The well flows artesian at 760 gpm, and is capable of producing groundwater at approximately 2,100 gpm. Available information suggests that the lower aquifer is at least 500 feet thick in the vicinity of the proposed power plant site (Caithness 2000) and has an estimated areal extent of 25 to 80 square miles (Appendix D).

3.4.2 Environmental Consequences

The following sections outline the environmental issues related to groundwater, significance criteria used to assess impacts, and methodology and conclusions of the impact assessment. Also described are various mitigation measures that may be considered if ongoing groundwater level monitoring indicates that groundwater pumping to supply the Project is significantly impacting groundwater levels in the upper aquifer, or the quantity of water discharged from springs.

3.4.2.1 Identification of Issues

The following is a list of identified issues that relate to groundwater. These identified issues form the basis for the assessment of potential impacts:

- Potential impacts on groundwater levels in the upper aquifer sufficient to impact users of groundwater in the upper aquifer.

- Potential impacts on groundwater levels in the upper aquifer sufficient to impact surface water flow in the Big Sandy River (also refer to Section 3.5).

- Potential impacts on the quantity of water discharged from springs and seeps.

Potential impacts on groundwater quality due to discharge of pollutants to the vadose zone from the evaporation pond or any other activities related to the Proposed Action.

3.4.2.2 Significance Criteria

Listed below are the significance criteria that have been established for the identified issues. Impacts would be considered significant if they would result in the following:

- Groundwater pumping of the lower aquifer to supply the Project would result in additional drawdown greater than 10 feet over any 5-year period in a neighboring well of record in the upper aquifer. The significance of 10 feet over 5 years is based on ADWR well spacing requirements.

- Groundwater pumping of the lower aquifer to supply the Project would result in any reduction of surface water flows in the Big Sandy River (also refer to Section 3.5, Surface Water).

- Groundwater pumping of the lower aquifer to supply the Project would result in any reduction in the quantity of water discharged from springs and seeps.

- Discharge of pollutants to the vadose zone from the evaporation pond or any other activities related to the Proposed Action would result in substantial degradation of groundwater quality.

3.4.2.3 Impact Assessment Methods

The impact assessment methods for this Project were developed by the Big Sandy EIS hydrology team (see inset). An effort was made to achieve consensus among the team members during the development of the impact assessment methods and at every ensuing stage of the Project.

The following tasks were performed to assess potential impacts on groundwater resources within the region of influence:

- Data Compilation and Evaluation – Available information was compiled and evaluated related to the hydrogeology and groundwater resources of the Big Sandy basin, with emphasis on the southern portion of the basin and the proposed groundwater production wellfield. This task included review of all relevant reports prepared by the proponent and its consultants. The objectives of this task were to independently evaluate and verify the accuracy and comprehensiveness of information provided by the proponent, and, where necessary, supplement this information. As part of this process, numerous meetings and conference calls were held among the various Project participants to discuss the ongoing data evaluation, field activities, and groundwater modeling.

- Aquifer Testing – An 11-day, constant-discharge aquifer test of one of the planned groundwater production wells (PW2) was performed by Caithness to obtain data on the hydraulic properties and sustainable yield of the lower aquifer, and to observe any impacts on groundwater levels in wells completed in the upper and middle aquifers. Aquifer test methods and preliminary results are described in the Caithness water resources report (Caithness 2000). Aquifer test data and results are discussed in detail in a subsequent report based on an independent review of the data (David Schafer & Associates 2000). A copy of this independent report is provided in Appendix D. Aquifer test methods and results are summarized in this section.

- Stable Isotope Sampling and Analysis – Twelve samples of groundwater and spring water were collected from various sources and analyzed for stable isotopes of oxygen and hydrogen. Stable isotope sampling and analysis methods and results are summarized in this section, and are described in detail in two URS technical memoranda provided in Appendix E (URS 2000a; 2000b).

Big Sandy EIS Hydrology Team

The Big Sandy EIS hydrology team was an ad hoc working group of hydrologists and other resource specialists that was assembled at the beginning of the Project at the direction of BLM and Western. The team consisted of representatives from the various cooperating agencies and their consultants, as well as from Caithness and its consultants. The team included participants from BLM, Western, USFWS, ADWR, the Hualapai Tribe, URS Corporation, David Schafer & Associates, Caithness, Greystone Consultants, and Manera, Inc.

The purpose of the hydrology team was to provide peer review of ongoing work by Caithness, and to develop a scope of work and provide peer review for the impact assessment. This process consisted of an initial team meeting in July 2000, during which the proposed impact assessment methods were developed, followed by numerous conference calls over the following eight months to review the progress at various stages.

The hydrology team initially Caithness' proposed plan for the 11-day aquifer test, then reviewed the aquifer test results and report. The team reviewed the approach proposed for isotope sampling and analysis, and the results of the study. The team also developed an overall approach for the development of the groundwater flow model, then reviewed the results of the model analysis throughout the modeling process. An effort was made to achieve consensus among the team members during the review of Caithness' scope of work, development of the impact assessment methods, and analysis of the data.

- Groundwater Modeling – A groundwater flow model of the southern portion of the Big Sandy basin was developed as part of the groundwater resources assessment. The purpose of the modeling effort was to create an understandable and technically sound groundwater flow model adequate for use in evaluating the long-term potential impact of the proposed Project on the groundwater and surface water resources of the Big Sandy basin. The USGS model MODFLOW, as embedded in Visual MODFLOW®, was used for the analysis. The groundwater flow model is described in detail in the groundwater technical report in Appendix F (URS 2001), and is summarized in this section. The results of the model analysis are presented as part of the impact assessment (Section 3.4.2.5).

- Impact Assessment – The groundwater modeling results were used to assess potential direct, indirect, and cumulative impacts on groundwater levels in the upper and middle aquifers, and on the quantity of water discharged from springs and seeps. The proposed evaporation ponds and other potentially discharging activities were reviewed to assess the potential impacts on groundwater quality. Particular consideration was given to the identified issues, and the significance criteria described in Section 3.4.2.2 were used to assess whether significant impacts potentially could occur.

Aquifer Testing

An 11-day, constant-discharge aquifer test was performed on production well PW2 to characterize the hydraulic properties of the aquifer, assess its suitability as a source of water for the proposed power plant, and evaluate the hydraulic connection between the lower, middle, and upper aquifers. The results of the test were used to assist in the development of the groundwater flow model. The test was designed and conducted by Caithness, with the concurrence of the EIS hydrology team.

A detailed description of the aquifer test, and an initial evaluation of the aquifer test data, were included in the Caithness water resources report (Caithness 2000b). A complete analysis of the data was performed by David Schafer & Associates and was presented in a subsequent report (David Schafer & Associates 2000; Appendix D).

Aquifer testing initially consisted of a step-drawdown test. The test was performed at four discrete pumping rates, beginning with the artesian flow rate of 760 gpm, and followed by increasing flow rates of 1,204, 1,800, and 2,100 gpm, respectively. Based on the results of the step-discharge test, a pumping rate of 2,000 gpm was selected for the constant-discharge test.

The constant-discharge aquifer test was initiated on September 11, 2000, and continued for approximately 11 days. The initial pumping rate of 2,000 gpm declined to about 1,950 gpm by the end of the test, for an average pumping rate of 1,960 gpm. After cessation of pumping, water level recovery was monitored for approximately 10 days.

Water levels were measured in the pumping well (PW2) and the three lower aquifer observation wells (OW2, OW3, and OW4). Water levels also were measured in the middle aquifer observation well (OWMA2), and five wells completed in the upper aquifer (OW1, OW7, OW8, Banegas, and Harris). Well locations are shown on Figure 3.4-5.

The results of the constant-discharge test are summarized as follows:

- The water level in the pumping well declined 150.2 feet during pumping, and recovered to within 95 percent of static conditions within the first few minutes of recovery.

- Total drawdowns in the three lower aquifer observation wells were similar, ranging from 7.3 feet in the nearest well (OW2) to 6.8 feet in the most distant well (OW3).

- All three lower aquifer observation wells recovered slowly during the recovery period, and never recovered to more than 85 percent of static conditions during the 10-day recovery period.

- No changes were measured in the water levels in the middle and upper aquifer observation wells in response to pumping of the lower aquifer during the test.

- There was a measurable decrease in the flow rate of Cofer Hot Spring during the test, indicating that this spring is hydraulically connected to the lower aquifer.

The following conclusions were drawn from the analysis of the constant-discharge aquifer test data (David Schafer & Associates 2000):

- The aquifer response to pumping exhibited the characteristics of both a porous medium and a fractured rock aquifer.

- The aquifer response was consistent with either a highly transmissive, porous medium, or a fractured aquifer with highly transmissive fractures and moderately transmissive blocks.

- Most of the pumping response reflected the effects of aquifer boundaries.

- The hydraulic response suggests an aquifer with an area of about 25 to 80 square miles.

- Linear drawdown response during pumping indicated that the cone of depression was fully developed throughout the extent of the aquifer.

- The data suggest that the lower aquifer is hydraulically separated from the middle and upper aquifers.

- The data suggest that if the arkosic gravel is laterally extensive, it is hydraulically separated from the lower aquifer.

- The aquifer test results are limited in that it was not feasible to run the test for a length of time sufficient to simulate operating conditions. In spite of this limitation, the aquifer test was critical in providing estimates of aquifer transmissivity and storativity for the groundwater flow model, confirming the extent of the volcanic aquifer, and refining the conceptual model of the southern portion of the Big Sandy basin.

Stable Isotope Sampling and Analysis

As part of the groundwater resource evaluation, samples of groundwater and spring water were collected from various sources and analyzed for stable isotopes of oxygen and hydrogen. The objectives of stable isotope sampling and analysis were to accomplish the following:

- assess the source(s) of recharge to the lower aquifer

- evaluate whether the upper, middle, and lower aquifers have distinct isotopic signatures, and are thus hydraulically disconnected

The stable isotopic composition of water (surface water or groundwater) depends on the characteristics of the water's source area and the effects of physical processes such as evaporation and mixing with other waters. If the aquifers in the Big Sandy basin (upper, middle, and lower) have different recharge sources and are hydraulically disconnected, it is conceivable that they would have different stable isotopic compositions. In addition, stable isotopes can be used to identify the recharge area for an aquifer. The information gained from stable isotope analysis was valuable to the assessment of impacts on groundwater resources because it contributed to the understanding of the basin hydrogeology and assisted in the development of the conceptual groundwater model.

