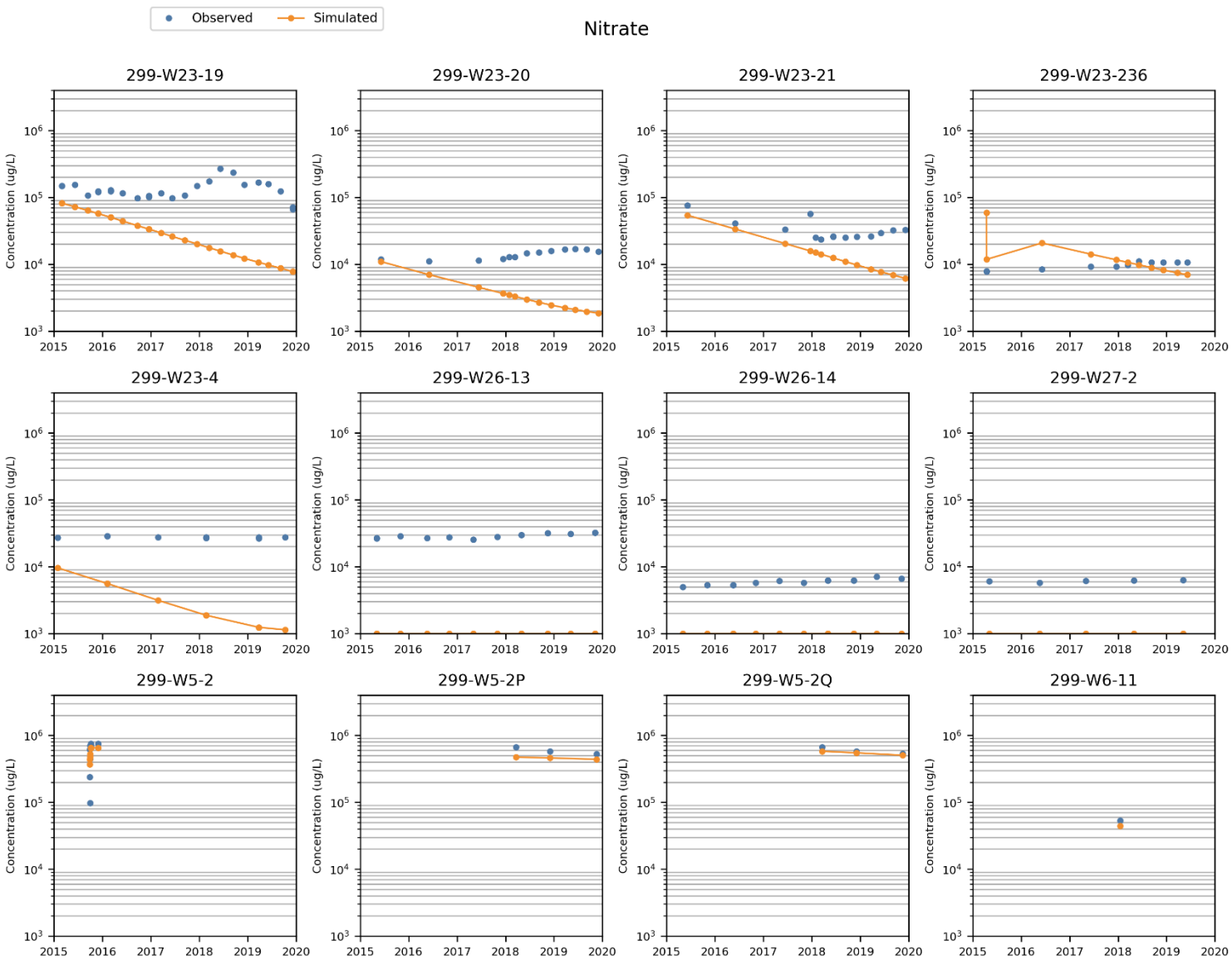

Figure B-48. Comparison of Simulated and Observed Concentrations for Nitrate (Page 11 of 17)

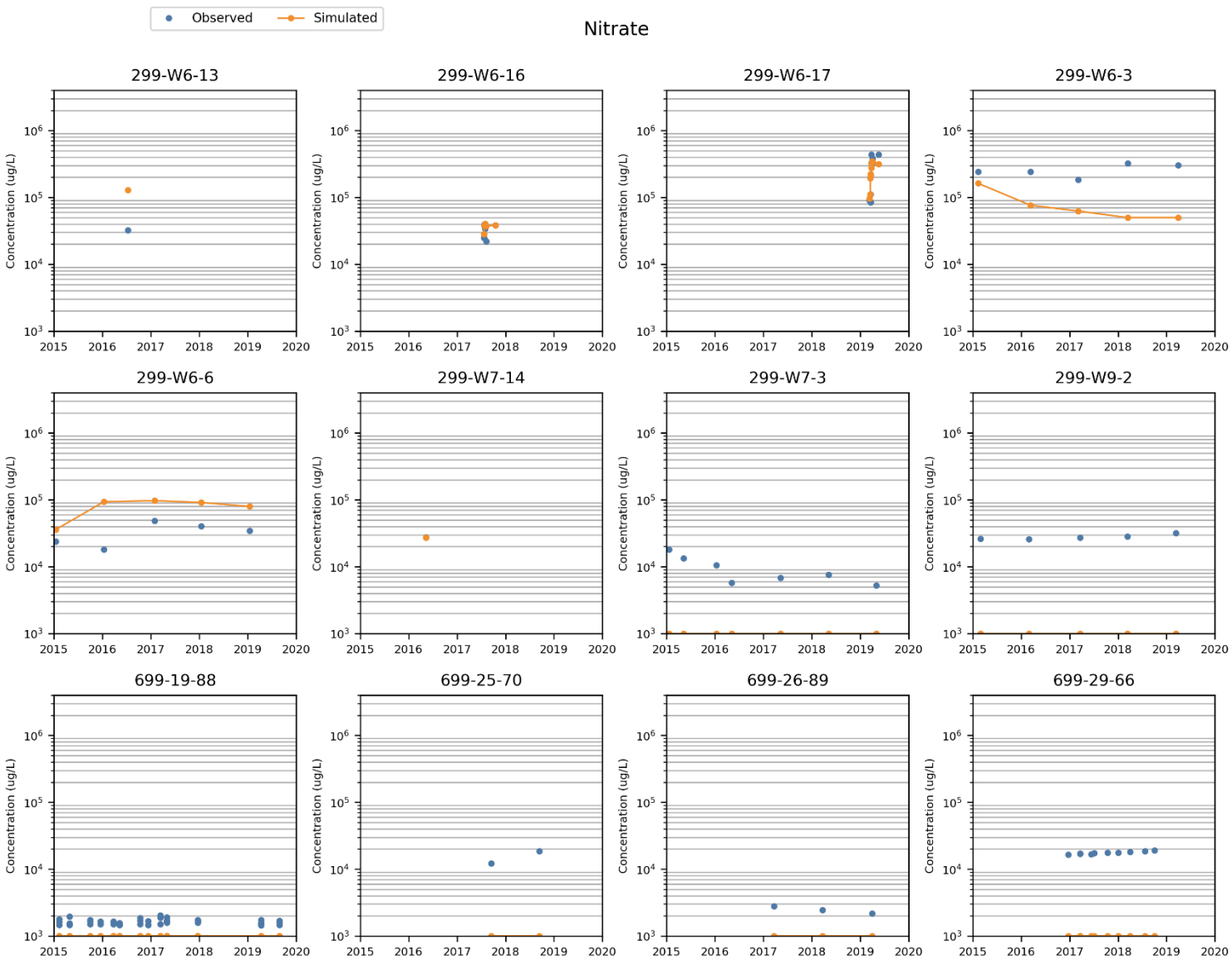

Figure B-49. Comparison of Simulated and Observed Concentrations for Nitrate (Page 12 of 17)

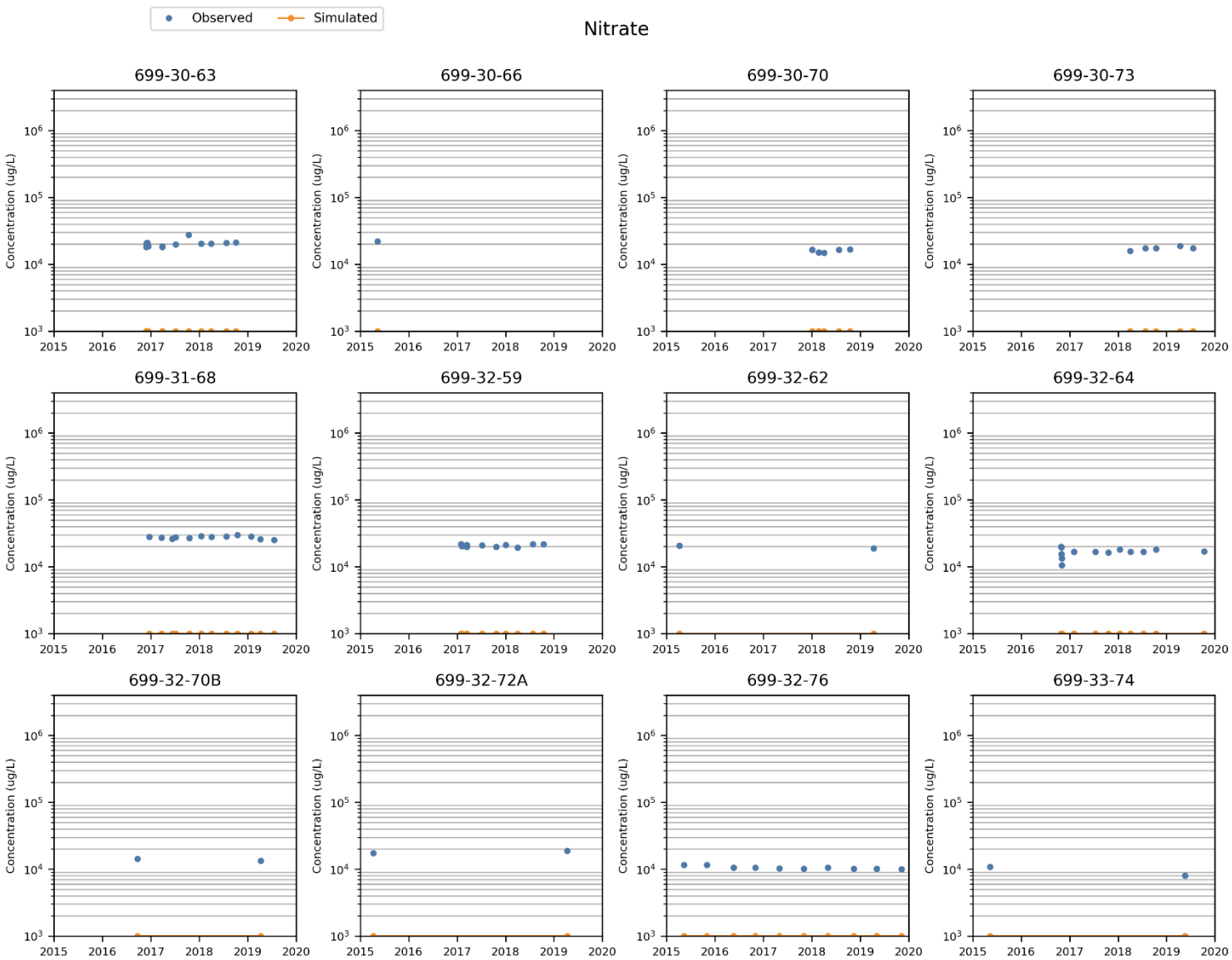

Figure B-50. Comparison of Simulated and Observed Concentrations for Nitrate (Page 13 of 17)

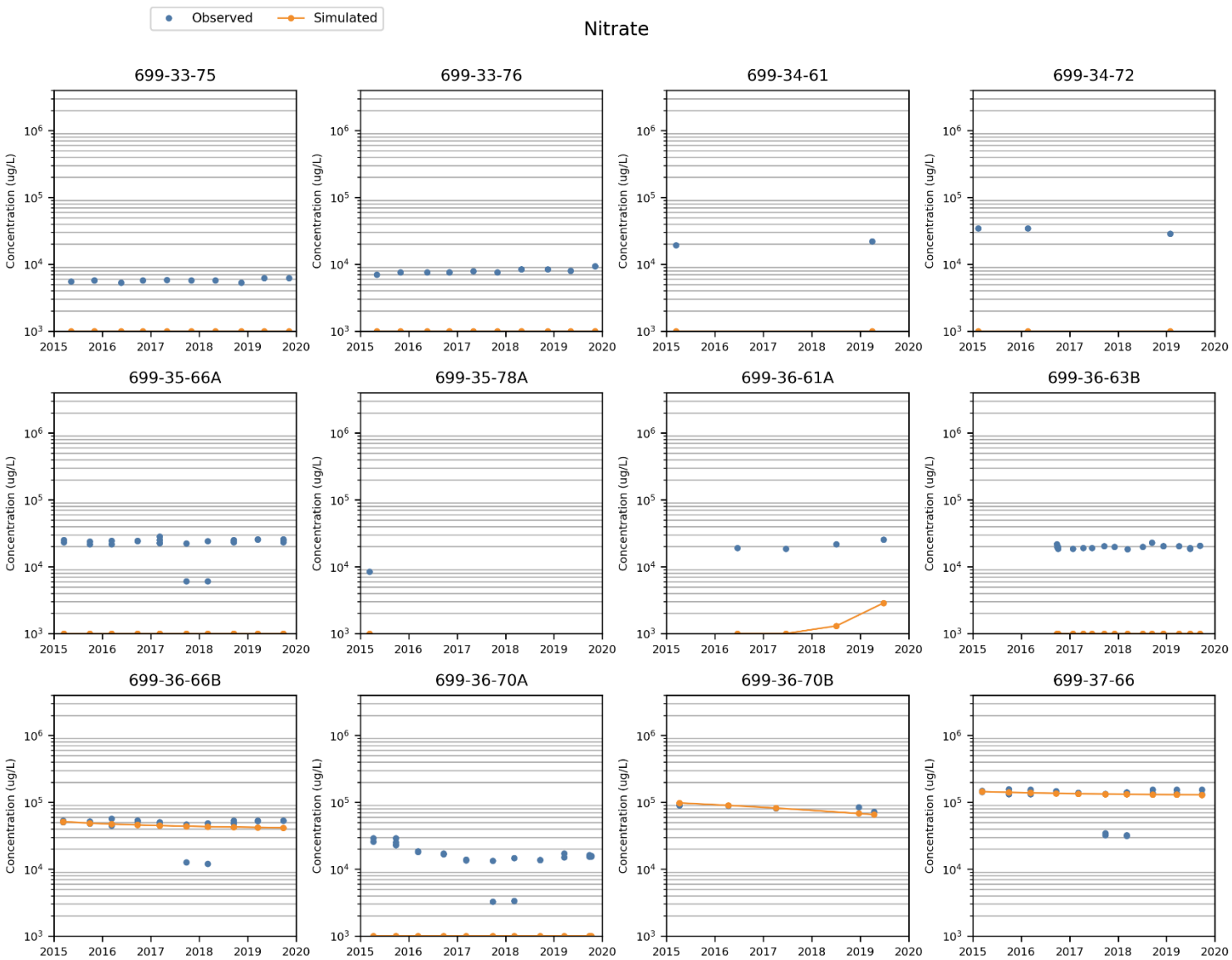

Figure B-51. Comparison of Simulated and Observed Concentrations for Nitrate (Page 14 of 17)

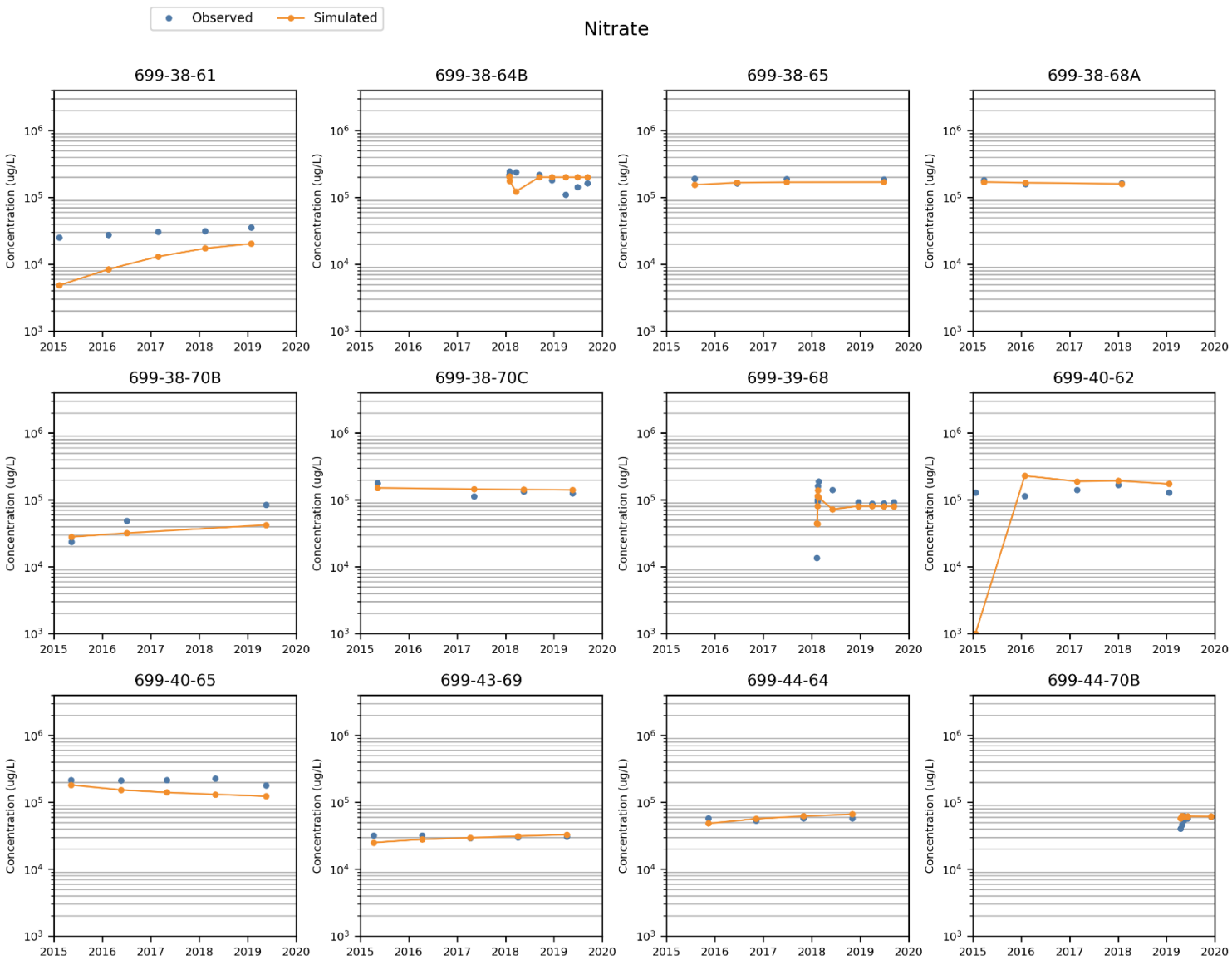

Figure B-52. Comparison of Simulated and Observed Concentrations for Nitrate (Page 15 of 17)

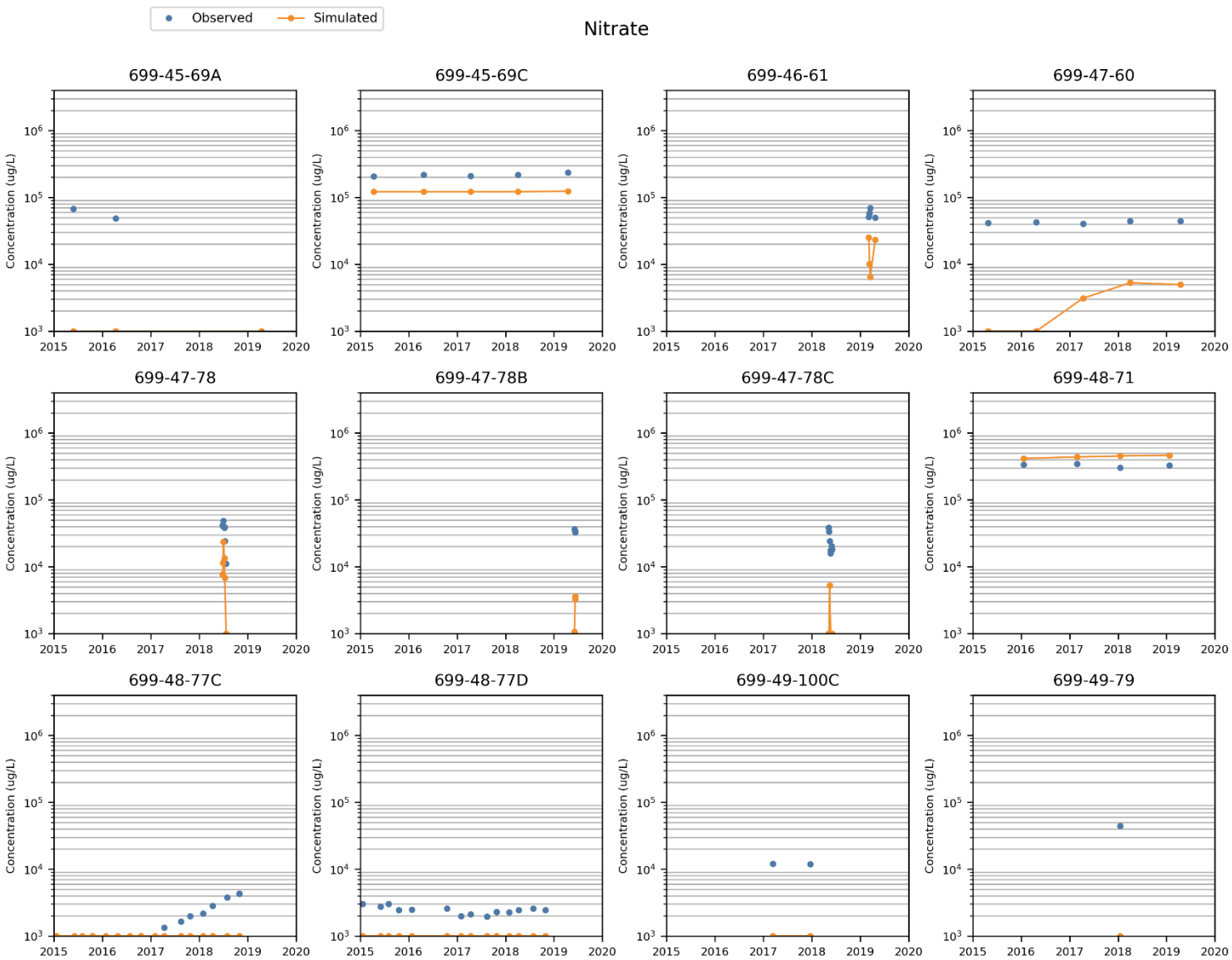

Figure B-53. Comparison of Simulated and Observed Concentrations for Nitrate (Page 16 of 17)

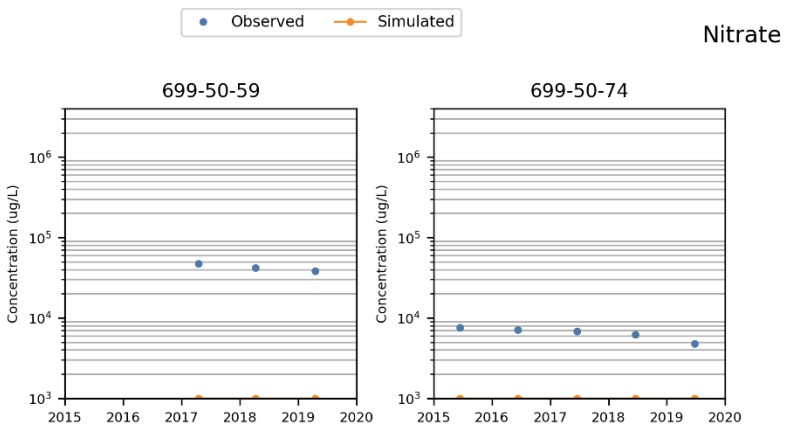

Figure B-54. Comparison of Simulated and Observed Concentrations for Nitrate (Page 17 of 17)

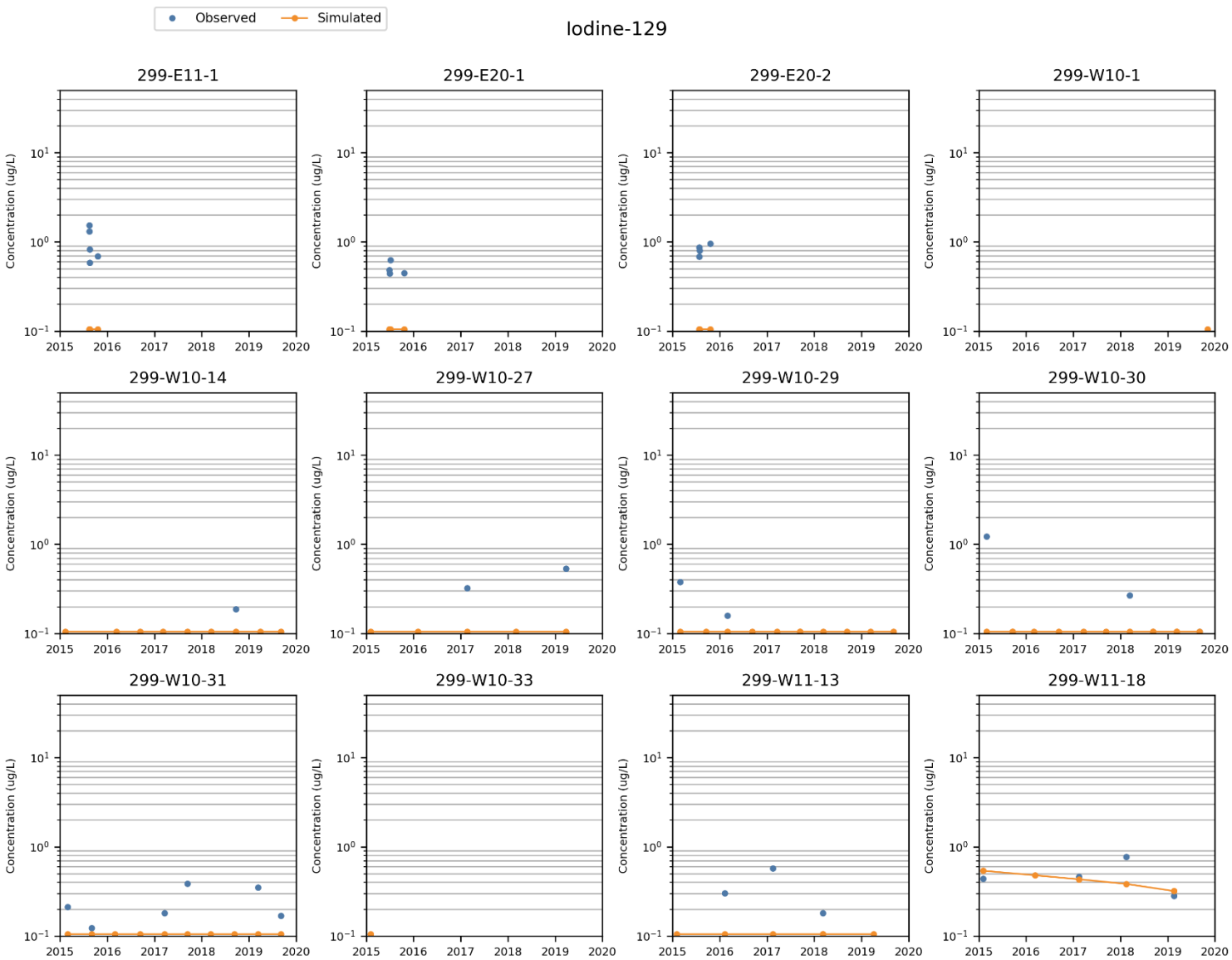

Figure B-55. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 1 of 13)

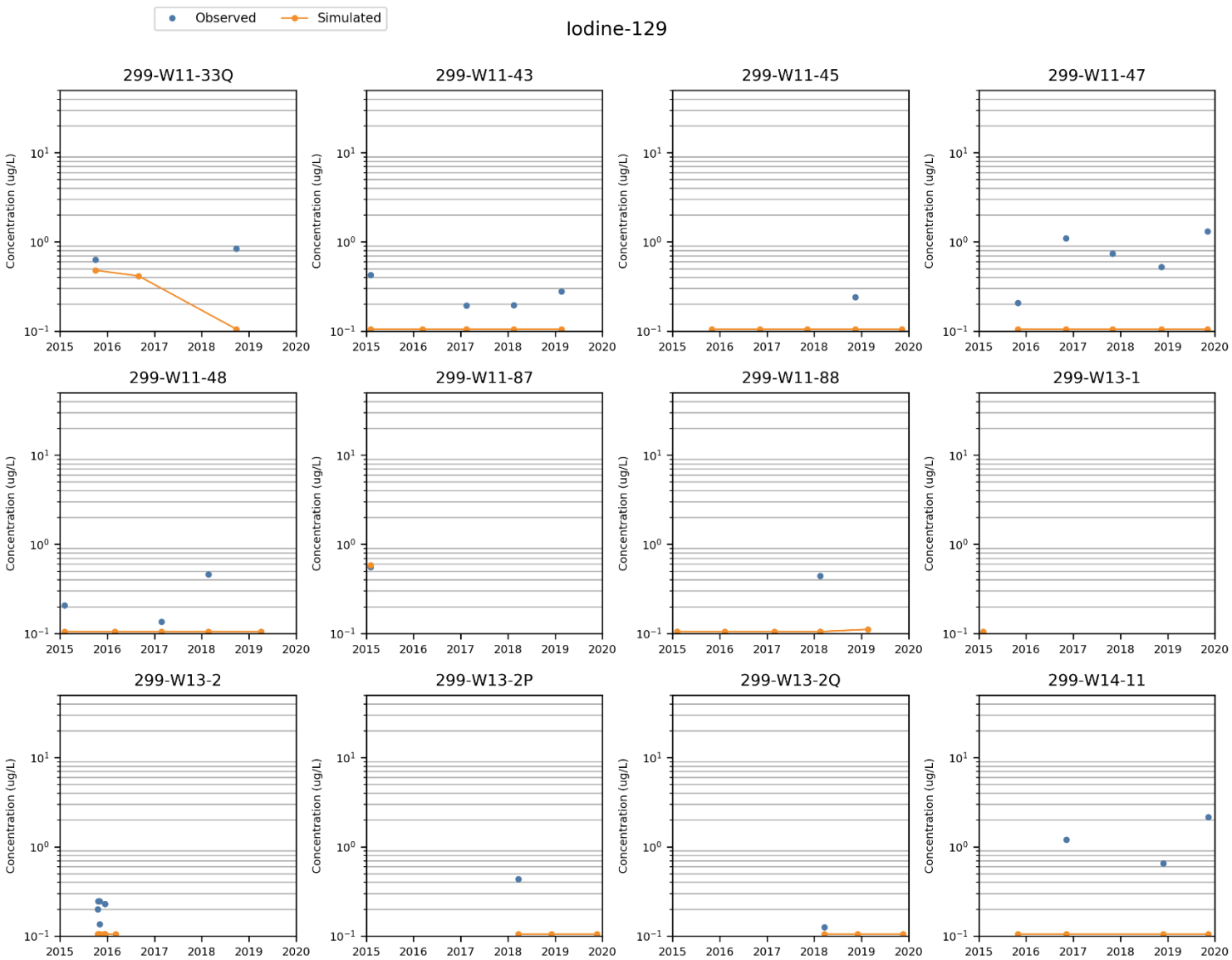

Figure B-56. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 2 of 13)

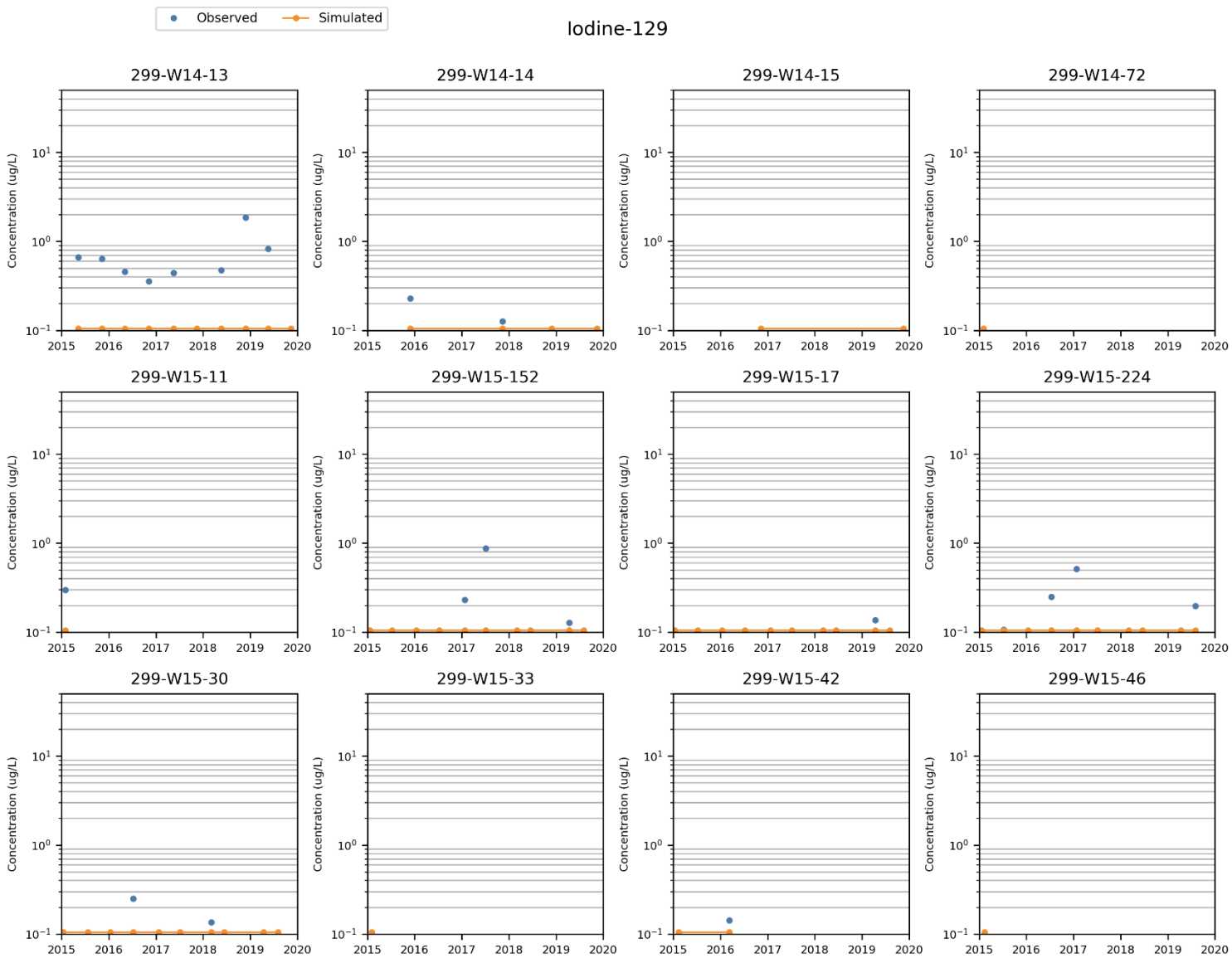

Figure B-57. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 3 of 13)

