SECTION 18

WATER RESOURCES

TABLE OF CONTENTS

SECTION	SECTION TITLE	PAGE NUMBER

SECTION 18 WATER RESOURCES 1
18.1 Surface Water Resources 1
18.1.1 Perennial and Intermittent Streams 2
18.1.1.1 Stream Channel Characteristics 2
18.1.1.2 Surface Water Flows 4
18.1.1.3 Surface Water Quality 9
18.1.2 Lakes, Reservoirs, Other Water Bodies 15
18.1.3 Discharges into Surface Water Bodies ..... 18~~181817~~
18.1.4 Surface Water Resources Information Collection and Analysis ..... 18~~181817~~
18.2 Groundwater Resources 18
18.2.1 Springs, Seeps, and Other Groundwater Discharges ..... 19~~191918~~
18.2.2 Wells ..... 20~~202019~~
18.2.3 Aquifers and Other Groundwater Resources 21
18.2.3.1 Groundwater Quantity ..... 24~~242423~~
18.2.3.1.1 Alluvial Aquifer Information ..... 25~~252524~~
18.2.3.1.2 Fruitland Formation Information ..... 27~~272726~~
18.2.3.1.3 Pictured Cliffs Sandstone Information ..... 30~~303029~~
18.2.3.2 Groundwater Quality ..... 32~~323231~~
18.2.3.2.1 Alluvial Groundwater Quality ..... 32~~323231~~
18.2.3.2.2 Fruitland Formation Groundwater Quality ..... 34~~343433~~
18.2.3.2.3 Pictured Cliffs Sandstone Groundwater Quality ..... 38~~373736~~
18.2.4 Groundwater Resources Information Collection and Analysis ..... 40~~404039~~
18.3 Hydrologic Model ..... 41~~414139~~
18.3.1 Groundwater Model Development ..... 42~~424140~~
18.3.2 Baseline Groundwater Model Results ..... 43~~424241~~
Personnel ..... 44~~444442~~
References ..... 44~~444443~~
~~SECTION 18 WATER RESOURCES ..... 1~~

~~18.1 Surface Water Resources ..... 1~~
~~18.1.1 Perennial and Intermittent Streams ..... 2~~
~~18.1.1.1 Stream Channel Characteristics ..... 2~~
~~18.1.1.2 Surface Water Flows ..... 4~~
~~18.1.1.3 Surface Water Quality ..... 9~~
~~18.1.2 Lakes, Reservoirs, Other Water Bodies ..... 15~~
~~18.1.3 Discharges into Surface Water Bodies ..... 17~~
~~18.1.4 Surface Water Resources Information Collection and Analysis ..... 17~~
~~18.2 Groundwater Resources ..... 17~~
~~18.2.1 Springs, Seeps, and Other Groundwater Discharges ..... 18~~
~~18.2.2 Wells ..... 19~~
~~18.2.3 Aquifers and Other Groundwater Resources ..... 20~~
~~18.2.3.1 Groundwater Quantity ..... 23~~
~~18.2.3.1.1 Alluvial Aquifer Information ..... 24~~
~~18.2.3.1.2 Fruitland Formation Information ..... 25~~
~~18.2.3.1.3 Pictured Cliffs Sandstone Information ..... 29~~
~~18.2.3.2 Groundwater Quality ..... 31~~
~~18.2.3.2.1 Alluvial Groundwater Quality ..... 31~~
~~18.2.3.2.2 Fruitland Formation Groundwater Quality ..... 33~~
~~18.2.3.2.3 Pictured Cliffs Sandstone Groundwater Quality ..... 36~~
~~18.2.4 Groundwater Resources Information Collection and Analysis ..... 38~~
~~18.3 Hydrologic Model ..... 39~~
~~18.3.1 Groundwater Model Development ..... 40~~
~~18.3.2 Baseline Groundwater Model Results ..... 41~~
~~Personnel ..... 43~~
~~References ..... 43~~

SECTION 18

WATER RESOURCES

LIST OF TABLES

TABLE NUMBER	TABLE TITLE
18.1-1	Watershed Areas for Permit Area and nearby USGS Gages
18.1-2	Baseline Peak Flow Measurements on Pinabete Arroyo and No Name Arroyo in 1997, 1998, 2007, and 2008
18.1-3	Comparison of Average Annual Flows at Five Regional USGS Gages for Selected Years between 1978 and 2010
18.1-4	SEDCAD™4 Estimated Peak Discharge and Sediment Yield
18.1-5	Peak Discharge Estimates for Watersheds Based on Drainage Area Using Regional Equations
18.1-6	Average Monthly Flow, Maximum Daily Flow, and Number of Zero Flow Days at USGS 09367934, Teec-Ni-Di-Tso Wash near Burnham, New Mexico
18.1-7	Average Monthly Flow, Maximum Daily Flow, and Number of Zero Flow Days at USGS 09367936, Burnham Wash near Burnham, New Mexico
18.1-8	Average Monthly Flow, Maximum Daily Flow, and Number of Zero Flow Days at USGS 09367938, Chaco River near Burnham, New Mexico
18.1-9	Average Monthly Flow, Number of Zero Flow Days and Annual Peak Flow at USGS 09367950, Chaco River near Waterflow, New Mexico
18.1-10	Days with Flow and Average Monthly Zero Flow Days at Site N (Upstream) and Site M (Downstream) on Burnham Wash Between October 1, 1977 and May 31, 1980
~~18.1-10~~18.1-11	No Name Impoundment Staff Gage Readings from 1998
~~18.1-11~~18.1-12	Baseline Surface Water Quality Analytes with Applicable Water Quality Standards, Methodologies, and Minimum Detection Limits
~~18.1-12~~18.1-13	Median Concentrations at Cottonwood Baseline Monitoring Stations
~~18.1-13~~18.1-14	Water Quality and Flow Data on Pinabete Arroyo between July 29, 1998 and July 21, 2008
~~18.1-14~~18.1-15	Water Quality and Flow Data on No Name Arroyo between July 29, 1998 and August 12, 2008
~~18.1-15~~18.1-16	Water Quality Data on Brimhall Wash for Site N (Upstream) and Site M (Downstream) Between March 14, 1990 and January 8, 1995

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SECTION 18

WATER RESOURCES

LIST OF TABLES (CONTINUED)

TABLE NUMBER	TABLE TITLE
~~18.1-16~~18.1-17	Comparison of Total Dissolved Solids and Total Suspended Solids at Site M (Downstream) on Brimhall Wash between February 1979 and September 1982
18.1-18~~18.1-17~~	Comparison of Total Dissolved Solids and Total Suspended Solids at Site N (Upstream) on Brimhall Wash between February 1979 and September 1982
~~18.1-18~~18.1-19	Surface Water Quality for Other Bodies of Water Within and Near the Pinabete Permit Area
18.2-1	Inventory of Water Wells and Groundwater Use
18.2-2	Water Levels in Pinabete Alluvial Monitoring Wells
18.2-3	Water Levels in Cottonwood Alluvial Monitoring Wells
18.2-4	Alluvial Monitoring Well Summary and Aquifer Test Results
18.2-5	Potentiometric Elevations in Coal Monitoring Wells and Piezometers
18.2-6	Coal Monitoring Well Summary and Aquifer Test Results
18.2-7	Water Depths and Potentiometric Elevations in the Pictured Cliffs Sandstone Monitoring Wells and Piezometers
18.2-8	Water Depths in the Pictured Cliffs Sandstone Monitoring Wells from 1970s and 1980s
18.2-9	Pictured Cliffs Sandstone Monitoring Well Summary and Aquifer Test Results
18.2-10	Relevant Groundwater Quality Use Criteria
18.2-11	Baseline Water Quality at Cottonwood Arroyo Alluvial Wells
18.2-12	Water Quality at Pinabete Arroyo Alluvial Well PA-1
18.2-13	Water Quality at Pinabete Arroyo Alluvial Well PA-2
18.2-14	Water Quality at No Name Arroyo Alluvial Well NNA-1
18.2-15	Water Quality at No. 3 Coal Seam Well KF-98-02
18.2-16	Baseline Water Quality in the Fruitland Coals at Navajo Mine
18.2-17	Water Quality at No. 8 Coal Seam Well KF2007-01
18.2-18	Water Quality at Pictured Cliffs Sandstone Well KPC-98-01
18.2-19	Water Quality at Pictured Cliffs Sandstone Well KPC2007-01

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18.2-20 Water Quality at Pictured Cliffs Sandstone Monitoring Well GM-21
18.2-21 Water Quality at Pictured Cliffs Sandstone Monitoring Well GM-20
~~18.2-22 Water Quality at Pictured Cliffs Sandstone Monitoring Well GM-19~~

SECTION 18

WATER RESOURCES

LIST OF TABLES (CONTINUED)

TABLE NUMBER **TABLE TITLE**

~~18.2-23~~18.2-22 Water Quality at Pictured Cliffs Sandstone Monitoring Well GM-19
18.2-23 Water Quality at Pictured Cliffs Sandstone Monitoring Well GM-30A
18.3-1 Measured and Modeled Recharge Rates

Field Code Changed
Field Code Changed
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Field Code Changed
Field Code Changed

SECTION 18

WATER RESOURCES

LIST OF FIGURES

FIGURE NUMBER	FIGURE TITLE	
18.1-1	Schematic of Single-Stage Sediment Sampler	Field Code Changed
18.1-2	Schematic of Crest Stage Gage	Field Code Changed
18.1-3	Pinabete Arroyo Stiff Diagrams	Field Code Changed
18.1-4	Piper Plot Diagram for Surface Water Samples from Pinabete Arroyo, No Name Arroyo, and Brimhall Wash	Field Code Changed
18.1-5	No Name Arroyo Stiff Diagrams	Field Code Changed
18.1-6	Brimhall Wash Stiff Diagrams – Upstream (Site N) and Downstream (Site M)	Field Code Changed
18.2-1	Baseline Potentiometric Elevations at Location VWP2007-05	Field Code Changed
18.2-2	Baseline Potentiometric Elevations at Location VWP2007-03	Field Code Changed
18.2-3	Baseline Potentiometric Elevations at Location VWP2007-02	Field Code Changed
18.2-4	Baseline Potentiometric Elevations at Location VWP2007-01	Field Code Changed
18.3-1	Modeled Baseline Potentiometric Surface for the Pictured Cliffs Sandstone	Field Code Changed
18.3-2	Modeled Baseline Potentiometric Surface for the No. 3 Coal Seam	Field Code Changed
18.3-3	Modeled Baseline Potentiometric Surface for the No. 8 Coal Seam	Field Code Changed
18.3-4	Modeled Baseline Saturation for a North-South Section at Pinabete Permit Area	Field Code Changed

SECTION 18

WATER RESOURCES

LIST OF EXHIBITS

EXHIBIT NUMBER	EXHIBIT TITLE
18.1-1	Regional Surface Water Features and Monitoring Locations
18.1-2	Surface Water Features and Stream Monitoring Locations
18.1-3	Cross-Sections Cottonwood Arroyo
18.2-1	Inventory of Water Supply Wells and Springs
18.2-2	Hydrogeologic Cross-Sections, Monitoring Wells, and Piezometers
18.2-3	No. 3 Coal Seam Potentiometric Surface
18.2-4	No. 8 Coal Seam Potentiometric Surface
18.2-5	Pictured Cliffs Sandstone (PCS) Potentiometric Elevations

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Field Code Changed
Field Code Changed
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Field Code Changed
Field Code Changed

SECTION 18

WATER RESOURCES

LIST OF APPENDICES

APPENDIX NUMBER	APPENDIX TITLE
18.A	Baseline Channel Inventories of Pinabete Arroyo and No Name Arroyo from 1998 and 2007 (Edited ~~2012~~2013)
18.B	SEDCAD™4 Modeling of Baseline Flood Flows and Sediment Yields
18.C	Laboratory Reports for Pesticide and PCB Analyses of Pond Waters
18.D	Quality Assurance and Quality Control Results for Baseline Surface Water Quality Data from 2007 to 2008
18.E	Monitoring Well and Vibrating Wire Piezometer Completion Diagrams
18.F	Aquifer Testing Results from 1998 and 2007
18.G	Quality Assurance and Quality Control Results for Baseline Groundwater Quality Data from 2007 to 2008

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SECTION 18

WATER RESOURCES

LIST OF REVISIONS DURING PERMIT TERM

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SECTION 18 WATER RESOURCES

The water resources baseline information and assessment provides a description of the pre-mine conditions of surface and groundwater flow and water quality within the permit area and adjacent areas. This baseline assessment is developed for the proposed Pinabete Mine Plan permit area (permit area). The proposed permit area will be within portions of the Area 4 North and Area 4 South resource areas of the ~~BHP Navajo Coal~~ Navajo Transitional Energy Company (~~BNCC~~NTEC) mining lease, located on the western flank of the San Juan Structural Basin. The coal seams to be mined are associated with the Cretaceous Age Fruitland Formation (Section 17, Geologic Information). The baseline resource assessment for this permit application package establishes the foundation for the determination of probable hydrologic consequences for the proposed surface mine operation (Section 41, Probable Hydrologic Consequences) and for the design of water resources reclamation plans (Section 35, Hydrologic Reclamation Plan) that may be needed to protect surface and groundwater resources.

This baseline evaluation includes a review of reports and data concerning water resources of the region obtained from state and federal agencies, as well as the information developed for ~~BNCC~~NTEC's Navajo Mine and by CONSOL Energy's (formerly Consolidated Coal) Burnham Mine. ~~BNCC~~NTEC implemented a baseline hydrologic monitoring program to obtain additional site-specific information from four ephemeral stream monitoring sites, three surface water impoundment sites, 12 groundwater monitoring wells and piezometers, and 14 vibrating wire piezometers, located within ~~BNCC~~NTEC mining lease Area 4 South and Area 5 that were installed in 1998 and 2007 to supplement the existing information.

18.1 Surface Water Resources

The Pinabete Mine Plan permit area is generally bounded by Pinabete Arroyo along the southwest side of the proposed permit area, by Navajo Mine permit area (Office of Surface Mining Reclamation and Enforcement (OSM) Permit No. NM-0003F) on the north, by the South Fork of Cottonwood Arroyo on the northeast, and the mining lease boundary on the east and west. The Pinabete mining area extends across approximately 8.75 square miles (sq mi) (5,569 acres) of the ~~BNCC~~NTEC mining lease (Exhibit 18-1-1). Information pertaining to the No Name Arroyo, Brimhall Wash, and selected other regional drainages features are included in this Section to provide additional regional surface water information.

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Pinabete Arroyo and the South Fork of the Cottonwood Arroyo are the primary surface water features within the permit area. Portions of the permit area also drain to the mainstem of the Cottonwood Arroyo and to an unnamed tributary to the Chaco River. The mainstem of the Cottonwood Arroyo and the Chaco River are outside of the permit area and will not be directly affected by proposed mining in the permit area. Cottonwood Arroyo, Pinabete Arroyo, and No Name Arroyo flow directly into the Chaco River. Cottonwood Arroyo has a watershed area of 79.8 sq mi. Pinabete Arroyo has a watershed of 60.3 sq mi,

and No Name Arroyo has a watershed of 11.5 sq mi, (Table 18.1-1). The Chaco River flows north into the San Juan River and drains an area of approximately 4,350 sq mi.

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Annual precipitation within the immediate area of the permit area is low, averaging 5.7 inches, and rainfall amounts vary considerably from year to year (Section 12, Climate). The average monthly precipitation varies from 0.1 to 1.2 inches per month, with the most precipitation occurring in July, August, and September (Section 12, Climate). The average annual evaporation rate for this area is about 55 inches per year (Section 12, Climate). Due to the great differential of excess evaporation over precipitation, surface water flow in streams in the permit area occurs only in response to major storm events and base flow is nonexistent.

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18.1.1 Perennial and Intermittent Streams

Although the flow in Pinabete Arroyo and Cottonwood Arroyo is ephemeral, these streams are defined by OSM regulation 30 CFR 701.5 as intermittent because the drainage basin area is greater than 1 sq mi.

Cottonwood Arroyo has a drainage area of about 79.8 sq mi, including approximately 12.4 sq mi of the Chinde Wash that is diverted to the North Fork of the Cottonwood Arroyo by the Amarillo Canal. Slightly less than six percent of the Cottonwood Arroyo watershed lies within the permit area. The South Fork of the Cottonwood flows through the permit area. The drainage area of the South Fork of the Cottonwood upstream of the permit boundary is approximately 18.3 sq mi. An additional 2.7 sq mi are within the permit area, for a total drainage area of approximately 21.1 sq mi (Table 18.1-1 and Exhibit 18.1-2).

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While the Pinabete Arroyo has a total drainage basin of approximately 60.3 sq mi, the size of the drainage basin area upstream of the point where Pinabete Arroyo exits the mine permit boundary is approximately 55.~~5~~7 sq mi (Table 18.1-1 and Exhibit 18.1-2). ~~BNCC~~NTEC has assembled baseline information on Pinabete Arroyo, Cottonwood Arroyo, and No Name Arroyo. ~~BNCC~~NTEC has obtained baseline information on flow and water quality of Cottonwood Arroyo at three stations CNS-1, CS-1 and CN-1 as shown on Exhibit 18.1-2 and as described in Chapter 7 of Navajo Mine Permit Application Package (PAP) (OSM Permit No. NM-0003F) (BNCC 2009).

