NUMERICAL MODELING OF HYDROLOGIC CONDITIONS AT THE LOST CREEK INSITU RECOVERY URANIUM PROJECT, WYOMING

LOST CREEK PROJECT

SWEETWATER COUNTY, WY

November 2010

(Revised January 2011)

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Introduction

Lost Creek ISR, LLC (LC ISR) plans to develop and extract uranium from insitu recovery (ISR) mine units within the HJ Horizon of the Battle Spring Formation at the Lost Creek Project Area (LCPA). LC ISR has submitted an application to the U.S. Nuclear Regulatory Commission (NRC) for a Source Materials License (SML) (LC ISR, 2010a) and an application to the Wyoming Department of Environmental Quality (WDEQ) for a Permit to Mine (LC ISR, 2010b) to conduct ISR operations at the LCPA.

Numerical groundwater flow models were developed using site-specific data to evaluate mine unit scale issues related to ISR production and restoration operations at the site. This report describes the development of the numerical model and summarizes the results of numerical simulations used to address LC ISR, NRC and WDEQ concerns regarding ISR operations at the LCPA.

Purpose and Objectives

The numerical groundwater flow model was developed to support LC ISR in planning and operation of the ISR project. The numerical model is used to assess potential impacts of ISR mining on the HJ Horizon aquifer. The focus of the modeling effort is on proposed Mine Unit 1 (MU1). Model simulations were developed to:

- assess the extent and magnitude of drawdown that may occur during production and restoration phases of the project by refining previously presented analytical estimates;
- estimate flare during wellfield production;
- assess the adequacy of monitor ring well spacing for detection of potential excursions; and
- evaluate the capability to recover an excursion within an acceptable period of time.

The model was developed to allow adequate discretization within the wellfields such that the impacts of individual wells can be discerned. This feature of the model will enable its use as a tool to assist LC ISR in the day-to-day operation of the ISR project.

Conceptual Model

Detailed description of the geology and hydrogeology of the LCPA can be found in the NRC SML and WDEQ Permit to Mine applications (LC ISR, 2010a and 2010b) and in the WDEQ-Land Quality Division (LQD) Mine Unit 1 Application

(LC ISR, 2010c). A conceptual hydrologic model for the LCPA is summarized below.

As previously described, the focus of the model simulations is on the area of MU1 (Figure 1). The aquifer being simulated is the HJ Horizon, which is the primary uranium production zone for the LCPA. The HJ Horizon is continuous throughout MU1 with a total thickness ranging from 100 to 150 feet (ft) and averaging approximately 120 ft. The HJ Horizon dips to the northwest at approximately 3 degrees. The top of the HJ Horizon ranges from 6,518 to 6,622 ft above mean sea level (ft amsl) across MU1 (Figure 2). The Lost Creek Shale overlies the HJ Horizon within the LCPA. Beneath the HJ Horizon is the Sage Brush Shale.

A key structural feature that influences the hydrology within MU1 is the Lost Creek Fault. The Lost Creek Fault trends northeast-southwest through MU1 and is downthrown to the south. Displacement within the HJ Horizon along the Lost Creek Fault ranges from 40 feet on the west end to 80 feet on the eastern end (Figure 1). Near the center of MU1, there is a fault splay south of the Lost Creek Fault that is downthrown to the north. Displacement along the fault splay ranges from 14 to 28 feet, increasing to the east. These faults significantly impede groundwater flow, as observed during several hydrologic tests conducted in the LCPA (Petrotek Engineering Corporation, 2007a, 2007b and 2009). The faults are not impermeable, but act as partial hydraulic barriers to groundwater flow, as will be described further.

The HJ Horizon has been subdivided into the Upper (UHJ), Middle (MHJ) and Lower (LHJ) Sands with the majority of the mineralization occurring in the MHJ. Based on the results of extensive exploratory and delineation drilling by LC ISR and the results of numerous pumping tests (Petrotek 2007a, 2007b and 2009), no laterally extensive confining units have been observed between the UHJ, MHJ and LHJ Sands. The HJ Horizon behaves as a single hydrostratigraphic unit except where the Lost Creek Fault and splay act as partial hydraulic barriers to groundwater flow.

Water-level data collected in December 2008 from HJ Horizon monitor wells indicate the static non-pumping potentiometric surface ranges from 6,735 ft amsl along the east edge of MU1 to approximately 6,776 ft amsl along the west edge (Figure 3). The displacement in the potentiometric surface across the Lost Creek Fault illustrates the hydraulic barrier effect of the fault. The potentiometric surface is from 5 to 20 feet higher on the north side of the fault under static, non-pumping conditions. The potentiometric surface of the HJ Horizon within MU1 indicates a hydraulic gradient to the west-southwest of approximately 0.005 ft/ft (26.4 ft/mi) north of the fault and approximately 0.009 ft/ft south of the fault (47.5 ft/mi).

Transmissivity of the HJ Horizon calculated from the MU1 north and south hydrologic tests ranged from 51 to 129 ft^2/d (381 to 965 gpd/ft) (Petrotek 2009).

The average transmissivity from the north test was 79 ft^2/d ft (591 gpd/ft) and for the south test was 93 ft^2/d (696 gpd/ft). However, drawdowns resulting from these tests were strongly influenced by the hydraulic barrier effects of the Lost Creek Fault and splay. As described in the June 2010 LC ISR responses to WDEQ-LQD comment no. 105, image well theory was used to calculate a value of transmissivity without the effects of the fault (by treating the fault as a no flow boundary). The value of transmissivity that is calculated when eliminating the effects of the fault is approximately double that estimated from the pump test data. Representative values for transmissivity are in the range of 140 to 180 ft^2/d for the north side of the fault and 170 to 200 ft^2/d for the south side. Using the average thickness of the HJ Horizon of 120 ft, and the recalculated transmissivity values (that account for the presence of the fault), the hydraulic conductivity is in the range of 1.2 to 1.5 ft/d north of the fault and 1.4 to 1.7 ft/d south of the fault.

Storativity of the HJ Horizon estimated from the hydrologic testing conducted at the LCPA is in the range of 3.6×10^{-5} to 4.3×10^{-4}. Storativity calculated without the influence of the fault was 7.0×10^{-5}. Total porosity of the HJ Horizon is estimated at 26 percent (personal communication with LLC, ISR personnel, 2010).

Groundwater velocity in the HJ Horizon under representative aquifer conditions of hydraulic conductivity of 1.4 ft/d, hydraulic gradient of 0.007 ft/ft and porosity of 26 percent is 0.038 ft/d or 13.8 ft/yr.

The HJ Horizon is bounded above and below by areally extensive confining units identified as the Lost Creek Shale and the Sagebrush Shale, respectively. The overlying aquifer to the HJ Horizon is the LFG Sand. The potentiometric surface of the overlying LFG Sand is typically 10 to 25 feet higher than the HJ Horizon. The underlying aquifer to the HJ Horizon is the UKM Sand. The potentiometric surface of the UKM Sand is typically at least 20 feet lower than the HJ Horizon on the north side of the Lost Creek Fault. South of the Lost Creek Fault, the potentiometric surface of the UKM Sand is up to 20 feet lower toward the east, but only 2 to 5 feet lower to the west. Although hydrologic test data indicate that some hydraulic communication exists between the HJ Horizon and overlying or underlying units (at least under the large hydraulic stress applied during the tests), the hydraulic response is generally minimal.

Comparison of drawdown at locations where an underlying or overlying monitor well exists next to an HJ monitor well indicates a ratio of greater than 30. In other words, thirty feet of drawdown within the HJ Horizon at a specific location would equate to one foot or less of drawdown at the same location in the overlying or underlying aquifer.

There are no known surface sources of recharge to the HJ Horizon within the LCPA or areas of discharge from the HJ Horizon. There are no surface water bodies within the LCPA. The Sweetwater Mill Pit is located approximately three miles southwest of the LCPA. It is unknown if the Sweetwater Mill Pit intercepts strata that are the stratigraphic equivalent of the HJ Horizon. It is also unknown if the Pit acts as a hydrologic source or sink to groundwater in the HJ Horizon aquifer system. Regardless, as will be described under the simulations section of this report, simulated drawdown impacts resulting from ISR operations at LCPA are minimal (less than five feet) at distances as far as the Sweetwater Mill Pit. For these reasons, the Sweetwater Mill Pit was not included as a hydrologic boundary in the numerical models.

LC ISR has delineated the initial uranium production unit (identified as MU1). The area that will be under pattern in MU1 is reported by LC ISR as 2,115,594 ft^2 (LC ISR, 2010c). This total area includes some stacked well patterns to effectively mine multiple ore zones within the HJ Horizon. MU1 will include 12 header houses. Each header house will control up to 20 well patterns.

Average ore zone thickness is estimated at 12 feet (LC ISR, 2010c). Anticipated production rates will be between 30 and 35 gpm per well pattern with a net 0.5 to 1.5 percent bleed (overproduction). Average production flow will be slightly less than 6,000 gpm.

Model Code

Three-dimensional analysis of groundwater flow in the HJ Horizon 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 LCPA 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 the two. MODFLOW also supports variable thickness layers (i.e. variable aquifer bottoms and tops. Documentation of all aspects of the MODFLOW code is provided in the users manuals (McDonald, 1988 and 1996).

A particle-tracking code was utilized that could readily incorporate information collected from the MODFLOW groundwater flow model. The code chosen was MODPATH, Version 3 (Pollock, 1994), which was designed to use 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. MODPATH is also a public domain code that is well accepted in the scientific community. Full documentation of the MODPATH code is provided in the MODPATH users guide (Pollack, 1994).

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, Version 5.0 (Environmental Simulations, Inc., 2007).

Model Domain and Grid

The model domain encompasses an area of 100 square miles with north-south and east-west dimensions of 52,800 ft (10 miles). The model grid is centered over the LCPA. The extent of the model domain is illustrated in Figure 4.

The model grid was designed to provide adequate spatial resolution within the LCPA in order to simulate response of the aquifer to typical extraction and injection rates anticipated for the Lost Creek uranium project. The model grid was extended a considerable distance from the wellfield boundaries to minimize impacts of exterior boundary conditions on the model solution in the area of interest.

Cell dimensions within the area of the two proposed wellfields are 25 foot by 25 foot. Cell dimensions are gradually increased to a maximum size of 400 feet by 400 feet near the edges of the model. The model consists of 258 rows and 385 columns and contains 99,330 active cells. The model origin (southwest corner) corresponds to Wyoming State Plane Central NAD 83 easting and northing coordinates of 2,185,100 ft and 569,100 ft, respectively.

Because of the presence of overlying and underlying confining units, only the HJ Horizon was simulated. As previously described, hydraulic communication between the HJ Horizon and overlying or underlying units is minimal. Comparison of drawdown at locations where an underlying or overlying monitor well exists next to an HJ monitor well indicates a ratio of greater than 30. For purposes of this modeling effort, the model contains a single layer representing the HJ Horizon. The base of the model and the top of the model are no flow boundaries that simulate the overlying and underlying confining units. This model design represents a conservative approach to simulating the maximum drawdown within the HJ Horizon during ISR production because there can be no contribution from “leaky” confining units. The top and bottom elevation of the HJ Horizon correspond the top and base of the model, respectively. The data within the LCPA are based on site borings. The geologic dip of these surfaces are projected out to the model limits.

Boundary Conditions

Boundary conditions imposed on a numerical model define the external geometry of the groundwater flow system being studied as well as internal sources and sinks. Boundary conditions assigned in the model were determined from observed conditions. Descriptions of the types of boundary conditions that can be implemented with the MODFLOW code are found in McDonald and Harbaugh (1988). Boundary conditions used to represent hydrologic conditions at the Lost Creek site included general-head (GHB), areal recharge and wells. The locations of the GHB and recharge boundary conditions within the model are illustrated in Figure 4. 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 LCPA model to account for inflow and outflow from the model domain and to establish the regional groundwater gradient across the model domain. In the LCPA model, GHBs were assigned along the perimeter of the model domain. The values of head assigned to the GHBs represent the regional potentiometric surface, and ranged from 5,232.9 ft along the northeast edge of the model to 5,021.5 ft along the southwest edge. The values were adjusted during model calibration to replicate, to the extent possible, the difference in potentiometric surface within the HJ Horizon across the Lost Creek Fault.

Recharge to the HJ Horizon is believed to occur along the north and east edges of the basin where the Battle Spring Formation crops out. In order to maintain the potentiometric head difference across the Lost Creek Fault, a zone of recharge was applied to the northeast portion of the model domain (Figure 4). This recharge zone represents infiltration recharge to the HJ Horizon in the area near where the unit crops out.

The MODFLOW well package was used to simulate extraction and injection wells of the ISR project. The well 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 100 feet on a side. 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 wellfields to minimize perimeter boundary effects on the interior of the model where the hydraulic stresses were applied.

The Lost Creek Fault has been demonstrated, through various hydrologic tests, to act as a partial hydraulic barrier to groundwater flow. The Lost Creek Fault and associated fault splays were not modeled using the boundary condition functions available in the MODFLOW code. Instead, the fault system is modeled as a zone of low hydraulic conductivity as described in the following section of this report. The use of a low hydraulic conductivity zone to represent the Fault allows for limited groundwater flow across the Fault, particularly under the large stresses imposed during the hydrologic tests that were conducted at the site.

Aquifer Properties

Input parameters used in the model to simulate aquifer properties are consistent with site-derived data including; top and bottom elevations of the HJ Horizon, hydraulic gradient, hydraulic conductivity, storage coefficient and porosity.

The top and bottom elevations of the HJ Horizon were determined from picks in over 350 borings provided by LC ISR. Gridded contour maps were generated using the contouring program Surfer, Version 9.0 (Golden Software, 2009). The maps were imported into Groundwater Vistas to represent the top and bottom elevations of the HJ Horizon. The initial potentiometric surface of the HJ Horizon was determined from depth to water measurements in the LCPA monitor well network. Those values are provided in Table 1. A contour map of that surface was also generated in Surfer and used as initial conditions in the model simulations.

As previously described, the transmissivity of the HJ Horizon determined from pumping tests was slightly higher on the south side of the Lost Creek Fault. Representative hydraulic conductivity values north of the fault are 1.2 to 1.5 ft/d and on the south side of the fault are 1.4 to 1.7 ft/d. Three zones were used to characterize hydraulic conductivity within the model domain (Figure 4). One zone represents the base value for the model including the area north of the Lost Creek Fault. A second zone represents the higher values south of the Lost Creek Fault that were recognized in the pumping tests. A third zone represents the hydraulic conductivity of the Lost Creek Fault and splay. The values for each of the zones were adjusted during calibration to provide the best overall fit to selected data sets, as described under the calibration simulations section of this report. The final calibrated values, as shown on Figure 4, were as follows: north of the Fault-1.35 ft/d; south of the Fault-1.65 ft/d; and the Fault (including associated fault splays)-0.001 ft/d. Additional discussion regarding the calibration of the model is described under the Calibration Simulations section of this report.

Specific storage is a measure of the water released from storage due to compaction of the aquifer and expansion of water in response to a decline in head. Specific storage is the storage term used for confined aquifers, where lowering of the potentiometric surface in response to pumping does not result in physical dewatering of the aquifer. Specific storage multiplied by the saturated thickness of an aquifer is referred to as storativity or storage coefficient. Storativity of a confined aquifer system is typically in the range of 5×10^{-3} to 10^{-6} or less. The range of storativity calculated from site pumping tests was from 3.6×10^{-5} to 4.3×10^{-4}. A value of 1.0×10^{-4} was used for the LCPA model simulations.

Porosity of the aquifer is used in the model to estimate groundwater velocity. Groundwater velocity is calculated from the Darcy equation as follows:

$$v = ki/n$$

where

v = average interstitial groundwater velocity
k = hydraulic conductivity
i = hydraulic gradient
n = porosity (effective)

The porosity for the HJ Horizon is estimated from site data as 26 percent.

Calibration Simulations

Groundwater flow model calibration is an integral component of groundwater modeling applications. Calibration of a numerical groundwater flow model is the process of adjusting model parameters to obtain a reasonable match between field measured values and model predicted values of heads and fluxes (Woessner and Anderson, 1992). The calibration procedure is generally performed by varying estimates of model parameters (hydraulic properties) and/or boundary condition values from a set of initial estimates until an acceptable match of simulated and observed water levels and/or flux is achieved. Calibration can be accomplished using trial and error methods or automated techniques (often referred to as inverse modeling).

The focus of this model is on the response of the aquifer to hydraulic stresses imposed on a mine unit scale. LC ISR conducted hydrologic tests on both sides of the Lost Creek Fault in 2009 that were designed to demonstrate hydraulic connection to the monitor well ring placed around MU1. The tests were run at high enough rates and for long enough duration to record measurable drawdown at all of the monitor ring wells. The results of these hydrologic tests were used to calibrate the numerical model. Additionally, water level data that were collected under static, non-pumping conditions were included in the calibration effort. The variables that were primarily used to calibrate the model to both pumping and non-pumping conditions were hydraulic conductivity of the HJ Horizon and the Lost Creek Fault and splay, recharge in the northeast portion of the model, and initial heads of the general head boundaries along the perimeters of the model.

