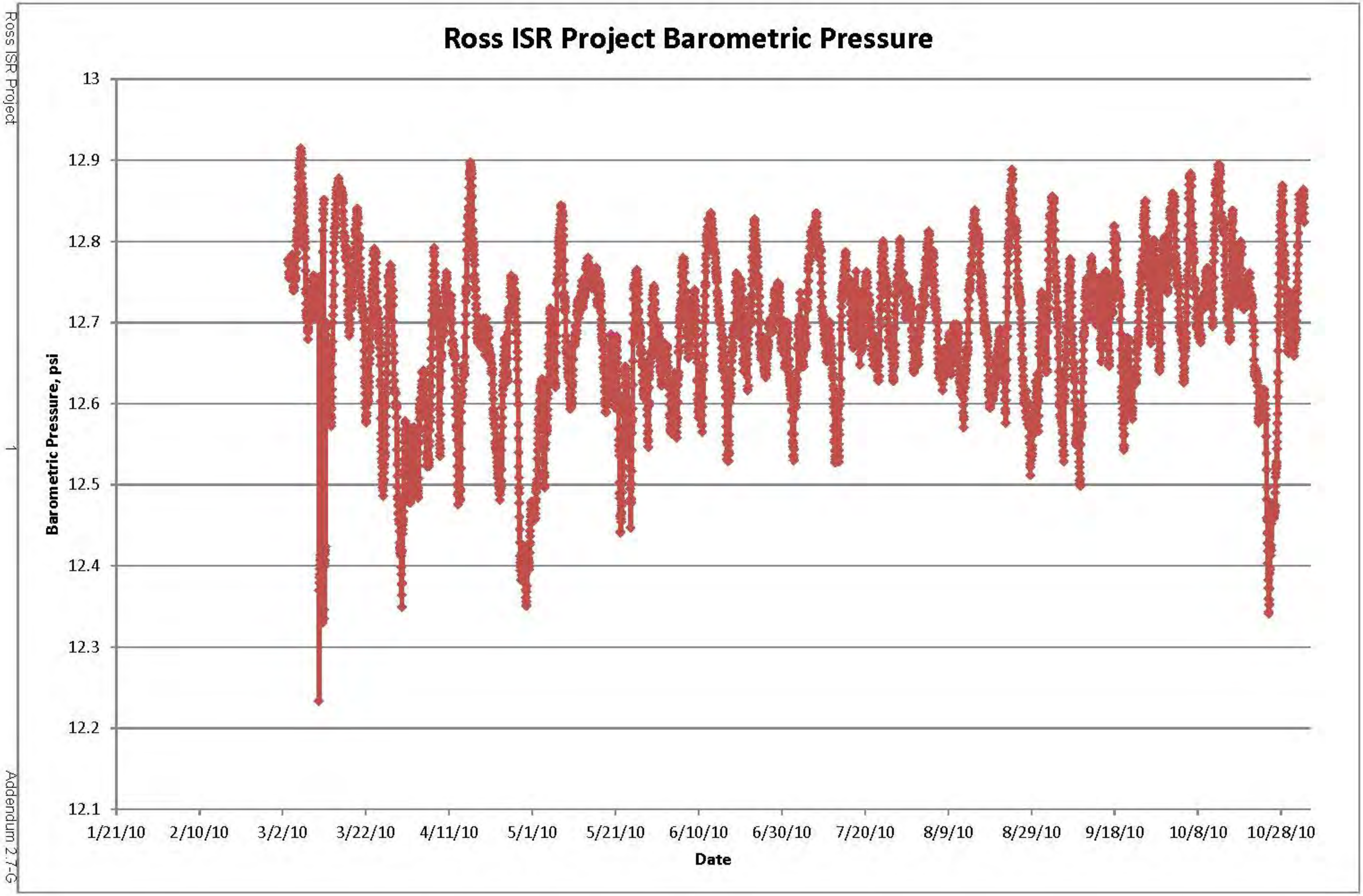
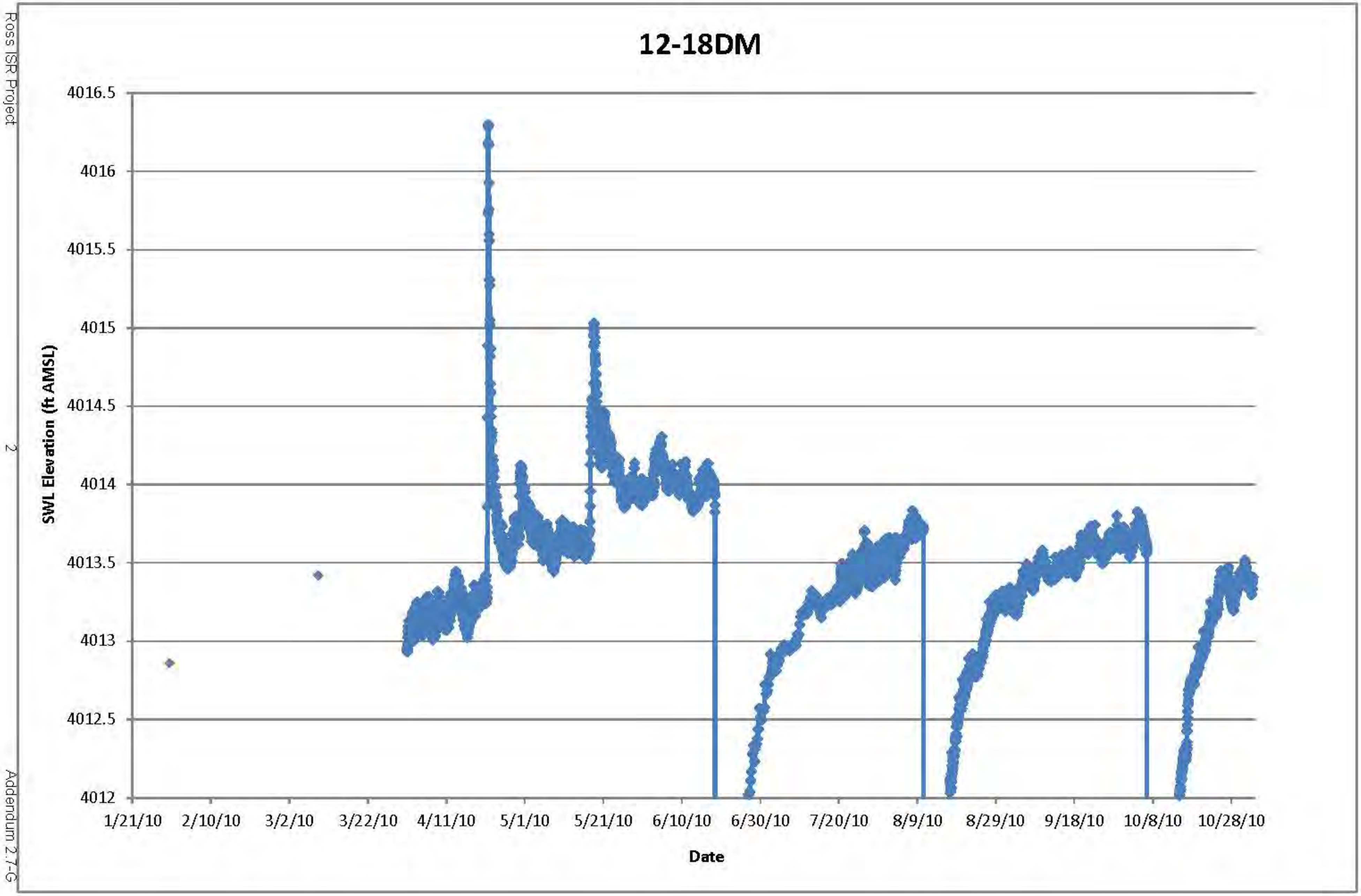
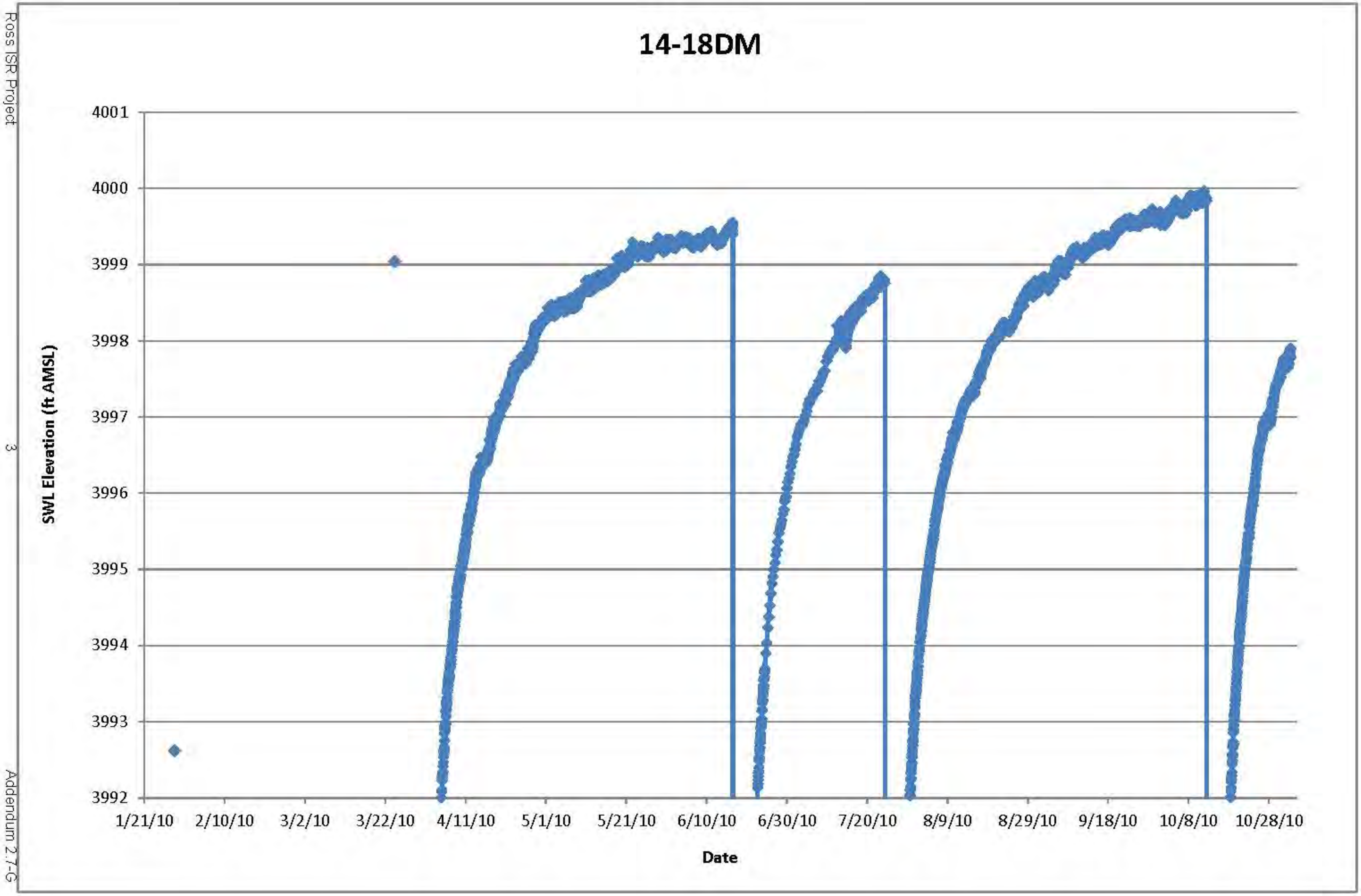
ADDENDUM 2.7-G

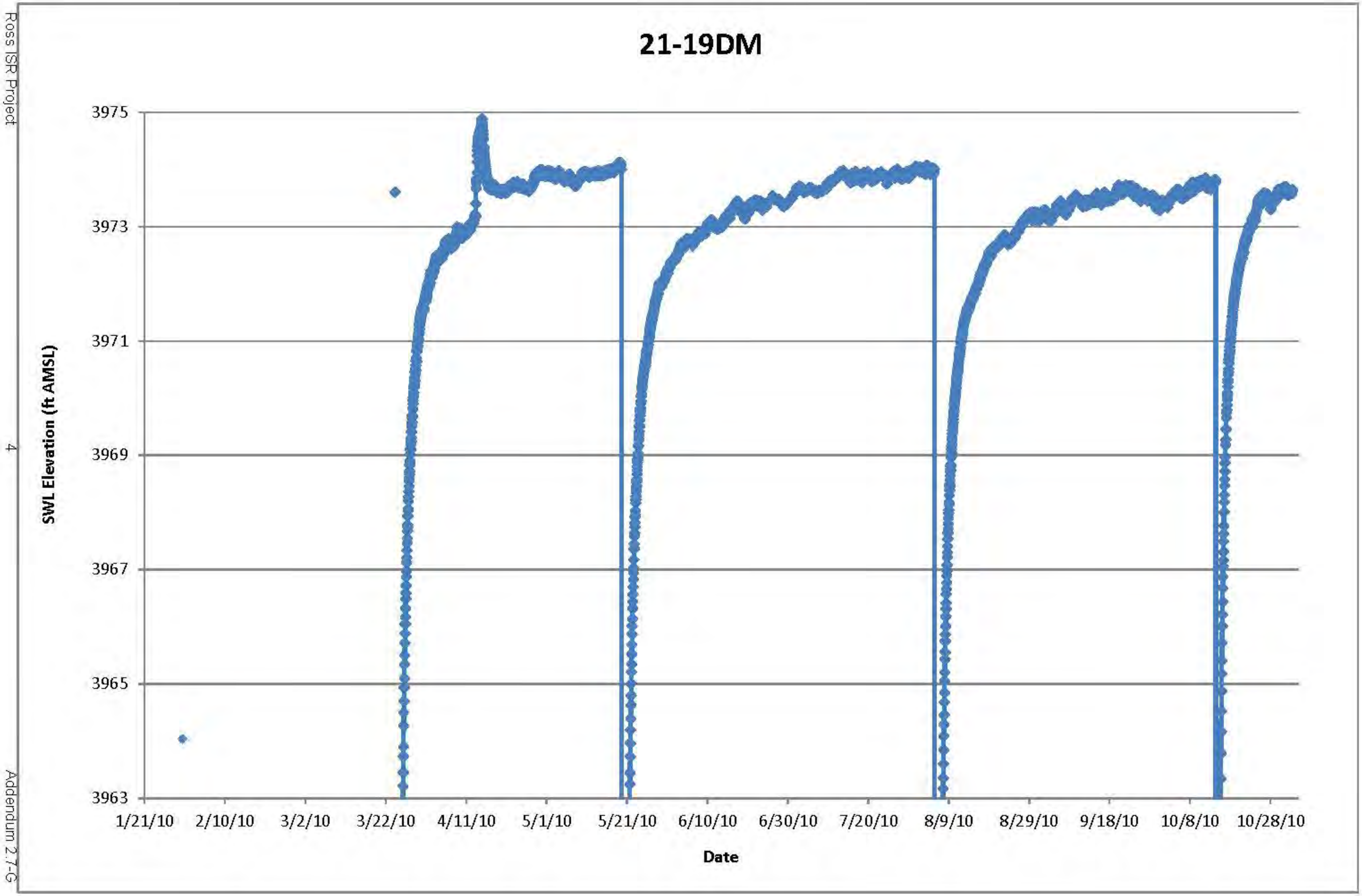
REGIONAL BASELINE MONITOR

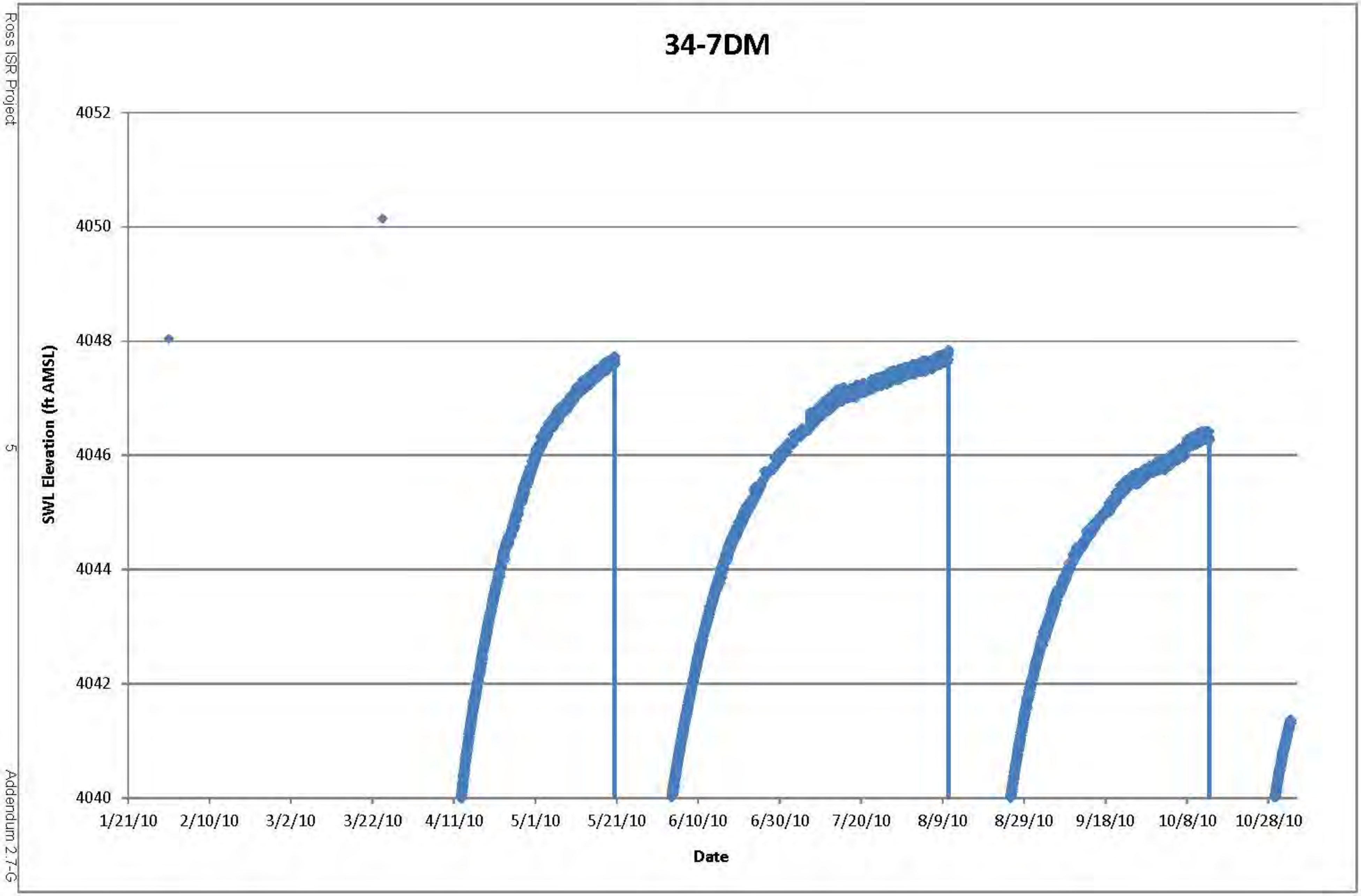
WELL HYDROGRAPHS

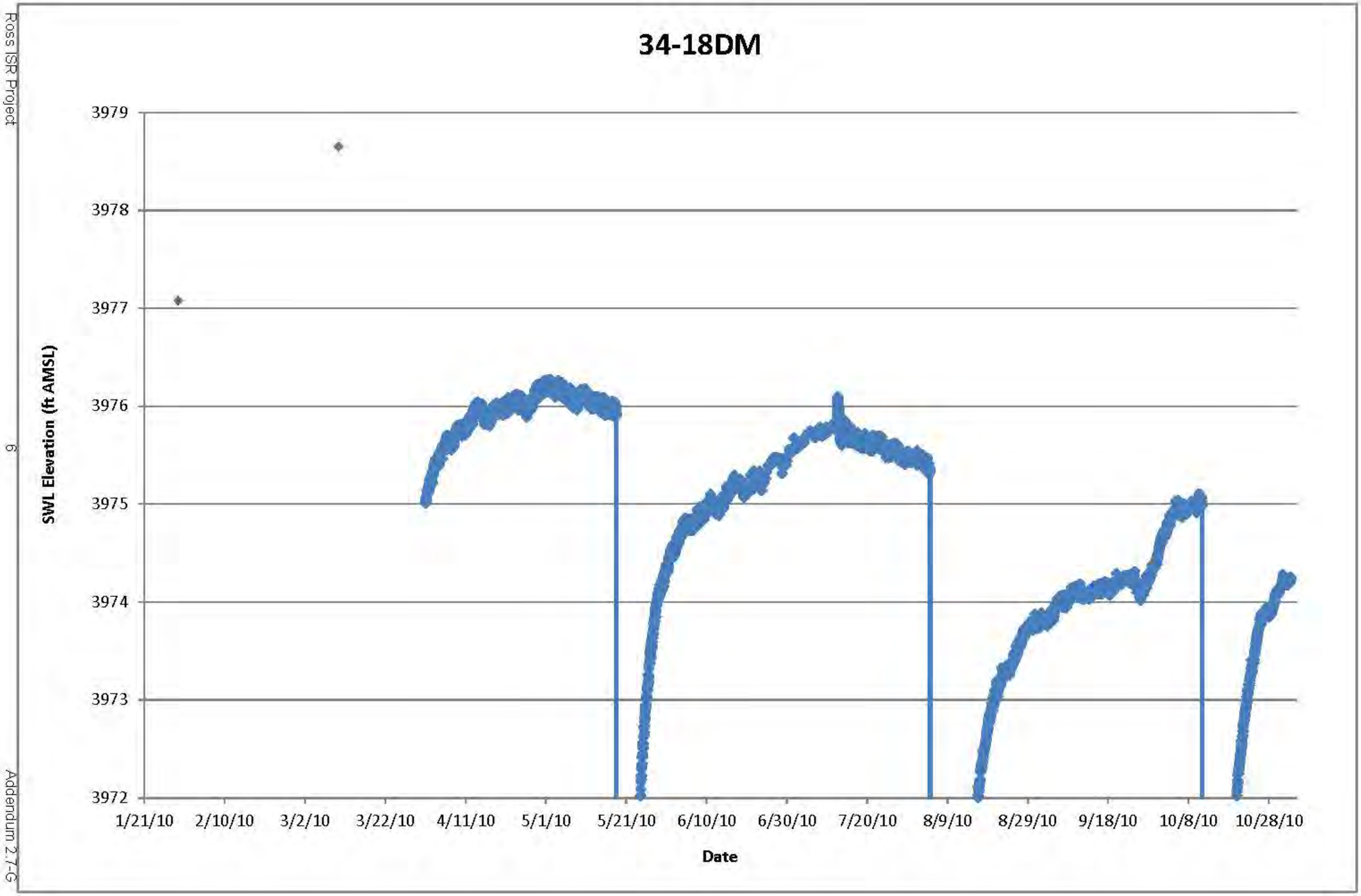

Ross ISR Project Barometric Pressure
Barometric Pressure, psi
13
12.9
12.8
12.7
12.6
12.5
12.4
12.3
12.2
12.1
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

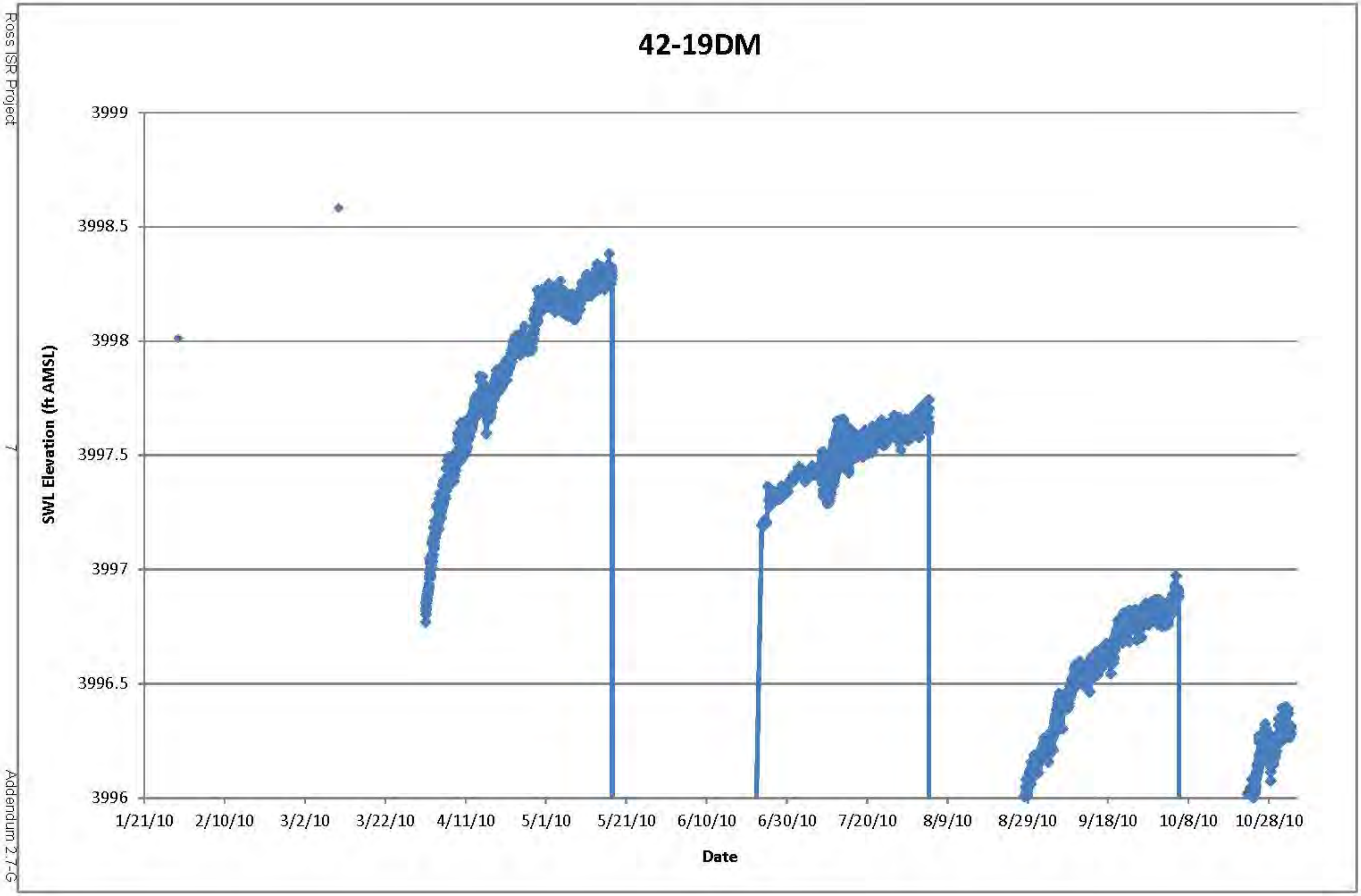

12-18DM
4016.5
4016
4015.5
4015
4014.5
4014
4013.5
4013
4012.5
4012
SWL Elevation (ft AMSL)
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

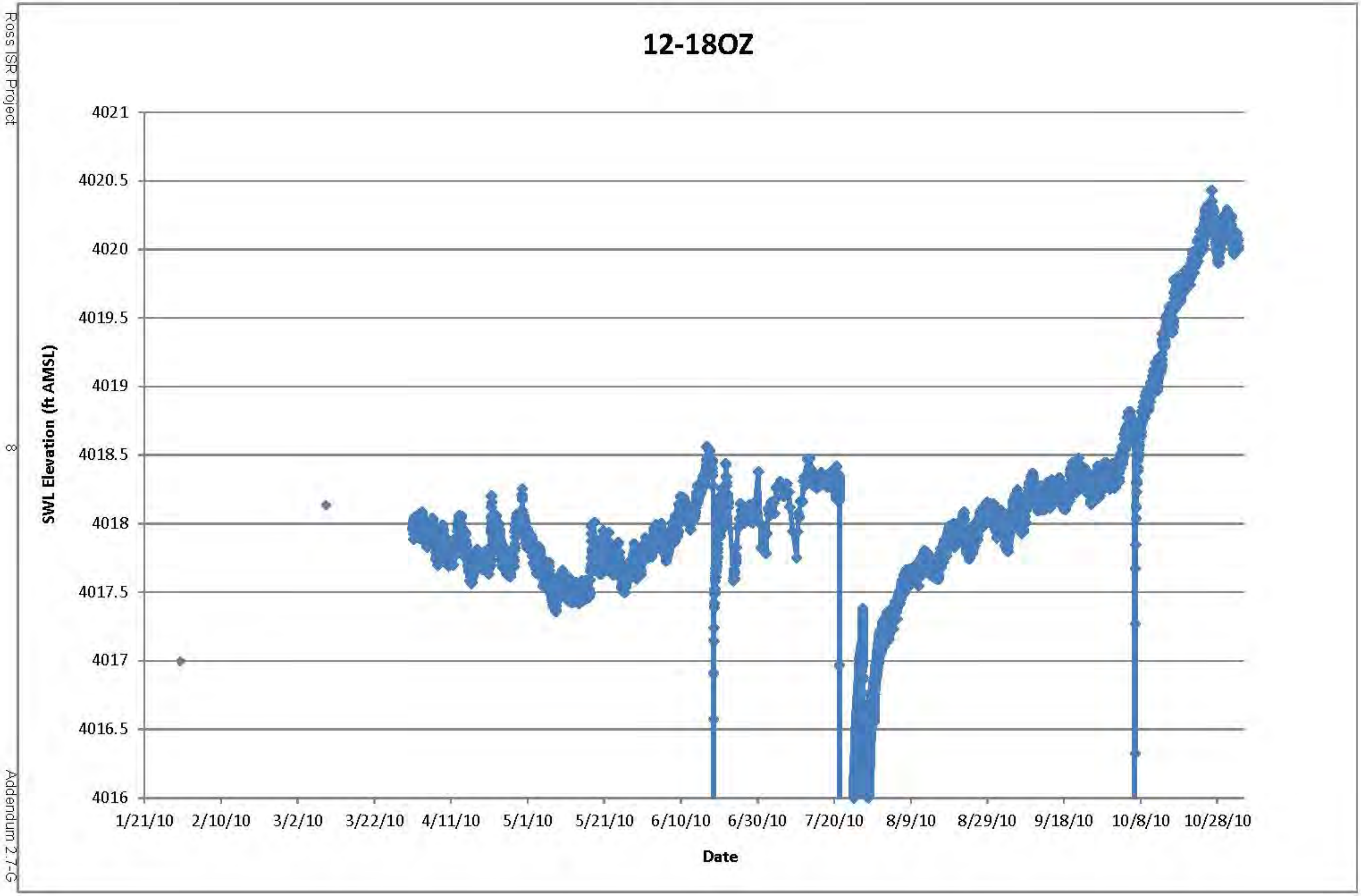

14-18DM
4001
4000
3999
3998
3997
3996
3995
3994
3993
3992
SWL Elevation (ft AMSL)
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

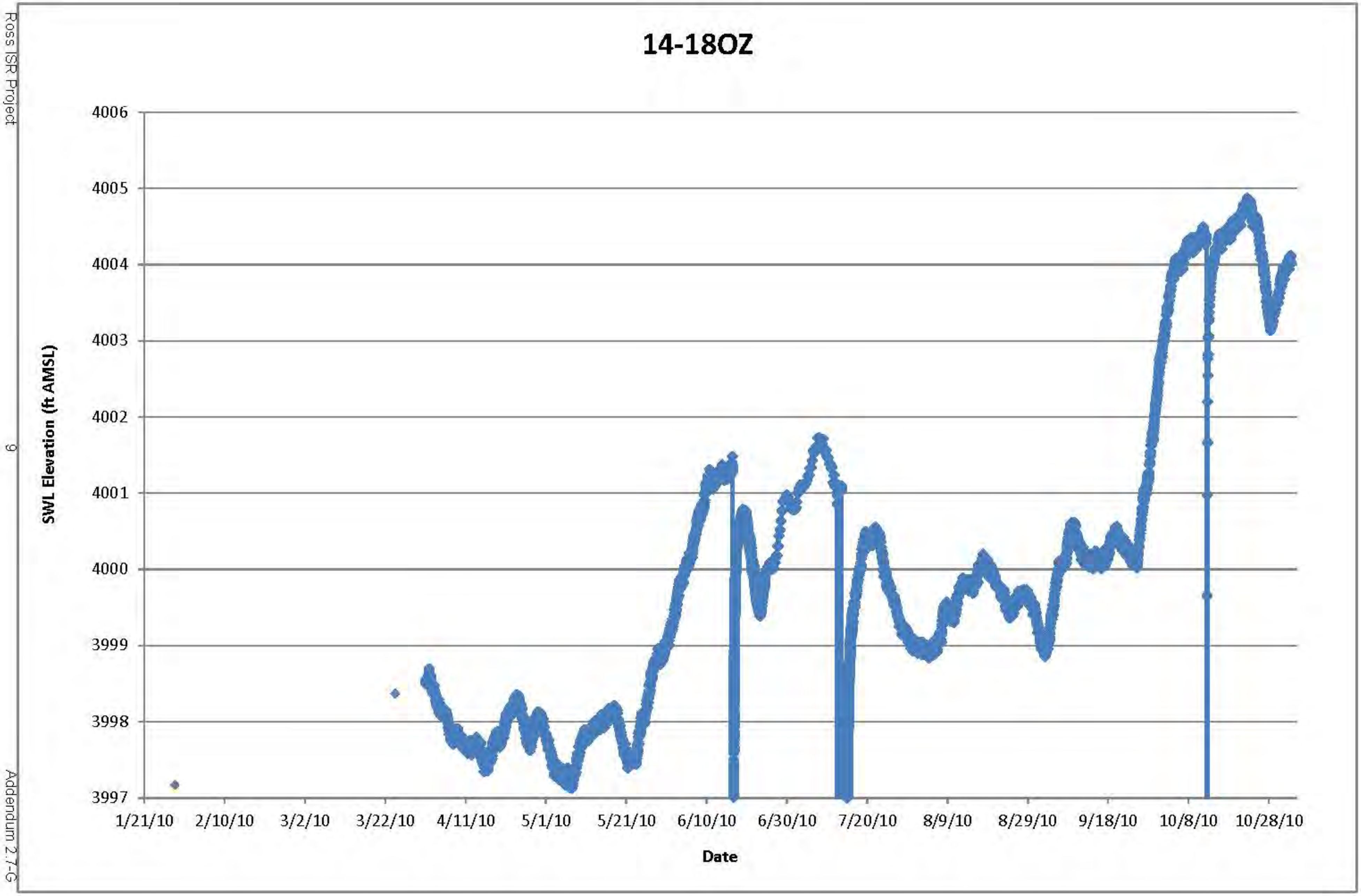

21-19DM
3975
3973
3971
3969
3967
3965
3963
SWL Elevation (ft AMSL)
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

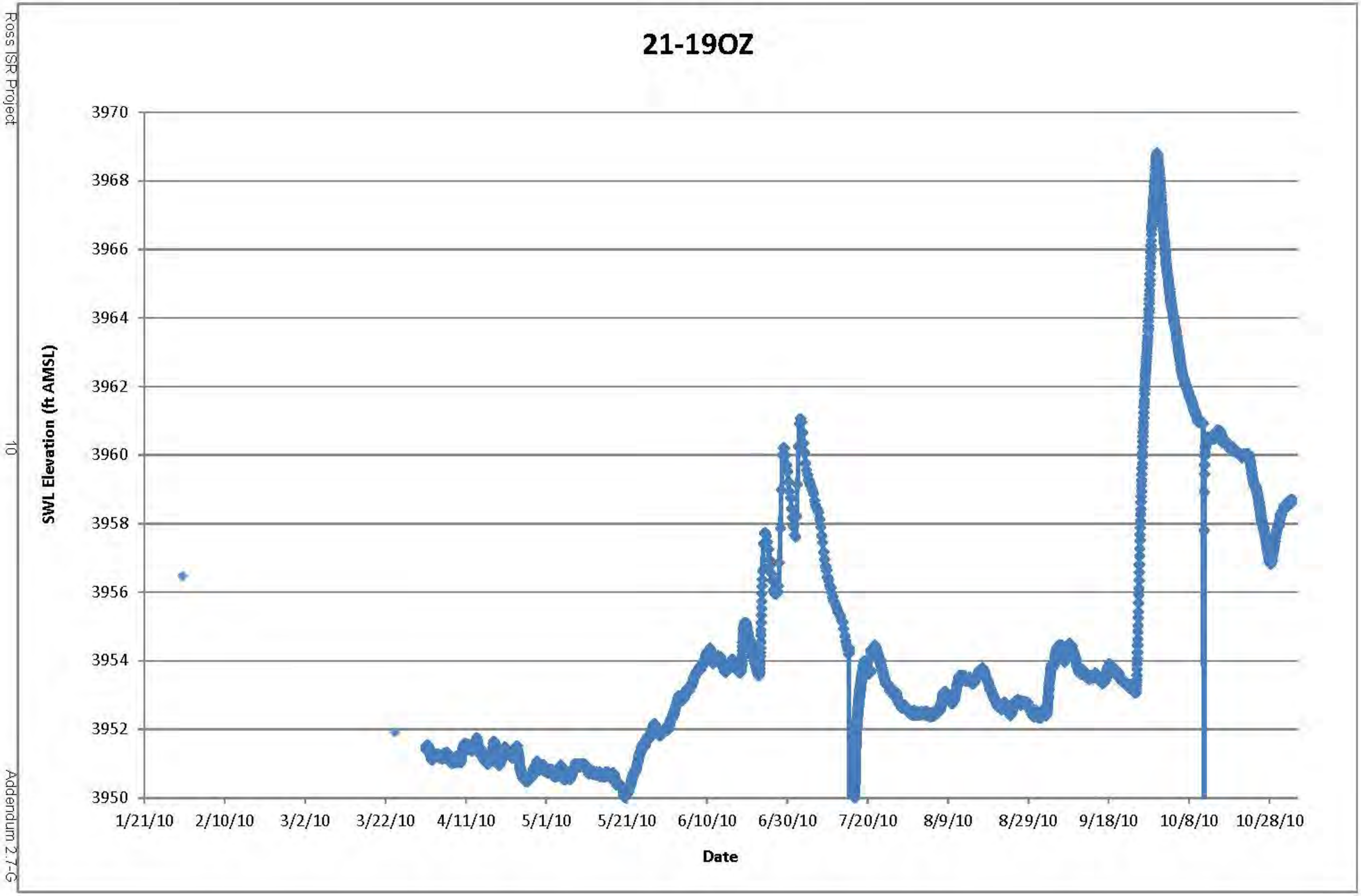

34-7DM
4052
4050
4048
4046
4044
4042
4040
SWL Elevation (ft AMSL)
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date


34-18DM
SWL Elevation (ft AMSL)
3979
3978
3977
3976
3975
3974
3973
3972
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

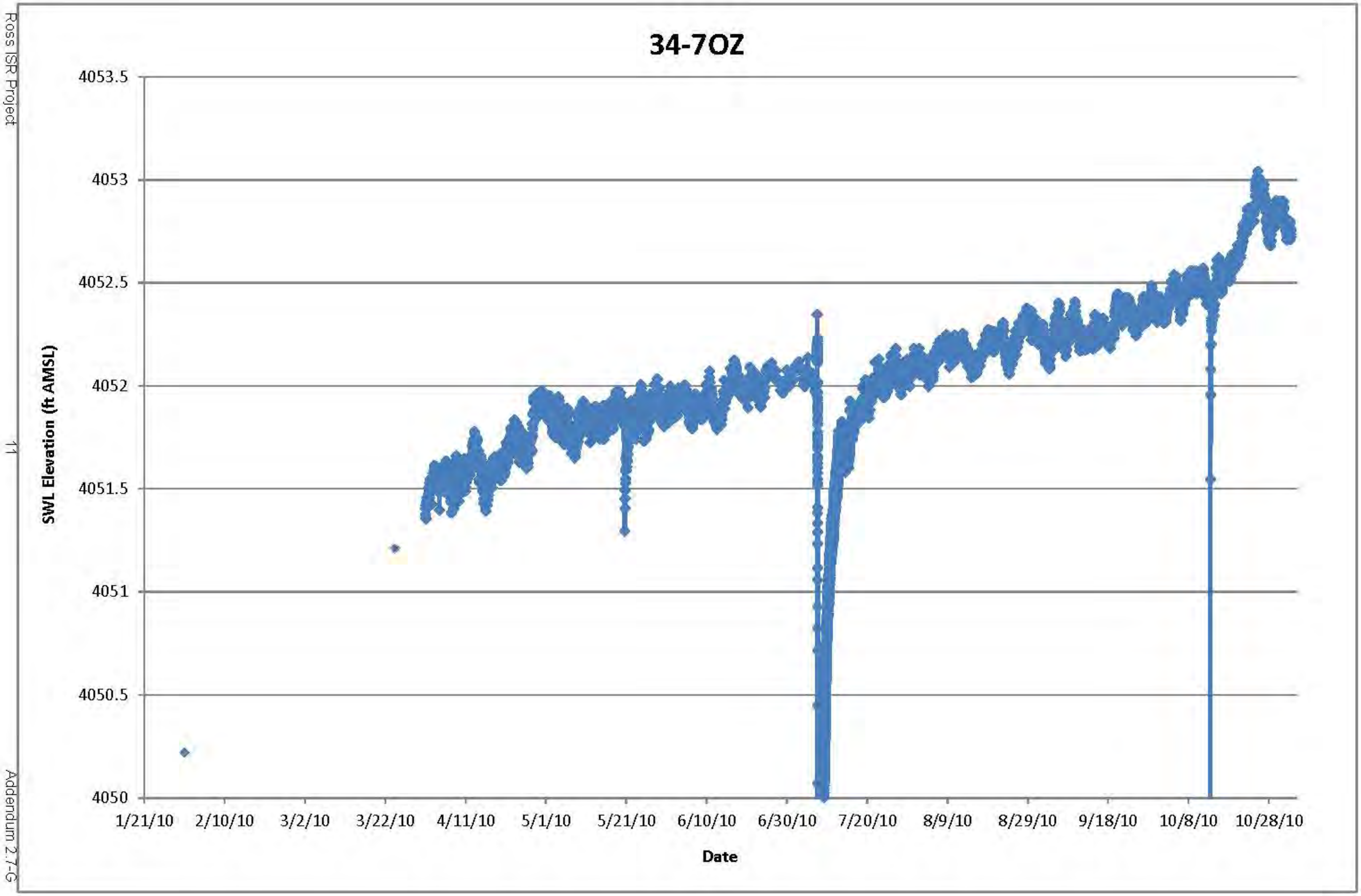

42-19DM
SWL Elevation (ft AMSL)
3999
3998.5
3998
3997.5
3997
3996.5
3996
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date


12-18OZ
SWL Elevation (ft AMSL)
4021
4020.5
4020
4019.5
4019
4018.5
4018
4017.5
4017
4016.5
4016
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

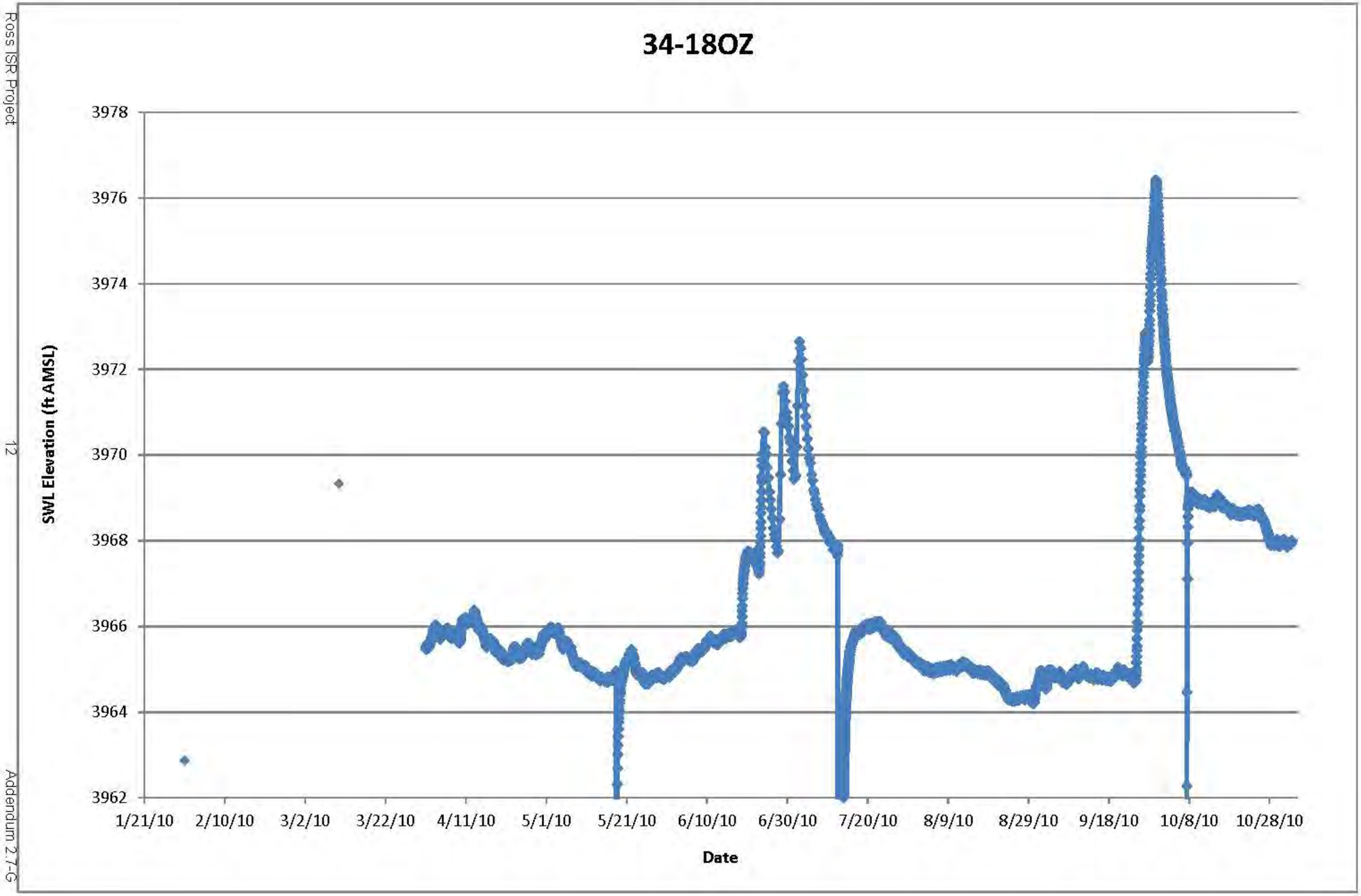

14-18OZ
SWL Elevation (ft AMSL)
4006
4005
4004
4003
4002
4001
4000
3999
3998
3997
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

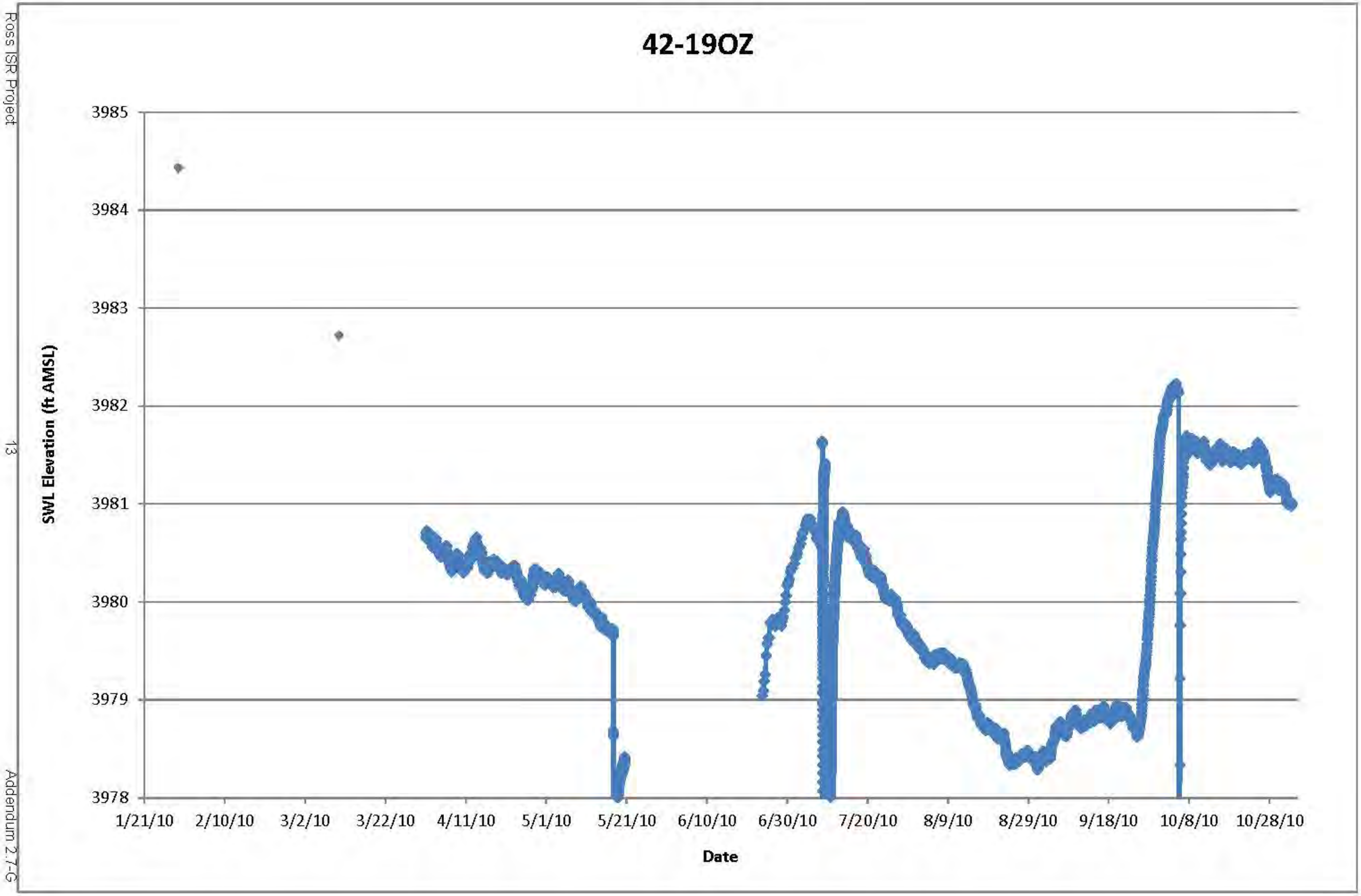


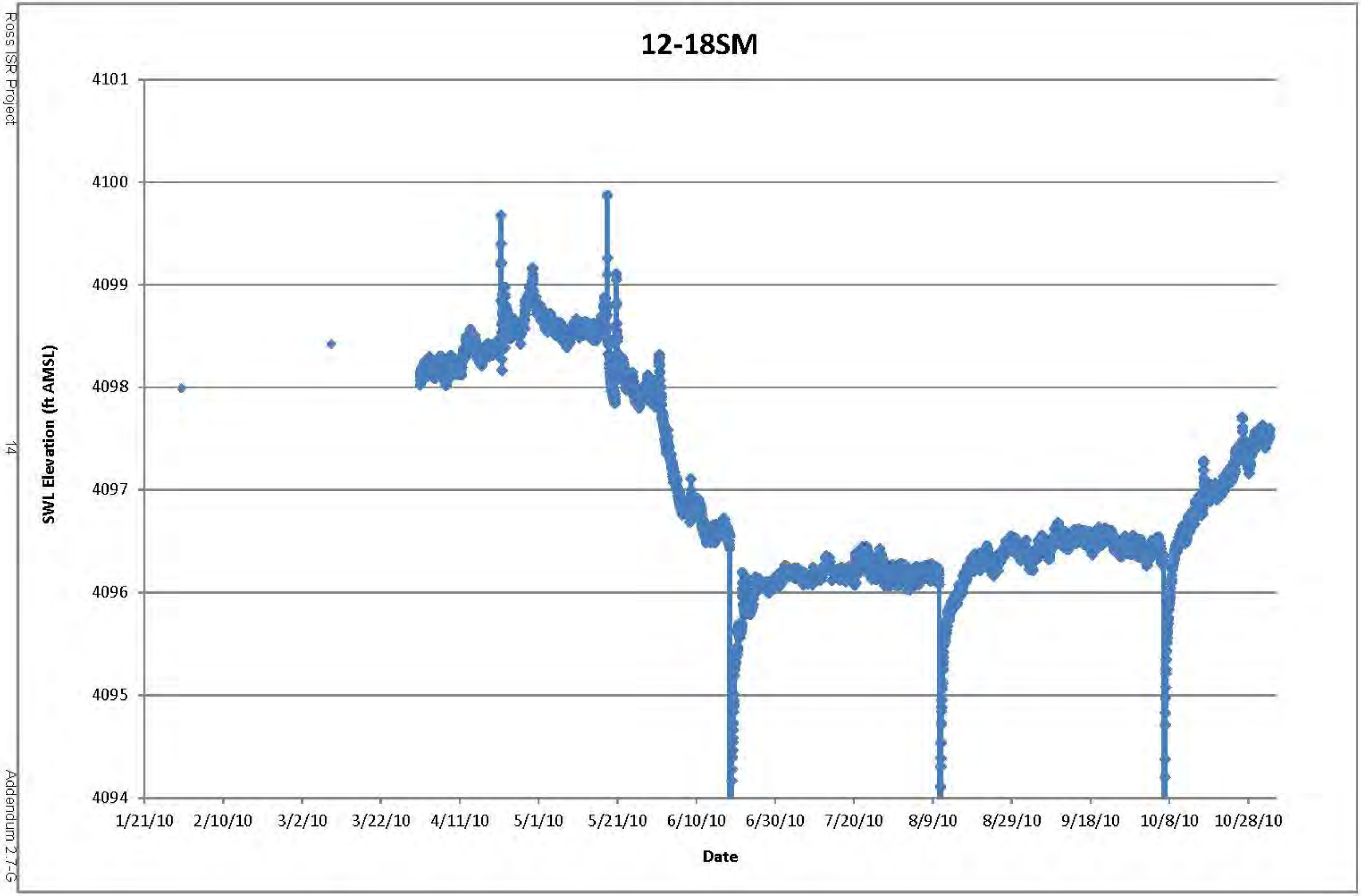
21-19OZ
SWL Elevation (ft AMSL)
3970
3968
3966
3964
3962
3960
3958
3956
3954
3952
3950
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

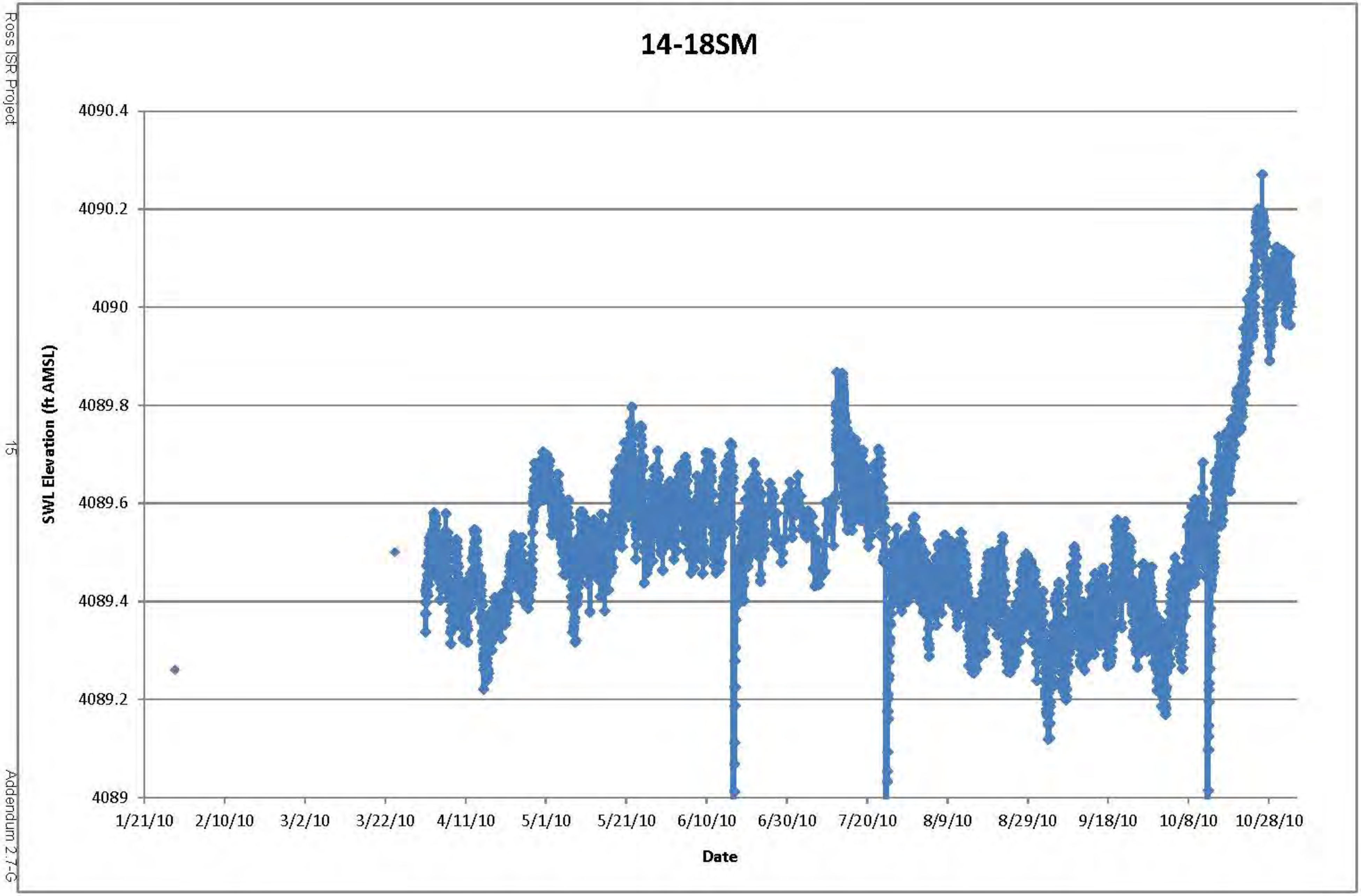


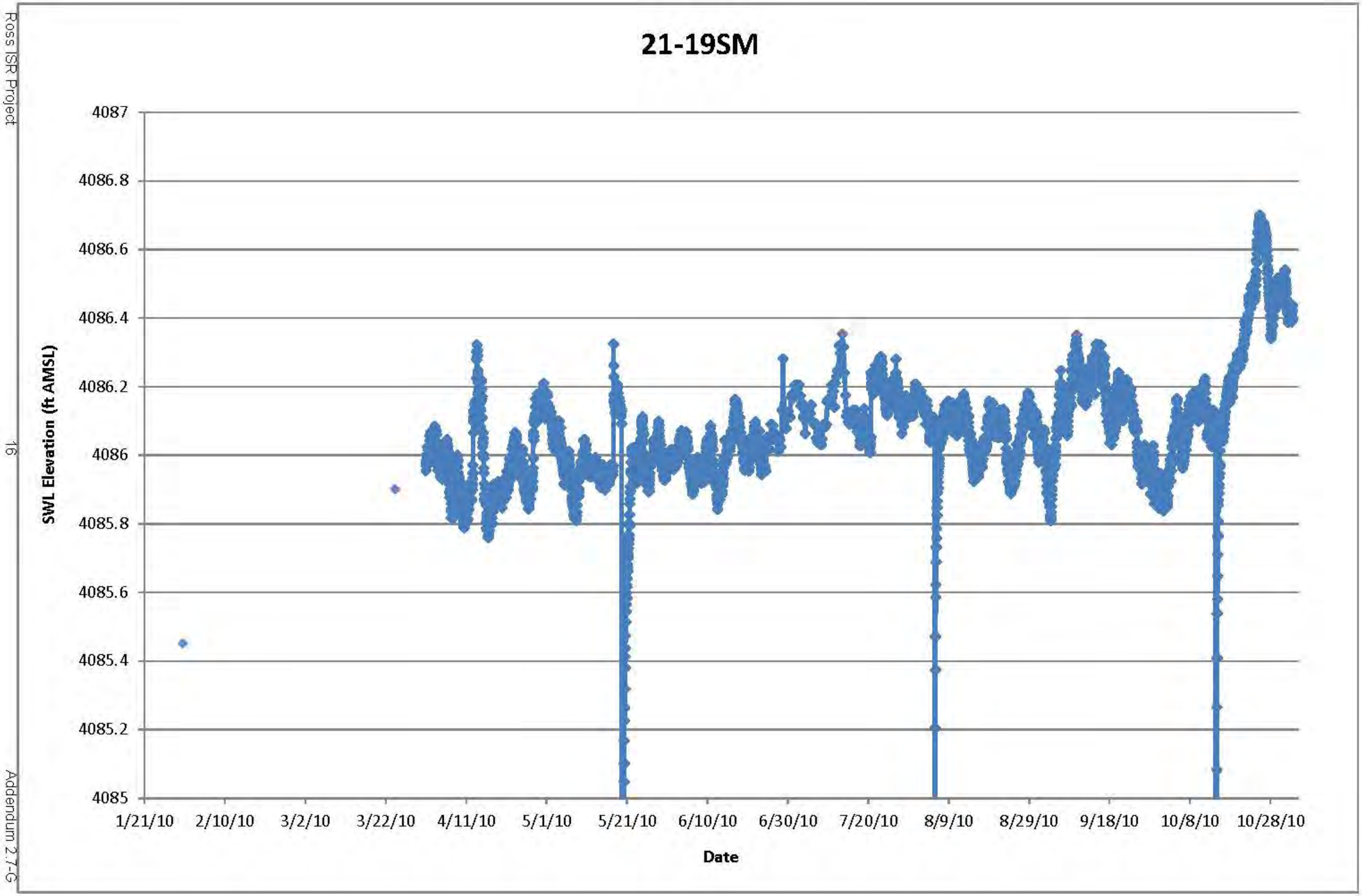
34-7OZ
4053.5
4053
4052.5
4052
4051.5
4051
4050.5
4050
SWL Elevation (ft AMSL)
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

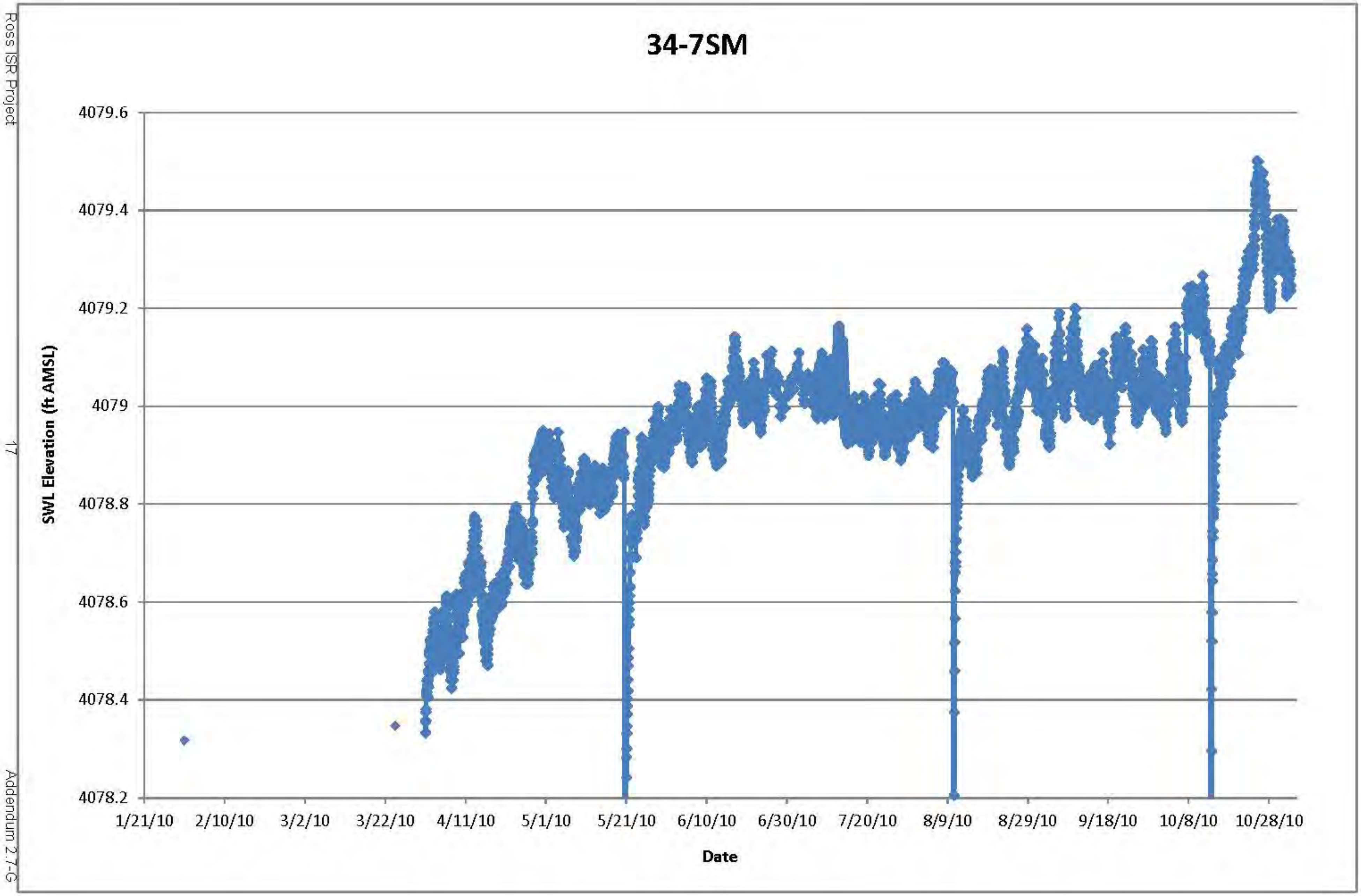

34-18OZ
SWL Elevation (ft AMSL)
3978
3976
3974
3972
3970
3968
3966
3964
3962
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

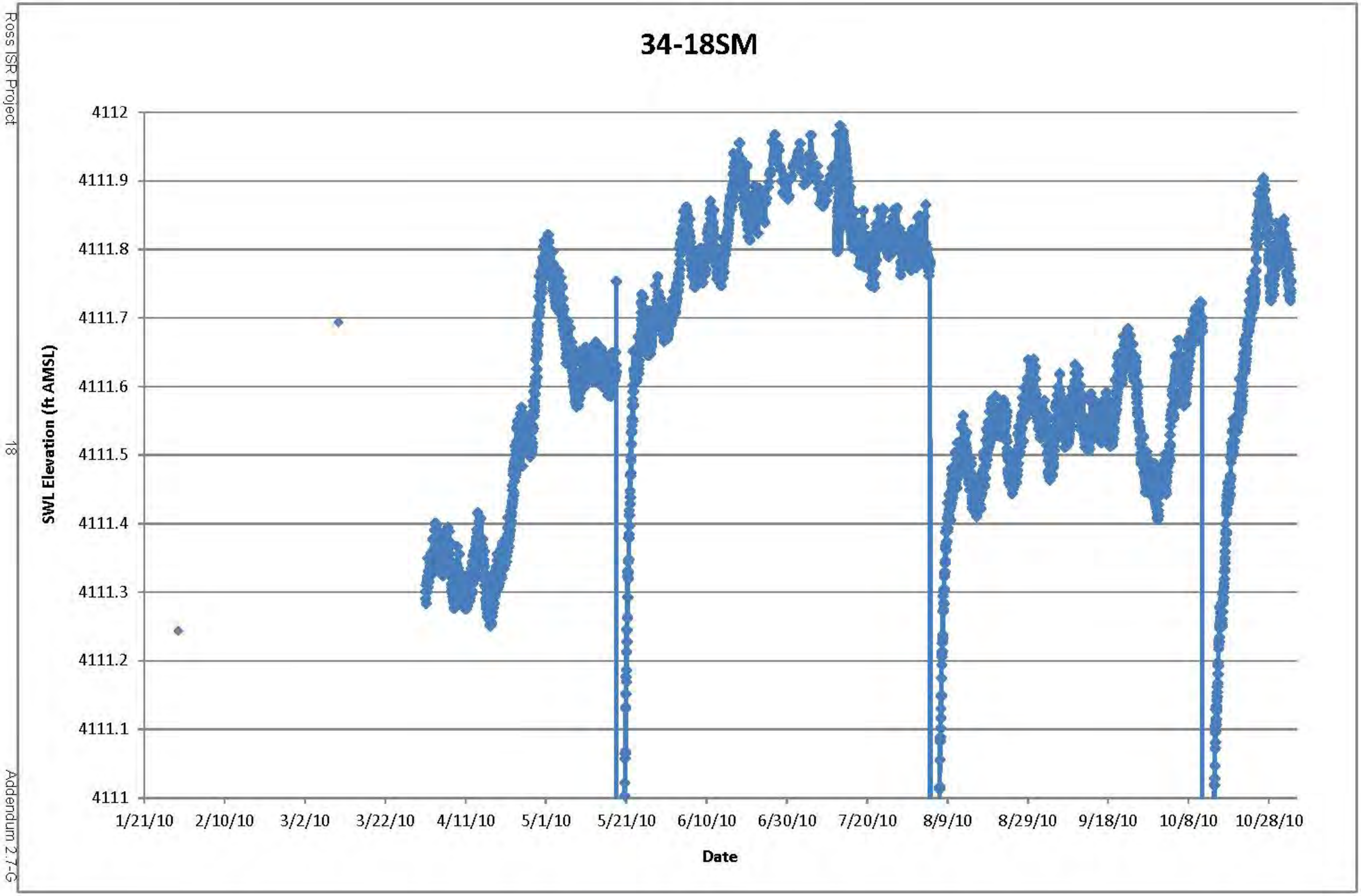

42-19OZ
SWL Elevation (ft AMSL)
3985
3984
3983
3982
3981
3980
3979
3978
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