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18.1.1.1 Stream Channel Characteristics

The stream channels of Pinabete Arroyo and the South Fork of the Cottonwood Arroyo will not be directly disturbed by proposed mining within the permit area. Culverts will be installed on these streams for the Burnham Road relocation. Construction of the Burnham road and culvert crossings may result in a temporary increase in sediment if storm runoff occurs during construction but, in the long-term, the crossings will be an improvement, due to the anticipated reduction in sediment loads, over the fords that currently exist where the Burnham Road crosses these streams. Stream buffer zones will be demarcated

along these channels to prevent unauthorized disturbance of the designated channel reaches. Stream Buffer Zones are discussed further in Section 40.4.

The South Fork of the Cottonwood Arroyo is a major sand bed ephemeral drainage that passes through the northeastern portion of permit area. Exhibit 18.1-1 shows the watershed area and drainage configuration for Cottonwood Arroyo, including the South Fork of the Cottonwood Arroyo. Cottonwood Arroyo is characterized by a rapid increase in discharge from a dry channel to peak discharge, followed by a recession to low discharge over several hours. These rapidly varying flows can transport large ~~of~~ amounts of sediment and cause extensive change to channel morphology, particularly noted at surface water station CNS-1. Total sediment and total dissolved solids concentrations are similar to regional values and average 97,989 mg/L and 656 mg/L, respectively.

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The configuration of the sand bed channel of the segment of South Fork of the Cottonwood Arroyo, within the permit area, changes in response to the dynamics of sediment transport and deposition during the short duration high intensity flow events that naturally occur in the region. Exhibit 18.1-3 shows channel cross sections from monitoring stations in Cottonwood Arroyo before and after the large flow events that occurred in July and August 1999. The cross-sections, taken in early June 1999 and again in January 2000, show the amount of channel transformation due to large flow events. Only minor changes in channel cross section were observed at stations CS-1 and CN-1 while particularly large changes occurred at station CNS-1. At station CNS-1, the north bank (cut-bank) of the channel moved approximately 60-feet horizontally and channel bottom width increased from about 60 feet to 95 feet between the two survey events in June 1999 and January 2000. In addition to the loss of sediment on the cut-bank, some sediment was temporarily stored as evidenced by the formation of sand bars on the opposite bank and the sediment deposition on the flood plain from out of bank flows.

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The main channel segments of Pinabete Arroyo and No Name Arroyo within ~~BNCC~~NTEC's mining lease are similar to the sand bed channel characteristics of the South Fork of the Cottonwood Arroyo. These segments were inventoried in 1998 and 2007 to establish baseline characteristics. The results of the baseline channel inventory for Pinabete Arroyo and No Name Arroyo are included in Appendix 18.A. The purpose of this inventory was to document the channel conditions prior to mining, including bedrock outcrops, and indicators of channel instability such as knick points, channel cut banks, and channel scour or deposition. The channel bed and bank materials, cross sections, and vegetation characteristics were also noted. These properties provide an indication of the capacity of the stream channels to adjust and recover from potential changes in flows that may occur as a result of mining and reclamation.

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Exhibits in Appendix 18.A display the channel profiles for Pinabete and No Name Arroyos and their tributaries within and adjacent to ~~BNCC~~NTEC's mining lease. The channel cross sections for the

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corresponding segments of Pinabete Arroyo and No Name Arroyo at the stream monitoring stations are also provided on exhibits in Appendix 18.A.

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Pinabete Arroyo is braided in many locations, reflecting the highly variable discharge rates, high bed load, limited vegetation, and high width to depth ratio. Channel depths range from 4 to 10 feet with widths varying from 20 to 80 feet. The main Pinabete Arroyo channel profile is mildly concave with slopes of 0.55% or higher at the upstream segment near the eastern permit boundary and decrease to about 0.33% downstream near the western permit boundary (Appendix 18.A). Sinuosity is relatively high downstream from Station P-1 for 1,500 feet, upstream and downstream of P-3 for 1,500 feet, and between P-5 and P-6 for 2,500 feet. No knick points, or convex segments, are present in the channel profile in the vicinity of the permit area. The channel maintains a slightly concave graded profile even though there may be continual reworking of sandy channel bed and bank materials. Minor changes in channel geometry and local slope may occur as a result of variation in the properties of channel materials and channel vegetation or in response to changing patterns of floods. Contributing tributaries are incised for as much as 300 feet upstream and exhibit head cuts ranging in height from 2 to 5 feet. Suspended sediment concentrations in storm runoff events are very high with TSS concentrations ranging from 10,200 to 521,000 mg/L in 26 baseline samples collected from Pinabete Arroyo (Table 18.1-13). For additional information refer to the 1998 and 2007 channel morphology reports in Appendix 18.A.

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The main No Name Arroyo channel profile, plotted on exhibits in Appendix 18.A, was developed from 1-foot contour topography generated from aerial surveys conducted in 2008. It exhibits a variable slope with several knick points and convex segments, typical of an unstable channel. The knick point present in the channel profile near inventory location NNA-2 is associated with a 15-foot head cut and a deeply incised channel downstream of this location. Smaller head cuts were also found upstream of this point at locations just below the No Name Impoundment and at several points upstream of the No Name Impoundment. Sediment deposition is occurring at the impoundment where the Burnham Road (BIA Road No. 3005 and Navajo Road N-5082) crosses the No Name Arroyo. This deposition reduces sediment load in water that is released in outflows from the No Name Impoundment. The low sediment concentrations in impoundment outflows has accelerated erosion in the channel bed immediately downstream of the impoundment (Williams and Wolman 1984) and evidently contributes to the head cutting and channel incision observed in the reach further downstream of the impoundment. More detailed information on the channel morphology may be reviewed in the 1998 and 2007 channel morphology reports in Appendix 18.A.

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18.1.1.2 Surface Water Flows

Between 1990 and 2000, ~~BNCC~~NTEC performed baseline monitoring of surface water flows and water quality in Cottonwood Arroyo at three stations, CS-1 (South Fork), CN-1 (North Fork), and CNS-1 (main channel). Data collected during the ten years of baseline monitoring were submitted to OSM as part of the

quarterly hydrologic reports and annual hydrologic reports for Navajo Mine (BNCC 2009). From 1990 through 1996, monitoring consisted of single stage sediment samplers in conjunction with crest gauges. From 1997 through 1999, monitoring consisted of automated samplers and ultrasonic water level sensors.

Storm runoff hydrographs for several flow events were generated from the measurements from ultrasonic water level sensors and are provided in Appendix 7-1 of the Navajo Mine PAP (BNCC 2009). These results indicate that for most flow events, runoff volumes (acre/feet) decrease from upstream to downstream. However, the two storm events in early August 1999 were an exception to this, in which runoff volumes increased from upstream to downstream. The loss of water from upstream to downstream is apparently the result of water infiltrating into the sand bed of the progressively widening channel downstream. The two flow events in early August 1999 that show a slight net increase in the total runoff volume from upstream to downstream were preceded by several flow events in late July 1999. These frequent flow and precipitation events would produce high antecedent moisture within the channel bottom, which in turn may limit channel bed infiltration. Also, intense precipitation between the monitoring stations, such as the 2.6 inches of precipitation recorded in August 1999 at MET II, may also account for the increase in flow at the downstream station during these events.

The hydrograph shape for most of the storm runoff events at the Cottonwood stations, particularly in the summer, is characterized by a very sharp rise or spike in the rising limb with a very short duration peak, followed by a gradual falling limb of the hydrograph (BNCC 2009). This hydrograph shape is characteristic of flash flows in ephemeral channels due to high intensity thunderstorms. The shape of the hydrograph and the duration and timing for an individual flow event is similar between stations (Appendix 7-1, Navajo Mine PAP, OSM Permit No. NM-0003F) (BNCC 2009).

Baseline surface water monitoring stations were established on No Name Arroyo and Pinabete Arroyo downstream of ~~BNCC~~NTEC's mining lease in 1998 as shown on Exhibit 18.1-1. Prior to monitoring in year 2007, the lower Pinabete station was moved upstream approximately 6,000 feet from its 1998 location to provide a more suitable location closer to the mine permit boundary. Surface water monitoring stations were also installed on Pinabete Arroyo and No Name upstream of ~~BNCC~~NTEC's mining lease. The monitoring stations were installed on relatively uniform straight channel segments and consisted of two or more single-stage samplers (Figure 18.1-1) and crest-stage gages (Figure 18.1-2) installed upstream and downstream of the single stage samplers to measure the slope of the water surface during the peak flow at the monitoring station.

Peak flow estimates (Q) reported in cubic feet per second (cfs) at each of the monitoring station locations (Table 18.1-2) were developed using Manning's equation as specified below:

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$$Q(cfs) = \cancel{1.49 \times \frac{1}{n} \times A \times r^{\frac{2}{3}} \times S^{\frac{1}{2}}}$$
$$1.49 \times \frac{1}{n} \times A \times r^{\frac{2}{3}} \times S^{\frac{1}{2}}$$

The slope of the water surface (S) at each monitoring station location was determined from the measurements at the upstream and downstream crest-stage gages or from the slope of the channel when one of the crest stage gage readings was missing or erroneous. The cross-sectional area (A) and the hydraulic radius (r) corresponding to each measured crest-stage were digitized from the channel cross section at the monitoring station location.

The averages for the cross-sectional area (A) and the hydraulic radius (r) from the two crest stage gage locations at each station were used in Manning's equation to estimate flow except when one of the crest stage gage readings was missing or erroneous. In that case, the single value for A or r was used. The site-specific Manning roughness coefficient (n) was determined for each location during the stream channel inventory using the procedure for small channels as described in Gray (1970). Peak flows determined from crest-stage measurements during the 1997-1998 and 2007-2008 baseline monitoring period at the upstream and downstream sites on Pinabete Arroyo and No Name Arroyo are provided in Table 18.1-2.

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Flows in the arroyos draining ~~BNCC~~NTEC's mining lease are flashy and occur in response to short duration, high intensity precipitation events usually during the seasonal thunderstorm months of July through November. The thunderstorms are usually localized and the intense rainfall may not extend throughout the drainage area of the arroyo. Consequently, there may not be much consistency among flows measured upstream or downstream or in adjacent drainages as indicated in Table 18.1-2. Zero flow was recorded between November 1997 and June 1998 ~~on~~at both the Pinabete Arroyo and No Name Arroyo ~~watersheds~~monitoring stations. Summer monsoonal rains in 1998 resulted in peak storm flows of 22.5 cfs at the upper Pinabete Arroyo site (Upper Pinabete), and 1,717 cfs at the downstream Pinabete Arroyo site (Lower Pinabete). The adjacent, but significantly smaller No Name Arroyo watershed exhibited a peak flow of 1.5 cfs at the upstream site (Upper No Name) in July, while no flow was reported at the No Name Arroyo downstream site (Lower No Name). The maximum peak flow of 2,307 cfs was observed in Pinabete Arroyo at the downstream site (Lower Pinabete) in August 1998, while the maximum peak flow observed in No Name Arroyo was 38.8 cfs at the downstream site (Lower No Name) in October 1998. Peak flow measured during 2007 and 2008 ranged from 0.2 to 7.5 cfs at the Pinabete Arroyo upstream site and from 0.4 to 46.6 cfs at the Pinabete Arroyo downstream site (Table 18.1-2). These peak flows are lower than the peak flows observed at the Pinabete Arroyo crest-stage gages in 1998. The downstream Pinabete Arroyo site was destroyed as a result of substantial flows in the arroyo during the week of August 4, 2008; the monitoring station was replaced the week of August 25, 2008 in approximately the same location as the previous monitoring station. Peak flow measurements during 2007 and 2008 ranged from

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0.7 to 19.1 cfs at the upstream No Name Arroyo site. ~~The gages were damaged during a flow event in 2008 and were replaced.~~ The peak flow ~~estimates~~measurements during 2007 and 2008 for the No Name Arroyo downstream site ranged from ~~immeasurable~~zero to 111.1 cfs in 2007 and 2008 (Table 18.1-2). The upstream No Name Arroyo site was destroyed as a result of substantial flows in the arroyo during the week of August 4, 2008; the monitoring station was replaced the week of August 25, 2008 in approximately the same location as the previous monitoring station. These peak flows at the lower No Name Arroyo location were higher than measured previously at this location during 1998. The 1998 water year appears to be an average water year, based on the examination of regional flows at two U.S. Geological Survey (USGS) gages along the San Juan River in Farmington and Shiprock (Table 18.1-3).

SEDCAD™4 (SEDCAD) modeling was performed on Pinabete Arroyo, No Name Arroyo, and Cottonwood Arroyo to better characterize the flow and sediment regimes. Information used to develop the SEDCAD projections and modeling results are provided in Appendix 18.B. Table 18.1-4 provides a summary of the SEDCAD model results for peak flows and sediment yield for selected storm frequency events for the two surface water monitoring stations on Pinabete Arroyo, the two stations on No Name Arroyo, the South Fork Cottonwood Arroyo, Cottonwood Arroyo at Station CSN-1, and Cottonwood Arroyo at its confluence with the Chaco River.

About 48 percent of the Cottonwood Arroyo watershed is occupied by badlands which accounts for the high discharge and flow intensities observed in this stream. Peak flows from a 10-year, 6-hour (10yr-6hr) event on Cottonwood at Station CSN-1 located near the mining lease boundary are predicted to be about 2,~~879 cfs~~871 cfs (Table 18.1-4). The Cottonwood Arroyo channel between the mining lease boundary and its mouth with the Chaco River has a uniform gradient. Suspended sediment concentrations are high during storm runoff events and the sandy channel bed and bank materials are reworked by the larger flood events.

The SEDCAD peak flow predictions for the Pinabete Arroyo, No Name Arroyo, and Cottonwood Arroyo are less than the predictions using USGS method for ungaged streams in northwestern New Mexico (Table 18.1-5). The USGS method was developed in cooperation with the Bureau of Indian Affairs to estimate the magnitude and frequency of peak discharges for ungaged streams within the Navajo Nation in Arizona, Utah, Colorado, and New Mexico (Waltemeyer 2006). Peak discharge estimates in Table 18.1-5 were calculated for Pinabete Arroyo, No Name Arroyo, and Cottonwood Arroyo using the regional equations developed in Waltemeyer (2006)

The SEDCAD predictions are thought to be more reliable, since the modeling incorporated detailed site-specific information on soils (e.g., K-factor and erodible particle size distributions) and cover values that were incorporated into subwatershed characterizations. In addition, the model accounts for the attenuation in flood flows associated with the No Name Impoundment on the No Name Arroyo.

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Supplemental information is available from USGS regional sites located on Burnham Wash, a tributary to Brimhall Wash located southeast of the permit area (Site 9367936), the Teec-Ni-Di-Tso Wash, located within the region but further south from the Burnham Wash (Site 9367934), and ~~the~~two Chaco River ~~gage (Site~~gages (Sites 9367938 and 9367950) (Exhibit 18.1-1). The first two sites have watersheds of 8.6 sq mi and 7.2 sq mi respectively, very similar in size to the 8.2 sq mi of the No Name Arroyo watershed above the mining lease boundary. ~~The~~During the period of record, the monthly average flow at Teec-Ni-Di-Tso Wash ranged from 0 to 2.2 cfs for all months and all years of data, with ~~an~~the highest average maximum daily flow of ~~3.6~~10 cfs in ~~January~~August for the 5-year period between 1978 and 1982 (Table 18.1-6). The maximum daily flow at this site occurred on 8/24/1982 with 45 cfs. This 5-year period had 2 years in the 25-50% quartile, 2 years in the 50-75% quartile, and 1 year, 1979, in the top quartile for daily flow (Table 18.1-3). Average zero daily flow days/month for the period of record ranged from 10 to 27 days, with the most days of flow in January and the fewest days of flow in June. The results for Burnham Wash, located southeast of the permit area on a tributary to Brimhall Wash, were similar (Table 18.1-7) to those reported for the Teec-Ni-Di-Tso Wash (Table 18.1-6). The monthly average flow in Burnham Wash for all months during the period ranged from 0~~.02~~ to ~~1.02~~5.48 cfs, with ~~an~~the highest average maximum daily flow of ~~4.8~~14 cfs in ~~January~~May for the 5-year period between 1978 and 1982. The maximum daily flow at this site occurred on 5/6/1978 with 71 cfs. Average zero daily flow days/month for the period ranged from 7 to 26 days, with the most days of flow in January and February and the least days of flow in June and July.

