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ASSESSMENT OF CORRECTIVE MEASURES FOR MULTIUNIT 1 AND THE URS

Coal Combustion Residuals Rule Groundwater Monitoring System Compliance

Four Corners Power Plant

Fruitland, New Mexico

Submitted to:

Arizona Public Service

Submitted by:

Wood Environment & Infrastructure Solutions, Inc.
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LIST OF ACRONYMS AND ABBREVIATIONS

§	Section
AECOM	AECOM Technical Services, Inc.
amsl	above mean sea level
APS	Arizona Public Service
CCR	coal combustion residuals
CFR	Code of Federal Regulations
COCs	Constituents of Concern
CM(s)	corrective measure(s)
CSM	Conceptual Site Model
CWTP	Combined Waste Treatment Pond
DFADA	Dry Fly Ash Disposal Area
FCPP	Four Corners Power Plant
FGD	flue gas desulfurization
ft	foot, feet
GWPS	groundwater protection standard
HDPE	high density polyethylene
LAI	Lined Ash Impoundment
LDWP	Lined Decant Water Pond
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
Multiunit 1	CCR multiunit comprised of the LAI and LDWP
NIT	North Intercept Trench
SIT	South Intercept Trench
SSI	statistically significant increase
SSL	statistically significant level
URS	Upper Retention Sump
URT	Upper Retention Tank
Wood	Wood Environment & Infrastructure Solutions, Inc.

1.0 INTRODUCTION

On behalf of Arizona Public Service (APS), Wood Environment & Infrastructure Solutions, Inc. (Wood) prepared this report documenting an Assessment of Corrective Measures (CMs) for two existing coal combustion residuals (CCR) units located at the Four Corners Power Plant (FCPP) in Fruitland, New Mexico (the Site).

The CM assessment documented herein was conducted in accordance with 40 Code of Federal Regulations (CFR) Part 257 (herein referred to as the CCR Rule; Federal Register, 2018) to support future selection of remedies for groundwater impacts. The CCR Rule became effective on October 19, 2015 and established standards for the disposal of CCR in landfills and surface impoundments at applicable sites. APS has conducted CCR Rule groundwater compliance activities at the Site and performed statistical assessments of collected groundwater data. Based on the results of these statistical evaluations, there is evidence to suggest that releases from Multiunit 1 (comprised of the Lined Ash Impoundment [LAI] and the Lined Decant Water Pond [LDWP]) and the former Upper Retention Sump (URS) have impacted downgradient groundwater at concentrations that exceed applicable Groundwater Protection Standards (GWPSs) and require corrective action.

The remainder of this section (Section 1.0) provides a summary description of the power generating facility, Site CCR units, the facility's environmental setting, and groundwater compliance activities conducted at the Site to date which form the basis for this CM assessment. Section 2.0 identifies the nature and extent of the Constituents of Concern (COCs) by unit with documentation of unit-specific conditions affecting CM assessment. Section 3.0 defines the objective of CMs, screens applicable technologies, develops alternatives for evaluation, and documents a CM assessment for each unit. Future requirements for remedy selection are listed in Section 4.0. Section 5.0 presents report references.

1.1 Site Background

1.1.1 Facility and CCR Unit Descriptions

Facility Description. FCPP is an operating power plant owned by APS and four other utilities. The plant burns low sulfur coal in two electrical generating units (Units 4 and 5) and has a net generating capacity of 1,540 megawatts. FCPP formerly had five generating units and a capacity of 2,040 megawatts; Units 1, 2, and 3 were retired in December 2013 and decommissioned between 2014 and 2016. Coal burned at the plant is generally sourced from the nearby Navajo Mine (Navajo Transitional Energy Company, 2016).

Facility Location. The plant and associated infrastructure are located approximately 20 miles southwest of the city of Farmington in northwestern New Mexico (Figure 1-1). The land on which the plant resides is leased from the Navajo Nation and is primarily located in Section 36, Township 29 North, and Range 16 West.

The plant is situated on the southern bank of Morgan Lake, an approximately 1,300-acre man-made lake that has a maximum storage capacity of 39,000 acre-foot (ft) of water and supplies cooling water to the plant. Morgan Lake was formed by damming a westerly flowing stream (now known as 'No Name Wash') and is replenished by an underground pipeline (i.e., aqueduct) that routes flow from the San Juan River located approximately 3 miles north of the FCPP. The typical water surface elevation of the lake is 5,330 ft above mean sea level (amsl).

CCR Unit Descriptions. Plant infrastructure includes three single CCR units and one CCR multiunit (referred to as Multiunit 1) which are located in the main plant area and to the west of the plant within the FCPP lease boundary (also known as the disposal area), respectively (Figure 1-2). Table 1-1 summarizes the location, function, operation, size/construction, and history of each unit. The boundaries of CCR units depicted in Figure 1-2 are based on available historical plans for the units.

Multiple monitoring well systems (which consist of background wells and downgradient waste boundary wells for each unit) are in place at FCPP to monitor groundwater conditions associated with the site CCR units. The installation of these networks is documented in the *CCR Monitoring Well Network Report and Certification* and is identified as compliant with 40 CFR Section (§)257.91(a) through (e) (AECOM, 2017).

1.1.2 Environmental Setting

Unless otherwise noted, the following information is abstracted from AECOM Technical Services, Inc. (AECOM), 2017.

Climate. The plant is located in a semi-arid climate on the western flank of the San Juan Basin. The area receives an average of 8.6 inches of precipitation and 12.6 inches of snow per year.

Topography. The main plant area of the FCPP is located at an elevation of approximately 5,340 to 5,360 ft amsl in the Colorado Plateau physiographic province of northwestern New Mexico. This area is characterized by rolling terrain, steep escarpments, and incised drainages/arroyos. In the vicinity of the plant, the ground surface is relatively flat, sloping to the west at approximately 20 ft per mile; however, surface drainage immediately near Morgan Lake flows towards the lake. About one mile west of the plant, the level ground surface drops rapidly to 5,200 ft amsl. Chaco Wash (a.k.a. the Chaco River) is located west of this abrupt change in elevation and ephemerally flows north to the San Juan River.

Surface Water Hydrology. The plant is located approximately 3 miles south of the San Juan which provides the chief drainage for the Four Corners region and is a major tributary of the Colorado River. The Morgan Lake Dam discharges to 'No Name Wash' which flows west of the lake to Chaco Wash, a major tributary of the San Juan River. Chaco Wash is an ephemeral stream that flows in response to precipitation and snow melt within its extensive drainage basin located in western New Mexico.

Site Geology. The San Juan Basin is a structural depression that lies at the eastern edge of the Colorado Plateau which is typified by horizontal layered sequences of sedimentary rock, primarily sandstones, siltstones, and claystones (Dames & Moore, 1988). The dominant geographic feature in the vicinity of FCPP is the Hogback Monocline located to the west of the plant; this monocline is a steep (38 degree) eastward-dipping flank composed of Cretaceous sedimentary rock (Dames & Moore, 1988).

There are two 'uppermost geologic units' that underlie the FCPP site and immediate vicinity. These units are expected to influence groundwater flow and variations in naturally occurring constituent concentrations across the site. The units are as follows (in descending order):

- **Pictured Cliffs Sandstone**: The Pictured Cliffs Sandstone is the uppermost geologic unit beneath the plant, the former URS, and another CCR unit in the vicinity, the Combined Waste Treatment Pond (CWTP), as depicted in Figure 1-2. This unit is a fine- to medium-grained marine sandstone. The lower portions of the Pictured Cliffs Sandstone represent a transitional sequence between this formation and the underlying Lewis Shale as indicated by alternating thin beds of very fine-grained sandstone and silty shale. The lower Pictured Cliffs Sandstone consists of gray sandy shale with yellow to brown sandstone units that represent a transitional sequence between this formation and the underlying Lewis Shale as indicated by alternating thin beds of very fine-grained sandstone and silty shale. The Pictured Cliffs Sandstone forms a capstone on an exposed cliff face located between the plant site and the CCR units located to the west (i.e., Multiunit 1 and the Dry Fly Ash Disposal Area [DFADA]).

- **Lewis Shale**: The Lewis Shale is a marine shale that contains evaporite deposits resulting in naturally occurring saline groundwater conditions. The Lewis Shale is the uppermost geologic unit that underlies Multiunit 1 and the DFADA and spans west of the Pictured Cliffs Sandstone cliff face approximately 1.5 miles westward to the base of the Hogback Monocline. The regional thickness of the Lewis Shale is approximately 500 ft and is underlain by Cliff House Sandstone. The Lewis Shale consists of a weathered shale subunit overlying a hard, unweathered shale subunit. The weathered Lewis Shale varies from brown to gray-brown to light gray in color. The thickness of the weathered shale varies between 11 and 47 ft with an average thickness of 30 ft within the vicinity of the site (Dames & Moore, 1988). The weathered shale is not as thick when overlain by Pictured Cliffs Sandstone in the vicinity of the plant site. This subunit contains thin sandstone lenses that vary in thickness from 1 to 7 ft; the sandstone is fine to very fine-grained and cemented by calcium carbonate (Dames & Moore, 1988). The unweathered shale is significantly less permeable than the weathered shale. The unweathered Lewis Shale is gray-brown to blue-gray to dark gray in color. The unweathered shale is very fine-grained to silty and contains periodic siltstone and sandstone lenses (Dames & Moore, 1988). The surface of the unweathered shale slopes towards the Chaco Wash at approximately the same slope as land surface (Dames & Moore, 1988) but displays some irregularity resulting in varying levels of saturated thickness in the weathered shale. The Lewis Shale is variably saturated and hydraulically interconnected with alluvial deposits of Chaco Wash. The low-permeability unweathered shale underlying the Pictured Cliffs Sandstone results in a perched saturated zone beneath the plant.

Applicable Hydrostratigraphy. Three general hydrostratigraphic units are conceptualized beneath the FCPP and associated CCR units. These units form the basis for the Conceptual Site Model (CSM) developed by AECOM (2017) for designing the site CCR groundwater monitoring system and are the working basis for statistically evaluating groundwater conditions underlying the site.

The first hydrostratigraphic unit (Pictured Cliffs Sandstone) is dominant only under the plant area, which is located in an elevated area south of Morgan Lake (Figure 1-2). Two CCR units (i.e., the URS and CWTP) reside within this area. The Pictured Cliffs Sandstone is the uppermost water bearing unit for the plant area and extends from ground surface (between approximately 5,340 to 5,360 ft amsl) to approximately 5,300 ft amsl in the plant area. Groundwater in this area is strongly influenced by Morgan Lake (at a surface elevation of approximately 5,330 ft amsl) and generally flows northward towards the lake. However, construction and operations of the plant have resulted in disturbed ground conditions and associated impacts are not well understood.

The second hydrostratigraphic unit (Weathered Lewis Shale/Alluvium) underlies the Pictured Cliffs Sandstone in the plant area and the Multiunit 1/DFADA CCR units in the disposal area, approximately 1 mile west of the plant (Figure 1-2). The Weathered Lewis Shale and the hydraulically connected alluvial deposits along Chaco Wash are designated as the uppermost water bearing unit in the disposal area. Although the Lewis Shale is geologically continuous in this area, it is unsaturated in the vicinity of the DFADA. The water table in the Weathered Lewis Shale can exhibit local seasonal fluctuations that are attributed to interactions between rates of groundwater recharge from precipitation and surface water (i.e., Morgan Lake, No Name Wash, and Chaco Wash) and discharges from historical unlined ponds. Groundwater flow generally follows the surface topography and descends to the west-southwest in the disposal area, mainly in the weathered shale and in local alluvial channels that drain toward Chaco Wash.

The third hydrostratigraphic unit (Unweathered Lewis Shale) consists of the Unweathered Lewis Shale and is a regionally extensive confining unit that forms the base of the uppermost aquifers in the plant and disposal areas.

Ambient Groundwater Quality. APS began evaluating groundwater and the hydrogeology in the area of the Plant as early as 1971. Due to the natural heterogeneity of the geologic and hydrogeologic conditions underlying the FCPP, background constituent concentrations are expected to be spatially heterogeneous (varying) across the site. The site is also expected to exhibit both spatial and temporal heterogeneity attributable to local climatic regimes, potential leakage from Morgan Lake, and potential operational activity at the site.

1.2 Basis for Corrective Measures Assessment

The groundwater monitoring and corrective action process defined in the CCR Rule includes a phased approach to groundwater monitoring for each CCR unit:

- Detection Monitoring: This groundwater monitoring phase focuses on a set of constituents (listed in Appendix III of the CCR Rule) that are relatively mobile components of CCR and therefore represent indicators of possible impacts from CCR in groundwater. If statistically significant increases (SSIs) of any of the Appendix III constituents relative to background conditions are detected in the downgradient waste boundary wells, and cannot be demonstrated to be associated with a source other than the CCR unit, then groundwater monitoring moves into assessment monitoring.
- Assessment Monitoring: This groundwater monitoring phase focuses on the constituents listed in Appendix IV of the CCR Rule. The Appendix IV constituents are generally less mobile and occur at lower concentrations in groundwater than the Appendix III constituents. Concentrations of Appendix IV constituents in downgradient wells are compared to GWPSs. The GWPSs, established for Appendix IV constituents only, are the higher of either the federal Safe Drinking Water Act Maximum Contaminant Level (MCL), an alternative risk-based GWPS identified in the CCR Rule, or a statistically-driven background threshold value for each constituent.
- Groundwater Characterization and Corrective Action Assessment: If exceedances of the GWPSs are determined to be occurring in the downgradient boundary wells at statistically significant levels (SSLs) and no alternative sources for the exceedances can be demonstrated, then both additional groundwater characterization and assessment of corrective actions are initiated. Following assessment of corrective measures, a remedy (or set of remedial activities) is selected and implemented as the groundwater corrective action program for the CCR unit. According to the CCR Rule, groundwater corrective action will continue until compliance with the GWPSs has been attained in all impacted wells and sustained for a period of three consecutive years.

APS initiated CCR groundwater detection monitoring at FCPP in November 2015 and completed collection of at least eight initial rounds of monitoring at all wells in October 2017 in accordance with the CCR Rule. Statistical analysis of Appendix III constituent data collected during detection monitoring was completed in January 2018 and concluded that there is enough evidence to declare an SSI over background for one or more Appendix III constituents at both Multiunit 1 and the URS (Amec Foster Wheeler Environment & Infrastructure, Inc., 2018).

On the basis of this analysis, assessment monitoring was initiated at the two CCR units and a statistical evaluation of Appendix IV constituent monitoring data was conducted. Table 1-2 summarizes GWPSs derived for each constituent by unit and identifies constituents and wells at which SSLs of the constituent over GWPSs have been reported. As indicated, there was sufficient evidence to declare GWPS exceedances for cobalt and molybdenum concentrations downgradient of Multiunit 1 (Wood, 2018a) and for fluoride concentrations downgradient of the URS (Wood, 2018b).

2.0 NATURE AND EXTENT OF COCS

This section presents the current understanding of site conditions relevant to an assessment of CMs for Multiunit 1 and the URS based on Site information available through April 2019. Unit-specific CSMs are presented to integrate unit construction/operation, hydrogeologic conditions, observed COC concentration distributions, and potential COC migration pathways. These summary CSMs were developed to assist in developing and evaluating CMs in Section 3.0.

2.1 Multiunit 1

Figure 2-1 shows relevant Multiunit 1 infrastructure including the layout of the LAI and the LDWP, the locations of closed evaporation and ash ponds relative to Multiunit 1, an existing groundwater intercept trench system installed downgradient of the disposal area to address discharges from past and current CCR facilities, and groundwater monitoring wells completed in the Weathered Lewis Shale/Alluvium, which is the uppermost aquifer underlying Multiunit 1 per the CCR groundwater monitoring system certification report (AECOM, 2017).

Figures 2-2 and 2-3 present current iso-concentration contour maps for cobalt and molybdenum at Multiunit 1, respectively, based on the results of monitoring well installation activities and groundwater sampling conducted in November and December 2018 during a *Hydrogeologic Investigation of Multiunit 1 and the URS* (Wood, 2019a). The extent of impact is defined by the respective COC GWPSs. Table 2-1 summarizes concentrations of COCs and select water quality parameters in samples collected from wells located downgradient of Multiunit 1 during the Hydrogeologic Investigation and the first CCR assessment monitoring event of 2019.

Table 2-2 presents chemical properties impacting the mobility of Site COCs in aquifer environments.

2.1.1 <u>Characterization</u>

Key points of the summary CSM for Multiunit 1 are as follows:

- Multiunit 1 is located in the disposal area adjacent to other active and closed CCR facilities including the DFADA to the south, closed Ash Pond 6 to the north, and the closed Evaporation Ponds to the west (Figure 2-1). Multiunit 1 was placed into service incrementally from 2003 to 2004 and was constructed on top of closed Ash Ponds 3, 4, and 5.
- Multiunit 1 is comprised of the LAI and the LDWP. The LAI receives fly ash, flue gas desulfurization (FGD) waste, and associated residuals as a slurry from the plant; the discharge occurs in the northeast portion of the pond. Decanted flow from the LAI discharges via a vertical drop structure through a toe drain in the LAI into the LDWP where it is returned to the plant for reuse. The working water surface elevations of the LAI and LDWP are 5,275.2 and 5,213.2 ft amsl, respectively.
- Both the LAI and LDWP are lined. The LAI has one 60 mil high density polyethylene (HDPE) liner and the LDWP has two 60 mil HDPE liners separated by a leak detection layer. The design of these liner systems was standard practice at the time the ponds were constructed; however, these systems do not meet the liner design criteria for existing units required by Section (§)257.70(b) of the CCR Rule (promulgated in 2015). The LAI and LDWP are considered unlined for the purpose of the rule.
- Groundwater in the Weathered Lewis Shale and associated alluvium flows to the west-southwest along the top of the Unweathered Shale toward Chaco Wash. To the west of the Site, the Chaco

flows ephemerally from the south (at a flow line elevation of approximately 5,046 ft amsl near MW-87) to the north of the Site boundary (at a flow line elevation of approximately 5,040 ft amsl).

- The water table in the Weathered Lewis Shale/Alluvium exhibits localized seasonal fluctuations that are attributed to interactions between the rates of groundwater recharge from surface water and discharges from historical unlined ponds. Preferential and/or seasonal groundwater flow pathways are known to occur in the Weathered Lewis Shale; it is common for wells installed in this unit to indicate the presence of little to no water depending on location.
- Due to the nature of the Lewis Shale and past activity in the disposal area, APS has observed an inverse relationship between total dissolved solids (i.e., sulfate) and boron in collected groundwater data. This relationship is attributed to the dissolution of natural gypsum present in the marine shale by seepage from past ash disposal.
- The iso-concentration map for the Multiunit 1 COC cobalt (Figure 2-2) indicates that this constituent is present at concentrations that exceed the GWPS (0.01 milligrams per liter [mg/L]) downgradient of the LDWP and upgradient of the South Intercept Trench (SIT; see Section 2.1.2). The cobalt iso-concentration contour in Figure 2-2 is only depicted hydraulically downgradient of the LDWP. Further investigation is needed to evaluate the northern extent of cobalt impacts associated with Multiunit 1.
- Although not monitored in December 2018 with other CM characterization efforts (it was dry), the cobalt concentration at new monitoring well MW-87 exceeded the GWPS in March 2019 (Table 2-1). Based on a likely correlation between the presence of water in this well and flow in Chaco Wash, as well as coal mining activities within the Chaco Wash drainage basin, the occurrence of elevated cobalt concentrations at MW-87 may be associated with surface water impacts upstream of the Site.
- The iso-concentration map for the Multiunit 1 COC molybdenum (Figure 2-3) indicates that the extent of this constituent at concentrations that exceed the GWPS (0.1 mg/L) is smaller than that for cobalt. It is suspected that the difference in distribution is associated with the chemical properties of these constituents, but the attributable mechanism(s) are not clear at this time. From November 2018 through March 2019, molybdenum concentrations exceeded the GWPS at monitoring wells located directly downgradient of Multiunit 1 (at MW-61 and MW-75), upgradient of Multiunit 1 (at MW-49A), and near Chaco Wash (at MW-87). As indicated above for cobalt, the elevated molybdenum concentrations observed at MW-87 may be associated with surface water impacts upstream of the Site.

