REVIEW AND ANALYSIS

OF

NAVAJO AQUIFER MATERIAL DAMAGE CRITERIA

FOR

PEABODY WESTERN COAL COMPANY'S

KAYENTA MINE COMPLEX

THE OFFICE OF SURFACE MINING RECLAMATION AND ENFORCEMENT

PROGRAM SUPPORT DIVISION

DENVER, COLORADO

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1.0 INTRODUCTION

In 1991, the Office of Surface Mining Reclamation and Enforcement (OSMRE) entered into a settlement with the Hopi Tribe called an "Agreement Concerning Review of Certain Data" (hereinafter, the "Agreement"). The Agreement requires OSMRE to review and analyze annual hydrological reports prepared by Peabody Western Coal Company (PWCC) and the United States Geological Survey (USGS). During these reviews, OSMRE must relate the data in the reports to the material damage criteria for the Navajo aquifer system (N-aquifer) found in the current cumulative hydrologic impact assessment (CHIA) of the PWCC Black Mesa Kayenta Mine Complex (OSMRE, 1989, 2008, 2011a, 2016). The Agreement was established when the 1989 CHIA was effective. Since implementation of the 1989 CHIA, the CHIA document was revised in 2008, 2011, and 2016. Material damage criteria for the N-aquifer were established and modified during the revision process. As part of the Agreement, OSMRE has agreed to review (1) hydrologic monitoring data on the N-aquifer that PWCC collected pursuant to permit AZ-0001C (and subsequent AZ-0001D, AZ-0001E, and AZ-0001F permits), and (2) water-quality and -quantity data collected by the USGS in ongoing investigations and published reports. The Navajo Tribal Authority (NTUA), PWCC, the Hopi Tribe, the Western Navajo, Chinle, and Hopi Agencies of the Bureau of Indian Affairs (BIA) have assisted in the collection and submittal of hydrologic data (Mason, 2022).

This report contains the results of OSMRE's review and analysis of the following reports:

- PWCC 2020 Annual Hydrological Data Report (PWCC-20HDR) (PWCC, 2021)
- PWCC 2021 Annual Hydrological Data Report (PWCC-21HDR) (PWCC, 2022)

- Groundwater, Surface-Water, and Water-Chemistry Data, Black Mesa Area, Northeastern Arizona – 2016-2018" (USGS 2016-2018 Report) (Mason, 2021)
- Groundwater, Surface-Water, and Water-Chemistry Data, Black Mesa Area, Northeastern Arizona – 2018-2019" (USGS 2018-2019 Report) (Mason, 2022)

The PWCC hydrological data reports describe monitoring PWCC completed during calendar years 2020 and 2021 and includes summary data from previous years. This evaluation also considers the USGS 2016-2018 Report and USGS 2018-2019 Report, which provide the results of groundwater, surface-water, and water-chemistry monitoring in the Black Mesa area from November 2016 to December 2019.

The following OSMRE analysis evaluates the hydrologic impacts of PWCC's wellfield pumping. In 2014, PWCC's wellfield consisted of eight production wells: NAV2, NAV3, NAV4, NAV5, NAV6, NAV7, NAV8 and NAV9. In 2015, well NAV5 was reclaimed and abandoned, and wells NAV3 and NAV9 were idled. Additionally, in 2016, well NAV4 was reclaimed and abandoned, and well NAV7 sealed from zones previously open to the D-aquifer and idled for water quality sampling. OSMRE compared N-aquifer monitoring data contained in the PWCC and the USGS reports with baseline conditions presented in the Black Mesa Kayenta Complex CHIA. The CHIA for the PWCC Black Mesa Kayenta Complex was completed in 1989 and updated in 2008, 2011, and 2016. The material damage criteria and assessment approaches have been modified during the updates, and the material damage criteria in the 2016 CHIA are currently in effect. The criteria were established to evaluate potential impacts to water quality and quantity related to existing and foreseeable uses. This report will not repeat information contained in the CHIA, except for purpose of comparison of information provided in the PWCC and USGS data reports. For a full discussion of the definition of baseline conditions, identification of hydrologic concerns, development of material damage criteria and the analysis of mining related impacts for the N-aquifer, please see the PWCC Kayenta Complex CHIA (OSMRE, 2016).

In accordance with 30 CFR 816.41, a coal mine operator must meet the following four hydrologic performance standards: (1) minimize disturbance of the hydrologic balance within the permit and adjacent areas, (2) prevent material damage to the hydrologic balance outside the permit area, (3) assure the protection or replacement of water rights, and (4) support approved post mining land uses in accordance with the terms and conditions of the approved permit. The CHIA establishes material damage criteria for N-aquifer hydrologic impacts that may result due to coal mining activities of the Kayenta Mine Complex.

2.0 GEOLOGIC SETTING AND WELL COMPLETIONS

The PWCC Kayenta Mine Complex is in the Black Mesa area in northeastern Arizona (Figure 1). The mesa is a prominent feature with cliff height more than 1,200 feet on the north and northeast sides and is incised by several major drainages. Figure 2 is a generalized stratigraphic column showing rock formations and major aquifer zones of the Black Mesa area.

The N-aquifer system in the Black Mesa area consists of the Wingate Sandstone, the Kayenta Formation, and the Navajo Sandstone. The N-aquifer system is approximately 1,100 feet thick beneath the lease area. The Carmel Formation overlies the N-aquifer system and is approximately 140 feet thick beneath the lease area. The D-aquifer system is approximately 1,040 feet thick beneath the lease area and overlies the Carmel Formation and consists of the Entrada Sandstone, the Morrison Formation and the Dakota Sandstone. The Carmel Formation, a shaly siltstone and massive mudstone, confines the N-aquifer from the D-aquifer and generally is not considered a water-bearing unit or a part of the D-aquifer. However, the Carmel Formation may produce water from limited zones. The Mancos Shale is a regionally extensive formation several hundred feet thick beneath the lease area that restricts vertical flow between the PWCC mining operations in the Mesa Verde Group and the D- and N-aquifer systems where PWCC withdrawals groundwater. Both the D- and N-aquifer systems are confined by the Mancos Shale in the vicinity of the Kayenta Mine Complex and in much of the Black Mesa area. A confined aquifer is bounded above and below by beds of low hydraulic conductivity, and its potentiometric head is measured as the level to which water rises above the top of the aquifer in a well installed in the aquifer. Whereas, an unconfined aquifer is not overlain by a confining bed and its hydrologic head is represented by the water table level.

AZ-0001F is the current permit issued to PWCC to mine at the Kayenta Mine Complex (PWCC 2023). The permit application package gives detailed geologic and hydrologic information on the lease area (PWCC, 2023, Ch 15). PWCC monitors the N-aquifer quality and water levels within the lease area at production wells NAV2, NAV4, NAV5 (abandoned January 2015), NAV7, NAV8, NAV9, and non-pumping observation wells NAV3P and NAV6P. Wells NAV2 through NAV6 were drilled in 1967-1968, NAV7 was drilled in 1972, NAV8 was drilled in 1980 and NAV9 was drilled in 1983. NAV3P and NAV6P are abandoned well bores that have been converted to N-aquifer observation wells and used for monitoring purposes instead of production wells NAV3 and NAV6 since 1995. NAV1 was a test well drilled to examine all the different water-bearing units as part of the slurry pipeline feasibility study (Stetson, 1966). Figure 3 shows the locations of PWCC's N-aquifer production wells within the lease area. Construction and completion information and lithologic logs for each of the N-aquifer wells are included in the permit application package (PWCC, 2023, Ch.15).

Table 1 presents a tabulation of the length of completed well intervals in geologic formations. All PWCC production wells penetrate the geologic formations of the N-aquifer. However, each well is completed in different water-bearing zones of the N-aquifer. Of particular interest are production wells NAV2, NAV6 and NAV8, which may have different water quality characteristics due to differences in well completion compared to other PWCC production wells. The annular space around a portion of the blank casing adjacent to the D-aquifer in NAV2 is not grout sealed. Therefore, D-aquifer water has the potential to migrate into the well bore at NAV2 and potentially cause local degradation of the N-aquifer water quality. NAV6 is the only well that is not at least partially completed in the overlying Carmel Formation. NAV8 is the only well not drilled past the Navajo Sandstone into the underlying Kayenta Formation and Wingate Sandstone.

The permit application package describes PWCC's monitoring program in detail (PWCC, 2023, Ch. 16). PWCC monitors the N-aquifer in the lease area for water quality, water level elevation, and pumping volume. For active pumping wells, field measurements are taken for pH, specific conductivity, total dissolved solids (TDS), salinity, and temperature quarterly, and a sample collected from each well for laboratory analysis of a larger suite of chemical parameters. For idled production wells, water quality samples are collected once every five years prior to permit renewal. Water-level data are collected using a combination of data loggers and an airline bubbler system. Well production is measured using totalizing flow meters. The pumpage values are reported quarterly to OSMRE, USGS, Hopi Tribe, and Navajo Nation and are included in the annual hydrology monitoring report.

Groundwater levels from 34 wells installed in the N-aquifer were measured for the USGS 2018-2019 Report (Figure 4). Six of the wells measured for groundwater level are continuously monitored USGS observation wells dedicated for monitoring the N-aquifer and not water supply wells. The six dedicated USGS observation monitoring wells are identified on Figure 4 as: BM1, BM2, BM3, BM4, BM5, and BM6. Withdrawal volume information from the N-aquifer is compiled primarily on the basis of metered data from individual wells operated by BIA, NTUA, and Hopi Tribe. In 2019, groundwater quality was measured at zero wells and four springs. The four monitored spring locations are Pasture Canyon Spring, Moenkopi School Spring, Burro Spring, and Unnamed Spring near Dennehotso.

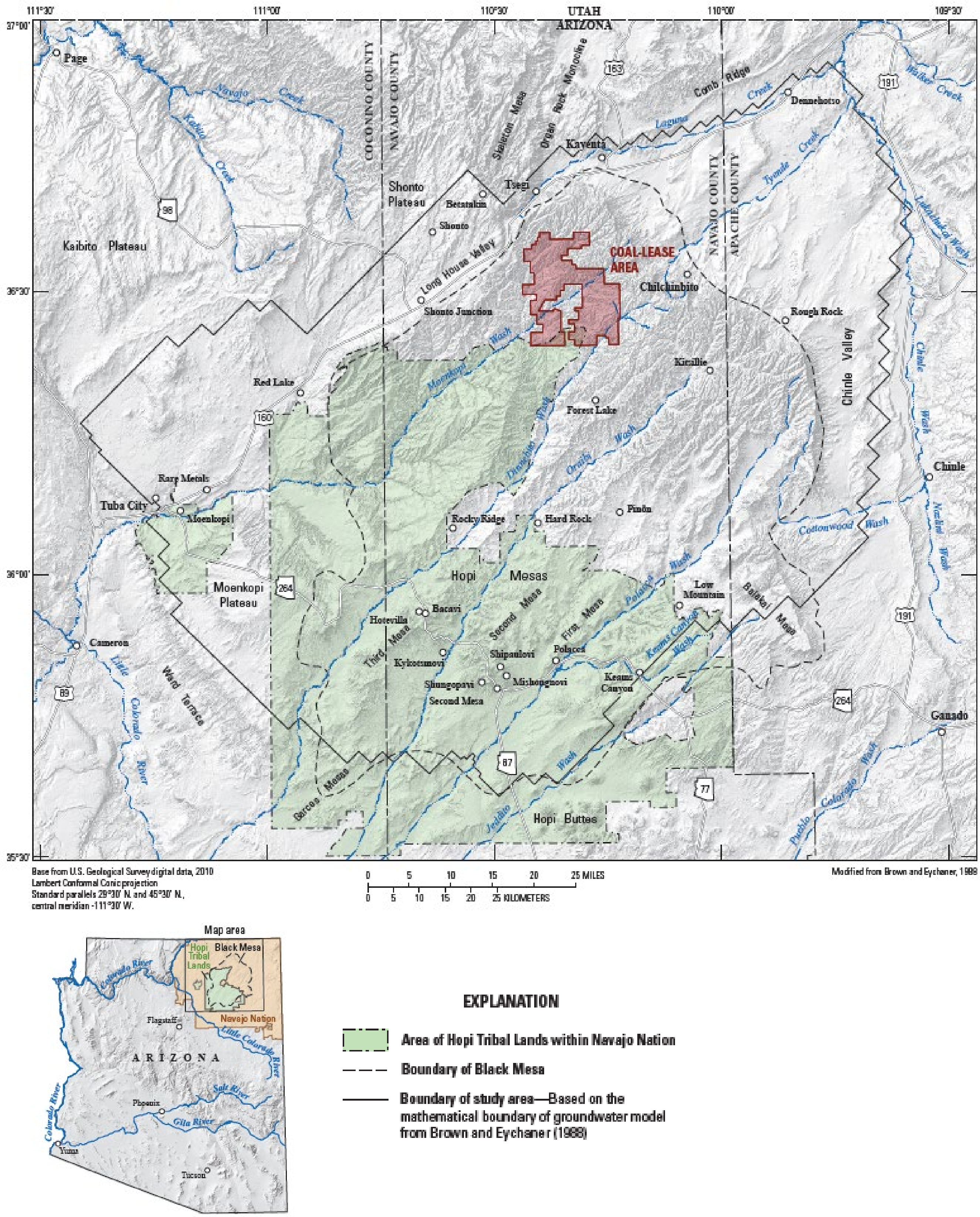

Figure 1. N-aquifer Monitoring Area and Coal Lease Area (Mason, 2022).