Sample Locations

Groundwater samples were collected from five wells, including two upper aquifer wells (OW-7 and OW-8), one middle aquifer well (OWMA-2), and two lower aquifer wells (PW-2 and OW-4). Samples also were collected from Cofer Hot Spring, a seep along Sycamore Creek, three springs in the Aquarius Cliffs (Arrowweed, Deer, and Halo), and two springs in the Hualapai Mountains (Wild Cow and Chappo). Thus, a total of five groundwater samples and seven spring water samples were collected and analyzed for oxygen and hydrogen stable isotopes.

Results and Conclusions

Complete results of stable isotope sampling and analysis, including data and graphs, are presented in two technical memoranda provided in Appendix E (URS 2000a; 2000b).

The primary conclusions drawn from the analysis are as follows:

- The Aquarius Cliffs to the east of the proposed power plant site are likely the primary recharge source to the lower aquifer. This conclusion was made based on the similar stable isotopic compositions of the lower aquifer groundwater samples and the samples collected from springs located in the Aquarius Cliffs. This conclusion also was supported by the dissimilar isotopic compositions of the lower aquifer groundwater samples and those collected from springs located in the Hualapai Mountains.

- The upper, middle, and lower aquifers generally have distinguishable stable isotopic compositions. This suggests that they may have distinguishable recharge sources and supports conclusions made from test hole drilling and aquifer testing that the aquifers are hydraulically disconnected.

- The lower aquifer is the source for Cofer Hot Spring. This conclusion was made based on similar stable isotopic compositions of the lower aquifer groundwater samples and Cofer Hot Spring, and supports findings from aquifer testing.

Groundwater Modeling

A groundwater flow model of the southern portion of the Big Sandy basin was developed to provide a technically defensible tool for use in evaluating the long-term potential impacts of the Proposed Action on the groundwater and surface water resources of the Big Sandy basin. The groundwater flow model was based on the conceptual model of the area developed during the data evaluation, and was constructed using the USGS model MODFLOW, as embedded in Visual MODFLOW®.

The groundwater flow model was developed by URS with the concurrence of the EIS hydrology team. A detailed description of the model, including development, calibration, sensitivity analyses, and results of model simulations, is provided in the groundwater technical report in Appendix F (URS 2001). The groundwater model in summarized in this section.

Model Development

A three-dimensional, finite-difference groundwater flow model was constructed to represent the pumping and potentially impacted layers. The model domain encompasses the southern half of the Big Sandy basin as far south as Granite Gorge, and is defined on the east and west by the granite outcrops. The model domain extends from ground surface to the deepest part of the basin fill, 5,000 feet below ground surface.

The geology was simplified into the following seven-layer framework:

- upper basin fill (upper aquifer)

- lakebed clay (lacustrine deposit)

- lower basin fill (middle aquifer)

- aquitard above the volcanic aquifer

- volcanic (lower) aquifer

- aquitard below the volcanic aquifer
- arkosic gravel

The layers all overlie essentially impermeable granitic bedrock.

The model domain and boundary conditions are shown on Figure 3.4-6. The model grid consists of 62 columns, 85 rows, and seven layers, and covers an area of about 466 square miles. Recharge is distributed along the mountain fronts, and as infiltration in the permeable volcanic outcrops of the Aquarius Cliffs (Figure 3.4-7). Evapotranspiration was distributed by vegetation type along the Big Sandy River, with an assumed extinction depth of 50 feet; the locations of the pumping wells are those proposed by Caithness (Figure 3.4-8). The model boundary conditions include the following:

- no-flow boundaries at the margins of the basin and either side of Granite Gorge
- constant-head boundary at the northern edge of the model representing inflow of recharge from the northern part of the valley
- wall boundary around the outside edge of the volcanic aquifer to maintain artesian pressures in the aquifer
- drain at Cofer Hot Spring representing connection via a fault to the volcanic aquifer
- general head boundary at the marsh near the Denton well representing evaporative losses to surface water and groundwater
- general head boundary at Granite Gorge representing subsurface outflow via the gorge.

The following three additional simplifying assumptions were used in the model analysis:

- An aquitard exists as a skin around the volcanic aquifer. This assumption is consistent with the aquitard and artesian heads observed in the wells, and with the results of the aquifer test which indicate that the volcanic aquifer is hydraulically isolated from the middle and upper aquifers.
- The volcanic aquifer was assumed to be a uniform porous medium. This assumption was tested by analyzing long-term pumping data using both a porous medium model and a block and fracture model. The results of the analyses were almost identical.
- A uniform pumping rate was applied at the four proposed pumping well locations.

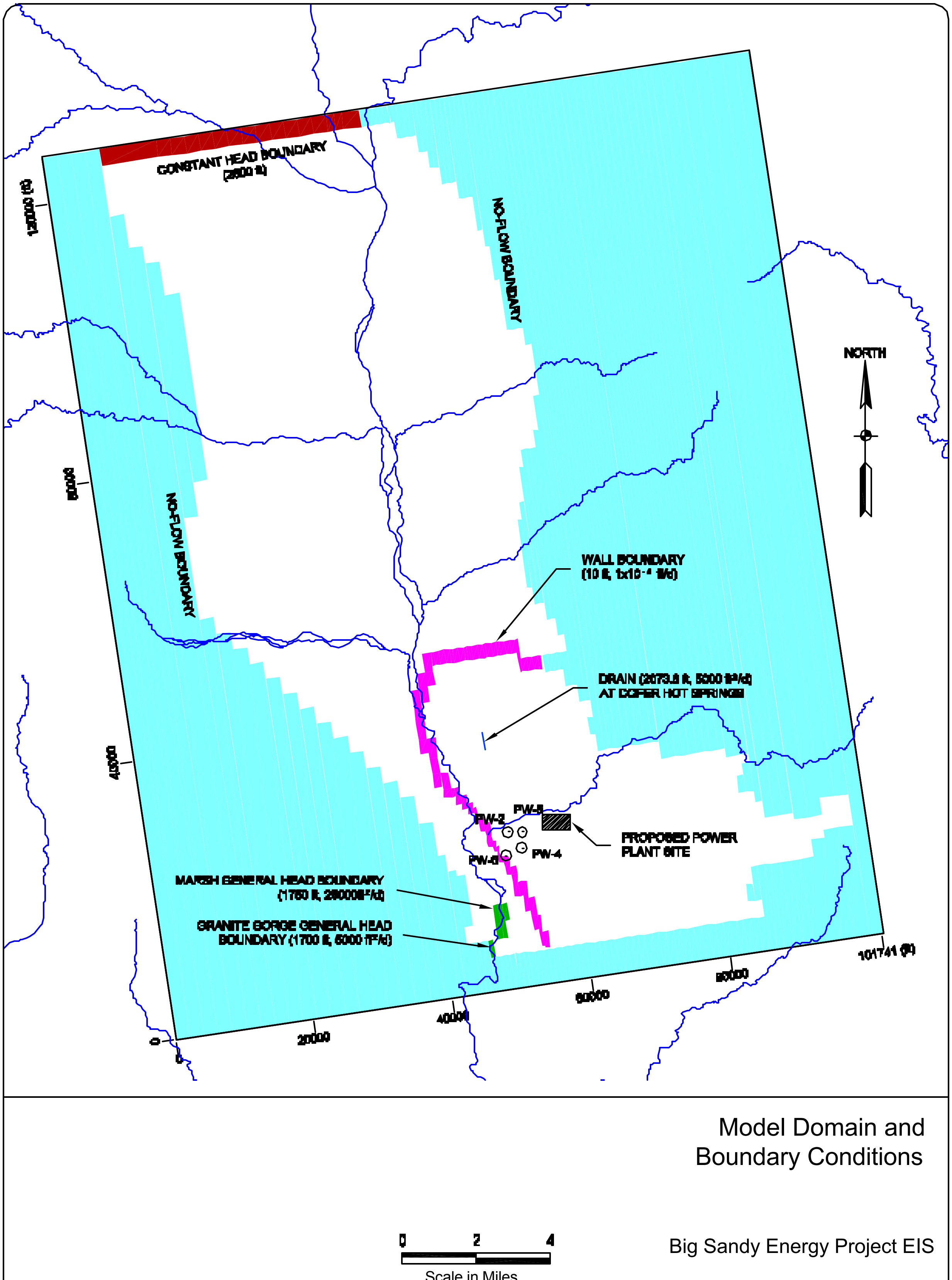
Model Calibration

Model calibration typically consists of the following steps:

- specify calibration criteria and protocol
- modify model assumptions and/or uncertain input data to obtain a realistic simulation
- evaluate the model predictions versus observations
- examine "calibrated" model output and evaluate the results

Steady State Calibration

The model was first calibrated to steady state conditions, followed by transient calibration. Steady state calibration was achieved by varying the hydraulic conductivities of the hydrogeologic units within reported ranges, and varying the infiltration rates such that the sum of the recharge was equivalent to about 5 percent of the precipitation rate, in a set of more than 50 test calculations. The mean error between predicted and observed heads was used to assess each subsequent run, and the best calibrated run