2.1.2 Remedial Efforts Conducted to Date

APS has completed several CMs over the life of the facility to address environmental impacts in the disposal area. These CMs include the construction of lined facilities with the closure of unlined ash ponds and the installation/operation of an intercept trench system along the western boundary of the disposal area.

Construction of Lined Facilities and Closure of Unlined Ash Ponds. With the commissioning of the LAI in 2003, the last operating unlined ash pond present at the Site (Ash Pond 6) was removed from service, allowed to dewater, and subsequently capped. Figure 2-4 presents summary hydrographs for select disposal area groundwater monitoring wells which demonstrate the impact that transitioning from an unlined ash pond to a lined ash pond had on groundwater elevations. Figure 2-1 depicts the locations of monitoring wells presented in Figure 2-4. In addition to the steady declining trend in water levels observed at MW-6 and MW-18 after closure activities mitigated discharges from Ash Pond 6, Figure 2-4 also shows a regular undulating response in water levels that is evident before and after closure of Ash Pond 6. This response may be the result of seasonal precipitation and recharge into the aquifer.

Installation and Operation of an Intercept Trench System. APS currently operates a 7,600-ft long intercept trench system that was installed in two interconnected sections along the western boundary of the Site lease boundary (Figure 2-1). The North Intercept Trench (NIT) was constructed from April 2011 through September 2011 and was placed in service on October 31, 2011. The SIT, which is located hydraulically downgradient of Multiunit 1 and the closed Evaporation Ponds, was constructed from February 2013 to December 2013 and was placed in service on December 6, 2013. The purpose of the intercept trench system was to intercept and collect seepage from the closed and existing CCR units as it flowed westward towards Chaco Wash, thus preventing any potential groundwater contamination from impacting the wash.

The NIT and SIT are constructed similarly; both consist of a minimum 4-ft wide collector trench filled with drainage rock and a 6-inch HDPE perforated pipe set at the base of the trench which is located at the interface between the Weathered and Unweathered Lewis Shale. Seepage water collected in the pipe drains by gravity to multiple level-controlled sumps constructed at low points in the trench where it is then extracted via submersible pumps, metered, routed to a collection sump, and then pumped to the LDWP. The average rate of groundwater extraction from the SIT from April 2015 through April 2019 was approximately 43,500 gallons per day; however, the rate of groundwater extracted from the SIT has slowly been declining since the beginning of weekly record keeping in April 2015.

Since the SIT was constructed after the NIT, the design of the SIT includes enhancements to trench design intended to make the trench more effective at intercepting and collecting groundwater flow. The primary enhancement was the use of various geosynthetic materials at the interface between a layer of filter sand placed on the upgradient flow side of the sloped construction trench and trench backfill, thereby channeling flow intercepted along the entire face of the trench to the base of the trench where the HDPE perforated pipe is located. In a region that was known to intercept a higher rate of seepage flow (see Figure 2-1), a geomembrane with limited permeability was placed at the filter sand/backfill interface; in other regions, the geosynthetic material was a geotextile composite.

Figure 2-5 presents the SIT in cross section including changes in grade of the trench base (the SIT is 35 to 50 ft deep), the location of the SIT sumps, and the extent of the high flow zone where the geomembrane liner was installed. Water levels in both upgradient and downgradient monitoring wells relative to the SIT are also presented. As illustrated in this figure, upgradient groundwater elevations are higher than downgradient elevations which indicates that the trench is effectively intercepting and removing groundwater from the system. The long-term impact of trench operations is also depicted in Figure 2-4 with hydrographs presenting water levels over time for select monitoring wells located upgradient and downgradient of the trench. As indicated in this figure, there was a more pronounced decrease in groundwater levels when the trench systems were first constructed; the rate of decline has slowed thereafter but levels continue to decrease.

As discussed in Section 2.1.1, groundwater quality data collected as part of CM characterization efforts generally indicate that the SIT is effectively removing enough impacted groundwater to remediate cobalt and molybdenum concentrations downgradient of the trench to levels that comply with GWPSs. However, further investigation of groundwater elevations in the region north of the identified extent of cobalt impacts is planned (Figure 2-2). The recent exceedances of cobalt and molybdenum concentrations at new downgradient well MW-87 also require ongoing evaluation to assess whether elevated concentrations are seasonal and associated with water quality in the Chaco when the river flows. These planned activities supporting remedy selection and design are identified in Section 4.1.

2.1.3 Unit Closure Planning

Current closure plans for the LAI and LDWP include closure of the units by leaving the CCR in place, dewatering the liquid CCR present in the unit via evaporation/use in operations, grout-abandoning connective process piping, re-grading the surface of the units to prevent ponding of stormwater, placement of a final cover system after the units are dewatered, and construction of perimeter drainage channels to provide stormwater diversion around the footprints of the units (AECOM, 2016a and 2016b).

Multiunit 1 is scheduled to cease receiving CCR and discharges from seepage collection systems in the disposal area (including the NIT and SIT) in October 2020. After that time, the plant will continue to use decanted water from the LDWP in operations, and groundwater extracted from the NIT and SIT will be discharged to a future Return Water Pond (to be located east of Multiunit 1) that is currently in design. Additional dewatering of the LAI and LDWP will occur from ongoing evaporation.

2.2 URS

Figure 2-6 shows relevant URS infrastructure including the footprints of both the former URS and the new Upper Retention Tank (URT). The URS was demolished from June 2018 to December 2018 and the URT was constructed from August 2018 to November 2018 (Section 2.2.2). Figure 2-6 also presents the locations of associated groundwater monitoring wells completed in the Pictured Cliffs Sandstone, which is the uppermost aquifer underlying the URS per the CCR groundwater monitoring system certification report (AECOM, 2017).

Figure 2-7 shows the current iso-concentration contour map for fluoride at the URS based on the results of monitoring well installation activities and groundwater sampling conducted in November and December 2018 during a *Hydrogeologic Investigation of Multiunit 1 and the URS* (Wood, 2019a). The extent of impact is defined by the COC GWPS. Table 2-3 summarizes concentrations of the COC and select water quality parameters in samples collected from wells located downgradient of the URS during the Hydrogeologic Investigation and the first CCR assessment monitoring event of 2019.

2.2.1 Characterization

Key points of the summary CSM for the URS are as follows:

- The URS was located in the southern portion of the plant area (Figure 2-6) which is underlain by the Pictured Cliffs Sandstone hydrostratigraphic unit. Based on the results of groundwater monitoring conducted as part of CCR compliance activities, the predominant direction of groundwater flow in the Pictured Cliffs Sandstone is towards Morgan Lake.
- The URS was a surge pond for process water associated with the plant's FGD system and was placed in service around 1983. The process water contains elevated levels of fluoride. The pond was approximately 1 acre in size and was lined with soil cement on the bottom and on the inside slopes of the pond. The level in the pond varied with operation of the FGD system.
- Prior to demolition of the URS, groundwater levels were locally elevated in the vicinity of the unit suggesting that the URS was in hydraulic communication with underlying groundwater. Groundwater monitoring conducted in November 2018 (after most of the URS had been drained) indicated that the extent of mounding under the URS was limited and had declined from levels observed while the sump was in operation (Wood, 2019b).
- The iso-concentration map for the URS COC fluoride (Figure 2-7) indicates that the highest concentrations of this constituent are generally associated with wells that are hydraulically downgradient of the CCR unit (i.e., MW-66 and MW-67), although fluoride concentrations in upgradient well MW-69 and sidegradient well MW-68 are also elevated. As indicated in Figure 2-7, the relatively low hydraulic conductivity associated with the Pictured Cliffs Sandstone has mitigated the migration of the fluoride plume from the unit.

2.2.2 Remedial Efforts Conducted to Date

APS has responded to the fluoride GWPS exceedance at the URS by collecting additional information that may be useful in corrective measures assessment (i.e., aquifer testing at MW-66) and expediting closure of the URS by removing all CCR from the unit and constructing the new URT which performs the same function as the former URS.

Aquifer Testing in the Vicinity of the URS. Wood conducted aquifer testing at MW-66 in May 2019 to evaluate the maximum sustainable pumping rate at the well and local aquifer properties. Appendix A documents the field activities conducted, the results of step and constant rate testing, and a discussion of aquifer test results. Collected data indicate that an extraction rate of no greater than 1.5 gallons per minute per well is sustainable for potential corrective measures involving extraction wells. The results of a Cooper-Jacob straight line analysis suggest that the hydraulic conductivity of the aquifer in the vicinity of MW-66 ranges from 4.2 to 5.3 ft per day.

URS Closure Activities. Activities conducted to prepare for URS closure are as follows:

- A temporary cofferdam was constructed in the southwest corner of the old URS footprint to constrain flows and allow demolition of the URS and construction of the new URT while the FGD system continued to function. The cofferdam remained in use until December 10, 2018, at which point, all inflow to the old URS was halted and diverted to the URT.
- Prior to demolishing the URS, stored liquid in the URS was removed and transferred to the LAI. The wet material or sludge that remained was removed by Riley Industrial Services, Inc. using vacuum

trucks. After the wet material was removed, the soil-cement lining of the URS was demolished and removed. In addition, a minimum of 2 ft of soil beneath the soil-cement lining was over-excavated in accordance with foundation requirements for the replacement concrete tank. After the over-excavated soil was removed, a visual observation was conducted to verify all CCR-impacted material had been removed. The demolished and removed materials were disposed of by placing them in the DFADA. Removal of the existing soil cement layer and the old pump station, along with any remaining CCR sediments, began on June 25, 2018 and was completed on December 14, 2018.

- A new concrete tank (the URT) was erected in the footprint of the closed URS to replace the function of the URS. Construction of the new tank started in August 2018 and was completed on October 19, 2018. The free-standing tank was filled and hydrostatically tested for leaks in accordance with American Concrete Institute 350.1, *Specifications for Tightness Testing of Environmental Engineering Concrete Containment Structures*. Following successful testing, soil was backfilled around the tank for final completion. The tank was completed on November 5, 2018.

2.2.3 Unit Closure Planning

On July 24, 2018, APS published an amended closure plan for the URS that detailed the plan to close the unit by removal of CCR and replace the unit with a new concrete tank (AECOM, 2016c). A notice of intent to initiate closure of the URS was published December 10, 2018. The new tank was placed into service and CCR disposal to the former URS impoundment ceased on December 10, 2018. Closure by removal will not be complete until fluoride concentrations in the URS monitoring network no longer exceed the GWPS.

3.0 CORRECTIVE MEASURES ASSESSMENT

In accordance with 40 CFR §257.96 of the CCR Rule, after an Appendix IV constituent has been detected at an SSL exceeding a GWPS, assessment of CMs must be conducted to prevent further releases, remediate any releases that have occurred, and restore affected areas to original conditions. The assessment must include an analysis of the effectiveness in meeting all of the requirements and objectives of the remedy as described in §257.97 of the CCR Rule (Selection of Remedy). Remedies must:

1) Be protective of human health and the environment;
2) Attain the GWPS;
3) Control the sources(s) of releases so as to reduce or eliminate, to the maximum extent feasible, further releases of Appendix IV constituents into the environment;
4) Remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, taking into account factors such as avoiding inappropriate disturbance of sensitive ecosystems; and
5) Comply with standards for management of wastes as specified in §257.98(d) of the CCR Rule.

In consideration of these remedial objectives, this section screens applicable technologies for each unit, assembles retained technologies into developed alternatives, and then assesses the alternative CMs using the criteria defined in §257.96 of the CCR Rule (Assessment of Corrective Measures). The criteria include:

1) Performance, reliability, ease of implementation, and potential impacts of appropriate remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination;
2) Time required to begin and complete the remedy; and
3) Institutional requirements, such as state or local permits or other requirements or public health requirements that may substantially affect the implementation of the remedy(s).

As identified in Section 2.0, APS has implemented existing CMs at both Multiunit 1 and the URS and developed closure plans for the units in accordance with §257.102(b) of the CCR Rule (Criteria for Conducting the Closure or Retrofit of CCR Units). These CMs are incorporated into the CM alternatives developed for the Site.

3.1 Multiunit 1

3.1.1 Technology Screening

Table 3-1 presents a description of the individual technologies considered applicable to Multiunit 1 as CMs based on the unit-specific CSM presented in Section 2.1. The benefits, constraints, risks, and an assessment of the relative time to benefit from implementation of the technology are also summarized for the individual technologies in Table 3-1.

Evaluation of benefits, constraints, risks, and the relative time to benefit was conducted using technical judgement and the following considerations:

- Benefits include a lowered risk to human health or environmental receptors; reduced concentrations, volumes, or overall quantities of COC mass in the aquifer; decreased liability and increased acceptance of the public; efficient or enhanced implementation leading to increases in technology effectiveness; and preservation of existing or future uses.

- Constraints include site factors that adversely impact the performance, reliability, or ease of implementation; or an extensive amount of pre-design work that is required to implement the technology.
- Risks include adverse safety impacts or an increase in the potential of exposure to receptors of residual contamination.
- Relative time to benefit included assessment on a scale that identified technologies that had already been implemented as 'fast' and technologies that leave COCs in place to attenuate over time as 'slow'.

The existing technologies implemented or currently identified for future implementation at Multiunit 1 were retained and include:

- Technology A - Draining Multiunit 1 with closure of the CCR in place using engineering control measures to limit the introduction of stormwater into the unit, thereby controlling the ongoing source of seepage from the unit in the future;
- Technology C - Installing an intercept trench system to collect groundwater seepage downgradient of Multiunit 1/closed units in the vicinity, and
- Technology E – Ongoing natural attenuation of COCs.

These technologies are supplemented in Table 3-1 with two strategies to remove more of the potential source of groundwater impacts:

- Technology B - Excavation of the CCR contained in Multiunit 1 as a change to the current closure strategy; and
- Technology D - Capture of impacted groundwater directly downgradient of Multiunit 1 with new containment wells at potentially high contaminant flux locations.

Removal of CCR as part of closure implementation would reduce the mass of COCs present at the Site and limit the potential for ongoing mobilization of COCs into groundwater. However, the duration required for impacts to be mitigated would not be appreciably shortened compared to CCR closure in place because the CCR would still require dewatering prior to excavation and the duration required to implement an excavation and disposal program would be extensive. The earliest date that discharges to Multiunit 1 could cease and draining/evaporation of free liquid in the ponds could begin is 2020, when the Return Water Pond will be placed in service. Excavation of CCR as part of closure would also have the following constraints and risks:

- Potential cross-media impacts during excavation, transport, and final placement at a suitable location;
- Logistical difficulties in locating and/or constructing a suitable facility for the excavated waste; and
- Likely concerns by the public regarding the high volume of traffic associated with transporting large quantities of waste in transportation corridors where the public could be exposed to the waste.

Given the potential benefit of this technology, removal of CCR as part of closure implementation is retained.

Installing containment wells sited directly downgradient of Multiunit 1 would be limited in effectiveness because well placement would be constrained by plant infrastructure/operations and flow paths in the Weathered Lewis Shale are preferential and difficult to discern. Moreover, the impacts of groundwater extraction with containment wells would likely be localized because groundwater extraction in the Weathered Lewis Shale is severely limited by aquifer properties (i.e., low hydraulic conductivity and thin saturated interval). Given that a more effective remedial measure without these issues has already been implemented (i.e., the intercept trench system), Technology D was not retained for further consideration.

3.1.1 Development and Evaluation of Alternatives

Evaluation of CM alternatives included incorporating the retained technologies listed in Table 3-1 into CM Alternative 1 (i.e., closure of the Multiunit 1 with CCR in place or via CCR removal, operation of the existing intercept trench system, and natural attenuation of COCs in the impacted alluvial aquifer). Table 3-2 summarizes this alternative and presents the results of an alternative assessment using the CCR Rule CM assessment criteria noted in the introduction to this section. Figure 3-1 visually depicts the alternative using the current known extent of cobalt since the extent of molybdenum is smaller.

Section 4.1 identifies planned CM pre-design activities that will be conducted to refine the summary CSM for the Multiunit 1 and inform remedy development and selection.

3.2 URS

The technology screening process and CM assessment documented for the URS was informed by the development of a simplified numerical groundwater flow and contaminant transport model for the vicinity of the former URS which reflects the current understanding of the unit-specific CSM summarized in Section 2.2. Appendix B documents the specifications for and use of the Four Corners Power Plant URS Groundwater Model (the Groundwater Model) as part of this assessment, including the modeling platform, structure, parameters, calibration data, model run development, and model run results. The observed distribution of the COC in groundwater (fluoride at the URS) in November/December 2018 was used as the basis for contaminant transport modeling.

3.2.1 Technology Screening

Table 3-3 presents a description of the individual technologies considered applicable to the URS as CMs based on the unit-specific CSM presented in Section 2.2. Evaluation of benefits, constraints, risks, and the relative time to benefit from implementation of the technology was conducted in a manner similar to that described for the Multiunit 1 in Section 3.1.1.

As indicated in Table 3-3, the existing technologies implemented or identified for future implementation at the URS (i.e., Technology A - Replacement of the URS and Technology B - Natural attenuation) have been retained. Supplemental technologies that were identified to reduce the duration of the remedy and quantity of COC mass in the aquifer include containment wells (Technology C) and a passive treatment trench sited in close proximity to the former URS (Technology D).

Installation of a groundwater containment system targeting high concentrations of fluoride in groundwater could substantively reduce the duration that this constituent remains elevated at concentrations that exceed the GWPS. The primary issues associated with this approach include:

- The low extraction flow rates achievable in the sandstone aquifer which limit the influence of containment system operations; and
- Infrastructure and plant operational constraints that limit where wells can be placed and where discharges from the wells can be routed back to the URT.

All identified technologies were retained except the downgradient passive interceptor trench. This approach is not well demonstrated in situ, is subject to fouling, and would have a finite operational life.

3.2.2 Development and Evaluation of Alternatives

Like the evaluation of CM alternatives for Multiunit 1, evaluation of CM alternatives for the URS included incorporating existing and planned technologies listed in Table 3-3 into CM Alternative 1 (i.e., replacement of the URS and natural attenuation of fluoride in the impacted alluvial aquifer). CM Alternative 1 was assessed against a comparable alternative (CM Alternative 2) that is comprised of retained containment technologies from CM Alternative 1 plus the installation of new containment wells. Table 3-4 summarizes these CMs and presents the results of an assessment of these alternatives using the CCR Rule CM assessment criteria. Figures 3-5 and 3-6 visually depict these alternatives for further comparison.

As indicated in Table 3-4, the estimated time to complete the remedy for CM Alternative 1 is generally within a typical facility planning period (i.e., 17 years to slightly greater than 30 years); however, if the hydraulic conductivity of the sandstone aquifer is lower than estimated, the presence of fluoride at concentrations that exceed the GWPS could be extended. The estimated time to complete the remedy for CM Alternative 2 is significantly shorter, on the order of 6 to 7 years.

The estimated durations of remedial implementation, volumes of extracted groundwater, and locations of containment infrastructure derived from the Groundwater Model are approximations of these parameters in a complex aquifer environment based on currently available information. The values presented in this CM assessment should be considered for alternative evaluation purposes only.

Section 4.1 identifies planned CM pre-design activities that will be conducted to further evaluate the infrastructure and operational constraints of constructing a potential groundwater containment system.

4.0 FUTURE WORK

4.1 Pre-Design Studies

Additional site characterization is necessary prior to selection and design of the Multiunit 1 and URS remedies. Currently planned activities include:

- *Further Assessment of Groundwater Elevations in the Disposal Area*. Additional supplementary site wells will be monitored to further evaluate groundwater elevations in the region north of the identified extent of cobalt impacts to ensure that assessment of trench effectiveness includes groundwater that can reasonably be attributed to Multiunit 1.
- *Evaluation of COC Exceedances at MW-87*. Continued sampling of monitoring well MW-87 when water is present, with supplemental analysis of general water quality parameters, will be conducted to assess whether the COC exceedances at MW-87 are associated with flow in the Chaco River or Site CCR units. If upgradient and downgradient monitoring of the Chaco River (when flowing) is possible, samples will be concurrently collected and analyzed.
- *Assessment of Logistical Constraints for a Potential URS Groundwater Containment System*. Given the congested area around the former URS and proximity to a controlled-access region of the plant, investigation of constraints and stakeholder engagement with plant operations personnel will be conducted to identify suitable locations for potential new containment wells and routing of discharge piping to the URT or a sump that discharges to the URT.