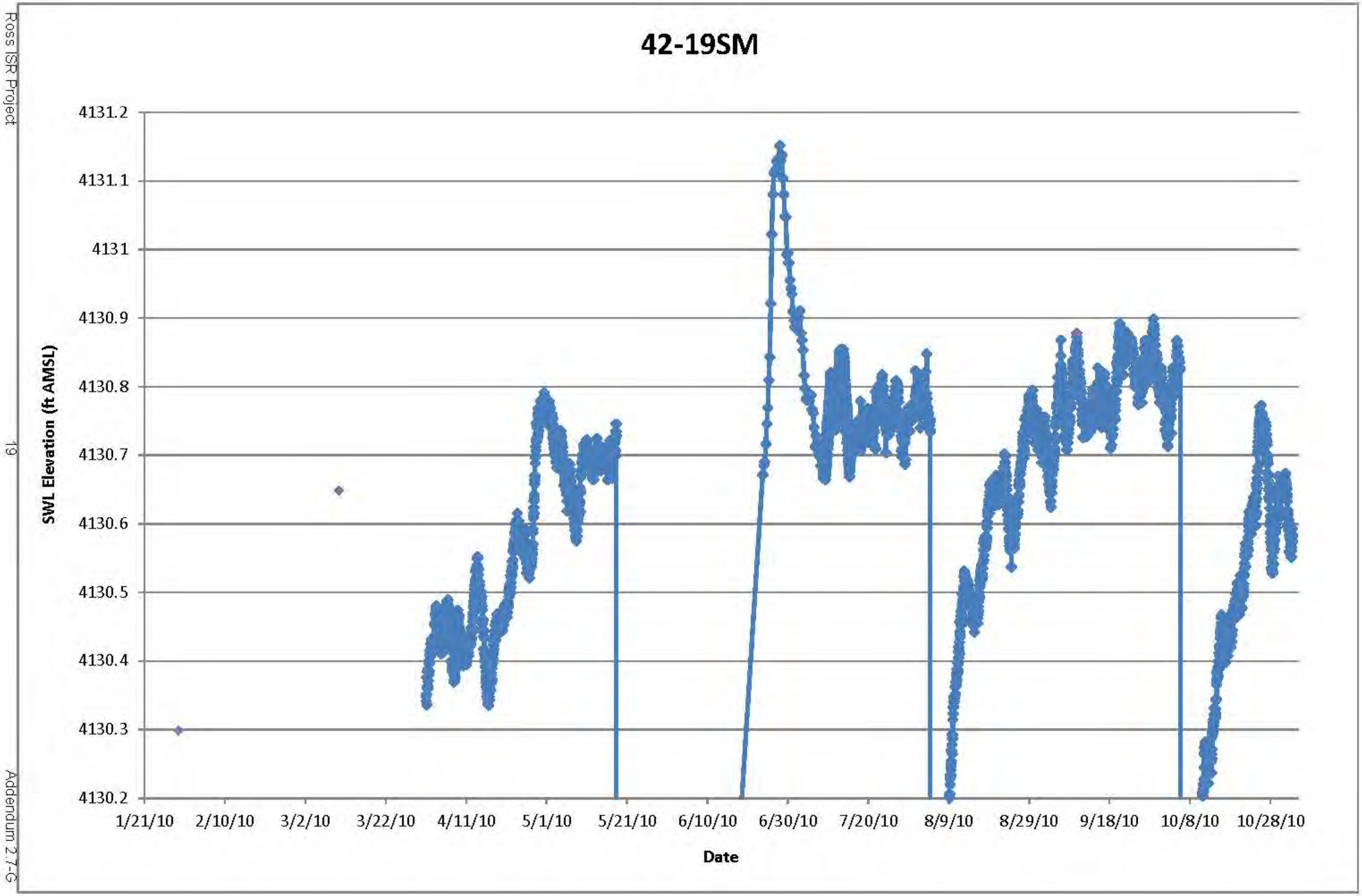

12-18SM
SWL Elevation (ft AMSL)
4101
4100
4099
4098
4097
4096
4095
4094
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

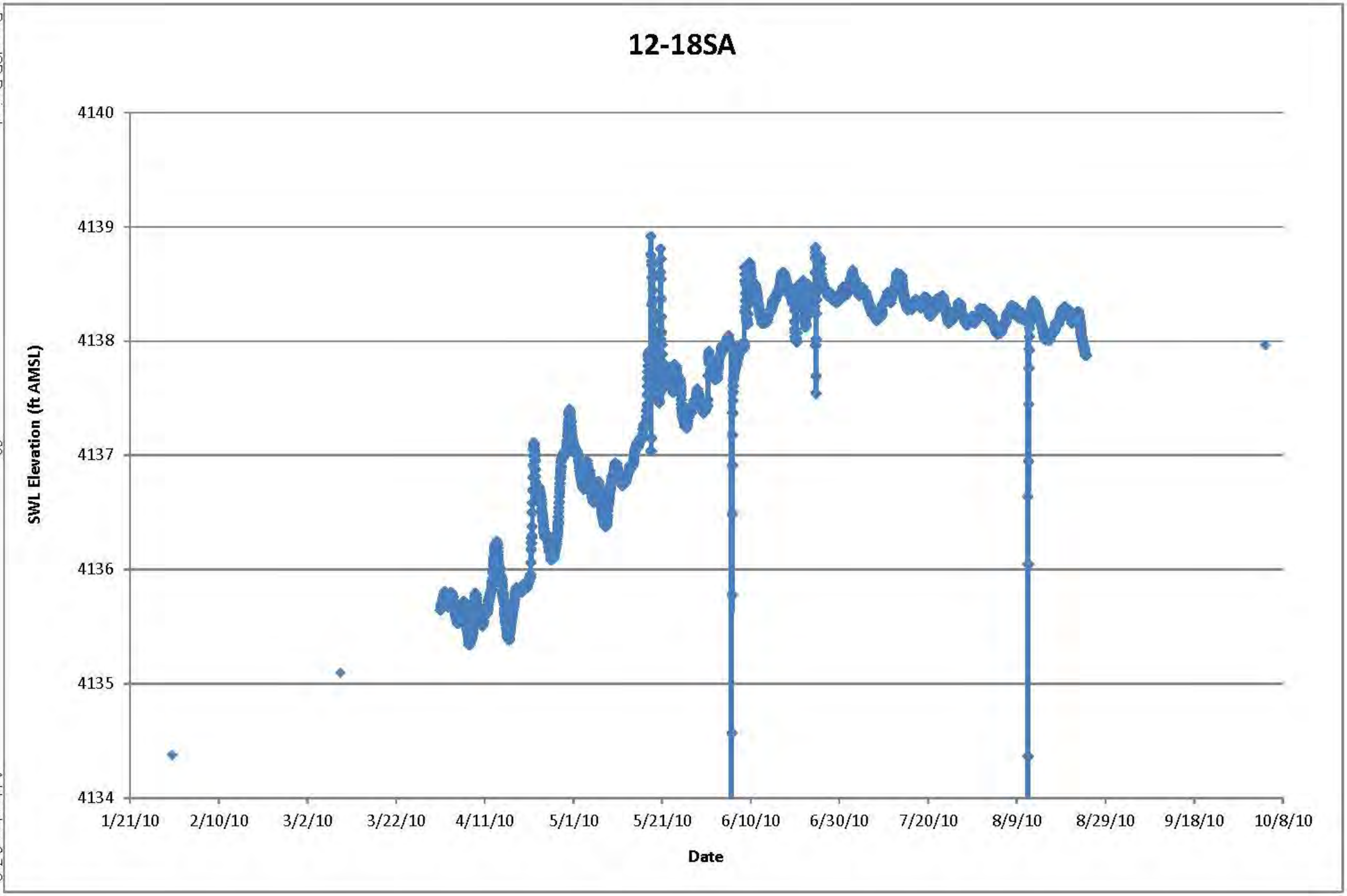

14-18SM
SWL Elevation (ft AMSL)
4090.4
4090.2
4090
4089.8
4089.6
4089.4
4089.2
4089
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

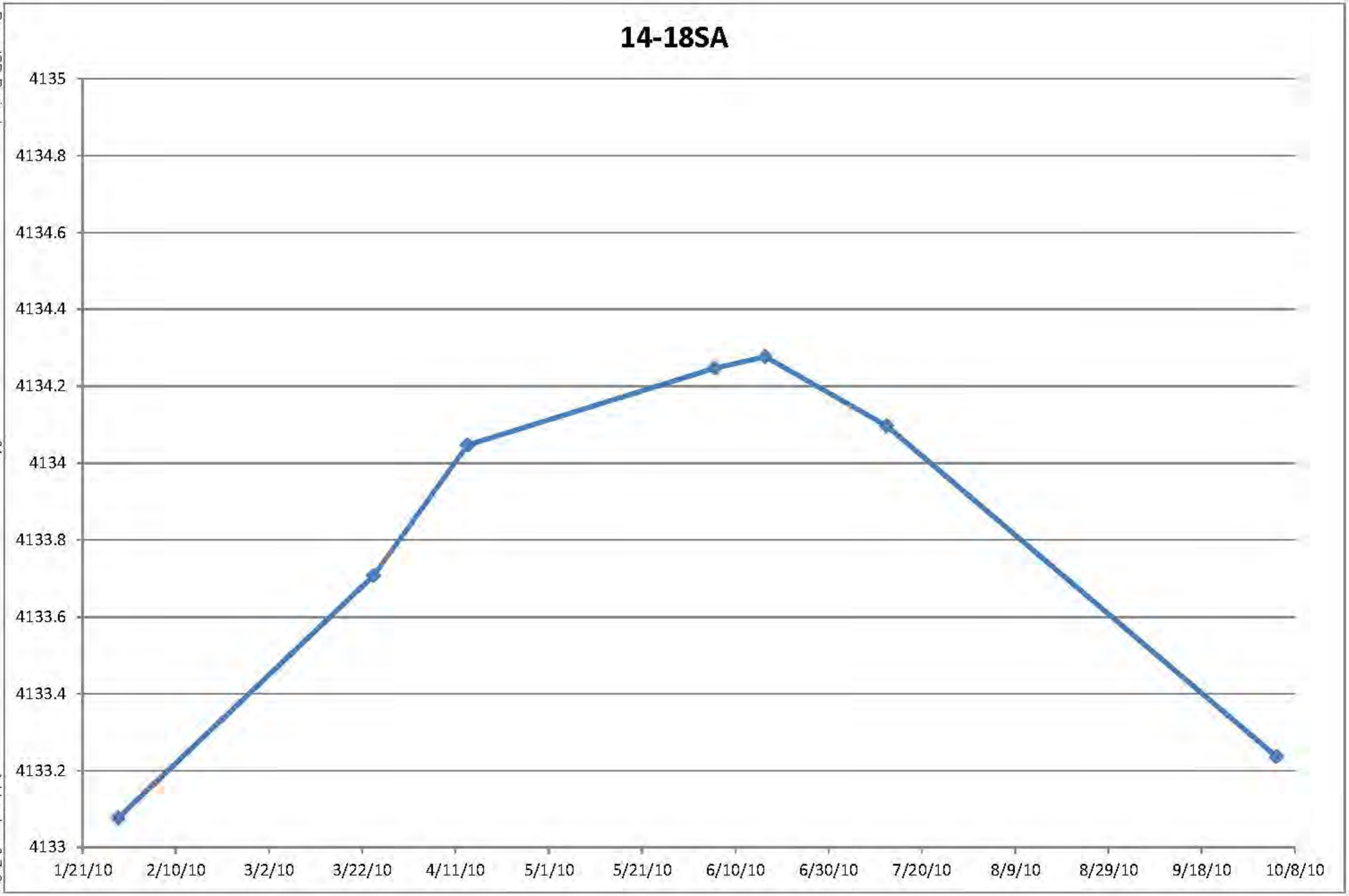

21-19SM
SWL Elevation (ft AMSL)
4087
4086.8
4086.6
4086.4
4086.2
4086
4085.8
4085.6
4085.4
4085.2
4085
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

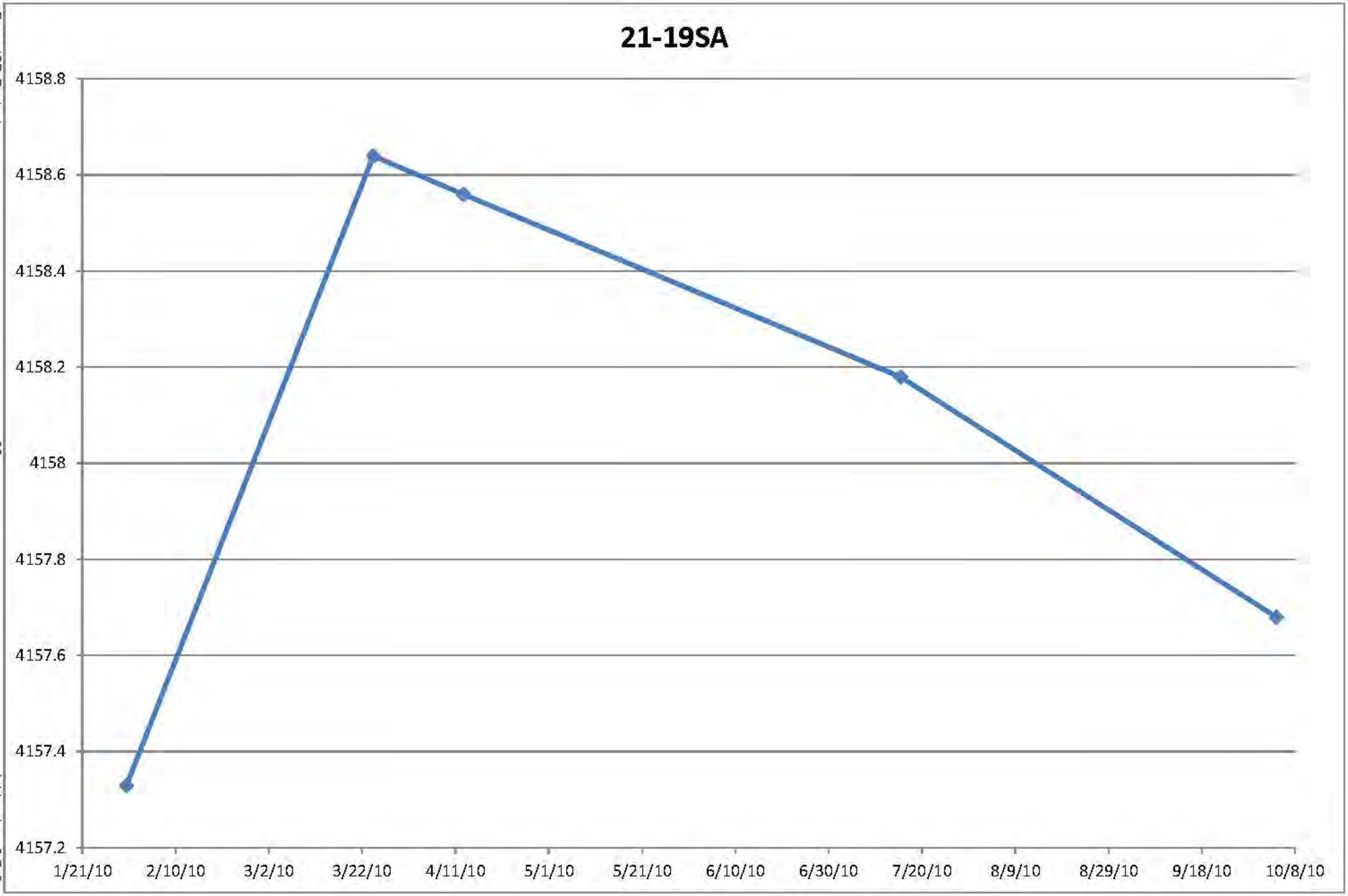

34-7SM
SWL Elevation (ft AMSL)
4079.6
4079.4
4079.2
4079
4078.8
4078.6
4078.4
4078.2
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date


34-18SM
SWL Elevation (ft AMSL)
4112
4111.9
4111.8
4111.7
4111.6
4111.5
4111.4
4111.3
4111.2
4111.1
4111
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

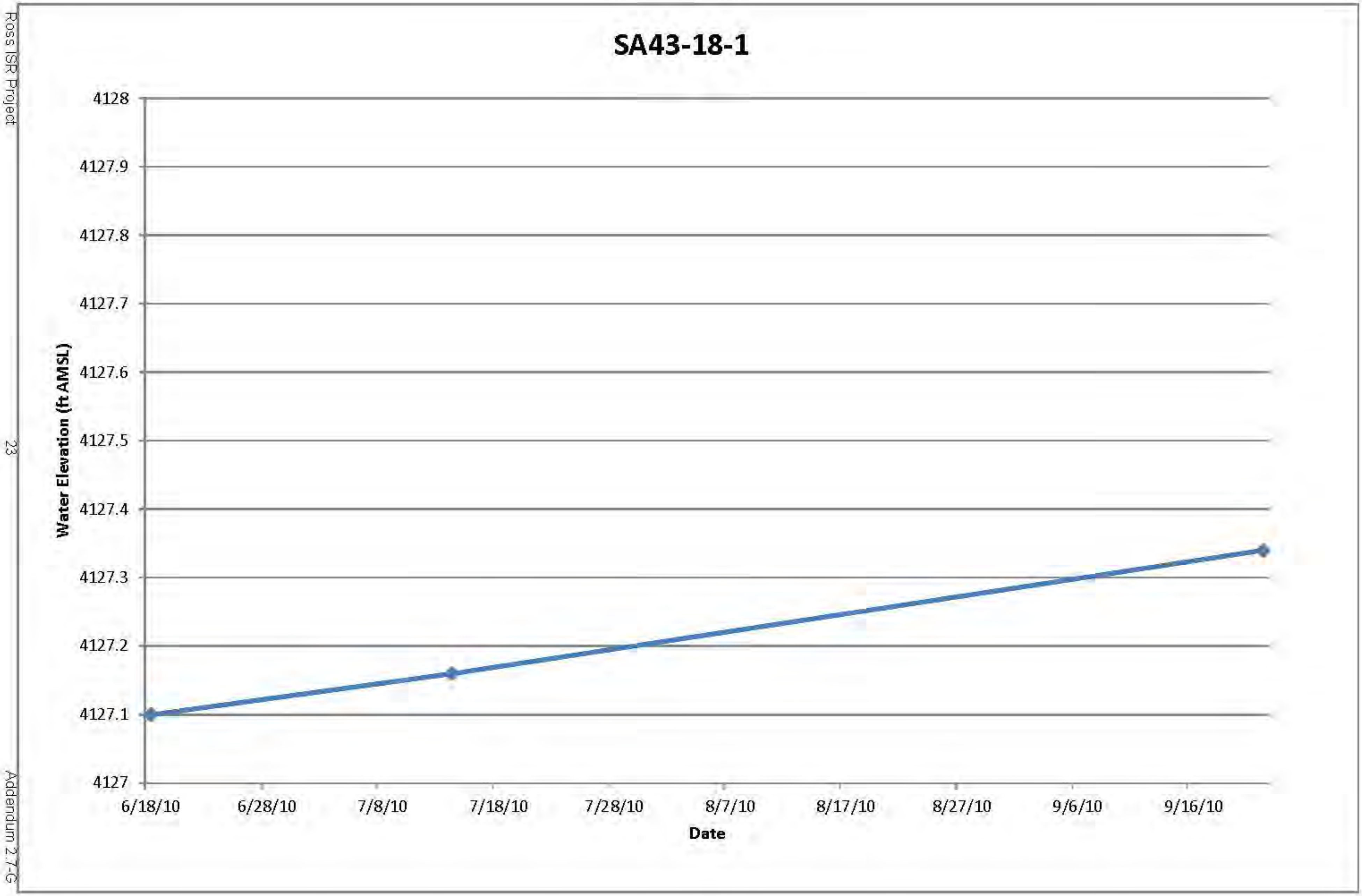

42-19SM
4131.2
4131.1
4131
4130.9
4130.8
4130.7
4130.6
4130.5
4130.4
4130.3
4130.2
SWL Elevation (ft AMSL)
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
10/28/10
Date

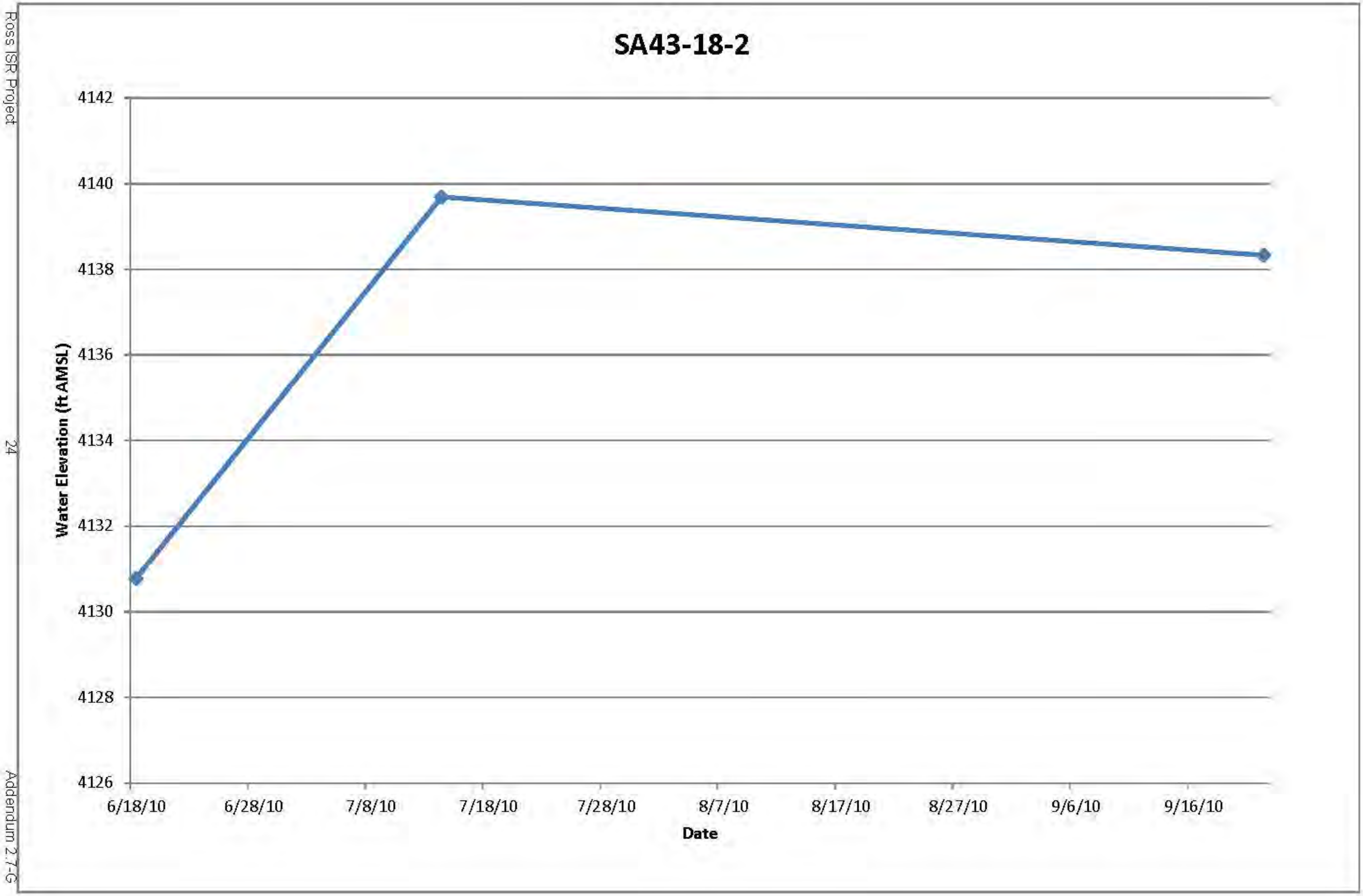

12-18SA
SWL Elevation (ft AMSL)
4140
4139
4138
4137
4136
4135
4134
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10
Date

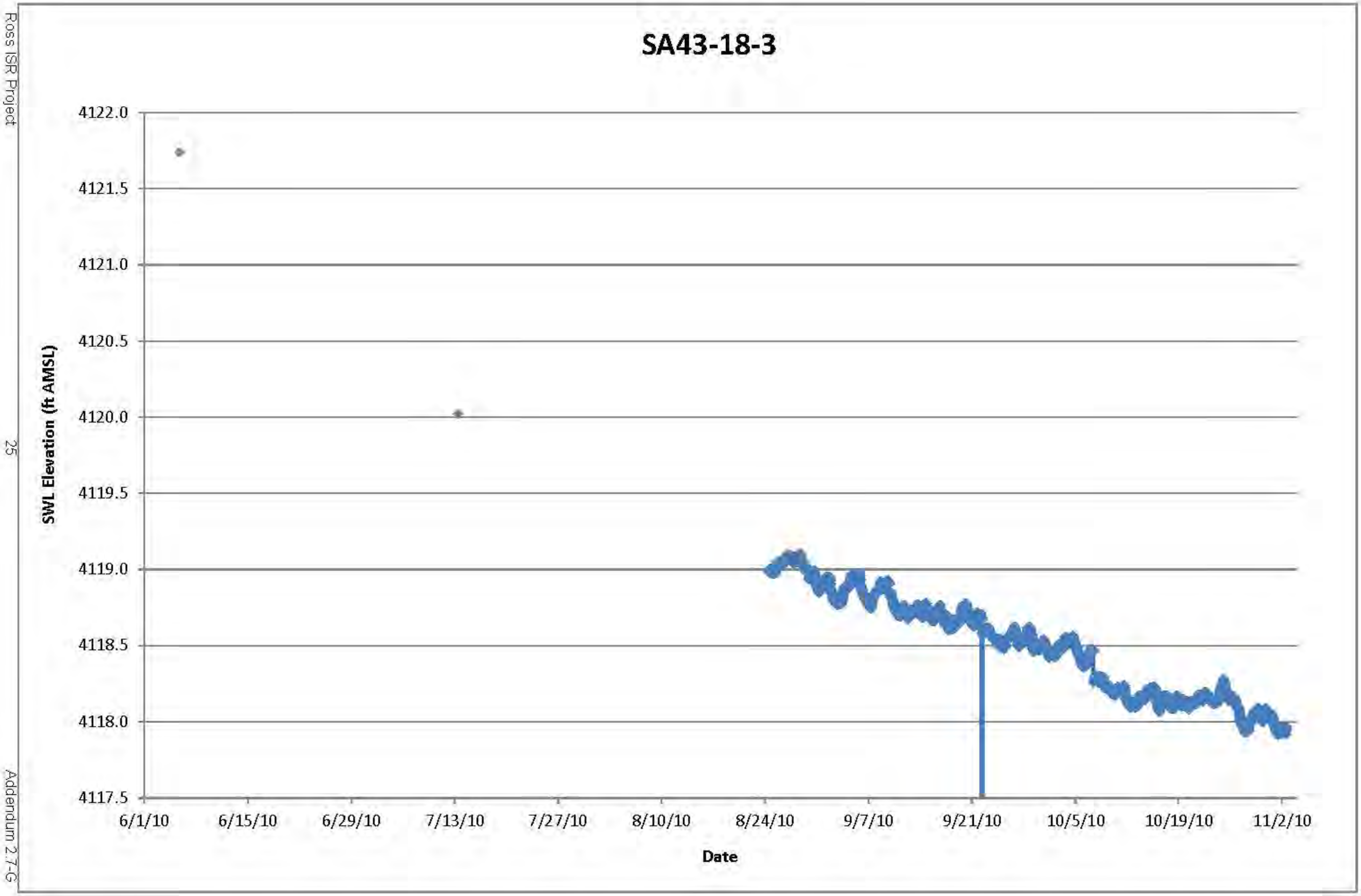

14-18SA
4135
4134.8
4134.6
4134.4
4134.2
4134
4133.8
4133.6
4133.4
4133.2
4133
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10


21-19SA
4158.8
4158.6
4158.4
4158.2
4158
4157.8
4157.6
4157.4
4157.2
1/21/10
2/10/10
3/2/10
3/22/10
4/11/10
5/1/10
5/21/10
6/10/10
6/30/10
7/20/10
8/9/10
8/29/10
9/18/10
10/8/10

Ross ISR Project 23 Addendum 2.7-G




SA43-18-2
Water Elevation (ft AMSL)
4142
4140
4138
4136
4134
4132
4130
4128
4126
6/18/10
6/28/10
7/8/10
7/18/10
7/28/10
8/7/10
8/17/10
8/27/10
9/6/10
9/16/10
Date


SA43-18-3
SWL Elevation (ft AMSL)
4122.0
4121.5
4121.0
4120.5
4120.0
4119.5
4119.0
4118.5
4118.0
4117.5
6/1/10
6/15/10
6/29/10
7/13/10
7/27/10
8/10/10
8/24/10
9/7/10
9/21/10
10/5/10
10/19/10
11/2/10
Date

ADDENDUM 2.7-H

GROUNDWATER MODEL

EXECUTIVE SUMMARY
GROUNDWATER MODELING OF POTENTIAL IMPACTS
ASSOCIATED WITH THE ROSS ISR URANIUM PROJECT

This executive summary is intended to orient the reader to the groundwater model developed in support of the Ross ISR Uranium Project. Enough detail is provided within this summary to generally describe the model development and results. However, as the name implies, this is a summary and the interested reader is referred to the whole report for specific details related to the modeling effort.

BACKGROUND

Strata Energy (Strata) plans to develop the Ross in situ recovery (ISR) uranium project in western Crook County approximately 20 miles north of Moorcroft, WY, adjacent to the ranching community of Oshoto. Strata has developed a groundwater model to analyze the potential direct, indirect, and cumulative hydrological effects of the project on both regional and individual wellfield bases. The primary goals of the regional groundwater model were to:

1) Identify potential impacts (if any) to adjacent water rights.
2) Estimate long-term impacts from ISR operations.
3) Identify potential impacts to the surficial aquifer and surface impoundments.

Modeling goals on an individual wellfield basis were to:

1) Estimate adequate perimeter monitoring well offset/setback distances for the wellfield.
2) Demonstrate the ability to identify and remedy a lateral excursion (i.e., lixiviants moving past the monitor wells).
3) Wellfield optimization, including bleed.
4) Evaluate restoration time/efficiency.

HYDROGEOLOGY

The Ross ISR Project is located on the eastern periphery of the Powder River structural basin and western margin of the Black Hills uplift. Within the proposed project area, uranium deposits lie primarily within the Upper Cretaceous Fox Hills and Lance Formations. Underlying the Lance Formation is the Fox Hills Formation, which overlies the Upper Cretaceous Pierre Shale. The dominant structural feature in the vicinity of the Ross Project area is the

Black Hills Monocline, an area of near-vertical dip on the western flank of the Black Hills Uplift. West of the monocline, strata are nearly flat-lying (2 degree dip westward into the Powder River Basin). The Pierre Shale outcrop to the east of the project area provides a natural hydrologic barrier to easterly groundwater movement within the project area.

The proposed ISR operations will focus on uranium mineralization within the Fox Hills aquifer and lower Lance Formation aquifers. The ore-containing aquifer is referred to as the ore zone (OZ). The OZ is a highly confined regional aquifer separated from overlying and underlying aquifers by a persistent shale. The unit underlying the OZ is referred to as the deep monitoring zone (DM) and is separated from the OZ aquifer by up to 50 feet of shale. Underlying the DM is the Pierre Shale, a regional confining layer. The nearest aquifer overlying the OZ unit is called the shallow monitoring zone (SM), which is separated from the OZ unit aquifer by approximately 20 to 35 feet of shale. The SM aquifer is also confined by shale of varying in thickness which typically ranges from 10 to 25 feet or more. Above the SM several thin sandstone and shale complexes exist between the SM and the ground surface. The thin sandstone and shale complexes located above the SM are not regionally extensive and the water-bearing strata are thin and discontinuous. For the purposes of this model, this marginal water-bearing portion of the Lance formation is referenced to as the Lance aquitards. Overlying the Lance aquitards is the water table aquifer, referred to within the project area as the SA or surficial aquifer unit.

Within the proposed project area, groundwater flow directions are variable; within the SA aquifer flow is in a generally easterly direction while groundwater flow in the Lance and Fox Hills strata is down dip, generally to the west and the north. The Fox Hills and Lance outcrops located at the eastern edge of the proposed project area are recharge zones for the SM and OZ aquifers. Recharge also enters the project area from the south. Figure ES-1 depicts the conceptual groundwater flow system within the Ross Project area.

GROUNDWATER USE

Wells completed within the proposed Ross Project area provide water for stock, domestic, and industrial uses. Except at the outcrop, the SM and OZ aquifers are deeper than the typical reported completion depths of the stock wells within the project area. Most of the stock/domestic wells (typically low yield) within the area appear to be completed within the thin sands of the Lance Formation aquitards. Due to the hydrologic separation between the Lance Formation aquitards and the OZ and SM aquifers, the Lance aquitards are not expected to be impacted by ISR operations. Near the OZ and SM outcrop on the eastern periphery of the Ross project area the aquifers are much shallower and several stock/domestic wells located in this area are likely completed within the OZ aquifer.

Several operating oil fields are located within the greater Oshoto region. These fields produce from the Minnelusa Formation, and are currently undergoing waterflood operations. The water flood source wells are completed in the OZ interval. Three oil field water supply wells owned by Merit Energy Company (Merit) are located within the Ross Project area and have been in operation since approximately 1980. Due to withdrawals, pumping from the industrial wells over the last 30 years, the 2010 OZ potentiometric surface exhibits a well defined cone of depression. Much is known about the OZ aquifer within the region because the 30 years of pumping have essentially served as a long-term regional pumping test. By simulating pumping over the last 30 years, the calibrated groundwater model was verified by comparing measured and modeled changes to the potentiometric surface.

Pre-1980 potentiometric surfaces were developed for the OZ and SM aquifers using well completion and head data from the Wyoming State Engineer's Office, the Wyoming Oil and Gas Conservation Commission, the historic Nubeth research and development uranium project, and ground surface elevations from naturally occurring seeps emanating from the Fox Hills outcrop some 7 to 11 miles north of the Ross Project. Monitor wells constructed by Strata Energy in 2009 and 2010 were used in development of the 2010 potentiometric surfaces for all the layers.

MODEL CONSTRUCTION

The numerical groundwater model utilizes the USGS modular finite-difference groundwater model MODFLOW (MacDonald and Harbaugh, 1988) and the pre/post processor Groundwater Vistas (Rumbaugh and Rumbaugh, 2002). Groundwater Vistas and MODFLOW were chosen for this modeling effort because they are widely used and accepted by both industry and regulatory agencies.

The model grid is oriented parallel to the geologic strike of the Fox Hills outcrop, which is generally north-south. The model domain covers approximately 22 square miles. The finite difference grid consists of 176 rows and 165 columns. The model contains of seven layers which are described below and depicted on Figure ES-2.

Layer 1 Represents the SA unit. This layer includes the top 20 feet of the entire model domain, and is comprised primarily of surficial alluvial and colluvial deposits, as well as a number of thin Lance bedrock sands interbedded with shales that form shallow discontinuous aquifers that are believed to provide recharge as well as receive discharge from the alluvial system where they come into contact with it.

Layer 2 Represents the Lance aquitards above the SM confining interval.

Layer 3 Represents the SM confining interval/shales.

Layer 4 Represents the Shallow Monitoring (SM) zone. This is the first aquifer above the OZ confining interval and will be monitored during ISR.

Layer 5 Represents the OZ confining interval. This is a thick shale that separates the OZ aquifer from the SM aquifer.

Layer 6 Represents the OZ unit.

Layer 7 Represent the Fox Hills basal confining shale between the OZ and the DM units, which is simulated.

Hydraulic Parameters

The hydraulic parameters used in the groundwater model include hydraulic conductivity, storage, recharge, and evapotranspiration. The hydraulic conductivity values used within the model were based on pumping tests performed by Nubeth in the late 1970's and by Strata in 2010. Where measured data were not available, hydraulic conductivity was estimated using literature values. Through the calibration process initial estimated hydraulic conductivity values were adjusted in order to meet head targets. Calibrated horizontal and vertical hydraulic conductivities used within the model are presented in Tables 1 and 2.

Table 1. Horizontal Hydraulic Conductivity Summary

		Model Hydraulic Conductivity Values (ft/day)			
Layer	**Aquifer Unit**	**Minimum**	**Maximum**	**Predominant Inside Ross Project area**	**Predominant Outside Ross Project area**
1	Alluvium/top 20 feet	5.00	15.00	5.00	5.00
2	Lance aquitard	0.10	0.10	0.10	0.10
3	Confining unit	$7x10^{-4}$	$7x10^{-4}$	$7x10^{-4}$	$7x10^{-4}$
4	Lance SM	0.003	3.00	Varies	0.32
5	Confining unit	$5.0x10^{-4}$	$5.0x10^{-4}$	$5.0x10^{-4}$	$5.0x10^{-4}$
6	Lance/Fox Hills OZ	0.01	3.00	Varies	0.19

Table 2. Vertical Hydraulic Conductivity Summary

		Model Hydraulic Conductivity Values (ft/day)			
Layer	**Aquifer Unit**	**Minimum**	**Maximum**	**Predominant Inside Ross Project area**	**Predominant Outside Ross Project area**
1	Alluvium/top 20 feet	3.00	10.00	3.00	3.00
2	Lance aquitard	0.54	0.54	0.54	0.54
3	Confining unit	$1.45x10^{-5}$	$1.45x10^{-5}$	$1.45x10^{-5}$	$1.45x10^{-5}$
4	Lance SM	0.002	2.1	Varies	0.21
5	Confining unit	$6.5x10^{-6}$	$6.5x10^{-6}$	$6.5x10^{-6}$	$6.5x10^{-6}$
6	OZ	0.08	2.10	Varies	0.12

Storage coefficients were developed for each layer based on measured data and/or research on similar materials. Storage coefficients were then adjusted within the estimated ranges during model calibration. MODFLOW2000 utilizes specific storage (Ss) rather than a storage coefficient. As such, all storage coefficients were converted to a specific storage value prior to input in the model by multiplying the storage coefficient by the model layer thickness. Each layer was assigned a unique specific storage value which did not vary spatially. Specific storage values used for each layer are summarized in Table 3.

Table 3. Summary of Specific Storage Values by Layer

Layer	**Aquifer Unit**	**Model Specific Storage Values (1/ft)**
1	Alluvium/top 20 feet 1	0.19 within alluvium, 0.1 outside of alluvium[1]
2	Lance aquitard	$5x10^{-7}$
3	Confining unit	$4x10^{-6}$
4	Lance SM	$7.6x10^{-6}$
5	Confining unit	$4x10^{-6}$
6	Lance/Fox Hills OZ	$9.7x10^{-6}$

[1]Alluvium values are specific yield (dimensionless)

Water enters the model vertically as recharge from infiltration and horizontally as regional groundwater flow from areas adjacent to the model. Flow from adjacent areas is indirectly calculated through the calibration process and the use of general head boundaries. The distribution of recharge from natural precipitation within the project area was developed based on USDA-NRCS soils data. Vertical recharge throughout the model domain varied from 0.07 inch per year to 0.22 inch per year.

Boundary Conditions

Water leaves the model domain by three mechanisms: 1) water flow is within the confined aquifers downgradient to the north and to the west, 2) water within the alluvium is removed by evapotranspiration, and 3) water leaves the project area through alluvial underflow. Water is also removed artificially by pumping wells. Pumping wells within the project area are treated as transient stresses.

General head boundary conditions were positioned to simulate the natural gradient. Evapotranspiration and underflow are simulated by drains located where Good Lad Creek and the Little Missouri River cross the Pierre Shale outcrop. Model boundary conditions vary slightly from layer to layer and are discussed in detail in Section 4.4 of the full report.

CALIBRATION

Model calibration and verification was accomplished in two steps. The first step was a steady-state Pre-1980 simulation. The goal of the steady-state simulation was to match, as closely as possible, the modeled potentiometric surface elevations to measured pre-1980 potentiometric surface elevations. To calibrate the steady state model, two parameters, recharge and hydraulic conductivity, were adjusted until the modeled potentiometric surface matched the pre-1980 potentiometric surface developed from available well data

The second calibration step (verification) involved the construction of a transient model. Wells were inserted into the model and assigned variable pumping rates for each stress period based on available pumping records to simulate the industrial wells within the model domain. The goal of the transient portion of the model was to match the drawdown that has occurred over the last 30 years due to withdrawals from the industrial wells. Monitor well data collected by Strata in 2009 and 2010 were used to calibrate the transient runs. During the calibration process hydraulic conductivity values were adjusted until the modeled 2010 head distribution closely fit measured values.

It was not possible to calibrate the transient model using homogenous layer properties. Furthermore, hydraulic conductivity information from 1978 and 2010 pumping tests indicates that the hydraulic conductivity within the SM and the OZ layers is not constant throughout the proposed Ross Project area. To add realistic heterogeneity to the hydraulic conductivity and improve model predictions, another calibration technique known as pilot points was utilized in conjunction with PEST (a model-independent parameter estimation program). With this method, measured hydraulic conductivity values were inserted into the model as targets. User-defined pilot points were then inserted into the model. Each pilot point was given an initial value and a minimum and maximum range based on measured hydraulic properties. PEST was then used to develop hydraulic conductivity estimates based on target well head data and known hydraulic conductivity targets for each pilot point. The pilot point calibration procedure was used only within and immediately adjacent to the proposed Ross Project area because no hydraulic conductivity data are available outside of the project area. Pilot point calibration was performed only for the hydraulic conductivity within the SM and OZ aquifers. Due to the pilot point techniques used to calibrate the model, the calibrated model represents a reasonable, non unique solution. To the extent that additional targets can be collected the model calibration and the hydraulic conductivity heterogeneity can be further refined.

The resulting hydraulic conductivity distribution yielded a very good fit between the modeled and measured head values within the OZ aquifer. Figure ES-3 shows the 2010 modeled potentiometric surface within the OZ aquifer. Within the OZ aquifer, the calibration was good with the largest residual less than 2.5% of the total estimated drawdown near the industrial water supply wells. The residuals within the SM zone are higher (up to 21 feet). However, the confidence interval for the calibration targets is plus or minus 20 feet, as a result, calibration within the SM was considered acceptable.

A sensitivity analysis was performed on the calibrated model to determine which parameters most impacted the calibration. In these analyses six parameters, horizontal hydraulic conductivity, vertical hydraulic conductivity, specific storage, recharge, general head boundary elevations, and general head conductance were varied. The most sensitive parameter within the groundwater model is the hydraulic conductivity, both vertical and horizontal.

OPERATION SIMULATION

The calibrated model was used to simulate ISR operations within the Ross Project area. The ISR simulation was a generalized scenario based on currently mapped mineralization. The simulation included two ISR units (unit 1 and unit 2) operating simultaneously. The ISR units were further divided into modules containing approximately 40 production wells each. A total of 10 modules within unit 1 and 7 modules within unit 2 were simulated.

The ISR operations were divided into three stages, including ISR production, groundwater sweep, and groundwater restoration. During production, each recovery well was estimated to operate at 17.5 gpm with a bleed rate of 1.25 percent (0.219 gpm per production well). A 3 month sweep period was simulated with an estimated flowrate of 1.31 gpm per recovery well. Modeled aquifer restoration activities lasted approximately 6 months. During typical restoration activities each recovery well operated at 12.8 gpm. The bleed rate during restoration depended on if restoration occurred concurrent with ISR production in other wellfields. With excess bleed available from adjacent modules, bleed was 3.2 percent (0.41 gpm per recovery well). When excess water was not available from adjacent modules, the estimated restoration bleed was 8.8 percent (1.125 gpm per production well).

To simulate the regional impacts of ISR, bleed rates were assigned to each recovery well during ISR, groundwater sweep, and restoration, thus simulating the net withdrawal from the aquifer that would be expected from balanced wellfields. Operations of the three existing industrial wells within the project area during ISR recovery presents a unique problem. Strata has been in communication with the owner of these wells, Merit Energy Co. (Merit), and is currently exploring alternative water sources that would allow Merit to suspend use of the wells before and during ISR operations. Currently the goal is to discontinue use of the Merit wells approximately two years prior to ISR.

Given the uncertainty associated with the future status of the Merit wells, two ISR scenarios have been simulated. Scenario 1 assumes an alternative water supply is found and the Merit wells are taken out of operation 2 years prior to ISR and kept out of operation until full aquifer recovery occurs after ISR operations. Scenario 2 assumes no alternative water supply and that the Merit oil field water supply wells are in operation during ISR operations.

As would be expected, the bulk of ISR impacts occur within the OZ aquifer. Predicted impacts to the SM aquifer are minimal during ISR operations. Although the impacts within layers 1 and 2 are minimal, minor impacts occur near the outcrop of the OZ aquifer. Conceptually, near the outcrop, water from the Little Missouri River infiltrates into the SM and OZ aquifers. Water not infiltrating into the OZ and SM aquifers exits the model via drains installed where Good Lad Creek and the Little Missouri River cross the outcrop. Prior to ISR operations an estimated 1.5 gpm was leaving the model via the drains. At the end of ISR operations no water was exiting the model via the drains, indication that a minimal increase in exfiltration may occur in the ephemeral streams where they cross the outcrop.

Figures ES-4 and ES-5 present modeled drawdowns within the OZ aquifer at the end of restoration activities during ISR scenarios 1 and 2, respectively. Figure ES-66 presents the available OZ potentiometric head above the top of the OZ aquifer in 2010. A comparison between Figures ES-5 and ES-6 indicates that at the end of ISR operations the potentiometric surface will remain above the top of the OZ aquifer. For approximately 1 year near the end of the restoration period, however, the OZ potentiometric surface drops below the top of the OZ aquifer immediately adjacent to industrial well 19XX-State (the phenomenon is short-lived and the water level recovers to above the top of the aquifer prior to the end of ISR aquifer recovery operations) under both scenarios. A review of the activities in this area indicates that, during the period in which the potentiometric surface drops below the top of the OZ aquifer, simultaneous groundwater sweep and restoration activities are occurring within the adjacent wellfields. The simulated scenario tends to be conservative because groundwater sweep and restoration activities were simulated at maximum rates without optimizing the wellfield progression. Adjustments in the wellfield progression schedule and flowrates will minimize the possibility that the potentiometric surface will drop below the top of the aquifer.

IMPACTS

To assess the impacts on wells within the region, simulated water levels were monitored during the ISR simulation at the locations of wells completed in the OZ aquifer. The maximum modeled decrease in head that occurred in each well during the ISR simulation is presented in Table 4. As shown on Table 4, drawdowns within Scenario #1 are less severe than drawdowns in Scenario #2. In fact, within Scenario #1 industrial well 22X-19 experienced a significant net increase in head due to the assumption that use of the well was discontinued. Well locations are depicted on Figure ES-3.

Table 4. Maximum Modeled Well Drawdowns during ISR Simulation

Well	Layer	Use	Drawdown Scenario #1 (ft)	Drawdown Scenario #2 (ft)
*Strong Well	6(OZ)	Domestic/ stock	5	7.3
SOPHIA #1A	6(OZ)	Industrial	14.7	26.3
KIEHL WATER WELL #2	4(SM) & 6 (OZ)	Industrial	1.8 - SM 1.6 - OZ	2.3 - SM 3.4 - OZ
22X-19	6(OZ)	Industrial	-50	110
19XX STATE	6(OZ)	Industrial	79	158
789V STATE	6(OZ)	Industrial	101	176
ENL Kiehl Well #1	6(OZ)	Industrial	3.2	5.0
WSW#1 West Kiehl Unit	6(OZ)	Industrial	-0.8	1.8
*WESLEY TW02 P103666W2	6(OZ)	Domestic/ stock	30.8	33.1

* Modeled drawdowns may be overestimated due to model edge effects.

Based on ISR simulations, the three industrial wells currently in use by Merit may be impacted. If these wells continue to operate during ISR operations, water levels within the OZ aquifer may drop to the point that the potentiometric head within the aquifer locally drops below the top of the aquifer. This decrease in the potentiometric head may have implications for ISR operations as well as for Merit.

The ISR simulation modeled herein assumes a constant bleed and constant sweep. Under the modeled ISR scenario, interference between wellfields has been noted. To minimize interference, Strata is currently exploring other options such as alternate ISR progression scenarios, pre-ISR aquifer conditioning, and alternate ISR operation schedules. This groundwater model offers Strata a planning tool that can be used to minimize wellfield interference and optimize ISR production.

If arrangements can be made to temporarily suspend pumping from the Merit water supply wells, the regional impacts presented in Scenario 1 are likely the most realistic impacts. Due to the abstraction introduced by the Merit wells, ISR wellfields located immediately adjacent to Merit's wells will be difficult to operate with Merit's wells in operation. The abstraction caused by Merit's wells decreases substantially at distances more than 0.25 mile from the wells. As such, it may be possible for the Merit wells to continue operating during active ISR in the northernmost and southernmost proposed wellfields. Further modeling will be necessary to determine the most efficient method to operate ISR wellfields if Merit's wells are operated during ISR operations.

RECOVERY SIMULATION

Recovery was simulated for 5, 10, 20, 50 and 100-year periods after cessation of ISR operations. In general, drawdowns within the SM layer are minor (up to 15 feet in scenario 2 and 5 feet in scenario 1). Within the OZ aquifer full recovery takes between 5 and 10 years for scenario 1. For scenario 2 recovery to a maximum residual drawdown of 10 feet takes between 10 and 20 years with most of recovery occurring within the first 10 years (recovery vs. time follows an exponential curve).

To asses monitor ring spacing and excursion recovery an ISR simulation with both injection and production wells was developed for a sample wellfield using a model with 25 foot grid spacing. Operation of a balanced ISR wellfield was then simulated for 90 days. At an upgradient and downgradient location within the sample wellfield an out-of-balance well pattern was simulated to evaluate monitor ring spacing and excursion recovery. Each out-of-balance wellfield was simulated by shutting down one recovery well operating at 17.5 gpm for 30 days while the injection wells were allowed to operate at normal rates. At the end of 30 days, the recovery well was started again and the injection rate within the pattern were reduced by a net 17.3 gpm for 45 days.

Results of the excursion simulation indicate that a monitor ring well spacing on 600 foot centers (both laterally and perpendicular from the wellfield) would be adequate to detect an excursion even on the upgradient side of the wellfield. Typical head responses during the excursion simulation are presented in Figure ES-7. The excursion simulation also indicated it would be possible to recover an excursion 600 feet from the wellfield within 20 days or less on both the upgradient and downgradient sides of the wellfield. Since the groundwater velocity is proportional to hydraulic conductivity, an increase in the local hydraulic conductivity would result in an increased travel distance during an excursion. However, the head change and the excursion recovery time would be similar. The simulated excursion recovery is expected to be realistic even with different field conditions.

FLARE EVALUATION

A horizontal flare evaluation was performed using MODPATH Version 3.0 on a representative wellfield. Groundwater Vista's Telescopic Mesh Refinement (TMR) tool was used to develop a model with increased grid resolution within wellfield. The domain of the flare model was a smaller domain with tighter grid spacing (12.5 feet within the wellfield and 25 feet outside the wellfield). To further simplify the refined model, only the regional ore zone (which was divided into 3 layers for this analysis) and the ore zone confining shale were simulated. Throughout the horizontal flare evaluation a constant bleed of 1.25% was maintained. Flowrates within the recovery wells varied from approximately 11 gpm to 19.7 gpm with an average recovery rate of 16.2 gpm per well. To simulate flare an ISR simulation with both injection wells and recovery wells was modeled using MODFLOW. The ISR simulation started with a steady state pre-ISR potentiometric surface and then continued through 21 months of active ISR operations. Sixteen hypothetical particles were placed in each cell containing an injection well. MODPATH was then used to track the particle movement throughout the simulation. The ratio of the area calculated from the circumscribed particle traces to the wellfield area provides the horizontal wellfield flare factor. The calculated horizontal flare ratio was 1.32 for the current wellfield layout and is shown on Figure ES-8. In general, the calculated flare is believed to be a conservative horizontal flare estimate. Additional well placement optimization will likely minimize the total expected flare.

The flare simulation included injection and recovery well flowrates, well placement, and wellfield shape. During the simulation, changes to well flow rates were found to significantly affect the flare. Well placement can also significantly affect not only the flare but the efficiency of the ISR operations. In general, a more regular the well pattern results in a more efficient wellfield, assuming the formation has relatively homogeneous hydraulic properties.

CONCLUSIONS

The groundwater model includes three separate phases; calibration to steady state, verification to current conditions, transient, and uranium recovery simulation. The steady state simulation represents pre-1980 conditions. There are several existing wells within the project area that may be impacted by proposed ISR. The results of the model indicate that the most impacted wells will be the oilfield water supply wells located within the Ross Project area. If these wells continue operating during ISR, water levels within these wells could decrease below the level of the pumps. Modeling indicates that existing stock and domestic wells within the region will see only minor drawdowns as a result of ISR operations. The Ross ISR Project is expected to decrease the heads within the OZ aquifer which in turn may increase the amount of water infiltrated to the OZ aquifer where it outcrops beneath the Little Missouri River and Good Lad Creek alluvium. The effects would be minor, as the modeled increase in infiltrated water at the outcrops was less than 2 gpm.

The model was also used to evaluate monitor well offset distances as well as to evaluate the ability of the proposed wellfield to recover any potential excursions in the ore zone aquifer. During the excursion analysis the model demonstrated that monitor wells could be effectively placed up to 600 feet from the wellfield and a potential excursion could be recovered back to the monitor well in less than 30 days. The model also demonstrates that a monitoring system that continuously monitors water levels within the monitor wells could be effectively used to detect excursions.

Based on experience gained during ISR and excursion simulations, the model also expected to be a useful tool for final wellfield planning and operations. The model will assist in balancing wellfields, progression planning and bleed rate optimization.

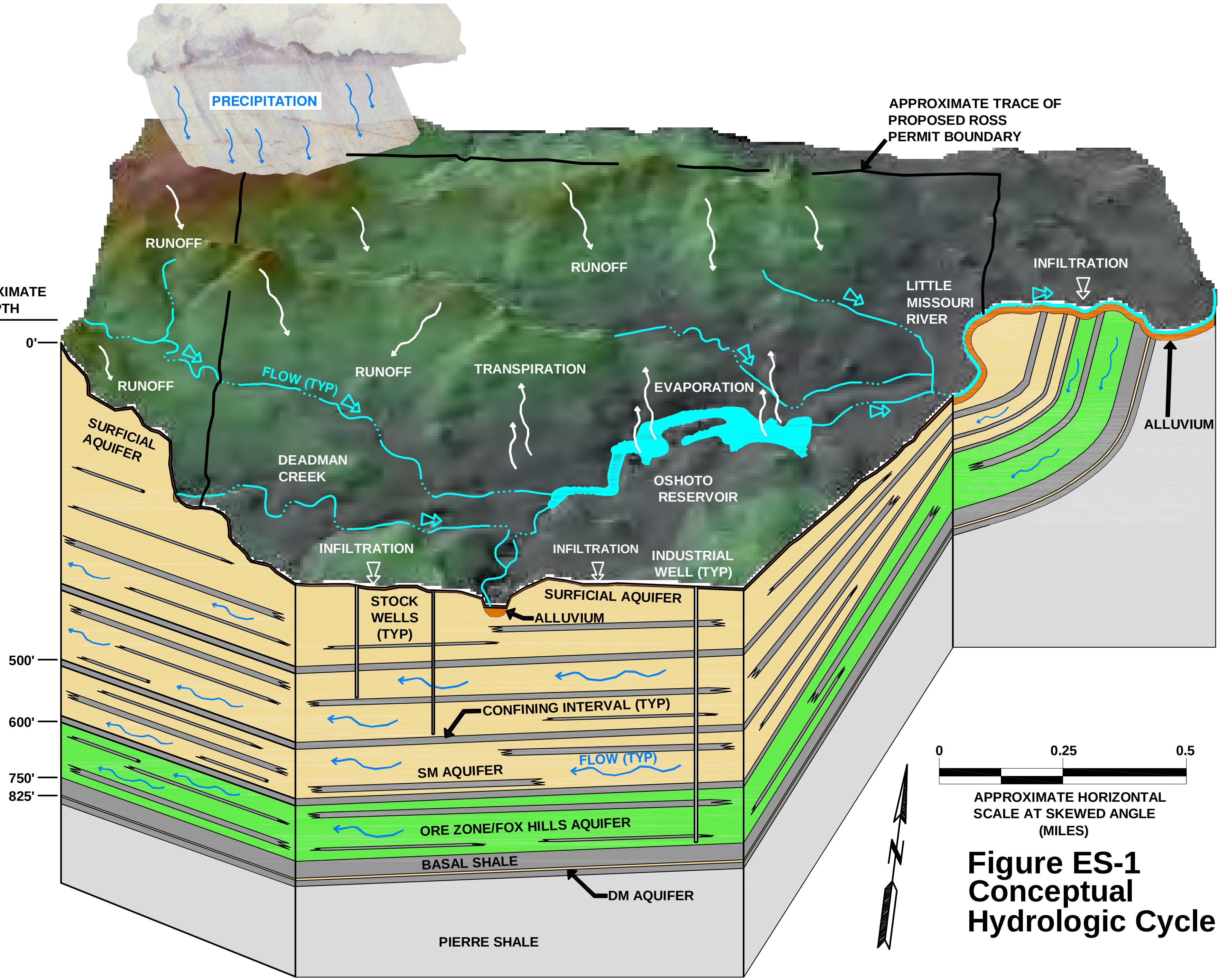
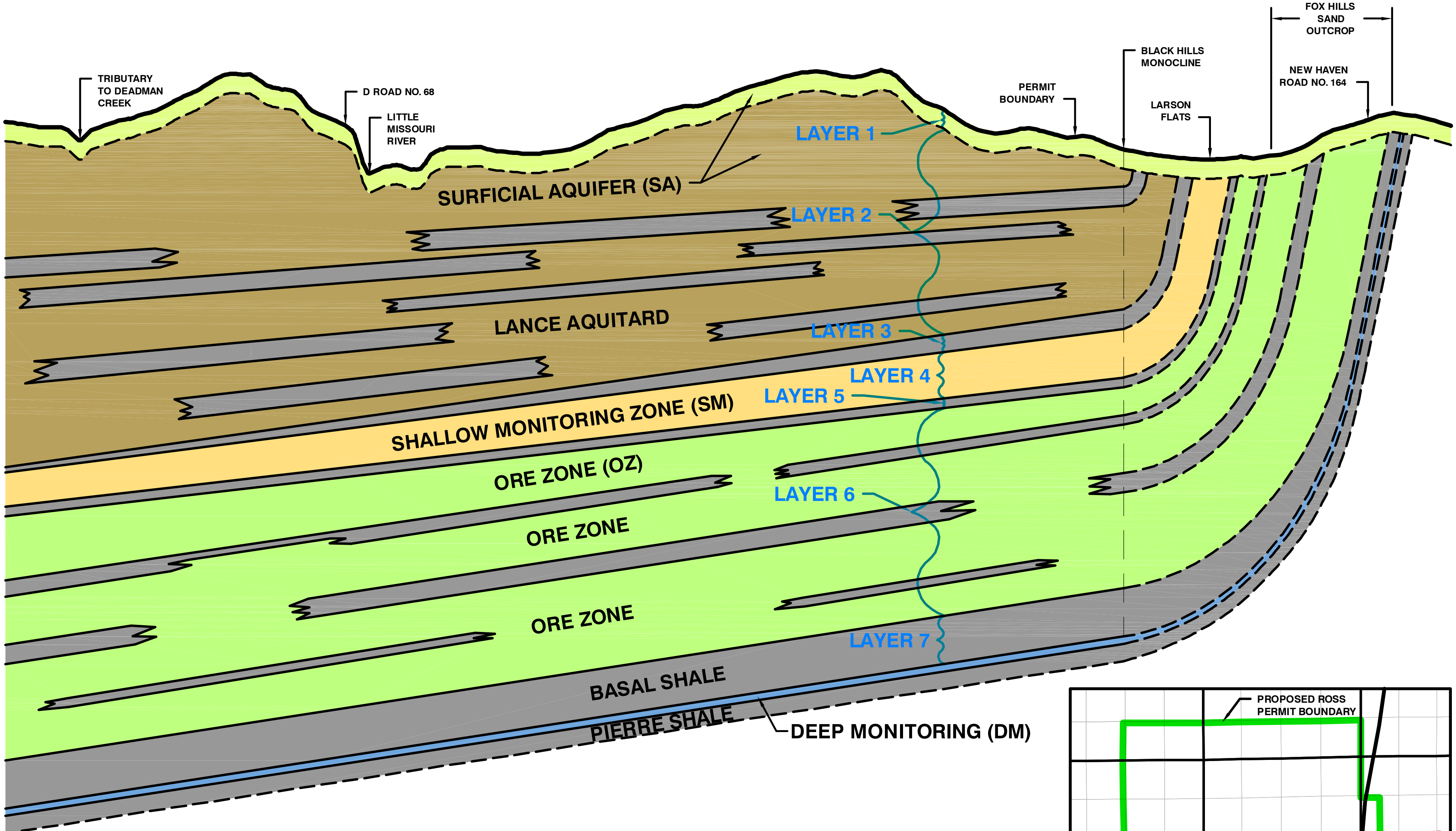
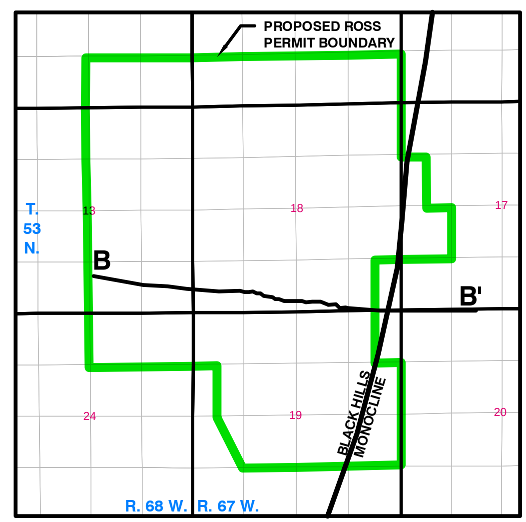


Figure ES-1
Conceptual
Hydrologic Cycle

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_3D_WATER.dwg, GWMES_FIGURE_ES-1, 12/21/2010 9:54:25 AM





Black Hills Monocline adapted from Sutherland, W.M., 2008, Geologic Map of the Devils Tower 30' X 60' Quadrangle, Crook County, Wyoming, Butte and Lawrence Counties, South Dakota, and Carter County Montana: Wyoming State Geological Survey Map Series 81, Scale 1:100,000.

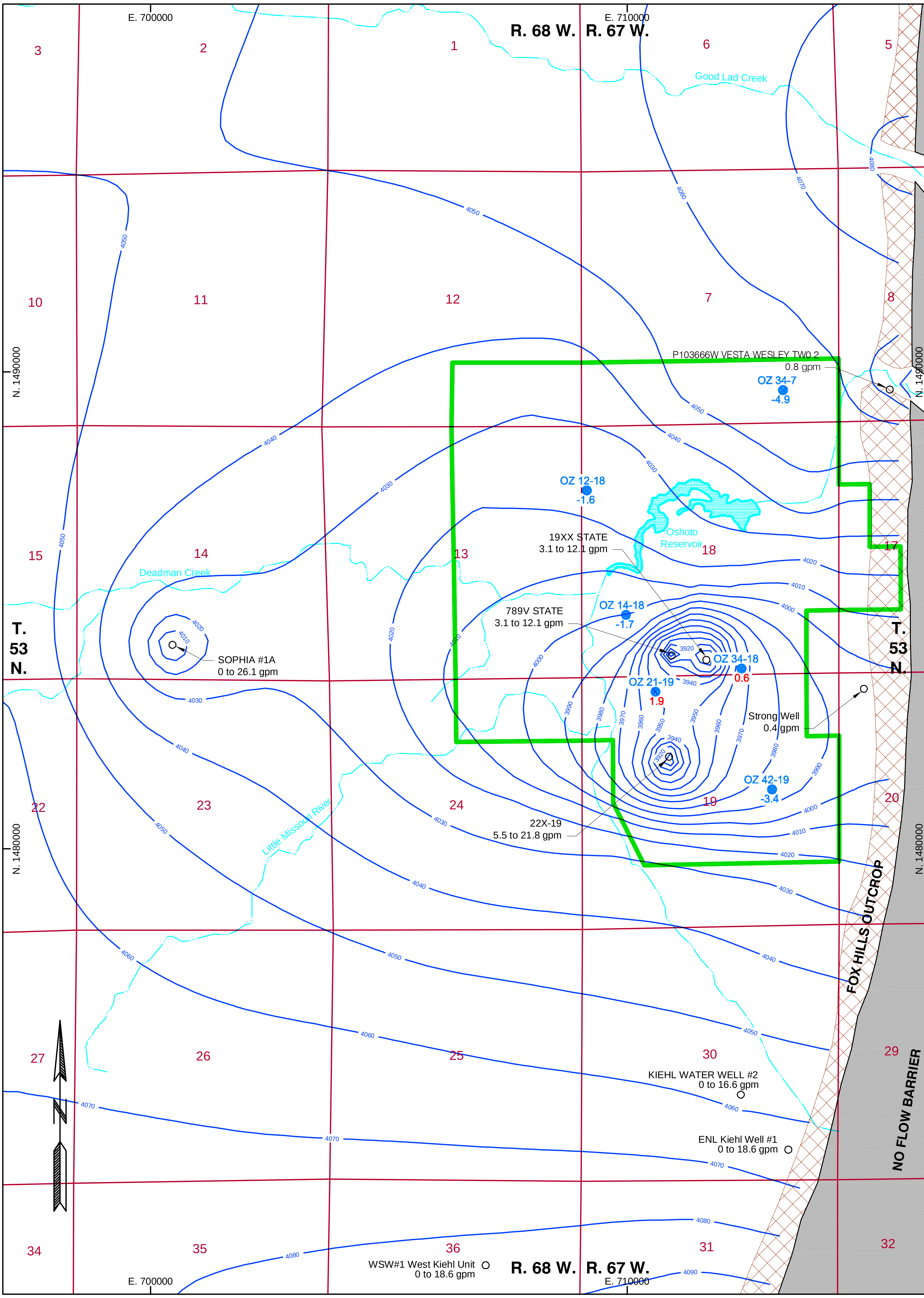
Fox Hills sand outcrop adapted from Halberg, L.L., Et. Al., Geologic Map of the Sundance 30' X 60' Quadrangle, Crook and Weston Counties, Wyoming and Lawrence and Pennington Counties, South Dakota: Wyoming State Geological Survey Map Series 78, Scale 1:100,000.

CONCEPTUAL CROSS SECTION B-B'

NOT TO SCALE

Figure ES-2.

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_CONCEP_XS.dwg, GWMES_FIGURE_ES-2, 12/21/2010 9:56:42 AM



ROSS PROJECT AREA

LEGEND

PROPOSED ROSS PERMIT BOUNDARY

4100 POTENTIOMETRIC SURFACE

Est WS 2 -1.4 TARGET (COMPUTED WL HIGHER THAN OBSERVED)

Est WS 1 4.5 TARGET (COMPUTED WL LOWER THAN OBSERVED)

KIEHL WATER WELL #2 0 to 16.6 gpm — ADJACENT WATERWELLS IN OPERATION WITH FLOWRATE DURING VERIFICATION

0 1000 2000 4000

GRAPHIC SCALE (FEET)

Fox Hills sand outcrop adapted from Halberg, L.L., Et. Al., Geologic Map of the Sundance 30' X 60' Quadrangle, Crook and Weston Counties, Wyoming and Lawrence and Pennington Counties, South Dakota: Wyoming State Geological Survey Map Series 78, Scale 1:100,000.

