APPENDIX 6.2-A

Numerical Modeling of Groundwater Conditions Related to In Situ Recovery (Petrotek, 2010)

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NUMERICAL MODELING OF GROUNDWATER CONDITIONS RELATED TO INSITU RECOVERY AT THE DEWEY-BURDOCK URANIUM PROJECT, SOUTH DAKOTA

Introduction

Powertech (USA) Inc., has submitted an application to the U.S. Nuclear Regulatory Commission (NRC) for a Source Materials License (SML) to conduct in-situ recovery (ISR) of uranium from the Dewey-Burdock Project in South Dakota (Powertech, 2009). Wellfield-scale modeling simulations were conducted in response to the Request for Additional Information (RAI) from NRC presented to Powertech in a correspondences dated May 19, 2010 and May 28, 2010. The target ore zone at the Dewey site is the lower Fall River Formation, and this is the aquifer represented in these hydrological modeling simulations. Ore is also present in the Lakota Formation to the south at the Burdock site area, but flow in this aquifer is not simulated.

The following lists the specific RAIs presented by NRC that are addressed in this report (references to pore volume are not addressed in this report):

Correspondence dated May 19, 2010, entitled "Summary of April 8, 2010, Teleconference Addressing Technical Issues, Powertech (USA), Inc., Proposed Dewey-Burdock In-Situ Recovery Facility (TAC No. J00606)".

- Section III (Miscellaneous Issues), #4(d): *The applicant includes a flare factor of 1.5 in its calculation of restoration costs. In addition ground water restoration costs are based on treatment of 10 pore volumes. Provide justification for the flare factor and for using 10 pore volumes total.*

Correspondence dated May 28, 2010, entitled "Request for Additional Information, Powertech (USA), Inc., Proposed Dewey-Burdock In Situ Recovery Facility (TAC No. J00606)".

- Section 5.7.8, #10: *On page 3-14 of the Technical Report, the applicant proposes for the perimeter monitoring ring to be 400 feet from the production well field, with a minimum spacing between wells of a spacing that ensures a 70 degree angle. The applicant references three NUREG guidance documents on the proposed spacing but does not justify the spacing based on site-specific hydrogeological and geochemical conditions. Please provide the appropriate justification.*
- Section 6.1, #7: *The application did not include estimates on the pore volume for a wellfield, porosity, or flare factors. The staff needs this information to evaluate the financial assurance calculations and the proposed schedule and water balance for the restoration process. Please provide this information for staff to review.*

A numerical groundwater flow model was developed to evaluate wellfield-scale issues related to ISR production at the site. This report describes the development of the numerical model and summarizes the results of numerical simulations used to address NRC concerns regarding ISR operations at the site.

Models and simulations presented in this report are not intended to fully characterize the regional groundwater flow system and are based on data currently available. It is noted that there are hydrologic complexities to the site and surrounding area, such as aquifer heterogeneities and recharge and fault boundaries that may require further characterization. This modeling exercise is provided for the analysis of wellfield flare and demonstrating hydraulic control at the monitor well ring. The modeling presented in this report is site specific and is not intended to represent the regional groundwater flow system.

Purpose and Objectives

The numerical groundwater flow model was developed to support Powertech in planning and operation of the ISR project. The numerical model was used to assess impacts of ISR mining on lower Fall River Formation in the Dewey area of the proposed Dewey-Burdock Uranium Project. Model simulations were developed to:

- Evaluate the wellfield balance and net bleed at the proposed F-13 wellfield.
- Estimate wellfield flare during mining operations.
- Demonstrate that proposed monitor well spacing is adequate to detect any potential excursions, specifically by simulating an excursion out of the wellfield.
- Demonstrate that hydraulic control of the simulated excursion can be established by changing injection/extraction rates and altering groundwater flow direction at the perimeter monitor well ring.

The model was developed to allow adequate discretization within the wellfields such that the impacts of individual wells can be discerned.

Conceptual Model

Description of the geology and hydrogeology of the Permit Area can be found in the SML application (Powertech, 2009). Based on that document and hydrologic testing conducted in 2008 (Knight Piesold, 2008), a conceptual hydrologic model for the Dewey area at the Dewey-Burdock Project is summarized below.

The aquifer being simulated is the lower Fall River Formation, which is the proposed uranium production zone at the Dewey area. The total thickness of the Fall River Formation is approximately 165 feet in the area. There are three distinct ore zones of about 10 to 15 feet thick within the lower Fall River sandstone interval. This sandstone at the base of the Fall River is approximately 75 feet thick, and dips to the south-southwest at approximately 0.01 ft/ft. This interval of the lower Fall River Formation is the aquifer that was modeled in the following simulations.

The Fall River Formation is a confined aquifer system at the Dewey area, with a hydraulic gradient generally following the dipping beds to the south-southwest. Measured gradients in the Dewey area are locally as high as 0.01 ft/ft, but generally are

closer to an average of 0.006 ft/ft (Knight Piesold, 2008). A hydraulic gradient of 0.006 ft/ft is utilized for all baseline (non-pumping) conditions around the simulated wellfield. There is also a vertical-upward hydraulic gradient of approximately 0.2 ft/ft measured between well screens in the lower sandstone versus the upper sandstone in the Fall River Formation. For the purposes of these simulations that focus on hydraulic behavior within the monitoring well ring, this vertical gradient was not considered, nor was potential leakage from or into overlying and underlying layers.

Results of hydrologic testing conducted in 2008 (Knight Piesold, 2008) provided the basis for aquifer parameters values used in the modeling. Results of testing in the Dewey area in the lower Fall River indicate an average transmissivity of 255 ft^2/day and average storativity of 4.6×10^{-5}. Based on an assumed 75-foot thickness of the lower Fall River, the hydraulic conductivity is calculated as 3.4 ft/day. Total porosity of the lower Fall River was estimated at 29 percent, based on analysis of core samples. These values were the initial values used in the model calibration simulations. The initial values were modified during model calibration.

Average groundwater velocity under the stated aquifer conditions of hydraulic conductivity of 3.4 ft/d, hydraulic gradient of 0.006 ft/ft and porosity of 29 percent is 0.07 ft/d, or 26 ft/yr.

Anticipated production rates were assumed to be approximately 20 gallons per minute (gpm) per well pattern, with a net bleed (overproduction) of approximately 1%. Figure 1 shows the wellfield layout that was modeled in the Dewey area.

Model Code

Three-dimensional analysis of groundwater flow in the lower Fall River aquifer system was performed with the finite difference groundwater flow model (MODFLOW), developed by the U.S. Geological Survey (USGS) (McDonald 1988, 1996). MODFLOW was selected for simulating groundwater flow at the Dewey site because it is capable of a wide array of boundary conditions, in addition to being a public domain code that is well accepted in the scientific community. MODFLOW can be used to simulate transient or steady-state saturated groundwater flow in one, two, or three dimensions. The code simulates groundwater flow using a block-centered, finite-difference approach. Modeled aquifers can be simulated as unconfined, confined, or a combination of thereof.

Advective transport was evaluated using MODPATH, Version 3, developed by the USGS (Pollock, 1994). MODPATH's particle-tracking code was utilized because it is compatible with model outputs from the MODFLOW groundwater flow model and is suitable for flowpath analysis of steady-state or transient simulations, and is a widely accepted public domain code. MODPATH utilizes the output head files from MODFLOW to calculate particle velocity changes over time in three dimensions.

MODPATH was used to provide computations of groundwater seepage velocities and groundwater flow directions at the site.

The pre/post-processor Groundwater Vistas (Environmental Simulations, Version 5, 2007) was used to assist with input of model parameters and output of model results. Groundwater Vistas serves as a direct interface with MODFLOW and MODPATH. Groundwater Vistas provides an extensive set of tools for developing, modifying and calibrating numerical models and allows for ease of transition between the groundwater flow and particle tracking codes. Full description of the Groundwater Vistas program is provided in the Users Guide to Groundwater Vistas 5 (Environmental Simulations, Inc., 2007).

Model Domain and Grid

The model encompasses an area of approximately 1,530 square miles and is shown on Figure 2. The model domain is aligned to the prevailing potentiometric gradient to the southwest (model is oriented 26 degrees east of north) and the model grid is centered over the F-13 wellfield. Northeast-southwest dimensions are 206,840 feet (39.2 miles), and northwest-southeast dimensions are 206,562.5 feet (39.1 miles).

The model grid was designed to provide adequate spatial resolution within the wellfield area in order to simulate response of the aquifer to typical extraction and injection rates anticipated at the Dewey area in the lower Fall River Formation. The model grid was extended a considerable distance from the wellfield boundaries to minimize potential impacts of exterior boundary conditions on the model solution in the area of interest.

Cell dimensions within the area of the proposed wellfield are 17.5 feet by 17.5 feet. Cell dimensions are gradually increased to a size of 1,500 feet by 1,500 feet near the edges of the model. The model consists of 476 rows and 291 columns, and contains 138,516 active cells.

Model Boundary Conditions

Boundary conditions imposed on a numerical model define the external geometry of the groundwater flow system being studied. Boundary conditions assigned in the model were determined from available reported potentiometric conditions (Knight Piesold, 2008). Descriptions of the types of boundary conditions that can be implemented with the MODFLOW code are found in McDonald and Harbaugh (1988).

This numerical model was designed for a conceptual evaluation of wellfield flare and near-wellfield groundwater movement, and is not a rigorous conceptualization of the potential heterogeneities and hydrogeologic boundaries present in the larger regional groundwater flow system.

Boundary conditions used to represent hydrologic conditions at the Dewey site include general-head boundaries (GHB) and wells (extraction and injection). The locations of the GHB conditions within the model are illustrated in Figure 2. Discussion of the placement and values for these boundary conditions is provided below. The placement and values for the well boundary conditions are described under the simulation discussion.