4.2 Public Notice and Remedy Selection

After placing this report documenting the CM assessment for the Multiunit 1 and URS in the facility's operating record in accordance with §257.96(d) of the CCR Rule, APS will select a remedy as soon as feasible. Assessment monitoring of groundwater at Multiunit 1 and the URS will continue throughout remedy selection and implementation.

As required by §257.96(e) of the CCR Rule, the results of this CM assessment will be made available to interested and affected parties through a public meeting at least 30 days prior to selecting remedy or remedies for Multiunit 1 and the URS.

5.0 REFERENCES

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TABLES

Table 1-1
Description of Coal Combustion Residual Units

CCR Unit	Location	Function	Operation	Size/Construction	History
Upper Retention Sump (URS)	*Plant Area* NW1/4 of Section 36, T29N, R16W	*Single CCR unit*. Impoundment. Surge pond for FGD system.	Historically, FGD system discharge was discharged into the URS via 10 plus controlled/monitored lines. Pond contents were recirculated back into the FGD process via a pump chamber located on the south end of the pond. Solids were periodically removed from the sump.	- 1.07 acres in areal extent - Soil-cement liner on bottom and inside slopes	Placed in service around 1983. Pond demolshed in 2018 and replaced with an above-ground concrete tank in the footprint of the former URS.
Combined Waste Treatment Pond (CWTP)	*East of Plant, Adjacent to Morgan Lake* SE1/4 of Section 25, T29N, R16W	*Single CCR Unit*. Impoundment. Detention pond used as a settling and stabilization basin for ash-impacted and other Plant wastewater flows prior to discharge to Morgan Lake in accordance with an NPDES permit.	The primary source of water to the CWTP is from hydrobins which separate transport water from bottom ash generated in plant Units 4 and 5. Seven earthen basins in the western edge of the CWTP promote sediment settling prior to the water decanting into the main portion of the CWTP and then overflowing into the cooling water discharge canal at the northeast corner of the pond.	- 13.7 acres in areal extent	Constructed in 1978.
Lined Ash Impoundment (LAI)	*Disposal Area* E1/2 of Section 34, T29N, R16W	*Part of a CCR multiunit with the LDWP* that receives fly ash, flue gas desulfurization (FGD) waste and associated residuals as a slurry from the plant. Impoundment.	Waste is discharged into the pond in the northeast portion of the pond. Decanted flow discharges via a vertical drop structure through a toe drain into the LDWP.	- 75 acres in areal extent - 60 mil HDPE liner - 5,364 acre-ft design capacity - 5,275.2 ft AMSL maximum working level	Constructed on top of closed Ash Ponds 4 and 5 and placed in service in 2004.
Lined Decant Water Pond (LDWP)	*Disposal Area* E1/2 of Section 34, T29N, R16W	*Part of a CCR multiunit with the LAI* that receives decanted water from the LAI. Impoundment.	Decanted water is discharged into the LAI via gravity; the water is pumped from the LDWP back to the plant for reuse in operations.	- 45 acres in areal extent - Two 60 mil HDPE liners separated by a leak detection layer - 435 acre-ft design capacity - 5,213.2 ft AMSL maximum working level	Constructed on top of closed Ash Pond 3 and placed in service in 2003.
Dry Fly Ash Disposal Area (DFADA)	*Disposal Area* SE1/4 of Section 34, T29N, R16W	*Single CCR unit*. Landfill. Disposal of dry fly ash, bottom ash, and construction debris. In the future, FGD solids will be mixed with fly ash at the plant and landfilled in the DFADA.	The DFADA is filled in general accordance with a stacking plan. Leachate generated from the DFADA cells is pumped into trucks and used for dust control or can be transferred to the LDWP.	- 3 conjoined cells (DFADA 1, 2, and 3) with areal extents of 37 acres, 32 acres, and 15 acres, respectively - 3,125 acre-ft design capacity - DFADA 1: compacted clay overlain by 60 mil HDPE liner and drainage layer - DFADA 2 and 3: geosynthetic clay liner overlain by 60 mil HDPE liner and drainage layer - Leachate collection system drains each DFADA cell - DFADA 4 is planned but not yet constructed	Constructed in 2007 (DFADA 1), 2012 (DFADA 2), and 2014 (DFADA 3).

Notes:
AMSL - above mean sea level
CCR - Coal combustion residuals
CWTP - Combined Waste Treatment Pond
DFADA - Dry Fly Ash Disposal Area
FGD - flue gas desulfurization
ft - feet
HDPE - high density polyethylene
LAI - Lined Ash Impoundment
LDWP - Lined Decant Water Pond
NPDES - National Pollutant Discharge Elimination System
URS - Upper Retention Sump

Table 1-2
Summary of Initial Appendix IV Constituent Statistical Analyses

	Multiunit 1					URS				
Constituent	**BTV [mg/L]**	**GWPS [mg/L]**	**Basis for GWPS**	**Location of SSLs Over GWPS**	**Range of Exceeding LCLs [mg/L]**	**BTV [mg/L]**	**GWPS [mg/L]**	**Basis for GWPS**	**Location of SSLs Over GWPS**	**Range of Exceeding LCLs [mg/L]**
Antimony	0.01	0.01	BTV	None	---	0.01	0.01	BTV	None	---
Arsenic	0.0086	0.01	US EPA MCL	None	---	0.013	0.013	BTV	None	---
Barium	0.042	2	US EPA MCL	None	---	0.051	2	US EPA MCL	None	---
Beryllium	0.001	0.004	US EPA MCL	None	---	0.001	0.004	US EPA MCL	None	---
Cadmium	0.002	0.005	US EPA MCL	None	---	0.001	0.005	US EPA MCL	None	---
Chromium	0.02	0.1	US EPA MCL	None	---	0.01	0.1	US EPA MCL	None	---
Cobalt	0.01	0.01	BTV	MW-61 and NW-75	0.016 to 0.043	0.016	0.016	BTV	None	---
Fluoride	5	5	BTV	None	---	4	4	BTV/ US EPA MCL	MW-66, MW-67, MW-68, and MW-69	11 to 26
Lead	0.01	0.015	Alternative Risk-Based GWPS	None	---	0.005	0.015	Alternative Risk-Based GWPS	None	---
Lithium	1.8	1.8	BTV	None	---	0.8	0.8	BTV	None	---
Mercury	0.0002	0.002	US EPA MCL	None	---	0.0002	0.002	US EPA MCL	None	---
Molybdenum	0.12*	0.1	Alternative Risk-Based GWPS	MW-75	0.15	0.011	0.1	Alternative Risk-Based GWPS	None	---
Selenium	0.092	0.092	BTV	None	---	0.45	0.45	BTV	None	---
Thallium	0.017	0.017	BTV	None	---	0.0014	0.002	US EPA MCL	None	---
Combined Radium	4.43	5	US EPA MCL	None	---	5.4	5.4	BTV	None	---

Notes:
BTV - Background Threshold Value
GWPS - Groundwater Protection Standard
LCL - Lower Confidence Limit
mg/L - milligrams per liter
SSLs - statistically significant levels
US EPA MCL - United States Environmental Protection Agency Maximum Contaminant Level

* Inadequate temporal detrending in the background data defaults to using the US EPA MCL or Alternative Risk-Based GWPS, as applicable

Table 2-1
Water Quality Data Collected During Recent Groundwater Monitoring at Multiunit 1

			Analyte Concentration by Location and Date						
			DMX4	DMX6	MW6	MW6	MW7	MW7	MW7
Analyte	Units	GWPS	12/15/18	12/16/18	12/16/18	3/19/19	11/4/18	12/17/18	3/19/19
Boron	mg/L	---	2.6	2.6	6.3	---	7.4	8.3	---
Calcium	mg/L	---	420	420	400	---	320	350	---
Chloride	mg/L	---	780	2300	1500	---	680	640	---
pH	SU	---	7.7	7.3	7.3	---	7.4	7.4	---
Sulfate	mg/L	---	9100	14000	11000	---	6100	5600	---
Total Dissolved Solids	mg/L	---	15000	22000	17000	---	9900	9300	---
Antimony	mg/L	0.01	<0.020	---	---	<0.0010	---	---	<0.0010
Arsenic	mg/L	0.01	<0.010	---	---	0.00069	<0.00050	---	0.00051
Barium	mg/L	2	0.016	---	---	0.019	0.014	---	0.016
Beryllium	mg/L	0.004		---	---	<0.0010	---	---	<0.0010
Cadmium	mg/L	0.005	<0.0020	---	---	<0.00010	<0.00010	---	<0.00010
Chromium	mg/L	0.1	<0.020	---	---	<0.0010	---	---	<0.0010
Cobalt	mg/L	0.01	<0.010	---	---	0.0050	0.00056	---	<0.00050
Fluoride	mg/L	5	<0.80	<0.80	<0.80	<0.80	---	<0.80	<0.40
Lead	mg/L	0.015	<0.010	---	---	0.0010	<0.00050	---	<0.00050
Lithium	mg/L	1.8	0.67	---	---	1.2	0.83	---	0.79
Mercury	mg/L	0.002	---	---	---	<0.00020	---	---	<0.00020
Molybdenum	mg/L	0.1	0.013	---	---	0.017	0.0070	---	0.0054
Selenium	mg/L	0.092	0.027	---	---	0.00054	0.0035	---	0.0054
Thallium	mg/L	0.017	<0.0020	---	---	<0.00010	0.00010	---	<0.00010
Alkalinity as CaCO3	mg/L	---	380	790	500	---	---	470	---
Alkalinity, Phenolphthalein	mg/L	---	<6.0	<6.0	<6.0	---	---	<6.0	---
Bicarbonate Alkalinity as CaCO3	mg/L	---	380	790	500	---	---	470	---
Carbonate Alkalinity as CaCO3	mg/L	---	<6.0	<6.0	<6.0	---	---	<6.0	---
Hydroxide Alkalinity as CaCO3	mg/L	---	<6.0	<6.0	<6.0	---	---	<6.0	---
Magnesium	mg/L	---	730	560	600	---	---	420	---
Potassium	mg/L	---	40	58	45	---	---	32	---
SiO2, Silica	mg/L	---	11	---	---	---	---	---	---
Sodium	mg/L	---	2800	6000	4300	---	---	1900	---

Notes:
Constituents of concern are highlighted in dark green; concentrations greater than the GWPS are bolded.

Acronymns:
AWQS = Aquifer Water Quality Standard
GWPS = Groundwater Protection Standard
mg/L = milligrams per liter
NS = no standard
SU = standard units

Table 2-1
Water Quality Data Collected During Recent Groundwater Monitoring at Multiunit 1

			Analyte Concentration by Location and Date						
			MW8	MW8	MW15	MW16	MW17R	MW17R	MW38R
Analyte	Units	GWPS	11/4/18	3/19/19	12/16/18	12/16/18	12/17/18	3/19/2019	12/15/2018
Boron	mg/L	---	14	---	8.8	6.6	38	---	19
Calcium	mg/L	---	390	---	440	400	450	---	410
Chloride	mg/L	---	1200	---	990	1000	400	---	440
pH	SU	---	7.3	---	7.2	7.4	7.5	---	7.6
Sulfate	mg/L	---	10000	---	6500	11000	4000	---	8900
Total Dissolved Solids	mg/L	---	15000	---	12000	17000	6200	---	13000
Antimony	mg/L	0.01	---	<0.0010	<0.020	---	<0.020	<0.0010	<0.020
Arsenic	mg/L	0.01	0.00064	<0.00050	<0.010	---	<0.010	<0.00050	<0.010
Barium	mg/L	2	0.0090	0.011	0.022	---	0.027	0.017	0.026
Beryllium	mg/L	0.004	---	<0.0010	---	---	---	<0.0010	---
Cadmium	mg/L	0.005	0.00015	0.00029	<0.0020	---	<0.0020	0.0013	<0.0020
Chromium	mg/L	0.1	---	<0.0010	<0.020	---	<0.020	0.0017	<0.020
Cobalt	mg/L	0.01	<0.00050	<0.00050	<0.010	---	**0.091**	**0.065**	**0.093**
Fluoride	mg/L	5	<0.80	0.41	<0.80	---	<0.80	<0.40	<0.80
Lead	mg/L	0.015	<0.00050	<0.00050	<0.010	---	<0.010	0.0027	<0.010
Lithium	mg/L	1.8	1.1	1.1	0.91	---	0.41	0.41	0.80
Mercury	mg/L	0.002	---	<0.00020	---	---	---	<0.00020	---
Molybdenum	mg/L	0.1	0.011	0.011	<0.010	---	<0.010	0.0014	<0.010
Selenium	mg/L	0.092	0.0014	0.0013	0.016	---	0.019	0.00055	0.044
Thallium	mg/L	0.017	<0.00010	<0.00010	<0.0020	---	<0.0020	0.00021	<0.0020
Alkalinity as CaCO3	mg/L	---	---	---	610	550	130	---	270
Alkalinity, Phenolphthalein	mg/L	---	---	---	<6.0	<6.0	<6.0	---	<6.0
Bicarbonate Alkalinity as CaCO3	mg/L	---	---	---	610	550	130	---	270
Carbonate Alkalinity as CaCO3	mg/L	---	---	---	<6.0	<6.0	<6.0	---	<6.0
Hydroxide Alkalinity as CaCO3	mg/L	---	---	---	<6.0	---	<6.0	---	<6.0
Magnesium	mg/L	---	---	---	550	1200	260	---	680
Potassium	mg/L	---	---	---	38	46	19	---	39
SiO2, Silica	mg/L	---	---	---	14	---	14	---	17
Sodium	mg/L	---	---	---	2100	2900	1000	---	2500

Notes:
Constituents of concern are highlighted in dark green; concentrations greater than the GWPS are bolded.

Acronymns:
AWQS = Aquifer Water Quality Standard
GWPS = Groundwater Protection Standard
mg/L = milligrams per liter
NS = no standard
SU = standard units

Table 2-1
Water Quality Data Collected During Recent Groundwater Monitoring at Multiunit 1

			Analyte Concentration by Location and Date						
			MW38R	MW49A	MW49A	MW56	MW57	MW57	MW61
Analyte	**Units**	**GWPS**	**3/19/2019**	**11/4/2018**	**3/19/2019**	**12/16/2018**	**12/15/2018**	**3/19/2019**	**11/3/2018**
Boron	mg/L	---	---	1.8	---	3.0	2.1	---	37
Calcium	mg/L	---	---	380	---	420	430	---	470
Chloride	mg/L	---	---	590	---	1500	510	---	340
pH	SU	---	---	7.4	---	7.1	7.5	---	8.6
Sulfate	mg/L	---	---	19000	---	12000	7800	---	3600
Total Dissolved Solids	mg/L	---	---	27000	---	19000	12000	---	5300
Antimony	mg/L	0.01	<0.0010	---	<0.0010	<0.020	<0.020	<0.0010	---
Arsenic	mg/L	0.01	0.00051	0.0012	0.0011	<0.010	<0.010	<0.00050	0.00084
Barium	mg/L	2	0.018	0.020	0.027	0.029	0.023	0.018	0.015
Beryllium	mg/L	0.004	<0.0010	---	<0.0010	---	---	<0.0010	---
Cadmium	mg/L	0.005	0.00011	0.00027	<0.00010	<0.0020	<0.0020	<0.00010	0.00088
Chromium	mg/L	0.1	<0.0010	---	0.0036	<0.020	<0.020	<0.0010	---
Cobalt	mg/L	0.01	**0.17**	0.0020	<0.00050	<0.010	<0.010	0.0021	**0.018**
Fluoride	mg/L	5	<0.40	<0.80	0.92	<0.80	<0.80	<0.40	---
Lead	mg/L	0.015	0.00053	<0.00050	<0.00050	<0.010	<0.010	<0.00050	0.00086
Lithium	mg/L	1.8	0.45	1.2	0.56	1.1	0.80	0.66	0.35
Mercury	mg/L	0.002	<0.00020	---	<0.00020	---	---	<0.00020	---
Molybdenum	mg/L	0.1	0.016	0.014	**0.15**	<0.010	<0.010	0.011	0.090
Selenium	mg/L	0.092	0.0037	0.0016	0.0018	0.21	0.022	<0.00050	0.00061
Thallium	mg/L	0.017	<0.00010	0.0016	0.00083	<0.0020	<0.0020	<0.00010	0.00016
Alkalinity as CaCO3	mg/L	---	---	---	---	650	470	---	---
Alkalinity, Phenolphthalein	mg/L	---	---	---	---	<6.0	<6.0	---	---
Bicarbonate Alkalinity as CaCO3	mg/L	---	---	---	---	650	470	---	---
Carbonate Alkalinity as CaCO3	mg/L	---	---	---	---	<6.0	<6.0	---	---
Hydroxide Alkalinity as CaCO3	mg/L	---	---	---	---	<6.0	<6.0	---	---
Magnesium	mg/L	---	---	---	---	1300	610	---	---
Potassium	mg/L	---	---	---	---	54	42	---	---
SiO2, Silica	mg/L	---	---	---	---	20	17	---	---
Sodium	mg/L	---	---	---	---	3400	2200	---	---

Notes:

Constituents of concern are highlighted in dark green; concentrations greater than the GWPS are bolded.

Acronymns:

AWQS = Aquifer Water Quality Standard

GWPS = Groundwater Protection Standard

mg/L = milligrams per liter

NS = no standard

SU = standard units

Table 2-1
Water Quality Data Collected During Recent Groundwater Monitoring at Multiunit 1

			Analyte Concentration by Location and Date						
			MW61	MW61	MW74	MW75	MW75	MW75	MW87
Analyte	**Units**	**GWPS**	**12/15/2018**	**3/19/2019**	**3/19/2019**	**11/3/2018**	**12/15/2018**	**3/19/2019**	**3/19/2019**
Boron	mg/L	---	40	---	---	24	25	---	---
Calcium	mg/L	---	490	---	---	430	450	---	---
Chloride	mg/L	---	310	---	---	310	280	---	---
pH	SU	---	8.7	---	---	8.3	8.4	---	---
Sulfate	mg/L	---	3500	---	---	4300	4300	---	---
Total Dissolved Solids	mg/L	---	5500	---	---	6200	6600	---	---
Antimony	mg/L	0.01	<0.020	<0.0010	<0.0010	---	<0.020	<0.0010	0.0037
Arsenic	mg/L	0.01	<0.010	0.00054	0.0049	0.00060	<0.010	<0.00050	0.0023
Barium	mg/L	2	0.019	0.016	0.014	0.017	0.022	0.019	0.023
Beryllium	mg/L	0.004	---	<0.0010	<0.0010	---	---	<0.0010	<0.0010
Cadmium	mg/L	0.005	<0.0020	0.00093	<0.00010	0.0018	<0.0020	0.0018	0.00013
Chromium	mg/L	0.1	<0.020	<0.0010	0.0063	---	<0.020	<0.0010	<0.0010
Cobalt	mg/L	0.01	**0.022**	**0.019**	<0.00050	**0.045**	**0.046**	**0.045**	**0.032**
Fluoride	mg/L	5	1.3	1.1	2.4	1.2	1.2	1.1	<0.80
Lead	mg/L	0.015	<0.010	0.0012	<0.00050	0.0030	<0.010	0.0030	0.00062
Lithium	mg/L	1.8	0.37	0.37	0.65	0.39	0.41	0.40	1.1
Mercury	mg/L	0.002	---	<0.00020	<0.00020	---	---	<0.00020	<0.00020
Molybdenum	mg/L	0.1	**0.10**	0.092	0.012	**0.18**	**0.17**	**0.17**	**0.12**
Selenium	mg/L	0.092	0.023	0.00072	0.14	0.0026	0.026	0.0026	0.090
Thallium	mg/L	0.017	<0.0020	0.00016	<0.00010	0.00018	<0.0020	0.00017	<0.00010
Alkalinity as CaCO3	mg/L	---	85	---	---	---	87	---	---
Alkalinity, Phenolphthalein	mg/L	---	<6.0	---	---	---	<6.0	---	---
Bicarbonate Alkalinity as CaCO3	mg/L	---	75	---	---	---	87	---	---
Carbonate Alkalinity as CaCO3	mg/L	---	9.8	---	---	---	<6.0	---	---
Hydroxide Alkalinity as CaCO3	mg/L	---	<6.0	---	---	---	<6.0	---	---
Magnesium	mg/L	---	120	---	---	---	220	---	---
Potassium	mg/L	---	20	---	---	---	21	---	---
SiO2, Silica	mg/L	---	7.7	---	---	---	6.9	---	---
Sodium	mg/L	---	1000	---	---	---	1200	---	---

Notes:
Constituents of concern are highlighted in dark green; concentrations greater than the GWPS are bolded.