STRATA ENERGY

REVISIONS

Date	Description

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

GWM TECHNICAL REPORT
FIGURE ES-3

2010 MODEL VERIFIED SURFACE FOR LAYER 6 (OZ)

Drawn By: RAM
Checked By: RBM
Date: 10-10

WWC ENGINEERING
www.wwcengineering.com

FILE: ROSS_GWM_CALIB_POT_SURF

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_CALIB_POT_SURF.dwg, GWMES_FIGURE_ES-3, 12/21/2010 9:58:50 AM

Strata Energy-Ross Project

GW-Model ISR Simulation Layer 6 (OZ) Stress Period 25 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Modeled Drawdown At The End Of ISR Operations

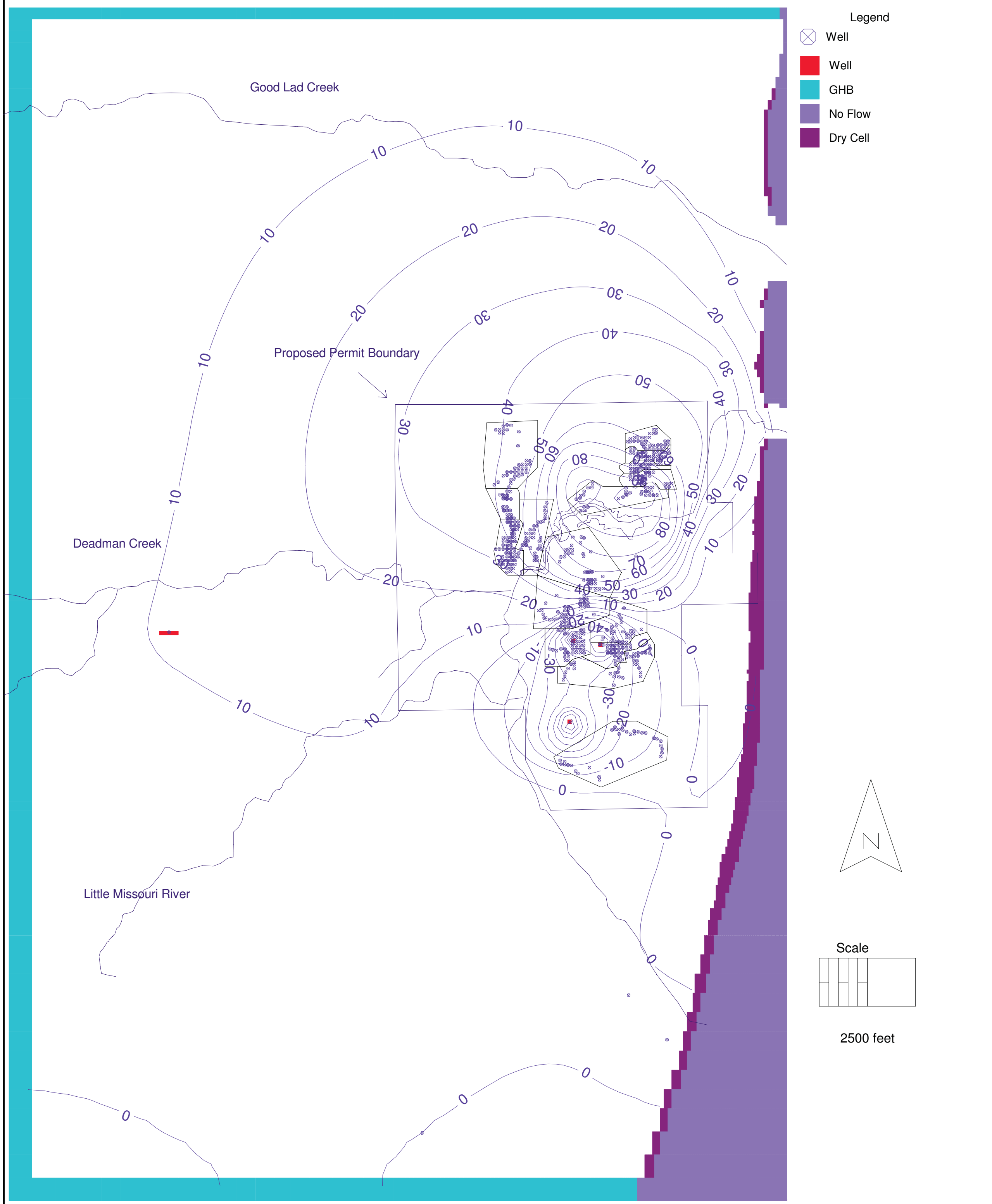


Figure ES-4

Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 25 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown At The End Of ISR Operations

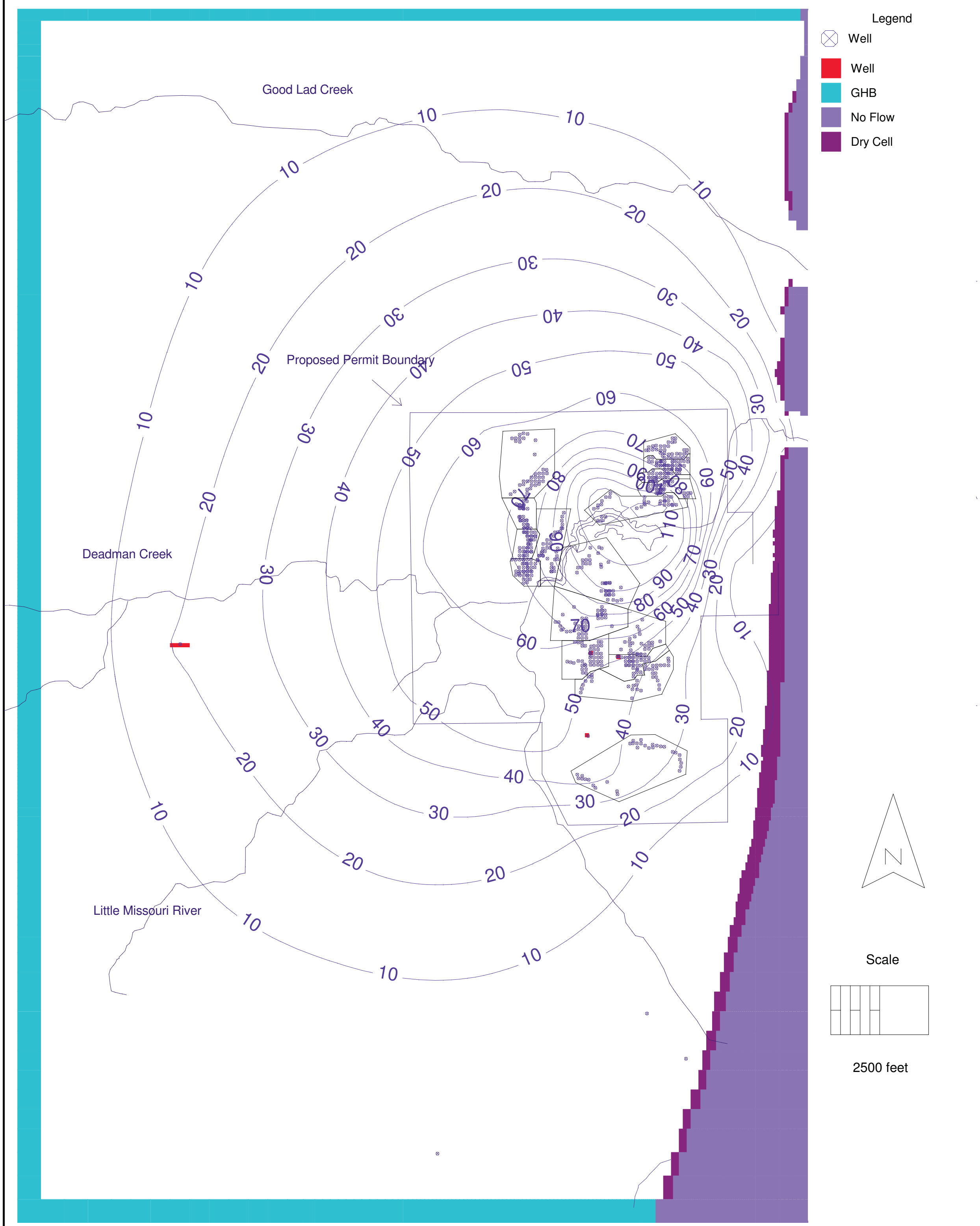
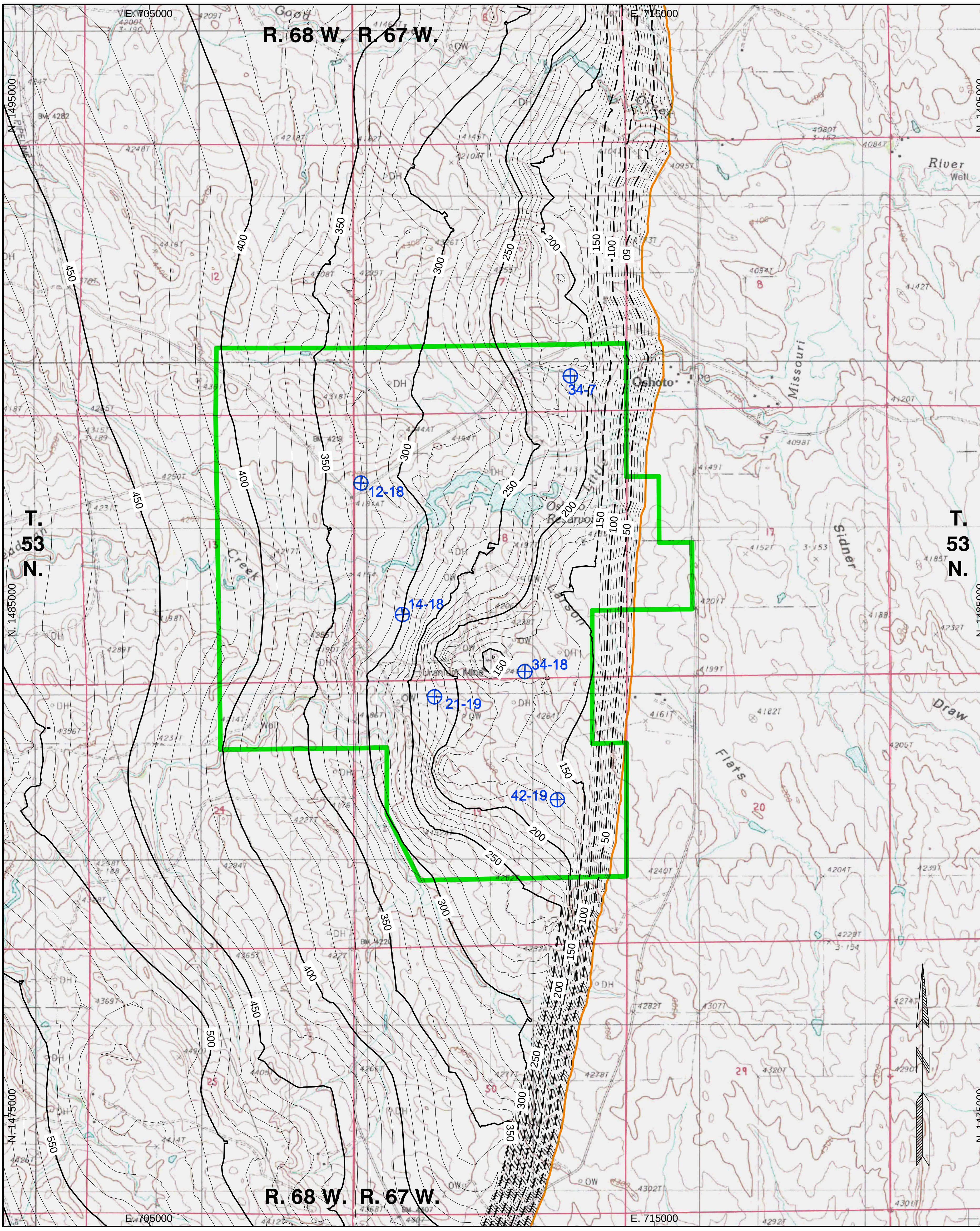


Figure ES-5



LEGEND

PROPOSED ROSS PERMIT BOUNDARY

ISOPACH LINE (10' CONTOUR INTERVAL) OF POTENTIOMETRIC HEAD ABOVE ORE ZONE INTERVAL. CONTOUR LINES ARE DASHED WHERE POTENTIOMETRY AND STATIGRAPHIC STRUCTURE WERE PROJECTED ALONG THE BLACK HILLS MONOCLINE FLEXURE.

EDGE OF AQUIFER

21-19 REGIONAL BASELINE MONITOR WELL CLUSTER

NOTE:

TOP OF ORE ZONE SURFACE DERIVED FROM GEMCOM GEMS© SOFTWARE CUSTOMIZED FOR STRATA ENERGY, INC. AND DEVELOPED IN SUPPORT OF SITE SPECIFIC GROUNDWATER MODEL. 2010 POTENTIOMETRIC SURFACE GENERATED FROM GW VISTAS© GROUNDWATER MODEL USING MODFLOW. THIS FIGURE REPRESENTS THE DIFFERENCE BETWEEN THOSE TWO SURFACES.

0 1000 2000 4000

GRAPHIC SCALE (FEET)

STRATA ENERGY

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

REVISIONS	
Date	Description

GWM TECHNICAL REPORT
FIGURE ES-6

ISOPACH OF AVAILABLE POTENTIOMETRIC HEAD IN 2010 ABOVE THE ORE ZONE AQUIFER

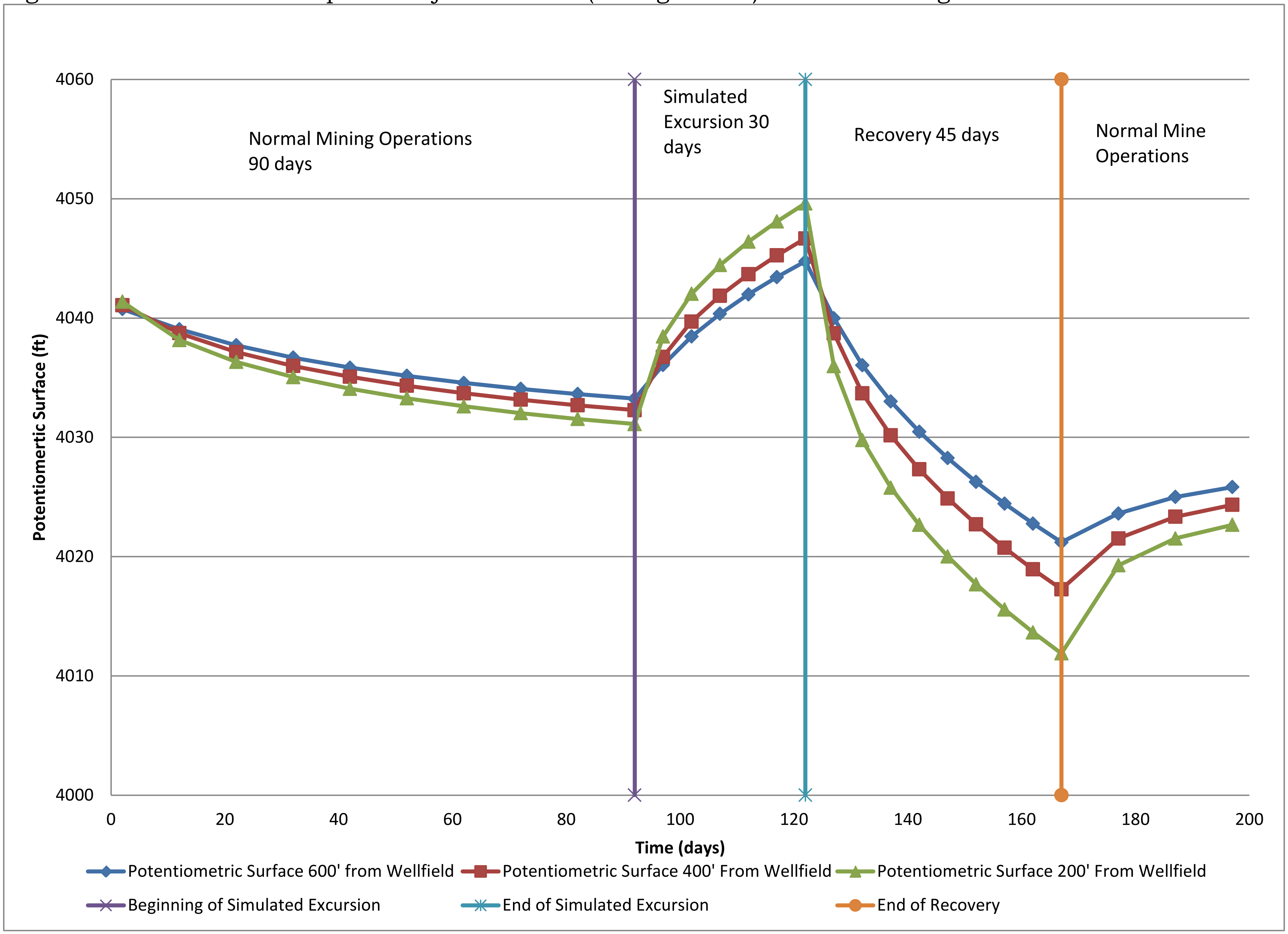
Drawn By: RAM
Checked By: BJS
Date: 11/21/10

WWC ENGINEERING
www.wwcengineering.com

FILE: ROSS_GEO_OZ_CONHEAD_ISO.DWG

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_ER_GEO_OZ_CONHEAD_ISO.dwg, GWMES_FIGURE_ES-6, 12/21/2010 10:02:09 AM

Figure ES-7. Head Response Adjacent to SW (downgradient) Wellfield during Simulated Excursion



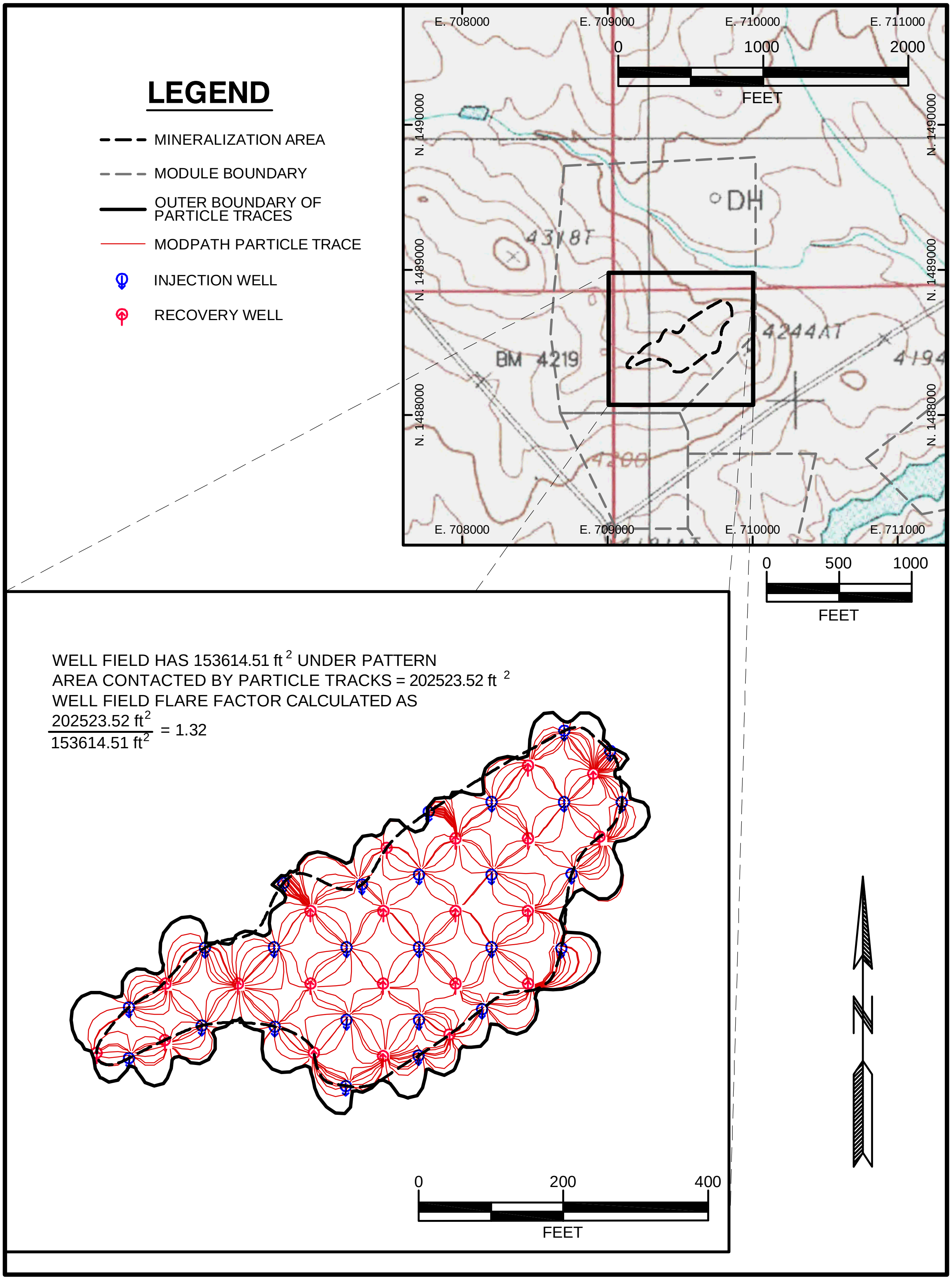


Figure ES-8. Wellfield Flare at 1.25% Bleed

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF APPENDICES

GROUNDWATER MODELING OF POTENTIAL IMPACTS ASSOCIATED WITH THE ROSS ISR URANIUM PROJECT

1.0 INTRODUCTION

Strata Energy (Strata) plans to develop an *in-situ* recovery (ISR) uranium facility in western Crook County near Oshoto, WY. The project is known as the Ross ISR Project and is located on private, state, and federal surface. The proposed permit boundary encompasses 1,721 acres and is roughly 2 miles north-south and 1.5 miles east-west. The project area is located approximately 20 miles north of Moorcroft, WY adjacent to the ranching community of Oshoto, WY. The general location of the proposed Ross ISR project area is depicted on Figure 1.0-1.

As part of the permitting process, Strata is required to analyze the potential direct, indirect, and cumulative hydrological effects of the project. WWC Engineering was commissioned to develop a numerical groundwater flow model to estimate groundwater impacts resulting from the proposed Ross ISR Project as well as analyze and optimize planned recovery operations. The groundwater model was constructed to evaluate both regional as well as localized impacts from ISR operations and to optimize wellfields.

The primary goals of the regional groundwater modeling activities were as follows:

1) Identify potential impacts (if any) to adjacent water rights
2) Estimate long-term impacts from ISR operations
3) Identify potential influences to the surficial aquifer and surface impoundments

The primary goals of the localized groundwater modeling activities were as follows:

1) Estimate adequate perimeter well offset/setback distances for the wellfield
2) Demonstrate the ability to identify and remedy a lateral excursion (i.e., lixiviants moving past the monitor wells)
3) Wellfield optimization

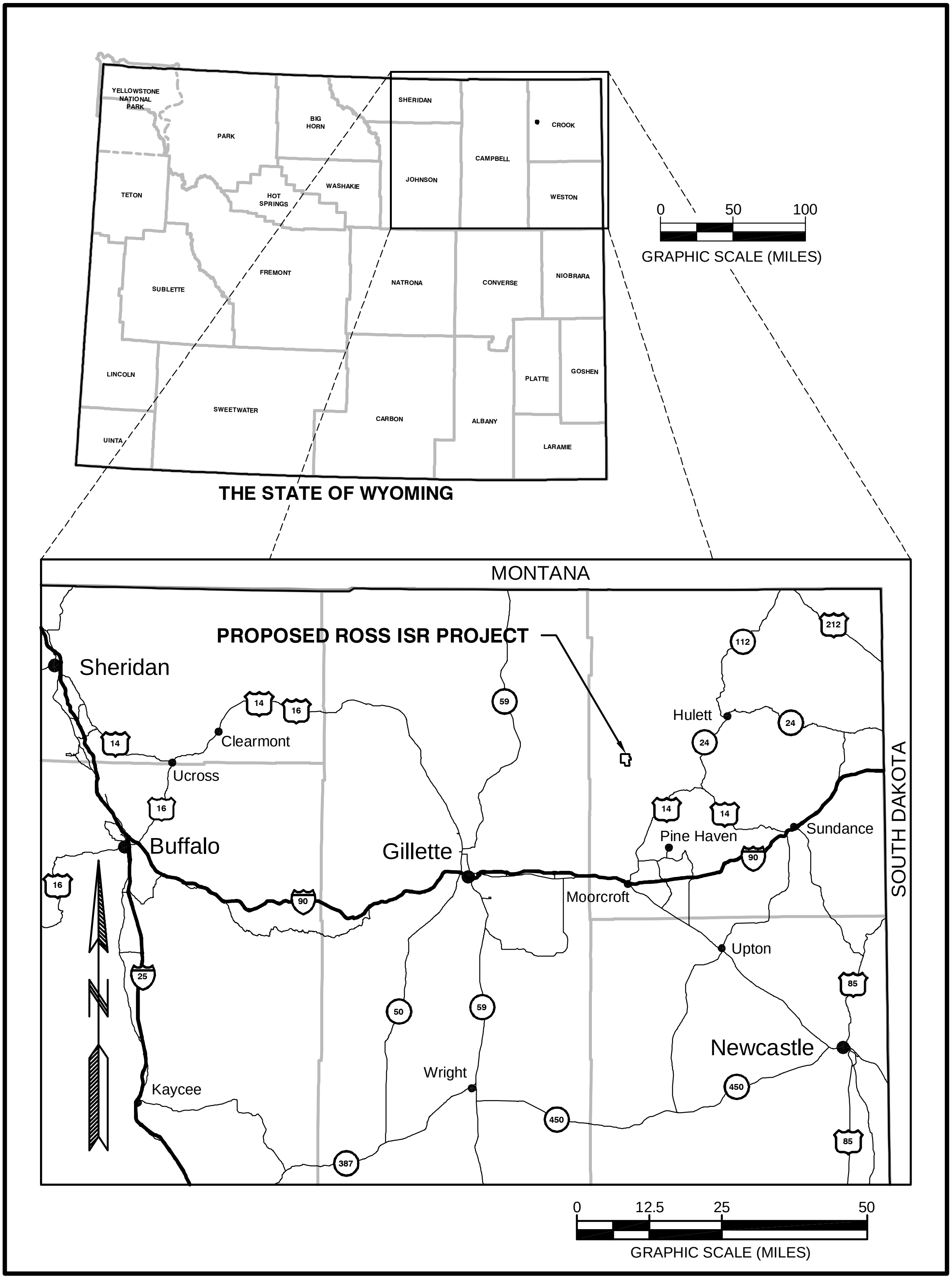


Figure 1.0-1. Ross Project General Location Map

4) Optimize wellfield bleed rate

5) Evaluate restoration time/efficiency analysis

This report presents the model conceptualization, documentation, and results for the numerical model used to estimate impacts to the groundwater flow system resulting from the Ross ISR Project. The numerical groundwater model presented herein utilizes the United States Geological Survey (USGS) modular finite-difference groundwater model, MODFLOW (MacDonald and Harbaugh 1988) and the pre/post processor Groundwater Vistas (Rumbaugh and Rumbaugh 2002). The Ross ISR groundwater model was developed primarily to evaluate impacts within and immediately adjacent to the proposed project area. To minimize edge effects, the northern, western, and southern edges of the model extend approximately 10,000 feet from the project boundaries.

The Black Hills Monocline is located near the eastern edge of the permit boundary and the outcrop of the Pierre Shale which forms a natural hydrologic barrier. As such, the eastern portion of the model is represented by a no-flow boundary. Within the proposed project area Strata has acquired a significant amount of borehole and hydrogeological information. Outside of the project area borehole data and hydrogeological information are sparse. The results of this model therefore become less reliable with distance from the proposed project area.

Following standard practice, simplifying assumptions were made in order to construct the model. Hydrogeological information was limited to a few observation points, the most reliable of which include monitor well and aquifer test results developed in 1978 and 1979 for the Nubeth R&D solution mining project and the more recent pump testing performed in 2010 by WWC Engineering in support of the Ross Project. In general, the model is most accurate near the monitor wells and within the layers in which the monitor wells were completed and where hydraulic data is available. Understandably, results become less reliable further from the monitor wells.

2.0 CONCEPTUAL MODEL

2.1 Hydrogeologic Setting

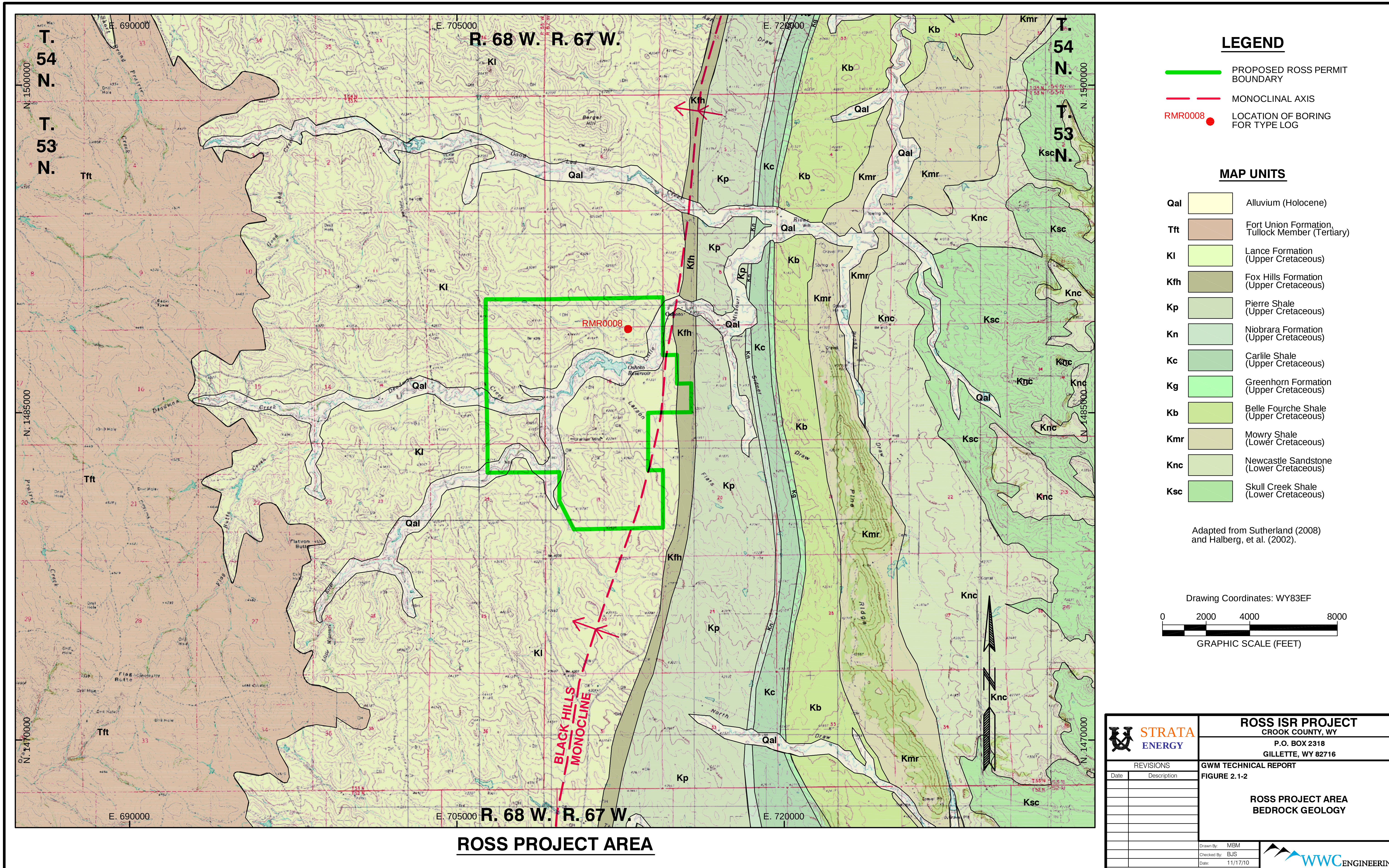
The Ross ISR Project is located on the eastern periphery of the Powder River structural basin and western margin of the Black Hills uplift. The Powder River Basin is an asymmetrical synclinal basin bounded by the Black Hills uplift on the east, the Miles City Arch on the north, the Big Horn Uplift and Casper Arch on the west and the Laramie Uplift and Hartville Uplift on the south. The regional stratigraphic column is depicted in Figure 2.1-1. Within the proposed project area the uranium deposits lie primarily within the Upper Cretaceous Fox Hills and Lance Formations. The proposed project area is situated near the Lance Formation outcrop. Underlying the Lance Formation is the Fox Hills Formation, which overlies the upper Cretaceous Pierre Shale. The dominant structural feature in the vicinity of the proposed Ross project area is the Black Hills Monocline, an area of near-vertical dip on the western flank of the Black Hills Uplift. West of the monocline, strata are nearly flat-lying (2 degree dip westward into the Powder River Basin). Figure 2.1-2 portrays the bedrock geology along with a line representing the western edge of the Black Hills Monocline in the Oshoto Area. East of this line the strata dip steeply with the Fox Hills Formation outcropping less than 1,000 feet east of the proposed Ross project area. An 85 degree dip to the west was measured by WWC Engineering just east of Oshoto in the SESW, Sec 8, T53N, R67W. Figure 2.1-3 depicts a generalized geologic cross section within the Oshoto area.

The Pierre Shale is a thick marine shale (roughly 2,400 feet thick in the proposed project area) that generally yields very little water and represents a regional confining interval (Langford 1964). The Fox Hills Formation is a sequence of marginal marine to estuarine sediments deposited during the eastward regression of the late Cretaceous Interior Seaway. In the area of the Black Hills Uplift and Powder River Basin, offshore marine deposits of the Pierre Shale grade upward into transitional marine sediments of the near-shore Fox Hills Formation. The Fox Hills Formation has been divided into an upper

GENERAL OUTCROP SECTION OF THE BLACK HILLS AREA

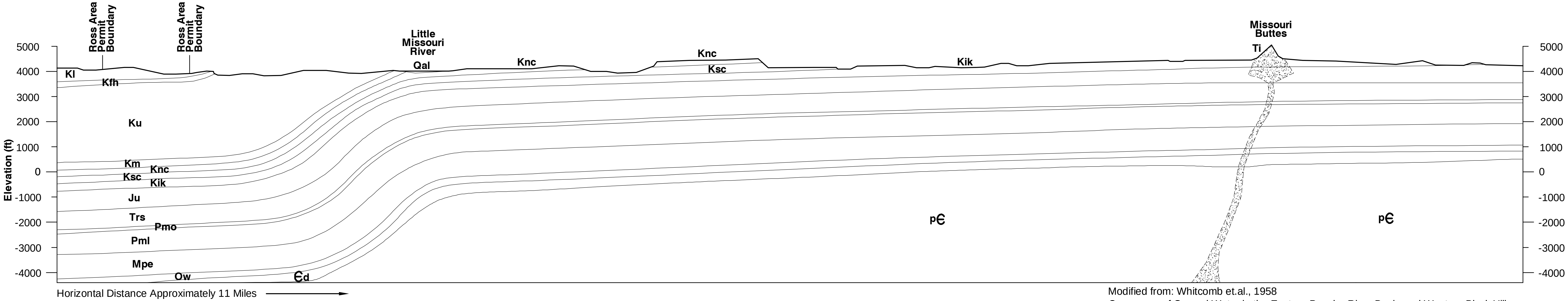
		FORMATION	SECTION	THICKNESS IN FEET	DESCRIPTION
QUATERNARY		SANDS AND GRAVELS		0-50	Sand, gravel, and boulders.
TERTIARY	PLIOCENE	OGALLALA GROUP		0-100	Light colored sands and silts.
TERTIARY	MIOCENE	ARIKAREE GROUP		0-500	Light colored clays and silts. White ash bed at base
TERTIARY	OLIGOCENE	WHITE RIVER GROUP		0-600	Light colored clays with sandstone channel fillings and local limestone lenses
TERTIARY	PALEOCENE	FORT UNION FORMATION: TONGUE RIVER MEMBER		0-425	Light colored clays and sands, with coal-bed farther north.
TERTIARY	PALEOCENE	FORT UNION FORMATION: CANNONBALL MEMBER		0-225	Green marine shales and yellow sandstones, the latter often as concretions.
TERTIARY	PALEOCENE	FORT UNION FORMATION: LUDLOW MEMBER		0-350	Somber gray clays and sandstones with thin beds of lignite.
CRETACEOUS	? UPPER	HELL CREEK FORMATION (Lance Formation)		425	Somber-colored soft brown shale and grey sandstone, with thin lignite lenses in the upper part. Lower half more sandy. Many loglike concretions and thin lenses of iron carbonate.
CRETACEOUS	UPPER	FOX HILLS FORMATION		25-200	Grayish-white to yellow sandstone
CRETACEOUS	UPPER	PIERRE SHALE Sharon Springs Mem.		1200-2000	Principal horizon of limestone lenses giving teepee buttes Dark-gray shale containing scattered concretions. Widely scattered limestone masses, giving small tepee buttes Black fissile shale with concretions
CRETACEOUS	UPPER	NIOBRARA FORMATION		100-225	Impure chalk and calcareous shale
CRETACEOUS	UPPER	Turner Sand Zone CARLILE FORMATION Wall Creek Sands		400-750	Light-gray shale with numerous large concretions and sandy layers. Dark-gray shale
CRETACEOUS	UPPER	GREENHORN FORMATION		(25-30)	Impure slabby limestone. Weathers buff.
CRETACEOUS	UPPER	GRANEROS GROUP		(200-350)	Dark-gray calcareous shale, with thin Orman Lake limestone at base.
CRETACEOUS	UPPER	GRANEROS GROUP: BELLE FOURCHE SHALE		300-550	Gray shale with scattered limestone concretions. Clay spur bentonite at base.
CRETACEOUS	LOWER	GRANEROS GROUP: MOWRY		150-250	Light-gray siliceous shale. Fish scales and thin layers of bentonite
CRETACEOUS	LOWER	GRANEROS GROUP: MUDDY: DYNNESON / NEWCASTLE		20-60	Brown to light yellow and white sandstone.
CRETACEOUS	LOWER	GRANEROS GROUP: SKULL CREEK SHALE		170-270	Dark gray to black shale
CRETACEOUS	LOWER	INYAN KARA GROUP: FALL RIVER [DAKOTA (?)] ss		10-200	Massive to slabby sandstone.
CRETACEOUS	LOWER	INYAN KARA GROUP: LAKOTA FM: Fuson Shale		10-188	Coarse gray to buff cross-bedded conglomeratic ss, interbedded with buff, red, and gray clay, especially toward top. Local fine-grained limestone.
CRETACEOUS	LOWER	INYAN KARA GROUP: LAKOTA FM: Minnewaste ls		0-25	
CRETACEOUS	LOWER	INYAN KARA GROUP: LAKOTA FM		25-485	
JURASSIC		MORRISON FORMATION		0-220	Green to maroon shale. Thin sandstone.
JURASSIC		UNKPAPA SS		0-225	Massive fine-grained sandstone.
JURASSIC		SUNDANCE FM: Redwater Mem, Lak Member, Hulett Member, Stockade Beaver, Canyon Spr. Mem		250-450	Greenish-gray shale, thin limestone lenses Glauconitic sandstone; red ss. near middle
JURASSIC		GYPSUM SPRING		0-45	Red siltstone, gypsum, and limestone
TRIASSIC ?		SPEARFISH FORMATION Goose Egg Equivalent		250-700	Red sandy shale, soft red sandstone and siltstone with gypsum and thin limestone layers. Gypsum locally near the base.
PERMIAN		MINNEKAHTA LIMESTONE		30-50	Massive gray, laminated limestone.
PERMIAN		OPECHE FORMATION		50-135	Red shale and sandstone
PERMIAN / PENNSYLVANIAN		MINNELUSA FORMATION		350-850	Yellow to red cross-bedded sandstone, limestone, and anhydrite locally at top. Interbedded sandstone, limestone, dolomite, shale, and anhydrite. Red shale with interbedded limestone and sandstone at base.
MISSISSIPPIAN		PAHASAPA (MADISON) LIMESTONE		300-630	Massive light-colored limestone. Dolomite in part. Cavernous in upper part.
DEVONIAN		ENGLEWOOD LIMESTONE		30-60	Pink to buff limestone. Shale locally at base.
ORDOVICIAN		WHITEWOOD (RED RIVER) FORMATION		0-60	Buff dolomite and limestone.
ORDOVICIAN		WINNIPEG FORMATION		0-100	Green shale with siltstone
CAMBRIAN		DEADWOOD FORMATION		10-400	Massive buff sandstone. Greenish glauconitic shale, flaggy dolomite and flatpebble limestone conglomerate. Sandstone, with conglomerate locally at the base.
PRE-CAMBRIAN		METAMORPHIC and IGNEOUS ROCKS			Schist, slate, quartzite, and arkosic grit. Intruded by diorite, metamorphosed to amphibolite, and by granite and pegmatite.

Figure 2.1-1. Regional Stratigraphic Column
Modified from WGA Guidebook for 20th Annual Field Conference (1968)

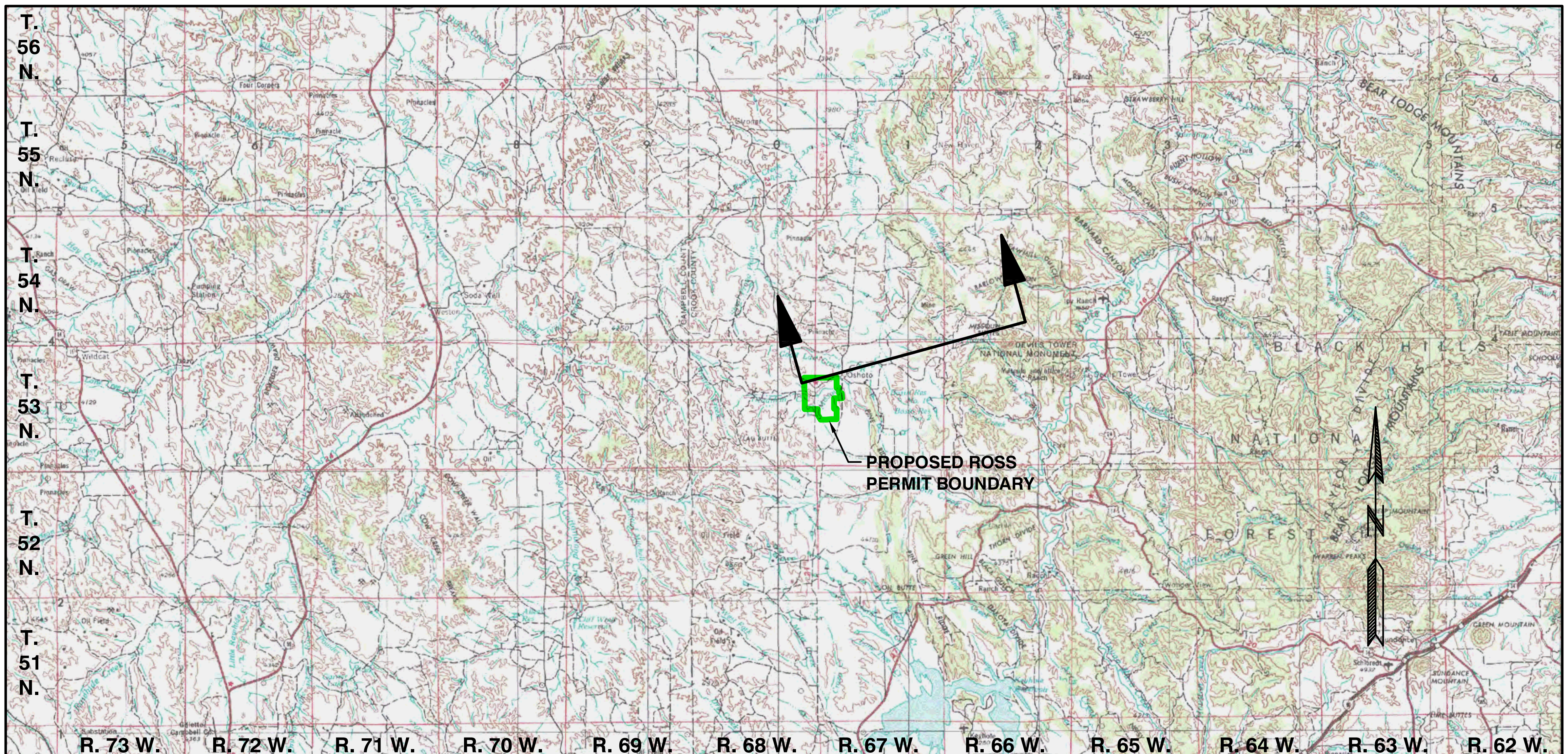


ROSS PROJECT AREA

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_ER_GEOLOGY.dwg, GWM_FIGURE_2.1-2, 12/18/2010 12:41:07 PM



Modified from: Whitcomb et.al., 1958
Occurence of Ground Water in the Eastern Powder River Basin and Western Black Hills
N.E. Wyoming WGA Thirteenth Annual Field Conference



CROSS SECTION LOCATION

0 3 6 12
GRAPHIC SCALE (MILES)

LEGEND

Qal	Quaternary Alluvium
Ti	Tertiary Intrusives
Kl	Lance Formation
Kfh	Fox Hills Formation
Ku	Upper Cretaceous, undivided
Km	Mowry Shale
Knc	Newcastle Sandstone
Ksc	Skull Creek Shale
Kik	Inyan Kara Group
Ju	Jurassic, undivided
Trs	Spearfish Formation
Pmo	Minnekahta Limestone and Opeche Formation
Pml	Minnelusa Sandstone
Mpe	Pahasapa and Englewood Limestones
Ow	Whitewood Limestone
Єd	Deadwood Formation
pЄ	Precambrian

STRATA ENERGY

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

REVISIONS
Date	Description

GWM TECHNICAL REPORT
FIGURE 2.1-3

GENERALIZED GEOLOGIC CROSS SECTION DEPICTING BLACK HILLS MONOCLINE IN THE OSHOTO AREA

Drawn By: MBM
Checked By: MJE
Date: 11/22/10

WWC ENGINEERING
www.wwcengineering.com

FILE: ROSS_ER_GEO_XS_PRB

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_ER_GEO_XS_PRB.dwg, GWM_FIGURE_2.1-3, 12/18/2010 12:43:46 PM and a lower unit by Dodge and Spencer (1977). Sediments of the lower unit consist of offshore-marine and transitional-marine shale, siltstone, and very fine-grained sandstone and is not known to contain uranium ore deposits. The estuarine sediments of the upper unit consist of uranium-bearing organic, thinly-bedded claystone, siltstone, and sandstone (Dodge and Spencer 1977). The Lance Formation, which lies conformably upon the Fox Hills Formation, records the deposition of continental deposits following withdrawal of the Upper Cretaceous Sea in the Powder River Basin (Dunlap 1958). The Lance Formation depositional environment has been interpreted as being fluvio-deltaic in origin (Buswell 1982). The Lance Formation consists of a mixture of non-marine deposited sandstones and floodplain mudstones with thin beds of coal (Connor 1992). Within the proposed project area, mineralization primarily occurs within the sandstones of the upper Fox Hills Formation and overlying lower Lance Formation.

2.2 Hydrostratigraphic Units

For the purpose of this modeling study, the primary units of interest are the Fox Hills Formation and the overlying Lance Formation. Specifically, the sandstones of the upper Fox Hills Formation and the lower Lance Formation are targeted for uranium ISR. For the purposes of this analysis, the targeted ISR unit is also referred to as the ore zone (OZ). The uranium ore-bearing sands of the upper Fox Hills and lower Lance formations are saturated and capable of transmitting groundwater; therefore, the OZ is defined as an aquifer. Regulations require that the overlying and underlying aquifers stratigraphically closest to the uranium mineralization be monitored during ISR to identify any vertical excursions as well as characterized to determine the level of hydraulic isolation with the OZ. The first water-bearing interval that lies stratigraphically above the OZ is within the Lance Formation and is referred to as the Shallow Monitoring Zone (SM). The first water-bearing interval that lies stratigraphically below the uranium-bearing sands of the OZ in the upper Fox Hills is a thin sandstone near the base of the Fox Hills Formation and is referred to as the

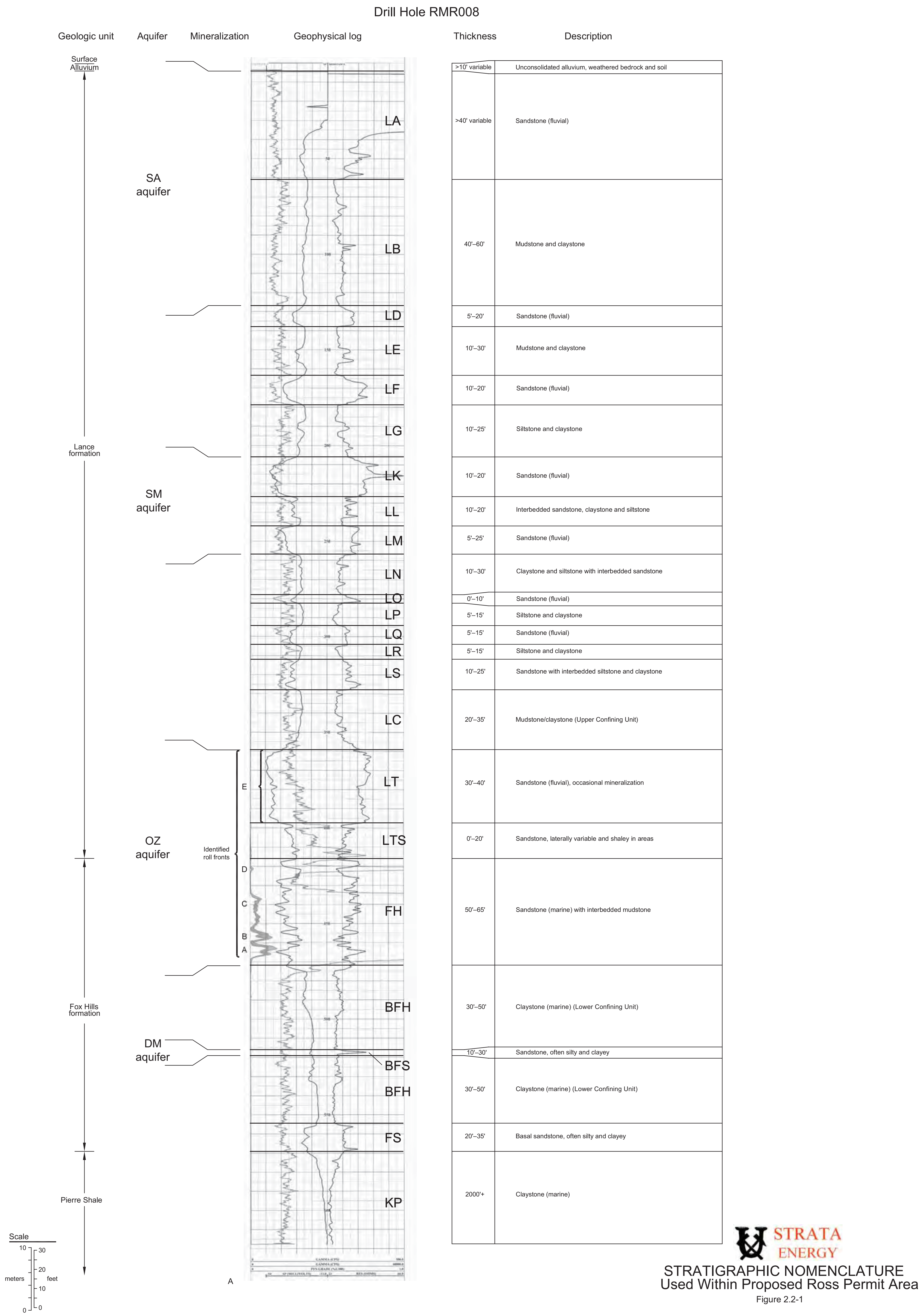
Deep Monitoring Zone (DM). Figure 2.2-1 details the hydrostratigraphic units within the Ross project area.

Underlying the Fox Hills Formation are the dark gray, silty marine shales of the Pierre Shale. Due to the thickness (greater than 2,000 feet) and low permeability, the Pierre Shale is considered a regional confining layer. Between the OZ and the DM is a very fine-grained shale interval roughly 50 feet thick, which is believed to be continuous throughout the model area and serves as a confining unit. Several additional shale units have been identified within the Lance Formation. These shale units (shales, claystones, mudstones and siltstones) may serve as localized confining units. For example, overlying the OZ aquifer is a sequence of thinly interbedded mudstones, claystones, and siltstones that typically ranges from around 55 to 145 feet thick and that has been determined to be areally continuous throughout the proposed project area. This fine-grained sedimentary sequence is referred to as the Upper Confining Unit.

Measured hydrostatic elevations indicate that aquifers within the project area are artesian with heads decreasing into each successive lower unit. Several sandstone and shale zones have been noted on the bore logs between the SM and the ground surface. The thin sandstone and shale complexes located above the SM are not regionally extensive and the water-bearing strata are thin and discontinuous. As such, for the purposes of this model, this marginal water-bearing portion of the Lance formation is called the Lance aquitards.

2.3 Groundwater Flow System

Within the proposed project area the groundwater flow is complicated due to the fact that surface waters drain in a generally easterly direction while the underlying strata dip to the west as shown on Figure 2.3-1 which depicts the conceptual water cycle near Oshoto, Wyoming. Groundwater within the alluvial groundwater system associated with the Little Missouri River flows to the east. The saturated alluvium is a source of groundwater recharge to



STRATIGRAPHIC NOMENCLATURE
Used Within Proposed Ross Permit Area
Figure 2.2-1

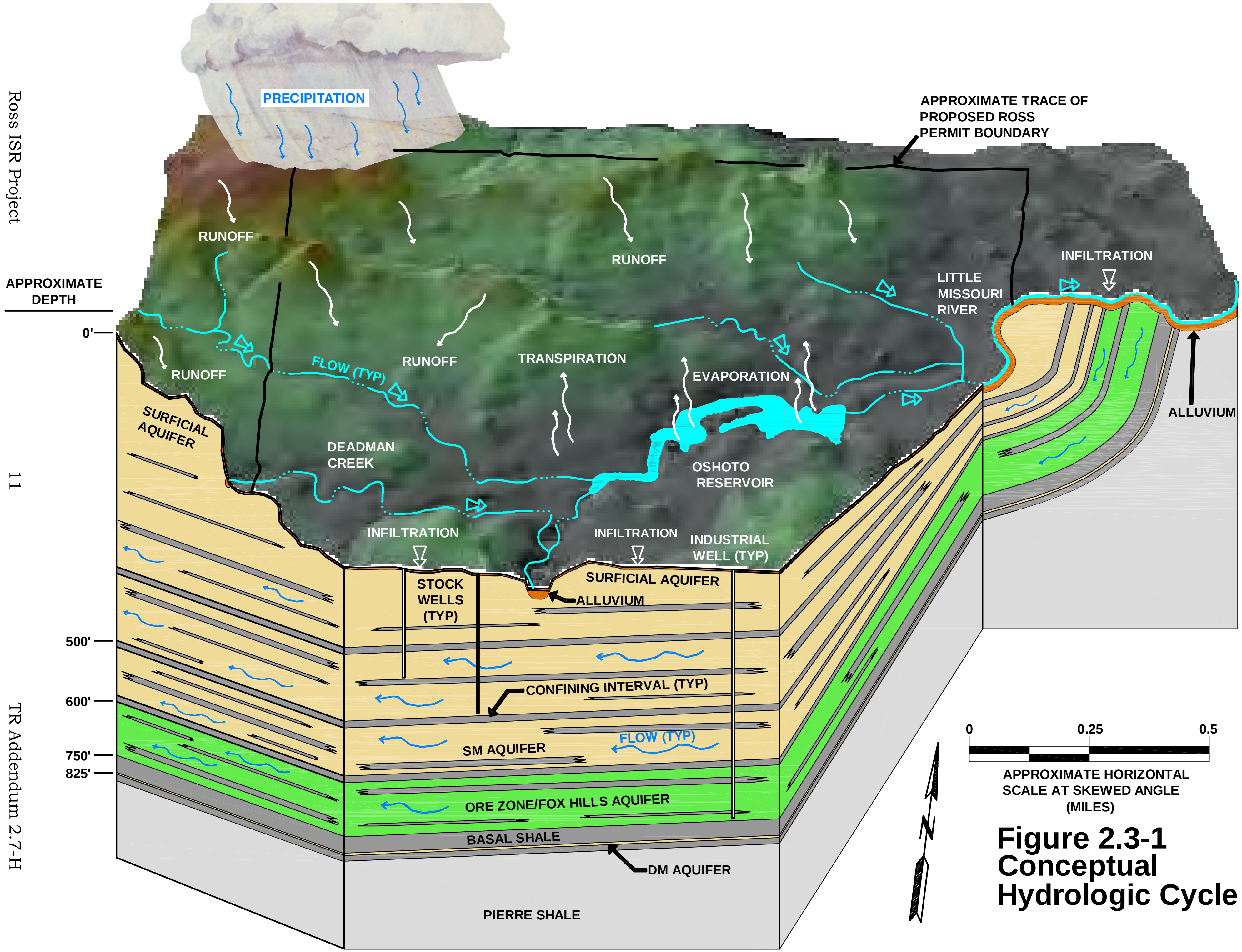


Figure 2.3-1 Conceptual Hydrologic Cycle

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_3D_WATER.dwg, GWM_FIGURE_2.3-1, 12/21/2010 9:54:20 AM the permeable subcropping strata that dip westerly. Groundwater flow in the Lance and Fox Hills strata is down dip, generally to the west and the north as shown on Figure 2.3-1. The Fox Hills and Lance outcrops at the eastern edge of the proposed project area are believed to be the principal recharge areas for the SM and OZ aquifers. Based on information presented by Buswell (1982) and water level information measured at the Fox Hills outcrop, groundwater within the proposed project area may also have a northerly component of flow, which means that recharge may also enter the project area from the south. With the exception of lateral recharge from the adjacent formation, the most significant recharge to the Fox Hills and Lance aquifers within the proposed project area is expected to occur as vertical groundwater leakage from the alluvium in the areas where the Little Missouri River and Good Lad Creek cross the Fox Hills and Lance Formation outcrops (see Figure 2.3-1). Recharge may also occur from natural precipitation at the outcrops outside of the areas of alluvial deposits, although recharge occurring at the outcrops outside of the alluvium is believed to be minor compared to that occurring at the subcrops beneath the saturated stream valleys.

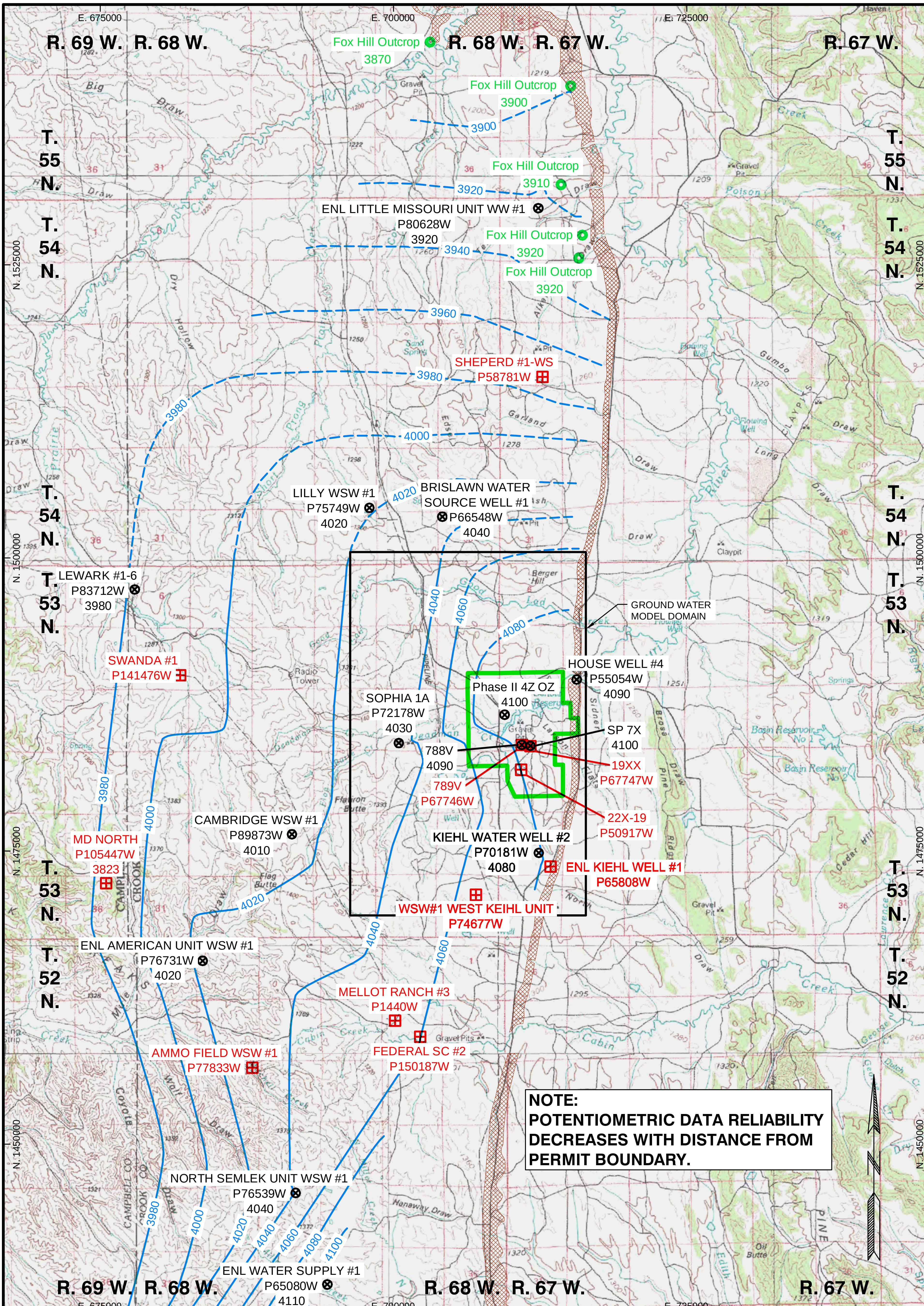
Within the greater Oshoto region, there are several oilfields currently in operation. Most of the oilfields target the Minnelusa Formation which is several thousand feet below the OZ aquifer. However, beginning in the late 1970s/ early 1980s, the oil companies began injecting water into the oil-bearing formation to stimulate oil production. The water used to flood the oilfields originates from Fox Hills Formation wells. Many of the Fox Hills wells used to stimulate the oilfield have been in operation for up to 30 years. As a result, within the Fox Hills Formation the 2010 potentiometric surface has been lowered near the Fox Hills oilfield water supply wells. Since most of the water supply wells have been constructed since 1980, the 1980 potentiometric surface is considered the pre-abstraction potentiometric surface.

A review of the Wyoming State Engineer's water rights database indicates that most of the permitted stock and domestic wells within the region are completed within Lance sandstones not in hydrologic communication with the

OZ aquifer. Furthermore, it is believed that only a small portion of the stock and domestic wells may be completed within the SM aquifer. Due to the fact that throughout the Ross project area the SM and OZ aquifers are relatively deep for stock and domestic wells (400 ft +) the only portions of these aquifers believed to supply stock and domestic wells are those right at the outcrop where the aquifers are relatively shallow. As depicted on Figure 2.3-1, most of the local stock and domestic wells are not in hydraulic communication with the OZ aquifer and will be minimally impacted by ISR operations within the OZ. Section 4.9 describes impacts to adjacent wells within the Ross project area in more detail.

The pre- 1980 hydrostatic head map developed for the OZ aquifer (Figure 2.3-2 in the Oshoto area indicates that its potentiometric surface elevation decreases in the down-dip direction. The potentiometric surface presented on Figure 2.3-2 is based on pre-abstraction (pre-1980) hydrostatic information obtained from an exhaustive search of completed wells within the greater Ross area and historical data from previous ISR attempts within the proposed project area. Within the proposed Ross Project area, unpublished data from the Nubeth Research and Development Project conducted by Nuclear Dynamics in the late 1970s was the most reliable potentiometric data source (Hamilton 1979; Manera 1978; and Stoick 1980). The data compiled for the Nubeth Project were obtained from a few monitor wells located within the historic Nubeth project area.

Well completion and head data from the Wyoming State Engineer's Office database (SEO 2010) and the Wyoming Oil and Gas Conservation Commission database (WOGCC 2010) were used to help develop the regional pre-1980 potentiometric surface. In addition to well data, naturally occurring seeps from the Fox Hills outcrop were used as additional data points in developing the OZ potentiometric surface map. As depicted on Figure 2.3-2, several miles north of the proposed Ross Project area the Little Missouri River flows back across the Black Hills Monocline near its intersection with Prairie Creek. At this location



Drawing Coordinates: WY83EF

0 3/4 1-1/2 3
GRAPHIC SCALE (MILES)

LEGEND

- PROPOSED ROSS PERMIT BOUNDARY
- 4000 POTENTIOMETRIC SURFACE
- POTENTIOMETRIC SURFACE INFERRED
- P76539W 4040 — WELL COMPLETED IN ORE ZONE WITH 1980 WATER LEVEL
- P141476W 3951 — INDUSTRIAL WELL FROM WHICH A PRE-1980 WATER LEVEL COULD NOT BE OBTAINED
- Fox Hill Outcrop 3920 — FOX HILLS POTENTIOMETRIC SURFACE INFERRED FROM AERIAL PHOTO ANALYSIS WITH WATER LEVEL
- FOX HILLS OUTCROP

STRATA ENERGY

REVISIONS
Date Description

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

GWM TECHNICAL REPORT
FIGURE 2.3-2

APPROXIMATE PRE-1980 POTENTIOMETRIC SURFACE FOR THE OZ AND AQUIFER DATA POINTS USED TO DEVELOP SURFACE

Drawn By: RAV
Checked By: BJS
Date: 10-20-10

WWC ENGINEERING
www.wwcengineering.com

FILE:

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_PRE_POT_OZ.dwg, GWM_FIGURE_2.3-2, 12/20/2010 11:22:02 AM

Prairie Creek bisects the Fox Hills outcrop. The ground surface elevation at this location is lower than the potentiometric surface elevation of the OZ near the proposed Ross Project area. A review of aerial photography of the area indicates several areas of alkali deposits where water appears to be emanating/discharging from the Fox Hills outcrop. Based on this evidence, the ground surface elevation at the alkali zones was considered to be the potentiometric surface elevation for the OZ aquifer in the area where Prairie Creek bisects the outcrop.

The information collected from the SEO and WOGCC databases included well completion locations, intervals, and initial estimated water surface elevations. Within the database there are many instances where information is missing or not deemed reliable. As a result, not all of the wells in the database were useful in preparing the initial pre-1980 potentiometric surface. Furthermore, within the greater Oshoto area, there are several water supply wells used for oilfield stimulation. Based on SEO and WOGCC records, most of these water supply wells originate within the Fox Hills sandstones and well construction started about 1980. As a result, many of the wells constructed after 1985 are believed to have been impacted by drawdowns from previously constructed oilfield water supply wells. Figure 2.3-2 depicts and Table 2.3-1 details the locations of the wells used to develop the pre-1980 potentiometric surface. In addition, industrial wells permitted by the SEO since 1980 from which reliable water level data could not be obtained are also included on Figure 2.3-2. The SEO and WOGCC records do not always indicate whether a well is currently in operation, although it is often possible to accurately estimate production rates from the WOGCC database if the operation of the oilfield is understood. Within the model domain operational flow rates for the industrial wells have been researched and are documented later in this report. Outside of the model domain less is known about the operation of the industrial facilities. However, not all of the industrial wells shown on Figure 2.3-2 are believed to be currently in operation. The naturally occurring seep locations used to develop the potentiometric surface are also depicted in Figure

Table 2.3-1. Wells and Points Used to Establish the Pre Abstraction Potentiometric Surface for the Ore Zone

SEO Permit #	Name	Data Source*	Lat	Long	Water level
P55054W	House Well #4	SEO	44.5874	-104.9385	4095.0
NA	788V	Nubeth	44.5722	-104.9567	4089.7
NA	Phase II 4Z OZ	Nubeth	44.5792	-104.9621	4099.0
NA	SP 7X	Nubeth	44.5719	-104.9537	4098.6
P70181W	Kiehl Water Well #1	SEO	44.5437	-104.9467	4081.0
P83712W	Lewark #1-6	SEO	44.6086	-105.0830	3980.0
P72178W	Sophia #1A	SEO	44.5728	-104.9967	4030.0
P89873W	Cambridge WSW #1	SEO	44.5475	-105.0370	4045.0
P76731W	ENL American Unit WSW #1	SEO	44.5218	-105.0610	4025.0
P76539W	North Semlek Unit WSW #1	SEO	44.4674	-105.0307	4041.0
P65080W	ENL Water Supply #1	SEO	44.4460	-105.0204	4112.0
P75749W	Lily WSW #1	SEO	44.6277	-105.0062	4023.0
P66548W	Brislawn Water Source Well #1	SEO	44.6256	-104.9823	4036.0
P80628W	ENL Little Missouri Unit WW #1	SEO	44.6977	-104.9507	3924.0
NA	Fox hills outcrop inferred point from seep	Topo/areal photography	44.7366	-104.9860	3875.0
NA	Fox hills outcrop inferred point from seep	Topo/areal photography	44.7263	-104.9399	3899.0
NA	Fox hills outcrop inferred point from seep	Topo/areal photography	44.7032	-104.9432	3915.0
NA	Fox hills outcrop inferred point from seep	Topo/areal photography	44.6914	-104.9362	3923.0
NA	Fox hills outcrop inferred point from seep	Topo/areal photography	44.6860	-104.9375	3925.0

* SEO=Wyoming State Engineers Office online database. SEO well location and water levels were cross checked with the Wyoming Oil and Gas Conservation Commission's (WOGCC) online database for wells included in the WOGCC database.

2.3-2 and detailed in Table 2.3-1. With the limited number of wells northwest of the model domain, the pre-1980 regional potentiometric surface shown on Figure 2.3-2 is approximate. Fortunately, the information collected from the various Nubeth reports is quite dependable and the pre-1980 potentiometric surface within the project area is considered reliable. The pre-1980 potentiometric surface extends to the edge of the groundwater model domain in most places, which allows boundary conditions to be established for use within the groundwater model.

In order to establish an initial pre-1980 potentiometric surface for the SM aquifer, an approach similar to that taken to define the OZ aquifer potentiometric surface was initially attempted. However, the SM aquifer is not as regionally continuous as the OZ aquifer and it was therefore difficult to correlate the SM aquifer from well to well, especially when a well was at a significant distance from the proposed Ross Project area and geologic cross sections and boreholes were not available. In general, all of the wells within the region that are used for industrial purposes are believed to target the OZ aquifer. As a result, there are very few wells representative of pre-1980 SM aquifer heads. Furthermore, a review of all the wells in the SEO database indicated that the information contained within the database is, in many cases, not detailed enough to ascertain whether or not the well was completed within an equivalent SM aquifer. Even if it was possible to determine that the well was completed in the target SM aquifer, there was still uncertainty in the accuracy of the reported water levels and the ground surface elevation from which the water levels were measured. As a result, it was not possible to develop an accurate potentiometric surface for the SM aquifer using wells from the SEO database. As an alternative to creating an independent potentiometric surface for the SM aquifer, the initial SM potentiometric surface was approximated by adjusting the OZ potentiometric surface up by 30 feet as described in the following paragraphs.

Three oilfield water supply wells (789V, 19XX, and 22X-19) exist within the proposed Ross project area and are depicted on Figure 2.3-2. According to WOGCC records, these wells have been in operation since approximately 1980. Based on the results of WWC's aquifer pump tests and groundwater monitoring (WWC 2010), it was noted that due to the oilfield water supply wells within the project area the OZ potentiometric surface has been significantly impacted (the 2010 potentiometric surface is detailed within Section 4.7.2). Of the monitor wells constructed by WWC, 34-7OZ at just over a mile away from the nearest pumping well, is at the greatest distance from these industrial wells. The water level at well 34-7SM was approximately 30 feet higher than the water level at well 34-7OZ in 2010.

