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Revision 0

200-BP-5 Treatability Test Technical Support Capture Zone Analysis

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

ch2m SM

P.O. Box 1600
Richland, Washington 99352

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Revision 0

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H. Rashid
INTERA, Inc.

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APPROVED
By Ashley Jenkins at 12:45 pm, Feb 16, 2016

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The B complex ECF is nearly done – as senior reviewer I agreed the methodology and results were fine. There were a few editorial items I found that Helal is fixing. I can sign the form and FAX I suppose, but can you sign for me?

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Environmental Calculation File

200-BP-5 Treatability Test Technical Support Capture Zone Analysis

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Terms

BMC	B-Complex TMR model
CHD	constant head (the time-variant specified-head package of MODFLOW used to simulate specified head boundaries that can change within or between stress periods)
ECF	environmental calculation file
FS	Feasibility Study
F&T	fate and transport
HFB	horizontal flow barrier (the horizontal flow barrier package of MODFLOW used to simulate barriers to flow by reducing the conductance between individual pairs of cells)
HISI	Hanford Information System Inventory (database)
P2R	Plateau to River (model)
P&T	pump-and-treat
REC	remediation evaluation case
RI	Remedial Investigation
TEDF	Treated Effluent Disposal Facility
TMR	telescopic mesh refinement

1 Purpose

A local area submodel of the Plateau-to-River (P2R) Model was developed with telescopic mesh refinement (TMR) and used to simulate drawdowns and capture zones of extraction wells in the vicinity of the B-Complex for different P&T scenarios. The drawdown and capture zone analyses were performed to ensure that the P&T remedial actions under consideration are hydraulically feasible.

A pumping test was carried out in well 299-E33-268 to evaluate the hydraulic properties of the Hanford and Cold Creek formations in the vicinity of the B-complex. Drawdown equilibrated after only 3 days due to the high transmissivity of the aquifer. The test analysis resulted in minimum, average, and maximum estimates of hydraulic conductivity and specific yield.

The purpose of this environmental calculation file (ECF) is to evaluate the drawdowns simulated with the TMR model by comparison to the drawdowns observed in the 3-day pumping test, and subsequently evaluate drawdowns and capture zones assuming 5 years of pumping in well 299-E33-268. The drawdown analyses performed for the 3-day pumping test are carried out through comparison to drawdown in well 299-E33-268 as well as drawdowns in a number of observation wells located inside and around the B-Complex. Three parameter sets of hydraulic conductivity and specific yield are used corresponding to the minimum, average, and maximum values derived from the pumping test. The same parameter sets are then used to evaluate drawdowns and capture zones for a 5-year pumping period and assuming three different scenarios corresponding to low, medium, and high pumping rate.

2 Background

A detailed description of the site background is provided in Chapter 3 of DOE/RL-2009-127, Draft A.

3 Methodology

The methodology for developing a TMR MODFLOW model is outlined in Leake and Claar (1999). The basic concept consists of using a numerical model with a relatively large domain and extracting simulated outputs from that model to develop the model inputs for a model with a relatively smaller domain where more detailed model discretization is desired. The boundary conditions for the sub-domain model are extracted from simulated results of the larger model. This method provides consistency between the larger domain and the sub-domain and allows the model to be used more efficiently for investigating local scale issues (Leake and Claar, 1999).

Calculations are performed using the TMR model extracted from the P2R numerical F&T model as described in ECF-200BP5-15-0009, *Evaluation of Plume Capture and Hydraulic Performance for B-Complex Vicinity Submodel for 200-BP-5 and 200-PO-1 Operable Units Feasibility Study Evaluation of Remedial Alternatives.* Both the P2R and the B-Complex TMR models are implemented in MODFLOW to calculate groundwater flow. The TMR model spans the B-Complex and Gable Gab evaluation areas of the P2R Model. In general, an investigated scenario is simulated with the P2R Model and the calculated hydraulic heads are mapped on the TMR model boundaries to create the boundary conditions for the TMR. Similarly, initial hydraulic heads for the TMR model are extracted from the parent P2R simulation. Flow properties are extracted from the P2R Model and mapped onto the corresponding TMR model grid blocks. As discussed in Section 7, the P2R Model corresponding to the no-action scenario was used to parent all of the TMR simulations. Accordingly, flow properties were changed in the TMR model variants alone without re-running the parent P2R Model. A comparison of this approach to TMR models that were derived from P2R Model variants that take into account pumping scenarios as well as modified flow properties is also discussed in Section 7.

4 Assumptions and Inputs

4.1 Model Domain

The spatial discretization of the TMR Model is selected to provide as accurate a representation as possible of the drawdown and capture zone while allowing the model to produce results in a reasonable time. To this end, variable horizontal gridding was applied, with model nodes separated by 2 m in the vicinity of preliminary extraction and injection well locations and extending as far as 200 m elsewhere. Figure 4-1 shows the TMR grid. Layer elevations from the P2R Model were then interpolated bi-linearly on the TMR grid. Figure 4-2 shows a comparison between the parent P2R Model and the TMR model.

4.2 Simulation Periods

The simulations with the TMR model comprise two groups: (1) simulations carried out for comparison to the 3-day pumping test, and (2) simulations carried out for the evaluation of the 5-year pumping scenario. The simulated timeframes are selected accordingly.

Simulating the 3-day pumping test was performed by first computing a steady-state period to be sure there are no artificial transient effects. A 3 day transient stress period is then simulated with the test pumping rate, and then another transient period is simulated to represent the recovery phase after pumping stopped.

The 5-year pumping scenario was simulated by first computing a steady-state stress period. Each subsequent year is simulated with 8 transient stress periods, each simulated with 6 time steps corresponding to two-month increments.

4.3 Processes Simulated and Limitations to the Simulation

The MODFLOW/MT3DMS family of numerical groundwater simulators estimates groundwater flow and fate and transport based using packages that represent certain processes occurring in nature. For this simulation the processes and corresponding simulation packages are shown in Table 4-1. The table includes any limitations that the implementation of the particular package in MODFLOW/MT3DMS may impose on the model.

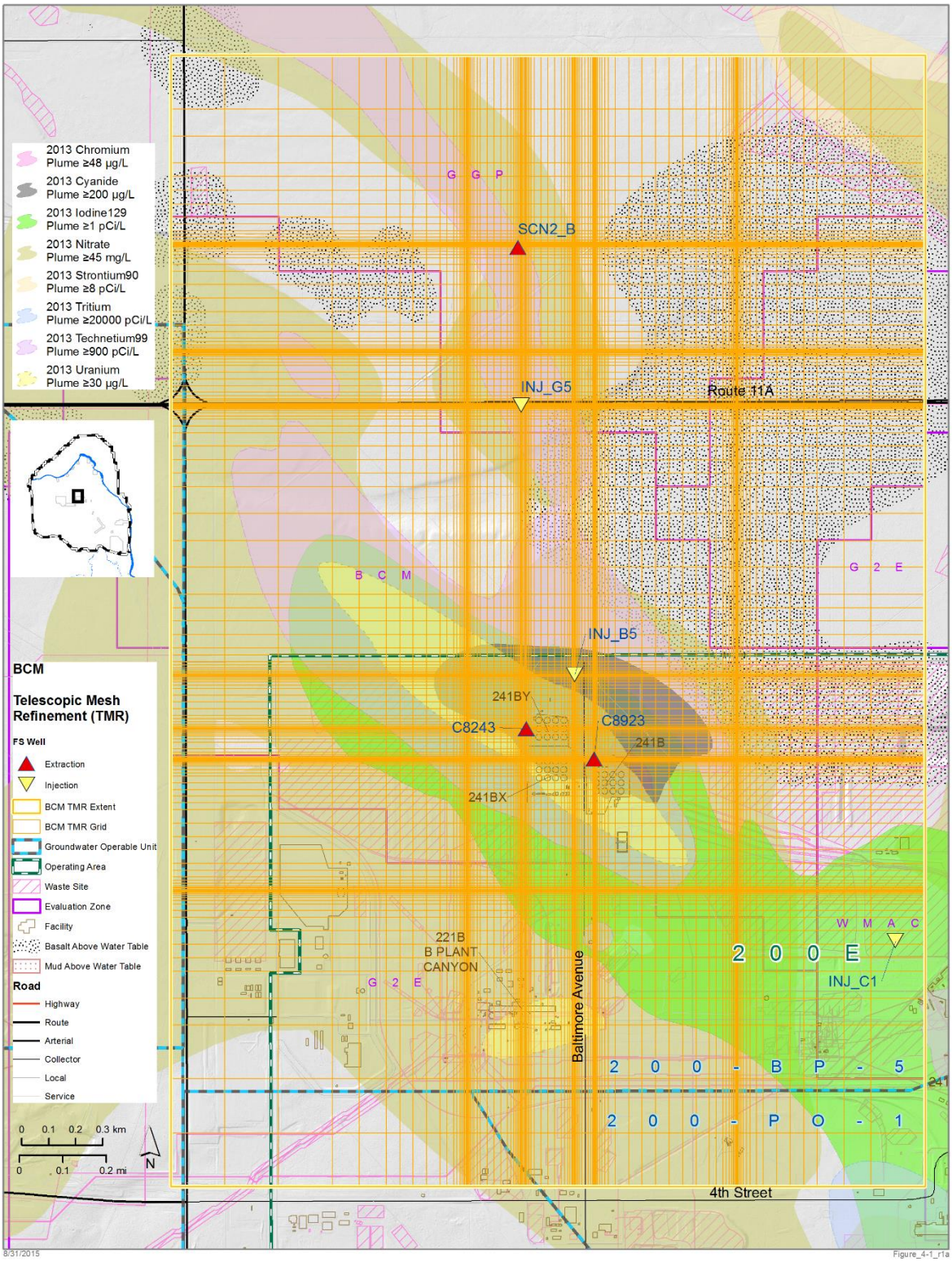


Figure 4-1. B-Complex TMR Model Extent

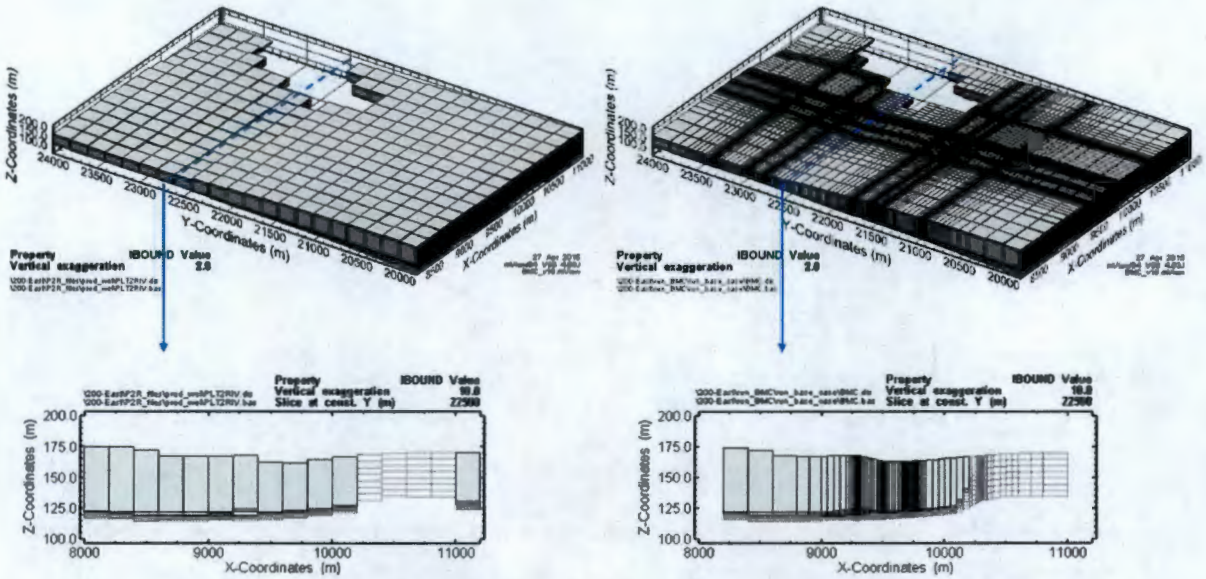


Figure 4-2 Comparison between P2R Model (left) and B-Complex TMR Model Mesh (right)

Table 4-1. Groundwater Processes, Simulated Packages, and Limitations for the P2R Model

Groundwater Process		MODFLOW/MT3DMS Package	Limitations (if any)
Groundwater Flow	Recharge	Recharge Package	Considered recharge that arrives at the groundwater
	Columbia River	River Package	
	Injection/Extraction	Well Package	No multiwell interaction
	Head at model boundaries	CHD package	Assessment of remedial alternatives that effect flow of water should be sufficiently far from boundaries as to not significantly influence flow through the CHD boundaries
	May Junction Fault	HFB Package	

4.4 Hydrostratigraphy of the Unconfined Aquifer

The geologic representation for the model is derived from the Hanford South Geoframework Model (HSGM) (ECF-Hanford-13-0029, *Development of the Hanford South Geologic Framework Model, Hanford Site, Washington*). The HSU definitions presented in ECF-Hanford-13-0029 include the Hanford and Cold Creek formations and the Ringold formation with the Taylor Flat, Unit E, Upper Mud, and Unit A members of that formation. Seven model layers are used to represent the seven HSUs are defined in the HSGM. Assignment of a numerical cell to an HSU is not dependent on model layer. The details regarding the assignment of HSUs to model layers are recorded in CP-57037, *Plateau to River Groundwater Transport Model Package Report*. The hydraulic properties of the HSUs in the P2R Model were estimated through model calibration as described in CP-57037.

The assignment of the HSUs in the B-Complex TMR was carried out by identifying and mapping the HSUs from the P2R Model onto the TMR grid for each layer. The HSUs per model layer in the TMR are shown in Figure 4-3. In the largest part of the model, the Hanford and Cold Creek formations corresponding to the paleo-channel lie directly above the basalt. Ringold Unit A is present below the Hanford/Cold Creek formation in the south, whereas Ringold Unit E and Ringold mud HSU's are only locally present at the south corners of the model. The hydraulic properties were then assigned to each HSU in the TMR using the values from the P2R Model calibration as shown in Figure 4-3. Furthermore, Figure 4-4 shows cross-sections of horizontal hydraulic conductivity in the west-east direction for Y = 21,000 and Y = 23,000 m, and in the north-south direction for X = 9,000 and X = 10,300 m. White cells with gray edges denote inactive cells of the basalt. It is indicated that the hydrostratigraphy in the TMR model domain is dominated by the high-permeability Hanford/Cold Creek formation (K = 17,000 m/d). Bottom elevations of the Hanford/Cold Creek formation range approximately between 110 and 120 m in the central part of the model. The north-south cross-sections indicate that the Hanford/Cold Creek formation dips in the northernmost part of the model, and in the south where it contacts the underlying Ringold units. Bottom elevations are somewhat higher in the north, where the thickness of the Hanford/Cold Creek formation decreases.

4.5 Boundary Conditions

The boundary conditions for the numerical model represent interactions with the aquifer by water external to the model. These include water infiltrating through the vadose zone that becomes recharge, movement to and from the Columbia River, liquid discharges from waste sites, and extraction and injection at well locations. Figure 4-5 illustrates the locations and types of boundary conditions used to construct the P2R Model. The details of each of these boundary conditions are discussed below.

4.5.1 Upper Boundary (Recharge)

The recharge boundary condition represents water that from the top surface of the model infiltrates through the vadose zone until reaching the saturated zone. This water can originate naturally or by anthropogenic sources such as waste site discharge. Each of these types of sources of recharge was included in the model using the MODFLOW Recharge package which represents recharge as a specified flux (i.e., second-type or Neumann) boundary condition.

Natural Recharge

The natural component of recharge includes water originating as precipitation and infiltration through the vadose zone that ultimately reaches the saturated zone as recharge.

