Attachment 3

FINAL WASH-PLANT REFUSE DISPOSAL HYDROLOGIC IMPACT EVALUATION REPORT

Black Mesa Mine Complex
Kayenta, Arizona

Prepared for:

Peabody Western Coal Company

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EXECUTIVE SUMMARY

Peabody Western Coal Company (PWCC), retained Western Water & Land, Inc. (WWL) to assist in the process of preparing a comprehensive revision to the Mining and Reclamation Plan for the Black Mesa and Kayenta Mines (Black Mesa Mine Complex - BMMC). This revision includes the construction and operation of a coal wash plant facility at the Black Mesa Mine. The coal-washing facility will be used to refine the separation of coal and mine waste materials. It is estimated that the coal-washing facility will produce approximately 1.38 million tons per year of mine waste (refuse) materials. Preliminary wash plant design forecasts a mixture of coarse (plus 100-mesh) and fine (minus 100-mesh) materials will be produced as refuse. Total annual refuse should be approximately 1.38 million tons per year, made up of about 0.62 million tons of coarse materials with a 7.0 percent surface moisture, and about 0.76 million tons of fine materials with a 40 percent surface moisture.

Western Water & Land, Inc. (WWL) was retained by PWCC to evaluate the potential hydrologic impact to wash-plant refuse disposal at the BMMC. The assessment will be incorporated into the upcoming mine-plan revision to support plans for proper disposal of the wash-plant refuse in accordance with regulations promulgated as part of the Surface Mining Control and Reclamation Act of 1977. The work included the following tasks: 1) evaluate potential refuse disposal sites, 2) recommend the most favorable site with regard to minimizing hydrologic impact, and 3) analyze the potential hydrologic impact of refuse disposal at the recommended site. This report presents the results of these tasks.

WWL's technical approach involved a detailed examination of each potential refuse disposal site within the following Coal Resource Areas (CRAs): N-6, J-3, J-7, and J-23. The primary evaluation criteria included:

- Depth to groundwater
- Potential for re-saturation of replaced spoil
- Background geochemistry
- Available refuse storage space

Data and information examined to support these criteria are shown in Table 3.1, and primarily included groundwater occurrence and behavior information, water quality data, Wepo Formation characteristics (corehole data), and potential storage volume. General information collected during a site visit was also used.

WWL concluded that the J-23 CRA presents the most favorable characteristics for refuse disposal that will result in minimal hydrologic impact. The J-23 CRA will not be developed until 2011, 2 to 3 years after the wash plant begins operation. However, the estimated bottom of the pit will be at least 150 ft above the interpreted Wepo Aquifer potentiometric surface. In addition, the interpreted potentiometric surface is relatively uniform, of low gradient and does not diverge or converge to a local discharge area (surface drainage). The J-23 CRA is expected to have sufficient storage volume for refuse disposal, as mining operations are expected to remove 5,000,000 cubic yards of coal annually. The estimated volume of wash-plant refuse produced on an annual basis is 1,000,000 yds^3.

CRAs N-6 and J-7, which are active pits nearing the end of their mineable resources, were considered areas of potential greater impact because the interpreted Wepo Aquifer potentiometric surface extends upwards of 30 feet above the estimated bottom of the pits. In addition, the final footprints of the N-6 and J-7 pits will be in close proximity (500 ft) to the major surface-water drainages of Coal Mine Wash and Yucca Flat Wash. The N-6 and J-7 pit bottom elevations would be below or near the surface elevations of these drainages, presenting another potential hydrologic impact should groundwater migrate from the pits.

The J-3 Reclaimed CRA was mined in the 1970s and 1980s and is now fully reclaimed. The J-3 Reclaimed CRA may have a potential for hydrologic impact in the long-term as the interpreted Wepo Aquifer potentiometric surface forms a hydraulic divide along the ridge where J-3 is located. Should refuse leachate migrate to a continuous saturated zone in the Wepo Formation, groundwater flow has the potential to occur in multiple directions at relatively moderate to steep hydraulic gradients. Groundwater underlying the J-3 area may eventually discharge into Coal Mine Wash to the west and Moenkopi Wash to the southeast.

Although the J-23 CRA was selected as the most favorable site for minimal hydrologic impact, it is anticipated the area will not be fully developed and able to receive refuse for a period of 2 to 3 years after start-up of the coal wash plant. Therefore, PWCC directed WWL to evaluate hydrologic impact of a 3 year disposal scenario at the N-6 pit and long-term disposal at the J-23 CRA.

The technical approach used to assess the potential hydrologic impact of wash-plant refuse disposal in the N-6 and J-23 CRAs focused on the following tasks:

1. A comparison of ambient groundwater and surface water quality to the potential chemical composition of refuse leachate water

2. A study of the fate of refuse leachate (potential quantity and migration from the refuse disposal area)

The objective of the first task of comparing the water quality of ambient Wepo Aquifer and estimated refuse leachate was to evaluate the potential for refuse leachate to degrade ambient groundwater quality in the Wepo Aquifer. This work was conducted by an in-depth data compilation, reduction, and statistical analysis. The objective of the second task, the evaluation of leachate fate, was to evaluate leachate quantity and the potential migration from the disposal sites. This task was assessed by the use of analytical and numerical flow and transport models.

The data generated to approximate the leachate composition of the wash-plant refuse consisted of 23 (including 2 duplicate samples) interburden samples obtained from a corehole drilling program conducted in the summer of 2003. The core samples consisted of Wepo strata composited from within mineable coal seams or thin non-coal strata immediately below the mineable seams. The samples were submitted to the analytical laboratory for Synthetic Precipitation Leaching Procedure (SPLP) analysis of metals and wet chemistry parameters. The core samples were also analyzed for total metals and soil characteristic parameters.

The results of Task 1, the comparison of ambient water quality of the Wepo Aquifer with analytical data generated to approximate the leachate composition of the wash-plant refuse, indicated that leachate produced as a result of acid rain infiltrating the refuse material likely contains higher concentrations of aluminum, arsenic, barium, mercury, selenium, vanadium, and zinc than does natural groundwater in the vicinity of the J-23 and N-6 Mining Areas. It is expected that metals concentrations in groundwater induced leachate would likely be less than those reported on the basis of the SPLP analyses. On the basis of the saturated paste extraction results, nitrate and nitrate/nitrate concentrations are expected to be higher in the refuse material than in natural groundwater in the vicinity of the N-6 Mining Area. Nitrate and nitrate/nitrite concentrations are expected to be less in the refuse material than in natural groundwater in the vicinity of the J-23 Mining Area. Analyte concentrations in leachate derived from the refuse material are expected to be similar or less than the concentrations in natural groundwater for the other metals listed in Table 4.1 and inorganic constituents listed in Table 4.2.

The potential accumulation and migration of refuse leachate from the refuse disposal areas in the N-6 Pit and J-23 Pit were studied through the use of the application of the unsaturated flow and transport model HYDRUS2D®, and a two-dimensional analytical saturated flow model, (TDAST®).

HYDRUS2D was initially used to evaluate transient drainage of the refuse. The results of the transient drainage simulations showed that drainage of the refuse would take hundreds of years, and that little drainage would be realized during mining operations. In the extreme long-term, a simulation for over a time of 600 years, the generated leachate would be equivalent to approximately 5.3 ft (1.6 m) of saturated thickness in the refuse.

Long-term fate of the leachate was further modeled using TDAST at the N-6 Pit and HYDRUS2D at the J-23 Pit. In the case of the N-6 Pit, it was conservatively assumed that, in a worse-case scenario, pit inflows into the pit from the Wepo Aquifer would eventually saturate the refuse deposits placed in the pit. TDAST results indicated that only a fraction (approximately 0.07) of the leachate solutes would be present a distance 500 ft downgradient of the pit after 25 years of simulated transport. The addition of solutes in the ambient Wepo Aquifer groundwater resulted in a minor increase in overall solute concentrations. A mixing calculation shown in Calculation No.2 (Appendix C) and Table 4.5 also showed minimal change in ambient Wepo groundwater quality.

The J-23 Pit was evaluated for potential leachate migration by way of unsaturated flow into the underlying Wepo Aquifer. A one-dimensional application of HYDRUS2D was used to assess unsaturated flow into the Wepo Formation below accumulated drainage from wash-plant refuse.

The results of the HYDRUS2D simulation showed that unsaturated flow and solute transport of refuse leachate in the Wepo Formation is limited to a saturation depth of 8 ft (2.4 m) (Figure 4.8). Increases in water content, i.e. the wetting front, occurred at approximately 30 ft (9 m) below the refuse/Wepo contact. Solute transport simulations (Figure 4.9) confirm this conclusion, and show that solute concentrations after 200 years of infiltration are equal to or less than 0.2 of the original leachate concentration at a depth 32.8 ft (10 m) below the refuse/Wepo contact.

On the basis of the HYDRUS2D simulations, unsaturated flow and solute transport of the refuse leachate is extremely limited and will not approach the interpreted Wepo Aquifer potentiometric surface below the J-23 Pit within a 200-year period. It is also important to note that should refuse leachate with its full source concentration infiltrate into a continuous saturated zone of the Wepo Aquifer, the resulting concentrations of solute would be similar to the results of the TDAST simulations performed for the N-6 Pit. Saturated simulations of solute transport for the J-23 pit would result in smaller concentrations than the N-6 Pit simulations (for the same time and distance), because the J-23 Mine Area is characterized by a smaller hydraulic gradient.

Conclusions

The J-23 Mine Area provides the most favorable location for disposal of refuse generated by coal-washing operations to be conducted at the BMMC. The pit in the J-23 area will be located in an area where the projected potentiometric surface of the Wepo Aquifer exhibits a relatively uniform and low hydraulic gradient, the bottom of the pit will be located approximately 150 ft above the projected potentiometric surface of the Wepo Aquifer, and no primary surface water drainages are located in the immediate vicinity of the pit.

The interim use (3 years) of the N-6 Pit and long-term use of the J-23 Pit for wash-plant refuse disposal will result in minimal increases in water quality analyte concentrations in the case of saturated flow in the Wepo Aquifer and minimal migration in the case of unsaturated flow. Overall, the disposal of wash-plant refuse at BMMC will have a negligible impact on water quality and quantity in the mine area.

1.0 INTRODUCTION

Peabody Western Coal Company (PWCC) is preparing a comprehensive revision to the Mining and Reclamation Plan for the Black Mesa and Kayenta Mines (Black Mesa Mining Complex – BMMC). This revision includes the construction and use of a coal wash plant facility at the Black Mesa Mine. The coal-washing facility will be used to refine the separation of coal and mine waste materials. It is estimated that the coal-washing facility will produce 1.38 million tons per year of mine waste (refuse) materials.

Western Water & Land, Inc. (WWL) was retained by PWCC to (1) evaluate potential refuse disposal sites, (2) recommend the most favorable site with regard to minimizing hydrologic impact, and (3) analyze the potential impact of refuse disposal in the recommended site(s). This report presents the results of these tasks and is organized in the following main sections:

1.0 Introduction
2.0 Hydrogeologic Setting
3.0 Refuse Disposal Site Evaluation
4.0 Hydrologic Impact Analysis
5.0 Summary and Conclusions

1.1 Background

PWCC owns and operates the Black Mesa and Kayenta surface mines. The mines, collectively referred to as the Black Mesa Mine Complex (BMMC), are located approximately 15 miles southwest of the town of Kayenta, Arizona on approximately 101 square miles of land leased from the Navajo Nation and Hopi Tribe (Figure 1.1). Collectively, the mines produce approximately 12 million tons per year of coal used to generate electricity. The Black Mesa Mine began operation in 1970, and currently produces approximately 4.6 million tons of coal from two active pits. The Kayenta Mine began full production in 1973. The Kayenta Mine currently produces approximately 7.8 million tons of coal from three active pits.

PWCC is preparing to file a substantial revision to the mining and reclamation plans for the mines to extend mining through calendar year 2025. The Black Mesa Mine plans to routinely clean coal using a wash plant facility in order to meet their customer's coal quality requirements. Life-of-mine plans for the Black Mesa Mine anticipate average annual coal production to be about 6.2 million tons of coal. A majority of this annual coal production will be washed at the plant, and result in refuse material that will be disposed of at an appropriate site near the plant. Preliminary wash plant design forecasts a mixture of coarse (plus 100-mesh) and fine (minus 100-mesh) materials will be produced as refuse. Total annual refuse should be approximately 1.38 million tons per year, made up of about 0.62 million tons of coarse materials with a 7.0 percent surface moisture and about 0.76 million tons of fine materials with a 40 percent surface moisture.

2.0 HYDROGEOLOGIC SETTING

The hydrogeologic setting described in this section focuses on the geology and hydrogeology of the Wepo Formation and the underlying Toreva Formation and Mancos Shale. These strata are of most interest and concern with respect to evaluating the probable hydrologic impacts of wash-plant refuse disposal. The source of information for this section originates from the Geology (Chapter 4) and Hydrologic Description (Chapter 15) sections of the Mining and Reclamation Plan (MRP) for the Black Mesa and Kayenta Mines (PWCC 1985a). For a more complete description of the main aquifer units on the Black Mesa please see this reference.

2.1 Geology

This section summarizes the hydrostratigraphy of the coal-bearing and underlying strata. The geology and hydrology of the Black Mesa Mine area is discussed in detail in Chapters 4 and 15 in the MRP (PWCC 1985a).

The Black Mesa is an extensive plateau whose rim is defined by Cretaceous-age rocks of the Mesaverde Group. Coal deposits mined at the Black Mesa Complex occur within the Wepo Formation, the middle member of Mesaverde Group. The Wepo Formation is underlain by the Toreva Formation and overlain by the Yale Point Sandstone. All three formations are present only on Black Mesa. The Mesaverde Group is underlain by the Mancos Shale, also of Cretaceous age (PWCC 1985a). Geologic formations older than the Mancos Shale are discussed in Chapter 4 of the PWCC mine permit (PWCC, 1985a).

The Wepo Formation consists of a thick sequence of interbedded mudstone, siltstone, sandstone and coal. The thicker sandstone beds tend to have conglomeratic bases of chert and silicified limestone pebbles. The Wepo Formation ranges from approximately 320- to 740-feet (ft) thick on the Black Mesa and is approximately 640-ft thick in the mine area. The formation dips gently to the west. Some clinker or burn (burned coal and baked shale) areas are present in the upper part of the Wepo Formation and occur as resistant ledges, ridges, or knobs on the surface. Coal strata in the Wepo Formation occur in seven somewhat consistent horizons identified in descending order as 1) violet, 2) green, 3) blue, 4) red, 5) yellow, 6) brown, and 7) orange. The mineable coal strata vary from 3- to 8-ft thick, infrequently coalescing to 20-ft thick beds. Generally, the coal is considered to be primarily of durain and fusain composition, derived from sedges and grasses rather than decomposed swampy forests (PWCC, 1985a).

Overburden and interburden thickness in the area of the mine pits varies from approximately 200 ft to 220 ft.

The underlying Toreva Formation in the south portion of Black Mesa consists of three members: (1) the upper sandstone member; (2) the middle carbonaceous shale member; and (3) the lower sandstone member. The upper sandstone member is a poorly-sorted fine to coarse-grained sandstone. The middle carbonaceous shale member is in gradational contact with the lower sandstone member and consists of thinly-bedded carbonaceous mudstone, varicolored siltstone units with coal, and thick lenses of poorly sorted fine-to coarse-grained sandstone (PWCC, 1985). The lower sandstone member consists of fine- to medium-grained quartz sandstone. The lower part of this member may have units of thin-bedded siltstone and fine-grained mudstone as it transitions to the underlying Mancos Shale (PWCC, 1985a).

The subdivisions of the Toreva Formation in the north half of Black Mesa are: (1) a basal unit which consists primarily of fine- to medium-grained quartz sandstone, some coal, carbonaceous shale and thin-bedded siltstone; (2) a middle shale unit consisting of firmly-cemented siltstone and a few sandstone ledges; and (3) an upper unit which consists of very coarse- to medium-grained poorly sorted sandstone. Formation thicknesses range from 141 to 325 feet (PWCC, 1985a).

The Mancos Shale is fissile marine shale underlying the Toreva Formation and attains thicknesses between 500 and 1,000 ft in the Black Mesa area. Descriptions of the Mancos Shale in the area of the mine indicate a formation that consists predominately of silty mudstone with some bentonite and minor beds of very fine-grained sandstone.

Geologic structure in the Black Mesa region consists of northwest-trending gentle folds and faults of small displacement. In the area of the Black Mesa Mine Complex, most folds are oriented north and most faults are oriented west. There is minor evidence of faulting on the surface with the throw of the major faults not exceeding 40 ft. There is little evidence of faulting and fracture zones on the exposed cuts and highwalls of the mined pits (PWCC 1985a, and Willson, 2003).

2.2 Hydrogeology

Groundwater storage, recharge, movement and quality in the Black Mesa Mine area are partially to totally controlled by facies changes and stratigraphic position (stratigraphy); anticlines, synclines, monoclines, basins and upwarps (structure); downcutting of drainage systems (erosional stage); and the average amount of precipitation available for recharge (PWCC 1985a).

The hydrogeology of the Wepo Formation in the area of the mining operations has been studied by PWCC through research done by others, the installation and hydraulic testing of wells, and monitoring of groundwater levels and water quality and surface-water hydrology features. Mine pits have also been examined to better understand the Wepo groundwater conditions.

On the basis of wells installed strictly within the Wepo "Aquifer", the aquifer is considered of limited regional aquifer capability. The Wepo Aquifer is of poor water quality and most wells do not continuously yield usable amounts of groundwater. Sulfate in the Wepo wells monitored by PWCC ranges from 2 to 4,760 milligrams per liter (mg/L), with a mean of 853 mg/L. Total dissolved solids (TDS) in the same monitored wells ranges from 320 to 8,010 mg/L, with a mean of 1,833 mg/L. Pumping rates during hydraulic testing in the Wepo wells averaged 11.7 gallons per minute (gpm).

Groundwater potential in the Wepo Formation is low. The conglomeratic zones, where saturated, should yield some water to wells. Thicknesses range from 304 ft near Yale Point to 743 ft east of Cow Springs. The formation thins to the northeast (PWCC 1985a).

The Mancos Shale is generally considered impermeable and hydraulically isolates the underlying D-aquifer system from the overlying "Upper Cretaceous Aquifers" in the Mesaverde Group.

Groundwater yields from the Toreva Formation in both sections of Black Mesa are dependent on the degree of lensing of the sandstone units with the shale, siltstone, and mudstone units as well as the grain sizes and degree of sorting of the sand grains. In the southern portion of Black Mesa, the better water yielding units are: (1) the upper part of the lower sandstone member which contains no mudstone; (2) sections of the middle carbonaceous member, which unlike most of the member contains almost all sandstone; and (3) the upper part of the upper sandstone member, which is very coarse-grained and conglomeratic. In the northern half of Black Mesa, the best water yielding units are the upper parts of the lower and upper sandstone subdivision, where the grain size is generally coarser and percentage of silt is less (PWCC 1985a).

Groundwater in the Wepo and Toreva Formations is present under both water table and artesian conditions. Artesian conditions occur in the Wepo and Toreva Formations away from their outcrops.

Unconfined conditions prevail along the perimeter of the Mesa. Groundwater is primarily obtained from sandstone units within the formations, especially where these sandstone beds are hydraulically connected. Due to the interbedding nature of the sandstone units with siltstone and mudstone beds, depths to groundwater can be variable from place to place. In places where sandstone units are underlain by coal, siltstone, or mudstone beds, perched water tables of limited storage and hydraulic connection exist. In several areas where the contact between the Toreva Formation and the impermeable Mancos Shale is exposed, groundwater discharges in the form of springs and provides an important source of domestic water (PWCC 1985a). Groundwater movement and well yields in the Wepo and Toreva Formations are in part controlled or limited by depths of erosion along Polacca and other principal washes on Black Mesa, which could act as groundwater sinks (PWCC 1985a).

Groundwater is primarily obtained from the Toreva Formation and only secondarily from the Wepo Formation. Well yields range from 10-15 gpm. The groundwater is of marginal to unsuitable drinking water quality. Sulfate and total dissolved solids concentrations usually exceed the recommended drinking water limits, and the range of fluoride concentrations (0.1-2.1 parts per million [ppm]) exceeds the recommended limit of 1.8 ppm for fluoride in drinking water supplies in the Black Mesa area (PWCC 1985a)..

The Quaternary-age alluvial deposits can locally provide significant amounts of groundwater in the region. Along some of the larger washes, deposits more than 200 ft thick exist from which water yields of from 10 to 1,000 gpm are obtained. Along the smaller washes, alluvial thicknesses range from 25-80 feet, and water yields are on the order of 10 to 50 gpm. In the northern part of Black Mesa, the alluvial veneer is very thin, and the well yields are small. During times of drought, many of these wells may be dry (PWCC 1985a).

3.0 REFUSE DISPOSAL SITE EVALUATION

This section discusses the evaluation of potential refuse disposal sites at Black Mesa Mine including the potential site candidates, the evaluation criteria and process, data compilation and findings, and concludes with a site-specific interpretation section that recommends a preferred site disposal area.

3.1 Potential Refuse Disposal Sites

PWCC originally specified that four potential refuse disposal areas be evaluated. These sites included Coal Resource Areas (CRAs) J7, N6, J27, and J3. CRAs J7 and N6 are existing pits and are still being mined, whereas J27 and J3 have been mined and are now reclaimed areas. During the site visit (September 8, 2003), WWL was asked to also evaluate CRA N-11. However, PWCC subsequently determined that CRAs N-11 and J-27 should not be considered for waste disposal and that one additional CRA, J-23, should be included in the evaluation. CRA J-23 is a proposed pit, and it will be several years (2008) before mining reaches bottom of coal in this area.

3.2 Evaluation Criteria

PWCC and WWL developed primary criteria for evaluating the suitability of using a CRA for disposing of coal-washing refuse. These criteria focused on the physical characteristics of the mine areas suited for long-term disposal of refuse. Long-term disposal scenarios are considered of potential greater hydrologic impact due to the potentially greater volume of transient drainage produced by the refuse materials. WWL did not evaluate mine areas on the basis of administrative or economical criteria such as proximity to the proposed coal wash facility. The primary evaluation criteria included:

- Depth to groundwater
- Potential for re-saturation of re-graded spoil
- Background geochemistry
- Available refuse storage space

In addition, WWL used two screening criteria to initially rank the potential refuse disposal areas. These criteria included proximity to surface water features and the apparent configuration of the Wepo Aquifer potentiometric surface as presented on the potentiometric surface map (Drawing No. 85610).

3.3 Evaluation Process

The evaluation of refuse disposal sites involved a compilation of information acquired from (1) a site visit to the Black Mesa Mine and (2) the review of available and relevant hydrogeologic data.

The purpose of the site visit to the Black Mesa Mine was to view the potential refuse disposal sites, discuss the mining history and hydrogeologic conditions of each site, and to acquire data needed to conduct the assessment. An important part of the site visit was to observe and examine the hydrogeologic conditions at each potential refuse disposal area including mine area topography, surface hydrology (seeps, springs, and streams), pit highwall characteristics (rock composition, fracture density, and seepage faces), and other physical attributes.

The review of pertinent hydrogeologic data was of primary importance in assessing the refuse disposal sites. Data considered to potentially contribute to the assessment of the refuse sites included:

- Piezometric and potentiometric surface maps
- Well, borehole, and corehole logs (lithology)
- Well construction diagrams
- Well, borehole, corehole location maps
- Aquifer hydraulic test data
- Geologic map and formation descriptions
- Geologic structure map/descriptions
- Geophysical data
- Geotechnical data
- Mine maps of potential refuse disposal areas
- Bottom of coal and projected bottom of pit footprints for potential refuse disposal areas
- Map showing surface hydrology features, and environmental monitoring sites (streams, ponds, and springs)

The information obtained on the site visit and all written, electronic, or verbally communicated information was reviewed. Some data were reduced to expedite data review and interpretation. Generally, the data were reviewed on an individual mine area basis using the established criteria. Table 3.1 presents the data provided to support evaluation of the potential disposal areas.

3.4 Site Visit

WWL visited the Black Mesa Mine on September 8th, 2003. The purpose of the visit was to visually inspect the potential disposal sites to receive coal-wash refuse materials. In addition, WWL interviewed and discussed with PWCC employees the availability of data required to fully evaluate the suitability of the potential refuse disposal sites.

During the site visit WWL (Mr. Bruce Smith) toured the potential refuse disposal sites in CRAs J-7, J-27, J-3, N-6, and N-11. CRAs J-27 and J-3 have been mined out and reclaimed. CRAs J-7, N-6, and N-11 are actively being mined. CRA J-23 was not visited as it is not currently under development. A close inspection of the exposed Wepo Formation on the pit faces was not permissible because of mine safety protocols. Pit faces and the existing pit bottoms were observed from a distance of at least 300 ft.

PWCC scientists and engineers were interviewed concerning hydrogeologic information of the Wepo Formation within the CRAs, both as observed on pit highwalls and from borehole data. In addition, inquiries were made about rock fracture density and other geologic structures including jointing, fracture zones, faults, seepage or inflows within the mine pits, and if any exposed zones of the Wepo Formation show tendencies to seep groundwater. The Mine Geologist at the BMMC stated that neither the pit exposure of the Wepo Formation or borehole lithology revealed notable zones of increased fracture density, but that the study of fracture density has not been necessary to support normal mining operations. The geologist indicated that there were fairly uniform fractures throughout the Wepo Formation and that there were no characteristic zones of seepage from the Wepo Formation in most of the CRAs being considered for potential refuse disposal. However, he further indicated that local perched groundwater zones were occasionally intercepted during drilling of boreholes. The average spacing for drilling exploration boreholes is approximately 330 ft, with a 100- to 150-ft spacing used in outcrop areas and a 660-ft spacing used for corehole drilling. The geologist said there was little water intercepted at most of the drilling locations (Willson 2003).

3.5 Data Compilation and Findings

Assessment findings relative to each of the evaluation criteria listed in Section 3.2 of this report are discussed separately below.

3.5.1 Depth to Groundwater

In 1985, PWCC prepared a potentiometric surface map (Drawing No. 85610) using groundwater levels recorded for monitoring wells completed within the Wepo Formation and located throughout the Black Mesa Mine Complex area. In addition, a preliminary map (PWCC 2003?) of potentiometric water levels in 2003 has recently been developed by PWCC. An assessment of historic and recent water level data from the Wepo wells indicates that the general potentiometric surface configuration has not significantly changed since the initial map was prepared in 1985. Mean water-level elevations for the period of record from 1980 to the present, are generally within 5 ft above or below the elevations used to create the 1985 map, and the regional flow direction and gradients have generally remained consistent over time. However, it is possible that local groundwater flow directions and hydraulic gradients have changed near some of the pits that have been mined since the potentiometric surface map was prepared in 1985.

Of the local evident changes in the potentiometric surface since 1985, the decrease in water levels in Wepo Well 53 is of particular importance for this study because of the well's proximity to CRA N-6 (N-6 Pit). The 2003 draft potentiometric surface map indicates a depressed water level in the N-6 Pit vicinity as a result of the decreased water level in Well 53. The 2003 map would suggest that the potentiometric surface may exceed the final pit bottom topography by 5 to 10 feet, whereas, the 1985 potentiometric surface may exceed the final pit bottom topography by as much as 15 to 25 feet. Assuming that the noted decreases in the Wepo potentiometric surface are mostly caused by mining operations (pit excavations), it is logical to further assume that the potentiometric surface will recover after the pit areas are reclaimed. Therefore, the 1985 potentiometric surface (Drawing 85610) and well data proximal to the potential refuse disposal sites were used to assess potential elevation of re-saturation for post-mining scenarios.

A comparison of the 1985 potentiometric surface and the anticipated bottom of pit or coal topography indicates that southern portion of the final pit footprint for CRA N-6 and the western portion of the final footprint for CRA J-7 will lie as much as 25 ft and 45 ft below the potentiometric surface, respectively. The pit bottom for the J-23 area will lie at least 150 feet above the potentiometric surface. The bottom of coal surface for the mined and reclaimed J-3 area ranges from 20 ft below to 100 ft above the potentiometric surface. The area below the potentiometric surface in the J-3 area is limited to a small depression in the northwest portion of the mined area.

An examination of the configuration of the potentiometric surface over the Black Mesa Mine Complex indicates a surface that generally mimics surface topography on a less precise scale. Generally, all mining areas with the exception of J-3 fall in areas of singular flow direction and gradient. Area J-3 is situated on a hydraulic divide, where flow lines in the Wepo Aquifer diverge to Moenkopi Wash to the east southeast and Coal Mine Wash to the west. The attitude of the Wepo Aquifer potentiometric surface in the J-23 area is relatively flat, compared to other mine areas, with a uniform westerly hydraulic gradient of 0.008 to 0.013 ft/ft.

The potentiometric surface also indicates that the Wepo Aquifer intercepts and discharges to certain areas of Moenkopi Wash and Coal Mine Wash.

3.5.2 Potential for Re-Saturation of Spoils

A review of pit inflow calculations and well and borehole logs was conducted to support evaluation of the potential for re-saturation of spoil.

3.5.2.1 Pit Inflows

Chapter 18 (Probable Hydrologic Consequences) in the MRP (1985a) presents pit inflow calculations for several of the CRAs, most of which have been reclaimed or are currently being mined. As mining operations progress, similar pit inflow calculations are prepared for new CRAs. These calculations generally predict pit inflows ranging from several thousands of gallons to over 10 million gallons per year for the various pits.

The total inflows for the J-1/N-6 Pit were projected to range from approximately 50,000 gallons in 1972 to 3,182,179 gallons in 2003. As mining has progressed over the last several decades, it has generally been observed that pit inflows were overestimated, and in some cases no inflow has occurred at all. For example, initial mining of the southern portion of the N-6 Pit saw enough pit inflow to require pumping, but subsequent mining of this pit to the north has not resulted in any observed pit inflows. As another example, the J-7 Pit has not shown any significant inflows and no seepage face is present on the highwalls or bottom of the pit (Cochran 2003).

3.5.2.2 Well and Borehole Logs

Wepo well and exploration borehole logs were examined for wells and boreholes located within or near the potential refuse disposal areas. A summary of borehole information is presented in Appendix A.

An examination of the lithologic logs for wells constructed in the Wepo Formation do not indicate extensive zones of wet conditions or that water was seeping into the borehole during drilling operations. Personal communication with PWCC personnel at the Black Mesa Mine confirmed that during drilling, very few of the boreholes yielded water, yet when allowed to sit for a period of time, some boreholes gradually yielded water and were completed as wells. Wells were apparently screened either across the stratigraphic intervals considered most favorable for yielding groundwater or on the basis of the observed depth to water in the borehole. Multiple screened intervals were installed in some wells; however, the multiple intervals were not isolated from one another with a grout seal. Static groundwater levels within the wells are typically located well above the screened intervals, supporting the concept of confined conditions in the Wepo Aquifer (this applies to wells that been constructed with hydraulic seals above the upper-most screened interval).

Of the corehole data available, four logs were available for the J-23 area, three logs were available for the J-7 area, and 16 logs were available for the N-6 area. Some of the borehole summaries indicate isolated intervals of lost circulation, lost core, and damp or wet conditions. However, wet conditions were not reported in the corehole logs from the J-7 and J-23 areas. As a group, the N-6 area corehole logs indicated the presence of isolated wet or damp conditions over the entire length of each corehole, typically extending from 18 ft to 228 ft.

3.5.2.3 Wepo Well Water Levels

To further evaluate the potential for re-saturation of spoils, an examination of Wepo well water levels in wells in the vicinity of the potential refuse disposal mine areas was conducted to assess the sensitivity of the Wepo Aquifer potentiometric surface to hydrologic stresses. Water level elevations for 14 Wepo wells (Wells 40, 43 through 48, 53, 58 through 61, 65, 86, and 90), were plotted over time (Appendix B). The period of record was generally from 1986 to 2003.

An examination of the water level fluctuations over time did not indicate a regional trend in water levels that might support more long-term climatic influences. This observation supports the confined nature of the Wepo Aquifer. However, some wells have shown distinct increasing or decreasing trends in water level elevations. For example, Well 44 exhibited steady water levels (with the exception of seasonal fluctuations) until 1992 when water level elevations began to increase; water levels have increased a total of 10 ft to the present date. Well 43 showed relatively steady levels until 1988, after which levels dropped 5 ft by 1991, leveled off until 1993 and then increased 1ft through 1997. The cause of the water level fluctuations in the Wepo wells is uncertain without a detailed analysis of well installation procedures and assessment of potential impacts caused by mining activities proximal to each well. PWCC (1985) stated that a primary factor influencing Wepo well water levels is pumping during sampling and hydraulic testing. Some wells are slow to recover after drawdown from pumping events. The data also suggest that mining activities (Well 53) and surface water discharge (Wells 60 and 61) may have an influence on local water levels in the Wepo Aquifer. Section 3.5.1 discusses water levels in Well 53 and the potential relationship to mining activities.