In the 1977 aquifer test for the Nubeth Project, potentiometric surfaces for two sandstone zones were measured (Hamilton 1977). The potentiometric surface of the sand zone equivalent to the OZ aquifer was approximately 4,089 feet, while the potentiometric surface of the next aquifer above the OZ was 4,127 to 4,130 feet (40 feet higher). A review of the completion intervals reported for the upper aquifer indicate that it was completed in the SM zone, as well as additional sands above the SM aquifer. Since the completion interval for the Nubeth well includes several sands above the SM zone, the potentiometric elevation measured at this well is likely higher than would be expected if the well were completed in only the SM zone. Based on the data presented above, the SM potentiometric surface was approximated in the groundwater model at 30 feet above the elevation of the OZ potentiometric surface.

The upper-most Lance Formation sandstones (approximately 300-500 ft above the ore zone) in the proposed project area are believed to be in hydraulic communication with the alluvial aquifer system where they come into contact. At these locations, the alluvial system and these Lance sandstones have the same potentiometric surface. The upper-most sandstones within the Lance Formation in the proposed project area are discontinuous and do not form a regional aquifer. Groundwater flow within these sandstones is expected to parallel the SM and the OZ groundwater movement flowing to the west and the north where upper Lance sandstones are locally continuous. The recharge mechanism for these upper-most Lance sandstone is primarily from infiltration during precipitation events and from alluvial aquifers that are in communication with the sandstone. To the west of the project area the Little Missouri River, Good Lad Creek, and Prairie Creek have incised valleys which may capture some of the water flowing downdip within these perched Lance sandstones. Several shales with very low permeability exist between the upper-most Lance sandstones and the SM and OZ aquifers, therefore they are not believed to be in hydraulic communication (except very near their respective outcrops). As such, the upper Lance sandstones are not detailed to a great degree within the model. Rather, a potentiometric surface was developed based on measured alluvial water levels and the stream channel elevations within the project area. These water surfaces were then extrapolated out to the edges of the model domain where they were used to help establish the boundary conditions.

2.4 Hydrologic Boundaries

The hydrologic boundaries within the model include both internal and external boundaries. The model boundaries also vary from layer to layer. The hydrologic boundaries within the model are described within the following sections.

2.4.1 External Boundaries

The primary physical groundwater flow boundary is the Pierre Shale outcrop to the east. Since the underlying impermeable Pierre Shale outcrops just east of the Fox Hills outcrop, it serves as a hydrologic barrier to groundwater movement to or from the east. As a result, the Pierre Shale outcrop is represented by a no flow boundary.

To the south, west, and north of the Ross Project area, where there are no known natural hydrologic boundaries within either the Lance Formation or Fox Hills Formation, these model boundaries within the Lance and Fox Hills Formations are represented by general head boundaries. Heads assigned to the general head boundaries were based on pre-1980 SEO well data, Nubeth data, and extrapolated potentiometric surfaces discussed in the previous section. The surficial drainage boundaries of the Little Missouri River, Deadman Creek, and Good Lad Creek roughly coincide with the south, west and north boundaries of the model domain, respectively. The top layer within the model is hydraulically connected to the surficial drainage system. Each drainage divide is represented by a no-flow boundary in the top layer of the model. Where the surficial drainages extend beyond the model domain the boundary is represented by a recharge boundary condition.

2.4.2 Internal Boundaries

The only internal features that have been identified within the Ross model area are several small ephemeral streams. The streams are predominantly located within the uppermost layer of the model. Since the streams are not perennial, they were not modeled as streams. However, the streams do provide a mechanism for recharge where they cross the Lance and Fox Hills outcrops. Within the model the streams are represented by regions of higher permeability located in the bottoms of the drainages. This effectively simulates the water-bearing alluvium located within the ephemeral streams.

2.5 Hydraulic Properties

Hydraulic properties needed to characterize each aquifer or confining unit include hydraulic conductivity, storage coefficient (for confined aquifers), specific yield (for unconfined aquifers), and leakance. Available information for each of these properties is described within the following sections.

2.5.1 Hydraulic Conductivity

Hydraulic conductivity is one of the most critical hydraulic parameters as shown later in this report. Within the OZ Aquifer the hydraulic conductivity has been measured by pump testing at several locations within the Ross project area from historic Nubeth testing and testing conducted in 2010. Outside of the project area no measured hydraulic conductivity is available. A small amount of hydraulic conductivity information is available within the project area for the SM aquifer. No site specific hydraulic conductivity information is available for the confining layers or the surficial aquifers. As a result, published literature was relied on to estimate hydraulic conductivities for the surficial and confining layers. Hydraulic conductivity values available for each of the layers are detailed within this section.

2.5.1.1 Pierre Shale

The Pierre Shale is roughly 2,200 feet thick in the project area. Locally, the Pierre Shale is relatively uniform and void of any water-bearing strata and acts as a regional confining layer. Site-specific hydraulic conductivity tests have not been performed for the Pierre Shale, but the hydraulic conductivity has been estimated on the order of 2.6×10^{-10} to 2.6×10^{-9} ft/day by Neuzil (1993) outside of the region. Estimates of the vertical hydraulic conductivity outside of the region for the Pierre Shale are in the range of 5×10^{-8} to 5×10^{-4} ft/day (Kansas Geological Survey 1991). The thickness and low permeability of the Pierre Shale makes it a regional confining unit. On the east side of the project area the Pierre Shale outcrop marks the eastern extent of the overlying Ross area aquifers.

2.5.1.2 Fox Hills Formation

Within the project area, the Fox Hills Formation consists of lower and upper sandstone members separated by interbedded shales and silts. The sandstone members represent the water-bearing strata within the lower Fox Hills Formation. Both sandstone units are believed to be continuous throughout the project area although in places they are relatively thin. The lower sandstone member contains two sandstone packages, of which the upper package is the nearest aquifer below the uranium-bearing sands in the upper Fox Hills Formation, and is also referred to as the deep monitoring zone (DM). The DM zone is separated from the upper Fox Hills ore-bearing sandstone by 30 to 50 feet of shale. Recent head data from monitor wells completed in the DM zone and overlying OZ interval indicate there is a downward vertical gradient with up to 14 feet of head differential between the two zones. Aquifer tests performed in July of 2010 by WWC Engineering indicate the DM zone is hydraulically isolated from overlying water-bearing units. Furthermore, analyses of water quality performed by WWC in 2010 in the DM zone and the OZ unit indicate a distinct difference in the chemical characteristics. These differences in water quality suggest no mixing of water between the two zones. No aquifer tests have been performed to determine the hydraulic conductivity of the DM sands. However, when WWC Engineering has collected water samples from the DM zone it has had a very small yield. The DM monitor wells typically pump dry at a pumping rate of less than ½ gallon per minute. The bore logs for the monitor wells indicate that the DM sandstone is finer grained and contains more silt than the OZ sands. As such, the hydraulic conductivity of the DM zone is expected to be less than the hydraulic conductivities measured in the ore-bearing Fox Hills sandstone presented in this report. The DM aquifer was not modeled with the 7 layer groundwater model. As discussed in the following paragraphs, the intervening shale between the two aquifers effectively isolates them from each other which means that any attempt to model the DM would show negligible response to changes in the overlying OZ aquifer.

Due to the thickness (30 to 50 feet) of shale and silt separating the DM zone from the OZ aquifer and the observed head differential between the OZ and DM, this interval is considered to be a confining interval. This interval is also referred to as the basal confining unit for the purposes of the model. Although vertical hydraulic conductivities are not available for the basal confining shale, the vertical hydraulic conductivity is expected to be comparable to that of the Pierre Shale, which has been estimated to range from 5×10^{-8} to 5×10^{-4} ft/day.

The sandstones within the upper Fox Hills Formation contain uranium and are the primary target of the Ross ISR Project. Due to the variable nature of the near-shore depositional environment in which the sandstones were deposited, the thickness and lithologies vary across the project area with sometimes significant differences over short distances. This phenomenon can be seen on the geologic cross sections contained in Strata's permit applications for the Ross ISR uranium project. The upper Fox Hills Formation ranges from thick, bedded, blocky sandstones to thin, interbedded sandstones, siltstones and shales. Within the project area the gross sand thickness of the upper Fox Hills Formation is approximately 150 feet, although local variations of up to 50 feet or more are not unusual. The upper Fox Hills sandstones, shales, and silts have been studied extensively through core analysis and aquifer tests. Hydraulic parameters for the Fox Hills formation and adjacent shales measured from core data are summarized in Table 2.5-1. Hydraulic parameters for the OZ aquifer measured from aquifer tests are summarized on Table 2.5-2. For the purposes of the regional groundwater model, hydraulic parameters measured from the aquifer tests are considered more applicable than the core data. The aquifer tests were performed at several locations within the modeled layer and are considered more representative of that entire layer, whereas core data are representative only of conditions at the specific location from which the core was collected.

The multiple well partial penetration tests performed near the 12-18OZ monitor well were the only aquifer tests from which the vertical to horizontal anisotropy could be estimated. Results from the 12-18OZ pump tests indicate the vertical to horizontal anisotropy within ore-bearing sands is approximately 1. As shown on Table 2.5-1, the ratio of vertical hydraulic conductivity to horizontal hydraulic conductivity measured from the cores is approximately 0.7. Within the shales the vertical to horizontal anisotropy is much greater. The vertical hydraulic conductivity in the shale is at least an order of magnitude less than the horizontal hydraulic conductivity; in many cases the vertical hydraulic conductivity was measured several orders or magnitude lower than the horizontal hydraulic conductivity. The locations of the core holes and monitoring wells, where pump tests were conducted, which were used to develop hydraulic conductivity estimates are presented on Figure 2.5-1.

2.5.1.3 The Lance Formation

The Lance Formation depositional environment has been interpreted as being fluvio-deltaic in origin (Tschudy 1975). The Lance Formation consists of a mixture of non-marine deposited sandstones and floodplain mudstones with thin beds of coal (Connor 1992). The depositional environment of the Lance Formation created a stratigraphy that is complicated and vertically heterogeneous. Within the Ross ISR Project area, the lower portions of the Lance formation have specific project implications due to several factors including the presence of uranium, a shale confining layer, and the first water-

Table 2.5-1. Core Data-Hydraulic Parameters for Fox Hills Formation

Sample Number[1]	Depth (ft)	Porosity (%)	Horizontal K (ft/day)	Vertical K (ft/day)	Ratio of Vert to Horiz K	Lithology
Hydraulic Parameters for Fox Hills Formation Sandstones						
RMRD 0004	520.3	40.7	8.8			Sandstone minor shale
RMRD 0004	509.8	46.6	5.2			Sandstone very fine grained grey
RMRD 0004	510.5	45.9	11.9			Sandstone very fine grained grey
RMRD 0004	504.8	43.9	2.4			Sandstone very fine grained gray with shale thin 1-2 cm shale breaks
RMRD 0003	451.9	41.3	3.7			Sandstone very fine grained dark grey coarsening upwards sequence.
RMRD 0003	446.5	38.9	2.6			Sandstone very fine grained dark grey coarsening upwards sequence.
RMRD 0003	440.4	42.0	4.3			Sandstone very fine grained light grey
RMRD 0001	578.6	42.2	5.6			Sandstone fine grained light grey shale commons shale clasts to 12 cm
RMRD 0001	534	41.1	3.8			Sandstone minor shale
Nubeth 477V	379.8		3.6	3.3	0.91	sandstone
Nubeth 477V	381.8		3.8	1.2	0.33	sandstone
Nubeth 477V	390.3		4.6	4.2	0.91	sandstone
Nubeth 477V	411		6.1	4.5	0.74	sandstone
Nubeth 477V	433.5		5.5	4.5	0.82	sandstone
Nubeth 477V	450.5		3.0	2.6	0.86	sandstone
Nubeth 477V	500	34	4.0	4.0	0.99	sandstone
Nubeth 477V	506.5	37.8	4.7	2.6	0.55	sandstone
Nubeth 477V	507	35.6	4.1	0.4	0.09	sandstone
Nubeth 477V	511	36.2	7.0	4.5	0.64	sandstone
Nubeth 477V	517	28.6	8.2	6.0	0.73	sandstone
Nubeth 477V	543	36.4	5.5	4.8	0.87	sandstone
Nubeth 477V	557	32.2	5.5	4.8	0.87	sandstone
RMD0007	456	41.7	4.5	1.4	0.31	Sandstone; light grey, firm, moderately friable.
RMRD 0003	482.1	42.24	4.12			silt very fine grained grey
		Average	**5.1**	**3.5**	**0.7**	
		STDEV	**2.1**	**1.6**	**0.3**	
Hydraulic Parameters for Fox Hills Formation Silt						
RMRD 0001	543	38.8	0.18			siltstone siltstone with thin sandy layers
Nubeth 477V	508	32.8	0.66	0.03	0.05	siltstone/mudstone
Nubeth 477V	524	19.6	0.11	0.07	0.67	siltstone/mudstone
Nubeth 477V	531	27.6	0.53	0.46	0.88	siltstone/mudstone
RMD0007	448.4	33.4	0.16	0.05	0.32	Siltstone, dark grey, laminated, few breaks on bedding, firm.
		Average	**0.3**	**0.2**	**0.5**	
		STDEV	**0.2**	**0.2**	**0.4**	
Hydraulic Parameters for Fox Hills Formation Cemented Sandstone						
RMRD 0001	585.9	14.3	0.003			Sandstone Carbonate Cement at 585' to 586'

Table 2.5-1. Core Data-Hydraulic Parameters for Fox Hills Formation (Continued)

Sample Number[1]	Depth (ft)	Porosity (%)	Horizontal K (ft/day)	Vertical K (ft/day)	Ratio of Vert to Horiz K	Lithology
Hydraulic Parameters for Fox Hills Formation Shale						
RMRD 0001	589.5	37.4	0.163			Shale Black dense
RMRD 0001	588.8	38.1	0.135			Shale Black dense
Nubeth 477V	482.5	24.1	0.003	0.00002	0.007	shale/siltstone
Nubeth 477V	490.6	27.8	0.079	0.010	0.132	shale/mudstone
Nubeth 477V	417-421		0.007	0.002	0.220	shale/siltstone
Nubeth 477V	544	29.8	0.029	0.002	0.064	shale
Nubeth 477V	573	25.9	0.018	0.00002	0.001	shale
RMD0006	325	24.1	0.142	0.001	0.007	Claystone; grey, competent, few carbonaceous laminations
RMD0006	333.5	24.2	0.148			Claystone; light brown, bioturbation, competent
RMD0006	465.5	30.2	0.037	0.009	0.240	Claystone siltstone; interlaminated, even claystones are silty
RMD0007	477.2	28.7	0.057			Claystone; dark grey, firm
		Average	**0.074**	**0.003**	**0.096**	
		STDEV	**0.062**	**0.004**	**0.103**	
Hydraulic Parameters for Fox Hills Formation Shale/Sandstone mix						
RMRD 0003	473.7	42.9	3.03			Shale grey with sandstone 1-2 cm sandstone interbeds
RMRD 0003	473	40.7	1.72			Shale grey with sandstone 1-2 cm sandstone interbeds
RMRD 0003	458.7	34.5	0.31			Shale with sand
RMRD 0003	454.3	34.0	0.17			Shale with sand
RMRD 0002	407.5	28.9	0.08			Sandstone fine grained shaly shale clasts to 8 cm
RMRD 0004	502	38.6	0.32			Shale dark grey with sandstone shale with thin sandstone beds
RMD0006	434.6	28.8	0.05	0.03	0.62	Clay pebble zone in sand matrix
		Average	**0.81**	**0.03**	**0.62**	
		STDEV	**1.14**			
Hydraulic Parameters for Fox Hills Formation Sandstone/Silt Mix						
RMRD 0003	491.1	43.4	0.72			Sandstone very fine grained silty carbon and py stringers above lower shale contact
RMRD 0003	462.7	45.3	2.05			Sandstone very fine grained light grey with silt poorly sorted
RMRD 0001	560.8	38.8	1.25			Sandstone with silt
RMD0007	469.2	37.4	1.43	0.44	0.31	Silty sandstone; light grey with numerous dark clay fragments
RMRD 0001	571.12	31.9	0.37			Sandstone very fined grained light grey Fine to very fine grained
		Average	**1.16**	**0.44**	**0.31**	
		STDEV	**0.55**			

[1]Nubeth sample information is from Hamilton, 1977. RMRD 0001, RMRD 0002, RMRD 0003, RMRD 0004 data are from core analysis conducted by Strata in 2009-2010.

Table 2.5-2. Summary of Aquifer Parameters from Pump Tests in the Ore Zone

2010 Pump Tests for Strata Energy in 2010 (WWC 2010)						
Well ID	**Well Type**	**Interpretation Method**	**Transmissivity (ft^2/day)**	**Contributing Aquifer Thickness (ft)**	**Hydraulic Conductivity[2] (ft/day)**	**Storativity (unitless)**
34-7 OZ	Pumping	Theis Recovery	172.50	60	2.88	n/a
42-19 OZ	Pumping	Theis Recovery	13.40	90	0.15	n/a
34-18 OZ	Pumping	Theis Recovery	19.80	105	0.19	n/a
14-18 OZ	Pumping	Theis Recovery	23.80	30	0.79	n/a
21-19 OZ	Pumping	Theis Recovery	25.60	35	0.73	n/a
12-18 OZ	Pumping	Theis Recovery	70.80	94	0.75	n/a
OW1B57-1[1]	Obs. Well	Theis Recovery	96.70	25	3.86	0.0001600
OW1B58-1[1]	Obs. Well	Theis Recovery	80.5	18	4.50	0.0000580
OW1B60-1[1]	Obs. Well	Theis Recovery	84.5	16	5.30	0.0000620
OW1B57-1[1]	Pumping	Theis Recovery	80.30	25	3.21	n/a
OW1B58-1[1]	Obs. Well	Hantush, 1961	111.00	18	6.17	0.0000350
OW1B60-1[1]	Obs. Well	Hantush, 1961	90.80	16	5.68	0.0000130
12-18 OZ	Obs. Well	Theis Drawdown (Confined)	103.90	94	1.11	0.0001100

1977 Pump Tests for Nuclear Dynamic, Inc. (Hamilton 1977, pg 4)

Well ID	**Well Type**	**Interpretation Method**	**Transmissivity (ft^2/day)**	**Aquifer Thickness (ft)**	**Hydraulic Conductivity (ft/day)**	**Storativity (unitless)**
788V	Obs. Well	Theis	19.22	121.00	0.16	0.0000850
789V	Pumping	Jacob Recovery	18.46	118.00	0.16	n/a
791V	Obs. Well	Theis	21.24	114.00	0.19	0.0000990
797V	Obs. Well	Theis	16.83	119.00	0.14	0.0002400

1977 Pump Tests for Nuclear Dynamic, Inc. (Manera 1978)

Well ID	**Well Type**	**Interpretation Method**	**Transmissivity (ft^2/day)**	**Aquifer Thickness (ft)**	**Hydraulic Conductivity (ft/day)**	**Storativity (unitless)**
SP3X	Obs. Well	Jacob Recovery	13.90	85.00	0.16	0.0000500
SP4X	Obs. Well	Jacob Recovery	12.83	85.00	0.15	0.0000750
SP6X	Obs. Well	Jacob Recovery	17.51	85.00	0.21	0.0000450
SP11X	Obs. Well	Jacob Recovery	24.87	85.00	0.29	0.0000500
SP12X	Obs. Well	Jacob Recovery	17.25	85.00	0.20	0.0000470
SP19X	Pumping	Jacob Recovery	29.41	85.00	0.35	n/a
SP78X	Obs. Well	Jacob Recovery	14.30	85.00	0.17	0.0000830

1 Partially penetrating wells located near 12-18OZ.
2 Hydraulic conductivity values are in the horizontal direction.

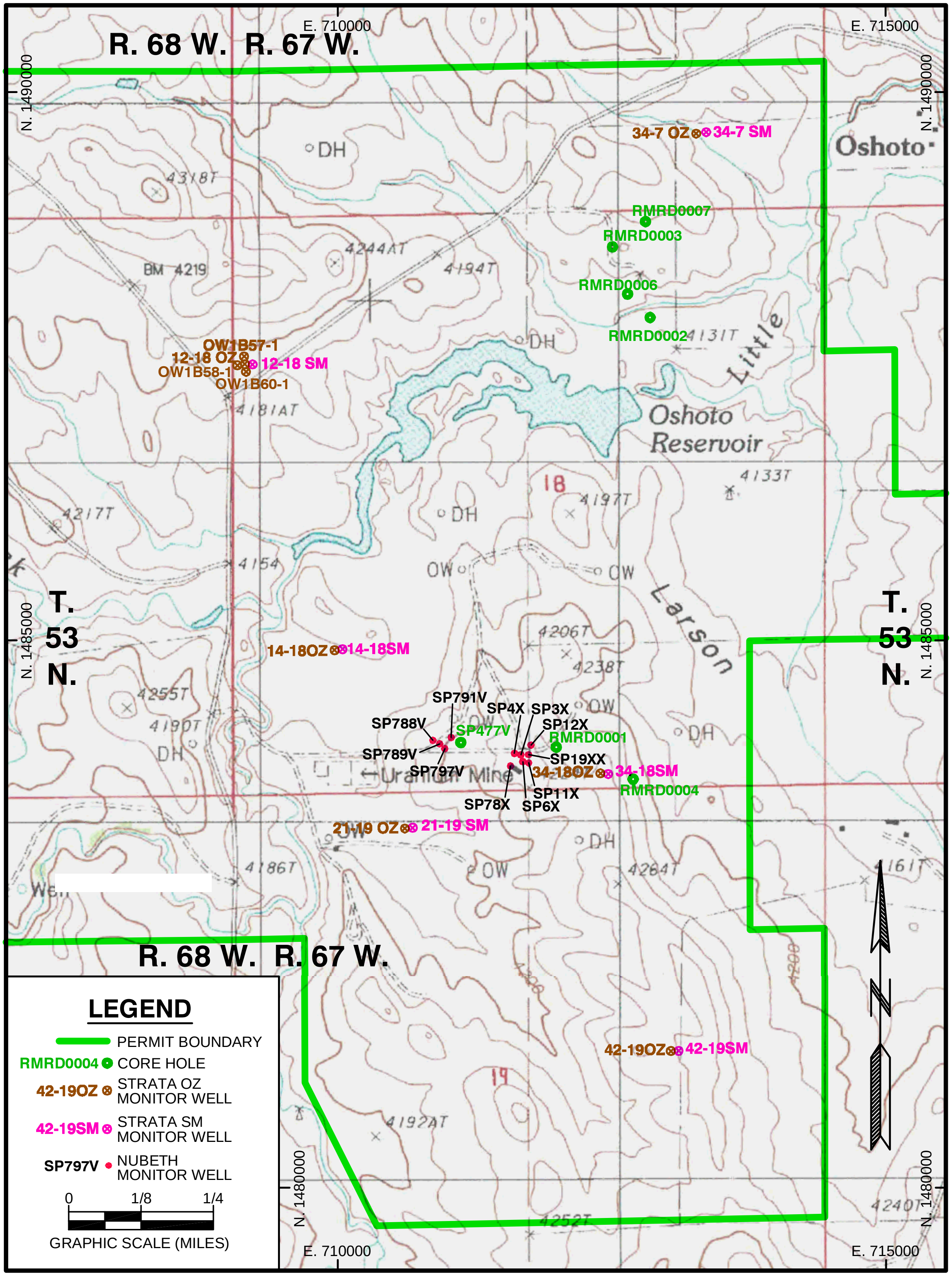


Figure 2.5-1. Locations of Core Holes and Monitoring Wells Used to Develop Hydraulic Conductivity Estimates

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_HYD_CON_LOSS.dwg, GWM_FIGURE_2.5-1, 12/20/2010 11:23:30 AM bearing interval above the ore-bearing zone. At the base of the Lance Formation, the uranium-bearing sandstone ranges in thickness from 30 to 50 feet within the Ross ISR Project area. Above the uranium-bearing sandstone a shale layer varying in thickness from 20 feet to 35 feet, locally called the OZ confining shale acts as upper confinement. The OZ confining shale serves as a confining unit that separates the mineralized sands from the water-bearing SM zone immediately above. The core test results presented in Table 2.5-1 for the shales are the only available measured hydraulic conductivity values for the confining shale. As such, core sample hydraulic conductivity values were used as initial starting values for the hydraulic conductivity of the confining shale. Hydraulic conductivity values for the confining intervals were then adjusted during the model calibration process until horizontal and vertical hydraulic conductivity values of 5×10^{-4} and 6.5×10^{-6} ft/ day, respectively, were utilized for the upper confining shale. This vertical hydraulic conductivity value is comparable to the published values for the Pierre Shale which range from 5×10^{-4} to 5×10^{-8} ft/day.

The shallow monitoring zone (SM) is located above the OZ confining shale. Hydraulic conductivities within the project area for the SM aquifer have been estimated based on drawdowns measured during baseline sampling from 2010. Within the Ross Project area the hydraulic conductivities measured within the SM aquifer range from 0.004 ft/day to 0.8 ft/day. The measured hydraulic conductivity values in the SM aquifer are presented in Table 2.5-3.

Table 2.5-3. Hydraulic Conductivity Values for the SM Aquifer

Based on 2010 water sampling recovery curves (WWC 2010)						
Well ID	**Well Type**	**Interpretation Method**	**Transmissivity (ft^2/day)**	**Screened Thickness (ft)**	**Hydraulic Conductivity (ft/day)**	**Storativity (unitless)**
34-7 SM	Pumping	Theis Recovery	29.10	35	0.800	n/a
42-19 SM	Pumping	Theis Recovery	0.15	30	0.005	n/a
34-18 SM	Pumping	Theis Recovery	0.09	20	0.004	n/a
14-18 SM	Pumping	Theis Recovery	33.44	45	0.740	n/a
21-19 SM	Pumping	Theis Recovery	20.00	55	0.360	n/a
12-18 SM	Pumping	Theis Recovery	6.80	10	0.700	n/a

Above the SM zone is a confining shale referred to as the SM confining shale. No project-specific hydraulic parameters have been measured for the SM confining shale. As with the OZ confining shale, an estimated hydraulic conductivity value for the SM confining shale was derived through trial and error during the calibration process. Calibrated horizontal and vertical hydraulic conductivity values of 7×10^{-4} and 1.45×10^{-5} ft/day, respectively, were utilized for the SM confining shale. This value for vertical hydraulic conductivity is comparable to the published values for the Pierre Shale which range from 5×10^{-8} to 5×10^{-4} ft/day.

Above the SM confining shale is a sequence of thin sands, shales, and silts, which varies in thickness from zero feet where it has been eroded off at the outcrop to nearly 1,000 feet near the west edge of the model domain. This region is referred to as the Lance aquitards. Hydraulic parameters for the Lance aquitards have not been extensively studied. Due to the number of confining shale intervals within the Lance aquitards, they have minimal influence on the SM and OZ aquifers. As such, the only hydraulic conductivity values developed for the Lance aquitards were the model calibrated horizontal and vertical hydraulic conductivity values of 1 and 0.54 ft/day, respectively. These values are higher than would be expected if the Lance aquitards were truly modeled. Since the primary focus of this modeling exercise is on the SM and OZ aquifers, and the Lance aquitards have minimal effects on the SM and OZ aquifers, the Lance aquitards serve as a place holder in the model and are not modeled in detail.

Lying stratigraphically above the Lance aquitards is a sequence of many thin interbedded sands and shales. Some of these sands, which are predominantly thin and areally discontinuous, contain water and may be used locally for livestock and domestic water supplies, however, are not considered to be regionally significant. These shallow sands are believed to provide recharge, as well as receive recharge, from the alluvial/colluvial aquifer system and are considered to be part of the surficial aquifer (SA unit). Where these shallow sands are intersected by surface drainages in the area they may have an impact on the alluvial groundwater and surface water system.

2.5.1.4 Alluvium

There is a minimal amount of recent alluvium within the Ross Project area and the alluvium only has implications to the OZ where it crosses the OZ unit outcrop. Small areas of alluvial and colluvial deposits have been mapped within the model domain by the USGS, most of which lie adjacent to the main channels of the Little Missouri River and Good Lad Creek. Where these deposits are saturated they form a surficial, watertable aquifer. In locations where a shallow Lance Formation sandstone lens is in communication with the alluvium, the surficial aquifer (SA unit) may extend from the alluvium into the sandstone lens. No hydraulic conductivity measurements have been performed on the surficial aquifer within the project area. However, within the region, the hydraulic conductivity of the alluvium of the Belle Fourche River has been estimated to range from 0.1 to 24 ft/day with an average in the range of 5 ft/day (Whitcomb and Morris 1964). The alluvium of the Little Missouri River and Good Lad Creek is thought to have hydraulic conductivities along the same order of magnitude as the Belle Fourche River.

2.5.2 Storage/Specific Yield

An average storativity (S) and specific yield (Sy) were assumed to be uniformly distributed in each layer. For confined aquifers, changes in storage are calculated using specific storage (Ss). Ss is calculated by dividing the storativity by the aquifer thickness. For unconfined aquifers Sy is used to calculate changes in storage. The surficial aquifer (layer 1) is the only aquifer within this model which is not confined. As such, Sy was used in layer 1 with the rest of the layers using Ss values.

The storativity for the OZ aquifer has been measured at several locations within the Ross Project area and is summarized in Table 2.5-1. Measured values of storativity within the OZ aquifer range from 1.3×10^{-5} to 2.4×10^{-4} with an average of 8.1×10^{-5}. The corresponding specific storage values assuming an average aquifer thickness of 100 feet in the OZ aquifer would range from 1.3×10^{-7} to 2.4×10^{-6} with an average of 8.1×10^{-7}. No measured values of storativity are available for the other layers. However, due to noted similarities between the OZ and SM aquifers the storativity within the SM aquifer is assumed to be similar to that of the OZ aquifer.

Within the shale confining layers there are no measured storativity values available. As such, an initial value of Ss for the shale confining layers was estimated based on textbook values and then adjusted during calibration of the model. Using Equation (2.5-1) from Freeze and Cherry (1979).

(Equation 2.5-1) $$Ss=\rho g(\alpha+n\beta)$$

Where:

- ρ=density of water = 1 000 kg/m^3
- g=acceleration of gravity = 9.8 m/s^2
- α=aquifer compressibility = 1.5 x 10^{-11} to 1.5 x 10^{-9} N/m^2 (elastic compressibility of shale, Carmichael 1986)
- n=porosity = 0.29 (Average value Table 2.5-1)
- β=compressibility of water (4.6 x 10^{-10} N/m^2)

The resulting calculated value of Ss is in the range of 4.4 x 10^{-7} ft^{-1} to 5 x 10^{-6} ft^{-1}. The confining layers are composed primarily of over consolidated shale. The onsite geologist overseeing the coring operation reported that when core from the confining shale was hit with a geologist's hammer it was more likely to break than dent which indicates the shale is well consolidated. As such, the confining shale possesses a very low elastic compressibility. The low elastic compressibility of the shale means that when hydraulic head is decreased within the shale, very little compaction of the shale will occur. Hart et al., (2006) presented measured Ss values for the Maquoketa Formation Shale in Wisconsin. Their values ranged from 6.8 x 10^{-7} ft^{-1} to 2 x 10^{-6} ft^{-1} with the lower bound being a minimum Ss value. As such, an Ss value of 5 x 10^{-6} ft^{-1} is a reasonable approximation of the Ss in the Ross area confining shales.

As with the confining layers, there have been no measurements of specific storage within the Lance aquitards. Ss values measured from the OZ aquifer are the best estimates available for the Lance aquitards. As such, Ss values for the Lance aquitards were estimated within the measured range of Ss values for the OZ aquifer (1.3×10^{-7} to 2.4×10^{-6}).

The Sy for the surficial aquifer has not been measured within the project area. However, Whitcomb and Morris (1964) compiled estimated Sy values for the alluvium and the Lance Formation within the region. Based on their measured values, Sy was estimated at 0.19 for the alluvium and 0.10 for the bedrock Lance Formation aquifers.

2.5.3 Leakance

MODFLOW can calculate leakance between the model layers automatically. The leakance is calculated based on the vertical hydraulic conductivity and the layer thickness. Given the low permeability in the vertical direction within the OZ confining shale, the leakance between the SM and OZ layers is expected to be low.

2.6 Water Budget

2.6.1 Recharge

Recharge within the OZ and SM aquifers is expected to be a twofold process with recharge entering the aquifers from the outcrop as well as flowing into the Ross area from the south. The primary source of surficial recharge at the outcrop is expected to be the Little Missouri and Good Lad Creek alluvial systems where they cross the outcrop of each aquifer. Additional recharge may also occur from natural precipitation along the outcrop, although this recharge is limited due to low precipitation rates and relatively high evapotranspiration rates in comparison to precipitation rates.

Recharge to the surficial aquifers is expected to primarily occur via natural precipitation. A small portion of the natural precipitation infiltrates into the Lance formation. A portion of this infiltrated water then finds its way into the alluvium of the Little Missouri and Good Lad Creek. Another portion of the water infiltrated into the Lance Formation travels downdip into the formation to the west.

It is difficult to ascertain just what portion of total precipitation ends up as runoff or recharge. The amount of precipitation that infiltrates and percolates down to the water table will vary based on topography, vegetation, soils, and climatic conditions. Within the recharge zone portion of the Ross Project Area, there are a number of different vegetative covers, soils, and topographical features. Driscoll and Carter (2001) developed recharge estimates for the Black Hills Region of South Dakota. Although their study area did not include the Ross Project area the study was performed within the same region and is thought to be applicable to conditions within the Ross Project area. In general the recharge rates developed by Driscoll and Carter were highly variable ranging from 0.04 inches per year within the Cretaceous-Sequence Confining Unit and up to 2.93 inches per year within the Madison and Minnelusa Formations. Since the Ross Project area lies on the western periphery of the Black Hills where precipitation is much less and the Lance Formation is much less permeable, recharge within the Ross Area is thought to be much closer to 0.04 inches per year than 2.93 inches per year.

Recharge rates can be highly affected by conditions on the soil horizon. The bulk of precipitation returns to the atmosphere through evapotranspiration. Recharge only occurs when water infiltrates below the plant root depth (Carter and Driscoll 2001). To account for conditions on the soil horizon soils mapping developed by the NRCS (USDA NRCS 2009) was used to spatially vary the recharge rates throughout the model area. Hydrologic information compiled by the NRCS for each soil complex was used to approximate infiltration rates for each expected soil complex. Section 4.2.3 describes the process used to develop initial recharge rate estimates in more detail.

2.6.2 Evapotranspiration

Along the main channels of the ephemeral drainages within the Ross Project area there are several locations where wetland vegetation has been identified. Evapotranspiration (ET) at these locations is expected to result in water removed from the alluvial system. Grass ET estimates for the Moorcroft area range from 31.44 to 44.74 inches per year with a mean of 36.85 inches per year (Pochop, et al. 1992). Assuming an average precipitation rate of 13 inches per year, the resulting net annual evapotranspiration rate is 23.85 inches per year. Using an aerial photograph, the locations of significant wetland vegetation were identified within the model. These areas were assigned an initial evapotranspiration rate of 23.85 inches per year. Adjustments to the areal extent of evapotranspiration as well as the evapotranspiration rates were then made during the calibration process in order to meet target discharge rates and heads within the project area.

2.6.3 Drains

As described in Section 2.3, within the lower confined layers groundwater flow is to the west and north into the Powder River Basin. Within the domain of the model no natural drains exist for the confined layers. Water supply wells constructed for oilfield development within the Fox Hills Formation serve as artificial drains. However, the water supply wells were modeled as wells rather than drains. Within the surficial layer the alluvium of Good Lad Creek and the Little Missouri River serve as drains to the system. After water in the alluvium crosses the Pierre Shale outcrop, it no longer has a hydrologic connection to the modeled system. Drains installed in both the Little Missouri and the Good Lad drainages where they cross the outcrop simulate water leaving the model. No field measurements have been taken to characterize the true alluvial underflow leaving the model at the drains. Given the wide variability of estimates which may be used to calculate the size of the alluvium and the hydraulic conductivity within the alluvium, estimates of alluvial underflow vary from nearly 0 gallons per minute (gpm) to as much as 10 gpm. The drains also represent water leaving from evapotranspiration and surficial runoff from the alluvium, which is harder to quantify. For the purposes of model calibration a pre-abstraction steady state target outflow of less than 10 gpm was maintained at the drains.

3.0 COMPUTER CODES

3.1 Software

The numerical groundwater model utilizes the USGS modular finite-difference groundwater model MODFLOW (MacDonald and Harbaugh 1988) and the pre/post processor Groundwater Vistas (Rumbaugh and Rumbaugh 2002). Groundwater Vistas with MODFLOW2000 and MODFLOW88/96 were chosen for this modeling effort because they are widely accepted within the groundwater modeling community. Groundwater Vistas and MODFLOW have been used to construct other groundwater flow models for ISR projects in the past and are widely used and accepted by both industry and regulatory agencies.

3.2 MODFLOW Input Files

Eight MODFLOW packages were used in the Ross ISR Project groundwater model. The packages include:

- Basic - Basic Package containing starting heads, constant heads, and some options
- Block centered flow - bcf used in MODFLOW88/96, contains aquifer property data and grid spacings.
- Output Control – Determines what model results to print and save to files during simulation
- Solver – PCG2 was primarily utilized to solve the partial differential equations in MODFLOW although for calibration purposes other solvers were used to help achieve convergence
- Well – Well boundary conditions
- Drain - Drain boundary conditions package
- General Head – General head boundary conditions
- Recharge – Recharge boundary condition
- ET-Evapotranspiration boundary condition

In addition to the MODFLOW packages described above two packages specific to MODFLOW2000 were used. They include:

- LPF-Layer-Property Flow
- DIS-Discretization

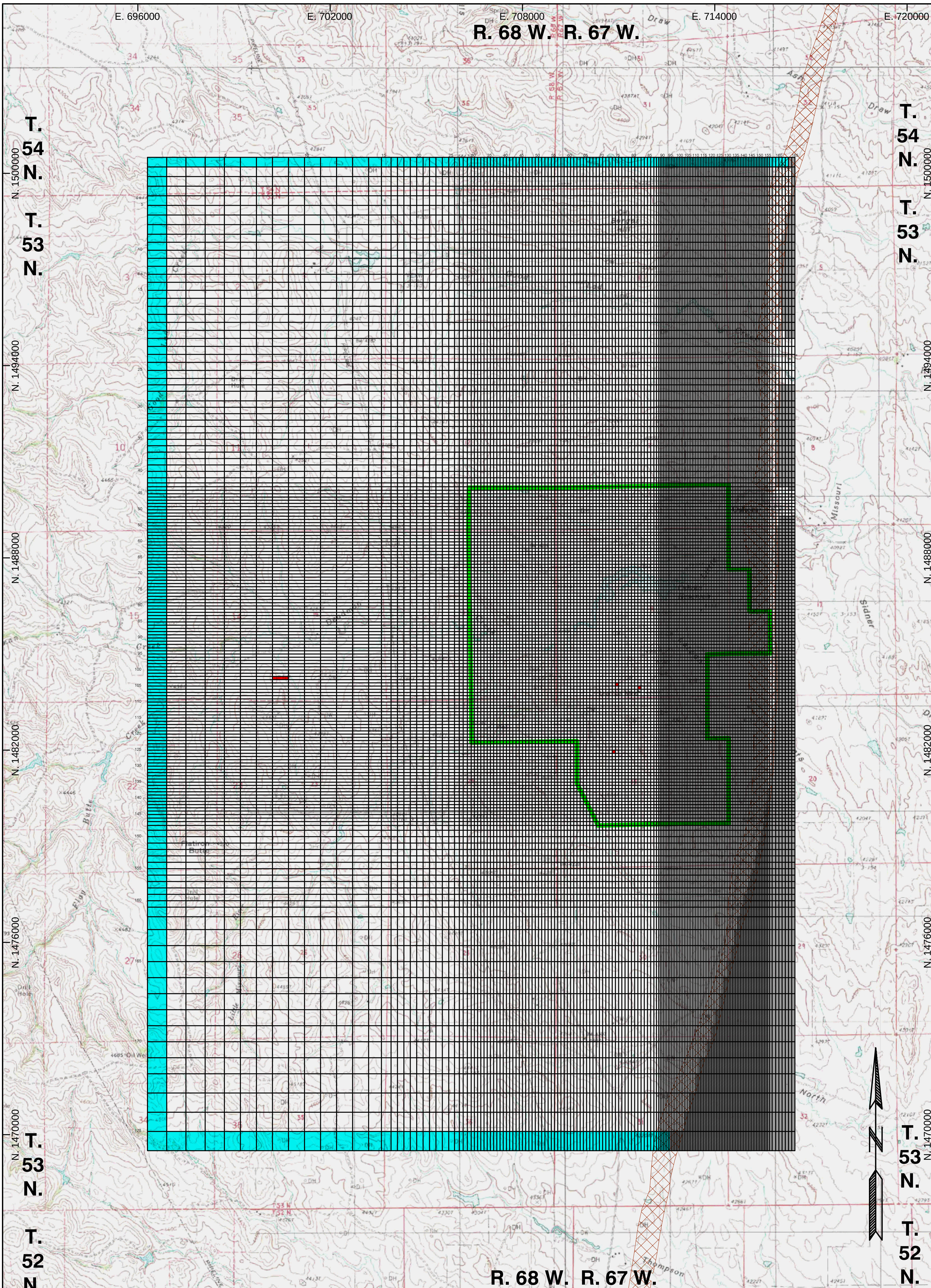
3.3 Limitations and Assumptions

As with any modeling software there are a number of limitations and assumptions built into the code. MacDonald and Harbaugh (1988) describe limitations and assumptions within the MODFLOW code in detail. Rumbaugh and Rumbaugh (2002) describe the limitations and assumptions built into Groundwater Vistas. Many of the assumptions and limitations within the modeling software are the result of inaccuracies inherent in modeling a natural system and are generally similar for all modeling software. Limitations and assumptions specific to this modeling effort are primarily due to the paucity of data on physical and hydraulic characteristics of the aquifers and confining units, as described in detail within this report.

4.0 MODEL CONSTRUCTION

4.1 Model Domain

The model grid is oriented parallel to the geologic strike of the Fox Hills outcrop, which is generally north-south. The model area encompasses some 14,376 acres. The model is constructed with a variably spaced grid having a minimum cell spacing of 50 x 100 ft in the project area and a maximum spacing of 300 x 600 ft near the edges of the model area. The maximum increase in size between adjacent cells is limited to less than 1.5 times in order to eliminate numerical errors (Anderson and Woessner 1992). The finite difference grid consists of 176 rows along the north-south axis and 165 columns along the east-west axis, covering distances of 31,000 feet and 20,200 feet, respectively. The model grid is depicted on Figure 4.1-1. The model domain was sized to minimize edge effects. During the initial model development stage a smaller model domain was used. However, edge effects from the smaller model domain were unacceptable. ISR simulation drawdowns discussed within Section 4.9 of this report indicate that with the expanded model domain edge effects are very minor. The model consists of seven layers which are defined as follows:



ROSS PROJECT AREA

LEGEND

- MODEL GRID
- FOX HILLS OUTCROP (RECHARGE ZONE)
- CONSTANT HEAD BOUNDARY
- NO FLOW BOUNDARY (REPRESENTS CONFIGURATION IN LAYER 6)

0 1500 3000 6000

GRAPHIC SCALE (FEET)

Fox Hills sand outcrop adapted from Halberg, L.L., Et. Al., Geologic Map of the Sundance 30' X 60' Quadrangle, Crook and Weston Counties, Wyoming and Lawrence and Pennington Counties, South Dakota: Wyoming State Geological Survey Map Series 78, Scale 1:100,000.

STRATA ENERGY

REVISIONS	
Date	Description

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

GWM TECHNICAL REPORT
FIGURE 4.1-1

GROUNDWATER MODEL GRID

Drawn By: RAM
Checked By: BJS
Date: 10-10

WWC ENGINEERING
www.wwcengineering.com

FILE: ROSS_TR_GWM_GRID

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_GRID.dwg, GWM_FIGURE_4.1-1, 12/20/2010 11:25:20 AM

- Layer 1- Represents the SA unit. This layer includes the top 20 feet of the entire model domain, and is comprised primarily of surficial alluvial and colluvial deposits, as well as a number of thin Lance bedrock sands interbedded with shales that form shallow discontinuous aquifers that are believed to provide recharge as well as receive discharge from the alluvial system where they come into contact with it.

- Layer 2-Represents the Lance aquitards above the SM confining interval.

- Layer 3-Represents the SM confining interval. Located within the Lance Formation, this layer represents a thick shale that separates the SM from the Lance aquitards above.

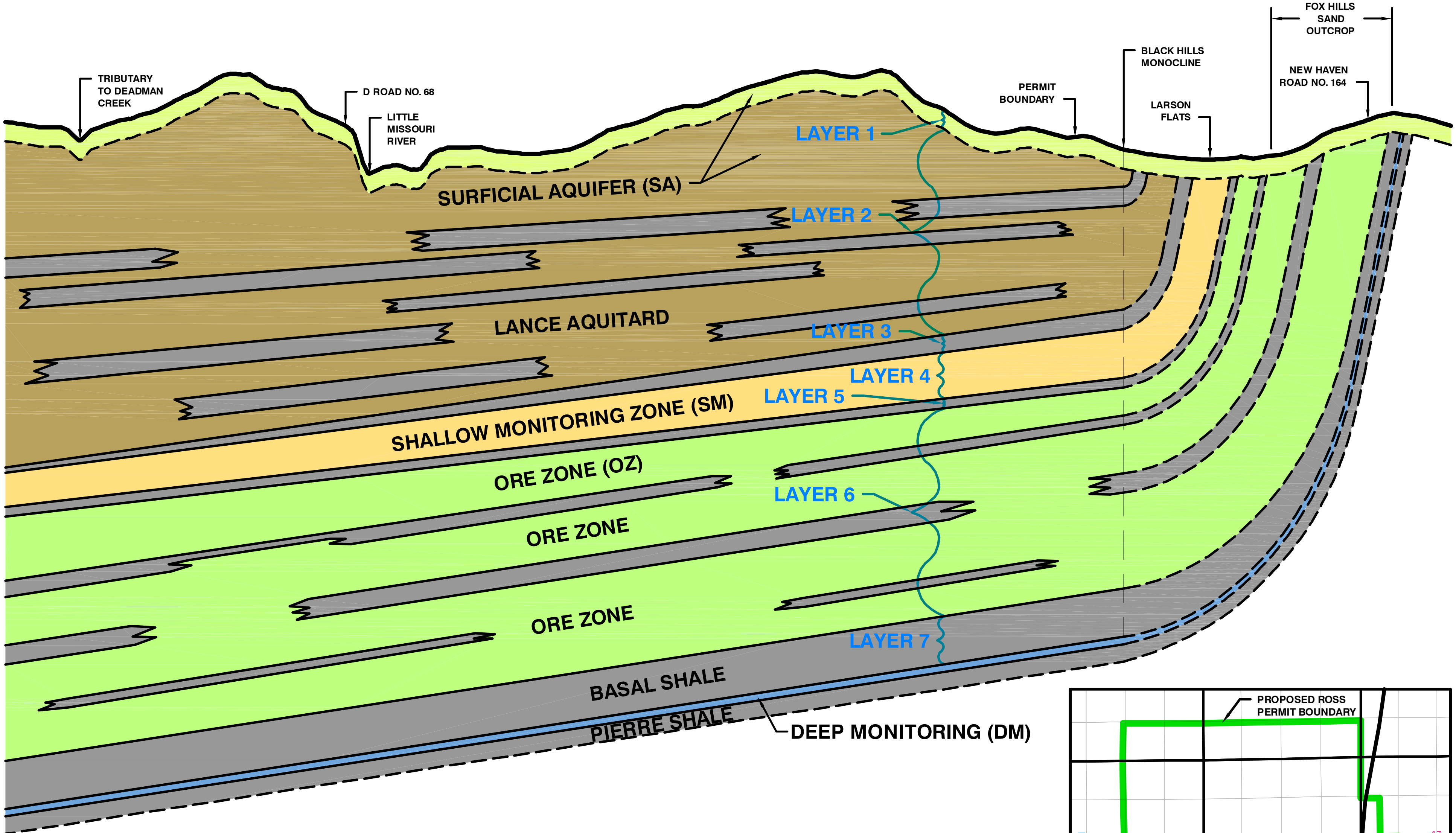
- Layer 4-Represents the Shallow Monitoring (SM) zone. Located within the Lance Formation, this is the first aquifer above the OZ confining interval and will be monitored during ISR.

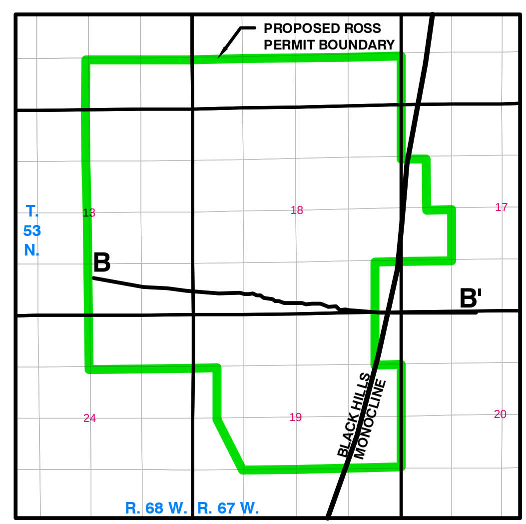
- Layer 5-Represents the OZ confining interval. Located within the Lance formation this is a thick shale that separates the OZ aquifer from the SM aquifer.

- Layer 6-Represents the ore containing aquifer. This aquifer is located within the lower Lance and upper Fox Hills formations.

- Layer 7-Represent the Fox Hills basal confining shale between the OZ and the DM.

The model simulates layer 7 as an impermeable boundary. Given that, the underlying shale averages 50 or more feet thick within the project area, and hydrologic testing do not indicate communication between the OZ and DM, this is a reasonable assumption. Figure 4.1-2 depicts a conceptual cross sectional view within the Ross Project area. The upper and lower surfaces for each layer were developed based on a 2 step process. West of the Black Hills monocline, the layer surfaces were developed based on geologic boreholes within the project area. To develop the layer surfaces, electric logs from current and historical exploration efforts within the greater Oshoto area were loaded into geologic modeling software Gemcom. Picks at each stratigraphic break were made manually for boreholes. Stratigraphy for the groundwater model was based on electric logs from the 2010 monitor well clusters. In areas where the





Black Hills Monocline adapted from Sutherland, W.M., 2008, Geologic Map of the Devils Tower 30' X 60' Quadrangle, Crook County, Wyoming, Butte and Lawrence Counties, South Dakota, and Carter County Montana: Wyoming State Geological Survey Map Series 81, Scale 1:100,000.

Fox Hills sand outcrop adapted from Halberg, L.L., Et. Al., Geologic Map of the Sundance 30' X 60' Quadrangle, Crook and Weston Counties, Wyoming and Lawrence and Pennigton Counties, South Dakota: Wyoming State Geological Survey Map Series 78, Scale 1:100,000.

CONCEPTUAL CROSS SECTION B-B'

NOT TO SCALE

Figure 4.1-2.

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_CONCEP_XS.dwg, GWM_FIGURE_4.1-2, 12/20/2010 11:26:50 AM geology is complicated between the monitor well clusters and to the north, south, and west of the project area additional boreholes were used to help define the surface. The geologic model was then used to prepare a 3D surface representative of each layer. East of the Black Hills Monocline no borehole information was available. However, the Fox Hills outcrop has been mapped by the USGS. Using the Fox Hills outcrop as a guide, the surface of each layer was extrapolated to the surface. Actual cross sections from the groundwater model cut at various rows are depicted on Figure 4.1-3. The location of each row where the cross sections were cut are presented in Figure 4.1-1.

4.2 Hydraulic Parameters

The hydraulic parameters used in the groundwater model include hydraulic conductivity, storage, recharge, and evapotranspiration. Specific values for each parameter are described in the following sections. As previously described in Section 2.5, the modeling approach was to calculate reasonable starting values (as presented in Section 2.5). Then, during the calibration process the values were updated as necessary to meet the various calibration targets. The calibration process is described in more detail within Section 4.5.

4.2.1 Hydraulic Conductivity

Known hydraulic conductivity information available for the model area is discussed in Section 2.5.1.2. The hydraulic conductivities assigned within the model were based on the data presented in that section and subsequent calibration runs Table 4.2-1 summarizes the horizontal hydraulic conductivity values used for each layer and Table 4.2-2 summarizes the vertical hydraulic conductivity values used for each layer. During the calibration process, the vertical hydraulic conductivity was typically calculated by multiplying the horizontal hydraulic conductivity by 0.7 in all layers except for the shale layers where the vertical hydraulic conductivity was several orders of magnitude lower than the horizontal hydraulic conductivity. Figures 4.2-1, 4.2-2, and 4.2-3 present the spatial distribution of the hydraulic conductivities assigned to

Figure 4.1-3. Actual East West Cross Sections From Various Rows Within the Ground Water Model

HORIZONTAL SCALE 1" = 1/2 MILE VERTICAL EXAGGERATION 4X

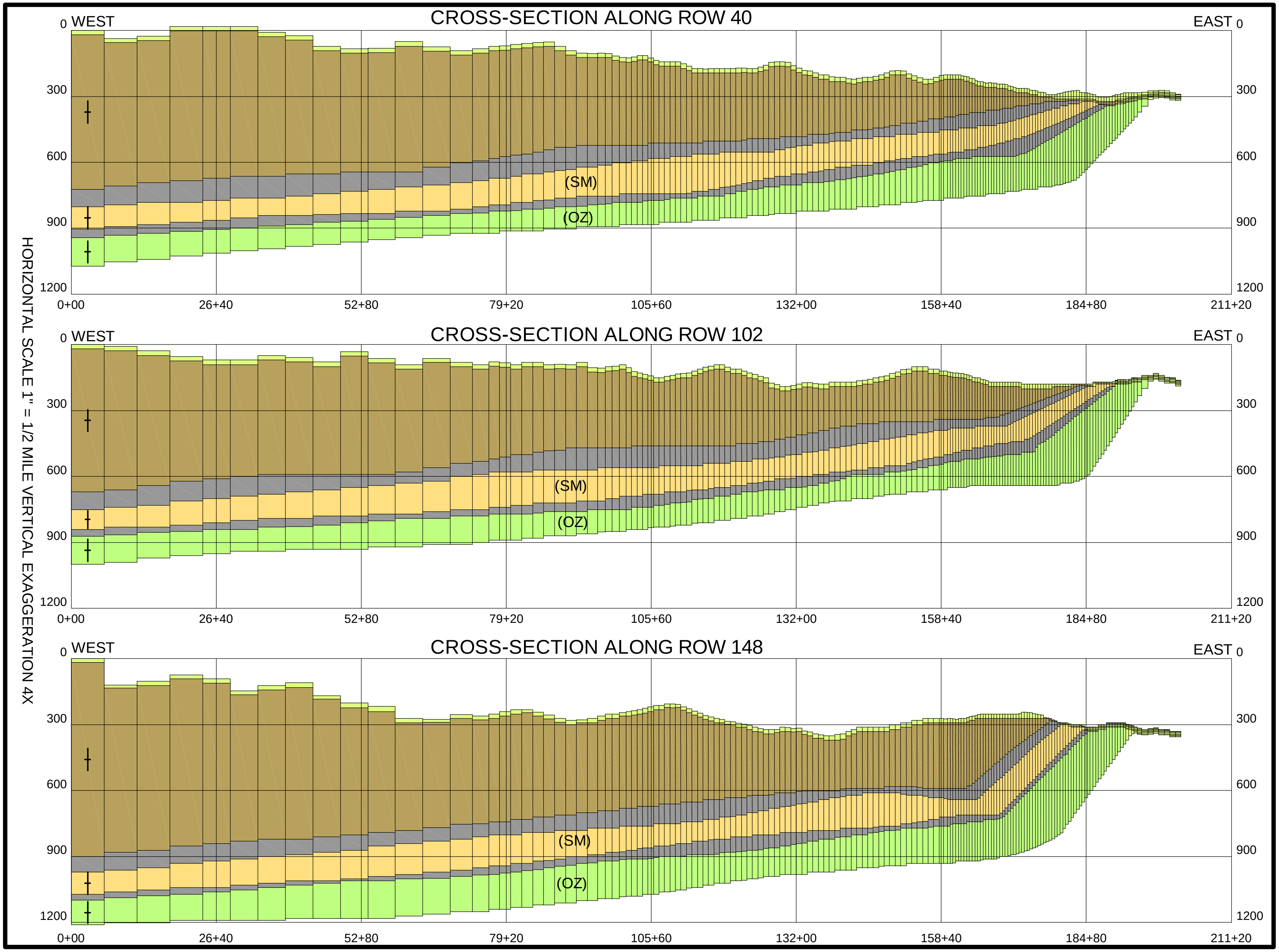


Table 4.2-1. Summary of Horizontal Hydraulic Conductivity Values Used in the Model

Layer	Aquifer Unit	Model Hydraulic Conductivity values (ft/day)			
		Minimum	Maximum	Predominant Inside Ross Project Area	Predominant Outside Ross Project Area
1	Alluvium/top 20 feet	5.00	15.00	5.00	5.00
2	Lance aquitard	0.10	0.10	0.10	0.10
3	Confining unit	$7x10^{-4}$	$7x10^{-4}$	$7x10^{-4}$	$7x10^{-4}$
4	Lance SM	0.003	3.00	Varies	0.32
5	Confining unit	$5.0x10^{-4}$	$5.0x10^{-4}$	$5.0x10^{-4}$	$5.0x10^{-4}$
6	Lance/Fox Hills OZ	0.01	3.00	Varies	0.19

Table 4.2-2. Summary of Vertical Hydraulic Conductivity Values Used in the Model

Layer	Aquifer Unit	Model Hydraulic Conductivity values (ft/day)			
		Minimum	Maximum	Predominant Inside Ross Project Area	Predominant Outside Ross Project Area
1	Alluvium/top 20 feet	3.00	10.00	3.00	3.00
2	Lance aquitard	0.54	0.54	0.54	0.54
3	Confining unit	$1.45x10^{-5}$	$1.45x10^{-5}$	$1.45x10^{-5}$	$1.45x10^{-5}$
4	Lance SM	0.002	2.1	Varies	0.21
5	Confining unit	$6.5x10^{-6}$	$6.5x10^{-6}$	$6.5x10^{-6}$	$6.5x10^{-6}$
6	Lance/Fox Hills OZ	0.08	2.10	Varies	0.12

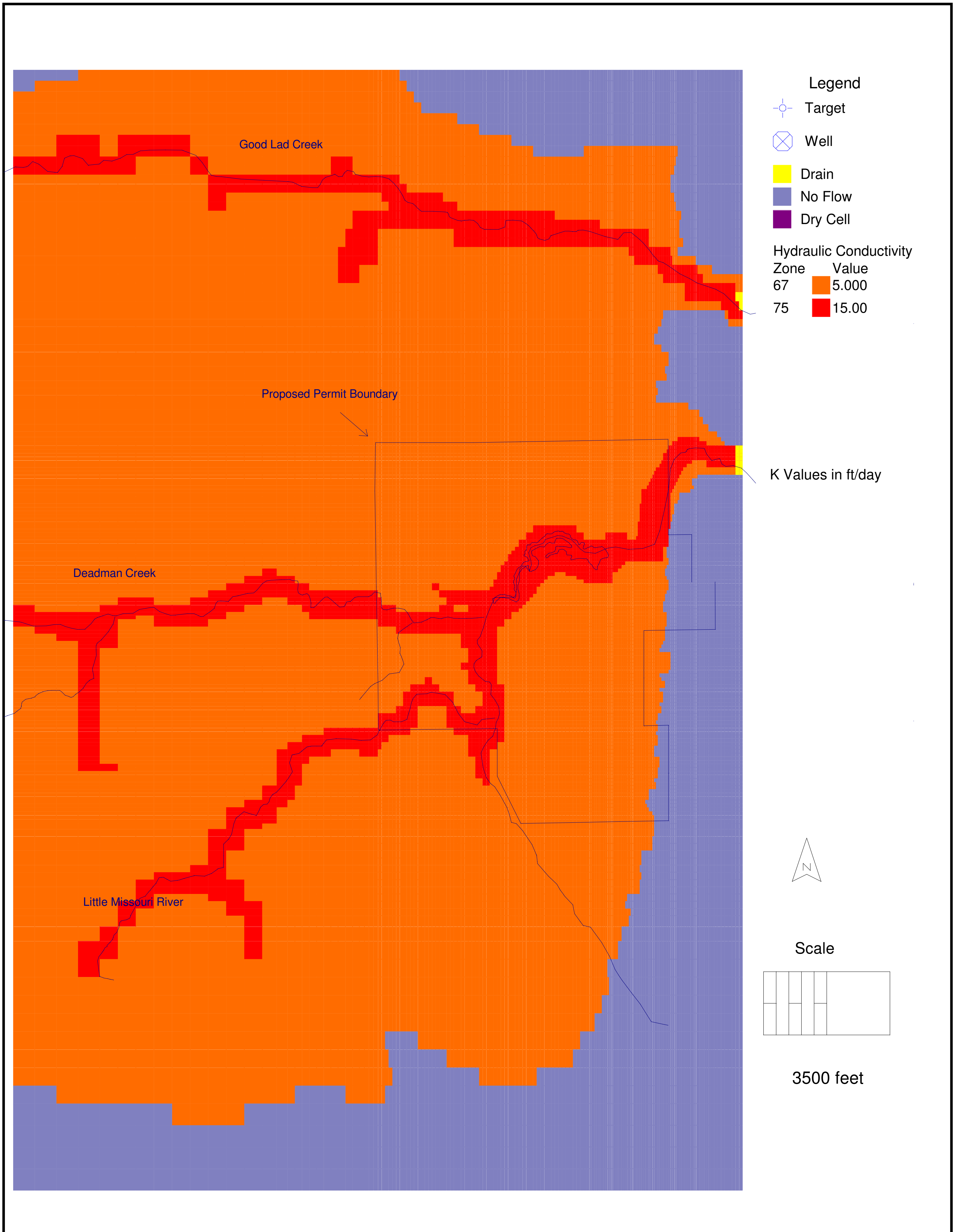


Figure 4.2-1 Spatial Distribution of Hydraulic Conductivity Assigned to Layer 1 (SA)

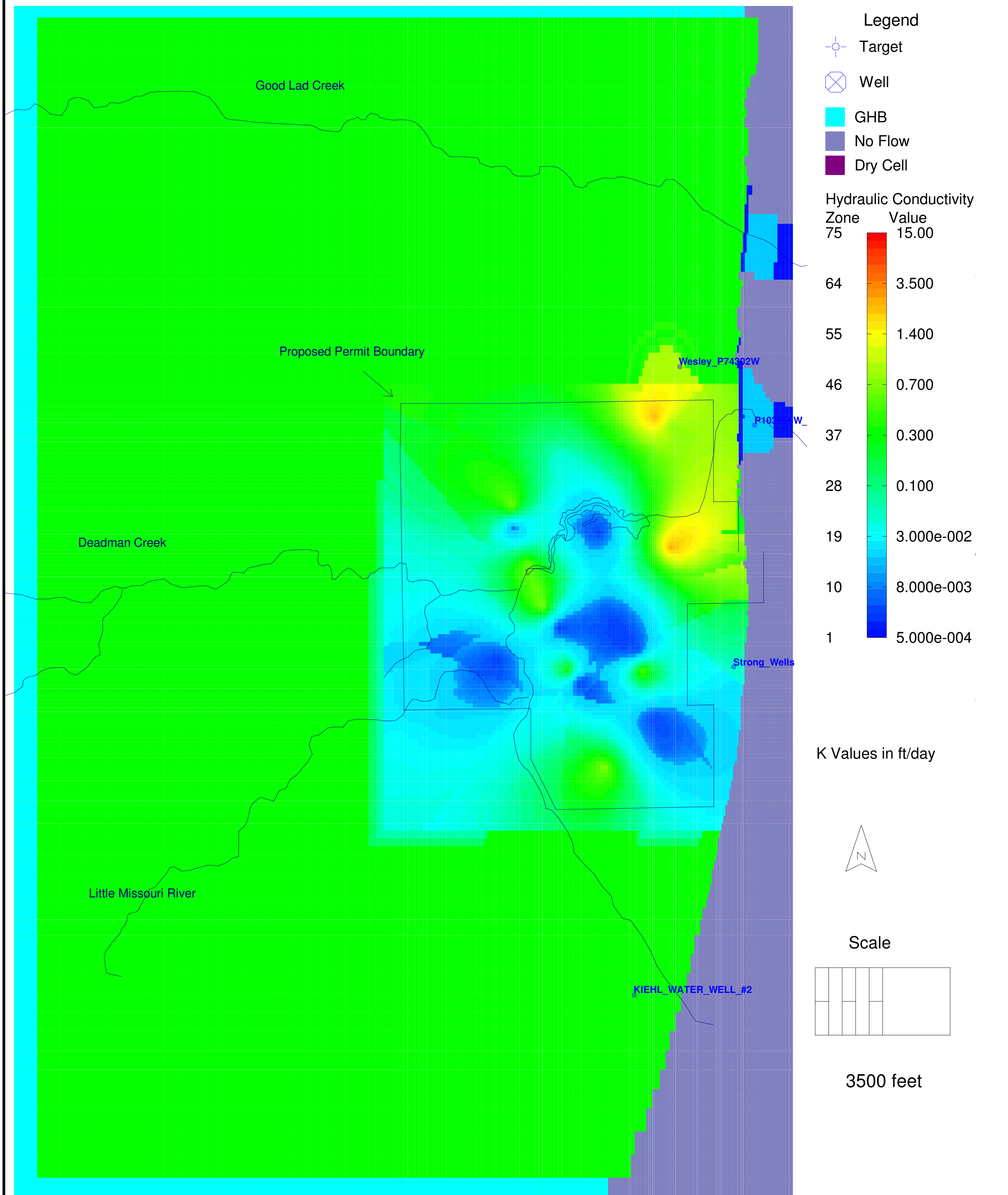


Figure 4.2-2 Spatial Distribution of Hydraulic Conductivity Assigned to Layer 4 (SM)

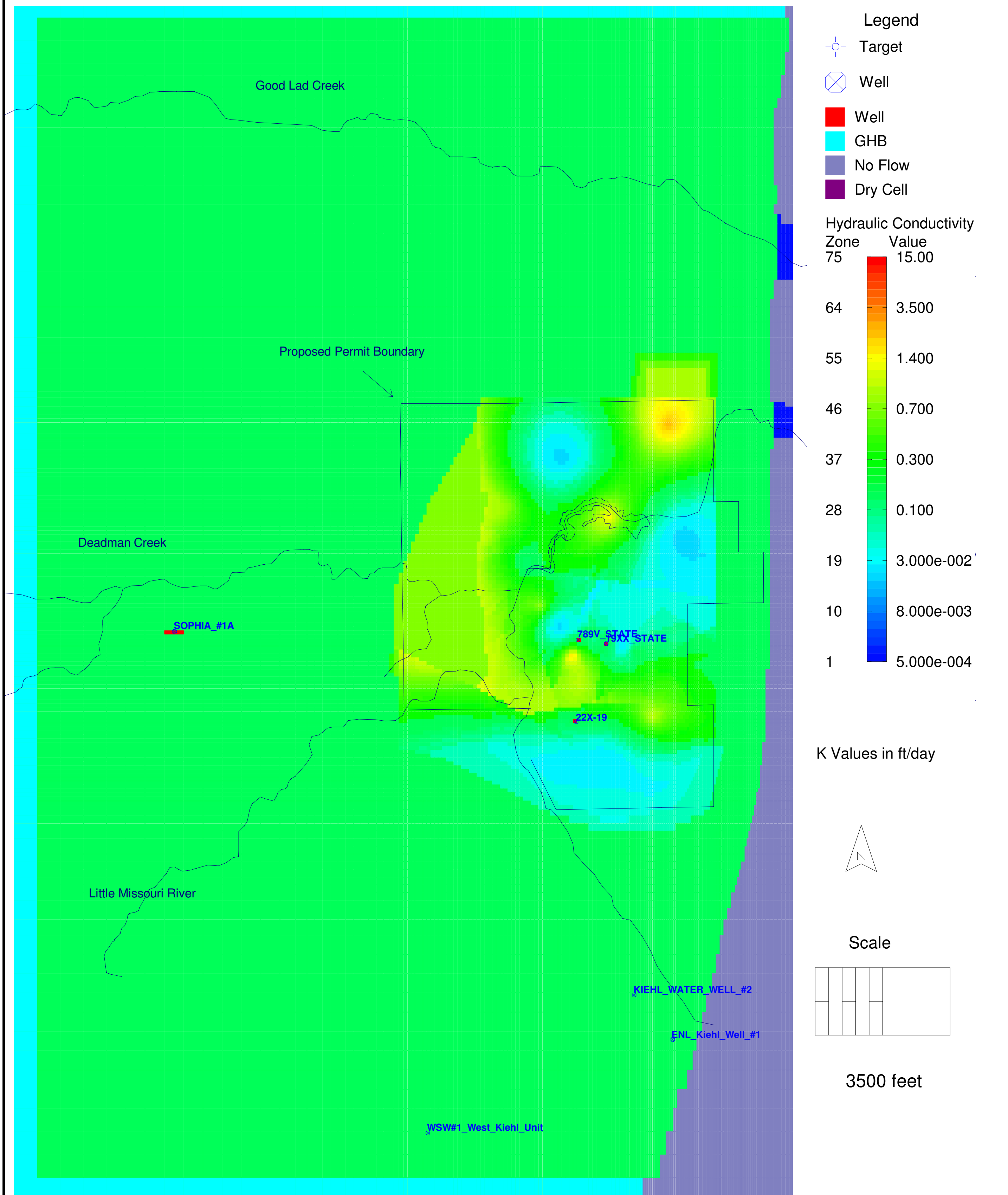


Figure 4.2-3 Spatial Distribution of Hydraulic Conductivity Assigned to Layer 6 (OZ)

layers 1, 4, and 6, respectively. The hydraulic conductivity was not spatially varied within layers 2, 3, and 5 except near the outcrop beneath Good Lad Creek and the Little Missouri River. Groundwater Vistas does not allow layers to truncate prior to the edge of the model. As a result, where the drainages cross the outcrop and the top layers do not become inactive it was necessary to vary the hydraulic conductivity to simulate vertically dipping strata through the layers.