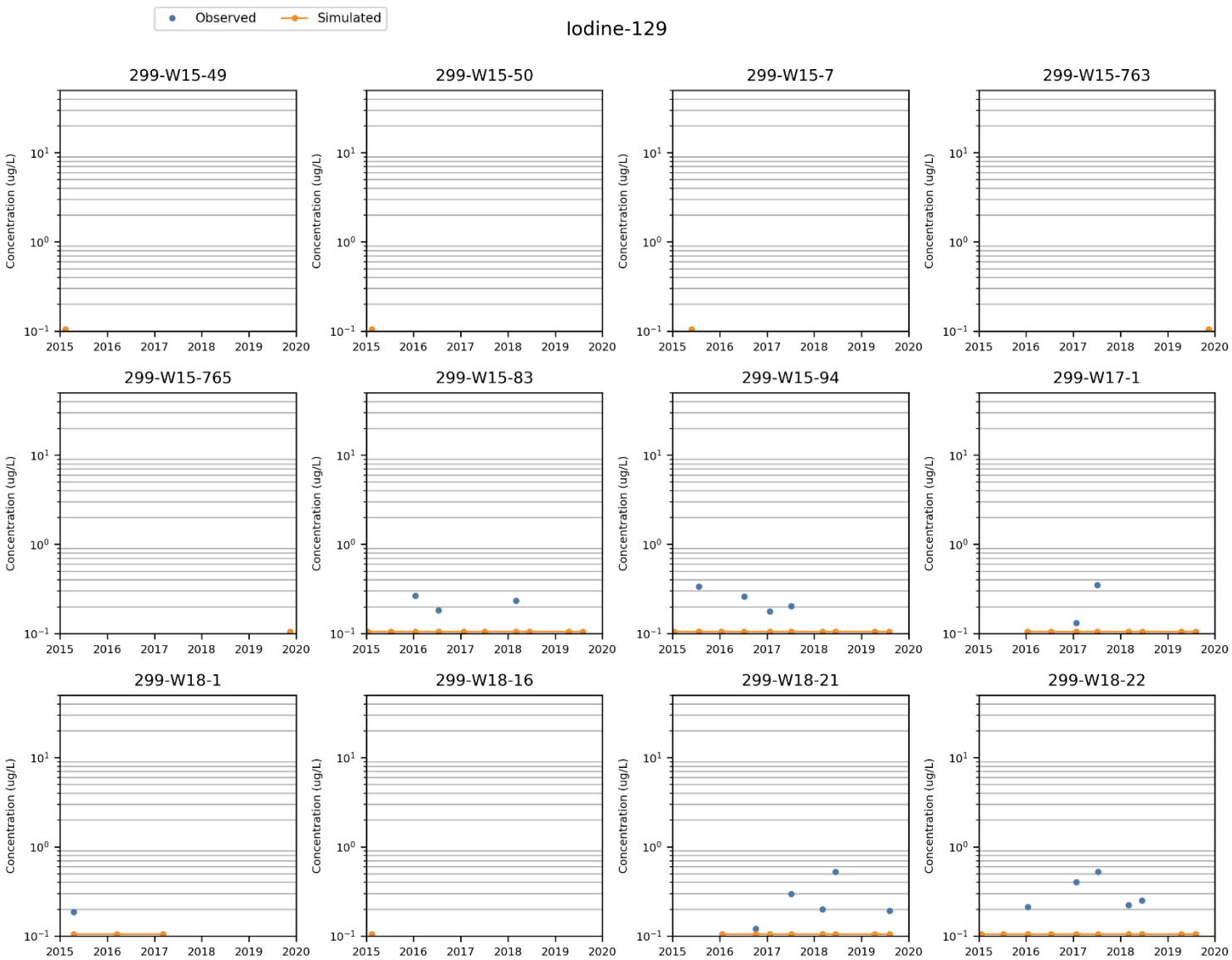

Figure B-58. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 4 of 13)

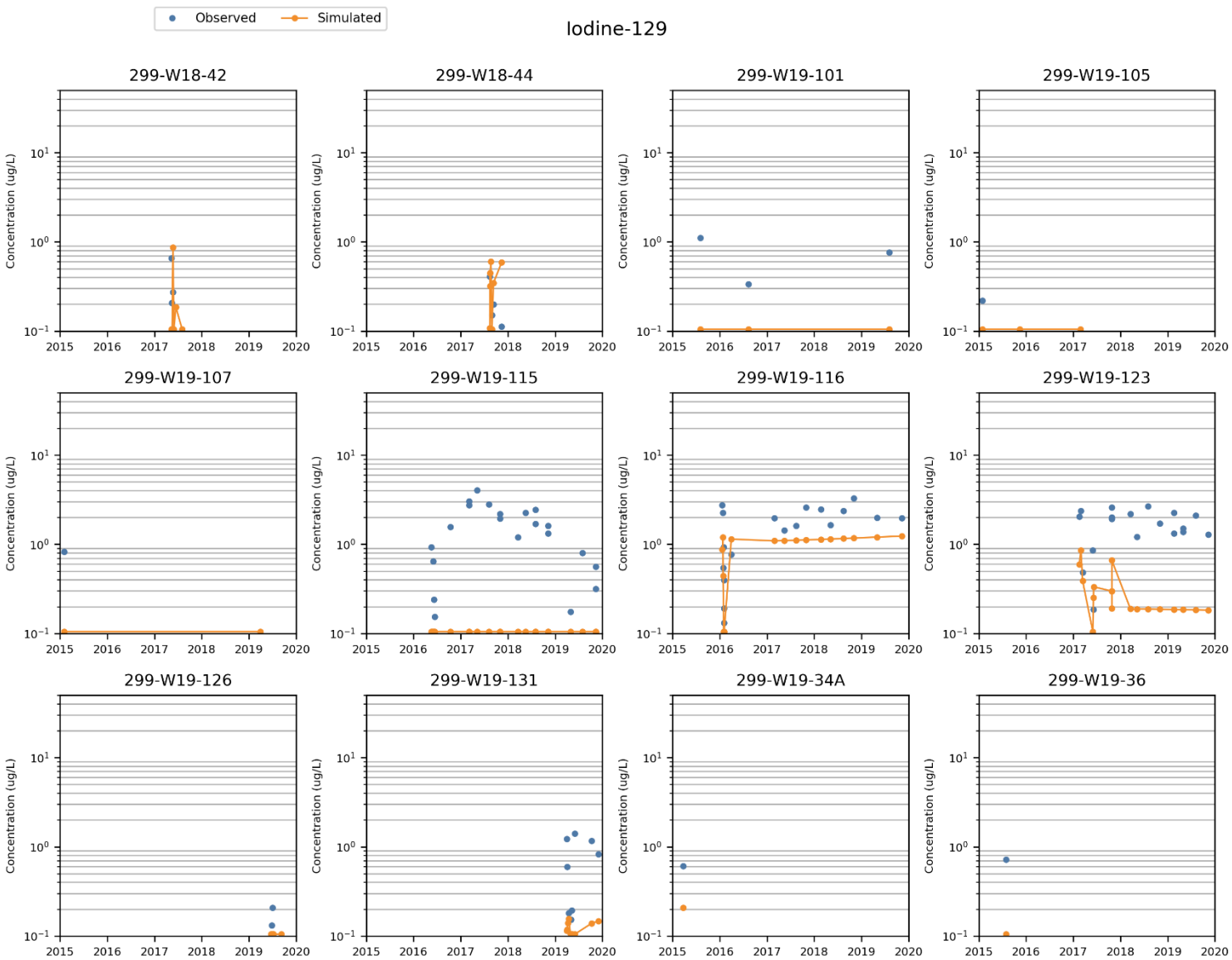

Figure B-59. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 5 of 13)

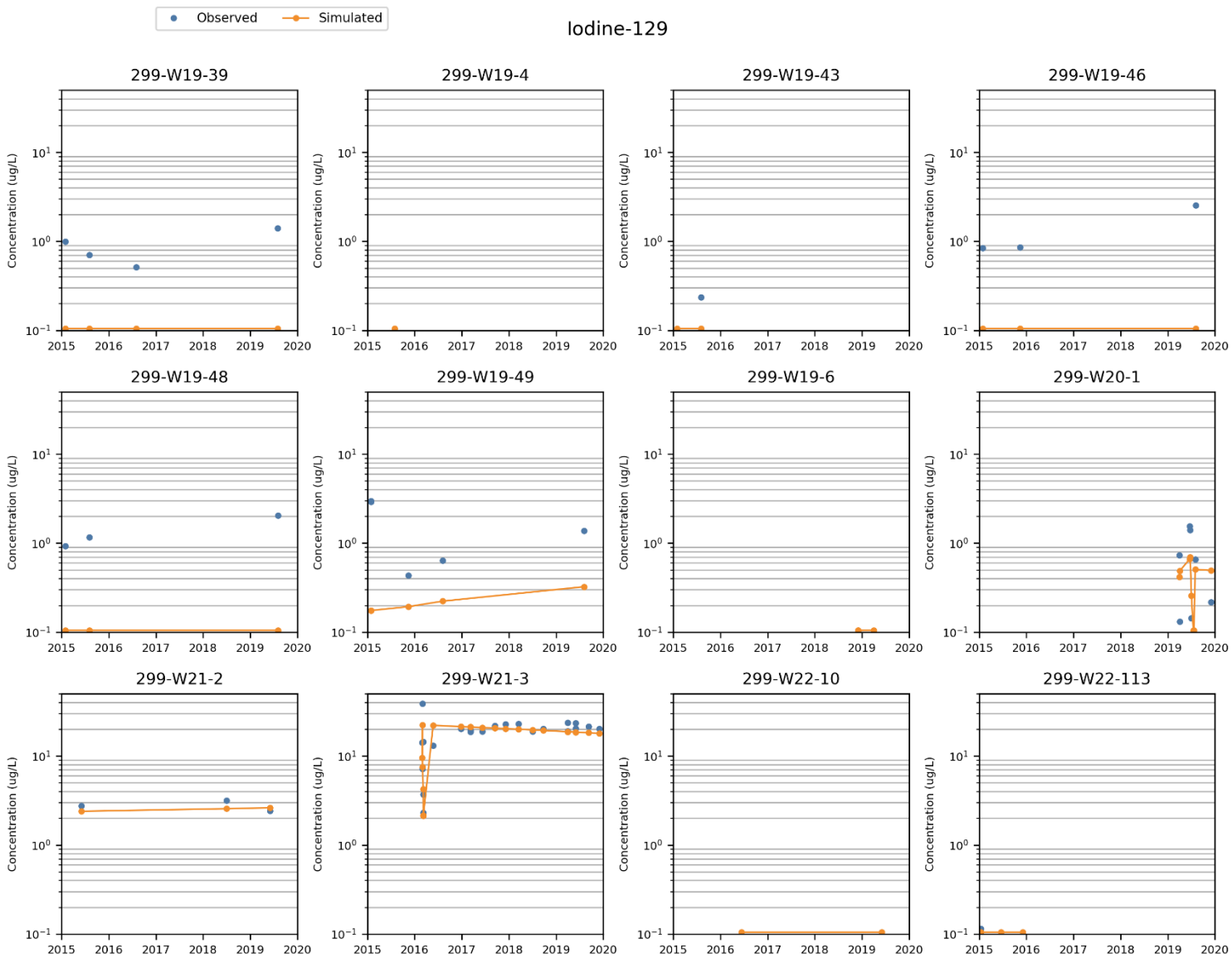

Figure B-60. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 6 of 13)

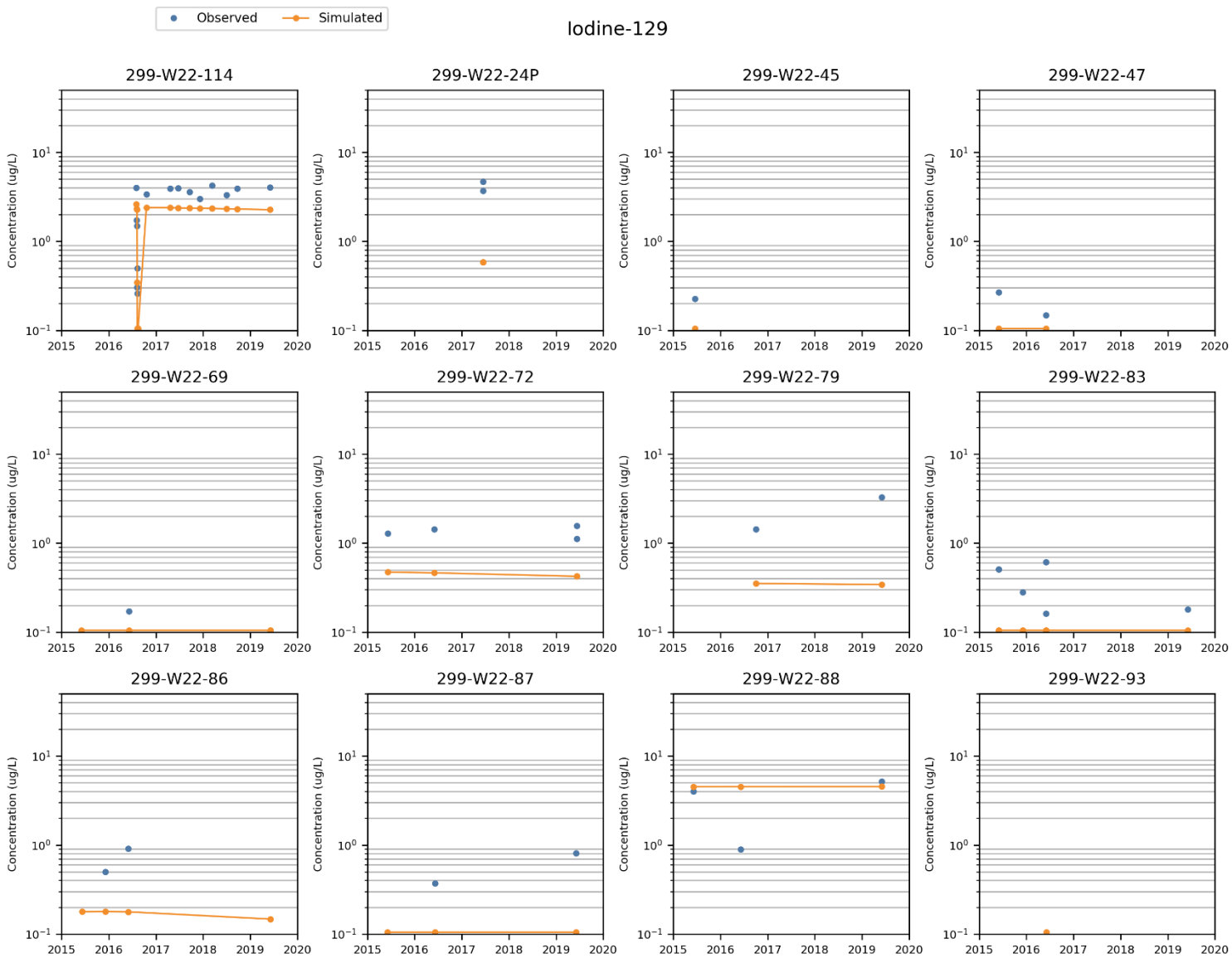

Figure B-61. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 7 of 13)

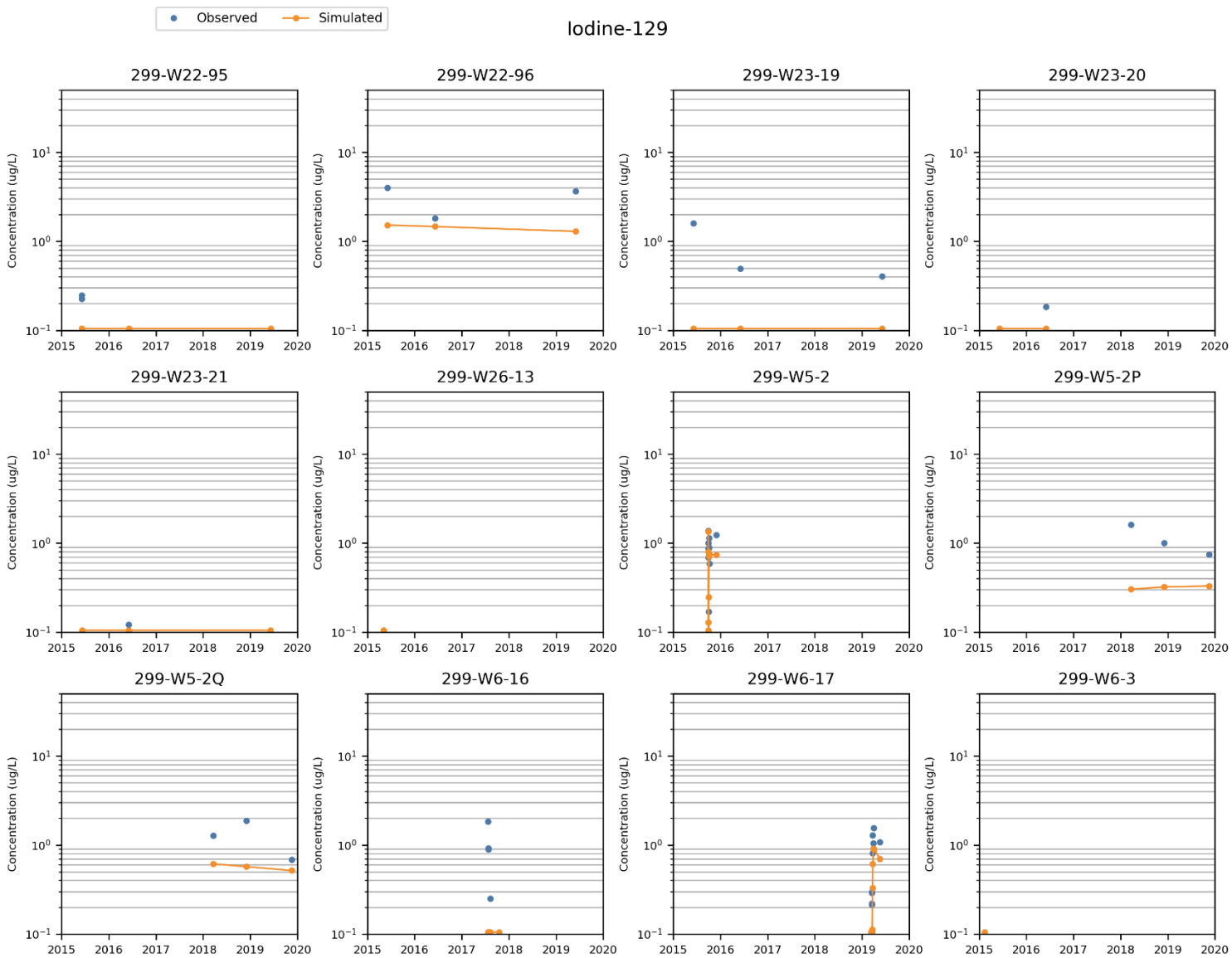

Figure B-62. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 8 of 13)

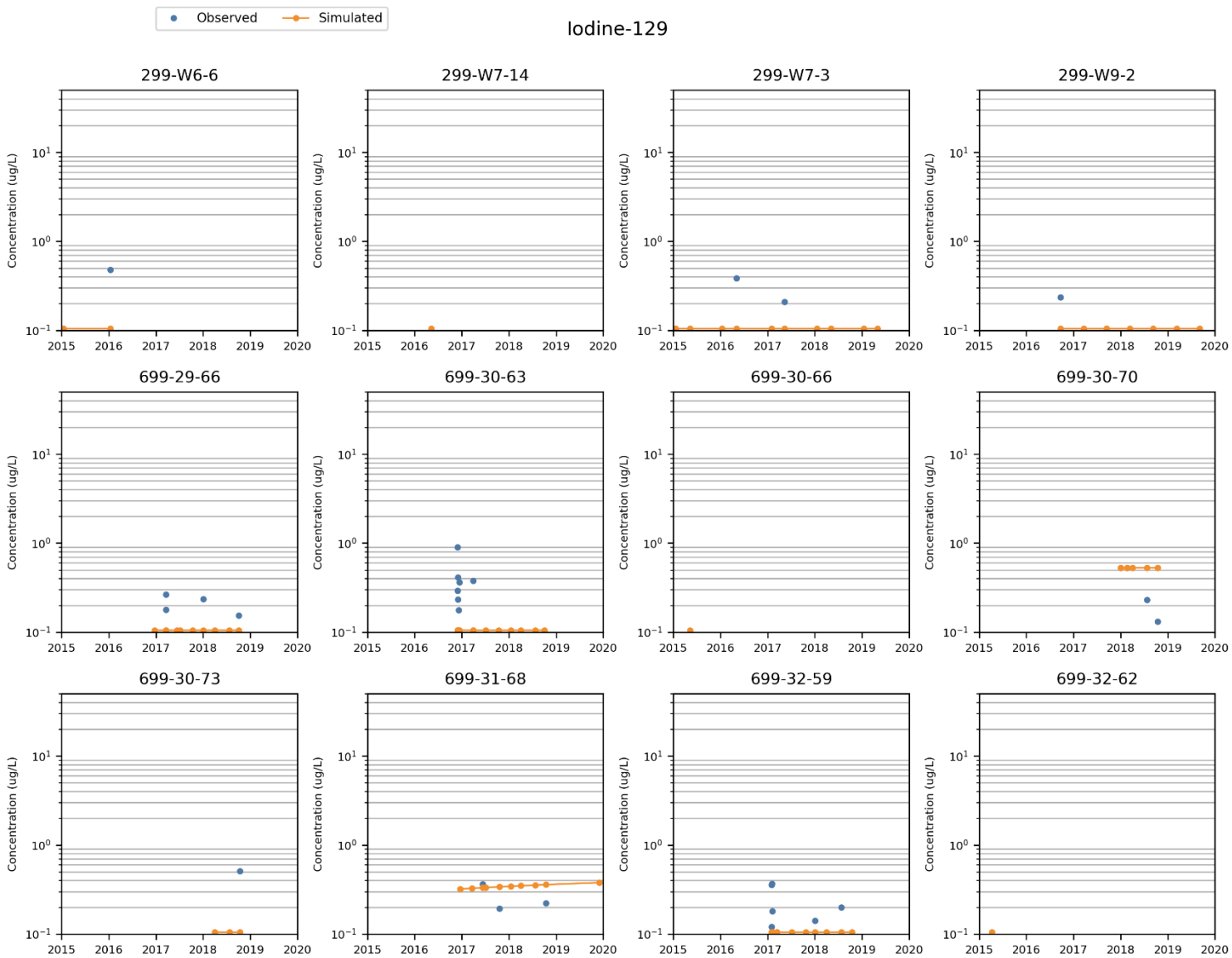

Figure B-63. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 9 of 13)

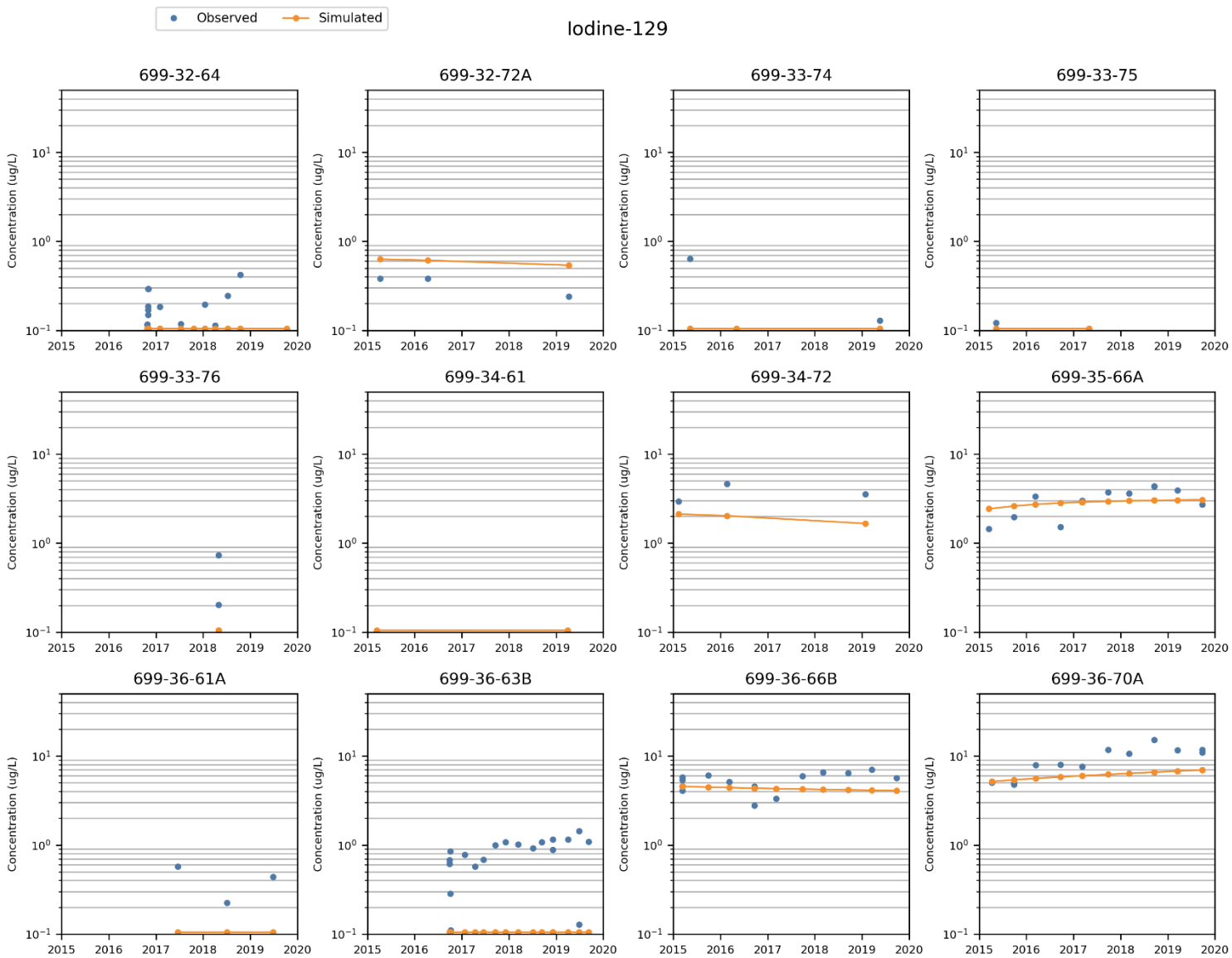

Figure B-64. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 10 of 13)

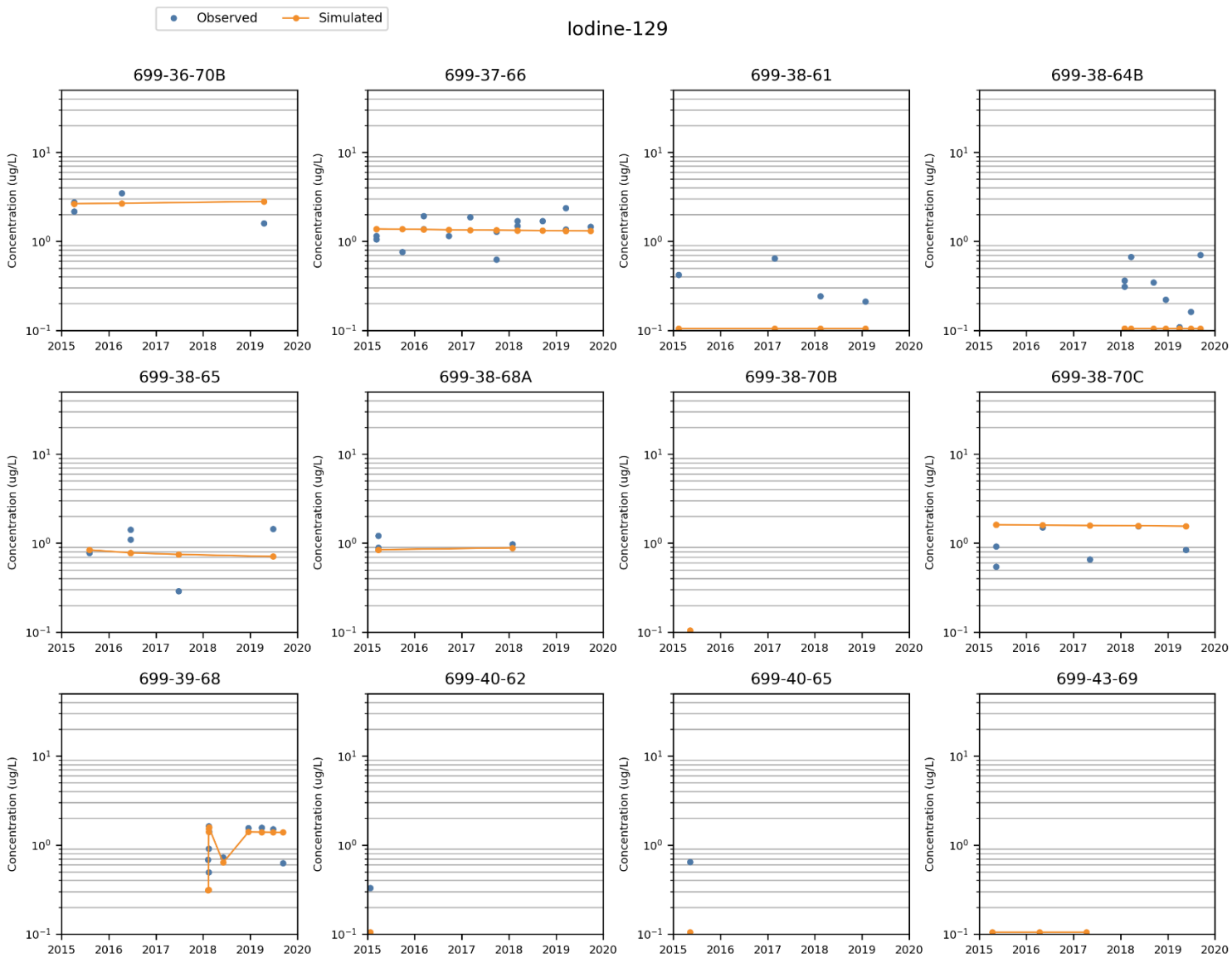

Figure B-65. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 11 of 13)

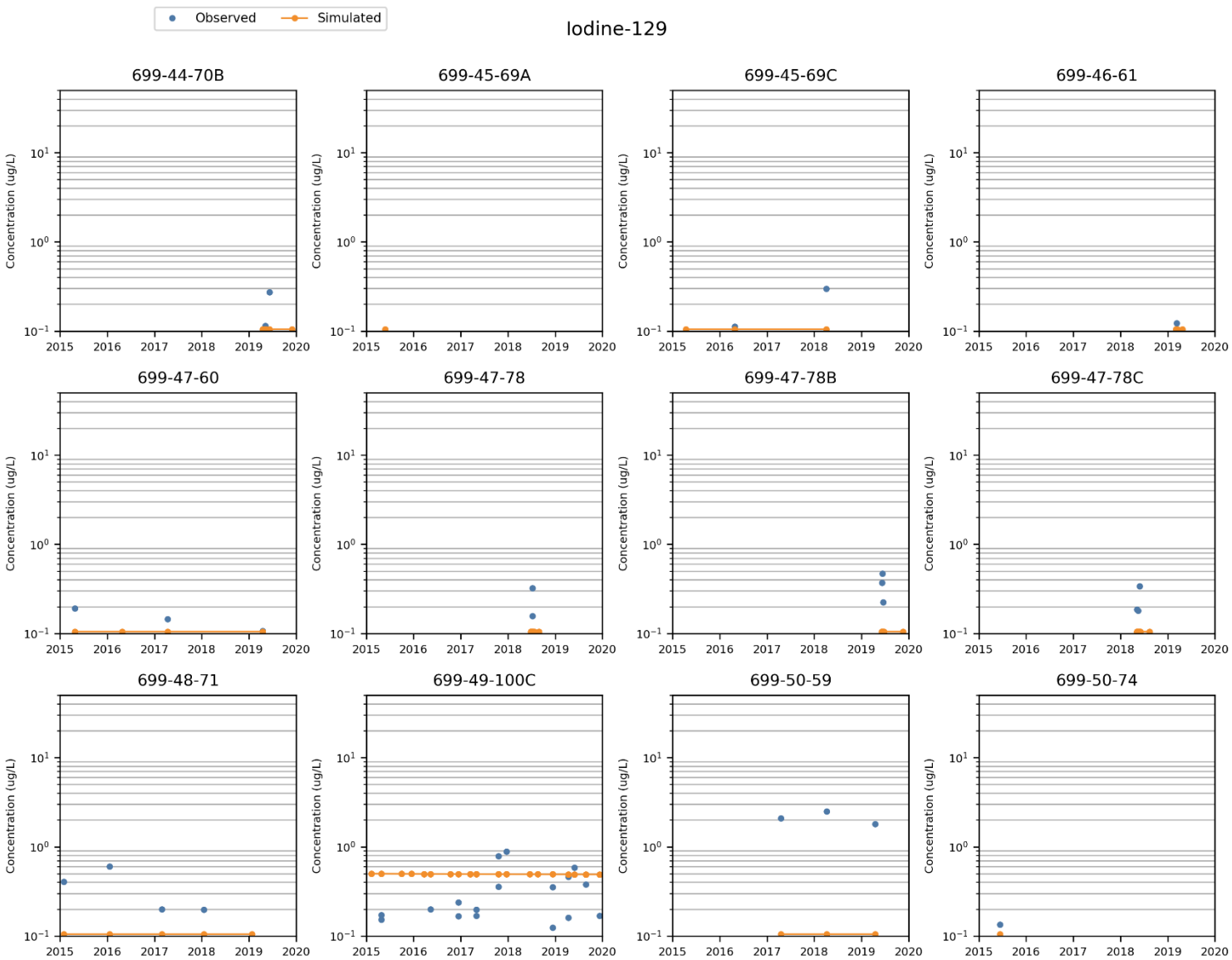

Figure B-66. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 12 of 13)

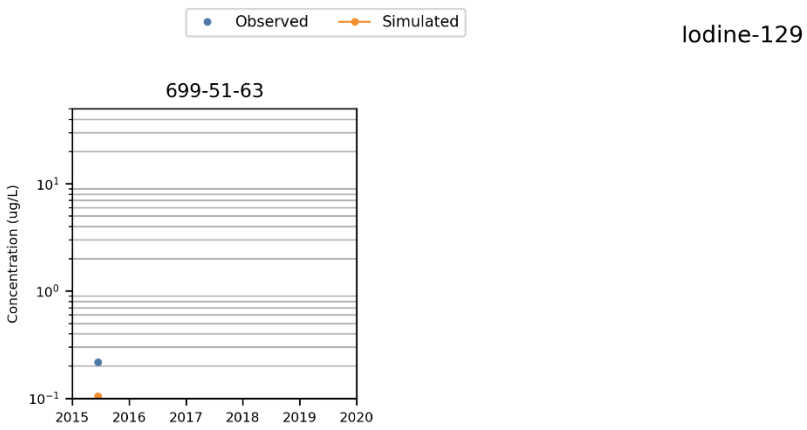

Figure B-67. Comparison of Simulated and Observed Concentrations for Iodine-129 (Page 13 of 13)