Stream flow in the Chaco River is ephemeral upstream of the existing Four Corners Power Plant (FCPP) as indicated by observations and supported by the five years of flow monitoring on the Chaco River at the USGS Site 09367938 near Burnham, New Mexico (Exhibit 18.1-1). Measurable flows at this station occurred only in response to rainfall or snow melt events. Annual peak storm flows for the 1978 to 1982 (5-year) monitoring period ranged from 950 to 6,740 cfs. The number of flow days per month on the Chaco River is quite variable, with zero flow during many months and flow every day during April 1982 (Table 18.1-8). Average number of days of zero flow per month ranged from 27.6 days in June to 13.2 days in March (Table 18.1-8). The flow monitoring results at this station show that streamflow in the Chaco River occurs as discrete flow events that range from less than one day to more than several weeks that are separated by periods of zero flow that can range several days to several months.

Stream flow in the Chaco River below the Four Corners Power Plant (FCPP) was gaged by the USGS Site 09367950, Chaco River near Waterflow, New Mexico, between 11/1/1975 and 9/30/1994. This site is approximately nine channel miles west of Morgan Lake. Flows normally reflect discharges related to operations at FCPP, and were largely perennial. The median number of days of no flow for each month is zero (Table 18.1-9). However, there are years in the record of periods of no flow for every month of the year. The maximum period of no flow days varies from 3 days for February to 30 days for July (Table

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18.1-9). The average monthly flows vary from 21 cfs for December and June to 108 cfs for August. Peak daily flows associated with storm events for Water Years 1976 through 1994 ranged from 1,170 cfs in Water Year 1980 to 6,410 cfs in Water Year 1987 (USGS 2013). The annual peak flows occurred mostly in August during the monsoon season, but the highest flow during the period of record of 6,410 cfs, occurred on November 4, 1986.

Additional perspectives on flow in Pinabete Arroyo can be derived from monitoring performed at the CONSOL Energy's Burnham Mine on Brimhall Wash, located south of permit area (Exhibit 18.1-1). Part of the Brimhall Wash drainage lies immediately south and adjacent to Pinabete Arroyo. Both streams drain areas with similar landforms, soils, vegetation, and elevations. Brimhall Wash drainage is slightly larger at 85.2 sq mi as compared to Pinabete Arroyo with a 60.3-sq mi watershed. Brimhall Wash was monitored daily over a 3-year period, between October 1, 1977 and May 31, 1980, at two locations: Site M (downstream) and Site N (upstream) (Burnham Mine Permit Application Package on file at the OSM library in Denver, Colorado). Both sites experienced from 0 to 4 flow days/month for most months during the monitoring period, with a maximum of 10 flow days during August 1978 at Site N (~~Table 18.1-9),~~Table 18.1-10). These results show that runoff from summer thunderstorms is localized and that channel conveyance losses can be considerable. For example, while 10 flow days were observed during August 1978 at the Site N, zero flow days were observed during August 1978 at Site M (~~Table 18.1-9),~~Table 18.1-10). Runoff patterns on Pinabete Arroyo are expected to be similar to those observed at Brimhall Wash.

The No Name Impoundment is filled periodically by runoff from storm events. Water was first observed in the No Name Arroyo impoundment in November 1997 and remained in the impoundment until June 1998. A staff gage was installed in the impoundment during the spring of 1998. Staff gage levels were recorded on a monthly basis during year 1998 and as soon as possible after major precipitation events. These results are provided in ~~Table 18.1-10,~~Table 18.1-11. It appeared that water was lost from this impoundment by both seepage and evaporation. The impoundment was dry from late June until July 26, 1998, when it refilled to the spillway elevation during a storm runoff event. Water remained in the impoundment beyond December 1998. The invert of the spillway on the No Name Impoundment was surveyed in 2008 and was found to be 6 feet above the low point within the impoundment. The survey also showed that the storage capacity of the impoundment at the spillway invert elevation is 19.7 acre feet (ac-ft) and would cover an area of 8 acres. Spillway and elevation-area capacity details for the structure can be reviewed in the baseline SEDCAD runs on "No Name Watershed w/Impoundment", Structure 8, in Appendix 18.B.

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18.1.1.3 Surface Water Quality

The Navajo Nation has adopted the Navajo Nation Surface Water Quality Standards (Navajo Nation Environmental Protection Agency [NNEPA] 2008) which established various surface water use quality standards. These standards apply to all Waters of the Navajo Nation which include, but are not limited to,

ephemeral, intermittent, and perennial streams, springs, wetlands, and any natural or man-made depressions or basins that impound water within the border of the Navajo Nation. The standards associate specific uses with specific stream reaches including the Cottonwood Arroyo, Brimhall Wash, and the Chaco River. Specific uses have not been identified for No Name Arroyo and Pinabete Arroyo. ~~It is likely that~~However, No Name Arroyo and Pinabete ~~Arroyos would share the standards with the Chaco River as they~~Arroyo are both nonperennial tributaries~~.~~ of the Chaco River, which is itself a tributary of the San Juan River. Standards have been set for non-perennial tributaries of the San Juan River. Designated uses for Cottonwood Arroyo, Brimhall Wash, and the Chaco River above Dead Man's Wash include livestock watering (LW), aquatic & wildlife habitat (A&WHbt), fish consumption (FC), and secondary human contact (ScHC) standards (NNEPA 2008). The applicable standards for the designated uses have been identified on ~~Table 18.1-11.~~Table- 18.1-12. The NNEPA has no water quality standard for total dissolved solids (TDS), sulfate, or fluoride but relevant livestock use criteria from Lardy, Stoltenow, and Johnson (2008) have been included in ~~Table 18.1-11~~Table 18.1-12 to help assess the suitability of surface water for livestock use. The Navajo Nation surface water quality standard for suspended sediment applies only to surface water that is at or near base flow and does not apply to surface water during or soon after a precipitation event and is therefore not applicable to ephemeral flows (NNEPA 2008).

The USGS monitoring records indicate that sizeable peak flows periodically occur due to high intensity thunderstorm events. The duration of flow resulting from these events is extremely short and typical of ephemeral runoff events. Sampling of such short-duration stream flows with passive single-stage samplers ensures the collection of samples from episodic events. In addition, samplers can be located at several stages within the stream, thereby enabling collection of samples at different flow depths. Figure 18.1-1 shows the design for the single-stage sediment sampler and Figure 18.1-2 shows the crest stage gage design. The intake on the single-stage samplers points downstream to reduce plugging from debris that might be present in the stream flow. Each sample location along in Pinabete Arroyo and No Name Arroyo had three single-stage sediment samplers at different locations along the channel cross section. Single-stage sediment samplers were also used from 1990 through 1996 at the three Cottonwood Arroyo monitoring stations, CS-1 (South Fork), CN-1 (North Fork), and CNS-1 (main channel). These stations were replaced by automated samplers and ultrasonic water level sensors for the baseline monitoring period from 1997 through 1999.

Analytical results of water samples collected at these monitoring stations are summarized in ~~Tables 18.1-12, 18.1-13, and 18.1-14 and are discussed below.~~Tables- 18.1-13, 18.1-14, and 18.1-15 and are discussed below. Flows associated with the water quality samples from the single-stage samplers were inferred from the estimated peak flow for the crest-stage measurements obtained at the same time that the samples were collected.

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Samples collected by the automated sampler on the Cottonwood stations CN-1, CS-1, and CNS-1 were analyzed for chemistry and total sediment. For each sample/flow event, only the first sample bottle collected was analyzed for chemistry from each station with the remaining samples analyzed for total sediment. A total of 314 water samples were collected from these stations between 1997-1999, with 255 of these samples analyzed for total sediment and 59 samples analyzed for chemistry. An additional 233 samples were obtained from 1990 to 1997 at these stations from the single stage samplers and from occasional grab samples.

~~Table 18.1-12~~Table 18.1-13 provides a summary of the median concentrations for water quality analysis results from samples collected at each of these Cottonwood baseline monitoring stations. These results show that for all three stations the dominant water type is a sodium sulfate. The median ~~total dissolved solids~~TDS concentration~~ (TDS)~~ for CN-1 is 780 mg/L with a range of 290-6,220 mg/L. The median TDS concentration for CS-1 is 675 mg/L with a range of 305-9,060 mg/L and for CNS-1 the median TDS concentration is 610 mg/L with a range of 315-15,600 mg/L. These values indicate a slight decrease in TDS concentration from upstream to downstream. More importantly, these values are typical of regional TDS concentrations for surface water quality. Station CN-1 has a slightly higher concentration of sulfate and TDS, which may reflect slightly different soil types in the watershed and possible Navajo Indian Irrigation Project (NIIP) impacts. The median pH values range from 7.95 to 8.4 on the three Cottonwood sites. The median total iron values range from 174 mg/L to 225.5 mg/L and the median total manganese concentrations range from 4.2 mg/L to 10.15 mg/L. None of these three parameters present a risk to the identified uses.

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Surface water data were collected and analyzed for different parameters during the three years of water monitoring conducted between 1998 and 2008 at stations on Pinabete and No Name Arroyos. Samples were acquired from two sites in Pinabete Arroyo, Upper Pinabete (upstream), and Lower Pinabete (downstream). Samples were collected at the Upper Pinabete site on four dates in 1998, two dates in 2007, and two dates in 2008 (~~Table 18.1-13),~~Table 18.1-14). Samples were collected at the Lower Pinabete site on five dates in 1998, four dates in 2007, and two dates in 2008 (~~Table 18.1-13),~~Table 18.1-14). On some of the sample dates, samples were obtained from more than one of the single-stage sample containers at a sampling location.

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The surface water in Pinabete Arroyo is a sodium sulfate type (Figure 18.1-3 and Figure 18.1-4) and had a hardness ranging from 29 to 413 mg/L as calcium carbonate ($CaCO_3$), with a median value of hardness of 108 mg/L as $CaCO_3$. Table 18.1-12 identifies hardness related limits based on 105 mg/L, which is the lowest median value among reported hardness levels from No Name, Pinabete, and Cottonwood Arroyos.

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The conductivity for all the surface water samples from Pinabete Arroyo ranged from 396 to 1,940 micro Siemens per centimeter (µS/cm), with a median value of ~~723~~750 µS/cm. The pH ranged from 7.0 to 8.56. Dissolved aluminum values for all samples ranged from <0.1 to 2.3 mg/L, with a median value of <0.~~27~~1 mg/L. The chronic aquatic standard for dissolved aluminum is 0.087 mg/L, so virtually all baseline background samples were elevated above that level. Total suspended solids (TSS) values ranged from 10,200 mg/L to 521,000 mg/L, with a median value of 79,200 mg/L. These high sediment loads are consistent with water quality from ephemeral drainages in arid regions. Boron concentrations ranged from< 0.~~06~~05 to 0.9 mg/L~~.~~, with a median concentration of <0.1 mg/l based on all samples including less than MDL results. Most of the cadmium results were less than the detection limit of 0.~~00055~~00005 mg/L but ~~four~~ three samples detected cadmium at concentrations above the hardness dependent chronic aquatic and wildlife ~~crition~~criterion of 0.~~00026~~00025 mg/L. Copper concentrations ranged from 0.006 to 0.026 mg/L, with a median value of 0.009 mg/L and approximately half the samples above the hardness dependent chronic aquatic and wildlife ~~crition~~criterion of 0.~~00956~~00934 mg/L. Fluoride concentrations range from <0.20 to 1.19 mg/L. The Upper Pinabete station had dissolved iron concentrations which ranged from <0.05 to 7.00 mg/L while the Lower Pinabete station had values which ranged from <0.02 to 20.3 mg/L. Total iron values ranged from 125 to 1,940 mg/L at the ~~upstream~~downstream site and ranged from 6 to 1,220 mg/L at the ~~downstream site.~~ upstream site. Total manganese levels ranged from 2.2-24.4 mg/L at the Upper Pinabete station and from 4.1 mg/L to 55.9 mg/L at the Lower Pinabete station. The NNEPA has no surface water quality ~~standard~~standards associated with total iron~~. For three events, mercury levels were~~ or total manganese. Mercury was detected ~~at~~ in six of fifteen samples. All of these detected concentrations ~~in excess of~~exceeded the chronic aquatic and wildlife habitat ~~standard~~criterion of 0.~~001 µg/L. For all other events,~~000001 mg/l but only one of the samples exceeded the acute aquatic and wildlife habitat criterion of 0.0024 mg/l. However for the nine samples, where the mercury levels were reported as less than the ~~detection limit, but the~~ method detection limit (MDL), the MDL for mercury of 0.~~2 µg~~0.0002 mg/L is higher than the chronic aquatic and wildlife habitat ~~standard.~~criterion but less than the acute aquatic and wildlife habitat criterion. Dissolved selenium ~~concentrations range from <0.001 to 0.007 mg/L with some of the concentrations~~was detected in ~~excess of~~twelve of the 26 analysis results for samples from Pinabete Arroyo. Seven of the twelve detections for selenium exceeded the chronic aquatic and wildlife habitat standard of 0.002 mg/L. Also, the MDL for selenium is higher than the chronic aquatic and wildlife habitat criterion in thirteen of the fourteen less than MDL reports. The reported selenium results range from <0. 001 to 0.007 mg/L with a median value of <0.005 mg/l based on all samples including less than MDL results.

Samples were acquired from two sites in No Name Arroyo, Upper No Name (upstream) and Lower No Name (downstream), during the 3 years of water monitoring conducted between 1998 and 2008. Samples were collected at the Upper No Name site on two dates in 1998 and on three dates in 2008 (~~Table 18.1-14).~~Table 18.1-15). Samples were collected at the Lower No Name site on three dates in 1998, one date in

2007, and one date in 2008 (~~Table 18.1-14).~~Table 18.1-15). On some of the sample dates, samples were obtained from more than one of the single-stage sample containers at a sampling location. The water at the upstream site (Upper No Name 3) is a sodium-bicarbonate type, while the downstream site (Lower No Name 1) is a sodium sulfate type (Figure 18.1-4 and Figure 18.1-5). Hardness ranged from 32 to 558 mg/L, with a median value of 106 mg/L. Conductivity ranged from 150 to 1,330 µS/cm, with a median value of 314 µS/cm. The conductivity results are consistent with the TDS concentrations, which ranged from 100 mg/L to 1,030 mg/L, with a median value of 353 mg/L. The pH ranged from 7.83 to 8.4 at the Upper No Name site, and ranged from 7.17 to 8.00 at the Lower No Name site. Dissolved aluminum ranged from <0.~~15~~1 to 1.65 mg/L. ~~Eight~~All four of ~~13~~the detections of dissolved aluminum ~~values are~~were elevated above the aquatic and wildlife habitat limit of 0.087 mg/L~~, but the detection~~. Also, the MDL of 0.1 mg/l is above the aquatic and wildlife habitat limit of 0.087 mg/L for the other ~~5~~9 samples~~ exceeded the limit.~~, which were reported as less than detection. This is often related to the high concentrations of some analytes that can interfere with detection of ~~other~~low concentration analytes ~~at very low concentrations~~resulting in high MDLs for the affected low concentration analytes.

Total suspended solids (TSS) values ranged from 367 mg/L to 395,000 mg/L, with a median value of 16,300 mg/L. The two samples collected on August 13, 1998 at the Lower No Name station also show increasing suspended solids with increasing flow as the #2 sampler is set at a higher intake stage. These samples also exhibit considerable variation in major ion concentrations between samples collected at different intake stages during the same runoff event. Dissolved iron concentrations ranged from <0.05 mg/L to 3.31 mg/L on No Name Arroyo, while total iron concentrations ranged from 3 to 6,020 mg/L on sampling at Upper No Name and 1 to 419 mg/L for sampling on Lower No Name. Boron concentrations ranged from <0.05 to 0.5 mg/L~~,~~ and fluoride concentrations ranged from 0.19 to 0.89 mg/L, ~~and dissolved~~with six of the 18 samples indicating fluoride at less than the MDL of 0.2 mg/l. Dissolved selenium was detected at a concentration of 0.001 mg/l in 5 of the 17 results reported in Table 18.1-14. Twelve of the selenium results indicated selenium at less than detection but the detection limits for these samples ranged from 0.001 to 0.01 mg/L. Total manganese concentrations ~~were less than 0.1 mg/L.~~ranged from 0.13 to 4.36 mg/L at the Upper No Name site, and from 0.02 to 25.5 mg/L at the Lower No Name site.

Analysis results of samples from two sites in Brimhall Wash were provided in the Burnham Mine Permit Application Package, on file in the Office of Surface Mining Library in Denver, Colorado. Seventeen samples were collected at the upstream site (Site N), and 19 samples were collected at the downstream site (Site M) between March 14, 1990 and January 8, 1995 (~~Table 18.1-15).~~Table 18.1-16). Both sites exhibit sodium sulfate-type waters (Figure 18.1-6), with a median hardness of ~~113 mg/L $CaCO_3$. Specific conductance varies substantially, with recorded results ranging from 142 to 27,800 µS/cm. The highest value was recorded following a large storm event on July 23, 1990. Excluding that value, the average~~

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~~specific conductance was 1,277 µS/cm. Total dissolved solids ranged from 10 to 27,500 mg/L, with a median value of 940 mg/L.~~146 mg/L $CaCO_3$ at Site M (downstream) and 111 mg/L $CaCO_3$ at Site N (upstream). A reading of 0.6 on 9/29/93 was filtered out of the data set. There is evidence that there was an inadequate quantity of the sample, and the pH reading was probably taken on an acidified sample. With the 0.6 pH outlier removed, the pH at Site N ranged from 6.95 to 8.2, with a median value of 7.93. The pH at Site M ranged from 7.16 to 8.58 with a median value of 7.96. Specific conductance and TDS vary substantially, with specific conductance results ranging from 142 to 27,800 µS/cm and TDS ranged from 360 to 24,600 mg/L at the two sites. Site N (upstream), the median TDS of 960 mg/L and the median specific conductance of 1210 µS/cm were higher than the medians at Site M (downstream). Three of 36 samples exhibited TDS levels above the relevant livestock use criterion of 3,000 mg/L (Lardy et.al. 2008).