3.5.2.4 Hydraulic Testing Data

Data provided by PWCC indicated that 23 Wepo wells were tested for hydraulic parameters using pumping tests and modified slug tests. A summary of these data is presented in Table 3.2.
The arithmetic average of transmissivity values for the Wepo wells is 116.6 gallons per day per foot (gpd/ft); the geometric mean is 36.24 gpd/ft. Two pumping tests resulted in estimates of the storage coefficient with an average of 8.2×10^{-5}, indicating confined conditions.

The hydraulic conductivity of the Wepo Aquifer has not been directly measured, and because the confining strata in the Wepo Aquifer have not been clearly delineated, estimates of the hydraulic conductivity are problematic. PWCC (1985) reports that Cooley and others (1969) measured the permeability of sandstone rock cores from the Wepo Formation, the results of which ranged from 0.0009 to 0.02 gpd/ft^2 (0.003 ft/day). Alternatively, an average hydraulic conductivity value estimated on the basis of the screened interval in the hydraulically-tested Wepo wells is 0.11 ft/day which is similar to an estimate initially used for approximating groundwater flow for a tracer test conducted at Pond BM-A1 (WWL 2002). The data do not show strong trends with respect to other well parameters. However, a plot of the transmissivity data does suggest a weak inverse correlation with respect to depth to water or water level elevation (Figure 3.1). That is, the smaller the depth to water, the greater the transmissivity value. This relationship can be attributed to greater weathering and fracture density in the shallow portion of the formation.

3.5.3 Background Geochemistry

Ambient geochemical conditions of groundwater within the Wepo Aquifer was assessed on the basis of analytical results reported for samples collected from Wepo monitoring wells located in the vicinity of each CRA. The analytical results were obtained from the PWCC database, which contains monitoring results for samples collected from a network of 36 wells over a monitoring period extending from 1986 through 2002. The monitoring wells evaluated for the various mining areas are as follows:

Mine Area	J-3	J-7	J-23	N-6
Wells	WEPO45	WEPO47	WEPO65	WEPO40
	WEPO86	WEPO47R	WEPO66	WEPO43
	WEPO90	WEPO60	WEPO67	WEPO53

Background geochemistry was evaluated by computing summary statistics for the metals and inorganic concentrations reported in the PWCC database for samples collected from local-area Wepo wells in the vicinity of each mining area and for lease-wide Wepo wells. Summary statistics for metals concentrations are presented in Table 3.3, and summary statistics for inorganic concentrations are presented in Table 3.4.

Examination of Table 3.3 shows that the mean concentrations of metals in groundwater are generally consistent among the four mining areas and the lease-wide well network. Of the analytes shown, the mean concentrations of magnesium and selenium are higher for the lease-wide well than for the local-area wells. The wells comprising the J-7 well network generally exhibit the best water quality, containing lower metals concentrations and lower frequencies of detection for several of the analytes than the other local area wells. The wells comprising the J-3 and J-23 well networks exhibit the lowest water quality, containing higher metals concentrations for several of the analytes than the other local-area wells. Concentrations exceeding the detection limit occur most frequently in wells comprising the J-23 well network.

Table 3.4 presents summary statistics for inorganic concentrations reported in the PWCC database for the local-area and lease-wide wells. The table shows that the mean concentrations among the local-area and lease-wide wells are generally consistent with only minor variations between the groups. The most notable exception is that the mean concentration of nitrate-nitrite in the lease-wide wells is higher than in the local area wells. Of the local area wells, the wells comprising the J-3 well network contain the highest mean concentrations, while the wells comprising the J-7 well network contain the lowest mean concentrations. The mean pH values for the lease-wide and local area wells range from 7.7 in the J-23 wells to 8.3 in the J-7 wells.

3.5.4 Disposal Area Storage

The estimated storage volume for each potential disposal area was provided by the PWCC engineering department at Black Mesa Mine. The estimated final pit volumes for waste storage are as follows:

- CRA J-3: 3,500,000 cubic yards (existing area available for waste)
- CRA J-7: 1,777,500 (pit volume)
- CRA N-6: 9,160,000 (pit volume)
- CRA J-23: Not yet available

The final J-23 Pit will be approximately 9500 feet long and 135 feet wide. Overburden and interburden displaced by stripping equipment each year will be approximately 16,000,000 cubic yards with approximately 2 1/4 cuts (sequences) per year. Annually, approximately 5,000,000 cubic yards of coal will be removed from the J-23 Pit. During the life of mining in the J-23 CRA, several locations near the progressing pit configuration could be used for disposing of refuse that will not interfere with the production-related operations of the pit. It will not be difficult to deposit the estimated 1,000,000 cubic yards of waste per year on the pit bottom and or between spoil peaks. However, J-23 will not be available for waste disposal for about 2-3 years after start-up of coal-washing operations and subsequent production of waste.

3.6 Site-Specific Interpretation

The information obtained and compiled during the site visit and upon review of hydrogeological data provided by PWCC indicates that the variable hydrogeology of the Wepo Aquifer complicates the task of selecting a potential refuse disposal area in the designated CRAs.

Of the criteria examined, depth to groundwater and the potential for re-saturation are of most importance with regard to hydrologic impact. It is apparent that, on the basis of observations at the mine, pit inflows do not always occur when mined pits penetrate below the potentiometric surface. It is postulated that the most probable causes for the lack of inflow include (1) pit bottoms did not penetrate the confining layer(s) in the Wepo Aquifer, (2) evaporation rates exceed discharge rates (Darcy flux) at the seepage face, and (3) the existence of discontinuous or variable saturation within the Wepo Aquifer (isolated perched zones). The latter point emphasizes the uncertainty associated with the interpreted potentiometric surface.

Groundwater inflows would not be expected at pits that have been extended below the potentiometric surface but have not penetrated the confining strata. In addition, water levels in wells adjacent to such pits would not be impacted (e.g., show drawdown) as a result of pit operations. The presence of confining strata has been assumed to exist at the mine site but has not been explicitly delineated. The relatively thin beds of shale, sandstone, and coal and their repetitious interbedded nature complicate the delineation of a discrete and single confining zone in the Wepo Aquifer. On the basis of static water levels, screened intervals, and anticipated pit bottom elevations, the possibility for a confining zone exists between the top of the screened intervals in Wepo wells nearest to Pits N-6 and J-7 and the bottom elevations of the pits.

Conversely, pits that have penetrated the confining strata would be expected to yield groundwater from the base of the pit and from the portion of the highwalls that extend below the confining strata. In this case, the inflow rate would be dependent on the aquifer hydraulic properties. Strata with low hydraulic conductivity may yield groundwater so slowly that evaporation rates prevent significant accumulation of water in the pits. It is also probable that the heterogeneous nature of the Wepo Aquifer accounts for inconsistent predictions of pit inflows. Groundwater in the Wepo Aquifer probably occurs in discontinuous lenses with limited amount of storage. In such cases, flow into pits that have penetrated confining strata may occur only in local perched zones and not uniformly throughout a particular zone or horizon.

Any or all of the above situations may exist within the mining areas at the Black Mesa Mining Complex. Additional site-specific studies would be needed to fully assess the mechanisms controlling groundwater flow in and around the mining areas in the Wepo Formation.

3.6.1 J-23 Mine Area

The J-23 CRA is considered the most favorable CRA for refuse disposal because (1) the projected bottom of the coal layer is at least 150 ft above the potentiometric surface of the Wepo Aquifer, (2) the potential for re-saturation of the waste from groundwater inflow from the Wepo Aquifer is minimal, (3) groundwater quality in the local area is generally consistent with the lease-wide area, and (4) the area available for storage is projected to be sufficient for the refuse material. The Wepo potentiometric surface in the mine area forms a broad uniform flow area (no convergent or divergent flow lines). On the basis of the Drawing No. 85610, the potentiometric surface across the mine area has a hydraulic gradient of 0.013. The hydraulic gradient calculated from mean water levels (95 to 594 observations per well) for Wells 65, 66, and 67, is 0.008. In addition, the mine area is not located near any large surface drainage features.

Although the J-23 CRA is a new mine area, and the hydrogeologic conditions of the pit can not be observed first hand, the available corehole data from the area do not indicate that perched groundwater conditions exist in the area. Based on the corehole log information and observations at other mined areas, the probability of re-saturation of spoils due to seepage from perched groundwater conditions is considered to be low.

3.6.2 N-6 and J-7 Mine Areas

The N-6 and J-7 CRAs were not considered the most suitable locations for long-term refuse disposal for similar reasons. The primary disadvantages for disposal in these areas are that final pit bottom elevations are below the interpreted potentiometric surface of the Wepo Aquifer and that both CRAs are in close proximity to surface drainages and associated alluvial aquifers.

The N-6 CRA is not the preferred long-term refuse disposal site on the basis of the screening criteria because the Wepo Aquifer potentiometric surface ranges from 14 ft (north end) to 25 ft (south end) above the bottom of the final pit elevations. The minimum water level elevations in Wells 40 and 53 are 32.9 ft and 91 ft above the bottom of pit elevations for the north and south ends of the pit, respectively. In addition, the final pit has a moderately steep hydraulic gradient of 0.021 in the middle area of the pit and a hydraulic gradient of 0.038 in the northern portion of the pit. The potentiometric surface indicates that Wepo groundwater in the vicinity of the pit may ultimately discharge to Coal Mine Wash, which is located only 400 ft north of the north end of the pit.

The J-7 Mine Area is similar to the N-6 Mine Area with respect to its suitability for refuse disposal. The anticipated final J-7 Pit bottom will range from approximately 12 ft above (east end) to 45 ft below (west end) the Wepo Aquifer potentiometric surface. The minimum water level elevation in the nearest Wepo Aquifer well, Well 48 (now abandoned), is 43 feet above the lowest anticipated pit bottom. The hydraulic gradient in the area of the J-7 Pit is 0.017 with flow to the west and southwest toward Yucca Flat Wash. The potentiometric surface shown in Drawing No. 85610 indicates a convergence of Wepo Aquifer flow lines at Yucca Flat Wash suggesting the wash provides a discharge point for the aquifer. The convergence of the flow lines becomes more significant approximately 0.5 miles downstream of the J-7 Pit.

Although the elevation of the potentiometric surface higher than the projected bottoms of the N-6 and J-7 Pits, no significant inflows have been observed at either pit to date. There are several possible explanations for the lack of substantive evidence supporting projected pit inflows. First, while the pit bottoms extend below the potentiometric surface, the pit excavations may not have fully penetrated the confining strata, and therefore, the pits have not intercepted the saturated strata with hydraulic head expressed by the mapped potentiometric surface. Alternatively, the pits may have in fact penetrated some or all of the confining strata, but groundwater flows from the saturated zones so slowly that evaporation along the pit margins limits surface expressions of the flow. Thirdly, saturated intervals comprising the Wepo Aquifer can be discontinuous and the pits may be located in areas that are not hydraulically connected to localized saturated intervals. Regardless of the reason for the lack of observed seepage into the pits, the available site hydrologic data indicate that the potential exists for groundwater to flow into pits.

The deepest elevation of the J-7 Pit will be approximately 6,240 ft and the stream channel of Yucca Flat Wash, which lies 500 ft to the south, is approximately 6,300 ft. The relatively short distance from the alluvial aquifer in Yucca Flat Wash to the J-7 Pit increases the risk for migration of alluvial groundwater associated with the drainage to intercept the pit, and conversely, for fluids generated in the pit to migrate to the alluvial aquifer, potentially discharging along the drainage.

Metals and inorganic concentrations in monitoring wells near the N-6 and J-7 Pits are generally consistent with the overall concentrations reported for the Wepo Aquifer. However, metals concentrations in samples collected from J-7 wells are typically lower than those reported for samples from the other local-area and the lease-wide well network, implying that Wepo Aquifer water quality with respect to metals in the J-7 CRA is slightly better than elsewhere within the lease area at the site with respect to metals.

The storage volume available at each pit is likely to be sufficient for refuse disposal. The final N-6 Pit storage volume will be approximately 9,160,000 cubic yards (based on uncompacted refuse). The potential storage volume of the J-7 Pit is 1,777,500 cubic yards. On the basis of the potentiometric surface, the potential exists for the portion of the J-7 Pit that lies west of approximately the 30,000 easting coordinate to become saturated with groundwater inflow. Therefore, the storage volume available in the portion of the pit that is expected to remain dry (east of approximately the 30,000 easting coordinate) would be less than 1,777,500 cubic yards.

3.6.3 J-3 Mine Area

The J-3 CRA was mined in the 1970's and 1980's and has since been reclaimed (recontoured and revegetated). An examination of the former pit bottom with respect to the Wepo Aquifer potentiometric surface (Drawing No. 85610) indicates that the former bottom of pit ranges from 20 ft below to 125 ft above the potentiometric surface. However, the pit bottom area below the potentiometric surface is restricted to a relatively small depression along the north boundary of the pit.

Three Wepo wells are located in the J-3 CRA. Water levels in Wepo Wells 86 and 90, located just north of the northern former pit boundary, indicate an increase in water levels of approximately 10 and 5 ft, respectively, since the beginning of the monitoring period in 1986. Water levels in these wells have been relatively stable since 1993. The mean water level elevations for Wells 86 and 90 are 6,500 ft and 6,503 ft above mean sea level (amsl), respectively, and indicate that the distance between the bottom of pit and the potentiometric surface shown by Drawing. No. 85610 may actually be approximately 10 feet less than indicated.

Wepo Well 45 is located near the center of the J-3 reclaimed CRA. The mean water level elevation of Well 45 for the period of record (1986 to present) is 6,438.7 ft. Similar to Wells 86 and 90, Well 45 showed initial increase in water levels of approximately 4 ft and has been relatively stable since 1996. The mean water level elevation also indicates that local water levels have increased 5 to 10 ft compared to levels indicated by the potentiometric surface shown on Drawing 85610.

The hydraulic gradient across the J-3 reclaimed CRA is 0.018 along the pronounced hydraulic divide that is formed by the Wepo Aquifer potentiometric surface. This divide is indicative of a potential recharge area, with diverging flow paths to the west-southwest to Coal Mine Wash and to the east-southeast to Moenkopi Wash. The distances to Coal Mine Wash and Moenkopi Wash from the hydraulic divide near the center of the reclaimed CRA are approximately 7,000 ft and 8,000 ft, respectively. Distances to prominent tributaries to these washes are 3,400 ft and 4,800 ft respectively. The indicated (Drawing No. 85610) hydraulic gradient between the hydraulic divide to the north-trending tributary is 0.03.

There are no corehole data readily available for the J-3 reclaimed CRA, nor are there data that refer to pit inflow observations or the geotechnical, geochemical, or hydraulic properties of the spoil material used during reclamation to backfill the J-3 Pit.

Based on the interpreted hydrologic setting in the vicinity of the J-3 reclaimed CRA, the potential for resaturation of the refuse material would be minimal since the base of the pit largely lies above the projected potentiometric surface of the Wepo Aquifer. However, the data indicate that the long-term potential exists for any constituents leaching from the refuse to flow along divergent flow paths and possibly discharge along primary drainage features in the area.

Metals and inorganic concentrations reported for samples collected from Wepo wells in the vicinity of the J-3 Mine Area are generally consistent with the concentrations reported for samples collected from other local-area wells and the lease-wide well network. However, the J-3 wells do tend to contain slightly higher mean concentrations of alkalinity, carbonate, bicarbonate, chloride, and fluoride in comparison to other local-area and lease-wide wells. The slightly elevated concentrations for these analytes in the J-3 wells do not impact the selection criterion regarding background geochemistry.

The storage area available for refuse disposal in the J-3 Mine Area is considered to be adequate. It is estimated that storage area available at J-3 is approximately 3,500,000 cubic yards. Disposal of refuse at the J-3 reclaimed CRA would occur directly on the already reclaimed surface, and would focus on the filling of existing surface depressions.

The J-3 reclaimed CRA is not recommended as a disposal area primarily due to its location on a hydraulic divide in the Wepo Aquifer as indicated in Drawing No. 85610. Although disposal of wash plant refuse would occur on the existing reclaimed surface, above the Wepo potentiometric surface, long-term potential migration of leachate from the site may involve multidirectional flow toward the primary surface-water drainages of Coal Mine Wash and Moenkopi Wash under relatively moderate to steep hydraulic gradients. In addition, disposal of refuse in the J-3 reclaimed CRA may involve further excavation work, such as top soil removal, to prepare the surface prior to refuse disposal; and additional revegetation efforts would be required in an area that has already been successfully reclaimed.

4.0 HYDROGEOLOGIC IMPACT ANALYSIS

In accordance with regulations promulgated in the Surface Mining Control and Reclamation Act (SMCRA) of 1977, PWCC is required to assess the probable hydrologic consequences of the mining operations. The disposal of wash-plant refuse materials presents a potential impact to the overall hydrologic balance within and adjacent to the lease area of the Black Mesa Mining Complex, and must therefore be evaluated. The evaluation of potential impacts to the hydrologic balance focuses on two primary components: (1) groundwater and surface water quantity (alterations to the existing flow conditions), and (2) groundwater and surface water quality degradation.

4.1 Summary of Regulations

Hydrologic impact assessment involves an evaluation of applicable performance standards as described in 30 Code of Federal Regulations (CFR) Part 816 as they related to protection of the hydrologic balance and disposal of coal mine waste. These regulations state that surface mining and reclamation operations are to minimize disturbance of the hydrologic balance within the permit and adjacent areas, to prevent material damage to the hydrologic balance outside the permit area, to assure protection or replacement of water rights, and to support approved post-mining land uses in accordance with conditions of the permit and regulation performance standards. Potential changes to the hydrologic balance include groundwater and surface water impacts. Applicable groundwater impacts include the potential for significant acid, toxic, or other pollutant infiltration to groundwater, and the change in potential use of groundwater. Applicable surface water impacts include the potential for significant acid, toxic, or other pollutant drainage to surface water, and the potential to affect surface water quality and flow rates.

4.2 Refuse Disposal Conceptual Model

The conceptual model of wash-plant refuse disposal at the Black Mesa Mine centers on the disposal of wash-plant refuse in a previously mined area. As discussed in Section 3.6.1, the J-23 CRA was selected as the optimal CRA for refuse disposal that would most-likely result in minimal hydrologic impact to the hydrologic balance within the lease area. However, the J-23 CRA is a proposed pit, and is yet to be developed. It is anticipated that wash-plant refuse will be produced for a period of 2 to 3 years before the J-23 CRA will be available to receive the waste materials. Therefore, to accommodate wash-plant refuse disposal during the 2 to 3 year beginning period for the wash plant operations, PWCC plans to dispose of the wash plant refuse in the N-6 Pit.

4.2.1 N-6 Pit

As discussed in Section 3.6.2, the bottom elevations of the final N-6 Pit will be as much as 25 ft below the Wepo Aquifer potentiometric surface (Drawing No. 85610). However, current observations do not indicate seepage (pit inflows) into the N-6 Pit in areas below the potentiometric surface. The fact that groundwater inflow has not been observed at the N-6 Pit suggests a hydrogeologic conceptual model that isolates this region of the Wepo Formation as unsaturated or at least not fully saturated. The unsaturated regions may exist because underlying confining strata were not penetrated during mining, or because of a number of other reasons including low hydraulic conductivity or high evaporation rates all of which are related to strata heterogeneity. The possibility of a discontinuous Wepo Aquifer has been suggested by PWCC (1985).

Alternatively, a conservative analysis will consider a worse-case scenario in which any wash-plant materials deposited in the N-6 Pit are resaturated due to pit inflows, meteoric precipitation, or transient drainage from the refuse.

The post-mining configuration of the N-6 Pit is estimated to be a long, north-trending open pit with side walls sloping away from an undulating floor at the angle of repose (approximately 38°). Figure 4.1 shows a plan view of the estimated final N-6 Pit. Disposal of wash-plant refuse in the N-6 Pit will occur on the pit bottom and the spoil slopes. Figure 4.2 shows a schematic profile of the pit with refuse disposal material. In a three-year period, approximately 3,000,000 yds^3 or 32% of the final N-6 Pit volume will be filled with wash-plant refuse. To minimize the amount of wash-plant refuse that is potentially re-saturated, the pit filling will be confined to a restricted area of the pit. Other spoil material will be placed around the wash-plant refuse to meet final reclamation grading plans.

The wash-plant refuse materials are expected to contain approximately 40% surface moisture content. Some of this moisture may be lost by evaporation or drainage during the handling process prior to disposal. As a conservative measure, it is assumed that the refuse will have 40% moisture content after placement in the disposal area. Although annual evaporation rates are high (approximately 45 inches) and annual precipitation is low (approximately 6.8 inches) at the Black Mesa Mining Complex, this conservative approach may also account for moisture gained by precipitation on the refuse materials (Cochran 2003).

Issues of primary importance in evaluating the hydrologic impact of refuse disposal are the volume and quality of transient drainage water from the wash-plant refuse and the long-term impact to groundwater quality due to the potential re-saturation of the refuse from pit inflow groundwater.

4.2.2 J-23 Pit

The interpreted potentiometric surface of the Wepo Aquifer in the J-23 CRA is relatively uniform, with flow to the west at a hydraulic gradient of approximately 0.013. An evaluation of this surface and the estimated bottom of coal pit topography shows that the final bottom elevations of the J-23 CRA will be at least 150 feet above the Wepo potentiometric surface (Figure 4.3). Because of the complicated nature of groundwater in the Wepo Formation (discussed in Section 3.6), the physical location of the top of the confined aquifer or confining zone is not known. In reality groundwater in the Wepo Formation may originate from a complex combination of perched unconfined and confined zones as well as a more widespread confined aquifer at depth.

Long-term disposal of refuse in the J-23 Pit will result in several hydraulic and solute transport processes that may impact the local hydrology. These processes include (1) transient drainage of inherent water content after refuse placement, (2) potential unsaturated flow and transport (percolation) of drainage water and solutes into the underlying unsaturated Wepo Formation, and (3) saturated flow and solute transport in the Wepo Aquifer in the case that percolating drainage intercepts the Wepo Aquifer. Conceptually, the processes of transient drainage of the refuse pore water will likely occur; however, the process and impact of unsaturated flow into the Wepo Formation, and the more remote occurrence of transient drainage reaching a ubiquitous Wepo Aquifer zone appears less probable. The latter flow and transport processes seem less likely to cause impact because of the questionable nature of the Wepo Aquifer, and the apparent low hydraulic conductivity of the interbedded shales, sandstones, and coal beds of the Wepo Formation. Furthermore, if a distinct stratum or even a complex series of confining strata exist above the Wepo Aquifer, these strata are expected to impede vertical flow from above elevations.

4.3 Technical Approach

The technical approach used to assess the potential hydrologic impact of wash-plant refuse disposal in the N-6 and J-23 Pits, focuses on the following tasks:

- Water Quality – Comparison of ambient water quality of groundwater to the potential chemical composition of refuse leachate water.

- Refuse Leachate Fate and Transport – Evaluation of the potential quantity and migration of refuse leachate from the refuse disposal area.

The first task of comparing the water quality of ambient Wepo Aquifer and estimated refuse water was conducted by an in-depth data compilation, reduction, and statistical analysis. The second task, refuse leachate fate and transport, was evaluated by the use of analytical and numerical flow and transport models.

4.3.1 Water Quality

To address the potential chemical contamination of groundwater coming in contact with the wash-plant refuse, the assessment approach consisted of data collection, compilation and reduction, followed by an interpretation task. The interpretation task involved comparing summary statistics of two data sets: (1) the ambient ground water quality data of the Wepo Aquifer and (2) the analytical results from the surrogate overburden and interburden materials. In addition, statistical tests were performed to further evaluate the different data sets.

4.3.1.1 Data Collection, Compilation, and Reduction

The data types needed to evaluate hydrologic impact(s) included groundwater chemistry data from the Wepo Aquifer, analytical data from Synthetic Precipitation Leaching Procedure (SPLP) testing of interburden and overburden samples, total metals and wet chemistry analytical data, soil acidity and toxicity characterization analyses, and hydraulic parameter data for the Wepo Aquifer.

PWCC conducted sampling and analysis of materials representative of overburden and interburden materials and coal-wash refuse. The overburden and interburden samples were considered "run-of-mine" coal that will probably become wash-plant refuse. Samples were collected from twenty-one select exploration core holes drilled in the following un-mined coal resource areas: J-2, J-4, J-6, J-14, J-15, J-23, N-6/N-11, N-9, and N-10. Samples were "composited" by grabbing thin sections of non-coal (shales, mudstones, etc.) found within the thicker, mineable coal seams in each core, and a thin (0.3 foot thick) section of the Wepo formation immediately below each mineable coal seam. These 21 new cores were obtained during the summer of 2003 (see Drawing No. 85613, Overburden and Impact Core Location Map in PWCC 2003). The sampling and analysis effort was conducted as follows:

- A total of 23 composite samples, including 2 duplicates, were collected for SPLP metals analysis (aluminum, arsenic, barium, boron, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, mercury, potassium, selenium, silver, sodium, vanadium and zinc) and SPLP inorganic analysis (alkalinity, bicarbonate, carbonate, hydroxide, chloride, fluoride, conductivity, total dissolved solids, and pH). The analyses were performed using EPA Method 1312 (EPA, 2003).

- Six selected composite samples, including 1 duplicate, were collected for total metals (aluminum, arsenic, barium, boron, cadmium, calcium, chromium, copper, iron, lead, manganese, mercury, silver, vanadium and zinc) using Method 200.7, and wet chemistry analysis (chloride, nitrate [as N], nitrate and nitrite [as N], nitrite [as N], total phosphate, and sulfate) using EPA Methods 4500Cl, $4500SO_4$, 353.3 and 365.3 (mg/L on paste extractant), and total Kjeldahl nitrogen (mg/kg, Method 351.3).

- Six composite samples, including 1duplicate, were collected for soil characterization analyses including pH (saturated paste), electrical conductivity, percent moisture, calcium (meq/L), magnesium (meq/L), sodium (meq/L), sodium adsorption ratio, percent sand, silt, and clay, soil class, total percent sulfur, percent pyritic sulfur, acid potential, neutralization potential, acid-base potential, pyritic acid potential, pyritic acid-base potential, total selenium, acid-base DTPA selenium, soluble selenium, and percent calcium carbonate. Three other composite samples were analyzed for a partial list of the parameters.

- A 20-drum bulk sample of raw coal was collected at the mine and submitted to a pilot- scale coal-wash testing facility. The wash testing was conducted to examine physical parameters associated with coal-wash process performance.

Existing data and data specifically collected for the hydrologic impact assessment were compiled from electronic and hard copy media provided by PWCC. The data were input into electronic (Excel®) spreadsheets, as necessary, to facilitate rapid data organization and reduction. A large portion of the existing information included Wepo Aquifer chemical analytical data, hydraulic testing analysis data, and water level data. In addition, existing mine maps of surface topography, the Wepo Aquifer potentiometric surface, mine areas, wells, environmental monitoring sites, bottom of coal elevations, and final pit footprints, were used throughout the assessment process.

4.3.1.2 Analysis and Interpretation

The interburden and overburden core samples were analyzed using EPA Method 1312 – SPLP (EPA 2003). The SPLP method is used to evaluate the composition of potential leachate from a solid waste material and is commonly used in the mining industry. The method involves the use of an extraction fluid that simulates the acidity of precipitation (rain, snow, etc.) that would fall on the waste. Precipitation is typically acidic due to air pollution impacts of heavy industrialization and coal utilization areas. In the western United States, the pH of the extraction fluid used is 5.0 (Alforque 2003). The waste to liquid ratio is 1:20 by weight. The waste and fluid mixture is agitated for 18 $\pm$ 2 hours and filtered with 0.6 to 0.8 μm glass filter before analysis. A mixture of sulfuric acid and nitric acid is used to prepare the extraction fluid. The analysis of sulfate and nitrate may therefore be affected. PWCC did not analyze for sulfate or nitrate in the SPLP extractant. Sulfate and nitrate were analyzed in the samples collected for soil characteristic parameters.

The groundwater geochemical records for the Wepo Aquifer were obtained from the PWCC database. The database contains water-quality records for samples collected from a network of 36 wells over a monitoring period extending from 1986 through 2002. The SPLP analytical results from the core samples collected in the un-mined areas were used as surrogate analytical data for actual refuse material. The refuse samples were analyzed for SPLP metals and SPLP inorganics (Table 4.1), and paste extraction inorganics (Table 4.2). These analytical results were used to assess analyte levels in potential refuse leachate relative to ambient groundwater-quality conditions within the Wepo Aquifer. The analytes projected to be present at higher concentrations in the refuse leachate than in natural groundwater are considered more likely to contribute to potential degradation of ambient groundwater conditions. Conversely, the analytes projected to be present at lower concentrations in the refuse leachate than in natural groundwater are considered less likely to contribute to potential degradation of ambient groundwater conditions.

A comparison of summary statistics for metals concentrations reported for refuse samples (SPLP) and groundwater samples collected from wells in the vicinity of CRA's J-23 and N-6 (local-area wells) and wells comprising the lease-wide well network (lease-wide wells) is presented in Table 4.3. As shown, summary statistics were computed for the sample sets containing reported concentrations at or above the method detection limit. Of the 19 SPLP metals analyses performed on the refuse samples, the mean concentrations of seven metals exceeded the mean concentrations reported for the lease-wide and local-area samples. The seven metals with mean concentrations in the refuse samples greater than the mean concentrations in the lease-wide and local-area samples were aluminum, arsenic, barium, copper, mercury, vanadium, and zinc. For each of these metals, a Student's t-test was performed to assess the significance of the difference between the mean values. Except for copper, the test results indicate that there is a statistical difference between the mean concentrations at the 0.05 level of significance. For copper, there is no statistical difference between the mean concentrations of the refuse samples and the lease-wide samples at the 0.05 level of significance. There is a statistical difference between the mean concentrations of the refuse samples and the local-area samples at the 0.05 level of significance; however, it should be noted that the concentrations reported for these samples were at or near the method detection limit. Selenium was the only other analyte with a mean concentration in the refuse samples higher than the local-area wells but lower than the lease-wide wells. Student's t-test results indicate that there is a statistical difference between the mean values of the refuse samples and the J-23 and N-6 samples at the 0.05 level of significance.

A comparison of summary statistics for inorganic concentrations in refuse samples (SPLP and paste extraction) and groundwater samples collected from wells in the vicinity of CRAs J-23 and N-6 (local-area wells) and wells comprising the lease-wide well network (lease-wide wells) is presented in Table 4.4. Sulfate, nitrate, and nitrate/nitrite are the only analytes with mean concentrations in the refuse samples that are higher than the mean concentrations for the site- wide and/or local-area wells. The mean concentration of sulfate in the refuse sample is higher than the mean concentration in the lease-wide wells and the local-area wells. T-test results for comparison of the means for sulfate indicate that there is no statistical difference between the means at the 0.05 level of significance. The mean concentrations of nitrate and nitrate/nitrite in the refuse samples are higher than the mean concentration in the local-area wells at N-6 but lower than the mean concentrations in the lease-wide and J-23 wells. T-test results for comparison of the means for nitrate and nitrate/nitrate indicate that there is a statistical difference between the means for both analytes at the 0.05 level of significance.

The mean pH value for the refuse samples (8.6) was higher than the mean pH value for the lease-wide wells (7.9), J-23 wells (7.7) and N-6 wells (8.0). Because the mean values of pH for the lease-wide and local-area wells are greater than 5.0 (the pH of the SPLP extraction fluid) it is expected that the metals concentrations reported for the refuse samples over-estimate the concentrations in leachate produced as a result of groundwater infiltrating the refuse material.

Results of the geochemical assessment indicate that leachate produced as a result of acid rain infiltrating the refuse material likely contains higher concentrations of aluminum, arsenic, barium, mercury, selenium, vanadium, and zinc than does natural groundwater in the vicinity of the J-23 and N-6 CRAs. In the absence of geochemical modeling, the levels anticipated in leachate produced as a result of groundwater infiltrating the refuse material cannot be accurately assessed; however, it is expected that metals concentrations in groundwater induced leachate would likely be less than those reported on the basis of the SPLP analyses. On the basis of the saturated paste extraction results, nitrate and nitrate/nitrate concentrations are expected to be higher in the refuse material than in natural groundwater in the vicinity of the N-6 CRA. Similarly, nitrate and nitrate/nitrite concentrations are expected to be less in the refuse material than in natural groundwater in the vicinity of the J-23 CRA. Analyte concentrations in leachate derived from the refuse material are expected to be similar or less than the concentrations in natural groundwater for the other metals listed in Table 4.3 and inorganic constituents listed in Table 4.4.

Soil Characteristics Data

Soil characteristics data consists of soil analysis parameters that are used to access soil suitability for plant growth. The wash-plant refuse will not be used for shallow soils or substrate for revegetation efforts at the mine. The refuse will be disposed in previously mined areas and buried below the root zone with spoil and other non-toxic soils. However, a brief discussed of the soil characteristics is important for a comprehensive assessment of potential refuse composition.