The GHB was used in the Dewey Area model to account for inflow and outflow from the model domain on all sides. GHBs were assigned along the edges of the model domain by extrapolating available potentiometric data (Knight Piesold, 2008), including observed water level elevations and observed hydraulic gradients. GHBs were used because the groundwater elevation at those boundaries can change in response to simulated stresses. In the Dewey wellfield model, GHBs were assigned to all four sides of the model. The values of head assigned to the GHBs ranged from 4,269 feet above mean sea level (ft amsl) along the north edge of the model and 3,036 ft amsl, along the south edge. The values of head assigned to the GHBs on the west and east sides of the model vary linearly between assigned heads at the north and south boundaries of the model. This configuration represents a hydraulic gradient of 0.006 ft/ft to the southwest, consistent with water levels and hydraulic gradients observed in the lower Fall River monitor wells.

The wellfield configuration includes a series of 5-spot well patterns with an extraction well located in the center, surrounded by four injection wells. Each well pattern is approximately 70 feet on a side. Figure 1 presents the wellfield layout of injection and extraction wells, and the perimeter monitor well ring. Extraction and injection rates applied to the wells are described under the simulation discussions of this report.

The model domain was extended a suitable distance from the location of the proposed production wellfield to minimize perimeter boundary effects on the interior of the model where the hydraulic stresses were applied.

Aquifer Properties

Input parameters used in the model to simulate aquifer properties are consistent with site-derived data, including the following:

- Top and bottom elevations of the lower Fall River sandstone, of approximately 3,066 feet above mean sea level (ft amsl) and 2,991 ft amsl at the southwest corner of the modeled wellfield
- Saturated thickness of 75 feet
- Hydraulic gradient of 0.006 ft/ft
- Hydraulic conductivity of 3.4 ft/day and storativity of 4.6×10^{-5}, based on hydrologic testing (to be modified by model calibration)
- Porosity of 29%, based on core analysis

For the purposes of a wellfield-scale model simulating ISR production, the additional geologic and hydrogeologic complexities that are present in the Dewey area were not included, owing to the lack of data. The wellfield is located on a homoclinal limb of the Fall River Formation, but the aquifer is represented as an extension of the stratigraphic dip observed near the wellfield. Thus, the observed top of the lower Fall River sandstone is extended to the model boundaries at a dip of 0.01 ft/ft, though limited local data and regional mapping indicates that the degree of dip in both the up-dip and down-dip directions decreases.

Static water level conditions within the model domain are similarly presented. Utilizing a potentiometric elevation of 3,654 ft amsl at the southwest corner of the wellfield, an average measured gradient of 0.006 ft/ft is extended to the edges of the model boundaries.

A hydrologic test conducted in 2008 (Knight Piesold, 2008) in the Dewey area included a pump test at well DB-07-32-03C for 3.08 days, at a constant rate of 30.2 gpm. The median reported aquifer transmissivity (T) for the lower Fall River (estimated thickness of 75 feet) was approximately 255 ft^2/day, which corresponds to a hydraulic conductivity of 3.4 ft/day. Median storativity (S) was determined to be 4.6×10^{-5}. These two values (T = 3.4 ft/day; S = 4.6×10^{-5}) represent starting aquifer input values for the wellfield model calibration to the results of testing.

No attempt was made to calibrate the model to natural background potentiometric conditions because of limited data.

Modeled Aquifer Response versus 2008 Hydrologic Testing

The groundwater model was calibrated to the 2008 pump test conducted in the Dewey area (Knight Piesold, 2008). The pumping well (DB-07-32-03C) is completed in a portion of the lower Fall River (ore zone), and three observation wells completed to the ore zone were monitored. The pumping well and two closest observation wells are located within or near the wellfield. Overlying and underlying wells were also monitored, but because the model is a single layer, the overlying and underlying data was not utilized in the calibration.

The pumping well was simulated at a constant rate of 30.2 gpm for 3.08 days. The initial condition was the previously described potentiometric surface with a hydraulic gradient of 0.006 ft/ft. Simulated drawdown at the three observation wells was compared to the pump test results and hydraulic conductivity and storativity values were varied in the model input to attempt a best fit to the limited hydrologic data. No attempt was made to compare the results of the pumping well drawdown at the end of the test, due to the lack of data regarding well efficiency at this well.

The following table briefly summarizes the results of the 2008 testing:

Well	Type	Radial Distance to Pumping Well (ft)	Observed Drawdown at End of Pumping (ft)
DB 07-32-3C	Pumping	0	44.8
DB 07-32-05	Observation	265	13.0
DB 07-32-4C	Observation	467	9.8
DB 07-29-7	Observation	2,400	1.5

During calibration, model input parameters for K and S were varied from the average reported aquifer parameters (K = 3.4 ft/day, S = 4.6 x 10^{-5}, Knight Piesold [2008]). Table 1 summarizes the calculated residual values (difference between observed versus model results of drawdown), and shows that a K value of 3.1 ft/day and S value of 4 x 10^{-5} provides the best match to observed drawdowns. The model output at the distal observation well (DB 07-29-7, 2,400 ft distant) overpredicts drawdown in all simulated cases. The purpose of the modeling simulations are to simulate flow at a wellfield scale and within the monitoring well ring (spaced 400 feet from the ore body wellfield patterns, therefore the drawdown fit at the two closest wells was weighed more heavily in the choice of aquifer parameters for the wellfield model (see Table 1). Based on this approach, a conductivity of 3.1 ft/day and storativity of 4 x 10^{-5} were determined to best fit the limited hydrologic data available. Figure 3 presents the simulated drawdown versus observed drawdown.

Dewey Wellfield Balance and Determination of Flare

The wellfield balance and flare determination simulation was conducted to (1) attempt to balance injection and production volumes within the wellfield while minimizing excursion potential and (2) track groundwater particle pathways that illustrate the horizontal flare around the wellfield. The following wellfield simulation was run for a period of two years, and flare was evaluated at the end of this time frame.

Input parameters for the modeled aquifer are a K value equal to 3.1 ft/day and S equal to 4 x 10^{-5}. Total wellfield overproduction (bleed) in this simulation is 1.0%. Balancing was conducted by starting with an idealized wellfield balance, with each extraction well producing at 20 gpm. Each injection well rate is defined by the number of neighboring extraction wells. An interior injection well surrounded by four extraction wells and injects at a rate of 19.8 gpm (1.0% bleed). For an exterior injection well adjacent to three extraction wells, the injection rate is 75% of an interior well, and 50% and 25% for an injection well adjacent to two and one extraction wells, respectively.

Total production at the 104 extraction wells is 2080 gpm, equivalent to 20 gpm per well. Total injection at the 160 injection wells is 2059.2 gpm, ranging in rate from 3.2 gpm to 20.8 gpm. Figure 4 presents the modeled wellfield, with posted extraction and injection volumes at each of the 264 wells.

Particle tracking by MODPATH was implemented utilizing multiple particles originating in the model cell of each of the exterior injection wells. Figure 5 presents the particle flowpaths of the balanced wellfield at 1.0% bleed, and the perimeter of the particle traces were traced. Horizontal flare is calculated by taking the ratio of the flare perimeter and boundary of the injection wells. Horizontal flare was minimized by adjusting injection rates at specific wells while maintaining the overall balance at a 1% bleed. Horizontal flare is calculated at 1.19 by dividing the area of particle traces by the exterior boundary of the wellfield. Vertical flare cannot be evaluated in the single-layer model that was utilized in this simulation, but it is expected that the magnitude of vertical flare is similar, or less, in scale to horizontal flare. Due to the vertical anisotropy likely present in the sand layers (i.e., horizontal conductivity is greater than vertical conductivity) and the presence of overlying and underlying confining layers, it is likely that flare in the vertical dimension is less than in the horizontal. Therefore, a total flare value of 1.4 is reasonable and appropriate for the Dewey wellfield.

Simulated Regional Drawdown and Wellfield Potentiometric Levels

Regional drawdown was evaluated based on the results of the two-year operational simulation conducted in the wellfield flare evaluation. Based on the model results, regional drawdown impacts of 5 feet and 1 foot are approximately 14,000 ft (2.7 mi) and 68,000 ft (12.9 mi), respectively (see Figure 6). Figures 7 and 8 present the modeled potentiometric surface of the ore zone near the wellfield and modeled drawdown near the wellfield, respectively.

For model verification, an analytical Theis equation is used to compare the radius of drawdown from the wellfield. Using the Theis solution in a spreadsheet produced by the USGS (Halford and Kuniansky, 2002), a pumping rate of 20.8 gpm (i.e., 2080 gpm – 2059.2 gpm) over a two-year period is used. Results of this calculation indicate that the radius of 5-foot and 1-foot of drawdown is approximately 16,000 feet and 80,000 feet, respectively, which compares well to the results of the modeling simulations.

The wellfield model simulates a homogeneous and isotropic aquifer, without any potential hydrogeologic boundaries (e.g., recharge and/or fault boundaries). The presence of potential boundaries at some distance from the wellfield, or heterogeneity within the wellfield could increase or decrease the overall drawdown within the wellfield area, and may require changes in the overall wellfield balance, but is not expected to significantly alter flow within the wellfield.

Dewey Wellfield Simulated Excursion

In order to assess the proposed 400 foot monitoring well spacing (i.e., wells spaced approximately 400 feet distant from the wellfield, and laterally spaced 400 feet apart in the monitor well ring), an excursion was simulated to illustrate that the spacing is adequate to detect a potential excursion that might occur.

To simulate the excursion, the extraction well at the extreme southwest corner of the wellfield was turned off, with all remaining injection and extraction wells operating at the same rates evaluated in the 1% bleed wellfield flare simulation. This location in the wellfield was utilized because the downgradient and southern portion of the wellfield would be most susceptible to particles exiting the hydraulic sink of the wellfield and traveling southwest with the regional groundwater gradient. Particles to track the flow of injectate from the wellfield during the simulated excursion were placed at the three downgradient injection wells.

Figure 9 presents the particle paths originating from the "out of balance" corner of the wellfield. Figure 10 presents the simulated potentiometric surface at this time near the wellfield. Groundwater flow vectors at the end of the excursion simulation are presented in Figure 11 and illustrate that groundwater flow in the southern area near the monitoring wells is dominantly to the south, in the direction of regional hydraulic gradient. As can be observed from Figure 9, the modeled excursion would eventually intersect the perimeter monitor wells. Therefore, the proposed 400 foot monitoring well spacing is adequate to detect any potential excursion.

