

CUMULATIVE HYDROLOGIC IMPACT ASSESSMENT

of the

Peabody Western Coal Company

Kayenta Mine Complex



United States Department of the Interior
Office of Surface Mining Reclamation and Enforcement
Western Region

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List of Acronyms and Abbreviations

3D Model	regional three-dimensional numerical flow model of D and N aquifers
ac-ft	acre-feet
AgL	agricultural livestock watering
AgI	agricultural irrigation water
AgWS	agricultural water supply
ALJ	administrative law judge
A&W _e	aquatic and wildlife - ephemeral
A&WHbt	aquatic and wildlife habitat
BIA	Bureau of Indian Affairs
BOR	Bureau of Reclamation
C aquifer	Coconino aquifer
CCL	Candidate Contaminant List
cfs	cubic feet per second
CHIA	cumulative hydrologic impact assessment
CIA	cumulative impact area
CFR	Code of Federal Regulations
CG	crest gage
CWA	clean water act
D aquifer	Dakota aquifer
DWS	domestic water supply
EA	environmental assessment
EIS	environmental impact statement
ft/sec	feet per second
FC	fish consumption
FR	federal register
gpd/ft	gallons per day per foot

GWR	groundwater recharge
HTWQS	Hopi Tribe water quality standards
HUC	hydrologic unit code
KMC	Kayenta Mine Complex
LW	livestock watering
MAD	Median Absolute Deviation
MDL	method detection limit
mg/L	milligrams per liter
mi ²	square miles
N aquifer	Navajo aquifer
NNSWQS	Navajo Nation surface water quality standards
NPDES	National Pollutant Discharge Elimination System
OSMRE	Office of Surface Mining Reclamation and Enforcement
PAP	permit application package
PBC	partial body contact
PCC	Primary Contact Ceremonial
PHC	Probable Hydrologic Consequences
PWCC	Peabody Western Coal Company
PWS	public water supply
ROD	Record of Decision
ScHC	secondary human contact
SMCRA	Surface Mining Control and Reclamation Act
TDS	total dissolved solids
TSS	total suspended solids
µg/L	micrograms per liter
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
WRP	Water Resource Program

1 INTRODUCTION

The Office of Surface Mining Reclamation and Enforcement (OSMRE) is the regulatory authority for coal mining and reclamation operations under the Surface Mining Reclamation and Control Act of 1977 that occur on Hopi Tribe and Navajo Nation surface. As such, OSMRE is responsible for the review and decisions on all permit applications to conduct surface coal mining and reclamation operations. The Peabody Western Coal Company (PWCC) permit area, located on both Navajo Nation and Hopi Tribe surface area, is required to have a cumulative hydrologic impact assessment (CHIA), prepared by the regulatory authority, which assesses whether the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area (30 Code of Federal Regulations (CFR) § 780.21(g)).

A CHIA is an assessment of the probable hydrologic consequences (PHC) of the proposed operation and all anticipated coal mining upon surface and groundwater systems in the cumulative impact area (CIA). The PHC is prepared by the applicant as required by 30 CFR § 780.21(f), and approved by the regulatory authority. Congress identified in the Surface Mining Coal and Reclamation Act (SMCRA) (U.S. Congress, 1977) that there is “a balance between protection of the environment and agricultural productivity and the Nation’s need for coal as an essential source of energy” (SMCRA, 1977 Sec 102(f)). The hydrologic reclamation plan required by the rules at 30 CFR § 780.21(h) recognizes that disturbances to the hydrologic balance within the permit and adjacent area should be minimized, material damage outside the permit area should be prevented, applicable Federal, Tribal, and State water quality laws should be met, and the rights of present water users protected. Additionally, 30 CFR § 816.42 states “discharges of water from areas disturbed by surface mining activities shall be made in compliance with all applicable State and Federal water quality laws and regulations and with the effluent limitations for coal mining promulgated by the United States Environmental Protection Agency (USEPA) set forth in 40 CFR part 434.” Discharges of disturbed area runoff at the Kayenta Mine Complex are conducted in accordance with the terms and conditions of National Pollutant Discharge Elimination System (NPDES) permits issued by the USEPA and certified by the Navajo Nation and Hopi Tribe under the Clean Water Act (CWA).

OSMRE considered USEPA approved water quality standards for the Hopi Tribe (effective August 24, 2011) and Navajo Nation (effective March 26, 2009) as part of the impact assessment. Additionally, protection of existing and reasonably foreseeable water uses within the various delineated cumulative impact areas was a focus of this assessment. The following summary table identifies water resources evaluated and approach for impact assessment (Table 1). Table 1 indicates that; (1) the hydrologic monitoring program is adequate for OSMRE’s CHIA, (2) impacts within the permit area have been minimized, and (3) material damage outside the permit area has been prevented. This CHIA supersedes the previous Black Mesa Kayenta Mine Complex CHIA’s (OSMRE, 2011a), (OSMRE, 2008), (OSMRE, 1989).

Kayenta Mine Complex Material Damage Summary			
Water Resource	Impact Minimization	Adequate Monitoring Program	Designed to Prevent Material Damage Outside the Permit Area
Surface Water Quality	Sediment Control Structures	YES: Historical Upstream Data and Active Downstream Monitoring	YES (see Chapter 5)
Surface Water Quantity	Western Alkaline Rule Implementation	YES: Historical Upstream Data and Active Downstream Monitoring	YES (see Chapter 5)
Alluvial Quality	Sediment Control Structures	YES: Historical Upstream Data and Active Downstream Monitoring	YES (see Chapter 5)
Alluvial Quantity	Western Alkaline Rule Implementation	YES: Historical Upstream Data and Active Downstream Monitoring	YES (see Chapter 5)
Wepo Quality	Water Rights and Replacement in Accordance with 30 CFR 816(h)	YES: Active Spoil Backfill and Adjacent Pit Monitoring	YES (see Chapter 5)
Wepo Quantity	Water Rights and Replacement in Accordance with 30 CFR 816(h)	YES: Active Spoil Backfill and Adjacent Pit Monitoring	YES (see Chapter 5)
N-Aquifer Quality	PWCC wellfield modified to only pump N aquifer water in 2016	YES: Accordance with PAP and Settlement No. DV-2012-3-R	YES (see Chapter 5)
N-Aquifer Water Levels	Negotiated Rate Royalty (per acre foot) with Hopi and Navajo Nation	YES: Accordance with PAP and USGS Monitoring Program	YES (see Chapter 5)
N-Aquifer Discharge	Negotiated Rate Royalty (per acre foot) with Hopi and Navajo Nation	YES: Accordance with PAP and USGS Monitoring Program	YES (see Chapter 5)

Table 1. Kayenta Mine Complex Material Damage Assessment Summary

The finding that the mining operation is designed to prevent material damage to the hydrologic balance outside the permit area is supported by the following chapters. The CHIA is organized as follows:

- Chapter 1
 - Describes the regulatory environment.
 - Describes general background of the Kayenta Mine Complex.
- Chapter 2
 - Assesses cumulative impact potential with active coal mines.
 - Delineates the surface water CIAs.
 - Delineates the groundwater CIAs.
- Chapter 3 identifies water resource uses and designations in the CIAs.
- Chapter 4 provides a description of baseline surface and groundwater quantity and quality within the CIAs.
- Chapter 5 contains an impact assessment of the Kayenta Mine Complex on surface water and groundwater quantity and quality, and includes a determination of:
 - The adequacy of the monitoring program to assess potential impacts;
 - The minimization of impacts within the permit area; and
 - The prevention of material damage outside the permit area.

1.1 Regulatory Environment

Surface coal operations on Hopi Tribe and Navajo Nation surface are managed through the coordination of several regulatory agencies. Depending on the permitting action, multiple regulatory agencies may be involved in the review, comment, and public participation process. Regulatory agencies that may have a permitting action or compliance interest on the PWCC permit include:

- OSMRE (regulatory authority for coal operations on Hopi Tribe and Navajo Nation surface)
- Bureau of Indian Affairs (protect and improve trust assets of the Tribes)
- Hopi Tribe Water Resources Program (develop and administer water quality standards)
- Navajo Nation EPA (develop and administer water quality standards)
- Navajo Nation Minerals Department (represent Tribal mineral interests)
- Navajo Nation Water Management Branch (implement Navajo Nation's Water Code)
- U.S. Environmental Protection Agency (issue and administer NPDES permits)
- U.S. Fish and Wildlife Service (ensure protection of threatened and endangered species)
- Bureau of Land Management (ensures maximum resource recovery)
- U.S. Army Corps of Engineers (issue permits and associated impact assessments for the discharge of fill material into waters of the United States, including wetlands under section 404 of the CWA)

1.1.1 CHIA Revision Purpose

The CHIA is not updated at a specified interval. 30 CFR § 780.21(g)(2) states “an application for permit revision shall be reviewed by the regulatory authority to determine whether a new or updated CHIA shall be required.” On May 1, 2012, OSMRE received a Life of Mine (LOM) significant permit revision application from Peabody Western Coal Company (PWCC) for the Kayenta Mine Complex (KMC). The May 1, 2012, permit revision application was updated by PWCC on December 18, 2013, February 10, 2014, and May 2, 2014. The revision application includes adding support facilities located on the Black Mesa Mine to the Kayenta Mine permanent program permit area, mining of new coal resource areas (J21 West, N10, and N11 Extension), and updating the N-aquifer groundwater flow model used for impact assessment and the associated protection of the hydrologic balance information included in the PAP at Chapter 18.

The 2016 Kayenta Mine Complex CHIA is also updated to comply with Settlement Conditions associated with Docket No. DV-2012-3-R. Specific to hydrology, Settlement Conditions state:

(1) OSM shall update the Kayenta Mine Complex CHIA in conjunction with its disposition of the 2013 Significant Permit Revision application. If PWCC withdraws that application, OSM shall update the Kayenta Mine Complex CHIA in conjunction with PWCC's next significant permit revision application or in conjunction with the next minor permit revision that affects the Probable Hydrologic Consequences determination of the permit, whichever occurs first.

Response: OSMRE's disposition of the 2013 Significant Permit Revision application requires an Environmental Impact Statement (EIS), which is anticipated for Record of Decision (ROD) in the Fall of 2017.

(2) In the updated Kayenta Mine Complex CHIA, 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).

Response: OSMRE has identified numeric water levels as material damage criteria at windmills and community supply wells monitored by the USGS and screened in the confined N aquifer. Material damage water levels for community supply wells are based on economic and lift cost considerations. Material damage water levels for windmills are based on the depth of the drop pipe intake on the windmill. Graphical illustration of the measured water levels and material damage criteria are provided in Appendix A.

(3) OSM shall produce a written assessment of the need and potential for increased N aquifer spring monitoring. This written evaluation will be documented in the CHIA update and developed in consultation with the Hopi Tribe, Navajo Nation, PWCC, and USGS.

Response: During the development of the NGS-KMC EIS, several spring inventories were evaluated and discussed in collaboration with the Hopi Tribe, Navajo Nation, PWCC, USGS, Bureau of Reclamation (BOR), and BOR's consultant AECOM (Leake and others, 2016) BOR, 2016). The NGS-KMC EIS and OSMRE Kayenta Mine Complex CHIA have similar purpose and needs for evaluation of impacts. As such, OSMRE coordinated a field evaluation of regional D and N aquifer baseflow and spring discharge. The written evaluation of the need and potential for increase N aquifer spring monitoring is provided as Appendix B.

(4) In the updated Kayenta Mine Complex CHIA, OSM will consider formulating material damage criteria for N aquifer discharge that is not based on the PWCC 3D Model.

Response: The PWCC 3D Model was updated in 2014 (Tetra Tech, 2014). The 2014 updated model was peer reviewed by the USGS (Leake and others, 2016). The following statements are provided in the USGS review Summary and Conclusions (Leake and others, 2016):

- The PWCC (Tetra Tech, 2014) model is a recently calibrated model that can simulate the effects of past groundwater development in the D and N aquifers in the Black Mesa Area.
- The combination of MODFLOW packages used in the PWCC model to represent real hydrologic features leads to improved simulation capabilities in comparison to previous models including the original PWCC (1999) model, the USGS model (Brown and Eychaner, 1988), and the WNHN model (HDR Engineering Inc., 2003).
- This evaluation found no problems with the PWCC model that would preclude its use by the NGS-KMC EIS team. Given the complexity of the N and D aquifer system in the study area and the amounts and types of data available, the calibration of the PWCC model described in Tetra Tech (2014) seems to be reasonable. Observed streamflow in most of the major washes is simulated reasonably well.

Based on the summary and conclusions provided in the USGS review, the updated 2014 PWCC groundwater flow model is the best tool available to evaluate PWCC effects on N aquifer discharge, and will be used for formulating material damage criteria.

(5) 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.

Response: 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). 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, 2016).

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, 2016).

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, 2016).

(6) OSM will accept information from Appellants prior to or during preparation of the updated Kayenta Mine Complex CHIA. OSM will make the CHIA update publicly available in conjunction with the public release of the NGS-Kayenta Mine Complex Draft EIS.

Response: OSMRE did not receive information from Appellants related to the CHIA since the execution of the settlement agreement. The updated Kayenta Complex CHIA will be publicly available September 2016 in conjunction with the public release of the NGS-KMC Draft EIS.

Compared to the 2011 CHIA, the 2016 CHIA for PWCC operations:

- 1) Implements Settlement Conditions associated with Docket No. DV-2012-3-R.
- 2) Utilizes 2014 PWCC Groundwater Flow Model for predictive impacts. The 2014 PWCC Model underwent a technical review by the USGS (Leake and others, 2016).
- 3) Utilizes results from the Draft NGS-KMC EIS.
- 4) Evaluates surface water resources using the Median Absolute Deviation (MAD) and relates to the effective 2011 Hopi Tribe Water Quality Standards (HTWQS), and the effective 2009 Navajo Nation Surface Water Quality Standards (NNSWQS).

1.1.2 Cumulative Impact Area

A CIA is defined at 30 CFR § 701.5 as, “. . . the area, including the permit area, within which impacts resulting from the proposed operation may interact with the impacts of all anticipated mining on surface- and ground-water systems.” The CIA is an area where impacts from the coal mining operation, in combination with additional coal mining operations, may cause material damage (OSMRE, 2002). The size and location of a given CIA will depend on the surface water and groundwater system characteristics, the hydrologic resources of concern, and projected impacts from the operations included in the assessment (OSMRE, 2007). For this CHIA, two surface water CIAs and two groundwater CIAs are delineated to assess impacts associated within these distinct hydrologic resource areas.

1.1.3 Material Damage to the Hydrologic Balance

Sections 507(b)(11) and 510(b)(3) of SMCRA, and 30 CFR § 780.21(g) require OSMRE to determine that a mining and reclamation operation has been designed to prevent material damage to the hydrologic balance outside the permit area. “Hydrologic balance” is defined at 30 CFR § 701.5 as, “the relationship between the quality and quantity of water inflow to, water outflow from, and water storage in a hydrologic unit such as a drainage basin, aquifer, soil zone, lake or reservoir. It encompasses the dynamic relationships among precipitation, runoff, evaporation, and changes in ground and surface water storage.”

“Material damage to the hydrologic balance” is not defined in SMCRA or at 30 CFR § 701.5. The intent of not developing a programmatic definition for “material damage to the hydrologic balance” was to provide the regulatory authority the ability to develop a definition based on regional environmental and regulatory conditions. Therefore, for the purpose of this CHIA;

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.

1.1.4 Material Damage Criteria

Except for water quality standards and effluent limitations required at 30 CFR § 816.42, the determination of material damage criteria is the discretion of the regulatory authority (48 FR 43972-43973, 1983 and 48 FR 43956, 1983). Material damage criteria for both groundwater and surface water are related to existing standards, and based on the protection of water uses. The material damage criteria are reviewed after submittal of the PWCC annual reclamation status report to OSMRE.

1.2 Kayenta Mine Complex Background

The Kayenta Complex Mine is located within the boundaries of the Hopi Tribe and Navajo Nation reservations and has operated since 1973. The Black Mesa Mine operated in a permit area adjacent to the Kayenta Mine and was active from 1970 through 2005. The two (2) surface mine operations are collectively considered the Kayenta Mine Complex. The Black Mesa Mine operated under Initial Program and Administrative Delay pursuant to 30 CFR 750.11(c). The Kayenta Mine permanent program permit was issued on July 6, 1990. The permanent program permit is AZ-0001E and was renewed four times; on July 6, 1995, on July 6, 2000, on July 6, 2005, and lastly on July 6, 2010. Since technical updates to the PAP are ongoing, reference to specific chapters in the PAP use the year 2016 as reference since the permit is complete and up to date at the publishing of this CHIA document.

The Kayenta Mine Complex encompasses an area of 65,387 acres and is located in northeastern Arizona on Black Mesa, southwest of Kayenta, Arizona (Figure 1). The Navajo Nation has exclusive surface and mineral interests for 24,858 acres in the northern portion of the Kayenta Mine Complex. In the remaining 40,529 acres of the Kayenta Mine Complex, the Hopi Tribe and Navajo Nation have joint and equal interests in the mineral resources that underlie the land surface. Navajo Nation coal resource areas are identified as “N” areas, and joint coal resource interest areas are identified as “J” area (Figure 2). Active coal mining occurs in the N-9, J-19, and J-21 coal resource areas. Coal royalties are based on surface area, and water royalties for PWCC’s wellfield pumping are paid equally to the Hopi Tribe and Navajo Nation based on metered wellfield production.

From 1970 to 2005, coal mined at the Black Mesa mine was transported 273 miles to the Mohave Generating Station near Laughlin, Nevada via a coal slurry pipeline. The Mohave Generating Station consumed approximately four to five million tons of coal annually (PWCC, v.1, ch.2, 2016). Coal

produced at Kayenta Mine is currently transported 83 miles to the Navajo Generating Station near Page, Arizona via an electric railroad. The Navajo Generating Station consumes seven to eight million tons of coal annually (PWCC, v.1, ch.2, 2016).

PWCC uses the strip mining method to recover the coal resources at the Kayenta Mine Complex. Strip mining involves the removal of overburden material covering the coal using blasting and draglines. The coal is then removed by shovels or front-end loaders and transported to coal preparation facilities using haulage trucks. After the coal removal, the overburden material is regraded to the approximate original topographic contours, conforming to topography to support the approved post-mining land uses. Stockpiled topsoil and other suitable material are then spread on top of the graded overburden material to support the re-establishment of approved post-mining vegetation. PWCC must then demonstrate the persistence of re-established vegetative cover sufficient to support post-mining land use.

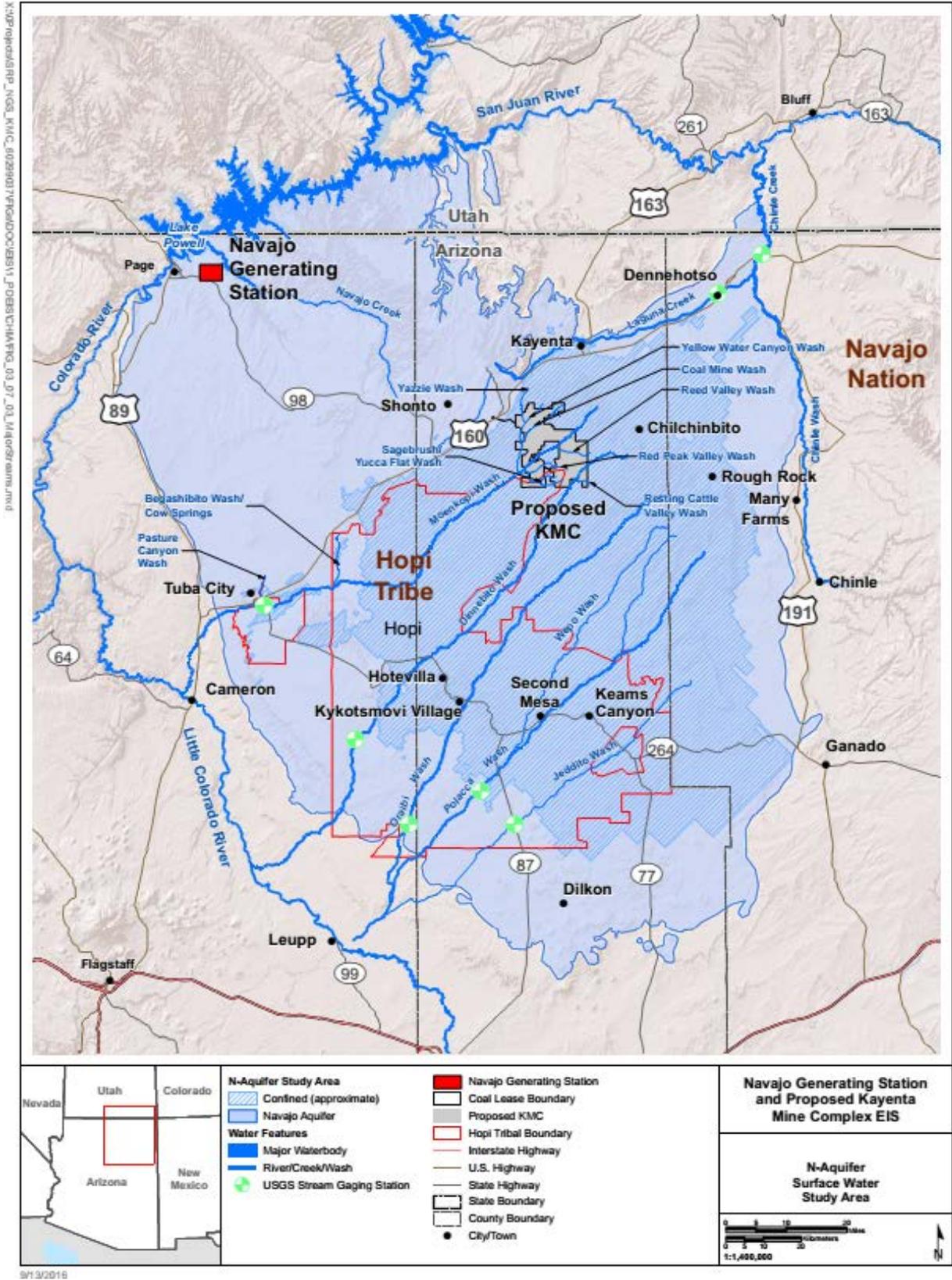


Figure 1: Kayenta Mine Complex Location Map (BOR, 2016, Figure 3.7-3).

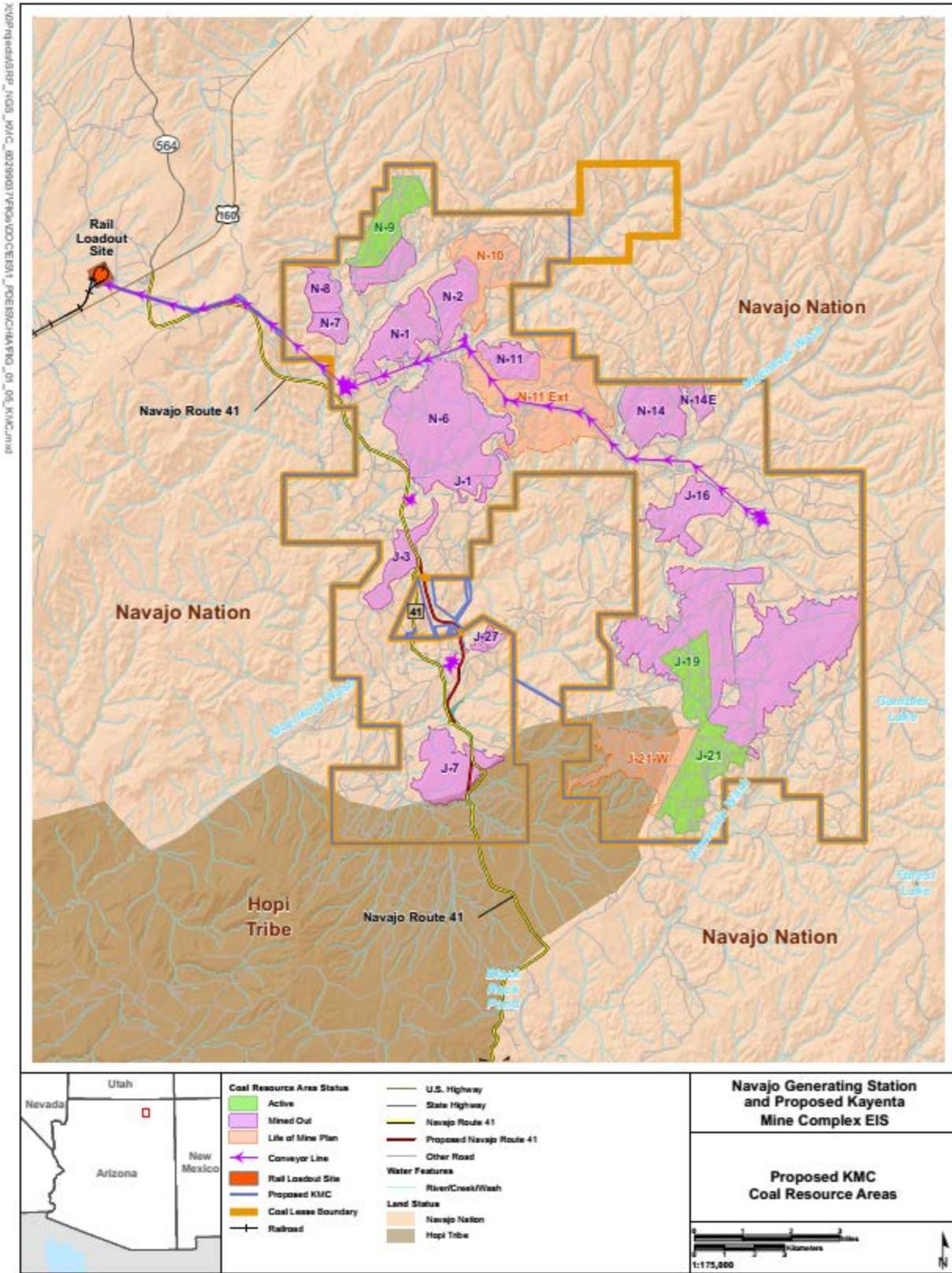


Figure 2: Kayenta Mine Complex Coal Resource Areas (BOR, 2016, Figure 1-5).

2 DELINEATION OF CUMULATIVE IMPACT AREA

A CIA is defined at 30 CFR § 701.5 as, “. . . the area, including the permit area, within which impacts resulting from the proposed operation may interact with the impacts of all anticipated mining on surface- and ground-water systems.” A CIA considers an area where impacts from the coal mining operation, in combination with additional coal mining operations, may cause material damage. Material damage implies quantifiable adverse degradation or reduction of surface or ground waters outside the permit area, resulting in the inability to utilize water resources for existing or reasonably foreseeable uses. CIA delineation for the Kayenta Mine Complex consists of both surface water and groundwater delineations, with impact areas delineated for both surface and ground waters based upon the resource extent and potential use impacts.

2.1 Surface Water Cumulative Impact Area

The United States is divided into 21 surface water regions, and further sub-divided into 221 sub-regions (USGS, 1987). Sub-regions are further sub-divided into 378 hydrologic accounting units, and finally a fourth level of classification, 2264 cataloging units. The subdivisions provide a mechanism to classify each hydrologic unit by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system. The Little Colorado River sub-region encompasses 29,900 square miles, and assigned a HUC of 1502. The Little Colorado River 1502 is sub-divided into 18 cataloging units. Kayenta Complex mining and reclamation operations occur in 2 of the 18 cataloging units: Dinnebito Wash (HUC 15020017) and Moenkopi Wash (HUC 15020018). Dinnebito Wash and Moenkopi Wash discharge to the Little Colorado River at two independent downstream locations (Figure 1). Since mining operations at the Kayenta Complex are the only existing or proposed coal operations in either Moenkopi Wash (HUC 15020018) or Dinnebito Wash (HUC 15020017), surface water impacts will not be cumulative with other coal mining operations unless the impacts extend to the Little Colorado River.

McKinley Mine, located in the Upper Puerco Watershed (HUC 15020006), and the Kayenta Mine Complex are the only active coal mining and reclamation operations in the Little Colorado (HUC 1502) (Figure 3). McKinley Mine is approximately 190 stream miles from the first point McKinley Mine impacts could become cumulative with Kayenta Mine Complex impacts at the confluence of the Little Colorado River and Dinnebito Wash. McKinley Mine ceased coal production in December 2009, and is currently completing final reclamation.

Figure 3 presents the mean annual flow measured on Dinnebito Wash (station 09401110), Moenkopi Wash (station 09401260), and the Little Colorado River (station 09402000). Compared to the mean annual flow at station 09402000, mean annual flow at stations 09401110 and 09401260 are 2.3- and 4.8-percent respectively, of the Little Colorado River flow measured at station 09401260. The spatial separation of McKinley Mine from the Little Colorado River and Dinnebito Wash confluence, and the magnitude of mean annual surface flow on the Little Colorado River compared to contributing flow volumes, make it impracticable to distinguish potential coal mine water quality impacts at the confluence of the Little Colorado River and Dinnebito Wash. Therefore, the McKinley Mine is excluded from the Kayenta Mine Complex CIA, and a smaller watershed area for assessment of probable hydrologic impacts attributed to the Kayenta Mine Complex operations will be delineated.

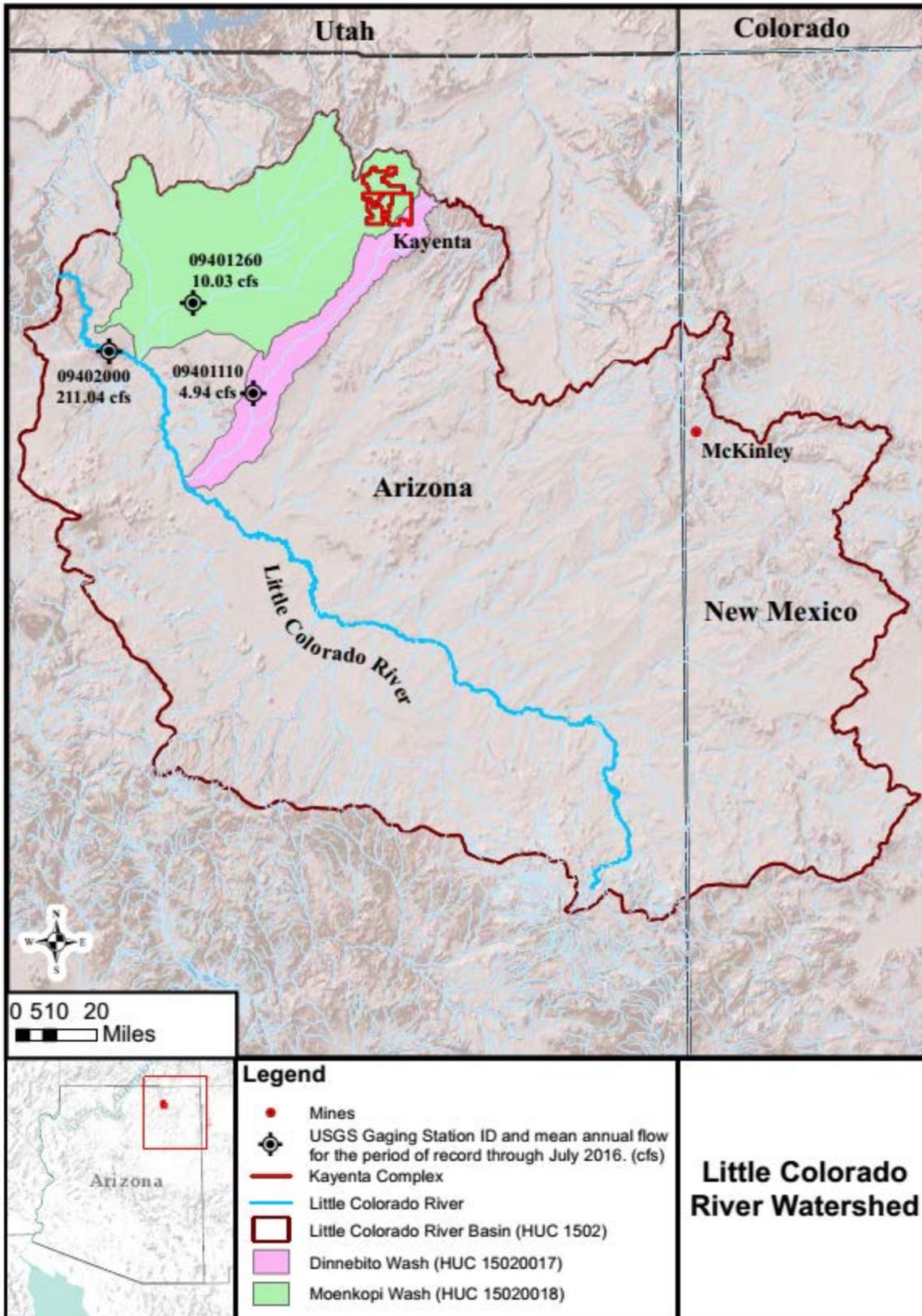


Figure 3: Mining and Reclamation Operations in the Little Colorado River Watershed

2.1.1 Downstream Impact Potential

Approximately 30 stream miles downstream of the Kayenta Mine Complex, Rocky Ridge is the only community along the main channel of Dinnebito Wash. Historically, an attempt was made to dam Dinnebito Wash at Rocky Ridge and impound storm flow water for potential use. Currently, only remnants of the Dinnebito Dam remain, and there are no structures or equipment indicating Dinnebito Wash is utilized for irrigation water at Rocky Ridge (OSMRE, 2011b).

Moenkopi, adjacent to Tuba City, is the only community along the main channel of Moenkopi Wash, approximately 70 stream miles downstream of the Kayenta Mine Complex. At this area, Moenkopi residents may dig pits in the Moenkopi alluvium for agricultural irrigation on fields adjacent to Moenkopi Wash (OSMRE, 2016). The pits are dug in the channel alluvium until the pits remain saturated. The shallow alluvial water may be pumped from in-channel pits during the growing season in order to reduce the amount of sediment extracted with the irrigation water. Suspended sediment generated during storm flow events precludes farmers in the Moenkopi area from utilizing flowing storm water directly on the crop fields. The high sediment loads transported during storm flow events create problems with the pumping equipment, as well as limits the productivity of the crop if the fine silt is applied over the field.

OSMRE recognizes that subflow in the Moenkopi Wash alluvium is part of the hydrologic balance and important to local farmers in the Moenkopi community, and potentially Rocky Ridge. Subflow in the alluvium is part of the flow system, and a decrease in surface water flow contribution to the hydrologic system may affect subflow and ultimately surface water use (OSMRE, 2016).

2.1.2 Surface Water Impact Areas

Mining and reclamation operations on the Kayenta Mine Complex occur in the headwater areas of Dinnebito Wash (HUC 15020017) and Moenkopi Wash (HUC 15020018), which are tributary to the Little Colorado River (Figure 3). Moenkopi Wash (HUC 15020018) drains an area of 2,635 square miles (mi²), and Dinnebito Wash (HUC 15020017) drains an area of 743 mi² before discharging to the Little Colorado River. The United States Geological Survey (USGS) maintains a gaging station on both Moenkopi Wash (station No. 09401260) and Dinnebito Wash (station No. 09401110) (Figure 3). Gaging station 09401260 has a continuous period of record at the same location beginning in 1977, and the continuous period of record for gaging station 09401110 began in 1993. The Moenkopi Wash gaging station is located approximately 1-2 miles from the area local farmers dig pits in the alluvium. The Dinnebito Wash gaging station is approximately 30 stream miles downstream from Rocky Ridge.

USGS gaging stations 09401260 and 09401110 provide valuable information on the hydrology of the Moenkopi and Dinnebito watersheds. However, the watershed areas monitored by the two gaging stations cannot be used exclusively to assess surface water quantity and quality impacts of the Kayenta Mine Complex due to the size of the watershed monitored. Surface water impacts from the Kayenta Mine Complex are most effectively evaluated using monitoring information close to the permit area. PWCC collects surface water quality and quantity information at locations 25, 26, 34, and 155 (Figure 4). Therefore, OSMRE has delineated two surface water areas for hydrologic impact assessment: one for Moenkopi Wash (253 mi²) one for Dinnebito Wash (51 mi²) (Figure 5). The Moenkopi Wash CIA will use information from monitoring locations 25, 26, and 155 near the downgradient permit boundary on Moenkopi Wash for mine impact assessment. The Dinnebito Wash CIA will use information from monitoring location 34 near the downgradient permit boundary on Dinnebito Wash for mine impact assessment.

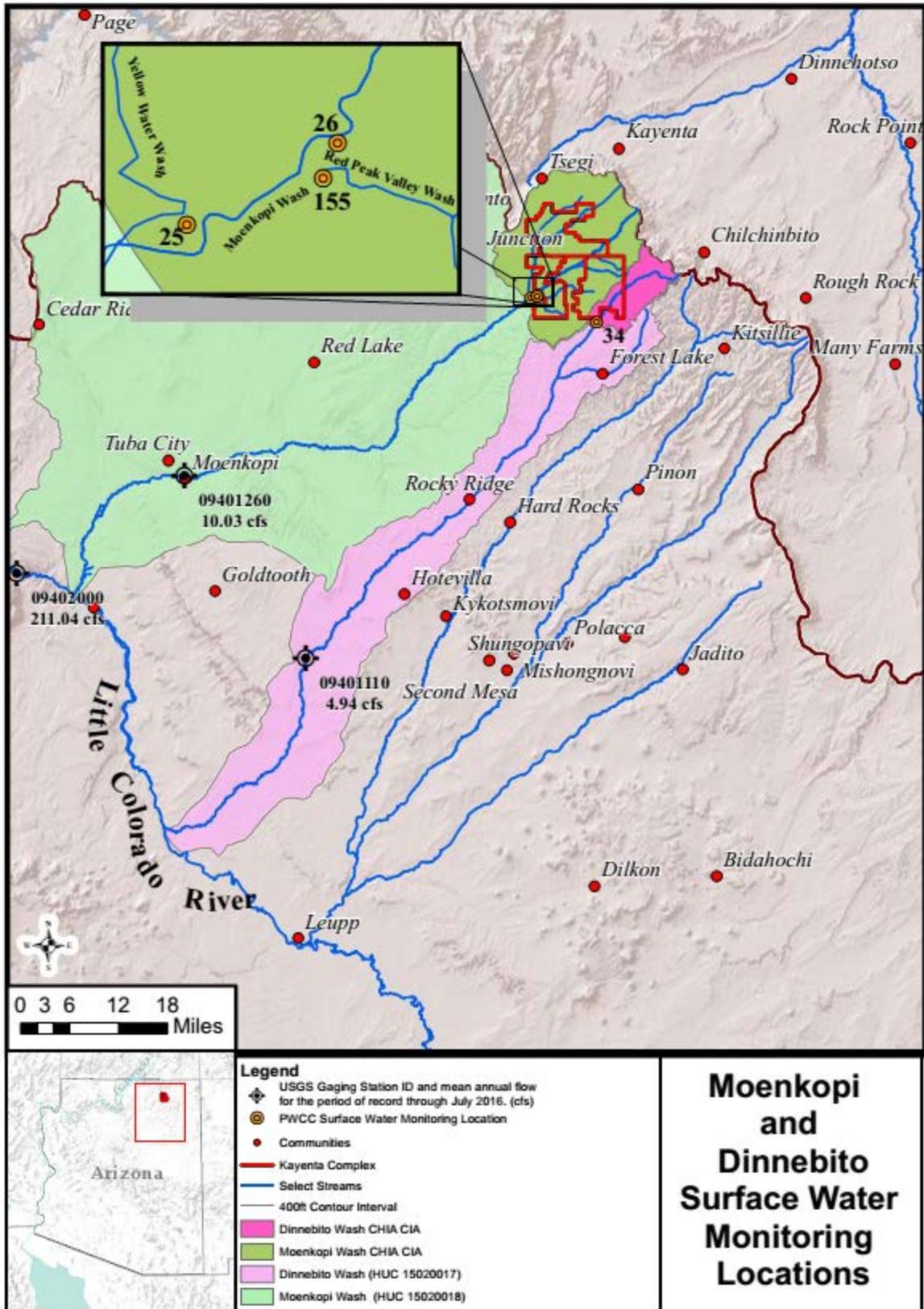


Figure 4: Moenkopi and Dinnebito Surface Water Monitoring Locations

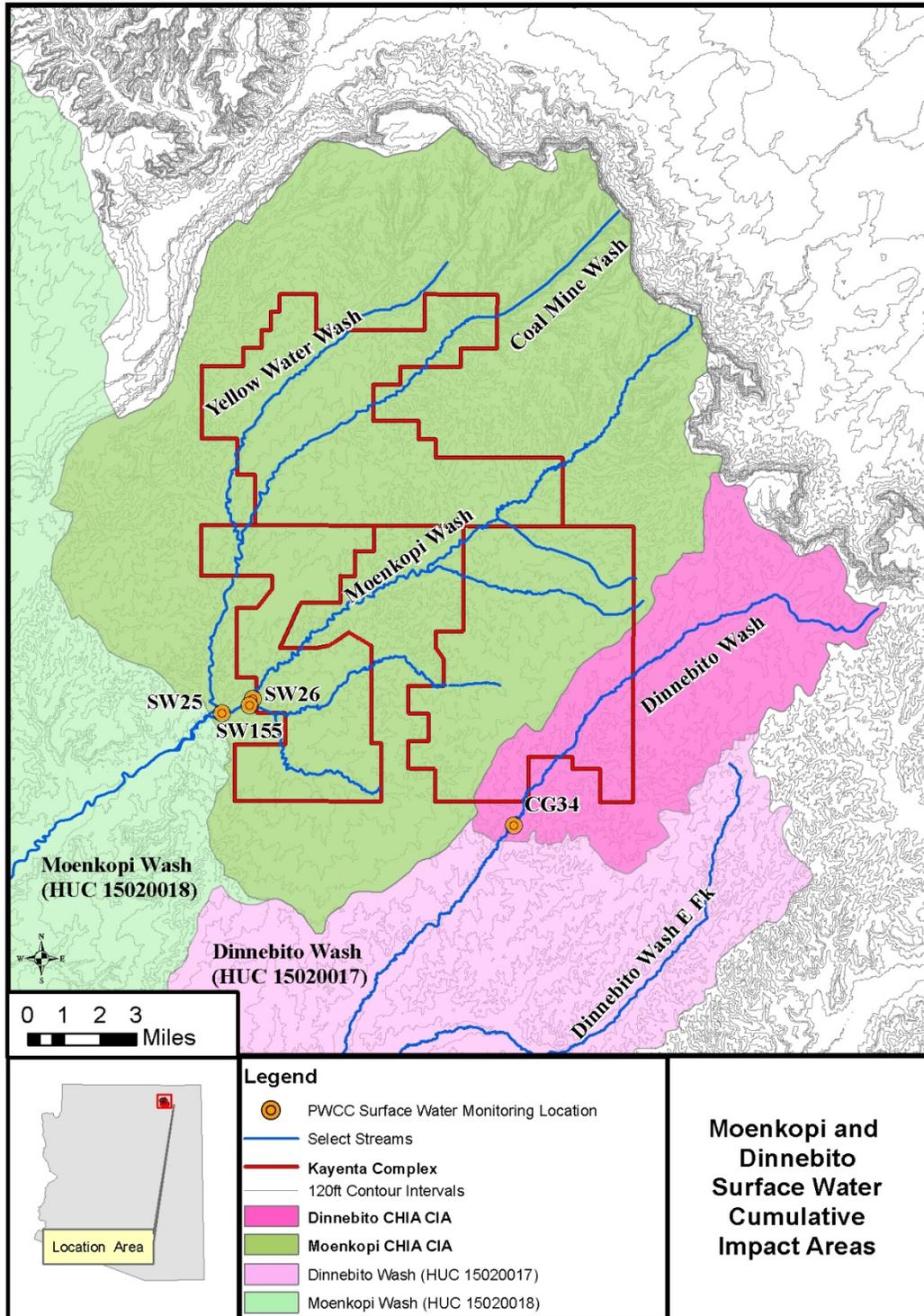


Figure 5: Moenkopi and Dinnebito Surface Water Cumulative Impact Areas, Kayenta Complex

2.2 Groundwater Cumulative Impact Area

Kayenta Mine Complex operations occur in the Wepo Formation of the Mesa Verde Group (Figure 6). The Yale Point sandstone is above the Wepo Formation and present between the eastern boundary of the Kayenta Mine Complex and the rim of Black Mesa. The Yale Point Sandstone is recharged by direct precipitation and will discharge to stream channels above the Kayenta Mine Complex or recharge the underlying Wepo Formation. The Toreva Formation of the Mesa Verde Group underlies the Wepo Formation. Geologic mapping indicates the Wepo Formation is discontinuous over the areal extent of Black Mesa, varies in thickness from 130-740 feet where present, and intertongues with the overlying Yale Point Sandstone on the northeastern mesa rim and underlying Toreva Formation (Repenning and Page, 1956).

The Black Mesa area has three regional aquifer systems: Dakota aquifer system (D aquifer), Navajo aquifer system (N aquifer), and Coconino aquifer system (C aquifer) (Figure 6). The D Aquifer is separated from the Mesa Verde Group by the Mancos Shale (Figure 7). The D aquifer and N aquifer are separated by the siltstone Carmel Formation. The PWCC water supply wellfield currently withdraws water from wells screened in the N aquifer. The N aquifer system is confined below by the Chinle Formation, which separates the N aquifer from the C aquifer.

2.2.1 Mesa Verde Group

The Yale Point sandstone may discharge at outcrop areas above the Kayenta Mine Complex and will not be influenced by mining operations. There are no known use locations of water in the Yale Point sandstone northeast of the permit area. Lithologic drill logs of the Wepo Formation indicate water yielding units consisting of single sandstone beds, multiple sandstone beds which are hydraulically connected, fractured coal seams, and sandy shales of limited extent (PWCC, v.1, ch.4, 2016). Historical and existing use locations of Wepo Formation water have been identified within the permit and adjacent area (Figure 8). The Toreva Formation is not disturbed during mining operations, and there are no water use locations within the permit or adjacent area. Therefore, delineation of the CIA for the Mesa Verde Group will focus on the Wepo Formation.

The Wepo Formation is completely incised by Moenkopi Wash near the southwest corner of the permit area where the Mancos Shale is exposed at the surface. Therefore, water quantity and quality impacts cannot propagate past the exposed area prior to impact detection at surface water monitoring stations 25, 26, and 155. Additionally, a Wepo water level contour map indicates the water level contours generally mimic the surface topography (PWCC, v.9, ch.15, 2016), flowing to discharge areas where the alluvial washes incise the Wepo Formation. Geologic and hydrologic mapping were applied to delineate the CIA for the Wepo Formation. Since the Wepo Formation is in hydrologic communication with the alluvial washes, alluvial aquifers are included in the CIA.

The Wepo Formation CIA is bound to the west by Yellow Water Wash, and to the southeast by Dinnebito Wash. The Wepo Formation CIA also includes the upgradient sides of mine areas N-7/8, N-9, N-11, N-14, J-21, and any historical or existing use location in the adjacent area. Water level contours for the Wepo Formation south of the Kayenta Mine Complex indicate that groundwater flow is from the east to the discharge zone in Moenkopi Wash west of the Kayenta Complex; therefore, the southern extent of the CIA has been delineated parallel to the Wepo flow paths (Figure 8).

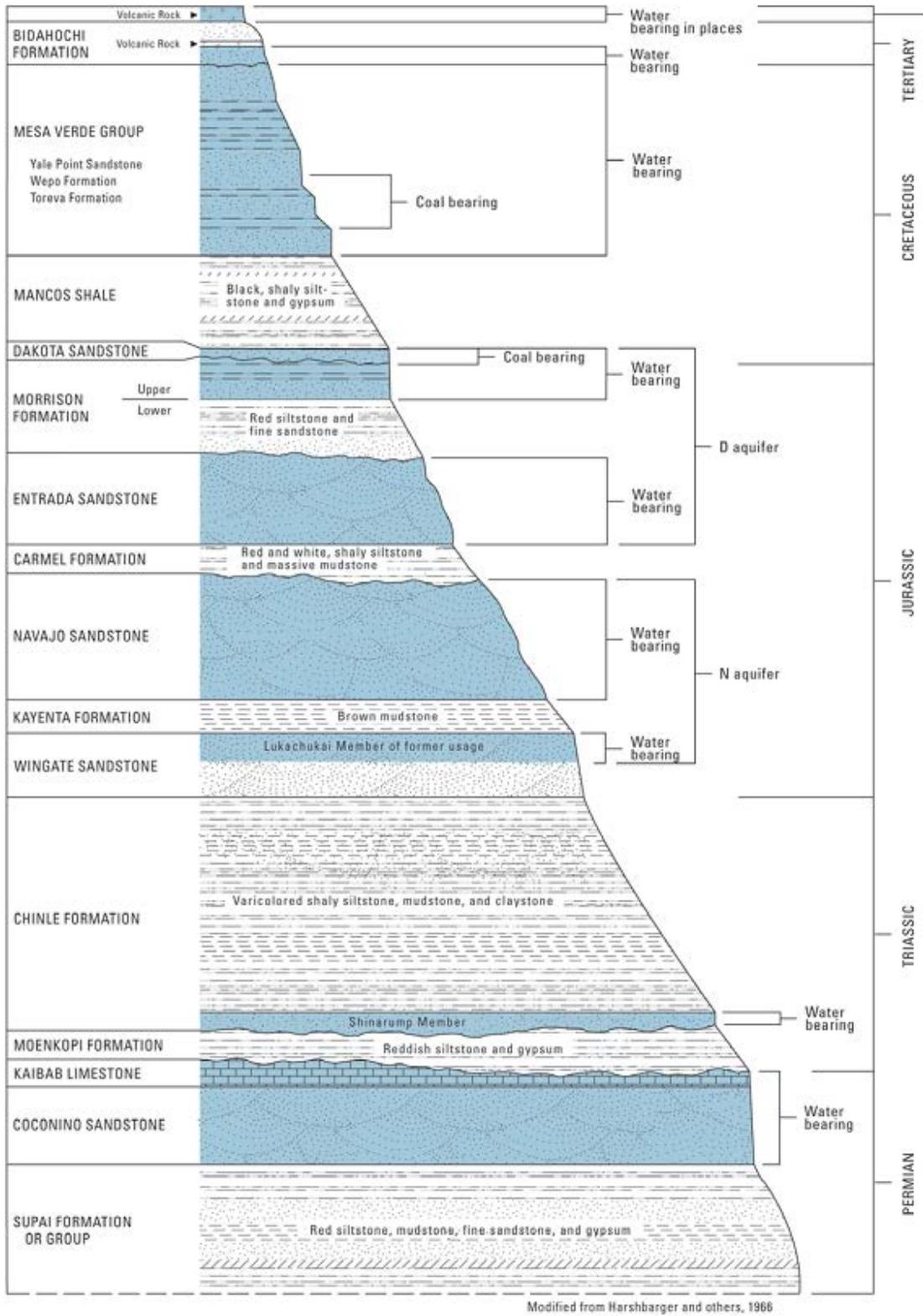


Figure 6: Stratigraphic Sequence of the Black Mesa Area (Macy and Unema, 2014)

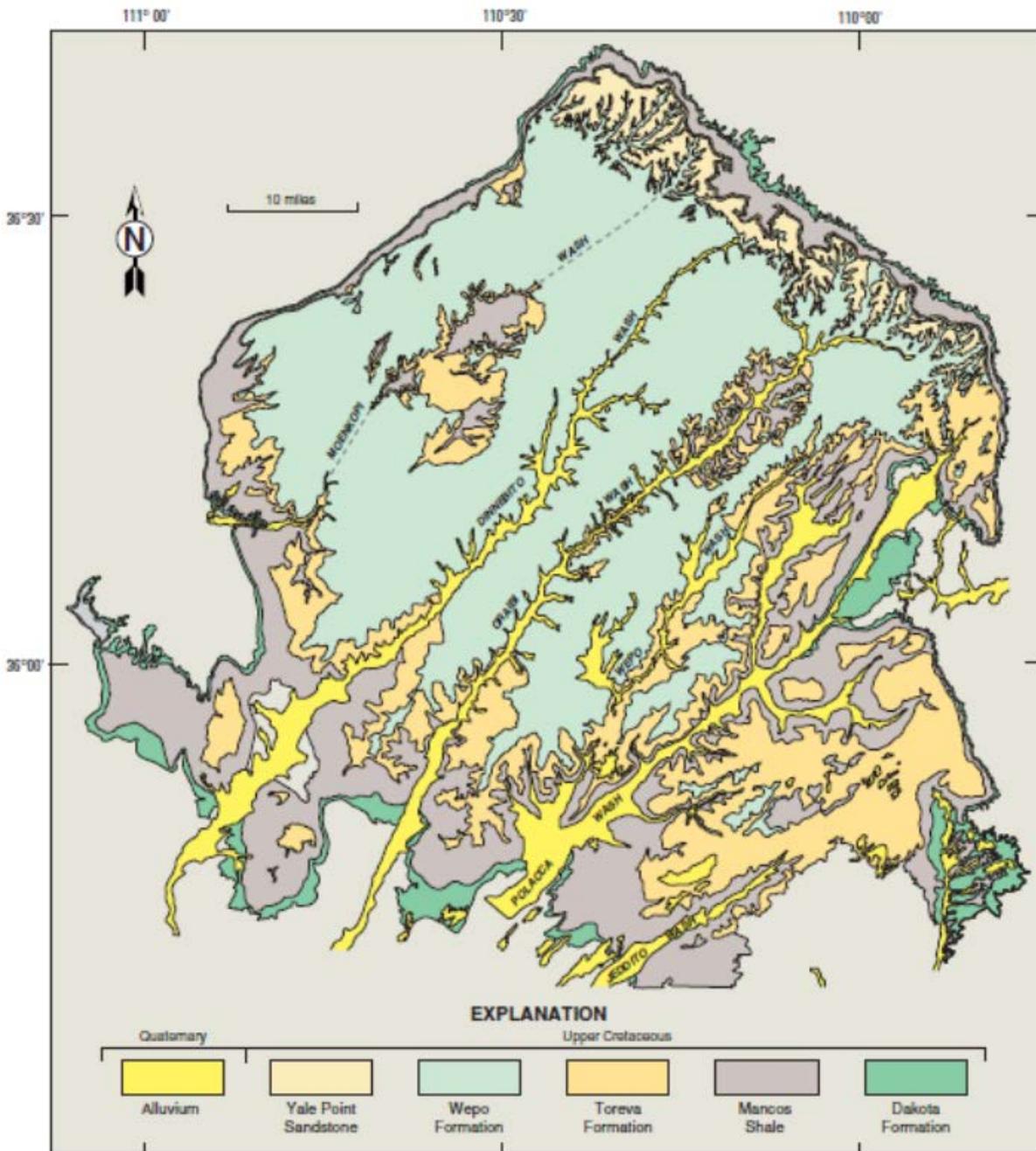


Figure 7: Black Mesa Area Surface Geology, Northeastern Arizona (Nations, et. al. 2000).

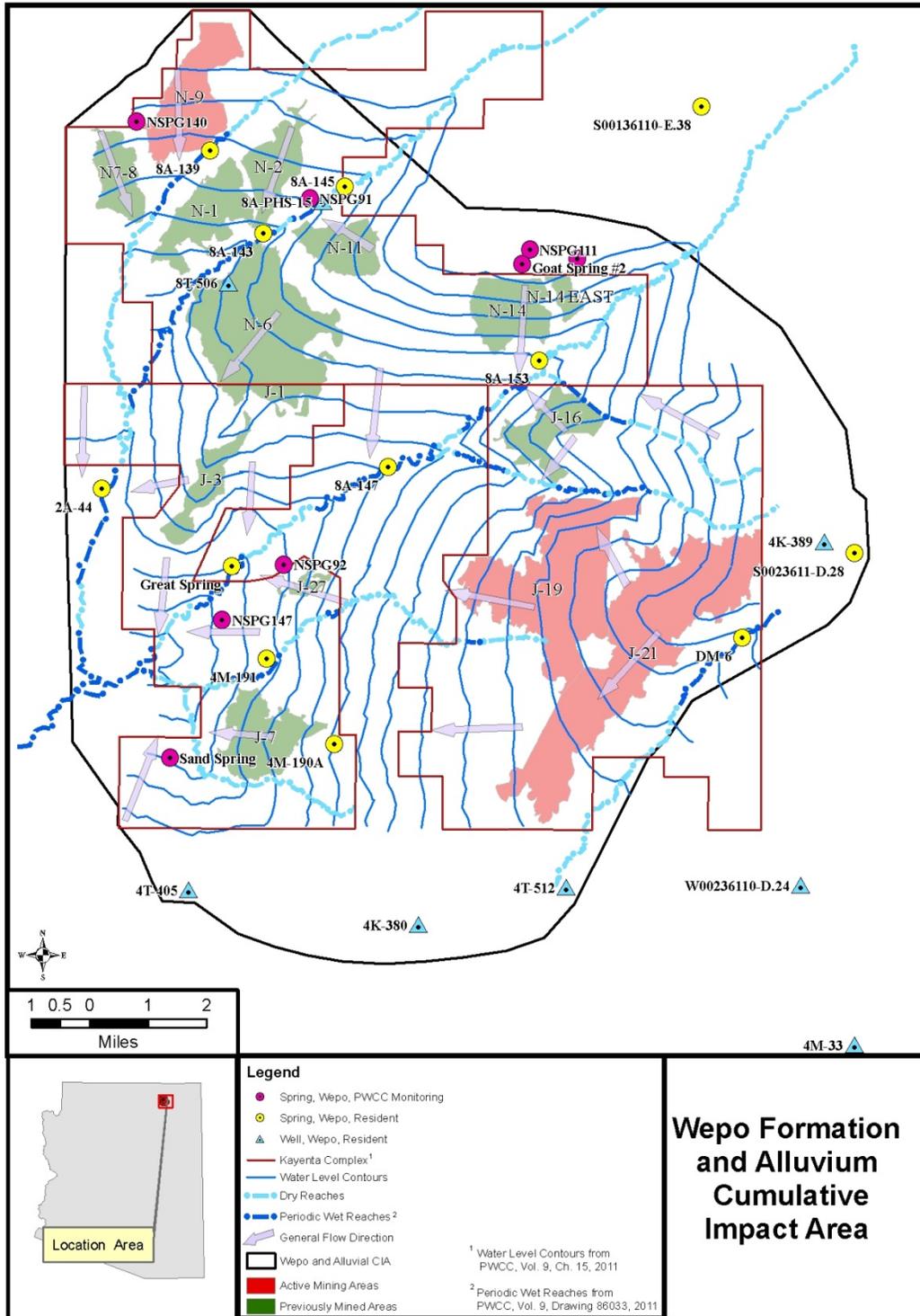


Figure 8: Wepo Formation and Alluvium Cumulative Impact Area, Kayenta Complex

2.2.2 N Aquifer

In 1999, PWCC completed a report that presented a regional three-dimensional numerical model of the Black Mesa Basin groundwater flow system (PWCC, 1999). In 2014, PWCC updated the groundwater flow model to include data collected through 2012, and utilized updated improvements in groundwater flow model techniques and solutions (Tetra Tech, 2014). The USGS completed a technical evaluation of the 2014 PWCC model (hereinafter, the “3D Model”) which included consideration of the MODFLOW version used, model grid, time discretization, recharge, internal and perimeter boundary conditions, aquifer storage properties and hydraulic diffusivity, and model calibration (Leake and others, 2016). The 3D Model represents the most comprehensive compilation and evaluation of geologic and hydrologic data for the purpose of evaluating PWCC pumping effects of the D and N aquifers. The USGS concluded that the combination of MODFLOW packages used in the 2014 PWCC 3D Model to represent real hydrologic features leads to improved simulation capabilities in comparison to previous models (Leake and others, 2016). Additionally, the placement and types of artificial boundaries do not seem to limit the usefulness of the model for evaluation the effects of pumping in the coal-lease area (Leake and others, 2016). The 3D Model considers the cumulative effect of all groundwater use from PWCC, Navajo Nation, and Hopi community pumping centers on the aquifers and associated surface flows. OSMRE relies on the 3D Model for water resource impact predictions, and will reference summary statements and conclusions throughout this assessment supported by the 3D Model report. The 3D Model boundary is considered the CIA for the N aquifer (Figure 9).

The 3D Model boundary is described in the 3D Model report (PWCC, 1999) (Tetra Tech, 2014). It is based on the lateral extent of rocks comprising the N aquifer as well as hydrologic features. The lateral extent of the N aquifer bounds the 3D Model on the west, south, and southeast (Figure 7). From Cedar Ridge to near Bidahochi, north toward the vicinity of Round Rock; this boundary is a no-flow boundary (PWCC, 1999). East of the Kayenta Mine Complex, Chinle Wash is a hydrologic boundary, and is a discharge area for flow both east and west of Chinle Wash (PWCC, 1999). “The northern boundary is placed along the interpreted groundwater divide that extends eastward from Cedar Ridge to Preston Mesa, northeastward to Skeleton Mesa east of Kaibito to the Shonto Plateau. The boundary then extends southeastward east of Tsegi Canyon to a point where it is defined by the northern extent of the Wingate hydrostratigraphic unit along the Comb Ridge monocline” (PWCC, 1999).

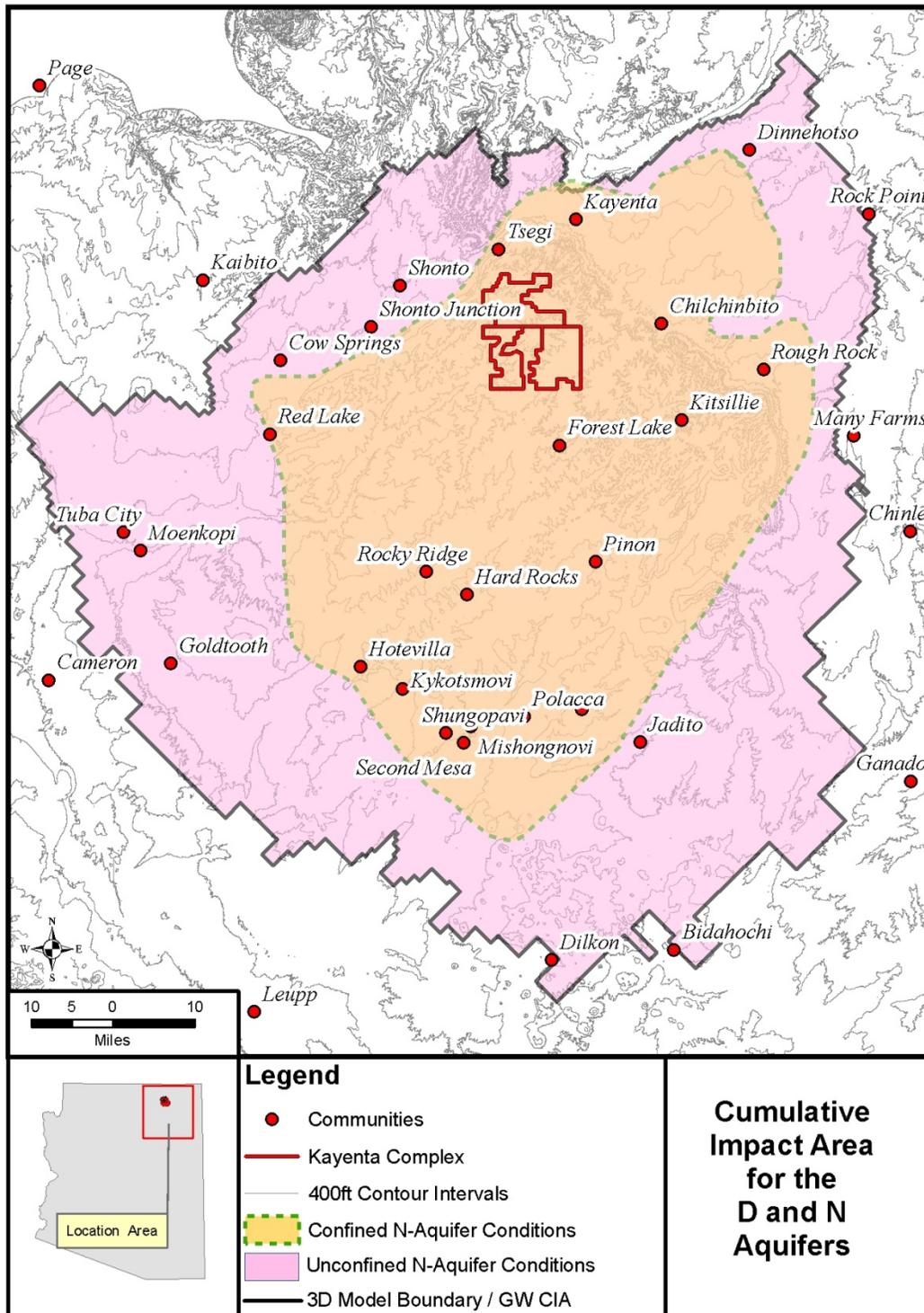


Figure 9: N aquifer Cumulative Impact Area, Kayenta Mine Complex

3 WATER RESOURCE USES AND DESIGNATIONS

As the regulatory authority, OSMRE has the responsibility of assessing the potential impacts of the mining and reclamation operations on the hydrologic balance, and to provide a determination for the potential to materially damage the hydrologic balance outside the permit area. Material damage implies that a quantifiable adverse degradation or reduction of surface or ground waters outside the permit area has occurred, precluding the utilization of water resources for existing and foreseeable uses. The existing and foreseeable water uses within the surface water and groundwater CIA's include:

- Domestic Water Supply
- Industrial Water Supply,
- Agricultural Water Supply,
- Livestock Watering,
- Secondary Human Contact and Partial Body Contact,
- Aquatic & Wildlife, and Fish Consumption.
- Primary Contact Ceremonial (Hopi Tribe), and
- Groundwater Recharge (Hopi Tribe).