Soil characteristics analyses were conducted on selected interburden and overburden core samples collected in the summer of 2003. As previously noted, the interburden and overburden core samples are seen as surrogate media for the coal wash-plant refuse. Table 4.2 presents the soil characteristics results for the interburden and overburden core samples. The table also presents maximum threshold values and mine site mean values for some parameters at the mine.

Table 4.2 indicates that the sodium adsorption ratio (SAR) and total selenium are slightly above the maximum threshold values in 3 and 4 of the 7 samples analyzed for these parameters, respectively. Sample 307-074-03R is a replicate sample of sample 307-074-03; the SAR values for both samples slightly exceeded the SAR threshold of 35 for samples containing between 20 and 35% clay. The 4 samples that exceeded the total selenium concentration threshold of 2.5 mg/L did not exceed 3.0 mg/L (sample 307-074-12 was reported at 3.050 mg/L). Because of the analytical method used, the total selenium concentrations presented in Table 4.2 are not considered representative of the selenium concentrations that would leach from the refuse materials. The SPLP results shown in Table 4.1 are considered more representative of potential leachate concentrations.

4.3.2 Refuse Leachate Fate

Conceptually, the disposal of refuse materials may result in changes in water quantity and water quality in local hydrologic systems should refuse leachate migrate to and mix with these systems. The potential migration of refuse leachate from the mine area can be segregated into 4 main components or processes: (1) transient drainage of inherent moisture content after refuse placement, (2) saturated flow in the Wepo Aquifer in the case that percolating drainage intercepts the Wepo Aquifer, (3) potential percolation of drainage water into the underlying unsaturated Wepo Formation, and (4) potential transport of solutes in the Wepo Aquifer.

4.3.2.1 Refuse Transient Drainage

The first flow process investigated was the transient drainage of water in the wash-plant refuse material. The purpose of the transient drainage analysis was to confirm that pore water within the refuse will drain by gravity and to obtain an estimate of the volume of drainage over a period of time. An evaluation of the volume of water generated by transient drainage is relevant to assessing the potential impact on local hydrologic conditions at the N-6 Pit and J-23 Pit.

The volume of the refuse drainage was estimated using the HYDRUS2D® numerical flow and transport program (IGWMC 1999). HYDRUS2D is designed for modeling variably saturated media. The HYDRUS2D simulations were configured to match the hypothetical geometry of each final pit area and assumed a conservative scenario of instantaneous deposition and a maximum refuse thickness of 70 ft (Lehn 2003). The simulation was constructed to simulate drainage and saturation of the bottom portion of the refuse material, i.e. no drainage was allowed from the bottom of the model domain but allowed to build-up and saturate the bottom of the refuse material. The model domain consisted of a two-dimensional vertical section of a single material type, wash-plant refuse. All boundaries were set at no-flow, as only gravity drainage and water generated were being evaluated. The initial condition moisture content for the refuse was set at 0.24 (24 %), the volumetric moisture content converted from expected mass content in Calculation No. 1 (Appendix C).

HYDRUS2D requires the input of unsaturated hydraulic parameters unique to each material type being modeled for variably saturated flow and transport conditions. (HYDRUS2D input parameters are in metric units, therefore, where appropriate, discussion of the HYDRUS2D modeling will cite both English and metric units). The parameters used in the model simulations for the refuse material are as follows:

Input Parameter	Refuse Material
Residual water content (θr)	0.0715
Saturated water content (θs)	0.3881
A (cm^{-1})/(ft^{-1})	0.0204 / 0.6218
N	1.2681
K_s (cm/day)/(ft/day)	6.22 / .204
L	-1.7092
Hydrus2D media type	NA

The parameters for the refuse material were estimated using Rosetta®, an unsaturated parameter estimation program (Schaap 2000). The program uses sieve analysis and bulk density data to estimate the unsaturated parameters (more accurate estimations would require additional laboratory analysis). The geotechnical data used for the refuse material were approximations from Hazen Research, Inc., the laboratory that conducted the pilot washing of the 20-drum sample of raw coal (Section 4.3.1.1). Hazen reported an approximate composition of the refuse of 47 % sand, 20% silt, and 33% fines (Reeves 2003). A bulk density estimate of 1.6 grams/cubic centimeter was provided by PWCC (Cochran 2003).

N-6 Pit Refuse Drainage

Intuitively, the volume of water added to the N-6 Pit as a result of transient drainage from the refuse materials would be expected to have a negligible impact on the Wepo Aquifer as the local interpreted potentiometric surface appears depressed (2003 potentiometric surface) either as a result of mining activities or natural causes (local unsaturated conditions). Nonetheless, a HYDRUS2D simulation was conducted to confirm this hypothesis.

As previously discussed, it is anticipated that the N-6 Pit will be used for refuse disposal for a period of 3 years, before the J-23 Pit will be ready to receive the refuse. In a 3-year period, an estimated 3,000,000 yds^3 will be deposited in the N-6 Pit. PWCC estimates that the maximum thickness of refuse will be 70 ft. In the case of the N-6 Pit, the final pit configuration is expected to be 5,600 ft long by 330 ft wide. Assuming a refuse deposit of maximum thickness, the 3-year refuse deposit configuration would be 70 ft high by 335 ft wide bye 3,454 ft long. This configuration will accommodate 3,000,000 yds^3 of refuse material. A HYDRUS2D simulation was configured for the N-6 Pit geometry and performed to provide an estimate of the transient drainage volume from 3 years of refuse disposal.

It is important to note the drainage volume outcome is expected to be sensitive to the configuration of the transient simulation domain. That is, a narrower, deeper instantaneous deposit of refuse would yield the same volume of water but would have a thicker saturated interval, and would also take longer to drain. Conversely, a shallower refuse deposit would yield relatively the same amount of water in less time.

The result of the simulation showed that the volume of water that drains by gravity from the 3-year deposit of refuse material is of little consequence. The simulation indicated that gravity drainage of the deposit will not yield significant water at the bottom of the refuse for many years (Figure 4.4). In fact, the head build-up at the bottom of the refuse becomes relatively stable at 5.3 ft [1.6 meters (m)] after approximately 560,000 days (1,534 years) of drainage (Figure 4.5). Water does not begin to build-up at the bottom of the refuse for over 100 years.

PWCC has estimated that 1,000,000 cubic yards of refuse will be produced on an annual basis. Calculation No. 1 (Appendix C) indicates that approximately 24 % (by volume) of the refuse will be "surface" water, water held by tension to the refuse material. During actual mine operations, the refuse material will be deposited over a long time interval and in different locations.

J-23 Pit Refuse Drainage

The J-23 Pit will be actively mined for approximately 14 years. Transient drainage of water from the refuse will occur erratically depending on disposal location within the pit, climatic conditions, compaction, and other handling procedures of the wash-plant refuse.

As mentioned in Section 3.5.4, the final pit configuration for the J-23 Pit will be approximately 9,500 ft long by 131 ft wide. The volume of the final pit configuration will hold only a few years production of wash-plant refuse. However, sufficient area will be available for refuse disposal during mining operations; refuse material will be disposed in selected areas of the pit as it advances toward the final pit configuration as space becomes available. The HYDRUS2D model for the J-23 Pit was a vertical section 70 ft (21 m) high and 131 ft (40 m) wide. The boundary and initial conditions were set the same as the N-6 Pit simulation.

Similar to the N-6 Pit HYDRUS2D simulation, the results of the transient drainage simulation for the J-23 Pit indicates an extraordinary amount of time is required to drain the refuse materials. Figure 4.6 shows the head build-up at the bottom of the refuse material (given an impermeable bottom boundary). The figure indicates that most of the water has drained from the refuse material within approximately 250,000 days (685 years). Calculation No. 1 (Appendix C) indicates that a volume of approximately 793,400 ft^3 of water is drained from a 70 ft thick deposit of refuse in an annual production of 1,000,000 yds^3 in this period of time. The "drainage factor", the total volume of water drained divided by the total volume of refuse, is 3%. This drainage factor only applies to deposits 70 ft thick. The results show that only 12.2 % of the original water in the refuse material drained from the refuse and that this drainage occurred over a large period of time. Obviously, the transient drainage simulation indicates that drainage of refuse water within a time frame applicable to mine operations is not an issue. It is likely no free water will be generated by the refuse before reclamation activities are implemented; Figure 4.7 indicates that measurable drainage will not occur for decades.

4.3.2.2 N-6 Pit Saturated Flow and Transport Analysis

Even though the transient drainage model simulations indicated very slow drainage of the refuse material in the pits, the long-term fate of the leachate solutes was thoroughly explored by evaluating the potential hydraulic pathways after gravity drainage. For the N-6 Pit, it was assumed that the worse-case scenario for leachate migration would be saturated flow and transport due to pit inflows within the Wepo Formation. A two-dimensional flow and transport analytical model, TDAST® (Javandel and others 1987), was used to examine potential contaminant migration from the N-6 Pit. The program assumes saturated, isotropic conditions and uses the convection-dispersion equation to predict solute transport due to groundwater flow and hydraulic dispersion. The applicable hydraulic and transport input parameters include longitudinal (D_L) and transverse dispersion (D_T), average groundwater velocity (v), retardation factor (R), a source decay factor, and the length of the source.

The average groundwater velocity (v) is equal to the hydraulic conductivity (K) times the hydraulic gradient (I) divided by the effective porosity (n_e). The values of hydraulic conductivity, hydraulic gradient, and porosity used to calculate v were 0.11 ft/day, 0.038 ft/ft, and 0.25, respectively. The hydraulic conductivity value is the mean value of K values calculated from Wepo well transmissivity values and total screened interval (ft). The hydraulic gradient of 0.038 was measured from Drawing No. 85610 on the north end of the N-6 Pit. The value for n_e was taken as a reasonable porosity for sandstones and shales as stated in Freeze and Cherry (1979).

The hydrodynamic longitudinal and transverse dispersion coefficients are calculated from the equations:

$D_L = Đ + \alpha_L v$ and $D_T = Đ + \alpha_T v$ where:

Đ is the effective diffusion coefficient in porous media as determined by Đ = wD* (w is an empirically determined constant less than 1 and D* is the diffusion coefficient for specific ions or electrolytes), α_L and α_T are the longitudinal and transverse dispersivity, respectively, and v is velocity vector. Typical effective diffusion coefficients are of the order of 1×10^{-4} to 1×10^{-5} ft^2/d.

Dispersivity values are scale and time dependent and are usually estimated by the scale of the area of study (direct determination of dispersivity on a field scale would involve a complex and expensive test method). The scale and time dependence of these parameters was ignored. The N-6 Pit analysis involves a study of transport from the pit to a potential alluvial aquifer in Coal Mine Wash, a distance of 500 ft. Two values for longitudinal dispersivity were selected for model simulations; one at one-tenth (50 ft) and one at one-quarter (125 ft) of the total distance being evaluated. The transverse dispersivity was assumed to be one-tenth of the longitudinal dispersivity, or 5 ft. and 12.5 ft, respectively.

The retardation factor, R, is defined as:

$$R = (1 + \rho_b K_d / n_e) \qquad \text{where:}$$

ρ_b is the bulk density (M/L^3)
K_d is the distribution coefficient

The following conservative measures were assumed in developing the TDAST model simulations:

- The N-6 Pit and wash-plant refuse is saturated to an elevation equal to the Wepo Aquifer potentiometric surface and hydraulically connected to the Wepo Aquifer.
- Contaminants leaching from the wash-plant refuse are representative of the SPLP analysis and constant over time.
- No retardation due to adsorption or chemical precipitation occurs during solute transport from the pit.
- No source degradation was modeled.
- Homogeneous isotropic conditions are assumed
- Model results are two-dimensional and therefore flow and solute transport is assumed uniform with depth of the aquifer.

In addition, it was inherently assumed that Wepo groundwater flowing through the refuse would produce the same concentrations as the SPLP analysis. SPLP analysis uses an acidic extractant (pH = 5.0) whereas the Wepo Formation groundwater has a pH of 7.9. It is likely that Wepo groundwater will not leach solutes from the refuse materials to the degree of the SPLP procedure.

The input parameters chosen for the simulation of flow and transport at the N-6 Pit are shown below.

TDAST Input Parameter	Input Value	
	Simulation Refuse 5 (α_L = 50 ft)	Simulation Refuse 6 (α_L = 125 ft)
Average Groundwater Velocity (v)	0.0167 ft/d (0.0051 m/d)	0.0167 ft/d (0.0051 m/d)
Longitudinal Dispersion (D_L)	0.84 ft^2/d (0.078 m^2/d)	2.09 ft^2/d (0.194 m^2/d)
Transverse Dispersion (D_T)	0.084 ft^2/d (0.0078 m^2/d)	0.209 ft^2/d (0.0194 m^2/d)
Retardation Factor (R)	1.0	1.0
One-half length of source (ft)	1209 ft (369 m)	1209 ft (369 m)

The program input was configured to simulate a constant source of contaminant from the north end of the N-6 Pit, the end closest to the alluvial aquifer in Coal Mine Wash. The length of the source was estimated to be 500 ft, and situated perpendicular to the primary flow direction (west). The two dimensional program calculates dimensionless solute concentration for a x and y coordinate grid as specified in model input. The x direction was parallel to groundwater flow direction, and the y direction was perpendicular to the groundwater flow direction. The program assumes homogeneous, isotropic conditions and output was therefore assumed to represent estimates of uniform dispersion throughout the entire saturated aquifer thickness.

The TDAST program produces a dimensionless concentration output that indicates concentration of a solute relative to the source concentration (C/C_o), where C_o is the initial source concentration. In the case of the dissolved metal aluminum, the original concentration is assumed to be the average result from the SPLP analysis of the surrogate interburden and overburden samples, a concentration of 2.6 mg/L. The program calculates the C/C_o ratios for a two-dimensional coordinate X and Y for a specific time as designated in the input file. A value of 0.5 indicates that the concentration at that point and time is one-half the value of the initial source concentration.

In addition to use of the TDAST program, mixing calculations were performed to assess the impact on Wepo groundwater quality in response to the elevated concentrations reported on the basis of the SPLP and saturated paste extraction analyses performed on the refuse samples. As discussed in Section 4.3.1.2, elevated concentrations relative to Wepo groundwater was observed for aluminum, arsenic, barium, mercury, nitrate, nitrate/nitrite, selenium, vanadium, and zinc. Calculation No. 2 (Appendix C) was conducted to evaluate mixing of pit inflow water in the N-6 Pit and leachate water generated by gravity drainage of the refuse material. The calculation, based on a number of assumptions, indicates that mixing of the two waters will result in almost imperceptible concentration changes in ambient Wepo groundwater. Mixing calculation results are presented in Table 4.5.

Information on the vertical hydraulic gradients within the Wepo Formation at Black Mesa Mine is not available. However, well hydraulic data suggest a horizontal hydraulic conductivity value of approximately 0.11 ft/d, or 3.9 x 10^{-5} centimeters per second (cm/s) for the Wepo Formation (Section 3.5.2.4). Vertical hydraulic gradients are common in variably saturated strata, and a reasonable estimate of a vertical hydraulic conductivity value for the Wepo Formation is an order of magnitude smaller than horizontal hydraulic conductivity value. Vertical flow and transport to the Toreva Formation is therefore expected to be minimal (at least an order of magnitude less than indicated in the two-dimensional analytic model conducted for the evaluation of horizontal flow).

Model Results and Interpretation

Two TDAST simulations were conducted, one with a longitudinal dispersivity of 50 ft (15.2 m) and one with the longitudinal dispersivity of 125 ft (30.4 m). The results of the two simulations indicated that in a 25 year period the C/C_o values for the 50 ft and 125 ft longitudinal dispersivity simulations are 0.005 and 0.066 at a distance approximately 500 ft (152 m) directly downgradient from the source. At the 25-year time, this concentration was calculated over a 150-ft (45.7 m) wide region or plume perpendicular to the flow direction. In the case of aluminum, the source concentration would conservatively be assumed to be 2.6 mg/L, the mean concentration from the interburden/overburden SPLP analysis data. Therefore, the dispersed concentration at a distance 500 ft from the source after 25 years of potential solute migration from the N-6 Pit is estimated to be 0.005 x 2.6 mg/L, or 0.013 mg/L. In the case of the 100 ft longitudinal dispersivity simulation, the concentration of aluminum at the same location and time would be 0.066 x 2.6 mg/L, or 0.17 mg/L.

It is worth noting again that the conservative measures mentioned above and intrinsic to the TDAST model simulations should be considered when interpreting the model results. For example, the lack of retardation in the simulations provides a greater concentration (C/C_o) result than a simulation with retardation.

On the basis of the TDAST output and the conservative approach to model development, the impact to groundwater quality in the Wepo Aquifer from disposal and potential leaching of wash-plant refuse is considered minimal. Using a conservative model approach, the projected concentrations of solutes derived from the refuse material would be 7 percent of the initial concentrations at a distance of 500 ft downgradient of the pit and 25 years into the future.

Results of the TDAST simulations were used to assess the potential impact to ambient groundwater quality for the analytes reported at statistically significant higher mean concentrations in the refuse material than in ambient groundwater. A comparison of mean analyte concentrations from SPLP data, ambient groundwater, and TDAST-calculated concentration downgradient of the N-6 Pit is provided below.

	Mean Dissolved Concentrations (mg/L)				
Analyte	**Inter- and Overburden SPLP Data**	**Wepo Wells**	**Coal Mine Wash Alluvial Wells 80, 80R, 81, and 81R**	**TDAST Result[a] (α_L = 125 ft & C/C_0 =0.066)**	**Sum of TDAST and Wepo Mean**
Aluminum	2.6	0.12	2.68	0.172	0.292
Arsenic	0.005	0.002	0.002	0.0003	0.0023
Barium	0.427	0.105	0.015	0.028	0.133
Mercury	0.0009	0.0003	0.00008[b]	0.00006	0.00036
Nitrate	0.43	0.08	2.44	0.03	0.11
Nitrate/Nitrite	0.42	0.07	2.44	0.03	0.10
Selenium	0.006	0.002	0.002	0.0004	0.0024
Vanadium	0.048	0.010	0.008[b]	0.003	0.013
Zinc	0.135	0.040	0.047	0.009	0.049

[a] Calculated concentration estimate based on C/C_0 value for simulation with longitudinal dispersivity of 125 ft, C/C_0 is for location of 500 ft downgradient of refuse source and 25-year simulation time using inter-burden and overburden source value.
[b] Based partially on undetected results (one-half of detection limit).

As shown above, alluvial groundwater in Coal Mine Wash near the north end of the N-6 Pit is in some cases of poorer quality than the groundwater within the Wepo Aquifer. In addition, the estimated water quality from the TDAST simulation plus the ambient concentration from the Wepo Aquifer does not greatly differ from the alluvial well data. These concentrations were summed to approximate the resulting concentrations because the TDAST simulations assume that Wepo groundwater flows through the refuse and increases its solute concentrations directly, not by mixing of two different water sources.

4.3.2.3 J-23 Pit Numerical Flow and Transport Modeling

Similar to the N-6 Pit approach, simulations subsequent to the refuse drainage analysis addressed potential long-term unsaturated flow from the J-23 CRA into the underlying Wepo Formation. A two-dimensional numerical unsaturated flow and transport model, HYDRUS2D® was used to more fully assess these hydrologic processes. It was initially intended to use HYDRUS2D to model a domain that included both the refuse and Wepo Formation material types and the processes of refuse transient drainage and infiltration into the underlying Wepo Formation. This proved unfeasible because of excessive run times associated with a finely discretized domain. A domain with a coarse grid (1.64 ft or 0.5 m) took upwards of 7 hours to run and would result in unrealistic pressure head results. Ultimately, the critical questions to address: (1) will refuse drainage leachate infiltrate into the Wepo Formation, and (2) if so, what is the resulting leachate concentration at a specified distance and time; were addressed by using a one-dimensional grid with HYDRUS2D.

HYDRUS2D requires the input of unsaturated hydraulic parameters unique to each material type being modeled for variably saturated flow and transport conditions. The parameters used to model unsaturated flow in the Wepo Formation are as follows:

Input Parameter	Wepo Formation
Residual water content (θr)	0.07
Saturated water content (θs)	0.36
α (m^{-1}) / (ft^{-1})	0.50 / 0.15
N	1.09
K_s (m/day) / (ft/day)	0.0048 / 0.0157
L	0.5
Hydrus2D media type	Silty clay

Wepo Formation parameters were estimated from an internal library of parameters provided in HYDRUS2D. The parameters used for the Wepo Formation were labeled "silty clay", and were selected as such because of their saturated vertical hydraulic conductivity values which were similar to the estimated value for the Wepo Aquifer materials.

It is anticipated that some of the refuse drainage water that has accumulated in the bottom of the mine pit will percolate into the underlying Wepo Formation. The goal of modeling unsaturated flow in the Wepo Formation was to estimate if leachate water in the pit had the potential to migrate beyond the interpreted potentiometric surface below the mine pit. The interpreted potentiometric surface in the Wepo Aquifer is at least 150 ft below the planned bottom of the J-23 Pit.

Because the potentiometric surface is interpreted to represent head from confined groundwater within the Wepo Formation, the formation may or may not be saturated below this surface. In addition, it is possible that the unconfined lenses of groundwater exist above the interpreted potentiometric surface. Therefore, the modeling approach involved a domain of unsaturated Wepo Formation from the bottom of the pit to an elevation approximately equal to the potentiometric surface (150 ft or 45.7 m). The results of the refuse transient drainage modeling (Section 4.3.2.1) showed that up to 5.3 ft (1.6 m) of head could build-up on the pit floor at the interface of the refuse and Wepo Formation. Although HYDRUS2D modeling showed that the accumulation of transient drainage of refuse for the J-23 Pit would take place over an excessive amount of time (Figure 4.7), the model for infiltration into the Wepo Formation was restricted to a 200-year simulation with a flux rate on the top boundary equal to 2×10^{-5} ft/day (5.5×10^{-6} m/day). This flux rate is the approximate average flux rate as predicted by HYDRUS2D for the J-23 Pit refuse transient drainage during the time period modeled (Figure 4.7). The flux rate was applied using an "atmospheric" boundary condition in which a precipitation rate equal to the flux rate is applied. Evaporation and transpiration were set to zero. The lower boundary represented a free drainage boundary, a condition where water is allowed to drain under a unit gradient by gravity. This boundary was seen as more realistic than a saturated water table or constant head boundary at the potentiometric surface. Initial conditions in the Wepo domain were set equal to a pressure head of -328 ft (-100 m), a condition indicating highly unsaturated conditions (on the basis of corehole data and consistent with the silty clay material selected to represent the Wepo Formation). A unit concentration (value of 1) was used for source solute concentrations in the refuse leachate.

The results of the HYDRUS2D simulation showed that unsaturated flow and solute transport in the Wepo Formation of refuse leachate is limited. Figure 4.8 shows that after 200 years of simulated unsaturated infiltration, the refuse leachate progresses to and saturates Wepo Formation to an approximate depth of 8 ft (2.4 m) below the refuse/Wepo contact (within Wepo Formation). For quality presentation purposes, Figure 4.8 does not show all isolines, therefore, the actual pressure head of zero is not distinctly represented. Increases in water content, i.e. the wetting front is located approximately 30 ft (9 m) below the refuse/Wepo contact. Solute transport simulations (Figure 4.9) confirm this conclusion, and show that solute concentrations after 200 years of infiltration are equal to or less than 0.2 of the original leachate concentration at a depth 32.8 ft (10 m) below the refuse/Wepo contact. On the basis of the HYDRUS2D simulations, unsaturated flow and solute transport of the refuse leachate is extremely limited and will not approach the interpreted Wepo Aquifer potentiometric surface below the J-23 Pit within a 200-year period.

It is important to note that should refuse leachate with its full source concentration infiltrate into a continuous saturated zone of the Wepo Aquifer, the resulting concentrations of solute would be similar to the results of the TDAST simulations performed for the N-6 Pit. Saturated simulations of solute transport for the J-23 Pit would result in smaller concentrations than the N-6 Pit simulations (for the same time and distance), because the J-23 CRA is characterized by a smaller hydraulic gradient.

In conclusion, the evaluation of refuse leachate fate, as supported by analytical and numerical modeling tools, indicates that impact to the hydrologic balance of water quantity and quality at BMMC will be negligible and in most probably immeasurable.

5.0 SUMMARY AND CONCLUSIONS

The objectives of this study were to (1) evaluate potential refuse disposal sites and recommend the most favorable site(s) based on specific criteria and (2) analyze the potential probable hydrologic impact of refuse disposal in the recommended site(s). The specific criteria used for evaluation and selection of a preferred site(s) included depth to groundwater, potential for resaturation of spoil, background geochemistry, and available refuse storage space. The technical approach used to assess the potential hydrologic impact of wash-plant refuse disposal at the selected site(s) included comparison of ambient water quality of groundwater to the potential chemical composition of refuse leachate water and evaluation of the potential migration of refuse leachate from the refuse disposal area. Potential migration of refuse leachate was evaluated with the use of analytical and numerical flow and transport models.

5.1 Refuse Disposal Site Evaluation and Selection

The J-23 Coal Resource Area (CRA) was identified as site having the most favorable characteristics for refuse disposal with respect to hydrologic impact. The estimated bottom of the pit will be at least 150 ft above the interpreted Wepo Aquifer potentiometric surface. In addition, the interpreted potentiometric surface is relatively uniform, of low gradient and does not diverge or converge to a local discharge area (surface drainage). The J-23 CRA is expected to have sufficient storage volume for refuse disposal as mining operations are expected to remove 5,000,000 yds^3 of coal annually. The estimated volume of refuse produced on an annual basis is 1,000,000 yds^3.

Coal Resource Areas N-6 and J-7, which are pits nearing completion, were considered areas of potential greater impact because the interpreted Wepo Aquifer potentiometric surface extends upwards of 30 feet above the estimated bottom of the pits. In addition, the final footprints of the N-6 and J-7 pits will be in close proximity (500 ft) to the major surface-water drainages of Coal Mine Wash and Yucca Flat Wash. The N-6 and J-7 pit bottom elevations would be below or near the surface elevations of these drainages, presenting another potential hydrologic impact should groundwater migrate from the pits.

The J-3 Reclaimed CRA was mined in the 1970s and 1980s and is now fully reclaimed. The J-3 Reclaimed CRA may have a potential for hydrologic impact in the long-term as the interpreted Wepo Aquifer potentiometric surface forms a hydraulic divide along the ridge where J-3 is located. Should refuse leachate migrate to a continuous saturated zone in the Wepo Formation, groundwater flow has the potential to occur in multiple directions at relatively moderate to steep hydraulic gradients. Groundwater underlying the J-3 area may eventually discharge to Coal Mine Wash to the west and Moenkopi Wash to the southeast.

Although the J-23 CRA was selected as the most favorable site for minimal hydrologic impact, the area will not be fully developed and able to receive refuse for an anticipated period of 2 to 3 years after start-up of the coal wash plant. Therefore, PWCC directed WWL to evaluate the potential hydrologic impacts of a 3-year refuse disposal scenario at the N-6 Pit and long-term refuse disposal at the J-23 Mine Area.

5.2 Probable Hydrologic Impact Assessment

Ambient water quality for the Wepo Aquifer across the site and in the vicinity of the N-6 and J-23 Mine Areas was compared to analytical data generated to approximate the leachate composition of the wash-plant refuse. Results of the geochemical assessment indicate that leachate produced as a result of acid rain infiltrating the refuse material likely contains higher concentrations of aluminum, arsenic, barium, mercury, selenium, vanadium, and zinc than does natural groundwater in the vicinity of the J-23 and N-6 CRAs. In the absence of geochemical modeling, the levels anticipated in leachate produced as a result of groundwater infiltrating the refuse material cannot be accurately assessed; however, it is expected that metals concentrations in groundwater induced leachate would likely be less than those reported on the basis of the SPLP analyses. On the basis of the saturated paste extraction results, nitrate and nitrate/nitrate concentrations are expected to be higher in the refuse material than in natural groundwater in the vicinity of the N-6 Mining Area. Similarly, nitrate and nitrate/nitrite concentrations are expected to be less in the refuse material than in natural groundwater in the vicinity of the J-23 CRA. Analyte concentrations in leachate derived from the refuse material are expected to be similar or less than the concentrations in natural groundwater for the other metals listed in Table 4.1 and inorganic constituents listed in Table 4.2.

The potential accumulation and migration of refuse leachate from the refuse disposal areas in the N-6 Pit and J-23 Pit were studied through the use of the application of the unsaturated flow and transport model HYDRUS2D®, and a two-dimensional analytical saturated flow model, (TDAST®).

HYDRUS2D was initially used to evaluate transient drainage of the refuse. The evaluation of transient drainage from the refuse was based on refuse deposit configurations that had a maximum thickness of 70 ft and estimates of refuse properties as estimated from material produced by raw coal pilot washing Reeves (2003). The results of the transient drainage simulations showed that drainage of the refuse would take hundreds of years, and that little drainage would be realized during mining operations. In the extreme long-term, a simulation for a time of over 600 years, the generated leachate would be equivalent to approximately 5.3 ft of saturated thickness in the bottom layer of the refuse material.

Long-term fate of the leachate was further modeled using TDAST at the N-6 Pit and HYDRUS2D at the J-23 Pit. In the case of the N-6 Pit, it was conservatively assumed that, in a worse-case scenario, pit inflows into the pit from the Wepo Aquifer would eventually saturate the refuse deposits placed in the pit. TDAST models convection and dispersion of solutes in saturated media. Model input requires half the source length, retardation and decay factors, and the average groundwater velocity which is dependent on hydraulic conductivity. Diffusion coefficients and longitudinal and transverse dispersivity values are also required. The input used in the model included an average hydraulic conductivity of 0.11 ft/day (3.8×10^{-5} cm/sec) for the Wepo Aquifer derived from PWCC's hydraulic test data. Retardation was conservatively assumed to be 1, i.e. no adsorbtion. Reasonable values for diffusion and dispersivity were used. TDAST results indicated that only a fraction (approximately 0.07) of the initial solute concentrations reported in the leachate would be present a distance 500 ft downgradient of the pit after 25 years of simulated transport. When combined with solute concentrations in the Wepo Aquifer, the resulting concentrations are less than or similar to alluvial groundwater quality in Coal Mine Wash near the north end of the N-6 Pit. In addition, calculations performed to assess direct mixing of refuse leachate and Wepo groundwater in the vicinity of the pit further demonstrate that solute concentrations in the refuse material would have minimal impact on Wepo groundwater quality.

The J-23 Pit was further evaluated for potential leachate migration by way of unsaturated flow into the underlying Wepo Aquifer. A one-dimensional application of HYDRUS2D was used to assess unsaturated flow into the Wepo Formation below accumulated drainage from wash-plant refuse. The model for infiltration into the Wepo Formation was restricted to a 200-year simulation with a flux rate on the top boundary equal to 2×10^{-5} ft/day (5.5×10^{-6} m/day). This flux rate is the approximate average flux rate as predicted by HYDRUS2D for the J-23 Pit refuse transient drainage during the time period modeled (Figure 4.7). A unit concentration (value of 1) was used for source solute concentrations in the refuse leachate.

The results of the HYDRUS2D simulation showed that unsaturated flow and solute transport of refuse leachate in the Wepo Formation is limited to a saturation depth of 8 ft (2.4 m) (Figure 4.8). Increases in water content, i.e. the wetting front is located approximately 30 ft (9 m) below the refuse/Wepo contact. Solute transport simulations (Figure 4.9) confirm this conclusion, and show that solute concentrations after 200 years of infiltration are equal to or less than 0.2 of the original leachate concentration at a depth 32.8 ft (10 m) below the refuse/Wepo contact.

On the basis of the HYDRUS2D simulations, unsaturated flow and solute transport of the refuse leachate is extremely limited and will not approach the interpreted Wepo Aquifer potentiometric surface below the J-23 CRA within a 200-year period.

Should refuse leachate with its full source concentration infiltrate into a continuous saturated zone of the Wepo Aquifer, the resulting concentrations of solute would be similar to the results of the TDAST simulations performed for the N-6 Pit. Saturated simulations of solute transport for the J-23 CRA would result in smaller concentrations than the N-6 Pit simulations (for the same time and distance), because the J-23 CRA is characterized by a smaller hydraulic gradient.

5.3 Conclusions

The J-23 CRA provides the most favorable location for disposal of refuse generated by coal-washing operations to be conducted at the BMMC. Mining in the J-23 CRA will be conducted in an area where the projected potentiometric surface of the Wepo Aquifer exhibits a relatively uniform and low hydraulic gradient, the bottom of the pit will be located approximately 150 ft above the projected potentiometric surface of the Wepo Aquifer, and no primary surface water drainages are located in the immediate vicinity of the pit. However, mining activities in the J-23 CRA will not be conducted for the first 2 to 3 years of the wash-plant operations. Because of this, the N-6 Pit has been selected to receive refuse during this two to three year interim period.

A detailed evaluation and statistical comparison of ambient groundwater quality with potential refuse leachate composition and the application of analytical and numerical flow and transport modeling software demonstrate that impact to the hydrologic balance of water quantity and quality at BMMC will be negligible and most probably immeasurable.