The adequacy of model calibration is judged by examining model residuals. A residual, as defined for use in this modeling report, is the difference between the observed change in groundwater elevation and the change in groundwater elevation predicted by the model. The objective of model calibration should be the minimization of the residual mean, residual standard deviation, and residual sum of squares (RSS) (Duffield, et al, 1990). The mean residual is the arithmetic average of all the differences between observed and computed water levels. A positive sign indicates that the model has under-predicted the observed drawdown level and a negative sign indicates over-prediction. The residual standard deviation quantifies the spread of the differences between observed and predicted drawdown around the mean residual. The ratio of residual standard deviation to the total head change across the model domain should be small, indicating the residual errors are only a small part of the overall model response (Anderson and Woessner, 1992). The RSS is computed by adding the square of each residual and is another measure of overall variability. For a statistically accurate model calibration, the residuals and the statistics based on the residual should approach zero.

Calibration was achieved by comparing field-measured (observed) water levels and drawdown from the LCPA monitor wells with heads predicted by MODFLOW for the same wells under simulated non-pumping and pumping conditions of the HJ Horizon aquifer. The model was calibrated to three distinct sets of data. Both the north and south hydrologic tests conducted by LC ISR in 2009 (Petrotek 2009) were simulated. The north test was run for 2 days at an average pumping rate of 70.9 gpm. The south hydrologic test was run for a period of 2.9 days at an average pumping rate of 58.1 gpm. The model was calibrated to the drawdown data from each test (Table 2). A non-pumping simulation was calibrated to the December 8, 2008 water-level data that was collected 18 days after completion of the north side hydrologic test (Table 1). That data set is the most comprehensive water level measurement round that represents aquifer conditions relatively unimpacted by pumping stresses.

The calibration was an iterative process to find the set of model parameter values that provided the best match to all three data sets. Three discrete zones of hydraulic conductivity were delineated and the values of the zones were adjusted during calibration to provide the best fit to the water level and drawdown data previously described. The three hydraulic conductivity zones included the area north of the Fault, the area south of the Fault, and the Fault itself." The final calibrated hydraulic conductivity zone values are shown on Figure 4.

The potentiometric surface of the calibrated static, non-pumping simulation is shown in Figure 5. Calibration residuals are also shown on the figure. A plot comparing observed (measured) water levels to the simulated values is shown on Figure 6. Results of the North and South Hydrologic tests are shown on Figures 7 and 8, respectively. Plots comparing observed (measured) drawdown to the simulated values are shown on Figures 9 and 10, respectively. Calibration statistics from each of the three simulations are listed in Table 3.

As previously noted, the observed drawdown response during the North and South hydrologic tests indicated that the Lost Creek Fault acts as a partial hydraulic barrier. During both hydrologic tests, there was measureable drawdown on opposite sides of the Lost Creek Fault from where pumping was being conducted. However, that drawdown was an order of magnitude less than what would have been expected if the Lost Creek Fault were not present. One objective in the calibration process was to replicate the magnitude of drawdown across the Lost Creek Fault (and splay) from pumping. The final calibration was successful in achieving that objective, resulting in some drawdown across the Lost Creek Fault in each hydrologic test simulation, but generally on the order of 1 foot or less. Based on the calibration results, the modeled value for the hydraulic conductivity of the Lost Creek Fault and fault splay of 1 $x10^{-3}$ ft/d appears reasonable. The hydraulic characteristic of the Lost Creek Fault acting as a partial hydraulic barrier is reasonably represented in the following model simulations.

Model Simulations

This numerical groundwater flow model was developed to evaluate the impacts of ISR operations on the HJ Horizon during typical ISR operations. Simulations were performed using the numerical model to address requests for additional information posed by the NRC in response to the SML license application. The simulations described in this report provide:

- a demonstration of the hydraulic impacts that the ISR operation will potentially have on the HJ Horizon aquifer, including the extent and magnitude of drawdown outside the LCPA;
- an estimate of horizontal wellfield flare factor under typical operating rates;
- an assessment of the adequacy of monitor ring well spacing for detection of potential excursions; and
- an evaluation of the capability to recover an ISR excursion within an acceptable period of time.

Description of each of the model simulations is provided below. Model input and output files for each simulation are provided on CD as Attachment A.

Initial Conditions

The initial condition for the simulations was the potentiometric surface resulting from the static, non-pumping calibration simulation. The potentiometric surface for that simulation is shown in Figure 6.

Hydraulic Impacts of ISR Production and Restoration

Model simulations were run to represent ISR production and restoration. The operational parameters for these simulations are described below. The configuration of the well patterns, including both extraction and injection wells for MU1 are illustrated on Figure 11. Note that the number of well patterns simulated in the model is less than the number projected by LC ISR because vertically stacked well patterns are not included in the one layer model. The simulated well patterns were placed over the footprint of the orebodies with a spacing of approximately 100 feet between production wells. This resulted in a total of 183 well patterns.

The MU1 model simulates the following ISR operations:

- production for 26 months (791 days),
- groundwater sweep for 12 months (365 days),
- reverse osmosis (RO) for 18 months (548 days),

The recirculation stage of restoration was not simulated because this activity does not result in consumptive use of groundwater. Recovery of the aquifer following termination of all ISR operations was simulated for a period of 60 months (1825 days).

LC ISR anticipates that initial production will begin with a single header house (of approximately 20 production wells) and then steadily increase with the addition of one header house per month until full production capacity is attained. At the projected rate, full production capacity (slightly less than 6000 gpm) will occur approximately 9 months after startup. Each header house is expected to be in production for a period of one year. Production at MU1 is projected to span a period of 26 months.

For purposes of the model simulation, MU1 was divided into three wellfields, noted on Figure 11 as A, B and C. The production simulation was divided into five stress periods. Stress period one represents the startup and production of wellfield A which has 55 production wells and runs for 4 months (122 days). Stress period two adds wellfield B (57 more production wells) to the total and runs for another 4 months (122 days). Stress period three represents peak production in MU1 as wellfield C (with 71 production wells) is added to the simulation. This stress period runs for 213.5 days. Stress period four represents the shut-in of wellfield A and continued production in wellfields B and C. Stress period five simulates the shut-in of wellfield B, leaving only wellfield C in production. Table 4 indicates the operational parameters and net bleed for each of the stress periods in the production simulation. Total length of the production simulation is 26 months (791 days).

Extraction for most of the production wells was simulated as 32 gpm (6,160.4 ft^3/d). The injection well rates were variable depending on the position of the injection well relative to the well pattern. Injection rates were generally between 7.9 and 31.7 gpm (1,524.7 and 6,098.8 ft^3/d) per well. A few production and injection wells were adjusted outside these ranges to balance the wellfield and maintain an inward hydraulic gradient. The overproduction in the five stress periods ranged from 9.3 to 38.2 gpm which represent a net bleed rate of 0.52 to 0.77 percent (Table 4). The bleed represents the net consumptive use of the aquifer during the simulated ISR production. The maximum overproduction occurs during stress period three which represents full production capacity. This stress period also represents the maximum drawdown in the production simulation. The LCPA Operations Plan indicates that the typical range of operational bleed for an ISR operation is from 0.5 to 1.5 percent. Results of the simulations indicates that a bleed rate of 0.77 or less during production is adequate to control lixiviant. The results of the modeling are based on site specific aquifer properties determined from numerous hydrologic tests and provide a best estimate for operational bleed rates.

The potentiometric surface for the LCPA is shown in Figure 12. Drawdown during the simulation production at full capacity within the LCPA is shown in Figure 13. The impacts of individual wells can be observed at this scale. The overall drawdown across the wellfield is greater than 15 feet. The maximum drawdown within the wellfield is approximately 55 feet. Figure 14 shows the drawdown across the entire model domain during full production capacity. The five-foot drawdown contour extends radially approximately 13,000 (2.5 miles) from the centroid of MU1 and a maximum of approximately 2 miles outside the Permit Boundary.

Groundwater sweep was simulated at a rate of approximately 30 gpm for a period of approximately 12 months (365 days). The total extraction was evenly distributed between the 183 extraction wells at a rate of 0.16 gpm (31.5 ft^3/d) per well. Drawdown at the end of groundwater sweep within the LCPA is shown in Figure 15.

The length of RO treatment is based on the treatment of six pore volumes (PVs) of impacted groundwater. The calculation of one PV is as follows:

- PV = Area x Ore Thickness x Horizontal Flare x Vertical Flare x Porosity x Conversion

Substituting the standard horizontal and vertical flare factors used by WDEQ

- PV (in gallons) = A (ft^2) x T (ft) x 1.2 x 1.2 x P x 7.48 gallons/ft^3).

For MU1, the following values are used to calculate the PV

- Mine Unit Area = 2,115,594 ft^2
- Average Thickness = 12 ft
- Average Porosity = 0.26

The MU1 PV is calculated as

- PV = 2,115,594 ft^2 x 12 ft X 1.2 x 1.2 x 0.26 x 7.48 gallons $ft/^3$ = 71,096,957 gallons
- 6 PV =6 x 68,362,458 gallons = 426,581,742 gallons

Treatment of 6 PVs for RO treatment was simulated over a period of eighteen months. To extract and treat 6 PVs within eighteen months requires groundwater recovery at a rate of approximately 541 gpm. The RO plant will have the capacity to treat approximately 800 gpm of water. Approximately 12.5 percent of the treated water will be reject brine that will be disposed of in a deep disposal well or through some other waste disposal methods. At 541 gpm, the reject brine will be approximately 67.6 gpm. This results in a net loss of approximately 67.6 gpm to the HJ Horizon aquifer during RO restoration.

Rather than assign extraction and injection rates to select wells to simulate extraction of 541 gpm and reinjection of 473.4 gpm, the 67.6 gpm (13,013 ft^3/d) net loss was distributed over all the well patterns within the wellfield using only extraction wells. The extraction rate was 0.37 gpm (71.1 ft^3/d) per well. The simulation was run for 18 months (548 days). Drawdown at the end of RO within the LCPA is shown in Figure 16. Figure 17 shows the drawdown across the entire model domain after completion of RO. The five-foot drawdown contour extends radially approximately 18,400 ft (3.5 miles) from the centroid of MU1 and a maximum of 17,250 ft (3.3 miles) outside the permit area.

Simulation of recovery of the aquifer following completion of restoration indicates that water levels within the HJ Horizon should return to within 0.5 foot of pre-ISR levels within one year.

Previous analysis of drawdown impacts was performed using the Theis analytical solution and the results were submitted to WDEQ-LQD. However, as noted in the submittal, the analysis significantly overestimates the drawdown because the Theis analytical solution assumes that no recharge is occurring to the aquifer during the period of pumping. In actuality, regional recharge continually occurs to the HJ Horizon. Using the representative aquifer parameters previously cited for thickness (120 ft), hydraulic conductivity (1.4 ft/d) and hydraulic gradient (0.007 ft/d), a one-mile wide cross-sectional area of the HJ Horizon aquifer will transmit approximately 32 gpm of groundwater under static non-pumping conditions. As the potentiometric surface is drawn down within the HJ Horizon during ISR operations, the rate of groundwater movement from areas surrounding the mine unit will increase (because of the change in hydraulic gradient). This lateral recharge, limits the extent of drawdown away from the mine unit.

The LCPA numerical model provides a better representation of aquifer conditions and hydraulic stresses imposed on the HJ Horizon during ISR operations than the previous analytical solutions because it simulates the natural groundwater flux that is occurring in the aquifer.

Wellfield Flare Factor

Results of the production simulation were used to estimate the amount of horizontal flare that can be expected during typical ISR operations. Particle tracking was used to illustrate the movement of water from the outer injection wells. Particles were placed at the locations of all injection wells located on the perimeter of the wellfield. The particle tracks represent the movement of injectate through the HJ Horizon aquifer.

Figure 18 shows the results of the particle tracking for MU1. An area was circumscribed around the outermost extent of all the particles from the wellfield. The ratio of the area circumscribing the particles to the area under well pattern provides the horizontal wellfield flare factor. The area under well pattern for the model simulation was slightly less than the value reported by LC ISR (1,879,874 ft^2 compared to 2,115,594 ft^2). For MU1, the horizontal flare factor is calculated as 1.043. Note that the simulated horizontal flare factor calculated from the model simulation is considerably lower than the 1.2 factor previously used to calculate the MU1 PV.

Excursion Detection

The production and restoration model used in the previous simulations was modified to evaluate if an excursion could be detected using the current monitor ring well spacing at MU1. A hypothetical excursion was simulated by reducing the pumping rate at an extraction well in one well pattern on each side of the Lost Creek Fault, along the west edge of MU1 (Figure 19). The west edge of MU1 was selected for the excursion simulation because the natural hydraulic gradient is toward the west-southwest. Wellfield fluids in the western portion of MU1 should have the greatest probability of moving outside the hydraulic control of the wellfield if an "out of balance" event occurs. The production rate in each of the two extraction wells was reduced to approximately 25 percent of the original operating rate to simulate an "out of balance" situation. The two extraction wells had previously been simulated as producing at a rate of 32 gallons per minute (gpm), or 6,160.4 ft^3/d. No change was made to the injection well rates or locations in or around the neighboring well patterns for this simulation. All other extraction and injection wells were simulated at the same rates presented in the production simulation previously described. The change in production for this simulation is a reduction of 64 gpm resulting in a net "under-production" of 4 gpm for MU1.

Particles were placed at the injection wells in the well patterns with the reduced rate extraction wells. The particles show the flowpath of injectate from the injection wells (Figure 19). As shown on the figure, particles travel away from the wellfield and toward the monitor well ring. This hypothetical simulated excursion represents the loss of lixiviant during the production phase of ISR. The simulation shows that some particles from both well patterns that are "out of balance" will reach (and be detected by) monitor wells in the monitor ring. The 500 ft spacing between MU1 monitor ring wells is adequate for detection of the simulated excursion.

Excursion Recovery

Recovery of the excursion was also simulated. For the recovery simulation, particles were placed at the monitor well where the excursion was "detected".

The model was run for an additional 30 days under the “out of balance” conditions (Figure 20). This allowed for the excursion to continue to migrate away from the wellfield during the time it would take to conduct resampling, and develop a response to the excursion. A line of particles was then placed at the downdip limit reached by the particles during the 30-day interval. This line represents the maximum distance that the excursion traveled beyond the monitor well (Figure 20). The simulation was resumed with rates at the two extraction wells increased to the original 32 gpm production rate. Select injection wells in the two well patterns were shut-in. For the south well pattern, injection was reduced by 32 gpm and extraction increased by 32 gpm resulting in a net change of 64 gpm. For the north well pattern, the injection was reduced by 40 gpm and extraction increased by 32 gpm for a net change of 72 gpm.

Results of the simulation show that the excursion moves back inside the well ring within less than 30 days. Hydrographs of the two monitor wells where the excursions were detected show the rapid response to the excursion recovery action (Figure 21). Within less than one day after beginning excursion recovery there is over 10 feet of drawdown at both monitor wells. These results are consistent with the response of the aquifer during the north and south hydrologic tests.

Model Limitations

As with any modeling effort, there are numerous assumptions, uncertainties and limitations associated with the LCPA numerical model. The model is based on currently available site-specific data for the HJ Horizon aquifer. The data are concentrated within the LCPA. The model domain extends several miles beyond the LCPA. Model input parameters, such as top and bottom of the aquifer, and effective hydraulic conductivity, are projected based on the gradients or values present within the LCPA. The selection of property zones is based on the fit to calibration targets and is non-unique. These factors present levels of uncertainty in the model simulation results.

The model simulates a single layer, representing the HJ Horizon. Continuity of the HJ Horizon in all directions is assumed. The use of the GHB boundary condition implies an infinite acting aquifer. The model does not account for hydraulic communication between the HJ Horizon and overlying and underlying hydrostratigraphic units.

Although there is uncertainty associated with the numerical modeling of the LCPA, the model simulations provide a reasonable assessment of the hydraulic response of the HJ Horizon to typical ISR operations, and are suitable for that purpose. Although not necessarily unique, model output provides a valuable tool for understanding expected system trends and responses.

Summary

A numerical model was developed to evaluate the response of the HJ Horizon aquifer to hydraulic stresses imposed by the proposed operation of the Lost Creek ISR uranium project. The model was developed using site-specific data for the HJ Horizon aquifer including; potentiometric surface, hydraulic gradient, hydraulic conductivity, aquifer thickness, storativity and porosity. The model treats the HJ Horizon as a single layer aquifer system.

The model was calibrated to three discrete data sets, including; static non-pumping water levels and drawdown data from hydrologic tests conducted on the north and south sides of the Lost Creek Fault. The calibrated model was used to simulate the operational cycle of MU1 of the Lost Creek ISR uranium project, from production through restoration. Results of the model simulations indicate the following.