Dewey Wellfield Simulated Excursion Recovery

To demonstrate that any potential excursion to the monitoring well ring can be hydraulically controlled, the previously simulated excursion was recovered by adjusting wellfield production/injection. Injection rates at the three downgradient injection wells were set to zero, and the two downgradient extraction wells were adjusted to pump at a rate of 24 gpm each.

Figure 12 presents the potentiometric surface near the simulated excursion at approximately one hour after the recovery was initiated. As can be seen in this figure and contrasted with the potentiometric levels during the excursion (see Figure 10), a local gradient from the southernmost monitor well back to the wellfield is induced. Figure 13 illustrates the velocity vectors of groundwater flow at the same time, which has been reversed and modeled groundwater flow at the area of the simulated excursion is moving back towards the wellfield.

The previously simulated excursion, where a single extraction well was turned off, was run for an additional 30 days, and particles just inside the perimeter monitor well boundary at the downgradient side of the wellfield were tracked. At the end of the 30 days, the excursion recovery was initiated and particles representing the downgradient extent of the simulated excursion were tracked for a period of 60 days. Figure 14 illustrates the simulated groundwater flowpaths immediately adjacent to the monitor well for this scenario, as well as illustrating that the excursion recovery scenario is adequate to reverse the hydraulic gradient and reverse the direction of groundwater flow at a distance of 400 ft, and pull the simulated excursion back inside the perimeter boundary. This figure also provides an indication of the scale of simulated groundwater travel times, as groundwater migrates only approximately 3 ft in the 30 day simulated

excursion scenario, and a similar distance for the 60 day recovery. Differences in velocity at this location during the excursion and subsequent recovery are because the induced hydraulic gradient during recovery is lower than the regional gradient that was simulated during the out-of-balance wellfield excursion.

In order to assess the validity of this simulation, an analytical Theis solution for a confined aquifer was utilized. The excursion recovery represents an additional 28 gpm of production (24 gpm at one well previously not operating, and the other well increased from 20 gpm to 24 gpm) and a deduction of approximately 16 gpm (see Figure 4 for posted injection rates), a net pumping rate of 44 gpm. At a distance of 400 ft from the pumping well, the drawdown at one hour is estimated to be approximately 4 feet. Therefore, the Theis solution verifies the results of the modeling simulation that indicate the local gradient can be influenced at a distance of 400 ft. This relatively rapid response at this distance is due to that fact that the lower Fall River is a relatively low-storage system (based on hydrologic testing).

Summary

Numerical modeling was conducted to evaluate wellfield-scale issues related to ISR production at the Dewey-Burdock Project. Wellfield flare was determined and the proposed 400 foot well spacing was demonstrated through modeling to be adequate to detect a potential excursion at this distance. Model simulations also demonstrated that hydraulic control of the simulated excursion can be established by changing wellfield operational rates at this distance away from the wellfield.

Horizontal flare from a balanced wellfield operating at a 1% net bleed was determined to be 1.19. Vertical flare was not evaluated, but considering a similar scale of flare in this direction, total wellfield flare is estimated at approximately 1.4.

An excursion was simulated by varying the wellfield balance, and particle pathways representing the flow of injectate indicate that the 400 foot monitoring well spacing is adequate to detect the excursion away from the wellfield. The recovery of a potential excursion was also demonstrated by varying the wellfield balance to reverse the hydraulic gradient at this distance and change the direction of travel of groundwater back towards the wellfield.

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References

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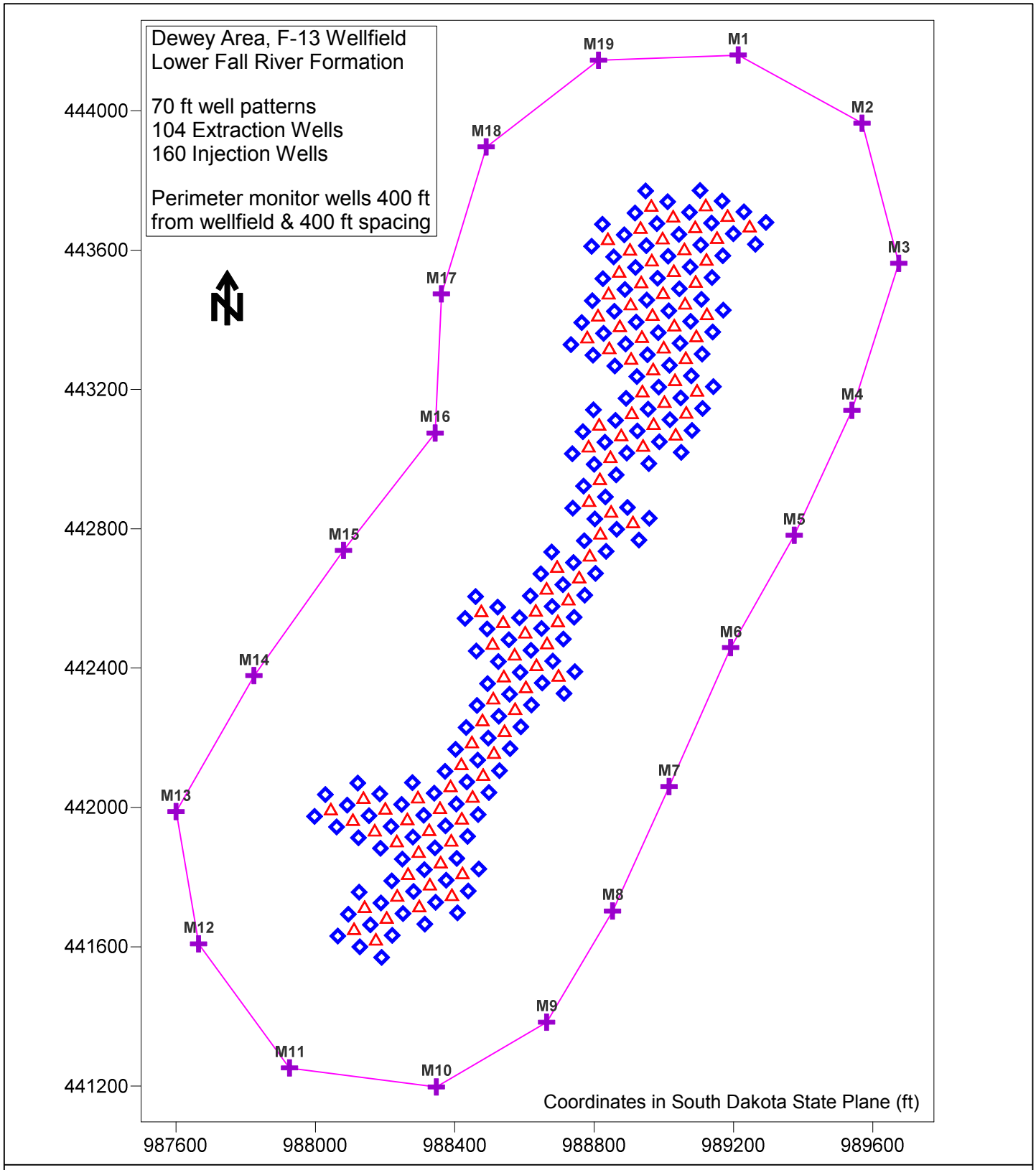
Powertech (USA) Inc., 2009. Dewey-Burdock Project Application for NRC Uranium Recovery License, Fall River and Custer Counties, South Dakota, Technical Report (separate cover) & Environmental Report (separate cover). February 2009.

Table 1. Dewey Wellfield Model, Calibration of Model to 2008 Hydrologic Testing

	Drawdown Residual* (DB 07-32-05) (265 ft from PW)	Drawdown Residual* (DB 07-32-04C) (467 ft from PW)	Drawdown Residual* (DB 07-29-7) (2,400 ft from PW)	Residual Sum of Squares, 2 Closest Wells[1]
K = 3.1 ft/day				
S=3e-5	-0.34	-1.11	-3.03	1.35
S=4e-5	**0.23**	**-0.53**	**-2.5**	**0.33**
S=5e-5	0.68	-0.09	-2.09	0.47
S=6e-5	1.04	0.28	-1.77	1.16
K = 3.2 ft/day				
S=3e-5	0.01	-0.83	-2.94	0.69
S=4e-5	0.57	-0.37	-2.43	0.46
S=5e-5	1	0.16	-2.03	1.03
S=6e-5	1.35	0.51	-1.72	2.08
K = 3.4 ft/day				
S=3e-5	0.67	-0.31	-2.79	0.55
S=4e-5	1.19	0.21	-2.3	1.46
S=5e-5	1.6	0.62	-1.93	2.94
S=6e-5	1.93	0.95	-1.63	4.63
K = 3.6 ft/day				
S=4e-5	1.75	0.65	-2.18	3.49
S=5e-5	2.13	1.03	-1.83	5.60
S=6e-5	2.45	1.34	-1.54	7.80

Notes:
* - A positive sign indicates underprediction of drawdown; negative sign indicates model output drawdown more than observed drawdown.
1 - Calibration based on evaluation at two closest monitoring wells, as indicated in text.
Bold indicates best fit utilized for wellfield model simulations.