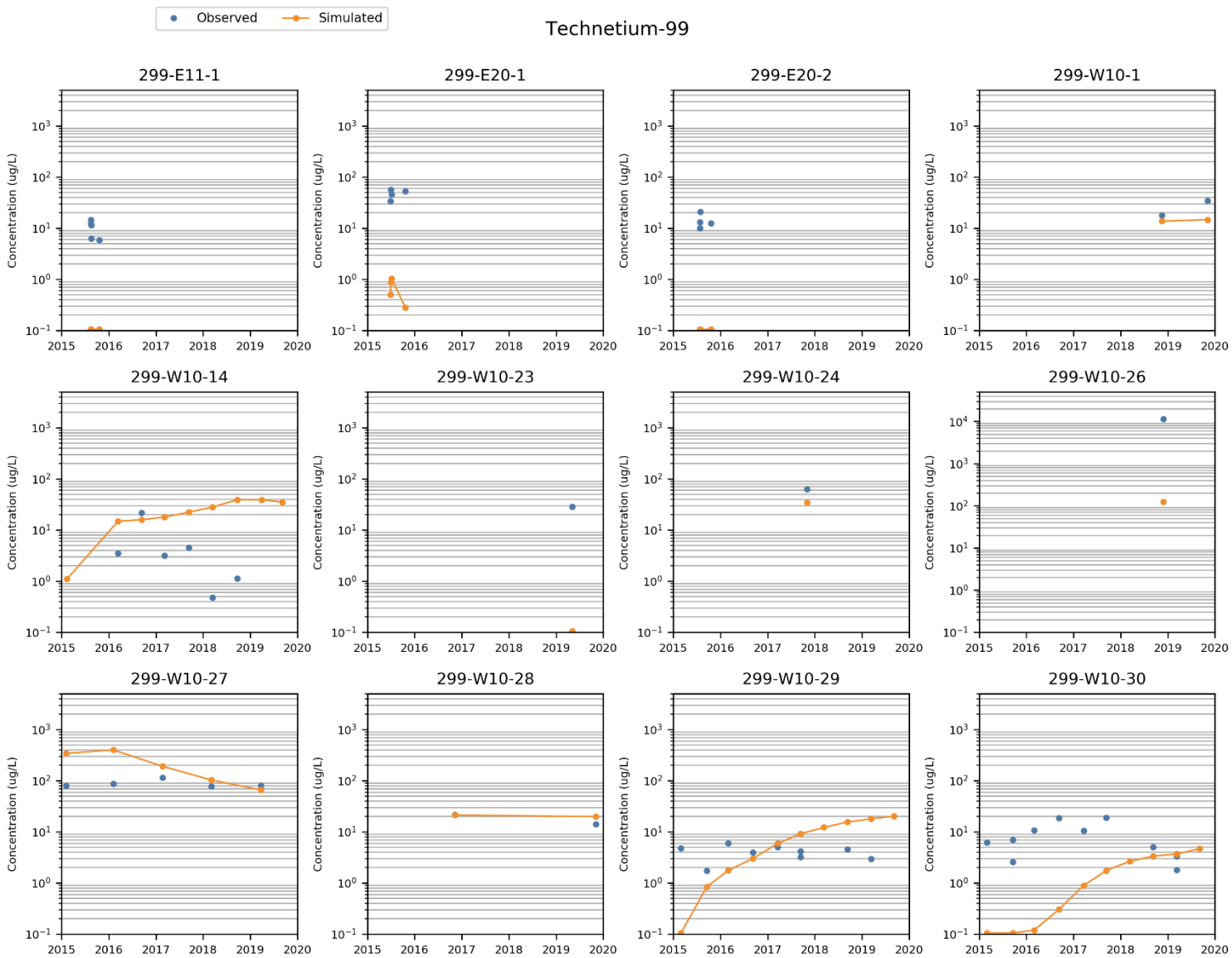

Figure B-68. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 1 of 14)

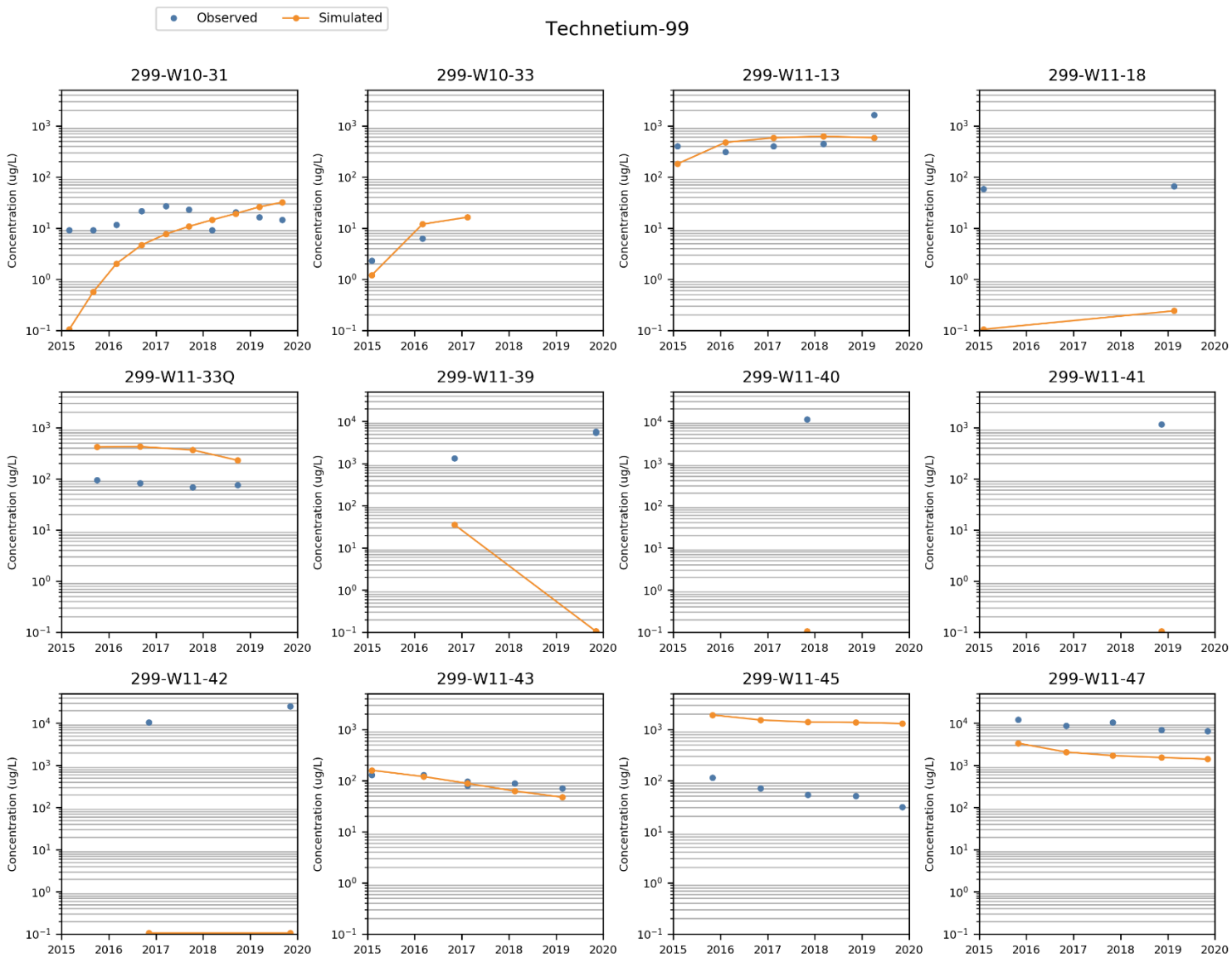

Figure B-69. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 2 of 14)

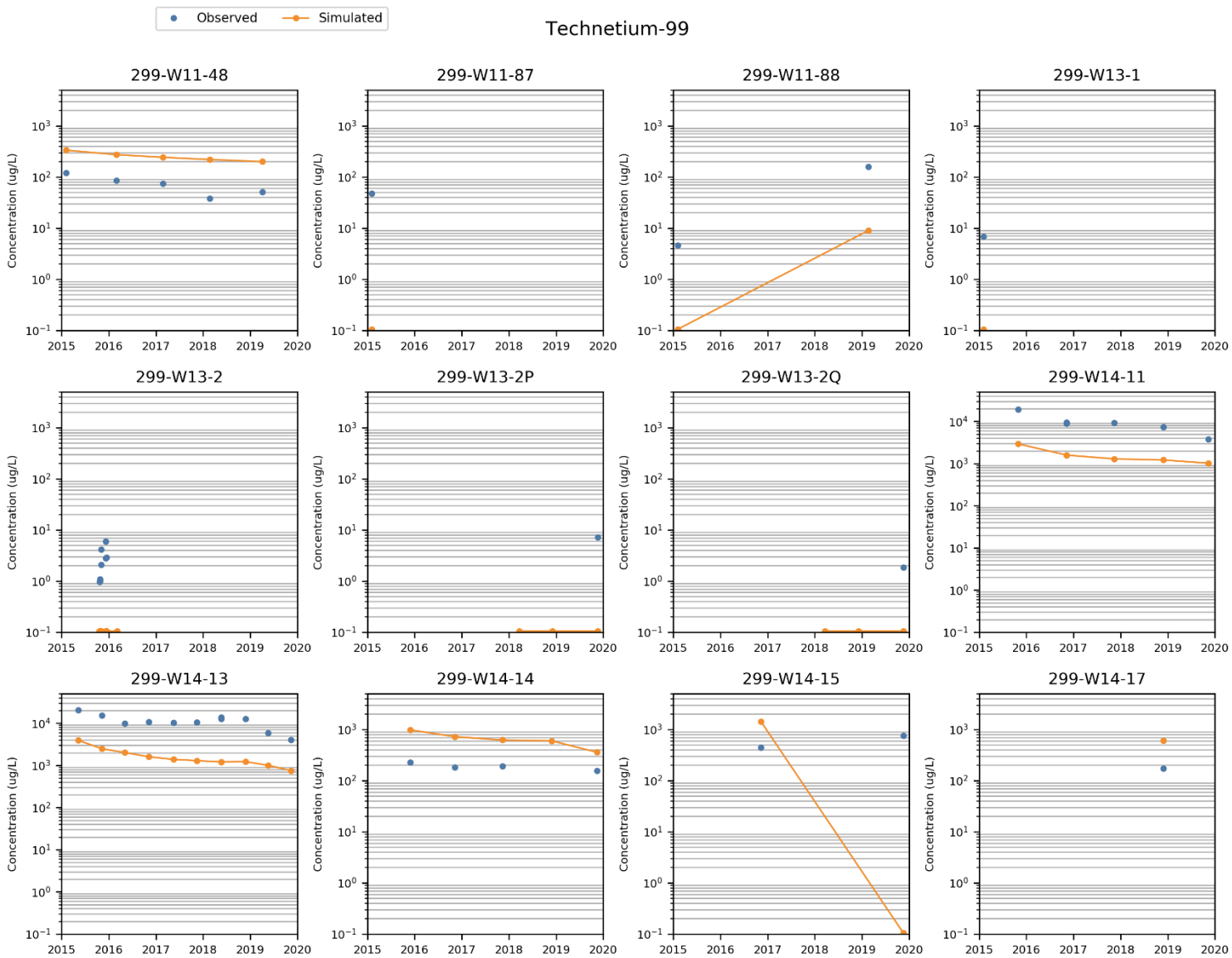

Figure B-70. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 3 of 14)

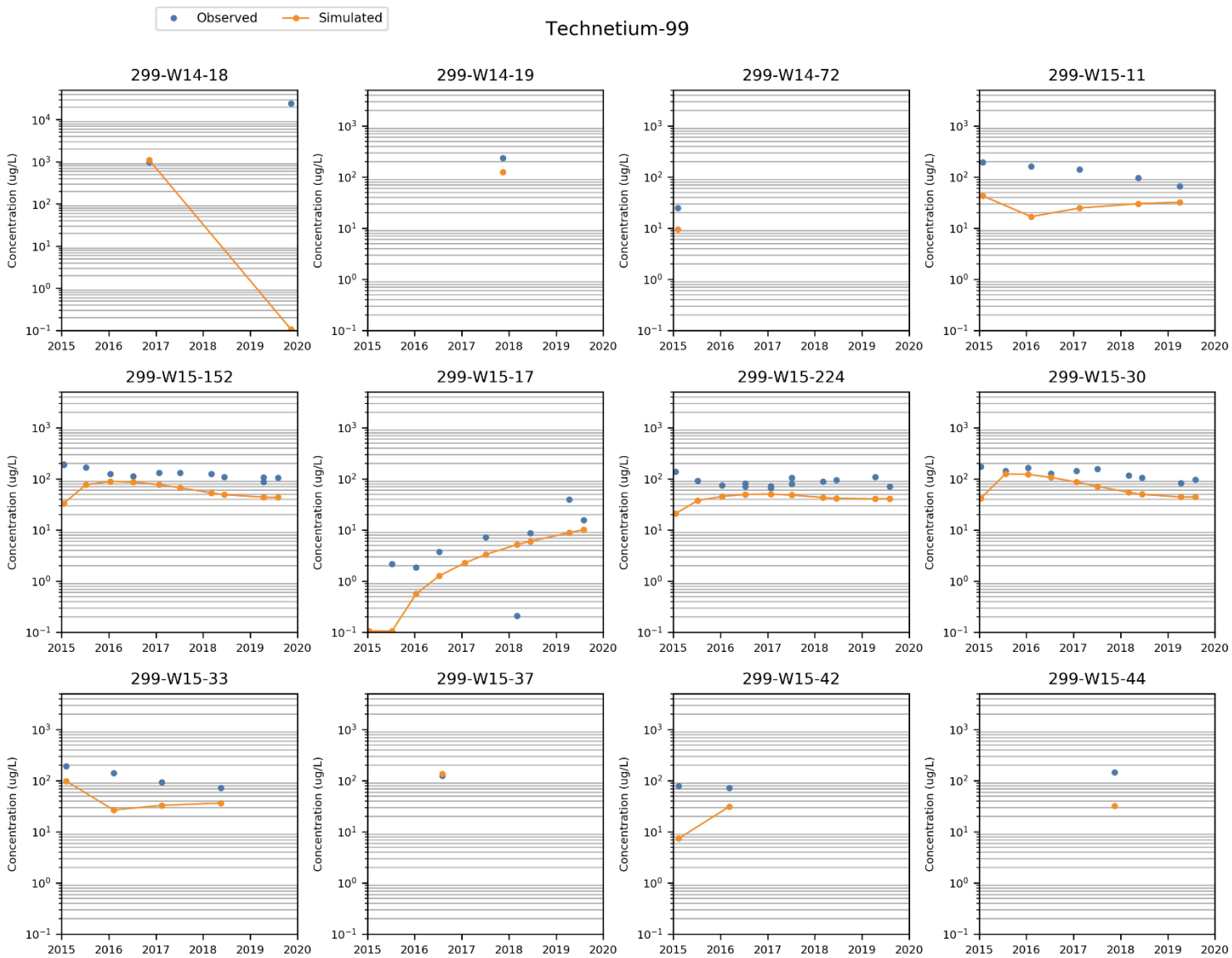

Figure B-71. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 4 of 14)

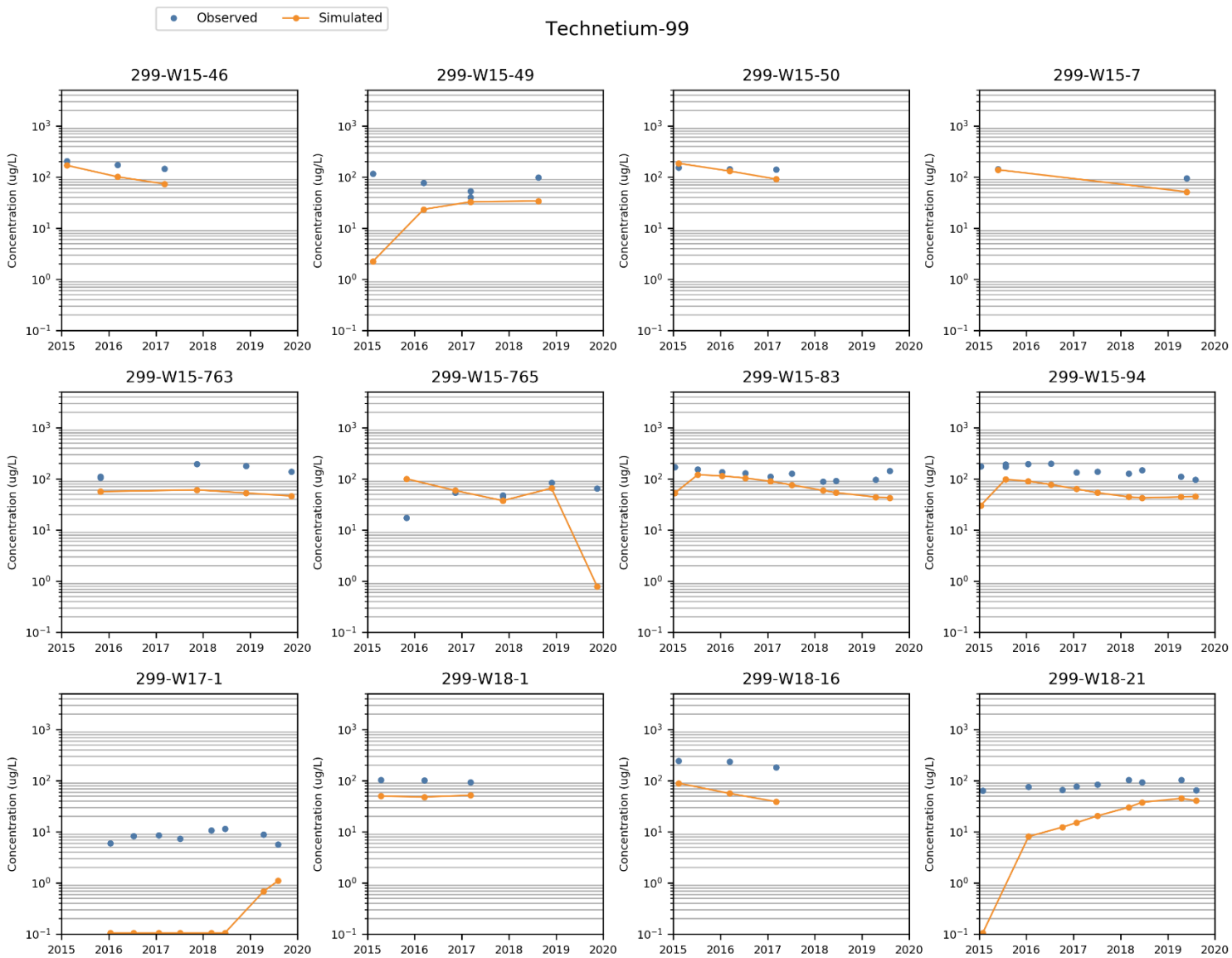

Figure B-72. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 5 of 14)

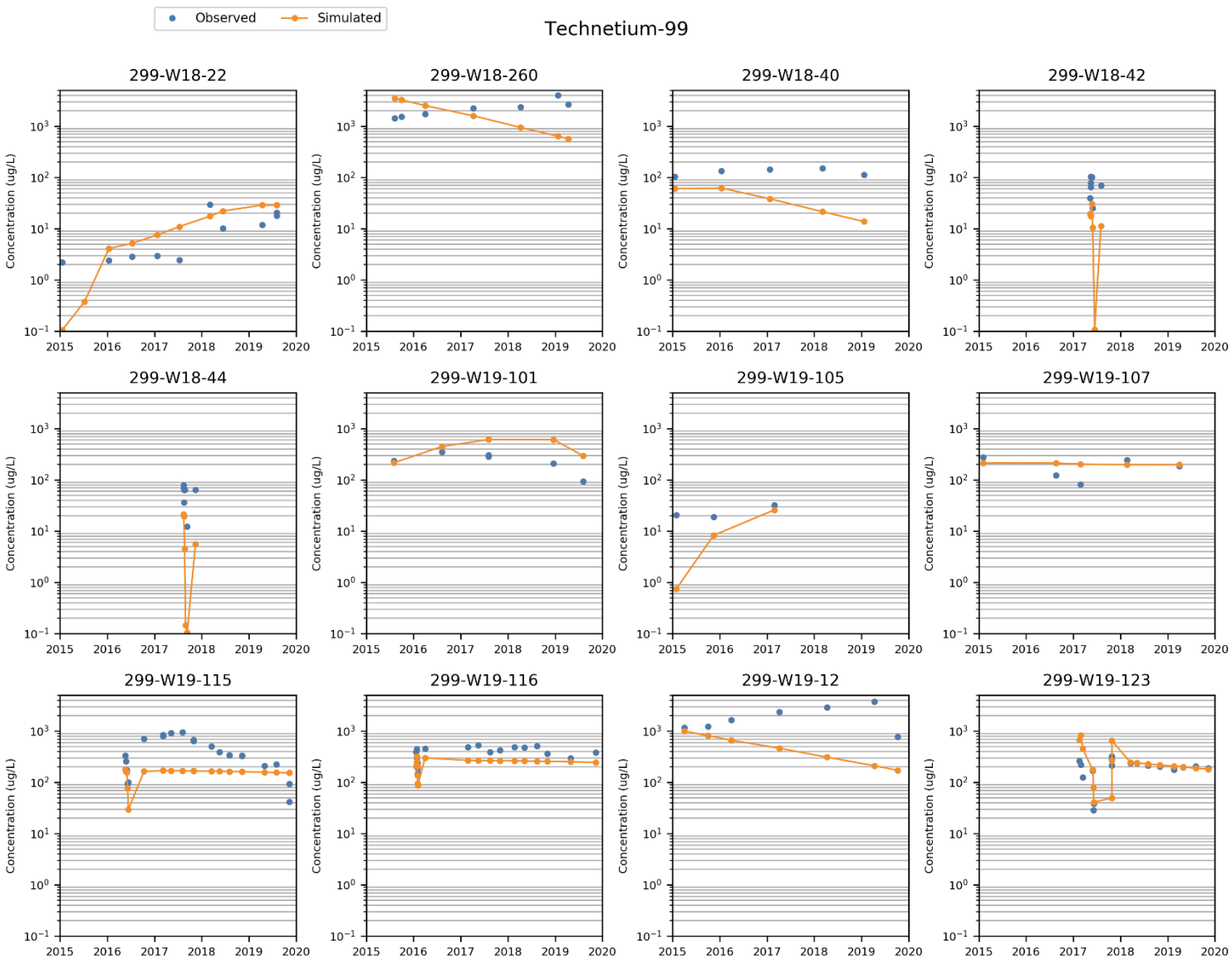

Figure B-73. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 6 of 14)

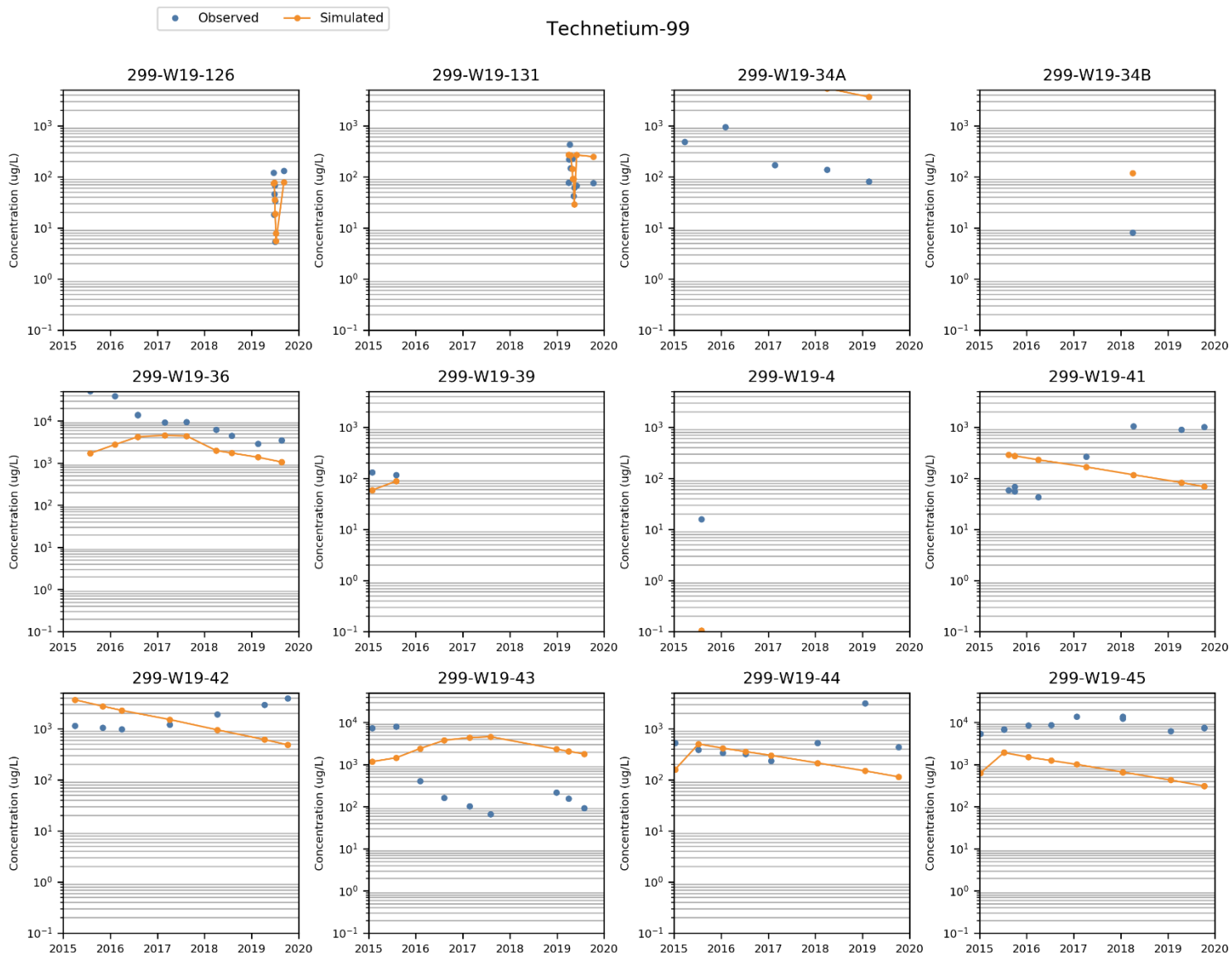

Figure B-74. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 7 of 14)

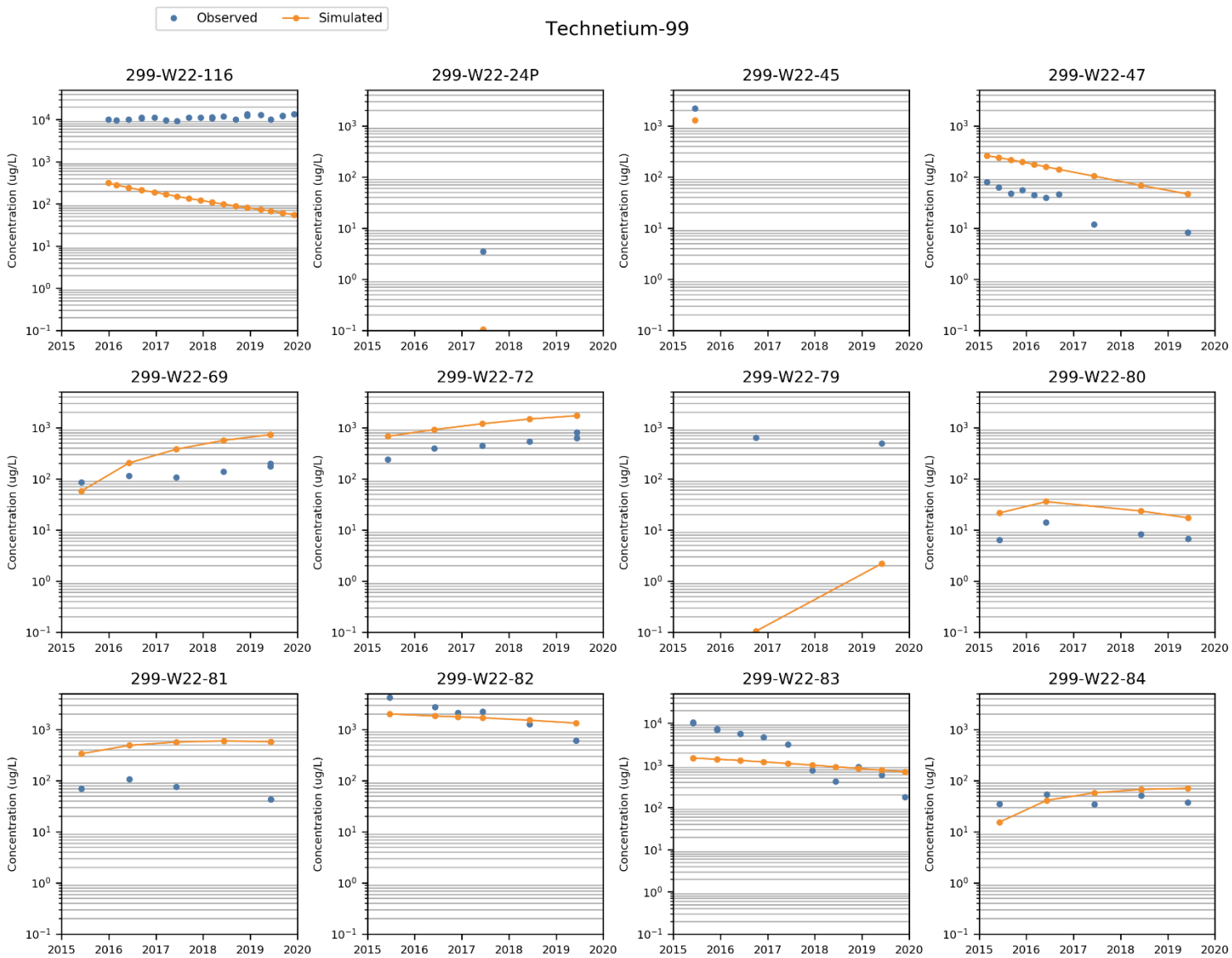

Figure B-75. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 8 of 14)

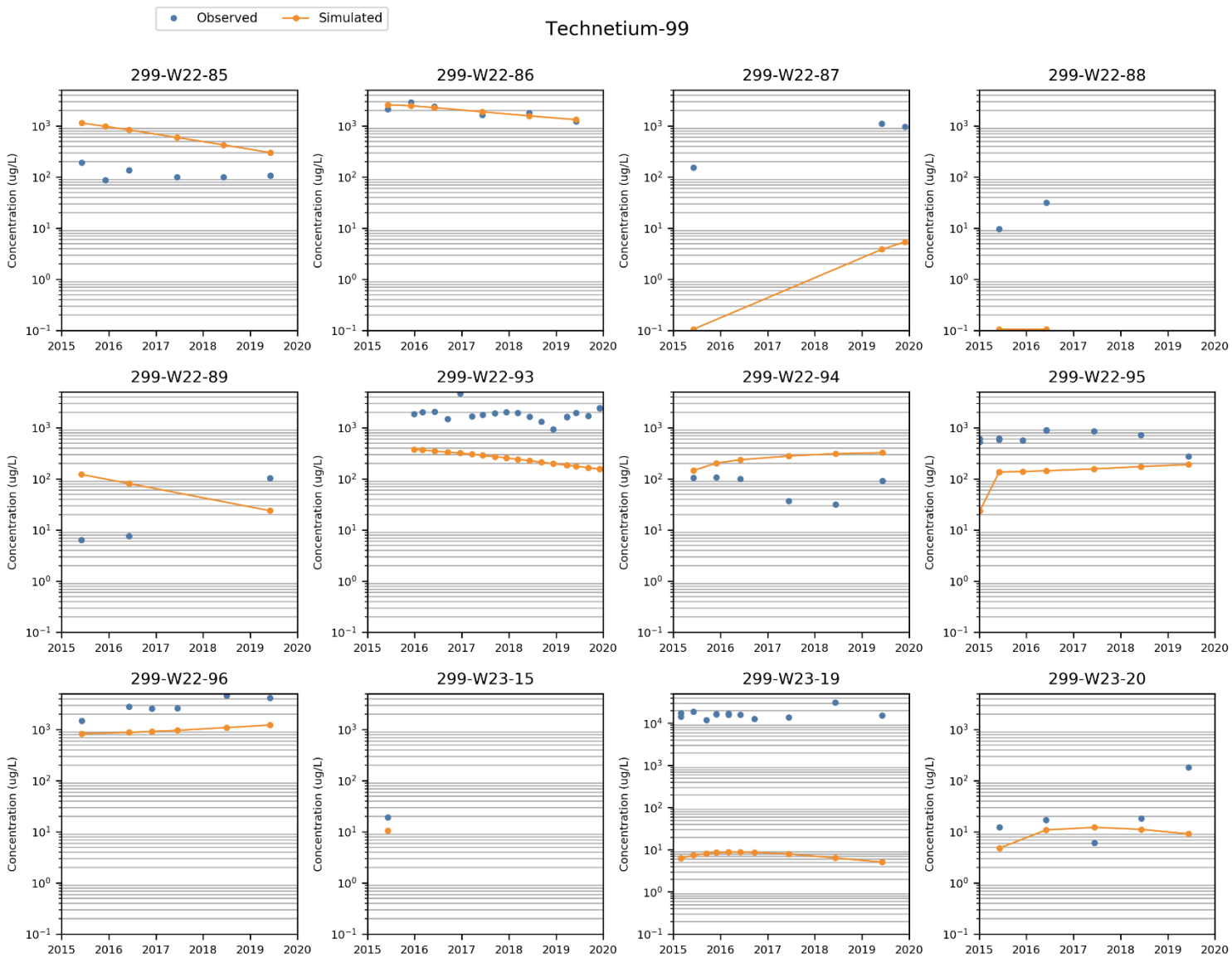

Figure B-76. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 9 of 14)

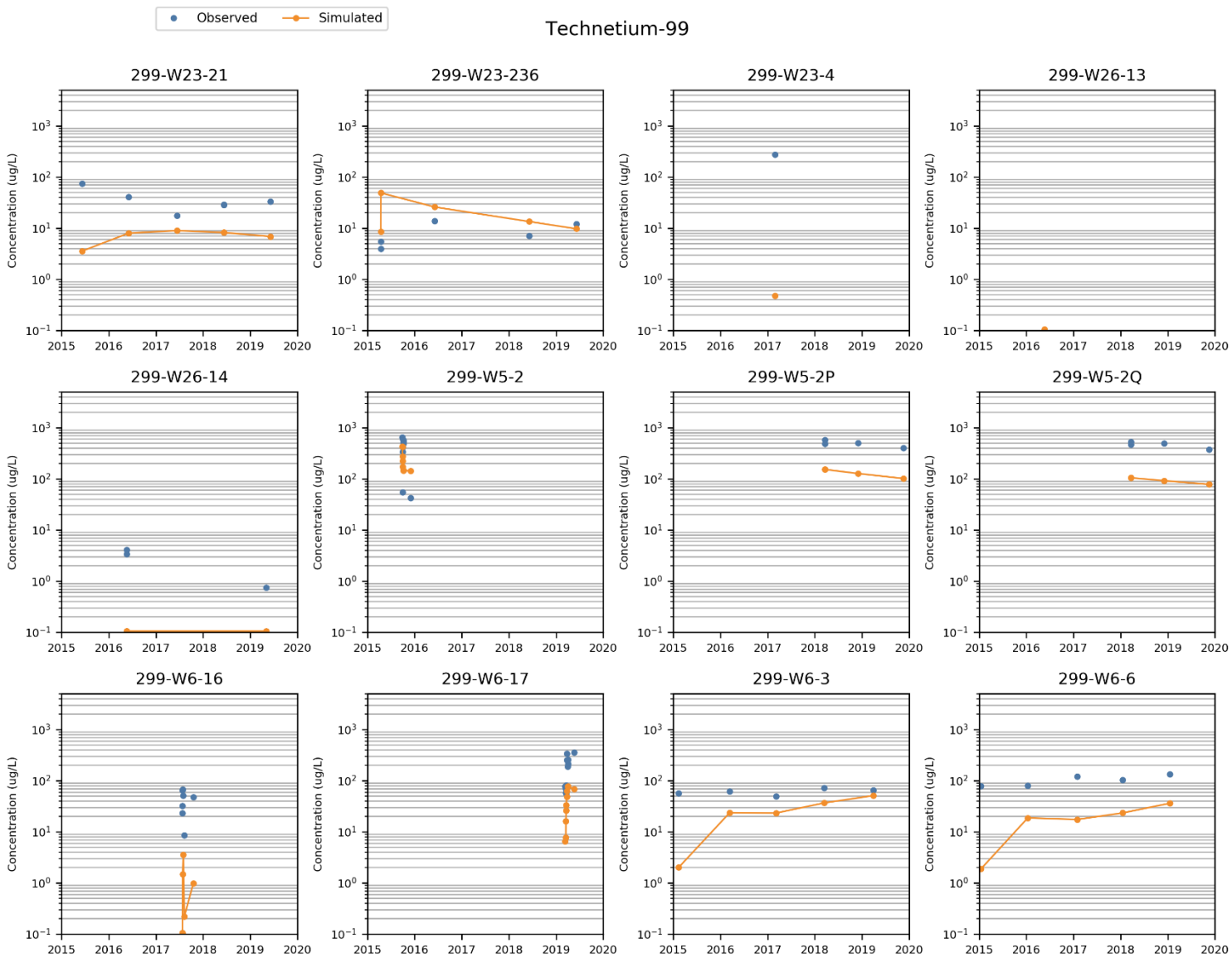

Figure B-77. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 10 of 14)