4.2.2 Storage Coefficients

As described in Section 2.5.2, estimated storage coefficients were developed for each layer based on measured data and/or research on similar materials. Storage coefficients were then adjusted within the estimated ranges during model calibration. MODFLOW2000 utilizes specific storage (Ss) rather than a storage coefficient. As such, all storage coefficients were converted to a specific storage value prior to input in the model. Each layer was assigned a unique specific storage value which did not vary spatially. Specific storage values used for each layer are summarized on Table 4.2-3. Since it was possible that the potentiometric surface could drop below the top of the OZ aquifer a specific yield value of 0.1 was assigned to Layer 6.

Table 4.2-3. Summary of Specific Storage Values by Layer

Layer	**Aquifer Unit**	**Model Specific Storage Values (1/ft)**
1	Alluvium/top 20 feet [1]	0.19 within alluvium, 0.1 outside of alluvium
2	Lance aquitard	$5x10^{-7}$
3	Confining unit	$4x10^{-6}$
4	Lance SM	$7.6x10^{-6}$
5	Confining unit	$4x10^{-6}$
6	Lance/Fox Hills OZ	$9.7x10^{-6}$

[1]Alluvium values are specific yield (dimensionless)

4.2.3 Recharge

As described in Section 2.6.1 recharge enters the model from adjacent aquifers through the natural groundwater gradient as well as from precipitation and streamflow at the outcrop. Recharge from adjacent areas within the aquifer is indirectly calculated through the calibration process and the use of general head boundaries at the model edge. The distribution of recharge from natural precipitation within the project area was developed based on USDA-NRCS soils data (USDA-NRCS 2009). The NRCS has assigned for (A, B, C, or D) hydrologic soil groups for each mapped soil complex. No soils in the project area are in Group A. A B hydrologic soil group indicates the soil has a moderate infiltration rate, a C represents a soil with a slow infiltration rate, and a D soil has a very slow infiltration rate (Viessman and Lewis 1996). The B, C, and D soils were then assigned recharge coefficients, based on retention loss rates presented by the USBR (1977). Soils with hydraulic ratings of B, C, and D were assigned recharge coefficients of 1, 0.5, and 0.33, respectively. Within the Ross groundwater model domain an initial recharge rate of 0.6 inches per year was assigned to B rated hydrologic soils. The C and D soil recharge rates were assigned by multiplying the respective coefficients by 0.6 inches. Recharge rates applied to each soil type were then adjusted during model calibration until head and discharge targets within the alluvial drains were met. In this way calibrated recharge values for the entire model domain were developed.

Calibrated recharge was applied to the top layer throughout the model domain. In regions where the top layer was inactive (such as a no flow boundary), Groundwater Vistas applies recharge to the next highest active layer (Rumbaugh 2010). For example, at the outcrop where the OZ aquifer has 5 inactive layers above, Groundwater Vistas applies the recharge directly to the OZ layer. Calibrated recharge rates for the soils are presented in Table 4.2-4. Figure 4.2-4 depicts the spatial distribution of recharge within the model domain. For most of the stream drainages, the model domain extends nearly to the top of the respective drainage divides. However, upstream from the domain,

Table 4.2-4. Model Calibrated Recharge Rates within the Ross Project Area

NRCS Hydrologic Soil Rating	Model Calibrated Recharge Rate	
	ft/day	inch/yr
B	$5.1\text{x}10^{-5}$	0.22
C	$2.55\text{x}10^{-5}$	0.11
D	$1.7\text{x}10^{-5}$	0.07

Flag Butte Creek and Deadman Creek have drainage areas of roughly 1,670 acres and 1,231 acres, respectively. Since the upstream drainage area for each drainage is significant, one cell with a higher recharge rate of 3.02×10^{-4} ft/day (1.3 in/yr) was placed at the intersection of the model and the stream channel. This higher rate simulates an increased recharge from the upstream alluvium.

4.3 Sinks

Within the model domain there are three methods by which water naturally leaves the domain: 1) Water within the confined aquifers naturally flows to the north and to the west down dip away from the project area, 2) Water within the alluvium is removed by evapotranspiration, and 3) Water leaves the project area through alluvial flow down the natural drainages. Water is also removed artificially by pumping wells within the project area. The volume of water removed by pumping wells has been significant, however it is not a natural stressor on the system. As such, pumping wells within the project area are treated as transient stressors to the system and are described in more detail later in this report.

General head boundary conditions were used to simulate the natural gradient and thus simulate water leaving the model within the confined layers. The general head boundary conditions are described in more detail within Section 4.4. Within the surficial system evapotranspiration and drains are used to simulate water leaving the model. As described in Section 2.6.2, an evapotranspiration component was assigned to cells in which evapotranspiration is expected to occur. The number of cells with evapotranspiration and the evapotranspiration rate were then adjusted during

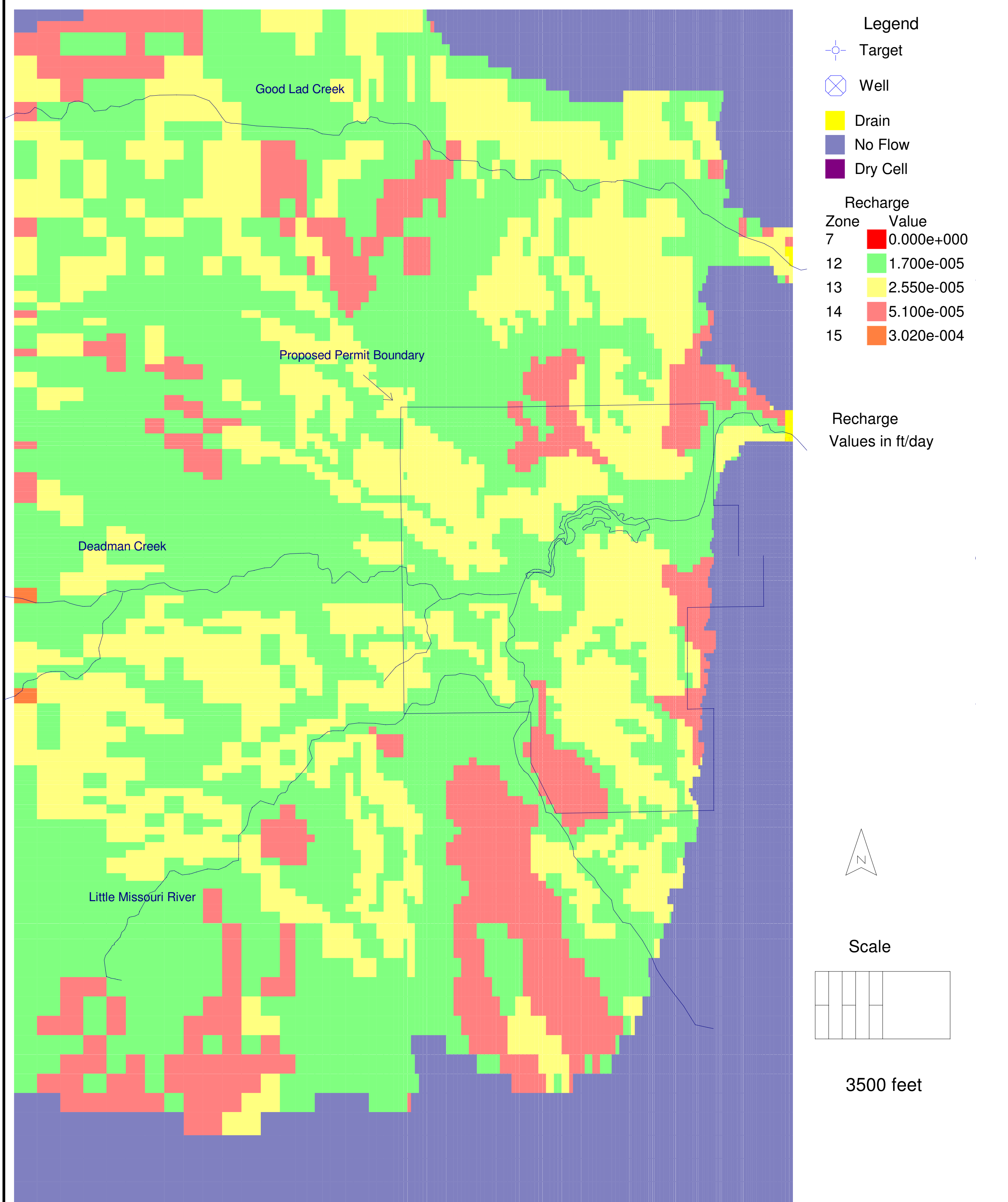


Figure 4.2-4 Spatial Distribution of Recharge Within the Model Domain

model calibration to improve calibration of the model. The calibrated evapotranspiration rate was 4.8 x 10^{-3} ft/day (21 inches per year). The location of the cells in which evapotranspiration were simulated within the model are shown on Figure 4.3-1. Drains were also used to simulate evapotranspiration and alluvial water leaving the model. Drains were installed near the eastern extent of the model where Good Lad Creek and the Little Missouri River cross into the Pierre Shale outcrop. The drains were set at an elevation just below the existing ground surface which represents the alluvial water surface. The locations of the drains within the groundwater model domain are also depicted on Figure 4.3-1.

4.4 Boundary Conditions

The boundary conditions within the model vary slightly from layer to layer. For each layer the boundary conditions are summarized below:

Layer 1 - The boundary conditions within layer 1 are shown on Figures 4.2-1 and 4.3-1. Since Layer 1 represents the surficial system, the drainage divide for each ephemeral drainage serves as a natural no flow boundary. The southern and northern bounds of the model domain cross several natural drainage divides which are represented by no flow boundary cells. Recharge to the surficial system is expected to occur primarily from precipitation. Therefore, a recharge boundary condition is applied to the entire model domain. The eastern portion of the model is represented by a no flow boundary just to the west of the Lance Formation outcrop. This allows recharge to enter directly into the underlying layers that outcrop to the east. Where the Little Missouri River and Good Lad Creek cross the Pierre Shale, drains set at an elevation to represent the alluvial water surface serve as the boundary conditions.

Layers 2 (Lance aquitard), 4 (SM), and 6 (OZ) - These layers are represented by general head boundaries along the south, west and north portions of the model domain. In each layer the east portion of the model is represented by a no flow boundary that follows the outcrop of each respective

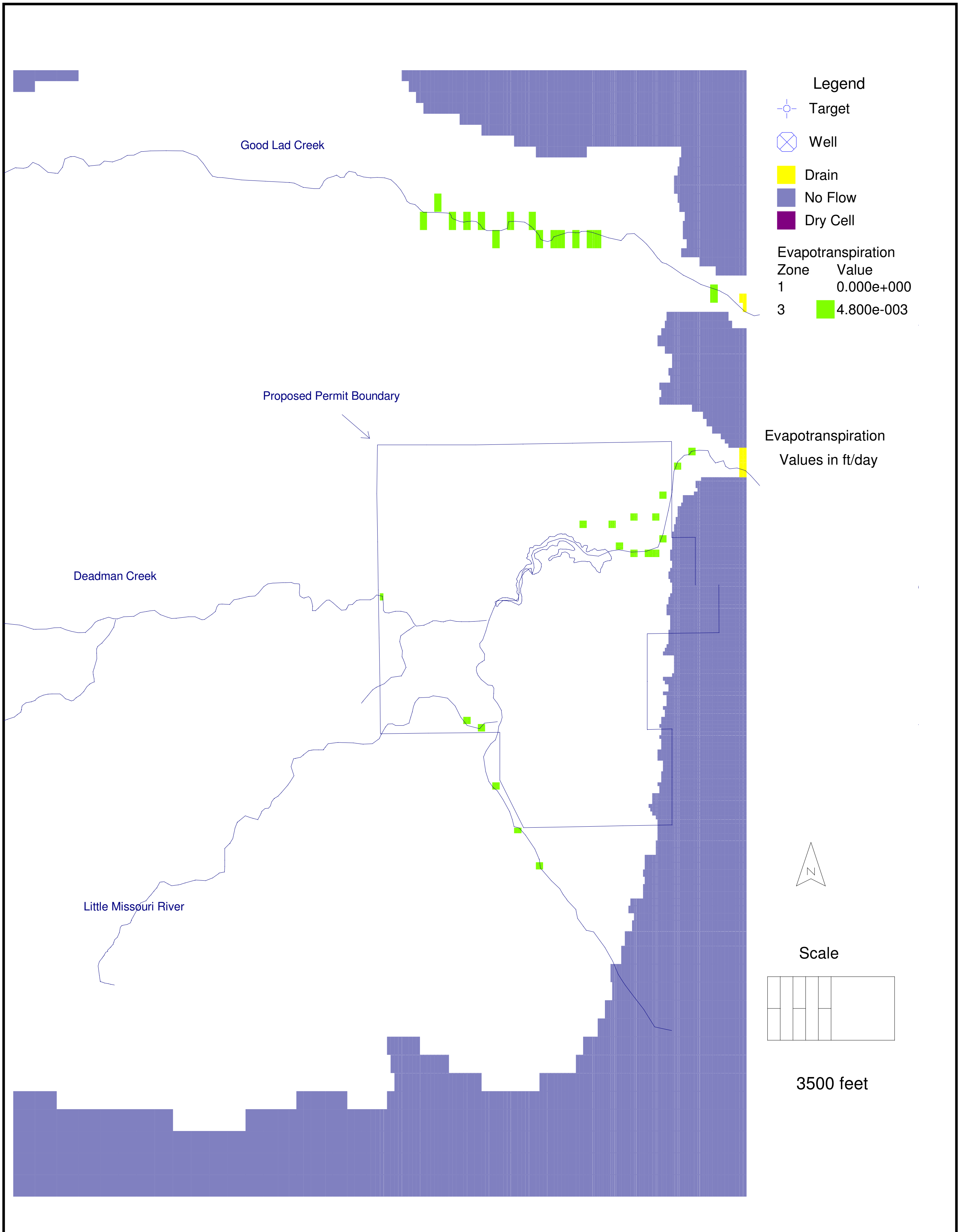


Figure 4.3-1 Spatial Distribution of Evapotranspiration and Drain Cells

underlying layer. General head boundaries were chosen because they can be used to establish a gradient but can be adjusted so that they do not flood the model like a constant head boundary condition might. Each general head boundary was assigned an elevation as well as a conductance term. The elevation for each general head boundary was based on pre-1978 potentiometric surfaces. Figure 2.3-1 depicts the pre-1978 estimated potentiometric surfaces used for the surficial aquifer and the OZ. The general head boundary for the SM surface was based on the OZ surface less 30 feet. The general head boundary for layer 2 was varied from 4,140 to 4,160 feet along the southern and western model boundaries with highest elevation at the southwest corner. The northern general head boundary in layer 2 varied from 4,140 to 4,110 feet decreasing towards the east. The elevations of the general head boundaries are the primary driver of the potentiometric head near the boundaries. The conductance term allows the modeler to, in effect, increase or decrease the hydraulic conductivity from the general head boundary cell. The conductance term for each general head boundary cell was set so that it mimicked the hydraulic conductivity of the adjacent cells as much as possible so as not to flood the system with excess water nor limit the water flow to the point that the resulting drawdowns were unrealistically severe.

Layers 3 and 5 – These layers represent the confining shales. The confining shales are not aquifers and have very low hydraulic conductivities. As such no-flow boundary conditions were placed on all sides of these layers.

4.5 Calibration Targets and Goals

Important features that are available to calibrate the groundwater model include existing water wells, 1977-1979 Nubeth monitoring wells and pump tests, 2010 Strata monitoring wells and pump tests, and stream elevations. Calibration and verification of the model was a two-step process using all available data.

The first calibration step was a steady-state simulation. The goal of the steady-state simulation was to match as close as possible the modeled potentiometric surface elevations to the pre-1980 potentiometric surface elevations for the SM and the OZ aquifers. Impacts from oilfield water supply wells pumping have been much less in the surficial layer as well as the Lance aquitards so it was possible to use newer data to develop these potentiometric surfaces. Discharge volumes from the drains in layer 1 were also used to help calibrate the steady state surface in Layer 1.

The second calibration step (verification) involved the construction of a transient model to simulate the effects of the wells used to provide water for oilfield stimulation. The goal of the transient portion of the model is to match the drawdowns that have occurred over the last 30 years from the pumping. Using MODFLOW2000 it was possible to develop a two stage model where the first time step represents the steady state simulation and the subsequent time steps are transient.

4.6 Numerical Parameters

The PCG2 solver within MODFLOW was utilized as the primary solver package. The maximum number of outer iterations was set at 2,500, the maximum number of inner iterations was set at 250, and the head change criterion for convergence was set to 0.005. Occasionally the PCG2 solver will meet the closure criteria for both head and flux (residual) within outer iterations, but not between successive outer iterations. This results in the model iterating until the maximum number of outer iterations has been reached. Environmental Simulations, Inc. (Rumbaugh and Rumbaugh 2002) has added a modification to the PCG2 solver in MODFLOW to automatically force convergence in this situation. By forcing convergence, the simulation may not be valid. If the simulation is not valid it will show up as an error in the mass balance. Therefore, the mass balance was checked after each simulation to ensure that the simulation was valid.

4.7 Calibration and Verification

Calibration of a regional groundwater model is challenging because relatively little information is available on the subsurface conditions. For example within the Ross model domain all of the hydraulic information available is located within the proposed Ross project area. Virtually no hydraulic conductivity data and very little potentiometric data are available outside of the proposed project boundary. Nevertheless, during the calibration process by taking known information and applying engineering judgment where information is not known, it was possible to develop a calibrated model that reasonably approximates the physical system. In general, during the calibration process much is learned about the system. The primary goal of this modeling exercise is to evaluate impacts from ISR within the OZ aquifer. To that end, the bulk of the calibration and verification process is focused on improving predictions within the OZ aquifer.

Measured or known potentiometric heads throughout the project area are the primary calibration targets. During calibration, model computed water levels are compared to the observed water levels at the calibration targets. Within the Ross Project area calibration targets are available for two discrete time periods, pre-1980 and 2010. The pre-1980 period is considered the pre-abstraction steady state period because before 1980 there were no oilfield water supply wells operating within the OZ aquifer. The period from 1980 to 2010 is considered the transient period because during this period there has been a significant amount of drawdown within the OZ aquifer due to the oilfield water supply wells. Pre-1980 Nubeth water levels are used for the steady state calibration while measurements taken by Strata in 2009 and 2010 are used to calibrate the transient runs. After each simulation the model-computed target levels are subtracted from the observed target levels to produce a residual. A positive residual indicates that the computed water level is lower than the measured level. Conversely, a negative residual indicates that the computed water level is higher than the field measured water level.

Simple statistics are then applied to the residuals to evaluate the improvement, or lack thereof of each successive model simulation. The sum of squared residuals in particular is useful in determining trends towards or away from calibration in successive model runs. The closer the sum of squared residuals is to zero the better the model calibration. Other statistical measures such as the residual mean can also be used to evaluate the effectiveness of the model calibration. A residual mean close to zero indicates that the positive and negative residuals are balanced.

4.7.1 Calibration Approach

The calibration approach was an iterative process continuously moving towards a more refined model. The first step was to construct a working model with the proper number of layers representing the geology within the project area. The first model was a relatively simple steady state model utilizing homogenous hydraulic properties in each layer. A structured sensitivity approach was taken to adjust the parameters. This method takes specified parameters and makes several model runs while changing the parameter over a specified range. Upon a review of the calibration statistics from each model run, the parameter that best optimizes the model results is chosen and the model is updated. This process was repeated until a steady state calibration was achieved.

Once steady state calibration had been achieved, the verification started by adding transient targets as well as pumping wells to the model. The pumping wells are summarized in Table 4.7-1 with flow rates for each well detailed in Appendix A. The figures within Section 4.7.2 detail the locations of the pumping wells. Wells believed to be completed above the SM interval were ignored for the purposes of the model.

The resulting model was a combined steady state and transient model. The first time step was steady state with no wells discharging. Each subsequent time step simulated wells discharging at their estimated discharge rate for each respective time period. A structured sensitivity approach similar to the one taken with the steady state model was then applied to the transient model. Unfortunately, it was not possible to calibrate the transient model using homogenous layer properties. Furthermore hydraulic conductivity information

Table 4.7-1. Summary of Pumping Wells in Ross Groundwater-Model Domain

Well	Easting[1]	Northing[1]	Layer	Use	Flowrate[2] (gpm)
Strong Wells	714963	1483356	6 (OZ)	Domestic/stock	0.4
Sophia #1A	700456.92	1484277.9	6 (OZ)	Oilfield	0 to 26.1
Kiehl Water Well #2	712381.38	1474845.8	4 (SM) and 6 (OZ)	Oilfield	0 to 16.6
22X-19	710875.88	1481932.5	6 (OZ)	Oilfield	5.5 to 21.8
19XX State	711658.65	1483960.9	6 (OZ)	Oilfield	3.1 to 12.1
789V State	710930.43	1484055.2	6 (OZ)	Oilfield	3.1 to 12.1
ENL Kiehl Well #1	713378	1473690	6 (OZ)	Oilfield	0 to 18.6
WSW#1 West Kiehl Unit	707029	1471267	6 (OZ)	Oilfield	0 to 18.6
Wesley TW02 P103666W	715506	1489632	6 (OZ)	Domestic/stock	0.8

1 Easting and northing coordinates based on Wyoming NAD 83 E coordinate system.
2 Flowrates for oilfield wells are variable and detailed within Appendix A.

from the 2010 pump tests indicates that the hydraulic conductivity within the SM and the OZ layers is not constant throughout the proposed Ross Project area.

To add realistic heterogeneity to the hydraulic conductivity distribution within the model another calibration technique known as pilot points was utilized in conjunction with PEST (a model-independent parameter estimation program). With this method known hydraulic conductivity values (from Table 2.5-2) were inserted into the model as hydraulic conductivity targets. User defined pilot points were then inserted into the model. Each pilot point was given an initial value and a minimum and maximum range based on measured hydraulic properties. PEST was then able to develop hydraulic conductivity estimates based on target well head data and known hydraulic conductivity targets for each pilot point. The pilot point calibration procedure was used only within and immediately adjacent the proposed Ross Project area because no hydraulic conductivity data is available outside of the project area. Pilot point calibration was performed only for the hydraulic conductivities within the SM and OZ aquifers.

4.7.2 Verification/Calibration Results

The resulting hydraulic conductivity distribution yielded a very good fit between the modeled potentiometric surface and the target wells within the OZ aquifer. Within the SM aquifer the calibration was acceptable as well. Table 4.7-2 summarizes the calibration targets as well as the calculated residuals and statistics from the calibrated model. Calibrated pre-1980 potentiometric surfaces are presented for the SM and OZ aquifers in Figures 4.7-1 and 4.7-2, respectively. Calibrated 2010 potentiometric surfaces for the surficial aquifer, the SM and the OZ aquifer are presented in Figures 4.7-3, 4.7-4, and 4.7-5. Since the impacts to the surficial aquifer have been minimal for the last 30 years, the 2010 surface presented for the surficial aquifer is considered representative of both the pre-1980 surface and the 2010 surface.

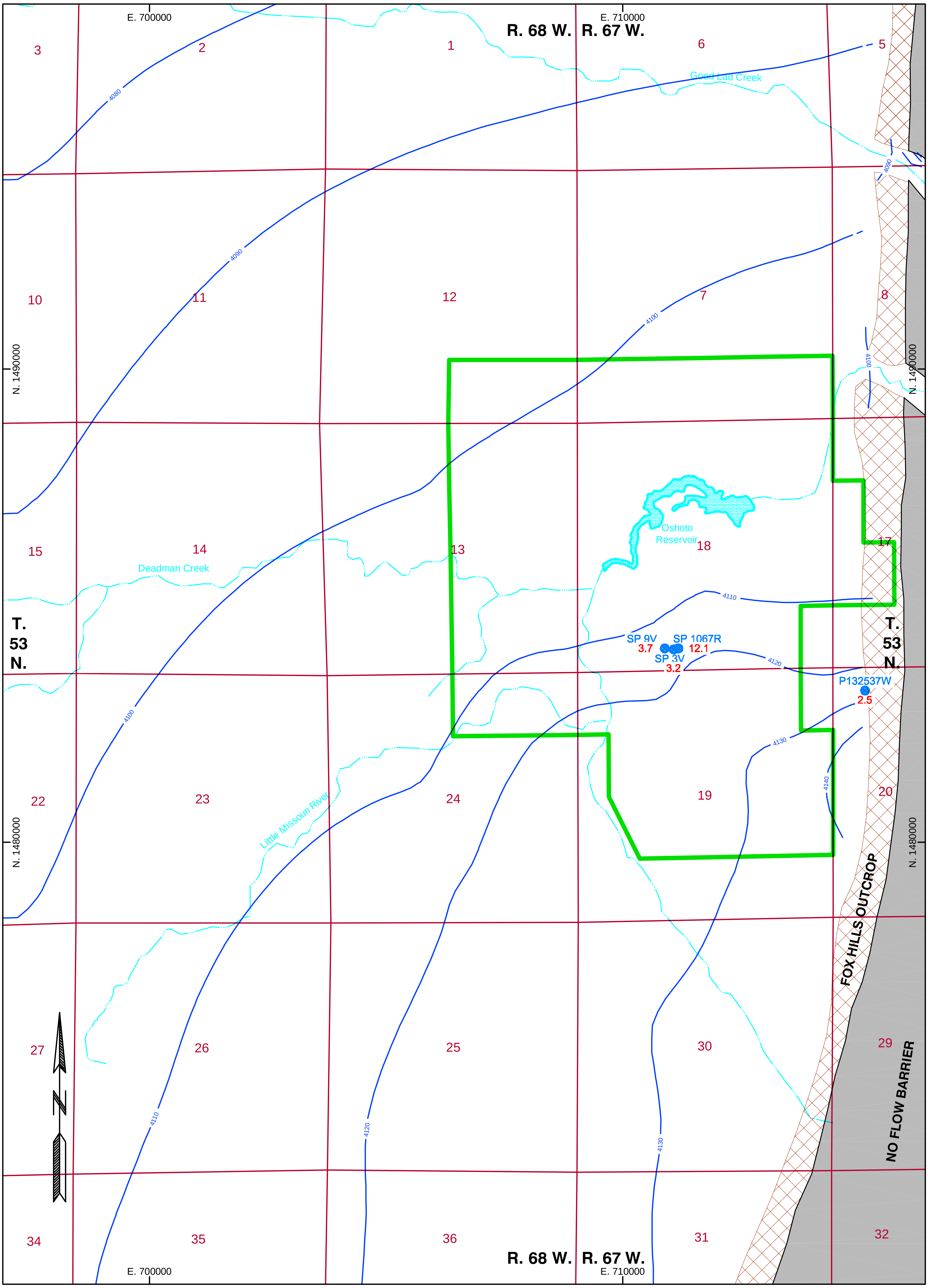
As shown in Table 4.7-2 GW-Vistas allows a weight to be assigned to each calibration target. Most of the calibration targets were assigned a weight of 1. However, since some of the targets within layer 1 were estimated based on stream elevations, these targets were assigned a weight less than one, to account for the fact that the actual elevations had not been physically verified. Several other targets within layers 1 and 2 were assigned weights less than 1 because they were either at wells where the observed water levels were from questionable sources or the targets were believed to be in local aquifers that may be perched. Within the OZ aquifer the simulated drawdown near the oilfield water supply wells is approximately 200 ft. As shown on Table 4.7-2 the largest residual within the OZ aquifer was 4.9 feet at 34-7OZ. The estimated error is therefore less than 2.5% of the total estimated drawdown. The residuals within the SM zone are higher. However, this discrepancy should be put into perspective with the confidence of the calibration targets. The 2010 heads measured by Strata within the SM are quite reliable. As discussed within Section 2.3 there is very little pre-1980 potentiometric data available for the SM aquifer. As a result, the confidence interval for the pre-1980 SM potentiometric surface is plus or minus 20 feet. Given the uncertainty associated with the pre-1980 SM potentiometric surface, the calibration within this aquifer may be

Table 4.7-2. Calibration Targets, Residuals, and Statistics for Calibrated Model

Name	Zone	Time	Easting[1]	Northing[1]	Layer	Observed	Computed	Weight	Residual
Est_WS_1	SA	2010	709226.7	1496147	1	4,131.3	4,126.8	0.5	4.5
Est_WS_4	SA	2010	715804.7	1494403	1	4,085	4,087.1	1	-2.1
43-18-1	SA	2010	713127.1	1485580	1	4,125.3	4,129.4	1	-4.1
Oshoto_Reservoir	SA	2010	711990.9	1487390	1	4,122	4,127.5	1	-5.5
Est_WS_3	SA	2010	713634.8	1495821	1	4,099.4	4,104.9	0.75	-5.5
P55052W	SA	2010	712745.8	1488277	1	4,111	4,122.6	0.75	-11.6
P55054W	SA	2010	715597.5	1489647	2	4,095	4,081.5	1	13.5
P55055W	SA	2010	713564	1491145	2	4,140	4,130.2	1	9.8
SA_21-19	SA	2010	710640.4	1483328	2	4,157	4,149.7	0.75	7.3
Est_WS_2	SA	2010	711021.8	1495786	2	4,115	4,116.4	0.5	-1.4
SA43-18-3	SA	2010	713776.8	1486289	2	4,122.9	4,124.4	1	-1.5
SA_12-18	SA	2010	709207.1	1487495	2	4,134	4,139.7	1	-5.7
SA_34-7	SA	2010	713331.1	1489602	2	4,112.5	4,119.5	1	-7.0
SA_14-18	SA	2010	710003	1484949	2	4,133	4,141.1	0.75	-8.1
SM_42-19	SM	2010	713103.3	1481253	4	4,130.5	4,109.4	1	21.1
SP_1067R	SM	1980	711173.9	1484097	4	4,129.1	4,116.9	1	12.1
SM_34-18	SM	2010	712463.3	1483778	4	4,111	4,100.8	1	10.2
SM_12-18	SM	2010	709220.1	1487513	4	4,101	4,091.0	1	10.0
SP_9V	SM	1980	710885	1484096	4	4,120	4,116.3	1	3.7
SP_3V	SM	1980	711075.4	1484077	4	4,120	4,116.8	1	3.2
P132537W	SM	1980	715117.7	1483205	4	4,129	4,126.5	1	2.5
SM_14-18	SM	2010	710044.8	1484916	4	4,089.3	4,090.6	1	-1.3
SM_21-19	SM	2010	710676.9	1483292	4	4,085.5	4,092.1	1	-6.6
SM_34-7	SM	2010	713357.1	1489635	4	4078.3	4,095.1	1	-16.8
Phase_II_4Z_0Z	OZ	1980	709467.2	1486628	6	4,099	4,089.2	1	9.8
OZ_7X	OZ	1980	711665.9	1483969	6	4,098.6	4,094.7	1	3.9
OZ_21-19	OZ	2010	710590.9	1483295	6	3,951.3	3,949.4	1	1.9
OZ_34-18	OZ	2010	712395.6	1483781	6	3,966	3,965.4	1	0.6
OZ_12-18	OZ	2010	709149.7	1487517	6	4,021	4,022.6	1	-1.6
OZ_14-18	OZ	2010	709971.9	1484905	6	3,998	3,999.7	1	-1.7
OZ_42-19	OZ	2010	713035.6	1481246	6	3,981	3,984.4	1	-3.4
788V	OZ	1980	710838.4	1484032	6	4,089.7	4,093.7	1	-4.0
OZ_34-7	OZ	2010	713265.9	1489620	6	4,051.5	4,056.4	1	-4.9

[1]Northing and Easting coordinates based on WY-NAD83EF

Residual Mean	0.65
Abs. Res. Mean	6.26
Res. Std. Dev.	7.84
Sum of Squares	2043.14
Min. Residual	-16.85
Max. Residual	21.10
Number of Observations	33.00



ROSS PROJECT AREA

Drawing Coordinates: WY83EF

LEGEND

PROPOSED ROSS PERMIT BOUNDARY

4100 POTENTIOMETRIC SURFACE

Est WS 2 -1.4 TARGET (COMPUTED WL HIGHER THAN OBSERVED)

Est WS 1 4.5 TARGET (COMPUTED WL LOWER THAN OBSERVED)

0 1000 2000 4000

GRAPHIC SCALE (FEET)

Fox Hills sand outcrop adapted from Halberg, L.L., Et. Al., Geologic Map of the Sundance 30' X 60' Quadrangle, Crook and Weston Counties, Wyoming and Lawrence and Pennington Counties, South Dakota: Wyoming State Geological Survey Map Series 78, Scale 1:100,000.

STRATA ENERGY

REVISIONS

Date	Description

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

GWM TECHNICAL REPORT
FIGURE 4.7-1

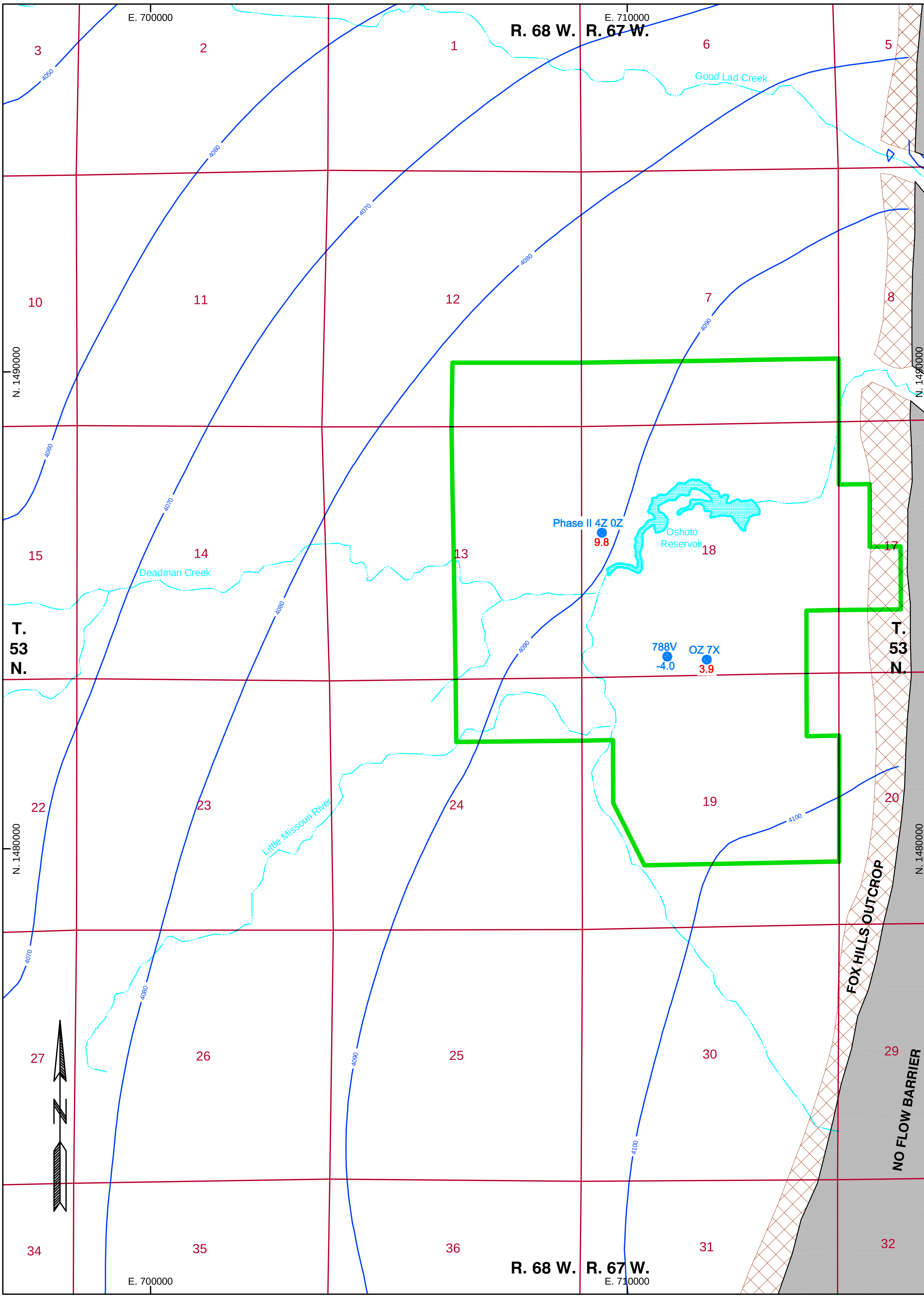
1980 MODEL CALIBRATED SURFACE FOR LAYER 4 (SM)

Drawn By: RAM
Checked By: RBM
Date: 10-10

WWC ENGINEERING
www.wwcengineering.com

FILE: ROSS_GWM_CALIB_POT_SURF

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_CALIB_POT_SURF.dwg, GWM_FIGURE_4.7-1, 12/20/2010 11:29:23 AM



ROSS PROJECT AREA

Drawing Coordinates: WY83EF

LEGEND

PROPOSED ROSS PERMIT BOUNDARY

4100 POTENTIOMETRIC SURFACE

Est WS 2 -1.4 TARGET (COMPUTED WL HIGHER THAN OBSERVED)

Est WS 1 4.5 TARGET (COMPUTED WL LOWER THAN OBSERVED)

0 1000 2000 4000

GRAPHIC SCALE (FEET)

Fox Hills sand outcrop adapted from Halberg, L.L., Et. Al., Geologic Map of the Sundance 30' X 60' Quadrangle, Crook and Weston Counties, Wyoming and Lawrence and Pennington Counties, South Dakota: Wyoming State Geological Survey Map Series 78, Scale 1:100,000.

STRATA ENERGY

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

REVISIONS	
Date	Description

GWM TECHNICAL REPORT
FIGURE 4.7-2

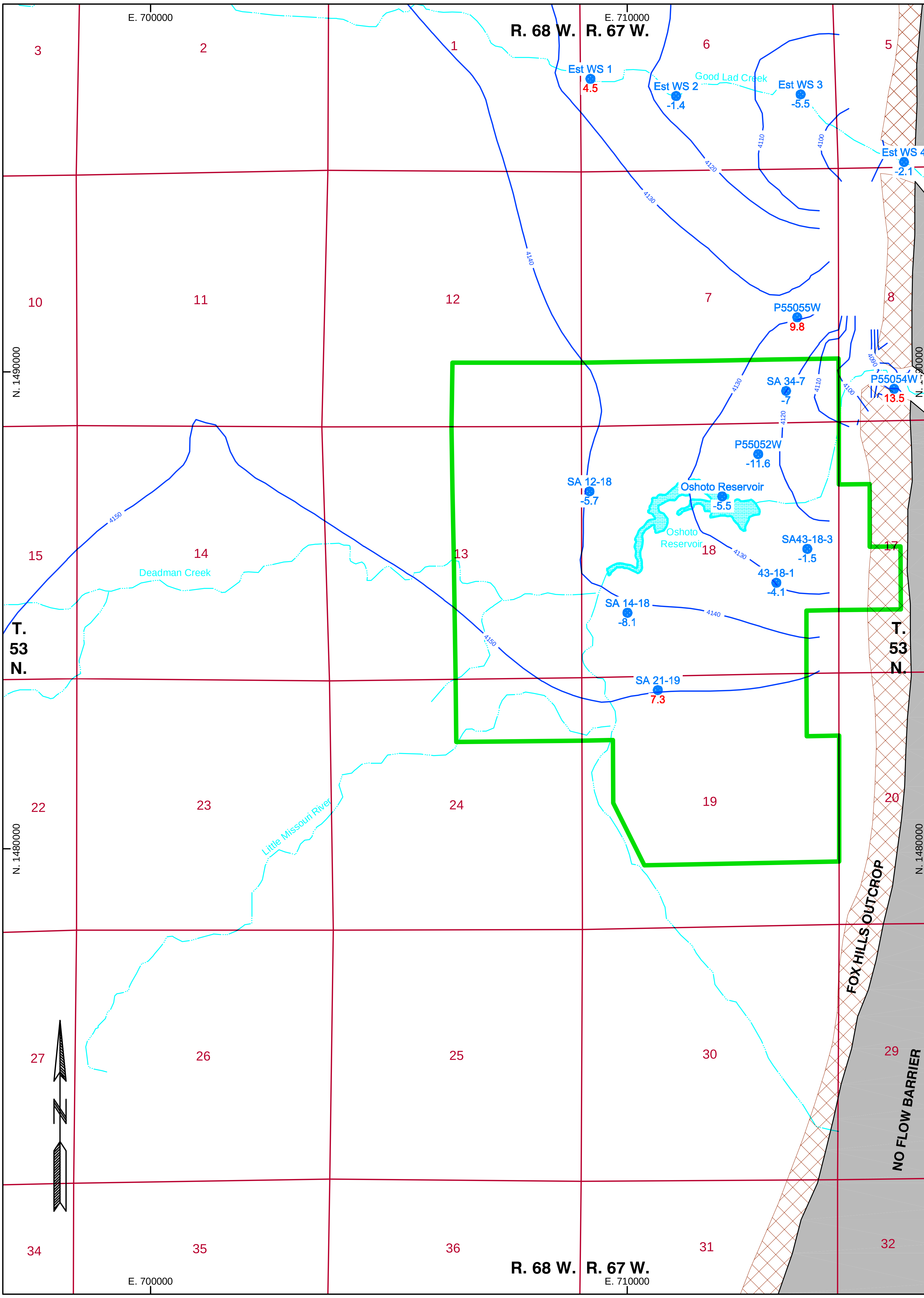
1980 MODEL CALIBRATED SURFACE FOR LAYER 6 (OZ)

Drawn By: RAM
Checked By: RBM
Date: 10-10

FILE: ROSS_GWM_CALIB_POT_SURF

WWC ENGINEERING
www.wwcengineering.com

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_CALIB_POT_SURF.dwg, GWM_FIGURE_4.7-2, 12/20/2010 11:29:29 AM



ROSS PROJECT AREA

Drawing Coordinates: WY83EF

LEGEND

PROPOSED ROSS PERMIT BOUNDARY

4100 POTENTIOMETRIC SURFACE

Est WS 2 -1.4 TARGET (COMPUTED WL HIGHER THAN OBSERVED)

Est WS 1 4.5 TARGET (COMPUTED WL LOWER THAN OBSERVED)

0 1000 2000 4000

GRAPHIC SCALE (FEET)

Fox Hills sand outcrop adapted from Halberg, L.L., Et. Al., Geologic Map of the Sundance 30' X 60' Quadrangle, Crook and Weston Counties, Wyoming and Lawrence and Pennigton Counties, South Dakota: Wyoming State Geological Survey Map Series 78, Scale 1:100,000.

STRATA ENERGY

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

REVISIONS

Date	Description

GWM TECHNICAL REPORT
FIGURE 4.7-3

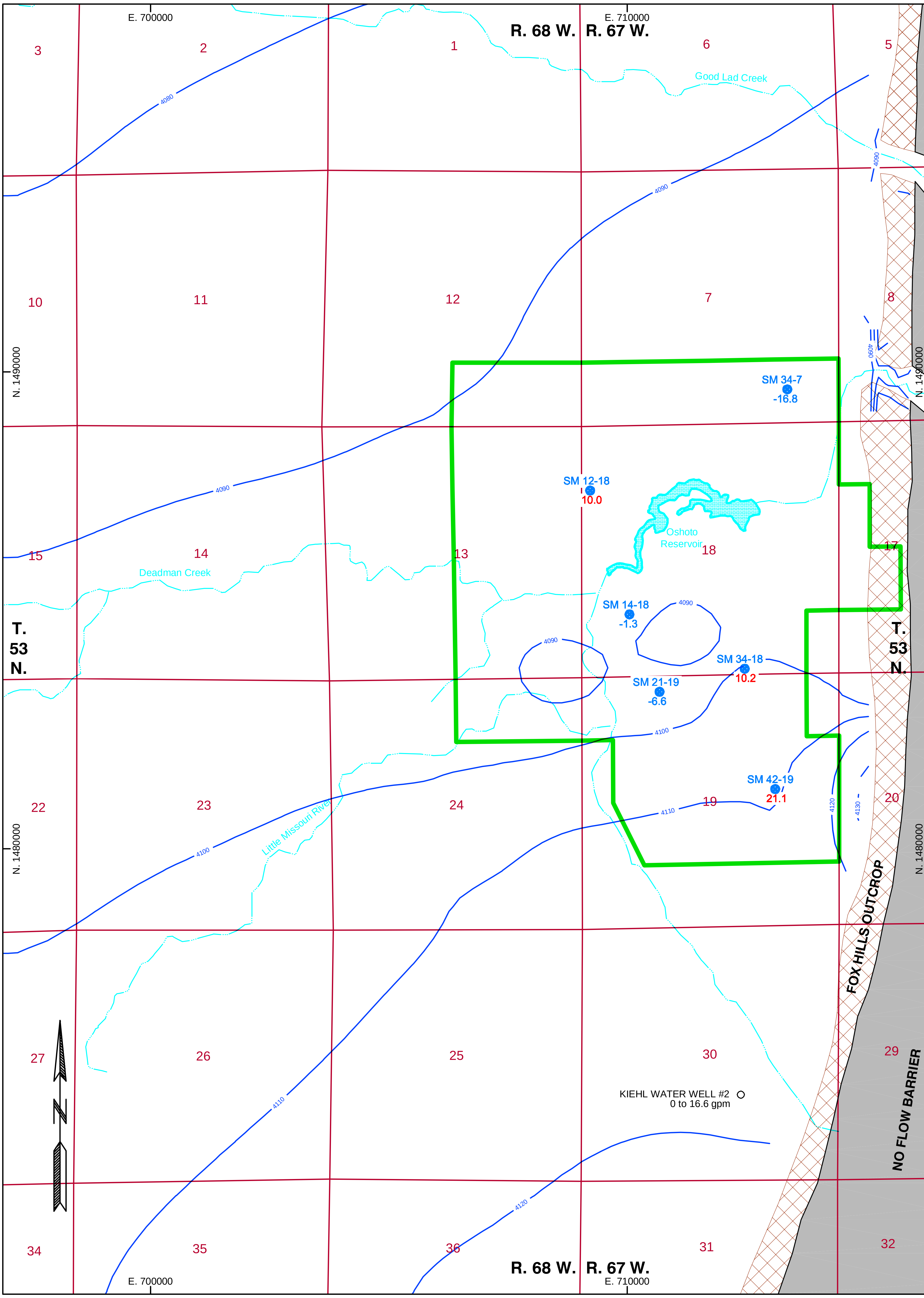
2010 MODEL VERIFIED SURFACE FOR SURFICIAL AQUIFER

Drawn By: RAM
Checked By: RBM
Date: 10-10

WWC ENGINEERING
www.wwcengineering.com

FILE: ROSS_GWM_CALIB_POT_SURF

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_CALIB_POT_SURF.dwg, GWM_FIGURE_4.7-3, 12/20/2010 11:29:35 AM



ROSS PROJECT AREA

Drawing Coordinates: WY83EF

LEGEND

PROPOSED ROSS PERMIT BOUNDARY

4100 POTENTIOMETRIC SURFACE

Est WS 2 -1.4 TARGET (COMPUTED WL HIGHER THAN OBSERVED)

Est WS 1 4.5 TARGET (COMPUTED WL LOWER THAN OBSERVED)

KIEHL WATER WELL #2 0 to 16.6 gpm ADJACENT WATERWELLS IN OPERATION WITH FLOWRATE DURING VERIFICATION

0 1000 2000 4000

GRAPHIC SCALE (FEET)

Fox Hills sand outcrop adapted from Halberg, L.L., Et. Al., Geologic Map of the Sundance 30' X 60' Quadrangle, Crook and Weston Counties, Wyoming and Lawrence and Pennigton Counties, South Dakota: Wyoming State Geological Survey Map Series 78, Scale 1:100,000.

STRATA ENERGY

REVISIONS

Date	Description

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

GWM TECHNICAL REPORT
FIGURE 4.7-4

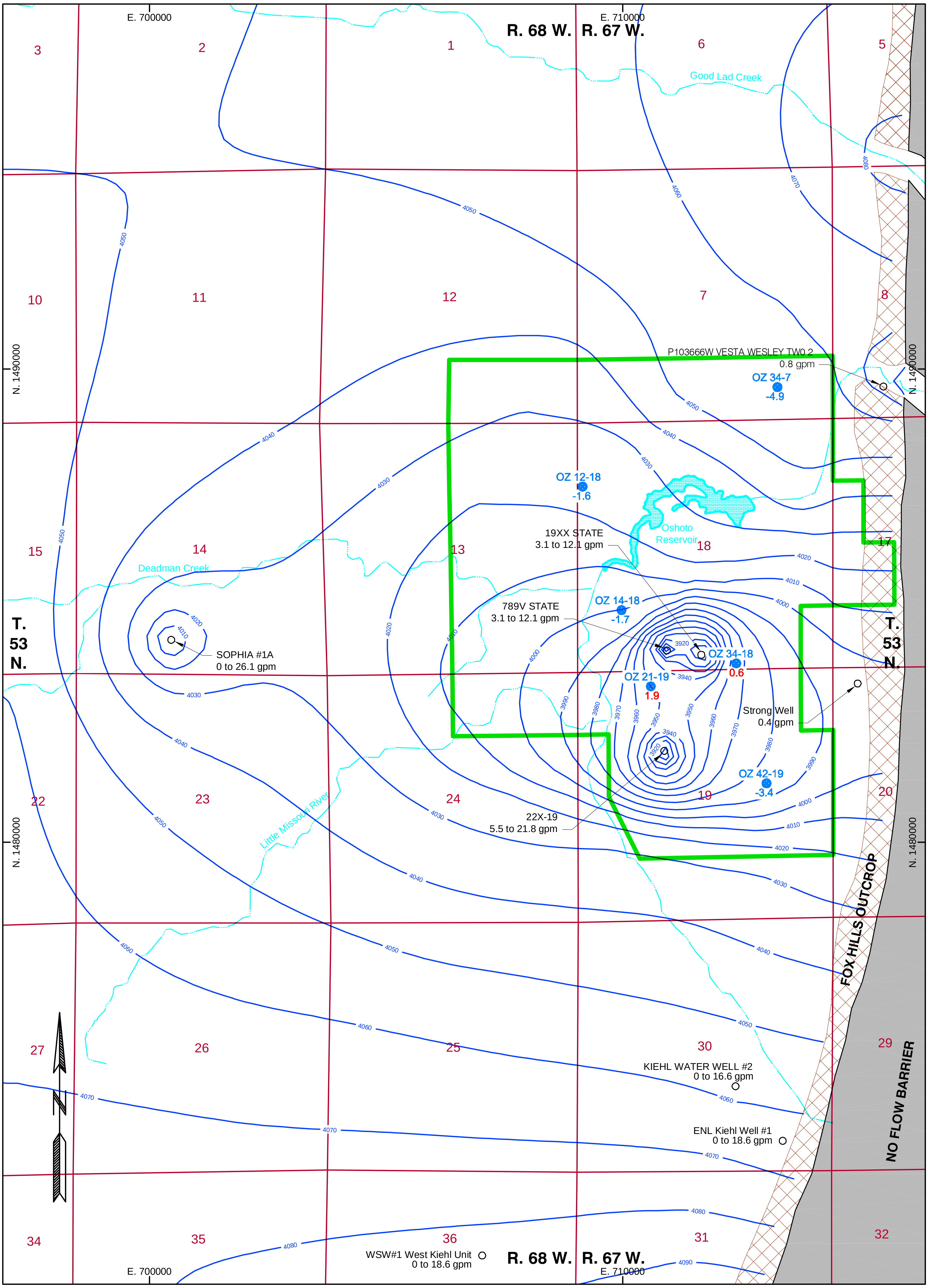
2010 MODEL VERIFIED SURFACE
FOR LAYER 4 (SM)

Drawn By: RAM
Checked By: RBM
Date: 10-10

WWC ENGINEERING
www.wwcengineering.com

FILE: ROSS_GWM_CALIB_POT_SURF

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_CALIB_POT_SURF.dwg, GWM_FIGURE_4.7-4, 12/20/2010 11:29:40 AM



ROSS PROJECT AREA

Drawing Coordinates: WY83EF

LEGEND

PROPOSED ROSS PERMIT BOUNDARY

4100 POTENTIOMETRIC SURFACE

Est WS 2 -1.4 TARGET (COMPUTED WL HIGHER THAN OBSERVED)

Est WS 1 4.5 TARGET (COMPUTED WL LOWER THAN OBSERVED)

KIEHL WATER WELL #2 0 to 16.6 gpm — ADJACENT WATERWELLS IN OPERATION WITH FLOWRATE DURING VERIFICATION

0 1000 2000 4000

GRAPHIC SCALE (FEET)

Fox Hills sand outcrop adapted from Halberg, L.L., Et. Al., Geologic Map of the Sundance 30' X 60' Quadrangle, Crook and Weston Counties, Wyoming and Lawrence and Pennington Counties, South Dakota: Wyoming State Geological Survey Map Series 78, Scale 1:100,000.

STRATA ENERGY

REVISIONS	
Date	Description

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

GWM TECHNICAL REPORT
FIGURE 4.7-5

2010 MODEL VERIFIED SURFACE FOR LAYER 6 (OZ)

Drawn By: RAM
Checked By: RBM
Date: 10-10

WWC ENGINEERING
www.wwcengineering.com

FILE: ROSS_GWM_CALIB_POT_SURF

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_CALIB_POT_SURF.dwg, GWM_FIGURE_4.7-5, 12/20/2010 11:29:47 AM

better than reported. Furthermore, the SM aquifer is not as regionally extensive as the OZ aquifer. A review of the geologic cross sections indicates that the 42-19SM and 34-7SM monitor wells are completed within sands that have minimal hydrologic connection, which may explain the large residuals at these well locations.

Many of the calibration targets used within the SA are based on channel elevations. Since some of the elevations were obtained from available topo maps and the water level within the alluvium is expected to vary seasonally, there could be up to 10 feet of error in the target elevations. As a result, residuals of less than 10 feet were deemed reasonable within the SA.

In assessing the adequacy of the calibration it is also necessary to clarify the main goal of the model which was primarily to evaluate the impacts from ISR within the OZ aquifer. For this reason most of the calibration effort was focused on the OZ aquifer (layer 6) with the SM aquifer (layer 4) being the second most important calibration target. Due to the confinement of the OZ and SM aquifers, they have very little contact with the top layers (layers 1 and 2) except at the outcrop. As a result, the primary purpose of layers 1 and 2 within the model were to help develop reasonable recharge estimates for the OZ before, during, and after ISR. Given the supporting role that layers 1 and 2 play within the model, it was not necessary to go through the level of effort that was used to calibrate Layers 4 and 6 (i.e. adding heterogeneity to the hydraulic conductivities.) Furthermore, not as much measured data is available for layers 1 and 2 as is available for layers 4 and 6, so intensive calibration efforts focused on layers 1 and 2 were not justified. Based on all the available information, this calibrated model presents a reasonable calibrated solution. As more site specific aquifer information, and measured water levels become available the model can be updated.

4.8 Sensitivity Analysis

In order to assess which input parameters are most critical to the model results, a sensitivity analysis was performed on the calibrated model to determine which parameters impacted the calibration the most. In this analysis six parameters, horizontal hydraulic conductivity, vertical hydraulic conductivity, specific storage, recharge, general head boundary elevations, and general head conductance were varied. The details and results from the sensitivity analysis for each parameter are presented in the following sections. For each parameter that was varied a number of statistics are presented. The statistics presented are based on the residuals calculated from the head targets described in Table 4.7-2. Most of the statistics such as the sum of square residuals, residual mean, residual standard deviation, and average drawdown are common statistical values calculated on the residuals. For some of the sensitivity evaluations a sensitivity coefficient specific to GW-Vistas is also presented. The sensitivity coefficient is computed as:

Si=(DelRss*ParmValue/(DelParmValue*RSS)

Where Si is the sensitivity coefficient reported by GW-Vistas, DelRss is the change in Sum of Squared Residuals from the base value of the parameter, ParmValue is the initial parameter value for the base case, DelParmValue is the change in parameter value for the sensitivity run, and RSS is the base case sum of squared residuals (Rumbaugh and Rumbaugh 2007).

4.8.1 Model Sensitivity to Horizontal Hydraulic Conductivity

To evaluate the model's sensitivity to horizontal hydraulic conductivity, one zone within each model layer was adjusted both up and down one order of magnitude. Within Layers 1, 4, and 6, heterogeneity has been built into the model within the Ross project area. As such, only the zone with the largest area within the layer was varied. Within layers 4 and 6, zones 38 and 31 were varied, respectively. These zones represent the hydraulic conductivity located outside of the Ross project area (see Figures 4.2-2 and 4.2-3). Within layer 1, zone 67 which lies outside of the alluvium was varied (see Figure 4.2-1). The results of each sensitivity evaluation are presented in Table 4.8-1.

Table 4.8-1. Model Sensitivity to Horizontal Hydraulic Conductivity

Run	Multiplier	Hydraulic K (ft/day)	Sum of Square Residuals	Residual Mean	Residual Std. Dev.	Average Drawdown	Sensitivity
Parameter: Kx Zone: 67 Layer 1 – Alluvial Aquifer							
1	0.1	0.5	2833	7.2	9.3	19.2	3147
2	1	5	2043	6.3	7.8	19.7	0
3	10	50	2092	6.3	7.9	19.7	232
Parameter: Kx Zone: 27 Layer 2 – Alluvial Aquifer/Lance Aquitards							
1	0.1	0.01	40570	24.2	32.2	7.5	45077
2	1	0.1	2043	6.3	7.8	19.7	0
3	10	1	5235	9.2	12.3	21.7	582
Parameter: Kx Zone: 2 Layer 3 – SM Confining Interval							
1	0.1	0.00004	2039	6.3	7.8	19.7	2265
2	1	0.0004	2043	6.3	7.8	19.7	0
3	10	0.004	2062	6.3	7.9	19.7	229
Parameter: Kx Zone: 38 Layer 4 – SM Aquifer							
1	0.1	0.032	2723	7.2	9.0	17.7	3025
2	1	0.32	2043	6.3	7.8	19.7	0
3	10	3.2	5336	9.0	11.8	23.3	593
Parameter: Kx Zone: 1 Layer 5 – OZ Confining Interval							
1	0.1	0.00005	2201	6.6	8.1	-19.8	2445
2	1	0.0005	2043	6.3	7.8	-19.7	0
3	10	0.005	2197	6.6	8.1	-19.8	244
Parameter: Kx Zone: 31 Layer 6 – OZ Aquifer							
1	0.1	0.019	68139	27.1	41.0	-38.0	75708
2	1	0.19	2043	6.3	7.8	-19.7	0
3	10	1.9	21338	17.6	24.6	9.0	2371

As shown on Table 4.8-1, model layers 3 and 5 are not sensitive to changes in horizontal hydraulic conductivity as seen in the lack of variance in the residual sum of squares. Since these layers are the confining layers, the vertical hydraulic conductivity is a much more sensitive parameter. Layer 6 was the most sensitive to changes in horizontal hydraulic conductivity with both an increase and a decrease in hydraulic conductivity significantly affecting the sum of square residuals. Zone 27 was also quite sensitive to an increase in hydraulic conductivity but not as sensitive to a decrease in hydraulic conductivity. Zone 27 represents most of layer 2, although zone 27 is also used in several locations within layers 4 and 6. As such, the increased sensitivity of zone 27 can also be attributed to changes in layers 4 and 6 as well as changes in layer 2. In general, except within the confining intervals represented by layers 3 and 5, the model is quite sensitive to changes in the horizontal hydraulic conductivity. Given that the geologic stratigraphy within the region is such that the sandstone aquifer units are relatively homogeneous horizontally, but have multiple thin shale/siltstone partings that vertically separate each sandstone unit, the fact that the sandstones are sensitive to changes in the horizontal hydraulic conductivity is realistic

4.8.2 Model Sensitivity to Vertical Hydraulic Conductivity

To evaluate the model's sensitivity to vertical hydraulic conductivity, one zone within each model layer was adjusted both up and down one order of magnitude. Within Layers 1, 4, and 6, where heterogeneity has been built into the model within the Ross project area only, the zone with the largest area within the layer was varied. Within layers 4 and 6, zones 38 and 31 were varied, respectively. These zones represent the hydraulic conductivity located outside of the Ross permit boundary. Within layer 1, zone 67 which lies outside of the alluvium was varied. The results of each vertical hydraulic conductivity sensitivity evaluation are presented in Table 4.8-2.

As shown on Table 4.8-2, layers 3 and 5 are the most sensitive to changes in the vertical hydraulic conductivity as seen in the variance in the residual sum of squares. Layer 5 is the most sensitive to an increase in the vertical hydraulic conductivity. Because Layer 5 is so sensitive to an increase in the vertical hydraulic conductivity, the model calibrated value is believed to be realistic within the current model configuration. Furthermore, due to the fact that both an increase and a decrease in the vertical hydraulic conductivity impact the calibration, it is clear that the vertical hydraulic conductivity has been optimized in both layers 3 and 5. Changes in the vertical hydraulic conductivity have almost no impact to the other model layers as the sum of square residuals indicate. In general, it is the confining layers that are most sensitive to changes in the vertical hydraulic conductivity, which is consistent with the site conceptual model.

Table 4.8-2. Model Sensitivity to Vertical Hydraulic Conductivity

Run	Multiplier	Hydraulic K (ft/day)	Sum of Square residuals	Residual Mean	Residual Std. Dev.	Average Drawdown (ft)	Sensitivity
Parameter: Kz Zone: 67 Layer 1 – Alluvial Aquifer							
1	0.1	0.3	2207	6.6	8.2	19.8	2451
2	1	3	2043	6.3	7.8	19.7	0
3	10	30	2042	6.3	7.8	19.7	227
Parameter: Kz Zone: 27 Layer 2 – Alluvial Aquifer/Lance Aquitards							
1	0.1	0.054	2185	6.6	8.1	19.8	2427
2	1	0.54	2043	6.3	7.8	19.7	0
3	10	5.4	2048	6.3	7.8	19.7	227
Parameter: Kz Zone: 2 Layer 3 – SM Confining Interval							
1	0.1	1.45E-06	8447	12.2	15.5	21.4	9384
2	1	1.45E-05	2043	6.3	7.8	19.7	0
3	10	1.45E-04	5141	9.4	12.5	19.4	571
Parameter: Kz Zone: 38 Layer 4 – SM Aquifer							
1	0.1	0.021	2045	6.3	7.8	19.7	2271
2	1	0.21	2043	6.3	7.8	19.7	0
3	10	2.1	2043	6.3	7.8	19.7	227
Parameter: Kz Zone: 1 Layer 5 – OZ Confining Interval							
1	0.1	6.50E-07	7081	11.6	14.6	18.1	7866
2	1	6.50E-06	2043	6.3	7.8	19.7	0
3	10	6.50E-05	24011	19.3	27.0	20.4	2668
Parameter: Kz Zone: 31 Layer 6 – OZ Aquifer							
1	0.1	0.0123	2110	6.3	8.0	20.2	2344
2	1	0.123	2043	6.3	7.8	19.7	0
3	10	1.23	2081	6.3	7.9	19.7	231

4.8.3 Model Sensitivity to Adjustments in Recharge

Within the calibrated model, recharge was determined empirically based on modeling experience. Actual recharge rates are largely unknown and believed to be variable from year to year and season to season. To assess the consequences of gross errors in the recharge rate a sensitivity analysis was performed. The recharge rate was adjusted up and down by 50 percent. The results of these adjustments are presented in Table 4.8-3.

Table 4.8-3. Model Sensitivity to Recharge

Run	**Multiplier**	**Sum of Square Residuals**	**Residual Mean**	**Residual Std.**
Parameter: Recharge Zone: All Layer: 1-6				
1	0.5	7605	9.8	11.6
2	1	2043	6.3	7.8
3	1.5	3667	-6.4	8.3

As shown in Table 4.8-3 the model is quite sensitive to recharge. Both an increase and a decrease in the recharge rates impacted the model calibration. As expected, when the recharge is increased the mean residual decreases indicating that the water level is generally higher than the observed targets. When the recharge rate is decreased the residual mean increases meaning that the water level is generally lower than the observed target water levels. Overall based comparisons of the sum of residual squares, the calibrated recharge rate is optimized to the current available data. As ISR progresses and additional water level data is available over time, it may be possible to further optimize the recharge rate. However, within the current model configuration the recharge rate is adequate to perform model simulations.

4.8.4 Model Sensitivity to Specific Storage

Storage coefficient and specific yield dictate how much water can be removed from an aquifer per unit of drawdown. Specific yield is used in unconfined aquifers and specific storage is used in confined aquifers. Within the Ross groundwater model layers 2 through 6 are confined and layer 1 is unconfined. A higher storage coefficient or specific yield corresponds to a greater amount of water in storage. To assess how dependent the results of the model were on the storage coefficient (layers 2-6) and specific yield (layer 1), the storage coefficient was adjusted up and down by an order of magnitude. The results of the storage coefficient and specific yield sensitivity analysis are presented in Table 4.8-4.

Table 4.8-4. Model Sensitivity to Specific Storage and Specific Yield

Run	Multiplier	*Specific Storage K (ft/day)	Sum of Squared Residuals	Residual Mean	Residual Std. Dev.	Average Drawdown	Sensitivity
Parameter: Sy Zone: 2 Layer 1 – Alluvial Aquifer							
1	0.1	0.01	2062	6.2	7.9	19.8	2290
2	1	0.1	2043	6.3	7.8	19.7	0
3	10	1	2001	6.3	7.8	19.0	222
Parameter: Ss Zone: 1 Layer 2 – Alluvial Aquifer/Lance Aquitards							
1	0.1	5.00E-08	2043	6.3	7.8	19.7	2269
2	1	5.00E-07	2043	6.3	7.8	19.7	0
3	10	5.00E-06	2045	6.3	7.8	19.6	227
Parameter: Ss Zone: 7 Layer 3 – SM Confining Interval							
1	0.1	4.00E-07	2042	6.3	7.8	19.7	2268
2	1	4.00E-06	2043	6.3	7.8	19.7	0
3	10	4.00E-05	2028	6.3	7.8	19.1	225
Parameter: Ss Zone: 6 Layer 4 – SM Aquifer							
1	0.1	7.60E-07	1978	6.2	7.7	19.6	2197
2	1	7.60E-06	2043	6.3	7.8	19.7	0
3	10	7.60E-05	2073	6.5	7.8	17.1	230
Parameter: Ss Zone: 4 Layer 5 – OZ Confining Interval							
1	0.1	4.00E-07	2050	6.2	7.8	19.7	2277
2	1	4.00E-06	2043	6.3	7.8	19.7	0
3	10	4.00E-05	2036	6.7	7.8	17.2	226
Parameter: Ss Zone: 5 Layer 6 – OZ Aquifer							
1	0.1	9.70E-07	2961	6.9	9.4	19.6	3289
2	1	9.70E-06	2043	6.3	7.8	19.7	0
3	10	9.70E-05	147768	24.7	65.9	6.1	16419

*Specific yield was varied in the sensitivity analysis within unconfined layer 1.

As shown in Table 4.8-4 the specific storage was most sensitive within layer 6. Because most of the significant stressors to the aquifer system (i.e. oilfield water supply wells) are located within layer 6, increases in the storage coefficient increase the water available, which in turn decreases the average drawdown in the aquifer.

Conversely, a decrease in the storage coefficient results in less water thus increasing the drawdown in the aquifer. Due to the fact that the model quite accurately predicts the drawdowns within layer 6 and the storage coefficient is quite sensitive, the calibrated storage coefficient value used in layer 6 is believed to accurately represent the modeled system. Furthermore, the calibrated storage coefficient used in layer 6 is reasonable based on pump test data and literature values. In general the rest of the model layers are not very sensitive to changes in the storage coefficient or specific storage.

4.8.5 Sensitivity to General Head Boundary Head Elevations

Within layers 2, 4, and 6 general head boundaries (GHB) were placed to the south, west, and north of the model domain. The initial heads assigned to the GHB in layers 4 and 6 were based on the pre-1980 potentiometric surface for the OZ aquifer (the heads in the SM were estimated to be 30 feet higher than the heads in the OZ). The heads assigned to the GHB in layer 2 were loosely based on potentiometric surfaces in the surficial aquifer and then calibrated within the model. To evaluate the impacts that an increase or a decrease in the heads assigned to the GHB would have on the calibration of the model, sensitivity analyses were performed assuming that the heads were increased and decreased by 20 feet. Each layer was analyzed separately in order to quantify the impacts that changes to the heads assigned to the GHBs in each layer would have on the model calibration. Table 4.8-5 presents the calculated sensitivity to GHB heads in each layer.

As shown on Table 4.8-5 the model is not particularly sensitive to changes in the head assigned to the GHBs. In general, decreases in the GHB elevations had a greater impact than increases on the calibrated model. The biggest impact to the sum of squared residuals occurred when the GHB head in layer 6 was decreased. A decrease in the GHB head elevation in layer 4 had a similar impact. Increases in the GHB head in layer 6 had almost no impact on the calibration of the model. Given that the expected error within the initial elevation estimates is on the order of ±20 feet and the model is not particularly

Table 4.8-5. Model Sensitivity to Changes in Head Assigned to the GHBs.