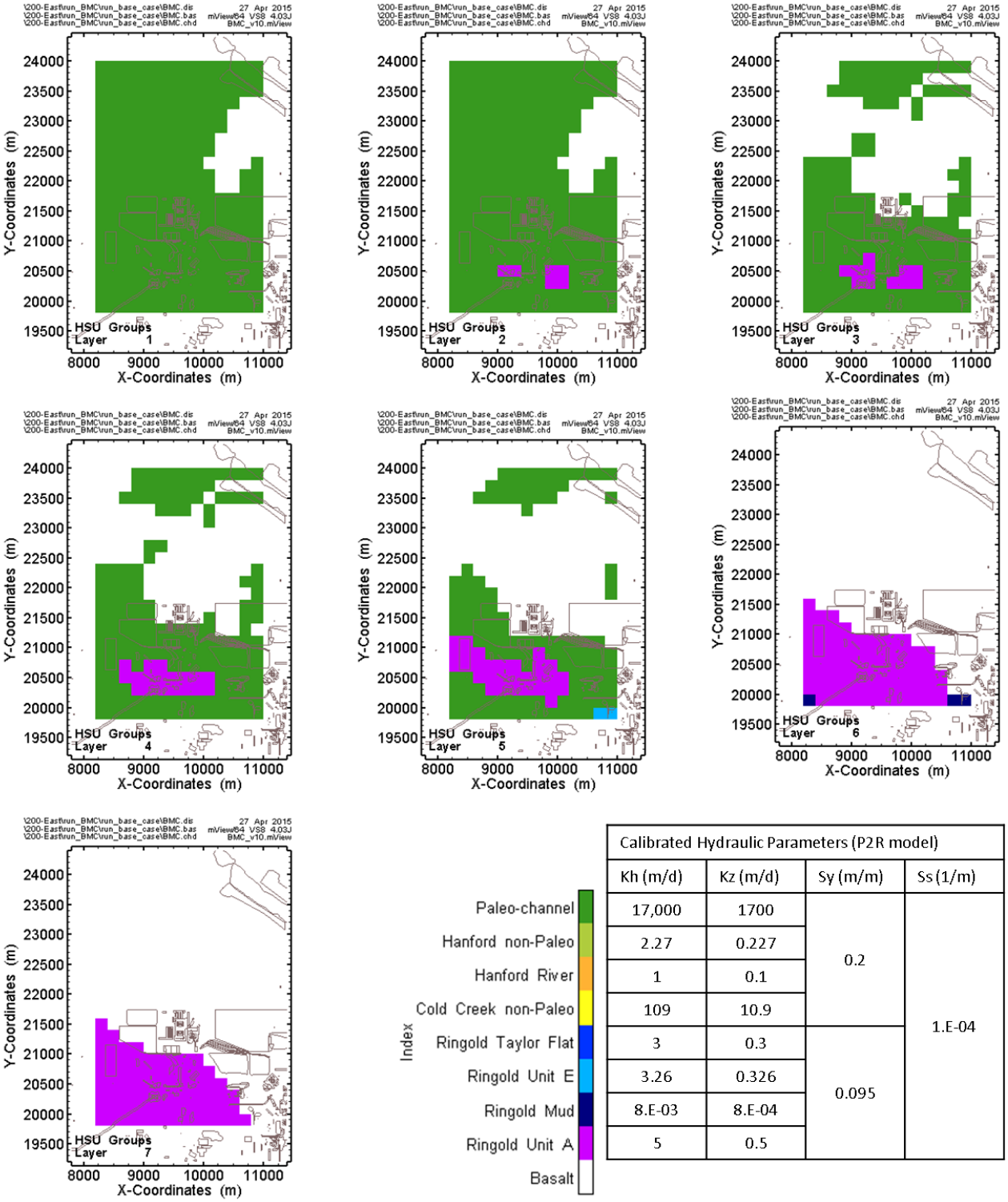
Anthropogenic Recharge

The anthropogenic component of recharge includes fluxes from surface water discharge due to operations at the Hanford Site, including the Treated Effluent Disposal Facility (TEDF).

The upper boundary conditions for the TMR model are extracted for each stress period from the P2R Model. Coordinates from the P2R Model grid faces coincide with grid faces in the finer TMR mesh, so that recharge values from the P2R Model are essentially mapped onto the first layer of the TMR grid. Figure 4-6 shows an example of recharge mapped from the P2R to the BMC TMR for the first stress period of the transient simulation.

4.5.2 Lower Boundary

The base of the numerical model (bottom of model layer 7) is simulated as a no-flow boundary.



Calibrated Hydraulic Parameters (P2R model)			
Kh (m/d)	Kz (m/d)	Sy (m/m)	Ss (1/m)
17,000	1700	0.2	1.E-04
2.27	0.227		
1	0.1		
109	10.9		
3	0.3	0.095	
3.26	0.326		
8.E-03	8.E-04		
5	0.5		

Figure 4-3. Hydrostratigraphic Units (HSUs) in the B-Complex TMR Model Layers

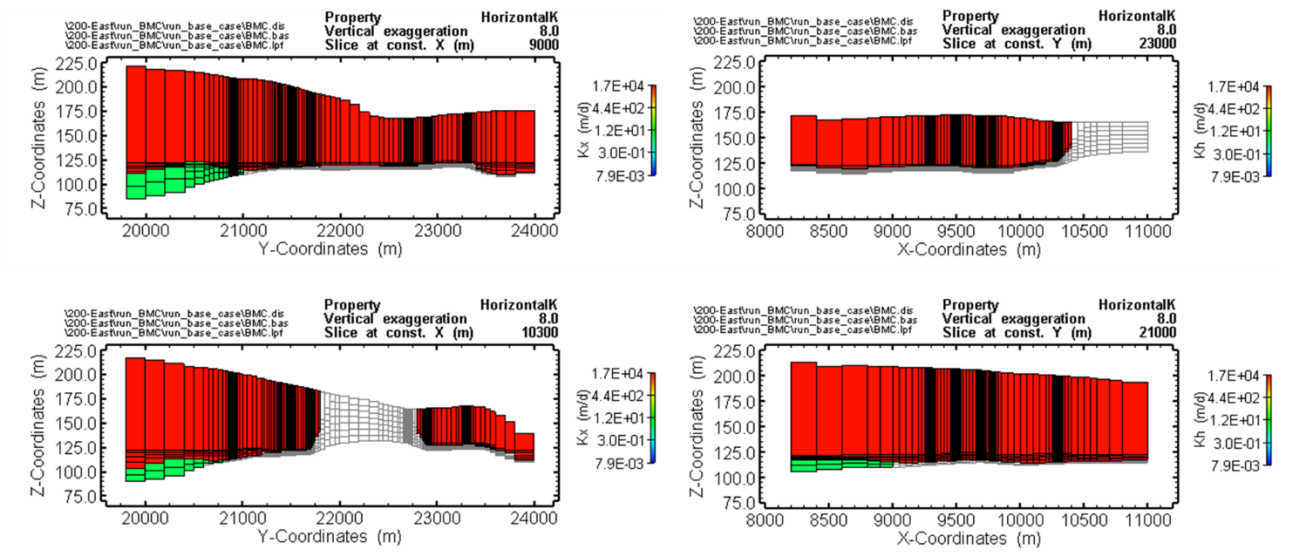


Figure 4-4. Cross-sections of Hydraulic Permeability in the B-Complex TMR Model (left: constant X; right: constant Y)

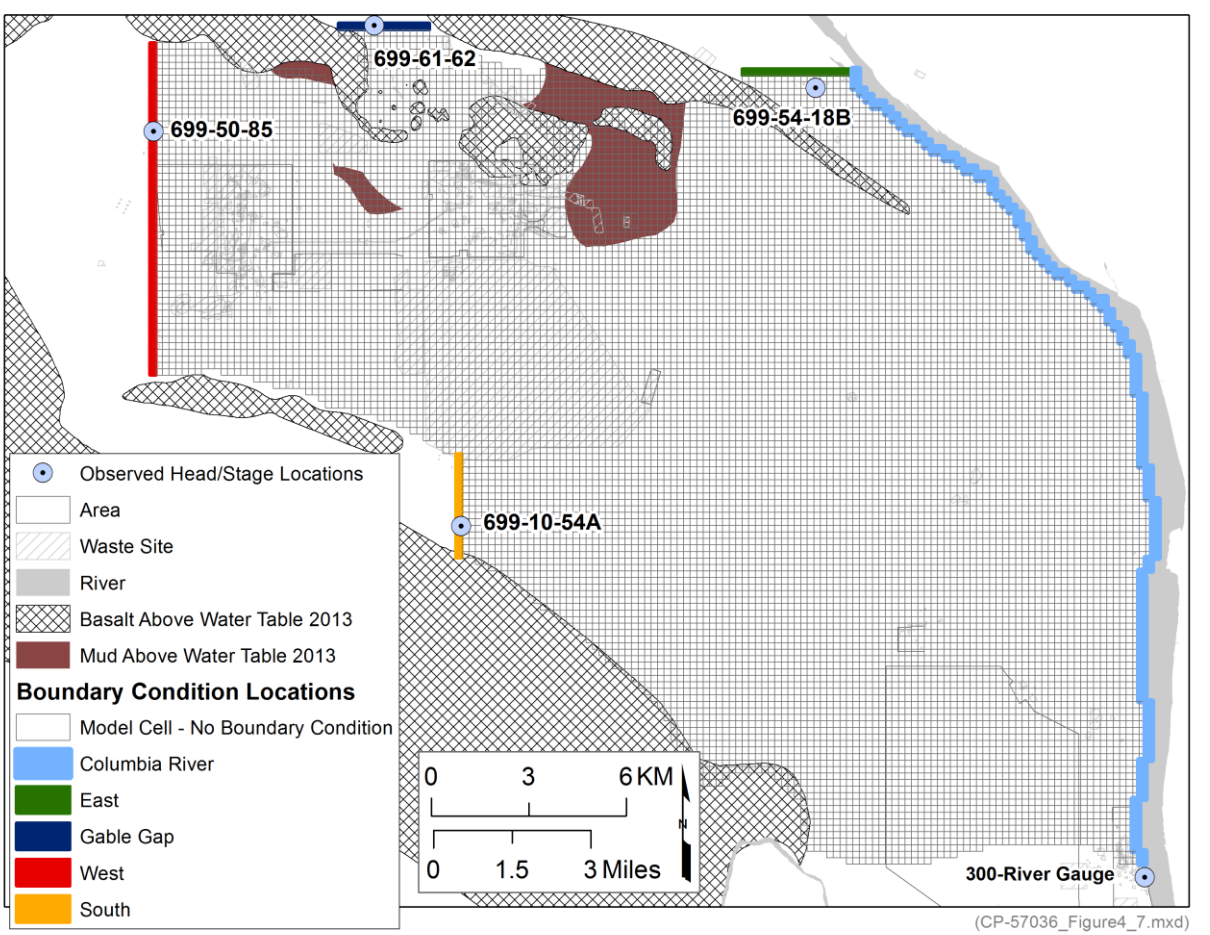


Figure 4-5. Boundary Condition Locations used for the P2R Model

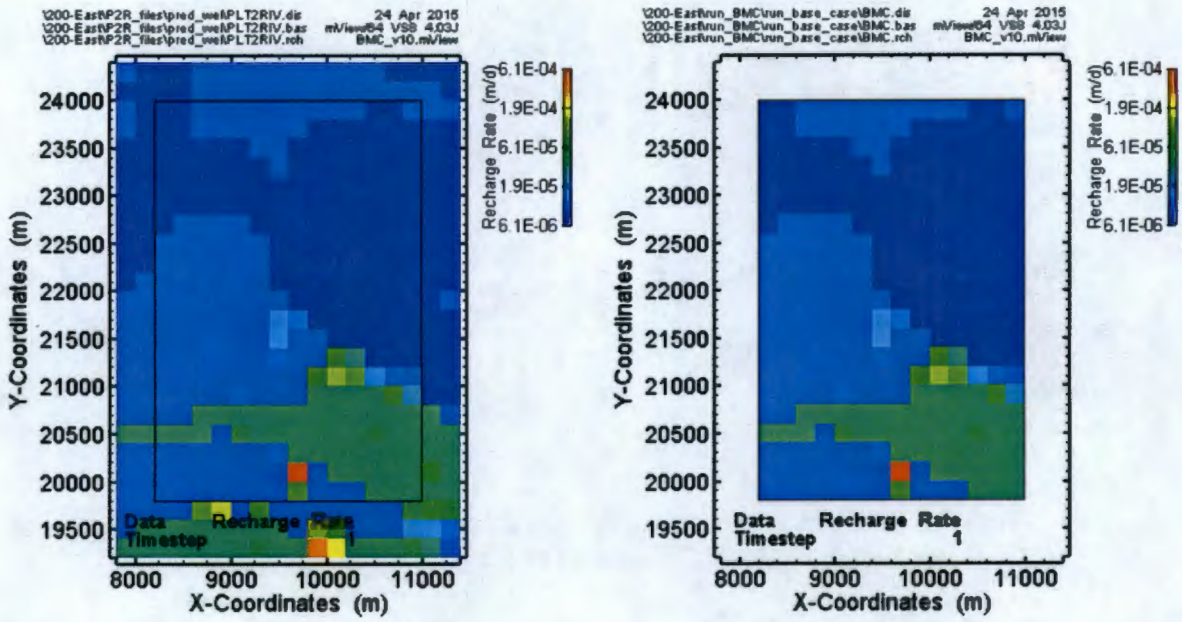


Figure 4-6. Recharge Interpolation from the P2R Model Grid onto the TMR Grid for the First Stress Period of the Transient Simulation

4.5.3 Lateral Boundaries

Lateral boundaries in the P2R Model are assigned one of the following types:

- Specified head boundaries;
- No-flow boundaries;
- Mountain-front inflow boundaries;
- General head boundaries (Columbia River).

The lateral boundary conditions for the TMR model are extracted from the P2R Model and mapped onto the TMR grid.

First, nodes that need to be inactive in the TMR were identified by mapping the P2R properties onto the TMR grid for each layer as explained in Section 4.4 (i.e. basalt above groundwater). Boundary nodes belonging to the basalt were assigned no-flow boundaries.

The remaining active boundary nodes were assigned specified head boundary conditions. For this, heads simulated with the parent P2R Model were mapped onto the active TMR nodes along the lateral boundaries of the TMR grid for each of the 51 stress periods and for each model layer. An example is shown in Figure 4-7. The boundary heads were then written out as time-dependent specified head boundaries using the CHD package of MODFLOW.

Mountain-front inflow boundaries and general head boundaries associated with the Columbia River are not present in the B-Complex TMR domain.

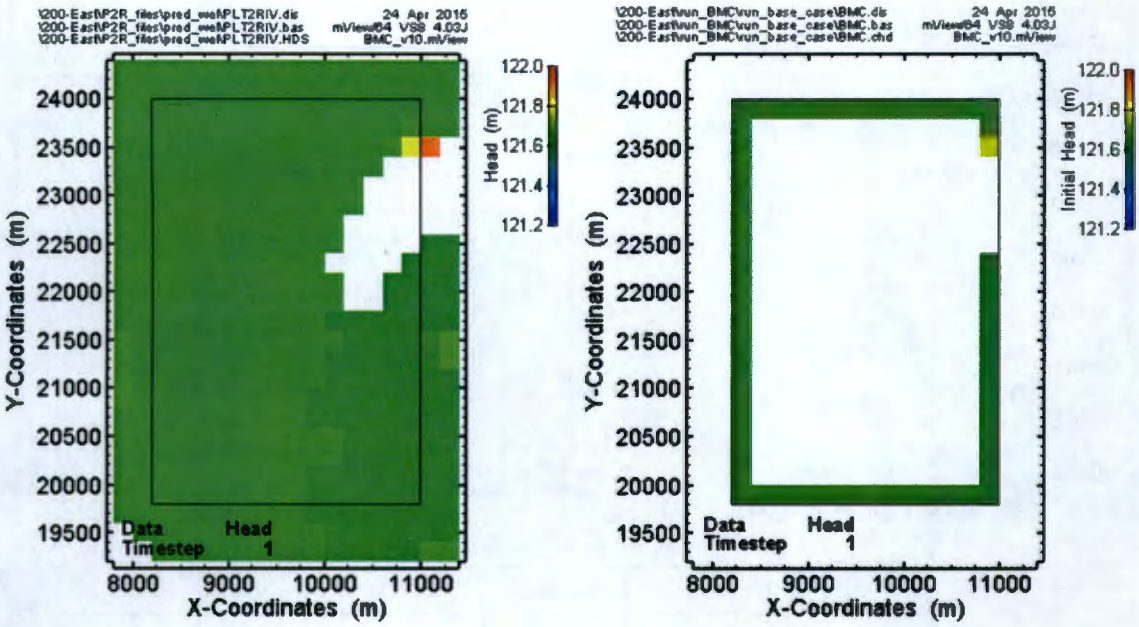


Figure 4-7. Interpolation of Heads from the P2R to the TMR Grid Boundaries for the First Stress Period of the Transient Simulation

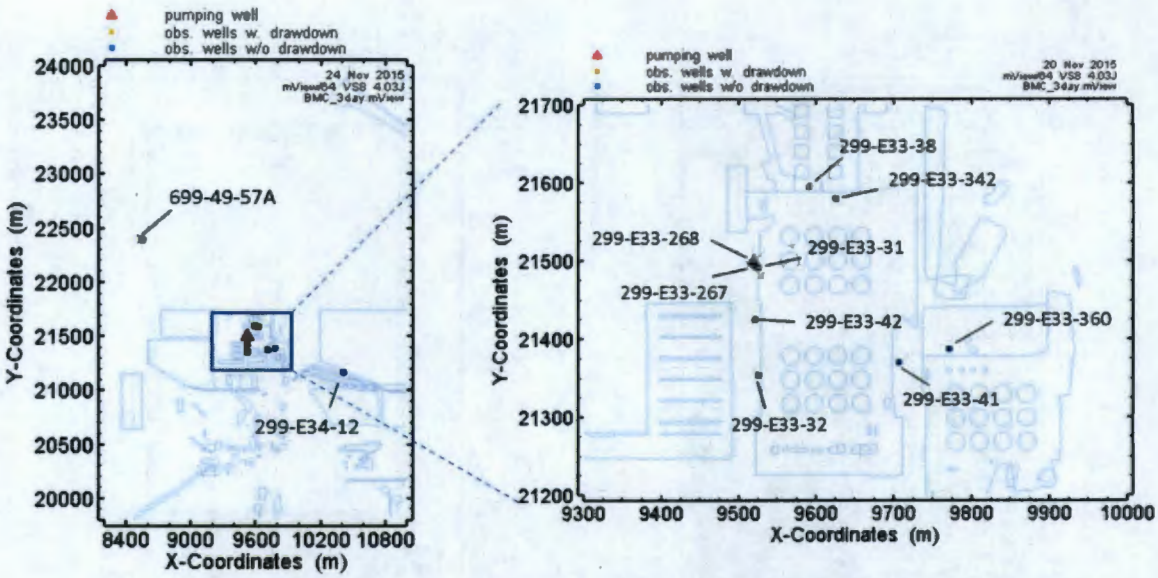
4.5.4 Pumping and Observation Wells

Pumping in well 299-E33-268 is modeled using the Modified Multi-Node Well Package (MNW2). Additional well locations were used to evaluate drawdowns during the 3-day pumping test and the 5-year pumping scenarios. The locations of the wells and drawdowns measured at the end of the 3-day pumping test are shown in Figure 4-8. Drawdown was measured in observation wells marked in yellow, whereas observation wells marked in blue did not indicate any measurable drawdown.

