GLORIETA GEOSCIENCE, INC.

HYDROGEOLOGY OF NATIONS DRAW AREA: ANALYSIS OF POTENTIAL IMPACTS ON ZUNI SALT LAKE FROM PROPOSED FENCE LAKE MINE GROUNDWATER DIVERSIONS

Prepared for:

The Zuni Tribe

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EXECUTIVE SUMMARY

On behalf of the Zuni Tribe, Glorieta Geoscience, Inc. (GGI) has been actively studying the impacts of pumping from the Dakota aquifer at the proposed Salt River Project (SRP) Fence Lake Mine on Zuni Salt Lake since 1996. After completing an extensive review of existing literature pertaining to the area, conducting field work in the Zuni Salt Lake area, and analyzing long-term pumping tests in analogous fractured sandstone aquifers since our 1997 report, GGI has reached the following conclusions:

- The proposed Fence Lake Coal Mine, Zuni Salt Lake, and Nations Draw lie along the Jemez Lineament. GGI's analysis of Cretaceous formation outcrops located northwest of Zuni Salt Lake shows that the Atarque Sandstone and the main body of the Dakota Sandstone are highly fractured with numerous, open fractures. Video logs show that the Dakota Sandstone is fractured in the subsurface at the location of the pumping well (FL-36) (McGurk and Stone, 1986). The Whitewater Arroyo Tongue and Rio Salado Tongue of the Mancos Shale do not exhibit open fracturing. The interbedded Paguate and Twowells Tongues of the Dakota Sandstone are thin, moderately fractured, poorly sorted, sandstone beds within the Mancos Shale. SRP's contention that the Mancos Shale contains open, transmissive fractures is contradicted by GGI's field observations, as well as their own geologic investigations which: (1) identify bentonite aquicludes within the Mancos Shale; and (2) conclude that the Mancos Shale clays and shales were swollen in the OB3 recompletion report.

- The Dakota Sandstone is continuous in the subsurface between the proposed Fence Lake Coal Mine and Zuni Salt Lake (PAP,1993/1994). Pumping effects from the proposed Fence Lake Coal mine or (in the case of Myers [1992]) a hypothetical coal mine in the San Augustine coal fields will propagate to Zuni Salt Lake and affect water levels and water chemistry in the lake, as was concluded by Myers (1992), Page (1993), Core (1996), Drakos and Lazarus (1997b), and BIA (King Engineering, 2001). These studies all contradict and cannot be reconciled with the assertion made by SRP and contained in the CHIA (1994), PAP (1993/1994), and FSEIS (1996) that pumping effects will not extend beyond a radius of 3700 or 3708 feet from FL-36 during the life of the proposed Fence Lake Mine.

- There is no credible evidence to support SRP's contention that the main body Dakota Sandstone aquifer should be evaluated as a "leaky-confined" aquifer using the Hantush method in the Nations Draw area between the Fence Lake Coal Mine and Zuni Salt Lake. GGI's analyses of SRP pumping test data from Dakota Sandstone wells FL-36 and FL-36 (OB1) demonstrate that the Dakota Sandstone responds to pumping as a confined aquifer within the study area. This assessment is supported by analyses of the same data by BIA

(King Engineering, 2001) and the Office of the State Engineer (OSE) (Core, 1996). GGI's analysis of the hydrogeologic setting of this area is consistent with the conclusions of Myers/USGS (1992) Core/OSE (1996), and King/BIA (2001); that is, the Dakota Sandstone aquifer in this area behaves as a confined aquifer and pumping effects are more accurately evaluated using the Theis method.

- GGI's application of a Theis-type model to evaluate pumping effects from SRP's proposed Fence Lake Coal Mine predicts a decline in head in the Dakota Sandstone aquifer at Zuni Salt Lake of between four and five feet after pumping at the mine site at a discharge of 85 gpm for 40 years. This predicted effect is significantly different than the one proposed by SRP. GGI's conclusion cannot be reconciled with SRP's claim that pumping effects will not extend beyond a radius of 3708 feet from the mine's pumping center, resulting in zero drawdown and no depletions at Zuni Salt Lake. GGI contends that SRP's inappropriate selection of the Hantush method is based on: (1) a flawed analysis of the pumping test data, (2) an unsupported conjecture that fractures in the Mancos Shale are open and highly transmissive, (3) a willingness to ignore their own conclusion that bentonite beds in the Mancos Shale are aquicludes (SRP PAP, 1993/1994), and (4) a dismissal of the 1992 USGS study (Myers, 1992) to show that SRP's pumping of the Dakota cannot transmit effects to ZSL. SRP's analysis of the Dakota Sandstone as a leaky aquifer seriously underestimates pumping effects on water levels in the confined Dakota Sandstone and therefore underestimates potential impacts on Zuni Salt Lake.

- Pumping the quantity of water proposed for the mine (85 gallons per minute (gpm), = 137 acre-feet per year for forty years under the proposed pumping schedule) from the Dakota Sandstone aquifer will cause drawdowns in the Dakota aquifer over a large area (Myers, 1992; Core, 1996; Drakos and Lazarus, 1997b; King Engineering, 2001), causing significant impacts on the water levels and the salt balance in Zuni Salt Lake.

- Drawdowns at Zuni Salt Lake may have been substantially underestimated by all investigators using analytical methods that do not account for preferential drawdown in the Dakota Sandstone along the structurally controlled Nations Draw photolinear. Numerical modeling is the best available methodology for properly and completely evaluating all aspects of the hydrologic regime associated with the mine area and Zuni Salt Lake. GGI is prepared to construct a multi-layer, steady-state numerical model to better estimate drawdown at Zuni Salt Lake.

- Based on GGI's simple analytical and numerical models, estimated drawdown at Zuni Salt Lake resulting from pumping 85 gpm for 40 years is between 4 and 5 feet. Since Zuni Salt Lake is usually less than 4 feet deep (Myers, 1992), pumping 85 gpm from the Dakota aquifer for 40 years at the proposed Fence Lake Coal Mine will dramatically affect the water balance, salt formation, and water levels in Zuni Salt Lake. Initial effects could be transmitted to the lake in less than 18 months. These impacts would adversely affect uses of Zuni Salt Lake by the Zuni Tribe and could devastate the lake.

- Based on results of the GGI Theis model, pumping 137 ac-ft per year at the Fence Lake Mine for 40 years will result in significant drawdown effects on Zuni Salt Lake for more than 110 years after pumping ceases at the mine. GGI's modeling also demonstrates that significant delayed and residual effects will occur at Zuni Salt Lake long after SRP ceases its groundwater diversions at the Fence Lake Coal Mine.

- The monitoring wells currently in place in the Dakota aquifer are poorly designed and are insufficient to accurately predict drawdown and prevent harm to Zuni Salt Lake as a result of pumping from the Dakota aquifer at the mine site.

- It is extremely risky to ignore SRP's pumping effects on Zuni Salt Lake and accept MMD/SRP's claim that monitoring wells will 'protect' the lake. Geologic/hydrologic evidence demonstrates overwhelmingly that the SRP/MMD analysis is wrong; the only appropriate course for SRP/MMD now is to recognize that their analysis is incorrect and exclude usage of the Dakota aquifer by SRP.

- The required two-year baseline monitoring data should start after SRP has documented proper recompletion of well FL-36(OB3)

- Until SRP has properly characterized the Dakota Sandstone aquifer system, a water level monitoring program cannot be properly designed. Neither FL-36 (OB2) nor any of the other existing monitoring wells provide any realistic protection for Zuni Salt Lake. The lake could be seriously harmed in a relatively short time, while MMD is debating whether the 'action levels' have been met. It is dangerous and professionally unacceptable to rely on a 'monitoring well field' designed and interpreted by those who refuse to correctly and completely characterize the aquifer they propose to monitor.

- Groundwater diversions by SRP at the Fence Lake Coal Mine will upset the hydrologic balance of Zuni Salt Lake and its associated aquifers. Both the quantity and quality of water in Zuni Salt Lake will be adversely impacted by the proposed groundwater diversions.

- There is no record of SRP's ownership of water rights for mine related uses.

- The Zuni Tribe has been utilizing the waters of Zuni Salt Lake since time immemorial. Any water usage by SRP at the Fence Lake Coal Mine is junior and subordinate to Zuni's uses. The changes in water quality and water quantity that result from SRP's groundwater diversions would constitute impairment of Zuni's senior water right. The monitoring program proposed by SRP and supported by MMD will not protect the senior water rights of Zuni Pueblo.

- **SRP/MMD must conduct a long term (30 day) pumping test at a discharge sufficient to stress the Dakota aquifer (~300 gpm). Prior to conducting the pumping test,**

additional monitoring wells need to be installed at the locations and in the formations specified in this report on pages 57-58, 62-63, and Appendix G. Only by conducting such a test can the Dakota aquifer be adequately characterized to allow accurate predictions of the effects of pumping at the mine site on Zuni Salt Lake.

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INTRODUCTION

Zuni Salt Lake (ZSL) is a saline lake contained in a maar located approximately 20 miles northwest of the town of Quemado in Catron County, New Mexico. The lake has important spiritual and cultural significance for the Zuni people and numerous other native peoples in the region. The Salt River Project (SRP) has proposed the establishment of a surface coal mine approximately eight to ten miles northeast of Zuni Salt Lake (at the western boundary of the mine lease area). During operation of the mine, groundwater will be pumped from one (or all) of the three major aquifers underlying the mine site for which SRP has declared water rights. SRP proposes to use the Dakota Sandstone aquifer (also referred to as the Dakota aquifer) as a primary water source for the mine using well FL-36, located 12.5 miles northeast of the lake.

This report summarizes work conducted by GGI over the past five years for the Pueblo of Zuni and presents GGI's findings and conclusions regarding the hydrologic regime of the Nations Draw area. GGI's work specifically focused on the hydrologic balance between Zuni Salt Lake and underlying aquifers, and addresses the hydrologic consequences of the proposed Fence Lake Coal Mine on Zuni Salt Lake with the objective of protecting the lake's hydrologic balance with respect to both water quantity and quality. This report also evaluates studies prepared by consultants for SRP and a recent United States Bureau of Indian Affairs (BIA) study (King Engineering, 2001).

OVERVIEW OF RECENT WORK

GGI's Involvement with the Zuni Salt Lake – Fence Lake Mine Project

Glorieta Geoscience, Inc. (GGI) was retained by the Pueblo of Zuni to evaluate potential effects of ground water diversions from the Salt River Project's (SRP) proposed Fence Lake Mine on Zuni Salt Lake (ZSL). GGI began the investigation during the first week of October 1996. Mr. Paul Drakos, Senior Geologist at GGI and Mr. Jay Lazarus, Senior Geohydrologist at GGI, performed limited fieldwork during an initial site visit from October 14 to October 15, 1996. On January 23 and 24, 1997, Mr. Drakos and Mr. Lazarus conducted a follow up visit to develop a

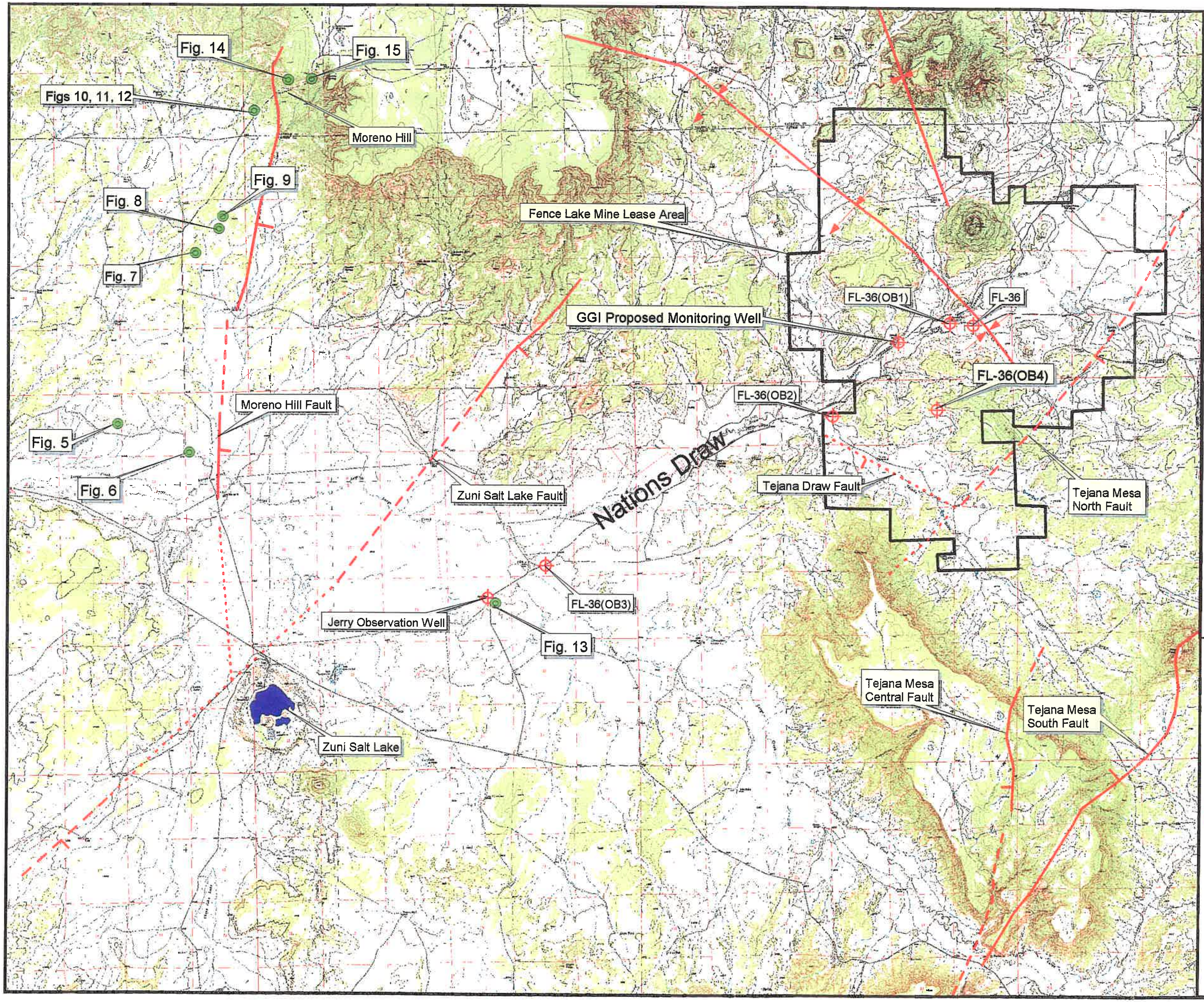

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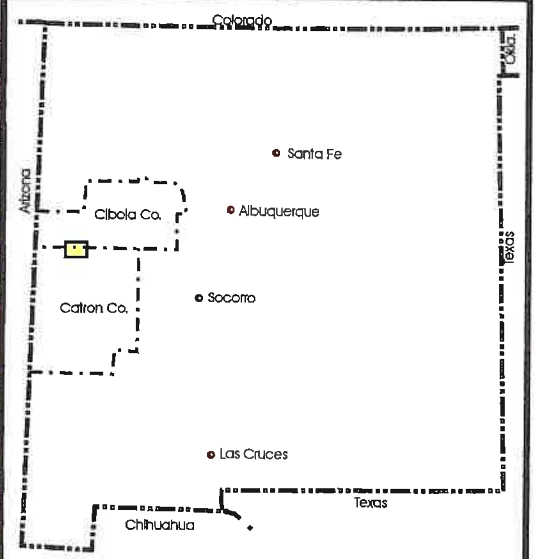
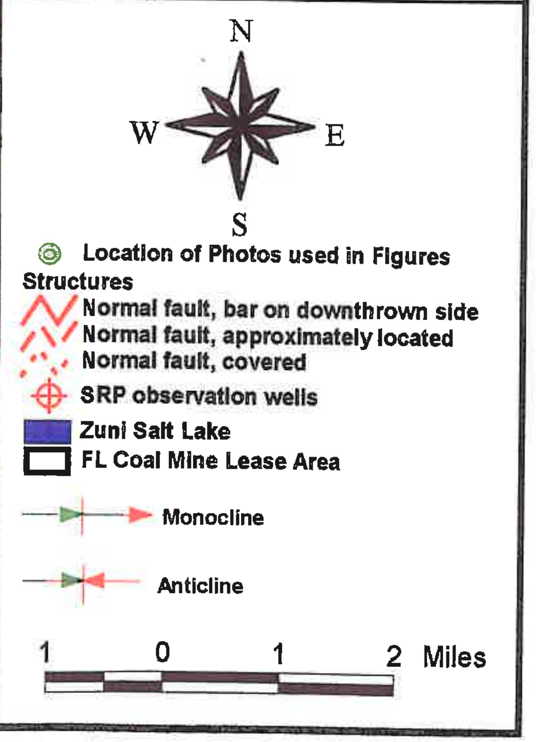
Figure 1. Location of the Zuni Salt Lake - Fence Lake Mine study area, showing wells, photos and structures referred to in text. Base map from USGS 1:24,000 topographic series. Well locations from SRP PAP (1993) and PAP supplement 97-02 (1997). Structures from Campbell (1989), SRP PAP (1993), Anderson (1994), King (2001), Chamberlain et al. (1994) and GGI field work.



Approximate location of study area (shown in yellow)



more detailed field-based hydrogeologic model of the area, to examine stratigraphy, to measure water levels in area wells, and to examine fractures in the sandstone and shale units in the Zuni Salt Lake and Nations Draw area. During the January 1997 fieldwork, GGI observed open fractures in the Dakota Sandstone, Atarque Sandstone, and sandstone units within the Moreno Hill Formation, but noted a lack of open fractures in the Mancos Shale and other shales in the area. Photographs of aquifer analogues are shown in Figures 5-16 (locations of photographs are shown in Figure 1). The significance of these observations is discussed in the hydrogeologic setting and pumping test analysis sections of this report. Additional fieldwork conducted in 2000 yielded significant information about the structural geology of the area (see structural geology section below).

GGI reviewed SRP's hydrology materials submitted to the New Mexico Mining and Minerals Division (MMD) in its November 1, 1993 Permit Application Package (PAP), including: pumping test data, well logs, descriptions of stratigraphy and stratigraphic setting, and proposed pumping effects from wells completed into the main body of the Dakota Sandstone, the Atarque Sandstone, the Moreno Hill Formation, and valley fill alluvium. GGI also analyzed the MMD's December, 1994 Cumulative Hydrologic Impact Assessment (CHIA), that purports to study the hydrologic effects of the water uses proposed by SRP. GGI also carefully reviewed the 1990 Bureau of Land Management (BLM) Supplemental Environmental Impact Statement (SEIS) and the 1996 Office of Surface Mining (OSM) Final Supplemental Environmental Impact Statement (FSEIS), all of which examined the same proposed uses. In addition, GGI analyzed SRP's pumping test data from wells completed into both the Dakota Sandstone and Atarque Sandstone and researched SRP's water rights file at the New Mexico Office of the State Engineer (OSE).

After reviewing available data and field observations, GGI then constructed a one-layer ground water model to calculate drawdown in the Dakota aquifer at Zuni Salt Lake. A summary of the model is presented beginning on page 48 and in Appendix D. GGI has also examined independent studies of the area by the U.S. Geological Survey (Myers, 1992), OSE (Core, 1996), by Stetson Engineering (Page, 1993), and by the Bureau of Indian Affairs (King Engineering, 2001). Finally, GGI has reviewed the comments of the Office of Surface Mining (2001) and Duke Engineering & Services (2001a) on the 2001 BIA report.

BIA Report on the Hydrology of Zuni Salt Lake-Fence Lake Mine

In 1999(?) King Engineering was retained by the BIA to conduct an independent review and evaluation of existing geologic/hydrogeologic studies of the effects of SRP's proposed Dakota aquifer diversions, to conduct additional original research, and to make recommendations about future courses of action. The report prepared by King Engineering (hereafter referred to as the "BIA Report") concluded that pumping from the Dakota aquifer at the Fence Lake Mine would have deleterious effects on Zuni Salt Lake. The conclusions of this report are as follows (see p. 72 and 73 of the BIA Report):

1. "The Dakota Sandstone certainly contributes flow and minerals to Zuni Salt Lake and the Cinder Cone Lake. Interrupting the flow of Dakota Sandstone water into the lakes will definitely alter the hydrology and salt dynamics of the site."

2. "None of the data suggests that the mine site and Zuni Salt Lake are not hydrologically connected through the Dakota Sandstone. No structural features have been identified that would suggest that they are isolated hydrologic units, and standard geologic practice is to assume continuity of a formation unless evidence to the contrary exists."

3. "Pumping in the quantities proposed in the PAP, FSEIS, and CHIA will produce significant drawdown in the Dakota Sandstone aquifer at Zuni Salt Lake. The drawdown predicted by the Hantush method is low because the aquifer appears to behave as a confined rather than leaky confined aquifer, and the assumptions and boundary conditions necessary for the correct application of the method are absent from this site. The drawdown predicted by the Theis method is also lower than would actually occur, because of the invalidity of the assumptions regarding boundary conditions and aquifer hydraulic properties."

4. "The proposed monitoring plan and pump test would be of little help in protecting Zuni Salt Lake from adverse effects of pumping at the mine site. The location and construction of the monitoring wells severely compromises confidence in the data. The most problematic wells are the ones closest to Zuni Salt Lake. Analysis of the data confirms that OB3 has caved, and is not in communication with the main body of the Dakota Sandstone. Data from OBJerry is dominated by the operation of an active stock well a few tens of

> feet away, producing large daily swings that would mask longer term trends in the aquifer head produced by pumping at the mine site. Irregularities in the maintenance and operation of the data acquisition equipment evident in the data produce serious concerns about the quality of the data and the use of that data for establishing baseline parameters for setting action levels."

These conclusions are consistent with those offered by GGI in 1997, with one exception. The BIA report concludes that the Dakota Sandstone rather than the Yeso Formation is the principal source of the salt that precipitates in ZSL and provides geochemical data to support this. The BIA conclusion on the origin of the salt is important, because it means that SRP pumping from the Dakota aquifer will directly impair salt chemistry as well as the amount of water reaching ZSL. The BIA report also demonstrates that, with the high pan evaporation rates and low precipitation at Zuni Salt Lake, the ground water supplying water to the lake does not have to be particularly saline to begin with. GGI is generally in agreement with the BIA report and its principal author, Dr. King.

Duke Engineering & and Services Critique of the BIA Report

Following the release of the BIA report in February 2001, a report was released by Duke Engineering & Services (DE&S), a Duke Energy Company apparently retained by SRP and/or their attorneys, that reviewed the BIA Report and commented on the conclusions reached by King Engineering. The author of the DE&S report is not identified. DE&S's report reflects no original field work or visits to the mine site or ZSL. The primary purpose of the DE&S report appears to be to discredit the BIA report and to cause as much confusion as possible regarding hydrologic issues associated with pumping from the Dakota aquifer at the proposed Fence Lake Mine (FLM). They also contradict hydrologic conclusions reached by Myers/USGS (1992), although DE&S selectively (and erroneously) cites Myers to support their contradictory conclusions. The main (and erroneous) conclusions of the DE&S report are as follows:

1. The Dakota aquifer is a leaky-confined aquifer rather than a confined aquifer
2. Zones of recharge for the Dakota aquifer are located near the mine site and will prevent significant drawdown in the Dakota.
3. There is no geologic evidence that structures in the Nations Draw area influence groundwater flow.

4. The monitoring well system and proposed well monitoring plan are sufficient to prevent harm to Zuni Salt Lake in the event that drawdown in the Dakota does occur
5. The Dakota aquifer is not the source of salinity in Zuni Salt Lake

GGI strongly disagrees with DE&S's conclusions.

DE&S critique of Drakos and Lazarus (1997b)

GGI received a copy of a DE&S report critiquing Drakos and Lazarus (1997b) on May 24, 2001. Due to the deadline of May 30th for submittals, GGI will not present detailed comments on this latest DE&S report at this time. However, GGI will be responding in detail to the DE&S report at a later date. Initial comments on the report include:

1. Once again, no authorship or statement of the identity of DE&S's client is provided.
2. DE&S recycles many of the same misrepresentations of earlier work and inaccurate and misleading statements used in their critique of the BIA report (many of which are addressed in the body of this report and in Appendix A). In particular, DE&S grossly misrepresents the work of Myers (1992), and makes the claim that when Myers (1992) stated that the Dakota is a confined aquifer, he really meant that it is a leaky-confined aquifer.
3. DE&S apparently makes the argument that site specific data (pumping tests and outcrop analogues) should be ignored in characterizing the aquifer in the vicinity of Fence Lake Mine and Zuni Salt Lake. Instead, they imply that regional modeling studies of the San Juan Basin are more appropriate. The site specific data were the basis for approval of the mining permit and are clearly more appropriate for considering localized effects of pumping at the mine site on Zuni Salt Lake.

GGI strongly disagrees with DE&S's conclusions.

Office of Surface Mining (OSM) Critique of BIA Report

Following the release of the BIA report in February 2001, OSM reviewed the report and reached the following conclusions:

1. Whether or not the Dakota Sandstone aquifer is providing water/salts to Zuni Salt Lake is unimportant, because the monitoring program will prevent drawdown in the Dakota before Zuni Salt Lake can be harmed.
2. Actual drawdown rates in the Dakota aquifer may exceed those predicted by either the Theis or Hantush model due to structural controls on groundwater flow in the

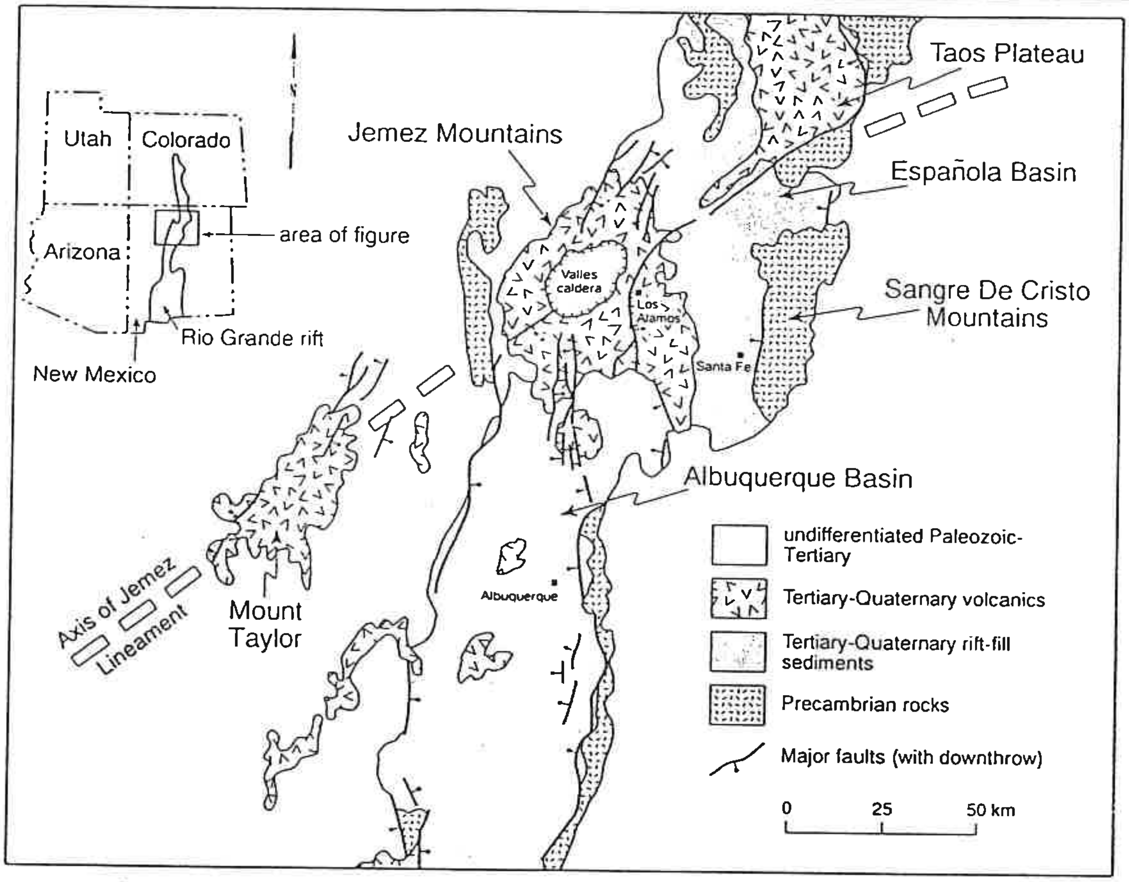
area. However, it does not matter, because the monitoring program will prevent drawdown in the Dakota aquifer before Zuni Salt Lake can be harmed.

3. Despite several problems (such as FL-36(OB3) being improperly completed and not accurately monitoring the Dakota aquifer, shifts in monitoring well data due to poor maintenance/calibration, and lack of geophysical logs penetrating the full thickness of the Dakota Sandstone in two of the monitoring wells), the monitoring program is well designed and will prevent harm to Zuni Salt Lake. OSM does point out that MMD has required that FL-36(OB3) be repaired. OSM cites the proposed pumping test (which will be used to, "1) determine the effectiveness of the Dakota aquifer Monitoring Program, 2) make any modifications to the monitoring plan that are necessary as a result of the test, and 3) assure that the cut-off action levels are appropriate to adequately protect Zuni Salt Lake from any adverse effects") to support its position that the monitoring network will be sufficient protection for Zuni Salt Lake if the SRP/OSM/MMD hydrologic assessment of the area is incorrect.

While the OSM report acknowledges some important issues (collapse of FL-36(OB3), structural controls on groundwater flow, probability of greater than predicted drawdowns in the Dakota aquifer) that will be addressed later in this report, GGI strongly disagrees with the majority of their conclusions. In particular, GGI concludes that the monitoring well network will not protect Zuni Salt Lake and OSM should not rely on this "fallback position" to support their conclusions. The pumping test (outlined in modification 97-02 to the PAP) referred to in the OSM memo likely will not provide sufficient aquifer data to allow the monitoring well network to be reconfigured in such a way as to prevent harm to Zuni Salt Lake and in no way reflects the configuration of the pumping test requested by GGI in 1997 (see pumping test sections below). OSM disregards the numerous SRP/MMD errors that BIA points out; OSM was the lead agency producing the 4/96 FSEIS that fully endorsed the SRP/MMD hydrology analysis. An admission by OSM now that they were incorrect would concede that the OSM NEPA compliance was indeed flawed and erroneous on the critical hydrology issues.

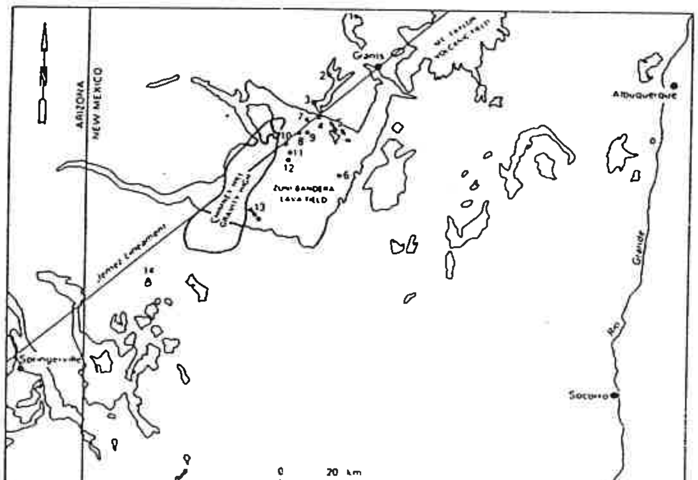
HYDROGEOLOGIC SETTING

Zuni Salt Lake, Nations Draw, Largo Wash, and the Fence Lake Coal Mine lease area (the study area; Figure 1) are underlain by rocks that range in age from Precambrian to Quaternary. Zuni



Location map showing relationship of the Jemez Mountains volcanic field to basins of the north-central Rio Grande rift. Valles caldera denotes Valles/Toledo caldera complex. Major fault zones of the region are shown; ball symbol on downthrown side.

Source: Self,et al.,Field excursions to the Jemez Mountains, New Mexico New Mexico Bureau of Mines and Mineral Resources, Bulletin 134, 1996



Index map of volcanic rocks of west-central New Mexico. Significant vents are identified by number: (1) El Tintero, (2) Cerro Colorado, (3) Paxton Springs, (4) Bandera Crater, (5) El Calderon, (6) McCartys, (7) Cerrito Arizona, (8) Cerro Negro, (9) Cerro Hueco, (10) Cerro Piedrita, (11) Cerro Lobo, (12) Cerro Chato, (13) Cerros de las Mujeres, and (14) Zuni Salt Lake.

Source: Laughlin, et al. Tectonic Setting and History of Late-Cenozoic Volcanism in West-Central New Mexico. New Mexico Geological Society, Albuquerque Contry, 1982.