Model Domain and
Boundary Conditions

Big Sandy Energy Project EIS

Figure 3.4-6

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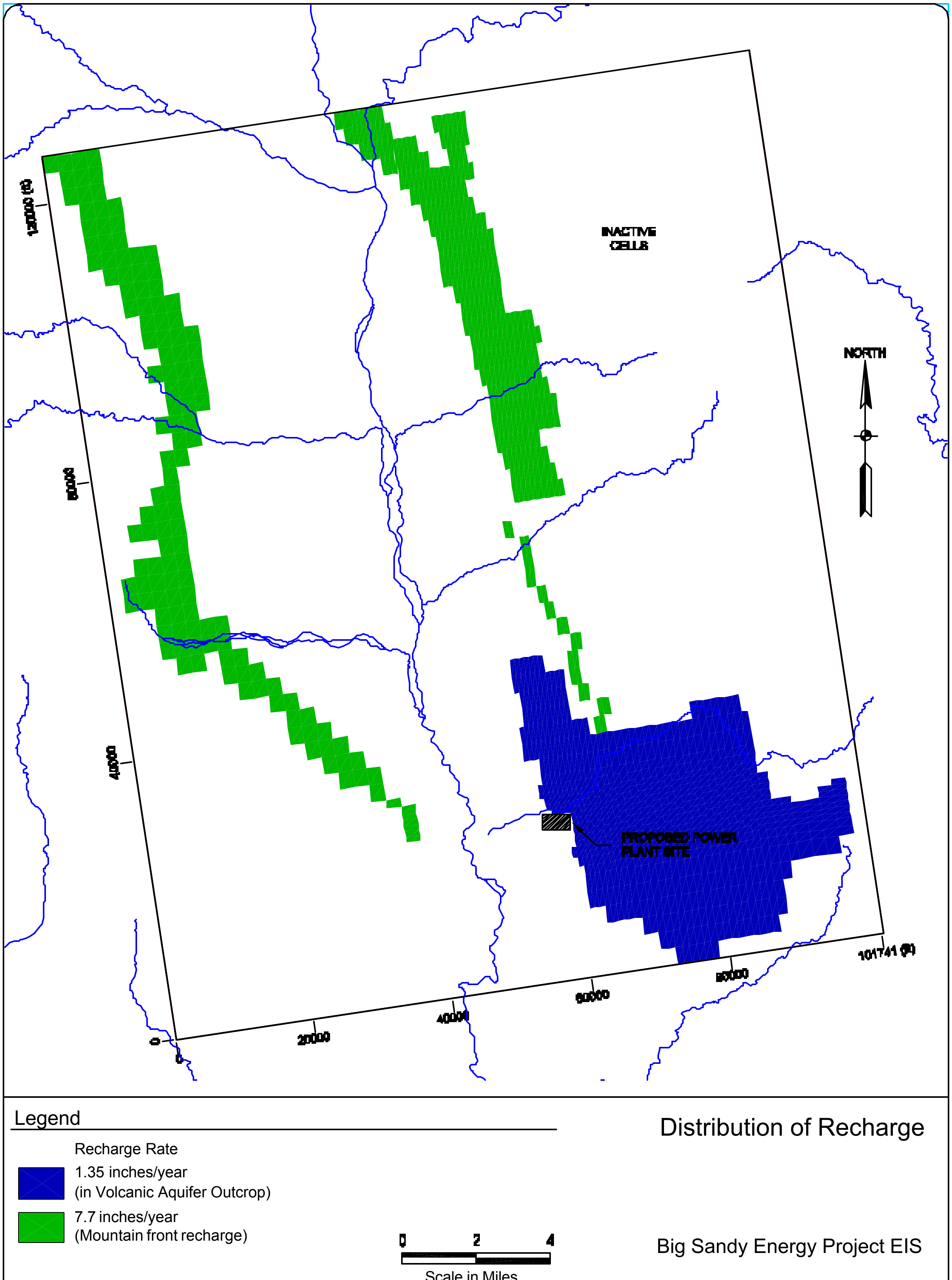

Distribution of Recharge

Big Sandy Energy Project EIS

Figure 3.4-7

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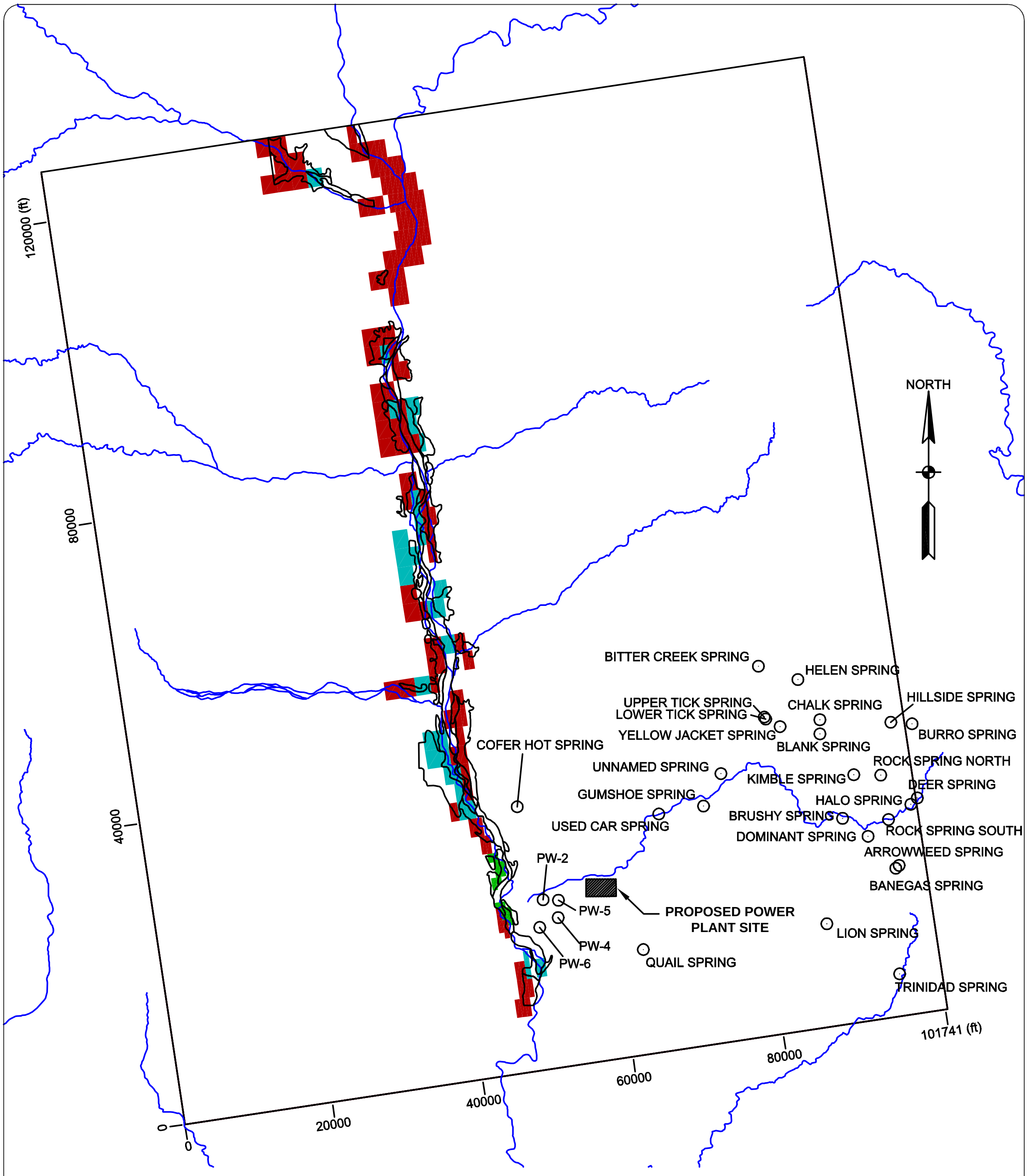


Legend

Evapotranspiration

Mesquite

Salt Cedar

Cottonwood

0 2 4

Scale in Miles

Distribution of Evapotranspiration, Springs, and Pumping Wells

Big Sandy Energy Project
Groundwater Technical Report

Figure 3.4-8

was selected to be the model run that accomplished the following:

- minimized the mean error between predicted and observed heads
- matched reasonably well the expected flow rates through the Granite
- matched observed vertical hydraulic gradients between the three aquifers near the proposed power plant site
- satisfied the calibration criterion of normalized root mean square error less than 10 percent
- was well balanced and conserved mass

The steady state calibrated model yielded flow rates and head values that matched observed values reasonably well.

Transient Calibration

The transient calibration was performed using the data from the constant-discharge aquifer test. Due to the observed responses of the lower aquifer observation wells during the test, the following three methods of representing the lower aquifer were tested:

- uniform conductivity, confined aquifer
- uniform conductivity, confined/unconfined aquifer
- fracture and block model

A one-layer model subset of the Big Sandy model was used for the analysis. The seven-layer model was then applied to verify the conclusions. The results of the analysis indicated the following:

- The fracture and block model gives the best match to observed drawdowns at the wells distant from the pumping center.
- The drawdown at the pumping well is best matched by the confined/unconfined model, but not adequately matched by any model.

Based on these results, the uniform conductivity model was used in the basin model, and the fracture and block model was used in the single-layer model, to evaluate long-term pumping. The predicted drawdowns from the two models were nearly identical, suggesting that either approach could be used in the full-scale basin model. Since the uniform hydraulic conductivity model required fewer model cells without loss of accuracy, this approach was chosen for the remaining model runs.

Sensitivity Analyses

Sensitivity analyses were conducted to evaluate the following:

- if alternate conclusions about impacts could be drawn from an alternate, equally valid model
- which of the uncertain model parameters are the most sensitive
- the range of results considering uncertain parameters
- likely accuracy of model results

The following uncertain input parameters key to the analysis of impacts were identified in hydrology team meetings:

- aquitard hydraulic properties
- specific yield of the volcanic aquifer
- extent of the volcanic aquifer near Granite Gorge

In addition, three other parameters were tested that were found to affect predicted impacts:

- The effect of assuming different lateral extents of the lakebed clay was assessed. It was found that reducing the lateral width of the lakebed clay in the model resulted in decreasing the predicted hydraulic gradient between the middle and upper aquifers, causing a mismatch with observed heads.

- The effect of different recharge rates into the volcanic aquifer (1.35 to 1.85 in/yr) was tested in conjunction with the aquitard hydraulic conductivity tests. It was found that recharge rates greater than 1.6 in/yr led to inaccurate hydraulic gradients between the volcanic and middle aquifers.

- The effect of a three-fold smaller assumed evaporation rate at the marsh was investigated. It was found that this change affected the relative flow rates through the marsh and gorge and the predicted drawdowns resulting from pumping.

The effect of assuming a larger extent of lakebed clay, including the entire area beneath the marsh, was tested. It was found that the predicted drawdowns and reductions in flow rates due to pumping were unchanged as a result.

The results of the sensitivity analyses indicated that extending the aquifer to Granite Gorge, and increasing the hydraulic conductivity of the aquitard to 1 x 10^{-4} feet per day, produced high error values and therefore were infeasible solutions. The remaining solutions consisted of varying the specific yield from 7 percent, to 11 percent (base case), to 15 percent, and varying the aquitard hydraulic conductivity from 4 x 10^{-5} ft/d (combined with a higher recharge rate, worst realistic case) to 1 x 10^{-6} ft/d. Running these five sensitivity cases to simulate the 11-day aquifer test produced drawdown values in the volcanic aquifer ranging from 7.2 to 7.5 feet, which correlate with the drawdowns observed during the test.