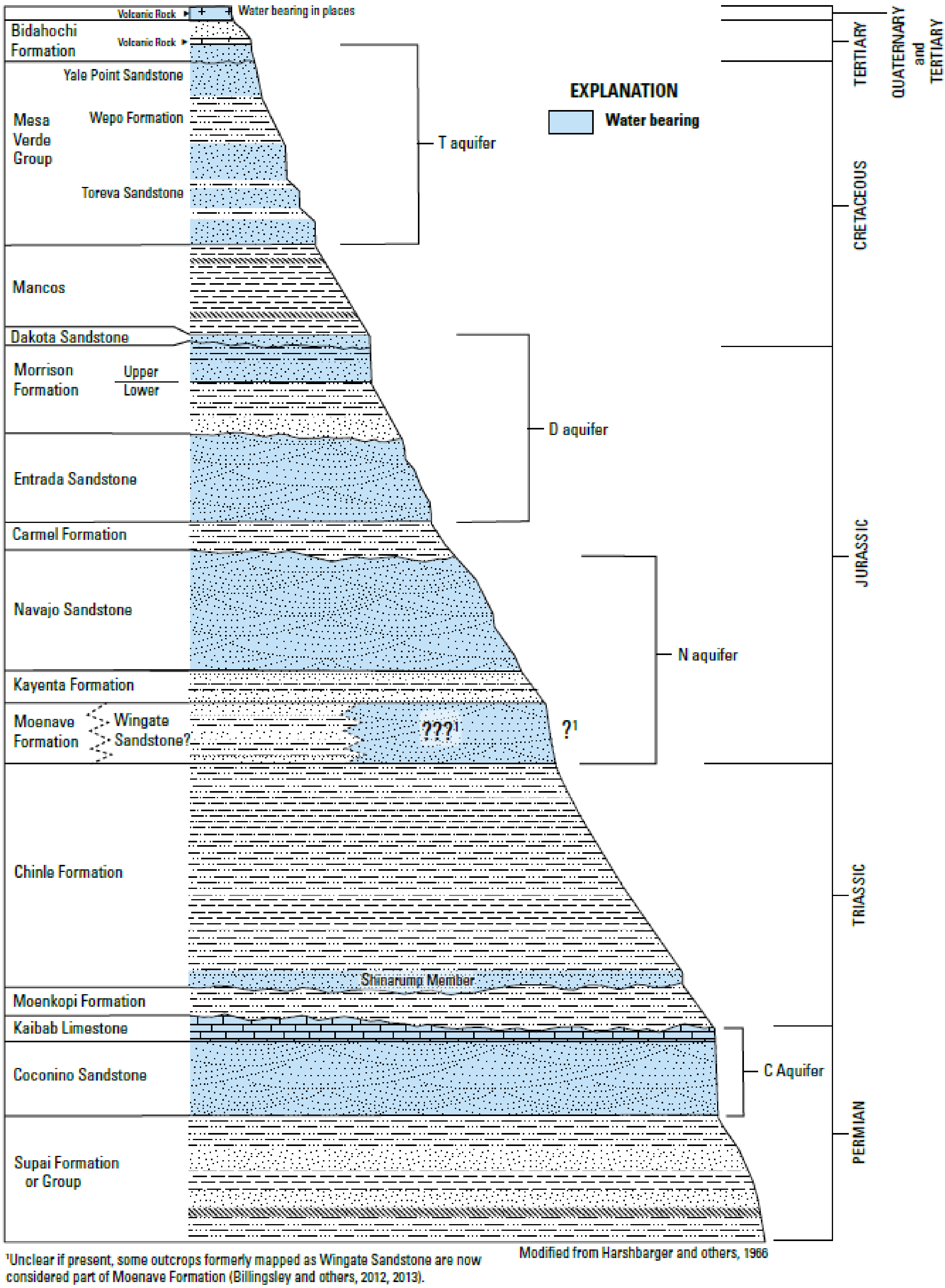

Figure 2. Rock Formations and Major Aquifer Zones of the Black Mesa Area (Mason, 2022).

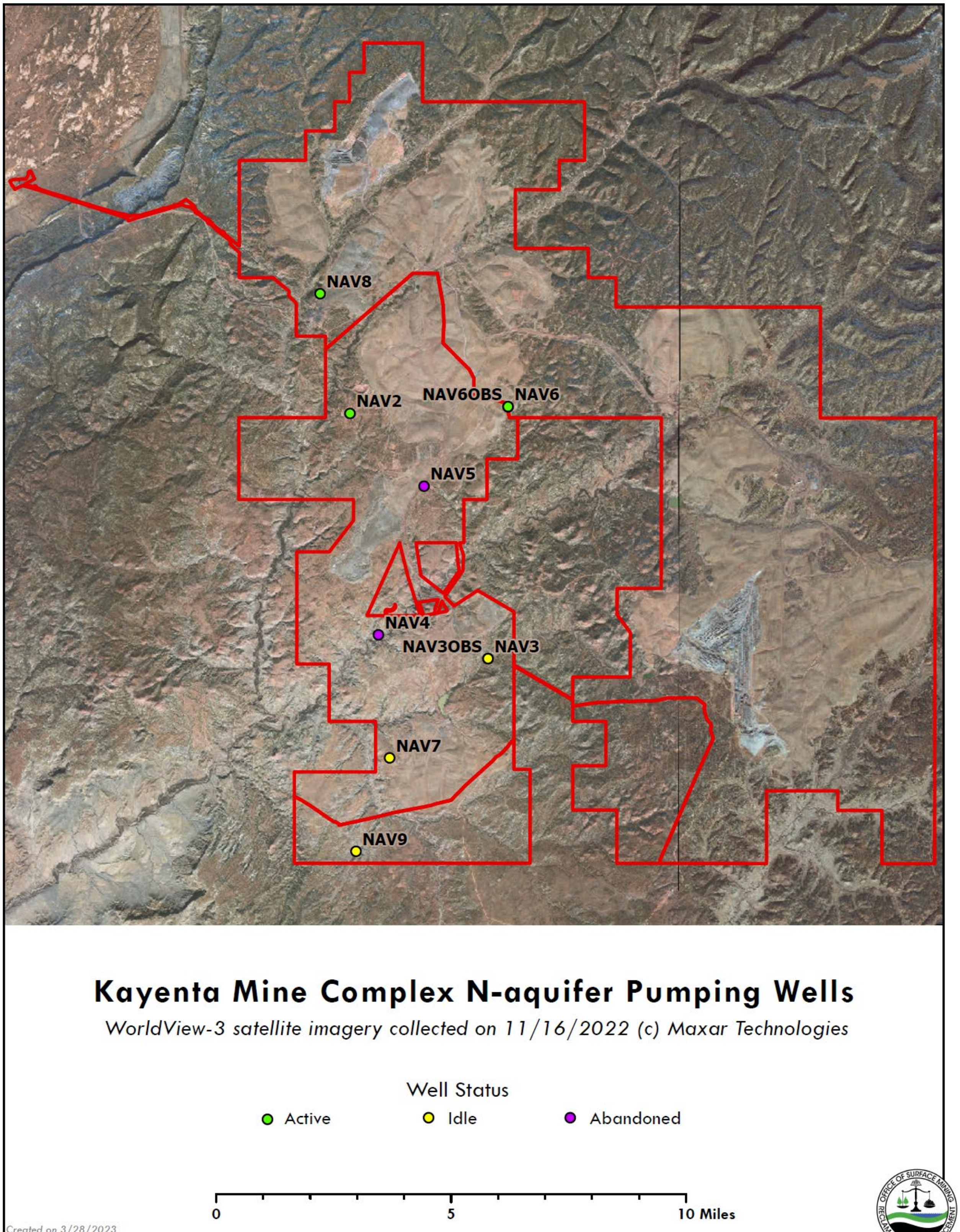

Figure 3. PWCC Lease Boundary and PWCC N-Aquifer Well Locations.

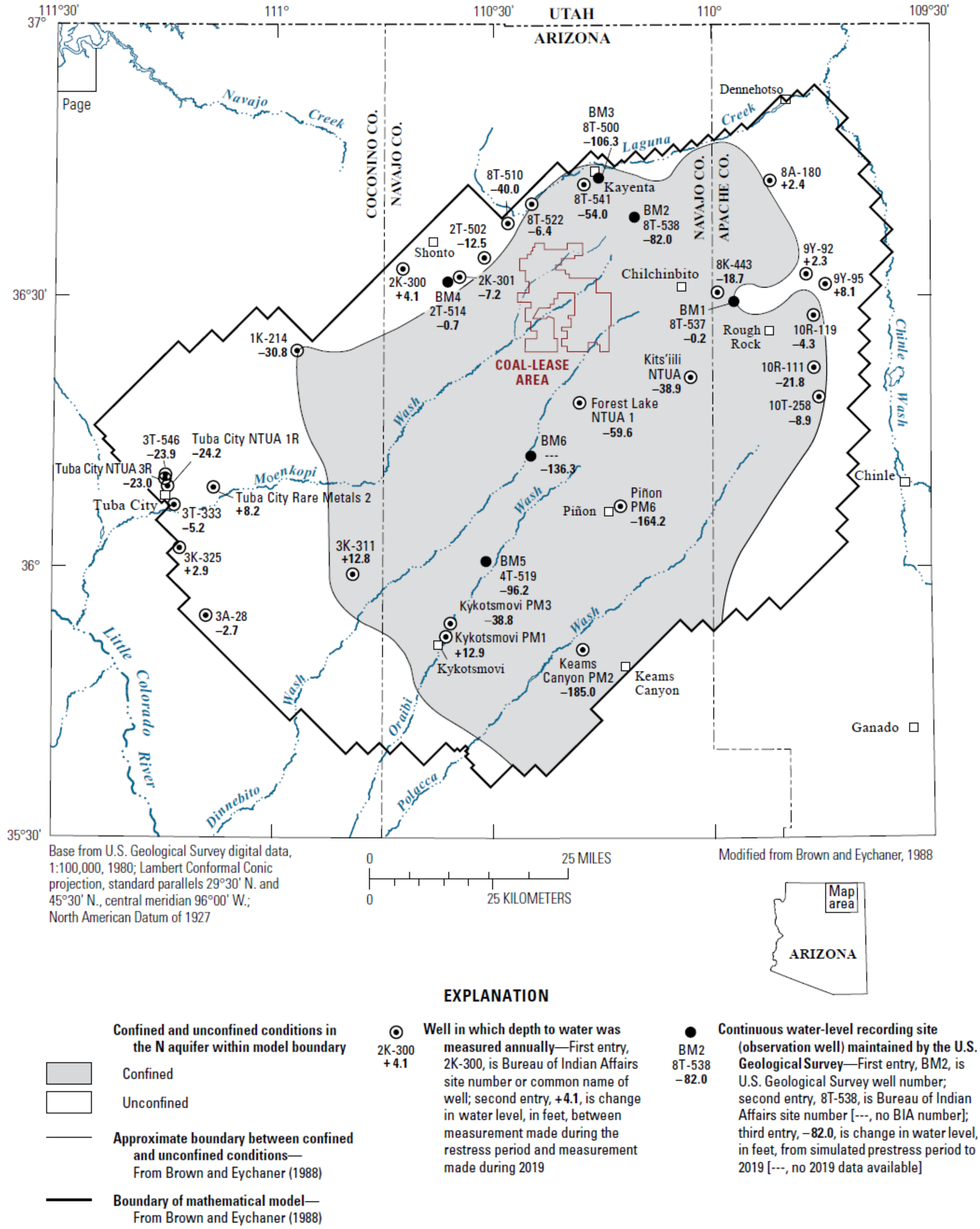

Figure 4. 2019 N-aquifer Monitoring Locations Change from Pre-stress Period (Mason, 2022).

