Modeling of Ground-Water Flow in the Pierce Gulch Sand Aquifer: Five Models: History, Updates, and Predictions of Impacts Caused by Pumping at the M3 Eagle Planned Residential Community Ada County, Idaho

Prepared for:

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November 26, 2008

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m3companies

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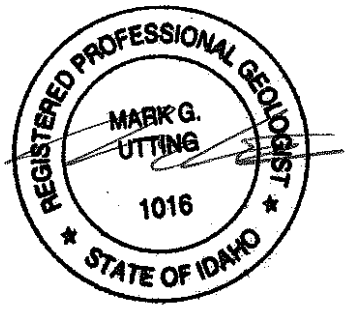
Prepared for:
M3 Eagle, LLC



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EXECUTIVE SUMMARY

A recently developed three-dimensional, "Modflow" ground-water-flow model developed to include the greater M3-Eagle-Star vicinity, predicts that after 50 years of pumping from three wells at an average, continuous rate of 1,500 gallons per minute (gpm) from each well, drawdown impacts (water level declines) in wells completed in the Pierce Gulch Sand Aquifer one-half mile from the M3 Eagle property will be on the order of 10 to 20 feet. Drawdown impacts in wells completed in the shallower, unnamed alluvial aquifer overlying the Pierce Gulch Sand Aquifer are predicted to be about two-thirds of those predicted for the Pierce Gulch Sand Aquifer. To be conservative (likely to over-predict), the average annual volume of water pumped by the three wells in the simulation is about 10-percent greater than the amount of 6,535 acre-feet per year (equivalent to about 4,051 gpm or 9.02 cfs) requested by M3 Eagle to supply its Master Planned Community after full build-out (anticipated about 25 to 30 years after project start up).

The new model (called the "M3 model" in this report) supersedes four earlier ground-water flow models constructed by various entities over the past 26 years that included the greater M3-Eagle-Star vicinity ("Lindgren model"-1982, "USGS model"- 1991, "TVHP model"- 2004 and "U of I model"– 2007). The previous four models were unable to simulate and predict impacts to wells near the M3 Eagle property because these models were:

- Constructed with cell sizes that were too large (Lindgren, USGS and TVHP models),
- Developed with too few layers or layers not capable of modeling stratigraphic dip to realistically simulate the Pierce Gulch Sand Aquifer and overlying aquifers/aquitards (Lindgren, USGS, TVHP and U of I models),
- Set up with boundary conditions that did not allow ground-water flow in the Pierce Gulch Sand Aquifer (or for that matter, any modeled aquifers) to move to the Payette Valley as measured in the field (TVHP model), or
- Did not calibrate to transient conditions (U of I model).

The M3 model was constructed specifically to be able to predict ground-water flow in the greater M3-Eagle-Star vicinity while three of the four previous models were designed to consider flow over much larger areas and therefore, with much less detail. In addition, the M3 model does not have the problems associated with the previous four models because the team developing the model was able to learn from the previous models.

The new M3 model:

- covers 520 square miles,
- contains almost 82,000 active cells,
- comprises seven active layers
- has cell sizes as small as 330 feet on a side,
- was constructed with boundary conditions far from the M3-Eagle-Star vicinity that are unaffected by simulated pumping from the M3 site, and

- was calibrated to three long-term (one week to one month) aquifer tests.

The M3 model was developed by Pacific Groundwater Group (PGG) of Seattle Washington in close cooperation with Hydro Logic, Inc (HLI) in an interactive fashion. This collaborative effort allowed for efficient transfer of HLI's understanding of the hydrogeology of the project area in constructing and calibrating the model. Personnel at HLI have both developed numerical flow models in the past and have worked directly with key personnel at PGG over the past 20 years resulting in a strong, team-oriented, approach. This approach avoided the difficulties that often occur when models are generated without a strong understanding of field conditions or when regular interactions are limited between the modelers and personnel with direct knowledge of the hydrogeology of the modeled area. One of the goals of the M3 model was to accurately incorporate the real subsurface geologic section including the dip and thickness of sub-units as closely as possible, to create a realistic model that could be improved over time and serve as a useful tool in understanding the aquifer.

The M3 model was initially developed and calibrated to the Eaglefield and Lexington Hills aquifer tests, conducted near Eagle, Idaho. During the calibration process, it became apparent to the modeling team that water levels simulated by the model in the vicinity of the M3 Eagle property, were lower than those measured in the field during 2006 and 2007. As a result, two parallel models were developed: one that generally "honored" the aquifer transmissivities calculated from 17 pumping tests in the region (the "Tmatch" model) and one that allowed water levels to better match the field measured values (the "Hmatch" model). Both models met calibration criteria. Both models also generated predictions of drawdowns that would be caused by pumping from the M3 Eagle property that were generally similar (generally with a few feet of each other). By using the two parallel models for predictions, the results are presented as a range (e.g., "Predicted drawdowns one-half mile from the M3 property boundary range from 10 to 20 ft after 50 years of pumping."). Presenting a range of results brackets the uncertainty of the models. Uncertainty in the amount of pumping within the modeled area was also considered by calibrating both the Tmatch and Hmatch models with two estimates of total pumping: one smaller and one larger, resulting in a total of four separate predictions (Tmatch model based on the smaller pumping totals, Tmatch model based on the larger pumping totals, Hmatch model based on the smaller pumping totals and Hmatch model based on the larger pumping totals). In the end, the four predictions are all in close agreement, indicating that the uncertainty in the transmissivity and pumping data do not cause significant differences in model predictions.

Even though we consider the M3 model is the best predictive tool developed to date to assess changes to the ground-water system in the greater M3-Eagle-Star vicinity, we consider it a "work in progress." It was constructed such that it can be used for future simulations and can be updated as new information is obtained. In fact, the model presented in this report has been updated and revised three times since it was developed and presented in its original form in the one-year progress report included in Appendix A. Each of these updates (included in Appendix B) represents an improvement based on additional knowledge of the aquifer, water use or other features of the flow system.

Because the M3 model is an ongoing process and because it is best understood within the context of all four reports, this HLI model overview report combines and synthesizes the information from the four reports into one location and helps to explain the model in lay terms. Future update-information that should be considered includes: additional pumping-test data from new, high-quality aquifer tests of the Pierce Gulch Sand Aquifer; improved recharge analyses; improved analyses of leakage from canals, rivers and drains; and pumping test data from aquifers other than the Pierce Gulch Sand Aquifer (for example the Willow Creek Aquifer, the shallow unnamed alluvial aquifer and aquifers beneath the Payette River Valley).

The M3 model conservatively estimates ground-water underflow across the southeast boundary of the model (beneath the west Boise area) to be on the order of 102 to 115 cubic feet per second (cfs) from this region. This amount is at the lower end of the range quantified in several reports issued as part of the Treasure Valley Hydrologic Project which estimated 80 to 150 cfs of leakage from the New York Canal in the area east of Cole Road, and 21 to 110 cfs of leakage from the Boise River upstream from the Capital Bridge in Boise, for a combined total of 100 to 260 cfs (to two significant figures). The model was used to estimate the impacts of the reduction of flow from these two sources by simulating the decline in water levels that might result, if flow were to be reduced by twenty percent (through pave over or canal lining). The model predicted that water levels in the M3-Eagle-Star vicinity might decline by 2 to 5 ft north of the Boise River. Because the emphasis of the M3 modeling effort focused on the regions north of the Boise River and because of the closeness of the Meridian area to the model's southeastern boundaries, we do not consider predictions south of the river to be valid.

This modeling overview report discusses the history of numerical model development in the Treasure Valley. It includes key figures from three of the five models along with discussion of the improvements made with each model and what we consider to be their limitations in predicting pumping impacts in the M3 Eagle vicinity. We also include as Appendix A the original Pacific Groundwater report ("one-year progress report") that details model construction, initial calibration and the initial predictions when it was believed that seven wells might be needed to meet the initial, planned water requirements for the project. Three technical memoranda discussing updates and improvements to the model and the most recent simulations with the most up-to-date versions of the M3 model are also included in Appendix B. Appendix C contains the Conclusions and Recommendations sections from the two models (TVHP and U of I models) that preceded the M3 model.

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Table of Contents

EXECUTIVE SUMMARY i
INTRODUCTION 1
GROUND-WATER MODELS: WHAT THEY ARE, HOW THEY WORK AND MODLFOW 4
Description of a Ground Water Model 4
Modflow 6
A Ground-Water-Flow Model as One of Many Tools 7
AN OVERVIEW OF THE HISTORY OF GROUND-WATER-FLOW MODELS THAT INCLUDE THE M3-EAGLE-STAR VICINITY 8
Older Models 8
TVHP Model 8
U of I Model 10
M3 MODEL 13
Why the M3 Model was Developed 13
The M3 Model as an On-going Process 14
M3 Model: Initial Development 15
M3 Model: Water Budget Input 19
Well Pumpage 19
Surficial Recharge: Precipitation and Irrigation 21
M3 Model: Steady-State Calibrations 22
Development of Two Parallel Models through the Water-Level Calibration Process 23
Initial Steady-Stated Calibration Statistics and Results 24
Most-Recent (November 2008) Steady-State Calibration Statistics and Results 25
Mass Balance: Amount of Water Pumped by Wells 26
Table 1 Mass Balance Comparison of Well Pumpage Volumes: 27
Mass Balance: Flow to the Pierce Gulch Sand Aquifer from Outside the Model Domain 27
Mass Balance: Changes in Flow to the Pierce Gulch Sand Aquifer Caused by a Reduction of Seepage from the New York Canal 28
M3 Model: Initial Transient Calibrations 29
M3 Model: Transient Calibration to SVR #7 Test and Higher Total Pumping 30
M3 Model: Prediction of Impacts 31
M3 Model: Overview of Results 33
THE "BIG PICTURE" – THE ROLE OF MODELS AND RECOMMENDATIONS FOR ADDITIONAL WORK 34
The Role of Models 34
Conclusions 36
Recommendations for Additional Work 37
REFERENCES 40
FIGURES 43
Figure 1. Domain of the TVHP Model 45
Figure 2. Two Representative Cross-Sections from the TVHP Model 46
Figure 3. Potentiometric Contours from the TVHP Model 47
Figure 4. Model Domain and Grid Outline of the U of I Model 48

Figure 5. Representative Model Cross Section from the U of I Model 49
Figure 6. Domain of the M3 Model 50
Figure 7. Model Grid and Cells in the M3 Model 51
Figure 8. Land Use by Category in the M3 Model Area 52
Figure 9. Potentiometric Contours and Ground-Water Flow-Directions from the Initial M3 Model..... 53
Figure 10. Potentiometric Contours and Ground-Water Flow-Directions from the Higher-Pumping Rate/ Recalibrated M3 Model 54
Figure 11. Tmatch Model-Generated Simulations of the Change in Water Levels Caused by a 20-Percent Reduction in Recharge from Southeast of Model Domain - Higher Pumping Rate Model 55
Figure 12. Hmatch Model-Generated Simulations of the Change in Water Levels Caused by a 20-Percent Reduction in Recharge from Southeast of Model Domain - Higher Pumping Rate Model 56
Figure 13. Initial Transient-Calibration Hydrographs for Two Aquifer Tests - Lower Pumping Rate Model 57
Figure 14. Transient-Calibration Hydrographs for SVR #7 from the SVR #7 Aquifer Test - Higher Pumping Rate Model 58
Figure 15. Transient-Calibration Hydrographs for Lexington Hills #1 and Eaglefield #2 – Higher Pumping Rate Hmatch Model..... 59
Figure 16. Tmatch and Hmatch Model-Generated Drawdowns from Pumping at 4,500 gpm - Lower Pumping Rate Model 60
Figure 17. Tmatch and Hmatch Model-Generated Drawdowns from Pumping at 4,500 gpm - Higher Pumping Rate Model..... 61
APPENDICIES 63
APPENDIX A – PACIFIC GROUNDWATER GROUP REPORT OF JUNE 4, 2008 A-1
APPENDIX B –PGG MEMORANDA B-1
APPENDIX C - CONCLUSIONS AND RECOMMENDATIONS FROM TVHP AND U OF I REPORTS..... C-1

INTRODUCTION

This section of the report gives an overview of the work conducted, explains why the newest ground-water-flow model (the "M3 model") was developed, presents a very brief overview of the five models developed for the Treasure Valley area that include at least a portion of the greater M3-Eagle-Star vicinity, and outlines the structure of the report.

This report presents the results of a recently completed, "Modflow," three-dimensional, transient, computer-based, ground-water flow model of the greater M3-Eagle-Star vicinity (called the "M3 model" in this report). It also presents a summary and overview of the four ground-water flow models (that included this general geographic area) that preceded the latest model. The purpose of this report is to summarize the results and predictions of the new model, explain the significance of these results and show how this new model was built upon the recently-developed conceptual understanding of ground-water flow within the M3-Eagle-Star vicinity. A secondary purpose is to summarize the highlights of the results and recommendations of the previous models and to show the historical development of ground-water flow models pertinent to the M3-Eagle-Star vicinity.

The M3 model was developed by Pacific Groundwater Group (PGG) of Seattle, WA in close collaboration with Hydro Logic, Inc. (HLI) of Boise, ID. The PGG/HLI collaborative effort was calibrated to both a) water level data collected during 2007 ("steady-state" calibration) and b) three major Pierce Gulch Sand Aquifer tests conducted over the past seventeen years ("transient calibration"). This new, transient model simulates and predicts the potential impacts from pumping ground water from the regional Pierce Gulch Sand Aquifer in support of the municipal water-right application for up to 6,535 acre-feet per year, made by M3 Eagle for its Master Planned Community (Givens Pursley, 2008).

The M3 model predicts that impacts (interference reductions of well water levels) at full project build out, after 50 years of pumping from three on-site supply wells, each pumping at a continuous, annual average of 1,500 gpm (about 10-percent more than is currently planned) would be on the order of 10 to 20 feet, at some areas within one-half mile of the M3 property boundary. Since much of the M3 property is surrounded by BLM and or currently undeveloped lands, we expect impacts to existing wells completed in the Pierce Gulch Sand Aquifer outside of this "buffer zone" to be even less. Impacts to wells outside this buffer zone competed in the shallow unnamed aquifer directly overlying the Pierce Gulch Sand Aquifer in the Valley areas are predicted to be smaller.

The M3 model updates, and significantly builds upon, the two models that preceded it. A model developed by Douglas (2007) at the University of Idaho (the "U of I model"), the direct predecessor to the M3 model, was able to generally simulate water level data collected during 2006 ("quasi-steady-state" calibration), but was unable to accurately simulate previous aquifer tests. Because transient calibration was not possible for the U

of I model, it cannot be considered reliable and accurate to simulate and predict the impacts of ground water development from the M3 Eagle property.

The U of I model was highly significant, however, in that it verified the conceptual model in which ground water flows from the Boise River Valley to the Payette River Valley as described in HLI (2007a). It is important because it included the Pierce Gulch Sand Aquifer as a distinct hydrostratigraphic unit for the first time, based upon Douglas's review of both historical hydrogeologic data, and the more recent data presented in HLI (2007a). The U of I model is also significant because it updated the model that preceded it, the Treasure Valley Hydrologic Project ("TVHP model" – Petrich, 2004).

The TVHP model was the first "modern" (post millennial) ground-water flow model that included the greater M3-Eagle-Star vicinity along with a much wider modeled area. Because it covered a much wider area than the two more recent models, the TVHP model has a much coarser focus and did not consider the Pierce Gulch Sand Aquifer as a separate and distinct hydrostratigraphic feature. It also was set up with boundaries that forced the ground water within all the aquifers beneath the north Ada County foothills (including the M3 Eagle property) to stay within the Boise River Valley and flow toward the southwest contrary to what is now known (portions of the ground water in the Pierce Gulch Sand Aquifer flow toward the west and northwest toward the Payette River Valley) as indicated by recent hydrogeologic studies (HLI 2007a and b), USGS studies such as Parliman (1998) and Newton (1991), and by the two more recent models. The construction of the TVHP model *prohibited* the simulation of ground-water flow toward the Payette River Valley through the designation of the region between the Boise River Valley and the Payette River Valley as a no-flow boundary. Because of its regional focus, boundary conditions that forced ground water to flow toward the southwest, and the non-incorporation of the Pierce Gulch Sand Aquifer, it was not, and cannot now, be used to assess ground-water development from beneath the north Ada County foothills area.

Prior to the TVHP, two models were developed to simulate ground-water flow within the Boise River Valley. The first was the "Lindgren model," developed as part of a U of I master's thesis (Lindgren, 1982) while the second, the "USGS model" developed as part of the Regional Aquifer System Analysis (Newton, 1991) also simulated flow in the area. Because of the age and the relatively coarse focus of these models, the TVHP model was considered an update and a refinement to these older models.

Since the development of the first model (Lindgren), a considerable volume of detailed, technical information has been developed through test well drilling, geophysical surveys, aquifer tests, geochemical assessments, water level measurements and more. The newer, more-accurate, and more-complete data have allowed each subsequent model to be more detailed and more accurate than its predecessor. In addition, the need to predict impacts from projected ground water development in the north Ada County foothills area has resulted in the two most-recent models being more focused on, and more accurate for, analyses of this geographic region.

The four most-recent models were developed using the computer code "Modflow," developed by the USGS (McDonald-Harbaugh, 1988, 1996 and Harbaugh et al, 2002). Each model used the data as interpreted by the modeler, in the construction of a set of "cells," assembled as rows, columns and layers to represent an approximation of the subsurface hydrogeology of the modeled area. Each cell within the model was assigned hydraulic properties selected to allow the simulation of subsurface flow. The assigned properties for each cell were based upon the interpretation of the existing data available at the time.

The M3 model was prepared in stages. The model was originally functional in June of 2008. A report prepared by Pacific Groundwater Group (PGG) discussing the model and a predictive simulation of seven wells, each pumping at 1,000 gpm over a 26-year full-build-out period for the M3 Eagle Master Planned Community is included in its entirety as Appendix A. Since that time, PGG conducted additional calibration of the M3 model based on the data collected during a major nine-day aquifer test using well SVR #7 (located near the center of the M3 property). In addition, a more conservative model was developed to explore the uncertainty of pumping within the modeled area. This model increased overall pumping rates from numerous wells whose owners either do not measure or do not report the quantities of water pumped throughout the year. PGG then used the recalibrated model to predict pumping impacts that more accurately reflect the current projected development of ground water from beneath the M3 property, consistent with M3's revised water rights application. This simulation uses three wells, each pumping at 1,500 gpm over a 50-year period (representing the full potential impact about 25 years after full build-out). The additional calibrations and the additional predictive simulations were each summarized in a brief Technical Memorandum. Lastly, PGG was directed to consider the potential impacts to the ground-water-flow system should recharge originating as seepage from the Boise River and the New York Canal be reduced by twenty percent. All three reports (each presented as a Technical Memorandum) are included in their entirety in Appendix B. None of these four PGG reports have been previously issued or submitted to the Idaho Department of Water Resources (IDWR) prior to their inclusion in this HLI summary report.

Both the U of I and TVHP models have been documented in previously-issued reports submitted to IDWR. Since both of these reports are substantial in size, only the Conclusion and Recommendations portions of these reports along with a few selected figures are included in this report. Chapter Six (Conclusions and Recommendations) from the U of I model (Douglas, 2007) is included in Appendix C. A few key figures from Douglas are reproduced within our report. Appendix C also contains Chapter 12 (Conclusions and Recommendations) from the TVHP report (Petrich, 2004). Key figures from Petrich are also reproduced within our report. These figures have been modified slightly by adding the M3 Eagle project location and in some cases, ground-water-flow arrows as appropriate on figures showing water-level contours. These modifications were included to assist the reader in locating the M3 Eagle property and in understanding ground-water-flow directions.

The goal of this report is to explain ground-water models in a simplified, less-technical format, briefly summarize the history of ground-water-flow models that include at least a portion of the greater M3-Eagle-Star vicinity, assemble the pertinent information from the three most recent model reports, explain the results and significance of modeling in less-technical terms for the lay reader (who may be less likely to read a highly technical report on a ground-water model), explain the limitations of each model, and to recommend what we believe should be undertaken in support and improvement of the modeling effort.

Each section of this report works toward meeting this goal. The first section of this report is this introduction. The second section explains ground water modeling and particularly Modflow, as used by the four most-recent models. The third section of the report discusses the history and development of ground-water-flow models pertinent to the M3-Eagle-Star vicinity. The fourth section summarizes the development, calibration and predictive simulations of the M3 model. The fifth section of this report presents our recommendations for additional work to be done to support and improve the current M3 model.

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GROUND-WATER MODELS: WHAT THEY ARE, HOW THEY WORK AND MODLFOW

This section of the report explains that ground water models are a series of mathematical equations that represent a simplification of our understanding of how ground water flows. These equations can be solved by a computer in order to replicate historical hydraulic data and to predict the changes in water levels that would occur under different hydrologic situations, such as pumping from new wells. The four most-recent of the five models reviewed in this report were constructed using the computer code, "Modflow," developed by the USGS. Modflow consists of a series of modules or "building blocks" that can be assembled by a skilled modeler to represent the subsurface of the earth in a hydraulic simulation. A well-calibrated Modflow model can be used to predict the impacts from new wells and to explore many "what if" situations.

Description of a Ground Water Model

A ground water model is simply a series of mathematical equations representing ground-water flow. These equations can indicate water levels, flow rates and more. All ground-water models start with the very simple, but very powerful, ground-water flow equation

(developed in 1856 by Henry Darcy) that relates the quantity of flow to the change in the level (or pressure) of water as it flows through a porous zone of sand or gravel ("aquifer"). The Darcy equation relates the rate of flow through an aquifer, proportionally to the change in water level ("head") and a property of the aquifer that indicates its ability to allow water to flow through it ("permeability" or "hydraulic conductivity"). A very simple ground-water model may use only one Darcy equation and assume that all the properties of the aquifer are the same everywhere within the aquifer and that all the changes that are going to occur, have occurred. This situation is represented as a simple, one-dimensional, "steady-state," model of a homogeneous system, a situation that rarely occurs outside of a laboratory.

Because the real world is highly variable often with a lack of subsurface data and with changes that occur over time such as pumping, seasonal recharge, river flow, etc., a simplified, one-equation approach can only give a very rough approximation of how water flows through a subsurface system. Instead, a separate equation must be developed for each small portion of a water-bearing zone (aquifer) and for each zone where water is present but cannot be readily extracted by a well ("aquitard"). Each of these subsurface zones has different properties such that a series of equations becomes very complex and in many situations, impossible to solve directly. Changes over time must also be considered and are assessed using an equation that considers the change of water content (or "storage") within each cell. The real world is, in fact, far too complex and difficult to model using a few simple equations with simple solutions.

A computer model approximates the subsurface with a series of cells (or blocks), generally aligned as rows and columns within one or more layers. An equation[1] is developed for each cell. A model could be very simple with only one layer and a few dozen cells. A complex model could have many rows, columns and layers resulting in a hundred thousand or more cells. The computer "solves" all of the equations of the model when the solution of the equation in one cell balances with the solutions to the equations of the cells surrounding it. The computer takes tiny steps as it considers the solution in one cell and then compares it to the solutions in the surrounding cells, until the balance is achieved. Typically, millions of computations are needed for a model to generate results. Because the model must approximate the properties of each cell, the equations for each cell result in small errors – the difference between the model's calculated results and those that it might achieve, were it to run longer through additional iterations. The modeler specifies how small these errors must be for the results to be acceptable. After each step or iteration of a model run, the largest error observed within the model domain is compared with the maximum acceptable error specified by the modeler. When the largest observed error anywhere in the model is smaller than the specified largest-allowed error, the model is said to have "converged" with the resulting output (generally a water level or "head" specified for each cell) considered to be precise to within the specified acceptable error. When the model results are compared with, and are similar to, real-world data (such as water levels carefully measured in wells that have been accurately

[1] In the case of the Modflow models discussed in this report, the equation is a "finite-difference equation" whereby a complex differential equation is approximated by a simplified, linear equation. Some models use the "finite-element" technique which is not discussed in this report.

located and with accurately known well construction details) the model is said to be "calibrated."

Modflow

The US Geological Survey (USGS) developed a computer code called "Modflow" to assist in the modeling of ground-water flow. Modflow (and its earlier predecessors) is probably *the* most, widely accepted ground-water flow model code in use within the USA. The code is not specific to any one ground-water system. Rather it consists of a series of modules that allow the modeler to represent a wide variety of subsurface conditions, with a wide variety of model inputs and boundaries, solved with a wide variety of solution packages. Modflow is highly flexible and allows the modeler to represent many physical situations from vertical slices of a flow system; to a flat, two-dimensional approximation of a ground-water flow system; to a multi-layer, three-dimensional simulation of the ground-water flow system with rivers, wells, precipitation, drains and more. Modflow can simulate a flow system that has had as much time as it needs to reach equilibrium such that nothing is changing: water levels are constant, river flows are unvarying, and rainfall (considered as recharge) is constant. The result is a "steady-state" model. Modflow can also simulate a system where wells start and stop pumping, river levels rise and fall, seasonal rainfall varies, and other hydraulic changes occur. The result is a "transient" model. Modflow can be used to simulate simplified systems where the properties of an aquifer do not vary with position or direction of flow ("homogeneous and isotropic") to systems where properties are different at different locations within the system ("inhomogeneous") and/or vary, depending on the direction of ground-water flow ("anisotropic").

It is up to the modeler to determine which modules are needed and which data should be used in setting up the model. Modflow has modules allowing the simulation of varying aquifer and aquitard properties, wells, rivers, drains, recharge, inflow and outflow along model boundaries and more. Input data are needed for each of these modules. These data are typically: aquifer and aquitard properties, water levels, pumping rates, river and canal levels, river and canal bed properties, recharge rates, flow into and from the model from more distal areas and more. These data come from a variety of sources including field testing, historical data records, air photos (for land use assessment), computer data bases for Geographical Information Systems (GIS) and more. A skilled modeler must be able to evaluate the various sources of data, select the data that are appropriate and applicable. A good modeler must also be able to make sound, scientifically-based estimates of the data input values for regions where data are sparse or non-existent.

Because not every cell of the model has accurate data available, a modeler typically conducts a "sensitivity analysis" to assess which data are important to know and which data can be estimated with only small errors in the results when data-value estimates are incorrect. In a sensitivity analysis, the values of one selected portion of a data set (for example, river leakage) are changed, often by a power of ten (ten times larger or ten times smaller). All other parameters are held unchanged. When a parameter is changed by a power-of-ten and the change in model results is small (and acceptable), the model is

said to "insensitive" to that particular parameter. When the change in model results is large, the model is said to be "sensitive" to that parameter. By conducting a number of sensitivity analyses, the modeler can mathematically demonstrate which types of data are important to know accurately and which data types are less important and can be estimated based on sound hydrogeologic judgment (based on experience) with little resulting error.

Because of its power, flexibility and wide acceptance, the two most-recent models developed and reviewed in this report, were based on Modflow-2000 (Harbaugh et al, 2000). Both models used a form of graphical interface to assist in constructing the model and in viewing the results. The TVHP model started with older versions of Modflow: Modflow (McDonald and Harbaugh, 1988) and Modflow-96 (McDonald and Harbaugh, 1996) but was apparently run in its final version using Modflow-2000. It, too, was constructed and operated using various graphical interfaces. The USGS model also used an older version of Modflow in its construction.

A Ground-Water-Flow Model as One of Many Tools

All ground-water-flow models are just one of many tools used to understand ground-water flow and to predict what might happen under certain hydraulic conditions. No ground-water-flow model can ever be 100-percent accurate. There are always portions of the model that are based on best estimates for input data. We can never know with 100-percent certainty the properties of the geologic materials at all subsurface points. The estimates for various inputs may result in small errors in model predictions. They may also generate errors that are larger, especially in areas where the accuracy of the model is not considered as important compared with the areas of focus where an understanding of ground-water flow is important. Nonetheless, through sensitivity analyses, the modeler can develop an understanding of the relative significance of the predictive results.

A model is also an important tool to help indicate where it is important to develop additional information. Often data are collected that appear to be complete and only when input to the model, do data gaps become apparent. For this reason, the development of a model should be considered an on-going process and not a product that remains static and "final." Models are typically calibrated to show that they can replicate historical data. Over time, the model should be "verified" through the collection of additional data and rerunning of the model. When simulations do not match the actual hydraulic response of the system, the model needs to be adjusted. The adjustment (recalibration) allows the model to be improved, resulting in an increase in the confidence of the accuracy of the model. Through this iterative process the model becomes a more valuable tool.

In the end, all models will have some inaccuracies and therefore be at least partially "wrong." Even so, they are valuable as one of many tools. The model should not be considered the "be-all-and-end-all" understanding of a ground-water-flow system. However, when the physical, geochemical, and hydraulic data are all consistent with the results of a flow model, the confidence in the understanding of the system is increased.

AN OVERVIEW OF THE HISTORY OF GROUND-WATER-FLOW MODELS THAT INCLUDE THE M3-EAGLE-STAR VICINITY

Five transient, ground-water-flow models that have included at least a portion of the M3-Eagle-Star vicinity have been developed over the past 26 years. Each of these models has increased in its complexity and improved upon its predecessor. The latest model (the "M3 model") includes the most up-to-date hydrogeologic information, has the greatest detail and finest focus, and is the only existing model capable of predicting future impacts from pumping withdrawals (with relative accuracy) from beneath the north Ada County area that includes the M3-Eagle-Star vicinity. The M3 model was specifically developed and calibrated to allow for credible predictions of planned ground-water withdrawals from the Pierce Gulch Sand Aquifer in support of M3Eagle's municipal water rights application.

Older Models

The oldest computer-based, numerical, ground-water-flow model of the Treasure Valley was developed by Lindgren (1982) as part of a University of Idaho Master's thesis. This model (the "Lindgren model") was very simple in comparison to what has been developed since. It was designed to give a general understanding of ground-water flow in the Treasure Valley. The Lindgren model was two dimensional (one layer) and assumed (among other things) a system with only one aquifer up to 1,000 ft thick. It also assumed that the upland to the north of the Payette River was a no-flow, impermeable boundary. The Lindgren model was based upon a finite-difference model developed by de Sonneville (1972), originally designed for simulation of the Eastern Snake River Plain aquifer system. The model was calibrated to steady-state (1972) conditions but had difficulty in its transient calibration. It did not include the current understanding of ground-water flow through the Pierce Gulch Sand Aquifer to the Payette Valley beneath the north Ada County foothills. Because of its age, over-simplification of the ground water system in the north Ada County area, its coarse focus and difficulty in transient calibration, the Lindgren model was never designed to (and cannot) simulate future ground-water withdrawal from beneath the North Ada County area.

The second significant regional ground-water flow model that included the M3-Eagle-Star vicinity was developed by the USGS (Newton, 1991) as part of their Regional Aquifer System Analysis program. This regional simulation model used a very-coarse grid (with cells 2 miles on a side), consisted of three layers, and simulated the upper 500 feet of the model as a single unconfined aquifer bounded on top by a water table. The current understanding of the Pierce Gulch Sand Aquifer as a confined aquifer (with locally strong, upward flow gradients as high as 40 feet above ground surface) was not, and could not be simulated by the USGS model. Similarly to its predecessor, the USGS model was never designed to (and cannot) simulate future ground-water withdrawal from the North Ada County area.

TVHP Model

The third numerical model to incorporate at least a part of the greater M3-Eagle-Star vicinity within its model domain was developed as part of the Treasure Valley

Hydrologic Project (Petrich, 2004). This TVHP model was a significant update to its predecessors. It consisted of four layers with cells one-mile on a side. The domain of the model and its mile-on-a-side grid pattern (Figure 1), shows that the surface water divide (the crest of the foothills) defines the hydraulic boundary of the model in the M3-Eagle-Star vicinity. Similarly to its predecessor the TVHP model was designed to simulate regional flow and regional-scale impacts. Petrich states that "the direct use of the model for evaluating small-scale (e.g. individual wells) issues is limited." Our review supports this conclusion of Petrich's and indeed, our understanding of this model suggests that the mile-on-a-side cell size would make predictions on this scale to be only approximate.

The model divided the ground-water system into four layers. The upper portion of the ground-water-flow system was treated as a water table (unconfined) aquifer. This upper aquifer was assumed to be 200 feet thick with the top of the aquifer (the water table) defined as a plane connecting similar elevations of the Boise and Snake rivers. The modelers ruled out using direct geologic information (including the flood plain and terrace gravels of the present-day and ancestral Boise River) to define the upper aquifer. The TVHP model has an "intermediate" confined aquifer in the next 200 feet below the water table aquifer, with two more confined layers each 400 thick, lying below, for a total of 1,200 ft of saturated, water-bearing strata. The presence, distribution, and hydraulic role of the Pierce Gulch Sand Aquifer in ground-water flow toward the Payette River Valley were not incorporated into the TVHP model. Two representative cross-sections from the TVHP model report showing the vertical layout of the cells are shown in Figure 2. The details of the hydrostratigraphic layering now known to exist in the M3-Eagle-Star vicinity cannot be incorporated into this simplified layering system. The figure also shows leakage from the New York Canal and the Boise River as significant sources of recharge to the underlying ground-water system, an important contribution of the TVHP model. The recharge is indicated by the downward flow lines beneath the Boise River and the New York Canal.

The TVHP model assumed the surface water divide to be a "no-flow" (impermeable) boundary in the north Ada County area. Because of this no-flow boundary, ground-water flow in this area within all four layers is forced to flow to the south and west. Figure 3, reproduced from the TVHP report, shows ground-water potentiometric contours ("a water level map") with lower-elevation contours to the southeast of the M3 Eagle property and therefore all ground water flowing toward the southwest with none flowing toward the Payette Valley. [We have added flow arrows and the general location of the M3 property to assist the reader.]

The TVHP was not designed to, and therefore cannot, accurately simulate planned future withdrawals from beneath the M3 Eagle property or from the greater M3-Eagle-Star vicinity for three reasons. The first is the lack of inclusion of the Pierce Gulch Sand Aquifer as the regional water supply aquifer in this area. Using only two layers (one "water table" and one "confined") to simulate the upper 600 feet of the ground-water flow system is not adequate to properly simulate ground-water flow in the Pierce Gulch Sand Aquifer. The second reason is the no-flow boundary that forces all ground-water to flow to the southwest. Two series of water level data, one collected in 2006 and the other

in 2007, both show portions of the ground water in the North Ada County area flowing toward the west-northwest, to the Payette River Valley, as do two USGS reports (Parliman, 1998, and Lindholm, et al, 1983). The third reason is the coarse grid of the model. Simulations with grid cells one mile on a side can only show very coarse, approximate water-levels that would be inadequate for reliable predictions of future well-pumping impacts.

The TVHP model report lists a series of conclusions and recommendations (included in Appendix C). Many of the recommendations refer to additional modeling runs to assess various hydrologic situations. Other recommendations included: expanding monitoring (of water levels), the installation of multi-completion monitoring wells, and refining the grid size (smaller cells) in some areas. Since the model report was issued in 2004, monitoring has expanded in the M3-Eagle-Star vicinity, four multi-completion wells have been installed on the M3 Eagle property and two models with refined grids have been constructed.

U of I Model

The U of I model (Douglas, 2007) was the fourth numerical model developed to simulate ground-water flow within an area that includes the M3-Eagle-Star vicinity and the first attempt to specifically develop a model that could simulate planned withdrawals from the M3 Eagle property. Although it was not able to simulate the planned M3 ground-water withdrawals, it was a significant improvement upon its predecessors for analyzing ground-water flow in the M3-Eagle-Star vicinity. Some of the improvements include: a - refined (reduced) cell size, eight layers (although many played no significant role in the simulation of the greater M3-Eagle-Star vicinity), specific incorporation of the Pierce Gulch Sand Aquifer into the model, and boundary conditions that reflect the current understanding of ground-water flow from the Boise River Valley to the Payette River Valley. These improvements are discussed below.

The U of I model was calibrated to "quasi-steady-state conditions" in that it was able to generally replicate the water levels collected during summer of 2006. As such, it verified the feasibility of the conceptual understanding that ground water flows northward beneath the north Ada/Canyon county foothills, a significant advancement. It was not able, however, to replicate transient aquifer-pumping-test data. The U of I model is not, therefore, capable of predicting future well pumping scenarios from the M3 Eagle property.

The U of I model covers an area of 713 square miles, using a model grid of 62 by 46 cells, each one-half-mile on a side. Each cell is one-fourth the size of the cells in the TVHP model and 1/16 of the size of the USGS model, a significant improvement. The modeled area was much larger than the focus area of the M3-Eagle-Star vicinity in order to be able to incorporate natural boundaries to the system. As with most models, the focus area received more attention and detail in the incorporation of hydrogeologic information into the model. The model domain and grid outline reproduced from Douglas

(2007) are shown in Figure 4. The M3 Eagle property boundary is included in the figure to assist the reader.

The U of I model used eight layers, strictly defined by elevation, to simulate ground-water flow, as shown by the representative model cross section in Figure 5. Because of this definition by elevation, the upper three layers and the bottom layer played only a minor role in the simulation. In the eastern part of the model domain, the upper two layers represent the higher elevations (mostly bedrock and low-permeability sediments that we do not consider to be in significant hydraulic connection to the aquifers in the valleys). In the western part of the model domain, the top three layers lie above ground surface and therefore drop out of the flow simulation. The bottom layer represents 1,850 feet of low-permeability sediments (mostly clays) that are not an active part of the cold-water flow system of the region. Thus, most of the simulation takes place using four layers.

The Pierce Gulch Sand Aquifer is simulated within portions of Layers 5, 6 and 7 of the U of I model. However, since these layers are defined strictly by elevation, and the Pierce Gulch Sand Aquifer dips toward the southwest at approximately 100 feet per mile, the properties of each cell represent an average of the properties of the Pierce Gulch Sand Aquifer and the other sediments sharing the physical space of each cell. The inclusion of the Pierce Gulch Sand Aquifer into the model is an improvement over earlier models. In our opinion, however, the positioning of the layers based on elevation and not to the actual orientation of the Pierce Gulch Sand Aquifer reduces the ability of the model to specifically predict the effects of well pumping within the Pierce Gulch Sand Aquifer, alone.

The model uses a thin, low-permeability layer (between elevations of 2,500 and 2,503 ft above mean sea level) to force the Pierce Gulch Sand Aquifer and other aquifers shared by layers 5, 6 and 7) to act as confined aquifers. This three foot layer does not represent a layer existing in the "real world" although it does confine the deeper aquifers and keep the lower-elevation surfaces of the model from flooding and becoming lakes.

The U of I model used boundaries that allowed ground-water to flow from the Boise River Valley to the Payette River Valley as was indicated by water level data collected in 2006 (incorporated into the U of I model) and 2007(obtained after the model was substantially completed). The physical boundaries of the model are many miles from the focus area of the M3-Eagle-Star vicinity and do not, as with some previous models force all ground water in the Pierce Gulch Sand Aquifer to flow toward the Boise River from areas beneath the north Ada/Canyon County foothills. Each model cell along the boundaries was defined as "no-flow" (no ground water flowing into or out of the model) or "general head." (A general head is a specified water level at a specified distance from the boundary of the model along with a specified hydraulic term – "conductance," that controls the rate of flow. The effect of a general head boundary is to allow flow into or out of the model in areas where such flow is known to exist, but defined by water levels sufficiently far from the model's boundary such that pumping from a focus area within the model (away from the boundary) does not change the inflow or outflow. The modeler

picks the water level, distance and conductance that replicates the flow and then verifies that pumping from the focus area does not significantly affect the flow at the boundary.)

The U of I model report lists several recommendations to improve upon the model (All of which, are include in Appendix C). In broad categories, these included:

- additional monitoring,
- improved analysis of recharge,
- inclusion of all canals and ditches,
- improved analysis of water withdrawals,
- additional aquifer tests, especially from beneath the M3 Eagle property,
- inclusion of storage coefficients (for transient analysis), and
- inclusion of improved hydraulic information from zones above and below the Pierce Gulch Sand Aquifer.

These recommendations represent improvements that could be made to the existing model. The model *could* be updated by using the data generated through each of these improvements and by recalibrating the model. Undoubtedly, the updated model would be an improvement. However, we believe that the U of I model has limitations that ultimately would make it less valuable than a new model that took full advantage of the newly-developed information in its initial construction.

The timing of the construction and calibration of the U of I model and the timing of the ongoing HLI hydrogeologic investigation of the greater M3-Eagle-Star vicinity, limited the end results and usefulness of the model. The U of I modeling program had a "data cut-off" date of early summer 2007. Any data or new understandings of the ground-water system collected after this date could not be incorporated into the modeling process. However, considerable work *was* conducted during and after summer of 2007: additional water levels have been collected and analyzed; aquifer test have been conducted and analyzed; additional test wells have been constructed; geochemical samples have been collected, analyzed and modeled; additional borehole geophysical analyses have been conducted; and pumping tests from throughout the region have been reanalyzed. The information gathered since early summer 2007 has expanded the understanding of the flow system that would lead to an improved model. Unfortunately, the deadlines imposed through the Master's thesis process could not be stretched to match the timing of additional data collection. In an ideal world, the modeling would not begin until the data collection and analysis process was substantially complete. This was not possible, however.

In summary, the U of I model was an improvement over previous models. It used smaller cells and more layers, recognized and incorporated the Pierce Gulch Sand Aquifer, and recognized and incorporated model boundaries that better represent the flow system as it is now known. Since its completion, however, significant additional data have been collected and the understanding of the ground-water-flow system of the greater M3-Eagle-Star vicinity has increased. In addition, the limitations of the U of I model make it less useful as a model upon which to build a predictive tool.

For these reasons, a new model was needed for M3 to be able to simulate (with reasonable confidence) its planned water withdrawal from the Pierce Gulch Sand Aquifer beneath the M3 Eagle property. This new model (the "M3 model") was developed to build upon the improvements made by the U of I model, incorporate the additional hydrogeologic understanding gained after summer 2007, and learn from, and improve upon the limitations revealed through the U of I modeling process and all previous models. The M3 model is discussed in the following section of the report.

M3 MODEL

The fifth ground-water-flow model of the greater M3-Eagle-Star vicinity (the "M3 model"), developed by Pacific Groundwater Group of Seattle, WA in close collaboration with Hydro Logic, Inc. of Boise ID, was calibrated to both "steady-state" and "transient conditions." The M3 model consists of two separate models: one calibrated to best match existing water level data and one calibrated to best "honor" the transmissivities (a property of the aquifer) indicated through the analysis of 17 aquifer tests. The two models generate similar predictions and serve to bracket uncertainty in the data. The M3 model predicts that at full build-out of the M3 Master Planned Community, after 50 years of annual-average pumping at 1,500 gpm from each of three on-site supply wells, drawdown impacts to wells completed in the Pierce Gulch Sand Aquifer would be on the order of 10 to 20 feet, at some areas within one-half mile of the M3 property boundary. Impacts to wells at a similar distance competed in the shallow unnamed aquifer overlying the Pierce Gulch Sand Aquifer are predicted to be smaller. A mass-balance analysis indicates that currently, all the wells within the model domain pump only 9 to 14 percent of the ground water flowing into the system. Pumping from the M3 Eagle project at full build-out would increase this total by about 0.9 percent, a relatively small amount. The model calculates that about 102 to 115 cubic feet per second (cfs) flow into the Pierce Gulch Sand Aquifer from the southeastern regions beyond the model domain (Boise and Meridian). Field measurements made in this area as part of the Treasure Valley Hydrologic Project indicate a total of 100 to 260 cfs seeps from the Boise River and the New York Canal into underlying aquifers, supporting the conservative nature of the model-calculated inflow. The model predicts that water levels in the Pierce Gulch Sand Aquifer beneath the greater Eagle vicinity north of the Boise River would decline by about 2 to 5 ft (and probably by less than 1 foot beneath the M3 property), if flow entering the model from the southeast were to be reduced by 20 percent. Such a reduction might occur were the seepage from the New York Canal to be significantly reduced. The M3 model updates, and significantly builds upon the four models that preceded it.

Why the M3 Model was Developed

Because the U of I model could not serve as the predictive tool needed to assess the potential impacts of the development of the ground water needed for the completion of the M3 Eagle Planned Community, Hydro Logic, Inc. (HLI), through the authorization of M3 Eagle, LLC, hired Pacific Groundwater Group (PGG) to develop a transient, three-

dimensional, calibrated, numerical (computer based), ground-water-flow model, in close collaboration with HLI. The three-dimensional Modflow model was developed to simulate realistic and defensible predictions of impacts to existing wells that could be caused by municipal water-supply wells pumping from the Pierce Gulch Sand Aquifer beneath the M3 Eagle property,. The model predictions are made in support of the M3 Eagle Planned Community that has applied for a municipal water right of 6,535 acre-feet per year that it will require at full project-build-out, expected to take about 25 to 30 years, once construction begins (Givens Pursley, 2008).

Specifically, the M3 model was developed to:

- build upon the understanding and improvements made through the U of I modeling process,
- move beyond the limitations of the U of I model, and
- incorporate the improved on-going understanding of the hydrogeology of the greater M3-Eagle-Star vicinity provided by M3's hydrogeologic studies.

The model was developed as a tool to better understand the ground-water-flow situation in the greater M3-Eagle-Star vicinity. We do not consider it to be the ultimate understanding and definitive tool for ground water analyses. Rather it is one of many tools that help to clarify how ground water flows beneath the M3 Eagle property and in the North Ada County area. The predictions made by the model are unlikely to be 100-percent accurate. Rather, we believe that they give a reasonable range of likely impacts at various points within a few miles of the M3 property. Further away, where there was less emphasis on data collection and analysis, predictions are likely to be less accurate.

The M3 Model as an On-going Process

The M3 model was developed as a "living" model intended to be improved upon and refined over time as more data are collected and analyzed and new information becomes available. The model was initially developed, (and continues to be developed) as an on-going and evolving process and not a "final product." It has been, and will continue to be, improved and updated over time.

Because on its on-going nature of this project, PGG has issued several reports detailing the model at various points in its development. The first report was issued approximately one year after the modeling effort was started. This report, dated June 4, 2008 (included in Appendix A) detailed the initial model, its steady-state calibration, its transient calibration to two long-term aquifer tests ("Lexington Hills test" and Eaglefield test") and its 7-well simulation of what was initially believed to be M3's water requirements and the ability of the aquifer to supply only 1,000 gpm per supply well. As discussed, below this report presented the development of two parallel models (the Tmatch model and Hmatch model) to accommodate and explore uncertainties in the data and to allow a bracketed prediction of impacts to reflect these uncertainties.

A second update to the model was issued after HLI completed the analysis of a major aquifer test ("SVR #7 test"). The data obtained from this test, were the first for a long-term (9-day) aquifer test from beneath the M3 property and the first from the northern part of the model focus-area. Based on the SVR #7 test data, PGG recalibrated both the Tmatch and Hmatch models. The recalibration was presented in a Technical Memorandum dated July 26, 2008 (included in Appendix B).

A third update to the model was issued to revise the predictions of full-build-out pumping from beneath the M3 property using the recalibrated model, the reduced water requirements for the M3 property and the new understanding that individual supply wells with yields in excess of 2,000 gpm would likely be possible from the Pierce Gulch Sand Aquifer beneath parts of the M3 property. The revised predictive simulation was presented in a Technical Memorandum dated September 22, 2008 (included in Appendix B).

A fourth update to the model was issued after it was decided to make the model more "conservative" (likely to predict greater impacts from pumping) by exploring the uncertainty in well pumping data from supply wells within the model domain. Since very little record of actual well pumping amounts is available in the public record, estimates were made for the initial calibration and the calibration using the SVR #7 data. In this more conservative recalibration, larger amounts of pumping were assigned to various supply wells throughout the model domain, in order to explore whether the additional withdrawals would significantly affect predictions of impacts caused by pumping from beneath the M3 site. Both the Tmatch and Hmatch versions of the model were recalibrated using these higher pumping rates. The newly recalibrated model was then used to predict impacts caused by long-term pumping from the M3 property using both Tmatch and Hmatch versions of the model. The higher-existing-pumping-rate model was also used to explore possible changes to the ground-water-flow system that might be caused, were seepage from the New York Canal to be reduced. The revised calibration, the revised 50-year drawdown impacts and the possible changes to the ground-water-flow system from changes in New York Canal seepage were presented in a Technical Memorandum dated November 14, 2008 (also included in Appendix B).

Because the model is evolving and because the latest (November, 2008) version of the model can only be understood in the context of the previous versions, we summarize the process and development of the model with the perspective of having synthesized the initial report and the three memoranda, below.

M3 Model: Initial Development

Pacific Groundwater Group began developing a seven-layer, three-dimensional ground-water-flow model (the M3 model) in close collaboration with Hydro Logic, Inc., shortly after it was realized that all of the existing models (including the U of I model) could not accurately predict the impacts of the proposed pumping of ground water from beneath the

M3 Eagle site. HLI worked closely with PGG to help streamline the modeling process[2]. When PGG recognized that additional data were needed, HLI was usually able to collect, process, and analyze the data needed for the model. When HLI recognized data gaps from areas within the model domain, PGG was able through various modeling activities ("sensitivity analyses") to assess whether the data were critical to the model. In some situations when reviewing model output, PGG found results were best interpreted based on HLI's on-the-ground hydrogeologic experience within the model domain. Through this interactive process, the quality of the model was significantly improved.

The model was developed using Groundwater Vistas - Version 5 (ESI, 2007) which is a graphical interface for Modflow 2000. Solutions were obtained using the "Preconditioned Conjugate-Gradient Method" which is a mathematical solution package that solved the hundreds of thousand of equations within the model, in a timely and stable manner.

The M3 model covers a 520 square mile area, uses almost 100,000 cells (about 82,000 active), and has variable cell size (330 feet on a side in model focus areas and up to one-half mile at the model boundaries). The smaller cell sizes allows for the most-precise predictions to-date of water levels at specific areas within the model focus area. All cells are oriented north-south/west-east and positioned to lie within the public land survey system (township/range/section/quarter-section/quarter-quarter-section). The model domain is presented in Figure 6, while the model grid is shown in Figure 7, both reproduced from the initial M3 model report (PGG, 2008a).

The model has seven layers, oriented to represent the hydrogeology specific to the M3-Eagle-Star vicinity and greater modeled area. The Pierce Gulch Sand Aquifer is modeled in Layers 5, 6 and 7. The three layers are oriented to dip to the southwest as indicated in HLI (2007a) whereby the geophysical logs from 13 wells and 36 boring logs presented on Well Driller's Reports and other consultant's reports were used to construct a contour map of the bottom of the Pierce Gulch Sand Aquifer. Thus, the layers simulating the Pierce Gulch Sand Aquifer are oriented to our best understanding of the position of this hydrostratigraphic unit. Three layers were used to allow for partial penetration of both pumping and observation wells used to calibrate the model under transient conditions (discussed below) and to allow for future changes to the model to reflect differing properties of the aquifer as a function of depth, as we learn more about it.

The layers overlying the Pierce Gulch Sand Aquifer were constructed to best represent the aquifers and aquitards in the model domain. A lower-permeability layer (Layer 4) was assigned to overlie the Pierce Gulch Sand Aquifer and represents a confining layer present beneath much of the Boise River Valley and parts of the foothills. In areas where this confining layer is not present (such as in the Willow Creek Aquifer and beneath the Payette River Valley) the properties of the various aquifers present at the elevation of

[2] The collaboration between HLI and PGG was strong in part because of the history between the project manager at HLI (Mark Utting) and the project manager at PGG (Peter Schwartzman). Mr. Utting is a former principal at PGG, has produced several ground-water-flow models and worked with Mr. Schwartzman on dozens of projects over the past 19 years. Through this mutual experience and mutual understanding of the modeling process, the collaboration between HLI and PGG was strong and seamless.

Layer 4 were assigned based on various sources such as consultant's reports and Well Driller's Reports. In the Boise River Valley and parts of the upland, Layer 3 consists of a shallow, generally confined aquifer that represents the "shallow, unnamed alluvial aquifer" described in HLI, 2008b. In various PGG reports the term "middle aquifer" was adopted for Layer 3, as a simpler description. Layer 2 consists of a shallow, lower-permeability confining layer beneath much of the Boise River Valley and portions of the upland. In a manner similar to that of Layer 4, aquifer properties were assigned to Layer 2 where the Willow Creek Aquifer is present and beneath the Payette River Valley. Layer 1 represents the Boise River Gravels in the Boise Valley and unnamed alluvial gravels in the Payette Valley.

In the greater North Ada County area where extensive characterization through test well drilling and aquifer pumping test analyses has taken place, hydrostratigraphic properties were assigned based on relatively "hard" data. Outside of the main area of focus, layers were assigned properties as indicted by various sources including consultant's reports, the files at HLI, Well Driller's Reports and various IDWR sources. We believe that the layer properties in the North Ada County area are more likely to be accurate than those assigned to the parts of model domain in Canyon, Payette and Gem counties.

Modeling sensitivity runs demonstrated that an eighth layer below the Pierce Gulch Sand Aquifer to accommodate upwelling of geothermal water into the coldwater system (modeled with Layers 1 through 7), was unnecessary. Based on the known upward flow gradients and properties of the underlying Terteling Springs mudstone, modeling runs were conducted to calculate the significance of an "eighth layer" and the water it might contribute. The runs assumed a uniform upward flow gradient beneath the entire model domain based on field observations from wells completed within sand layers within the Terteling Springs mudstone, located in the southeast parts of the model domain. The differences between runs with and without this upward flow from beneath the Pierce Gulch Sand Aquifer were found to be so small (maximum increase in water levels in the Pierce Gulch Sand Aquifer of less than 0.1 foot) that an eighth layer was deemed unnecessary.

The M3 model made great use of Graphical Information System ("GIS") analyses and Digital Elevation Models ("DEM") for generating inputs for the model. Land-use GIS data were used to input recharge based on agriculture, rainfall and sources of irrigation water (surface water from canals versus ground-water from wells). GIS was also used to input leakage from canals and ditches and seepage in and out of rivers in the model domain, all based on digital data available from the USGS and other sources. GIS was also used to input recharge from septic drainfields in non-sewered areas.

Model boundaries were selected based in part HLI's field research and in part on the experience of the previous four models that indicated the surface water divides in north Ada and Canyon counties are *not* boundaries to ground-water flow. Boundaries used in the model consisted of "no-flow," "river," "constant-head," "recharge," and "general head." No-flow conditions were assigned where hydrogeological analysis indicated that ground water neither flowed in or out of the model boundary cell. River boundaries were

assigned based on the mean water levels in the Boise River, Payette River and Lake Lowell, estimated permeabilities and estimated thickness of the river or lake bottoms. Constant heads (fixed water levels) were assigned to parts of the southwestern, northwestern and northeastern portions of the model where water levels are known and assumed to lie too far away from, and therefore unaffected by, pumping within the model focus area. General heads (as explained on page 11, above) were initially assigned to the southeastern edge of the Pierce Gulch Sand Aquifer (at the model boundary) where ground-water flows into the model, originating from areas lying to the east of the model domain, as seepage from the Boise River and the New York Canal,. As part of a sensitivity analysis, these general head boundaries were converted to "constant flux" (flow) boundaries. This conversion maintained the inflow to the Pierce Gulch Sand Aquifer at the same rate as that calculated by the general-head boundary. The conversion did not alter the water levels calculated by the model during the initial simulation of pumping from the M3 Eagle property (seven wells pumping at 1,000 gpm each) demonstrating that the general-head boundary cells along the southeast corner of the model do not generate additional flow during the simulation of pumping. During the latest simulation (three new M3 supply wells pumping at 1,500 gpm each and total existing pumping increased throughout the model domain) the general head boundary was converted to a constant flux boundary to eliminate the possibility that pumping might artificially induce additional flow during the simulation. The constant flux boundaries were also used to explore the possible impacts in the future were flow to be reduced from lining the New York Canal (discussed below).

The properties and positions of the various hydrostratigraphic units were initially estimated based on analyses of pumping tests (for aquifer properties), and a combination of geophysical logs from HLI and the files of United Water of Idaho, and review of lithologic logs included with consultant's reports and Well Driller's Reports on file with IDWR (for aquifer position). Initial profiles at 13 locations with borehole geophysical logs and 36 locations with lithologic logs (a total of 49 wells) were then contoured to generate three dimensional spatial positioning of the aquifer and aquitards in the model domain. The contours were then modified, based on HLI's hydrogeologic knowledge of the area to accommodate known contacts between hydrostratigraphic units (such as between the Pierce Gulch Sand Aquifer and the Willow Creek Aquifer) as well as known structural boundaries (such as defined by the West-Boise-Eagle fault system).

In areas where little direct hydraulic data were available from pumping tests, we used best professional judgment to interpret the lithologic data to estimate aquifer properties using relationships between the type of deposit (sands, gravels, clays, etc.) and permeability, porosity and storativity (a property of the aquifer that relates the amount of water released during pumping). Because some of these initial estimates of aquifer and aquitard properties were uncertain, the effects of these uncertainties on the results of model simulations were investigated during the calibration process (discussed below).

M3 Model: Water Budget Input

A water budget analysis used as input to the model was conducted as a joint effort between HLI and PGG using a combination of new-data analyses and data reported and used in the Treasure Valley Hydrologic Project model. The water budget consisted of quantifying the various sources of water flowing into and out of the model domain through all of its boundaries. To begin with, an analysis prepared by HLI was used to set up the M3 model. As the model progressed, PGG and HLI realized that the model domain needed to be expanded in order to make sure that pumping simulations from beneath the M3 Eagle property were neither: **a**) affected by the model boundaries nor **b**) caused changes in inflow or water levels at the model boundaries. In order to quantify the various components of inflow and outflow in the expanded model domain, PGG took the various analyses conduced by HLI and used GIS methods of analysis to apply the concepts used in the initial HLI analyses, as is discussed below.

The water budget (discussed below) assessed the various sources of water flowing into and out of the model. Sources of inflow included recharge from: precipitation; irrigation; septic drainfields; and seepage from canals, ditches and rivers. Inflow also included "underflow" from ground water entering the model from aquifers along the boundaries of the model. Outflow from the model boundaries included: ground-water pumped from wells, ground water discharged to rivers and ditches and ground water leaving the model domain.

<u>Well Pumpage</u>

Well pumpage (the volume of water pumped) from within the model domain is poorly documented. Municipal suppliers typically monitor monthly pumpage totals but do not always report them to a central recording agency in a timely manner. Pumping rates from industrial, irrigation, stock, fisheries, housing-development and single-family domestic wells are rarely measured or reported. Because of the lack of "quality" data, HLI estimated the annual average pumping rates for supply wells in the model domain. The latest version of the model documented in the PGG Technical Memorandum dated November 14, 2008, resulted in a model calibration that used estimates of pumping within the model domain that were greater than those used in the previous versions of the model. In this most-recent model, the total pumping from within the model domain averaged over the year is 144 cfs which is about 60 percent greater than the 90 cfs yearly-averaged pumping used in the initial modeling efforts documented in the various reports and memoranda prior to the November 2008 Technical Memorandum. We consider the calibration and simulations conducted using the higher pumping rates to be more conservative and therefore better suited for use in the predictive simulations of long-term pumping from beneath the M3 property. The following discussion summarizes the method and assumptions used in the larger estimate (144 cfs) of pumping from the model domain.

Water withdrawals from municipal supply wells were estimated based on water-rights analyses. Average annual municipal pumping rates were assumed to be 15 percent of the allowed maximum (peak) pumping rate listed in all of the water rights for a municipal supplier. The 15-percent rate was based on a detailed comparison of actual pumpage and

water rights of the Eagle Water Company. During 2005, the Eagle Water Company's total pumping averaged over the year was 14.3 percent of their instantaneous water rights. During 2006, their average pumping was 15.3 percent of their instantaneous water rights. A review of other municipal suppliers in the area indicated a similar proportion of actual use to authorized, instantaneous permitted rates. Based on our analysis, we have assumed an average annual pumping rate equal to 15 percent of the instantaneous rate listed on the water rights for all of the municipal wells in the model domain.

This average-annual rate of 15 percent is a relatively small portion of the instantaneous water right rate for two reasons. The first is that municipal water rights are granted to allow a municipal supplier to meet their peak demand, a rate that occurs only for a few short periods during the year. At other times, water demand is much less and therefore the average pumping rate over the year is far less than the authorized peak rate. The second reason for the relatively small average rate is that municipal suppliers typically have water rights in excess of what they need today, in anticipation of future needs as their population base grows and service area expands. By having a water right in excess of today's needs, municipal suppliers are prepared for tomorrow's growth.

Domestic wells associated with residential developments were assumed to pump at an average of 30 percent of their peak water rights. A domestic water right was assumed to be for a multi-connection residential-development if the name listed on the water right was a corporation, partnership or company *and* the right was in excess of 0.2 cfs (about 90 gpm). It is likely that some water rights associated with residential-development wells were not identified using this method when the listed name on the water right was an individual. This type of error is considered "conservative" (i.e., indicating a rate likely to be too large and therefore likely to result in less water available for additional development). If not identified for residential development use, a domestic well with a yield greater than 0.2 cfs would be assigned an annual average, continuous, pumping rate equivalent to its instantaneous-water-right rate, a rate that is likely to be much higher than actual use.

Fisheries and wildlife enhancement supply wells were assumed to pump at their full annual water right allocation averaged over the year. If no annual limit was listed on the water right, we assumed that these type of wells pump at 30 percent of their listed peak water right rate.

Commercial and industrial wells were assigned pumping rates equal to their full annual volumetric limit averaged over the year. This rate is likely too high, but we found no basis for reducing this rate.

Wells associated with fire-protection water rights were assumed to pump so little over the course of a year that we assumed a resulting model-input of zero.

Irrigation well pumpage was estimated based on an application rate of 2.6 feet per year and a GIS analysis of irrigated acres. (We assumed that energy costs associated with ground-water pumping would limit over-application of irrigation water.) An initial

assessment assuming that irrigation wells used *all* of their allocated annual withdrawal water rights resulted in an estimated use that was unrealistically high, as some of these wells are only used to supplement surface water during drought years.

Domestic (individual home) well pumpage was estimated based on the IDWR well-record database and the assumptions of per capita consumption used in the TVHP model. The TVHP model assumed 230 gallons per day (gpd) per person and 2.9 persons per well (Urban, 2004). We counted the number of domestic wells listed in the IDWR well database on a per-quarter-section basis and then multiplied this total number of wells per quarter-quarter section by 667 gpd/well (230 gpd per person x 2.9 persons per well). When the model domain was extended to the south beyond the original model domain, a directly-counted, water rights analysis was not specifically conducted for the additional area added to the model domain. Rather, the average domestic well pumpage from the township lying directly to the north of the new area added to the model domain (which had a per-quarter-section accounting of domestic wells) was applied to the new area (in lieu of a per-quarter-section analysis). Because domestic pumping is such a small component of the overall water budget and because domestic pumping was assumed to be derived from the uppermost aquifer, the errors introduced by this method are considered to be small and insignificant to predictions of pumping from beneath the M3 property.

Other listed water right usages such as storage, recreational, diversion to storage, heating and cooling, etc, were generally listed as secondary uses on their water rights. Wells associated with these rights were assigned a pumpage based on their primary listing (first listing) on the water right.

Surficial Recharge: Precipitation and Irrigation

Recharge into the top active layer of the model was initially calculated based on rates used in the TVHP model and a land use analysis. Recharge for each type of land use was based on the total of precipitation plus irrigation minus runoff and evapotranspiration (water removed by plants and direct evaporation). Recharge rates from the TVHP project were quantified based on land use in Urban (2004) who presented seven land-use categories along with a recharge rate for each category. These rates varied from 0.0 feet per year (ft/yr) for “industrial” land use to 0.45 ft/yr for “surface-water irrigated farmland.” The rates used in Urban were used in the recharge analysis for the M3 model.

A visual analysis of land use type by quarter section was initially prepared by Nimmer (2007) for input to the U of I model and later for used as input to the M3 model, with the results shown in Figure 8. In this analysis, Nimmer estimated the dominant land use within each quarter section based on visual analysis of land-use data downloaded from the USGS, based on the National Atlas (NA) land-cover map. A grid oriented to the Public Land survey system (PLS) was placed on top of the NA data (which had a different orientation) and one of the seven land-use categories (associated with recharge rates listed in Urban, 2004) was assigned by Nimmer to each quarter section using “best-professional judgment.” In areas dominated by irrigated farmland, Nimmer assumed that farm lands lying topographically below nearby irrigation canals were irrigated with surface water and assigned the higher application rate associated with this irrigation

source, as listed in Urban. Nimmer assumed that water used to irrigate farmlands topographically above nearby irrigation canals originated from wells and applied the lower application rate associated with this source in Urban.

After the model domain was expanded southward, additional land use and associated recharge rates were needed for the added area. At this point, Pacific Groundwater Group updated the Nimmer analysis with a new GIS analysis of land use for the entire model domain. This analysis assessed land use on a model cell-by-cell basis. In cells with more than one land use type, a weighted average based on percentage of area for each land use was calculated and the appropriate rate applied. Based on instruction from HLI, PGG also assumed that irrigated farmlands topographically below a nearby irrigation canal were irrigated with surface water and not ground water. Although conceptually similar, this cell-by-cell computer-based GIS analysis is more accurate than the manual analysis initially conducted by Nimmer.