4.5.5 Initial Hydraulic Head Distribution

The initial hydraulic head distribution was determined using a steady state stress period at the beginning of the simulation where boundary conditions assignments matched the first transient simulation period.

As with boundary conditions, the initial conditions are extracted from the node values in the P2R Model.



Well	299-E33-268	299-E33-267	299-E33-E31	299-E33-42	299-E33-38	299-E33-342
Distance from 299-E33-268 (m)	0	4.62	9.23	74.31	119.8	133.92
Drawdown (m)	0.02	0.013	0.011	0.002	0.006	0.006

Figure 4-8. Pumping and Observation Well Locations and Measured Drawdown

5 Software Applications

Software used to perform this calculation are approved, managed, and used in compliance with the CH2M Hill Plateau Remediation Company (CHPRC) requirements of PRC-PRO-IRM-309, *Controlled Software Management*.

5.1 Exempt Software

Microsoft Excel®[1] is site-licensed software used as "flat file" spreadsheets that are wholly incorporated into this calculation and verified during the technical review of this report, and is therefore rated as exempt software (PRC-PRO-IRM-309, Section 1.3, Exemptions). Excel® spreadsheets were used to tabulate average monthly and long-term hydraulic head and river stage data for model input, and chart modeling results produced by MODFLOW-2000 and MT3DMS-MST.

[1] Excel is a registered trademarks of Microsoft Corporation in the United States and other countries.

5.2 Approved Software

MODFLOW-2000-MST is an approved calculation software (CHPRC-00258, *MODFLOW and Related Codes Software Management Plan*). PEST, ArcGIS®[2], and Groundwater Vistas™[3] are approved support software (CHPRC-00258).

5.2.1 MODFLOW-2000-MST

- Software Title: MODFLOW-2000-MST
- Software Version: CHPRC Build 6 (executable "(mf2k-mst-chprc06dp.exe"), double precision compilation
- Hanford Information System Inventory (HISI) Identification Number: 2517 (Safety Software, Level C)
- Authorized Workstation type and property number: Personal Computer, PSC-Lithium and Personal Computer, ID tag KXGVD
- Authorized Users: H Rashid and A Papafotiou
- Software Vendor Documents:
  - Harbaugh et al. (2000), *MODFLOW-2000, the U.S. Geological Survey modular ground-water model -- User guide to modularization concepts and the Ground-Water Flow Process*
  - SSPA (2012a), *Documentation for: MODFLOW-2000-SSPA Build 006 Modifications and options added to MODFLOW-2000*
- CHPRC Software Control Documents:
  - CHPRC-00257, *MODFLOW and Related Codes Functional Requirements Document*
  - CHPRC-00258, *MODFLOW and Related Codes Software Management Plan*
  - CHPRC-00259, *MODFLOW and Related Codes Software Test Plan*
  - CHPRC-00260, *MODFLOW and Related Codes Requirements Traceability Matrix*
  - CHPRC-00261, *MODFLOW and Related Codes Acceptance Test Report*

5.2.2 MODFLOW & Related Codes Support Software

CHPRC-00257 distinguishes calculational software from supporting software because these two groups of software are classified and graded differently. The basis for the difference is that calculational software, including MODFLOW-2000-MST, calculate results that will be used to support decision-making and as such, constitute safety software graded to level C. In contrast, supporting software includes graphical interfaces, visualization, and input preparation support but not calculation of results that directly support

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[2] ArcGIS is a registered trademark of ESRI in the United States and other countries.

[3] Groundwater Vistas is a trademark of Environmental Simulation, Inc.

decision-making, and are therefore not rated as safety software. The support software items identified in CHPRC-00258 and used in this calculation were:

- **MODPATH**: USGS version of MODPATH version 6.0 (mp6x64.exe) was used for capture zone analysis.
- **Groundwater Vistas®:** (*Guide to Using Groundwater Vistas* [Rumbaugh and Rumbaugh, 2007].) Used graphical tools for model input/output review. Groundwater Vistas™ was used in pre-processing some input files.
- **mView:** Used for developing the TMR model, interpolating information from the P2R Model, and generating MODFLOW input. Provided post-processing tools including extraction and visualization of simulated heads, flows, and pathlines.
- **ArcGIS®[4]:** (The ESRI Guide to GIS Analysis, Volume 1: Geographic Patterns and Relationships [Mitchell, 1999].) Provided visualization tool for assessing simulated plume distributions, identifying extraction/injection well coordinates and mapping auxiliary data. ArcGIS® was used in pre- and post-processing simulation results.
- **PEST**: ([Doherty, 2007]) Used for automated calibration. Pre- and post-processing utilities distributed with the support software PEST were used to facilitate efficient simulation execution.
- **ARANZ LeapFrog-Hydro®**: Used to assign model layers based on current interpretation of geologic units present within the model domain.
- **Microsoft Excel®:** Developed model input files and used to calculate average monthly and daily hydraulic head and river stage estimates.

5.3 Software Installation and Checkout

Safety Software (MODFLOW-2000-MST and MT3DMS-MST) was checked out and installed in accordance with procedures specified in CHPRC-00259. Executable files were obtained from the Software Owner, installation tests identified in CHPRC-00259 were performed and confirmed, and Software Installation and Checkout Forms were completed and approved for installations used to perform model runs reported in this calculation. A copy of the Software Installation and Checkout Forms for the authorized users and authorized workstations for software used that requires this documentation are provided in Attachment A to this ECF.

5.4 Statement of Valid Software Application

The preparers of this calculation attest that the software identified above, and used for the calculations described in this calculation, is appropriate for the application and used within the range of intended uses for which it was tested and accepted by CHPRC. Because MODFLOW-2000-MST is graded as Level C software, use of this software is logged in the HISI under the corresponding entries (Identification Numbers 2517 and 2518). These software items were used within the limitations identified in CHPRC-00257. Installations of the software are operating correctly, as demonstrated by installation testing performed on the workstations mentioned above and documented in the Software Installation and Checkout Form (Attachment A).

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[4] ArcGIS® is a registered trademark of ESRI Corporation.

6 Calculation

The pumping test was carried out in well 299-E33-268 to measure drawdowns and estimate hydraulic properties of the Hanford/Cold Creek formation. The test lasted 3 days and resulted in estimated minimum, average, and maximum values of hydraulic conductivity and specific yield. Based on the previous analyses performed with the B-Complex TMR model (ECF-200BP5-15-0009), different pumping rates are considered for a pumping period of 3 to 5 years for this well. This section describes how the 3-day pumping test and the 5-years pumping scenarios were implemented in the numerical simulations carried out with the B-Complex TMR model, with the specific objective of comparing simulated to measured drawdowns, and evaluating capture zones by means of particle tracking.

6.1 Transient Simulations

The transient simulations are split into two groups depending on the purpose of the model, namely: (1) the simulations carried out for comparison to the 3-day pumping test, and (2) the simulations carried out for the evaluation of the 5-year pumping scenarios.

The simulations used for the comparison to the 3-day pumping test are implemented in the B-Complex TMR by assigning the corresponding pumping rate of 125 GPM in well 299-E33-268 between September 01 and September 03 2015 (see also Section 4.2). Four different sets of hydraulic conductivity and specific yield are used in different simulation variants, corresponding to the unchanged parameters of the P2R and TMR model, and the minimum, average, and maximum values estimated with the pumping test (Table 6-1). Moreover, an additional simulation is performed using hydraulic conductivity fitted to drawdown in well 299-E33-268 by trial-and-error. As the 3 day pumping period was too short to create a capture zone or affect hydraulic heads at the boundaries of the TMR, the P2R Model corresponding to no-pumping (i.e. no remediation actions implemented) was used to parent the daughter TMR model.

The simulations carried out to evaluate the 5-year pumping scenarios are implemented by assigning a pumping rate in well 299-E33-268 between January 1, 2016 and December 31, 2020 (see also Section 4.2). Similarly to the 3-day pumping test simulations, four sets of hydraulic conductivity and specific yield are implemented corresponding to the unchanged TMR parameters, and the average, minimum, and maximum values estimated with the pumping test (Table 6-1). For each parameter set, three scenarios are simulated corresponding to a pumping rate of 50, 100, and 150 GPM in well 299-E33-268. For 3-day pumping test simulations and drawdown analysis on 5-year pumping scenarios, the TMR model has been derived from both pumping and no-pumping runs of the P2R Model to allow comparison and evaluation of the hydraulic head boundary effects. Particle tracking analysis on 5-year pumping scenarios was first carried out with the TMR model derived from the no-pumping P2R simulation. Moreover, the TMR model was then calibrated to fit the gradient (i.e., magnitude and direction) in the vicinity of the B-complex. The calibrated flow model was used for the particle tracking analysis. The details of the calibration process is described in Section 6.1.1.

Table 6-1. Parameter Sets used in the Numerical Simulations

Parameter Set	Hydraulic Conductivity (m/d)	Specific Yield (-)
Unchanged TMR values	17,000	0.20
Average values	18,800	0.21
Minimum values	15,800	0.11
Maximum values	21,300	0.31

6.1.1 Flow Model Calibration

The CHD boundary conditions of the B-complex TMR were calibrated to match the current interpretation of the water table surface in the vicinity of the B-complex area (Figure 6-1). The gradient of the water table surface (i.e., magnitude and direction) in the vicinity of B-complex was calculated from the current interpretation of the water table surface and used as the primary calibration targets in the calibration setup. Though the main goal for the calibration was to match the water table gradient in the vicinity of B-complex, a few heads along the interpreted contour lines of the water table were also used as the calibration targets so that there were enough targets within the model domain for overall consistency. The PEST (Doherty, 2007) parameter estimation software was used to facilitate estimates of CHD boundary conditions along with manual adjustments. The following steps were followed to construct and run the PEST model for B-complex TMR:

1. All the MODFLOW model files are same as the base B-complex TMR model (derived from no pumping scenario of P2R Model) except the CHD package.
2. The CHD boundary condition was parameterized by points interpolated over the model grid via ordinary kriging. This approach is termed the "pilot point" method of parameterization (Doherty, 2003).
3. Pilot points are chosen such a way so that there is always at least 2 pilot points and a maximum of 5 pilot points along a row/column for each layer. Moreover, pilot points are distributed spatially so that at least 2-3 points are available for interpolation within the correlation scale range (range). A total of 16 pilot points (i.e., PEST adjustable parameters) were finalized to be used in the PEST framework for calibrating CHD boundary conditions. For any layer, if a pilot point falls into an inactive cell the point is removed from the calculation. For example, all the 16 pilot points in layer 1 were used to calculate CHD boundary condition as all of them fall into active CHD boundary cells. On the other hand, only 5 pilot points in Layer 7 were used to calculate CHD boundary as 11 other pilot points fall into the inactive cells.
4. A zonation file for each model layer was created using the Groundwater Vistas software where CHD boundary cells were assigned to one zone and rest of the model cells were assigned to another zone.
5. The PEST groundwater utility PPK2FAC was used to generate kriging factors from the pilot points at each layer for all the CHD boundary cells. A spherical variogram with a correlation range of 1,000 m was used to characterize spatial variability of CHD boundary conditions. The PEST groundwater utility FAC2REAL was used to calculate CHD at each boundary cell based on the pilot point values and kriging factors generated by PPK2FAC program. A Fortran code (dochd.exe) was used to read the FAC2REAL generated CHD boundary condition and write in MODFLOW CHD package format.
6. PEST was used to get a calibrated model which fits the observation targets reasonably. Some of the PEST estimated parameters were manually adjusted for conceptual reasonableness.

The location of the pilot points that were used to calculate CHD boundary condition are shown in Figure 6-1. Figure 6-1 also shows the current interpretation of the water table surface contours and the hydraulic gradient network locations which were used as observation targets to calibrate the model. A comparison between current interpretation of water table contour and simulated water table contour is shown in Figure 6-2. The comparison between observed and simulated hydraulic gradient (i.e., magnitude and direction) is tabulated in Table 6-2. Table 6-2 clearly shows that the simulated hydraulic gradient fits

reasonably to observed data. Calibrated CHD boundary condition was used for all the stress periods in the flow model for particle tracking analysis.