Maps showing the location of the Jemez lineament and associated volcanic fields in New Mexico		Figure # 2	
Project: Zuni Salt Lake	Site: Zuni Salt Lake	Drawn: CMT	Date: 02/27/97
		Approved: PD	File: Figure 2

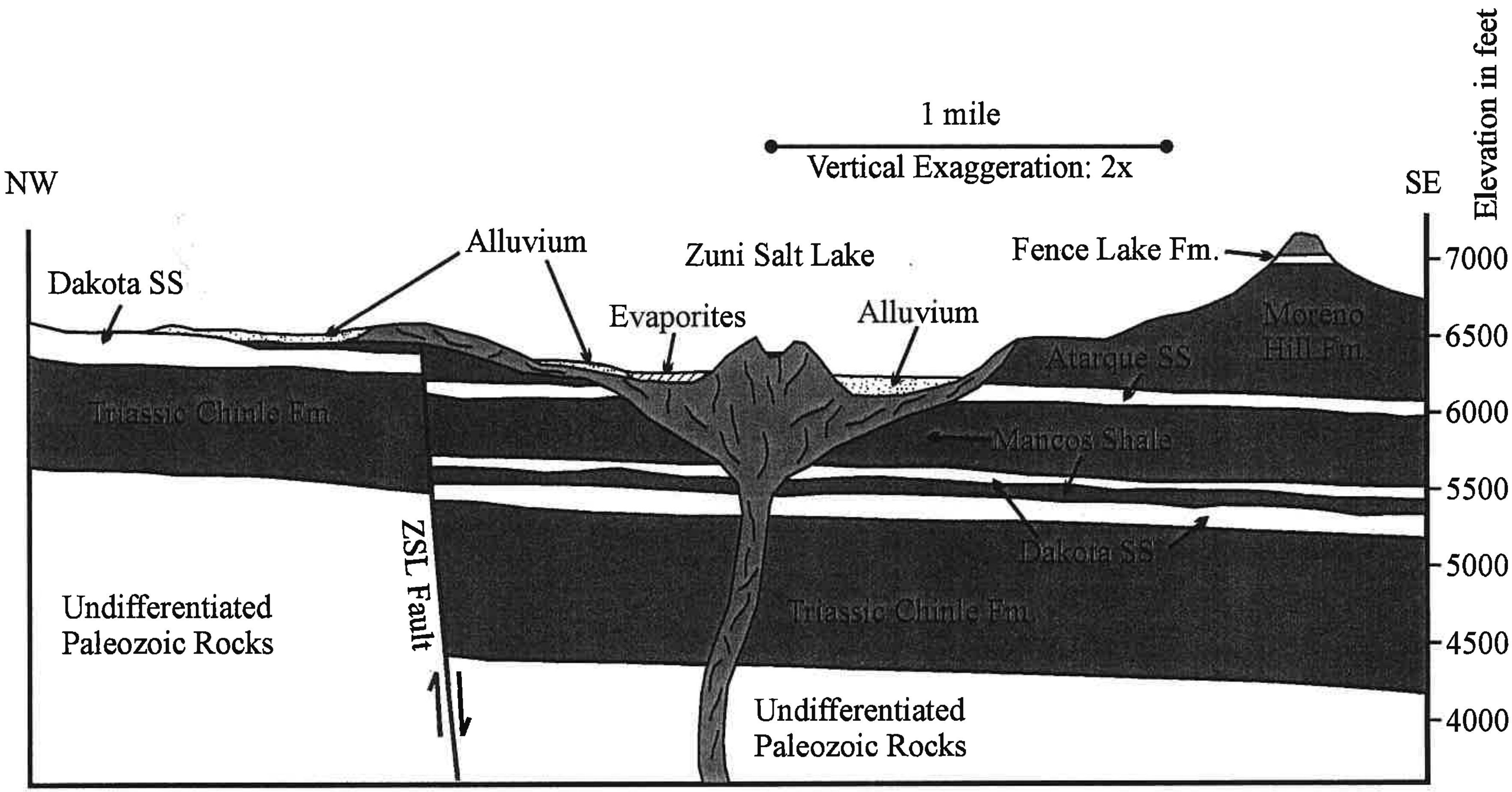
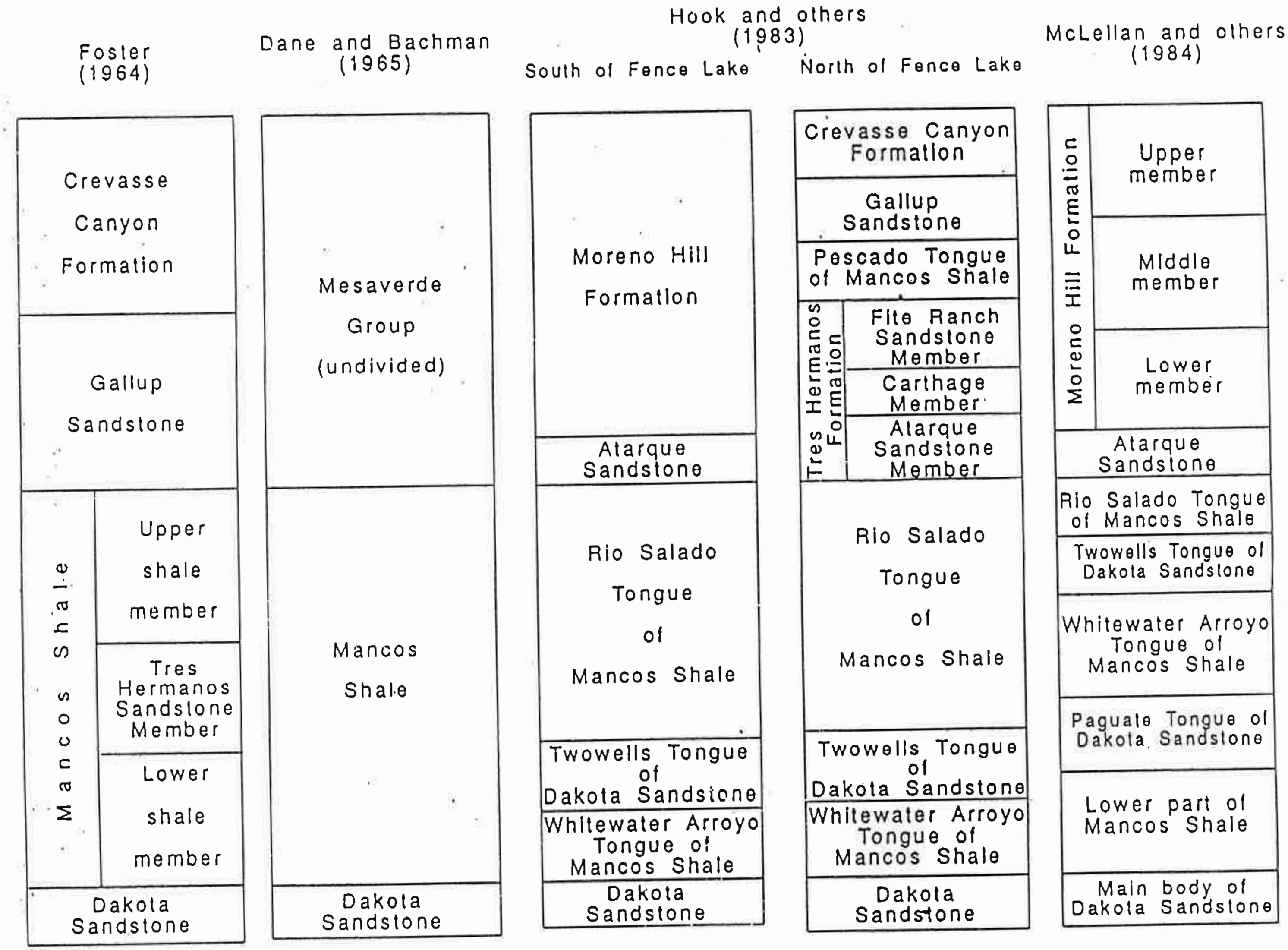


Figure 3. Schematic hydrogeologic cross section of Zuni Salt Lake Area. Modified from Anderson (1994)

Salt Lake and Nations Draw lie along the Jemez Lineament, a southwest to northeast trending zone of structural weakness expressed by a series of volcanic centers extending from the Springerville volcanic field in Arizona to the Taos Plateau volcanic field in New Mexico and Colorado, and including the Jemez Mountains, the Mt. Taylor/Zuni-Bandera Volcanic field, and Zuni Salt Lake (Figures 2 and 3). The Jemez Lineament is also defined by a series of northeast-trending faults (Laughlin et al., 1982).

The oldest rocks underlying the study area include undifferentiated Precambrian rocks, which are overlain by a Permian section that includes the Abo Formation, the Yeso Formation, the Glorieta Sandstone, and the San Andres Limestone (Figures 3,4). These formations are not exposed within the study area but have been identified in deep exploratory drill holes in the region. Although Permian formations are not utilized for ground water production within the study area, it is likely that Permian formations contribute water to Zuni Salt Lake by upward flow through the vent from which Zuni Salt Lake Maar erupted. Eruption of the maar created a fracture zone of limited areal extent underlying Zuni Salt Lake, thereby facilitating upward movement of water from aquifers with artesian heads (Bradbury, 1971; Myers, 1992; SRP Permit Application Package (PAP), 1994). According to Bradbury (1971) and the PAP (1993/1994), the saline water feeding Zuni Salt Lake is likely derived in part from dissolution of evaporite beds within the Yeso Formation. However, the BIA report (King Engineering, 2001) proposes that "The preponderance of evidence indicates that the source of salinity in the lake is evaporation of low salinity Dakota and Atarque aquifer waters, alluvial aquifer waters, and surface runoff."

The Triassic Chinle Formation overlies the Permian section and is exposed in outcrop approximately 4.5 miles northwest of Zuni Salt Lake. The Chinle Formation at this location is reddish-brown to maroon, non-fractured mudstone (Figure 5). The Chinle Formation is generally treated as a confining bed or aquitard, although small quantities of water are produced from thin lenses of poorly sorted sandstone in some areas (Myers, 1992).



Nomenclature for Cretaceous Rocks in Nations Draw Area		Figure # 4	
Project: Zuni Salt Lake	Site: Zuni Salt Lake	Drawn: CMT	Date: 02/28/97
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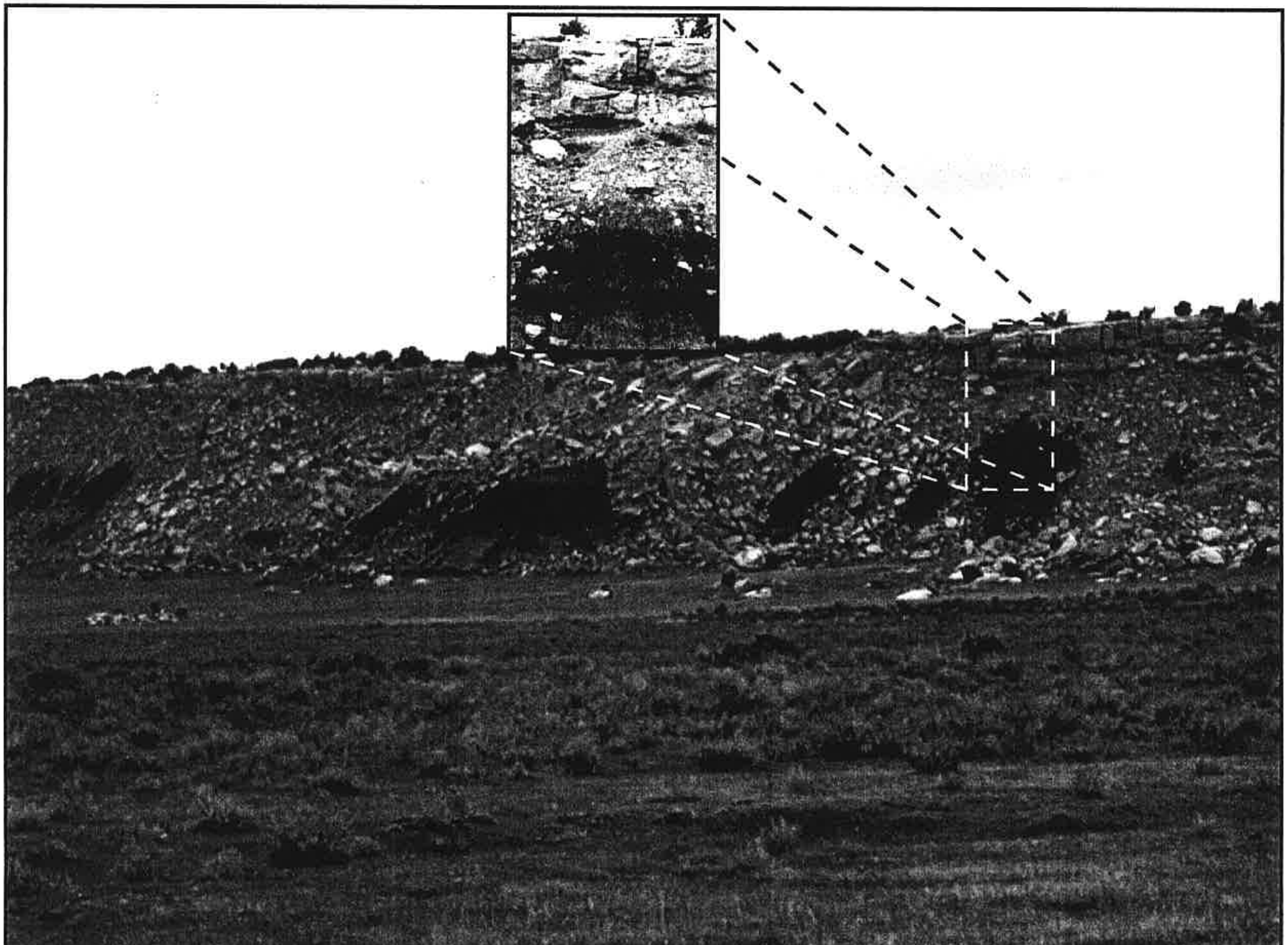


Figure 5. Dakota Sandstone overlying mudstone of the Chinle Formation. Inset shows fractured nature of the Dakota and the lack of fractures propagating into the Chinle.

Most of the formations exposed in the study area are of Cretaceous age and include at least two important regional aquifers, the Dakota Sandstone and the Atarque Sandstone. From oldest to youngest , the Cretaceous formations include: the Main Body of the Dakota Sandstone, the lower part of the Mancos Shale, the Paguate Tongue of the Dakota Sandstone, the Whitewater Arroyo Tongue of the Mancos Shale, the Twowells Tongue of the Dakota Sandstone, the Rio Salado Tongue of the Mancos Shale, the Atarque Sandstone, and the Moreno Hill Formation (Figures 3, 4). These formations are described in the following paragraphs.

The main body of the Dakota Sandstone unconformably overlies the Chinle Formation throughout the study area (Figure 5). According to Myers (1992), the main body of the Dakota Sandstone ranges in thickness from 20 to 105 feet. GGI observed a 40-foot thick cross-bedded, fractured sandstone in outcrop approximately 4½ miles northwest of Zuni Salt Lake (Figure 6), with an additional 5 to 10 feet of dark gray shale beds at the base of the sandstone. According to Campbell (1989), the main body of the Dakota Sandstone is a 65 to 85-ft. sequence of marine and non-marine sediments, with a 15 to 25-ft. thick cross-bedded, resistant sandstone at the base of the formation. The main body of the Dakota Sandstone is a productive aquifer in many localities, with secondary porosity in the form of open fractures contributing significantly to production (Myers, 1992). McGurk and Stone (1986) report that a video log of the base of well FL-36 (the proposed pumping well for the mine) showed the Dakota Sandstone to be fractured, with conglomerate present at the base of the unit. The main body Dakota Sandstone outcrops observed by GGI are highly fractured, with numerous open, vertical fractures (Figures 5 and 6).

The lower part of the Mancos Shale "is a 55-75 ft. thick, dark-gray or dusky-yellow marine shale with interbedded claystones and siltstones" (Campbell, 1989) and overlies the main body of the Dakota Sandstone. The lower part of the Mancos Shale is a slope-forming unit that is poorly exposed in the study area (Figure 7). Bentonite beds may be present within the lower part of the Mancos Shale (Campbell, 1989). The predominance of marine shale and the presence of bentonite beds support treating the lower part of the Mancos Shale as a confining bed (McGurk and Stone, 1986; PAP, 1993/1994).

Figure 6. Fractured main body Dakota Sandstone above talus slope of Dakota Sandstone covering Chinle Formation.

Figure 7. Paguate Tongue of Dakota Sandstone boulder remnant and Fence Lake Formation gravel overlying the lower Mancos Shale

The Paguate Tongue of the Dakota Sandstone is a fine-grained, poorly-sorted, poorly-cemented sandstone (Campbell, 1989), which overlies the lower part of the Mancos Shale. The Paguate Tongue is poorly exposed in the vicinity of the study area and was observed in outcrop by GGI approximately 6 miles north-northwest of Zuni Salt Lake as boulder remnants underlying a gravel lag of the Fence Lake Formation (Figure 7). Although SRP well logs generally show a Paguate Tongue thickness of 40 feet, and Campbell indicates a thickness of 20 to 55 feet, the Paguate Tongue observed in outcrop was less than 10 feet thick. The Paguate Tongue sandstone produces water at windmills in some locations, but does not appear to be an important regional aquifer.

The Whitewater Arroyo Tongue of the Mancos Shale is an olive-gray to dark gray shale that overlies the Paguate Tongue of the Dakota Sandstone. The Whitewater Arroyo Tongue is 65 to 85 feet thick and includes a one-foot thick bentonite layer (Campbell, 1989). The Whitewater Arroyo Tongue was observed in outcrop in steep, gullied hill slopes underlying the Twowells Tongue of the Dakota Sandstone (Figure 8). In outcrop, the Whitewater Arroyo Tongue shale did not exhibit open fractures. Small fractures present near the top of the Whitewater Arroyo Tongue were filled with gypsum. The lack of open fracturing within the shale, the presence of gypsum-filled fractures, and the presence of an extensive one-foot thick bentonite bed indicates that the Whitewater Arroyo Tongue of the Mancos Shale should be treated as a confining bed. The bentonite bed is present in SRP's borehole geophysical logs and GGI identified this bed (or an equivalent) in the field during a 1997 GGI-led field trip for Zuni, OSM, BLM and other Federal agencies and interested tribes. According to SRP, the bentonite may act as an aquiclude, preventing leakage from the overlying Twowells Tongue (McGurk and Stone, 1986; PAP, 1993/1994 p. 12-11), supporting GGI's conclusion that the Mancos Shale is properly treated as a confining layer.

The Twowells Tongue of the Dakota Sandstone overlies the Whitewater Arroyo Tongue of the Mancos Shale and is a fine- to medium-grained sandstone sequence with a thickness of 27 to 39 ft (Campbell, 1989). In outcrop northwest of Zuni Salt Lake, GGI observed the flat-bedded, fine

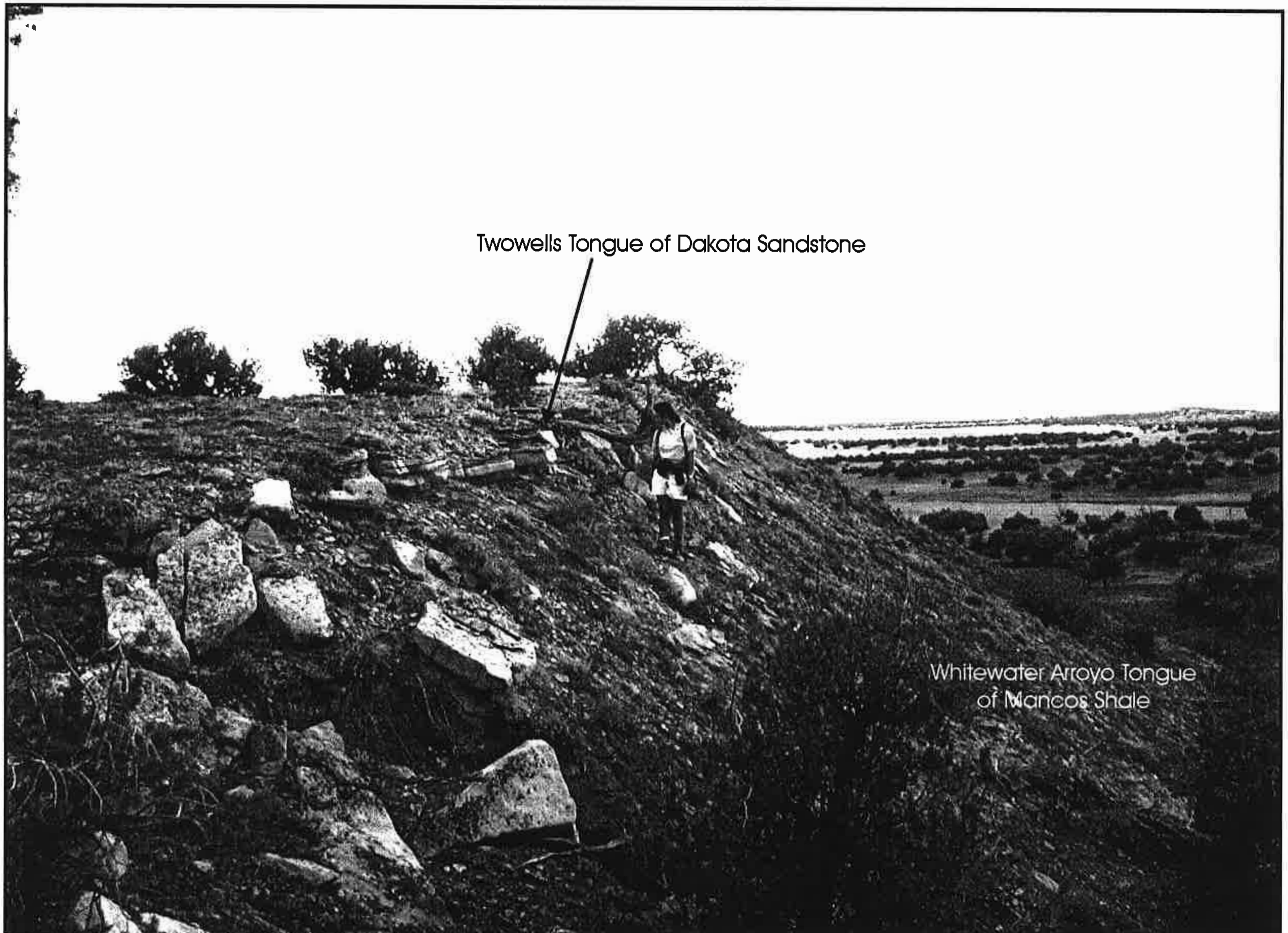


Figure 8. Twowells Tongue of Dakota Sandstone; approximately 3 to 6 feet thick where exposed in outcrop between Zuni Salt Lake and Moreno Hill.

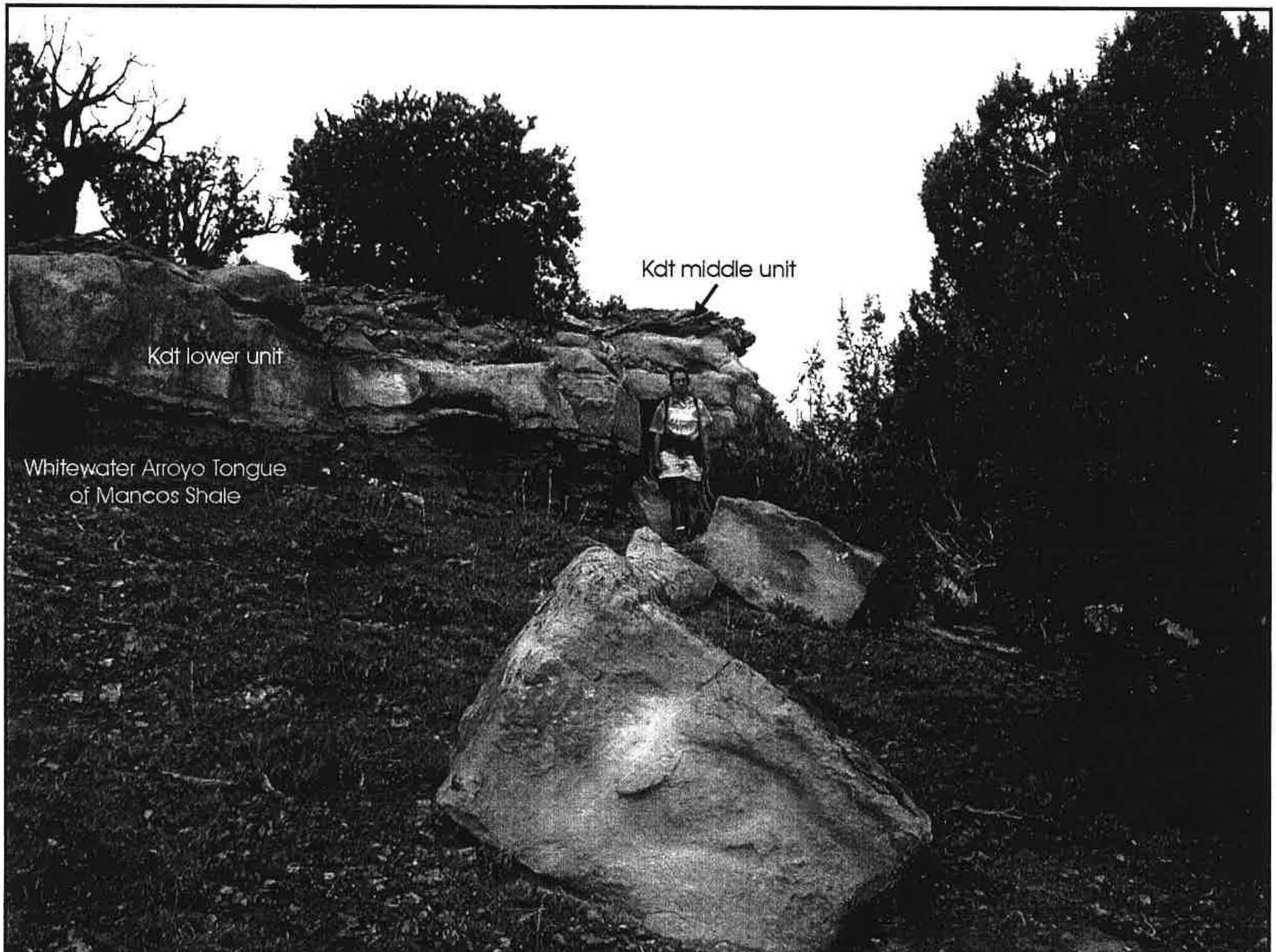


Figure 9. Twowells Tongue of Dakota Sandstone overlying the Whitewater Arroyo Tongue of Mancos Shale

to medium-grained lower unit and the extensively bioturbated middle unit of the Twowells Tongue (Figure 9). The thickness of the Twowells Tongue observed by GGI ranged from 4 to 6 ft. Although thicker sections may produce small amounts of water, the Twowells Tongue section observed in outcrop in the area between Zuni Salt Lake and Moreno Hill does not appear to be an important regional aquifer.

The Rio Salado Tongue of the Mancos Shale, which overlies the Twowells Tongue of the Dakota Sandstone, was observed in outcrop by GGI at the base of Moreno Hill, an escarpment located approximately 8-9 miles north of Zuni Salt Lake (Figures 1 and 10), where it is a gray, olive-gray, to dark gray shale. The Rio Salado Tongue is 130 to 300 ft thick and contains thin beds of fossiliferous limestone concretions and calcarenite (Campbell, 1989). The top of the Rio Salado Tongue grades into the Atarque Sandstone over a 10- to 12-ft thick transition zone consisting of interbedded thin sandstone and shale beds (Figures 11 and 12). Fractures present in the overlying Atarque Sandstone die out (decrease in aperture) in the transition zone; approximately 10% of the fractures propagate into the upper part of the Rio Salado Tongue, where they are present as closed fractures (Figure 12). Based on the thickness of this unit and the observed lack of fracturing, the Rio Salado Tongue is interpreted as a confining bed or aquitard within the study area.

The Atarque Sandstone is a regressive beach sand, that is approximately 45 feet thick at the base of Moreno Hill escarpment (Roybal et al., 1987; confirmed by GGI field observations). The Atarque Sandstone observed in outcrop is a fine- to medium-grained, yellow, quartz sandstone that is well-fractured with open, vertical fractures (Figure 12). A fossil rich marker bed (coquina) was identified near the top of the Atarque during the course of GGI field work (Figure 13). The coquina, which is present in the Atarque throughout the study area, serves as a valuable aid to mapping the extent of the formation and the presence of geologic structures. The Atarque Sandstone is considered part of the Mesaverde Group aquifer by Myers (1992), which he describes as a semiconfined to confined aquifer in the vicinity of the site. The Atarque

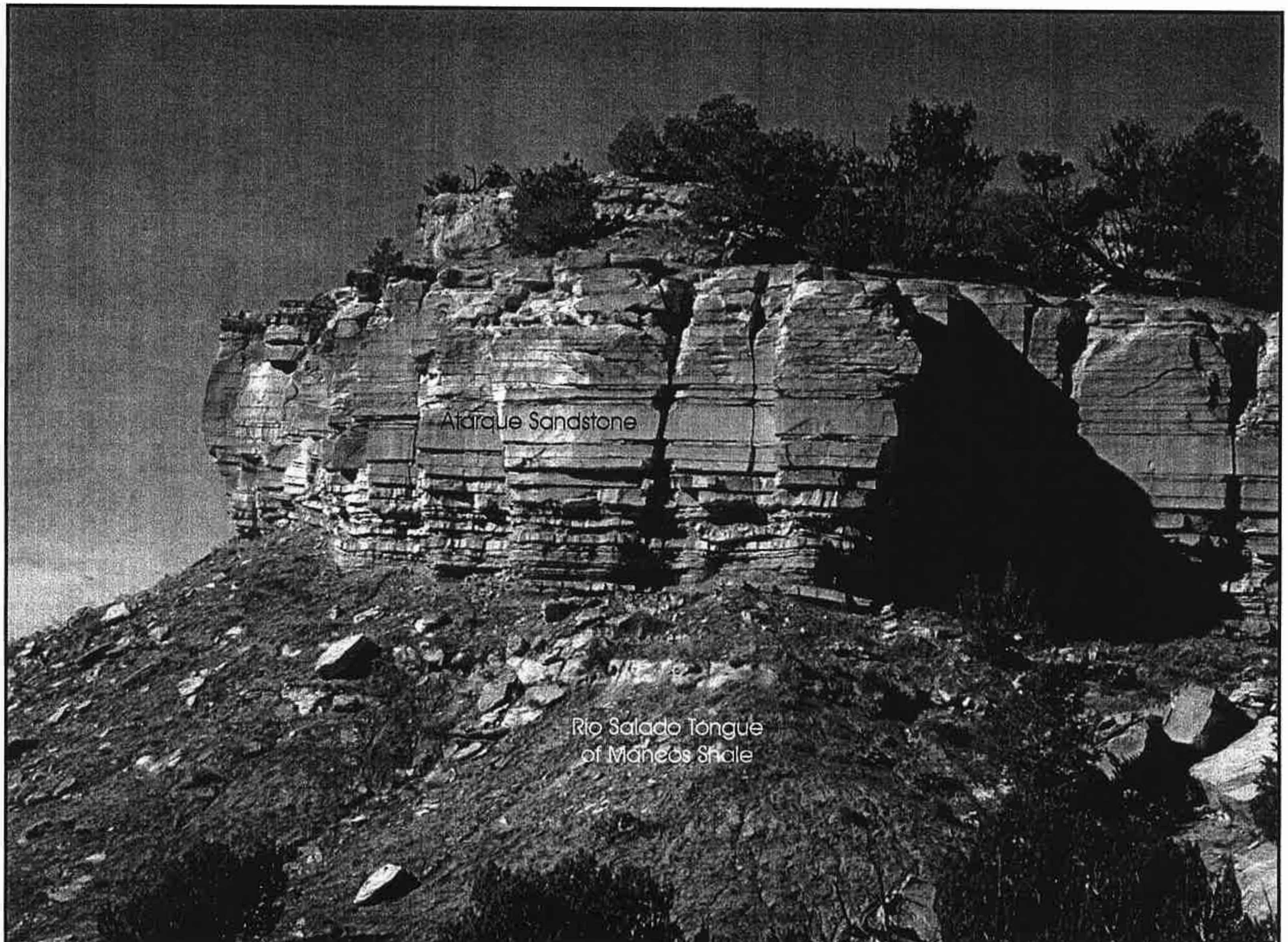


Figure 10. Atarque Sandstone overlying Rio Salado Tongue of the Mancos Shale. Note open fractures in Atarque Sandstone and closed fractures or absence of fractures in Rio Salado Tongue of the Mancos Shale

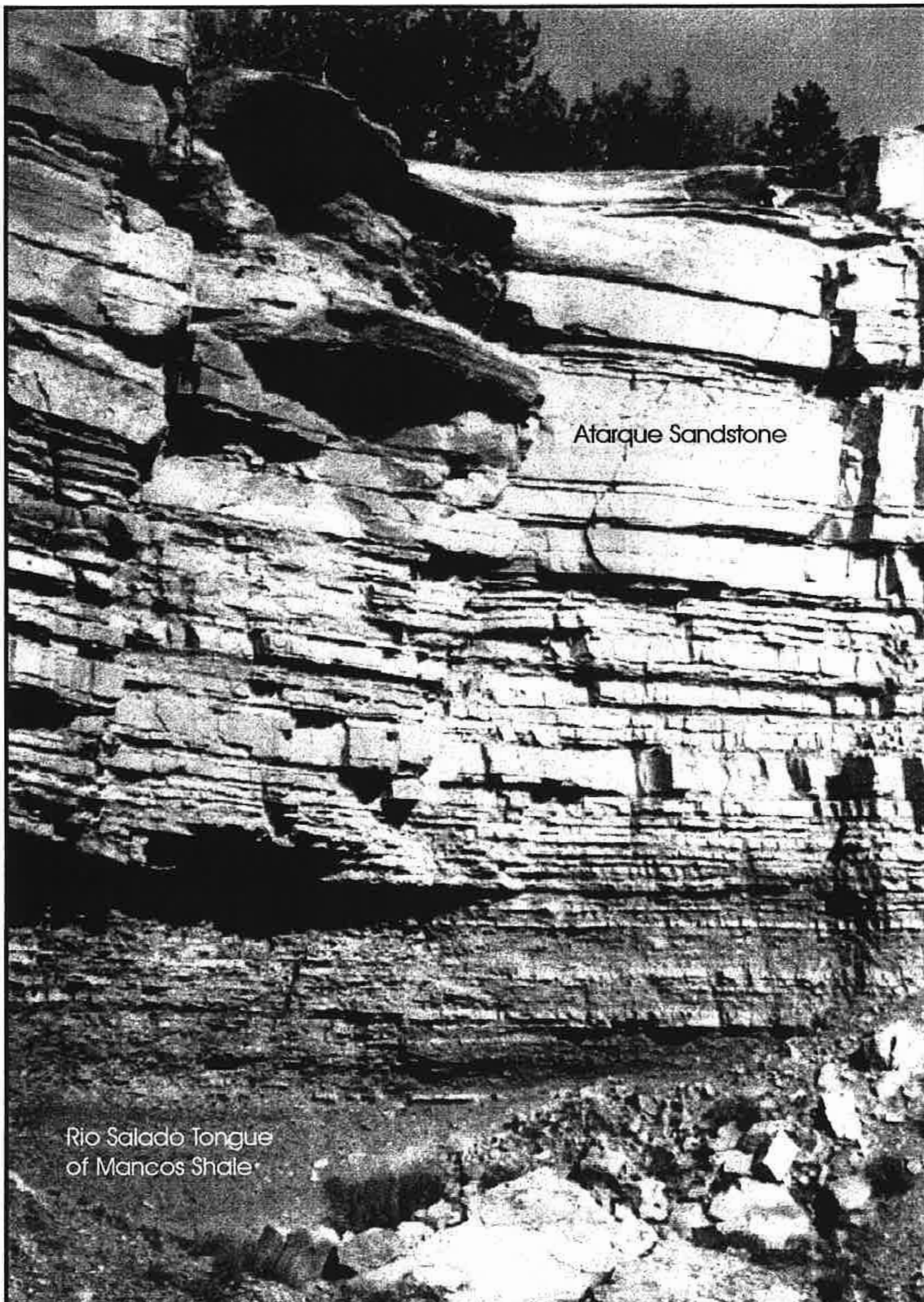


Figure 11. Atarque Sandstone overlying the Rio Salado Tongue of Mancos Shale
Note the absence of fractures in the Mancos.

Figure 12. Fractured Atarque Sandstone, with fractures dying out (decreasing in aperature) across the 10-12 foot thick transition zone overlying the Rio Salado Tongue of Mancos Shale.

Figure 13. Boulder of the distinctive coquina marker bed from near the top of the Atarque Sandstone.

Sandstone is likely a productive aquifer, with secondary porosity in the form of open fractures contributing significantly to production.

The Atarque Sandstone is overlain by the Moreno Hill Formation, which is subdivided into Lower, Middle, and Upper Members. The Lower Member contains the coal seams that SRP proposes to mine. The Lower and Middle Members of the Moreno Hill Formation are an interbedded sandstone, siltstone, shale and coal sequence exposed at Moreno Hill (Figure 14) and, along with the Upper Member, are exposed throughout the study area. The abundance of petrified wood found at the base of the Lower Member (Figure 15) marks the contact between the Moreno Hill Formation and the underlying Atarque Sandstone. Hydrologic characteristics of the Moreno Hill Formation are highly variable depending on lithology and structure (Brown, Consulting Report to SRP). The Moreno Hill Formation underlying Fence Lake Coal Mine does not appear to be in direct hydrologic communication with Zuni Salt Lake.

The Moreno Hill Formation is overlain by the Tertiary Baca Formation. The Baca Formation consists of red, yellow, and gray sandstone, arkosic sandstone, and shale with lenses of conglomerate (Myers, 1992). The Baca Formation is hydrologically disconnected from Zuni Salt Lake. Therefore, Baca Formation hydrology will not be discussed further in this report. In some areas the Moreno Hill Formation is overlain unconformably by the Tertiary Fence Lake Formation (Figure 16). The Fence Lake Formation outcrop observed by GGI was a basalt boulder conglomerate with a calcic cement matrix. The Fence Lake Formation may contain lenses of perched water but likely contains little or no water in the study area (Myers, 1992) and the formation is hydrologically disconnected from Zuni Salt Lake. Therefore, Fence Lake Formation hydrology will not be discussed further in this report.

Several prominent volcanic flows and features are located within the study area including the Oligocene-age Techado Mountain Basalt, the Miocene-age Veteado Mountain Basalt, the Pliocene- or Miocene-age Tejana Mesa Basalt, the 12.6 ± 0.8 million year old (Miocene-age) Cerro Prieto basaltic andesite neck and Zuni Salt Lake Maar (Anderson, 1994, Baldridge et al.,

Figure 14. Interbedded sandstone and shale in the Lower Member of the Moreno Hill Formation.

Figure 15. Petrified logs in the base of the Lower Member Moreno Hill Formation, overlying the Atarque Sandstone.

Figure 16. Middle Member of Moreno Hill Formation overlain unconformably by the Fence Lake Formation

1989; Campbell, 1989; Coal Mine Reclamation Bureau, 1994). Zuni Salt Lake Maar was formed by volcanic and phreatic explosions in the late Pleistocene (Bradbury, 1971; Myers, 1992).

Quaternary alluvium consisting of clay, silt, sand, and gravel is present in valley bottoms and along drainages throughout the study area. Major drainages in the study area, including Frenches Draw and Nations Draw, are underlain by at least 67 feet of alluvium (Love and Hawley, 1984). According to Brown (SRP Consulting Report) the maximum thickness of alluvium within the Fence Lake Coal Mine area is greater than 190 feet. Numerous wells are completed into the Quaternary alluvium within the study area (Myers, 1992), although with the Cretaceous bedrock formations forming the boundaries of the drainages, alluvial aquifers likely pinch out at the margins of Nations Draw, and are limited in areal extent. Water levels in alluvial aquifers are influenced by seasonal precipitation and recharge.

HYDROLOGIC/CHEMICAL BALANCE OF ZUNI SALT LAKE

According to Bradbury (1971), Myers (1992), and SRP's 1994 PAP, Zuni Salt Lake has between five and seven major sources of water. According to the PAP, the following are the major sources of water for Zuni Salt Lake: (1) direct precipitation - fresh water; (2) direct runoff from the interior of the crater - probably fresh water; (3) ephemeral stream flows from the south as induced only by major precipitation events in the watershed containing Cheap John Lake - probably fresh water; (4) flow from Smith Spring - fresh water; (5) flow from the eastern shore seeps - fresh to brackish water; (6) seeps at the toe of the western cinder cone which contains the Cinder Cone Pool - brine water; and (7) water coming directly up the vent to feed the Cinder Cone Pool and seeps which feed directly into the floor of the Zuni Salt Lake - brine water.