Surficial Recharge: Canals and Ditches

Recharge from canal and ditch leakage was also calculated for input to each active upper cell of the M3 model. Initially, Nimmer conducted a visual analysis of the major canals on a quarter-mile basis for input to the model. After the model domain was expanded, PGG conducted a GIS analysis for the entire model domain using data which included minor canal reaches and ditches along with the main canals. The PGG analysis also included surficial geologic materials with different leakage rates depending on the relative permeability of the materials (sands and gravels versus silts and clays). Based on the TVHP data included in Urban (2004), sands and gravels were assumed to have a leakage rate of 0.75 cfs per mile. Silts and clays were assumed to have leakage rates of 0.0 cfs/mile (no significant leakage).

Surficial Recharge: Septic Drainfields

Recharge from septic drainfields was calculated based on the presence of domestic wells. It was assumed that houses supplied by domestic well water supplies were unsewered and that each well indicated the presence of a septic drainfield. The number of wells per quarter section was tallied as part of Nimmer (2007). Based on Urban (2004), a drainfield recharge rate of 45 gpd per person along with the 2.9 people per household (as assumed in the domestic well pumpage analysis) was applied to the uppermost layer of the model. The total rate per quarter section was calculated as the number of wells in the quarter section times 45 gpd per person times 2.9 people per well.

M3 Model: Steady-State Calibrations

The M3 model was initially calibrated to steady-state conditions with the results reported in PGG, 2008a. Later, after several updates to the model, the steady-state calibration was revised as reported in PGG, 2008d. The following discussion pertains to the initial and revised steady-state calibrations presented in the appropriate PGG report, as indicated. Steady-state calibrations were based on matching water level data collected during summer of 2007 and presented in HLI (2007b). Although not a true steady state, these conditions represent a “snapshot” of the conditions of “today” before pumping from the

M3 site has occurred and therefore represent a quasi-steady-state condition from which to simulate future pumping. The water level data collected during the summer of 2007 were obtained from wells that were located (vertically and horizontally) through survey-grade GPS with estimated vertical accuracies of ±0.08 feet (HLI, 2008c). Geologic, geophysical and well-construction data from these wells were reviewed to identify the aquifer associated with each measured water level. Primarily, only wells that: a) were properly sealed, and b) had well screens identifiably within the Pierce Gulch Sand Aquifer, the Willow Creek Aquifer, or Payette Valley aquifers (an aquifer or aquifer system that appears to be contiguous with portions of the Pierce Gulch Sand Aquifer and the Willow Creek Aquifer), were used in the calibration. In addition, one well near the northwestern edge and one well near the southwestern edge of the model domain were used that were not surveyed. These wells were located using Google Earth with elevations estimated to be within ±10 feet. Because these wells lie so far from the model focus area, we believe potential errors introduced through the lack of survey are likely to be insignificant in the calibration process.

Development of Two Parallel Models through the Water-Level Calibration Process

Two parallel models were developed during the steady-state calibration process, after it became apparent that model-simulated water-levels beneath the M3 Eagle site were low, in comparison to measured levels. Either the aquifer system was more complex than originally set up in the model or the actual transmissivities of the various aquifers varied from the values initially input to the model (both tested and estimated). This realization led to the development of two parallel models: the "Hmatch model" and the "Tmatch model." The two models were used to "bracket" the predictions of impacts caused by pumping. As is discussed below, the difference between predictions made by the two models is relatively small, thereby helping to reduce possible concern about the differences between the two models.

The "Hmatch model" was developed to better match the predicted and measured ground-water levels ("heads"). The Hmatch model required that transmissivities of the Pierce Gulch Sand Aquifer be adjusted at some locations beyond the acceptable range of values originally selected for the calibration process. Since many of the input values were either estimated from lithologic information on Well Driller's Reports or from poorly conducted pumping tests, this departure from the original input values appears reasonable. The criteria for defining the range of allowable deviation within the Hmatch model was as follows: all wells within a transmissivity zone (of which there are 20) could have their transmissivity adjusted by no more than 0.33 to 3 times the log-average of the initial transmissivities for that zone. Only one value had to be adjusted outside of this range. The transmissivity associated with the Eaglefield #2 aquifer test had to be reduced by a multiplier of 0.2 in order to obtain the desired match. Because this zone also includes several well tests reporting transmissivities much lower than that of the well used in the calibration (UWID State and Linder test well) and because of the effects of an unknown pumping well and other problems associated with this test (as discussed in HLI, 2008), this adjustment is considered acceptable. It is probable that additional calibration focusing on this area would result in the single-transmissivity zone being divided into multiple zones with different average values for representative transmissivity. The water

levels generated by the Hmatch model were closer to the target values than those generated by the Tmatch model, as discussed below.

The "Tmatch model" was developed to better honor the initial transmissivity values input[3] to the model. In the Tmatch model, transmissivities were allowed to vary within a smaller range, during the calibration process. Transmissivity was allowed to be adjusted by no more than ± 50 percent of the log-average of the observed transmissivities for that zone. The water levels generated by the Tmatch model were not as close to the target values than those generated by the Hmatch model.

Initial Steady-Stated Calibration Statistics and Results

Both the Tmatch and Hmatch models met generally accepted calibration criteria, indicating that both models are statistically capable of modeling the ground-water-flow system. The models used three criteria (calculated by Groundwater Vistas) to quantify the degree of success in calibration:

- "residual mean" or "RM" (the average of the differences between the observed and calculated water levels,
- "absolute residual mean" or "ARM" (the average of the differences between the observed and calculated water levels, without consideration of whether the calculated water levels were above or below the measured levels), and
- "percentage standard deviation to the observed range" or "PSD/R" (a statistical analysis of the results that considers how the calculated values compare with the actual values in terms of the size of the range of target values).

The results for the initial Tmatch model were:

- RM = 2.71 feet (in other words, the average difference in the predicted values from the measured values was 2.71 ft,
- ARM = 13.99 feet (in other words, the average difference in the magnitude of predicted values from the measured values was 13.99 ft,
- PSD/R = 6.2% (in other words, the standard deviation of the predicted values was only 6.2 % of the range of the measured values).

The results for the initial Hmatch model were:

- RM = 2.82 feet (in other words, the average difference in the predicted values from the measured values was 2.82 ft,
- ARM = 9.75 feet (in other words, the average difference in the magnitude of predicted values from the measured values was 9.75 ft,

[3] Transmissivity is not directly input to the model. Rather, hydraulic conductivity is used instead, which is calculated by dividing transmissivity (calculated from pumping test data) by aquifer thickness (measured through geophysical logging or high-quality lithologic logging). Because transmissivity is directly calculated from pumping test data, we use this term in our discussion of the various models. In effect, the model calculates transmissivity using the hydraulic conductivity and the saturated thickness at each cell.

- PSD/R = 4.8 % (in other words, the standard deviation of the predicted values was only 4.8 % of the range of the measured values).

The target for the PSD/R for both models was 10%, a standard well met by both models. An RM of less than 3 feet for both models indicates the overall average errors in the predictions are small. An ARM of less than 15 feet is also good, but points out that the simulated water levels ("heads") beneath the M3 site were low, a situation we consider conservative in that calculated water-levels below those measured may indicate that additional water may be flowing into the model beyond that which is assumed. (In other words, more water may be "available" from the M3 Eagle area than indicated by the model.)

Figure 9 (reproduced from PGG, 2008a) shows that part of the ground water within the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity flows from the southeast to the northwest where it ultimately discharges to the Payette River basin. Another part of the ground water in the Pierce Gulch Sand Aquifer flows toward the northwest but then turns southwesterly and remains within the Boise River Valley. The initial model generated the ground-water level contours shown in Figure 9 while we have added the flow arrows in dark blue to indicate the flow paths toward the Payette River Valley and in light blue to show the flow paths where flow remains in the Boise River Valley. The flow path arrows are oriented based on the assumption that ground water flows at right angles to water-level contours. The figure also shows residual errors with values in blue indicating that the model-calculated levels are lower than those actually measured and red indicating that calculated levels are above those actually measured. The Hmatch model generates water levels (heads) that are closer to those actually measured during the summer of 2007, than those generated by the Tmatch model.

Most-Recent (November 2008) Steady-State Calibration Statistics and Results

Both the Tmatch and Hmatch models using the increased pumping from within the model domain (as presented in PGG, 2008d) met calibration criteria, indicating that both models are statistically capable of modeling the ground-water-flow system.

The calibration statistics for the revised Tmatch model were:

- RM = 8.92 feet,
- ARM = 15.16 feet
- PSD/R = 5.9%

The calibration statistics for the revised Hmatch model were:

- RM = 6.38 feet,
- ARM = 10.22 feet
- PSD/R = 4.6 %

The calibration statistics for the revised model are similar to those of the initial models. An RM of less than 9 feet for both models indicates the overall average errors in the predictions are slightly larger for the revised steady-state models (but, as discussed

below, allowed for better transient calibration). The ARM values for both models are similar to those of the previous model while the PSD/R values for the revised models are slightly better than those of the initial models.

Figure 10 (reproduced from PGG, 2008d) shows steady-state Hmatch-model and Tmatch-model ground-water flows that are similar to those of the initial models. These steady-state potentiometric contour maps also show that some of the ground water within the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity flows from the southeast to the northwest to the Payette River basin while some of it flows toward the northwest but then remains within the Boise River Valley. Similarly to the initial models, the revised Hmatch model generates water levels that are closer to those measured during 2007, than those generated by the revised Tmatch model.

Mass Balance: Amount of Water Pumped by Wells

The Tmatch and Hmatch steady-state calibrations for the initial and the revised models included mass balance analyses with resulting errors of less than 1 percent, an error that we believe, supports successful model calibration. In other words, when all of the sources of water going into the model are added up and compared with all the sources of water going out of the model, the difference is less than 1 percent of the total. (A steady-state model that does not have the input and output flows equal to within 1 percent is less likely to be properly calibrated, in our opinion.)

The mass balance analysis shown in Table 1 (next page) indicates that the total ground water pumped from the model domain (which includes, Eagle, Star, Meridian, Emmett, Caldwell and all the smaller communities within the area) represents about 9 to 14 percent of all the water flowing into the ground-water system within the model domain. The total average annual pumping from the entire model domain was calculated to be about 90 to 144 cfs, while the total input to the ground water system (recharge at the surface, seepage from the Boise River, New York Canal and other surface water sources) was calculated to be about 1030 to 1040 cfs. The relatively small proportion of pumping to total inflow is supported by water levels throughout the area that have remained generally stable[4] over the past decades, in spite of increased ground water development.

The model indicates that upon completion, the M3 Eagle Master Planned Community would pump about 1 percent of the total inflow to the model domain. This increase is relatively small and likely to be insignificant to overall flow within the system. For comparison, the average annual withdrawal of 9.03 cfs planned for full build-out of the M3 Eagle project, is small in comparison to the flow in many of the surface water ditches and canals in the area. For example the Farmer's Union Ditch (often called the Farmer's Union Canal) typically flows at well over 100 cfs during the summer. The combined flow of the Boise River and the New York Canal is more than 2,000 cfs during the summer.

[4] Although minor, some local, well-specific, water level declines have apparently occurred. We believe these declines are attributable to unsealed or poorly sealed wells that have allowed ground water to move along the annular space outside of the well casing, acting in effect, as a well that is continuously pumping. The continuous flow causes a local water level decline that is unrelated to overall aquifer water levels. The decline occurs as water flows from one aquifer (the Pierce Gulch Sand Aquifer) to overlying aquifers.

M3 pumping would represent about 6 to 9 percent of total pumping within the model domain area, based on the range of estimated total current pumping within the model domain. The smaller percentage of total pumping represented by M3's proposed pumping is based on the larger estimate of total pumping within the model domain, while the larger percentage is based on a comparison with the smaller estimate of total pumping.

Table 1 Mass Balance Comparison of Well Pumpage Volumes:

Initial Model Results -June 4 report (smaller estimate of total pumping)			**Revised Model Results** -November 14 Memo (larger estimate of total pumping)		
INFLOW	cfs	% of total Inflow	**INFLOW**	cfs	% of total Inflow
Surficial Recharge	542	52.4%	Surficial Recharge	542	52.1%
Underflow via SE model corner	102	9.9%	Underflow via SE model corner	115	11.0%
Dry Creek	4	0.4%	Dry Creek	4	0.4%
Lake Lowell	17	1.6%	Lake Lowell	17	1.6%
Boise River Seepage	87	8.4%	Boise River Seepage	81	7.8%
Payette River Seepage	282	27.3%	Payette River Seepage	282	27.1%
TOTAL:	**1034**	**100.0%**	**TOTAL:**	**1041**	**100.0%**
WELL OUTFLOW			**WELL OUTFLOW**		
Domestic	14	1.3%	Domestic	60	5.8%
Municipal, Commercial, Irrigation	76	7.3%	Municipal, Commercial, Irrigation	84	8.1%
TOTAL:	**90**	**8.7%**	**TOTAL:**	**144**	**13.8%**
With M3			*With M3*		
Domestic	14	1.3%	Domestic	60	5.8%
Municipal, Commercial, Irrigation	76	7.3%	Municipal, Commercial, Irrigation	84	8.1%
M3	9	0.9%	M3	9	0.9%
TOTAL:	**99**	**9.5%**	**TOTAL:**	**153**	**14.7%**
M3 percentage of Inflow:		***0.9%***			***0.9%***
M3 percentage of total pumping:		***9.1%***			***5.9%***

<u>Mass Balance: Flow to the Pierce Gulch Sand Aquifer from Outside the Model Domain</u>

The M3 model calculated that about 102 cfs to 115 cfs (about 65 to 74 million gallons per day – "mgd") of ground water flows into the southeast corner of the model through the Pierce Gulch Sand Aquifer. This rate of "underflow" was calculated through a series of "general head boundary" analyses based on measured water levels, "conductances" (based on transmissivities) and distances. In these general head boundary analyses, flow was calculated based on the water-level difference over a known distance, through which the ground water flows, through an aquifer with known transmissivity. In the analyses the transmissivities of the Pierce Gulch Sand Aquifer, as calculated from numerous pumping tests in the Meridian area, were assumed to also represent the region between the model's southeastern boundary and the region beneath the Boise River upstream from the Capital Bridge. The water levels reported in the Meridian and Boise areas (beneath the river and the New York Canal) were used to establish the water level differences. The distance was measured directly from USGS topographic maps. Using these input values, the model calculated inflow through the general head boundary.

Based on analyses included in the Treasure Valley Hydrologic Project (Petrich and Urban, 2005; and Urban, 2004), we assume that a significant portion of this general head flow into the model's southeastern boundary originated as seepage from both the Boise River and the New York Canal. Urban reported a Boise River loss to the underlying ground-water system of 15,000 ac-ft/yr (about 21 cfs) during 1996 and about 77,000 ac-ft/yr (about 110 cfs) during 2000. Both sets of measurements were made over the reach upstream from Capital Bridge. Urban also reported seepage from the New York Canal system over its whole length at an average rate of 13 percent of total diverted flow. Hutchings and Petrich (2002) indicate the New York Canal lost 80 to 150 cfs in a set of four measurements made in the reach upstream from Cole Road. The combined leakage to the underlying ground water system from these two sources therefore appears to range from about 100 to 260 cfs (to two significant figures). Based on the typical accuracy of methods to measure surface water flow rates (which range from ±5 to ±20 %) it is not possible to determine the proportion of water originating from the two identified sources. It appears possible that the underflow into the model from the southeast may originate from any combination of the two sources. The quantities of loss indicated in these three Treasure Valley Hydrologic Project reports are similar to, and therefore supportive of, the inflow calculated by the M3 model.

Mass Balance: Changes in Flow to the Pierce Gulch Sand Aquifer Caused by a Reduction of Seepage from the New York Canal

An analysis of changes in inflow to the model from the southeast indicated that water levels in the Pierce Gulch Sand Aquifer beneath greater Eagle vicinity could change by about 5 feet near Eagle and about 2 to 3 ft near the M3 property were inflow to the Pierce Gulch Sand Aquifer to be reduced by 20 percent. The 20-percent reduction of total inflow to the model from the southeast might occur should seepage be reduced from the New York Canal. We know of no current plans to line the canal or change its flow but since part of the recharge to the Pierce Gulch Sand Aquifer comes from outside of the model domain and because the TVHP analyses support the Boise River and the New York Canal as sources of recharge to the Pierce Gulch Sand Aquifer, we believe it is prudent to at least assess these potential changes.

The revised model was used in this analysis with the general head boundary from the original model converted to a constant flux (flow) boundary. In this analysis, the flows of 107 cfs (Tmatch model) and 115 cfs (Hmatch model) calculated through the general head boundary, were reduced by 20 percent to 86 cfs and 92 cfs (respectively) and represented as a constant flux boundary. The difference in water levels between the two model runs (100 percent of calculated inflow and 80 percent of calculated inflow) were calculated and plotted.

Changes in water level maps from PGG (2008d) excerpted in Figures 11 (Tmatch model) and 12 (Hmatch model) indicate that water levels in the greater M3-Eagle-Star vicinity will not change significantly even if recharge to the Pierce Gulch Sand Aquifer from the southeast is reduced by 20 percent through the lining of the New York Canal. These model figures indicate that Pierce Gulch Sand Aquifer water levels beneath the greater Eagle vicinity north of the Boise River would decline by 2 to 5 ft. Changes beneath the

M3 site are likely to 1 ft or less. Declines of this magnitude (1 to 5 ft) are unlikely to affect the overall yield of properly designed and constructed wells. Poorly constructed and inefficient wells that are marginal in their operation, could have yields affected, however, as they could be by other equally-possible factors, such as changes in seasonal recharge or changes in land use.

The M3 model simulates much larger changes in water levels in the south Meridian area. Such predictions, however, are likely to be inaccurate because of the proximity of the modeled constant-head boundary to this portion of the aquifer. The model's simulations in this area should only be used as a very general guideline.

M3 Model: Initial Transient Calibrations

After the Tmatch and Hmatch models were successfully calibrated to steady-state conductions, they were calibrated to transient conditions by replicating two long-term aquifer tests conducted in the greater Eagle area: the 30-day-Lexington Hills aquifer test and the 7-day Eaglefield aquifer test. Calibration was accomplished primarily by adjusting the storage parameters that control aquifer behavior ("storativity" and "specific yield"). These parameters quantify how much water is released from storage within an aquifer when water levels decline (for example through the pumping of a well). Transient calibration also included some changes in transmissivity along with verification that steady-state calibrations remained valid.

The transient calibrations consisted of comparing model-simulated and actual observation well drawdowns measured during the two tests. The transient calibration started from the steady-state model that was then allowed to simulate a 100-day period prior to the start of each test to allow the model to start off with pre-test water levels that were stable. The model was then allowed to simulate the duration of the test (7 or 30 days) with a pumping well placed within the cell at the location of the pumping well and the drawdown response noted at the cell representing the observation well (HLI, 2008b).

Figure 13a and 13b (reproduced from PGG, 2008a) show excellent agreement between the calculated and observed drawdowns from the two tests, for the Hmatch model. All of the simulations are within a few hundredths of a foot throughout much of the test periods. Because the measured drawdown-data were not corrected for barometric effects (CH2M-Hill, 1991; and Holladay, 2006) small differences between the calculated and measured levels are observed on the plots. These differences are smaller than potential unaccounted-for barometric effects.

Figure 13c shows that the Tmatch model did not accurately simulate the 7-day Eaglefield test. Better matches were achieved in trial calibrations by allowing larger changes in transmissivity and by the inclusion of a fault in the area. (A fault is suggested by the extension southward of a fault mapped on the M3 site.) However, because the Tmatch model was designed to "honor" the tested transmissivities with only minimal changes from the initial input values and because faults have yet to be mapped near the Eaglefield test and observation wells, the calibration shown in the figure was allowed to stand. The

good match generated by the Hmatch model and the small differences between Tmatch and Hmatch simulations of water level changes caused by pumping from beneath the M3 property (discussed below), indicate that the poor Tmatch-transient simulation of the Eaglefield test is not significant.

M3 Model: Transient Calibration to SVR #7 Test and Higher Total Pumping

Following completion of the initial transient calibrations to the 30-day Lexington Hills and 7-day Eaglefield aquifer tests, the Tmatch and Hmatch models were successfully calibrated to replicate the 9-day SVR #7 aquifer test, conducted during March of 2008. This test and resulting additional calibration are particularly valuable in that few reliable data were available from the northern portions of the Pierce Gulch Sand Aquifer lying beneath the M3 Eagle property, prior to the SVR #7 test. The additional calibration involved matching the measured response of two observation wells monitored during the SVR #7 test with simulations generated by both the Tmatch and Hmatch models, using the larger estimate of overall total pumping. In addition, the recalibrated Hmatch model was used to resimulate the Eaglefield #2 and Lexington Hills #1 aquifer tests. We believe that this set of calibrations (presented in the PGG, 2008d, included in Appendix B) is the most "conservative" (i.e., most likely to over-predict pumping impacts) model developed to date for assessing potential drawdown interference from pumping beneath the M3 property. The calibrations resulted in the recognition (and inclusion in the model) of higher transmissivities and somewhat lower storativities in the M3 Eagle property vicinity.

The simulated and measured drawdowns for the two observation wells (reproduced from PGG, 2008d and shown in Figures 14a and 14 b) are relatively close: within a 0.1 foot in the Big Gulch observation well (close to the pumping well) for much of the test and within a few hundredths of a foot for the beginning and end of the test for TW #4 Zone 2 well, located about 4,500 ft from the pumping well. The discrepancy between the calculated and observed data from the nearby Big Gulch observation well may be the result of discretization error. The model predicts water levels that represent the average water levels within each model cell. Only when the observation well and the pumping well lie exactly at the center of a cell do the calculated water levels equal the actual levels. Since neither well lies at the exact center of the cell in which it is located, a small error in drawdown predictions develops. This "discretization" error becomes smaller as the distance between the observation and the pumping wells becomes larger.

The discrepancy between the calculated and observed data from the further-away observation well (TW #4) may be the result of imperfect corrections to the raw data to remove the effects of atmospheric pressure changes. As seen in both hydrographs in Figure 14, the observed data show a drop and subsequent rise in drawdowns that would not normally be associated with a constant-rate aquifer test. This fall and rise in water levels is more likely a result of imperfect or incomplete corrections applied to the raw water level data.

A resimulation of the 30-day Lexington Hills #1 aquifer test (Figure 15a) and the 7-day Eaglefield #1 aquifer test (Figure 15b) using the recalibrated Hmatch model generated almost identical results to the simulations conducted with the initial Hmatch model. The differences between the older-calibration simulation and the newer-recalibration simulation were very small because the SVR-#7-calibrated model resulted in changes to only small portions of the Pierce Gulch Sand Aquifer lying several miles away from the area affected by the tests. This comparison demonstrates that the changes to the model made in the region of the M3 Eagle property have only limited effects on parts of the model lying miles far to the south.

The Tmatch model was not used to resimulate the Lexington Hills or Eaglefield tests because the changes to the Hmatch model produced only small changes in the simulated drawdowns associated with these two tests. Changes that were likely to be even smaller would have resulted in the Tmatch model because of its generally larger transmissivities. Because the Hmatch changes were so small a recalibration to the Tmatch model was not warranted.

M3 Model: Prediction of Impacts

The transient M3 Tmatch and Hmatch models predict that drawdown impacts to other wells completed in the Pierce Gulch Sand Aquifer at locations one-half mile from the M3 Eagle property boundary would be on the order to 10 to 20 feet. The model predicted these drawdowns based on simulations of three wells located on the southwest portion of the M3 Eagle property, each pumping continuously at an annual average rate of 1,500 gpm, 50 years after all wells had come on line, and the project completed (full build-out).

Four versions of the model were run resulting in four simulations to bracket the results. The four models included both smaller and larger total pumping versions of the Tmatch and Hmatch models. Having four simulations, all showing relatively similar results, helps to demonstrate that the uncertainty in the data (that led to the development of four separate model versions) is not considered significant. The range of values for the transmissivity of the aquifer and the range of values in the estimate of total pumping from within the model domain do not result in a large difference in drawdown predictions made by the M3 models.

The four predicted drawdowns predicted to be caused by pumping 1,500 gpm from each of three wells pumping from the Pierce Gulch Sand Aquifer beneath the M3 property are shown in Figures 16 and 17. Figure 16 (from PGG, 2008c) shows a) Tmatch and b) Hmatch models calibrated using the lower total pumping rates in the model domain while Figure 17 (from PGG 2008d) shows a) Tmatch and b) Hmatch models calibrated using the higher total pumping rates in the model domain. The four drawdown prediction figures show that most of the significant predicted drawdown occurs beneath the M3 property and within a buffer zone consisting of US Bureau of Land Management (BLM) land surrounding the M3 property. Beyond this buffer, the predicted drawdowns become smaller with distance from the pumped wells, located on figures.

The pumping rates used in the simulations are about 10 percent greater than the average pumping requested in the water rights application. Analyses for the annual average water demand indicate that the project will require 6,535 acre-feet per year (equivalent to 4,051 gpm, averaged over the year) at full build-out (Givens and Pursley, 2008). An average pumping rate of 1,500 gpm appears feasible from wells completed in the Pierce Gulch Sand Aquifer beneath the M3 property at the locations shown on the two figures. The 10-percent overage allows for predictions of drawdown effects that are more conservative than those that would occur at the actual requested total average rate of 4,051 gpm.

Short-term pumping rates would be higher during periods of peak water demand. However, during other times of the year wells would be pumped at a rate much lower than the 4,500 gpm total used in the simulation. Over the year, however, the combination of higher and lower pumping rates would result in an average equivalent to that used in the simulation.

Although drawdowns during periods of higher pumping near (and in) the M3 supply wells would be higher than those shown in the two figures, the higher-rate, short-term pumping is not expected to cause drawdowns at locations beyond the BLM buffer zone surrounding the M3 property that are more than a few feet higher than those shown in the figures. Because these peak pumping events would only last for a few days, distal wells would only be affected minimally (beyond the predicted long-term averages shown in the two figures) for two reasons. The first is that peak pumping would occur during summer when irrigation causes seasonal water levels in the Pierce Gulch Sand Aquifer to be at their higher levels (as demonstrated by long-term water-level monitoring). The larger drawdowns caused by the peak pumping would be offset by the higher water levels caused by irrigation. The second reason is that the short-term, larger drawdowns associated with peak pumping rates would take time to propagate outward from the pumping wells. The SVR #7 aquifer test demonstrated that drawdown effects ("expanding cone of water-level depression") took many days to become measureable several miles away. Short-term, high-rate well pumping lasting several days would be followed by reduced pumping rates after peak demand passed, allowing water levels in the aquifer to rise again.

The model shows that impacts to wells completed in the shallower un-named aquifer(s) overlying the Pierce Gulch Sand Aquifer will be smaller than those predicted for wells completed in the Pierce Gulch Sand Aquifer. The initial model predicted drawdowns in the shallower aquifer that are on the order of 2/3 of those predicted for the Pierce Gulch Sand Aquifer (PGG, 2008a). Because the model was not directly calibrated to the shallow aquifer, these drawdown predictions can only be considered an approximation. It is highly probable, however, that after 50 years of pumping from the Pierce Gulch Sand Aquifer, the drawdowns in the shallower aquifer will be less than those in the underlying, deeper Pierce Gulch Sand Aquifer. These predictions can only serve as guidelines until the shallow, un-named aquifer is directly included in model calibrations o r until long-term monitoring is implemented. Such calibration can only be made after several tests of this shallow aquifer have been completed and analyzed. No long-term shallow aquifer tests are known to have taken place as of this time (November, 2008). Direct monitoring

of the shallow aquifer (currently in process) will likely be a much better indication of how the shallow aquifer responds to pumping from the Pierce Gulch Sand Aquifer.

M3 Model: Overview of Results

The M3 Tmatch and Hmatch models recalibrated to steady-state and transient conditions and the larger estimate of total pumping from within the model domain, are the best models developed to date for predictions of impacts to wells completed in the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity. The M3 Hmatch model is especially able to replicate the three existing, long-term aquifer tests conducted in the greater M3-Eagle-Star vicinity over the past 17 years. Simulations of the planned ground-water development for the M3 Eagle project indicate drawdown impacts on the order of 10 to 20 feet in wells completed in the Pierce Gulch Sand Aquifer one-half mile from the M3 property. (Most existing wells, both those completed in the Pierce Gulch Sand Aquifer and those completed in other shallower aquifers, lie more than one-half mile away because much of the M3 property is surrounded by a buffer of BLM land along the south and east and mostly undeveloped lands to the north and west)

Water budget analyses indicate that current pumping from all wells within the entire model domain of 520 square miles represents about 9 to 14 percent of all of the water flowing into the ground-water system of the model. The addition of the planned pumping from M3 Eagle would increase this amount by about 0.9 percent, a relatively small increase.

The model estimates that about 102 to 115 cfs (about 65 to 74 mgd) flows into the Pierce Gulch Sand Aquifer from areas lying to the southeast of the model domain. This water is believed to originate as seepage from the Boise River and the New York Canal. Field measurements made as part of the Treasure Valley Hydrologic Project indicate a combined seepage rate of 100 to 260 cfs (to two significant figures) from these two sources in this area, supporting the inflow rate independently calculated by the M3 model.

Based on the model not being calibrated to replicate responses in the unnamed alluvial aquifer overlying the Pierce Gulch Sand Aquifer, the model estimates that wells completed in this aquifer may have drawdown impacts that are on the order of 2/3 of those predicted for wells completed in the Pierce Gulch Sand Aquifer at similar locations. However, because the M3 model was not calibrated to aquifers other than the Pierce Gulch Sand Aquifer, it cannot be used to accurately predict aquifer response from pumping in any aquifer besides the Pierce Gulch Sand Aquifer. Additional aquifer testing (to generate calibration data) followed by specific calibration for the Willow Creek Aquifer, the shallow unnamed aquifer and aquifers within the Payette River Valley would be necessary to use the M3 model for predictions in these aquifers.

Both the Hmatch and Tmatch models generated water levels that are somewhat lower than those actually measured during the summers of 2006 and 2007. Through the modeling process, several methods were attempted to increase the water levels in the

model. These methods included: allowing more water to flow into the Pierce Gulch Sand Aquifer from the southeast, increasing the transmissivity along the eastern portions of the Pierce Gulch Sand Aquifer, decreasing the transmissivities to the northwest of the M3 Eagle property, increasing seepage recharge in the Dry Creek area, increasing upward flow from beneath the Pierce Gulch Sand Aquifer (geothermal water upwelling), extending the fault mapped on the M3 Eagle property to the southeast to the Eaglefield area, and increasing surficial recharge. None of these methods could be totally justified based on the available existing data. Therefore, the modeled water-levels were allowed to remain somewhat low and the model considered conservative in that the lower water levels would result in less available drawdown and larger predicted impacts from pumping from wells completed on the M3 Eagle property.

The model indicates that a 20 percent reduction in the recharge from the area to the southeast of the model domain caused by reducing seepage from the New York Canal (should it occur) would cause water levels in the Pierce Gulch Sand Aquifer in the greater M3-Eagle-Star vicinity north of the Boise River, to drop by about 2 to 5 feet. These declines in water levels are unlikely to affect the predictions of drawdowns caused by pumping from beneath the M3 property, simulated by the model.

THE "BIG PICTURE" – THE ROLE OF MODELS AND RECOMMENDATIONS FOR ADDITIONAL WORK

The Role of Models

We believe it is important to note that a model is only a tool that is useful to understand and manage water use within a ground-water system. We believe that the M3 model is the best tool developed to date for the North Ada County area, to try to understand how future changes to the system such as additional pumping, changers in land use, or changes in recharge, might affect existing and future water supplies. Currently the M3 model has been used to predict impacts caused by ground-water development from the Pierce Gulch Sand Aquifer beneath the M3 Eagle property, that are likely to occur over a 50 year period, to existing wells. No other models or simplified analyses can provide better insight into changes in water levels and flow rates that might occur in the future. However, we wish to emphasize that the M3 model (or any other model, for that matter) cannot and should not be relied upon by itself to give exact answers to future "what if" questions. Models are based on our best understanding of the flow system but because much of what we need to know to construct the model lies underground where it cannot be directly seen, models can never be 100-percent accurate. Fortunately, general understandings and reasonable predictions of future behavior are often what we need to know in making water-resource planning decisions. If the model generally replicates our best understanding of a ground-water flow system (by simulating water levels that compare reasonably well with measured levels) and is able to replicate pumping events of the past (again, by replicating water levels, in this case drawdowns, that occurred during an aquifer pumping test), it gives us confidence that predictions of future pumping events

are likely to be similar to what would actually occur. Such is the case for the predictions made by the M3 model, which simulates both past water levels and past pumping tests.

Equally as important as model predictions, however, is the insight the model gives into key information and data gaps. Through sensitivity analyses, a model helps direct us toward the information that is more critical in predicting changes to ground-water flow and allows us not to be misdirected toward information that is less important. By increasing or decreasing the values of various data values within the model, we can see how much such changes make to predictions. When changing the values of a certain type of input parameter causes relatively large changes in the results, we learn that improving our understanding of the actual values of that parameter through more and improved data collection, would improve our understanding of the system and increase our confidence in future predictions. When changing an input parameter value causes only small changes in the results, we learn that a better understanding of the actual value is unlikely to improve our understanding of the system or increase our confidence in future predictions; we would be better off directing resources (time and money) toward developing an improved understanding of input data to which the model is more sensitive.

Also important, is how the model can be used to direct and make the most use of monitoring to allow for the best management of the system. Even with the development that has already occurred, water level data collected from many wells in the greater M3-Eagle-Star vicinity over the past 50 years, indicate that water levels have generally remained constant,[5]. Additional ground-water development is all but certain to occur in the future, while other factors such as changes in land use, lining of canals and global climate change are also likely. The best way to manage changes is to monitor water levels at key locations and revise management strategies accordingly. Because increases in pumping volumes tend to occur incrementally (as do other changes) the changes that would occur to water levels in wells, would also occur incrementally. A properly designed monitoring program should be able to identify changes as they occurred incrementally and allow for proper management changes *before* a crisis develops.

Such management options might include redirection of surface water resources. Should a decision be made to line the various canals and ditches affecting the model domain, the model could be used to assess where such action might significantly impact ground water use. Currently, surface water passes through the model domain at many thousands of cubic feet per second via the Boise River, New York Canal, Payette River, Farmer's Union Ditch and many other canals and ditches. Total average ground water use is currently only a few percent of this total. If the model indicated that canal seepage was important to maintain ground water supply, surface water rights might be acquired to allow for artificial recharge to maintain this recharge source. Likewise, if the model

[5] Most water levels measured in properly sealed wells in the greater M3-Eagle-Star vicinity have remained relatively constant. Some poorly sealed (or unsealed) wells have allowed water to flow from one aquifer to another, effectively acting as a continuously pumping well. Such a well causes a localized "cone of depression" that leads to the water level dropping over time, unrelated to an overall decline in aquifer water levels or ground water overdraft.

indicated that climatic change and a subsequent reduction of surficial recharge caused significant impacts to ground water use, a similar redirection of surface water rights or a redirection or retirement of irrigation rights at key locations, might be undertaken. The model could be used to help identify where such changes might be made and how large they should be.

In summary, the model is only one of many tools that should be used to best manage the ground water resources of the region. It is not the final and definitive oracle of ground water management. The M3 model should be in on-going and continuing development, and updated as new and improved information is acquired. It should be used to direct the collection of new information by identifying what information is important and where it is most critical. The model should also be used to help direct, design and assess ground water level monitoring programs.

Conclusions

The following summarizes the major conclusions of this report. The main body of the report should be consulted for additional details and information.

1. Five regional numerical groundwater flow models have been constructed over the past 26 years for the area that includes at least a portion of the greater M3-Eagle-Star vicinity. Only the most recent, the M3 model, is adequate to simulate potential drawdowns caused by the proposed pumping from beneath the M3 Eagle Master Planned Community property.

2. Four previous models (Lindgren, USGS, TVHP, and U of I) had some combination of: too few layers, layers not correlating to actual sub-surface geology, cell sizes that were too large, poor or no calibration to transient conditions, or non-representative boundary conditions, to allow them to be useful for predicting pumping impacts in the North Ada County area.

3. The M3 model consists of 7 layers, almost 80,000 active cells, covers 520 square miles and was calibrated to both steady-state conditions (water levels measured during the summer of 2007) and transient conditions (three aquifer tests lasting from one week to one month). The model was developed using Modflow and Groundwater Vistas. This model is, in our opinion, the preferred model for future updates as more hydrogeologic information becomes available.

4. Four versions of the M3 model were ultimately developed to address the uncertainty in the data. The four model predictions of potential pumping impacts were similar, indicating that the uncertainties in the data do not result in significantly different model predictions.

5. The M3 model in its most conservative version (the Hmatch model calibrated to the larger estimate of total existing pumpage) indicates that pumping at an annual average of 1,500 gpm from each of three supply wells completed in the Pierce

Gulch Sand Aquifer beneath the M3 Eagle property, would cause interference drawdowns (reduction in water levels) in wells completed in the Pierce Gulch Sand Aquifer at a distance of one-half mile from the M3 property boundary, of 10 to 20 ft. Interference drawdowns of 5 to 10 ft are predicted at a distance of 2 miles from the property boundary, in wells completed in the Pierce Gulch Sand Aquifer.

6. Simulations using the most conservative version (the Hmatch model calibrated to the larger estimate of total existing pumping) indicate that a 20-percent reduction in underflow originating in part from seepage from the Boise River and the New York Canal in the areas to the east and south of the model domain, would cause a reduction in water levels in the Eagle vicinity north of the Boise River, on the order of 2 to 5 ft and around 1 ft beneath portions of the M3 Eagle property.

Recommendations for Additional Work

During the review of the five models presented in this overview report, and especially after reviewing the M3 model, we became aware of uses of the M3 model and additional improvements that should be considered. Based upon our review, we offer the following recommendations:

1. Future modeling efforts to predict impacts to ground water in the greater M3-Eagle-Star vicinity should be based on the M3 model. This model has: sufficiently small cell size, sufficient layering, proper orientation and thickness of the layers in space to best represent the Pierce Gulch Sand Aquifer, boundaries that allow realistic flow within the Pierce Gulch Sand Aquifer and a demonstrated ability to adequately replicate both steady-state and transient conditions in the greater M3-Eagle-Star vicinity to make a viable model for the area. The M3 model overcomes the short comings of the previous four models in predicting impacts from ground water development in this part of the Treasure Valley.

2. The M3 model should be recalibrated as additional, high-quality aquifer test-data from the Pierce Gulch Sand Aquifer become available. These tests would help to refine the understanding of the aquifer parameters of transmissivity, storativity and specific storage for this regional aquifer.

3. Water budget inputs, especially surficial recharge, canal and drain leakage and river seepage should be refined and input to the model. The current model uses many values calculated and/or estimated as part of the Treasure Valley Hydrologic Project. Additional input based on high-quality field measurements would improve confidence in model predictions. Such data may be difficult and/or expensive to obtain.

4. Average and total pumping rates from major supply wells within the model domain are not well known. We recommend that monthly municipal pumping totals should be reported to a centralized location (such as IDWR) along with

details on well construction and location. We believe that the major water purveyors in the area are keeping records that would benefit overall water management, were this information made common knowledge. Irrigation pumpage is totally unknown. Few, if any, irrigation or industrial/commercial wells measure and report total pumpage – it is unknown whether these wells pump at, below, or above their allowed water rights.

5. If the model is to be used to predict impacts caused by pumping from wells completed in the Willow Creek Aquifer; shallow, unnamed alluvial aquifers; or the aquifers beneath the Payette River Valley; long-term aquifer tests should be conducted in these aquifers and the model recalibrated to reflect the new information generated from these tests. Water use information is also needed from these aquifers to allow for improved model calibration.

6. The model should be used to further assess the potential impacts to the ground water system supplying Eagle, Star, Meridian and (in the future) the M3 Eagle project, from changes in recharge originating as seepage from the numerous canals in the model domain. Possible changes in canal operations (such as lining to reduce seepage loss or changes in overall flow rates) may occur in the future. The model should give a general indication of the sensitivity of the ground-water-flow system to changes in these sources.

7. If the model is to be used to better predict impacts cause by pumping from the Eaglefield area, additional testing and calibration is recommended. The very high values of transmissivity generated from pumping test analyses at some locations and much smaller values at other nearby locations, suggests that the specific hydrogeology in this area is not fully understood. The presence of faulting and offsetting of the Pierce Gulch Sand Aquifer and the potential coupling of sand units not technically a part of the Pierce Gulch Sand Aquifer, but possibly coupled hydraulically, may have affected well response during the Eaglefield Well #2 aquifer test used in the calibrations discussed in this report. The lack of a clear understanding in the Eaglefield area does not appear to be necessary for predictions made for pumping from beneath the M3 property as demonstrated by the similarity of predictions made by the Tmatch and Hmatch versions of the model.

8. If additional high-quality geophysical and/or hydrogeologic information becomes available from within the greater M3-Eagle-Star vicinity, it should be incorporated into the model to help understand why the M3 model's simulations of water levels are below those actually measured in the vicinity of the M3 Eagle property. In addition, sensitivity analyses by changing aquifer properties using smaller zones within the model than are currently used, may help to indicate where the additional information might be sought. By identifying and simulating possible changes to the model that help to raise the water levels beneath the M3 Eagle site, these areas should be targeted for the collection of additional data.

9. All new production supply well drilling projects should have the benefit of professional hydrogeologic supervision and data acquisition which should be centralized to the public domain. M3 Eagle and UWID monitoring wells are good examples to follow.

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FIGURES

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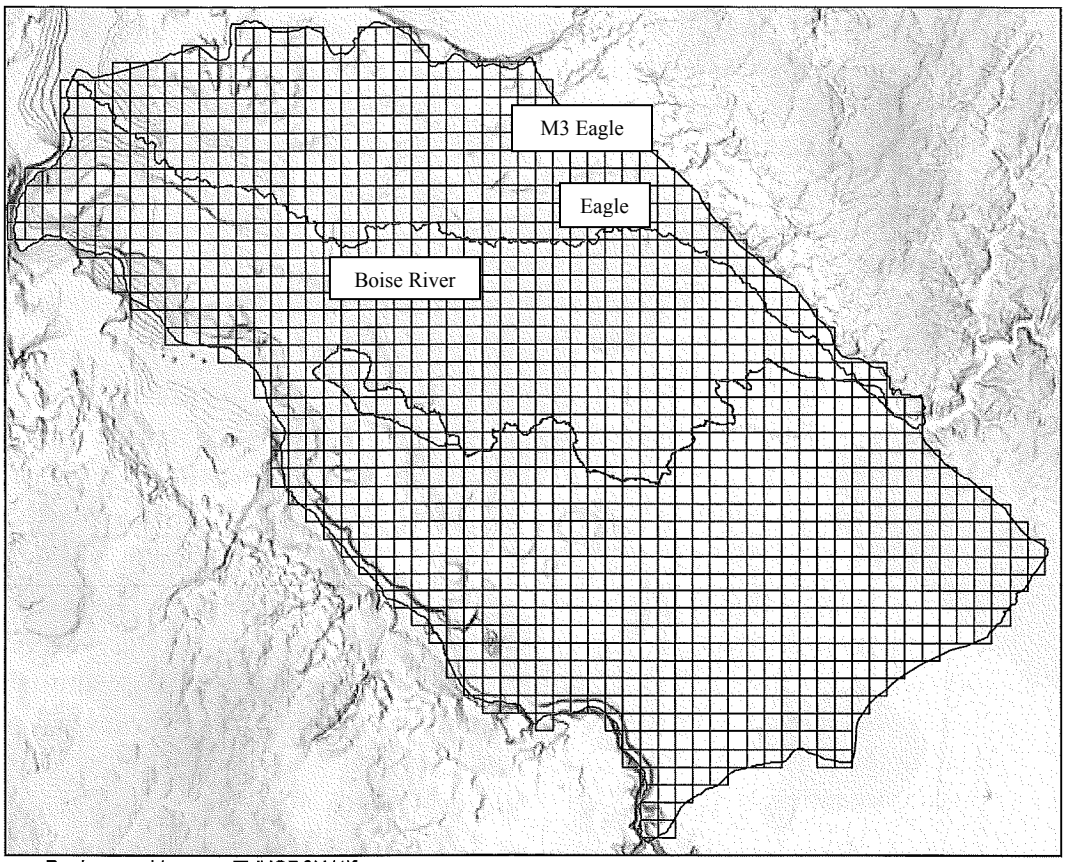
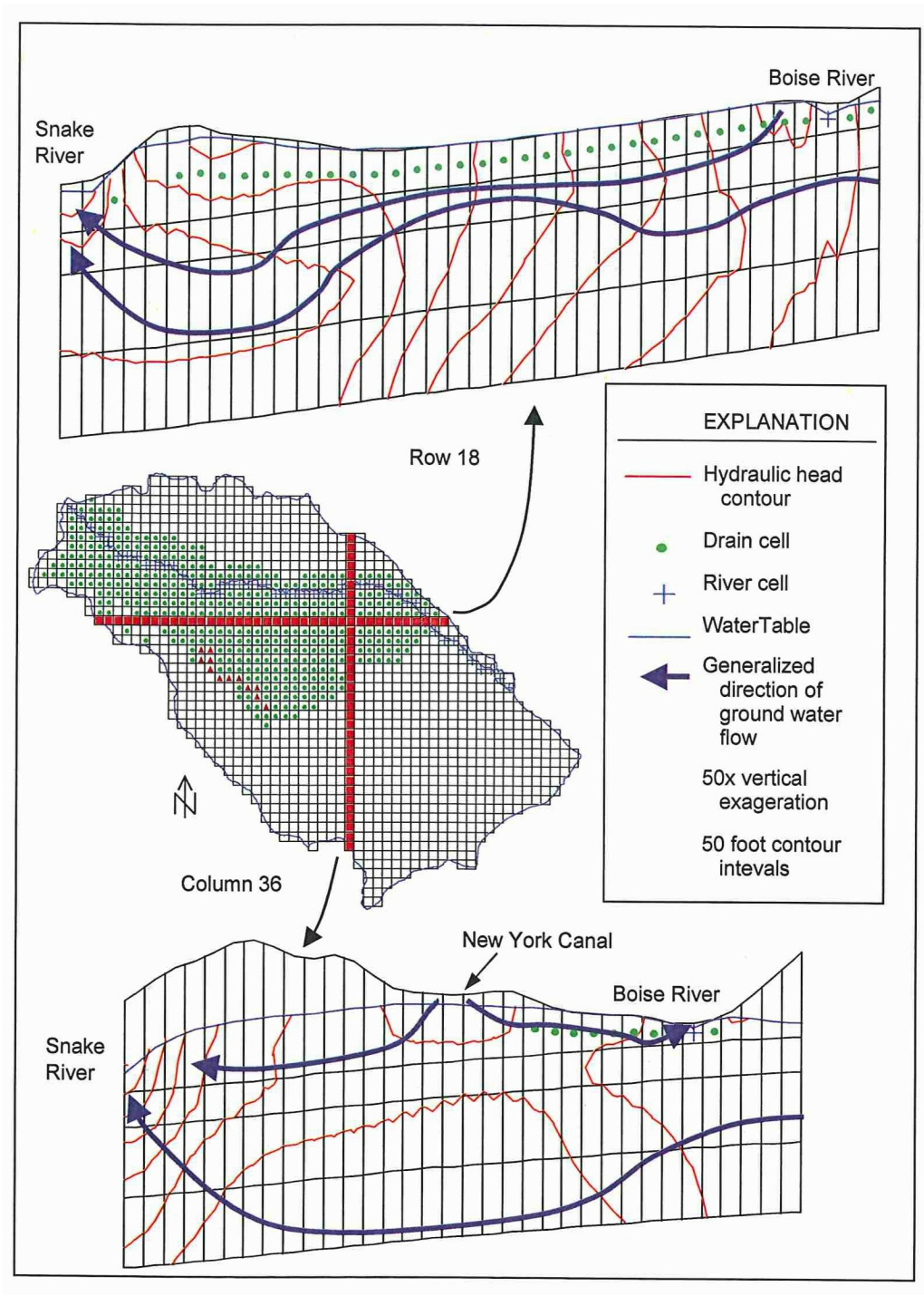
Figure 1. Domain of the TVHP Model



Background image: TVHSB&W.tif

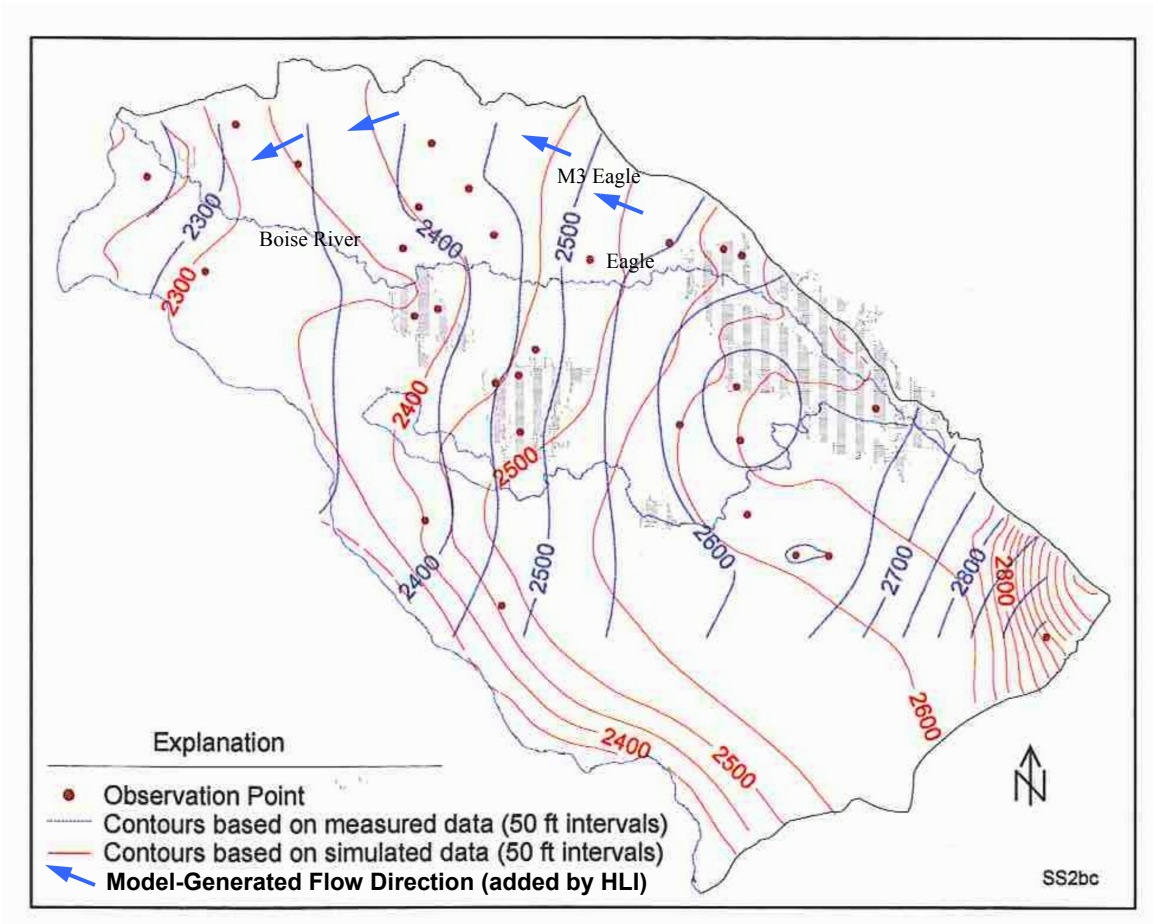
Domain of TVHP model from Petrich (2004) showing topographic divide in Foothills north of Eagle as northern boundary of model.

Figure 2. Two Representative Cross-Sections from the TVHP Model



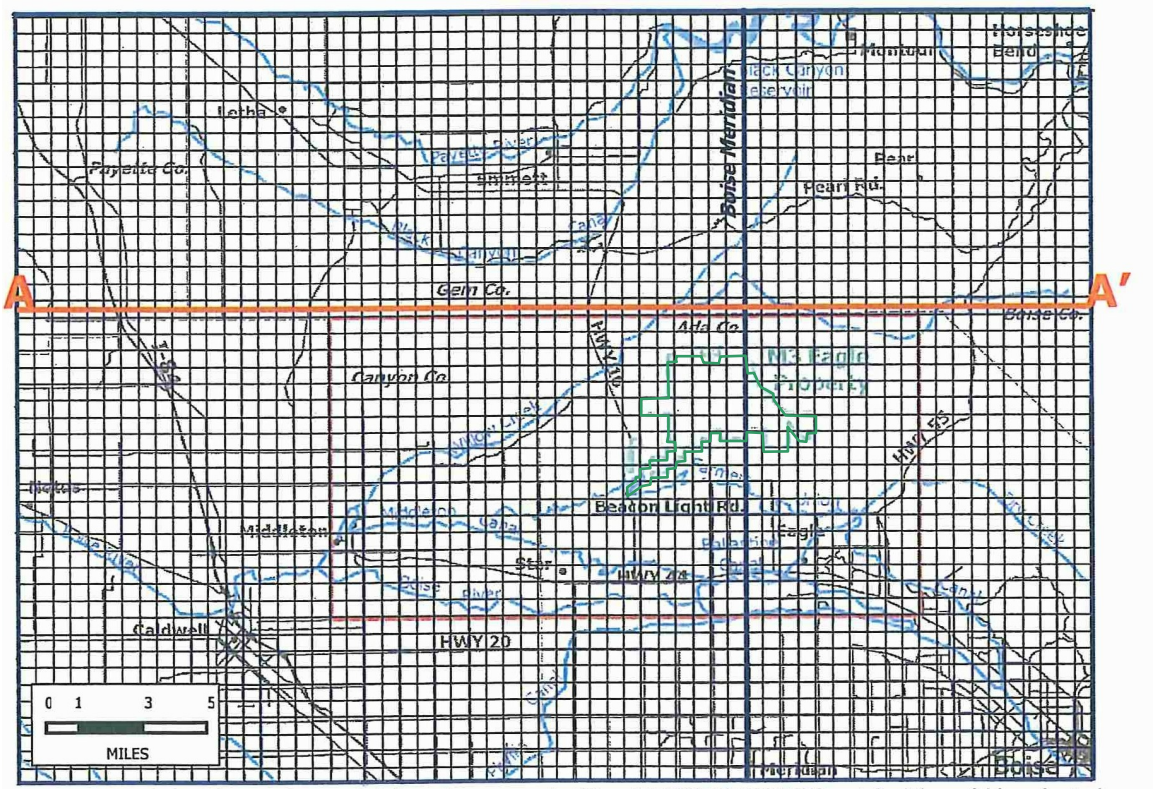
Two representative cross-sections from the TVHP model (Petrich, 2004) showing recharge from the Boise River (downward flow line in upper cross-section beneath the Boise River) and New York Canal (downward flow lines in lower cross-section).

Figure 3. Potentiometric Contours from the TVHP Model



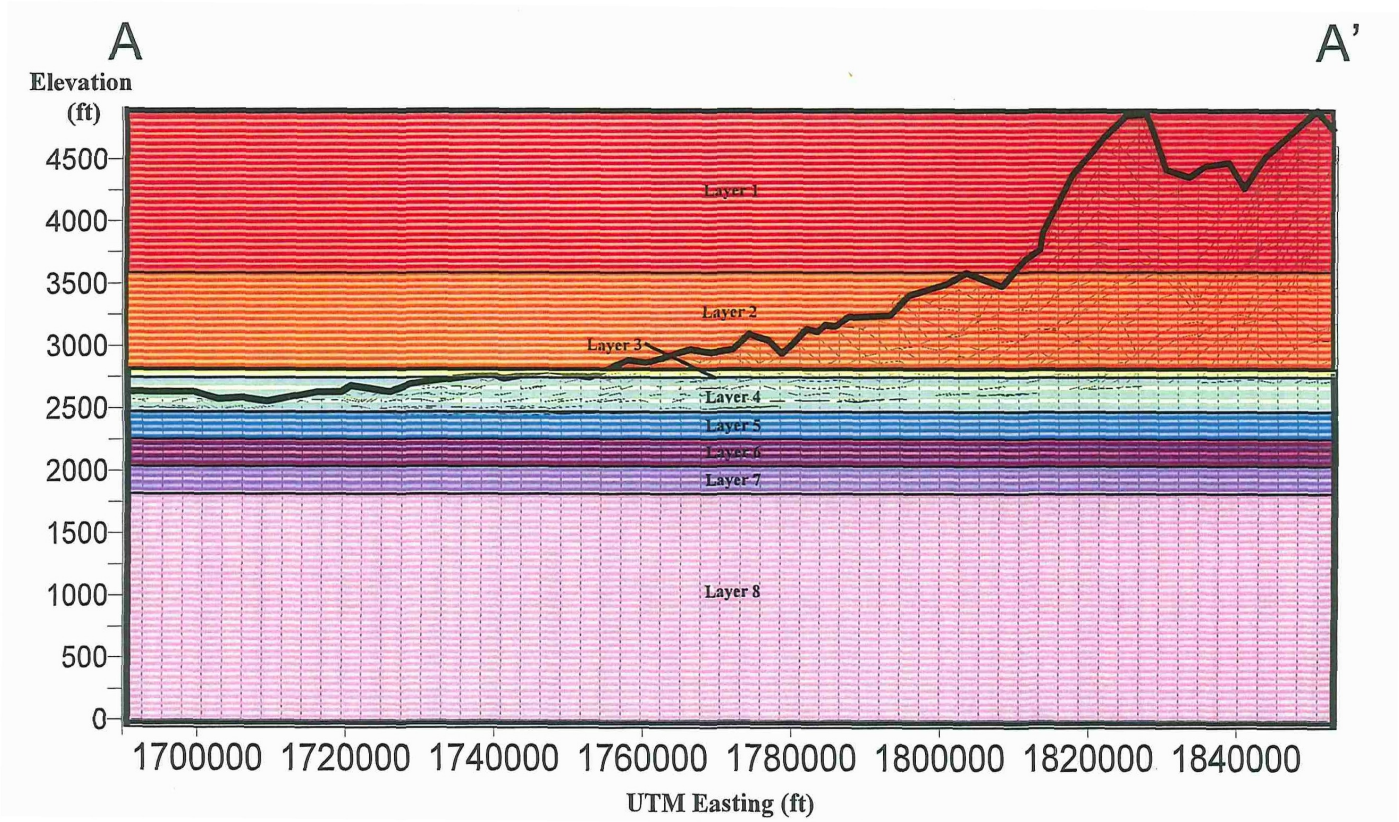
Model-based and measured-data-based contours from Layer 2 of the TVHP model (Petrich, 2004) showing flow direction in layer that would include the Pierce Gulch Sand Aquifer with flow direction forced toward southwest by model boundaries.

Figure 4. Model Domain and Grid Outline of the U of I Model



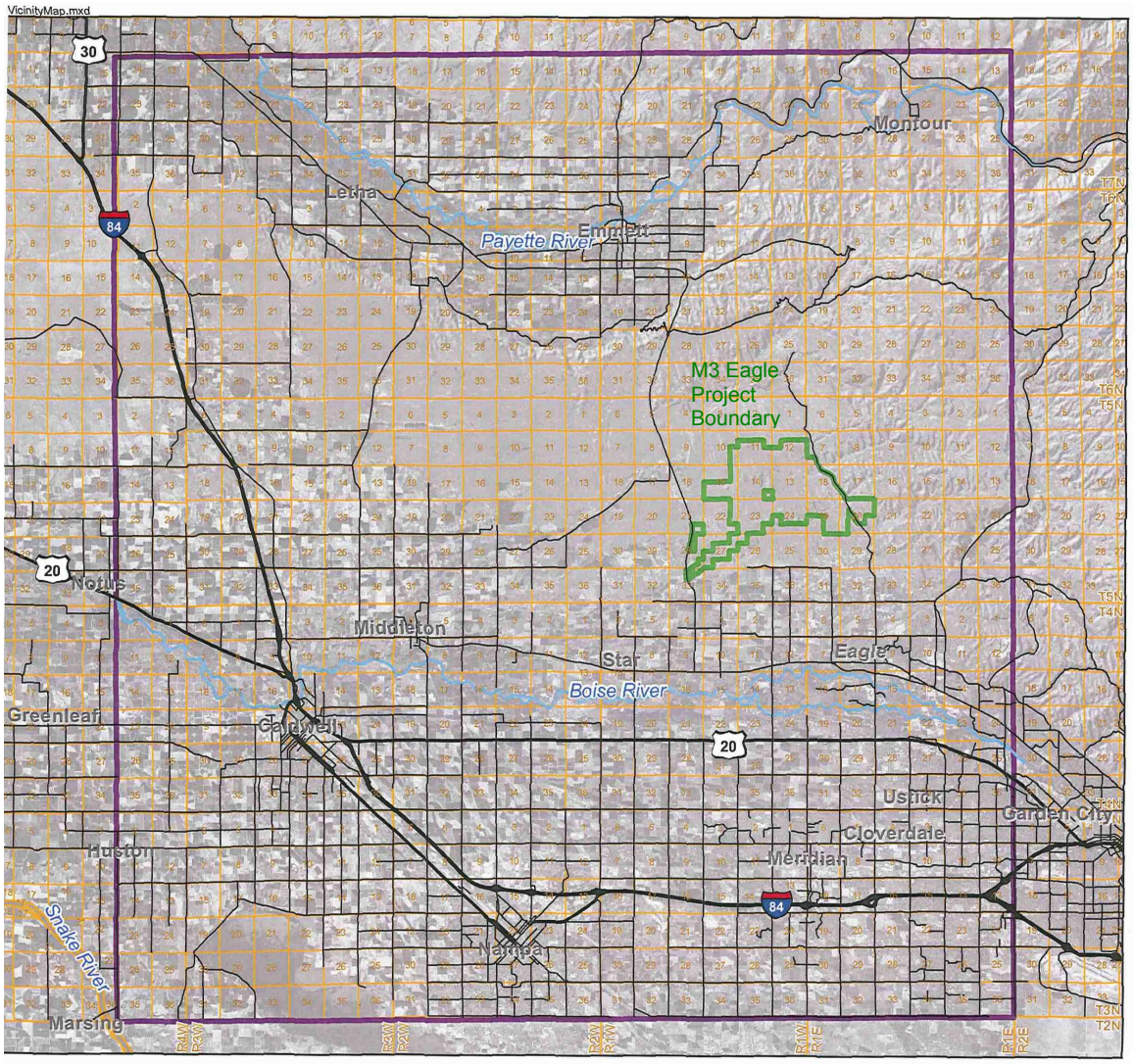
Domain of the U of I model showing that the northern boundary lies to the north of the Payette River and is therefore, unlikely to affect flow near the M3 Eagle project, from Douglas, 2007.

Figure 5. Representative Model Cross Section from the U of I Model



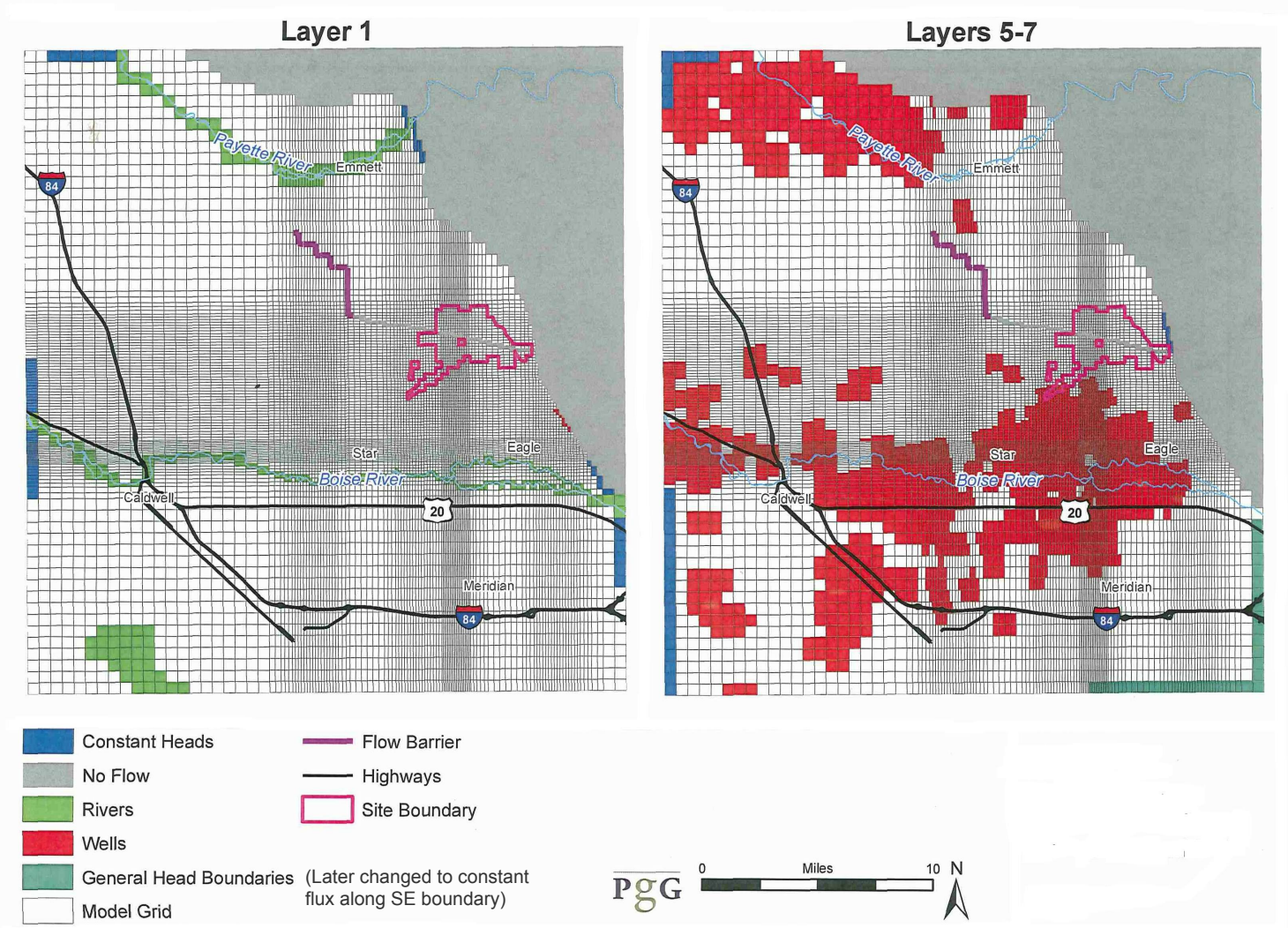
Representative cross-section from the U of I model (Douglas, 2007) showing: a) horizontal layering, b) Layers 1 and 2 representing uplands in the east and above ground (inactive) in the west, very thin Layer 3 (3 ft thick) to add confinement and d) large thickness of Layer 8 which represents Terteling Springs clays and mudstones.