- Simulation of production at the rates of nearly 6,000 gpm, with less than a one percent bleed, results in drawdown of less than five feet in the HJ Horizon within approximately two miles of the permit boundary.
- Although the Operation Plan cites a range of operational bleed from 0.5 to 1.5 percent, modeling simulations indicate that a bleed of less than 0.8 percent will be necessary to control and contain lixiviant during production operations of the Lost Creek ISR uranium project. Those model simulations are based on site specific aquifer properties derived from numerous hydrologic test.
- Simulation of the treatment of 6 PVs during RO restoration of MU1 at a net extraction rate of 67.6 gpm results in drawdown of less than five feet within three and one half miles of the permit boundary. This simulation represents the maximum anticipated drawdown during Lost Creek ISR operations, because it is during RO restoration that the largest consumptive rate of groundwater will occur.
- Simulated horizontal wellfield flare factor, determined from the rates and well patterns used, is approximately 1.043, much lower than industry projections.
- Model runs indicate that a monitor well ring spacing of 500 feet from the wellfield and 500 feet between monitor wells is adequate for detection of the hypothetical excursion.
- Results of the modeling also indicate that the hypothetical excursion detected at the monitor well ring can be hydraulically controlled within 30 days of recovery startup.

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NUMERICAL MODELING OF HYDROLOGIC CONDITIONS

AT THE LOST CREEK INSITU RECOVERY

URANIUM PROJECT, WYOMING

LC ISR LLC

(November 2010, Revised January 2011)

FIGURES

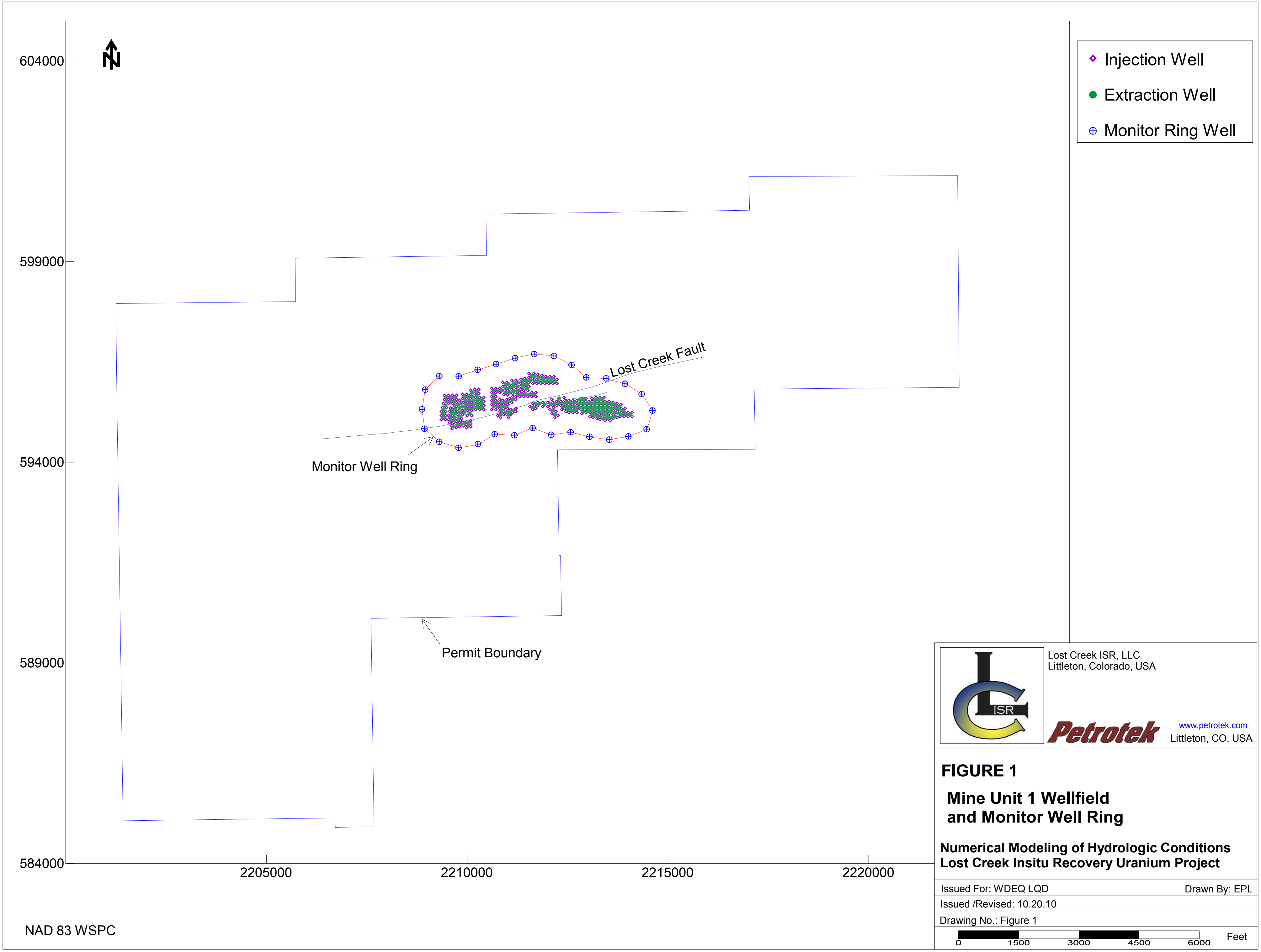

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FIGURE 1

Mine Unit 1 Wellfield and Monitor Well Ring

Numerical Modeling of Hydrologic Conditions Lost Creek Insitu Recovery Uranium Project

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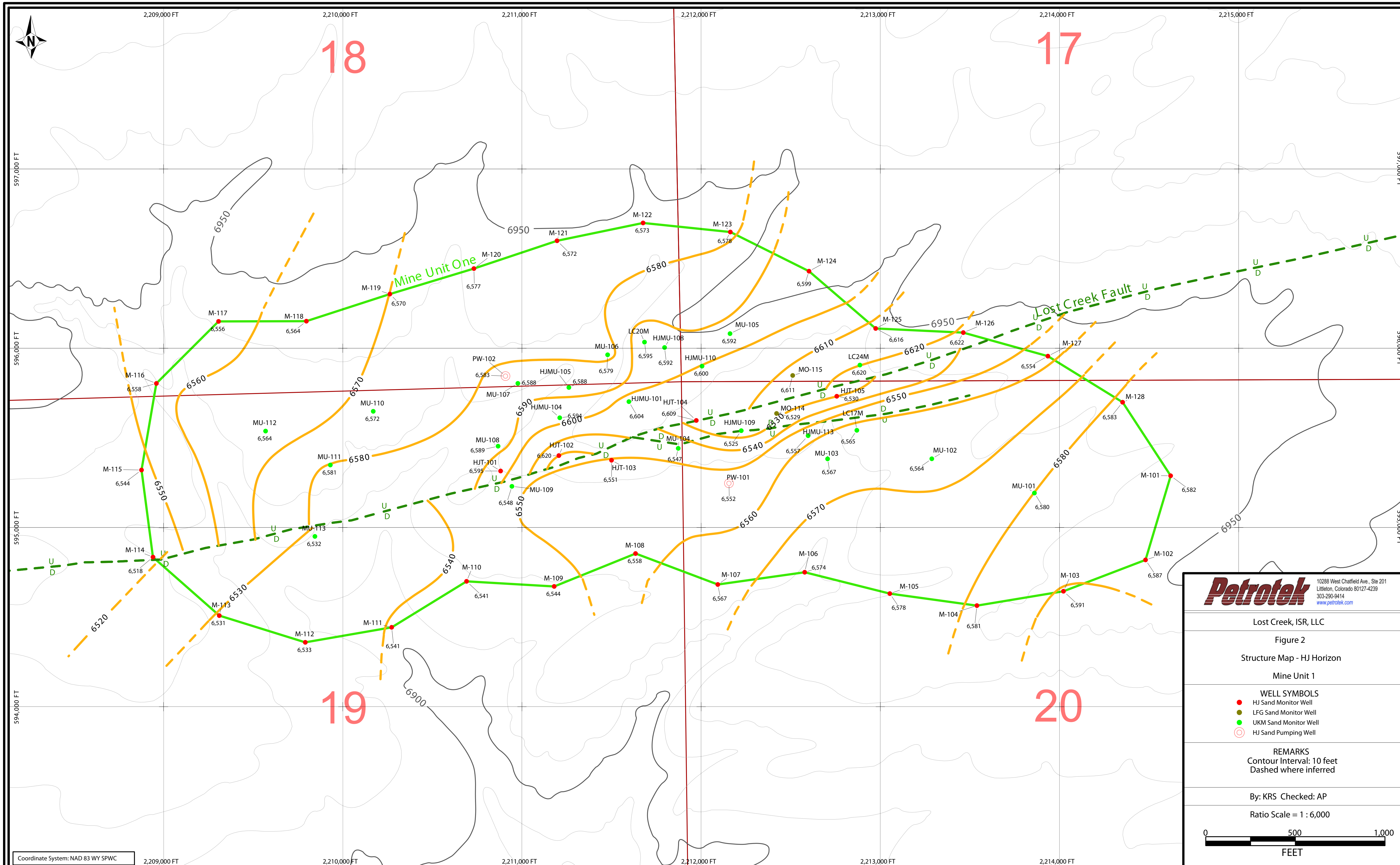
Drawn By: EPL
Issued /Revised: 10.20.10
Drawing No.: Figure 1

0 1500 3000 4500 6000 Feet



18
17
19
20
N
Mine Unit One
Lost Creek Fault
2,209,000 FT
2,210,000 FT
2,211,000 FT
2,212,000 FT
2,213,000 FT
2,214,000 FT
2,215,000 FT
597,000 FT
596,000 FT
595,000 FT
594,000 FT
6950
6900
6520
6530
6540
6550
6560
6570
6580
6590
6600
6610
6620
M-101
M-102
M-103
M-104
M-105
M-106
M-107
M-108
M-109
M-110
M-111
M-112
M-113
M-114
M-115
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M-118
M-119
M-120
M-121
M-122
M-123
M-124
M-125
M-126
M-127
M-128
MU-101
MU-102
MU-103
MU-104
MU-105
MU-106
MU-107
MU-108
MU-109
MU-110
MU-111
MU-112
MU-113
HJMU-101
HJMU-104
HJMU-105
HJMU-108
HJMU-109
HJMU-110
HJMU-113
HJT-101
HJT-102
HJT-103
HJT-104
HJT-105
MO-114
MO-115
LC17M
LC20M
LC24M
PW-101
PW-102
U
D
Coordinate System: NAD 83 WY SPWC
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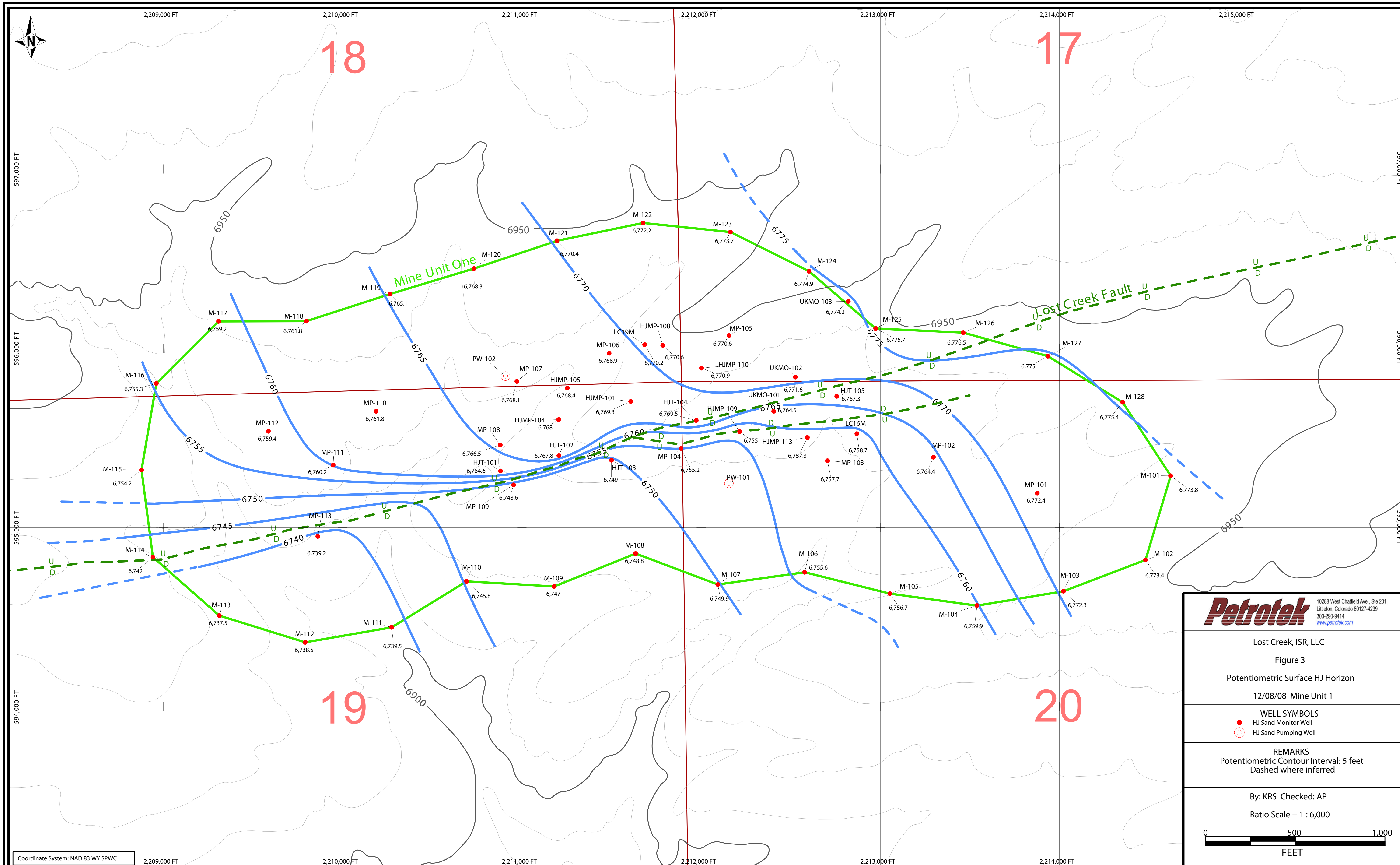
Figure 2
Structure Map - HJ Horizon
Mine Unit 1
WELL SYMBOLS
HJ Sand Monitor Well
LFG Sand Monitor Well
UKM Sand Monitor Well
HJ Sand Pumping Well
REMARKS
Contour Interval: 10 feet
Dashed where inferred
By: KRS Checked: AP
Ratio Scale = 1 : 6,000
0
500
1,000
FEET



18
17
19
20
Mine Unit One
Lost Creek Fault
2,209,000 FT
2,210,000 FT
2,211,000 FT
2,212,000 FT
2,213,000 FT
2,214,000 FT
2,215,000 FT
597,000 FT
596,000 FT
595,000 FT
594,000 FT
6950
6900
6775
6770
6765
6760
6755
6750
6745
6740
U
D
M-101 6,773.8
M-102 6,773.4
M-103 6,772.3
M-104 6,759.9
M-105 6,756.7
M-106 6,755.6
M-107 6,749.9
M-108 6,748.8
M-109 6,747
M-110 6,745.8
M-111 6,739.5
M-112 6,738.5
M-113 6,737.5
M-114 6,742
M-115 6,754.2
M-116 6,755.3
M-117 6,759.2
M-118 6,761.8
M-119 6,765.1
M-120 6,768.3
M-121 6,770.4
M-122 6,772.2
M-123 6,773.7
M-124 6,774.9
M-125 6,775.7
M-126 6,776.5
M-127 6,775
M-128 6,775.4
UKMO-103 6,774.2
UKMO-102 6,771.6
UKMO-101 6,764.5
MP-101 6,772.4
MP-102 6,764.4
MP-103 6,757.7
MP-104 6,755.2
MP-105 6,770.6
MP-106 6,768.9
MP-107 6,768.1
MP-108 6,766.5
MP-109 6,748.6
MP-110 6,761.8
MP-111 6,760.2
MP-112 6,759.4
MP-113 6,739.2
PW-101
PW-102
LC19M 6,770.2
LC16M 6,758.7
HJMP-108 6,770.6
HJMP-110 6,770.9
HJMP-105 6,768.4
HJMP-101 6,769.3
HJMP-104 6,768
HJMP-109 6,755
HJMP-113 6,757.3
HJT-105 6,767.3
HJT-104 6,769.5
HJT-102 6,767.8
HJT-101 6,764.6
HJT-103 6,749
Coordinate System: NAD 83 WY SPWC
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Figure 3
Potentiometric Surface HJ Horizon
12/08/08 Mine Unit 1
WELL SYMBOLS
HJ Sand Monitor Well
HJ Sand Pumping Well
REMARKS
Potentiometric Contour Interval: 5 feet
Dashed where inferred
By: KRS Checked: AP
Ratio Scale = 1 : 6,000
0
500
1,000
FEET