Table 1. PWCC Pumping Wells Screened Aquifer Zone (feet) (PWCC, 2023, Ch. 15).

NAV Well Number	D-Aquifer Screened Interval (feet)			N-Aquifer Screened Interval (feet)			
	Morrison	Entrada	Carmel	Navajo	Kayenta	Wingate	Chinle
2[(a)]	0	0[(a)]	27	735	150	194	0
3/3P	0	0	10	690	170	268	0
4[(c)]	26	160	150	700	60	308	0
5[(b)]	203	155	150	725	155	229	0
6/6P	0	0	0	684	160	294	18
7[(d)]	0	122	150	690	165	206	0
8	0	0	163	787	0	0	0
9	0	0	4	710	150	245	0

(a) Well Number 2 is not completed in the D-aquifer; however, the annular space around its blank casing adjacent to the D-aquifer is not grout sealed. Therefore, D-aquifer water has the potential to migrate into the well bore.
(b) Reclaimed and Abandoned January 2015.
(c) Reclaimed and Abandoned August 2016.
(d) D-aquifer zone sealed August 2016.

3.0 ANALYSIS OF PWCC AND USGS HYDROLOGIC DATA MONITORING REPORTS

The following evaluates available PWCC and USGS data using N-aquifer material damage criteria identified for water quantity and quality to determine if material damage has occurred as a result of PWCC's wellfield pumping.

3.1 Aquifer Response to Pumping

On December 31, 2005, PWCC reduced pumping from approximately 4,500 ac-ft/year to approximately 670 ac-ft/year, averaging 1,235 ac-ft/year for the 10-year period 2010-2019. The N-aquifer system is responding to the reduction in PWCC pumping. Response to this change will first be observed at the PWCC pumping center, then at the more distant USGS monitoring wells that are less influenced by municipal or industrial pumping. OSMRE utilizes three components to assess the aquifer response to the reduced PWCC pumping volumes. These components are:

(1) A Groundwater Flow Model.
(2) USGS Observation Wells Located Outside the Lease Area.
(3) PWCC Observation Wells Located Within the Lease Area.

3.1.1 PWCC Groundwater Flow Model

PWCC submitted a groundwater flow model of the D- and N-aquifers to OSMRE in 1999 for use to evaluate and predict the effect of PWCC pumping on the groundwater system (PWCC, 1999). OSMRE considered the flow model appropriate for determination of hydrologic consequences in September 2004. However, OSMRE made an additional request for a validation of the groundwater model at that time. In 2005, a supplemental report to the flow model was provided to OSMRE that further evaluated the sensitivity of model assumptions that may influence drawdown predictions, specifically N-aquifer system thickness and aquifer structure. The supplemental report also validated model predictions by comparing simulated and measured water levels for the BM wells through 2004 (PWCC, 2005). The model validation was completed again in 2010 using measured water level data through 2009, and results incorporated into the PWCC PHC (PWCC, 2023, Ch. 18). Although some deviation from the predictions was apparent, the overall trends continued to remain in good agreement. In 2012, OSMRE requested that the model be recalibrated, as new data had been collected over a 16-year period that could be used to recalibrate and improve the model predictive accuracy. PWCC updated the flow model as part of a published Draft Environmental Impact Statement, and this model (hereinafter: the 3D Flow Model) replaces the previous transient groundwater flow model developed and calibrated initially during the late 1990s and maintained during the period between 1999 and 2014 (BLM, 2017).

Figure 5 illustrates simulated water level change from baseline in three continuously recorded USGS monitoring wells in the Black Mesa area. BM-2 is approximately nineteen miles to the northeast of the PWCC NAV pumping wells, and approximately seven miles to the southeast of the Kayenta municipal pumping center. The proximity of BM-2 to Kayenta municipal pumping makes it difficult to differentiate the effects of Kayenta municipal pumping from PWCC industrial pumping solely using water level measurements. In 2019, Kayenta community pumped 380.4 acre-feet and PWCC pumped 672.8 acre-feet (Mason, 2022). However, the utility of the calibrated 3D Flow Model allows the allocation of total drawdown impacts to be quantified. Of the total drawdown from all pumping since baseline conditions, the 3D Flow Model simulated total drawdown at BM-3 near Kayenta community at 108.06 feet in 2005, and of the total drawdown 3.36 feet was attributed to PWCC pumping (BLM, 2017).

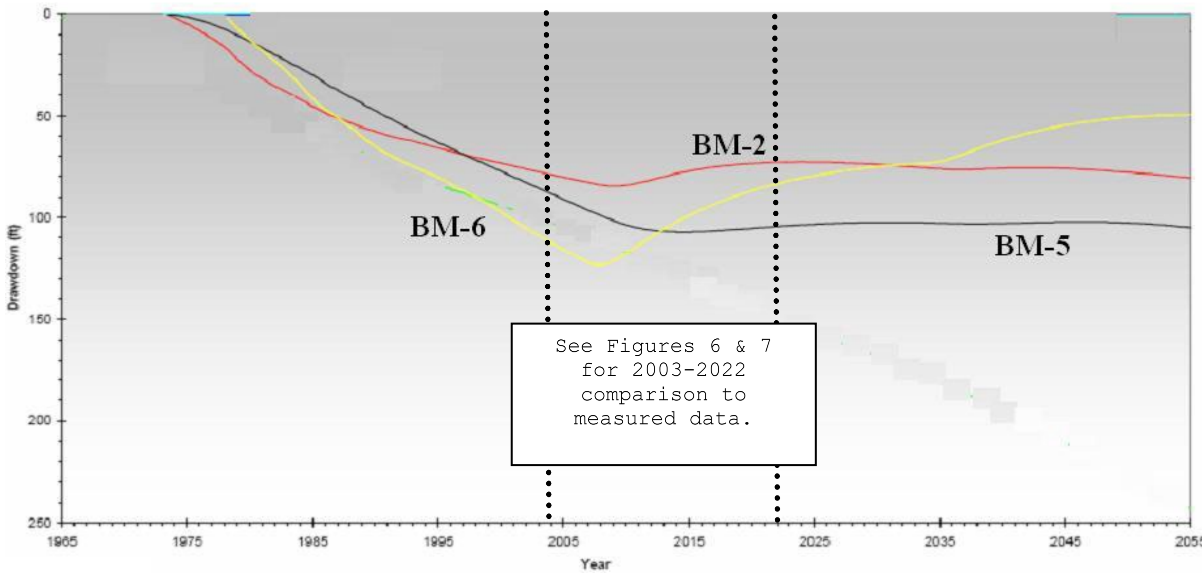

Figure 5. 3D Flow Model Simulated Water Level Response: BM-2, BM-5, BM-6 (BLM, 2017).

USGS monitoring well BM-5 is approximately 30 miles south of the PWCC NAV pumping wells, within 15 miles of most Hopi Tribe municipal pumping locations, and some Navajo Nation pumping locations. In 2019, 734.8 acre-feet of municipal pumping from the Hopi Tribe and Navajo Nation occurred in the confined N-aquifer within 15 miles of BM-5. Figure 5 illustrates that the continued hydrologic stress to the N-aquifer around the area of BM-5, coupled with water level recovery in response to reduced PWCC pumping, will cause water level measurements to stabilize at BM-5. The 3D Flow Model projects maximum drawdown occurred at BM-5 in 2010. The 3D Flow Model was also used to evaluate PWCC allocation of impacts at the Hopi village of Kykotsmovi located 11 miles south of BM-5. Of the total drawdown from all pumping since baseline conditions, the 3D Flow Model simulated a total drawdown of 30.86 feet at Kykotsmovi PM3 in 2005, and of the total drawdown 15.19 feet was attributed to PWCC pumping (BLM, 2017).

USGS monitoring well BM-6 is a good gauge for monitoring PWCC impacts to the confined N-aquifer system due to the long period of continuous water level measurements, the remoteness from significant municipal pumping, and proximity to the PWCC wellfield. BM-6 is approximately 17 miles south of the PWCC wellfield, and approximately 13 miles northwest of the Navajo Nation Pinon municipal pumping center. Pinon pumped 359.7 acre-feet in 2019 (Mason, 2022). The 3D Flow Model simulates a relatively quick recovery response at BM-6 from PWCC reduced pumping. Figure 5 illustrates water levels in BM-6 are projected to stabilize at approximately year 2030 in response to PWCC reduced pumping volume and continued nearby municipal pumping. Another recovery curve begins in 2030, a few years after PWCC pumping is projected to be discontinued and municipal pumping continued (Figure 5).

3.1.2 USGS Observation Wells Located Outside the Lease Area

Model predictions are validated with field measurements. The USGS has monitored withdrawals and water level changes in the Black Mesa area since 1971. N-aquifer monitoring well BM-6 was installed in April 1977 and well BM-5 installed in April 1972. USGS monitoring wells BM-5 and BM-6 provide a good indication of overall regional N-aquifer response due to their location in the confined N-aquifer relative to pumping areas. Since real time data for these wells is collected and publicly available at http://waterdata.usgs.gov/az/nwis/gw, the most current data is included due to the reporting value in this assessment.

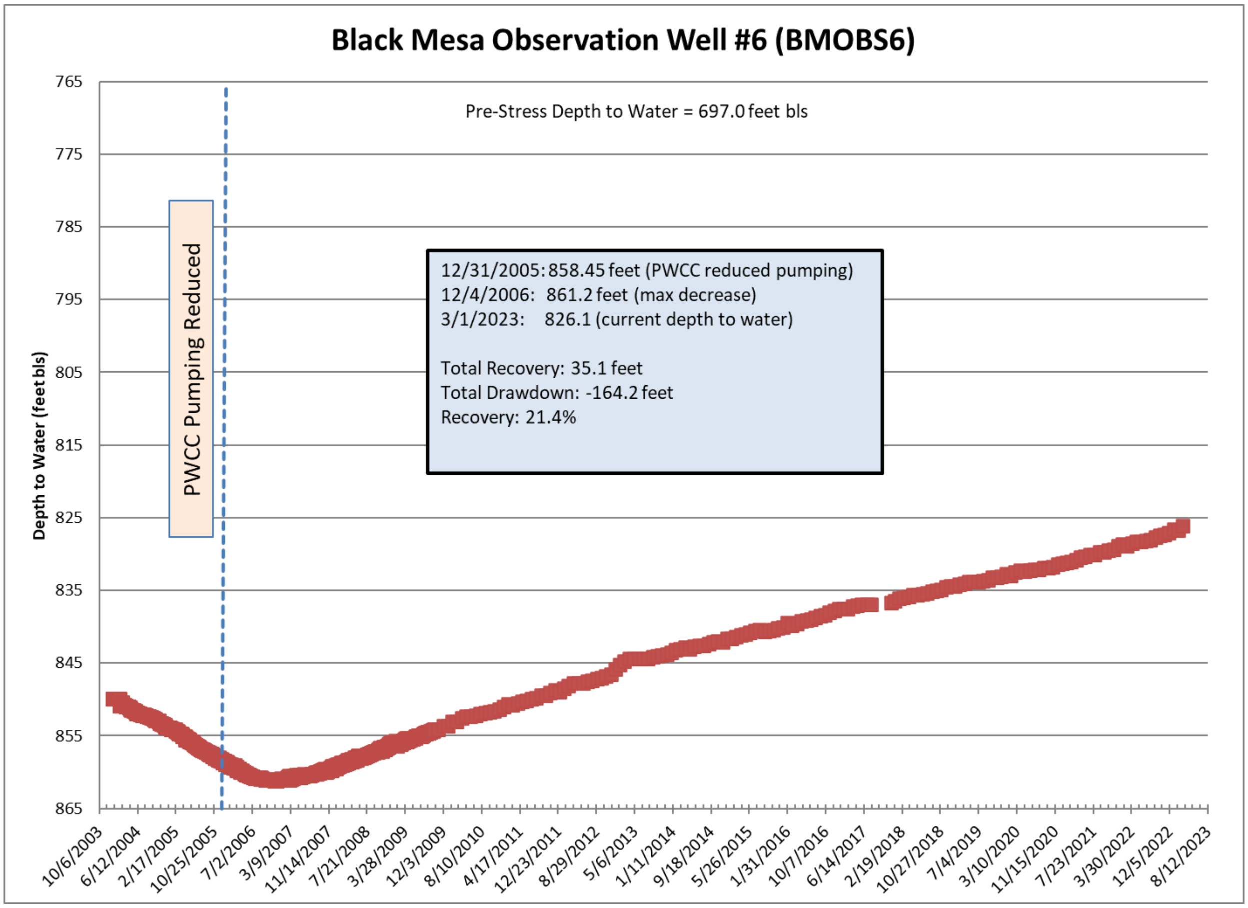

Figure 6. Black Mesa Observation Well BM-6 Water Level Measurements (USGS, 2023).