Extraction Well

Injection Well

Monitor Well

Monitor Well Ring

0 ft 200 ft 400 ft

Petrotek

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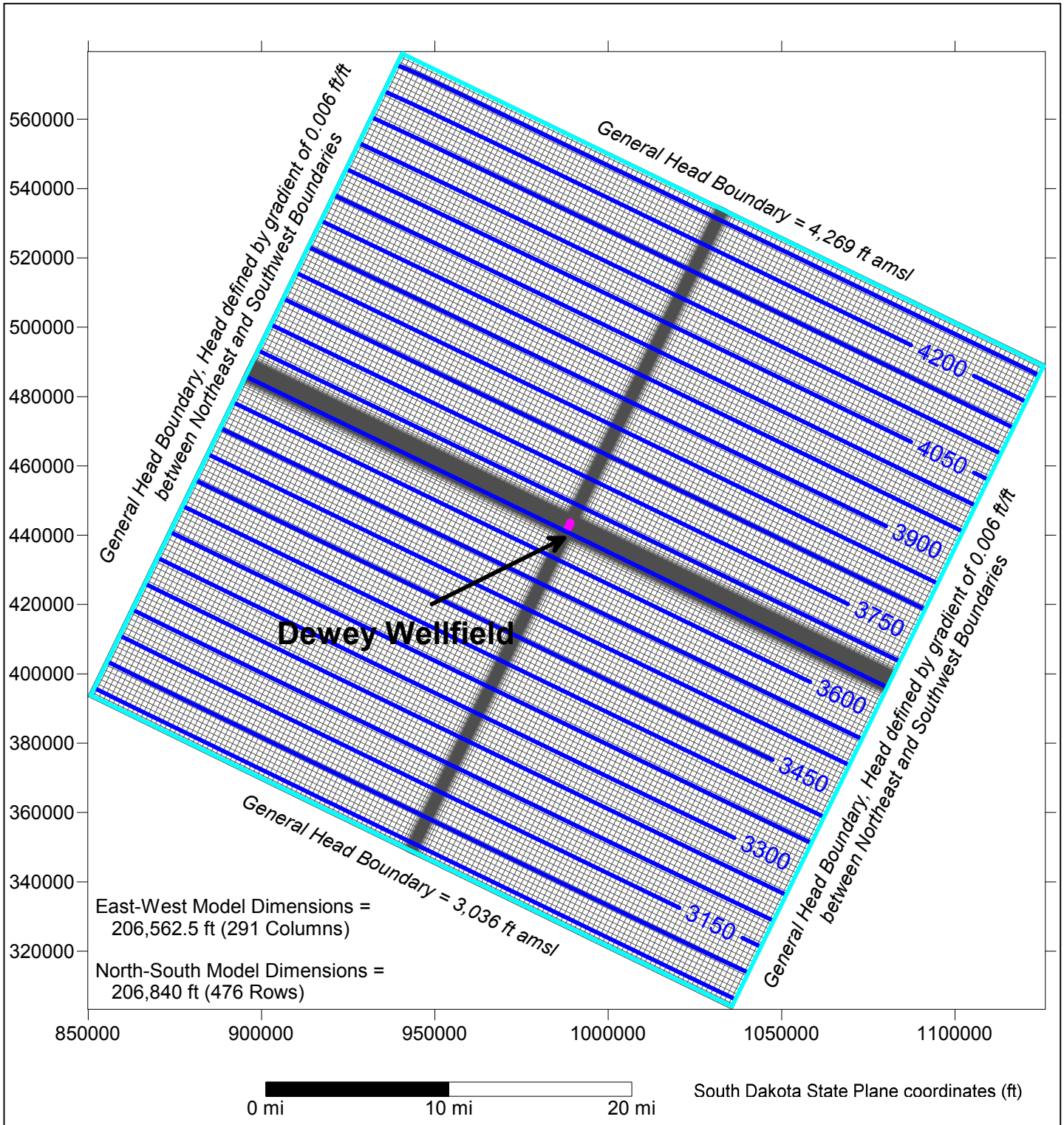
POWERTECH (USA) INC.

Figure 1. Dewey Model Wellfield

Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig1_Dewey Wellfield.srf Date: 10/22/10



Monitor Well Ring

General Head Boundary

Static Potentiometric Surface (ft amsl)
Contour interval = 50 feet

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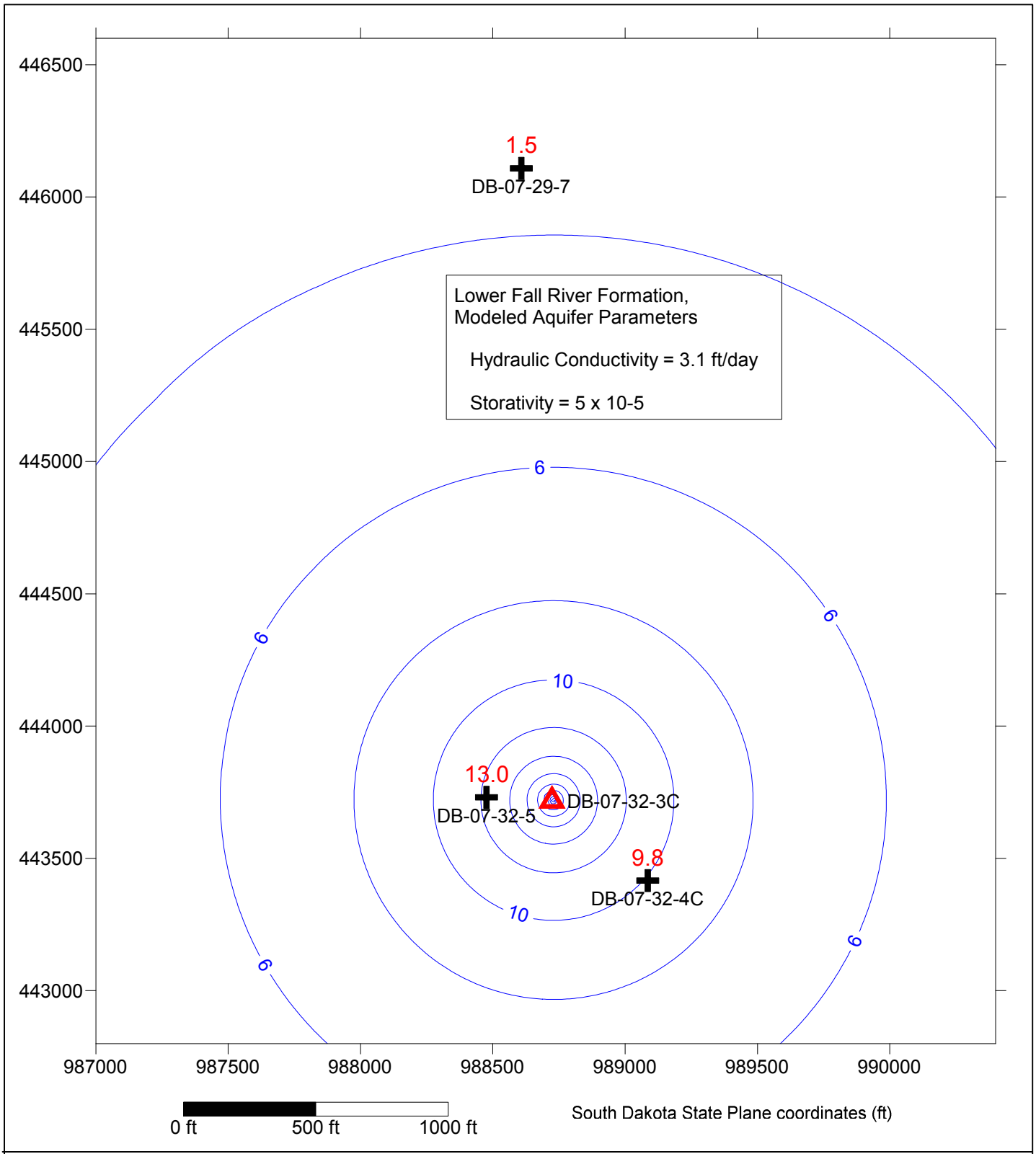
Figure 2. Model Domain, Boundary Conditions, Background Potentiometric Surface Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig2_Dewey WF Model.srf Date: 10/22/10



Pumping Well

Observation Well

13.0 Observed Drawdown (ft)

Simulated Drawdown
Contour Interval = 2 foot

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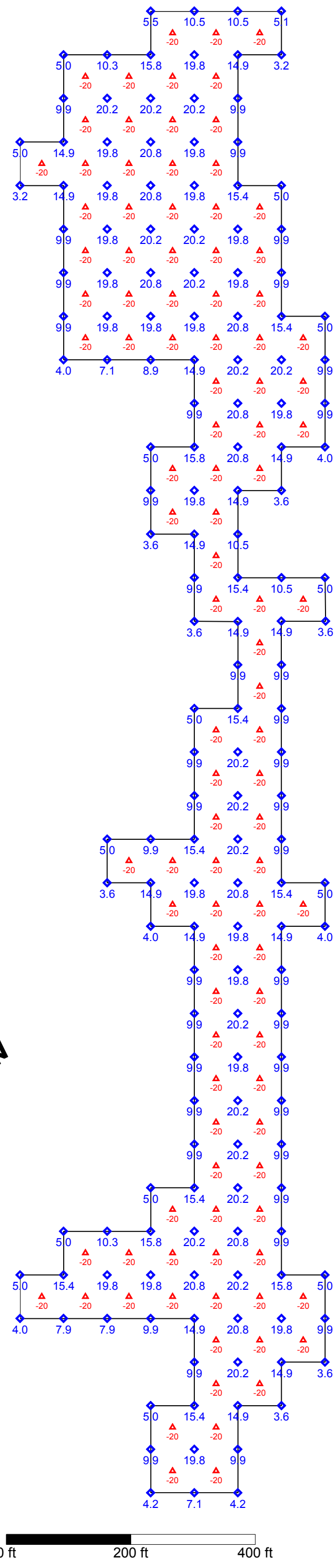
Figure 3. Dewey Area 2008 Pump Test Calibration Results
Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig3_PT Calibration.srf Date: 10/22/10



Note:
Dewey F-13 Wellfield balanced and simulated for a period of 2 years, at 1% bleed.