Pumping Analysis

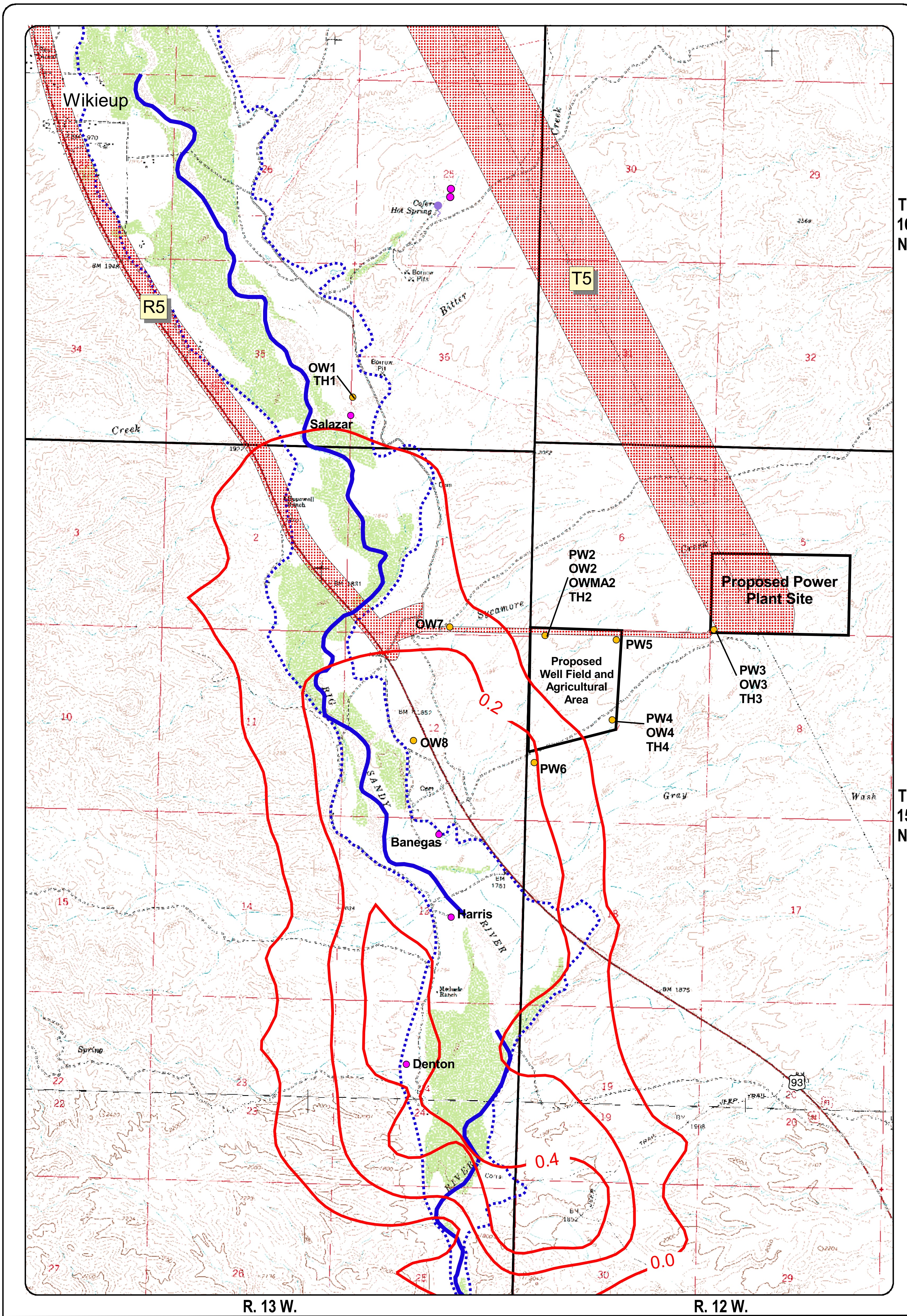
Following calibration and sensitivity analyses, the model was used to predict potential impacts of 40 years of pumping at the maximum annual pumping rate of 3,000 gpm (4,850 ac-ft/yr).

Predicted Drawdowns for the Base Case

The results for the base case (specific yield = 11 percent) are shown on Figure 3.4-9 and on Figures 34 through 36 in Appendix F. The predicted drawdowns in the lower aquifer (Figure 34 in Appendix F) show an almost uniform drop in water levels of about 85 feet (refer ahead to Figure 3.4-11). In the middle aquifer (Figure 35 in Appendix F), a small zone of less than 4 feet of drawdown is predicted as a result of 40 years of pumping. This zone is centered above the pumping area and extends outward in areas where the lakebed clay thins. In the upper aquifer (Figure 36 in Appendix F), a small area of less than 0.5 foot of drawdown is predicted as a result of 40 years of pumping. This area is shown in detail on Figure 3.4-9. The predicted area of potential drawdown extends along the Big Sandy River from south of the US 93 bridge to Granite Gorge, and is greatest in the vicinity of the Denton well.

Predicted Drawdowns for the Worst Realistic Case

The case where aquitard hydraulic conductivity is 4 x 10^{-5} ft/d represents the worst realistic case for predicted impacts, because this case leads to the greatest predicted drawdowns in the middle and upper aquifers. Predicted drawdowns for this case are shown on Figure 3.4-10 and on Figures 37 through 39 in Appendix F. The predicted drawdowns in the lower aquifer (Figure 37 in Appendix F) show an almost uniform drop in water levels of about 85 feet. In the middle aquifer (Figure 38 in Appendix F), a small zone of approximately 12 ft of drawdown is predicted as a result of 40 years of pumping. This zone is centered above the pumping area and is greatest in the vicinity of Cofer Hot



Legend

- Wells and Test Holes Completed by Caithness
- Other Wells
- Springs
- Approximate Limit of Big Sandy River Alluvium
- Predicted Drawdown in Feet
- Approximate Extent of Perennial Flow in the Big Sandy River Under Base-Flow conditions

Project Components
- Pipeline Corridor Segments
  Proposed Pipeline Corridor - R1, C1, T3, C3, T4,R5
  Alternative R Corridor - R1, R2, R3, C3, R4, R5
  Alternative T Corridor - T1, T2 T3, C3, T4, T5

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Predicted Drawdown in the Upper Aquifer After 40 Years of Pumping (Base Case)

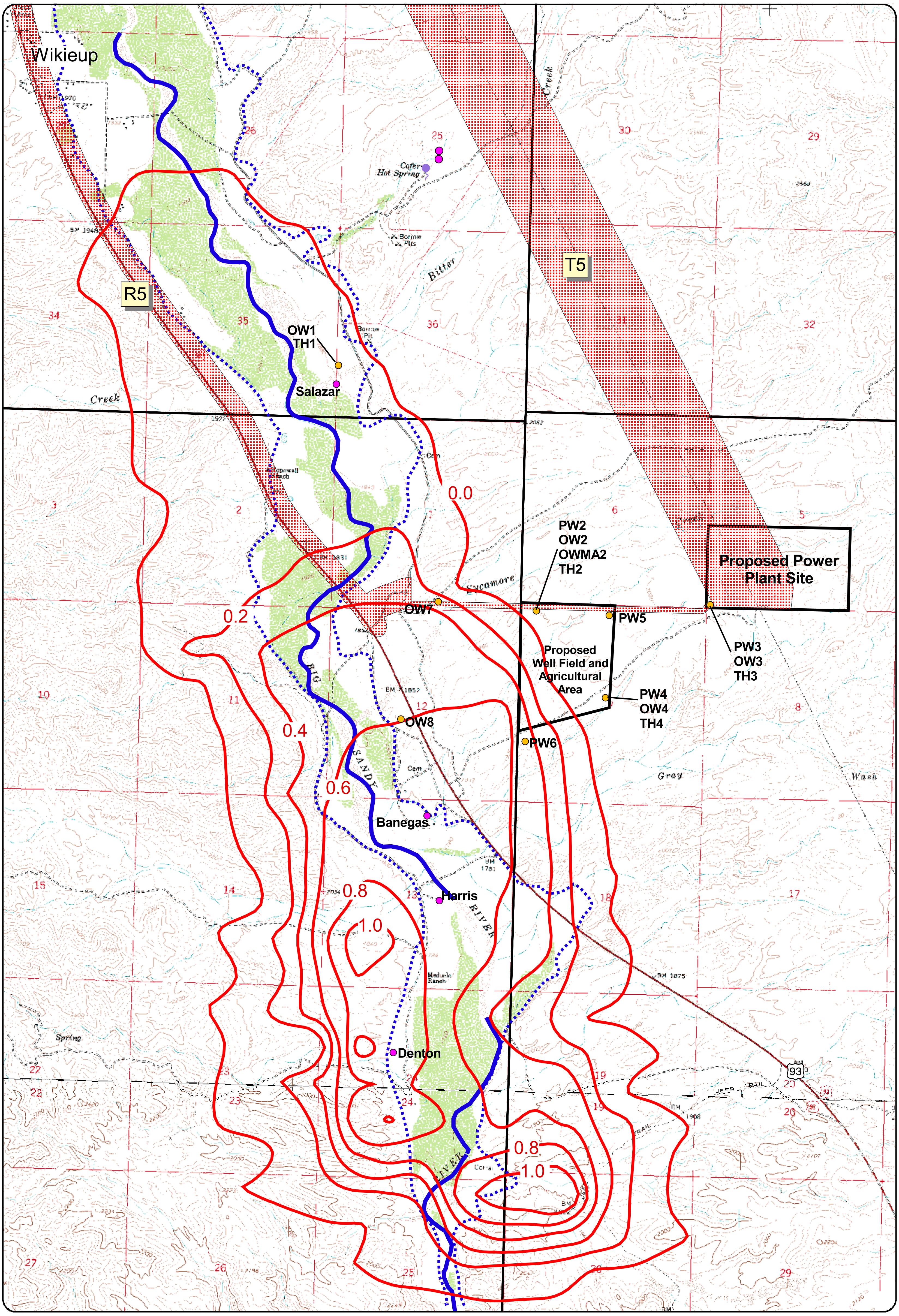
Big Sandy Energy Project EIS

0 0.5 1
Scale in Miles

Universal Transverse Mercator Projection
1927 North American Datum
Zone 12

N

Figure 3.4-9



Legend

- Wells and Test Holes Completed by Caithness
- Other Wells
- Springs
- Approximate Limit of Big Sandy River Alluvium
- Predicted Drawdown in Feet
- Approximate Extent of Perennial Flow in the Big Sandy River Under Base-Flow conditions

Project Components
- Pipeline Corridor Segments
  - Proposed Pipeline Corridor - R1, C1, T3, C3, T4,R5
  - Alternative R Corridor - R1, R2, R3, C3, R4, R5
  - Alternative T Corridor - T1, T2 T3, C3, T4, T5

N

0 0.5 1

Scale in Miles

Universal Transverse Mercator Projection
1927 North American Datum
Zone 12

Predicted Drawdown in the Upper Aquifer After 40 Years of Pumping - Aquitard Hydraulic Conductivity of 4 x 10^{-5} ft/d (Realistic Case)

Big Sandy Energy Project EIS

Figure 3.4-10

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Spring. In the upper aquifer (Figure 39 in Appendix F), an area of less than 1 foot of drawdown is predicted as a result of 40 years of pumping. This area is shown in detail on Figure 3.4-10. The predicted area of potential drawdown is more extensive than that predicted by the base case, and extends from south of Wikieup to Granite Gorge. The area extends along the Big Sandy River, with the area of greatest predicted drawdown (0.6 ft to less than 1 ft) extending from the vicinity of monitor well OW8 to Granite Gorge.