Flows ~~at the sites were~~in Brimhall Wash are storm related and sediment laden. Total suspended solids at the two sites ranged from 11,800 to 128,420 mg/L, with a median value of ~~57,660~~112,960 mg/L~~.~~ at Site N (upstream) and 46,200 mg/l at Site M (downstream). Total iron values range from 0.27 to 7480 mg/L, with a median value of ~~202 mg/L.~~388 mg/L at Site N (upstream) and 23 mg/l at Site M (downstream). Total manganese values range from 0.2 to 13.8 mg/L with a median value of 0.83 mg/L at Site N (upstream) and 0.265 mg/l at Site M (downstream). Boron concentrations were all reported as less than detection, with detection limits varying from 2.5 to 5 mg/l. Fluoride concentrations ranged from ~~0.02 to 0.36 mg/L and fluoride concentrations ranged from~~ <0.1 to 2.0 mg/L, with a median of ~~0.9 mg/L.~~1.05 mg/L at Site N (upstream) and 0.65 mg/l at Site M (downstream). Total selenium was analyzed three times and was always less than the method detection limit at <0.005 mg/L~~, although the method detection limit for selenium slightly exceeds~~. One sample at Site M (downstream) was analyzed for dissolved selenium with a reported concentration of 0.03 mg/L. The dissolved selenium in the one sample and the method detection limit for total selenium in the other samples exceed the aquatic and wildlife habitat standard of 0.002 mg/L. Total mercury was detected in only one of four samples at a concentration of 0.0006 mg/L and was less than the method detection limit of 0.0005 mg/L in the other three samples. Both the detected value and the detection limit for total mercury exceed the chronic aquatic and wildlife habitat limit of 0.001 ug/L. This was also the case with total selenium, which had a detection limit of 0.005 mg/L, while the chronic aquatic and wildlife habitat criterion is 0.002 mg/L. Sulfate concentrations varied substantially, with results ranging from 29 to 18,100 mg/L and a median value of ~~356 mg/L.~~375.5 mg/L at Site N (upstream) and 356 mg/l at Site M (downstream). Six of 35 values for sulfate exceeded the relevant criterion for livestock use of 1,000 mg/L.

From a general water quality characterization perspective, the samples from the Pinabete Arroyo, No Name Arroyo, and Brimhall Wash monitoring locations (~~Table 18.1-13, Table 18.1-14, and Table 18.1-15~~Table 18.1-14, Table 18.1-15, and Table 18.1-16, respectively) appeared to exhibit higher concentrations of major ions and TDS in the first major runoff event of the season as compared to subsequent events. The results

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from the Upper No Name monitoring station show lower levels of TSS, settleable solids, TDS, and major ion concentrations than were observed at the Lower No Name station or at either of the Pinabete Arroyo monitoring stations. The sodium adsorption ratios were also lower in the samples taken from the No Name Arroyo stations as compared to the Pinabete Arroyo stations.

Changes in TDS and TSS concentrations at upstream and downstream locations on Brimhall Wash were evaluated in the Burnham Mine Permit Application Package on file in the Office of Surface Mining Library in Denver, Colorado (~~Table 18.1-16 and Table 18.1-17). These results show median TDS concentrations~~Table 18.1-17 and Table 18.1-18). These results were obtained from samples collected during the period from July 1979 through September 1982. These results show similar results for the upstream and downstream locations with a median TDS concentration of 845 mg/L at the upstream site (Site N) and 843 mg/L at the downstream site (Site M). Median TSS concentrations were 20,810 mg/L at the upstream site (Site N) and >20,000 mg/L at the downstream site (Site M). ~~Exceptionally high TSS concentrations were often associated with elevated TDS concentrations.~~

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The USGS monitored stream flow continuously over the period from November 1975 through September 1994 at Station 09367950 on the Chaco River near its mouth as shown on Exhibit 18.1-1. Suspended sediment concentrations were also monitored at this station over the period from October 1976 through September 1982. The stream-flow data show base flows ranging from 0 to 30 cfs during non-storm periods and annual peak storm flows ranging from 1,170 to 6,410 cfs. Discharges from Morgan Lake near the FCPP generate a perennial flow in this lower reach of the Chaco River. Suspended sediment concentrations vary with discharge and typically range from 300 to 5,000 mg/L, except during storm runoff events when concentrations typically range from 50,000 to 150,000 mg/L (USGS 2009).

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18.1.2 Lakes, Reservoirs, Other Water Bodies

There are no lakes or reservoirs within the permit area. However, there are ~~three~~four small impoundments within the permit area, one on a tributary to Cottonwood Arroyo and ~~two~~three on tributaries to Pinabete Arroyo as shown on Exhibit 18.1-2. These are stock watering ~~ponds~~ impoundments that catch surface flows from some tributary drainages. These impoundments extend across less than 2 acres each and are often dry. The stock water ponds are owned by the Navajo Nation and are not used for irrigation, consumption by humans, or purposes other than livestock watering.

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The small pond, on a tributary to Cottonwood Arroyo in Area 4 North on the northwest side of the permit area shown as ~~Pond 4N~~Gilmore Depression in Exhibit 18.1-2 has a limited drainage and is usually dry. Standing water has only been observed once in 15 years in the Gilmore Depression, and it was not sampled for water quality at that time. There are three impoundments within the Pinabete drainage; the Area 4N Pond, Area 4N/4S Pond, and Stevenson Well Pond. The Area 4N Pond is located on a tributary to the

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Pinabete Arroyo near the southwest boundary of the permit area. The Area 4N/4S Pond is located on a tributary to Pinabete Arroyo at the boundary between Area 4 North and Area 4 South as shown on Exhibit 18.1-2. The small stock impoundment on a tributary to Pinabete Arroyo designated as Stevenson's Well Pond provides a water source for local recharge of the alluvial well located immediately downgradient of the pond. ~~The third pond, located on a tributary to Pinabete Arroyo at the boundary between Area 4 North and Area 4 South, is designated as the 4N/4S Pond as shown on Exhibit 18.1-2.~~ Water samples ~~were~~have collected at ~~both~~three of these ~~ponds~~impoundments; the Area 4N Pond, Area 4N/4S Pond, and ~~at the Stevenson's~~Stevenson Well ~~Site pond~~Pond. The analytical results for the samples from these ~~ponds~~ impoundments are summarized in ~~Table 18.1-18.~~ Table 18.1-19.

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The concentration of dissolved aluminum in ~~one sample at~~ the two samples from Area 4N Pond and in five of six samples from the Area 4N/4S Pond ~~with a concentration of 0.38 mg/L~~ exceeded the chronic aquatic and wildlife limit of 0.087 mg/L. ~~The~~Also, for the sixth sample from the Area 4N/4S Pond, the selenium was reported as less than detection with a detection limit of 0.1 mg/l, which also exceeds the chronic aquatic and wildlife limit of 0.087 mg/L. The chronic aquatic and wildlife criterion for cadmium ~~limit~~ is hardness dependent. ~~There is no data~~Data on the hardness are available for some of ~~these~~the samples~~, but using~~ from these ~~ponds~~impoundments. Using the median hardness ~~along Pinabete~~ of ~~108~~77 mg/L for these pond samples, the dissolved cadmium chronic aquatic limit is 0.~~00026 mg/L (Table 18.1-11),~~00021 mg/L, which is exceeded by the concentrations observed in two of the five samples from the Area 4N/4S Pond and by two of the three samples from the Stevenson's Well Pond. The concentration of dissolved copper in two of the four samples from the Area 4N/4S Pond exceeded the estimated hardness dependent chronic aquatic and wildlife criterion for copper of 0.00716 mg/L. The concentration of ~~0.00107 mg/L at the 4N/4S Pond, and 0.01397~~dissolved lead in one of the five samples from the Area 4N/4S Pond exceeded the estimated hardness dependent chronic aquatic and wildlife criterion for lead of 0.00189 mg/L~~ at~~. The concentration of dissolved selenium in one of two samples from the Area 4N Pond exceeded the chronic aquatic and wildlife criterion for selenium of 0.002 mg/L. None of samples from the Area 4N/4S Pond exceeded the chronic aquatic and wildlife criterion for selenium of 0.002 mg/L but the detection limit of 0.01 mg/L reported for dissolved selenium in two of the four samples exceeded the criterion. Likewise, the detection limit of 0.01 mg/L reported for dissolved selenium in one of the three samples from the Stevenson's Well ~~Site pond~~Pond exceeded the chronic aquatic and wildlife criterion for selenium. Finally, the detected values for mercury and the detection limits for mercury in samples from all three ~~ponds~~impoundments exceeded the chronic aquatic and wildlife criterion for mercury. Samples collected in 2007 and 2008 from these ~~ponds~~ impoundments were also analyzed for pesticides and polychlorinated biphenyls (PCBs). These results show that pesticides and PCB values were below detection limits (Appendix 18.C).

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Other ~~ponds~~ impoundments are found within the study area but outside the permit area. The largest of these is the No Name Impoundment located on the No Name Arroyo channel at the intersection of Burnham Road (BIA Road 3005 and Navajo Road N-5082) and No Name Arroyo. This impoundment holds varying amounts of water depending upon the occurrence of storm runoff. Water containment is seasonal according to the monthly monitoring that occurred in 1997 and 1998. The No Name Impoundment contained water from December 1997 past June 11, 1998. When the water level in the impoundment was checked again on July 21, 1998, it was dry and appeared to have been dry ~~from~~for some time. Following storms on July 26, 1998, the impoundment refilled with water, reflecting the fact that storage in the impoundment is dependent on surface water inflow from storm events. Enhanced vegetation growth immediately downstream of the No Name Impoundment strongly suggests that localized groundwater is present due to seepage from the impoundment.

Water quality samples have been collected at No Name Impoundment. Grab samples were obtained monthly in 1998 from the No Name Impoundment when it contained water and was free of ice cover. The analytical results for the water quality samples from the impoundment are summarized in ~~Table 18.1-18,~~Table 18.1-19. Comparison of the monthly sample results shows higher concentrations of major ions, TDS, and Sodium Adsorption Ration (SAR) in April and May as the impoundment was drying up than in July and August after the impoundment was filled by major storm runoff events on July 26, 1998 and August 21, 1998. Based on these results, the water in the No Name Impoundment appears to be acceptable for livestock watering use even when concentrated by evaporation during storage. Data collected in 2007 and 2008 show PCB values were below detection limits (Appendix 18.C). There were elevated concentrations of dissolved aluminum above chronic aquatic and wildlife habitat standard. Cadmium chronic aquatic habitat standards are hardness dependent, and the No Name Impoundment had a median hardness of ~~117.5 mg/L $CaCO_3$ from 1998 sampling, which results in a standard of 0.00028 mg/L for cadmium. Dissolved cadmium concentrations were 0.00025 mg/L on April 10, 2008 and 0.01397 mg/L on August 12, 2008. The median hardness of 117.5 generates a chronic aquatic habitat standard of 0.01028 for copper, and the dissolved copper concentrations were 0.0285 mg/L on April 10, 2008 and 0.0088 mg/L August 12, 2008.~~46 mg/L $CaCO_3$ from the pond samples that have hardness results as reported in Table 18.1-19. The concentration of dissolved cadmium in one of the three samples from the No Name Impoundment exceeded the estimated hardness dependent chronic aquatic and wildlife limit for cadmium of 0.00014 mg/L. The concentration of dissolved copper in all three of the samples from the No Name Impoundment exceeded the estimated hardness dependent chronic aquatic and wildlife limit for copper of 0.00461 mg/L. The concentration of dissolved lead in one of the three samples from the No Name Impoundment exceeded the estimated hardness dependent chronic aquatic and wildlife limit for lead of 0.00107 mg/L. Finally, mercury was not detected in the analysis of three samples from the No Name Impoundment but the detection limits for mercury for these samples exceeded the chronic aquatic and wildlife criterion for mercury.

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18.1.3 Discharges into Surface Water Bodies

There are no springs, seeps, or man-made discharges into surface water bodies within or adjacent to the permit area.

18.1.4 Surface Water Resources Information Collection and Analysis

~~BNCC~~NTEC has obtained baseline information on flow and water quality of Cottonwood Arroyo at three stations CNS-1, CS-1 and CN-1 during the period from 1990 through 1999. ~~BNCC~~NTEC also implemented a baseline hydrologic monitoring program on Pinabete and No Name Arroyos in 2007 and 2008 to supplement monthly data collected in 1998. Water quality and flow information was obtained during this baseline monitoring program from two stream monitoring sites located near the permit boundary on Pinabete Arroyo and from two monitoring stations on No Name Arroyo near the mining lease boundary. Samples were also collected and analyzed for water quality at two impoundments located within the permit area and at the No Name Impoundment located on No Name Arroyo south of the permit area.

A crest-stage gage and single-stage sediment sampler were installed near the upstream and downstream permit boundaries on Pinabete Arroyo and No Name Arroyo. The locations of the crest stage gages and sediment samplers are shown on Exhibit 18.1-1. The designs of the single-stage sediment sampler and crest stage gage are shown in Figure 18.1-1 and Figure 18.1-2, respectively. Surveyed channel profiles and cross sections were established at the crest-stage gage locations. All water samples included field measurements of pH, temperature, and specific conductance. Water quality parameters, consisting of total suspended solids, settleable solids and ~~total dissolved solids~~TDS, dissolved and total iron and manganese, major cations and anions, 12 trace metals, 3 minor anions, and 2 radium isotopes. The sampling suite and associated data for Pinabete Arroyo and No Name Arroyo samples are summarized on ~~Table 18.1-12 and Table 18.1-13, respectively.~~Table 18.1-14 and Table 18.1-15, respectively. Quality assurance and quality control information for the 2007-2008 surface water data is provided in Appendix 18.D.

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Channel profiles and cross sections at the crest stage gage locations were surveyed in 2007 and compared to the survey performed in 1998. This comparison provided limited evidence of midterm morphological changes for the project area and provided insights into channel stability~~.~~ (Appendix 18.A).

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18.2 Groundwater Resources

The groundwater baseline assessment provides a description of the pre-mine conditions for each water-bearing stratum, including the coal seams and any potentially impacted strata below the lowest coal seam to be mined. The baseline assessment also establishes the foundation for the determination of probable hydrologic consequences for the surface coal mine operation (Section 41, Probable Hydrologic

Consequences) and for the design of water monitoring and mitigation plans that may be needed to ensure that there is no material damage to groundwater resources.

A number of studies of the geology and groundwater hydrology have been conducted by the New Mexico Bureau of Mines and Geology and the USGS in the vicinity of the permit area. ~~BNCC~~NTEC has also conducted extensive drilling and exploration within its mining lease, which, together with data from the nearby Navajo Mine, provide information about the geology and groundwater hydrology of the area to be mined. ~~BNCC~~NTEC has also implemented a groundwater monitoring program (Section 42, Monitoring, Maintenance, Inspections, and Examinations) to obtain site-specific information on groundwater levels, aquifer characteristics, and groundwater quality to supplement the existing information.

18.2.1 Springs, Seeps, and Other Groundwater Discharges

Direct recharge of overburden is quite low due to the arid climate with average annual precipitation of less than 6 inches and annual evaporation rate of about 55 inches (Section 12, Climate). Recharge rates measured by chloride mass balance methods on undisturbed areas at the nearby Navajo Mine ranged from 0.002 to 0.09 in/yr (Stone 1987). Due to the very low rates of recharge, groundwater discharge rates are also quite low and insufficient to sustain base flow at any streams in the vicinity of the permit area, including the Chaco River.

Site reconnaissance and review of springs identified by the New Mexico Office of the State Engineer (NMOSE) (2010) Navajo Settlement Agreement found no springs within or adjacent to the permit area. Several springs were identified outside the adjacent area as shown on ~~Exhibit 18.2-1,~~Exhibit 18.2-1 and are owned by the Navajo Nation. One spring, S-0846 (BIA NO. U-30), was identified about 2.5 miles north of the permit area, immediately west of Navajo Mine Area 3 on Lowe Arroyo. The use of this spring was listed as unknown and the spring was not found during site reconnaissance. Also, the Cottonwood Springs, BIA designations 13R-103 and 13R-104, are identified as spring S-0127 in the NMOSE (2010) Navajo Settlement Agreement. These springs are on upper Cottonwood Arroyo about 4.2 miles northeast of the permit area. Finally, two springs, #52 and #53, were identified in an inventory of wells and springs conducted by Billings and Associates, Inc. (BAI) in ~~1985~~1987 for the Navajo Mine. The approximate locations for these springs from the BAI inventory are shown on Exhibit 18.2-1. It is possible that these springs may be the same as the Cottonwood Springs since a number of the springs and wells in the BAI inventory were not mapped accurately. The ownership of springs #52 and #53 is also attributed to the Navajo Nation.