Of particular interest to Zuni Pueblo and GGI is the groundwater that comes directly up the vent to feed Zuni Salt Lake. In the unanimous opinion of the USGS (Myers, 1992), the State Engineer (Core, 1996), the BIA (King Engineering, 2001), and GGI, this is the water source that would be most directly affected by SRP's planned pumping of the main body Dakota Sandstone aquifer. The vent that was the source of the eruption of Zuni Salt Lake Maar penetrates every aquifer in the stratigraphic column and is likely manifested as a vertical fracture zone.

According to SRP:

> "the resulting vent serves as a conduit for fluids to move within it, thereby providing the opportunity for water from every aquifer intercepted by the vent to be present in the vent. The Atarque Sandstone and Mesaverde Formation are the stratigraphically highest formations intercepted by the vent. The blend of waters from aquifers below the Mesaverde formation eventually manifests on the surface, either through discharges into the floor of the Cinder Cone Pool or through discharges into the floor of the maar." (PAP 1993/1994 p. 12-38)

Additionally:

> "All aquifers below the Atarque Sandstone at the location of the Zuni Salt Lake could potentially be under artesian conditions. If all the aquifers that intersect the vertical vent at depth are confined, then all aquifers should drive the growing column of water upwards as the water seeks the lowest pressure in the system, which would probably be at the ground surface. However, if the head in any aquifer were less than the head at the point of intersection with the vent, then water could be forced from the rising column in the vent outward into the surrounding formation. Thus, as in an uncased well, the static water level (or lake level), which results when several aquifers are intersected, represents an average head of all the aquifers intersected by the vent." (PAP 1993 [original] p. 12-35).

This paragraph was later deleted by SRP in the May, 1994 PAP; SRP could not explain at the 1996 MMD hearing why it was deleted or by whom.

According to Bradbury (1971) and the PAP (1993/1994), the saline water feeding Zuni Salt Lake is likely derived in part from dissolution of evaporite beds within the Yeso Formation. The BIA Report (King Engineering, 2001) proposes that "The preponderance of evidence indicates that the source of salinity in the lake is evaporation of low salinity Dakota and Atarque aquifer waters, alluvial aquifer waters, and surface runoff." As is clearly shown in SRP Figure 12-1 from the 1993 PAP, and in a Stetson Engineering Report to Zuni Pueblo (Page, 1993), the Dakota Sandstone is continuous in the subsurface between the proposed Fence Lake Coal Mine and Zuni Salt Lake. Pumping effects from the proposed Fence Lake Coal mine could therefore be propagated to Zuni Salt Lake and affect water levels and salinity in the lake, as was pointed out by Myers (1992) and Stetson Engineering (Page, 1993). GGI's model, discussed beginning on page 48 and in Appendix D, supports Myers and Page's hypotheses that pumping in the Dakota Sandstone at the Fence Lake Mine will adversely effect water levels at Zuni Salt Lake.

Regardless of the ultimate source of the salts in Zuni Salt Lake, any reduction in the flow of Dakota aquifer water into the maar will change both the hydrologic and chemical balance of Zuni Salt Lake. All of GGI's research, as outlined in the remainder of this report, indicates that pumping from the Dakota aquifer at the Fence Lake Mine will reduce the flow of water from the Dakota aquifer into Zuni Salt Lake.

STRUCTURAL GEOLOGY

Regional Structures

Zuni Salt Lake is located along the central portion of the Jemez Lineament (Figure 2). The Jemez Lineament is one of a series of northeast-trending lineaments that cross the western U.S. The Jemez lineament is characterized by northeast trending normal and oblique-slip faults and numerous volcanic features. The Jemez Lineament is approximately 30 miles (50 km) wide in the vicinity of Zuni Salt Lake, based on the location of the volcanic centers in west-central New Mexico that define its boundaries (Figure 2) (Laughlin et al., 1982). Several northeast trending photolinears have been identified in the vicinity of Zuni Salt Lake and the proposed Fence Lake Mine (Figure 1) and are referred to as the Nations Draw lineament. Both the Zuni Salt Lake maar and the Cerro Prieto basaltic-andesite neck in the mine lease are located on the Nations Draw lineament which is easily identifiable on aerial and satellite imagery. The proposed Fence Lake Mine Dakota Sandstone production well (FL-36) and observation well FL-36(OB1), which have a total combined declared groundwater diversion of 968 ac-ft per year, are also located on the Nations Draw photolinear. In GGI's 1997 report to the Zuni Pueblo, it was suggested that the Nations Draw photolinear was the surface expression of subsurface structures that could influence groundwater flow in the area and that additional field work should be conducted to determine the local structural expression (if any) of the Nations Draw lineament.

Any faults with offsets of greater than 105 feet (the maximum thickness of the main body of the Dakota Sandstone in the region) will result in a significant disruption of groundwater flow in the Dakota aquifer. Regardless of the sense of motion on a fault (i.e. whether the Dakota Sandstone is uplifted or downdropped), an offset of this magnitude would place the Dakota Sandstone against either the Mancos shale (if the Dakota Sandstone were uplifted) or the Chinle Formation (if the Dakota Sandstone were downdropped). Both of these formations have significantly lower permeability than the Dakota Sandstone, so placing the Dakota Sandstone against either formation would disrupt flow patterns in the Dakota aquifer. Northeast-southwest oriented structures (faults) along the Fence Lake Mine-Zuni Salt Lake corridor would act as barriers to recharge from the northwest and southeast, thereby greatly increasing the effects of pumping Dakota Sandstone wells at the Fence Lake Mine on Zuni Salt Lake. Conversely, northwest-southeast oriented faults cutting across Nations Draw would lessen the effects of pumping at the mine on the lake. The magnitude of the reduction of flow across structural boundaries (and the resulting effects on the lake from pumping at the mine) could best be evaluated by conducting a properly configured, long-term pumping test in the Nations Draw area. As previously suggested by GGI, and supported by the BIA Report, all structures should be identified prior to running such tests.

To this end, GGI conducted field studies in late November and early December 2000 to determine the nature of the linear features observed on topographic maps and air photos. The goal of the study was to field-check published geologic maps of the Nations Draw area and verify the location of faults identified in the BIA report (King Engineering, 2001; compiled from various published and unpublished sources). The results of GGI's field studies are described below.

<u>Results of GGI's Field Work in the Nations Draw Area</u>

The primary focus of GGI's fieldwork was to field check existing maps of the area north and west of Nations Draw (Campbell, 1989; King Engineering, 2001) to ensure their accuracy, and correlate stratigraphic units in the area. During this initial reconnaissance, GGI identified unique characteristics of various units that made it possible to validate or invalidate the existence of the geologic structures proposed by previous investigators. In particular, the presence of a distinctive shell-rich marker bed (coquina) in the Atarque Sandstone allowed GGI to easily trace the lateral extent of the unit and distinguish it from sandstone beds present in adjacent units.

After verifying that Campbell's (1989) map was accurate, the GGI study mapped out the contact between the Atarque Sandstone and the Moreno Hill Formation in the Nations draw area, paying particular attention to areas that had not previously been mapped in detail. By tracing out this contact, which is relatively easy to identify in the field, GGI was able to verify the presence of many of the structures identified in the BIA Report.

Moreno Hill Fault – The Moreno Hill Fault is a N-NE trending, down to the SE normal fault mapped by Campbell (1989) and included on the BIA Report summary map. GGI's mapping of the fault confirmed the existence of the fault and supports Campbell's (1989) location of the fault, shown in Figure 1. In the SW ¼ of Section 24, T4N, R18W the Moreno Hill fault places the Rio Salado Tongue of the Mancos Shale in the hanging wall against the main body of the Dakota Sandstone in the footwall, indicating a minimum vertical offset along the fault of 210 feet, and a maximum vertical offset of 540 feet at this location. North of this location, offset along the fault becomes progressively less, while to the south it is commonly covered in alluvium, making determinations of offset difficult. It is probable, however, that equal or greater offsets than described above are present to the south of section 24 in Nations Draw. Anderson (1994) indicated that the Moreno Hill Fault merges with or is truncated by the Zuni Salt Lake Fault (see below) near Zuni Salt Lake. GGI agrees with this interpretation due to the lack of evidence for the Moreno Hill Fault south of Zuni Salt Lake.

Zuni Salt Lake Fault – The Zuni Salt Lake Fault is a NE trending, down to the SE normal fault originally mapped by Anderson (1994). The majority of the fault, as previously mapped in Largo Wash, is covered by Quaternary deposits, however it is shown cropping out in Cretaceous rocks at the southern end of Santa Rita Mesa. GGI mapped this area and found little evidence of a large fault. However, it is possible that small normal faults mapped by GGI in the area could be antithetic or synthetic splays from a larger structure that is covered by Quaternary deposits.

To the southwest of Largo Wash, the Zuni Salt Lake Fault is better exposed and shows evidence of 300 to 600 feet of stratigraphic throw (Anderson, 1994; Chamberlin et al., 1994). It is GGI's opinion that, while the Zuni Salt Lake fault is a small feature to the northeast of Largo Wash, it becomes a major feature to the southwest and, therefore, is most likely a significant feature in the subsurface near Zuni Salt Lake and across Largo Wash.

Tejana Mesa North Fault – The Tejana Mesa North Fault is a NE trending normal fault whose southwest terminus is adjacent to the north end of Tejana Mesa. The location of the fault is shown as approximate and/or covered by Chamberlin et al. (1994), and was not mapped by Roybal (1982). GGI's mapping of the area around this proposed structure found no surface evidence of a fault. Where exposed on the east side of Tejana Mesa, beds that cross the strike of the Tejana Mesa North Fault (Middle and Upper Moreno Hill Formation, Baca Formation, and the Quaternary basalts capping the mesa) are continuous and show no evidence of either folding or faulting. However, structure contour maps of the base of coal beds in the mine lease area to the northeast of Tejana Mesa indicate offsets in the contoured beds of approximately 100 feet along the trend of the Tejana Mesa North Fault. The fact that the fault is not observed in surface exposures but is seen on contour maps created from drilling data indicates either that the faulting occurred after deposition of the Lower Member of the Moreno Hill Formation but prior to deposition of the Middle and Upper Members (the members with the most exposure at the surface in the study area) or the fault dies out to the southwest and is not exposed outside the mine lease area.

Tejana Mesa Central Fault – The Tejana Mesa Central Fault is a N-NE trending, down to the NW normal fault originally mapped by Roybal (1982). On Roybal's (1982) map, the fault cuts Tertiary sediments (Baca Formation) and is truncated by overlying Tertiary basalt flows. This relationship suggests a latest Tertiary or early Quaternary episode of NW-SE directed extension. GGI's examination of this fault supports this interpretation, with the exception that the Tertiary basalt flow is either offset or draped across the fault. Evidence for the fault includes the presence of a large (60-80 feet high) basalt scarp that crosses Tejana Mesa along the trend of this fault. Due to its poor exposure, GGI was unable to determine if this scarp was a result of faulting of the basalt or folding of the basalt over a blind fault, although faulting of the basalt is a likely explanation. Either scenario would argue for a period of late Tertiary to Quaternary tectonism in the region, and the Tejana Mesa Central Fault appears to have at least 60 – 80 feet of offset. A period of Late Cenozoic extension in the area is described by Guilinger (1982).

Tejana Mesa South Fault – The Tejana Mesa South Fault is a NE trending, down to the NW normal fault that cuts across the southeast end of Tejana Mesa. The fault was initially mapped by Roybal (1982) and Guilinger (1982), and was included on the BIA Report map. Due to time constraints GGI has, as of this date, been unable to look at this fault in detail in the field. However, a study of aerial photographs of the area shows a distinct photolinear where the fault is mapped. Chamberlin et al. (1994) estimated stratigraphic offset on this fault (which they call the Mesa Tinaja fault) of approximately 400 feet. Future field studies by GGI will attempt to verify this offset in the field.

It is likely that the Tejana Mesa Central Fault and the Tejana Mesa South Fault are related in some way to one another, either as antithetic splays from a larger fault, or as a master fault with an antithetic splay. The two faults appear to merge at the southern margin of Tejana Mesa, but limited exposure makes it unclear which is the dominant fault.

Tejana Draw Fault – The Tejana Draw Fault is the only significant (mapped for a distance of at least one mile) NW trending structure identified in the study area on the BIA Report map or in any other published literature available to GGI. McGurk and Stone (1986) refer in their text to structures in the Nations Draw Area but, as of this writing, GGI has not been able to obtain a copy of their maps because SRP has been unwilling to release them citing corporate confidentiality reasons. The Tejana Draw Fault was not mapped by Roybal (1982) and GGI could find no geologic evidence in the field to support the presence of a fault at this location. Rocks in the Tejana Draw area are relatively flat lying (uniform dips <5°) and laterally continuous, suggesting they have not been tectonically disrupted. However, structure contour maps of the base of coal units in the mine lease area compiled by SRP show a northeast trending structure at the location of the Tejana Draw Fault shown on the BIA report map. The structure has a maximum offset of 60 to 70 feet at its southeasternmost extent, but shows offset of approximately ten feet to zero where it enters Nations Draw. This suggests that the fault dies out to the northwest and is not a significant feature in the subsurface within Nations Draw.

In summary, GGI's fieldwork confirmed the presence of several northeast trending faults with significant offsets in the study area. These faults limit the lateral extent of the Dakota aquifer to the northwest and southeast between the mine and Zuni Salt Lake, thereby amplifying the effects of pumping on the lake caused by diversions from the Dakota aquifer wells at the mine site. GGI could find no evidence of any structures cutting across Nations Draw that could mitigate the effects of pumping at the mine on Zuni Salt Lake; therefore it is imperative that a properly designed, long-term aquifer pumping test be run with a properly designed monitoring well network in place to determine the effects of structures on groundwater flow and the effects of pumping on Zuni Salt Lake. At this time, such a test has not been conducted, and the monitoring well network, which has been shown to be inadequate (see below), cannot serve as a proxy for this critically important test. No provision of the existing permit requires such an aquifer test, and SRP has consistently refused to agree to one.

The following section is an overview of the results of the limited-duration pumping tests that SRP has conducted on various aquifers in the study area. While none of the pumping tests conducted to date were run long enough with a high enough discharge to stress the aquifer adequately for accurate aquifer characterization, the results do indicate that a properly designed pumping test that stresses the aquifer will yield valuable information about the role of structures in groundwater flow and the propagation of pumping effects from the mine site to Zuni Salt Lake.

EVALUATION OF SRP PUMPING TEST DATA

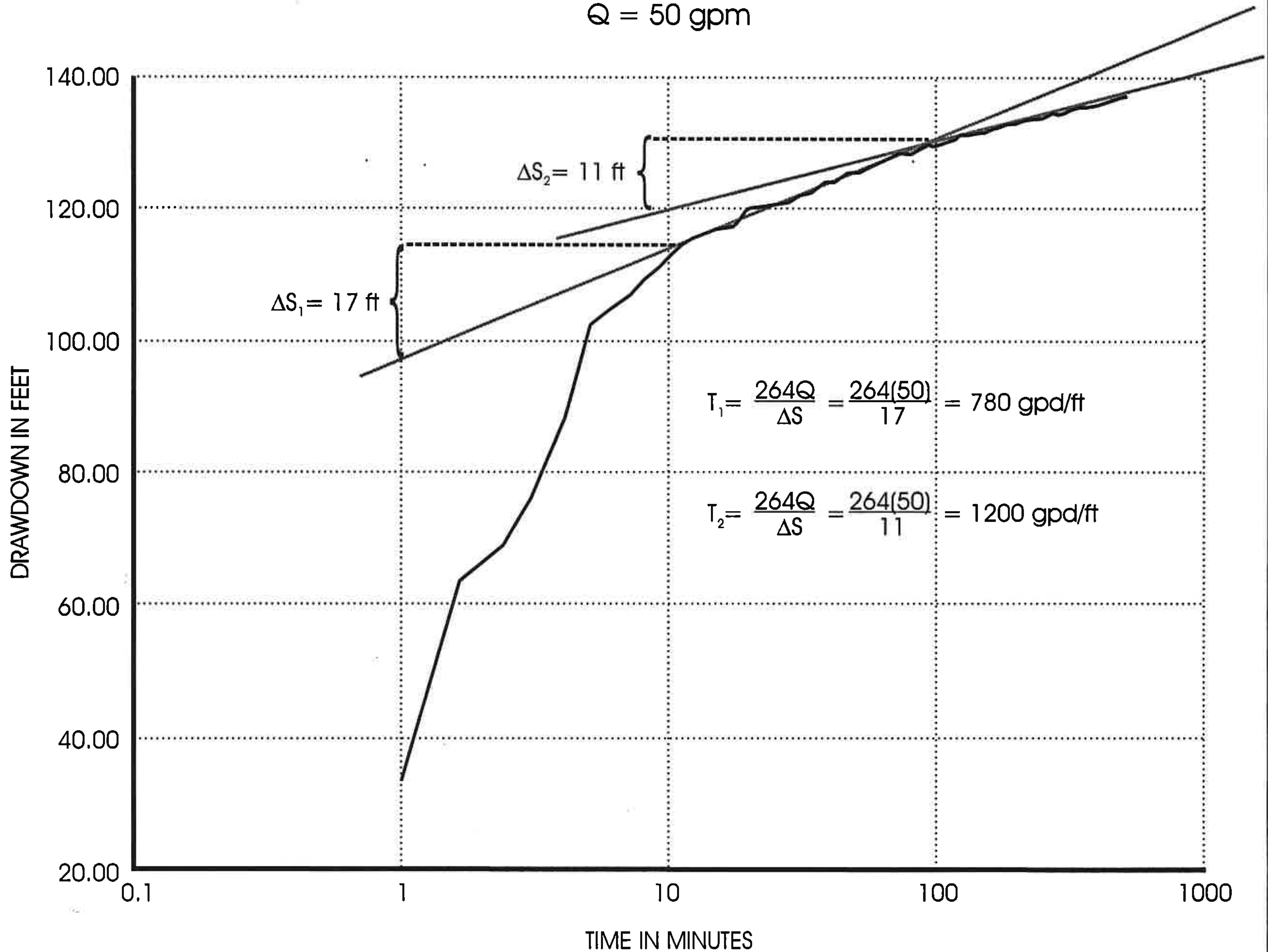
Quaternary Alluvium Pumping Tests

SRP has conducted several pumping tests using wells completed into the valley fill alluvium within the coal lease area. Brown discusses two pumping tests conducted in the vicinity of Fence Lake No. 1 Mine site in the southern portion of the project area, from which recovery data indicate transmissivity values in the range of 2200 to 2500 gpd/ft. Well 317-11-14 M1 was pumped for 721 minutes (12 hours) at an average Q of 50 gpm. The 50 gpm discharge was not sufficient to stress the well, so *T* was calculated only from the recovery data. Because the aquifer was not stressed, the *T* value calculated from the recovery data from this test is not valid and should be disregarded. Well 317-11-14 OB1 was pumped at an average Q of 8 gpm for 249 minutes. *T* calculated from drawdown data shown in Attachment B-2 of the report was 1080 gpd/ft. Other pumping tests included in Attachment B-2 (e.g. well 317-11-14 OB2) show *T* values ranging from 70 gpd/ft to 474 gpd/ft. Another test, run for 180 minutes at a Q of 10 gpm produced less than 0.1 ft of drawdown (for the duration of the test) after the first two minutes of pumping and should not be used to estimate aquifer coefficients. The transmissivity of the alluvium is apparently highly variable, although a sand and gravel layer typically found at depths greater than 80 feet is a locally productive aquifer.

Atarque Aquifer Pumping Tests

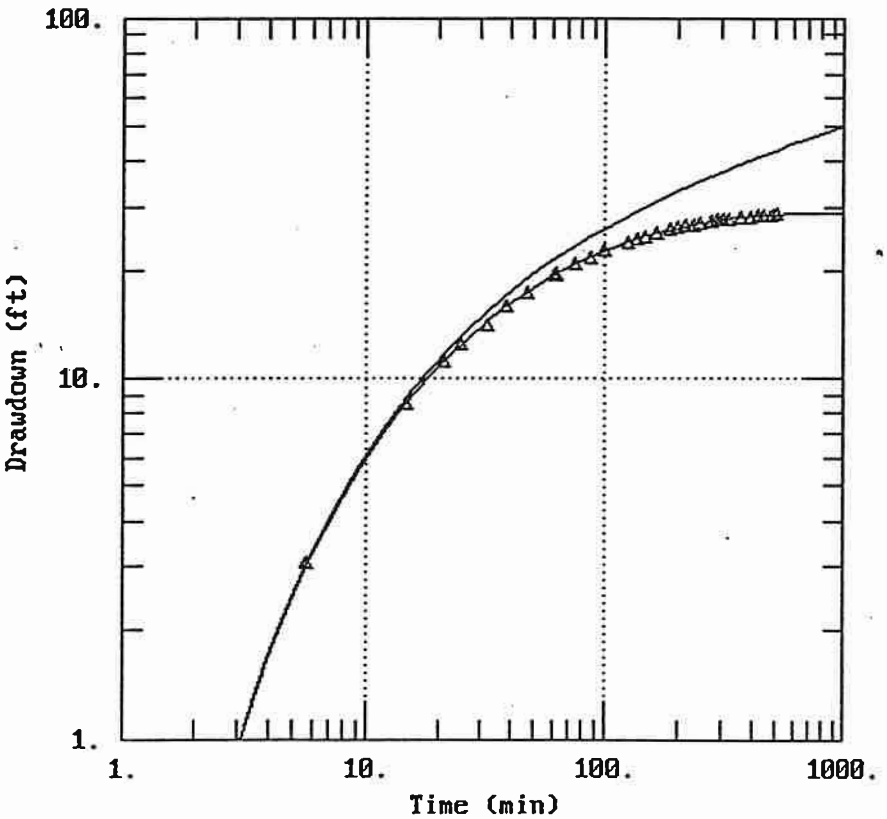
SRP conducted a 510-minute pumping test on the Atarque Sandstone aquifer pumping well located in section 36, T4N, R17W (within the same section as FL-36 and FL-36-OB1) at an average discharge of 50 gpm on March 13, 1994. A semi log plot of drawdown data from the pumping well included in the PAP indicates that the drawdown curve from later-time data flattens slightly in comparison to earlier-time data (Figure 17), suggesting a recharge boundary or a leaky aquifer response.

FIGURE 17. SRP DRAWDOWN PLOT OF ATARQUE PUMPING WELL -- TESTED ON 3/13/94
Q = 50 gpm



IENT: Zuni Pueblo	COMPANY: Data collected by SRP
OCATION: Fence Lake Mine	PROJECT: 6052

ATARQUE OBS WELL DRAWDOWN DATA, 3/13/94



DATA SET:
ATARQUE.DAT
10/18/96

AQUIFER MODEL:
Leaky

SOLUTION METHOD:
Hantush (no stor.)

PROJECT DATA:
test date: 3/13/94
test well: "Production Well"
obs. well: "Observation Well"

TEST DATA:
$Q = 6.7\ ft^3/min$
$r = 167.\ ft$
$r_c = 0.17\ ft$
$r_w = 0.33\ ft$
$b = 150.\ ft$

PARAMETER ESTIMATES:
$T = 0.051\ ft^2/min$ = 550 gpd/ft
$S = 3.49E-05$
$r/B = 0.2972$

AQTESOLV

Figure 18. Drawdown plot of observation well during Atarque aquifer pumping test

SRP monitored an observation well in the Atarque sandstone during the pumping test and collected sufficient data to construct a definitive curve. A logarithmic plot generated by SRP from the Atarque observation well located 167 ft. from the production well indicate that a Hantush-Jacob (1955) leaky aquifer solution with no storage in the confining bed provides a good curve match for the data (Figure 18). Based on SRP's lithologic log from the Atarque production well, leakage would be derived from an interbedded sandstone or coal bed within the Moreno Hill Formation or from the alluvium. However, to definitively demonstrate that the leaky aquifer solution is appropriate, a pumping test should be conducted during which observation wells are monitored both in the Atarque Sandstone and in the overlying Moreno Hill Formation aquifer.

Dakota Aquifer Pumping Tests

SRP conducted a pumping test in 1983 on a production well located in the vicinity of the Fence Lake Mine, which GGI infers has been designated FL-36. Neither raw data from this pumping test, nor SRP's (1983) internal report on the pumping test, have been provided to GGI or included in the PAP, CHIA, or FSEIS. Myers (1992) reports a transmissivity value calculated from the 1983 pumping test on FL-36 of 5300 gallons per day per ft (gpd/ft)(Appendix B), and a hydraulic conductivity of 6.8 ft/day. Myers also provides information on pumping rate (350 gpm) and duration of the test (28.5 hours). The only statement Myers makes about the recovery data is that "Artesian flow resumed within 3 minutes after the test was completed." GGI has no further information regarding the 1983 pumping test. It is noteworthy that Myers (1992) found nothing in those data to indicate that the Dakota was not confined, and he concluded that the Theis method of confined aquifer analysis would be the best analytical method to use to calculate the effects of pumping from the Dakota aquifer in the San Augustine Coal Area (which includes the Fence Lake Mine).

In 1994, SRP conducted two separate pumping tests using FL-36 (OB1) as the pumping well and FL-36 as an observation well (Figure 1). Based on data available to GGI, no other wells were monitored during the pumping tests, although nearby wells completed into the Atarque

Sandstone had been completed at the time of the tests. GGI compiled data plots using SRP's pumping test data for each test and analyzed the data as described below.

SRP conducted a 500-minute test on FL-36 (OB1) at an average discharge rate (Q) of 302 gpm on March 16, 1994. A semi logarithmic plot of drawdown data from the pumping well indicates that the data fit a Cooper-Jacob (1946) straight line solution very well for the time period after which casing storage effects are negligible (Figure 19). Casing storage effects were calculated using the methodology described in Driscoll (1986, p.232-234). An example of the calculation of casing storage effects is presented in Appendix B for the December, 1994 50-hour pumping test.

Drawdown data were collected periodically from observation well FL-36 during the test. However, the apparent resolution of the transducer readings of 1 psi during the first 200+ minutes of the test (allowing for an unacceptably high incremental change of 2.31 feet of drawdown) and the relatively few drawdown measurements taken (9 measurements total after the start of pumping; see Appendix B) did not produce usable data for aquifer analysis (Figure 20).

The inflection point observed in the drawdown plot from the pumping well between three and ten minutes (Figure 19) is related to casing storage effects, and is not an indication of a leaky aquifer response, as has been asserted by SRP. SRP's use of the pumping well to obtain a curve match for a leaky aquifer solution is a highly questionable and self-serving methodology. The reference cited by SRP for the leaky aquifer solution (Hall, 1996) states unequivocally, on p. 253, that "If time vs. drawdown data is plotted from an **observation well** on a semi-log graph, the slope is similar to the slope o33btained from the Jacob plot in a confined aquifer, except where the drawdown levels off due to leakage through the leaky confining layer."

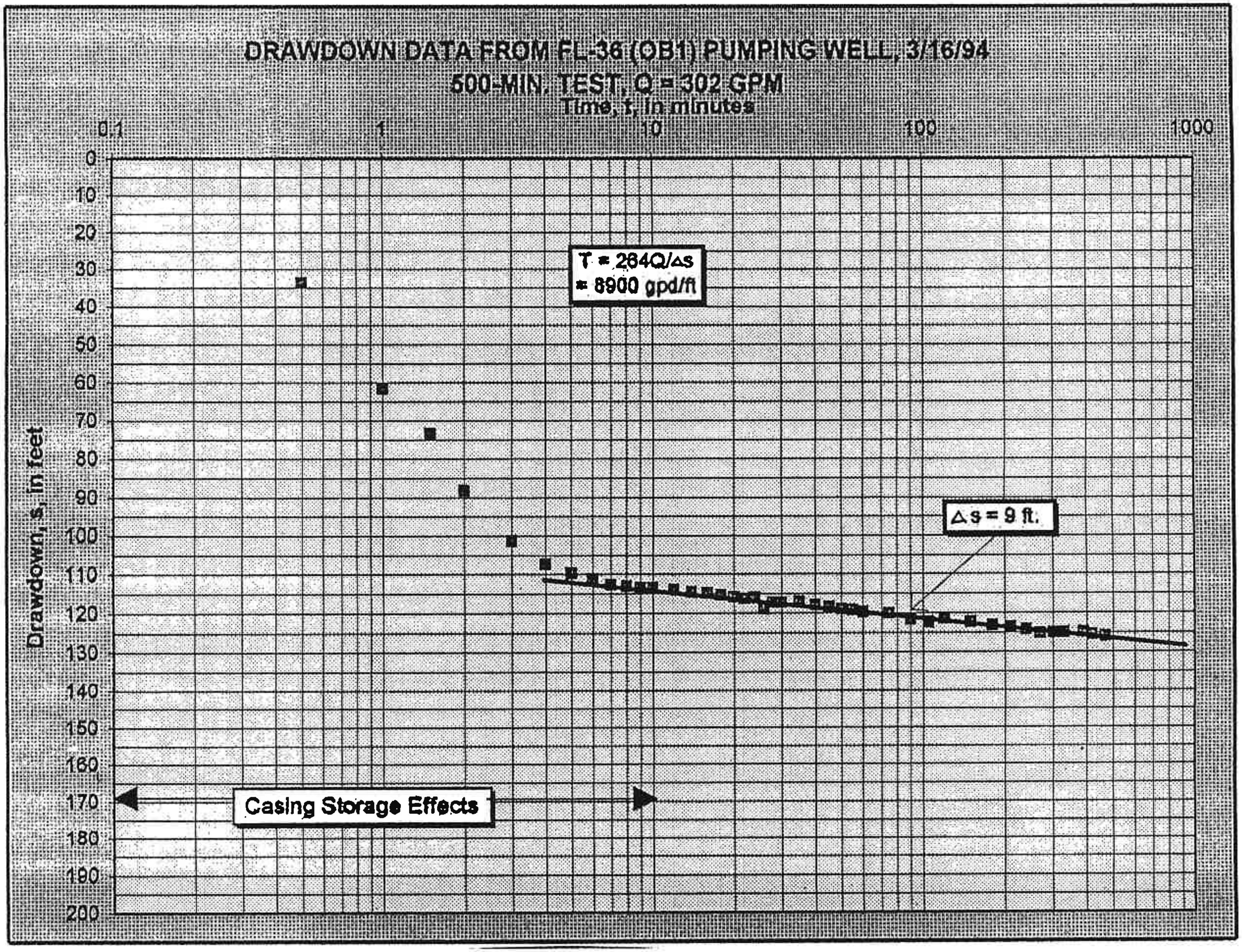
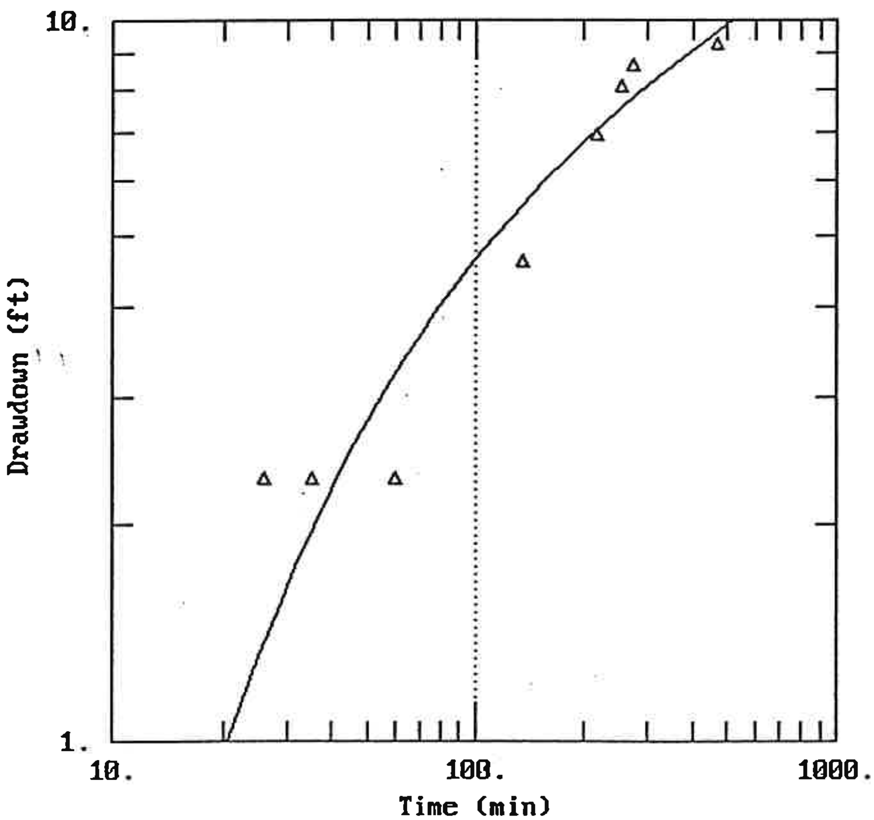


Figure 19. Drawdown plot from 500 minute pumping test of FL-36(OB1)

ENT: Zuni Pueblo	COMPANY: Data Collected by SRP
CATION: Fence Lake Mine	PROJECT: 6052

FL-36 OBS WELL DRAWDOWN DATA 3/16/94



DATA SET:
ZUNI394.DAT
10/18/96

AQUIFER MODEL:
Confined

SOLUTION METHOD:
Theis

PROJECT DATA:
test date: 3/16/94
test well: FL-36(OB1)
obs. well: FL-36

TEST DATA:
Q = 40.4 ft^3/min
r = 500. ft
r_c = 0.33 ft
r_w = 0.33 ft
b = 105. ft

PARAMETER ESTIMATES:
T = 0.9189 ft^2/min
S = 0.0002583

AQTESOLV

Figure 20. Drawdown plot of observation well during 500 minute pumping test of FL-36(OB-1).

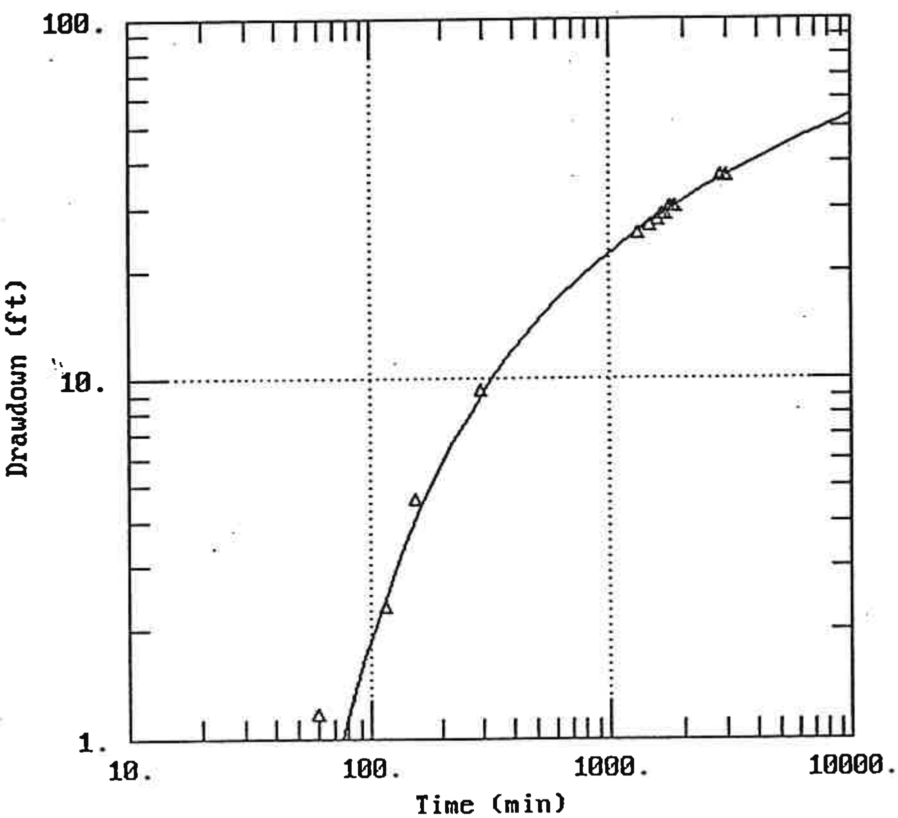
Drawdown data were also collected periodically from observation well FL-36 during the 50-hour test (described below on pages 43 and 44); however, drawdown data were not collected between 295 minutes (when drawdown (*s*) was 9.24 feet) and 1315 minutes (when s was 25.41 feet) (Figure 21; Appendix B). With the entire middle part of the curve missing from the observation well data, a variety of different curve matches will fit the late-time data. GGI obtained a good Theis curve match to the late time data and therefore contends that a Theis analysis is most appropriate based on a variety of criteria including: (1) the use of proper methodology for hydrologic analysis; (2) selection of the method of analysis that most closely represents the geologic and hydrologic conditions in an area; and, (3) comparison with drawdown data from the pumping well. According to United States Geological Survey (USGS) Water Supply Paper 2220 (Heath, 1983), when geologic and hydrologic conditions in an area are not well known, "the common practice is to prepare a data plot of *s* versus *t* on logarithmic paper and match it with the Theis type curve. If the data closely match the type curve, the values of T and S determined by using the Theis equation should be reliable." GGI's examination of outcrops exposing the shale beds which overlie the main body of the Dakota Sandstone indicate that, contrary to assertions made by SRP, shale beds in the study area are not extensively fractured, and that fractures which extend into shale units from overlying sandstone beds are discontinuous or closed. Finally, drawdown data from the pumping well exhibit a steepening in the curve (e.g. greater than predicted drawdown) after 500 minutes. A leaky aquifer response should exhibit the opposite effect, or a flattening in the curve and less than predicted drawdown for the late-time data. The method of analysis that most closely represents the geologic and hydrologic conditions in the area is therefore a Theis analysis based on a confined aquifer model. **The pumping test data from the March and December, 1994 Dakota aquifer pumping tests exhibit no evidence of a leaky aquifer response.** The BIA Report (King Engineering, 2001) agrees with this conclusion.