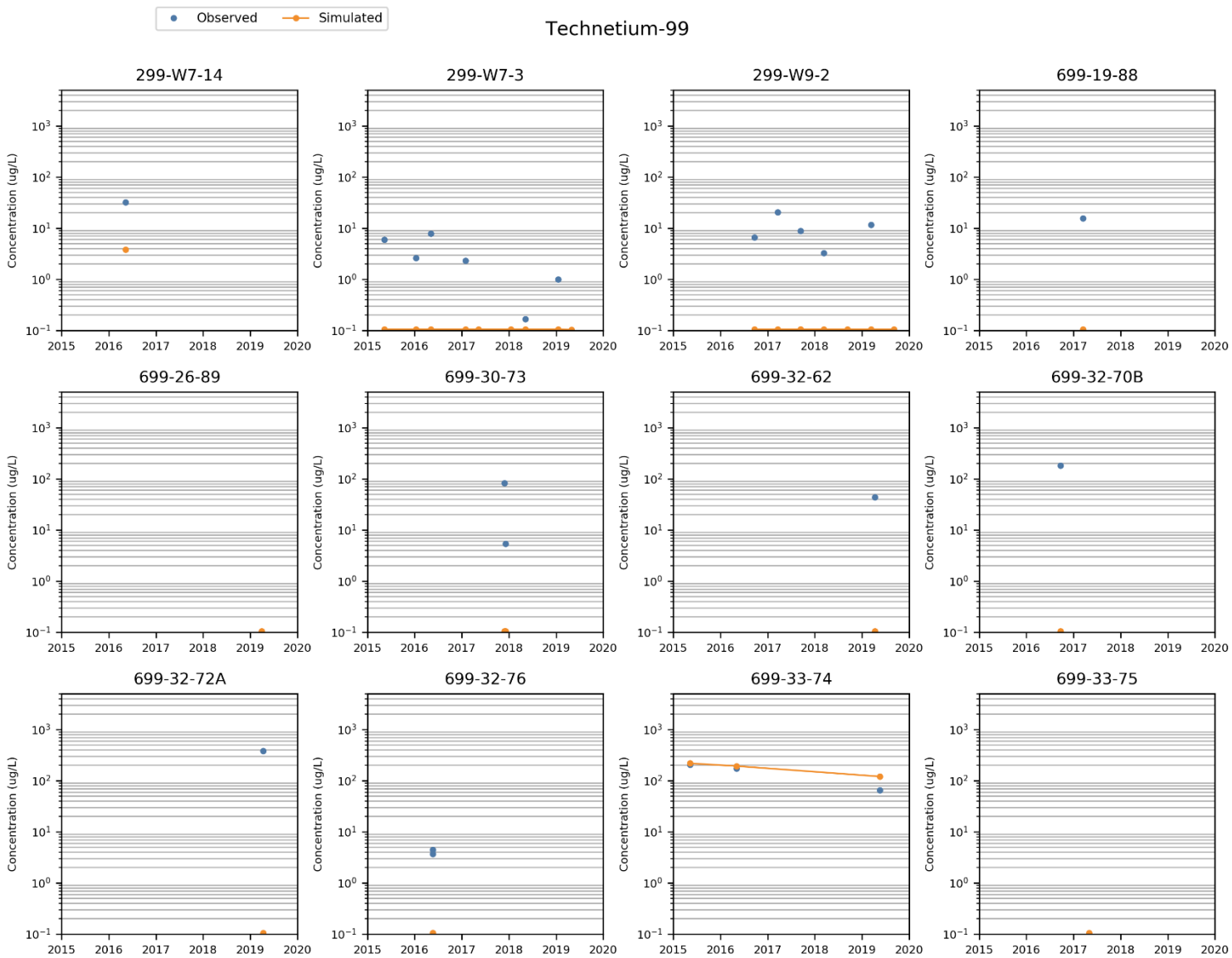

Figure B-78. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 11 of 14)

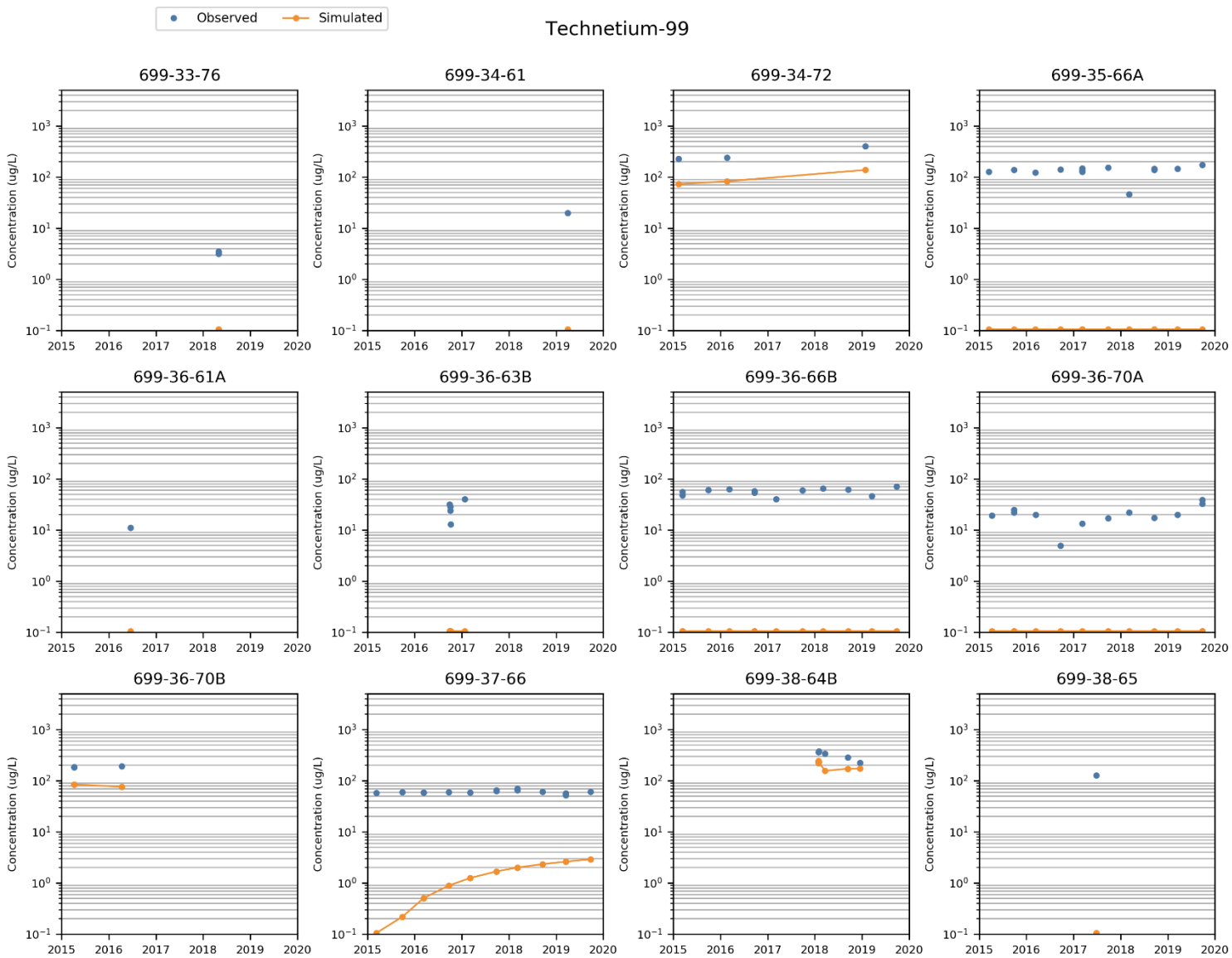

Figure B-79. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 12 of 14)

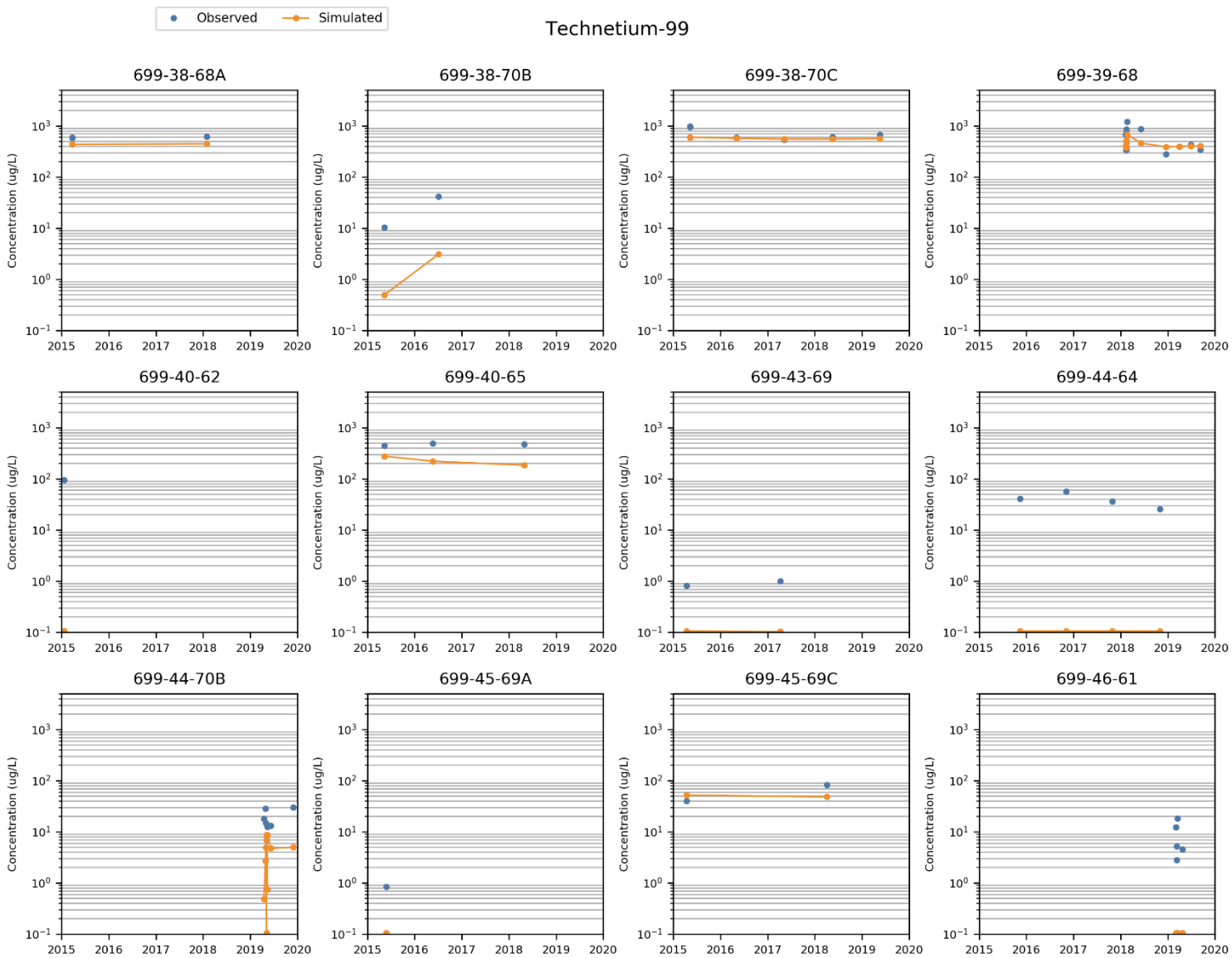

Figure B-80. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 13 of 14)

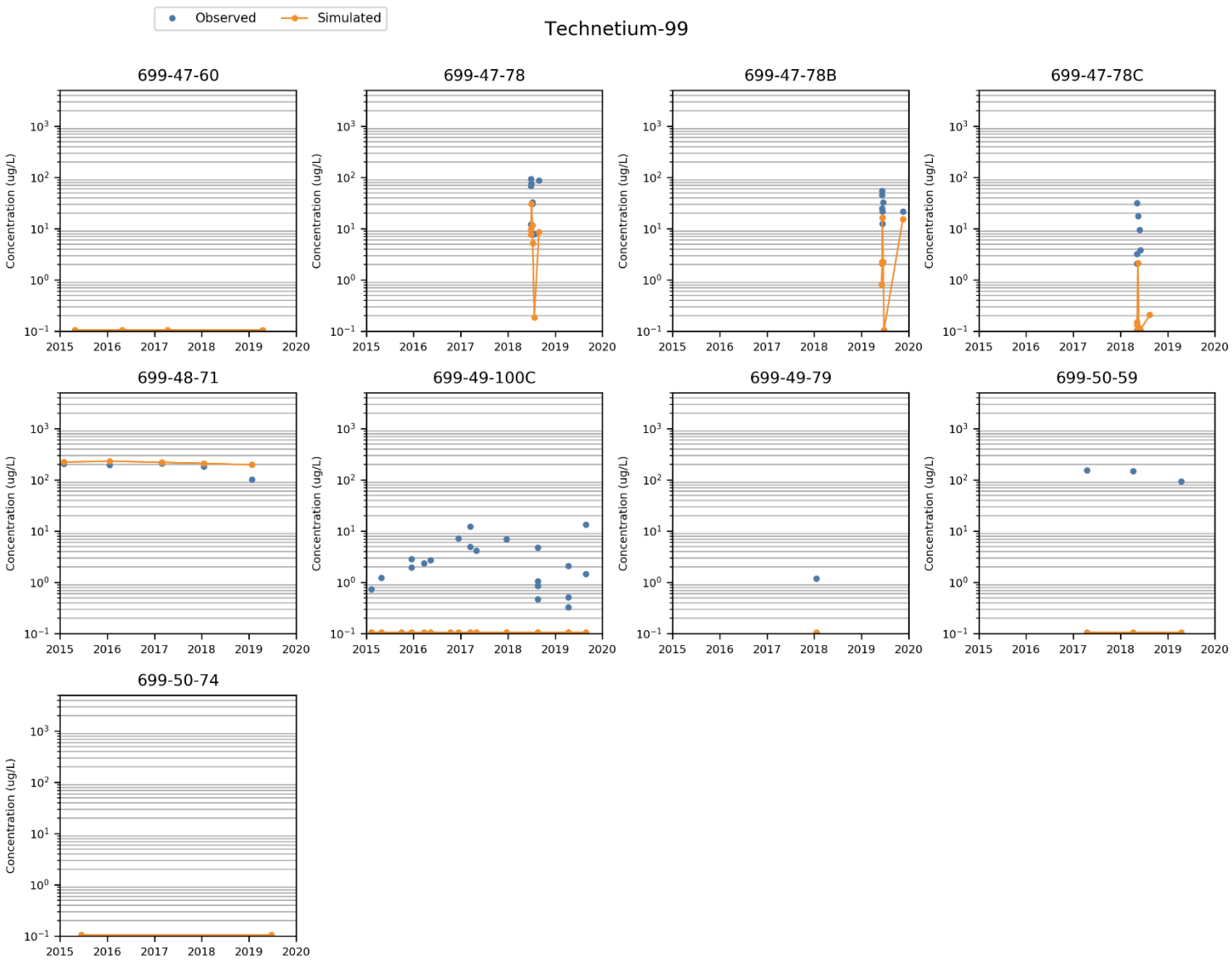

Figure B-81. Comparison of Simulated and Observed Concentrations for Technetium-99 (Page 14 of 14)

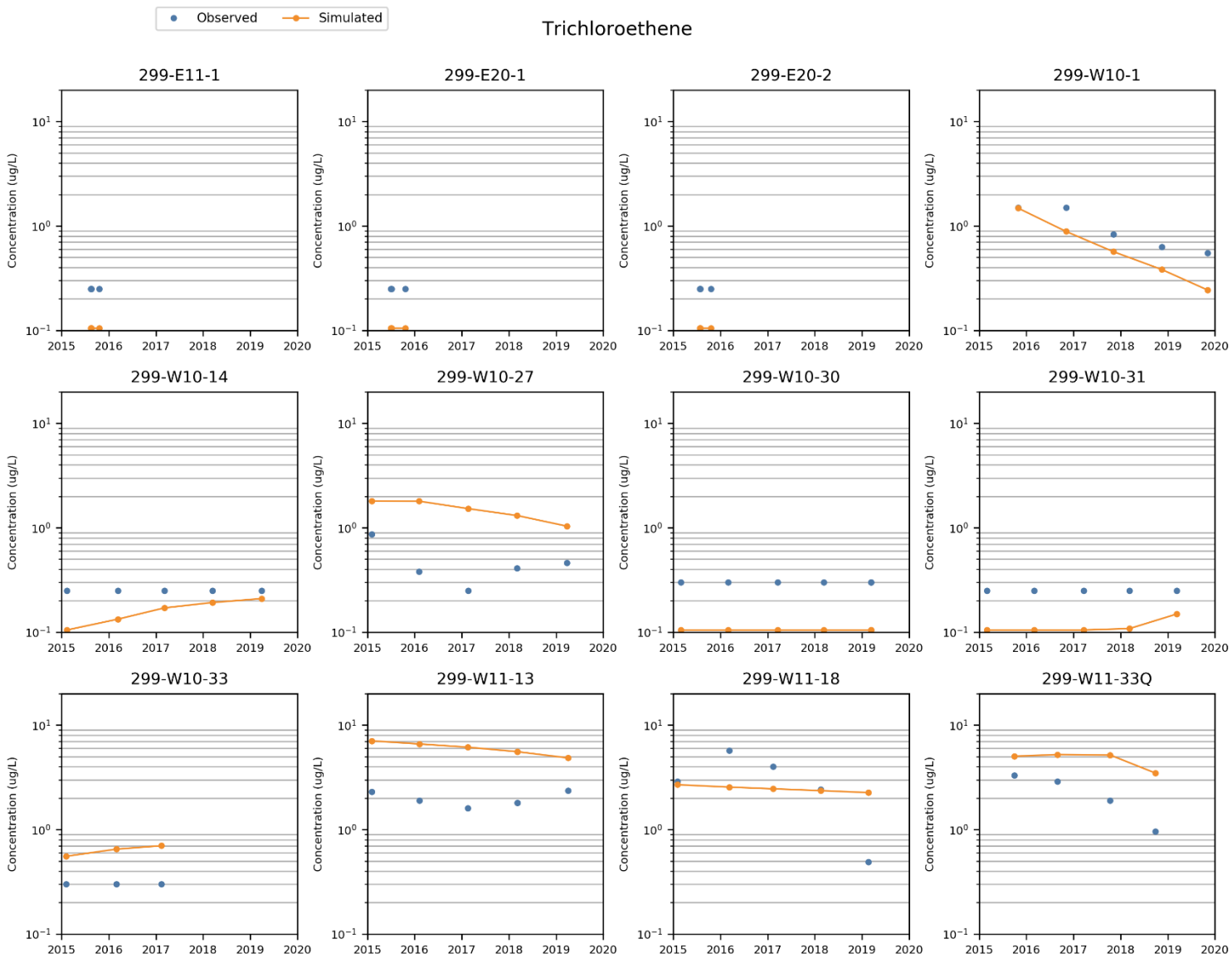

Figure B-82. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 1 of 12)

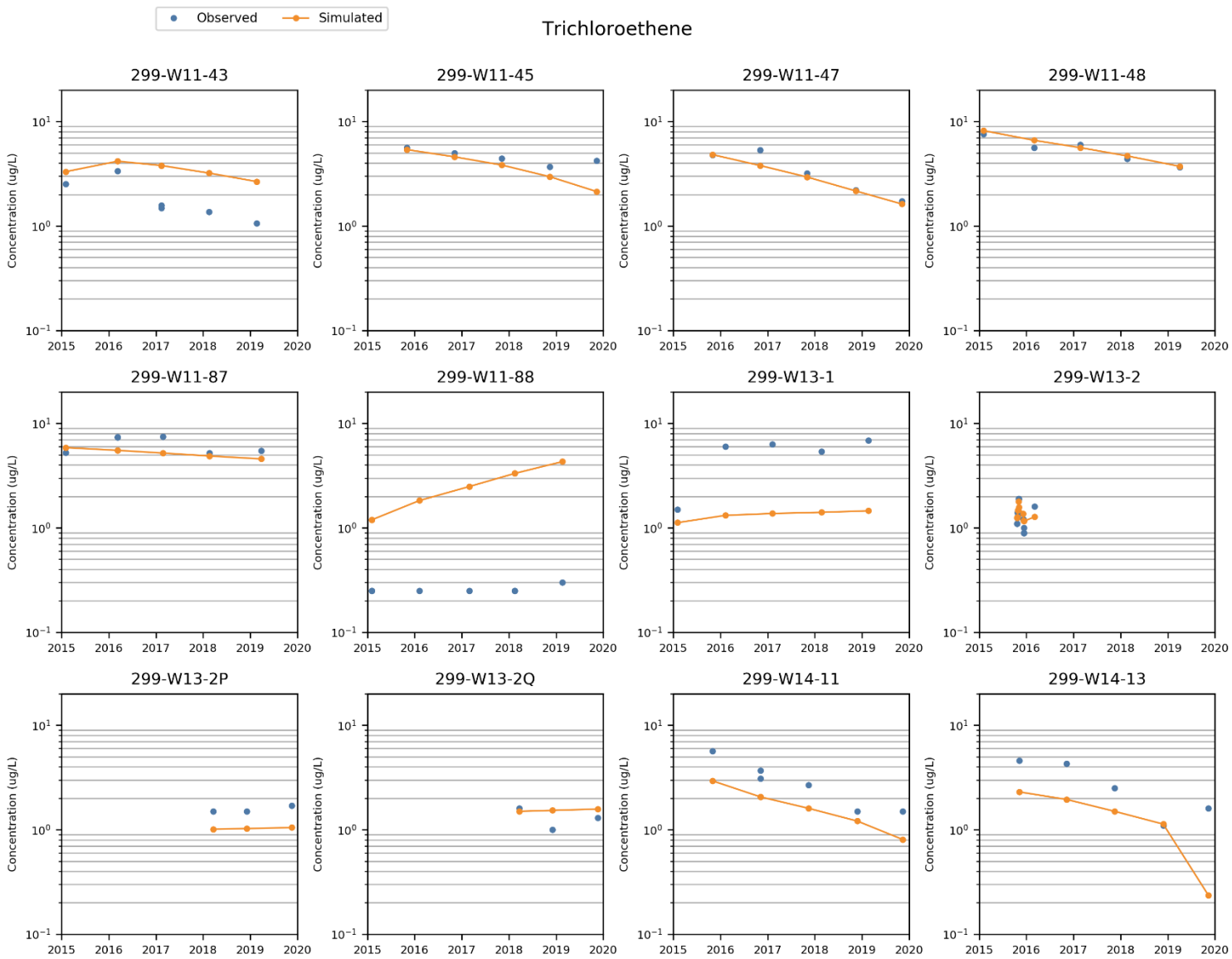

Figure B-83. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 2 of 12)

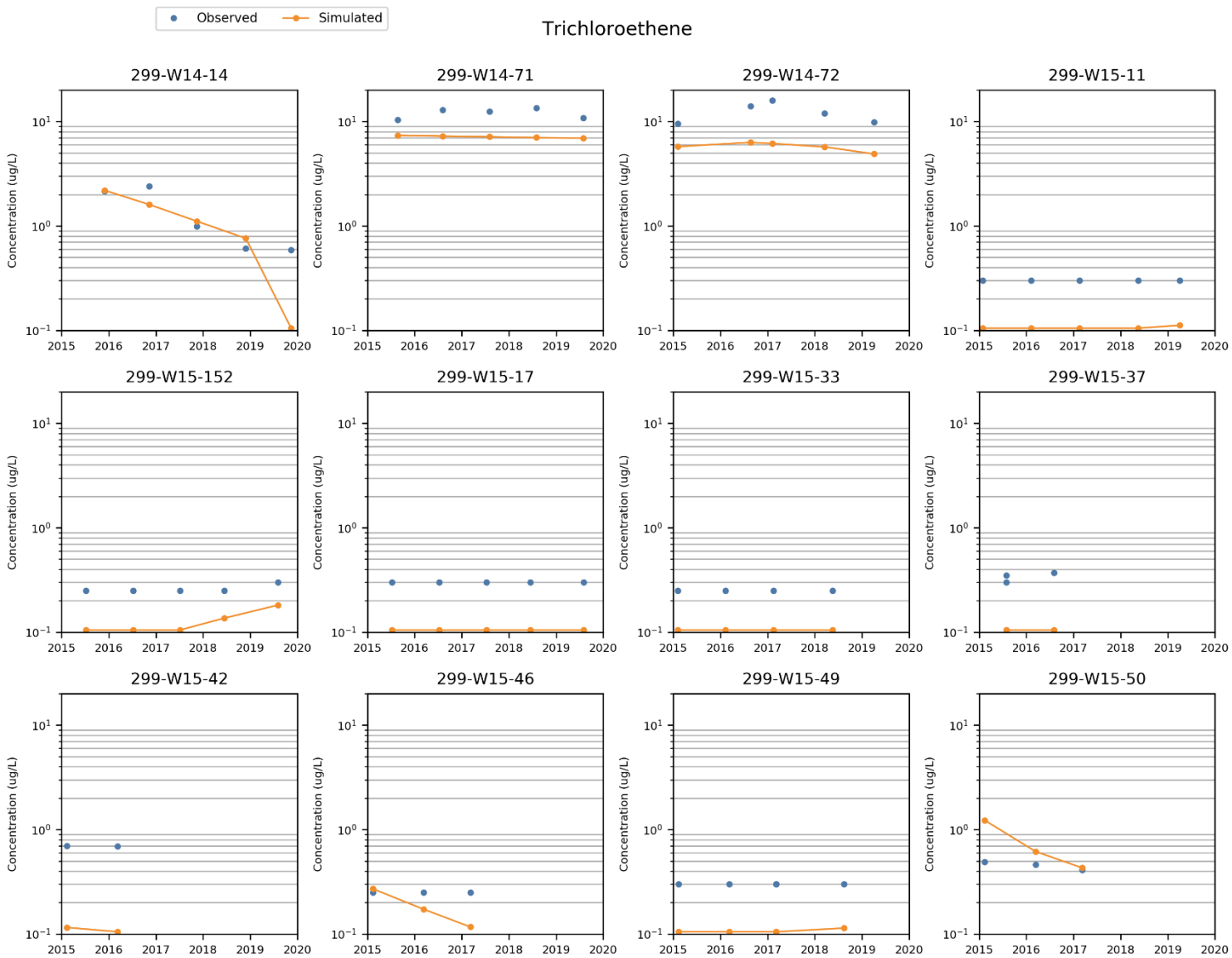

Figure B-84. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 3 of 12)

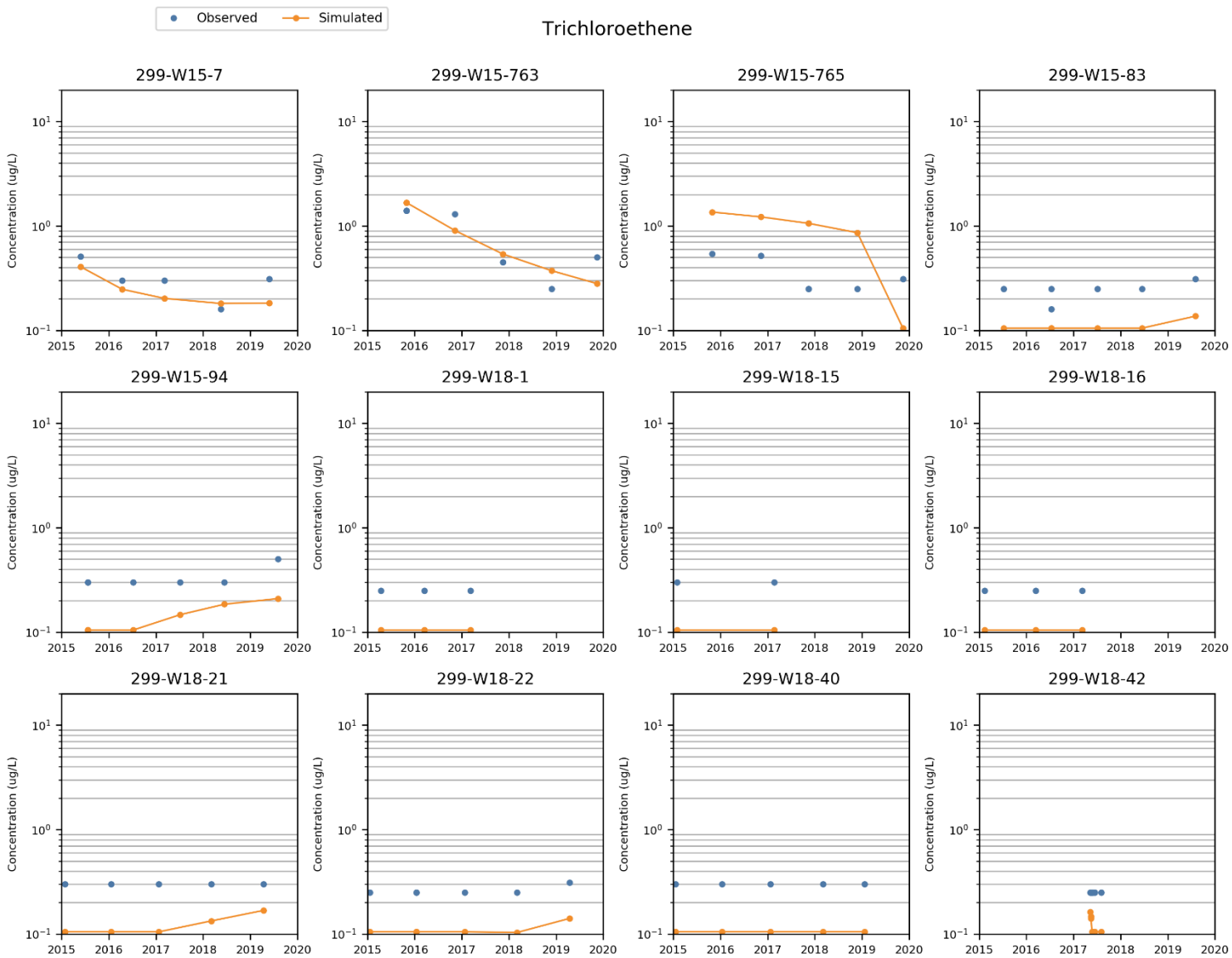

Figure B-85. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 4 of 12)

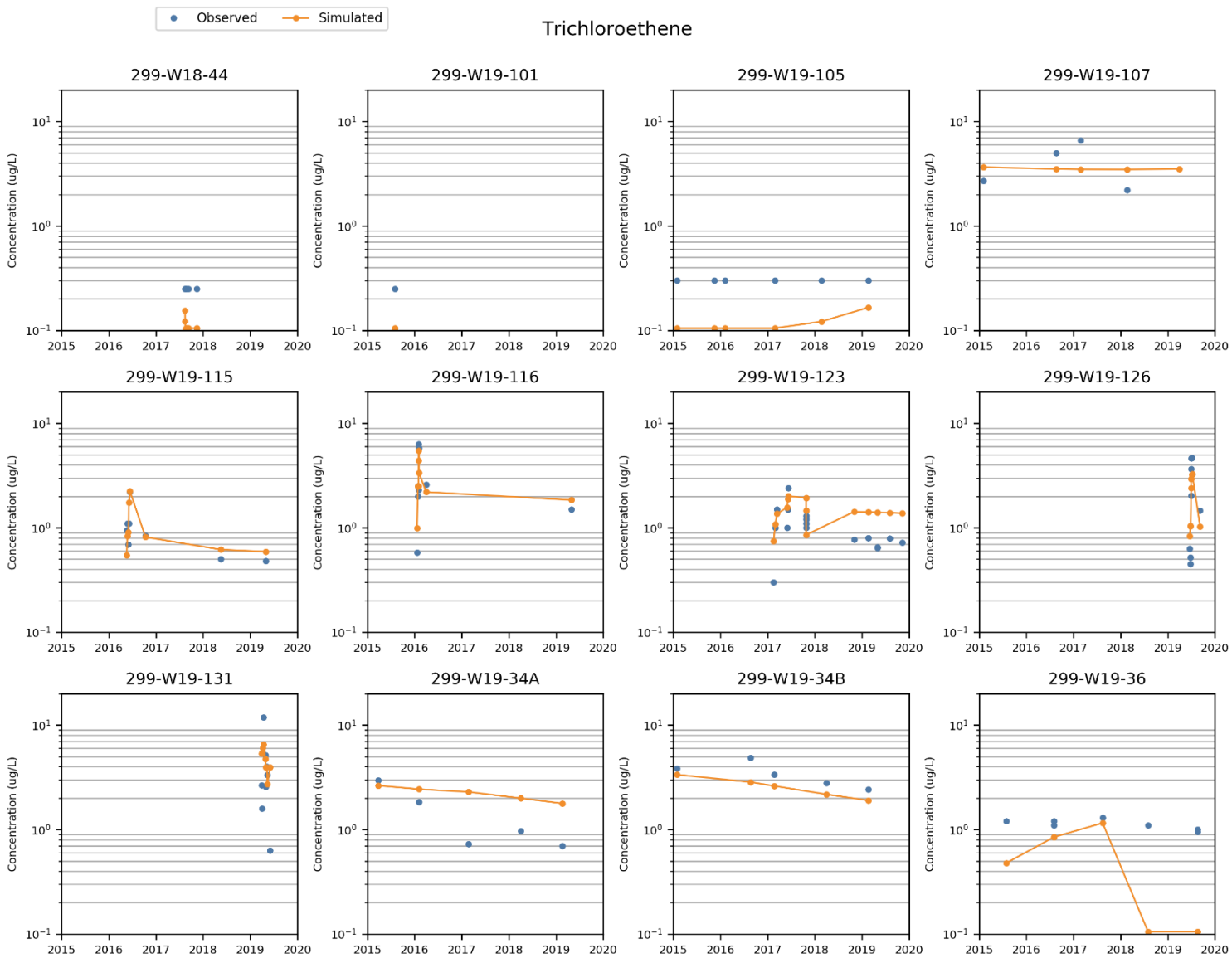

Figure B-86. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 5 of 12)

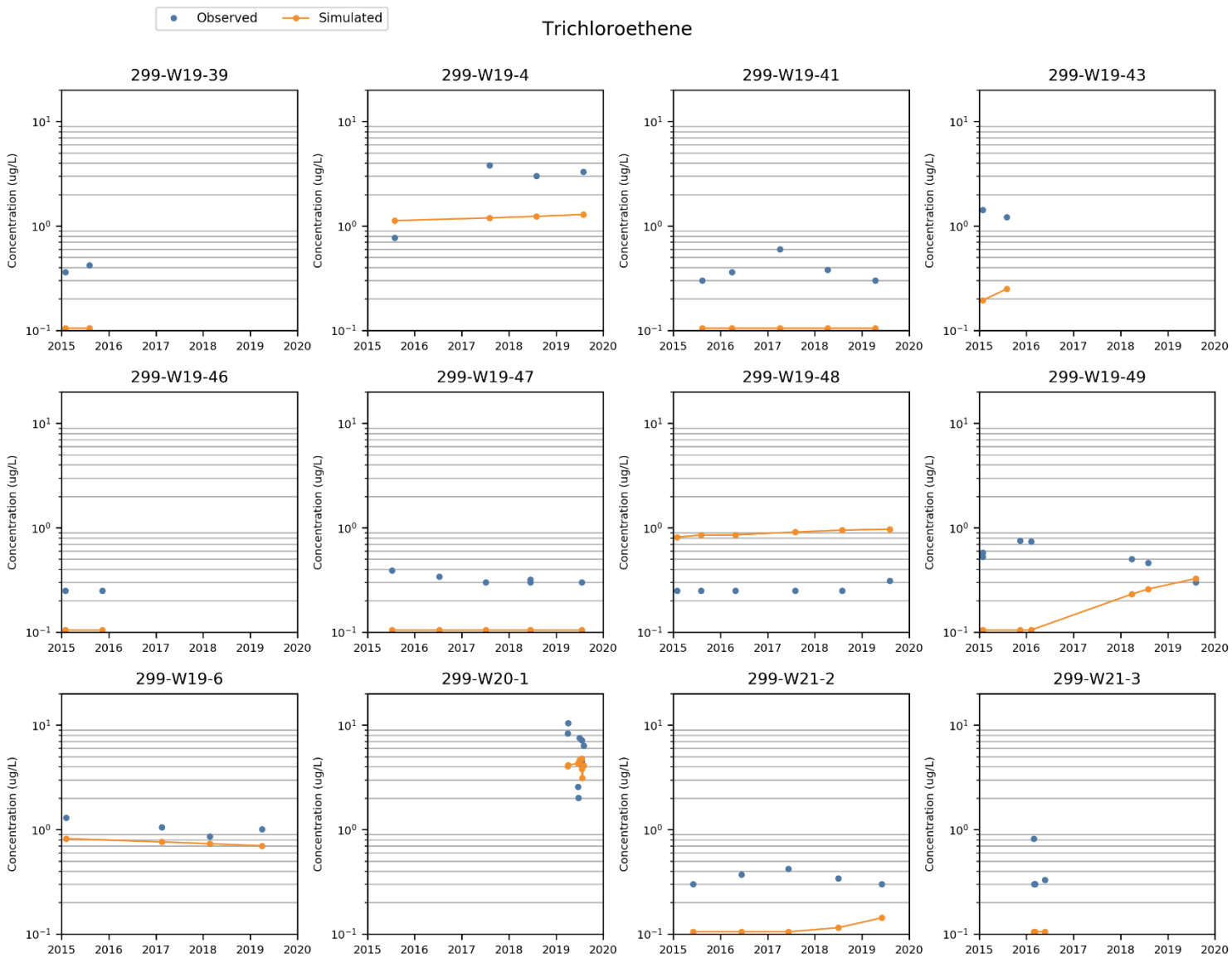

Figure B-87. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 6 of 12)