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An intermittent artificial seep was also identified during the site reconnaissance at a location immediately below the surface impoundment on No Name Arroyo. Enhanced vegetation, consisting of dense salt cedar, brush, and grass, occurs for several hundred feet downstream of the No Name impoundment. This seep is

the result of the surface impoundment and not a location of groundwater discharge and is not shown on Exhibit 18.2-1. One location for potential groundwater discharge was identified during the site reconnaissance by enhanced vegetation growth and salt deposits along the on the channel bed and banks at a location on Pinabete Arroyo approximately 1,400 feet upstream of the Burnham Road crossing. These features suggest the presence of a groundwater discharge that is insufficient to sustain flow (Brown 1976). The groundwater source may be from the No. 8 coal seam, which outcrops in the vicinity of this location or it could be from the alluvium, which is known to be partially saturated upstream near the eastern permit boundary at alluvial well PA-1. It is unlikely that these salt deposits are due to evaporation of residual runoff because they occur along the channel bed and bank, not in depressions, and do not extend upstream or downstream of this isolated location.

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Groundwater flow directions in the Pinabete alluvium follow the surface water down gradient towards the Chaco River. However, there are no indications of groundwater discharge along the Chaco River in the vicinity of Pinabete Arroyo. The only springs and seeps noted along the Chaco River are far to the north near the FCPP where Stone et.al. (1983) report that several short reaches of the Chaco River flow due to springs issuing from the alluvium. This surface water flow is discussed in Section 18.1.1.

Based on the potentiometric surfaces presented in Section 18.2.4, flow directions in the Fruitland coals are toward the north-northeast. Potentiometric gradients in the Pictured Cliffs Sandstone (PCS) are toward the north. The northerly gradients in these potentiometric surfaces are influenced by the topographic low along the San Juan River valley. There may also be some local influence of topographic lows along the Chaco River tributaries on potentiometric gradients in these units. Potential rates of discharge from these bedrock units are extremely low due to the low recharge rates and low hydraulic conductivity of these units.

18.2.2 Wells

An inventory of water supply wells located within and adjacent to the permit area was prepared from well information from a several sources. The sources include the water supply wells identified by the NMOSE (2010) Navajo Settlement Agreement, the inventory of wells conducted by Billings & Associates, Inc. (BAI) in ~~1985~~1987 for the Navajo Mine, wells identified in the "Groundwater Operations Manual and Well Survey for Navajo Mine and Vicinity" that was completed by Metric Corporation (1991), and wells found in review of permits on file at the Navajo Nation Water Resource Management office in Fort Defiance, Arizona.

The study area for the inventory presented in this section extends from Chaco River and its alluvium on the west to about four miles east of ~~BNCC~~NTEC's mining lease shown in Exhibit 18.2-1. Relevant information on the wells shown in Exhibit 18.2-1 is provided in Table 18.2-1. Wells that were installed for the sole purpose of monitoring are not shown on Exhibit 18.2-1. These monitoring wells, including the

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monitoring wells that have been abandoned, are depicted on Exhibit 18.2-2. Although the completion zone for some of the wells is not specified in the information sources, it is believed that almost all of the water wells located within the study area are completed within the alluvium of the Chaco River, Pinabete Arroyo, and Brimhall Wash due to their locations on Exhibit 18.2-1. Only four of the wells in Table 18.2-1 are believed to be completed in bedrock formations. Well 13-AW (13T-513) is a flowing artesian oil and gas well that was converted to stock water use that is sourced from bedrock below the PCS, most likely from the Menefee Formation. ~~The completion zone for well W-606,~~This well was included in the well survey by Metric Corporation (1991) and the coordinates and condition of the well were field verified. At the time of the survey the well was operational and flowing. The well depth from top of casing was measured at 530 feet. The completion zone for well W-606 (13-15-1), located in Area 5 of the ~~BNCC~~NTEC mining lease, is not specified. This well was capped and welded shut during the site reconnaissance and the well depth could not be measured. However, based on the depth reported by Metric Corporation (1991), this well may be completed within the PCS. Likewise, Tribal Well 13-7-2, located approximately 300-feet south of the Burnham Chapter House, is a PCS well that was originally installed for water supply for Burnham. It was replaced and abandoned due to poor yield and poor water quality. Finally, Well #90, located along the Chaco River north of Brimhall Wash, was identified ~~as a PCS well in the BAI inventory for Navajo Mine. These water-bearing units are deeper than the PCS but it is possible that the uppermost screen interval in this well could be within the PCS.~~in the BAI survey for Navajo Mine as a PCS well with a depth of 131 feet.

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The following three water wells were indicated to be within the permit area from one or more of the various sources of available information used for the well inventory:

- Well W-0345 (13R-48) is a dug alluvial well located on Pinabete Arroyo west of the Burnham Road. This well includes a hand pump and tank and is used for stock watering.
- Well #70 is identified in the ~~1985~~1987 BAI inventory for the Navajo Mine as a dug alluvial well. This well could not be found in the site reconnaissance and alluvium does not exist at the location identified by BAI.
- Well W-0343 (13-5-1) is an alluvial well located on a tributary to Pinabete Arroyo adjacent to the Burnham Road. This well is recharged by an adjacent man-made pond (Stevenson Well Pond) and is equipped with a hand pump. This well is also referred to as the Stevenson Well.

Well W-0344 (#93) identified as a Pinabete alluvial well several hundred feet south of the permit area at a location adjacent to the Burnham Road was not found in the site reconnaissance.

18.2.3 Aquifers and Other Groundwater Resources

The hydrogeologic units within and adjacent to the permit area that could potentially be affected by proposed mining and reclamation within permit area include:

- The alluvium of the Chaco River, Cottonwood Arroyo, and Pinabete Arroyo
- The coal seams of the Fruitland Formation
- The Pictured Cliffs Sandstone (PCS), located below the Fruitland Formation No. 2 coal seam

Alluvial fill deposits occur in the valley bottoms of the Cottonwood Arroyo and Pinabete Arroyo, within the permit area, along the Chaco River to the west of the permit area and along portions of No Name Arroyo southwest of the permit area. However, these deposits are not considered Alluvial Valley Floors (AVF). Refer to Section 19 (Alluvial Valley Floors) for information on the negative determination for AVF within and adjacent to the permit area. Portions of the alluvium of Cottonwood Arroyo and Pinabete Arroyo are saturated and will yield water to wells, as evidenced by the dug wells completed in the alluvium of both the Cottonwood Arroyo and Pinabete Arroyo as indicated in Section 18.2.2 (Exhibit 18.2-1). The alluvium of the Chaco River also contains groundwater as indicated by the dug wells located adjacent to the Chaco River (Exhibit 18.2-1). As stated in Section 18.2.1, the groundwater is not sufficient for sustained base flow in any of these drainages.

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The alluvium of No Name Arroyo was found to be dry based on alluvial monitoring well GM-23, which was installed in 1976 in association with a proposed coal gasification project and screened only in the alluvium of No Name Arroyo. This well was plugged and abandoned in 1994 by ~~BNCC~~NTEC at the request of the OSM. Two new alluvial monitoring wells, NNA-1 and NNA-2, were installed in 1998 at locations upstream and downstream of the No Name Impoundment as shown in Exhibit 18.2-2. Water level monitoring data from these wells further support the dry character of the alluvium along No Name Arroyo. However, saturated conditions may occasionally occur within the alluvium of No Name Arroyo for a relatively short distance downstream of the No Name Impoundment due to seepage from the impoundment. The No Name Impoundment is discussed in Section 18.1.2.

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Groundwater is also found in the coal units of the Fruitland Formation and in the PCS, which underlies the Fruitland Formation in the permit area. The geologic strata within the permit and adjacent area dip gently to the east toward the center of the San Juan Basin at an angle of 1 to 2 degrees. A more thorough description of the regional and localized geology of the permit area is provided in Section 17 (Geologic Information). Based on both regional and site-specific information, the Fruitland Formation and associated coal units, and the PCS are unsaturated or partially saturated near the outcrop of these units on the western side of the permit area but become saturated to the east and down dip of the outcrop.

Based on baseline information obtained from water level elevations measured in the wells and piezometers, the general groundwater flow directions in the Fruitland Formation within Area 3, Area 4 North, Area 4 South, and Area 5 of the ~~BNCC~~NTEC mining lease are vertically downward through the interbedded shale and coal units of the Fruitland Formation and into the PCS and laterally within individual coal seams

toward the north-northeast with some localized flow toward the topographic lows along the Cottonwood Arroyo and Pinabete Arroyo. Although the vertical hydraulic conductivities of the interbedded shales in the Fruitland Formation are quite low, recharge rates are lower still. Direct recharge rates measured by chloride mass balance methods on undisturbed areas at the Navajo Mine ranged from 0.002 to 0.09 in/yr (Stone 1987). The highest recharge rate of 0.09 in/yr was for valley terraces while the lowest recharge rate of 0.002 in/yr was for badland areas. Recharge from upland flats averaged 0.03 in/yr. Based on the research by Kearns and ~~Hendricks~~Hendricks (1998), areal recharge is thought to occur during very large precipitation events and during extended wet periods with increasing soil moisture. Recharge is expected to be higher from saturated alluvium and surface impoundments. Although Stone's research (1986 and 1987) did not include recharge estimates for surface impoundments, it does provide an estimate of an average recharge rate of 0.16 in/yr from depressions within reclaimed mine areas at the Navajo Mine.

Based on ~~BNCC~~NTEC's mining experience at Navajo Mine, the coals, overburden, and interburden in the Fruitland Formation are not expected to yield much water during mining. The saturated sands that occur in the Fruitland Formation are of limited extent and only yield significant water when recharged by water from the NIIP. NIIP influences do not extend into the drainages associated with the permit area, although the North Fork of the Cottonwood Arroyo does receive direct discharges of water from irrigation canals. The direct discharges occur when an over supply of water in the canal is released directly to the stream channel. Direct discharge is highly variable, occurs quickly, and can last up to 12 hours. However, usually there is no flow in Cottonwood Arroyo and it retains the characteristics of an ephemeral stream. The pre-mine groundwater in the Fruitland Formation throughout most of the ~~BNCC~~NTEC mining lease will not support beneficial use because of the very low well yields and poor water quality. As indicated in ~~Section~~ Section 18.2.2, there are no known water supply wells completed in the Fruitland Formation within or adjacent to the permit area.

The PCS is a well-cemented, low-permeability, marine sand and is the first water-bearing unit below the lowest coal seam to be mined (No. 2 coal seam). Based on the information in Section 17 (Geologic Information), the PCS is approximately 110 to 120 feet thick and follows the structure of the Fruitland Formation, dipping to the east at approximately 2 degrees, although the structure varies locally. The PCS conformably overlies the Lewis Shale, with the contact marked by a zone of interbedded sandstones and mudstones in the lower part of the PCS (Stone et.al. 1983). It outcrops just west of the mine area and east of the Chaco River. Within and adjacent to the permit area, the general groundwater flow in the PCS is toward the north. The PCS is also a natural gas reservoir in the San Juan Basin. Stone et.al. (1983) state that the PCS cannot be considered a major aquifer and it is important only because it is the water-bearing horizon immediately underlying the coals in the Fruitland Formation.

Water yields from monitoring wells completed in the PCS at the ~~BNCC~~NTEC's mining lease are quite low. Two of the PCS wells, KPC2007-2 and KPC2007-3, installed within the ~~BNCC~~NTEC Navajo mining lease south of the permit area were quickly pumped or bailed dry during conventional sampling. The yield from PCS monitoring well KPC98-01, located west of the permit area wells was sufficient to sustain a rate of about 0.4 gallons per minute (gpm) during a constant rate pumping test. The fourth PCS monitoring well KPC2007-01 was installed within the permit area. This well was pumped dry after about 140 minutes during a constant-rate pumping test at a rate of about 0.95 gpm with most of the pumped water derived from well bore storage.

There are no known water supply wells completed in the PCS within or adjacent to the permit area. As indicated in Section 18.2.2, one water supply well, 13-7-2, was installed in the PCS south of the ~~BNCC~~NTEC mining lease near the Burnham Chapter House as shown in Exhibit 18.2-1. This well was originally completed as a water supply for the Burnham Chapter House but was replaced and abandoned due to the poor yield and poor water quality. ~~Another well, 13-15-1,~~Well #90, located west of the permit area and Chaco River, was identified in the BAI survey for Navajo Mine as domestic and stock use. Another well, W-0606 (13-15-1), located south of the permit area and within Area 5 of ~~BNCC~~NTEC's mining lease could also be screened in the PCS as discussed in Section 18.2.2. This well has been identified as a stock well.

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18.2.3.1 Groundwater Quantity

Monitoring wells and vibrating wire piezometers (VWPs) were installed in the Fruitland coal seams, in the alluvium of Pinabete Arroyo and No Name Arroyo, and in the PCS in 1998 and in 2007 for baseline hydrogeology characterization of Area 4 South and Area 5 of ~~BNCC~~NTECs mining lease. The No. 3 coal seam was the target for much of the characterization of the Fruitland Coal because the No 3 coal seam is continuous over most of Area 4 South and Area 5 of the ~~BNCC~~NTEC mining lease. The No. 2 and No 3 coal seams are hydrologically connected and sometimes merge within the mining lease area. Three monitoring wells and three VWPs were installed in the No. 3 coal seam. Four VWPs were also installed within the No. 2 coal seam within Area 4 South and Area 5 of the ~~BNCC~~NTEC mining lease.

The upper coal seams (Nos. 6, 7, and 8) do not exist over the entire lease area but outcrop toward the western limits of the mine lease and are washed out within portions of the drainages, particularly along Pinabete Arroyo. The No. 8 coal seam is typically the thickest coal seam and is believed to exhibit the highest hydraulic conductivity of the coals. All coal seams include splits and partings, although these are most extensive in the No. 8 coal seam as indicated in Section 17 (Geologic Information). The No. 8 coal seam depicted in the cross sections in Exhibit 18.2-2 includes splits and partings. The groundwater monitoring and hydrogeologic characterization program for Area 4 South and Area 5 of ~~BNCC~~NTEC's

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mining lease also included the installation of one monitoring well and one VWP in the No. 8 coal seam, one VWP in the No. 7 coal seam and one VWP in the No. 6 coal seam.

Four monitoring wells and four VWPs were installed in the PCS within Areas 4 South and 5 of the ~~BNCC~~NTEC mining lease. Well KPC2007-03 was installed to measure water levels within the PCS at the western boundary of the ~~BNCC~~NTEC mining lease. The 2007 drilling program work plan called for installation of a No. 2 coal monitoring well at this location along the western boundary of the ~~BNCC~~NTEC mining lease. However, the No. 2 coal seam was observed to be dry during drilling at this location so the well was completed in the upper part of the PCS to monitor water levels. The PCS well KPC2007-02 was installed to measure water levels and to characterize baseline water quality within the PCS up gradient of Area 4 South. Sampling of this well found high pH and elevated calcium, which is an indication of well-grout influence. Consequently, this well has been used only for water level monitoring in the baseline program. The PCS well KPC2007-01 was installed to measure water levels and to characterize baseline water quality within the PCS within the permit area. The VWPs were installed to measure potentiometric levels within the PCS and various coal units within the permit area. Completion diagrams for the monitoring wells installed in years 1998 and 2007 as well as VWPs installed in 2007 are provided in Appendix 18.E.

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Historical water level data collected during the mid-1970s are also available for six wells that were completed in the PCS within or adjacent to the ~~BNCC~~NTEC mining lease for a previously proposed project. The locations for these PCS monitoring wells are shown on Exhibit 18.2-2. Historical baseline water quality data were also obtained at five of these PCS wells. These PCS monitoring wells and piezometers were plugged and abandoned in 1994. Historic water level monitoring data and pumping test data are also available for the PCS well O-1, located at the Burnham Mine situated southeast of ~~BNCC~~NTEC mining lease as shown on Exhibit 18.2-2. These data, together with data from the adjacent Navajo Mine and other regional sources, supplement the recent baseline groundwater information obtained for Area 4 South and Area 5 of ~~BNCC~~NTEC's mining lease.

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18.2.3.1.1 Alluvial Aquifer Information

Baseline monitoring of the alluvium of Cottonwood Arroyo was conducted at four alluvial well monitoring locations shown on Exhibit 18.2-2. Baseline water quality information obtained prior to year 1983 from the monitoring wells GM-17 and QACW-2 (GM-18) are included in Appendix 6-C of the Navajo Mine PAP (BNCC 2009). Well GM-17 is completed in the alluvium of North Fork of the Cottonwood Arroyo. A dug well, GM-18, completed in the alluvium of Cottonwood Arroyo west of the permit area, was converted for use as a monitoring well and is designated as QACW-2 in ~~Exhibit 18.2-2~~Exhibit 18.2-2. This well was included in the Navajo Mine quarterly monitoring program (OSM Permit No. NM-0003F) (BNCC 2009). However, the well is usually dry and relatively few samples have been obtained during baseline

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monitoring. Water quality samples could not be obtained from alluvial monitoring well QACW-1 because it was dry or had insufficient water for sampling during baseline monitoring from 1987 through 1998. The well was subsequently removed by the advance of mining operations in Area 3. ~~BNCC~~NTEC has also performed baseline monitoring of well QACW–2B completed in the alluvium of Cottonwood Arroyo west of the permit area as shown in Exhibit 18.2-2. This well is a dug well that has been used for stock water supply and is not owned by ~~BNCC~~NTEC.