Predicted Drawdowns Versus Time

Predicted drawdowns versus time for the base and sensitivity cases are shown on Figures 3.4-11 through 3.4-13. The most sensitive parameters tested are specific yield and aquitard hydraulic conductivity. Under worst realistic case conditions (aquitard hydraulic conductivity = 4×10^{-5} ft/d) potential impacts of less than 1 ft of drawdown in the upper aquifer are predicted to occur as a result of 40 years of pumping. The lower aquifer is predicted to require approximately 130 years to recover to within 90 percent of static conditions.

Predicted Flow Rates Into the River Alluvium

The modeling results predict a reduction in groundwater flow from the middle aquifer to the upper aquifer as a result of 40 years of groundwater pumping. This reduction in flow is expressed as a reduction in outflow at Granite Gorge (Figure 3.4-14), a small decrease in evapotranspiration, and a relatively large reduction in evaporative losses at the marsh at the southern end of the basin.

Groundwater flow rates to the river alluvium were predicted for the base and sensitivity cases. It was predicted that drops in flows to the marsh, gorge and, to a small degree, to evapotranspiration outside the marsh, due to project pumping, would occur. The potential decrease in flows is predicted to occur gradually over the period of pumping. Both the response and recovery times were predicted to be very slow.

It was concluded from these results that:

- the base case and less-evaporative marsh cases bracket the data for outflows from the Big Sandy basin at the south end of the valley.
- alternate marsh scenarios predict a redistribution of flows between the gorge and the marsh, but do not significantly change the predicted overall decline in flow rates in the southern end of the valley
- for the realistic worst case, overall groundwater flow to the alluvium is predicted to decline by up to 1 percent (350 gpm or 564 ac-ft/yr).

The overall predicted drop in flow rates to the river alluvium comprise: drops in evapotranspiration, drops in flow to the marsh, and drops in outflow through the gorge. These predicted drops in flow vary from zero to a maximum after 40 years of pumping, as shown in Table 3-4.3.

Conclusions

Predicted water level drawdowns for the base case (specific yield = 11 percent) and worst realistic case (aquitard hydraulic conductivity = 4×10^{-5} ft/d) as a result of 40 years of pumping groundwater at the maximum proposed annual pumping rate of 3,000 gpm (4,850 ac-ft/yr) to support the Proposed Action are as follows:

- lower aquifer: 85 ft (both cases)
- middle aquifer: less than 4 ft (base case) to approximately 12 ft (worst realistic case)
- upper aquifer: less than 0.5 ft (base case) to less than 1 ft (worst realistic case)

The predicted area of potential drawdown in the upper aquifer under worst-realistic-case

TABLE 3.4-3 PREDICTED DROP IN FLOW RATES TO THE RIVER ALLUVIUM OVER TIME				
Time Since Pumping Began (Years)	Predicted Drop in Flow Rate to River Alluvium			
	Base Case		Realistic Worst Case: Aquitard conductivity of $4x10^{-5}$ ft/d	
	(gpm)	(ac-ft/yr)	(gpm)	(ac-ft/yr)
0	0	0	0	0
10	32	52	60	97
20	72	116	145	234
30	112	181	230	371
40 (pumping stops)	155	250	317	511
50	168	271	350	564
60	170	274	365	589
70	166	268	371	598
80	161	260	371	598
90	155	250	371	598
100	151	244	371	598

conditions extends along the Big Sandy River from south of Wikieup to Granite Gorge. The area of greatest predicted drawdown (0.6 ft to less than 1 ft) extends from the vicinity of monitor well OW8 to Granite Gorge. The worst-realistic-case model predictions also indicate up to 1 percent (approximately 564 ac-ft/yr) reduction in groundwater flow from the middle aquifer to the upper aquifer This reduction in flow is expressed as a reduction in outflow at Granite Gorge, a small decrease in evapotranspiration, and a relatively large reduction in evaporative losses at the marsh at the southern end of the basin.

Model Limitations

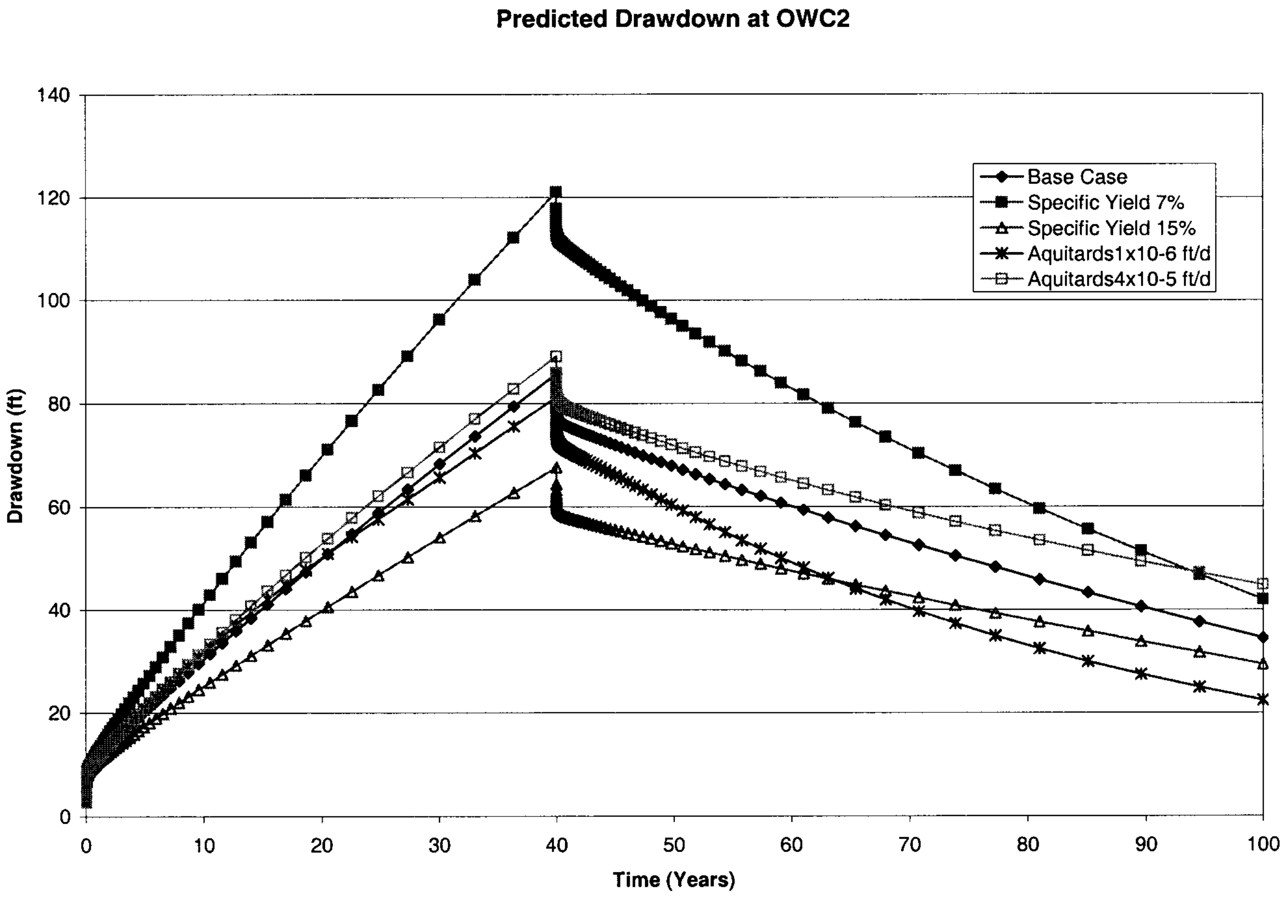
The groundwater flow model is limited to the simulation of pumping in the volcanic aquifer and its effects on the water levels in the southern portion of the Big Sandy basin. Although conservative estimates have been tested in the model sensitivity analyses, unmapped geologic features could change the actual impacts. The assumptions used in the model have been discussed in the previous sections. The likely effects of the main assumptions on the predicted impacts due to pumping are summarized in the following sections.

Geology and Extent of Volcanic Aquifer

A different extent of volcanic aquifer than that modeled would result in a different distribution of projected impacts. A smaller aquifer extent would result in a greater impact on drawdowns in the volcanic aquifer, and less impact in the upper aquifer (due to less coverage by the lakebed clays). A larger aquifer extent than modeled would result in a lesser impact on drawdowns in the volcanic aquifer, and more impact in the upper aquifer (due to less coverage by the lakebed clays). Therefore, these two effects tend to offset one another since drawdowns in the volcanic aquifer are directly related to impacts in the middle and upper aquifers.