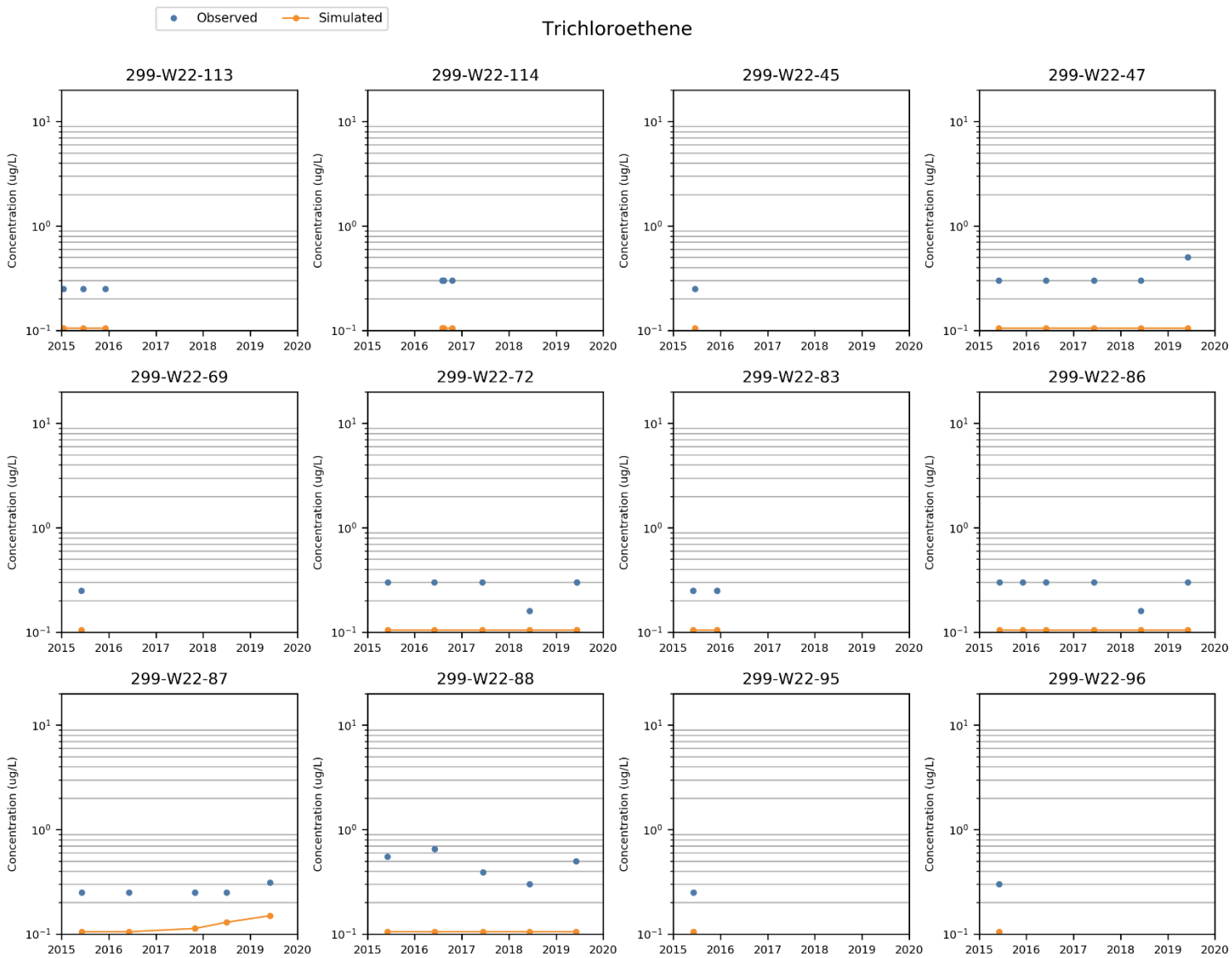

Figure B-88. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 7 of 12)

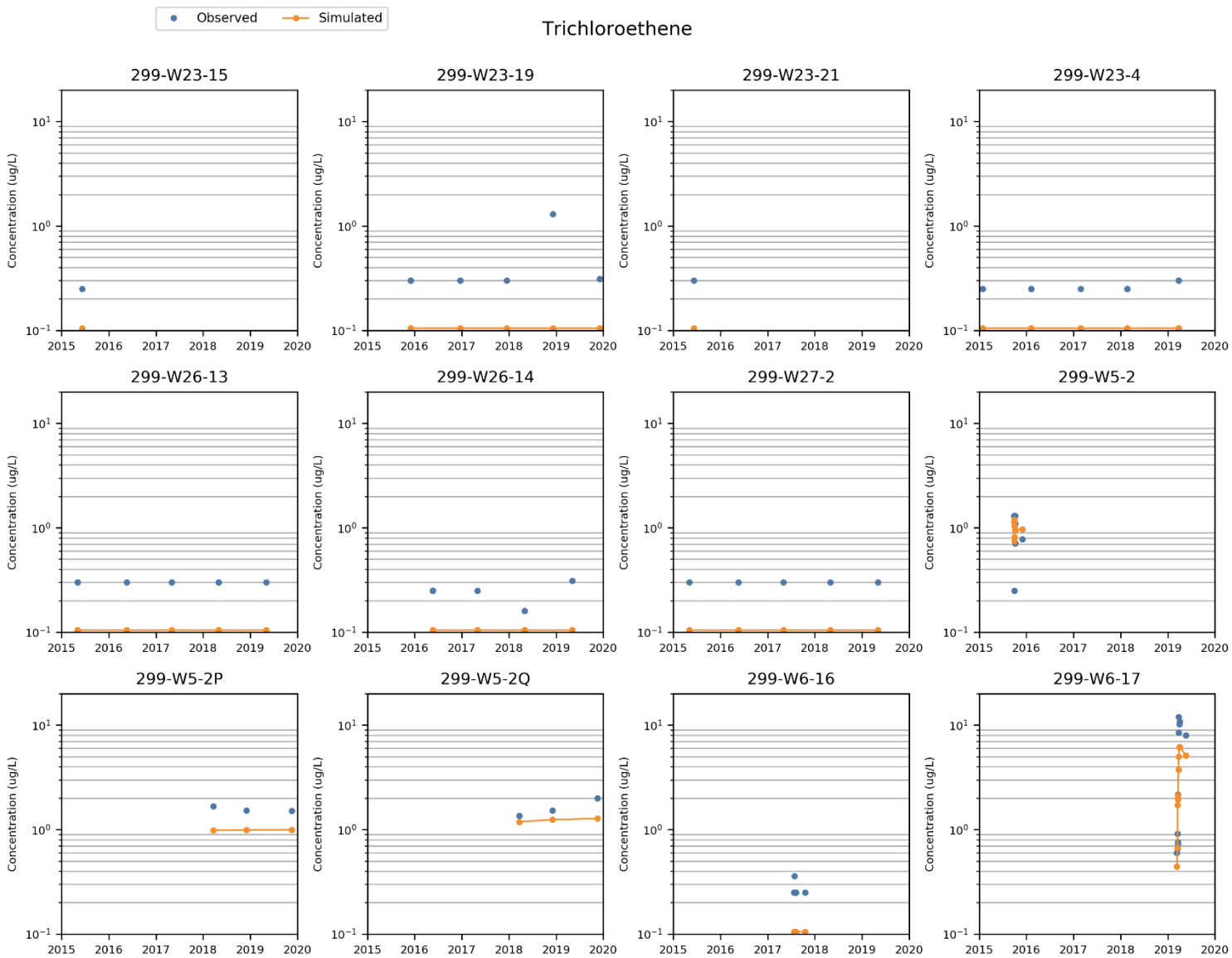

Figure B-89. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 8 of 12)

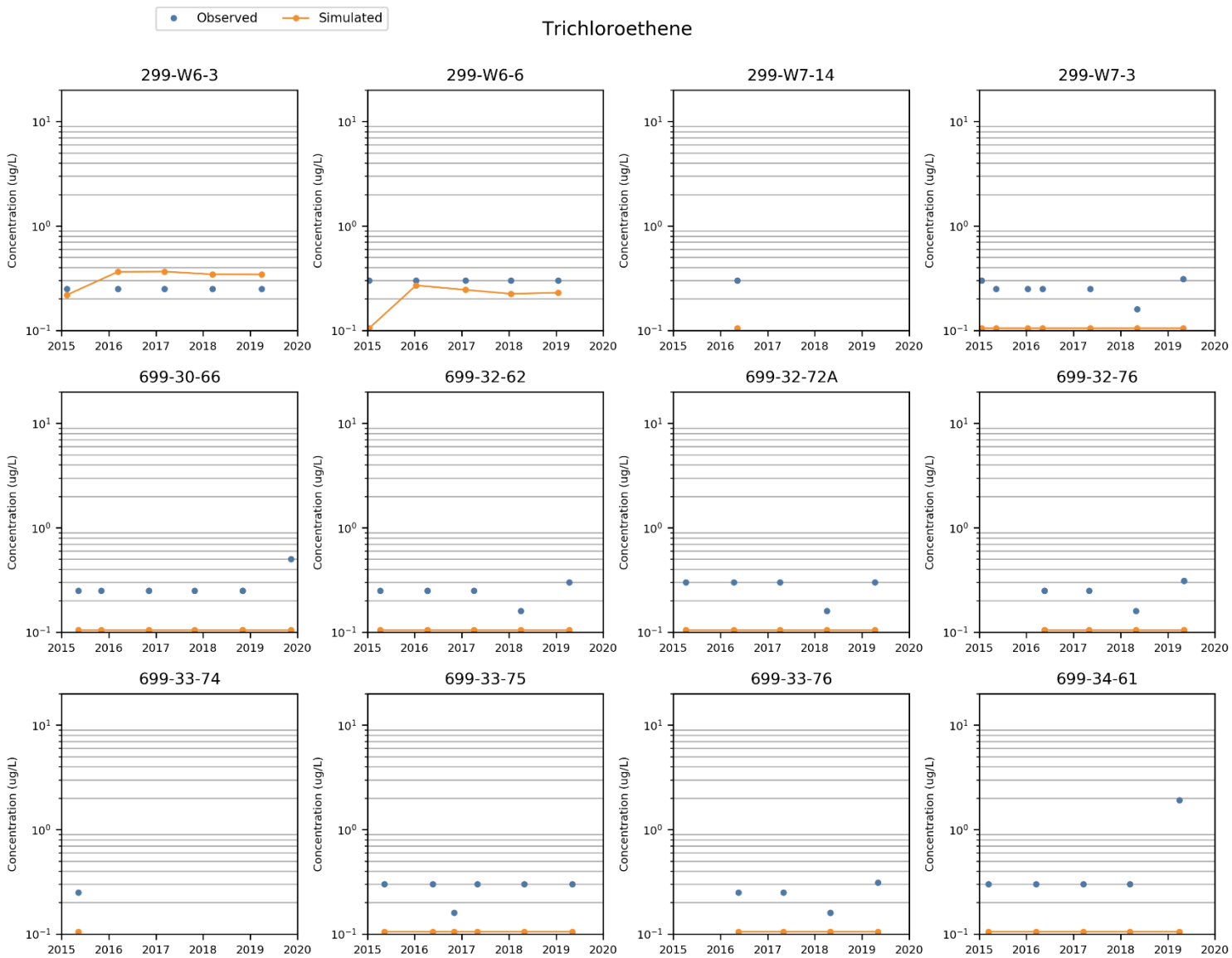

Figure B-90. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 9 of 12)

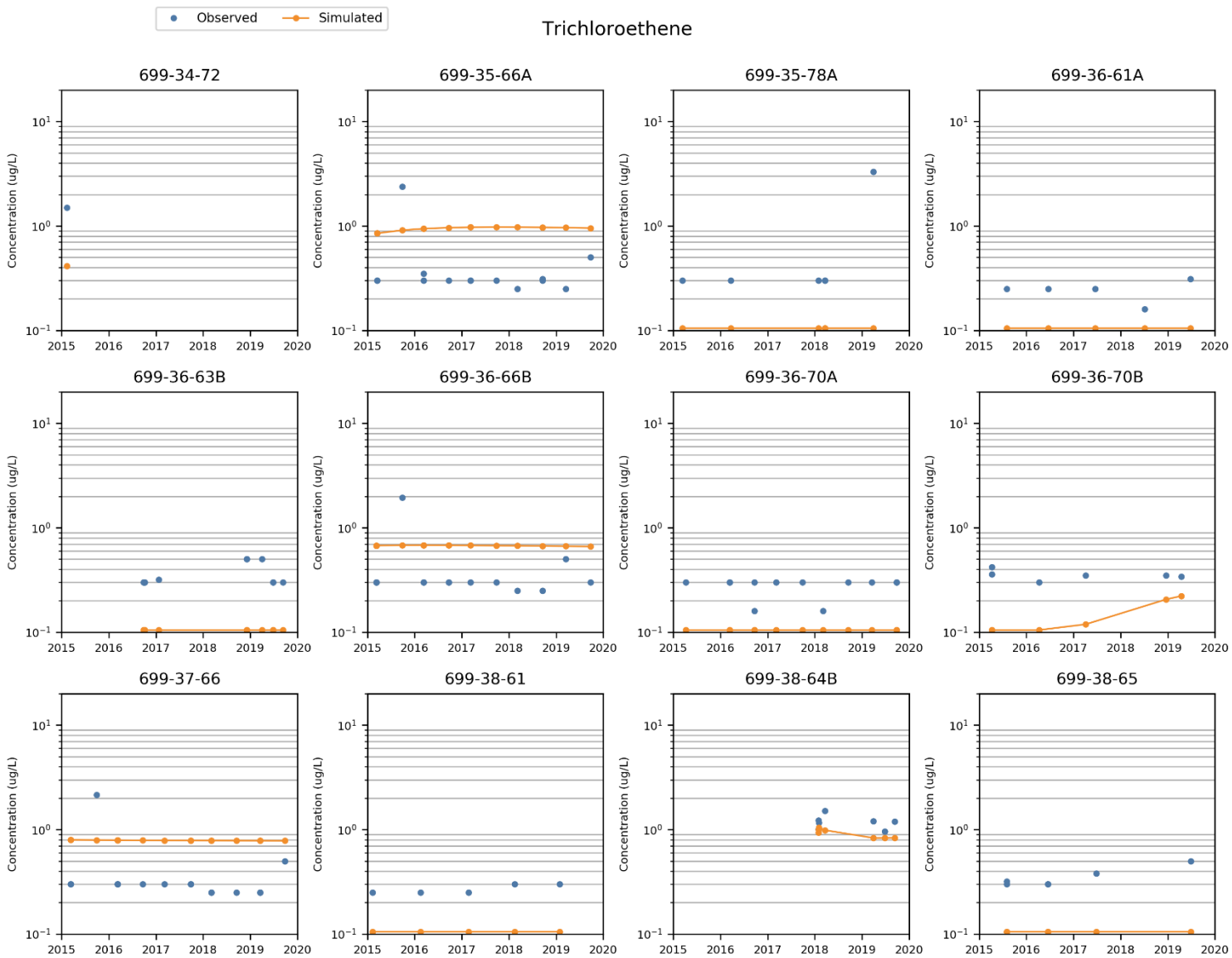

Figure B-91. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 10 of 12)

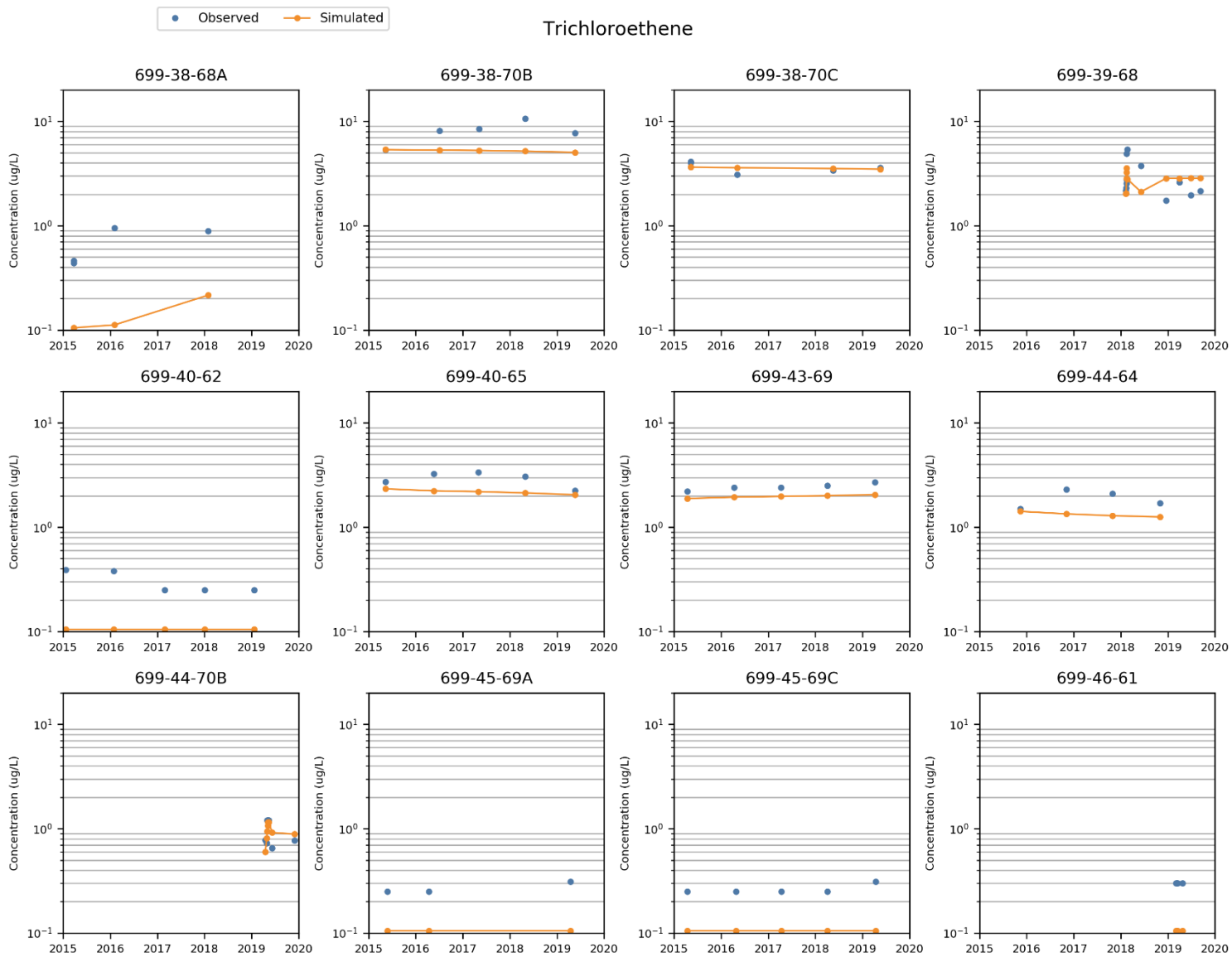

Figure B-92. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 11 of 12)

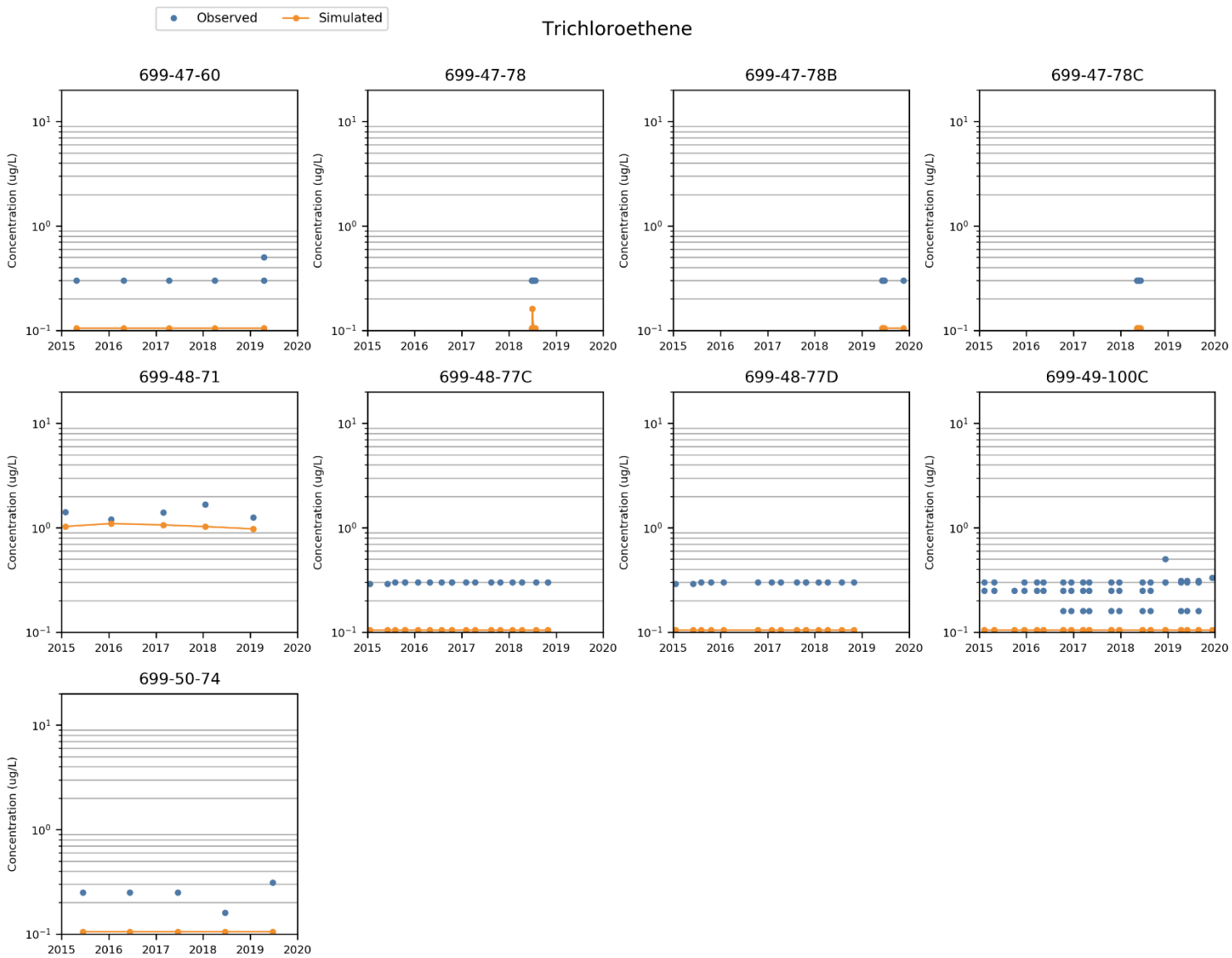

Figure B-93. Comparison of Simulated and Observed Concentrations for Trichloroethene (Page 12 of 12)

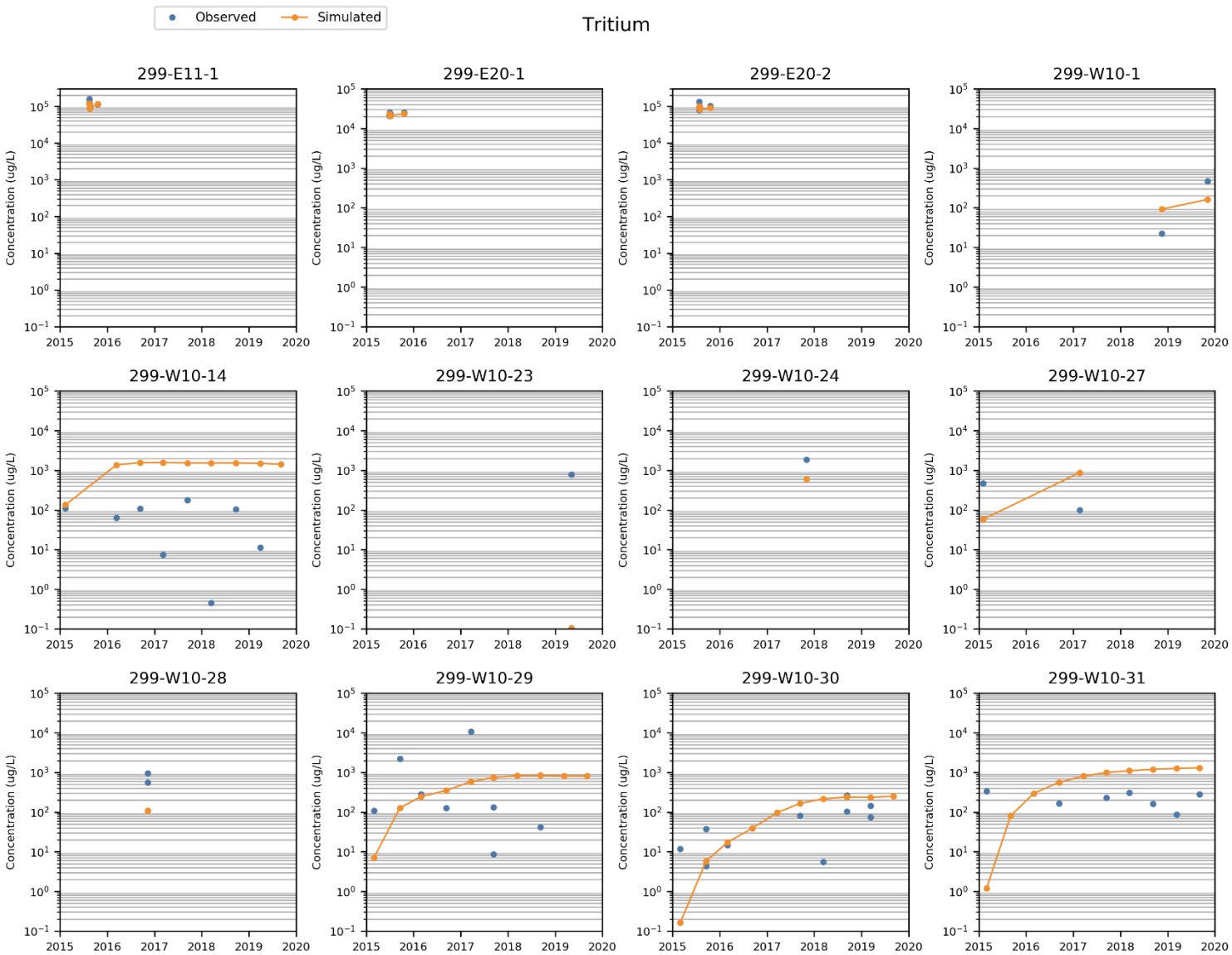

Figure B-94. Comparison of Simulated and Observed Concentrations for Tritium (Page 1 of 16)

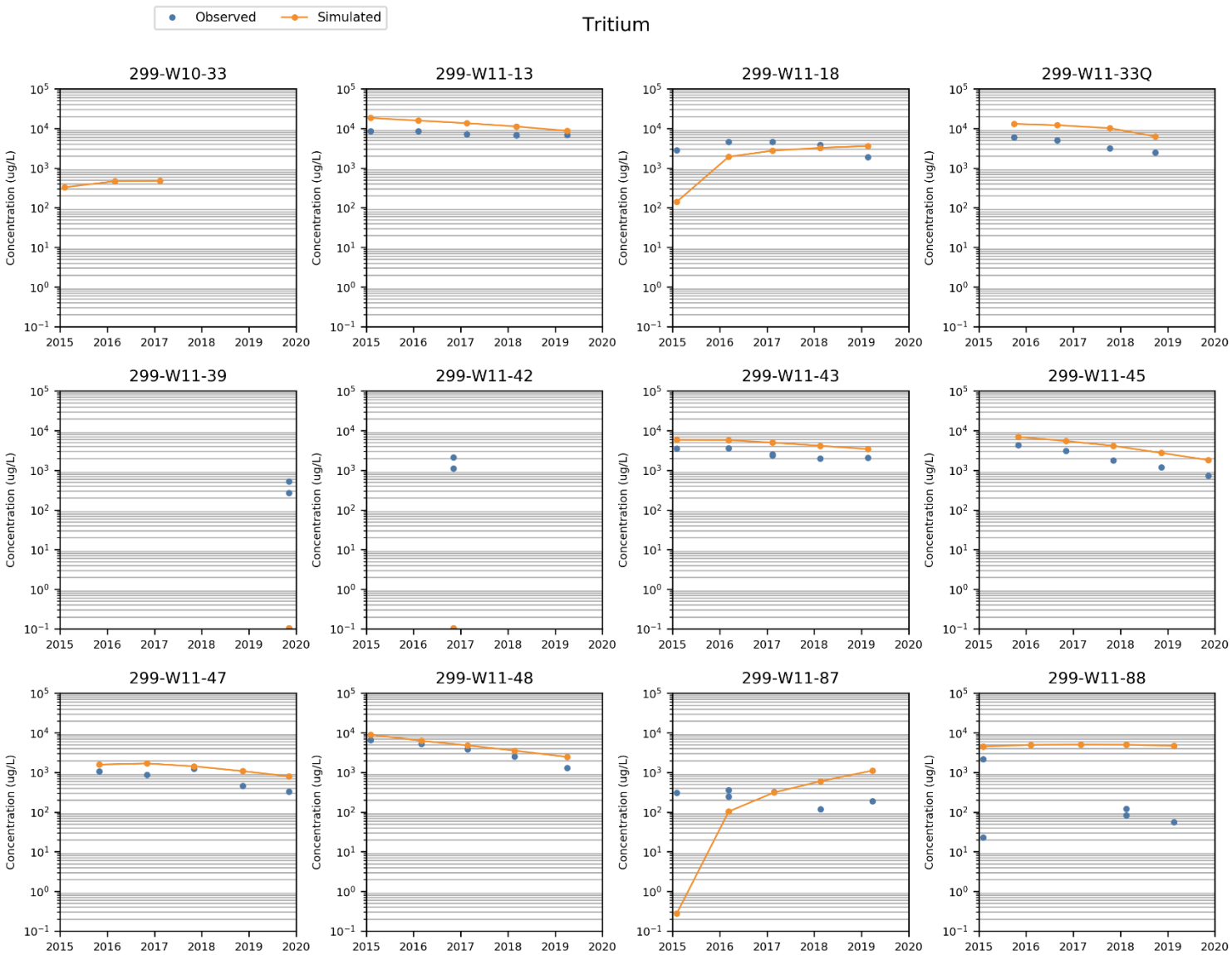

Figure B-95. Comparison of Simulated and Observed Concentrations for Tritium (Page 2 of 16)

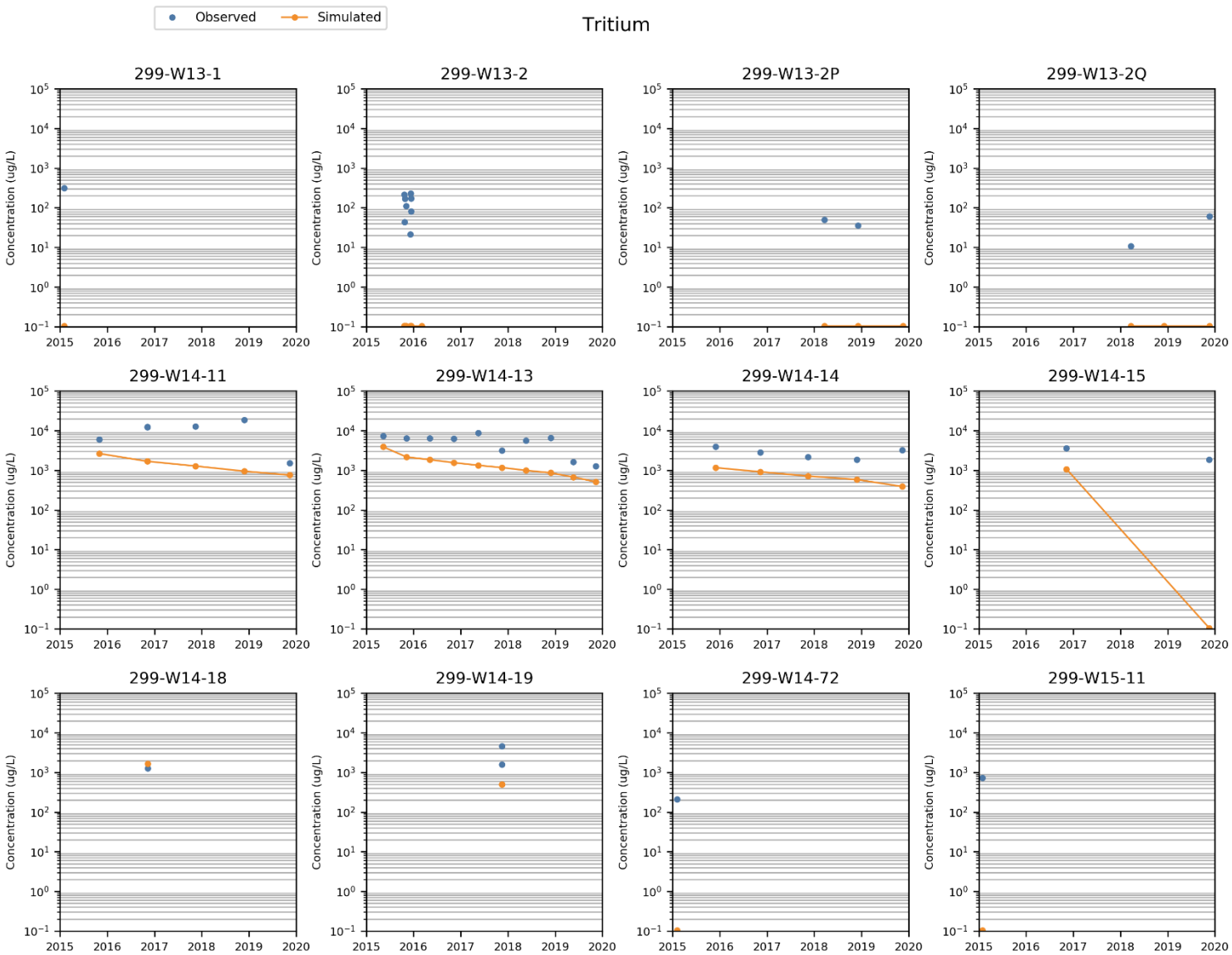

Figure B-96. Comparison of Simulated and Observed Concentrations for Tritium (Page 3 of 16)