3.1 Domestic Water Supply

Domestic water supply is a water body that supports the use of water as a potable water supply (Hopi Tribe, 2011; and NNEPA, 2009). The Hopi Tribe Water Resources Program has designated the N aquifer as a domestic water supply (DWS). The effect of PWCC pumping on the N aquifer on Hopi Tribe and Navajo Nation domestic water supply wells is a concern addressed in this assessment. Domestic water supply concern areas identified include all water supply wells within the groundwater CIA for the N aquifer. Figure 10 illustrates the location of water supply well systems and annual withdraw for calendar year 2011. Well systems may consist of more than one well at locations illustrated on Figure 10. Concern has been raised by Hopi Tribe and Navajo Nation members that drawdown from PWCC pumping will reduce the amount of water in water supply wells, increase electrical cost associated with lifting water an additional height to the wellhead, damage the stability of the aquifer matrix, and induce poorer quality D aquifer water to potentially degrade N aquifer water.

Water supply standpipes are available for public water hauling as part of the PWCC distribution system. The water available for public supply meets compliance with public water supply (PWS) permit ID #NN0400287. The water accessed by the two public standpipes is hauled by area residents and used for both domestic water supply and livestock consumption. The public water stands are located near the N-6 and N-14 mining reclamation areas, and account for approximately 61 ac-ft per year of the total use at the Kayenta Mine Complex (PWCC, v.11, ch.18, 2016).

3.2 Industrial Supply Water

Kayenta Mine Complex is the only location in the CIAs using water for industrial purposes. On February 1, 1964, Sentry Royalty (a wholly owned subsidiary of Peabody Coal Company at the time) entered into a coal lease agreement with the Navajo Tribe. The agreement provided approval "...to develop and utilize water for use in its mining operations, provided, however, that at the conclusion of mining operation all wells will be left properly cased and that any water not utilized in mining operations shall be made readily available for local Navajo use" (Sentry, 1964).

On June 6, 1966 the Grant of Right to Use Water was further clarified in separate lease agreements between Sentry Royalty and both the Hopi Tribe and Navajo Nation. The agreements established that Sentry Royalty would "...develop and utilize water obtained from wells located on the leased premises for use in its mining operations including the transportation by slurry pipeline of coal mined from the leased premises..." (Stetson, 1966), and royalty rates for water use were established. In 1987, new coal lease and royalty agreements were signed by Hopi Tribe, Navajo Nation, and PWCC, and received Secretarial approval by the Department of Interior (PWCC, 1987). Additionally, the Secretary of Interior reserves the right to require PWCC to provide water in quantity and quality equal to that formerly available or obtain water for its mining operation from another source if monitoring data indicate material damage to the hydrologic balance is occurring due to PWCC pumping.

PWCC began pumping in 1968 at 100 ac-ft per year (Macy and Unema, 2014). The water use rate increased to 3,680 ac-ft per year in 1972 (Macy and Unema, 2014). From 1972 to 2005 PWCC annual pumping fluctuated between 2,520 ac-ft and 4,740 ac-ft; averaging 3,980 ac-ft (Macy and Unema, 2014). Water pumped from the PWCC wellfield was utilized for the transportation of coal to the Mojave Generating Station, dust suppression, and potable water for mine facilities. Approximately 70-percent of the pumped water was used for transportation of coal via a coal slurry pipeline during this period. Coal was pulverized onsite into a powder and mixed with water to make a slurry consistency of approximately 50-percent coal and 50-percent water. The slurry was then transported approximately 273 miles through an underground pipeline to the Mojave Generating Station, the coal burned, and the water utilized as part of the cooling process at the power plant. The Mojave Generating Station and the coal slurry line are no longer operational. The coal slurry pipeline ceased operation on December 31, 2005. PWCC pumping has reduced by approximately 70-percent since 2005, averaging 1,255 ac-ft from 2006 to 2011 (Macy and Unema, 2014).

3.3 Agricultural Water Supply

Agricultural water supply means the use of water for irrigation of crops which could be used for human consumption (Hopi Tribe, 2011; NNEPA, 2009). Corn and bean fields are usually located at the foot of the mesas, on sand slopes, in small canyons, along alluvial plains in washes, and in the valleys between mesas in order to maximize the limited surface moisture available (Hopi Tribe, 2016). Another method of cultivation involves gardening on self-irrigated terraces along the mesa walls below villages. Terrace irrigation is possible because of the perennial springs at each village that originally permitted settlement (Hopi Tribe, 2016). In the southern area of Black Mesa, these springs emanate from the Toreva Formation and formations comprising the D aquifer system. In the Moenkopi and Tuba City area, the perennial springs used for irrigation purposes emanate from the unconfined N aquifer.

As presented in section 2.2.1, during the growing season Hopi and Navajo farmers in the Moenkopi area may dig a pit in the Moenkopi channel alluvium until water is reached. The alluvial water is pumped from the pit and piped to the adjacent fields, providing supplemental irrigation water when necessary. HTWQS designate all aquifers as Agricultural Irrigation (AgI) water. NNSWQS designate Moenkopi Wash as Agricultural Water Supply (AgWS). HTWQS designate Moenkopi Wash and Dinnebito Wash as AgI.

3.4 Livestock Watering

Livestock watering means the use of water as a supply for consumption by livestock (Hopi Tribe, 2011; NNEPA, 2009). Livestock watering is a pervasive practice in the CIAs; with livestock typically accessing water at springs and in-channel pools when the opportunity is available. Windmills drilled into water bearing formations that are of suitable water quality for livestock watering provide a more reliable source for livestock watering. HTWQS designate all aquifers, Moenkopi Wash, and Dinnebito Wash as

Agricultural Livestock Watering (AgL). NNSWQS designate Moenkopi Wash and Dinnebito Wash as Livestock Watering (LW).

3.5 Secondary Human Contact and Partial Body Contact

Water designated to support secondary human contact (ScHC) means the “the use of water which may cause the water to come into direct contact with the skin of the body, but normally not the point of submergence, ingestion of the water, or contact of the water with membrane material of the body” (NNEPA, 2009). The Hopi Tribe provides a similar use designation for incidental and infrequent contact and defines as partial body contact (PBC). “Partial body contact means the use of a stream reach, spring, reservoir, and other water body in which contact with the water may, but need not, occur and in which the probability of ingesting water is minimal; examples are fishing and boating (Hopi Tribe, 2011). NNSWQS identify Dinnebito Wash and Moenkopi Wash as meeting ScHC designation. The HTWQS identify Dinnebito and Moenkopi Wash as meeting the PBC use designation.

3.6 Primary Contact Ceremonial

The HTWQS designate that primary contact ceremonial (PCC) means “the use of a stream, spring, reservoir, impoundment, or other water body for religious or traditional purposes by members of the Hopi Tribe; such use involves immersion and intentional or incidental ingestion of water, and it requires protection of sensitive and valuable aquatic life and riparian habitat” (Hopi Tribe, 2011). The USGS undertook a study to identify and characterize springs identified by various methods (Leake et al. 2016). A total of 104 springs characterized as “likely” were identified as emanating from D- and N Aquifer stratigraphic units. The database was compiled from a variety of sources; however, most spring and seep locations were identified from available maps without field verification.

3.7 Aquatic Wildlife Habitat and Fish Consumption

Aquatic and Wildlife Habitat (A&WHbt) water means “the use of the water by animals, plants or other organisms, including salmonids and non-salmonids, and non-domestic animals (including migratory birds) for habitation, growth or propagation” (NNEPA, 2009). Similarly, the Hopi Tribe establish Aquatic and Wildlife (ephemeral) (A&W_e) as “the use of an ephemeral water by animals, plants, or other organisms, excluding fish, for habitation, growth, or propagation” (Hopi Tribe, 2011). Fish consumption (FC) supports the use of water by humans for harvesting aquatic organism for consumption. Harvestable aquatic organisms include, but are not limited to fish, shell-fish, turtles, crayfish, frogs, and salamanders (Hopi Tribe, 2011) (NNEPA, 2009).

3.8 Groundwater Recharge

“Groundwater recharge (GWR) use means any surface water that recharges an aquifer. Surface waters designated as groundwater recharge must meet the standards for the aquifer being recharged as well as surface water standards” (Hopi Tribe, 2011). Additionally, the Hopi Tribe Water Resources Program may designate water as “unique waters”. The Moenkopi Wash watershed from Blue Canyon Springs to the confluence of Begashibito Wash has been classified as a unique Hopi surface water area (Hopi Tribe, 2011). The N aquifer and all areas recharging the N aquifer are classified as unique groundwater (Hopi Tribe, 2011).

4 BASELINE HYDROLOGIC CONDITIONS

The issuance SMCRA established that surface coal mining operations are to be conducted as to protect the environment, and to assure that a balance between the protection of the environment and the production of coal as a source of energy is maintained (SMCRA, Section 102(d) and (f), 1977). Therefore, as presented in OSMRE's guidance document for the preparation of PHC's and CHIA's, the goals in establishment of baseline hydrologic conditions are to characterize the local hydrology, understand the regional hydrologic balance, and identify any water resource or water use that could be affected by the mining operation (OSMRE, 2002). The guidance document is consistent with 30 CFR 780.21. However, mining operations at the Kayenta Complex commenced prior to the issuance of SMCRA, making quantification of baseline conditions for impact assessment uncertain for some hydrologic resources due to the absence of pre-mining information since it was not required prior to 1977.

In compliance with the issuance of SMCRA, PWCC initiated an extensive hydrologic monitoring program documenting the interaction between the surface water system and alluvial and Wepo groundwater systems within the permit area. Additionally, the USGS began regional monitoring assistance in the mid 1970's. The continued monitoring conducted by the USGS in the Black Mesa area is designed to track the effects of industrial and municipal pumpage on ground water levels, stream and spring discharge, and ground water chemistry (Macy and Unema, 2014).

Although the majority of hydrologic information was collected after mining operations began at the Kayenta Mine Complex, the data collected from the mid 1970's to present provide insight on water quality and quantity. The groundwater models that have been developed also greatly assist with assessing hydrologic conditions and changes within the CIAs.

4.1 Surface Water

The drainages in the surface water CIAs are considered ephemeral and intermittent based on OSMRE definitions at 30 CFR 701.5. An ephemeral stream is when a stream flows only in direct response to precipitation in the immediate watershed or in response to the melting of a cover of snow and ice, and which has a channel bottom that is always above the local water table. An intermittent stream is considered a stream, or reach of a stream, that is below the water table for a least some part of the year, and obtains its flow from both surface runoff and groundwater discharge. PWCC refers to reaches of channels whose channel beds are located periodically below the local water table as wet reaches (PWCC, v.9, ch.15, 2016). OSMRE further defines intermittent at 30 CFR 701.5 as a stream, or reach of stream, that drains a watershed of a least one square mile.

4.1.1 Surface Water Regulatory Requirements

Water Quality

Surface water runoff from areas disturbed by mining operations is required to be managed in a manner that prevents additional contribution of suspended solids to stream flow outside the permit area to the extent possible with the best technology currently available, and otherwise prevents surface water pollution (30 CFR 816.41(d)). PWCC complies with 30 CFR 816.41(d) by designing, constructing, and maintaining siltation structures, impoundments, and diversions. Additionally, PWCC complies with 30 CFR 816.41(d) by monitoring in-stream surface water quality according to the approved monitoring plan in the PAP. The Moenkopi surface water CIA includes 253 mi² of the 2,635 mi² Moenkopi Wash (HUC 15020018), and the Dinnebito surface water CIA includes 51 mi² of the 743 mi² Dinnebito Wash (HUC

15020017). However, all water in the Moenkopi and Dinnebito surface water CIA's does not pass through siltation structures or impoundments due to the absence of mining disturbance in some areas, or compliance as a NPDES western alkaline outfall.

PWCC is required to submit a quarterly report to the USEPA regarding NPDES Permit #NN0022179. The NPDES reports document the water quality and quantity of discharge to the washes when high runoff events exceed the storage capacity design of the structure and surface water discharge to the wash occurs. Additionally, PWCC may dewater ponds in order to ensure sufficient design capacity by either transferring water to nearby ponds with available capacity, or by discharging water into the downstream wash in accordance with the NPDES permit.

Water Quantity

PWCC is required to reclaim lands disturbed by mining so the lands may be returned to the appropriate land management agency in a condition compatible with and capable of supporting the approved post-mining land uses. The approved Kayenta Mine Complex post-mining land uses are livestock grazing and wildlife habitat, which are consistent with the pre-mining land uses. As such, PWCC "has designed its reclamation efforts to return mined lands to the land use of livestock grazing and wildlife habitat" (PWCC, v.8, ch.14, 2016). In order to support the livestock grazing and wildlife habitat post-mining land uses, and after consultation with the Navajo Nation, Hopi Tribe, and the Bureau of Indian Affairs (BIA), PWCC proposed the construction and retention of 51 permanent surface water structures to ensure an adequate distribution of post-mining water resources in order to promote a greater viability of post-mining land use success. The reclamation plan has been previously agreed to by the BIA and the Hopi Tribe and Navajo Nation. By the year 2019, there will be 50 permanent impoundments, 115 temporary impoundments, and 101 reclaimed impoundments (BOR, 2016).

The retention of surface water impounded by temporary and permanent impoundments was contested by the Hopi Tribe in 1991, and presented before Administrative Law Judge (ALJ) John R. Rampton, Jr. (Rampton, 1991). ALJ Rampton's decision concluded that trust responsibilities are owed equally to both the Hopi Tribe and the Navajo Nation, who dispute each other's water rights claims. ALJ John H. Kelly reaffirmed ALJ Rampton's decision on June 5, 1992 (Kelly, 1992). To date, these water rights claims have not been adjudicated. Therefore, OSMRE cannot determine which tribe holds adjudicated water rights that require protection until the water claims are adjudicated.

While OSMRE does not have the authority to make determinations of possible violations of adjudicated water rights between the Hopi Tribe and Navajo Nation, OSMRE evaluates surface water quantity related to existing and foreseeable downstream uses and the impact of the mining and reclamation operations on the hydrologic balance.

4.1.2 Surface Water Baseline Quantity

Precipitation that does not infiltrate into the subsurface, or return to the atmosphere by evapotranspiration, flows in the washes as surface water. The nature of the surface water flow depends on the type of precipitation and behavior of the storm. "Forty-six percent of the annual precipitation is received in the months of July, August and September, and sixty-four percent is received in the period April through September" (PWCC, v.8, ch.11, 2016). The majority of surface runoff results from precipitation from April through September. A much smaller amount of runoff occurs in other months, such as snowmelt derived runoff in February and March.

The average channel gradient in the permit area is approximately 1%, which induces high velocities during runoff events (PWCC, v.9, ch.15, 2016). The high velocity is reflected in most hydrographs by a short time to peak and a quick reduction in flow after the storm ends. Velocities measured by PWCC

personnel using current meters commonly exceed 5 feet per second (ft/sec) and have been as high as 10 ft/sec or greater during large flow events. PWCC monitoring also indicates that it is not uncommon to have a time to peak of two to three minutes at the various monitoring stations (PWCC, v.9, ch.15, 2016). Multiple peak hydrographs are a characteristic observed during monitoring of the Black Mesa hydrology. The multiple peaks are likely the result of the localized nature, movement, and varying intensity of the thunderstorms that cause runoff. PWCC observations indicate that a thunderstorm cell might produce intense rain in a small upper tributary, move to other tributaries within the same watershed, and may change intensity as the thunderstorm cell migrates over the area, producing multiple runoff surges at downstream monitoring stations (PWCC, v.9, ch.15, 2016).

Stream monitoring sites were established to characterize the surface water regime related to surface water quantity (Figure 11). Above-mining and below-mining monitoring sites were selected on the primary drainages in the CIA: Yellow Water Wash, Coal Mine Wash, Moenkopi Wash, Red Peak Valley Wash, and Dinnebito Wash. The flow monitoring provides information on the hydrograph characteristics representing a range of drainage areas, watershed shapes, slopes, channel densities, and vegetative characteristics. Once the flow hydrographs are characterized for the snowmelt, convective and frontal storm events, the information provides reasonable flow volume estimates from the peak flow measurements. The flow quantity estimates are based on a strong correlation identified during regression analysis between peak flow and flow volume for the various type of flow event (PWCC, v.9, ch.15, 2016).

PWCC demonstrated through the use of upstream and downstream flow hydrographs for a storm event occurring entirely in the watershed above the upstream site that the upstream hydrographs only provide information on the channel transmission losses and the dampening effects these losses will have on the shapes and peaks of the downstream hydrographs (PWCC, 2001). Therefore, in 2002, OSMRE approved the reduction of continuous flow monitoring at upstream monitoring locations since PWCC demonstrated characterization of the surface water quantity and quality regime and the potential for surface water impacts. Additionally, no significant mining-related disturbance is present upgradient of the Kayenta Mine Complex and the distinct geographic edge of Black Mesa.

PWCC currently monitors surface water at downstream monitoring locations 155 (Red Peak Valley Wash), 25 (Coal Mine Wash), 26 (Moenkopi Wash), and 34 (Dinnebito Wash). Locations 155, 26, and 25 collect continuous flow stage levels during storm flow events using ultrasonic gages mounted to a platform over the wash at established channel control sections. Location 34 is a crest gage (CG) used to measure peak flow, and the peak measurement can be applied to the appropriate hydrograph type to approximate the total discharge event. In 2010, PWCC installed monitoring location 34 near CG34, which has the same continuous monitoring design capabilities as locations 25, 26, and 155. These gaging locations provide useful surface water quantity information during the evaluation of potential impact to the hydrologic balance outside the permit area.

Monitoring locations 25, 26, and 155 measure surface water runoff that does not pass through PWCC dams, ponds, or impoundments; with the exception of overflow quantities that periodically occur due to discharges from sediment control structures and are reported as part of compliance with the NPDES permit. During the NN0022179 permit term (2005-2009), discharges from precipitation events ranged from 0 ac-ft in 2009 to 57.81 ac-ft in 2007, averaging 21.28 ac-ft per year over the 5-year period. Combined measured surface flow at monitoring locations 25, 26, and 155 varies annually for the period 1987-2008. Total combined runoff for these three locations was a low (124.1 ac-ft) in 1991, and a maximum (4,105.8 ac-ft) in 2006; averaging 1,488.5 ac-ft from 1987-2008 (PWCC, v.11, ch.18, Table 15, 2016). Based on the combined drainage area for the three locations (253 mi²), less the total PWCC impounded area during each calendar year, an average annual runoff of 0.15-inches was calculated for the Moenkopi surface water CIA (PWCC, v.11, ch.18, Table 15, 2016).

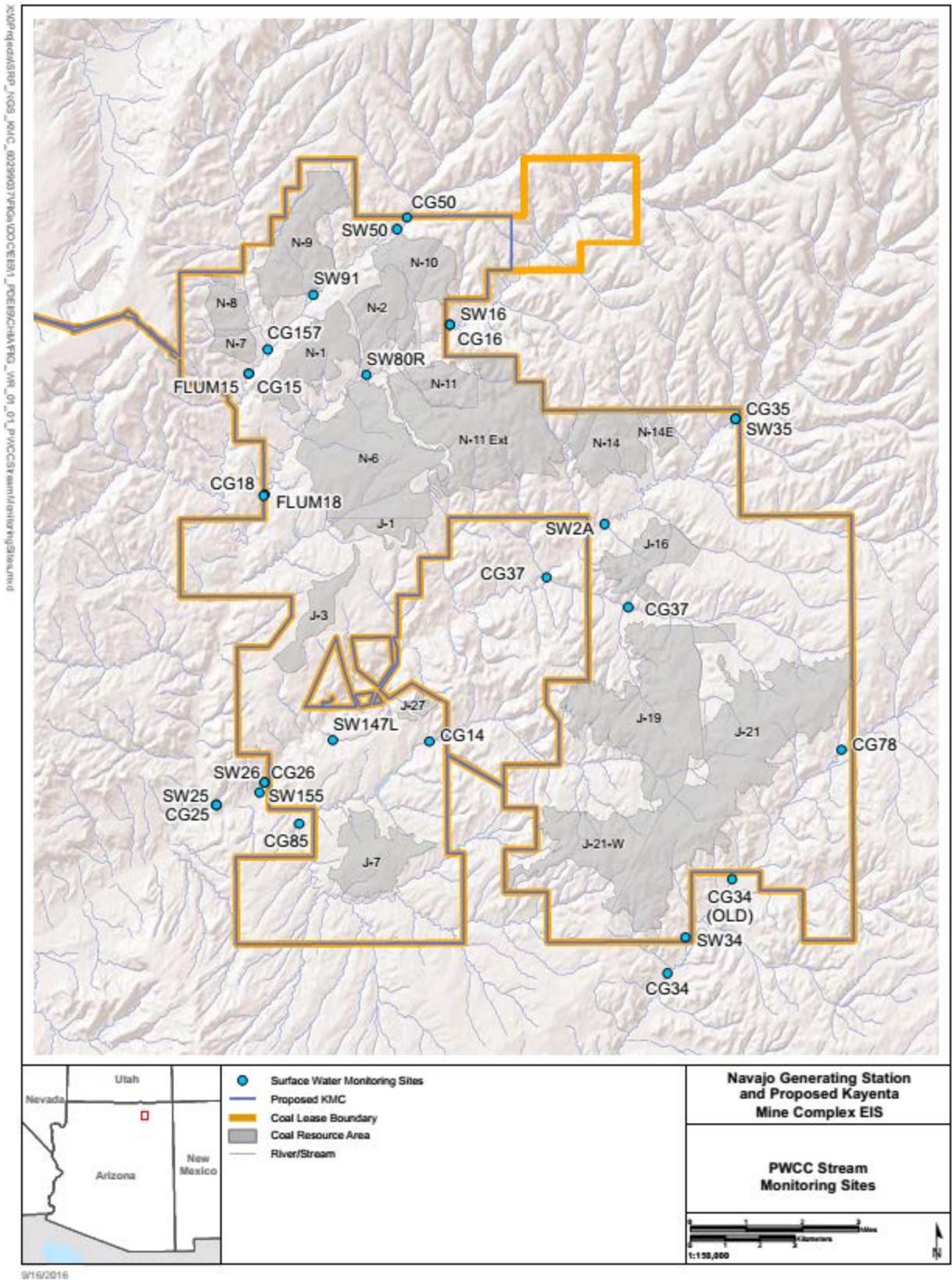


Figure 11: PWCC Surface Water Monitoring Locations (BOR, 2016, Figure WR-1.1)

4.1.3 Surface Water Baseline Quality

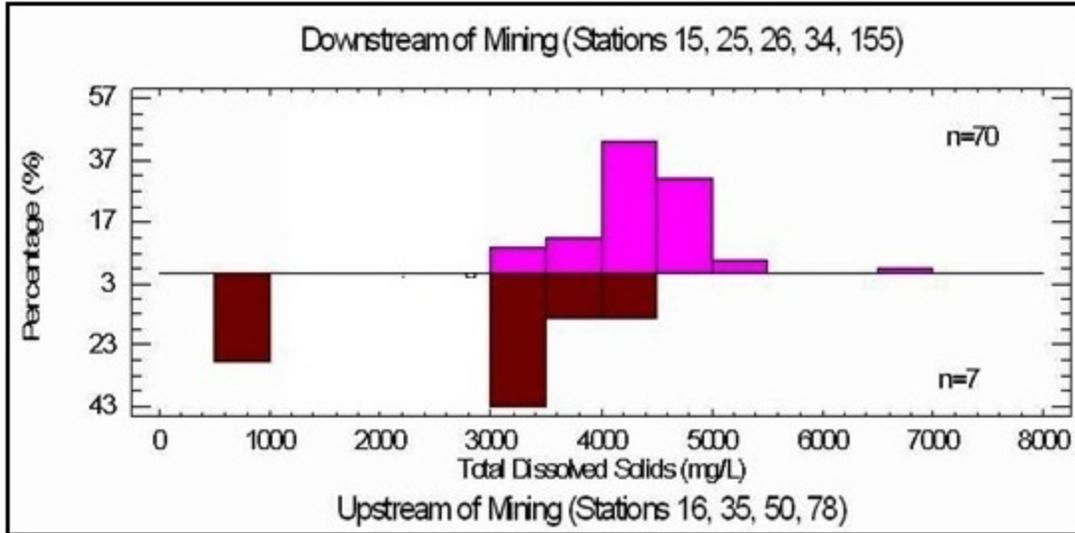
Surface water quality varies based on the type of runoff: storm water runoff, snowmelt runoff, or baseflow runoff (PWCC, v.9, ch.15, 2016). Data collected from surface water monitoring locations from September 1980 to June 1985 indicates that the dominant dissolved ions are calcium, magnesium, sometimes sodium, bicarbonate and sulfate (PWCC, v.9, ch.15, 2016). Dominant water types are calcium-magnesium sulfate and calcium-magnesium bicarbonate (PWCC, v.9, ch.15, 2016). Surface water flows in the Dinnebito Wash and Moenkopi Wash CIAs primarily originate from storm water runoff, and resulting flows can be classified as flash floods of varying magnitude (PWCC, v.9, ch.15, 2016). Storm water runoff in the CIAs can entrain the channel wash sediment. The amount of entrained sediment can be expressed as total suspended solids (TSS). The PWCC monitoring program established that as the flow discharge increases, TSS concentrations will increase (PWCC, v.9, ch.15, 2016). A maximum TSS concentration of 994,000 milligrams per liter (mg/L) was recorded during the 1980 to 1985 monitoring period (PWCC, v.9, ch.15, 2016).

The USGS collected surface water quality samples in December 1973 and then quarterly through the second half of 1975 in Moenkopi Wash approximately one mile downstream of the permit boundary (retired Station No. 09401240). Samples collected at retired USGS station 09401240 had mean sulfate concentrations of 1,600 mg/L and total dissolved solids (TDS) concentrations of 2,691 mg/L. The USGS also periodically collected water quality samples throughout the mid 1970's in Moenkopi Wash, Yellow Water Canyon Wash, and Coal Mine Wash within and adjacent to the Kayenta Complex.

TDS a valuable indicator of water quality conditions in surface water flow, and represents a broad measure of the overall quality of surface water. Figure 12 compares baseflow and storm flow TDS values between stations located upstream and downstream of mining activity. The data indicate that upstream baseflow TDS is consistent with downstream baseflow TDS concentrations. However, the Wepo Formation outcrops, and sub-crops in the alluvium, across the permit area; trending northwest to southeast. Therefore, baseflow is more prevalent on the downstream channels, and downstream water quality is influenced by the quality of water discharging from the Wepo Formation. Storm flow TDS is consistent when comparing upstream and downstream locations. Concentrations of TDS and other constituents are greater at downstream sampling locations compared to upstream sampling locations, likely attributed to the overlying Yale Point Sandstone. The Wepo Formation is present adjacent to the stream channels, but approximately 80% of the surface area between the eastern Kayenta Mine Complex boundary and the rim of the mesa has been mapped as Yale Point sandstone (Repenning and Page, 1956). The Yale Point does not contribute as much of a dissolved load to the surface water compared to the Wepo. Within the Kayenta Mine Complex, the land surface is dominated by the Wepo Formation at surface, and the Yale Point is present only in the northeastern extension of the permit area. Therefore, within the permit area, runoff has a higher dissolved load, and the Wepo-influenced water recharges the alluvium in stream channels with higher TDS water. A review of sulfate data indicates that the distribution relationship is consistent with the TDS baseflow – stormflow relationship.

Table 2 provides summary information for upstream surface water monitoring locations for the Dinnebito Wash and Moenkopi Wash CIAs of the Kayenta Complex. Surface water monitoring location 78 represents upstream water quality for the Dinnebito Wash CIA. Surface water monitoring locations 16, 35, and 50 represent the upstream water quality for the Moenkopi Wash CIA. Storm flow water quality data collected between 1986 and 2010 is presented relative to the most protective WQS considering HTWQS (Hopi Tribe, 2011) and NNSWQS (NNEPA, 2009).

Baseflow TDS



Stormflow TDS

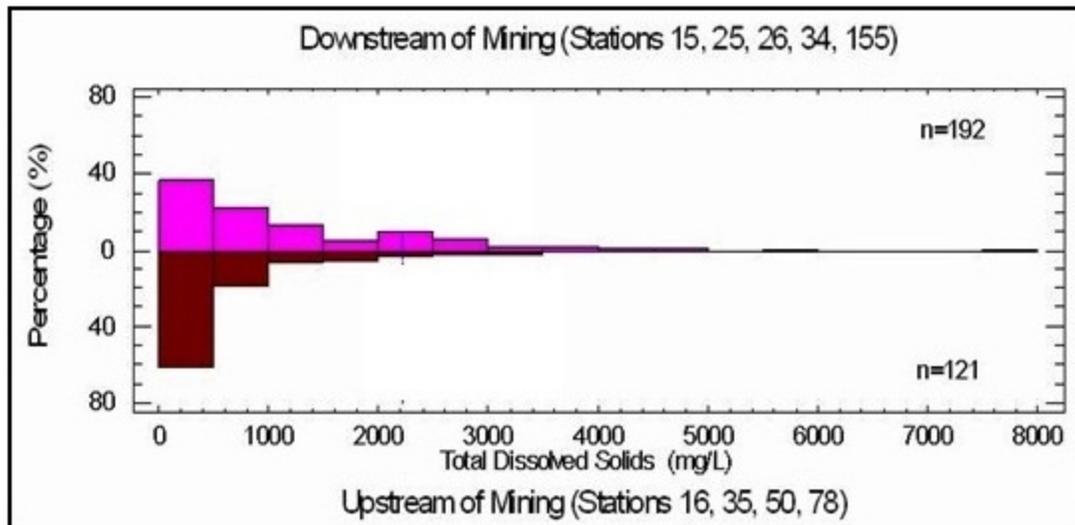


Figure 12: Comparison of Upstream and Downstream TDS Surface Water Quality Data for Baseflow and Stormwater flow (1986-2004).

Chemical Parameter	Most Protective WQS	WQS	Units	Type	Dinnebito Wash CIA				Moenkopi Wash CIA			
					Location 78				Locations 16, 35, and 50			
					Storm Water Samples				Storm Water Samples			
# Samples	Low	Median	High	# Samples	Low	Median	High					
Aluminum	Aquatic (NN)	0.75 (T)	mg/L	Dissolved	n=20	0.03	0.1	0.5	n=45	0.05	0.5	1.1
Antimony	Aquatic (NN)	88	µg/L	Dissolved	n=15	1	200	485	n=38	1	200	860
Arsenic	Aquatic (HT)	230	µg/L	Dissolved	n=20	1	20	30	n=45	1	20	30
Barium	Secondary Contact (NN)	98000 (T)	µg/L	Dissolved	n=17	90	195	500	n=44	20	250	1500
Bicarbonate	NNS	NNS	mg/L	Dissolved	n=34	39	95	390	n=86	26.8	94	1022
Boron	Agricultural (NN)	1000 (T)	µg/L	Dissolved	n=35	20	100	500	n=87	10	10	10
Calcium	NNS	NNS	mg/L	Dissolved	n=35	32	173	570	n=88	14	60	580
Cadmium	Fish Consumption (NN)	8 (T)	µg/L	Dissolved	n=18	3	5	20	n=42	10	100	504
Chloride	Aquatic (HT)	230 (T)	mg/L	Total	n=34	1	17.9	282	n=88	2	5	15
Chromium	Agricultural (HT)(NN)	1000 (T)	µg/L	Dissolved	n=18	10	20	50	n=41	1	7	69
Copper	Agricultural (NN)	200	µg/L	Dissolved	n=20	10	10	30	n=45	10	20	50
Fluoride	Secondary Contact (NN)	56 (T)	mg/L	Total	n=34	0.1	0.5	1.9	n=88	0.1	0.3	0.8
Iron	NNS	NNS	mg/L	Total	n=27	1.57	444.5	3871.0	n=76	7.75	352	4125
Lead	Secondary Contact (NN)	15 (T)	µg/L	Dissolved	n=18	20	20	540	n=41	20	20	280
Magnesium	NNS	NNS	mg/L	Dissolved	n=35	7	78.7	1300	n=88	2.7	13	247
Manganese	Agricultural (HT)	10 (T)	mg/L	Total	n=28	0.12	16	84	n=76	0.2	10	79
Mercury	Aquatic (HT)	0.01	µg/L	Dissolved	n=18	0.1	1	2.0	n=42	0.1	1	20
Molybdenum	Agricultural (HT)	0.01	µg/L	Dissolved	n=15	1	200	500	n=40	1	200	500
Nickel	Fish Consumption (NN)	4600 (T)	µg/L	Dissolved	n=15	20	20	300	n=40	10	50	300
Nitrate as N	Secondary Contact (NN)	1493 (T)	mg/L	Total	n=33	0.0	0.96	82.9	n=88	0.01	0.9	7.5
Nitrite as N	Secondary Contact (NN)	93.3 (T)	mg/L	Total	n=33	0.00	0.05	0.9	n=88	0.00	0.04	1
NO3+NO2	Livestock Watering (NN)	132	mg/L	Total	n=33	0.24	1.29	83	n=70	0.02	0.99	8.5
pH	All Uses	< 9.0	s.u.	Total	n=33	6.2	7.3	8.0	n=88	6.8	7.4	8.2
Selenium	Aquatic (HT)	2 (T)	µg/L	Dissolved	n=20	1	5	50	n=46	1	10	50
Silver	Secondary Contact (NN)	4670 (T)	µg/L	Dissolved	n=15	10	20	30	n=40	5	20	40
Sodium	NNS	NNS	mg/L	Dissolved	n=35	7.2	87	1740	n=88	1	4	108
Sulfate	Aquatic (HT)	250 (T)	mg/L	Total	n=34	48	900	9096	n=88	10	150	3060
TDS	Aquatic (HT)	500	mg/L	Total	n=34	170	1444	13250	n=88	72	440	6620
Vanadium	Agricultural (HT)(NN)	100 (T)	µg/L	Dissolved	n=20	5	20	500	n=45	5	100	1000
Zinc	Agricultural (HT)(NN)	10 (T)	mg/L	Dissolved	n=20	0.01	0.02	0.10	n=45	0.01	0.02	0.5

NNS - No Numeric Standard
WQS - Water Quality Standard

mg/L - milligrams per liter
µg/L - micrograms per liter

NN - Navajo Nation
HT - Hopi Tribe

CIA - Cumulative Impact Area
T- Total

Table 2. Storm water sample ranges for upstream locations, Kayenta Mine Complex (1986-2010).

4.2 Groundwater

The proposed mining effect on groundwater quantity and quality is a hydrologic impact consideration related to the Kayenta Mine Complex. The coal resource areas mined at the Kayenta Complex are in the Wepo Formation of the Mesa Verde Group, and the alluvial channels are locally connected to the formations of the Mesa Verde Group. PWCC utilizes groundwater from water supply wells within the Kayenta Mine Complex, withdrawing groundwater from the N aquifer. The N aquifer is utilized regionally by Hopi and Navajo communities for domestic supply water, the overlying D aquifer is utilized in isolated areas where the water quantity and quality supports domestic or livestock water supply use. A third regional aquifer system, C aquifer, exists below the N aquifer and is confined from the N aquifer by siltstone, mudstone, and claystone comprising the Chinle Formation.

4.2.1 Groundwater Regulatory Requirements

30 CFR 816.41(h) states that a water supply of an owner of interest used for domestic, agricultural, industrial, or for other legitimate use that is adversely impacted by contamination, diminution, or interruption proximately resulting from surface mining activities shall be replaced. PWCC use of water for mining operations is authorized based on previous and current permit agreements. The coal leases from the Navajo Nation and Hopi Tribe state that Peabody may “develop and utilize water obtained from wells located on the leased premises for use in its mining operations including the transportation by slurry pipeline of coal mined from the leased premises...” (Stetson, 1966). PWCC commits to proper protection and maintenance of the production wells in accordance with the leases. PWCC will seal and properly abandon all monitoring wells in the alluvial and Wepo aquifers and remove the surface installations and instrumentation, unless the Tribes request retention of specific wells in the groundwater monitoring program.

4.2.2 Alluvium

Geomorphic mapping of the alluvium and colluvium along the principal washes and tributaries in the permit and adjacent area in 1980 identified that Dinnebito, Reed Valley, lower Coal Mine, and lower Moenkopi (2-mile segment downstream from permit boundary) washes have the largest amount of alluvium and saturated material (PWCC, v.11, ch.17, 2016). During 1980, PWCC conducted studies to determine the presence of alluvial valley floors. The studies concluded that the potential for agricultural practices in alluvial areas on and adjacent to the Kayenta Mine Complex is limited, and alluvial valley floors do not exist on or immediately adjacent to the Kayenta Mine Complex (PWCC, v.11, ch.17, 2016). The headwater reaches of all washes, and side tributaries, contain little to no alluvial water. PWCC has installed approximately one hundred wells, and replacement wells when necessary to characterize and monitor the hydrogeologic conditions of the alluvium (Figure 13). Seismic refraction surveys were completed to evaluate alluvium thickness and saturation (Figure 14). This section will assess baseline water quantity and agricultural livestock use quality with information from the alluvial monitoring well program on the primary washes and tributaries within the surface water CIAs. The surface water CIAs will be used for evaluation of the alluvium due to the shallow and variable alluvial thickness and high infiltration rates in the channel alluvium, which provide a mechanism for the surface water system and alluvial groundwater system to interact with each other.

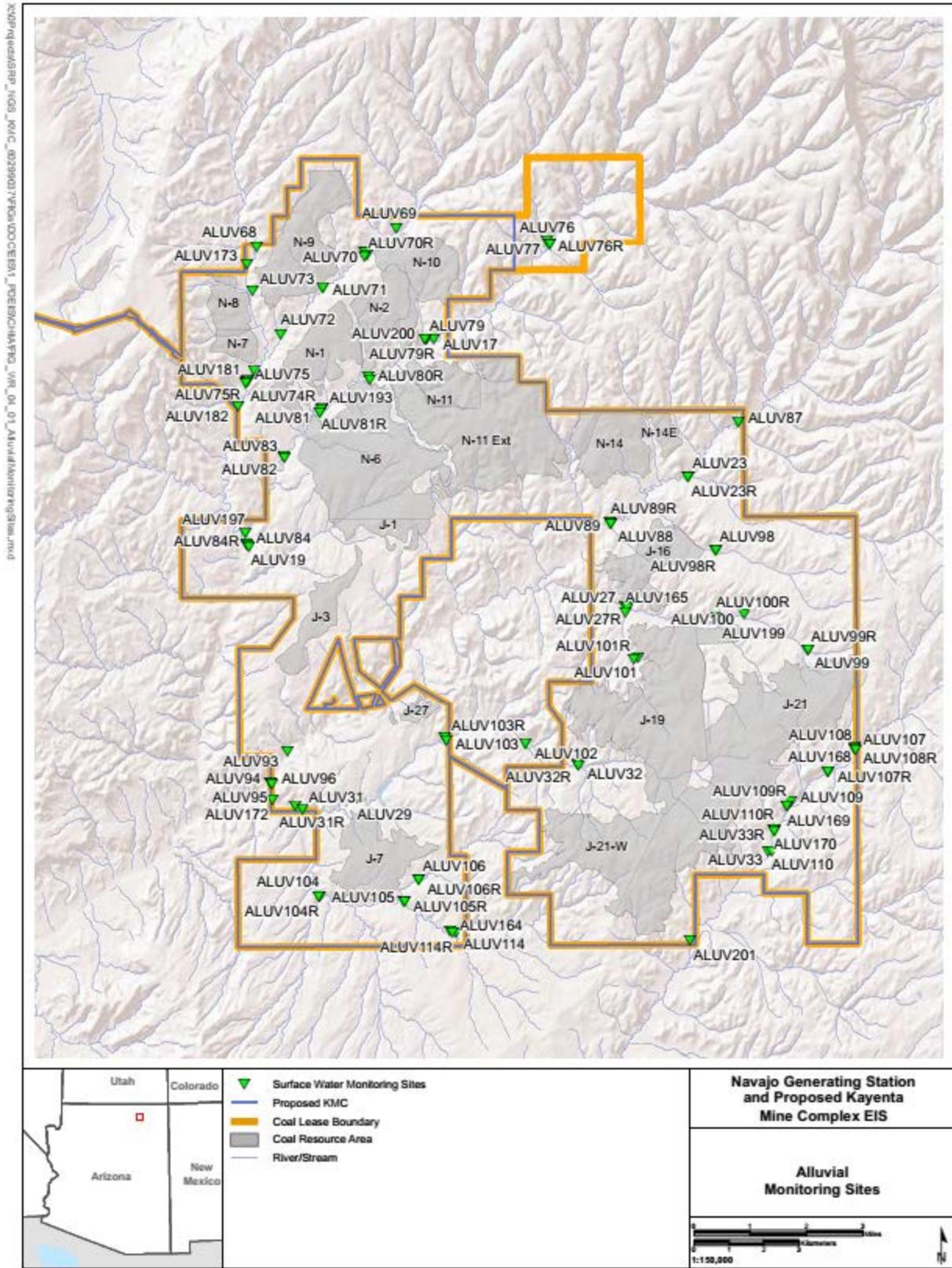


Figure 13: PWCC Alluvial Water Monitoring Locations (BOR, 2016, Figure WR-4.1)

4.2.2.1 Alluvial Baseline Quantity

Saturated thicknesses and saturated cross-sectional areas were estimated for the primary washes within the permit area using borehole lithology, groundwater monitoring wells, and the geophysical technique of seismic refraction. The major washes investigated include Reed Valley Wash, Red Peak Valley Wash, Yellow Water Canyon Wash, Coal Mine Wash, Yucca Flat Wash, Moenkopi Wash, and Dinnebito Wash.

Seismic evaluation at locations within the Kayenta Mine Complex and at select adjacent areas resulted in average saturated thicknesses from 3 feet to 34 feet, while saturated cross-sectional areas ranged from 900 square feet to 40,000 square feet (Figure 14). Thinnest saturated areas in the permit area were present at Upper Red Peak Valley Wash, Upper Yellow Water Canyon Wash and Upper Yucca Flat Wash, while greatest saturated thicknesses were found at Lower Yellow Water Canyon Wash, Lower Coal Mine Wash, Lower and Upper Dinnebito Wash, and Middle Reed Valley Wash. Greatest saturated cross-sectional areas were found along Dinnebito, Lower Moenkopi and Coal Mine Washes (PWCC, v.9, ch.15, 2016).

Groundwater gradients were also evaluated on both micro-scale (180-foot length) and macro-scale (lengths of several thousand feet) along the alluvial channels using seismic refraction and water levels in the alluvial ground water monitoring wells. Gradients on a macro-scale ranged from 0.007-0.025 feet/foot, and 0.002-0.028 feet/foot on a micro-scale (PWCC, v.9, ch.15, 2016).

Additionally, a review of borehole lithology identified that the alluvium consists of poorly sorted sediments ranging from clays to cobbles. The alluvium varies in width and depth within the same wash and compared to other washes. The variation is a result of previous channel scour and associated sediment deposition. Subsequent events of channel scour and sediment deposition further add to the heterogeneity and anisotropy of the alluvial system. The variations in alluvial material influence the hydraulic conductivity of the saturated material throughout the various washes, and ultimately the transmissivity which is the product of hydraulic conductivity and saturated thickness. “The ability of an aquifer to transmit water is described by its hydraulic conductivity. The hydraulic conductivity is integrated in the vertical dimension to give an average transmission characteristic known as transmissivity, or hydraulic conductivity times the aquifer’s saturated thickness” (Anderson and Woessner, 1992).

Transmissivity for the alluvial washes was evaluated in the permit area at 19 locations using time-distance drawdown aquifer tests in pits excavated into the alluvium or slug injection tests in the alluvial well bores (Figure 15). Time-drawdown pit tests were performed when meaningful drawdown responses could not be obtained in the alluvial wells prior to depleting all the water from the well bores. Therefore, where alluvial water levels were shallow and hydraulic conductivity high, pit pumping tests were performed. Transmissivity values from pit pumping tests near alluvial wells 74, 84, 88, and 95 ranged from 1870-5100 gallon per day per foot (gpd/ft), and transmissivity values derived from slug injection tests ranged from 21-1517 gpd/ft (PWCC, v.9, ch.15, 2016). The heterogeneity of the channel alluvium identified during review of the borehole lithology is evident in the transmissivity results for the various washes, which typically vary an order of magnitude within the same wash.

The alluvium is recharged from infiltration of surface water runoff from direct precipitation, and from groundwater emanating from saturated areas of the Mesa Verde Group in communication with the valley alluvium. The alluvial channels have not downcut to elevations in the permit area where the channels truncate the Toreva Formation of the Mesa Verde Group. Therefore, the groundwater portion of recharge is predominantly derived from saturated areas of the Wepo Formation of the Mesa Verde Group truncated by alluvial channels, and minor contribution from the Yale Point Sandstone Formation of the Mesa Verde Group in the northern and northeastern areas of Black Mesa above the permit area (PWCC, v.9, ch.15, 2016). Recharge to the alluvium from the truncated saturated areas of the Wepo Formation account for the maintenance of alluvial water levels during extended dry periods.

Seismic refraction surveying noted the occurrence of water level gradients from the Wepo Formation to the alluvium at alluvial monitoring locations 31R, 77, 100R, 103, 107, and 110R (PWCC, v.9, ch.15, 2016). Typically, alluvial monitoring well hydrographs show gradual water level declines in the spring and late fall, and water level rises during the summer monsoon period and during wet winters in response to the infiltration of surface water runoff.

Alluvial groundwater flow rates are driven by local hydrologic gradients, which vary depending on magnitude, frequency, and duration of the surface runoff and subsequent infiltration rates. Alluvial water discharge to the atmosphere by transpiration of phreatophytes along the alluvial channels is a factor at localized areas. Water level fluctuations during the spring and summer months have been observed at alluvial monitoring wells 33R, 83, 84, and 95 near tamarisk phreatophytes (PWCC, v.11, ch.18, 2016).

4.2.2.2 Alluvial Baseline Quality

Water quality of the alluvial drainages was evaluated for agricultural livestock watering use with the alluvial monitoring well network (Figure 13). Table 3 presents water quality summary statistics for upstream alluvial monitoring wells for the Dinnebito Wash CIA and Moenkopi Wash CIA related to Agricultural Livestock Watering WQS.

The nature of recharge to the alluvium varies depending on the season of the year. The majority of alluvial recharge occurs during the monsoon season of July, August, and September when surface water flow events infiltrate into the channel alluvium. Recharge to the alluvium also occurs as a result of surface water runoff generated from snowmelt events typically occurring in February and March. When surface water runoff is not recharging the alluvium from downward infiltration of surface water, the dominant recharge process occurs from horizontal flow of the Wepo Formation discharging into the adjacent alluvium, typically during April and May. Therefore, the nature of recharge may potentially have seasonal influence on alluvial water quality.

In order to assess the potential seasonal influence on alluvial water quality within the primary alluvial washes, statistical analysis of sulfate was evaluated for time periods when the alluvium is recharged by storm water flow, snow melt runoff, or contribution from the Wepo Formation. The first part of the analysis evaluated the entire group of sulfate concentrations within each major wash broken down by dominant recharge mechanism, determined by sample collection date, and compared recharge mechanisms. The second part of the analysis evaluated the differences in sulfate concentrations between the monitoring locations within each wash after grouping the data by recharge mechanism, and compared location differences. Parametric and non-parametric statistical methods were applied to evaluate the statistical significance of the means and medians of the data grouped by recharge mechanism. Normality of the data distribution was also considered. If the data were normally distributed, then ANOVA, Cochran, Barlett, Hartley, and Levene analyses were considered. If the data were not normally distributed, then the Kruskal-Wallis method was considered.

The results indicate that differences in alluvial water quality based on comparing recharge mechanism are not statistically significant at the 95% confidence interval for the four primary alluvial drainages (PWCC, v.11, ch.18, 2016). However, statistical differences are apparent when comparing concentrations in alluvial wells from different locations within the same alluvial drainage. Location based statistical differences are also apparent in all sampled alluvial drainages when comparing the different recharge mechanisms. The local seasonal influences of the different recharge mechanisms may effect on the water quality variability at any location, but not significantly compared to the water quality variability from location to location. Therefore, OSMRE evaluated upstream alluvial monitoring wells and downstream alluvial monitoring wells for comparison. If impacts are identified at downstream alluvial monitoring locations, evaluation of specific stream reaches may be necessary.

Chemical Parameter	Agricultural Livestock Watering WQS	WQS	Units	Type	Dinnebito Wash CIA				Moenkopi Wash CIA			
					Location 108R			Locations 69, 77, and 87				
					# Samples	Low	Median	High	# Samples	Low	Median	High
Aluminum	HT	5	mg/L	Dissolved	n=37	0.03	0.05	0.5	n=129	0.03	0.05	2
Arsenic	HT and NN	200	µg/L	Dissolved	n=37	0.5	1	32	n=99	0.5	1	20
Bicarbonate	NNS	NNS	mg/L	Dissolved	n=36	242	305	354	n=132	193	338	827
Boron	NN	5000	µg/L	Dissolved	n=37	10	100	160	n=129	20	110	500
Calcium	NNS	NNS	mg/L	Dissolved	n=37	479	561	666	n=132	106	214	604
Cadmium	HT and NN	50	µg/L	Dissolved	n=37	3	5	50	n=132	3	5	300
Chloride	NNS	NNS	mg/L	Total	n=37	30	59	77	n=129	3	26	230
Chromium	HT and NN	1000	µg/L	Dissolved	n=37	10	10	90	n=129	5	10	500
Copper	HT and NN	500	µg/L	Dissolved	n=37	10	10	60	n=129	5	10	500
Lead	HT and NN	100	µg/L	Dissolved	n=37	20	20	200	n=129	1	20	400
Magnesium	NNS	NNS	mg/L	Dissolved	n=37	201	242	289	n=132	21	205	1470
Mercury	HT	10	µg/L	Dissolved	n=37	0.1	0.2	0.5	n=132	0.1	0.2	1
Selenium	HT and NN	50	µg/L	Dissolved	n=37	1	1	10	n=132	1	2	10
Sodium	NNS	NNS	mg/L	Dissolved	n=37	260	314	401	n=132	78	165	1570
Sulfate	NNS	NNS	mg/L	Total	n=37	2390	2774	3005	n=132	175	1470	9410
TDS	NNS	NNS	mg/L	Total	n=37	4058	4311	4640	n=132	460	2312	15100
Vanadium	HT and NN	100	µg/L	Dissolved	n=37	5	10	50	n=129	5	10	500
Zinc	HT and NN	25	mg/L	Dissolved	n=37	0.01	0.01	0.12	n=129	0.01	0.01	0.5

NNS - No Numeric Standard
WQS - Water Quality Standard

mg/L - milligrams per liter
µg/L - micrograms per liter

NN - Navajo Nation
HT - Hopi Tribe

CIA - Cumulative Impact Area
T- Total

Table 3. Alluvial water quality sample ranges for upstream locations, Kayenta Mine Complex (1986-2010).

Seasonal water quality was documented using TDS in the alluvial wells to evaluate the water quality variability in the PHC demonstration (PWCC, v.11, ch.18, 2016). Data were grouped into dominant recharge mechanisms based on seasonal recharge characteristics to the alluvium: snowmelt recharge, Wepo recharge, and rainfall recharge. TDS concentrations are typically lower in alluvial wells during rainfall recharge as the infiltrated rain water has a diluting effect on alluvial water quality. When Wepo recharge is dominant during the dry period, Wepo Formation water having typically elevated TDS concentrations is the major recharge source water. The elevated TDS concentrations are reflected in the alluvial monitoring wells. Similarly, elevated TDS concentrations are observed in alluvial monitoring wells during the snowmelt period. Higher TDS concentrations during the snowmelt period in the alluvial wells may be attributed to a combination of the increased residence time for snowmelt to interact with mineral facies, or recharge from the Wepo still acting as the dominant recharge mechanism. Therefore, seasonality of the recharge water adds to the variability in the data, but the water quality variability between monitoring locations is most significant for impact evaluation regardless of recharge mechanism.

Due to the statistical variability in between locations, trend analysis was performed at each location. A time series plot of each parameter of interest was developed and fit with a least squares trend line best fitting the data for trend analysis. The slope of the trend line was determined to have a positive or negative trend, and whether the slope of the trend was statistically different from zero at the 95% confidence interval (PWCC, v.11, ch.18, 2016). The trends identified will be further discussed in the impact evaluation in Chapter 5. However, the trends for the monitoring well furthest upstream of all mining impacts in the sampled drainages will be discussed.

Monitoring well 69 is located in Yellow Water Canyon Wash, and upstream of all mining activities. Negative trends for sulfate, calcium, sodium, and magnesium, and positive trends in bicarbonate and TDS were identified at location 69 based on the period of record; however, no trend has a slope significantly different than zero. Monitoring well 77 is located in Coal Mine Wash, upgradient of all mining activities. Negative trends for sulfate, calcium, sodium, magnesium, and TDS were identified at location 77; however, none of the negative slopes are significantly different than zero. Location 77 does have a positive trend for bicarbonate that is significantly different than zero. Monitoring well 87 is located on Moenkopi Wash upstream of all mining activities and has a negative sulfate trend slope not significantly different than zero, a negative trend for calcium, sodium, magnesium, TDS, and a positive trend slope for bicarbonate. Monitoring location 108R located in Moenkopi Wash upstream of all mining activities has mixed trend slope results for the primary parameters of interest. Sulfate and calcium trends are not significantly different than zero at location 108R. Positive trends for sodium, bicarbonate, and TDS, and a negative trend for magnesium are apparent at location 108R for the period of record. Overall, the upstream background locations typically have a signature of elevated sulfate concentrations, with the exception of the upper reach of Coal Mine Wash, and the upstream water quality is not changing appreciably.

4.2.3 Wepo Formation

The Mesa Verde Group is the uppermost lithology on Black Mesa and includes in the Yale Point Sandstone, Wepo Formation, and Toreva Formation. The Wepo Formation consists of the coal mined at the Kayenta Mine Complex, and the mining operations may intercept local areas of groundwater from the Wepo Formation. This section characterizes the nature of water quantity and quality for the Wepo Formation within Wepo Formation CIA delineated in Section 2.2.1 using information collected at PWCC Wepo sampling locations (Figure 16).

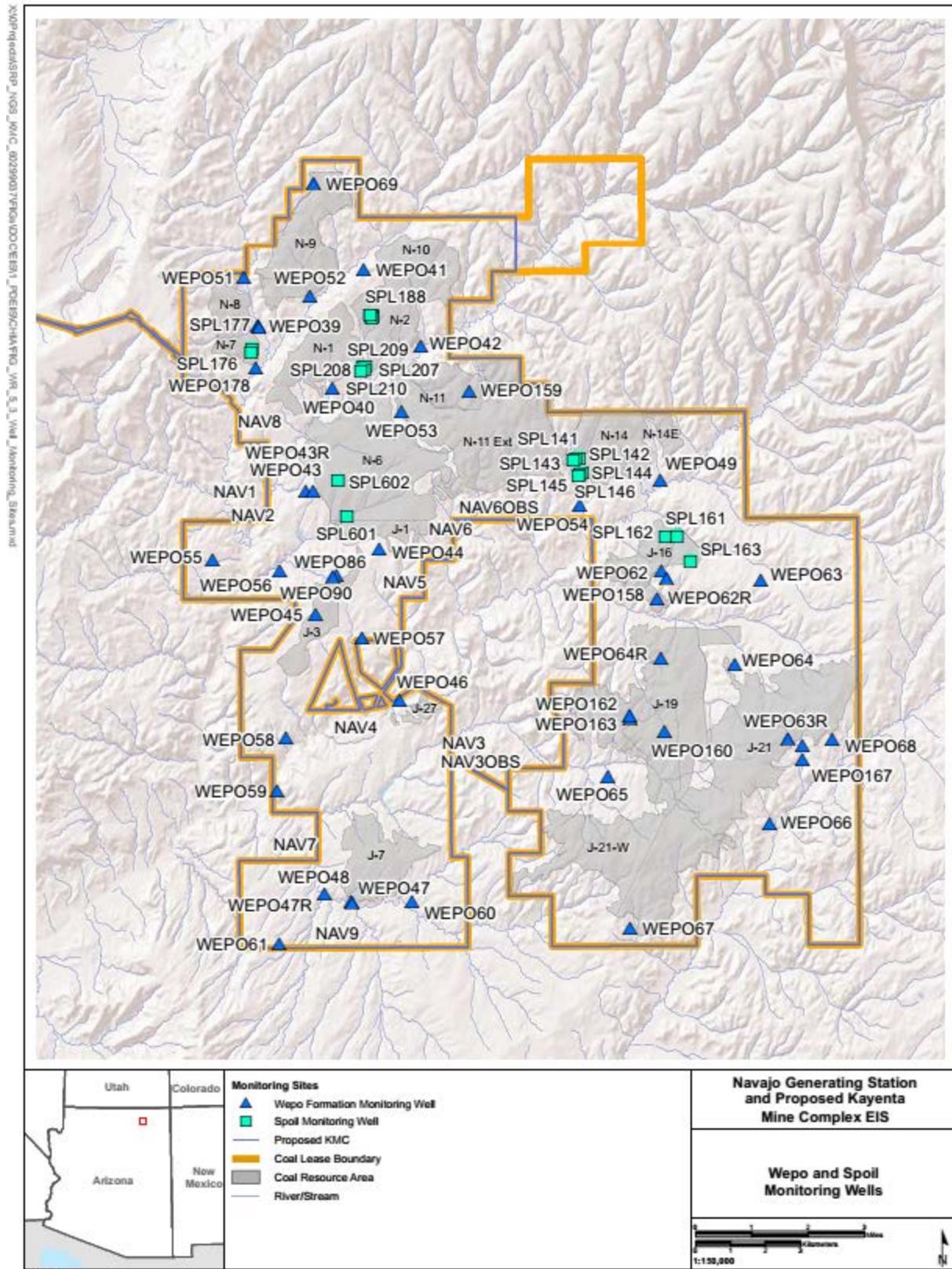


Figure 16: Wepo and Spoil Monitoring Wells, Kayenta Mine Complex (BOR, 2016, Figure WR-5.3)

4.2.3.1 Wepo Formation Baseline Quantity

Wepo Formation monitoring wells were primarily located downgradient of existing and potential surface mine areas. Additional Wepo Formation wells were installed upgradient from mine areas, within reclaimed mine pits, and in areas where mining is not anticipated to occur to provide further characterization of the Wepo aquifer and use potential. Well logs indicate the Wepo Formation is highly heterogeneous throughout the CIA delineated in Section 2.2.1 (Figure 8). The Wepo Formation contains low yielding perched aquifers that pinch out or are vertically displaced by minor structural deformation identified within the Kayenta Mine Complex (PWCC, v.11, ch.18, 2016). Figure 17 illustrates the coal bed sequence in the previously mined N-6 resource area. The coal deposits are typically five to fifteen feet thick and separated by interburden deposits. Some minor geologic structural deformation has been identified in the permit area identified by small stratigraphic offsets in the Wepo Formation.



Figure 17: Wepo Formation in N-6 with minor offset (photos by OSMRE, 5-25-2005).

The primary alluvial drainages (Yellow Water Canyon Wash, Coal Mine Wash, Moenkopi Wash, and Dinnebito Wash) and associated tributaries truncate the Wepo Formation in areas within the CIA. Throughout the permit area, the Wepo Formation receives direct recharge from surface precipitation since it is exposed at the surface (Repenning and Page, 1956). Infiltrated precipitation source water flows towards areas of lower elevation until the water discharges to the surface as surface flow, or the alluvial drainages as baseflow. Therefore, the groundwater flow paths for water in the Wepo Formation are typically oriented towards the primary alluvial drainages and towards the mine pits when Wepo Formation water is intercepted (Figure 8). Since the flow paths are oriented toward the alluvial drainages, the groundwater contours generally mimic the surface topography.

The surface topography is highest to the northeast of the permit area and lowest to the southwest. Since the water level contours generally mimic the surface topography, regional Wepo Formation groundwater flow is toward the southwest and locally toward the alluvial drainages. Therefore, groundwater impact to the Wepo Formation will not extend significantly north of the mined coal resource areas based on groundwater flow direction. The eastern boundary of the CIA is defined by coal resource area J-21 and Dinnebito Wash. Similar to the northern coal resource areas, potential groundwater impacts will not propagate in the opposite direction of the flow path near J-21, which defines part of the eastern CIA boundary. Dinnebito Wash provides a hydrologic boundary to Wepo groundwater impacts. Dinnebito Wash has incised the Wepo Formation, allowing Wepo Formation water to discharge to the wash. The discharged water to Dinnebito Wash is monitored as part of the alluvial monitoring program. The southern CIA boundary crosses two surface water drainages: Moenkopi Wash and Dinnebito Wash. Therefore, some Wepo Formation water discharges to Dinnebito Wash and some discharges to Moenkopi Wash. The southern boundary was delineated to mimic surface topography divides. The western boundary of the CIA was delineated considering Yellow Water Canyon Wash and Coal Mine Wash as hydrologic boundaries. Downcutting of surface water in Yellow Water Canyon Wash and Coal Mine Wash have incised the Wepo Formation and allows discharge of Wepo water to these two washes.

Twenty-two Wepo wells were tested to characterize the water production potential of the Wepo Formation within the CIA. The Wepo Formation transmissivity values in the CIA, which relate the water production potential, vary four orders magnitude; from 0.1 gpd/ft at well 62, to 666 gpd/ft at well 51 (Figure 18). The median transmissivity is 40 gpd/ft, and mean transmissivity 121 gpd/ft.

Where the Wepo Formation is in hydrologic communication with the alluvium, the Wepo may receive recharge from surface water that has infiltrated into the alluvium. When the alluvium is saturated during surface flow events, the hydraulic gradient may temporarily reverse until the surface flow event and water in alluvial bank storage dissipates. Temporary and localized influence of the surface water and alluvial groundwater on the Wepo monitoring system has been observed shortly after surface flow events in several Wepo monitoring wells in close proximity to the alluvium (PWCC, v.9, ch.15, 2016).

4.2.3.2 Wepo Baseline Quality

Table 4 presents water quality summary statistics for parameters with an Agricultural Livestock Watering WQS, and major cations and anions, for the wells screened in the Wepo Formation within the Kayenta Mine Complex. The major cations and anions include TDS, sulfate, magnesium, calcium, bicarbonate, sodium, and chloride. The following Wepo wells are considered background wells due to significant distance from area disturbed by mining: 54, 55, 56, 57, 58, 59, 61, 65, and 67. Additional monitored Wepo wells may also be representative of background conditions based on the water quality results from the monitoring period, but OSMRE has identified the above listed wells as representative of background for this assessment.

The TDS concentrations in the selected background Wepo Formation wells range from 446 mg/L at well 61 to 2,000 mg/L at well 59. The median TDS concentration for all of the background Wepo Formation wells is 779 mg/L. Sulfate concentrations in background Wepo Formation wells range from 2 mg/L at well 55 to 1,200 mg/L at well 59. The median sulfate concentration for all background Wepo wells is 121 mg/L. Magnesium concentrations in background Wepo Formation wells range from 0.3 mg/L to 91 mg/L with a median concentration of 2.1 mg/L. Calcium concentrations in background Wepo Formation wells range from 1 mg/L to 188 mg/L with a median concentration of 9.8 mg/L. Sodium concentrations range from 160 mg/L to 744 mg/L with a median concentration of 270 mg/L. Chloride concentrations range from 3 mg/L to 48 mg/L in background Wepo Formation wells with a median concentration of 11 mg/L.