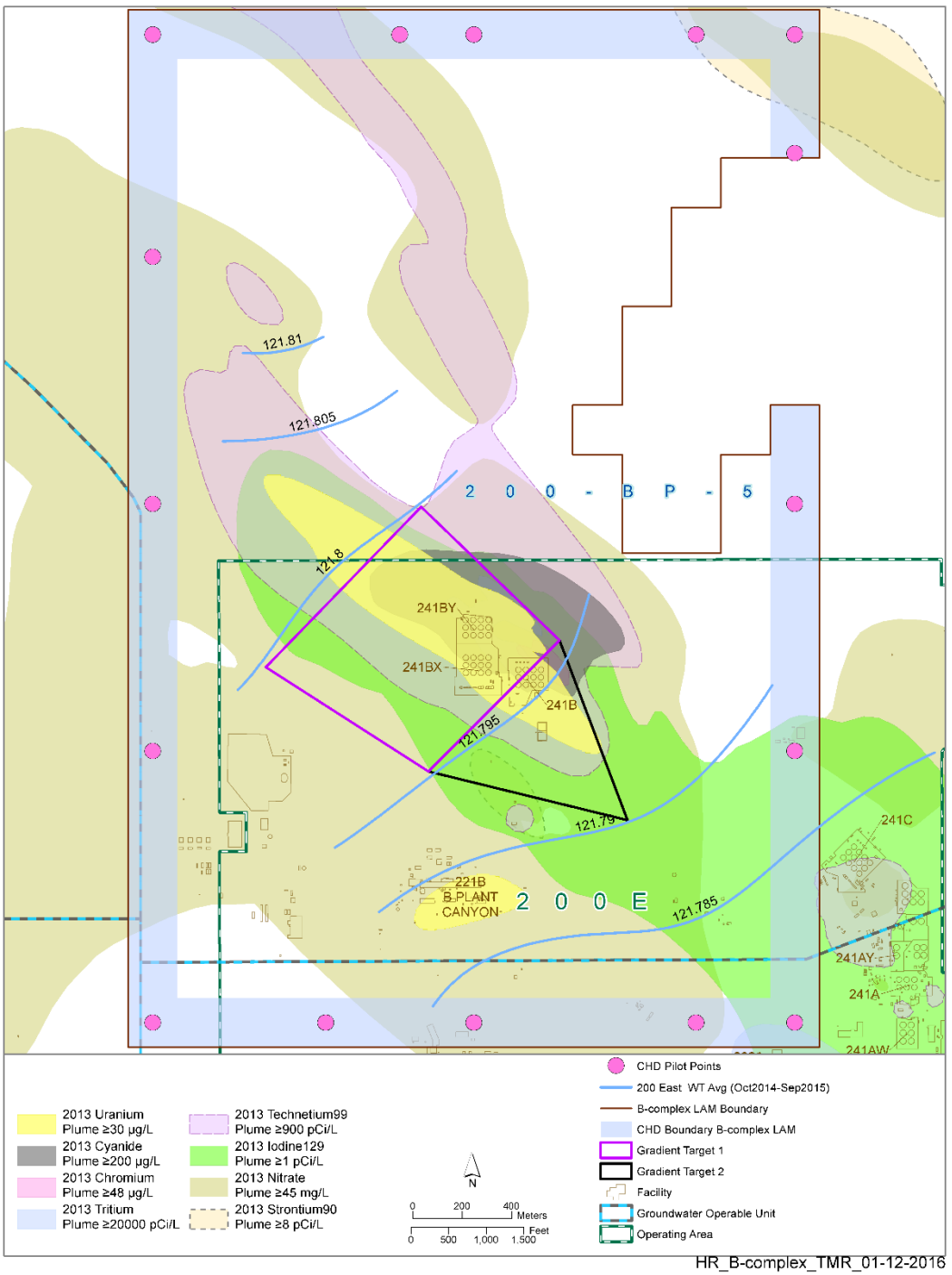

Figure 6-1. Pilot Point Locations, Current Interpretation of Water Table, and Calibration Targets within B-Complex TMR Model

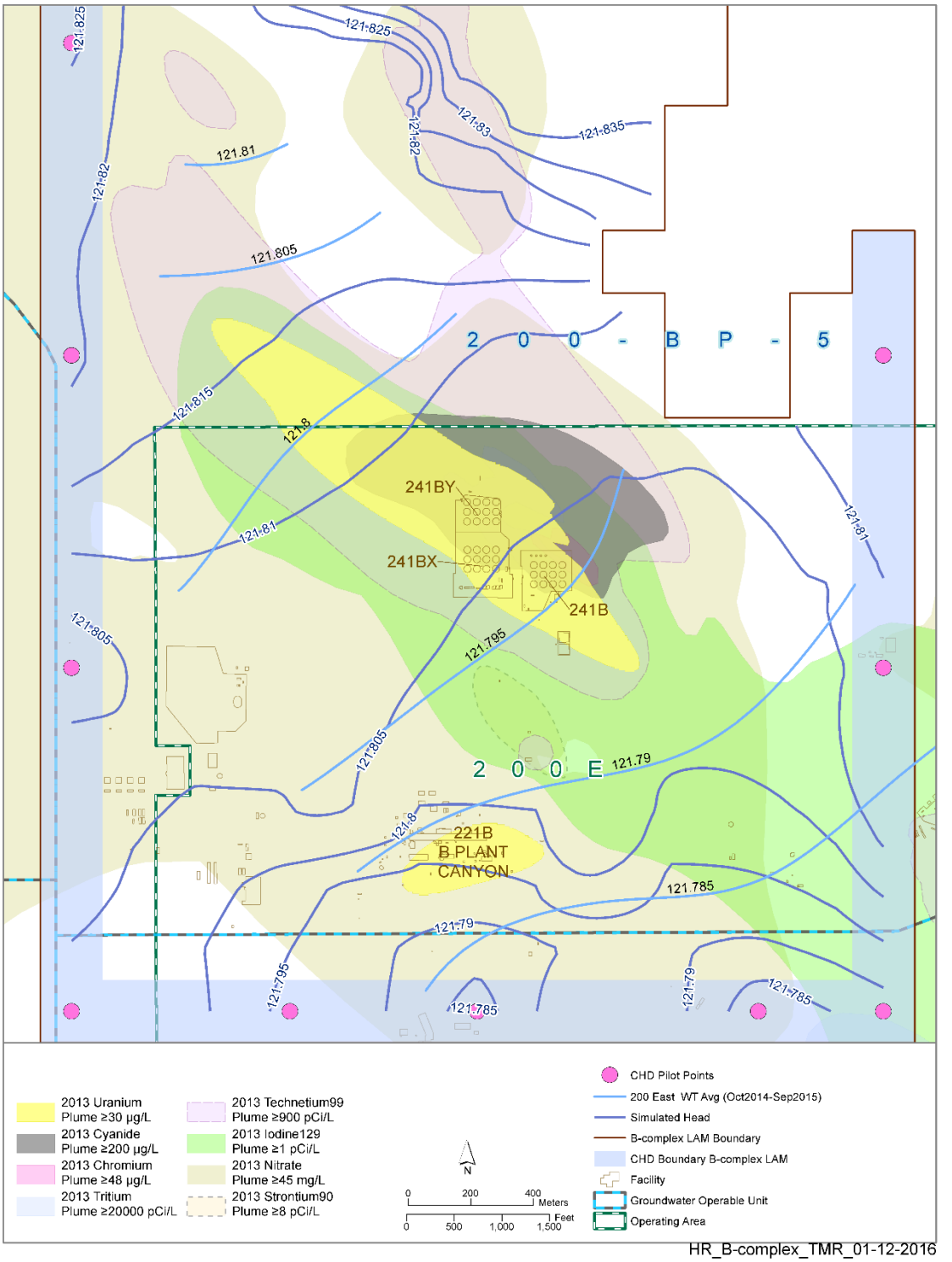

Figure 6-2. Comparison between Current Interpretation of Water Table Contours and Simulated Head Contours at Water Table in the Vicinity of B-Complex Area

Table 6-2. Comparison between Observed and Simulated Hydraulic Gradient

Target Name	Observed Azimuth (Degree)	Simulated Azimuth (Degree)	Residual Azimuth (Degree)	Observed Magnitude (m/m)	Simulated Magnitude (m/m)	Residual Magnitude (m/m)
Target 1	135.00	143.42	-8.42	6.5E-06	8.21E-06	-1.71E-06
Target 2	135.00	130.87	4.13	7.1E-06	5.56E-06	1.54E-06

6.2 Particle Tracking

Particle tracking algorithms allow the estimation of pathlines for a given velocity field in an aquifer by appropriate interpolation of the velocity vectors. Each pathline is therein constructed as a series of locations of a particle at different times. When the calculation of particle locations is carried out with *forward tracking*, particles are released at specified locations (i.e. contaminant sources) and then tracked downgradient for a time frame specified by the user (i.e. until the end time of the flow simulation). On the other hand, *backward tracking* allows to identify the origin of particles that end up at locations specified by the user at selected times. Both methods are available in MODPATH and result in a pathline file that includes all discrete locations of every particle after each time step. It is thus possible to post-process this output and estimate all traveled distances and travel times associated with any location selected in an aquifer.

The transient hydraulic simulations carried out with the B-Complex TMR provide hydraulic heads and cell-to-cell flows across the model domain. In the simulations of the 3-day pumping test, no capture zone was formed due to the short time of pumping. In the case of the 5-year pumping scenarios, hydraulic heads and cell-to-cell flows simulated with the calibrated flow model are subsequently used as input for MODPATH simulations in order to delineate the capture zone of well 299-E33-268. For this, particles are released at the well location at the end of the 5-year pumping period, and tracked backwards.

7 Results/Conclusions

This section presents the results of all numerical simulations carried out with the B-Complex TMR model for the pumping test and capture zone evaluation. In Section 7.1, the metrics used to evaluate and compare numerical simulations are presented. Section 7.2 presents the results from the 3-day pumping test simulations. Section 7.3 presents the results from the capture zone analysis of the TMR model based on 5-year pumping scenarios.

7.1 Comparison and Evaluation Metrics

The following presents the comparison and evaluation metrics used for the 3-day pumping test simulations (Section 7.1.1) and for the 5-year pumping scenarios (Section 7.1.2).

7.1.1 3-day Pumping Test

The simulations for the 3-day pumping test are evaluated by means of drawdown analysis. To calculate drawdown at the pumping and observation well locations, an additional simulation is carried out using the parameter set and hydraulic head boundaries from each scenario but at the same time deactivating the

pumping well. Consequently, the head difference between the original scenario simulation (with wells) and the additional simulation (without wells) is calculated to filter out head changes related to the transient boundary condition and thus obtain the local "net" changes at the well locations due to water extraction and injection. The time-histories of calculated drawdown are then compared to the maximum drawdown measured after 3 days of testing at the corresponding locations (Figure 7-1, left). Time on the horizontal axis corresponds to days after the beginning of the pumping test. Measured drawdowns are thus assigned to $t = 3$ days for comparison to the simulation. The well locations and values of measured drawdowns are shown in Figure 4-8.

7.1.2 5-year Pumping Scenarios

The simulations for the 5-year pumping scenarios are evaluated by means of drawdown analysis as well as capture zone analysis.

Drawdowns are calculated in a similar manner as done for the 3-day pumping test simulations. In this case, time on the horizontal axis corresponds to time from the beginning of the simulation, thus pumping takes place between $t = 3$ years and $t = 8$ years (Figure 7-1, right).

Pathlines and travel times are always calculated for particles backtracked from the location of the extraction well. The capture zone maps were created using Groundwater Vistas to preprocess the pathlines into ArcGIS® format. The distance between two arrows of particle pathlines (Figure 7-9) denote the distance traveled by the particle in a year.

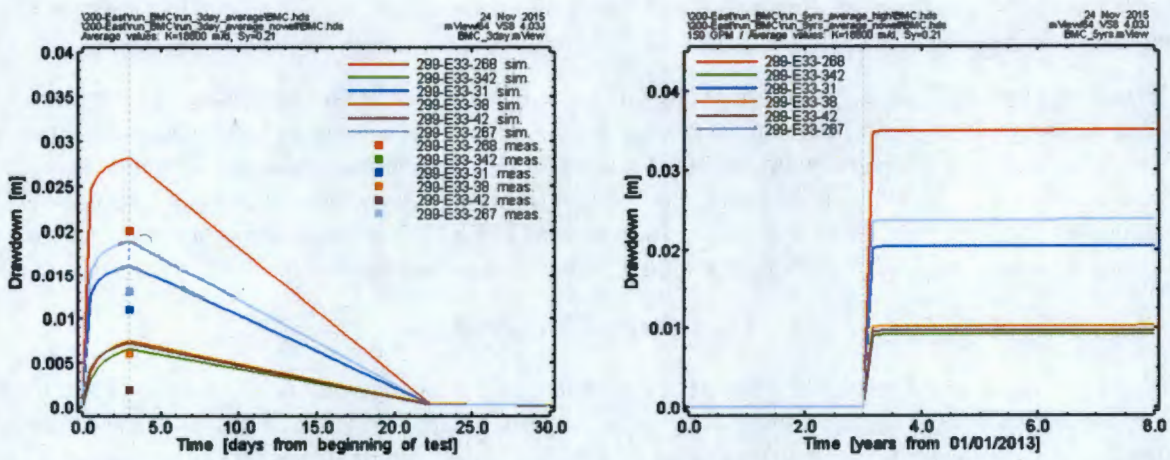

Figure 7-1. Examples of Time-histories of Drawdown Calculated at Selected Well Locations for the 3-day Pumping Test (left) and the 5-year Pumping Scenario (right)

7.2 3-day Pumping Test Simulations

This section provides the drawdown analyses performed for the 3-day pumping test simulations. First, a simulation is carried out with the unchanged parameters of the TMR and parent P2R Model (Section 7.2.1). Subsequently, the average, minimum, and maximum parameter estimates are used (Sections 7.2.2, 7.2.3, and 7.2.4, respectively) to simulate the test. Finally, an additional simulation is carried out using a hydraulic conductivity value hand-fitted to match the drawdowns measured closest to the pumping well (Section 7.2.5).

7.2.1 Unchanged TMR Parameters

The drawdowns simulated with the original TMR model parameters are compared to the measured drawdowns in Figure 7-2 (left figure shows time-histories from wells with measured drawdown, right figure shows wells with zero measured drawdown). Simulated drawdown in pumping well 299-E33-268 reaches 31 mm after 3 days (compared to 20 mm measured drawdown). Simulated drawdown in observation wells 299-E33-267 and 299-E33-31, both located within 10 meters distance from the pumping well, reaches 20.7 mm and 17.7 mm, respectively (compared to 13 mm and 11 mm measured drawdown, respectively). It is indicated that the deviation between simulated and measured drawdown in these three wells is systematic (i.e. similar difference in drawdown between wells 299-E33-268 and 299-E33-267 both in simulation and measurement). On the other hand, drawdowns in the more remote observation wells with distances between 74 and 134 m from pumping well indicate a different pattern (i.e. drawdowns in wells 299-E33-38 and 299-E33-42 are almost identical in the simulation but differ in the measurement). Finally, simulated drawdowns in wells where measured drawdown was zero (distances between 144 and 277 m from pumping well) are below 5 mm (Figure 7-2, right).

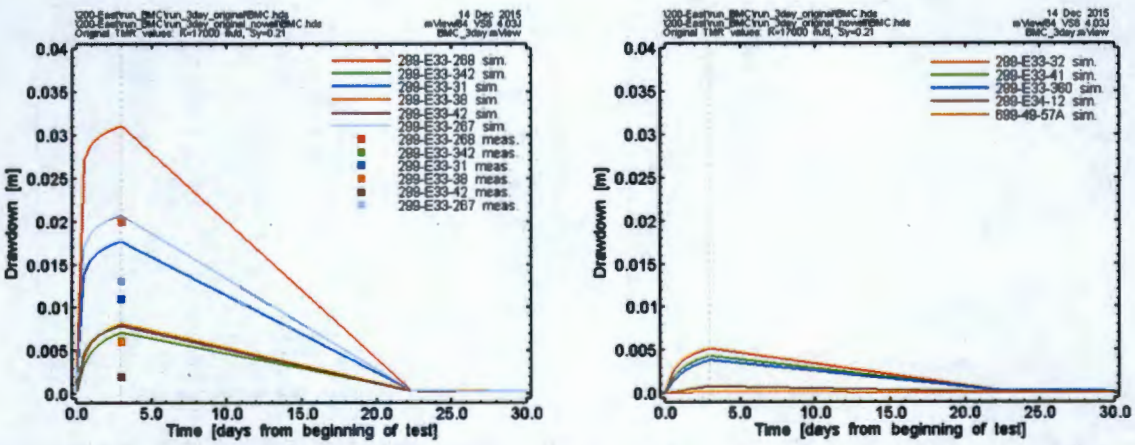

Figure 7-2. Comparison between Measured Drawdown and Calculated Drawdown with the Original TMR Parameters; Drawdown Time-history in Wells with (left) and without (right) Measurable Drawdown

7.2.2 Average Parameters

The drawdowns simulated with the average estimates of parameters are compared to the measured drawdowns in Figure 7-3. Overall, the drawdown comparison is similar as that presented for the unchanged TMR model parameters. In this case, simulated drawdown in pumping well 299-E33-268 is decreased to 28.2 mm due to the higher hydraulic conductivity. Drawdowns in observation wells 299-E33-267 and 299-E33-31 are accordingly decreased to 18.8 mm and 16.1 mm, respectively. Changes in simulated drawdown compared to the previous simulation are negligible in the rest of the observation wells.

To further clarify the differences between simulated and measured drawdowns at the different well locations, different cross-plots of residuals are constructed, as shown in Figure 7-4. The cross-plot between residuals and distance from the pumping well (Figure 7-4, top right) does not indicate any distinguishable correlation or reliable spatial pattern. However, the residual value is biased on the amount of drawdown, i.e. wells close to the pumping location may result in higher residual even though the agreement between model and measurement is qualitatively better compared to more remote locations where the drawdown is

smaller. Residuals are therefore normalized with the corresponding simulated drawdown and then plotted once more with distance (Figure 7-4, bottom left). Normalized residual equal to one indicates maximum relative deviation, which occurs in observation wells with some simulated drawdown but zero measured drawdown. Normalized residual equal to zero indicates agreement between model and measurement. It is shown that a correlation exists between normalized residual and distance from pumping well 299-E33-268, except for wells 299-E33-38 and 299-E33-342 which are both located in the northeast of 299-E33-268. The cross-plot between normalized residuals and measured drawdown (Figure 7-4, bottom right) indicates a similar effect. Higher drawdowns (i.e. closer to the pumping well) relate to lower residuals, whereas wells 299-E33-38 and 299-E33-42 result in outliers. Despite the limited number of data points, this behavior could indicate a structural feature of the Hanford/Cold Creek formation with hydraulic conductivity varying towards the northeast; an effect which is not accounted for the in the TMR model that assumes uniform parameters for each formation across the model domain. Alternatively, it is the lowest values of drawdown that show this behavior which also may due to the amount of measurement error relative to the size of the measurement itself.