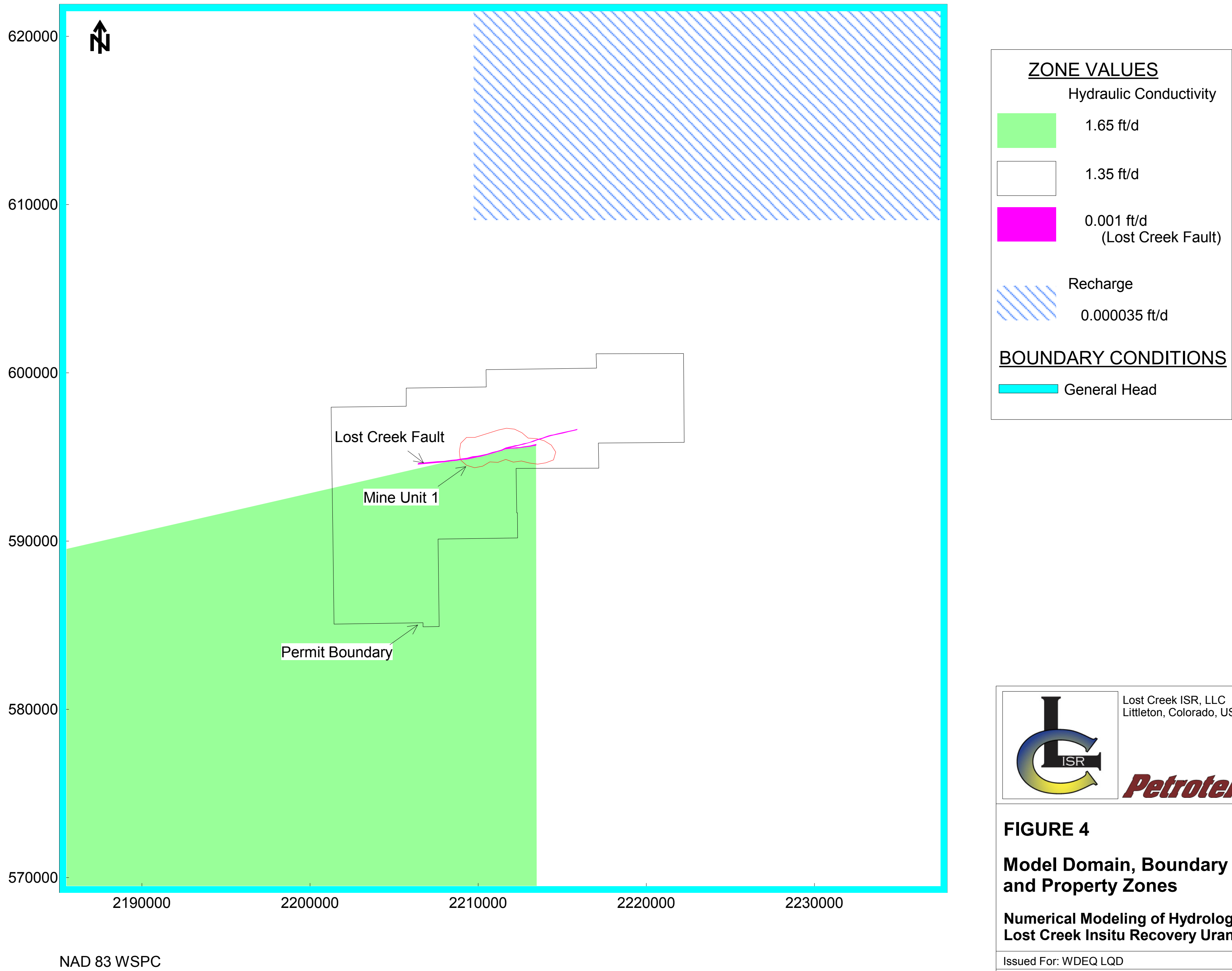

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FIGURE 4

Model Domain, Boundary Conditions and Property Zones

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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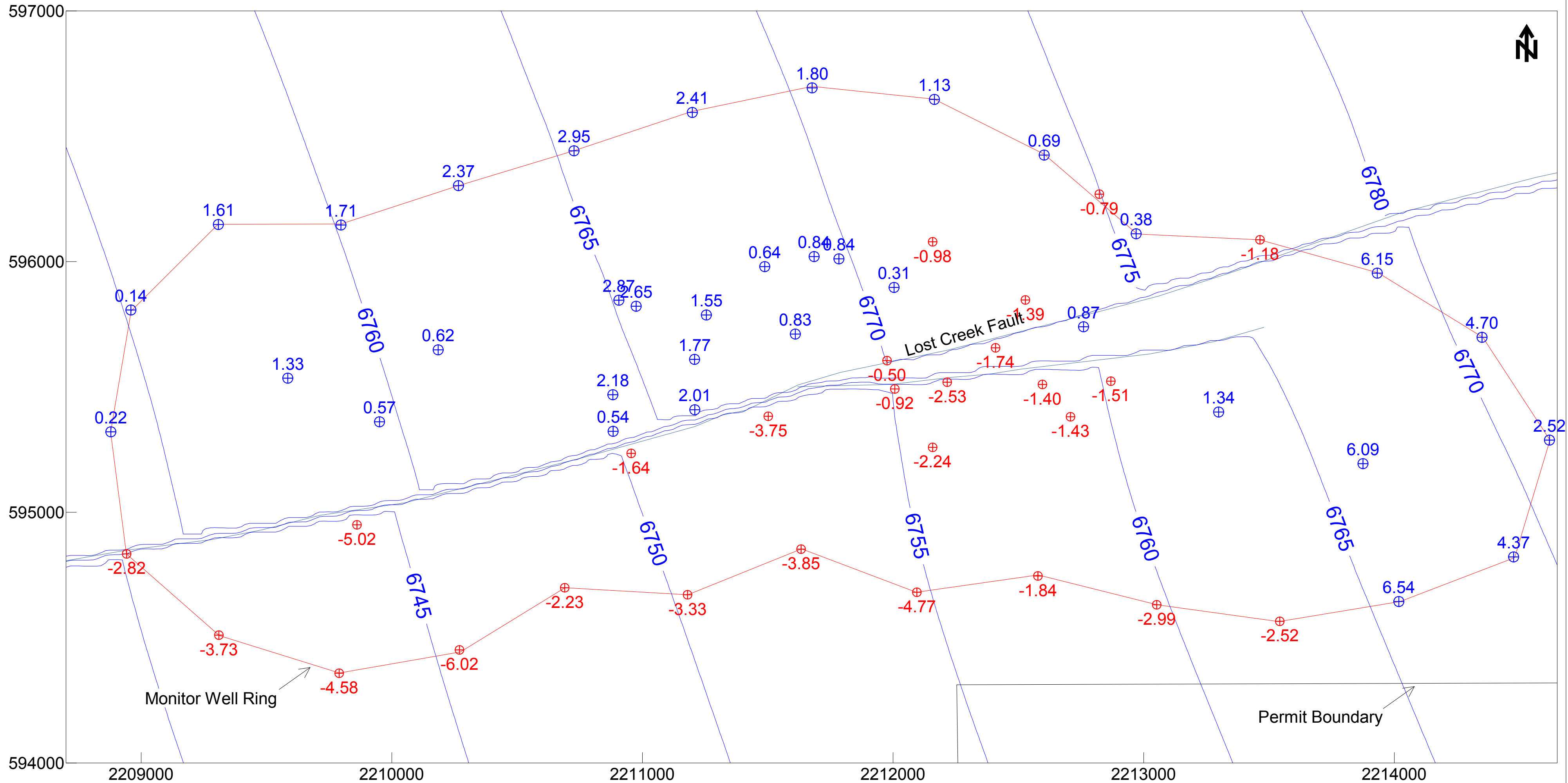
Drawing No.: Figure 4

0 1 2 3 Miles



Calibration Residual = Observed Value - Simulated Value

⊕ Calibration Target With Positive Residual (ft)
Model underpredicts potentiometric head

⊕ Calibration Target With Negative Residual (ft)
Model overpredicts potentiometric head

Potentiometric Contour
(Contour Interval = 5 feet)

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FIGURE 5
Simulated Potentiometric Surface and Residuals
HJ Horizon, Non-pumping Conditions
Mine Unit 1
Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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Drawn By: EPL
Issued /Revised: 10.20.10
Drawing No.: Figure 5

0 250 500 750 1000 Feet

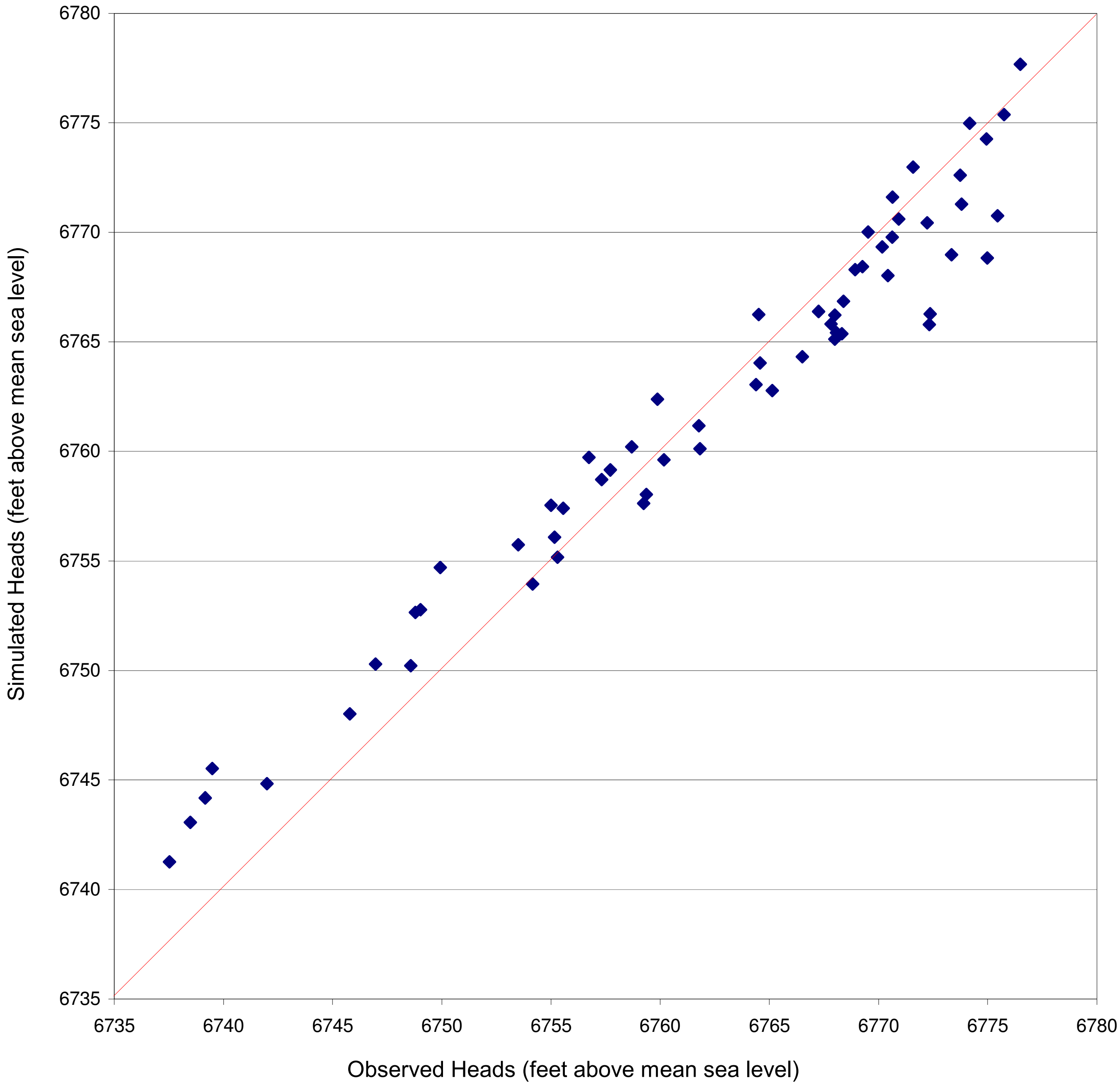

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FIGURE 6
Observed Versus Simulated Heads
Non-Pumping Condition
Calibration Simulation

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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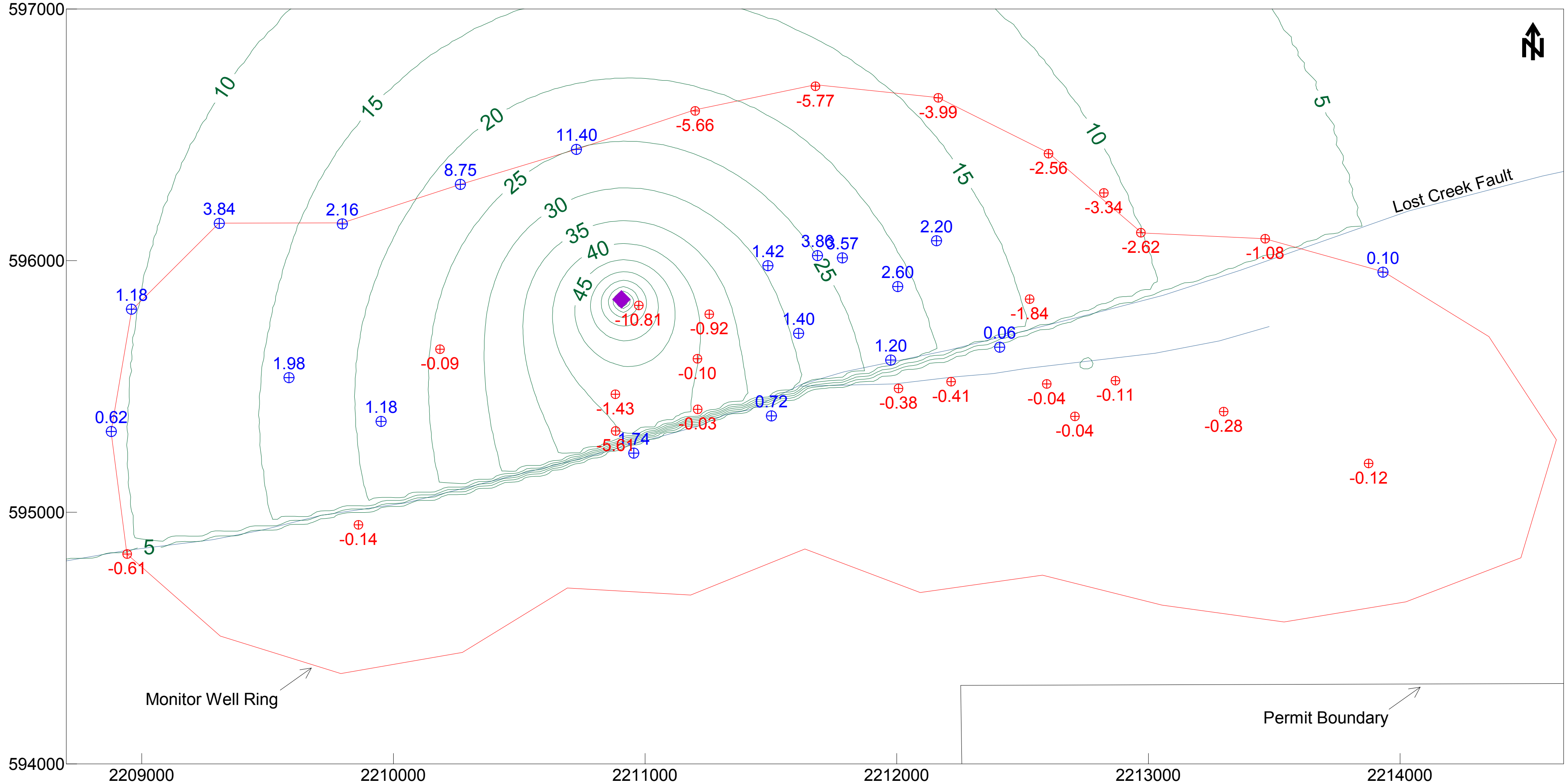
Drawing No.: Figure 6



Calibration Residual = Observed Value - Simulated Value

- Calibration Target With Positive Residual (ft) Model underpredicts drawdown
- Calibration Target With Negative Residual (ft) Model overpredicts drawdown
- Pumping Well (PW-102)
- Drawdown Contour (Contour Interval = 5 feet)