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Two alluvial monitoring wells, PA-1 and PA-2, were installed in 1998 within the alluvium of Pinabete Arroyo near dug water wells at the locations shown on Exhibit 18.2-2. Two alluvial monitoring wells, NNA-1 and NNA-2, were also installed in the alluvium of No Name Arroyo at locations upstream and downstream of the No Name Impoundment as shown on Exhibit 18.2-2.

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Water levels were measured monthly at each of the alluvial monitoring wells. Table 18.2-2 summarizes the water level readings in each of the Pinabete alluvial monitoring wells during the baseline monitoring program. The water level readings in each of the Cottonwood alluvial monitoring wells during the monitoring period are summarized in Table 18.2-3. The No Name alluvial well NNA-2 has been dry during the entire baseline monitoring program. The No Name alluvial well NNA-1, located down gradient from the No Name Impoundment, has been dry except during the latter half of 1998 when seepage associated high water levels in the impoundment provided a source of water for the alluvium at this well. The data for the Pinabete alluvial wells show a decline in water levels during the spring and early summer of 1998 followed by a rise in water levels due to thunderstorm runoff events in late summer and fall of 1998. In 2007, water levels declined slightly from August through December.

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Well completion and aquifer test results for the alluvial monitoring wells are summarized in Table 18.2-4. Well completion diagrams for the Pinabete and No Name alluvial wells are provided in Appendix 18.E. Well completion diagrams could not be found for the Cottonwood alluvial wells. Aquifer test data and interpretation results for the monitoring wells installed in year 1998 are provided in Appendix 18.F. The calculated or measured hydraulic conductivities for the Pinabete Arroyo alluvium of 51.3 feet per day (ft/day) (1.8×10^{-2} centimeter per second (cm/sec)) and 11.1 ft/day (4.1×10^{-3} cm/sec) are within the range expected for clean sand and are considerably higher than the bedrock values in the area. Well yields from the alluvium, however, are limited by a very low saturated thickness of about 5 feet or less.

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Saturated thickness in the No Name alluvial wells was insufficient to permit a pumping test or slug test. The hydraulic conductivity of the No Name alluvium is expected to be considerably lower than the Pinabete Arroyo alluvium due to the high percentage of fine-grained alluvial silts and clays, as evidenced by the well logs. Slug Tests or pumping tests were never performed on the Navajo Mine monitoring wells in the alluvium of Cottonwood Arroyo. Well completion records could not be found for any of these wells.

Two of the monitoring wells in the alluvium of Cottonwood Arroyo (QACW-2 and QACW-2B) are dug wells that were converted for monitoring. Well QACW-1 was dry and has been mined through. Well GM-17 is completed in the alluvium of the North Fork of Cottonwood and is not hydrologically adjacent to the Pinabete Permit Area. Interpretation of pumping test or slug test on these wells would be problematic without well completion details.

18.2.3.1.2 Fruitland Formation Information

Groundwater production from the Fruitland coal seams is quite limited. The majority of exploration drill holes through the Fruitland Formation within ~~BNCC~~NTEC mining lease Area 4 South and Area 5 did not yield measurable groundwater during drilling. Measurable water was encountered at a few locations. Specifically, three boreholes located within the northeast portion of Area 4 South produced water at rates estimated at greater than 10 gpm. This groundwater is believed to be associated with the No. 6 and the No. 8 coal seams. Measurable water was also encountered in the No. 8 coal seam during completion of the No. 3 Coal seam well KF-98-03. At this location, groundwater was first encountered in the unconsolidated sand and gravel above the No. 8 coal seam at a depth of about 22 feet. The No. 8 coal seam was encountered in the depth interval from 24 to 38 feet. Water was produced at a rate of about 2 to 3 gpm from the coal and the overlying sand and gravel.

In 2007, well KF2007-01 was completed in the No. 8 coal seam to characterize the groundwater near the permit boundary to the east of the No. 3 coal seam well KF-98-03. Well KF2007-01 is the only coal seam well within ~~BNCC~~NTEC mining lease Area 4 South and Area 5 with sufficient yield to permit the application of a constant rate pumping test to determine hydraulic characteristics of the coal. The water yields from wells KF-98-02, KF-98-03, and KF-98-04, completed in the No. 3 coal seam, are all very low and these wells are quickly pumped or bailed dry during conventional sampling. The locations for the four additional coal monitoring wells are shown on Exhibit 18.2-2, along with the wells previously installed for groundwater monitoring within Area 3 at the Navajo Mine. Completion diagrams and lithologic logs for these additional coal monitoring wells are provided in Appendix 18.E.

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Potentiometric elevations measured at the monitoring wells and VWPs completed in the Fruitland coal seams within ~~BNCC~~NTEC mining lease Area 4 North, Area 4 South, and Area 5 are provided in Table 18.2-5. Wide fluctuations in water levels in the No. 3 coal seam wells occurred during the 1998 monitoring period. These fluctuations were the result of well development, aquifer testing, and sampling. A considerable amount of time is required for water levels in these wells to approach equilibrium due to the low hydraulic conductivity of the coal. Quarterly sampling using micro-purge sampling techniques was performed for the sampling program starting in 2007 so that the magnitude of fluctuation resulting from sampling was limited.

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Well KF-98-04 was designated to be screened in the first saturated bedrock unit adjacent to the alluvium of Pinabete Arroyo near alluvial well PA-1. The purpose of this well was to help evaluate the relationship between water levels in alluvium and water levels in the bedrock underlying the alluvium. The first saturated bedrock below the alluvium was at a depth of about 63 to 64 feet in the No. 3 coal seam, demonstrating that the saturated alluvium within the Pinabete Arroyo at this location is perched above the underlying unsaturated bedrock. Monitoring well KF-98-04 has remained dry throughout most of the 2007-2008 monitoring period, with only 0.1 foot of saturation recorded on October 4, 2007.

Static water level readings could not be obtained monthly at well KF-98-03 after October 4, 2007 because this well was being periodically purged and bailed as part of a program to remove influence from grout that may have penetrated portions of the sand pack surrounding the screened interval in this well. This well and two of the new PCS wells (KPC2007-02 and KPC2007-03) exhibited low yield and pH levels ≥ 12, indicating that the annular space cement grout may have penetrated the bentonite seal on top of the sand pack surrounding the screened interval in these wells during well completion. The grout penetration is believed to be the result of the low hydraulic heads in the coal combined with the high-pressure head of the grout seal placed in the annular space. The monitoring wells with the largest annular cement interval are also the wells with unusually high pH values that are indicative of grout intrusion. The low yield of the No. 3 coal seam at well KF98-03 has also limited the prospect of grout removal by well purging. Consequently, in the fall of 2007, acid treatment was used to remediate cement contamination of the monitoring well sand pack materials. Due to the very low yield at these wells, bailing and purging of wells KF-98-03 and KPC2007-02 have continued, reducing the times when static water level measurements could be taken at these wells.

In 1998, a displacement (slug) test was performed at well KF-98-02 and bailed recovery tests were conducted at wells KF-98-03 and KF-98-04 to determine transmissivity and hydraulic conductivity in the No. 3 coal seam. Test results found very low transmissivity values ranging from 0.01 to 0.001 square feet per day (ft^2/day) and hydraulic conductivity values ranging from 0.002 to 0.00013 ft/day ($3.5x10^{-7}$ to $4.6x10^{-8}$ cm/sec) as summarized in Table 18.2-6. These values are consistent with the hydraulic conductivity values of 0.001, 0.002, 0.0014, and 0.003 ft/day estimated for the No. 2, No. 3, and No. 4-6 coal seam wells, respectively, at the KF84-22 well series located at the Navajo Mine Area 4 North (Table– 18.2-6). Well KF84-22A was not tested at this location but hydraulic conductivity values ranging from 0.004 to 0.06 ft/day ($1.4x10^{-5}$ to $1.4x10^{-6}$ cm/sec) with a geometric mean of 0.033 ft/day ($1.16x10^{-5}$ cm/sec) were estimated from tests at three No. 8 seam coal wells (SJKF84#3, SJKF84#4, and SJKF84#5) located adjacent to the Navajo Mine. These results are comparable to the hydraulic conductivity value of 0.056 ft/day ($2x10^{-5}$ cm/sec) estimated for the No. 8 coal seam well KF2007-01 as described in Appendix– 18.F and summarized in Table 18.2-6.

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In a separate set of tests, the transmissivity and hydraulic conductivity values calculated from the observation well response during a pumping test of the No. 8 coal seam well, G-20, located at the San Juan Mine were 0.017 ft^2/day and 0.001 ft/day ($3.5x10^{-7}$ cm/sec), respectively (San Juan Coal Company 2009). These results for the hydraulic conductivity of No. 8 coal at the San Juan Mine are lower than the values from well tests at ~~BNCC~~NTEC's mining lease. However, the observation well response from the pumping test for this well at the San Juan Mine is useful because it provides a reliable estimate for the storage coefficient of $4.2x10^{-4}$ for the No. 8 coal seam.

Potentiometric elevations in the saturated coal units and the underlying PCS were also measured using VWPs installed at five locations throughout ~~BNCC~~NTEC's mining lease in Area 4 South and Area 5 as shown on Exhibit 18.2-2. VWP construction details are provided in Appendix 18.E. Potentiometric elevations measured at the VWPs completed in the coals are summarized in Table 18.2-5. The December 2007 measurements of potentiometric elevations in the coal wells and VWPs were used to estimate the potentiometric surface for the No. 3 and No. 8 coal seams at the site as presented in Exhibit 18.2-3 and Exhibit 18.2-4, respectively. The potentiometric levels measured on July 6, 1989 at the No. 2 and No. 3 coal seams at the KF84-22 well series located north of the permit area were also used in developing the potentiometric surfaces in these exhibits. The potentiometric gradients in both the No. 2 and No. 3 coal units indicate groundwater flow components toward the north-northeast in the vicinity of these monitoring wells and piezometers.

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Potentiometric gradients in the upper coal seams in the vicinity of the permit area are expected to be generally toward the northeast, similar to the gradients observed in the No. 2 and No. 3 coals, although local gradients may be influenced by the lower elevations along Pinabete Arroyo, No Name Arroyo, and Cottonwood Arroyo. The No. 6, No. 7, and No. 8 coal seams outcrop along the valleys of Pinabete Arroyo, No Name Arroyo, and Cottonwood Arroyo within the mining lease area. Field observations of salt deposits and enhanced vegetation production suggest that local discharge may occur from the No. 8 coal at the coal subcrop beneath the Pinabete alluvium as discussed previously in Section 18.2.1.

Potentiometric elevations in the monitored coal units and in the underlying PCS were plotted for four of the nested VWP locations, to depict vertical gradients and possible seasonal patterns. Plots were not prepared for the VWP2007-4 location for the reason that only one VWP was installed in the PCS at this location because the overlying Fruitland coal units appeared to be dry during piezometer installation. Figure 18.2-1 shows consistent potentiometric elevations over time for the No. 2 coal seam and the PCS at location VWP2007-05. The slightly higher potentiometric elevation in the PCS indicates a slight upward gradient from the PCS to the Fruitland Formation at this location.

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A plot of the potentiometric levels in the No. 2 and No. 3 coal seams and the PCS at well VWP2007-03 is provided in Figure 18.2-2. The results show consistent downward gradients from the No. 3 coal seam to the PCS. The wide fluctuation in potentiometric levels in well KPC2007-02 is due to the bailing and purging of this well. Figure 18.2-3 shows the potentiometric levels in the PCS and in the upper and lower coal units at the VWP2007-02 location. The results show high downward gradients from the No. 8 coal seam to the No. 3 coal seam and slight upward gradients from the PCS to the No. 3 coal seam.

A plot of potentiometric elevations in the PCS and in No. 6, No. 3, and No. 2 coal seams at well VWP2007-01 is provided in Figure 18.2-4. The results show consistent downward gradients from the No. 6 coal to the PCS, with the highest vertical gradients between the No. 6 and the No. 3 coal seams. The plot also includes water levels measured in the PCS well KPC2007-01 at the VWP2007-01 location. Measured water elevations in well KPC2007-01 are consistently about 6 feet lower than the potentiometric elevation measured in the PCS at VWP2007-01. The VWP in the PCS at this location is installed at the top of the PCS, while the well screen and filter pack extend through about 75 feet of the PCS. The difference between the two measurements suggests that hydrostatic heads are higher at the top of the PCS at this location and decline with depth. Thus, downward gradients are believed to continue through the PCS at this location.

18.2.3.1.3 Pictured Cliffs Sandstone Information

The PCS underlies the Fruitland Formation and follows the structure of the Fruitland coal seams. The PCS is a marginal water resource due to the low permeabilities, poor water quality, gas production, and low yields (Stone et.al. 1983). The PCS conformably overlies and intertongues with the Lewis Shale. As discussed previously, the PCS appears to be on the order of 110 to 120 feet thick within ~~BNCC~~NTEC's mining lease Areas 4 North, Area 4 South, and Area 5.

Well KPC-98-01 was installed in 1998 west of the permit area near the PCS outcrop at the location shown in Exhibit 18.2-2. In 2007, wells KPC2007-01, KPC2007-02, and KPC2007-3 were completed in the PCS at the locations shown in Exhibit 18.2-2. Completion diagrams and lithologic logs for these PCS wells are provided in Appendix 18.E.

VWPs were installed in the PCS at four of the five VWP locations as shown on Exhibit 18.2-2. A VWP was not installed in the PCS at the VWP2007-03 location because monitoring well KPC2007-02 was installed in the PCS at this location. Construction diagrams and lithologic logs for these VWP installations are provided in Appendix 18.E. Potentiometric elevations measured at the PCS wells and the VWPs installed in the PCS are summarized in Table 18.2-7.

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Historical water level data collected during the mid-1970s are also available in a report by Science Application, Inc. (1979) for six wells that were completed in the PCS within or adjacent to Area 4 North, Area 4 South, and Area 5 of ~~BNCC~~NTEC's mining lease (Table 18.2-8). These abandoned PCS monitoring wells are designated as GM wells with water elevations shown on Exhibit 18.2-5. These PCS monitoring wells and piezometers were plugged and abandoned in 1994. Historic water level monitoring data are also available for the PCS monitoring well O-1 located at the Burnham Mine southeast of ~~BNCC~~NTEC's mining lease as shown in Exhibit 18.2-2.

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The December 2007 measurements of potentiometric elevations in the PCS wells and VWPs installed in the PCS were used to estimate the potentiometric surface presented in Exhibit 18.2-5. The potentiometric elevations measured during the 1970s at the abandoned PCS monitoring wells were also used to develop this potentiometric surface for the PCS. The potentiometric gradients in PCS indicate an overall northerly gradient. There is a slight easterly component in the gradients at the southern end of the site due to a structural high in the PCS along the southeast perimeter of Area 5 of ~~BNCC~~NTEC's mining lease. There are also local gradients toward the topographic lows along No Name Arroyo, Pinabete Arroyo, and Cottonwood Arroyo.

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An aquifer test was conducted in 1975 at well T4-1 installed in the PCS near the western side of Area 5 of ~~BNCC~~NTEC's mining lease as shown in Exhibit 18.2-2. The drawdown and recovery measurements were recorded at the pumped well and at observation well GM30A, located 55.8 feet from the pumping well, and at observation well T4-2 located 12.5 feet from the pumping well. The top of the PCS is approximately 146 feet below ground surface at the test location while the static water level was at a depth of 134 feet, demonstrating confined conditions at the test location (Science Application Inc. 1979). The results of this aquifer test are summarized in Table 18.2-9, along with the results of tests performed at the PCS monitoring wells installed as part of this baseline monitoring program. The testing results and interpretations performed for the PCS baseline monitoring wells are provided in Appendix 18.F.

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The hydraulic conductivity from the recovery response at well GM-30A from the pumping test at the PCS well T4-1 was 0.0016 ft/day (5.6×10^{-7} cm/sec). The storage coefficient determined from the observation well response at GM-30A was 3.4×10^{-5}. The highest hydraulic conductivity estimate for the PCS near the permit area was 0.02 ft/day (7.0×10^{-6} cm/sec) obtained from the test at monitoring well KPC-98-01, located northwest of the mining lease as shown on Exhibit 18.2-2. The PCS is unconfined at this location. The results for this well are consistent with the aquifer test results of 0.032 ft/day (1.1×10^{-5} cm/sec) from a slug test at Well O-1 completed in the PCS at the Burnham Mine but higher than the range from 0.01 to 0.0001 ft/day (3.5×10^{-6} to $3.5\ 10^{-8}$ cm/sec) obtained from the slug tests at the three other PCS monitoring wells as summarized in Table 18.2-9.