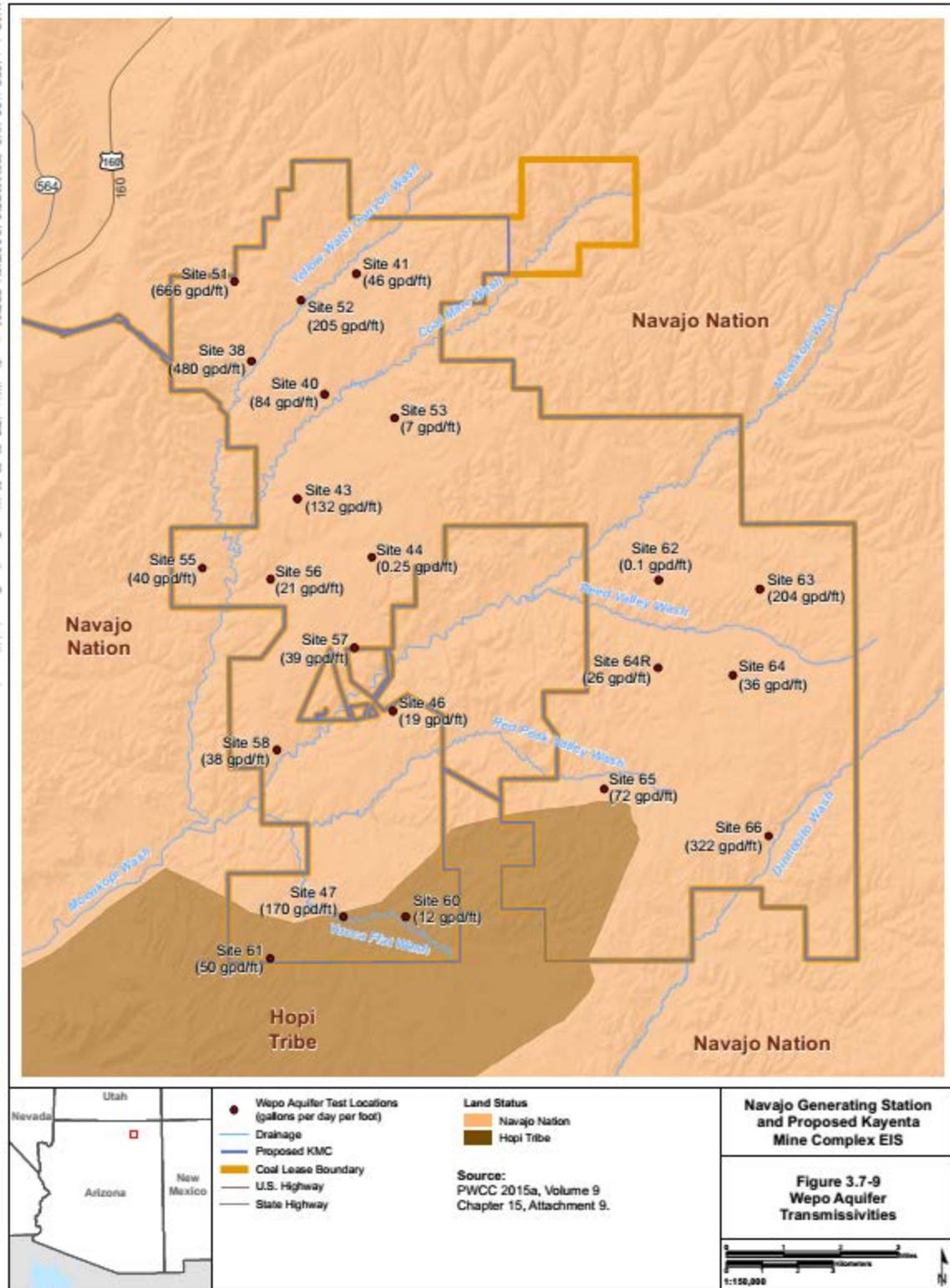


Figure 18: Wepo Aquifer Transmissivities, Kayenta Mine Complex (BOR, 2016, Figure 3.7-9).

Chemical Parameter	Agricultural Livestock Watering WQS	WQS	Units	Type	Background Wepo Wells			
					Locations 47, 55, 56, 57, 59, 61, 65, 67			
					# Samples	Low	Median	High
Aluminum	HT	5	mg/L	Dissolved	n=212	0.03	0.05	1.69
Arsenic	HT and NN	200	µg/L	Dissolved	n=212	0.1	1	20
Bicarbonate	NNS	NNS	mg/L	Dissolved	n=212	200	434	2228
Boron	NN	5000	µg/L	Dissolved	n=212	20	200	1200
Calcium	NNS	NNS	mg/L	Dissolved	n=212	1	9.8	188
Cadmium	HT and NN	50	µg/L	Dissolved	n=212	3	5	20
Chloride	NNS	NNS	mg/L	Total	n=212	3	11	48
Chromium	HT and NN	1000	µg/L	Dissolved	n=212	5	10	30
Copper	HT and NN	500	µg/L	Dissolved	n=212	5	10	50
Lead	HT and NN	100	µg/L	Dissolved	n=212	1	40	200
Magnesium	NNS	NNS	mg/L	Dissolved	n=212	0.3	2.1	91
Mercury	HT	10	µg/L	Dissolved	n=212	0.1	0.2	1
Selenium	HT and NN	50	µg/L	Dissolved	n=212	1	1	11
Sodium	NNS	NNS	mg/L	Dissolved	n=212	160	270	744
Sulfate	NNS	NNS	mg/L	Total	n=212	2	121	1200
TDS	NNS	NNS	mg/L	Total	n=369	446	779	2000
Vanadium	HT and NN	100	µg/L	Dissolved	n=212	5	5	500
Zinc	HT and NN	25	mg/L	Dissolved	n=212	0.005	0.01	0.08

NNS - No Numeric Standard
WQS - Water Quality Standard
CIA - Cumulative Impact Area

mg/L - milligrams per liter
µg/L - micrograms per liter
T- Total

NN - Navajo Nation
HT - Hopi Tribe

Table 4. Wepo Formation water quality sample ranges for background locations, Kayenta Mine Complex (1986-2010).

4.2.4 D Aquifer

The D aquifer is regionally extensive throughout the Black Mesa area (Figure 19), and limited water is currently withdrawn from the D aquifer system by communities and windmills. Historically, the PWCC wellfield withdrew limited D aquifer water from PWCC NAV wells with screened portions of D aquifer. However, from 2014 - 2016 wells with screened interval into the D aquifer were either cased off or properly abandoned after Tribal approval. Currently, no PWCC pumping wells are open to the D aquifer.

The D aquifer is composed, in order of oldest to youngest, of the Entrada Sandstone of the Summerville Formation, the Cow Springs Sandstone, the sandstone members of the Morrison Formation and the Dakota Sandstone. The Entrada Sandstone consists of three members, represented by two facies: a clean sandstone facies in the upper and lower members, and a silty facies in the middle member. The Summerville Formation is comprised of an upper sandy facies and a lower silty facies. The thickness of the Summerville Formation is variable where tongues of the Cow Springs Sandstone constitute part of the formation. The Cow Springs sandstone deposits are extensive, ranging from 230 feet to 449 feet in the southwest portion of the CIA. The tongues of the Cow Springs sandstone also intertongue extensively with members of the Morrison Formation. In the northeast part of the CIA, the Cow Springs sandstone is hydraulically connected with the Recapture and Salt Wash Members of the Morrison Formation. In the southwestern CIA area, the Cow Springs is hydraulically connected to the Entrada Sandstone and Dakota Formation, as the Morrison is absent in this area. The Dakota sandstone ranges in thickness from 40 feet to 150 feet, regionally thinning to the south and southwest on Black Mesa. Additional detail of the D aquifer lithology can be found in the documentation for the regional three-dimensional numerical model of the Black Mesa Basin (3D Model) (PWCC, 1999).

The D aquifer system is a complex hydraulic interconnection of several formations and members. However, an evaluation of D aquifer water level and water chemistry data indicates that the Mancos shale confining unit above, and the Carmel Formation below, allows these interconnected formations to behave as a regional aquifer system.

4.2.4.1 D aquifer Baseline Quantity

Water quantity for the D aquifer system is based on the hydraulic properties of the formations comprising the system. Hydraulic properties of horizontal and vertical hydraulic conductivity, saturated thickness, flow gradients, and aquifer storage of the D aquifer formations assist in the evaluation of water quantity. Stetson (1966) installed a test well in the permit area as part of a wellfield development feasibility study for the Kayenta Mine Complex. Isolating and stressing the saturated 1,050 feet of Entrada, Morrison, and Dakota Formations comprising the D aquifer system at this location for 700 minutes, at a rate of 23 gallons per minute, produced 59 feet of drawdown in the pumping well (Stetson, 1966). Using the Theis recovery test for hydraulic property analysis, a transmissivity of 440 gallons/day/foot (hydraulic conductivity of 0.056 ft/day) was calculated based on the natural rate of recovery (Stetson, 1966).

Similar horizontal conductivity values as Stetson (1966) were developed for formations comprising the D aquifer system through steady state calibration of the 3D Model (PWCC, 1999). Steady state calibration involves adjusting hydraulic conductivity and storage values until model simulated D aquifer water levels generally agree with regional measured water level elevations in D aquifer wells prior to significant pumping. For the 3D Model, steady state conditions occurred prior to 1956; however, hydraulic head measurements up through the end of 1969 were included as calibration targets for equilibrium conditions to increase the areal coverage due to the limited measurements made prior to 1956. Community pumping effects were localized at Kayenta, Kykotsmovi, Rocky Ridge, and Rough Rock prior to 1969, and significant pumping at the PWCC wellfield did not begin until 1970 (Macy and Unema, 2014); therefore, the inclusion of hydraulic head water levels from 1956-1969 for equilibrium conditions is appropriate.

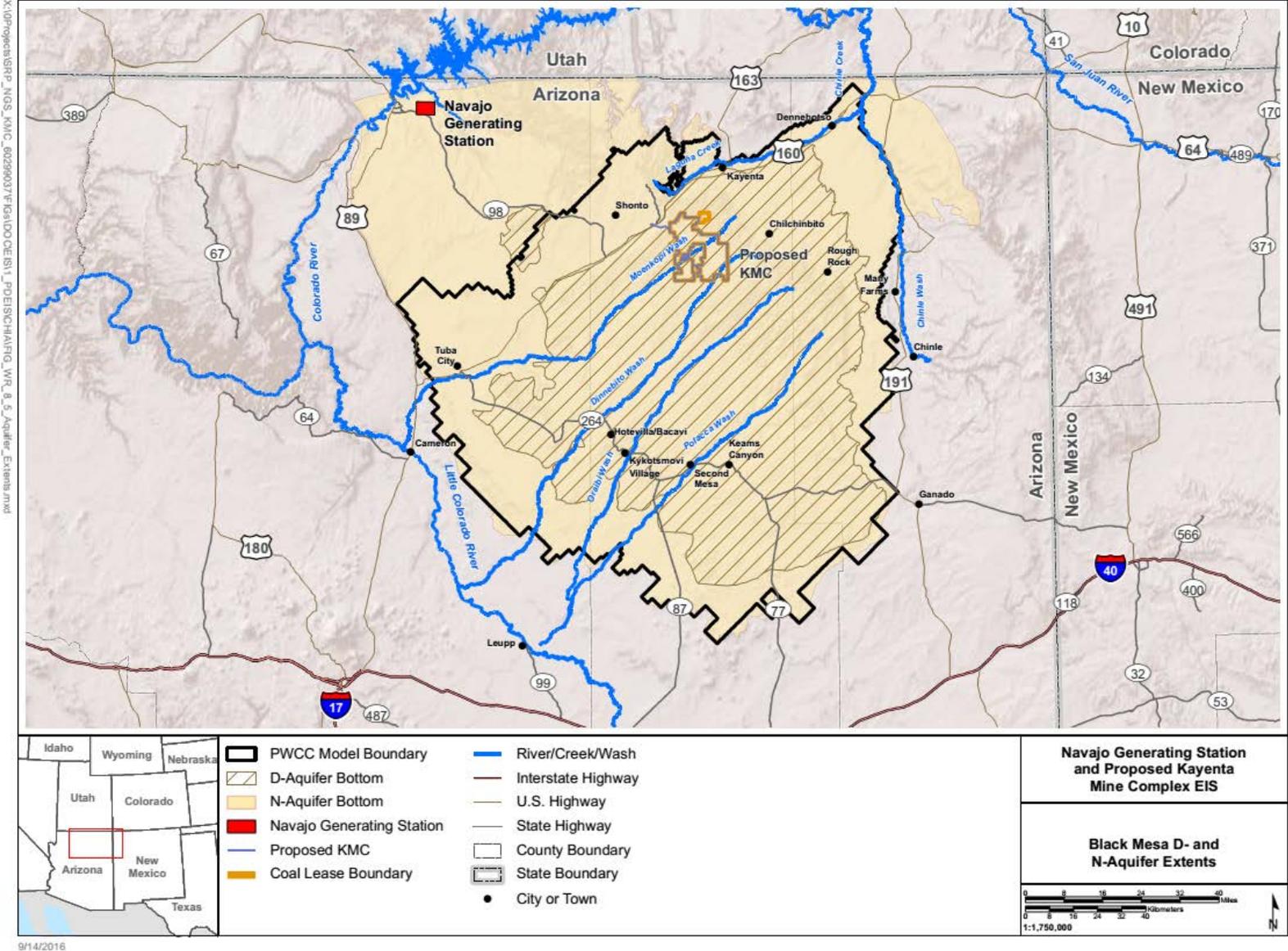


Figure 19: Black Mesa D and N Aquifer Extents (BOR, 2016, Figure WR-8.5).

After review of well log information, water level measurements, water chemistry, geologic structure information, and spring elevations, water level data from wells and springs were used as D aquifer steady state calibration targets for the 3D Model pre-pumping simulation (Figure 20). The resultant steady state potentiometric surface map for the D aquifer is illustrated as Figure 21. The D aquifer system is recharged from direct precipitation on ephemeral streams in areas where D aquifer formations are exposed at the surface or covered by permeable veneer of unconsolidated sediments. Steady state (pre-significant pumping) D aquifer flow occurred from the recharge area in the southeast and east predominantly toward the west and southwest and through the center of the basin. Steady state D aquifer discharge occurred northeast to Laguna Creek and along downcut washes intercepting the D aquifer formations near the southern Hopi communities.

4.2.4.2 Dakota Aquifer Baseline Quality

As water recharging the D aquifer flows toward the discharge areas, water-rock reactions dissolve formation constituents changing the groundwater chemistry along the flow path. Thin section analysis of rocks comprising the D aquifer reveal the persistence of alkali and plagioclase feldspars, clays, iron oxides, chert, and calcium-carbonate cement (GeoTrans Inc., 1993). The dissolution of feldspar contributes calcium, sodium, potassium, aluminum, and silicon into solution along the flow path. Then, the exchange of calcium and sodium ions in the clays and lignite found in the Dakota Sandstone contribute to the formation of sodium bicarbonate type water along the flow path (Truini and Longworth, 2003). Additionally, the dissolution of sulfate from gypsum and lignite stringers contributes to increases in sulfate along the D aquifer flow paths. The overall quality of the D aquifer tends to have higher dissolved concentrations of boron, chloride, sodium, and sulfate compared to N aquifer water, resulting in elevated TDS concentrations (Truini and Longworth, 2003). Elevated ion concentrations and TDS often limit the use and development of the D aquifer in the region.

Groundwater will flow from areas of high potential energy to areas of lower potential energy, and follow the path of least resistance. Since the D aquifer is confined above by the Mancos Shale, and below by the Carmel Formation having a low hydraulic conductivity compared to the formations comprising the D aquifer, flow is generally horizontal from east to west along the D aquifer flow paths. However, measured water levels defining the D aquifer potentiometric surface are typically higher than measured water levels of the underlying N aquifer potentiometric surface in the area of the confined D aquifer. Figure 22 illustrates the hydraulic head differences between the D and N aquifers. Therefore, a vertical flow potential exists for poorer quality D aquifer water to flow through the Carmel Formation to the underlying N aquifer.

The baseline vertical flow potential from the D aquifer to the N aquifer was investigated by the USGS using geochemical and isotopic analysis (Truini and Longworth, 2003). The findings indicate that vertical flow leakage from the D aquifer to the N aquifer has been occurring for thousands of years, and has a higher likelihood of occurring in the southern part of Black Mesa (Truini and Longworth, 2003). Truini and Macy (2006) related the thickness and lithology of the Carmel Formation to groundwater leakage in the southern part of Black Mesa using borehole-geophysical data and lithologic descriptions from drill logs. Figure 23 illustrates the approximate area where groundwater leakage likely occurs.

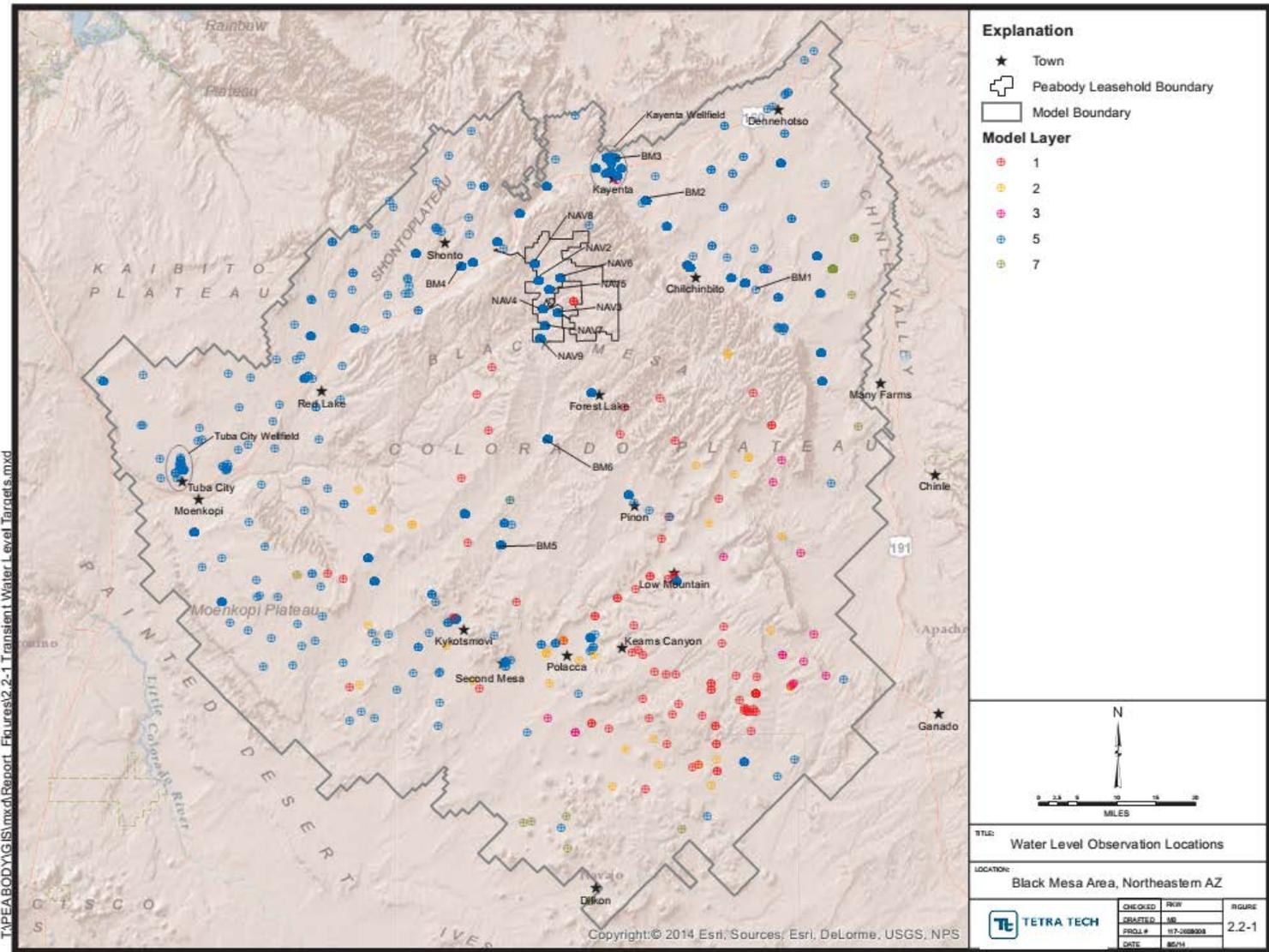


Figure 20: D aquifer (Layer 3) and N aquifer (Layer 5) Steady State Target Water Level Locations, Black Mesa, Arizona (PWCC, 2016).

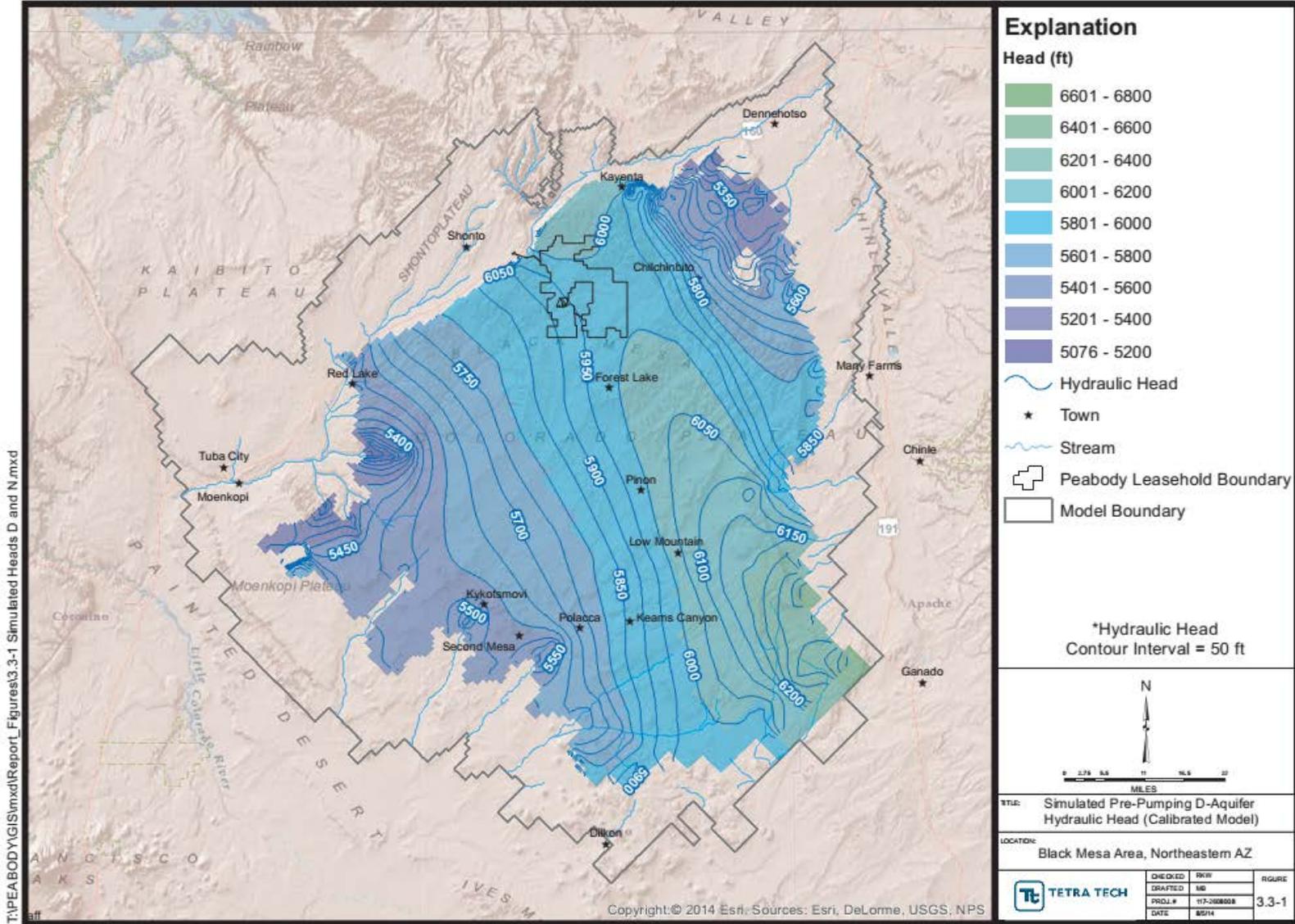


Figure 21: D aquifer Steady State Potentiometric Surface, Black Mesa, Arizona (PWCC, 2016).

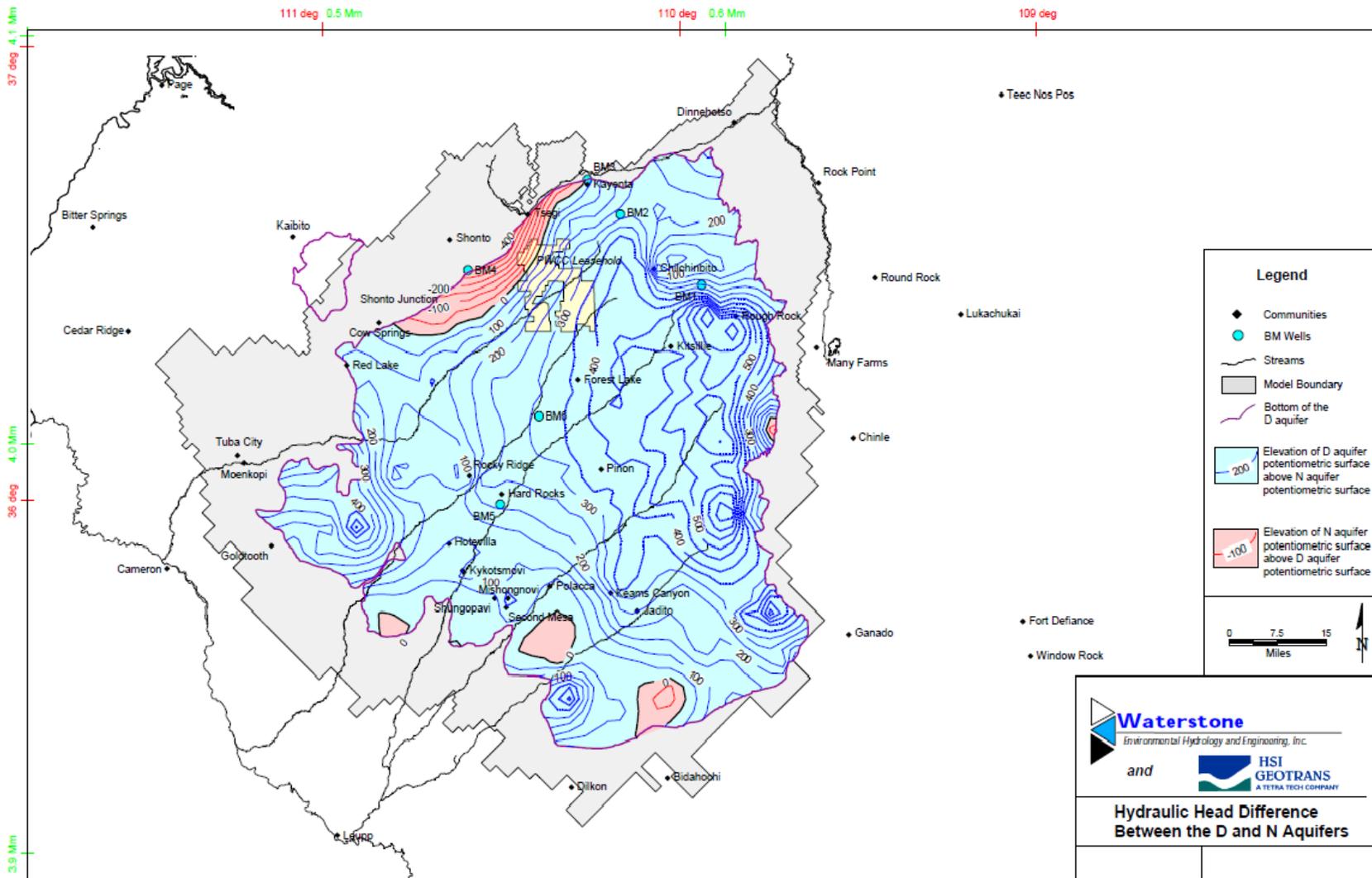


Figure 22: Hydraulic Head Difference Between the D and N Aquifers, Black Mesa, Arizona (PWCC, 1999).

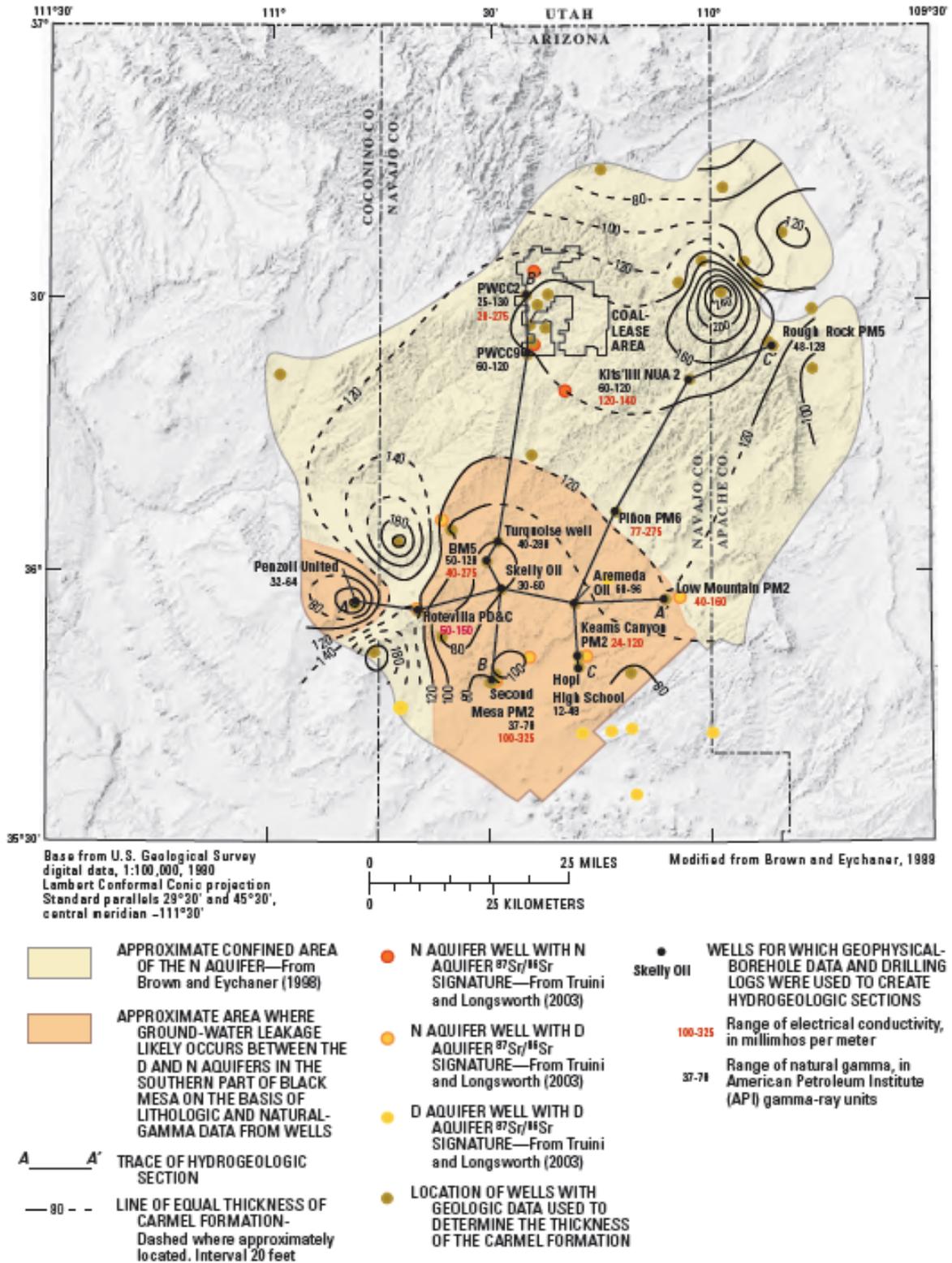


Figure 23: Approximate area where groundwater leakage likely occurs between the D and N aquifers in the southern part of Black Mesa (Truini and Macy, 2006).

4.2.5 N Aquifer

The N aquifer is known for its well sorted massive sandstone matrix, high water production potential, and drinking quality water. The N aquifer is comprised of (in ascending stratigraphic order) the Wingate Sandstone, Moenave Formation, Kayenta Formation, and the Navajo Sandstone. The combination of these hydrologically connected formations range in thickness from less than 100 feet around the perimeter of Black Mesa to approximately 1700 feet in the center of the Black Mesa Basin. In the center of the groundwater CIA, the stratigraphy of the N aquifer dips steeply into a synclinal basin, facilitating confined aquifer conditions (Figure 24). The N aquifer is separated from the C aquifer below by the low permeability Chinle Formation and is effectively confined from the D aquifer above by the Carmel Formation over much of the Black Mesa area (Figure 23). The Carmel Formation is discontinuous in some areas, and leakage between the D and N aquifers likely occurs in these discontinuous areas via vertically oriented fractures (PWCC, 1999).

4.2.5.1 N Aquifer Baseline Quantity

N aquifer is recharged by rainfall infiltrating on exposed formations of the N aquifer system around the perimeter of Black Mesa (Figure 25), and leakage from the overlying D aquifer. Before extensive pumping of the N aquifer, the hydrologic system was approximately in equilibrium, or steady state. A system is in equilibrium when the inflow equals the outflow, and aquifer storage remains constant. Prior to significant pumping in 1970, aquifer storage was essentially constant; therefore, the volume of water infiltrating into the N aquifer system as recharge equaled the volume discharged as springs and baseflow into washes.

After review of well log information, water level measurements, water chemistry, geologic structure information (Figure 26), and spring elevations (Figure 26), water level data spring locations were used as N aquifer steady state calibration targets for the 3D Model pre-pumping simulation (Figure 20). The resultant steady state potentiometric surface map for the N aquifer is illustrated as Figure 27. N aquifer recharge occurs in areas to the north and northwest near Tsegi and Shonto on exposed outcrop areas east of Black Mesa. N aquifer flow during steady state conditions was predominantly towards the southwest and northeast from a ground water divide through the center of the basin; discharging to Laguna Creek to the northwest and along downcut washes intercepting the N aquifer formations to the southwest.

4.2.5.2 N Aquifer Baseline Quality

Since 1971, the USGS has worked in partnership with PWCC, BIA, and the Hopi Tribe and Navajo Nation to perform monitoring of wells, springs, and stream flows outside the permit area. The primary N aquifer water types are calcium bicarbonate and sodium bicarbonate. Calcium bicarbonate water is generally found in the recharge areas of the N aquifer, and sodium bicarbonate water in the confined area of the N aquifer. Figure 28 illustrates the N aquifer water type collected annually by the USGS as part of the ongoing regional monitoring program (Macy and Unema, 2014). The N aquifer water quality for USGS monitored wells typically meet water quality standards for domestic water supply, except for locations on the eastern edge of the mesa where TDS and sodium concentrations are elevated.

The USGS evaluated the geochemistry of Black Mesa using geochemical and isotopic analysis (Truini and Longworth, 2003). The USGS evaluation identifies that downward leakage is most likely to occur in the southern part of Black Mesa based on the geologic and hydrologic environment in that area (Truini and Longworth, 2003). In the northern part of Black Mesa, isotopic analysis revealed significant statistical differences between the D aquifer and N aquifer water (Truini and Longworth, 2003). The statistical difference in the northern area suggests that the leakage potential under natural pre-pumping conditions was not as great compared to the southern area.

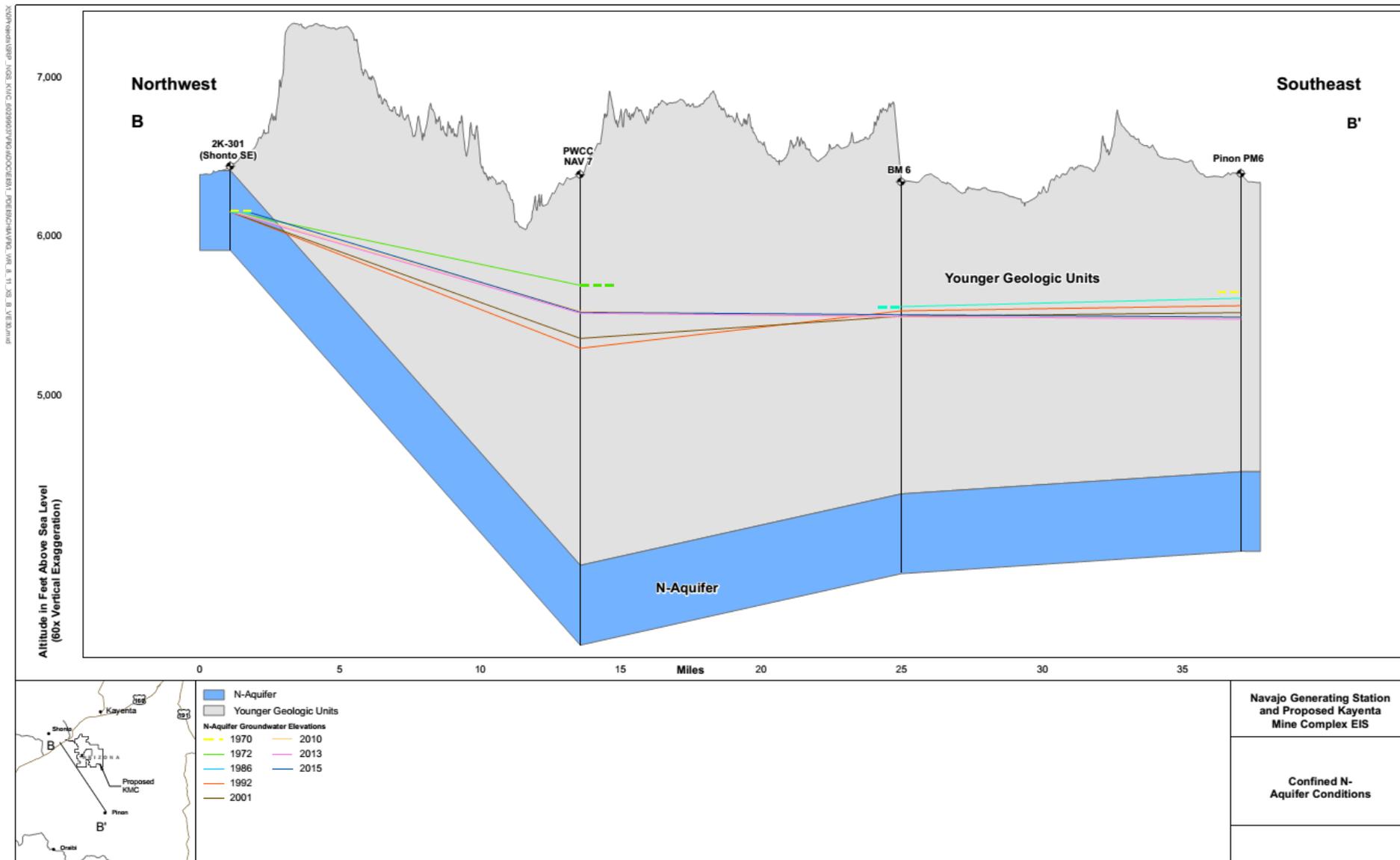
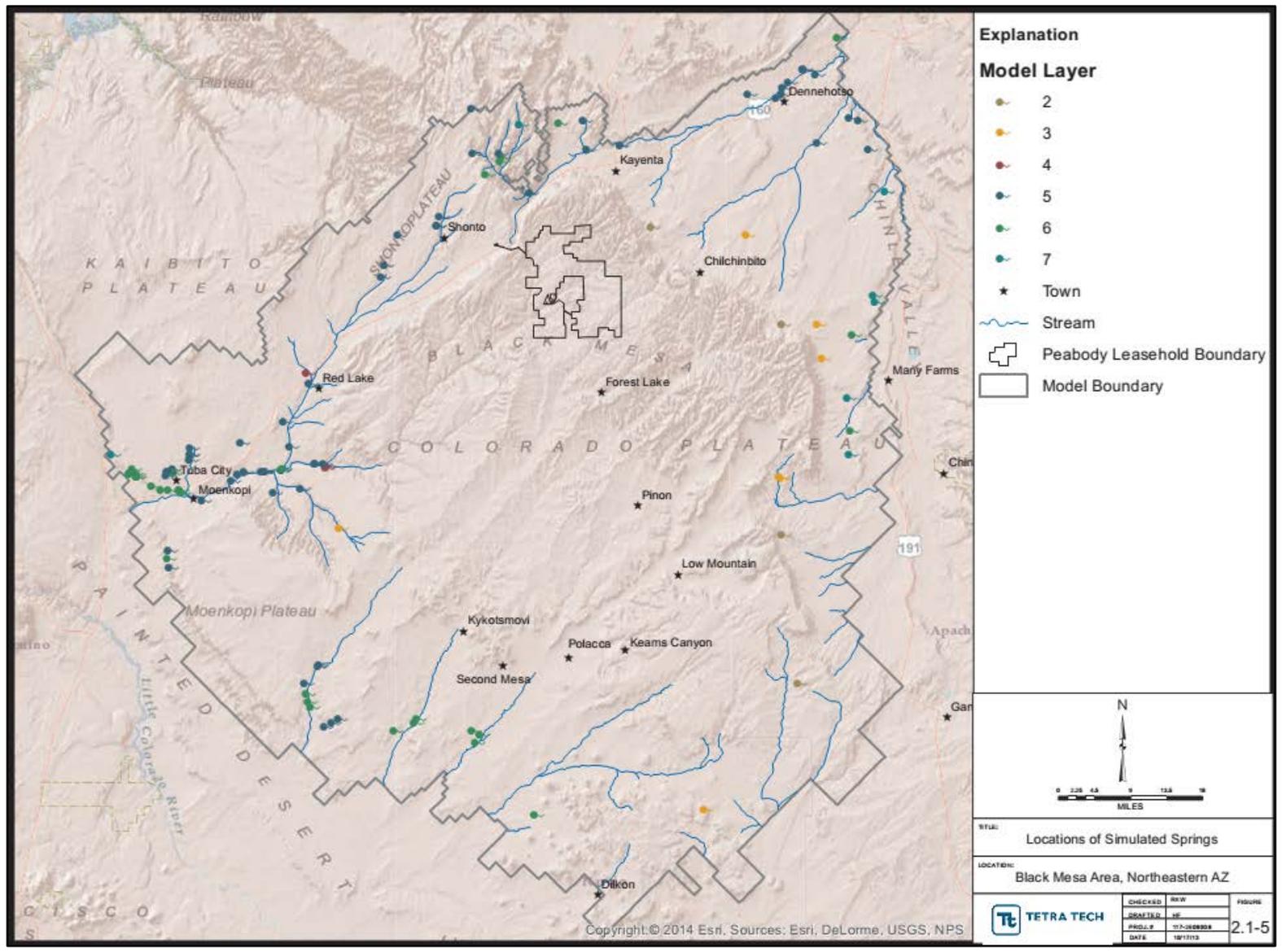


Figure 24: Confined N Aquifer Conditions, Black Mesa, Arizona (BOR, 2016, Figure WR-8.11).



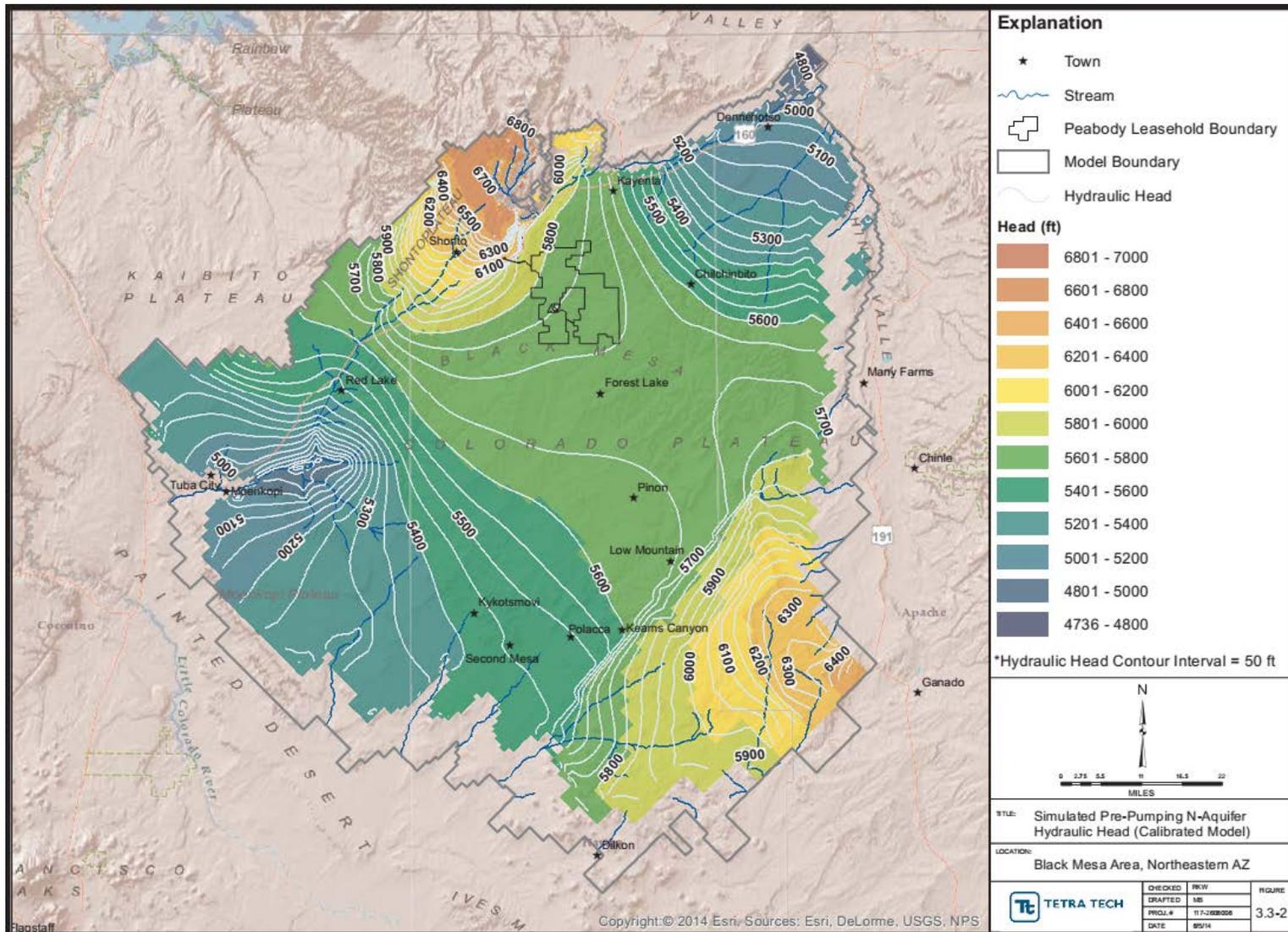


Figure 27: N aquifer Steady State Potentiometric Surface, Black Mesa, Arizona (PWCC, v.11. ch.18, 2016).

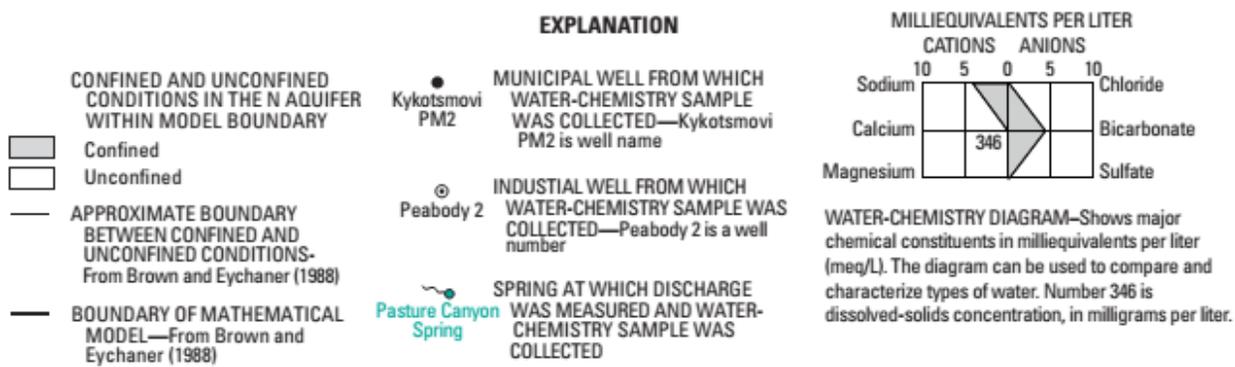
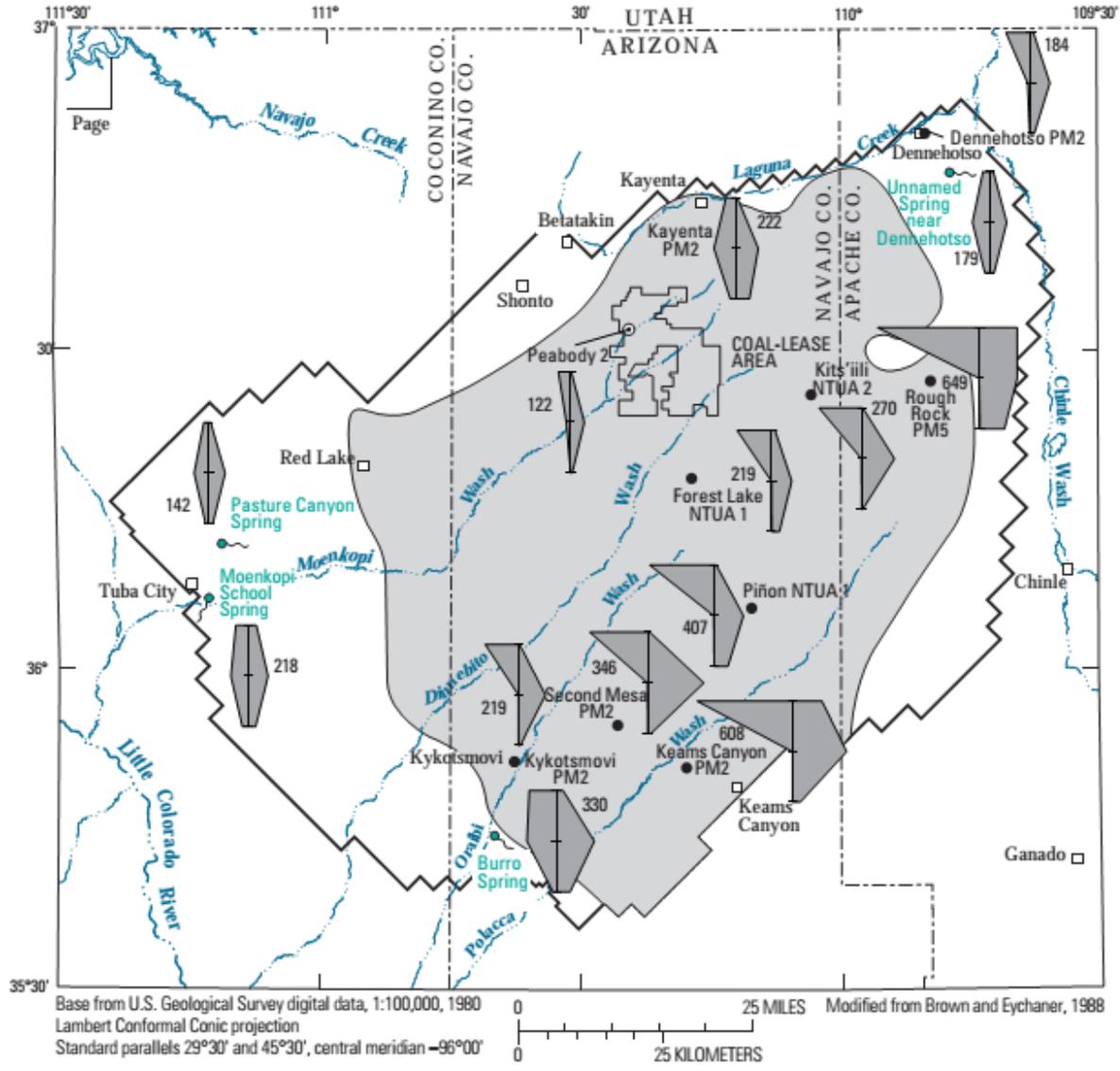


Figure 28: N aquifer Water Quality Type, 2012 Results (Macy and Unema, 2014).

In 2006, the USGS applied the results of the geochemical and isotope analysis to a study that evaluated the Carmel Formation, which confines the N aquifer and separates the overlying poorer quality D aquifer water from the better quality N aquifer. The results indicate that thickness and lithology of the Carmel Formation are factors influencing groundwater leakage between the D aquifer and N aquifer. Areas where the Carmel Formation is 120 feet thick or less coincide with areas where $^{87}\text{Sr}/^{86}\text{Sr}$ isotope analysis indicate that overlying D aquifer water has historically mixed with underlying N aquifer water under natural conditions (Truini and Macy, 2006). In the vicinity of the PWCC wellfield, the Carmel Formation has a thickness greater than 120 feet.

5 HYDROLOGIC IMPACT ASSESSMENTS

Required by 30 CFR 780.21(g), as the regulatory authority, OSMRE shall provide an assessment of the probable cumulative hydrologic impacts of the mining operation upon surface water and groundwater systems in the cumulative impact area. After assessing the PHC presented in the PAP for the operation, and considering cumulative hydrologic impacts from all mining operations and other available information, OSMRE shall make a determination of whether or not the mining operation has been designed to minimize disturbances to the hydrologic balance within the permit and adjacent areas, and to prevent material damage to the hydrologic balance outside the permit area.

The assessment presented in Chapter 5 of this document considers available quantity and quality information related to surface water and groundwater potentially affected by the Kayenta Mine Complex operation. The assessment will determine if the potential exists for the operation to create material damage to the hydrologic balance outside the permit area. If the potential exists for material damage to the hydrologic balance outside the permit area, then OSMRE will establish material damage criteria for the resource.

5.1 Surface Water

OSMRE evaluated surface water quantity and quality related to the overall hydrologic balance and potential impact of the Kayenta Mine Complex on stream uses. OSMRE also evaluated that the monitoring program has been appropriately designed to provide the surface water quantity and quality information necessary to assess potential impacts per 30 CFR 780.21(g). Potential offsite surface water quality impacts are related to WQS for irrigation, livestock, aquatic and wildlife habitat, fish consumption, and secondary human contact.

5.1.1 Surface Water Monitoring Program

Above-mining and below-mining locations were selected on the primary washes transecting the Kayenta Mine Complex (Yellow Water Canyon Wash, Coal Mine Wash, Moenkopi Wash, Dinnebito Wash) in order to identify above-mining and below-mining relationships. Additionally, major tributaries to Moenkopi Wash within the Moenkopi Wash CIA (Reed Valley Wash, Red Peak Valley Wash, and Yucca Flat Wash) were monitored to evaluate potential contributing impacts to Moenkopi Wash. The primary washes, Moenkopi tributaries within the permit area, and corresponding monitoring locations are displayed on Figure 11.

A variety of monitoring techniques and instrumentation were utilized to characterize the surface water hydrologic regime. Surface water quantity monitoring techniques included the use of current meters, slope-area methodology, pulse generators coupled with stilling wells and data loggers, crest-stage gages, portable cutthroat flumes, and visual estimates when flow conditions precluded the use of other measuring devices (PWCC, v.11, ch.16, 2016).

PWCC may request modification to the surface water monitoring program after baseline is defined, surface water and groundwater interaction is characterized, and the magnitude of seasonal or natural variability is documented. When the magnitude and extent of potential impacts exceed hydrologic consequence projections identified in the PHC, the data collection frequency or geographic monitoring locations may need to be expanded. Conversely, when the monitoring program has sufficiently established background conditions and natural or seasonal variability, the frequency and data collection localities may be relaxed. As such, OSMRE approved the reduction of all above-mining and tributary

surface water monitoring locations in July of 2001 and July of 2002 since the provided data adequately fulfilled the monitoring objectives. Therefore, above-mining and tributary surface water monitoring locations 14, 16, 18, 35, 37, 50, 78, 85, and 157 were removed from the active monitoring program. PWCC continues to collect surface water quantity information at locations 15, 25, 26, 155, and 34.

Based on the surface water quantity monitoring information collected before the approved monitoring reduction, coupled with the continued monitoring at locations 15, 25, 26, 34, and 155, OSMRE finds that the surface water quantity program is currently sufficient for OSMRE to make the required evaluation for material damage potential in this CHIA. Continued surface water quantity monitoring at locations 15, 25, 26, 34, and 155 is necessary to reinforce hydrologic impact conclusions presented in the PHC of the permit application, and assess potential material damage impact.

5.1.2 Surface Water Quantity

Information from the monitoring locations determined multiple peak hydrographs are a characteristic of the area hydrology. PWCC calculated an average annual runoff of 0.15-inches in the Moenkopi CIA (PWCC, v.11, ch.18, 2016). Applying the runoff factor to the area of the Moenkopi CIA yields an estimated average annual baseline runoff of 1,972 ac-ft, and 402 ac-ft for the Dinnebito CIA. Baseline runoff was determined using measured flow data from undisturbed area, and applying the runoff factor to the entire assessment area. Average annual measured surface flow in the Moenkopi CIA from 1987-2008 was 1488 ac-ft. During the 2005 – 2009 monitoring period, discharges reported for NPDES permit #NN0022179 averaged 21.28 ac-ft from surface water impoundments.

5.1.2.1 Impact Potential to Existing and Foreseeable Uses

SMCRA requires that all surface mining and reclamation activities be conducted to minimize disturbance of the hydrologic balance within the permit and adjacent areas, and prevent material damage to the hydrologic balance outside the permit area. In order to protect the surface water hydrologic balance, and following 30 CFR 816.41(d)(1), PWCC shall prevent additional contribution of suspended solids to stream flow outside the permit area to the extent possible using the best technology currently available. Therefore, PWCC constructs surface water impoundment structures adjacent to areas disturbed by mining to capture suspended solids transported during runoff events. Nine Mine Safety and Health Administration (MSHA) sized structures have been constructed on tributaries confluent to Moenkopi Wash, and the PHC predicts that portions of the stream channel above and below the structures will be affected (PWCC, v.11, ch.18, 2016). “The reach immediately above a dam will gradually aggrade headward as more and more water is impounded until a pool level is reached that is in equilibrium with water gains and losses. Channel reaches below the dams will become incised by smaller active meandering channels whose widths are a function of drastically reduced runoff potential, channel gradients and sediment load particle size ranges” (PWCC, v.11, ch.18, 2016). “It is estimated that more than 320 sediment ponds and several permanent internal impoundments have been or will be constructed during the life of the mining operation” (PWCC, v.11, ch.18, 2016). The construction of sediment control structures, and the coordinated removal of temporary structures, assists in minimizing mining impacts. However, the construction of surface water impoundments potentially reduces surface water quantity outside the Moenkopi CIA and Dinnebito CIA during runoff events compared to baseline conditions when only a few local impoundments existed.

Figures 29 and 30 illustrate the total annual acreage potentially generating runoff to impoundments in the Moenkopi and Dinnebito CIAs (PWCC, v.22, drawing 85406, 2016). The annual acreage generating runoff to impoundments may vary from year to year based on mining and reclamation schedules. The contributing acreage to impoundments reaches a maximum of 47,321 acres for the Moenkopi CIA in

2021, and 3,651 acres for the Dinnebito CIA in 2011. The graphs are scaled to the size of the Dinnebito CIA (33,087 acres) and Moenkopi CIA

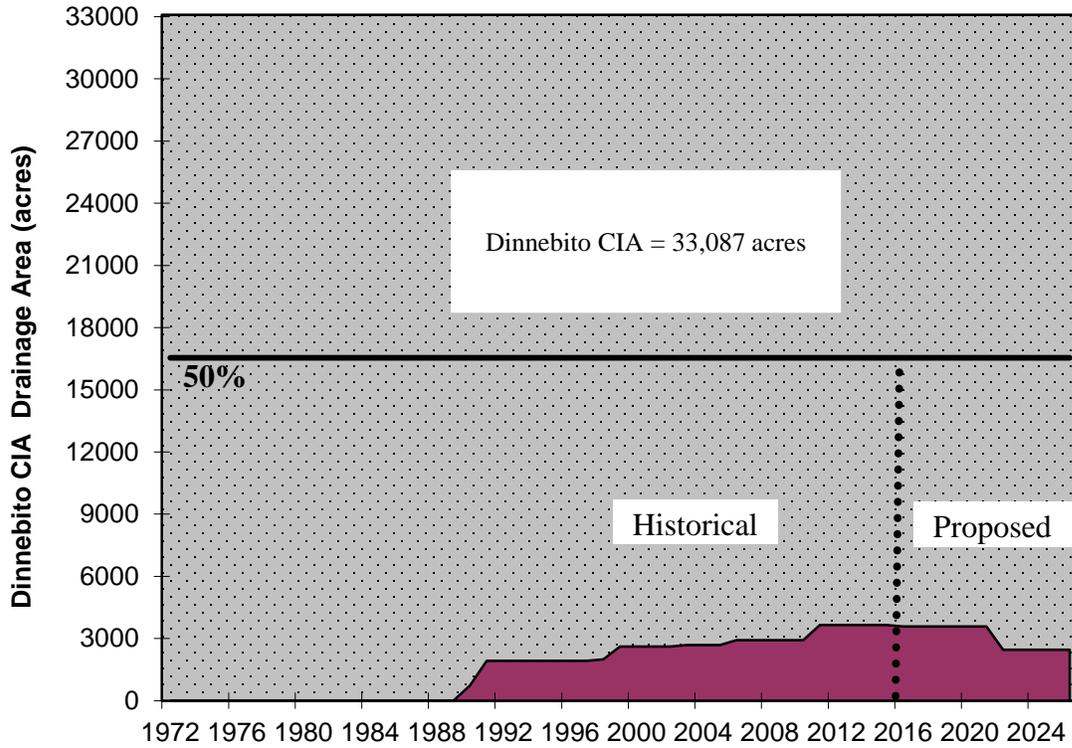


Figure 29: Dinnebito CIA Acres Managed with Impoundments, Kayenta Mine Complex.

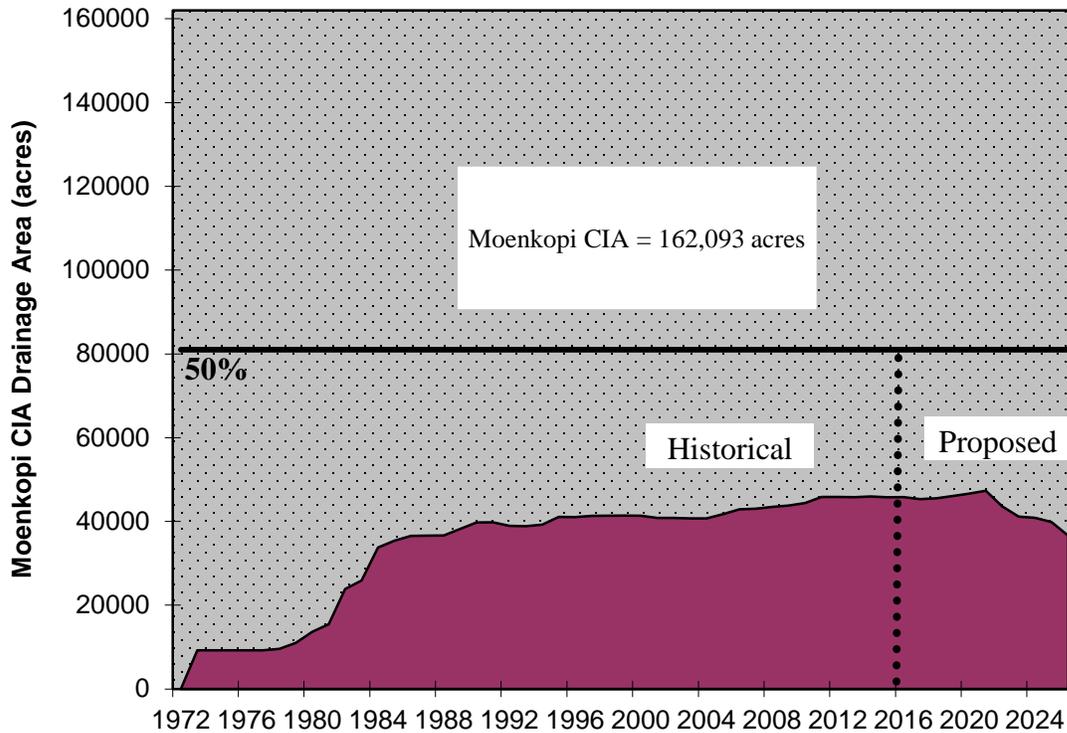


Figure 30: Moenkopi CIA Acres Managed with Impoundments, Kayenta Mine Complex.