Run	Head Change (ft)	Sum of Square Residuals	Residual Mean	Residual St. dev.	Average Drawdown (ft)	Sensitivity
Parameter: GHB Head Reach: 45 Layer 2 – Alluvial Aquifer/Lance Aquitards						
1	-20	3197	7.0	9.2	23.0	152
2	0	2043	6.3	7.8	19.7	2042
3	20	2341	6.9	8.2	16.8	123
Parameter: GHB Head Reach: 46 Layer 4 – SM Aquifer						
1	-20	4942	8.8	10.8	26.3	235
2	0	2043	6.3	7.8	19.7	2042
3	20	2050	6.6	7.1	13.7	108
Parameter: GHB Head Reach: 47 Layer 6 – OZ Aquifer						
1	-20	5391	10.1	11.4	25.3	257
2	0	2043	6.3	7.8	19.7	2042
3	20	2744	7.7	8.4	14.7	144

sensitive over this range, the current modeled GHB heads are considered reasonable approximations of the actual system.

4.8.6 Sensitivity to General Head Boundary Head Conductance.

Within layers 2, 4, and 6 general head boundaries (GHB) were placed to the south, west, and north of the model domains. Each GHB has a conductance term associated with it. The conductance term dictates how much water is released into or out of the model through the GHB. The higher the conductance term the more water the GHB cell is able to absorb from or release into the model. To evaluate impacts an increase or a decrease in the conductance assigned to the GHB would have on the calibration of the model sensitivity analyses were performed assuming the conductance was increased and decreased by a factor of 10. Each layer was analyzed separately in order to quantify the impacts that changes to the conductance assigned to the GHBs in each layer would have on the model calibration. Table 4.8-6 presents the calculated sensitivity to GHB conductance in each layer.

Table 4.8-6. Model Sensitivity to GHB Conductance.

Run	Multiplier	Conductance	Sum of Squares	Residual Mean	Residual Std.	Average Drawdown	Sensitivity
Parameter: GHB Head Reach: 45 Layer 2 – Alluvial Aquifer/Lance Aquitards							
1	0.1	0.1	2420	6.9	8.2	16.3	2687
2	1	1	2043	6.3	7.8	19.7	0
3	10	10	2744	6.6	8.8	21.6	305
Parameter: GHB Head Reach: 46 Layer 4 – SM Aquifer							
1	0.1	120	2201	6.6	8.1	19.8	2444
2	1	1200	2043	6.3	7.8	19.7	0
3	10	12000	2044	6.3	7.8	19.7	227
Parameter: GHB Head Reach: 47 Layer 6 – OZ Aquifer							
1	0.1	2.4	2052	6.2	7.8	20.0	2278
2	1	24	2043	6.3	7.8	19.7	0
3	10	240	2199	6.6	8.1	19.8	244

As shown on Table 4.8-6 the model is not very sensitive to changes in the GHB conductance term within the ranges used in the calibrated model. This indicates that the conductance terms are in line with adjacent hydraulic conductivity values. It also indicates that the boundary conditions do not significantly impact the model results.

Based on the sensitivity analysis results presented, the most sensitive parameter within the groundwater model is the hydraulic conductivity, both vertical and horizontal. Fortunately, within the project area where the impacts from gross errors in the hydraulic conductivity will have the most impacts, several measured hydraulic conductivity values were available to improve model calibration. Outside of the Ross Project area the hydraulic conductivity is largely unknown, although calibrated values have been developed. Within the Ross project area there is a significant amount of heterogeneity in the spatial distribution of the hydraulic conductivity. The heterogeneity presented in the calibrated model is based on available head and hydraulic conductivity targets. Due to the pilot point techniques used to calibrate the model, the calibrated model presented herein represents a reasonable calibrated solution but not a unique solution. As a result, except very close to locations where the hydraulic conductivity has been measured, the general hydraulic conductivity trends presented within the model are reasonable although the hydraulic conductivity value assigned to each specific cell may or may not represent actual values encountered in the field. To the extent that additional targets can be collected, the model calibration and the hydraulic conductivity heterogeneity can be further refined.

4.9 ISR Simulation

The calibrated model was used to simulate ISR within the Ross Project area. The primary goal of the ISR simulation described in this section was to evaluate the regional impacts of ISR. As shown on Figure 4.7-5, the presence of three industrial oilfield water supply wells within the Project Area have the potential to significantly impact ISR development. To evaluate the net impacts that would result from the industrial wells, two ISR scenarios were simulated. One scenario assumed that the wells did not operate during ISR operations and the other scenario assumed that the wells did operate during ISR operation.

The ISR process includes both recovery and injection wells. In a balanced wellfield the recovery wells pump at a slightly higher rate than the injection wells which produces a cone of depression around the recovery wells and around the wellfield itself. The excess water removed from the aquifer by the recovery wells is referred to as bleed. The cone of depression developed from the bleed prevents injected fluids from leaving the wellfield.

The proposed ISR process consists of two phases which include uranium recovery followed by groundwater sweep and restoration stability. During the recovery phase, lixiviants are injected using the injection wells and recovered with leached mineral at the recovery wells. The net regional effect of the recovery process is the loss of the bleed water from the system. Locally, it is important to establish expected flow patterns and local impacts that may result from ISR. During the groundwater sweep phase, water is removed from the aquifer but no water is injected into the aquifer. The restoration stability phase is similar to the ISR phase except that the water removed from the aquifer is treated prior to being re-injected. The following sections describe the ISR simulation in more detail.

4.9.1. Wellfield Configuration

Strata is still in the exploratory drilling process within the proposed Ross project area. As a result, delineation of mineralization areas and wellfields have not been finalized. The ISR wellfields and wellfield progression used for this simulation are preliminary based on current available information. As Strata finalizes wellfield delineation through continued exploration, updated simulations can be performed at the Ross ISR Project. The preliminary ISR scenario used in this simulation includes 2 ISR units, units 1 and 2, which will be operated simultaneously. The ISR units are further broken into modules which contain approximately 40 recovery wells each. For this simulation, there were 10 modules within unit 1 and 7 modules within unit 2. ISR simulations started simultaneously within units 1 and 2. Table 4.9-1 depicts the simulated ISR schedule. Figure 4.9-1 depicts the module locations as well as an approximate trace of the mineralization.

4.9.2. Operational Parameters.

During the production simulation each wellfield module was estimated to operate at a maximum rate of 700 gpm which translates to approximately 17.5 gpm per well. Estimated bleed rate during production was estimated at 1.25 percent (8.75 gpm per module, 0.219 gpm per recovery well). Groundwater sweep operations were estimated to remove 50 percent of the pore volume of the wellfield. Based on the 3 month sweep period presented in Table 4.9-1, the estimated flowrate during sweep was 1.31 gpm per recovery well. Aquifer restoration activities were assumed to last approximately 6 months (actual time may vary based on field conditions). The bleed during restoration is expected to vary depending on whether or not restoration is occurring concurrent with ISR in other wellfields. When restoration is occurring in one module and ISR is simultaneously occurring in another module, excess bleed from the module

Table 4.9-1. Simulated ISR Schedule in GW-Vistas

Modflow Stress Period	Begin Stress Period (yr)	End Stress Period (yr)	Module 1-1 & 2-1	Module 1-2 & 2-2	Module 1-3 & 2-3	Module 1-4 & 2-4	Module 1-5 & 2-5	Module 1-6 & 2-6	Module 1-7 & 2-7	Module 1-8	Module 1-9	Module 1-10
1	0	2										
2	2	2.25	ISR	ISR								
3	2.25	2.5	ISR	ISR	ISR							
4	2.5	2.75	ISR	ISR	ISR	ISR						
5	2.75	3	ISR	ISR	ISR	ISR	ISR					
6	3	3.25	ISR	ISR	ISR	ISR	ISR					
7	3.25	3.5	ISR	ISR	ISR	ISR	ISR					
8	3.5	3.75	ISR	ISR	ISR	ISR	ISR					
9	3.75	4			ISR	ISR	ISR	ISR	ISR			
10	4	4.25				ISR	ISR	ISR	ISR	ISR		
11	4.25	4.5					ISR	ISR	ISR	ISR	ISR	
12	4.5	4.75	Sweep	Sweep				ISR	ISR	ISR	ISR	ISR
13	4.75	5	Restore	Restore	Sweep			ISR	ISR	ISR	ISR	ISR
14	5	5.25	Restore	Restore	Restore	Sweep		ISR	ISR	ISR	ISR	ISR
15	5.25	5.5			Restore	Restore	Sweep	ISR	ISR	ISR	ISR	ISR
16	5.5	5.75				Restore	Restore			ISR	ISR	ISR
17	5.75	6					Restore	Sweep			ISR	ISR
18	6	6.25						Restore				ISR
19	6.25	6.5						Restore	Sweep			
20	6.5	6.75							Restore	Sweep		
21	6.75	7							Restore	Restore		
22	7	7.25								Restore	Sweep	
23	7.25	7.5									Restore	Sweep
24	7.5	7.75									Restore	Restore
25	7.75	8										Restore
26	8	13										
27	13	18										
28	18	28										
29	28	58										
30	58	108										

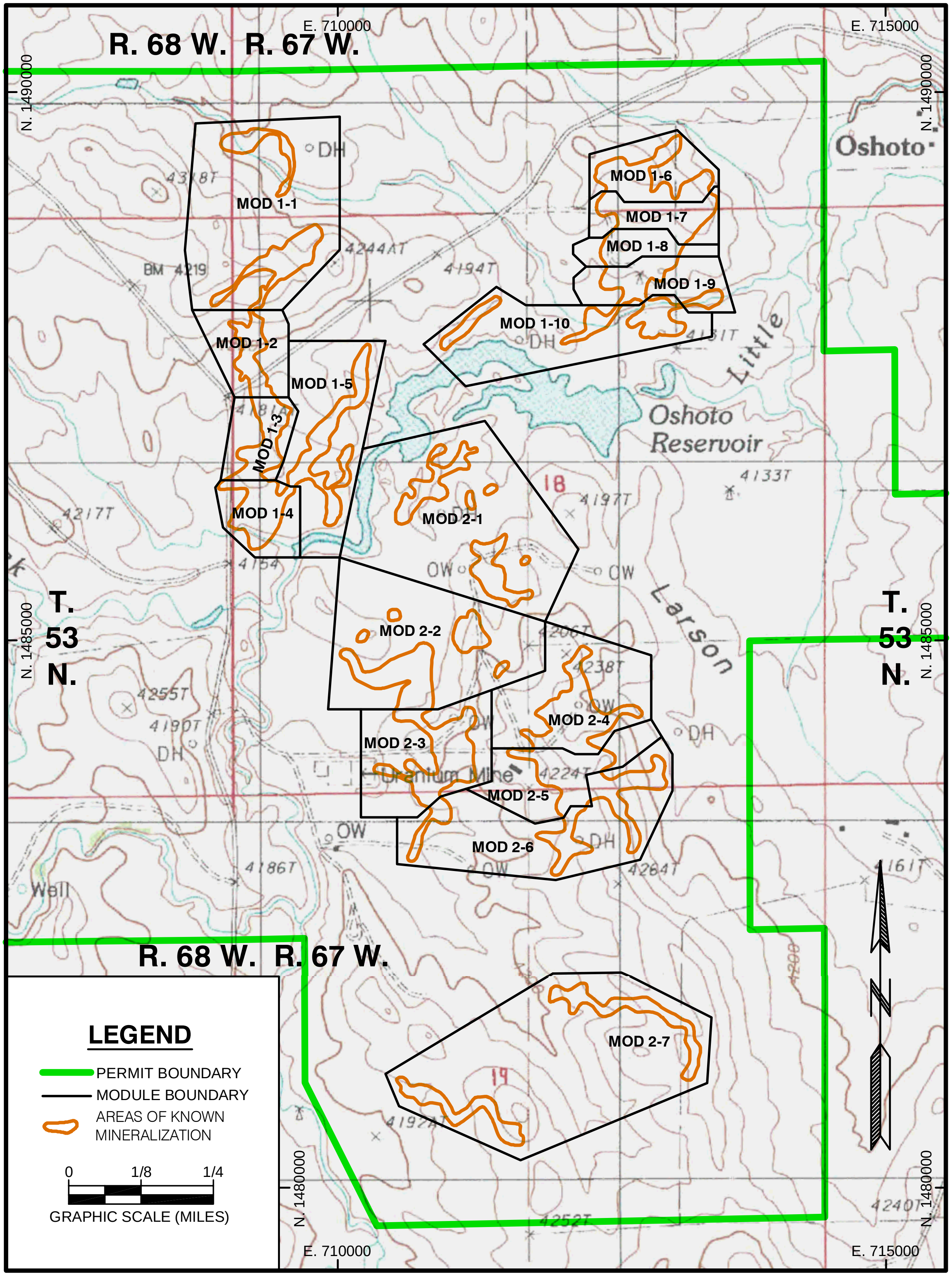


Figure 4.9-1. Simulated Wellfield Layout

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_LAYOUT.dwg, GWM_FIGURE_4.9-1, 12/20/2010 11:30:52 AM undergoing ISR will be used to offset RO losses within the module in restoration.

During typical restoration activities, each module is expected to operate at approximately 513 gpm (roughly 12.8 gpm per recovery well assuming 40 production wells per model). When excess bleed is available from adjacent modules, the estimated bleed is 16.5 gpm per module (0.41 gpm per recovery well, or 3.2 percent bleed). When excess water is not available from adjacent modules, the estimated restoration bleed is 45 gpm per module (1.125 gpm per recovery well or 8.8 percent bleed).

The maximum estimated flow rates above were used to develop an ISR simulation. To simulate the regional impacts of ISR each proposed recovery well was imported into the model. Bleed rates were then assigned to each recovery well during ISR, groundwater sweep, and restoration. This has the effect of simulating the net withdrawal from the aquifer that would be expected from balanced wellfields. To evaluate localized impacts to the wellfield, recovery and injection wells were added to the model. The introduction of injection wells increases the complexity of the model and, in order to maintain wellfield balance, is an iterative procedure. For the purposes of this report only a small sample wellfield was simulated with both injection and recovery wells. The localized evaluations that include both recovery and injection wells are described in more detail within Sections 4.11 and 4.12.

During ISR most of the existing industrial, stock, and domestic water wells within the region and tabulated in Table 4.7-1 are expected to continue operating. Table 4.9-2 tabulates the expected discharges during ISR simulation for each well. In general, no changes in flow rates are expected within the stock and domestic wells. Estimated flow rates for the oilfield water supply wells were developed based on average historical flowrates for the last two years of recorded flow (2008 and 2009). Three of the oilfield water supply wells (22X-19, 19XX, and 789V) are located immediately adjacent to modules 2-6 and 2-7. Strata has been in communication with the owner, Merit Energy Co. (Merit), of these wells and is currently exploring alternative water sources that will allow

Table 4.9-2. Well Pump Rates during ISR Simulation

Well	Easting[1]	Northing[1]	Layer	use	Flowrate[2] (gpm)
Strong Wells	714963	1483356	6 (OZ)	Domestic/stock	0.4
Sophia #1A	700456.92	1484277.9	6 (OZ)	Oilfield	10.8
Kiehl Water Well #2	712381.38	1474845.8	4 (SM) and 6 (OZ)	Oilfield	3.4
22X-19	710875.88	1481932.5	6 (OZ)	Oilfield	0/19
19XX State	711658.65	1483960.9	6 (OZ)	Oilfield	0/10.5
789V State	710930.43	1484055.2	6 (OZ)	Oilfield	0/10.5
ENL Kiehl Well #1	713378	1473690	6 (OZ)	Oilfield	3.4
WSW#1 West Kiehl Unit	707029	1471267	6 (OZ)	Oilfield	0
Wesley TW02 P103666W	715506	1489632	6 (OZ)	Domestic/stock	0.8

[1]Easting and northing coordinates based on Wyoming NAD 83 E coordinate system.
[2]Flowrates for 22X-19, 19XX-State, and 789V State vary depending on model scenario.

them to suspend using the wells before and during ISR. Currently, the goal is to have the Merit wells shut off approximately 2 years prior to ISR. Given the uncertainty associated with the future status of the Merit wells, two ISR scenarios have been simulated. Scenario 1 assumes that an alternative water supply is found and the Merit wells are taken out of operation 2 years prior to ISR, and kept out of operation until ISR operations cease. Scenario 2 assumes that an alternative water supply source could not be located and that the Merit oilfield water supply wells are in operation during ISR operations at the assumed 2008-2009 average flow rates.

4.9.3. ISR Simulation Results

Results from Scenario 1, in which the Merit Oil supply wells are assumed to be turned off 2 years prior to ISR and during ISR, are presented in Appendix B. Results from Scenario 2, which simulates the Merit wells operating during ISR, are presented in Appendix C. For layers 4 and 6 the total estimated drawdowns at the end of active ISR and during recovery within each layer are presented as well as potentiometric surfaces before and at the end of ISR operations. Modeled potentiometric surfaces for layer 6 at selected stress periods and time steps during ISR are also included in the appendices. Since modeled drawdowns within layers 1 and 2 are minimal, results for these layers are not included in the appendices.

Although the impacts from ISR within layers 1 and 2 are minimal, modeled impacts do occur near the outcrop of the OZ aquifer. Conceptually, near the outcrop water from the Little Missouri River infiltrates into the SM and OZ aquifers. Water not infiltrating into the OZ and SM aquifers exits the model via drains installed where Good Lad Creek and the Little Missouri River cross the outcrop. Prior to ISR operations, an estimated 1.5 gpm was leaving the model via the drains. At the end of ISR operations no water was exiting the model via the drains. In addition, the cells near the edge of the model and adjacent to the drains had become dry. The dry cell assumption in the model is probably unrealistic due to surface/groundwater interactions which are ignored in the model. Both streams are ephemeral streams and for some portion of the year each stream does flow, although the flow rate varies widely from year to year and season to season. This ephemeral flow is expected to provide additional recharge not accounted for in the model and thus eliminate the dry cells. The resulting impact from lowering the water levels within the OZ is that at the outcrop the water levels are expected to be lowered as shown in the model. The OZ outcrop is relatively narrow, approximately 950 and 800 feet where it intersects the Little Missouri River and Good Lad Creek, respectively. Across the short stream length crossing the OZ outcrop, standing pools of water would be expected to infiltrate faster due to lowered water levels. However, since the length of the outcrop is so short, the net effect to the ephemeral streams is expected to be minimal.

The figures in the appendices show that the bulk of ISR impacts occur within layer 6. For example, at the end of ISR operations the maximum modeled drawdown in layer 6 was approximately 160 feet in Scenario 1 and 200 feet in Scenario 2 whereas the maximum drawdown in layer 4 was 5 feet and 20 feet for scenarios 1 and 2, respectively. In general, the impacts to the SM (layer) are predicted to be minimal during ISR operations. Pump testing indicates isolation of SM relative to OZ, so the minimal impact prediction is reasonable. Assuming Strata is able to find an alternate water supply source for the Merit oil wells as planned, the impacts on the SM will be very minimal as shown in Appendix B.

Regionally, within layer 6, modeled drawdowns occurred primarily within and just north of the Ross Project area. Model predicted drawdowns to the south and to the west were less severe. To assess the impacts on wells within the region, water levels were monitored during the ISR simulation at each well location. The maximum modeled change in head that occurred in each well during the ISR simulations are presented in Table 4.9-3. As shown on Table 4.9-3, the drawdowns within Scenario 1 are much less severe than the drawdowns in Scenario 2. In fact, there was a significant net increase in head within the Merit wells in Scenario 1, as they continue to recover. The Wesley TW02 well had the most severe drawdown of any non oilfield wells within Scenario 1. This well is located within the mapped Fox Hills outcrop and supplies water to Strata's current field office. Within the model this well is located very near the edge of the model. During the ISR simulation, cells adjacent to the one in which well Wesley TW02 is located go dry. As such, the severe drawdown predicted at the well may be as much a product of edge effects and the inherent numerical instability of the modeling equations with adjacent dry cells, as a true result. Furthermore, immediately adjacent to the Wesley TW02 well location, real geological data is unavailable because no boreholes have been drilled, and no site specific hydraulic conductivity values are available. As such, predicted drawdowns presented for the Wesley TW02 well may be over estimated by the model. Nevertheless, it would be prudent to monitor this well during ISR. As additional drilling and hydrologic information becomes available updates to the model may also help yield more realistic results.

The Strong well is also located near the outcrop of the OZ and SM. Because of its proximity to the edge of the model the predicted drawdowns may also be impacted by model edge effects. However, at the location where the Strong well is simulated, the geology is more realistically represented than

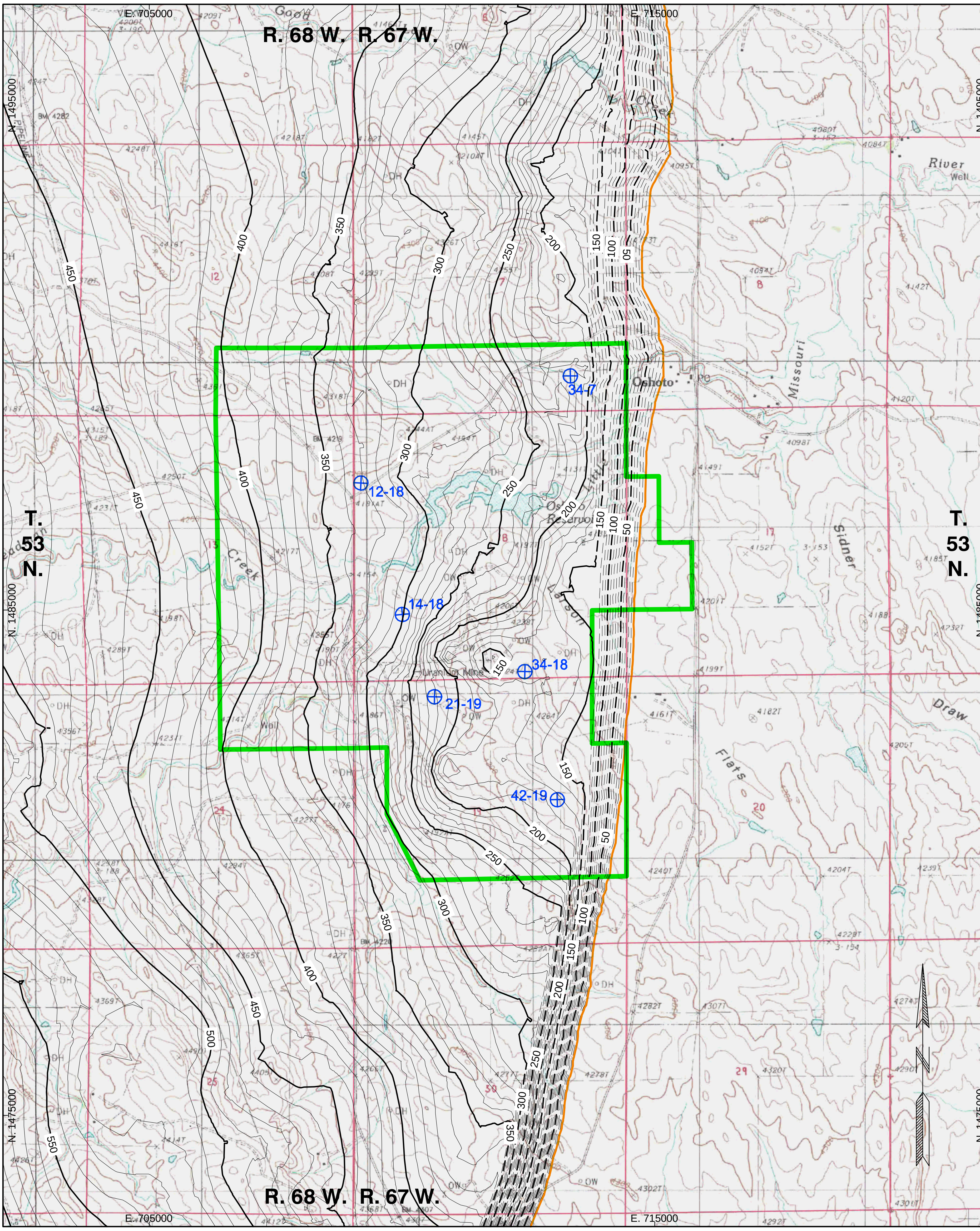
Table 4.9-3. Maximum Modeled Well Drawdowns during ISR Operations

Well	Easting[1]	Northing[1]	Layer	Use	Drawdown Scenario 1 (ft)[2]	Drawdown Scenario 2 (ft)[2]
Strong Wells*	714963	1483356	6 (OZ)	Domestic/stock	5	17.3
Sophia #1A	700456	1484277	6 (OZ)	Oilfield	14.7	26.3
Kiehl Water Well #2	712381	1474845	4 (SM) and 6 (OZ)	Oilfield	1.8–lyr 4 1.6 –lyr 6	2.3 –lyr 4 3.4 –lyr 6
22X-19	710875	1481932	6 (OZ)	Oilfield	-50	110
19XX State	711658	1483960	6 (OZ)	Oilfield	79	158
789V State	710930	1484055	6 (OZ)	Oilfield	101	176
ENL Kiehl Well #1	713378	1473690	6 (OZ)	Oilfield	3.2	5.0
WSW#1 West Kiehl Unit	707029	1471267	6 (OZ)	Oilfield	-0.8	1.8
* Wesley TW02 P103666W	715506	1489632	6 (OZ)	Domestic/stock	30.8	33.1

1 Easting and northing coordinates based on Wyoming NAD 83 E coordinate system.
2 All drawdowns calculated from current 2010 potentiometric surface.
* Drawdowns may be impacted by model edge effects. Modeled drawdowns may be greater than actual.

the geology near the Wesley TW02 well. As a result, the predicted drawdown within the Strong well is believed to be more realistic.

Figure 4.9-2 presents an isopach of the available potentiometric head above the top surface of the OZ aquifer in 2010. As shown on Figure 2.9-2 available head above the top of the OZ aquifer varies from 150 ft near the Merit wells to 400 feet near the western edge of the permit boundary. As shown in Appendix B, simulated ISR drawdowns are in the range of 100 to just over 200 ft near the wellfields when the Merit wells are assumed to be off during ISR operations. Assuming the Merit wells are in operation, the drawdowns are higher. Given the available potentiometric head presented in Figure 4.9-2, operation of the Merit wells and the ISR wellfields simultaneously may cause the potentiometric surface within the OZ aquifer to drop below the top of the aquifer in the region immediately adjacent to the Merit wells if special operational procedures are not followed. Throughout the rest of the wellfield there is enough available potentiometric head that under the modeled



Drawing Coordinates: WY83EF

LEGEND

PROPOSED ROSS PERMIT BOUNDARY

100 ISOPACH LINE (10' CONTOUR INTERVAL) OF POTENTIOMETRIC HEAD ABOVE ORE ZONE INTERVAL. CONTOUR LINES ARE DASHED WHERE POTENTIOMETRY AND STATIGRAPHIC STRUCTURE WERE PROJECTED ALONG THE BLACK HILLS MONOCLINE FLEXURE.

EDGE OF AQUIFER

21-19 ⊕ REGIONAL BASELINE MONITOR WELL CLUSTER

NOTE:

TOP OF ORE ZONE SURFACE DERIVED FROM GEMCOM GEMS© SOFTWARE CUSTOMIZED FOR STRATA ENERGY, INC. AND DEVELOPED IN SUPPORT OF SITE SPECIFIC GROUNDWATER MODEL. 2010 POTENTIOMETRIC SURFACE GENERATED FROM GW VISTAS© GROUNDWATER MODEL USING MODFLOW. THIS FIGURE REPRESENTS THE DIFFERENCE BETWEEN THOSE TWO SURFACES.

0 1000 2000 4000

GRAPHIC SCALE (FEET)

STRATA ENERGY

ROSS ISR PROJECT
CROOK COUNTY, WY
P.O. BOX 2318
GILLETTE, WY 82716

REVISIONS	
Date	Description

GWM TECHNICAL REPORT
FIGURE 4.9-2

ISOPACH OF AVAILABLE POTENTIOMETRIC HEAD IN 2010 ABOVE THE ORE ZONE AQUIFER

Drawn By: RAM
Checked By: BJS
Date: 11/21/10

WWC ENGINEERING
www.wwcengineering.com

FILE: ROSS_GEO_OZ_CONHEAD_ISO.DWG

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_ER_GEO_OZ_CONHEAD_ISO.dwg, GWM_FIGURE_4.9-2, 12/18/2010 2:47:36 PM scenarios, the potentiometric surface will be maintained above the top of the OZ aquifer.

Based on the ISR simulation, the only wells that are likely to be impacted by ISR operations are the three wells currently in use by Merit for water flood operations within the project area. If these wells continue to operate during ISR operations, the water levels within the OZ aquifer may go below desired levels. Furthermore, the operation of these wells within the active wellfields may result in severe wellfield imbalances. The estimated combined discharge rate for the three Merit wells is approximately 40 gallons per minute, which is equivalent to the bleed that would result from just under 5 modules. Because the discharge rates from the Merit wells are significant, in comparison to the discharge rates from ISR, it will be imperative that Merit use an alternative water source that will not result in drawdowns within the OZ during ISR within the immediate vicinity of the Merit Wells.

In the event that Strata is able to find an alternative water source and eliminate pumping from the Merit wells prior to ISR operations, aquifer recovery is expected to occur rapidly. Within 2 years the water level within each well rises by nearly 100 feet. Under ISR Scenario 1 (Merit wells off) the only period in which problems occur is during stress period 15 where the potentiometric surface drops below the top of the aquifer in several cells within the module 2-5 region. This region is immediately adjacent to well 19XX-State and the potentiometric surface drops below the top of the aquifer during the groundwater sweep simulation. Even though the 19XX-State well is assumed to be off during this time, the lowered potentiometric surface is still likely a result of residual drawdown from the well. Simulation #2 indicates that, with the 19XX-State in operation during ISR operations, the extent of the area in which the potentiometric surface drops below the top of the aquifer covers more cells, which would be expected. In reality, the simulated scenario is probably not reasonable because Strata is proposing to do a selective groundwater sweep and the flow rates would not necessarily be a "one size fits all" scenario for all modules. The estimated 17.5 gpm well flow rate is expected to be closer to the maximum flow rate rather than the minimum. Where the hydraulic conductivity is low a production rate of 17.5 gpm may not be achievable. The current ISR simulation assumes that all recovery well rates will be equal to 17.5 gpm to conservatively predict maximum estimated impacts from ISR production.

The ISR scenario modeled for this report is a conservative simulation to evaluate potential ISR impacts and not the final ISR scenario. Developing the final ISR unit progression will be an iterative procedure that will require balancing flows within each wellfield to maximize efficiency. The ISR simulation modeled for this report assumes a constant bleed and constant sweep. A review of the potentiometric surfaces modeled during ISR simulation indicates that it may be necessary to adjust the bleed rates between modules as well as adjusting the wellfield progression to maximize efficiency. For example, when ISR was simulated in module 2-2 the relic cone of depression left by the Merit wells indicated that a bleed rate of 1.25 percent may be higher than necessary to contain ISR fluids. Conversely, the bleed may have to be increased to optimize ISR production within module 1-6. Furthermore, under the modeled ISR scenario interference between wellfields has been noted. To minimize interference, Strata is currently exploring other options such as alternate mine progression scenarios, pre-ISR aquifer conditioning, and alternate ISR schedules. Strata intends to use this groundwater model as the primary tool to minimize interference and optimize ISR production.

This ISR simulation achieved the goal of predicting regional impacts. If arrangements can be made to temporarily suspend pumping from the Merit oilfield water supply wells, the regional impacts presented in Scenario 1 are probably the most realistic impacts. Due to the abstraction introduced by the Merit wells, the ISR wellfields located immediately adjacent to the wells will be difficult to operate with the Merit wells in operation through ISR operations. Generally, operating a wellfield in the immediate vicinity of the Merit wells will require excessive bleed in order to contain ISR fluids within the wellfield. The abstraction caused by Merit's wells decreases substantially at distances more than 0.25 miles from the wells. As such, it may be possible for the Merit wells to continue operating during active ISR in the northernmost and southernmost proposed wellfields. Further modeling will be required to determine the most efficient way to operate ISR wellfields in tandem with Merit wells.

Scenario 2 likely over-estimates the impacts to the regional aquifer that would result from ISR. As previously mentioned, Strata is currently working with Merit to identify alternative water sources for the oilfield and anticipates that a solution will be arrived at that will eliminate the abstractions caused by the water supply wells. As such, it is unlikely that the Merit wells will be in operation during ISR operations and Scenario 2 likely over estimates net consumptive water use from the OZ aquifer. The groundwater model presented herein is an effective tool that can be used to balance wellfields, help sequence uranium recovery, and predict expected impacts from alternative ISR scenarios. Given the wide variability in aquifer conditions and distance between available measured aquifer parameters, it will be necessary to do additional site specific aquifer testing at each wellfield. Information from the site specific can then be incorporated into the model to improve the resolution of the model. The increased model resolution will help further refine and optimize operational parameters for each wellfield. The simulation presented herein is designed to present to the reader conservative impacts from ISR development. As Strata continues exploration efforts and finalizes the wellfield delineation, several ISR simulation iterations with the groundwater model will be necessary to optimize and develop the final wellfield design packages.

4.10 Recovery

To simulate water-level recovery, the model was run for 5, 10, 20, 50 and 100-year periods after the cessation of ISR operations. In Scenario 1 it was assumed that the Merit water supply wells did not resume pumping after ISR was complete. In Scenario 2 it was assumed that there was no change in operation of Merit's wells before, during, or after the Ross ISR Project. In both scenarios all other domestic and industrial wells within the model domain were assumed to operate at flow rates presented in Table 4.9-2. The residual drawdowns during recovery are presented in Appendices B and C. Residual drawdowns presented in Appendices B and C are based on the 2010 modeled potentiometric surfaces presented in figures 4.7-4 and 4.7-5.

In general, the figures within appendices B and C show that recovery to a residual drawdown of less than 10 feet from the 2010 modeled potentiometric surface is expected to occur quite quickly. Within the SM aquifer, drawdowns at the end of ISR operations for Scenario 1 would be insignificant (less than 10 feet). Within Scenario 2, recovery to a drawdown of less than 10 feet takes less than 5 years. Within the OZ aquifer full recovery takes between 5 and 10 years for Scenario 1. For Scenario 2 recovery to a drawdown of 10 feet takes between 5 and 10 years with most of recovery occurring within the first 5 years (recovery vs. time follows an exponential curve). As previously noted, Scenario 2 assumes the Merit water supply wells continued operating after ISR ceases. The longer recovery time in Scenario 2 is attributed to the Merit wells. Full recovery to pre-Ross levels would not occur until the Merit wells are shut off, but that is outside Strata's control after ISR operations are complete.

4.11. Excursion Control and Retrieval

Based on the results presented herein, Strata has determined that a monitor ring spacing would be effective at identifying an excursion up to 600 ft from the proposed wellfield. To asses monitor ring spacing and excursion recovery an ISR simulation with both injection and recovery wells was developed for a small portion of the wellfield. An excursion simulation utilized an out of balance wellfield in module 1-1 as depicted in Figure 4.11-1. To increase the resolution around module 1-1, model grid spacing was decreased to 25 foot squares within and immediately adjacent to the wellfield. To minimize the number of cells within the model and thus minimize the size of the output files the grid spacing was increased up to 1,000 feet near the outer edges of the model. This excursion simulation assumes that prior to the beginning of the Ross project, the Merit water supply wells had been shut in for

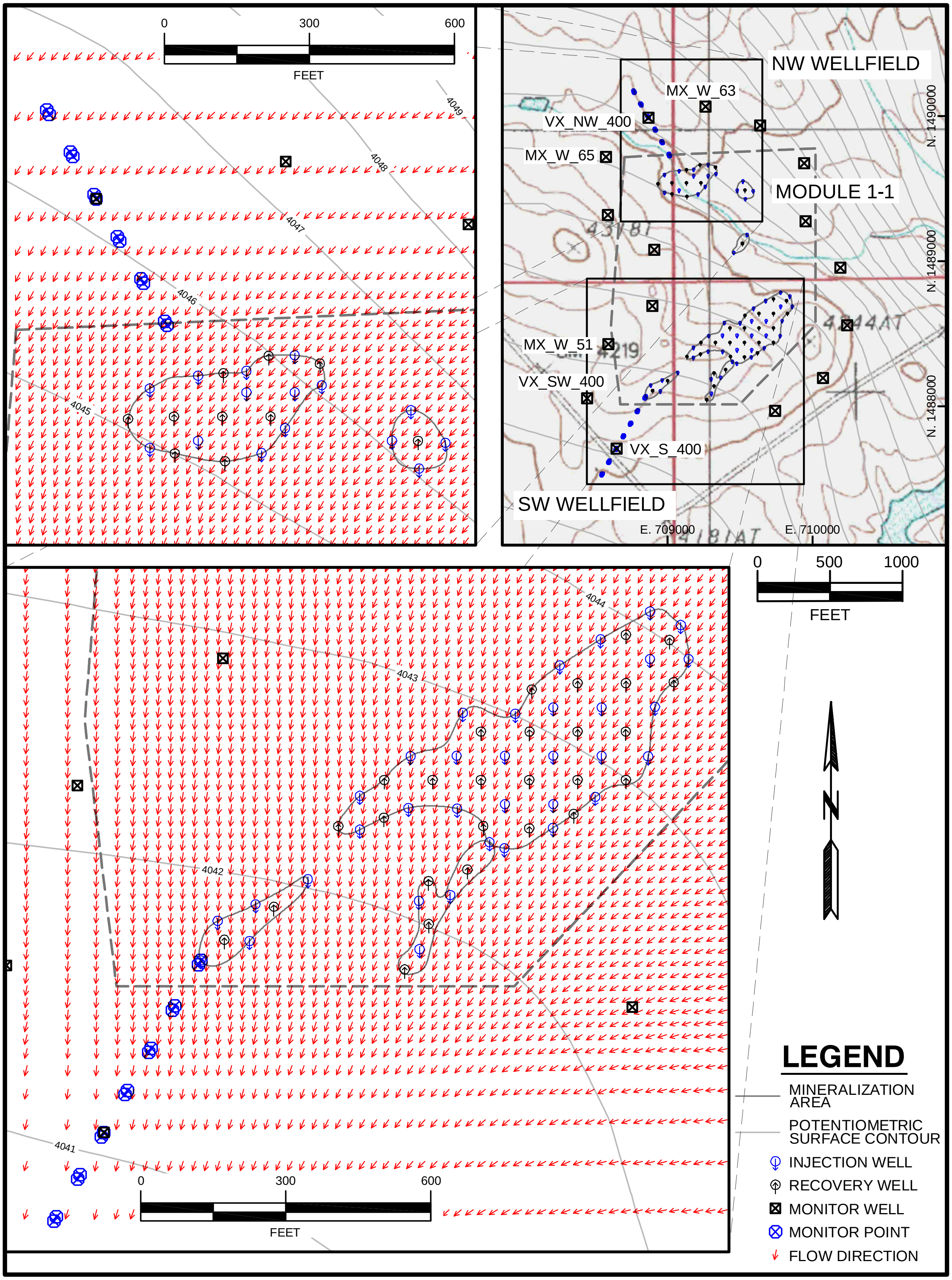


Figure 4.11-1. Pre-ISR Groundwater Flow in Module 1-1

approximately 2 years and follows the assumptions of Scenario 1. All other wells within the region were left operating at the rates described in Table 4.9-2. To simplify the analysis only wellfields within module 1-1 are included in this simulation.

Prior to performing the excursion evaluation, several well patterns within module 1-1 were balanced by trial and error using Groundwater Vistas. For this exercise the wellfield balance was less rigorous than the balance used to describe the flare in Section 4.12. An upgradient wellfield in the north part of module 1-1 and a downgradient wellfield in the southwest portion of module 1-1 were chose to evaluate the monitor well spacing. To conservatively show that an excursion would be detected in the upgradient wells, the bleed in the north wellfield was simulated at a rate higher than normal (i.e. an upgradient monitor well would detect an excursion even when the wellfield cone of depression is steeper than normal away from the well). The north wellfield had 9 recovery wells operating at 17.5 gpm (157.5 gpm total). The wellfield also included 11 injection wells with a combined injection rate of 151.2 gpm. The net bleed in the north wellfield was approximately 4%. The south wellfield was balanced at the average estimated bleed rate of 1.25%. Since the south wellfield simulates an excursion to the downgradient side of the wellfield, the average bleed set to 1.25% is conservative (i.e. a downgradient excursion would be harder to recover if the bleed rate is minimal because the cone of depression is shallower). The southern simulated wellfield had 27 recovery wells operating at 17.5 gpm (472.5 gpm) the southern wellfield had 35 injection wells operating at various flow rates for a total combined injection rate of 466.6 gpm and 1.25% bleed.

Using the balanced module 1-1 wellfield the excursion simulation was broken into five modeled time increments (stress periods). The stress periods represent pre-Ross conditions, ISR operations at Ross, out of balance with possible excursion, out of balance recovery, and back to normal ISR operations. Each stress period is described in more detail below.

Stress period 1 – Lasts 1 day and represents existing conditions with no uranium recovery occurring. The only wells operating during stress period 1 are those described in Table 4.9-2 which are in operation throughout the entire simulation.

Stress period 2 - Represents a 90-day wellfield operation period. This period represents a typical operating scenario with a balanced wellfield.

Stress period 3 – Is a 30-day period that represents the out of balance wellfield used to simulate an excursion. During stress period 3 the wellfield is taken out of balance by shutting off 2 recovery wells at different locations within the wellfield. One of the recovery wells is located on the down gradient, southwest side (SW), of the wellfield and the other is located on the northwest (NW) side of the wellfield (upgradient). Figure 4.11-1 depicts the modeled flow directions and potentiometric surface prior to ISR operation. The flow rates for the unbalanced recovery wells varied from 17.5 gpm in stress period 2 to 0 gpm in stress period 3 and then back to 17.5 gpm for stress periods 4 and 5.

Stress period 4 – Is a 45-day period representing the excursion reversal phase. For this phase the two recovery wells are turned on at their previous 17.5 gpm rate and the adjacent injection wells are either turned off or the injection rate reduced. In order to develop similar comparisons from location to location, the total decrease in injection rate was 17.3 gpm between the adjacent injection wells at both the NW and SW excursion sites.

Stress period 5 – is a 30-day period representing the recommencement of normal ISR operations after the excursion has been corrected. During this period all the injection and recovery wells are turned back to their balanced wellfield production rates.

As shown on Figure 4.11-1, several simulated monitor points were strategically established radiating out from the NW and SW out of balance well locations. The heads recorded by the model during each time step at each monitor point are graphed for the NW and SW simulated wellfield imbalances in Figures 4.11-2 and 4.11-3, respectively. The graphs for each wellfield show potentiometric surfaces for pre-ISR conditions, after 90 days of normal ISR,

Figure 4.11-2. Modeled Potentiometric Surfaces Near the Northwest Simulated Excursion

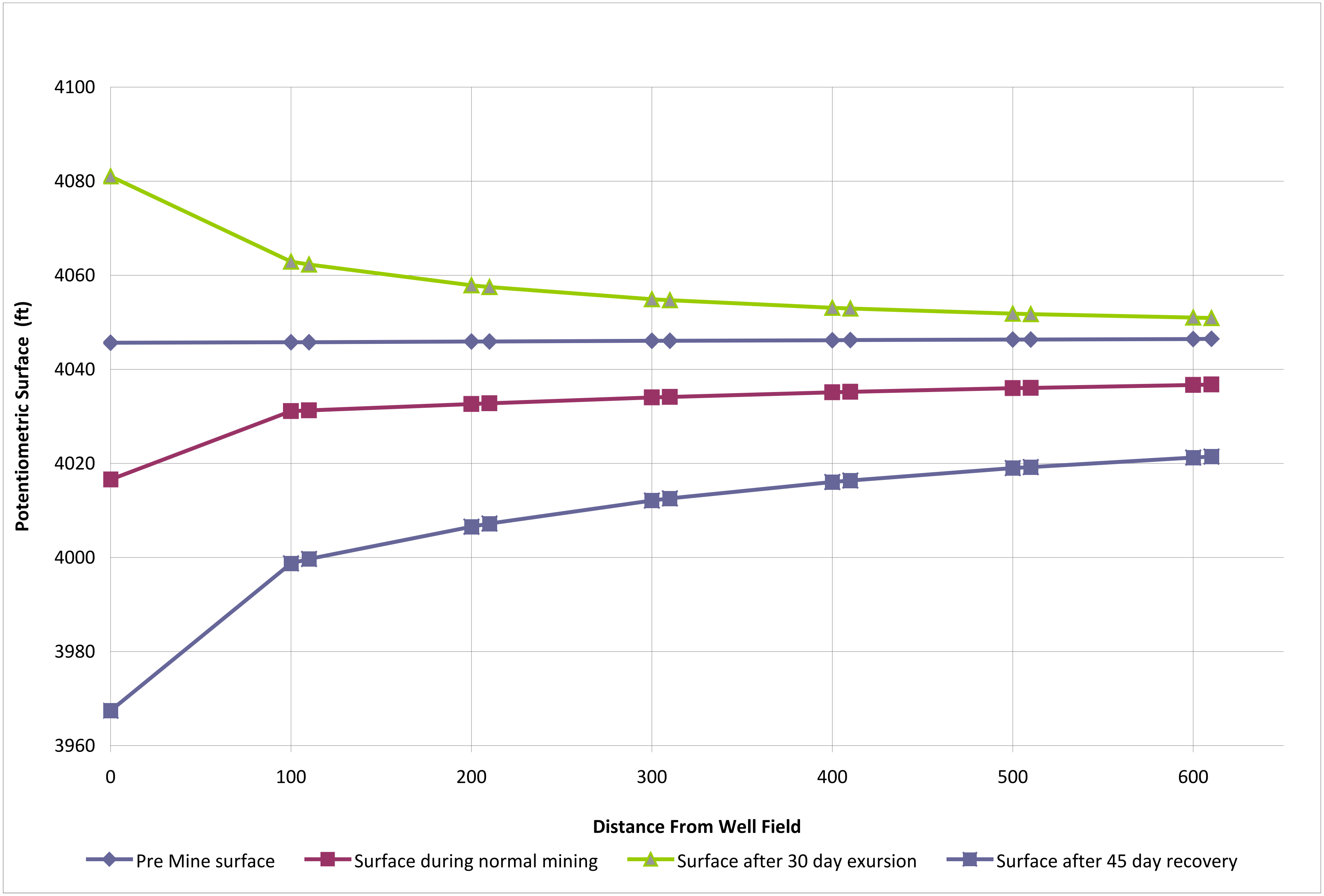
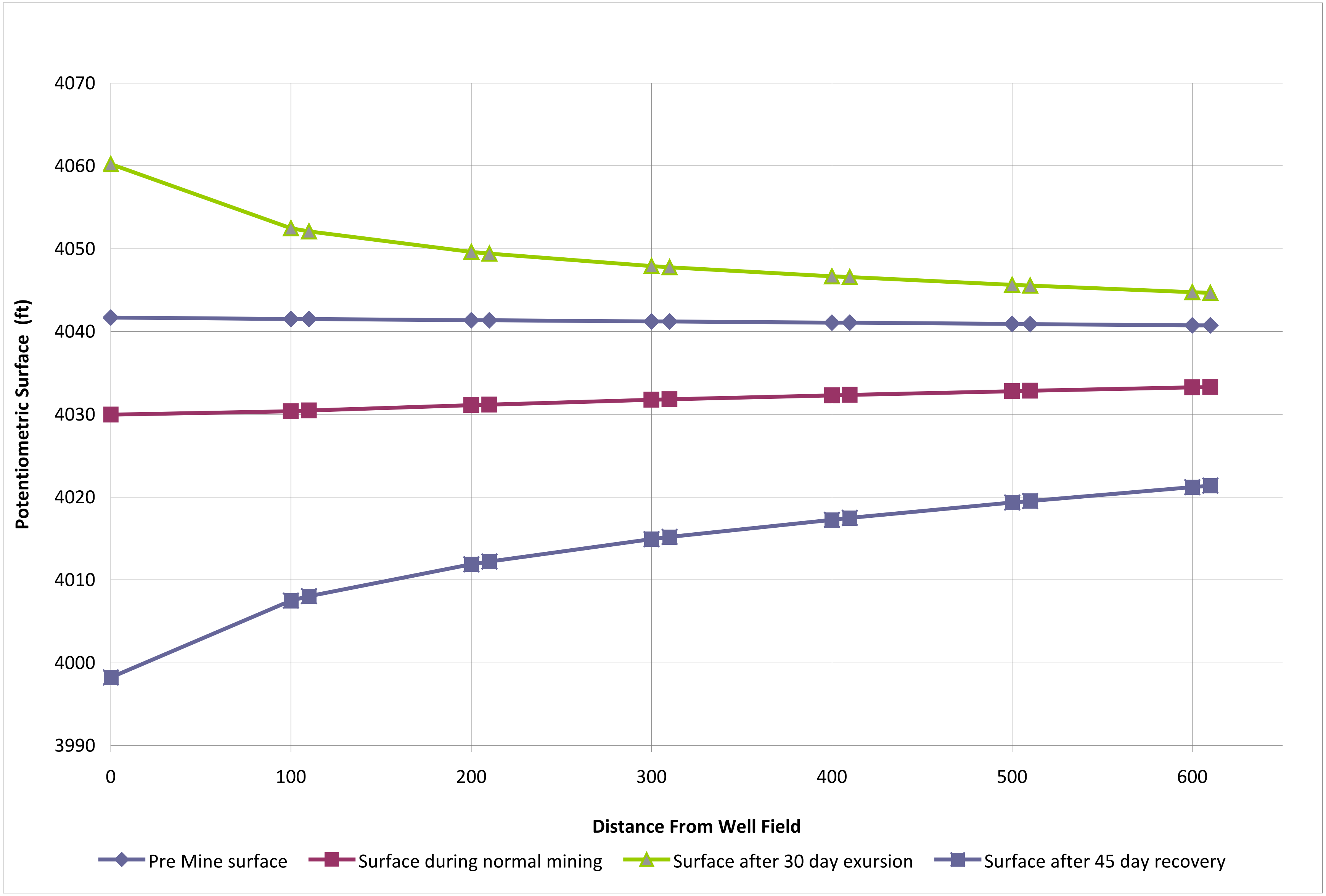


Figure 4.11-3. Modeled Potentiometric Surfaces Near the Southwest Simulated Excursion



after 30 days of excursion simulation, and after 45 days of excursion reversal. Within the SW simulation, the pre-Ross ISR surface indicates that the initial groundwater gradient was actually away from the wellfield which can be seen in Figures 4.11-1 and 4.11-2. Within the NW simulation the gradient is shallow but the recovery wells are down gradient as shown on Figures 4.11-1 and 4.11-3. As shown on Figures 4.11-2 and 4.11-3, during normal ISR, drawdowns are towards the wellfield, which indicates a well-balanced wellfield that is capturing all ISR fluids. Figure 4.11-4 depicts modeled flow directions at each simulation location during normal ISR operations. During the simulated excursion the hydraulic gradient is away from the wellfields. Figure 4.11-5 depicts the location of each simulated out of balance recovery well and the modeled flow direction during the excursion. The simulated surface during recovery is towards the wellfield and much steeper than the potentiometric surface calculated during normal ISR. The steeper potentiometric surface indicates that during recovery fluid is moving towards the wellfield at a much higher rate than during normal ISR operations which is also depicted on Figures 4.11-2. 4.11-3, and 4.11-6

To determine how far the simulated excursion traveled and the time necessary to correct the excursion, monitor points were placed 10 feet apart along the same alignment at specific distances from wellfield (i.e. 200 and 210 feet, 400 and 410 feet, etc.). A hydraulic gradient was then determined at each location. Based on the hydraulic gradient calculated between the two monitor points a groundwater velocity was calculated at each point using Equation 4.11-1.

Equation 4.11-1 $V=-k/n*dh/dl$

Where:
V=velocity (ft/day)
k= hydraulic conductivity (ft/day)
N=porosity (assumed to be 0.3)
dh/dl=hydraulic gradient

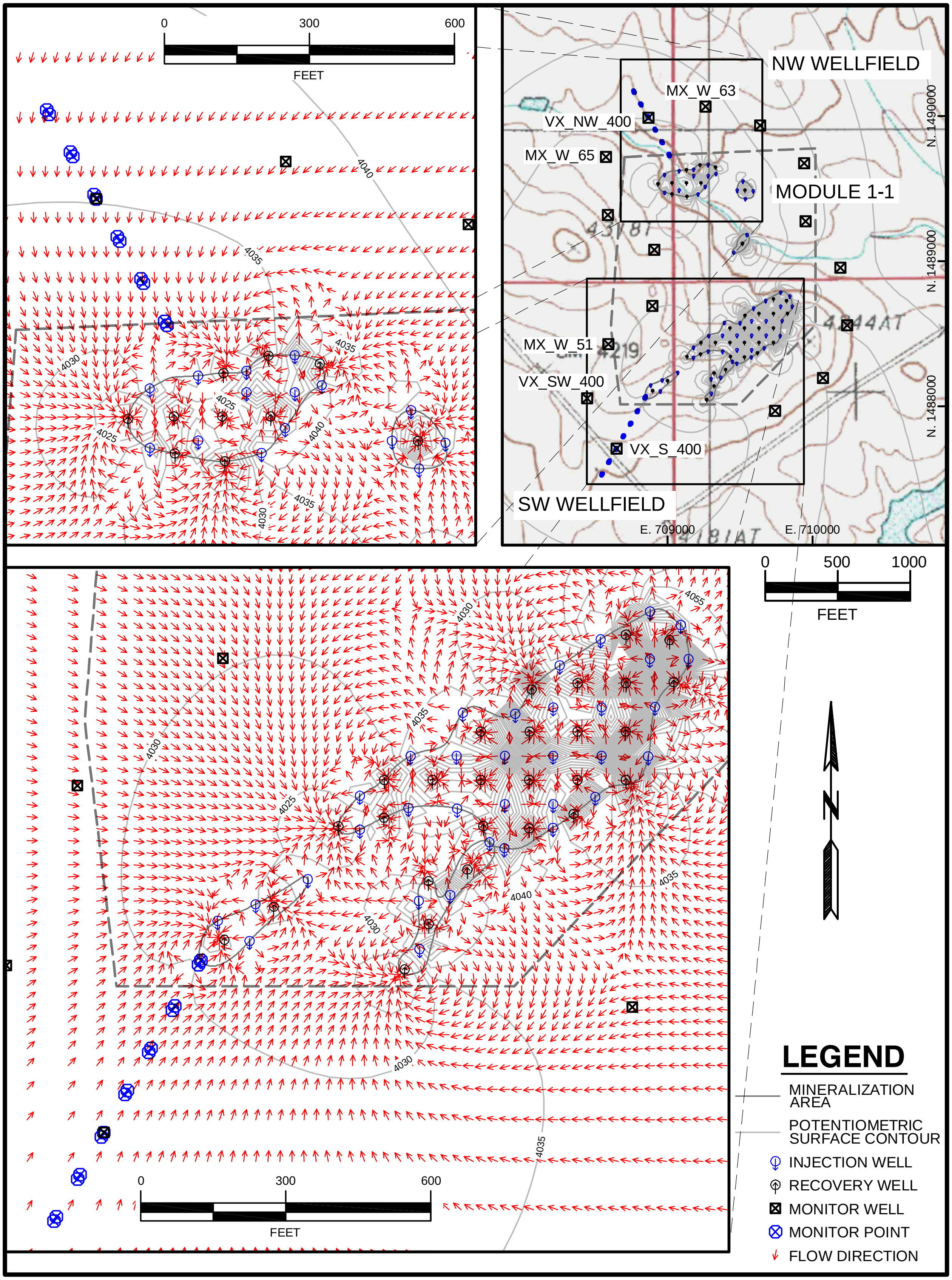


Figure 4.11-4. Groundwater Flow During Normal ISR in Module 1-1

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_MINE_VECT.dwg, GWM_FIGURE_4.11-4, 12/20/2010 11:50:43 AM

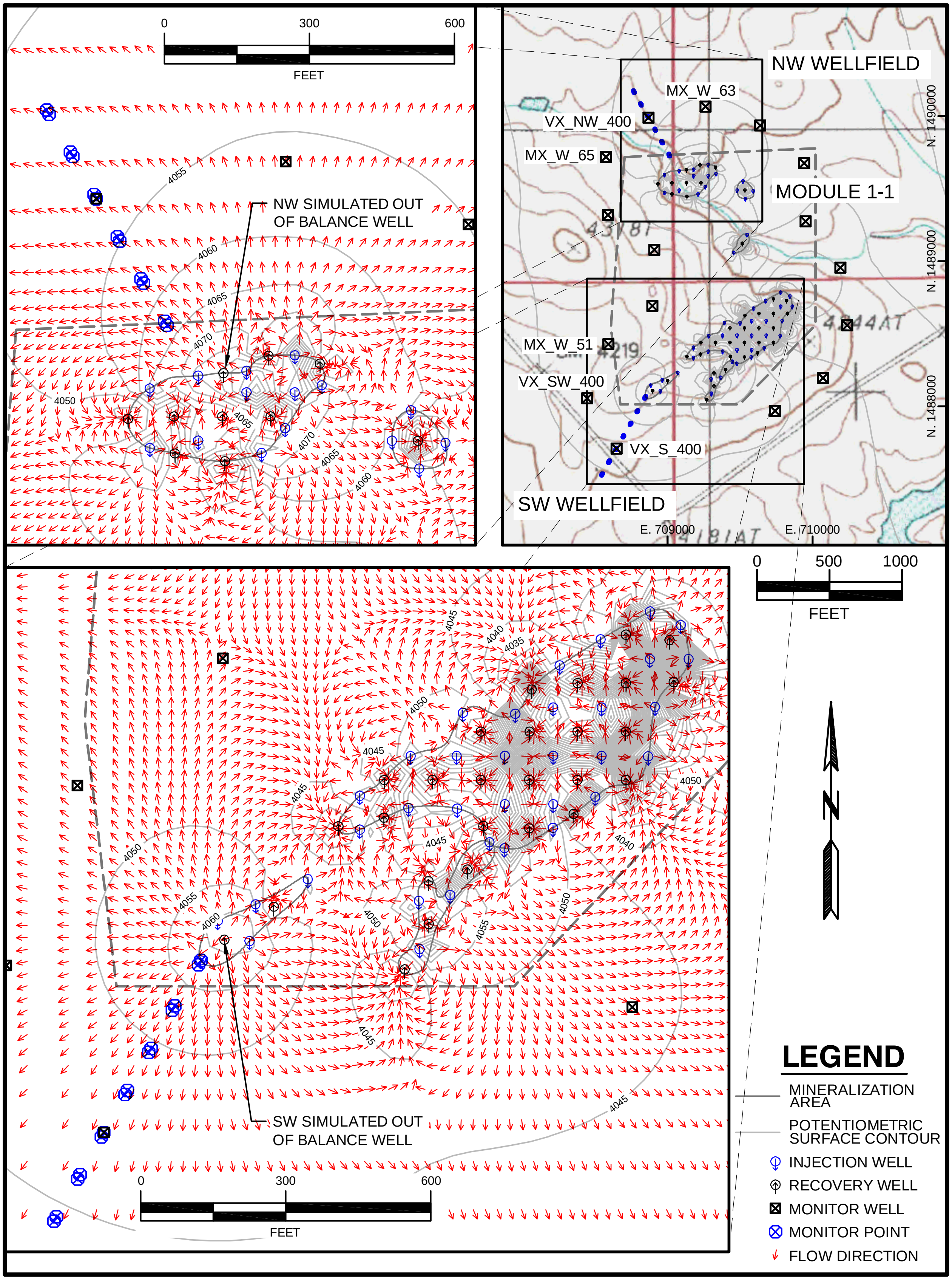


Figure 4.11-5. Groundwater Flow During Excursion in Module 1-1

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_EXCUR_VECT.dwg, GWM_FIGURE_4.11-5, 12/20/2010 11:51:53 AM

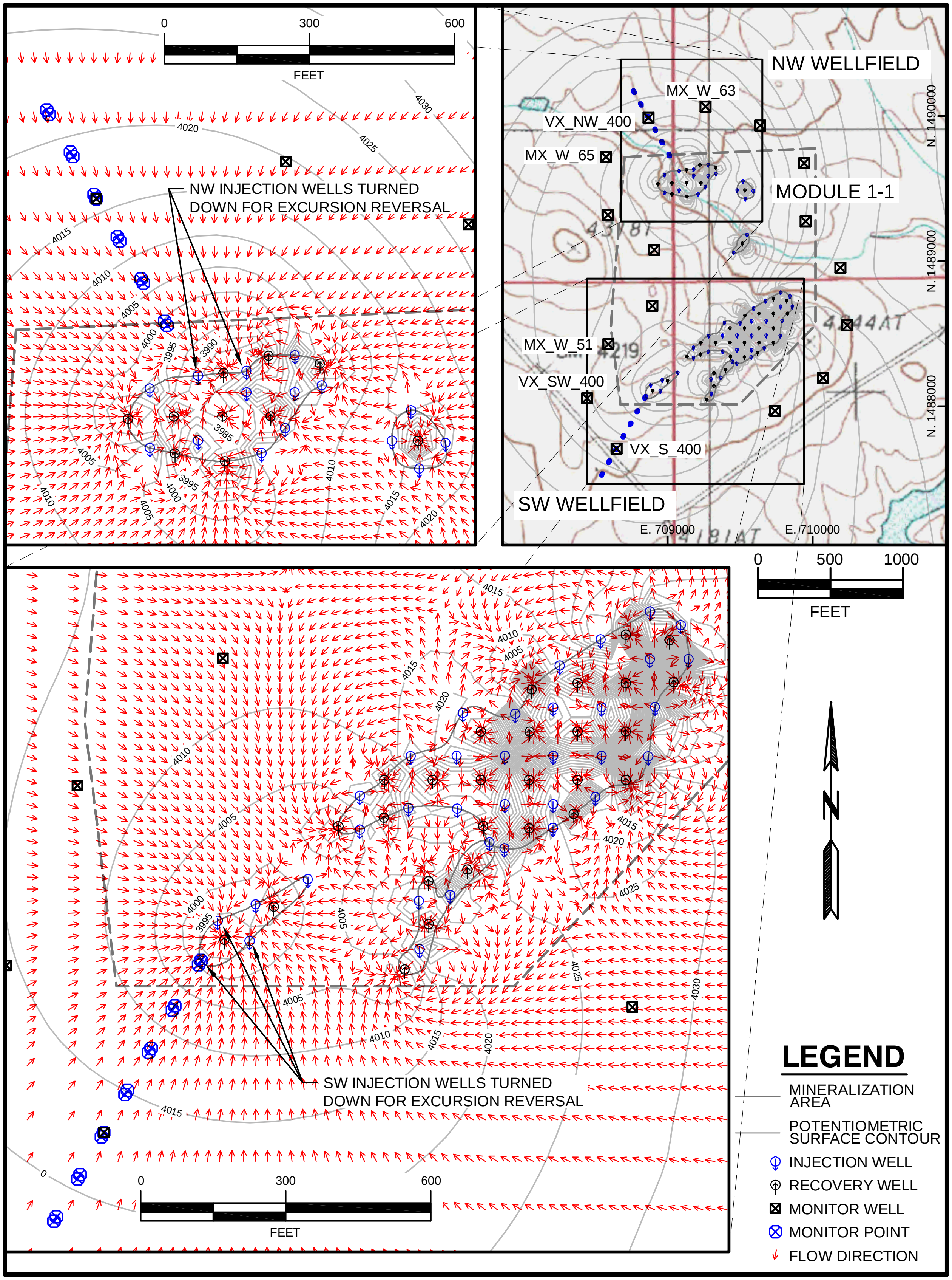


Figure 4.11-6. Groundwater Flow During Excursion Reversal in Module 1-1

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_RECOV_VECT.dwg, GWM_FIGURE_4.11-6, 12/20/2010 11:53:01 AM

The calculated groundwater velocity at each monitor point was then multiplied by the incremental time in order to determine how far the groundwater moved. Tables 4.11-1 and 4.11-2 demonstrate the actual groundwater movement near the NW and SW simulated excursions, respectively. As shown on Table 4.11-1, the total distance that the groundwater traveled during the simulated 30-day excursion ranged from 1.15 ft to 0.22 feet 200 and 600 feet from the wellfield, respectively, near the NW simulated excursion. The total time that it took to reverse the excursion ranged between 15 and 20 days. Near the SW simulated excursion the water moved a little further ranging from 0.42 to 1.52 feet during the 30 day-excursion 200 and 600 feet from the wellfield, respectively. The time it took to recover the water at the SW wellfield was approximately 20 days. The differences can be attributed to the differences in hydraulic conductivity and the natural gradient at each simulated excursion location. The hydraulic conductivity near the SW excursion area was between 0.75 and 1 ft/day while the hydraulic conductivity near the NW excursion ranged from 0.35 to 0.5 ft/day. The natural groundwater gradient at the SW excursion area is away from the wellfield which also contributes to the longer recovery time.

The results in tables 4.11-1 and 4.11-2 show that using head as the indicator, it is possible to detect and correct an excursion within a 30-day time frame. While the calculated velocity is low, the head change could be easily detected. The change in head is apparent within Figures 4.11-7 and 4.11-8 which show the head response at various distances from the wellfield through the simulation.