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FIGURE 7

Simulated Drawdown with Residuals
HJ Horizon, North Hydrologic Test
Mine Unit 1

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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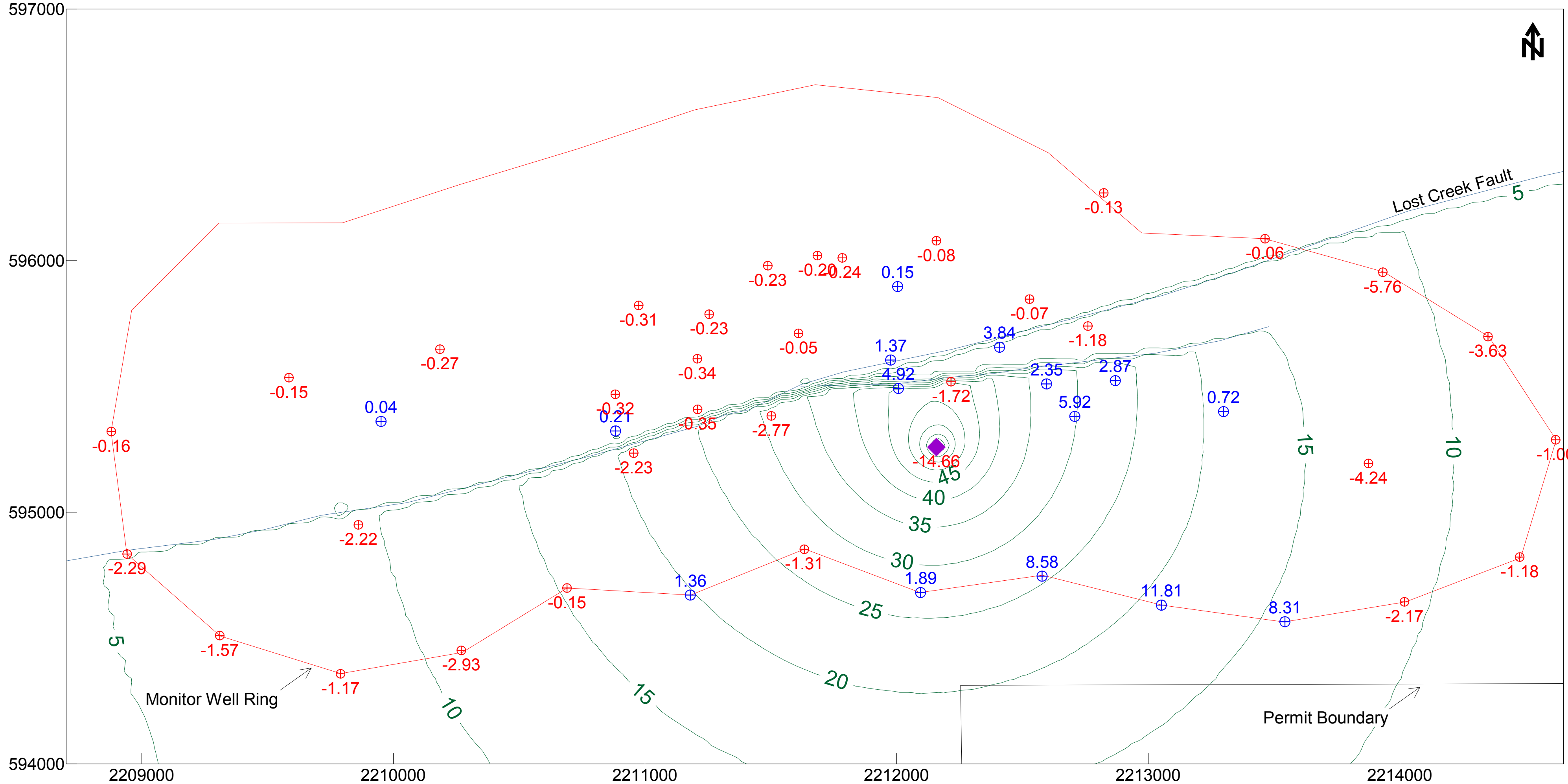
Drawn By: EPL
Issued /Revised: 10.20.10
Drawing No.: Figure 7

0 250 500 750 1000 Feet



Calibration Residual = Observed Value - Simulated Value

⊕ Calibration Target With Positive Residual (ft)
Model underpredicts drawdown

⊕ Calibration Target With Negative Residual (ft)
Model overpredicts drawdown

◆ Pumping Well (PW-101)

Drawdown Contour
(Contour Interval = 5 feet)

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FIGURE 8

Simulated Drawdown with Residuals
HJ Horizon, South Hydrologic Test
Mine Unit 1

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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Drawing No.: Figure 8

0 250 500 750 1000 Feet

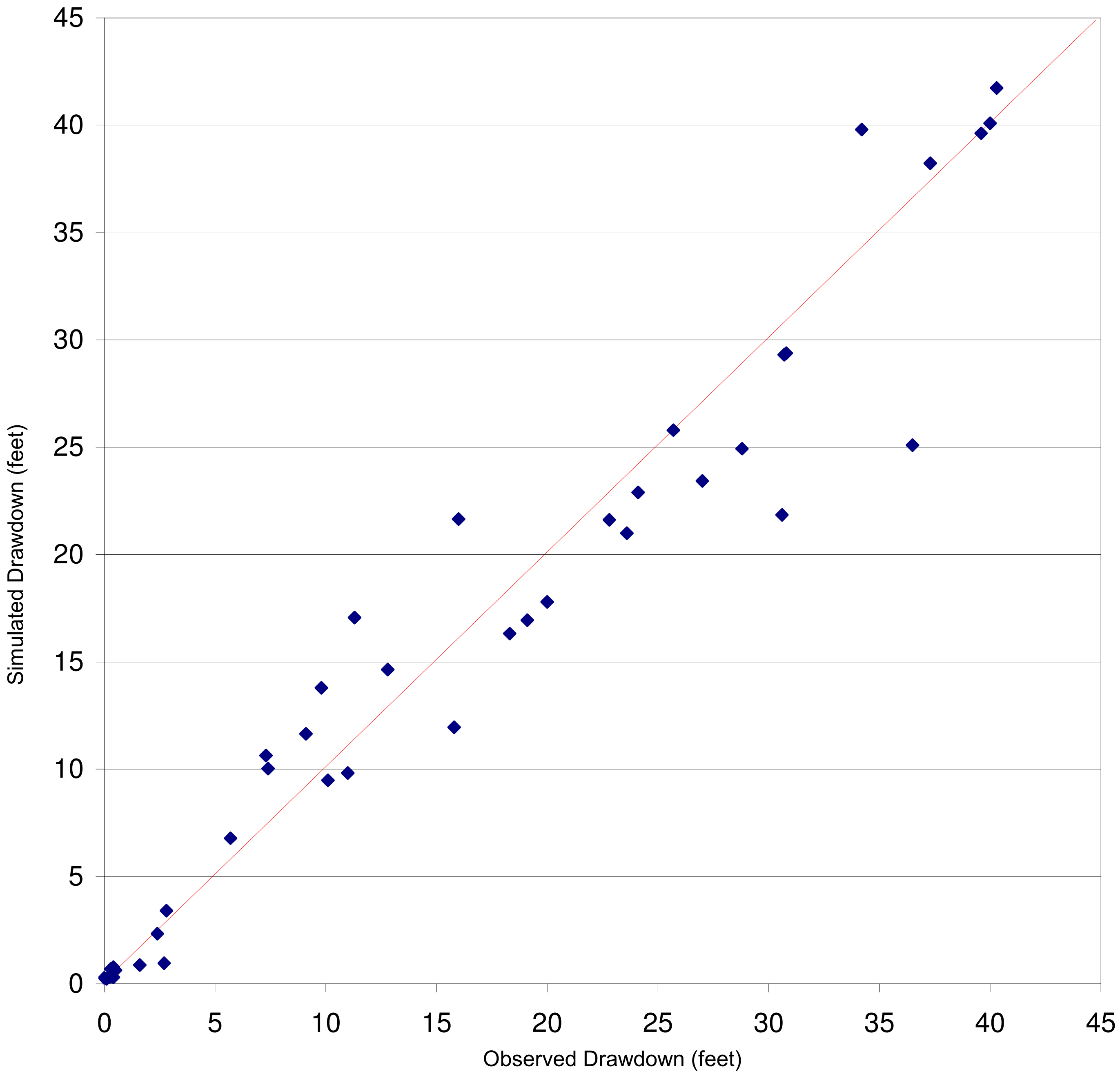

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FIGURE 9
Observed Versus Simulated Drawdown
North Hydrologic Test
Calibration Simulation

Numerical Modeling of Hydrologic Conditions
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Drawing No.: Figure 9

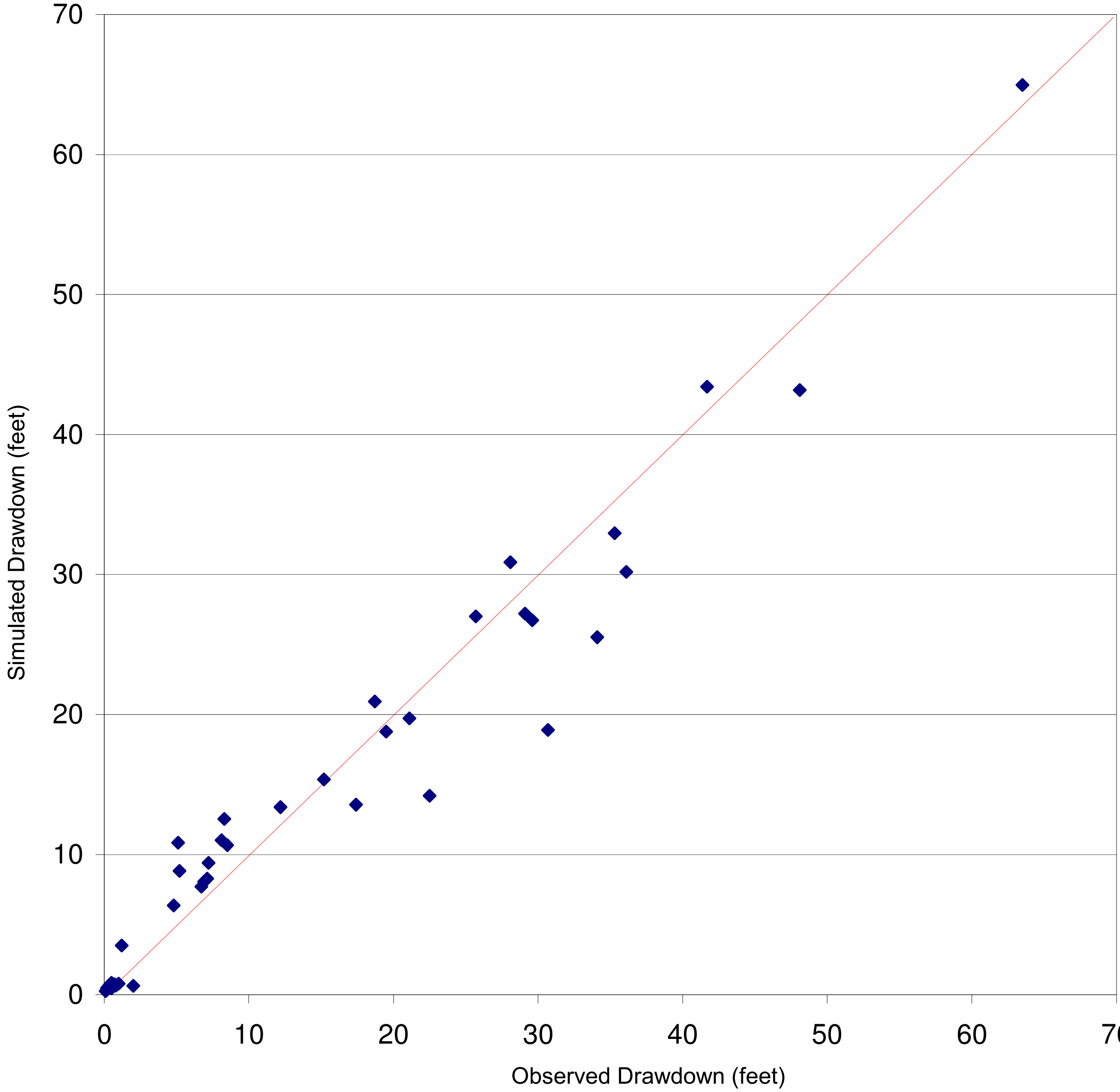

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FIGURE 10

Observed Versus Simulated Drawdown
South Hydrologic Test
Calibration Simulation

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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Drawing No.: Figure 10

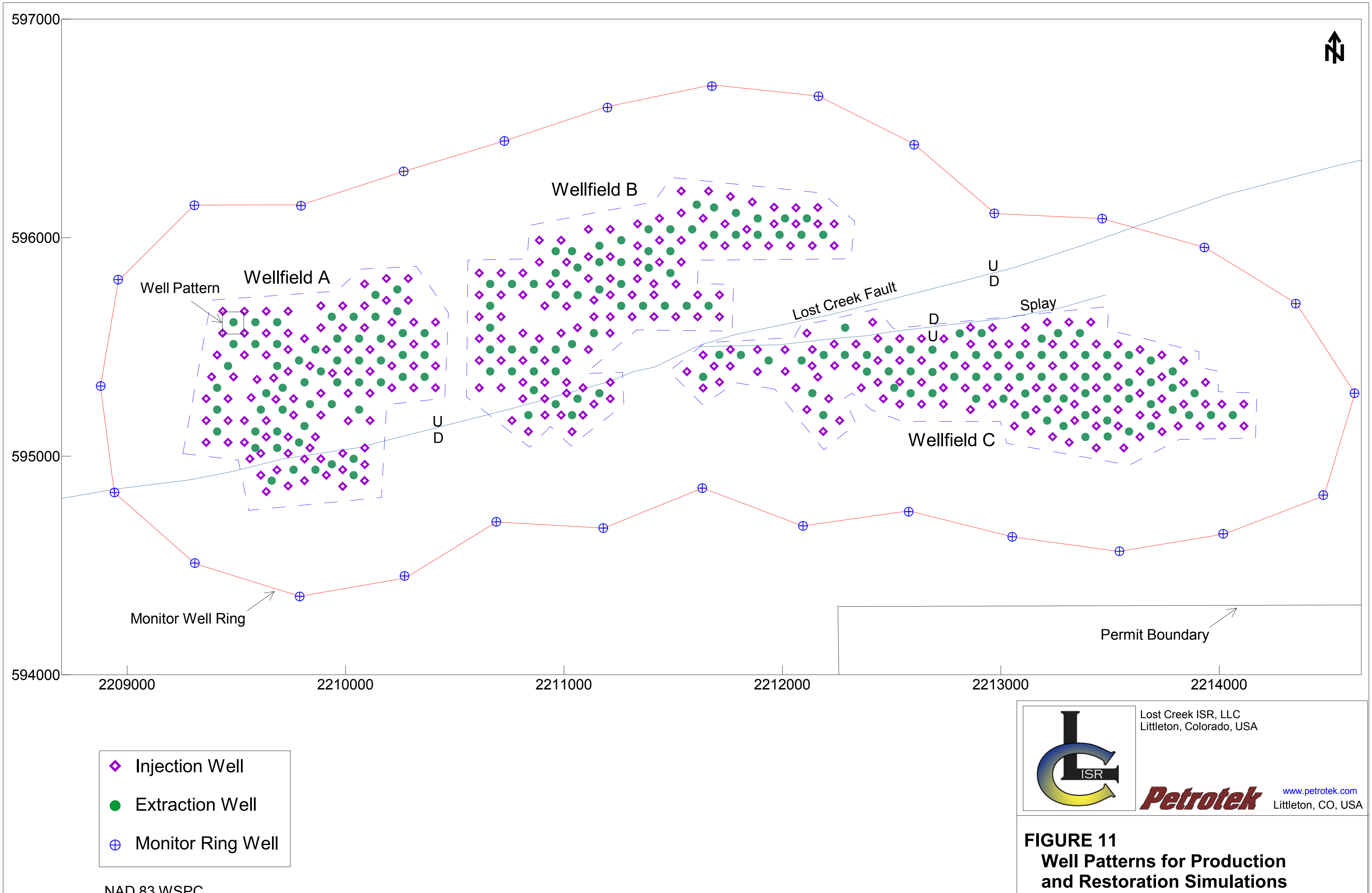

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FIGURE 11
Well Patterns for Production and Restoration Simulations Mine Unit 1