▲	Extraction Well
◆	Injection Well
-20	Extraction Well Pump Rate (gpm)
5.0	Injection Well Pump Rate (gpm)

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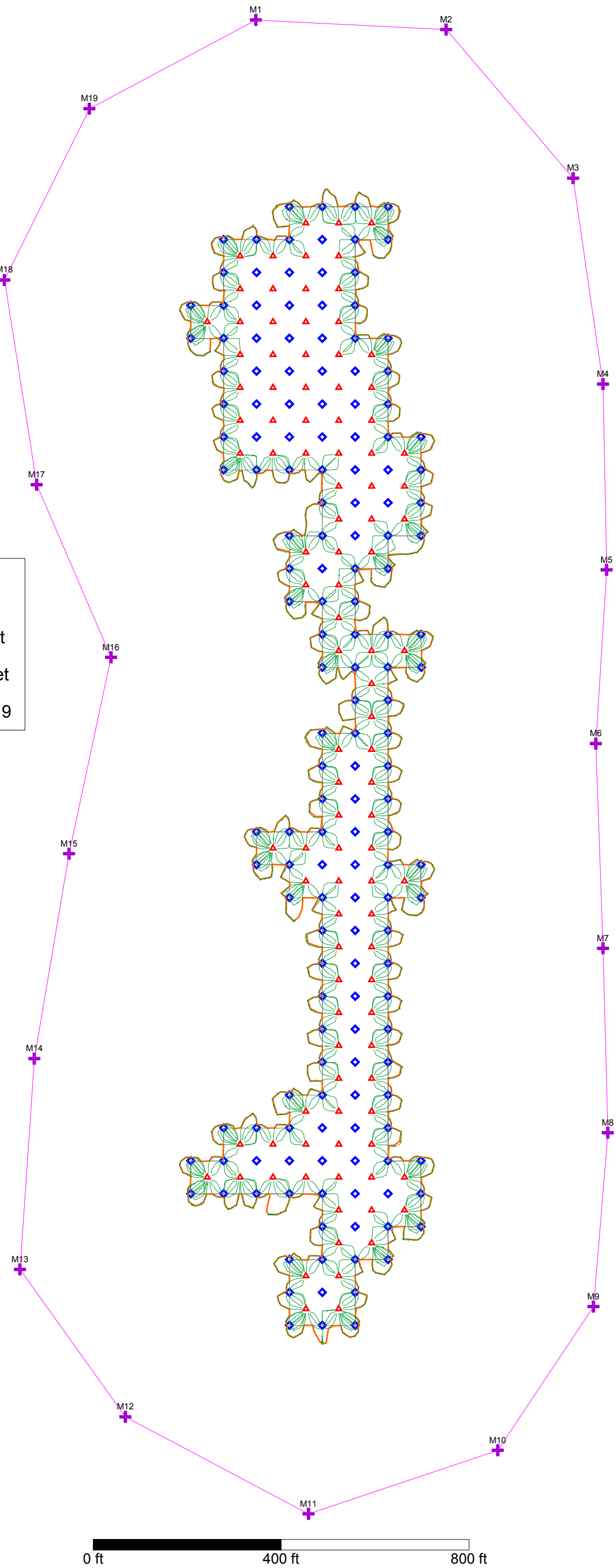
Figure 4. Balanced Wellfield Rates, 1% Bleed
2-Year Simulation
Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig4_1% Bleed Rates.srf Date: 10/22/10



Horizontal Wellfield
Flare Calculation:

Injection Well Boundary, Area = 509,593 sq. feet

Particle Trace Boundary, Area = 607,185 sq. feet

Horizontal Well Flare = 607,185 / 509,593 = 1.19

Note:
Dewey F-13 Wellfield balanced and simulated for a period of 2 years. Groundwater flow particles were tracked along injection well boundary over simulated interval.

N

- Extraction Well
- Injection Well
- Monitor Well
- Monitor Well Ring
- Particle Flow Path
- Horizontal Flare Boundary

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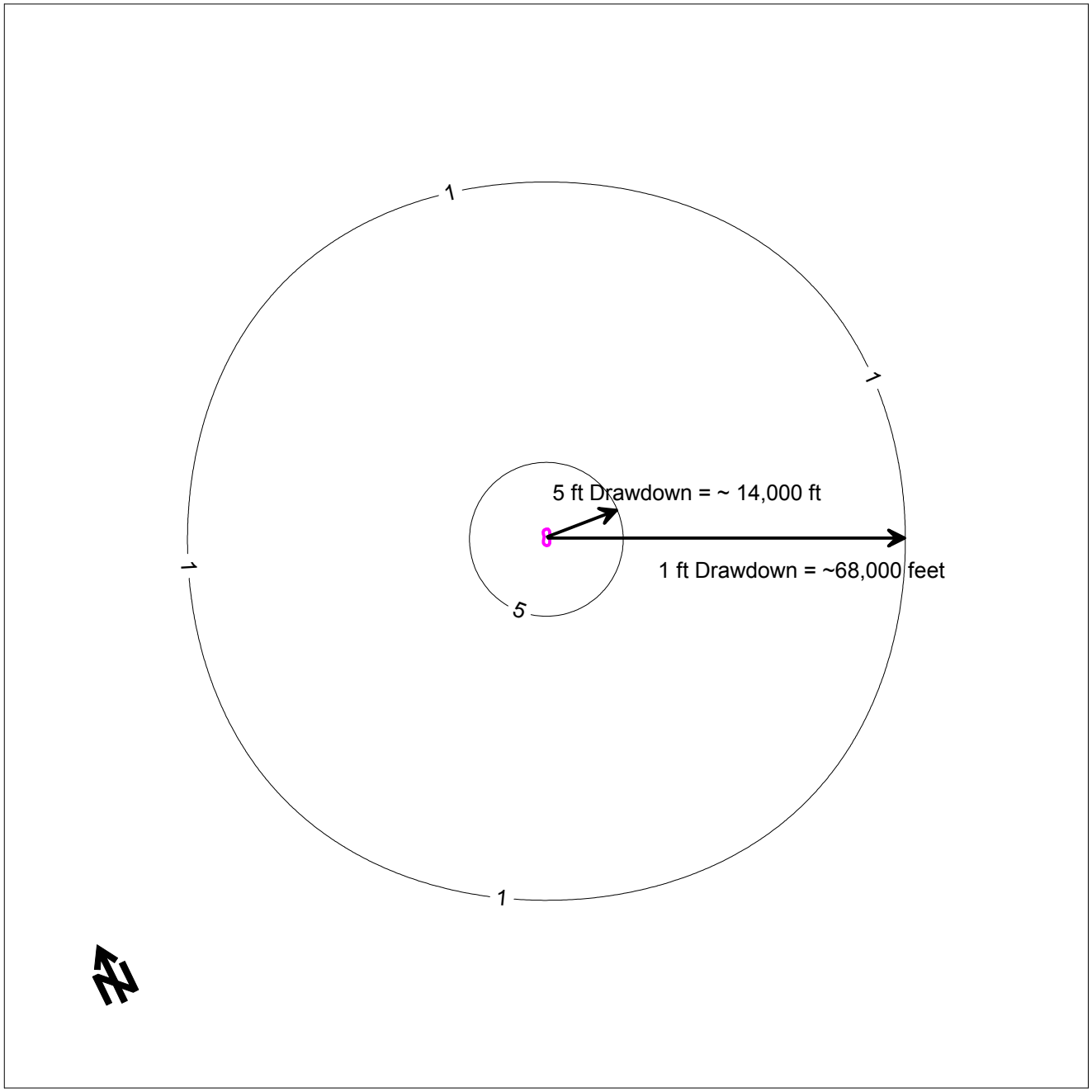
Figure 5. Wellfield Flare, 1% Bleed
2-Year Simulation
Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig5_WF Flare_1%.srf Date: 10/22/10



Monitor Well Ring

Drawdown Contour (ft)

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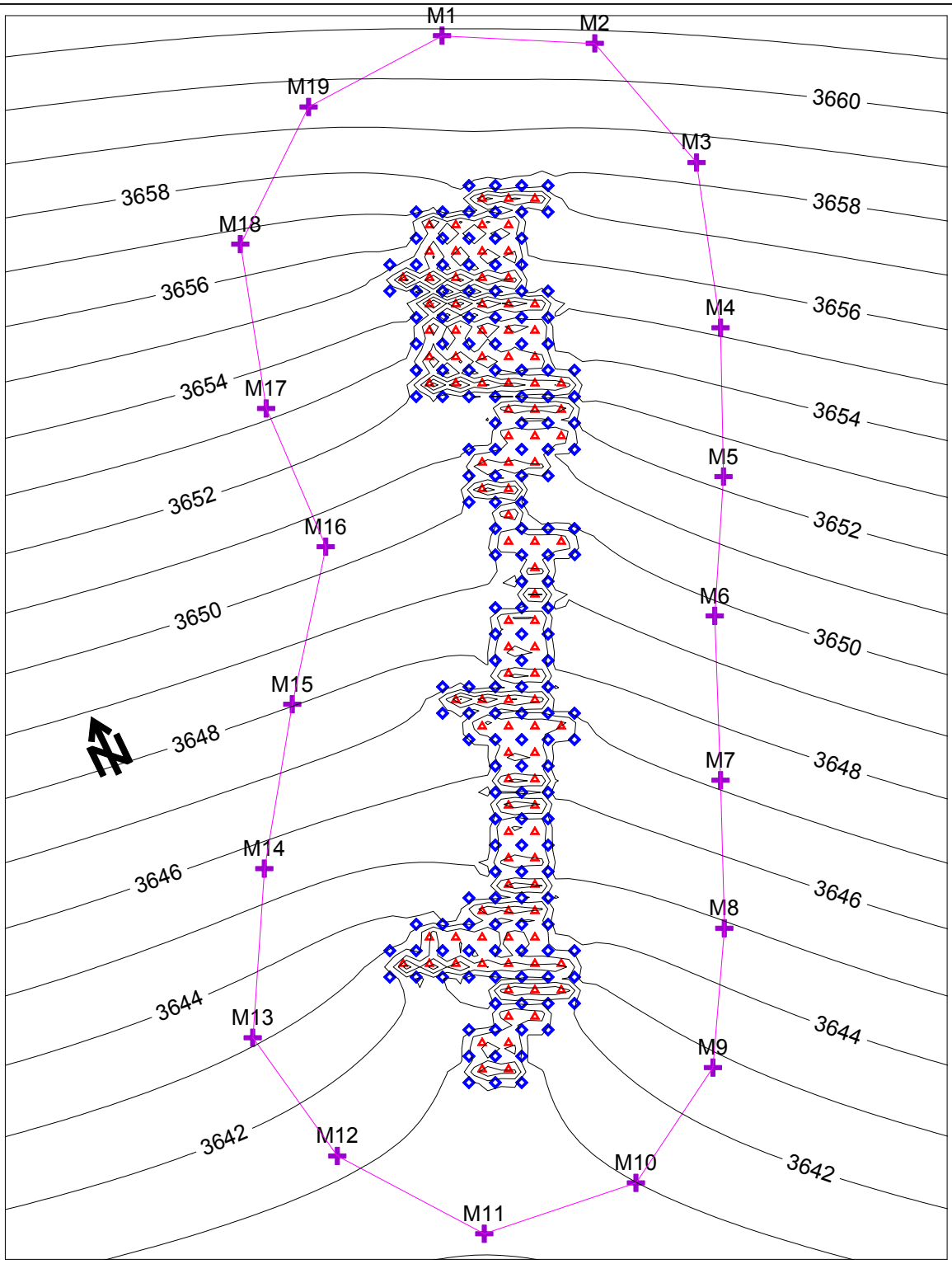
Figure 6. Simulated Regional Drawdown, 1% Bleed
2-Year Simulation
Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig6_RegionalDDN.srf Date: 10/22/10