Based on the significant and relatively instantaneous (the aquifer remains confined throughout all operations) head change noted at each monitor point during the simulation, recording pressure transducers could be used to monitor the wellfield balance. By watching the day to day trends the wellfield operator can determine which wells may need to be adjusted in order to eliminate the risk of an excursion. Based on the results of this simulation

Table 4.11-1. Modeled Heads and Groundwater Flow Rates at Selected Monitor Points Near NW Simulated Excursion

Distance from wellfield (ft)		610	600	600			410	400	400			210	200	200		
K (ft/day)				0.5					0.4					0.35		
Period	Time (days)	Head (ft)	Head (ft)	Velocity (ft/day)	Dist per day (ft)	Total Dist (ft)	Head (ft)	Head (ft)	Velocity (ft/day)	Dist per day (ft)	Total Dist (ft)	Head (ft)	Head (ft)	Velocity (ft/day)	Dist per day (ft)	Total Dist (ft)
Pre-ISR	2	4046.470	4046.458	0.002	0.00	0.00	4046.217	4046.203	0.002	0.00	0.00	4045.917	4045.901	0.002	0.00	0.00
Normal ISR 90 days	12	4044.508	4044.469	0.007	0.07	0.07	4043.469	4043.401	0.009	0.09	0.09	4041.623	4041.503	0.014	0.14	0.14
	22	4042.814	4042.764	0.008	0.08	0.15	4041.532	4041.450	0.011	0.11	0.20	4039.377	4039.241	0.016	0.16	0.30
	32	4041.458	4041.403	0.009	0.09	0.24	4040.075	4039.988	0.012	0.12	0.32	4037.811	4037.669	0.017	0.17	0.46
	42	4040.345	4040.287	0.010	0.10	0.34	4038.904	4038.814	0.012	0.12	0.44	4036.580	4036.436	0.017	0.17	0.63
	52	4039.410	4039.350	0.010	0.10	0.44	4037.931	4037.839	0.012	0.12	0.56	4035.569	4035.423	0.017	0.17	0.80
	62	4038.609	4038.548	0.010	0.10	0.54	4037.104	4037.010	0.012	0.12	0.68	4034.716	4034.568	0.017	0.17	0.98
	72	4037.913	4037.851	0.010	0.10	0.64	4036.389	4036.295	0.013	0.13	0.81	4033.983	4033.834	0.017	0.17	1.15
	82	4037.303	4037.240	0.010	0.10	0.75	4035.764	4035.669	0.013	0.13	0.94	4033.343	4033.194	0.017	0.17	1.32
	92	4036.762	4036.698	0.011	0.11	0.85	4035.212	4035.117	0.013	0.13	1.06	4032.780	4032.631	0.017	0.17	1.50
Simulated Excursion 30 days	97	4039.395	4039.390	0.001	0.00	0.00	4039.682	4039.725	-0.006	-0.03	-0.03	4041.930	4042.167	-0.028	-0.14	-0.14
	102	4042.309	4042.338	-0.005	-0.02	-0.02	4043.464	4043.561	-0.013	-0.06	-0.09	4047.067	4047.384	-0.037	-0.19	-0.32
	107	4044.895	4044.942	-0.008	-0.04	-0.06	4046.447	4046.567	-0.016	-0.08	-0.17	4050.528	4050.870	-0.040	-0.20	-0.52
	112	4047.149	4047.207	-0.010	-0.05	-0.11	4048.922	4049.053	-0.017	-0.09	-0.26	4053.241	4053.595	-0.041	-0.21	-0.73
	117	4049.138	4049.203	-0.011	-0.05	-0.16	4051.056	4051.195	-0.018	-0.09	-0.35	4055.527	4055.888	-0.042	-0.21	-0.94
	122	4050.920	4050.991	-0.012	-0.06	-0.22	4052.944	4053.088	-0.019	-0.10	-0.45	4057.523	4057.889	-0.043	-0.21	-1.15
Excursion Reversal 45 days	127	4046.877	4046.837	0.007	0.03	0.03	4045.395	4045.274	0.016	0.08	0.08	4040.963	4040.582	0.045	0.22	0.22
	132	4042.144	4042.040	0.017	0.09	0.12	4039.009	4038.783	0.030	0.15	0.23	4031.962	4031.424	0.063	0.31	0.54
	137	4037.949	4037.811	0.023	0.11	0.24	4034.072	4033.805	0.036	0.18	0.41	4026.122	4025.538	0.068	0.34	0.88
	142	4034.329	4034.172	0.026	0.13	0.37	4030.052	4029.763	0.038	0.19	0.60	4021.664	4021.060	0.071	0.35	1.23
	147	4031.165	4030.996	0.028	0.14	0.51	4026.633	4026.331	0.040	0.20	0.80	4017.978	4017.360	0.072	0.36	1.59
	152	4028.358	4028.179	0.030	0.15	0.66	4023.643	4023.332	0.041	0.21	1.01	4014.803	4014.176	0.073	0.37	1.96
	157	4025.833	4025.647	0.031	0.15	0.81	4020.982	4020.663	0.042	0.21	1.22	4012.000	4011.366	0.074	0.37	2.32
	162	4023.539	4023.348	0.032	0.16	0.97	4018.578	4018.255	0.043	0.22	1.44	4009.486	4008.847	0.075	0.37	2.70
	167	4021.436	4021.241	0.033	0.16	1.13	4016.387	4016.059	0.044	0.22	1.66	4007.205	4006.562	0.075	0.38	3.07
Normal ISR 30 days	177	4023.338	4023.215	0.020	0.20	0.20	4020.471	4020.301	0.023	0.23	0.23	4016.394	4016.156	0.028	0.28	0.28
	187	4025.150	4025.055	0.016	0.16	0.36	4022.959	4022.829	0.017	0.17	0.40	4019.844	4019.661	0.021	0.21	0.49
	197	4026.396	4026.312	0.014	0.14	0.50	4024.444	4024.328	0.015	0.15	0.55	4021.600	4021.431	0.020	0.20	0.69

Table 4.11-2. Modeled Heads and Groundwater Flow Rates at Selected Monitor Points Near the SW Simulated Excursion

Distance from wellfield (ft)		610	600	600			410	400	400			210	200	200		
K (ft/day)				0.75					1					0.85		
Period	Time (days)	Head (ft)	Head (ft)	Velocity (ft/day)	Dist per day (ft)	Total Dist (ft)	Head (ft)	Head (ft)	Velocity (ft/day)	Dist per day (ft)	Total Dist (ft)	Head (ft)	Head (ft)	Velocity (ft/day)	Dist per day (ft)	Total Dist (ft)
Pre-ISR	2	4040.731	4040.747	-0.004	0.00	0.00	4041.061	4041.076	-0.005	0.00	0.00	4041.355	4041.369	-0.004	0.00	0.00
Normal ISR 90 days	12	4039.072	4039.062	0.003	0.03	0.03	4038.754	4038.733	0.007	0.07	0.07	4038.197	4038.159	0.011	0.11	0.11
	22	4037.739	4037.717	0.006	0.06	0.08	4037.176	4037.144	0.011	0.11	0.18	4036.374	4036.323	0.014	0.14	0.25
	32	4036.709	4036.681	0.007	0.07	0.15	4036.025	4035.987	0.013	0.13	0.30	4035.110	4035.054	0.016	0.16	0.41
	42	4035.878	4035.846	0.008	0.08	0.23	4035.117	4035.075	0.014	0.14	0.44	4034.131	4034.071	0.017	0.17	0.58
	52	4035.187	4035.152	0.009	0.09	0.32	4034.370	4034.326	0.015	0.15	0.59	4033.333	4033.271	0.018	0.18	0.76
	62	4034.602	4034.565	0.009	0.09	0.41	4033.742	4033.696	0.015	0.15	0.74	4032.666	4032.601	0.018	0.18	0.94
	72	4034.099	4034.061	0.010	0.10	0.51	4033.205	4033.157	0.016	0.16	0.90	4032.097	4032.031	0.019	0.19	1.13
	82	4033.664	4033.624	0.010	0.10	0.61	4032.740	4032.691	0.016	0.16	1.07	4031.606	4031.539	0.019	0.19	1.32
	92	4033.283	4033.242	0.010	0.10	0.71	4032.335	4032.284	0.017	0.17	1.23	4031.177	4031.109	0.019	0.19	1.51
Simulated Excursion 30 days	97	4036.051	4036.069	-0.004	-0.02	-0.02	4036.696	4036.742	-0.015	-0.08	-0.08	4038.321	4038.458	-0.039	-0.19	-0.19
	102	4038.404	4038.448	-0.011	-0.05	-0.08	4039.625	4039.700	-0.025	-0.13	-0.20	4041.858	4042.028	-0.048	-0.24	-0.43
	107	4040.297	4040.354	-0.014	-0.07	-0.15	4041.786	4041.873	-0.029	-0.15	-0.35	4044.264	4044.446	-0.051	-0.26	-0.69
	112	4041.914	4041.980	-0.016	-0.08	-0.23	4043.576	4043.671	-0.032	-0.16	-0.51	4046.211	4046.400	-0.054	-0.27	-0.96
	117	4043.357	4043.429	-0.018	-0.09	-0.32	4045.147	4045.249	-0.034	-0.17	-0.68	4047.900	4048.095	-0.055	-0.28	-1.24
	122	4044.672	4044.749	-0.019	-0.10	-0.42	4046.566	4046.672	-0.035	-0.18	-0.85	4049.415	4049.615	-0.057	-0.28	-1.52
Excursion Reversal 5 days	127	4040.023	4039.987	0.009	0.05	0.05	4038.810	4038.727	0.028	0.14	0.14	4036.173	4035.966	0.059	0.29	0.29
	132	4036.140	4036.053	0.022	0.11	0.15	4033.834	4033.696	0.046	0.23	0.37	4030.036	4029.766	0.076	0.38	0.68
	137	4033.119	4033.008	0.028	0.14	0.29	4030.321	4030.161	0.054	0.27	0.64	4026.076	4025.784	0.083	0.41	1.09
	142	4030.602	4030.476	0.032	0.16	0.45	4027.497	4027.322	0.058	0.29	0.93	4022.974	4022.669	0.087	0.43	1.52
	147	4028.397	4028.259	0.034	0.17	0.62	4025.066	4024.880	0.062	0.31	1.24	4020.335	4020.020	0.089	0.45	1.97
	152	4026.413	4026.266	0.037	0.18	0.80	4022.902	4022.708	0.065	0.32	1.56	4018.005	4017.682	0.092	0.46	2.43
	157	4024.600	4024.446	0.038	0.19	1.00	4020.941	4020.740	0.067	0.33	1.89	4015.906	4015.576	0.094	0.47	2.90
	162	4022.927	4022.767	0.040	0.20	1.20	4019.142	4018.936	0.069	0.34	2.24	4013.992	4013.656	0.095	0.48	3.37
	167	4021.373	4021.208	0.041	0.21	1.40	4017.481	4017.269	0.071	0.35	2.59	4012.230	4011.889	0.097	0.48	3.86
Normal ISR 30 days	177	4023.710	4023.614	0.024	0.24	0.24	4021.632	4021.528	0.035	0.35	0.35	4019.400	4019.278	0.035	0.35	0.35
	187	4025.075	4024.999	0.019	0.19	0.43	4023.425	4023.342	0.028	0.28	0.63	4021.621	4021.521	0.028	0.28	0.63
	197	4025.902	4025.834	0.017	0.17	0.60	4024.414	4024.338	0.025	0.25	0.88	4022.757	4022.664	0.026	0.26	0.89

Figure 4.11-7. Head Response Adjacent to NW Wellfield during Simulated Excursion

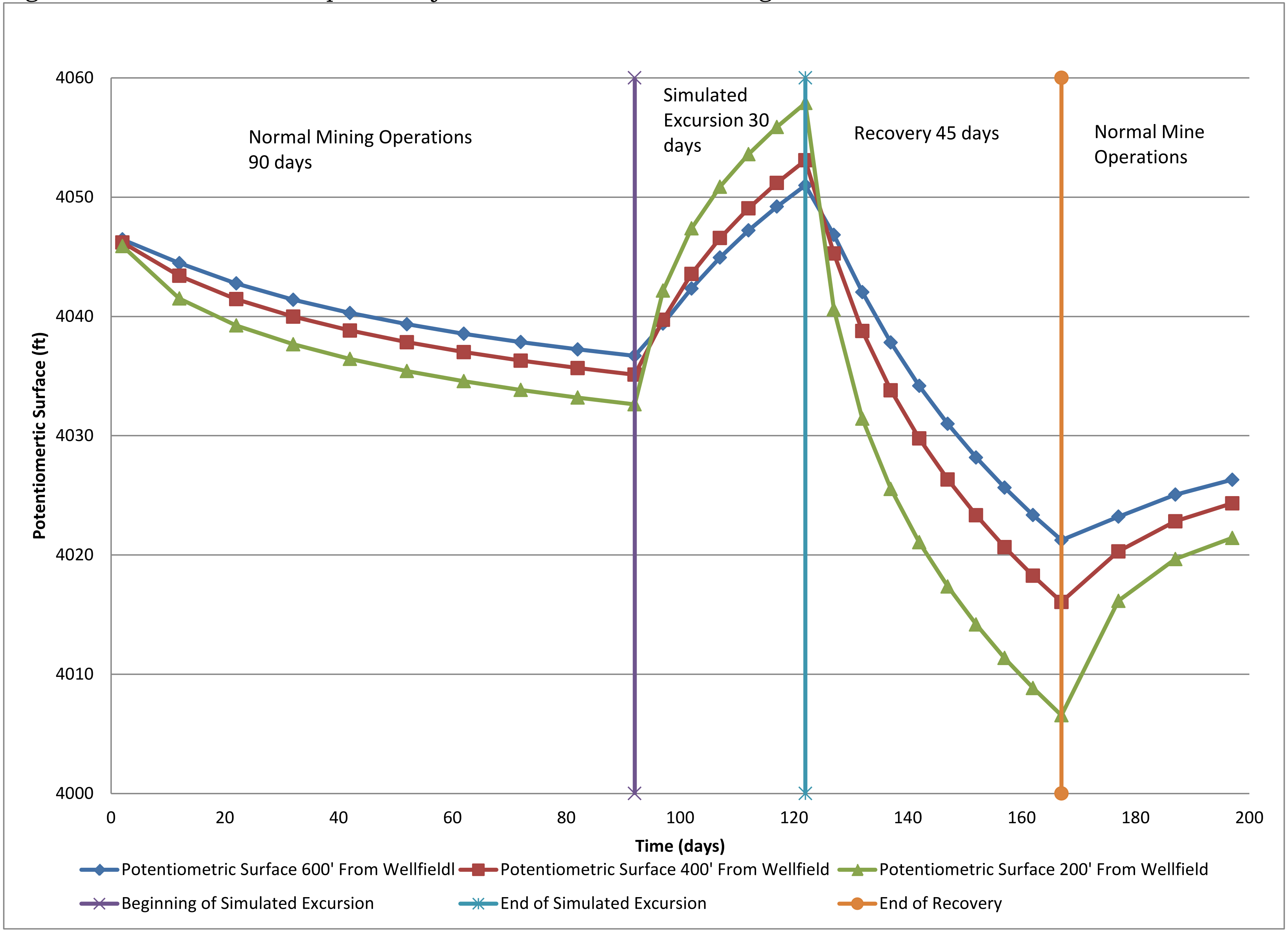
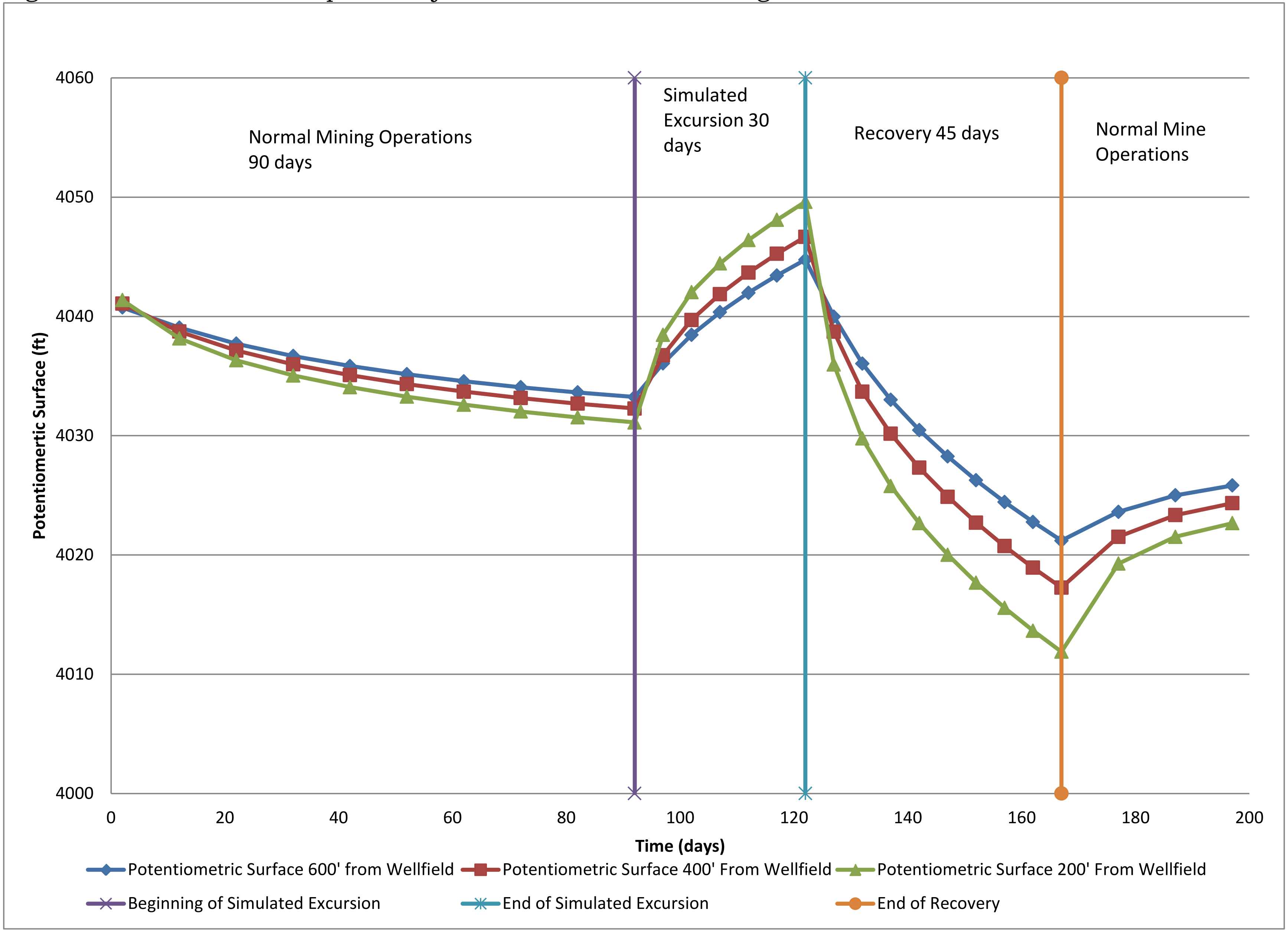


Figure 4.11-8. Head Response Adjacent to SW Wellfield during Simulated Excursion



monitor wells could be successfully placed up to 600 feet from the wellfield and an excursion could be both identified as well as recovered.

To ensure that a potential excursion could not occur undetected between monitor wells, an additional evaluation to check the lateral monitor well spacing was performed. During the excursion simulation presented in Figure 4.11-5 sample monitor wells which are also shown on Figure 4.11-5 were installed on 400 ft spacing laterally around the wellfield. At each simulated excursion location, the head during the excursion at three 400 ft laterally spaced wells was graphed. Figure 4.11-9 shows the head response at the three 400 ft laterally spaced monitor wells near the northwest wellfield excursion and Figure 4.11-10 shows the head response near the southwest wellfield excursion. In both cases, the head response at all three lateral wells indicates that a hydraulic anomaly would have been detected from pressure transducers installed in the monitor wells. Furthermore, the flow vectors in Figure 4.11-5 also indicate that all three sample monitor wells would have seen particles from the modeled excursion. The three sample monitor wells at each simulated excursion location are spaced 400 feet apart. Therefore, the total monitored distance from outside well to outside well is 800 ft. Since an excursion head response is seen in all three wells, it follows that wells spaced 600 ft apart would also see a similar head response. Figures 4.11-7 and 4.11-8 show that the head response 600 ft and 400 ft from the wellfield is also similar. As such, lateral monitor well spacing up to 600 ft is adequate to detect an excursion.

This model was developed primarily to assess regional impacts. As such, it simulates the entire OZ aquifer as one homogenous layer, which is a valid assumption from a regional standpoint. However, at a wellfield scale within the Ross Project area the validity of this assumption varies from location to location. Where the ore containing sandstone is thick, a continuous homogeneous layer assumption is reasonable. Within areas where the sands are thin and locally isolated the thick homogeneous layer assumption used in the model may underestimate the groundwater velocity during an excursion.

Figure 4.11-9. Head Response at Laterally Spaced Monitor Points Adjacent to NW Wellfield during Simulated Excursion

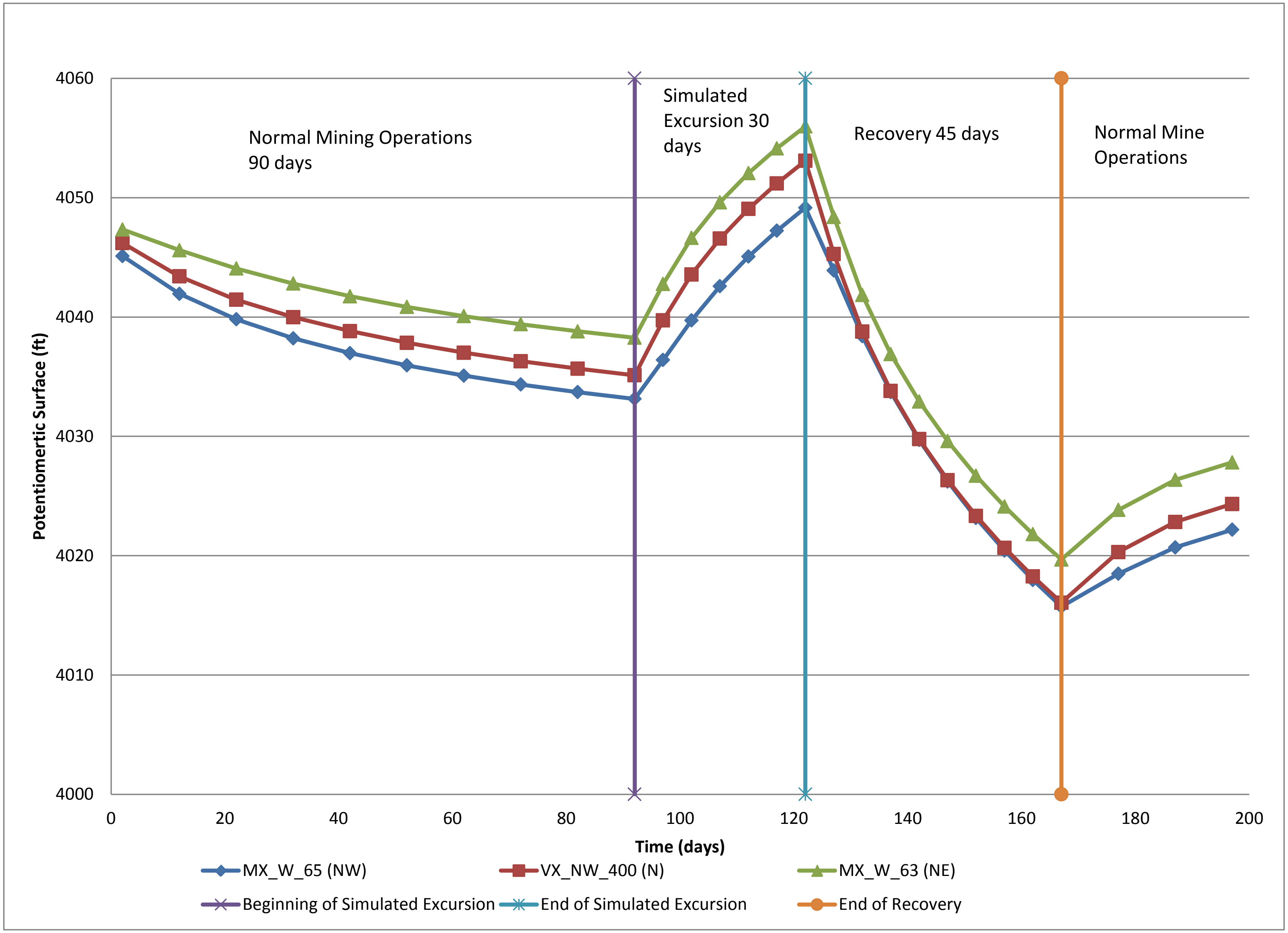
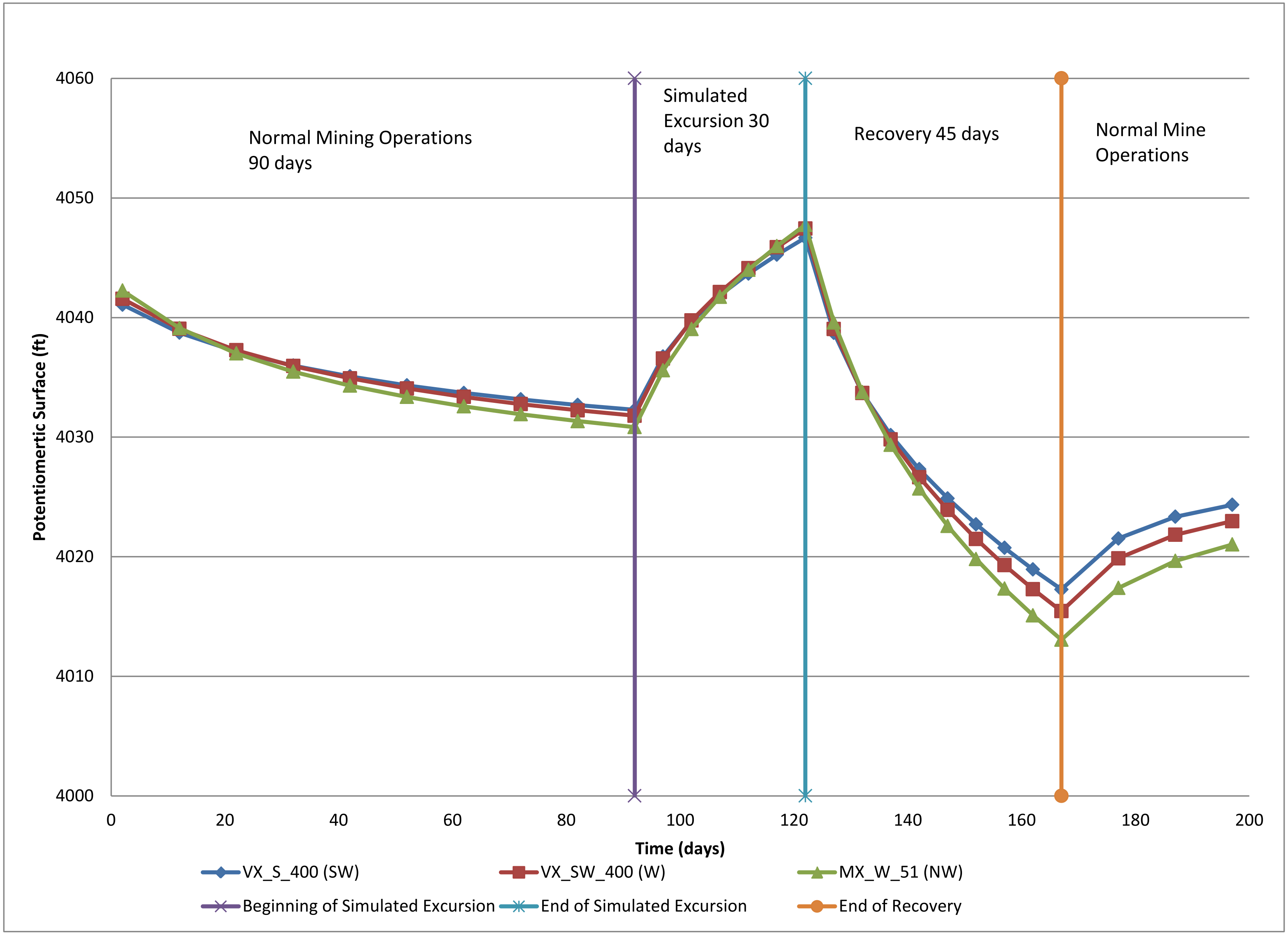


Figure 4.11-10. Head Response at Laterally Spaced Monitor Points Adjacent to SW Wellfield during Simulated Excursion



Aquifer tests performed by WWC Engineering have shown that discrete intervals in which the ore is contained tend to have higher hydraulic conductivities than the aquifer as a whole. For example, the measured hydraulic conductivity in the partially penetrating OW1B58 well near the 12-18 cluster (presented in Table 2.5.2) was as high as 6.2 feet per day over the contributing aquifer.

To evaluate the maximum change in groundwater travel distance from an ore zone sandstone with increased hydraulic conductivity, an additional calculation was performed using a hydraulic conductivity of 6.2 feet per day. The calculation was based on the heads calculated at the SW simulated excursion. As a result of increasing the hydraulic conductivity to 6.2 feet per day, the total travel distance during the 30-day excursion was calculated at 3.5 feet at the 600 foot monitor point. A reversal of 3.7 feet occurred within 20 days. Note that while the total calculated distance of the groundwater flow was greater, the recovery occurred in the same amount of time as previous calculations presented in Table 4.11-2 (just less than 20 days). Since the groundwater velocity is linearly related to the hydraulic conductivity (as shown in Equation 4.11-1), an increase in the local hydraulic conductivity is expected to result in an increased travel distance both during an excursion and the subsequent recovery efforts. However, the head change and the excursion recovery time are expected to be similar for similar recovery efforts.

The results presented herein for a simulated out of balance wellfield depict realistic head changes that could be observed over the simulated time period. Depending on the local geology, stratification, and hydraulic conductivity the distance that the water travels during the simulated excursion and subsequent recovery may vary. In general, the travel distance calculated from an estimated 6.2 ft/day hydraulic conductivity is expected to be a maximum, whereas the travel distance calculated from the lower, model-calibrated hydraulic conductivities are expected to be minimums. In both cases the time to reverse the excursion is expected to be identical.

4.12 Horizontal Flare Evaluation

A horizontal flare evaluation was performed using MODPATH Version 3.0 (Pollack 1994) on a representative wellfield within the Ross Project. The representative wellfield is located within Module 1-1. Figure 4.9-1 shows the location of Module 1-1 in relation to the proposed project area. Adjacent wellfields targeting other roll fronts were ignored in this analysis to minimize abstractions. The sample wellfield consists of 21 recovery wells and 26 injection wells. Throughout the horizontal flare evaluation a constant bleed of 1.25% was maintained. Flowrates within the recovery wells varied from approximately 11 gpm to 19.7 gpm with an average recovery rate of 16.2 gpm per well. The total recovery rate was approximately 340.16 gpm. Injection well operational rates varied from 0.4 gpm to 27 gpm. Throughout the simulation a net bleed of 1.25% was maintained with a resulting injection rate of 335.9 gpm. For this simulation it was necessary to increase the grid resolution in order to more accurately simulate the injection and recovery wells within the wellfield.

Groundwater Vista's Telescopic Mesh Refinement (TMR) tool was used to increase the grid resolution within the modeled wellfield. The TMR tool allows the creation of a more refined model within a subregion of a larger scale model. Using the TMR tool a new model domain approximately 5,000 feet in the east-west direction by 5,335 feet in the north-south direction was delineated. The groundwater vistas TMR tool exported all the aquifer properties such as hydraulic conductivity, specific storage, and potentiometric surfaces for each layer within the selected area to a separate file. The TMR file was then imported into the new model with a smaller domain and tighter grid spacing (12.5 feet within the wellfield and 25 feet outside the wellfield). Using the exported heads from the regional model, the TMR tool automatically sets up new constant head boundary conditions around the new model domain. For this simulation the potentiometric surface used to establish the constant head boundary conditions was a post 2010 potentiometric surface assuming that the Merit industrial wells had been turned off for 2 years. Figure 4.12-1 depicts the refined model domain as well as the initial estimated potentiometric surface used for the flare evaluation presented herein.

Regional model simulations indicate that leakage through the confining shale near the representative wellfield is negligible. As such, to further simplify the refined model, the top four layers were deleted so that the only layers simulated in the flare analysis were the regional ore zone and the ore zone confining shale. Partial penetration pump testing performed by WWC engineering near the location of the representative wellfield indicates that the ore-bearing sandstones have a higher hydraulic conductivity than the rest of the aquifer as a whole. To simulate the higher hydraulic conductivity expected within the ore-bearing sandstone the regionally simulated ore zone was split into three layers. The result was a four layer model bounded on the bottom by an impermeable boundary. The bottom two layers (layers 3 and 4) were each 15 feet thick with the balance of the regionally simulated ore zone making up layer 2. Layer 1 represents the ore zone confining shale. No changes from the regionally calibrated hydraulic conductivity values were made for layers 1, 2, and 4. Within layer 3 the hydraulic conductivity within module 1-1 as well as immediately adjacent to module 1-1 was increased to 3 ft/day (the original hydraulic conductivities ranged from approximately 0.1 ft/day to 0.7 ft/day). This represents a system where sandstones with higher permeability are localized within a relatively small region surrounded by less permeable strata. ISR simulations were performed within layer 3.

To simulate flare an ISR simulation with both injection wells and recovery wells was modeled using MODFLOW. The ISR simulation started with a steady state pre-ISR potentiometric surface and then continued through 21 months of active ISR operations. MODPATH uses the heads and the velocities calculated during the MODFLOW simulation to track the movement of a hypothetical particle. Sixteen hypothetical particles were placed in each cell containing an injection well. The results of the particle tracking are illustrated on Figure 4.12-2. Figure 4.12-3 illustrates the modeled potentiometric surface after 21

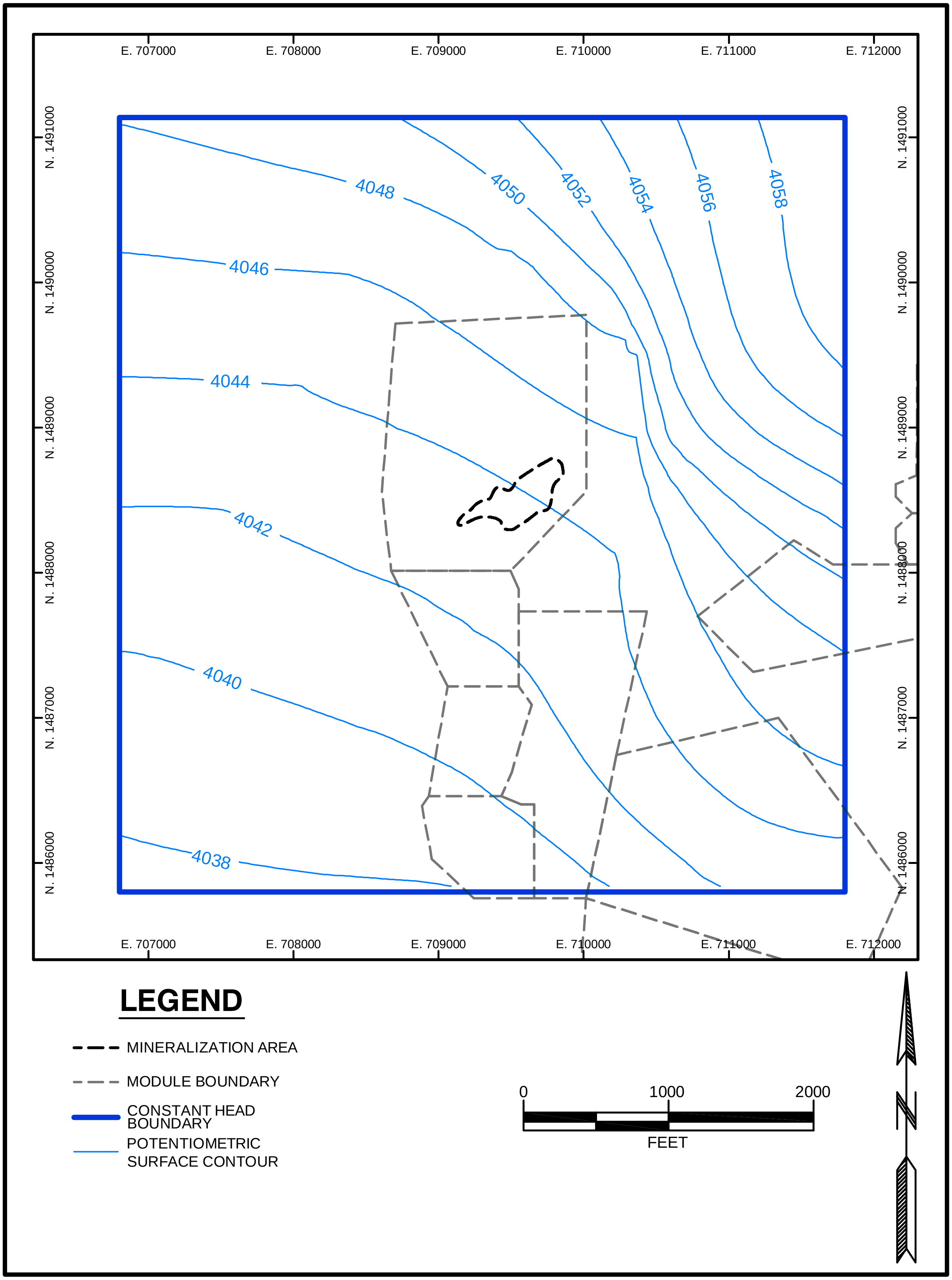


Figure 4.12-1. Refined Model Domain with Pre-ISR Potentiometric Surface

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_FLARE_EVAL.dwg, GWM_FIGURE 4.12-1, 12/20/2010 11:56:11 AM months of ISR operations. The ratio of the area calculated from the circumscribed particle traces to the wellfield area provides the horizontal wellfield flare factor. As illustrated on Figure 4.12-2, the calculated horizontal flare ratio was 1.32 for the current wellfield layout.

In general, the flare presented here is believed to be a conservative estimate of the horizontal flare. As shown in Figure 4.12-2 there are several locations where particle traces indicate well placement could be further optimized to minimize flare outside of the mineralized zone. Furthermore, at several locations the particle traces travel a significant distance from the injection wells and the resulting particle travel path is quite long. These particles with long travel paths move at a much slower rate which also minimizes the migration rate of ISR fluids. As such, even though the particle traces indicate a large flare, the outer portions of flare will contain low concentrations of ISR fluids.

During the flare modeling exercise the flare was found to be most sensitive to injection and recovery well flowrates, well placement, and wellfield shape. During the simulation, changes to well flow rates were found to significantly affect the flare. Well placement can also significantly affect not only the flare but the efficiency of the ISR operations. In general a more regular the well pattern, results in a more efficient wellfield, assuming the formation has relatively homogeneous hydraulic properties. As shown on Figure 4.12-2, wellfield shape also affects the flare. The large blocky portion of the wellfield has less relative flare than the relatively narrow portion of wellfield on the west.

Additional sensitivity simulations were also performed to assess the flare response to changes in hydraulic conductivity. When the hydraulic conductivity was reduced from 3 feet/day to 1 feet/day within module 1-1, the resulting change in the calculated flare was very minimal (less than 1%). When the flare evaluation was performed using the heterogeneous regional calibrated hydraulic conductivity values, the resulting change in the flare was minimal as

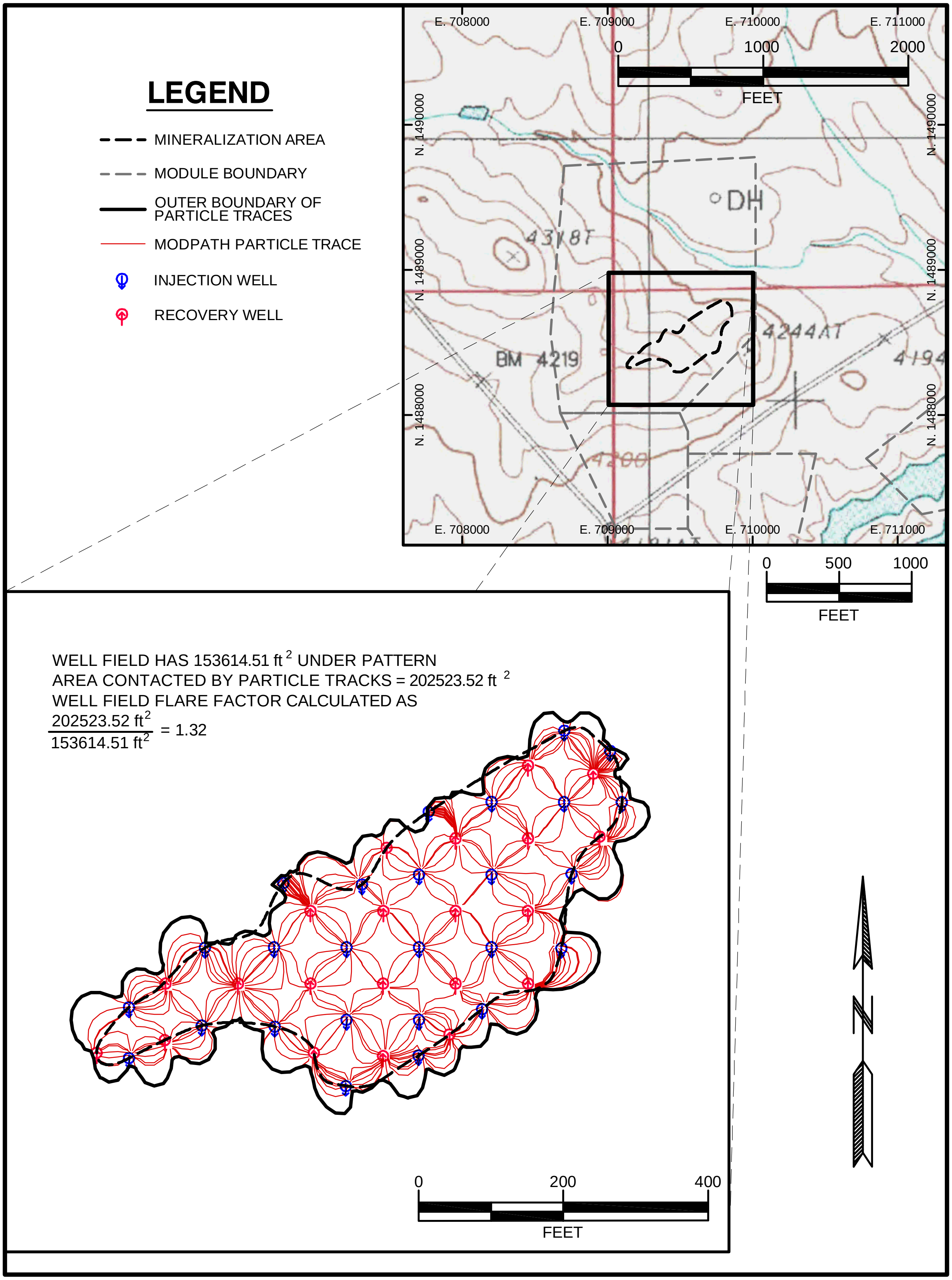


Figure 4.12-2. Wellfield Flare at 1.25% Bleed

K:\Peninsula_Minerals\09142\DWGS_WY83E\ROSS_GWM_FLARE_EVAL.dwg, GWM_FIGURE 4.12-2, 12/20/2010 11:56:15 AM

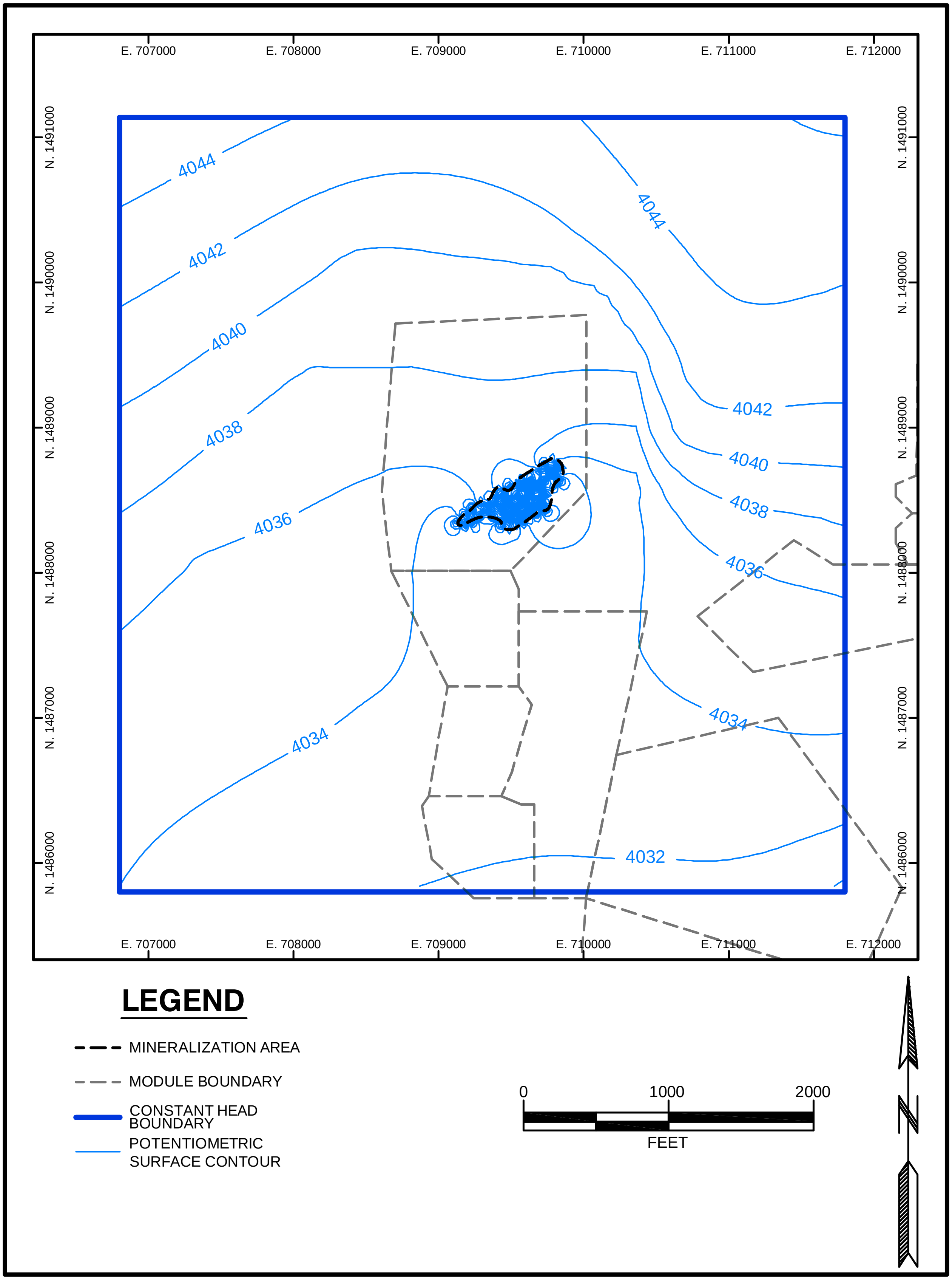


Figure 4.12-3. Potentiometric Surface After 21 Months of ISR Operations

well. During the latter simulation the most significant change was in the well balance where it was noted that due to the heterogeneous hydraulic conductivity values adjustments to the wellfield balance were needed to minimize flare and optimize ISR.

4.13 Summary and Conclusions

The Ross Groundwater Model was constructed primarily to predict the groundwater impacts of ISR uranium recovery within Strata's proposed Ross area and to provide operational feedback. Construction of the model is in keeping with Section 5.2.3 of Strata's Pre-Operational Baseline Monitoring Plan which has been approved by NRC and WDEQ/LQD. The data used to construct the groundwater model was compiled from monitor wells, exploration drilling, and core holes developed by Strata within the last 2 years; monitor wells, exploration drilling, and core holes developed in support of the Nubeth ISR pilot project in the late 1970's; well data available from both the WOGCC and SEO; USGS geological mapping; NRCS soils mapping; and a number of published papers.

The groundwater model includes three separate phases; calibration to steady state, verification to current conditions, transient, and uranium recovery simulation. The steady state simulation represents pre-1980 conditions. The transient verification portion of the groundwater model simulates drawdowns that have occurred in the ore zone from 1980 to 2010, mostly due to wells used to obtain water. Between 1980 and 2010 several oilfield water supply wells have been in operation and have significantly lowered the potentiometric surface within the OZ aquifer. The transient model matched the changes in the pre-1980 aquifer levels to the 2010 aquifer levels based on estimated oilfield water supply well discharge rates reported by the WOGCC. Based on the calibrated and verified model an ISR simulation was performed to predict the drawdowns from the proposed Ross ISR Project.

There are several existing wells within the project area that may be impacted by proposed ISR. The results of the model indicate that the most impacted wells will be the oilfield water supply wells located within the Ross Project area. If these wells continue operating during ISR, water levels within these wells could decrease below the level of the pumps. Modeling indicates that existing stock and domestic wells within the region will see only minor drawdowns as a result of ISR operations. The Ross ISR Project is expected to decrease the heads within the OZ aquifer which in turn may increase the amount of water infiltrated to the OZ aquifer where it outcrops beneath the Little Missouri River and Good Lad Creek alluvium. The effects would be minor, as the modeled increase in infiltrated water at the outcrops was less than 2 gpm.

The model was also used to evaluate monitor well offset distances as well as to evaluate the ability of the proposed wellfield to recover any potential excursions in the ore zone aquifer. During the excursion analysis the model demonstrated that monitor wells could be effectively placed up to 600 feet from the wellfield and a potential excursion could be recovered back to the monitor well in less than 30 days. The model also demonstrates that a monitoring system that continuously monitors water levels within the monitor wells could be effectively used to detect excursions.

Based on experience gained during ISR and excursion simulations, the model also expected to be a useful tool for final wellfield planning and operations. The model can be used to help balance the wellfields and it can be used to help plan progression from module to module. As a byproduct of the wellfield balancing performed with the model, the bleed rate will be optimized for each ISR module. Conditions encountered in the field during operation may require site specific adjustments. However, use of the model will provide a good starting point to commence operations.

5.0 REFERENCES

Anderson, M.P. and W.W. Woessner, 1992, Applied Groundwater Modeling Simulation of Flow and Advective Transport, Academic Press, Inc., San Diego, CA. USA. 381 p.

Buswell, M.D., 1982, Subsurface Geology of the Oshoto Uranium Deposit, Crook County, Wyoming. Unpub. M.S. Thesis, S.D. School of Mines and Technology, 84 p.

Carter J.M. and D.G. Driscoll, 2001, Estimated Recharge to the Madison and Minnelusa Aquifers in the Black Hills Area, South Dakota and Wyoming, Water Years 1931-98. U.S. Geological Survey Water-Resources Investigations Report 01-4278.

Carmichael, R.S. (ed.). 1986. Handbook of Physical Properties of Rocks. CRC Press Inc., Boca Raton, FL v. II 345pp. as cited in Robson, S.G. and Banta, E.R. 1990, Determination of Specific Storage by Measurement of Aquifer Compression Near a Pumping Well. *Ground Water* Vol 28, No.6: 868-874.

Connor, C.W., 1992. Lance Formation – Petrography and Statigraphy, Powder River Basin and Nearby Basins, Wyoming and Montana. U.S. Geological Survey Bulletin, 1917.

Dodge, H.W. Jr., and Spencer, C.W., 1977, Thinning of the Fox Hills Sandstone, Crook County, Wyoming -- A Possible Guide to Uranium Mineralization. in Campbell, J.A., ed., Short papers of the U.S. Geological Survey, Uranium-Thorium Symposium: U.S. Geological Survey Circular 753, P 50-51.

Driscoll, D.G., and J. M. Carter, 2001, Hydrologic Conditions and Budgets for the Black Hills of South Dakota, Through Water Year 1998. U.S. Geological Survey Water-Resources Investigations Report 01-4226.

Dunlap, C.M., 1958, The Lewis, Fox Hills and Lance Formations of Upper Cretaceous Age in the Powder River Basin, Wyoming. Wyoming Geological Association, Thirteenth Annual Field Conference Guidebook, Powder River Basin, pp. 109-110.

Freeze, R.A. and Cherry, J.A., 1979, Groundwater, Prentice-Hall, Inc., Englewood Cliffs, N.J. 604p.

Hamilton, J.L., 1977. Hydrologic Information Vicinity Proposed In-Situ Uranium Leaching Site Oshoto, Wyoming. Unpublished report prepared for Nuclear Dynamics, August 30, 1977.

Hart, D.J., K.R. Bradbury, and D.T. Feinstein, 2006. The Vertical Hydraulic Conductivity of an Aquitard at Two Spatial Scales. *Groundwater Vol 44, No. 2: 201-211*

Kansas Geological Survey. “Open-File Report. 91-1.” 1991. <http://www.kgs.ku.edu/Dakota/vol3/fy91/rep06.htm> (14 April 2010).

Langford, R.H., 1964, Ground-Water Resources and Geology of Northern and Western Crook County, Wyoming. U.S. Geological Survey Water-Supply Paper 1698, Prepared in Cooperation with the State Engineer of Wyoming.

Lohman, S.W., 1979, Ground-Water Hydraulics: U.S. Geological Survey Professional Paper 708, pp. 52-54

MacDonald, M. and A. Harbaugh, 1988, A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, U.S. Geological Survey Techniques of Water Resource Investigations, Book 6, Chapter A1. 586 p.

Manera, P.A., 1977, Aquifer Analysis Near Oshoto Reservoir, Crook County , Wyoming. Unpublished report prepared for Nuclear Dynamics revised November 22, 1977.

Manera, P.A., 1978, Aquifer Analysis Area 10 Five Spot Test Oshoto Reservoir, Crook County, Wyoming. Unpublished report prepared for Nuclear Dynamics revised November 22, 1977.

Martin, L.J., D.L. Naftz, H.W. Lowham and J.G. Rankl, 1988, Cumulative Potential Hydrologic Impacts of Surface Coal Mining in the Eastern Powder River Structural Basin, Northeastern Wyoming: U.S. Geological Survey Water-Resources Investigations Report 88-4046, 201p.

Neuzil, C.E., 1993. Low fluid pressure within the Pierre Shale: a transient response to erosion, Water Resource Res., 29, 2007–2020.

Pochop, Larry, Travis Teegarden, Greg Kerr, Ronald Delaney and Victor Hasfurther, October 1992. "Consumptive Use and Consumptive Irrigation Requirements in Wyoming," University of Wyoming, Cooperative Extension Service, Department of Rangeland Ecology & Watershed Management and The Wyoming Water Research Center, WWRC Publication No. 92-06.

Pollack, D.W., 1994, User's Guide for MODPATH/MODPATH-PLOT, Version3: A particle tracking post-processing package for MODFLOW, the U.S. Geological Survey finite-difference ground-water flow model., U.S. Geological Survey Open-File Report 94-464. Reston, Virginia.

Rehm, B.W., G.H. Groenewold, and K.A. Morin, 1980, Hydraulic Properties of Coal and Related Materials, Northern Great Plains: Ground Water, v. 18, no. 6, pp. 99-109. In Martin, L.J., D.L. Naftz, H.W. Lowham, and J.G Rankl, 1988, Cumulative Potential Hydrologic Impacts of Surface Coal Mining in the Eastern Powder River Structural Basin, Northeastern Wyoming: U.S. Geological Survey Water-Resources Investigations Report 88-4046, 201p.

Rumbaugh, J.O. and D.B. Rumbaugh, 2002, Groundwater Vistas, Version 3.33, Software and User's Manual. Environmental Simulations, Inc.

Rumbaugh, J.O. and D.B. Rumbaugh, 2007, Guide to using Groundwater Vistas, Version 5, Environmental Simulations, Inc.

Rumbaugh, J.O. 2010, Personal communication via e-mail April 2010.

Stoick, A.F., 1980, Feasibility report on Phase II Well Field May 16, 1980. Unpublished report prepared by Nuclear Dynamics.

Tschudy, B.D., 1975, Palynological evolution of some Fort Union and Lance Formation samples from Crook and Weston Counties, Wyoming: U.S. Geol. Survey Open File Report 75-502.

U.S. Department of the Interior Bureau of Reclamation, 1977. Design of Small Dams. A Water Resources Publication. United States Government Printing Office, Washington D.C. Appendix A Page 544.

U.S. Department of Agriculture, Natural Resources Conservation Service, 2009. Soil Survey Geographic (SSURGO) database for Crook County, WY. http://SoilDataMart.nrcs.usda.gov/

Viessman W. and L. Lewis. 1996, Introduction to Hydrology.-4th ed. HarperCollins College Publishers, New York, NY.

Whitcomb, H.A. and Morris, D.A., 1964, Groundwater resources and geology of Northern and Western Crook County, Wyoming: United States Department of the Interior U.S.G.S water supply paper 1698 prepared in cooperation with the State Engineer of Wyoming. United States Government Printing office, Washington, D.C.

WWC Engineering, 2010 Ross Area Aquifer Pump Test Results.

Wyoming Oil and Gas Conservation Commission (WOGCC), March 2010, [Online well database]. <http://wogcc.state.wy.us/>

Wyoming State Engineer's Office (SEO), March 2010, [Online water rights database]. <http://seo.state.wy.us/>

APPENDIX A

Estimated Flow Rates for Oilfield Supply Wells
within the Ross GW Model Domain

Estimated Flow Rates for Oil Field Supply Wells Within the Ross Project Area

Year	Modflow Stress Period	Flow rate[1] (gpm)						
		WSW#1 West Kiehl Unit	ENL Kiehl Well #1	KIEHL WATER WELL #2	22X-19	19XX STATE	789V STATE	SOPHIA #1A
All	1	Steady state stress period no flow for wells						
1980*	2	0.0	0.0	0.0	19.8	11.0	11.0	0.0
1980	3	0.0	0.0	0.0	11.1	6.2	6.2	0.0
1981	4	0.0	0.0	0.0	9.2	5.1	5.1	0.0
1981	5	0.0	0.0	0.0	5.5	3.1	3.1	0.0
1982	6	0.0	0.0	0.0	8.8	4.9	4.9	0.0
1982	7	0.0	0.0	0.0	6.4	3.6	3.6	0.0
1983	8	0.0	0.0	0.0	8.6	4.8	4.8	0.0
1983	9	0.0	0.0	0.0	7.2	4.0	4.0	0.0
1984	10	0.0	0.0	0.0	8.3	4.6	4.6	0.0
1984	11	0.0	0.0	0.0	12.2	6.8	6.8	0.0
1985	12	0.0	0.0	0.0	16.7	9.3	9.3	0.0
1985	13	0.0	7.6	7.6	19.3	10.7	10.7	0.0
1986	14	0.0	8.8	8.8	18.3	10.2	10.2	0.0
1986	15	0.0	13.7	13.7	18.7	10.4	10.4	0.0
1987	16	0.0	16.1	16.1	18.1	10.1	10.1	0.0
1987	17	10.3	15.8	15.8	18.7	10.4	10.4	0.0
1988	18	16.6	13.2	13.2	19.0	10.5	10.5	0.0
1988	19	16.2	15.5	15.5	16.1	8.9	8.9	0.0
1989	20	15.3	14.5	14.5	15.8	8.8	8.8	0.0
1989	21	13.7	13.7	13.7	15.5	8.6	8.6	0.0
1990	22	15.5	14.3	14.3	19.5	10.8	10.8	0.0
1990	23	12.0	13.7	13.7	19.3	10.7	10.7	0.0
1991	24	11.5	12.1	12.1	16.1	9.0	9.0	0.0
1991	25	9.9	12.8	12.8	18.9	10.5	10.5	0.0
1992	26	9.7	16.6	16.6	19.1	10.6	10.6	0.0
1992	27	9.5	18.6	18.6	18.6	10.4	10.4	0.0
1993	28	9.1	15.6	15.6	19.4	10.8	10.8	0.0
1993	29	5.4	14.2	14.2	19.4	10.8	10.8	0.0
1994	30	9.5	13.7	13.7	18.4	10.2	10.2	0.0
1994	31	3.4	14.2	14.2	19.1	10.6	10.6	0.0
1995	32	5.6	13.9	13.9	17.6	9.8	9.8	0.0
1995	33	1.8	14.0	14.0	19.6	10.9	10.9	0.0
1996	34	6.9	12.7	12.7	21.4	11.9	11.9	12.5
1996	35	7.6	9.0	9.0	20.2	11.2	11.2	20.6
1997	36	8.1	9.4	9.4	19.7	10.9	10.9	20.5
1997	37	9.1	9.4	9.4	20.0	11.1	11.1	21.4
1998	38	4.7	7.7	7.7	19.6	10.9	10.9	12.4
1998	39	4.0	9.2	9.2	19.6	10.9	10.9	5.1
1999	40	0.0	7.3	7.3	19.6	10.9	10.9	0.0

Estimated Flow Rates for Oil Field Supply Wells Within the Ross Project Area

Year	Modflow Stress Period	Flow rate[1] (gpm)						
		WSW#1 West Kiehl Unit	ENL Kiehl Well #1	KIEHL WATER WELL #2	22X-19	19XX STATE	789V STATE	SOPHIA #1A
1999	41	0.0	6.2	6.2	20.7	11.5	11.5	0.0
2000	42	0.0	5.7	5.7	19.3	10.7	10.7	16.7
2000	43	0.0	5.6	5.6	20.5	11.4	11.4	17.0
2001	44	0.0	5.5	5.5	21.2	11.8	11.8	16.5
2001	45	0.0	4.3	4.3	20.9	11.6	11.6	16.4
2002	46	0.0	5.5	5.5	19.9	11.0	11.0	20.1
2002	47	0.0	4.6	4.6	19.6	10.9	10.9	26.1
2003	48	0.0	5.5	5.5	19.4	10.8	10.8	24.2
2003	49	0.0	7.1	7.1	19.1	10.6	10.6	24.4
2004	50	0.0	6.9	6.9	17.6	9.8	9.8	24.4
2004	51	0.0	1.9	1.9	18.0	10.0	10.0	23.3
2005	52	0.0	8.2	8.2	19.3	10.7	10.7	24.9
2005	53	0.0	7.8	7.8	19.8	11.0	11.0	22.1
2006	54	0.0	6.5	6.5	21.7	12.0	12.0	24.2
2006	55	0.0	5.0	5.0	21.8	12.1	12.1	20.9
2007	56	0.0	4.8	4.8	19.5	10.8	10.8	10.8
2007	57	0.0	2.3	2.3	19.3	10.7	10.7	6.9
2008	58	0.0	4.9	4.9	19.4	10.8	10.8	15.5
2008	59	0.0	5.3	5.3	17.1	9.5	9.5	13.2
2009	60	0.0	2.2	2.2	19.9	11.1	11.1	4.4
2009	61	0.0	1.2	1.2	19.4	10.8	10.8	10.0

[1]Flowrates based on WOGCC database http://wogcc.state.wy.us/

*Production for last 5 months of 1979 added to 1980 flowrate.

Domestic Wells: Monthly discharge rates are not available for domestic wells . Estimated flow rates for domestic wells are estimated based on typical household water use and are assumed to be constant within the groundwater model.

APPENDIX B

Predicted Drawdowns for Scenario 1, Merit Oil Wells
Shut Off 2 Years Prior to Ross ISR Operations

Strata Energy-Ross Project

GW-Model ISR Simulation Layer 4 (SM) Stress Period 1 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

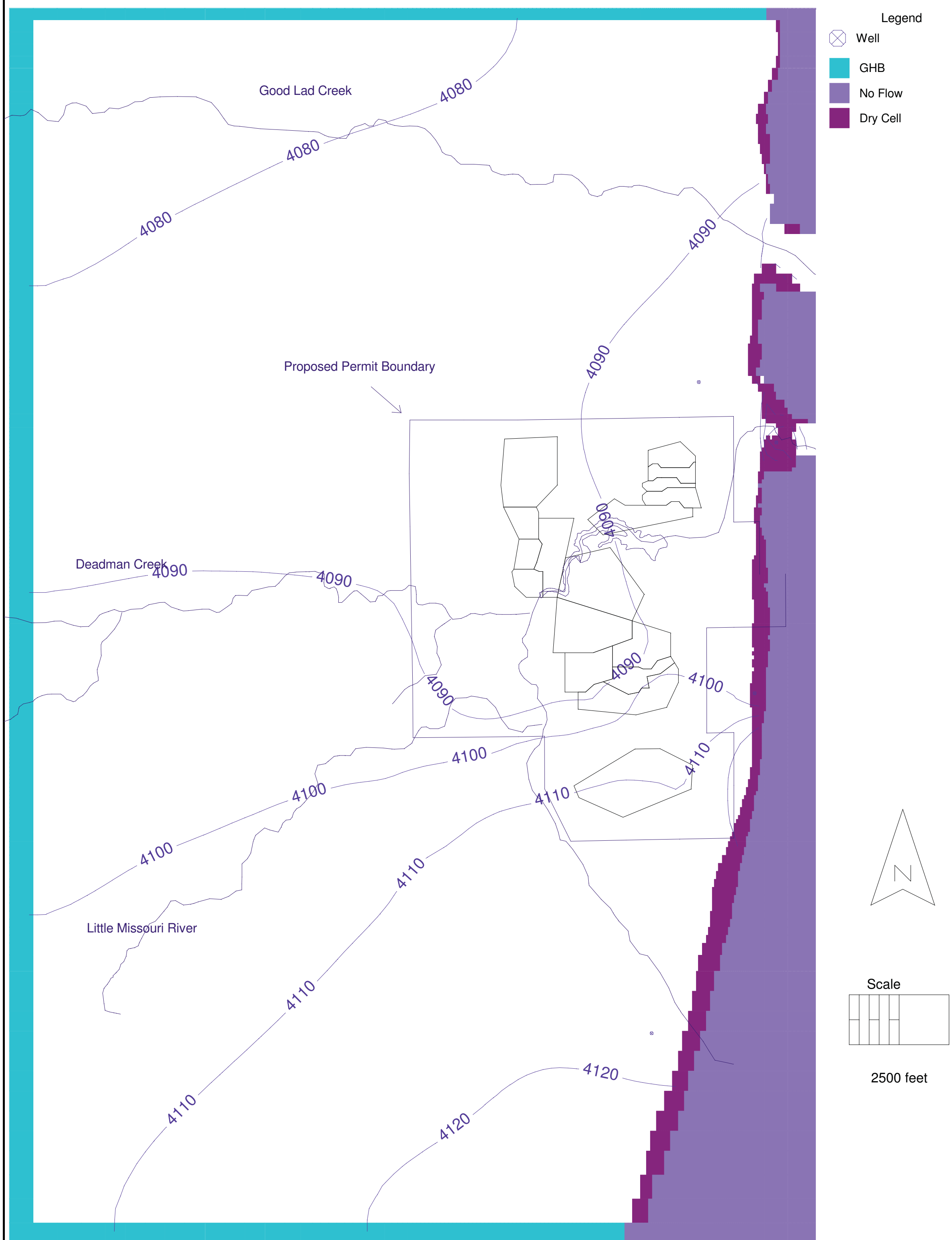
Potentiometric Surface Prior to ISR (Merit Wells Turned Off For 2 years)

Strata Energy-Ross Project

GW-Model ISR Simulation Layer 4 (SM) Stress Period 25 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Potentiometric Surface At The End Of ISR Operations



Strata Energy-Ross Project

GW-Model ISR Simulation Layer 4 (SM) Stress Period 25 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

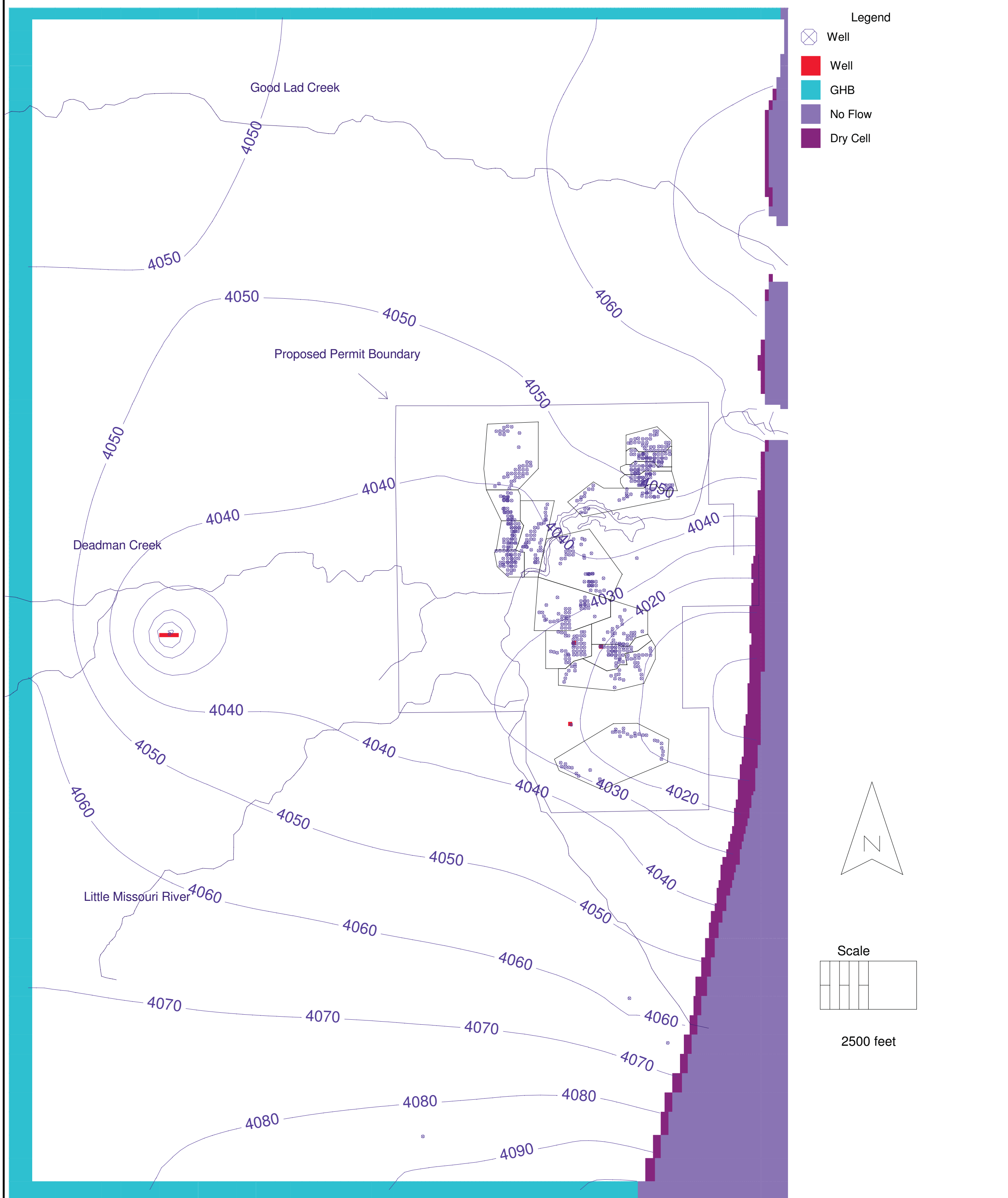
Modeled Drawdown At The End Of ISR Operations

Strata Energy-Ross Project

GW-Model ISR Simulation Layer 6 (OZ) Stress Period 1 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Potentiometric Surface Prior to ISR (Merit Wells Turned Off For 2 years)

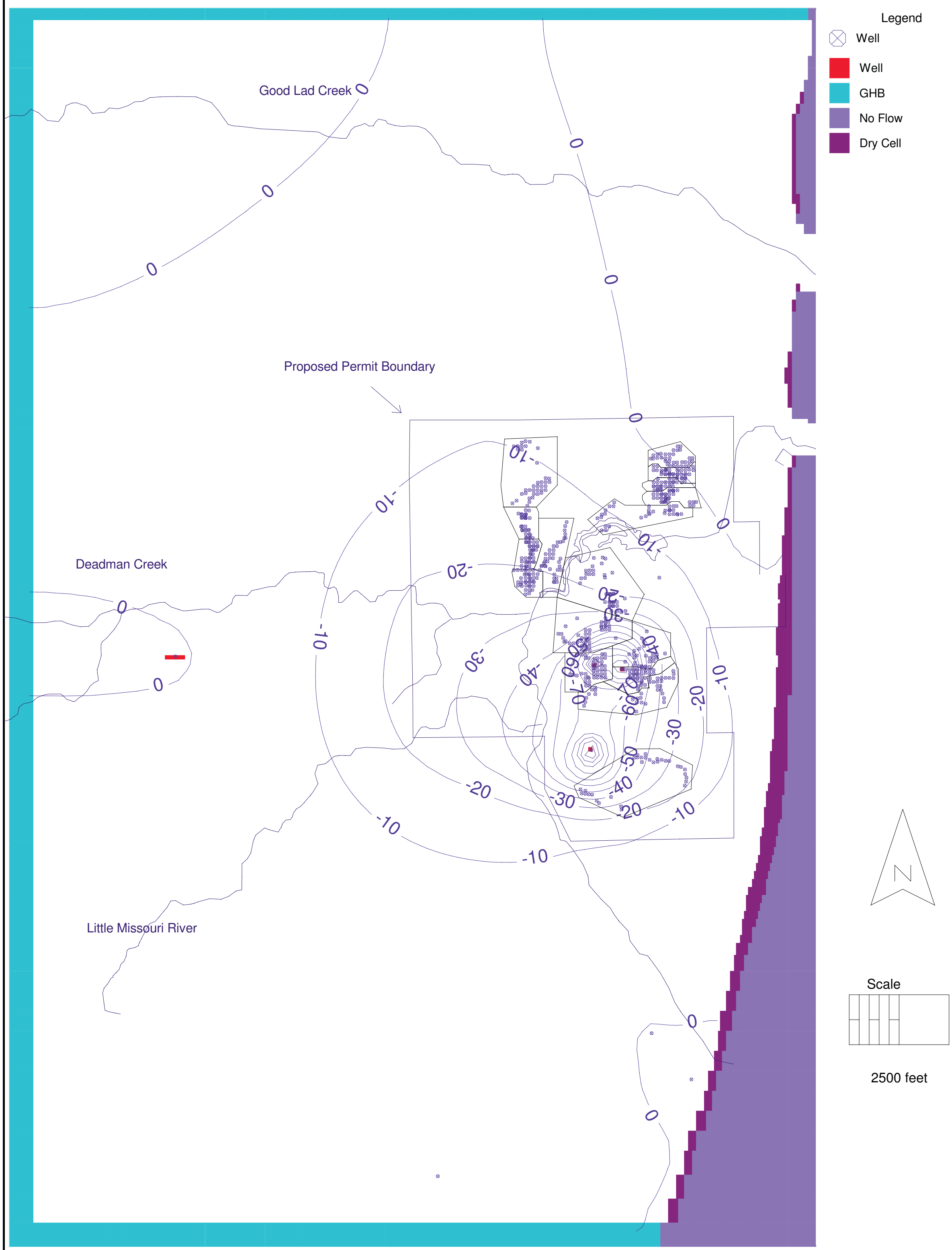


Strata Energy-Ross Project

GW-Model ISR Simulation Layer 6 (OZ) Stress Period 1 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Modeled Recovery Prior To ISR Operations (Merit Wells Turned Off For 2 Years)