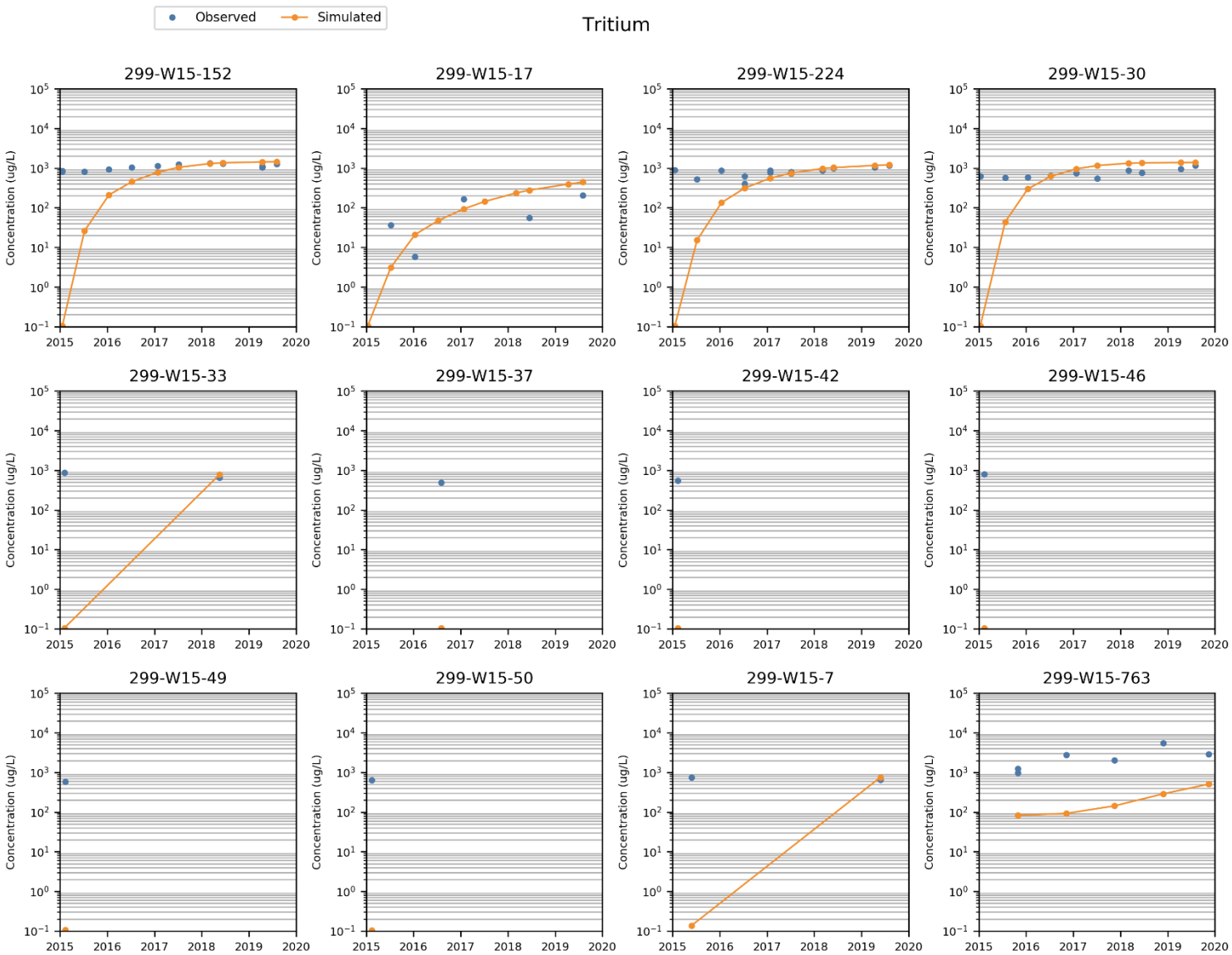

Figure B-97. Comparison of Simulated and Observed Concentrations for Tritium (Page 4 of 16)

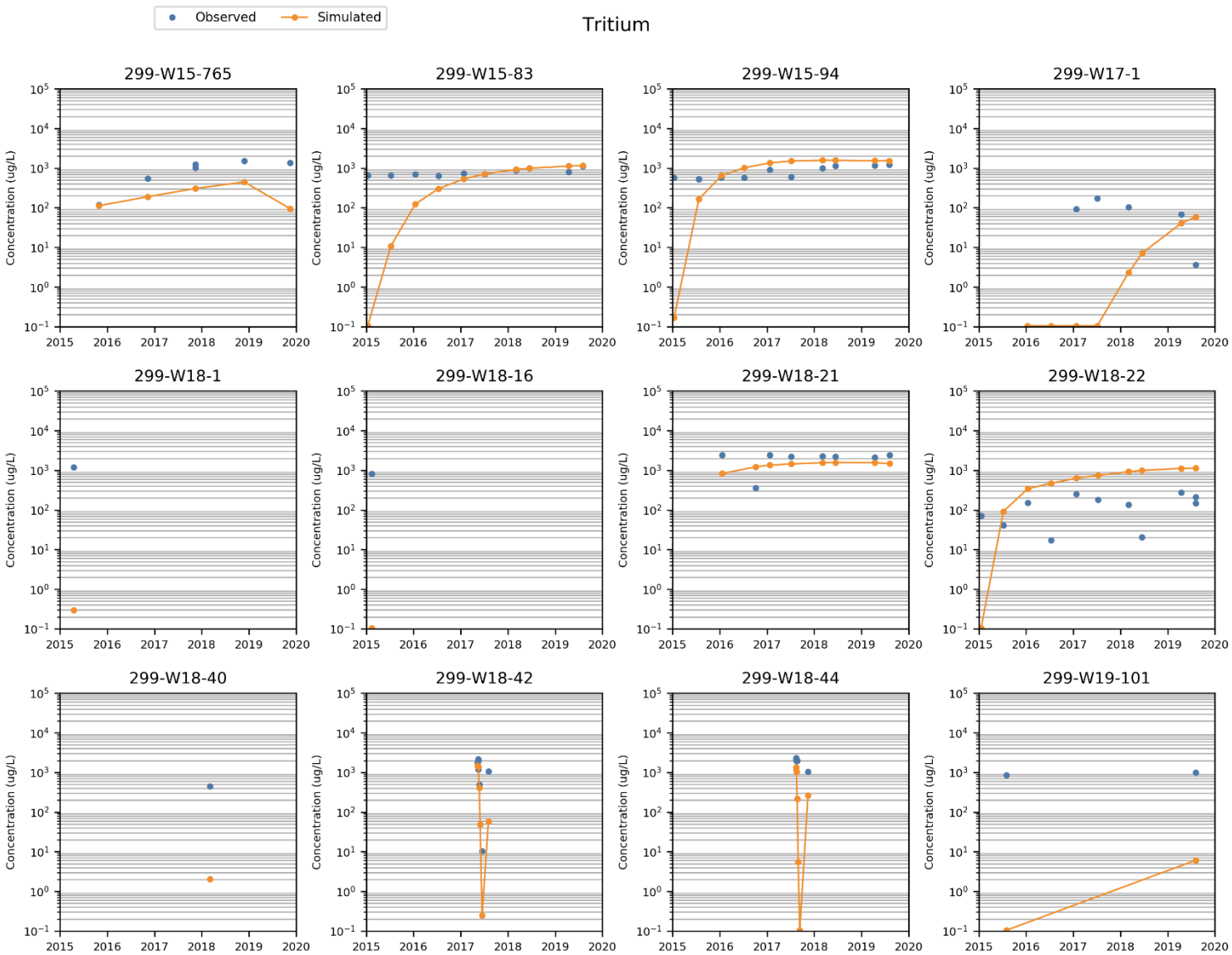

Figure B-98. Comparison of Simulated and Observed Concentrations for Tritium (Page 5 of 16)

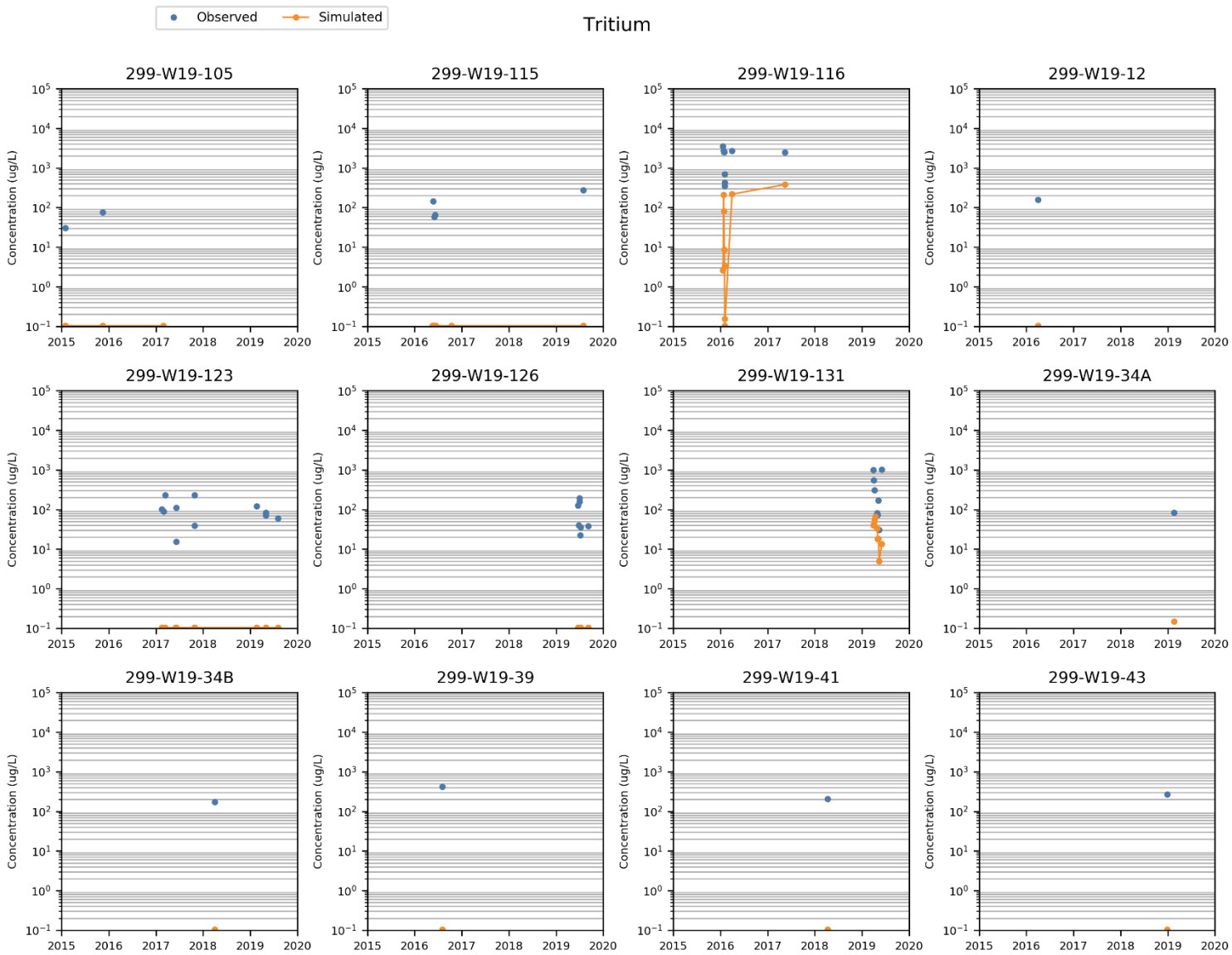

Figure B-99. Comparison of Simulated and Observed Concentrations for Tritium (Page 6 of 16)

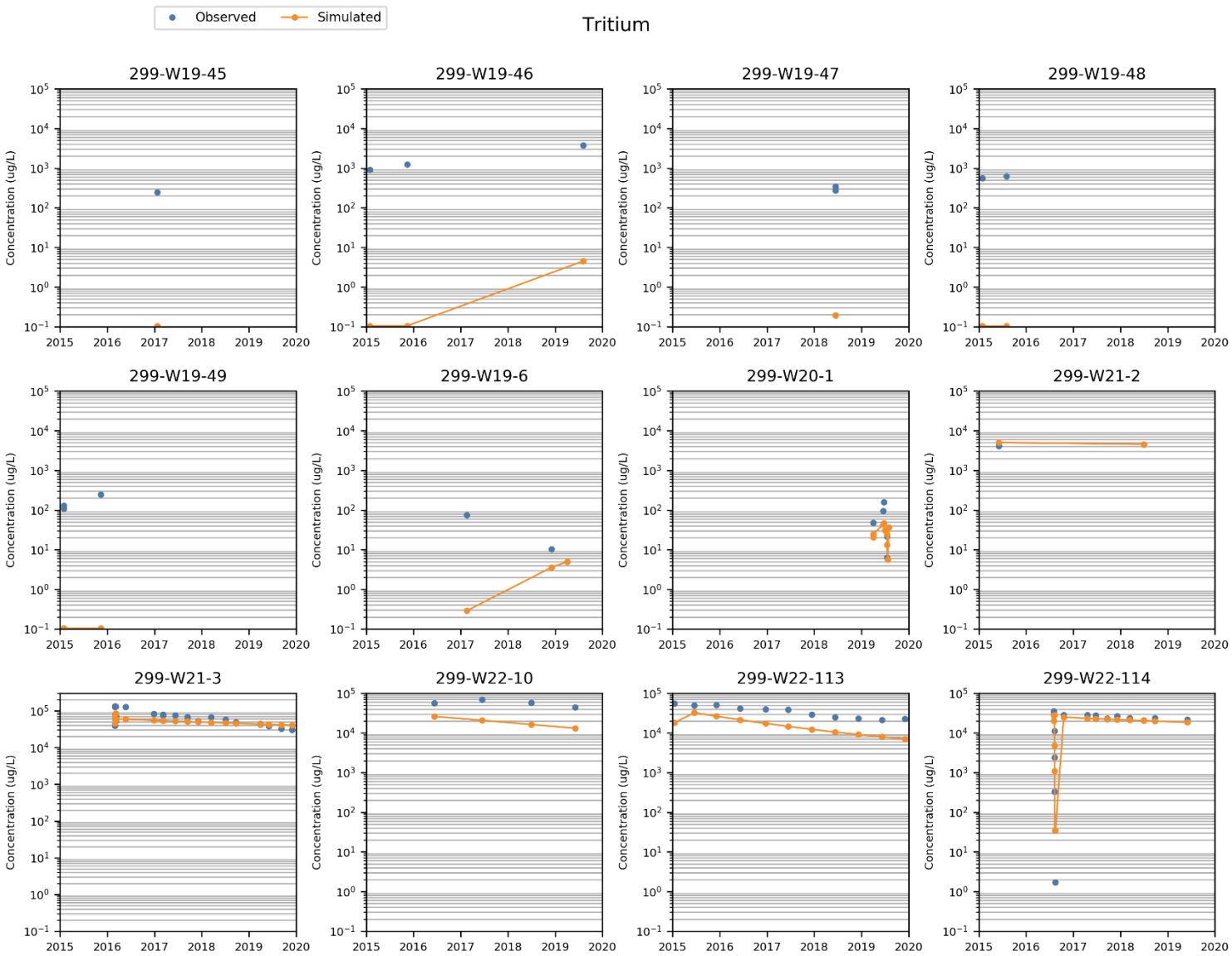

Figure B-100. Comparison of Simulated and Observed Concentrations for Tritium (Page 7 of 16)

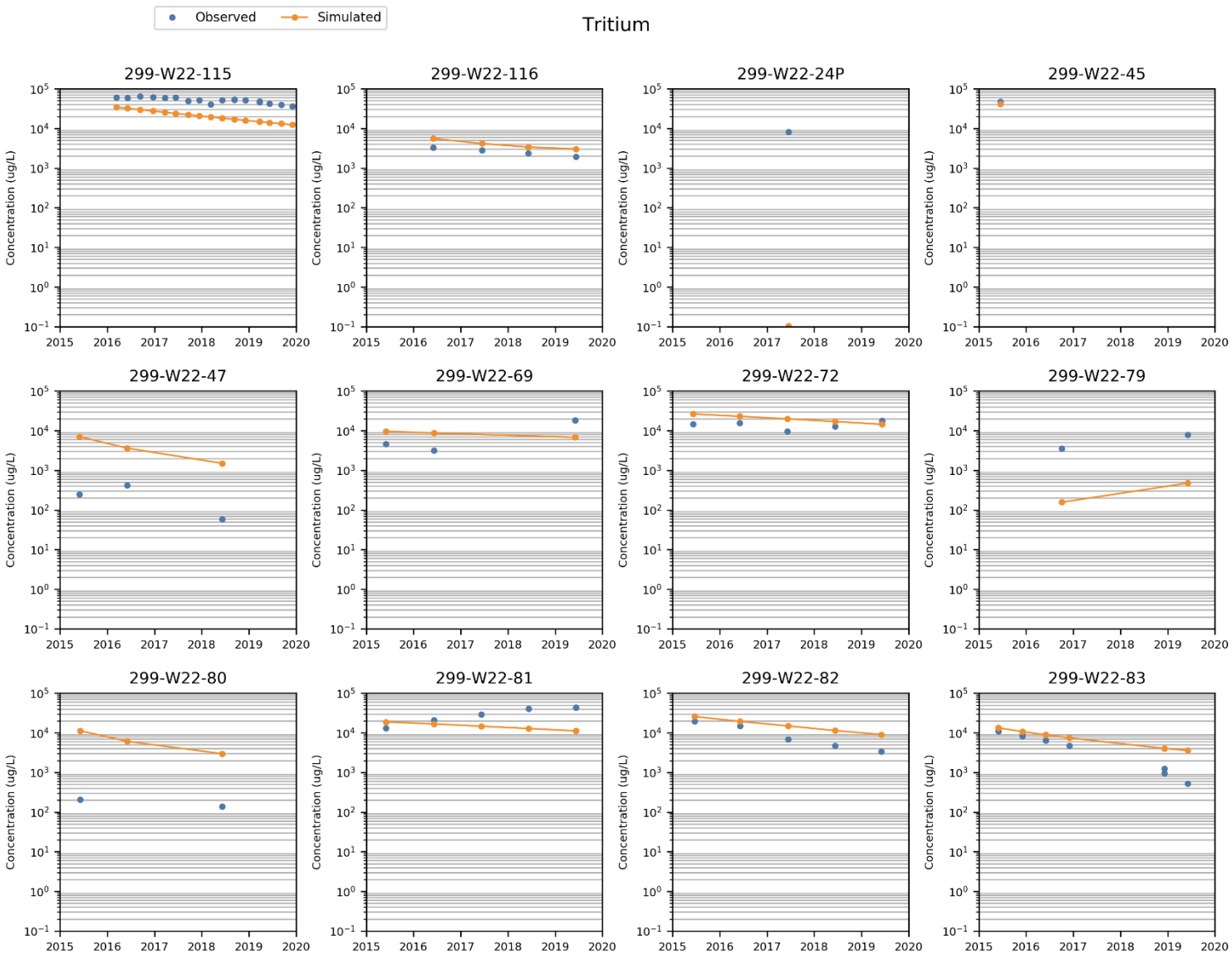

Figure B-101. Comparison of Simulated and Observed Concentrations for Tritium (Page 8 of 16)

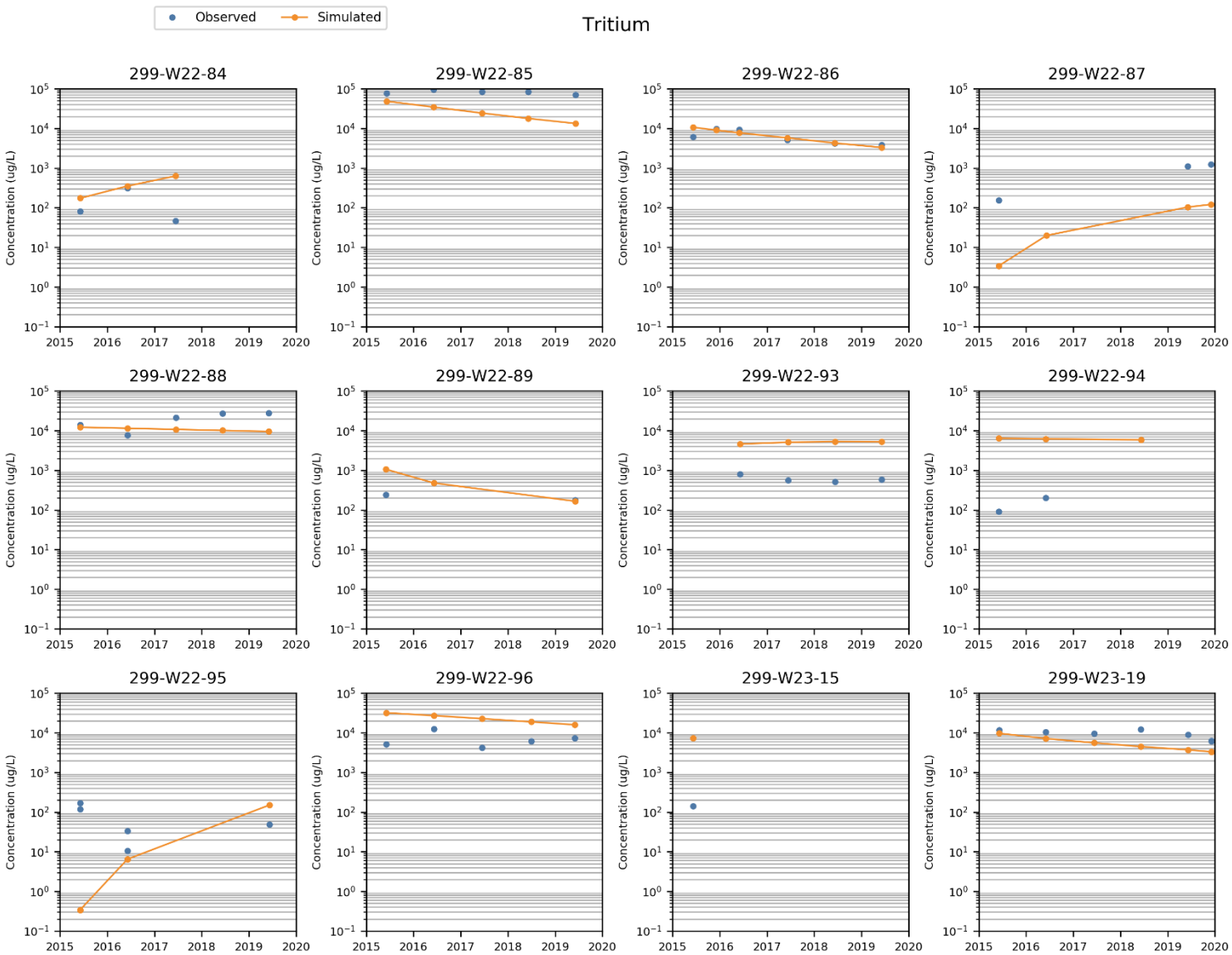

Figure B-102. Comparison of Simulated and Observed Concentrations for Tritium (Page 9 of 16)

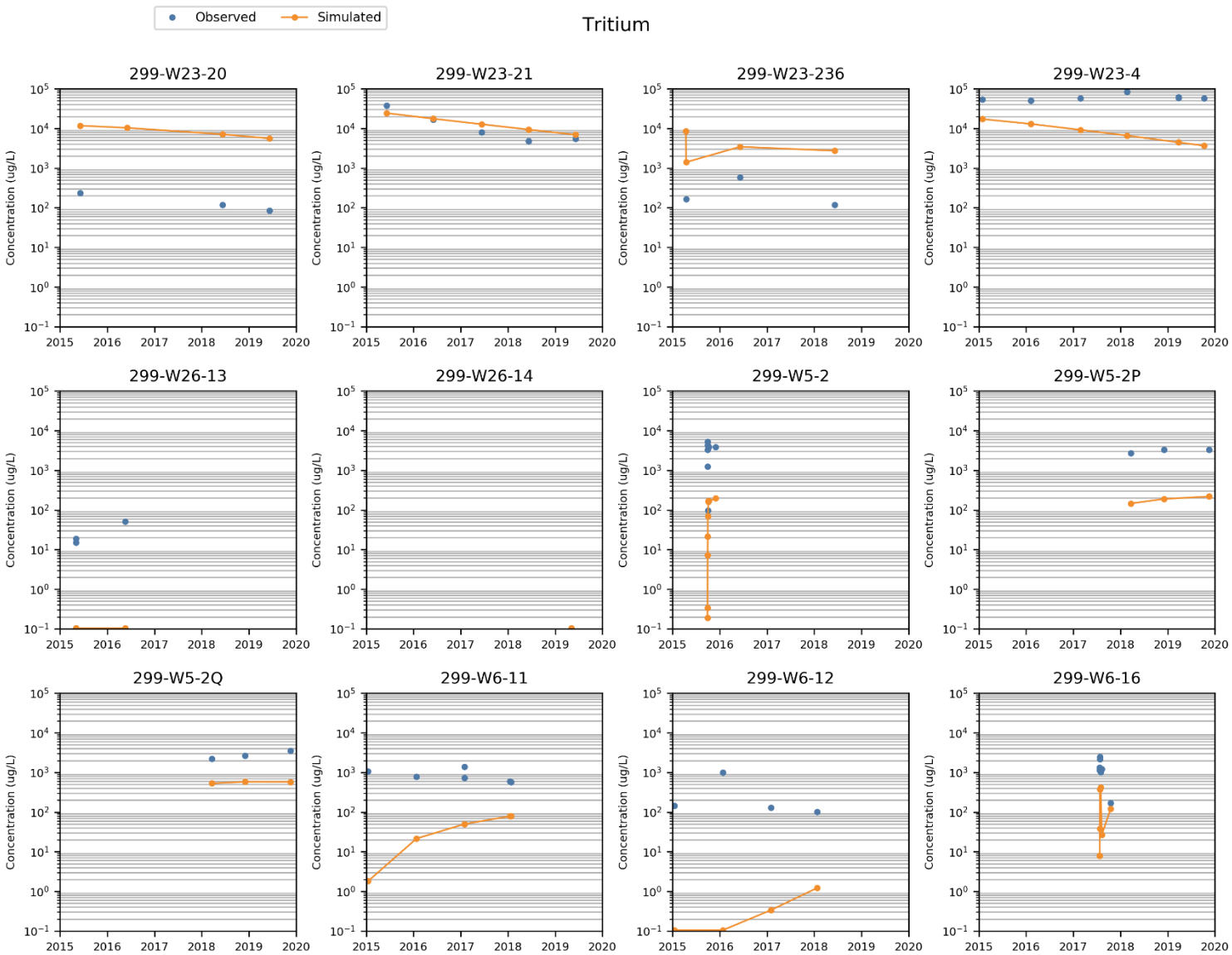

Figure B-103. Comparison of Simulated and Observed Concentrations for Tritium (Page 10 of 16)

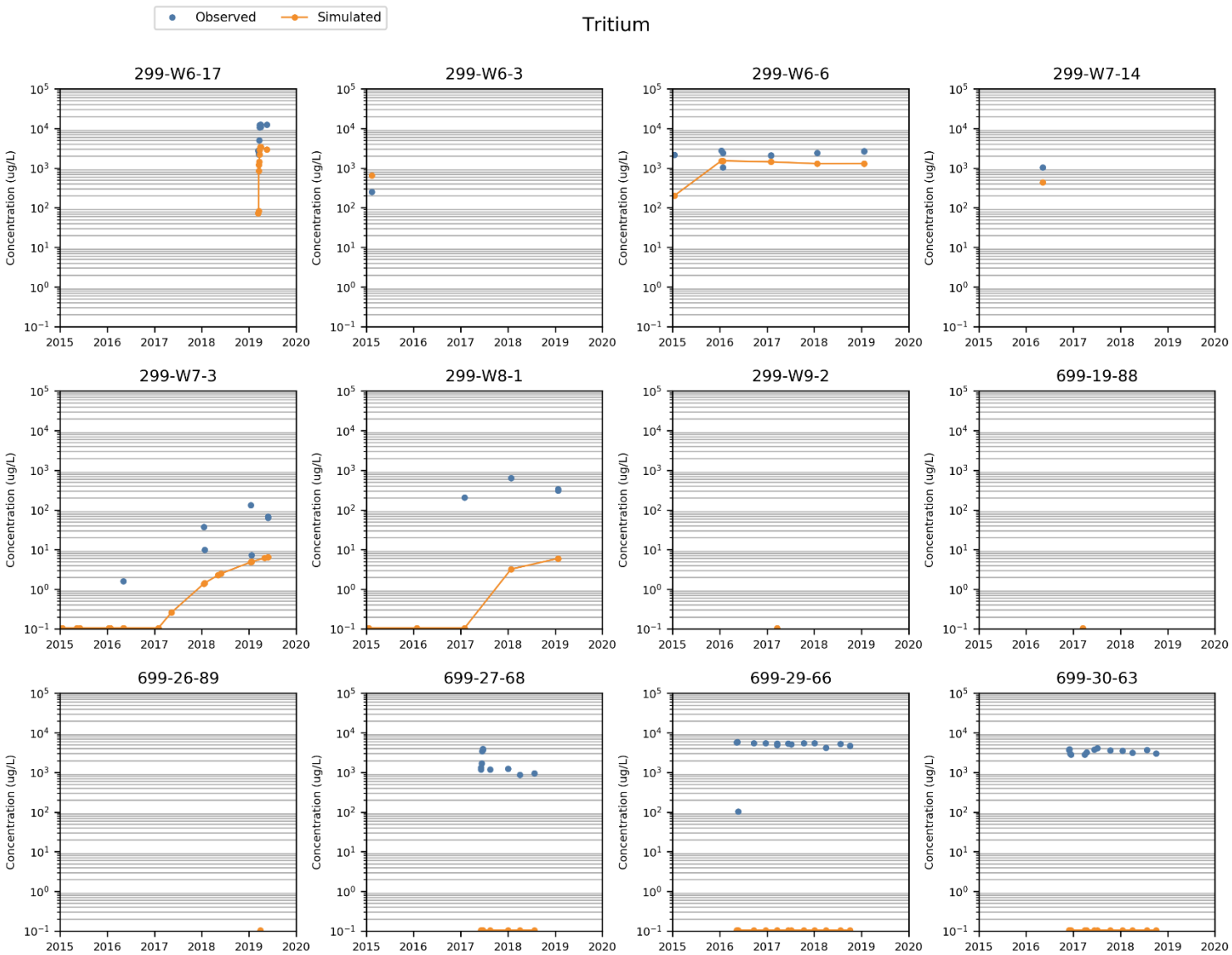

Figure B-104. Comparison of Simulated and Observed Concentrations for Tritium (Page 11 of 16)

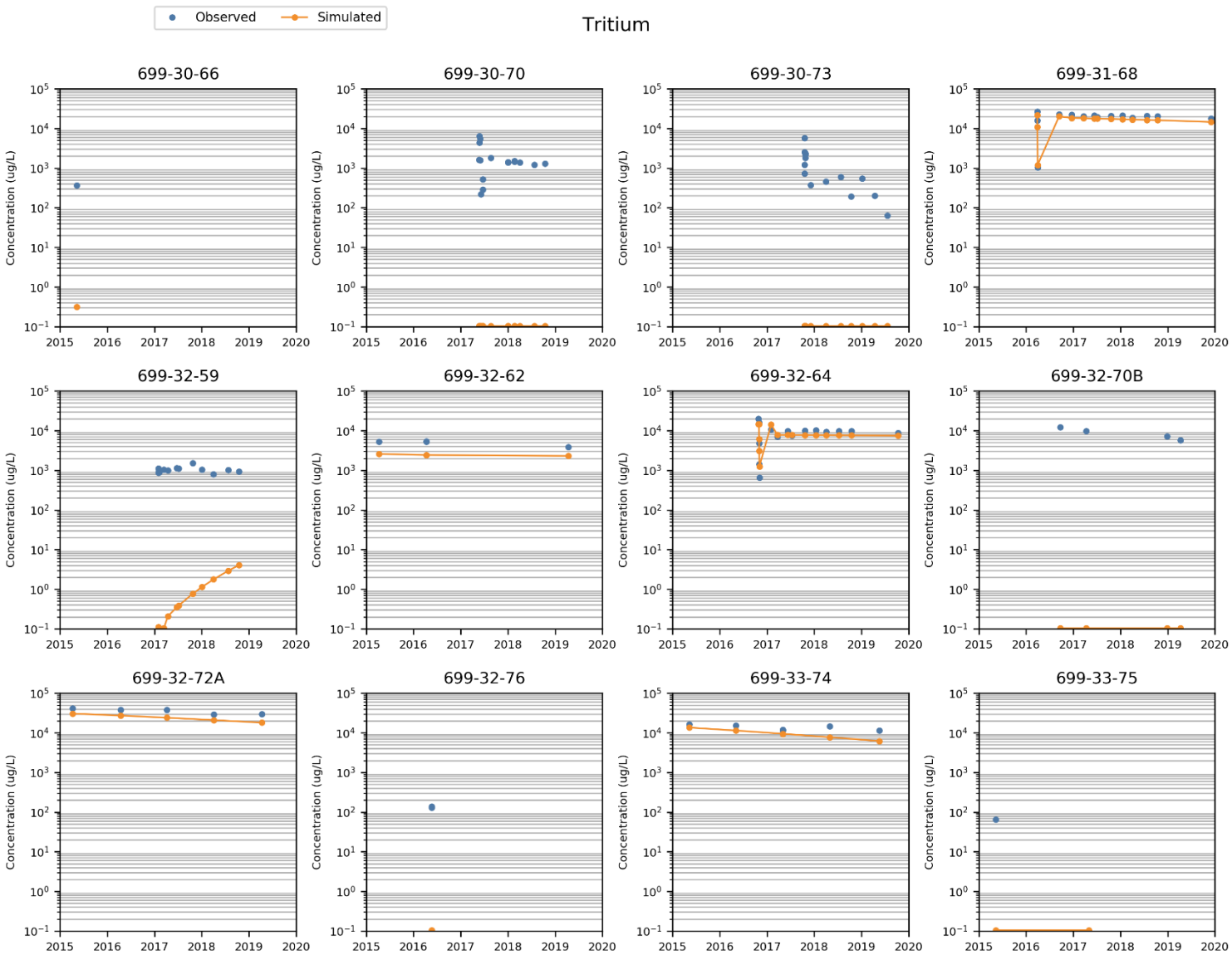

Figure B-105. Comparison of Simulated and Observed Concentrations for Tritium (Page 12 of 16)