Figure 6 illustrates water level measurements collected at BM-6 from 1/1/2004 through 3/1/23. Consistent with PWCC model predictions, the N-aquifer responded to PWCC reduced pumping, and measured water levels began to rise in BM-6 during December 2006. BM-6 reached a maximum depth to water of 861.2 feet below land surface December 4, 2006, which represented a decline of 164.2 feet from the pre-stress water level of 697.0 feet below ground surface. In response to reduced PWCC pumping, the N-aquifer water level at BM-6 recovered 35.1 feet since December 2006. The depth to water rose to 826.1 feet below land surface as of March 1, 2023, which represents a 21.4-percent recovery from the December 2006 low.

Based on USGS monitoring at well BM-5, Figure 7 illustrates a continued decline in N-aquifer water levels several years after PWCC reduced N-aquifer pumping. USGS monitoring well BM-5 is approximately 30 miles south of the PWCC wellfield and within 15 miles of most Hopi municipal pumping locations, and some Navajo Nation pumping locations. In 2019, 734.8 acre-feet were pumped from the confined N-aquifer within 15 miles of BM-5. This continued hydrologic stress to the N-aquifer around the area of BM-5, coupled with water level recovery in response to reduced PWCC pumping, will likely result in the stabilization of water level measurements at BM-5. Figure 7 indicates that a low water level measurement of 427.80 feet occurred on November 27, 2011. The March 1, 2023, water level measurement of 417.51 feet below land surface represents a 10.29-foot water level rise from the November 2011 recorded low.

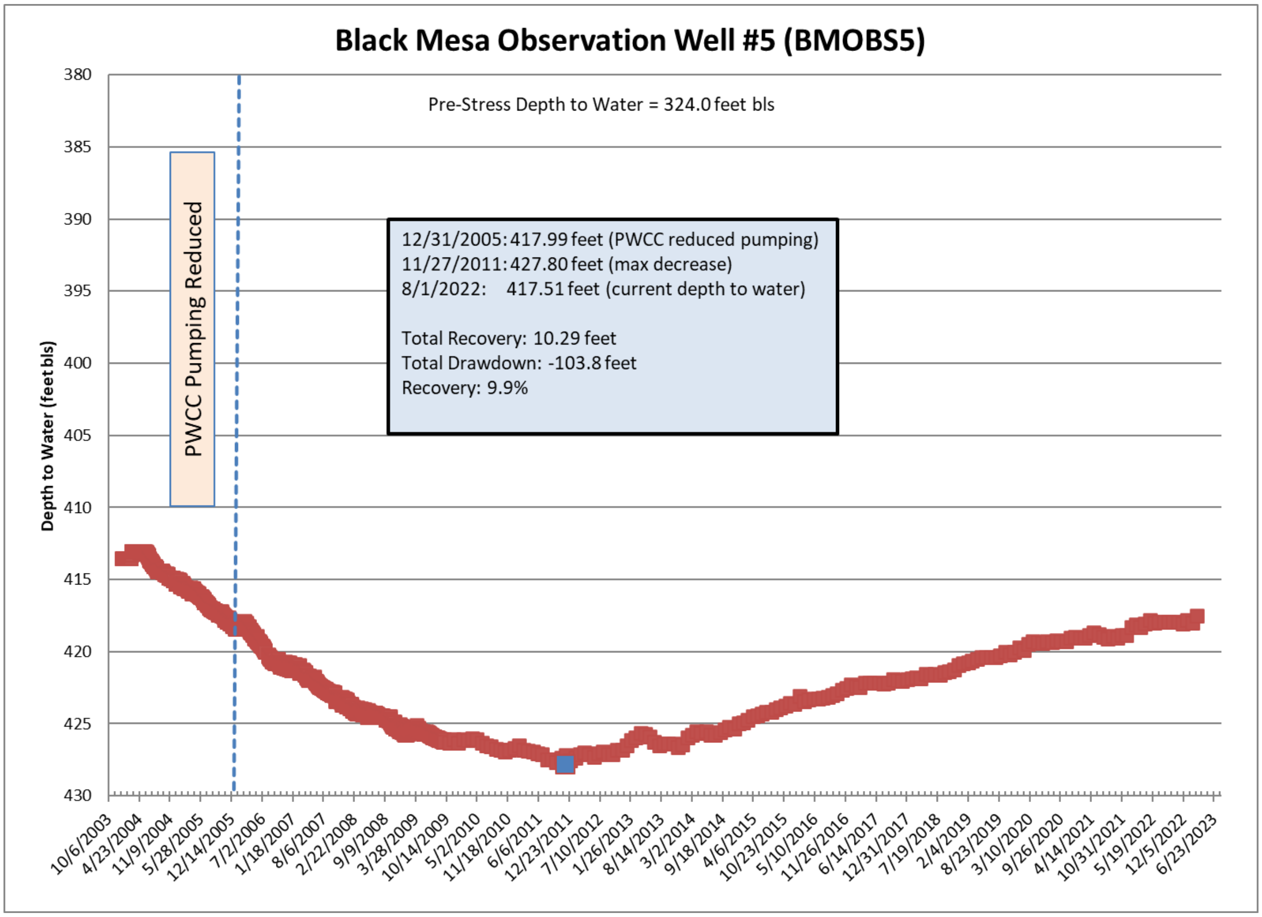

Figure 7. Black Mesa Observation Well BM-5 Water Level Measurements (USGS, 2023).

3.1.3 PWCC Observation Wells Located within the Lease Area

PWCC was the dominant user of water from the confined N-aquifer from 1970-2005. As such, the PWCC pumping activity caused the most significant drawdown in the confined N-aquifer at the PWCC wellfield. As a result of PWCC's reduced pumping, aquifer response will first be apparent at the PWCC pumping center. Opposed to the delayed response measured at USGS wells BM-6 and BM-5, water level response to reduced PWCC pumping on 1/1/2006 was immediate at the PWCC NAV pumping wells within the PWCC lease area.

N-aquifer water level response is measured within the lease area at observation monitoring wells NAV3OBS and NAV6OBS (Figure 8). Observation monitoring well NAV3OBS is within the lease area and the PWCC well field (near idled pumping well NAV3), and NAVOBS6 is near idled pumping well NAV6. Note that N-aquifer response for NAVOBS6 was shifted to the response at idled pumping well NAV6 in 2014. Static depth to water at NAVOBS3 was 730 feet below ground surface when initially completed. Static depth to water at NAVOBS6 and NAV6 was 895 feet. Maximum depth to water for NAVOBS3 occurred in 2005, measured at 1155 feet below ground surface, or 425 feet of drawdown. Maximum depth to water for NAVOBS6 occurred in 2004, measured at 1344 feet below ground surface, or 449 feet of drawdown. Water level measurements in 2021 were 881 and 1100 feet below ground surface at NAV3OBS (274 feet recovery) and NAV6 (244 feet recovery) respectively. Since maximum drawdown, static water level has recovered by 64.5% at NAV3OBS and 54.3% at NAV6.

NAVOBS3:

$$\frac{Total\ Recovery}{Total\ Drawdown} * 100 = Percent\ Recovery \qquad \frac{274\ feet}{425\ feet} * 100 = 64.5\%\ Recovery$$

NAVOBS6/NAV6:

$$\frac{Total\ Recovery}{Total\ Drawdown} * 100 = Percent\ Recovery \qquad \frac{244\ feet}{449\ feet} * 100 = 54.3\%\ Recovery$$

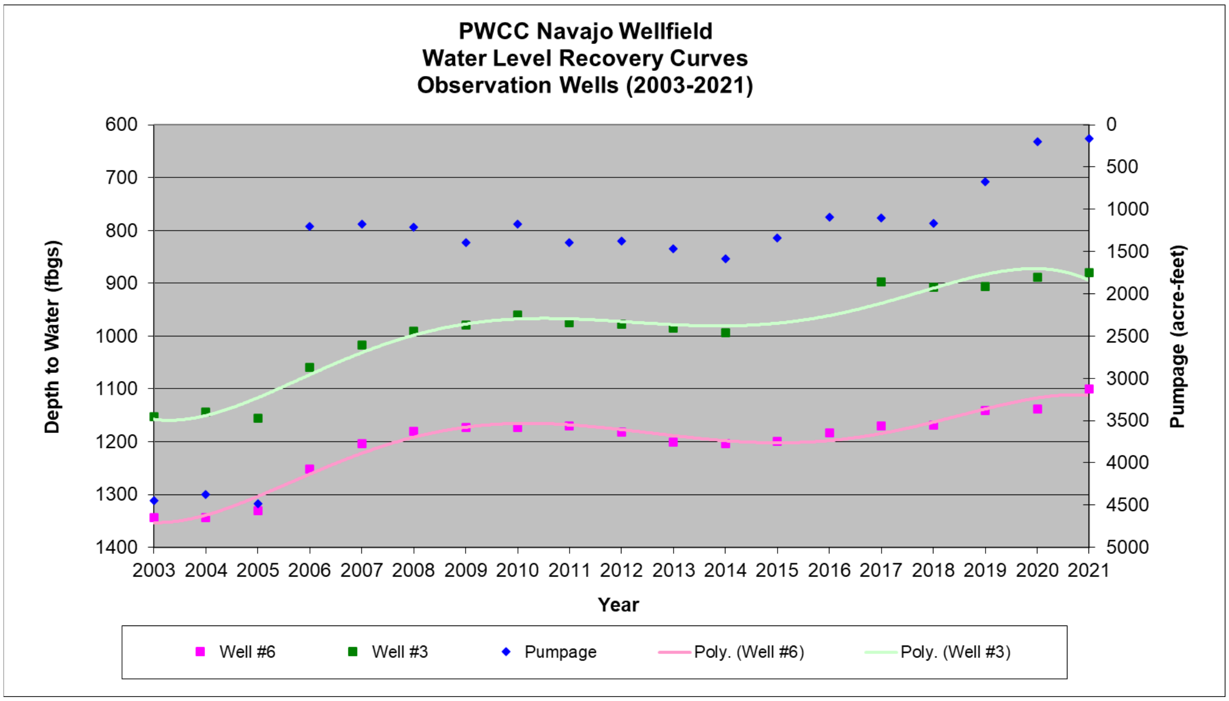

Figure 8. Observation Wells NAVOBS3 and NAV6/6OBS Response (PWCC, 2022, Table 20).

3.2 Confined N-aquifer Water Quantity Review and Analysis

EVALUATION CRITERION: Numeric water levels that will be physically measured for all wells screened in the confined area of the N-aquifer that are monitored by the USGS (OSMRE, 2016)

This section discusses the development of 'material damage' criteria as required by the "Stipulated Settlement Agreement of Appellants to Nizhoni Ani et.al. February 2012 Request for Review", IV. Hydrology Claims: No. 2 which states:

OSM shall identify and adopt, as material damage criteria for the Navajo Sandstone Aquifer ("N-Aquifer"), numeric water levels that will be physically measured for all wells screened in the confined area of the N-aquifer that are monitored by the U.S. Geological Survey (USGS).

OSMRE has defined 'material damage' as:

Material damage to the hydrologic balance outside the permit area means any quantifiable adverse impact from surface coal mining and reclamation operations on the quality or quantity of surface water or groundwater that would preclude any existing or reasonably foreseeable use of surface water or groundwater outside the permit area.

Given the large size of the N-Aquifer system, its artesian head, depth, thickness and the amount of groundwater in storage, "precluding any existing or reasonably foreseeable use" of groundwater is an economic rather than physical concern. Historic mine pumping has declined from a high of about 4,500 ac-ft in 2005 to approximately 670 ac-ft in 2019 and will be further reduced in the future until ceasing completely. PWCC wellfield pumping was reported at 204 ac-ft in 2020, and 162 ac-ft in 2021. The question is not one of physical availability but of the cost to supply water from significant depth to users at the land surface.

<u>AFFORDABILITY OF WATER</u>

Many Navajo residents within the N-Aquifer study area reside in communities that receive water service through the Navajo Tribal Utility Authority (NTUA). Many Hopi have water service through village water systems. However, some members of both tribes in the study area have no water service, relying on hauled water for potable use. Transportation costs are typically many times higher than the commodity costs of the water itself.

Poverty rates among residents in the N-Aquifer study area are high; an estimated 38 percent of all households live in poverty, that is, with annual household income below the Federal poverty thresholds. Households in poverty have fewer economic resources and adjustment options to respond to increases in prices. Economic data from the Census Bureau suggests that while some Navajo and Hopi households in the study area have incomes above the poverty level, median household and per capita incomes are still below the corresponding values for off-reservation areas in Coconino and Navajo counties and across Arizona. Consequently, increases in commodity prices, such as water costs, may result in greater economic hardships for individuals living on the reservations within the N-Aquifer study area (Dutton 2016).