Extraction Well

Injection Well

Monitor Well

Monitor Well Ring

Simulated Head (ft amsl)
Contour Interval = 1 foot

0 ft 400 ft 800 ft

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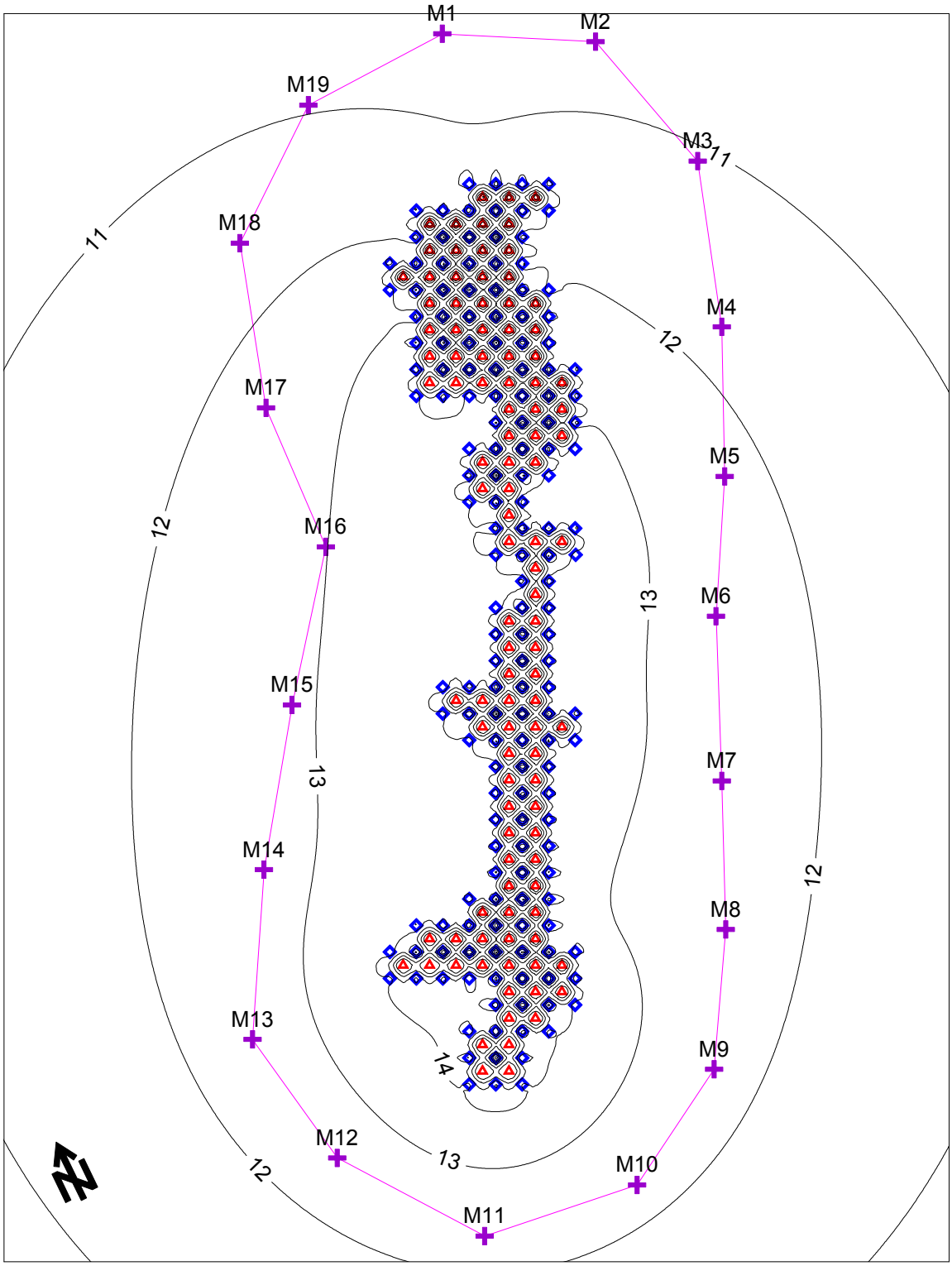
Figure 7. Local Potentiometric Surface
1% Bleed, 2-Year Simulation
Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig7_2yrHead_1%Bleed.srf Date: 10/22/10



Extraction Well

Injection Well

Monitor Well

Monitor Well Ring

Simulated Drawdown (ft)
Contour Interval = 1 foot

0 ft 400 ft 800 ft

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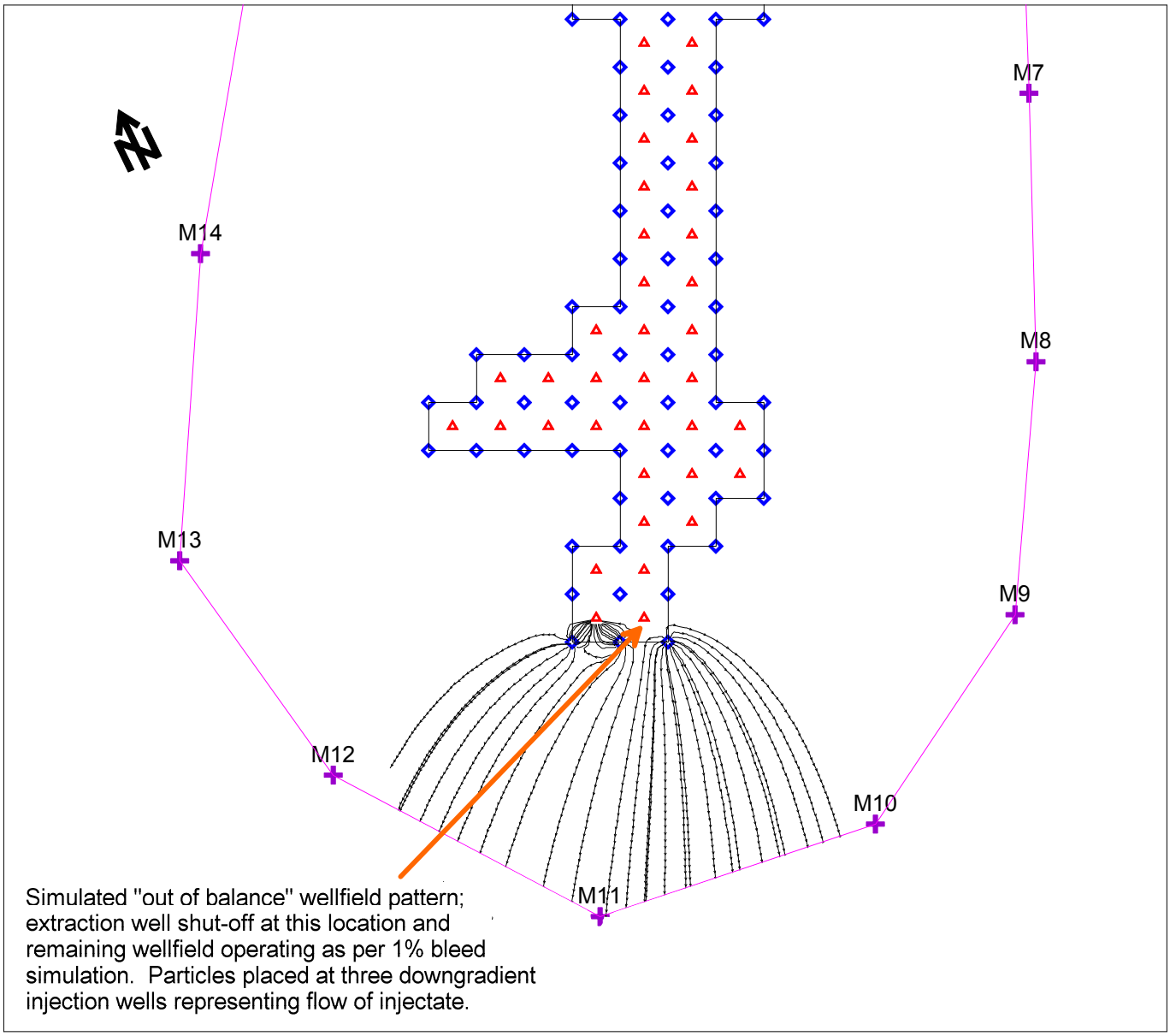
Figure 8. Local Simulated Drawdown
1% Bleed, 2-Year Simulation
Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig8_2yrDDN_1%Bleed.srf Date: 10/22/10