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FIGURES

FIGURE 1.1. Black Mesa Mine Complex Location Map

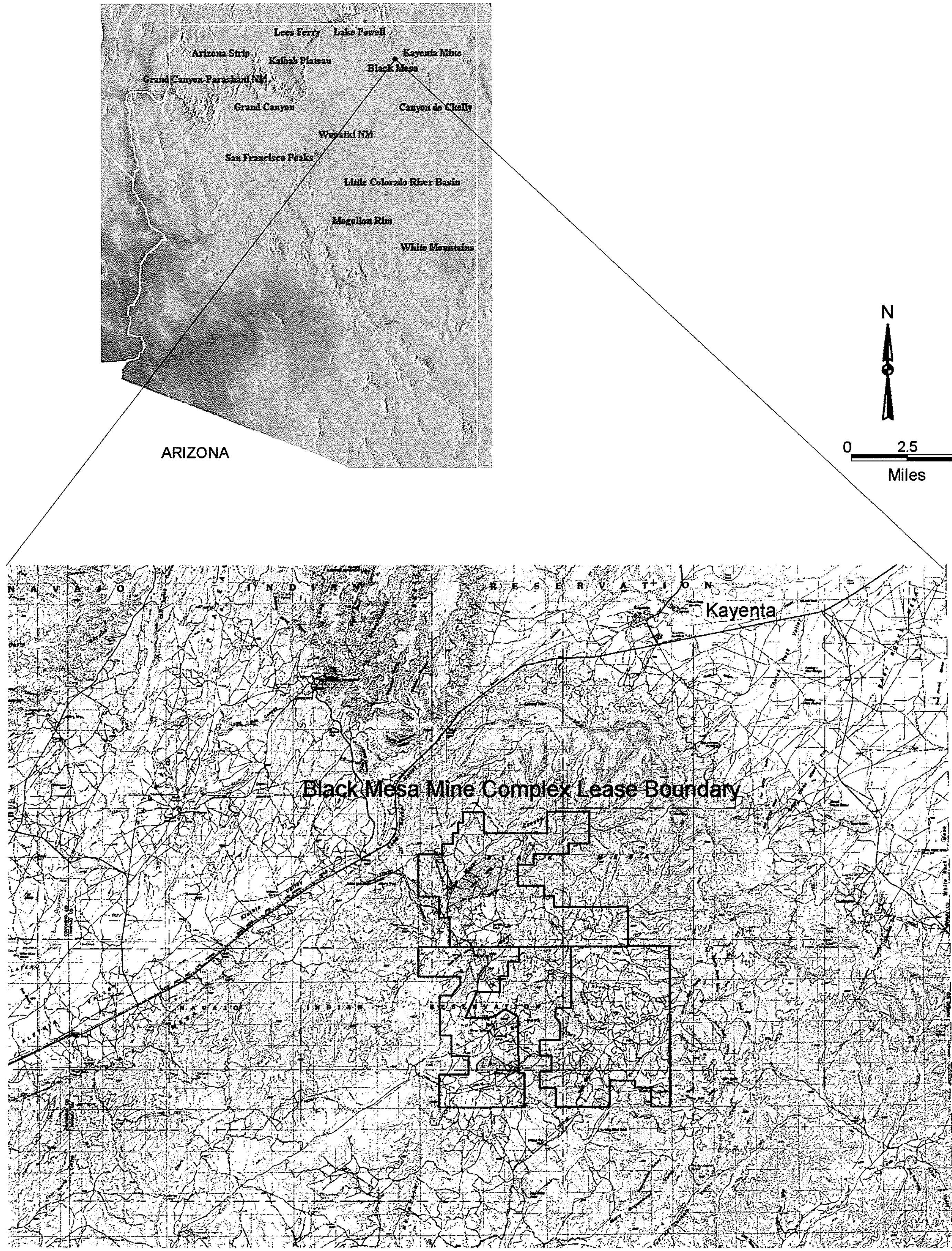
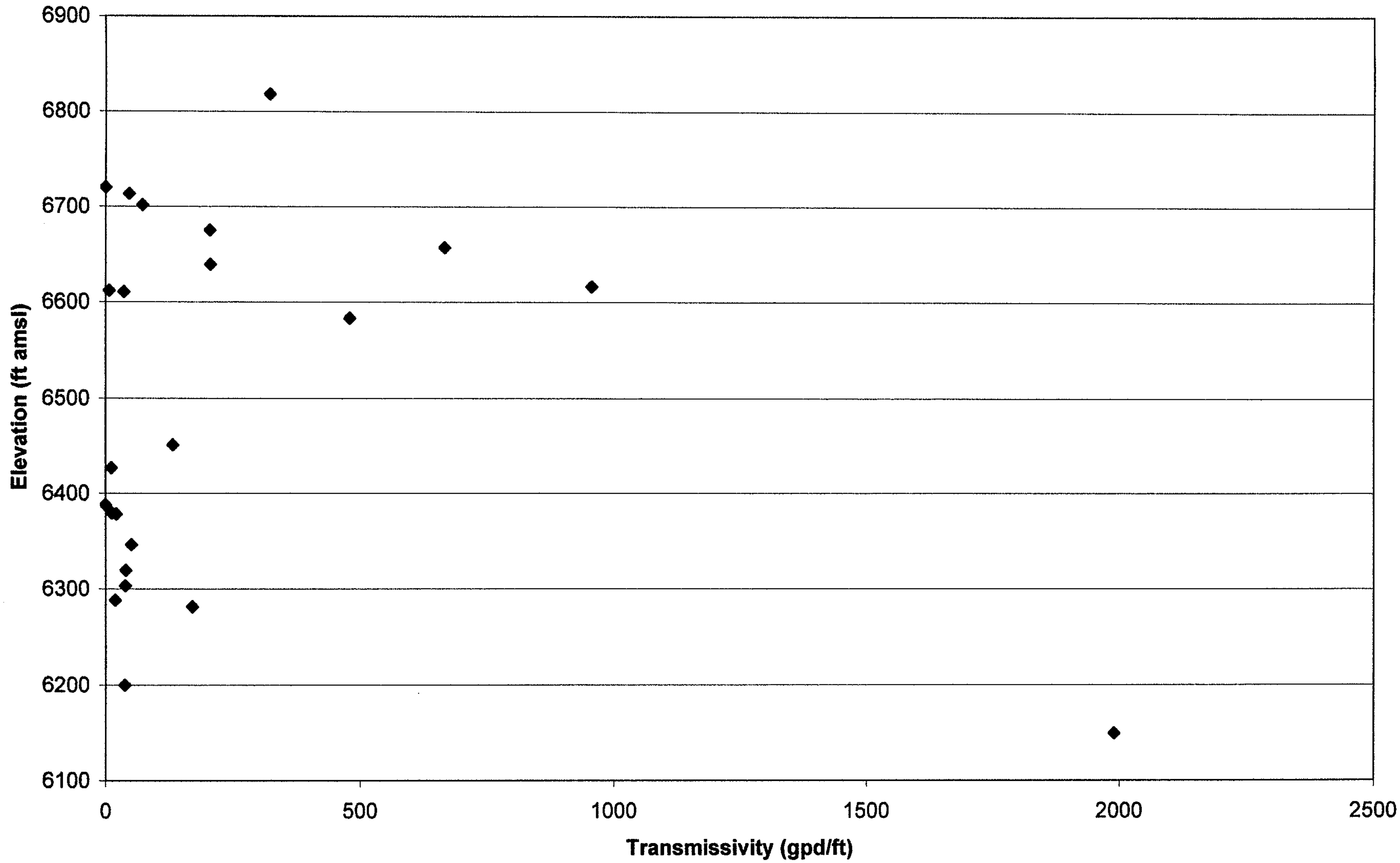


Figure 3.1. Transmissivity vs. Elevation for Wepo Aquifer Wells



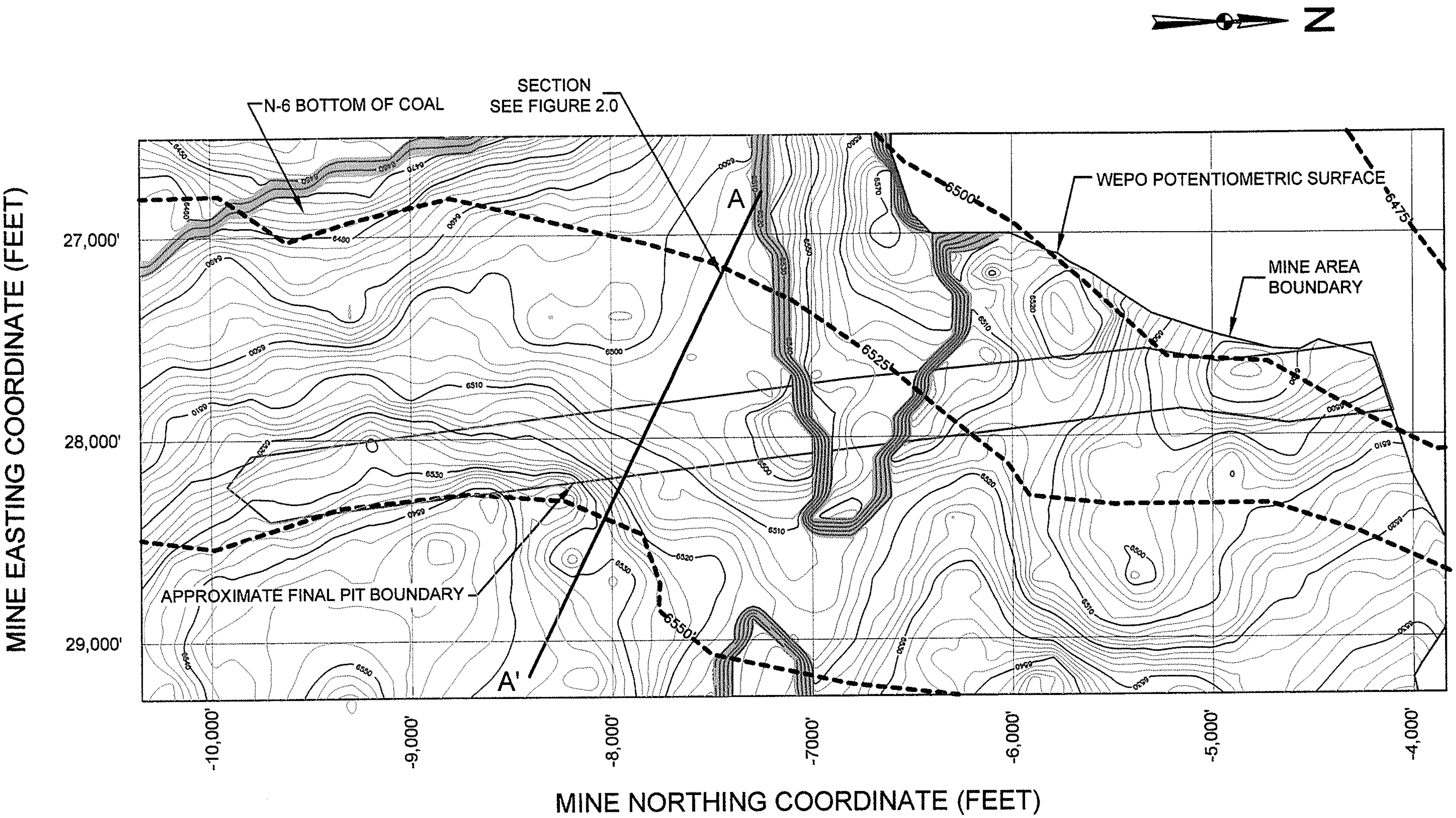


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FIGURE 4.1

FINAL N-6 PIT BOUNDARY WITH BOTTOM OF COAL TOPOGRAPHY AND WEPO AQUIFER POTENTIOMETRIC SURFACE.

DRAWING	DAG
CHECKED	BDS
DATE	12/18/03
PROJ. NO.	109.01.03

BLACK MESA MINE
KAYENTA, AZ.
PEABODY WESTERN COAL COMPANY

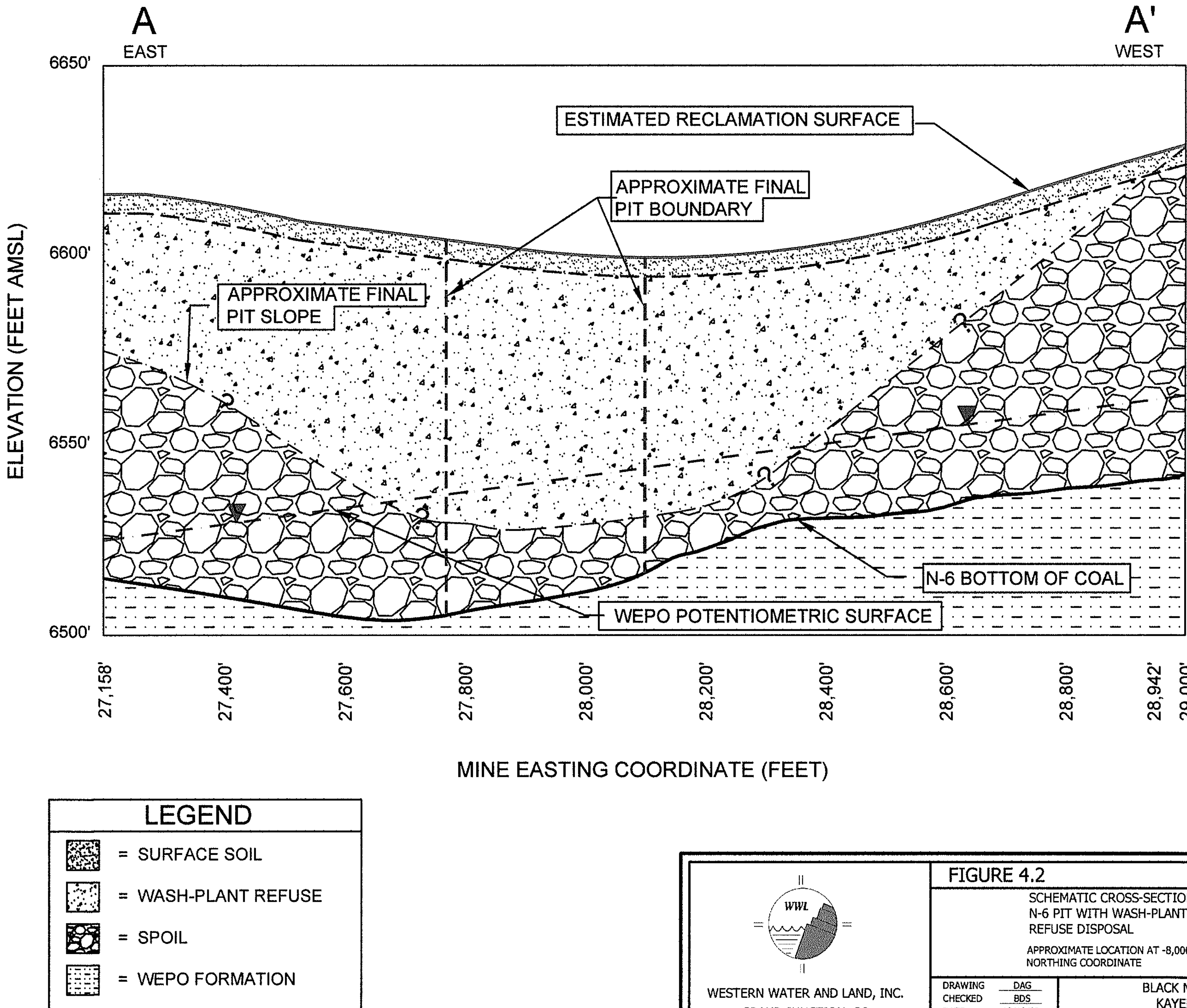

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FIGURE 4.2

SCHEMATIC CROSS-SECTION OF N-6 PIT WITH WASH-PLANT REFUSE DISPOSAL

APPROXIMATE LOCATION AT -8,000 NORTHING COORDINATE

DRAWING	DAG
CHECKED	BDS
DATE	12/18/03
PROJ. NO.	109.01.03

BLACK MESA MINE
KAYENTA, AZ.
PEABODY WESTERN COAL COMPANY

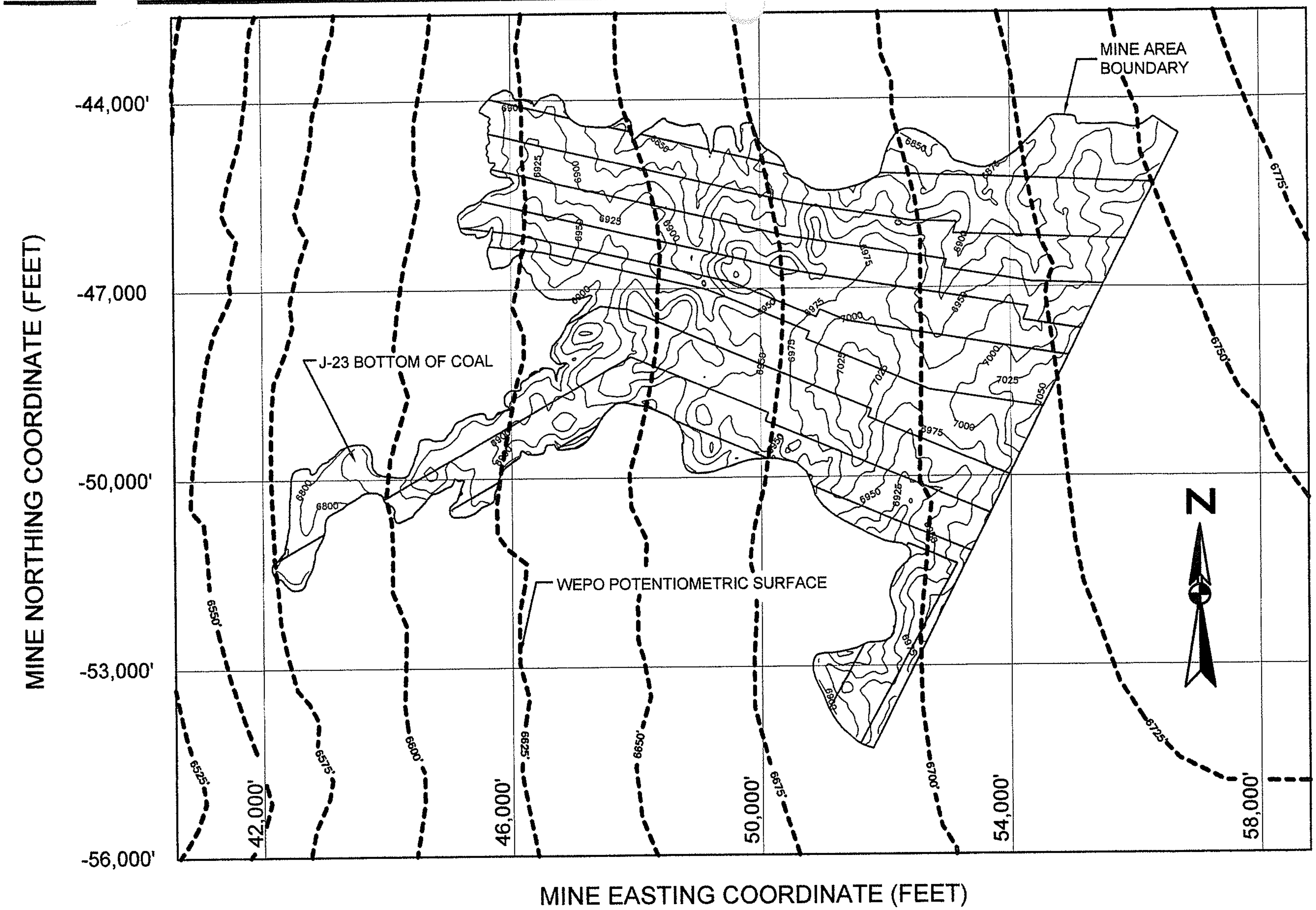

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FIGURE 4.3

J-23 MINE AREA WITH BOTTOM OF COAL TOPOGRAPHY AND WEPO AQUIFER POTENTIOMETRIC SURFACE

DRAWING	DAG
CHECKED	BDS
DATE	12/18/03
PROJ. NO.	109.01.03

BLACK MESA MINE
KAYENTA, AZ.
PEABODY WESTERN COAL COMPANY

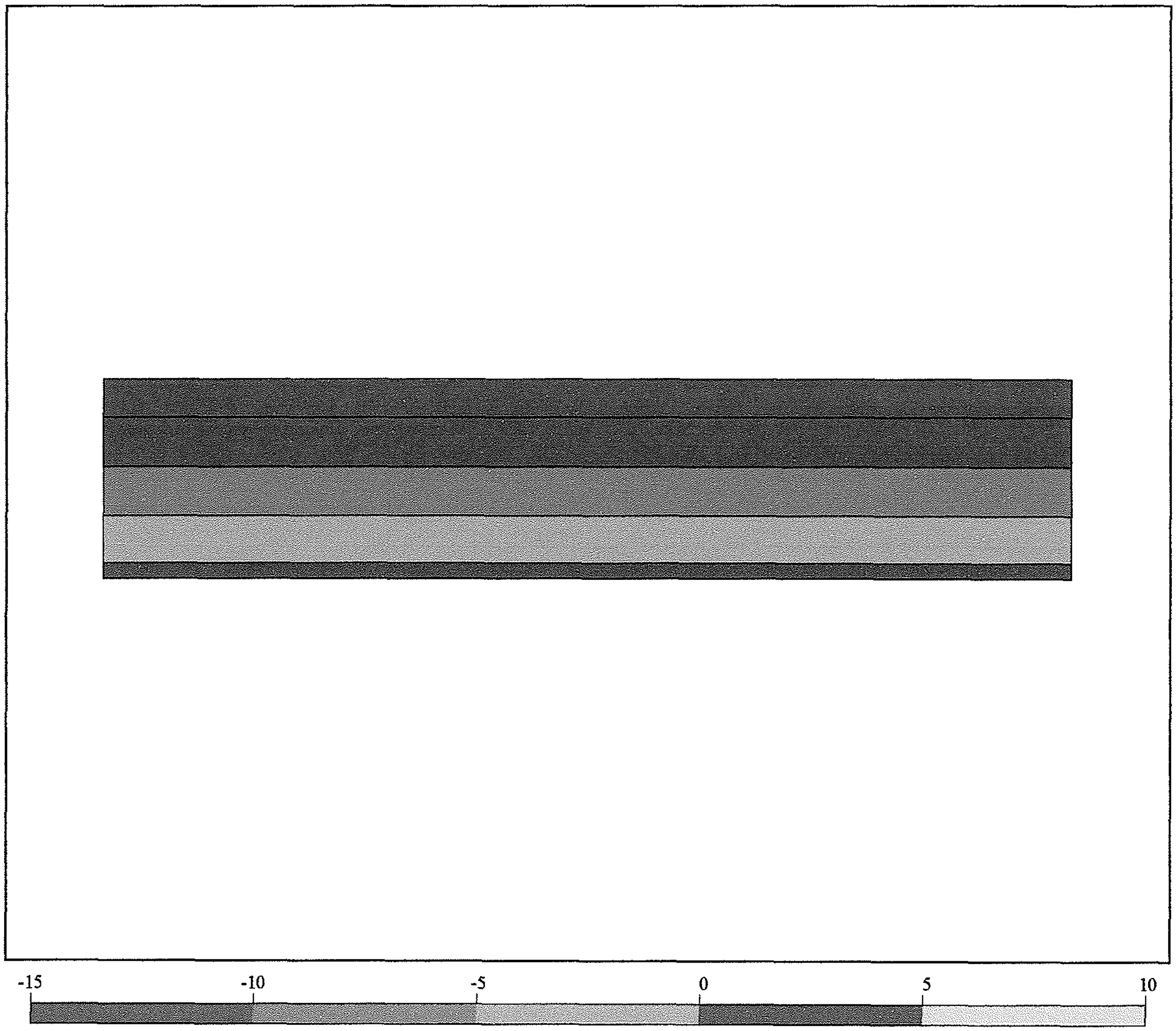
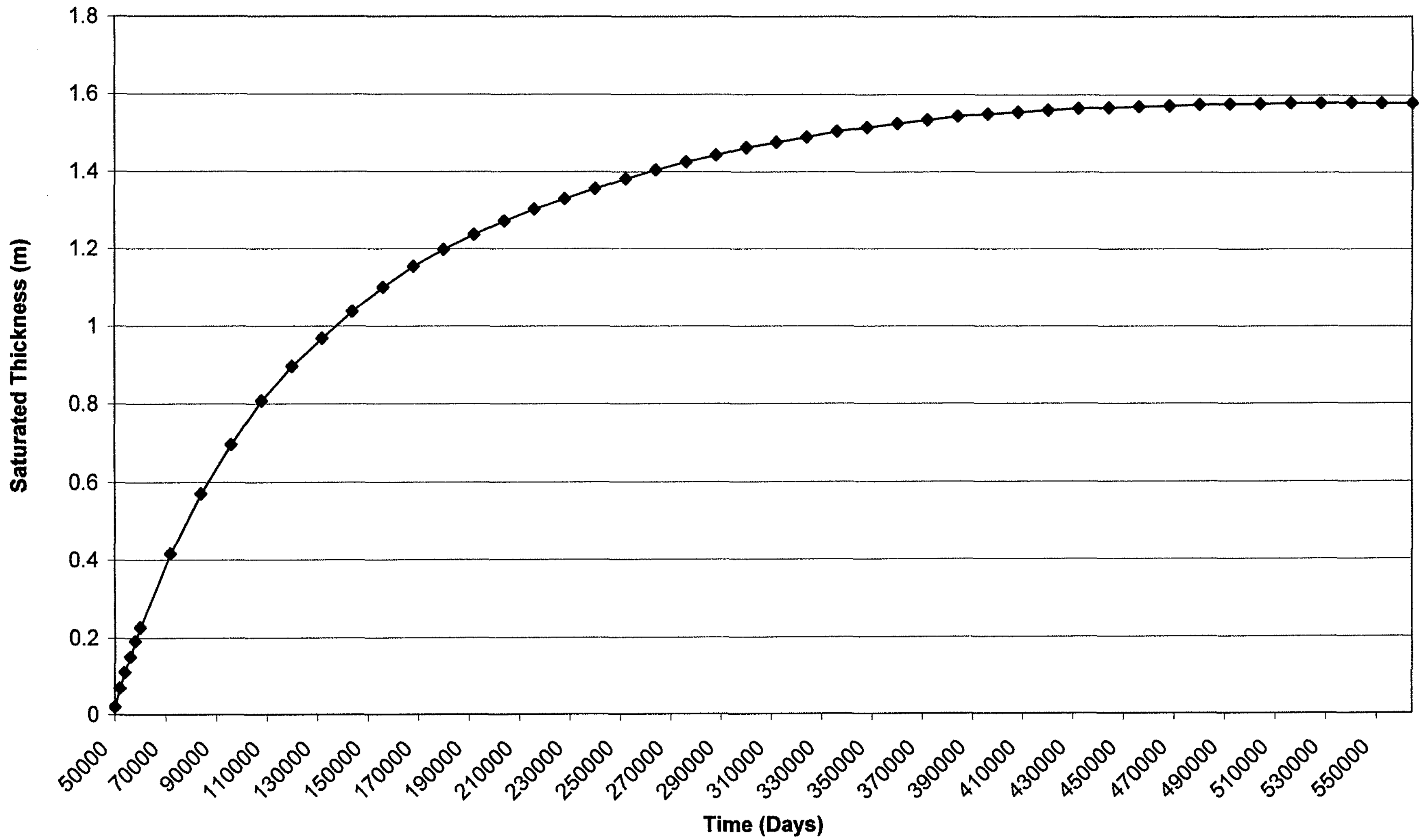


Figure 4.4. HYDRUS2D Simulation Results, Run N-6 Pit Final. N-6 Pit Refuse Material Transient Drainage, Pressure head distibution at time = 600,000 Days. 2-D Simulation with domain 70 ft (21 m) high by 335 ft (102 m) wide. Pressure head scale is in meters (saturated interval is blue).

Figure 4.5. N-6 Pit Refuse Drainage
(for refuse deposit approximately 70 ft high x 335 ft wide)



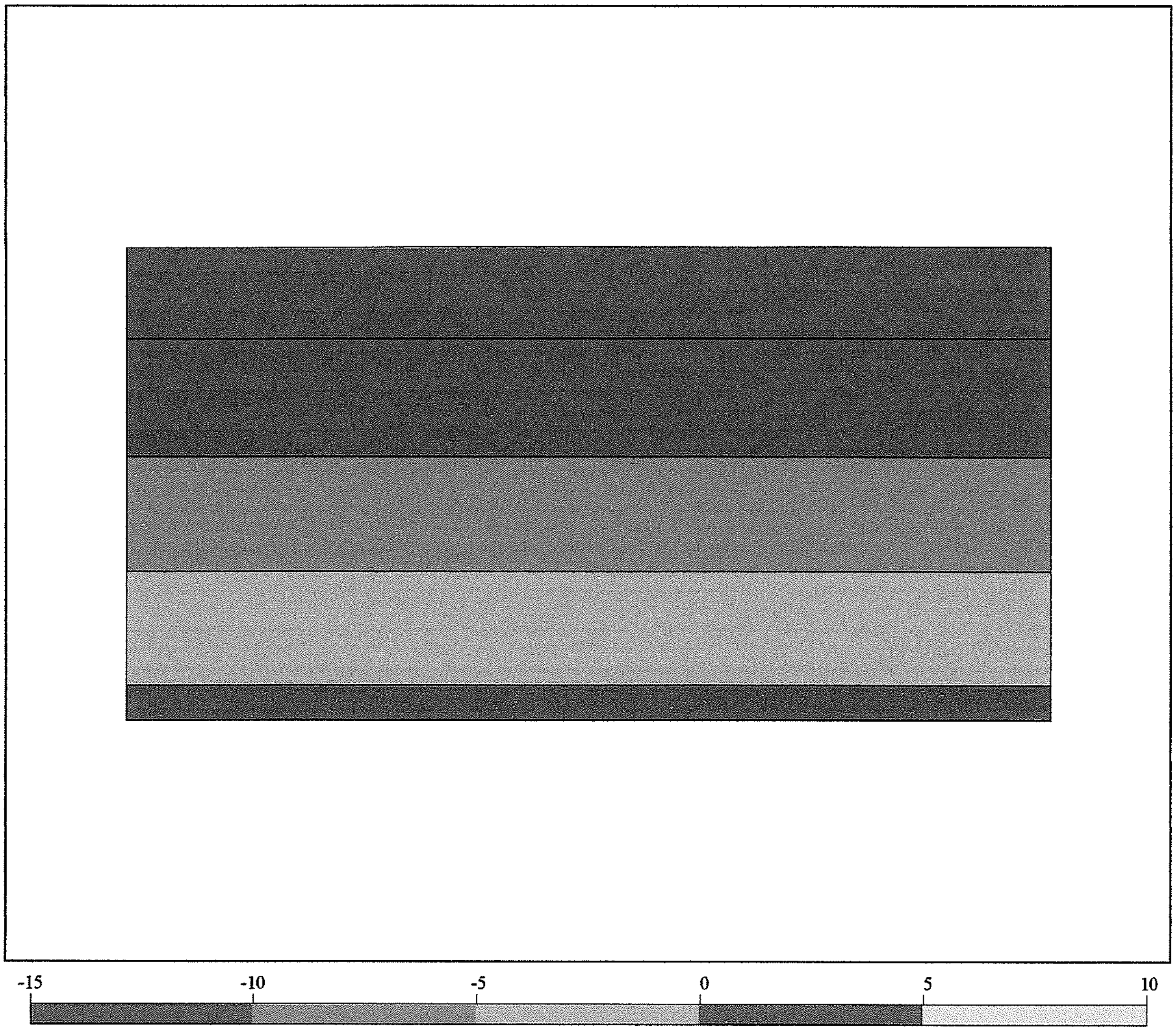
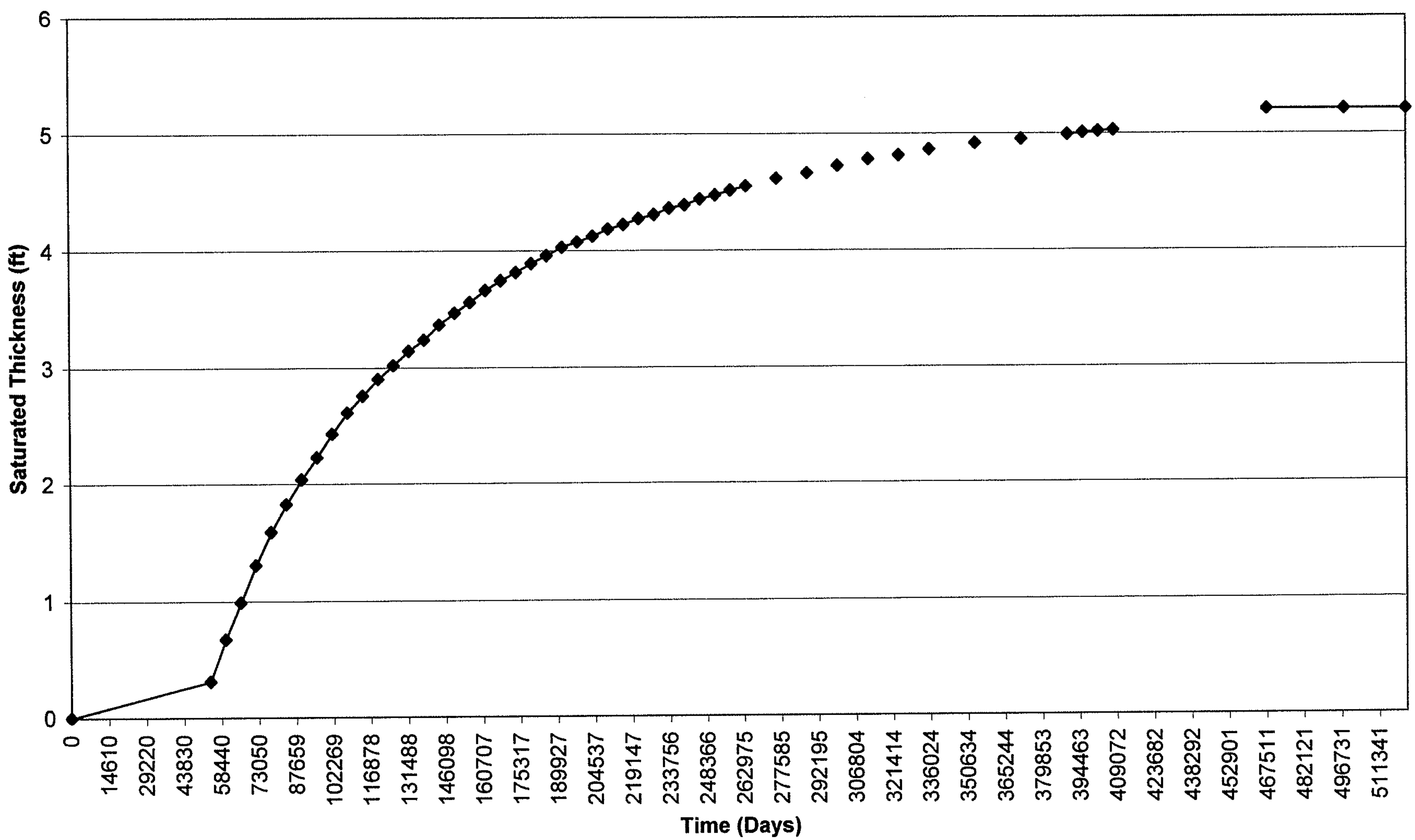


Figure 4.6. HYDRUS2D Simulation Reuslts, Run J23a. J-23 Pit Refuse Material Transient Drainage, Pressure head distribution at time = 600,000 days.
2-D Simulation with domain 70 ft (21 m) high by 103 ft (31 m) wide. Pressure head scale is in meters (saturated interval in blue).