Given the above economic considerations, OSMRE has determined that "precluding any existing or reasonably foreseeable use" of N-Aquifer groundwater at the Kayenta Mine Complex is defined as increasing the cost of pumping water by more than one (1) dollar per month per connection (household) as a result of declining water levels in community production wells due to drawdown caused by water supply pumping at the Kayenta Mine Complex. Thus, the material damage numeric water levels in the confined area N-Aquifer community water supply wells monitored (for water levels) by the USGS are based on limiting the decline in water level to less than the cost of electric power to lift groundwater of $1/household/month for wells that supply potable water to communities.

Some of the USGS monitored wells are windmills and primarily supply water for livestock use. Water level change in these wells does not have an economic impact unless the water level falls below the ability of the windmill to lift water to the surface. This level is the depth of the windmill's drop pipe installed in the well. If the water level is drawn down below the bottom of the drop pipe, the drop pipe and cylinder must be removed, lengthened and re-installed.

Review of the USGS monitored wells on Black Mesa indicate that 14 wells typically meet the criterion of being 'screened in the confined N-aquifer' and 'monitored for water level by the USGS'. The USGS BM-series monitoring wells were excluded since the use at these locations are for observation; therefore, the preclusion of use is not applicable. These wells are identified in Table 2, with key well data. Location of the wells are shown on Figure 4.

Table 2. USGS Monitored Wells Screened in Confined N-Aquifer (Mason, 2022).

Well Name	**Surface Elevation (ft msl)**	**2019 Depth to Water (ft bls)**	**Depth Top of N-Aquifer (ft bls)**	**Well Type [2]**
Forest Lake NTUA1 (4T-523)	6,654	1,155.6	NR[1]	P
Keams Canyon PM2	5,809	477.5	900	P
Kitsiili NTUA2	6,780	1,336.8	2,205	P
Kykotsmovi PM1	5,657	207.1	880	Pa
Kykotsmovi PM3	5,618	248.8	840	P
Pinon PM6	6,397	907.8	1,870	Pa
Howell Mesa (3K-311)	5,855	450.2	615	W
Marsh Pass (8T-522)	6,040	131.9	480	W
Kayenta West (8T-541)	5,885	284.0	700	W
Rough Rock (10R-119)	5,775	260.9	310	W
Rough Rock (10T-258)	5,903	309.9	460	W
Rough Rock (10R-111)	5,757	191.8	210	W
Sweetwater Mesa (8K-443)	6,024	548.1	590	W
White Mesa Arch (1K-214)	5,771	218.8	250	W

1. NR – Not reported
2. P – Community Production Well
   Pa –Community Production Well Abandoned
   W – Windmill Livestock Well

MATERIAL DAMAGE NUMERIC WATER LEVEL IDENTIFICATION

To set numerical water levels in the above wells to satisfy the material damage criteria, wells are divided into two categories: 1) community water supply wells, and 2) windmill equipped stock watering wells.

Community Water Supply Wells

As described above, the material damage water level is set based on the depth to water below land surface (ft bls) that would result in increasing the household cost of water by no more than $1 per month. This depth to water, or lift, is computed as described below.

The cost of pumping groundwater is given by the following equation (Campbell 1973):

$$Cost/Hour = \frac{(GPM)\ x\ (Lift)\ X\ (0.746)\ x\ (Elect\ Cost\ \$/KW-hr)}{(3960)\ x\ (Pump\ Eff)\ x\ (Motor\ Eff)}$$

Using typical Arizona well values for the following parameters:

- Pump efficiency (75 percent)
- Motor efficiency (90 percent)

The above equation with typical Arizona values was solved for lift, (in ft); the equation in this form is:

$$Lift = \frac{cost/hr}{\$\ KW-hr * GPM * 3.7411E-04}$$

To calculate the lift, it is necessary to estimate the usage, in gpm, per household. This was done by dividing the reported annual water system usage by the number of connections (households) served by the system. The systems with their annual withdrawal, number of households and use per household are given in Table 3.

Table 3. Confined N-Aquifer Water Systems Water Use (OSMRE, 2016).

Water System	2011 Withdrawal (gpm)	Number of Households	2011 Use Per Day Per Household (GPD)[1]
Forest Lake	9.6	49	282
Keams Canyon	36.6	142	371
Kits'illi	13.1	74	254
Kykotsmovi	41.4	250	239
Pinon	208.5	1427	210

1. GPD – gallons per day

The estimated use per household numbers for these systems average 271 gallons per day, which is more than twice the 108 average for all NTUA systems (NTUA 2015). The reasons for this are uncertain; however, since lift is inversely proportional to use (pumping rate), these values suggest the analysis is conservative.

The 2011 cost of electric power from NTUA is $0.07 KW-hr. To account for potential increases in power cost during the life of the mine the cost per kilowatt hour was increased by 30 percent to $0.091 KW-hr for this analysis. Since lift is inversely proportional to power cost, using a higher power cost results in a lower lift to meet the $1 dollar per month threshold, adding conservatism to the analysis.

Substituting per household use (in gpm) into the lift equation and converting $/hour to $/month gives the additional lift to increase the cost of water by one dollar ($1) per household per month. Results of this calculation for the water system supply wells included in Table 2 are given in Table 4. It is not known, in detail, which wells supply which households. Therefore, for purposes of assigning material damage water levels to each identified USGS monitored community water supply well, the same numeric water level value is assigned to all wells within the area of the relevant water system.

Table 4. Lift and Material Damage Numeric Water Level (OSMRE, 2016).

Well Name	Lift (ft)[1]	2012 Depth to Water (ft bls)	Material Damage Depth to Water (ft bls)	Material Damage Water Elevation (ft msl)
Forest Lake NTUA1 (4T-523)	274	1,174	1,448	5,206
Keams Canyon PM2	205	498	703	5,106
Kits'iili NTUA2	306	1,336	1,642	5,138
Kykotsmovi PM1	310	212	522	5,135
Kykotsmovi PM3	310	251	561	5,057
Pinon PM6	368	917	1,286	5,112

1. Lift resulting in a cost of $1/per month per household

Windmill Wells

As noted in Table 2, eight (8) of the USGS monitored confined N-Aquifer wells are windmills primarily used for livestock watering. For those monitored wells, a different basis for the numeric material damage water level is applied.

Once water levels in a windmill well fall below the bottom of the drop pipe, the windmill can no longer lift water to the surface; the drop pipe must be extended (deepened) for the windmill to continue to function. OSMRE has therefore set the material damage numeric water level equal to the depth of the windmill drop pipe. Unfortunately, the depth of the drop pipe was not available for two (2) of the windmill wells; Howell Mesa (3K-311) and White Mesa Arch (1K-214). For these windmills, the material damage water level was set at the top of the N-aquifer. On this basis, the material damage numeric water level for USGS monitored wells with windmills are given in Table 5.

Table 5. Material Damage Numeric Water Level for Windmill Wells (OSMRE, 2016).

Well Name	Top of N-Aquifer (ft bls)	Well Depth (ft bls)	2012 Depth to Water (ft bls)	Depth of Drop Pipe[1] (ft bls)	Material Damage Depth to Water (ft bls)	Material Damage Water Elevation (ft msl)
Howell Mesa (3K-311)	615	745	444	615[(1)]	615	5,240
Marsh Pass (8T-522)	480	933	128	189	189	5,851
Kayenta West (8T-541)	700	890	298	420	420	5,465
Rough Rock (10R-119	310	360	298	336	336	5,439
Rough Rock (10T-258)	460	670	257	336	336	5,567
Rough Rock (10R-111)	210	360	312	262	262	5,495
Sweetwater Mesa (8K-443)	590	720	199	588	588	5,436
White Mesa Arch (1K-214)	250	356	545	250[(1)]	250	5,521

(1) Drop pipe depth not available – Material Damage Water Elevation is Top of N-aquifer.

Numeric Water Levels are Conservative

The material damage numeric water levels given in Tables 4 and 5 are conservative since they do not differentiate between water level drawdown due to mine pumping and non-mine (community and windmill) pumping. The effects of all pumping are reflected in any change in water level. The threshold of economic impact ($1 dollar per month analysis) is protective of the most vulnerable population (those at or below the poverty level) and the cost of electric power is increased 30 percent, decreasing the material damage numeric depth to water value (shallower water level).

Differentiation of Change in Water Level Due to Pumping

As noted above, the material damage water levels do not differentiate between water level drawdown between PWCC mine-related pumping and that due to community, windmill and other pumping. Since OSMRE is responsible for regulating PWCC's activities and has no regulatory authority over community or other pumping, if a material damage level is reached in a given well, the pumping contributing to the drawdown must be assigned to PWCC and others. This will be accomplished by monitoring changes to pumping volumes by PWCC, the communities and any other withdrawals (including future industrial or other uses). Active windmills pump at generally consistent (and low) rates and can be excluded from the analysis. Changes in pumping rates can be input to the PWCC Black Mesa Groundwater Flow Model to estimate the relative change in water level at the well under consideration due to each pumping source. The amount of drawdown due to PWCC can be computed and a determination made if the material damage numeric water level has been exceeded due to PWCC withdrawals.

MATERIAL DAMAGE NUMERIC WATER LEVEL REVIEW

N-aquifer withdrawals and changes in N-aquifer potentiomentic head level are monitored to evaluate the confined N-aquifer quantity material damage criterion. Between the calendar years 1996 and 2005, PWCC pumped a total of 4,013 to 4,640 acre-feet per year from all its production wells, averaging 4,336 acre-feet per year for the same period (Mason, 2022). The Bureau of Indian Affairs, Navajo Tribal Authority, and Hopi Tribe operate about 70 municipal water supply wells. Also, there are about 270 windmills in the Black Mesa Area that are used to withdraw water from the D- and N-aquifers. Figure 10 illustrates water withdrawn from the N-aquifer by industrial (PWCC) and municipal users through 2019, as estimated on the basis of USGS information (Mason, 2022). Municipal withdrawals are shown as confined and unconfined sources. A total of 3,070 acre-feet were pumped from the N-aquifer in 2019 (Mason, 2022). Figure 11 illustrates the locations of the confined and unconfined pumping centers and quantities of water pumped at each pumping center in 2019. Figure 4 illustrates monitored well locations and water level changes from the 1965 pre-stress period.

Industrial use accounted for 21.8-percent of the total N-aquifer use in 2019, and 33.3-percent of the total use in the confined N-aquifer (Mason, 2022). PWCC pumping was reduced on December 31, 2005, when use of the coal slurry pipeline to the Mojave Generating Station ceased. Table 6 summarizes annual withdrawal from the N-aquifer since 1965, separated by industrial confined pumped quantity, municipal confined pumped quantity, and municipal unconfined pumped quantity.

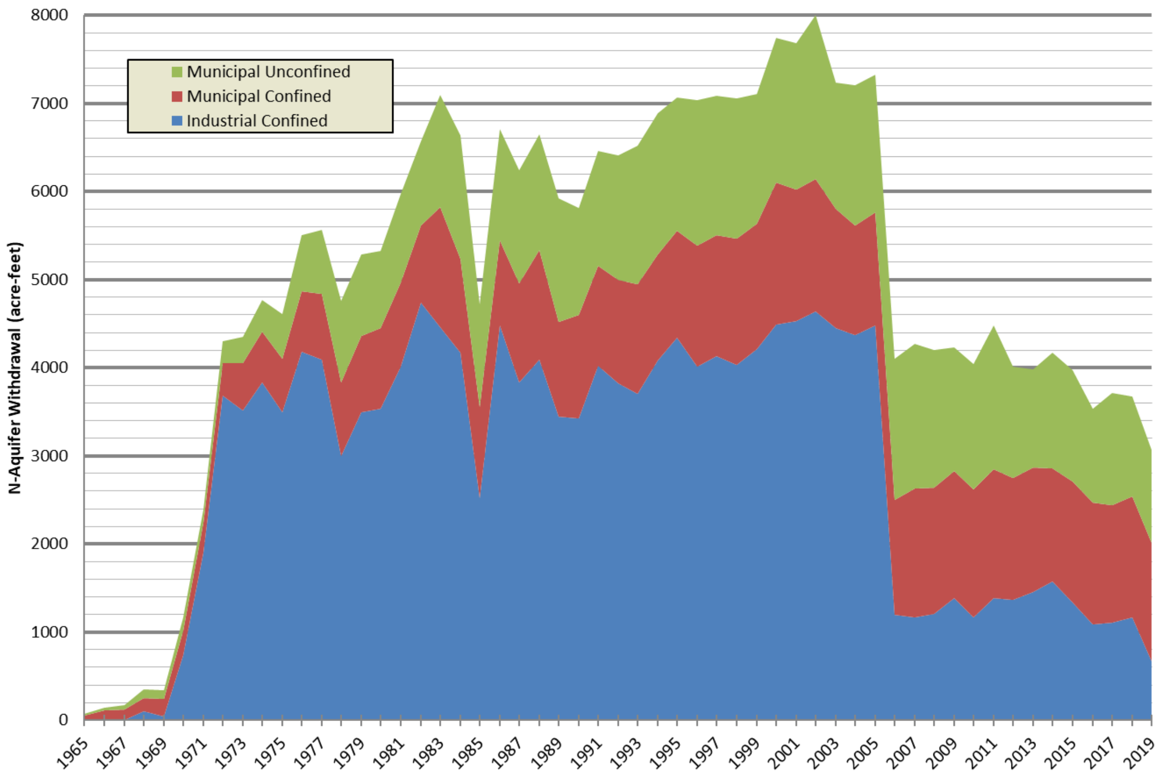

Figure 9. Historical Total N-Aquifer Withdrawal 1965 - 2019 (Mason, 2022).