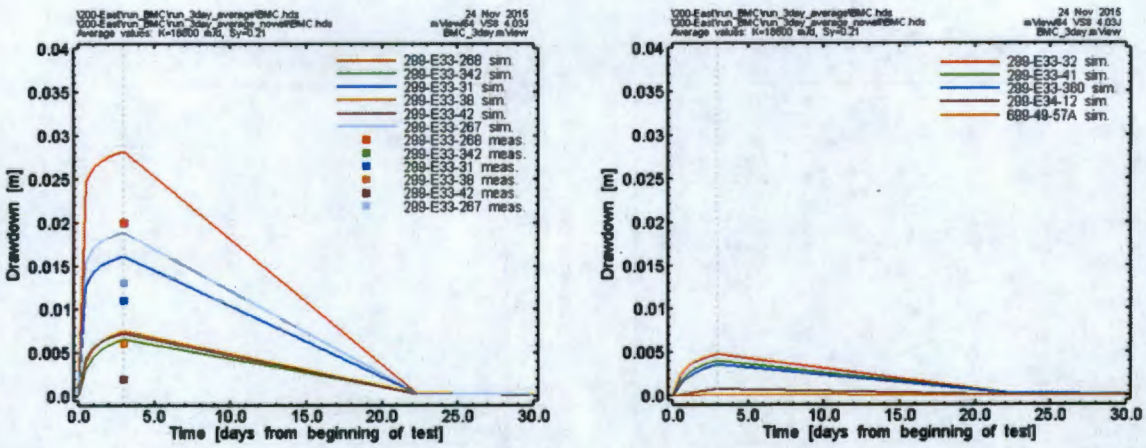

Figure 7-3. Comparison between Measured Drawdown and Calculated Drawdown with the Average Parameters; Drawdown Time-history in Wells with (left) and without (right) Measurable Drawdown

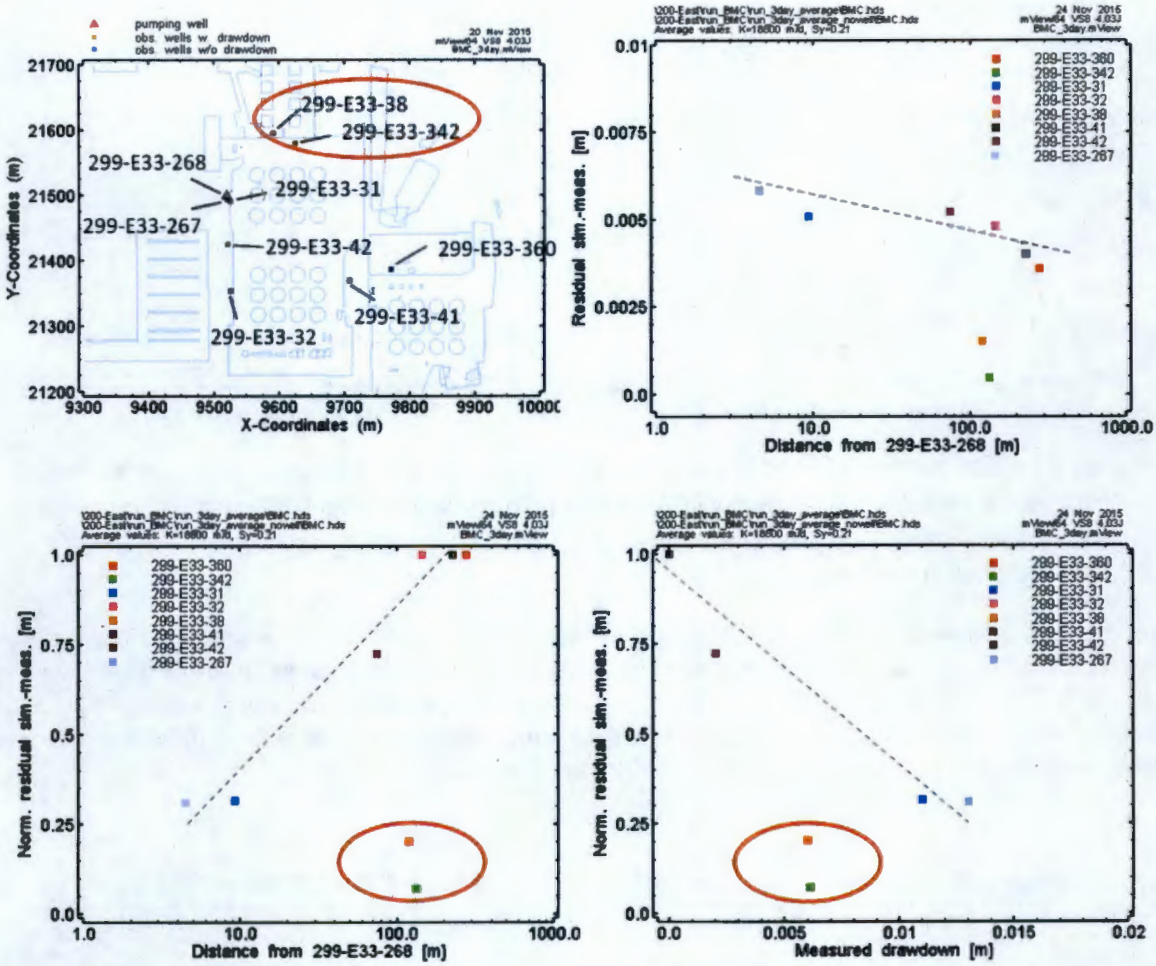

Figure 7-4. Analysis of Residuals between Measured and Calculated Drawdown with the Average Parameters: Absolute Residuals vs Distance (top right); Normalized Residuals vs Distance (bottom left); and Normalized Residuals vs Measured Drawdown (bottom right)

7.2.3 Minimum Parameters

The drawdowns simulated with the minimum estimates of parameters are compared to the measured drawdowns in Figure 7-5. In general, this simulation results in the highest deviation from the measured values. Simulated drawdown in pumping well 299-E33-268 is increased to 34.1 mm due to the lower hydraulic conductivity. Drawdowns in observation wells 299-E33-267 and 299-E33-31 are increased to 23.0 mm and 19.7 mm, respectively. Simulated drawdowns in wells with zero measured drawdown are below 6 mm (Figure 7-5, right).

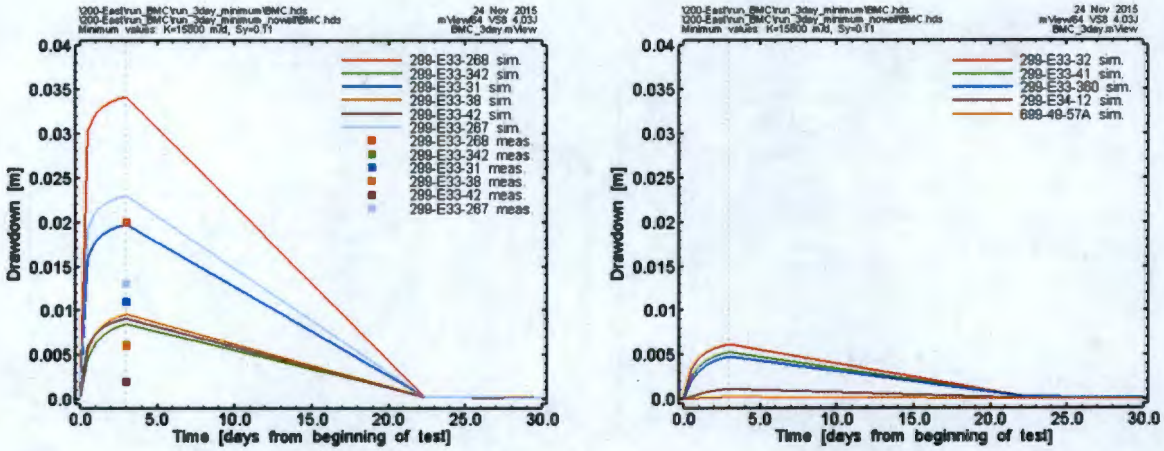

Figure 7-5. Comparison between Measured Drawdown and Calculated Drawdown with the Minimum Parameters; Drawdown Time-history in Wells with (left) and without (right) Measurable Drawdown

7.2.4 Maximum Parameters

The drawdowns simulated with the maximum estimates of parameters are compared to the measured drawdowns in Figure 7-6. It is indicated that the increased permeability results in lower drawdowns and therefore also in less deviation from the measured values. Simulated drawdowns in wells 299-E33-268, 299-E33-267, and 299-E33-31 are 24.6, 16.3, and 14.0 mm, respectively. Simulated drawdowns in wells with zero measured drawdown are below 4 mm (Figure 7-6, right).

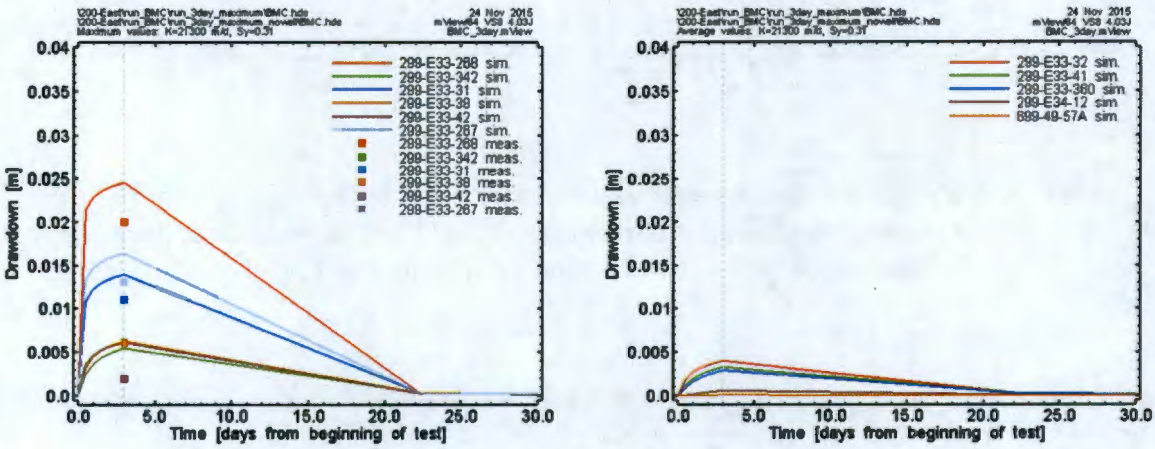

Figure 7-6. Comparison between Measured Drawdown and Calculated Drawdown with the Maximum Parameters. Drawdown Time-history in Wells with (left) and without (right) Measurable Drawdown

7.2.5 Fitted Hydraulic Conductivity

In this simulation, the hydraulic conductivity of the Hanford/Cold Creek formation is increased stepwise until the simulated maximum drawdown in well 299-E33-268 matches the measured value. It is emphasized here that this is not a systematic parameter fit, but rather a simple trial-and-error fit always assuming an anisotropy factor of 10. The horizontal hydraulic conductivity value found through this fitting procedure

was 26,200 m/d. The resulting drawdowns are compared to the measured values in Figure 7-7. It is indicated that reasonable agreement is achieved for wells 299-E33-268, 299-E33-267, and 299-E33-31, whereas some deviations are observed for the rest of the wells. This is may be due to some heterogeneity of the Hanford/Cold Creek formation (possibly to the northeast as indicated by the residual analysis) that is not accounted for in the model.

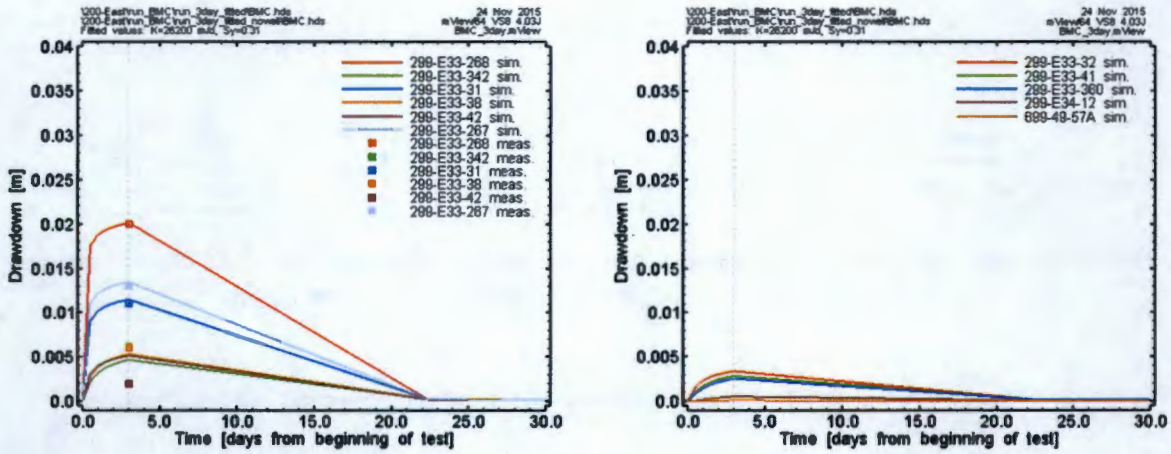

Figure 7-7. Comparison between Measured Drawdown and Calculated Drawdown with Fitted Permeability: Drawdown Time-history in Wells with (left) and without (right) Measurable Drawdown

7.3 5-years Pumping Simulations

The results of the 5-years pumping simulations will be presented in the following. The TMR model is used to evaluate drawdowns and capture zones using the unchanged TMR parameters in Section 7.3.1, and the estimated average, minimum, and maximum parameters in Sections 7.3.2, 7.3.3, and 7.3.4, respectively.

7.3.1 Unchanged TMR Parameters

The TMR model with unchanged parameters is used to simulate the 5-year pumping scenario for the three pumping rates considered (50, 100, and 150 GPM).

Drawdown analysis

Figure 7-8 shows the drawdowns simulated in pumping well 299-E33-268 and in the observation wells nearest to 299-E33-268. Similarly to the 3-day pumping test simulations, maximum drawdowns are reached very quickly after the onset of pumping (i.e. within one time step) due to the high hydraulic conductivity of the Hanford/Cold Creek formation. In well 299-E33-268 the drawdown reaches 12.8, 25.7, and 38.8 mm for 50, 100, and 150 GPM, respectively. Consistently with the 3-day pumping test analyses, the observation wells with the highest drawdown are 299-E33-267 and 299-E33-31, followed by 299-E33-38, 299-E33-42, and 299-E33-342.

Capture zone analysis

Capture zones simulated after 5 years of pumping with 50, 100, and 150 GPM are shown in Figure 7-9, Figure 7-10, and Figure 7-11, respectively. In general, hydraulic heads do not show significant differences between the three variants. As indicated by the drawdown analysis, head differences for increasing pumping rates lie within a range of 26 mm in the vicinity of the pumping well. On the other hand, the shape and width of the capture zone change. The capture zone for 100 and 150 GPM has similar width and travel

length whereas the capture zone for 50 GPM is significantly narrower. In addition, the capture zone with 150 GPM pumping rate also extends to the south-east side of the model domain.

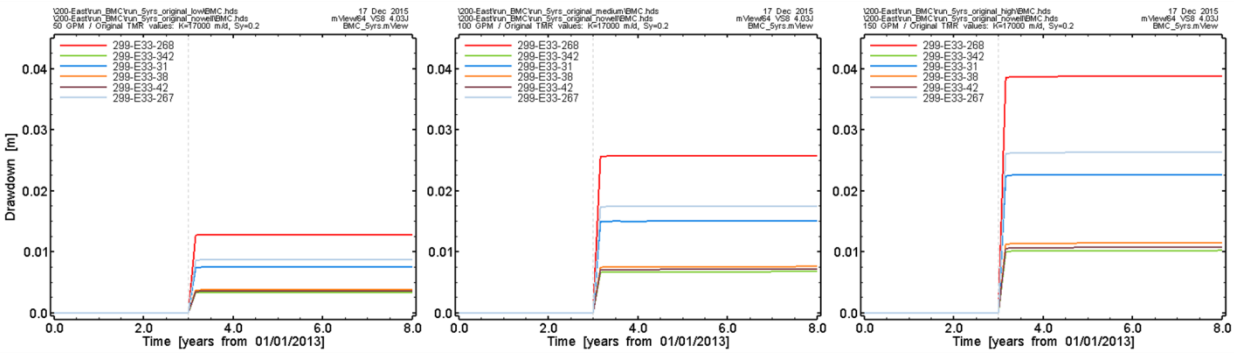

Figure 7-8. Comparison between Drawdowns Simulated with the TMR model with Unchanged Parameters and Pumping Rate of 50 (left), 100 (middle), and 150 GPM (right).