Acronymns:
AWQS = Aquifer Water Quality Standard
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mg/L = milligrams per liter
NS = no standard
SU = standard units

Table 2-2
Constituent of Concern Properties Impacting Mobility in Aquifer Environments

Constituent	General Behavior	pH and Redox Sensitivities	Adsorption Characteristics	Solubility Characteristics
Cobalt	Cationic metal ion	More mobile at low pH and reducing conditions	Likely pH and adsorbent dependent	Forms numerous complexes that somewhat increase solubility (organic matter, chloride, etc.) Cobalt carbonate precipitation can limit solubility to low values
Fluoride	Anion	Not redox or pH sensitive	Not readily adsorbed to soils; little retardation	Soluble in water
Molybdenum	Behaves as an oxi-anion (molybdate, etc.), not as a metallic cation	Dependent on redox conditions (mostly +4 and +6, but also +3)	Adsorbs to iron oxide coatings on soils	Can form low solubility metal molybdate compounds (e.g., iron and calcium)

Table 2-3
Water Quality Data Collected During Recent Groundwater Monitoring at the URS

			Analyte Concentration by Location and Date							
			MW66	MW66	MW67	MW67	MW68	MW68	MW69	MW69
Analyte	**Units**	**GWPS**	**11/2/18**	**3/18/19**	**11/3/18**	**3/17/19**	**11/3/18**	**3/17/19**	**11/3/18**	**3/17/19**
Boron	mg/L	---	140	---	170	---	150	---	92	---
Calcium	mg/L	---	470	---	470	---	460	---	470	---
Chloride	mg/L	---	1800	---	2000	---	1500	---	1200	---
pH	SU	---	7.3	---	7.4	---	7.2	---	7.3	---
Sulfate	mg/L	---	12000	---	13000	---	11000	---	8700	---
Total Dissolved Solids	mg/L	---	20000	---	19000	---	18000	---	14000	---
Antimony	mg/L	0.01	---	<0.0010	---	<0.0010	---	---	---	<0.0010
Arsenic	mg/L	0.013	0.0015	0.0012	0.0016	0.0016	0.0030	0.0035	0.0042	0.0032
Barium	mg/L	2	0.023	0.023	0.017	0.014	0.0081	0.0084	0.012	0.010
Beryllium	mg/L	0.004	---	<0.0010	---	<0.0010	---	<0.0010	---	<0.0010
Cadmium	mg/L	0.005	---	0.00016	---	<0.00010	---	0.00014	---	0.00021
Chromium	mg/L	0.1	---	0.0010	---	<0.0010	---	<0.0010	---	<0.0010
Cobalt	mg/L	0.016	0.012	0.017	0.0061	0.0058	0.0038	0.0026	0.0041	0.0031
Fluoride	mg/L	4	**25**	**23**	**16**	**15**	**12**	**9.2**	**11**	3.1
Lead	mg/L	0.015	---	<0.00050	---	<0.00050	---	<0.00050	---	<0.00050
Lithium	mg/L	0.8	0.38	0.37	0.39	0.37	0.42	0.37	0.35	0.27
Mercury	mg/L	0.002	---	<0.00020	---	<0.00020	---	<0.00020	---	<0.00020
Molybdenum	mg/L	0.1	0.019	0.016	0.037	0.036	0.0078	0.0067	0.012	0.011
Selenium	mg/L	0.45	0.0020	0.0024	0.0043	0.0050	0.11	0.14	0.025	0.038
Thallium	mg/L	0.002	0.0011	0.0011	0.00078	0.00086	0.0016	0.0010	0.00024	0.00020
Alkalinity as CaCO3	mg/L	---	---	---	---	---	---	---	---	---
Alkalinity, Phenolphthalein	mg/L	---	---	---	---	---	---	---	---	---
Bicarbonate Alkalinity as CaCO3	mg/L	---	---	---	---	---	---	---	---	---
Carbonate Alkalinity as CaCO3	mg/L	---	---	---	---	---	---	---	---	---
Hydroxide Alkalinity as CaCO3	mg/L	---	---	---	---	---	---	---	---	---
Magnesium	mg/L	---	---	---	---	---	---	---	---	---
Potassium	mg/L	---	---	---	---	---	---	---	---	---
SiO2, Silica	mg/L	---	---	---	---	---	---	---	---	---
Sodium	mg/L	---	---	---	---	---	---	---	---	---

Notes:
Constituents of concern are highlighted in dark green; concentrations greater than the GWPS are bolded.

Acronymns:
AWQS = Aquifer Water Quality Standard
GWPS = Groundwater Protection Standard
mg/L = milligrams per liter
NS = no standard
SU = standard units
URS = Upper Retention Sump

Table 2-3
Water Quality Data Collected During Recent Groundwater Monitoring at the URS

			Analyte Concentration by Location and Date							
			MW70	MW70	MW71	MW71	MW72	MW72	MW73	MW73
Analyte	Units	GWPS	11/2/18	3/18/19	11/2/18	3/18/19	11/3/18	3/17/19	11/3/18	3/18/19
Boron	mg/L	---	88	---	0.56	---	0.22	---	1.7	---
Calcium	mg/L	---	510	---	470	---	470	---	480	---
Chloride	mg/L	---	1100	---	520	---	450	---	660	---
pH	SU	---	7.0	---	7.0	---	7.0	---	7.0	---
Sulfate	mg/L	---	6400	---	11000	---	11000	---	7500	---
Total Dissolved Solids	mg/L	---	11000	---	16000	---	16000	---	12000	---
Antimony	mg/L	0.01	---	<0.0010	---	<0.0010	---	<0.0010	---	<0.0010
Arsenic	mg/L	0.013	0.0043	0.0054	0.0046	0.0069	0.0031	0.0034	<0.00050	<0.00050
Barium	mg/L	2	0.010	0.0099	0.0098	0.010	0.0075	0.0077	0.022	0.023
Beryllium	mg/L	0.004	---	<0.0010	---	<0.0010	---	<0.0010	---	<0.0010
Cadmium	mg/L	0.005	---	<0.00010	---	<0.00010	---	<0.00010	---	0.00013
Chromium	mg/L	0.1	---	<0.0010	---	<0.0010	---	<0.0010	---	<0.0010
Cobalt	mg/L	0.016	0.0041	0.0040	<0.00050	<0.00050	0.0020	0.0022	0.0078	0.0038
Fluoride	mg/L	4	2.7	2.3	<2.0	<0.80	<2.0	<0.80	<0.80	<0.80
Lead	mg/L	0.015	---	<0.00050	---	<0.00050	---	<0.00050	---	<0.00050
Lithium	mg/L	0.8	0.32	0.32	0.35	0.32	0.37	0.36	0.31	0.26
Mercury	mg/L	0.002	---	<0.00020	---	<0.00020	---	<0.00020	---	<0.00020
Molybdenum	mg/L	0.1	0.0064	0.0057	0.00079	0.00066	0.00078	0.00095	0.0026	0.0017
Selenium	mg/L	0.45	0.19	0.24	0.27	0.37	0.13	0.13	0.0062	0.0069
Thallium	mg/L	0.002	0.00029	0.00029	0.00031	0.00031	0.00088	0.00095	0.00020	0.00025
Alkalinity as CaCO3	mg/L	---	---	---	---	---	---	---	---	---
Alkalinity, Phenolphthalein	mg/L	---	---	---	---	---	---	---	---	---
Bicarbonate Alkalinity as CaCO3	mg/L	---	---	---	---	---	---	---	---	---
Carbonate Alkalinity as CaCO3	mg/L	---	---	---	---	---	---	---	---	---
Hydroxide Alkalinity as CaCO3	mg/L	---	---	---	---	---	---	---	---	---
Magnesium	mg/L	---	---	---	---	---	---	---	---	---
Potassium	mg/L	---	---	---	---	---	---	---	---	---
SiO2, Silica	mg/L	---	---	---	---	---	---	---	---	---
Sodium	mg/L	---	---	---	---	---	---	---	---	---

Notes:
Constituents of concern are highlighted in dark green; concentrations greater than the GWPS are bolded.

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mg/L = milligrams per liter
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Table 2-3
Water Quality Data Collected During Recent Groundwater Monitoring at the URS

			Analyte Concentration by Location and Date							
			MW83	MW83	MW84	MW84	MW85	MW85	MW86	MW86
Analyte	**Units**	**GWPS**	**12/15/18**	**3/18/19**	**12/15/18**	**3/17/19**	**12/15/18**	**3/20/19**	**12/15/18**	**3/18/19**
Boron	mg/L	---	2.5	---	110	---	30	---	120	---
Calcium	mg/L	---	470	---	490	---	510	---	480	---
Chloride	mg/L	---	130	---	1400	---	680	---	1300	---
pH	SU	---	7.5	---	7.1	---	7.3	---	7.1	---
Sulfate	mg/L	---	3400	---	8300	---	5400	---	9400	---
Total Dissolved Solids	mg/L	---	5200	---	14000	---	8700	---	13000	---
Antimony	mg/L	0.01	<0.0025	<0.0010	<0.0025	<0.0010	<0.0025	<0.0010	<0.0025	<0.0010
Arsenic	mg/L	0.013	<0.0010	0.0023	<0.0010	0.00065	0.0013	0.0043	<0.0010	0.0011
Barium	mg/L	2	0.022	0.034	0.018	0.020	0.026	0.016	0.019	0.016
Beryllium	mg/L	0.004	---	<0.0010	---	<0.0010	---	<0.0010	---	<0.0010
Cadmium	mg/L	0.005	<0.00050	<0.00010	<0.00050	0.00021	<0.00050	<0.00010	<0.00050	0.00012
Chromium	mg/L	0.1	<0.0025	<0.0010	<0.0025	0.0010	<0.0025	0.0028	<0.0025	0.0025
Cobalt	mg/L	0.016	0.0040	<0.00050	0.011	0.0071	0.0017	<0.00050	0.0092	0.0043
Fluoride	mg/L	4	1.8	1.2	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80
Lead	mg/L	0.015	<0.00050	<0.00050	0.00067	<0.00050	0.00058	<0.00050	0.00065	<0.00050
Lithium	mg/L	0.8	<0.20	<0.20	<0.20	0.20	0.25	0.25	0.32	0.30
Mercury	mg/L	0.002	---	<0.00020	---	<0.00020	---	<0.00020	---	<0.00020
Molybdenum	mg/L	0.1	0.010	0.053	0.0015	0.0091	0.0058	0.0052	0.0041	0.0028
Selenium	mg/L	0.45	<0.0030	0.0012	<0.0030	0.0036	0.12	0.16	<0.0030	0.0050
Thallium	mg/L	0.002	<0.00050	<0.00010	<0.00050	0.00046	<0.00050	0.00023	0.00053	0.00057
Alkalinity as CaCO3	mg/L	---	250	---	410	---	380	---	330	---
Alkalinity, Phenolphthalein	mg/L	---	<6.0	---	<6.0	---	<6.0	---	<6.0	---
Bicarbonate Alkalinity as CaCO3	mg/L	---	250	---	410	---	380	---	330	---
Carbonate Alkalinity as CaCO3	mg/L	---	<6.0	---	<6.0	---	<6.0	---	<6.0	---
Hydroxide Alkalinity as CaCO3	mg/L	---	<6.0	---	<6.0	---	<6.0	---	<6.0	---
Magnesium	mg/L	---	270	---	1800	---	770	---	1700	---
Potassium	mg/L	---	3.2	---	33	---	18	---	30	---
SiO2, Silica	mg/L	---	21	---	14	---	19	---	20	---
Sodium	mg/L	---	610	---	660	---	780	---	630	---

Notes:
Constituents of concern are highlighted in dark green; concentrations greater than the GWPS are bolded.

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AWQS = Aquifer Water Quality Standard
GWPS = Groundwater Protection Standard
mg/L = milligrams per liter
NS = no standard
SU = standard units
URS = Upper Retention Sump

Table 3-1
Corrective Measure Technology Screening for Releases from Multiunit 1

Technology	Description	Benefits	Constraints and Risks	Relative Time to Benefit	Retained?
(A) Draining/evaporation of free liquid from the LAI/LDWP (i.e., Multiunit 1) and closure with CCR in place	Multiunit 1 is scheduled to cease receiving CCR and discharges from seepage collection systems in October 2020*. After that time, future discharges will be directed to the planned Return Water Pond. The plant will continue to use decanted water from the LDWP in operations and the remaining free liquid present in the ponds will be allowed to evaporate until a date when Multiunit 1 can be closed with CCR in place. Stormwater control measures would be implemented to limit seepage of residual water from the ponds after closure.	(1) Removes the hydraulic head of water in the unit that may be in communication with the underlying aquifer. (2) Reduces a potential contributing source of COC mass into the aquifer. (3) Promotes Multiunit 1 closure	(1) Given the construction of these ponds on top of historical ponds that could have discharged the COCs in the past, the impact of removing water that could be supplying an additional source of COCs may be negligible. (2) The ponds are sizable and may take a long time to dewater. (3) Although a low permeability cap will be installed on Multiunit 1 after it is dewatered and engineering control measures to divert stormwater away from Multiunit 1 will be put in place, if stormwater percolates through the drained Multiunit 1, impacted seepage from Multiunit 1 could be mobilized because the CCR remains in place. (4) Technology does not address existing impacts in groundwater downgradient of Multiunit 1.	Slow	Yes (part of the unit closure plan)
(B) Draining/evaporation of free liquid from the LAI/LDWP (i.e., Multiunit 1) and closure of the ponds through CCR removal	Multiunit 1 is scheduled to cease receiving CCR and discharges from seepage collection systems in October 2020*. After that time, future discharges will be directed to the planned Return Water Pond. The plant will continue to use decanted water from the LDWP in operations and the remaining free liquid present in the ponds will be allowed to evaporate until the CCR can be removed and placed in an appropriately lined facility.	(1) Removes a potential contributing source of COC mass into the aquifer. (2) Removes the hydraulic head of water in the unit that may be in communication with the underlying aquifer. (3) Promotes Multiunit 1 closure	(1) Given the construction of these ponds on top of historical ponds that could have discharged the COCs in the past, the impact of removing CCR that could be supplying an additional source of COCs may be negligible. (2) The ponds are sizable and will take a long time to dewater. (3) Technology does not address existing impacts in groundwater downgradient of Multiunit 1.	Slow	Yes
(C) Installation of an intercept trench seepage collection system downgradiant of closed Evaporation Ponds 1 and 2	A 7,600-ft long intercept trench system was installed in 2011 (north portion) and 2013 (south portion) along the western boundary of the APS lease boundary to intercept and collect seepage from the disposal area. Downgradient of Multiunit 1, the trench ranges from approximately 35 to 50 ft deep, following the geologic interface between the weathered and unweathered shale. The trench is filled with drainage rock and perforated pipe that is sloped to collection sumps for seepage removal with level controlled submersible pumps. Seepage collected from the trench system is currently discharged to the LDWP; after October 2020*, seepage will be discharged to a future Return Water Pond to be located east of Multiunit 1.	(1) Intercepts the width of the entire plume downgradient of Multiunit 1 that is migrating through the weathered shale. (2) Does not distinguish amoung sources of seepage; trench is located downgradient of the disposal area.	(1) Requires ongoing maintenance to ensure proper operation/effectiveness. (2) Does not intercept seepage present in the unweathered shale (if present)	Immediate (Existing System)	Yes (Existing System)

Table 3-1
Corrective Measure Technology Screening for Releases from Multiunit 1

Technology	Description	Benefits	Constraints and Risks	Relative Time to Benefit	Retained?
(D) Containment wells sited downgradient of Multiunit 1	A series of containment wells would target high contaminant flux locations downgradient of Multiunit 1. Extracted water would be discharged to the LDWP until 2020* when it would be routed to the Return Water Pond.	(1) Wells could be installed incrementally so that spacing and depths could be evaluated and adjusted to promote effectiveness.	(1) Flow paths in the weathered shale are preferential and difficult to discern; many wells at the site are dry. (2) Locating wells at the downgradient toe of Multiunit 1 would only address a portion of the impacted seepage in the disposal area; effectiveness of the system would be difficult to evaluate. (3) Containment flows from individual wells could potentially be very low with only localized impacts because of the low hydraulic conductivity and limited saturated thickness of the aquifer - quite a few wells could be required and cleanup may take a long time. (4) Well placement would be limited by plant infrastructure and operations.	Moderate	No
(E) Monitored natural attenuation of COCs in the impacted aquifer	The COCs would be allowed to naturally attenuate via dilution, dispersion, and adsorption. Groundwater monitoring would continue as long as COC concentrations exceed GWPSs.	(1) No active mitigation would be required.	(1) Additional monitoring wells could be required to monitor migration.	Slow	Yes (in combination with other technologies)

Notes:

* Dewatering of Multiunit 1 for pond closure is not feasible prior to 2020 when the planned Return Water Pond is placed in service. An alternative disposal facility cannot be sited, designed, and constructed any earlier than 2020.

CCR = coal combustion residuals
COCs = Constituents of concern (i.e., cobalt and molybdenum)
GWPS = Groundwater Protection Standard
ft = feet
Multiunit 1 = Lined Ash Impoundment (LAI) and Lined Decant Water Pond (LDWP)

Table 3-2
Evaluation of Corrective Measures for Multiunit 1

Corrective Measures	Performance and Reliability	Ease of Implementation	Potential Impacts[a]	Time to Begin Remedy	Time to Complete the Remedy	Institutional Requirements[b]
Alternative 1: (A/B) Draining/evaporation of free liquid from the LAI and LDWP (i.e., Multiunit 1) with closure either in place or by CCR removal (C) Installation of an intercept trench seepage collection system downgradiant of closed Evaporation Ponds 1 and 2 (E) Natural attenuation of COCs in the impacted aquifer	Dewatering or removal of CCR from Multiunit 1 removes a potential source of COC mass into the aquifer and removes the hydraulic head of water in the unit that may be in communication with the underlying aquifer. If CCR is removed after dewatering, the risk of future impacted seepage is lessened. Dewatering may take some time. The interceptor trench currently collects seepage containing COC mass from the width of the entire plume migrating through the weathered shale. The COCs are not generally present at concentrations exceeding GWPSs downgradient of the trench. The trench does not distinguish between the source of the seepage which is beneficial because closed units located in the vicinity of Multiunit 1 may be contributing COC mass to groundwater. Operation of the trench will be required for as long as COCs are present at concentrations exceeding GWPSs in groundwater upgradient of the trench. Some attenuation of COC concentrations over time can be expected. Reliability issues associated with operations can be addressed with regular maintenance of the system.	CMs for existing collection systems and wells are in place. Closure of Multiunit 1 will begin in 2020 when the future Return Water Pond will become operational. The plant will continue to use decanted water from the LDWP in operations. Additional dewatering will occur from ongoing evaporation. The ponds are sizable and will take a long time to dewater. Removal of CCR as part of closure would be logistically intensive, requiring locating and/or constructing a suitable faciliy and managing the transport of waste in large quantities between the unit and waste facility.	No human or ecological receptors are known to be impacted at this time - however, ongoing monitoring of the effectiveness of operations is required to protect downgradient Chaco Wash. There are no cross-media impacts associated with the CMs as long as the unit is closed in place. If excavation of CCR is conducted, there would be a potential for cross media impacts during excavation (to air via dust and to surface water via runoff), transport (through spills and/or transport vessel contamination) and final placement (if the receiving facility is not properly constructed or the integrity of the facility degrades with time). There would likely not be short-term community or sensitive environment risks assocated with the CMs if the unit is closed in place; if CCR excavation and transport off site is conducted, increased traffic and risk of spilling impacted waste could be a community concern. If the unit is closed in place, there would be limited construction safety issues associated with the CMs. If CCR excavation, transport, and placement is required, construction safety would need to be vigilently managed to prevent safety incidents.	CMs are in place. Multiunit 1 is scheduled to cease receiving CCR and discharges from seepage collection systems in October 2020.	The duration of future required operation of the intercept trench is difficult to estimate given the construction of the ponds on top of historical ponds that could have discharged the COCs in the past.	No institutional requirements are needed. However, if the CCR is removed, waste characterization and management activities would be required.