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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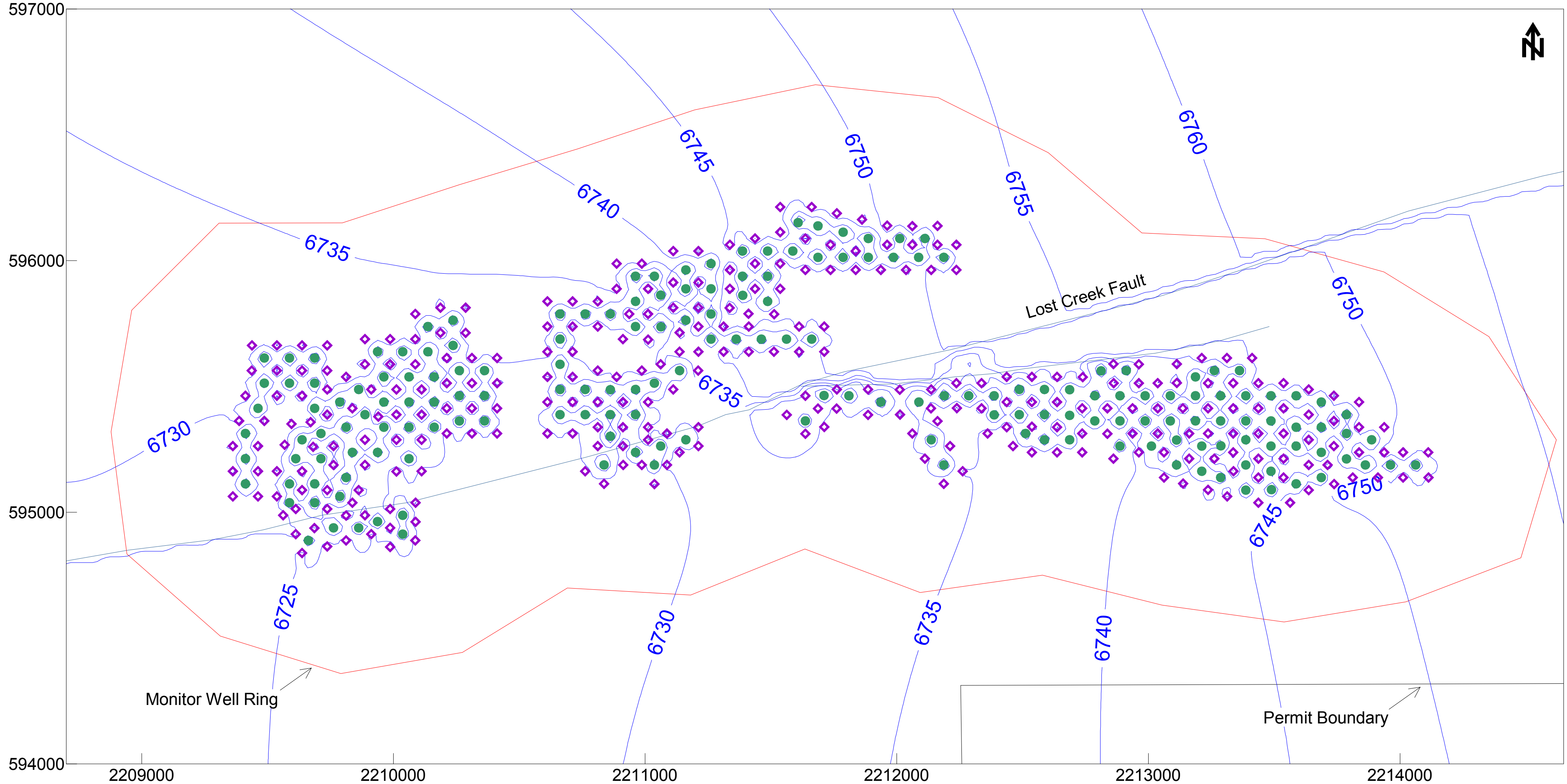
Drawing No.: Figure 11
0 250 500 750 1000 Feet



Injection Well	Production Cycle is 791 Days
Extraction Well	Extraction Rate is 5838 gpm (183 Wells)
Potentiometric Surface Contour (Contour Interval = 5 feet)	Injection Rate is 5800 gpm (297 Wells)
	Bleed is 0.66%

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FIGURE 12

Simulated Potentiometric Surface
HJ Horizon, At Maximum Production Rate
Mine Unit 1

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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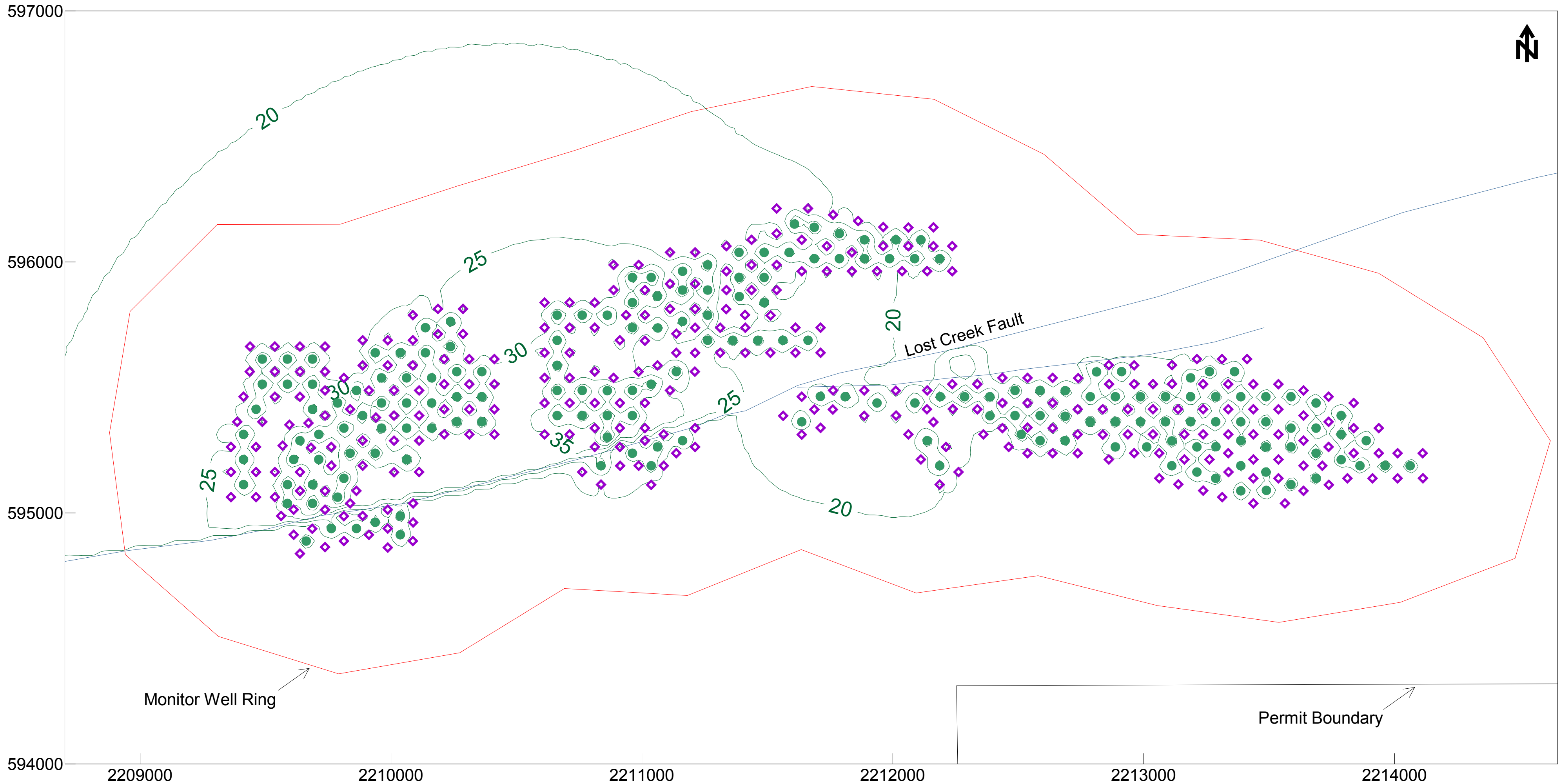
Drawing No.: Figure 12

0 250 500 750 1000 Feet



- Injection Well
- Extraction Well
- Drawdown Contour (Contour Interval = 5 feet)

NAD 83 WSPC

Production Cycle is 791 Days

Extraction Rate is 5838 gpm (183 Wells)

Injection Rate is 5800 gpm (297 Wells)

Bleed is 0.66%

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FIGURE 13
Simulated Drawdown, HJ Horizon At Maximum Production Rate Mine Unit 1

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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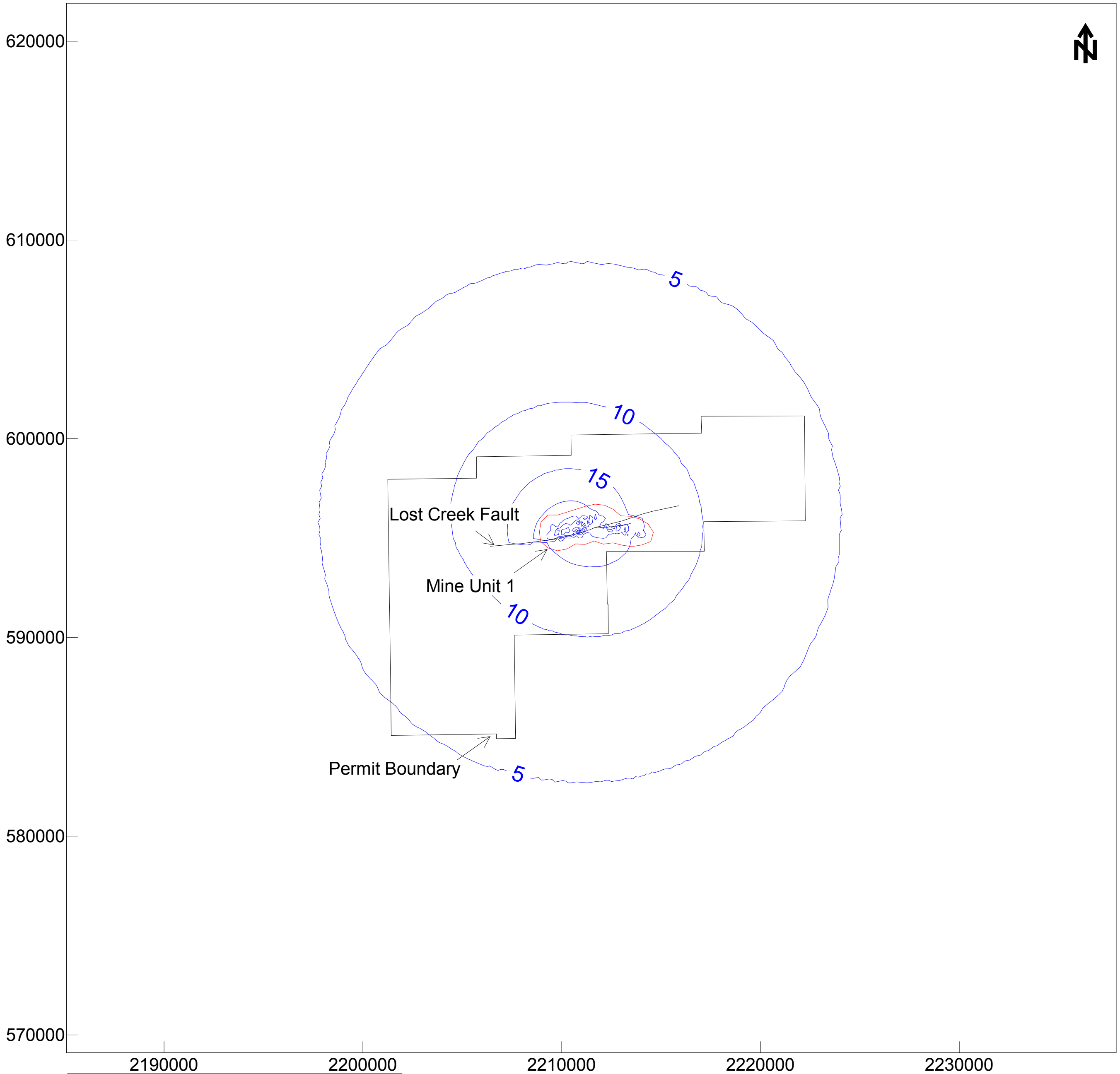
Drawing No.: Figure 13

0 250 500 750 1000 Feet



Production Cycle is 791 Days

Extraction Rate is 5838 gpm (183 Wells)

Injection Rate is 5800 gpm (297 Wells)

Bleed is 0.66%

NAD 83 WSPC

Contour Interval is 5 Feet

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FIGURE 14

Simulated Drawdown, HJ Horizon
At Maximum Production Rate
Model Domain

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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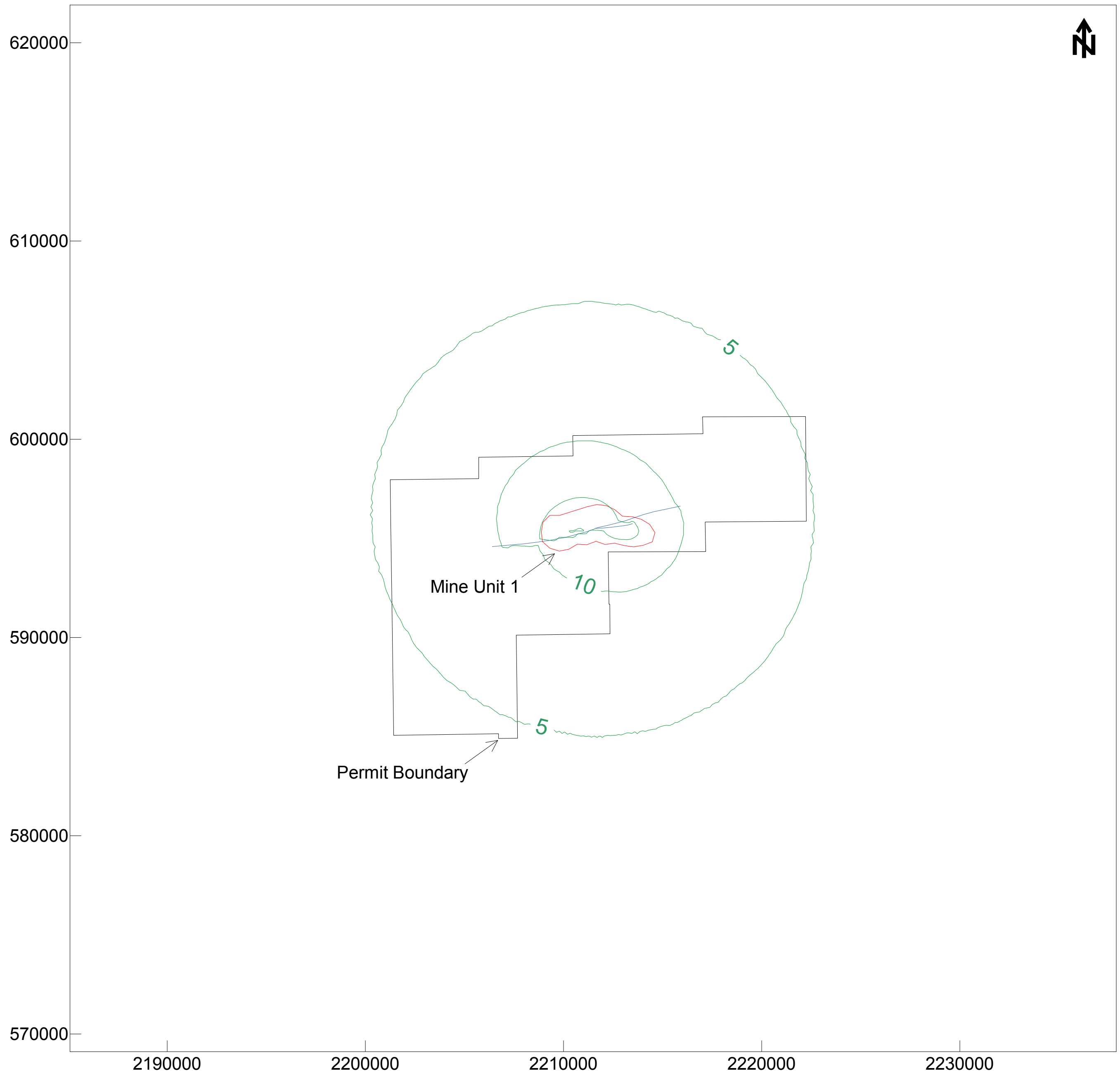
Drawing No.: Figure 14	