(162,093 acres). OSMRE must assess if the surface water quantities potentially generated from these maximum contributing acreages, and retained by impoundments, will impact the downstream irrigation, livestock, or aquatic and wildlife habitat water uses. The PHC concludes “Using the annual average runoff of 0.15 inches determined through 22 years of stream flow measurements collected at the three PWCC gages, the permanent impoundments may impound about 1.0 and 4.7 percent of the average annual runoff at the lower ends of the Dinnebito and Moenkopi basins, respectively” (PWCC, v.11, ch.18, 2016).

Surface water for irrigation use was attempted in the Dinnebito (HUC 15020017) near the community of Rocky Ridge; however, conditions limited the retention and use of surface water along Dinnebito Wash for agricultural water use. Variability in annual surface flow rates ranging three orders of magnitude, coupled with high sediment transport rates during flash flood events, likely limit the effectiveness of impoundments for agricultural use on Dinnebito Wash. However, the community of Moenkopi, approximately 70 miles downstream from the Kayenta Mine Complex along Moenkopi Wash, may use water in the alluvial channel for agricultural irrigation. Farmers in the Moenkopi Village area may dig pits in Moenkopi Wash to reach the saturated alluvium, pumping the saturated alluvium for irrigation water when necessary and available (OSMRE, 2016). Watering of livestock may occur along Moenkopi Wash and Dinnebito Wash at channel pools. However, the location, duration, extent, and quality of the resultant surface water pools the left behind downstream of the Kayenta Mine Complex are unknown.

Moenkopi and Dinnebito washes commonly experience flash flood events. The flash flood events scour the channel bottom, alter and extend the channel banks, and are capable of uprooting tamarisk populations with deep tap roots (OSMRE, 2009). The hydrologic environment of the ephemeral, sand-bed channels along Moenkopi and Dinnebito washes provides limited conditions for the sustainability of aquatic habitat. However, aquatic habitat has the potential for sustainability in a less aggressive environment

such as near seeps, springs, and surface water bodies. Therefore, it is likely that the retention of surface water runoff in impoundments within the Kayenta Mine Complex enhances the potential for successful establishment of aquatic and wildlife species within the permit area, and not create material damage outside the permit area.

The alluvium near the community of Moenkopi supports agricultural irrigation use and is recharged by three mechanisms: direct precipitation, infiltration of surface water runoff to the alluvium, and groundwater discharge to the alluvium. Infiltration from direct precipitation provides the smallest recharge of the three mechanisms since the annual average precipitation is 5.96-inches at Tuba City, adjacent to the community of Moenkopi (PWCC, 1999). Alluvial recharge from surface water runoff infiltration has greater effect based on a flow model simulated release of 644 ac-ft to Moenkopi Wash from the permit area (PWCC, v.11, ch.18, 2016). The results indicate the entire 644 ac-ft volume infiltrated to the alluvium between the permit area and 45 miles downstream (approximately 25 miles upstream of the Village of Moenkopi), or an infiltration rate of 14.5 ac-ft per mile (PWCC, v.11, ch.18, 2016). Essentially,

Short-term, rapid advance of the streamflow front over the initially dry alluvium occurs until the wetted channel is large enough to allow total infiltration to equal the release rate. Flow over the dry bed is influenced by [the ability of the material to adsorb] which initially pulls water into the dry soil at a higher infiltration rate than occurs under higher saturation conditions. As the materials become more saturated, the infiltration rate decreases, allowing the front to move further downstream. (GeoTrans, 1992).

A third recharge mechanism occurs on Moenkopi Wash approximately 40 miles downstream of the Kayenta Mine Complex, and approximately 30 miles upstream from the community of Moenkopi. In this segment, Moenkopi Wash alluvium is recharged by discharge from the N aquifer system in an area referred to as Blue Canyon in this document (Figure 31). Downcutting and erosion of Moenkopi Wash created a slot canyon exposing the Navajo Sandstone and creating features known locally as “the water caves” (OSMRE, 2016). The N aquifer hydraulic gradient near Blue Canyon induces groundwater discharge to Moenkopi Wash alluvium, providing a consistent source of recharge to the Moenkopi Wash alluvium. Regional numerical groundwater flow simulation quantifies the annual baseflow discharge to Moenkopi wash at 4,305 ac-ft prior to mining in 1955 (PWCC, 1999).



Figure 31: Blue Canyon on Moenkopi Wash (photo by OSMRE, 4-5-16).

The primary recharge mechanisms to the Moenkopi Wash alluvium are from both infiltration of surface water after storm flow events, and from N aquifer discharge at Blue Canyon. PWCC operations influence these two recharge mechanisms to Moenkopi Wash alluvium. One recharge mechanism is associated with surface water runoff, and the second mechanism is associated with groundwater discharge from the N aquifer. N aquifer groundwater discharge impacts to Moenkopi Wash alluvium are further discussed in Section 5.2.4.1. The Moenkopi CIA for surface water runoff area is 162,093 acres of the 1,689,600 acre Moenkopi watershed (HUC 15020017). Therefore, PWCC may manage a maximum of 9.6-percent of the Moenkopi watershed (HUC 15020017). OSMRE recognizes that decreases in surface flows are of concern to Moenkopi area farmers relying on sub-flow in Moenkopi Wash alluvium for agricultural irrigation supply water. Therefore, OSMRE will establish a surface water quantity material damage threshold and limit for the amount of surface area managed by surface water impoundments within the Kayenta Mine Complex to minimize potential surface water quantity impact on agricultural irrigation water supply.

5.1.2.2 Surface Water Quantity Material Damage

The surface water quantity monitoring program and PAP have provided sufficient information for OSMRE to assess surface water quantity impacts. After assessing the potential surface water quantity impact of the mining and reclamation operations on existing and foreseeable agricultural irrigation,

livestock, and aquatic and wildlife habitat water uses, OSMRE has determined that the operation has been designed to minimize surface water quantity impacts within the permit area and prevent material damage outside the permit and adjacent area by limiting the surface area managed by surface water impoundments. The Kayenta Mine Environmental Assessment (EA) (OSMRE, 2011c), identifies a level of moderate impact if the watershed area controlled by impoundments is between 30 to 50 percent of the total drainage area, and major impacts greater than 50-percent. Therefore, OSMRE defines surface water quantity material damage as greater than 50-percent of the Moenkopi CIA or Dinnebito CIA managed by surface water impoundments.

5.1.3 Surface Water Quality

Several recharge mechanisms influence surface water quality within the permit and adjacent area. Precipitation generates rainfall runoff in the ephemeral washes, entraining sands, silts, and clays, inducing elevated concentrations of total suspended solids (TSS). Elevated TSS concentrations influence the cation exchange capacity, and ultimately the surface water chemical composition. Recharge also occurs from baseflow in areas where Wepo Formation is in hydrologic communication with alluvium. Wet reaches are typically evident where Wepo Formation water discharges to channel alluvium, and most apparent when precipitation events have not recently occurred. The effect of precipitation on spoil surface area also influences the surface water quality. During mining and reclamation, surface water impoundments capture surface water runoff that was in contact with the spoil material. The impounded surface water may discharge over the spillway during precipitation events exceeding the 10-year 24-hour event design capacity, or infiltrate through the bottom of the impoundments, entering the Wepo Formation and alluvial and surface water systems.

5.1.3.1 Surface Water Quality Monitoring Program

Above-mining and below-mining locations were selected on the primary washes transecting the Kayenta Complex: Yellow Water Canyon Wash, Coal Mine Wash, Moenkopi Wash, Dinnebito Wash (Figure 11). The four primary washes are monitored in order to evaluate mining and reclamation impacts, and comparisons are made relative to NNSWQS (NNEPA, 2009) and HTWQS (Hopi Tribe, 2011). The document entitled: “Guidance for Assessing the Quality of Navajo Nation Surface Waters to Determine Impairment (Integrated 305(b) Reporting and 303(d) listing)” (NNEPA 2008) identifies the minimum number of sample values required to determine support of designated uses. Most WQS require a minimum 5 values in 3 years for use assessment. Dissolved oxygen, pH, suspended sediments, temperature, and turbidity require a minimum 10 values in 10 years for use assessment. Based on previously collected surface water information, coupled with continued monitoring at locations 2A, 25, 26, 34, 80R, 91, and 155, OSMRE finds the surface water quantity program sufficient for OSMRE to make the required evaluation for material damage potential in this CHIA. Continued surface water quantity monitoring is necessary to reinforce hydrologic impact conclusions.

5.1.3.2 Impact Potential to Existing and Foreseeable Uses

The surface water quality regime was characterized and monitored by PWCC using monitoring locations in the permit and adjacent area (Figure 11). The monitoring program was established to evaluate surface water quality impacts from overland flow on mine disturbed area to the washes, resulting in the addition of dissolved solids to the surface water system and potential for material damage to the hydrologic balance.

The NNEPA Water Quality Program (WQP) and Hopi Tribe Water Resources Program (WRP) have identified designated uses for Moenkopi and Dinnebito Washes, and identified WQS of chemical parameters which are considered to have the potential to adversely impact the designated water resource

use. Moenkopi Wash has the following designated uses: Secondary Human Contact, Agricultural Livestock Watering, Agricultural Irrigation Water Supply, Aquatic and Wildlife Habitat (acute and chronic), and Fish Consumption. Dinnebito Wash has the same water use designations as Moenkopi Wash with the exception of Agricultural Water Supply. The NNEPA WQP developed WQS in 2004, revised in 2007, passed by Navajo Nation Resources Committee on May 13, 2008, and approved by the U.S. EPA effective March 26, 2009. The Hopi Tribe WRP developed similar WQS in 2008, revised in 2010, and was approved by the U.S. EPA effective August 24, 2011. Water quality references in the NGS-KMC EIS use reference to the year of Tribal Committee approval, compared the year effective by the U.S. EPA presented in this CHIA. Table 5 provides the HTWQS (Hopi Tribe, 2011) applicable to the Dinnebito and Moenkopi CIAs. Table 6 provides the NNSWQS (NNEPA, 2009) applicable to the Dinnebito and Moenkopi CIAs.

Tables 7a and 7b provide summary statistics of downstream monitoring locations for chemical parameters with a WQS applicable to the Dinnebito Wash and Moenkopi Wash CIAs. The summary information considers non-detected concentrations to equal the method detection limit (MDL). For example, if a MDL is 100 mg/L, then the value is included in summary statistics as a detected concentration of 100 mg/L. Although the approach may skew the summary statistics, this approach was applied to both upstream and downstream assessment locations, and provides a method for cursory assessment. The highest reported concentrations at downstream monitoring locations were compared to the most protective WQS. Nine chemical parameters were above the most protective WQS: cadmium, chloride, lead, manganese, mercury, molybdenum, selenium, sulfate, and TDS. The remaining parameters evaluated will not be carried forward for assessment.

Chemical Parameter	Units	Groundwater (DWS, PCC, GWR)	Partial Body Contact (PBC)	Agricultural Livestock (Agl)	Agricultural Irrigation (Agl)	Aquatic and Wildlife (ephemeral) A&W _e - Acute	Aquatic and Wildlife (ephemeral) A&W _e - Chronic
Aluminum	mg/L	NNS	NNS	5.0 (D)	5.0 (D)	NNS	NNS
Antimony	µg/L	5.6	370	NNS	NNS	NNS	NNS
Arsenic	µg/L	10	280	200	2000	440 (D)	230 (D)
Barium	µg/L	2000	186,670	NNS	NNS	NNS	NNS
Beryllium	µg/L	4	1870	NNS	NNS	NNS	NNS
Boron	µg/L	1400	186,670	NNS	1000	NNS	NNS
Cadmium	µg/L	5	470	50	50	calculation	calculation
Chloride	mg/L	250	NNS	NNS	NNS	230	230
Chromium	µg/L	100	NNS	1000	1000	NNS	NNS
Chromium III	µg/L	NNS	1,400,000	NNS	NNS	calculation	calculation
Chromium VI	µg/L	20	2800	NNS	NNS	34 (D)	23 (D)
Cobalt	mg/L	NNS	NNS	1.0 (D)	0.05 (D)	NNS	NNS
Copper	µg/L	1300	9330	500	5000	calculation	calculation
Cyanide	µg/L	140	18,670	200	NNS	84	19
Fluoride	µg/L	4000	56,000	NNS	NNS	NNS	NNS
Iron	µg/L	300	NNS	NNS	NNS	NNS	NNS
Lead	µg/L	15	15	100	10,000	calculation	calculation
Manganese	µg/L	50	130,670	NNS	10,000	NNS	NNS
Mercury	µg/L	2	280	10	NNS	2.4 (D)	0.01 (D)
Methylmercury	µg/L	NNS	NNS	NNS	NNS	NNS	NNS
Molybdenum	mg/L	NNS	NNS	NNS	0.01 (D)	NNS	NNS
Nickel	µg/L	610	18,670	NNS	NNS	calculation	calculation
Nitrate as N	µg/L	10,000	1,493,330	NNS	NNS	NNS	NNS
Nitrite as N	µg/L	1000	93,330	NNS	NNS	NNS	NNS
NO3+NO2	µg/L	10,000	NNS	NNS	NNS	NNS	NNS
pH	-	5.0-9.0	6.5-9.0	6.5-9.0	4.5-9.0	6.0-9.0	6.0-9.0
Selenium	µg/L	170	4670	50	20	33	2.0
Silver	µg/L	35	4670	NNS	NNS	calculation	calculation
Sulfate	mg/L	250	NNS	NNS	NNS	250	250
TDS	mg/L	500	NNS	NNS	NNS	500	500
Thallium	µg/L	0.24	75	NNS	NNS	NNS	NNS
Uranium	µg/L	30 (D)	2800	NNS	NNS	NNS	NNS
Vanadium	µg/L	NNS	NNS	100	100	NNS	NNS
Zinc	µg/L	7400	280,000	25,000	10,000	calculation	calculation

All concentrations are total unless otherwise noted
calculation - value dependent on sample hardness

NNS - no numeric standard
D - Dissolved

µg/L - micrograms per liter
mg/L - milligrams per liter

Table 5. Hopi Tribe Water Resources Program 2008 Water Quality Standards (Hopi Tribe, 2011).

Chemical Parameter	Units	Secondary Human Contact (SchC)	Livestock Watering (LW)	Agricultural Water Supply (AgWS)	Aquatic and Wildlife (ephemeral) A&W _e Acute	Aquatic and Wildlife (ephemeral) A&W _e Chronic
Aluminum	µg/L	NNS	NNS	5000	750	87
Antimony	µg/L	370	NNS	NNS	88 (D)	30 (D)
Arsenic	µg/L	280	200	2000	340 (D)	150 (D)
Barium	µg/L	98,000	NNS	NNS	NNS	NNS
Beryllium	µg/L	1870	NNS	NNS	NNS	NNS
Boron	µg/L	126,000	5000 (D)	NNS	15000	10000
Cadmium	µg/L	470	NNS	50	calculation	calculation
Chloride	µg/L	4000	11	NNS	19	11
Chromium	µg/L	NNS	1000	1000	NNS	NNS
Chromium III	µg/L	1,400,000	NNS	NNS	calculation	calculation
Chromium VI	µg/L	2800	NNS	NNS	16 (D)	11 (D)
Cobalt	µg/L	NNS	1000 (D)	50 (D)	NNS	NNS
Copper	µg/L	9330	500 (D)	200 (D)	calculation	calculation
Cyanide	µg/L	18,670	5.2	NNS	22	5.2
Fluoride	mg/L	56,000	NNS	NNS	NNS	NNS
Iron	µg/L	NNS	NNS	NNS	NNS	NNS
Lead	µg/L	15	100	10,000	calculation	calculation
Manganese	µg/L	NNS	NNS	NNS	NNS	NNS
Mercury	µg/L	280	10	NNS	2.4	calculation
Methylmercury	µg/L	NNS	NNS	NNS	NNS	NNS
Molybdenum	µg/L	NNS	NNS	1000 (D)	NNS	NNS
Nickel	µg/L	18,670	NNS	NNS	calculation	calculation
Nitrate as N	µg/L	1,493,330	NNS	NNS	NNS	NNS
Nitrite as N	µg/L	93,330	NNS	NNS	NNS	NNS
NO ₃ +NO ₂	µg/L	NNS	132	NNS	NNS	NNS
pH	--	6.5-9.0	6.5-9.0	4.5-9.0	6.0-9.0	6.0-9.0
Selenium	µg/L	4670	50	20	33	2.0
Silver	µg/L	4670	NNS	NNS	calculation	NNS
Sulfate	mg/L	NNS	NNS	NNS	NNS	NNS
TDS	mg/L	NNS	NNS	NNS	NNS	NNS
Thallium	µg/L	75	NNS	NNS	700 (D)	150 (D)
Uranium	µg/L	2800	NNS	NNS	NNS	NNS
Vanadium	µg/L	NNS	100 (D)	100 (D)	NNS	NNS
Zinc	µg/L	280,000	25,000	10,000	calculation	calculation

All concentrations are total unless otherwise noted
calculation - value dependent on sample hardness
NNS - no numeric standard

µg/L - micrograms per liter
mg/L - milligrams per liter
D - Dissolved

Table 6. NNEPA Water Quality Program 2007 Surface Water Quality Standards (NNEPA, 2009).

Chemical Parameter	Most Protective WQS	WQS	Units	Type	Dinnebito Wash CIA				Moenkopi Wash CIA			
					Location 34				Locations 25, 26, and 155			
					# Samples	Low	Median	High	# Samples	Low	Median	High
Aluminum	Aquatic (NN)	0.75 (T)	mg/L	Dissolved	n=20	0.03	0.05	0.45	n=54	0.03	0.05	0.72
Antimony	Aquatic (NN)	88	µg/L	Dissolved	n=10	1	1	10	n=24	1	1	12
Arsenic	Aquatic (HT)	230	µg/L	Dissolved	n=17	0.8	1	5	n=46	0.5	1	51
Barium	Secondary Contact (NN)	98000 (T)	µg/L	Dissolved	n=12	50	70	200	n=32	20	100	270
Bicarbonate	NNS	NNS	mg/L	Dissolved	n=49	43.9	91	614	n=112	57	116	399
Boron	Agricultural (NN)	1000 (T)	µg/L	Dissolved	n=34	20	70	140	n=111	10	70	360
Calcium	NNS	NNS	mg/L	Dissolved	n=49	16	158	520	n=112	16.8	89.2	505
Cadmium	Fish Consumption (NN)	8 (T)	µg/L	Dissolved	n=17	3	5	10	n=50	3	5	10
Chloride	Aquatic (HT)	230 (T)	mg/L	Total	n=34	1	12	55	n=112	2	12	261
Chromium	Agricultural (HT)(NN)	1000 (T)	µg/L	Dissolved	n=18	10	10	10	n=52	10	10	50
Copper	Agricultural (NN)	200	µg/L	Dissolved	n=20	10	10	10	n=55	10	10	50
Fluoride	Secondary Contact (NN)	56 (T)	mg/L	Total	n=34	0.1	0.7	1	n=112	0.1	0.6	1.1
Iron	NNS	NNS	mg/L	Total	n=31	7.22	551.5	2960	n=103	0.05	274	2610
Lead	Secondary Contact (NN)	15 (T)	µg/L	Dissolved	n=16	20	20	60	n=49	20	20	60
Magnesium	NNS	NNS	mg/L	Dissolved	n=49	4	56.5	500	n=112	3	28	511
Manganese	Agricultural (HT)	10 (T)	mg/L	Total	n=31	0.13	12.9	26.4	n=103	0.014	7.96	64
Mercury	Aquatic (HT)	0.01	µg/L	Dissolved	n=15	0.1	0.2	0.2	n=46	0.1	0.2	2.3
Molybdenum	Agricultural (HT)	0.01	µg/L	Dissolved	n=10	1	3	50	n=28	1	1	50
Nickel	Fish Consumption (NN)	4600 (T)	µg/L	Dissolved	n=10	10	20	30	n=29	10	10	20
Nitrate as N	Secondary Contact (NN)	1493 (T)	mg/L	Total	n=34	0.99	2.4	6.1	n=111	0.02	1.5	14.9
Nitrite as N	Secondary Contact (NN)	93.3 (T)	mg/L	Total	n=34	0.01	0.01	0.03	n=111	0.01	0.06	0.37
NO3+NO2	Livestock Watering (NN)	132	mg/L	Total	n=34	0.99	2.5	6.1	n=94	0.02	1.7	15.1
pH	All Uses	< 9.0	s.u.	Total	n=34	6.5	7.7	8.3	n=112	6.5	7.7	8.5
Selenium	Aquatic (HT)(NN)	2	µg/L	Dissolved	n=17	1	2.9	20	n=48	0.7	1	5
Silver	Secondary Contact (NN)	4670 (T)	µg/L	Dissolved	n=10	5	10	10	n=29	5	10	20
Sodium	NNS	NNS	mg/L	Dissolved	n=49	3.9	48	680	n=112	5.4	47	780
Sulfate	Aquatic (HT)	250 (T)	mg/L	Total	n=34	30	660	2118	n=112	20	310	4880
TDS	Aquatic (HT)	500	mg/L	Total	n=34	122	1090	3094	n=112	94	580	7750
Vanadium	Agricultural (HT)(NN)	100 (T)	µg/L	Dissolved	n=20	5	10	16	n=54	5	10	30
Zinc	Agricultural (HT)(NN)	10 (T)	mg/L	Dissolved	n=20	0.01	0.01	0.03	n=55	0.01	0.01	0.18

NNS - No Numeric Standard
WQS - Water Quality Standard

mg/L - milligrams per liter
µg/L - micrograms per liter

NN - Navajo Nation
HT - Hopi Tribe

CIA - Cumulative Impact Area
T- Total

Table 7. Storm water sample ranges for downstream locations, Kayenta Mine Complex (1986-2010).

One downstream location in the Moenkopi CIA reported a dissolved cadmium sample at 10 mg/L. A review of the surface water quality data submitted in annual hydrologic monitoring reports (PWCC, 2016) indicates the elevated value is attributed to an elevated MDL. The median cadmium value for Moenkopi CIA downstream monitoring locations is 5 mg/L (Table 7), and less than the medium upstream monitoring locations for cadmium (Table 2). Therefore, the NNEPA fish consumption designated use does appear to be compromised due to the activities at the Kayenta Mine Complex.

One downstream location in the Moenkopi CIA reported a total chloride sample at 261 mg/L. The median chloride value for Moenkopi CIA downstream monitoring locations is 12 mg/L (Table 7), and consistent with the medium upstream monitoring locations for chloride (Table 2). The isolated elevated detection slightly above Hopi Tribe designated use for aquatic and wildlife habitat, and has not been repeated. Therefore, the Hopi Tribe designated use for aquatic and wildlife habitat use does not appear to be compromised due to the activities at the Kayenta Mine Complex.

All reported concentrations of lead are at the MDL. Median downstream values (Table 7) are consistent with median upstream values (Table 2). Reported lead values are less than agricultural livestock water supply WQS, but greater than PBC (Hopi Tribe, 2011) and SchC (NNEPA, 2009) WQS of 15 mg/L. The designated use for PBC and SchC, which are the same by definition, do not appear to be compromised due to the activities at the Kayenta Mine Complex.

Hopi Tribe WRP established a total manganese standard of 10 mg/L for agricultural irrigation. The NNEPA established no manganese standard for the designated uses in the Moenkopi and Dinnebito CIAs. Reported manganese concentrations are variable in both upstream and downstream monitoring location for Moenkopi and Dinnebito CIAs. Dinnebito upstream median total manganese concentrations is 16 mg/L, and 12.9 mg/L for the downstream monitoring location. Moenkopi upstream median total manganese is 10 mg/L, and 7.96 for the downstream monitoring locations. The highest manganese detection (64 mg/L) occurred at monitoring location 26 in 1991, and reported concentrations have been below 20 mg/L from 1997 – present. Based on comparison of upstream and downstream monitoring locations, the Hopi Tribe designated use for agricultural livestock watering does not appear to be compromised due to the activities at the Kayenta Mine Complex.

Upstream and downstream monitoring for dissolved mercury in both the Dinnebito and Moenkopi CIAs identified one detection at downstream monitoring location 25 (2.3 µg/L). All remaining mercury values are a result of a MDL between 0.1 – 0.2 µg/L. The Hopi Tribe WQS for A&W_e (chronic) is 0.01 µg/L. The designated uses do not appear to be compromised due to the activities at the Kayenta Mine Complex.

Molybdenum has a designated use WQS for agricultural water supply established by the Hopi Tribe WRP (10 µg/L) and NNEPA (1000 µg/L). All reported concentrations are a reflection of the MDL. When the MDL is less than 10 µg/L, no concentrations have been detected. Therefore, the agricultural water supply designated use does appear to be compromised from molybdenum concentrations due to the activities at the Kayenta Mine Complex.

Selenium WQS are available for all designated uses in the Dinnebito and Moenkopi CIAs. Both the Hopi Tribe WRP and NNEPA established a WQS of 20 µg/L for agricultural irrigation water, and a WQS of 2 µg/L for A&W_e (chronic). All storm water quality samples collected at downstream monitoring locations were less than 20 µg/L. Lower detections are a result of the level of MDL being reported. The designated use for A&W_e (chronic) does not appear to be compromised due to the activities at the Kayenta Mine Complex.

Hopi Tribe WRP established a sulfate designated use standard for A&W_e of 250 mg/L. This is the only designated use with a sulfate water quality standard applicable to the Moenkopi and Dinnebito CIAs. Results from upstream monitoring on Dinnebito Wash has a median sulfate concentration of 900 mg/L

(Table 2), compared to a median downstream concentration of 660 mg/L (Table 7). Results from upstream monitoring on Moenkopi Wash has a median sulfate concentration of 150 mg/L (Table 2), compared to a median downstream concentration of 310 mg/L (Table 7). Although the downstream median sulfate concentration for the Moenkopi CIA is double the upstream median, downstream concentrations are within established sulfate variability, and no increasing trends were identified during review of the monitoring data. Therefore, the designated use for A&W_e does not appear to be compromised due to the activities at the Kayenta Mine Complex.

TDS is very similar to sulfate for both designated uses and concentrations. A TDS WQS has been established by Hopi Tribe WRP for the designated use of A&W_e. This is the only designated use with a TDS water quality standard applicable to the Moenkopi and Dinnebito CIAs. Results from upstream monitoring on Dinnebito Wash have a median TDS concentration of 1444 mg/L, compared to a median downstream concentration of 1090 mg/L. Results from upstream monitoring on Moenkopi Wash have a median TDS concentration of 440 mg/L, compared to a median downstream concentration of 580 mg/L. Although the downstream median TDS are slightly higher than the upstream median, downstream concentrations are within established TDS variability, and no increasing trends are apparent in the downstream monitoring data (Figure 32). Therefore, the designated use for A&W_e does not appear to be compromised due to the activities at the Kayenta Mine Complex.

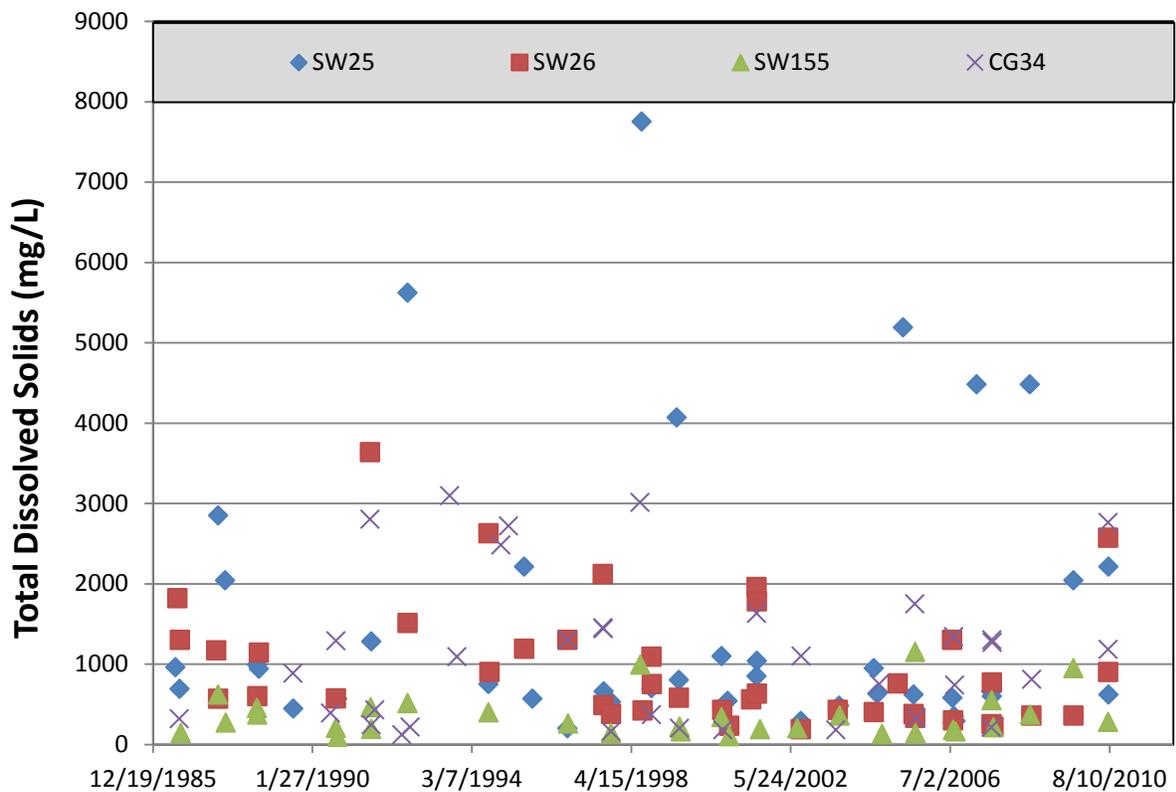


Figure 32. Downstream Surface Water TDS Concentrations, Kayenta Complex (1986 – 2010).

Navajo Generating Station – Kayenta Mine Complex EIS

The September 2016 Draft NGS-KMC EIS provides the following surface water quality summaries:

Moenkopi Wash

- long-term (1985-2005) runoff and baseflow for upstream locations 16, 35, 50 (BOR, Table WR-1.17, 2016)
- long-term (1985-2005) runoff and baseflow for downstream locations 25, 26, 155 (BOR, Table WR-1.18, 2016)
- near-term (2010-2014) runoff and baseflow for downstream location 25 (BOR, Table WR-1.8, 2016)
- near-term (2010-2014) runoff and baseflow for downstream location 26 (BOR, Table WR-1.11, 2016)
- near-term (2010-2014) runoff and baseflow for downstream location 155 (BOR, Table WR-1.13, 2016)

Dinnebito Wash

- long-term (1985-2005) runoff and baseflow for upstream location 78 (BOR, Table WR-1.18, 2016)
- long-term (1985-2005) runoff and baseflow for downstream location 34 (BOR, Table WR-1.20, 2016)
- near-term (2010-2014) storm runoff for downstream location 34 (BOR, Table WR-1.15, 2016)

The overall description of current near-term conditions (2010-2014) indicates occasional exceedances of tribal standards occur for total recoverable trace elements including aluminum, arsenic, cadmium, copper, lead, mercury, and vanadium; whereas, dissolved concentrations (TSS filtered from the sample prior to analysis) rarely exceed standards (BOR, 2016). Long-term (1985-2005) Dinnebito Wash data indicate that upstream inflows have greater TDS and sulfate concentrations as a natural background condition, and that typical values decline downstream (BOR, 2016). Long-term (1985-2005) Moenkopi Wash data indicate that upstream and downstream TDS and sulfate concentrations are typically within water quality guideline values, but greater downstream of the mine on Moenkopi Wash (BOR, 2016). In summary, “Because of the background contributions, and the likelihood of local adaptations to water quality by local livestock or wildlife, these would be minor localized impacts. Both upstream and downstream of the leasehold, water quality would continue to be influenced by highly localized precipitation conditions and geologic sources of these constituents” (BOR, 2016).

5.1.3.3 Surface Water Quality Material Damage

PWCC’s hydrologic balance protection plan includes an approach to handle earth materials and surface water runoff in a manner that minimizes the formation of acidic or toxic drainage, and prevents additional contributions of suspended solids and other water pollutants from entering streamflow outside the permit area to the extent possible. As such, all areas disturbed by the mining and reclamation operations drain to sediment settling and containment ponds or impoundments which are designed to contain at least the 10-year, 24-hour runoff event plus an additional amount of sediment storage. Pond discharges from flow events exceeding the pond capacity are monitored for effluent compliance concentrations and reported in accordance with the requirements of NPDES permit number NN0022179.

The surface water monitoring program has provided sufficient information for OSMRE to make the impact assessment. The Draft NGS-KMC EIS provided additional information to inform the impact assessment. After assessing the potential surface water quality impact of the mining operation on existing and reasonably foreseeable uses of Secondary Human Contact, Partial Body Contact, Agricultural Livestock Watering, Agricultural Water Supply, Aquatic and Wildlife Habitat (acute and chronic), and Fish Consumption water uses, OSMRE has determined that the operation has been designed to minimize surface water quality impacts within the permit area and prevent material damage outside the permit and adjacent area.

5.2 Groundwater

Coal resources mined at the Kayenta Mine Complex are within the Wepo Formation of the Mesa Verde Group. The Mesa Verde Group consists of the overlying Yale Point Sandstone, the Wepo Formation, and the underlying Toreva Formation. Alluvial channels truncate the Yale Point Sandstone and Wepo Formations within the assessment area delineated in Section 2.2.1, limiting regional horizontal flow. OSMRE will evaluate the potential of the Kayenta Mine Complex operation to result in contamination, diminution, or interruption of alluvial and Wepo Formation groundwater outside the permit area that may result in the inability to utilize water resources for existing and reasonably foreseeable livestock use.

As discussed in Section 3.2, PWCC utilizes groundwater from water supply wells within the permit area, which withdraw groundwater from the N aquifer system. The N aquifer is utilized regionally by Hopi and Navajo communities for domestic supply water, and the D aquifer is utilized in isolated areas where the water quantity and quality permits domestic and livestock water supply use. PWCC's past and present N aquifer use creates both water quantity and quality concerns that will be evaluated in this assessment.

5.2.1 Alluvium

OSMRE will evaluate whether the monitoring program has been appropriately designed to provide alluvial water quantity and quality information necessary to assess potential impacts in accordance with 30 CFR 780.21(g). OSMRE will also evaluate the potential impact of the Kayenta Mine Complex on downstream uses outside the permit area related to alluvial water quantity and quality, and potential impact to the existing and reasonably foreseeable use of agricultural livestock watering.

5.2.1.1 Alluvial Quantity

Alluvial washes within the permit area are characterized as having large variations in both vertical saturated thickness and cross-sectional width based on seismic refraction studies and drill log information. Variability of hydrologic characteristics was also confirmed through aquifer testing, where transmissivity results span three orders of magnitude (Figure 15). Additionally, the alluvial systems in the various washes are not continuous within the permit area. Some areas of the alluvium have up to 34-feet of saturated thickness, while other areas of the same wash may only have a thin veneer of unsaturated alluvium accumulated. OSMRE will evaluate the use potential based on water quantity availability and potential water quantity impact to the existing and foreseeable uses due to the Kayenta Mine Complex.

5.2.1.1.1 Alluvial Quantity Monitoring Program

The monitoring program of the valley alluvium for water quantity was implemented to characterize background conditions, natural seasonal fluctuations, and identify the existing and reasonably foreseeable use potential of alluvial water. Specifically, mining related water quantity impact on the potential use of alluvial water for livestock watering has been identified as a concern for this evaluation.

The monitoring program identified that the groundwater quantity in the alluvial system is variable, and fluctuations in the background alluvial monitoring well data are predominantly related to precipitation and associated infiltration of surface water flow. Also, since precipitation is spatially variable, water level trends will generally mimic each other, but the amplitudes may vary depending on the spatial distribution of precipitation events and the amount of runoff generated as surface flow in the washes. The general trend measured in alluvial background monitoring locations 69, 77, 87, and 108R has been decreasing. The four background monitoring locations, coupled with multiple wells along the alluvial washes, provide good information for evaluating water quantity variations. Therefore, OSMRE finds that the existing alluvial monitoring program, which includes wells upgradient of mining activities, wells at the

downgradient permit boundary of the primary washes, and wells along the primary washes, provide sufficient information for OSMRE's impact evaluation (Figure 13).

5.2.1.1.2 Alluvial Quantity Impact Potential to Existing and Foreseeable Uses

In order to quantify alluvium inflow reduction for comparison to outflow reduction, Darcy's Law was used. Darcy's Law relates outflow to hydraulic gradient, hydraulic conductivity of the porous medium, and a cross-sectional area. The calculations are detailed in Table 8. In 2002, the water levels declined from baseline in all background alluvial monitoring wells as follows: 77 (-0.27 feet), 108R (-3.63 feet), 69 (-3.66 feet), and 87 (-8.24 feet). Multiplying the channel width at each of the locations with the water level decline in saturated alluvium yields the cross-sectional area for background baseline evaluation. Next, water level pairs were identified for alluvial wells close to the background monitoring wells for hydraulic gradient calculations. Finally, hydraulic conductivity values were derived from pump test data performed on the specific background monitoring well. Since pump test data was not available for location 77, the average hydraulic conductivity value from 87, 108R, and 69, was used for quantity calculation at location 77. Additionally, no alluvial monitoring wells are in close proximity to locations 87 and 77; therefore, the average gradient from 108R and 69 was used for the gradient variable.

Inflow quantity reduction in the alluvium was largest for the two background tributaries comprising Coal Mine Wash. In 2002, the alluvial inflow to the permit area via Coal Mine wash decreased by approximately 7.73 ac-ft when compared with water level information from the early 1980's. Similarly, Dinnebito alluvium measured a 0.67 ac-ft inflow decline in 2002 and Moenkopi a 1.53 ac-ft decline in 2002, when compared to water level information in the early 1980's. Background inflow volume declines were compared to the volumetric flow declines at the downgradient permit boundaries (Table 8).

Alluvial Monitoring Well	Setting	Wash	Channel Width	Head Decline	Saturated X-Section Decrease (Area)	Well Pair for Gradient Calculation	Change in Head (dh)	Change in Length (dl)	Gradient (dh/dl) (i)	Hydraulic Conductivity (K)	Discharge (Q=KiA)	Discharge (Q=KiA)	Discharge (Q=KiA)
			feet	feet	feet ²		feet	feet		ft/year	feet ³ /year	gal/year	ac-ft/year
ALUV87	Background	Moenkopi	1000	8.24	8240				0.0126	640	66447	497061	1.53
ALUV108R	Background	Dinnebito	1600	3.63	5808	ALUV168	41.48	3261	0.0127	396	29256	218847	0.67
ALUV69	Background	Coal Mine	800	3.66	2928	ALUV13R	44.53	3572	0.0125	8888	324427	2426879	7.45
ALUV77	Background	Coal Mine	1100	0.27	297				0.0126	3308	12379	92603	0.28
Annual Alluvial Inflow Reduction											432509	3235390	9.93
ALUV95	Downstream	Moenkopi	640	2.78	1779	ALUV93	10.26	3416	0.0030	4047	21627	161778	0.50
ALUV170	Downstream	Dinnebito	1280	1.39	1779	ALUV169	15.11	2485	0.0061	4047	43782	327512	1.01
ALUV19	Downstream	Coal Mine	480	10.34	4963	ALUV197	1.59	1087	0.0015	4047	29381	219783	0.67
Annual Alluvial Outflow Reduction											94789	709074	2.18

Table 8: Alluvial Quantity Outflow Calculations for Primary Washes (2002).

Water level decreases of 0.27 feet to 8.24 feet have been measured at the background monitoring locations; therefore, decreases can be expected at the outflow areas since inflow to the alluvial aquifer system has decreased. Downgradient alluvial monitoring locations 19, 95 and 170 were used for comparison to the background information and assessment of potential mining related impact to existing and foreseeable livestock use. The water level declines at the three downgradient alluvial monitoring wells were as follows: 19 (-10.34 feet), 95 (-2.78 feet), and 170 (-1.39 feet). Using information of water level change, hydraulic conductivity, and hydraulic gradient, the total discharge reduction was determined and compared to the background reduction. Comparatively, Moenkopi Wash had a 1.53 ac-ft/yr inflow reduction at background location 87, and a 0.50 ac-ft/yr outflow reduction at downgradient location 95. Coal Mine Wash had a combined inflow reduction at background locations 69 and 77 of 7.73 ac-ft/yr, and a 0.67 ac-ft/yr reduction at downgradient location 19. Dinnebito Wash had an inflow reduction of 0.28 ac-ft/yr at background location 108R, and a 1.01 ac-ft/yr reduction at downgradient location 170.

Overall, alluvial quantity reductions have been measured in the background alluvial monitoring wells and downgradient alluvial monitoring wells adjacent to the permit boundary. Inflow quantity reductions are greater than outflow reductions. The discrepancy is likely the result of retaining storm flow surface water in impoundments and baseflow discharge from the Wepo Formation. The impoundments allow storm flow water to be temporarily retained, and the retained water subsequently infiltrates through the bottom of the retaining structure and into the channel alluvium.

Historically, five locations within the permit and adjacent area were developed for alluvial water use. The locations are identified as 8A-PHS-10, 4M-190, and Sagebrush Well within the permit area, while Reed Well and Grapevine Well are located adjacent to the permit boundary on Moenkopi Wash (Figure 8). Additionally, two alluvial springs that discharged at a flow rate of 1-2 gpm were identified in the northwestern portion of the permit area. The two alluvial springs are identified as 8A-140 and 8M-141.

The water quantity of the alluvial system is largely related to the surface water flow and subsequent infiltration to the alluvium. As such, fluctuations in alluvial water levels and spring flow rates are typical. The fluctuations limit sustainable development of the alluvium. For instance, Sagebrush well is a cistern (artificial underground tank for storing liquid), located in the middle of the channel, and not utilized or maintained for several decades. Storm flow events occasionally overtop the cistern; therefore, the sediment rich storm flow water has induced the cistern to become filled with sediment. Similarly, location 8A-PHS-10 has not been operated for several decades and occasionally overtopped by storm flow events. Location 4M-190 has been cataloged as a historical use location, but any identifiable structure has either washed away during storm events, or buried by accumulated sediment, as there have been no visible observations of the location for several decades. Reed Well and Grapevine Well are also cistern-like structures, abandoned for several decades, and no longer operable.

5.2.1.1.3 Alluvial Quantity Material Damage

The available quantity of alluvial water stored in the alluvial system varies depending on location within the alluvial channel and quantity of water infiltrated in response to storm flow events. Additionally, developing alluvial water for agricultural livestock use is maintenance intensive due to the sediment transported during storm flow events, evidenced by the condition of the historical use locations. Although the reliability of using the alluvial system for agricultural livestock water supply development is low and maintenance prohibitive, surface water impoundment structures from the mining operations locally enhance alluvial water quantity, and the operations will not compromise reasonably foreseeable use of alluvial water quantity. Therefore, OSMRE will not establish a material damage criterion related to alluvial water quantity, but continued water alluvial water quality monitoring in compliance with the approved permit is necessary.

5.2.1.2 Alluvial Quality

Alluvial water quality of the primary drainages within the Kayenta Mine Complex has been monitored for several decades. The water quality information will be utilized to assess potential development of the alluvial water for livestock watering, and evaluate the potential impact of the mining operations on the foreseeable livestock watering use within the permit and adjacent area.

5.2.1.2.1 Alluvial Quality Monitoring Program

Similar to the monitoring program objectives presented previously, monitoring of the valley alluvium for water quality was implemented to characterize background conditions, natural seasonal variations, and identify the existing and reasonably foreseeable use potential of the alluvial water for livestock watering. Seasonal variations will not be evaluated separately, since seasonal variation is apparent but not statistically significant between monitoring locations.

Figure 13 illustrates that alluvial water quality information has been obtained at approximately a hundred locations within the permit area. The active locations are sampled either annually or semi-annually. Semi-annual monitoring is typically done at locations where geochemical trending of some water quality parameters has been observed. Water quality samples are analyzed for a full suite of parameters consisting of parameters that have Arizona, Federal, or Navajo Nation livestock drinking water limits, all significant parameters necessary to perform QA/QC checks on laboratory data, and those parameters necessary to evaluate mining impacts (PWCC, v.11, ch.16, 2016).

The information obtained at abandoned or idled alluvial monitoring locations, coupled with ongoing monitoring of the existing locations, provide the necessary information to characterize background conditions, natural seasonal variations, and evaluate the water quality impact of the mining operations on the potential for watering livestock within the permit and adjacent area. Therefore, OSMRE finds that the alluvial monitoring is appropriately designed and implemented.

5.2.1.2.2 Alluvial Quality Impact Potential to Existing and Foreseeable Uses

Historical attempts have been made to develop alluvial water resources within in the permit and adjacent area. However, none of the locations have been utilized or maintained for several decades, and some of the locations have been either washed downstream during flood events or are filled with sediment. The lack of alluvial use locations within the permit and adjacent area is largely a function of the dynamic water quantity conditions in the channel alluvium, which is dependent on the duration and intensity of the surface water storm flow events. Another challenge pertinent to alluvial aquifer development is the fact that it is not continuously hydraulically connected through any significant geographic area. However, this evaluation will consider the potential to develop alluvial water within the permit and adjacent area to support livestock watering. HTWQS (Hopi Tribe, 2011) and NNSWQS (NNEPA, 2009) for agricultural livestock water supply will be used to support water quality evaluation of the alluvial aquifer.

Chemical parameters with an agricultural livestock water supply WQS, and major cations and anions are identified on Table 9. Downstream monitoring locations for the Moenkopi alluvial CIA identified one detection of cadmium above the agricultural livestock WQS (50 µg/L) at location 19. The elevated detection is a result of an elevated MDL in 1997, and subsequent concentrations have been less than the WQS the remainder of the monitoring period.

The Hopi Tribe WRP and NNEPA WQP established an agricultural livestock water supply WQS for lead at 100 µg/L. All reported concentrations are a result of the MDL. However, when the MDL is less than 100 µg/L, no positive concentrations above 100 µg/L have been identified.

Selenium concentrations measured at upstream and downstream alluvial monitoring locations are less than the agricultural livestock water supply WQS (50 µg/L), except for one detection (57 µg/L) at downstream monitoring location 172. The one selenium detection above 50 µg/L was followed by three samples that were less than 50 µg/L.

An agricultural livestock water supply WQS is not established for TDS. TDS is an aggregate indicator of the presence of a broad array of chemical constituents and provides a reasonable indication of the overall water quality. Elevated TDS concentrations typically correspond to elevated concentrations in one or more major cations or anions. Review of the upstream TDS data at location 87 indicates a significant increase from 2005 – 2010 (Figure 33). Monitoring location 87 is considered an upstream background location, and the cause for the significant increase is unknown. After the initial TDS increase at location 87 from 2005 – 2007, measured concentrations are returning to concentrations within the previously recorded range. The return to previously measured concentrations indicate the cause is likely not persistent, but the elevated TDS concentrations may migrate through the Moenkopi alluvium within the permit area. Measured TDS concentrations in downstream Moenkopi alluvial monitoring well 95, indicate the poorer quality water has not migrated to downstream alluvial well 95 (Figure 34). Overall, upstream and downstream monitoring of TDS indicates the range varies between 500 – 7000 mg/L. Continued monitoring at upstream and downstream monitoring locations continues to be necessary to assess if elevated concentrations are the result of mining related impacts from the Kayenta Mine Complex.

Navajo Generating Station – Kayenta Mine Complex EIS

The September 2016 Draft NGS-KMC EIS provides the following alluvial water quality summary:

“Both upstream and downstream concentrations of TDS and sulfate exceed concentrations recommended in literature for livestock. Some alluvial groundwater quality impacts would occur across the leasehold, but constituents would still generally reflect the background geologic setting. These would be minor impacts.”
(BOR, 2016)

5.2.1.2.3 Alluvial Quality Material Damage

Evaluation of alluvial water quality indicates water quality is subject to some seasonal variability and a large amount of variability from location to location. Agricultural livestock watering use was considered for evaluation; however, historical alluvial use locations within the alluvial cumulative impact area have all been abandoned and no attempts to develop alluvial water have been initiated over the past 40 years within the CIA. Accessibility to potable public water standpipes and retention of surface water impoundments for livestock watering make development of the saturated alluvium for livestock watering a challenging and maintenance-intensive alternative. After comparison of upstream water quality with downstream water quality related to WQS and major cations and anions, there are no indications that the mining operation is compromising the agricultural livestock supply water outside the permit area. The evaluation is supported by the Draft NGS-KMC EIS finding that water quality impacts across the leasehold would be minor. Alluvial water quality will continue to be monitored and evaluated against available livestock water quality standards.

Chemical Parameter	Agricultural Livestock Watering WQS	WQS	Units	Type	Dinnebito Wash CIA				Moenkopi Wash CIA			
					Location 170				Locations 19, 95, and 172			
					# Samples	Low	Median	High	# Samples	Low	Median	High
Aluminum	HT	5	mg/L	Dissolved	n=55	0.03	0.2	0.2	n=133	0.03	0.05	0.5
Arsenic	HT and NN	200	µg/L	Dissolved	n=55	1	1	6	n=133	0.5	1	7
Bicarbonate	NNS	NNS	mg/L	Dissolved	n=55	605	803.5	903	n=138	61	372	891
Boron	NN	5000	µg/L	Dissolved	n=55	210	290	380	n=134	30	120	310
Calcium	NNS	NNS	mg/L	Dissolved	n=55	440	504	596	n=135	60.3	463	600
Cadmium	HT and NN	50	µg/L	Dissolved	n=55	3	20	30	n=135	3	5	80
Chloride	NNS	NNS	mg/L	Total	n=55	32	46	70	n=137	10	43.5	96
Chromium	HT and NN	1000	µg/L	Dissolved	n=55	10	50	50	n=133	5	10	80
Copper	HT and NN	500	µg/L	Dissolved	n=55	10	50	80	n=133	5	10	50
Lead	HT and NN	100	µg/L	Dissolved	n=55	20	200	200	n=133	1	20	200
Magnesium	NNS	NNS	mg/L	Dissolved	n=55	421	483	629	n=137	17	260	610
Mercury	HT	10	µg/L	Dissolved	n=55	0.1	0.2	0.3	n=135	0.1	0.2	1.3
Selenium	HT and NN	50	µg/L	Dissolved	n=55	1	2.5	12	n=135	1	5	57
Sodium	NNS	NNS	mg/L	Dissolved	n=55	505	635.5	1150	n=137	63.1	310.5	737
Sulfate	NNS	NNS	mg/L	Total	n=55	3300	3960	5800	n=137	90	2523.5	4200
TDS	NNS	NNS	mg/L	Total	n=55	5718	6424	9540	n=138	420	4054	7120
Vanadium	HT and NN	100	µg/L	Dissolved	n=55	5	30	50	n=133	5	10	50
Zinc	HT and NN	25	mg/L	Dissolved	n=55	0.01	0.05	0.1	n=133	0.01	0.02	5.81

NNS - No Numeric Standard
WQS - Water Quality Standard

mg/L - milligrams per liter
µg/L - micrograms per liter

NN - Navajo Nation
HT - Hopi Tribe

CIA - Cumulative Impact Area
T- Total

Table 9. Downstream Alluvial Water Quality Summary (1986 – 2010), Kayenta Mine Complex.

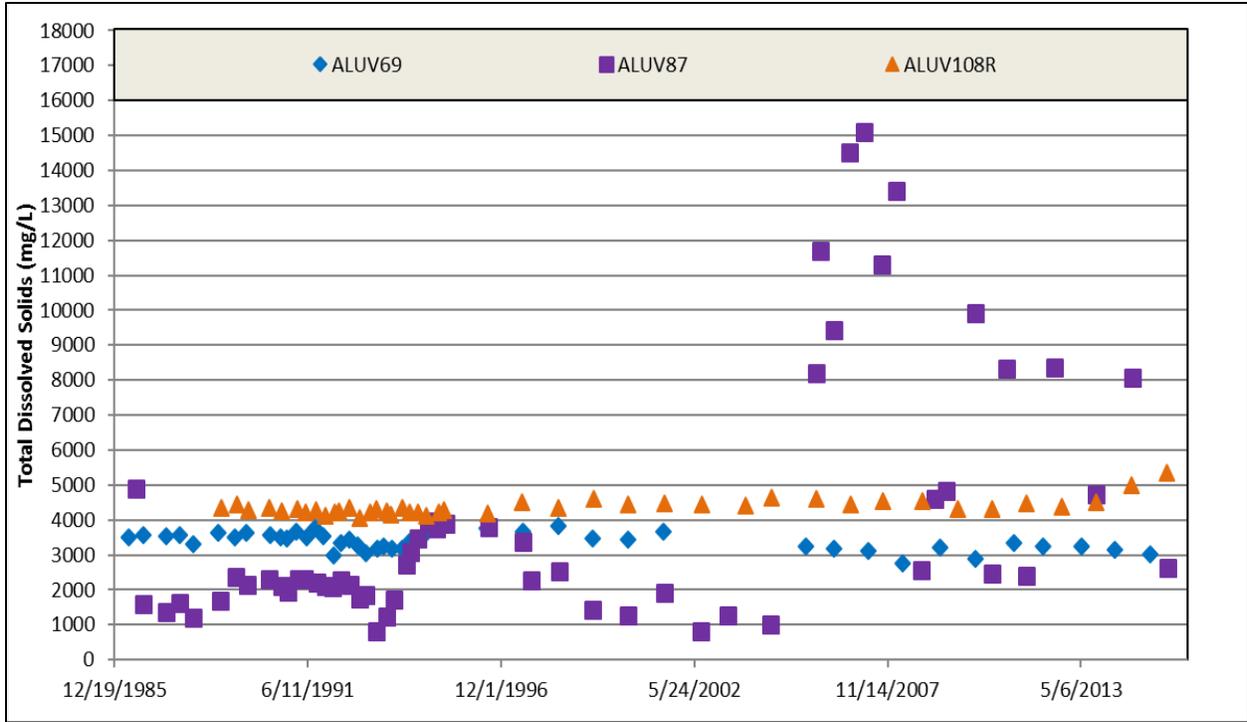


Figure 33. TDS Concentrations (1986 – 2015), Upstream Alluvial Monitoring Locations.

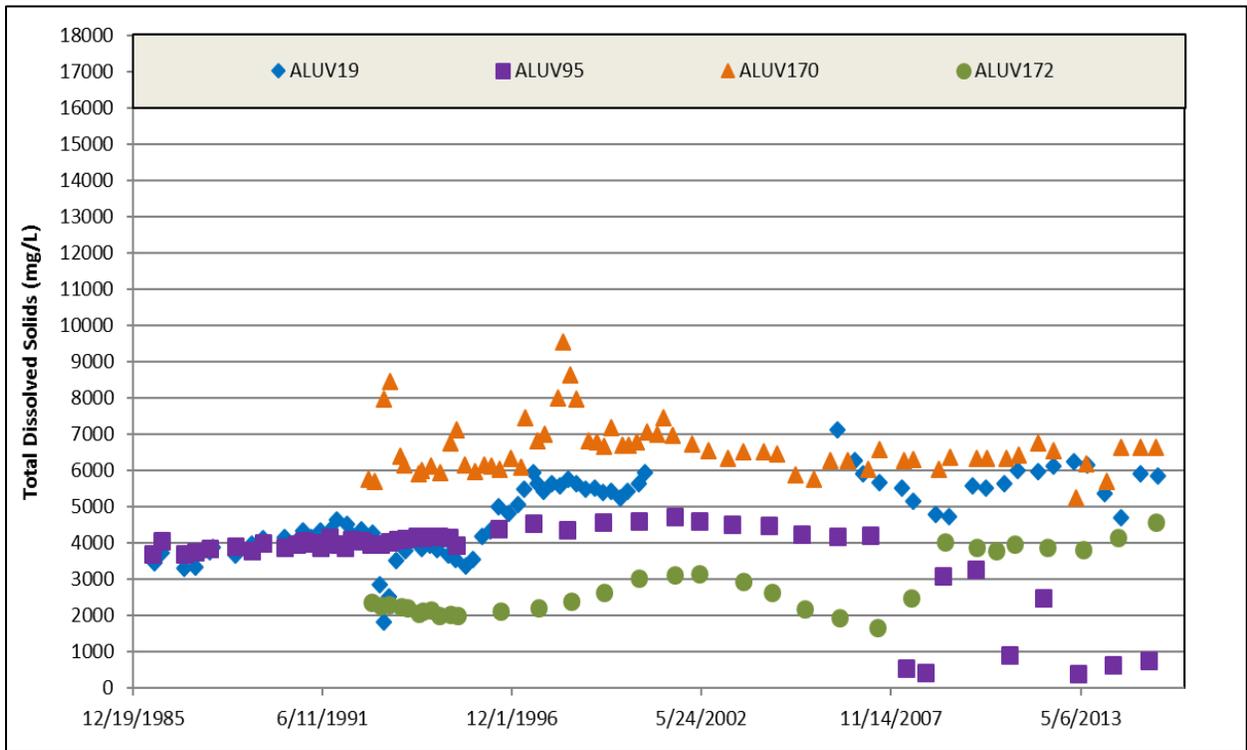


Figure 34. TDS Concentrations (1986 – 2015), Downstream Alluvial Monitoring Locations.

5.2.2 Wepo Formation

The Wepo Formation lies within the late Cretaceous Mesa Verde Group. Due to the late Cretaceous depositional environment, the water bearing zones of the Mesa Verde Group are largely perched and intertongue with less permeable material. The Wepo Formation contains low yielding perched aquifers in some locations, and the permeable aquifer zones pinch out or are vertically displaced owing to some minor structure within the Kayenta Mine Complex (PWCC, v.11, ch.18, 2016). The springs and seeps of the Mesa Verde Group identified within the permit area emanate from contact zones between the bottom of permeable sandstones and the top of relatively impermeable shale layers exposed along the sides of washes, discharging into the alluvium (PWCC, v.9, ch.15, 2016).

The depositional environment during the late Cretaceous left a thick complex sequence of intertonguing siltstone, mudstone, sandstone, and coal beds (Figure 6). The Wepo Formation contains some discontinuous saturated zones, but attempts to utilize this water source have received limited success. Coal resources in the Wepo Formation of the Mesa Verde Group are mined at the Kayenta Mine Complex, and may intercept groundwater from the upper part of the Wepo Formation. Limited interception of the saturated Wepo occurred during the mining of coal resource areas N-11, J-1/N-6, N-14, J-16, J-19/J-20, and J-21. Since surface mining will potentially intercept groundwater from the Wepo Formation, the hydrologic impacts in the Wepo Formation associated with mining were evaluated as part of the PHC determination (PWCC, v.11, ch.18, 2016). Similarly, OSMRE will evaluate the hydrologic consequences related to Wepo water quantity and quality, and assess the impact of the mining operations on the livestock water supply use of Wepo Formation water within the Wepo CIA.

5.2.2.1 Wepo Formation Quantity

PWCC observations of surface coal mining on Black Mesa has identified that “the permeable units within the Wepo Formation are perched aquifers in some locations, pinch out, or are vertically displaced owing to some minor structure within the Kayenta Complex” (PWCC, v.11, ch.18, 2016). Therefore, some conservative simplifying assumptions are necessary for impact evaluation of Wepo water quantity. The assumptions are conservative in that they overestimate the amount and areal extent of the Wepo water impacted. The overestimation of the annual water quantity withdraw allows for a protective delineation of a potential impact area for the Wepo Formation, and users of Wepo groundwater.

Assumptions of a continuous, confined, saturated Wepo Formation having a uniform thickness are significant simplifying assumptions for the purpose of hydrogeologic evaluation. Mining experience of the Wepo Formation, borehole data from geologic characterization of the coal resources throughout the Kayenta Mine Complex, and aquifer testing of monitoring wells in the Wepo aquifer zones support the conservative nature of the above assumptions (PWCC, v.10, ch.15, 2016). Wepo Formation Transmissivity, which reflects the ability of the aquifer to transmit water, are illustrated on Figure 18.

With respect to spoil material, which is predominantly composed of the Wepo Formation, these assumptions may not be as conservative. Where pit mining has occurred, replacing the original material of the Wepo Formation with spoil material, results in much higher porosity and permeability (PWCC, v.11, ch.18, 2016). This is due in part to the increase in surface area that occurs when coal is mined from the Wepo Formation, resulting in an increase of spoil material total volume, and changing the Wepo aquifer properties within the reclaimed areas of the Kayenta Mine Complex.

5.2.2.1.1 Wepo Formation Quantity Monitoring Program

Wepo monitoring locations have been installed within the Kayenta Mine Complex to assess water quantity impacts to the Wepo Formation water bearing units. Twenty-five Wepo monitoring wells are currently retained for evaluating impacts to the Wepo Formation. Recognizing the discontinuity of the Wepo aquifer, PWCC typically installed a Wepo monitoring well upgradient and downgradient of active and future coal pit areas to assess immediate water quantity impacts related to mining (Figure 16).

The historical and existing Wepo Formation monitoring well network provides the appropriate information to assess water quantity impacts attributed to the mining operations on the Wepo Formation. Therefore, OSMRE finds that the monitoring program of the Wepo Formation has been appropriately designed and implemented to provide the necessary information for hydrologic impact assessment.

5.2.2.1.2 Wepo Formation Quantity Impact Potential

Historical and existing users of the Wepo Formation water were identified within the Wepo CIA delineated in Section 2.2.1. Utilizing USGS, BIA, and Tribal databases, and PWCC field investigations, six Wepo well locations have been identified within the CIA, and are denoted by the following well IDs on Figure 8: 8T-506, 8A-PHS-15, 4K-309, 4T-512, 4K-380, 4T-405. Well 8T-506 is completed in both the Wepo and underlying Toreva Formation. The available information for additional wells only includes the location coordinates and suspected aquifer zone being developed.

Nineteen Wepo aquifer springs and seeps have been identified within the Wepo water quantity impact area using USGS, BIA, Tribal databases, and PWCC field investigations. The 19 springs are denoted by the following IDs: DM-6, Hogan Gulch Spring, Goat Spring #2, 4M-190A, 4M-191, 2A-44, 8A-147, NSPG91, NSPG92, NSPG111, NSPG140, NSPG147, 8A-153, 8A-139, 8A-143, 8A-145, Pine Spring, Great Spring, and Sand Spring (Figure 8). Field investigation of the water resources within and immediately surrounding the Kayenta Mine Complex indicates that many of these springs do not presently discharge, occur only as damp spots, or are indistinguishable in baseflow reaches (PWCC, v.11, ch.17, 2016). Spring locations NSPG140, NSPG91, NSPG92, NSPG111, NSPG147, Sand Spring, Goat Spring #2, and Hogan Gulch Spring are monitored for evaluation of Wepo spring water quantity impacts. Discharge at these eight springs ranges from 0 - 4.2 gallons per minute, with NSPG92 having the highest recorded flow rate of the eight springs at 4.2 gallons per minute (PWCC, v.11, ch.18, 2016). Although use of Wepo Formation water is limited due to both the hydraulic and water quality characteristics of the aquifer, PWCC has minimized impacts to designated and foreseeable uses through water supply replacement within the Kayenta Mine Complex. Given that the quantity of water available for use through this system is much greater than the original quantity that was used from the Wepo Formation, impacts to the designated uses have been minimized.

5.2.2.1.3 Wepo Formation Quantity Material Damage

OSMRE finds that the mining operations at the Kayenta Mine Complex will not adversely impact existing or potential users of the Wepo Formation water outside the permit area due to the areal discontinuity of the saturated Wepo Formation. Additionally, eight Wepo springs are monitored within the Kayenta Mine Complex and adjacent area. OSMRE has determined that the existing Wepo monitoring program is in compliance with 30 CFR 816.41, and PWCC shall continue the existing monitoring program for Wepo wells and Wepo springs. If the mining operation results in sustained spring flow depletion at these eight springs or well yield depletion at the eight wells, PWCC shall mitigate as required in 30 CFR 780.21. Therefore, OSMRE will not establish a material damage criterion specific to protection of Wepo water quantity.