Specific Yield of Volcanic Aquifer

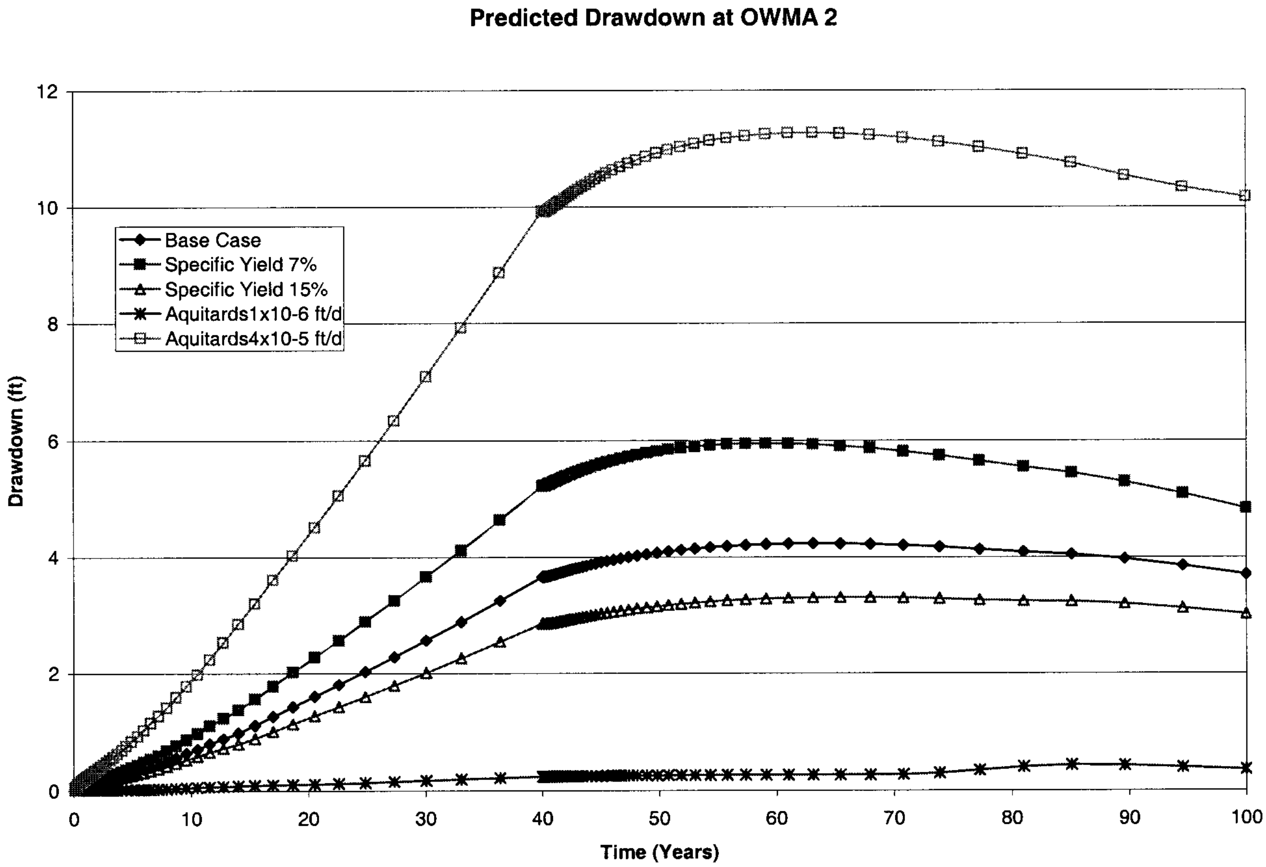
Greater or lesser specific yields in the volcanic aquifer than modeled would result in lesser or greater impacts in all three aquifers, respectively. The range of specific yields



Predicted Drawdown versus Time
in the Volcanic Aquifer (OWC 2)

Big Sandy Energy Project EIS

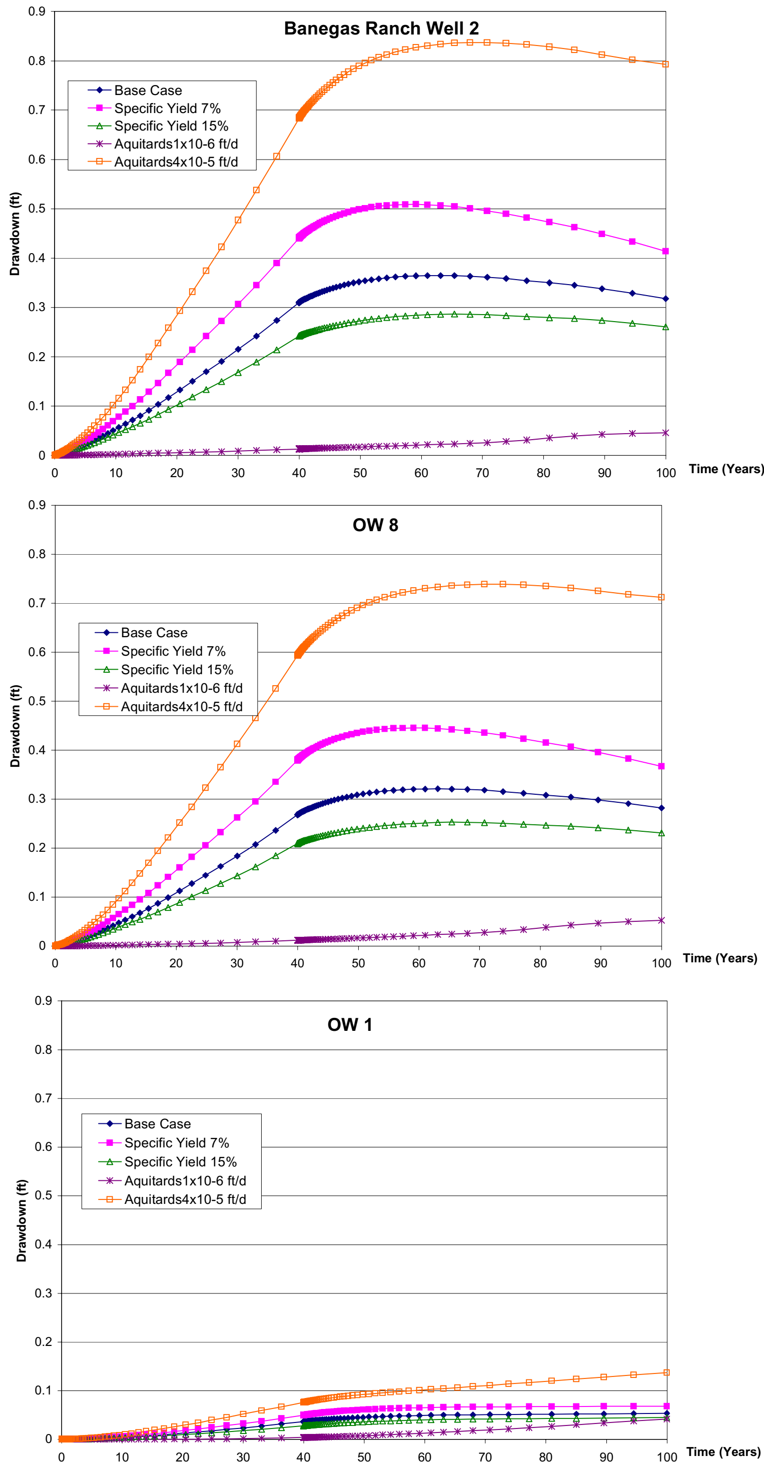
Figure 3.4-11



Predicted Drawdown versus Time
in the Middle Aquifer (OWMA 2)

Big Sandy Energy Project EIS

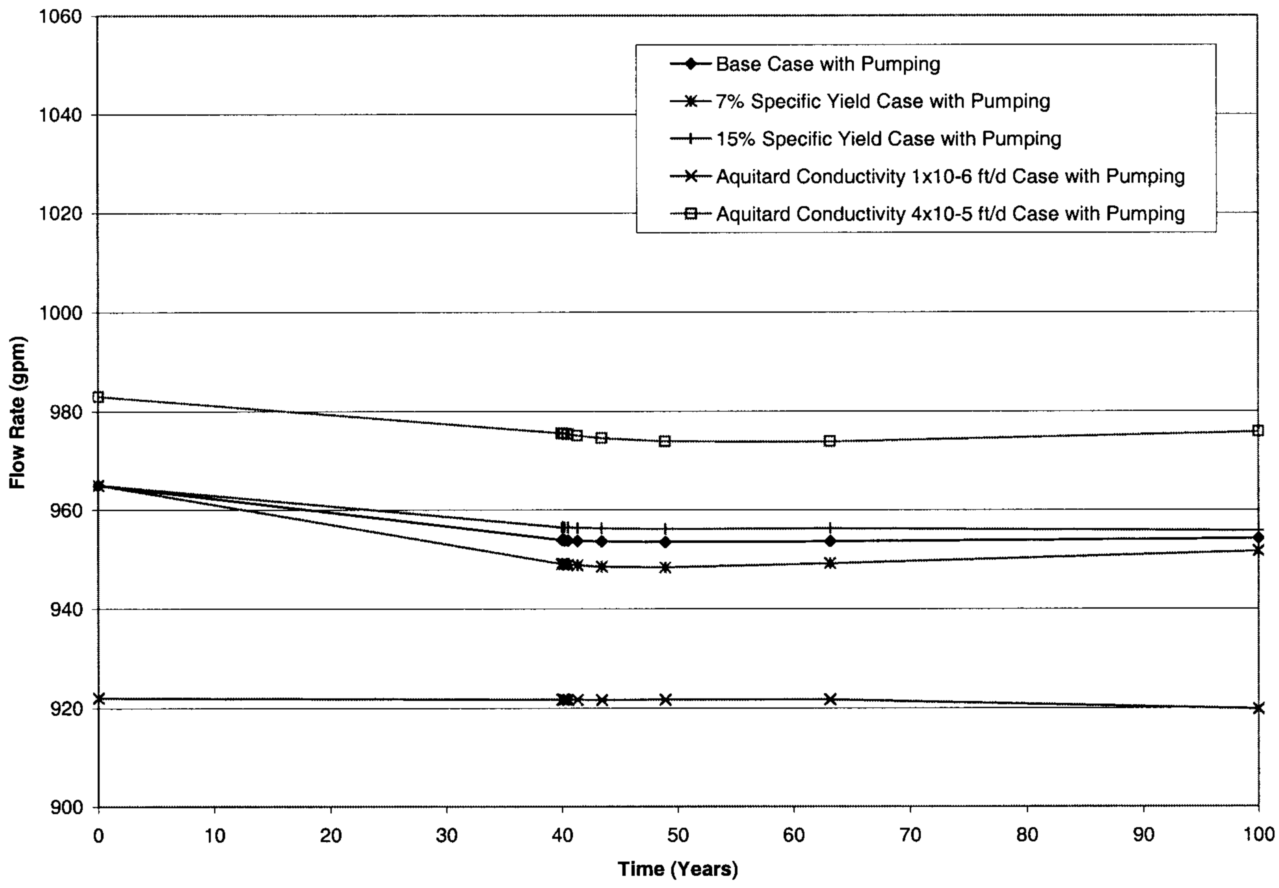
Figure 3.4-12



Predicted Drawdown versus Time
in the Upper Aquifer
(OW1, OW8 and Banegas Ranch Well 2)

Big Sandy Energy Project EIS

Figure 3.4-13



Predicted Granite Gorge Flow versus Time

Big Sandy Energy Project EIS

Figure 3.4-14

presented in the literature, consistent with the observed volcanic aquifer hydraulic properties, was tested and found to affect predicted impacts due to Project pumping by a factor of 0.5 percent.