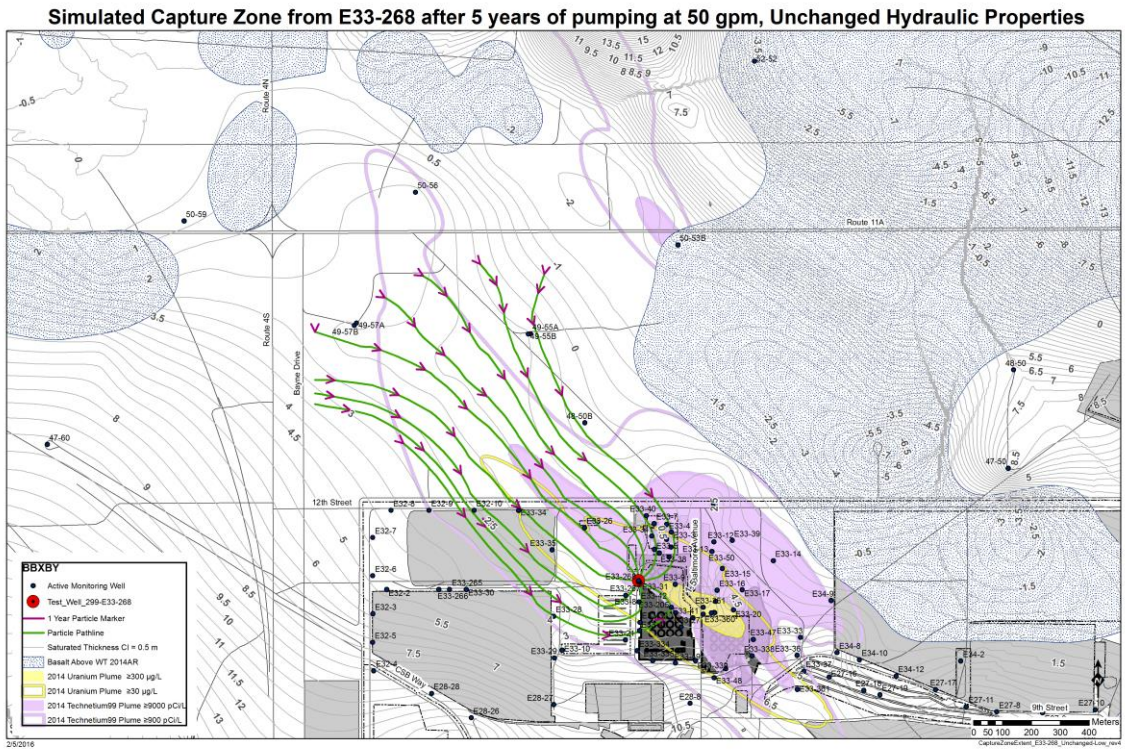

Figure 7-9. Predicted Hydraulic Capture Zone at 1-year Intervals for Unchanged Hydraulic Properties with 50 GPM Pumping (backward particle track)

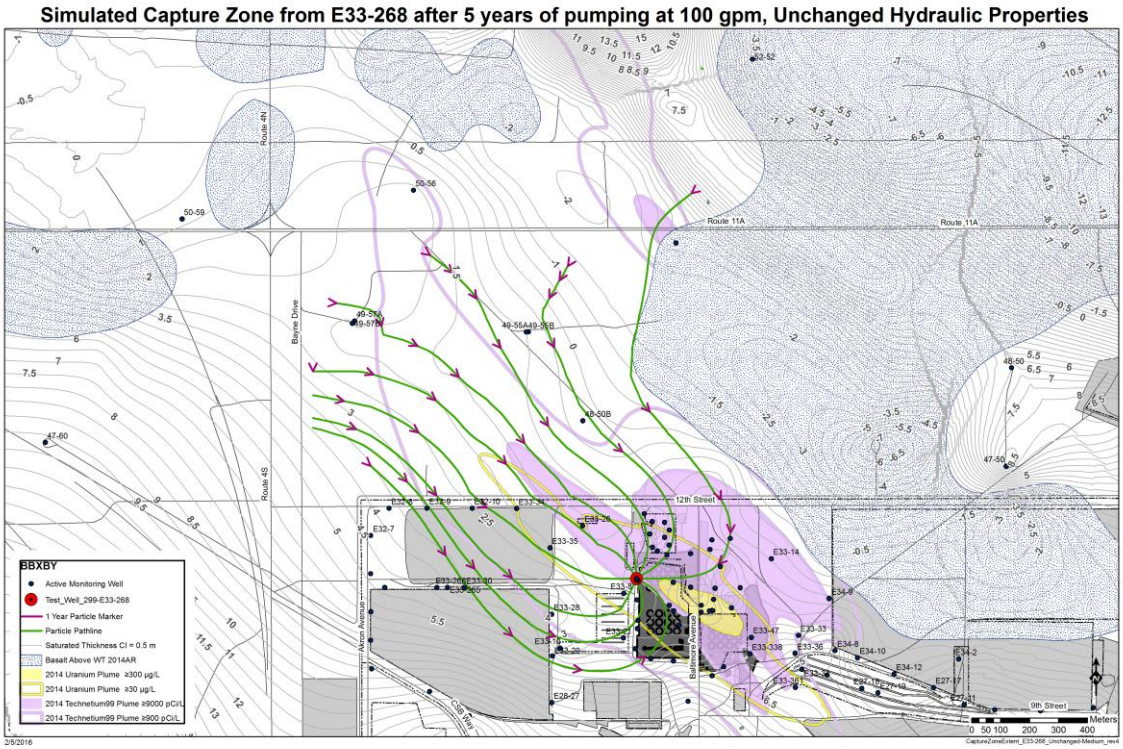

Figure 7-10. Predicted Hydraulic Capture Zone at 1-year Intervals for Unchanged Hydraulic Properties with 100 GPM Pumping (backward particle track)

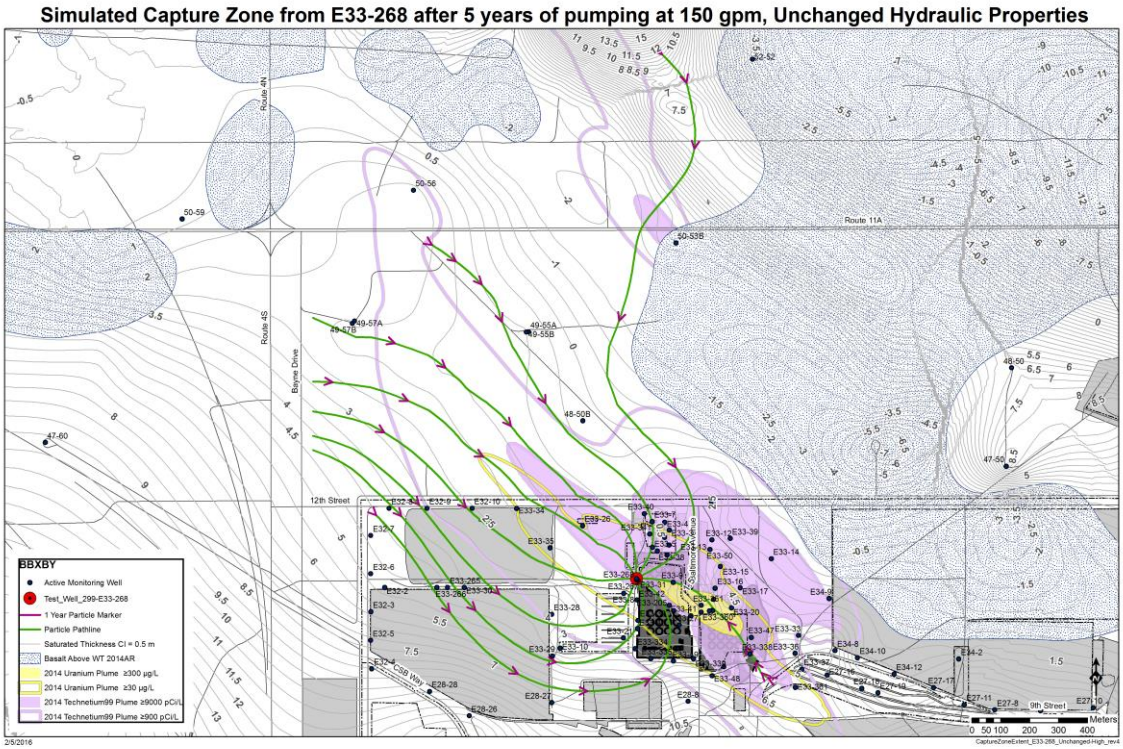

Figure 7-11. Predicted Hydraulic Capture Zone at 1-year Intervals for Unchanged Hydraulic Properties with 150 GPM Pumping (backward particle track)

7.3.2 Average Parameters

The input parameters are changed in the TMR model to the average estimates from the 3-day pumping test. The model is then used to simulate the 5-year pumping scenario for the three pumping rates.

Drawdown analysis

Figure 7-12 shows the drawdowns simulated in pumping well 299-E33-268 and in the observation wells nearest to 299-E33-268. Overall, the spatial and temporal evolution of drawdowns is similar to those from the TMR simulations with the unchanged model parameters. Drawdowns are however somewhat lower in this case due to the higher hydraulic conductivity. Drawdowns in well 299-E33-268 reach 11.6, 23.2, and 35.0 mm for 50, 100, and 150 GPM, respectively. Similarly to the previous, the observation wells with the highest drawdown are 299-E33-267 and 299-E33-31, followed by 299-E33-38, 299-E33-42, and 299-E33-342.

Capture zone analysis

The capture zones simulated after 5 years of pumping with 50, 100, and 150 GPM are shown in Figure 7-13, Figure 7-14, and Figure 7-15, respectively. Similarly to the simulations with the unchanged parameters, hydraulic heads vary up to approximately 24 mm for the three pumping rates used. The evolution of capture zones is also very similar. It is expected because the hydraulic conductivity for unchanged and average condition is very similar (17,000 m/d and 18,800 m/d).

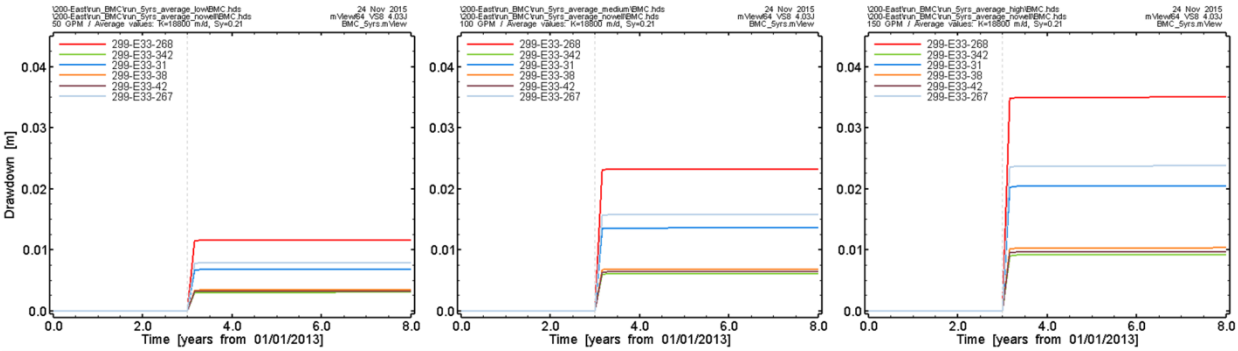

Figure 7-12. Comparison between Drawdowns Simulated with the TMR Model with the Average Parameters and Pumping Rate of 50 (left), 100 (middle), and 150 GPM (right)

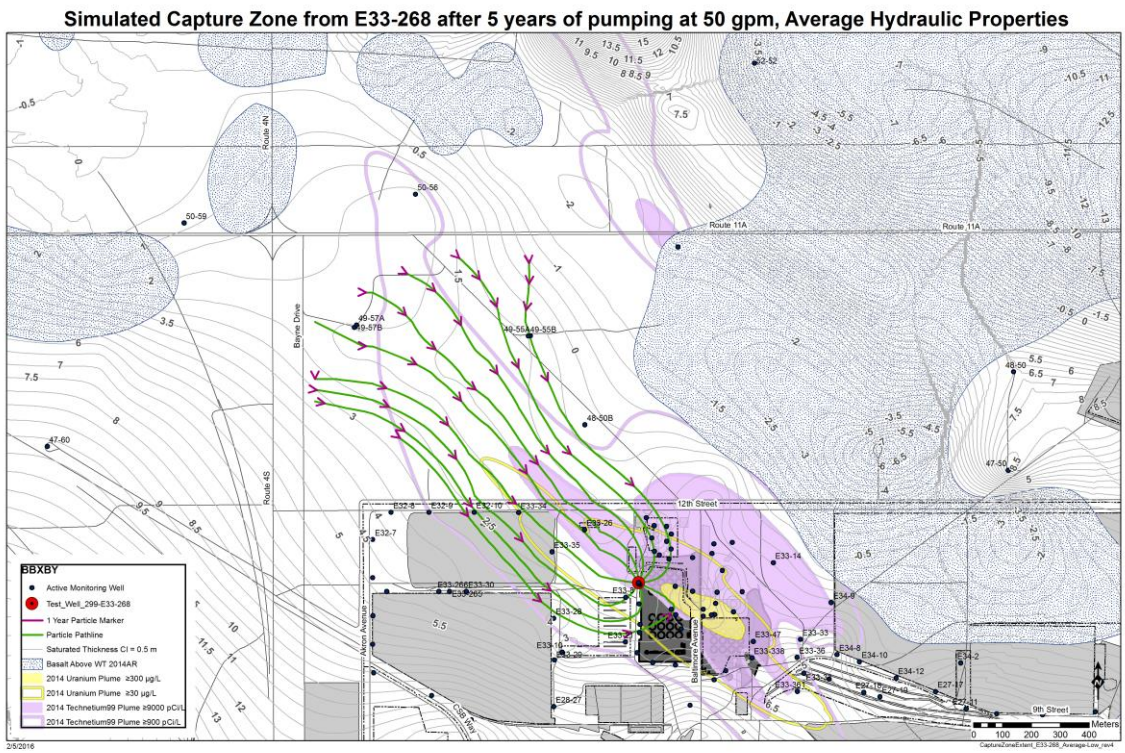

Figure 7-13. Predicted Hydraulic Capture Zone at 1-year Intervals for Average Hydraulic Properties with 50 GPM Pumping (backward particle track)

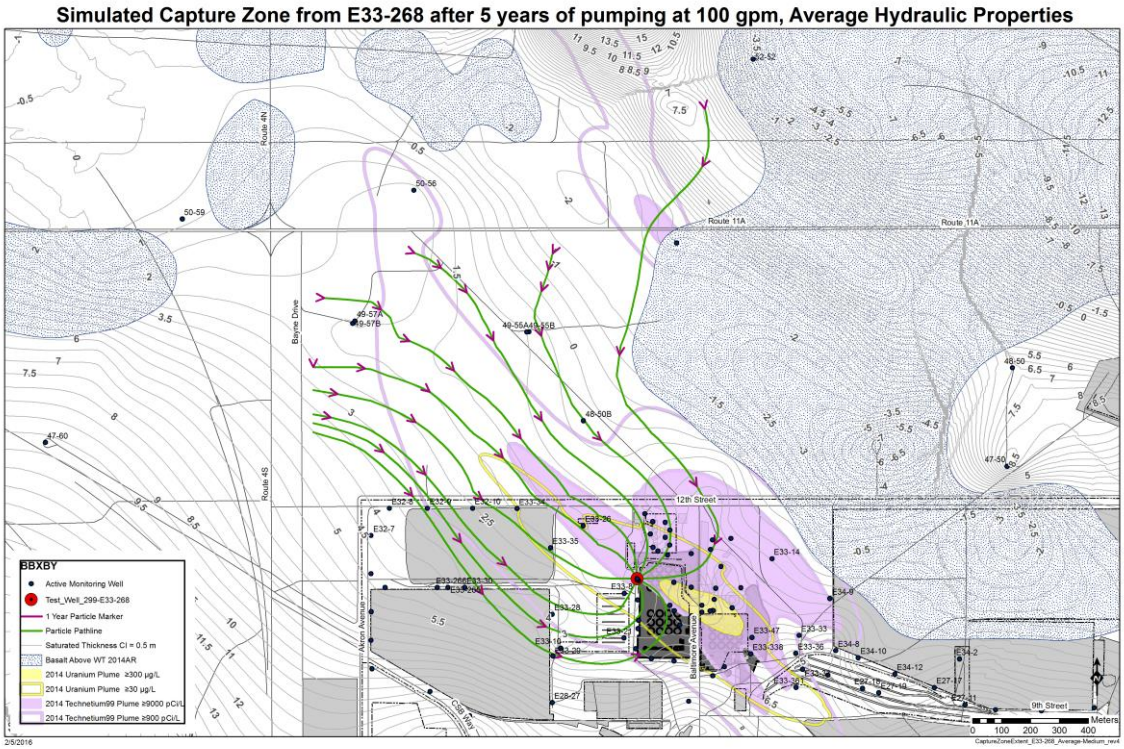

Figure 7-14. Predicted Hydraulic Capture Zone at 1-year Intervals for Average Hydraulic Properties with 100 GPM Pumping (backward particle track)