(a) Including safety impacts, cross-media impacts, and control of exposure to any residual contamination.
(b) Such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).

Notes:
Multiunit 1 = Lined Ash Impoundment (LAI) and Lined Decant Water Pond (LDWP)
CM(s) = corrective measure(s)
COCs = Constituents of concern (i.e., cobalt and molybdenum)
GWPSs = Groundwater Protection Standards

Table 3-3
Corrective Measure Technology Screening for Releases from the Upper Retention Sump

Technology	Description	Benefits	Constraints and Risks	Relative Time to Benefit	Retained?
(A) Replacement of the URS with an above ground tank	The URS has been demolished and replaced with an above ground tank (referred to as the Upper Retention Tank [URT]) precluding the ongoing discharge of water from this unit.	(1) Removes the source of COC mass into the aquifer. (2) Removes the hydraulic head of water in the unit that was previously contributing to a steep localized gradient at the sump location.	Not applicable.	Immediate (replacement tank is in place)	Yes
(B) Monitored natural attenuation of the COC in the impacted aquifer	The COC would be allowed to naturally attenuate via dilution, dispersion, and adsorption. Groundwater monitoring would continue as long as COC concentrations exceed GWPSs.	(1) No active mitigation would be required.	(1) The extent of the COC plume would continue to increase until the rate of attenuation exceeds the rate of migration; expansion of the plume could occur for some time before attenuating. (2) Additional monitoring wells may be required to monitor COC plume migration.	Slow	Yes
(C) Containment wells near the URS	Containment wells would target high COC concentration locations in the vicinity of the former URS; lower concentrations in the COC plume would be allowed to attenuate. Extracted water would be discharged to either the URT or a nearby drain sump located south of the bag houses (Sump 10) that discharges into the URT.	(1) Wells could be installed incrementally so that spacing and depths could be evaluated and adjusted to promote effectiveness. (2) Active mitigation would decrease cleanup time compared to passive treatment approaches.	(1) Containment flows from individual wells could potentially be very low (approximtely 1 gpm) with only localized impacts. (2) Well placement would be limited by plant infrastructure and operations.	Moderate	Yes
(D) Activated alumina-filled passive treatment trench (up to 40 ft deep)	An intercept trench filled with activated alumina would be installed perpendicular to groundwater flow, downgradient of the former URS, to promote in situ treatment of fluoride in groundwater.	(1) No active mitigation would be required. (2) Would likely intercept the entire plume if constructed properly.	(1) A predesign investigation would need to be conducted to design the trench and column test the water with activated alumina - the treatment technology is not well demonstrated in situ at full scale. High levels of total dissolved solids can foul the adsorbant and there may be potential interferance from other anions present in the groundwater. (2) The trench would have a finite adsorption capacity. (3) Plume treatment would be slow given the slow rate of plume migration. (4) Trench placement would be limited by plant infrastructure and operations.	Slow	No

Notes:
COC = constituent of concern (i.e., fluoride)
ft = feet
gpm = gallons per minute
GWPS = Groundwater Protection Standard
URS = Upper Retention Sump
URT = Upper Retention Tank

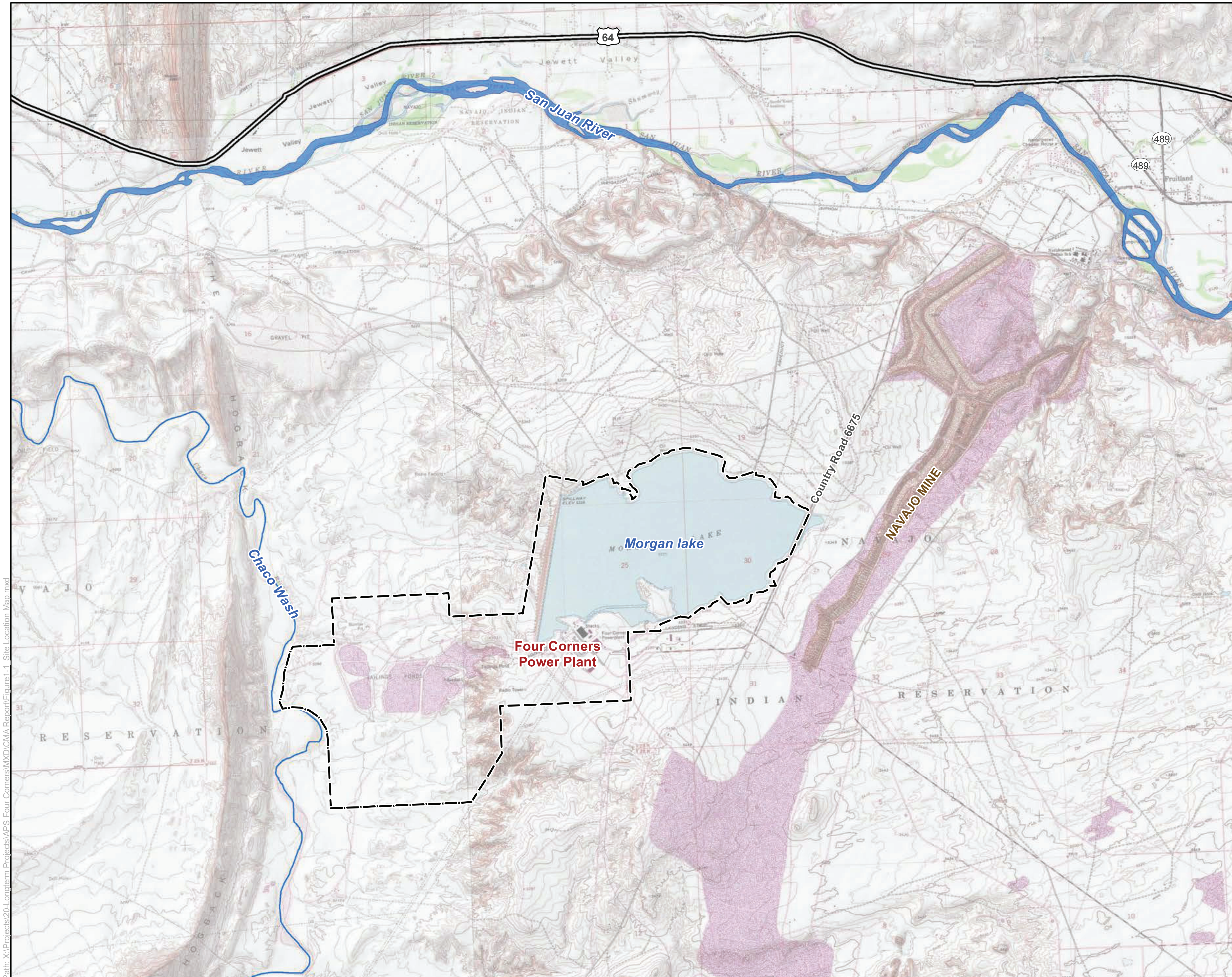
Table 3-4
Evaluation of Corrective Measures for the URS

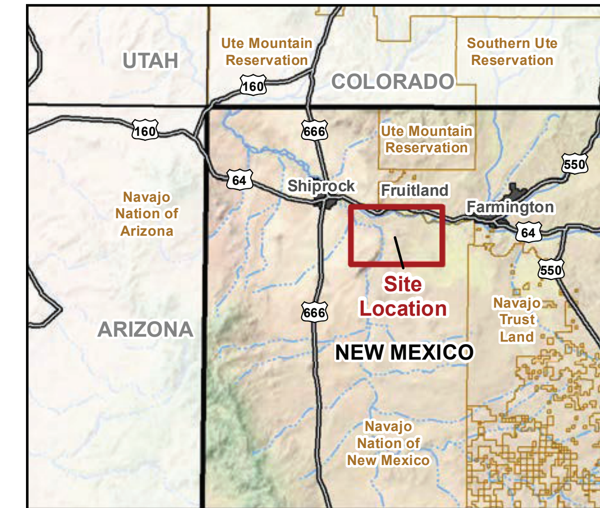
Corrective Measures	Performance and Reliability	Ease of Implementation	Potential Impacts[(a)]	Time to Begin Remedy	Time to Complete the Remedy	Institutional Requirements[(b)]
Alternative 1: (A) Replacement of the URS with an above ground tank (B) Monitored natural attenuation of the COC in the impacted aquifer *As modeled: The November 2018 fluoride plume and hydraulic heads after URS removal were evaluated in a steady state, single-layer groundwater flow model.*	Replacement of the URS removes the source of COC mass into the aquifer and the localized hydraulic head which contributed to plume migration. The size of plume is limited suggesting that natural attenuation may currently be occurring. However, given aquifer properties and hydraulic conditions, the COC is expected to be present at concentrations exceeding the GWPSs in downgradient groundwater for some time.	The URS has already been replaced with a new tank - implementation of the remedy would be complete with the exception that future monitoring wells may be required to monitor plume migration.	No human or ecological receptors are known to be impacted at this time. There are no cross-media impacts associated with the CMs. There are not anticipated to be any short-term community or sensitive environment risks assocated with the CMs. With the exception of potentially installing future monitoring wells, there are no construction safety and plant operational issues associated with the remedy.	Immediate; the CMs are in place.	*The groundwater model predicts fluoride will attenuate to concentrations less than the GWPS in 17 to over 30 years using a range of reasonable hydraulic conductivities.*	Not applicable.
Alternative 2: (A) Replacement of the URS with an above ground tank (B) Monitored natural attenuation of the COC in the impacted aquifer (C) Containment wells near the former URS *As modeled: The November 2018 fluoride plume, hydraulic heads after URS removal, and two pumping wells (upgradient of MW-66 and near MW-68) extracting groundwater at 1 gpm were evaluated in a steady state, single-layer groundwater flow model.*	Replacement of the URS removes the source of COC mass into the aquifer and removes the hydraulic head which promotes plume migration. New on-site containment wells targeting high COC concentrations would reduce the residual mass in the aquifer and magnitude of risk resulting from the existing plume by cleaning up the plume faster than natural attenuation alone. Operation of the groundwater containment system would require routine maintenance to promote effectiveness and reliability.	The URS has already been replaced with a new tank. Future wells may be required to monitor plume migration. Containment well siting may be difficult given plant infrastructure/operational constraints. Trenching will be required to install return piping for the extracted groundwater to the URS replacement tank.	No human or ecological receptors are known to be impacted at this time. There are no cross-media impacts associated with the CMs. There would be no short-term community or sensitive environment risks assocate with the CMs. There could be construction safety and plant operational issues associated with additional well and pipe installation.	Construction of the containment system would require design of a groundwater extraction system including siting and installation of new wells, subgrade piping and connection to either the URS replacement tank or a nearby drain sump located south of the bag houses (Sump 10).	*The groundwater model predicts fluoride will attenuate to concentrations less than the GWPS in 6 to 7 years with containment well operation and natural attenuation to address residual COC mass in the system using a range of reasonable hydraulic conductivities.*	Not applicable.

Notes:
URS = Upper Retention Sump
COC = Constituent of concern (i.e., fluoride)
GWPS = Groundwater Protection Standard

(a) Including safety impacts, cross-media impacts, and control of exposure to any residual contamination.
(b) Such as state or local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).

FIGURES





Area of Detail

Legend

Four Corners Power Plant Lease Boundary

0 0.4 0.8 Miles

N

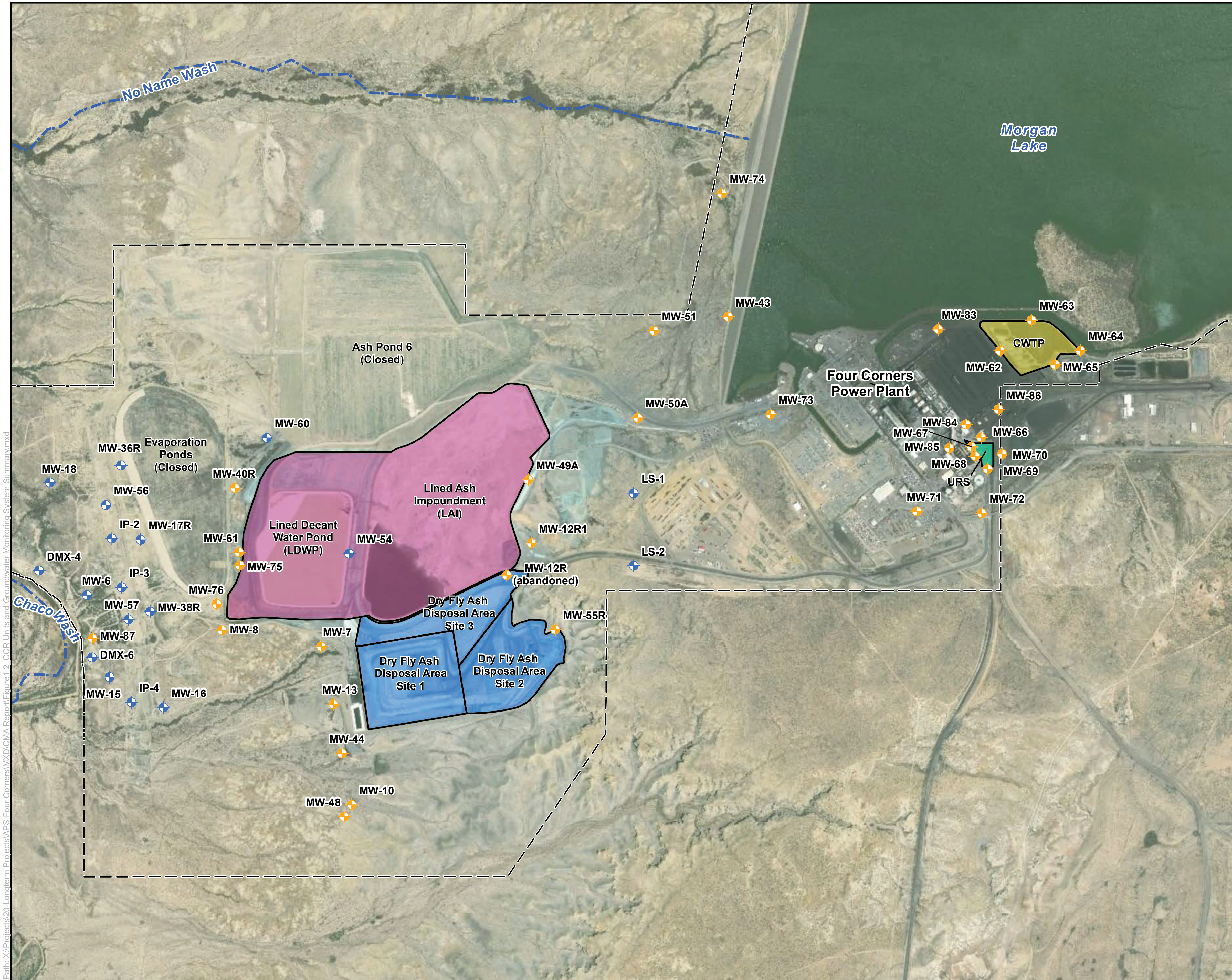
Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

FIGURE **1-1**

Site Location Map

Job No.	14-2018-2068
PM:	NC
Date:	6/12/2019
Scale:	1"= 0.8 miles

Path: X:\Projects\20 Longterm Projects\APS Four Corners\MXD\CMA Report\Figure1-1 Site Location Map.mxd



Legend

- CCR Monitoring Well Location
- Supplementary Site Monitoring Well Location
- Four Corners Power Plant Lease Boundary
- Ephemeral Surface Water Feature

CCR Units

- Multiunit 1(LAI and LDWP)
- Dry Fly Ash Disposal Area (DFADA)
- Combined Waste Treatment Pond (CWTP)
- Upper Retention Sump (URS)

Notes:

CCR	Coal Combustion Residuals
CWTP	Combined Waste Treatment Pond
URS	Upper Retention Sump

0 350 700 1,400 Feet

N

Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

FIGURE 1-2

CCR Units and Monitoring System Summary

Job No.	14-2018-2068
PM:	NC
Date:	6/12/2019
Scale:	1" = 1400'

Legend

- Ephemeral Surface Water Feature
- North Intercept Trench
- South Intercept Trench
- Four Corners Power Plant Lease Boundary
- CCR Unit Boundary

Notes:

MW-49A Well identification

0 165 330 660 Feet

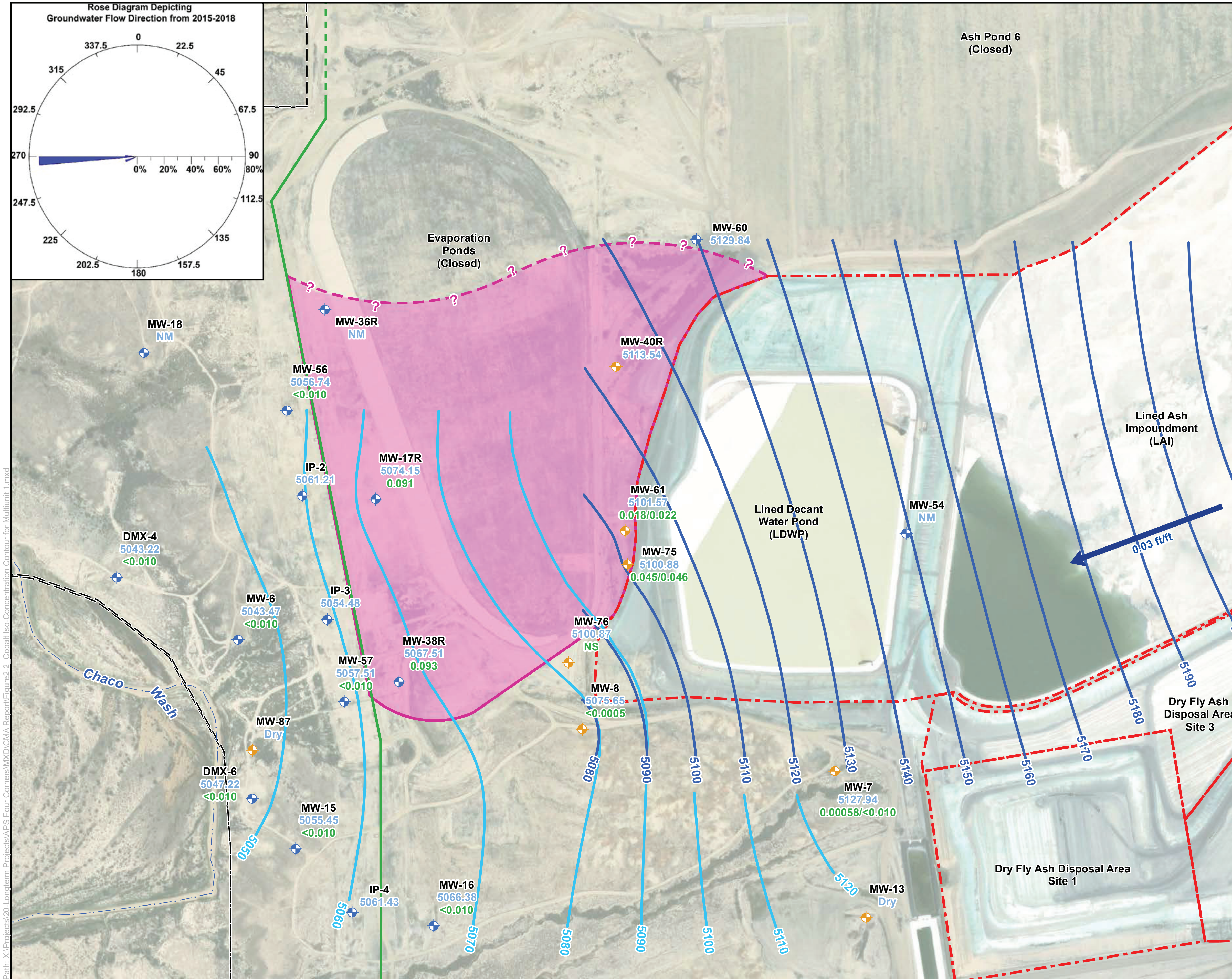
N

Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

FIGURE 2-1

Existing Infrastructure at Multiunit 1

Job No.	14-2018-2068
PM:	NC
Date:	6/12/2019
Scale:	1" = 660'