5.2.2.2 Wepo Formation Quality

The removal of overburden and coal occurs in the Wepo Formation of the Mesa Verde Group at the Kayenta Mine Complex. The Wepo Formation is incised by surface water drainages within the permit and adjacent area, causing noncontiguous saturated conditions within the Wepo Formation. However, these noncontiguous saturated sections of the Wepo Formation may be developed for water use. As presented previously, elevated TDS in the Wepo water limits development for domestic water supply within the permit area, but Wepo water may be utilized for livestock watering at some locations.

5.2.2.2.1 Wepo Formation Quality Monitoring Program

Mining areas that intercept a portion of saturated Wepo Formation act as groundwater sinks, and the adjacent formation water will flow back toward the mined area in some locations and potentially saturate a portion of the backfill spoil material replaced in the coal resource areas. Due to the potential for backfill spoil material to re-saturate and cause water quality degradation, several focused spoil water studies were conducted in coal resource areas N-7, N-2, N-14, and J-16, which intercepted Wepo Formation water. Eleven spoil wells were installed in the N-2 spoil; two in the N-7 spoil, two in N-6 spoil; six in N-14 spoil, and three wells in the J-16 spoil (Figure 16).

The historical and existing Wepo monitoring well network and focused spoil saturation studies provide the necessary information to assess water quality impacts attributed to the mining operations on the Wepo aquifer. Therefore, OSMRE finds that the hydrologic characterization and monitoring program of the Wepo aquifer system have been appropriately designed and implemented to provide the necessary information for hydrologic impact assessment.

5.2.2.2.2 Wepo Formation Quality Impact Potential

The concentrations of major cations and anions identified at background Wepo monitoring wells were compared to the median concentrations from spoil monitoring wells. Spoil water quality provides an indication of local water quality impacts of mining on Wepo Formation water. The major cation concentrations of sodium, calcium, and magnesium are illustrated on Figure 35. The major anion concentrations of chloride, bicarbonate, and sulfate are illustrated on Figure 36. Since TDS provides an indication of the overall water quality, Figure 37 illustrates background Wepo TDS concentrations compared to the median spoil TDS concentration.

Limited precipitation and associated infiltration to groundwater, and the discontinuous nature of water bearing zones in the Wepo Formation cause resaturation of the spoil material in the reclaimed mine pits to be slow. Many of the spoil wells that have been installed to monitor the potential effects of reclamation are still dry. Any impacts adjacent to the mine pits are minimized due to the shift of the hydraulic gradient towards the mine pits caused by this extremely slow rate of resaturation. This limits any effective transport of spoil water to adjacent areas of the Wepo aquifer.

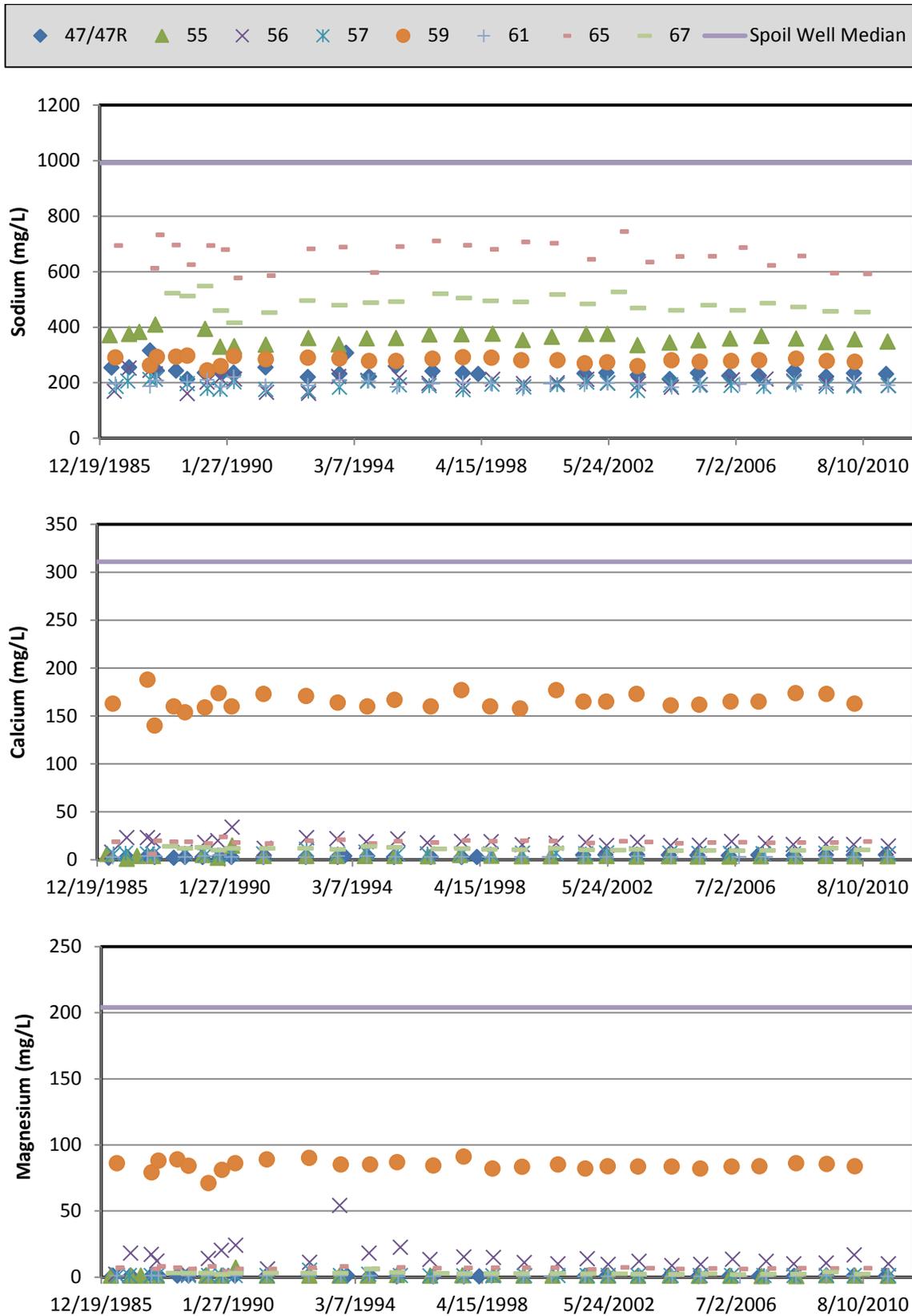


Figure 35. Wepo Background Wells and Spoil Median Concentration for Major Cations.

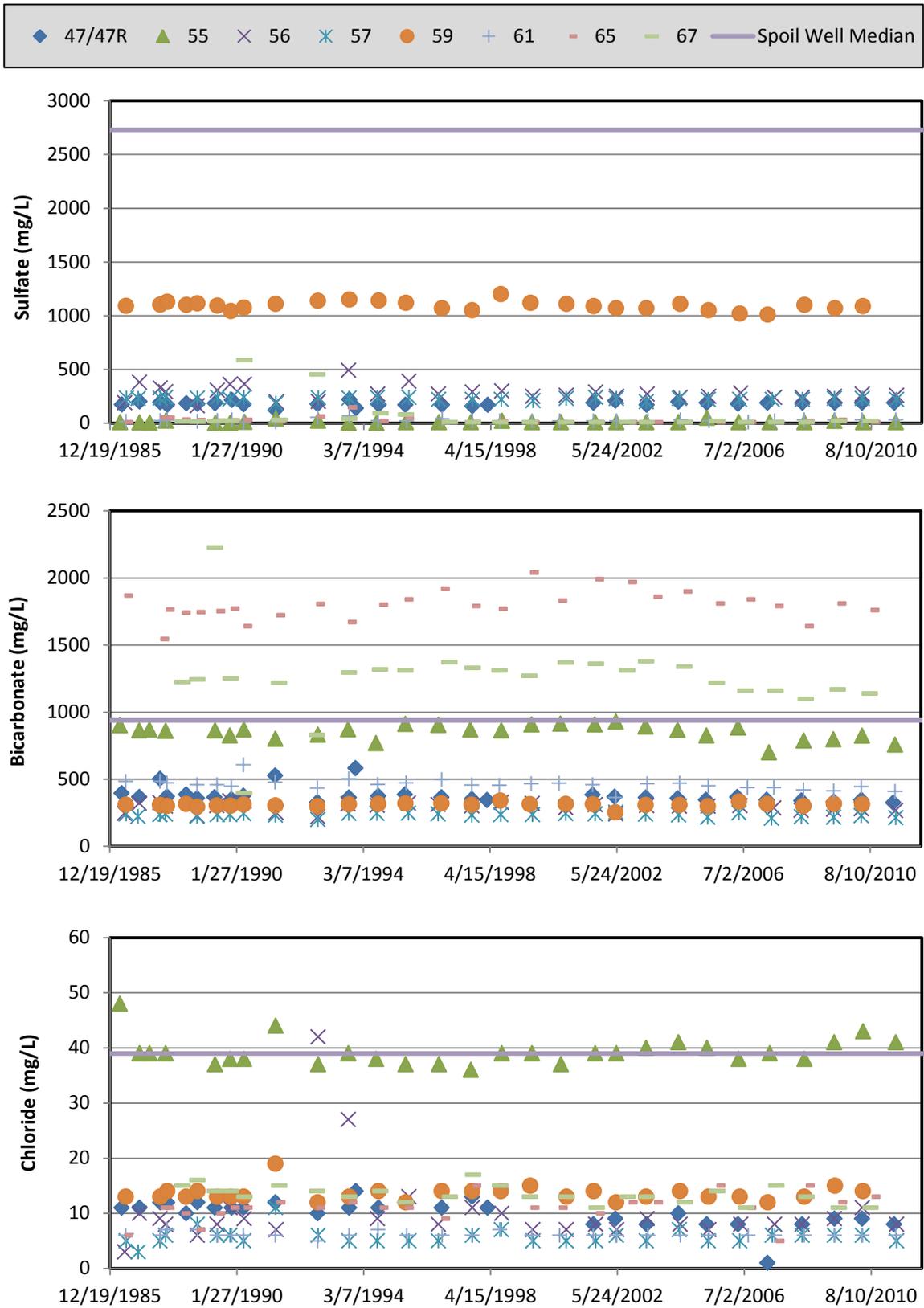


Figure 36. Wepo Background Wells and Spoil Median Concentration for Major Anions.

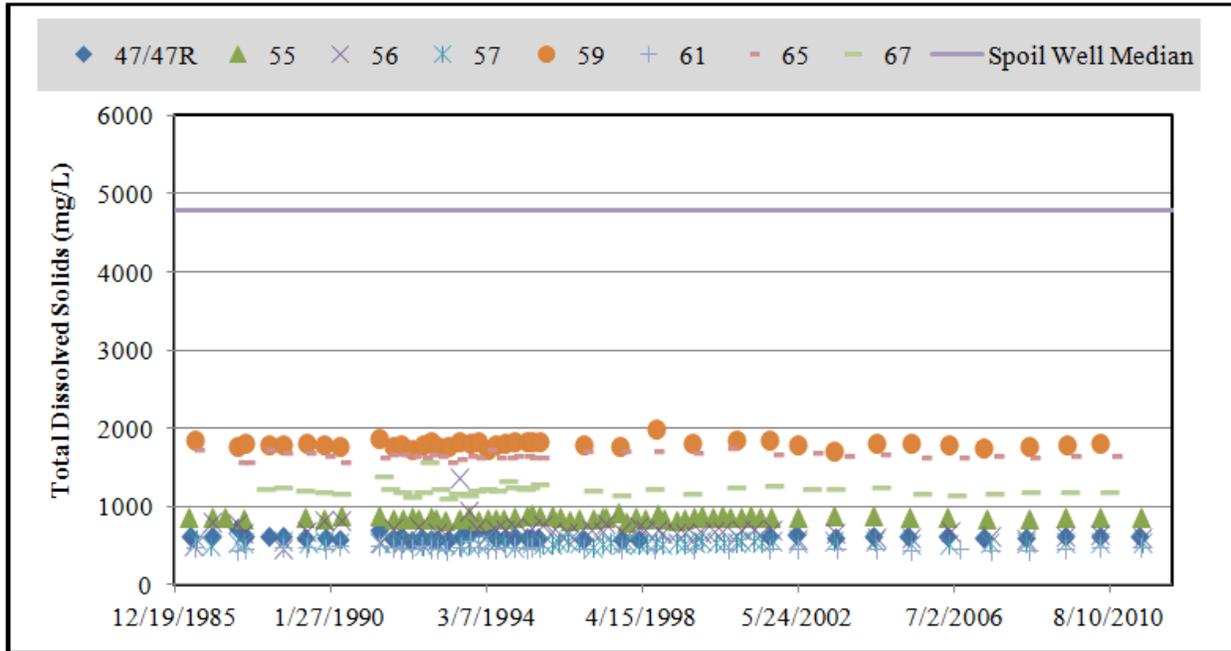


Figure 37. Wepo Background Wells and Spoil Median Concentration for TDS.

Navajo Generating Station – Kayenta Mine Complex EIS

The September 2016 Draft NGS-KMC EIS provides the following Wepo water quality observations:

“Dissolved trace elements are generally at low concentrations or are undetected throughout the leasehold. Sulfate and bicarbonate concentrations vary, and sodium is typically a dominant constituent. The median background bicarbonate concentration is about 170 mg/L. Higher sulfate and lower bicarbonate concentrations occur within smaller locales in the coal leasehold. The median background TDS concentration is about 860 mg/L, but higher values occur in some parts of the leasehold.” (BOR, 2016, Page 3.7-33)

“Historical water quality reductions from long-term mining activities have occurred, but concentrations have generally remained within livestock watering criteria or recommended values. Some springs or seeps issuing from the Wepo Formation downgradient of mining activities may have become more mineralized, but remain within background water quality ranges at springs within the leasehold. Existing Wepo aquifer groundwater quality typically continues to support aquatic and wildlife uses at springs.” (BOR, 2016, Page 3.7-108)

5.2.2.2.3 Wepo Formation Quality Material Damage

The impact of mining at the Kayenta Mine Complex on Wepo Formation water quality outside of the permit area has been negligible with respect to livestock uses. Historically, there has been only isolated use of water from the Wepo Formation for livestock, and generally the water quality prevents it from being a widespread water source within the permit and adjacent area. Although spoil water could conceivably migrate into Wepo Formation along the periphery of backfilled mine pits, the hydraulic

gradient is toward the spoil from the Wepo Formation. Combined with the low hydraulic conductivity and the discontinuous nature of Wepo Formation, there is no indication that water from the spoil is migrating or would migrate to any great extent into the Wepo Formation. Spoil water quality for major cations, anions, and TDS are elevated compared to background concentrations; however, the potential for degraded water quality migration outside the mine pit area is limited. If water quality migration outside the mine pit area occurred, the alluvial water quality monitoring program in the receiving alluvial channels will identify the migration of associated impacts. Therefore, OSMRE will not establish a material damage criterion specific to mining impacts on Wepo Formation water quality. OSMRE annually evaluates monitoring data to ensure impacts to the Wepo Aquifer are minimized to the mine pit areas.

5.2.3 D aquifer

The D aquifer is confined above by the vertically thick and regionally extensive Mancos Shale Formation. The D aquifer is confined below by the Carmel Formation in the northeastern area of Black Mesa, and the Carmel Formation becomes semi-confining toward the southwest edge of Black Mesa. Baseline conditions for the D aquifer system were established using water quality analysis (including isotope evaluation) and using groundwater modeling. The 3D Model (PWCC, v.11, ch.18, 2016) was developed to evaluate the potential mining related impact on the D and N aquifers separated by the Carmel Siltstone Formation. However, it should be noted that substantially less historical and transient information exists for the D aquifer system compared to the N aquifer system. A reasonable steady state (pre-significant pumping) water level map was provided using the available D aquifer historical information (Figure 21).

PWCC operates water supply wells within the Kayenta Mine Complex to support mining and reclamation operations. Historically, some water supply wells were partially screened in D aquifer hydrologic units (Table 10). Water supply wells NAV2, NAV3, NAV4, NAV5, NAV6, NAV7, and NAV8 screened in portions of the Entrada sandstone (overlying the Carmel Formation), and NAV2 and NAV5 also screened in portions of the Morrison Formation (overlying the Entrada Formation). However, on January 23, 2015, after Tribal and OSMRE approval, NAV5 was abandoned, and NAV3 and NAV9 were idled. Then, following Tribal and OSMRE approval, PWCC eliminated wellfield communication with and chemical influence from the D aquifer between December 2015 and March 2016 by abandoning NAV4 and rehabilitating NAV7 by sealing off the Entrada Formation.

Since the D aquifer system water is partially or solely relied on at some communities for municipal water supply, agricultural use, and cultural use, the water quantity impacts associated with mine related drawdown are of concern and the subject of evaluation in this section.

5.2.3.1 D aquifer Quantity

The D aquifer system is not extensively developed for water supply use. Wells that pump water from the D aquifer system are typically windmills, providing water for agricultural livestock water supply. PWCC eliminated wellfield communication with D aquifer in March 2016. The communities of Chilchinbito, Kitsillie, and Kykotsmovi withdraw water from the D aquifer system for domestic water supply.

Two windmill wells are within 15-miles of the PWCC pumping center: locally identified as 4T-402 and 4K-387 (Figure 20). Windmill well 4T-402 withdraws water from the Dakota Sandstone Formation and is approximately 1-mile from the PWCC pumping center. Windmill well 4K-387 is screened in both the Cow Springs and Dakota Formations, and is approximately 15-miles from the PWCC pumping center. 2012 simulated drawdown attributed to PWCC pumping is greatest at well 4T-402, and is estimated at 40 feet of drawdown (PWCC, v.11, ch.18, 2016). The more distant windmill, 4K-387, is estimated to realize approximately 20-feet of drawdown related to PWCC and community pumping; however, the location is no longer available for use (PWCC, v.11, ch.18, 2016).

Table 10: PWCC Pumping Wells Screened Aquifer Zone (feet) (PWCC, v.11, ch.15, 2016).

Well Number	D-Aquifer			N-Aquifer			
	Morrison	Entrada	Carmel	Navajo	Kayenta	Wingate	Chinle
2	0 ¹	0 ¹	27	735	150	194	0
3/3P	0	0	10	690	170	268	0
4	26	160	150	700	60	308	0
5	203	155	150	725	155	229	0
6/6P	0	0	0	684	160	294	18
7	0	122	150	690	165	206	0
8	0	0	163	787	0	0	0
9	0	0	4	710	150	245	0

¹Well 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. D-aquifer water has the potential to migrate into the well bore.

5.2.3.1.1 D aquifer Quantity Material Damage

Figure 38 illustrates the D aquifer model simulated drawdown attributed to PWCC and community pumping at years 2005 and 2012 (PWCC, v.11, ch.18, 2016). Water quantity concerns have been identified for domestic and agricultural water supply. The windmill in closest proximity to PWCC pumping has an available water column of approximately 600 feet, and windmill well 4K-387 is no longer operational. Therefore, OSMRE finds that PWCC impact on locations 4T-402 and 4K-387 will not adversely affect the existing or reasonably foreseeable use at these locations. If the water availability is compromised at location 4T-402, PWCC is responsible for water replacement in accordance with 30 CFR 816.41(h). Therefore, OSMRE will not establish a material damage criterion for the D aquifer quantity due to the absence of potential impact on domestic supply water, livestock supply water, or agricultural supply water.

5.2.3.2 D aquifer Quality Material Damage

Figure 22 illustrates difference in confined aquifer potentiometric surface between the D aquifer and N aquifer systems. Section 4.2.4.2 characterizes the overall D aquifer system quality as poor, compared to the N aquifer system. The natural hydrologic impact potential is for poorer quality D aquifer water to migrate downward to the N aquifer system (Truini and Longworth, 2003). PWCC eliminated wellfield communication with D aquifer in March 2016. Since no hydrologic mechanism is present for PWCC operations to impact D aquifer quality, the mining and reclamation operations will not cause material damage outside the permit area.

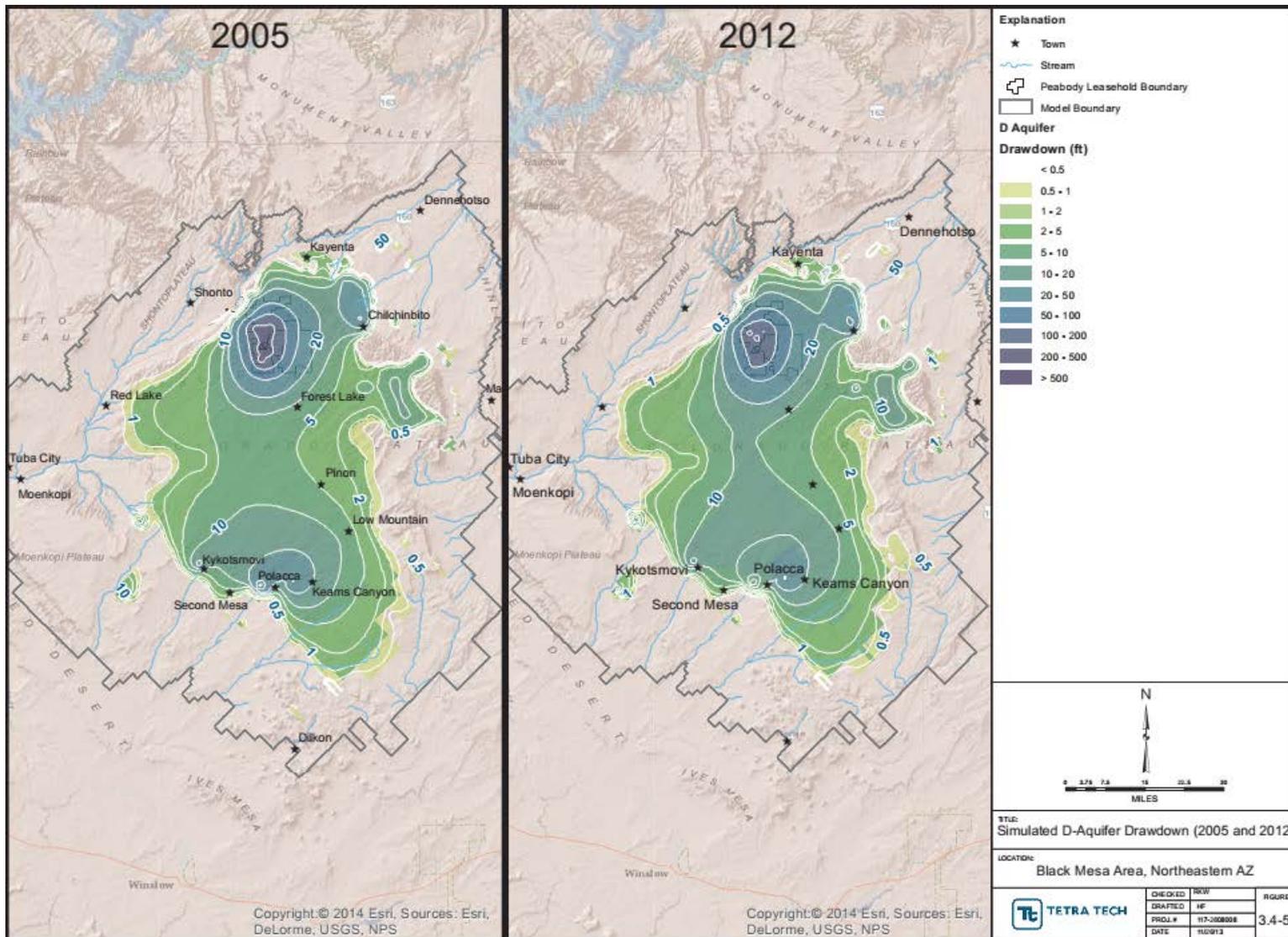


Figure 38: Groundwater Model Simulated D aquifer Drawdown in 2005 and 2012 (PWCC, v.11, ch.18, 2016).

5.2.4 N aquifer

PWCC pumping of the confined N aquifer prompted several concerns related to reduction in water pressure. The following N aquifer groundwater pumping concerns of PWCC coal mining and reclamation operations will be evaluated:

- Impact of PWCC drawdown on community water supply wells.
- Impact on N aquifer baseflow to area washes.
- Impact on N aquifer spring discharge.
- Potential for land subsidence related to N aquifer drawdown.
- Potential for water quality degradation from the overlying D aquifer.

PWCC commissioned the development of a regional groundwater flow model for the D aquifer and N aquifer systems (3D Model), to be used for predicting and assessing potential mining related hydrologic impacts. “Work on the Peabody 3D model (3D Model) began in 1997, and was completed in 1999. The 3D model included 7 layers, and incorporated formations in the D aquifer (Dakota, Morrison, Cow Springs, and Entrada), the Carmel formation (which serves as a confining bed for the underlying N aquifer), and the formations in the N aquifer (Navajo, Kayenta, and Wingate). It was calibrated using water-level and pumping information available through 1996. Calibration was performed using PPEST (Doherty, 1998), a parallel parameter-estimation software package, to optimize the calibration process and result in an unbiased calibration. The water budget for the 3D Model was based on somewhat limited streamflow data, and very limited spring discharge and evapotranspiration (ET) information. The uncertainty in the water budget was evaluated by explicitly admitting that the uncertainty existed and calibrating four different models based on different assumptions about the recharge and discharge rates. As the intended use of the model was to evaluate the effects of Peabody’s pumping, the calibration effort concentrated on matching the observed drawdown in the Black Mesa observation wells, with less emphasis on water levels and community drawdown” (PWCC, v.11, ch.18, Attachment IV, 2016).

As described in the permit application package, “The intent of this model is to replace the previous transient groundwater flow model developed and calibrated initially during the late 1990s, and maintained during the period between 1999 and 2012” (PWCC, v.11, ch.18, Attachment IV, 2016). The addendum replaces Chapter 5 from the 1999 model report. “Important goals of the 1999 3D model and current model include:

1. Improve the general understanding of Black Mesa groundwater flow processes and system parameters;
2. Provide a robust tool for making informed decisions about the effects of PWCC’s pumpage based on (1) high-quality hydrogeologic data on PWCC’s past pumpage and responses in the BM monitoring wells and (2) water budget (recharge and discharge) information;
3. Estimate the effects of community pumpage based on recent measurements of pumpage and revised estimates of earlier pumping, and on water-level measurements made in production wells and the BM monitoring wells; and
4. Predict relative changes in discharge to streams and springs caused by changes in pumpage.

The primary purpose for updating the model is for use in preparing the PHC section in PWCC’s permit applications for their operations at the Kayenta Mine Complex. As a result of the improvements

implemented throughout the model and the availability of additional pumping and water-level information near the communities, the model can also be used to evaluate the cumulative effects of PWCC and community pumping.” (PWCC, v.11, ch.18, Attachment IV, 2016)

The 2014 updated model was peer reviewed by the USGS (Leake and others, 2016). The following statements are provided in the USGS review Summary and Conclusions (Leake and others, 2016):

- The PWCC (Tetra Tech, 2014) model is a recently calibrated model that can simulate the effects of past groundwater development in the D and N aquifers in the Black Mesa Area.
- The combination of MODFLOW packages used in the PWCC model to represent real hydrologic features leads to improved simulation capabilities in comparison to previous models including the original PWCC (1999) model, the USGS model (Brown and Eychaner, 1988), and the WNHN model (HDR Engineering Inc., 2003).
- This evaluation found no problems with the PWCC model that would preclude its use by the NGS-KMC EIS team. Given the complexity of the N and D aquifer system in the study area and the amounts and types of data available, the calibration of the PWCC model described in Tetra Tech (2014) seems to be reasonable. Observed streamflow in most of the major washes is simulated reasonably well.

Based on the summary and conclusions provided in the USGS review, the updated 2014 PWCC groundwater flow model is the best tool available to evaluate PWCC effects on N aquifer discharge, and will be used for formulating material damage criteria.

The 3D Model accounts for approximately 70-percent reduction in PWCC pumping, which occurred after December 31, 2005, and makes N aquifer potentiometric surface predictions based on community and PWCC pumping, and PWCC only pumping scenarios through the life-of-mine and reclamation operations (2057).

5.2.4.1 N aquifer Quantity

Groundwater flows from areas of high groundwater hydraulic head to areas of lower groundwater hydraulic head. The areas of high groundwater head occur near the predominant recharge areas to the northwest and southeast of the Black Mesa basin (Figure 27). The aquifer naturally discharges as springs and baseflow to the northeast and southwest of the Black Mesa basin at areas of lower groundwater elevation. Prior to N aquifer pumping, the steady-state flow system pattern had a hydrologic groundwater divide oriented northwest to southeast, and passing near the southwest corner of the Kayenta Complex (Figure 27). A groundwater divide is a non-structural boundary from which groundwater moves away from the divide in both directions, and flow does not occur across the boundary. The steady-state flow system was developed from the evaluation of all available water levels in the Black Mesa basin.

After evaluating the quality of available water level information, several hundred wells (Figure 20) and springs (Figure 26) were retained for the development of a steady-state potentiometric surface, and used as pre-pumping calibration targets. In a calibrated steady-state model, simulated water levels should not significantly differ from measured water levels. The difference between the simulated and measured water levels is considered the residual error, and represents the difference between model derived hydraulic head and field measured target values. The procedure for calibrated steady-state model development is explained in greater detail in the permit application package (PWCC, v.11, ch.18, Attachment IV, Section 2, 2016).

Groundwater pumped from the confined N aquifer is released from aquifer storage, making it important to understand the concept of aquifer storage. The N aquifer is approximately 2500 feet below ground surface at the Kayenta Mine Complex. Due to significant depth, N aquifer matrix is under a tremendous

amount of stress from the weight of the overlying rock and water. The pressure of the water and the structural skeleton of the aquifer material together support the downward stresses induced by the weight of the overlying material. The difference between the downward stress and the water pressure is considered the effective stress, that part of the downward stress that is supported by the aquifer matrix (structural skeleton). The water and the aquifer matrix itself respond to the applied effective stress by expanding and contracting.

For instance, water fills the void spaces of the Wingate Sandstone, Moenave Formation, Kayenta Formation, and the Navajo Sandstone forming the N aquifer. When the N aquifer is pumped, water pressure decreases due to a reduction in interstitial pore water pressure caused by the pumping well. Therefore, the water pressure that was initially countering the downward stresses is reduced, and the stress load borne by the aquifer matrix increases. Since the net pressure is less (original water pressure minus pumping induced pressure decline) when pumping occurs, water levels decline when compared to the original steady state condition. This pumping induced water level change between pre- and post-pumping is known as drawdown; and its areal extent known as the cone of depression. Additionally, the expansion and contraction of the water in the aquifer and the aquifer matrix itself are characterized by the change in total hydraulic head in a well. The total hydraulic head is reflected in the static water level found in the well bore and respond to changes in the hydrostatic (water) pressure. The water levels in the confined N aquifer reflect the hydrostatic pressure regime in the aquifer and are an indication of the net stresses exerted on the N aquifer.

Specific storage is defined as the volume of water that a unit volume of aquifer takes into or releases from storage under a unit change in hydraulic head under saturated aquifer conditions (Freeze and Cherry, 1979). As the cone of depression grows, a larger area of aquifer material is available to contribute water to the pumping well. Therefore, drawdown near the pumping center will occur quickly at first, with drawdown exponentially slowing as a greater volume of aquifer material is influenced. In the confined area of the N aquifer system for the Black Mesa basin, PWCC and community pumping has occurred from 1968 to present. The most recent USGS N aquifer monitoring reports that the hydrographs for all but one of the dedicated Black Mesa (BM) observation wells have shown consistent water level declines in the confined area since 1972 (Macy and Unema, 2014). Due to the generally constant pumping volume from 1969-2005, the rate of static water level decline has slowed in recent years as the cone of depression has encompassed a larger contributing area. The increase in the volume of aquifer influenced by pumping has allowed more water to be released from storage, thus slowing the rate of growth of the cone of depression.

5.2.4.1.1 N aquifer Quantity Monitoring Program

As PWCC and community pumping has continued in the Black Mesa region since 1968, the flow system has changed, and the system is no longer in steady-state equilibrium as water continues to come from aquifer storage in the confined N aquifer attributed to the decrease in N aquifer water pressure from pumping. The changes are monitored by the USGS using an areally extensive monitoring network of the confined and unconfined portions of the N aquifer (Figure 39). Of the wells monitored, 6 are dedicated for the sole purpose of monitoring water level changes, and are not pumped for any beneficial use. Wells that are periodically pumped may give a false representation of the drawdown in the regional aquifer system since small cones of depression develop at the pumping wells. Therefore, in an effort to get the best annual representation the regional aquifer system using available wells, the USGS attempts to only collect and report a water level measurement after the well remains idle for an appropriate period of time. The idle, non-pumping, period will vary from location to location depending on the magnitude of pumping stress at the various community wells or remote windmills. If the recent pumping occurred at the location at the time of data collection, a drawdown value will not be reported since it will give a false representation of the regional aquifer drawdown.

Six monitored wells in the USGS monitoring program are not pumped, and identified as BM-1 through BM-6 (Figure 39). The BM-well series were installed in the early 1970's, and have a nearly complete non-equilibrium water level record. Monitoring wells BM-2, BM-3, BM-4, BM-5, and BM-6 are equipped with automated continuous recording devices that record a water level measurement every 15-minutes, and the data is posted to a USGS website every 4-hours (USGS, 2016).

The BM-well series are primarily completed in the Navajo Sandstone, and were specifically located and installed for the purpose of evaluating drawdown related to pumping of the N aquifer. Since the BM-well series are not pumped for water supply purposes, the water levels represent true N aquifer system drawdown. Therefore, the quality of water level data in the BM-well series is extremely high for OSMRE's regulatory purposes. OSMRE finds that the N aquifer groundwater quantity monitoring program is currently sufficient for OSMRE to make the required evaluation for material damage potential in this CHIA.

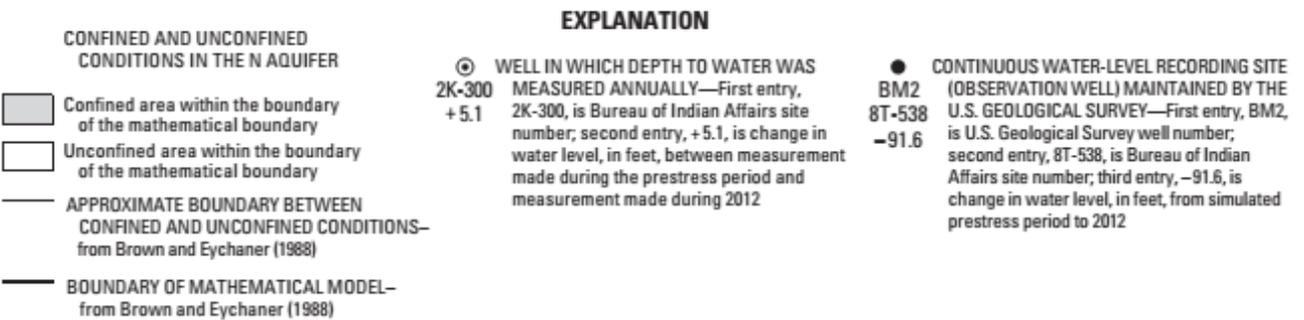
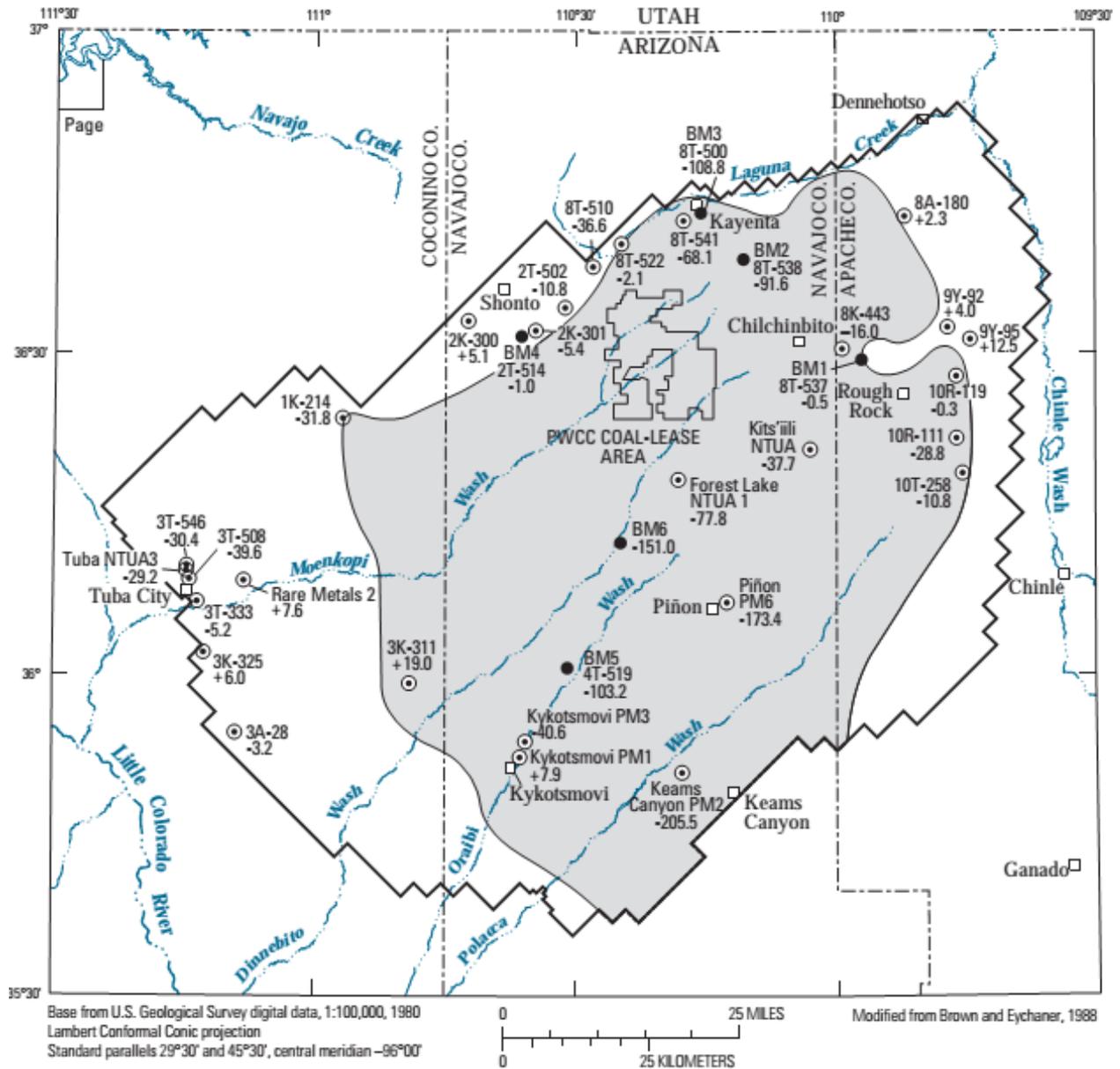


Figure 39: N aquifer level changes from the pre-stress period to 2012 (Macy and Unema, 2014).

5.2.4.1.2 Transient Modeling

Changes in the regional groundwater system over time can be identified by using a numerical groundwater flow model to simulate known pumping rate stresses in the hydrologic system after calibration of steady-state conditions (i.e. baseline) and pumping conditions. Most notably, the extent and magnitude of N aquifer system drawdown can be reasonably simulated for the regional system. The simulation of changing drawdown over time is considered transient modeling. Similar to the steady-state simulation, the transient model simulates all the inflows and outflows to the hydrologic system through time, and uses various snapshots in time of the measured drawn down water levels as calibration targets.

The high quality data and the spatial distribution of the BM-well series locations provided justification to weight the BM-well series data with a higher confidence compared to other transient calibration target locations. Specific information on the weighting factors for the drawdown residuals can be found in the 3D Model report (PWCC, v.11, ch.18, Attachment IV, Section 2, 2016). Since the BM-well series have the most complete water level records, and were installed specifically for evaluating N aquifer drawdown, considerable effort was taken to numerically simulate the measured drawdown in the BM-wells while honoring the geologic model. After reviewing the calibrated transient model, OSMRE has determined that the calibrated model provides acceptable agreement with the measured water level changes. Figure 40 illustrates a comparison of measured (black) water levels and model simulated (blue) at location BM-6 for the dataset (through 2012) including the period after PWCC reduced their pumping at the end of 2005.

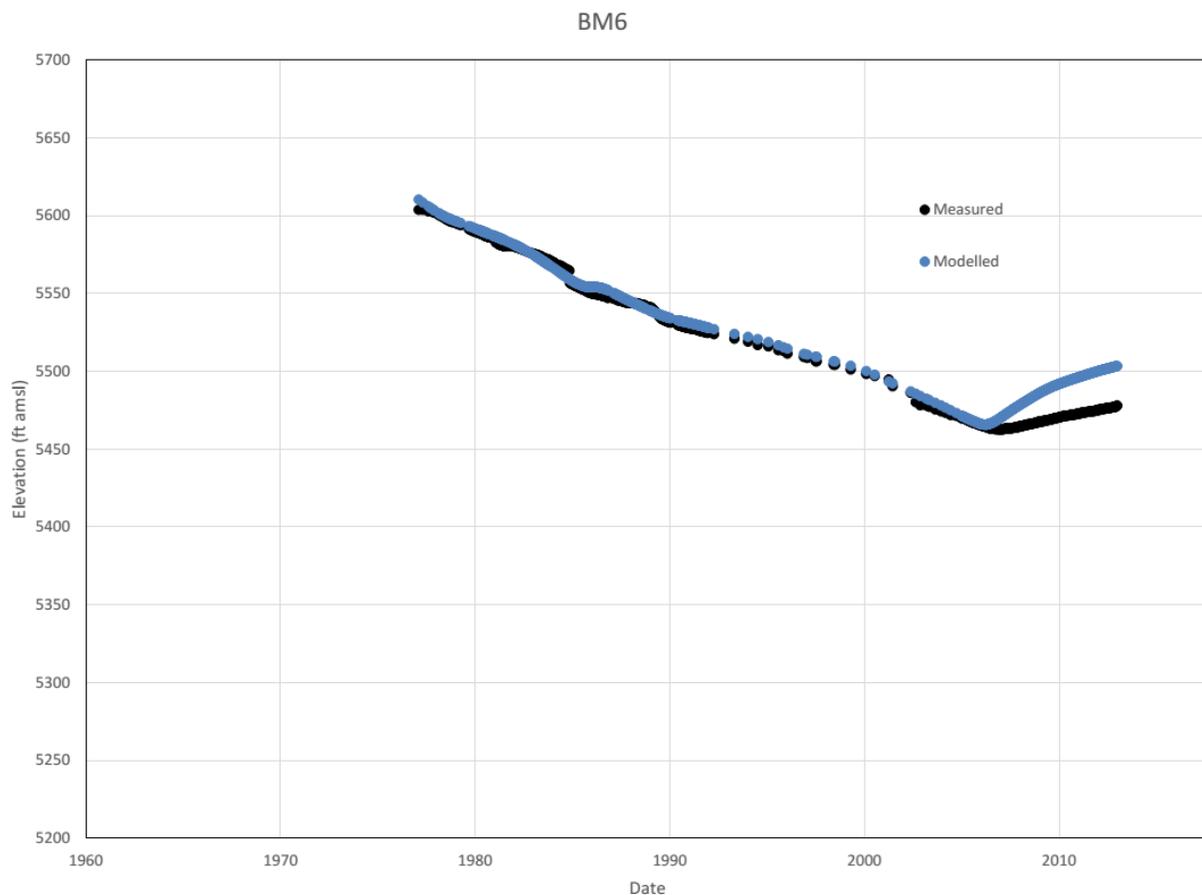


Figure 40: Measured (Black) and Model Simulated (Blue) Water Level at BM-6 (PWCC, v.11, ch.18, Attachment IV, Figure 3.4-1, 2016).

In summary, PWCC provided a numerical groundwater flow model of the Black Mesa basin for the D aquifer system and the N aquifer system; representing the D aquifer system as three hydrogeologic units, the N aquifer system as three hydrogeologic units, and separated by a low permeability confining unit. The model was successfully calibrated to simulate non-pumping equilibrium conditions (pre-1956), and then was successfully calibrated to simulate measured drawdown from 1956 through 2012. Once the transient groundwater model can adequately simulate drawdown when compared to measured drawdown while honoring the conceptual geologic model, the flow model is considered calibrated, and can be used for predictive simulations. Several sensitivity analyses provided support that the 3D Model will reasonably simulate predictive drawdown effects from PWCC pumping and community pumping while honoring the conceptual geologic model (PWCC, v.11, ch.18, Attachment IV, Section 4, 2016). The 3D Model will be used to evaluate concerns related to the PWCC pumping of the N aquifer, including (1) impact to USGS monitored confined N aquifer water supply wells, (2) impact to irrigation users in the Moenkopi area, and (3) impact to N aquifer baseflow and spring discharge.

5.2.4.1.3 N aquifer Impact Potential to Existing and Foreseeable Uses

Community Water Supply Wells

PWCC began pumping the N aquifer system to support mining operations at the Kayenta Mine Complex in 1968 at 100 ac-ft/yr (Macy and Unema, 2014). By 1972, the annual pumping rate increased to 3,682 ac-ft. From 1972 through 2005, the average annual pumping rate was 3,983 ac-ft/yr, with the highest annual withdraw of 4,643 ac-ft occurring in 2002 (Macy and Unema, 2014). On January 1, 2006, the annual use of N aquifer decreased to an approximate rate of 1,400 ac-ft/yr.

Community pumping for municipal water supply also occurs in the confined N aquifer. In 1968, municipal community pumping in the confined N aquifer was 150 ac-ft (Macy and Unema, 2014). Municipal pumping rates steadily increased to 1,610 ac-ft of annual withdraw in the confined N aquifer in 2000, and averaged 1,448 ac-ft from 2007 - 2011 (Macy and Unema, 2014).

As described previously, groundwater pumping reduces pore water pressure. Since the net pressure is less (original water pressure minus pumping induced pressure decline) when pumping occurs, water levels have declined when compared to the original steady state condition. The pumping induced water level change between pre- and post-pumping is known as drawdown; and the areal extent of which is known as the cone of depression. It is the cone of depression in the confined N aquifer, represented by changes in pore water pressure, which has been raised as a concern by area residents.

As water is released from confined storage and the cone of depression grows, a larger area of aquifer material is available to contribute water to the pumping well. Therefore, drawdown near the pumping center will occur quickly at first, with drawdown exponentially slowing as a greater volume of aquifer material is influenced. Figure 41 illustrates the extent and magnitude of drawdown created by PWCC and community pumping from 1969 to 2005, and from 1969 to 2012. Although the saturated thickness in the confined N aquifer has not changed, the drawdown contours represent a reduction in water pressure. Since a 70-percent reduction in PWCC pumping began on January 1, 2006, Figure 41 (year 2005) illustrates the approximate magnitude and extent of PWCC pumping influence on the N aquifer. Figure 41 (year 2012) illustrates a less pronounced cone of depression at the PWCC permit area indicated by the 200-foot drawdown contour. USGS monitoring of the BM-well series, provides field measured confirmation for the simulated drawdown. The BM-well series had the following drawdown on December 31, 2005: BM-2 (85-feet), BM-3 (100-feet), BM-4 (0-feet), BM-5 (90-feet), and BM-6 (155-feet). Similar to measuring drawdown in the confined N aquifer, water level increases are expected in response to the reduced pumping rate at the PWCC wellfield. Since the drawdown measured at the BM-wells is a combination of both PWCC pumping and community pumping, complete recovery is not expected due to continued pumping.

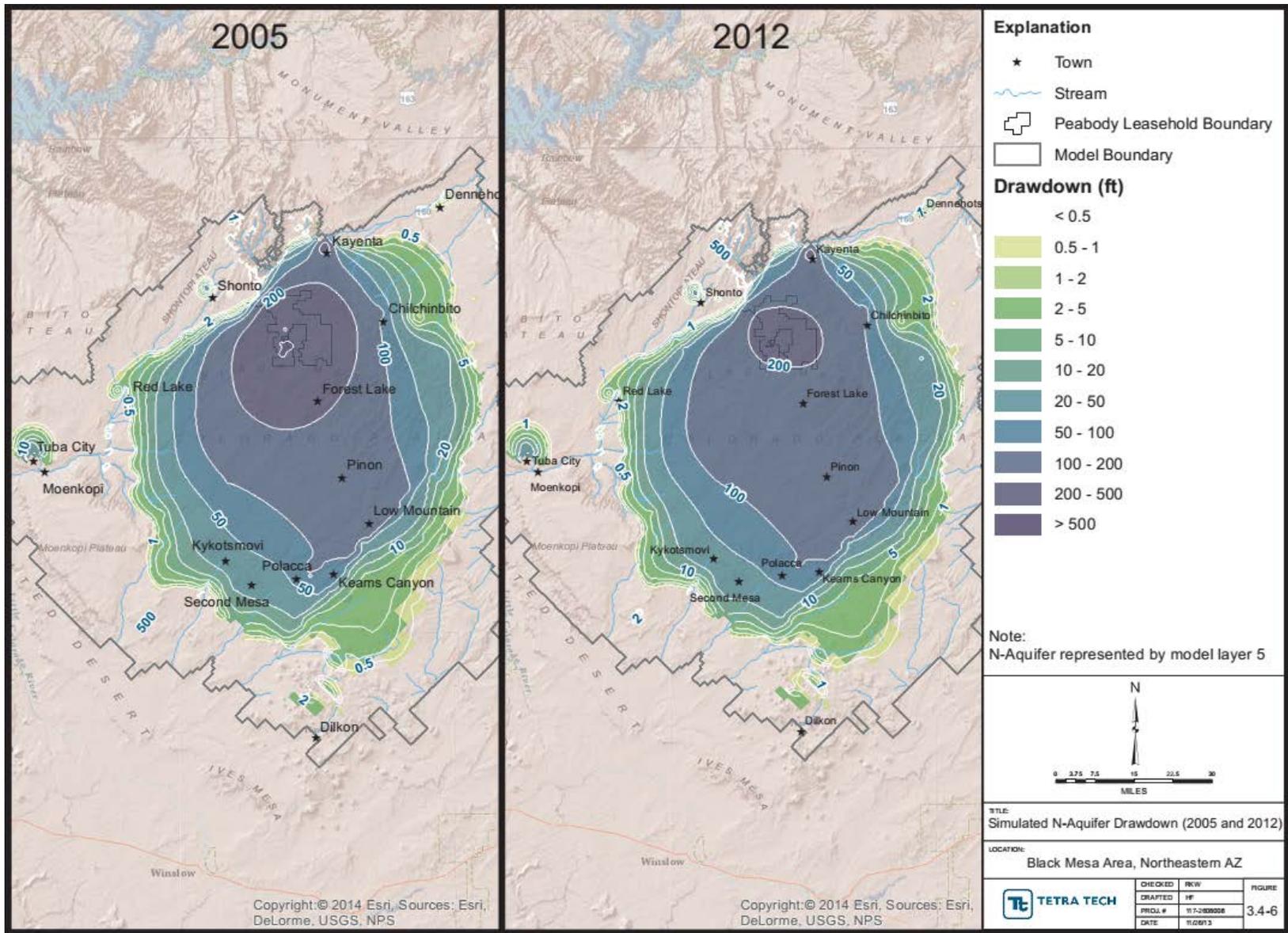


Figure 41: Simulated N aquifer Drawdown - 2005 and 2012; PWCC and Community Pumping (PWCC, v.11, ch.18, Attachment IV, 2016).

PWCC wellfield pumping does not preclude the ability to develop the water resource for municipal water supply. However, the lowering of the potentiometric surface causes an increase in electrical power costs to lift the water to surface. Settlement Condition (2) associated with Docket No. DV-2012-3-R states:

In the updated Kayenta Mine Complex CHIA, 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 identified numeric water levels as material damage criteria at windmills and community supply wells monitored by the USGS and screened in the confined N aquifer. Material damage water levels for community supply wells are based on economic and lift cost considerations. Material damage water levels for windmills are based on the depth of the drop pipe intake on the windmill. Graphical illustration of the measured water levels and material damage criteria are provided in Appendix A.

N aquifer Baseflow

Baseflow represents groundwater discharge to surface water that has seeped into a stream bed. Baseflow occurs in unconfined conditions, and the discharge rate is dependent on the water table elevation height in relation to surface water elevation in the receiving streambed. The N aquifer water level elevations adjacent to the various washes where the exposed N aquifer is unconfined are typically higher than the surface water elevations in the various washes, allowing for baseflow discharge to occur. In the N aquifer CIA, baseflow from the N aquifer occurs at Chinle Wash, Laguna Creek, Pasture Canyon, Moenkopi Wash, Dinnebito Wash, Oraibi Wash, Polacca Wash, Jadito Wash, and Cow Springs; there are areas where surface stream activity has eroded through the overlying geologic units, exposing the N aquifer in the various washes. Settlement Condition (4) associated with Docket No. DV-2012-3-R states:

In the updated Kayenta Mine Complex CHIA, OSM will consider formulating material damage criteria for N aquifer discharge that is not based on the PWCC 3D Model.

The PWCC 3D Model was updated in 2014 (Tetra Tech, 2014). The 2014 updated model was peer reviewed by the USGS (Leake and others, 2016). The following statements are provided in the USGS review Summary and Conclusions (Leake and others, 2016):

- The PWCC (Tetra Tech, 2014) model is a recently calibrated model that can simulate the effects of past groundwater development in the D and N aquifers in the Black Mesa Area.
- The combination of MODFLOW packages used in the PWCC model to represent real hydrologic features leads to improved simulation capabilities in comparison to previous models including the original PWCC (1999) model, the USGS model (Brown and Eychaner, 1988), and the WNHN model (HDR Engineering Inc., 2003).
- This evaluation found no problems with the PWCC model that would preclude its use by the NGS-KMC EIS team. Given the complexity of the N and D aquifer system in the study area and the amounts and types of data available, the calibration of the PWCC model described in Tetra Tech (2014) seems to be reasonable. Observed streamflow in most of the major washes is simulated reasonably well.

Based on the summary and conclusions provided in the USGS review, the updated 2014 PWCC groundwater flow model is the best tool available to evaluate PWCC effects on N aquifer discharge, and will be used to formulate material damage criteria for N aquifer discharge.

Using the 3D Model, impacts to baseflow discharge at the above listed washes can be assessed. Table 11 presents simulated the discharge rates (in cubic feet per second) at years 1956 (pre-pumping), 2005 (max PWCC pumping), and 2012 (model calibrate period), and corresponding percent reductions from PWCC and community pumping. Washes simulated with the highest reduction in baseflow in 2012 due to N aquifer pumping include Chinle Wash, Laguna Creek, and Polacca Wash. However, the flow reduction for the three washes with highest simulated reduction in baseflow is largely attributed to community N aquifer pumping, not PWCC pumping. As a result of groundwater pumping between 1956 and 2005, simulated discharge into the seven streams list below decreased by 283 af/yr (0.37 cfs), or approximately 4 percent (PWCC, v.11, ch.18, Attachment IV, Section 3.2.2.1, 2016).

Table 11: Simulated Stream Discharge Reductions (cfs) Due to Pumping (PWCC, v.11, ch.18, Attachment IV, Table 3.2-3, 2016).

Streams	Segment	Reach	1956	2005	Percent Reduction	2012	Percent Reduction
Moenkopi	96	35	1.641	1.640	0.1%	1.639	0.15%
Dinnebito	107	1	0.198	0.200	-0.9%	0.200	-1.0%
Oraibi	108	29	0.000	0.000	0.0%	0.000	0.0%
Polacca	40	25	0.125	0.107	14.8%	0.102	18.1%
Laguna	100	27	0.374	0.343	8.1%	0.337	9.8%
Chinle	101	4	0.359	0.328	8.8%	0.321	10.5%
Jadito	74	4	0.063	0.062	0.6%	0.062	0.75%

Moenkopi Wash is the only wash potentially impacted by PWCC pumping in the Black Mesa area that relies on N aquifer baseflow water for a designated use. Hopi and Navajo farmers in the Moenkopi area may pump water from Moenkopi Wash alluvium to irrigate crops. Since baseflow provides a constant source of water to saturate the alluvium, reduction in Moenkopi baseflow attributed to PWCC pumping is a concern. However, as presented in Table 11, Moenkopi baseflow reductions attributed to total pumping do not exceed 1% of the total baseflow.

Consistent with the Kayenta Mine EA (OSMRE, 2011c), simulated percent reduction in baseflow discharge attributable to PWCC pumping will be used for impact assessment criteria. The impacts are considered major if simulated reduction in groundwater discharge is greater than 30-percent. Therefore, OSMRE will establish the material damage level as a 30-percent simulated reduction in groundwater discharge.

N aquifer Spring Discharge

The N aquifer system is regionally continuous throughout the groundwater CIA in the Black Mesa Basin. The N aquifer system is hydraulically confined in the interior of the Black Mesa Basin and becomes unconfined around the basin where the hydrologic formations are exposed at the surface. Similar to baseflow, the discharge rate is dependent on the water table elevation height in relation to surface water elevation in the receiving channel. The N aquifer water level elevations where the exposed N aquifer is unconfined are typically higher than the elevations of the adjacent downcut channels and formation outcrop areas, allowing for spring discharge to occur and formation water to seep at the formation outcrop areas.

Springs and seeps may emanate from the N aquifer formations along the confined—unconfined boundary. The Hopi communities at the southern extent of Black Mesa were largely settled due to their proximity to springs and seeps. However, due to its stratigraphic position above the N aquifer system, springs and seeps from the D aquifer system discharge near the Hopi communities, and the N aquifer system

discharges as baseflow approximately 5-10 miles south of the Hopi communities where the washes downcut through the N aquifer formations. Springs and seeps also emanate on the western edge of Black Mesa at and near the communities of Moenkopi and Tuba City. Area residents are concerned about four specific springs and seeps in the Moenkopi and Tuba City area related to PWCC pumping, although it is acknowledged that more than four springs exist in this area. The four springs are known as Pasture Canyon Spring, Kerley Valley Spring, Red Point Outcrop Spring, and the Moenkopi School Spring. The subject of this impact assessment is whether PWCC pumping at Kayenta Mine Complex will significantly and measurably impact spring discharge and the associated cultural and irrigation water uses.

Figure 41 illustrates the cone of depression for PWCC and community pumping at 2005 and 2012, and illustrates that confined aquifer pumping effects do not propagate out to the unconfined N aquifer in the Tuba City and Moenkopi area. It appears that local pumping in this area will impact spring flow and baseflow based on the proximity of springs to the local pumping areas. In 2011, Tuba City pumped 1162 ac-ft, and Moenkopi pumped 87.1 ac-ft from the unconfined N aquifer (Figure 10). The lack of potential impact in the Tuba City area from PWCC pumping is in part due to differences in the type of aquifer system at the PWCC pumping center compared to the Tuba City pumping center. Additionally, a characterization of the subsurface geologic structure indicates that fractures are present in the Navajo Sandstone, primarily in a north to south orientation (Macy, 2012). “Water preferentially moves along the [Tuba City] syncline from the northwest to southeast, and springs are evident where the syncline intersects with Moenkopi Wash” (Macy, 2012). Both the Tuba City and PWCC pumping centers withdraw water from the N aquifer; however, the N aquifer is unconfined at Tuba City and confined at the PWCC wellfield.

Pumped water comes from aquifer storage. In a confined setting, aquifer storage is small (0.005 – 0.00005) compared to larger values (0.01 – 0.30) in an unconfined setting (Freeze and Cherry, 1979). Since the values are small in a confined setting, a larger area is influenced (represented as drawdown or changes in pressure head) to accommodate the water withdraw demand. Although the pressure head component of water level elevation changes, the saturated thickness remains unchanged in a confined aquifer. In an unconfined setting, the saturated thickness of the aquifer changes in response to pumping; therefore, the values of water coming from storage are much higher. As modeled and measured, PWCC effects of pumping the confined area of the N aquifer propagate out to the confined-unconfined boundary, where the hydrologic characteristics change. The change in hydrologic characteristic from confined to unconfined limit measurable effects of PWCC pumping beyond this boundary. Conversely, the hydrologic characteristics of pumping an unconfined system at Tuba City is why the effects of drawdown do not propagate very far from Tuba City even though a significant volume of water is withdrawn annually. Although the effects of Tuba City pumping do not extend very far from the Tuba City pumping, the N aquifer springs of concern are in close proximity to the Tuba City pumping, causing potential impact to spring flows in the area. Table 12 provides model simulated results of reductions due to PWCC and community N aquifer pumping at locations monitored by the USGS.

Table 12: Discharge Reductions for Springs Simulated as Streams (cfs) Due to Pumping (PWCC, v.11, ch.18, Attachment IV, Table 3.2-3, 2016).

	Segment	Reach	1956	2005	Percent Reduction	2012	Percent Reduction
Pasture	21	5	0.323	0.281	12.9	0.270	16.2
Moenkopi SS	105	1	0.000	0.000	0.0	0.000	0.0
Burro	106	1	0.000	0.000	0.0	0.000	0.0
Unnamed	38	1	0.008	0.008	0.0	0.008	0.0

Due to the current N aquifer water withdraws at Tuba City, and the Village of Moenkopi to a lesser extent, which are near the N aquifer springs of concern, reductions in flow discharge are likely to occur as predicted community pumping trends continue. Burro Spring is thought to exist near approximate location of the confined—unconfined boundary, and Moenkopi is located on the confined N aquifer. “Zero flow was produced by the [3D] model at Moenkopi and Burro Spring sites. This is thought to be due to the complexities in the local geologic environment and the limitation of vertical discretization to simulate these complexities at these locations (Tetra Tech, 2014)” (BOR, 2016, Page 3.7-61). Measured discharge at Burro Spring is statistically variable from year to year, but consistently flowing at less than a gallon a minute. No additional N aquifer springs have been identified for monitoring as part of the USGS cooperative effort concerning the monitoring of N aquifer hydrologic resources. The Black Mesa water resource monitoring program was established in 1971 by the USGS in cooperation with the Arizona Department of Water Resources. In 1983, the BIA entered into the cooperative effort.

The September 2016 Draft NGS-KMC EIS provides the following D and N aquifer spring observations:

- “No change in flow at the four USGS monitored springs is predicted as a result of the proposed mine related pumping under either the 3-Unit Operation or 2-Unit Operation.” (BOR, 2016, Page 3.7-62)
- “Because proposed mine-related pumping would generate either no or very small reductions in flows or water levels at D and N aquifer springs and seeps, the potential impacts from either Proposed Action options would be negligible.” (BOR, 2016, Page 3.7-64).

Land Subsidence

There are three mechanisms that contribute to the compressibility of a porous medium. Compressibility can be achieved by: (1) compression of water, (2) compression of individual sand grains, and (3) by rearrangement of sand grains into a more closely packed configuration (Freeze and Cherry, 1979). The compressibility of individual well-sorted quartz sand grains is considered negligible, but the rearrangement of sand grains can often be the cause of land subsidence from pumping. Pore water pressure typically supports the packing arrangement of the aquifer material in unconsolidated basin fills. Therefore, when pore water pressure decreases in unconsolidated basin fills, the packing arrangement may change to a more closely packed arrangement. The closer arrangement may result in a decrease in aquifer thickness, which translates to the surface as a depression, or subsidence.

When the N aquifer is pumped, the pore water pressure decreases, and water comes from aquifer storage. Theoretically, the opportunity exists for the N aquifer sand grains to rearrange and cause subsidence. However, rearrangement of the aquifer material from pumping typically occurs in younger poorly sorted unconsolidated basin deposits; but the N aquifer is an old consolidated well sorted sandstone deposit. The N aquifer sediments are more than 135 million years old, and are buried deep enough that the majority of compaction and rearrangement has already occurred. Because the rocks in the Black Mesa area are presently being eroded, the rocks in the N aquifer have been subjected to greater stresses in the geologic past than they are currently. GeoTrans (1993) used eleven thin sections of rock sampled from the Navajo Sandstone to evaluate grain size, mineral content and cementation. The results of the evaluation identified that the high overburden pressure over the extensive period of time caused the quartz grains to weld together, confirming that subsequent rearrangement of the aquifer material would be minimal, if any. Additionally, the quartz sand grains comprising the Navajo Sandstone were concave/convex, which supports the concept that rearrangement of the aquifer material has already been realized from the high overburden pressure over the significant period of time due to the concave/convex deformation observed in the quartz grains.