0 1 2 3 Miles



GWS Cycle is 365 Days

Net Extraction Rate is 30 gpm

NAD 83 WSPC

Contour Interval is 5 Feet

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FIGURE 15

Simulated Drawdown, HJ Horizon
End of Groundwater Sweep
Model Domain

Lost Creek Permit Area

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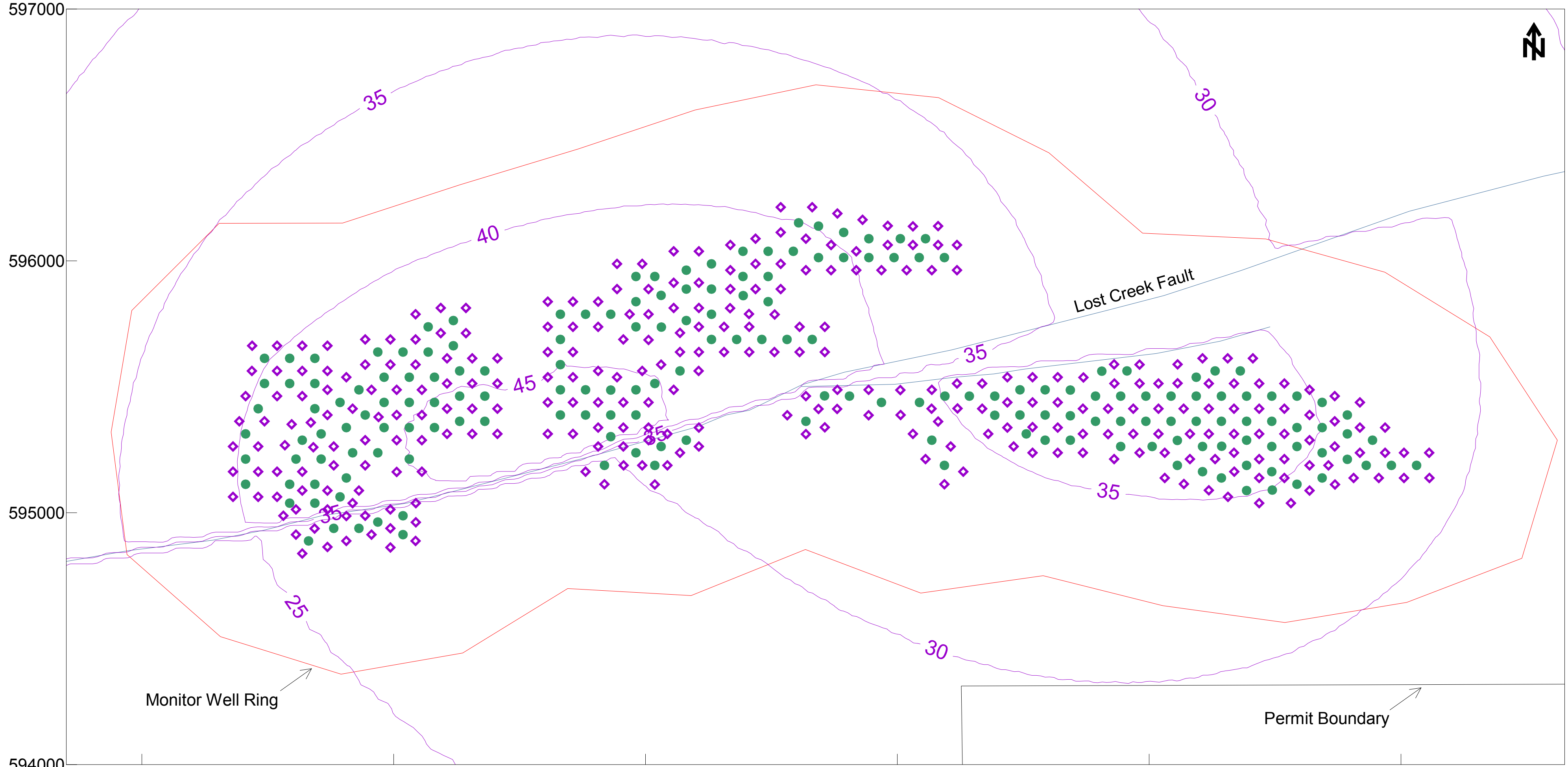
Drawing No.: Figure 15

0 1 2 3 Miles



Injection Well

Extraction Well

Drawdown Contour
(Contour Interval = 5 feet)

NAD 83 WSPC

RO Cycle is 548 Days

Net Extraction Rate is 67.6 gpm

From 541 gpm Treatment Stream

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FIGURE 16

Simulated Drawdown, HJ Horizon
End of Reverse Osmosis
Mine Unit 1

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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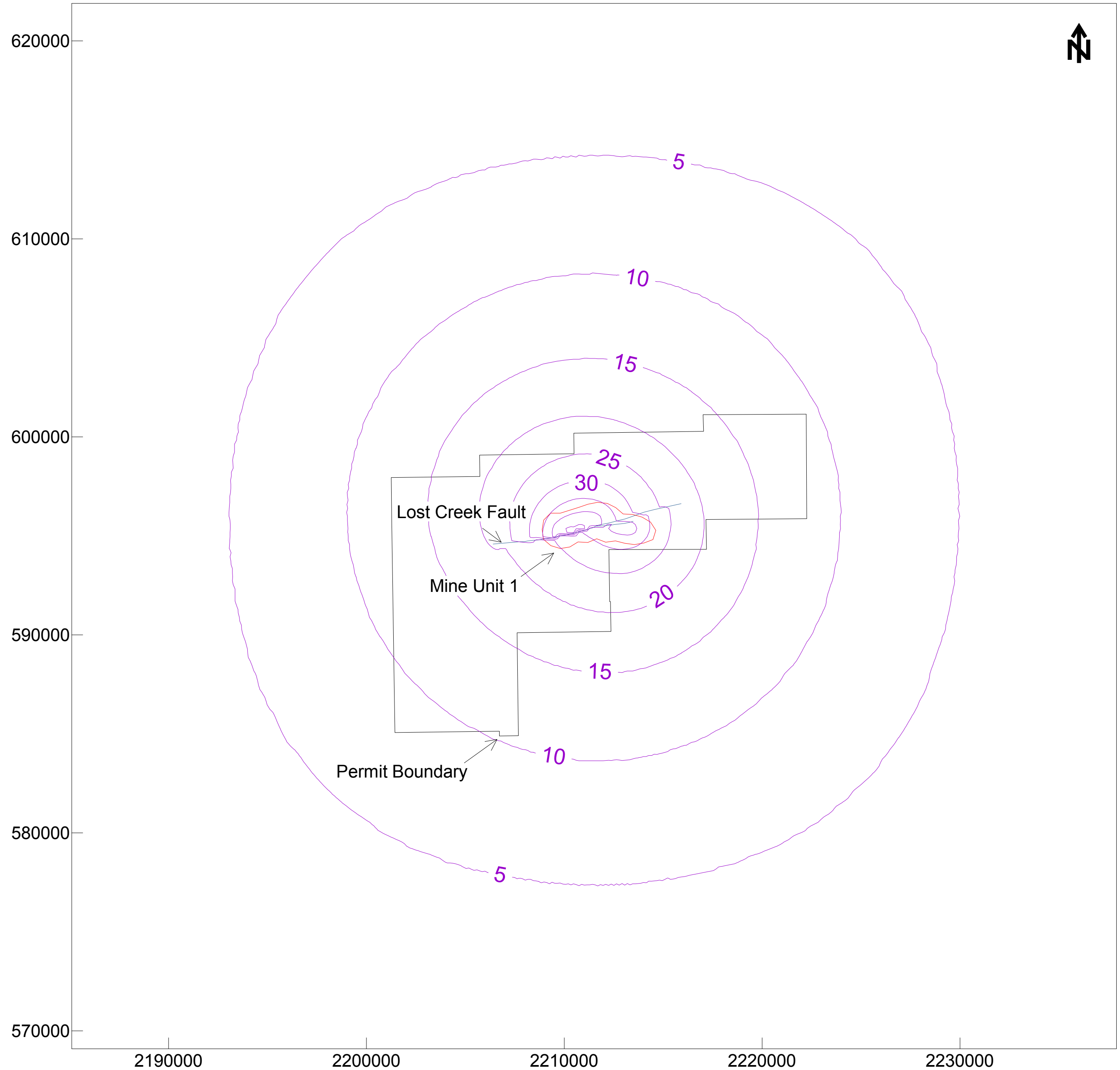
Issued /Revised: 10.20.10

Drawing No.: Figure 13

0 250 500 750 1000 Feet



RO Cycle is 548 Days

Net Extraction Rate is 67.6 gpm

From 541 gpm Treatment Stream

NAD 83 WSPC

Contour Interval is 5 Feet

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Petrotek www.petrotek.com Littleton, CO, USA

FIGURE 17

Simulated Drawdown, HJ Horizon End of Reverse Osmosis Model Domain

Numerical Modeling of Hydrologic Conditions Lost Creek Insitu Recovery Uranium Project

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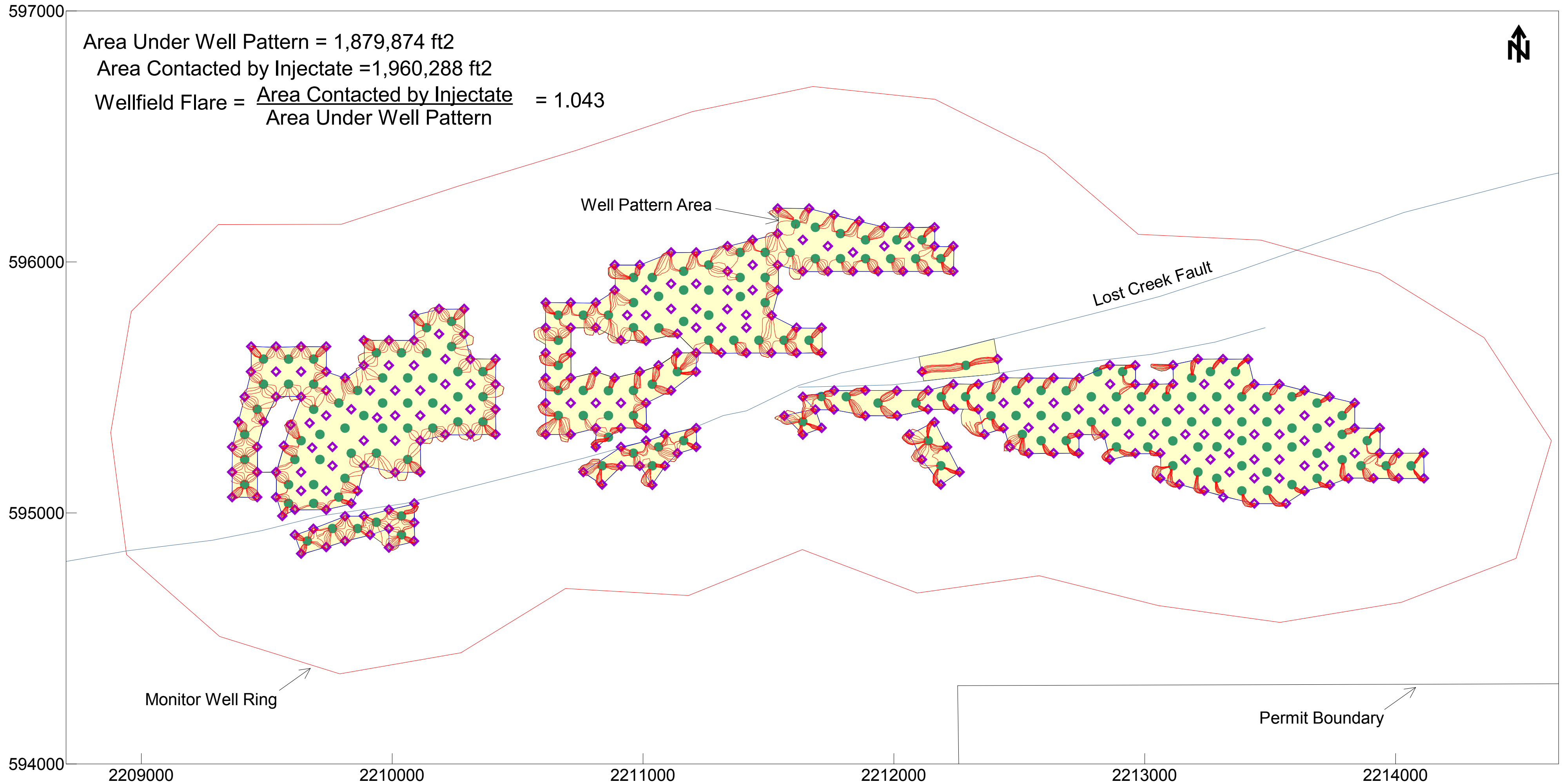
Drawing No.: Figure 17

0 1 2 3 Miles



Injection Well

Extraction Well

Groundwater Flowpath (Particle Tracking)

Area Contacted by Injectate (Plus Area Within Well Pattern)

Extraction Rate is 5838 gpm (183 Wells)

Injection Rate is 5800 gpm (297 Wells)

Bleed is 0.66%

NAD 83 WSPC

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Littleton, CO, USA

FIGURE 18
Simulated Wellfield Flare HJ Horizon
At Maximum Production Rate
Mine Unit 1

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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Drawing No.: Figure x5

0 250 500 750 1000 Feet

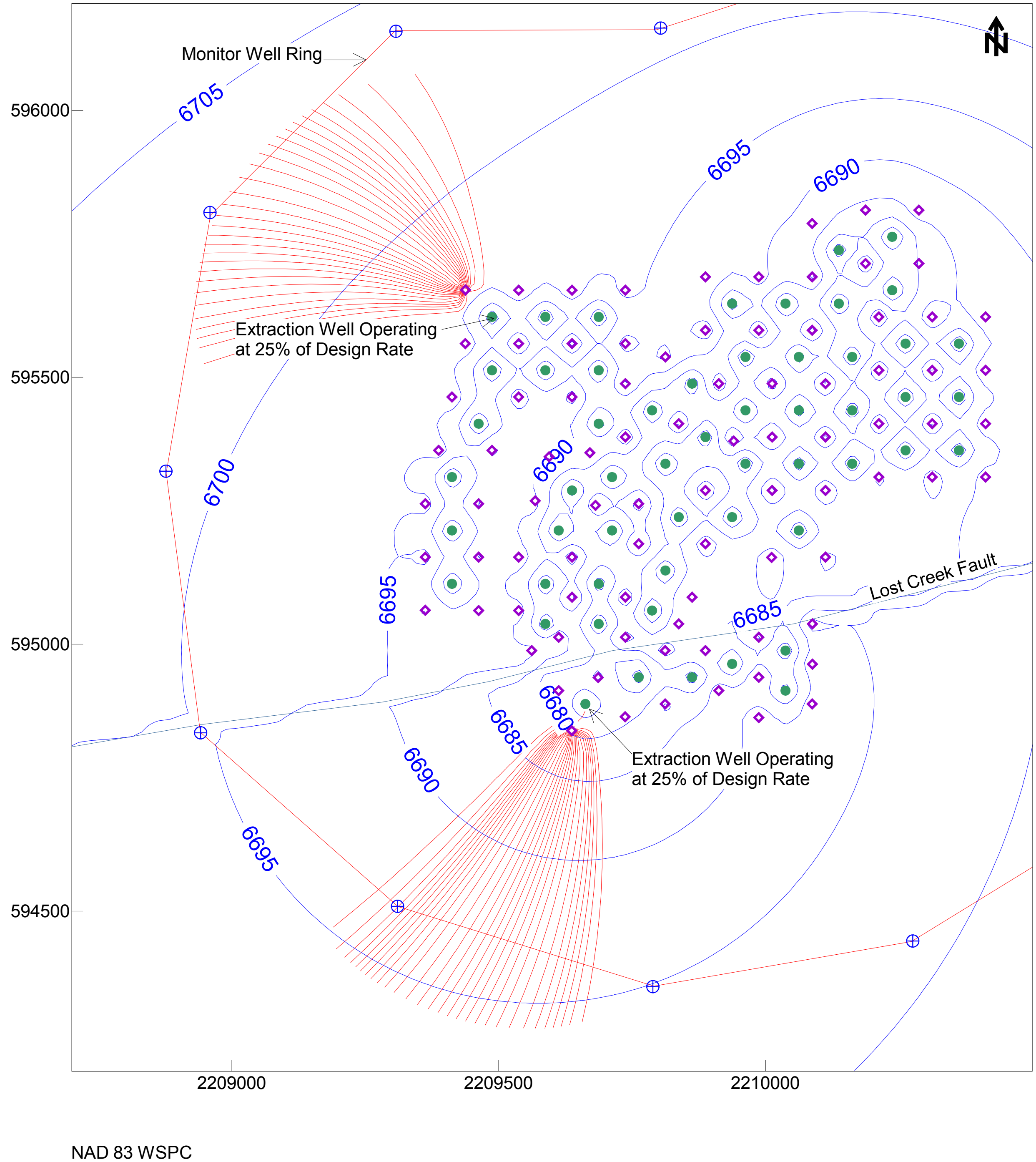

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FIGURE 19
Excursion Detection Simulation Potentiometric Surface and Particle Tracks, Mine Unit 1

Numerical Modeling of Hydrologic Conditions
Lost Creek Insitu Recovery Uranium Project