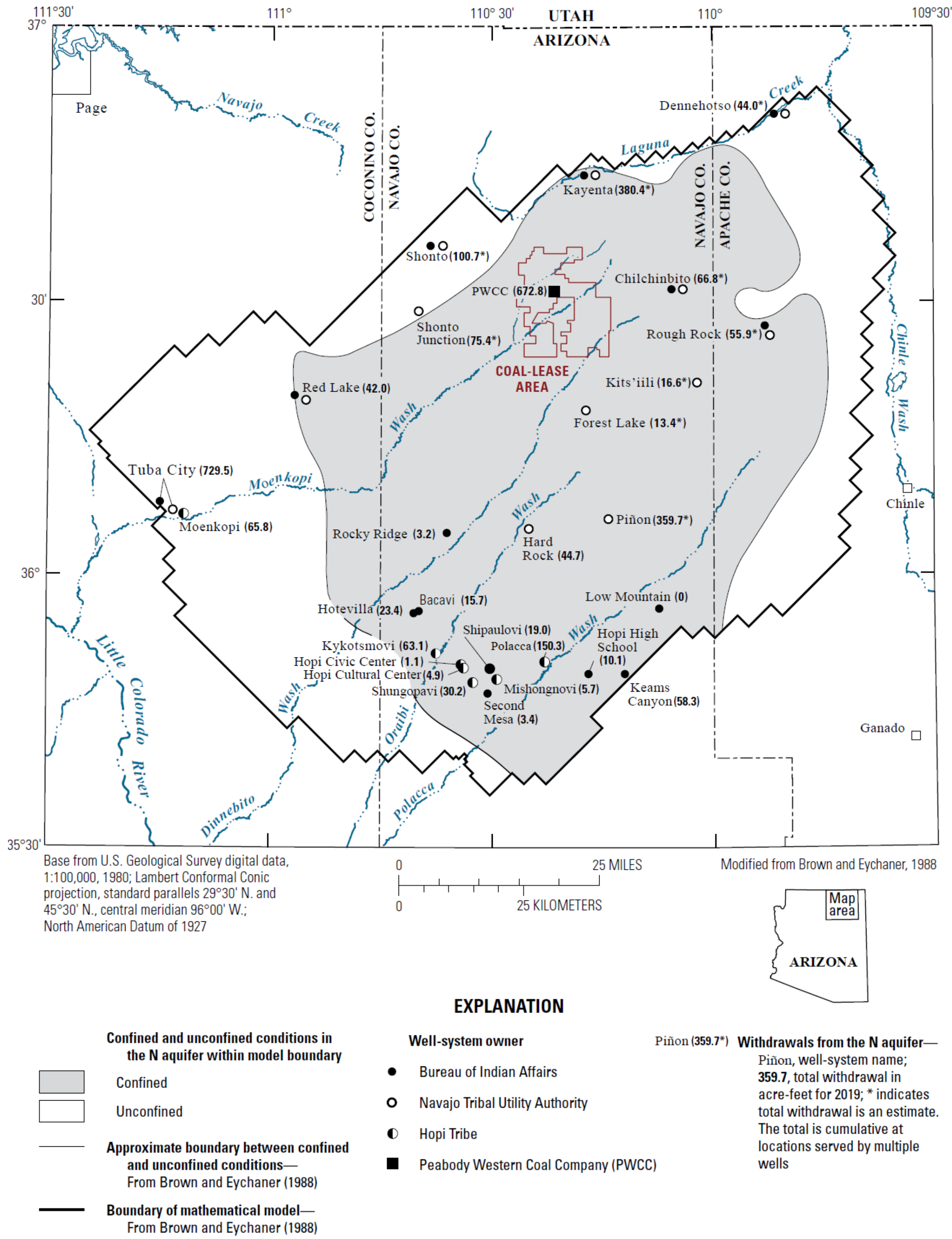

Figure 10. 2019 N-aquifer Pumping Centers and Volume (Mason, 2022).

Table 6. N-Aquifer Pumping Volumes (acre-feet) 1965 – 2019 (Mason, 2022).

Year	Industrial Confined	Municipal Confined	Municipal Unconfined	Total
1965	0	50	20	70
1966	0	110	30	140
1967	0	120	50	170
1968	100	150	100	350
1969	40	200	100	340
1970	740	280	150	1170
1971	1900	340	150	2390
1972	3680	370	250	4300
1973	3520	530	300	4350
1974	3830	580	360	4770
1975	3500	600	510	4610
1976	4180	690	640	5510
1977	4090	750	730	5570
1978	3000	830	930	4760
1979	3500	860	930	5290
1980	3540	910	880	5330
1981	4010	960	1000	5970
1982	4740	870	960	6570
1983	4460	1360	1280	7100
1984	4170	1070	1400	6640
1985	2520	1040	1160	4720
1986	4480	970	1260	6710
1987	3830	1130	1280	6240
1988	4090	1250	1310	6650
1989	3450	1070	1400	5920
1990	3430	1170	1210	5810
1991	4020	1140	1300	6460
1992	3820	1180	1410	6410
1993	3700	1250	1570	6520
1994	4080	1210	1600	6890
1995	4340	1220	1510	7070
1996	4010	1380	1650	7040
1997	4130	1380	1580	7090
1998	4030	1440	1590	7060
1999	4210	1420	1480	7110
2000	4490	1610	1640	7740
2001	4530	1490	1660	7680
2002	4640	1500	1860	8000
2003	4450	1350	1440	7240
2004	4370	1240	1600	7210
2005	4480	1280	1570	7330
2006	1200	*1300*	*1600*	*4100*
2007	1170	1460	1640	4270
2008	1210	1430	1560	4200
2009	1390	1440	1400	4230
2010	1170	*1450*	1420	*4040*
2011	1390	*1460*	1630	*4480*
2012	1370	*1380*	1260	*4010*
2013	1460	*1410*	*1110*	*3980*
2014	1580	*1280*	*1310*	*4170*
2015	1340	*1370*	*1260*	*3970*
2016	1090	*1380*	*1070*	*3540*
2017	1110	1330	*1270*	*3710*
2018	1170	*1370*	*1130*	*3670*
2019	670	*1340*	*1060*	*3540*

Italicized Pumping Volumes are Estimated

Table 7 presents water levels measured by the USGS at selected community wells and windmills in the confined N-aquifer monitored by the USGS in 2019. The pre-stress N-aquifer water levels of these selected wells were compared to the current water levels. The feet from each material damage water level are also presented based on 2019 water level measurements published by the USGS. As indicated in Table 7, water levels remain above established material damage water levels in all wells in the confined N-aquifer monitored by the USGS. Therefore, based on available information, OSMRE concludes that material damage to the hydrologic balance of the confined N-aquifer, attributable to mining, has not occurred based on the 2016 CHIA criterion for N-aquifer quantity.

Table 7. 2019 Water Level Comparison to Material Damage Levels (Mason, 2022)

Location	Well ID	Units	Pre-Stress Water Level (feet bgs)	Material Damage Water Level (feet bgs)	2019 Water Level (feet bgs)	Feet from Pre-Stress Water Level	Feet from material damage level
Forest Lake	4T-523	Feet	1096	1448	1155.6	-59.6	292.4
Pinon	PM6	Feet	743.6	1285	907.8	-164.2	377.2
Keams Canyon	PM2	Feet	292.5	703	477.5	-185.0	225.5
Kits'iili	NTUA 2	Feet	1297.9	1642	1336.8	-38.9	305.2
Kykotsmovi	PM1	Feet	220	522	207.1	12.9	314.9
Kykotsmovi	PM3	Feet	210	561	248.8	-38.8	312.2
Howell Mesa	3K-311	Feet	463	615	450.2	12.8	164.8
Kayenta West	8T-541	Feet	230	420	284.0	-54.0	136
Marsh Pass	8T-522	Feet	125.5	189	131.9	-6.4	57.1
Rough Rock	10R-119	Feet	256.6	336	260.9	-4.3	75.1
Rough Rock	10T-258	Feet	301	336	309.9	-8.9	26.1
Rough Rock	10R-111	Feet	170	262	191.8	-21.8	70.2
Sweetwater Mesa	8K-443	Feet	529.4	588	548.1	-18.7	39.9
White Mesa Arch	1K-214	Feet	188	250	218.8	-30.8	31.2

3.3 Confined N-aquifer Water Quality Review and Analysis

EVALUATION CRITERION: Safe Drinking Water Act standards for arsenic, boron, chloride, selenium, sulfate, and TDS water quality constituents at PWCC N-aquifer supply wells.

The next evaluation criterion addresses the potential degradation of N-aquifer water quality. Since PWCC pumping increases the pre-mining leakage potential between the D aquifer and N-aquifer, the degradation of N-aquifer quality due to mine related pumping is a monitored hydrologic concern. The USGS predicted that any increase in leakage from the D aquifer would first appear as increased total TDS (Eychaner, 1983). The USGS (Eychaner, 1983) also identified increased chloride and sulfate concentrations as important indicators of increased D aquifer leakage. Therefore, the USGS and PWCC have compiled and evaluated TDS, chloride, and sulfate concentrations in N-aquifer wells since the early 1980's. To date, "the USGS Black Mesa monitoring program has not detected any significant changes in the major-ion water chemistry of the N-aquifer that are related to induced leakage" (Thomas, 2002) (Truini and Longsworth, 2003).

OSMRE has received and reviewed N-aquifer production well water quality for several decades for TDS, sulfate, and chloride in addition to many other water quality parameters. Settlement Condition (5) associated with Docket No. DV-2012-3-R states:

> In the updated Kayenta Mine Complex CHIA, OSM shall add, as part of the N-aquifer water quality material damage criteria at PWCC N-aquifer wells, numeric water quality parameters including but not limited to arsenic, selenium, and boron that will be evaluated through laboratory analysis. OSM shall modify the monitoring plan to require monitoring for such parameters at the PWCC N-aquifer wells and with the same frequency as other N-aquifer water quality material damage parameters. OSM shall not establish material damage criteria for any parameter in excess of U.S. Safe Drinking Water Act standards or current concentration of that parameter, whichever is higher, at the PWCC N-aquifer wells. If the U.S. Safe Drinking Water Act does not establish a standard for a particular parameter, OSM shall not establish a material damage criterion in excess of Hopi or Navajo Nation livestock watering standards or the current concentration of that parameter, whichever is higher.

PWCC N-aquifer wells are monitored for a suite of water quality parameters at a frequency provided in the approved permit Hydrologic Monitoring Program (PWCC, v.11, ch.16, Table 12). Since 2015, PWCC monitors two types of N-aquifer wells: active and idle. NAV3 and NAV9 were idled during 2015. NAV7 was rehabilitated to eliminate hydraulic communication with the overlying D aquifer and idled during March 2016. In agreement with the Tribes, idled monitoring wells will be sampled for water quality no less than every 5-years. Idled wells are scheduled for water quality sampling in 2024. NAV5 was permanently abandoned on January 23, 2015, in accordance with Tribal approval. NAV4 was abandoned March 2016. NAV2, NAV6, and NAV8 are actively pumped to support mining and reclamation operations. The following describes the U.S. Safe Drinking Water Act standards for arsenic, selenium, and boron.

Effective January 23, 2006, the arsenic drinking water standard is 10 µg/L. Arsenic concentrations are evaluated through laboratory analysis and monitored at the same frequency as other N-aquifer water quality material damage parameters as described in the approved permit (PWCC, v.11, ch.16, 2023).