Figure 4.7. J-23 Refuse Trasient Drainage
(for refuse deposit approximately 70 ft high by 130 ft wide)



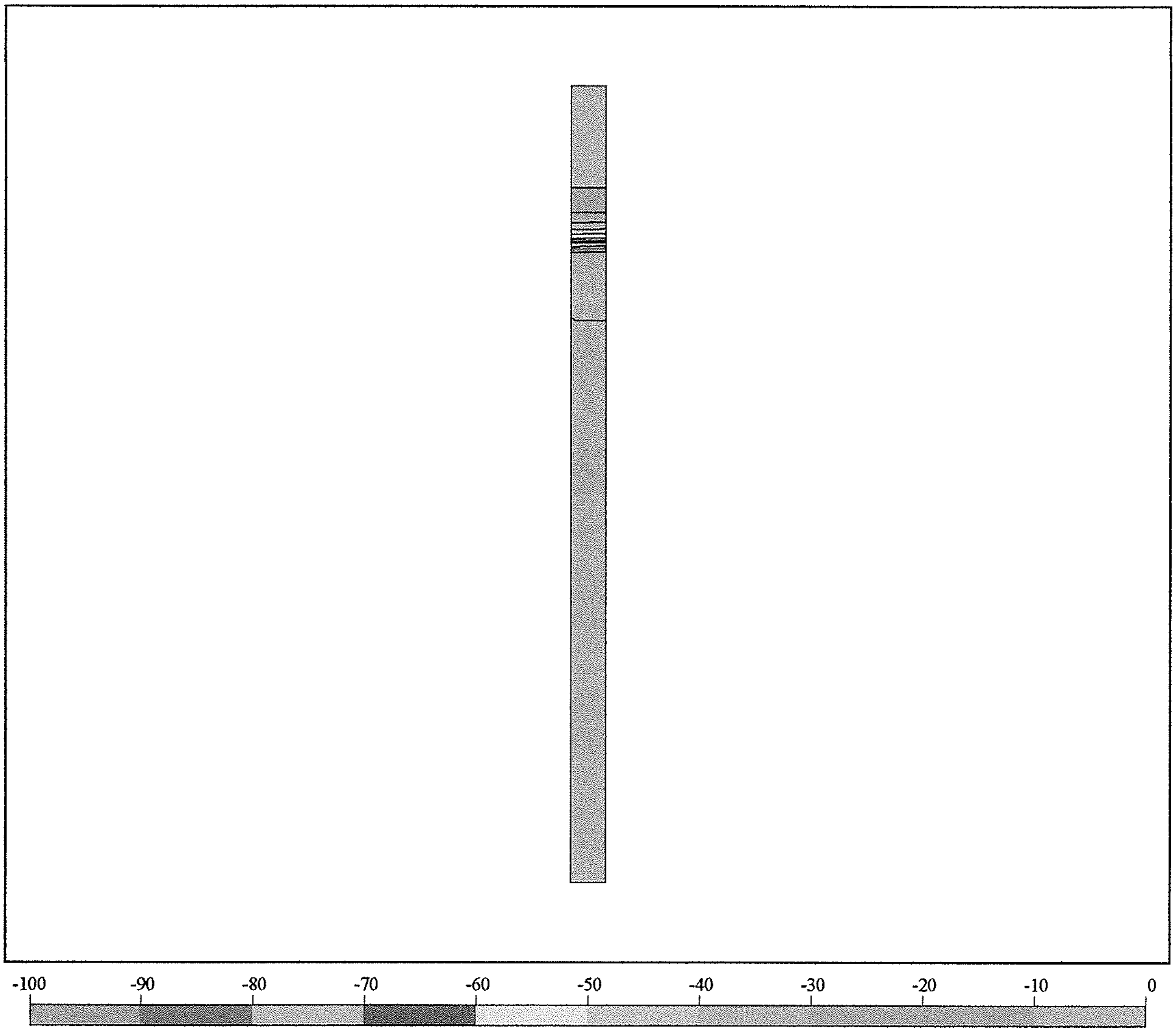


Figure 4.8. HYDRUS2D Simulation Run W111D5. Infiltration of Refuse Leachate in the Wepo Formation Showing Pressure Head Distribution.
1-D Simulation, Time = 73,000 days, vertical depth of 150 ft (45 m). Pressure head scale in meters (p = 0 is saturated condition). Flux is 2E-5 ft/d (5.5E-6 m/d).

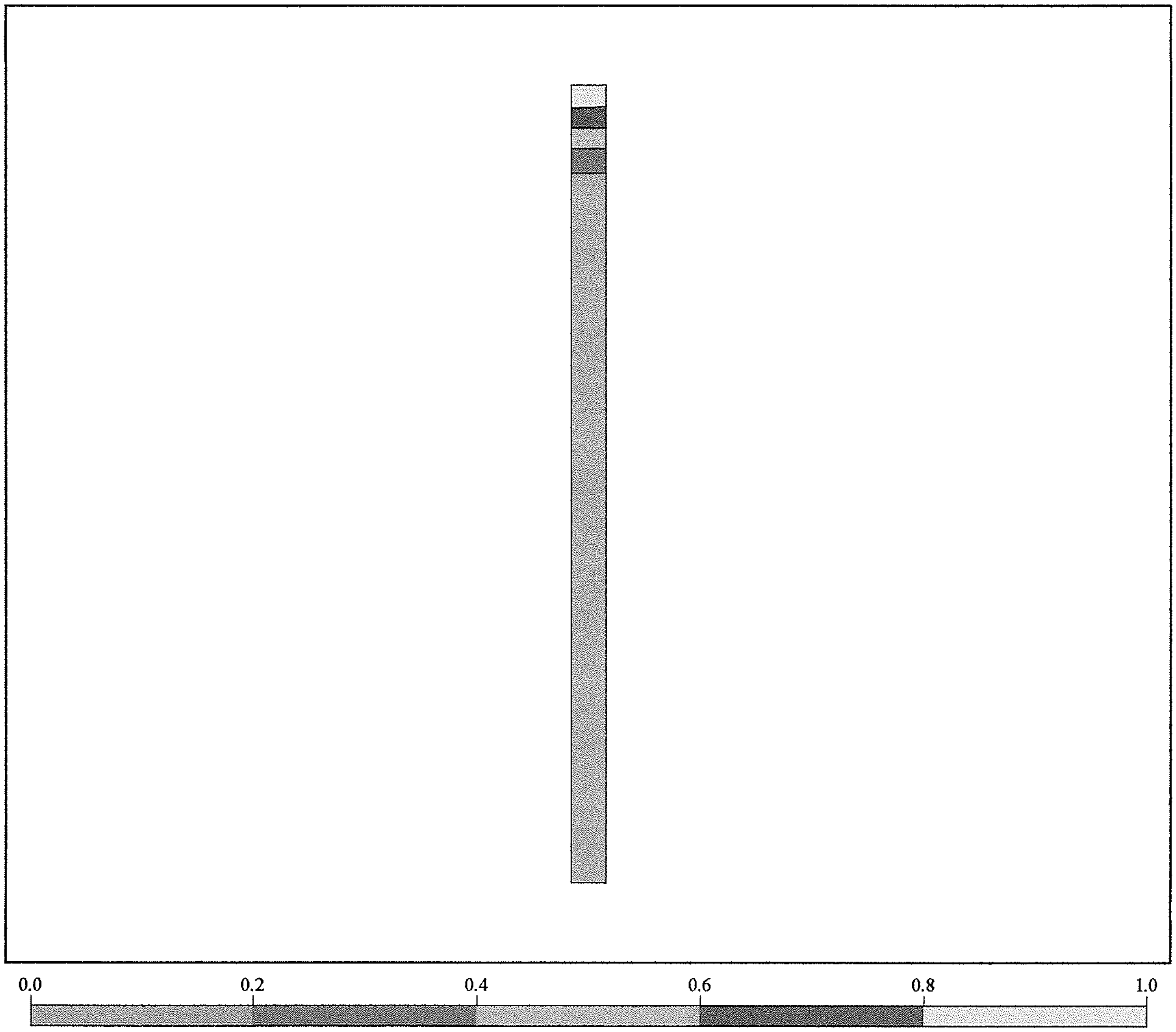


Figure 4.9. HYDRUS2D Simulation Results: Run W111D5. Infiltration of Refuse Leachate in the Wepo Formation Showing Solute Concentration.
1-D Simulation, Time = 73,000 days, vertical depth of 150 ft (45 m). Unit concentration at source (top of domain). Flux is 2E-05 ft/d (5.5E-06 m/d).

TABLES

Table 3.1. Data Available and Evaluated for Potential Refuse Disposal Site Assessment

Data Available and Evaluated	Mine Area			
	J-3	J-7	N-6	J-23
Hydrogeology (Wepo Aquifer)				
Hydrogeologic descriptions	●	●	●	●
Local Potentiometric surface	●	●	●	●
Groundwater levels	●	●	●	●
Groundwater geochemical data	●	●	●	●
Hydraulic test results	●	●	●	●
Surface-water features (map)	●	●	●	●
Geology (Wepo Formation)				
Geologic descriptions	●	●	●	●
Borehole lithology	Not Available	Few	●	Moderate
Structural geology information	General	General	General	General
Field observations	Limited	Limited	Limited	NA
Other information				
Post-mining topography	●	●	●	●
Alluvial aquifer geochemistry	Not Evaluated	Not Evaluated	●	Not Evaluated
Suitable spoil characteristics	●	●	●	Not Available
Geotechnical data	Not Available	Not Available	Limited	Not Available
Geophysical data	Not Available	Not Available	Not Available	Not Available
Shallow spoil parameter thresholds	Applies to entire mine site			
Surrogate Refuse geochemistry	Surrogate borehole sample SPLP data collected from 21 boreholes			
Spoils – Hydraulic testing data	Three tests performed (SPL176 (poor data), SPL177, and SPL 209			

Table 3.2. Wepo Aquifer Hydraulic Testing Results
Black Mesa Mine, Arizona

Well ID	Transmissivity (gpd/ft)	Storage Coefficient S	Estimated Aquifer Thickness (ft)	Screened Interval Thickness (ft)	Water Column Hydraulic Conductivity (ft/day)	Screen Hydraulic Conductivity (ft/day)	DTW (ft bmp)	Water Elevation (ft amsl)	TD (ft)	Pump Depth (ft bgs)	Surface Elevation (ft amsl)	Elev. Mon. Point (ft amsl)	Upper Screen (ft bgs)	Lower Screen (ft bgs)	Test Type
38	480	1.90E-05	191.11	207	0.34	0.31	28.89	6583.31	220		6612.2	6612.78	13	220	pump/
40	84														Mod. Slug
41	46		283.54	130	0.02	0.05	66.46	6713.54	350		6780	No	220	350	Mod. Slug
42[a]	956		198.49	168	0.64	0.76	4.51	6616.19	203	175	6620.7	6623.35	32	200	pump
43	132		206.07	140	0.09	0.13	143.93	6450.67	350	215	6594.6	6597.3	195	335	Mod. Slug
44	0.25		188.27	68	0.00	0.00	161.73	6388.27	350	275	6550		282	350	Mod. Slug
45	11.5		248.62	200	0.01	0.01	92.38	6426.62	341	208	6519		130	330	Mod. Slug
46	19.2		203.83	105	0.01	0.02	156.17	6288.23	360	215.24	6444.4		155	260	Mod. Slug
48	170	1.45E-04	191.83	180	0.12	0.13	28.17	6281.23	220	125	6309.4	6309.63	40	220	Pump
49[a]	1297		344.07	342	0.50	0.51	5.93		350	150			8	350	Pump
51	666		306.35	100	0.29	0.89	43.65	6657.35	350	140	6701	6701.7	250	350	Pump
52	205		336.45	280	0.08	0.10	13.55	6639.25	350	185	6652.8	6653.6	70	350	Pump
53	6.9		280.62	160	0.00	0.01	69.38	6611.82	350	215	6681.2	na	190	350	Pump
54[a]	347		306	230	0.15	0.20	44		350	160			120	350	Pump
55	40		188.14	160	0.03	0.03	161.86	6319.64	350	271	6481.5	6481.5	190	350	Mod. Slug
56	21		307.87	220	0.01	0.01	39.13	6378.57	347	271	6417.7	6420.28	130	350	Mod. Slug
57	39		159.37	200	0.03	0.03	155.63	6303.27	315	220	6458.9	6461.38	115	315	Mod. Slug
58	38		215.27	200	0.02	0.03	134.73	6199.97	350	260	6334.7	na	150	350	Mod. Slug
59[a]	1990		202.65	235	1.31	1.13	147.35	6149.25	350	215	6296.6	na	115	350	Pump
60	12		267.7	175	0.01	0.01	81.3	6379.9	349	215	6461.2	na	175	350	Mod. Slug
61	51		191.13	180	0.04	0.04	158.87	6346.33	350	271	6505.2	na	170	350	Mod. Slug
62	0.1		246.14	200	0.00	0.00	103.86	6720.14	350	225	6824	6824	150	350	Mod. Slug
63	204		123.38	155	0.22	0.18	226.62	6675.28	350	300	6901.9	na	195	350	Mod. Slug
64	36		118.46	230	0.04	0.02	231.54	6610.46	350	275	6842	6842.6	120	350	Mod. Slug
64R	25.9		74.97		0.05		54.03		129	100	nd	nd	nd	nd	Mod. Slug
65	72		237.68	160	0.04	0.06	112.32	6701.68	350	157	6814	na	190	350	Mod. Slug
66	322		266.82	235	0.16	0.18	83.18	6818.42	350	185	6901.6	6903.2	115	350	Pump
Wepo Wells															
Arithmetic Mean	116.60	8.20E-05	219.71		0.07	0.11									
Harmonic Mean	1.57		194.31		0.00	0.00									
Geometric Mean	36.24		208.32		0.02	0.03									

Notes: [a] Well completed in Wepo and Toreva Formations

gpd = gallons per day

amsl = above mean sea level

ft = feet

bgs = below ground surface

bmp = below monitoring point

Table 3.3: Comparison of Summary Statistics for Metals Concentrations in Groundwater Samples Collected from Site-Wide and Local-Area Wells

Analyte	Number of Samples		Concentrations ≥ Detection Limit			
	Total	Concentration ≥ Detection Limit	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Std Dev (mg/L)
Aluminum						
Site-Wide Wepo Wells	648	76	0.03	1.69	0.123	0.218
J-3 Wepo Wells	54	11	0.05	0.12	0.073	0.023
J-7 Wepo Wells	47	4	0.05	0.14	0.075	0.044
J-23 Wepo Wells	59	10	0.05	0.32	0.114	0.080
N-6 Wepo Wells	61	11	0.04	0.29	0.098	0.073
Arsenic						
Site-Wide Wepo Wells	649	155	0.001	0.040	0.002	0.003
J-3 Wepo Wells	54	22	0.001	0.006	0.003	0.002
J-7 Wepo Wells	47	4	0.001	0.002	0.002	0.001
J-23 Wepo Wells	59	21	0.001	0.008	0.002	0.002
N-6 Wepo Wells	61	12	0.001	0.007	0.002	0.002
Barium						
Site-Wide Wepo Wells	385	360	0.004	1.41	0.105	0.160
J-3 Wepo Wells	52	35	0.03	0.121	0.058	0.024
J-7 Wepo Wells	26	25	0.01	0.06	0.034	0.011
J-23 Wepo Wells	34	33	0.03	0.53	0.246	0.170
N-6 Wepo Wells	42	38	0.01	1.41	0.149	0.303
Boron						
Site-Wide Wepo Wells	650	640	0.02	1.2	0.240	0.188
J-3 Wepo Wells	56	56	0.1	0.6	0.312	0.086
J-7 Wepo Wells	47	46	0.05	0.29	0.185	0.060
J-23 Wepo Wells	59	59	0.2	0.4	0.288	0.048
N-6 Wepo Wells	61	58	0.02	0.66	0.280	0.246
Cadmium						
Site-Wide Wepo Wells	648	18	0.003	0.020	0.008	0.003
J-3 Wepo Wells	54	1	0.006	0.006	0.006	----
J-7 Wepo Wells	47	1	0.008	0.008	0.008	----
J-23 Wepo Wells	59	0	----	----	----	----
N-6 Wepo Wells	61	2	0.008	0.009	0.0085	0.0007
Calcium						
Site-Wide Wepo Wells	656	654	1	543	92	109
J-3 Wepo Wells	56	55	1	305	31	58
J-7 Wepo Wells	47	47	2	38	7.6	7.2
J-23 Wepo Wells	59	59	6	338	94	111
N-6 Wepo Wells	62	62	1	389	87	114

Table 3.3 (cont.): Comparison of Summary Statistics for Metals Concentration in Groundwater Samples Collected from Site-Wide and Local-Area Wells

Analyte	Number of Samples		Concentrations ≥ Detection Limit			
	Total	Concentration ≥ Detecion Limit	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Std Dev (mg/L)
Chromium						
Site-Wide Wepo Wells	648	13	0.01	0.20	0.02	0.05
J-3 Wepo Wells	54	2	0.01	0.01	0.01	0
J-7 Wepo Wells	47	0	----	----	----	----
J-23 Wepo Wells	59	4	0.01	0.01	0.01	0
N-6 Wepo Wells	61	1	0.01	0.01	0.01	----
Copper						
Site-Wide Wepo Wells	648	30	0.01	0.36	0.03	0.64
J-3 Wepo Wells	54	2	0.01	0.01	0.01	0
J-7 Wepo Wells	47	3	0.01	0.01	0.01	----
J-23 Wepo Wells	59	1	0.01	0.01	0.01	----
N-6 Wepo Wells	61	4	0.01	0.01	0.01	0
Iron						
Site-Wide Wepo Wells	656	492	0.01	14.8	1.0	2.0
J-3 Wepo Wells	56	38	0.01	3.24	0.6	1.1
J-7 Wepo Wells	47	20	0.01	0.74	0.01	0.2
J-23 Wepo Wells	59	47	0.02	2.1	0.5	0.6
N-6 Wepo Wells	62	45	0.01	4.5	1.0	1.4
Lead						
Site-Wide Wepo Wells	648	23	0.020	0.100	0.041	0.023
J-3 Wepo Wells	54	5	0.02	0.1	0.042	0.033
J-7 Wepo Wells	47	1	0.06	0.06	0.06	----
J-23 Wepo Wells	59	1	0.020	0.020	0.020	----
N-6 Wepo Wells	61	4	0.02	0.08	0.058	0.026
Magnesium						
Site-Wide Wepo Wells	650	607	0.39	773	61.3	92.6
J-3 Wepo Wells	56	47	0.39	240	24.3	52.6
J-7 Wepo Wells	47	34	0.4	11	2.12	2.26
J-23 Wepo Wells	59	59	2	206	44.9	58.0
N-6 Wepo Wells	61	55	0.7	82	37.5	28.6
Manganese						
Site-Wide Wepo Wells	648	605	0.005	2.88	0.153	0.230
J-3 Wepo Wells	54	54	0.005	1.24	0.123	0.202
J-7 Wepo Wells	47	40	0.005	0.170	0.035	0.038
J-23 Wepo Wells	59	48	0.007	0.110	0.054	0.032
N-6 Wepo Wells	61	52	0.005	0.700	0.151	0.213

Table 3.3 (cont.): Comparison of Summary Statistics for Metals Concentration in Groundwater Samples Collected from Site-Wide and Local-Area Wells

Analyte	Number of Samples		Concentrations ≥ Detection Limit			
	Total	Concentration ≥ Detecion Limit	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Std Dev (mg/L)
Mercury						
Site-Wide Wepo Wells	648	12	0.0001	0.0007	0.0003	0.0002
J-3 Wepo Wells	54	1	0.0001	0.0001	0.0001	----
J-7 Wepo Wells	47	0	----	----	----	----
J-23 Wepo Wells	59	0	----	----	----	----
N-6 Wepo Wells	61	2	0.0003	0.0003	0.0003	0
Potassium						
Site-Wide Wepo Wells	649	649	1	36	7.0	5.0
J-3 Wepo Wells	56	56	1	13	4.1	2.6
J-7 Wepo Wells	47	47	1	5	2.3	0.9
J-23 Wepo Wells	59	59	4.5	23	8.5	3.9
N-6 Wepo Wells	61	61	1	19	7.5	5.4
Selenium						
Site-Wide Wepo Wells	648	67	0.001	0.560	0.038	0.098
J-3 Wepo Wells	54	11	0.001	0.084	0.012	0.025
J-7 Wepo Wells	47	2	0.001	0.003	0.002	0.001
J-23 Wepo Wells	59	17	0.001	0.003	0.002	0.712
N-6 Wepo Wells	61	3	0.001	0.002	0.002	0.001
Silver						
Site-Wide Wepo Wells	387	6	0.01	0.02	0.013	0.005
J-3 Wepo Wells	37	1	0.02	0.02	0.020	----
J-7 Wepo Wells	26	2	0.01	0.01	0.010	0
J-23 Wepo Wells	34	0	----	----	----	----
N-6 Wepo Wells	44	1	0.010	0.010	0.010	----
Sodium						
Site-Wide Wepo Wells	656	656	15	1570	492	366
J-3 Wepo Wells	56	56	320	1479	762	332
J-7 Wepo Wells	47	47	213	835	315	127
J-23 Wepo Wells	59	59	416	1180	694	175
N-6 Wepo Wells	62	62	41	1436	607	496
Vanadium						
Site-Wide Wepo Wells	648	30	0.005	0.020	0.010	0.003
J-3 Wepo Wells	54	4	0.010	0.010	0.010	0
J-7 Wepo Wells	47	1	0.006	0.006	0.006	----
J-23 Wepo Wells	59	5	0.005	0.020	0.010	0.006
N-6 Wepo Wells	61	5	0.010	0.010	0.010	0

Table 3.3 (cont.): Comparison of Summary Statistics for Metals Concentration in Groundwater Samples Collected from Site-Wide and Local-Area Wells

Analyte	Number of Samples		Concentrations ≥ Detection Limit			
	Total	Concentration ≥ Detecion Limit	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Std Dev (mg/L)
Zinc						
Site-Wide Wepo Wells	641	200	0.005	1.23	0.04	0.11
J-3 Wepo Wells	53	26	0.01	0.07	0.02	0.02
J-7 Wepo Wells	47	9	0.01	0.02	0.01	0.00
J-23 Wepo Wells	59	17	0.01	0.25	0.03	0.06
N-6 Wepo Wells	61	16	0.01	0.20	0.04	0.05

Table 3.4: Comparison of Summary Statistics for Inorganic Concentrations in Groundwater Samples Collected from Site-Wide and Local-Area Wells

Analyte	Number of Samples		Concentrations > Detection Limit			
	Total	Concentration > Detection Limit	Min Value	Max Value	Mean Value	Standard Deviation
Alkalinity as CaCO3 (mg/L)						
Site-Wide Wepo Wells	650	650	146	2240	687	481
J-3 Wepo Wells	56	56	650	1980	1295	492
J-7 Wepo Wells	47	47	290	819	419	132
J-23 Wepo Wells	59	59	326	1670	1110	302
N-6 Wepo Wells	61	61	224	838	567	159
Bicarbonate as CaCO3 (mg/L)						
Site-Wide Wepo Wells	421	421	146	2629	742	522
J-3 Wepo Wells	32	32	680	2155	1410	573
J-7 Wepo Wells	32	32	283	999	431	174
J-23 Wepo Wells	38	38	740	1869	1226	313
N-6 Wepo Wells	39	39	366	893	640	169
Carbonate as CaCO3 (mg/L)						
Site-Wide Wepo Wells	421	174	0	210	10	21
J-3 Wepo Wells	32	20	0.0	61	19	21
J-7 Wepo Wells	32	21	0	28	11	8
J-23 Wepo Wells	38	15	0.0	50	10	17
N-6 Wepo Wells	39	26	0.0	29	9.3	11
Hydroxide as CaCO3 (mg/L)						
Site-Wide Wepo Wells	263	0	---	---	---	---
J-3 Wepo Wells	18	0	---	---	---	---
J-7 Wepo Wells	21	0	---	---	---	---
J-23 Wepo Wells	25	0	---	---	---	---
N-6 Wepo Wells	19	0	---	---	---	---
Chloride (mg/L)						
Site-Wide Wepo Wells	650	650	3	388	27	29
J-3 Wepo Wells	56	56	16	388	44	50
J-7 Wepo Wells	47	47	7	25	13	4
J-23 Wepo Wells	59	59	6	108	25	20
N-6 Wepo Wells	61	61	9	54	27	15
Conductivity (ums/cm^2)						
Site-Wide Wepo Wells	1609	1605	435	7560	2368	1469
J-3 Wepo Wells	144	144	1206	6940	2814	1352
J-7 Wepo Wells	99	99	850	3190	1279	474
J-23 Wepo Wells	132	132	1736	5844	3052	1224
N-6 Wepo Wells	153	152	917	6420	2600	1806

Table 3.4 (cont.): Comparison of Summary Statistics for Inorganic Concentrations in Groundwater Samples Collected from Site-Wide and Local-Area Wells

Analyte	Number of Samples		Concentrations ≥ Detection Limit			
	Total	Concentration ≥ Detection Limit	Min Value	Max Value	Mean Value	Standard Deviation
Fluoride (mg/L)						
Site-Wide Wepo Wells	654	647	0.1	23	3.0	3.3
J-3 Wepo Wells	54	54	1.6	8.1	4.9	2.0
J-7 Wepo Wells	47	47	0.4	5.7	1.6	0.8
J-23 Wepo Wells	59	59	0.7	15	4.2	4.3
N-6 Wepo Wells	62	62	0.7	12	4.2	3.7
Nitrate as N (mg/L)						
Site-Wide Wepo Wells	648	330	0.01	293	4.1	25.9
J-3 Wepo Wells	54	36	0.01	293	9.6	49.0
J-7 Wepo Wells	47	21	0.02	0.57	0.09	0.13
J-23 Wepo Wells	59	43	0	1.65	0.43	0.52
N-6 Wepo Wells	61	28	0.02	0.39	0.08	0.08
Nitrate-Nitrite as N (mg/L)						
Site-Wide Wepo Wells	490	254	0.02	270	3.37	22.4
J-3 Wepo Wells	40	25	0.03	5.2	0.52	1.41
J-7 Wepo Wells	36	15	0.02	0.57	0.11	0.15
J-23 Wepo Wells	46	36	0.02	2.3	0.53	0.60
N-6 Wepo Wells	41	18	0.02	0.19	0.07	0.05
Nitrite as N (mg/L)						
Site-Wide Wepo Wells	648	118	0.01	2.95	0.17	0.40
J-3 Wepo Wells	54	18	0.01	0.34	0.05	0.09
J-7 Wepo Wells	47	9	0.01	0.21	0.11	0.09
J-23 Wepo Wells	59	10	0.01	2.28	0.39	0.73
N-6 Wepo Wells	61	15	0.01	1.23	0.20	0.33
pH (s.u.)						
Site-Wide Wepo Wells	648	648	4.5	8.8	7.9	0.5
J-3 Wepo Wells	54	54	7.1	8.8	8.1	0.5
J-7 Wepo Wells	47	47	7.6	8.7	8.3	0.3
J-23 Wepo Wells	59	59	4.5	8.4	7.7	0.6
N-6 Wepo Wells	61	61	6.5	8.7	8.0	0.6
Sulfate (mg/L)						
Site-Wide Wepo Wells	656	615	2	4760	853	916
J-3 Wepo Wells	56	56	29	2474	456	599
J-7 Wepo Wells	47	47	121	1058	259	174
J-23 Wepo Wells	59	50	8	3050	914	1026
N-6 Wepo Wells	62	62	12	2676	1069	1032

Table 3.4 (cont.): Comparison of Summary Statistics for Inorganic Concentrations in Groundwater Samples Collected from Site-Wide and Local-Area Wells

Analyte	Number of Samples		Concentrations ≥ Detection Limit			
	Total	Concentration ≥ Detection Limit	Min Value	Max Value	Mean Value	Standard Deviation
TDS (mg/L)						
Site-Wide Wepo Wells	1248	1248	320	8010	1833	1355
J-3 Wepo Wells	119	119	610	4648	1940	1019
J-7 Wepo Wells	72	72	566	2056	877	366
J-23 Wepo Wells	98	98	1118	5038	2310	1223
N-6 Wepo Wells	123	123	590	4400	1846	1471

Table 4.1. Results of Synthetic Precipitation Leaching Procedure for Metals in Peabody Interburden Core Samples