Pumping Test Boundary Conditions

SRP conducted a 50-hour (3000-minute) test on FL-36 (OB1) at an average Q of 311 gpm December 13 through 15, 1994. Casing storage effects are negligible after approximately 12 minutes as shown by the calculations in Appendix B. A semi log plot of drawdown data from

CLIENT: Zuni Pueblo	COMPANY: Data Collected by SRP
LOCATION: Fence Lake Mine	PROJECT: 6052

FL-36 OBSERVATION WELL DRAWDOWN DATA



DATA SET:
ZUNIT2.DAT
03/27/97

AQUIFER MODEL:
Confined

SOLUTION METHOD:
Theis

PROJECT DATA:
test date: 12/13/94 - 12/15/94
test well: FL-36(OB1)
obs. well: FL-36

TEST DATA:
$Q = 41.6\ ft^3/min$
$r = 500.\ ft$
$r_c = 0.33\ ft$
$r_w = 0.33\ ft$
$b = 105.\ ft$

PARAMETER ESTIMATES:
$T = 0.2334\ ft^2/min$
$S = 0.0004897$

AQTESOLV

Figure 21. Drawdown plot of observation well (FL-36) during 50 hour pumping test of FL-36(OB1)

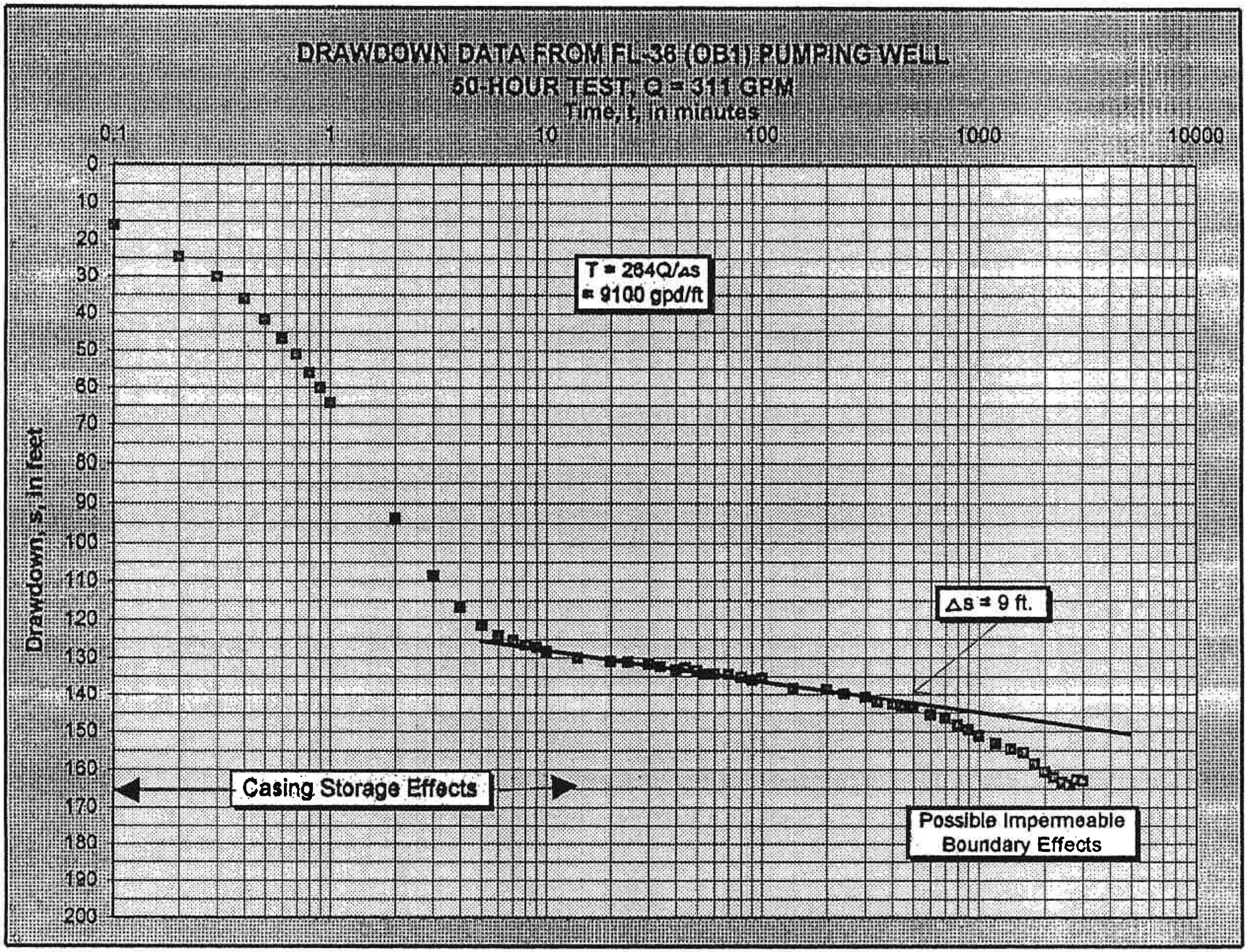


Figure 22. Drawdown plot from 3000 minute pumping test of FL-36(OB1)

the pumping well indicates that the data fit a Cooper-Jacob (1946) straight-line solution very well for the time period between 10 and 500 minutes (Figure 22). This represents the time period after which casing storage effects are negligible and prior to possible impermeable boundary effects (Figure 19). GGI interprets steepening of the drawdown curve after 500 minutes to be the result of an impermeable boundary representing the lateral extent of the highly fractured Dakota Sandstone aquifer within Nations Draw. Calculations based on the drawdown curve (using an S of 6.3 x 10^{-4}, t = 800 min. (0.6 day), and the early-time T of 9000 gpd/ft), and solving for radial distance r_o, using the equation:

> $r_o = [0.3Tt/S]^{1/2}$ derived from rearranging the equation $S = 0.3Tt/r_o^2$, where
> S = coefficient of storage
> T = coefficient of transmissivity, in gpd/ft
> t = time since pumping started, in days
> r_o = intercept of extended straight line at zero drawdown, if ft

(Driscoll, 1986, p. 237)

indicate that the boundary is located a radial distance of approximately 1600 feet from FL-36(OB1). This distance corresponds to the approximate location of the fold axis of a monocline shown by King (2001) northeast of FL-36(OB1). On page 11-23 of the PAP, SRP describes this monocline as a "prominent fold." This monocline may be the northeast boundary of a structurally isolated section of the Dakota aquifer that is bounded on the southwest end by the Zuni Salt Lake Fault. This feature could cause drawdown effects to be magnified southwestward towards Zuni Salt Lake. A longer term pumping test (such as that proposed by GGI and outlined beginning on page 58 and appendix G) will determine if other structures mapped in the region have similar impacts on groundwater flow.

USGS, the office of the New Mexico State Engineer (OSE), Bureau of Indian Affairs (2001) and DE&S (2001a) Analyses of Dakota Sandstone Aquifer in the Vicinity of Proposed Fence Lake Coal Mine

On April 18, 1996, Mr. Monte Anderson of MMD requested that the OSE review SRP's well test on FL-36 (OB1). Mr. Andy Core of the OSE Hydrology Bureau performed the interagency review that is summarized in a May 3, 1996 OSE memo. In analyzing SRP's pumping test data, Mr. Core used the Cooper-Jacob approximation to the Theis method for estimating aquifer transmissivity. Core concluded that the shape of the drawdown curve of the pumping well is suggestive of a confined fractured aquifer as described by Krusman and de Ridder (1991, page 50) and predicted pumping effects would reach many miles beyond the 3700+ feet calculated by SRP/MMD. The report said that "noticeable effects" of pumping FL-36 would reach FL-36(OB2) – 2.5 miles away – in as little as four weeks. The MMD did not put the Core/OSE Report in the SRP permit record, it was discovered in the State Engineer's SRP file and is included here in Appendix C.

Myers (1992, p. 23) analyzed the 1983 SRP pumping test on FL-36 and states " because the main body of the Dakota Sandstone is a confined aquifer, the withdrawal of water could lower water levels in wells completed in the aquifer throughout a large area." The BIA Report (King Engineering, 2001) refers to the 1993 Dakota aquifer pumping tests and states that "We concur with Drakos and Lazarus (1997) the pump tests do not show any indication of leaky behavior. Casing effects are common in pump tests, and are routinely recognized as such" (pg. 25). The BIA Report continues "In the final analysis, there is evidence that the Dakota Sandstone aquifer is confined by the Mancos Shale and we see no clear evidence to the contrary. In considering impacts on ZSL of pumping at the mine site, it is conservative and prudent to assume that the aquifer is confined" (pg. 26). King Engineering (2001) also agrees with GGI's interpretation of the inflection in the drawdown curve representing a structural boundary (pg. 20). King concludes this discussion by stating that both Theis and Hantush methods are non-conservative because they are incapable of accounting for the anisotropy introduced by the geologic structure in the area (pg. 27). GGI stands by the conclusion reached by Drakos and Lazarus (1997b) that Theis is the better *analytical* method to use for estimating drawdowns in the Dakota aquifer in the vicinity of FLM and ZSL. GGI, however, agrees with Dr. King that a numerical groundwater flow model that includes the structural boundaries of the aquifer would ultimately be a more accurate method of evaluating pumping effects from the Fence Lake Mine. GGI has consistently maintained that, due to geologic structures creating limits to the aquifer, the Theis analysis likely under-represents pumping effects from the Fence Lake mine, and supports King (2001) on this point.

In their analyses of the Dakota Sandstone aquifer, DE&S is apparently attempting to convince the reader that the Dakota aquifer is not a confined aquifer and that the Dakota aquifer receives rapid and substantial recharge when pumped. DE&S has distorted facts and conclusions reached by other researchers, and the DE&S report contains misrepresentations of earlier reports. Specific examples of misrepresentations are included in Appendix A.

The conclusions outlined by DE&S regarding recharge to the Dakota Sandstone aquifer and treating the Dakota as a leaky rather than as a confined aquifer are not based on sound geohydrology, nor on the geohydrologic data compiled by SRP and should be disregarded.

PROPAGATION OF PUMPING EFFECTS IN CONFINED AND LEAKY CONFINED FRACTURED SANDSTONE AQUIFERS

In 1997, GGI developed a simplified numerical model to predict drawdown at Zuni Salt Lake resulting from SRP's proposed mine diversion. GGI ran a one-layer, two dimensional groundwater flow model using the U.S. Geological Survey's MODFLOW code. The model incorporates a uniform value for transmissivity of 700 ft^2/day (5200 gpd/ft) and storage coefficient of 0.00049 for the Dakota Sandstone aquifer. These aquifer coefficients are derived from SRP's Dakota Sandstone pumping tests and are consistent with values used by Myers (1992) and Core (1996). GGI ran the model for 40 years at the discharge rate of 85 gpm (137 acre-ft/yr), the proposed mine discharge. Estimated drawdown at Zuni Salt Lake resulting from pumping 85 gpm for 40 years was between 4 and 5 feet (Appendix D). Since Zuni Salt Lake is usually less than 4 feet deep (Myers, 1992), pumping 85 gpm from the Dakota aquifer for 40 years at the proposed Fence Lake Coal Mine will dramatically affect the water balance and water levels in Zuni Salt Lake.

GGI has also developed a Theis model to calculate residual and delayed effects resulting from SRP's proposed pumping from the Dakota aquifer. The model was run to estimate the effects of pumping 137 acre-ft/year at the Fence Lake Mine for the 40-year anticipated life of the mine on Zuni Salt Lake. For the model, the pumping rate from well FL-36 was assumed to be a constant discharge of 85 gallons per minute (gpm) (137 acre-ft/year) for 40 years. Observation points were set up in the model correlating to the actual distances of the existing observation wells (FL-36, FL-36 (OB1), FL-36 (OB2), FL-36 (OB3), FL-36 (OB4), Jerry Observation Well) and Zuni Salt Lake. One additional observation point, called Well X, was placed at a distance of 1610 feet from the pumping well. A transmissivity (T) of 5200 gpd/ft (700 ft^2/day) and a storage coefficient (S) of 0.00049 were used. These values are the same as the parameters used in the 1997 model by GGI (Drakos and Lazarus, 1997b). The Theis model was set up to record recovery data (residual drawdown) after the pump was shut off at 40 years. Model output data are presented in Appendix E and show where significant changes in drawdown and residual drawdown occur. Table 1 summarizes the Theis output to show key values at each of the observation points.

The first key drawdown (s) value is 0.1 feet. This is the value at which drawdown can first be reliably measured in observation wells using field instruments. The table shows the time in days at which a drawdown of 0.1 feet will reach each of the observation points. The next row of the table shows the time in days in which a drawdown of 0.5 feet can be measured at each of the observation points. This time is also shown in years in the third row of data. This value was chosen to represent significant observed drawdown because a drop of 0.5 feet at ZSL will be detrimental to the quality and quantity of water. The maximum drawdown (s_{max}) in feet and the time in days and years at which this drawdown occurs are shown in the next three rows of the table.

Table 1. Theis Model Results for the 40-year "life of the mine" pumping calculations. Pumping rate is 85 gpm, T = 5200 gpd/ft, S = 0.00049

	Observation Points - Distance from pumping well in ft							
	FL-36 0.5 ft	OB1 500 ft	Well X 1610 ft	OB4 5812 ft	OB2 13897 ft	OB3 40957 ft	Jerry 46645 ft	ZSL 66512 ft
t @ s=0.1 ft (day)	<1	<1	<1	4	19	153	184	401
t @ s=0.5 ft (day)	<1	<1	<1	30	90	365	460	900
t @ s=0.5 ft (year)						1	1.3	2.5
s_{max} (ft)	**48.6**	**22.7**	**18.3**	**13.5**	**10.3**	**6.3**	**5.8**	**4.5**
t @ s=s_{max} (day)	14600	14600	14600	14600	14600	14646	14664	14756
t @ s=s_{max} (year)	40	40	40	40	40	40.1	40.2	40.4
t @ s'=0.5 (day)	62275	62275	62275	62275	62275	61975	61900	61500
t @ s'=0.5 (year)	170.6	170.6	170.6	170.6	170.6	169.8	169.6	168.5
t @ s'=0.1 (day)	279493	279493	279493	279493	279493	279310	279127	278761
t @ s'=0.1 (year)	765.7	765.7	765.7	765.7	765.7	765.2	764.7	763.7

s = drawdown ft   s' = residual drawdown ft

The maximum drawdown at ZSL is predicted to be 4.5 feet after 40.4 years. **This maximum drawdown at ZSL is predicted to occur 156 days after the 40 years of pumping ceases at FL-36.** This delayed effect is a function of the transmissivity and storage of the aquifer as well as the distance from the pumping well. The delay in maximum drawdown time increases with increasing distance from FL-36.

The next four rows of the table show the residual drawdown (s') values in feet and times in days and years. The same values of 0.5 ft and 0.1 feet are used to show the progress of recovery at each of the observation points. The residual drawdown effects show the reverse trend of the drawdown. The observation points that are farther from the pumping well recover to the noted s' values sooner than those closer to the well. The "full recovery" value is determined to be an s' value of 0.1 ft, which is determined to be the smallest increment of recovery that is reliably measurable. **Full recovery at ZSL is calculated to be 763.7 years after commencing pumping at the Fence Lake Mine or 723.7 years after the pump is shut off.**

Based on results of the GGI Theis model, pumping 137 ac-ft per year at the Fence Lake Mine for 40 years will result in significant drawdown effects on Zuni Salt Lake for more than 110 years after pumping ceases at the mine.

SRP contends that its pumping effects will not extend a distance of greater than 3708 ft from the pumping well (FL-36) at a pumping rate of either 85 gpm or 300 gpm. This predictive scenario is contradicted by studies conducted by Myers (1992), Core (1996), Drakos and Lazarus (1997b), King Engineering (2001), and this report. All of these models predict that effects will extend many miles from a pumping center in the confined Dakota Sandstone aquifer. Unfortunately, SRP's faulty modeling was the basis of excluding ZSL from the "critical impact area" of the CHIA. The CHIA was used as the basis for the FSEIS' recommendation in favor of approval of the Life of Mine Plan, and was apparently the basis for MMD's approval of the permit. Because these predictive scenarios are flawed and incorrect, GGI contends that the original mine permit was erroneously approved.

It is interesting to note that DE&S, SRP's consultant, acknowledges in several places in their report that pumping effects in the Dakota Sandstone aquifer will be transmitted distances of thousands of feet to miles over time periods of weeks to months. These distances are much greater than the 3700 feet radius of zero drawdown presented in the PAP (1993/1994) and the CHIA (1994). In Appendix E, GGI discusses DE&S' conclusions regarding propagation of pumping effects and presents the results of several aquifer tests in analogous hydrogeologic environments, in which pumping effects in confined and leaky confined fractured sandstone aquifers are propagated distances of thousands of feet to miles, over time frames of minutes to days.

This conclusion, which even DE&S analysis seems to support (see further discussion in Appendices A and E), makes it illogical and highly dangerous to assume that leakance will limit pumping effects to some 3700 feet, as proposed by SRP.

ANALYSIS OF SRP'S MONITORING WELL NETWORK

Overview of SRP's Monitoring Plan

SRP, in the 1993 PAP, proposed a monitoring plan for the Dakota aquifer in the study area. The monitoring plan was amended in 1997 with the addition of two more wells completed into the Dakota aquifer. The addition of these wells brought the total number of SRP wells completed in the Dakota aquifer to six. Locations of all SRP wells completed into the Dakota aquifer are shown in Figure 1. Based on information provided in SRP's Modification 97-02 to the Fence Lake Mine, Permit No. 96-04 (the New Mexico State permit), dated June 26, 1997, wells FL-36(OB2), FL-36(OB3), and FL-36(OB4) will be utilized for a Dakota aquifer monitoring program. **This agreement is between SRP and MMD and the following discussion does not imply GGI's or Pueblo of Zuni's agreement to this plan.**

Modification 97-02 to the PAP outlines a monitoring well program that requires two years of water level data to be collected from FL-36(OB2), FL-36(OB3), and FL-36(OB4), which will be used to determine "action levels" for each well (pre-determined cut-off water levels for each well; if water levels fell below the action level, pumping from the Dakota aquifer at the mine site would have to be halted). The proposed action levels would be calculated based on three standard deviations from the mean plus one foot, based solely on the baseline data. However, the criteria for determining action levels may be modified with the approval of MMD after the two years of data collection. Modification 97-02 also states "*data will be compared among the wells to determine seasonal variations (magnitude and frequency) and to determine action levels.*" Exactly how seasonal variations will be accounted for is not described.

Modification 97-02 directs SRP to *"Install pressure transducers in FL-36, FL-36(OB1), FL-36(OB2), FL-36(OB3), and FL-36(OB4) to further refine baseline aquifer data and to expand the historic data collected from the Dakota aquifer."* GGI analyzed data from FL-36, FL-36(OB1), FL-36(OB2), FL-36(OB3), FL-36(OB4), and the Jerry Observation well provided to GGI by MMD. Water level data are measured using dedicated transducers (pressure-sensitive devices placed below the water table inside each well and attached to an automatic recorder) that record water levels in each well on an hourly basis. Data plots, statistical analyses, and a discussion of analytical methods are included in Appendix F. The measuring point (MP) from which water pressure or depth to water was calculated was not referenced to ground level or a surveyed datum in the data set provided to GGI. **Because action levels may be defined based on water level changes of less than two feet (see below), it is critical that first-order surveyed MP locations be established and included with the data sets.** MP height above or below ground surface should also be provided. The earliest data provided to GGI are from 4/14/98 (OB1 and OB4). The data record starts on 8/20/98 for OB2 and on 2/23/99 for OB3. FL-36(OB3) is a replacement well for the Jerry observation well, which also has a record of water levels, but although SRP has voluntarily installed transducers in these wells, the permit does not appear to be written in a manner that allows the Jerry observation well data to be used to extend the period of record for FL-36(OB3).

GGI's Analysis of Monitoring Well Water Level Data

Data from the observation wells (summarized in Appendix F) were provided to MMD by SRP, and given to GGI in electronic format by MMD. Statistical analyses of these data were conducted by GGI, independently of the statistics provided by MMD. In the course of GGI's statistical analyses, it was noticed that the mean (the value commonly referred to as 'average', that is the sum of all data points divided by the number of points) water level values included in the data sets for each well were, in fact, calculated as median (the number that, if the data were sorted in ascending order would be exactly in the middle) water level values and, in many cases, median water levels in the wells differ significantly from mean water level values. **Because the action levels stipulated in the groundwater-monitoring program are based on three standard deviations from the *mean* water level plus one foot, this discrepancy is very significant**. The data summaries below and in Appendix B include a mean value, as well as a 'median' value (the number incorrectly reported as the mean value in the data set received from MMD) to show the difference between the two methods. The *mean* values reported here are the values that should be used when determining action levels.

All monitoring program wells exhibited problems in their compilation of background water level data, either with transducer malfunctioning (e.g. gaps in time between some measurements, periodic erratic readings, or shifts in data resulting from improper [or lack of] calibration of transducers following replacement or repair), or problems with well completions that resulted in the well collapsing. These problems are documented in reports from SRP to MMD and are summarized in Appendix F. For purposes of analysis, GGI removed data points collected when the recorders were malfunctioning.

Table 2. Summary of Raw Water Level Data

Well Name	Mean Water Level (ft)[1]	Water Level Fluctuation (ft)	Median Water Level (ft)[1]	Standard Deviation	Proposed Action Level (ft)[1,2]
FL-36	193.47	56.24	192.88	4.90	N/A
FL-36(OB1)	198.32	7.69	198.22	0.57	N/A
FL-36(OB2)	239.94	364.55	239.34	11.86	203.36
FL-36(OB3)[3]	-14.86	3.99	-14.54	1.43	-20.15
FL-36(OB4)	99.33	72.75	99.68	8.14	72.91

[1]Negative values indicate depth to water, positive values are potentiometric heads above ground level

[2]Based on mean water levels and standard deviations from the available data set and the action level criteria outlined by SRP and MMD

[3]Well FL-36(OB3) has collapsed and is not accurately monitoring the Dakota aquifer, two years of additional data (post 5/1/01) must be gathered and analyzed for the statistics to be meaningful.

A summary of mean and median (reported as mean in the electronic files provided to GGI) water levels, standard deviations, and proposed action levels (for monitoring wells only) are included for both the raw (Table 2) and corrected (Table 3) data. Even a cursory review of these summary statistics reveals that action levels in monitoring wells are significantly impacted by variations in data caused by recorder malfunctions.

Table 3. Summary of Corrected Water Level Data

Well Name	Mean Water Level (ft)[1]	Water Level Fluctuation (ft)	Median Water Level (ft)[1]	Standard Deviation	Proposed Action Level (ft)[1,2]
FL-36	193.04	2.03	192.86	0.54	
FL-36(OB1)	198.33	2.30	198.22	0.57	
FL-36(OB2)	239.54	2.15	239.34	0.56	236.86
FL-36(OB3)[3]	-14.82	4.07	14.47	1.46	-20.20
FL-36(OB4)	99.88	3.08	99.76	0.53	97.29

[1]Negative values indicate depth to water, positive values are potentiometric heads above ground level

[2]Based on mean water levels and standard deviations from the available data set and the action level criteria outlined by SRP and MMD

[3]Well FL-36(OB3) has collapsed and is not accurately monitoring the Dakota aquifer, two years of additional data (post 5/1/01) must be gathered and analyzed for the statistics to be meaningful.

Especially problematic are the unreliable data from well FL-36(OB3) (the closest well to the lake in the proposed monitoring program) and well FL-36(OB4). The problems with FL-36(OB3) are a result of poor well design and completion, and it is GGI's opinion that the base of the well collapsed, sealing it off from the Dakota aquifer. This opinion has been confirmed by BIA (King Engineering, 2001) and MMD (Monte Anderson, *pers. comm.)*. Video logs run into FL-36(OB3) revealed that the hole had collapsed (Monte Anderson, *pers. comm.)* and MMD required SRP to repair the well.

A drawing of SRP's recompletion of OB3 was submitted to MMD and received by GGI on May 24, 2001. SRP specifically states that "an obstruction (apparently comprised of swollen clay and shale) was detected near the base of the well casing." **SRP's statement regarding the "swollen clay" supports GGI assertion that the Mancos Shale acts as a confining bed, especially since the shale swells when wetted.**

The proposed recompletion of OB3 is a difficult undertaking, especially placing two bentonite seals below the water table in a well that has a history of collapse with an annular space of only 1.25 inches (4 ¾ in open hole and 2 in [2 ¼ in o.d.] steel piezometer). Prior to MMD accepting that this well has been properly recompleted, SRP should be required to provide: (1) copies of all field notes and measurements from the recompletion of OB3; (2) drillers notes and activity sheets; (3) copies of drillers bid sheets/completion specifications, and (4) copies of drillers invoices. None of the data collected from FL-36(OB3) to date should be used to construct a baseline data set and to determine cutoff action levels because there is no way of knowing exactly when the hole collapsed. **Documentation of repairs to FL-36(OB3) must be provided to GGI and Zuni for evaluation purposes.**

An additional two years of data from the date that the well was repaired and the water level returned (or returns) to static in FL-36(OB3) must be collected to comply with the requirement of two years of data collection for establishment of baseline conditions and statistical calculations of cutoff action levels.

Data gaps observed in FL-36(OB4) are symptomatic of one of the problems with the monitoring well network: there are no backups for transducers which, in the course of ordinary monitoring, periodically cease operating properly. In well FL-36(OB4), there are gaps in the data of 23, 16, 18, and 47 days, with an additional period of 34 days when the data logger was recording water levels but the data fluctuated greatly (over 72 feet of fluctuation), indicating a recorder malfunction. Similar data gaps and transducer malfunctions are seen in the other monitoring wells (FL-36(OB2) and FL-36(OB3), as well as the wells not in the monitoring network. If action levels were to be exceeded during one of these periods of recorder malfunction, it could go undetected for weeks or months (if the current records are an indication), and by the time it was discovered and pumping ceased, Zuni Salt Lake could already have been impacted, and irreparably damaged.

Proposed "Monitoring Program Pump Test"

The ground water monitoring plan for the Dakota aquifer, as outlined in modification 97-02 to the PAP prohibits the use of water from FL-36, for mining purposes, until at least two years of monitoring data have been collected from the Dakota monitoring wells, followed by an "*extended pump test.*" According to Modification 97-02, "*MMD will determine the design and duration of the test based on the baseline data gathered.*" The purpose of the test will be to "determine the effectiveness of the monitoring program." An explanation of how the baseline data will be used by MMD to determine the duration of the "extended pump test" is not provided anywhere. The permit language appears to give MMD sole responsibility for the test design. DE&S implies that Drakos and Lazarus (1997b) did not understand the purpose of the planned "pump test" (pg. 9 of DE&S, 2001a), and OSM suggests that GGI is in agreement with the pump test as it is presented in Modification 97-02 to the Fence Lake mine permit, dated June 26, 1997 (pg. 6 of May 1, 2001 OSM Memo). Neither assertion is correct. As was clearly stated by Drakos and Lazarus (1997b), "A longer and properly configured pumping test could definitively demonstrate whether leakage occurs through the Mancos Shale, and whether pumping effects extend beyond a radius of 3708 feet." GGI reiterated its position and provided a more detailed description to Keith Kirk of OSM of the configuration of the proposed test prior to a meeting with OSM, SRP, and MMD in May, 1997 (Appendix G). MMD chose to ignore GGI's request that the test be run long enough to properly characterize the aquifer, and instead decided to require the "Monitoring Program Pump Test" "described" in Modification 97-02. Essential details of how the test will be run (pumping rate(s), duration, monitoring, etc.) were not provided in Modification 97-02. **GGI and Zuni Pueblo have never agreed to the design of this test, as is stated in the August 28, 1997 memo from Keith Kirk to OSM** (Appendix G).

GGI and Zuni are only interested in a pumping test that is designed to characterize the aquifer, as described in the May 23, 1997 Memo from Drakos to Kirk (Appendix G). MMD has never described how the "Monitoring Program Pump Test" will be used to "determine the effectiveness of the monitoring program" or to achieve any of the other stated goals of the test.

WATER RIGHTS CONSIDERATIONS

Contrary to its asserted claims (PAP, 1993/1994), SRP does not own any water rights for mining related purposes at the Fence Lake mine. Documents provided by SRP in its PAP, and records located by GGI in the OSE show that claims to ownership of water rights filed by SRP have neither been recognized (permitted) by the OSE nor adjudicated by a court of competent jurisdiction. SRP's mining-related use claims are as follows (other permits and declarations of ownership filed by SRP are for relatively small amounts of water for stock and domestic purposes):

Table 4. Summary of SRP Declared Water Rights					
Declaration Number	**OSE File Number**	**Common Name**	**Source Aquifer**	**Quantity Ac-ft/yr**	**Land Ownership**
02-153	G-537	FL-36	Dakota	484	State Land
02-154	G-538		Alluvium	322	State Land
02-155	G-539		Alluvium	80	State Land
NA	G-293	Atarque Prod. Well	Atarque	161	State Land
NA	G-294	FL-36(OB1)	Dakota	484	State Land

These declarations are problematic for the following reasons:

1. In its PAP (1993/1994) SRP is claiming that its maximum annual water requirement will be 85 gpm, or 137 acre-feet. Since the five declarations are for the same mine, any claim to a water right in excess of 137 acre-feet is speculative and would be disallowed by the OSE under its current practice for evaluating declarations.

2. SRP's claim that the source of water under declarations G-294 and G-537 is the Dakota Sandstone is not consistent with hydrologic claims made by SRP that the source of water to these wells is leakage from the overlying Mancos Shale.

3. All five declarations were filed on wells located on public lands under the control of the State Land Office (SLO). In accordance with the Pettibone Decision of the Montana Supreme Court, the SLO does not recognize private claims of water right ownership on public lands. SRP only has an exclusive right to use sufficient water to meet the purposes of the mine (SLO council B. Frederick, pers. comm., 2001).

The Zuni have been utilizing the waters of Zuni Salt Lake throughout the Tribe's history, i.e. from time immemorial. Any water usage by SRP at the Fence Lake Coal Mine is junior and subordinate to Zuni's uses. The changes in water quality and water quantity at ZSL that will result from SRP's groundwater diversions could constitute impairment of Zuni's senior water right, and would be subject to injunction and/or decision to prohibit usage from the declared wells.

CONCLUSIONS

1. SRP has identified and completed production wells into three aquifers within the coal lease area: the Dakota Sandstone, the Atarque Sandstone, and Quaternary alluvium.

2. GGI's analysis of SRP pumping test data from Dakota Sandstone wells FL-36 and FL-36 (OB1) demonstrates that the Dakota Sandstone responds to pumping as a confined aquifer within the study area. This assessment is supported by analyses of the same data conducted by BIA (King Engineering, 2001) and the OSE (Core, 1996).

3. The proposed Fence Lake Coal Mine, Zuni Salt Lake, and Nations Draw lie along the Jemez Lineament. GGI's analysis of Cretaceous formation outcrops located northwest of Zuni Salt Lake shows that the Atarque Sandstone and the main body of the Dakota Sandstone are highly fractured with numerous, open fractures. Video logs show that the Dakota Sandstone is fractured in the subsurface at the location of the pumping well (FL-36) (McGurk and Stone, 1986). The Whitewater Arroyo Tongue and Rio Salado Tongue of the Mancos Shale do not exhibit open fracturing. The interbedded Paguate and Twowells Tongues of the Dakota Sandstone are thin, moderately fractured, poorly sorted, interbedded sandstone beds within the Mancos Shale. SRP's contention that the Mancos Shale is fractured with open, transmissive fractures is contradicted by field observations, as well as their own geologic investigations identifying bentonite aquicludes within the Mancos Shale.

4. The Dakota Sandstone is continuous in the subsurface between the proposed Fence Lake Coal Mine and Zuni Salt Lake. Pumping effects from the proposed Fence Lake Coal mine or (in the case of Myers [1992]) a hypothetical coal mine in the San Augustine coal fields will propagate to Zuni Salt Lake and affect water levels and water chemistry in the lake, as was concluded by Myers (1992), Page (1993), Core (1996), GGI (Drakos and Lazarus, 1997b), and BIA (King Engineering, 2001). These studies all contradict and cannot be reconciled with the assertion made by SRP and contained in the CHIA (1994), PAP (1993/1994), and FSEIS (1996) that pumping effects will not extend beyond a radius of 3700 or 3708 feet from FL-36 during the life of the proposed Fence Lake Mine.

5. Based on GGI's model, estimated drawdown at Zuni Salt Lake resulting from pumping 85 gpm for 40 years is between 4 and 5 feet. Since Zuni Salt Lake is usually less than 4 feet deep (Myers, 1992), pumping 85 gpm from the Dakota aquifer for 40 years at the proposed Fence Lake Coal Mine will dramatically affect the water balance, salt formation, and water levels in Zuni Salt Lake. Initial drawdown effects could be transmitted to the lake in less than 18 months. These impacts would adversely affect uses of Zuni Salt Lake by the Zuni Tribe and could devastate the lake.

6. Based on results of the GGI Theis model, pumping 137 ac-ft per year at the Fence Lake Mine for 40 years will result in significant drawdown effects on Zuni Salt Lake for more

than 110 years after pumping ceases at the mine. GGI's modeling also demonstrates that significant delayed and residual effects will occur at Zuni Salt Lake long after SRP ceases its groundwater diversions at the Fence Lake Coal Mine.

7. Drawdowns at Zuni Salt Lake may have been substantially underestimated by all investigators using analytical methods that do not account for preferential drawdown in the Dakota Sandstone along the structurally controlled Nations Draw photolinear.

8. The monitoring well network currently in place in the Dakota aquifer is poorly designed and is insufficient to accurately predict drawdown and delayed and residual effects of pumping. These proposed monitoring well network will not prevent harm to Zuni Salt Lake as a result of pumping from the Dakota aquifer at the mine site.

9. It is unscientific and extremely risky to ignore SRP's pumping effects and act as if monitoring wells will 'protect' the lake. Geologic/hydrologic evidence demonstrates overwhelmingly that the SRP/MMD analysis is wrong; the only appropriate course for MMD now is to recognize that and exclude usage of the Dakota aquifer by SRP.

10. The required two-year baseline monitoring data should start after SRP has documented proper recompletion of well FL-36(OB3)

11. Until SRP has properly characterized the Dakota Sandstone aquifer system, a water level monitoring program cannot be properly designed. Neither FL-36 (OB2) nor any of the other existing monitoring wells provide any realistic protection for Zuni Salt Lake. The lake could be seriously harmed in a relatively short time frame, while MMD is debating whether the 'action levels' have been met; it is dangerous and professionally unacceptable to rely on a 'monitoring well field' designed and interpreted by those who refuse to correctly and completely characterize the aquifer they propose to monitor.

12. GGI's evaluation of existing pumping test data, fracture patterns observed in outcrops, and evaluation of all other available data from the PAP (1993/1994) and area geohydrology studies, indicate that no evidence exists for calculating long-term drawdowns in the main body Dakota Sandstone aquifer in the Nations Draw area between the Fence Lake Coal Mine and Zuni Salt Lake using leaky-confined aquifer analytical methods.

13. Groundwater diversions by SRP at the Fence Lake Coal Mine will upset the hydrologic balance of Zuni Salt Lake and its associated aquifers. Both the quantity and quality of water in Zuni Salt Lake will be adversely impacted by the proposed groundwater diversions both during and long after the period of mine operation.

14. The analytical methodology used by SRP to calculate drawdowns in the Dakota Sandstone aquifer does not represent the hydrologic regime of the Fence Lake Coal Mine area. Numerical modeling is the best available methodology for properly and completely

evaluating all aspects of the hydrologic regime associated with the mine area and Zuni Salt Lake.

15. There is no record of SRP's ownership of water rights for mine related uses.

16. The Zuni have been utilizing the waters of Zuni Salt Lake since time immemorial. Any water usage by SRP at the Fence Lake Coal Mine is junior and subordinate to Zuni's uses. The changes in water quality and water quantity that result from SRP's groundwater diversions could constitute impairment of Zuni's senior water right. The monitoring program proposed by SRP and supported by MMD will not protect the senior water rights of Zuni Pueblo.