PWCC also evaluated the results of triaxial compression tests on Navajo Sandstone samples taken at outcrops in the unconfined portion of the N aquifer. Pressures ranging between 400 psi and 2,000 psi

were applied during testing, with the highest pressures being equivalent to the effective stress on the Navajo Sandstone in the center of the Black Mesa Basin. Compressibility determined from the results of the applied pressures during laboratory testing ranged from 2.78×10^{-7} ft²/lb to 3.04×10^{-8} ft²/lb, which results in the potential aquifer thickness reduction ranging from 1.93 feet to 17.44 feet in the center of the basin where impacts would be most realized (GeoTrans, 1993). The results of the testing are conservatively biased toward greater compressibility for the following reasons:

- (1) The samples were taken from unconfined outcrops where Navajo Sandstone compaction and stress release has partially occurred.
- (2) The outcrop samples encountered some degree of weathering and loss of cementation.
- (3) The compression test samples were oriented to apply the maximum loading parallel to the bedding planes, where the actual stress on the aquifer material is nearly perpendicular to the bedding plane. A sample loaded perpendicular to the bedding is expected to be stiffer, resulting in less compression than those loaded parallel to the bedding planes.

The compaction results derived from laboratory testing identified that the potential for measurable surface subsidence to occur as a result of PWCC wellfield pumping, is unrealistic. The conservative bias of the laboratory tests suggests that using samples from the confined area, and stressing the samples perpendicular to the bedding plane would result in less than 17-feet of reduction in N aquifer thickness. Additionally, a 17-foot reduction in N aquifer thickness would not likely translate through 2000-feet of overlying sediments to result in a 17-foot reduction in land surface. Rather, the overlying sediments would likely experience minute deformation to compensate for the change in thickness, resulting in immeasurable surface elevation change. PWCC also conducted video surveys of several Black Mesa mine water supply wells, the most recent occurring in September 2004 on well NAV5. No evidence of casing distress was noted in any of the surveyed well as might be expected if significant compression of the Navajo Sandstone or overlying units has occurred.

However, on February 13, 2003 and May 1, 2003 representatives from OSMRE, Navajo Nation Minerals Dept, Navajo Nation Water Resources Dept, USGS, PWCC, and Black Mesa residents investigated a report of land subsidence south of the lease boundary (OSMRE, 2004). Land subsidence features in the form of sinkholes, cracks, and slumps were reported near Forest Lake, about seven miles south of the Kayenta Complex. After investigation, the representatives identified that all of the subsidence features of concern were either in or adjacent to unconsolidated alluvial valley deposits. Several years of severe drought prior to the year 2003 produced desiccation cracks in the near surface, fine-grained, unconsolidated alluvial sediments. During periods of short and intense rainfall, surface runoff piped through the cracks. The piped water enlarged the cracks in the unconsolidated alluvium until the surface was undermined, forming near surface cavities that collapsed and became small sinkholes, and eventually larger slump areas within the alluvium.

PWCC has provided documentation to suggest that structural collapse of the N aquifer is unlikely. Additionally, field investigations have not revealed documented evidence to indicate the structural collapse of the N aquifer. Therefore, OSMRE finds that material damage to the structural stability of the N aquifer has not occurred, and the potential to cause material damage to existing and foreseeable uses is not supported by the available data and observations.

5.2.4.1.4 N aquifer Quantity Material Damage

PWCC pumping of the confined N aquifer system has reduced the water pressure within the N aquifer system. The reduction in water pressure does not limit the ability of the communities to utilize the N aquifer water resource for existing and foreseeable domestic water supply. However, a regional N aquifer monitoring network with reliance on the BM-wells, and local water level monitoring at the PWCC

wellfield will continue to be monitored to verify impact predictions. OSMRE will protect the N aquifer water resource by establishing material damage criteria as established in Appendix A. Additionally, N aquifer baseflow will be assessed with the calibrated and validated 3D Model, and OSMRE will establish the material damage level as a 30-percent simulated reduction in groundwater discharge.

OSMRE finds that PWCC has adequately demonstrated the minimization of impact to N aquifer spring flow for the N aquifer springs of concern attributed to PWCC pumping. Additionally, the NGS-KMC DEIS concludes that “Proposed mine-related pumping would generate either no or very small reductions in flows or water levels at D and N aquifer springs and seeps, the potential impacts from either Proposed Action options would be negligible” (BOR, 2016, Page 3.7-64). Therefore, OSMRE will not establish a material damage criterion for potential impacts to the reduction of N aquifer spring discharge. Regional N aquifer monitoring with reliance on the BM-wells, and a local water level monitoring at the PWCC wellfield will continue to be evaluated to verify impact predictions.

5.2.4.2 Navajo Aquifer Quality

Groundwater flows from areas of high hydraulic head potential to areas of low hydraulic head potential, and generally follows the flow path of least resistance. The total hydraulic head potential is reflected in the static water level measured in the wellbore. The water levels in the confined N aquifer reflect the hydrostatic pressure regime in the aquifer and are an indication of the net stresses exerted on the N aquifer.

The D aquifer system water predominantly flows horizontally due to the Carmel Formation aquitard separating the D aquifer and N aquifer systems. However, D aquifer water levels typically have a higher groundwater levels compared to N aquifer water levels, which means that there is a downward component of groundwater flow (Figure 22). Water level drawdown from pumping of the N aquifer system creates a greater difference between D aquifer and N aquifer water levels; therefore, the downward movement of water increases as drawdown increases. The rate at which water moves is determined by the vertical permeability of the Carmel Formation, its thickness, and the difference in water levels between the D and N aquifers.

The N aquifer is characterized as having a good water quality compared to the overlying D aquifer (Truini and Macy, 2006). In general, N aquifer water meets water quality standards for domestic supply established by NNEPA and HTWRP, while D aquifer water is not as good and typically does not meet domestic supply water quality standards. Therefore, a hydrologic impact concern related to N aquifer pumping is an increase in the leakage rate of poorer quality D aquifer water to the N aquifer, significantly degrading N aquifer water quality.

The USGS evaluated the hydrogeology of Black Mesa using geochemical and isotopic analysis, concluding that “the similarity of ground-water ages in the D aquifer to ages in the N aquifer suggests that leakage has been occurring for thousands of years” (Truini and Longworth, 2003). The USGS evaluation also concluded that leakage is most likely to occur in the southern part of Black Mesa based on the geologic and hydrologic environment in that area (Truini and Longworth, 2003). In the northern part of Black Mesa, isotopic analysis revealed significant statistical differences between the D aquifer and N aquifer water (Truini and Longworth, 2003). The statistical difference in the northern area suggests that the leakage potential under natural pre-pumping conditions was not as great compared to the southern area. However, the pumping and associated drawdown created by PWCC has increased the potential leakage in the northern area compared to equilibrium steady-state conditions.

The evaluation by the USGS indicates that the rate of leakage of water from the D aquifer to the N aquifer in the northern area under pre-pumping conditions was small. Otherwise, the water in the N aquifer would have been impacted by the D aquifer water because the leakage has been occurring for thousands

of years. If the natural leakage rate was low, a significant increase in leakage rate (for example, a 100-percent increase or doubling the leakage rate) would have immeasurable effect on the quality of water in the N aquifer. Conversely, if the rate of pre-pumping leakage was higher, the impact on the water quality could be appreciable with a smaller percentage increase in leakage rate. Thus, monitoring water quality is a better approach to measuring impact than estimating percentage increases in the leakage rate.

5.2.4.2.1 N aquifer Quality Monitoring Program

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 remains a 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 Longworth, 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. 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, 2016).

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, 2016).

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, 2016).

Figures 42, 43, and 44 illustrate concentrations at PWCC N aquifer wells for the last 15 years for TDS, sulfate, and chloride, respectively. Figures 45, 46, and 47 illustrate concentrations of arsenic, boron, and selenium, respectively, during the 5-year period (2011-2015). All reported concentrations of arsenic, boron, chloride, selenium, sulfate, and TDS are below available drinking water standards.

All samples from PWCC pumping wells at the Kayenta Mine Complex have maintained a TDS concentration of less than 350 mg/L over the last 15 years. Additionally, all samples from PWCC pumping wells typically have maintained a chloride concentration less than 10 mg/L over the last 15 years. 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 over the last 15 years. Concentrations of arsenic are often not detectable, but no more than half the limit for drinking water. Similarly, concentrations of boron selenium are typically not detectable, and an order of magnitude below drinking water standards.

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.

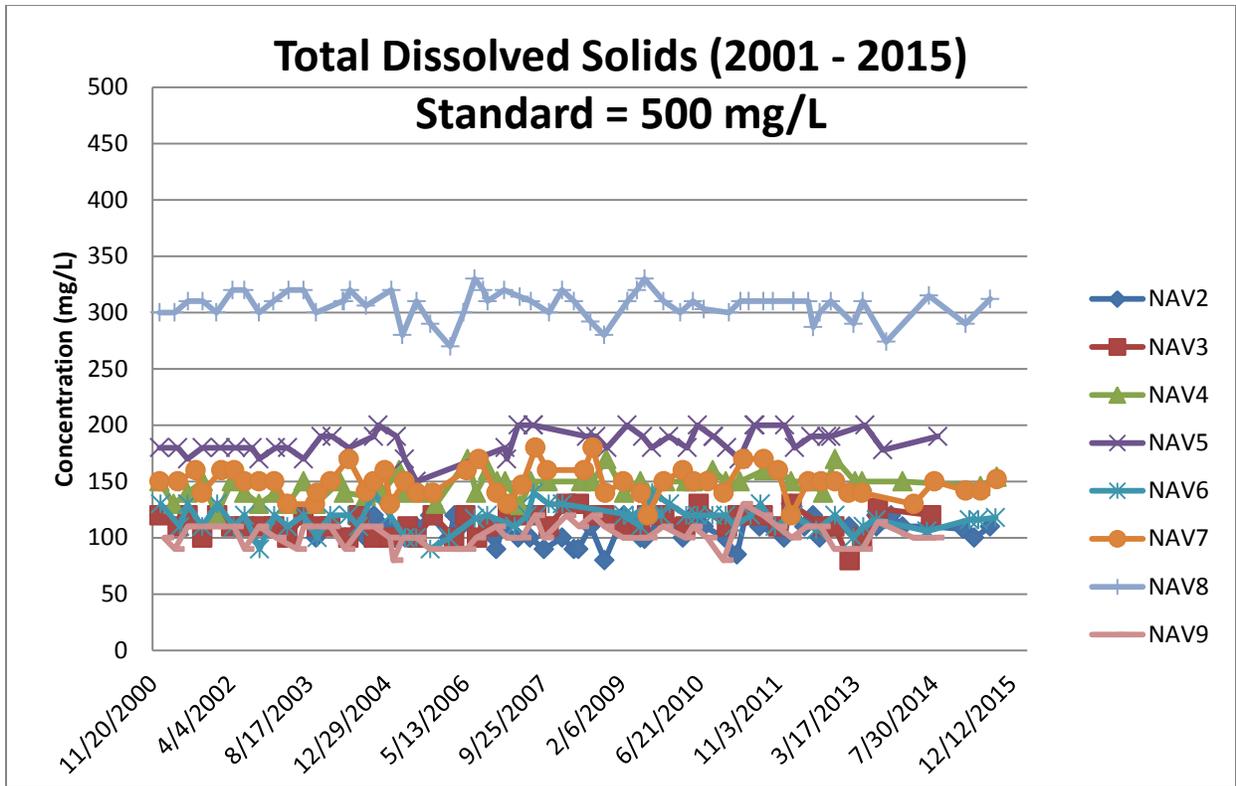


Figure 42: TDS Concentrations in PWCC NAV Wells (2001 – 2015).

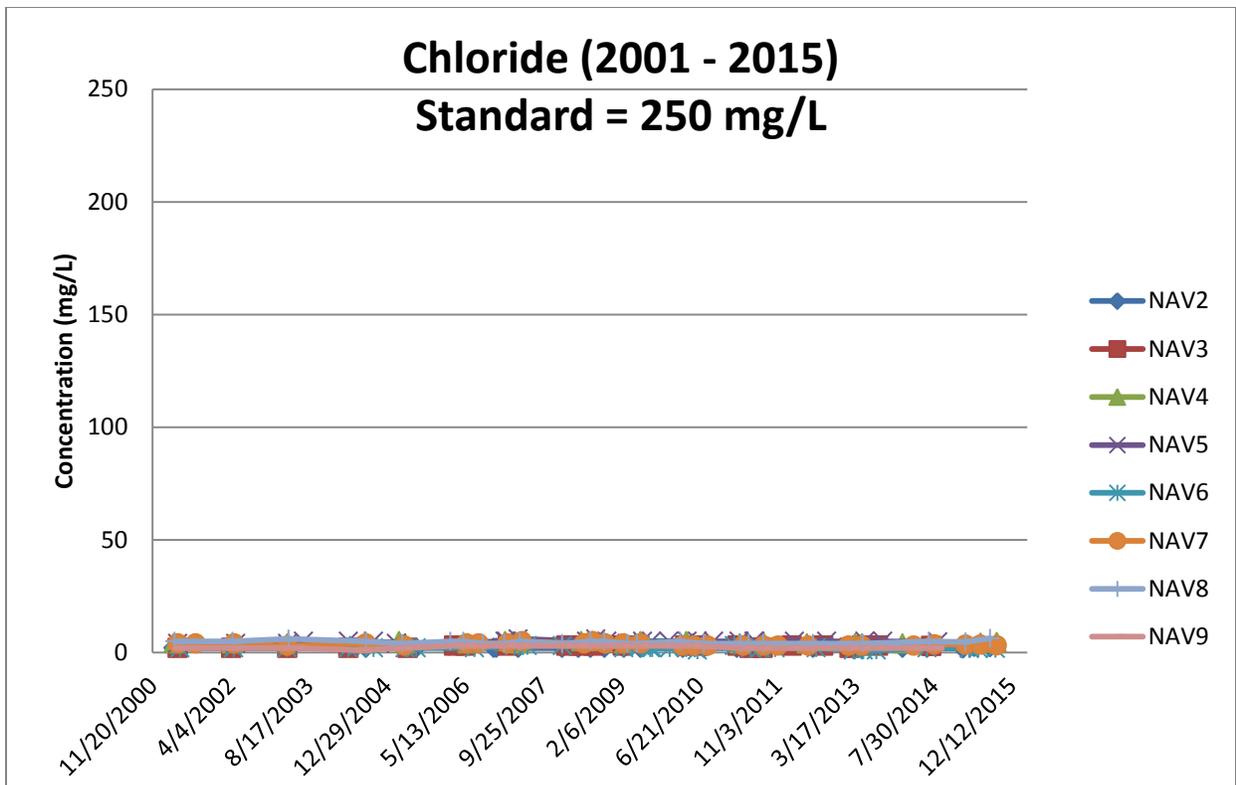


Figure 43: Chloride Concentrations in PWCC NAV Wells (2001 – 2015).

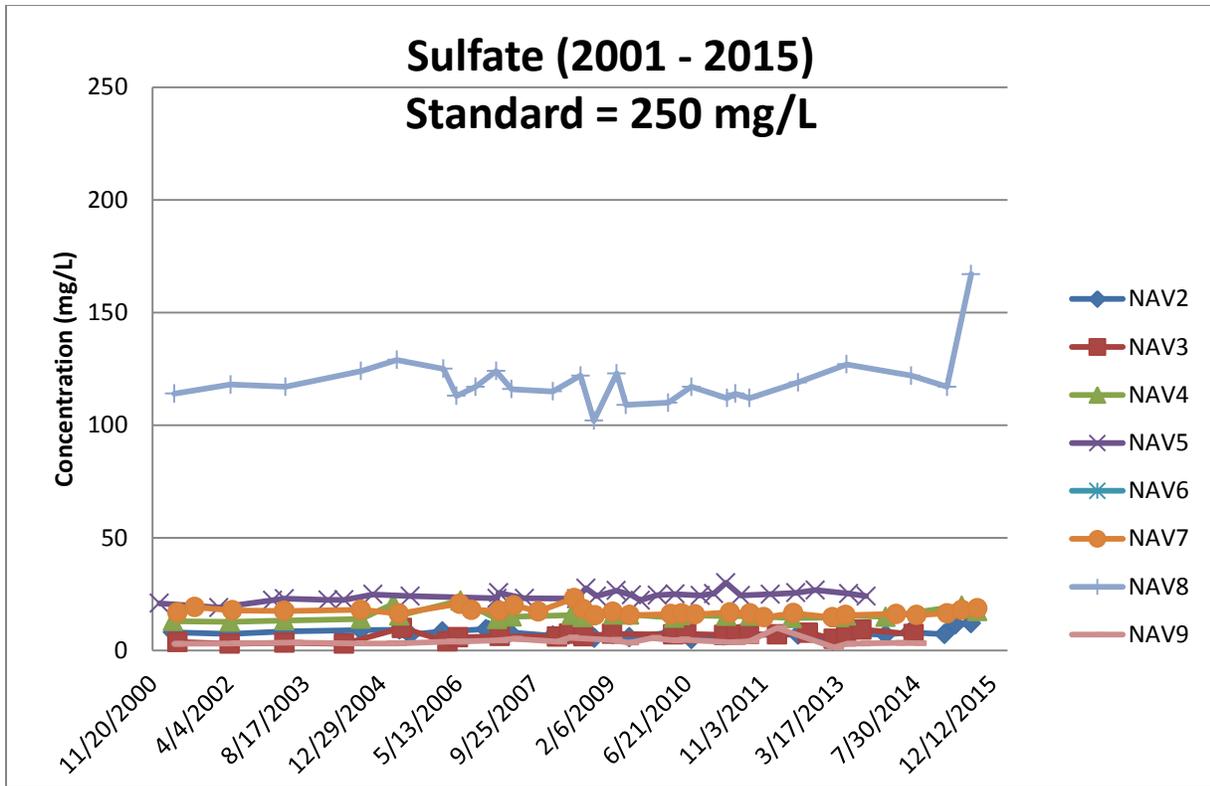


Figure 44: Sulfate Concentrations in PWCC NAV Wells (2001 – 2015).

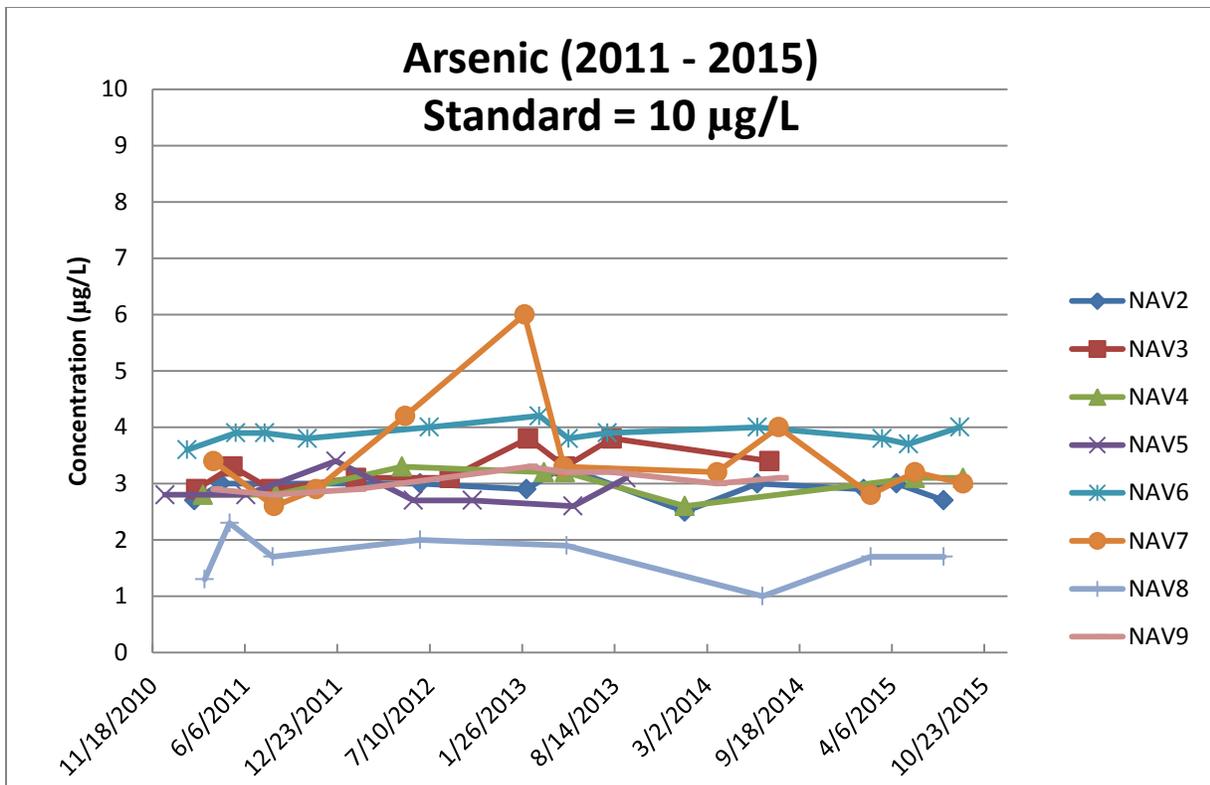


Figure 45: Arsenic Concentrations in PWCC NAV Wells (2011 – 2015).

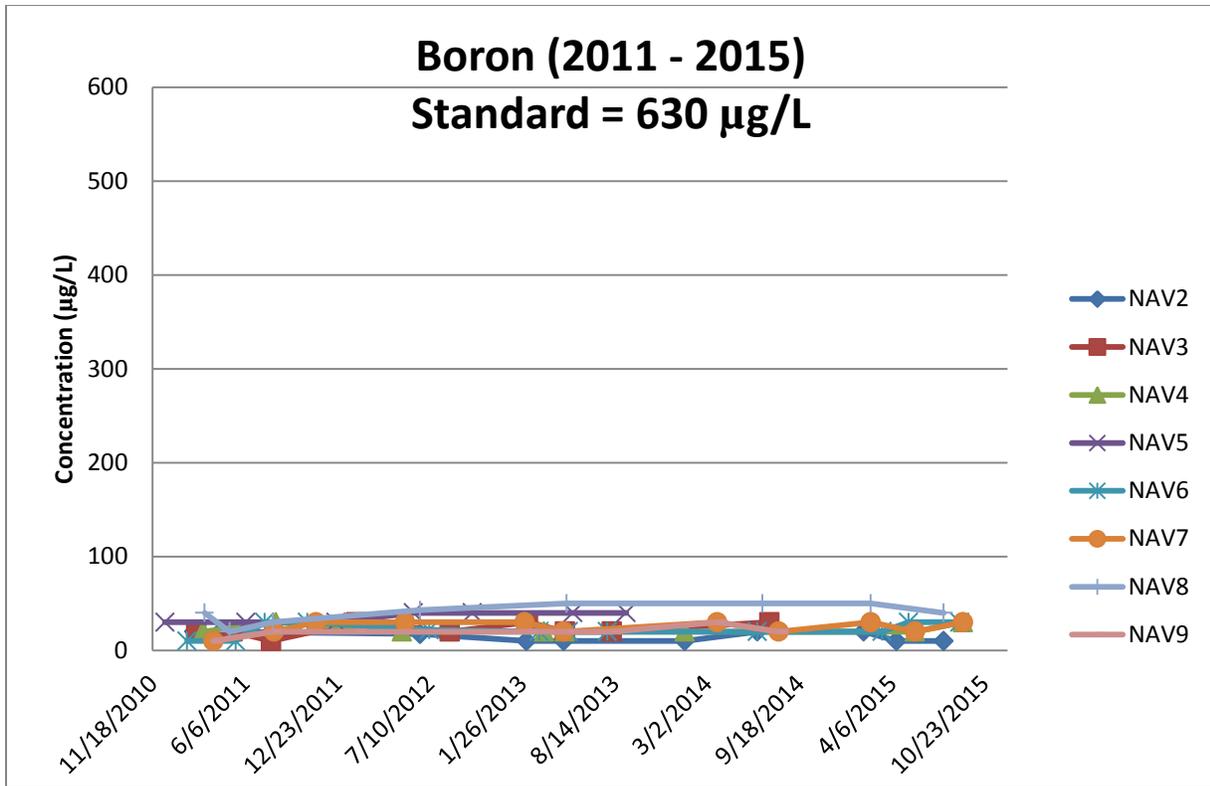


Figure 46: Boron Concentrations in PWCC NAV Wells (2011 – 2015).

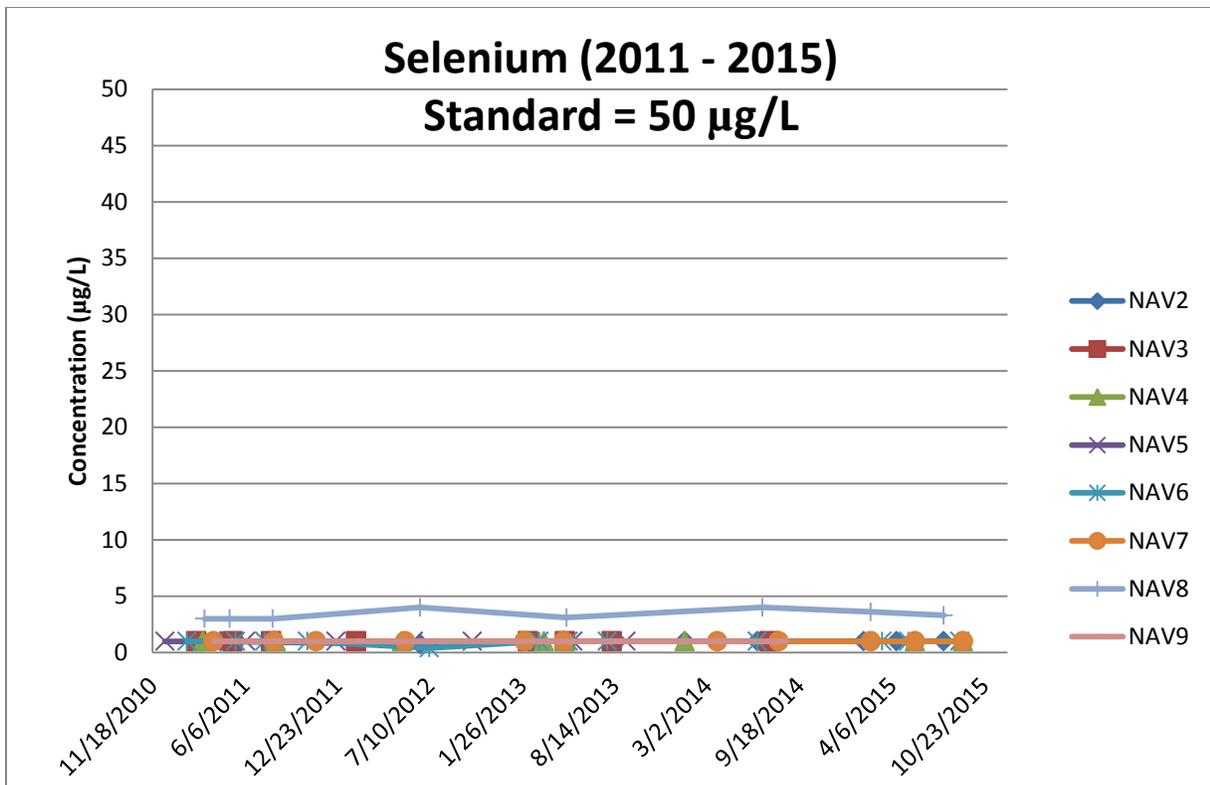


Figure 47: Selenium Concentrations in PWCC NAV Wells (2011 – 2015).

5.2.4.2.2 N aquifer Quality Impact Potential to Existing and Foreseeable Uses

Mine related pumping has not degraded the N aquifer water quality, and significant degradation causing material damage to the existing and foreseeable uses is unlikely to propagate outside the areal extent of the permit boundary. Water quality of the PWCC wellfield will continue to be assessed in accordance with the monitoring requirements of the approved permit, and to ensure the N aquifer continues to meet water quality standards for arsenic, boron, chloride, selenium, sulfate, and TDS.

5.2.4.2.3 N aquifer Quality Material Damage

OSMRE will assess N aquifer water quality impacts based on water quality at the PWCC wellfield, since highest N aquifer water quality impact potential is in the vicinity of the wellfield based on drawdown. OSMRE will continue to evaluate water quality concentrations against the standards for domestic water supply. A level of material damage will be considered a PWCC NAV well no longer meeting water quality standards for arsenic, boron, chloride, selenium, sulfate, and TDS. To date, PWCC pumping of the N aquifer has not caused material damage to the quality of N aquifer. PWCC's operation of the Kayenta Mine Complex has been designed to prevent material damage to the quality of the N aquifer. However, water quality of the PWCC wellfield will continue to be assessed on an annual basis to ensure that the N aquifer continues to meet applicable water quality standards.

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APPENDIX A

MATERIAL DAMAGE CRITERIA N-AQUIFER WATER LEVELS

INTRODUCTION

This Appendix 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:

In the updated Kayenta Mine Complex CHIA, 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. This is particularly true for the proposed future mine plan; historic mine pumping has declined from a high of about 4,500 ac-ft in 2005 to approximately 1,400 ac-ft in 2011 and will be further reduced in the future until ceasing completely in 2057. The question is not one of physical availability but of the cost to supply water from significant depth to users at the land surface.

AFFORDABILITY OF WATER

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 KMC 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 have to be removed, lengthened and re-installed.

Review of the USGS monitored wells on Black Mesa, as of 2011, indicate 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; therefore, the preclusion of use is not applicable. These wells are given in Table 1, with key well data. Location of the wells is shown on Figure 1.

Table 1, USGS Monitored Wells Screened in Confined N-Aquifer

Well Name	Surface Elevation (ft msl)	2012 Water Level (ft msl)	2012 Depth to Water (ft bls)	Depth Top of N-Aquifer (ft bls)	Well Type ²
Forest Lake NTUA1 (4T-523)	6,654	5,480	1,174	NR ¹	P
Keams Canyon PM2	5,809	5,311	498	900	P
Kitsiili NTUA2	6,780	5,444	1,336	2,205	P
Kykotsmovi PM1	5,657	5,445	212	880	Pa
Kykotsmovi PM3	5,618	5,367	251	840	P
Pinon PM6	6,397	5,480	917	1,870	Pa
Howell Mesa (3K-311)	5,855	5,411	444	615	W
Marsh Pass (8T-522)	6,040	5,912	128	480	W
Kayenta West (8T-541)	5,885	5,587	298	700	W
Rough Rock (10R-119)	5,775	5,518	257	310	W
Rough Rock (10T-258)	5,903	5,591	312	460	W
Rough Rock (10R-111)	5,757	5,558	199	210	W
Sweetwater Mesa (8K-443)	6,024	5,479	545	590	W
White Mesa Arch (1K-214)	5,771	5,551	220	250	W

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

MATERIAL DAMAGE NUMERIC WATER LEVELS

In order 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 stockwatering 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):

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

Using typical Arizona well values for the following parameters:

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

The above equation with typical AZ 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 2.

Table 2, Confined N-Aquifer Water Systems Water Use

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.

Current 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 the 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 (\$) per household per month. Results of this calculation for the water system supply wells included in Table 1 are given in Table 3. 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 3, Lift and Material Damage Numeric Water Level

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 1, 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 4.

Table 4, Material Damage Numeric Water Level for Windmill Wells

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 3 and 4 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).

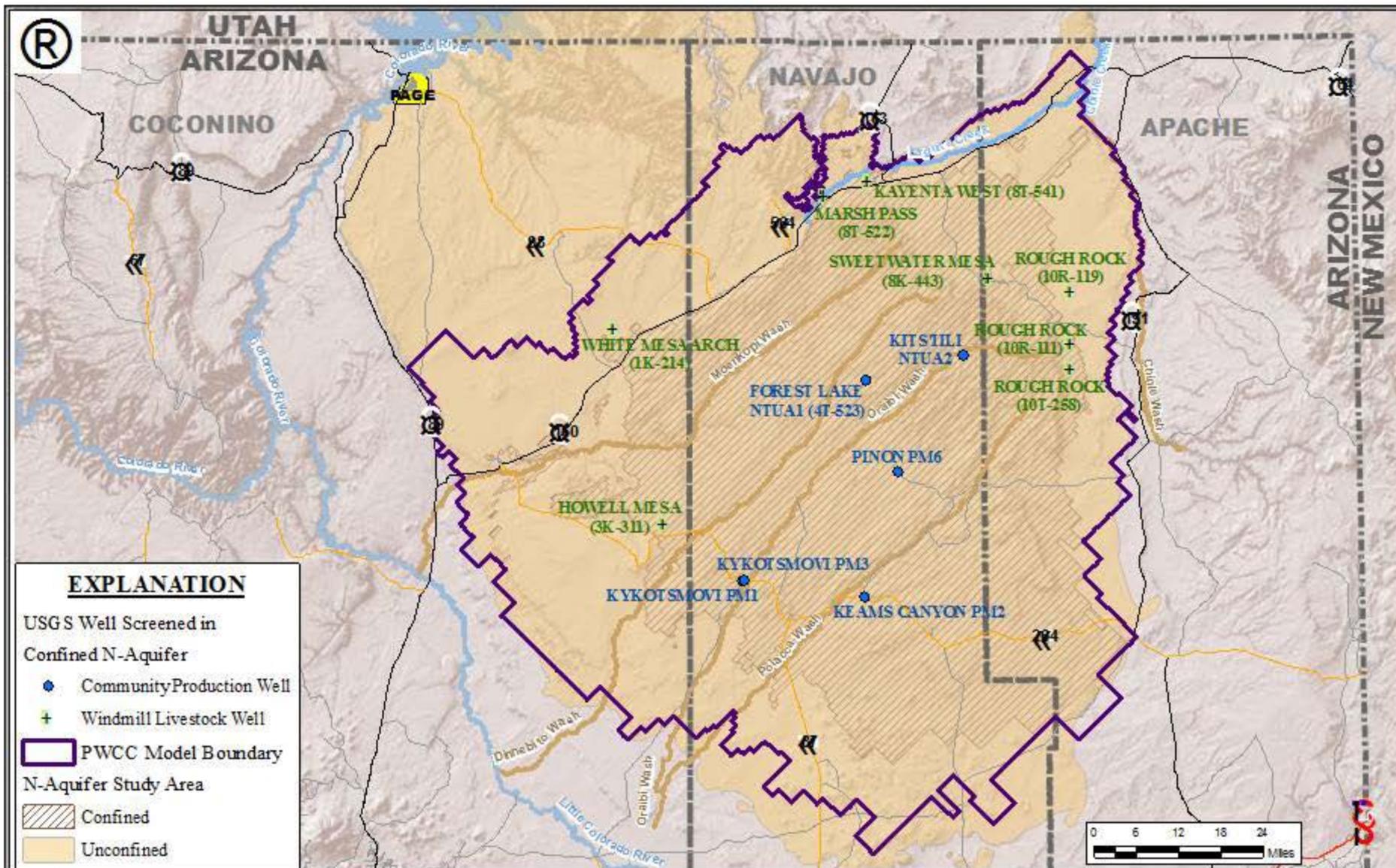
Differentiation of Change in Water Level Due to Pumping

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.

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**USGS MONITORED WELLS SCREENED IN
CONFINED N-AQUIFER LOCATION MAP**

Northeastern Arizona

Figure

LIFT (TDH) TO INCREASE WATER COST \$1 PER MONTH PER HOUSEHOLD

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

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

Where:

\$/kW/hr = 0.091

Pump Eff = 75%

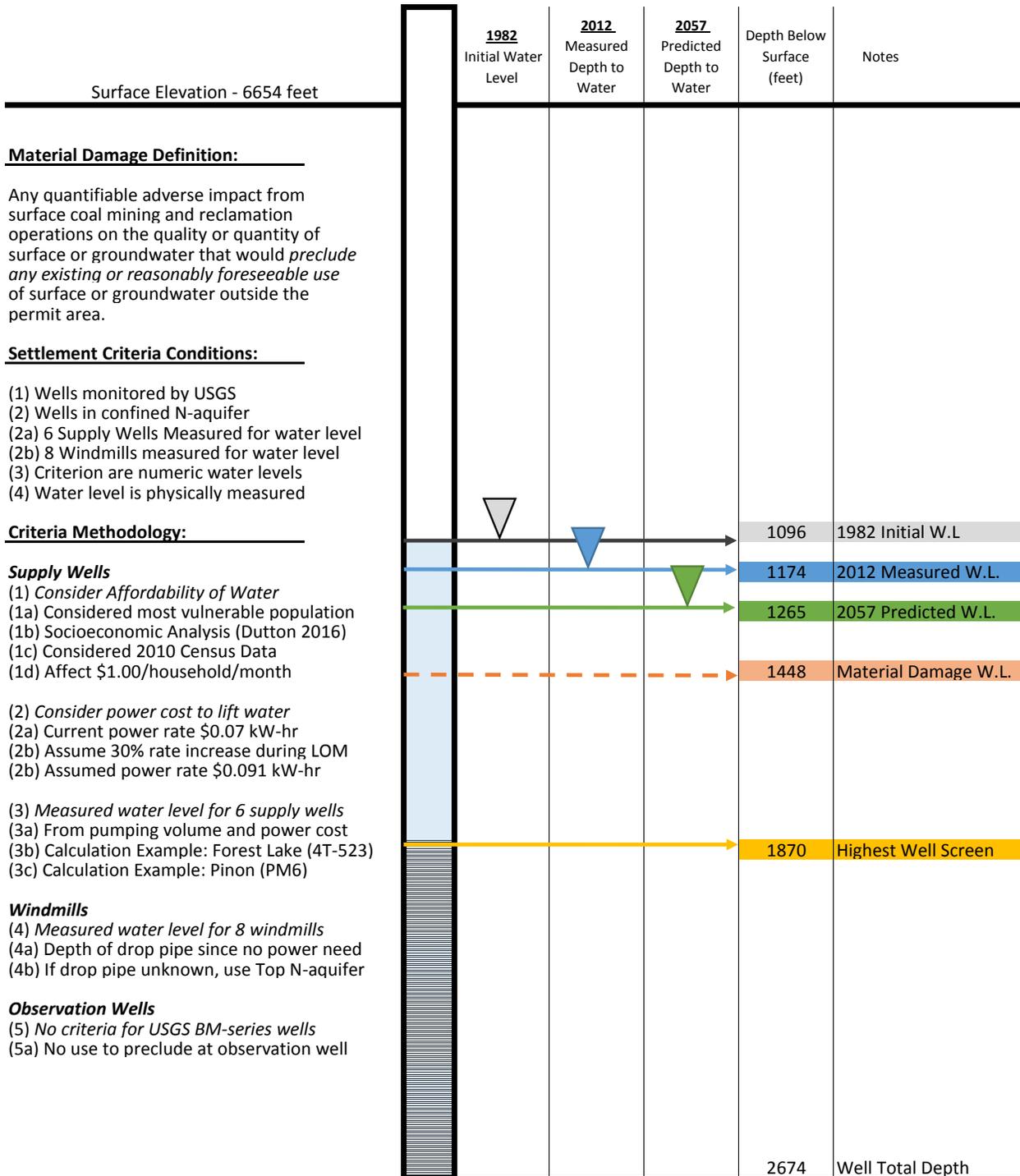
Motor eff = 90%

Denominator =	2673	Constant	\$0.0 KW/hr
Numerator =	0.00746 GPM*TDH @	2.79E-06	1
	0.01 KW/hr	5.58E-06	2
		8.37E-06	3
	0.06789 GPM*TDH @	1.12E-05	4
	0.091 KW/hr	1.4E-05	5
		1.67E-05	6
		1.95E-05	7
\$/hr =	2.79087E-06 GPM*TDH @	2.23E-05	8
	0.01 KW/hr	2.51E-05	9
		2.54E-05	9.1
	2.53969E-05 GPM*TDH @	2.79E-05	10
	0.091 KW/hr	3.07E-05	11
Lift=	\$/hr/2.79087-05*GPM @	3.35E-05	12
	0.01 KW/hr		
	\$/hr/2.53969E-05*GPM @		
	0.091Kw-hr		

Assume max increased cost of water per month = \$1 per connection (household)

Forest Lakes	afa	gpm	gpd	
2011 Q =	15.5	9.6	13828	56 gpcd (5 PPH)
Connections =	49	0.1960	282	
\$1/mo =	0.00136612	\$/hr		
Lift =	274	0.091 KW/hr		
Kayenta	afa	gpm		
2011 Q =	414	256		
Connections =	986	0.2601		
\$1/mo =	0.00136612	\$/hr		
Lift =	207	0.091 KW-hr		
Pinon	afa	gpm		
2011 Q =	337	209		
Connections =	1427	0.1463		
\$1/mo =	0.00136612	\$/hr		
Lift =	368	0.091KW-hr		
Kitsillie	afa	gpm		
2011 Q =	21	13		
Connections =	74	0.1758		
\$1/mo =	0.00136612	\$/hr		
Lift =	306	0.091 KW-hr		
Rough Rock	afa	gpm		
2011 Q =	19	12		
Connections =	127	0.0927		
\$1/mo =	0.00136612	\$/hr		
Lift =	580	0.091 KW-hr		
Kykotsmovi	afa	gpm		
2011 Q =	70	43		
Connections =	250	0.1735		
\$1/mo =	0.00136612	\$/hr		
Lift =	310	0.091 KW-hr		
Keams Canyon	afa	gpm		
2011 Q =	60	37		
Connections =	142	0.2618		
\$1/mo =	0.00136612	\$/hr		
Lift =	205	0.091 KW-hr		
Hotevilla	afa	gpm		
2011 Q =	24.5	15		
Connections =	144	0.1054		
\$1/mo =	0.00136612	\$/hr		
Lift =	510	0.091 KW-hr		

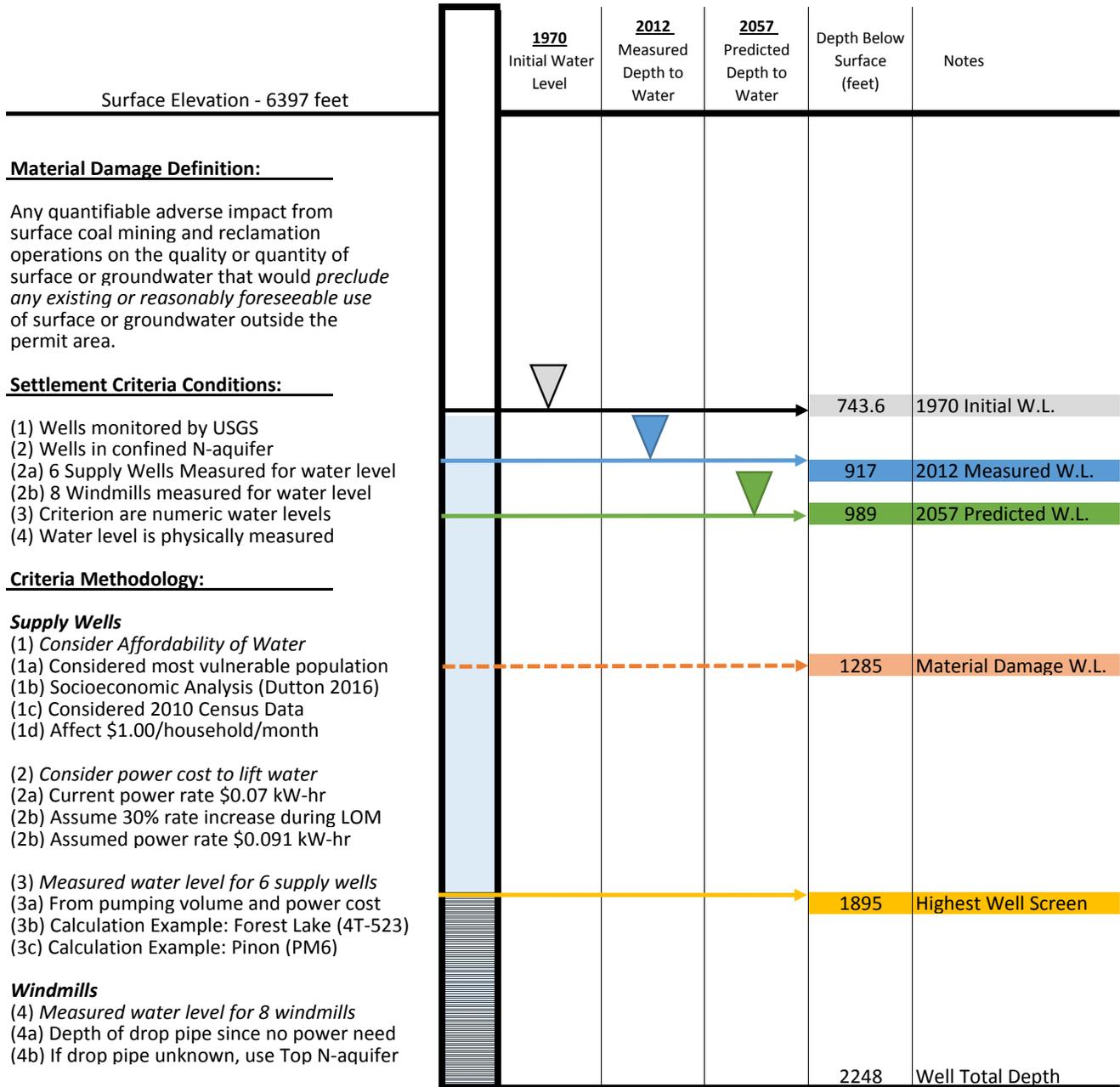
Forest Lake Supply Well 4T-523



Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWGCC, 2016); (Dutton, 2016)

Pinon Supply Well PM6



Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)

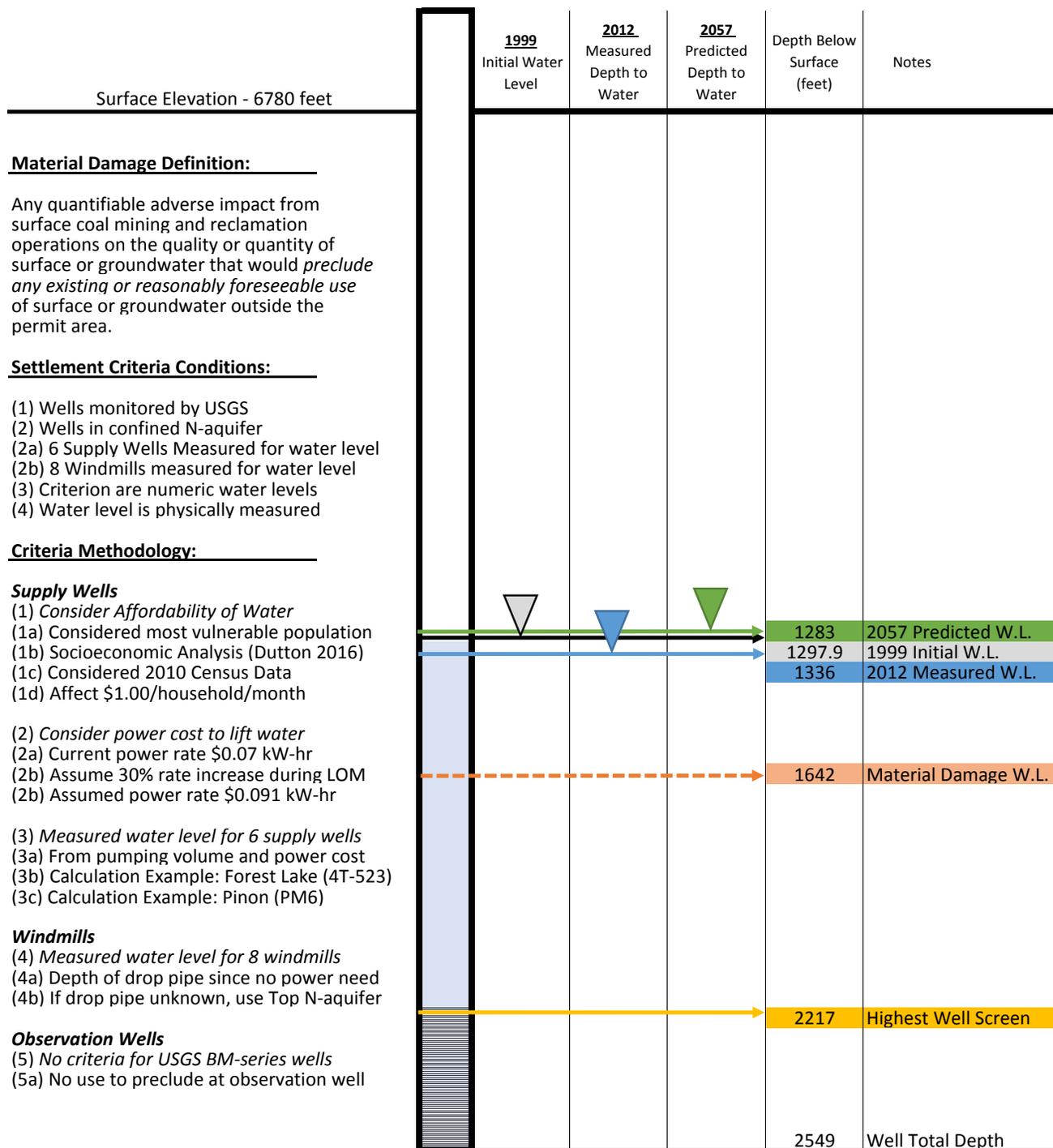
Keams Canyon Supply Well PM2

	<u>1970</u> Initial Water Level	<u>2012</u> Measured Depth to Water	<u>2057</u> Predicted Depth to Water	Depth Below Surface (feet)	Notes
Surface Elevation - 5809 feet					
Material Damage Definition:					
Any quantifiable adverse impact from surface coal mining and reclamation operations on the quality or quantity of surface or groundwater that would <i>preclude any existing or reasonably foreseeable use</i> of surface or groundwater outside the permit area.					
Settlement Criteria Conditions:					
(1) Wells monitored by USGS (2) Wells in confined N-aquifer (2a) 6 Supply Wells Measured for water level (2b) 8 Windmills measured for water level (3) Criterion are numeric water levels (4) Water level is physically measured					
Criteria Methodology:					
Supply Wells					
(1) Consider Affordability of Water					
(1a) Considered most vulnerable population					
(1b) Socioeconomic Analysis (Dutton 2016)					
(1c) Considered 2010 Census Data					
(1d) Affect \$1.00/household/month					
(2) Consider power cost to lift water					
(2a) Current power rate \$0.07 kW-hr					
(2b) Assume 30% rate increase during LOM					
(2b) Assumed power rate \$0.091 kW-hr					
(3) Measured water level for 6 supply wells					
(3a) From pumping volume and power cost					
(3b) Calculation Example: Forest Lake (4T-523)					
(3c) Calculation Example: Pinon (PM6)					
Windmills					
(4) Measured water level for 8 windmills					
(4a) Depth of drop pipe since no power need					
(4b) If drop pipe unknown, use Top N-aquifer					
Observation Wells					
(5) No criteria for USGS BM-series wells					
(5a) No use to preclude at observation well					
	▼		▼	292.5	1970 Initial W.L.
		▼		374	2057 Predicted W.L.
		▼		498	2012 Measured W.L.
				703	Material Damage W.L.
				906	Highest Well Screen
				1106	Well Total Depth

Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)

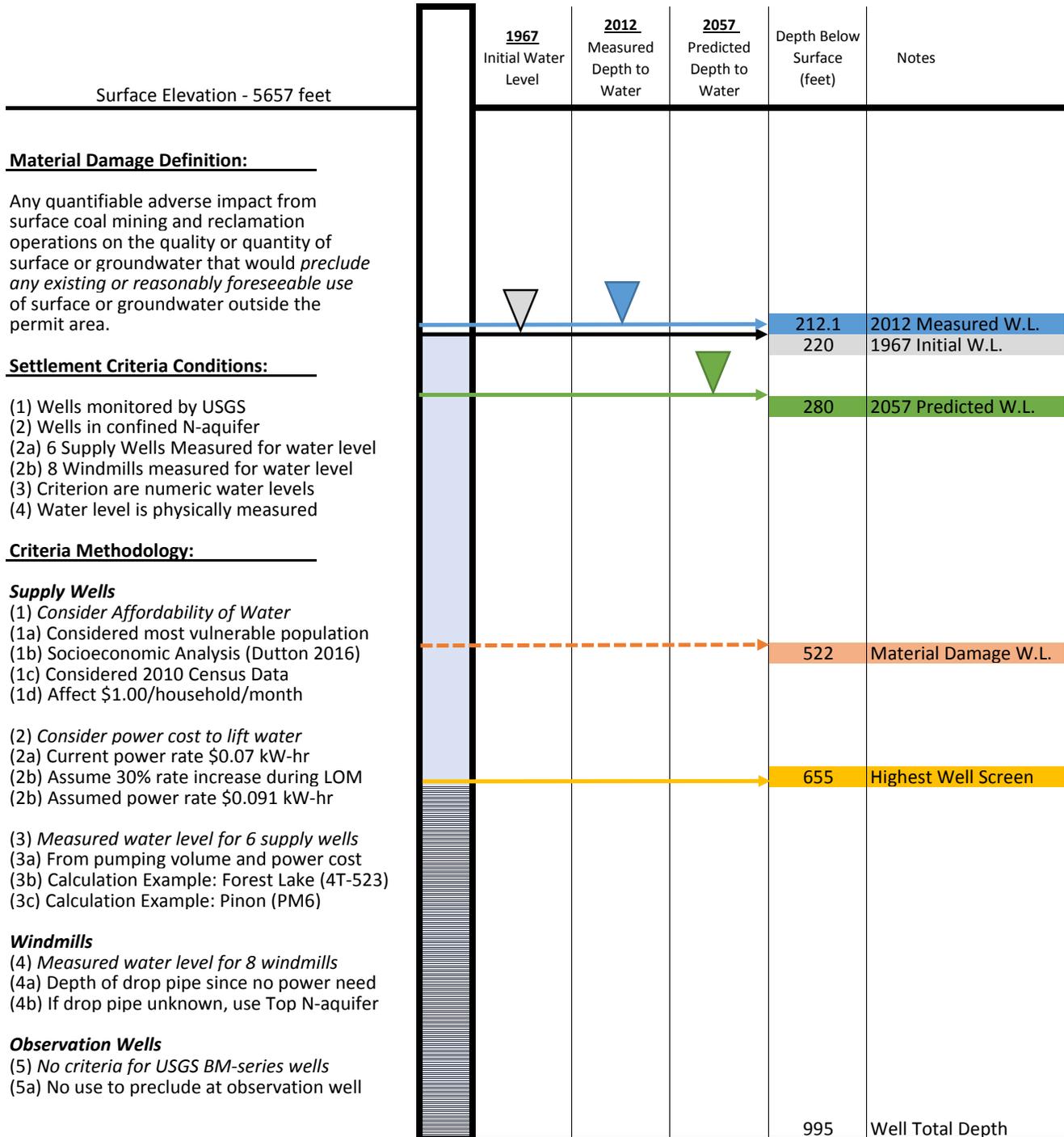
Kitsiili Supply Well NTUA2



Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWGCR, 2016); (Dutton, 2016)

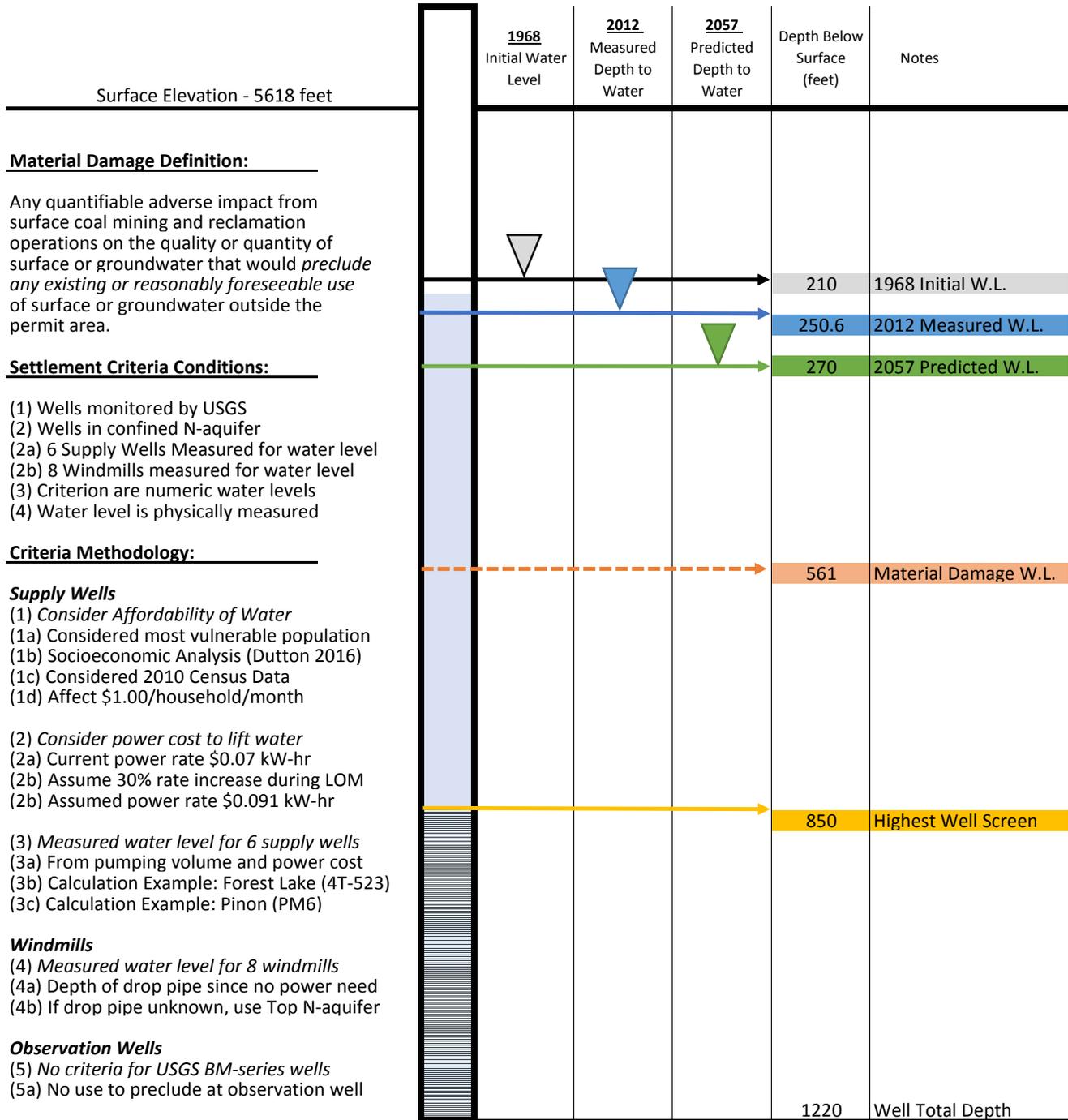
Kykotsmovi Supply Well PM1



Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWGCR, 2016); (Dutton, 2016)

Kykotsmovi Supply Well PM3



Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)

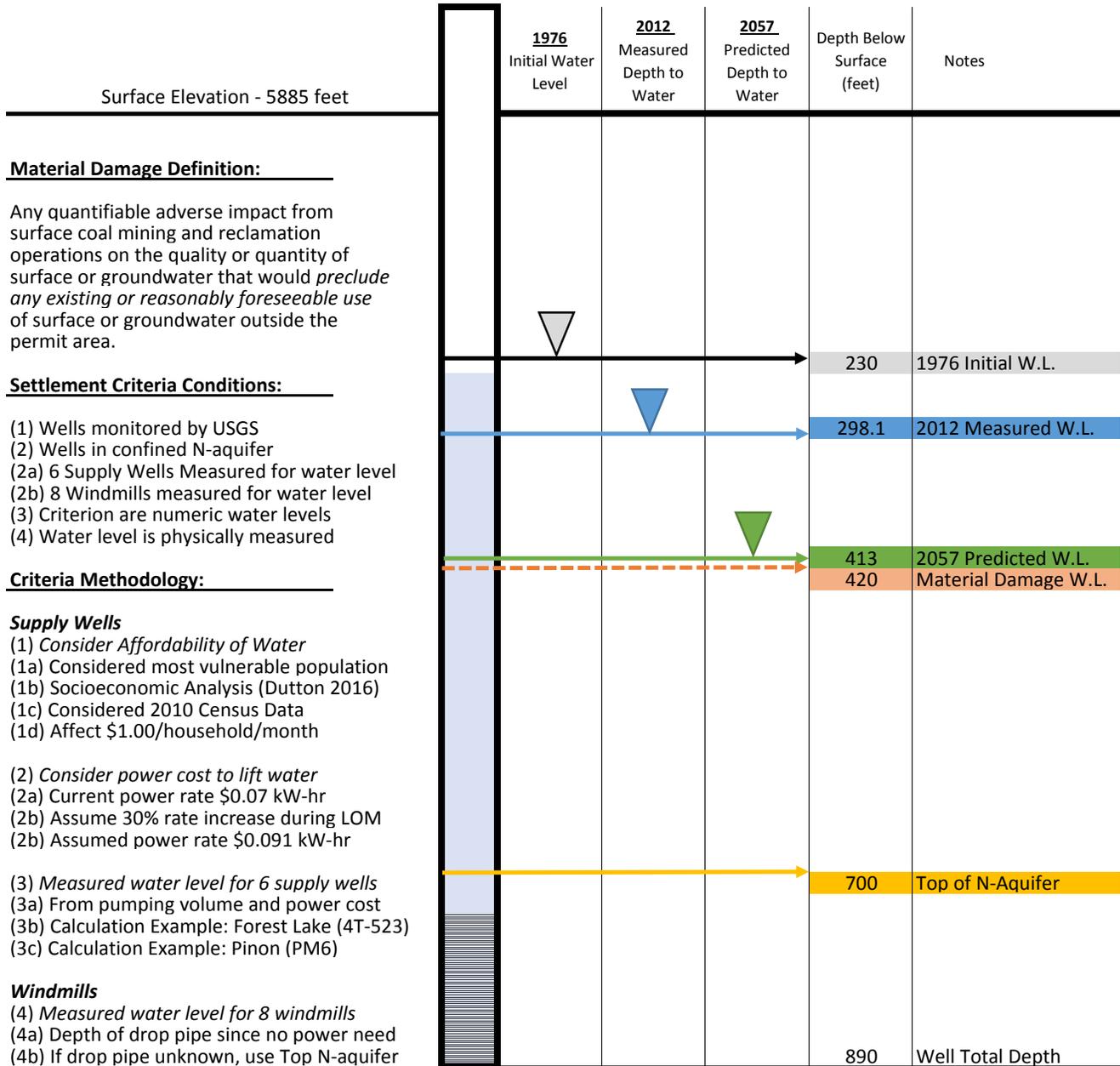
Howell Mesa Windmill (3K-311)

	<u>1953</u> Initial Water Level	<u>2012</u> Measured Depth to Water	<u>2057</u> Predicted Depth to Water	Depth Below Surface (feet)	Notes
Surface Elevation - 5855 feet					
Material Damage Definition:					
Any quantifiable adverse impact from surface coal mining and reclamation operations on the quality or quantity of surface or groundwater that would <i>preclude any existing or reasonably foreseeable use</i> of surface or groundwater outside the permit area.					
Settlement Criteria Conditions:					
(1) Wells monitored by USGS (2) Wells in confined N-aquifer (2a) 6 Supply Wells Measured for water level (2b) 8 Windmills measured for water level (3) Criterion are numeric water levels (4) Water level is physically measured					
Criteria Methodology:					
Supply Wells					
(1) <i>Consider Affordability of Water</i>					
(1a) Considered most vulnerable population					
(1b) Socioeconomic Analysis (Dutton 2016)					
(1c) Considered 2010 Census Data					
(1d) Affect \$1.00/household/month					
(2) <i>Consider power cost to lift water</i>					
(2a) Current power rate \$0.07 kW-hr					
(2b) Assume 30% rate increase during LOM					
(2b) Assumed power rate \$0.091 kW-hr					
(3) <i>Measured water level for 6 supply wells</i>					
(3a) From pumping volume and power cost					
(3b) Calculation Example: Forest Lake (4T-523)					
(3c) Calculation Example: Pinon (PM6)					
Windmills					
(4) <i>Measured water level for 8 windmills</i>					
(4a) Depth of drop pipe since no power need					
(4b) If drop pipe unknown, use Top N-aquifer					
Observation Wells					
(5) <i>No criteria for USGS BM-series wells</i>					
(5a) No use to preclude at observation well					
444	463			444	2012 Measured W.L.
				463	1953 Initial W.L.
				483	2057 Predicted W.L.
				615	Material Damage W.L.
				615	Top of N-Aquifer
				745	Well Total Depth

Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)

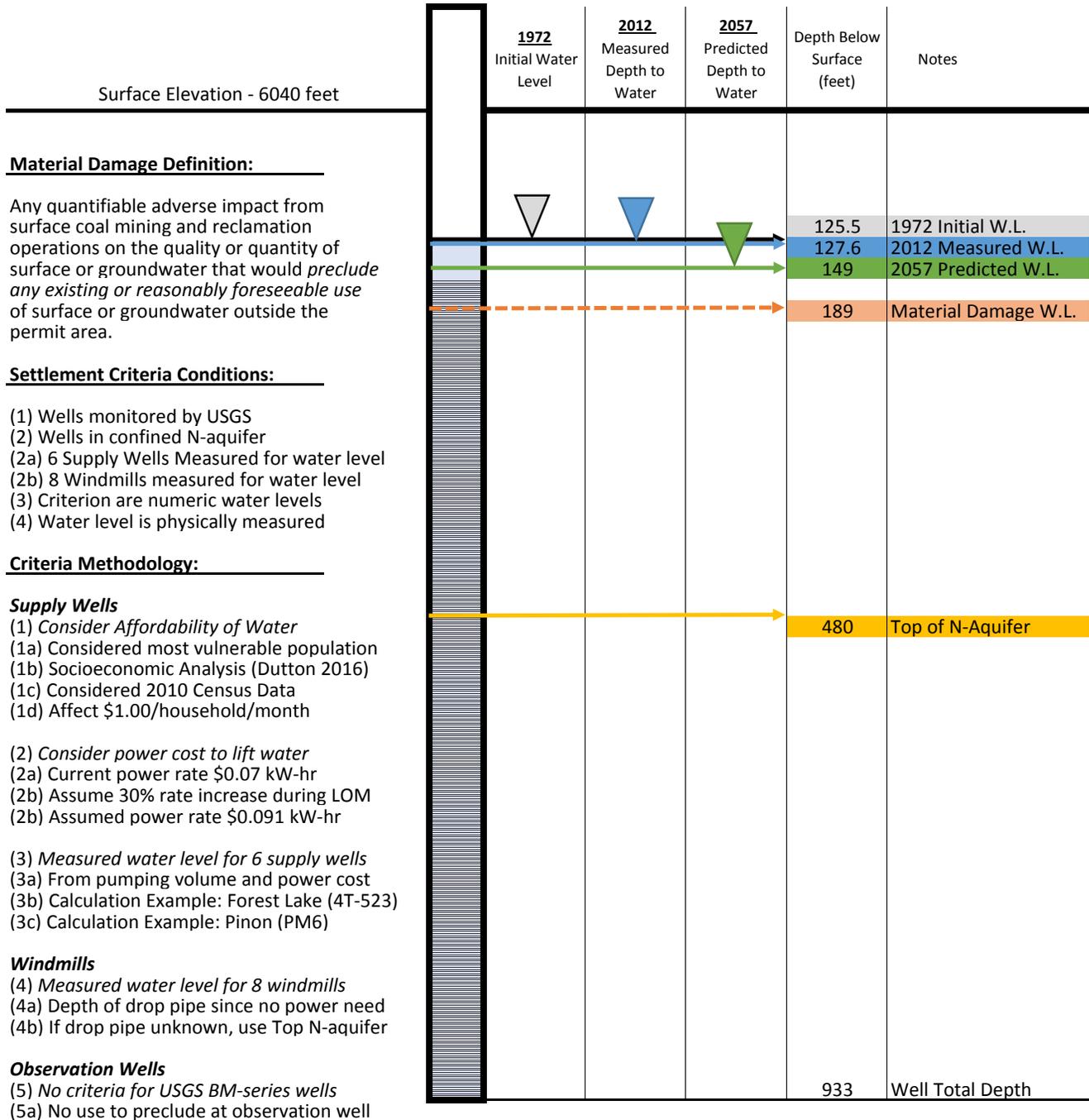
Kayenta West Windmill (8T-541)



Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)

Marsh Pass Windmill (8T-522)



Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)

Rough Rock Windmill (10R-119)

	<u>1953</u> Initial Water Level	<u>2012</u> Measured Depth to Water	<u>2057</u> Predicted Depth to Water	Depth Below Surface (feet)	Notes
Surface Elevation - 5775 feet					
Material Damage Definition:					
Any quantifiable adverse impact from surface coal mining and reclamation operations on the quality or quantity of surface or groundwater that would <i>preclude any existing or reasonably foreseeable use</i> of surface or groundwater outside the permit area.					
Settlement Criteria Conditions:					
(1) Wells monitored by USGS (2) Wells in confined N-aquifer (2a) 6 Supply Wells Measured for water level (2b) 8 Windmills measured for water level (3) Criterion are numeric water levels (4) Water level is physically measured					
Criteria Methodology:					
Supply Wells					
(1) <i>Consider Affordability of Water</i>					
(1a) Considered most vulnerable population					
(1b) Socioeconomic Analysis (Dutton 2016)					
(1c) Considered 2010 Census Data					
(1d) Affect \$1.00/household/month					
(2) <i>Consider power cost to lift water</i>					
(2a) Current power rate \$0.07 kW-hr					
(2b) Assume 30% rate increase during LOM					
(2b) Assumed power rate \$0.091 kW-hr					
(3) <i>Measured water level for 6 supply wells</i>					
(3a) From pumping volume and power cost					
(3b) Calculation Example: Forest Lake (4T-523)					
(3c) Calculation Example: Pinon (PM6)					
	▽	▽	▽	256.6	1953 Initial W.L.
				256.9	2012 Measured W.L.
				257.7	2057 Predicted W.L.
				310	Top of N-Aquifer
				336	Material Damage W.L.
				360	Well Total Depth

(Screened or open interval unknown)

Windmills

- (4) *Measured water level for 8 windmills*
- (4a) Depth of drop pipe since no power need
- (4b) If drop pipe unknown, use Top N-aquifer

Observation Wells

- (5) *No criteria for USGS BM-series wells*
- (5a) No use to preclude at observation well

Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)

Rough Rock Windmill (10T-258)

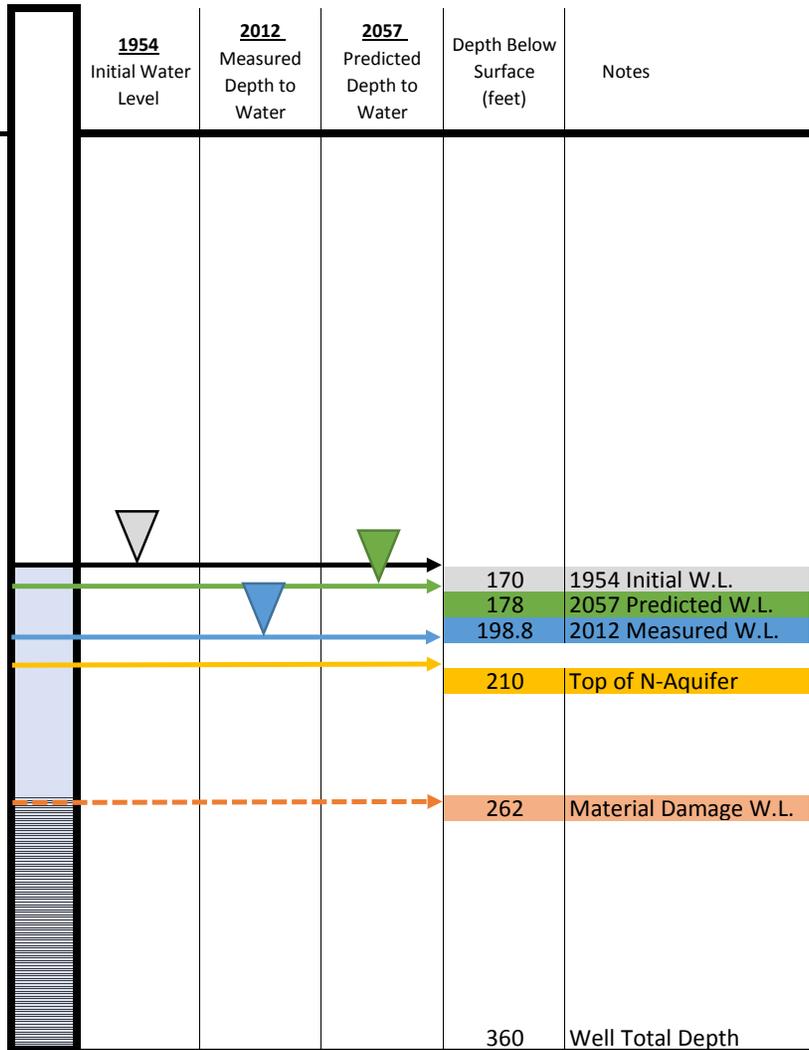
		<u>1960</u> Initial Water Level	<u>2012</u> Measured Depth to Water	<u>2057</u> Predicted Depth to Water	Depth Below Surface (feet)	Notes		
Surface Elevation - 5903 feet								
Material Damage Definition:								
Any quantifiable adverse impact from surface coal mining and reclamation operations on the quality or quantity of surface or groundwater that would <i>preclude any existing or reasonably foreseeable use</i> of surface or groundwater outside the permit area.								
Settlement Criteria Conditions:								
(1) Wells monitored by USGS (2) Wells in confined N-aquifer (2a) 6 Supply Wells Measured for water level (2b) 8 Windmills measured for water level (3) Criterion are numeric water levels (4) Water level is physically measured								
Criteria Methodology:								
Supply Wells								
(1) <i>Consider Affordability of Water</i>								
(1a) Considered most vulnerable population								
(1b) Socioeconomic Analysis (Dutton 2016)								
(1c) Considered 2010 Census Data								
(1d) Affect \$1.00/household/month								
(2) <i>Consider power cost to lift water</i>								
(2a) Current power rate \$0.07 kW-hr								
(2b) Assume 30% rate increase during LOM								
(2b) Assumed power rate \$0.091 kW-hr								
(3) <i>Measured water level for 6 supply wells</i>								
(3a) From pumping volume and power cost								
(3b) Calculation Example: Forest Lake (4T-523)								
(3c) Calculation Example: Pinon (PM6)								
Windmills								
(4) <i>Measured water level for 8 windmills</i>								
(4a) Depth of drop pipe since no power need								
(4b) If drop pipe unknown, use Top N-aquifer								
Observation Wells								
(5) <i>No criteria for USGS BM-series wells</i>								
(5a) No use to preclude at observation well								
		301	311.8	317	336	460	670	1960 Initial W.L. 2012 Measured W.L. 2057 Predicted W.L. Material Damage W.L. Top of N-Aquifer Well Total Depth

Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)

Rough Rock Windmill (10R-111)

	<u>1954</u> Initial Water Level	<u>2012</u> Measured Depth to Water	<u>2057</u> Predicted Depth to Water	Depth Below Surface (feet)	Notes
Surface Elevation - 5757 feet					
Material Damage Definition:					
Any quantifiable adverse impact from surface coal mining and reclamation operations on the quality or quantity of surface or groundwater that would <i>preclude any existing or reasonably foreseeable use</i> of surface or groundwater outside the permit area.					
Settlement Criteria Conditions:					
(1) Wells monitored by USGS (2) Wells in confined N-aquifer (2a) 6 Supply Wells Measured for water level (2b) 8 Windmills measured for water level (3) Criterion are numeric water levels (4) Water level is physically measured					
Criteria Methodology:					
Supply Wells					
(1) <i>Consider Affordability of Water</i>					
(1a) Considered most vulnerable population					
(1b) Socioeconomic Analysis (Dutton 2016)					
(1c) Considered 2010 Census Data					
(1d) Affect \$1.00/household/month					
(2) <i>Consider power cost to lift water</i>					
(2a) Current power rate \$0.07 kW-hr					
(2b) Assume 30% rate increase during LOM					
(2b) Assumed power rate \$0.091 kW-hr					
(3) <i>Measured water level for 6 supply wells</i>					
(3a) From pumping volume and power cost					
(3b) Calculation Example: Forest Lake (4T-523)					
(3c) Calculation Example: Pinon (PM6)					
Windmills					
(4) <i>Measured water level for 8 windmills</i>					
(4a) Depth of drop pipe since no power need					
(4b) If drop pipe unknown, use Top N-aquifer					
Observation Wells					
(5) <i>No criteria for USGS BM-series wells</i>					
(5a) No use to preclude at observation well					
Notes					
(1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057					
(2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)					
(3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports					
(4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)					
(5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)					



				170	1954 Initial W.L.
				178	2057 Predicted W.L.
				198.8	2012 Measured W.L.
				210	Top of N-Aquifer
				262	Material Damage W.L.
				360	Well Total Depth

Sweetwater Mesa Windmill (8K-443)

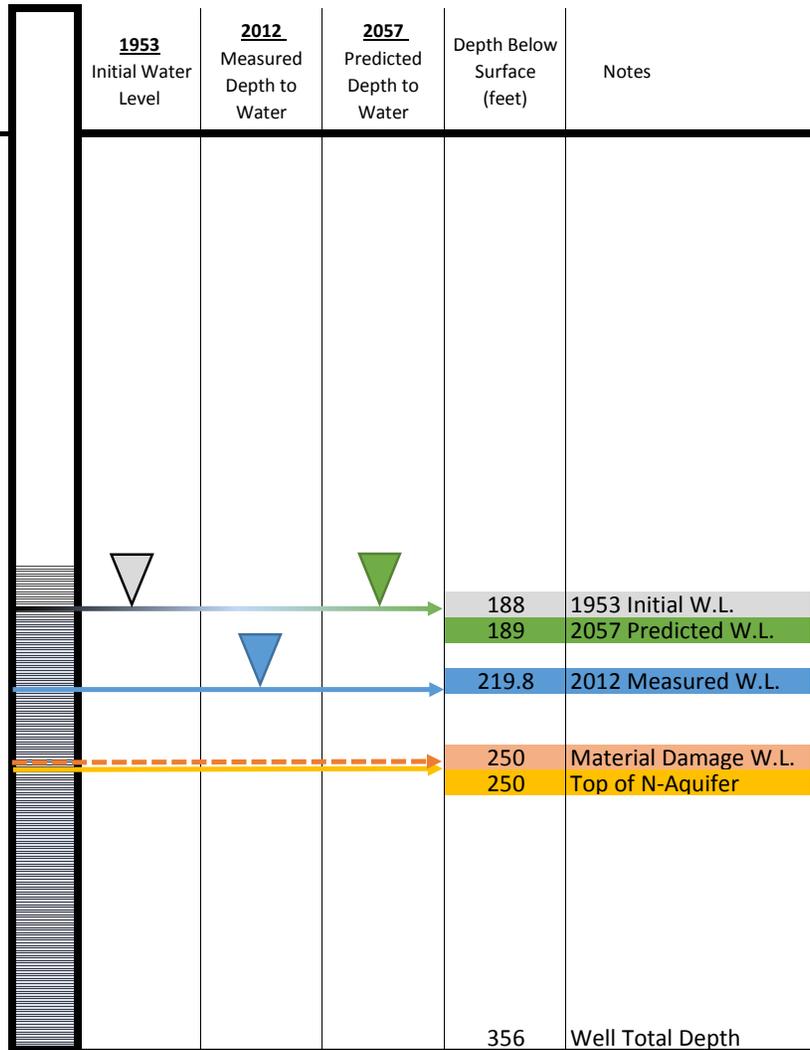
	<u>1967</u> Initial Water Level	<u>2012</u> Measured Depth to Water	<u>2057</u> Predicted Depth to Water	Depth Below Surface (feet)	Notes					
Surface Elevation - 6024 feet										
Material Damage Definition:										
Any quantifiable adverse impact from surface coal mining and reclamation operations on the quality or quantity of surface or groundwater that would <i>preclude any existing or reasonably foreseeable use</i> of surface or groundwater outside the permit area.										
Settlement Criteria Conditions:										
(1) Wells monitored by USGS (2) Wells in confined N-aquifer (2a) 6 Supply Wells Measured for water level (2b) 8 Windmills measured for water level (3) Criterion are numeric water levels (4) Water level is physically measured										
Criteria Methodology:										
Supply Wells										
(1) <i>Consider Affordability of Water</i>										
(1a) Considered most vulnerable population										
(1b) Socioeconomic Analysis (Dutton 2016)										
(1c) Considered 2010 Census Data										
(1d) Affect \$1.00/household/month										
(2) <i>Consider power cost to lift water</i>										
(2a) Current power rate \$0.07 kW-hr										
(2b) Assume 30% rate increase during LOM										
(2b) Assumed power rate \$0.091 kW-hr										
(3) <i>Measured water level for 6 supply wells</i>										
(3a) From pumping volume and power cost										
(3b) Calculation Example: Forest Lake (4T-523)										
(3c) Calculation Example: Pinon (PM6)										
Windmills										
(4) <i>Measured water level for 8 windmills</i>										
(4a) Depth of drop pipe since no power need										
(4b) If drop pipe unknown, use Top N-aquifer										
Observation Wells										
(5) <i>No criteria for USGS BM-series wells</i>										
(5a) No use to preclude at observation well										
		529.4	545.4	548	588	590	720			
					1967 Initial W.L.	2012 Measured W.L.	2057 Predicted W.L.	Material Damage W.L.	Top of N-Aquifer	Well Total Depth

Notes

- (1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057
- (2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)
- (3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports
- (4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)
- (5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)

White Mesa Arch Windmill (1K-214)

		<u>1953</u> Initial Water Level	<u>2012</u> Measured Depth to Water	<u>2057</u> Predicted Depth to Water	Depth Below Surface (feet)	Notes
Surface Elevation - 5771 feet						
Material Damage Definition:						
Any quantifiable adverse impact from surface coal mining and reclamation operations on the quality or quantity of surface or groundwater that would <i>preclude any existing or reasonably foreseeable use</i> of surface or groundwater outside the permit area.						
Settlement Criteria Conditions:						
(1) Wells monitored by USGS (2) Wells in confined N-aquifer (2a) 6 Supply Wells Measured for water level (2b) 8 Windmills measured for water level (3) Criterion are numeric water levels (4) Water level is physically measured						
Criteria Methodology:						
Supply Wells						
(1) <i>Consider Affordability of Water</i>						
(1a) Considered most vulnerable population						
(1b) Socioeconomic Analysis (Dutton 2016)						
(1c) Considered 2010 Census Data						
(1d) Affect \$1.00/household/month						
(2) <i>Consider power cost to lift water</i>						
(2a) Current power rate \$0.07 kW-hr						
(2b) Assume 30% rate increase during LOM						
(2b) Assumed power rate \$0.091 kW-hr						
(3) <i>Measured water level for 6 supply wells</i>						
(3a) From pumping volume and power cost						
(3b) Calculation Example: Forest Lake (4T-523)						
(3c) Calculation Example: Pinon (PM6)						
Windmills						
(4) <i>Measured water level for 8 windmills</i>						
(4a) Depth of drop pipe since no power need						
(4b) If drop pipe unknown, use Top N-aquifer						
Observation Wells						
(5) <i>No criteria for USGS BM-series wells</i>						
(5a) No use to preclude at observation well						
Notes						
(1) Life-of-Mine (LOM) Permit Application Period 2019 - 2057						
(2) Projected Mine Operation Pumping: 2019-2044 (1200 af), 2044-2047 (500 af), 2047-2057 (100 af)						
(3) Initial and Measured Water Level (W.L.), Screen Interval, and Total Depth, from USGS Annual Monitoring Reports						
(4) Predicted Water Level in 2044 and 2057 from SMCRA Life-Of-Mine Permit Application (Chapter 18, Appendix II-C)						
(5) References: (PWCC, 2016); (Macy, 2016); (SWG, 2016); (Dutton, 2016)						



				188	1953 Initial W.L.	
				189	2057 Predicted W.L.	
				219.8	2012 Measured W.L.	
				250	Material Damage W.L.	
				250	Top of N-Aquifer	
				356	Well Total Depth	

REGIONAL D- AND N-AQUIFER BASEFLOW AND SPRING DISCHARGE FIELD EVALUATION
BLACK MESA, ARIZONA – APRIL 4 – 7, 2016

Purpose: To assemble representatives responsible for and knowledgeable of Black Mesa surface and groundwater resources, and to assess the need and potential for increased monitoring; with emphasis on the Navajo Aquifer System.

The field evaluation is the culmination of in person working meetings, quarterly presentations, and teleconference updates during development of the NGS-KMC Draft EIS from April 2013 to April 2016. Appendix B is intended to satisfy Settlement Condition No.3 associated with Docket No. DV-2012-3-R, that states, “OSM shall produce a written assessment of the need and potential for increased N aquifer spring monitoring. This written evaluation will be documented in the CHIA update and developed in consultation with the Hopi Tribe, Navajo Nation, PWCC, and USGS.”

Objectives:

1. Discuss USGS Black Mesa Monitoring Program status and available monitoring results.
2. Identify the need and potential for increased monitoring of N aquifer discharge, and if additional information is necessary to evaluate industry and community water resource impacts.
3. Field verify N aquifer discharge Groups B, C, D, E, F1, and G are adequately characterized in the USGS spring inventory, and spring inventories used during impact analysis of surface coal mining operations.

The long-term effects of groundwater withdrawal from regional aquifers is a concern largely addressed through monitoring by the United States Geological Survey (USGS). USGS monitoring is supported through participation with the Arizona Water Commission, the Bureau of Indian Affairs (BIA), Navajo Tribal Utility Authority, Peabody Western Coal Company (PWCC), the Hopi Tribe, and the Western Navajo, Chinle, and Hopi Agencies of the BIA. Additionally, the Office of Surface Mining Reclamation and Enforcement (OSMRE) has a regulatory responsibility to complete a cumulative hydrologic impact assessment (CHIA) to assess hydrologic impacts associated with PWCC’s Kayenta Mine Complex surface mining and reclamation operations. OSMRE’s 2011 CHIA document was challenged and settled in May 2014 with the condition to assess the need and potential for increased N aquifer spring monitoring, and to develop the assessment in consultation with the Hopi Tribe, Navajo Nation, PWCC, and the USGS.

Further, the Navajo Generating Station – Kayenta Mine Complex (NGS-KMC) EIS necessitated an evaluation of the Black Mesa Regional D and N aquifers, impacts to baseflow and spring discharge, and impacts to uses of hydrologic resources associated with the proposed project. A review of available spring location and discharge information was completed and the figure below illustrates areas where N aquifer discharge is being monitored or likely to occur based on available information. Specifically, Groups B, C, D, E, F1, and G are of interest for this evaluation. Field verification will provide an understanding if the degree and magnitude of known discharge information is adequately captured through existing documentation and monitoring for assessing hydrologic impacts of the proposed NGS-KMC project.

These efforts are overlapping and often involve many of the same organizations and individuals. In an effort to be more efficient with time and resources, the Week of April 4th, 2016 provided an opportunity to consolidate these multiple efforts. The field stops provided and opportunity to further the discussion and review of D and N aquifer hydrologic resources, associated uses, and hydrologic impacts related to the objectives outlined above.

REGIONAL D- AND N-AQUIFER BASEFLOW AND SPRING DISCHARGE FIELD EVALUATION
BLACK MESA, ARIZONA – APRIL 4 – 7, 2016

Participants (listed with days of participation and listed as pictured from left to right):

James Boswell	Peabody Energy (M, W, Th)
Jamie Macy	USGS Arizona Water Science Center (M, T, W, Th)
Jon Mason	USGS Arizona Water Science Center (M, T, W, Th)
Jim Duffield	Hopi Water Resources Program (M, T, W)
Raymond Roessel	BIA Hopi Region (M, T, W, Th)
Bernadette Tsosie	BIA Navajo Region (M, T, W, Th)
Jim Burrell	AECOM Environment (representing Bureau of Reclamation) (M, T, W, Th)
Lisa Yellow Eagle	Navajo Nation Water Rights Protection (W, Th)
Randy Poleahla	Hopi Department of Natural Resources (M, T, W, Th)
Paul Clark	Office of Surface Mining Reclamation and Enforcement (M, T, W, Th)
Max Taylor	Hopi Water Resources Program (M)
Albert (not provided)	Hopi Water Resources Program (T, W, Th)
Yolanda Tahoe	Hopi Water Resources Program (T, W, Th)



Picture by: Bill Greenslade, Southwest Ground-water Consultants (working with AECOM) (M, T, W, Th)

Not Pictured

Ray Benally	Navajo Nation Department of Water Resources (M)
Jason John	Navajo Nation Department of Water Resources (M)
Robert Kirk	Navajo Nation Water Rights Protection (W, Th)
Lionel Puhuyesva	Hopi Water Resources Program (M)
Marie Shephard	Peabody Energy (M)
John Cochran	Peabody Energy (M)

REGIONAL D- AND N-AQUIFER BASEFLOW AND SPRING DISCHARGE FIELD EVALUATION
 BLACK MESA, ARIZONA – APRIL 4 – 7, 2016

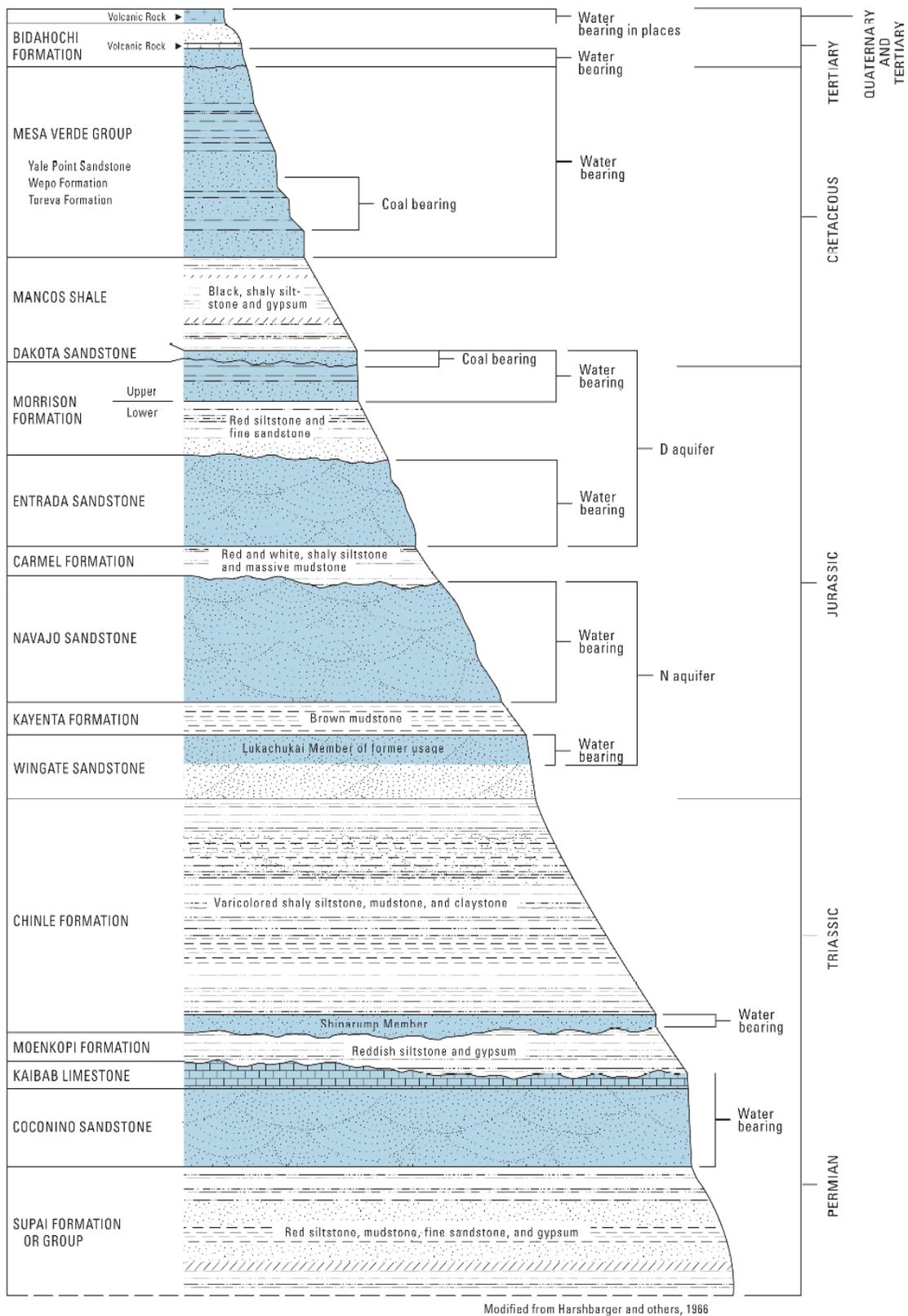
Precipitation Prior to Field Assessment:

Precipitation recorded February 5th in Flagstaff and February 1st in Kayenta, AZ; on ground snowmelt completed on February 12th. No additional measurable precipitation prior to field assessment.



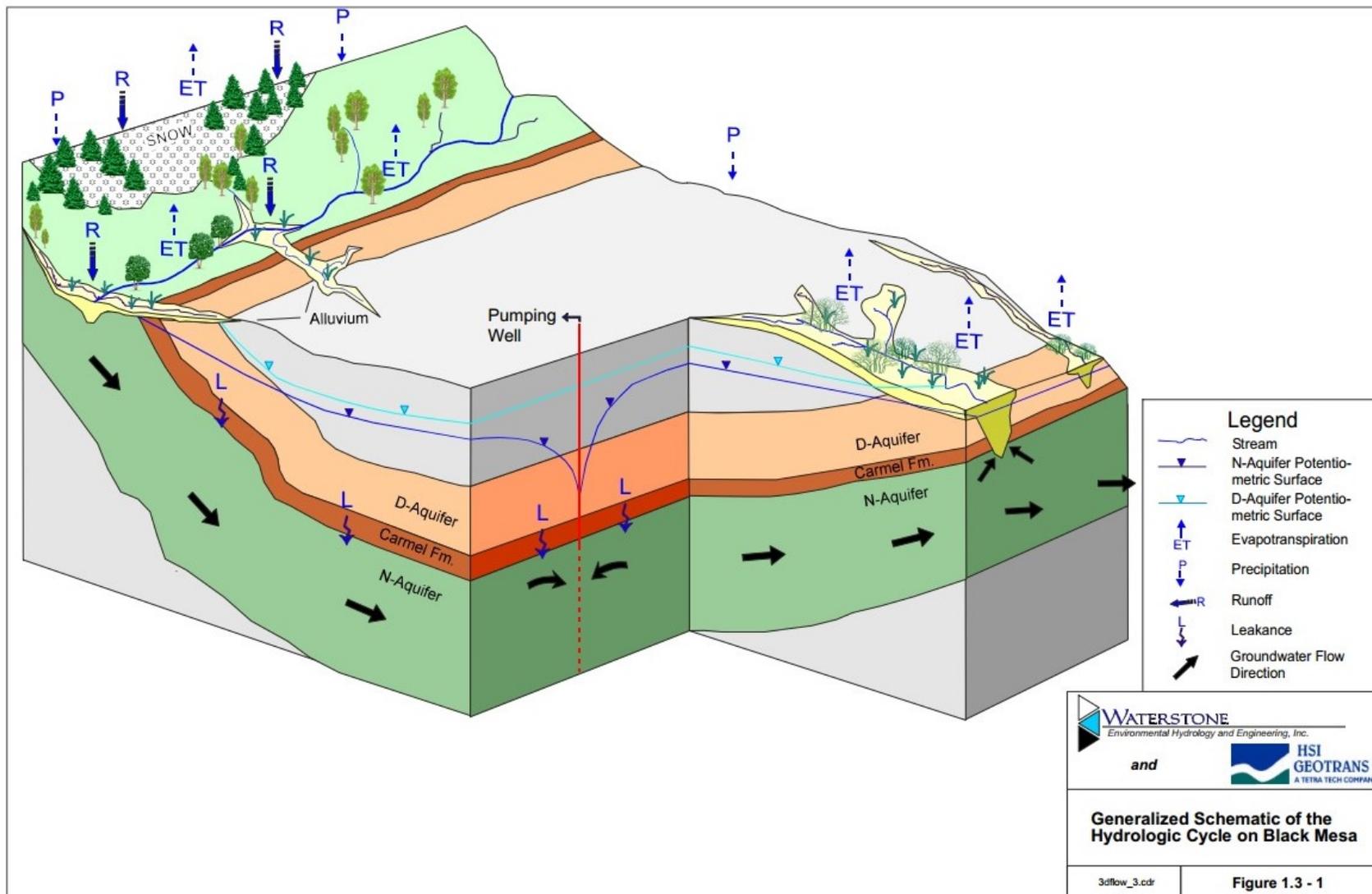
Weather history Flagstaff february 2016						Weather history Kayenta february 2016					
Day	High (°F)	Low (°F)	Precip. (inch)	Snow (inch)	Snow depth (inch)	Day	High (°F)	Low (°F)	Precip. (inch)	Snow (inch)	Snow depth (inch)
1 feb 2016	41.0	12.0	-	-	-	1 feb 2016	42.1	1.0	0.50	9.02	14.02
2 feb 2016	25.0	-7.1	-	9.80	12.01	2 feb 2016	32.0	3.0	0.00	0.00	12.99
3 feb 2016	30.9	-17.0	0.00	0.00	9.02	3 feb 2016	42.1	3.9	0.00	0.00	12.01
4 feb 2016	39.9	-9.9	0.00	0.00	9.02	4 feb 2016	42.1	3.0	0.00	0.00	12.01
5 feb 2016	39.9	-2.0	0.35	0.00	7.99	5 feb 2016	28.0	12.0	0.00	0.00	12.01
6 feb 2016	45.0	-0.9	0.00	0.00	7.01	6 feb 2016	43.0	12.0	0.00	0.00	10.98
7 feb 2016	46.0	7.0	0.00	0.00	5.98	7 feb 2016	44.1	12.9	0.00	0.00	9.02
8 feb 2016	51.1	33.1	0.00	0.00	5.98	8 feb 2016	46.0	30.0	0.00	0.00	5.98
9 feb 2016	55.9	15.1	0.00	0.00	5.98	9 feb 2016	50.0	30.0	0.00	0.00	4.02
10 feb 2016	63.0	12.9	0.00	0.00	5.98	10 feb 2016	55.9	30.0	0.00	0.00	4.02
11 feb 2016	60.1	12.9	0.00	0.00	5.00	11 feb 2016	59.0	35.1	0.00	0.00	2.99
12 feb 2016	63.0	16.0	0.00	0.00	4.02	12 feb 2016	60.1	37.9	0.00	0.00	0.98
13 feb 2016	62.1	18.0	0.00	0.00	0.00	13 feb 2016	61.0	35.1	0.00	0.00	0.00
14 feb 2016	60.1	16.0	0.00	0.00	0.00	14 feb 2016	55.9	32.0	0.00	0.00	0.00

REGIONAL D- AND N-AQUIFER BASEFLOW AND SPRING DISCHARGE FIELD EVALUATION
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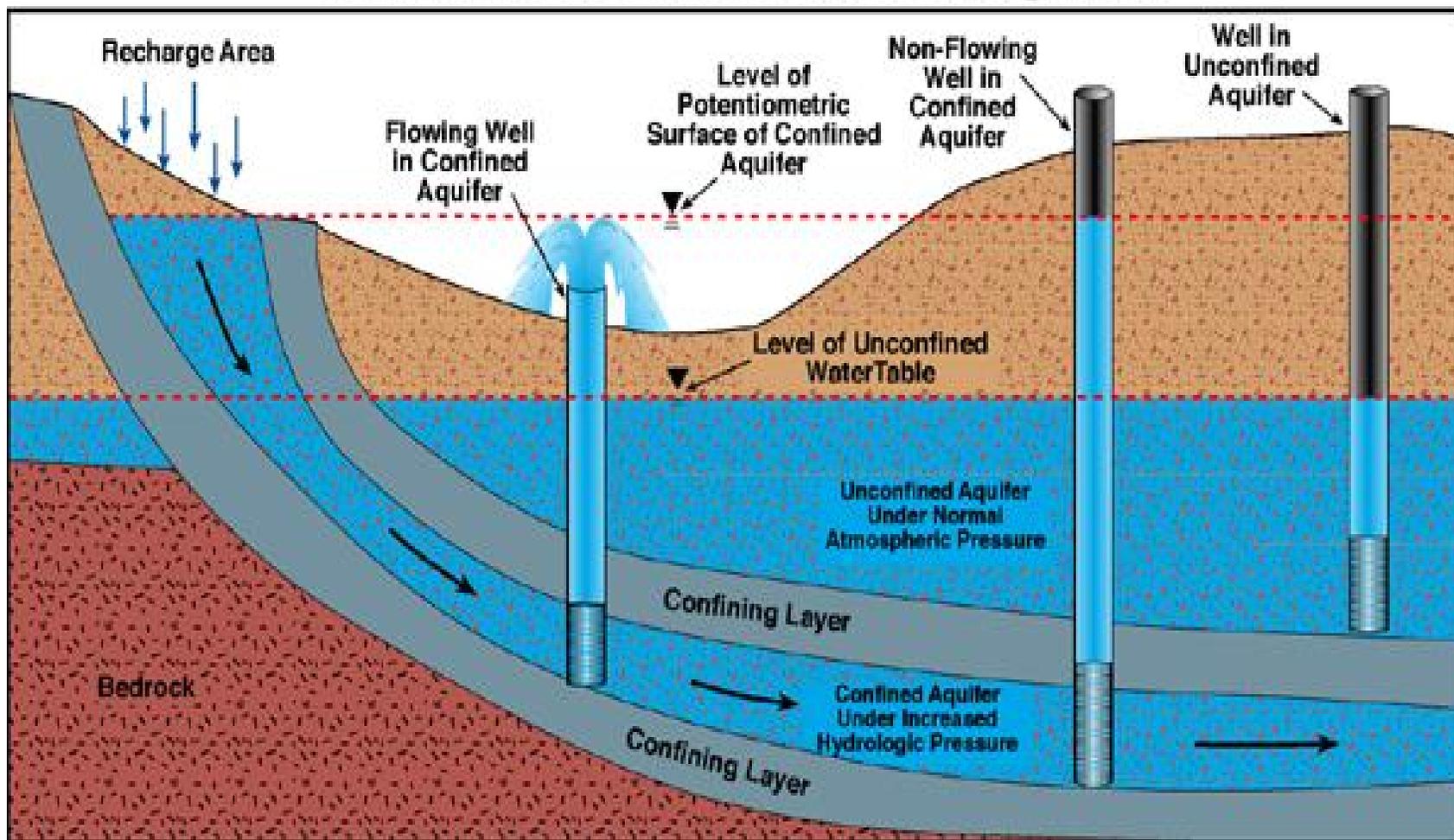


Rock Formations and Major Aquifer Zones of the Black Mesa Area (Macy and Unema, 2014).

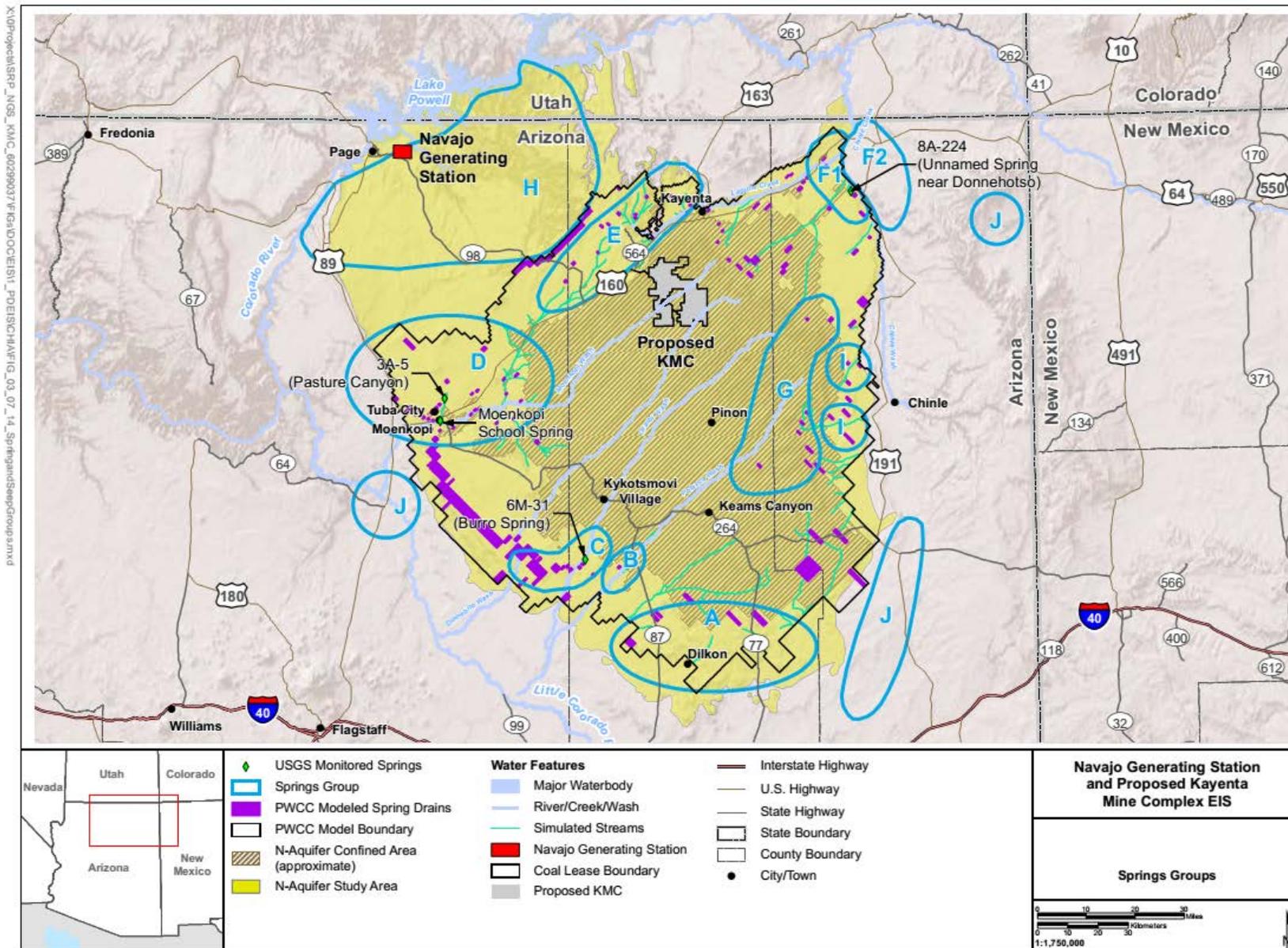
REGIONAL D- AND N-AQUIFER BASEFLOW AND SPRING DISCHARGE FIELD EVALUATION
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Potentiometric Surface and Flowing Wells

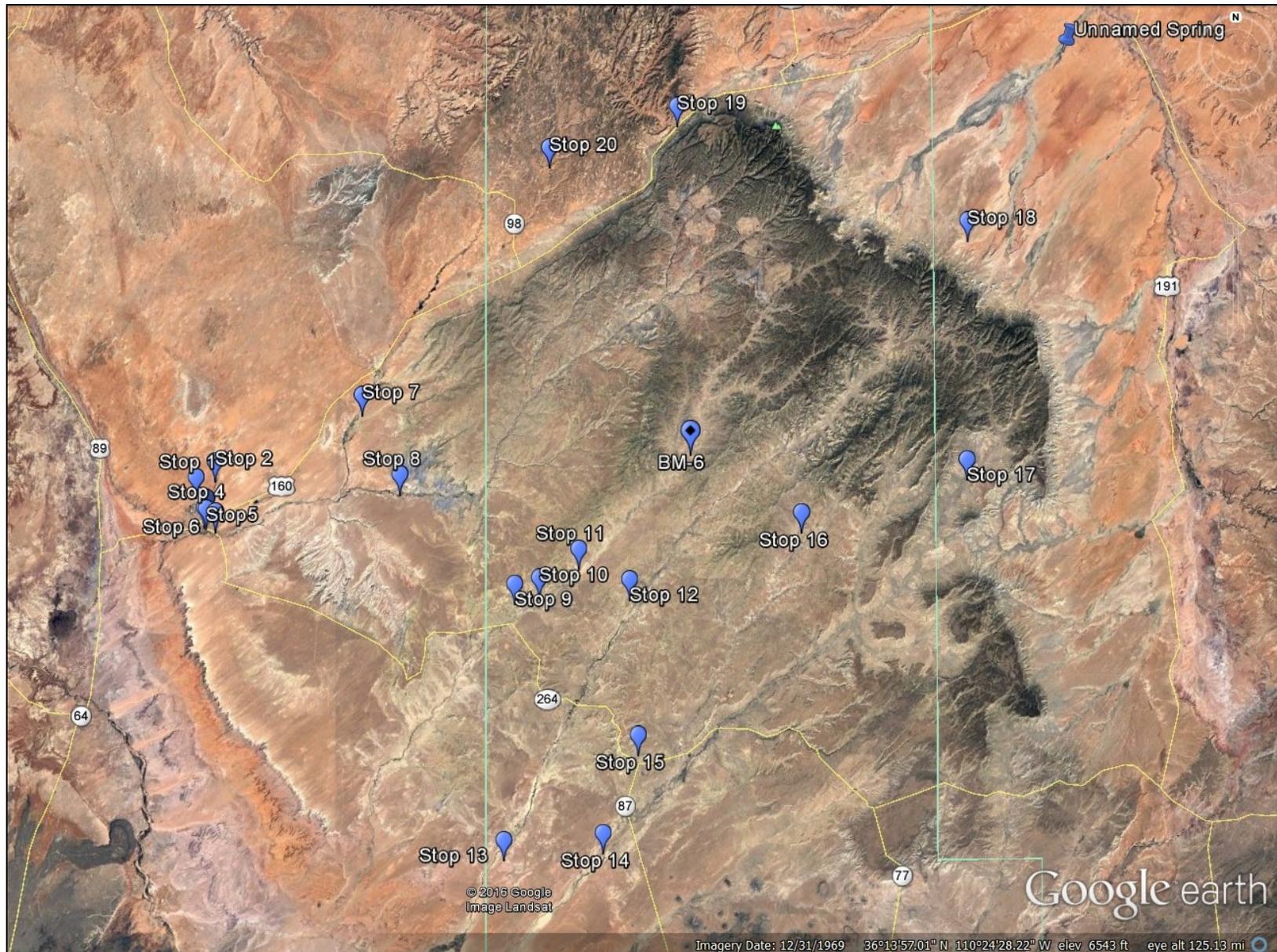


REGIONAL D- AND N-AQUIFER BASEFLOW AND SPRING DISCHARGE FIELD EVALUATION
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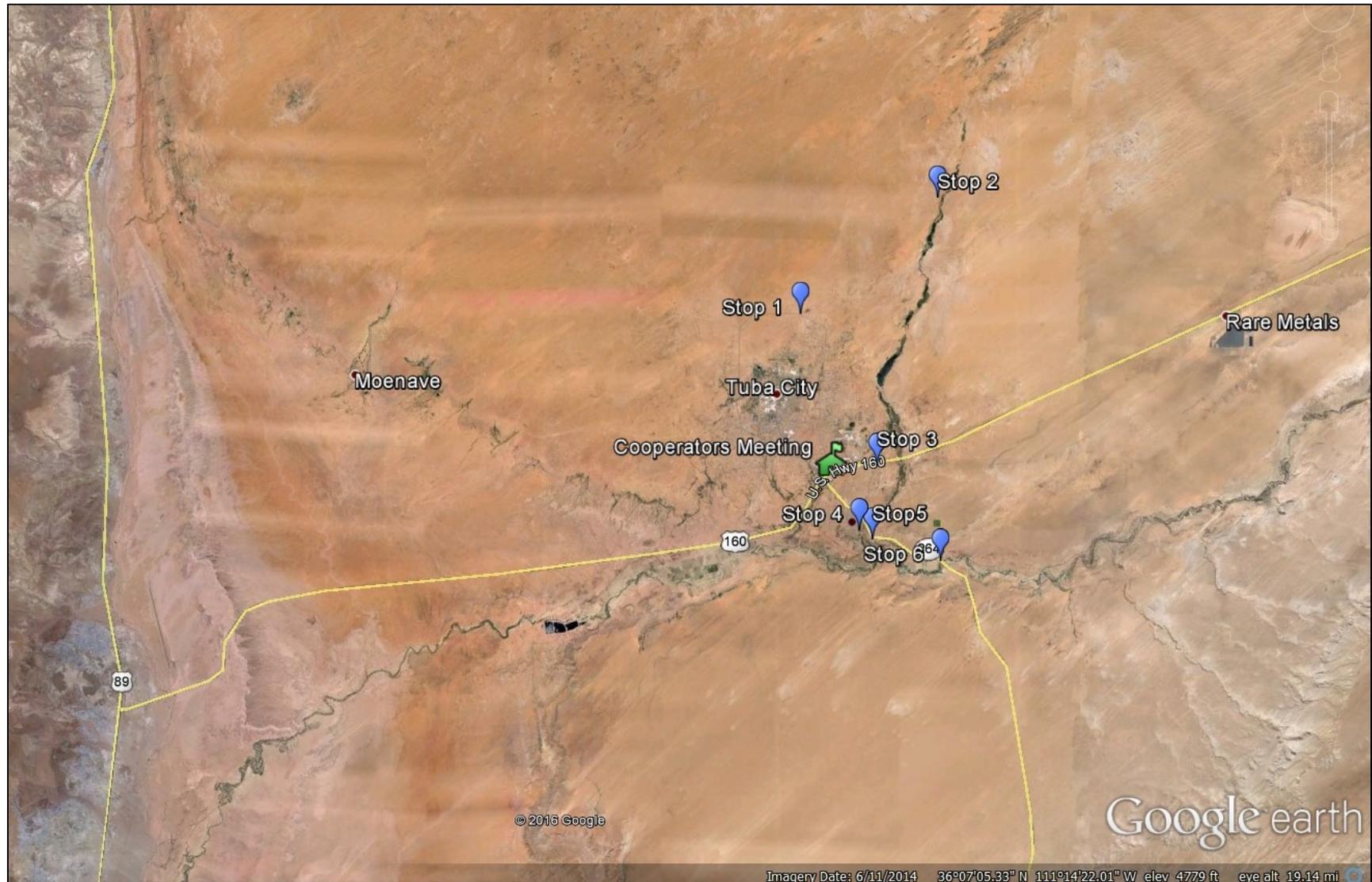


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REGIONAL D- AND N-AQUIFER BASEFLOW AND SPRING DISCHARGE FIELD EVALUATION
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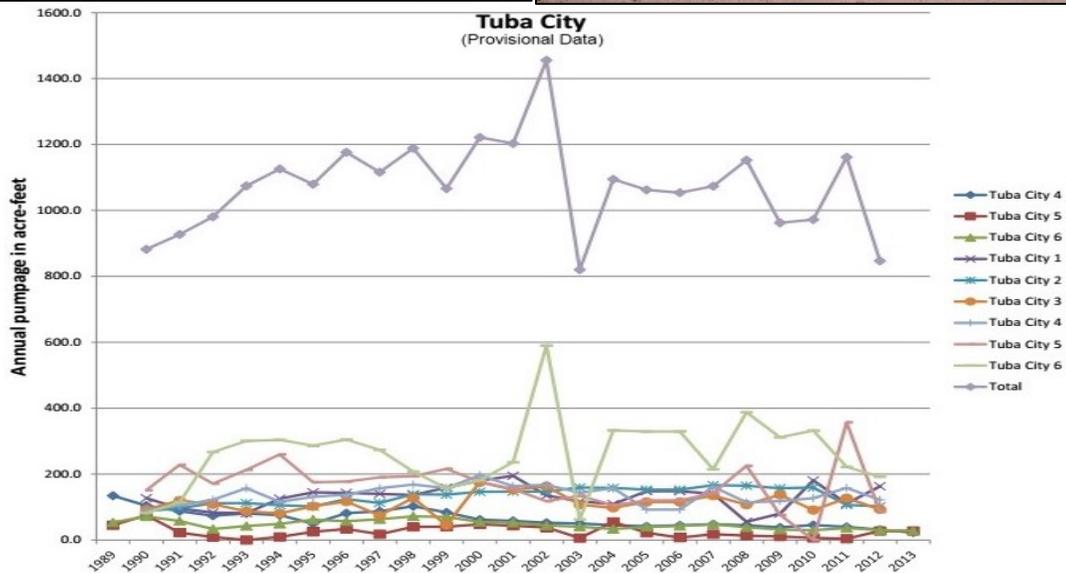


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Stop 1 (Spring Group D): Tuba City Wellfield



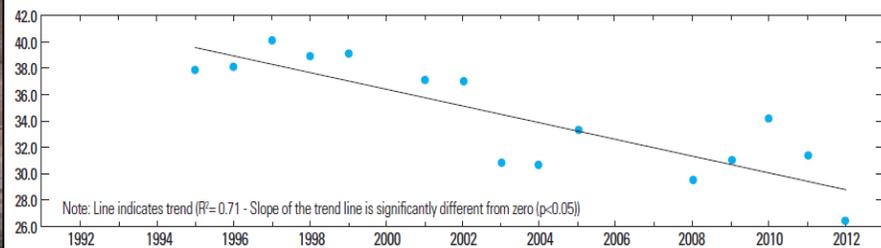
Group Discussion:

Nine (9) Production wells comprise the Tuba City Wellfield. We discussed the wellfield history of operation and the graph of annual production. The wells are positioned in a linear north-south pattern. The group discussed that the installation pattern was likely associated with large water bearing fractures in the Navajo Sandstone. Above, Jamie Macy (USGS) points to an area of high relief that receives above average precipitation compared to the surrounding area. Mr. Macy also indicates the Tuba City syncline trending northwest-southeast, which may provide recharge from the high relief area to the unconfined fractured Navajo Sandstone aquifer.

Key Reference:

Macy, J.P., 2012. Characterization of subsurface geologic structure for potential water resources near the Village of Moenkopi, Arizona, 2009-2010: U.S. Geological Survey Scientific Investigations Report 2012-5180, 24 p. (Available at <http://pubs.usgs.gov/sir/2012/5180/>.)

Stop 2 (Spring Group D): USGS Pasture Canyon Surface Water Monitoring Location 09401265

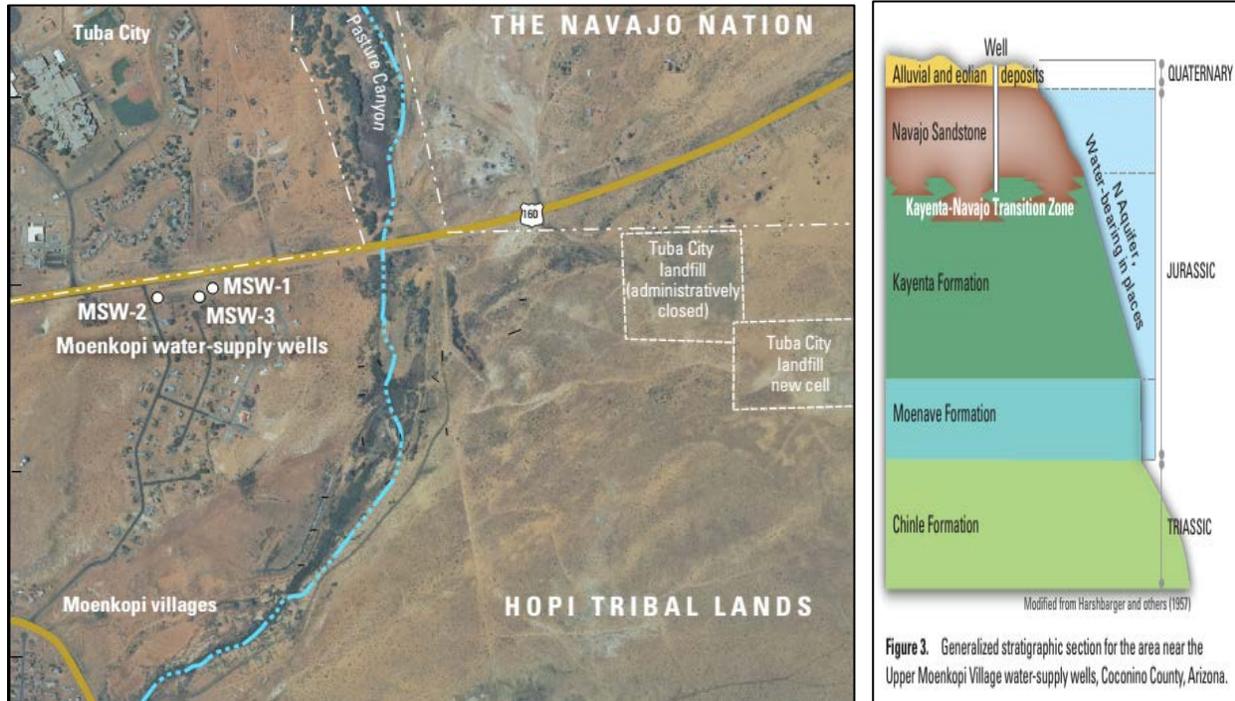


Pasture Canyon flow measured in gallons per minute (gpm) at USGS 09401265 (Macy and Unema, 2014).

Group Discussion:

Pasture Canyon is approximately 6 miles in length from the upper headwater near sand dunes to the mouth downstream at Moenkopi Wash, and thought to intercept the Tuba City syncline. Pasture Canyon has agricultural, recreational, aquatic, and biological uses, and is approximately 1.5 – 2.0 miles from the Tuba City wellfield. Measured water levels reflect influences of annual variations in precipitation recharge and pumping influences. Small caves approximately 10-20 feet deep and about 10-20 feet in height indicate where water seepage has weakened the formation. At the time of visit, the downstream Tuba City reservoir was under major renovation and drained at time of observation.

Stop 3 (Spring Group D): Moenkopi Wellfield

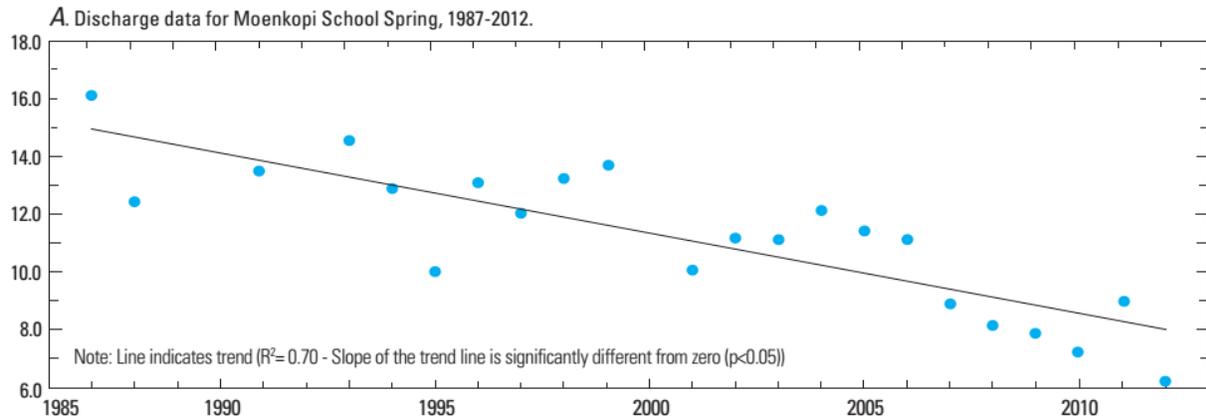


Group Discussion:

The productivity of three (3) Moenkopi water supply wells is limited. Efforts to identify and develop additional water supply capacity are underway. The group discussed the follow two (2) USGS scientific reports.

- Carruth, R.L., Beisner, Kimberly, and Smith, Greg, 2013, Quality, isotopes, and radiochemistry of water sampled from the Upper Moenkopi Village water-supply wells, Coconino County, Arizona: U.S. Geological Survey Open-File Report 2013-1162, 18 p. (above images from report).
- Macy, J.P., 2012, Characterization of subsurface geologic structure for potential water resources near the Villages of Moenkopi, Arizona, 2009–2010: U.S. Geological Survey Scientific Investigations Report 2012–5180, 24 p. (Available at [http://pubs.usgs.gov/sir/2012/5180/.](http://pubs.usgs.gov/sir/2012/5180/))

Stop 4 (Spring Group D): Hopi Susunova Spring



Susunova Spring (aka: Moenkopi School Spring) flow in gallons per minute (Macy and Unema, 2014).

Group Discussion:

On arrival, a local was filling several jugs of water from the spring discharge for household consumption. He noted the group water resource discussion, and politely commented that a lot more water used to flow from the pipe. The comment is supported by the above discharge hydrograph, illustrating a declining trend. The most recent measurement is a low for the 30-year period of record. The origin of the spring is thought to be associated with the fracture pattern consistent the other water bearing fractures in the Navajo Sandstone.

The group discussed that Susunova Spring is a place of cultural importance, and religious ceremonies are conducted at this location. Water from the discharge pipe is routed through irrigation ditches, and fields are irrigated based on agreed allocation within the tribe.

Stop 5 (Spring Group D): Moenkopi Overlook



Group Discussion:

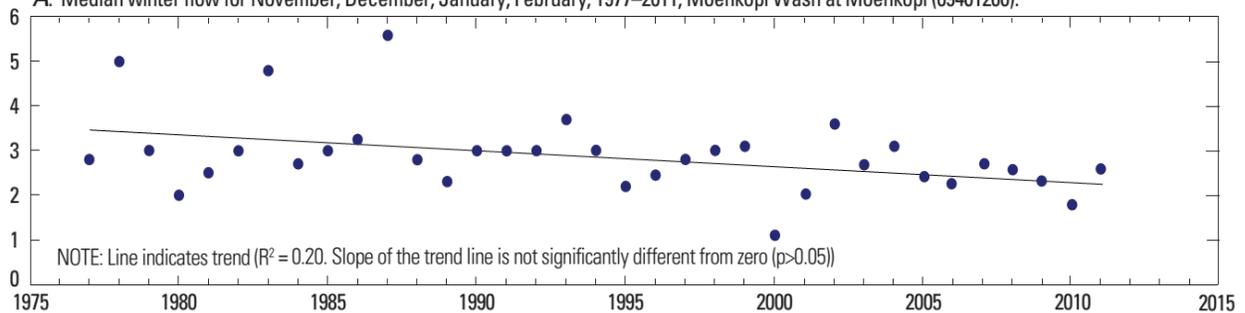
The practice of pumping water from Moenkopi Wash for supplemental irrigation water was discussed. During low flow periods, pits can be dug in Moenkopi Wash to expose the saturated alluvial and the water pumped to adjacent fields. Storm flow water is not used for supplemental irrigation since elevated suspended sediment load during runoff would either ruin pumps or damage crop productivity if applied.

The group also discussed Dripping Spring, which is a hanging garden emanating from a bedding plane adjacent to the highway. Navajo sedge and other sedges populate the seepage face, and is illustrated on the bottom right photo.

Stop 6 (Spring Group D): USGS Moenkopi Monitoring Station 09401260



A. Median winter flow for November, December, January, February, 1977–2011, Moenkopi Wash at Moenkopi (09401260).



Moenkopi Wash Location 09401260 discharge in cubic feet per second (Macy and Unema, 2014).

Group Discussion: Moenkopi HUC 15020018 Watershed drains an area of 2,635 square miles. USGS Monitoring Location 09401260 measures flow from 1,629 square miles of the Moenkopi Watershed. Discussed recent upgrades to monitoring equipment including a sonic monitor secured on the bridge for more reliable measurements. However, shifting sand bars continue to challenge accurate measurements, especially during low flow periods. Prayer feathers are often left at places of water resource significance.

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Stop 7 (Spring Group D): Begeshbito Wash



Group Discussion:

Begeshbito Wash is filled with Russian Olive limiting productive agricultural develop, although satellite imagery indicates remnants of agricultural plots. Far in the distance a few large cottonwoods still thrive, and are likely associated with water seeping from a local fracture in the surficial Navajo Sandstone Formation.

Stop 8 (Spring Group D): Blue Canyon Water Caves

The Hopi Tribe's Department of Natural Resources established the 2014 Blue Canyon Wilderness Visitation Policy. This area is part of the Hopi Indian Reservation and land use is managed by the Hopi Dept. of Natural Resources. Visitation by Non-Hopi Tribal Members is Restricted and by Permit Only. Visitors must be accompanied by a Hopi Licensed Tour Guide who is permitted to visit this area.