PARAMETER	METHOD	01M	02M	03M	04M	05M	06M	07M	08M	09M	10M	10RM	11M	12M	13M	14M	15M	16M	17M	18M	19M	20M	20RM	21M
Aluminum	200.7	0.1	1.8	1	1.5	1.2	1.2	1.1	2.4	1.4	2.8	5.4	3.3	4.2	2.3	3.1	3.7	9.8	3.3	1.6	1.4	2.5	2.5	1.5
Arsenic (c)	3114B	0.001	0.001	<0.001	<0.001	0.016	0.001	0.003	0.01	0.005	<0.001	0.001	0.001	0.005	0.002	0.011	0.006	0.001	<0.001	0.011	<0.001	0.008	0.007	0.003
Arsenic		0.001	0.001	0.0005	0.0005	0.016	0.001	0.003	0.01	0.005	0.0005	0.001	0.001	0.005	0.002	0.011	0.006	0.001	0.0005	0.011	0.0005	0.008	0.007	0.003
Barium	200.7	0.01	0.35	0.27	0.25	0.33	0.28	0.28	0.31	0.33	0.8	1.01	0.63	0.67	0.49	0.58	0.58	0.43	0.54	0.35	0.26	0.38	0.36	0.34
Boron ©	200.7	0.1	0.2	0.3	0.3	0.1	0.2	0.2	0.1	<0.1	0.1	0.2	0.1	<0.1	0.1	0.1	0.1	0.3	0.1	<0.1	0.1	<0.1	<0.1	0.1
Boron		0.1	0.2	0.3	0.3	0.1	0.2	0.2	0.1	0.0500	0.1	0.2	0.1	0.0500	0.1	0.1	0.1	0.3	0.1	0.0500	0.1	0.0500	0.0500	0.1
Cadmium ©	3113B	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium		0.0010	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Calcium ©	200.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Calcium		0.5	0.5	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500
Chromium ©	200.7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium		0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.01	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Copper ©	200.7	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Copper		0.0100	0.0100	0.02	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.05	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
Iron	200.7	0.0500	0.35	0.23	0.3	0.23	0.21	0.19	0.47	0.29	0.65	1.21	0.64	0.74	0.33	0.5	0.65	2.7	0.53	0.35	0.37	0.47	0.42	0.2800
Lead ©	3113B	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Lead		0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Magnesium ©	200.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Magnesium		0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500		0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500
Manganese ©	200.7	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008	<0.005	<0.005	<0.005	0.019	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Manganese		0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025		0.0025	0.0025	0.0025		0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Mercury	245.1	0.0005	0.0008	0.0008	0.0007	0.0008	0.0008	0.0007	0.0007	0.0007	0.0007	0.0008	0.0007	0.0009	0.0009	0.001	0.0011	0.0011	0.0009	0.001	0.001	0.0012	0.001	0.001
Potassium ©	200.7	1.3	1.3	0.8	1.3	<0.5	0.6	<0.5	<0.5	0.7	<0.5	0.8	0.9	0.8	<0.5	0.8	1.1	1.7	0.6	0.7	0.9	0.7	0.7	0.6
Potassium		1.3	1.3	0.8	1.3	0.2500	0.6	0.2500	0.2500	0.7	0.2500	0.8	0.9	0.8	0.2500	0.8	1.1	1.7	0.6	0.7	0.9	0.7	0.7	0.6
Selenium	3114B	0.001	0.011	0.006	0.005	0.01	0.007	0.008	0.008	0.005	0.003	0.004	0.005	0.007	0.004	0.008	0.007	0.005	0.002	0.008	0.004	0.007	0.008	0.006
Silver ©	200.7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver		0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Sodium	200.7	0.5	55.3	34.6	40.3	15.4	19.6	18.9	14	33.8	7.5	8	25.8	24.4	17.7	25.9	32.3	63.7	6.6	32.7	41.2	23.9	25.1	23
Vanadium ©	200.7	0.02	0.05	<0.02	0.05	0.05	<0.02	<0.02	0.04	<0.02	0.02	0.03	0.05	0.06	0.06	0.03	0.03	0.04	0.07	0.07	<0.02	0.09	0.09	0.02
Vanadium		0.02	0.05	0.0100	0.05	0.05	0.0100	0.0100	0.04	0.0100	0.02	0.03	0.05	0.06	0.06	0.03	0.03	0.04	0.07	0.07	0.0100	0.09	0.09	0.02
Zinc ©	200.7	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	0.16	0.06	<0.05	<0.05	<0.05	<0.05	0.41	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Zinc		0.0250	0.0250	0.0250	0.0250	0.0250	0.0250	0.0250	0.0250	0.0250	0.08	0.16	0.06	0.0250	0.0250	0.0250	0.0250	0.41	0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

PARAMETER	Min	Max	Mean	SD
Aluminum	0.1	9.8	2.5696	1.98596
Arsenic (c)	0.001	0.016	0.0052	0.0045
Arsenic	0.0005	0.016	0.0042	0.00442
Barium	0.01	1.01	0.4274	0.21346
Boron (c)	0.1	0.3	0.1556	0.07838
Boron	0.05	0.3	0.1326	0.08203
Cadmium (c)	All Below detection			
Cadmium	0.0005	0.001	0.0005	0.0001
Calcium (c)	All Below detection			
Calcium	0.25	0.5	0.2717	0.07203
Chromium (c)	0.01	0.01	0.01	0
Chromium	0.005	0.01	0.0052	0.00104
Copper (c)	0.02	0.05	0.0350	0.02121
Copper	0.01	0.05	0.0122	0.0085
Iron	0.05	2.7	0.5287	0.53122
Lead (c)	All Below detection			
Lead	0.0025	0.0025	0.0025	0
Magnesium (c)	0.4	0.4	0.4	0
Magnesium	0.25	0.25	0.2500	0
Manganese (c)	0.008	0.019	0.0135	0.00778
Manganese	0.0025	0.0025	0.0025	0
Mercury	0.0005	0.0012	0.0009	0.00017
Potassium (c)	0.6	1.7	0.9056	0.3096
Potassium	0.25	1.7	0.7630	0.38795
Selenium	0.001	0.011	0.0060	0.00244
Silver (c)	All Below detection			
Silver	0.005	0.005	0.0050	0
Sodium	0.5	63.7	25.6609	15.1633
Vanadium (c)	0.02	0.09	0.0483	0.02203
Vanadium	0.01	0.09	0.0400	0.02523
Zinc (c)	0.06	0.41	0.1775	0.16091
Zinc	0.025	0.41	0.0515	0.08381

PARAMETER	METHOD	01I	02I	03I	04I	05I	06I	07I	08I	09I	10I	10RI	11I	12I	13I	14I	15I	16I	17I	18I	19I	20I	20RI	21I
Alkalinity as $CaCO_3$	2320B	12	37	5	20	5	10	5	5	32	5	10	24	41	31	28	38	36	5	52	33	40	41	18
Bicarbonate as $CaCO_3$	2320B	12	37	5	20	5	10	5	5	32	5	10	24	37	29	26	38	36	5	46	31	36	33	18
Carbonate as $CaCO_3$ ©	2320B	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Carbonate as $CaCO_3$	2320B	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Hydroxide as $CaCO_3$ ©	2320B	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Hydroxide as $CaCO_3$	2320B	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Chloride ©	4500Cl	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Chloride	4500Cl	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Conductivity	2510B	264	346	216	167	94.8	120	121	83.1	194	44.2	44.2	154	132	97.6	153	144	384	38.4	180	254	131	131	139
Fluoride	4500F C	0.5	0.8	0.7	0.9	1.2	0.5	0.7	1	1	0.6	0.6	0.7	0.8	0.6	0.8	0.9	0.5	0.8	1	0.4	1.4	1.4	0.8
pH	150.1	7.26	7.84	7.75	8.3	9.24	8.39	8.34	9.14	9.05	7.98	8.01	8.18	9.25	9.31	8.8	8.7	5.26	9.2	9.71	8.57	10	10.1	9.33
TDS	2540C	70	75	55	20	5	5	5	5	60	5	5	45	40	15	40	55	215	25	80	120	40	55	20

PARAMETER	Min	Max	Mean	SD
Alkalinity as $CaCO_3$	5	52	23.1739	15.1887
Bicarbonate as $CaCO_3$	5	46	21.9565	13.7955
Carbonate as $CaCO_3$ ©	All Below Detection			
Carbonate as $CaCO_3$	5	5	5	0
Hydroxide as $CaCO_3$ ©	All Below Detection			
Hydroxide as $CaCO_3$	5	5	5	0
Chloride ©	All Below Detection			
Chloride	5	5	5	0
Conductivity	38.4	384	157.926	88.1887
Fluoride	0.4	1.4	0.8087	0.26953
pH	5.26	10.1	8.59609	1.03524
TDS	5	215	46.087	47.6721

Notes: © = Censored data are data whose summary statistics do not include data that were below detection limits. Uncensored data have had their summary statistics calculated using one-half the below detection value.

Table 4.2. Soil Toxicity and Acid Parameter Analytical Results for Interburden and Overburden Composite Samples From Coreholes

SAMPLE ID	307-074-03	307-074-03R	307-074-06	307-074-12	307-074-17	307-074-18	QC-18	QC-23	SC1-001	Maximum Threshold Values[1]	Mean Table 22-2-1[2]	Mean Table 22-2-2[2]
LOCATION	30352EO (N99)	30352EO (N99)	30356EO (N9)	30360EO (J14)	30367EO (J6)	30368EO (N99-S)						
SAMPLE DATE	7/11-12/03	7/11-12/03	7/21-22/03	7/25-26/03	08/05/03	08/06/03						
SAMPLE DEPTH	IB Comp	IB Comp	IB Comp	IB Comp	IB Comp	IB Comp						
PH UNITS	6.82	6.82	7.14	7.98	8.10	8.14		6.98		<4.5 to >9.0	7.3	7.7
EC MMHO/CM	4.81	4.87	3.31	2.05	0.58	2.15		5.33		>12.0	4.0	0.8
% SAT	48.3	48.6	40.8	42.4	40.8	43.3		50.5			45.3	45.3
CALCIUM MEQ/L	1.93	1.96	1.36	0.32	0.11	0.28		20.2				
MAGNESIUM MEQ/L	0.86	0.86	1.00	0.26	0.13	0.53		11.3				
SODIUM MEQ/L	45.7	43.5	29.5	19.0	5.57	20.0		33.0				
SAR	38.7	36.6	27.2	35.1	15.9	31.3		8.32		>40 / >35 / >25[3]	3.5	2.0
% SAND	50.0	52.5	56.3	62.5	63.8	67.5		37.5			43.5	29.2
% SILT	25.0	21.3	21.3	17.5	13.8	12.5		27.5		>45	24.6	28.8
% CLAY	25.0	26.25	22.5	20.0	22.5	20.0		35.0			31.9	42.0
CLASS	SCL	SCL	SCL	SCL/SL	SCL	SCL/SL		CL			CL	C
CARBON												
TOT S %	0.901	0.946	1.072	0.280	0.208	0.645	0.116					
SULFATE S%												
PYR S %	0.641	0.611	0.593		0.072	0.403	0.009					
ORG S%												
ACID POT TN/1000TN	28.1	29.6	33.5	8.75	6.51	20.1	3.63					
NEUT POT TN/1000TN	5.75	5.75	7.71	13.6	6.25	19.5	12.6					
A-B POT[4] TN/1000TN	-22.4	-23.8	-25.8	4.85	-0.26	-0.67	8.99			< -5	30.4	24.1
PYR A POT TN/1000TN	20.0	19.1	18.5		2.25	12.6	0.28					
PYRS A-B TN/1000TN	-14.3	-13.3	-10.8		4.00	6.89	12.3					
BORON[5] PPM										>10		
TOT SE[6] PPM	2.125	2.000	2.075	3.050	2.975	2.675	0.475		3.000	>2.5		
AB-DTPA[6] SE PPM	0.254	0.259	0.305	0.251	0.120	0.299	0.144			>0.31		
SOL SE[6] PPM	0.162	0.162	0.222	0.206	0.084	0.236		0.095		>0.26	0.1	
AVAIL NA MEQ/100GM												
EXCHG NA MEQ/100GM												
CEC MEQ/100GM												
ESP												
CO3												
SAMPLER												
NO3												
EFFVRS												
LIME EST												
%CACO3[7]	0.5755	0.5755	0.7715	1.3595	0.6245	1.9475	1.2615			>30		
ELEVATION												

Notes: 1. Black Mesa Mining Complex Threshold values for Minor Root Zone (Substratum-Spoil) 1 to 3 feet. Shaded values exceed threshold values.

1: Parameters and maximum threshold limits are based on OSMRE (1998) and site-specific justification documents that PWCC submitted to OSMRE in September 1998, November 1998, January 1999, February 1999, January 2000, and August 2001.

2.Table 22-2-1and Table 22-2-2 in: Peabody Western Coal Company, 1985. Mining and Reclamation Plan, Black Mesa and Kayenta Mines, Black Mesa Mine. Table 22-2-2 is "Suitable Spoil (Supplemental Surface Plant Growth Media) Characteristics for Reclamation Sites Located in the J-3, J-7, J-1/N-6, N-1, N-2, N-7/8, and J-21 Reclamation Areas. Table 22-2-2 is Suitable Spoil (Supplemental Surface Plant Growth Media) Characteristics of the Surface 6 to 12 Inches for Reclamation Sites Located in the J-3 Reclamation Area.

3. SAR for <20% clay, 20-35% clay, and >35% clay respectively. Suitable maximum SAR values for the minor root zone substratum spoil must be in the slight to no reduction zone of the infiltration hazard classes adapted from Ayers and Wescott (1989) as shown in Figure 1 in PWCC (1985) (revised 3/15/02).

4. Units are tons calcium carbonate equivalent per 1000 tons of material. Suitability levels based upon correspondence from OSMRE (August 6, 1987). The acid potential must be calculated from pyritic sulfur as specified in the New Mexico guidelines.

5. The hot water soluble boron analysis will only be included in the analytical suite for future soil and overburden baseline assessment where there is no existing HWS-B data, spoil collected from the N10 Reclamation area, and future reclamation areas where problem levels of HWS-B have been identified in the overburden. In all instances, HWS-B will only be determined for very dark gray to black carbonaceous shale and black weathered coal strata.

6. The hot water soluble and AB-DTPA extractable selenium analyses and standards will generally be used independently of each other at the BMMC because these two techniques are highly correlated with each other.

7. These suitability criteria are used only for the 0 to 1 and 1 to 3 foot increments of special reclamation areas including steep slopes, key habitats, cultural plantings, and main drainage channels where supplemental surface plant growth media are used.

Table 4.3: Comparison of Summary Statistics for Refuse Samples (SPLP-Metals) and Groundwater Samples Collected from the Site-Wide Well Network, J-23 Area, and N-6 Area

Analyte	Number of Samples		Concentrations > Detection Limit			
	Total	Concentration > Detection Limit	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Std Dev (mg/L)
Aluminum						
Refuse (SPLP)	23	23	0.10	9.80	2.57	1.99
Site-Wide Wepo Wells	648	76	0.03	1.69	0.12	0.22
J-23 Wepo Wells	59	10	0.05	0.32	0.11	0.08
N-6 Wepo Wells	61	11	0.04	0.29	0.10	0.07
Arsenic						
Refuse (SPLP)	23	18	0.001	0.016	0.005	0.005
Site-Wide Wepo Wells	649	155	0.001	0.040	0.002	0.003
J-23 Wepo Wells	59	21	0.001	0.008	0.002	0.002
N-6 Wepo Wells	61	12	0.001	0.007	0.002	0.002
Barium						
Refuse (SPLP)	23	23	0.010	1.01	0.427	0.213
Site-Wide Wepo Wells	385	360	0.004	1.41	0.105	0.160
J-23 Wepo Wells	34	33	0.03	0.53	0.246	0.170
N-6 Wepo Wells	42	38	0.01	1.41	0.149	0.303
Boron						
Refuse (SPLP)	23	18	0.1	0.3	0.156	0.078
Site-Wide Wepo Wells	650	640	0.02	1.2	0.240	0.188
J-23 Wepo Wells	59	59	0.2	0.4	0.288	0.048
N-6 Wepo Wells	61	58	0.02	0.66	0.280	0.246
Cadmium						
Refuse (SPLP)	23	1	0.001	0.001	0.001	---
Site-Wide Wepo Wells	648	18	0.003	0.020	0.008	0.003
J-23 Wepo Wells	59	0	---	---	---	---
N-6 Wepo Wells	61	2	0.008	0.009	0.0085	0.0007
Calcium						
Refuse (SPLP)	23	2	0.5	0.5	0.50	0.00
Site-Wide Wepo Wells	656	654	1	543	92	109
J-23 Wepo Wells	59	59	6	338	94	111
N-6 Wepo Wells	62	62	1	389	87	114
Chromium						
Refuse (SPLP)	23	3	0.01	0.01	0.01	0.00
Site-Wide Wepo Wells	648	13	0.01	0.20	0.02	0.05
J-23 Wepo Wells	59	4	0.01	0.01	0.01	0
N-6 Wepo Wells	61	1	0.01	0.01	0.01	---

Table 4.3 (cont.): Comparison of Summary Statistics for Refuse Samples (SPLP-Metals) and Groundwater Samples Collected from the Site-Wide Well Network, J-23 Area, and N-6 Area

Analyte	Number of Samples		Concentrations > Detection Limit			
	Total	Concentration > Detection Limit	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Std Dev (mg/L)
Copper						
Refuse (SPLP)	23	4	0.02	0.05	0.03	0.02
Site-Wide Wepo Wells	648	30	0.01	0.36	0.03	0.64
J-23 Wepo Wells	59	1	0.01	0.01	0.01	----
N-6 Wepo Wells	61	4	0.01	0.01	0.01	0
Iron						
Refuse (SPLP)	23	23	0.05	2.7	0.5	0.5
Site-Wide Wepo Wells	656	492	0.01	15	1.0	2.0
J-23 Wepo Wells	59	47	0.02	2.1	0.5	0.6
N-6 Wepo Wells	62	45	0.01	4.5	1.0	1.4
Lead						
Refuse (SPLP)	23	2	0.005	0.005	0.005	0.000
Site-Wide Wepo Wells	648	23	0.020	0.100	0.041	0.023
J-23 Wepo Wells	59	1	0.020	0.020	0.020	----
N-6 Wepo Wells	61	4	0.02	0.08	0.058	0.026
Magnesium						
Refuse (SPLP)	23	3	0.4	0.5	0.467	0.058
Site-Wide Wepo Wells	650	607	0.39	773	61.291	92.636
J-23 Wepo Wells	59	59	2	206	44.9	58.0
N-6 Wepo Wells	61	55	0.7	82	37.5	28.6
Manganese						
Refuse (SPLP)	23	4	0.005	0.019	0.009	0.007
Site-Wide Wepo Wells	648	605	0.005	2.88	0.153	0.230
J-23 Wepo Wells	59	48	0.007	0.110	0.054	0.032
N-6 Wepo Wells	61	52	0.005	0.700	0.151	0.213
Mercury						
Refuse (SPLP)	23	23	0.0005	0.0012	0.0009	0.0002
Site-Wide Wepo Wells	648	12	0.0001	0.0007	0.0003	0.0002
J-23 Wepo Wells	59	0	----	----	----	----
N-6 Wepo Wells	61	2	0.0003	0.0003	0.0003	0
Potassium						
Refuse (SPLP)	23	18	0.5	1.7	0.861	0.307
Site-Wide Wepo Wells	649	649	1	36	6.967	5.022
J-23 Wepo Wells	59	59	4.5	23	8.5	3.9
N-6 Wepo Wells	61	61	1	19	7.5	5.4

Table 4.3 (cont.): Comparison of Summary Statistics for Refuse Samples (SPLP-Metals) and Groundwater Samples Collected from the Site-Wide Well Network, J-23 Area, and N-6 Area

Analyte	Number of Samples		Concentrations > Detection Limit			
	Total	Concentration > Detection Limit	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Std Dev (mg/L)
Selenium						
Refuse (SPLP)	23	23	0.001	0.011	0.006	0.002
Site-Wide Wepo Wells	648	67	0.001	0.560	0.038	0.098
J-23 Wepo Wells	59	17	0.001	0.003	0.002	0.712
N-6 Wepo Wells	61	3	0.001	0.002	0.002	0.001
Silver						
Refuse (SPLP)	23	2	0.01	0.01	0.010	0.000
Site-Wide Wepo Wells	387	6	0.01	0.02	0.013	0.005
J-23 Wepo Wells	34	0	----	----	----	----
N-6 Wepo Wells	44	1	0.010	0.010	0.010	----
Sodium						
Refuse (SPLP)	23	23	0.5	63.7	25.661	15.163
Site-Wide Wepo Wells	656	656	15	1570	491.930	365.832
J-23 Wepo Wells	59	59	416	1180	694	175
N-6 Wepo Wells	62	62	41	1436	607	496
Vanadium						
Refuse (SPLP)	23	18	0.020	0.090	0.048	0.022
Site-Wide Wepo Wells	648	30	0.005	0.020	0.010	0.003
J-23 Wepo Wells	59	5	0.005	0.020	0.010	0.006
N-6 Wepo Wells	61	5	0.010	0.010	0.010	0
Zinc						
Refuse (SPLP)	23	6	0.05	0.41	0.135	0.141
Site-Wide Wepo Wells	641	200	0.005	1.23	0.039	0.106
J-23 Wepo Wells	59	17	0.01	0.25	0.03	0.06
N-6 Wepo Wells	61	16	0.01	0.20	0.04	0.05

Table 4.4: Comparison of Summary Statistics for Inorganic Concentrations in Refuse Samples (SPLP and Paste Extraction) and Groundwater Samples Collected from the Site-Wide Well Network, J-23 Area, andN-6 Area.A3

Analyte	Number of Samples		Concentrations > Detection Limit			
	Total	Concentration > Detection Limit	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Std Dev (mg/L)
Alkalinity as $CaCO_3$ (mg/L)						
Refuse (SPLP)	23	17	10	52	30	12
Site-Wide Wepo Wells	650	650	146	2240	687	481
J-23 Wepo Wells	59	59	326	1670	1110	302
N-6 Wepo Wells	61	61	224	838	567	159
Bicarbonate as $CaCO_3$ (mg/L)						
Refuse (SPLP)	23	17	10	46	28	11
Site-Wide Wepo Wells	421	421	146	2629	742	522
J-23 Wepo Wells	38	38	740	1869	1226	313
N-6 Wepo Wells	39	39	366	893	640	169
Carbonate as $CaCO_3$ (mg/L)						
Refuse (SPLP)	23	0	—	—	—	—
Site-Wide Wepo Wells	421	174	0	210	10	21
J-23 Wepo Wells	38	15	0.0	50	10	17
N-6 Wepo Wells	39	26	0.0	29	9.3	11
Hydroxide as $CaCO_3$ (mg/L)						
Refuse (SPLP)	23	0	—	—	—	—
Site-Wide Wepo Wells	263	0	—	—	—	—
J-23 Wepo Wells	25	0	—	—	—	—
N-6 Wepo Wells	19	0	—	—	—	—
Chloride (mg/L)						
Refuse (SPLP)	23	0	—	—	—	—
Refuse (Paste Extraction)	6	6	12	22	18	4
Site-Wide Wepo Wells	650	650	3	388	27	29
J-23 Wepo Wells	59	59	6	108	25	20
N-6 Wepo Wells	61	61	9	54	27	15
Conductivity (ums/cm^2)						
Refuse (SPLP)	23	23	38.4	384	158	88
Site-Wide Wepo Wells	1609	1605	435	7560	2368	1469
J-23 Wepo Wells	132	132	1736	5844	3052	1224
N-6 Wepo Wells	153	152	917	6420	2600	1806
Fluoride (mg/L)						
Refuse (SPLP)	23	23	0.4	1.4	0.8	0.3
Site-Wide Wepo Wells	654	647	0.1	23	3.0	3.3
J-23 Wepo Wells	59	59	0.7	15	4.2	4.3
N-6 Wepo Wells	62	62	0.7	12	4.2	3.7

Table 4.4 (cont.): Comparison of Summary Statistics for Inorganic Concentrations in Refuse Samples (SPLP and Paste Extraction) andGroundwater Samples Collected from the Site-Wide Well Network, J-23 Area, andN-6 Area

Analyte	Number of Samples		Concentrations > Detection Limit			
	Total	Concentration > Detection Limit	Min (mg/L)	Max (mg/L)	Mean (mg/L)	Std Dev (mg/L)
Nitrate as N (mg/L)						
Refuse (Paste Extraction)	6	6	0.02	0.69	0.43	0.31
Site-Wide Wepo Wells	648	330	0.01	293	4.09	25.9
J-23 Wepo Wells	59	43	0	1.65	0.43	0.52
N-6 Wepo Wells	61	28	0.02	0.39	0.08	0.08
Nitrate-Nitrite as N (mg/L)						
Refuse (Paste Extraction)	6	6	0.06	0.74	0.42	0.31
Site-Wide Wepo Wells	490	254	0.02	270	3.37	22.4
J-23 Wepo Wells	46	36	0.02	2.3	0.53	0.60
N-6 Wepo Wells	41	18	0.02	0.19	0.07	0.05
Nitrite as N (mg/L)						
Refuse (Paste Extraction)	6	6	0.02	0.11	0.06	0.04
Site-Wide Wepo Wells	648	118	0.01	2.95	0.17	0.40
J-23 Wepo Wells	59	10	0.01	2.28	0.39	0.73
N-6 Wepo Wells	61	15	0.01	1.23	0.20	0.33
pH (s.u.)						
Refuse (SPLP)	23	23	5.3	10.1	8.6	1.0
Site-Wide Wepo Wells	648	648	4.5	8.8	7.9	0.5
J-23 Wepo Wells	59	59	4.5	8.4	7.7	0.6
N-6 Wepo Wells	61	61	6.5	8.7	8.0	0.6
Sulfate (mg/L)						
Refuse (Paste Extraction)	6	6	30	2100	1071	897
Site-Wide Wepo Wells	656	615	2	4760	853	916
J-23 Wepo Wells	59	50	8	3050	914	1026
N-6 Wepo Wells	62	62	12	2676	1069	1032
TDS (mg/L)						
Refuse (SPLP)	23	17	15	215	61	48
Site-Wide Wepo Wells	1248	1248	320	8010	1833	1355
J-23 Wepo Wells	98	98	1118	5038	2310	1223
N-6 Wepo Wells	123	123	590	4400	1846	1471
Total Phosphate (mg/L)						
Refuse (Paste Extraction)	6	6	24.7	52.8	42.4	10.7
Site-Wide Wepo Wells	NA	NA	NA	NA	NA	NA
J-23 Wepo Wells	NA	NA	NA	NA	NA	NA
N-6 Wepo Wells	NA	NA	NA	NA	NA	NA

Table 4.5: Solute Concentration Mixing Calculations

Solute	Cp[1] (mg/L)	Cr (mg/L)	Qp x Cp (ft3/day * mg/L)	Qr x Cr (ft3/day * mg/L)	(Qp x Cp) + (Qr x Cr) (ft3/day * mg/L)	Ct (mg/L)
Aluminum	0.120	2.600	84.665	12.376	97.041	0.137
Arsenic	0.002	0.005	1.411	0.024	1.435	0.002
Barium	0.105	0.427	74.082	2.033	76.114	0.107
Mercury	0.0003	0.0009	0.2117	0.0043	0.2159	0.0003
Nitrate	0.080	0.430	56.443	2.047	58.490	0.082
Nitrate/Nitr	0.070	0.420	49.388	1.999	51.387	0.072
Selenium	0.002	0.006	1.411	0.029	1.440	0.002
Vanadium	0.010	0.048	7.055	0.228	7.284	0.010
Zinc	0.040	0.135	28.222	0.643	28.864	0.041

[1] Concentration of pit inflow solute taken from Tables 4.3 and 4.4 and corresponds to the mean concentration for site-wide or local-area N-6 wells, which ever is lower for the specified analyte.

Where:

Qp = pit inflow rate	Cp = concentration of pit inflow solute
Qr = refuse inflow rate	Cr = concentration of refuse solute

(Qp x Cp) + (Qr x Cr) = Qt x Ct

Qp =	705.54 ft^3/day	Wepo water pit inflow
Qr =	4.76 ft^3/day	Refuse water inflow
Qt =	710.30 ft^3/day	Total combined flow

APPENDIX A

Corehole and Well Borehole Summaries

J-7 Coal Resource Area

Borehole Data

- Wepo Well 47R, the replacement well for abandoned Wells 47 and 48, is collared at 6277.7 ft, has a TD of 302 ft, and is located approximately 1,000 ft west of the abandoned wells. During drilling (April 1, 1998) groundwater was noted at 56 ft and 160 to 165 ft. The well is perforated at depths of 52 to 62 ft, 82 to 112 ft, and 122 to 220 ft. Bentonite seals are at depths of 5 to 14 ft, 14 to 29 ft, 29 to 50 ft, 114 to 120 ft. and 272 to 302 ft. Well 47R has an average depth to water level of 31.5 ft. Assuming that alluvium is also approximately 20 ft thick in this area (Yucca Flat Wash), Wepo groundwater is currently not discharging to the alluvial aquifer in this area.

- Wepo Fm wells 47 and 48 (since been replaced by 47R), were located in Yucca Flat Wash, the main surface drainage south of the J-7 Pit. Well water levels may be influenced by surface flow and recharge from alluvium in Yucca Flat Wash.

- Borehole 47 lithology log shows 20 ft of alluvium (sand and gravel) "damp" gray shale from 24 to 31 ft, "wet" coal at 36.8 to 38.3 ft, "wet" gray shale at 38.3 to 43.5, "wet" dark shale at 54.4 t o 56.4, then interbedded gray shale with coal then interbedded sandstone and shale to 220 ft; last coal is 261.9 to 271.9. TD was 323 ft; well constructed to 220 ft. Perforations at 35-73', 83-108', 117-147', 172-220'. No discussion of fractures.

- Borehole 48 lithology log shows 20 ft of alluvium (sand and gravel), "damp" gray shale from 24 to 31.8 ft, "wet" coal at 36.8 to 38.3 ft, "wet" gray shale at 38.3 to 43.5, "wet" dark shale at 54.4 t o 56.4, then interbedded gray shale with coal then interbedded sandstone and shale to 220 ft; last coal is 261.9 to 271.9. TD was 323 ft; well constructed to 220 ft. Perforations. At 40-75', 85-120', 125-145', 172-220'. No discussion of fractures

Corehole Data

- Corehole 15418C: Collared at 6538.1 ft. TD is 248 ft. Corehole description shows interbedded shale and C sandstone with coal beds ranging from less than 1 ft to over 7 ft thick. No reports of lost circulation, fractured areas, or lost core.
- Corehole 23154C: Collared at 6463.6 ft. TD is 200 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 17 ft thick. Burnt zones at 20.2 to 24.2, 40.1 to 50.1, fractured at 50.1 to 57.4, cavity, lost core, loose and fractured 57.4 to 76.0, other lost core zones at 109.3 to 110.2, 169.3 to 170.0, 176.4 to 177, damp shale at 90-100,170 to176.4. No reports of lost circulation.
- Corehole 23156C: Collared at 6467.1. TD is 200 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 21.3 ft (RXX). Burnt shale zones, lost core, lost circulation at 2 to 30 ft, 36 to 42 ft, burnt, loose, lost core and fractured 42 to 44.7 ft, damp shale at 44.7 to 49.7 ft, lost core and

loose at and more burnt 49.7 to 66.4 ft, burnt 71.4 to 83 ft, damp shale at 159.4 to 163.5 ft, 173 to 180.6, 191 to 197.8 ft. Also, had lost core at 158.7, 163.5, 172, and 180.1.

N-6 Coal Resource Area

- The corehole data in the N-6 region indicate multiple wet zones and zones of lost circulation. The coreholes in proximity to the final pit footprint are 24099C, 24400C, and 24401C. The corehole logs for these boreholes indicate several wet intervals at elevations between 6,545 and 6,595. These wet zones do not correlate with the mapped potentiometric surface; they are at elevations greater than the potentiometric surface, but within the exposed pit elevation interval.

Geology

In the N-6 area, corehole logs 24099C, 24400C, and 24401C, which lie on a north-trending transect near the final pit footprint, indicate wet and damp conditions in the upper portions of the borehole. Wet conditions are more prevalent in corehole 24099C, which was located near the southern end of the final pit footprint.

- Corehole 21104C: Collared at 6726.0. TD is 245 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 12.9 ft (RXX at 120.3 ft bgs). Lost circulation at 10.0 to 10.4, 19.9 to 20, 21 to 22, 25 to 26, 30.2 to 31, 41.3 to 41.7, and 82.1 to 82.6. No lost circulation below 82.6 (may imply more dense, competent rock below this depth). Wet shale zones at 19.3 to 19.9, 20.0 to 20.4.

- Corehole 23160C: Collared at 6807.2. TD is 220 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 10.7 ft (RXX at 127.5 ft bgs). Lost circulation at 20.5 to 20.7, 23.4 to 23.8, 33.4 to 33.7, 55.8 to 56, 57.4 to 58, 86.1 to 86.8, 92.3 to 92.7, and 102. 9 to 103.5, 153.8 to 154, 163.8 to 164, and 203.8 to 204. Wet shale zones at 18.5 to 23.8 (with lost circ.), 55.5 to 57.4 (with lost circ.); wet coal and shale at 82.6 to 86.8 (with lost circ.), wet shale at 102.9 to 103.5 (with lost circ.),

- Corehole 23161C: Collared at 6729.5. TD is 200 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 11.3 ft (RXX at 117.3 ft bgs). Lost circulation at 31.2 to 31.5, 39 to 39.3, 145.2 to 146, 146 to 146 (loose), and 148 to 149 (and fractured). Wet shale zones at 30.8 to 31.5 (lost circ.), 32.7 to 33.3, 38.6 to 39, 80.7 to 98.4 (sand/shale), sandstone 146 to 148 (loose); damp sandstone 149 to 150.9 (fractured), damp sandstone or shale 154 to 163 (lost core), damp shale 163 to 166.2. Lost core 162.5 to 163, 189.7 to 190.

- Corehole 23162C: Collared at 6646.8. TD 200 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 11.3 ft (RXX at 81.4 ft bgs). Lost circulation at 22.9 to 23.1, 39 to 40, 49.4 to 50.2, 96.9 to 97.3, and 185.9 to 186.3. Wet shale and sandstone zones at 12 to 23.1, 39 to 42.

- Corehole 23163C: Collared at 6637.9. TD 180 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 12.3 ft (RXX at 99.7 ft bgs). Lost circulation is not reported. Lost core at 25 to 25.2, 51.7 to 52.3, 58.7 to 59.9, and 81.9 to 83.1. No reports of wet conditions.