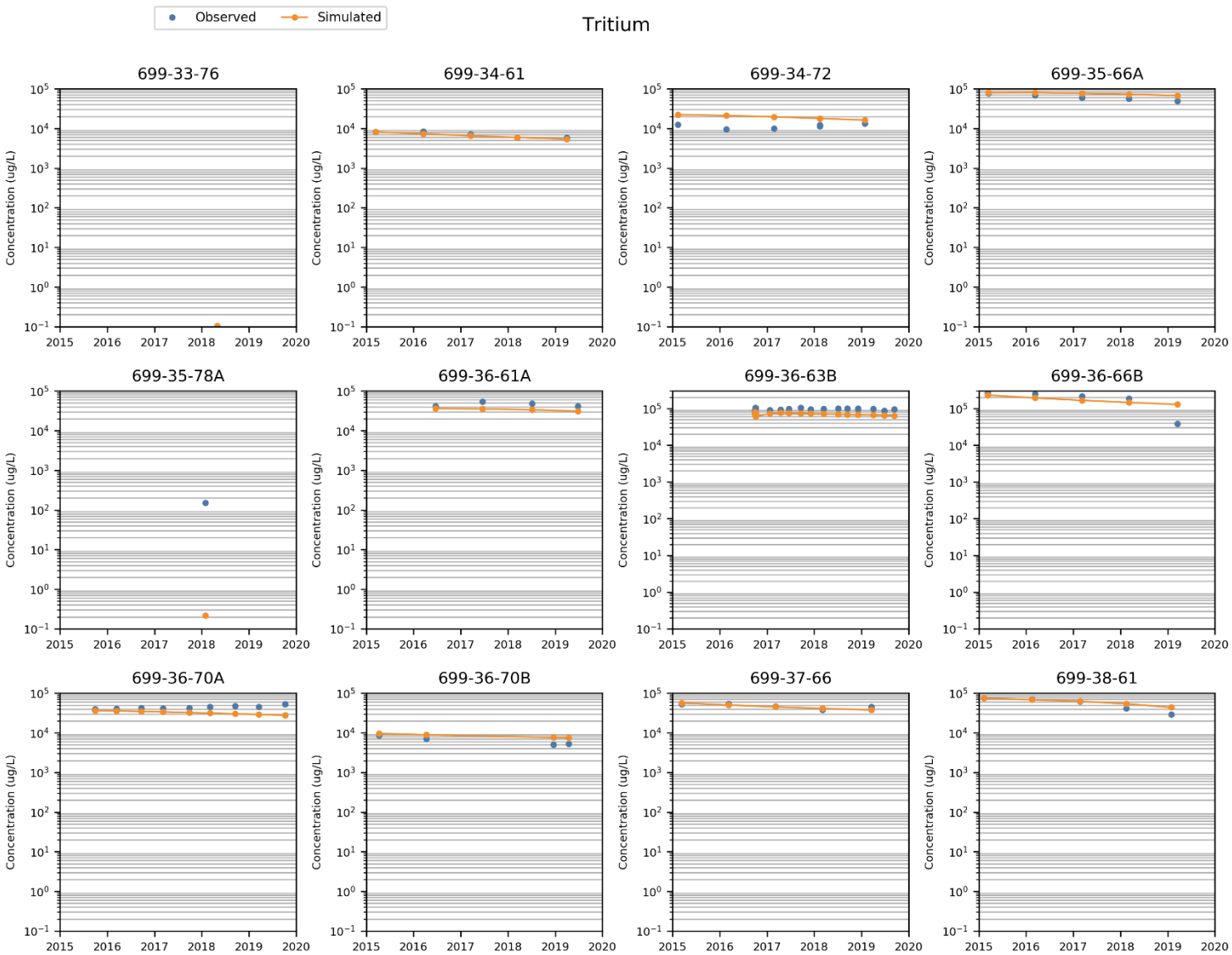

Figure B-106. Comparison of Simulated and Observed Concentrations for Tritium (Page 13 of 16)

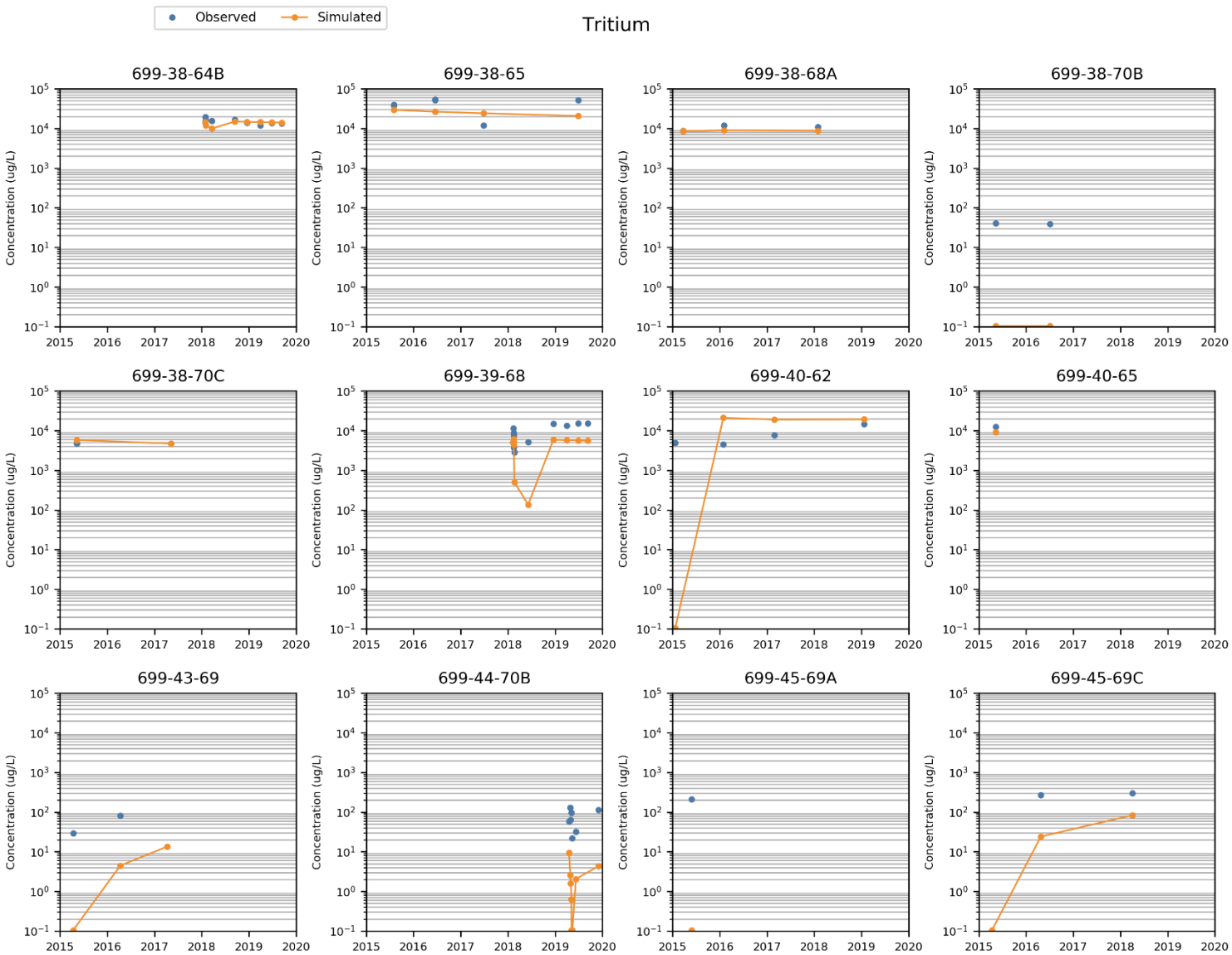

Figure B-107. Comparison of Simulated and Observed Concentrations for Tritium (Page 14 of 16)

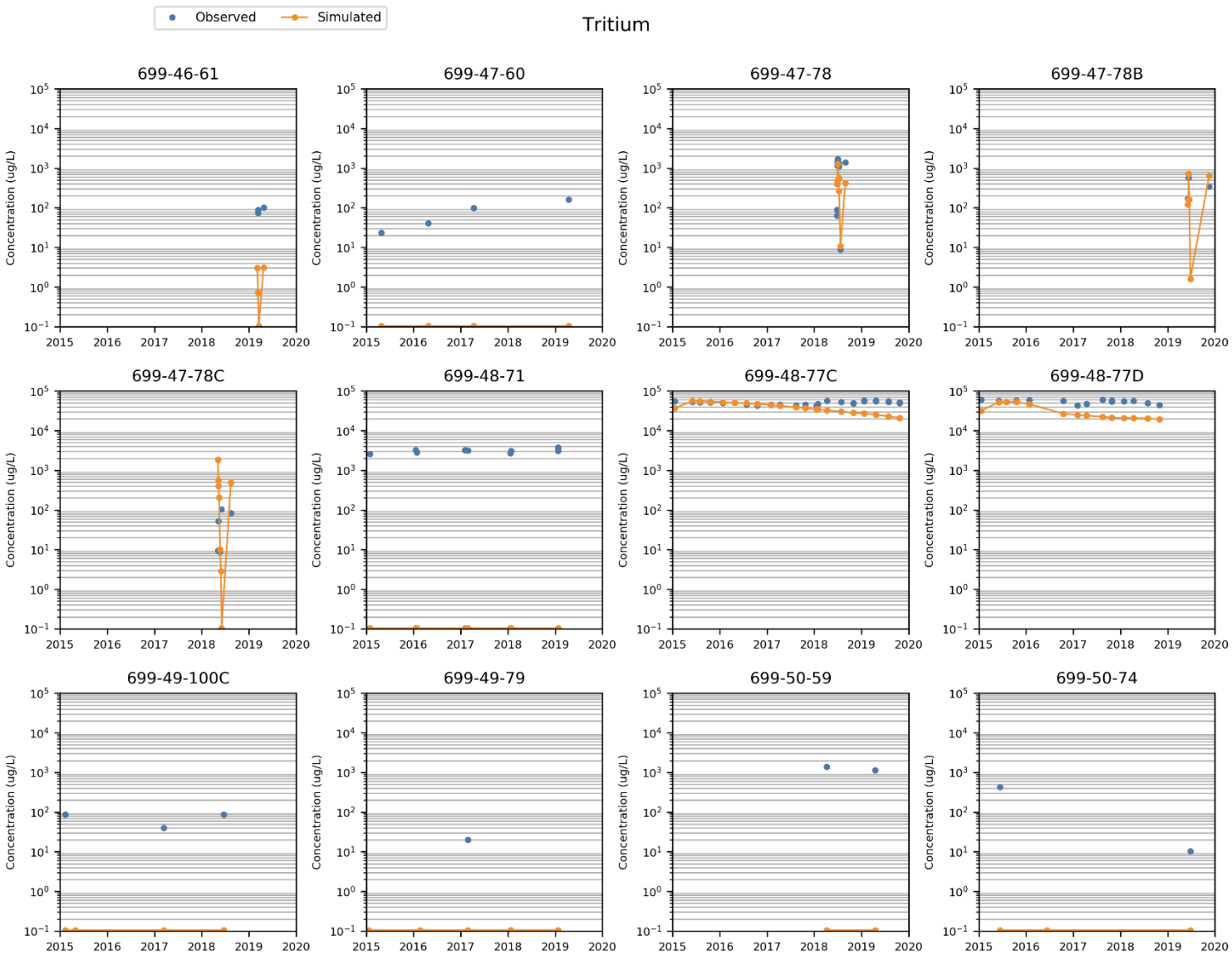

Figure B-108. Comparison of Simulated and Observed Concentrations for Tritium (Page 15 of 16)

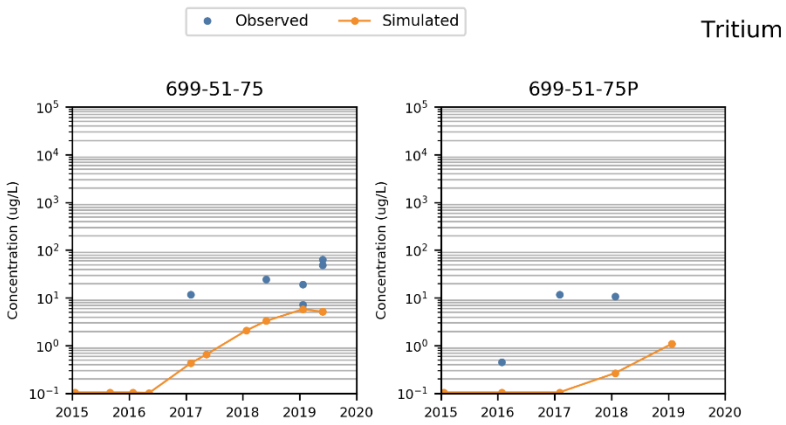

Figure B-109. Comparison of Simulated and Observed Concentrations for Tritium (Page 16 of 16)

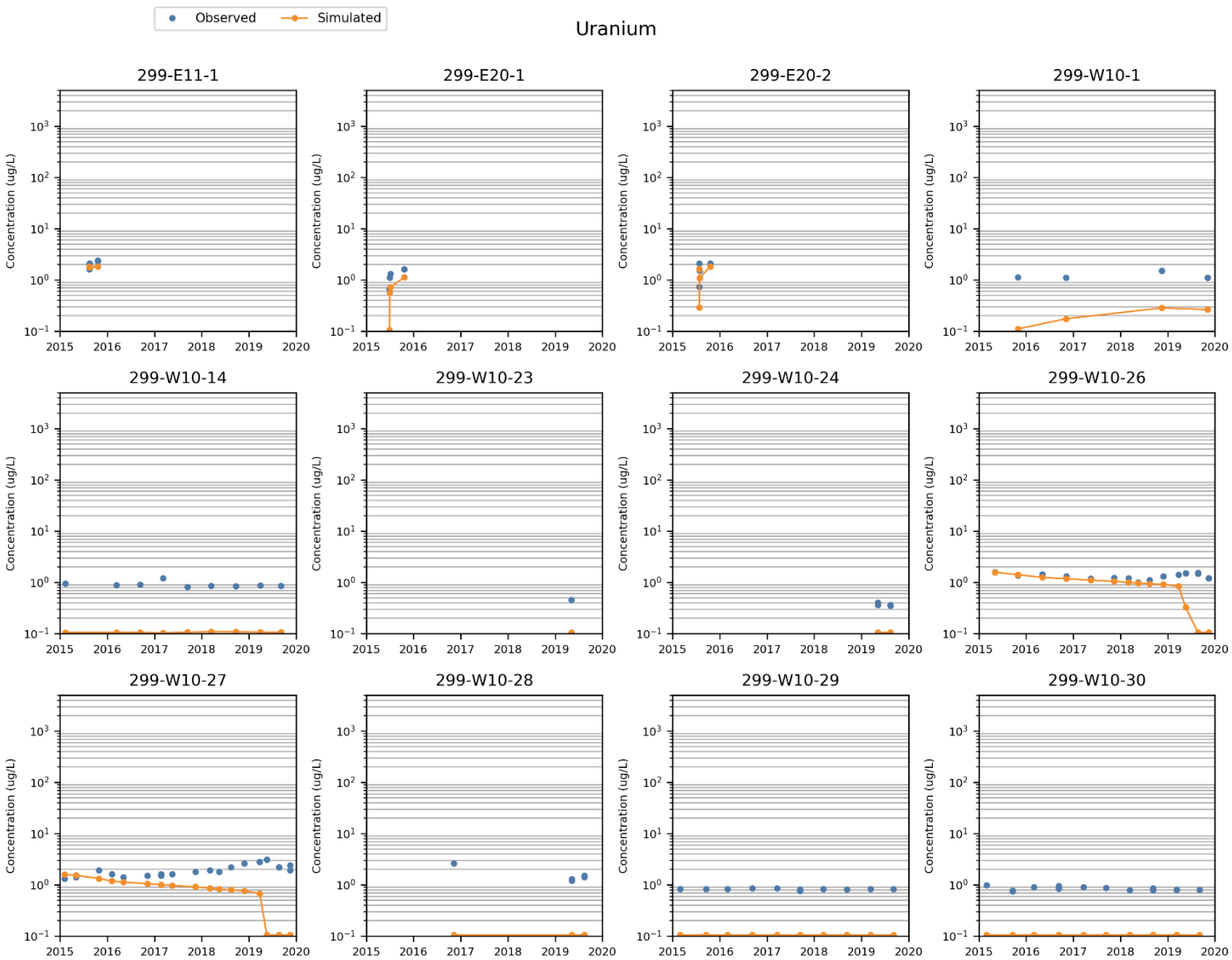

Figure B-110. Comparison of Simulated and Observed Concentrations for Uranium (Page 1 of 16)

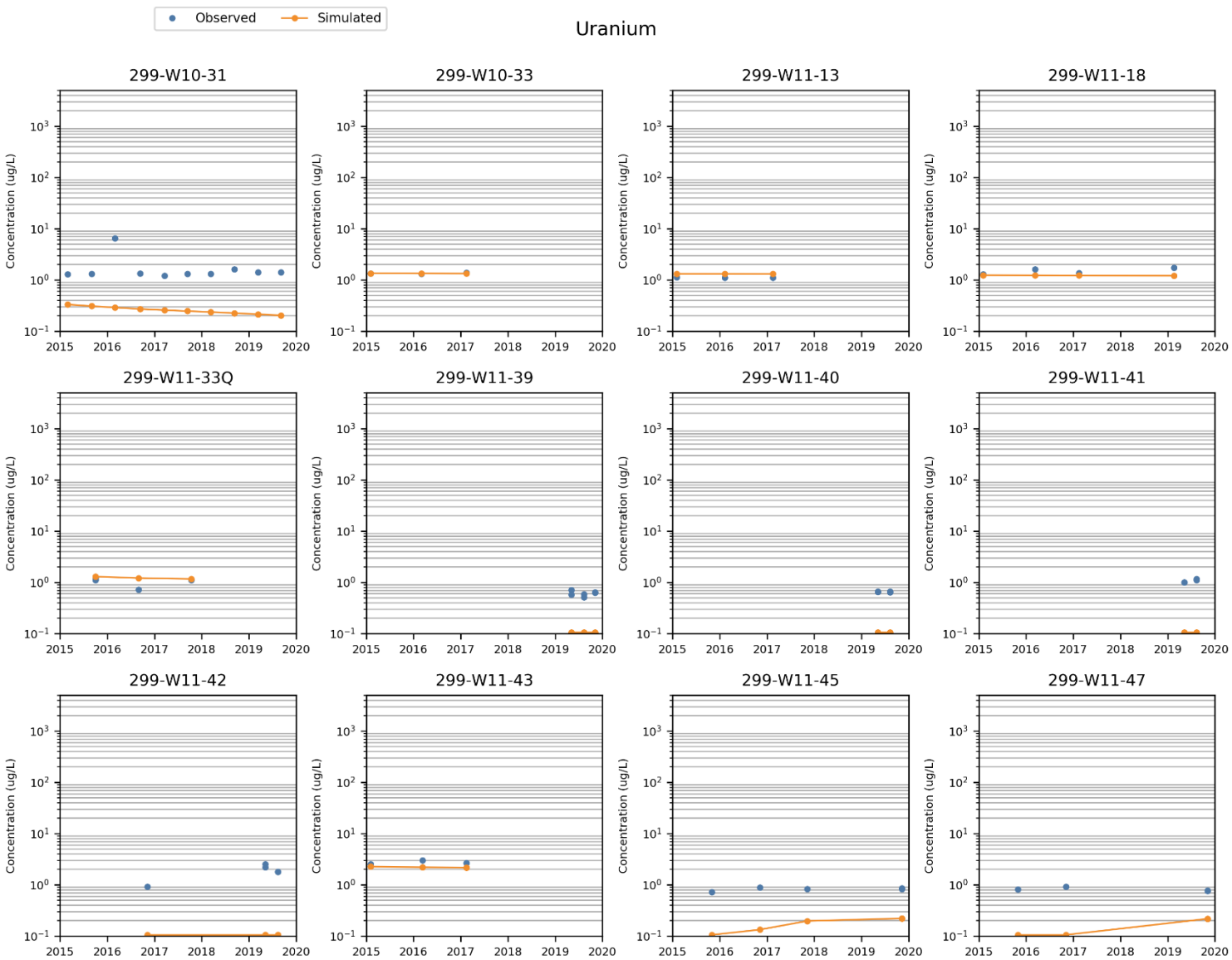

Figure B-111. Comparison of Simulated and Observed Concentrations for Uranium (Page 2 of 16)

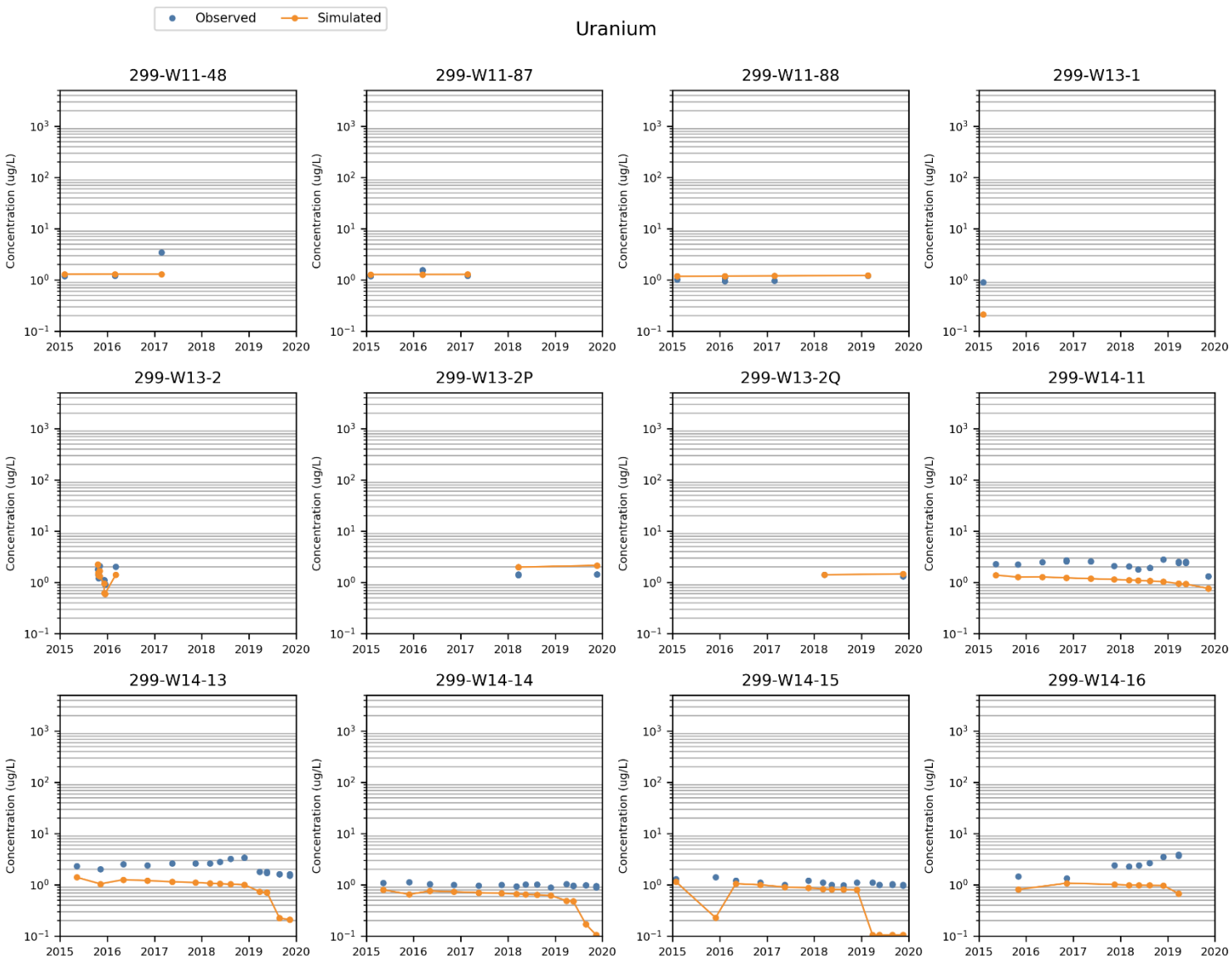

Figure B-112. Comparison of Simulated and Observed Concentrations for Uranium (Page 3 of 16)

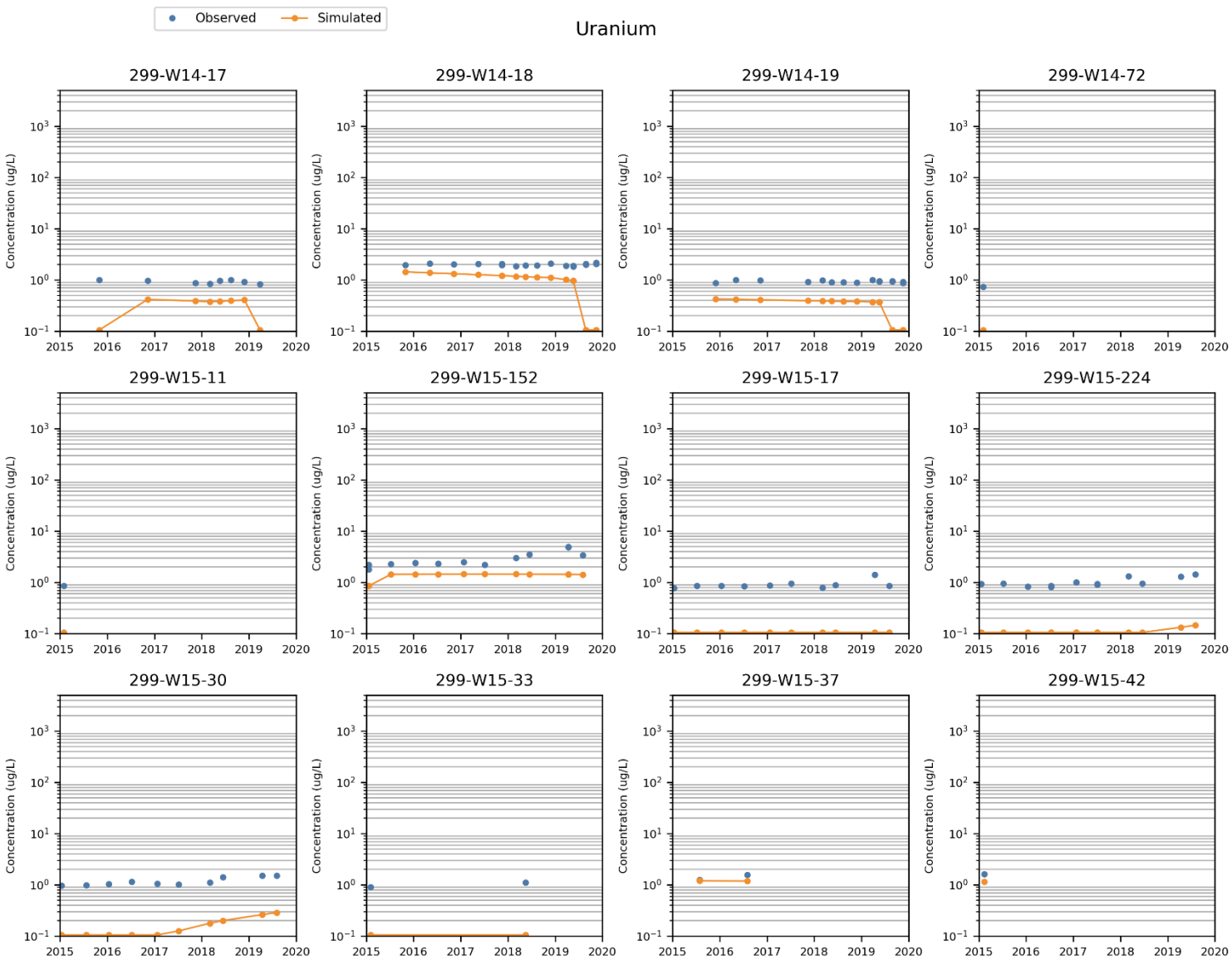

Figure B-113. Comparison of Simulated and Observed Concentrations for Uranium (Page 4 of 16)

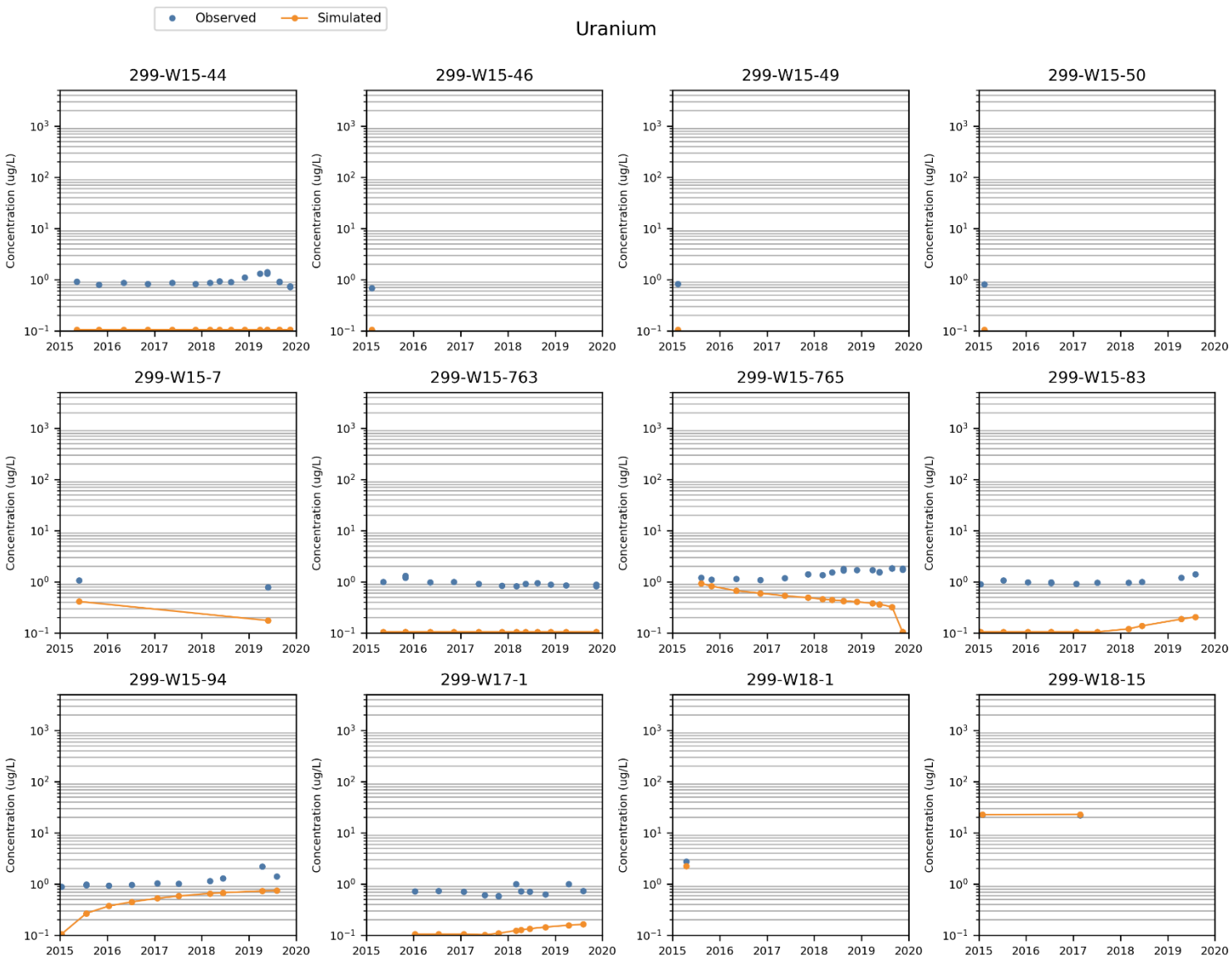

Figure B-114. Comparison of Simulated and Observed Concentrations for Uranium (Page 5 of 16)

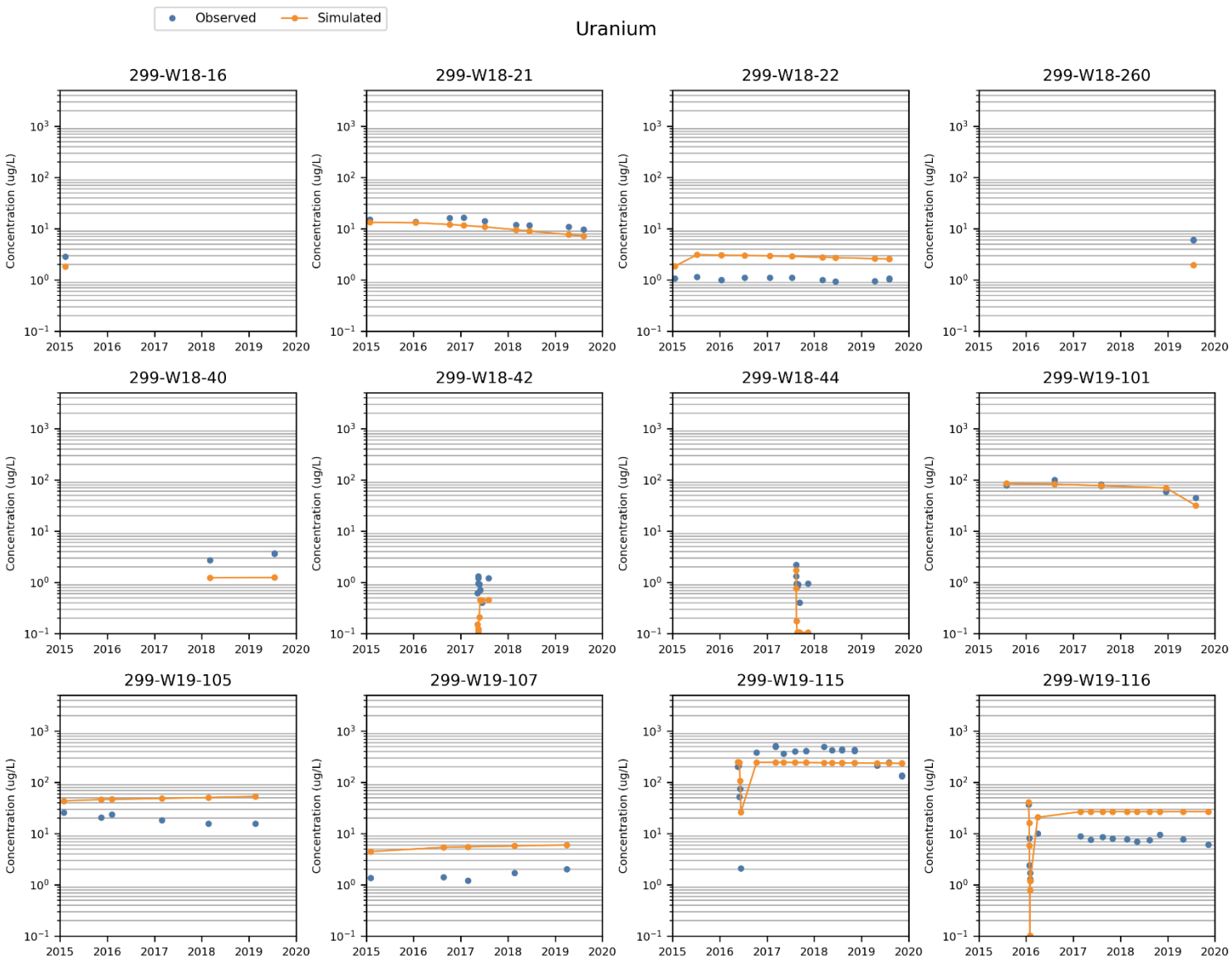

Figure B-115. Comparison of Simulated and Observed Concentrations for Uranium (Page 6 of 16)

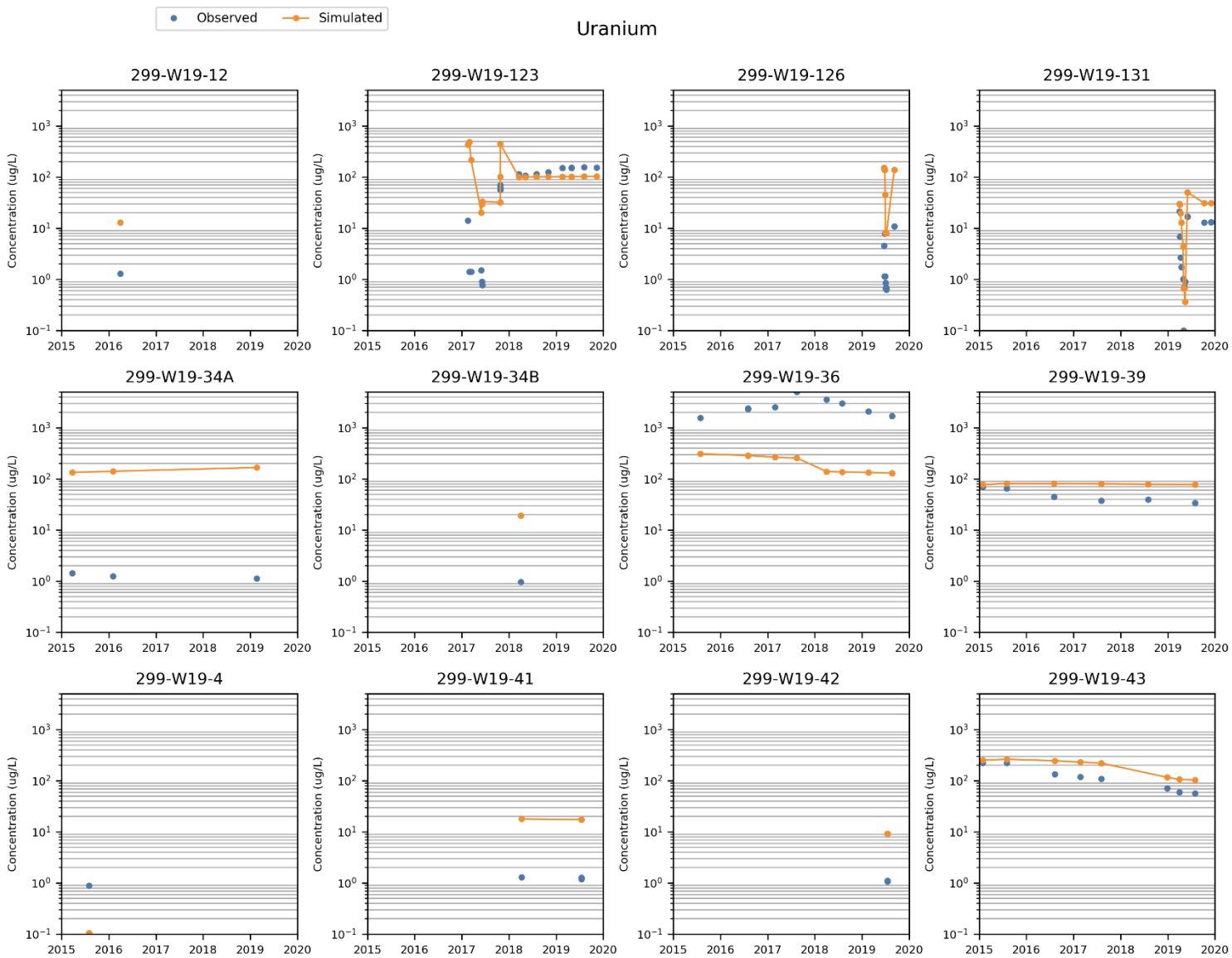

Figure B-116. Comparison of Simulated and Observed Concentrations for Uranium (Page 7 of 16)