0 ft 400 ft

Extraction Well

Injection Well

Monitor Well

Monitor Well Ring

Particle Flow Path

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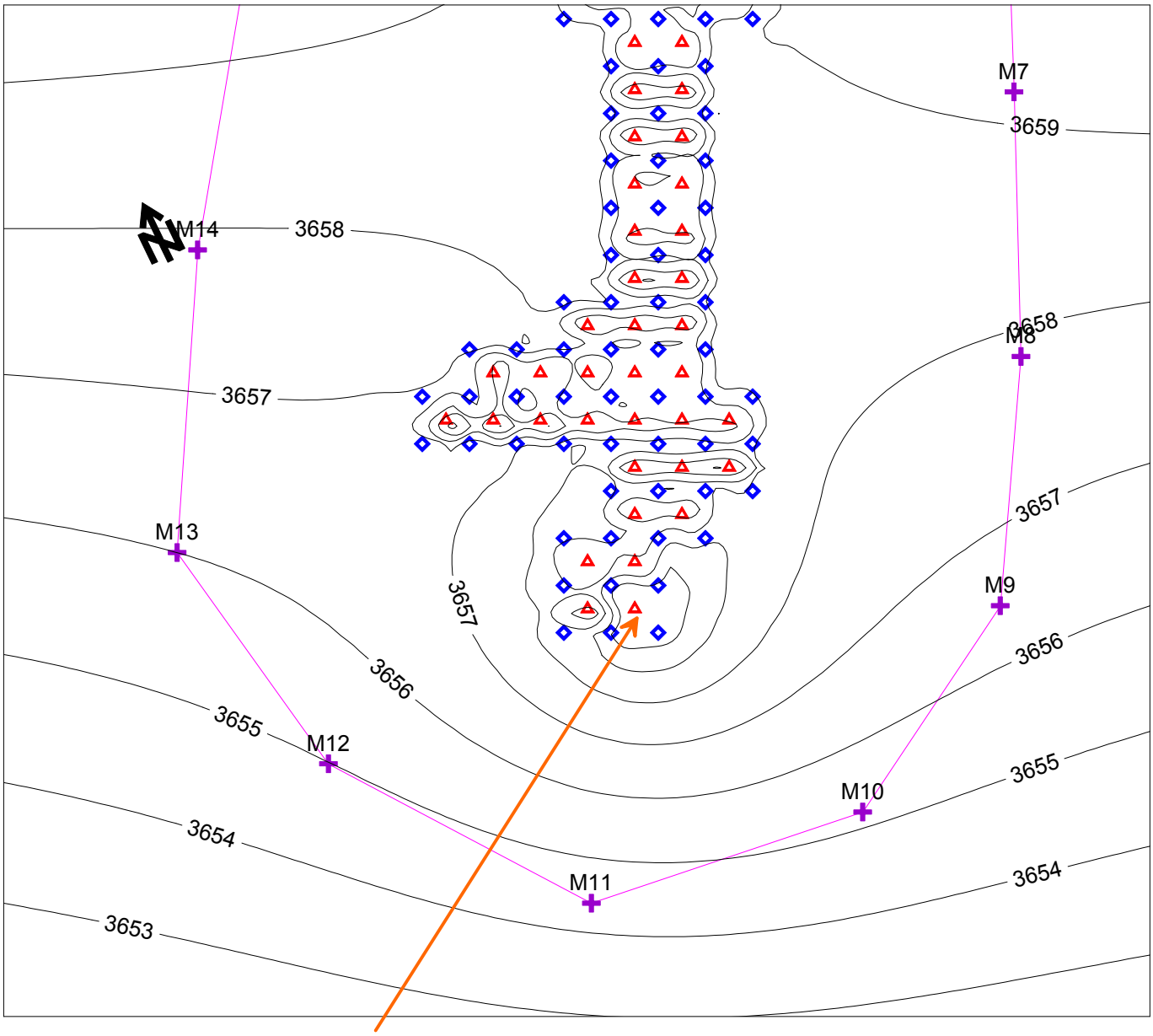
Figure 9. Simulated Excursion Flowpaths and Detection by Perimeter Monitor Wells Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig9_SimExc_Particles.srf Date: 9/30/10



Simulated "out of balance" wellfield pattern;
extraction well shut-off.

0 ft 400 ft 800 ft

Extraction Well

Injection Well

Monitor Well

Monitor Well Ring

Potentiometric Surface (ft amsl)
Contour Interval = 1 foot

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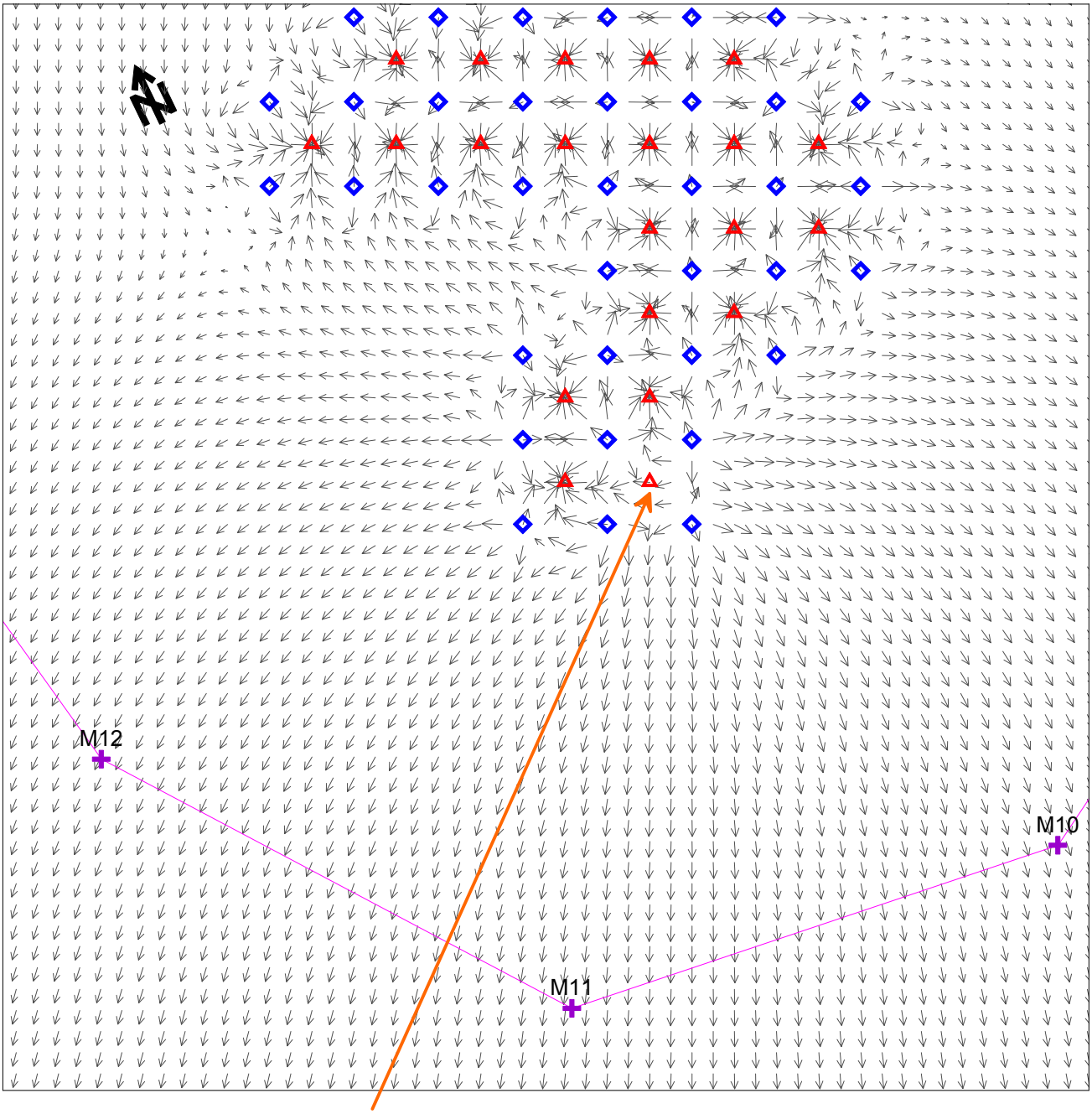
Figure 10. Potentiometric Surface, Simulated Excursion Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig10_SimExc_Head.srf Date: 10/22/10



Simulated "out of balance" wellfield pattern;
extraction well shut-off.

0 ft — 400 ft

- Extraction Well
- Injection Well
- Monitor Well
- Monitor Well Ring
- Groundwater Flow Velocity Vector

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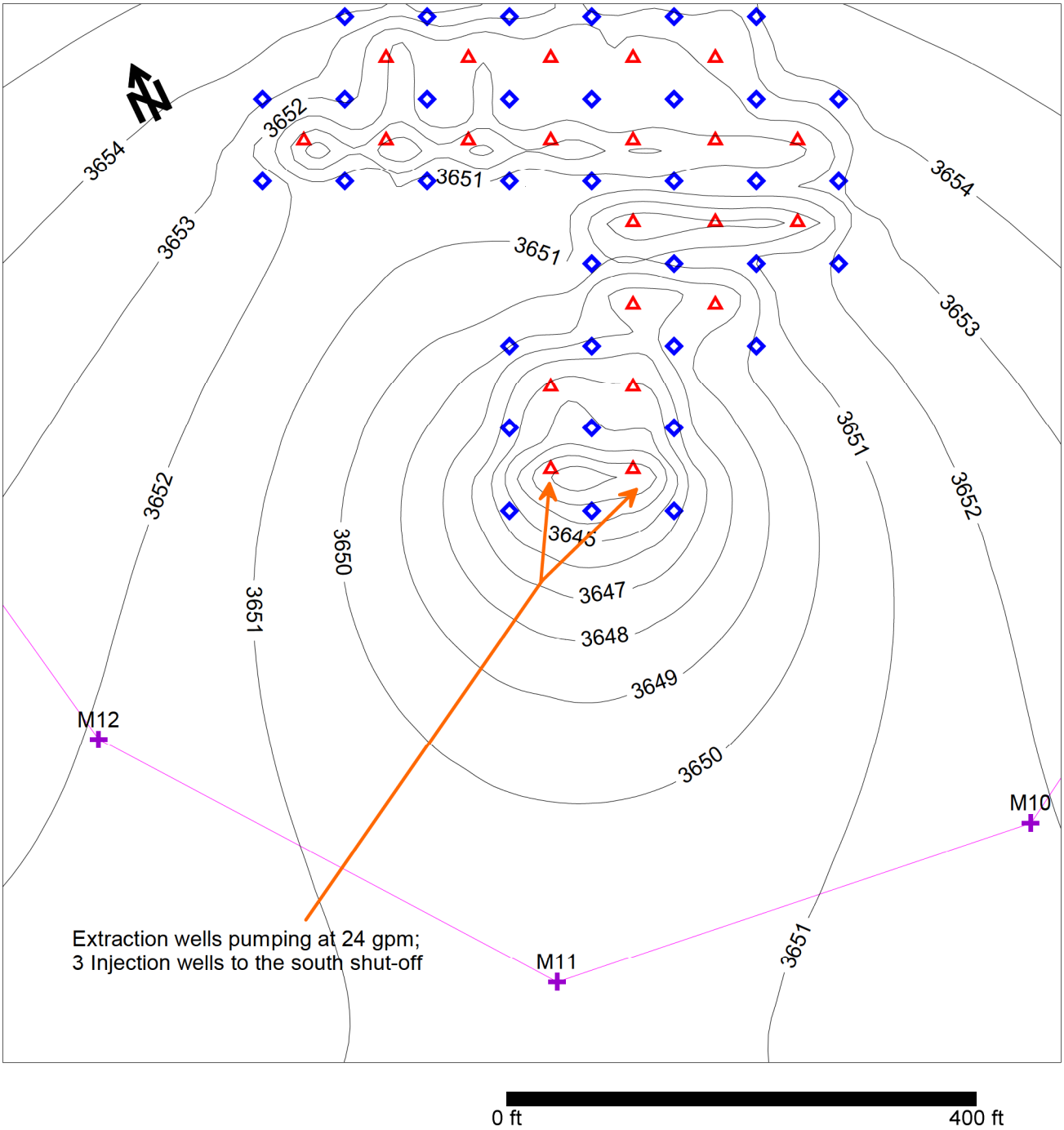
Figure 11. Velocity Vectors, Simulated Excursion
Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig11_SimExc_Vectors.srf Date: 10/22/10