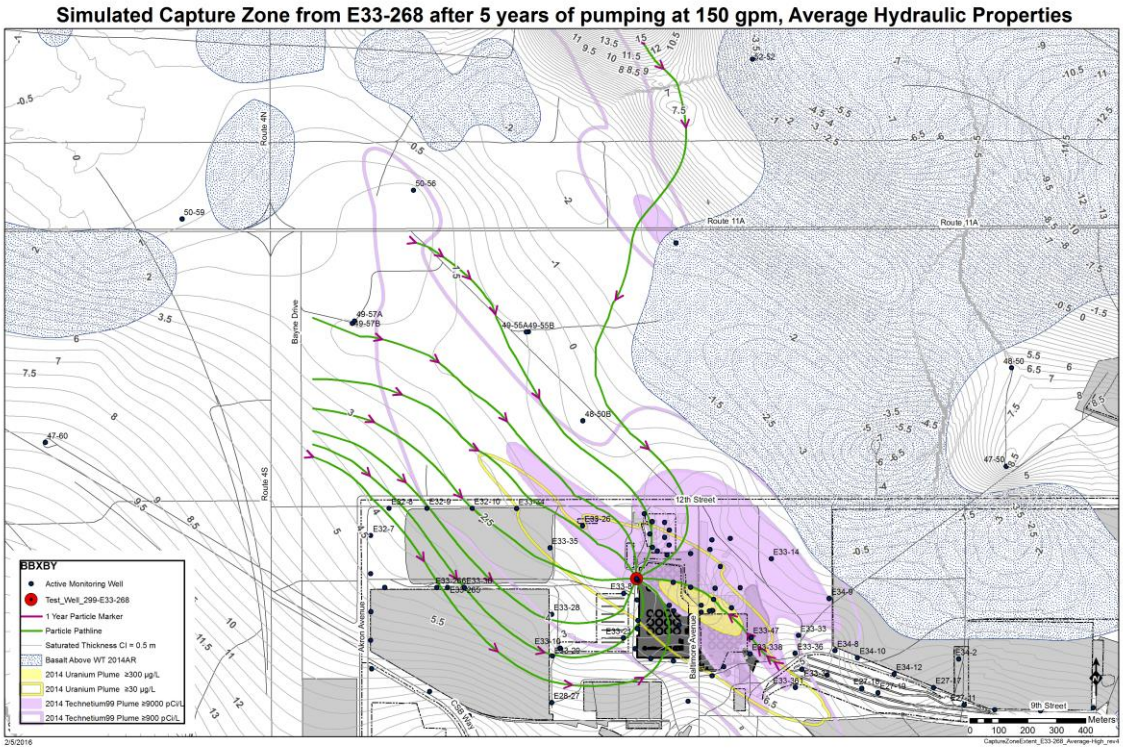

Figure 7-15. Predicted Hydraulic Capture Zone at 1-year Intervals for Average Hydraulic Properties with 150 GPM Pumping (backward particle track)

7.3.3 Minimum Parameters

The input parameters in the TMR model are now changed to the minimum estimates from the 3-day pumping test, and the 5-year pumping scenario is simulated for the three pumping rates.

Drawdown analysis

Figure 7-16 shows the drawdowns simulated in pumping well 299-E33-268 and in the observation wells nearest to 299-E33-268. It is indicated that the minimum estimate of hydraulic conductivity results in the highest estimates of drawdown in the pumping and observation wells. Drawdown in well 299-E33-268 reaches 13.8, 27.7, and 41.8 mm for 50, 100, and 150 GPM, respectively.

Capture zone analysis

The capture zones simulated after 5 years of pumping with 50, 100, and 150 GPM are shown in Figure 7-17, Figure 7-18, and Figure 7-19, respectively. As indicated by the drawdown analysis, head differences for increasing pumping rates lie within a range of 28.0 mm in the vicinity of the pumping well, which is slightly increased compared to the previous variants. Typically, the capture zone for same pumping rate with a lower hydraulic conductivity (i.e., lower transmissivity) should be wider than the capture zone with higher hydraulic conductivity. As expected, the capture zones are wider than the capture zones for unchanged and average parameter condition. However, the travel length is shorter compared to unchanged average parameter condition.

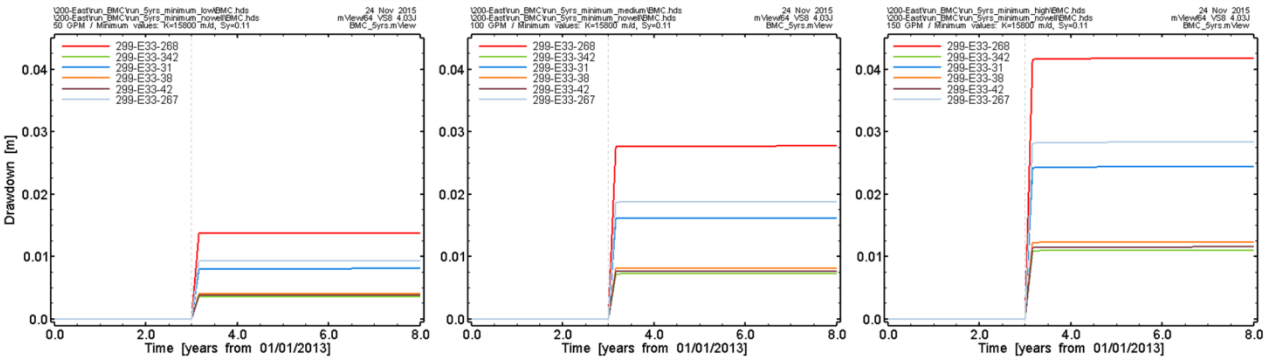

Figure 7-16. Comparison between Drawdowns Simulated with the TMR model with the Minimum Parameters and Pumping Rate of 50 (left), 100 (middle), and 150 GPM (right)

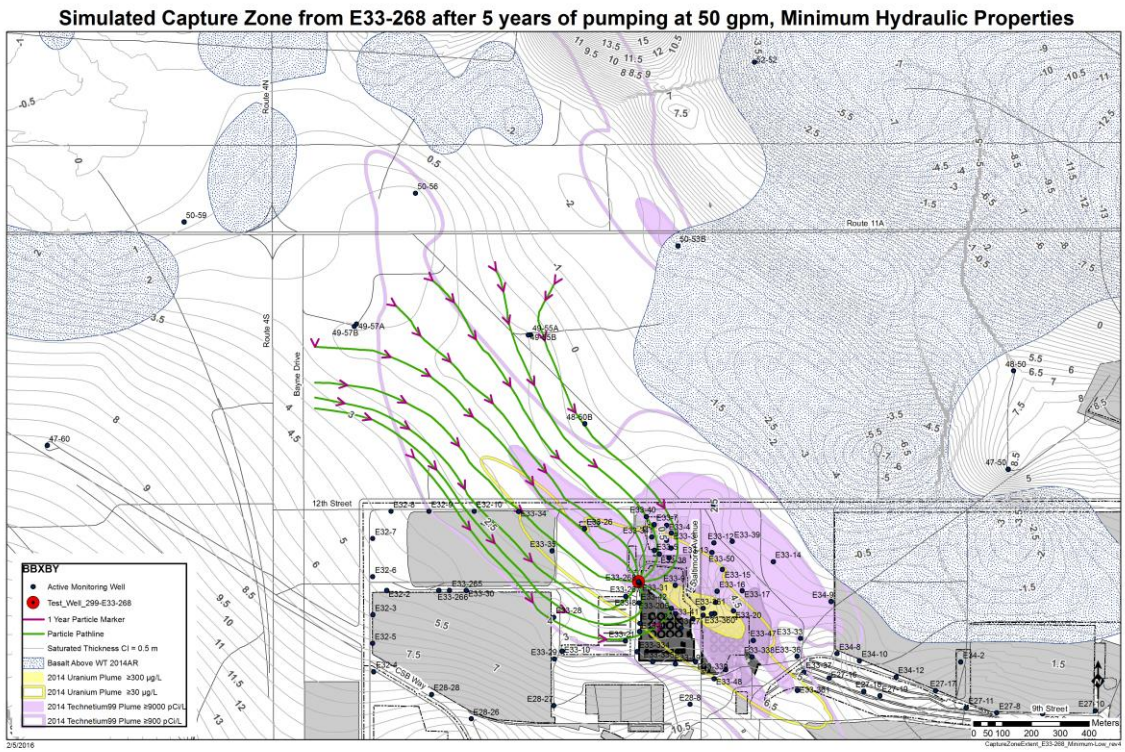

Figure 7-17. Predicted Hydraulic Capture Zone at 1-year Intervals for Minimum Hydraulic Properties with 50 GPM Pumping (backward particle track)

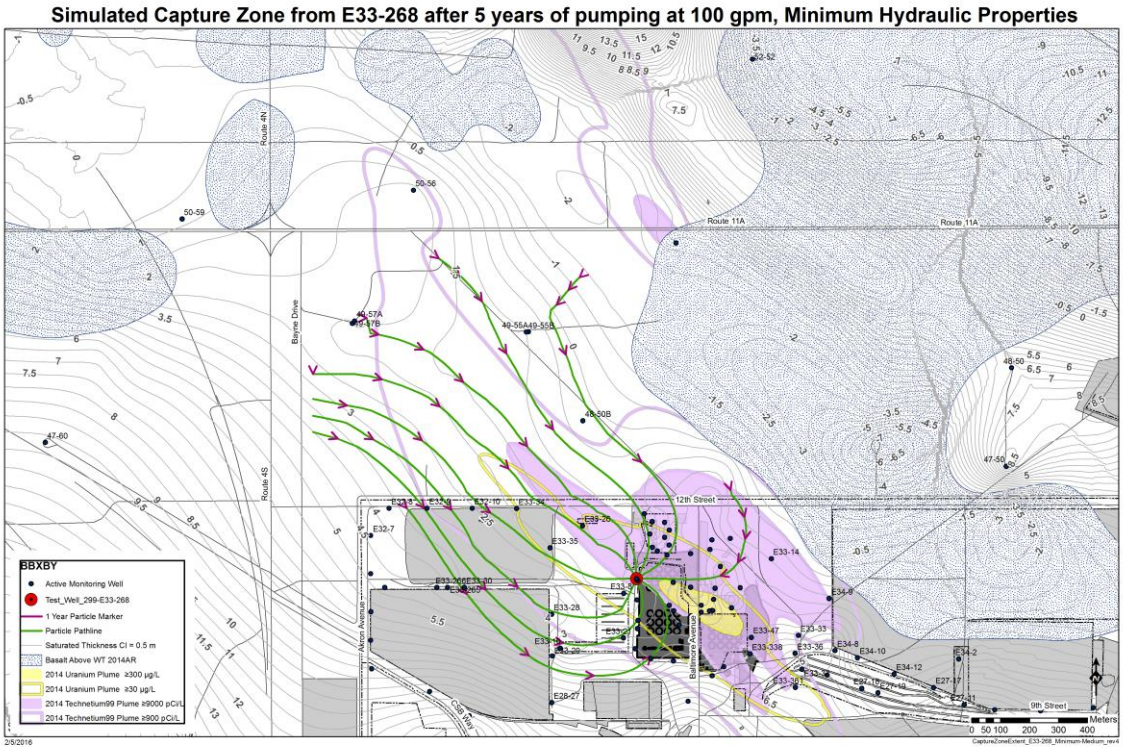

Figure 7-18. Predicted Hydraulic Capture Zone at 1-year Intervals for Minimum Hydraulic Properties with 100 GPM Pumping (backward particle track)

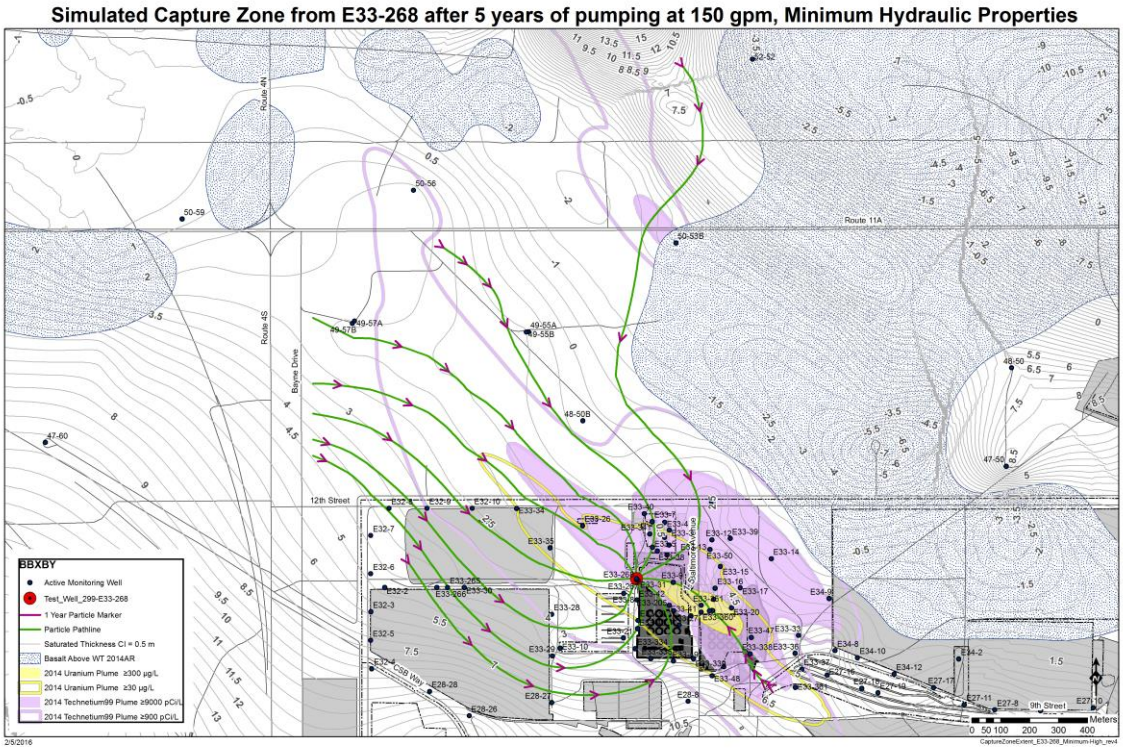

Figure 7-19. Predicted Hydraulic Capture Zone at 1-year Intervals for Minimum Hydraulic Properties with 150 GPM Pumping (backward particle track)

7.3.4 Maximum Parameters

The input parameters in the TMR model are now changed to the maximum estimates from the 3-day pumping test, and the 5-year pumping scenario is simulated for the same pumping rates.

Drawdown analysis

Figure 7-20 shows the drawdowns simulated in pumping well 299-E33-268 and in the observation wells nearest to 299-E33-268. In this case, the lowest drawdowns are observed among the simulation variants due to the maximum hydraulic conductivity value. Drawdown in well 299-E33-268 reaches 10.2, 20.5, and 30.9 mm for 50, 100, and 150 GPM, respectively.

Capture zone analysis

The capture zones simulated after 5 years of pumping with 50, 100, and 150 GPM are shown in Figure 7-21, Figure 7-22, and Figure 7-23, respectively. Due to the higher conductivity value, the hydraulic head change observed when increasing the pumping rate does not exceed approximately 21 mm. Similarly to the previous, the capture zone is narrower than the capture zone for unchanged, average and minimum condition.