17. **SRP/MMD must conduct a long term (30 day) pumping test at a discharge sufficient to stress the Dakota aquifer (~300 gpm). Prior to conducting the pumping test, additional monitoring wells need to be installed at the locations and in the formations specified in this report on pages 57-58, 62-63, and Appendix G. Only by conducting such a test can the Dakota aquifer by adequately characterized in such a way as to allow accurate predictions of the effects of pumping at the mine site on Zuni Salt Lake.**

RECOMMENDATIONS

Testing of Dakota Sandstone Aquifer

Modification 97-02 to the PAP (June 26, 1997) states that:

> "Prior to SRP being allowed to use any water for mining or construction purposes from FL-36 and after at least 2 years of baseline data has been gathered, an extended pumping test of the monitoring program for the Dakota aquifer will be performed. MMD will determine the design and duration of the test based on the baseline data gathered. The data collected during the pump test will be gathered from the following wells: FL-36(OB1), FL-36(OB2), FL-36(OB3) and FL-36(OB4). All data will be provided to MMD. MMD will evaluate the test results to: (a) determine the effectiveness of the Dakota aquifer Monitoring program, (b) make any modifications to the monitoring plan that are necessary as a result of the test and (c) assure that the cut-off action levels are appropriate to adequately protect Zuni Salt Lake from adverse affects. Zuni will be allowed to have observers present during the test period."

GGI has consistently stated over the past five years that a pumping test such as the one vaguely outlined above is not sufficient for numerous reasons. As previously discussed, the pumping test data compiled by SRP exhibit no evidence for characterizing the Dakota Sandstone as a leaky confined aquifer. A longer and properly configured pumping test could definitively demonstrate: (1) whether leakage occurs through the Mancos Shale as SRP contends, (2) whether pumping effects extend beyond a radius of 3708 feet, and (3) the magnitude and extent of delayed and residual effects of pumping. Based on the OSE's analysis and conclusions, SRP should perform a long term pumping test at a pumping rate of ~300 gpm to adequately stress the aquifer at FL-36. The pumping test should be run for 30 days or until SRP has measured substantial drawdown at FL-36 (OB2). The monitored recovery period should last for at least twice the length of the pumping phase, or until full recovery is measured in all wells that register drawdown during the pumping phase.

If a maximum of 1.5 feet of drawdown is observed at FL-36(OB3), the test should be terminated. Existing wells in the Atarque Sandstone, Moreno Hill Formation and the Dakota Sandstone aquifers should be used as observation wells. An additional water level observation well should be drilled into the Dakota aquifer between 5000 and 8000 feet to the southwest of FL-36.

Additional observation wells should be drilled into the Mancos shale and into the Paguate or Twowells Members of the Dakota Sandstone to determine the effects on these units from drawdown in the Main Body Dakota Sandstone.

The pumping test proposed by GGI is similar to the test configuration GGI and Zuni Pueblo requested in 1997, and should not be confused with the "Monitoring Program Pump Test" mentioned in MMD's Dakota Monitoring Plan Modification 97-02 (1997). **GGI and Zuni Pueblo have never agreed to MMD's proposed "Monitoring Program Pump Test" because it is not specifically designed be run long enough to evaluate the proper characterization of the aquifer.** GGI's objections to the design of the "Monitoring Program Pump Test" are detailed in a memo from GGI to Keith Kirk of OSM dated May 23, 1997 and an internal OSM memo dated August 28, 1997 (Appendix G).

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APPENDIX A: RESPONSES TO DE&S COMMENTS ON BIA REPORT

Duke Engineering & Services (DE&S), a Duke Energy Company, released a report entitled Comments on King Engineering's Report Entitled, "Potential Hydrological Impacts of Pumping at Fence Lake Coal Mine on Zuni Salt Lake" on April 24, 2001. The primary purpose of the DE&S report appears to be to discredit the BIA Report (King Engineering, 2001) and to cause as much confusion as possible regarding hydrologic issues associated with pumping from the Dakota aquifer at the proposed Fence Lake Mine. No authorship was given for the report. DE&S relies in many instances on unsound hydrology, selective citations of literature, and misrepresentation of previous work. GGI has therefore limited our references to the DE&S report in the main body of our report. However, because some statements contained in the DE&S report are incorrect and misleading, GGI believes it is necessary to address some of them in this appendix to refute their claims. While this appendix is by no means comprehensive (it would require a point-by-point write up of the DE&S report to address all of the problems contained therein), it addresses some of the misleading statements and conclusions made by DE&S.

Geology of Zuni Salt Lake Area

DE&S is critical of the BIA Report's description of the geology in the vicinity of ZSL. DE&S states that "Figure 2 of King Report fails to show the presence of the Permian rocks below the Triassic Chinle Formation…" (pg 5). Rocks below the Triassic Chinle Formation are clearly labeled on Figure 2 of the BIA report as "Undifferentiated Paleozoic Rocks," which all geologists should know include Permian rocks (the Paleozoic *Era* includes the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian *Periods*).

DE&S further demonstrates a lack of understanding of geology when arguing that King is incorrect in suggesting that the Atarque Sandstone discharges water to ZSL because, "The Atarque is mapped by Cummings (1968) as being some 500 feet above the lake surface on the west side of ZSL…" The Atarque west of the lake is offset across the Zuni Salt Lake fault west of ZSL, and is 500 ft above the lake surface where it is on the upthrown side of the fault. However, King Engineering cited Anderson (1994), *Geology of the Zuni Salt Lake 7½ Minute Quadrangle*, which shows the Atarque Sandstone in the crater wall of the ZSL maar (east of the ZSL fault, on the downthrown side of the fault), and shows the Atarque Sandstone below lake level in the accompanying cross section. Furthermore, SRP states in the PAP (1993/1994 p. 12-39) that the Atarque Sandstone is present in the walls of the maar. GGI confirmed that Atarque Sandstone is present in the maar wall on the north side of ZSL where the coquina near the top of the Atarque Sandstone was observed; it is possible that seeps and springs located on the northeast side of the floor of the maar discharge along the contact between the base of the Atarque and the top of the Mancos, or discharge from beds within the Atarque sandstone.

DE&S states that, *"Further observations of geologic maps in the region (e.g., McGurk and Stone, 1986; Campbell, 1989; and Chamberlin et al., 1994) show that it is common for other major faults to have orientations other than southwest to northeast, and that these faults may intercept the southwest-northeast trending ones at angles anywhere from 30 to 90 degrees. Accordingly, it is incorrect for the King Report to subsequently conclude that faults in the study area result in preferential flow along a southwest-northeast line." (p. 17).* This statement is untrue. All faults (major and minor) in the area of study shown by Chamberlin et al. (1994) trend to the northeast. It is only to the south (~20 miles south of the mine) that any faults shown (major or minor) have anything other than a northeast trend. Similarly, the only non-NE trending faults shown by Campbell (1989) are either located west of the Moreno Hill/ZSL fault or are very minor (intraformational) faults north of the study area. The Tejana Draw Fault, according to SRP structure contour maps of the mine area, dies out before encountering Nations Draw. GGI has repeatedly been denied access to the McGurk and Stone map(s) cited by DE&S and, therefore, cannot evaluate the alleged northwest trending faults shown on the map.

In a follow up to the previous misstatement, DE&S states that, *"Given that neither of these faults identified in the McGurk and Stone (1986) investigation* [Tejana Mesa Fault North and Tejana Mesa Fault South] *show vertical displacements larger than 250 feet, and the fact that the Zuni Salt Lake Fault terminates about 3 miles west of the FLM, there is no evidence to indicate that vertical offsets of 600 to 700 feet will occur on or close to FLM lease property." (p. 17)* The information provided in this statement demonstrates that these structures could very likely have an influence on groundwater flow in the area. A maximum offset of 105 feet is all that is needed to place the thickest section of the Dakota Sandstone against a shale or other low permeability rock (either the Mancos Shale or the Chinle Formation), thereby inhibiting flow into the Dakota.

Because these faults are located to the northeast of the "volcanic features where recharge is suspected," they would, in effect, isolate Nations Draw from these purported recharge sources. However, it is GGI's opinion that the volcanic features referred to by DE&S are not zones of recharge (see below)

Groundwater Recharge to the Dakota Aquifer

In order to support their conclusion that drawdown in the Dakota aquifer as a result of pumping at the mine site will be minimal, DE&S asserts that recharge to the Dakota occurs through fractures in the volcanic terrain near the mine and across faults and fractures in the Mancos Shale. In theory, fractures can be pathways for recharge to confined aquifers. However the available data do not support this assertion for the mine area. The 1990 draft SEIS and McGurk and Stone (1986) assert that "pump tests showed no evidence of a vertical connection between the underlying sandstone and the alluvium."

In addition, both the ESA and DE&S fail to note that the gradient between the deeper Dakota aquifer and the purported pathways of recharge is in the upward direction. DE&S presents the conjecture that all volcanic features in the area are conduits for rapid recharge to the Dakota aquifer. In areas where the Dakota aquifer is under artesian pressure, volcanic features that intrude the subsurface strata with fractures open to the depth of the Dakota Sandstone would allow groundwater to well up to the surface where it would discharge as springs (or, in the case of ZSL, as a lake). Springs are not present around the base of Cerro Prieto, nor around the other volcanic features listed by DE&S.

DE&S also argues that the relative freshness of water in the Dakota sandstone is proof of the presence of a nearby source of recharge (based on the assumption that the longer water is in an aquifer, the higher the concentrations of total dissolved solids will be). However, proximity to the area of recharge is only one explanation for the chemical characteristics of groundwater. The chemical makeup of the host rock plays a large role in determining the chemistry of the groundwater (the water cannot take into solution that which is not present in the host rock), so stating that the water quality in the Dakota aquifer in the FLM vicinity is good does not prove that rapid recharge is occurring. In addition, in fractured sandstone aquifers with low interstitial permeability, ground water flow is limited to movement through highly transmissive open fractures and little dissolution of interstitial cement occurs. Furthermore, DE&S ignore the fact that McGurk and Stone (1986) report that some of the water in the shallow subsurface in the vicinity of the mine is thousands of years old.

Characterization of the Dakota Aquifer

DE&S contends that data from pumping tests and reports in published literature indicate that the Dakota aquifer is a leaky aquifer that is receiving recharge from nearby sources. This contention is (despite their attempts to show otherwise) supported neither by pumping test results nor by published geological accounts. DE&S misused pumping test data and misquoted other workers to support their position.

DE&S's citation of Myers (1992) in support of the DE&S contention that recovery data from the FL-36 pumping test performed by SRP in 1983 are indicative of recharge to the aquifer is unfounded and untrue. This assertion is made multiple times, including on pg. 11, 12, and 16. Myers (1992) discusses the 1983 pumping test on pg. 10 of his report, where he provides information on pumping rate and duration of the test, and reported calculations of transmissivity (T) and hydraulic conductivity (k) from SRP (1983). The only statement Myers makes about the recovery data is that "Artesian flow resumed within 3 minutes after the test was completed." Myers (1992) makes no inferences regarding recharge based on the recovery data. GGI's interpretation of the available information (GGI has never been provided with data from this test, other than that reported by Myers [1992]) is that the recovery data as presented are meaningless. It is important to keep in mind that the artesian pressure in FL-36 corresponds to a static water level of 193.4 ft. **above ground surface** (based on transducer readings provided to GGI by MMD), so the only inference to be made is that the well recovered to within approximately 193.4 ft of static water level three minutes after the pump was shut off. The most likely explanation for this rapid recovery within the first 3 minutes of shutting off the pump is casing storage effects (which we know were large for the test on FL-36(OB1)), and well inefficiencies. It is GGI's opinion that DE&S's citation of Myers (1992) in support of the DE&S contention that recovery data from the FL-36 pumping test performed by SRP in 1983 are indicative of recharge to the aquifer is a misleading and untrue characterization of the Myers report.

To further substantiate their claim that 1983 recovery data show recharge to the aquifer, DE&S states that "Plotting recovery data from this test on semi-logarithmic graph paper (Driscoll, 1986) provides very persuasive evidence that nearby recharge is rapidly filling the well once pumping stops" (pg 12), and (referring to the rapid recovery of FL-36 to a flowing artesian state within three minutes after shutting off the pump) "Applying these data to a semi-logarithmic plot of residual drawdown versus dimensionless time (Driscoll, 1986) indicates that well FL36 is strongly affected by nearby recharge sources" (pg 13). These plots are not presented in the report, as common professional practice requires (see Drakos and Lazarus, 1997b). GGI has never been provided with data from the 1983 pumping test on FL-36, nor has GGI been given a copy of the internal SRP (1983) report, *Fence Lake Coal Leasehold Water Well Drilling and Testing*. GGI requested data from the 1983 pumping test in 1996 (Deposition of Lluria).

DE&S subsequently uses this unsubstantiated assertion of recharge to the aquifer as conclusive evidence to substantiate its claims of recharge to the aquifer, including on pg. 4, 12, 13, 16, 53, 54, and 56. Interestingly, at hearing in 1996, SRP did not attempt to rely on this 1983 test to support their hypothesis on recharge. Instead, they relied only on the two 1994 'pump tests' described in the main body of this report (beginning on page 36).

DE&S misrepresents both Myers (1992) and King Engineering (2001) in their argument presented on pg. 9 of the DE&S report, by stating that "The King Report misuses the Myers (1992) analysis by stating that Myers concluded the Dakota Sandstone was confined." On pg. 23 of Myers (1992), he states: "Because the main body of the Dakota Sandstone is a confined aquifer, the withdrawal of water could lower water levels in wells completed in the aquifer throughout a large area." Myers goes on to use the Theis method of analysis to predict drawdown in a confined aquifer for a variety of pumping scenarios and aquifer parameters to predict potential water-level declines in the main body of the Dakota Sandstone. Nowhere in the Myers (1992) report does he suggest that the body of the Dakota Sandstone be treated as anything but a confined aquifer.

Monitoring Well Network

DE&S's comments on the BIA Report devotes seventeen pages to an attempt to dispute the conclusions of the BIA Report regarding the problems with the monitoring well network and monitoring program design. The three basic unfounded arguments that DE&S makes in their monitoring well sections are: (1) King Engineering's analysis of all wells completed into the Dakota rather than only data from the wells that will be used in the monitoring program results in an inaccurate characterization of the monitoring program as inadequate, (2) The fact that geophysical logs in wells FL-36(OB2) and FL-36(OB4) do not penetrate the Dakota is not an indication of faulty well design because "both wells were flowing naturally after being drilled, making it impossible to lower the logging tool to the full boring depth," and (3) The extensive problems with well FL-36(OB3) documented in the BIA Report are of no consequence because, "DE&S understands that well OB3 has been repaired" (a statement repeated in various forms dozens of times in the DE&S report). DE&S also devotes a significant amount of space to critiquing the statistical methods used in the BIA Report. While GGI does not agree with DE&S's statistical arguments, the differences in DE&S's statistical results and those reported in the BIA report are relatively insignificant with respect to the major points listed above, and GGI will therefore not address these statistical issues in this report.

The DE&S report states that, *"The King Report's analysis of the monitoring wells is flawed and biased because it includes three wells that are not part of the FLM monitoring plan: FL36, OB1 and OB Jerry" (p. 19)*. While it would be incorrect to use these three wells to determine the action levels for the monitoring network (based on the proposed monitoring network as it now exists), these wells are completed into the same aquifers as the wells to be used in the actual monitoring network and, as such, a study of water levels in these three wells is relevant to the behavior of the aquifer as a whole. Furthermore, SRP's Dakota aquifer Monitoring Plan section of Modification 97-02 to the PAP (dated June 26, 1997) states that:

> "Of the six SRP wells which intersect the Dakota aquifer (FL-36, FL-36(OB1), FL-36(OB2), FL-36(OB3), FL-36(OB4), and the Jerry Monitoring Well), only one will be used for the mine water supply, namely FL-36. *All of the wells were drilled to assess the aquifer while only three of the wells (FL-36(OB2), FL-36(OB3), FL-36(OB4)) will be used to monitor the aquifer* [emph add]. The

> monitoring program is designed to ensure that use of the Dakota aquifer will not adversely affect Zuni Salt Lake.
>
> In particular, SRP will:
>
> 1. Install pressure transducers and recorders on FL-36, FL-36(OB1), FL-36(OB2), FL-36(OB3) and FL-36(OB4) *to further refine baseline aquifer data and to expand the historic data collected from the Dakota Aquifer* [emph. add]."

These statements from SRP make it clear that they recognized that data from wells not in the monitoring plan would be analyzed to characterize the aquifer, that to do so was important if Zuni Salt Lake was to be protected; it was therefore proper for King Engineering to include these data in their analyses. The fact that DE&S states that an analysis of data from wells not in the monitoring program was incorrect suggests that either they did not thoroughly review the PAP and supplements to the PAP, or they were selectively citing the PAP/supplements with the hope that the discrepancy would go unnoticed. King Engineering's conclusion that the monitoring well network is inadequate to protect Zuni Salt Lake, while taking into account data from wells not being used to establish cutoff levels, was based primarily on problems with wells designed to be used in the monitoring program. Specifically, the ineffectiveness of monitoring well FL-36(OB3) and questions about exactly what formations wells FL-36(OB2) and FL-36(OB4) are monitoring led King Engineering to the conclusion that the current monitoring network will not prevent harm to Zuni Salt Lake as a result of pumping at the Fence Lake Mine. GGI is in agreement with King Engineering.

The BIA Report points out that, "...geophysical logs point to a potential problem in OB2 and OB4. In these wells the electric logs either do not penetrate the full thickness of the main Dakota Sandstone or do not penetrate it all. It may be because the Mancos shale has sloughed and filled the bottom of the hole with cave between drilling and geophysical logging." DE&S explains the lack of complete geophysical logs by stating, "The electric logs did not extend to the full drilling depths of these two wells because both wells were flowing naturally after being drilled, making it impossible to lower the logging tool to the full boring depth." **This statement from the DE&S (2001a) report is incorrect.** *Artesian wells are commonly logged to full depth. Once the threshold pressure at the top of an artesian boring or well is overcome, the hole can be logged to total depth* (Mick Peterson, Southwest Geophysical Services, Inc., *pers. comm.* 5/14/01). In other words, if the logging tools could be lowered through the units overlying the Dakota Sandstone, they could have been lowered into the Dakota unless something was blocking the hole. In a conflicting report, the OSM memorandum (dated May 1, 2001) states that, "...SRP responded to this issue...by explaining that the logs were run prior to setting casing and prior to drilling through the Dakota Sandstone." While this method of completion and logging could explain why there are no logs of the Dakota Sandstone, the dual explanations cast doubt on the SRP's statements and field techniques. Specifically, it demonstrates that SRP gave conflicting reports of how the well was constructed and how geophysical logs were run to OSM and presumably to their own consultants (DE&S).

Furthermore, the explanation given to OSM makes little sense; even if the geophysical logs were run prior to drilling into the Dakota, it would be expected that logs would be run into the Dakota after casing the upper part of the hole and drilling into the Dakota to: (1) ensure that it really was the Dakota, (2) characterize the fracturing and geohydrologic properties of the Dakota in these locations, and (3) get an indication of water quality in the Dakota at these locations. Another puzzling aspect of the lack of geophysical logs from FL-36(OB2) and FL-36(OB4) is that geophysical logs do penetrate the full thickness of the Dakota Sandstone in FL-36(OB3), begging the question of why SRP would drill through the Dakota before logging FL-36(OB3) but not drill into the Dakota before logging FL-36(OB2) and FL-36(OB4). There may be a logical explanation for this, but until <u>one</u> consistent explanation is provided by SRP, the possibility remains that there were problems during well construction (i.e. something blocked the hole, preventing the logging tools from penetrating the Dakota) and that the fractured Dakota Sandstone has collapsed where the hole is not cased, and that such wells have not served as efficient monitoring wells in the past, and cannot serve as effective monitoring wells in the future.

The result of these conflicting (and in the case of DE&S, incorrect) explanations of the lack of complete geophysical logs suggests that there may indeed be serious problems with the completion of wells FL-36(OB2) and FL-36(OB4). Therefore, without further documentation of logging methods and problems encountered during logging, it cannot be stated with certainty that the hole remains open across the Dakota Sandstone.

While most reviewers of the well data suggest that it is probable, based on the positive correlations between FL-36, FL-36(OB1), FL-36(OB2) and FL-36(OB4) that OB2 and OB4 are currently monitoring the Dakota aquifer (King Engineering, 2001; DE&S, 2001a; OSM, 2001), they neglect the very real possibility that future collapses of the borehole(s) could cause significant problems with the monitoring network. OSM, in its response to questions raised in the BIA Report regarding the construction of monitoring wells, states, "All of the monitoring wells were completed by engineering companies (Halliburton and America Energy, Inc.) certified by the State of New Mexico…all of the wells were cemented using the casing method of grouting (originally known as the Halliburton method), thereby eliminating cementing problems." This indicates that all of the wells were completed in a similar, if not identical, fashion and, unless SRP can document otherwise, it must be assumed that this is the case. This again raises the question of why geophysical logs penetrate the Dakota in FL-36(OB3) but not in FL-36(OB2) and FL-36(OB4). Beyond that, the collapse of FL-36(OB3) and its subsequent inability to monitor the Dakota aquifer (see Appendix F), indicates that there is a very real possibility that similar problems could arise in wells completed into the same rock unit using the same completion methods. Well completion diagrams for FL-36(OB2) and (OB4) show that the Dakota aquifer has been left as an open hole. As such, these wells should be videologged to determine whether the Dakota has collapsed, as the Mancos and/or Dakota did in FL-36(OB3).

DE&S's goes on to argue that King Engineering's conclusion that well FL-36(OB3) was completed improperly and is not monitoring the Dakota aquifer is not important because, "DE&S understands that well OB3 has been repaired." In fact, based on when the DE&S report was submitted (April 24, 2001) and when, according to Monte Anderson of MMD, the well was repaired (late April, 2001) it is unlikely that well FL-36(OB3) had been repaired when the DE&S report was submitted, and had not been repaired at the time the BIA report was submitted (February, 2001). SRP should provide the OB3 recompletion data requested on page 56 of this report. However, issues of the timing of the well repairs are less important than the underlying issue: based on the data made available to GGI and OSM well FL-36(OB3) was improperly constructed in 1999, and the data that have been provided by transducers in the well are meaningless. Furthermore, it is in no way sufficient to simply report that the well has been repaired; any time modifications are made to a well, details of the modifications need to be provided so that future data collected from the well can be critically evaluated

APPENDIX B: DATA FROM SRP PUMPING TESTS AND CALCULATIONS OF CASING STORAGE EFFECTS

PUMPING TEST DATA SHEET FOR SRP 500-MIN. TEST ON DAKOTA FM OBSEVATION WELL FL-36

JOB: Zuni Salt Lake Technician: SRP presonnel
LOCATION: Fence Lake Mine, T4N, R17W, Sec WELL DEPTH: 1120 ft.
CASING TYPE: Steel/open hole MP COR: -0.67 ft.

DATE	TIME	ELAPSED TIME, t	WATER LEVEL, ft	DRAWDOWN, s, in feet	Q, GPM	COMMENTS
3/16/94		0		0.00		FL36(OB1) pumping
		8		0.00		rate = 302 gpm
		26		2.31		
		35		2.31		
		60		2.31		
		135		4.62		
		217		6.93		
		235		8.09		
		275		8.67		
		470		9.25		

GLORIETA GEOSCIENCE, INC.

PUMPING TEST DATA SHEET FOR SRP 500-MIN. TEST ON DAKOTA FM WELL FL-36(OB1)

JOB: Zuni Salt Lake   Technician: SRP presonnel

LOCATION: Fence Lake Mine, T4N, R17W, Sec 36   WELL DEPTH: 1120 ft.

CASING TYPE: Steel/open hole   Casing Diameter: 8 5/8" OD to 1023'; 6 7/8" open hole 1120'   MP COR: -0.67 ft.

DRAWDOWN DATA ONLY, FROM TRANSDUCER READINGS PROVIDED BY SRP

DATE	TIME	ELAPSED TIME, t	WATER LEVEL, ft	DRAWDOWN, s, in feet	Q, GPM	COMMENTS
3/16/94		0		0.00		Static water level as of
		0.5		33.61	311	3/16/96 = 103.04 ft.
		1		61.60		below TOC
		1.5		73.34		
		2		88.24		
		3		101.27		
		4		107.33		
		5		109.73		
		6		111.19		
		7		112.62		
		8		112.99		
		9		113.40		
		10		113.50		
		12		114.01		
		14		114.61		
		16		114.87		
		18		115.33		
		20		115.94		
		22		116.22		
		24		115.97		
		26		119.05		
		28		117.30		
		30		117.36		
		35		117.22		
		40		118.02		
		45		118.50		
		50		118.95		
		55		119.26		
		60		119.83		
		75		120.15		
		90		121.73		
		105		122.38		
		120		121.45		
		150		122.54		
		180		123.20		
		210		123.60		
		240		124.25		
		270		125.21		
		300		125.10		
		330		125.03		
		390		124.97		
		420		125.55		
		470		126.00		
		500		126.40		

PUMPING TEST DATA SHEET FOR SRP FIFTY-HOUR TEST ON DAKOTA FM WELL FL-36

JOB: Zuni Salt Lake Technician: SRP presonnel

LOCATION: Fence Lake Mine, T4N, R17W, Sec 36 WELL DEPTH: 1120 ft.

CASING TYPE: Steel/open hole Casing Diameter: 8 5/8" OD to 1023'; MP COR: MP COR: -1.2

DATE	TIME	ELAPSED TIME, t	PRESSURE (psi)	WATER LEVEL, ft	DRAWDOWN, s, in feet	Q, GPM	COMMENTS
12/13/94	12:35	0	66.0	152.46	0.00		
	13:35	60	65.5	151.31	1.16		
	14:30	115	65.0	150.15	2.31		
	15:10	155	64.0	147.84	4.62		
	17:30	295	62.0	143.22	9.24		
12/14/94	10:30	1315	55.0	127.05	25.41		
	12:45	1450	54.5	125.90	26.57		
	14:45	1570	54.0	124.74	27.72		
	15:45	1630	53.5	123.59	28.88		
	16:45	1690	53.5	123.59	28.88		
	17:45	1750	53.0	122.43	30.03		
	18:45	1810	53.0	122.43	30.03		
	19:45	1870	53.0	122.43	30.03		
12/15/94	11:35	2820	50.0	115.50	36.96		
	14:35	3000	50.0	115.50	36.96		

PUMPING TEST DATA SHEET FOR SRP FIFTY-HOUR TEST ON DAKOTA FM WELL FL-36(OB1)

JOB: Zuni Salt Lake Technician: SRP presonnel

LOCATION: Fence Lake Mine, T4N, R17W, Sec 36 WELL DEPTH: 1120 ft.

CASING TYPE: Steel/open hole Casing Diameter: 8 5/8" OD to 1023'; MP COR: -0.67 ft.
6 7/8" open hole 1120'

DRAWDOWN DATA ONLY, FROM TRANSDUCER READINGS PROVIDED BY SRP

DATE	TIME	ELAPSED TIME, t	WATER LEVEL, ft	DRAWDOWN, s, in feet	Q, GPM	COMMENTS
12/13/94		0		-0.160		Static water level as of
		0.1		16.125	311	3/16/96 = 103.04 ft.
		0.2		24.659		below TOC
		0.3		30.108		
		0.4		36.185		
		0.5		41.759		
		0.6		46.766		
		0.7		51.111		
		0.8		56.180		
		0.9		60.179		
		1		64.367		
		2		93.960		
		3		108.786		
		4		116.686		
		5		121.407		
		6		124.271		
		7		125.404		
		8		126.632		
		9		127.261		
		10		128.269		
		14		129.905		
		20		130.944		
		24		131.132		
		30		131.825		
		34		132.391		
		40		133.178		
		44		132.675		
		50		133.493		
		54		134.311		
		60		134.343		
		70		134.468		
		80		135.255		
		90		136.010		
		100		135.570		
		140		138.245		
		200		138.654		
		240		139.818		
		300		140.731		
		340		142.179		
		400		142.745		
		440		143.217		
		500		143.532		
		600		145.546		
		700		146.522		
		800		148.221		
		900		149.606		
		1000		151.179		
		1200		153.256		
		1400		154.672		
		1600		155.553		
		1800		158.605		
		2000		160.619		
		2200		162.098		
		2400		163.388		
		2600		164.049		
		2800		162.759		
		3000		163.042		

Summary of Pumping Test Data from Dakota Sandstone and Atarque Sandstone Aquifer Tests for Proposed Fence Lake Coal Mine.

Well Name	Aquifer	Total Depth (feet)	Screened or Open Interval (feet)	Pumping Test Length (minutes)	Date Start of Test	Transmissivity (gpd/ft)	Storage Coef-ficient	Source of Calculation	Solution	Comments
FL-36	Dakota Sand-stone	1080	1004-1080	1710	1983	5300	n.a.	Myers/SRP	Confined (Theis)	Test results reported in Myers (1992)
FL-36 (OB1)	Dakota Sand-stone	1120	1023-1120	500	3/16/94	8900	n.a.	GGI	Confined (Theis)	Insufficient obs. well data for curve fit
FL-36 (OB1)	Dakota Sand-stone	1120	1023-1120	3000	12/13/94	9100[A] 2000[B]	6.3×10^{-4}	GGI	Confined (Theis)	Insufficient obs. well data for curve fit
Jerry Obs Well	Dakota (?)	440	360-440	1540	3/10/94	15[C] 10[D]	n.a.	GGI	Confined (Theis)	Well is completed as open hole in Km and Kd
Atarque Production Well	Atarque Sand-stone	460	305-460	510	3/13/94	550	3.5×10^{-5}	GGI	Leaky (Hantush-Jacob)	T and S calculated from obs. well data

Notes:
[A] Transmissivity calculated from pumping well data.
[B] Transmissivity calculated from observation well data.
[C] Transmissivity calculated from drawdown data.
[D] Transmissivity calculated from recovery data.

CASING STORAGE CALCULATION FOR 12/94 PUMPING TEST

Well: ID FL - 36 (OB1)
d_c = 8" (inside diameter of well casing)
d_p = 4" (outside diameter of pump column)
Assume initial s = 65 ft.

Calculate Estimated t_c (time, in minutes, when casing storage effect becomes negligible):

$$t_c = \frac{0.6\,(d_c^2 - d_p^2)}{Q/s}$$ (see Driscoll, p. 233)

$$t_c = \frac{0.6\,(8^2 - 4^2)}{311/65} = \frac{28.8}{311/65} = 6 \text{ min.}$$

At 6 minutes, drawdown is 124.3 ft (read from time - drawdown graph). Use 124.3 ft for next calculation:

$$t_c = \frac{0.6\,(8^2 - 4^2)}{311/124.3} = 11.5 \text{ min.}$$

At 11.5 minute, drawdown is 129 ft (from time - drawdown graph). Use 129 ft for next calculation:

$$t_c = \frac{0.6\,(8^2 - 4^2)}{311/129} = 11.9 \text{ min.}$$

At 11.9 minute, drawdown is 129.3 ft (from time - drawdown graph). Use 129.3 ft for next calculation:

$$t_c = \frac{0.6\,(8^2 - 4^2)}{311/129.3} = 12 \text{ min.}$$

Thus, four iterations suggest casing storage effects will become negligible after approximately 12 minutes (e.g., t_c converges at around 12 minutes).

APPENDIX C: CORE, A., 1996, ANALYSIS OF A PUMPING TEST AT THE SALT RIVER PROJECT AGRICULTURAL IMPROVEMENT AND POWER DISTRICT PROPOSED FENCE LAKE MINE, CATRON COUNTY, NM: INTERNAL MEMO TO TOM MORRISON, CHIEF, HYDROLOGY BUREAU, OSE.

MEMORANDUM

EXHIBIT
ZUN14
BEAN & ASSOCIATES.

May 3, 1996

TO: Tom Morrison, Chief, Hydrology Bureau

FROM: Andy Core, Hydrology Bureau

SUBJECT: Analysis of a pumping test at the Salt River Project Agricultural Improvement and Power District proposed Fence Lake Mine, Catron County, NM

RE: 02-153, 02-154, 02-155, G-293 thru G-296

Summary

An interagency request for input on the adequacy of a pump test conducted at the prop[illegible] Fence Lake coal mine was received and a memorandum of findings prepared. The conclusions are: 1) the test was adequate to allow estimates of aquifer parameters to be made, 2) drawdown calculations indicate that adequate water appears to be available for the projected mine life at the projected rates of pumping, and 3) that the observation well most distant from the pumping well will experience a drawdown during the life of the mine.

Introduction

The Mining and Minerals Division of the NM Energy, Minerals & Natural Resources Department (MMD) made a formal request for aid, dated April 18, 1996, regarding the adequacy of a pump test conducted at the proposed Fence Lake coal mine belonging to the

Salt River Project Agricultural Improvement and Power District (SRP). The proposed mine area covers portions of T3N and T4N, R16W and R17W, NMPM, Catron County, NM. Declarations of Ownership of Water Rights numbered 02-153, 02-154, and 02-155, were filed with the State Engineer Office (SEO) on November 23, 1983, prior to declaration of the Gallup Basin extension by the State Engineer on March 14, 1994. New declarations, numbered G-293, G-294, G-295 and G-296, dated April 21, 1994, were filed with the SEO on April 22, 1994. The quantity of water appropriated as it appears upon the face of those declarations totals 1,595 acre-feet per annum (AFY). The pump test in question is associated with 02-153 and G-294. The test took place starting December 13, 1994 and lasted for 50 hours at a pumping rate of 311 gallons per minute (gpm).

The MMD request was specifically that the State Engineer provide an opinion concerning three issues: 1) was the pump test "adequate to provide information on the capability of the production well to fulfill the mines future water needs", 2) " whether the test was adequate to test the observation well OB-2", and 3) "whether at the predicted pumping rate of 85 gpm the OB-2 well would see a drawdown".

Analysis

The attached Table 1 indicates the location, depth, and open intervals in the pumping and observation wells. Drawdown data for the three wells were provided for the test period but recovery data were not submitted. Figure 1 shows the semi-logarithmic plot of the drawdown in the pumping well [G-294, FL 36 (OB-1)]. Figure 2 shows the semi-logarithmic plot of the drawdown in the near observation well [02-153, FL 36]. The test was conducted in the main body of the Cretaceous Dakota Sandstone which is confined and under considerable artesian pressure in the mine area. The shape of the drawdown curve of the pumping well suggests that fractures might play a role in porosity development within the Dakota aquifer (Kruseman and de Ridder, 1991, p. 50). However, no data was found to indicate the position of fractures or other boundaries. Therefore, no boundary conditions were introduced to the calculations described below.

Estimates of transmissivity (T), utilizing the Cooper-Jacob Method, made from middle and late pumping times on the pumping and observation well drawdown curves ranged from 2,353 to 8,849 gallons per day per foot (gpd/ft). This compares favorably with a value of 5,300 gpd/ft reported by SRP (U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement, May, 1990). However, I believe that an average value of 2,500 gpd/ft estimated from the late time data is probably more representative of conditions near the test site. An estimate of 0.00049 for the storativity (S) of the aquifer was made from the observation well data.

To assess the probable effects of pumping during the operation of the mine and utilizing the Theis Equation program which is the standard within the SEO, two sets of estimates of drawdown due to pumping were made for the pumping and observation wells listed in Table 1. The first set assumed a T of 5,300 gpd/ft, an S of 0.00049 and two pumping rates: 5 years of pumping at 75 gpm followed by 35 years of pumping at 85 gpm. Those pumping rates are predicted by SRP to represent the actual mine life (M. Anderson, pers. comm.). The second set assumed a T of 2,500 gpd/ft, an S of 0.00049 and two pumping rates: 5 years of pumping at 75 gpm followed by 35 years of pumping at 85 gpm. Table 2 indicates the drawdown results at various times.

To assess the probable effects of pumping on the distant observation well during the pump test and, again, utilizing the Theis Equation program, two sets of estimates of drawdown due to pumping were made for the pumping and observation wells listed in Table 1. The first set assumed a T of 5,300 gpd/ft, an S of 0.00049 and one pumping rate: 311 gpm. The second set assumed a T of 2,500 gpd/ft, an S of 0.00049 and one pumping rate: 311 gpm. Table 3 indicates the drawdown results at various times.

Conclusions

1) The pump test was conducted in such a fashion as to allow reasonable estimates of the aquifer parameters to be made.

2) Drawdown estimates using the aquifer parameters estimated from the pump indicate that the wells at the test site will not be dewatered by pumping at the projected rates during the life of the mine.

3) Drawdown estimates using the aquifer parameters estimated from the pump test data indicate that the far observation well would probably experience up to 18 feet of drawdown due to pumping at the projected rates during the life of the mine.

4) Drawdown estimates using the aquifer parameters estimated from the pump test data indicate that, during the pump test with pumping at a rate of 311 gpm, the far observation well would not experience a reasonably measurable drawdown until at least 25 days had passed. Such a time period is usually considered unfeasible for pump testing.