Legend

- CCR Monitoring Well Location
- Supplementary Site Monitoring Well Location
- Four Corners Power Plant Lease Boundary
- Ephemeral Surface Water Feature
- North Intercept Trench
- South Intercept Trench
- CCR Unit Boundary

Potentiometric Surface - November 2018

- (Dashed Where Inferred)
- Groundwater Flow Direction with Gradient (ft/ft)

Potentiometric Surface - December 2018

- (Dashed Where Inferred)

Cobalt Concentration (November/December 2018)

- >0.01 mg/L
- GWPS (0.01 mg/L; Dashed Where Inferred)

Notes:

MW-49A	Well identification
5240.67	Groundwater Elevation (ft amsl) measured in November/December 2018
0.014	Cobalt concentration (mg/L)
ft amsl	Feet above mean sea level
GWPS	Groundwater Protection Standard
mg/L	milligram per liter
NM	Not measured
NS	Not enough water to sample

0 275 550 1,100 Feet

N

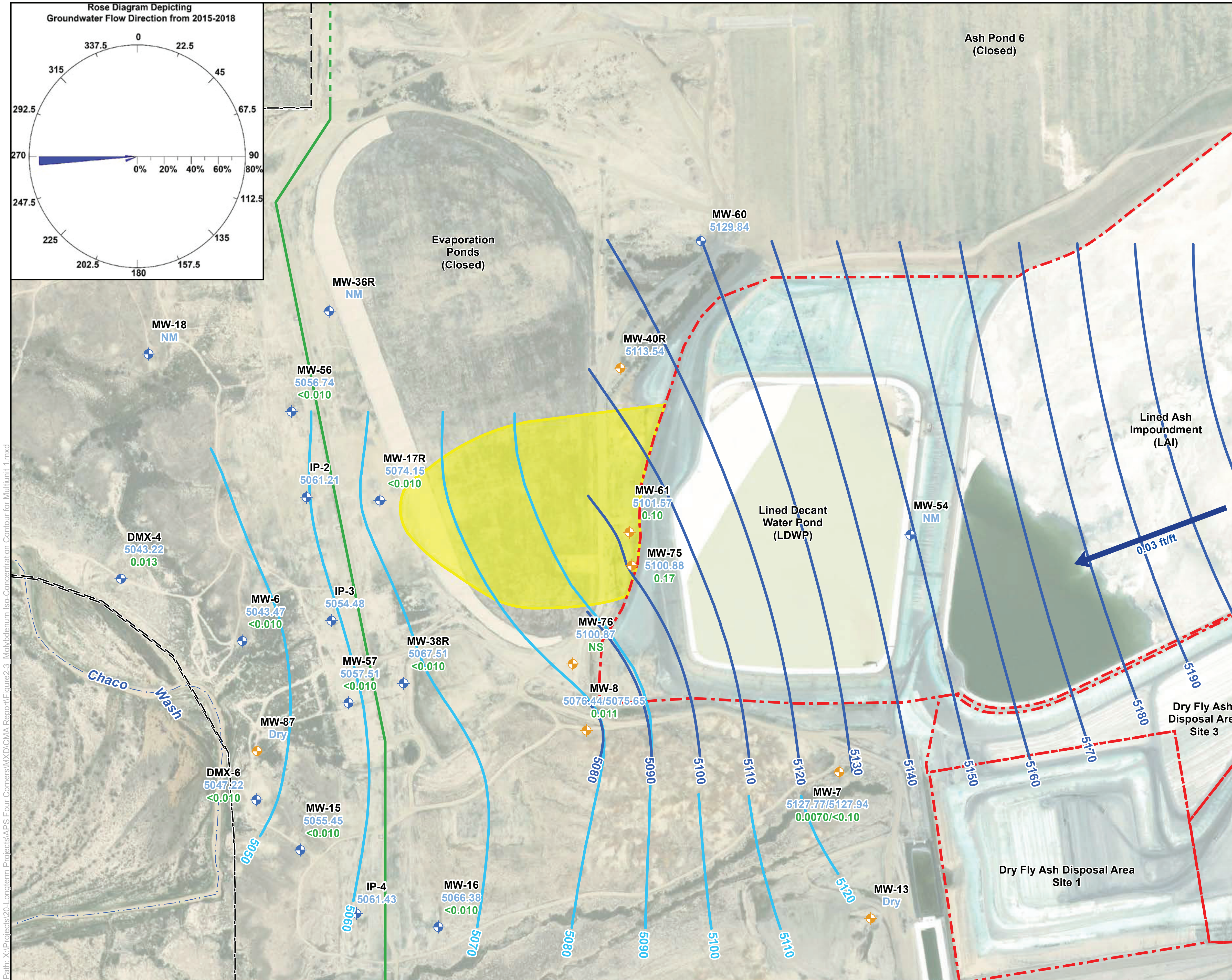
Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

FIGURE 2-2

Cobalt Iso-Concentration Map for Multiunit 1

Job No. 14-2018-2068
PM: NC
Date: 6/13/2019
Scale: 1" = 550'

wood.



Legend

- CCR Monitoring Well Location
- Supplementary Site Monitoring Well Location
- Four Corners Power Plant Lease Boundary
- Ephemeral Surface Water Feature
- North Intercept Trench
- South Intercept Trench
- CCR Unit Boundary

Potentiometric Surface - November 2018

- (Dashed Where Inferred)
- Groundwater Flow Direction with Gradient (ft/ft)

Potentiometric Surface - December 2018

- (Dashed Where Inferred)

Molybdenum Concentration (November/December 2018)

- >0.1 mg/L
- GWPS (0.1 mg/L; Dashed Where Inferred)

Notes:

MW-49A	Well identification
5240.67	Groundwater Elevation (ft amsl) measured in November/December 2018
0.014	Molybdenum concentration (mg/L)
ft amsl	Feet above mean sea level
GWPS	Groundwater Protection Standard
mg/L	milligram per liter
NM	Not measured
NS	Not enough water to sample

0 165 330 660 Feet

N

Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

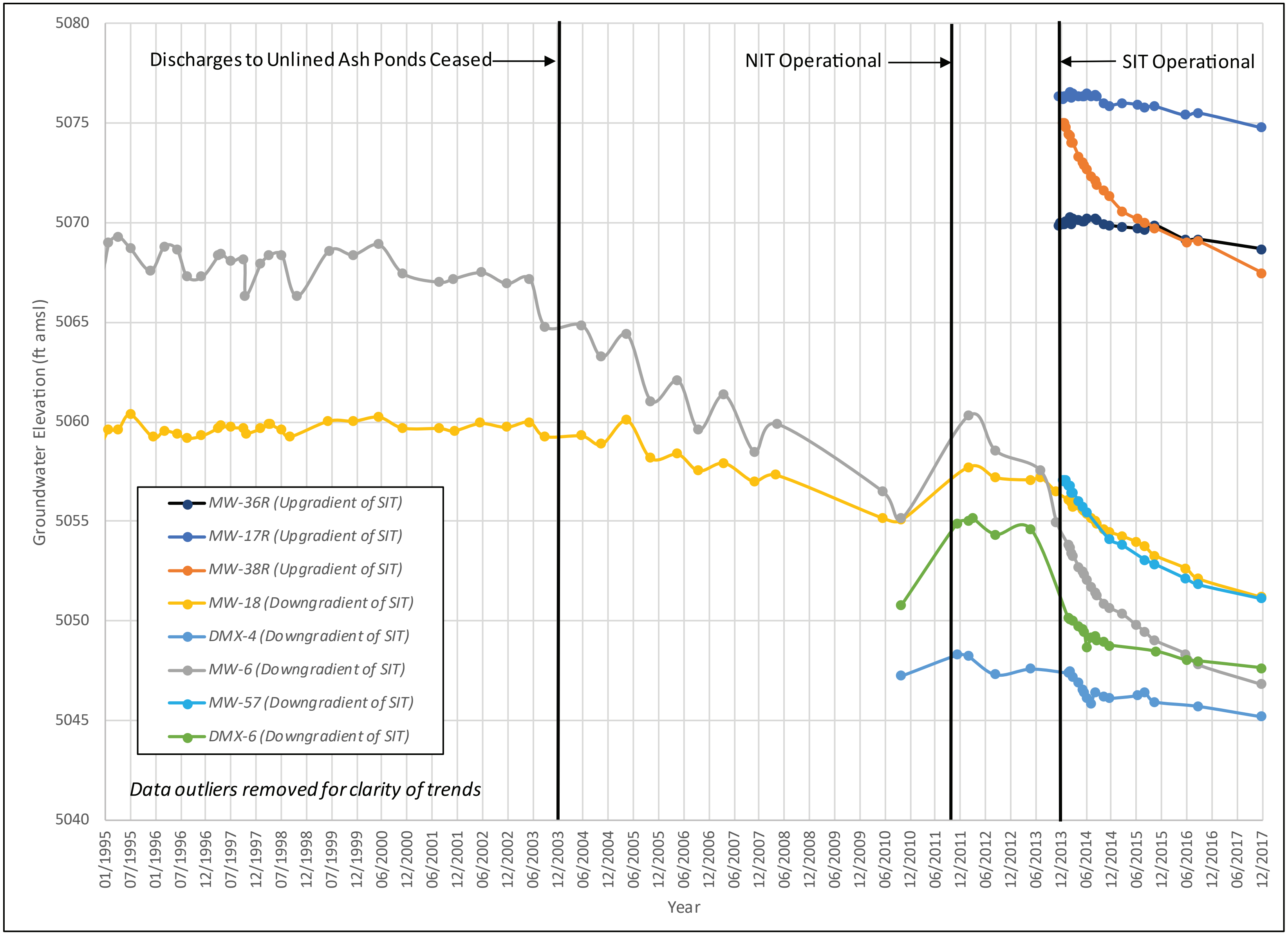
FIGURE 2-3

Molybdenum Iso-Concentration Map for Multiunit 1

Job No. 14-2018-2068
PM: NC
Date: 6/13/2019
Scale: 1" = 660'

wood.

Path: X:\Projects\20-Longterm Projects\APS Four Corners\MXD\CMA Report\Figure2-3_Molybdenum Iso-Concentration Contour for Multiunit 1.mxd



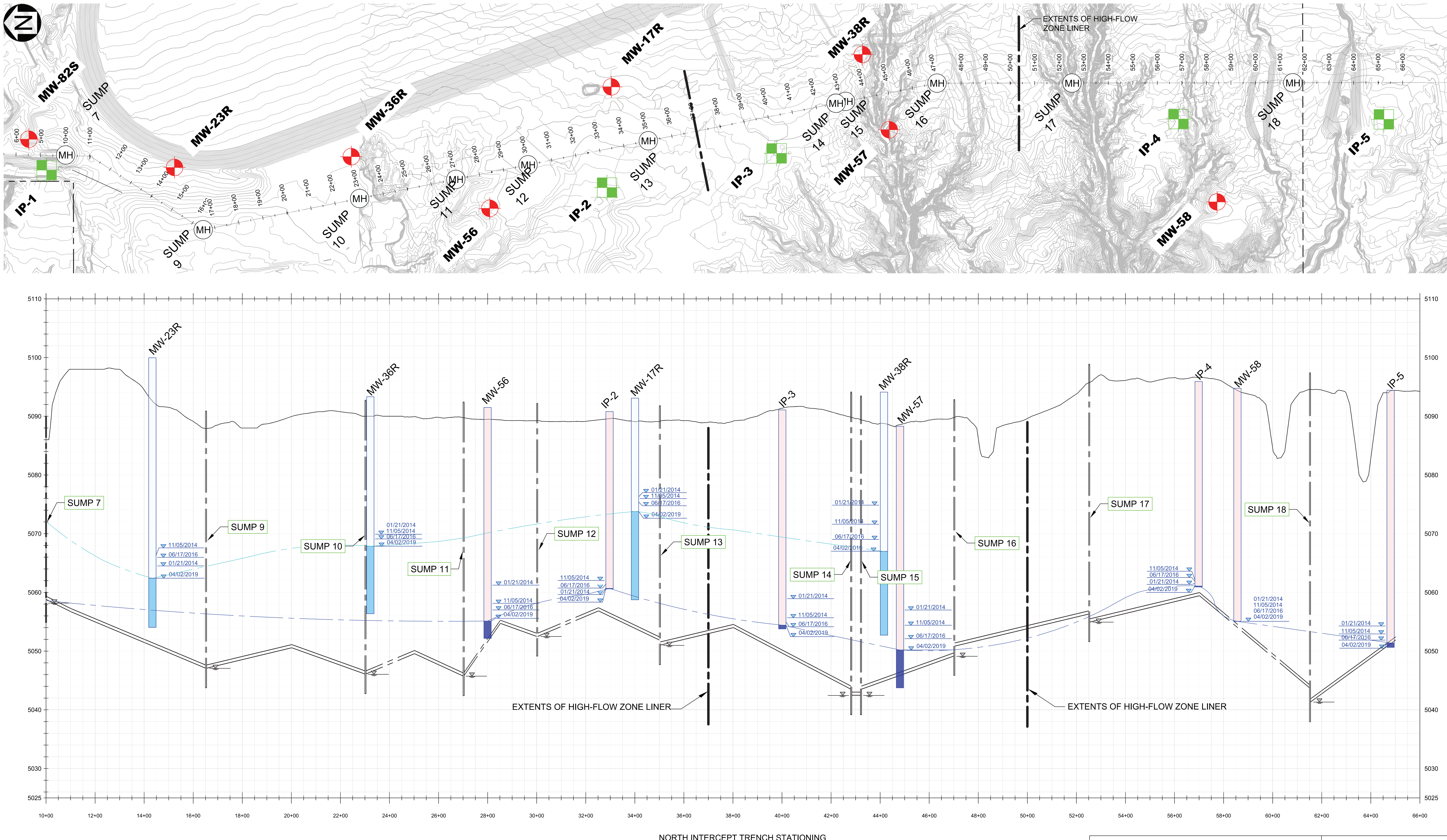
Job No.: 14-2018-2068
PM: NC
Date: 6/9/2019
Scale: As Shown

Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

Water Level Declines Following Corrective Measures Implementation

FIGURE
2-4

wood.



LEGEND

APPROXIMATE APRIL 2019 UP-GRADIENT GROUNDWATER LEVEL

APPROXIMATE APRIL 2019 DOWN-GRADIENT GROUNDWATER LEVEL

04/02/2019 — OBSERVED GROUNDWATER LEVEL AT LISTED DATE
EARLIER DATE INDICATES PREVIOUS REPORTED READING
LATER DATE INDICATES MOST RECENT MEASURED READING

DESIGN PUMPING LEVEL

UP-GRADIENT — DOWN-GRADIENT — OBSERVED WATER LEVEL

Source: Updated from APS Drawing FC-C-47-ADS-173709 prepared by AECOM

0 — 350 — 700
HORIZONTAL SCALE IN FEET

Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

South Intercept Trench Cross-Section Map

wood.

FIGURE 2-5

By: IR | Date: 04/19/2019 | Project No: 1420182068

Legend

- CCR Monitoring Well Location
- Four Corners Power Plant Lease Boundary
- CCR Unit Boundary

Notes:

MW-64	Well identification
CWTP	Combined Waste Treatment Pond
URS	Upper Retention Sump
URT	Upper Retention Tank

0 150 300 600 Feet

N

Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

FIGURE 2-6

Existing Infrastructure at the Former URS

Job No. 14-2018-2068
PM: NC
Date: 6/12/2019
Scale: 1" = 300'

wood.

The map shown here has been created with all due and reasonable care and is strictly for use with Wood Environment & Infrastructure Solutions, Inc. Project Number 14-2018-2068. This map has not been certified by a licensed land surveyor, and any third party use of this map comes without warranties of any kind. Wood Environment & Infrastructure Solutions, Inc. assumes no liability, direct or indirect, whatsoever for any such third party or unintended use.

Path: X:\Projects\20-Longterm Projects\APS Four Corners\MXD\CMA Report\Figure2-6_Existing Infrastructure at the Former URS.mxd

Legend

- CCR Monitoring Well Location
- CCR Unit Boundary
- Four Corners Power Plant Lease Boundary
- Groundwater Flow Direction with Gradient (ft/ft)

Potentiometric Surface - November 2018

- (Dashed Where Inferred)

Fluoride Concentration (November/December 2018)

- >4 mg/L
- GWPS (4 mg/L; Dashed Where Inferred)

Notes:

MW-64	Well identification
533.50	Groundwater Elevation (ft amsl) measured in November 2018
1.4	Fluoride concentration (mg/L) sampled in November/December 2018
CWTP	Combined Waste Treatment Pond
ft amsl	Feet above mean sea level
GWPS	Groundwater Protection Standard
mg/L	milligram per liter
NM	Not measured
URS	Upper Retention Sump
URT	Upper Retention Tank

0 150 300 600 Feet

N

Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

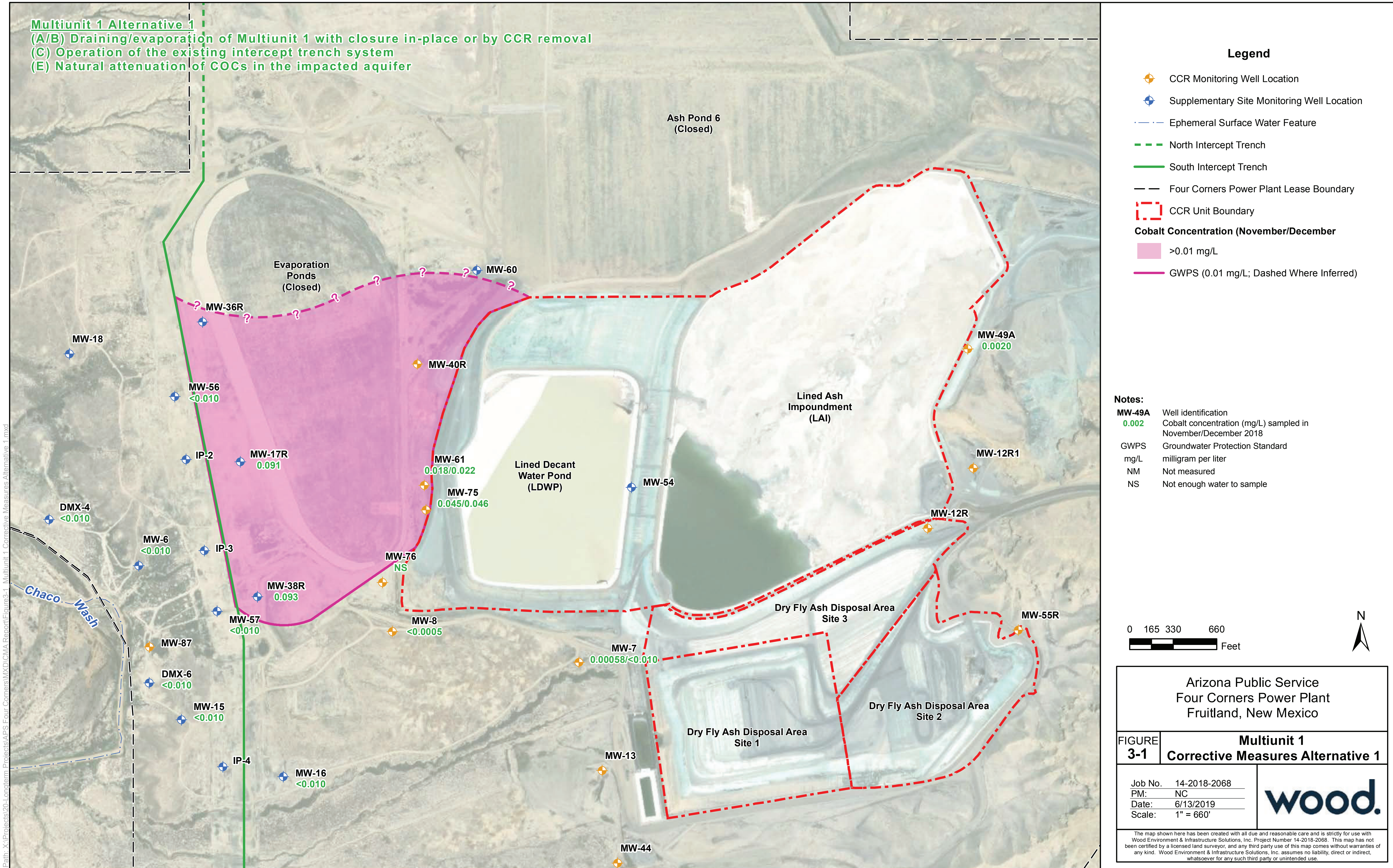
FIGURE **2-7**

Fluoride Iso-Concentration Map for the Former URS

Job No. 14-2018-2068
PM: NC
Date: 6/12/2019
Scale: 1" = 300'

wood.