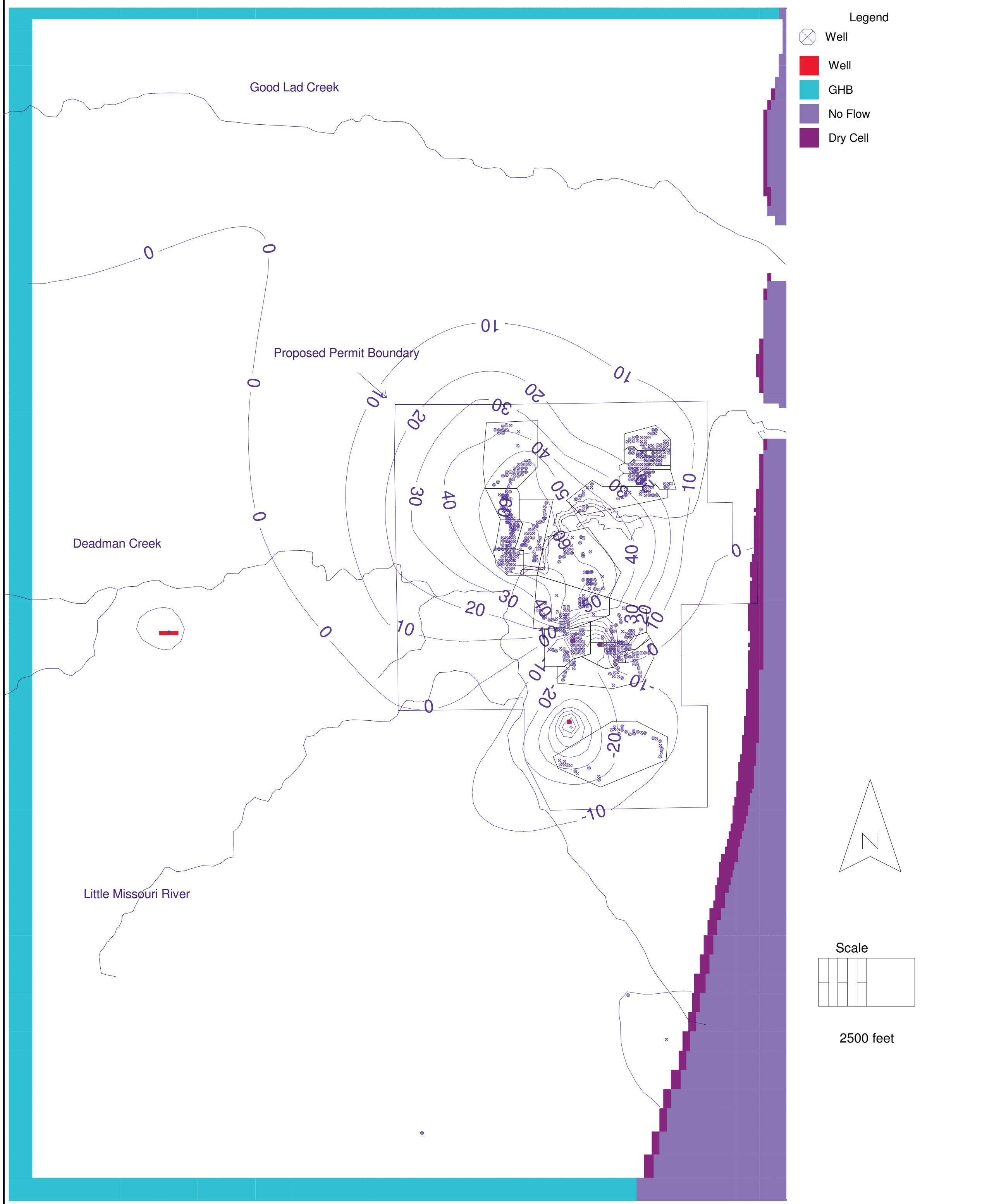


Strata Energy-Ross Project

GW-Model ISR Simulation Layer 6 (OZ) Stress Period 8 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Modeled Drawdown 1.75 Years After Beginning Of ISR Operations

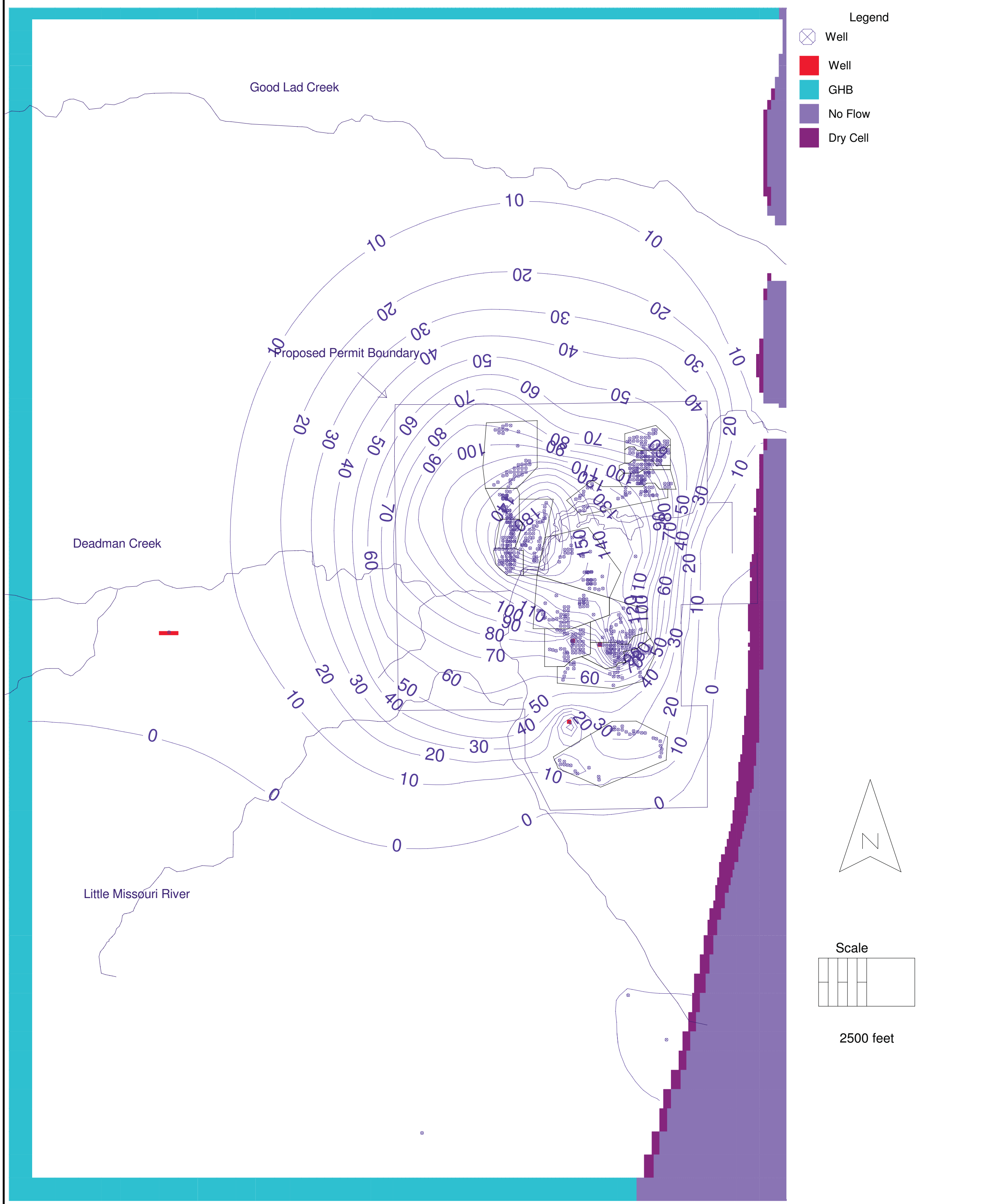


Strata Energy-Ross Project

GW-Model ISR Simulation Layer 6 (OZ) Stress Period 15 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Modeled Drawdown 3.5 Years After Beginning Of ISR Operations

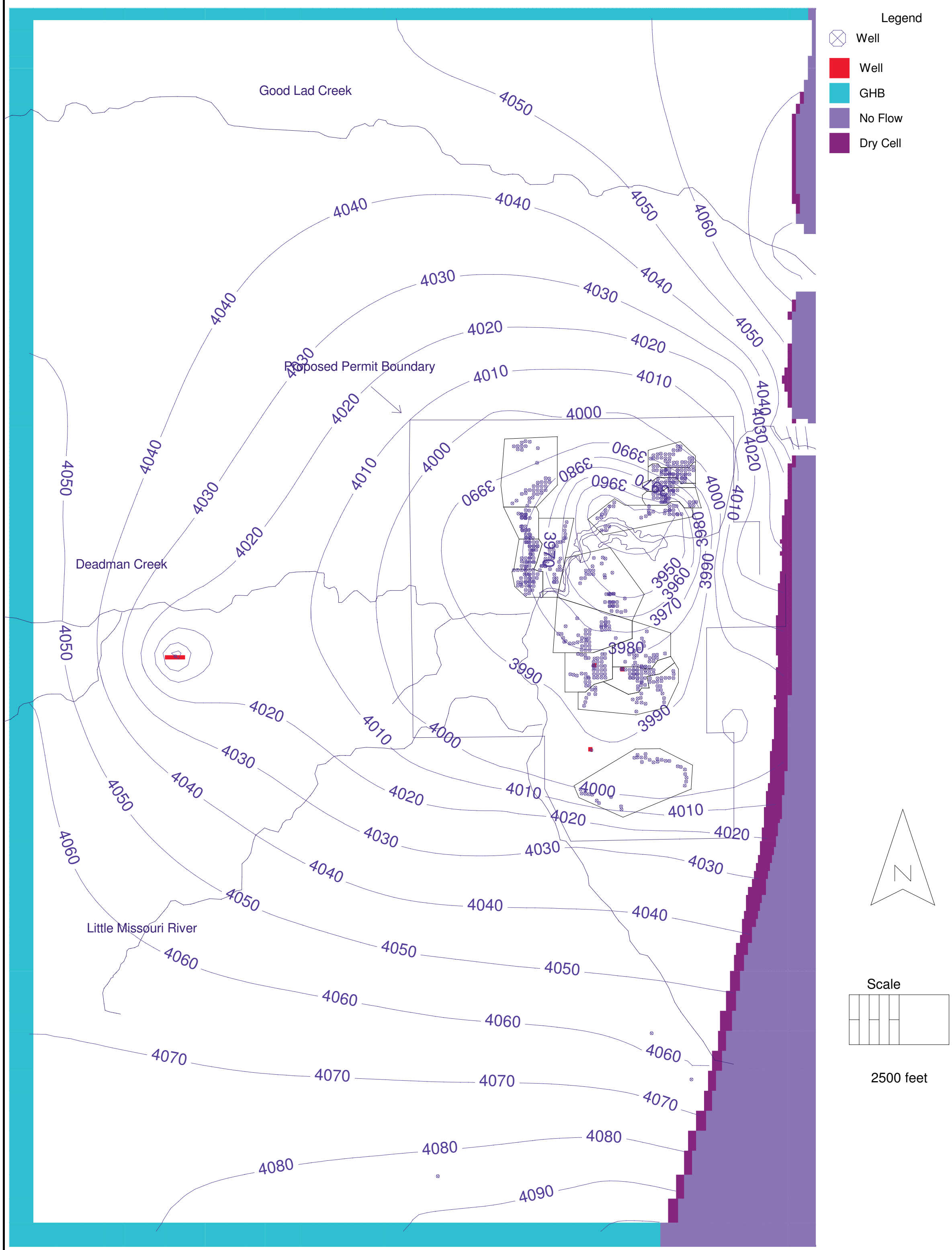


Strata Energy-Ross Project

GW-Model ISR Simulation Layer 6 (OZ) Stress Period 25 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Potentiometric Surface At The End Of ISR Operations

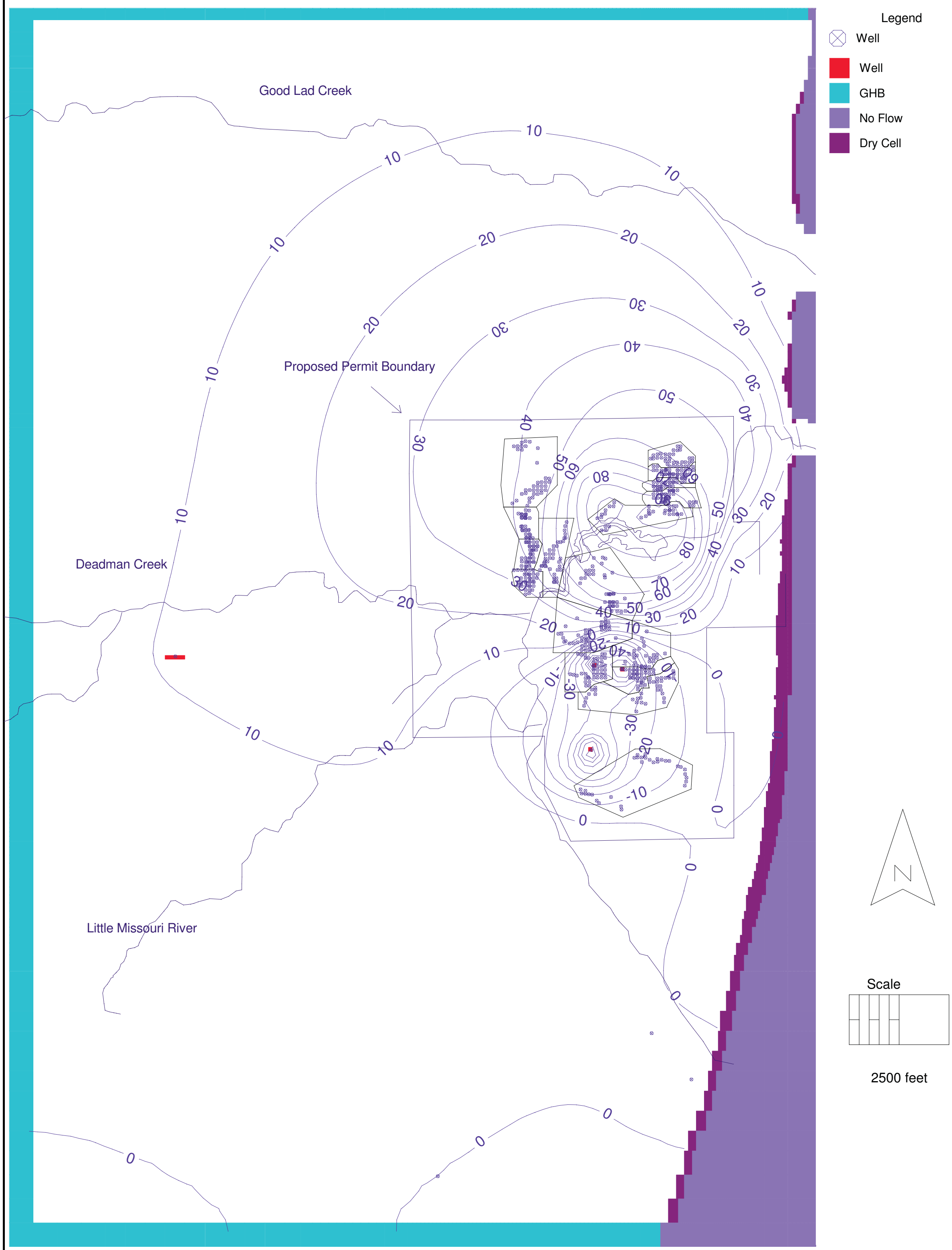


Strata Energy-Ross Project

GW-Model ISR Simulation Layer 6 (OZ) Stress Period 25 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Modeled Drawdown At The End Of ISR Operations

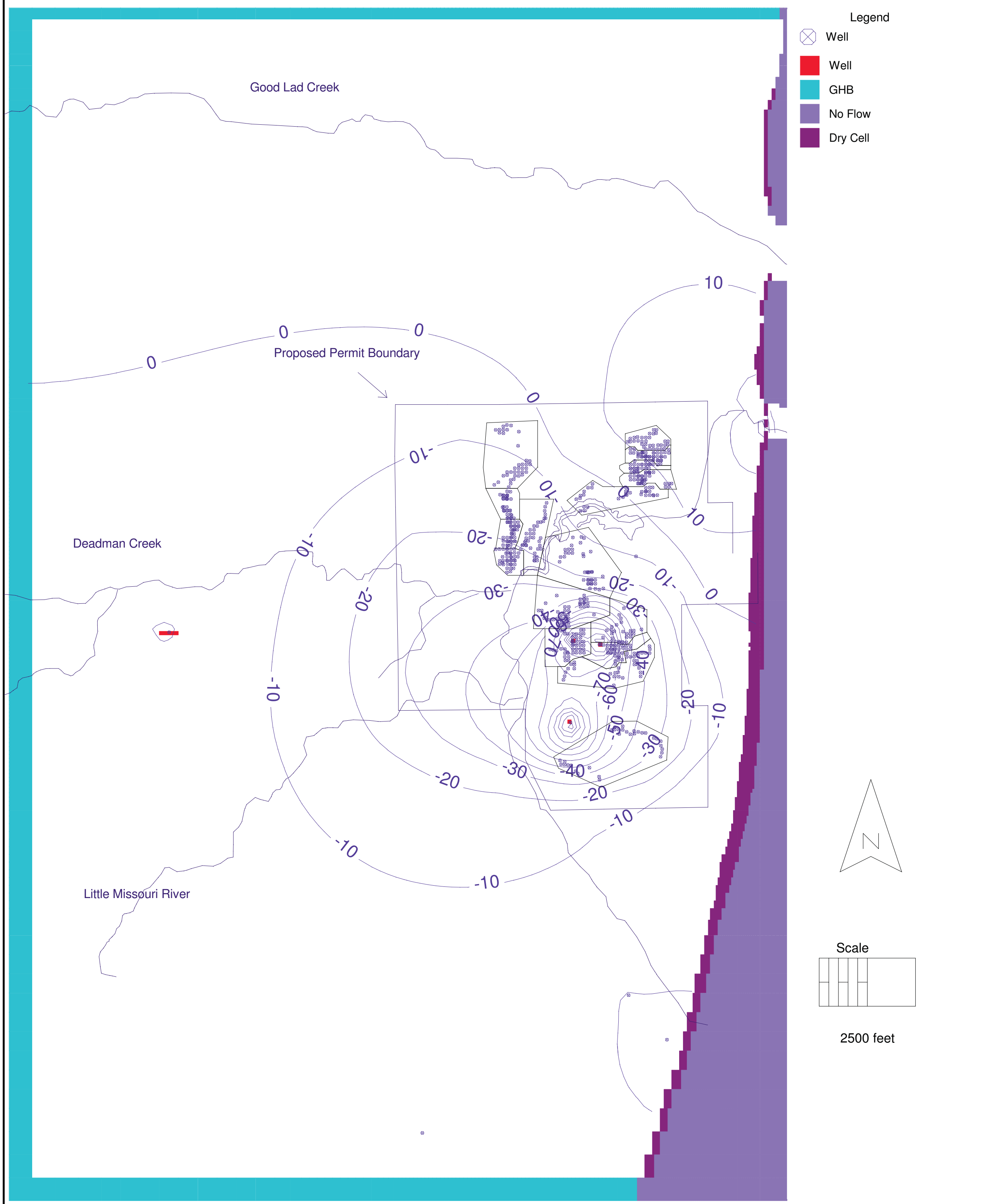


Strata Energy-Ross Project

GW-Model ISR Simulation Layer 6 (OZ) Stress Period 26 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Modeled Drawdown 5 Years After End Of ISR Operations

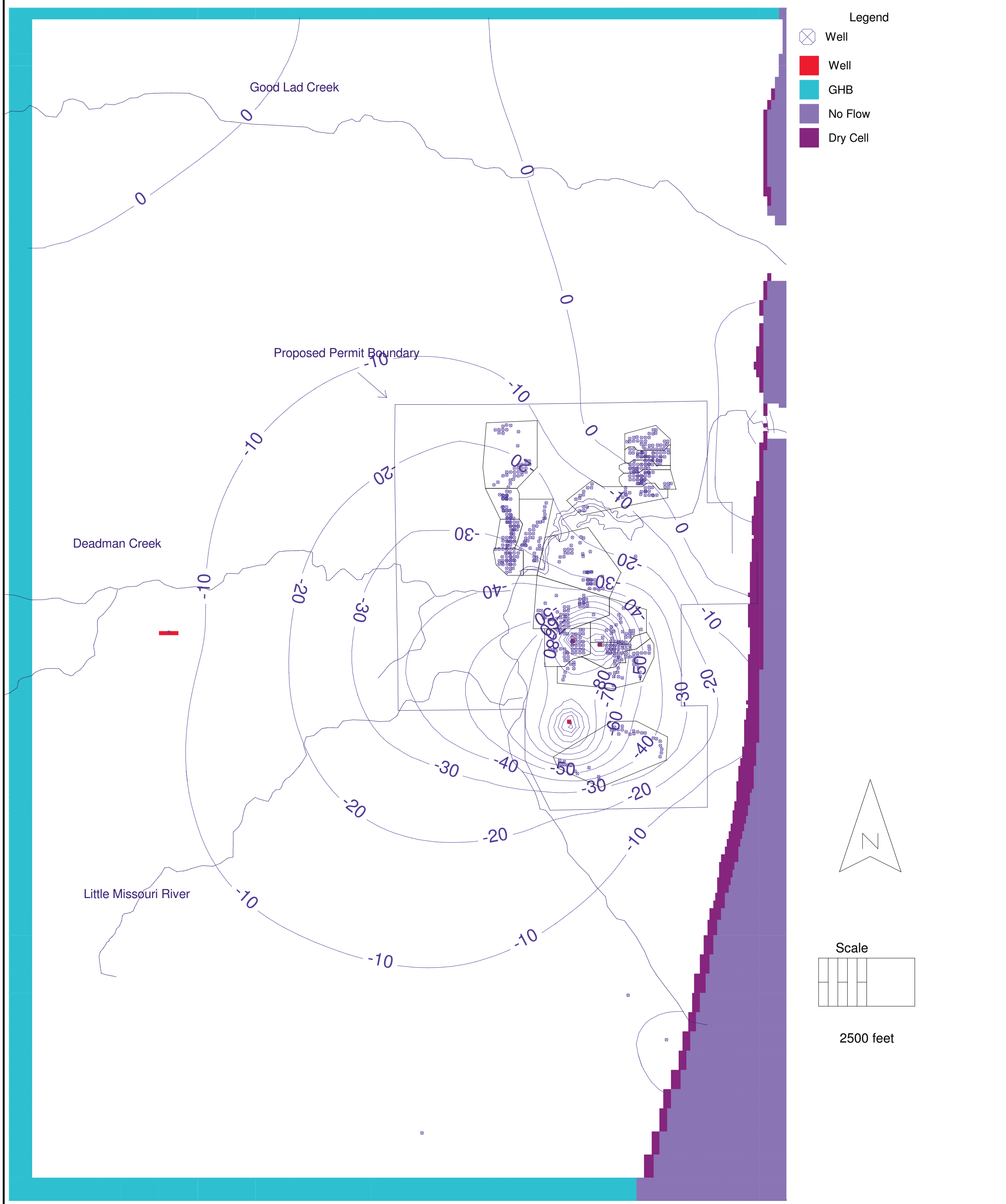


Strata Energy-Ross Project

GW-Model ISR Simulation Layer 6 (OZ) Stress Period 27 Time Step 5

Merit Oil Field Water Supply Wells Not Operating

Modeled Drawdown 10 Years After End Of ISR Operations



APPENDIX C

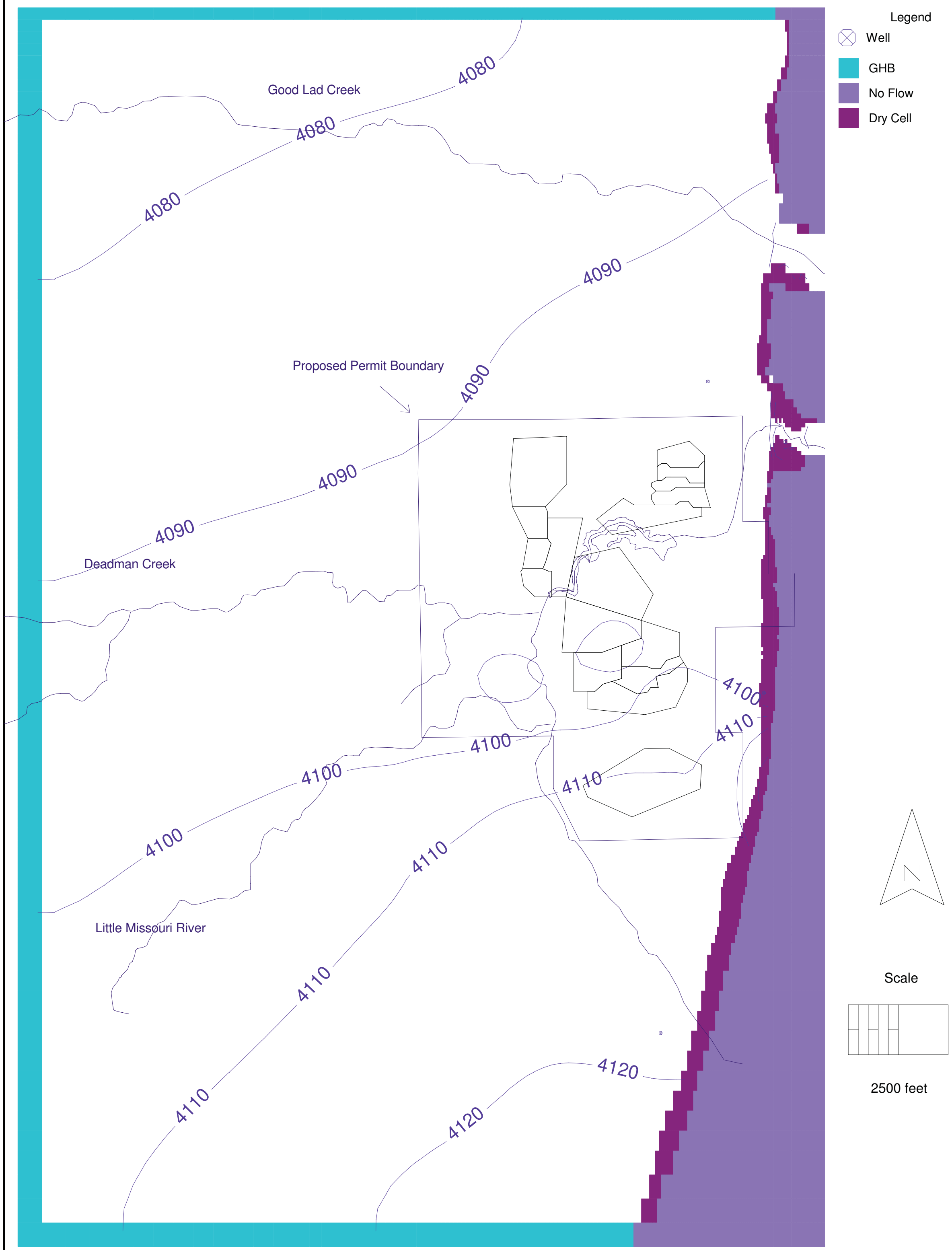
Predicted Drawdowns for Scenario 2, Merit Oil Wells Operating During ISR Operations

Strata Energy-Ross Project

GW-Model Mine Simulation Layer 4 (SM) Stress Period 1 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Potentiometric Surface Prior to ISR

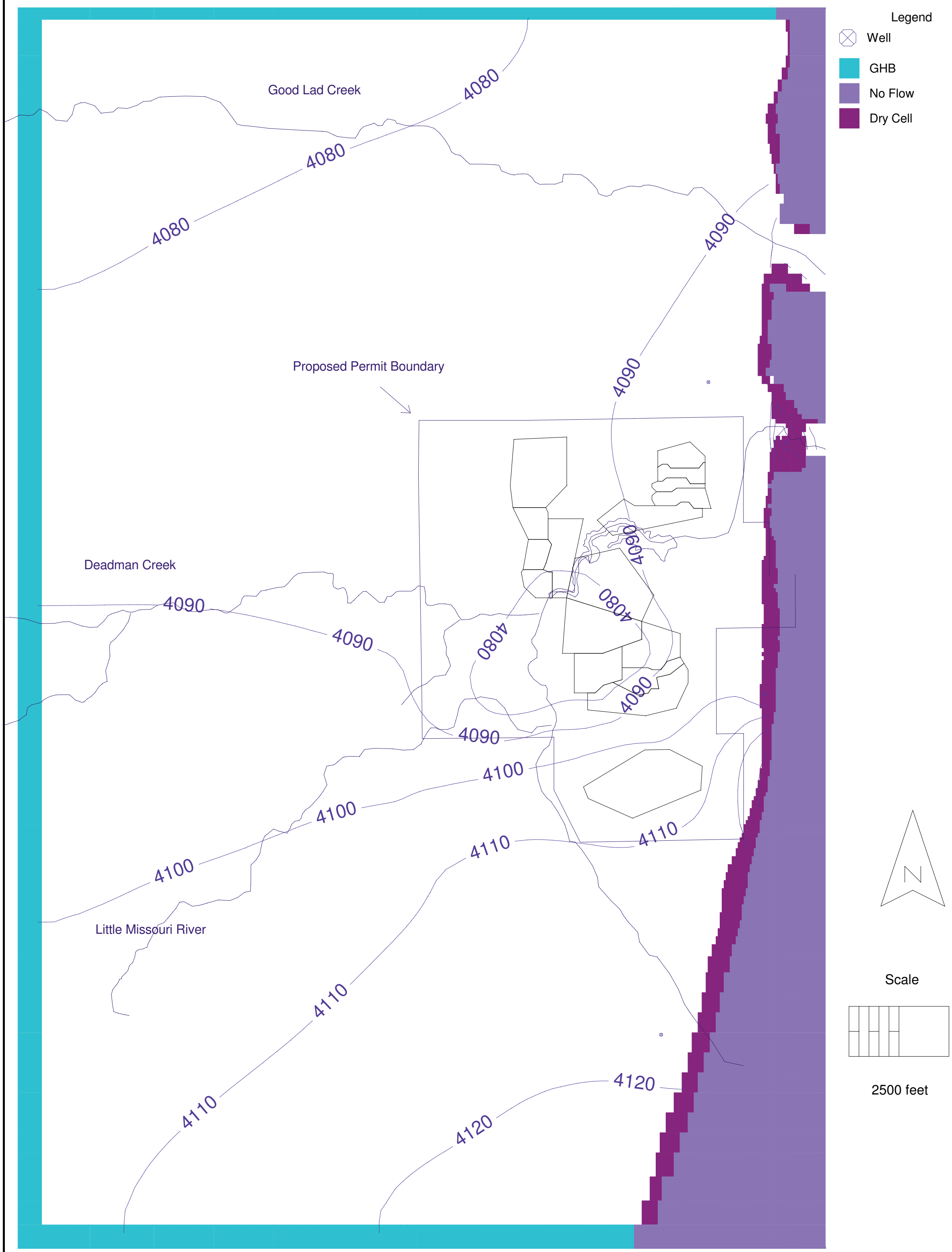


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 4 (SM) Stress Period 25 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Potentiometric Surface At The End Of ISR Operations

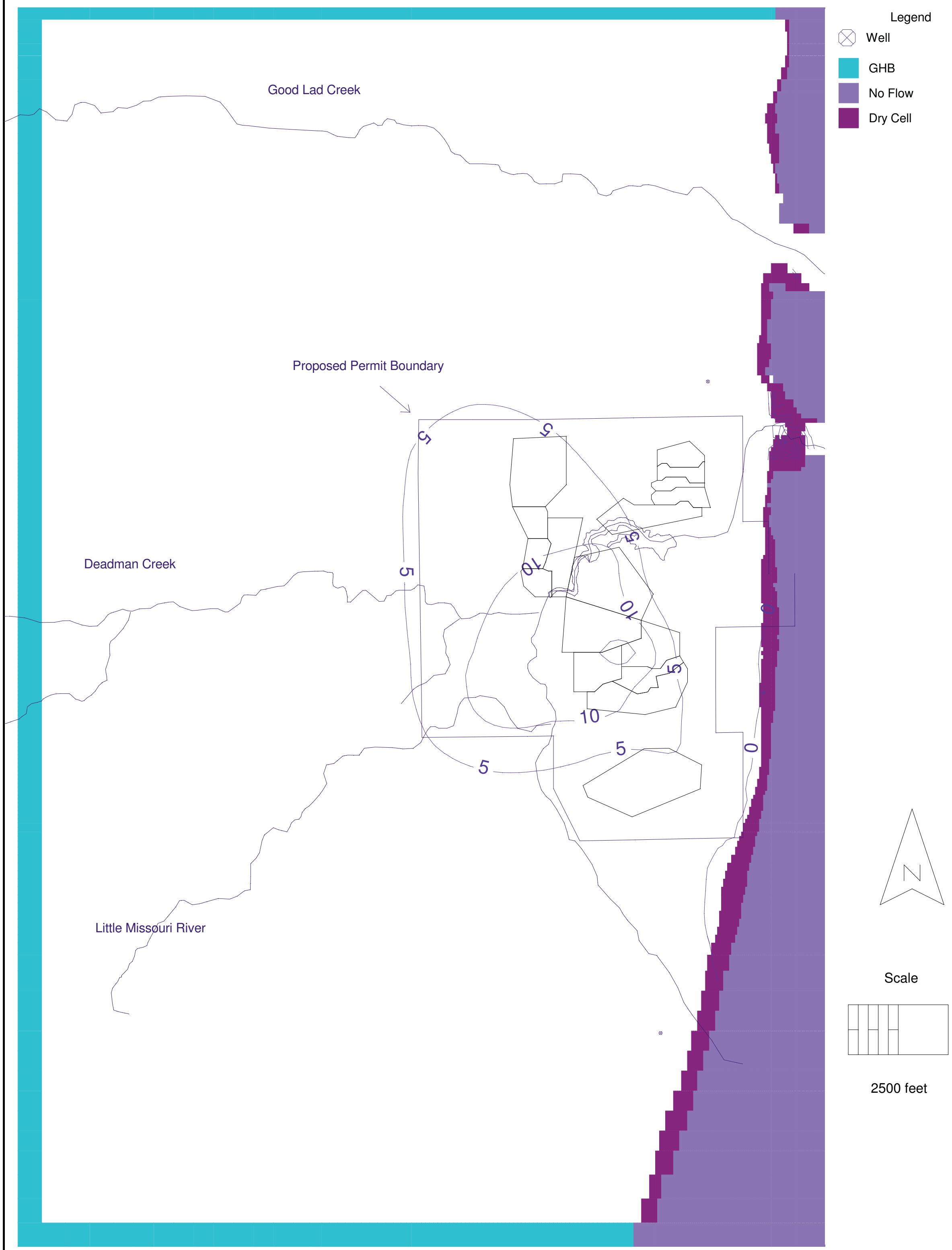


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 4 (SM) Stress Period 25 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown At The End Of ISR Operations

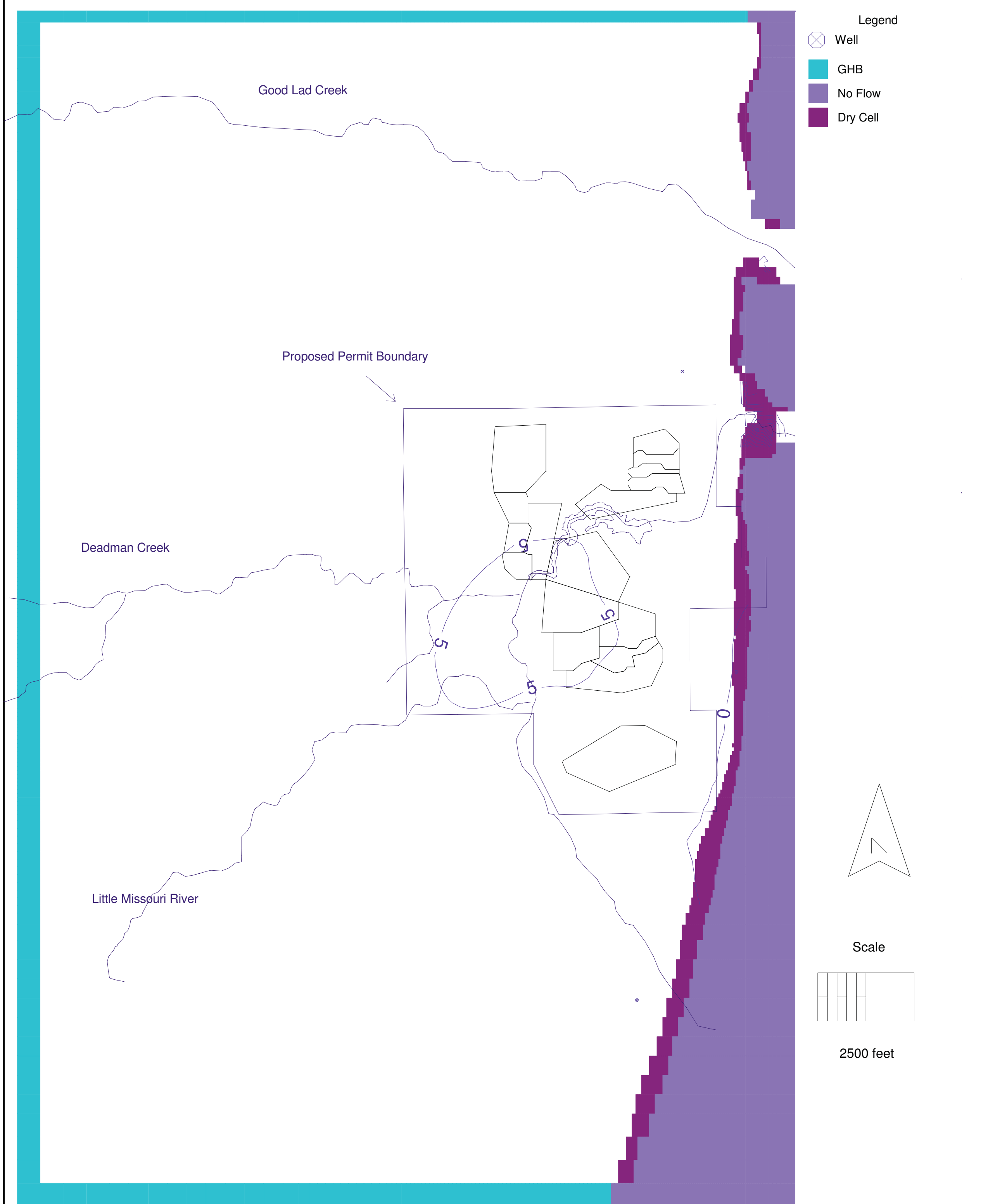


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 4 (SM) Stress Period 26 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown 5 Years After The End Of ISR Operations

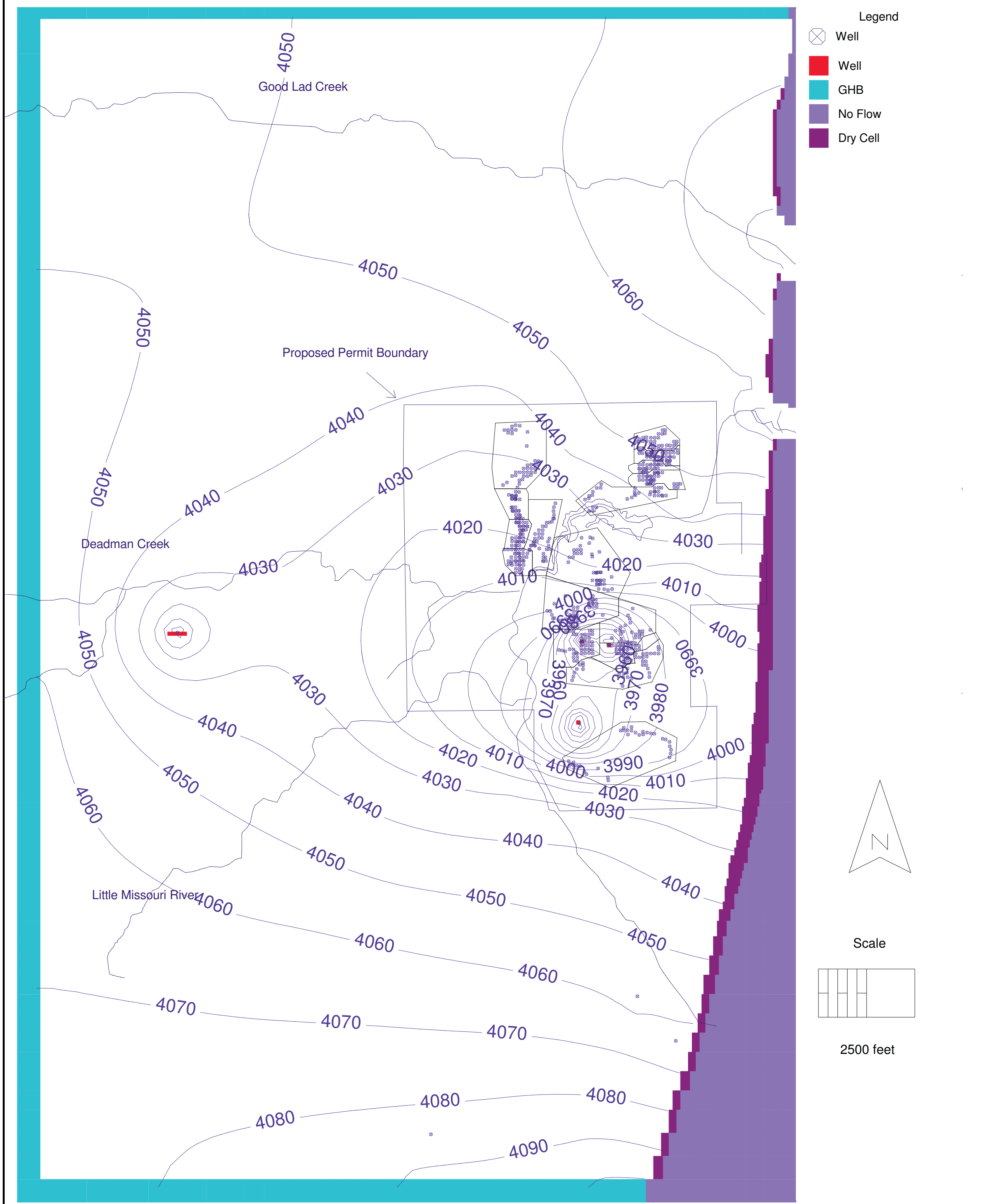


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 1 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Potentiometric Surface Prior to ISR

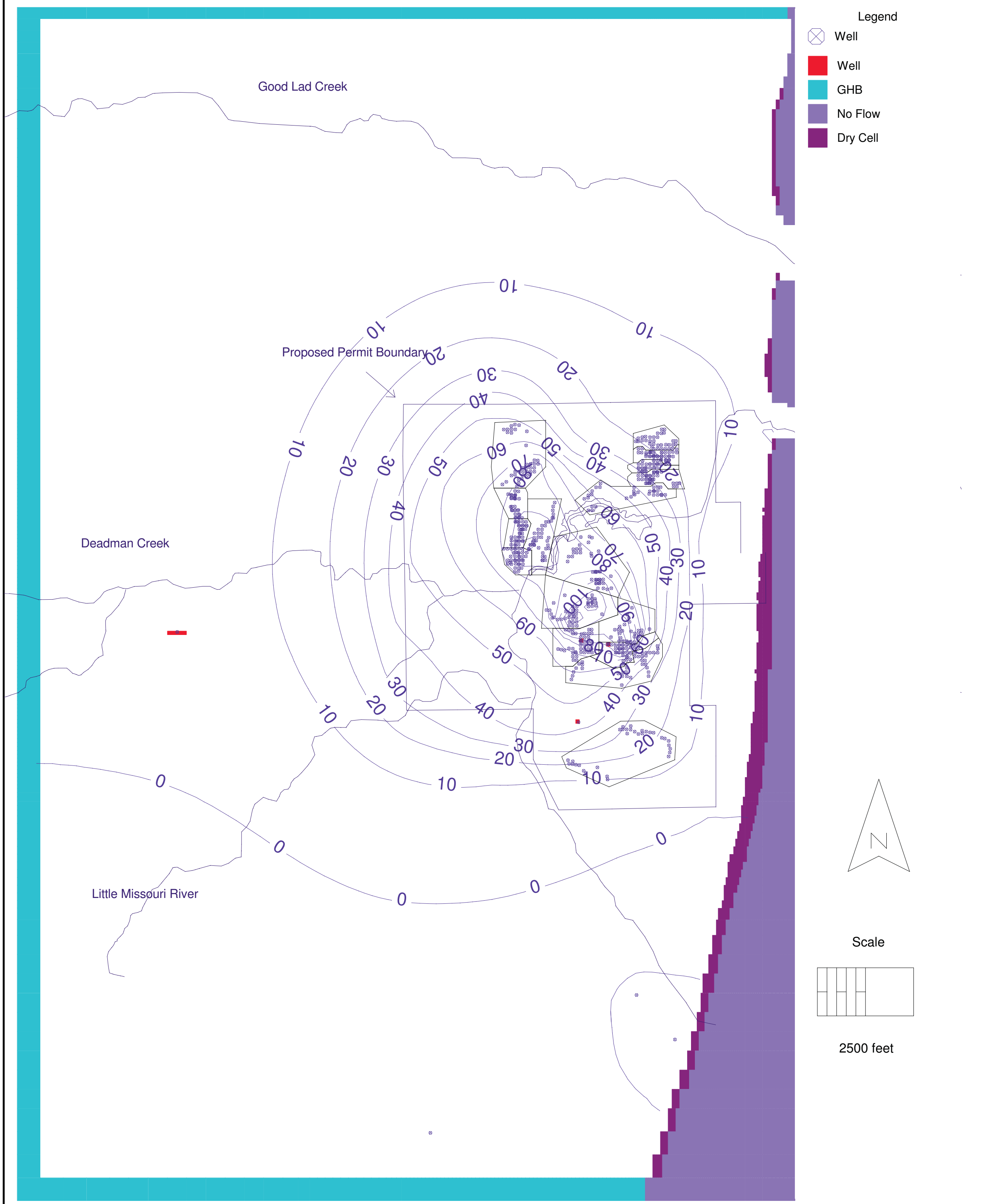


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 8 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown 1.75 Years After The Beginning Of ISR Operations

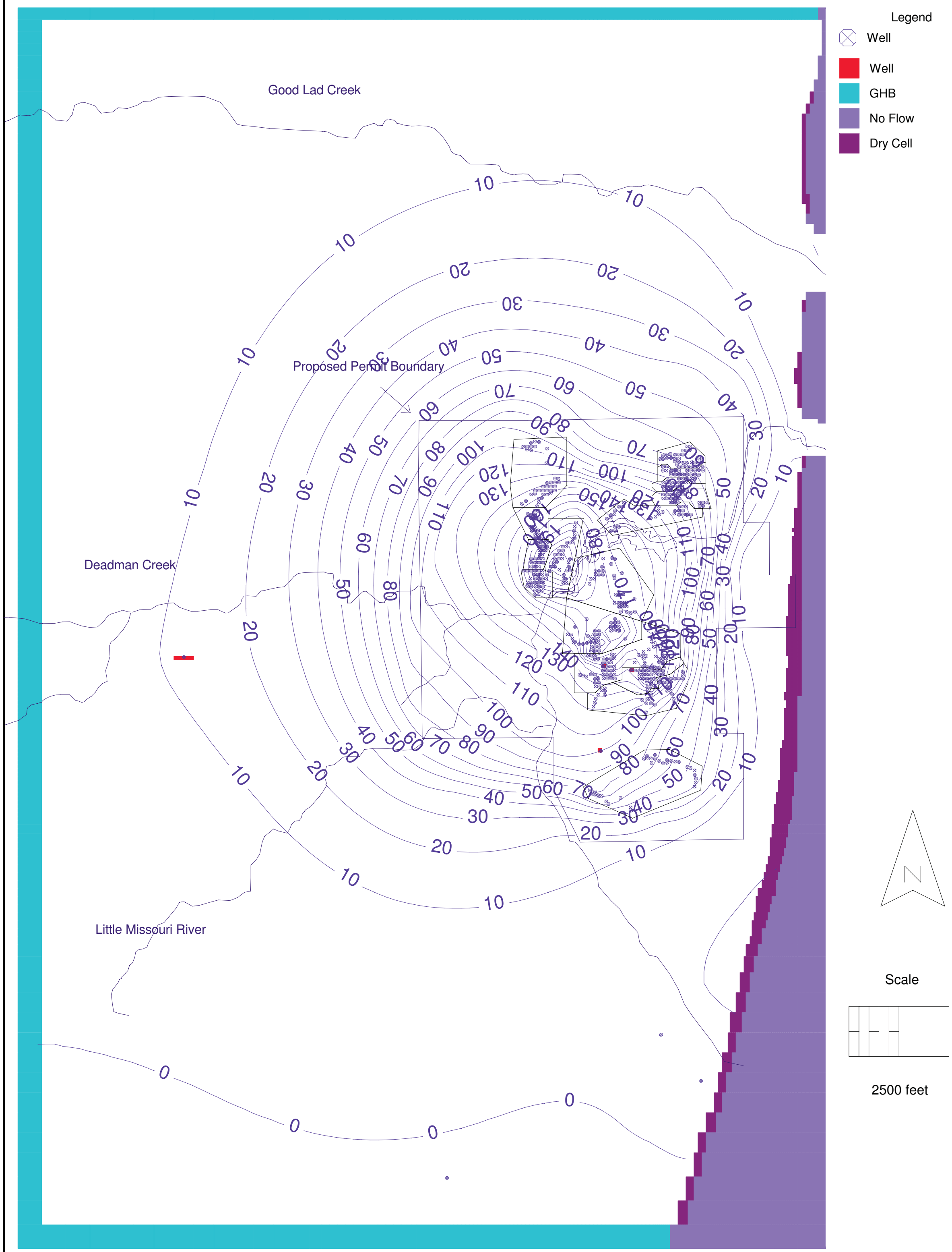


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 15 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown 3.5 Years After The Beginning Of ISR Operations

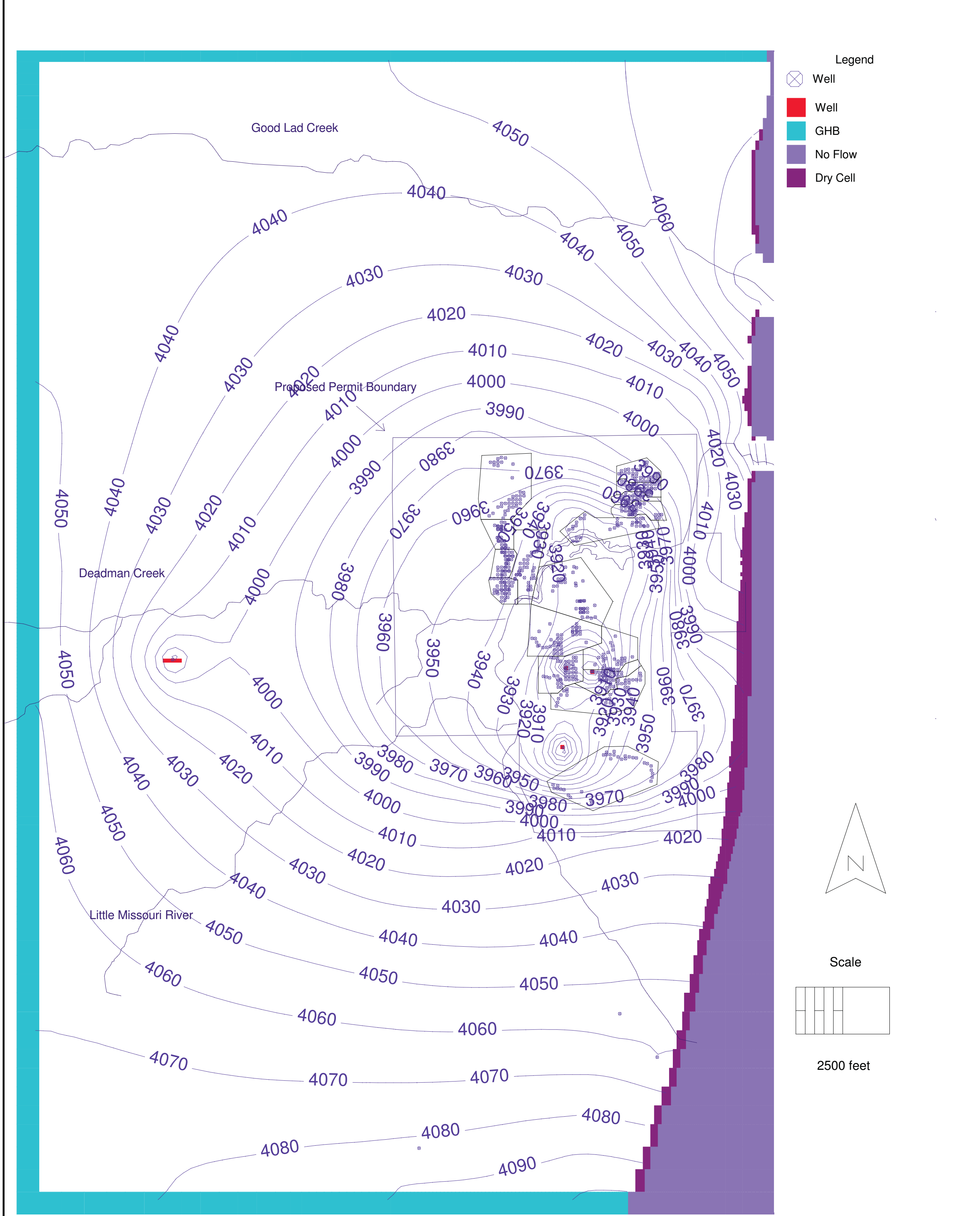


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 25 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Potentiometric Surface At The End Of ISR Operations

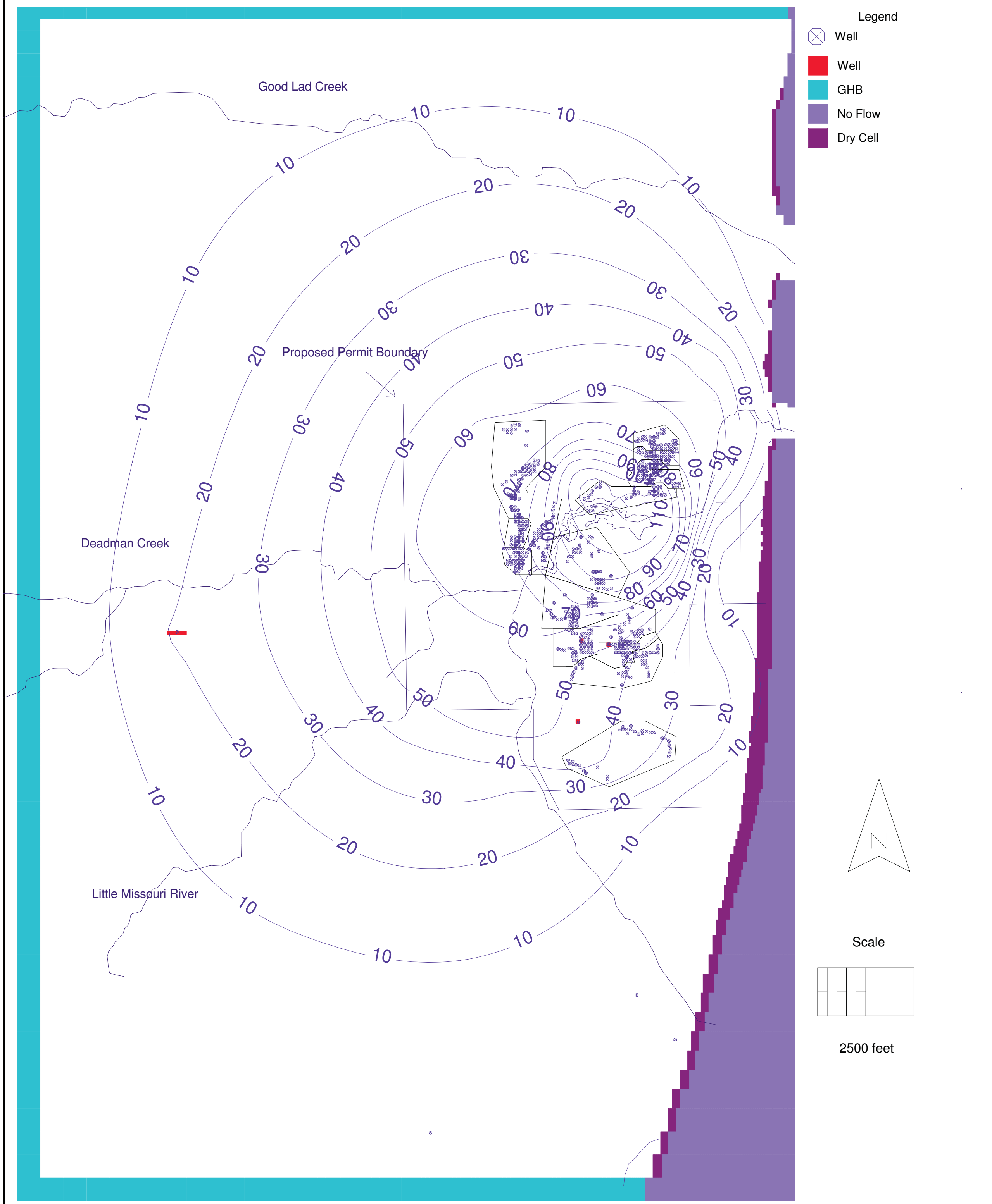


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 25 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown At The End Of ISR Operations

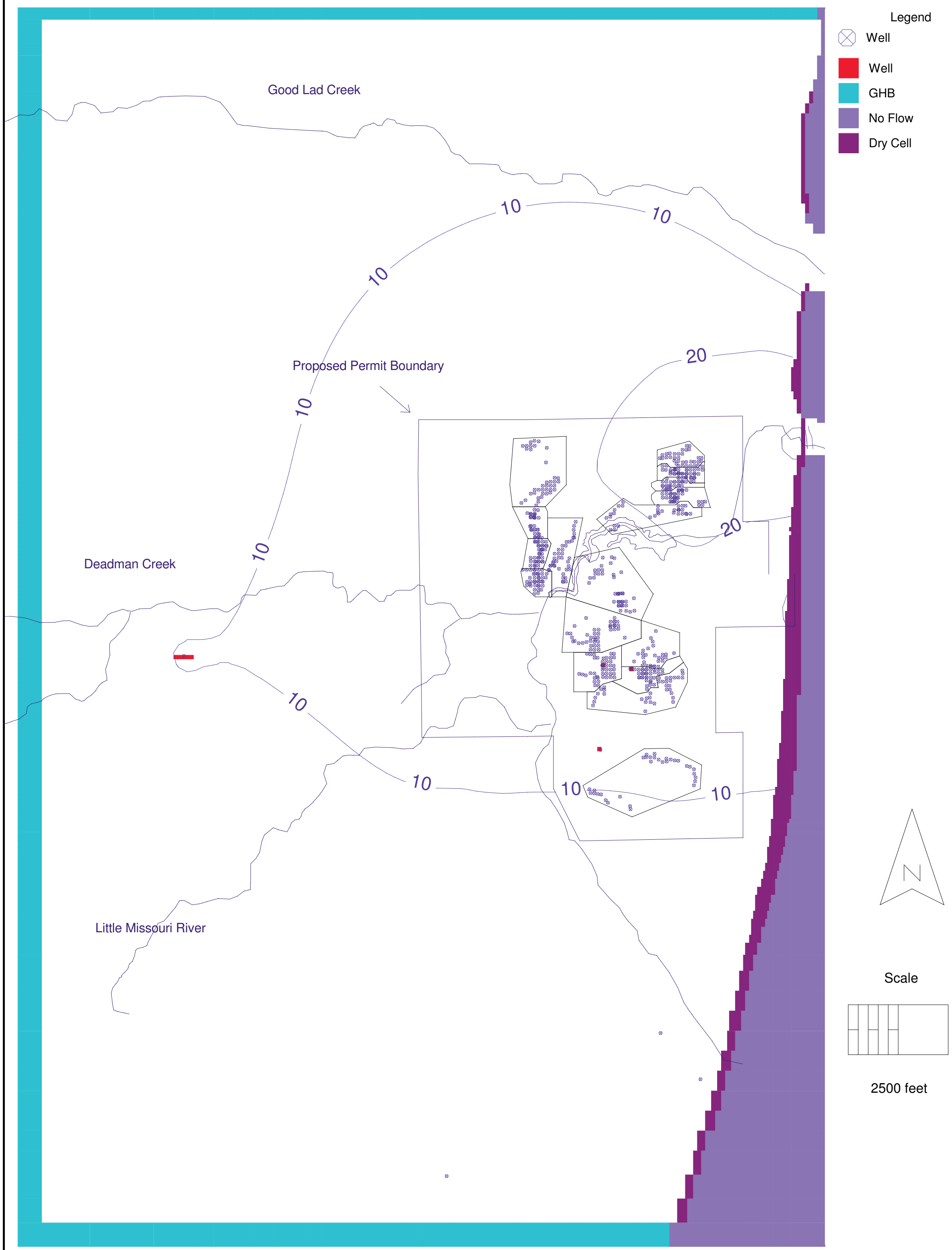


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 26 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown 5 Years After The End Of ISR Operations

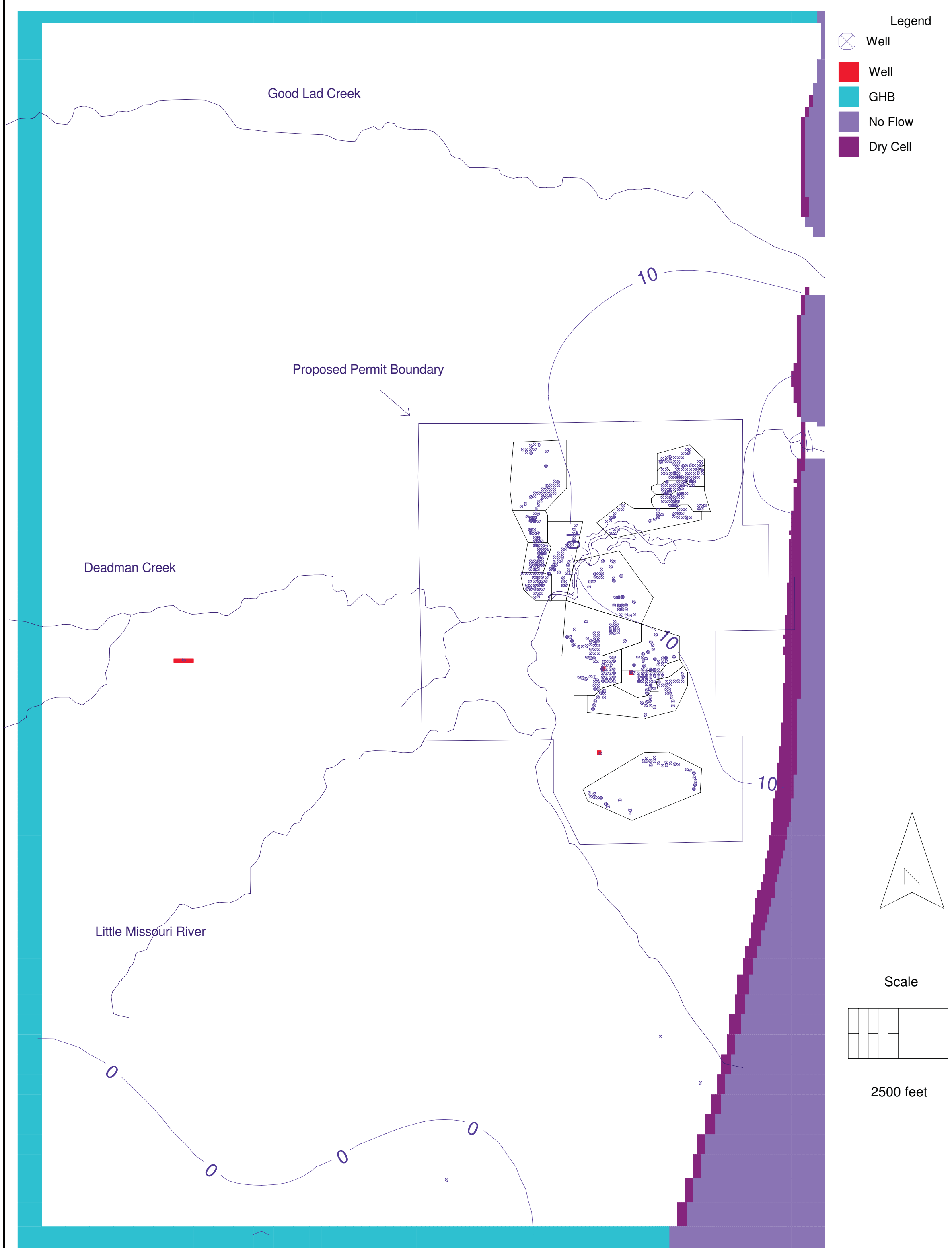


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 27 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown 10 Years After The End Of ISR Operations

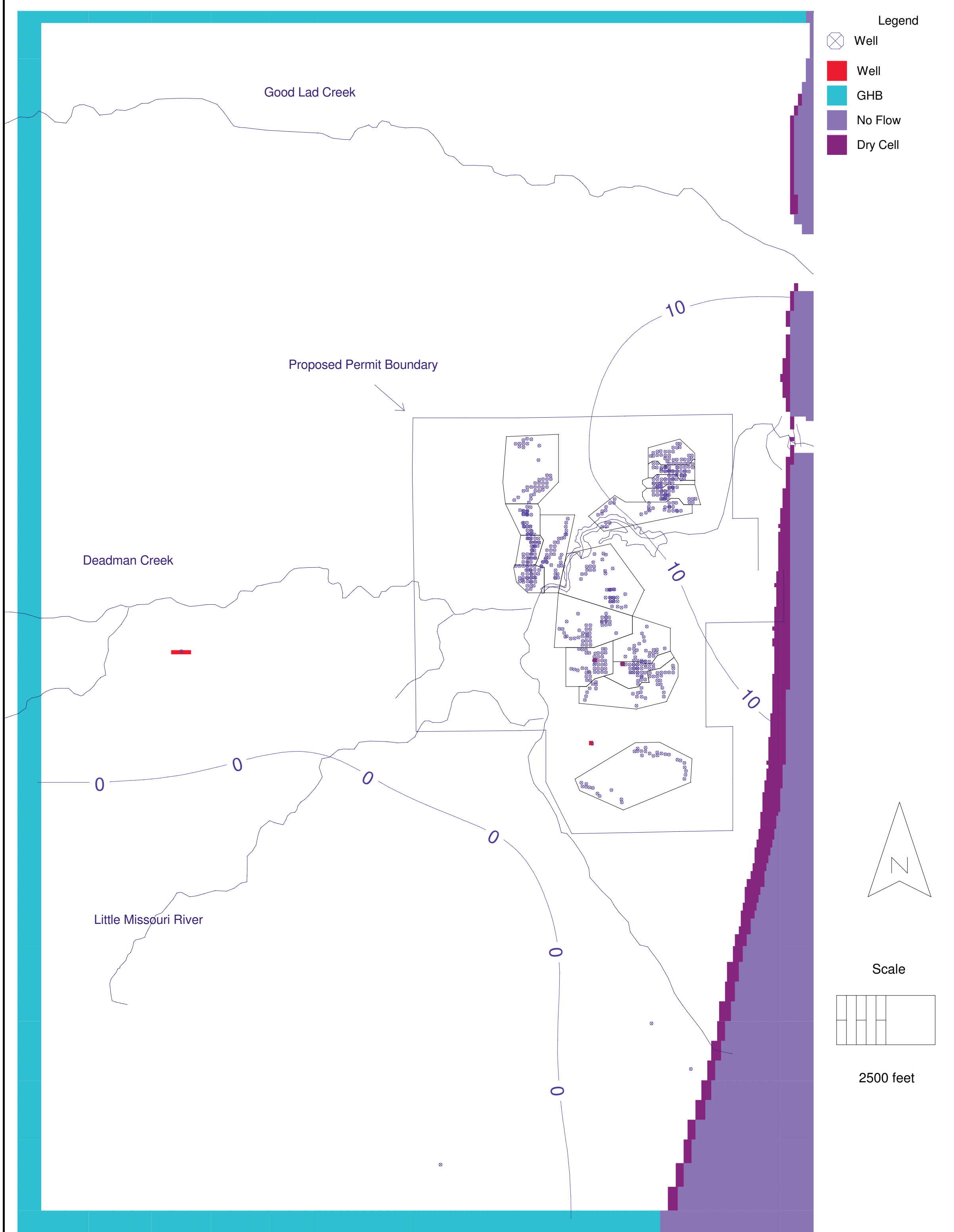


Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 28 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown 20 Years After The End Of ISR Operations



Strata Energy-Ross Project

GW-Model Mine Simulation Layer 6 (OZ) Stress Period 29 Time Step 5

With Merit Oil Field Water Supply Wells in Operation

Drawdown 50 Years After The End Of ISR Operations