References

Kruseman, G.P. and de Ridder, N.A., 1991, Analysis and Evaluation of Pumping Test Data, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands, Publication 47, pp. 377

U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement, May, 1990, Proposed Mining Plan and Permit Application, Fence Lake Mine, Catron and Cibola Counties, New Mexico and Apache County, Arizona, Draft Supplemental Environmental Impact Statement OSM-EIS-31, Volume II

Figure 1

Drawdown in Pumping Well

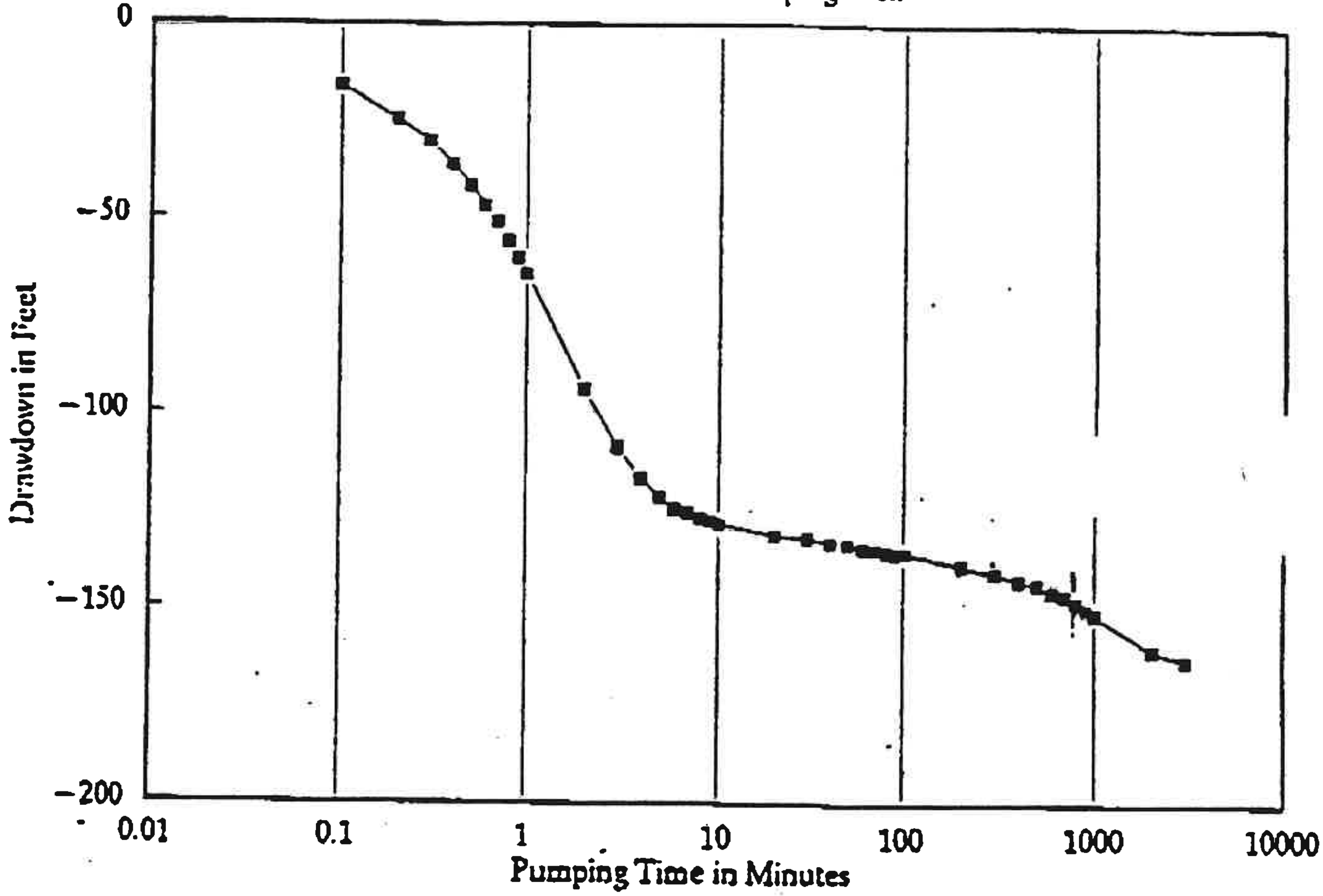
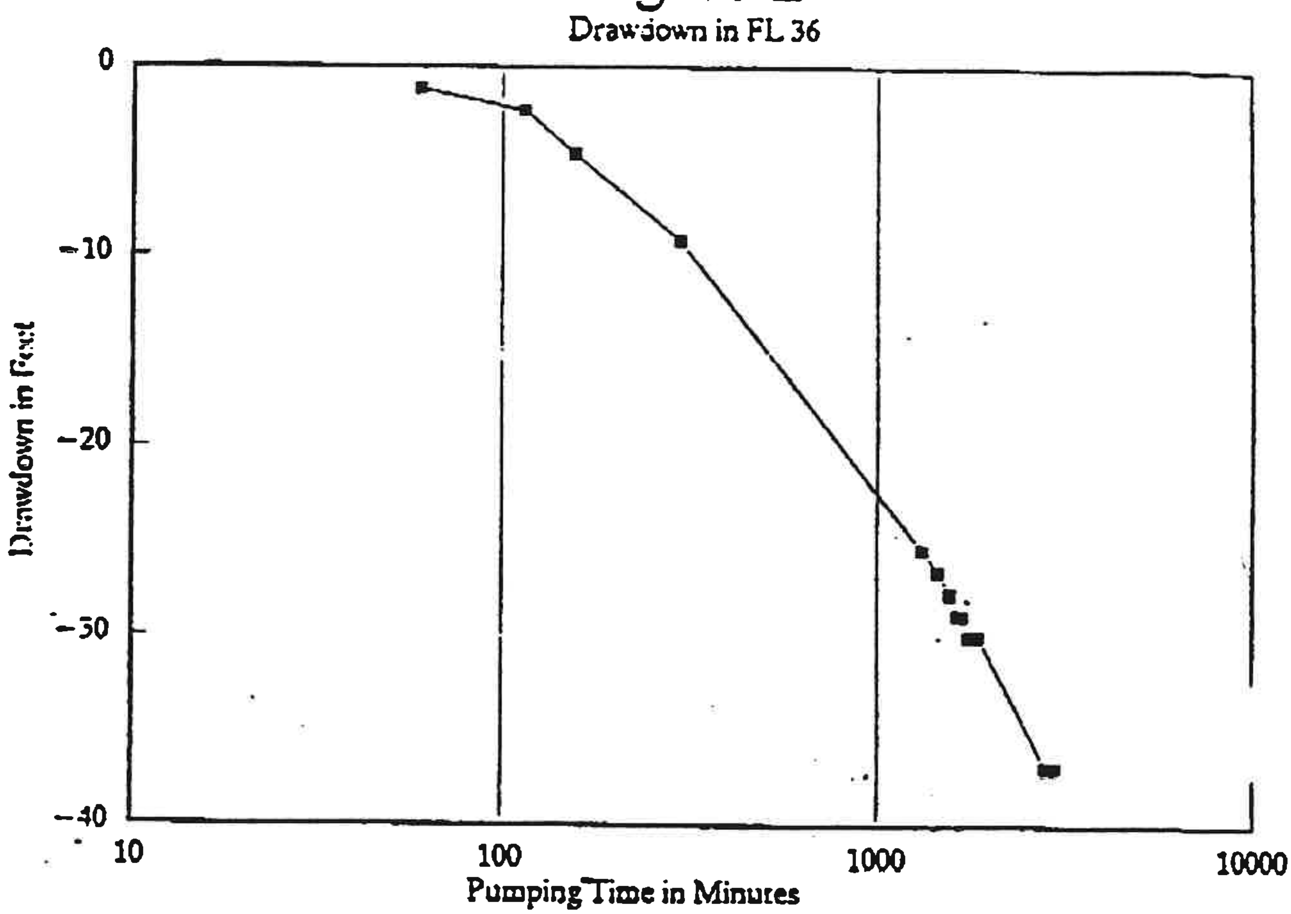


Figure 2


Drawdown in FL 36
0
-10
-20
-30
-40
10
100
1000
10000
Drawdown in Feet
Pumping Time in Minutes

C8

Table 1

Cretaceous Dakota Sandstone

Test Wells

State Plane West Zone Coordinates N (feet)	State Plane West Zone Coordinates E (feet)	Surface Elevation (feet)	Open Interval (feet)	SNP Well No.	Total Depth (feet)	Declaration Number	Comments
1,286,700	276,900	6620	1013-1120	FL 36 (OB-1)	1120	G-294	Pumping Well
1,286,700	277,400	6621	unknown	FL 36	1080	02-153	Near Observation Well
1,276,399	265,399	6581	900-1041	FL 36 (OB-2)	1041	none	Far Observation Well

Estimated Drawdown over the Life of the Mine

Table 2

T=5,300 gpd/ft
Q=75 gpm for 5 yrs followed by Q=85 gpm for 35 yrs

Years	Drawdown in Feet @ FL 36 (OB-1)	Drawdown in Feet @ FL 36	Drawdown in Feet @ FL 36 (OB-2)
1	33.9	13.7	3.1
5	36.4	16.3	5.6
10	42.4	19.6	[illegible]
20	43.8	20.9	[illegible]
30	44.6	21.8	9.5
40	45.1	22.3	10.1
	Pumping Well	Near Observation Well	Far Observation Well

T=2,500 gpd/ft
Q=75 gpm for 5 yrs followed by Q=85 gpm for 35 yrs

Years	Drawdown in Feet @ FL 36 (OB-1)	Drawdown in Feet @ FL 36	Drawdown in Feet @ FL 36 (OB-2)
1	69.2	26.5	4.2
5	74.8	32.0	9.3
10	87.1	38.7	12.8
20	90.0	41.6	15.7
30	91.6	43.2	17.3
40	92.8	44.4	18.4
	Pumping Well	Near Observation Well	Far Observation Well

Simulation of Pumping Test

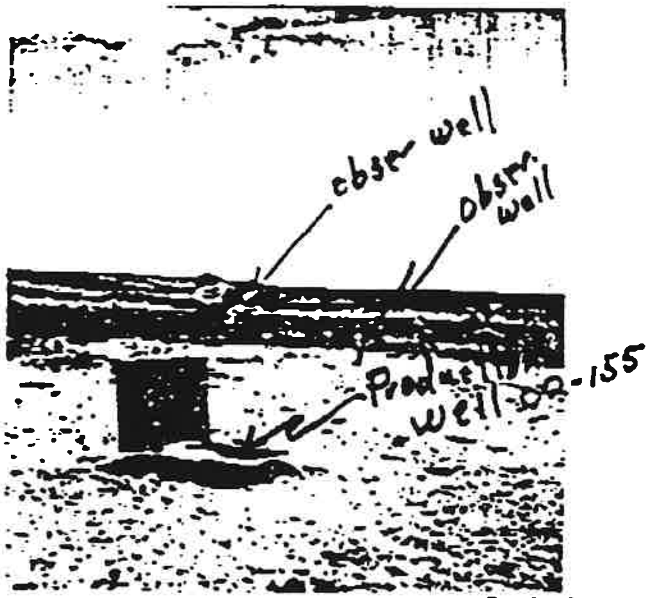
Table 3

T=5,300 gpd/ft
Q=311 gpm

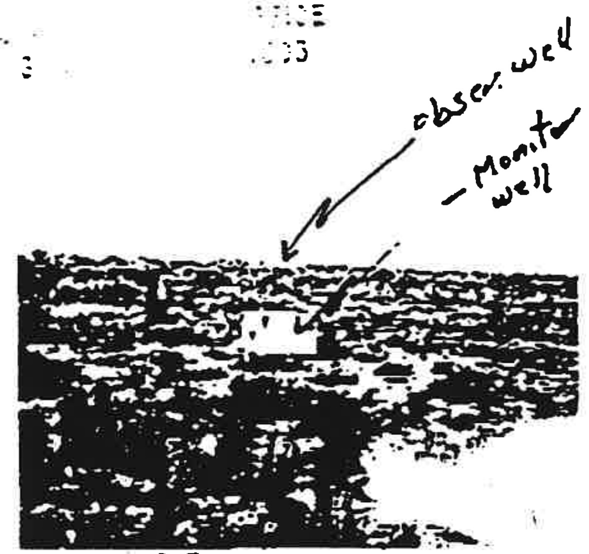
Days	Drawdown in Feet @ FL 36 (OB-1)	Drawdown in Feet @ FL 36	Drawdown in Feet @ FL 36 (OB-2)
1	100.817	17.529	0.000
5	111.640	28.122	0.001
25	122.462	38.897	0.836
50	127.122	43.552	2.622
75	129.849	46.277	4.167
100	131.783	48.210	5.[illegible]
	Pumping Well	Near Observation Well	Far Observat[illegible] We[illegible]

T=2,500 gpd/ft
Q=311 gpm

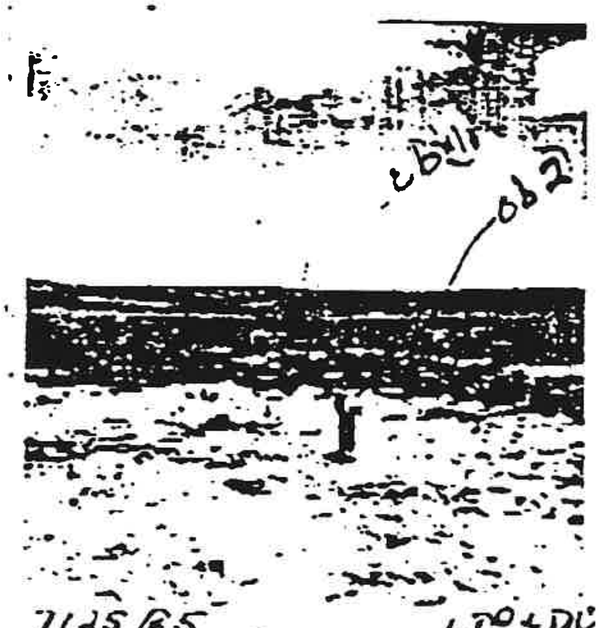
Days	Drawdown in Feet @ FL 36 (OB-1)	Drawdown in Feet @ FL 36	Drawdown in Feet @ FL 36 (OB-2)
1	203.021	27.116	0.000
5	225.964	49.043	0.000
25	248.907	71.778	0.219
50	258.788	81.633	1.567
75	264.568	87.405	3.358
100	268.669	91.501	5.146
	Pumping Well	Near Observation Well	Far Observation Well



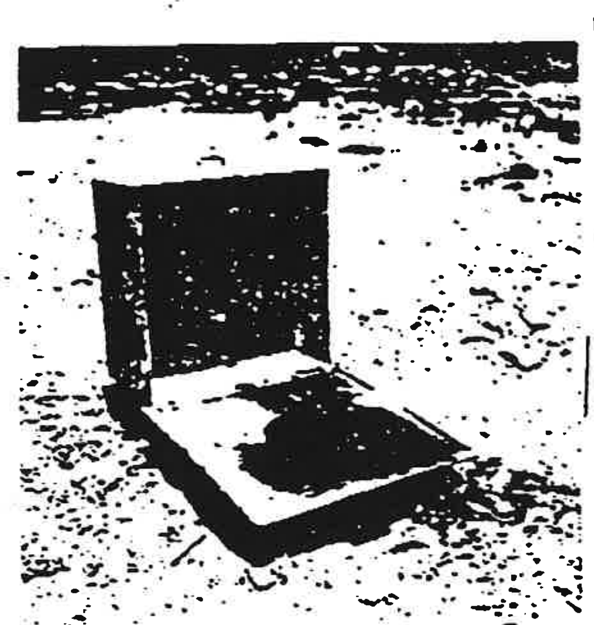
7/25/85 LTP & DU
Salt River Project
Production well + two(2) obser. wells
3N. 17W. 11 141 Catron Co



7/25/85 LT
Salt River Proj. Monitor + obser wells
4N. 17.W. 30



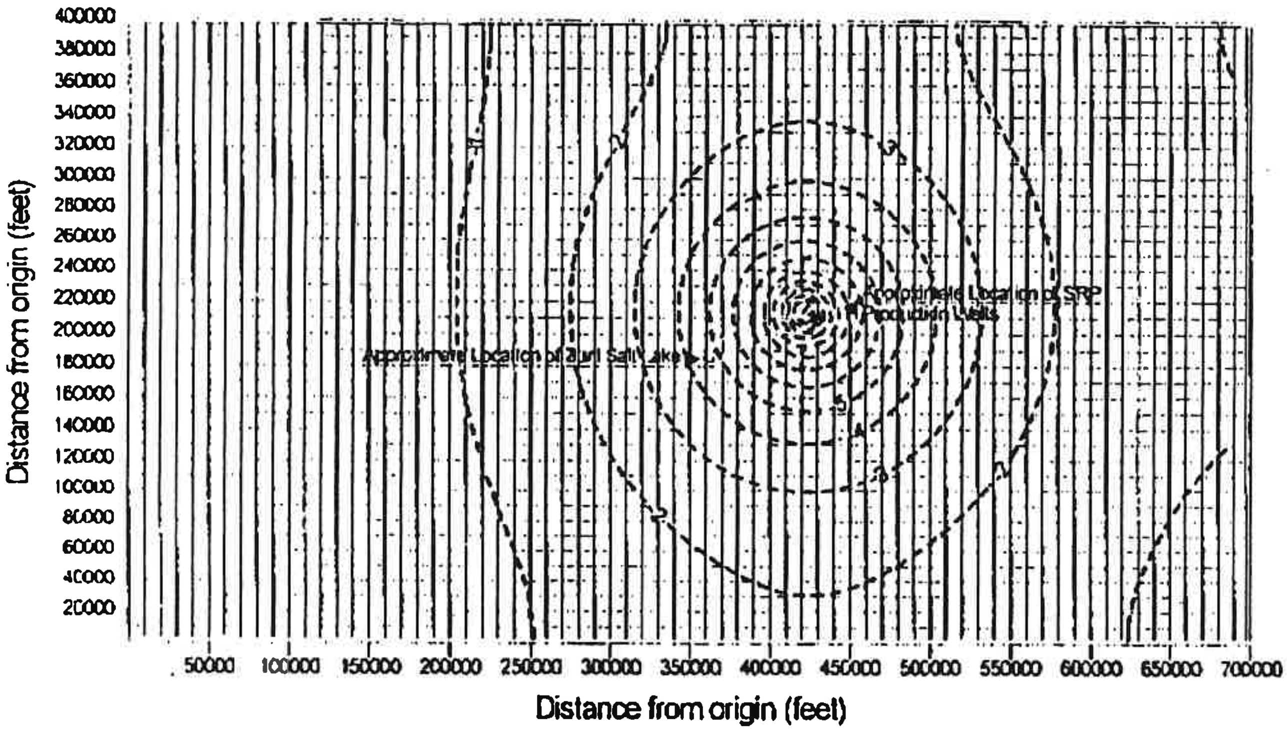
7/25/85 LTP & DU
Salt River Project 3N.17W.11.141
obs wells



7/25/85 LTP & DU
Salt River Project well DR-15
Production well
3N 17W. 11. 141 Catron Co

C12

DRAWDOWN IN FEET AFTER 40 YEARS, ZUNI SALT LAKE MODEL
Total Diversion = 85 gpm (137 acre-feet/year)



GLORIETA GEOSCIENCE, INC.

APPENDIX D: NUMERICAL MODELING OF PUMPING EFFECTS

The hydrologic investigations of confined aquifer systems/propagation of pumping effects previously discussed in the main body of this report relied on analytical modeling techniques (Theis and Hantush methods) to calculate water level declines in complex, multi-layered confined aquifer systems. These investigations conclusively demonstrate that analytical modeling techniques, such as the Hantush method used by SRP, will underestimate drawdowns at Zuni Salt Lake. **Freeze and Cherry (1979), after a chapter length discussion of the various techniques available for analyzing confined and leaky-confined aquifers, state under a subheading entitled "The Real World" that analytical methods "are most applicable when the unit of study is a well or well field. They are less applicable on a larger scale, where the unit of study is an entire aquifer...aquifer studies on the larger scale are usually carried out with the aid of models based on numerical simulation..."**

GGI is prepared to construct a multiple layer numerical model that will take into account geologic structures and the hydrologic characteristics of individual rock units.

In 1997, GGI developed a simplified numerical model to predict drawdown at Zuni Salt Lake resulting from SRP's proposed mine diversion. GGI ran a one-layer, two dimensional groundwater flow model using the U.S. Geological Survey's MODFLOW code. The model incorporates a uniform value for transmissivity of 700 ft^2/day (5200 gpd/ft) and storage coefficient of 0.00049 for the Dakota Sandstone aquifer. Boundaries of the model were chosen so that they would lie beyond the radius of zero drawdown, limiting boundary effects, and making the model conservative. These aquifer coefficients are derived from Dakota Sandstone pumping tests (see Appendix B) and are consistent with values used by Myers (1992) and Core (1996). GGI ran the model for 40 years at the discharge rate of 85 gpm (137 acre-ft/yr), the proposed mine discharge. Estimated drawdown at Zuni Salt Lake resulting from pumping 85 gpm for 40 years was between 4 and 5 feet (Figure D-1). Since Zuni Salt Lake is usually less than 4 feet deep (Myers, 1992), pumping 85 gpm from the Dakota aquifer for 40 years at the proposed Fence Lake Coal Mine will dramatically affect the water balance and water levels in Zuni Salt Lake.

DRAWDOWN IN FEET AFTER 40 YEARS, ZUNI SALT LAKE MODEL
Total Diversion = 85 gpm (137 acre-feet/year)

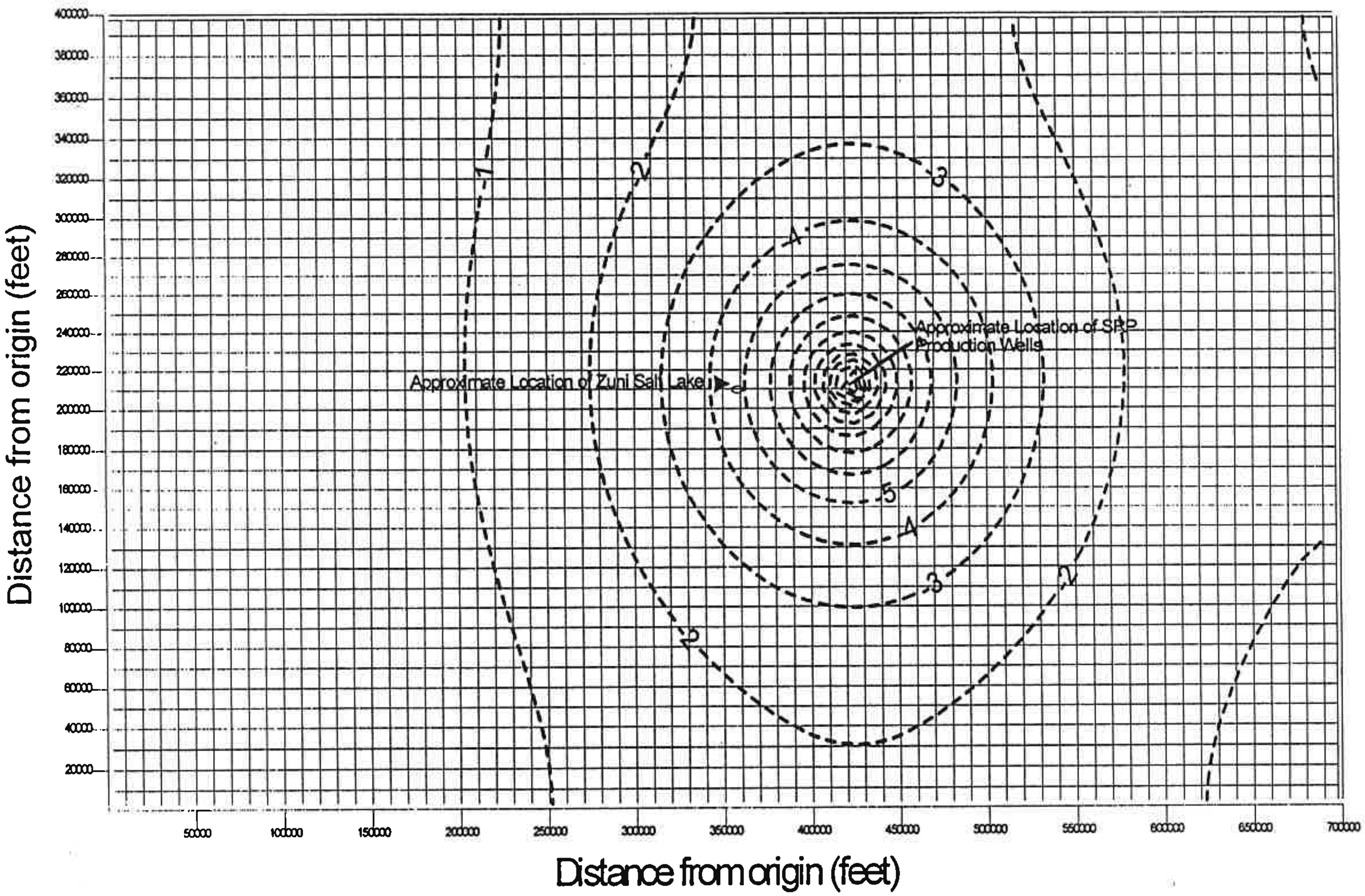


Figure D1. Modeled drawdown in feet after 40 years of pumping 85 gpm from the Dakota Sandstone aquifer.

Using analytical techniques, the USGS (Myers, 1992) also performed an independent analysis of impacts to Zuni Salt Lake. Myers concludes that the withdrawal of water from the Dakota Sandstone aquifer could lower water levels throughout a large area. He further concludes that any activity that lowers the potentiometric surface of groundwater in the Cretaceous rocks within the vicinity of Zuni Salt Lake could decrease the volume of water in the lake.

Based on previous experience working in confined fractured sandstone aquifers, the results of analytical and numerical modeling, and statements made by DE&S, GGI concludes that the effects of pumping at the Fence Lake Mine site will be transmitted great distances through the Dakota aquifer. Drawdown effects will extend to Zuni Salt Lake, possibly very rapidly, and will result in lowering of water levels and changes in water chemistry at the lake.

APPENDIX E: DISCUSSION OF THE PROPAGATION OF EFFECTS FROM PUMPING IN FRACTURED SANDSTONE AQUIFERS

SRP contends that, because the Dakota aquifer is a leaky aquifer, the effects of pumping at the Fence Lake Mine from the Dakota would not extend beyond 3708 feet from the pumping location. This conclusion is based on faulty analysis of pumping test data and the application of an inappropriate analytical model (Hantush method) to the study area. DE&S (2001a), however, indicate on numerous occasions in their text that the effects of pumping would extend much greater distances and be transmitted rapidly through the Dakota to Zuni Salt Lake.

DE&S (2001a) Comment No. 43

DE&S states "*the hydraulic characteristics of the Dakota aquifer are such that it would take weeks to months for continuous pumping at a stock well to be observed at wells located thousands of feet to miles away from either the stock well or from one another*."

1. Stock watering windmills generally produce 2-5 gpm while the wind is blowing. Since DE&S states that the effects of pumping the Dakota aquifer at low discharges for stock use can propagate great distances, one must infer that DE&S's conclusion regarding the impacts of low discharge stock wells would be significantly magnified in higher discharge production wells completed into the Dakota aquifer or other fractured sandstone aquifers such as the Atarque or Moreno Hill aquifers. **This statement by DE&S supports GGI's position that pumping effects caused by pumping the Dakota aquifer wells would propagate thousands of feet to miles in relatively short time periods, adversely affecting the water balance and water chemistry of Zuni Salt Lake.**

DE&S (2001a) Comment No. 47

DE&S states "…..it would take several months for drawdowns due to pumping in either area to be transmitted to other areas." GGI interprets the areas referred to in this statement to be pumping at the mine site or at OB3. The DE&S comment is discussing comparison of data between OB3 and the mine site wells.

1. The comment refers to drawdowns in the Dakota aquifer at wells OB2, OB3 and OB4.

2. OB3 is located between 6 and 7 miles from the mine site-pumping center.
3. OB4 is located approximately 6.7 miles from OB3.
4. OB2 is located approximately 5.3 miles from OB3.
5. The center of Zuni Salt Lake is located approximately 4.8 miles from OB3 and approximately 12.5 miles from the mine site pumping center.
6. Since DE&S states that it would take several months for drawdowns due to pumping in either area to be transmitted to other areas, it is a logical inference that pumping effects would be easily transmitted from the mine site pumping center beyond OB3 the additional 4.8 miles to Zuni Salt Lake within months or a similar time frame.
7. **DE&S' statement once again substantiates GGI's position that pumping effects caused by pumping the Dakota aquifer wells would propagate thousands of feet to miles in relatively short time periods, adversely affecting the water balance and water chemistry of Zuni Salt Lake.**

DE&S (2001a) Comment No. 49

DE&S states "Second, the hydraulic characteristics of the Dakota Sandstone are such that it would take weeks to months for the drawdown effects of continuous pumping near one well to be transmitted the distances that separate some of the mine site wells, which can be as large as 1.5 to 2.8 miles."

This statement, as written, supports GGI's conclusions (see previous comments). However, GGI has conducted aquifer tests on numerous confined, fractured sandstone aquifers with multiple observation wells. Based on GGI's water level measurements in observation wells located at thousands of feet from a given pumping well, DE&S's statement that "it would take weeks to months for drawdown effects to be transmitted .... 1.5 to 2.8 miles" is baseless. Some examples of GGI's observations are as follows:

1. City of Las Vegas, New Mexico Taylor Well Field, 17-day pumping test in fractured, confined Glorieta Sandstone aquifer: Q=350 gpm; distance to

observation well=6336 ft (1.2 miles); 0.05 ft drawdown in 15 minutes and 11.20 ft drawdown after 17 days (Lazarus and Drakos, 1997).

2. Indian Hills GWPA Hydrocarbon Contamination Site, Tijeras Canyon, Zuzax, New Mexico, 7 day pumping test in fractured leaky confined Abo Sandstone aquifer: Q=18.3 gpm; distance to observation well=2420 ft (0.46 miles); 0.05 ft drawdown in 330 minutes and 1.75 ft drawdown after 7 days (Drakos and Lazarus, 1997a, Drakos, 1997b, Drakos, et al, 1999).
3. Rio del Pueblo Subdivision, near Glorieta, San Miguel County, New Mexico, 50 hour pumping test in fractured confined Sangre de Cristo Sandstone aquifer: Q=33 gpm; distance to observation well=1100 ft (0.21 miles); 0.09 ft drawdown from original static water level in 623 minutes; 3.30 ft drawdown after 3000 minutes (Drakos, 1997a).

These data from analogous confined aquifers support GGI's position that pumping effects in fractured-confined and leaky-confined sandstone aquifers can be transmitted large distances over very short time periods, supporting GGI's conclusion that pumping effects from Dakota aquifer diversions at the mine site will be rapidly transmitted to Zuni Salt Lake, adversely affecting the water balance and water chemistry of Zuni Salt Lake. GGI references not available in the public domain will be made available upon request.

Delayed Effects

In addition to the observation that pumping effects can be rapidly transmitted through confined and leaky confined sandstone aquifers, GGI has observed delayed drawdown effects in observation wells long after the pumping well has been shut off. The delayed effects are particularly relevant to the flawed monitoring plan criteria proposed by MMD/SRP/OSM for the Dakota aquifer wells. Brown (1983, p.50) also discusses delayed effect in the Moreno Hill Formation aquifer. It is highly probable that after the long-term pumping test requested by GGI and Zuni to accurately characterize the aquifer system is completed, drawdown will continue to be observed at monitoring wells located thousands of feet to miles from the pumping well. Therefore, a pumping test designed to properly characterize the Dakota Aquifer system will require collection of drawdown and recovery data for a long enough duration to observe delayed drawdown effects in observation wells completed into the Dakota aquifer at distances of thousands of feet to miles from the mine-site pumping well.

In the following paragraphs, GGI presents results from two long-term pumping tests we have performed which clearly show delayed effects in confined and leaky-confined fractured bedrock aquifers.

1) Indian Hills GWPA Hydrocarbon Contamination Site, Tijeras Canyon, Zuzax, New Mexico, 7-week pumping test and pilot scale remediation in fractured leaky confined Abo Sandstone aquifer (Drakos and Lazarus, 1997a, Drakos, 1997b, Drakos, et al, 1999). There are three distinct fractured aquifers beneath the site within the Abo Formation and upper Madera Formation. In descending order, these Aquifers are referred to as Aquifer A, Aquifer B, and Aquifer C (Aquifers A & B are completed into the fractured Abo and Aquifer C is completed into fractured Abo and Madera).

A 7-week pumping test was run on IHMW17, a well completed into Aquifer B from March 26, 1996 through May 17, 1996. Water levels were measured in the pumping well and in observation wells completed into Aquifers A, B, C, and perched water zones overlying aquifer A at time intervals ranging from three days to two weeks. IHMW17 was pumped at an average discharge rate of 6.5 gallons per minute (gpm) for the first week, and then 11.2 gpm for the next two weeks. After three weeks of pumping, the pumping rate was reduced to an average discharge of 6.2 gpm. Average discharge was further reduced to 5.2 gpm on April 26, 1996 and 5.1 gpm on May 10, 1996.

Observation well IHMW18 (distance from pumping well=61.2 ft) drew down an additional 16 ft 49 days after the pump was shut off; observation well IHMW16 (distance from pumping well=43.5 ft) dried up during the pumping test and did not begin to recover until 49 days after the pump was shut off; observation well TBMW23 (distance from pumping well=694 ft) drew down an additional 16 feet 22 days after the pump was shut off; and; CAMW12 (distance from pumping well=2452 ft; 0.46 miles) drew down an additional 4 feet 15-20 days after the pump was shut off.

2) Birds of a Feather Subdivision, near Pecos, San Miguel County, New Mexico – 96 hour pumping test in fractured Madera Formation aquifer (Hodgins and Lazarus, 2001).

A 96-hour pumping test was conducted on a 750 ft deep test well completed into the fractured Upper Madera Formation aquifer, which consists of fractured limey shale, siltstone, limestone and sandstone. Two observation wells were also measured during and after the pumping test. The observation wells, referred to as the Meadow Well and the Windmill Well are located 973 feet (0.18 miles) and 1637 feet (0.31 miles) from the pumping well, respectively. The pumping well was pumped at an average discharge rate of 23 gpm.

The water level in the Meadow Well started to decline after approximately 500 minutes of pumping. The water level in both the Meadow Well and the Windmill Well continued to decline during the pumping test and long after the pump was shut off. The water level in the Meadow observation well drew down an additional 22 feet 150 days after the pump was shut off (through 5-17-01). The water level in the Windmill observation well drew down an additional 19 feet 150 days after the pump was shut off. The pumping well showed near full recovery after 25 days (within 0.46 feet of static).

Table of depth to water measurements at Birds of a Feather

Date	Relative timing of measurements	Pumping Well	Observation Wells: Meadow Well	Observation Wells: Windmill Well
12/15/00	before pumping test (static)	371.40	197.89	55.60
12/19/00	after 96 hrs pumping @ 23 gpm	393.00	200.18	67.86
12/20/00	24 hrs after pump shut off	377.00	200.29	67.85
12/21/00	48 hrs after pump off	375.85	201.02	68.25
1/2/01	14 days after pump off	372.82	205.66	71.38
1/12/01	25 days after pump off *	371.80	207.24	76.50
1/30/01	43 days after pump off	372.72	212.30	76.89
5/17/01	150 days after pump off	376.00	222.66	86.34

*~ full recovery in pumping well

The results of these pumping tests clearly show that no monitoring program can be properly designed without performing a long-term pumping test to accurately and properly characterize the aquifer, including delayed effects.

GGI has developed a Theis model to calculate residual and delayed effects resulting from SRP's proposed pumping from the Dakota aquifer. Model parameters, setup, and results are discussed in the main body of this report beginning on page 49. Model results indicate that drawdown effects will continue to be felt at ZSL for more than 110 years after the cessation of pumping at the mine. Output files from the model are contained in this appendix.