Inspection of the 5-year drawdown and capture zones over the suite of considered hydraulic properties shows little difference in capture zone for a given pumping rate. This is due to the modest variation (17,000 in the initial model to the 21,300 m/d maximum) in hydraulic conductivity.

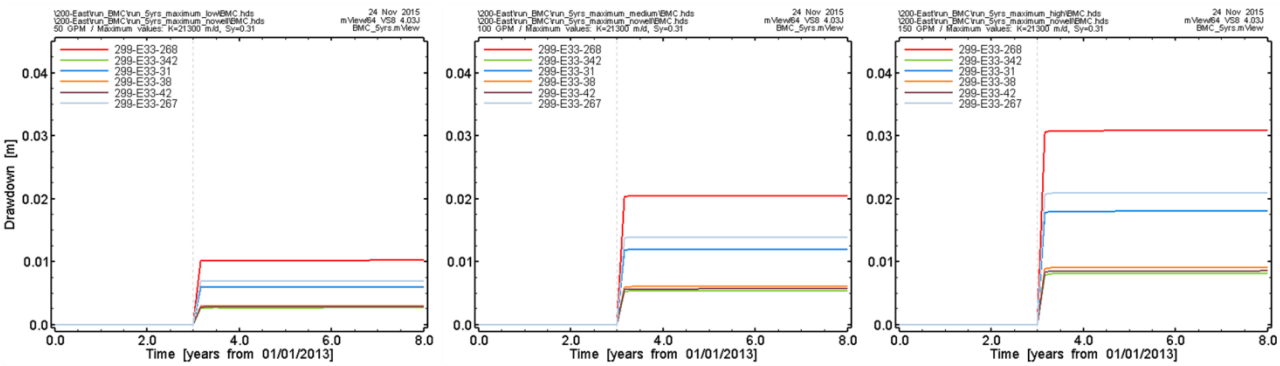

Figure 7-20. Comparison between Drawdowns Simulated with the TMR Model with the Maximum Parameters and Pumping Rate of 50 (left), 100 (middle), and 150 GPM (right)

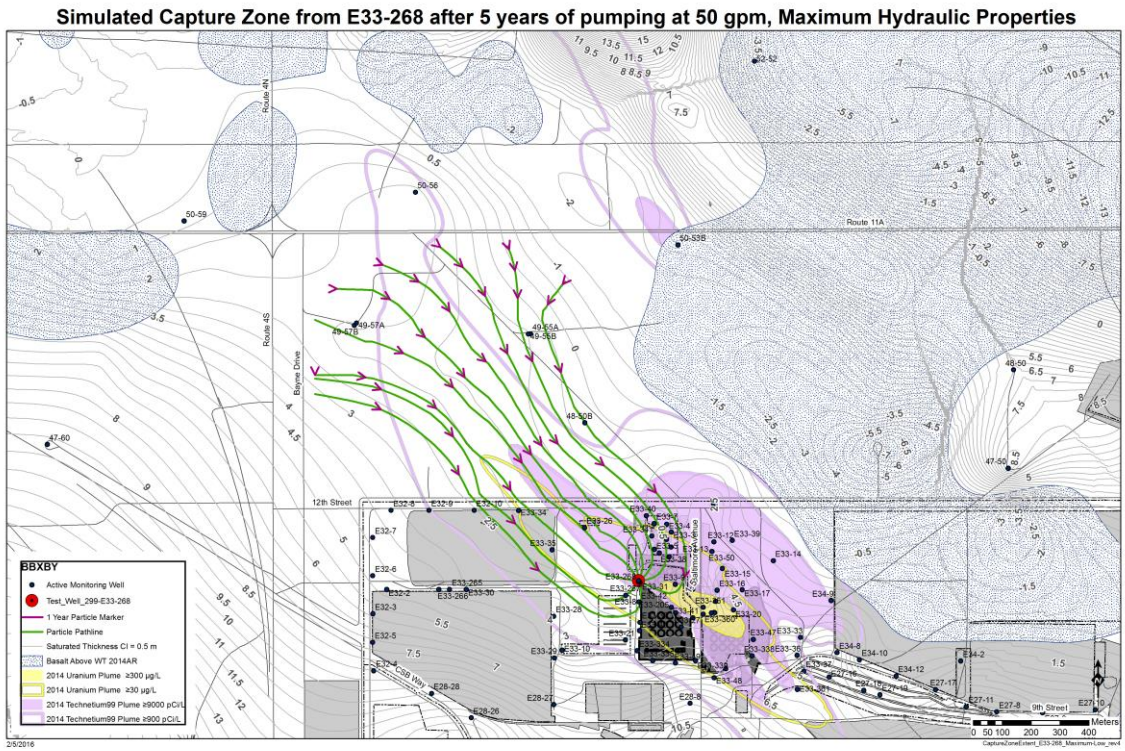

Figure 7-21. Predicted Hydraulic Capture Zone at 1-year Intervals for Maximum Hydraulic Properties with 50 GPM Pumping (backward particle track)

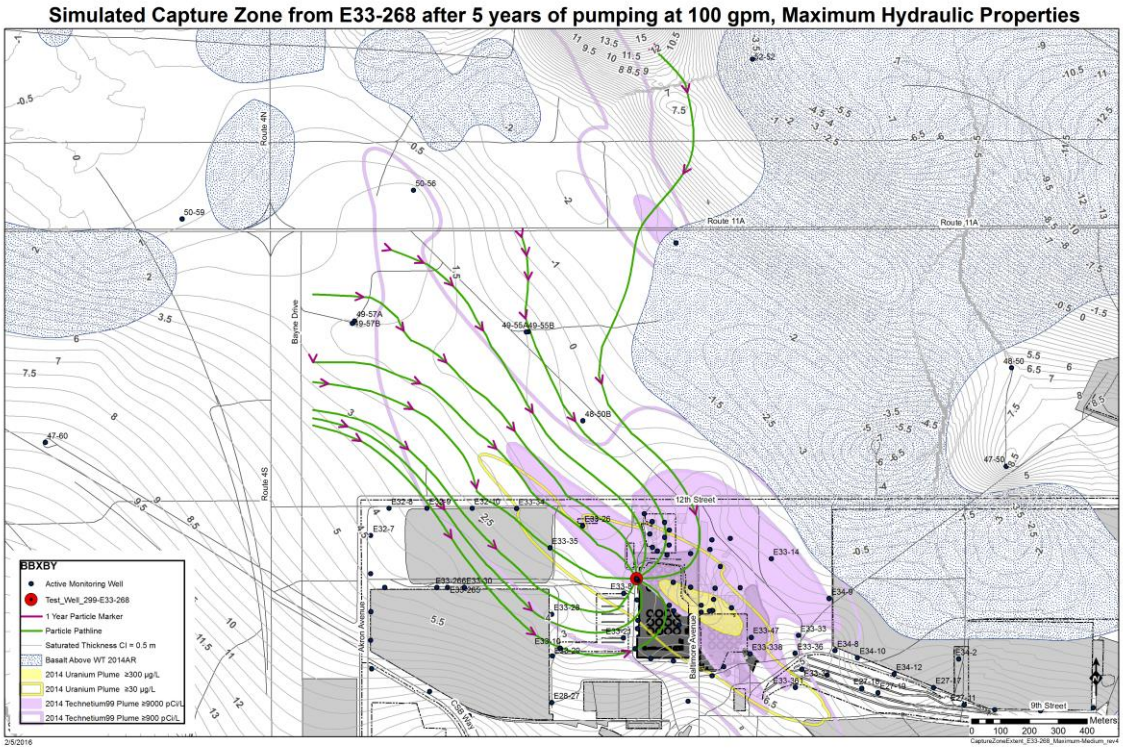

Figure 7-22. Predicted Hydraulic Capture Zone at 1-year Intervals for Maximum Hydraulic Properties with 100 GPM Pumping (backward particle track)

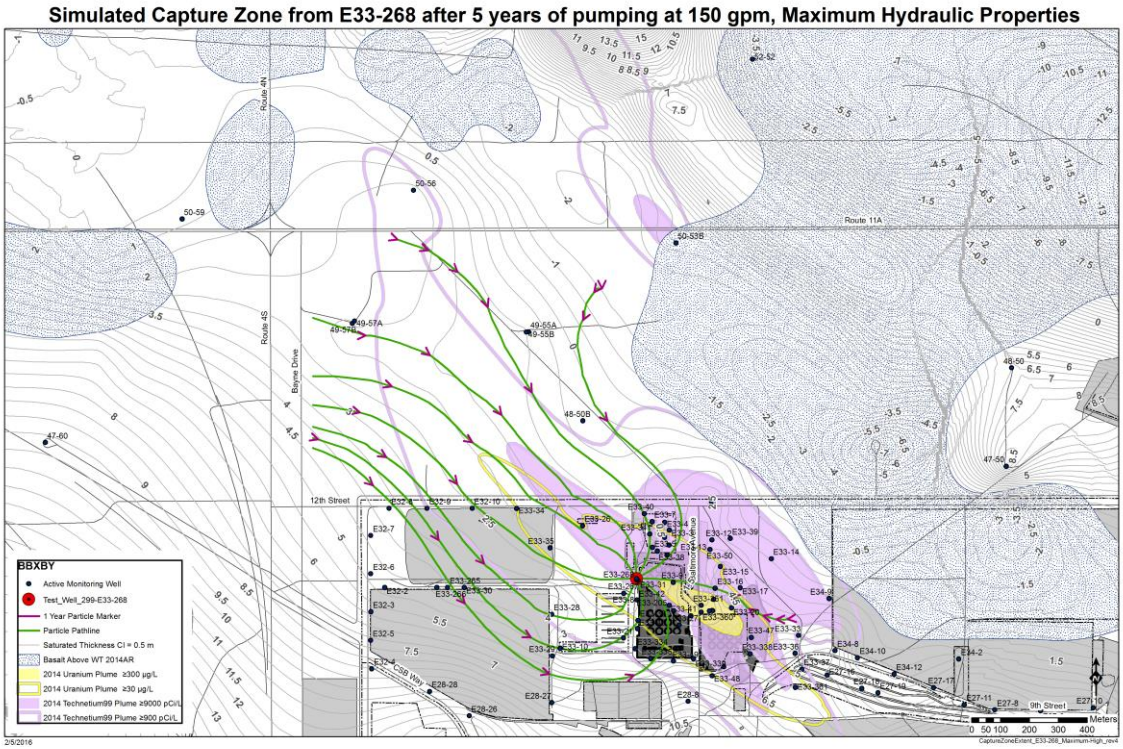

Figure 7-23. Predicted Hydraulic Capture Zone at 1-year Intervals for Maximum Hydraulic Properties with 150 GPM Pumping (backward particle track)

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Attachment A

Software Installation and Checkout Form

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:

Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: MODFLOW and Related Codes Software Version No.: Bld 6

EXECUTABLE INFORMATION:

2. Executable Name (include path):

Following executable files in directory: [redacted]

MD5 Signature (unique ID)	Executable File Name
C3B75ADEBC7F41F15F006A0A3AED2D21	mf2k-chprc06dp.exe
C3141B0D41E084601DC2C8EB746B189F	mf2k-chprc06sp.exe
4F9E3D4A5ECF0360C8247C4279FE25F1	mf2k-mst-chprc06dp.exe
0E38BD210A582EF42CC79145C14F8E69	mf2k-mst-chprc06sp.exe
EE4D6CE61E07E0218F81822CE54499DE	modpath-mst-chprc06dp.exe
F83D1B16B26887A8C9579373D919DF4F	modpath-mst-chprc06sp.exe
D3337D49ED0AAA92E6FE6A6EB027647A	mt3d-mst-chprc06dp.exe
E6A66025170D441389642CC0A7B59749	mt3d-mst-chprc06sp.exe

3. Executable Size (bytes): MD5 signatures listed above uniquely identify executable files

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

WC95463; Dell Latitude Laptop

5. Operating System (include version number):

Windows 7 Enterprise Service Pack 1

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

Lenovo Thinkpad W540 (PSC-Lithium)

7. Operating System (include version number):

Windows 8.1 Pro

8. Open Problem Report? ◉ No ○ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[redacted]5\test

10. Procedure(s):

CHPRC-00259 Rev 2, MODFLOW and Related Codes Software Test Plan

11. Libraries:

N/A (static linking)

12. Input Files:

MF-ITC-1 and MT-ITC-1 inputs

13. Output Files:

MF-ITC-1 and MT-ITC-1 outputs

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: MODFLOW and Related Codes — Software Version No. Bld 6

14. Test Cases:

MF-ITC-1 (both standard and MST versions of MODFLOW) - run for single & double precision
MT-ITC-1 - run for single and double precision

15. Test Case Results:

All tests returned identical results as base cases

16. Test Performed By: H Rashid

17. Test Results: ◉ Satisfactory, Accepted for Use ○ Unsatisfactory

18. Disposition (include HISI update): Installation approved, noted in HISI entry. -WEN

Prepared By:

19. Software Owner (Signature)	WE Nichols Print	Date

20. Test Personnel:

S M Helalur Rashid Sign	H Rashid Print	10/17/2014 Date
Sign	Print	Date
Sign	N/B (CHPRC-00259 Rev 2) Print	Date

Approved By:

21. Software SME (Signature)	Print	Date

A-6005-149 (REV 0)

CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM

Software Owner Instructions:

Complete Fields 1-13, then run test cases in Field 14. Compare test case results listed in Field 15 to corresponding Test Report outputs. If results are the same, sign and date Field 19. If not, resolve differences and repeat above steps.

Software Subject Matter Expert Instructions:

Assign test personnel. Approve the installation of the code by signing and dating Field 21, then maintain form as part of the software support documentation.

GENERAL INFORMATION:

1. Software Name: MODFLOW and Related Codes Software Version No.: Bld 6

EXECUTABLE INFORMATION:

2. Executable Name (include path):

Following executable files in directory: [redacted]

MD5 Signature (unique ID)	Executable File Name
C3B75ADEBC7F41F15F006A0A3AED2D21	mf2k-chprc06dp.exe
C3141B0D41E084601DC2C8EB746B189F	mf2k-chprc06sp.exe
4F9E3D4A5ECF0360C8247C4279FE25F1	mf2k-mst-chprc06dp.exe
0E38BD210A582EF42CC79145C14F8E69	mf2k-mst-chprc06sp.exe
D3337D49ED0AAA92E6FE6A6EB027647A	mt3d-mst-chprc06dp.exe
E6A66025170D441389642CC0A7B59749	mt3d-mst-chprc06sp.exe

3. Executable Size (bytes): MD5 signatures listed above uniquely identify executable files

COMPILATION INFORMATION:

4. Hardware System (i.e., property number or ID):

WC95463; Dell Latitude Laptop

5. Operating System (include version number):

Windows 7 Enterprise Service Pack 1

INSTALLATION AND CHECKOUT INFORMATION:

6. Hardware System (i.e., property number or ID):

KXGVD; Dell Vostro 430

7. Operating System (include version number):

Windows 7 Professional Service Pack 1

8. Open Problem Report? ◉ No ○ Yes PR/CR No.

TEST CASE INFORMATION:

9. Directory/Path:

[redacted]

10. Procedure(s):

CHPRC-00259 Rev 2, MODFLOW and Related Codes Software Test Plan

11. Libraries:

N/A (static linking)

12. Input Files:

MF-ITC-1 and MT-ITC-1 inputs

13. Output Files:

MF-ITC-1 and MT-ITC-1 outputs

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CHPRC SOFTWARE INSTALLATION AND CHECKOUT FORM (continued)

1. Software Name: MODFLOW and Related Codes — Software Version No.: Bld 6

14. Test Cases:

MF-ITC-1 (both standard and MST versions of MODFLOW)- run for single & double precision
MT-ITC-1 - run for single and double precision

15. Test Case Results:

FC: no differences encountered

16. Test Performed By: Alexandros Papafotiou

17. Test Results: (●) Satisfactory, Accepted for Use ( ) Unsatisfactory

18. Disposition (include HISI update): Installation Approved and recorded in HISI Entry 2517 (MODFLOW) and 2518 (MT3DMS

Prepared By:

19. _____ Software Owner (Signature) | WE Nichols Print | _____ Date

20. Test Personnel:

Sign	Print	Date
[signature]	Alexandros Papafotiou	02/05/2015
	N/R (CHPRC-00259 Rev 2)	

Approved By:

21. _____ Software SME (Signature) | _____ Print | _____ Date

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