Path: X:\Projects\20-Longterm Projects\APS Four Corners\MXD\CMA Report\Figure2-7_Fluoride Iso-Concentration Contour for URS.mxd


Multiunit 1 Alternative 1
(A/B) Draining/evaporation of Multiunit 1 with closure in-place or by CCR removal
(C) Operation of the existing intercept trench system
(E) Natural attenuation of COCs in the impacted aquifer
Ash Pond 6
(Closed)
Evaporation
Ponds
(Closed)
MW-60
MW-36R
MW-18
MW-40R
MW-56
<0.010
IP-2
MW-17R
0.091
MW-61
0.018/0.022
MW-75
0.045/0.046
Lined Decant
Water Pond
(LDWP)
MW-54
Lined Ash
Impoundment
(LAI)
MW-49A
0.0020
MW-12R1
MW-12R
DMX-4
<0.010
MW-6
<0.010
IP-3
MW-76
NS
MW-38R
0.093
Chaco Wash
MW-57
<0.010
MW-8
<0.0005
MW-87
MW-7
0.00058/<0.010
Dry Fly Ash Disposal Area
Site 3
MW-55R
DMX-6
<0.010
MW-15
<0.010
Dry Fly Ash Disposal Area
Site 2
Dry Fly Ash Disposal Area
Site 1
IP-4
MW-16
<0.010
MW-13
MW-44
Legend
CCR Monitoring Well Location
Supplementary Site Monitoring Well Location
Ephemeral Surface Water Feature
North Intercept Trench
South Intercept Trench
Four Corners Power Plant Lease Boundary
CCR Unit Boundary
Cobalt Concentration (November/December
>0.01 mg/L
GWPS (0.01 mg/L; Dashed Where Inferred)
Notes:
MW-49A Well identification
0.002 Cobalt concentration (mg/L) sampled in November/December 2018
GWPS Groundwater Protection Standard
mg/L milligram per liter
NM Not measured
NS Not enough water to sample
0 165 330 660
Feet
N
Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico
FIGURE
3-1
Multiunit 1
Corrective Measures Alternative 1
Job No. 14-2018-2068
PM: NC
Date: 6/13/2019
Scale: 1" = 660'
wood.
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Legend

- CCR Monitoring Well Location
- Four Corners Power Plant Lease Boundary
- CCR Unit Boundary

Fluoride Concentration (November/December 2018)

- >4 mg/L
- GWPS (4 mg/L; Dashed Where Inferred)

Notes:

MW-64	Well identification
1.4	Fluoride concentration (mg/L) sampled in November/December 2018
CWTP	Combined Waste Treatment Pond
ft amsl	Feet above mean sea level
GWPS	Groundwater Protection Standard
mg/L	milligram per liter
NM	Not measured
URS	Upper Retention Sump
URT	Upper Retention Tank

0 150 300 600 Feet

N

Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

FIGURE 3-2

URS Corrective Measures Alternative 1

Job No.	14-2018-2068
PM:	NC
Date:	6/12/2019
Scale:	1" = 300'

Path: X:\Projects\20-Longterm Projects\APS Four Corners\MXD\CMA Report\Figure3-2_URS Corrective Measures Alternative 1.mxd

Legend

- CCR Monitoring Well Location
- New Containment Wells
- Four Corners Power Plant Lease Boundary
- CCR Unit Boundary

Fluoride Concentration (November/December 2018)

- >4 mg/L
- GWPS (4 mg/L; Dashed Where Inferred)

Notes:

MW-64	Well identification
1.4	Fluoride concentration (mg/L) sampled in November/December 2018
CWTP	Combined Waste Treatment Pond
ft amsl	Feet above mean sea level
GWPS	Groundwater Protection Standard
mg/L	milligram per liter
NM	Not measured
URS	Upper Retention Sump
URT	Upper Retention Tank

0 150 300 600 Feet

N

Arizona Public Service
Four Corners Power Plant
Fruitland, New Mexico

FIGURE **3-3**

URS Corrective Measures Alternative 2

Job No.	14-2018-2068
PM:	NC
Date:	6/12/2019
Scale:	1" = 300'

Path: X:\Projects\20-Longterm Projects\APS Four Corners\MXD\CMA Report\Figure3-3_URS Corrective Measures Alternative 2.mxd

APPENDIX A

RESULTS OF A CONSTANT RATE AQUIFER TEST NEAR THE FORMER URS

Technical Memorandum

To:	Michele Robertson, RG Pamela Norris	**File No:**	14-2018-2068
From:	Emily LoDolce, PE	**Reviewed by:**	Natalie Chrisman Lazarr, PE
Date:	June 14, 2019		
Subject:	**RESULTS OF A CONSTANT RATE AQUIFER TEST NEAR THE FORMER URS** **Arizona Public Service Four Corners Power Plant – Fruitland, New Mexico**		

1.0 INTRODUCTION

This technical memorandum (memo) documents aquifer testing activities conducted at monitoring well MW-66 near the former Upper Retention Sump (URS), an existing coal combustion residuals (CCR) unit located at the Arizona Public Service Company (APS) Four Corners Power Plant (Site) in Fruitland, New Mexico. The memo is an appendix to a report documenting an *Assessment of Corrective Measures for Multiunit 1 and the URS* (the Main Report) prepared by Wood Environment & Infrastructure Solutions, Inc. (Wood).

The objective of the aquifer test at MW-66 was to evaluate the feasibility of potential corrective measures based on containment of groundwater impacted with fluoride downgradient of the URS. MW-66 was chosen for the test because samples collected from this well in November 2018 and March 2019 had the highest observed concentrations of fluoride (25 milligrams per liter [mg/L] and 23 mg/L, respectively) out of the wells sampled, and as such, MW-66 would likely be part of or located near a future groundwater extraction system used to contain impacted groundwater, if such a system is part of the selected remedy for the CCR unit. The aquifer test was designed to yield the following information:

- The maximum sustainable pumping rate at the well; and
- Local aquifer properties (transmissivity [T] and storativity [S]).

MW-66 is screened in the Pictured Cliffs Sandstone from 15 to 25 feet (ft) below ground surface (bgs) and is completed in a vault at grade with a fixed measurement point (the top of casing) elevation of 5,344.69 ft above mean sea level (amsl).

2.0 FIELD ACTIVITIES

The MW-66 step and constant rate tests were performed by Wood. Two Wood geologists experienced with the Site and aquifer testing mobilized to the Site on Monday, May 13th, 2019, with a submersible pump (Grundfos Redi-Flo3 Model 15-SQE-290), gasoline-powered generator, 200-ft water level meter, and four submersible pressure transducers (In-Situ LevelTroll 500). The pressure transducers were placed in MW-66 (the pumping well) as well as three observation wells (MW-67, MW-68, and MW-84) and manual water level measurements were taken at MW-66. The pressure transducers were programmed to record one observation every minute. Groundwater extraction flow rates were monitored using a McMaster-Carr totalizer (3/4-inch inlet inner diameter). Groundwater extracted from MW-66 was piped to a 7,500-gallon

4600 East Washington Street, Suite 600
Phoenix, Arizona 85034-1917
Tel: (602) 733-6000
Fax: (602) 733-6100
www.woodplc.com

water truck operated by FHI Plant Services, Inc. At the end of the aquifer testing, the groundwater produced from MW-66 was discharged into the Lined Ash Impoundment, a CCR unit located approximately one mile west of the former URS.

The four-hour step rate test was conducted on May 13, 2019 starting at 1:54 PM. The static water level (per the manual measurement) was 14.91 ft below measuring point (bmp). The objective of this test was to determine the appropriate pumping rate for the constant rate test. The test was initially planned for a total of three, two-hour steps, but ultimately only two steps were achieved due to the relatively small column of water in the well observed prior to testing (9.62 ft). This limited the available drawdown to approximately 7 ft from the static water level prior to testing (drawdowns above this level began to impact pump operation). Step 1 was conducted at 1.5 gpm and the final drawdown was 3.09 ft from the static water level, per the transducer. Step 2 was conducted at 2.3 gpm and the final drawdown was 7.24 ft from the static water level, per manual measurement. The step rate test ended at 6:19 PM after completing Step 2. A third step was not attempted as a higher pumping rate was found to be not tenable based on the amount of drawdown produced. At the end of the step rate test, Wood manually lowered the transducer in MW-66 to ensure it would stay below the water surface during the constant rate test.

MW-66 was allowed to recover for approximately 12 hours and then the 12-hour constant rate test was conducted on May 14, 2019 starting at 6:00 AM. The static water level (per the manual measurement) was 14.95 ft bmp, which represents a 99.7% recovery of the aquifer prior to beginning the constant rate test. The objective of the constant rate test was to collect drawdown data from MW-66 and the observation wells to allow for estimation of T and S. The average pumping rate during the 12-hour constant rate test was 1.5 gpm and the final drawdown was 3.11 ft from the static water level measured prior to testing. Two equipment issues occurred during the constant rate test that potentially impacted the final three hours of the test. First, at 11:30 AM (minute 331 of the test), Wood personnel noted that the totalizer had malfunctioned, possibly due to clogging from sediment extracted up from the bottom of MW-66. Second, at 2:34 PM (minute 515 of the test), the generator used to power the submersible pump in MW-66 shut down unexpectedly. Although field personnel successfully powered up the generator, they were unable to dial in the same pumping rate without the aid of the totalizer. The constant rate test ended at 6:00 PM on May 14, 2019. The transducers remained in the wells overnight. On May 15, 2019, Wood personnel returned to remove the transducers and demobilize from the Site.

3.0 AQUIFER TEST ANALYSIS

Data collected from the step and constant rate tests are provided in **Tables 1** and **2**, respectively. The results of the tests are shown graphically on **Figure 1** (step rate) and **Figure 2** (constant rate).

The four-hour step rate test demonstrated that pumping rates over approximately 1.8 gpm at MW-66 produced an unsustainable amount of drawdown. The specific capacities calculated at the end of each step are estimates of the productivity of MW-66. As expected, the higher pumping rate produces increased drawdown and subsequent lower specific capacity.

The constant rate test was conducted at a pumping rate of 1.5 gpm. For the first 8.6 hours of the test, the pumping rate was constant, as evidenced in **Figure 2** by the smooth drawdown curve. As discussed in **Section 2.0**, after the generator failed and was restarted, Wood personnel were not able to dial in the pump at 1.5 gpm, and so the drawdown after this point in the test is inconsistent with the first part of the test. The only impact to this analysis is the selection of log cycle to determine change in head; generally, the last log cycle in a constant rate test would be used for the calculation. In this case, two log cycles were chosen to provide a range of values to address the potentially increased uncertainty due to a shortened time frame. Results are not anticipated to be substantially affected because the rate of drawdown in the well appeared to have stabilized by the time the generator shut down.

Transmissivity was calculated using the Cooper-Jacob straight line approximation (Cooper and Jacob, 1946). The equation is:

$$Transmissivity\ T = \frac{264Q}{\Delta s};\ \text{where}$$

T = transmissivity in gallons per day per foot (gpd/ft)
Q = pumping rate (gpm)
Δs = drawdown over 1 log cycle (ft)

Two log cycles were selected: from minute 20 to minute 200 and from minute 40 to minute 400. The calculations are shown on **Figure 2**. Using the contact surface between the Pictured Cliffs Sandstone and the underlying Weathered Lewis Shale (URS, 2015) and the static water level in the well to approximate saturated thickness of the aquifer, hydraulic conductivity was calculated as:

$$Hydraulic\ conductivity\ K = \frac{T}{b};\ \text{where}$$

K = hydraulic conductivity in ft per day (ft/day)
T = transmissivity in square feet per day (ft^2/day)
b = saturated thickness of the aquifer, in ft

The boring log for MW-66 indicates that the Pictured Cliffs Sandstone contacts the Weathered Lewis Shale at 29 ft bmp. The static water level measured in MW-66 prior to testing was 14.91 ft bmp. The resulting saturated thickness of the aquifer is equal to 14.09 ft.

Data from observation wells MW-67, MW-68, and MW-84 were analyzed in the same way as the analysis performed for MW-66. The pumping at MW-66 was not found to have discernably impacted the water levels at these three observation wells. Thus, an analysis of storativity (which relies upon a pumping well and observation well pair) was not performed.

4.0 DISCUSSION

The constant rate test at MW-66 suggests that an extraction rate of no greater than 1.5 gpm per well is sustainable for potential corrective measures involving extraction wells. The results of the Cooper-Jacob straight line analysis suggest that hydraulic conductivity of the aquifer in the vicinity of MW-66 is 4.17 to 5.29 ft/day.

5.0 REFERENCES

Cooper, H.H. and C.E. Jacob, 1946. *A generalized graphical method for evaluating formation constants and summarizing well field history,* Am. Geophys. Union Trans., vol. 27, pp. 526-534.

URS, 2015. *FCCP* (sic) *Monitoring Well Install, Borehole MW-66.* Rotosonic drilling method. Completed on September 27, 2015.

TABLES

Table 1. Step Rate Test Data (MW-66)

Well: MW-66 **Step Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/13/2019 13:40	0		14.89						
5/13/2019 13:41	60		14.89						
5/13/2019 13:42	120		14.89						
5/13/2019 13:43	180		14.89						
5/13/2019 13:44	240		14.89						
5/13/2019 13:45	300		14.88						
5/13/2019 13:46	360		14.88						
5/13/2019 13:47	420		14.88						
5/13/2019 13:48	480		14.88						
5/13/2019 13:49	540		14.88						
5/13/2019 13:50	600		14.89						
5/13/2019 13:51	660		14.88						
5/13/2019 13:52	720		14.88						
5/13/2019 13:53	780		14.88						
5/13/2019 13:54	840	0	14.88	0.00	14.91	0	0.5	1	**Static Water Level for Step Test**
5/13/2019 13:55	900	1	15.29	0.41	15.19	0.28	0.5		**Begin Step 1**
5/13/2019 13:56	960	2	15.24	0.36	15.25	0.34	0.5		
5/13/2019 13:57	1020	3	15.29	0.41	15.29	0.38	0.5		
5/13/2019 13:58	1080	4	15.33	0.45	15.35	0.44	0.5		
5/13/2019 13:59	1140	5	15.44	0.56	15.49	0.58	0.75		
5/13/2019 14:00	1200	6	15.35	0.47	15.79	0.88	2		
5/13/2019 14:01	1260	7	15.95	1.07	16.13	1.22	2		
5/13/2019 14:02	1320	8	16.27	1.39	16.4	1.49	2		
5/13/2019 14:03	1380	9	16.48	1.60	16.53	1.62	2		
5/13/2019 14:04	1440	10	16.61	1.73	16.62	1.71	1.9	23	
5/13/2019 14:05	1500	11	16.72	1.84					
5/13/2019 14:06	1560	12	16.80	1.92					
5/13/2019 14:07	1620	13	16.89	2.01					
5/13/2019 14:08	1680	14	16.96	2.08					
5/13/2019 14:09	1740	15	17.02	2.14	16.94	2.03	1.8		
5/13/2019 14:10	1800	16	17.07	2.19					
5/13/2019 14:11	1860	17	17.12	2.24					
5/13/2019 14:12	1920	18	17.16	2.28					
5/13/2019 14:13	1980	19	17.20	2.32					
5/13/2019 14:14	2040	20	17.24	2.36	17.15	2.24	1.8		
5/13/2019 14:15	2100	21	17.28	2.40					
5/13/2019 14:16	2160	22	17.30	2.42					
5/13/2019 14:17	2220	23	17.33	2.45					
5/13/2019 14:18	2280	24	17.34	2.46					
5/13/2019 14:19	2340	25	17.38	2.50	17.36	2.45	1.8		
5/13/2019 14:20	2400	26	17.40	2.52					
5/13/2019 14:21	2460	27	17.42	2.54					
5/13/2019 14:22	2520	28	17.44	2.56					

5/13/2019 14:23	2580	29	17.45	2.57				
5/13/2019 14:24	2640	30	17.48	2.60	17.48	2.57	1.9	60
5/13/2019 14:25	2700	31	17.49	2.61				
5/13/2019 14:26	2760	32	17.50	2.62				
5/13/2019 14:27	2820	33	17.52	2.64				
5/13/2019 14:28	2880	34	17.54	2.66				
5/13/2019 14:29	2940	35	17.54	2.66				
5/13/2019 14:30	3000	36	17.55	2.67				
5/13/2019 14:31	3060	37	17.56	2.68				
5/13/2019 14:32	3120	38	17.58	2.70				
5/13/2019 14:33	3180	39	17.60	2.72				
5/13/2019 14:34	3240	40	17.61	2.73	17.6	2.69	1.5	75
5/13/2019 14:35	3300	41	17.63	2.75				
5/13/2019 14:36	3360	42	17.63	2.75				
5/13/2019 14:37	3420	43	17.65	2.77				
5/13/2019 14:38	3480	44	17.66	2.78				
5/13/2019 14:39	3540	45	17.68	2.80				
5/13/2019 14:40	3600	46	17.68	2.80				
5/13/2019 14:41	3660	47	17.69	2.81				
5/13/2019 14:42	3720	48	17.69	2.81				
5/13/2019 14:43	3780	49	17.70	2.82				
5/13/2019 14:44	3840	50	17.70	2.82	17.67	2.76	1.6	91
5/13/2019 14:45	3900	51	17.72	2.84				
5/13/2019 14:46	3960	52	17.71	2.83				
5/13/2019 14:47	4020	53	17.72	2.84				
5/13/2019 14:48	4080	54	17.73	2.85				
5/13/2019 14:49	4140	55	17.74	2.86				
5/13/2019 14:50	4200	56	17.75	2.87				
5/13/2019 14:51	4260	57	17.75	2.87				
5/13/2019 14:52	4320	58	17.76	2.88				
5/13/2019 14:53	4380	59	17.77	2.89				
5/13/2019 14:54	4440	60	17.78	2.90	17.75	2.84	1.8	109
5/13/2019 14:55	4500	61	17.78	2.90				
5/13/2019 14:56	4560	62	17.79	2.91				
5/13/2019 14:57	4620	63	17.80	2.92				
5/13/2019 14:58	4680	64	17.80	2.92				
5/13/2019 14:59	4740	65	17.80	2.92				
5/13/2019 15:00	4800	66	17.82	2.94				
5/13/2019 15:01	4860	67	17.82	2.94				
5/13/2019 15:02	4920	68	17.82	2.94				
5/13/2019 15:03	4980	69	17.83	2.95				
5/13/2019 15:04	5040	70	17.83	2.95	17.81	2.9	1.9	128
5/13/2019 15:05	5100	71	17.85	2.97				
5/13/2019 15:06	5160	72	17.86	2.98				
5/13/2019 15:07	5220	73	17.88	3.00				
5/13/2019 15:08	5280	74	17.88	3.00				
5/13/2019 15:09	5340	75	17.89	3.01				
5/13/2019 15:10	5400	76	17.89	3.01				
5/13/2019 15:11	5460	77	17.88	3.00				