Figure 6. Domain of the M3 Model



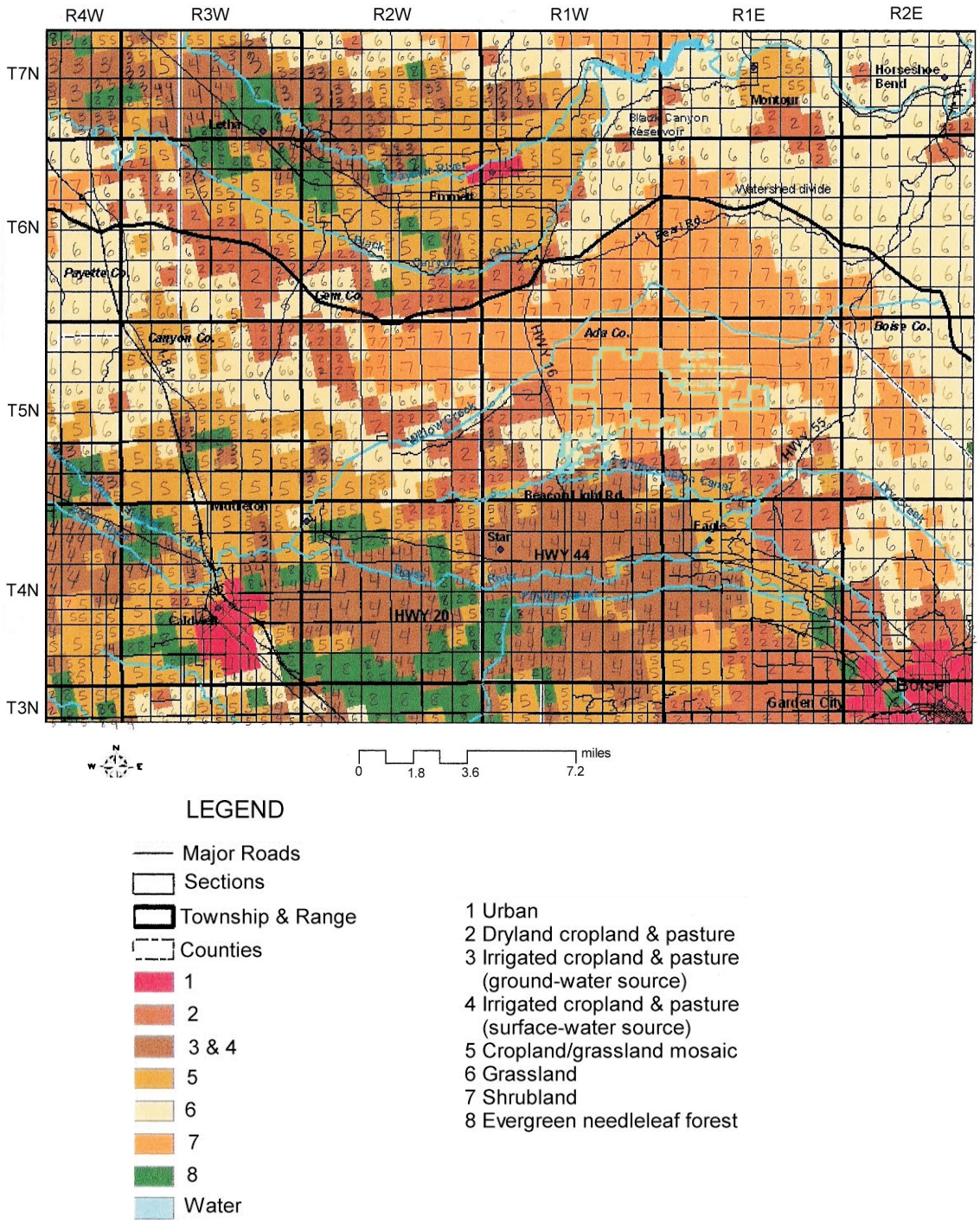
Domain of the M3 model showing boundaries well away from the M3 Eagle project, after PGG (2008a).

Figure 7. Model Grid and Cells in the M3 Model



Domain of M3 model showing variable cell size and boundary conditions, from PGG (2008a). Finer cell-size in M3 Eagle property and City of Eagle allows for better detail in transient calibration. Please see text for details.

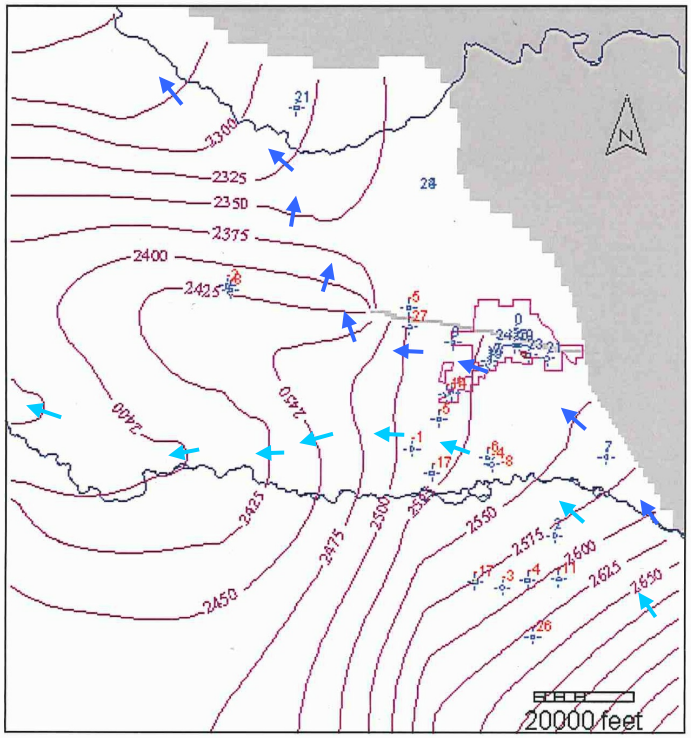
Figure 8. Land Use by Category in the M3 Model Area



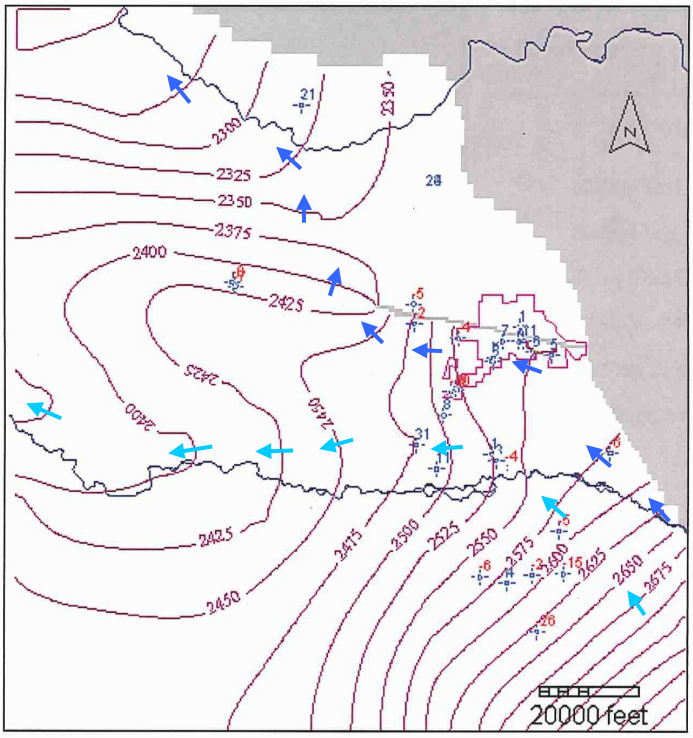
Land use manually categorized by quarter-section and reproduced from Nimmer (2007).

Figure 9. Potentiometric Contours and Ground-Water Flow-Directions from the Initial M3 Model

a) Tmatch model



b) Hmatch model

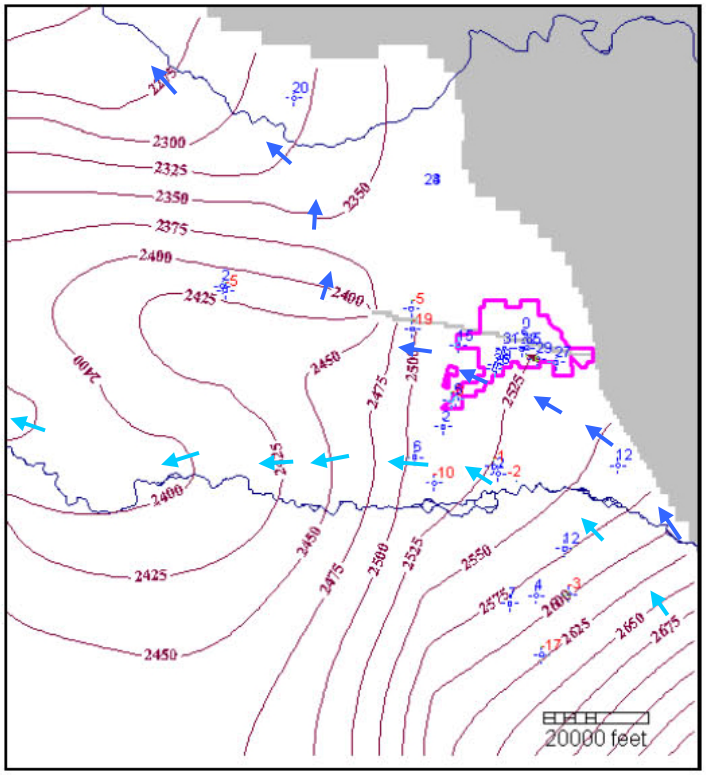


Steady-state potentiometric contours generated by initial M3 Tmatch and Hmatch models (with smaller overall estimates of well pumping within model domain) showing closer agreement to measured levels (smaller residuals) in Hmatch version, from PGG (2008a).

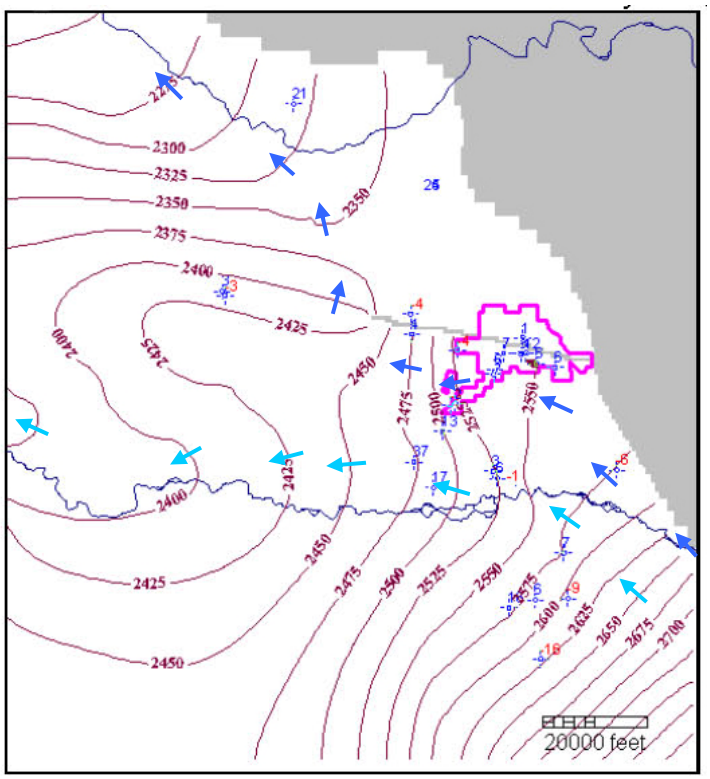
- Indicates flow in the Pierce Gulch Sand Aquifer that stays in the Boise River Valley
- Indicates flow in the Pierce Gulch Sand Aquifer that continues to the Payette River Valley

Figure 10. Potentiometric Contours and Ground-Water Flow-Directions from the Higher-Pumping Rate/ Recalibrated M3 Model

a) Tmatch model



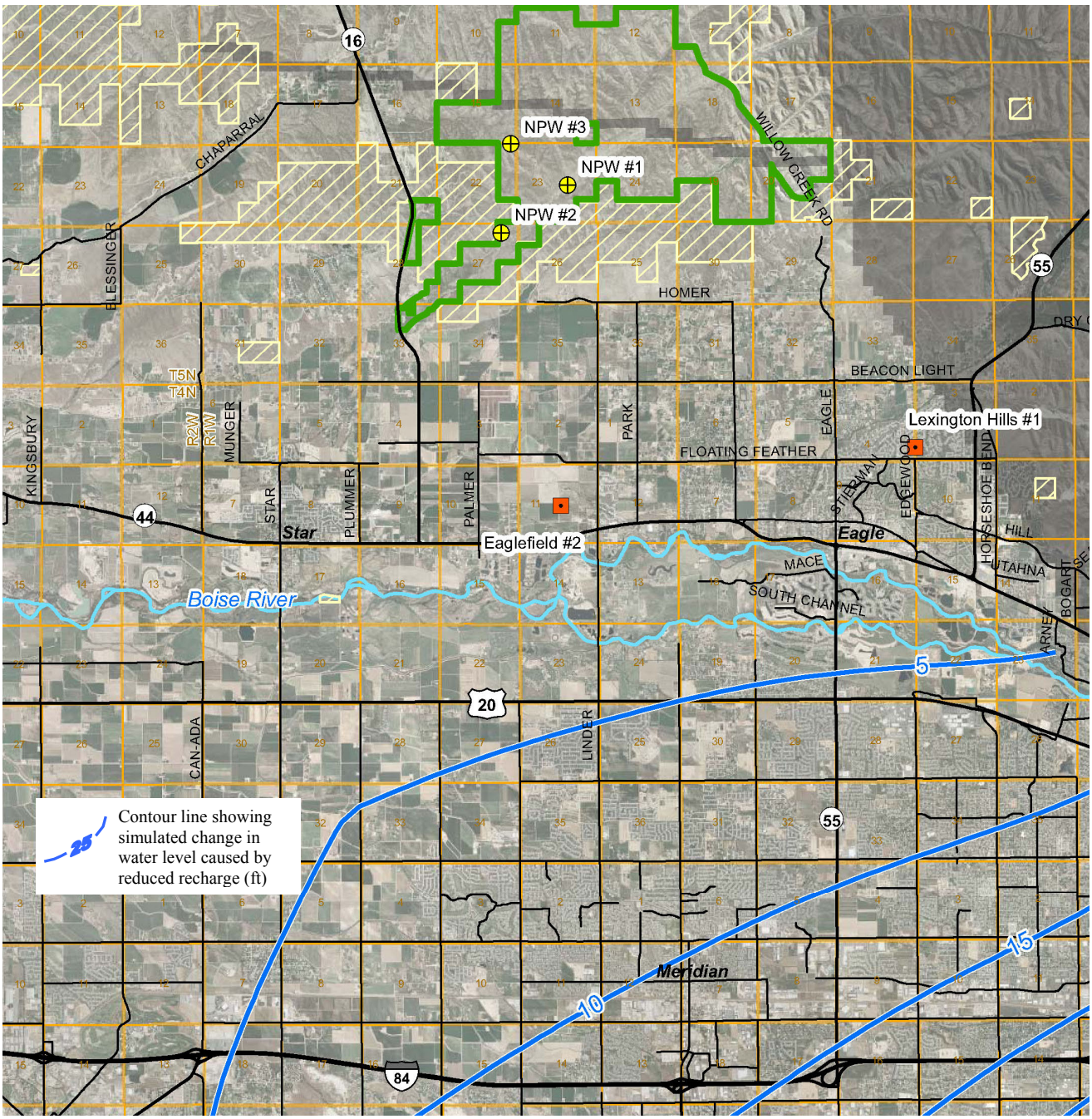
b) Hmatch model



Steady-state potentiometric contours generated by revised M3 Tmatch and Hmatch models (with larger overall estimates of well pumping within model domain) showing closer agreement to measured levels (smaller residuals) in Hmatch version, from PGG (2008d).

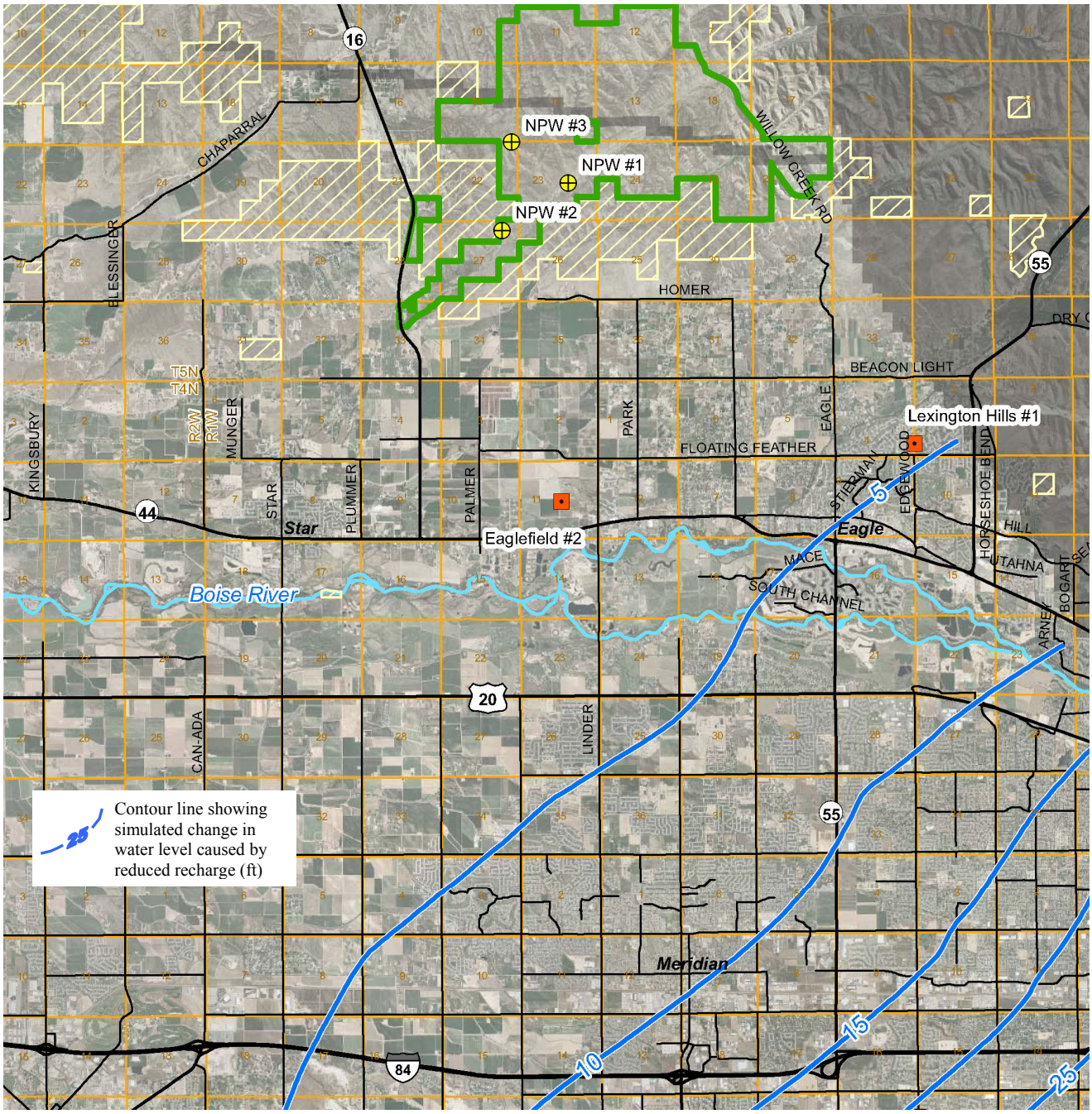
- Indicates flow in the Pierce Gulch Sand Aquifer that stays in the Boise River Valley
- Indicates flow in the Pierce Gulch Sand Aquifer that continues to the Payette River Valley

Figure 11. Tmatch Model-Generated Simulations of the Change in Water Levels Caused by a 20-Percent Reduction in Recharge from Southeast of Model Domain - Higher Pumping Rate Model



A prediction of water level changes caused by reduced recharge that might occur were the New York Canal to be lined to reduce seepage. Based on the Tmatch model with higher pumping rates within the model domain, from PGG (2008d).

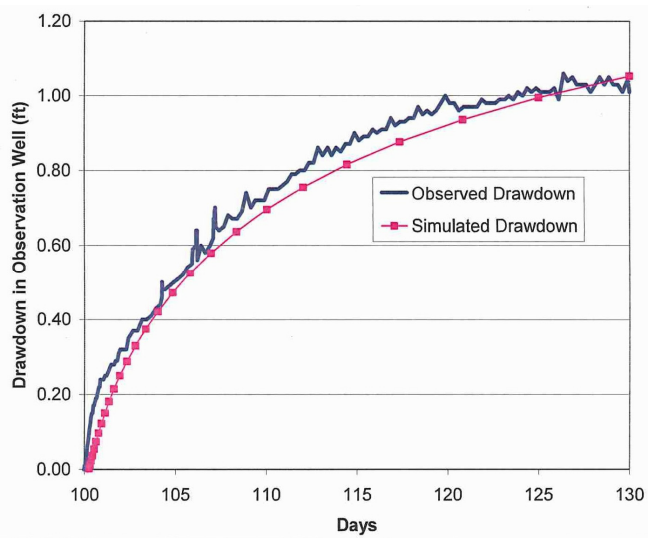
Figure 12. Hmatch Model-Generated Simulations of the Change in Water Levels Caused by a 20-Percent Reduction in Recharge from Southeast of Model Domain - Higher Pumping Rate Model



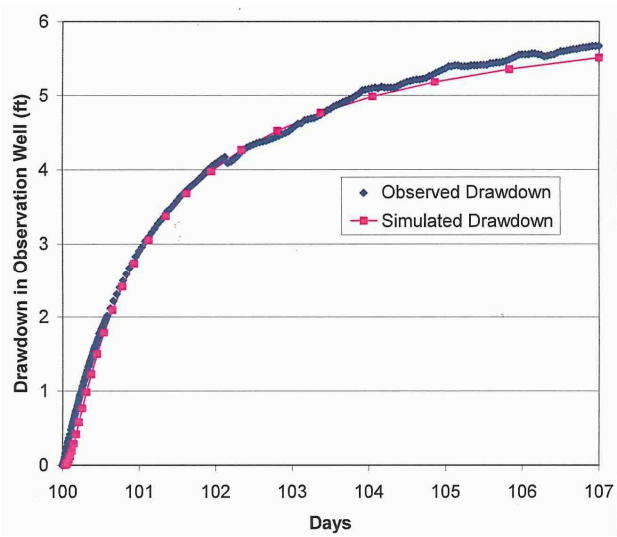
A prediction of water level changes caused by reduced recharge that might occur were the New York Canal to be lined to reduce seepage. Based on the Hmatch model with higher pumping rates within the model domain, from PGG (2008d).

Figure 13. Initial Transient-Calibration Hydrographs for Two Aquifer Tests - Lower Pumping Rate Model

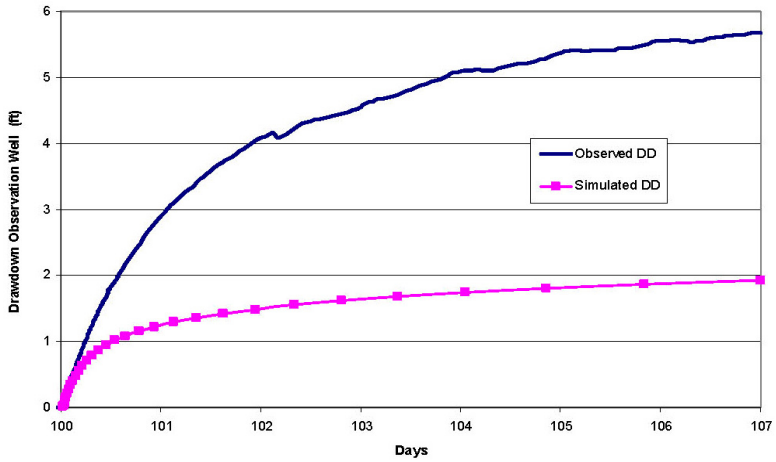
a) Lexington Hills Aquifer Test: Initial Hmatch Model



b) Eaglefield Aquifer Test: Initial Hmatch Model

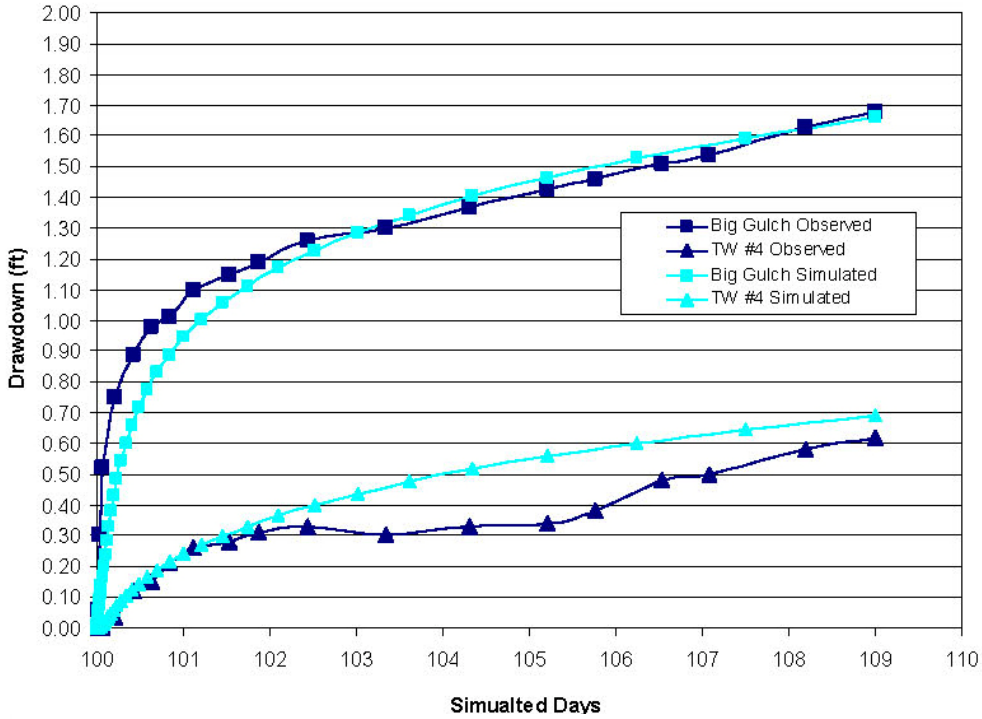


c) Eaglefield Aquifer Test: InitialTmatch Model

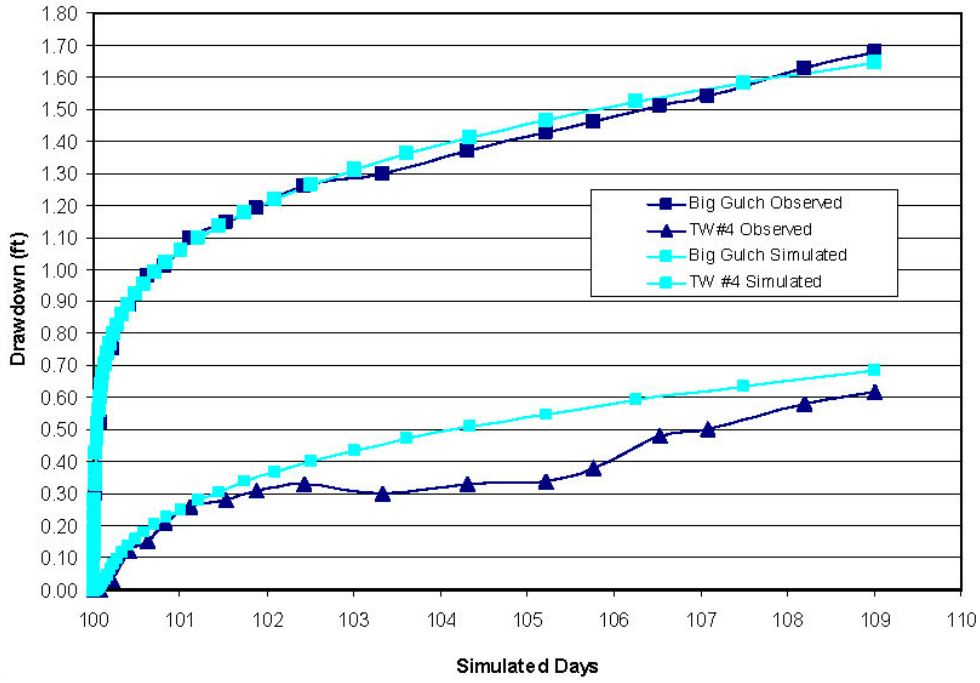


Transient calibration plots for observation wells from the Eaglefield and Lexington Hills aquifer tests, from PGG (2008a). Each simulation started after 100 days (with no pumping) to allow for equilibrium conditions before the test began. Plots show generally good match except for Tmatch model for Eaglefield test. Note that observed drawdowns from each test are not corrected for barometric effects or pre-test water level trends.

Figure 14. Transient-Calibration Hydrographs for SVR #7 from the SVR #7 Aquifer Test - Higher Pumping Rate Model



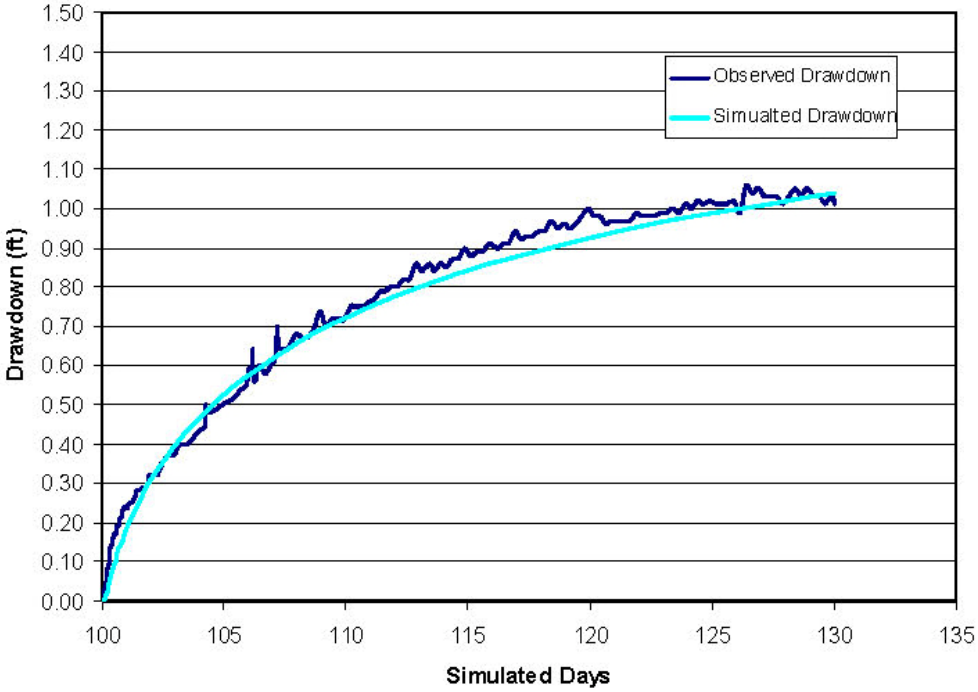
a) Tmatch model calibrated with higher total pumping in model domain.



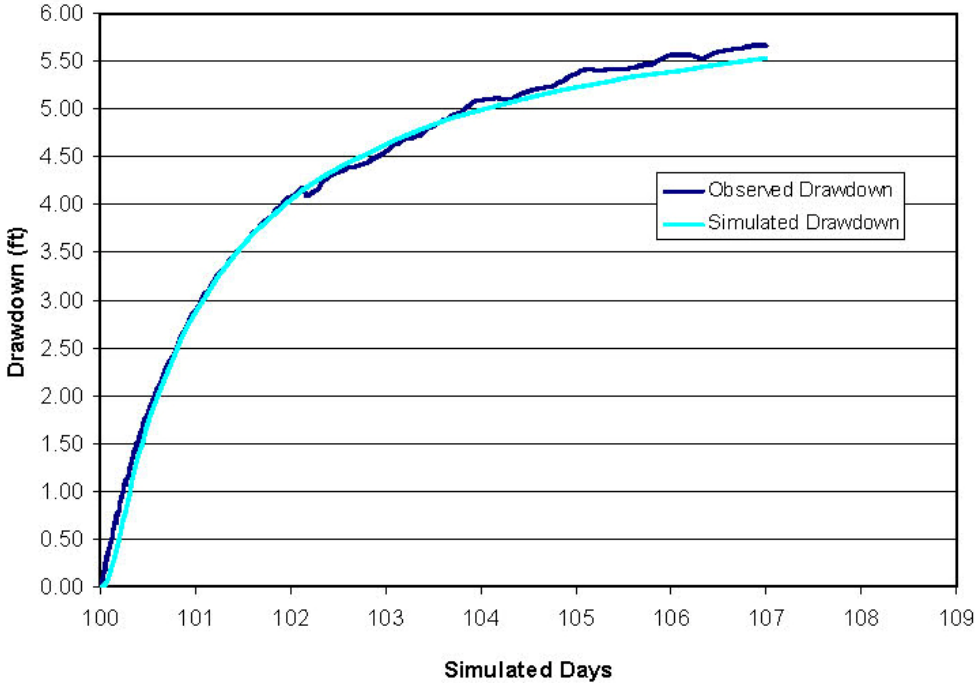
b) Hmatch model calibrated with higher total pumping in model domain.

Simulated and observed drawdowns for two observations wells during SVR #7 aquifer test, from PGG (2008d). Plots show generally good match. Decline in observed drawdown from "102" to "108" days for TW #4 (second through eighth day of test) likely caused by incomplete barometric and/or trend corrections. See text for details.

Figure 15. Transient-Calibration Hydrographs for Lexington Hills #1 and Eaglefield #2 – Higher Pumping Rate Hmatch Model



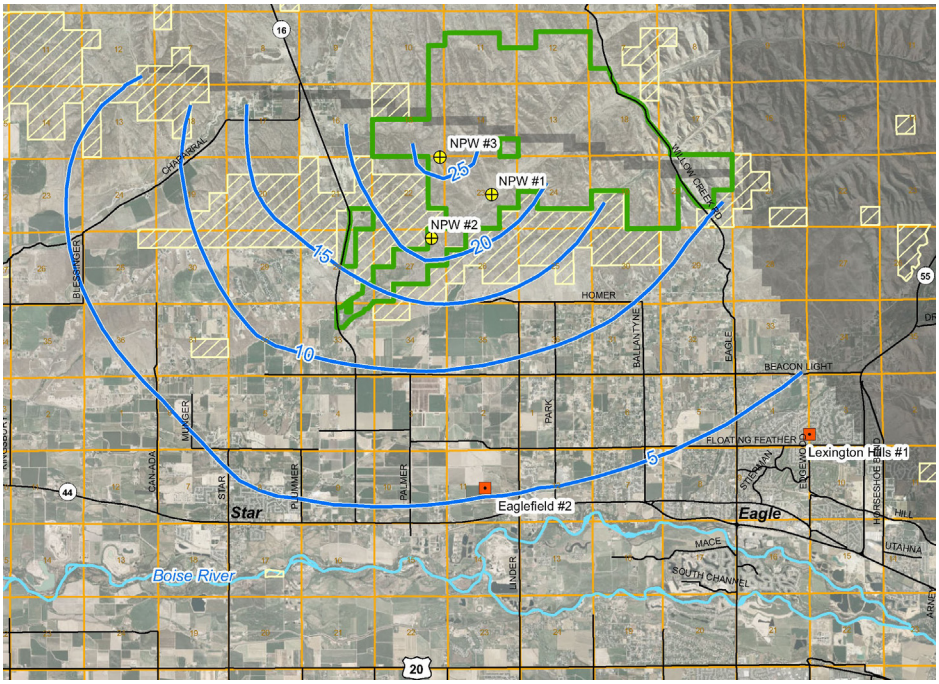
a) Lexington Hills #1 Observed and Simulated Drawdowns. Hmatch model calibrated with higher total pumping in model domain and SVR #7 Aquifer Test Data.



b) Eaglefield #2 Observed and Simulated Drawdowns. Hmatch model calibrated with higher total pumping in model domain and SVR #7 Aquifer Test Data.

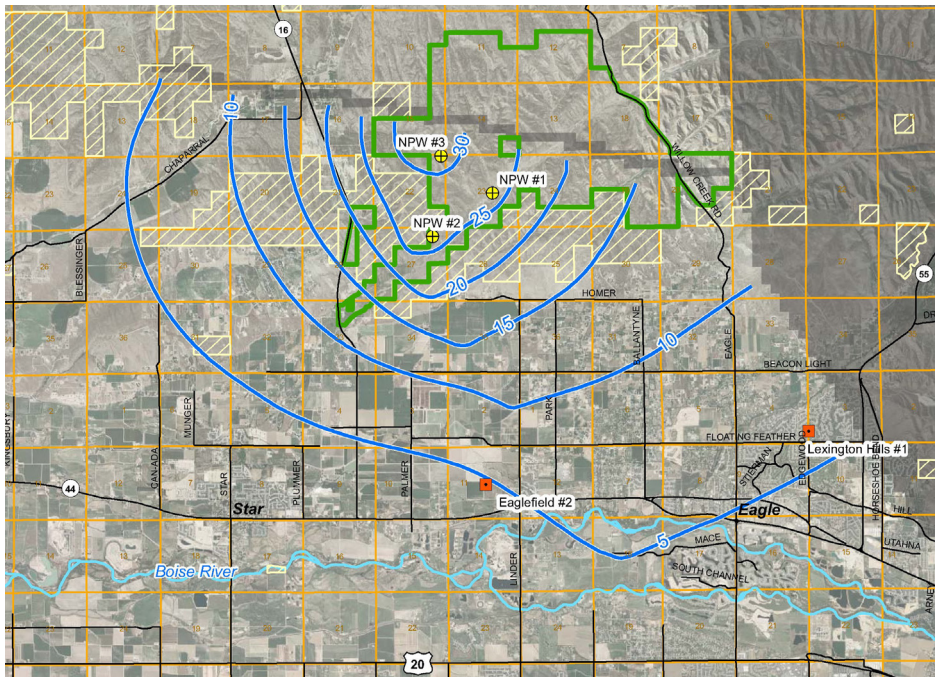
Simulated and observed drawdowns for two observations wells during SVR #7 aquifer test, from PGG (2008d). Plots show generally good match. Decline in observed drawdown from "102" to "108" days for TW #4 likely caused by incomplete barometric and/or trend corrections. See text for details.

Figure 16. Tmatch and Hmatch Model-Generated Drawdowns from Pumping at 4,500 gpm - Lower Pumping Rate Model



a) Tmatch Model after 50 years pumping at a combined 4,500 gpm at three proposed well locations ("NPW")

25 Contour line showing simulated drawdowns cause by pumping (ft)

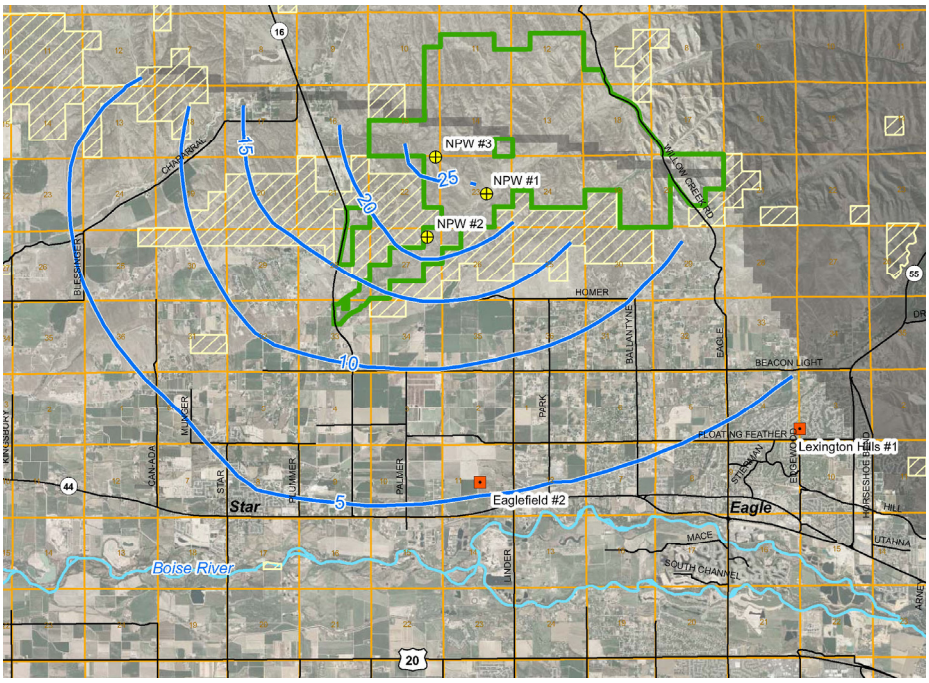


b) Hmatch Model after 50 years pumping at a combined 4,500 gpm at three proposed well locations ("NPW")

25 Contour line showing simulated drawdowns cause by pumping (ft)

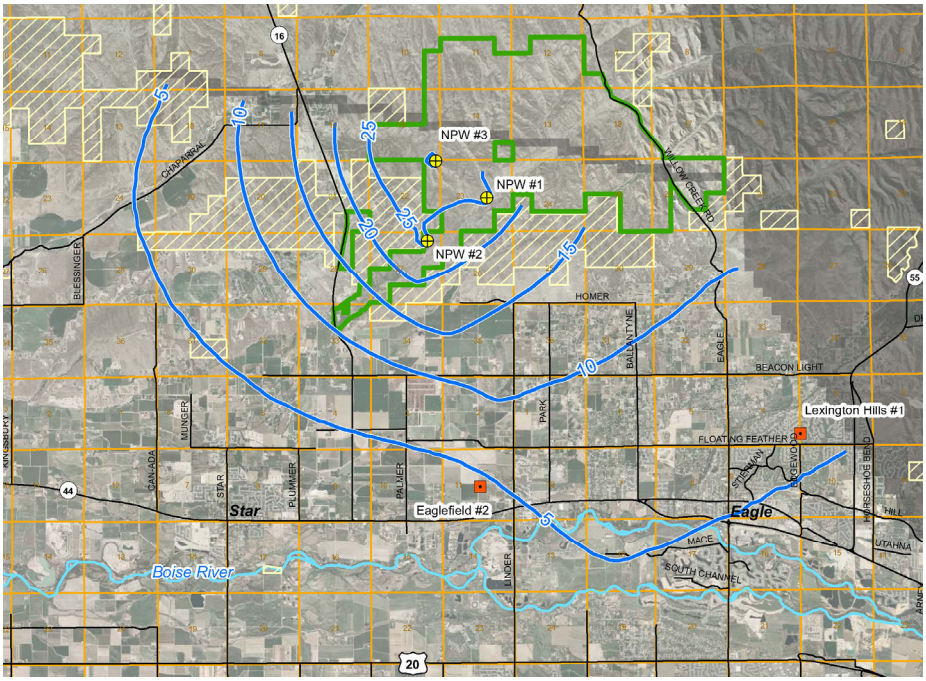
Two predictions of drawdown interference from pumping at 1,500 gpm from each of three wells using the two models (with lower pumping rates within the model domain) from PGG (2008c). (Drawdowns are smaller than those predicted from pumping at 7,000 gpm, shown in Figures 7-4 and 7-9 in PGG, 2008a, included in Appendix A).

Figure 17. Tmatch and Hmatch Model-Generated Drawdowns from Pumping at 4,500 gpm - Higher Pumping Rate Model



a) Tmatch Model after 50 years pumping at a combined 4,500 gpm at three proposed well locations ("NPW")

25 Contour line showing simulated drawdowns cause by pumping (ft)



b) Hmatch Model after 50 years pumping at a combined 4,500 gpm at three proposed well locations ("NPW")

25 Contour line showing simulated drawdowns cause by pumping (ft)

Two predictions of drawdown interference from pumping at 1,500 gpm from each of three wells using the two models (with higher pumping rates within the model domain) from PGG (2008d). Drawdowns beyond M3 property boundary are effectively the same as those simulated by the model with lower pumping rates within the model domain.

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APPENDICES

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APPENDIX A – PACIFIC GROUNDWATER GROUP REPORT OF JUNE 4, 2008

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PACIFIC groundwater GROUP

M3 EAGLE GROUNDWATER FLOW MODEL AND ANALYSIS OF PUMPING IMPACTS - FIRST YEAR PROGRESS REPORT

June, 2008

M3 EAGLE GROUNDWATER FLOW MODEL AND ANALYSIS OF PUMPING IMPACTS – FIRST YEAR PROGRESS REPORT

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June 4, 2008
JZ0705

TABLE OF CONTENTS

1.0 INTRODUCTION 1

1.1 PROJECT BACKGROUND 1
1.2 PROJECT SCOPE 1
1.3 WARRANTY 2

2.0 SUMMARY OF FINDINGS 2

3.0 CONCEPTUAL HYDROGEOLOGIC MODEL 4

4.0 MODEL CONSTRUCTION 4

4.1 MODEL CODE 4
4.2 MODEL DOMAIN AND DISCRETIZATION 5
4.3 BOUNDARY CONDITIONS 6
4.3.1 No-Flow Boundaries 6
4.3.2 Constant Head Boundaries 7
4.3.3 General Head Boundary 7
4.3.4 Recharge 7
4.3.5 Wells 8
4.3.6 Rivers 9
4.3.7 Vertical Low Permeability Boundary 10
4.4 AQUIFER AND AQUITARD PROPERTIES 10
4.4.1 Hydraulic Conductivity 10
4.4.2 Aquifer Transmissivity 11
4.4.3 Aquifer Storage Parameters 12

5.0 STEADY STATE MODEL CALIBRATION 12

5.1 TARGETS AND PRIOR INFORMATION 12
5.2 CALIBRATION PARAMETERS 13
5.3 STEADY STATE SENSITIVITY ANALYSIS 14
5.4 CALIBRATION RESULTS 14
5.4.1 Calibration to Observed Transmissivity 14
5.4.2 Calibration to Observed Heads 15
5.4.3 Mass Balance 15

6.0 TRANSIENT MODEL CALIBRATION 16

6.1 TRANSIENT STRESS PERIODS AND INITIAL HEADS 16
6.2 SIMULATED PUMPING AND OBSERVATION WELLS 17
6.3 AQUIFER TEST RESULTS (TARGETS) 17
6.4 CALIBRATION PARAMETERS 17
6.5 CALIBRATION RESULTS 18

7.0 PREDICTIVE ANALYSIS 18

7.1 PREDICTIVE PUMPING RATES AND POINTS 18
7.2 PREDICTIVE DRAWDOWN 19

8.0 MODEL USES AND LIMITATIONS 19

9.0 REFERENCES 21

TABLES

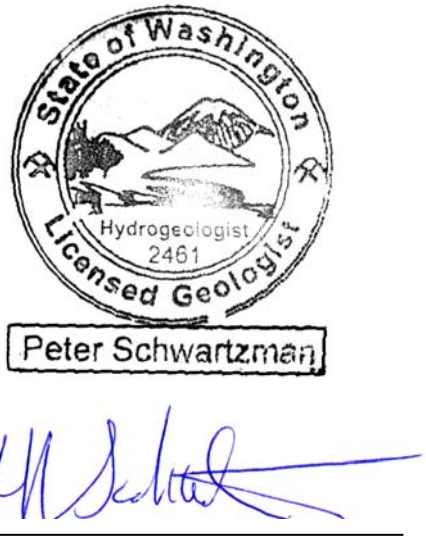
Table 4-1 Assigned Values of Recharge and Domestic Pumping in Peripheral Regions of the Model Based on Values from Similar Areas
Table 4-2 Landuse Recharge for Combined Irrigation and Natural Precipitation
Table 4-3 Summary of Calibrated Aquifer Property Zones
Table 4-4 Summary of Prior Information Transmissivity Values from Aquifer Tests
Table 5-1 Summary of Target Values, Calibration Residuals, and Statistics
Table 5-2 Water Budget for Steady State Model Calibrations

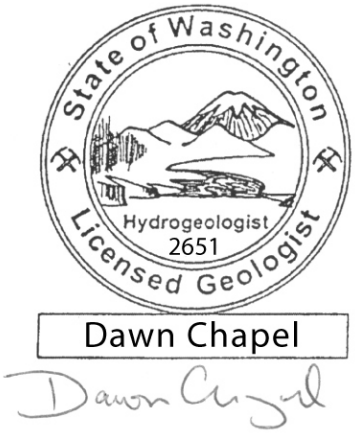
FIGURES

Figure 1-1 Vicinity Map
Figure 4-1 Model Grid and Boundary Conditions in Layers 1 and 5-7
Figure 4-2 Reference Surfaces Used in Model Construction
Figure 4-3 Distribution of Recharge
Figure 4-4 Hydraulic Conductivity Zones for Layers 1 and 2
Figure 4-5 Hydraulic Conductivity Zones for Layers 3 and 4
Figure 4-6 Hydraulic Conductivity Zones for Layers 5, 6 and 7
Figure 4-7 Modeled PGSA Transmissivity and Estimates from Aquifer Tests
Figure 4-8 Modeled Storage Coefficient Zones (PGSA)
Figure 5-1 Observed vs. Simulated Heads
Figure 5-2 Modeled Heads and Residuals in Layer 6 (PGSA)
Figure 6-1 Locations of Pumping and Observation Wells (Transient Calibration)
Figure 6-2 Modeled Drawdown in Hmatch Model (7-day and 30-day pumping test)
Figure 6-3 Modeled Drawdown in Tmatch Model (7-day pumping tests)
Figure 7-1 Proposed Supply Wells (M3 Site)
Figure 7-2 Simulated PGSA Drawdown After 4 Years (2013) - Tmatch Model
Figure 7-3 Simulated PGSA Drawdown After 8 Years (2017) - Tmatch Model
Figure 7-4 Simulated PGSA Drawdown After 16 Years (2025) - Tmatch Model
Figure 7-5 Simulated PGSA Drawdown After 26 Years (2035) - Tmatch Model
Figure 7-6 Simulated PGSA Drawdown After 4 Years (2013) - Hmatch Model
Figure 7-7 Simulated PGSA Drawdown After 8 Years (2017) - Hmatch Model
Figure 7-8 Simulated PGSA Drawdown After 16 Years (2025) - Hmatch Model
Figure 7-9 Simulated PGSA Drawdown After 26 Years (2035) - Hmatch Model
Figure 7-10 Simulated Drawdown in Middle Aquifer After 26 Years (2035) - Tmatch Model
Figure 7-11 Simulated Drawdown in Middle Aquifer After 26 Years (2035) - Hmatch Model
Figure 7-12 Simulated PGSA Drawdown at Eaglefield #2 Well
Figure 7-13 Simulated PGSA Drawdown at Lexington Hills #1 Well
Figure 7-14 Simulated PGSA Drawdown at Star #3 Well
Figure 7-15 Simulated PGSA Drawdown at Floating Feather Well
Figure 7-16 Simulated PGSA Drawdown at Homer Road
Figure 7-17 Simulated PGSA Drawdown at M3 Property

SIGNATURE

This report, and Pacific Groundwater Group's work contributing to this report, were reviewed by the undersigned and approved for release.





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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

A planned community by M3 Eagle, LLC in the foothills north of Eagle, Idaho proposes to install six new production wells in order to meet projected annual water demands of 6,535 acre-feet. As with any new groundwater withdrawal, pumping will cause some degree of local water level decline in the groundwater flow system over time. Groundwater level declines associated with M3 Eagle proposed pumping must be estimated to assess whether other nearby groundwater users would be impaired. The groundwater flow system in the M3 Eagle vicinity is complex, with multiple aquifers occurring at different depths, intervening aquitards, faulting, hydraulic connections between groundwater and surface water, multiple sources of recharge, and pre-existing groundwater withdrawals. Prediction of pumping drawdowns in a system of such complexity requires development of a groundwater flow model that represents all key components of the hydrogeologic system.

Hydro Logic, Inc. (HLI) characterized the hydrogeology of the M3 Eagle area, and retained and collaborated with Pacific Groundwater Group (PGG) to develop the numerical groundwater flow model. The project area and the model domain are shown on **Figure 1**. The model was calibrated to groundwater elevations measured in multiple wells, transmissivity estimates from multiple wells, and two aquifer tests. The model was then used to predict drawdown associated with proposed M3 Eagle groundwater withdrawals. Although the model presented in this report should be considered preliminary, we believe it is the best predictive tool developed to date to assess the impacts of groundwater development in the M3 Eagle vicinity. As time passes and additional data become available, the existing model will be improved through additional calibration and verification. These improvements and updates will be presented as addenda to this first-year progress report. This report, therefore, presents the status of the model one year into its development. We believe that this model as it is improved over time, will serve an important role in managing the groundwater resources of the M3 Eagle area.

1.2 PROJECT SCOPE

PGG's role in model development and prediction of pumping drawdown included the following:

- Development of a project geographic information system (GIS) that included roads, surface-water features, well distributions, irrigation ditches and canals, surficial geology, HLI's estimates of pumping and recharge distribution, land elevations and public land survey;
- Selection of a model domain of sufficient size to avoid undesirable boundary impacts during drawdown prediction, and discretization of the model grid to support accurate definition of drawdown throughout the domain;
- Development of model layering to represent hydrostratigraphic units and definition of hydraulic boundary conditions based on hydrogeologic interpretation by HLI;
- Delineation of surface-water bodies for representation in the groundwater flow model;
- Estimation of recharge from irrigation ditches and canals based on seepage rates provided by HLI;
- Compilation of pumping and recharge estimates into the groundwater flow model;
- Sensitivity analysis to identify model parameters that have the greatest influence on groundwater model results;

- Model calibration to groundwater elevations (steady state calibration) and aquifer test results (transient calibration) based on data provided by HLI;
- Consideration of model uncertainty; and,
- Use of the calibrated model to predict aquifer drawdowns over the course of M3 Eagle's proposed groundwater development.

It should be noted that some degree of uncertainty was identified during model calibration. Specifically, when PGG employed the best available estimates of aquifer transmissivity (provided by HLI) during model calibration, predicted groundwater elevations in the M3 Eagle vicinity were consistently too low. PGG was able to reproduce groundwater levels near the M3 site with sufficient departure from some of HLI's transmissivity estimates, In order to address this associated uncertainty, PGG developed two versions of the model: one that honored the transmissivity estimates ("Tmatch" model) and one that allowed departures from the transmissivity estimates in order to achieve a better match to measured water-level elevations ("Hmatch" model). Both versions of the model were used in the predictive analysis. Through the use of two models, we have effectively bracketed a range of drawdown impact-predictions. Since the differences in the drawdowns predicted by the two models were relatively small, we believe that the differences between the two models are relatively minor for the purposes of this investigation.

It should also be mentioned that development of the groundwater flow model was a collaborative effort between HLI and PGG. Model development almost always results in identification of data gaps and areas requiring further hydrogeologic interpretation. HLI collected additional data and performed additional hydrogeologic interpretation as questions arose during model design, construction, and calibration. Members of the HLI and PGG teams have worked together for almost 20 years. Because of this long-term relationship, the transfer of HLI's specific hydrogeologic understanding of the project vicinity needed to properly develop the model was greatly aided.

1.3 WARRANTY

The work was performed, and this report prepared using generally accepted hydrogeologic practices used at this time and in this vicinity for exclusive application to the study area and for the exclusive use of HLI. This is in lieu of other warranties, express or implied.

2.0 SUMMARY OF FINDINGS

1. **PGG developed a groundwater flow model in order to estimate drawdown associated with proposed pumping from M3 Eagle project.** The model represents the key components of the groundwater flow system, including: multiple hydrostratigraphic units (aquifers and aquitards), faulting, the Boise and Payette rivers, recharge from a variety of sources, and pumping for a variety of purposes. The model covers a sufficiently large domain (520 square miles) so that external boundaries do not affect estimation of drawdown.

2. **PGG worked closely with HLI to ensure that the structure of the computer model best matched the conceptual model of the groundwater flow system.** HLI provided maps and feedback regarding the structural surfaces of key hydrostratigraphic units, estimates of aquifer parameters from tested wells, and both groundwater elevation and aquifer test data to be used for calibration targets. HLI also provided interpreted data and guidance to facilitate model representation of pumping and recharge.

Finally, HLI provided input during the calibration progress, including supplemental data when data gaps were encountered.

3. **PGG calibrated the model to both steady-state and transient conditions.** The steady-state model was calibrated to observed groundwater levels in wells, whereas the transient model was calibrated to drawdown responses observed during aquifer tests. An iterative approach was used between the steady-state and transient calibrations. Both calibrations met standard criteria for successful calibration. Although the model represents the shallow, middle, and deep portions of the groundwater flow system, calibration emphasized conditions in the generally deep "Pierce Gulch Sand Aquifer" (PGSA) from which M3 Eagle proposes to withdraw groundwater.

4. **During calibration, some level of model uncertainty became apparent.** Specifically, when PGG employed the best available estimates of aquifer transmissivity (provided by HLI) during calibration, predicted groundwater elevations in the M3 Eagle vicinity were consistently too low. PGG was able to reproduce groundwater levels near the M3 site with sufficient departure from some of HLI's transmissivity estimates. In order to address this associated uncertainty, PGG developed two versions of the model: one that honored the transmissivity estimates ("Tmatch") and one that allowed departures from these estimates to achieve a better match to measured water-level elevations ("Hmatch"). Both of these model versions were used for predictive analysis, and thus bracket a range of predictive results.

5. **Both versions of the model met the criteria for successful steady-state calibration.** For steady state calibration, the ratio of residual standard deviation to the observed head range was less than the 10 percent calibration criteria. In addition, values of residual mean (RM) and absolute residual mean (ARM) ranged from 2.7 to 14 feet, which was considered reasonable compared to the head range in the area of PGSA calibration (about 200 feet),

6. **Successful transient calibration to two local pumping tests was achieved with the Hmatch model.** PGG also attempted to calibrate the Tmatch model to one of the tests, but could only achieve acceptable calibration by substantially decreasing (by a factor of five) the local transmissivity value in the area of the test. As the intent of the Tmatch model is to retain estimated transmissivity values (even at the expense of decreased matches to head or time-drawdown targets), the originally estimated transmissivity values were retained.

7. **PGG ran both models through 26 years of projected pumping at the M3 Eagle site in order to estimate both long-term and intermediate drawdowns throughout the project development.** At full build out, general drawdowns in the PGSA in the M3 pumping center are estimated to reach 30 to 50 feet (not including well-loss drawdowns specific to individual wells). PGSA drawdown is predicted to rapidly decline with distance outward from the pumping center, with only 5 feet of drawdown predicted 4 miles away at the Boise River. Drawdown in the Middle Aquifer[1] is predicted to be less than in the PGSA depending on location within the aquifer system. Drawdown maps are presented on **Figures 7-2** through **7-11**.

8. **The groundwater flow model was developed to estimate drawdown in the Pierce Gulch Sand Aquifer and the overlying Middle Aquifer, caused by pumping associated with the M3 project**. While the model includes all key elements of the shallow and intermediate portions of the groundwater flow system (e.g. alluvial aquifers along the Boise and Payette Rivers, the rivers themselves, the

[1] The Middle Aquifer (layer 3) is also referred to as the "shallow, unnamed, alluvial aquifer overlying the Pierce Gulch Sand Aquifer"

Middle Aquifer), the model was not calibrated to conditions in these portions of the system. Therefore, the model should not be used to simulate stresses and responses within those aquifer systems without further data review, possible design refinements and calibration.

3.0 CONCEPTUAL HYDROGEOLOGIC MODEL

The hydrogeology of the study area is described in the main body of this report. Key features of the conceptual hydrogeologic model represented by the groundwater flow model include:

- The Pierce Gulch Sand Aquifer (PGSA), which occurs close to the land surface near the M3 Eagle site and dips downwards to the southwest;
- The Willow Creek Aquifer (WCA), which occurs north and northeast of the M3 Eagle site;
- The West Boise-Eagle Fault, which hydraulically separates the PGSA and overlying shallow aquifers present to the southwest of the fault from low-permeability units lying to the northeast of the fault;
- The low-permeability sediments separating the PGSA from the WCA beneath the northeastern portions of the M3 Project site;
- The Boise River sand and gravel aquifer, an alluvial aquifer which occupies the extensive present-day floodplain of the Boise River;
- A regional aquitard that separates the Boise River alluvial aquifer from the PGSA;
- Water-bearing deposits within the regional aquitards, described by HLI as the "shallow, unnamed, alluvial aquifer overlying the Pierce Gulch Sand Aquifer, but for the purpose of this report, heretofore known as the "Middle Aquifer";
- Valley-fill deposits of the Payette River, including both water-bearing units and low permeability units. Occurrence of low permeability units creates confined conditions in the deeper portions of these deposits. PGG also assumed that the shallow valley-fill deposits include an alluvial aquifer, similar to the Boise River sand and gravel aquifer;
- Bedrock hills ("North Eagle Foothills") that effectively function as a "no-flow" boundary for the groundwater flow system in the unconsolidated sediments;
- Groundwater recharge based on precipitation, land cover, irrigation applications, and seepage losses from irrigation ditches;
- Pumping withdrawals for domestic, municipal, industrial, and irrigation uses;
- An overall west-northwest flow direction for groundwater in the PGSA with a potentially substantial source of recharge outside of the model domain (upstream on the Boise River) where the PGSA comes into close hydraulic contact with the river.

4.0 MODEL CONSTRUCTION

4.1 MODEL CODE

The three-dimensional, finite difference code "MODFLOW" (McDonald and Harbaugh, 1988; Harbaugh et al., 2000) was selected for this model because it has been thoroughly validated and is in common use by government agencies and consultants. Groundwater Vistas Version 5 (GV) (ESI, 2007) was used as

platform to organize input data, run the model, and view results. MODFLOW comes with several solver options: Slice-Successive Over-Relaxation (SSOR), Strongly Implicit Procedure (SIP), and the Preconditioned Conjugate-Gradient Method (PCG2). Different solvers may work better for different problems. The PCG2 solver was successful in solving the M3 model simulations.

4.2 MODEL DOMAIN AND DISCRETIZATION

The model domain occupies an area of 20 by 26 miles, including portions of the Boise Foothills, Payette River Valley, and Boise River Valley (**Figure 1-1**). The outer boundaries of the model domain were set at significant distances from the M3 site to minimize boundary effects on the estimation of drawdown. The M3 site is located in the northeast portion of the model domain near natural "no-flow" (bedrock) conditions in the Boise Foothills. The model represents the Willow Creek Aquifer (WCA) and Payette Valley Aquifer (PVA) in the north, and Pierce Gulch Sand Aquifer (PGSA), an unnamed alluvial aquifer overlying the Pierce Gulch Sand Aquifer (termed the "Middle Aquifer" in this report), the gravel aquifer that occupies the Boise River Valley in the south, and an alluvial aquifer beneath the Payette River valley to the north.

The model domain was discretized into a seven-layer, variable-spacing grid. The grid contains a total of 99,568 cells, 81,958 of which are active. Variable grid spacing included minimum spacing of 330 ft near the M3 site gradually increasing to a maximum of 2,640 ft (a half mile) at the outer model boundaries (**Figure 4-1**). This variable grid spacing allows detailed representation of hydrogeologic conditions and pumping drawdown in the M3 vicinity while covering a geographically extensive area and providing computational efficiency in running the model. The grid spacing was set so that single model cells, or multiple model cells, fit evenly within a quarter of a square-mile public land survey (PLS) "section". This allowed various data indexed to the PLS system (e.g. pumping, water rights) to be readily calculated and distributed among model cells. The model grid was aligned in an east-west direction, generally parallel to the major rivers.

Model layers were defined based on the hydrostratigraphic units discussed in Section 3 and HLI's hydrogeologic report. The top of the model domain (land surface) was defined based on a USGS digital elevation model (DEM). Model layer surfaces were defined relative to the top/bottom of the PGSA (and the WSA to the north), as represented in 13 borehole geophysical logs and 36 boring logs. Top/bottom PGSA surfaces dip to the southwest, and were defined based on contouring and interpolation between logs. A discontinuity was represented between the top/bottom elevations of the PGSA and the WPA in a manner consistent with the stratigraphic understanding of these units. The materials between the top and bottom surfaces of the PGSA were divided evenly into three model layers (5, 6, and 7). The PGSA top/bottom surfaces were extended beneath the Payette River Valley where the PGSA is absent. The top/bottom surfaces were also extended across the West Boise-Eagle Fault into the region occupied by the WCA. Model layering includes a discontinuity across the fault to represent its displacement. **Figure 4-2** contours the top and bottom reference surfaces, and shows the contact elevations for 36 boring logs interpreted to define these surfaces.