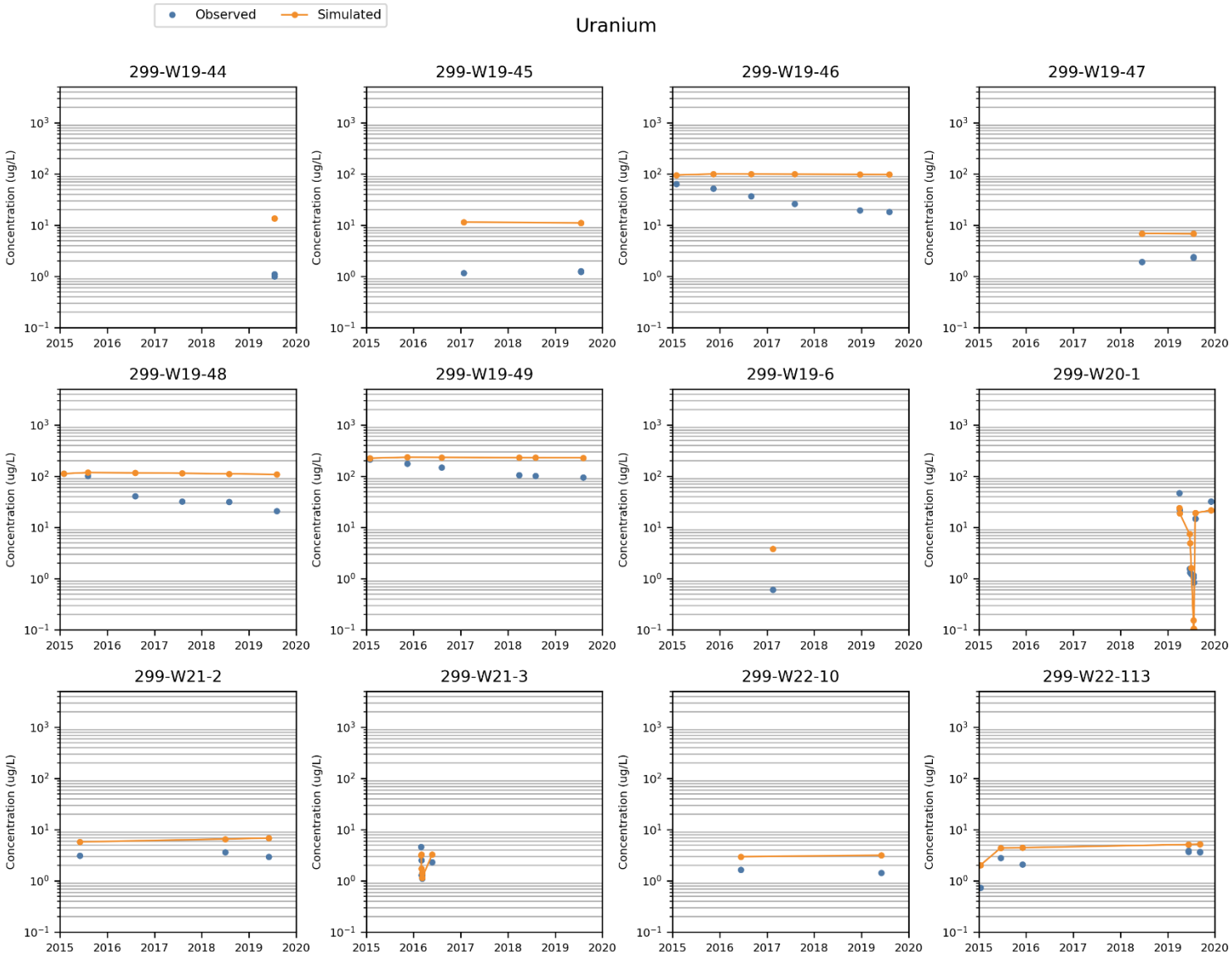

Figure B-117. Comparison of Simulated and Observed Concentrations for Uranium (Page 8 of 16)

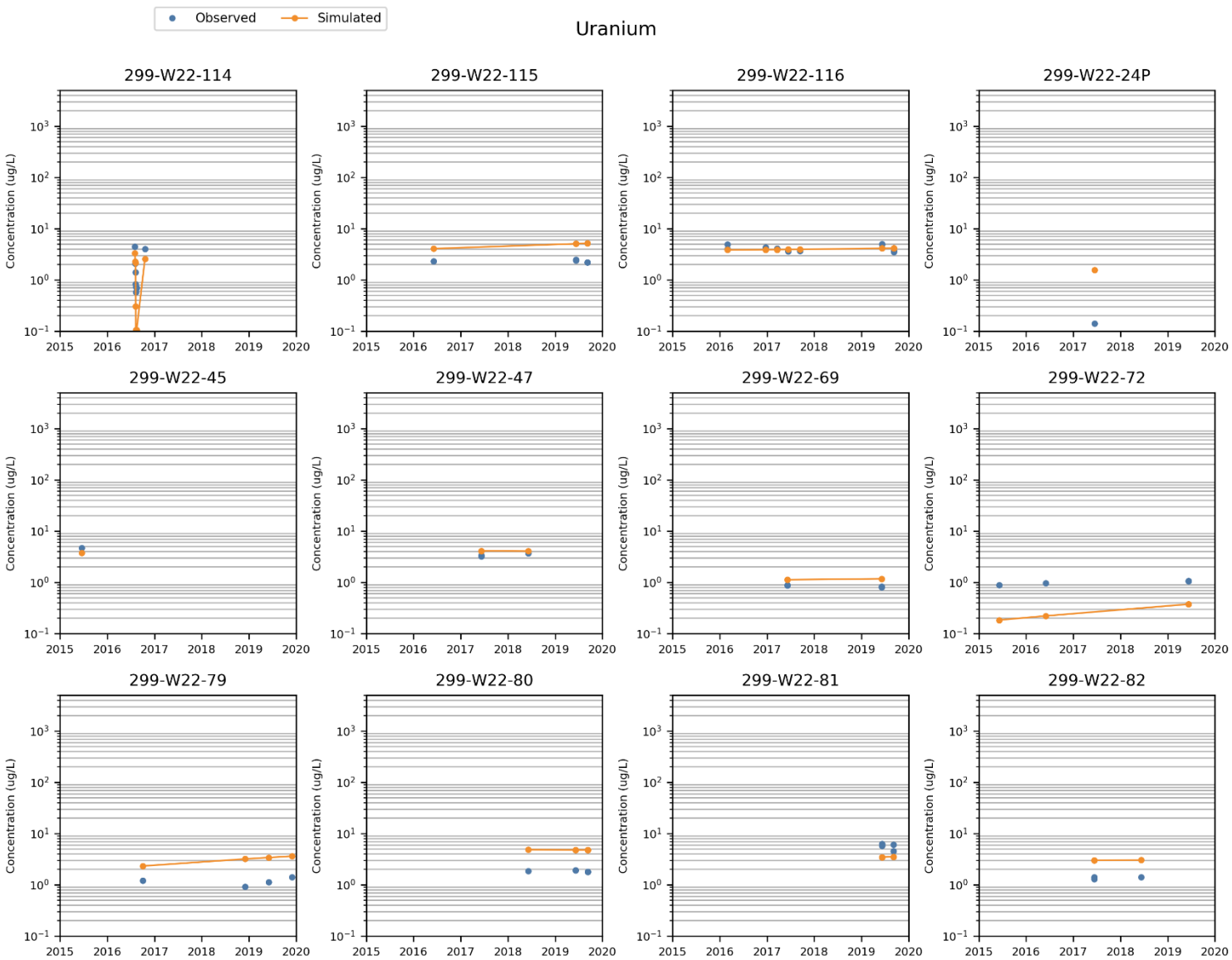

Figure B-118. Comparison of Simulated and Observed Concentrations for Uranium (Page 9 of 16)

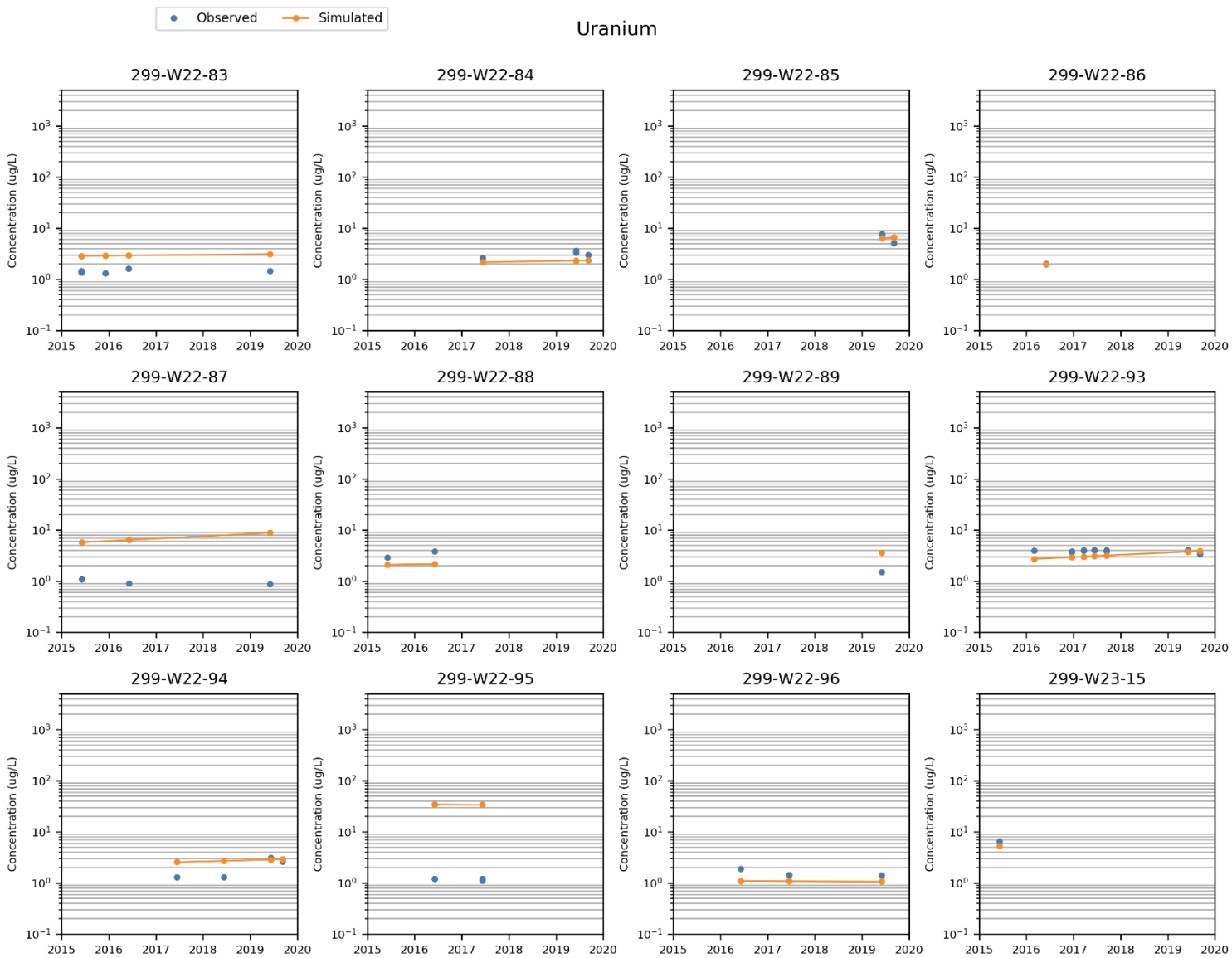

Figure B-119. Comparison of Simulated and Observed Concentrations for Uranium (Page 10 of 16)

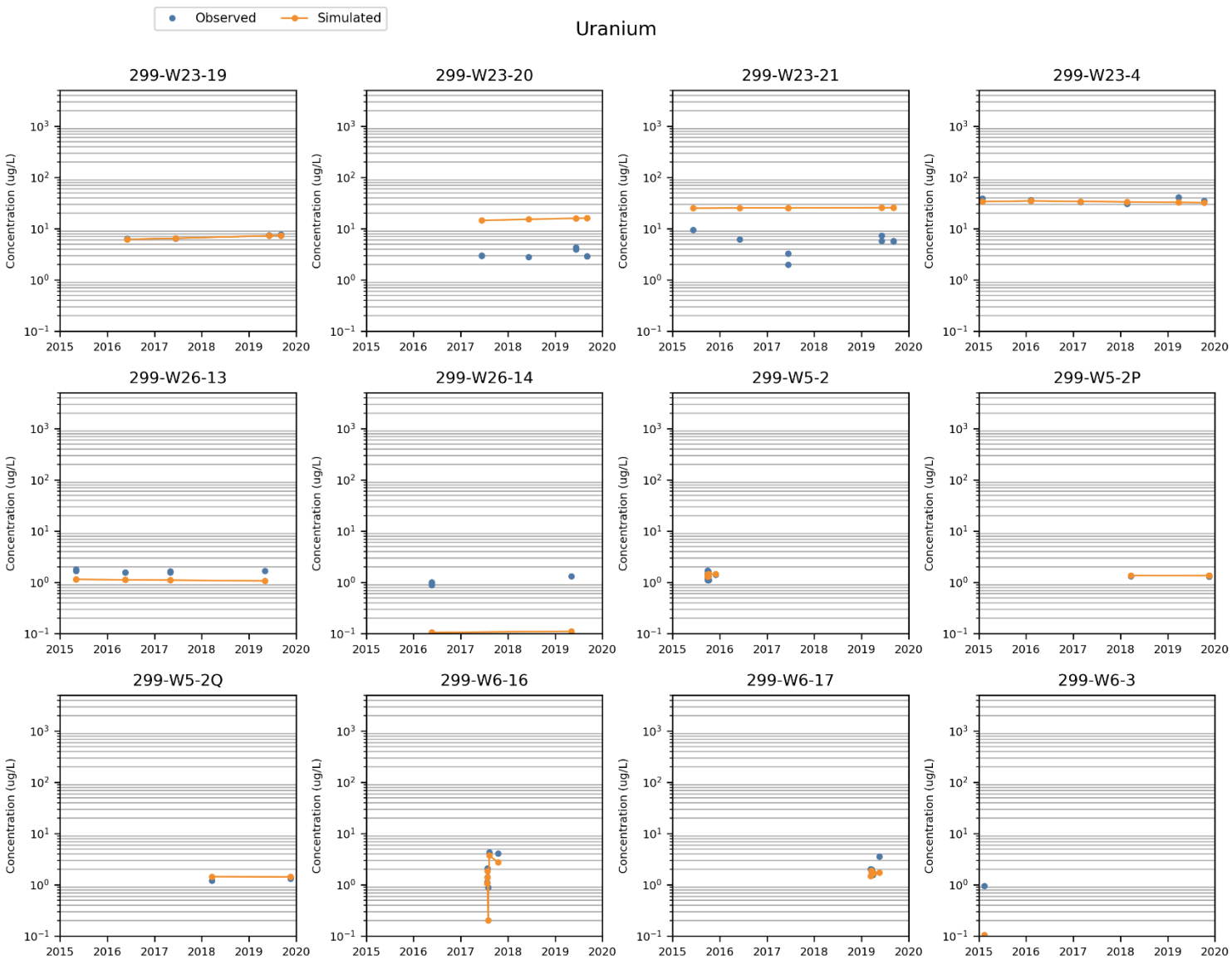

Figure B-120. Comparison of Simulated and Observed Concentrations for Uranium (Page 11 of 16)

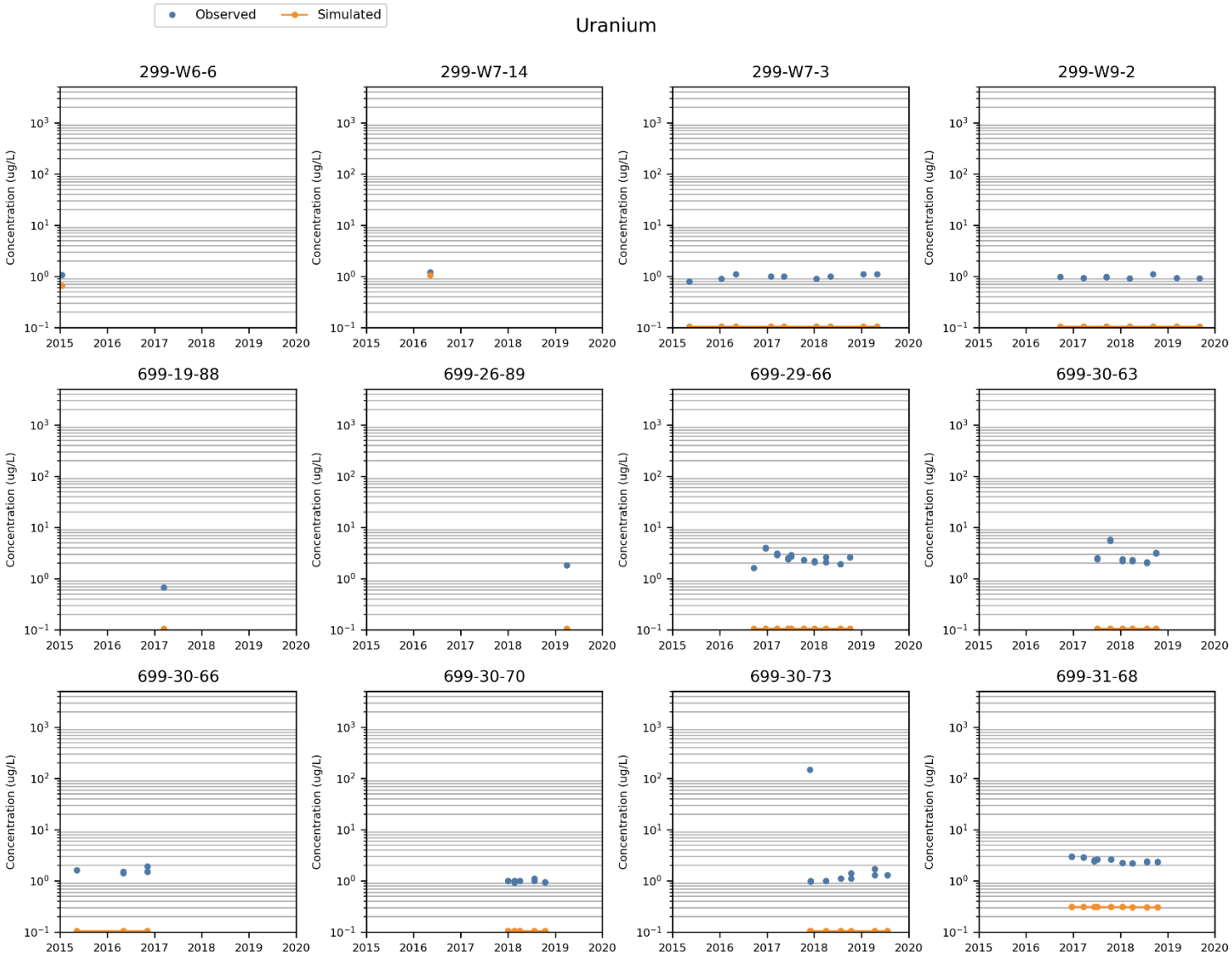

Figure B-121. Comparison of Simulated and Observed Concentrations for Uranium (Page 12 of 16)

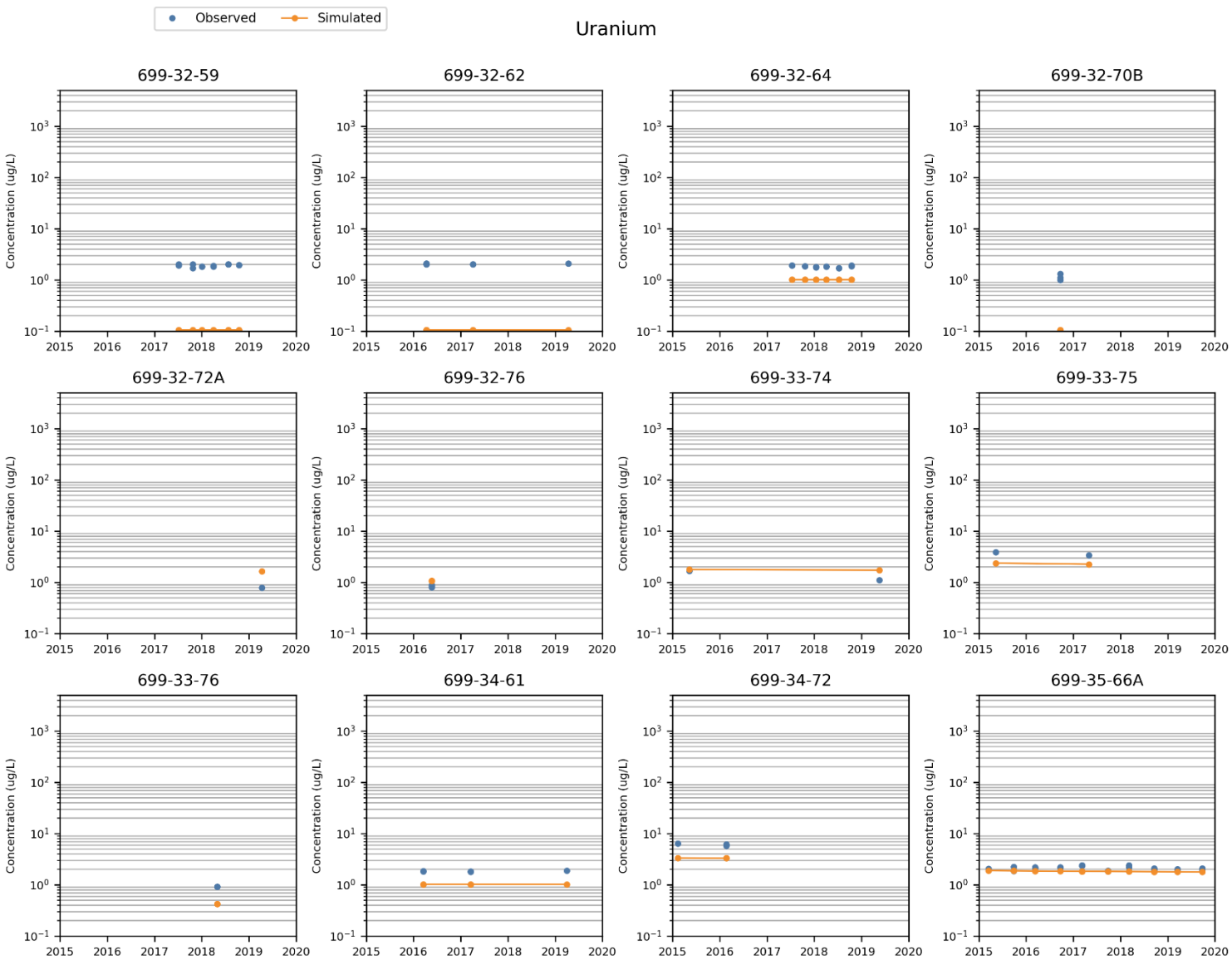

Figure B-122. Comparison of Simulated and Observed Concentrations for Uranium (Page 13 of 16)

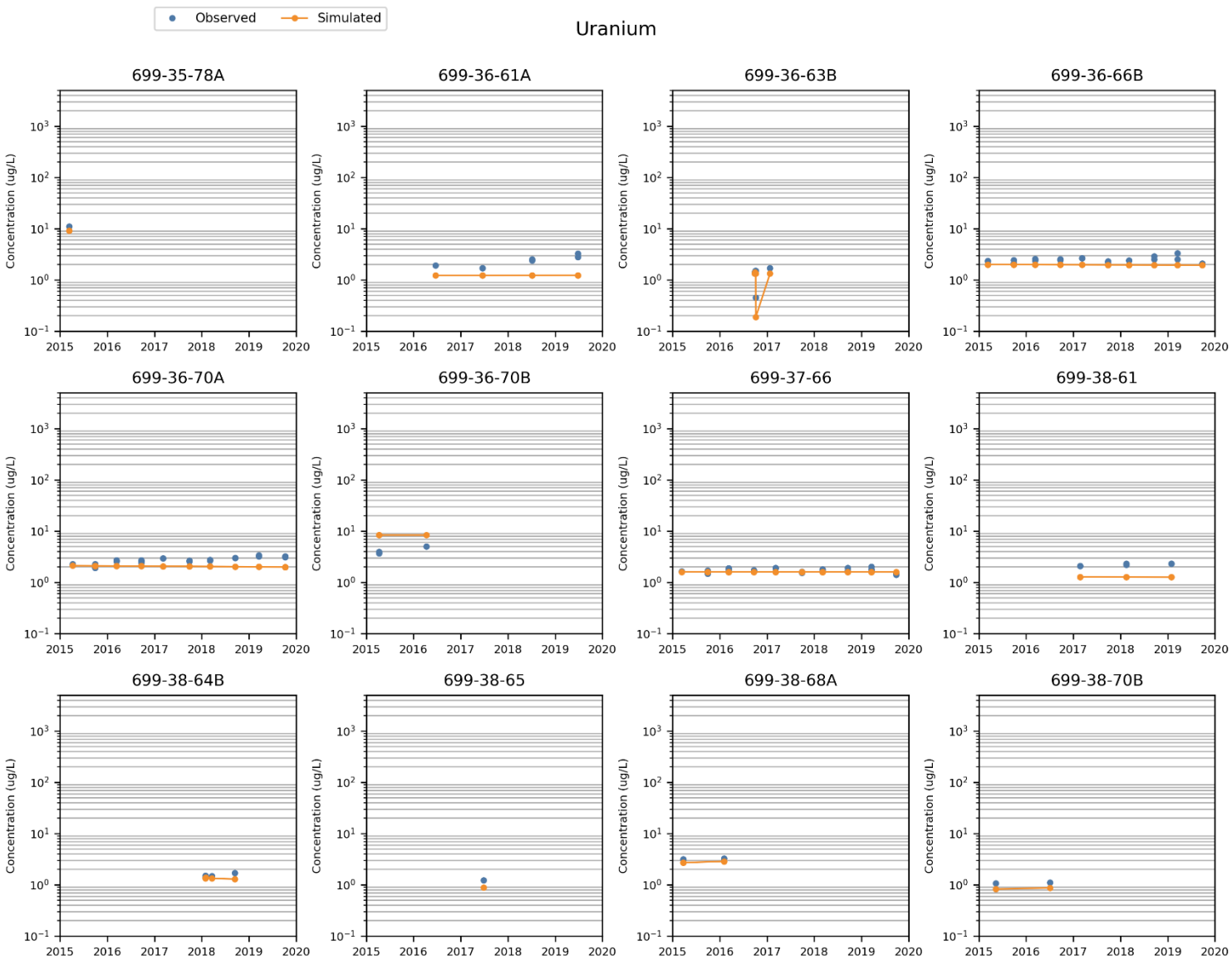

Figure B-123. Comparison of Simulated and Observed Concentrations for Uranium (Page 14 of 16)

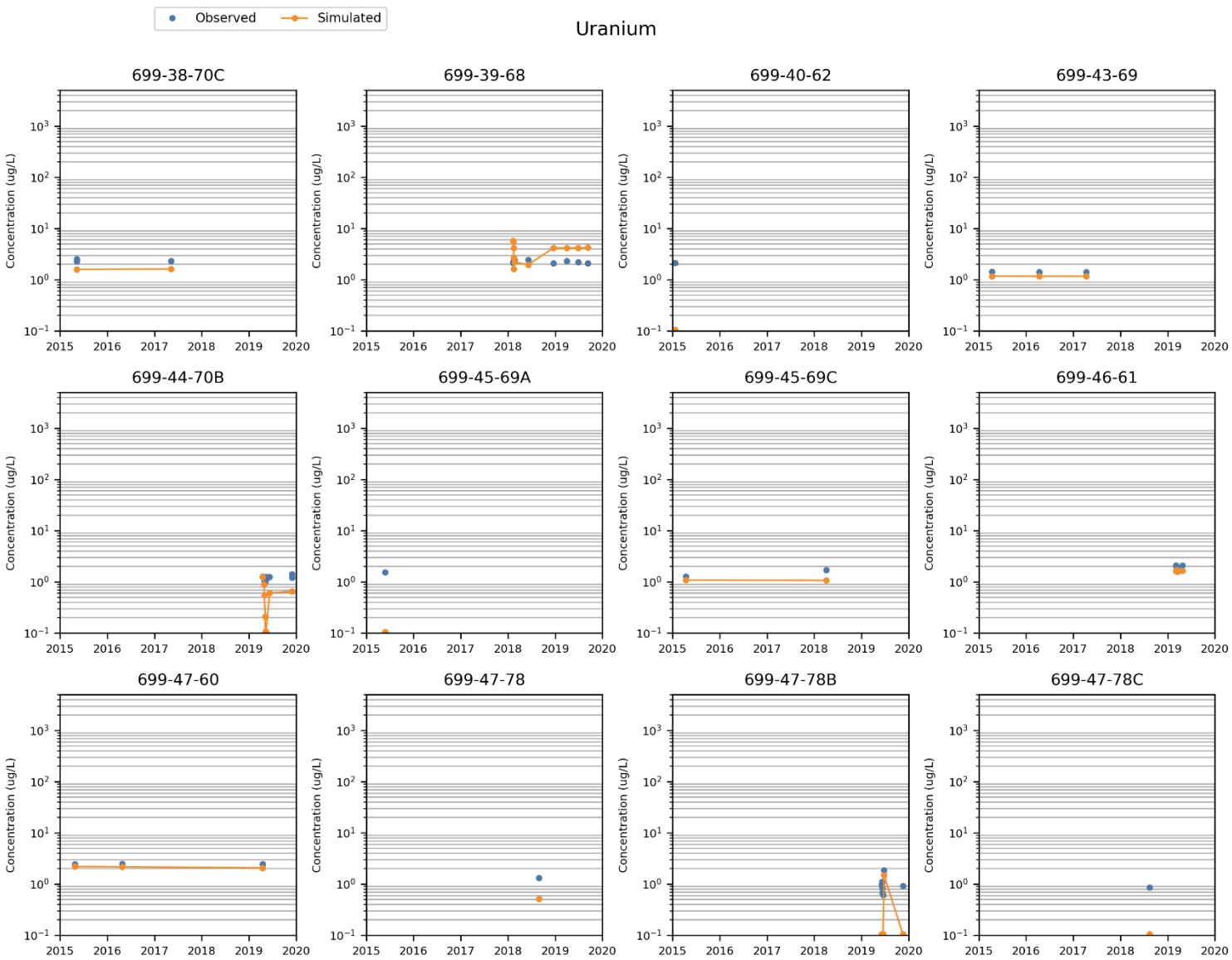

Figure B-124. Comparison of Simulated and Observed Concentrations for Uranium (Page 15 of 16)

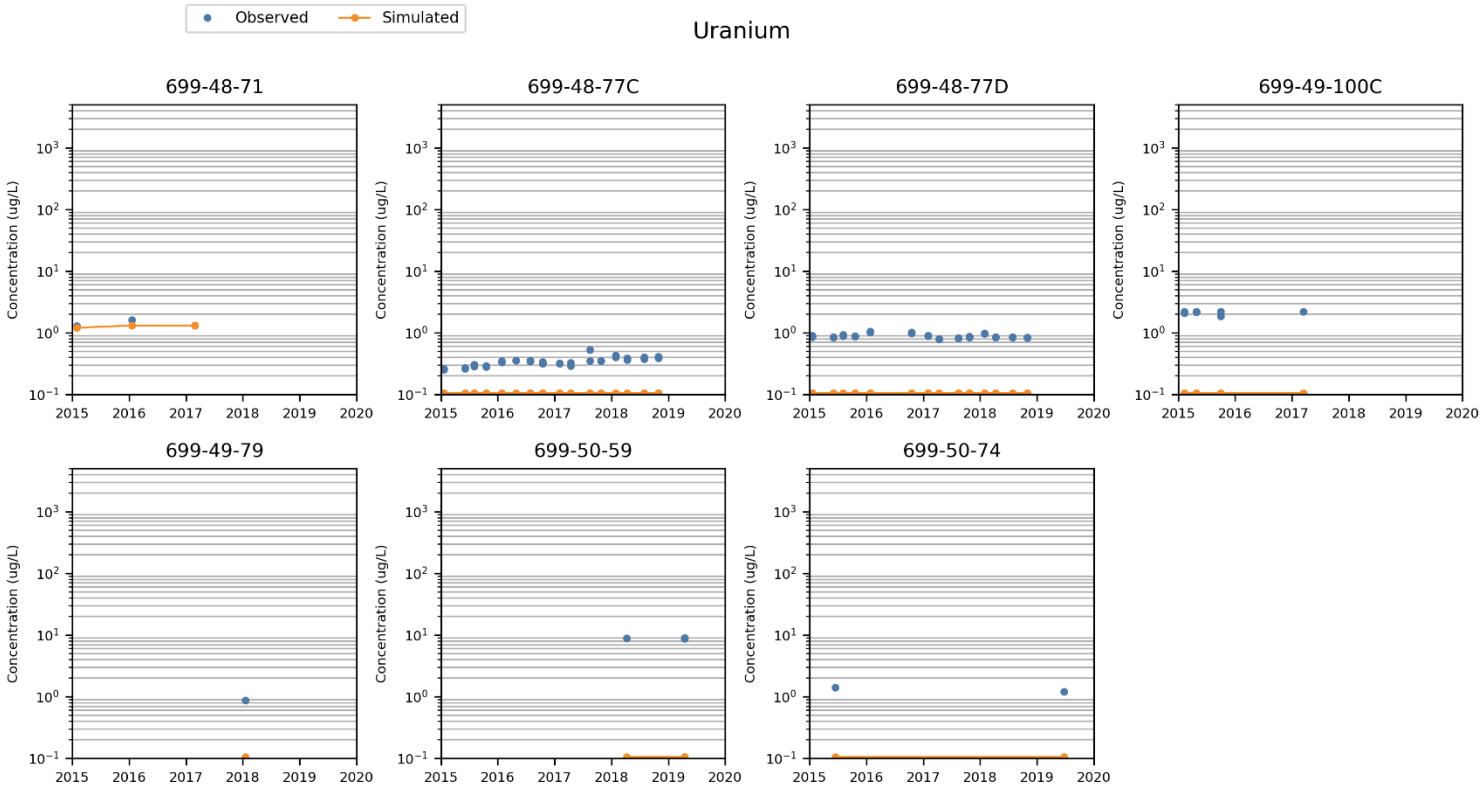

Figure B-125. Comparison of Simulated and Observed Concentrations for Uranium (Page 16 of 16)

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