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Pumping test results for the PCS monitoring well O-1 in the Burnham Mine permit application package are on file in the library of the OSM in Denver, CO. In this well test, pumping at a relatively high rate of 18.3 gpm could be sustained for only 8.7 minutes when most of the well-bore storage water was removed and the test had to be terminated. Although the results were interpreted in the Burnham Mine permit application package as a pumping test, this approach is not correct due to the predominant influence of well-bore storage. Consequently, the well test results have been reinterpreted as a slug test in this report. Slug test results indicate a hydraulic conductivity of 0.032 ft/day (1.1×10^{-5} cm/sec).

18.2.3.2 Groundwater Quality

The water quality characteristics of the Cottonwood, Pinabete and No Name alluvium, the Fruitland coal seams, and the underlying PCS have been determined from the baseline groundwater monitoring. The results are presented in the subsequent subsections and show that the groundwater within and adjacent to the permit area is poor and suitable only for marginal livestock use based on the relevant groundwater use criteria listed Table 18.2-10. The use criteria in Table 18.2-10 are not enforceable standards with respect to groundwater and are included only as a reference for the suitability of the groundwater quality for domestic water supply and for livestock use. These use criteria are mostly derived from the Navajo Nation surface water quality criteria (NNEPA 2008) for domestic water supply and for livestock watering use. Lardy, Stoltenow, and Johnson (2008) provide relevant livestock watering criteria for TDS, sulfate and fluoride but do not provide a livestock use criterion for chloride.

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18.2.3.2.1 Alluvial Groundwater Quality

Quarterly samples were obtained from the two alluvial monitoring wells installed in Pinabete Arroyo and four alluvial wells within the Cottonwood Arroyo. No samples have been obtained from No Name well NNA-2 because the well was dry throughout the baseline monitoring program in 1998 and in 2007-2008. Saturated conditions occurred during the latter half of 1998 at the No Name alluvial monitoring well NNA-1, located below the No Name Impoundment. Two quarterly samples were obtained from this well during this period. At other times during the baseline monitoring period this well has been dry and no samples were obtained. QACW-2 is usually dry and relatively few samples have been obtained during baseline monitoring. Water quality samples could not be obtained from alluvial monitoring well QACW-1 because it was dry or had insufficient water for sampling during baseline monitoring from 1987 through 1998. The analytical results for the water quality samples from these wells are summarized below.

The baseline water quality monitoring results for the Cottonwood alluvial wells are summarized in Table- 18-.2-11-. The number of samples and median values from three wells are identified: QACW-2, located near the confluence with Chaco; QACW-2B, located west and also downgradient of the lease boundary, and GM-17, located east and upgradient of the lease boundary. These results show the water quality of the alluvium of Cottonwood Arroyo to be a sodium-sulfate type of poor water quality with

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relatively high but variable TDS concentrations. ~~TDS concentrations at~~ The monitoring well QACW-2B~~, located near the mouth of Cottonwood Arroyo, ranged from 2,590 to 3,615 mg/L. This monitoring well~~ is a stock water well that was converted to a monitoring well and is referred to as well 13-R-28A in Exhibit 18.2-1. ~~Median sulfate concentrations exceed recommended livestock use criteria at all the Cottonwood alluvial wells.~~GM-17 reflects very saline conditions.

The median pH range for the three wells ranges from 6.9 to 7.9. These results are within a suitable range for stock watering. Median total iron values ranged from 0.03 to 1.4 mg/l. There are no stock watering criteria or domestic water supply criteria for iron or manganese, however EPA has established a secondary drinking water standard of 0.3 mg/L iron and 0.05 mg/L manganese, due to its staining qualities. The median total manganese baseline values in Cottonwood range from 0.02 to 1.765 mg/L. The likelihood of utilizing alluvial water for drinking water supply is slim. The median TDS from the three wells is 3,015 mg/L. This value slightly exceeds the suitable stockwatering criteria identified by the North Dakota Extension Service in Lardy, et al, 2008, in which 3,000 mg/L TDS is identified as suitable for most stock, and 3,000 – 5,000 mg/L bears observation, as it may not cause adverse effects for most stock, but it could affect growing or young stock. The median sulfate value from the three wells is 1,605 mg/L. Median sulfate concentrations exceed recommended livestock use criteria of 1000 mg/L at all the Cottonwood alluvial wells. Median concentrations of TDS and sulfate in the groundwater within the Cottonwood alluvial wells also exceeds the U.S. Environmental Protection Agency (USEPA) Secondary Drinking water use criteria of 500 mg/L TDS and 250 mg/L sulfate listed Table 18.2-10. Fluoride concentrations fluctuate in the alluvial groundwater and are often above relevant criteria for livestock and drinking water use~~.~~ of 2 mg/L, however the median value is 1.38 mg/L.

Water quality analytical results from quarterly monitoring at Pinabete alluvial wells, PA-1 and PA-2, are provided in ~~Table 18.2-12 and Table 18.2-13, respectively. These results~~Table 18.2-12 and Table 18.2-13, respectively. The baseline and upstream data exhibit pH values between 7.19 and 7.9, with a median value of 7.5, suitable for stock use. The results from the Pinabete alluvial wells show the water quality of the alluvium of Pinabete Arroyo to be a sodium-sulfate type with TDS concentrations ranging from 1,500 to 4,~~300 mg/L.~~310 mg/L. The quality of the alluvial groundwater varies although the TDS, sulfate, and fluoride concentrations usually exceed relevant criteria for livestock use. Water within the alluvium is unsuitable for drinking water use due to TDS, sulfate, fluoride, iron, and manganese concentrations above secondary drinking water standards. ~~The quality of the alluvial groundwater varies although the TDS, sulfate, and fluoride concentrations usually exceed relevant criteria for livestock use.~~The median total iron concentration is 3.535 mg/L, and the median total manganese level is 0.55 mg/L.

Water quality analytical results in Table 18.2-14, from sampling of the No Name Arroyo alluvial well NNA-1, show the water to be a sodium-sulfate type similar to Pinabete Arroyo but with much higher

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sulfate, sodium, and TDS concentrations. Water quality within the alluvium downstream of the No Name Impoundment is unsuitable for either drinking water or livestock water use. The pH of the two samples collected at the site was 7.6, total iron ranged from 0.17 to 1.56 mg/L and total manganese concentrations ranged from 0.13 to 0.66 mg/L. The water from the No Name Arroyo alluvial well exceeds EPA secondary drinking water standards for total iron and manganese.

Some information on the baseline water quality in the Chaco River Alluvium is provided by Thorn (1993). These results show considerable variability in the alluvial water quality with TDS concentrations ranging from 742 to 11,900 mg/L, sulfate concentrations from 350 to 6,600 mg/L, and fluoride concentrations ranging from 0.4 to 1.7 mg/L. Additional water quality information for the Chaco River alluvium is included in the well inventory included in Appendix 6.E of the Navajo Mine PAP (OSM Permit No. NM-0003F) (BNCC 2009). ~~The available water quality information from this well inventory show TDS concentrations ranging from 1,950 mg/L to 3,110 mg/L and sulfate concentrations ranging from 1,100 to 1,790 mg/L at wells located west of Areas 2, 3 and 4 at the Navajo Mine.~~Wells GM-24, GM-25 and GM-34 exhibited pH values ranging from ~~–~~6.5 – 8.1 with a median value of 7.67, on data collected between 11/16/1974 and 3/4/1977. No values for total iron were collected. Manganese (undifferentiated as to dissolved or total) ranged from 0.55- 4.6 mg/L with a median value of 1.98, exceeding the secondary drinking water standard. TDS values ranged from 1216 to 54,730 mg/L with a median value of 4101.5 mg/L. The median sulfate value was 1,800 mg/L and the median fluoride value was 0.86 mg/L. Manganese, TDS and sulfate values exceed recommended stock water criteria and secondary drinking water standards.

18.2.3.2.2 Fruitland Formation Groundwater Quality

The No. 3 coal seam well KF-98-04 has been essentially dry throughout the baseline monitoring period, with the exception of about 3 feet of initial saturation following well completion. Although a sample was obtained from this well in March 1998 following well completion, the well could not be purged and the water sample collected immediately following well completion cannot be considered to be representative of baseline conditions.

Water quality analytical results from the baseline sampling of the No. 3 coal seam well KF-98-02 are provided in Table 18.2-15. Results indicate some initial influence from drilling fluids or from the annular grout seal in the first two samples from this well. The reduction in both the pH and calcium concentrations with subsequent sampling suggests the reduction of any influence from drilling fluids or from the annular grout seal in subsequent samples from this well. The pH levels in this well have declined with time and the November 2007 results were within the range from 7 to 9 that is generally expected for the Fruitland coals within the San Juan Basin.

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~~As shown in Table 18.2-15, water quality within the No. 3 coal seam at monitoring well KF-98-02 is unsuitable for drinking water use due to concentrations of TDS, chloride, and boron above the Navajo Nation water quality criteria for drinking water use. The TDS concentrations in water at this monitoring location also exceed the relevant criterion for livestock use.~~ Based on the recent samples from the No. 3 coal seam well KF-98-02, the groundwater in the No. 3 coal seam at this location is a sodium-bicarbonate-chloride type, with TDS ~~of about 3,300 mg/L (Table 18.2-15).~~averaging 3,278 mg/L (Table 18.2-15). The ion composition results are consistent with the baseline coal water quality monitoring data at the Navajo Mine, which show the coal seams to be of a sodium-bicarbonate-chloride type, although TDS concentrations are higher at the Navajo Mine wells as indicated in Table 18.2-16. Well KF-98-02 exhibited a range of pH between 7.53 and 8.11 between 11/5/2007 and 11/20/2008, in 5 samples. Previous pH results exceeded the livestock upper end criteria of 9.0, due to completion issues, as mentioned above. Total iron concentrations range from 0.14 to 1.01 mg/L and total manganese values ranged from 0.007 mg/L and 0.039 mg/L. Most of the samples exceed the EPA secondary drinking water standard for total iron of 0.3 mg/L, in the unlikely event that water from this aquifer would be used for drinking water supply. The TDS concentrations in water at this monitoring location also exceed the relevant criterion for livestock use of 3000 mg/L. As shown in Table 18.2-15, water quality within the No. 3 coal seam at monitoring well KF-98-02 is unsuitable for drinking water use due to concentrations of TDS and chloride above the Navajo Nation water quality criteria for drinking water use with median values of 3160 mg/L and 925 mg/L, respectively. Boron concentrations ranged from 0.09 mg/L to 1.47 mg/L, with a median value of 0.4 mg/L, exceeding the Navajo Nation water quality criteria for drinking water use of 0.63 mg/L once.

~~Table 18.2-16~~Table 18.2-16 provides median concentrations from baseline monitoring of coal wells at the Navajo Mine. Samples collected in 1984 at monitoring wells SJKF84#2, SJKF84#3 and SJKF84#4 are considered to be baseline samples because these No. 8 Coal wells are a sufficient distance down gradient of Navajo Mine to not be impacted by mining (Chapter 11, Navajo Mine Permit Application Package (PAP) NM-0003F). The TDS concentrations in these down gradient wells ranged from 7,370 to 50,810 mg/L. Water quality monitoring data from the coal wells located within or adjacent to the Navajo Mine permit area also show very high concentrations of TDS in the coal seam groundwater, with median concentrations at individual wells ranging from 2,770 mg/L to 13,400 mg/L. The concentrations of TDS, chloride, and sodium,~~ and bicarbonate~~ are lower in the No. 3 coal seam monitoring well KF-98-02 in Table 18.2-15 in comparison to the median concentrations observed at the No. 3 coal seam monitoring well KF84-21A in Table 18.2-16. Lower concentrations of these constituents would be expected at well KF-98-02 because it is located up gradient from well KF84-21A and closer to the likely recharge source. The coal seam water quality results in Table 18.2-16 show that TDS concentrations increase with distance from the potential recharge areas, as TDS concentrations increase with depth at the nested well locations and increase from south to north toward the regional discharge location at the subcrop of the Fruitland Formation along the

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San Juan River Valley. Sulfate concentrations show spatial trends that are opposite of TDS with a general decrease in concentration with depth at the nested well locations and a decrease in concentration from south to north toward the regional discharge location along the San Juan River Valley. Bicarbonate concentrations in the up gradient coal wells ranges from 800 to over 1800 mg/l with pH ranging from 7 to 8.7. Freeze and Cherry (1979) note that for groundwater in this pH range to evolve such high bicarbonate concentrations, production of hydrogen ions is necessary. Production of hydrogen ion is believed to occur as a result of oxidation of sulfide minerals, which occur in the unoxidized coals and interburden of the Fruitland Formation. Oxidation of sulfide minerals also accounts for the gypsum precipitates in the weathered bedrock and higher sulfate concentrations in the shallow groundwater.

~~The coal seam water quality results in Table 18.2-16 show that TDS concentrations increase with depth and distance from the outcrop. Furthermore, TDS concentrations as high as 50,000 mg/L have been observed in the Fruitland coal units east and down dip of the Navajo Mine permit area (BNCC 2009). The TDS concentrations ranged from 43,035 to 50,810 mg/L at monitoring wells SJKF84#2 and SJKF84#3 installed in the No. 8 coal down dip of the Navajo Mine (Chapter 6, Navajo Mine Permit Application Package, BNCC 2009). The lower concentrations of TDS occur within close proximity to the coal outcrop, although concentrations of sulfate are higher near the outcrop and sulfate is generally absent down dip due to sulfate reduction.~~

The conceptual model of chemical evolution of natural groundwater in the Fort Union Formation of the Powder River Basin described by Van Vost and Reiten (1988) is believed to also apply to the Fruitland Formation in northwestern New Mexico. Ground-water quality in the Powder River Basin changes in a predictable fashion. Sulfate, bicarbonate and TDS concentrations increase as a result of oxidation of pyrite and other sulfide minerals and dissolution of carbonate minerals as groundwater migrates from recharge areas. Calcium and magnesium do not increase in proportion to the increase in bicarbonate concentrations due to cation exchange process. In the deeper coal aquifers, sulfate reduction and carbonate precipitation produce water quality that is dominated by sodium, bicarbonate and chloride (Van Vost and Reiten, 1988). The lower concentrations of TDS in the coal units in the Navajo Coal lease occur within closer proximity to recharge areas. The concentrations of sulfate decrease down gradient of recharge areas. This decrease is most likely the result of sulfate reduction as alternate explanations for the decrease in sulfate do not conform to the conceptual model of the groundwater flow system.

Water quality analytical results from the baseline sampling of the No. 8 coal seam monitoring well KF2007-01 are provided in Table 18.2-17. There was considerable fluctuation in the pH and in the concentrations of TDS and major ions observed in samples from this well. These fluctuations are not uncommon after completion of wells with very low rates of water production because it is not possible to fully develop the well. Stabilization of water quality parameters is expected to occur over time, similar to what has occurred at well KF-98-02. The pH has ranged from 8.12-9.56. Total iron concentrations have

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ranged from <0.05 to 1.2 mg/L and total manganese has ranged from <0.005 to 0.013 mg/L. Water quality within the No. 8 coal at this monitoring location is unsuitable for drinking water due to concentrations of pH, TDS, chloride, fluoride, ~~and~~ sulfate, and total iron that are above the USEPA secondary drinking water use criteria. The sulfate and TDS concentrations in coal water at this monitoring location often exceed relevant criteria for livestock use.

Baseline monitoring of coal wells located within and adjacent to the permit area indicated that well yields at most locations would not be sufficient to sustain use for livestock water supply. In limited locations where the coals may yield sufficient to occasionally fill a stock tank, the water could provide for marginal livestock use, although the recommended livestock criteria for TDS and sulfate are usually exceeded. The water quality would result in restrictions for use as a supply for young calves or as a long-term supply for cattle. Also, the water in the coal units would not be suitable for drinking water due to elevated TDS, chloride, boron, and sulfate concentrations. Based on the trends observed from sampling of coal wells at the ~~BNCC~~NTEC mining lease, concentrations of TDS, bicarbonate, and chloride appear to increase with depth and distance from the outcrop but sulfate concentrations appear to decrease.

There is also an apparent trend of increasing TDS, chloride, and bicarbonate concentrations and decreasing sulfate concentrations toward the north-northeast in the direction of the potentiometric gradient. This trend appears in concentrations observed at the No. 8 coal seam well KF84-22A in comparison with the concentrations observed at the No. 8 coal seam well KF84-18B located north-northeast of well KF84-22A. A similar trend is also observed in the comparison of results for the No. 3 coal seam well KF-98-02 with the down gradient No. 3 coal seam well KF84-21A.