Above the top-of-layer-5 reference surface, the overlying 4 layers were divided in the following manner:

- Model layer 1 was generally assigned a uniform thickness of 50 ft, except in portions of the Payette River valley where the top reference surface is relatively shallow.
- Areas with thinner material above top reference surface primarily occurred just north of the cliffs which flank the Payette River floodplain. In this area, if 50 ft were allocated to model layer 1, the

remaining thickness would be too small for layers 2 through 4. Therefore, the thickness above the PGSA top was divided evenly between layers 1 through 4.

- In all areas where layer 1 was assigned a thickness of 50 feet, the materials between the bottom of layer 1 and the top reference surface (top of layer 5) were divided evenly into three, equal thickness layers (2, 3 and 4).

4.3 BOUNDARY CONDITIONS

Boundary conditions included no-flow, constant head, general head, recharge, wells, rivers, and a vertical low-permeability barrier. **Figure 4-1** shows the boundary conditions for layer 1 and layers 5, 6, and 7 (same for all three layers). Boundary conditions in layers 2 through 4 are limited to pumping wells and the vertical low-permeability barrier which penetrates the entire model domain.

4.3.1 No-Flow Boundaries

No-flow boundaries vary by model layer based on expected flow conditions in the shallow and deep portions of the groundwater flow system, and the intended use of the model. In all layers, no flow occurs in the region designated as "inactive" due to the presence of low-permeability bedrock. All layers also include an internal no-flow boundary in the location where the bottom of the Pierce Gulch Sand Aquifer reaches the surface and the underlying contact with low-permeability clay and mudstones of the Terteling Springs Formation crop out. These low-permeability sediments cause a hydraulic disconnect between the aquifers on either side (PGSA and WCA). The use of a no-flow condition was computationally advantageous for ensuring no transfer in the contact vicinity. While the PGSA and WCA are hydraulically separated by the contact in the eastern model domain, they become hydraulically continuous toward the middle and the western portions of the domain.

In layer 1, portions of the model's exterior boundaries are specified as no flow. Specifically, the southern model boundary (southeast, south, and southwest) and the northern half of the western model boundary. Although these boundaries may not occur along groundwater divides, they are designated as no flow because:

1. Flow through the shallow system is dominated by conditions in the alluvial aquifers (along rivers), which *are* simulated with constant head boundaries along the exterior model boundaries. Heads along the entire boundary are therefore somewhat set by the alluvial constant head cells.

2. The no-flow portions of these external boundaries are far from the M3 pumping center, and actual conditions at this distance are not critical for the intended purpose of this model. More importantly, a highly accurate replication of shallow alluvial aquifer conditions is not necessary for the purpose of this model – to estimate drawdowns in the deep and shallow domestic aquifers associated with pumping at the M3 site.

3. Treating these values as no-flow is conservative, as it will tend to overestimate predicted drawdowns associated with pumping.

The exterior boundaries in layers 2 through 4 are all treated as no-flow. Horizontal flow is generally negligible in aquitards (layers 2 and 4); therefore, alternative representations are not needed. Surrounding the middle aquifer (layer 3) with no-flow conditions again provides conservative estimates of drawdown, which is the intended use of the model.

Layers 5, 6 and 7 all have the same boundary conditions with the exception that layer 7 has a no-flow boundary along the bottom of the layer. (Note: Section 5.3 discusses a sensitivity run where model simulation of layer 7 included upwelling from deep geothermal aquifers.) No-flow conditions are specified along the eastern half of the southern model boundary and the northern half of the western model boundary. Both of these external boundaries also include head-dependent boundary conditions (constant head and general head) which define inflows and out flows to the deep aquifer system. It was not necessary to specify head-dependent conditions along the entire length of the model's external boundaries to simulate the groundwater flow field. As described in Section 7, model predictions were performed in a conservative manner that maximizes drawdown and does not allow *any* additional flow to cross any of the model's exterior boundaries due to M3 pumping impacts.

4.3.2 Constant Head Boundaries

Constant head boundaries (CHB's) are specified in layer 1 and layers 5-7 (same in all three layers). The CHB's in layer 1 correspond to the upstream and downstream intersection of the stream alluvium with the external model boundaries, thus representing subflow into and out of the model domain. Head values were set based on river elevations in these locations. CHB's in layers 5-7 were positioned on the southern half of the western boundary and on the northwest corner of the model domain to represent subflow out of the PGSA and the Payette Valley aquifer, respectively. A small group of CHB cells was also placed against the no-flow cells representing bedrock to simulate inflow to the WCA. Head values at these locations were adjusted during calibration to match observed heads within the model domain. PGSA subflow into the model domain was simulated with a general head boundary (discussed below).

4.3.3 General Head Boundary

A general head boundary (GHB) was used to represent subflow into the PGSA along the southeast corner of model layers 5, 6 and 7. The GHB was preferred over a CHB due to the proximity of this external model boundary to the proposed M3 pumping center. The GHB places the location of the fixed head beyond the outer edge of the model domain. The GHB was conceptualized as a southwest-northeast trending line which is nearest to the model domain at the southeast corner of the grid. Distances from the exterior boundary of the grid to the "fixed head" simulated by the GHB ranged from around 2,500 feet at the southeast corner of the domain to as much as 34,000 feet at the GHB cells farthest from the corner. The "fixed head" location of the GHB represents an upstream location in the Boise River Valley where the PGSA has a stronger hydraulic connection to the river, its associated alluvium, and leakage from the New York Canal. The value of the fixed head was adjusted during calibration, and the hydraulic conductivity of the sediments between the GHB cells and the fixed head was maintained at or close-to the nearby hydraulic conductivity of the PGSA within the model domain (within a factor of 2). These adjustments were made to allow the model to generally match water levels measured across the City of Meridian in selected wells in the southeast portion of the model.

4.3.4 Recharge

Primary sources of recharge include precipitation, irrigation applications, seepage from ditches and canals, and effluent from septic systems. MODFLOW's recharge package was used to simulate areally distributed recharge over the uppermost aquifer in the model domain. Recharge was estimated for the primary sources and combined prior to model input. Total recharge is presented on **Figure 4-3**. The recharge input does not include seepage from the Boise and Payette rivers, which is simulated as a head-dependent boundary based on MODFLOW's river package.

Septic Recharge

Septic recharge was estimated based on well densities and the water budget evaluation of Urban (2004). The analysis assumed that there are 2.9 people per house at a recharge rate of 45 gal/day/person. For most of the model domain, HLI estimated septic recharge rates per quarter section based on well densities and the (conservative) assumption of only one house per well. After calculating recharge per quarter section, these values were distributed among the model grid cells using GIS (multiple cells may occupy the same quarter section in more refined portions of the grid). Initially, all quarter sections in the proposed model domain were analyzed for septic recharge. After a while it became apparent that a larger model area would reduce potential errors associated with pumping impacts reaching the boundaries of the model. A larger model was then constructed. Since an inventory of wells and septic drain field users had not been conducted in the newly added peripheral portions of the model, actual numbers were estimated. In these peripheral areas outside HLI's well-density accounting, recharge values were assigned (estimated) based on similar areas that were included in the well density analysis. Assigned values and the areas from which they were derived are listed on **Table 4-1**.

Ditch and Canal Recharge

Ditch/canal recharge estimation is based TVHP Water Budget Data (Urban, 2004). GIS analyses used the distribution of ditches, canals and surficial geology to calculate ditch recharge rates for high-permeability surficial geologic units. In the Boise River valley, a recharge rate of 0.75 cfs/mi was assigned to ditches/canals overlying high-permeability geologic deposits and 0 cfs/mi for ditches/canals overlying low-permeability geologic deposits. Geologic deposits were defined based on mapping by Othberg and Stanford (1992), with low-permeability units including Qbgc, Qs, Qwgs, Qwig, Tgf, and Ts and high-permeability units including the remaining mapped area. Outside the area mapped by Othberg et al, other areas with high-permeability deposits, including areas along the Payette River valley, received recharge values of 0.75 cfs/mile. HLI guided PGG in identifying these other high permeability areas, and PGG used GIS to calculate recharge per model cell based on the total length of ditches/canals in each cell.

Landuse Recharge

Landuse recharge includes recharge from incident precipitation and from irrigation applications. HLI estimated recharge rates based on the study by Urban (2004) as listed on **Table 4-2**. The landuse types in the model domain were identified based on GIS analyses. For model cells composed of more than one landuse type, weighted average recharge rates were computed. For areas without available landuse information, a minimal recharge rate (0.02 ft/yr) was applied as scrubland or grassland.

4.3.5 Wells

Groundwater withdrawals consist of water that is pumped from municipal, industrial, agricultural, and domestic wells. Domestic wells are typically shallower than water-supply wells for the other uses, and this analysis assumes that domestic wells withdraw from model layer 3 ("Middle Aquifer") whereas municipal, industrial, agricultural uses withdraw from layers 5-7 (PGSA). MODFLOW's well package was used to represent groundwater withdrawals.

Municipal and industrial groundwater withdrawals were estimated based on water right records by assuming that 15% of the allowable water-right amounts were actually used on an average annual basis. The 15%-use factor was based on review of consumption and water rights data for the Eagle Water Company (no other water use data were available from other municipal systems in the study). Water rights were compiled per quarter section and then distributed among associated model cells using GIS. In addition, for each model cell, pumping was distributed evenly between PGSA layers 5, 6, and 7. Details on pump-

ing rates for municipal and industrial groundwater withdrawals are available digitally on a CD provided with selected copies of this report.

Groundwater withdrawals for irrigation were estimated based on typical irrigation application rates, the distribution of irrigated acres, and whether a cell was likely to be irrigated from groundwater or surface-water sources. A linear application rate of 2.6 ft/year was estimated for irrigated areas of the model domain and the distribution of irrigation was identified based on irrigated areas stated in the water rights ("AFA"). In order to differentiate irrigated areas served by groundwater from those served by surface water, PGG used GIS to evaluate land-surface elevations relative to nearby ditch elevations. For the irrigated areas where land surface elevations exceeded nearby ditch/cannel elevations, all the water used for irrigation was assumed to be withdrawn from the PGSA. For irrigated areas where land surface elevations were below the ditch/cannel elevations, the areas were considered primarily irrigated by surface water, and only 10% of the irrigation application was assumed to be extracted from aquifer. Similar to the municipal and industry withdrawals, withdrawals were evenly distributed vertically throughout the three PGSA layers. Details on pumping rates for irrigation withdrawals are available digitally on a CD provided with selected copies of this report.

Domestic well pumping was estimated based on data derived from Treasure Valley Hydrologic Project (Urban, 2004, page: 3-9) which referenced an average household of 2.9 people using an average of 230 gal/day/person. HLI provided PGG with estimates of numbers of wells per quarter section based on Well Driller's Records on file with the Idaho Department of Water Resources (IDWR). PGG estimated domestic pumping by assuming a single household per well, and defined associated model withdrawals from the "Middle Aquifer" in layer 3. Similar to estimation of irrigation recharge, there were portions of the model domain that did not receive HLI's formal analysis after the model domain was enlarged. Instead, domestic pumping rates (cfs per quarter section) were assigned based on similar areas within the model domain. These assignments are summarized in **Table 4-1**. Details on pumping rates for domestic groundwater withdrawals are available digitally on a CD provided with selected copies of this report.

MODFLOW's well package was also used to "inject" water into the shallow groundwater system along the eastern model boundary, where Dry Creek enters the model domain and loses its water to streambed seepage. A cluster of small model cells can be seen along the bedrock (inactive cell) boundary in layer 1 (**Figure 4-1**), from which 8 cfs of water was injected into the aquifer. The value of 8 cfs was based on mean stream flow derived from USGS monitoring records from the Dry Creek stream gauge.

4.3.6 Rivers

MODFLOW's river package was used to simulate groundwater exchanges (gains and losses) with the Boise and Payette rivers. The rates of flow between rivers and an underlying aquifer are calculated in each simulation based on river stage, surrounding groundwater levels, the footprint of the riverbed, and riverbed conductance characteristics. Groundwater moves into the rivers if surrounding groundwater levels are higher than the river stage and vice versa if the groundwater levels are lower than the river stage. Major canals (e.g., New York Canal) were not simulated as river features because seepage from these channels was included in the recharge estimates.

GIS analyses were used to determine the length of the river segment within the model cell. A river width of 80 feet was applied to both Boise River and Payette River. River stage elevations were defined based on topographic contour elevations. The riverbed was assumed to be 4 feet less than the river stage. The riverbed hydraulic conductance is defined as:

$$COND = M/K_R L_R W_R$$

where K_R is the hydraulic conductivity of the riverbed material, L_R is the reach length, W_R is the river channel width, and M is the riverbed thickness (McDonald and Harbaugh, 1988). While K_R, and M may vary throughout the model domain, PGG generalized these to uniform parameters for each river. M for both rivers was assumed to be 5 feet. Values of K_R were adjusted during calibration, and ultimately ranged from 10 to 225 feet/day.

MODFLOW's river package was also used to simulate Lake Lowell in model layer 1 (**Figure 4-1**). The lake elevation (2,520 feet above mean sea level) was derived from the USGS topographic map. A lakebed thickness of 5 feet was assumed, and the hydraulic conductivity of the lakebed was adjusted to 0.01 feet/day during calibration to achieve a reasonably low rate of seepage loss. According to Freeze and Cherry (1979), this value represents the permeability of silt.

4.3.7 Vertical Low Permeability Boundary

A vertical low permeability boundary ("flow barrier") was used to extend the hydraulic disconnect where the contact between the bottom of the Pierce Gulch Sand Aquifer and the underlying clays and mudstones of the Terteling Springs Formation crops out at or near ground surface. No significant quantities of groundwater can flow across this contact because of its low permeability and the unsaturated nature of the Pierce Gulch Sand Aquifer at this location. The flow barrier extends through all model layers, and is shown on **Figure 4-1** as a purple line. Whereas the no-flow cells that directly represent the contact allow no groundwater flow to cross the contact, the flow barrier cells to the northwest allow limited flow in the region where the Pierce Gulch Sand Aquifer and WCA begin to co-mingle. The flow barrier was assigned a thickness of 1 feet and a hydraulic conductivity of 0.005 ft/day (equivalent to a 10 foot thick barrier with a permeability of 0.05 ft/day or according to Freeze and Cherry (1979), equivalent to silty sand).

4.4 AQUIFER AND AQUITARD PROPERTIES

The hydraulic properties of aquifers and aquitards are specified in the model using hydraulic conductivity (K), storage coefficient (S), and specific yield (S_y). Hydraulic conductivity can be further separated into its horizontal and vertical components (K_h and K_v). PGG used a method of zonation, where zones of like aquifer properties are distributed over continuous regions of active model cells. Groundwater Vistas calculates the transmissivity of a model layer based on its thickness and its K_h.

4.4.1 Hydraulic Conductivity

Zones of like K_h and K_v were sometimes designated across entire hydrostratigraphic units and sometimes designated as sub-regions within a given hydrostratigraphic unit. **Figures 4-4** through **4-6** show the K zonation throughout all of the model layers, and **Table 4-3** summarizes K values per zone for both versions of the model. Uniform, homogeneous K_h/K_v combinations were assigned to all aquifers and aquitards with the exception of the PGSA. This apparent simplification is justified where little information is available about hydrostratigraphic units. Not adding unwarranted complexity is referred to as the "principal of parsimony". The PGSA was assigned several zones based on analysis of aquifer test data in multiple wells. Values of K_h and K_v for individual zones were adjusted during calibration, and the boundaries of various sub-regions were sometimes shifted within the PGSA during calibration. Hydrostratigraphic units represented with a single zone include:

- The WCA is represented by Zone 10 in all layers from the land surface to the bottom of the model. The WCA occurs in the northeast portion of the model domain north and northwest of the contact be-

teen the Pierce Gulch Sand Aquifer and the underlying clays and mudstones of the Terteling Springs Formation. As with most aquifers, Zone 10 was assumed to have an anisotropy ratio (K_h/K_v) of 10, which remained constant during model calibration.

- Payette River shallow alluvium is represented by Zone 9 in layer 1 and parts of layer 2 (where layer 1 is thin). Zone 9 was assumed to have an anisotropy ratio of 10, which remained constant during calibration.
- Payette River valley fill is represented by Zone 6 in layers 2 through 7 with an anisotropy ratio of 1000. This high anisotropy reflects the fact that the valley fill contains both aquifers and aquitards (which significantly retard vertical flow). The anisotropy of Zone 6 was varied between 100 and 1000 during calibration.
- Boise River alluvial sand and gravel deposits are represented by Zone 7 in model layer 1. Zone 7 was assumed to have an anisotropy ratio of 10, which remained constant during calibration.
- Upland surficial aquifer deposits are represented by Zone 4 in the higher-elevation portions of model layer 1. Zone 4 was assumed to have an anisotropy ratio of 10, which remained constant during calibration.
- Aquitards separating the surficial aquifers from the PGSA are represented by Zone 1 in layers 2 and 4. The aquitards are assigned relatively low K values, and were also assigned an anisotropy ratio of 10.
- The "Middle Aquifer", between the surficial aquifer and the PGSA, was represented by Zone 2 in layer 3 with a constant anisotropy value of 10.
- The PGSA is represented by multiple zones with the same zone distribution in layers 5, 6 and 7. Most zones were assigned anisotropy ratios of 10; however, Zone 11 was assigned a value of 100 during calibration. This higher value represents the hydraulic effects of thin and discontinuous clay layers interbedded within the Pierce Gulch Sand Aquifer which are more numerous and form a larger percentage of the aquifer in the western portion of the modeled area (as compared to the eastern portion of the modeled area).

Model layers 1 through 5 were all specified as MODFLOW layer type "3", which allows unconfined conditions if the layer is not fully saturated and "dry" conditions if the layer falls above the regional water table. Beneath the uplands, portions of the top several layers are expected to be dry for this reason. Model layers 5, 6 and 7 are designated as MODLFOW layer type "0", which is always saturated.

4.4.2 Aquifer Transmissivity

Transmissivity (T) was calculated for each layer by Groundwater Vistas as the product of K_h and thickness. Therefore, T was not directly assigned to the model layers. T values for the PGSA and the WCA were previously estimated based on aquifer testing in various production and irrigation wells, and are summarized in **Table 4-4**. During calibration, K values were varied to achieve the best matches with available data. For the Hmatch model, acceptable ranges of K values were chosen such that the average simulated T values for each zone were within a range of one-third to three-times the average of the values estimated from aquifer tests within that zone. For the Tmatch model, PGG attempted to employ K values such that average simulated T values for each zone were within +/-50% of the average of the values estimated from aquifer tests within that zone (note that PGG employed log-averages for all averaging associated with T values, as T variations typically occur along a logarithmic distribution). Final distributions of PGSA T values from both versions of the model are discussed in Section 5.4.1.

4.4.3 Aquifer Storage Parameters

Values of storage coefficient (S) and specific yield (S_y) were adjusted during calibration. Acceptable values of S ranged from $5x10^{-3}$ to $5x10^{-5}$, whereas acceptable values of S_y ranged from 0.01 to 0.1 over short durations (e.g. 24-hour aquifer tests) and from 0.01 to 0.3 over longer durations (e.g. 30-day aquifer tests). Final calibrated values were S and S_y are discussed in Sections 6.4 and 6.5.

5.0 STEADY STATE MODEL CALIBRATION

Calibration is the process of adjusting model parameters (e.g. K_h, K_v) within acceptable, representative ranges to achieve the best match between model predictions and actual observations from the groundwater flow system. Flow system observations fall into two categories: "targets" and "prior information". Targets can be actual measurements of groundwater levels ("heads"), drawdowns in response to pumping, and/or gains or losses to surface water features ("streamflow seepage"). During steady state calibration, targets consisted primarily of head targets from water level elevations measured in wells. PGG also checked the model mass balance to ensure that predictions of streamflow seepage losses/gains were within reasonable orders of magnitude. Prior information includes knowledge gained from interpretation rather than direct measurement. Examples may include HLI's interpreted aquifer transmissivity values from pumping tests and associated hydraulic influence of boundaries within the flow system. During calibration, PGG referenced such transmissivity values to constrain K values assigned to the PGSA.

During calibration, it became apparent that not all of the head targets could be matched while honoring the prior-information transmissivity values estimated from aquifer testing. Specifically, the model tended to predict heads in the M3 vicinity lower than observed water-level elevations. In order to maximize confidence in observed head targets, HLI had the wellheads of key observation points surveyed to obtain better estimates of elevation. The model's difficulty in predicting heads near the M3 site suggest that either interpreted T values for the PGSA are not representative, or that the groundwater flow system contains additional complexities not indicated by the currently available data. In order to address the uncertainty associated with these possibilities, PGG expanded our calibration analysis to include two versions (realizations) of the model:

1. The "Tmatch" model realization maintained T values associated with the PGSA K zones that best honored prior-information T values.
2. The "Hmatch" model realization allowed larger departures from the prior-information T values in order to obtain better matches to water-level targets in the M3 Eagle vicinity.

Both model realizations are included in descriptions of steady-state and transient calibration. Both model realizations were used for predicting drawdowns associated with proposed M3 Eagle pumping.

5.1 TARGETS AND PRIOR INFORMATION

Table 5-1 presents a summary of the water-level targets used during steady-state calibration. Of the 37 wells, 13 are completed in the PGSA[2], 3 are completed in undifferentiated sediments above the PGSA, one is completed in the WCA, and 5 are completed in sediments interpreted to be laterally continuous with the PGSA and/or WSA. These 5 wells are located near Emmett in the Payette River valley, where hydrogeologic units have not been explicitly defined. However, the completion elevations and high

[2] PGSA completion is uncertain for two of these wells.

transmissivities of these wells are similar to both the PGSA and WCA, and hydrogeologic interpretation by HLI suggests that the sediments in which they are completed are likely hydraulically connected to both aquifers. The accuracy of target elevations is a function of accuracy of well head elevation and accuracy of depth to water. Surveyed well heads had elevation accuracies of 0.±08 ft. In the cases of monitoring wells under the control of HLI, water level accuracies were on the order of ±0.03 ft. In wells that were not surveyed and elevations were derived from the combined use of Google^{tm} Earth and USGS topographic maps the well head accuracies were on the order of ±20 ft. In domestic or other pumping wells were water levels may have been recovering from undetected pumping prior to measurement (and water levels may have been recovering) water levels representative of non-pumping conditions have an estimated accuracy of ±20 ft. At the extremes, we believe surveyed monitoring wells had water level elevations with a combined accuracy of about ±0.1 ft, while a non-surveyed supply wells had a combined accuracy of ±40 ft. HLI provided estimates of seasonal groundwater level fluctuations, which have been observed to range from 5 to 15 feet within the Eagle-Star-M3 vicinity.

Table 4-4 presents prior-information T values for wells tested in the PGSA and the WCA. Based on HLI's interpretation, T values in the PGSA range from about 5,000 to 110,000 ft^2/day. Interpreted T values for wells tested in the WCA range from 7,000 ft^2/day to 130,000 ft^2/day. Confidence in the reported T values varies, as some of the aquifer tests were not optimally conducted or showed complex responses.

Summary statistics are used to assess the "match" between observed and modeled heads and to evaluate whether the model is well calibrated. A well calibrated model strives to minimize the difference between observed and modeled heads (residual). Three statistics are generally used to evaluate the minimization of residual values. The residual mean (RM) is the sum of all residuals divided by the number of targets. Some residuals are positive and some negative and a well calibrated model that balances the two would result in a low RM-value. The Absolute Residual Mean (ARM) is the sum of the absolute values of the residuals divided by the number of targets. The ARM statistic is a measure of the overall average error. Finally, a comparison of the residual standard deviation to the overall range in target values throughout the model is assessed, with a value less than 10% generally considered good. The statistics indicate acceptable calibration results for both model realizations, as discussed in Section 5.4.2.

5.2 CALIBRATION PARAMETERS

Parameters varied during steady state calibration included K_h values of aquifers and aquitards, riverbed hydraulic conductivity (K_r) for the Boise and Payette rivers, and head values for the CHB's and the GHB.

Table 4-3 presents the acceptable ranges of K_h and K_v considered during calibration. Acceptable K_h ranges were based on sedimentary texture and conform with typical published values (e.g. Freeze and Cherry, 1979). The anisotropy values shown on **Table 4-3** were all held constant during calibration, except for the Payette River valley fill where anisotropy was allowed to range from 100 to 1000. These relatively high anisotropy values reflect the fact that the Payette River valley fill contains silty zones that were not explicitly simulated as aquitards, but were instead implicitly represented in the bulk properties of the unit. **Table 4-3** also presents the final values of K_h and K_v derived during the steady state calibration. As previously noted, the spatial distributions of parameter zones are presented in **Figures 4-4** through **4-6**.

Head values for the CHB's and GHB were adjusted manually to improve head matches near the boundaries and throughout the model domain.

5.3 STEADY STATE SENSITIVITY ANALYSIS

During the early phases of steady state calibration, PGG performed an initial sensitivity analysis to evaluate which model parameters had the greatest influence on calibration residuals (heads). Parameters considered in the initial sensitivity analysis included: Kv of aquitards (Zone 1 and anisotropy in Zone 6), Kr of riverbeds and lakebeds, head and conductance for GHB, and Kh for four zones within the PGSA. The sensitivity analysis provided the following insights:

- Calibration residuals were much more sensitive to the Kv of the regional aquitards than the anisotropy within the Payette River valley fill sediments (Zone 6). Relative to other parameters considered, aquitards Kv had a relatively large influence on calibration residuals.
- The model showed relatively low sensitivity to values of riverbed Kr. This is likely due to the fact that the shallow aquifer systems that are hydraulically connected to rivers are separated from the deeper PGSA by two aerially extensive aquitards, and because most of the calibration targets occur in the deep aquifer system.
- Calibration residuals showed relatively low sensitivity to the conductance value specified for the GHB, but very high sensitivity to the GHB head value. By inference, calibration residuals will also be quite sensitive to the CHB head values for the PGSA in layers 5 through 7.
- Calibration residuals showed low to high sensitivities to PGSA Kh zones, depending on the location of the zone. In general, zones that connected portions of the aquifer system (with calibration targets) to CHB's and GHB's had the highest sensitivities.

PGG also evaluated model sensitivity to upwelling into the PGSA from a deeper (hydrothermal) aquifer. Inflow from upwelling was estimated with Darcy's Law (Freeze and Cherry, 1979) assuming aquitard materials between the PGSA and an underlying geothermal aquifer with a Kv representative for clay of 1e-8 cm/sec (0.00003 ft/day). The hydraulic gradient into the PGSA was 0.05, based on measurements at UWID State and Linder wells. Inflow from upwelling was applied to the bottom of the PGSA (layer 7) by placing "injection wells" in each model cell, where flows were calculated based on flux (Darcy's Law) and the areal footprint of the cell. Including upwelling from the deeper aquifer caused an insignificant change in modeled head in the PGSA (maximum increase less than 0.1 feet). For this reason, upwelling was not carried forward in subsequent model calibration. Not simulating upwelling was also considered to be conservative for estimating drawdown due to proposed M3 Eagle pumping, as leakage from a deeper aquifer would tend to slightly reduce PGSA drawdowns associated with PGSA pumping.

5.4 CALIBRATION RESULTS

5.4.1 Calibration to Observed Transmissivity

The spatial distribution of transmissivity (T) values within the PGSA for the Tmatch and Hmatch models are shown in **Figure 4-7 (**associated calibrated hydraulic conductivity values are reported on **Table 4-3).** HLI's T value estimates from pumping tests are also plotted on the figure for comparison. Estimated T values are limited to areas within the vicinity of the M3 project site and southward. Twenty-five estimated values are available for comparison and range from about 5,000 ft^2/day to 130,000 ft^2/day with a log-average of about 21,000 ft^2/day.

The T estimates are fairly well represented in the Tmatch model, with values ranging smoothly from about 12,000 ft^2/day to 53,000 ft^2/day within the project site area and southward. A moderately high T zone ranging from 30,000 to 60,000 ft^2/day is represented within a portion of the M3 project site (Zone 12

in **Figure 4-6**). This slightly higher zone is based on an estimated value from two pumping tests at that location. The final log average T values for each zone are within the acceptable range of +/-50% of the observed log average T value in each zone, except for Zone 13 where the simulated log average T value is about 80% above the observed value.

Model T values show greater departure from the estimated vales in the Hmatch model (The basis for the Hmatch model calibration is discussed in the following section). The final log average T values for each zone are within the acceptable range of one-third to three-times the observed log average T value in each zone. Simulated T values in the Hmatch model also show stronger contrasting T zones with log average zone values ranging from about 5,800 ft^2/day to 46,000 ft^2/day. The stronger contrasts in values in the Hmatch model are due to low and high permeability zones added to the Hmatch model during calibration to improve the match between simulated and observed head targets. Both models; however, simulate log average T values within the range of values estimated from pumping tests.

5.4.2 Calibration to Observed Heads

Target residual values (observed minus modeled head) and calibration statistics for both models are summarized in **Table 5-1. Figure 5-1** provides a graphical comparison of observed versus modeled heads, and **Figure 5-2** shows the spatial distribution of calibration residuals for both models. Both models match the observed heads fairly well throughout the model domain except in the area of the M3 project site, where the Tmatch model simulated heads that are about 25 ft below the target heads. In order to achieve a better match to head targets in this area, the hydraulic conductivity zones in the PGSA were slightly modified. This was accomplished by extending a high hydraulic conductivity zone (Zones 3 and 5 in **Figure 4-6**) south of the project site along the eastern margin of the model domain. Zones 13 and 15 immediately west of these higher zones were also reduced by 2.5 to 5 times their values in the T Match model, a change supported by the conceptual model for the stratigraphy of the area. This change resulted in additional groundwater influx towards the project site and a subsequent higher simulated head value. Head targets within the M3 project site of the Hmatch model are within 10 ft of the observed values. Recent magnetometer data suggest there may be a northwest-southeast trending fault in the vicinity of the boundary between the high and low hydraulic conductivity zones represented in the Hmatch model. A low-permeability fault would have the same effect of focusing additional groundwater influx to the project site, although such a fault was not included in this modeling effort.

The residual calibration statistics for both models are summarized in **Table 5-1**. The residual mean (RM), absolute residual mean (ARM) and percentage of the residual standard deviation to the observed head range (RSD/R) are 2.71 feet, 13.99 feet, and 6.25% respectively for the Tmatch model and 2.82 feet, 9.75 feet, and 4.84% respectively for the Hmatch model. Based on the calibration criteria discussed above and the overall accuracy of the head targets shown on **Table 5-1**, these statistics indicate acceptable model calibration. The lower ARM and RSD/R values in the Hmatch model indicate a superior match to the observed heads.

5.4.3 Mass Balance

Table 5-2 presents a water budget summary for both the Tmatch and the Hmatch models. Water budget components are expressed as net inflow to the model, with negative values symbolizing model outflows. The water budget was reviewed during calibration, with attention primarily focused on the PGSA components. Primary components of inflow to the model include recharge, upgradient "subflow" in the alluvial sediments along the Payette River, and PGSA inflow from the GHB located in the southeast corner of the model. Primary components of outflow from the model include the Boise and Payette Rivers and groundwater pumping. Total groundwater pumping represents about 7 percent of the total model inflow.

The model ultimately represented several boundary conditions first conceptualized as "outflow" or "inflow" boundaries with flow in the opposite direction. Specifically, the PGSA CHB along the southwest model boundary and the Payette River valley fill aquifer CHB along the northwest model boundary both showed small inflows after calibration was complete, and the WCA CHB along the northeast model boundary showed a small outflow. The latter two boundaries could have been adjusted during calibration to achieve the expected flow directions; however, their influence on PGSA conditions was too small to be concerned with during calibration and in fact, the WCA CHB could have been removed altogether. Inflow or outflow are both acceptable from the PGSA CHB along the southwest model boundary, as this boundary was designated to help match observed heads in this vicinity.

Model predicted groundwater inflow to the Boise and Payette Rivers is on the order of 570 and 390 cfs, respectively. These values appear to be on the high side, and may reflect higher-than-actual K_h values for the alluvial aquifers associated with these rivers. PGG did not attempt to calibrate the model to shallow flow-system conditions. Our goal during calibration was to ensure that a shallow flow system was both *represented* and *connected* to the deeper flow system via an aquitard portrayed with a reasonable estimate of K_v. The fact that the model predicts much of the water introduced to the shallow flow system to *remain* in the shallow flow system and discharge to the rivers rather than flow vertically downward to the deep system suggests that the K_v assigned to the aquitards (0.02 ft/day or $7x10^{-6}$ cm/sec) is likely conservative in restricting induced seepage during predictive simulations of proposed M3 pumping.

6.0 TRANSIENT MODEL CALIBRATION

The steady-state calibration described above strives to adjust model parameters so that long-term average conditions are well represented in the model. A transient calibration, on the other hand, strives to adjust model parameters so that time varying stresses (e.g. seasonal changes in recharge or pumping rates) and corresponding responses to the aquifer system are well represented in the model.

A transient calibration was performed for both the Tmatch and Hmatch models to match simulated groundwater drawdown responses to observed responses from aquifer testing conducted in the field. Adjustments to model parameters included changes within acceptable ranges to values of K, S and S_y within the PGSA aquifer. Two pumping tests conducted in the PGSA with observed drawdown over time in relatively nearby observation wells were available as calibration drawdown targets: a 7-day pumping test at Eaglefield #2 and a 30-day pumping test at Lexington Hills #1. Note that the transient calibration for the Tmatch model only involved a single simulation of the 7-day pumping test, while the transient calibration for the Hmatch model involved two simulations; one of the 7-day pumping test and one of the 30-day pumping test. Additional transient calibration is possible in the future using the 30-day test with the Tmatch model and/or the results of a recent 9-day long test on M3 Well SVR-7

An iterative calibration approach between the transient and steady state models was necessary to ensure a good calibration match to both steady state target values and transient target values. This involved, through trial and error, adjustments to K values within the PGSA that would provide a good fit to both steady state and transient target values.

6.1 TRANSIENT STRESS PERIODS AND INITIAL HEADS

Each aquifer pumping test simulation consisted of two stress periods. A stress period is a duration of time during which hydraulic conditions (e.g. groundwater pumping) are considered to be constant. Each stress period is further divided into time steps for which a solution to the groundwater model is solved. The first

stress period for both transient simulations consisted of 100 days divided into 30 time steps with no changes to hydraulic conditions (pumping, recharge, etc) imposed. This stress period was applied to ensure that the initial heads were stable in the transient model. The second stress period for both transient simulations consisted of the aquifer pumping test duration; 7-days with 40 time steps and 30-days with 30 time steps. Initial heads for both simulations were the steady-state calibrated head solution for each model.

6.2 SIMULATED PUMPING AND OBSERVATION WELLS

HLI used geologist's lithologic logs, borehole geophysics and Well Driller's Reports to estimate which layers the pumping well is screened within the PGSA aquifer. The Lexington Hills #1 was assigned to the upper PGSA aquifer (layer 5) with a pumping rate of 732 gallons-per-minute (gpm) applied over the 30-day test period. The drawdown observation well for the Lexington Hills test, the Eagle Hills Golf Course well, was placed in the middle PGSA aquifer (layer 6). The Eaglefield #2 was assigned to layer 6 of the PGSA aquifer with a pumping rate of 1580 gpm applied over the 7-day test period. The drawdown observation well for the Eaglefield #2 test, monitoring well "UWIDState&Linder1A", was placed in the middle PGSA aquifer (layer 6). **Figure 6-1** shows the locations of these pumping and observation wells.

6.3 AQUIFER TEST RESULTS (TARGETS)

The observed drawdowns for the 7-day and 30-day tests and the final calibrated simulated drawdown using the Hmatch model are shown in **Figure 6-2**. The 7-day pumping test at the Eaglefield #2 resulted in about 5.5-ft of observed drawdown in the observation well after 7-days of pumping. The 30-day pumping test at the Lexington Hills #1 resulted in a little over 1-ft of observed drawdown in the observation well after 30-days of pumping. The final calibrated Hmatch model matches the observed drawdown for both tests fairly well (**Figure 6-2**). The 7-day pumping test simulated with the Tmatch model (**Figure 6-3)** was not as favorable without substantially decreasing the local transmissivity value of the aquifer as discussed below.

Calibration parameter adjustments, results, and the limitations of the Tmatch model to simulate the local 7-day pumping test are discussed below.

6.4 CALIBRATION PARAMETERS

Parameters adjusted during the transient calibration were K, S, and S_y within the PGSA. K-value zones 12, 13, 14, and 15 within the Tmatch model and K-value Zones 3, 5, 13, and 14 within the Hmatch model were adjusted within reasonable ranges during the calibration process (see **Figure 4-6** for zone maps). The calibration required an iterative trial and error process to achieve the best match to both steady-state and transient target values.

Simulated drawdowns were fairly sensitive to S values and it became necessary to create two zones of S-values in order to simulate the 7-day and 30-day pumping tests with the Hmatch model (**Figure 4-8**). A lower storage coefficient value (S=0.00035) was required to achieve a match to the 7-day pumping test and a higher value (0.005) was required to achieve a match to the 30-day pumping tests using the Hmatch model. The higher S-value boundary was chosen to correspond to the higher K-value Zones 3 and 5 extended in the Hmatch model. The same S-values and zonation were used in both the Hmatch and Tmatch models.

6.5 CALIBRATION RESULTS

The results of the transient calibration are plotted in hydrographs of observed and simulated drawdown (**Figures 6-2** and **6-3**). A fairly good match was achieved within acceptable ranges of aquifer parameter values for both pumping tests using the Hmatch model (**Figure 6-2**). The local transmissivity value required to match the 7-day pumping test and still maintain a good match to observed groundwater elevations in the Hmatch model was 7,700 ft^2/day. This is about 3 times less than the average transmissivity estimated from aquifer tests for this general area of the model (27,000 ft^2/day) and about 6 times less than the average transmissivity estimated from aquifer tests in the immediate vicinity of the 7-day pumping test (50,000 ft^2/day)

The Tmatch model also required a similarly low value of the local transmissivity to match the 7-day pumping test (from 41,000 ft^2/dy obtained during the steady state calibration to 7,500 ft^2/day). Since the Tmatch model was developed to emphasize a match to field estimates of transmissivity, the steady-state calibration values were honored over matching local aquifer conditions to the 7-day pumping test. The resulting Tmatch model under-predicts the 7-day final drawdown by about 35% (**Figure 6-3**). An attempt to simulate more drawdown by decreasing the S-value from 0.00035 to 0.0001 did not make a significant difference in the final simulated drawdown value. Therefore the same S and Sy zonation and values were left the same for both models.

Final calibrated aquifer property values for both models are summarized in **Table 4-3**. The mass balance error for all transient simulations was less than 0.02% and the additional pumping represented in the transient simulations is less than 0.5% additional mass flux in the model compared to the steady state models.

7.0 PREDICTIVE ANALYSIS

The two calibrated models were used to evaluate potential impacts from future water supply wells proposed at the M3 site. Transient simulations were performed to assess the impacts from adding progressively more water supply wells to the site. Impacts were evaluated by observing aquifer drawdown responses over time. Details of the predictive analysis are described below.

7.1 PREDICTIVE PUMPING RATES AND POINTS

The predictive simulations consisted of a 26 year (2009 to 2035) transient simulation with six proposed water supply wells progressively added every 4 years during the simulation. The locations of the six proposed water supply wells (PW #1, PW #3, PW #4, PW #5, PW #6 and PW #7) and schedule are shown in **Figure 7-1**. The locations were chosen by HLI and represent the approximate locations for future pumping wells. The exact locations may vary, depending on site specific topography, lot layouts and road designations. In the simulation, wells P1 and P4 begin operation in 2009, followed by P5 in 2013, P6 in 2017, P7 in 2021 and P3 in 2025. Each well operates at a constant rate of 1000 gpm once in operation and is assumed to fully penetrate the PGSA aquifer (layers 5 through 7). The model continues to run for another 10 years after the last well is added in order to observe maximum drawdown responses in aquifer.

A final steady-state simulation at full build-out pumping was performed to confirm that drawdown predicted at the end of the transient simulation is representative for long-term prediction.

7.2 PREDICTIVE DRAWDOWN

Figures 7-2 through **7-9** show "snapshot" maps of predicted drawdown in the PGSA after 4, 8, 16 and 26 years of pumping for both the Tmatch and Hmatch models. Steady state calibrated heads were used as the initial heads in the predictive simulations and the drawdown values shown in the figures are calculated as the change in the simulated heads over time compared to these initial heads. The series of snapshots shows how drawdown in the aquifer progresses with time during the 26 year simulation.

The predictive simulations indicate the drawdown at the end of the 26 year simulation in the PGSA aquifer occurs within the project site boundary near the proposed water supply wells with the largest drawdown centered on PW #3. In the general pumping vicinity, drawdowns of about 30-ft and 50-ft are (respectively) predicted by the Tmatch and Hmatch models. Larger drawdowns caused by well loss and aquifer conditions adjacent to the well screen are expected at the actual pumping wells, and will need to be evaluated during production-well installation and testing. Drawdown values decrease with distance from the M3 site, with both models predicting a maximum drawdown of about 5-ft in the vicinity of the Boise River (about 4 miles south of the project site).

Both predictive models were also run as steady state with all six proposed water supply wells pumping at 1000 gpm to evaluate the long term equilibrium drawdown. The results were essentially identical to the final drawdown at the end of the 26 year transient simulation, indicating the aquifer system has nearly approached equilibrium 10 years after the last well is brought into operation. In addition, PGG ran one of the predictive models in steady state with the PGSA GHB boundary (closest PGSA boundary to the M3 site) converted to a constant flux boundary, using the same flux as the steady state calibration (zero pumping from the M3 site). This formulation caused no significant change in predicted drawdown, thereby showing that the boundary is not inappropriately limiting drawdown by increasing model inflow.

Figures 7-10 and **7-11** show maps of predicted drawdown in the middle aquifer overlying the PGSA (layer 3) at the end of the 26 year simulation. The maximum drawdown in layer 3 at the end of the simulation is 20-ft for the Tmatch model and 25-ft for the Hmatch model. Note that in both models most of layer 3 is dry beneath the project site both before and after the proposed water supply wells are added to the models.

Figures 7-12 through **7-17** show hydrographs of simulated drawdown in the PGSA over time at the location of the proposed water supply wells and at six observation points south of the project site. Results from both the Tmatch and Hmatch models are shown in the figures. The location of the six observation points (M3 Site, Star #3, Eaglefield #2, Floating Feather, Lexington Hills #1, and Homer Road) are shown in **Figures 7-2** through **7-9**. Except for the Eaglefield #2 and Star #3 the simulated drawdowns are consistently higher in the Hmatch model. However, the differences between the two models are fairly small. Differences in predicted drawdown at the off-site wells range from 0.7 feet at Eaglefield #2 to 2.7 feet at Homer Road. The higher drawdown simulated at Eaglefield #2 and Star #3 with the Hmatch model is due to the lower K-value assigned in this area. Wells at on the M3 site exhibit 6 feet difference in simulated drawdown due to proximity to the pumping center.

8.0 MODEL USES AND LIMITATIONS

The following bullets summarize the appropriate uses and limitations of the model:

- Two model "realizations" were developed to bracket hydrogeologic representation of site conditions ("Hmatch" and "Tmatch"). Both models predict similar ranges of drawdown associated with pro-

posed M3 pumping within the PGSA. If future simulations are performed to estimate pumping drawdowns in the PGSA, both models should continue to be used to represent a range of predicted conditions.

- The model realizations are well suited for the designed purpose of predicting drawdown due to proposed M3 pumping from the PGSA. If a different pumping center not on the M3 site is simulated, model users should be careful to ensure that the pumping center is sufficiently far from CHB's and GHB's, so that pumping is not satisfied predominantly from these boundary conditions. As noted above, PGG confirmed that induced inflow from the GHB located immediately southeast of the M3 site does not inappropriately reduce predicted drawdown.

- Transient model calibration resulted in a specific zonation of S values within the PGSA. Calibration to additional aquifer tests could support further refinement of S zonation. Model users requiring highly accurate transient simulations should recognize that further refinement of the S zonation could effect the prediction of time-responses to pumping. PGG confirmed that transient predictions were approaching a steady state solution at late time (26 years of simulation).

- The model (i.e. both realizations) was not calibrated to hydrogeologic conditions in the shallow and middle aquifer systems. Model realizations should not be used to simulate hydraulic responses in either system without further calibration, nor should the water budget developed for these portions of the system be construed as accurate.

- The model (i.e. both realizations) was not calibrated to conditions in the WCA. PGG does not recommend using the model realizations for drawdown predictions in the WCA without additional WCA data collection and calibration. A CHB, positioned on the eastern (upgradient) extent of the CHB, has very little influence on the model. This CHB could be removed.

- Model calibration was performed to best available estimates of recharge, pumping, and target groundwater level elevations. Changes in the recharge estimates are unlikely to affect existing model calibration, as most of the recharge introduced to the model remains in the upper flow systems. Changes in PGSA pumping could affect model calibration, as could additional information data to be used for water level targets.

9.0 REFERENCES

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Table 4-1 Assigned Values of Recharge and Domestic Pumping in Peripheral Regions of the Model Based on Values from Similar Areas

Assigned to Section	Domestic Pumping Rates (cfs/Q Section)	Recharge Rates (cfs/Q Section)	Section Used to Originate the Average
T3NR1E	1.70E-04	3.33E-05	T4NR1E
T3NR1W	7.72E-05	1.51E-05	T4NR1W
T3NR2E	8.90E-07	1.74E-07	T4NR2E
T3NR2W	8.08E-05	1.58E-05	T4NR2W
T3NR3W	8.08E-05	1.58E-05	T4NR3W
T3NR4W	8.08E-05	1.58E-05	T4NR4W
T7NR3W, R4W, R1W	1.93E-05	3.78E-06	T7NR2W
T7NR1E	0.00E+00	0.00E+00	HLI direction
T6NR4W, R3W	5.32E-05	1.04E-05	T6NR2W
T5NR4W, R3W	4.93E-05	9.65E-06	T5NR2W
T4NR4W, R3W	8.08E-05	1.58E-05	T4NR2W
T6NR2E	0.00E+00	0.00E+00	HLI direction
T7NR3E	0.00E+00	0.00E+00	HLI direction

Table 4-2 Landuse Recharge for Combined Irrigation and Natural Precipitation

Recharge Rate (ft/yr)	Land Use No. (by HLI)	Dominant use within quarter mile
0.25	1	Urban/ Residential. Assumes mostly residential and that irrigation "excess" leads to recharge.
0.02	2	Dryland cropland pasture. Assumes AET uses almost all of "surplus" RF.
0.2	3	Irrigated cropland pasture - probable *ground* water source. Assumes power costs limit overwatering to quantities actually needed.
0.45	4	Irrigated cropland pasture - probable *surface* water source. Assumes flood irrigation and over watering.
0.11	5	Grassland/cropland mosaic. Assumes 50% each of 3 and 6.
0.02	6	Grassland. Assumes AET uses almost all of "surplus" RF.
0.02	7	Shrubland. Assumes AET uses almost all of "surplus" RF.
0.25	8	Evergreen needle/leaf forest. Assumes mostly Public/Recreational lands in Urban. Much is irrigated.

* Note: recharge values from the Treasure Valley Hydrologic Project (Urban, 2004)

Table 4-3 Summary of Calibrated Aquifer Property Zones

Zone Number	Description	Layers	Acceptable K or T Range During Calibration	"Tmatch" Model				"Hmatch" Model			
				Kh (ft/day)	Kv (ft/day)	Kh/Kv	S, Sy	Kh (ft/day)	Kv (ft/day)	Kh/Kv	S, Sy
1	Regional Aquitard	2 and 4	Kv range 0.003 to 0.3 ft/day	0.28	0.02	10	0.00035, 0.1	0.28	0.02	10	0.00035, 0.1
2	Middle Aquifer	3	K not varied during calibration	28.35	2.84	10	0.00035, 0.1	28.35	2.84	10	0.00035, 0.1
4	Upland Surficial Aquifer	1	Kh range 20 to 200 ft/day	100	10	10	0.00035, 0.1	100	10	10	0.00035, 0.1
6	Payette River Valley Fill	2 to 7	Kh 20-200 ft/day, Kh/Kv range from 100 to 1000	110	0.11	1000	0.00035, 0.1	110	0.11	1000	0.00035, 0.1
7	Boise River Alluvial Sand and Gravel	1	Kh range 1000 to 5000 ft/day	2834	283	10	0.00035, 0.1	2834	283	10	0.00035, 0.1
9	Payette River Shallow Alluvium	1 to 2	Kh range 1000 to 5000 ft/day	2000	200	10	0.00035, 0.1	2000	200	10	0.00035, 0.1
10	Willow Creek Aquifer (WCA)	1 to 7	Kh range 20 to 200 ft/day	110	11	10	0.00035, 0.1	110	11	10	0.00035, 0.1
11	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (5,092 ft2/d); Tmatch: +/- 50% of zone avg T (see note)	18.29	0.1879	100	(see note)	18.28	0.1879	100	0.00035, 0.1
12	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Tmatch: +/- 50% of zone avg T (40,000 ft2/d) (see note)	200	20	10	(see note)	n/a	n/a	n/a	n/a
13	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (17,087 ft2/d); Tmatch: +/- 50% of zone avg T (see note)	80	8	10	(see note)	15	1.5	10	0.00035, 0.1
14	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (33,194.66 ft2/d); Tmatch: +/- 50% of zone avg T (see note)	85	8.5	10	(see note)	35	3.5	10	0.00035, 0.1
15	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Tmatch: +/- 50% of zone avg T (17,345 ft2/d) (see note)	95	9	10	(see note)	n/a	n/a	n/a	n/a
3	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (23,465 ft2/d)(see note)	n/a	n/a	n/a	(see note)	125	12.5	10	0.005, 0.1
5	Pierce Gulch Sand Aquifer (PGSA)	5 to 7	Calibrated to T values. Hmatch: 1/3x to 3x zone avg T (17,395 ft2/d)(see note)	n/a	n/a	n/a	(see note)	220	22	10	0.005, 0.1
A	Riverbed K for the Boise River	1	10 - 1000 ft/day	n/a	10	n/a	n/a	n/a	10	n/a	n/a
B	Riverbed K for the Payette River	1	10 - 1000 ft/day	n/a	225	n/a	n/a	n/a	225	n/a	n/a

Notes:
Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity; T = transmissivity
The Tmatch model employs the same S/Sy zonation as the Hmatch model. These zones are shown for the PGSA on Figure 4.8.
Zone averages of T used for PGSA calibration are based on per-well T values presented on Table 4-4 (averages based on log averages)

Table 4-4 Summary of Prior Information Transmissivity Values from Aquifer Tests

Well ID	X	Y	Aquifer	Interpreted T Value (ft^2/d)	Interpreted T Value (gpd/ft)	Associated K Zone in Hmatch Model	Associated K Zone in Tmatch Model
KlingIrrigation	15888710	1784767	PGSA	4,900	36,750	13	13
M3-TW#1	15888355	1783754	PGSA	9,100	68,250	13	13
CarsonWell	15877225	1817228	PGSA	10,000	75,000	5	15
LexingtonHillsWell#1	15878263	1807674	PGSA	11,000	82,500	5	15
Legacy#1	15875774	1792090	PGSA	13,000	97,500	13	13
HolgateWell	15877828	1816709	PGSA	13,000	97,500	5	15
Star#1	15875728	1774447	PGSA	13,000	97,500	11	11
Star#3	15877429	1776912	PGSA	13,000	97,500	13	13
LDSEagle	15880313	1811730	PGSA	13,000	97,500	5	15
SVRWell#9	15896687	1803861	PGSA	16,000	120,000	5	15
RedwoodCreekWell	15875081	1801823	PGSA	17,000	127,500	3	15
RicksWell	15875081	1799323	PGSA	19,000	142,500	3	13
Meridian24-TEST	15849772	1795443	PGSA	23,000	172,500	14	14
UWIDStateandLinder1A	15872994	1794909	PGSA	27,000	202,500	13	13
FloatingFeatherIrrigationWell	15877591	1808490	PGSA	27,000	202,500	5	15
Meridian18-TEST	15851570	1806763	PGSA	32,000	240,000	14	14
Meridian19-TEST	15850820	1789997	PGSA	37,000	277,500	14	14
Meridian20-TEST	15851236	1800500	PGSA	37,000	277,500	14	14
SVR#7	15895143	1792303	PGSA	40,000	300,000	3	12
Meridian21-TEST	15839973	1801638	PGSA	40,000	300,000	14	14
EagleHillsGolfCourseWell	15875901	1816284	PGSA	60,000	450,000	5	15
EaglefieldWell#2(pumping)	15874442	1792983	PGSA	110,000	825,000	13	13
SVRWell#10	15904062	1805937	WCA	6,700	50,250	10	10
EmmettTW#9D	15934945	1778313	WCA	21,000	157,500	10	10
SVRWell#6	15901348	1797647	WCA	130,000	975,000	10	10

Note: Coordinate data, aquifer assignment and interpreted T values provided by HLI

Table 5-1 Summary of Target Values, Calibration Residuals, and Statistics

Well ID	Aquifer	X	Y	Row/Col/Layer	Observed Target Head (feet msl)	Weight	"Tmatch" Modeled Head (feet msl)	"Tmatch" Residual (feet)	"Hmatch" Modeled Head (feet msl)	"Hmatch" Residual (feet)
BIG-GULCH-STOCK	PGSA	1792066	15894335	44 / 74 / 6	2546	1	2527	19	2543	3
CityofEagle-Eaglefield	PGSA	1792983	15874442	74 / 75 / 6	2530	1	2534	-4	2527	3
CityofEagle-Legacy	PGSA	1792090	15875774	72 / 74 / 6	2525	1	2532	-6	2525	1
COLTONLaneBondCampbell	WCA	1776053	15905744	27 / 51 / 6	2358	1	2363	-5	2362	-5
EWC-WELL-3	PGSA	1815959	15876182	72 / 102 / 6	2570	1	2564	7	2577	-6
FLACK-4IN	PGSA	1797322	15898384	38 / 82 / 6	2555	1	2530	26	2547	8
FLACK-6IN	PGSA	1798272	15898438	38 / 83 / 6	2559	1	2530	29	2548	11
LITTLE-GULCH	PGSA	1800297	15896424	41 / 85 / 6	2556	1	2533	23	2550	6
M3-TW#1	PGSA	1783754	15888355	53 / 61 / 6	2504	1	2519	-14	2515	-10
M3-TW#2	PGSA	1793979	15898370	38 / 77 / 6	2551	1	2527	24	2544	7
M3-TW#3	PGSA	1785043	15898897	37 / 63 / 6	2528	1	2520	8	2531	-4
Meridian18-TEST	PGSA	1806763	15851570	92 / 90 / 6	2596	1	2606	-11	2610	-15
Meridian20-TEST	PGSA	1800500	15851236	92 / 85 / 6	2590	1	2594	-4	2592	-2
Meridian21-TEST	PGSA	1801638	15839973	97 / 86 / 6	2604	1	2630	-26	2630	-26
Meridian24-TEST	PGSA	1795443	15849772	93 / 78 / 6	2586	1	2589	-3	2582	4
Meridian26-TEST-1	PGSA	1805810	15860301	89 / 89 / 6	2583	1	2580	2	2587	-5
Meridian19-TEST	PGSA	1789997	15850820	92 / 70 / 6	2559	1	2576	-17	2565	-6
MOYLE	PGSA?	1780976	15872589	77 / 57 / 6	2503	1	2520	-17	2492	11
RIO-LOBO	PGSA	1740258	15908909	23 / 18 / 6	2413	1	2421	-8	2419	-7
RIVERBIRCH-GOLF	PGSA	1782324	15883356	61 / 59 / 6	2513	1	2518	-5	2504	8
S/L-EAST	PGSA	1794909	15872994	77 / 78 / 6	2530	1	2538	-8	2533	-4
S/L-WEST	PGSA	1794900	15872992	77 / 78 / 6	2530	1	2538	-8	2533	-4
SHALAKO	PGSA?	1739660	15909757	22 / 18 / 6	2416	1	2418	-2	2416	0
STAR-3	PGSA	1776912	15877429	70 / 52 / 6	2509	1	2510	-1	2478	31
SVR#6	WCA	1797644	15901350	34 / 82 / 6	2361	1	2361	0	2361	1
SVR#7	PGSA	1792303	15895143	43 / 74 / 6	2549	1	2527	23	2543	6
SVR#9	PGSA	1803869	15895751	42 / 88 / 6	2558	1	2538	21	2553	5
WILLOWBROOK	PGSA	1776266	15901879	33 / 51 / 6	2477	1	2504	-27	2479	-2
EmmetWell#9	WCA? / PGSA?	1778533	15928534	15 / 54 / 6	2383	1	2360	23	2360	23
EmmettTW-9S	WCA? / PGSA?	1778535	15928284	15 / 54 / 1	2383	0.02	DRY	N/A	DRY	N/A
EmmettTW-9M	WCA? / PGSA?	1778533	15928534	15 / 54 / 3	2383	0.2	2360	23	2360	23
EmmettTW-9D	WCA? / PGSA?	1778533	15928534	15 / 54 / 6	2384	1	2360	24	2360	24
EmmettWell#10	WCA? / PGSA?	1753130	15945710	8 / 24 / 6	2339	1	2318	21	2318	21
Caldwell#17Test	Above PGSA?	1726460	15842469	95 / 12 / 3	2430	0.2	2451	-21	2450	-20
NagelBev.Test	Above PGSA?	1753746	15841986	96 / 24 / 3	2460	0.2	2474	-14	2471	-11
Caldwell#19Test	Above PGSA?	1737638	15859014	89 / 17 / 3	2450	0.2	2423	27	2421	29
KLING-IRR	PGSA	1784767	15888710	53 / 63 / 6	2519	1	2520	-1	2520	0
CALIBRATION STATISTICS										
Residual Mean								2.71		2.82
Absolute Residual Mean								13.99		9.75
Range								265.34		265.34
Residual SD								16.58		12.83
Res SD/Range								6.2%		4.8%

Table 5-2 Water Budget for Steady State Model Calibrations

Water Budget Component	Boundary Type	Model Layer	Tmatch Net Inflow (cfs)	Hmatch Net Inflow (cfs)
Recharge	Recharge	Uppermost Active	542.44	542.44
Boise River Seepage	River	Layer 1	-573.27	-567.18
Payette River Seepage	River	Layers 1, 2, 3	-388.20	-387.58
Lake Lowell Seepage	River	Layer 1	16.59	16.73
Dry Creek Seepage Inflow	Wells	Layer 1	3.95	3.95
Domestic Pumping	Wells	Layer 3	-13.94	-13.93
Municipal, Industrial & Irrigation Pumping	Wells	Layers 5-7	-75.83	-75.83
Boise River Alluvial Aquifer Inflow	CHB	Layer 1	86.51	80.12
Boise River Alluvial Aquifer Outflow	CHB	Layer 1	10.76	10.91
Payette River Alluvial Aquifer Inflow	CHB	Layer 1	282.45	282.46
Payette River Alluvial Aquifer Outflow	CHB	Layer 1	-1.94	-1.93
PGSA Inflow from SE Model Boundary	GHB	Layers 5-7	102.79	101.86
PGSA Outflow at SW Model Boundary	CHB	Layers 5-7	6.33	6.52
Payette River Valley Fill Outflow	CHB	Layers 5-7	1.93	1.94
Willow Creek Aquifer Along NE Model Boundary	CHB	Layers 5-7	-0.46	-0.37
Model Mass Balance Error			*<1%*	*<1%*

VicinityMap.mxd

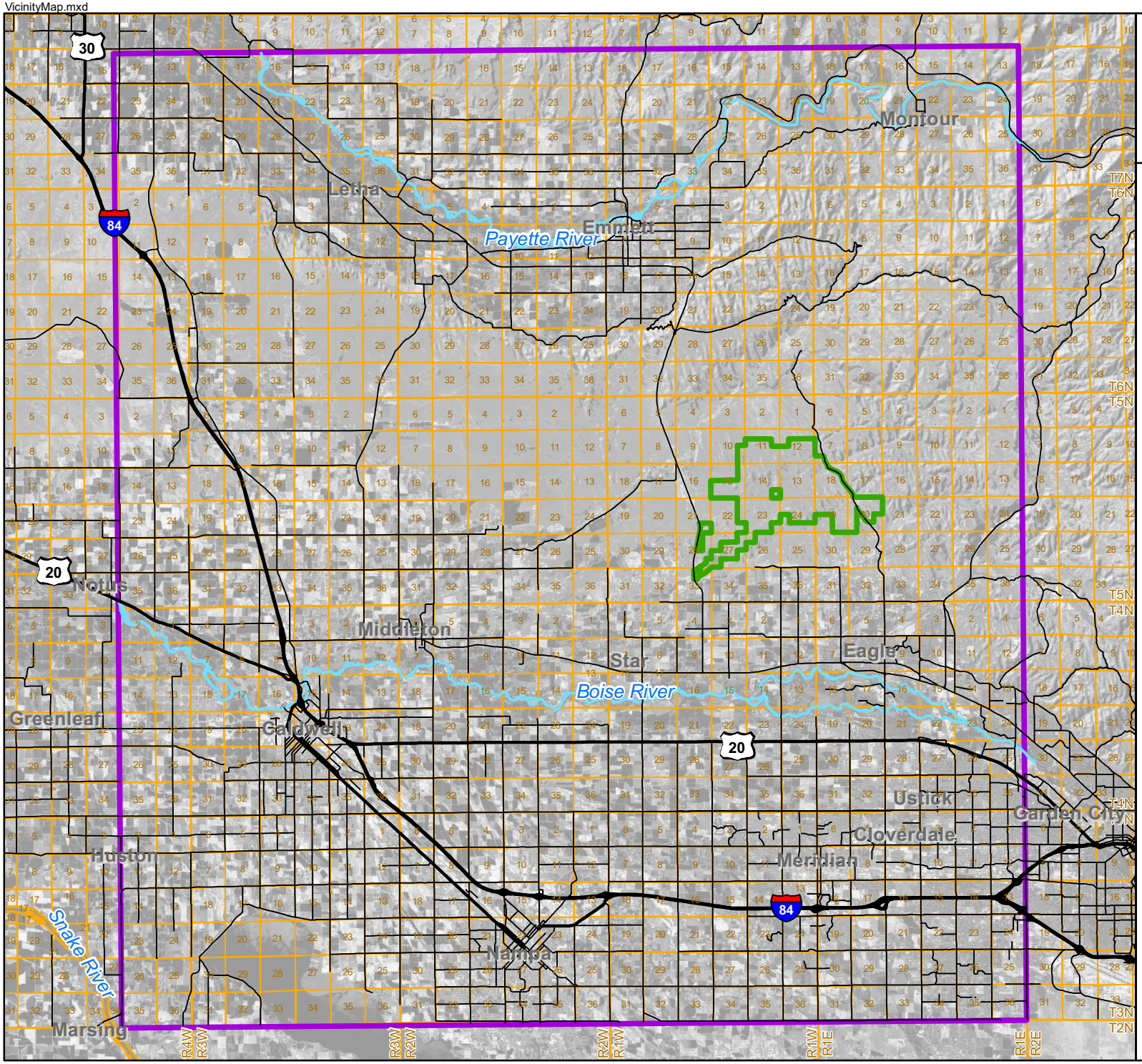


Figure 1-1

Vicinity Map

M3 Eagle Model
JZ0705

M3 Eagle Site Boundary

PGG Model Domain

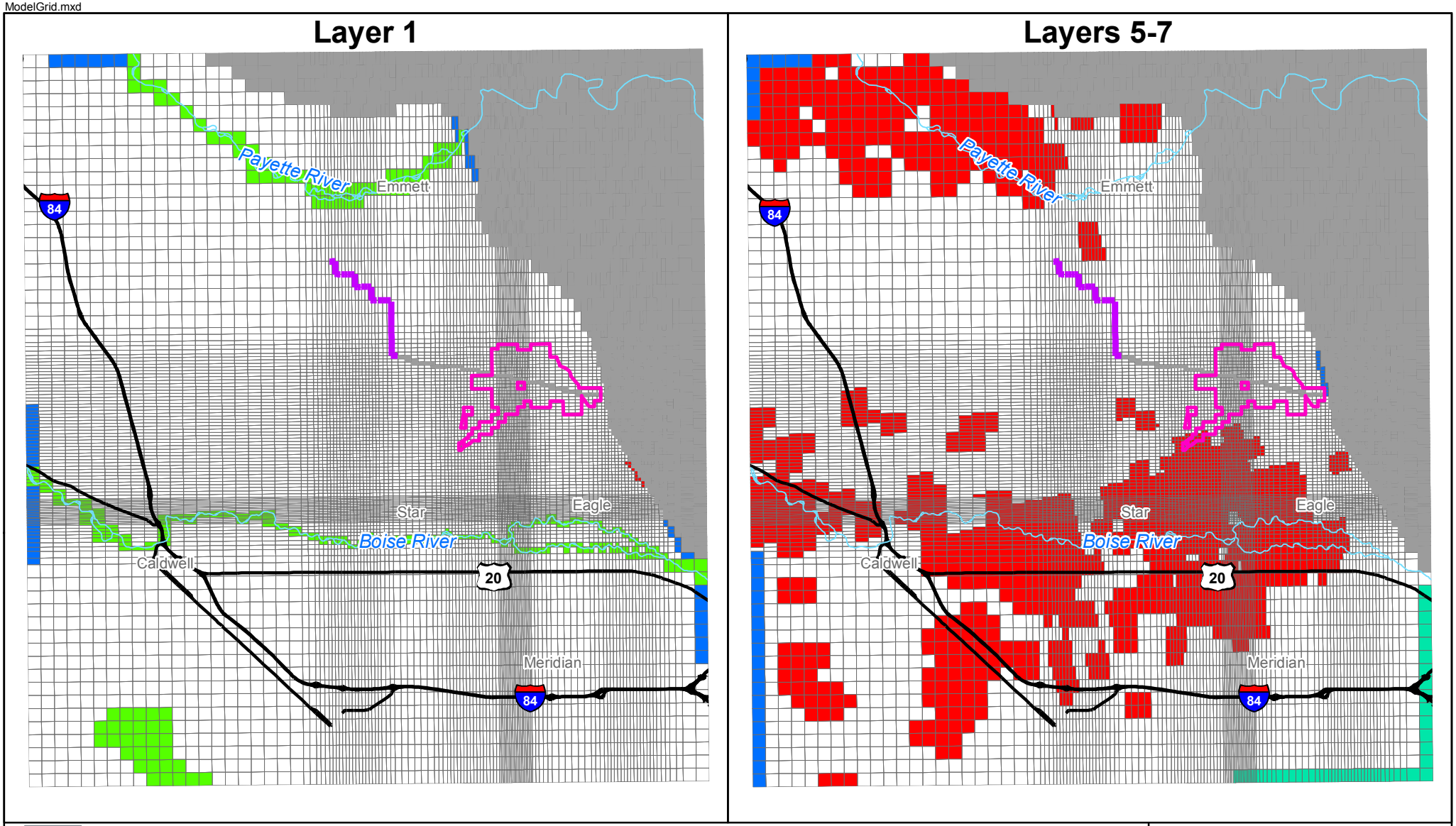
PgG

0 Miles 5

1:250000

N

ModelGrid.mxd



Constant Heads
No Flow
Rivers
Wells
General Head Boundaries
Model Grid
Flow Barrier
Highways
Site Boundary