- Corehole 23164C: Collared at 6607.2. TD 200 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 12.8 ft (RXX at 102.7 ft bgs). Lost circulation is not reported. Lost core at 22.2 to 23.2, 84.1 to 84.6. Damp shale and coal at 12.8 to 23.2, shale at 55.1 to 64.9. Wet shale and coal at 193.9 to 197.7.

- Corehole 23165C: Collared at 6664.7. TD 200 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 11.1 ft (RXX at 114.3 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 37.1 to 38, 39.6 to 40, and 199.8 to 200. Damp shale at 34.8 to 47.2, 171.9 to 182.4. No wet intervals reported.

- Corehole 23166C: Collared at 6798.6. TD 260 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 7.3 ft (BXX at 110.2 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 30 to 31, 34 to 34.5, 53.1 to 53.7, 71.3 to 71.8, 72.6 to 73.6, and 91.1 to 91.5. Damp shale or sandstone at 12 to 30, 72.6 to 73.6, 131.5, 164. 8, 213.1 to 216.9, 218.6 to 231.6. No wet intervals reported.

- Corehole 24093C: Collared at 6727.8. TD 270 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 11.7 ft (RXX at 184.3 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 21.8 to 22, 48 to 49, 57.8 to 58, and 101.8 to 102. Damp clay at 0 to 4, shale at 16.7 to 18.3, 49 to 49.8, 52 to 57.8, sandstone at 141.2 to 156.6. No wet intervals reported.

- Corehole 24094C: Collared at 6582.9. TD 230 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 12.7 ft (RXX at 122.3 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 38.2 to 38.8, 40.8 to 41.5, 51.3 to 51.6, 88.7 to 89.6, 112.3 to 112.5, and 122 to 122.3. Damp shale at 38.2 to 47.5, sandstone at 61.7 to 81.8. No wet intervals reported.
- Corehole 24095C: Collared at 6686.2. TD 280 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 9.3 ft (BXX at 176 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 16.6 to 17, 21.7 to 22, 37.6 to38, 40 to 41, 45.6 to 46. Damp clay at 17 to 18.4, shale at 45.6 to 46, 154.4 to 154.8, 163.8 to 169.3, sandstone at 232.2 to 243.8. No wet intervals reported.

- Corehole 24096C: Collared at 6665.1. TD 290 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 11.6 ft (RXX at 200.5 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 41.7 to 42, 61 to 62, 142.8 to 143.1, 215.5 to 216.1, 226.4 to 226.9, 254 to 254.2, 263.9 to 264, and 273.9 to 274.2. Damp shale at 40.5 to 41.7, 52 to 53.4, 56 to 61, 62 to 72, sandstone at

82.2 to 92.7, shale at 94.7 to 95, wet shale at 95.6 to 96.7, damp shale at 107.2 to 115.5, damp coal, shale, sandstone, damp sandstone at 163.5 to 171.7, damp shale at 181.3 to 183.8, wet shale and coal at 183.8 to 212.1, damp shale at 212.1 to 212.8, 213.7 to 214, 226 to 226.4, wet shale at 228 to 228.9.

- Corehole 24097C: Collared at 6649.1. TD 260 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 12.7 ft (RXX at 178 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 19.8 to 20, 34.2 to 35, 44 to 45, 52.8 to 53.2, 70.7 to 71.3, 80.9 to 81.3, and 129.9 to 130.4. Damp shale at 12 to 14.2, 16.2 to 20, 30.1 to 34.2, 40.3 to 44, 45 to 46, 46.7 to 49.5, 60.6 to 62.8, 71.3 to 78.1 78.6 to 80.9, sandstone and coal at 82 to 92.3, shale at 101.4 to 111.7, wet shale at 124.7 to 129.2, damp shale at 158.7 to 162, wet sandstone at 213 to 217.3, damp shale at 218.7 to 233.1.

- Corehole 24098C: Collared at 6589.1. TD 220 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 11.1 ft (BXX at 107 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 16.6 to 17.6, 20.6 to 21.6, 30 to 31, 35 to 35.4, 50.7 to 51.7, 132.5 to 133.7, 136.5 to 137.2, 145.8 to 146, 160.1 to 160.6, 164.9 to 165.4, 173 to 173.6, and 215 to 220. Burnt sandstone at 13.6 to 14.6. Damp shale at 17.6 to 20.6, 21.6 to 24.4, 25.4 to 29, damp coal at 31 to 32, damp shale at 32 to 35.4, 47.5 to 51.7, damp sandstone at 82.4 to 107, damp shale at 134.4 to 141.4, wet coal and shale at 194.8to 198.5. No wet intervals reported.

- Corehole 24099C: Collared at 6668.7. TD 225 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 10.8 ft (BXX at 109.2 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 31.8 to 32, 68.4 to 69.4, 78.5 to 79.5, 124.6 to 125.4, 131.6 to 133.5, 153.3 to 153.5, 207.5 to 208, 214 to 214.7, and 224.6 to 225. Damp shale at 38.2 to 47.5, 62 to 66.2, 67 to 68.4, damp coal and shale at 71.4 to 78.5, damp shale at 79.5 to 81.2, wet shale at 81.2 to 93.5, damp sandstone at 93.5 to 109.2, wet shale at 120 to 121.6, damp sandstone at 121.6 to 125.4, damp shale at 133.5 to 136.5.

- Corehole 24400C: Collared at 6614.8. TD 200 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 10.9 ft (BXX at 61.7 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 15 to 15.3, 19.7 to 20, 22.3 to 22.6, 39.6 to 40, 105.9 to 107, 132.7 to 133, 148.4 to 148.7, and 198.2 to 200. Damp shale at 12 to 15, 19.7 to 20, wet shale at 20 to 22.3, damp shale at 22.6 to 30, 31.2 to 32.1.

- Corehole 24401C: Collared at 6564.7. TD 130 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 7.2 ft (RXX at 58.9 ft bgs). Lost circulation at 90.7 to 111.4. Lost core in portions of intervals at 18.5 to 19, 20.5 to 22, 28.6 to 29.6, 34 to 35.5, 39.4 to 50, and 128.1 to 130. Burnt shale at 23.2 to 28.6, 29.6 to 34, sandstone at 35.5 to 39.4. Cavity in shale at 39.4 to 50. Damp shale at 12 to 18.5, wet shale at 19 to 20.5, damp shale at 22 to 23.2, 70.3 to 74.9.

- Corehole 24402C: Collared at 6668.3. TD 200 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 7.9 ft (GBX at 61 ft bgs). Lost circulation is not reported. Lost core in portions of intervals at 95.8 to 96.3, 96.5 to 97, 112.7 to 113.3, 114 to 114.8, 184.1 to 185.1, and 195 to 200. Damp shale at 0 to 7.5, sandstone at 12 to 50.1, wet coal at 113.3 to 114, damp shale at 185.1 to 200.

J-23 Coal Resource Area

Geology

- Corehole 30365EO: Collared at 7016.194 ft. TD 220 ft. Corehole description shows interbeded shale and sandstone with coal beds ranging from less than 1 ft to 23.9 ft (BXX at 78 ft bgs). "LC" (assume "LC" means lost core) was reported in portions of intervals at 0 to 3.8, 7.3 to 13.4, 20 to 21.8, 41.5 to 42, 50 to 50.4, 74 to 74.2, 121.1 to 122. Damp and wet conditions not reported.

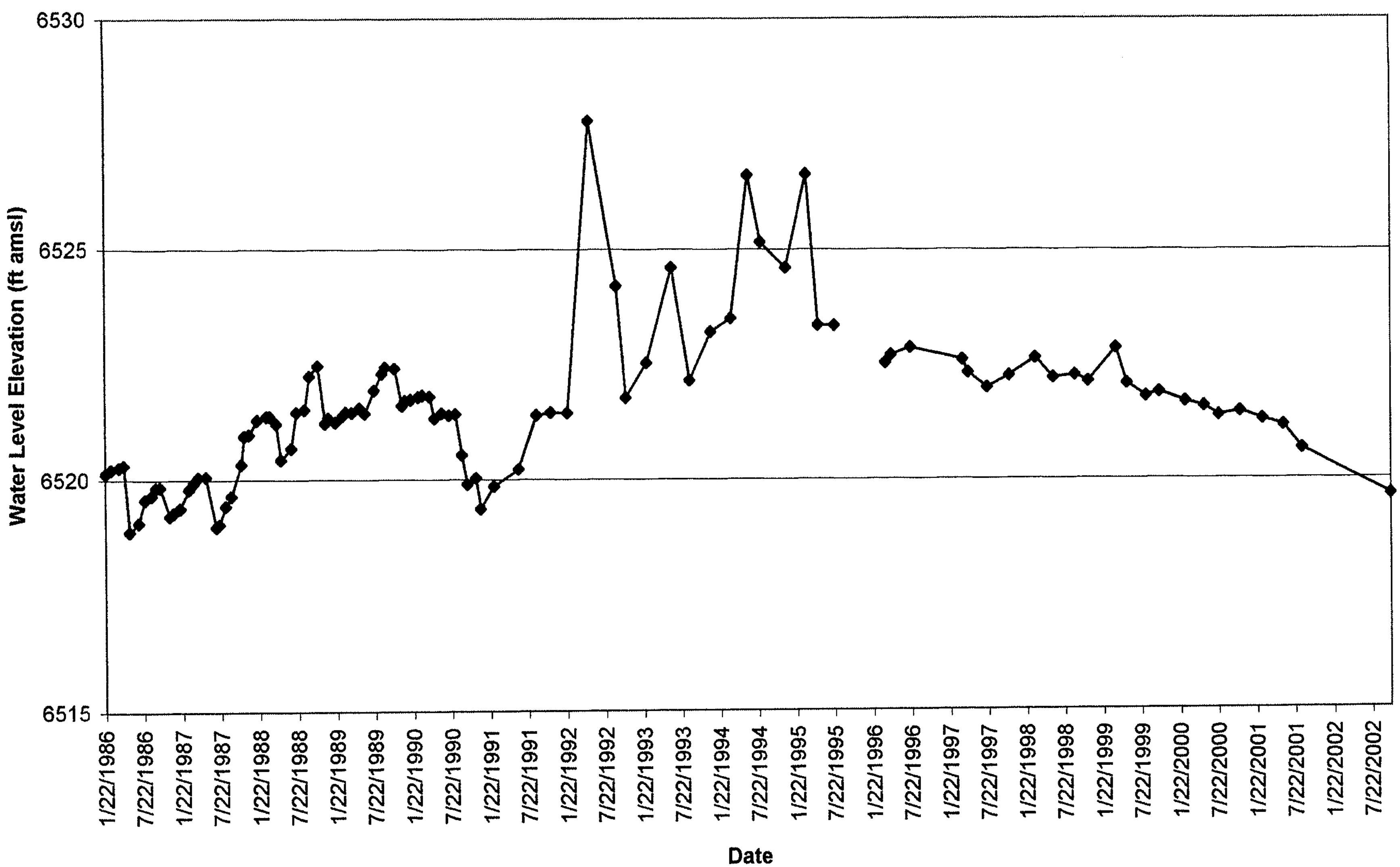
J-3 Reclaimed Coal Resource Area

The J-3 Mine Area is a reclaimed area that was originally mined in the 1970's and 1980's. No core hole or well bore hole data were immediately available.

APPENDIX B

Wepo Well Hydrographs

Wepo Well 40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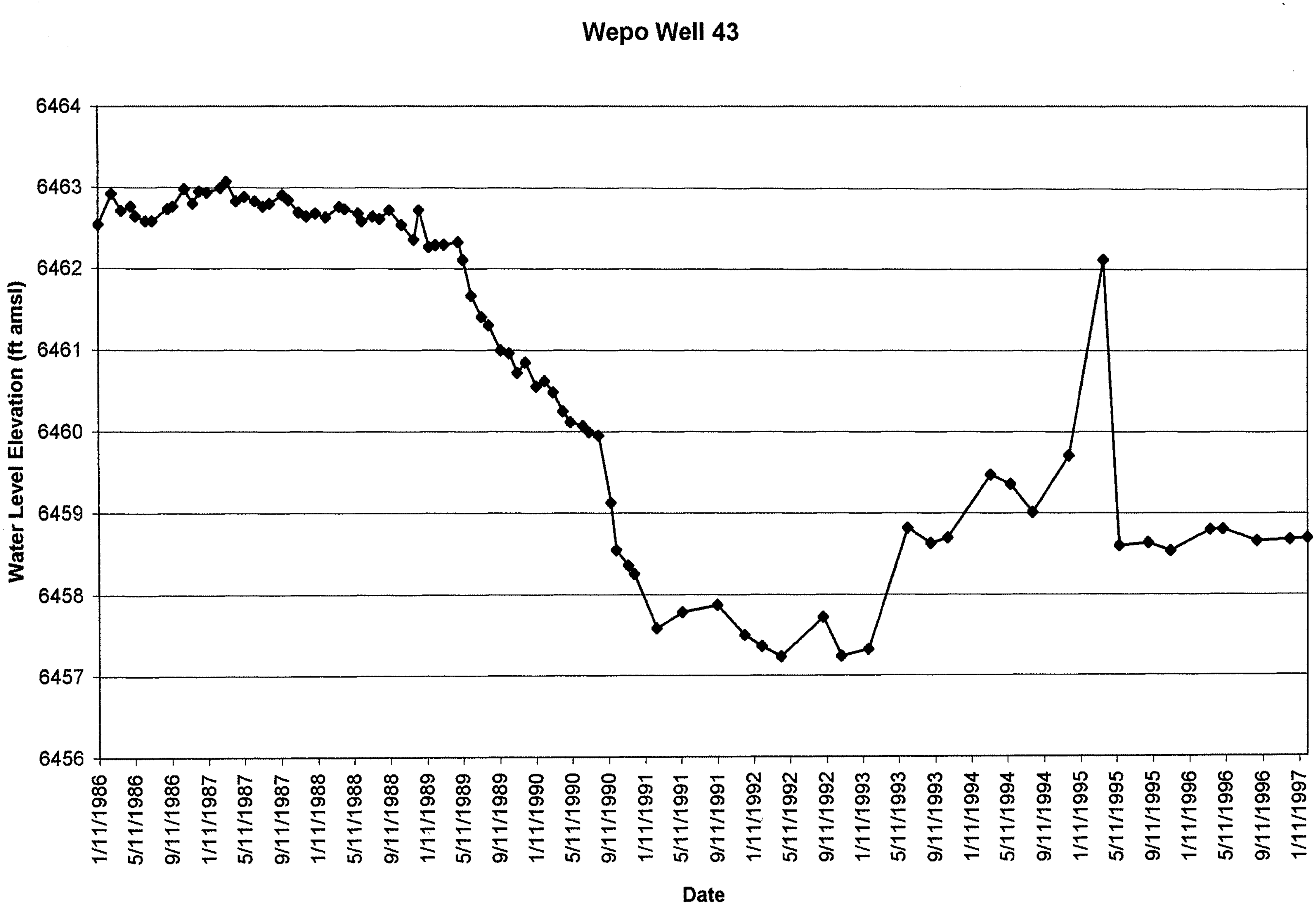
Date



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5/11/1994
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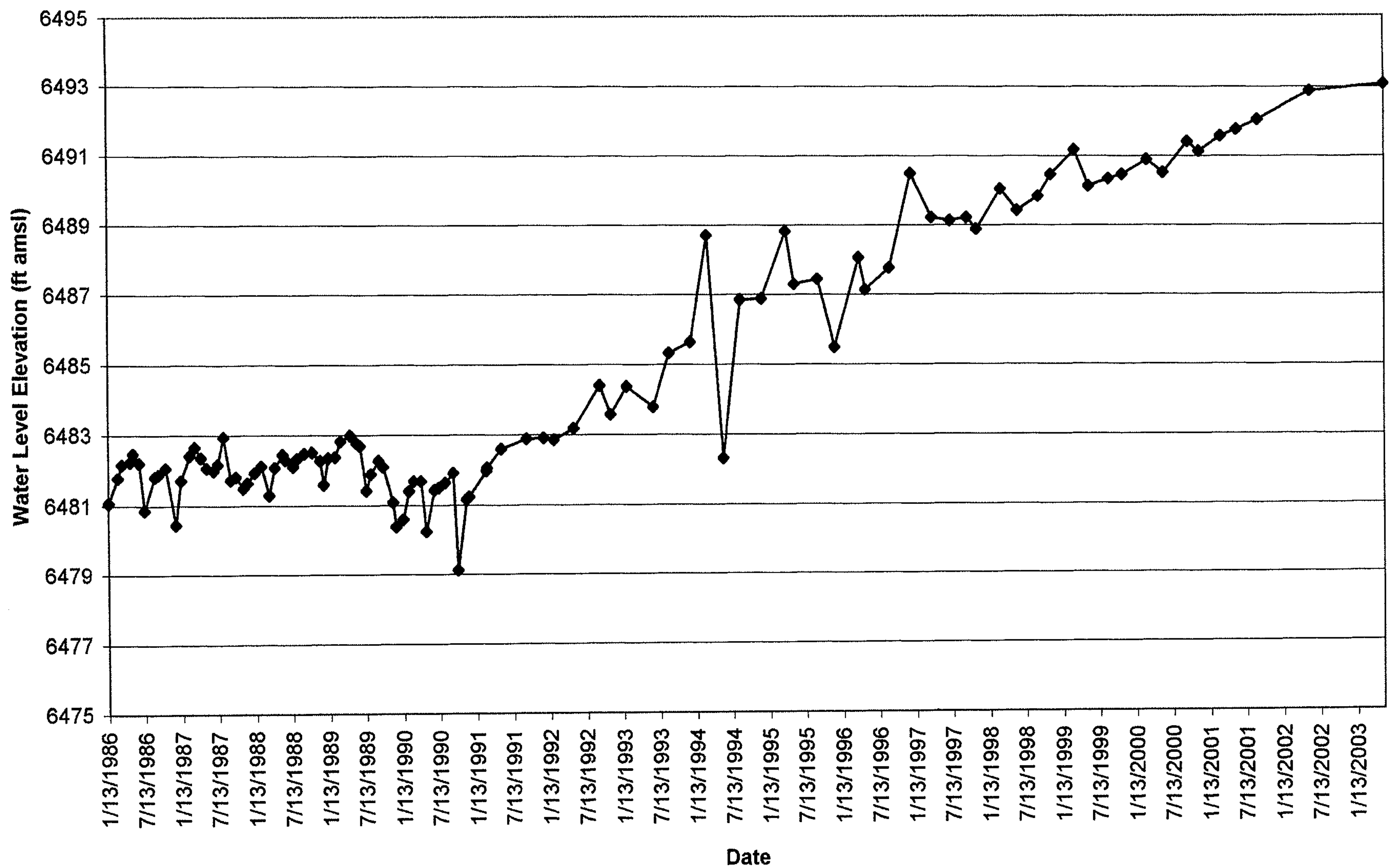
9/11/1996
1/11/1997
Date

Well 44



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Water Level Elevation (ft amsl)
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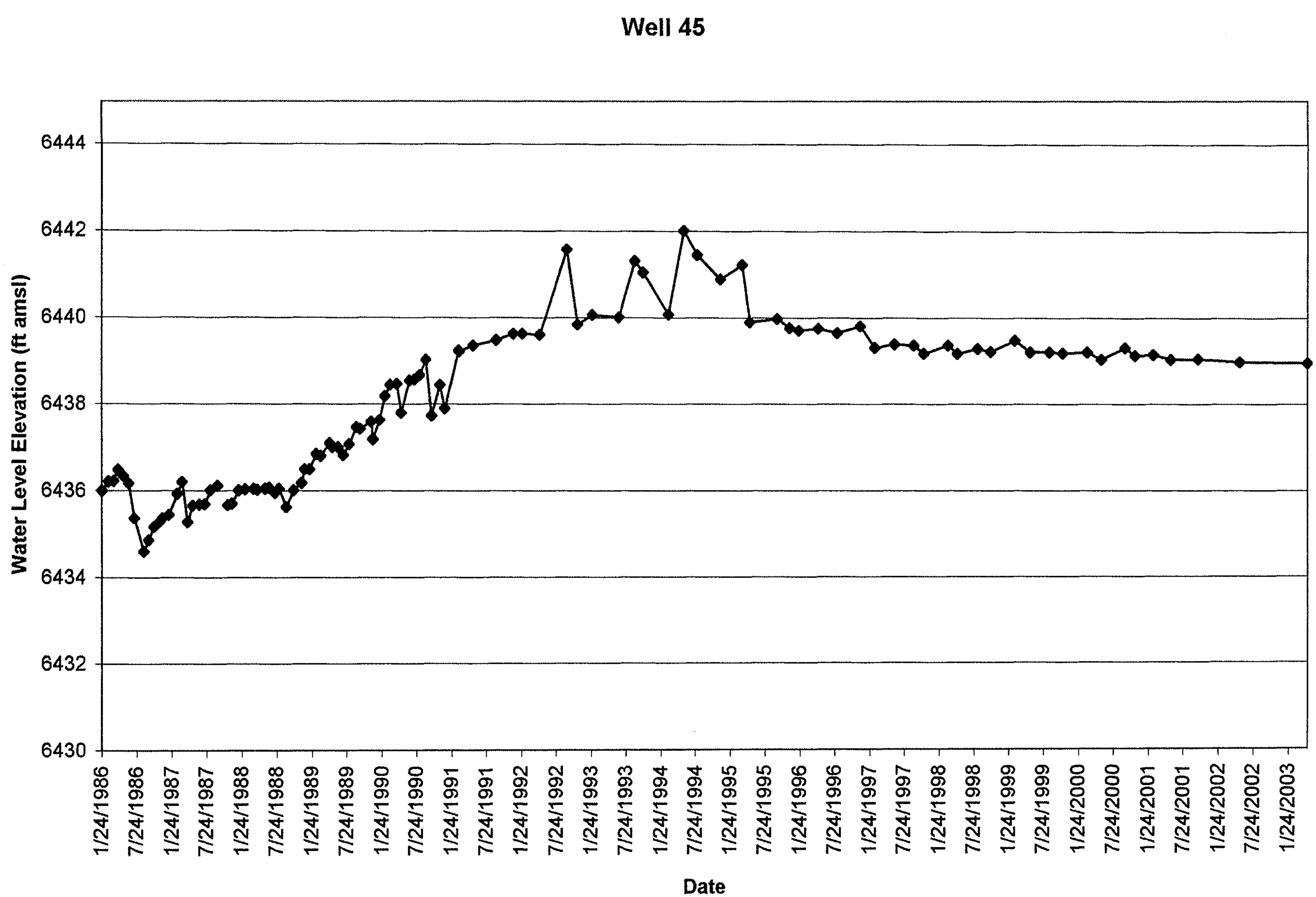
Date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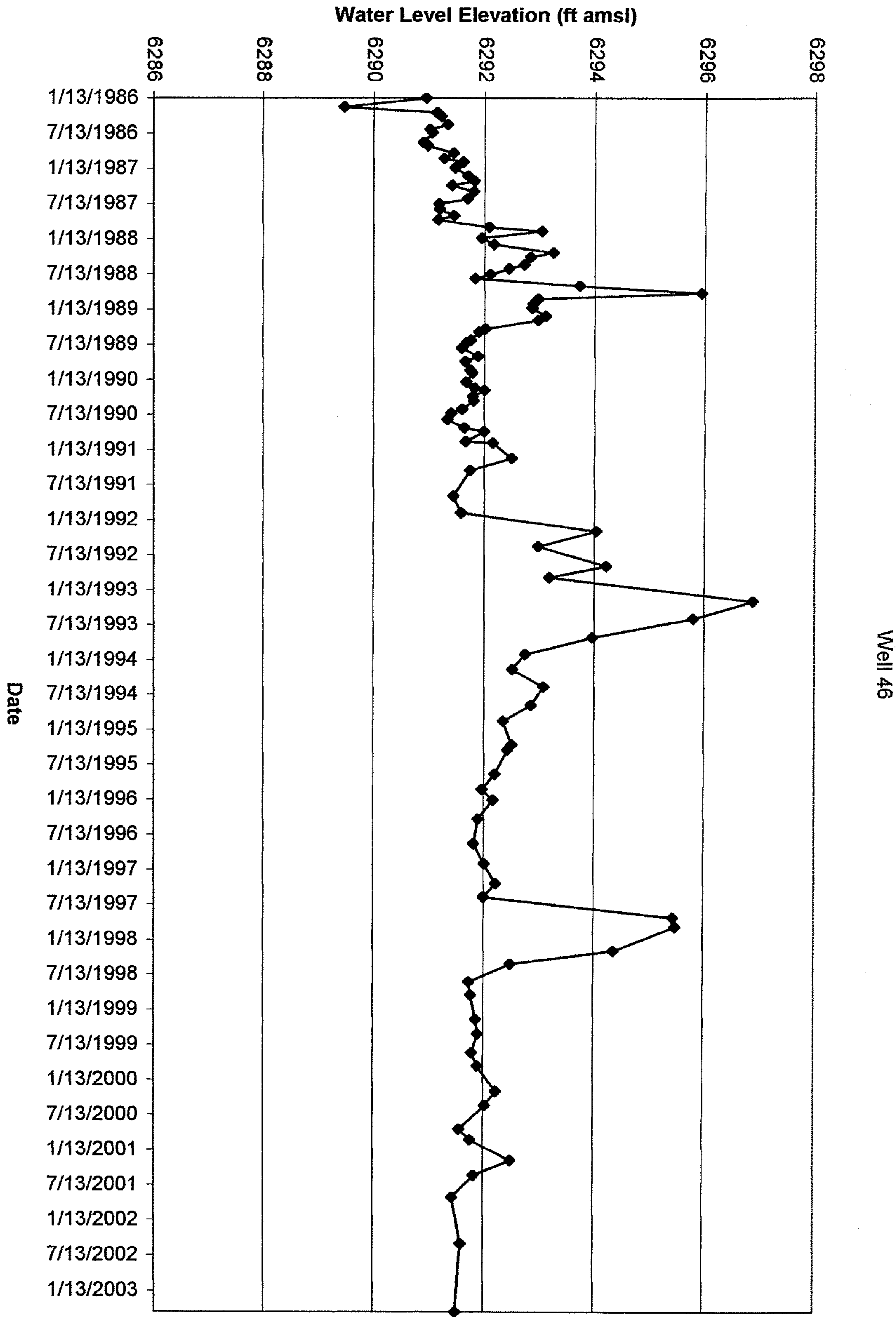
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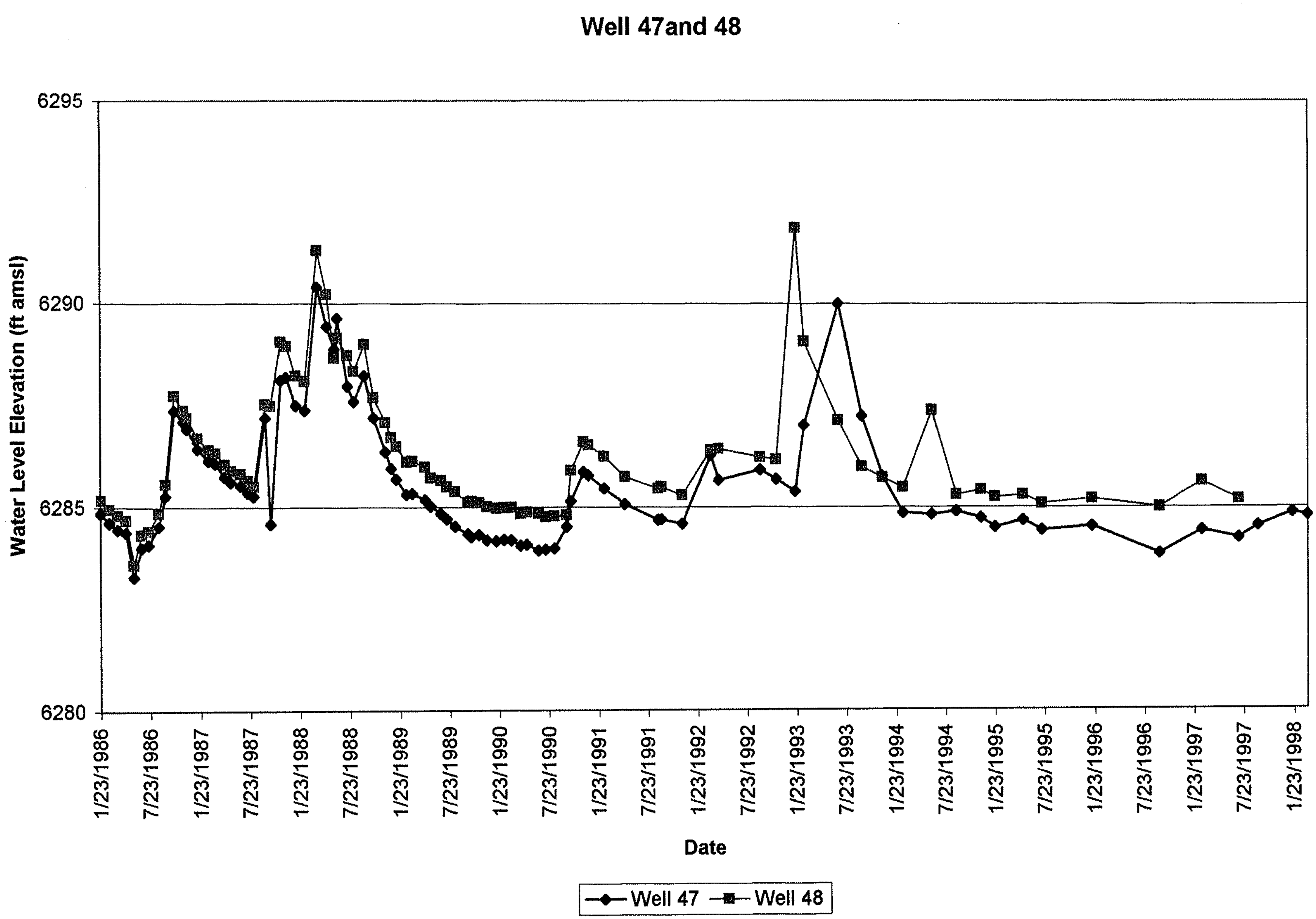

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Date
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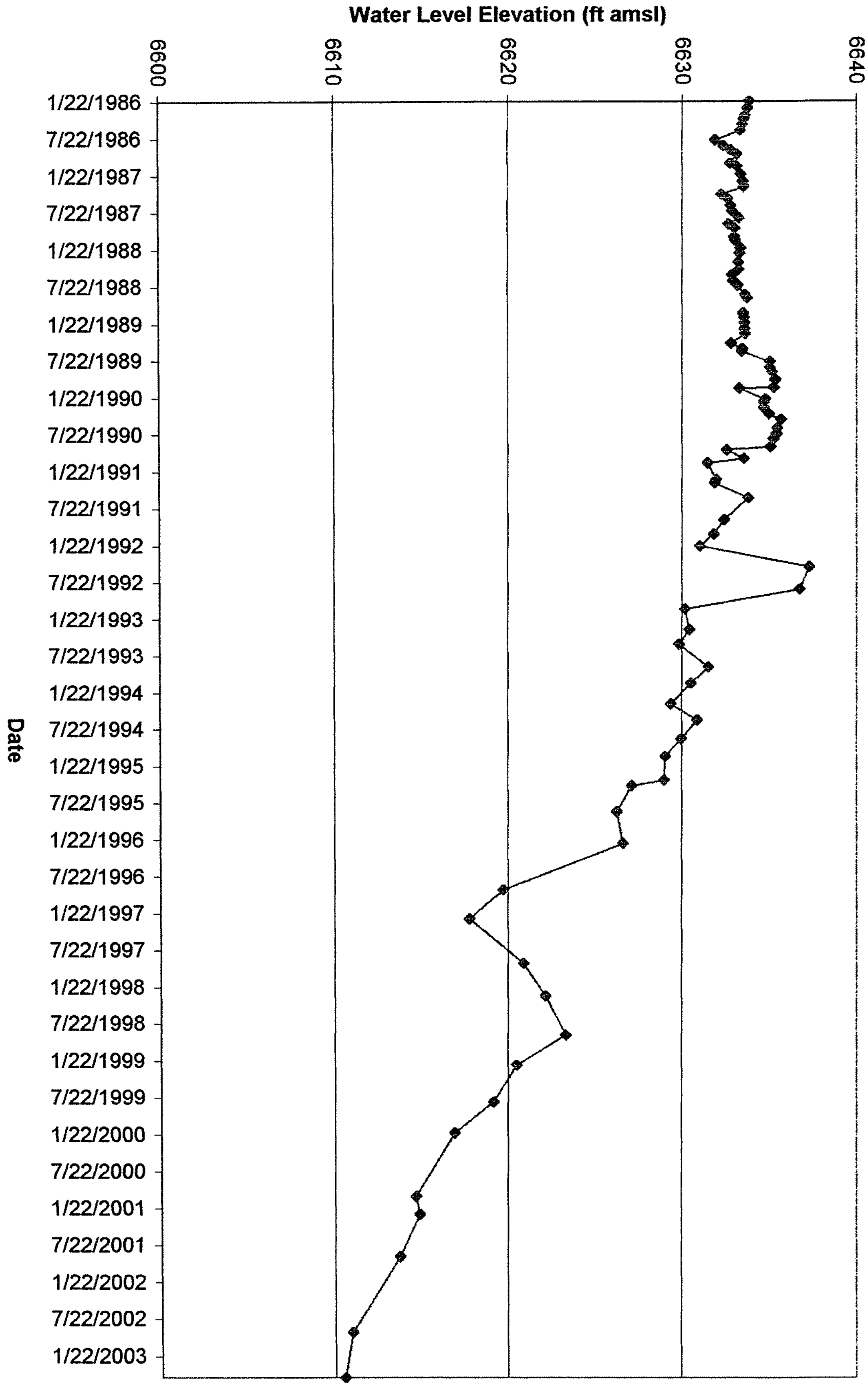
Well 48