Groundwater chemistry changes or evolves along its flow path from the recharge area to the discharge area. Precipitation is low in TDS, is naturally weakly acidic, and contains bicarbonate due to the solution of carbon dioxide in the air. In this portion of the San Juan Basin, the precipitation reaching the ground is immediately neutralized and acquires sodium, sulfate, and other ions. Water that has only a short residence time in the ground is still typically high in TDS concentrations, with sodium, sulfate, and bicarbonate the dominant ions as indicated by both the surface water and alluvial groundwater samples. Calcium is also present due to dissolution of calcium carbonate, but at concentrations that are considerably lower than sodium. Chloride concentrations are typically lower near the recharge areas, although both chloride and TDS can vary with the spatial variation in recharge rates and frequency of leaching of salts from the unsaturated zone.

As groundwater migrates through the saturated zones it is no longer in contact with atmospheric carbon dioxide and its capacity to dissolve carbonates diminishes. The chemistry of the groundwater continues to evolve as other soluble minerals dissolve and cation exchange processes reduce the proportion of calcium

and increase the proportion of sodium in solution. Sulfate reduction also occurs when groundwater transitions from oxidizing to reducing conditions, particularly within the coals.

18.2.3.2.3 Pictured Cliffs Sandstone Groundwater Quality

Water quality analytical results from the baseline sampling of PCS well KPC-98-01 are provided in Table 18.2-18. When the initial sample was collected from PCS monitoring well KPC-98-01 in 1998, it showed some influence of drilling fluids based on the low TDS, sulfate, and chloride and higher pH and nitrate observed in the initial well sample as shown in Table 18.2-18. It is suspected that the well was not fully developed due to low permeability and limited saturation. Sampling results starting in 2007 are more consistent and representative of baseline conditions within the PCS at this location. Based on the recent samples, the groundwater in the PCS at this location is a sodium-sulfate-bicarbonate type with TDS above 6,000 mg/L. Data acquired between 2007 and 2008 exhibited a pH range of 7.7 to 7.87, suitable for all uses. Data from the same period exhibited total iron levels ranging from 0.16 to 29.5 mg/L and total manganese levels ranging from 0.044 to 0.183 mg/L. More than half of the samples exhibited secondary drinking water use limitations -associated with total iron and total manganese.

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The ion composition results in water samples from well KPC-98-01 are consistent with the results from well KPC2007-01 (Table 18.2-19). TDS concentrations are quite similar at the two PCS wells with concentrations at well KPC2007-01 slightly below 6,000 mg/L and concentrations at well KPC-98-01 slightly above 6,000 mg/L. The groundwater in the PCS at these two locations is unsuitable for either domestic or livestock use due to the high TDS and sulfate concentrations.

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Water quality monitoring data for the PCS were also available from samples collected during the mid-1970s from five wells that were completed in the PCS within or adjacent to Area 4 North, Area 4 South, and Area 5 of ~~BNCC~~NTEC's mining lease. The locations for these PCS monitoring wells are shown on ~~Exhibit 18.2-2~~Exhibit 18.2-2.

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Water quality analytical results of the baseline samples from PCS monitoring well GM-21, located within Area 5, are provided in Table 18.2-20. The water quality results are consistent with the results from wells KPC-98-01 and KPC2007-01. The groundwater is a sodium-sulfate-bicarbonate type with TDS above 6,000 mg/L. TDS and sulfate concentrations would pose limitations to stock use. The pH ranged from 7.0 to 7.9, values which are not limiting for any uses. Total iron was collected once and was 0.41 mg/L and total manganese was also collected a single time and was 0.11 mg/L. Assuming the manganese value was representative, the water from this well exceeds secondary drinking water standards and could stain enamel fixtures.

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Historic baseline water quality results from PCS monitoring well GM-20 are summarized in Table 18.2-21. This well was located within the center of Area 4 South of ~~BNCC~~NTEC's Navajo mining lease. These results indicate TDS concentrations between 5,000 and 6,000 mg/L, which are comparable with results from the other PCS monitoring wells. The groundwater in the PCS at this location is a sodium-sulfate-chloride-bicarbonate type, with higher chloride concentrations than in the other nearby PCS monitoring wells. The earlier samples from this well also show an elevated groundwater pH. It is quite likely that this well also encountered some influence of grout intrusion that was not removed during well development or grout curing. The elevated pH influence does not appear in the later samples from this well. A single sample in September 1979 was analyzed for total iron and total manganese; levels were 0.03 mg/L and 0.29mg/L respectively. The total manganese concentration exceeds the secondary drinking water standard of 0.05 mg/L.

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Baseline water quality data for PCS monitoring well GM-19 are summarized in Table 18.2-22. This well was located within the proposed permit area. The resulting water type is similar to the water type from PCS monitoring well GM-20, although TDS concentrations are higher, ranging between 7,810 and 9,270 mg/L, with corresponding higher concentrations of sulfate, chloride, sodium, and bicarbonate. Sulfate concentrations ranged between 3685 and 4535 mg/L. The Pictured Cliffs Sandstone represented by this location would pose limitations for stock use due to the elevated TDS and sulfate concentrations. The pH ranged from 7.5 to 8.1 posing no limitations for use. Again, a single sample in September 1979 was analyzed for total iron and total manganese with levels of 0.01 mg/L and 0.12 mg/L respectively. Total manganese, chloride, sulfate, and TDS exceed secondary drinking water use criteria.

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Baseline water quality data for PCS monitoring well GM-30A are provided in Table 18.2-23. This well was located on the ~~west~~northwest side of Area 5 of ~~BNCC~~NTEC's mining lease. The pH ranges from 7.5 to 7.6 in three samples. The results indicate a sodium-sulfate-chloride type with TDS concentrations between 6,000 and 7,000 mg/L, and are comparable with the results from PCS monitoring wells within Areas 4 North, Area 4 South, and Area 5 of ~~BNCC~~NTEC's mining lease. The ion balance in the first sample from this well was poor but improved in the second sample. Anion-cation balances greater than ± 0.10 are often an indicator of poor quantitative results. Sometimes, a lack of ion balance can be explained by the presence of high metals in acidic waters or soluble silica in alkaline waters that may not have been considered in calculating the ion balance. However, in this case, it appears that the lack of balance is the low sulfate concentration reported in the first sample, which appears to be erroneous. All the other major ions were consistent between the two samples. A report for total iron and total manganese is reported from a September, 1979 sample. Total iron is 0.02 mg/L and total manganese is 0.05 mg/L. The total manganese concentration is the same as the secondary drinking water standard for manganese.

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The water sample results from well GM-28 are not included in this report because the ion balance was poor with 37% and 48% difference in the two samples. This well was located north of the permit area, as shown in Exhibit 18-2-2. Despite the poor ion balance, results for TDS are meaningful. The TDS concentrations in the samples from this well ranged from 4,334 to 6,580 mg/L. These results are consistent with the TDS concentrations observed at other PCS monitoring wells and slightly lower than the TDS concentration observed at well GM-19 located within the permit area. The pH ranged from 8.1 to 8.85 on two samples. No samples were analyzed for total iron or total manganese.

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In summary, groundwater quality data from monitoring wells located within and adjacent to the permit area indicate the groundwater in the PCS has high TDS concentrations, ranging from 5,000 mg/L to over 9,000 mg/L. Sulfate is the dominant anion, although the concentrations of chloride and bicarbonate are also relatively high. Sodium is the dominant cation. Magnesium and calcium concentrations are quite low and are typically less than the potassium concentrations, although potassium was not included in the samples from the GM wells that were collected during the 1970s. Generally, water quality changes are observed in the first few samples obtained from monitoring wells, apparently due to the difficulty in developing these low-yield wells. Thus, samples obtained after the initial two samples are believed to provide a better representation of baseline conditions.

The high concentrations of TDS, sulfate, chloride, and boron in the water from the PCS within and adjacent to the permit area preclude its use for domestic purposes. The PCS is also a poor source for livestock watering due to the very high TDS and sulfate concentrations, and low permeability and low yield, as stated in Section 18.2.3.1.3. The TDS and sulfate concentrations are lower in the water in the alluvium of Pinabete Arroyo, making it a better source for livestock use, although the TDS and sulfate concentrations in the alluvium are often above relevant criteria for livestock use.

18.2.4 Groundwater Resources Information Collection and Analysis

The baseline groundwater evaluation included a review of reports and data concerning groundwater resources of the region from New Mexico and federal agencies as well as the information provided in the permit application package and the groundwater monitoring reports for ~~BNCC~~NTEC's Navajo Mine and CONSOL Energy's Burnham Mine (monitoring reports on file at the OSM Library in Denver, Colorado). ~~BNCC~~NTEC has also conducted extensive drilling within the permit area which, together with data from the adjacent Navajo Mine and the nearby Burnham Mine, provide information about the geology and groundwater hydrology of the permit area and surrounding areas. ~~BNCC~~NTEC also implemented a groundwater monitoring program in 1998 and in 2007 and 2008 to obtain site-specific information on groundwater levels, aquifer characteristics, and groundwater quality for the previously proposed Navajo Mine Extension Project. The baseline monitoring program and assessment were developed in accordance with the "Work Plan for Baseline Groundwater Hydrology for the Navajo Mine Extension Project"

submitted to OSM on May 23, 2007. The focus of this baseline monitoring program encompassed areas within and adjacent to the permit area.

An inventory of permitted wells and springs was conducted based on information from several sources, including the New Mexico Office of the State Engineer (NMOSE) (2010) Navajo Settlement Agreement, the inventory of wells and springs conducted by Billings and Associates, Inc. (BAI) in ~~1985~~1987 for the Navajo Mine, wells identified in the "Groundwater Operations Manual and Well Survey for Navajo Mine and Vicinity" that was completed by Metric Corporation (1991), wells found in review of permits on file at the Navajo Nation Water Resource Management office in Fort Defiance, Arizona and a site reconnaissance for springs, seeps, and wells located within the permit area and adjacent area. Some of the data used in the discussion of baseline conditions were collected by other companies or organizations for other projects. As a result, the particular analytes considered and the associated detection limits may be slightly different from those included in ~~BNCC~~NTEC's baseline monitoring in years 2007 and 2008. Efforts have been made to address these differences within the discussion of the data or in the tables used to report the results. Quality assurance and quality control information for the 2007-2008 groundwater data is provided in Appendix 18.G.

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18.3 Hydrologic Model

Groundwater models are useful to support the interpretation of baseline hydrogeologic information. Furthermore, groundwater models are required for the predictive evaluations needed to prepare a probable hydrologic consequence (PHC) assessment of proposed mining and reclamation activities. Groundwater models used for a PHC assessment can range from simple empirical equations to complex numerical computer simulations of groundwater flow and chemistry.

Site-specific data or data representative of the site conditions are needed to apply groundwater models. Extrapolation of data from adjacent or nearby areas or using typical values for parameters from similar hydrogeologic environments is acceptable when the similarity of the areas is established. Numerical groundwater flow models can help to develop a better understanding of the hydrogeologic system, including the groundwater flow relationships between hydrogeologic units and between surface water and groundwater. Model calibration can also serve to revise the conceptual model of the groundwater system and provide a better assessment of the properties of hydrogeologic units on a regional scale that cannot be obtained solely from local pumping testing results.

The first step in developing a groundwater model is to establish the objectives of the study. Specific objectives of the groundwater model are as follows:

- The first objective is to provide a better understanding of the baseline groundwater flow systems within and adjacent to the proposed mining location.

- The second objective is to provide a better understanding of the likely groundwater changes that may occur during and after mining.

18.3.1 Groundwater Model Development

A multilayer, numerical, groundwater flow model has been developed to model the groundwater flow systems within and adjacent to the permit area. A detailed presentation of the numerical groundwater flow model is included in Appendix 41.B, in Section 41 (Probable Hydrologic Consequences). This report includes a description of the conceptual model of the groundwater flow system. A conceptual groundwater model is a complex hypothesis of the characteristics and functions of a hydrogeologic system, including recharge and discharge relationships, groundwater flow within and between hydrogeologic units, and the expected properties of these hydrogeologic units. An essential part of both the conceptual and numerical models is a graphical representation of the horizontal and vertical boundaries of the hydrogeologic system (the model domain) and the delineation of the hydrogeologic units within the model domain that are believed to have the primary controlling influence on groundwater flows. Another element of the conceptual model is to define, to the extent possible, the properties of these hydrogeologic units, including the thickness, hydraulic conductivities, and storage characteristics across the model domain. The conceptual model also includes the hydrogeologist's understanding of spatial relationships between and approximate rates of recharge and discharge, including the groundwater inflows and outflows from the model domain.

The delineation of the hydrogeologic units within and adjacent to permit area was based on the extensive geologic and groundwater information obtained from a variety of sources, including the baseline information presented in this baseline Section. Although the coal geology is complex with multiple coal bed splits and pinch outs, there is good correlation and spatial continuity for particular coal zones, or seams, at the Pinabete permit area and adjacent Navajo Mine. These coal seams may feature one coal bed, or they may include splits with multiple coal beds. For these reasons, the conceptual hydrogeologic model and the numerical groundwater model for the permit area and adjacent area handle the individual coal zones, or seams, as separate and distinct hydrogeologic units. The PCS, the first hydrogeologic unit below the Fruitland Formation, has been included in the groundwater flow model. The top of the Lewis Shale, below the PCS, has been included as the base of the model domain. The delineation of these hydrogeologic units within the permit area was created from the extensive geologic and groundwater information developed for the project. Information was also obtained from a variety of sources to help delineate the hydrogeologic units and define groundwater conditions for the portions of the model domain that are beyond the limits of the permit area.

18.3.2 Baseline Groundwater Model Results

The multilayer groundwater model was calibrated to obtain a good match with potentiometric surfaces and water levels established from the baseline groundwater studies at the permit area while maintaining consistency with the site-specific recharge estimates from Stone (1986) and the range of hydraulic conductivities associated with each hydrogeologic unit. During model calibration, hydraulic conductivities were applied only for the entire hydrogeologic unit and not spatially within a unit. Without a consistent geologic basis, spatial adjustments in hydrologic conductivities would lead to over-parameterization of the model to match modeled potentiometric levels with observed values. Although some of the differences between the modeled and observed potentiometric levels may be associated with spatial variation in hydrogeologic properties within a hydrogeologic unit, the chosen method for model calibration allows for the overall groundwater flow within each hydrogeologic unit and between units to be represented by the calibrated groundwater model.

Generally, a shale zone such as the Lewis Shale would be considered as an impermeable boundary. However, given the low recharge rates at the permit area, the overall low permeability of the Fruitland Formation shales and coals, and the relatively low permeability of the PCS, the flow conditions at the boundary between the PCS and Lewis Shale were found to be significant for calibrating the groundwater flow model. Providing for downward flow from the PCS into the Lewis Shale was required in order to reach an adequate calibration with recharge rates consistent with the measurements from Stone (1987). Downward flow and downward gradients are also indicated by hydrogeologic studies and tests of the Lewis Shale and the PCS immediately west of the permit area (Science Application, Inc. 1979).

Table 18.3-1 shows the relationship between the modeled recharge rates and the measurements by Stone (1987). Outside of the alluvial valleys, recharge rates were adjusted by slope within the range of estimates from Stone (1987) for badland areas and for upland flats. The modeled potentiometric surface for the PCS, the No. 3 coal seam, and the No. 8 coal seam are provided in Figure 18.3-1, Figure 18.3-2, and ~~Figure 18.3-3~~Figure 18.3-3, respectively. These results are consistent with the potentiometric surfaces developed from baseline monitoring in Section 18.2.4. However, the modeled potentiometric surfaces extend beyond the limits that could be depicted from well measurements. These potentiometric surfaces and flow patterns are consistent with the conceptual model and all the geologic and hydrogeologic information and the specified boundary conditions.

The results in Figure 18.3-1 show a component of groundwater flow from the PCS to the topographic lows along the west side of the model domain in the valleys of Brimhall Wash, No Name Arroyo, Pinabete Arroyo, and Cottonwood Arroyo. Although portions of the PCS along the western outcrop remain unsaturated, as indicated in Figure 18.3-1, the model estimates potentiometric elevations for these unsaturated zones.

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The results for the No. 3 coal seam in Figure 18.3-2 also show a component of groundwater flow to the topographic lows along the west side of the model domain in the valleys of No Name Arroyo, Pinabete Arroyo, and Cottonwood Arroyo. The No. 3 coal seam is not present over a portion of the Brimhall Wash drainage or along the western portion of the model domain. Also, the No 3 coal seam is unsaturated in areas along the western outcrop and remains unsaturated in the modeled potentiometric surface as indicated in Figure 18.3-2. A similar pattern is observed in Figure 18.3-3 for the No. 8 coal seam, although this coal is not present over a large portion of the Brimhall drainage or within a large portion of the No Name Arroyo and Pinabete Arroyo valleys within the permit area. In addition to the flow toward the topographic lows, there is a component of flow down dip to the northeast. Portions of the No. 8 coal seam near the western outcrop are unsaturated, as shown in Figure 18.3-3. Not shown in these figures for individual hydrogeologic units are the overall downward gradients and downward flow between units. In fact, the model predicts perched groundwater conditions in the shallower coals along the western portion of the permit areas as depicted by the north-south section in Figure 18.3-4.

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The calibrated numerical model helps confirm the conceptual model. The numerical model is well constrained and consistent with the recharge rates measured by Stone (1987) and with the hydraulic conductivities and heads measured within the various hydrogeologic units in the model domain.

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