PgG

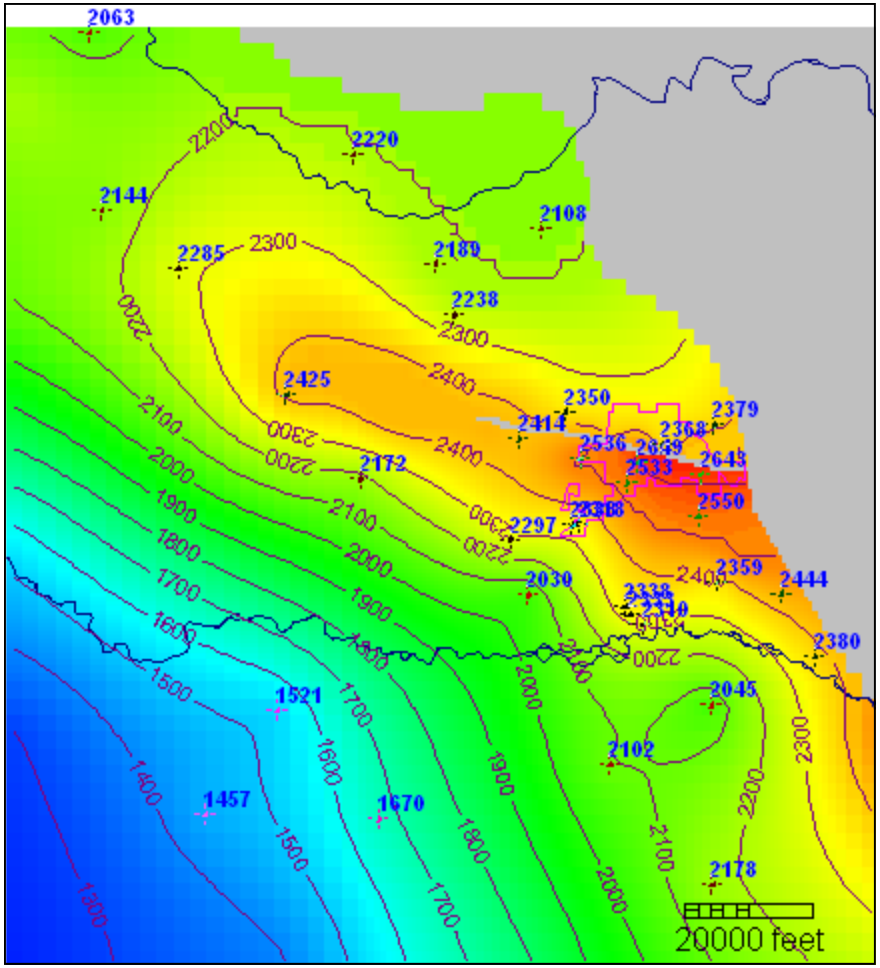
0 Miles 10 N

Figure 4-1

Model Grid and Boundary Conditions in Layers 1 and 5-7

M3 Eagle Model
JZ0705

Top of Layer 5



Bottom of Layer 7

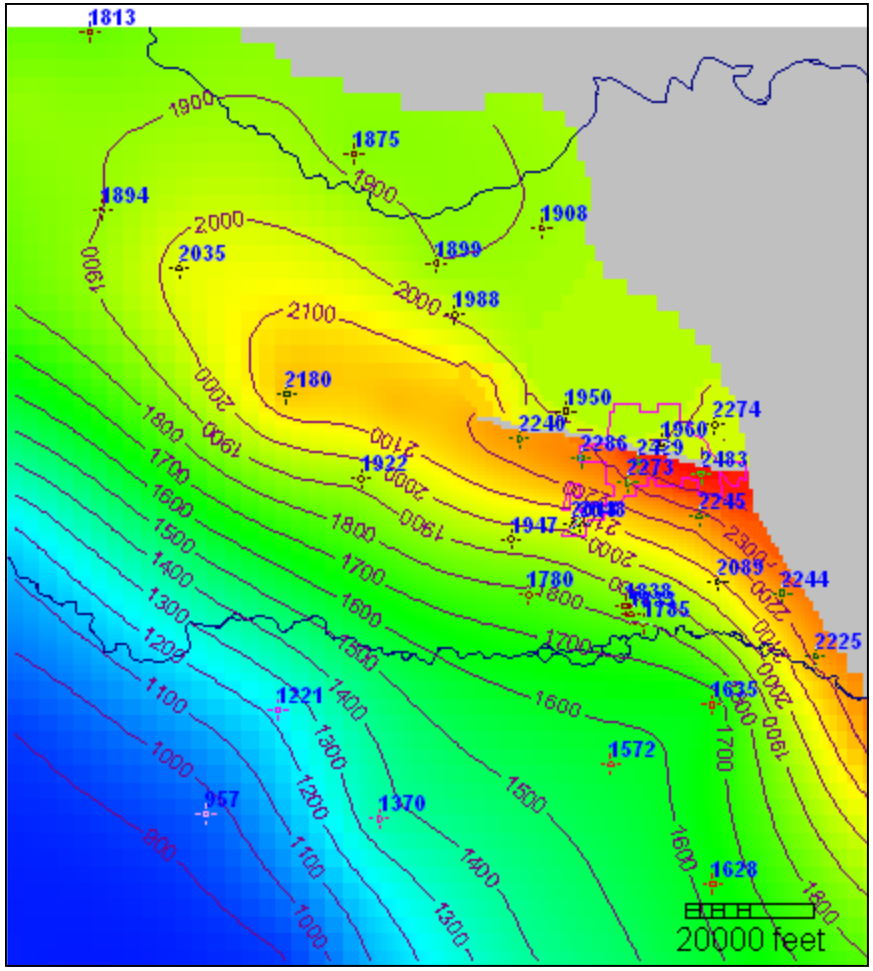


Figure 4-2
Reference Surfaces Used in Model Construction

M3 Eagle Model
JZ0705

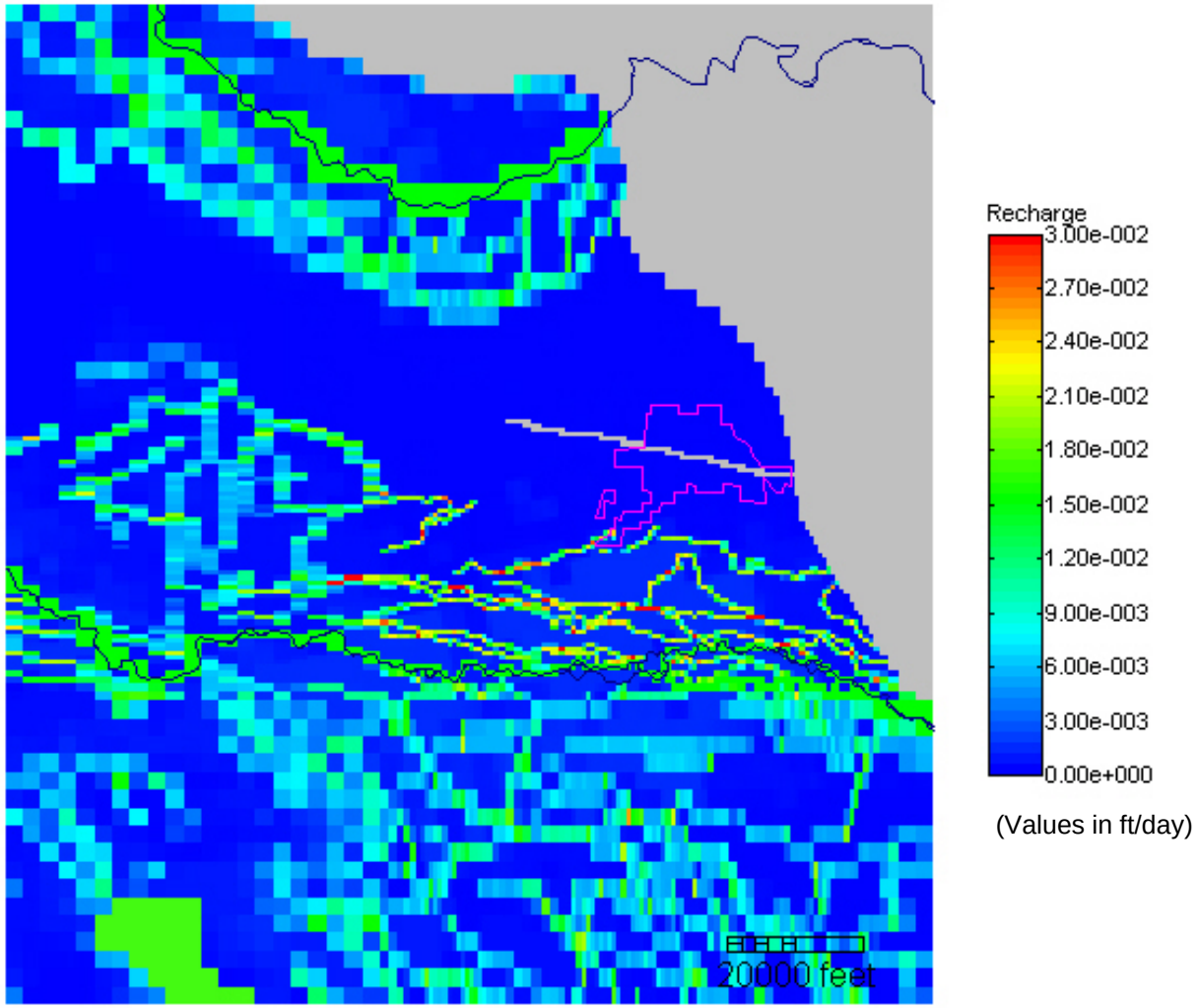
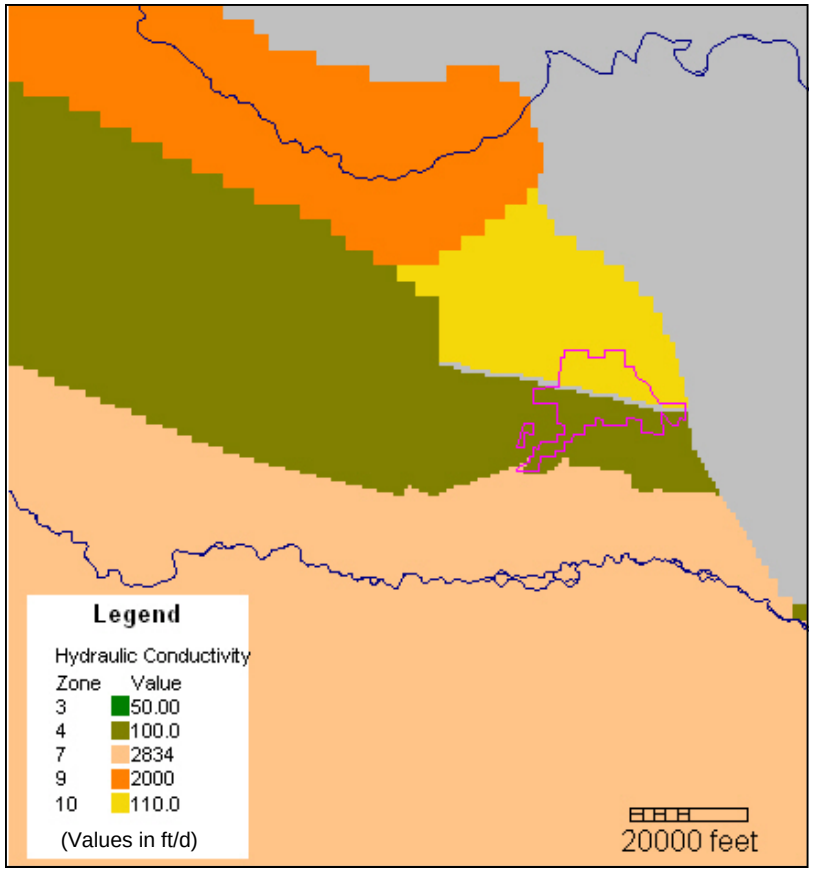


Figure 4-3
Distribution of Recharge

M3 Eagle Model
JZ0705

PgG

Layer 1



Layer 2

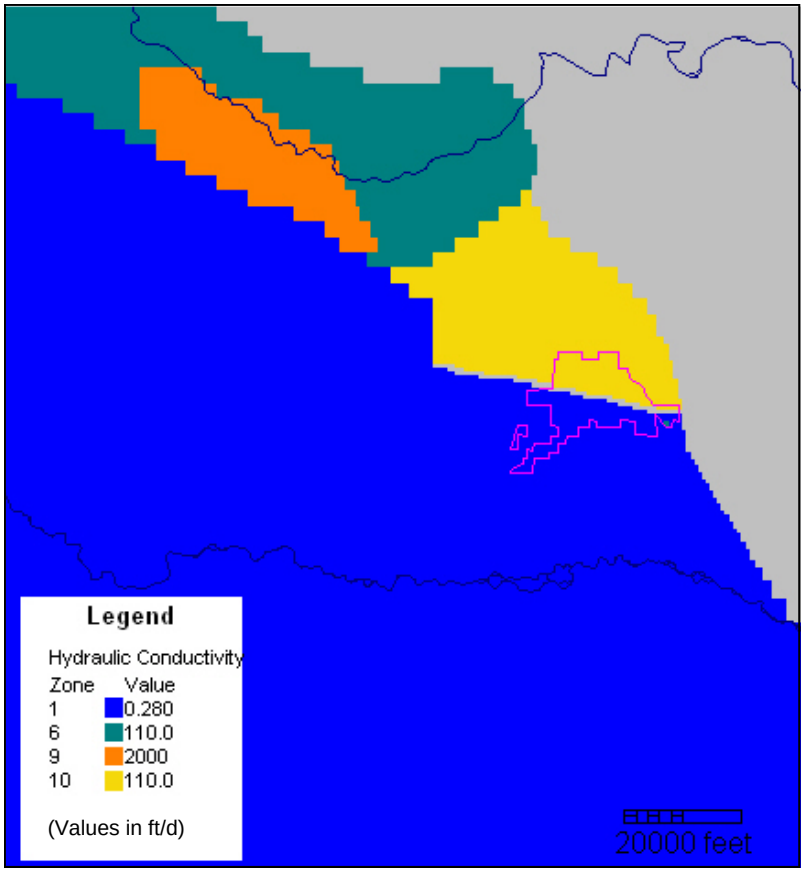
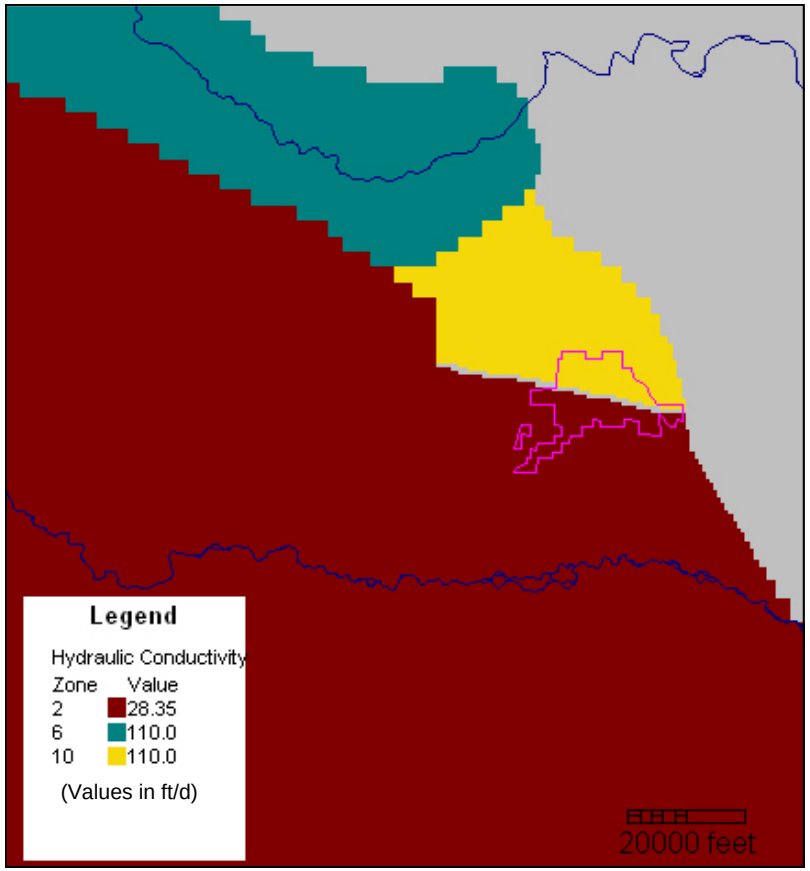


Figure 4-4
Hydraulic Conductivity Zones for Layers 1 and 2

M3 Eagle Model
JZ0705

PgG

Layer 3



Layer 4

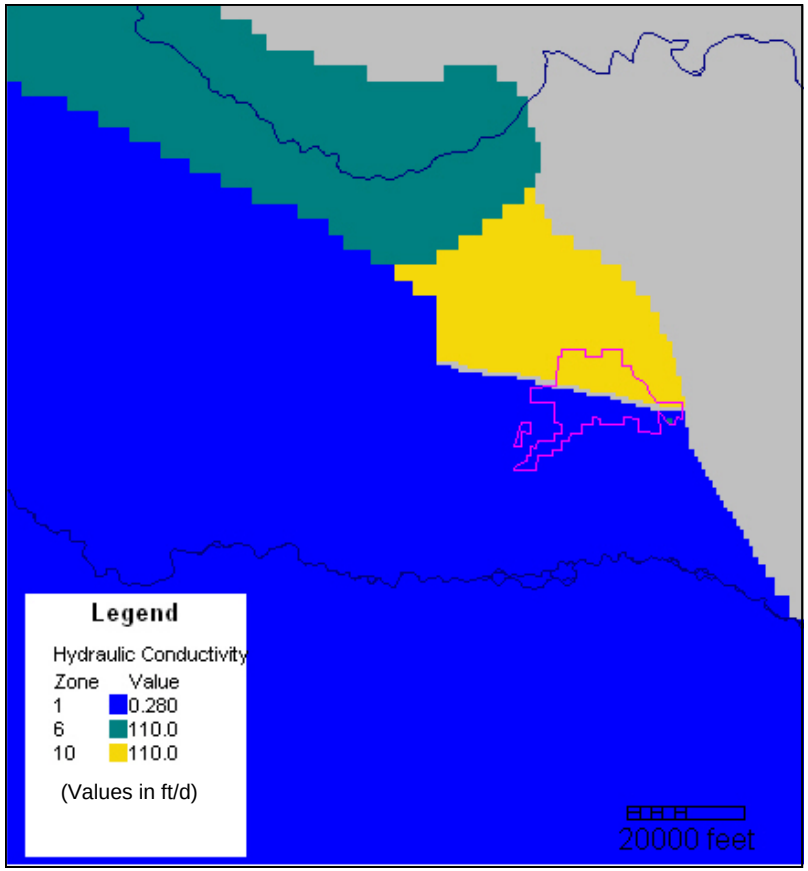
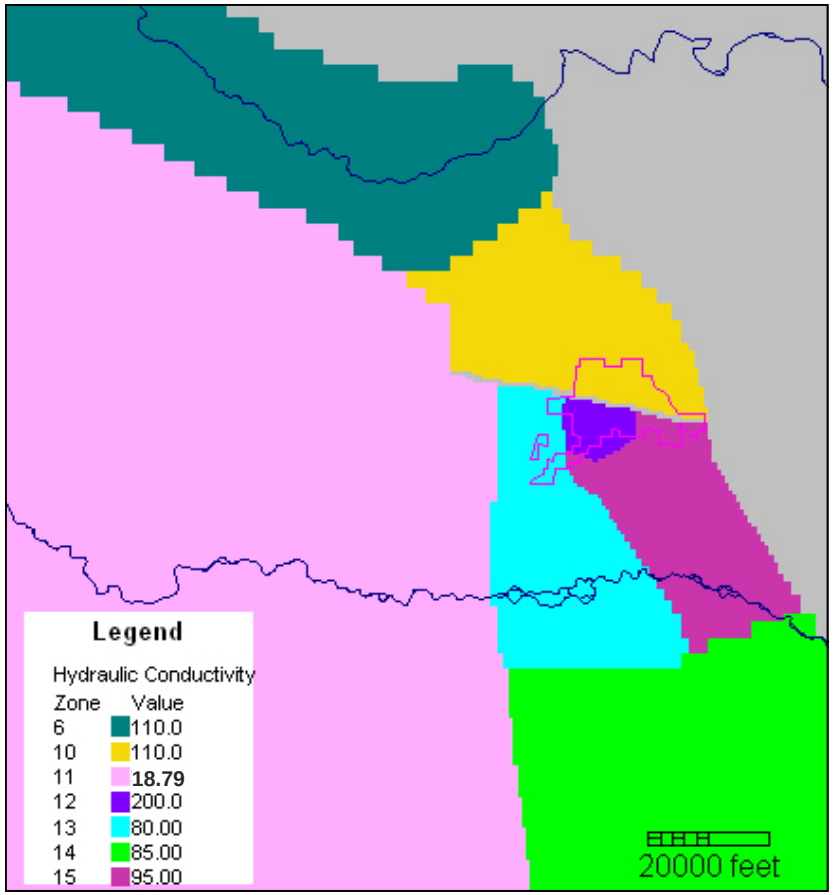


Figure 4-5
Hydraulic Conductivity Zones for Layers 3 and 4

M3 Eagle Model
JZ0705

PgG

Tmatch



Hmatch

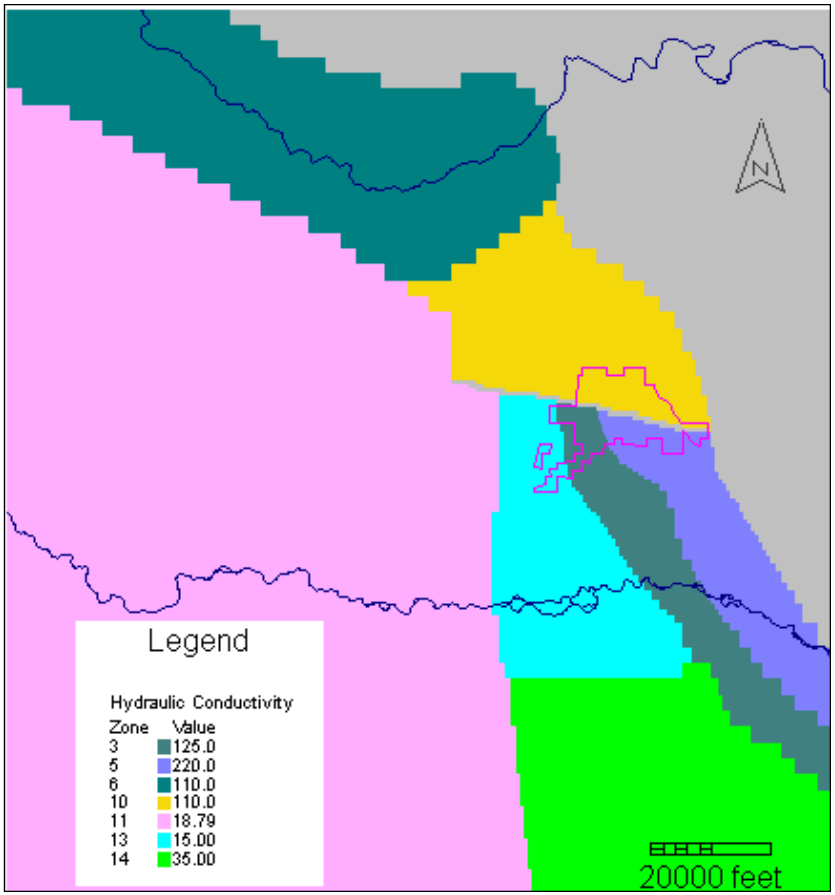
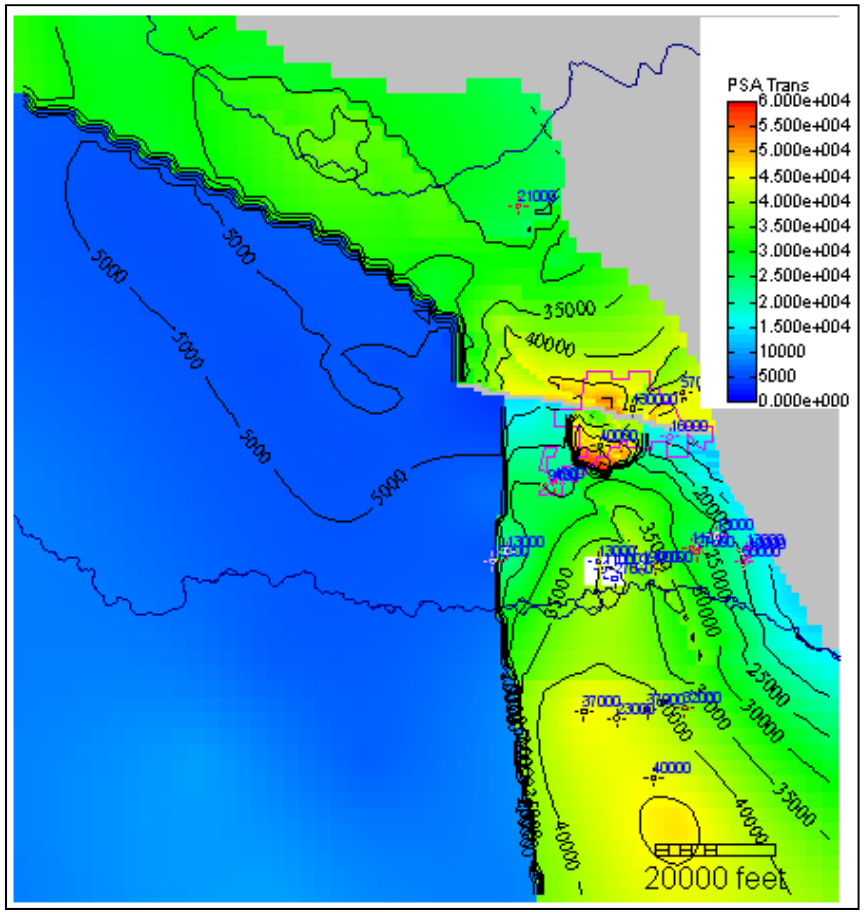


Figure 4-6
Hydraulic Conductivity Zones for Layers 5/6/7

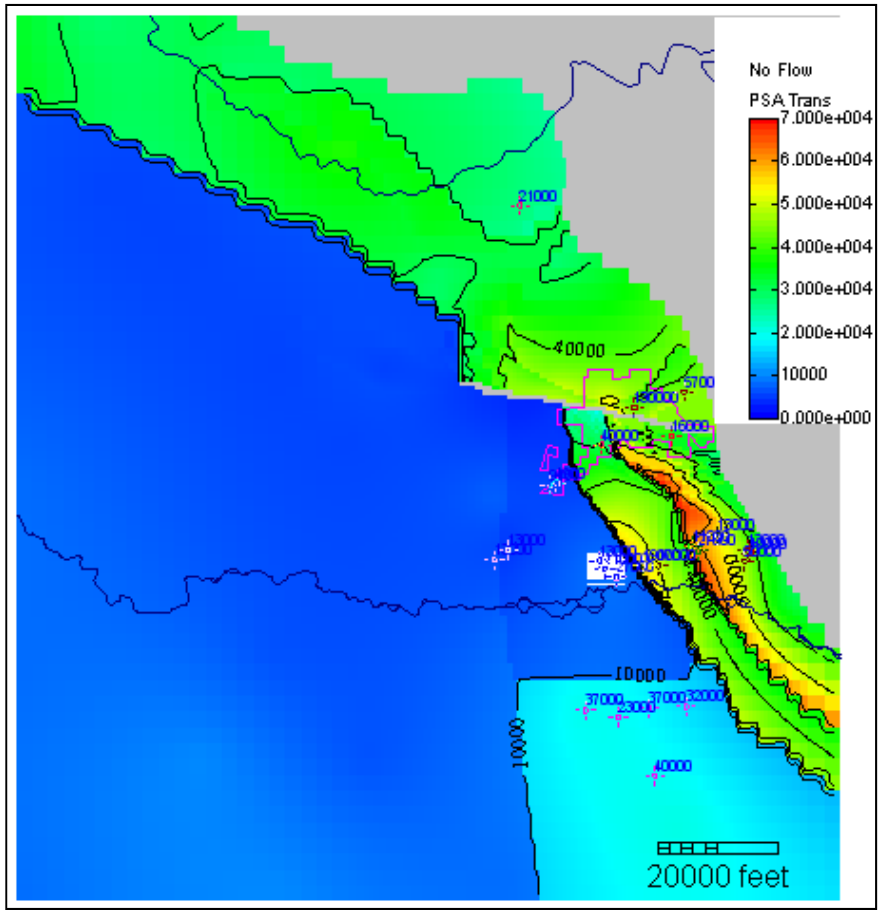
M3 Eagle Model
JZ0705

PgG

Tmatch



Hmatch



NOTE: Transmissivity estimates from aquifer tests summarized on Table 4-4. Values in ft^2/day.

Figure 4-7
Modeled PGSA Transmissivity and Estimates from Aquifer Tests

M3 Eagle Model
JZ0705

PgG

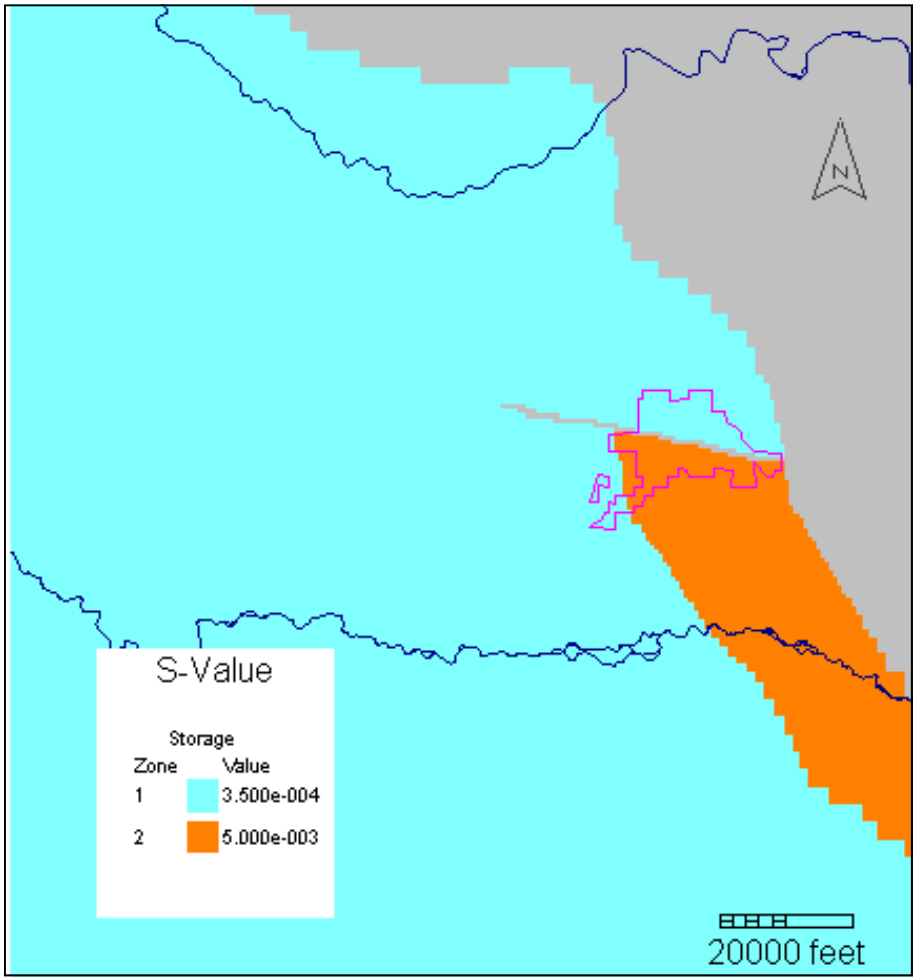
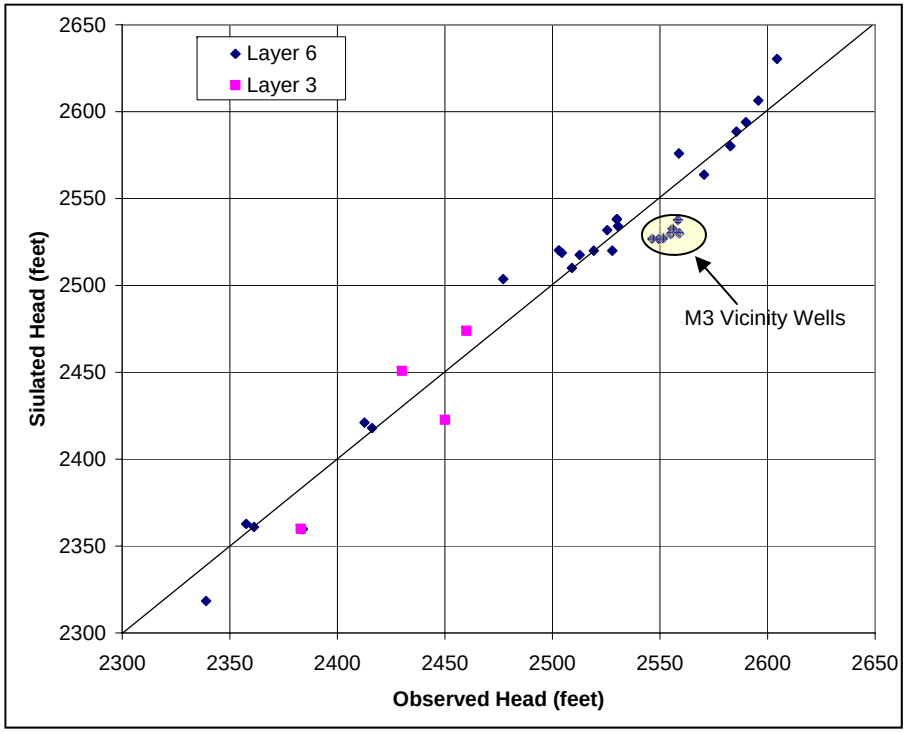


Figure 4-8
Modeled Storage Coefficient Zones (PGSA)

M3 Eagle Model
JZ0705

PgG

Tmatch Model



Hmatch Model

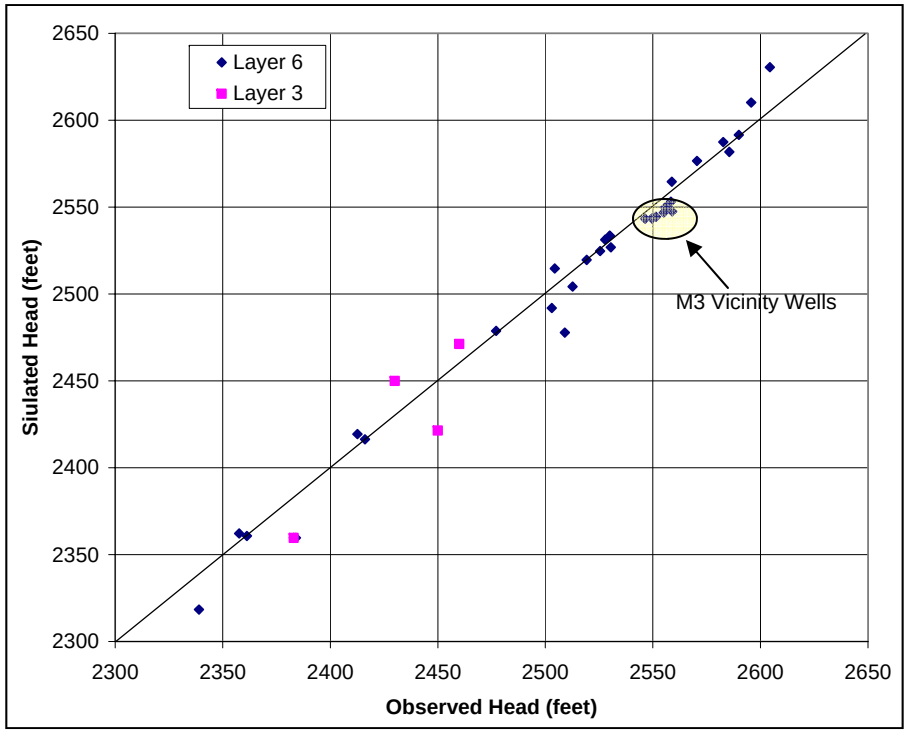
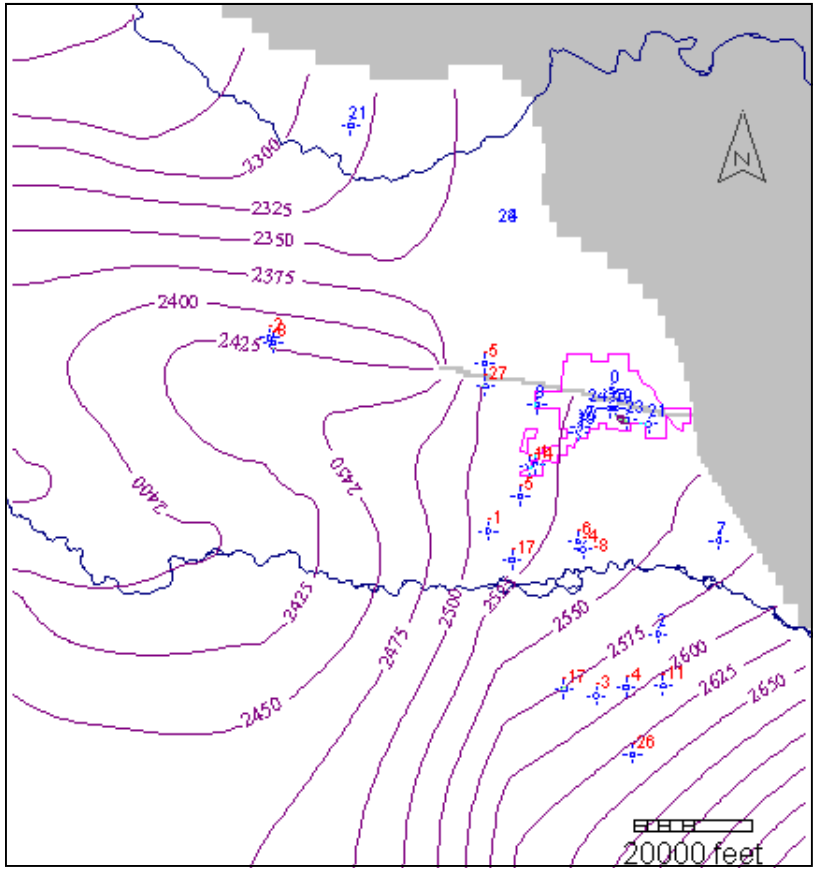


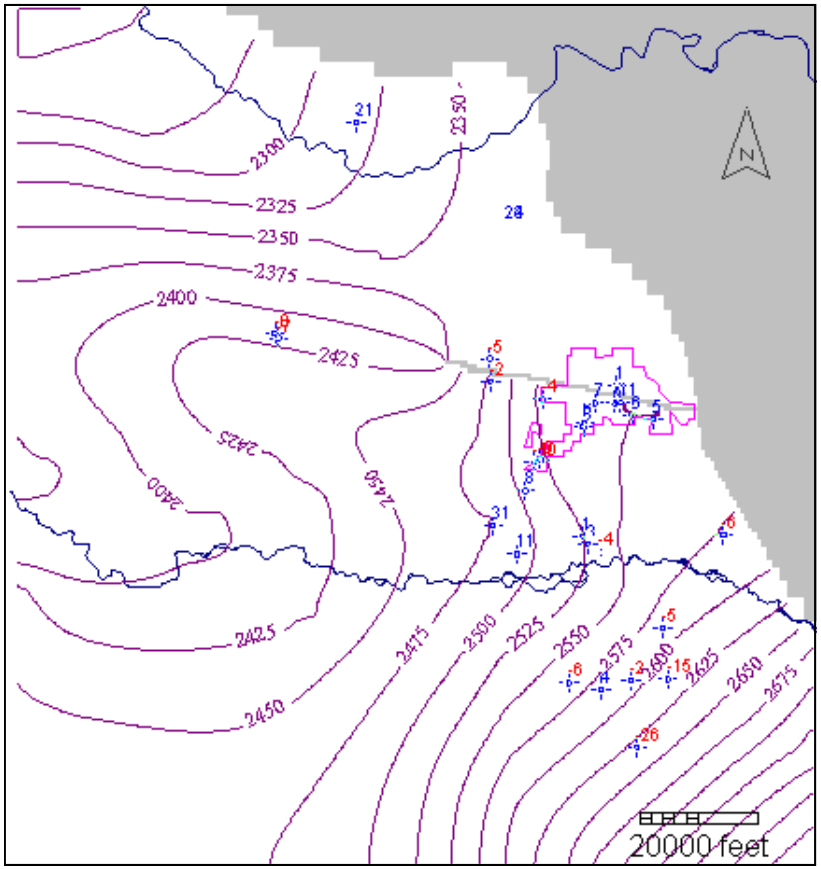
Figure 5-1
Observed versus Simulated Heads

M3 Eagle Model
JZ0705

Tmatch



Hmatch



NOTE: Target values and residuals listed on Table XX.

Figure 5-2
Modeled Heads and Residuals in Layer 6 (PGSA)

M3 Eagle Model
JZ0705

Pumping_and_Obs_Wells.mxd

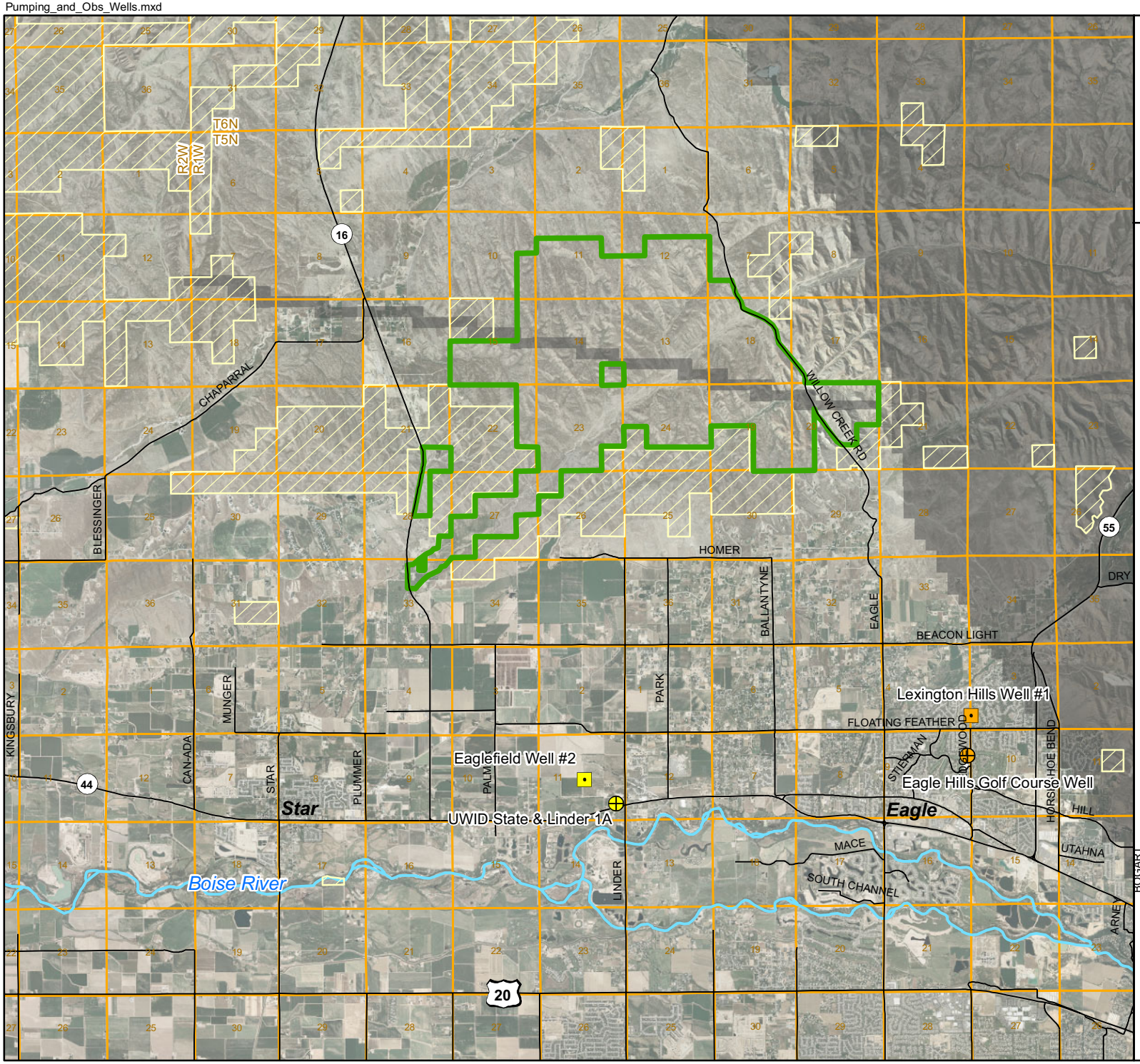


Figure 6-1

Locations of Pumping and Observation Wells (Transient Calibration)

M3 Eagle Model
JZ0705

- 30-Day Test Observation Well
- 30-Day Test Pumpnig Well
- 7-Day Test Observation Well
- 7-Day Test Pumping Well
- No Flow Zones
- M3 Eagle Site Boundary
- BLM
- sections

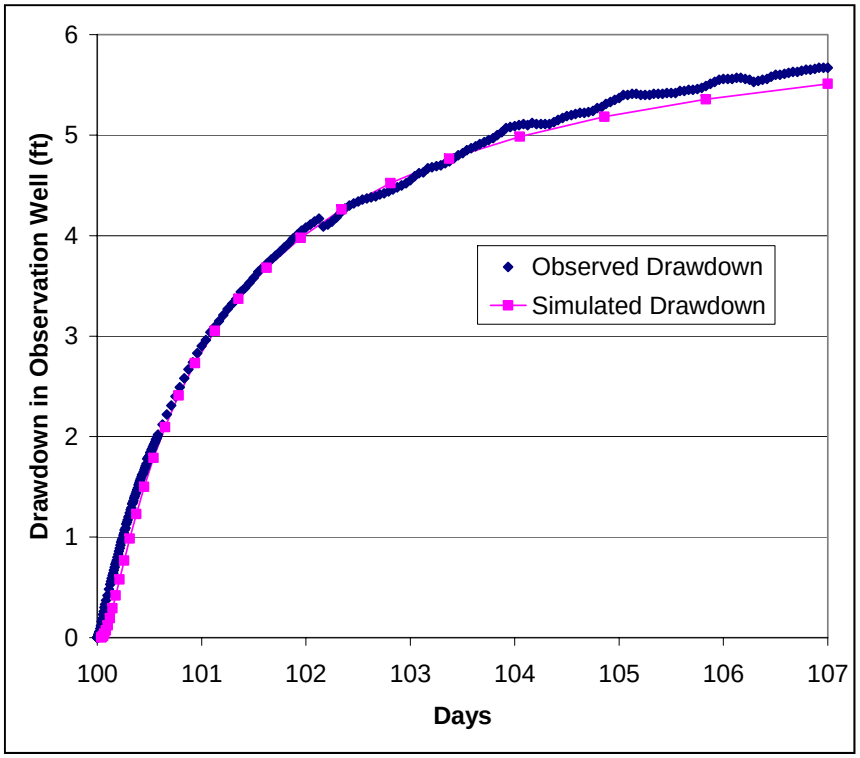
PgG

0 Feet 8,000

2006 Orthophoto

N

7-day pumping test



30-day pumping test

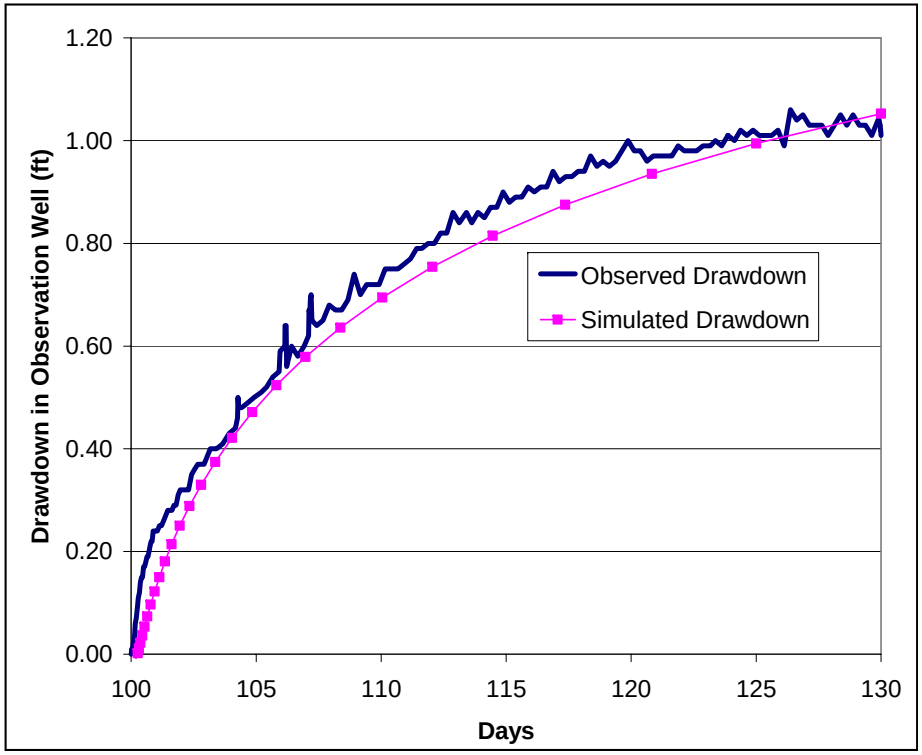


Figure 6-2
Modeled Drawdown in Hmatch Model (7-day and 30-day pumping tests)

M3 Eagle Model
JZ0705

PgG

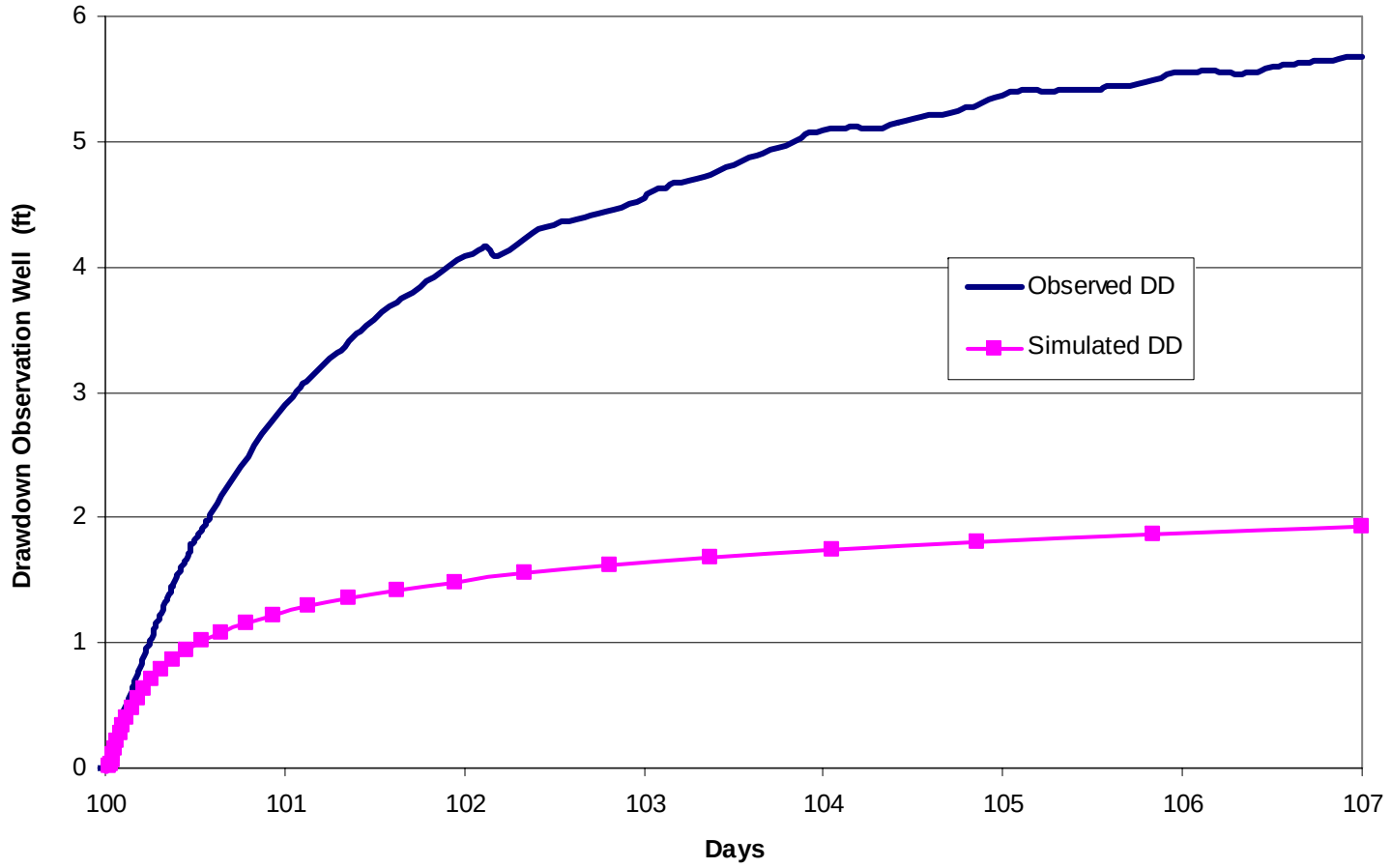


Figure 6-3
Modeled Drawdown in Tmatch Model (7-day pumping test)

M3 Eagle Model
JZ0705

PgG

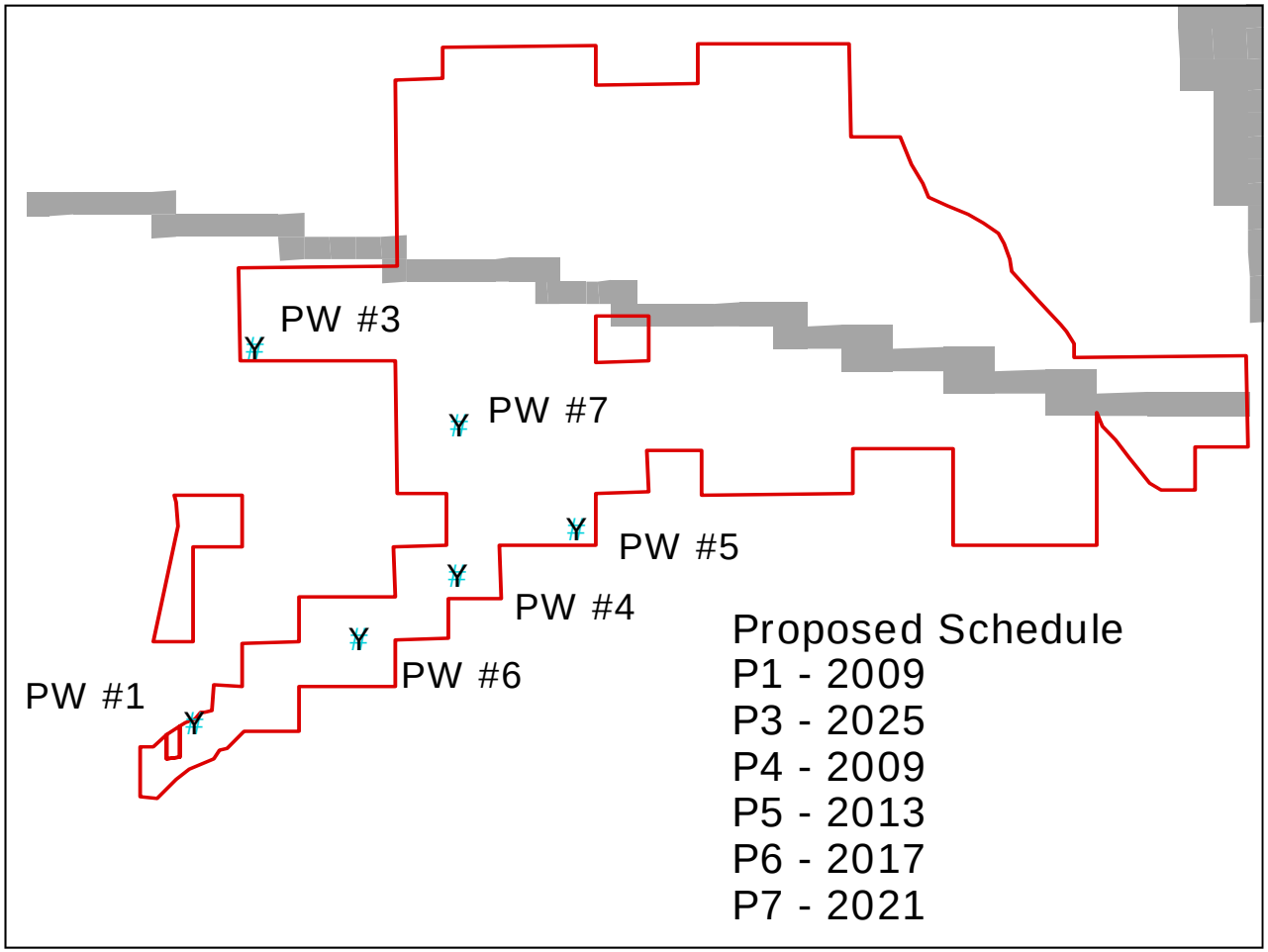


Figure 7-1
Proposed Supply Wells (M3 Site)

M3 Eagle Model
JZ0705

PgG

DrawDown_6.mxd

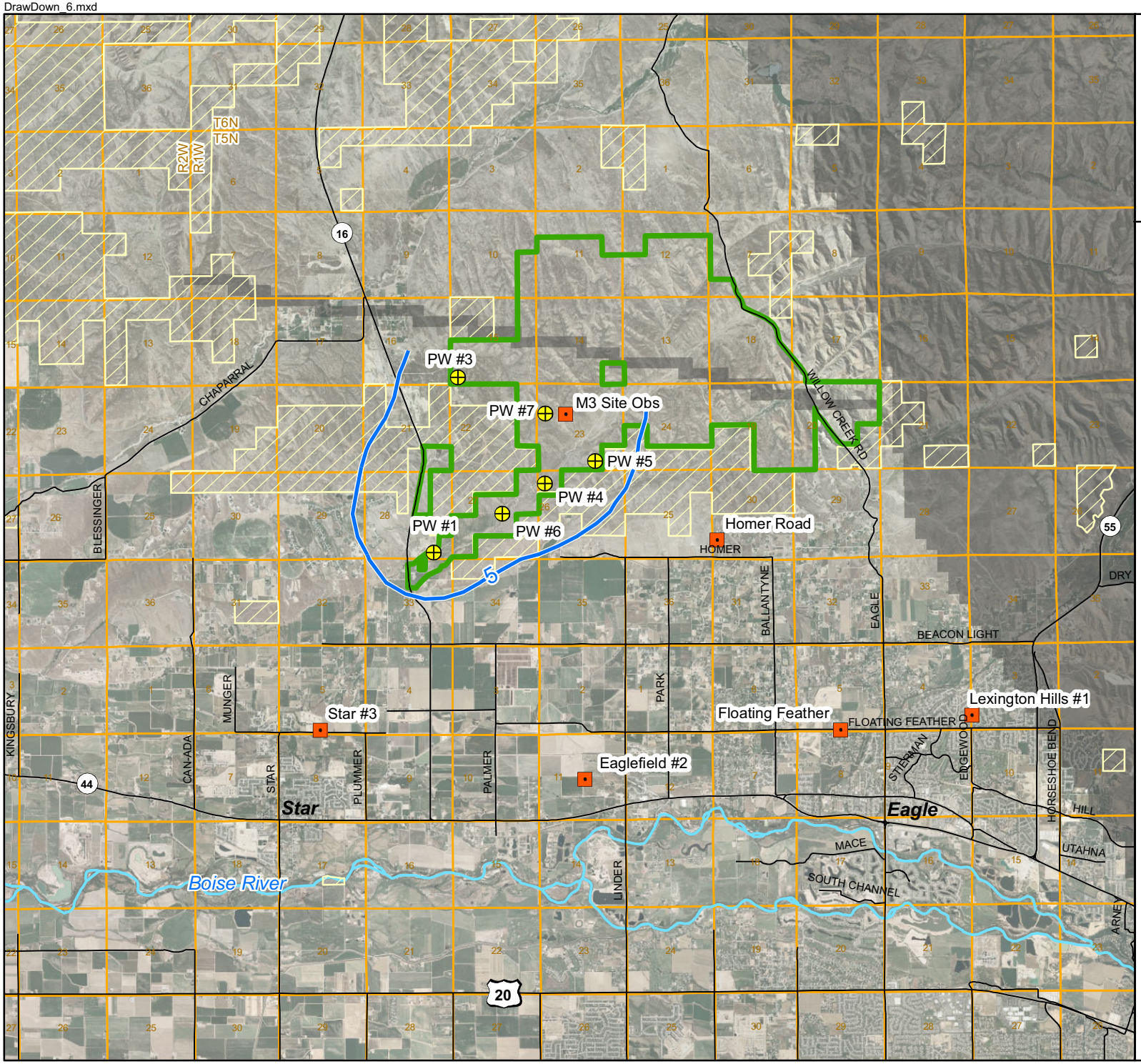


Figure 7-2

Simulated PGSA Drawdown After 4 Years (2013) - Tmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_7.mxd