Based on the results from the above-described pumping tests in confined and leaky-confined fractured bedrock aquifer systems and modeling of the aquifer, it is clear to GGI that drawdown effects caused by pumping the Dakota wells at the mine will be propagated great distances beyond the observation wells in the MMD/SRP proposed monitoring network. Due to delayed effects, drawdown will continue to propagate towards Zuni Salt Lake, even after the wells are shut off. If SRP wants to prove its unfounded contention that the Dakota behaves as a leaky-confined aquifer and, more importantly, that effects from pumping will not be propagated beyond 3708 ft from the pumping well, additional observation wells should be completed at the locations and into the formation specified in GGI's pumping test design (pp. 61-63), and a pumping test no shorter than 30 days should be conducted. Pumping should be from FL-36 with water levels monitored in the Dakota Sandstone, Mancos Shale, Atarque Sandstone, and Moreno Hill Formation. Water levels (drawdown/recovery) in the pumping well and observation wells completed into the Dakota and overlying formations must be measured for months or years after the pumping well is shut off. **The monitoring plan as proposed by SRP, endorsed by DE&S, and accepted/coauthored by MMD/OSM is severely flawed, has never been accepted by GGI or Zuni and, as it is presently configured, does not protect Zuni Salt Lake.**

Theis Output

Theis Model Output for 40 years of pumping at Fence Lake Mine (Life of Mine), Q = 85 gpm
(Theis equation)

At y = 0, there is no boundary
There is no other boundary to system

T = 5200. gpd/ft S = 0.000490

Number of pumping wells = 1
Coordinates of pumping wells and the no. of pumping rates

Well #	X Coordinate	Y Coordinate	No. of Pumping Rates
1	0.0	0.0	1

PUMPING SCHEDULES FOR THE WELLS
Well Schedule for Pumping Well Number 1

Pumping Rate	Pumping Time
Q(1) = 85.0 gpm	for 14600.000 days

Coordinates of Computation Points
(Number of computation points = 8)

Point #	X Coordinates feet	Y Coordinates feet	Name
1	0.0	.5	FL36
2	0.0	500.0	OB1
3	0.0	1610.0	Well X
4	0.0	5812.0	OB4
5	0.0	13897.0	OB2
6	0.0	40957.0	OB3
7	0.0	46645.0	Jerry
8	0.0	66512.0	ZSL

Image Control = 0.1000000E-04

E7

OUTPUT

All drawdown values in feet

	FL36	OB1	Well X	OB4	OB2	OB3	Jerry	ZSL
	X = 0.0	X = 0.0	X = 0.0	X = 0.0	X = 0.0	X = 0.0	X = 0.0	X = 0.0
	Y = 0.5	Y = 500.0	Y = 1610.0	Y = 5812.0	Y = 13897.0	Y = 40957.0	Y = 46645.0	Y = 66512.0
Time in days								
1	30.646	4.849	1.154	0.001	0	0	0	0
5	33.66	7.798	3.568	**0.301**	0	0	0	0
9	34.761	8.892	4.596	**0.754**	0.009	0	0	0
17	35.953	10.079	5.743	1.487	**0.091**	0	0	0
21	36.348	10.474	6.13	1.776	**0.157**	0	0	0
37	37.409	11.533	7.173	2.631	**0.471**	0	0	0
41	37.602	11.725	7.363	2.796	**0.551**	0	0	0
153	40.068	14.19	9.815	5.072	2.129	**0.101**	0.046	0.002
184	40.414	14.536	10.159	5.406	2.411	0.16	**0.082**	0.005
337	41.547	15.669	11.291	6.512	3.398	**0.507**	0.328	0.06
367	41.707	15.829	11.45	6.669	3.543	0.576	0.381	0.077
401	41.873	15.995	11.616	6.833	3.695	0.653	0.443	**0.099**
433	42.017	16.139	11.76	6.974	3.827	0.724	**0.5**	0.121

550	42.465	16.587	12.207	7.417	4.245	0.968	0.704	0.212
733	43.003	17.125	12.745	7.95	4.755	1.305	0.998	0.37
delta t = 183 days								
916	43.42	17.542	13.162	8.364	5.155	1.596	1.259	**0.531**
1099	43.761	17.883	13.503	8.704	5.485	1.85	1.492	0.688
1282	44.05	18.172	13.792	8.991	5.765	2.075	1.701	0.837
1465	44.3	18.422	14.041	9.239	6.009	2.277	1.89	0.979
1648	44.52	18.642	14.262	9.459	6.225	2.459	2.062	1.112
1831	44.718	18.839	14.459	9.656	6.418	2.625	2.22	1.238
2014	44.896	19.018	14.637	9.834	6.594	2.778	2.366	1.357
2197	45.059	19.181	14.8	9.996	6.754	2.92	2.502	1.47
2380	45.209	19.331	14.95	10.145	6.902	3.051	2.629	1.576
2563	45.348	19.469	15.089	10.284	7.038	3.175	2.747	1.677
2746	45.477	19.599	15.218	10.413	7.166	3.29	2.859	1.774
2929	45.598	19.719	15.339	10.533	7.285	3.399	2.965	1.865
3112	45.711	19.833	15.452	10.647	7.398	3.502	3.065	1.953
3295	45.818	19.94	15.559	10.753	7.504	3.599	3.16	2.037
3478	45.919	20.041	15.661	10.855	7.604	3.692	3.25	2.117
3661	46.015	20.137	15.757	10.95	7.699	3.781	3.336	2.195
3844	46.107	20.229	15.848	11.042	7.789	3.865	3.419	2.269
4027	46.194	20.316	15.935	11.129	7.876	3.946	3.498	2.34
4210	46.277	20.399	16.018	11.212	7.958	4.023	3.574	2.409
4393	46.357	20.479	16.098	11.291	8.037	4.098	3.647	2.476
4576	46.433	20.555	16.174	11.368	8.113	4.169	3.717	2.54
4759	46.507	20.629	16.248	11.441	8.186	4.238	3.785	2.602
4942	46.577	20.699	16.319	11.512	8.256	4.305	3.85	2.662
5125	46.646	20.767	16.387	11.58	8.324	4.369	3.913	2.721
5308	46.711	20.833	16.452	11.645	8.389	4.431	3.974	2.777
5491	46.775	20.897	16.516	11.709	8.452	4.491	4.033	2.832
5674	46.836	20.958	16.577	11.77	8.514	4.549	4.09	2.886
5857	46.896	21.017	16.637	11.829	8.573	4.606	4.146	2.937
6040	46.953	21.075	16.694	11.887	8.63	4.661	4.2	2.988

6223	47.009	21.131	16.75	11.943	8.686	4.714	4.253	3.037
6406	47.064	21.185	16.805	11.997	8.74	4.766	4.304	3.085
6589	47.116	21.238	16.857	12.05	8.792	4.816	4.353	3.132
6772	47.168	21.289	16.909	12.101	8.843	4.865	4.402	3.178
6955	47.218	21.339	16.959	12.151	8.893	4.913	4.449	3.222
7138	47.266	21.388	17.007	12.2	8.941	4.96	4.495	3.266
7321	47.314	21.435	17.055	12.247	8.988	5.005	4.54	3.308
7504	47.36	21.482	17.101	12.293	9.034	5.05	4.584	3.35
7687	47.405	21.527	17.146	12.338	9.079	5.093	4.627	3.391
7870	47.449	21.571	17.19	12.382	9.123	5.136	4.669	3.431
8053	47.492	21.614	17.233	12.425	9.166	5.177	4.71	3.47
8236	47.534	21.656	17.275	12.467	9.208	5.218	4.75	3.508
8419	47.575	21.697	17.316	12.509	9.249	5.257	4.789	3.545
8602	47.616	21.737	17.357	12.549	9.289	5.296	4.828	3.582
8785	47.655	21.777	17.396	12.588	9.328	5.335	4.866	3.618
8968	47.694	21.815	17.435	12.627	9.367	5.372	4.903	3.654
9151	47.732	21.853	17.473	12.665	9.405	5.408	4.939	3.688
9334	47.769	21.89	17.51	12.702	9.442	5.444	4.975	3.722
9517	47.805	21.927	17.546	12.738	9.478	5.48	5.009	3.756
9700	47.841	21.962	17.582	12.774	9.513	5.514	5.044	3.789
9883	47.876	21.997	17.617	12.809	9.548	5.548	5.077	3.821
10066	47.91	22.032	17.651	12.843	9.582	5.582	5.11	3.853
10249	47.944	22.066	17.685	12.877	9.616	5.614	5.143	3.884
10432	47.977	22.099	17.718	12.91	9.649	5.647	5.175	3.915
10615	48.01	22.131	17.751	12.942	9.682	5.678	5.206	3.945
10798	48.042	22.163	17.783	12.974	9.714	5.709	5.237	3.975
10981	48.073	22.195	17.814	13.006	9.745	5.74	5.268	4.004
11164	48.104	22.226	17.845	13.037	9.776	5.77	5.298	4.033
11347	48.134	22.256	17.875	13.067	9.806	5.8	5.327	4.061
11530	48.164	22.286	17.905	13.097	9.836	5.829	5.356	4.089
11713	48.194	22.316	17.935	13.127	9.865	5.858	5.384	4.117

E9

11896	48.223	22.345	17.964	13.156	9.894	5.886	5.413	4.144
12079	48.252	22.373	17.993	13.184	9.923	5.914	5.44	4.171
12262	48.28	22.401	18.021	13.212	9.951	5.942	5.468	4.197
12445	48.307	22.429	18.048	13.24	9.979	5.969	5.494	4.223
12628	48.335	22.457	18.076	13.268	10.006	5.995	5.521	4.249
12811	48.362	22.483	18.103	13.294	10.033	6.022	5.547	4.275
12994	48.388	22.51	18.129	13.321	10.059	6.048	5.573	4.3
13177	48.414	22.536	18.155	13.347	10.085	6.073	5.598	4.324
13360	48.44	22.562	18.181	13.373	10.111	6.098	5.623	4.349
13543	48.466	22.588	18.207	13.399	10.137	6.123	5.648	4.373
13726	48.491	22.613	18.232	13.424	10.162	6.148	5.673	4.396
13909	48.516	22.637	18.257	13.448	10.186	6.172	5.697	4.42
14092	48.54	22.662	18.281	13.473	10.211	6.196	5.721	4.443
14275	48.564	22.686	18.305	13.497	10.235	6.22	5.744	4.466
14458	48.588	22.71	18.329	13.521	10.259	6.243	5.767	4.488
14600	**48.607**	**22.728**	**18.348**	**13.539**	**10.277**	6.261	5.785	4.506
Mine closed - pumping stops								
delta t = variable								
14641	11.01	11.008	10.99	10.749	9.731	6.266	5.79	4.511
14646	10.795	10.794	10.777	10.561	9.633	**6.267**	5.791	4.511
14664	10.179	10.178	10.166	10.01	9.306	6.266	**5.793**	4.514
14756	8.522	8.521	8.516	8.452	8.139	6.175	5.755	**4.523**
15007	6.757	6.757	6.755	6.731	6.608	5.645	5.382	4.452
15373	5.601	5.601	5.6	5.587	5.523	4.983	4.822	4.192
15556	5.225	5.225	5.224	5.214	5.163	4.723	4.589	4.053
16105	4.44	4.44	4.439	4.433	4.402	4.124	4.036	3.672
16471	4.074	4.074	4.074	4.069	4.044	3.823	3.753	3.456
16654	3.92	3.92	3.92	3.915	3.893	3.693	3.629	3.358
16837	3.781	3.781	3.78	3.776	3.756	3.574	3.515	3.267
17020	3.654	3.654	3.653	3.65	3.631	3.464	3.41	3.18
17203	3.537	3.537	3.537	3.534	3.517	3.362	3.313	3.1

E10

E11

17386	3.43	3.43	3.43	3.426	3.411	3.268	3.222	3.023
17569	3.33	3.33	3.33	3.327	3.312	3.18	3.137	2.951
17752	3.238	3.238	3.237	3.235	3.221	3.097	3.057	2.883
17935	3.151	3.151	3.151	3.148	3.136	3.019	2.982	2.818
18118	3.07	3.07	3.07	3.068	3.056	2.946	2.911	2.757
18301	2.994	2.994	2.994	2.992	2.98	2.877	2.844	2.698
18484	2.922	2.922	2.922	2.92	2.909	2.812	2.78	2.642
18667	2.854	2.854	2.854	2.852	2.842	2.75	2.72	2.589
18850	2.79	2.79	2.79	2.788	2.779	2.691	2.663	2.538
19033	2.729	2.729	2.729	2.727	2.718	2.635	2.608	2.49
19216	2.671	2.671	2.671	2.67	2.661	2.582	2.556	2.443
19399	2.616	2.616	2.616	2.615	2.606	2.531	2.507	2.399
19582	2.564	2.564	2.564	2.562	2.554	2.483	2.459	2.356
19765	2.514	2.514	2.514	2.512	2.505	2.436	2.413	2.315
19948	2.466	2.466	2.466	2.464	2.457	2.391	2.37	2.275
20131	2.42	2.42	2.42	2.418	2.412	2.348	2.328	2.237
20314	2.376	2.376	2.376	2.374	2.368	2.307	2.287	2.2
20497	2.334	2.334	2.334	2.332	2.326	2.268	2.249	2.165
20680	2.293	2.293	2.293	2.292	2.286	2.23	2.211	2.13
20863	2.254	2.254	2.254	2.253	2.247	2.193	2.175	2.097
21046	2.216	2.216	2.216	2.215	2.21	2.158	2.141	2.065
21229	2.18	2.18	2.18	2.179	2.174	2.124	2.107	2.034
21412	2.145	2.145	2.145	2.144	2.139	2.091	2.075	2.004
21595	2.112	2.112	2.111	2.11	2.105	2.059	2.043	1.975
21778	2.079	2.079	2.079	2.078	2.073	2.028	2.013	1.947
21961	2.047	2.047	2.047	2.046	2.042	1.998	1.984	1.92
22144	2.017	2.017	2.017	2.016	2.011	1.969	1.955	1.894
22327	1.988	1.988	1.987	1.987	1.982	1.941	1.928	1.868
22510	1.959	1.959	1.959	1.958	1.954	1.914	1.901	1.843
22693	1.931	1.931	1.931	1.93	1.926	1.888	1.875	1.819
22876	1.904	1.904	1.904	1.904	1.9	1.862	1.85	1.795

23059	1.878	1.878	1.878	1.878	1.874	1.837	1.825	1.772
23242	1.853	1.853	1.853	1.852	1.849	1.813	1.802	1.75
23425	1.829	1.829	1.829	1.828	1.824	1.79	1.779	1.729
23608	1.805	1.805	1.805	1.804	1.8	1.767	1.756	1.707
23791	1.782	1.781	1.781	1.781	1.777	1.745	1.734	1.687
23974	1.759	1.759	1.759	1.758	1.755	1.723	1.713	1.667
24157	1.737	1.737	1.737	1.736	1.733	1.702	1.692	1.647
24340	1.716	1.716	1.716	1.715	1.712	1.682	1.672	1.628
24523	1.695	1.695	1.695	1.694	1.691	1.662	1.652	1.609
24706	1.674	1.674	1.674	1.674	1.671	1.642	1.633	1.591
24889	1.655	1.655	1.655	1.654	1.651	1.623	1.614	1.574
25072	1.635	1.635	1.635	1.635	1.632	1.605	1.596	1.556
25255	1.617	1.616	1.616	1.616	1.613	1.587	1.578	1.539
25438	1.598	1.598	1.598	1.598	1.595	1.569	1.561	1.523
25621	1.58	1.58	1.58	1.58	1.577	1.552	1.544	1.507
25804	1.563	1.563	1.563	1.562	1.559	1.535	1.527	1.491
25987	1.546	1.546	1.546	1.545	1.542	1.518	1.511	1.475
26170	1.529	1.529	1.529	1.528	1.526	1.502	1.495	1.46
26353	1.513	1.513	1.512	1.512	1.51	1.487	1.479	1.445
26536	1.497	1.497	1.496	1.496	1.494	1.471	1.464	1.431
26719	1.481	1.481	1.481	1.48	1.478	1.456	1.449	1.417
26902	1.466	1.466	1.466	1.465	1.463	1.441	1.434	1.403
27085	1.451	1.451	1.451	1.45	1.448	1.427	1.42	1.389
27268	1.436	1.436	1.436	1.436	1.433	1.413	1.406	1.376
27451	1.422	1.422	1.422	1.421	1.419	1.399	1.392	1.363
27634	1.408	1.408	1.408	1.407	1.405	1.385	1.379	1.35
27817	1.394	1.394	1.394	1.393	1.391	1.372	1.366	1.337
28000	1.38	1.38	1.38	1.38	1.378	1.359	1.353	1.325
28183	1.367	1.367	1.367	1.367	1.365	1.346	1.34	1.313
28366	1.354	1.354	1.354	1.354	1.352	1.334	1.328	1.301
28549	1.342	1.342	1.342	1.341	1.339	1.321	1.315	1.289

E12

28732	1.329	1.329	1.329	1.329	1.327	1.309	1.304	1.278
28915	1.317	1.317	1.317	1.317	1.315	1.298	1.292	1.266
29098	1.305	1.305	1.305	1.305	1.303	1.286	1.28	1.255
29200	1.298	1.298	1.298	1.298	1.296	1.28	1.274	1.249
61500	0.508	0.508	0.508	0.508	0.507	0.505	0.504	**0.5**
61900	0.504	0.504	0.504	0.504	0.504	0.501	**0.5**	0.497
61975	0.503	0.503	0.503	0.503	0.503	**0.5**	0.5	0.496
62275	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	0.498	0.497	0.493
102200	0.289	0.289	0.289	0.289	0.289	0.288	0.288	0.286
138700	0.208	0.208	0.208	0.208	0.208	0.208	0.208	0.207
175200	0.163	0.163	0.163	0.163	0.163	0.163	0.163	0.162
211700	0.134	0.134	0.134	0.134	0.134	0.134	0.134	0.133
248200	0.114	0.114	0.114	0.114	0.114	0.113	0.113	0.113
278761	0.101	0.101	0.101	0.101	0.101	0.101	0.101	**0.1**
279127	0.101	0.101	0.101	0.101	0.101	0.101	**0.1**	0.1
279310	0.101	0.101	0.101	0.101	0.101	**0.1**	0.1	0.1
279493	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	0.1	0.1	0.1
321200	0.087	0.087	0.087	0.087	0.087	0.087	0.087	0.087
357700	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078
394200	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071
722700	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
759200	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036
1343200	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
1744700	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
2146200	0.013	0.013	0.013	0.013	0.013	0.013	0.013	0.013
2547700	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
2949200	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
3350700	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
3642700	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008

E13

APPENDIX F: PLOTS AND SUMMARY STATISTICS OF WATER LEVEL DATA OBTAINED FROM SRP DAKOTA MONITORING WELLS

Analytical Methods

For wells FL-36(OB1), FL-36(OB2), and FL-36, GGI noted that some transducer readings were abnormally high or low. Furthermore, the change from values near the mean water levels to abnormally high values occurred within the span of one hour (between consecutive transducer readings). Although it is unclear what caused these large (but somewhat regular) fluctuations, it is clear that they represent erroneous data, and it is GGI's opinion that it would be worthwhile to remove these data points and re-examine the data in order to determine how the erroneous data points affect statistical summaries of the data . For each of the Dakota wells equipped with transducers, a summary of both the edited and unedited data are included. Data were also missing for some time periods for wells OB1, OB4, and the Jerry Well. The missing data (labeled on the attached graphs) are apparently attributable to repairs being made to the transducers by SRP or other technical difficulties (SRP Dakota Well Pressure Monitoring Reports, 1/15/97 through 3/31/01).

Data from the Jerry Observation well show, rather that a few abrupt abnormal readings, continuous wide fluctuations beginning on 7/9/00 and continuing until 2/2/01 (note: no data were collected between 10/14/00 and 12/1/00). Data collected between 2/2/01 and 3/7/01 (the last data collected) did not show large-scale fluctuations. Fluctuations in the Jerry well differ from those in the wells listed previously in that each fluctuation in water level occurred over a period of many hours and the fluctuations continued for at least three months. It is probable that these fluctuations in the Jerry Observation well readings were a result of pumping a nearby windmill for stock watering/irrigation purposes (located in UTM Grid zone 12, 710,558 m E, 3,816,768 m N). While conducting fieldwork in the area on 11/29/00 and 5/19/01, GGI observed this windmill in operation. Rather than try to correct each peak and valley over this period, GGI removed all data from 7/9/00 to 2/2/01 for comparison with the entire data set which included flawed data..

Throughout the rest of this appendix, numbers derived from data with the suspect data points removed will be given in parentheses following numbers derived from the raw data. **The critical information/conclusion is that the erratic data have a very large effect on the standard deviation calculations.** GGI believes that the edited data set should be used for action level calculations. This methodology is supported by the King Engineering and DE&S in the way that they analyze the data. Results of basic statistical analyses of the corrected (in parentheses) and uncorrected water level data, as well as plots of the water levels are given below.

Discussion of Results for Individual Wells

<u>FL-36 Transducer Data</u>

Transducer data from FL-36 are available from 9/30/98 through 3/7/01(GGI does not have earlier data from FL-36, during the time period when FL-36 was sometimes being used for water supply). Pressure data were converted to water elevations and show that water elevation fluctuated by 56.24 ft (2.03 ft) during the period of measurement. Clear seasonal fluctuations in water level data (such as recharge events associated with seasonal rainfall or snowmelt, or increased summer usage) are not observed in the data set from FL-36. These data indicate the well is no longer being used for stock watering. Although FL-36 will be used as a water supply well and is not part of the monitoring program, the following statistics were calculated:
Mean = 193.47 ft (193.04 ft), Median = 192.88 ft (192.86 ft), Standard deviation = 4.90 ft. (0.54 ft), Three standard deviations plus one ft. = 15.7 ft (2.62 ft).

<u>FL-36(OB1) Transducer Data</u>

Transducer data from FL-36(OB1) are available from 4/14/98 through 11/30/00. For reasons that are unclear to GGI at this time, no data were collected from FL-36 (OB1) between 6/10/00 and 8/6/00. Data were not collected after 11/30/00 at OB1 because, "The unit at OB1 froze out in early February 2001. Consequently, all data recorded after November 30, 2000 for the fourth quarter 2000 was lost." (SRP well monitoring report to MMD, 3/31/01). Available pressure data were converted to water elevation data, and

show that water elevation fluctuated by 7.69 ft (2.30 ft) during the period of observation. Clear seasonal fluctuations in water level data are not observed in the data set from FL-36(OB1). Although FL-36(OB1) is not part of the monitoring program, the following statistics were calculated:
Mean = 198.32 (198.33 ft), Median = 198.22 ft (198.22 ft), Standard deviation = 0.57 ft (0.55 ft). Three standard deviations plus one ft. = 2.71 ft (2.65 ft).

FL-36(OB2) Transducer Data

Transducer data from FL-36(OB2) are available from 8/20/98 through 3/7/01. Pressure data were converted to water elevation data, and show that water elevation fluctuated by 364.55 ft (2.15 ft) during the period of measurement. Clear seasonal fluctuations in water level data are not observed in the data set from FL-36(OB2). The following statistics were calculated from the FL-36(OB2) data set :
Mean = 239.94 ft (239.54 ft), Median = 239.34 ft (239.34 ft) standard deviation = 11.86 ft (0.56 ft). Three standard deviations plus one ft. = 36.58 ft (2.68 ft). Therefore, the action level for FL-36(OB2), based on the current data set and the proposed monitoring plan, would be 88.03 psi (102.54 psi) or 203.36 ft of water (236.86 ft). If the pressure in FL-36(OB2) fell below 88.55 psi (102.54 psi) during use of FL-36, all wells pumping from the Dakota would have to be turned off.

FL-36(OB3) Transducer Data

Beginning with the 1997 report, GGI has questioned whether or not FL-36(OB3) is monitoring the main body, Dakota Sandstone aquifer. FL-36(OB3) was left as an open hole completion from 360 to 440 ft, through the lower part of the Mancos shale (according to SRP well logs). FL-36(OB3) may be monitoring the Mancos shale, rather than the main body, Dakota Sandstone, rendering it useless for its intended purpose. The BIA report concluded that the well had collapsed and was not accurately monitoring water levels in the Dakota aquifer.

A video log of the well run recently under the supervision of MMD showed that the hole caved in below the bottom of the casing (Monte Anderson, MMD, *pers. comm.* 5/4/01) and therefore data from FL-36 (OB3) are unreliable. SRP repaired the well in late April of 2001 but, as of this writing, no post-repair data are available (Monte Anderson, MMD, *pers. comm.* 5/4/01). The Office of Surface Mining (OSM), in a 5/01/01memorandum to the Acting Assistant Secretary of the Bureau of Land and Minerals Management, agreed that the well was not completed properly and noted that MMD required the well to be repaired as part of the pending permit renewal application. The memo states that, "Although some of the early data collected at this well appears valid, additional data will be collected after the well has been repaired to satisfy the requirement for at least two years of baseline data prior to the pump test." It is not clear from the memo if the 'valid' early data would be added to post-repair data to determine the baseline for action levels, or if two additional years of data collection would be required. GGI strongly contends that two years of data following the repair of the well must be collected to meet the two-year baseline criteria as set forth in the Permit Application Packet (PAP). **Additionally, details of the well repair must be documented as described previously and provided to GGI.**

Although, as outlined above, the existing data from OB3 are probably not representative of the Dakota aquifer, they are included here to allow a future comparison to post-repair data from the well.

Transducer data from FL-36(OB3) are available from 2/23/99 through 3/8/01. Over this period, there were no large fluctuations in water level such as those observed in the other wells. However, there is a small data shift on 2/11/00 (an abrupt increase of 0.08 feet). The shift is due to the transducer being replaced by a freshly serviced unit (SRP report to MMD dated 6/12/00). Apparently, when these units were installed, they were not recalibrated, thereby causing a shift in the data. GGI compensated for this by subtracting 0.08 feet from all measurements taken after 2/11/00. Results of statistical analyses of uncorrected and corrected (in parentheses) data are given below.

Depth to water fluctuated by 3.99 (4.07) ft. during the period of measurement (FL-36(OB3) is not a flowing artesian well, therefore water measurements are depth to water, not water pressure). For non-flowing wells, MMD should require SRP to provide all depth to water measurements manually collected in the field in addition to transducer data. Seasonal fluctuations in water level may be responsible for variations in data during the first six months of the observed period, although such fluctuations are not observed after the fall of 1999. The following statistics were calculated from the FL-36(OB3) data set :

Mean = 14.86 ft (14.82 ft) (depth to water), standard deviation = 1.43 ft (1.46 ft). Three standard deviations plus one ft. = 5.29 ft (5.38 ft). Therefore, the action level for FL-36(OB3), based on the current data set, would be a depth to water of 20.15 ft (20.20 ft) from the MP. If the depth to water in FL-36(OB3) fell below 20.15 ft (20.24 ft) during use of FL-36, all wells pumping from the Dakota would have to be turned off.

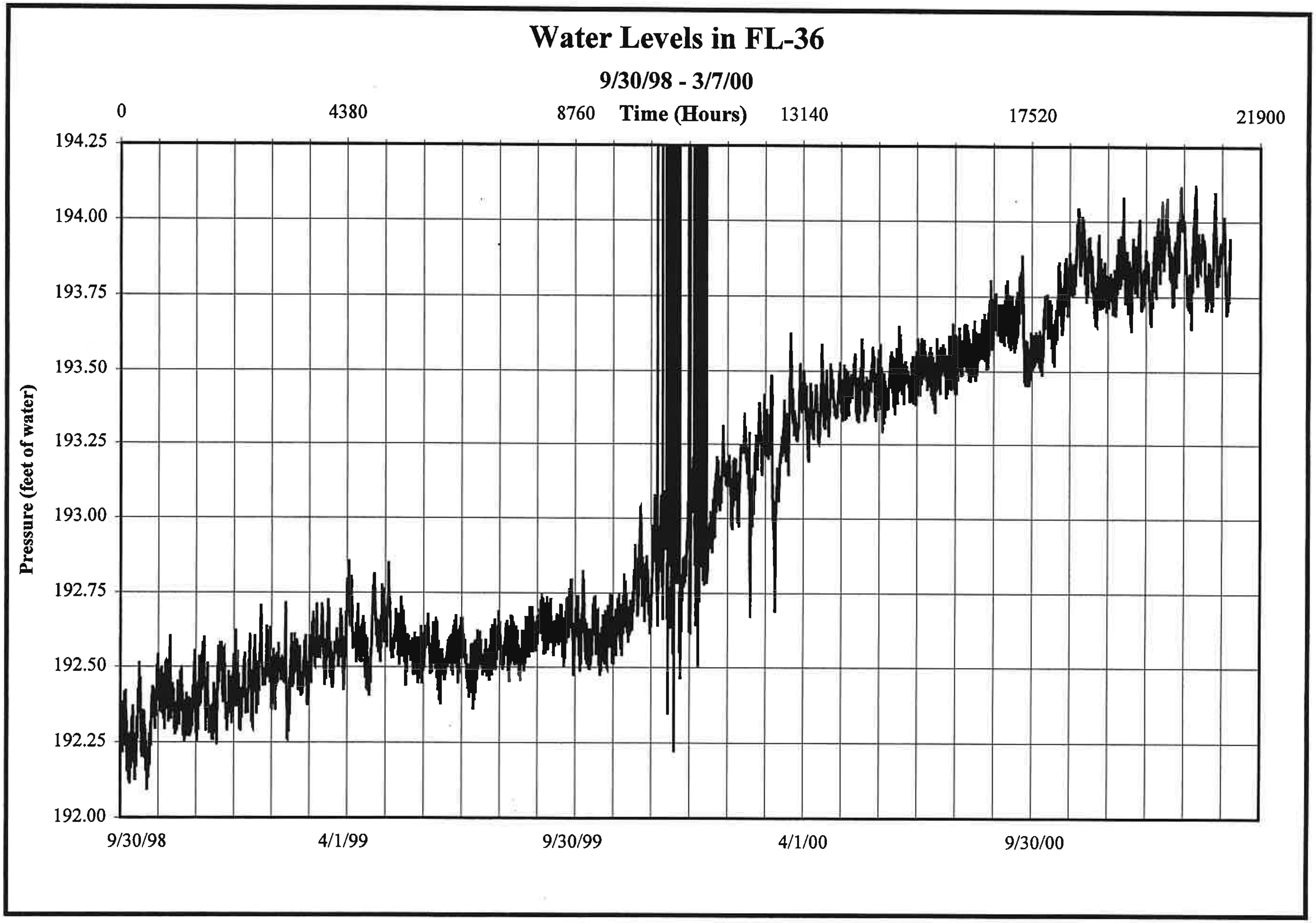
FL-36(OB4) Transducer Data

Transducer data from FL-36(OB4) are available from 4/14/98 through 9/4/99, 9/20/99 through 9/21/99, 10/9/99 through 10/13/00, and 11/30/00 through 3/7/01. Pressure data were converted to water elevation data, and show that ground water elevation fluctuated by 72.75 ft (3.08 ft) during the period of measurement. Although the data between June and December of 1999 are questionable due to the rapid fluctuations seen in this period, all but the most spurious points were left in the data set for the revised data analysis, because the fluctuations are generally not greater than 1.5 feet. Further winnowing of the data may yield more accurate results, but would significantly reduce the amount of data used for statistical analyses. Gaps in data collection occurred in the fall of 1999, further complicating data analysis and raising additional questions regarding the reliability of data from FL-36(OB4). Clear seasonal fluctuations in water level data are not observed in the data set from FL-36(OB4). The following statistics were calculated from the FL-36(OB4) data set :

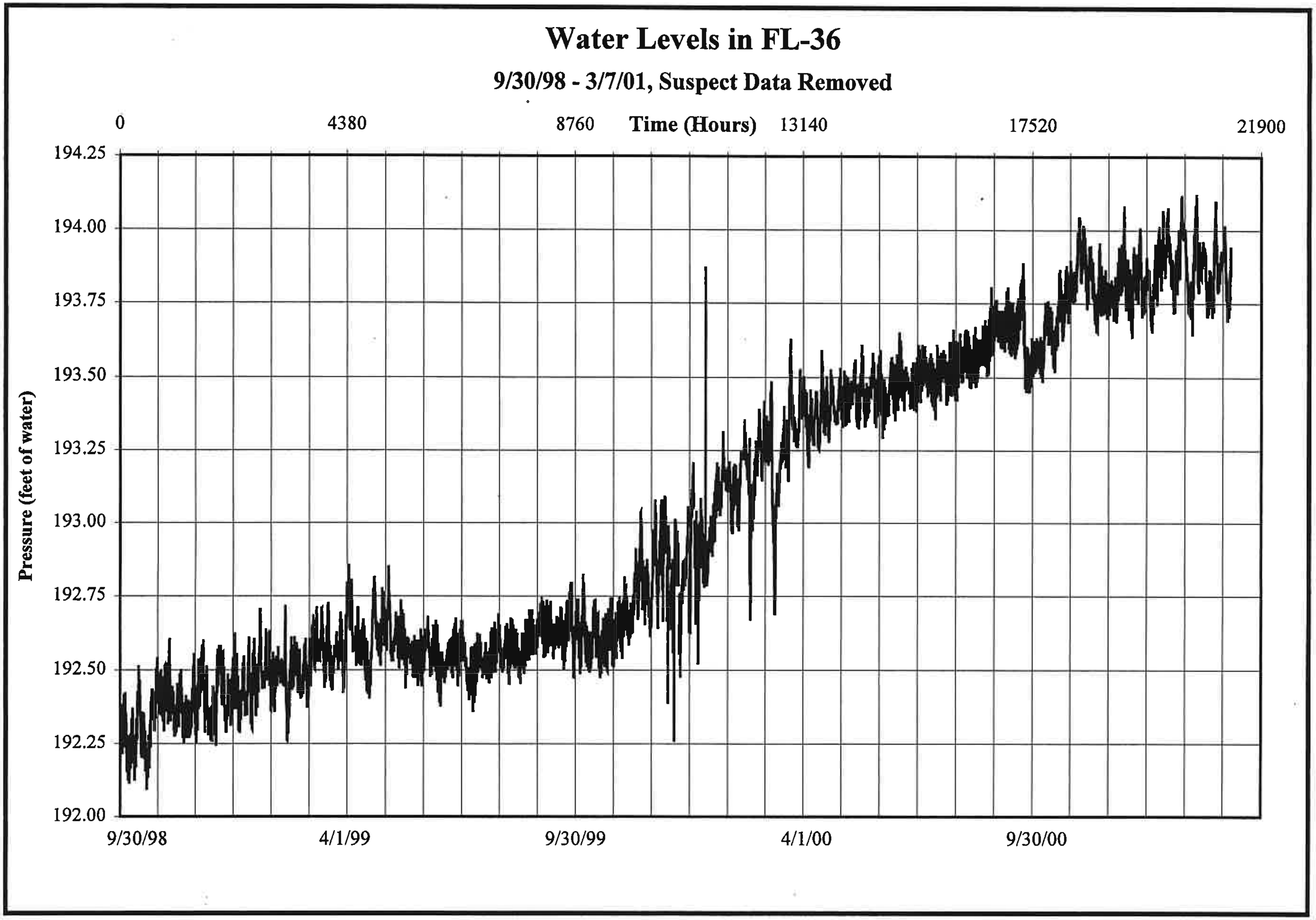
Mean = 99.33 ft (99.88 ft), Median = 99.68 ft (99.76 ft), Standard deviation = 8.14 ft (0.53 ft). Three standard deviations plus one ft. = 25.42 ft (2.59 ft). Therefore, the action level for FL-36(OB4), based on the current data set, would be 31.56 psi (42.12 psi), or

72.91 ft (97.29 ft) of water pressure. If the pressure in FL-36(OB2) fell below 31.56 psi (42.12 psi) during use of FL-36, all wells pumping from the Dakota would have to be turned off.