Selenium drinking water standard is 0.05 mg/L. Selenium concentrations are evaluated through laboratory analysis and monitored at the same frequency as other N-aquifer water quality material damage parameters as described in the approved permit (PWCC, v.11, ch.16, 2023).

Boron was identified on the second published EPA contaminant candidate list (CCL 2) in 2005. In May 2007, the Agency published a Federal Register (FR) notice announcing and requesting comment on its preliminary determinations for 11 of the 51 CCL 2 contaminants. In July 2008, EPA published its final determination that no regulatory action is appropriate or necessary for boron. Hopi Tribe drinking water standard for total recoverable boron is 1400 µg/L. Navajo Nation domestic water supply boron standard is 630 µg/L. Boron concentrations are evaluated through laboratory analysis and monitored at the same frequency as other N-aquifer water quality material damage parameters as described in the approved permit (PWCC, v.11, ch.16, 2023).

Figures 11, 12, 13, 14, 15, and 16 illustrate concentrations at PWCC N-aquifer wells from 2000-2022 for arsenic, boron, chloride, selenium, sulfate, and TDS, respectively. As illustrated in the graphs, all concentrations for these constituents have remained below all water quality concentration limits. Arsenic concentrations are typically measurable in all PWCC N-aquifer wells between 2-4 µg/L and below the 10 µg/L standard. Boron concentrations are often not detectable but reported as the method detection limit concentration that is far below the 630 µg/L standard. Chloride concentrations are measurable in all PWCC N-aquifer wells between 2-5 mg/L and below the 250 mg/L standard. Selenium concentrations are nearly always not detectable but reported as the method detection limit concentration of 1 µg/L that is far below the 50 µg/L standard. NAV8 has maintained sulfate concentrations of approximately 120 mg/L, compared to all other NAV wells with sulfate concentrations typically less than 30 mg/L from 2000-2019, and all below the 250 mg/L water quality standard. Lastly, all samples from PWCC N-aquifer wells at the Kayenta Mine Complex have maintained a TDS concentration of less than 350 mg/L from 2000-2021 and below the 500 mg/L TDS standard.

Slight variations in water quality between the various production wells are a result of the screened interval. For instance, as presented in Table 10, NAV8 is the only well not drilled past the Navajo Sandstone into the underlying Kayenta Formation and Wingate Sandstone. Therefore, NAV8 has consistently elevated TDS and sulfate concentrations when compared to the other NAV water supply wells. However, the use potential for the Navajo aquifer remains unchanged at all production wells and is suitable for domestic and livestock uses.

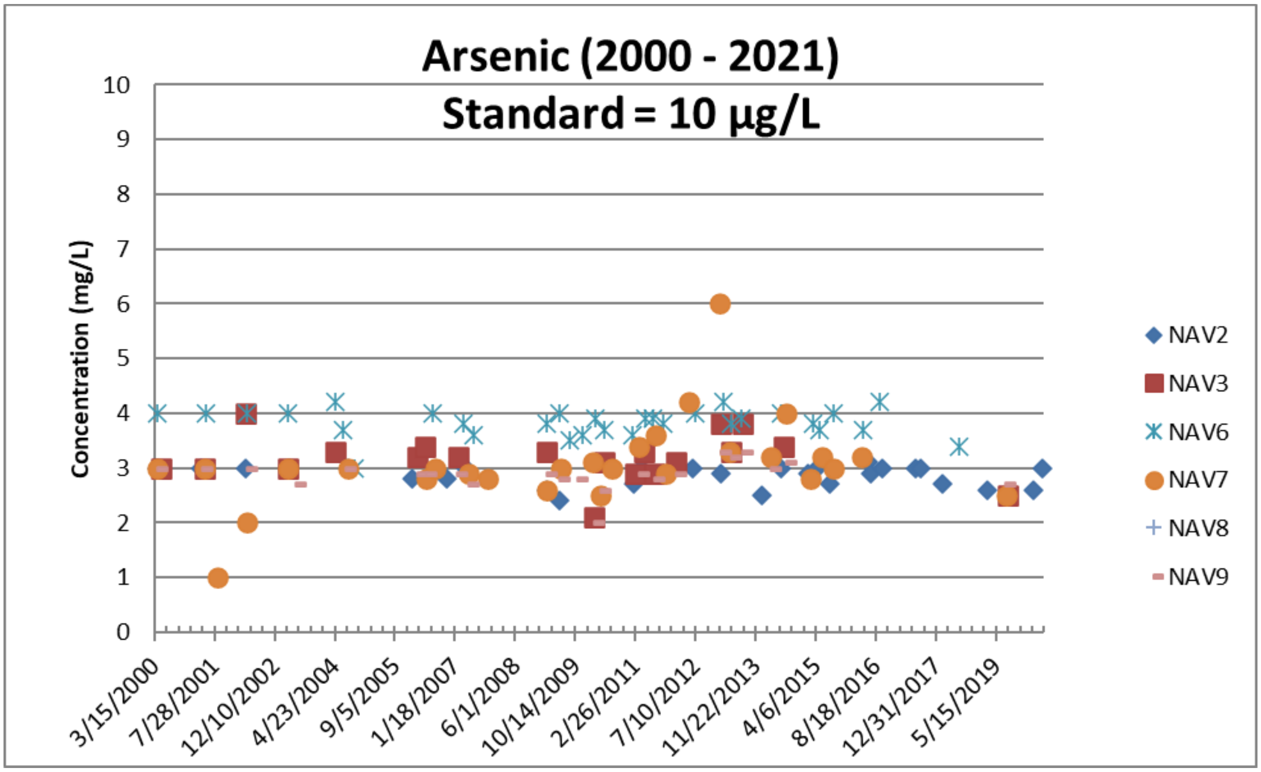

Figure 11. Arsenic Concentrations in PWCC N-aquifer Wells (2000 – 2021) (PWCC, 2022).

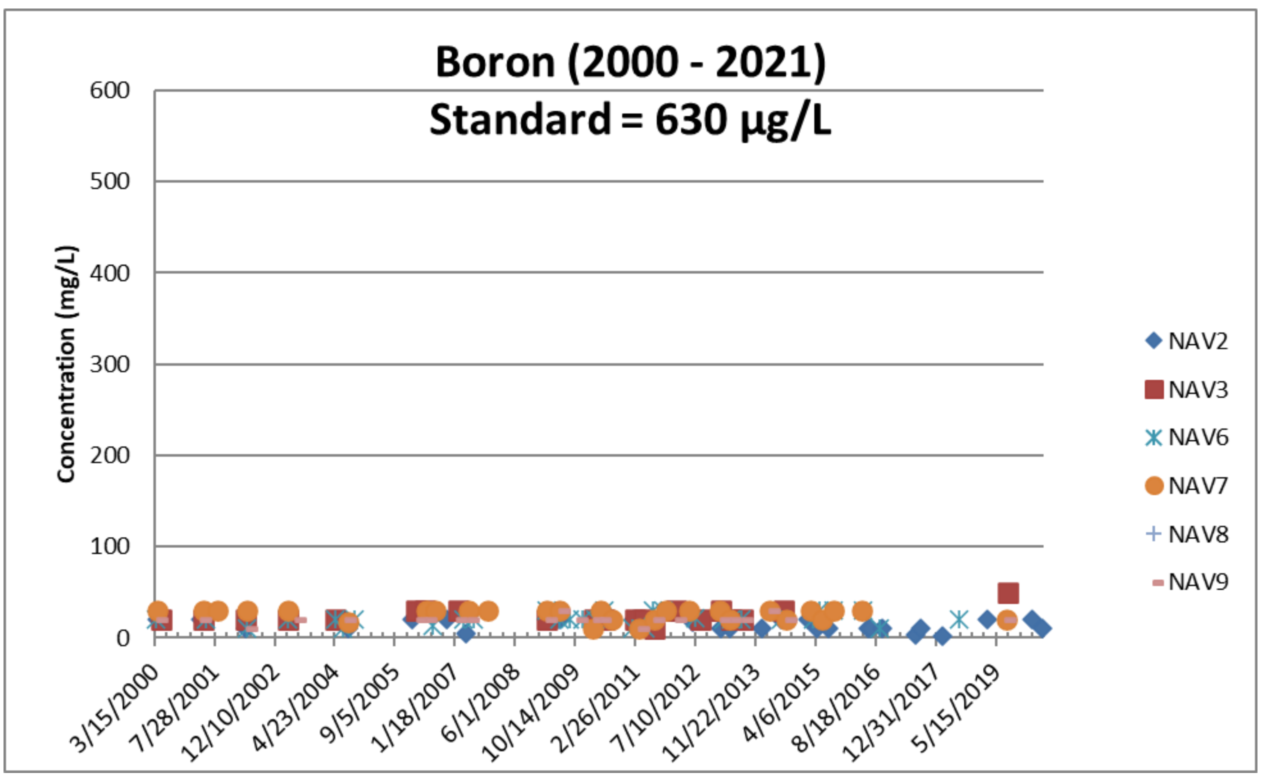

Figure 12. Boron Concentrations in PWCC N-aquifer Wells (2000 – 2021) (PWCC, 2022).

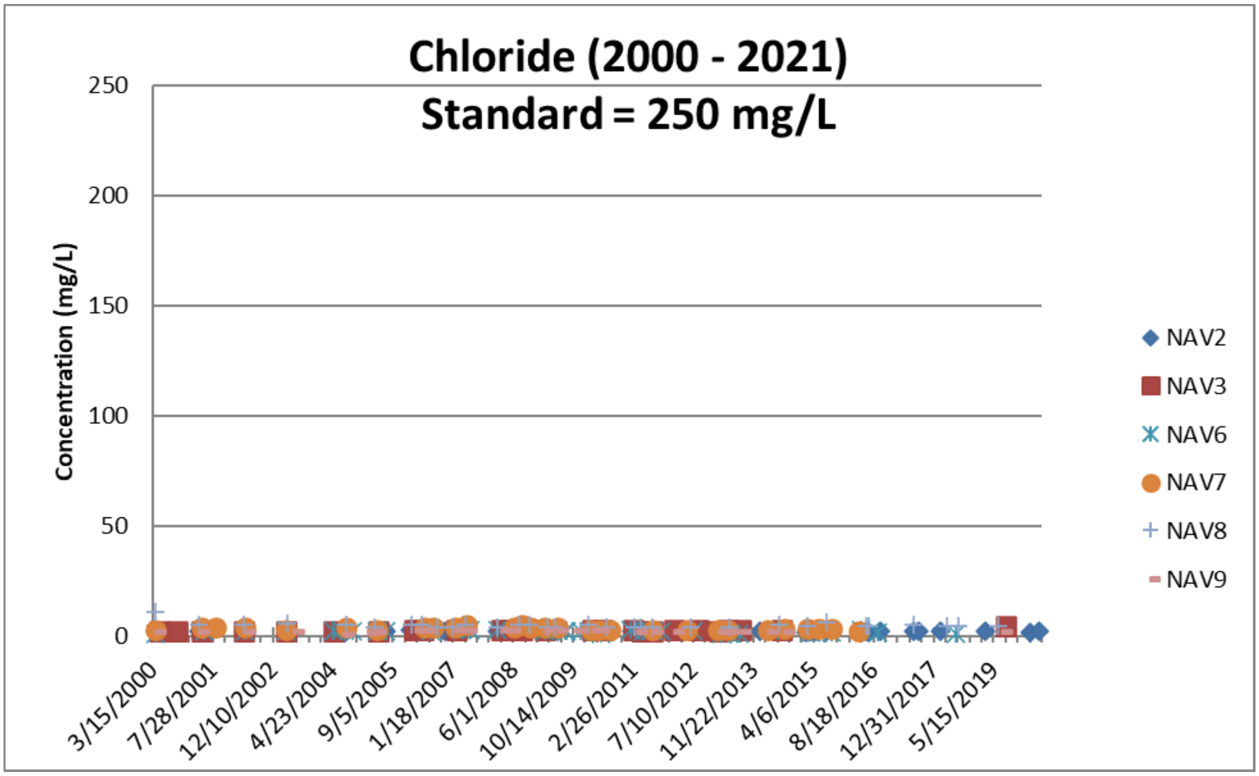

Figure 13. Chloride Concentrations in PWCC N-aquifer Wells (2000 – 2021) (PWCC, 2022).