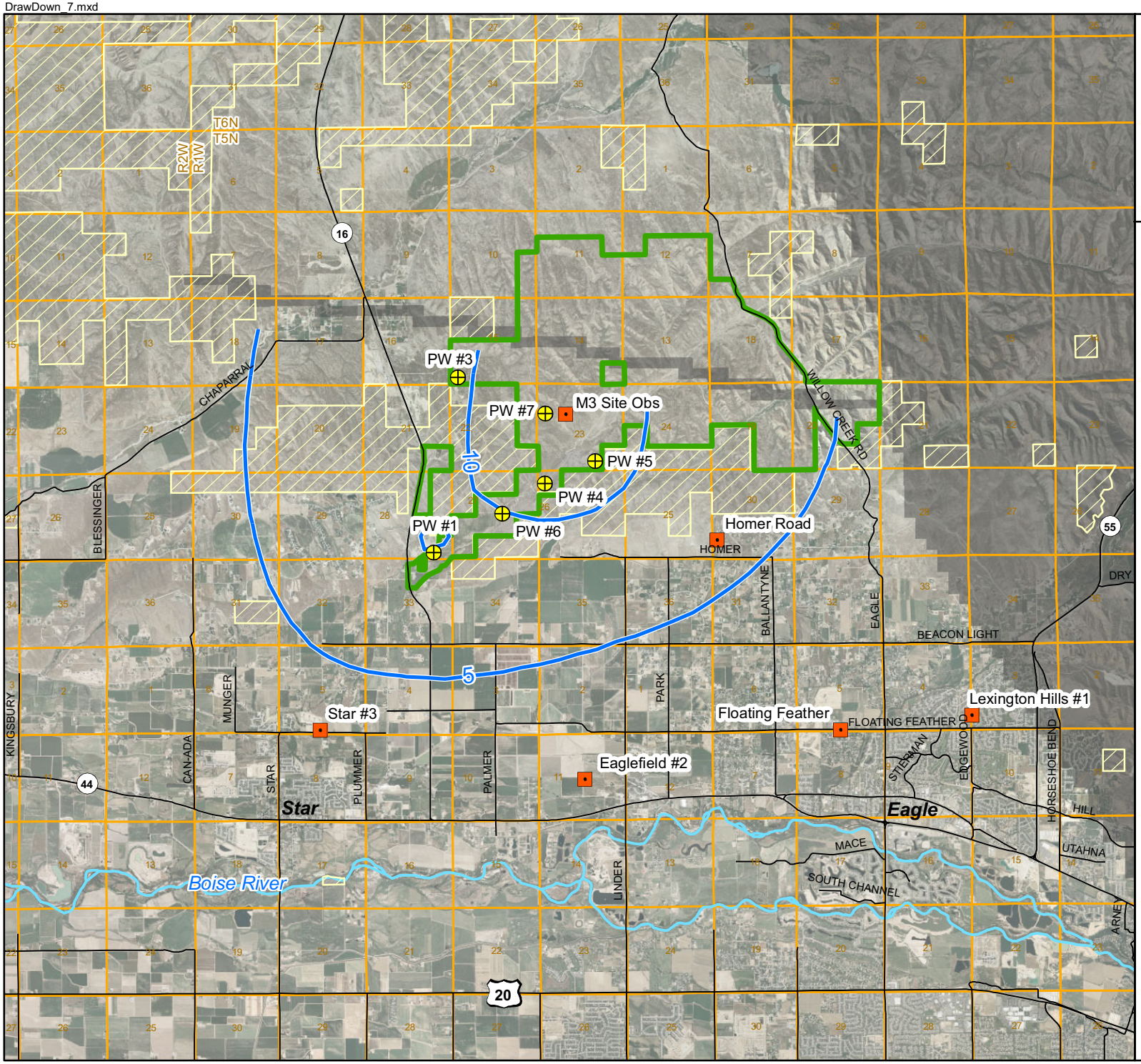


Figure 7-3

Simulated PGSA Drawdown After 8 Years (2017) - Tmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	**1000**	**2013**
PW #6	**1000**	**2017**
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_8.mxd

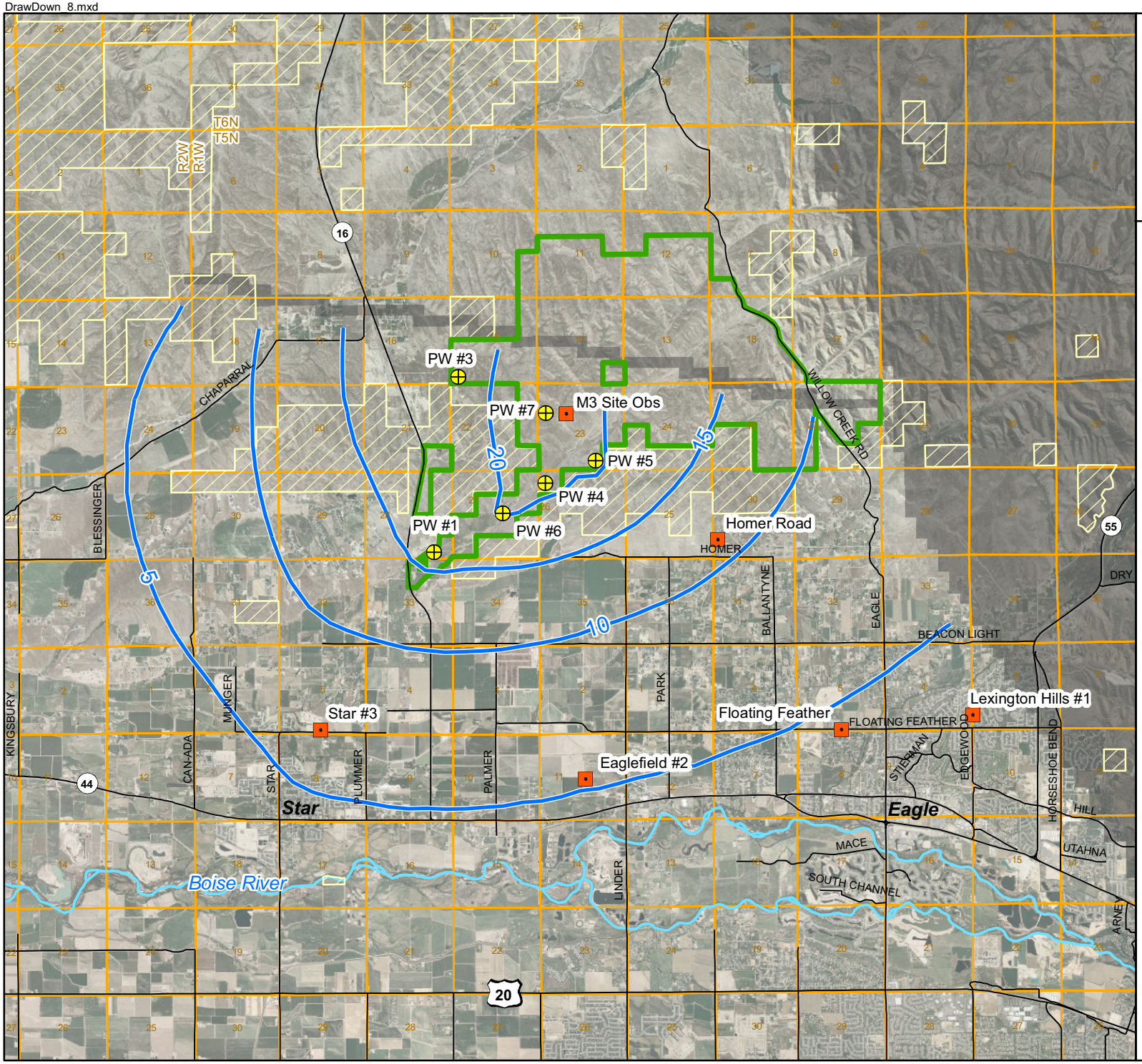


Figure 7-4

Simulated PGSA Drawdown After 16 Years (2025) - Tmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	1000	2009
PW #4	1000	2009
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_9.mxd

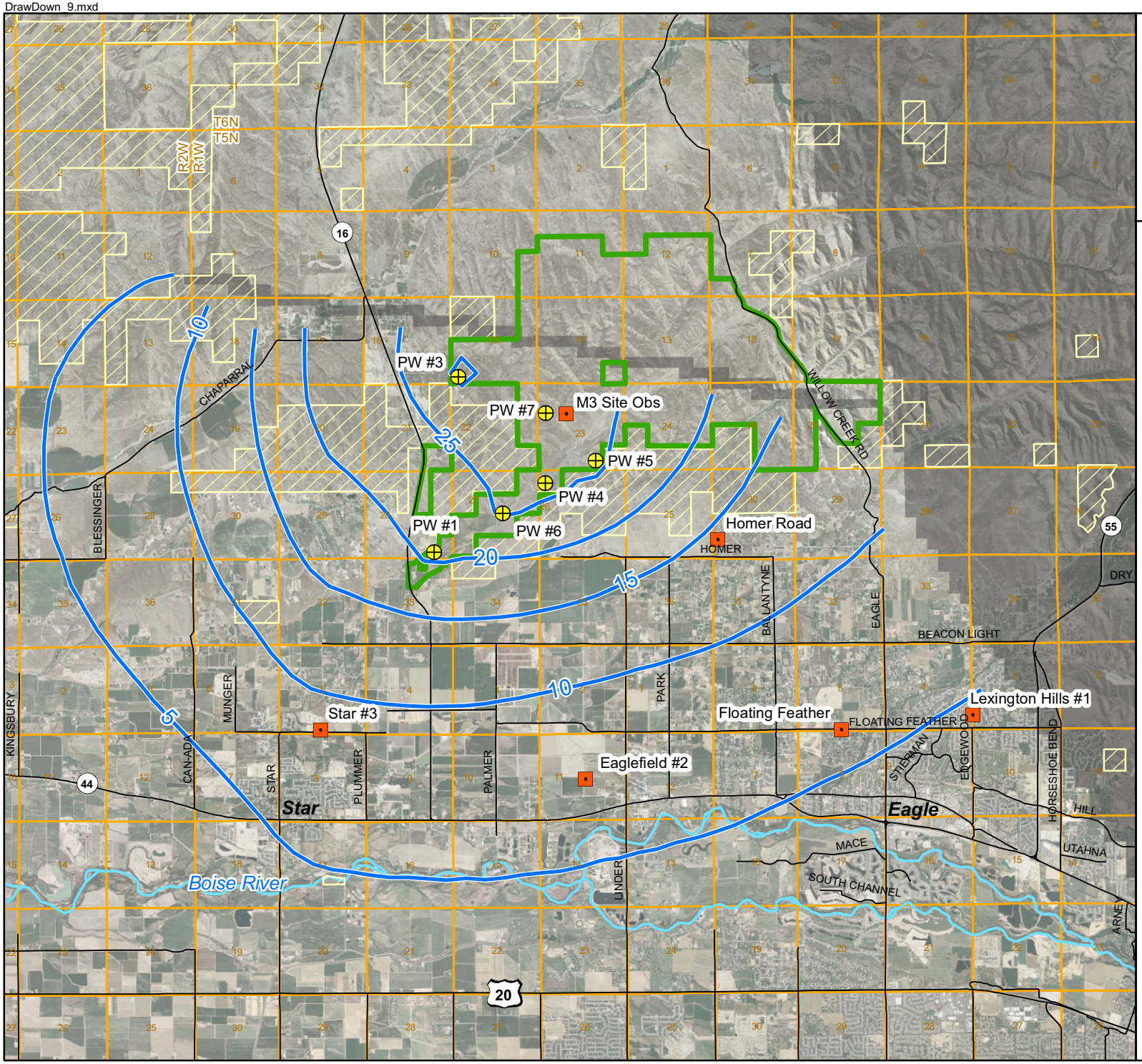


Figure 7-5

Simulated PGSA Drawdown After 26 Years (2035) - Tmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	1000	2009
PW #4	1000	2009
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_1.mxd

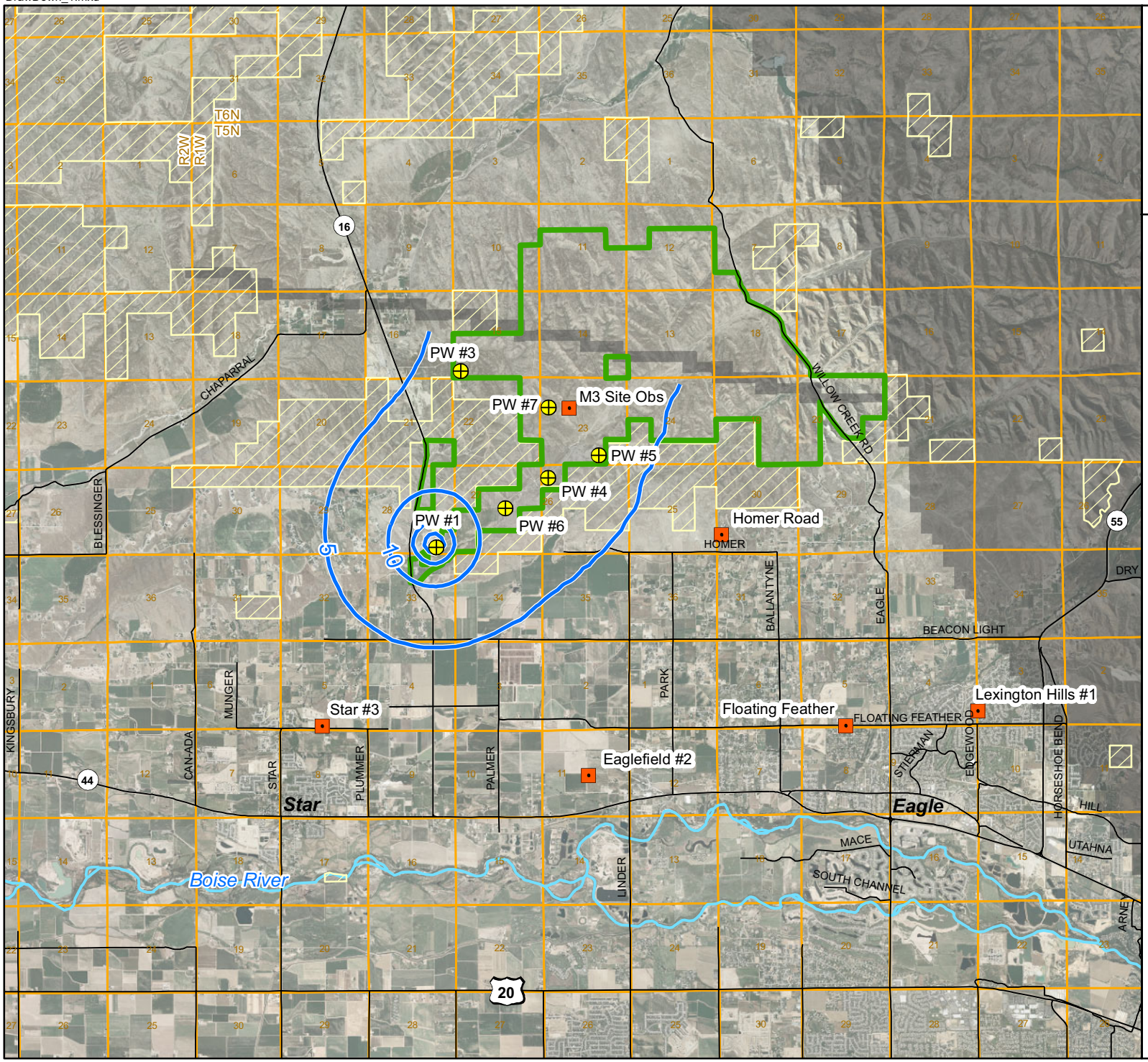


Figure 7-6

Simulated PGSA Drawdown After 4 Years (2013) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	1000	2013
PW #6	1000	2017
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_2.mxd

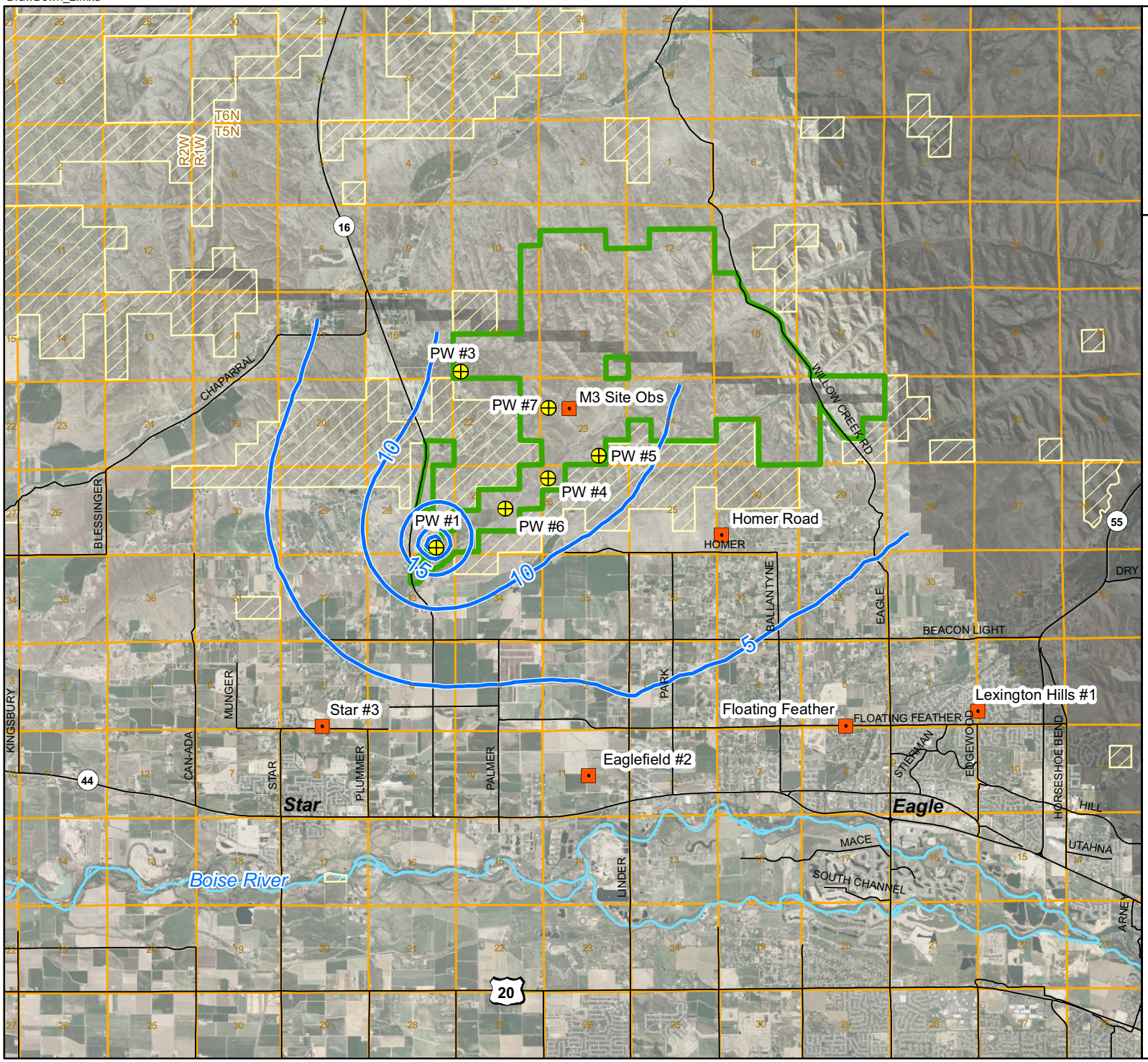


Figure 7-7

Simulated PGSA Drawdown After 8 Years (2017) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	**1000**	**2013**
PW #6	**1000**	**2017**
PW #7	1000	2021
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_3.mxd

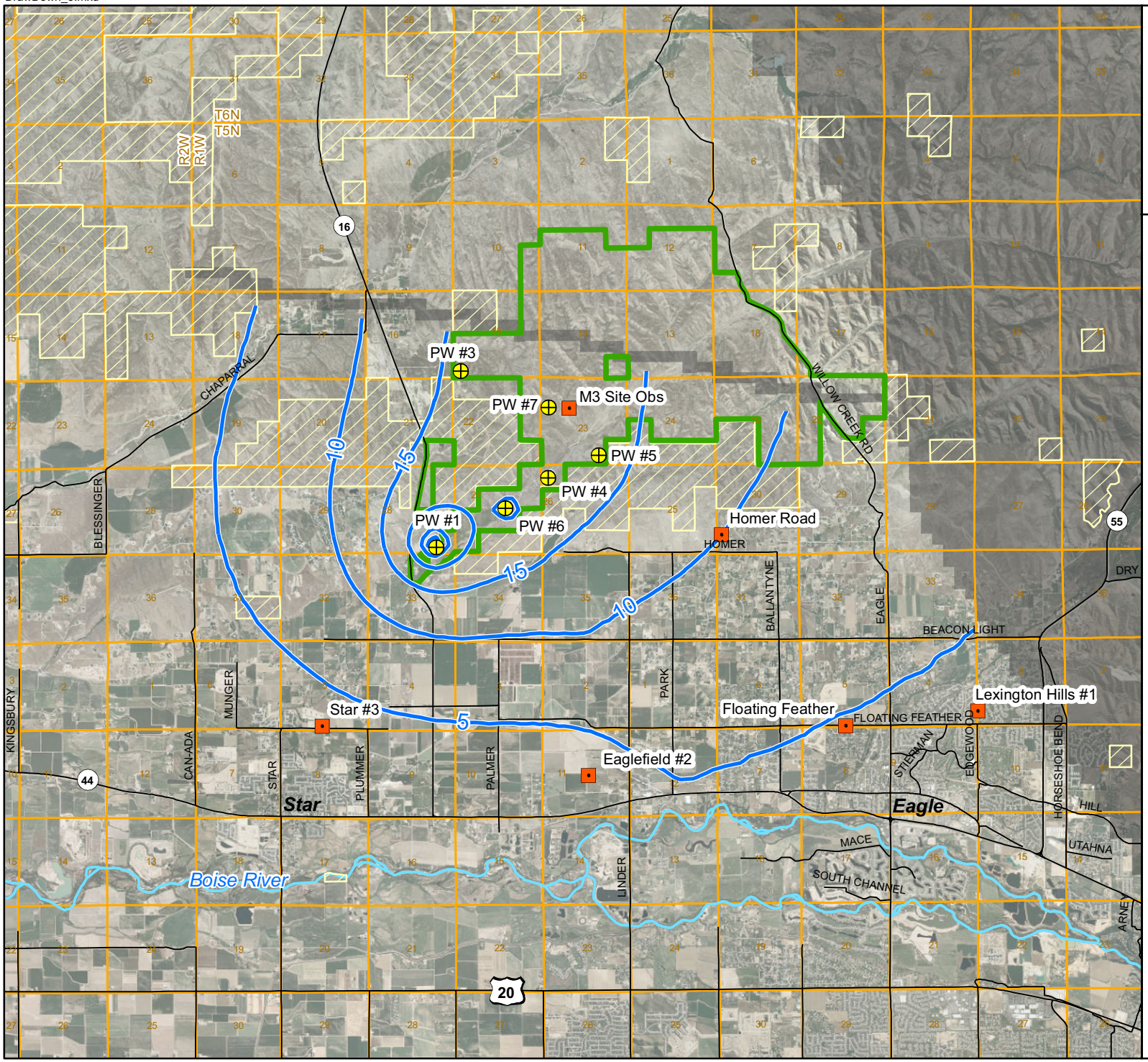


Figure 7-8

Simulated PGSA Drawdown After 16 Years (2025) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	**1000**	**2013**
PW #6	**1000**	**2017**
PW #7	**1000**	**2021**
PW #3	1000	2025

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_4.mxd

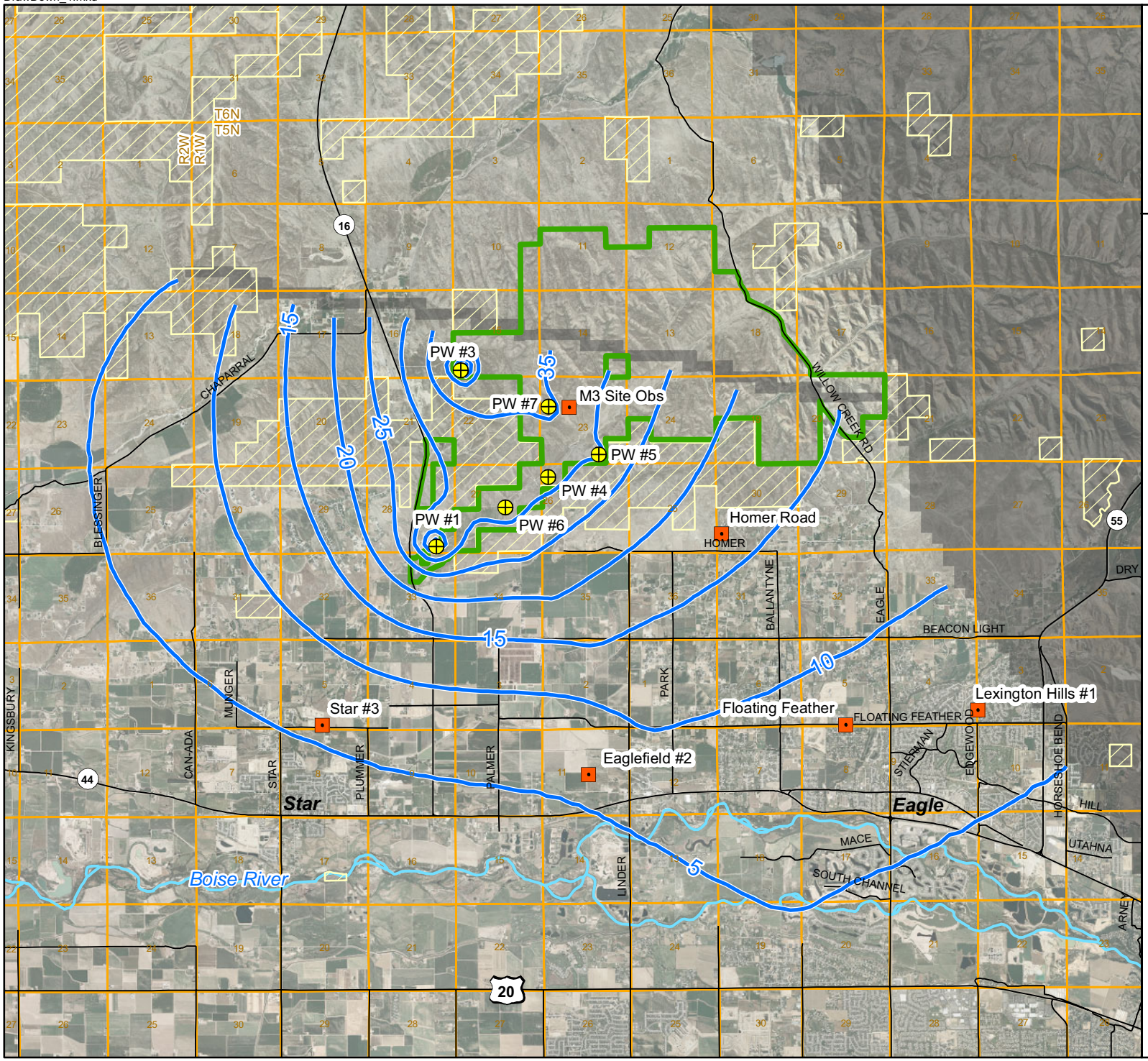


Figure 7-9

Simulated PGSA Drawdown After 26 Years (2035) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	**1000**	**2013**
PW #6	**1000**	**2017**
PW #7	**1000**	**2021**
PW #3	**1000**	**2025**

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_10.mxd

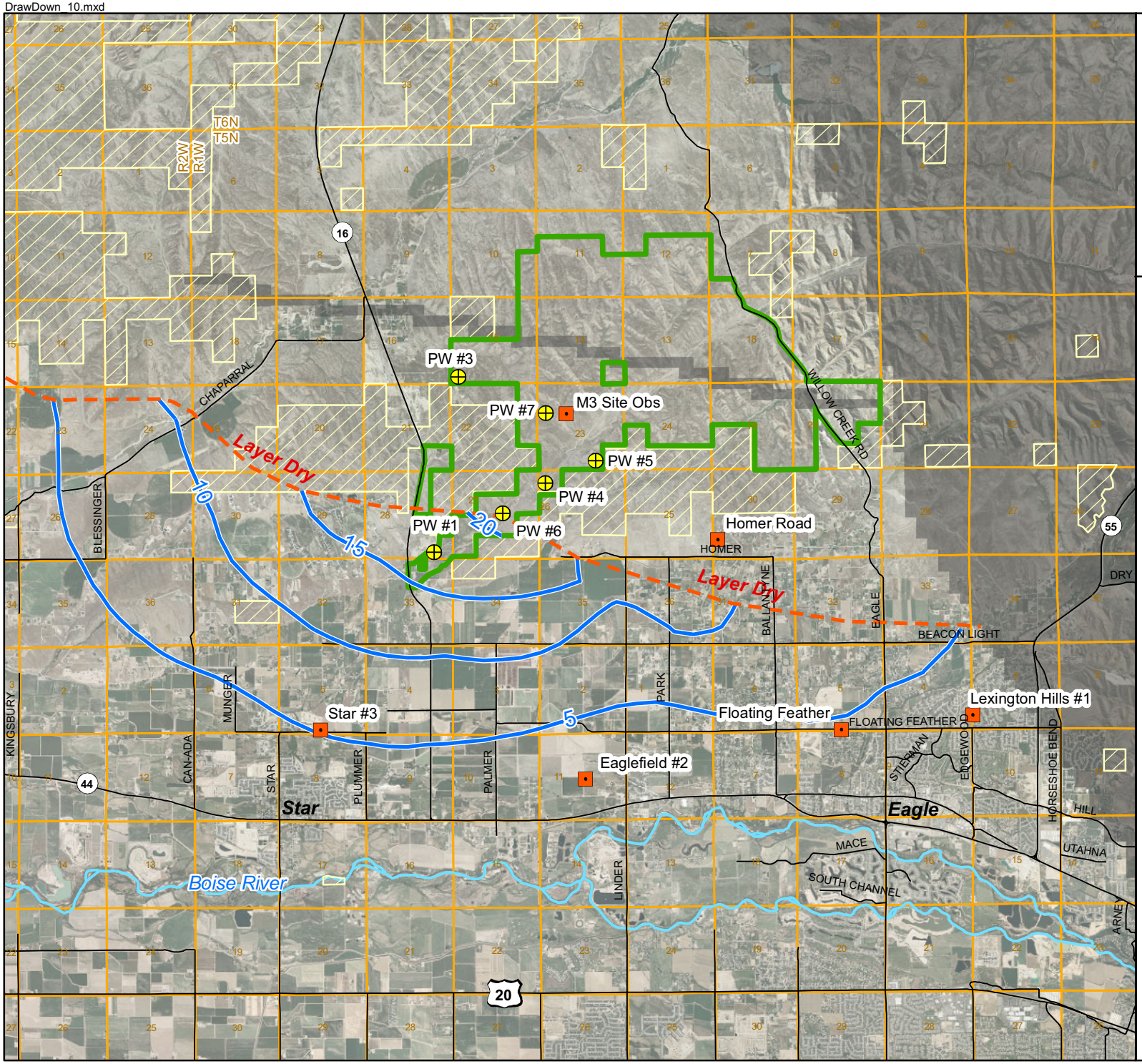


Figure 7-10
Simulated Drawdown in Middle Aquifer After 26 Years (2035) - Tmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	**1000**	**2013**
PW #6	**1000**	**2017**
PW #7	**1000**	**2021**
PW #3	**1000**	**2025**

PgG

0 Feet 8,000

2006 Orthophoto

N

DrawDown_5.mxd

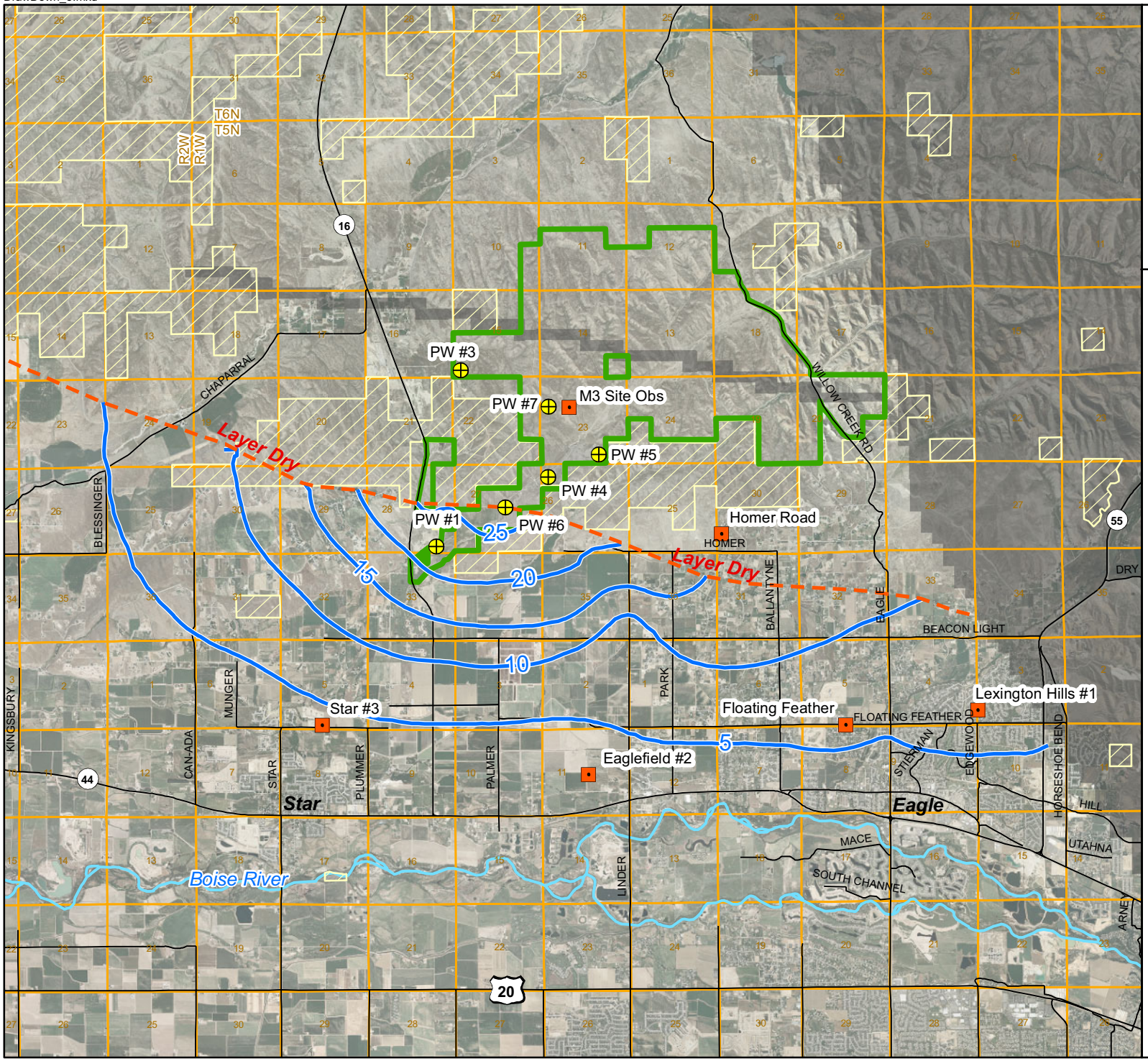


Figure 7-11
Simulated Drawdown in Middle Aquifer After 26 Years (2035) - Hmatch Model

M3 Eagle Model
JZ0705

- Proposed Production Wells
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

Pumping Schedule

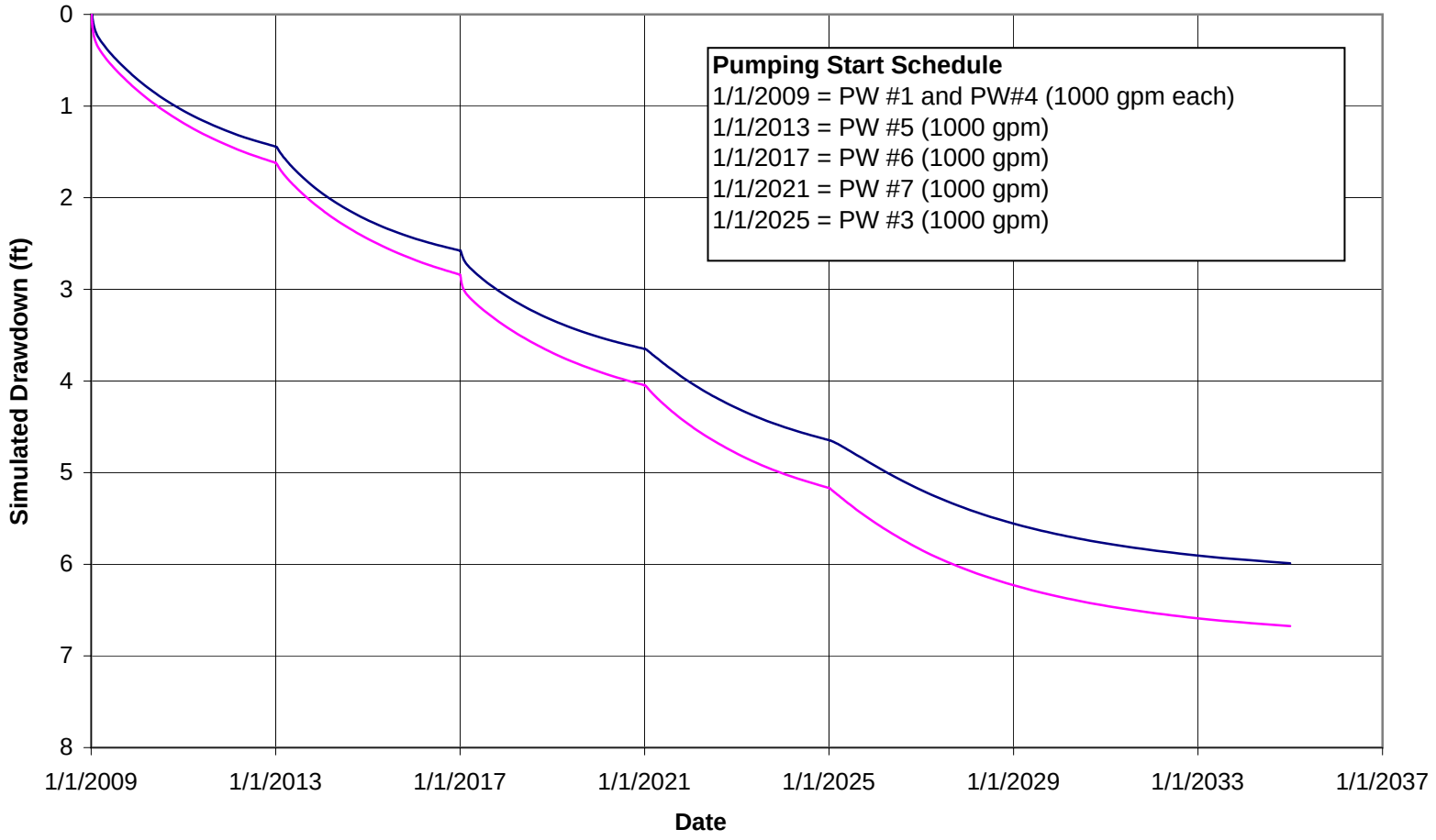
Well ID	GPM	Start Year
PW #1	**1000**	**2009**
PW #4	**1000**	**2009**
PW #5	**1000**	**2013**
PW #6	**1000**	**2017**
PW #7	**1000**	**2021**
PW #3	**1000**	**2025**

PgG

0 Feet 8,000

2006 Orthophoto

N



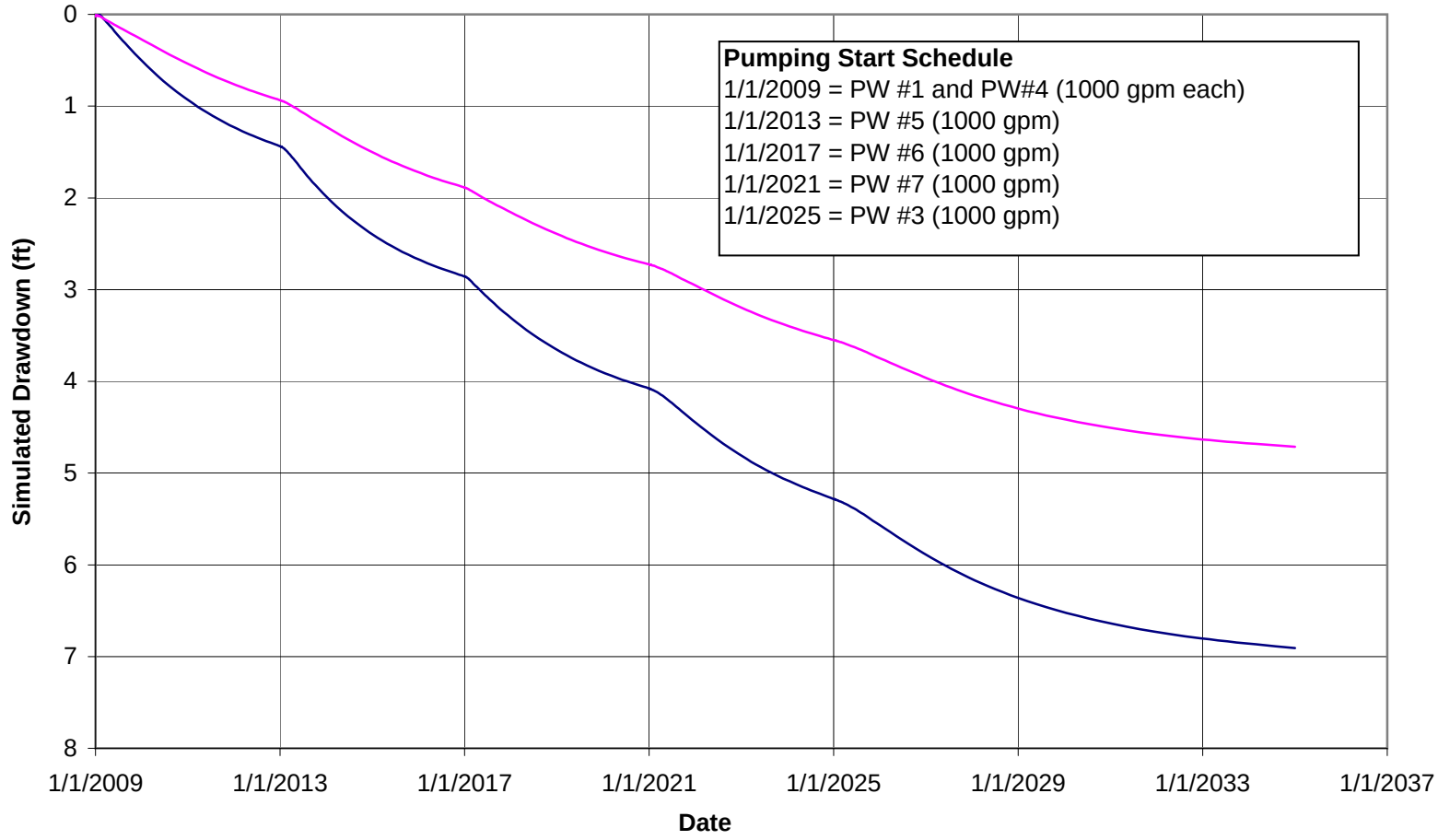
Hmatch Model

Tmatch Model

Figure 7-12 Simulated PGSA Drawdown at Eaglefield #2 Well

M3 Eagle Model
JZ0705

PgG



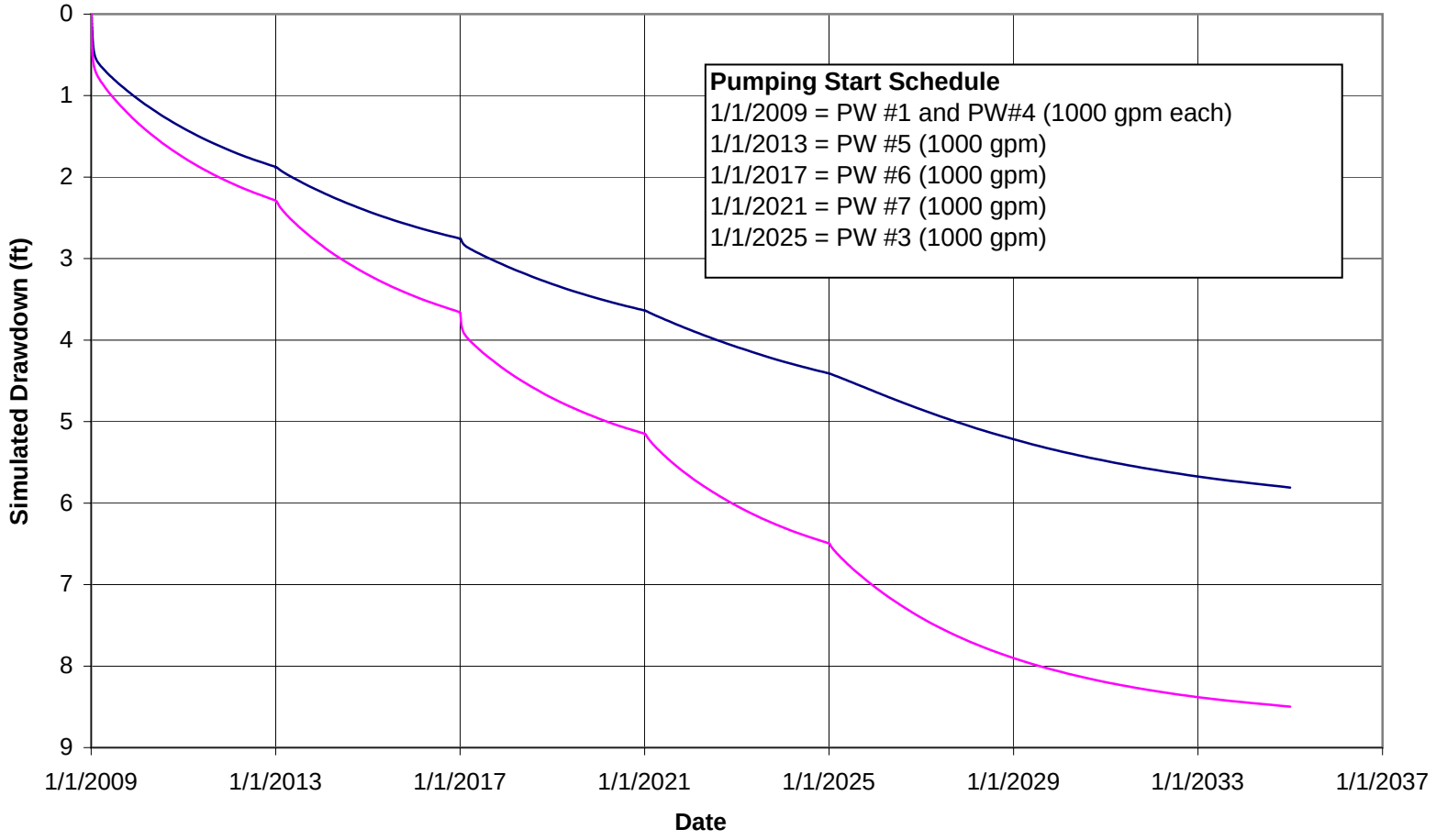
Hmatch Model

Tmatch Model

Figure 7-13 Simulated PGSA Drawdown at Lexington Hills #1 Well

M3 Eagle Model
JZ0705

PgG



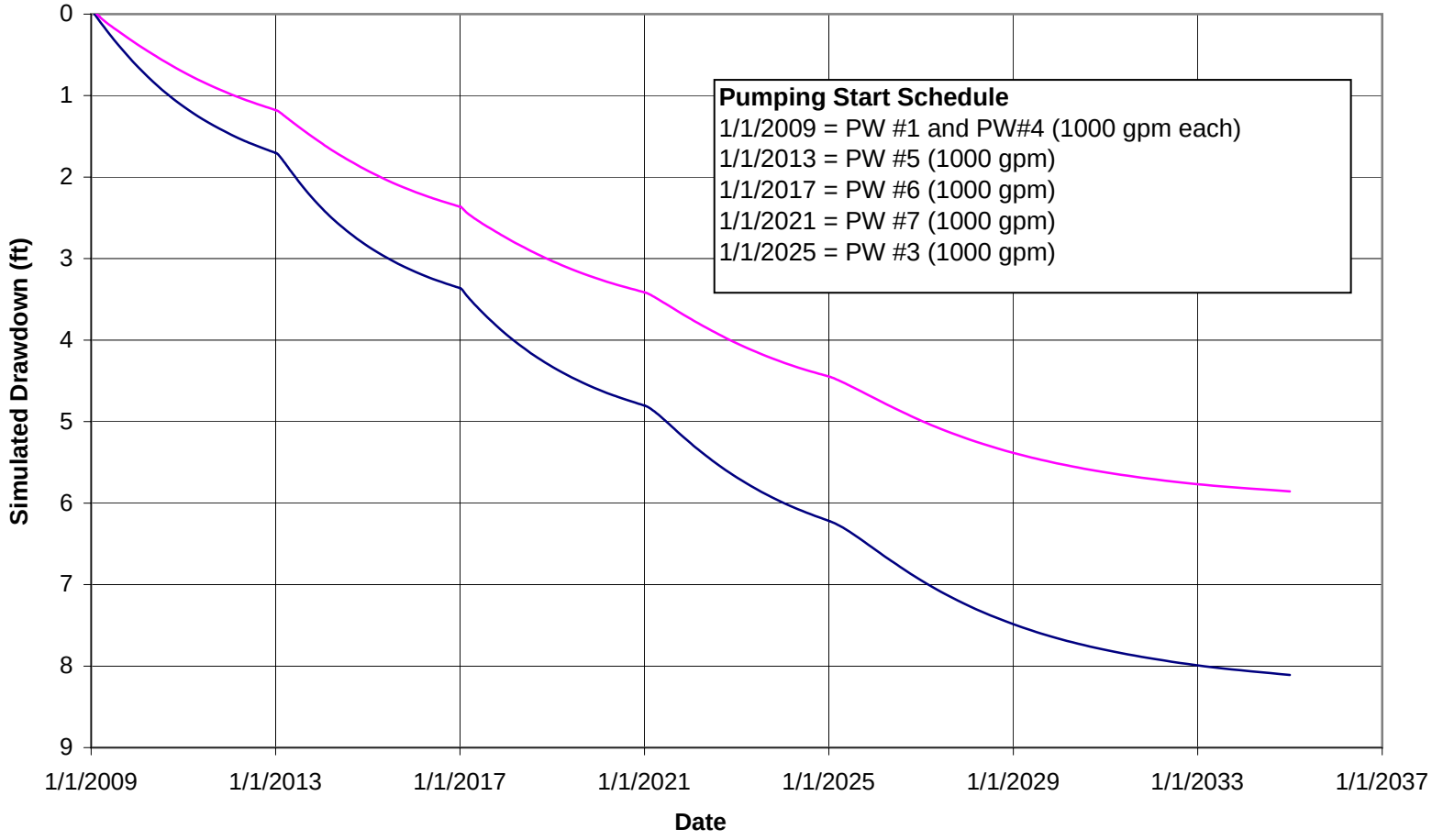
Hmatch Model

Tmatch Model

Figure 7-14 Simulated PGSA Drawdown at Star #3 Well

M3 Eagle Model
JZ0705

PgG



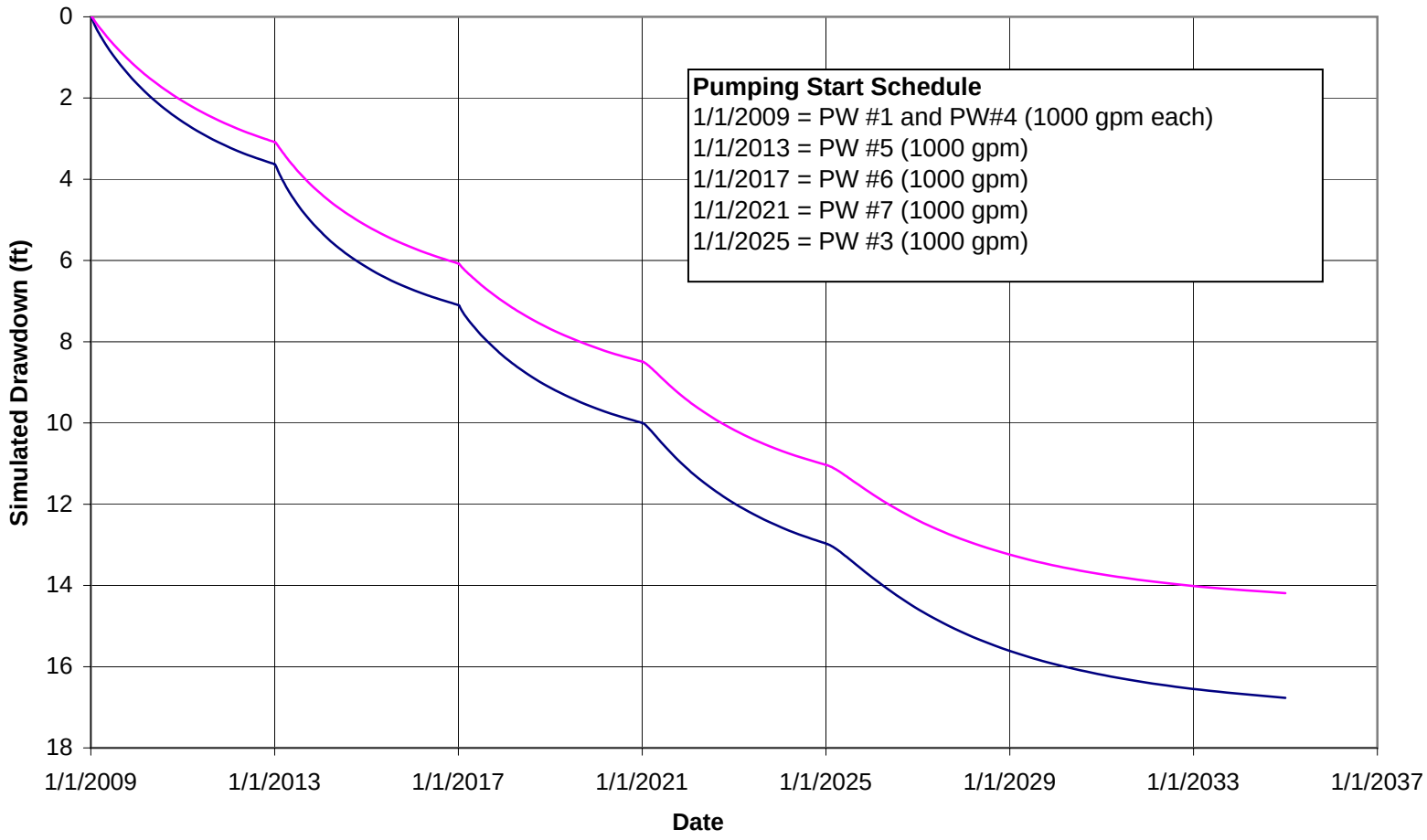
Hmatch Model

Tmatch Model

Figure 7-15 Simulated PGSA Drawdown at Floating Feather Well

M3 Eagle Model
JZ0705

PgG



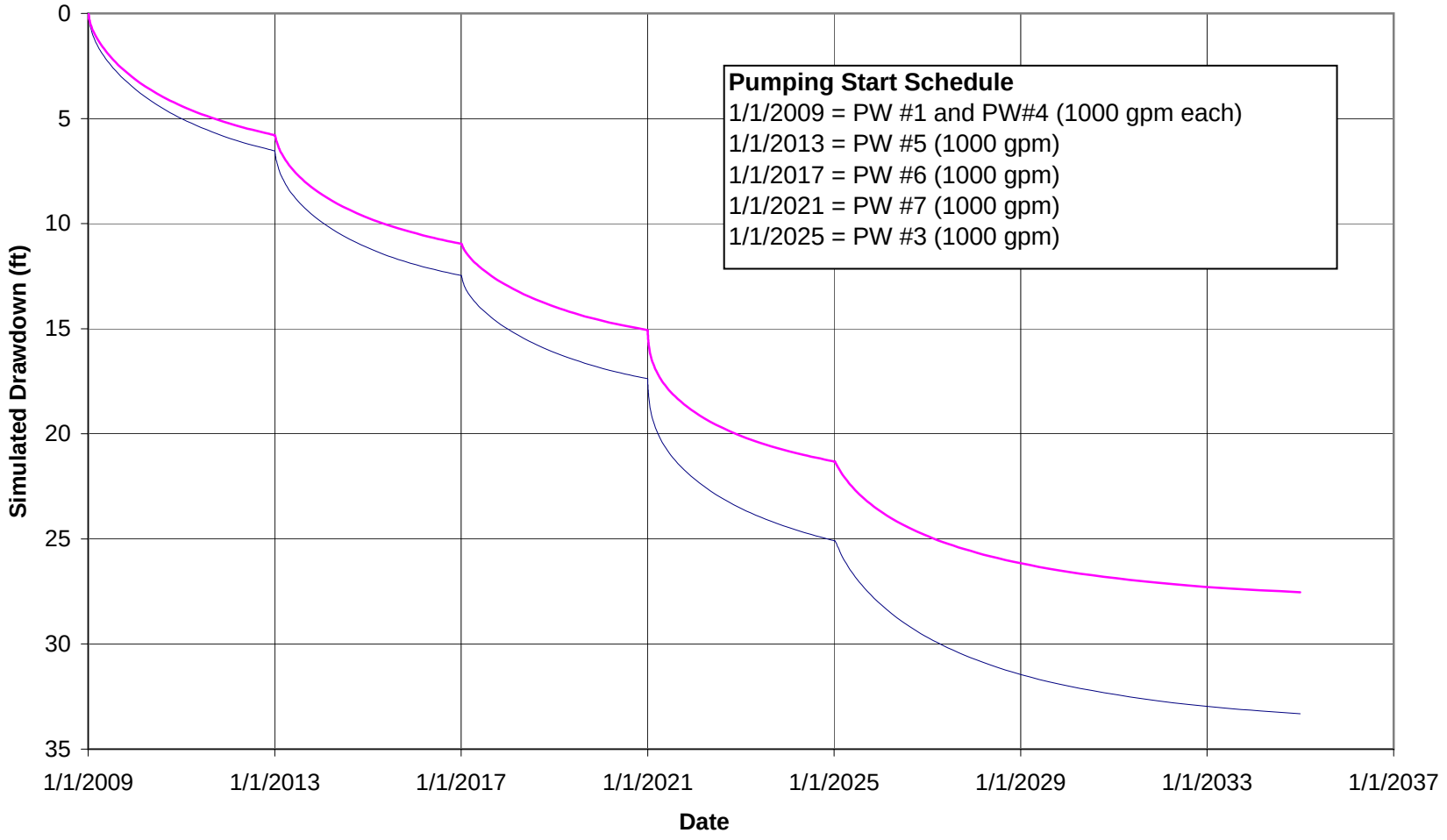
Hmatch Model

Tmatch Model

Figure 7-16 Simulated PGSA Drawdown at Homer Road

M3 Eagle Model
JZ0705

PgG



Hmatch Model

Tmatch Model

Figure 7-17 Simulated PGSA Drawdown at M3 Property

M3 Eagle Model
JZ0705

PgG

APPENDIX B –PGG MEMORANDA

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PACIFIC groundwater GROUP

Technical Memorandum

To: Mark Utting (Hydro Logic, Inc.)

From: Dawn Chapel and Peter Schwartzman (Pacific Groundwater Group)

Re: Transient Calibration to the SVR #7 Pumping Test (M3 Eagle Groundwater Flow Model)

Date: July 26, 2008

This memo summarizes the results of Pacific Groundwater Group's (PGG's) transient calibration of the M3 Eagle groundwater flow model to a recent hydraulic analysis of the 9-day SVR #7 constant rate pumping test in the Pierce Gulch Sand Aquifer (PGSA). The M3 Eagle model was previously developed and calibrated to both steady-state and transient conditions. The additional calibration effort was requested to see how well the current model simulates hydraulic responses observed at this more recent test and to perform a local model calibration if necessary. The following sections summarize the original model calibration effort, our transient calibration to the SVR #7 pumping test, and our assessment of this new calibration.

ORIGINAL MODEL DEVELOPMENT AND CALIBRATION

The M3 Eagle model was previously developed and calibrated to both steady-state and transient conditions. Two steady-state calibrations were developed with favorable results – one that emphasized best fit to interpreted aquifer transmissivity values ("Tmatch") and the other that emphasized best fit to observed groundwater levels ("Hmatch"). Transient calibrations included simulation of drawdown responses observed during the 30-day Lexington Hills #1 and the 7-day Eaglefield #2 pumping tests. The location of these test wells are shown in **Figure 1**. The Hmatch model was calibrated to both the Eaglefield #2 and Lexington Hills #1 pumping test with favorable results. A transient calibration of the Tmatch model was attempted for the Eaglefield #2 pumping test but was less favorable without a substantial reduction to the steady state calibrated transmissivity value. Since the Tmatch model was developed to emphasize a best fit to transmissivity, the transmissivity values developed in the steady-state calibration (i.e. close to values interpreted from pumping tests) were used for the predictive simulations.

Predictive simulations were run with both models to predict the effects on the groundwater flow system from proposed pumping at the M3 site. Results of the two model predictions were similar. The original model development, calibration, and predictive simulations were documented in the *M3 Eagle Groundwater Flow Model and Analysis of Pumping Impact* report to Hydro Logic, Inc. (PGG, 2008).

TRANSIENT CALIBRATION TO SVR #7 PUMPING TEST

Hydro Logic Inc. (HLI) requested that PGG perform model runs to ascertain whether the existing model(s) readily simulate the SVR #7 pumping test. Favorable results were achieved with the both the Hmatch and Tmatch models with local model refinements. The following sections describe the SVR #7 pumping tests, observation data, and PGG's transient calibration.

SVR #7 PUMPING TEST

HLI provided PGG with the pumping rate and observed aquifer drawdown values for the 9-day SVR #7 constant rate pumping test in the PGSA. Drawdown hydrographs were provided for two observation wells, the Big Gulch Stock well and the TW #4 Zone 2 well. The location of the SVR test wells are shown in **Figure 1**. HLI provided 20 representative drawdown values over the course of the 9-day test for each well. Big Gulch is located approximately 900-ft southwest of SVR #7 and TW #4 is located approximately 4,500-ft southwest of SVR #7. SVR #7 was pumped at a constant rate of 916 gallons-per-minute over the 9-day period.

Based on well completion elevations and screen lengths, HLI estimated SVR #7 well to be completed in the middle portion of the PGSA (model layer 6); the Big Gulch Stock well to be completed in the top of the PGSA (model layer 5); and the TW #4 well to be completed through the entire PGSA (model layers, 5, 6, and 7).

CALIBRATION AND SIMULATION OF THE SVR #7 PUMPING TEST

PGG used the Hmatch and Tmatch models to simulate the SVR #7 pumping test. Wells were placed in aquifer layers as described above. The transient simulation consisted of two stress periods; the first stress period consisting of 100 days of simulation with no pumping followed by the second stress period consisting of 9 days of simulation with pumping[1]. The model also simulates long term average pumping rates for irrigation, municipal, and domestic use, which were included in the initial Hmatch and Tmatch model calibrations as described in the PGG's original report (PGG, 2008).

A limited calibration effort was employed to match the observed drawdowns by adjusting model parameters within acceptable ranges in the vicinity of the SVR #7 pumping test.

The result of the calibration effort for the Hmatch model was a slight increase in local hydraulic conductivity in the PGSA such that a portion of Zone 3 (125 ft/day) was replaced with Zone 20 (160 ft/day) as shown on **Figure 1** and a decrease in local PGSA storage coefficient (S-value) such that a portion of Zone 2 (0.005) was replaced with

[1] PGG commonly employs this practice to establish that, prior to imposing new stresses, the transient model exhibits quasi steady state behavior. Steady state heads are used as initial conditions for the transient model.

Zone 3 (0.0005) as shown on **Figure 3**. The result of the calibration effort for the Tmatch model was also a slight decrease in the local hydraulic conductivity in the PGSA from 200 ft/day to 160 ft/day (Zone 12) as shown on **Figure 2**, and the same decrease in the local PGSA S-value performed on the Hmatch model (**Figure 3**). In addition, storage coefficient Zone 3 was assigned an Sy value of 0.025 rather than the value of 0.1 used in the Hmatch model. The reduction in the Sy-value for the Tmatch model was required due to nearby model cells in the Tmatch model within the PGSA converting to unconfined as described below.

The location of these localized model adjustments are shown in **Figures 1 through 3.** Additional documentation of model property zonation is presented in PGG, 2008.

The calibration for both models involved a balance between matching the observed drawdown at the Big Gulch well and the observed drawdown at the TW #4 well (**Figures 4 and 5**). Simulations of the observed drawdowns for both models were sensitive to the storativity value and required an order of magnitude decrease from the original S-value of 0.005 (Zone 2) to a new value of 0.0005 (Zone 3). This value is similar to the S-value of 0.00035 to the west (Zone 1) in the original model and reflects the spatial heterogeneity of aquifer properties within the PGSA. The Tmatch model also required a reduction in the local Sy-value from 0.1 (Zone 2) to 0.025 (Zone 3) due to nearby cells converting to unconfined. The SVR #7 pumping test is located in an area of the model where the PGSA is not fully saturated; unsaturated conditions occur in the overlying cells. When a model cell is not fully saturated, MODFLOW converts to using the Sy-value for storage calculations during a transient simulation. In the Tmatch model partial saturation cells within the PGSA are located in the immediate vicinity of the SVR #7 pumping well, whereas they are located further north in the Hmatch model. The simulated drawdown with the Tmatch model is therefore more sensitive to the value of Sy-value assigned in this area of the model. The required reduction of Sy from 0.1 to 0.025 to match the observed drawdown in the Tmatch model suggests a more "semi-confined" aquifer response. Sediment cementation has been observed in the PGSA in this area and therefore supports the interpretation of a locally semi-confined response.

The simulated drawdowns in both wells using the parameters described above provide a reasonable fit to the observed drawdowns (**Figures 4 and 5**). The maximum simulated drawdown at the end of the 9-day test in the nearby Big Gulch observation well was within 12% of the observed drawdown for the Hmatch model and 2% for the Tmatch model. During the middle time of the test, the two versions of the model bracket the observed drawdown at the Big Gulch observation well, with the Hmatch model simulated drawdown being about 7% lower than the observed drawdown and the Tmatch model simulated drawdown being about 5% higher than the observed drawdown.