The Blue Canyon Trading Post, opened in 1882 by Jonathan Williams, an unsuccessful prospector who decided to become a trader instead. He gave it up in 1889, and it was taken over by the federal government's Indian Service, which started an agency and a school there in 1900. C.H. Algert, another trader, built an extension on the government buildings, but also gave up shortly thereafter. While there, he managed to get the Post Office Department to open a facility there in 1900, and name it after him. It closed in 1903 when the federal government's BIA moved all its operations, including the school, to Tuba City. A Hubert Richardson then took over the post and its buildings; he ceased operations in 1921. There are the walls of some of the school buildings still standing, as well as some of the walls of the trading post itself.

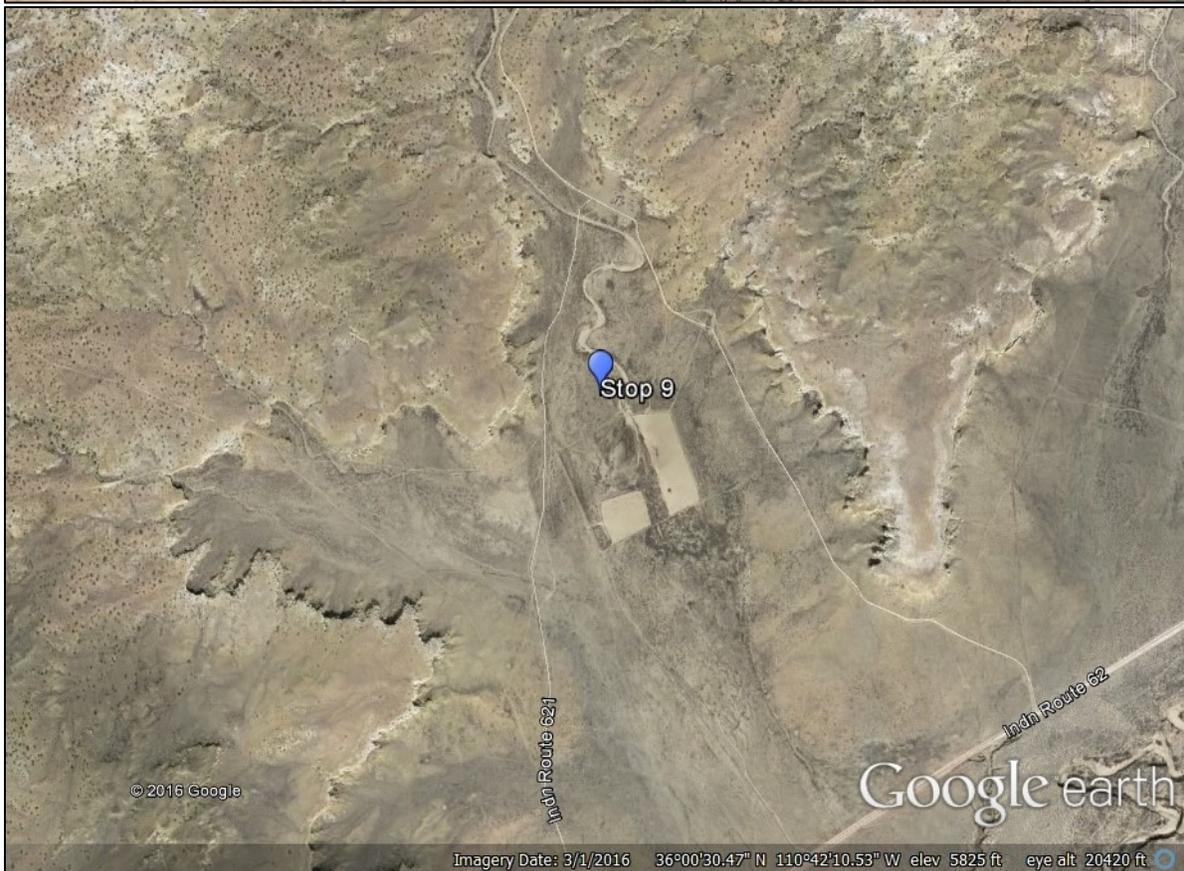
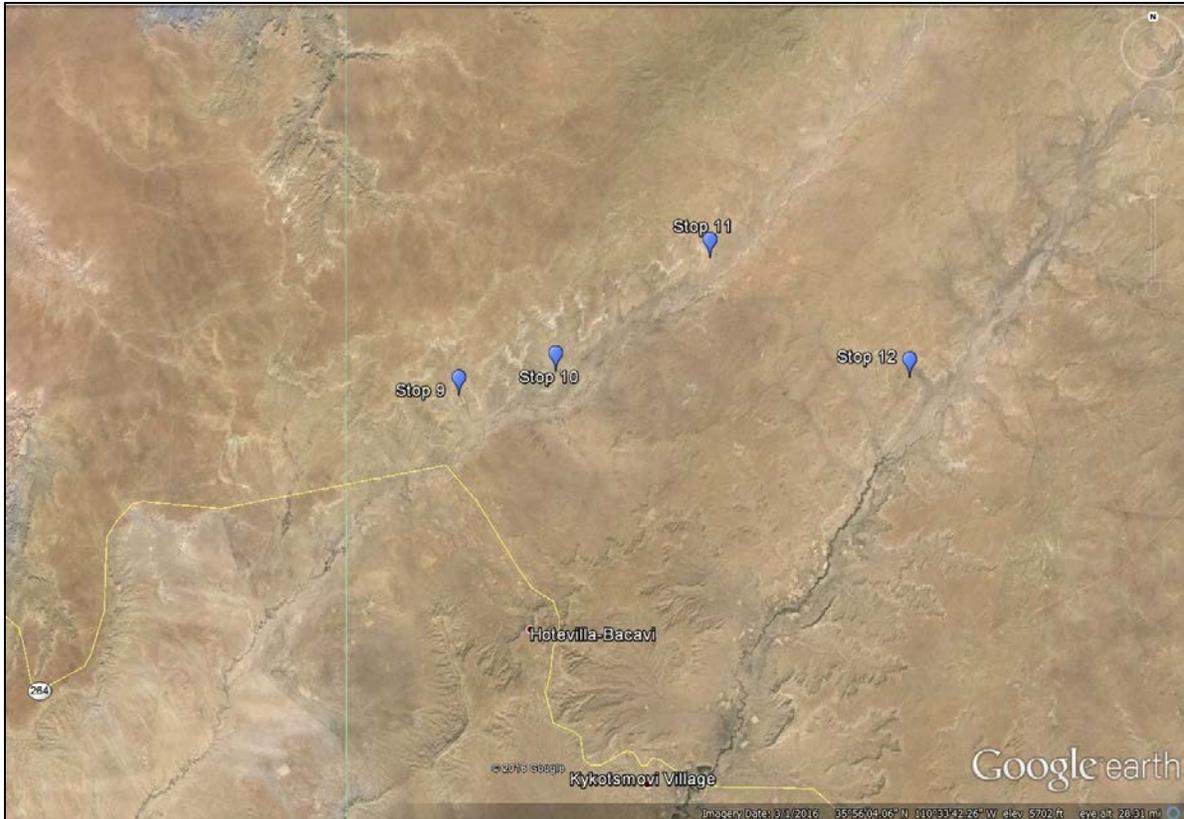


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Group Discussion: Location is on Moenkopi Wash approximately 20 miles upstream from Moenkopi Village. The group discussed the need and potential to enhance the existing monitoring program at Blue Canyon where no water monitoring occurs. Although there is not a need for additional monitoring to satisfy SMCRA permitting, or the NGS-KMC EIS decision, there is an information need for Hopi resource management. The information need is aligned with the Hopi BIA mission. Potential funding to support Hopi resource management in the Blue Canyon area was discussed with Hopi BIA, but rejected.

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Stop 9: Water Impoundment – Dry Farming

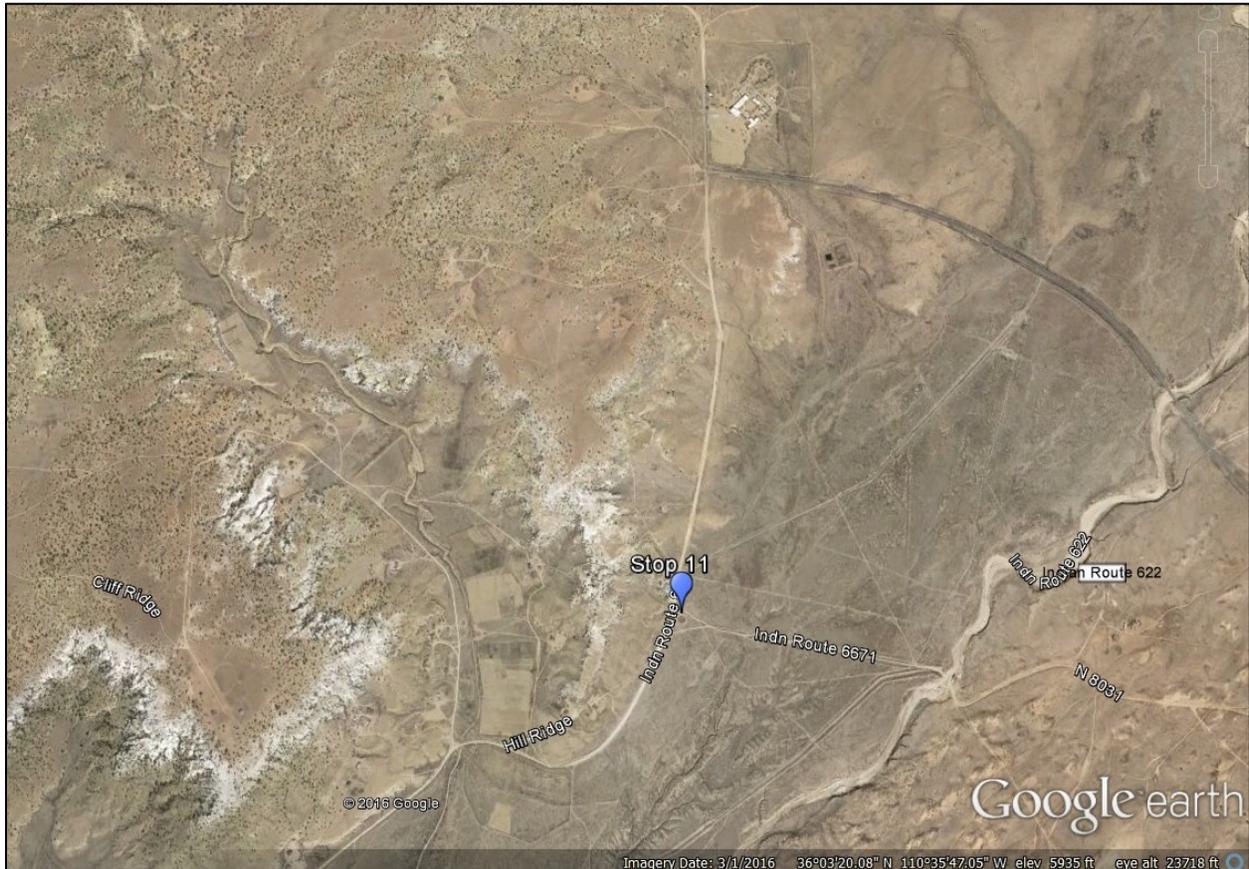
Group Discussion: Stop 9 presented an illustration of agricultural development in the arid region. Arroyos are partially dammed with earthen embankments to retain sufficient surface water and soil moisture to support a small farm plot. This practice occurs throughout the area.

Stop 10: Water Impoundment – Livestock Watering

Group Discussion: Some arroyos are a sufficient size to support measurable surface water when impoundments are created. Stop 10 is located at an arroyo adjacent to Stop 9, yet standing water is available. Note: Google imagery collected on same date.



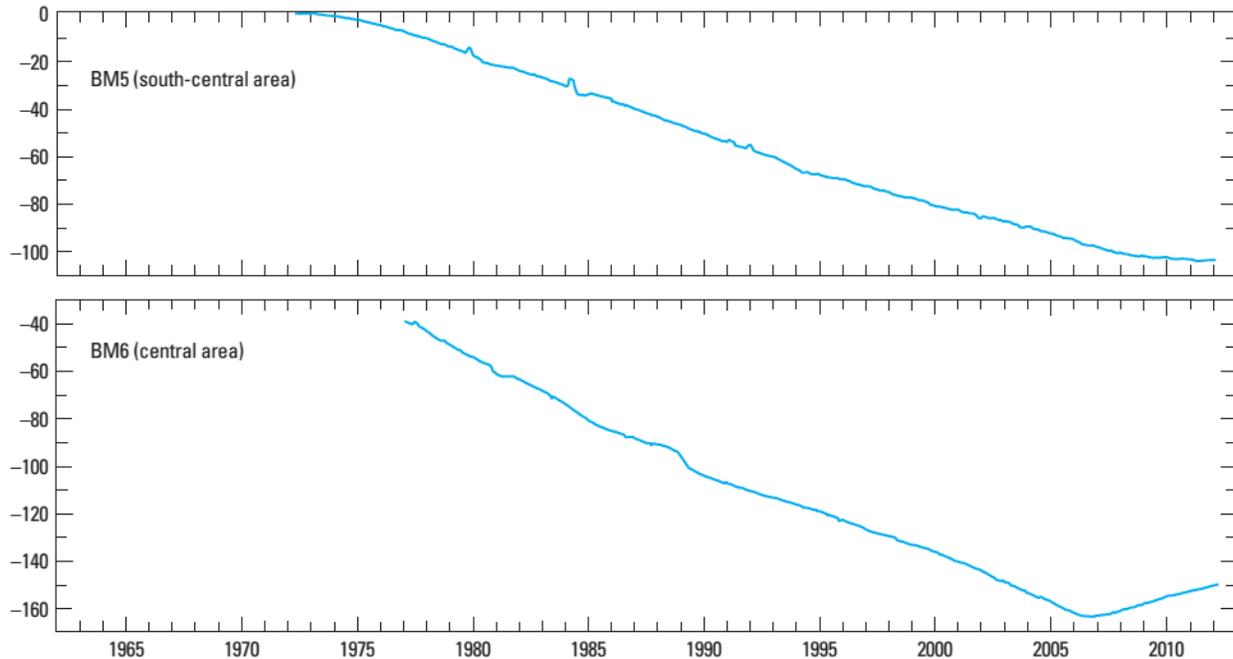
Stop 11: Dinnebito Dam



Group Discussion:

Pictured above is Dinnebito Wash, trending northeast-southwest. A tributary branch joins Dinnebito Wash. Agricultural development is apparent on the tributary but not on Dinnebito Wash. Similar to the dry farming technique discussed at Stop 9, farm plots in the tributary take advantage of the alluvial soil moisture, and implement earthen dams which route flow from the arroyo channel during storm flow events. The storm flow events on the main channel of Dinnebito Wash are too great a magnitude for sustainable agricultural development. Earthen road crossing structures such as Indian Route 5571 are often not sustainable. Indian Route 5571 is thought to be the location identified as Dinnebito Dam. A more modern paved highway with an engineered bridge crossing Dinnebito Wash is illustrated above and north of Indian Route 5571. See also the Dinnebito Wash discharge hydrograph illustrated below at Stop 14.

Stop 12: USGS Monitoring Well BM5



Group Discussion: All USGS BM-series monitoring wells are installed with satellite telemetry, and water level data is measured at 15-minute intervals and uploaded every 4-hours to the USGS webpage at: http://waterdata.usgs.gov/az/nwis/current/?type=gw&group_key=county_cd

BMOBS5 (BM5) is pictured below. The BM5 hydrograph indicates the Navajo aquifer is beginning to respond to PWCC reduced pumping, which occurred on January 1, 2006. BM6 is closer to the PWCC, and aquifer response to PWCC reduced pumping began in 2006.



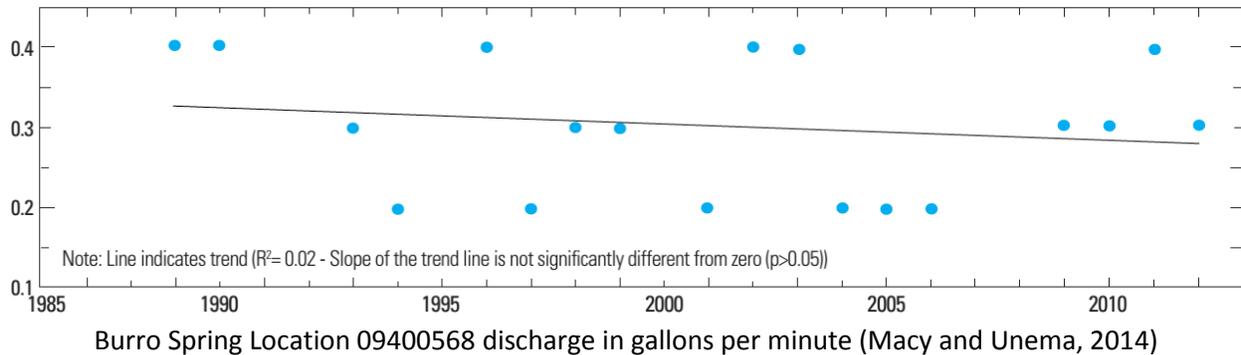
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Stop 13 (Spring Group C): Burro Spring



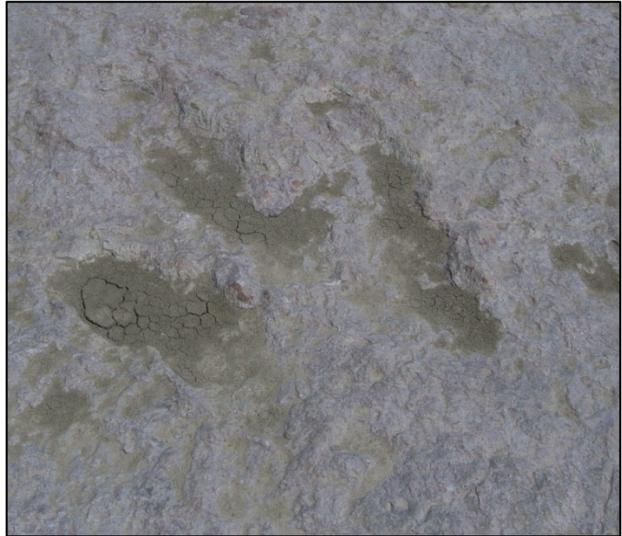
REGIONAL D- AND N-AQUIFER BASEFLOW AND SPRING DISCHARGE FIELD EVALUATION
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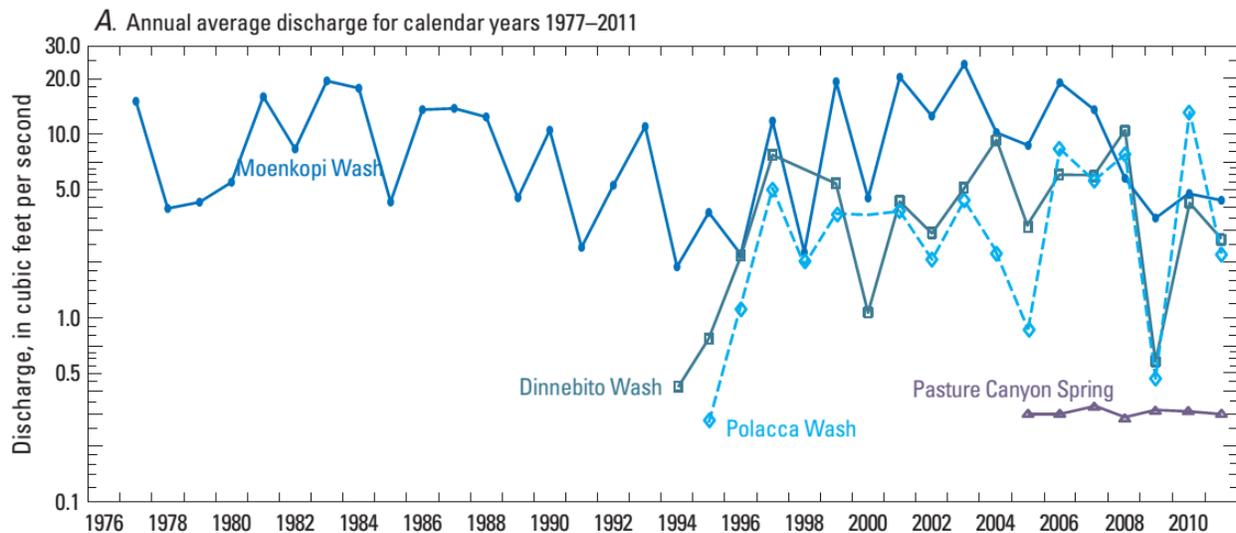
Group Discussion:

Burro spring emanates from a sandstone outcrop approximately ¼ mile east of Oraibi Wash. The area is thought to be hydrologic isolated from confined N aquifer based on the topographic relief observed by the group. Two springs in the area are named Burro Spring. One Burro Spring is developed with a water tank, pictured above, and flows less than USGS monitored Burro Spring. The USGS monitored Burro Spring is identified by the well house pictured above. A seepage area was observed adjacent to the USGS monitored Burro Spring location, but the seepage flow was not monitored.

Stop 14 (Spring Group B): Polacca Wash



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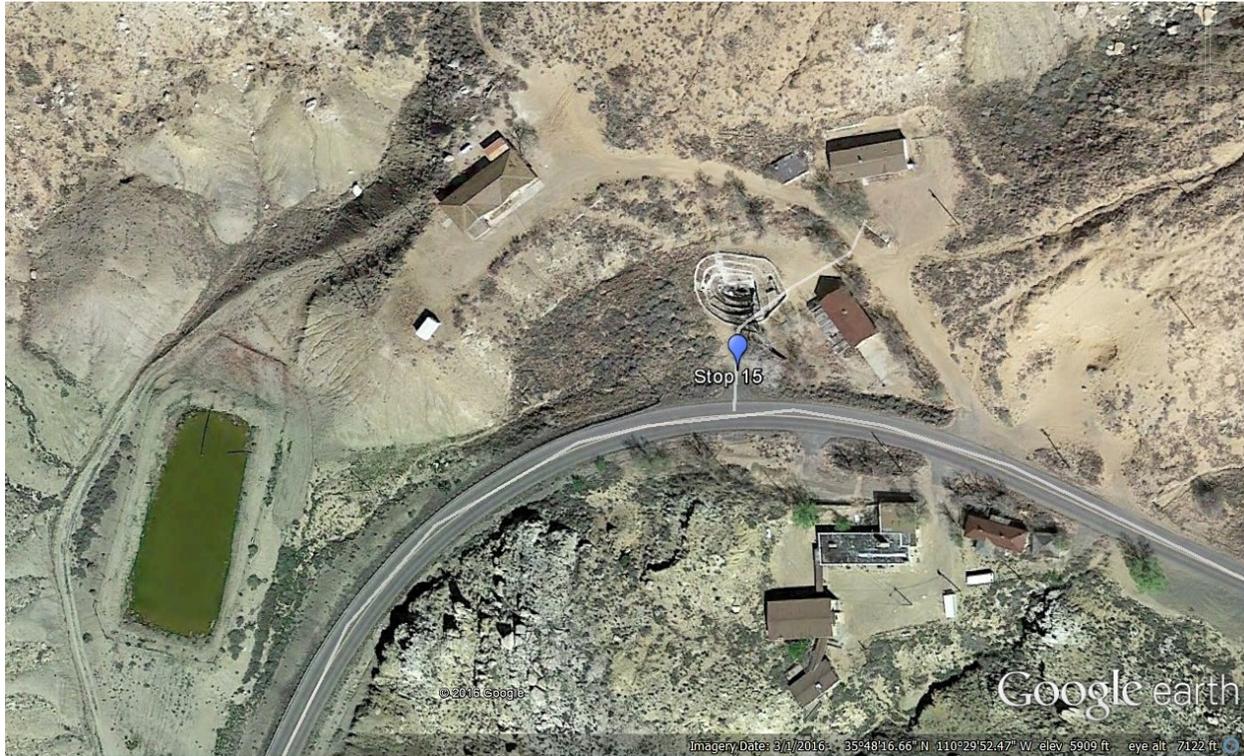


Polacca Wash flow relative to flow in other monitored washes in area (Macy and Unema, 2014)

Group Discussion:

The discharge location is identified by the 1997 Hopi Tribe Water Resources Program marker. Dinosaur tracks on the cap rock adjacent to the marker indicate the Formation is associated with the lower Morrison Formation, and discharge emanates from the underlying Entrada Sandstone. The presence of a conglomerate layer also supports that the lithology is associated with the D aquifer system. Noticeable salts covered the channel, further indicating the discharge emanates from the poorer quality D aquifer system. The USGS monitoring station is equipped with satellite telemetry as illustrated above.

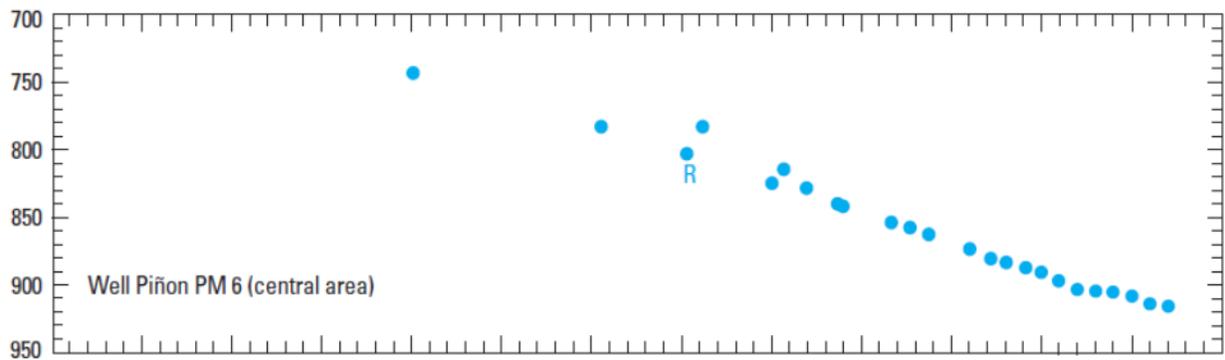
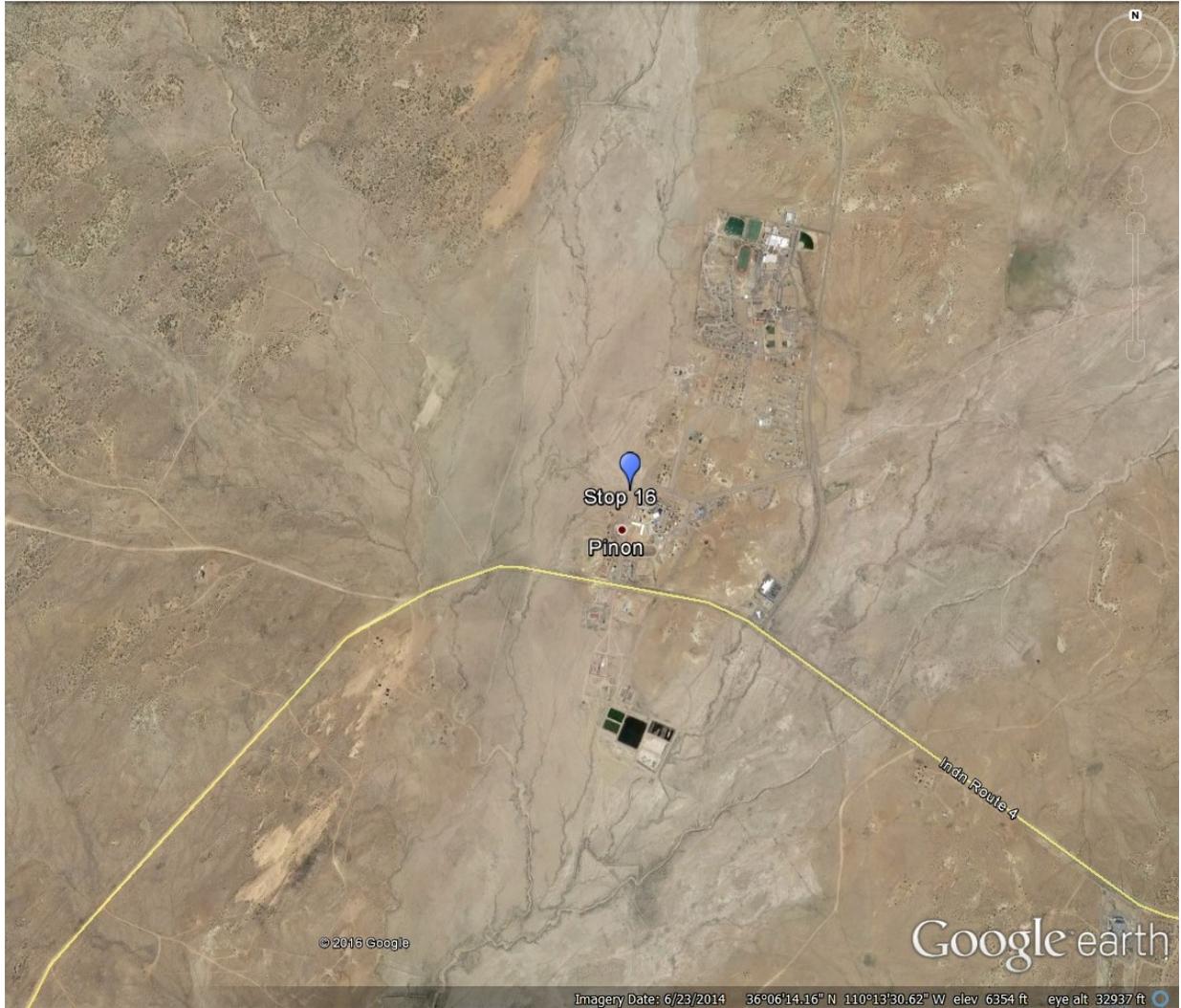
Stop 15: Flute Spring



Group Discussion:

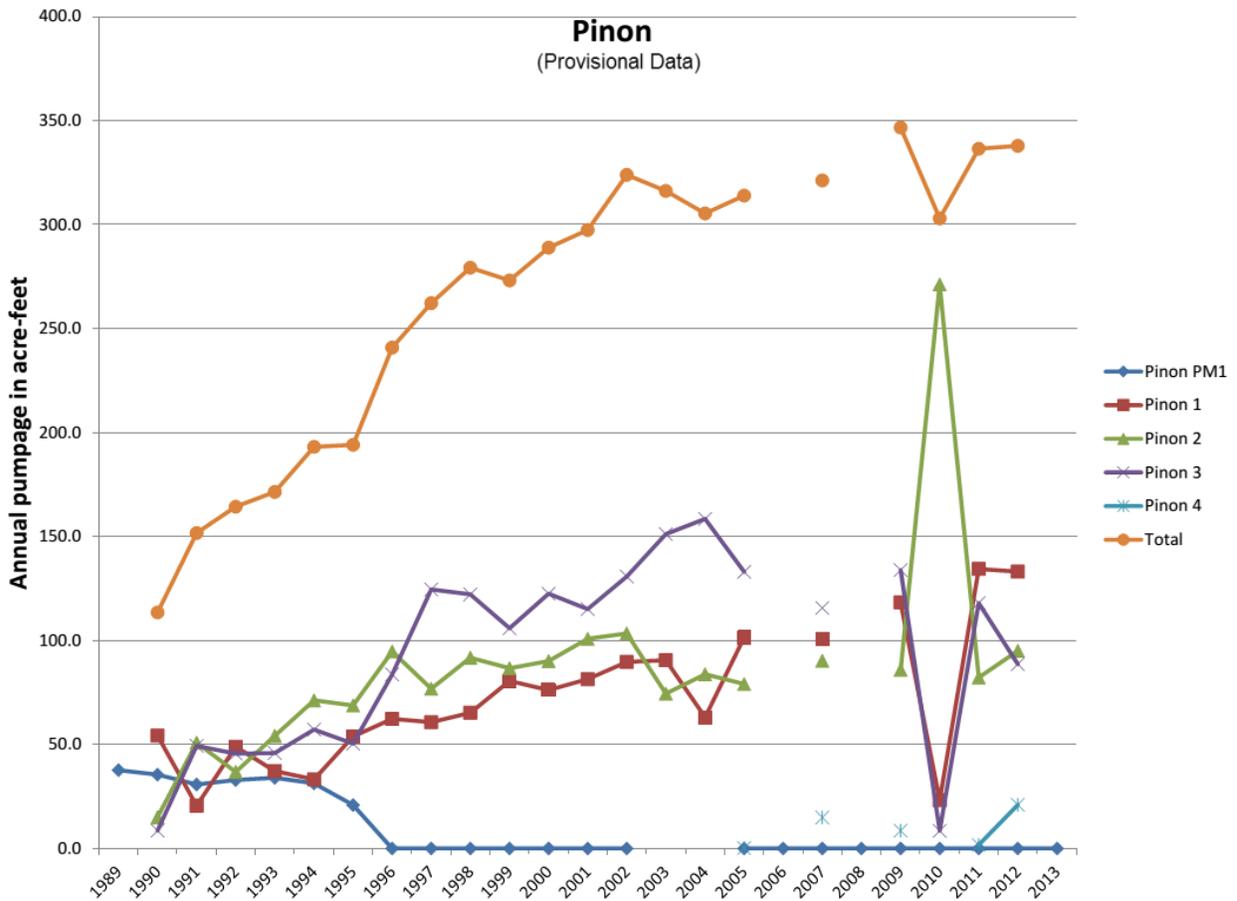
Flute Spring is near Second Mesa. Water has not been present at the spring from many years, but has been photographed with flute players sitting around the spring several decades ago. Locals report being able to dig down to expose the water, but the water table has dropped below the current depth. The depletion of water is thought to be attributable to PWCC N aquifer pumping; however, the spring location is positioned on the Toreva Formation. Spring depletion is likely attributable to a combination of climatic conditions and the influence of nearby Polacca pumping.

Stop 16: Pinon



Observed Water Level Measurements in feet below land surface (Macy and Unema, 2014).

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Group Discussion:

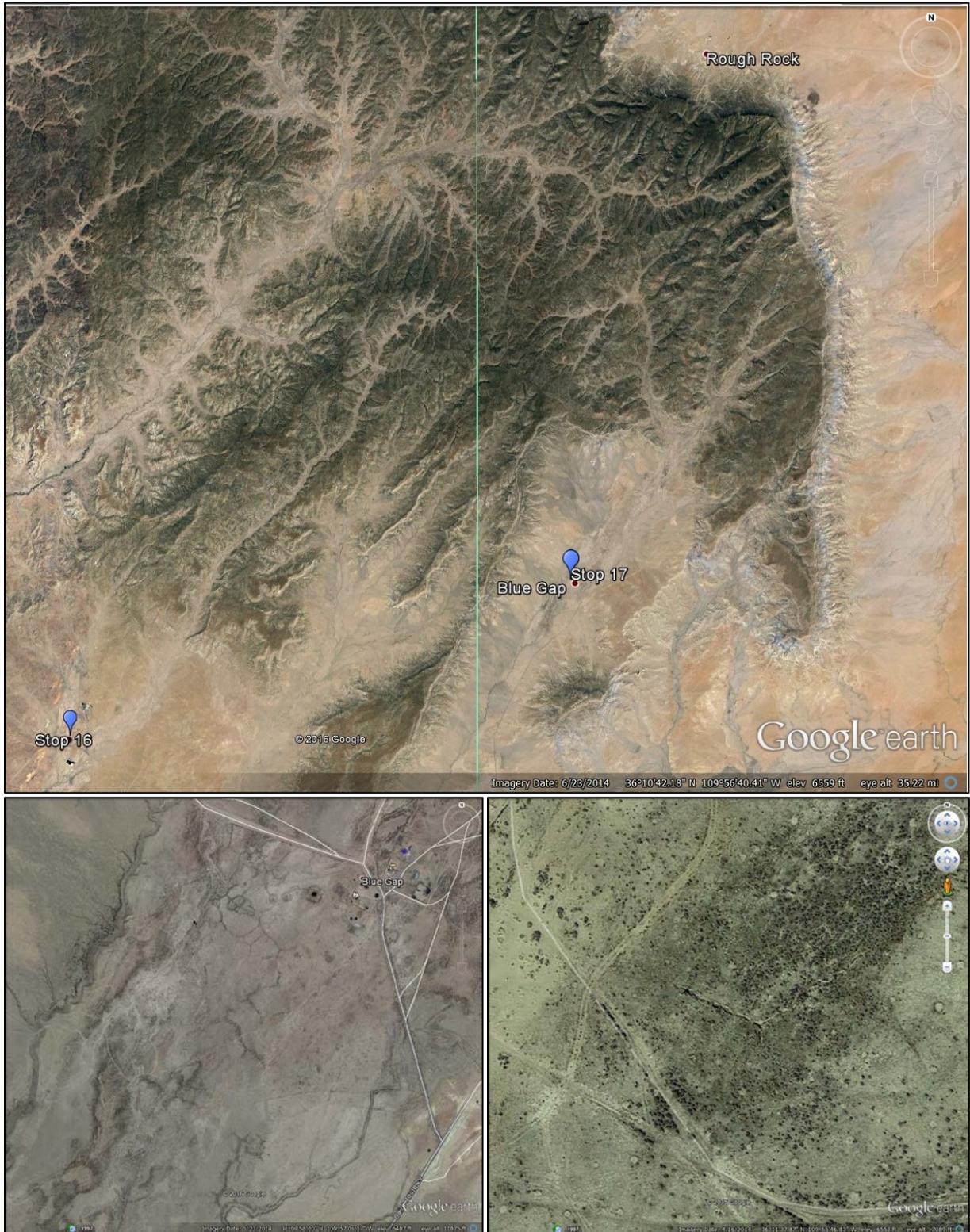
A highway closure prohibited the group from driving to Pinon.

Pinon is on a tributary headwater branch of Polacca Wash, and relies on a system of five (5) N aquifer wells for water supply. Water use tripled during growth and development from 1990 to 2000, and total use is beginning to stabilize at approximately 340 acre-feet per year. Pinon pumps the most water of all communities in the confined N aquifer, but was four (4) times less than PWCC industrial pumping of 1390 acre-feet in 2011.

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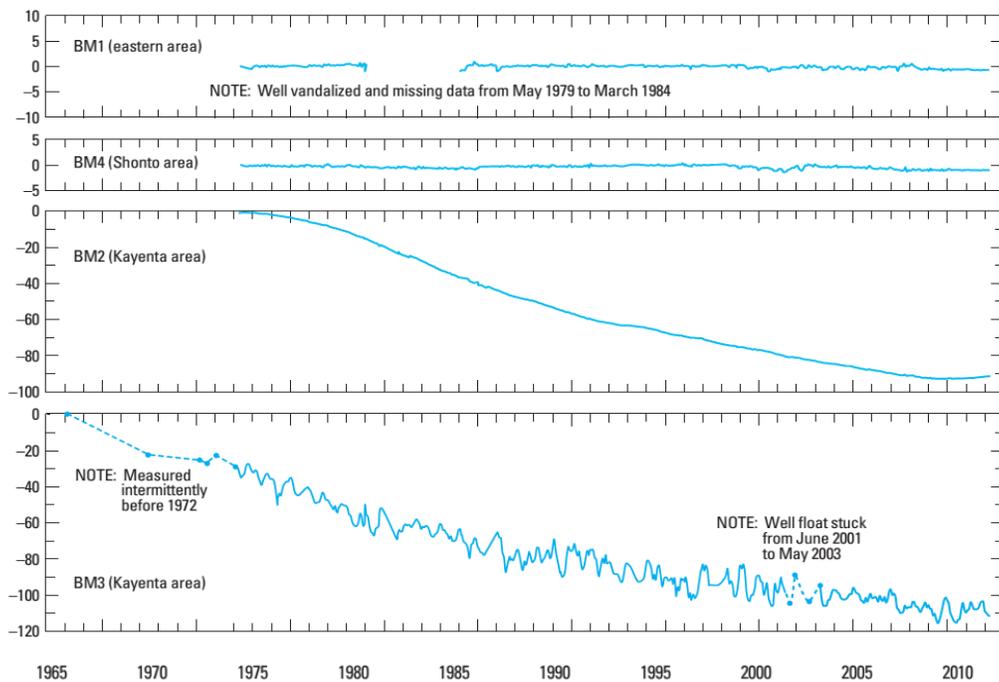
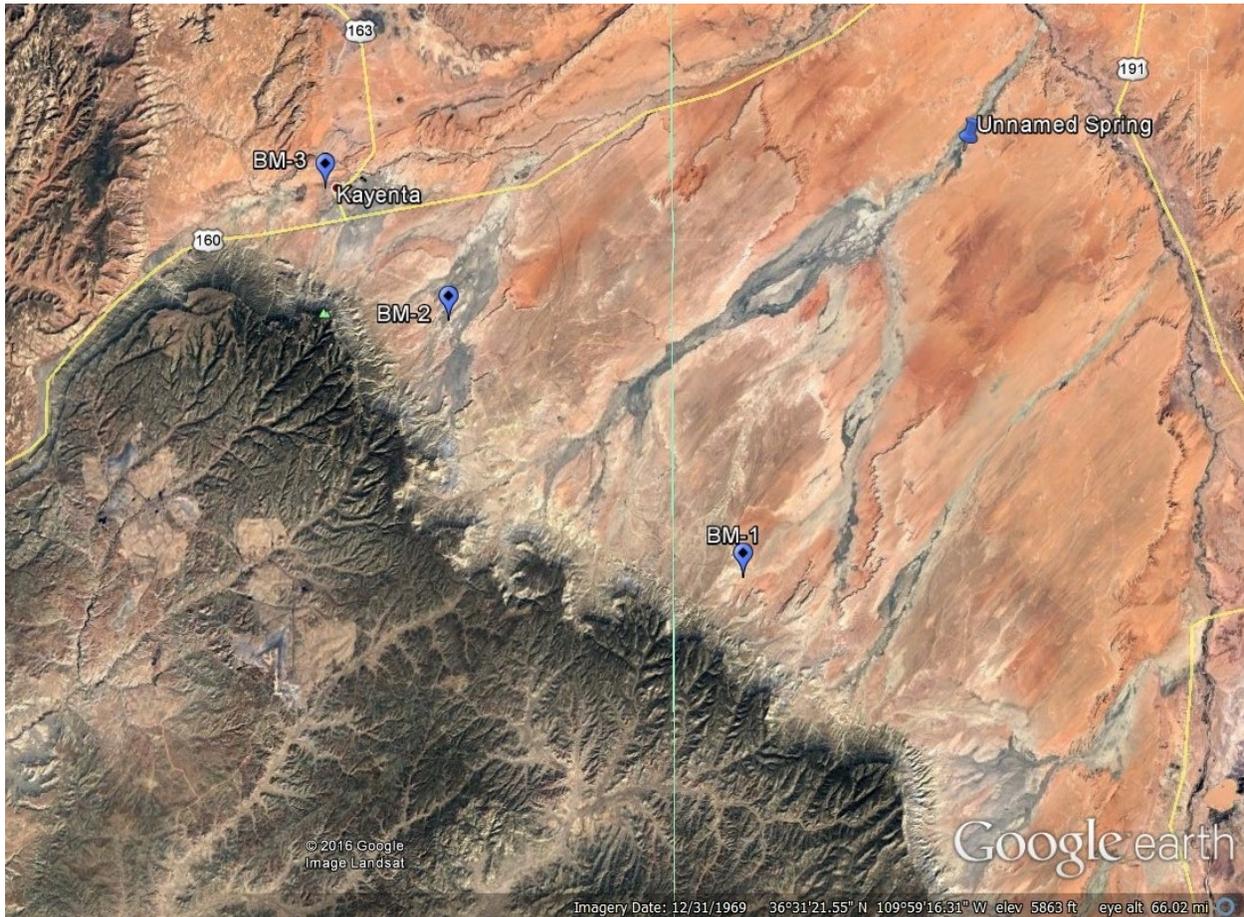
Stop 17 (Spring Group G): Blue Gap

A highway closure prohibited the group from driving to Blue Gap.



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Stop 18: USGS Monitoring Wells BM1, BM2, BM3

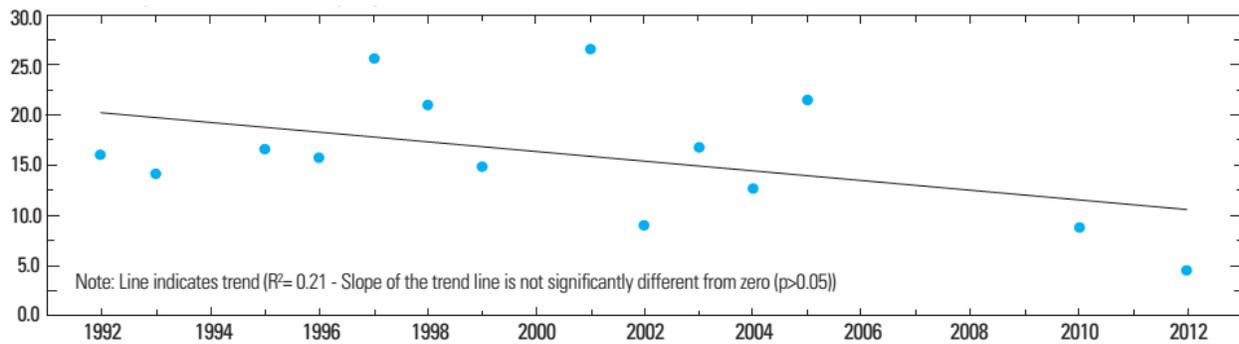


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Group Discussion:

Plots of observed water-level changes in continuous-record observation wells BM1 – BM4 over 1963-2012 in the N-aquifer, Black Mesa area, northeastern Arizona (Macy and Unema, 2014) are provided above. Wells BM1 and BM2 are located in the confined area of the N aquifer and have experienced little water level change over the period of record. Well BM2 is in the confined N aquifer, and monitoring indicates the water level is beginning to respond to reduced PWCC pumping. Well BM3 is located in the town of Kayenta and monitoring illustrates the variable influence of Kayenta wellfield pumping.

Unnamed Spring near Dennehotso (Spring Group F1)



Unnamed Spring near Dennehotso discharge in gallons per minute (Macy and Unema, 2014).

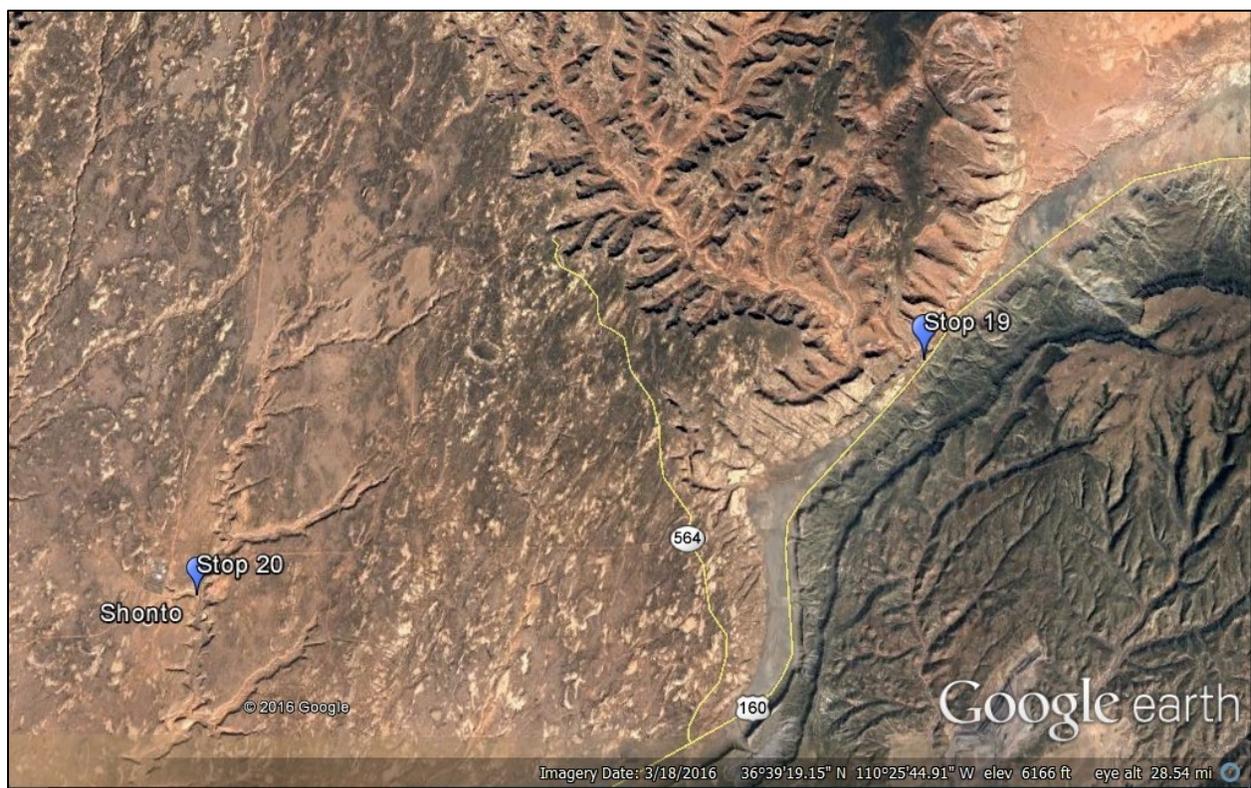
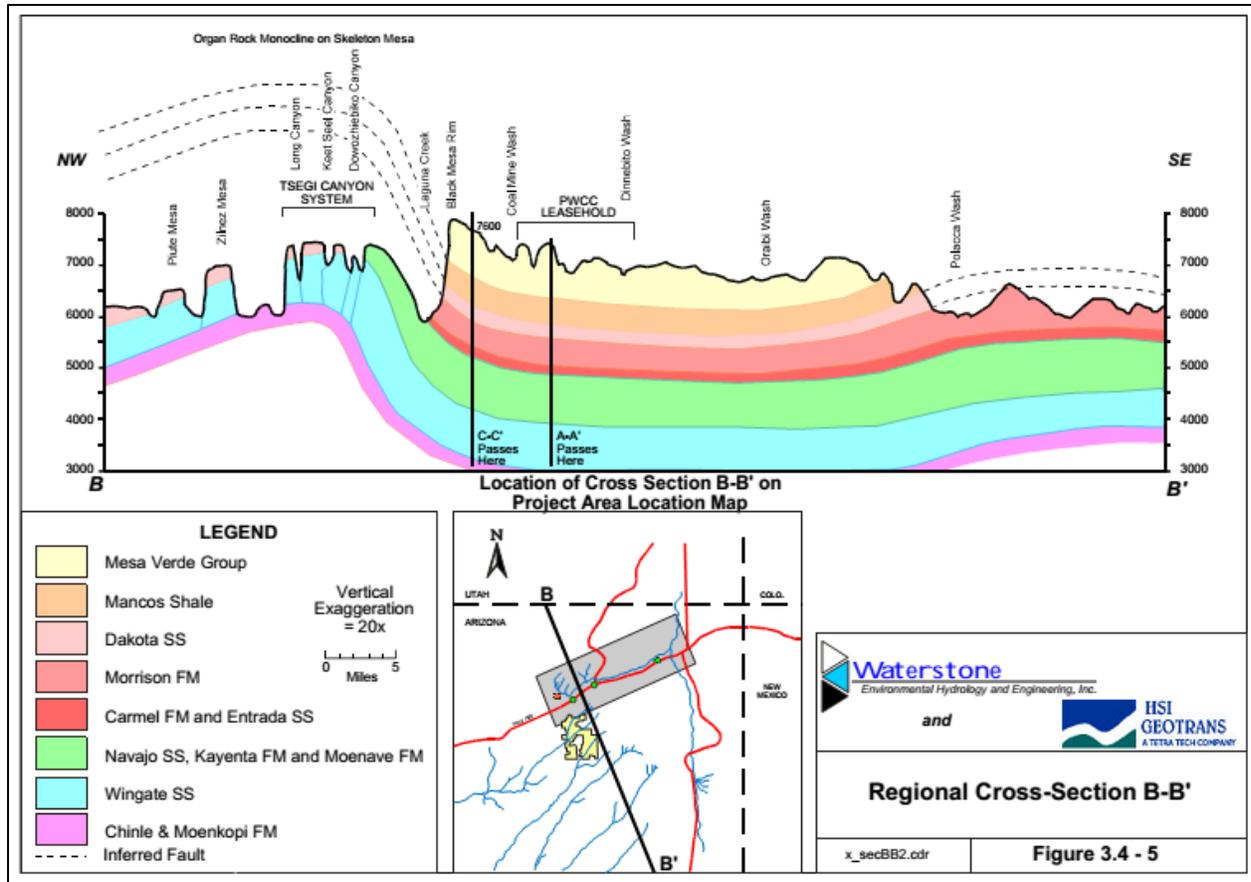
Group Discussion:

Unnamed Spring near Dennehotso was not visited by the group; however, discussed in relation to the measured water levels at the BM-series monitoring wells. The spring location can only be accessed via ATV as migrating sand dunes have made the approach impassable in recent years. Although the trend line is not significantly different than zero at Dennehotso Spring, recent measurements are the lowest on record at the location.

Stop 19 (Spring Group E): Tsegi Canyon Recharge Area



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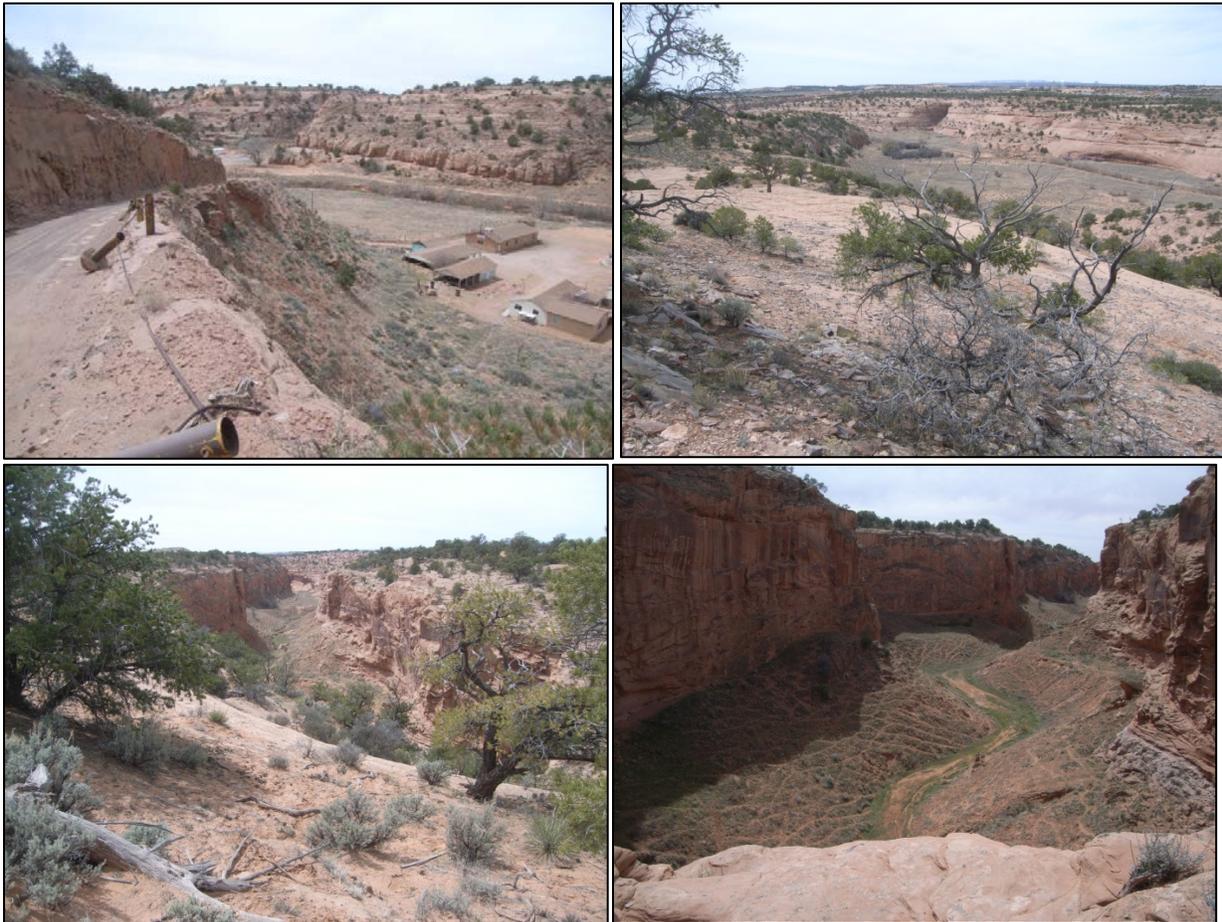


Group Discussion:

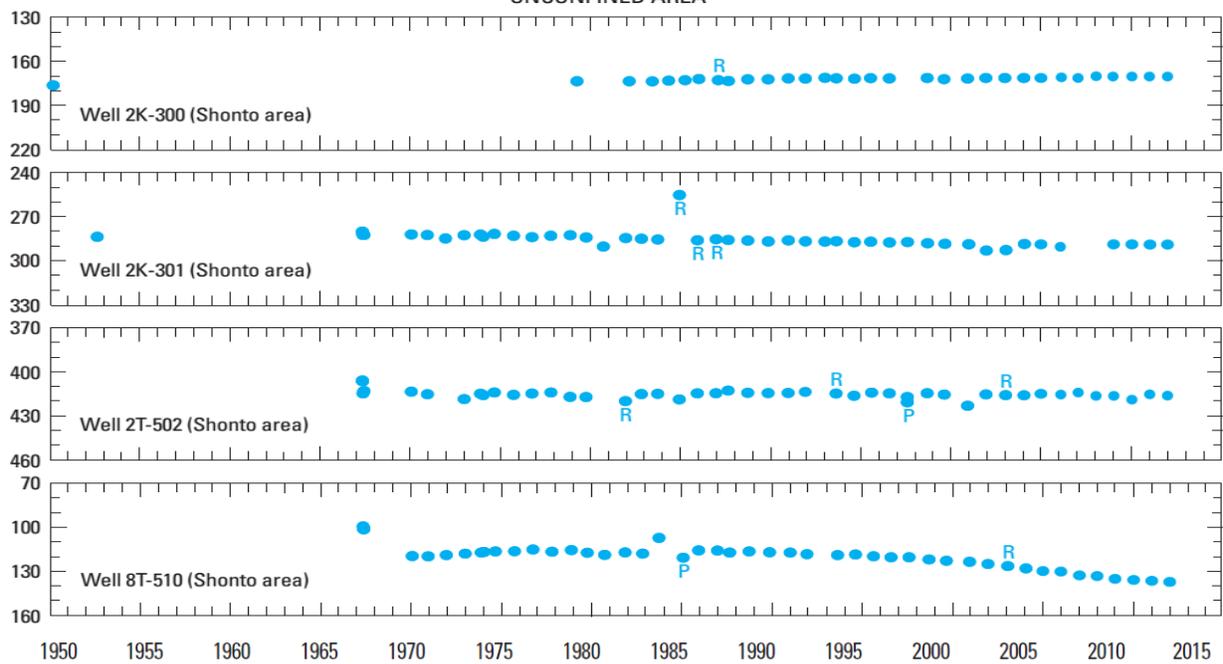
The structure of the Organ Rock Monocline facilitates recharge to the N aquifer north of Black Mesa. The first figure illustrates the dip of the Navajo Sandstone. The second figure a Tsegi Canyon illustrates the fracture pattern that allows hydrologic communication from the recharge area at Navajo National Monument to the N aquifer system. The cross section illustrates the lithology confining the N aquifer below the PWCC permit area. The aerial view illustrates the dendritic pattern of canyons incised in the Navajo Sandstone at Navajo National Monument, which with a major N aquifer recharge area. The surface water runoff is retained in the valley alluvium and recharged through fractures in the Navajo Sandstone. Pictured above is a view from the top of Black Mesa looking northeast. The view from Black Mesa illustrates the dip of the Navajo Sandstone, the valley alluvium where recharge predominantly occurs, and the PWCC coal conveyor belt in the foreground that conveys coal from the mine area to highway 160 where it is loaded on electric rail to Page, Arizona.

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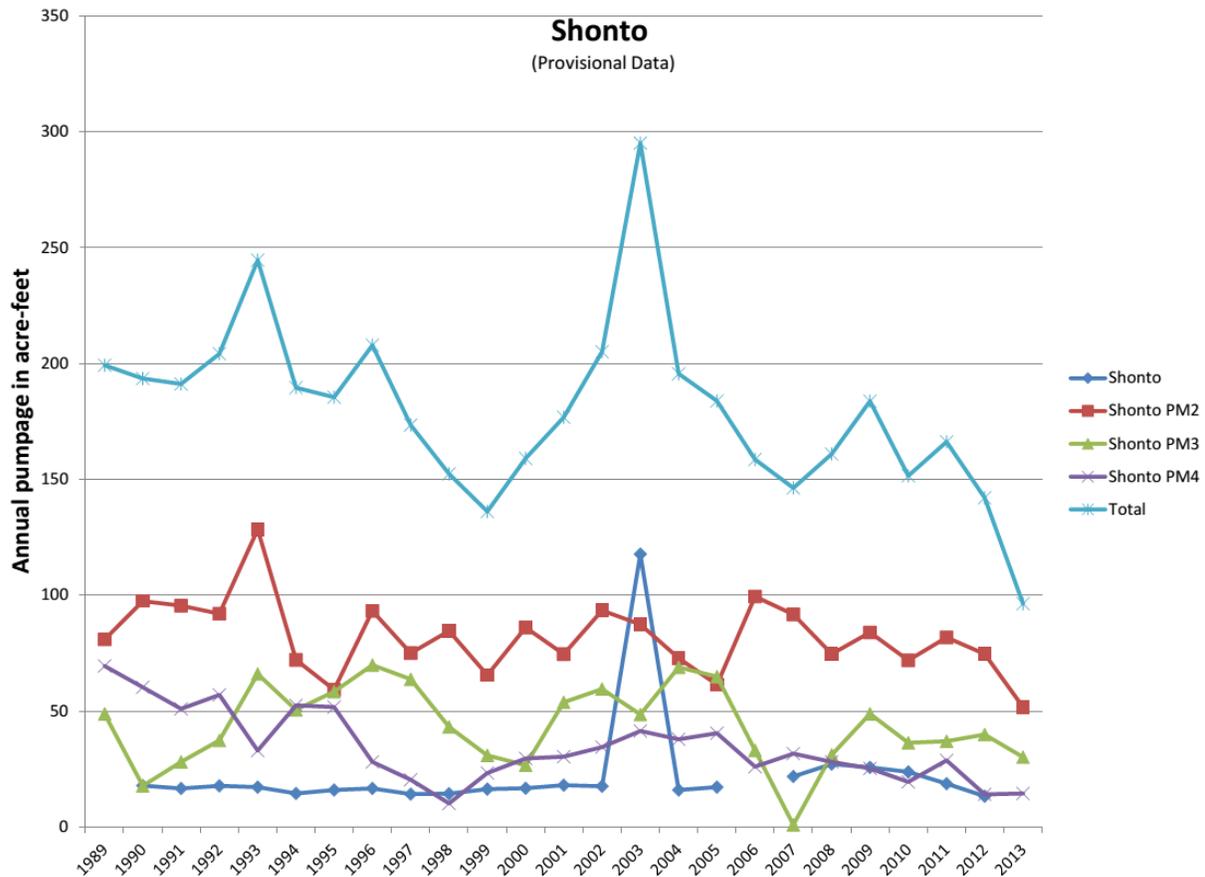
Stop 20 (Spring Group E): Shonto



UNCONFINED AREA



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Group Discussion:

A public water stand is available at Shonto for local water hauling. A fracture in the Navajo Sandstone creates as tributary from Navajo National Monument to Shonto, trending northeast to southwest. The tributary continues past Shonto, and becomes Begeshbito Wash, discussed at Stop 7. Begeshbito Wash ultimately joins Moenkopi Wash. Above, USGS monitoring from wells in the area (Macy and Unema, 2012) indicate little water level change over the period of record. However, well 8T-510 has recorded 36 feet of drawdown (Macy and Unema, 2012). Total groundwater pumping at Shonto is highly variable over the period of record since 1989, increasing from approximately 135 ac-ft in 1999 to approximately 300 ac-ft in 2002. Yet, the overall trend indicates a reduction in groundwater pumping over time, with the most recent measurement of approximately 100 ac-ft in 2013, the lowest during the period of record.

The headwater of the canyon picture above indicates good soil moisture in the valley alluvium based on productive vegetation. The interwoven pattern of trails in the picture is the product of a local corralling several horses in the canyon for livestock grazing.