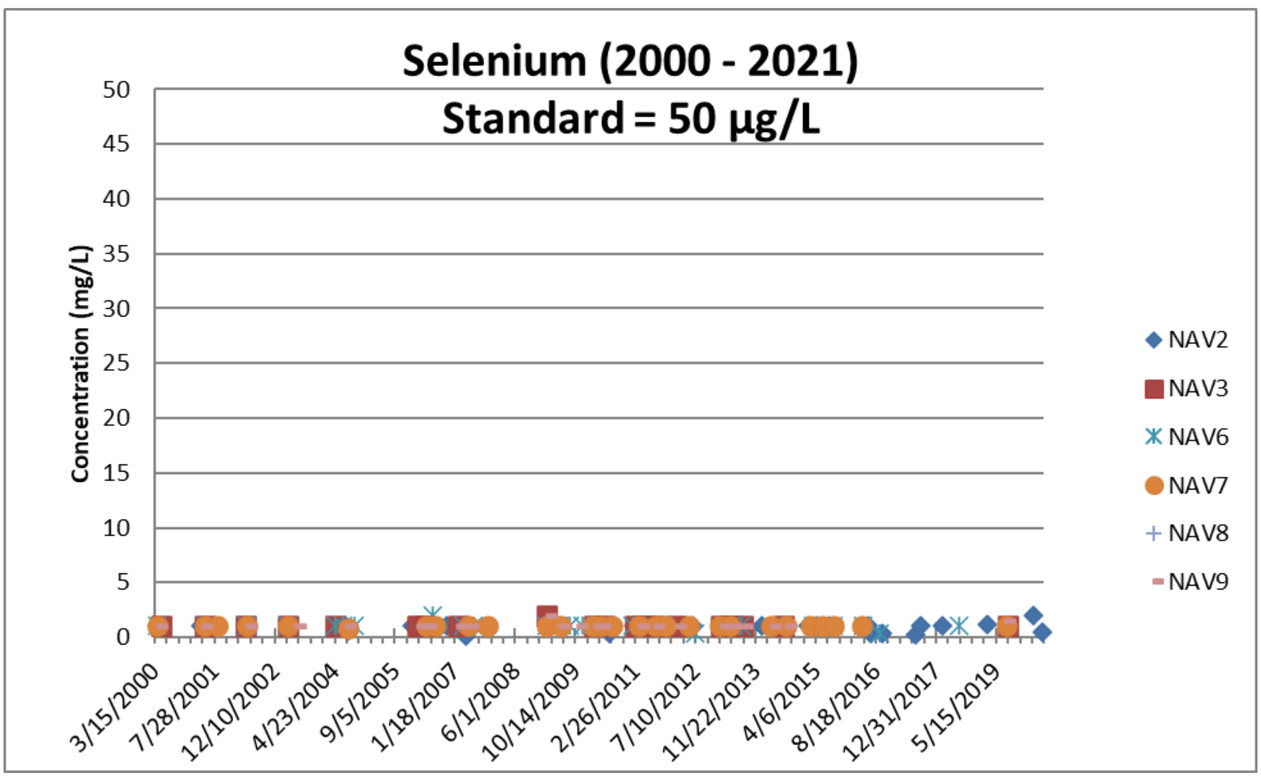

Figure 14. Selenium Concentrations in PWCC N-aquifer Wells (2000 – 2021) (PWCC, 2022).

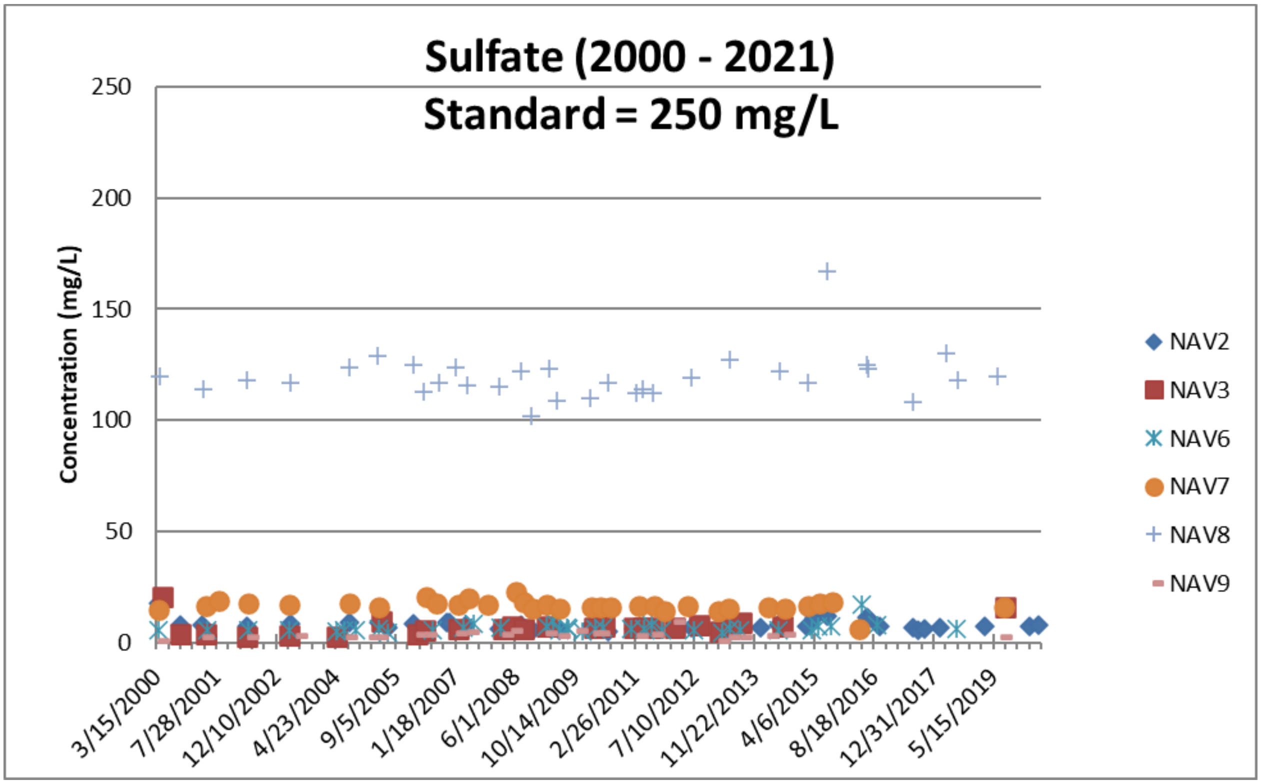

Figure 15. Sulfate Concentrations in PWCC N-aquifer Wells (2000 – 2021) (PWCC, 2022).

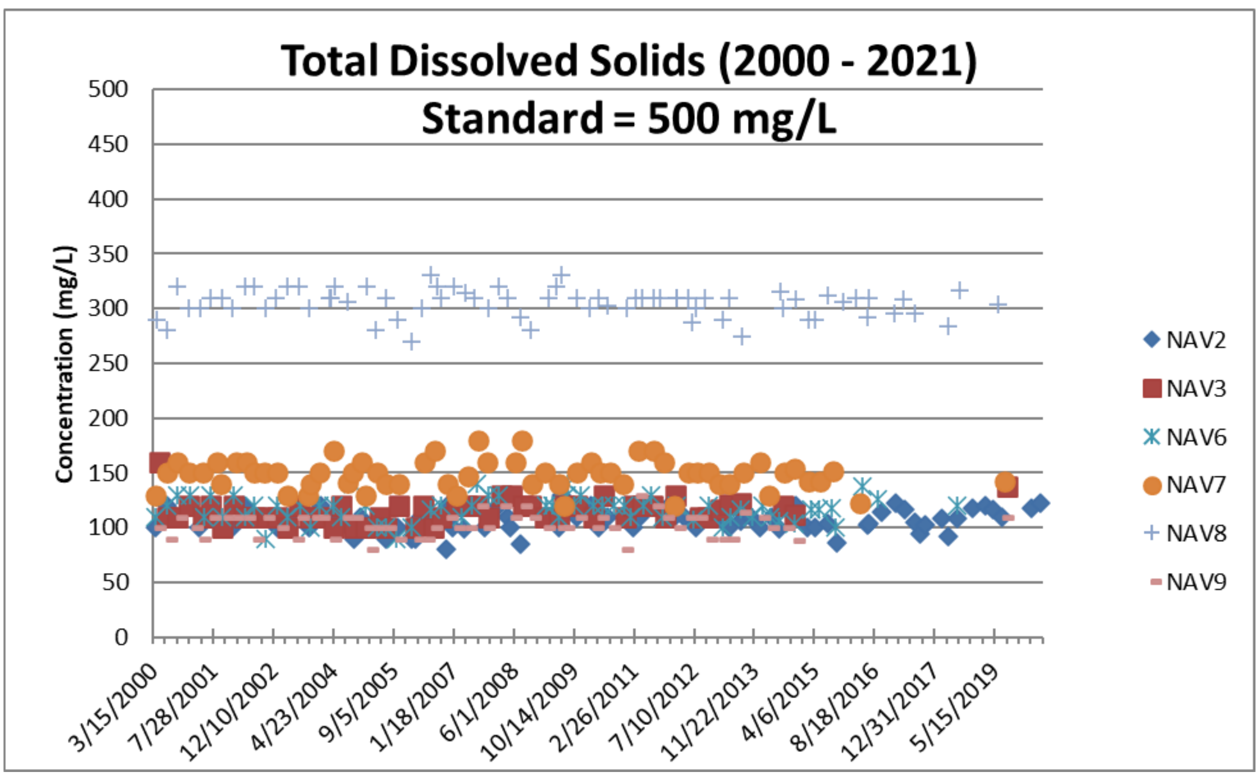

Figure 16. TDS Concentrations in PWCC N-aquifer Wells (2000 – 2021) (PWCC, 2022).

4.0 SUMMARY AND FINDING

OSMRE reviewed and analyzed the information contained in the PWCC data reports and USGS data from 2016 to 2021, comparing the information to historical monitoring data and to the Black Mesa Kayenta Complex CHIA evaluation criteria.

OSMRE utilized three components to assess the aquifer quantity response to the reduced PWCC pumping volumes. These components are:

- A Groundwater Flow Model.
- USGS Observation Wells Located Outside the Lease Area.
- PWCC Observation Wells Located Within the Lease Area.

Additionally, the development of 'material damage' criteria was required by the "Stipulated Settlement Agreement of Appellants to Nizhoni Ani et.al. February 2012 Request for Review", IV. Hydrology Claims: No. 2 which states:

> OSM shall identify and adopt, as material damage criteria for the Navajo Sandstone Aquifer ("N-Aquifer"), numeric water levels that will be physically measured for all wells screened in the confined area of the N-aquifer that are monitored by the U.S. Geological Survey (USGS).

Review of the USGS monitored wells on Black Mesa, as of 2019, indicated that 14 wells meet the criterion of being 'screened in the confined N-aquifer' and 'monitored for water level by the USGS'. The USGS BM-series monitoring wells were excluded since the use at these locations are for observation and not supply use. The pre-stress N-aquifer water levels of these selected wells were compared to the current water levels. Measured water levels remain above established material damage water levels in all wells in the confined N-aquifer monitored by the USGS. Therefore, based on available information, OSMRE concludes that material damage to the hydrologic balance of the confined N-aquifer, attributable to mining, has not occurred based on the 2016 CHIA criterion for N-aquifer quantity.

OSMRE also reviews and analyzes N-aquifer water quality for potential degradation. Chloride, sulfate, and TDS concentrations are primary trend indicators of potential degradation. Additionally, Settlement Condition (5) associated with Docket No. DV-2012-3-R states:

> In the updated Kayenta Mine Complex CHIA, OSM shall add, as part of the N-aquifer water quality material damage criteria at PWCC N-aquifer wells, numeric water quality parameters including but not limited to arsenic, selenium, and boron that will be evaluated through laboratory analysis. OSM shall modify the monitoring plan to require monitoring for such parameters at the PWCC N-aquifer wells and with the same frequency as other N-aquifer water quality material damage parameters. OSM shall not establish material damage criteria for any parameter in excess of U.S. Safe Drinking Water Act standards or current concentration of that parameter, whichever is higher, at the PWCC N-aquifer wells. If the U.S. Safe Drinking Water Act does not establish a standard for a particular parameter, OSM shall not establish a material damage criterion in excess of Hopi or Navajo Nation livestock watering standards or the current concentration of that parameter, whichever is higher.

Based on review of arsenic, boron, chloride, selenium, sulfate, and TDS water quality constituents against all applicable water quality standard limits indicates that the use potential for the Navajo aquifer remains unchanged at all production wells and is suitable for domestic and livestock uses.

OSMRE's review and analysis of available information contained in PWCC and USGS reports from 2016 to 2021 indicates that material damage has not occurred to the hydrologic balance of the N-aquifer outside of the PWCC Black Mesa Kayenta Complex lease area as a result of mining and reclamation.

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