The simulated drawdown in the more distant TW #4 observation well was almost identical for both versions of the model, with the maximum simulated drawdown being within 4% of the observed drawdown for the Hmatch model and within 6% of the observed drawdown for the Tmatch model (**Figures 4 and 5**)

ASSESSMENT OF NEW CALIBRATION AND FUTURE WORK

Our calibration involved a refinement of aquifer parameter values within the vicinity of the SVR #7 pumping test. Localized changes to aquifer properties provided a reasonable calibration to the observed drawdowns. To assess the effects of these localized model changes in other areas of the model domain, PGG used the newly calibrated Hmatch model to simulate the 7-day Eaglefield #2 pumping test (4 miles south of the SVR #7 site) that was used in the original calibration. The results, shown in **Figure 6,** indicate the localized refinements have little to no effect on the original calibration. The simulated and observed drawdowns for the Eaglefield #2 match very well – as they did in the original calibration.

The newly calibrated model was not used to assess the effects of the localized model refinements on the 30-day Lexington Hills #1 pumping test; although, given it's location of approximately 5.5 miles to south, it is our opinion that the effects are likely insignificant.

The newly calibrated models were also not used to assess changes to the PGSA drawdowns associated with proposed M3 Eagle pumping that were previously predicted by PGG (PGG, 2008). However, based on the facts that long term (26-year) predicted drawdowns were very similar to steady-state drawdown predictions (thus making long-term predictions insensitive to "S") and that changes to the model were small and local, PGG expects similar drawdown predications of long-term drawdown associated with the M3 Eagle project. While changes in long-term drawdowns are expected to be minimal, the time-evolution of the drawdown distribution may proceed faster than originally estimated due to the lower S/Sy values. Therefore, PGG recommends that both newly calibrated model versions are used to update existing long term PGSA drawdown predictions from proposed pumping at the M3 site.

Figure 1: Local PGSA K-Zones and Location of Pumping Test Wells (Hmatch Model)

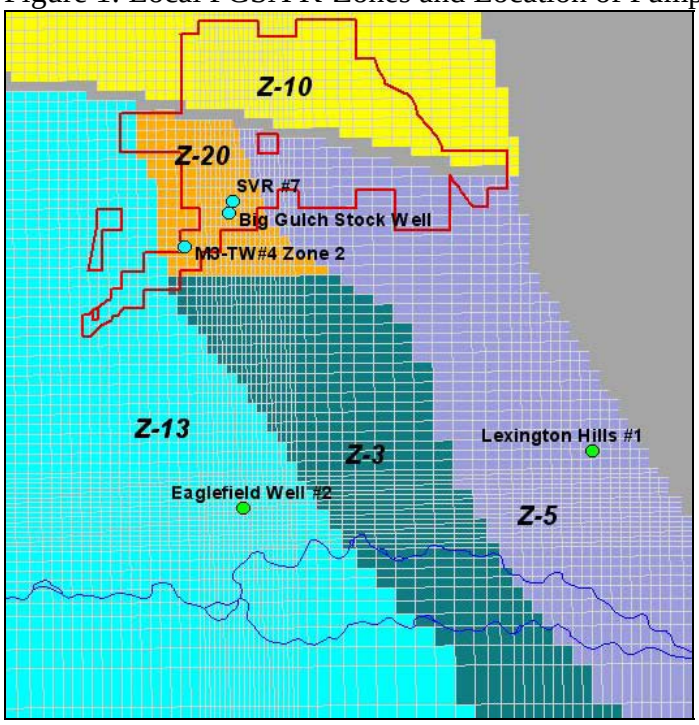


Figure 2: Local PGSA K-Zones and Location of Pumping Test Wells (Tmatch Model)

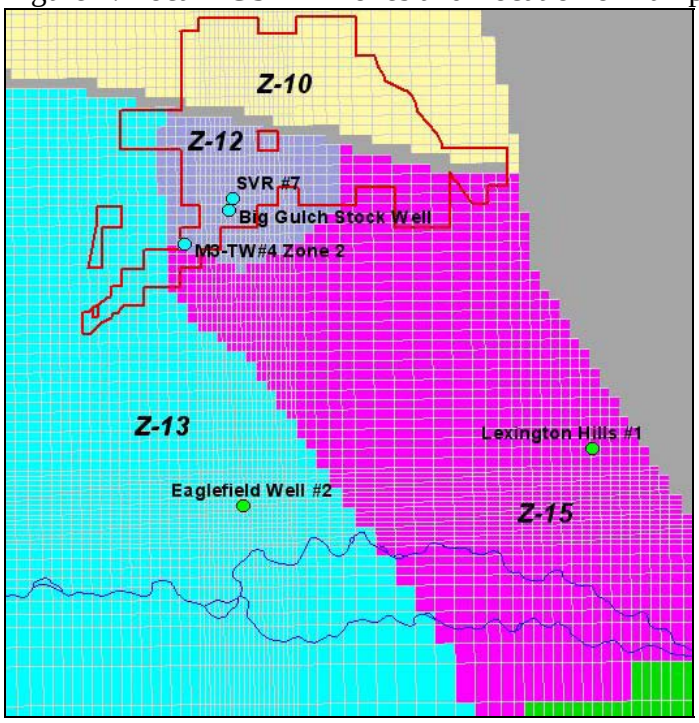


Figure 3: Local PGSA S-Zones and Location of Pumping Test Wells (Both Models)

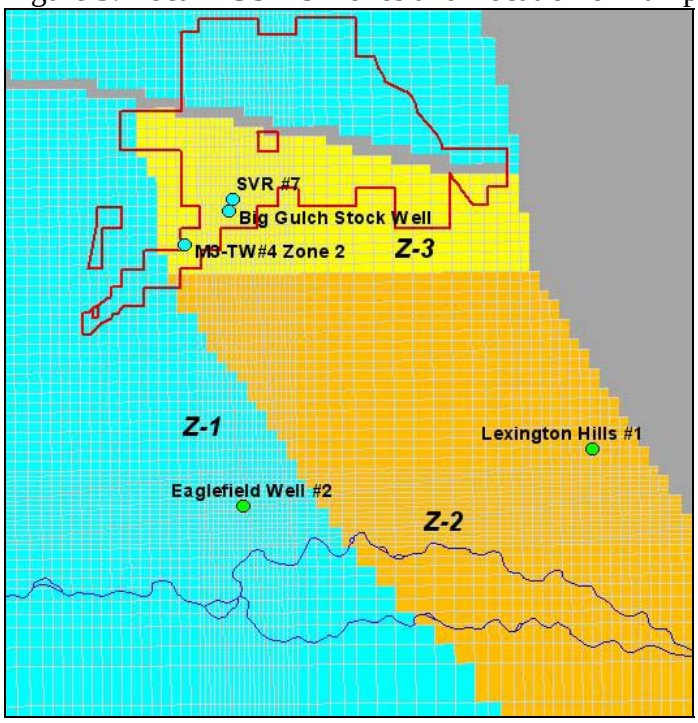


Figure 4: Simulated and Observed Drawdown SVR #7 Pumping Test (Hmatch Model)

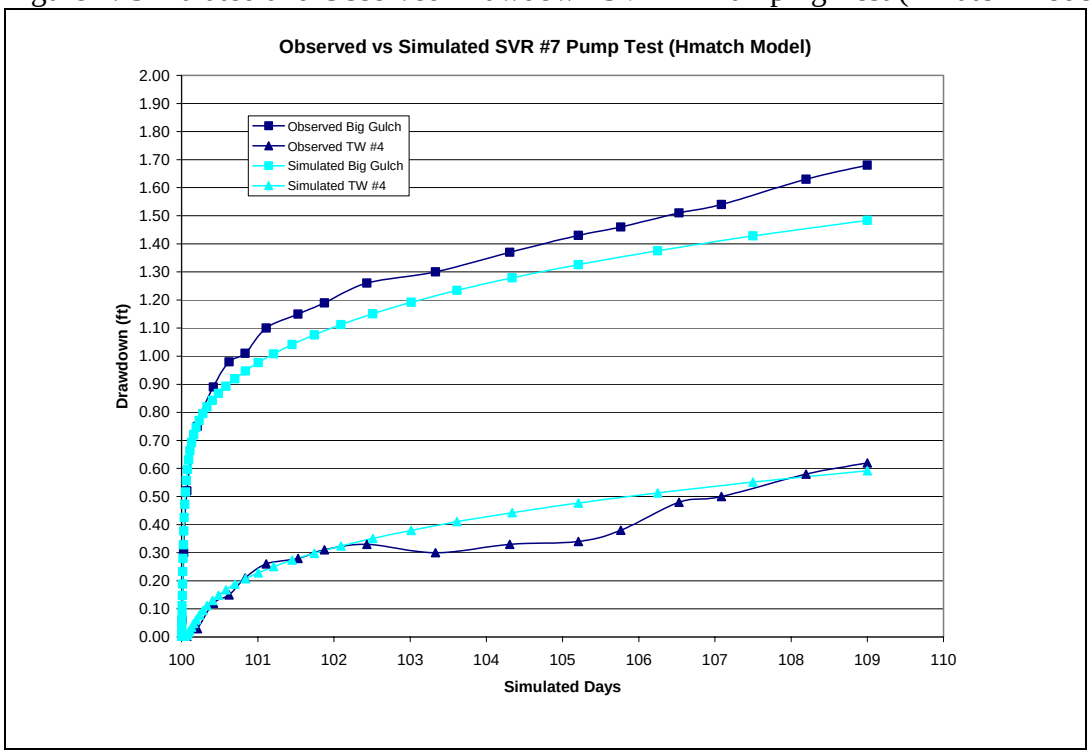


Figure 5: Simulated and Observed Drawdown SVR #7 Pumping Test (Tmatch Model)

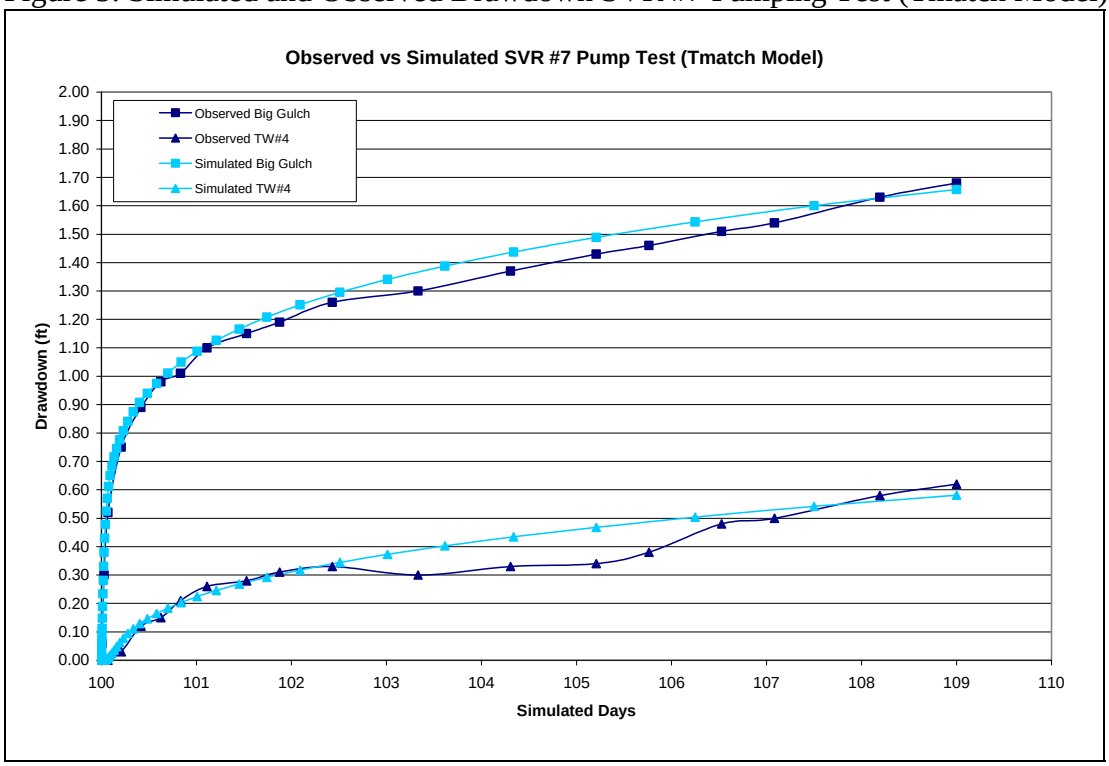
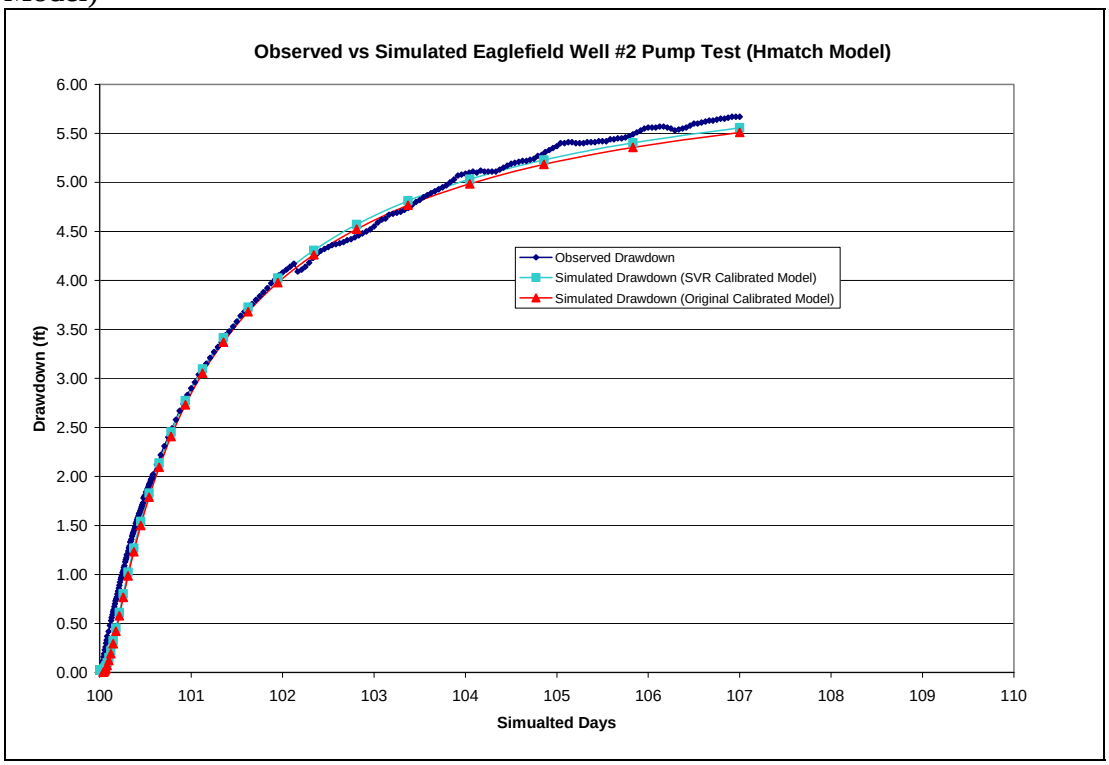


Figure 6: Simulated and Observed Drawdown Eaglefield Well #2 Pumping Test (Hmatch Model)



PACIFIC groundwater GROUP

Technical Memorandum

To: Mark Utting (Hydro Logic, Inc.)

From: Dawn Chapel and Peter Schwartzman (Pacific Groundwater Group)

Re: 50-Year Drawdown Simulation with Proposed NPW wells (M3 Eagle Groundwater Flow Model)

Date: September 22, 2008

This memo summarizes the results of Pacific Groundwater Group's (PGG's) simulation of drawdown from three proposed wells (NPW #1, #2, and #3) using the M3 Eagle groundwater flow model.

The M3 Eagle model was originally developed and calibrated to both steady-state and transient conditions and resulted in two model versions – one that emphasized best fit to interpreted aquifer transmissivity values ("Tmatch") and the other that emphasized best fit to observed groundwater levels ("Hmatch"). Using the two models in predictive simulations allows for a bracketing of results with the Hmatch model more "conservative" (likely to predict larger impacts) than the Tmatch model which is likely to predict smaller impacts.

Local refinements were later made to both models for an additional transient calibration to data recently generated from the SVR #7 pumping test in the Pierce Gulch Sand Aquifer (PGSA). The results of the later calibration were favorable and PGG and Hydro Logic Inc. (HLI) agreed that the newly calibrated models should be used to update predictive drawdown at the M3 site.

The following sections summarize these prior calibration efforts and the results of the simulated drawdown associated with the proposed NPW wells using the newly calibrated models.

ORIGINAL MODEL DEVELOPMENT AND CALIBRATION

The M3 Eagle model was previously developed and calibrated to both steady-state and transient conditions. Two steady-state calibrations were developed – one that emphasized best fit to interpreted aquifer transmissivity values ("Tmatch") and the other that emphasized best fit to observed groundwater levels ("Hmatch").

Transient calibrations included simulation of drawdown responses observed during the 30-day Lexington Hills #1 and the 7-day Eaglefield #2 pumping tests. The location of these test wells are shown in **Figure 1**. The Hmatch model was calibrated to both the

Eaglefield #2 and Lexington Hills #1 pumping test with favorable results. A transient calibration of the Tmatch model was attempted for the Eaglefield #2 but was less favorable without a substantial reduction to the steady state calibrated transmissivity value. Since the Tmatch model was developed to emphasize a best fit to transmissivity, the transmissivity values developed in the steady-state calibration (i.e. close to values interpreted from pumping tests) were used for the predictive simulations.

Predictive simulations were run with both models to predict the effects on the groundwater flow system from proposed pumping at the M3 site. Results of the two model predictions were similar. The original model development, calibration, and predictive simulations are documented in the *M3 Eagle Groundwater Flow Model and Analysis of Pumping Impact* report to Hydro Logic, Inc. (PGG, 2008).

TRANSIENT CALIBRATION TO SVR #7

HLI later requested that PGG perform additional calibration to simulate the 9-day SVR #7 constant rate pumping test. Favorable results were achieved with local refinements to both models. Well SVR #7 and nearby observation wells are shown in **Figure 1** and locally refined distributions of aquifer properties are shown in **Figures 1 through 3**.

The result of the SVR #7 transient calibration effort for the Hmatch model was a slight increase in local hydraulic conductivity in the PGSA such that a portion of Zone 3 (125 ft/day) was replaced with Zone 20 (160 ft/day) as shown on **Figure 1** and a decrease in local PGSA storage coefficient (S-value) such that a portion of Zone 2 (0.005) was replaced with Zone 3 (0.0005) as shown on **Figure 3**. The result of the calibration effort for the Tmatch model was also a slight decrease in the local hydraulic conductivity in the PGSA from 200 ft/day to 160 ft/day (Zone 12) as shown on **Figure 2**, and the same decrease in the local PGSA S-value performed on the Hmatch model (**Figure 3**). In addition, storage coefficient Zone 3 was assigned an Sy value of 0.025 rather than the value of 0.1 used in the Hmatch model. The reduction in the Sy-value for the Tmatch model was required due to nearby model cells in the Tmatch model within the PGSA converting to unconfined as described in the original technical memorandum (PGG, July 26, 2008). The reduction in Sy is consistent with HLI's interpretation of the PGSA being cemented beneath the M3 Eagle property along with a corresponding reduction in both porosity and Sy.

The effects of the local refinements on previous calibrations were also assessed with the new changes and we found little to no effect on the original calibration. The results of the SVR #7 calibration was documented by PGG in a technical memorandum *Transient Calibration to the SVR #7 Pumping Test (M3 Eagle Groundwater Flow Model)* dated July 26, 2008.

50 YEAR DRAWDOWN SIMULATION

PGG used the SVR #7 calibrated Hmatch and Tmatch models to simulate transient drawdown from three proposed wells operating for 50 years. HLI provided PGG with the location of the three proposed wells (NPW #1, #2, and #3) which are assumed to be fully screened within the PGSA (layers 5, 6, and 7). The locations of the three wells are shown in **Figure 4**. Each well was assigned an average constant pumping rate of 1500 gallons per minute. The transient simulation consisted of two stress periods; the first stress period consisting of 100 days of simulation with no pumping followed by the second stress period consisting of 50 years of simulation with pumping. The results of the simulations are discussed below.

50 YEAR DRAWDOWN RESULTS

The results of the 50 year simulation show that most of the drawdown occurs within the first 5 years of pumping and that relative equilibrium in the area of the pumping wells is achieved after about 20 years (**Figures 5 and 6**).

As was the case with the original model development, the Hmatch model simulates slightly higher drawdown than the Tmatch model. The maximum 50 year drawdown simulated in the PGSA (**Figures 7 and 8**) was 33-ft for the Hmatch model and 27-ft for the Tmatch model in the vicinity of Well NPW #3[1]. Drawdown values decreased to 5-ft or less in the vicinity of Boise River (approximately 4 miles south of the site) for the Hmatch model and 4-ft or less for the Tmatch model.

The maximum 50 year drawdown simulated in the Middle Aquifer[3] (layer 3) above the PGSA was 22-ft for the Hmatch model and 16-ft for the Tmatch model with drawdown values decreasing to 2-ft or less in the vicinity of the Boise River for both models (**Figures 9 and 10**). Note that in both models most of layer 3 is dry beneath the project site (north of the NPW wells) both before and after the proposed water supply wells were added to the model.

Small scale numerical noise in the drawdown distribution in the Middle Aquifer can be seen in **Figure 9** (isolated 5-ft drawdown contour between the continuous 10-ft and 5-ft contour intervals). This is due to predictive simulations of drawdown in the shallow portions of the model (layers 1 through 4) being affected by the variability of saturation in the upper layers of the model. This variable saturation is expressed as dry cells, and additional dry cells are created during the predictive simulations of NPW pumping. Creation of new dry cells in the shallowest layers cause some degree of "noise" in the distribution of predicted drawdown in underlying cells, in which simulated drawdown may be somewhat under predicted in isolated areas. This occurs when a model cell in the uppermost

[1] Note that the models cannot be used to estimate the drawdowns in the pumping wells because drawdown is averaged over the entire associated model cell (The cell dimensions at NPW #3 are 660-ft x 660-ft).
[3] The Middle Aquifer (layer 3) is also referred to as the "shallow, unnamed, alluvial aquifer overlying the Pierce Gulch Sand Aquifer"

layer (layer 1) becomes dry during the simulation and recharge gets apportioned to the next lowest layer. Layer 2 is an aquitard, and direct apportionment of recharge can raise the head locally in the receiving cell and the underlying cell in layer 3, thus causing an apparent reduction in local drawdown. This relic noise can be seen in **Figure 9** with the isolated 5-ft drawdown contour between the continuous 10-ft and 5-ft contour intervals. While local areas influenced by such relic noise tend to underpredict drawdown, the order of magnitude of model drawdown predictions in this general region of the model is still believed to be reasonable and representative.

Figure 1: Local PGSA K-Zones in PGSA (Hmatch model)

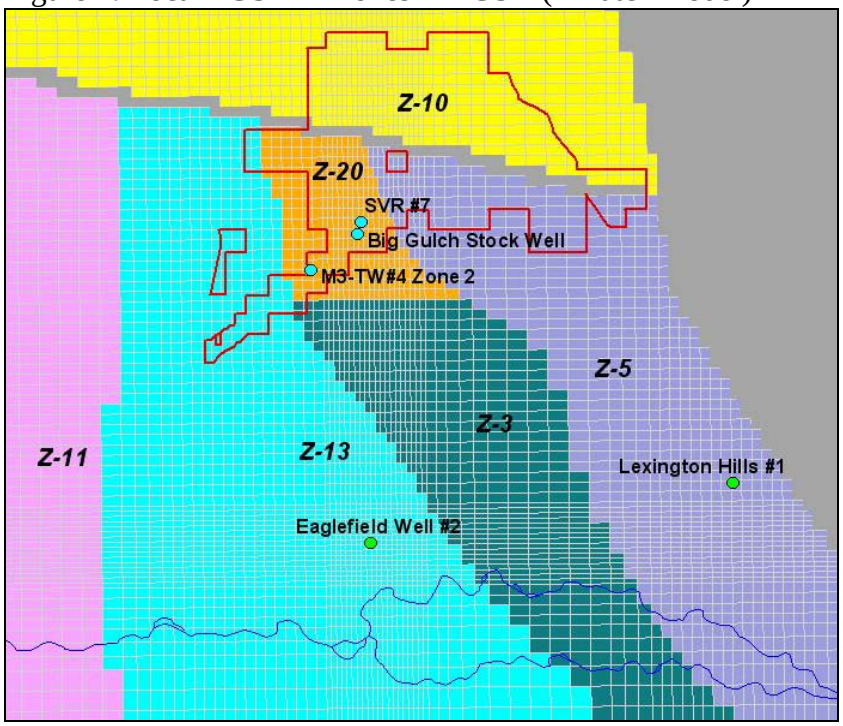


Figure 2: Local PGSA K-Zones in PGSA (Tmatch model)

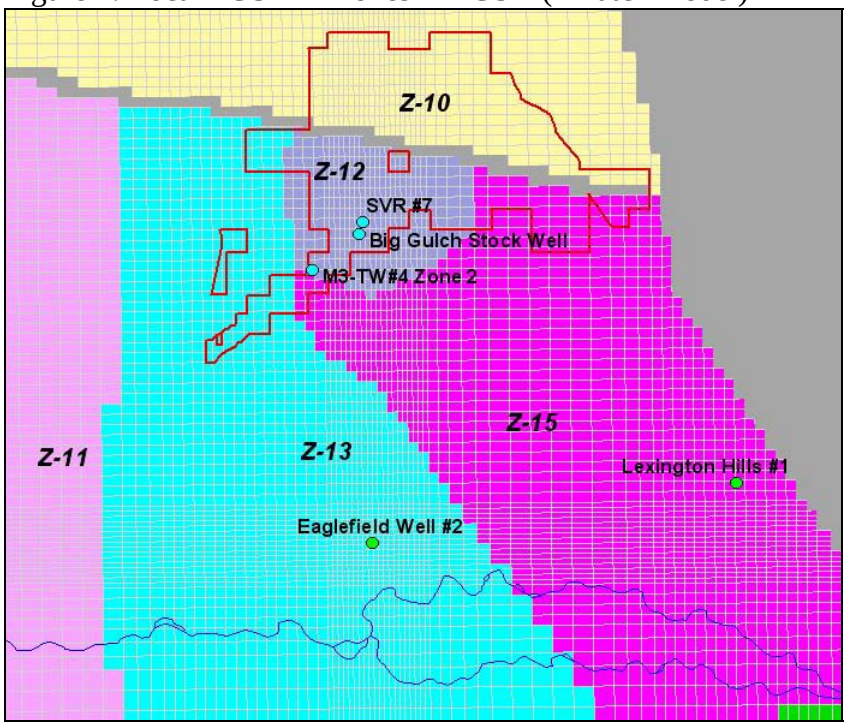


Figure 3: S-Zones in PGSA (Both models)

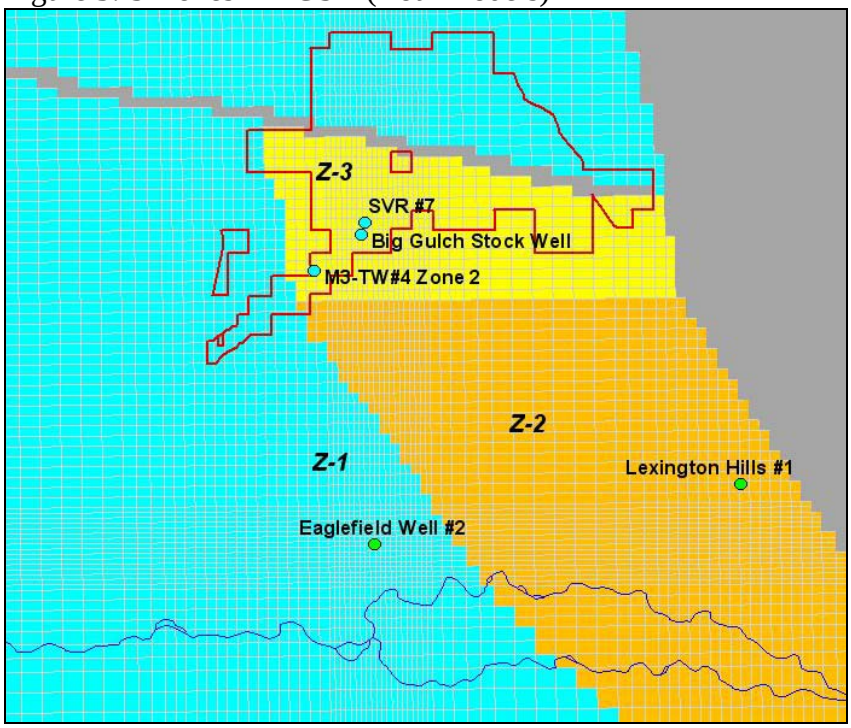


Figure 4: Location of Proposed NPW Pumping Wells

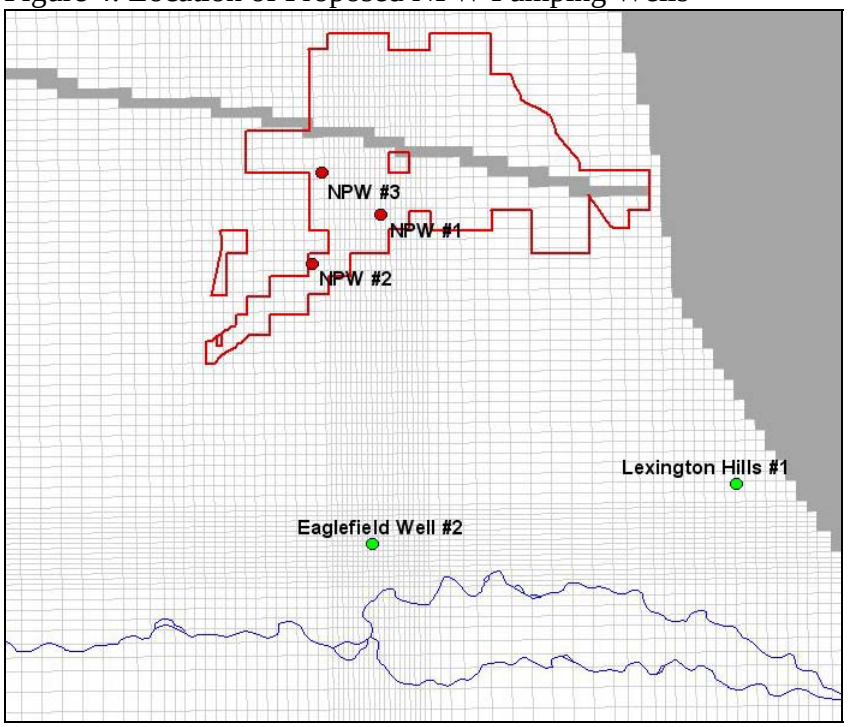


Figure 5: Percent of Total Simulated Drawdown at Pumping Wells (Hmatch)

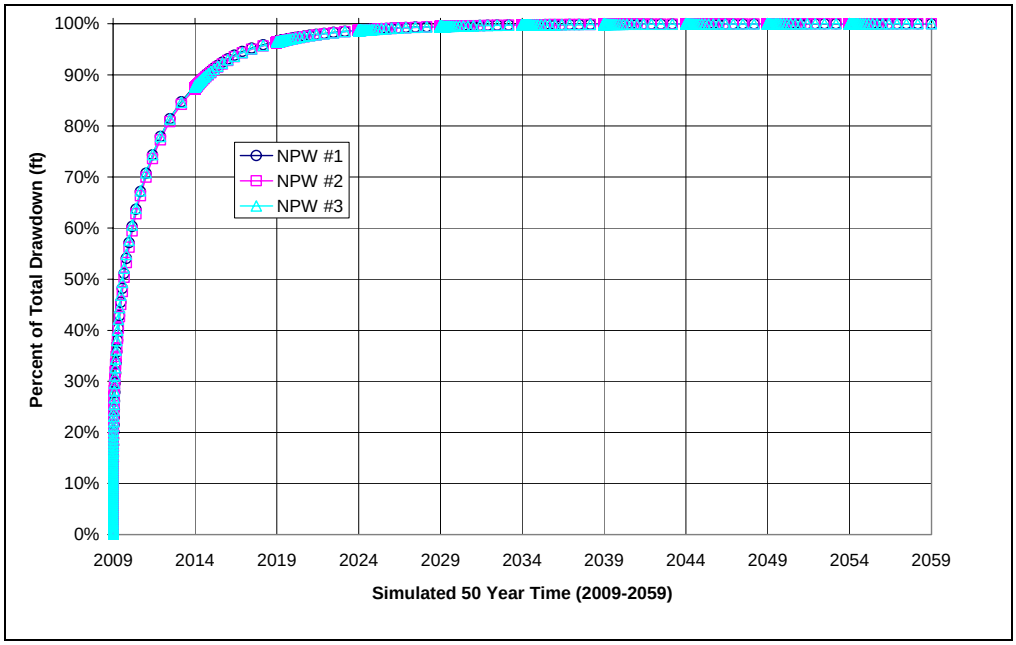
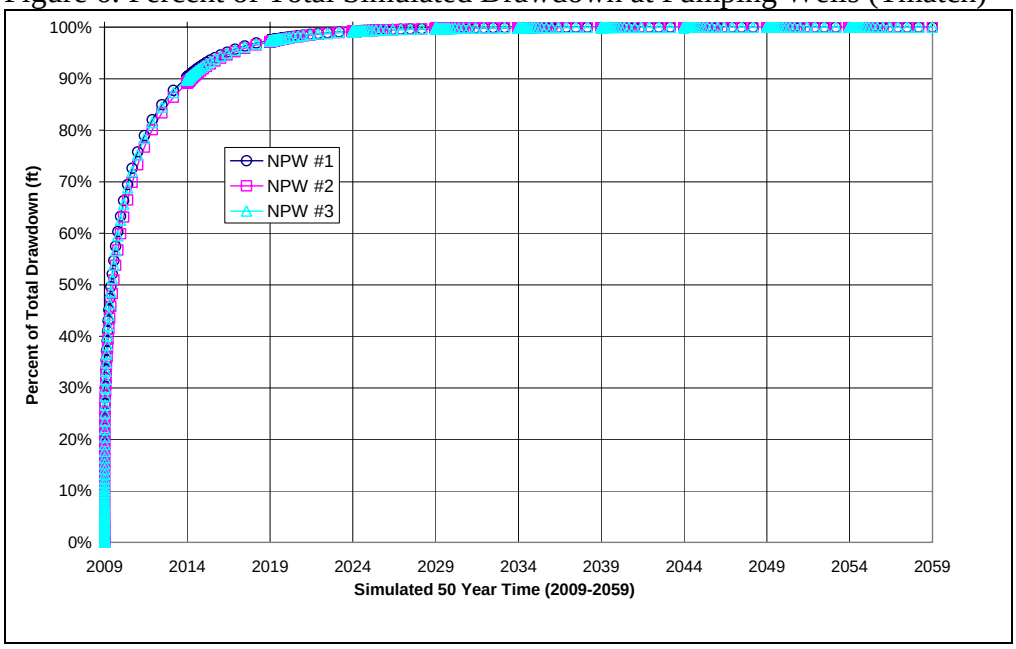


Figure 6: Percent of Total Simulated Drawdown at Pumping Wells (Tmatch)



NPWwells_DD_PGSA_50_Hmatch.mxd

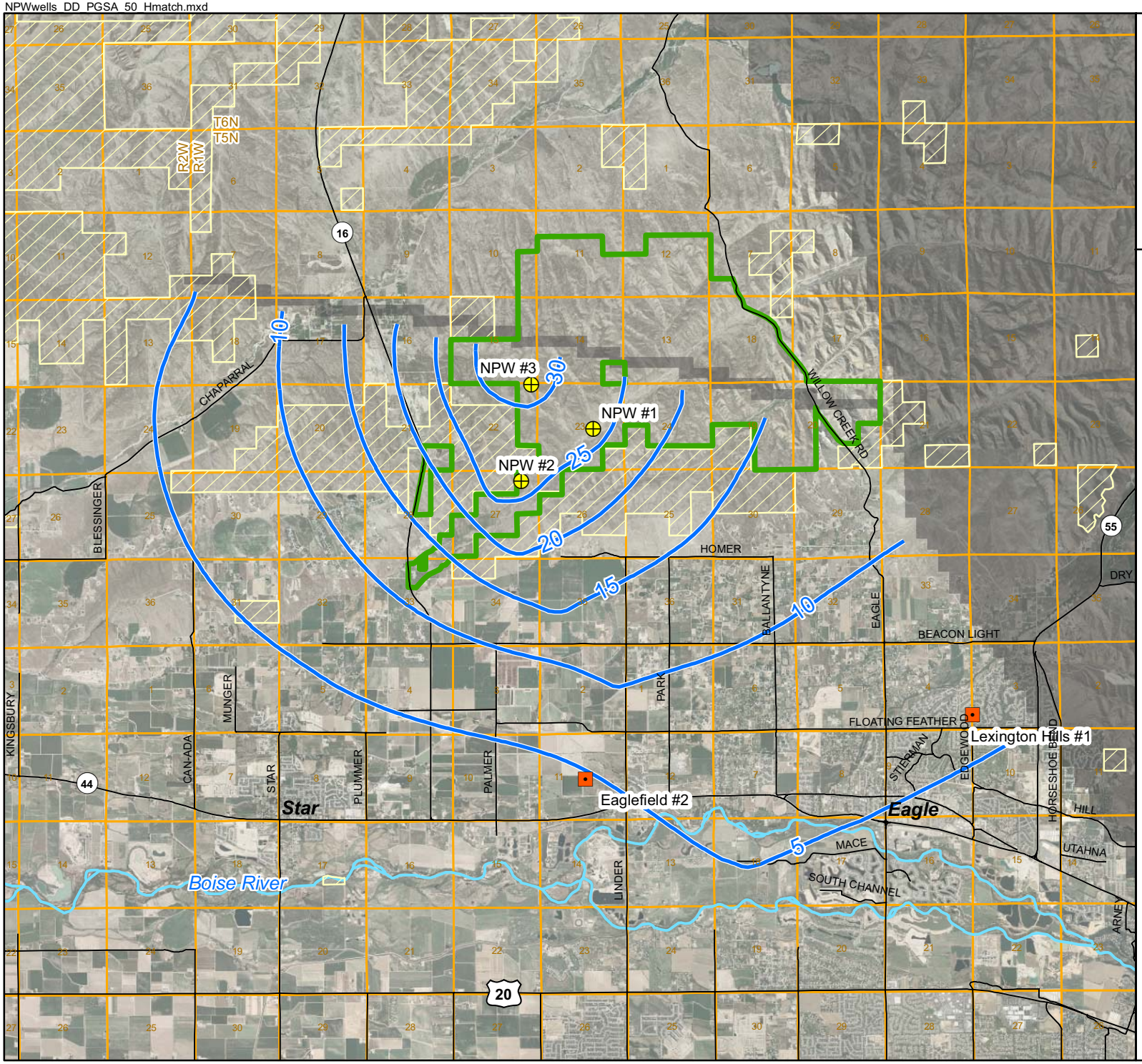


Figure 7

Simulated PGSA Drawdown After 50 Years (NPW wells) - Hmatch Model

M3 Eagle Model
JZ0705

NPW Wells
(Pumping at 1500 GPM)

Model Observation Wells

Drawdown in feet
(5 ft. contour interval)

No Flow Zones

Site Boundary

BLM Lands

PgG

0 Feet 8,000

2006 Orthophoto

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NPWwells_DD_PGSA_50_Tmatch.mxd

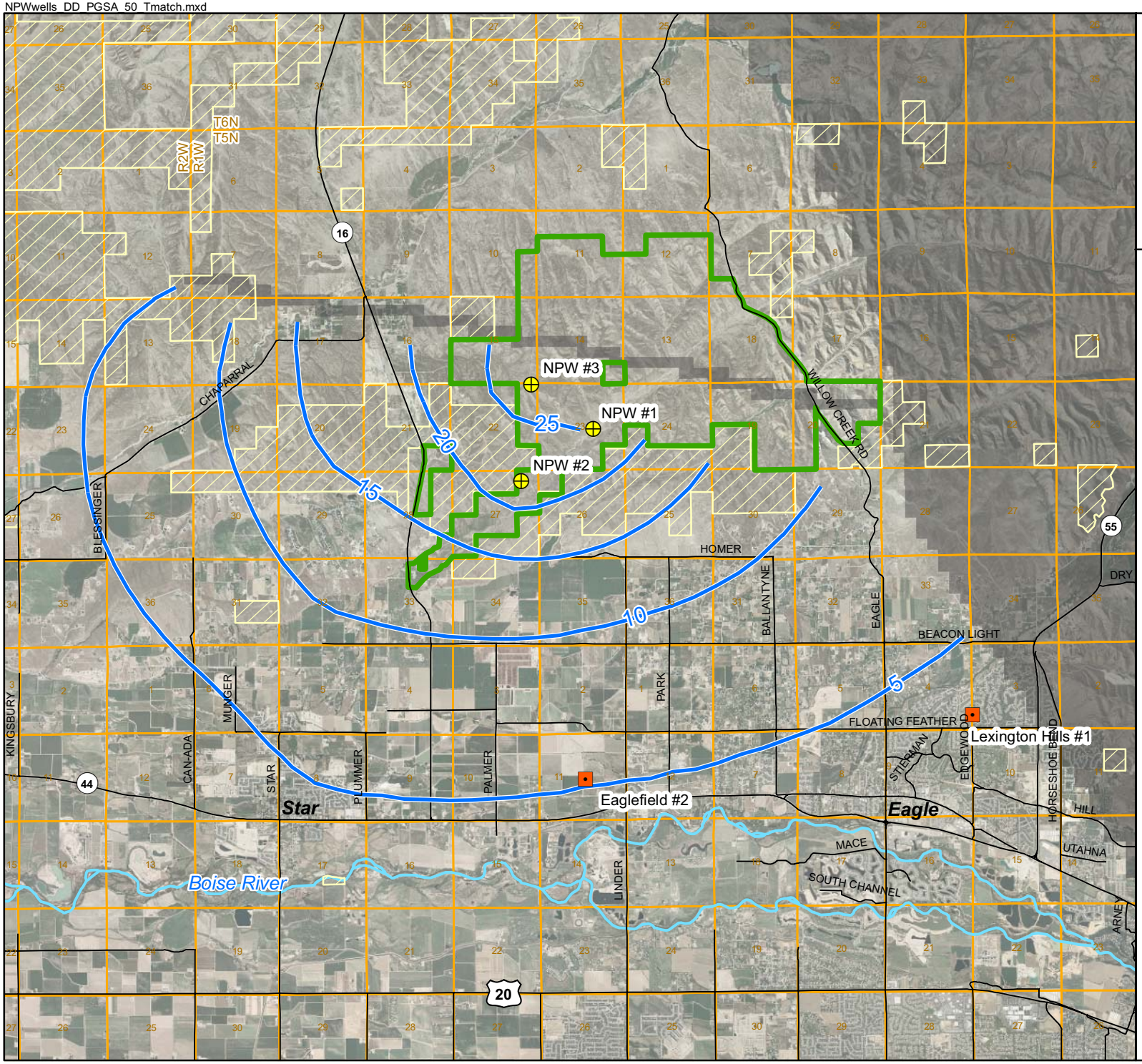


Figure 8

Simulated PGSA Drawdown After 50 Years (NPW wells) - Tmatch Model

M3 Eagle Model
JZ0705

- NPW Wells (Pumping at 1500 GPM)
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

PgG

0 Feet 8,000

2006 Orthophoto

N

NPWwells_DD_Middle_50_Hmatch.mxd

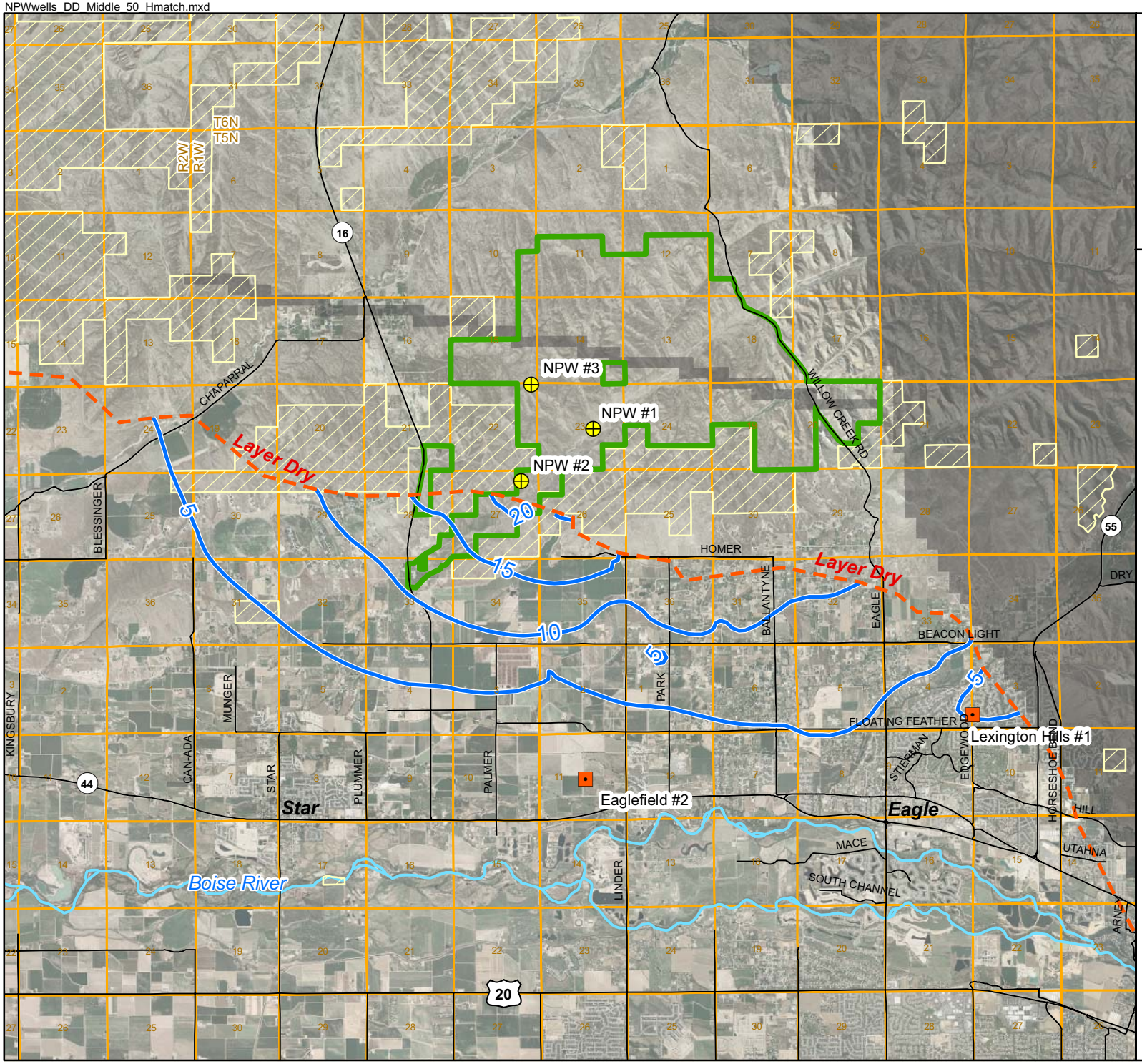


Figure 9

Simulated Middle Aquifer Drawdown After 50 Years (NPW wells) - Hmatch Model

M3 Eagle Model
JZ0705

- NPW Wells (Pumping at 1500 GPM)
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
  Isolated 5-ft contour reflects numerical noise associated with overlying model cell going dry.
- No Flow Zones
- Site Boundary
- BLM Lands

PgG

0 Feet 8,000

2006 Orthophoto

N

NPWwells_DD_Middle_50_Tmatch.mxd

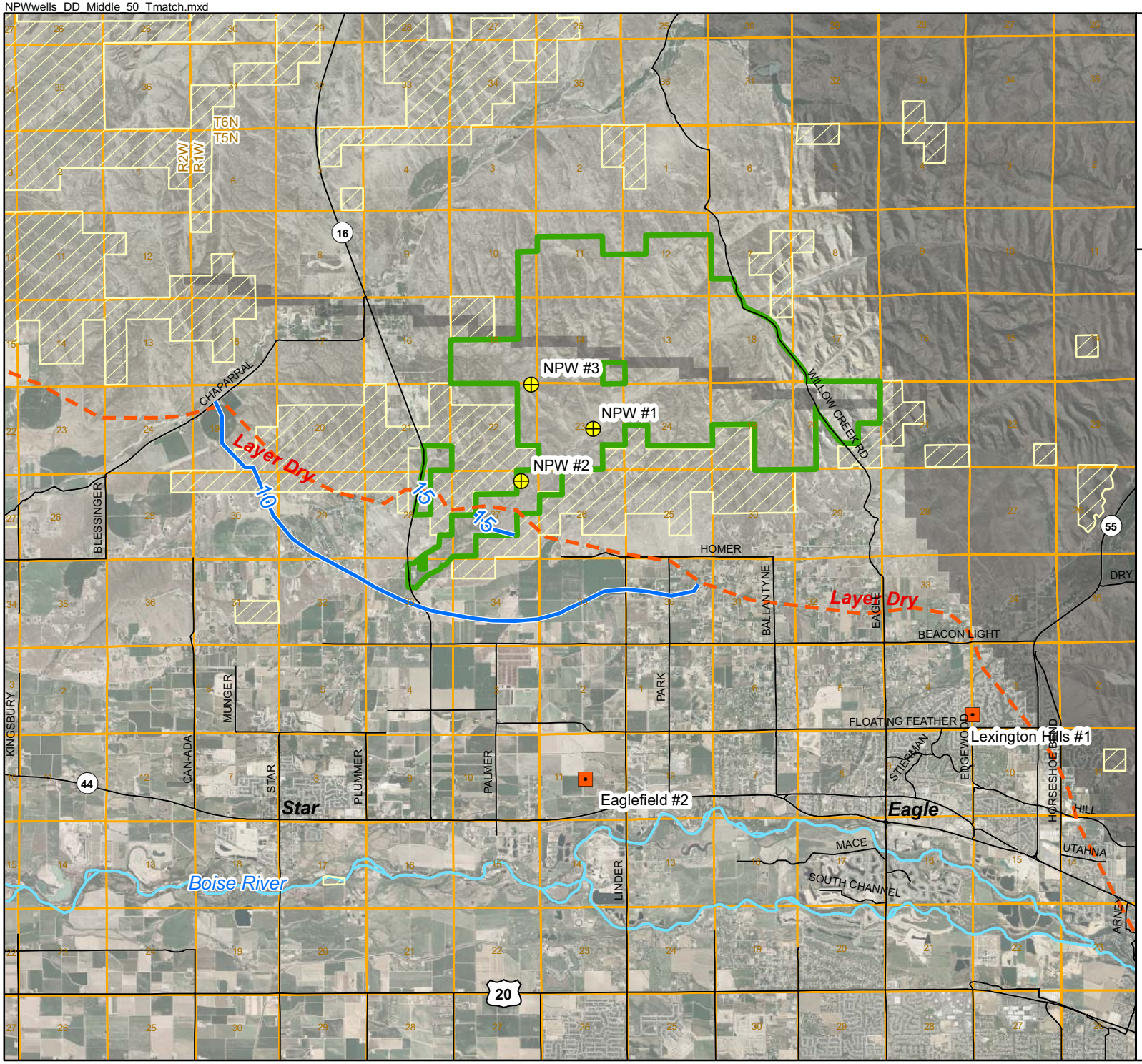


Figure 10

Simulated Middle Aquifer Drawdown After 50 Years (NPW wells) - Tmatch Model

M3 Eagle Model
JZ0705

- NPW Wells (Pumping at 1500 GPM)
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

PgG

0 Feet 8,000

2006 Orthophoto

N

PACIFIC groundwater GROUP

Technical Memorandum

To: Mark Utting (Hydro Logic, Inc.)

From: Dawn Chapel and Peter Schwartzman (Pacific Groundwater Group)

Re: Model Refinement and Recalibration; Re-simulation of 50-year Drawdown; and Assessment of Affects of Reduced Canal Leakage (M3 Eagle Groundwater Flow Model)

Date: November 14, 2008

This memo summarizes Pacific Groundwater Group's (PGG's) results for model refinement and recalibration associated with additional pumping introduced to the M3 Eagle groundwater flow model. The memo also presents new simulation results of drawdown from three proposed wells (NPW #1, #2, and #3) at the M3 Site using the refined model. Finally, the effects from a 20% reduction in recharge to the Pierce Gulch Sand Aquifer (PGSA) from reduced leakage in the New York canal are evaluated with the model. These topics are preceded by a review of prior development of the groundwater flow model.

PRIOR MODEL DEVELOPMENT

The M3 Eagle model was originally developed and calibrated to both steady-state and transient conditions and resulted in two model versions – one that emphasized best fit to interpreted aquifer transmissivity values ("Tmatch") and the other that emphasized best fit to observed groundwater levels ("Hmatch") The original modeling effort included predictive simulations of drawdown from progressively more pumping wells at the M3 Site over a 26 year period. The original model development, calibration, and predictive simulations are documented in the *M3 Eagle Groundwater Flow Model and Analysis of Pumping Impact* report to Hydro Logic, Inc. (PGG, 2008).

Local refinements were later made to both versions of the model for an additional transient calibration to the SVR #7 pumping test. The results of this calibration were favorable and PGG and HLI agreed that the newly calibrated models should be used to update predictive drawdown at the M3 site. HLI provided PGG with new well locations and associated maximum pumping rates, for which PGG performed a 50-year full pumping simulation. The results of the SVR #7 calibration were documented by PGG in a technical memorandum *Transient Calibration to the SVR #7 Pumping Test (M3 Eagle Groundwater Flow Model)* dated July 26, 2008. The results of the 50-year drawdown simulation (updated for the SVR #7 calibration) were documented by PGG in a technical memorandum *50-Year Drawdown Simulation with Proposed NPW wells (M3 Eagle Groundwater Flow Model)* dated September 22, 2008.

MODEL REFINEMENT AND RECALIBRATION

HLI recently determined that additional information on pumping from housing developments, fisheries and industrial uses was available and should be incorporated into the groundwater flow model. Additional information on pumping from the Cities of Meridian, Nampa and Caldwell were also incorporated into the model, thus resulting in increased pumping from both the Middle Aquifer and the PGSA. The following sections summarize model refinement through introduction of new pumping, re-calibration of both model versions, and associated predictive simulations of drawdown over 50 years of pumping at the M3 Site.

MODEL REFINEMENT

HLI provided PGG with additional groundwater withdrawal information to be added to the model. The information consisted of estimated pumping and construction information for individual wells operated by specific municipalities (e.g. Meridian, Nampa, Caldwell) along with estimates of groundwater withdrawals for housing developments, fisheries and industrial users grouped per quarter section for multiple wells. The grouped pumping estimates were assumed to represent withdrawals from the Middle Aquifer (layer 3 in the model); whereas the pumping estimates for municipalities were assigned to model layers based on the location and completion elevations of individual wells[1]. The total pumping added to the Middle Aquifer was 46 cfs (about a 30% increase from the original modeled Middle-Aquifer pumping and the total additional pumping added to the PGSA (layers 5, 6 and 7) was 8.3 cfs (about a 10% increase from the original modeled pumping from the PGSA). Pumping from all wells with completions in the PGSA was distributed across the entire thickness of the PGSA (layers 5-7).

MODEL RECALIBRATION

Model recalibration consisted of steady-state and transient recalibrations. As described in the original model report, steady-state recalibration for the Hmatch model emphasized achieving the best model matches to observed groundwater elevations within the PGSA whereas steady-state recalibration for the Tmatch model emphasized maintaining a match to estimated transmissivities within the PGSA. Transient recalibration focused on matching both models to the observed 9-day drawdown from the SVR #7 aquifer test at the M3 Site. Both original models had been successfully calibrated to the SVR #7 aquifer test. A transient recalibration to the 7-day Eaglefield #2 and 30-day Lexington Hills #1 aquifer tests was also performed for the Hmatch model. The original Hmatch model had been successfully calibrated to both these tests.

An iterative calibration approach between the transient and steady-state models was necessary to ensure a good calibration match to both steady-state target values and transient

[1] HLI provided spatial coordinates for the wells, PGG estimated wellhead elevations from the project Digital Elevation Model, and PGG compared completion interval elevations to model layer elevations to distribute wells over associated model layers.

target values. This involved, through trial and error, adjustments to hydraulic conductivity (K), storage coefficient (S) and specific yield (Sy) values within the PGSA that would provide a good fit to both steady state and transient target values.

The following sections summarize the steady-state and transient recalibration results

Steady-State Model Recalibration Results

The steady state calibration for the Hmatch model resulted in a slight increase in the hydraulic conductivity by 20% in PGSA Zone 5 (from 220 to 264 ft/day) and PGSA Zone 3 (from 125 to 150 ft/day) (**Figure 1**). The steady-state calibration for the Tmatch model resulted in a slight increase in the hydraulic conductivity by 25% in PGSA Zone 12 (from 160 to 200 ft/day) (**Figure 2**). The changes in local aquifer properties for the PGSA zones shown on **Figures 1** and **2** among the original model, the calibration to the SVR #7 aquifer test, and the current refined model are summarized in **Table 1** below.

Table 1: Local Changes to PGSA Hydraulic Conductivity, Storage Coefficient, and Specific Yield

Local Horizontal Hydraulic Conductivity (Kh) in PGSA							
Tmatch Model				Hmatch Model			
Local PGSA Zone Number	Kh (ft/day) Original Model	Kh (ft/day) Original SVR #7	Kh (ft/day) New Model	Local PGSA Zone Number	Kh (ft/day) Original Model	Kh (ft/day) Original SVR #7	Kh (ft/day) New Model
12	200	160	200	3	125	125	150
13	80	80	80	5	220	220	264
14	85	85	85	20	NA (was zone 3)	160	160
15	95	95	95	13	15	15	15
				14	85	85	85
Note: Kh/Kv = 10 for all zones listed above							

Local Storage Coefficient (S) and Specific Yeild (Sy) in PGSA							
Tmatch Model				Hmatch Model			
Local PGSA Zone Number	S/Sy Original Model	S/Sy Original SVR #7	S/Sy New Model	Local PGSA Zone Number	S/Sy Original Model	S/Sy Original SVR #7	S/Sy New Model
1	0.00035/0.1	0.00035/0.1	0.00035/0.1	1	0.00035/0.1	0.00035/0.1	0.00035/0.1
2	0.005/0.1	0.005/0.1	0.005/0.1	2	0.005/0.1	0.005/0.1	0.004/0.1
3	NA (was zone 2)	0.0005/0.025	0.0002/0.01	3	NA (was zone 2)	0.0005/0.1	0.0005/0.05

See Figures 1-3 for distribution of PGSA zones

The increase in the hydraulic conductivity for Zone 12 in the new Tmatch model and Zones 3 and 5 in the new Hmatch model were needed to both match target groundwater elevations and to match simulated drawdown values in the transient recalibrations (see below).

Final modeled heads and target residuals in the PGSA (layer 6) for the Hmatch and Tmatch models are shown in **Figures 4 and 5**. The target residuals were fairly similar to the original steady-state model calibration.

The residual mean (RM), absolute residual mean (ARM) and percentage of the residual standard deviation to the observed head range (RSD/R) for the original models and the newly calibrated models are summarized below in **Table 2** and are considered acceptable calibration results for both model realizations. Summary residual statistics are discussed in more detail in the original report (PGG, 2008).

Table 2: Summary of Head Target Statistics for Steady State Calibration

Statistic	Tmatch (Original)	Tmatch (New)	Hmatch (Original)	Hmatch (New)
RM	2.71	8.92	2.82	6.38
ARM	13.99	14.16	9.75	10.22
RSD/R	6.25%	5.93%	4.84%	4.64%

The final transmissivity values in the PGSA for both models were also within the acceptable ranges defined for the Hmatch and Tmatch calibrations, as described in the original report.

Transient Model Recalibration Results

The Hmatch and Tmatch models were both recalibrated to the 9-day constant rate SVR #7 aquifer test. The Hmatch model was also recalibrated to the 7-day Eaglefield #2 aquifer test and the 30-day Lexington Hills #1 aquifer test. Associated test wells are shown in **Figure 1.** In additional to the slight local modifications in hydraulic conductivity described above, the transient recalibration work required some slight local modifications to the storage coefficient (S) and specific yield (Sy) for both models. For the Hmatch model, a decrease in Sy from 0.1 to 0.05 in Zone 3 was required to match the 9-day SVR #7 aquifer test and a decrease in S from 0.005 to 0.004 in Zone 2 was required to match the 30-day Lexington Hills #1 aquifer test. For the Tmatch model, a decrease in the S from 0.0005 to 0.0002 and Sy from 0.025 to 0.01 in Zone 3 was required to match the 9-day SVR #7 aquifer test. **Figure 3** shows a map of the different S and Sy zones and **Table 1** summarizes these modifications.

As described in the original SVR #7 transient calibration memo (dated July 26, 2008), Sy is relevant to the transient calibration because the SVR #7 aquifer test occurs in an area where portions of the PGSA sediments are not fully saturated (unconfined). Furthermore, the reduced values of Sy suggest a more "semi-confined" aquifer response, which is consistent with cementation observed in the PGSA. Unconfined conditions in the PGSA are associated with unsaturated conditions in overlying model cells. In the original SVR #7 transient calibration the reduction in Sy was only required for the Tmatch model. With the addition of 30% more groundwater withdrawal in the Middle Aquifer (layer 3), more local cells in the uppermost layers of both models have drained to unsaturated and underlying areas of the PGSA represented as unconfined have therefore expanded.

Simulated versus observed drawdown for the Hmatch and Tmatch models for the two observation wells associated with the SVR #7 aquifer test (Big Gulch and TW #4) are shown in **Figures 6 and 7**. As shown in the figures, the newly modified models provide a reasonable match to the observed drawdown.

Simulated versus observed drawdown for the Hmatch model for the observations wells associated with the 30-day Lexington Hills #1 and the 7-day Eaglefield #2 aquifer tests are shown in **Figures 8 and 9.** As shown in the figures, the newly modified Hmatch model provides a reasonable match to the observed drawdown.

As described in the original report, the Tmatch model did not calibrate favorably to the 7-day Eaglefield #2 aquifer test without a substantial decrease in the local hydraulic conductivity of the PGSA. The Tmatch model underpredicted the maximum measured drawdown by about 35%. It should be noted, however, that HLI reported in its reanalysis of the 7-day Eaglefield #2 test, that pumping from an unidentified, nearby well (or wells) may have caused drawdowns that were not representative of aquifer response caused solely by pumping of the Eaglefield #2 well. Because of this uncertainty in the representativeness of the measured drawdowns and because the Tmatch model was developed to emphasize a match to field estimates of transmissivity, these transmissivity values were honored over matching local aquifer conditions to the 7-day aquifer test. As such, a recalibration effort to the 7-day aquifer test was not attempted with the newly modified Tmatch model.

NEW PREDICTIVE SIMULATIONS

PGG used the newly modified and recalibrated Hmatch and Tmatch models to simulate transient drawdown from three proposed wells operating for 50 years. HLI provided PGG with the location of the three proposed wells (NPW #1, #2, and #3) as shown in **Figure 10**. The wells are assumed to be fully screened within the PGSA (layers 5, 6, and 7). Each well was assigned an average constant pumping rate of 1500 gallons per minute. The transient simulation consisted of two stress periods; the first stress period consisting of 100 days of simulation with no pumping followed by the second stress period consisting of 50 years of simulation with pumping.

For the predictive simulations the general head boundary (GHB) used in both models to represent subflow into the PGSA along the southeast corner of the model in layers 5, 6, and 7 was converted to a constant flux boundary based on the steady-state calibrated solutions (**Figure 11**)[2]. The total constant-flux inflow was 114.77 cfs for the Hmatch model and 106.82 cfs for the Tmatch model. As described in the original report, the GHB represents an upstream location in the Boise River Valley where the PGSA has a stronger hydraulic connection to the river, its associated alluvium, and leakage from the New York Canal. Conversion to a constant flux boundary based on the steady-state solution takes a conservative approach for the predictive simulations in that additional flux from the boundary can not be induced during the simulations. Addition flux into the model from a general head boundary could result in less predicted drawdown.

HLI also requested that PGG perform sensitivity simulations with the model to assess pumping drawdown in the PGSA if the influx from the southeast boundary was reduced by 20%; the reduction representing reduced leakage from the New York Canal. The 20% reduction resulted in a total constant flux of 91.82 cfs assigned for the Hmatch model and 85.46 cfs for the Tmatch model. PGG simulated the reduction with both versions of the model in steady state to assess the long-term effects on groundwater levels caused by the reduced canal leakage.

[2] Model boundary conditions are described in more detail in the original report (PGG, 2008).

The results of the 50-year predictive simulation and the reduction of leakage from the New York Canal are summarized below.

NEW 50-YEAR PREDICTIVE SIMULATION

The results of the 50-year simulation are similar to the original predictive simulations and show that most of the drawdown occurs within the first 5 years of pumping and that relative equilibrium in the area of the pumping wells is achieved after about 20 years for both model versions (**Figures 12 and 13**).