Extraction Well

Injection Well

Monitor Well

Monitor Well Ring

Potentiometric Surface (ft amsl)
Contour Interval = 1 foot

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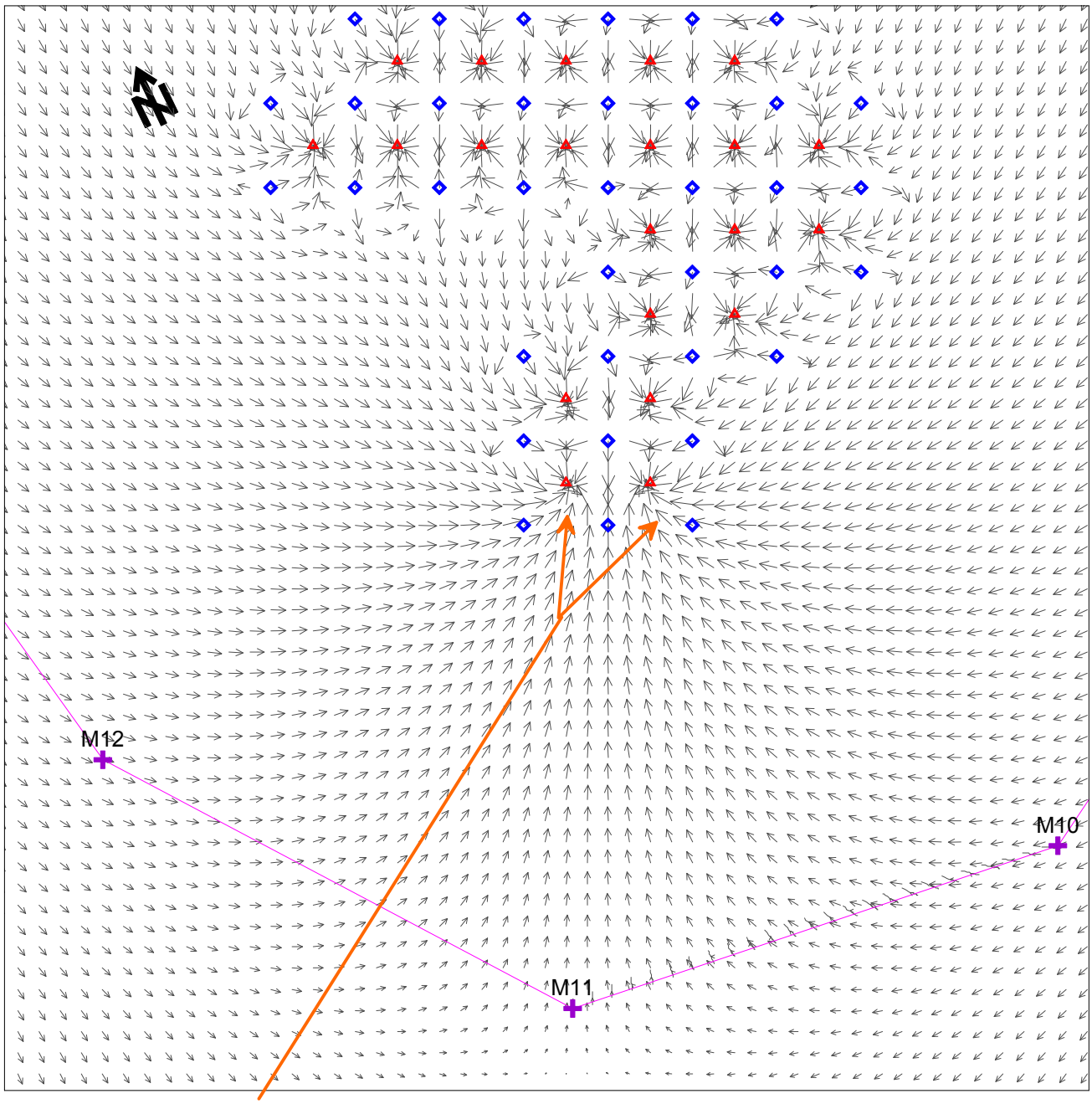
Figure 12. Potentiometric Surface (1 Hour), Simulated Excursion Recovery Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig12_Recovery_Head.srf Date: 10/22/10



Extraction wells pumping at 24 gpm;
3 Injection wells to the south shut-off

0 ft 400 ft

- Extraction Well
- Injection Well
- Monitor Well
- Monitor Well Ring
- Groundwater Flow Velocity Vector

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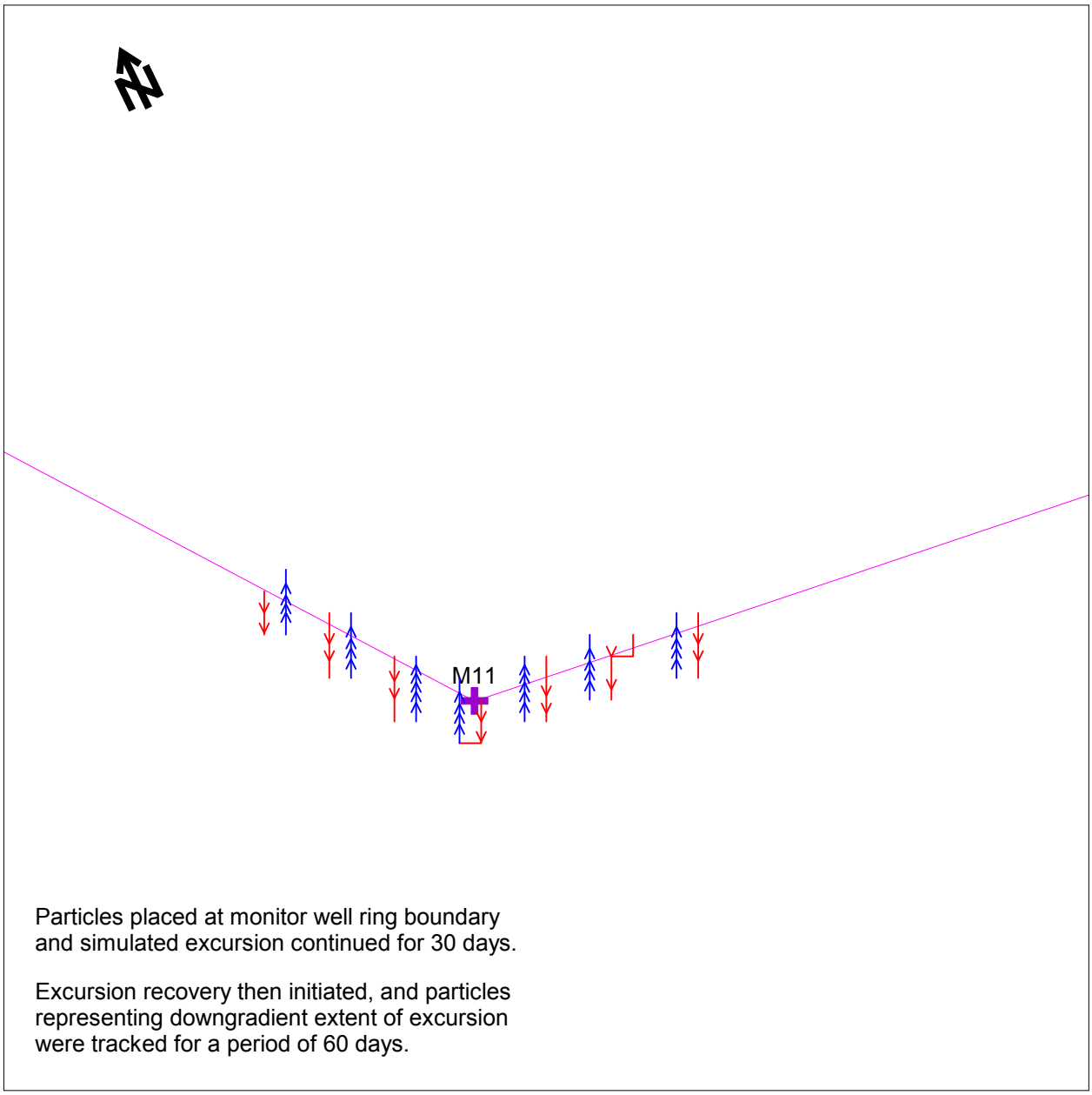
Figure 13. Velocity Vectors (1 Hour), Simulated Excursion Recovery Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig13_Recovery_Vector.srf Date: 10/22/10



Flowpath representing simulated excursion

Flowpath representing simulated recovery

Monitor Well

Monitor Well Ring

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Figure 14. Particle Flow Paths at Monitor Well Simulated Excursion & Recovery Dewey-Burdock Uranium Project, South Dakota

By: AP Checked: HD File ID:Fig14_Exc&RecovPath.srf Date: 10/22/10