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1/22/2003

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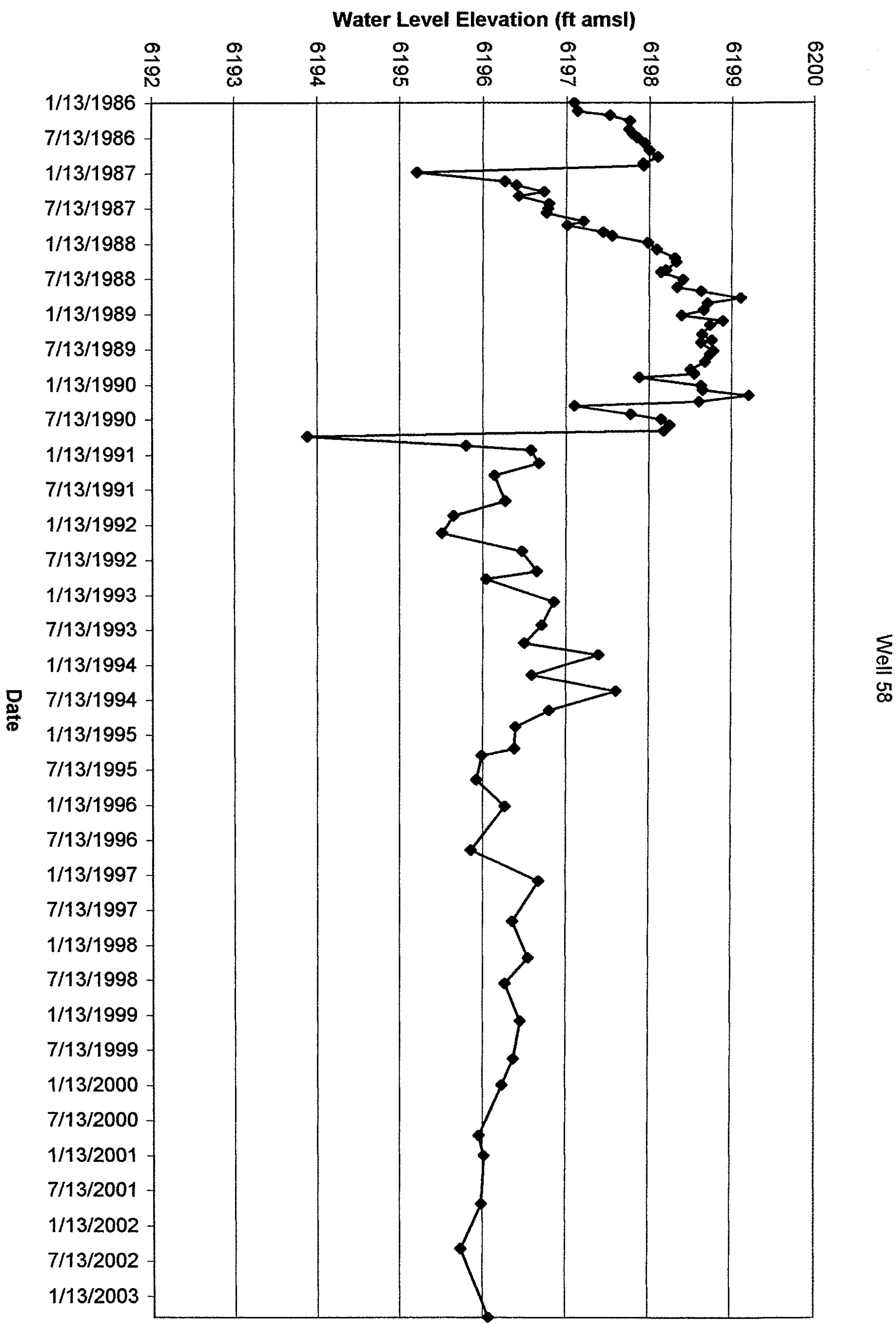
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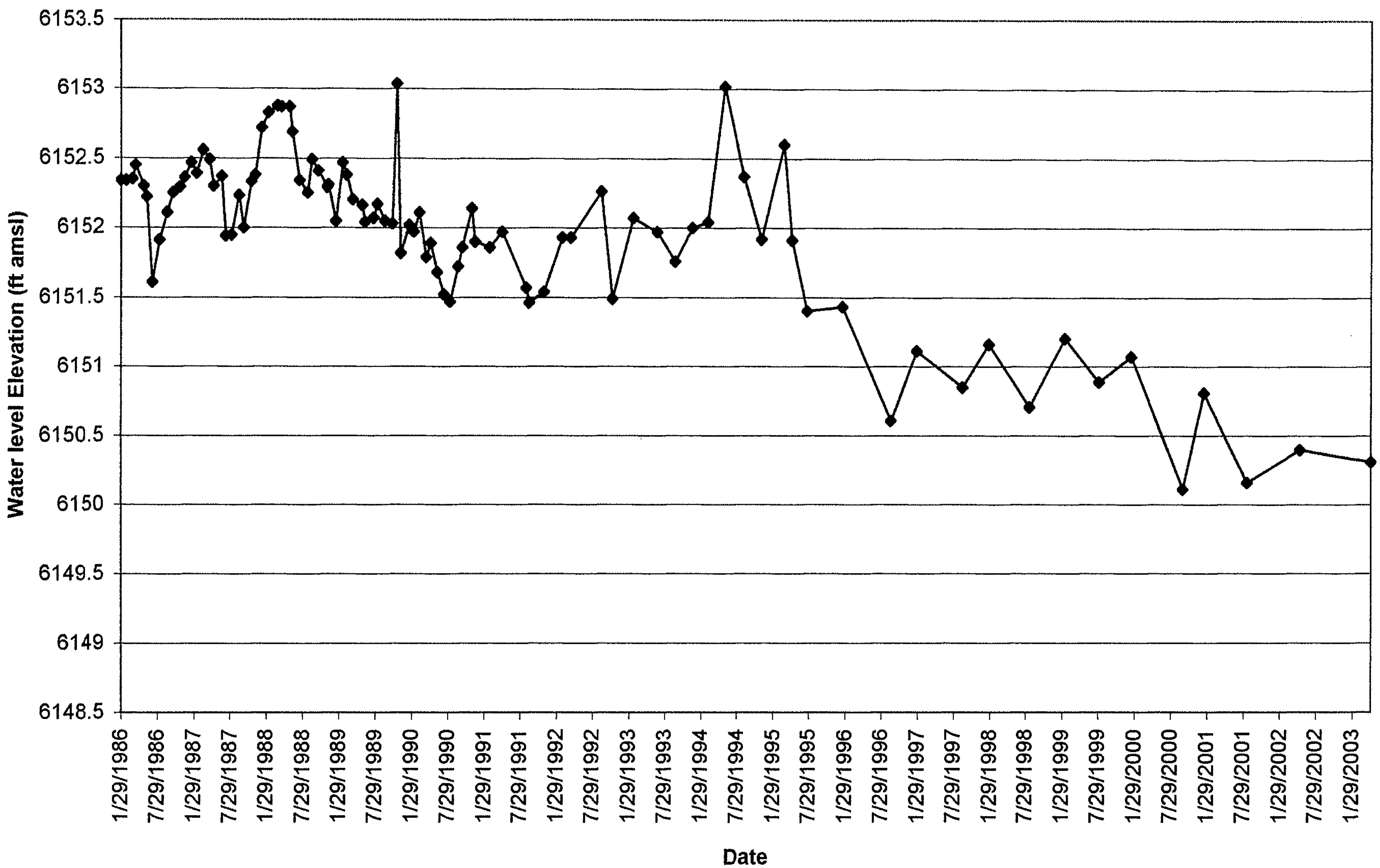
Well 59



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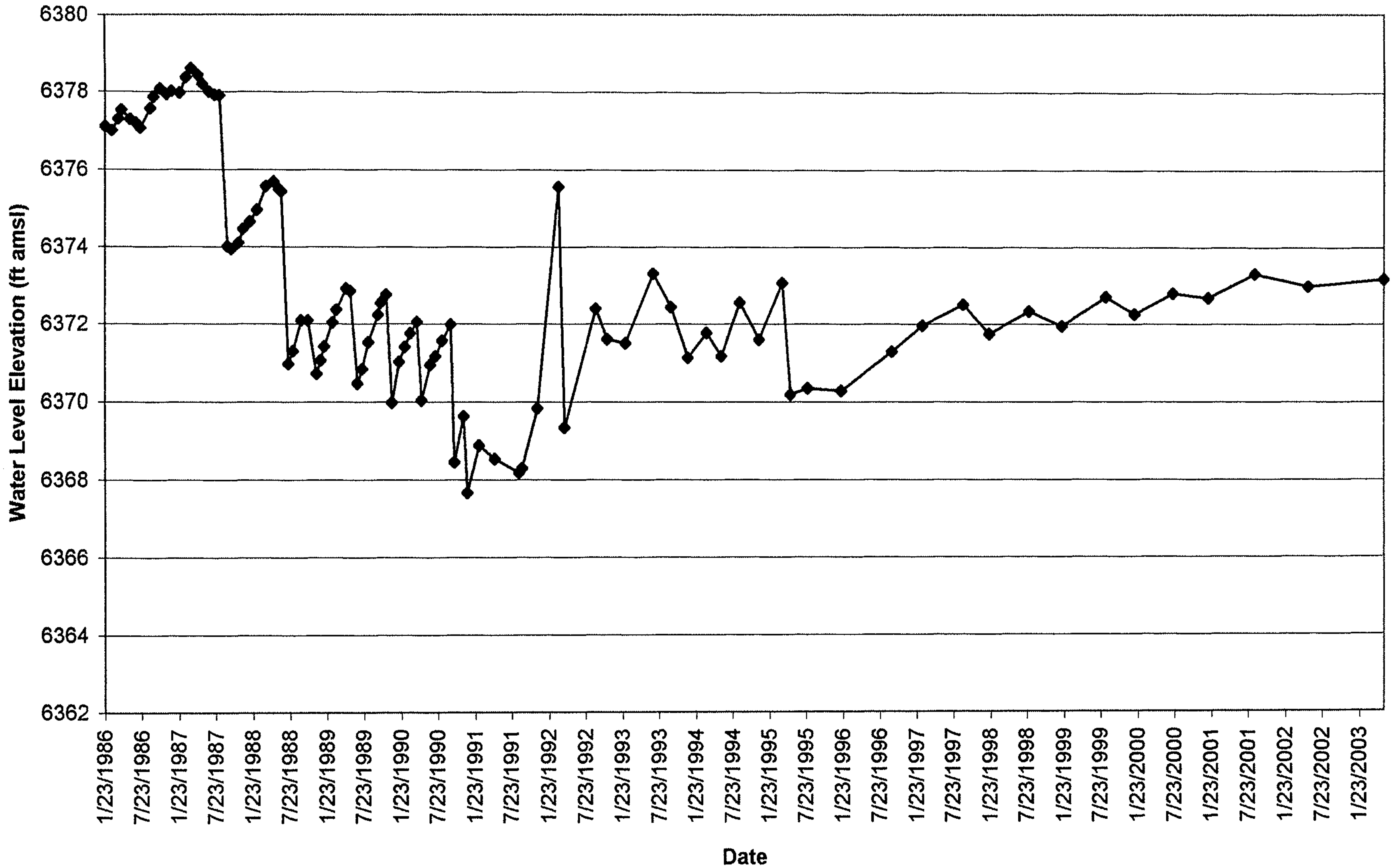

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6364
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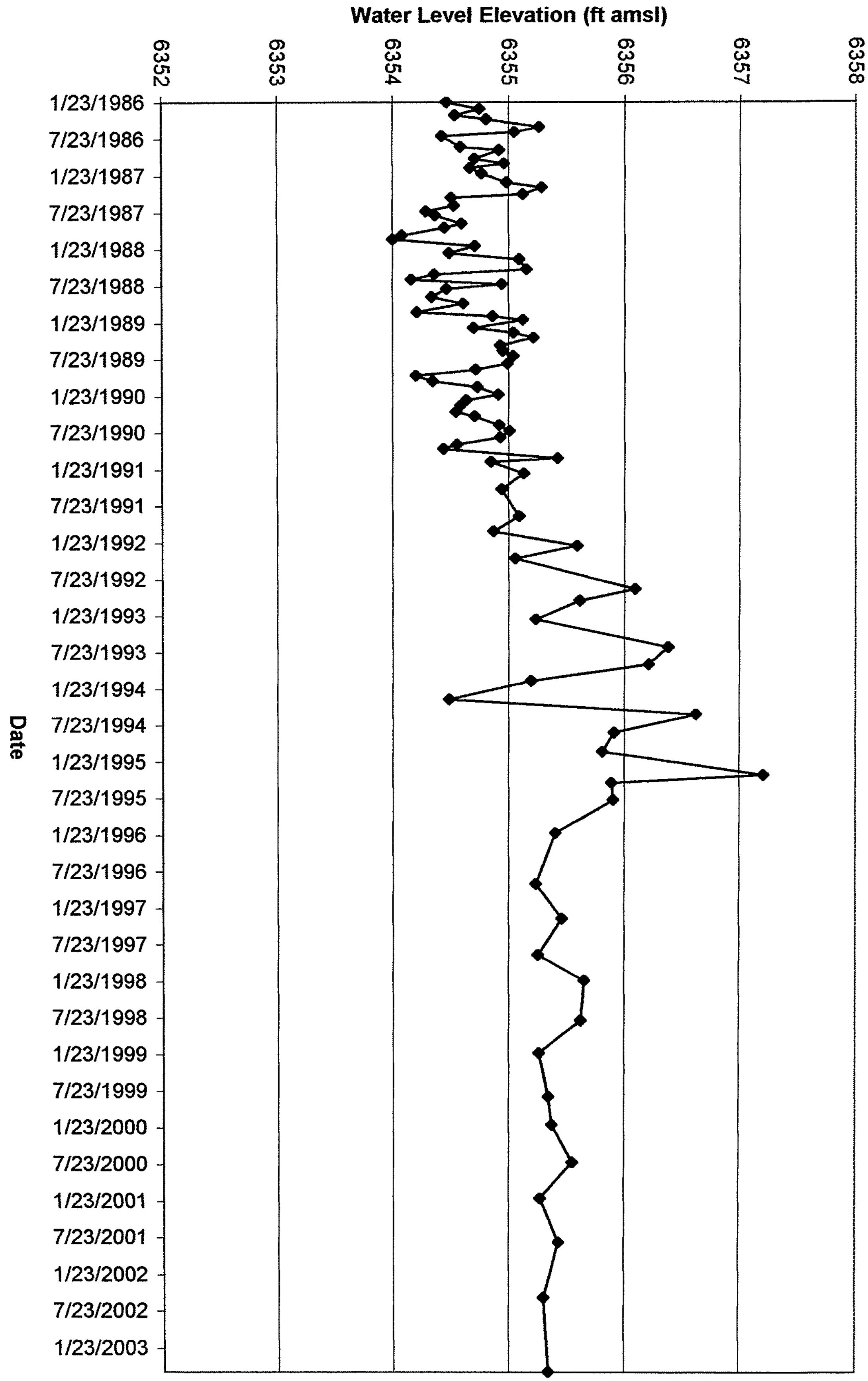
7/23/2002
1/23/2003
Date



Water Level Elevation (ft amsl)
6352
6353
6354
6355
6356
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6358
Date
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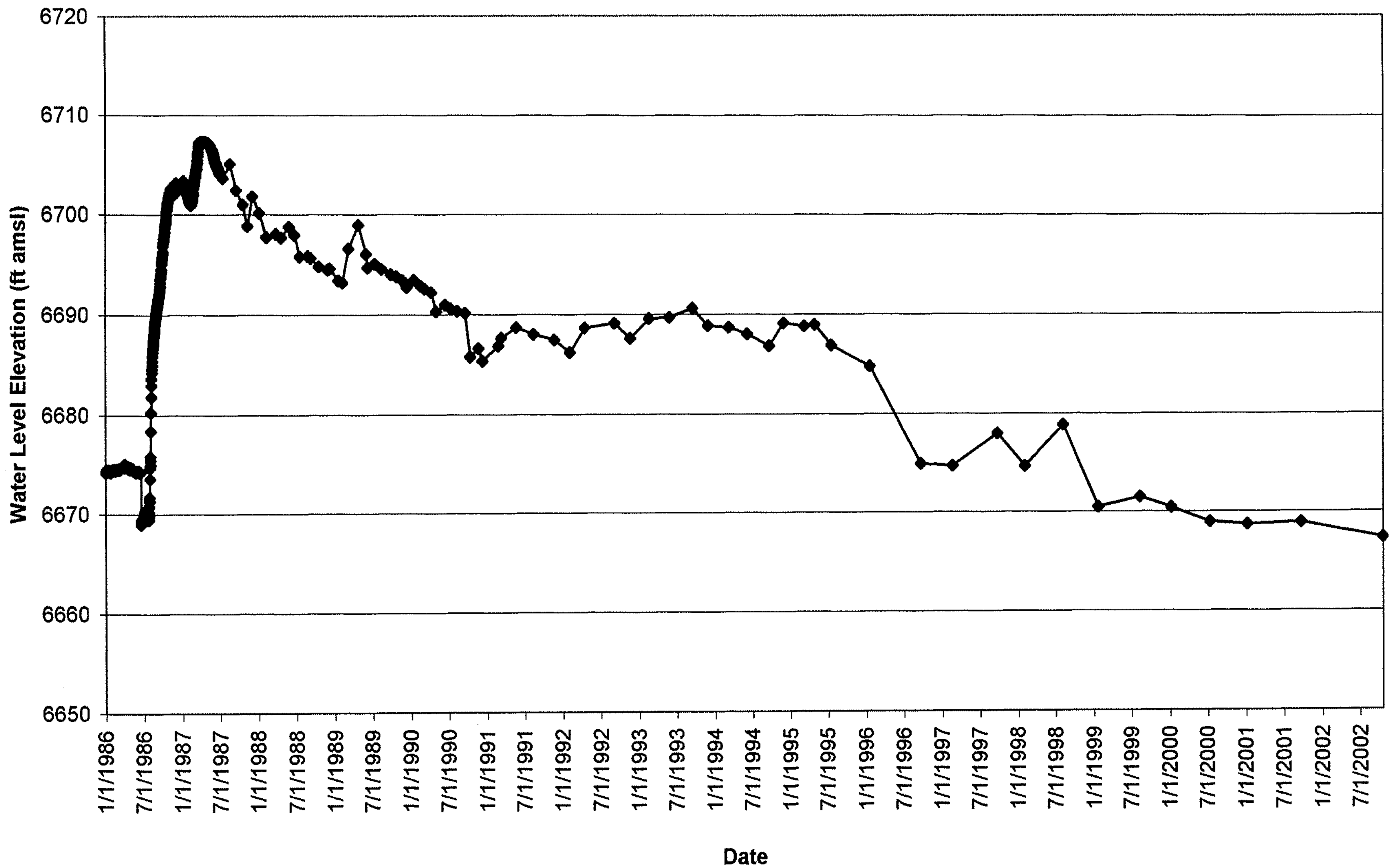
1/23/2003

Well 61

Well 65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6710
6700
6690
6680
6670
6660
6650
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7/1/1986
1/1/1987
7/1/1987
1/1/1988
7/1/1988
1/1/1989
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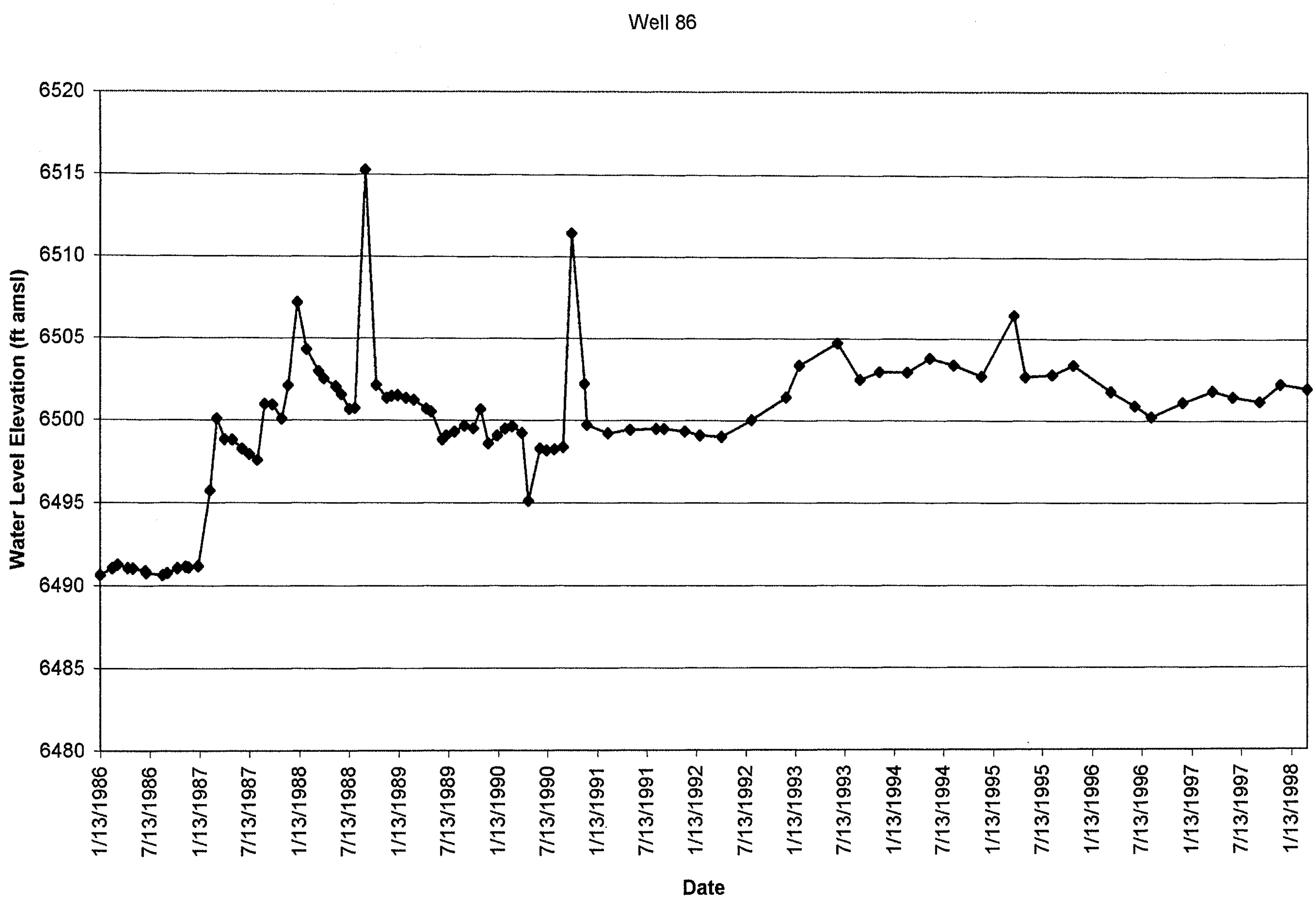
Date



Well 86
Water Level Elevation (ft amsl)
6520
6515
6510
6505
6500
6495
6490
6485
6480
1/13/1986
7/13/1986
1/13/1987
7/13/1987
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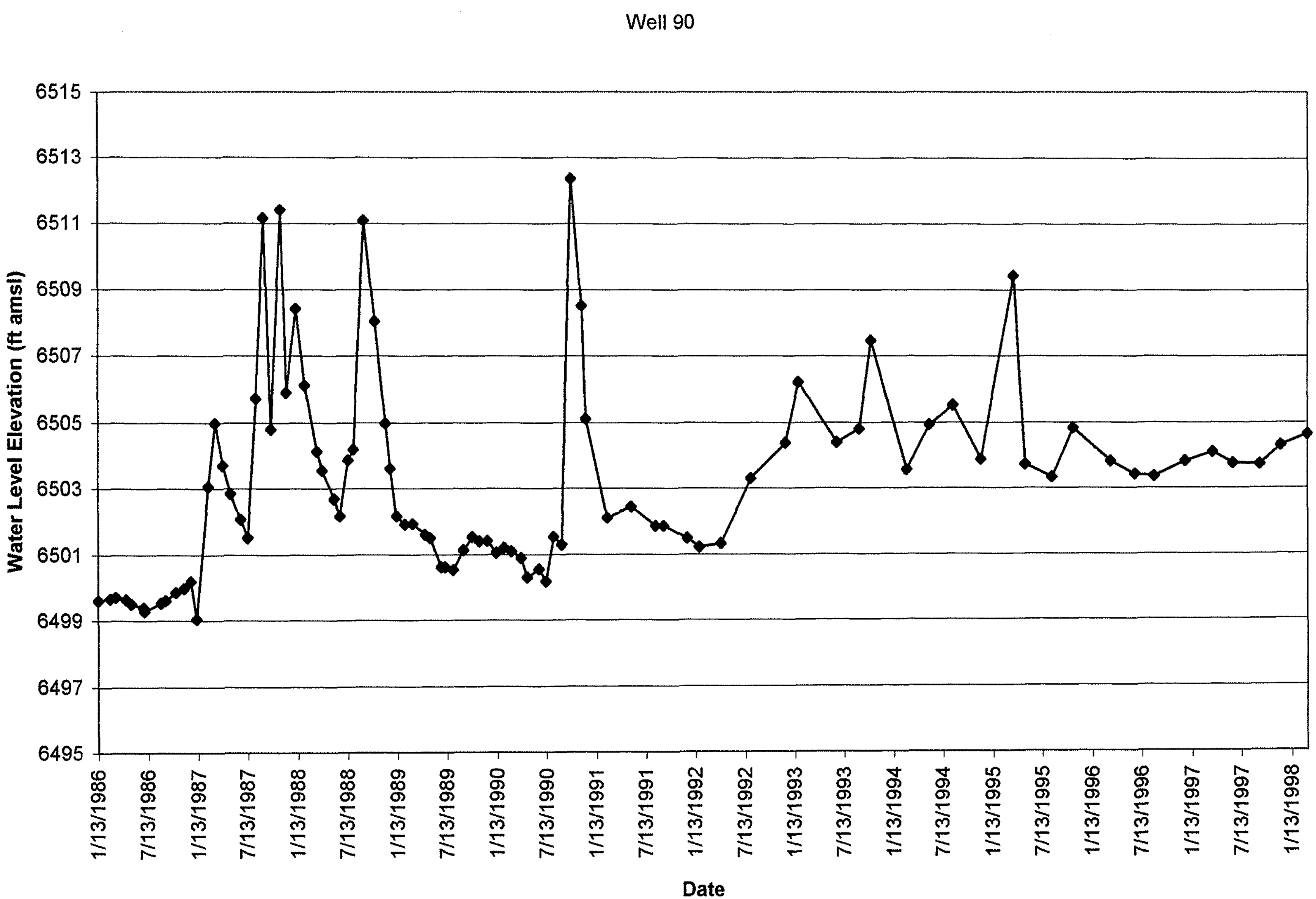
Date


Well 90
Water Level Elevation (ft amsl)
6515
6513
6511
6509
6507
6505
6503
6501
6499
6497
6495
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7/13/1986
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Date

APPENDIX C

Calculations

CALCULATION NO.1
Calculation of volume water content in wash-plant refuse.
Statement of Problem: Calculate theta, the water content by volume in the wash-plant refuse material.
Assume:
1. 45 % of refuse is coarse material with 7% moisture content and 55% is fine material at 40% moisture content
2. Weight of water is 1g/cm3
3. Saturated porosity is 0.3881 (from Rosetta software)
4. Use relationship: $O = w(p_b/p_w)$ where: O is volumetric water content, w = mass or gravimetric water content, p_b is bulk density of material, p_w is density of water (g/cm^3)

0.76455 Conversion yd^3/m^3

Volume Refuse per year (yds^3)	Volume Refuse per year (m^3)	Bulk Density lbs/ft^3	Bulk Density g/cm^3	Bulk Density g/m^3	Estimated wt. of Waste (g)	Estimated wt. of water (g)	Estimated vol. water (cm^3)	Estimated vol. water (m^3)
1,000,000.00	764,550.00		1.60	1,600,000.00				
Coarse Material yds3 per year								
450,000.00	344,047.50	66.40	1.06	1,063,622.16	365,936,545,332.10	25,615,558,173.25	25,615,558,173.25	25,615.56
Fine Material yds3 per year								
550,000.00	420,502.50	56.50	0.91	905,039.94	380,571,557,770.92	152,228,623,108.37	152,228,623,108.37	152,228.62
Total	764,550.00				746,508,103,103.02	177,844,181,281.61		
Total volume of water								
(m3)						177,844.18		177,844.18
(yd3)						232612.8851		
The overall moisture content by volume is:			**0.2326**		0.2326			
The overall moisture content by weight is:			0.2382					

Therefore, if given a 40 % by volume water content as O_s (100 % saturation), 24% of the waste by volume is actually saturated or 24/40 or 60% saturation.

CALCULATION NO. 2
Mixing Calculation for N-6 Pit Wash-Plant Refuse Leachate and Wepo Aquifer Groundwater

Statement of problem: Calculate the resulting concentration of solutes in refuse leachate when instantaneously mixed with Wepo Aquifer groundwater.

Assumptions:

Refuse Material Composition and Properties

1. The composition of refuse is based on information from Hazen Research:
   47% Sand, 20% Silt, 33 % Fines
2. PWCC estimates a bulk density of 1.6 g/cm3 or approximately 100 lbs/ft^3
3. The program Rosetta ™ was used to estimate the unsaturated hydraulic properties:

Qr = 0.0715%, Qs = 0.3881%, alpha =2.04, n =1.2681, Ks = 0.0622 m/d , L = 0.5
Qr is the residual water content; Qs is the volumetric saturation percent when pores are 100% saturated.
Ks is the saturated hydraulic conductivity; alpha, n, L are constants.

4. Instantaneous deposition and drainage of 3-year deposit of refuse in N-6 Pit.
5. Total deposit is 3,000,000 yds3 and contains 24% water content by volume (theta) per Calculation No. 1
6. Configuration of Refuse deposit in N-6 Pit:
   Refuse deposit is 70 ft high x 335 ft wide x 3454 ft long = 81,000,000.0 ft^3
   This is equivalent to 3,000,000 yds^3 or 3 years of disposal in the pit.

Pit Inflow from Wepo "Aquifer"

1. Seepage face thickness is the distance from the bottom of the pit to the potentiometric surface This is estimated to be 20 ft.		
2. Pit inflow rate is:	3,182,179.00 gallons/yr	(PWCC 1985)
or:	1,165.55 ft^3/day	
3. Assume uniform flow in all areas of pit.		
4. Final pit length:	5,706.00 ft	(Lehn 2003)
5. Pit inflow rate per linear ft of pit:	0.20 ft^3/day-ft	
6. Length of pit accepting refuse in 3 years with 70 ft thickness and 335 ft width:	3,454.00 ft	
7. Pit inflow along refuse deposit:	705.54 ft^3/day	
Estimated time to fill pit to pot. surface in refuse deposit:		
[(20 ft x 3454 ft x 335 ft) x 0.3881]/705.54 ft^3/day	12,729.73 days	
	34.88 years	
Volume of water in refuse from pit inflows:		
[(20 ft x3454 ft x 335 ft) x 0.3881]	8,981,332.58 ft^3	

Refuse Transient Drainage

1. Volume of water generated by transient drainage of refuse in 3 year deposit:		HYDRUS2D Simulation
After 500,000 days, HYDRUS2D simulation indicated 5.3 ft of saturation		(see attached plot)
Therefore: (5.3 ft x 335 ft x 3454 ft) x 0.3881	2,380,053.13 ft^3	
2. The approximate rate (assume linear relationship) that the drainage water is generated:		
2,380,053 ft^3 / 500,000 day	4.76 ft^3/day	
3.The Drainage Factor : Total volume of water drained/Total volume of refuse:		
2,380,053.13 ft^3 / 81,000,000 ft^3 =	0.03 %	
4. The percent water drained of total assumed water content:		
2,380,053.13 ft^3 /(81,000,000 ft^3 x 0.24) =	0.12 %	