As was the case with the original model, the Hmatch model simulates slightly higher drawdown than the Tmatch model. The 50-year maximum drawdown simulated in the PGSA was 31-ft for the Hmatch model and 27-ft for the Tmatch model in the vicinity of Well NPW #3 (**Figures 14 and 15**)[3]. Drawdown values decrease to 5-ft or less in the vicinity of Boise River (approximately 4 miles south of the site) for the Hmatch model and 4-ft or less for the Tmatch model. These results are very similar to the previous 50-year predictive simulations documented by PGG in a technical memorandum *50-Year Drawdown Simulation with Proposed NPW wells (M3 Eagle Groundwater Flow Model)* dated September 22, 2008. However, the new Hmatch model predicts about 2-ft less drawdown in the vicinity of the NPW pumping wells than the original Hmatch model. This is likely related to the 20% increase in local hydraulic conductivity required for the recalibration discussed above.

The use of a constant flux boundary for the southeast corner of the model in layer 5-7 versus the use of a general head boundary, as was done in the original 50-year predictive simulation, did not make a significant difference in the predicted drawdown values. Drawdown near the boundary was about 1-ft higher with the constant flux boundary for both versions of the model.

Tables 3 and 4 present water budget summaries for the Tmatch and the Hmatch models both with and without NPW pumping. The difference in mass balance with and without pumping indicates that more than 90% of the proposed NPW pumping are capturing water that would have discharged to the Boise River or that entered the model as subflow within the Boise River alluvium.

[3] Note that the models cannot be used to estimate the drawdowns in the pumping wells because drawdown is averaged over the entire associated model cell (The cell dimensions at NPW #3 are 660-ft x 660-ft).

Table 3: Water Budget for Steady-State and 50-Year Transient Hmatch Simulation

Water Budget Component	Boundary Type	Model Layer	Hmatch (SS No Pumping) Net Inflow (cfs)	Hmatch (50 Year Pumping) Net Inflow (cfs)	Hmatch (Difference) Difference[1] 50yr-SS (cfs)	Hmatch (Difference) Percent Contribution to NPW Pumping
Recharge	Recharge	Uppermost Active	542.44	542.44	0.00	0.00%
Boise River Seepage	River	Layer 1	-530.53	-521.58	8.95	89.27%
Payette River Seepage	River	Layers 1,2,3	-386.91	-386.72	0.19	1.92%
Lake Lowell Seepage	River	Layer 1	17.49	17.51	0.01	0.14%
Dry Creek Seepage Inflow	Wells	Layer 1	3.95	3.95	0.00	0.00%
Middle Aquifer Pumping (Domestic, Industrial)	Wells	Layer 3	-59.68	-59.51	0.17	1.72%
PGSA Pumping (Municipal, Industrial & Irrigation Pumping)	Wells	Layers 5-7	-84.09	-94.12	-10.03	NA
Boise River Alluvial Aquifer Inflow	CHB	Layer 1	80.95	81.57	0.62	6.21%
Boise River Alluvial Aquifer Outflow	CHB	Layer 1	11.76	11.78	0.02	0.20%
Payette River Alluvial Aquifer Inflow	CHB	Layer 1	282.48	282.49	0.01	0.07%
Payette River Alluvial Aquifer Outflow	CHB	Layer 1	-1.92	-1.91	0.00	0.01%
PGSA Inflow from SE Model Boundary	GHB[2]	Layers 5-7	114.77	114.77	0.00	0.00%
PGSA Outflow at SW Model Boundary	CHB	Layers 5-7	7.61	7.62	0.01	0.14%
Payette River Valley Fill Outflow	CHB	Layers 5-7	1.98	1.98	0.00	0.02%
Willow Creek Aquifer Along NE Model Boundary	CHB	Layers 5-7	-0.30	-0.27	0.03	0.31%
Model Mass Balance Error			*<1%*	*<1%*		

1. Negative number indicates more outflow simulated in the transient model. Positive number indicates more inflow
2. For the 50 year pumping simulation the boundary type was constant flux

Table 4: Water Budget for Steady-State and 50-Year Transient Tmatch Simulation

Water Budget Component	Boundary Type	Model Layer	Tmatch (SS No Pumping) Net Inflow (cfs)	Tmatch (50 Year Pumping) Net Inflow (cfs)	Hmatch (Difference) Difference[1] 50yr-SS (cfs)	Hmatch (Difference) Percent Contribution to NPW Pumping
Recharge	Recharge	Uppermost Active	542.44	542.44	0.00	0.00%
Boise River Seepage	River	Layer 1	-529.18	-520.05	9.13	88.60%
Payette River Seepage	River	Layers 1,2,3	-387.02	-387.00	0.01	0.14%
Lake Lowell Seepage	River	Layer 1	17.36	17.38	0.02	0.23%
Dry Creek Seepage Inflow	Wells	Layer 1	3.95	3.95	0.00	0.00%
Middle Aquifer Pumping (Domestic, Industrial)	Wells	Layer 3	-59.52	-59.39	0.14	1.33%
PGSA Pumping (Municipal, Industrial & Irrigation Pumping)	Wells	Layers 5-7	-84.09	-94.40	-10.30	NA
Boise River Alluvial Aquifer Inflow	CHB	Layer 1	88.50	88.84	0.34	3.35%
Boise River Alluvial Aquifer Outflow	CHB	Layer 1	11.61	11.64	0.04	0.37%
Payette River Alluvial Aquifer Inflow	CHB	Layer 1	282.49	282.47	-0.01	-0.14%
Payette River Alluvial Aquifer Outflow	CHB	Layer 1	-2.18	-1.92	0.26	2.48%
PGSA Inflow from SE Model Boundary	GHB[2]	Layers 5-7	106.82	106.82	0.00	0.00%
PGSA Outflow at SW Model Boundary	CHB	Layers 5-7	7.42	7.45	0.03	0.28%
Payette River Valley Fill Outflow	CHB	Layers 5-7	1.75	1.97	0.22	2.14%
Willow Creek Aquifer Along NE Model Boundary	CHB	Layers 5-7	-0.39	-0.34	0.05	0.48%
Model Mass Balance Error			*<1%*	*<1%*		

1. Negative number indicates more outflow simulated in the transient model. Positive number indicates more inflow
2. For the 50 year pumping simulation the boundary type was constant flux

Note that model results show a small (0.14-0.17 cfs) reduction in pumpage from the Middle Aquifer (model layer 3). This reduction is well within the bound of error associated with estimation of pumping in layer 3. It arises because cells within a small portion of layer 3 (e.g. south of the fault) become dry with the additional NPW pumping. However, PGG did not attempt to calibrate the model to the distribution of saturation in the Middle Aquifer, and predictions of change in saturation should be taken in the context of a non-calibrated portion of the model.

AFFECTS OF REDUCTION FROM NEW YORK CANAL LEAKAGE

The results of the steady state simulation with 20% reduced flux from the southeast boundary show decreases in groundwater elevations (**Figures 16 and 17**) within the PGSA. The simulation shows decreases in groundwater elevations near the M3 Site of about 3-ft for the Hmatch model and about 2-ft for the Tmatch model. Groundwater elevations near the Boise River also decreased from about 15-ft closest to the boundary to 2-ft near the Eaglefield #2 well for the Hmatch model and about 7-ft closest to the boundary to 3-ft near the Eaglefield #2 well for the Tmatch model.

The contours of groundwater level declines on **Figures 16 and 17** show a steep gradient leading from the southeast corner boundary towards the Boise River. The magnitude and

gradient of groundwater elevation reductions near the southeast boundary is affected, to some degree, by the modeled location of the general head boundary that provides inflow to the model. As actual inflow may enter the model more diffusely over a somewhat larger area, the associated decrease in flux may be distributed over a somewhat larger area. A more diffuse distribution would result in reduced but more spread-out drawdowns near the southeast corner of the model; but would likely have little effect on predicted groundwater-elevation declines closer to the project area. In other words, the modeled reduction in water levels near the modeled boundary should be considered to be an approximation.

Figure 1: Local PGSA K-Zones and Location of SVR #7 Test Wells (Hmatch Model)

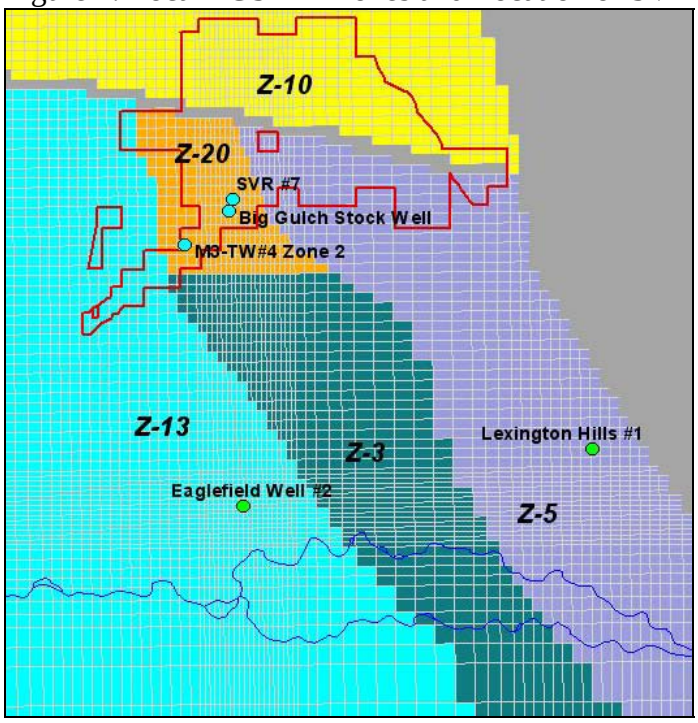


Figure 2: Local PGSA K-Zones and Location of SVR #7 Test Wells (Tmatch Model)

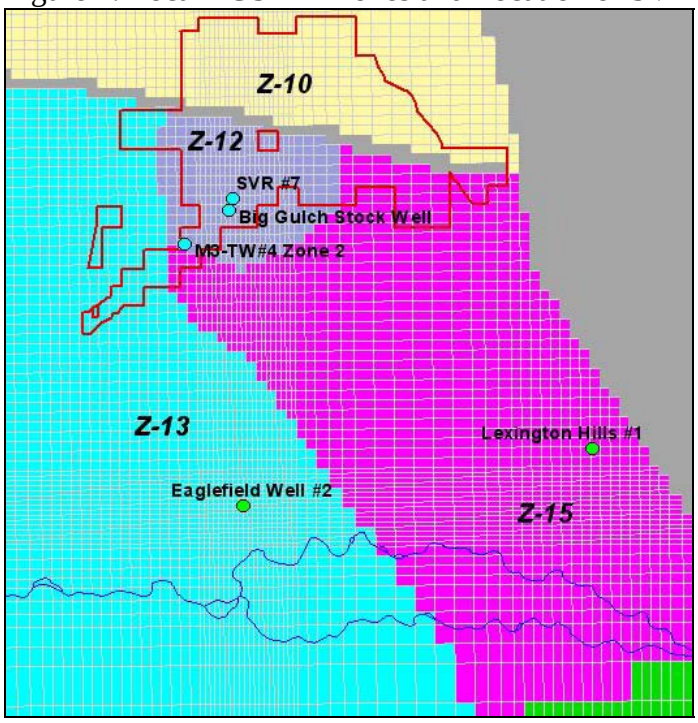


Figure 3: Local PGSA S-Zones and Location of SVR #7 Test Wells (Both Models)

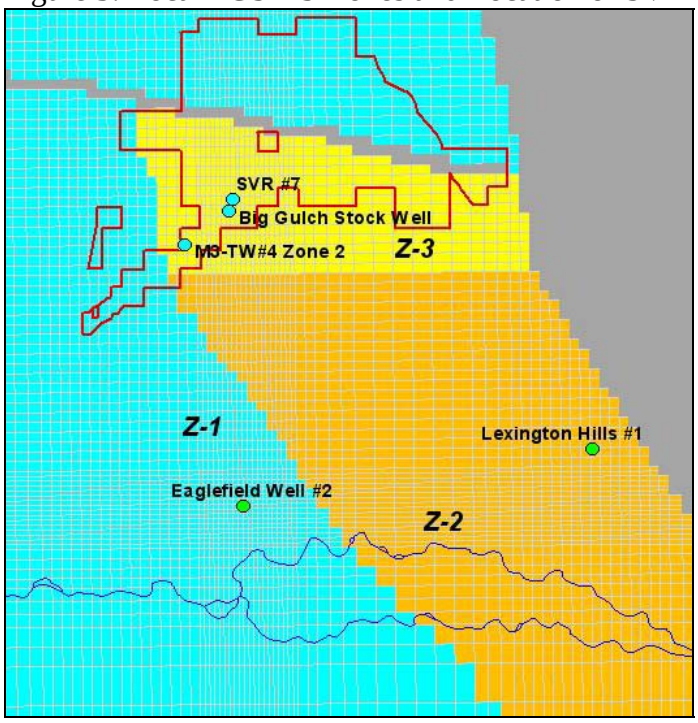


Figure 4: Modeled Heads and Residuals in Layer 6 (PGSA) – New Hmatch Model

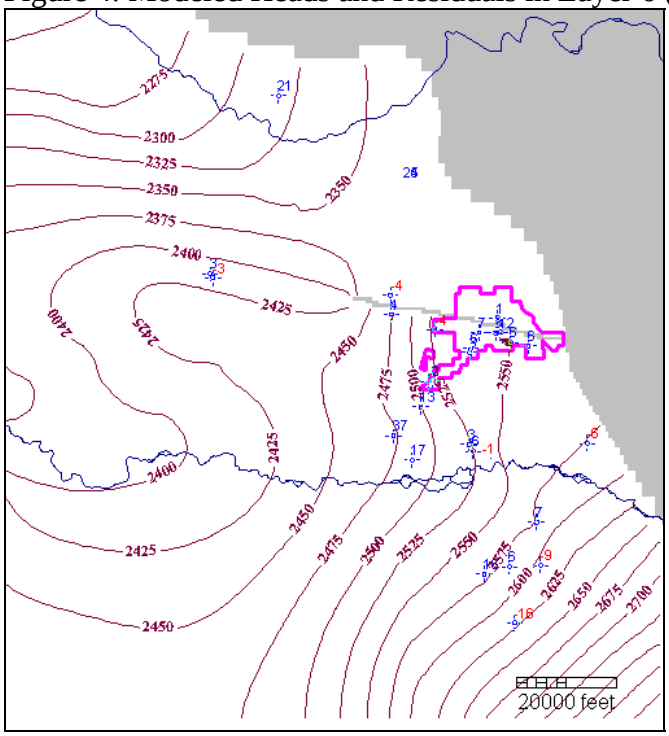


Figure 5: Modeled Heads and Residuals in Layer 6 (PGSA) – New Tmatch Model

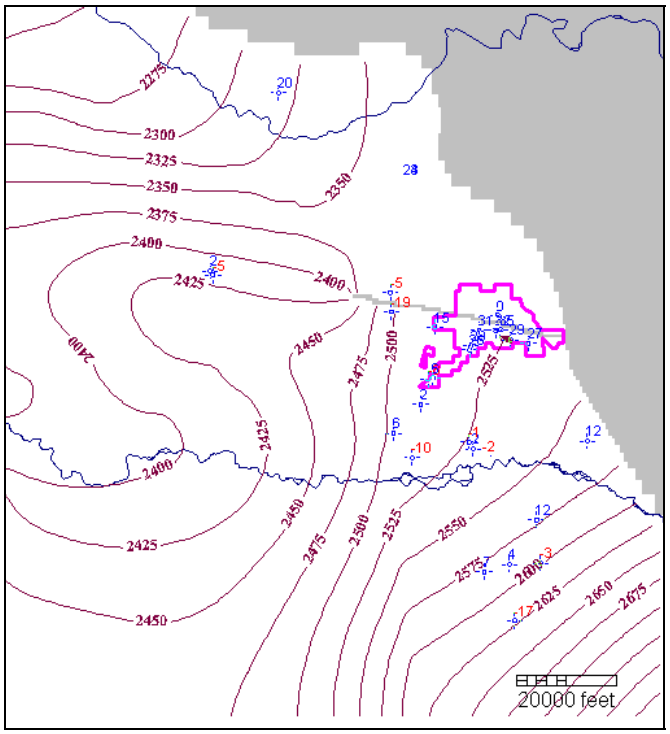


Figure 6: Simulated vs Observed Drawdown SVR #7 Aquifer Test (New Hmatch Model)

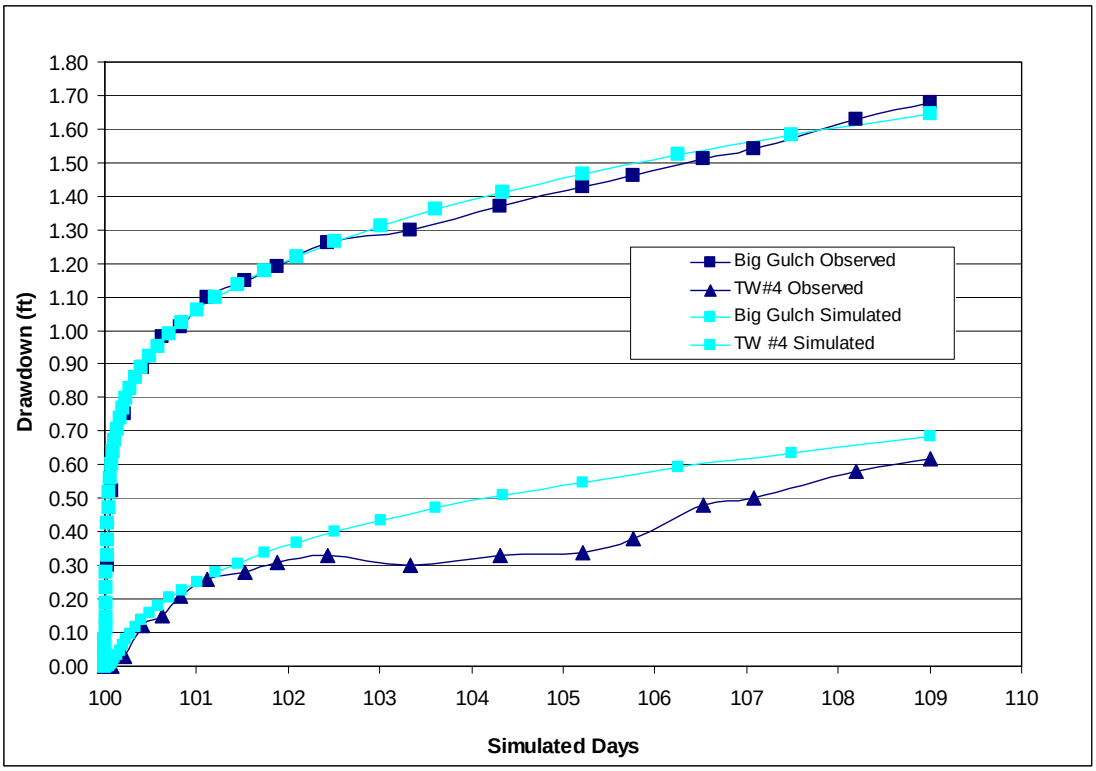


Figure 7: Simulated vs Observed Drawdown SVR #7 Aquifer Test (New Tmatch Model)

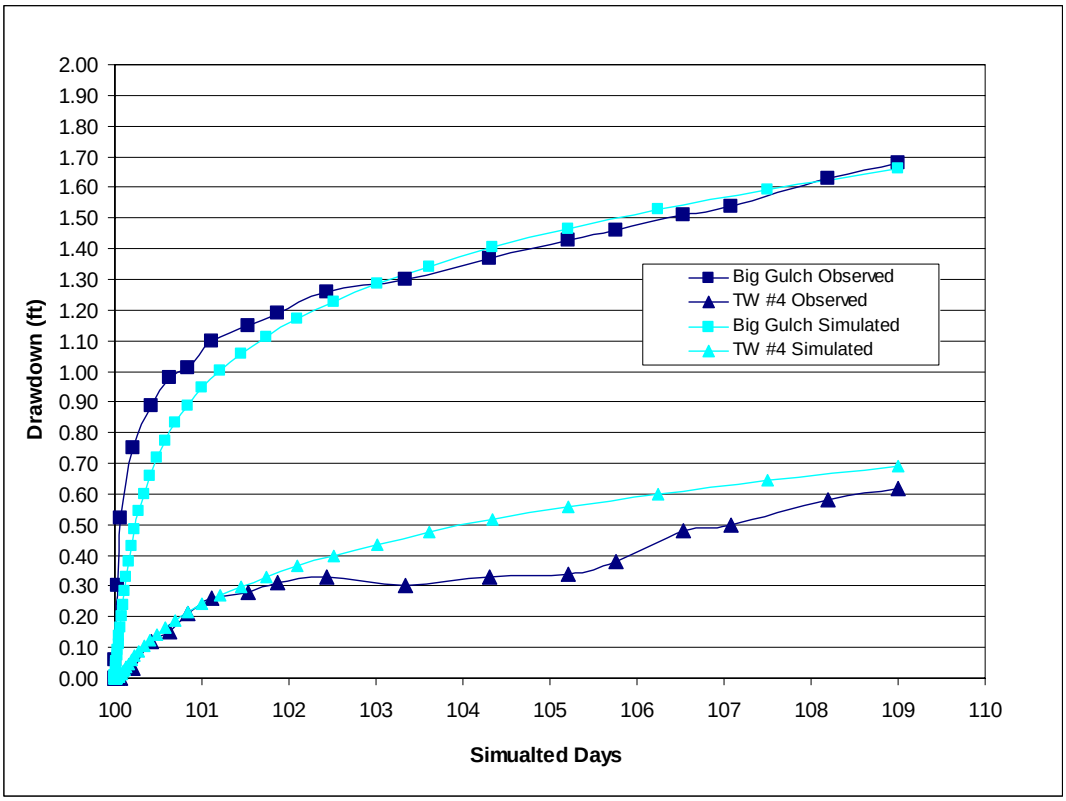


Figure 8: Simulated vs Observed Drawdown Lexington Hills #1 Aquifer Test (New Hmatch Model)

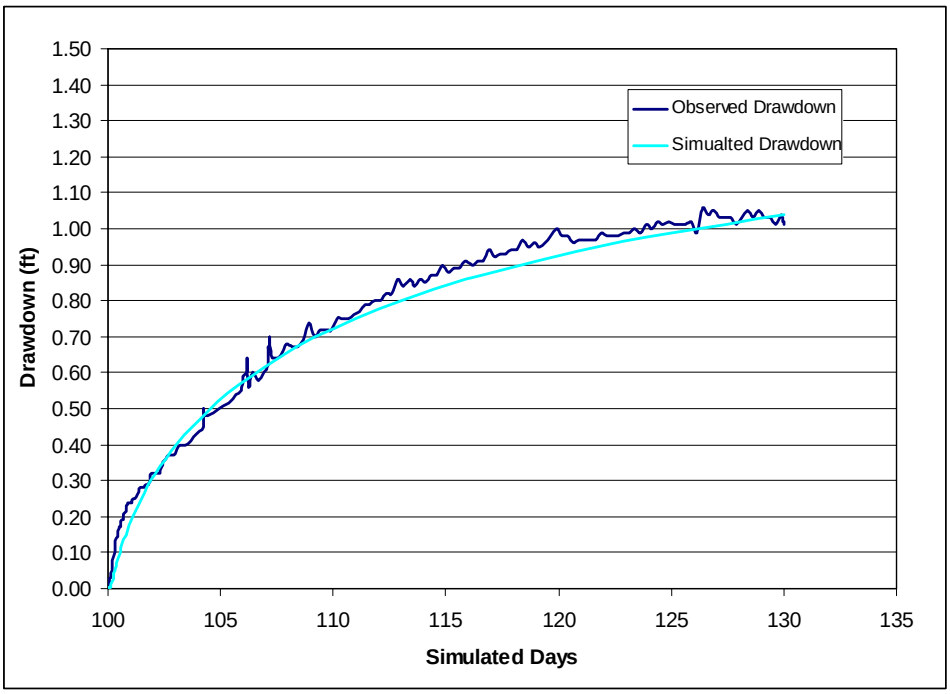


Figure 9: Simulated vs Observed Drawdown Eaglefield Well #2 Aquifer Test (New Hmatch Model)

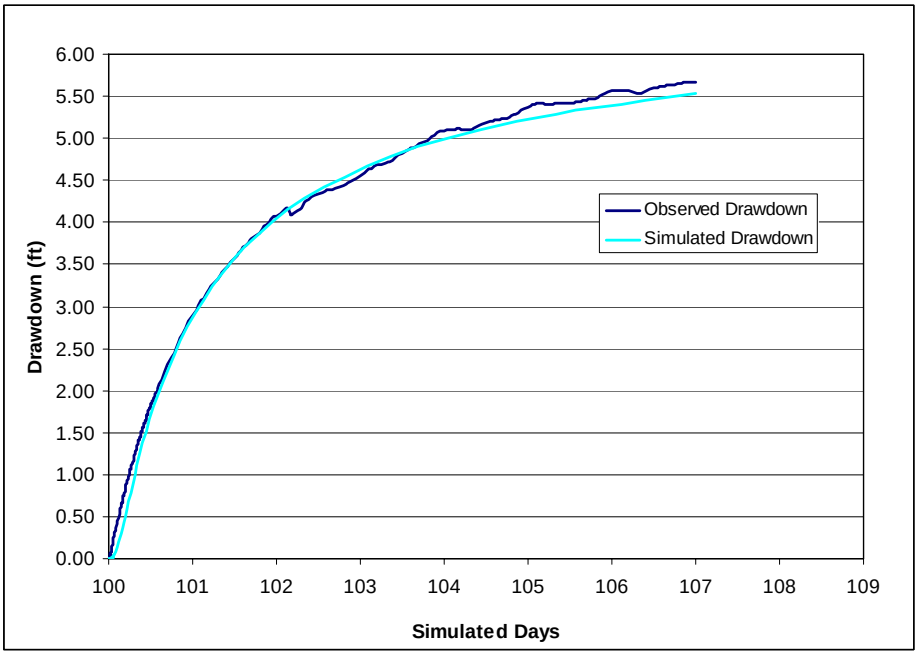


Figure 10: Location of Proposed NPW Pumping Wells

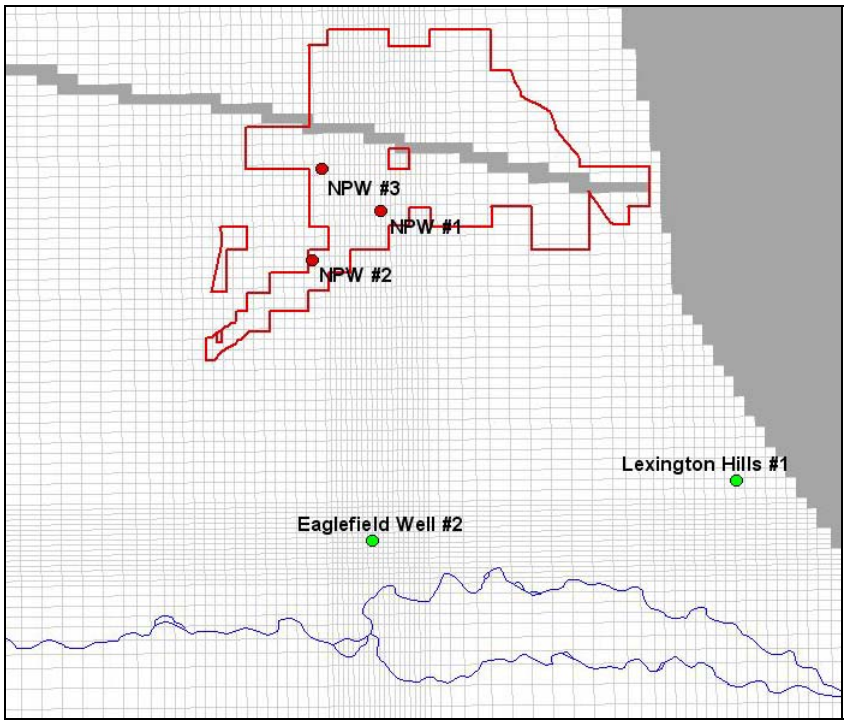


Figure 11: Location of General Head Boundary in southeast corner of model converted to Constant Flux Boundary for Predictive Simulation

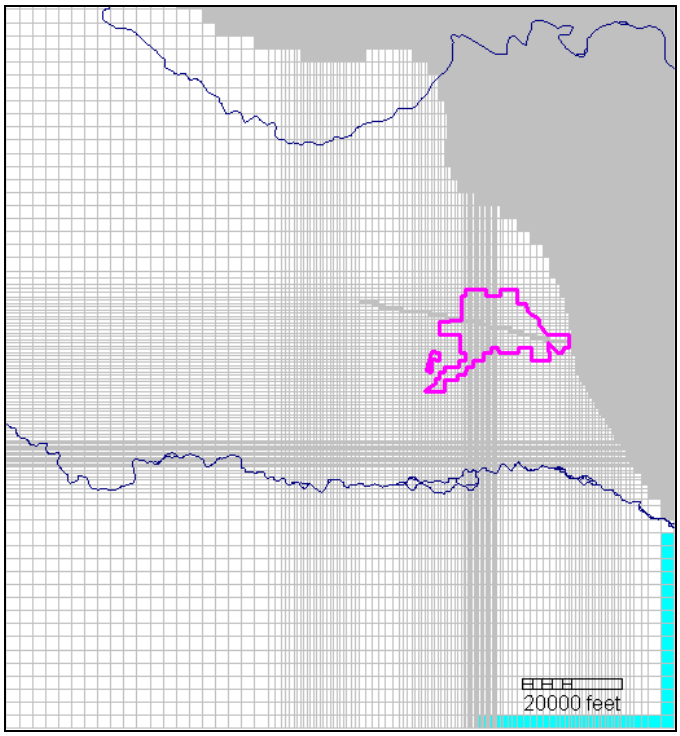


Figure 12: Percent of Total Simulated Drawdown at Pumping Wells (New Hmatch Model)

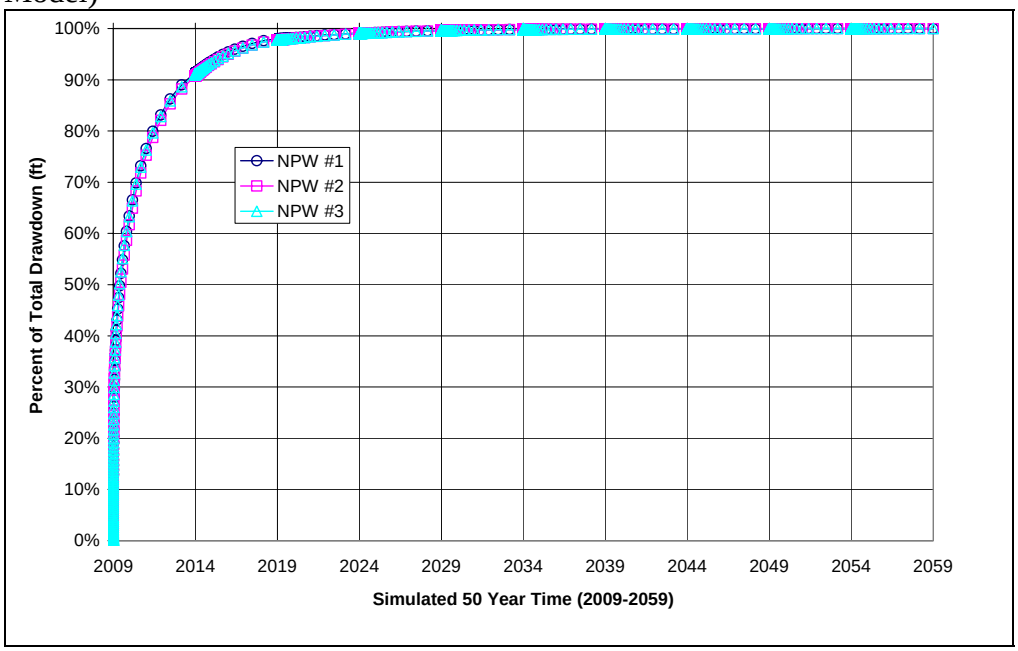
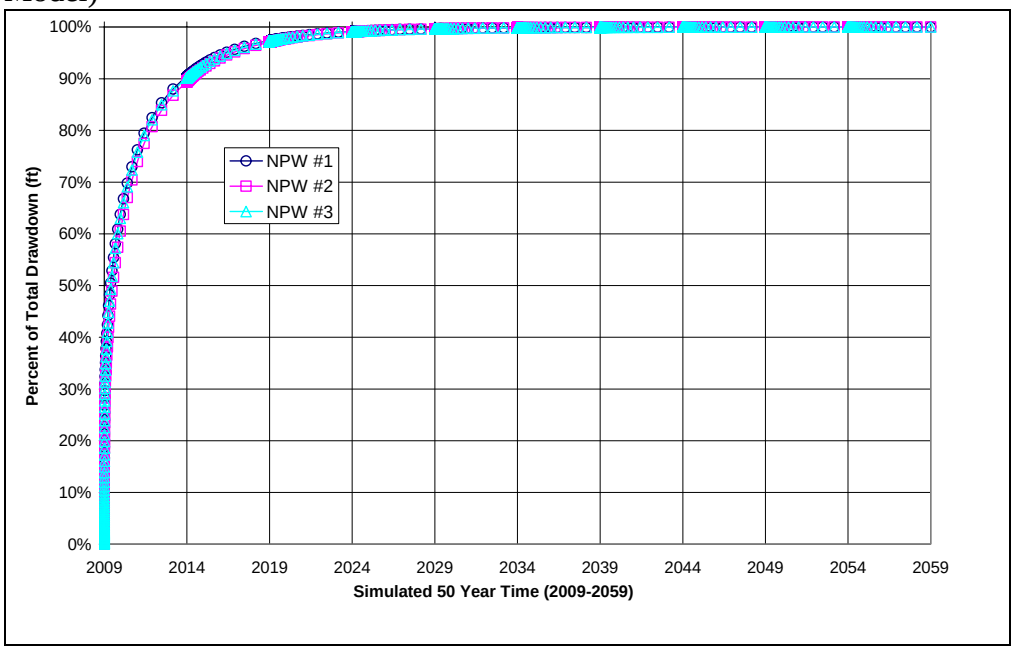


Figure 13: Percent of Total Simulated Drawdown at Pumping Wells (New Tmatch Model)



NPWwells_DD_PGSA_50_New_Hmatch.mxd

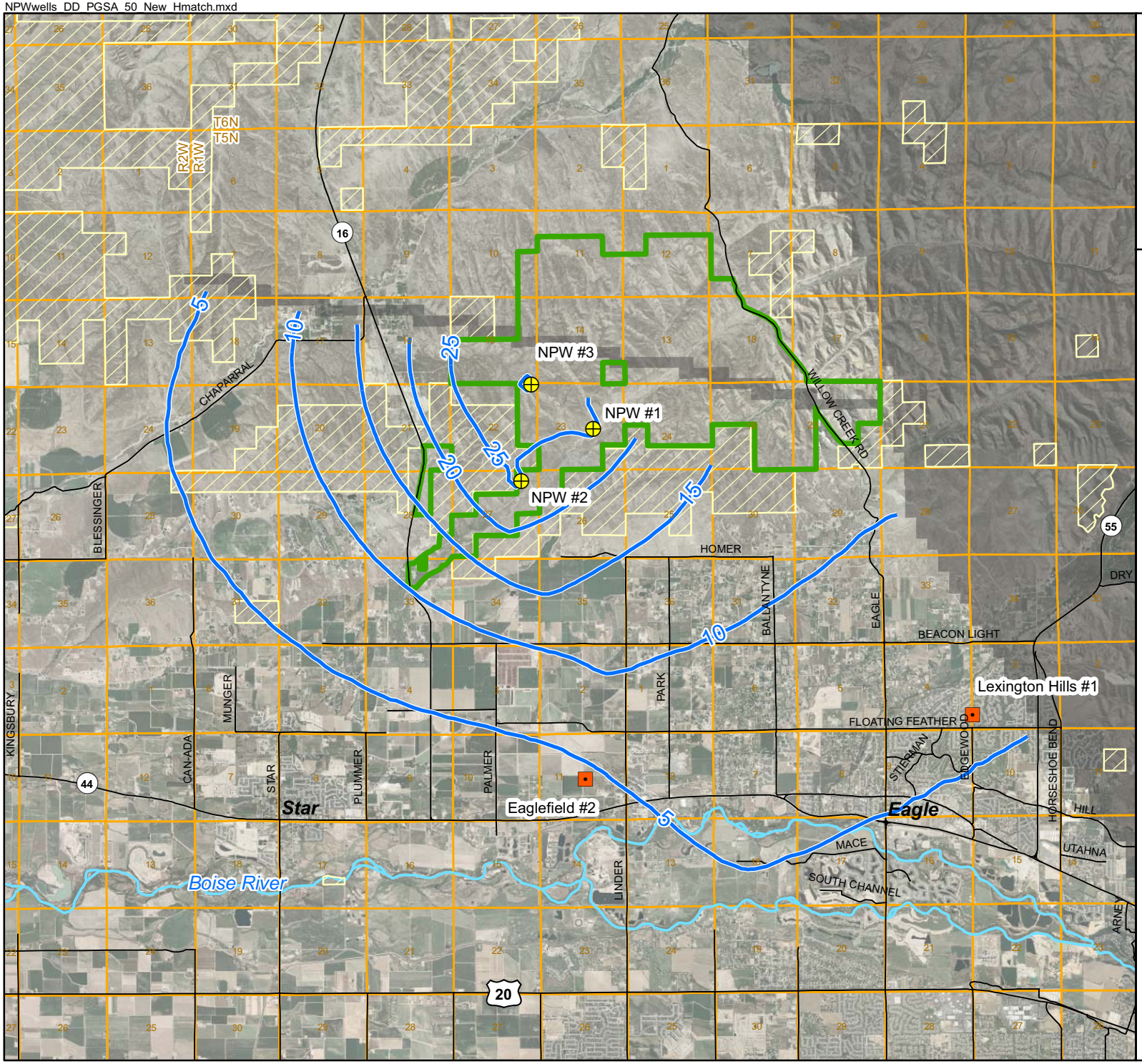


Figure 14

Simulated PGSA Drawdown After 50 Years (NPW wells) - New Hmatch Model

M3 Eagle Model
JZ0705

NPW Wells
(Pumping at 1500 GPM)

Model Observation Wells

Drawdown in feet
(5 ft. contour interval)

No Flow Zones

Site Boundary

BLM Lands

PgG

0 Feet 8,000

2006 Orthophoto

N

NPWwells_DD_PGSA_50_New_Tmatch.mxd

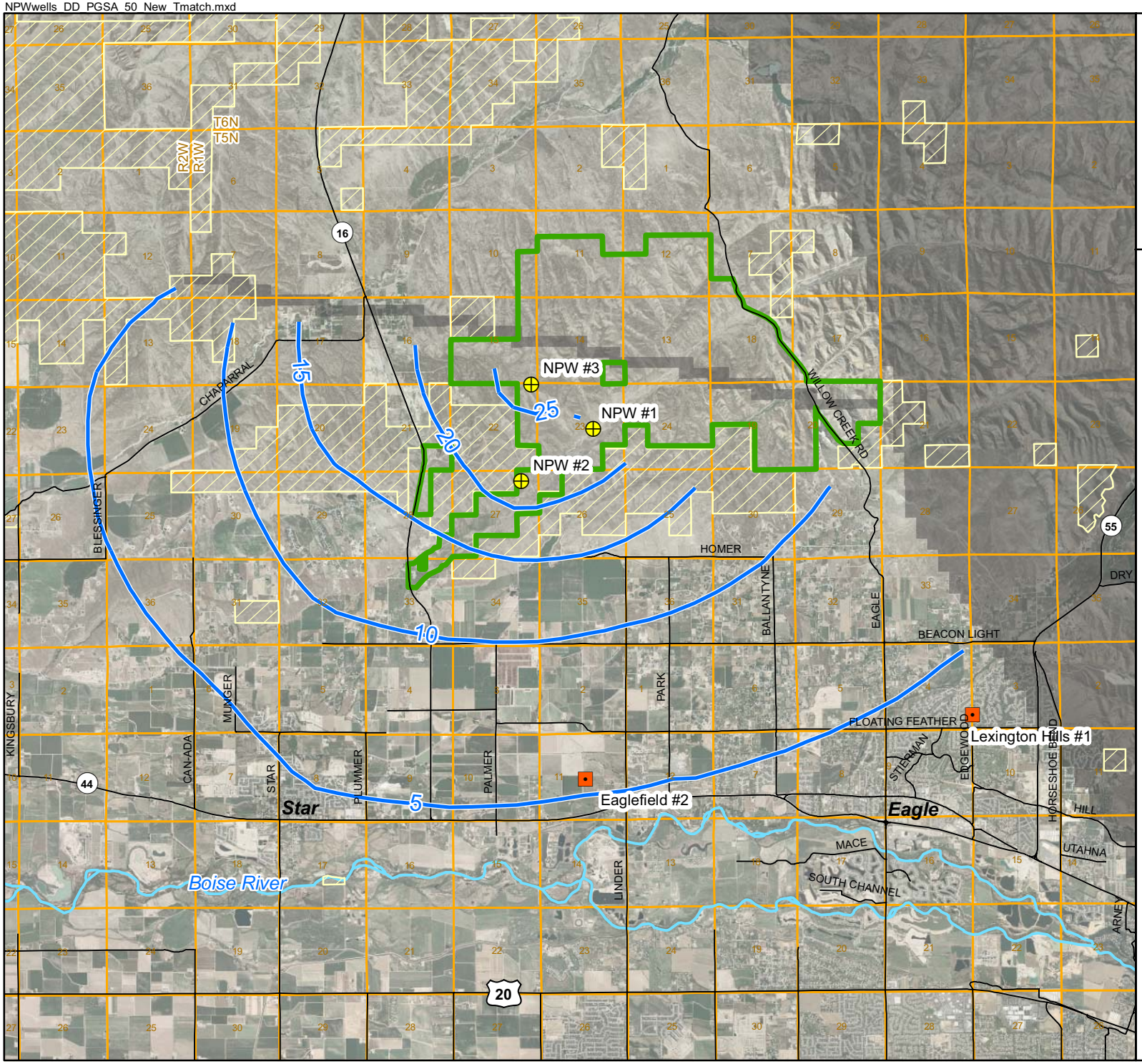


Figure 15

Simulated PGSA Drawdown After 50 Years (NPW wells) - New Tmatch Model

M3 Eagle Model
JZ0705

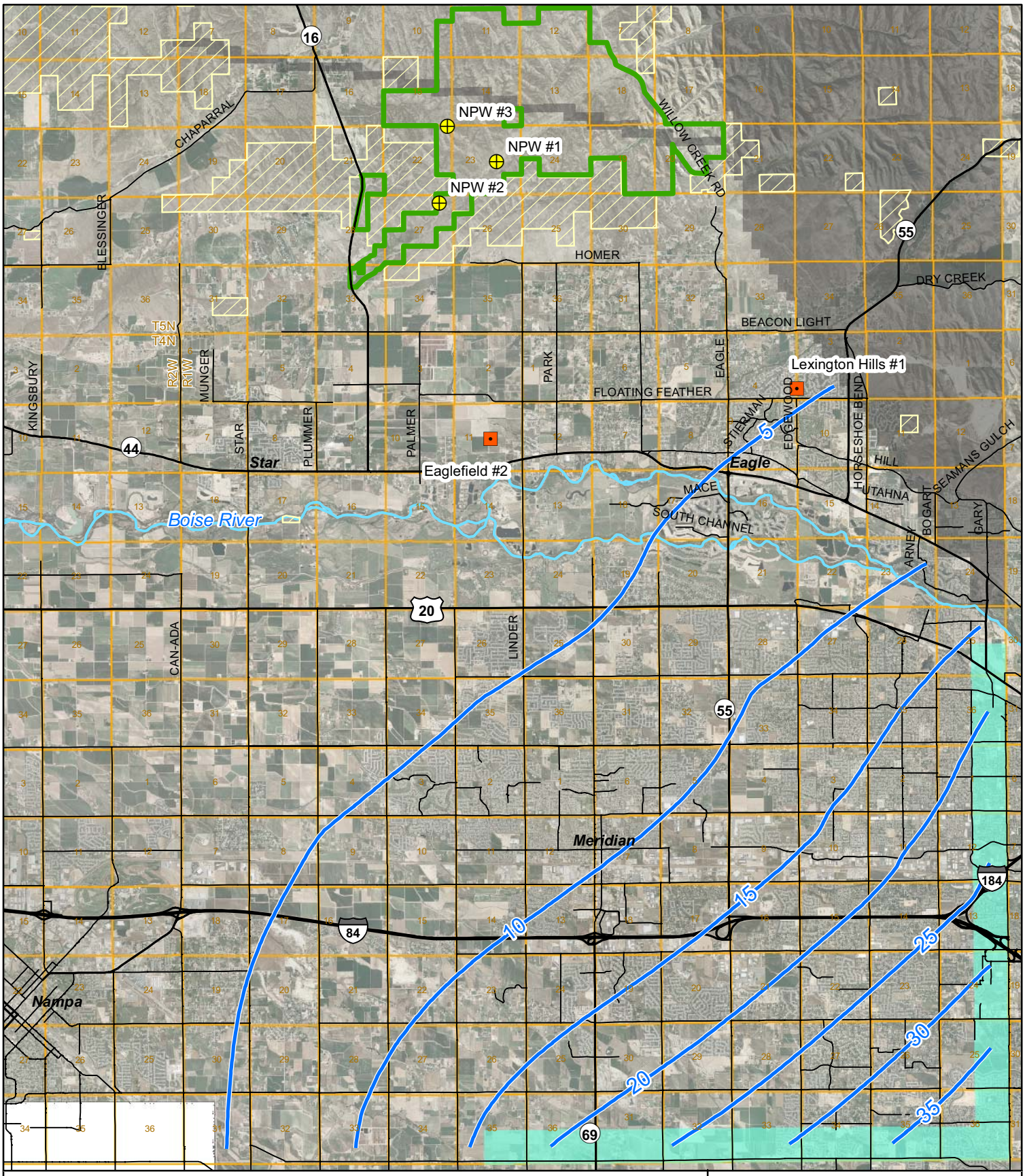
- NPW Wells (Pumping at 1500 GPM)
- Model Observation Wells
- Drawdown in feet (5 ft. contour interval)
- No Flow Zones
- Site Boundary
- BLM Lands

PgG

0 Feet 8,000

2006 Orthophoto

N



NPW Wells
(Pumping at 1500 GPM)

Model Observation Wells

Reduced Groundwater Level Contours, in feet
(5 ft. contour interval)

Constant Flux Boundary

No Flow Zones

Site Boundary

BLM Lands

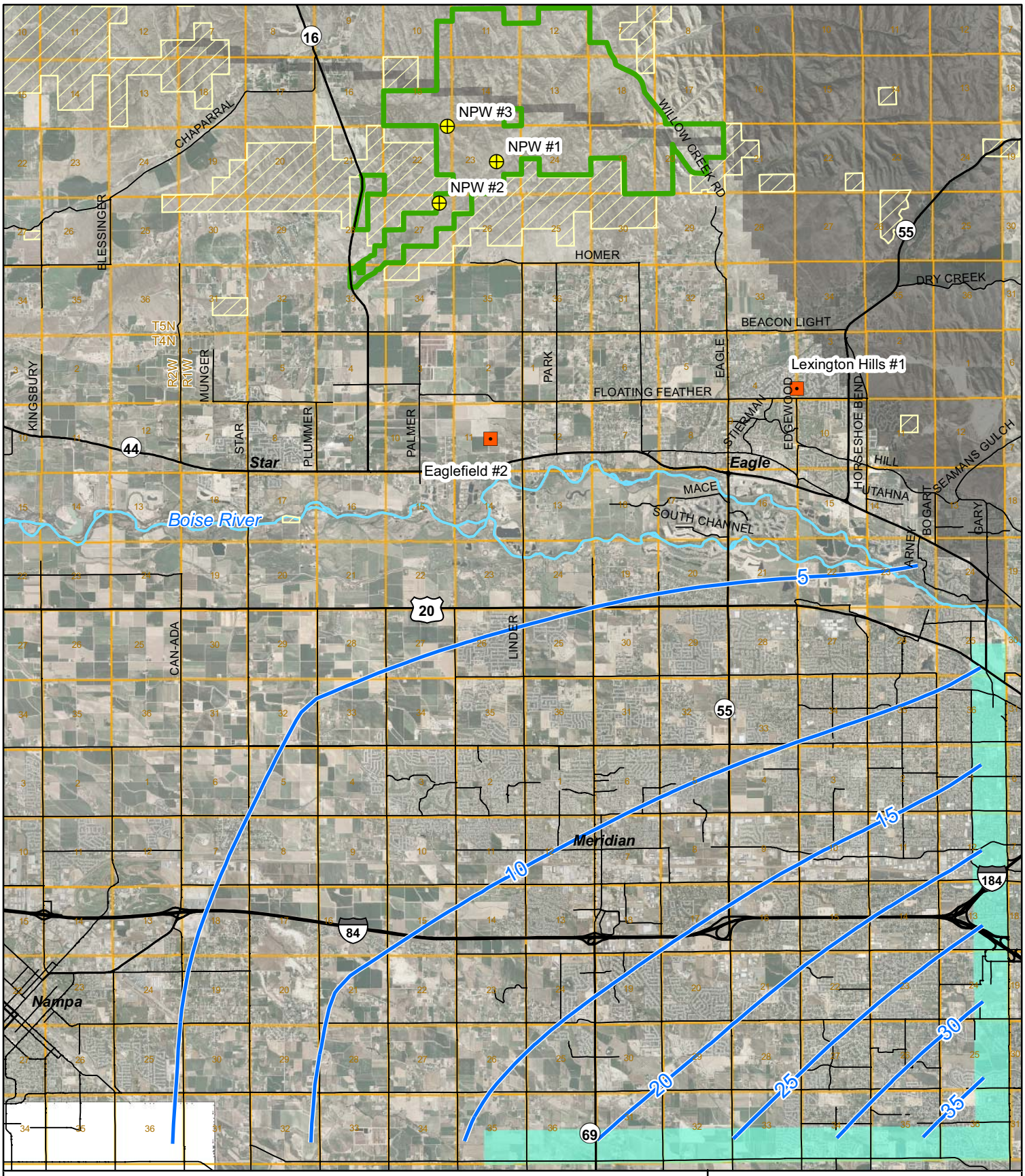
PgG

0 Feet 10,000
2006 Orthophoto

N

Figure 16
Simulated PGSA Steady State Reduction in Groundwater Levels (Reduced Canal Leakage) - New Hmatch Model

M3 Eagle Model
JZ0705



NPW Wells
(Pumping at 1500 GPM)

Model Observation Wells

Reduced Groundwater Level Contours, in feet
(5 ft. contour interval)

Constant Flux Boundary

No Flow Zones

Site Boundary

BLM Lands

PgG

0 Feet 10,000
2006 Orthophoto

N

Figure 17
Simulated PGSA Steady State Reduction in Groundwater Levels (Reduced Canal Leakage) - New Tmatch Model

M3 Eagle Model
JZ0705

APPENDIX C - CONCLUSIONS AND RECOMMENDATIONS FROM TVHP AND U OF I REPORTS

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12. CONCLUSIONS AND RECOMMENDATIONS

A numerical model was constructed to simulate regional-scale, steady-state, ground water flow in the Treasure Valley of southwestern Idaho. Conclusions from simulations using this model consist of the following:

1. PEST-calibrated parameter values indicate relatively higher K_h values in the uppermost aquifer zones, corresponding with known areas of coarser-grained sediments. PEST-calibrated parameter values also indicate relatively higher K_h and K_v values in areas of the eastern and central portion of the valley associated with fluvial deltaic deposition.
2. Simulated fluxes between model layers in the base calibration indicates a relatively small amount of water moving vertically between model layers, especially in the lower layers. Based on simulation results, most recharge occurring in shallow aquifer zones does not reach lower zones.
3. A 10% increase or decrease in recharge led to minimal changes in water levels or parameter value estimates. This is because shallow ground water levels in central portions of the basin are controlled, in part, by elevations of surface water channels. Decreased or increased recharge resulted in changes in the rates of water discharging to model drain, general head boundary (Lake Lowell), constant head (Snake River), and river (Boise River) cells.
4. Underflow does not appear to be consistently distributed along the Boise Front. The model experienced difficulty in applying rates as high as 8,000 ft^3/day/cell (similar to water budget estimates) in some model areas, especially in the far eastern portions of the model domain.
5. Simulated minimum water levels (maximum impact) indicated that some ground water level declines might occur with a 20% increase over 1996 levels. Simulated modest declines were observed in the Boise area in layers 1 and 2. Greater simulated declines were observed in the central portion of the valley (especially in the Lake Lowell area) in layers 3 and 4. Simulated water level declines and/or changes in mass balance components reflect a combination of parameter uncertainty and response to a changed hydraulic stress.
6. The simulated 20% increase in ground water withdrawals resulted in increased losses from the Boise River (23%), decreased discharge to agricultural drains (62%), and decreased discharge to the Snake River (9%). Again, simulated water level declines and/or changes in mass balance components reflect a combination of parameter uncertainty and response to a changed hydraulic stress.
7. Uncertainty in the model calibration limits a more precise description of responses to changes in recharge and/or withdrawals.
8. Changes in land use that lead to decreases in shallow-aquifer recharge may not have a substantial effect on shallow ground water levels until the water table elevations remain below those of nearby surface channels.

Additional simulations should be considered to better define aquifer system characteristics or scenario predictions. These include the following:

1. Maximum and minimum hydraulic head predictions with no changes in model stresses from the base simulation. Use the results from these simulations for comparisons in scenario predictions.
2. Increases and decreases of 30% (over 1996 levels) in aquifer recharge.
3. Across-the-board withdrawal increases and decreases in aquifer withdrawals over 1996 levels.
4. Increased local withdrawals in various locations in the valley to test responses in water levels and in recharge rates to lower model layers.
5. Simulations with reductions in recharge and increases in withdrawals to estimate at what point shallow ground water levels drop below drain elevations in the central portion of the valley.
6. Horizontal and vertical variations in underflow along the Boise Front.
7. Conduct additional simulations to refine the understanding of ground and surface water interaction in the Boise River corridor using a more refined grid than, and/or submodel of, the current model .
8. Develop response ratios for the interaction between ground water extractions and seepage from or discharge to surface channels.

Additional recommendations include the following:

1. Expand monitoring in areas showing recent ground water level declines.
2. Consider incorporating new monitoring data into the model as they become available.
3. Better define discharge rates to surface water channels to allow more constraint on simulated discharge.
4. Better define temporal diversion and return rates for transient simulations.
5. Refine model based on newly compiled diversion and return data.
6. Install additional multi-completion monitoring wells to expand vertical gradient data.
7. Search for opportunities to enhance ground water level monitoring in portions of the valley with relatively few current data.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.0 INTRODUCTION

The M3 Eagle Big Gulch Model provides a preliminary mathematical representation of a new, conceptual hydrogeologic model for ground water flow in the region between the Boise River near Eagle, Idaho and the Payette River near Emmett, Idaho. Although this preliminary ground water model is a work in progress, it provides a user-friendly, visual tool to help test and refine conceptual understanding of the ground water flow conditions that exist within the model domain. This chapter presents conclusions and recommendations developed during an 18-month investigation.

6.0.1 Conclusions

6.0.1.1 Hydrogeologic conclusions of the investigation

The following conclusions are derived from interpretation of hydrogeologic data presented by Squires et al. (2007), independent evaluation of well driller's reports, available water level data, aquifer test data summarized by HLI, and general accepted hydrogeologic theory:

(1) Ground water flow between the Boise River valley and the Payette River valley occurs primarily through sediments of the Pierce Gulch Sand aquifer system. The Pierce Gulch Sand aquifer system is 150 to 275 feet thick (possibly thicker in other areas) consisting of stratified granitic sand layers with interbedded layers of silt and clay. It is bounded on the north side by a southeast-northwest trending normal fault known as the West Boise-Eagle fault (Wood and Anderson, 1981). The Pierce Gulch Sand aquifer is generally underlain by clays and mudstones of the Terteling Springs

Formation and dips at an angle of about 1° to the southwest in the model domain. The aquifer system is truncated at by the unsaturated water table in the vicinity of Black Canyon Canal southwest of Emmett, the West Boise-Eagle fault northwest of Boise, and by the mudstones of the Terteling Springs Formation underneath in the vicinity of the fault.

(2) The Willow Creek aquifer (SPF, 2004) exists mostly on the north side of the West Boise-Eagle fault and extends from the foothills to the Payette River near Emmett, Idaho. The Willow Creek aquifer consists primarily of high hydraulic conductivity gravels and sands; however, the aquifer appears to be isolated from the regional ground water flow system in the Pierce Gulch Sand aquifer system by the West Boise-Eagle fault and mudstones of the Terteling Springs formation. Granite of the Idaho batholith, and overlying tertiary volcanics bound the Willow Creek aquifer on the eastern side of the model domain.

(3) The Pierce Gulch Sand aquifer system constitutes the primary ground water source for the cities of Star and Eagle, and the proposed M3 Eagle planned community. The aquifer system is believed to be moderately to highly productive based on the existence of many large production supply wells completed in the aquifer, and aquifer tests conducted in the vicinity of Eagle and the M3 Eagle Development property.

(4) Ground water recharge to the Pierce Gulch Sand aquifer system originates southeast of the model domain from seepage from the Boise River downstream of Diversion Dam, and from the dense network of canals in the Boise-Meridian area; ground water flows northwesterly under the Boise River in the Eagle, Idaho area in the direction of

the hydraulic gradient toward the natural ground water discharge areas in the Payette River valley near Letha, Idaho and the Snake River valley to the west.

6.0.1.2 M3 Eagle Big Gulch Model conclusions

The M3 Eagle Big Gulch Model is based predominantly on the conceptual hydrogeologic model developed for the model window area by HLI, water levels measured within the model window during the summer/fall of 2006, and water levels derived from the IDWR Ground Water Level Database for the rest of the model domain. The following conclusions are derived from the many simulations performed during development of the numerical model:

(1) The M3 Eagle Big Gulch Model is limited by the lack of a comprehensive database for model input.

(2) Preliminary results strongly support the conceptual model developed by HLI that ground water flows from the Boise River valley to the Payette River valley throughout the lower Boise River basin and the southern half of the proposed M3 Eagle development property.

(3) The general direction of ground water flow through the Pierce Gulch Sand aquifer system is from areas of higher head (water level) in the Boise River valley to areas of lower head in the Payette River valley. Seepage from the Boise River upriver from the modeled area and the New York canal is the primary source of recharge to the Pierce Gulch Sand aquifer.

(4) Based on model calibration of hydraulic conductivity and recharge, driving heads (higher heads) in the Pierce Gulch Sand aquifer system originate in the south and east Boise areas. However, canal seepage and surface irrigation just north of the Eagle

and Star areas contribute significant recharge to the shallow water table aquifer near the southwestern edge of the proposed M3 Eagle development property.

(5) Calibrated model values for hydraulic conductivity in the Eagle-Star vicinity are lower than previously expected based on results from aquifer tests conducted in the area.

(6) Based on model calibration of hydraulic conductivity and canal seepage, recharge estimates for the model window area are underestimated.

(7) Simulation of the steep water level contours between the outcrop of the Pierce Gulch Sand and the West Boise-Eagle fault zone is difficult. Additional work is needed to adequately define the ground water flow conditions in this area.

(8) Changes in land use and/or development that reduce canal leakage and/or irrigated areas are expected to reduce local recharge and cause ground water levels in domestic wells in the vicinity of Eagle to decline.

6.0.2 Recommendations

The M3 Eagle Big Gulch Model provides a useful tool for the mathematical evaluation of evolving conceptual, hydrogeologic models of the regional ground water flow conditions between the Boise River valley and the Payette River valley. The present model must be considered preliminary in nature, and more data and more simulations are required to calibrate the model. The following recommendations are suggested to improve the predictive capability of the M3 Eagle Big Gulch Model and are ranked according to priority with the first recommendation being the most important:

(1) Establish a water level monitoring network comprised of wells in the Pierce Gulch Sand aquifer system and other aquifers within the model domain. Monitor on a

regular basis to document seasonal changes that may occur and incorporate average water level conditions when simulating the model in steady-state conditions.

(2) Expand the monitoring network to acquire more water level measurements outside the model window.

(3) Incorporate new monitoring data into the model as it becomes available.

(4) Develop a detailed water budget for the model domain.

(5) Perform a more detailed analysis on recharge to incorporate better estimates into the model.

(6) Update recharge estimates as land use changes and as certain areas become more developed.

(7) Locate and map all canals within the model domain that were not previously simulated (specifically in the northwestern area of the model window) and incorporate all new data into the model.

(8) Improve the canal and river seepage estimates.

(9) Improve discharge estimates for municipal entities (cities and towns) in the model domain by acquiring year-to-year seasonal pumping estimates.

(10) Update domestic discharge estimates by documenting actual well withdrawals from the wells known to exist in each cell.

(11) Better define temporal conditions such as irrigation diversion rates, urban and rural domestic water use, periods of canal use, and seasonal water levels in wells.

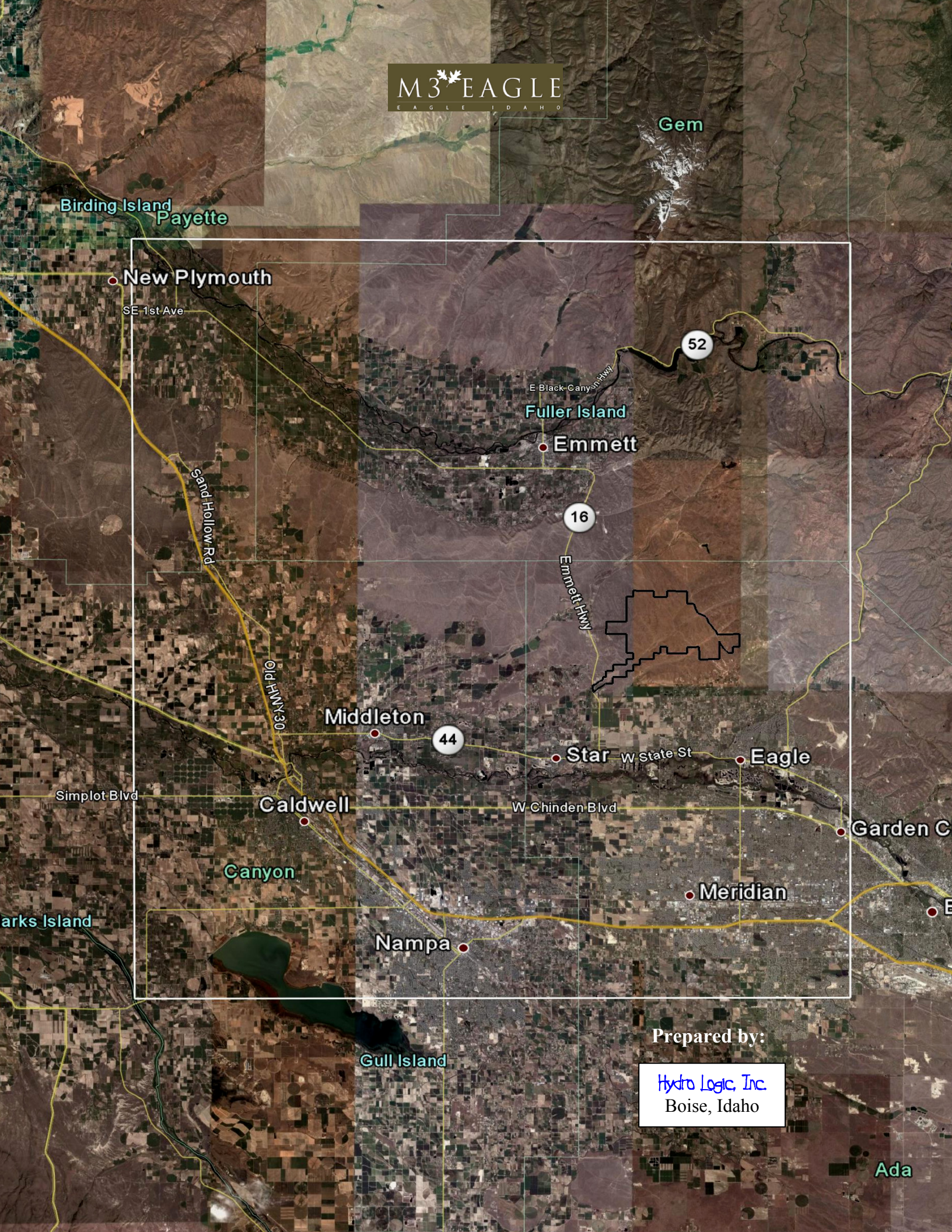
(12) Conduct long-term aquifer tests in the M3 Eagle property vicinity to better understan the effects of increased water development in the area.

(13) Estimate storage coefficients for all layers in the model throughout the model domain to prepare for transient model simulations.

(14) Conduct additional aquifer tests near the West Boise-Eagle fault to better understand the effects caused by pumping near that zone, and determine the best way to simulate the fault in MODFLOW.

(15) Obtain hydrogeologic data on the layers above and below the Pierce Gulch Sand aquifer system.

[End of Report]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EAGLE IDAHO
Gem
Birding Island
Payette
New Plymouth
SE 1st Ave
52
E Black Canyon Hwy
Fuller Island
Emmett
16
Sand Hollow Rd
Emmett Hwy
Old Hwy 30
Middleton
44
Star
W State St
Eagle
Simplot Blvd
Caldwell
W Chinden Blvd
Garden C
Canyon
Meridian
arks Island
Nampa
Gull Island
Ada
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