Hydraulic Conductivity of Volcanic Aquitards

Greater or lesser aquitard conductivities than those modeled would lead to greater or lesser impacts due to pumping, respectively. However, the aquitards confining the volcanic aquifer are known to be competent because of the 175-ft head drop observed across this interface. A range of aquitard conductivities was modeled and only a relatively narrow range of values produced predicted hydraulic heads and vertical gradients similar to those observed.

Recharge Rate into the Volcanic Aquifer

Greater or lesser recharge rates into the volcanic aquifer than those modeled would result in (1) a greater or lesser impact on the upper two aquifers, respectively, and (2) a lesser or greater impact on the volcanic aquifer than modeled, respectively. However, there is a realistic limit to the level of aquifer recharge that is likely to occur in this area of 12 in/yr precipitation. Recharge rates of two to three times the likely recharge rate were tested during sensitivity analyses.

Groundwater/Surface Water Interaction

The groundwater flow model is not capable of modeling the interaction between the groundwater and surface water flow in the Big Sandy River; therefore, the model was not used to predict any potential impacts on surface water flow from groundwater pumping.

Groundwater Flow to Marsh

The groundwater outflow at the marsh and through the Granite Gorge as underflow and/or streamflow are linked in that the basin water budget is balanced if changes in these two outflow components offset on another. At different times of the year the balance between these two components may vary, and also differ from that modeled. Both sets of outflows are modeled and reported separately. An alternate combination of outflows (less outflow from the marsh and more through Granite Gorge) was tested and is reported in Section 3.6 of the Groundwater Technical Report.

Summary

The model was tested with respect to observed current hydraulic heads in the three aquifers and observed responses during pumping. Many cases were rejected as being insufficiently accurate. A range of cases covering best-estimate and upper and lower limits for those parameters most sensitive to predicted impacts were evaluated. The model input data and assumptions that resulted in the best match to observed flows and heads were used to evaluate the likely effects of Project pumping.

3.4.2.4 Actions Incorporated Into the Proposed Action to Reduce or Prevent Impacts

The Proposed Action includes the following measures to reduce or prevent potential adverse impacts on groundwater.

Cofer Hot Spring

Cofer Hot Spring is privately owned, and is used by the owner for grazing and other uses. Caithness has agreed in concept to compensate for flow lost at Cofer Hot Spring, as described in Section 2.2.8.6, Actions to Compensate for Predicted Impacts on Cofer Hot Spring.

Groundwater Monitoring and Water Replacement Program

The groundwater model predicts a potential reduction in flow to the upper aquifer from the middle aquifer as a result of the Proposed Action. The potential reduction is predicted to range from approximately 0.5 percent (159 gpm or 256 ac-ft/yr) under base-case conditions to approximately 1 percent (350 gpm or 564 ac-ft/y) under worst-realistic-case conditions after 40 years of groundwater pumping (see "Pumping Analysis" in Section 3.4.2.3). This reduction in flow is expressed as a reduction in outflow at Granite Gorge, a small decrease in evapotranspiration, and a relatively large reduction in evaporative losses at the marsh at the southern end of the basin.

To prevent these potential adverse impacts, Caithness has agreed to monitor groundwater levels and to augment surface flows to prevent any impacts on the upper aquifer as a result of the Proposed Action.

Water Monitoring Approach

The principal objective of groundwater monitoring would be to assess the extent to which observed water level drawdowns correlate with model-predicted drawdowns, and to use this information to determine the amount of water to be added, and the timing of this water augmentation.

Potential impacts to the upper aquifer are of primary concern. Because groundwater levels in the upper aquifer tend to fluctuate in response to groundwater pumping and flow in the Big Sandy River, it is not feasible to discern impacts on groundwater levels in the upper aquifer through direct measurement. Groundwater levels would be measured in upper aquifer wells as part of the monitoring program to record the daily and seasonal fluctuations in the upper aquifer in response to groundwater pumping in the upper aquifer, flows in the Big Sandy River, and climatic cycles. However, the groundwater level data obtained from the upper aquifer would not be used to assess whether upper aquifer groundwater levels are being impacted by groundwater pumping in the lower aquifer.

As an alternative to direct monitoring of groundwater levels in the upper aquifer to assess impacts, groundwater levels would be monitored in the lower and middle aquifers to assess the extent to which observed groundwater levels in those two aquifers correlate with groundwater levels predicted by the groundwater flow model. In this way, the groundwater monitoring data from the lower and middle aquifers would be used as an early warning of potential impacts on groundwater levels in the upper aquifer.

The results of the groundwater flow model define a range of predicted reduction in flow from the middle aquifer to the upper aquifer as a result of the Proposed Action. If the observed groundwater level drawdowns in the lower and middle aquifers are within the model-predicted range of drawdowns, then the observed data would be used to determine the amount of water to be added, and the timing of water augmentation. If the observed groundwater level drawdowns in the lower and middle aquifers are outside of the model-predicted range of drawdowns, then the observed water level data would be used to re-calibrate the model prior to determining the amount of water to be added and the timing of this augmentation.

Wells to be Monitored

Groundwater level measurements would be collected from five existing wells in the vicinity of the proposed power plant. One well (OW-2) would be used to monitor the lower aquifer, one well (OWMA-2) would be used to monitor the middle aquifer, and three wells (OW-1, OW-8, and Banegas) would be used to monitor the upper aquifer. In addition, there is a recognized need for a second middle aquifer monitor well between the production wellfield and the marsh. This second middle aquifer monitor well would be installed and equipped for water level monitoring prior to initiating groundwater pumping for the Proposed Action. The location of the new middle aquifer monitor well would be selected based on consensus between Caithness and the applicable regulatory agencies.

Monitoring Frequency and Accuracy

Groundwater level measurements would be collected from the lower and middle aquifer monitor wells (OW2, OWMA2, and the new middle aquifer monitor well) at a frequency of once per day. Based on the rates of drawdown observed during the long-term aquifer test, it is anticipated that more frequent measurements would not be necessary. Groundwater level measurements would be collected from the upper aquifer monitor wells (OW-1, OW-8, and Banegas) four times per day to monitor anticipated diurnal fluctuations in groundwater levels.

Groundwater level measurements would be collected from the middle and upper aquifer monitor wells using either an electric sounder or an electronic pressure transducer. Because the lower aquifer monitor well is under artesian pressure, groundwater level measurements in that well (OW-2) would be collected using a pressure transducer. Groundwater levels obtained using an electric sounder would be measured to an accuracy of 0.01 foot. Groundwater levels obtained using a pressure transducer would be measured to 0.01 psi, or about 0.01 foot.

Monitoring Data Evaluation

Groundwater monitoring data would be compiled and evaluated quarterly, and reported annually. Emphasis would be placed on evaluation of the monitoring data from the middle aquifer wells (OWMA-2 and the new middle aquifer monitor well), because groundwater levels in the middle aquifer are more directly connected to groundwater levels in the upper aquifer.

At the end of each quarter, the groundwater level measurements from each well would be appended to the groundwater level database for that well and an updated water level hydrograph prepared. For the lower and middle aquifer hydrographs, the model-predicted groundwater level data would be superimposed on the observed data to allow model-predicted and observed drawdowns to be compared.

If the observed groundwater level drawdowns in the lower and middle aquifers are within the model-predicted range of drawdowns for the two aquifers, then the observed data would be used to determine the amount of water to be added, and the timing of water augmentation, based on the model-predicted range of flow reductions. If the observed groundwater level drawdowns in the lower and middle aquifers are outside of the model-predicted range of drawdowns for the two aquifers, then the observed water level data would be used by Caithness to re-calibrate the groundwater flow model. The re-calibrated model would then be used to determine the amount of water to be added.

Water Replacement

As noted above, the results of the groundwater model indicate that the potential reduction in flow from the middle aquifer to the upper aquifer as a result of the proposed action may range from 0.5 percent (159 gpm or 256 ac-ft/yr) to 1 percent (350 gpm or 564 ac-ft/yr). The model results also indicate that the area of greatest potential flow reduction is at the marsh, located near the southern boundary of the basin above Granite Gorge, and that addition of water at the marsh would avoid these flow reductions. Water could effectively be conveyed to the marsh via the Big Sandy River. Accordingly, Caithness has proposed that any augmentation water be directed into the Big Sandy River between the US 93 bridge crossing of the Big Sandy River and the marsh. Required augmentation would be provided at least one year in advance of the projected flow reduction (as determined by monitoring and the groundwater model).

The two sources of augmentation water are (1) a portion of the 4,850 ac-ft/yr maximum withdrawal of groundwater from the lower aquifer, and (2) conversion of existing surface water irrigation rights to stream flow rights in the Big Sandy River.

Groundwater from the lower aquifer would be supplied by constructing a pipeline from the groundwater production wellfield or the power plant and diverting a portion of the groundwater from the production wellfield or water from the proposed power plant water treatment system to the river.

Surface water also could be supplied by converting surface irrigation rights at Banegas Ranch and/or others to instream flow rights.

3.4.2.5 Impact Assessment

Proposed Action

Groundwater Quantity

Implementation of the Proposed Action including the communication facilities, or either of the alternatives, would result in identical impacts to groundwater quantity, and these effects are not separately identified.