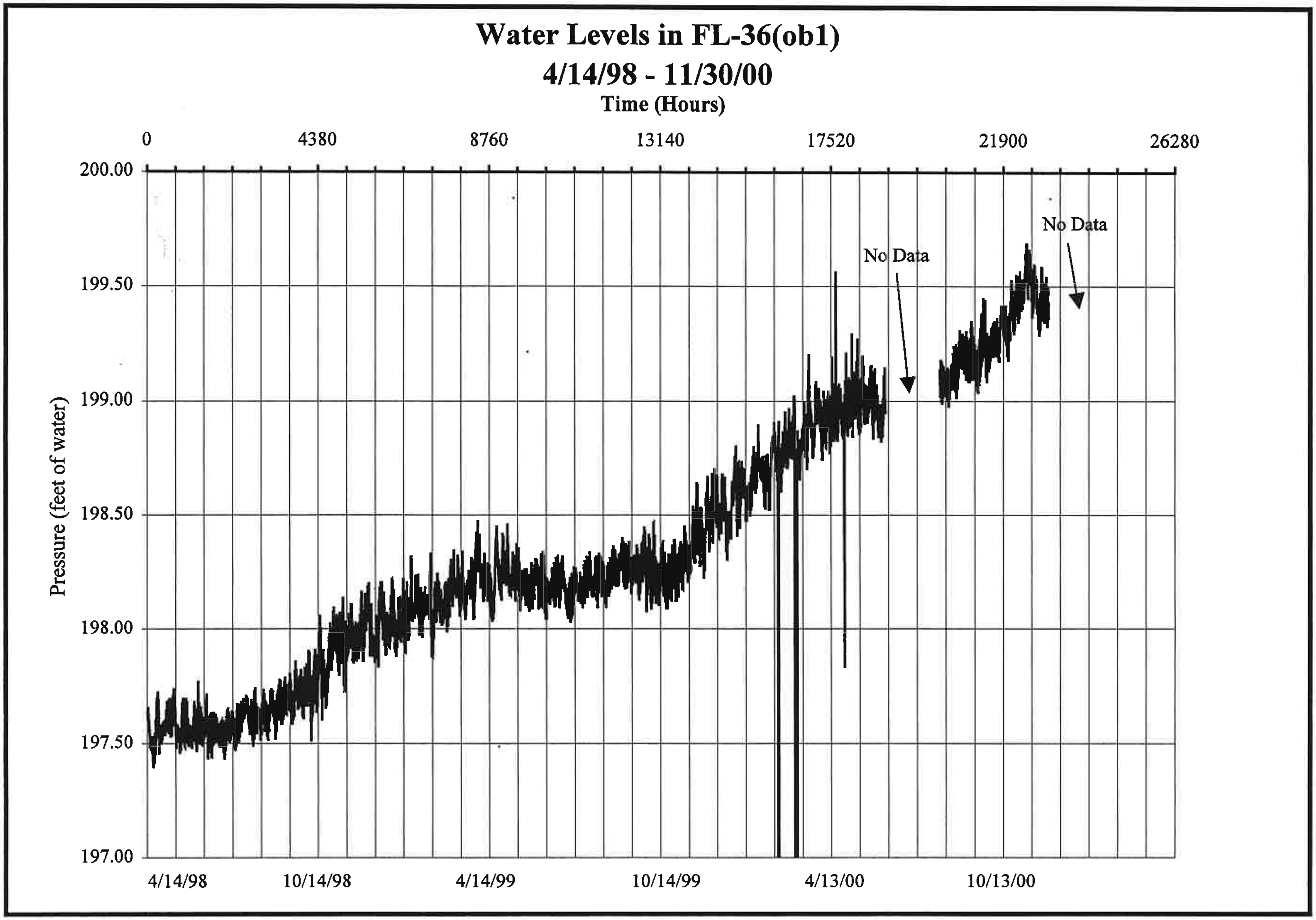
In their report prepared for the BIA in February, 2001, King Engineering performed numerous detailed statistical analyses of water level data from SRP's Dakota wells. Their analyses also showed that well FL-36(OB3) was improperly completed and was not providing reliable water level data. They concluded that there were significant problems with the other Dakota wells and that the monitoring well system is fundamentally flawed and inadequate to protect Zuni Salt Lake from the effects of pumping at the Fence Lake Mine. GGI agrees with this conclusion.


Water Levels in FL-36
9/30/98 - 3/7/00
Time (Hours)
0
4380
8760
13140
17520
21900
Pressure (feet of water)
194.25
194.00
193.75
193.50
193.25
193.00
192.75
192.50
192.25
192.00
9/30/98
4/1/99
9/30/99
4/1/00
9/30/00

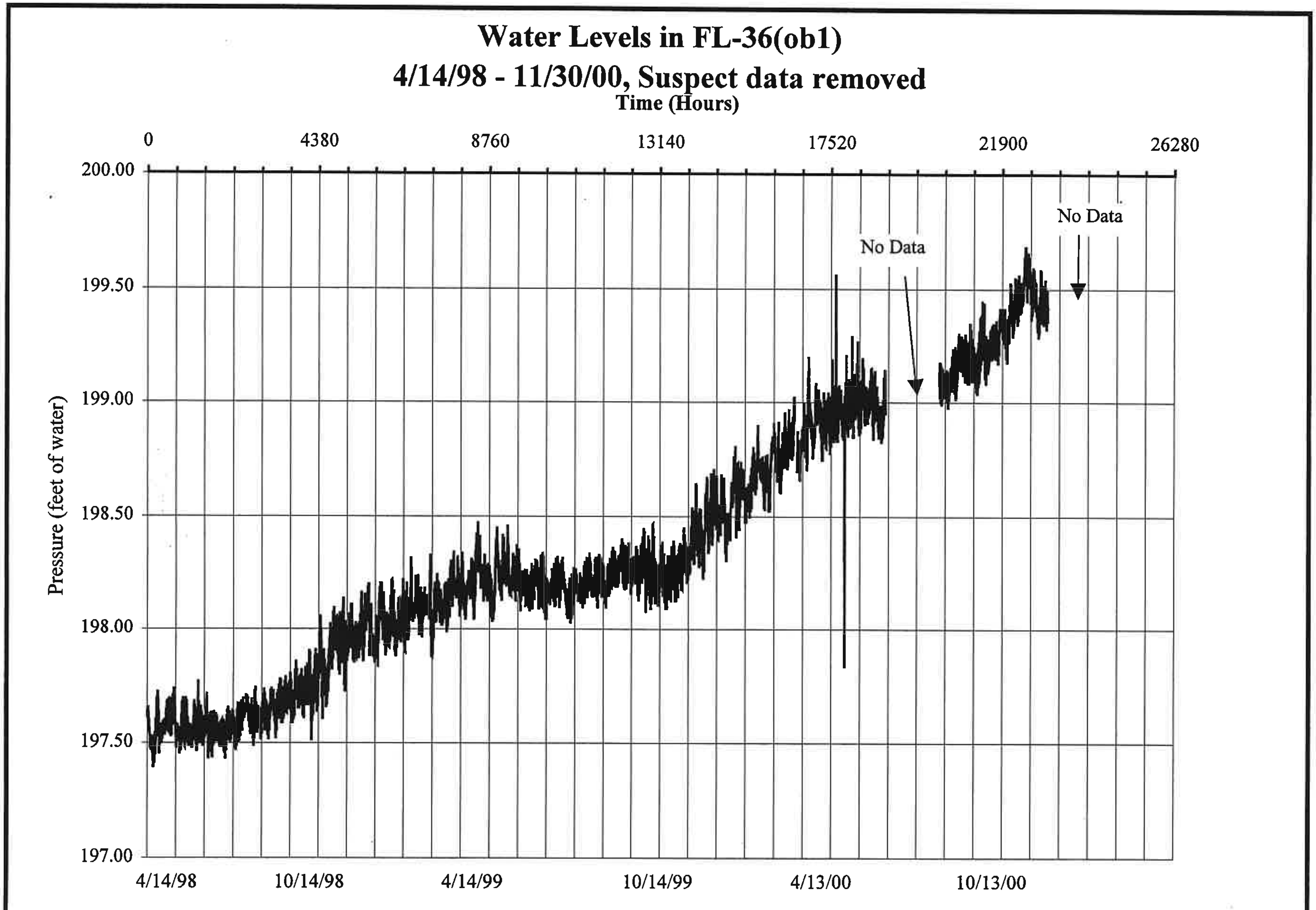
F7



Water Levels in FL-36
9/30/98 - 3/7/01, Suspect Data Removed
Time (Hours)
0
4380
8760
13140
17520
21900
Pressure (feet of water)
194.25
194.00
193.75
193.50
193.25
193.00
192.75
192.50
192.25
192.00
9/30/98
4/1/99
9/30/99
4/1/00
9/30/00



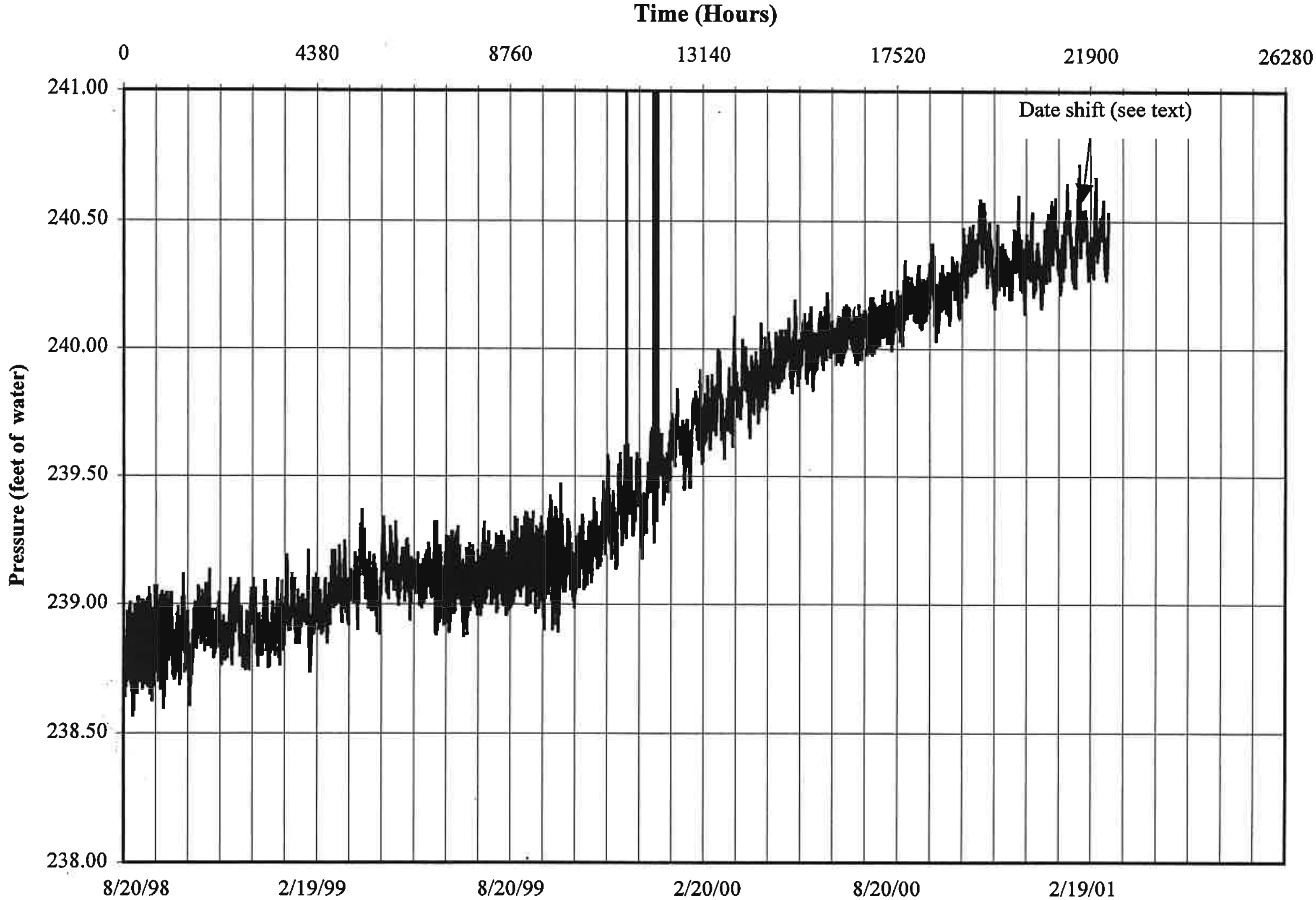
Water Levels in FL-36(ob1)
4/14/98 - 11/30/00
Time (Hours)
0
4380
8760
13140
17520
21900
26280
200.00
199.50
199.00
198.50
198.00
197.50
197.00
Pressure (feet of water)
No Data
No Data
4/14/98
10/14/98
4/14/99
10/14/99
4/13/00
10/13/00

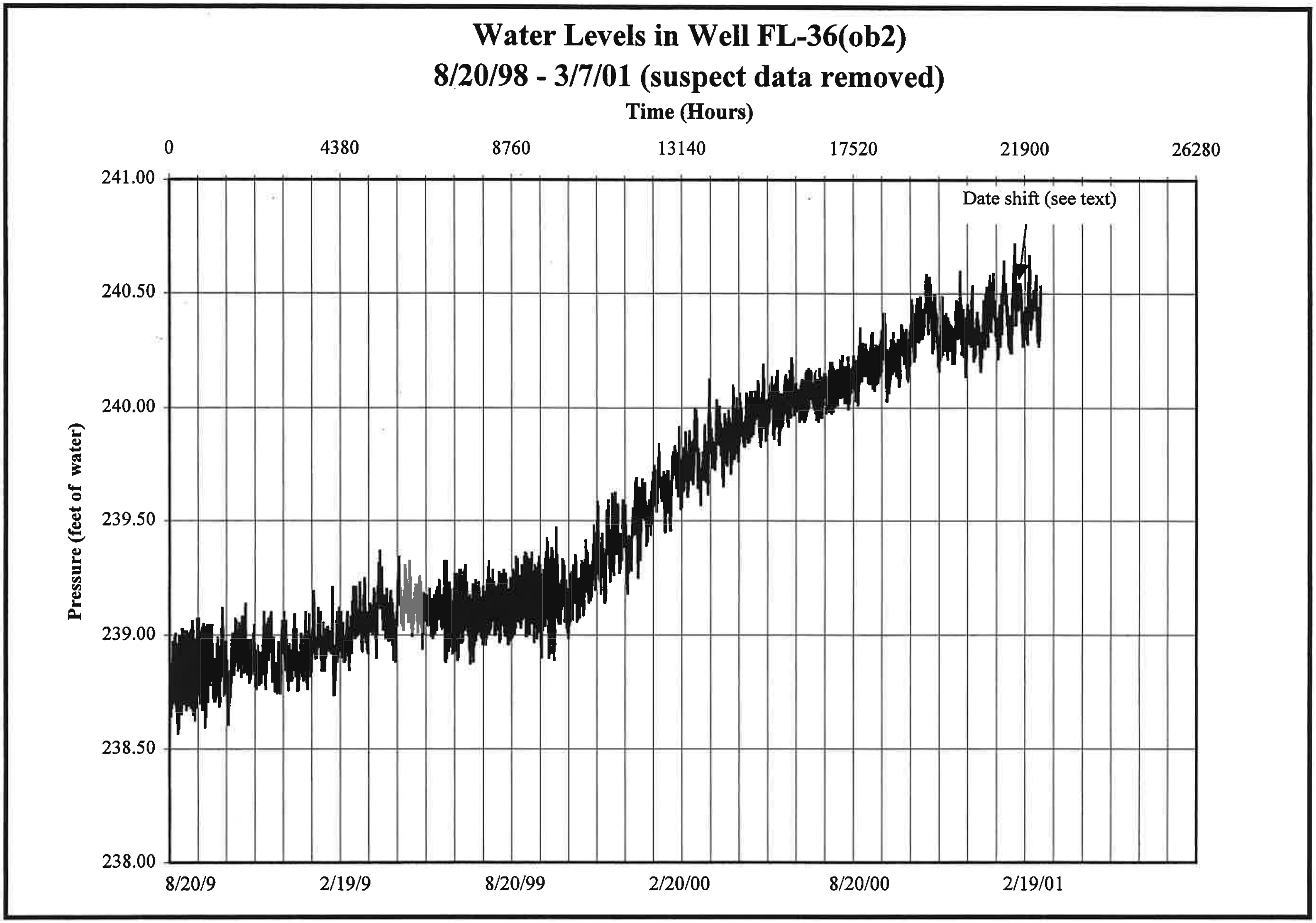


Water Levels in FL-36(ob1)
4/14/98 - 11/30/00, Suspect data removed
Time (Hours)
0
4380
8760
13140
17520
21900
26280
200.00
199.50
199.00
198.50
198.00
197.50
197.00
Pressure (feet of water)
No Data
No Data
4/14/98
10/14/98
4/14/99
10/14/99
4/13/00
10/13/00

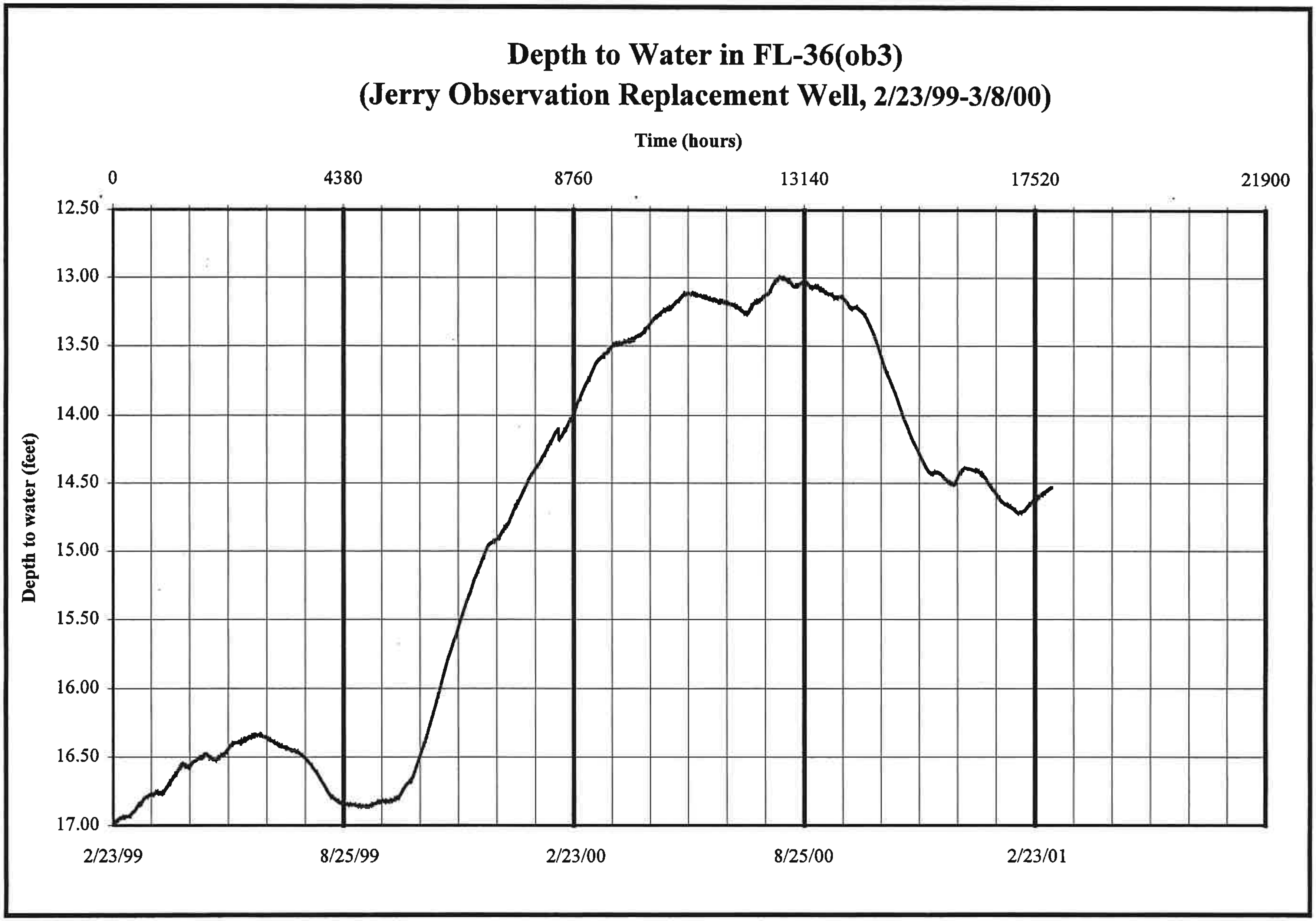
F10

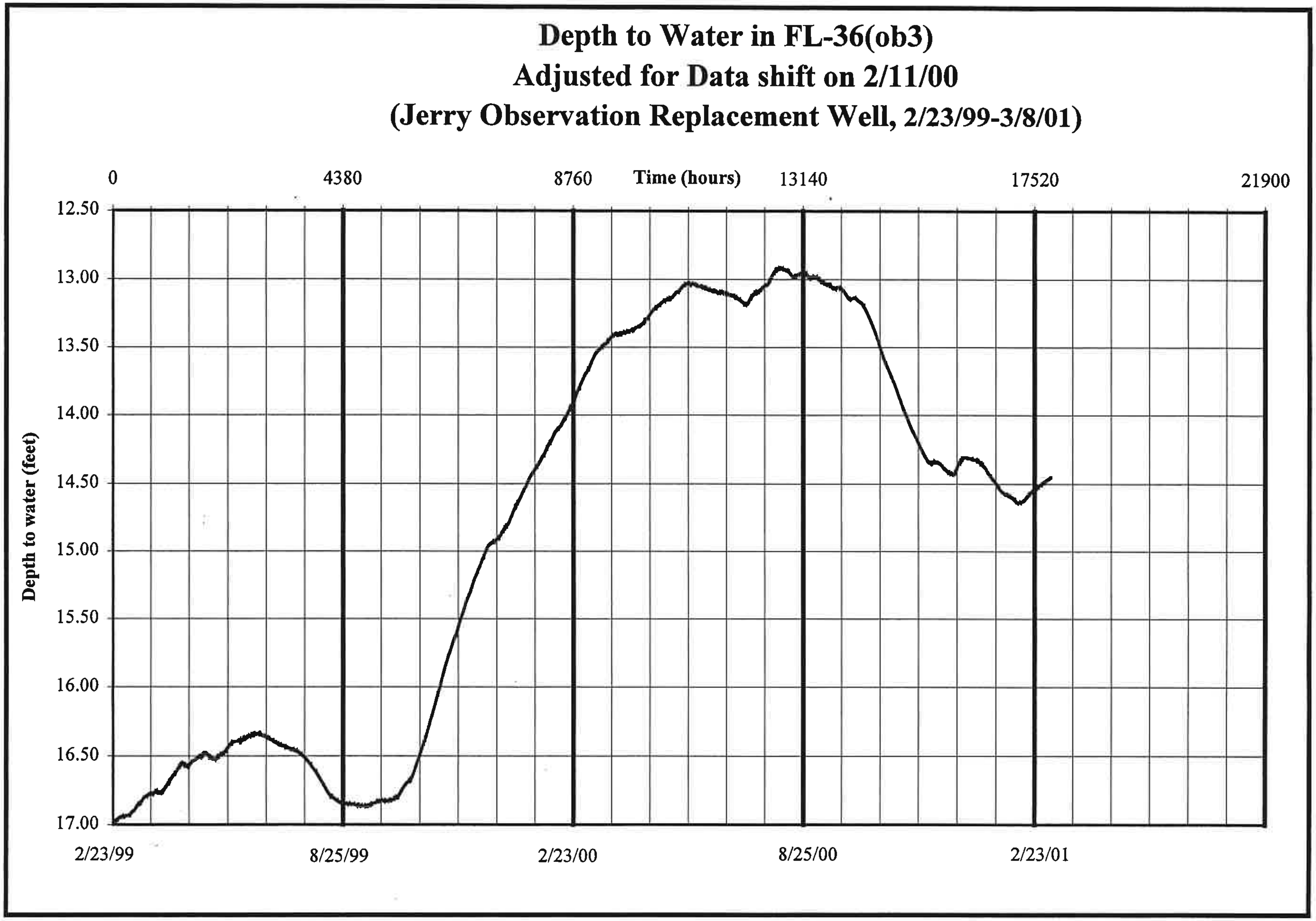
Water Levels in Well FL-36(ob2)
8/20/98 - 3/7/01





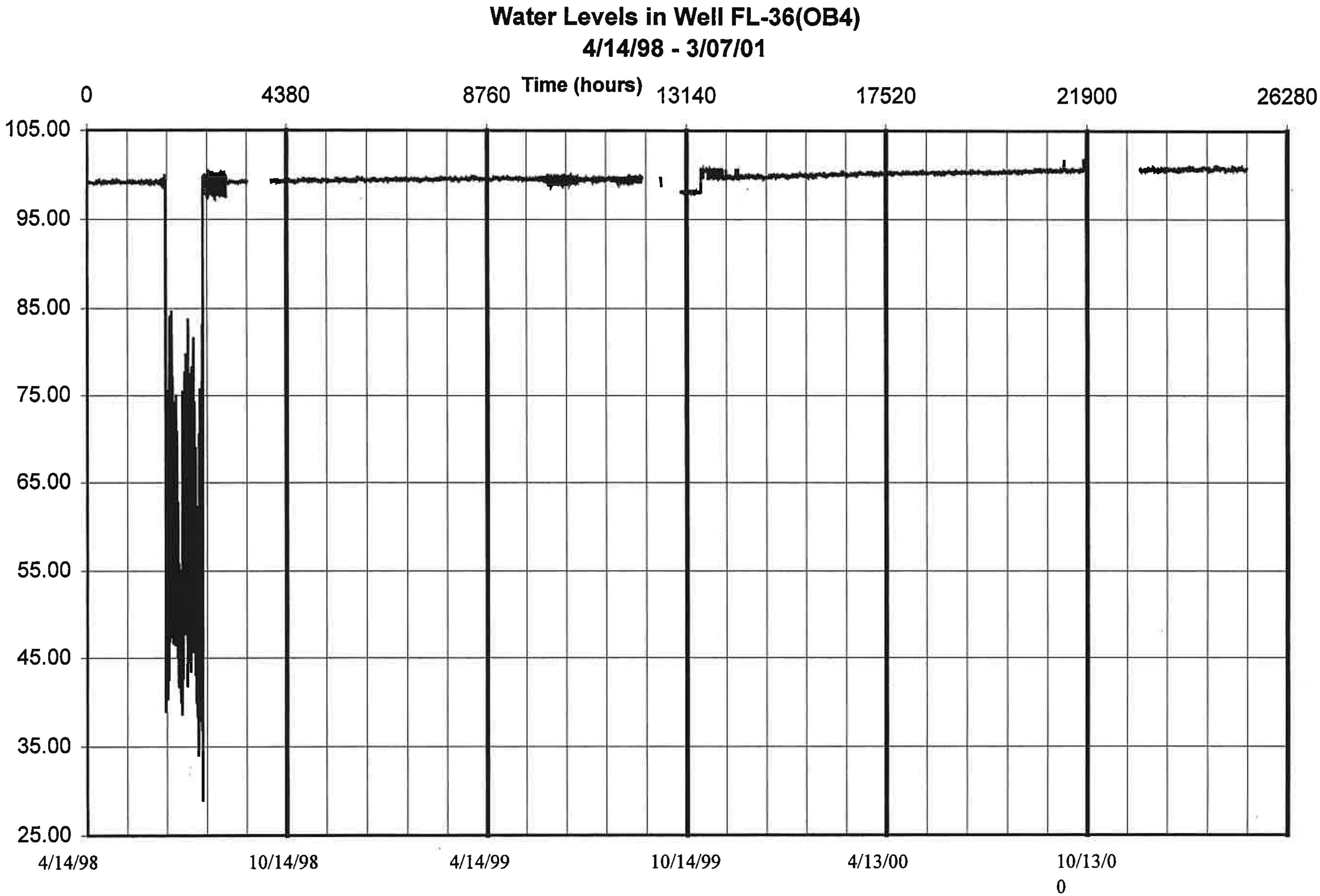
Water Levels in Well FL-36(ob2)
8/20/98 - 3/7/01 (suspect data removed)
Time (Hours)
0
4380
8760
13140
17520
21900
26280
Date shift (see text)
241.00
240.50
240.00
239.50
239.00
238.50
238.00
Pressure (feet of water)
8/20/9
2/19/9
8/20/99
2/20/00
8/20/00
2/19/01


Depth to Water in FL-36(ob3)
(Jerry Observation Replacement Well, 2/23/99-3/8/00)
Time (hours)
0
4380
8760
13140
17520
21900
12.50
13.00
13.50
14.00
14.50
15.00
15.50
16.00
16.50
17.00
Depth to water (feet)
2/23/99
8/25/99
2/23/00
8/25/00
2/23/01

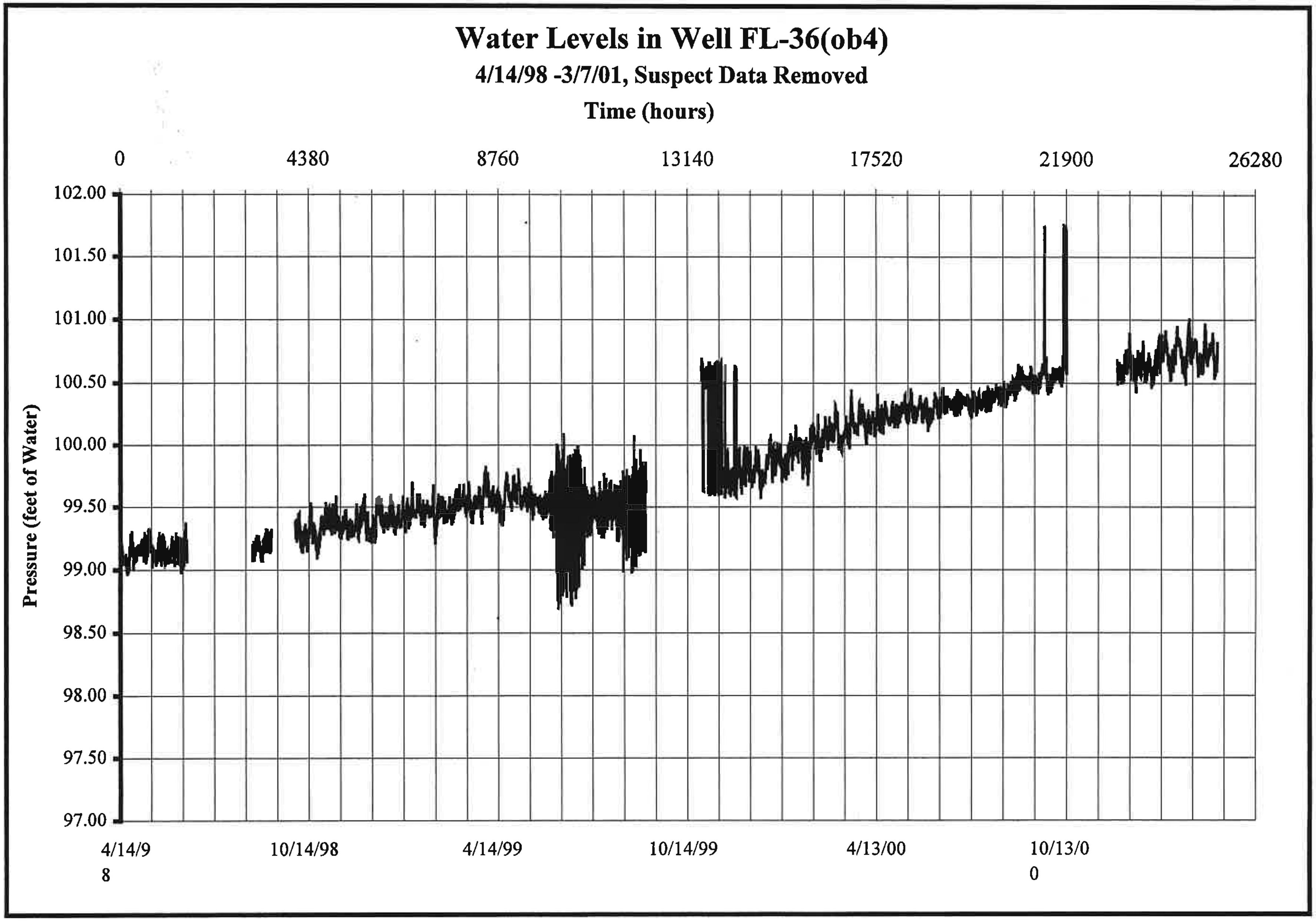


Depth to Water in FL-36(ob3)
Adjusted for Data shift on 2/11/00
(Jerry Observation Replacement Well, 2/23/99-3/8/01)
Time (hours)
0
4380
8760
13140
17520
21900
Depth to water (feet)
12.50
13.00
13.50
14.00
14.50
15.00
15.50
16.00
16.50
17.00
2/23/99
8/25/99
2/23/00
8/25/00
2/23/01

F14


Water Levels in Well FL-36(OB4)
4/14/98 - 3/07/01
Time (hours)
0
4380
8760
13140
17520
21900
26280
105.00
95.00
85.00
75.00
65.00
55.00
45.00
35.00
25.00
4/14/98
10/14/98
4/14/99
10/14/99
4/13/00
10/13/0
0

F15


Water Levels in Well FL-36(ob4)
4/14/98 -3/7/01, Suspect Data Removed
Time (hours)
0
4380
8760
13140
17520
21900
26280
102.00
101.50
101.00
100.50
100.00
99.50
99.00
98.50
98.00
97.50
97.00
Pressure (feet of Water)
4/14/98
10/14/98
4/14/99
10/14/99
4/13/00
10/13/00

F16

APPENDIX G: GGI CORRESPONDENCE WITH OSM REGARDING PROPOSED PUMPING TEST

GLORIETA GEOSCIENCE, INC.
P.O. Box 5727 Santa Fe, NM 87502
(505) 983-5446 Fax (505) 983-6482

MEMO

To: Keith Kirk
From: Paul Drakos PD
Subject: Meeting RE long-term pumping test configuration on May 28, 1997 in Albuquerque
Date: May 23, 1997

Thank you for the invitation to attend the meeting with OSM, SRP, MMD, and possibly BIA on Wednesday, May 28, 1997 at OSM offices in Albuquerque at 10:00 A.M. I will attend, and look forward to the opportunity to make progress in scheduling a long-term pumping test to properly characterize the Dakota sandstone aquifer in the proposed Fence Lake mine permit area. I do wish to make clear, however, that the position of GGI and of Zuni Pueblo with respect to configuration of a long-term pumping test remains the same as was described in GGI's February, 1997 report on p. 19 (conclusion #6):

A longer and properly configured pumping test could definitively demonstrate whether leakage occurs through the Mancos Shale, and whether pumping effects extend beyond a radius of 3708 feet. To determine if pumping effects will extend beyond 3708 feet, SRP should perform a 60 day pumping test on FL-36 or until SRP has measured substantial drawdown at FL-36 (OB2)... Existing wells in the Atarque Sandstone and the Dakota Sandstone aquifers should also be used as observation wells. An additional water level observation well should be drilled into the Dakota aquifer between 5000 and 8000 feet to the southwest of FL-36 (along Nations Draw, in the vicinity of the old Hubbell Ranch headquarters as we discussed in the field). If SRP continues to think that substantial leakage will be derived from the the Paguate and Two Wells Members of the Dakota, additional observation wells should be drilled into these two units.

I have also done some calculations to estimate how long it will take to observe drawdown at OB2 and at our proposed new observation well along Nations Draw. The Theis nonequilibrium equation was utilized to calculate estimated drawdown at FL-36 (OB2) and at the observation well proposed by GGI and Zuni Pueblo at a distance of 5000 feet from the pumping well. A pumping rate of 300 gallons per minute (gpm) or 57,754 ft^3/day from FL-36 was assumed for the proposed pumping test. Calculations were based on two separate transmissivity (*T*) values: 1) 9000 gpd/ft or 1200 ft^2/day, based on pumping well data from between 10 and 500 minutes in the March and December, 1994 pumping tests conducted by SRP; and, 2) 2500 gpd/ft or 340 ft^2/day, based on observation well data from the December, 1994 pumping test. A storage coefficient (*S*) of 0.00049 was used for all calculations. Calculated drawdowns at the times shown in Table 1 are based on the following set of equations:

$$u = \frac{r^2 S}{4Tt}$$

$$h_0 - h = \frac{Q}{4\pi T} W(u)$$

Table 1. Estimated drawdown at OB2 and proposed observation well at r = 5000 ft.

Time since start of pumping (days)		10	20	30	40	50
OB2 r = 13,500 ft.	High-T solution	0.28 ft. drawdown	0.95 ft. drawdown	1.7 ft. drawdown	2.3 ft. drawdown	
OB2 r = 13,500 ft.	Low-T solution		0.14 ft. drawdown	0.57 ft. drawdown	1.5 ft. drawdown	2.2 ft. drawdown
Well at 5000 ft.	High-T solution	4.0 ft. drawdown	6.4 ft. drawdown			
Well at 5000 ft.	Low-T solution	3.5 ft. drawdown	8.5 ft. drawdown			

xc: Mr. Andrew Othole, Lieutenant Governor, Pueblo of Zuni

MEMORANDUM

August 28, 1997

TO: Fence Lake File

FROM: Keith Kirk

SUBJECT: **Phone Conversation with Glorrieta Geoscience regarding the proposed Fence Lake Mine**

Today I spoke with Hydrologist Jay Lazarus of Glorrieta Geoscience Inc., the Zuni's Hydrologic Consultant on the Fence Lake Project. The purpose of the phone call was to get GGI's input on the material that I faxed to them 2 weeks ago that included the updated OSM hydrologic summary based on input from the State of New Mexico. This material was sent to GGI in preparation for OSM requesting that the Zuni "sign-off" on the OSM hydrologic analysis which was requested by Sylvia Bacca at the last briefing with her on this project.

Bottom line: GGI will be recommending to the Zuni that they **NOT** sign off on the OSM hydrology summary because the current modification to the permit granted by MMD does not contain provisions for the pump test to be run for a duration long enough to characterize the aquifer. The current modification has provisions for running the pump test only until the monitoring system is "tested".

The need to include this language has been GGI's position on this issue all along, i.e. that the pump test must be run long enough to characterize the aquifer not just test the monitoring program. BIA's correspondence with OSM indicates that their request for a long term pump test is also to better characterize the aquifer. Based on meetings with OSM, MMD, and GGI, SRP was aware of GGI's position on this matter prior to submitting the modification to the permit.

Based on this conversation with the Zuni's Hydrologic Consultants GGI it would appear futile for OSM to officially request the Zuni sign off on the OSM Summary Hydrology analysis.

A draft of this memo was faxed to GGI for their comment. Jay Lazarus confirmed on 8/28/97 that this accurately reflects our conversation.

Copies of this final memo were sent to MMD, SRP and GGI.

Document Name: GGI82897.wpd