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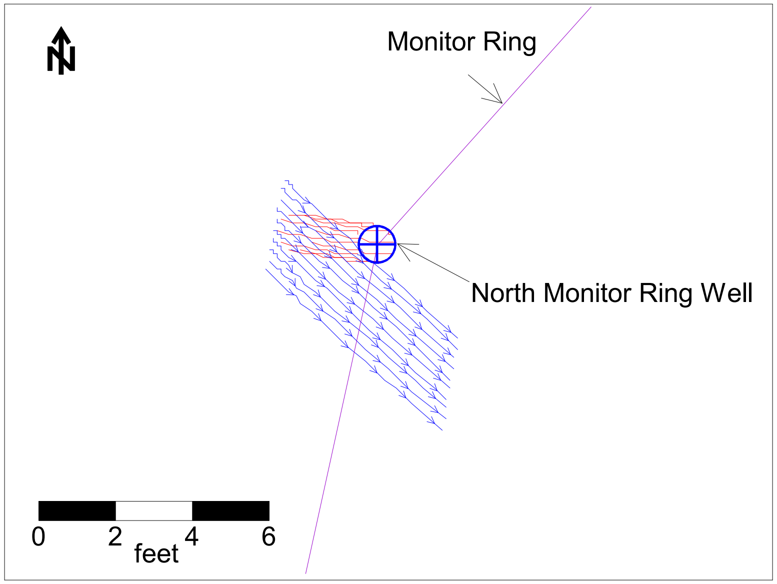
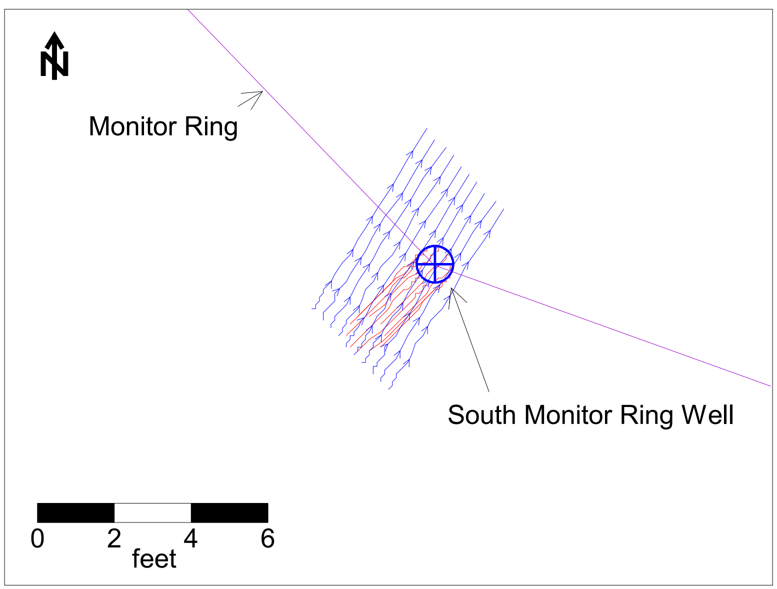
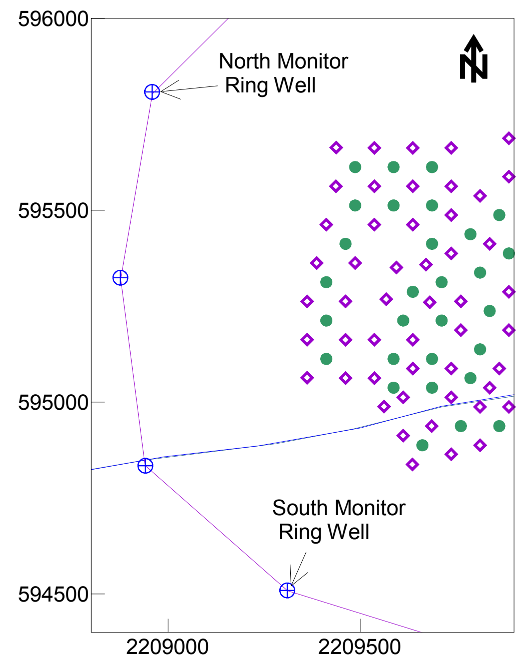
Issued /Revised: 10.20.10
Drawing No.: Figure 19

0 100 200 300 400 Feet







Groundwater Flowpaths

- During Excursion (30 Day Travel Time)
- During Excursion Recovery (60 Day Travel Time)

- Monitor Ring Well
- Injection Well
- Extraction Well

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FIGURE 20

Excursion Recovery Simulation and Particle Tracks Mine Unit 1

Numerical Modeling of Hydrologic Conditions Lost Creek Insitu Recovery Uranium Project

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Issued /Revised: 11.09.10

Drawing No.: Figure 20

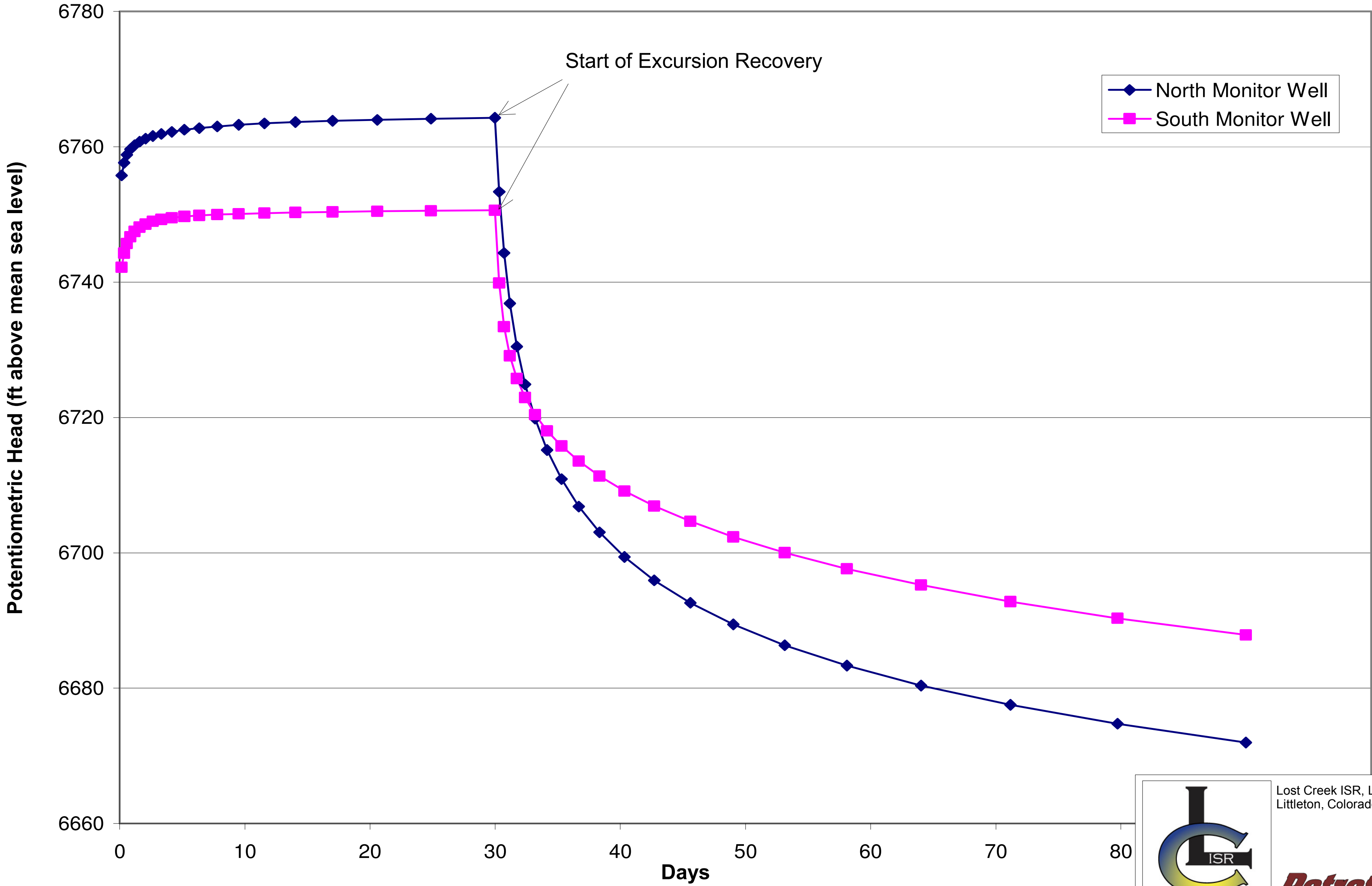

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FIGURE 21

Hydrographs of Monitor Wells During Excursion Recovery

Numerical Modeling of Hydrologic Conditions Lost Creek Insitu Recovery Uranium Project

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Issued /Revised: 10.20.10

Drawing No.: Figure 21

Feet

NUMERICAL MODELING OF HYDROLOGIC CONDITIONS

AT THE LOST CREEK INSITU RECOVERY

URANIUM PROJECT, WYOMING

LC ISR LLC

(November 2010, Revised January 2011)

TABLES

Petrotek

Table 1. HJ Horizon Water Level Measurements, 12/08/08, Lost Creek Project Area

Well	Easting	Northing	WL Elev.		Well	Easting	Northing	WL Elev.
PW-101	2212158	595259	6753.50		MP-101	2213875	595194	6772.37
PW-102	2210906	595846	6768.00		MP-102	2213299	595400	6764.39
M-101	2214619	595288	6773.81		MP-103	2212708	595381	6757.72
M-102	2214476	594822	6773.35		MP-104	2212007	595515	6755.16
M-103	2214018	594645	6772.33		MP-105	2212158	596079	6770.63
M-104	2213543	594565	6759.87		MP-106	2211488	595980	6768.93
M-105	2213052	594631	6756.74		MP-107	2210975	595822	6768.07
M-106	2212578	594746	6755.56		MP-108	2210882	595469	6766.51
M-107	2212095	594681	6749.93		MP-109	2210955	595235	6748.58
M-108	2211633	594854	6748.79		MP-110	2210185	595648	6761.78
M-109	2211180	594671	6746.97		MP-111	2209951	595361	6760.17
M-110	2210690	594700	6745.79		MP-112	2209585	595535	6759.37
M-111	2210270	594452	6739.49		MP-113	2209861	594950	6739.16
M-112	2209790	594358	6738.48		UKMO-101	2212409	595656	6764.52
M-113	2209310	594510	6737.53		UKMO-102	2212528	595847	6771.59
M-114	2208942	594834	6742.00		UKMO-103	2212823	596270	6774.18
M-115	2208879	595321	6754.16		HJMP-101	2211610	595711	6769.26
M-116	2208959	595808	6755.30		HJMP-104	2211208	595610	6768.00
M-117	2209308	596148	6759.24		HJMP-105	2211255	595787	6768.39
M-118	2209797	596146	6761.83		HJMP-108	2211784	596011	6770.62
M-119	2210266	596303	6765.14		HJMP-109	2212218	595543	6755.01
M-120	2210727	596442	6768.32		HJMP-110	2212005	595897	6770.92
M-121	2211199	596595	6770.43		HJMP-113	2212596	595510	6757.32
M-122	2211677	596693	6772.23		HJT-101	2210883	595323	6764.58
M-123	2212166	596647	6773.74		HJT-102	2211209	595409	6767.83
M-124	2212603	596425	6774.95		HJT-103	2211502	595383	6749.02
M-125	2212970	596111	6775.75		HJT-104	2211976	595605	6769.52
M-126	2213464	596087	6776.49		HJT-105	2212760	595740	6767.26
M-127	2213932	595954	6774.98		LC16M	2212869	595523	6758.70
M-128	2214350	595698	6775.45		LC19M	2211685	596020	6770.17

WL Elev.- Water Level Elevation Measured on 12/08/08
Coordinates are in NAD 83 Wyoming State Plane Central

Table 2. Drawdown Data, North and South Hydrologic Tests

North Hydrologic Test - Drawdown

Well Name	Distance from P.W.	Side of Fault	Maximum Drawdown
			[ft]
MP-107	70	N	(ft)
HJMP-105	351	N	48.6
HJMP-104	383	N	37.3
MP-108	385	N	40.0
HJT-101	530	N	40.3
HJT-102	534	N	34.2
MP-106	592	N	39.6
M-120	625	N	30.8
HJMP-101	713	N	36.5
MP-110	748	N	30.7
M-119	791	N	25.7
LC19M	796	N	30.6
M-121	808	N	28.8
HJMP-108	894	N	16.0
MP-111	1,082	N	27.0
HJT-104	1,093	N	22.8
HJMP-110	1,095	N	24.1
M-122	1,149	N	23.6
M-118	1,153	N	11.3
MP-105	1,268	N	19.1
MP-112	1,358	N	20.0
M-123	1,490	N	18.3
UKMO-102	1,618	N	9.8
M-117	1,630	N	12.8
M-124	1,792	N	15.8
M-116	1,949	N	9.1
UKMO-103	1,958	N	11.0
M-125	2,083	N	7.3
M-115	2,098	N	7.4
M-114	2,211	N	10.1
M-126	2,566	N	2.8
MP-109	608	S	5.7
HJT-103	755	S	2.7
MP-104	1,059	S	1.6
HJMP-109	1,343	S	0.4
MP-113	1,377	S	0.3
UKMO-101	1,510	S	0.5
HJMP-113	1,719	S	2.4
HJT-105	1,852	S	0.3
MP-103	1,858	S	1.9
LC16M	1,987	S	0.3
MP-102	2,431	S	0.2
M-127	3,029	S	0.0
MP-101	3,038	S	0.4
			0.1
PW-102	0	P.W.	111.1

South Hydrologic Test - Drawdown

Well Name	Distance from P.W.	Side of Fault	Maximum Drawdown
	(ft)		[ft]
HJMP-109	295	S	41.7
MP-104	331	S	48.1
UKMO-101	473	S	17.4
HJMP-113	507	S	35.3
MP-103	564	S	36.1
M-107	568	S	29.1
M-106	652	S	34.1
M-108	652	S	25.7
HJT-103	668	S	28.1
LC16M	765	S	29.6
HJT-105	773	S	12.2
M-105	1,089	S	30.7
M-109	1,132	S	21.1
MP-102	1,150	S	19.5
MP-109	1,202	S	18.7
M-104	1,543	S	22.5
M-110	1,563	S	15.2
MP-101	1,721	S	8.3
M-127	1,916	S	5.1
M-103	1,962	S	8.5
M-111	2,047	S	8.1
M-128	2,243	S	5.2
MP-113	2,314	S	7.2
M-102	2,364	S	7.1
M-101	2,465	S	6.7
M-112	2,525	S	6.9
M-113	2,938	S	4.8
HJT-104	395	N	2.0
HJMP-110	661	N	0.8
UKMO-102	699	N	0.6
HJMP-101	713	N	0.7
MP-105	825	N	0.5
HJMP-108	854	N	0.4
LC19M	905	N	0.4
HJT-102	962	N	0.5
MP-106	987	N	0.4
HJMP-104	1,015	N	0.4
HJMP-105	1,047	N	0.4
UKMO-103	1,213	N	0.4
HJT-101	1,276	N	1.0
MP-108	1,294	N	0.4
MP-107	1,313	N	0.3
M-126	1,555	N	0.5
MP-110	2,010	N	0.2
MP-111	2,211	N	0.5
MP-112	2,586	N	0.2
M-114	3,240	N	1.2
M-115	3,279	N	0.1
PW-101	0	P.W.	63.5

P.W. - Pumping Well
N - North of Lost Creek Fault
S - South of Lost Creek Fault

Table 3. Calibration Statistics for the Non-Pumping, and North and South Hydrologic Test Simulations

	Non-Pumping Conditions	North Hydrologic Test	South Hydrologic Test
Residual Mean	0.031	0.047	0.248
Absolute Residual Mean	2.22	2.28	1.97
Residual Standard Deviation	2.75	3.56	3.16
Sum of Squares	453.6	543.8	493.4
Residual Mean Squared Error	2.75	3.56	3.17
Minimum Residual	-6.02	-10.81	-5.76
Maximum Residual	6.54	11.40	11.81
Number of Observations	60	43	49
Range in Observations	38.96	48.60	63.40
Scaled Standard Deviation	0.071	0.073	0.050
Scaled Absolute Mean	0.057	0.047	0.031
Scaled Residual Mean Squared	0.071	0.073	0.050

Table 4. Operational Parameters, MU1 Production Simulation

			Wellfield A		Wellfield B		Wellfield C		Total		Total Production Rate		Total Injection Rate		Net Bleed	
Stress Period	Days in Stress Period	Total Elapsed Days	Production Wells	Injection Wells	Production Wells	Injection Wells	Production Wells	Injection Wells	Production Wells	Injection Wells	(ft^3/d)	(gpm)	(ft^3/d)	(gpm)	(gpm)	Percent
One	122.0	122.0	55	88	0	0	0	0	55	88	338,823	1,760.0	337,024	1,750.7	9.3	0.53
Two	122.0	244.0	55	88	57	99	0	0	112	187	690,667	3,587.6	686,035	3,563.6	24.1	0.68
Three	213.5	457.5	55	88	57	99	71	110	183	297	1,123,896	5,838.0	1,116,542	5,799.8	38.2	0.66
Four	152.5	610.0	0	0	57	99	71	110	128	209	785,073	4,078.0	779,519	4,049.2	28.8	0.71
Five	181.0	791.0	0	0	0	0	71	110	71	110	433,229	2,250.4	430,507	2,236.2	14.1	0.63

NUMERICAL MODELING OF HYDROLOGIC CONDITIONS AT THE LOST CREEK INSITU RECOVERY URANIUM PROJECT, WYOMING

LC ISR LLC

(November 2010, Revised January 2011)

Attachment A

Lost Creek Project Area Model Input and Output Files