The Project would not likely have a significant impact on surface water flows in the Big Sandy River, either in the vicinity of the Project area or downstream in Granite Gorge or below. As discussed in Section 3.4.2.3, pumping of groundwater for the Project from the lower aquifer without the actions incorporated into the Proposed Action to reduce or prevent impacts resulted in a predicted reduction in flow to the upper aquifer from the middle aquifer.

The model showed a reduction in outflow at Granite Gorge, a decrease in evapotranspiration, and a reduction in evaporative losses at the marsh at the southern end of the basin. However, actions are incorporated into the Proposed Action which are designed to prevent these impacts. To evaluate the effectiveness of these actions, additional analyses were conducted using the base case of the groundwater model (refer to Appendix F). Based upon a series of runs, the model indicated that placement into the marsh of an amount of water equal to the amount of water not delivered from the middle aquifer to the upper aquifer would prevent the occurrence of the effects of the predicted flow reduction (reduction in the outflow at Granite Gorge, decrease in evapotranspiration, and reduction in evaporative losses at the marsh), either at the marsh or any other location. With this augmentation of water to the marsh, the drawdown of the upper aquifer groundwater contours displayed in Figures 3.49 and Figure 3.4-10 was predicted to not occur.

As discussed in Section 3.4.2.3 and Appendix F, even though the model has been constructed with conservative assumptions and estimates and has been subject to substantial review by the hydrologic team, it is still subject to certain limitations, and the predicted results are not absolute. However, the groundwater monitoring and flow augmentation program includes the ongoing collection of additional geologic and hydrologic information, which would be used to improve the model as appropriate over time. This, combined with the commitment in the Proposed Action to adjust the amount of water to be added to the marsh, would substantially compensate for the model limitations and uncertainties.

As proposed, the augmented water would be added to the Big Sandy River between the US93 bridge over the Big Sandy River and the marsh, and would be derived from either a portion of the 4,850 ac-ft/yr maximum withdrawal of groundwater from the lower aquifer or the conversion of existing surface water irrigation rights to instream flow rights in the Big Sandy River. Groundwater from the lower aquifer would be supplied by constructing a pipeline from the groundwater production wellfield or the power plant water treatment system and diverting a portion of the produced groundwater to the river. The required water would be provided at least one year in advance of the projected flow reduction, as determined by comparing the results of the groundwater monitoring to the groundwater model results.

Augmenting the flow of the Big Sandy River at any point between the US93 bridge over the Big Sandy River and the marsh is expected to be as effective as delivering the water directly to the marsh because the Big Sandy River would act as a direct conduit for water to the marsh. Any water lost through infiltration would enter the groundwater and have essentially the same effect as delivering the water directly to the marsh (and specifically the groundwater system on which it is dependent). Evaporative losses would be very small over the up to 3-mile flow in the river, and by delivering the quantity of water predicted by the model at least one year in advance, the quantity of water and water levels in the upper groundwater/surface water systems are predicted to never be reduced below those which would occur without the Proposed Action.

Delivering the required water to the marsh from the lower aquifer (produced from the maximum groundwater withdrawal rate of 4,850 ac-ft/yr) would ensure that "new" water was introduced into the upper groundwater system, and thus effectively prevent the predicted impacts from occurring. As a result, no significant impacts to the surface flow in the Big Sandy River would likely occur.

If the needed water comes from the conversion of existing surface water irrigation rights to instream flow rights in the Big Sandy River, this would result in the placement of "new" water into the Big Sandy River only if the water rights so converted were for current, existing consumptive uses of this water. (The transfer of water rights not currently used would only prevent the occurrence of future flow reductions associated with the use of these rights.) Since the Proposed Action does not propose the conversion only of water rights for existing consumptive uses, implementation of this option would likely still result in reduction of evapotranspiration from the marsh and surface water flows in the Big Sandy River through the gorge, which would be a significant impact.

The groundwater model predicts that without water augmentation, the flow reduction in the upper aquifer as a result of the production of the groundwater from the lower aquifer is slow to develop and continues long after the production of groundwater for the Project power plant stops. Augmentation of water to the marsh may reduce the time period over which augmentation would be required, although it would likely need to continue far into the future. Implementation of a mechanism to ensure the continued application of this water would be appropriate, regardless of the water source option selected. The Proposed Action includes a groundwater monitoring program that provides for compiling and reporting groundwater data; implementing additional groundwater modeling, if necessary; and comparing the monitored groundwater information and the results of the groundwater model to determine the annual quantity of water to be added to the marsh. Establishment of a reporting and review mechanism between Caithness and the applicable regulatory agencies would be appropriate.

The Proposed Action would not have a significant impact on groundwater users in the upper aquifer regardless of which options is selected to reduce the outflow at Granite Gorge, decrease evapotranspiration, and reduce evaporative losses at the marsh. This is because the results of the groundwater flow model, which indicated that groundwater pumping of the lower aquifer to supply the project would result in a realistic worst case drawdown of less than 1 foot in the upper aquifer over after 40-years of pumping even without the addition of water, is substantially less than the significance criterion of 10 feet over any 5-year period in the upper aquifer.

The Proposed Action likely would have a significant impact on the volume of water discharged from Cofer Hot Spring. The available information indicates that the source of Cofer Hot Spring is connected to the lower aquifer and its flow would be reduced, or possibly eliminated, by the pumping of groundwater for the Project from the lower aquifer. Caithness has agreed in concept to compensate the private owner of Cofer Hot Spring for this reduction in flow. However, because any reduction in the quantity of water discharged from a spring is considered significant, this reduction in the flow to Cofer Hot Spring would be significant.

No impacts are anticipated to the volume of water discharged from other springs in the area because none of these springs are hydraulically connected to the portions of the lower, middle or upper aquifers that would be drawn down by the project.

Groundwater Quality

The Proposed Action would not have a significant impact on groundwater quality. The evaporation pond will be constructed in accordance with ADEQ's prescriptive Best Available Demonstrated Control Technology (BADCT) criteria, which call for a double liner equipped with a leak collection and removal system (LCRS). Because of these design and construction requirements, it is not anticipated that discharge of pollutants to the vadose zone through the lower liner will result in exceedances of numeric AWQS in groundwater at the point of compliance.

There are anticipated to be no other on-site activities at the proposed power plant or along the proposed gas pipeline route that would cause a discharge of pollutants to the vadose zone sufficient to result in a significant degradation of groundwater quality.

No-Action Alternative

If the Proposed Action is not constructed there would be no impact on groundwater quantity or quality from the Project within the Big Sandy basin. The groundwater production and monitoring wells completed on private land which were used to identify and test the lower aquifer would remain.

3.4.2.6 Mitigation and Residual Impacts

If adopted, the following measure would be implemented to avoid significant impacts if the option to convert existing surface water irrigation rights to instream flow rights in the Big Sandy River is selected:

- To ensure that water sufficient to compensate for the predicted reduction in flow is delivered to the marsh, only the conversion, approved by ADWR, of existing surface water irrigation rights to instream flow rights in the Big Sandy River for current, existing consumptive uses of this water would be accepted as water to augment the flow of the Big Sandy River and the marsh.

With the implementation of this measure, significant impacts to surface water flow in the Big Sandy River would be avoided.

If adopted, the following measures would be implemented to minimize adverse impacts to surface water flow in the Big Sandy River not considered to be significant:

- Appropriate financial assurance mechanisms sufficient to fund those activities necessary to ensure application of the water required to augment the water flow to the Big Sandy River marsh, even after the production of groundwater for the Project power plant stops, would be required from Caithness.

- To ensure that the results of the monitoring program would be appropriately compiled and evaluated, an independent expert would annually analyze the collected monitoring data and prepare a report providing an assessment of the monitoring data, an evaluation of the groundwater model, and any required actions regarding the monitoring program, the groundwater model, the water augmentation program, and the appropriate quantity of water to be added in accordance with accepted professional standards. The report would be provided to Caithness and agencies with regulatory responsibility or appropriate expertise.

- Caithness and agencies with regulatory responsibility or appropriate expertise may provide comments regarding the report and required actions. The independent expert would revise the report and required actions as it deems appropriate. Caithness would implement those actions contained in the revised report.

3.5 SURFACE WATER

This section describes the affected environment and environmental consequences relative to surface water resources. "Waters of the United States" has a strictly defined regulatory meaning pursuant to the Clean Water Act. Most waters of the United States addressed in this Draft EIS are dry most of the year. Waters of the United States are discussed in Section 3.12.

3.5.1 Affected Environment

The following sections describe the current surface water environment. The description of current conditions represents the baseline for the assessment of impacts and environmental consequences.

3.5.1.1 Region of Influence

The region of influence for assessing impacts on surface water resources includes all areas of the Proposed Action, including gas pipeline corridors and communication facilities, the southern portion of the Big Sandy River basin, and all connected watercourses downstream of the Proposed Action subject to substantial adverse impacts. Potential impacts of the Proposed Action and alternatives are limited to the specific areas potentially impacted by wastewater and/or stormwater generation and gas pipeline construction.

3.5.1.2 Existing Conditions

The proposed power plant site is located in the southeastern portion of the Big Sandy River basin (Figure 3.5-1). The primary drainage and surface water resource in the basin is the Big Sandy River. The Big Sandy River flows from its headwaters, which originate east of Kingman, to the south and drains into Alamo Reservoir. Alamo Reservoir is located at the confluence of the Big Sandy and Santa Maria rivers, which form the Bill Williams River. The Bill Williams River joins the Colorado River at Parker, Arizona.

The proposed power plant site and substation are located between Sycamore Creek and Gray Wash, which are both westerly flowing tributaries to the Big Sandy River. The proposed power plant site is crossed by several southerly and southwesterly flowing ephemeral drainages that are tributaries to Gray Wash (Figure 3.5-2). These drainages flow only at certain times of the year when they receive water from precipitation events or snowmelt from the mountainous areas to the east.

The Big Sandy River basin occupies an area of approximately 2,732 square miles. The average annual precipitation in the Big Sandy River basin is approximately 10 inches per year (Davidson 1973), and the average evaporation rate is approximately 95 inches per year. The Big Sandy River north of Wikieup is generally ephemeral with isolated perennial reaches. South of Wikieup the river is generally perennial with isolated ephemeral reaches (refer to Section 3.4.1.2).

Four stream gaging stations have been operated by USGS along the Big Sandy River, including one along Cottonwood Wash north of Kingman, two along tributaries to the Big Sandy River near Kingman, and one along the Big Sandy River about 14 miles south of Wikieup (station