5/13/2019 15:12	5520	78	17.89	3.01					
5/13/2019 15:13	5580	79	17.90	3.02					
5/13/2019 15:14	5640	80	17.90	3.02	17.88	2.97	1.8	146	
5/13/2019 15:15	5700	81	17.91	3.03					
5/13/2019 15:16	5760	82	17.92	3.04					
5/13/2019 15:17	5820	83	17.92	3.04					
5/13/2019 15:18	5880	84	17.93	3.05					
5/13/2019 15:19	5940	85	17.94	3.06					
5/13/2019 15:20	6000	86	17.94	3.06					
5/13/2019 15:21	6060	87	17.94	3.06					
5/13/2019 15:22	6120	88	17.94	3.06					
5/13/2019 15:23	6180	89	17.96	3.08					
5/13/2019 15:24	6240	90	17.96	3.08	17.93	3.02	1.6	162	
5/13/2019 15:25	6300	91	17.96	3.08					
5/13/2019 15:26	6360	92	17.98	3.10					
5/13/2019 15:27	6420	93	17.97	3.09					
5/13/2019 15:28	6480	94	17.98	3.10					
5/13/2019 15:29	6540	95	17.99	3.11					
5/13/2019 15:30	6600	96	17.99	3.11					
5/13/2019 15:31	6660	97	18.00	3.12					
5/13/2019 15:32	6720	98	18.00	3.12					
5/13/2019 15:33	6780	99	18.01	3.13					
5/13/2019 15:34	6840	100	18.01	3.13	17.98	3.07	1.8	180	
5/13/2019 15:35	6900	101	18.01	3.13					
5/13/2019 15:36	6960	102	18.02	3.14					
5/13/2019 15:37	7020	103	18.02	3.14					
5/13/2019 15:38	7080	104	18.03	3.15					
5/13/2019 15:39	7140	105	18.04	3.16					
5/13/2019 15:40	7200	106	18.04	3.16					
5/13/2019 15:41	7260	107	18.06	3.18					
5/13/2019 15:42	7320	108	18.06	3.18					
5/13/2019 15:43	7380	109	18.06	3.18					
5/13/2019 15:44	7440	110	18.07	3.19	18.04	3.13	1.7	197	
5/13/2019 15:45	7500	111	18.08	3.20					
5/13/2019 15:46	7560	112	18.08	3.20					
5/13/2019 15:47	7620	113	18.08	3.20					
5/13/2019 15:48	7680	114	18.10	3.22					
5/13/2019 15:49	7740	115	18.10	3.22					
5/13/2019 15:50	7800	116	18.10	3.22					
5/13/2019 15:51	7860	117	18.10	3.22					
5/13/2019 15:52	7920	118	18.11	3.23					Step 1 Average Pumping
5/13/2019 15:53	7980	119	18.11	3.23					Rate (Qavg) = 1.50 gpm
5/13/2019 15:54	8040	120	18.11	3.23	18.07	3.16	1.9	216	
5/13/2019 15:55	8100	121	18.11	3.23					Step 1 ending
5/13/2019 15:56	8160	122	18.11	3.23					drawdown (s) = 3.09 ft
5/13/2019 15:57	8220	123	18.11	3.23					
5/13/2019 15:58	8280	124	18.10	3.22					Step 1 duration (t) = 125 minutes
5/13/2019 15:59	8340	125	17.97	3.09					**End Step 1**
5/13/2019 16:00	8400	126	18.62	3.74					**Begin Step 2**

5/13/2019 16:01	8460	127	18.76	3.88				
5/13/2019 16:02	8520	128	16.41	1.53				
5/13/2019 16:03	8580	129	16.41	1.53				
5/13/2019 16:04	8640	130	16.44	1.56				
5/13/2019 16:05	8700	131	17.75	2.87	19.25	4.34	3.2	
5/13/2019 16:06	8760	132	18.93	4.05				
5/13/2019 16:07	8820	133	18.93	4.05	21.19	6.28	3.2	
5/13/2019 16:08	8880	134	18.93	4.05	20.25	5.34	3.2	
5/13/2019 16:09	8940	135	18.92	4.04				
5/13/2019 16:10	9000	136	18.93	4.05	20.9	5.99		
5/13/2019 16:11	9060	137	18.93	4.05	21.4	6.49	2.3	250
5/13/2019 16:12	9120	138	18.93	4.05	21.56	6.65	2.4	
5/13/2019 16:13	9180	139	18.93	4.05	22.29	7.38		
5/13/2019 16:14	9240	140	18.93	4.05	21.44	6.53		
5/13/2019 16:15	9300	141	18.93	4.05				
5/13/2019 16:16	9360	142	18.53	3.65				
5/13/2019 16:17	9420	143	18.00	3.12	19.29	4.38		
5/13/2019 16:18	9480	144	17.53	2.65				
5/13/2019 16:19	9540	145	17.89	3.01	19.58	4.67	2.3	
5/13/2019 16:20	9600	146	18.20	3.32	19.91	5.00		
5/13/2019 16:21	9660	147	18.46	3.58	19.98	5.07		
5/13/2019 16:22	9720	148	18.68	3.80	20.24	5.33		
5/13/2019 16:23	9780	149	18.90	4.02	20.29	5.38	2.2	
5/13/2019 16:24	9840	150	18.93	4.05	20.43	5.52		
5/13/2019 16:25	9900	151	18.93	4.05	20.57	5.66	2.1	275
5/13/2019 16:26	9960	152	18.93	4.05				
5/13/2019 16:27	10020	153	18.93	4.05				
5/13/2019 16:28	10080	154	18.93	4.05				
5/13/2019 16:29	10140	155	18.92	4.04				
5/13/2019 16:30	10200	156	18.93	4.05	21.23	6.32	2	285
5/13/2019 16:31	10260	157	18.93	4.05				
5/13/2019 16:32	10320	158	18.92	4.04				
5/13/2019 16:33	10380	159	18.93	4.05				
5/13/2019 16:34	10440	160	18.93	4.05				
5/13/2019 16:35	10500	161	18.93	4.05	21.48	6.57	2	295
5/13/2019 16:36	10560	162	18.92	4.04				
5/13/2019 16:37	10620	163	18.93	4.05				
5/13/2019 16:38	10680	164	18.93	4.05				
5/13/2019 16:39	10740	165	18.93	4.05				
5/13/2019 16:40	10800	166	18.93	4.05	21.92	7.01	2.2	306
5/13/2019 16:41	10860	167	18.93	4.05				
5/13/2019 16:42	10920	168	18.93	4.05				
5/13/2019 16:43	10980	169	18.92	4.04				
5/13/2019 16:44	11040	170	18.93	4.05				
5/13/2019 16:45	11100	171	18.93	4.05	21.75	6.84	2.3	315
5/13/2019 16:46	11160	172	18.93	4.05				
5/13/2019 16:47	11220	173	18.92	4.04				
5/13/2019 16:48	11280	174	18.93	4.05				
5/13/2019 16:49	11340	175	18.93	4.05				

Note: the water level in the well declined below the point where the pressure transducer was installed, as indicated by level depth to water values in red. Manual water level measurements used for Step 2 graph and analysis.

5/13/2019 16:50	11400	176	18.93	4.05				
5/13/2019 16:51	11460	177	18.93	4.05				
5/13/2019 16:52	11520	178	18.93	4.05				
5/13/2019 16:53	11580	179	18.93	4.05				
5/13/2019 16:54	11640	180	18.93	4.05				
5/13/2019 16:55	11700	181	18.93	4.05	21.37	6.46	2.1	336
5/13/2019 16:56	11760	182	18.93	4.05				
5/13/2019 16:57	11820	183	18.93	4.05				
5/13/2019 16:58	11880	184	18.93	4.05				
5/13/2019 16:59	11940	185	18.93	4.05				
5/13/2019 17:00	12000	186	18.93	4.05				
5/13/2019 17:01	12060	187	18.93	4.05				
5/13/2019 17:02	12120	188	18.93	4.05				
5/13/2019 17:03	12180	189	18.93	4.05				
5/13/2019 17:04	12240	190	18.93	4.05				
5/13/2019 17:05	12300	191	18.92	4.04	21.03	6.12	2.2	353
5/13/2019 17:06	12360	192	18.93	4.05				
5/13/2019 17:07	12420	193	18.93	4.05				
5/13/2019 17:08	12480	194	18.93	4.05				
5/13/2019 17:09	12540	195	18.92	4.04				
5/13/2019 17:10	12600	196	18.93	4.05				
5/13/2019 17:11	12660	197	18.93	4.05				
5/13/2019 17:12	12720	198	18.93	4.05				
5/13/2019 17:13	12780	199	18.93	4.05				
5/13/2019 17:14	12840	200	18.93	4.05				
5/13/2019 17:15	12900	201	18.93	4.05	21.43	6.52		370
5/13/2019 17:16	12960	202	18.93	4.05				
5/13/2019 17:17	13020	203	18.92	4.04				
5/13/2019 17:18	13080	204	18.93	4.05				
5/13/2019 17:19	13140	205	18.93	4.05				
5/13/2019 17:20	13200	206	17.80	2.92				
5/13/2019 17:21	13260	207	18.37	3.49				
5/13/2019 17:22	13320	208	18.85	3.97				
5/13/2019 17:23	13380	209	18.93	4.05				
5/13/2019 17:24	13440	210	18.93	4.05				
5/13/2019 17:25	13500	211	18.93	4.05	21.64	6.73	2.1	398
5/13/2019 17:26	13560	212	18.93	4.05				
5/13/2019 17:27	13620	213	18.93	4.05				
5/13/2019 17:28	13680	214	18.93	4.05				
5/13/2019 17:29	13740	215	18.92	4.04				
5/13/2019 17:30	13800	216	18.93	4.05				
5/13/2019 17:31	13860	217	18.93	4.05				
5/13/2019 17:32	13920	218	18.93	4.05				
5/13/2019 17:33	13980	219	18.93	4.05				
5/13/2019 17:34	14040	220	18.93	4.05				
5/13/2019 17:35	14100	221	18.92	4.04	22.06	7.15	1.1	409
5/13/2019 17:36	14160	222	18.93	4.05				
5/13/2019 17:37	14220	223	18.93	4.05				
5/13/2019 17:38	14280	224	18.93	4.05				

5/13/2019 17:39	14340	225	18.93	4.05					
5/13/2019 17:40	14400	226	18.93	4.05					
5/13/2019 17:41	14460	227	18.93	4.05					
5/13/2019 17:42	14520	228	18.93	4.05					
5/13/2019 17:43	14580	229	18.92	4.04					
5/13/2019 17:44	14640	230	18.93	4.05					
5/13/2019 17:45	14700	231	18.93	4.05	21.85	6.94	2.1	430	
5/13/2019 17:46	14760	232	18.93	4.05					
5/13/2019 17:47	14820	233	18.92	4.04					
5/13/2019 17:48	14880	234	18.93	4.05					
5/13/2019 17:49	14940	235	18.93	4.05					
5/13/2019 17:50	15000	236	18.93	4.05					
5/13/2019 17:51	15060	237	18.92	4.04					
5/13/2019 17:52	15120	238	18.92	4.04					
5/13/2019 17:53	15180	239	18.92	4.04					
5/13/2019 17:54	15240	240	18.92	4.04					
5/13/2019 17:55	15300	241	18.93	4.05	21.64	6.73	2.1	448	
5/13/2019 17:56	15360	242	18.93	4.05					
5/13/2019 17:57	15420	243	18.93	4.05					
5/13/2019 17:58	15480	244	18.93	4.05					
5/13/2019 17:59	15540	245	18.93	4.05					
5/13/2019 18:00	15600	246	18.92	4.04					
5/13/2019 18:01	15660	247	18.93	4.05					
5/13/2019 18:02	15720	248	18.93	4.05					
5/13/2019 18:03	15780	249	18.93	4.05					
5/13/2019 18:04	15840	250	18.92	4.04					
5/13/2019 18:05	15900	251	18.93	4.05	22.35	7.44			
5/13/2019 18:06	15960	252	18.93	4.05					
5/13/2019 18:07	16020	253	18.92	4.04					
5/13/2019 18:08	16080	254	18.93	4.05					
5/13/2019 18:09	16140	255	18.93	4.05					
5/13/2019 18:10	16200	256	18.93	4.05					
5/13/2019 18:11	16260	257	18.93	4.05					Step 2 Average Pumping
5/13/2019 18:12	16320	258	18.93	4.05					Rate (Qavg) = 2.3 gpm
5/13/2019 18:13	16380	259	18.92	4.04					
5/13/2019 18:14	16440	260	18.92	4.04					Step 2 ending
5/13/2019 18:15	16500	261	18.92	4.04	22.15	7.24	2.1	480	drawdown (s) = 7.24 ft
5/13/2019 18:16	16560	262	18.93	4.05					
5/13/2019 18:17	16620	263	18.93	4.05					Step 2 duration (t) = 138 minutes
5/13/2019 18:18	16680	264	18.92	4.04			2	486	**End Step 2**
5/13/2019 18:19	16740		16.93						**End Step Test**

Table 2. Constant Rate Test Data (MW-66)

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 5:59	58740	0.0001	13.07	0.00	14.95		0	486	Static water level
5/14/2019 6:00	58800	1	13.52	0.45					**Begin Constant Rate Test**
5/14/2019 6:01	58860	2	13.71	0.64	15.62	0.67	1.1		
5/14/2019 6:02	58920	3	13.83	0.76	15.76	0.81	1.5		Note: level depth to water as
5/14/2019 6:03	58980	4	14.12	1.05	16.2	1.25	1.5		indicated by the pressure transducer
5/14/2019 6:04	59040	5	14.30	1.24	16.22	1.27	1.2	492	is not consistent with the manual
5/14/2019 6:05	59100	6	14.44	1.37	16.39	1.44	1.5		water level. This is due to lowering
5/14/2019 6:06	59160	7	14.54	1.47	16.41	1.46	1.5		the transducer in the well during
5/14/2019 6:07	59220	8	14.61	1.55	16.49	1.54	1.5		Step 2 of the Step Rate Test on
5/14/2019 6:08	59280	9	14.67	1.60	16.54	1.59	1.3	497	May 13, 2019. The initial water level
5/14/2019 6:09	59340	10	14.72	1.65	16.59	1.64	1.5		programmed into the transducer
5/14/2019 6:10	59400	11	14.77	1.70	16.7	1.75	1.5		before the start of the tests was
5/14/2019 6:11	59460	12	14.81	1.74					not updated when the transducer
5/14/2019 6:12	59520	13	14.90	1.83					was lowered. This does not impact
5/14/2019 6:13	59580	14	15.00	1.93					the data quality or the analysis, which
5/14/2019 6:14	59640	15	15.04	1.97					is based on relative drawdown.
5/14/2019 6:15	59700	16	15.08	2.01	16.93	1.98	1.4	507	
5/14/2019 6:16	59760	17	15.11	2.04					
5/14/2019 6:17	59820	18	15.14	2.07					
5/14/2019 6:18	59880	19	15.17	2.10					
5/14/2019 6:19	59940	20	15.21	2.14					20 min to 200 min log cycle 1 for T1
5/14/2019 6:20	60000	21	15.23	2.16	17.13	2.18	1.5		
5/14/2019 6:21	60060	22	15.25	2.18					
5/14/2019 6:22	60120	23	15.27	2.20					
5/14/2019 6:23	60180	24	15.29	2.22					
5/14/2019 6:24	60240	25	15.31	2.24					
5/14/2019 6:25	60300	26	15.33	2.26	17.25	2.3	1.7	524	
5/14/2019 6:26	60360	27	15.35	2.28					
5/14/2019 6:27	60420	28	15.37	2.30					
5/14/2019 6:28	60480	29	15.38	2.31					
5/14/2019 6:29	60540	30	15.39	2.32					
5/14/2019 6:30	60600	31	15.41	2.34	17.26	2.31	1.5		
5/14/2019 6:31	60660	32	15.42	2.36					
5/14/2019 6:32	60720	33	15.45	2.38					
5/14/2019 6:33	60780	34	15.46	2.39					
5/14/2019 6:34	60840	35	15.48	2.41					
5/14/2019 6:35	60900	36	15.50	2.43	17.33	2.38	1.4	538	
5/14/2019 6:36	60960	37	15.51	2.44					
5/14/2019 6:37	61020	38	15.52	2.45					
5/14/2019 6:38	61080	39	15.54	2.47					
5/14/2019 6:39	61140	40	15.54	2.47					40 min to 400 min log cycle 2 for T2
5/14/2019 6:40	61200	41	15.55	2.48	17.4	2.45	1.5		
5/14/2019 6:41	61260	42	15.57	2.50					

Well: MW-66 **Constant Rate Test Data**

Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 6:42	61320	43	15.57	2.51					
5/14/2019 6:43	61380	44	15.57	2.50					
5/14/2019 6:44	61440	45	15.59	2.52					
5/14/2019 6:45	61500	46	15.60	2.53	17.49	2.54	1.7	555	
5/14/2019 6:46	61560	47	15.61	2.54					
5/14/2019 6:47	61620	48	15.62	2.55					
5/14/2019 6:48	61680	49	15.62	2.55					
5/14/2019 6:49	61740	50	15.63	2.56					
5/14/2019 6:50	61800	51	15.63	2.56	17.49	2.54	1.5		
5/14/2019 6:51	61860	52	15.65	2.58					
5/14/2019 6:52	61920	53	15.66	2.59					
5/14/2019 6:53	61980	54	15.66	2.59					
5/14/2019 6:54	62040	55	15.68	2.61					
5/14/2019 6:55	62100	56	15.68	2.61	17.51	2.56	1.5	570	
5/14/2019 6:56	62160	57	15.68	2.61					
5/14/2019 6:57	62220	58	15.70	2.63					
5/14/2019 6:58	62280	59	15.70	2.63					
5/14/2019 6:59	62340	60	15.72	2.65					
5/14/2019 7:00	62400	61	15.72	2.65	17.56	2.61	1.4	577	
5/14/2019 7:01	62460	62	15.73	2.66					
5/14/2019 7:02	62520	63	15.73	2.67					
5/14/2019 7:03	62580	64	15.74	2.67					
5/14/2019 7:04	62640	65	15.75	2.68					
5/14/2019 7:05	62700	66	15.75	2.68					
5/14/2019 7:06	62760	67	15.77	2.70					
5/14/2019 7:07	62820	68	15.77	2.70					
5/14/2019 7:08	62880	69	15.77	2.71					
5/14/2019 7:09	62940	70	15.79	2.72					
5/14/2019 7:10	63000	71	15.78	2.72	17.63	2.68	1.8	595	
5/14/2019 7:11	63060	72	15.80	2.73					
5/14/2019 7:12	63120	73	15.80	2.73					
5/14/2019 7:13	63180	74	15.80	2.73					
5/14/2019 7:14	63240	75	15.80	2.73					
5/14/2019 7:15	63300	76	15.81	2.74					
5/14/2019 7:16	63360	77	15.81	2.74					
5/14/2019 7:17	63420	78	15.82	2.75					
5/14/2019 7:18	63480	79	15.83	2.76					
5/14/2019 7:19	63540	80	15.83	2.76					
5/14/2019 7:20	63600	81	15.83	2.76	17.66	2.71	2.4	619	
5/14/2019 7:21	63660	82	15.83	2.76					
5/14/2019 7:22	63720	83	15.83	2.76					
5/14/2019 7:23	63780	84	15.84	2.77					
5/14/2019 7:24	63840	85	15.84	2.77					

Well: MW-66
Total Depth of Well: 24.5 ft

Constant Rate Test Data

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 7:25	63900	86	15.85	2.78					
5/14/2019 7:26	63960	87	15.85	2.78					
5/14/2019 7:27	64020	88	15.86	2.79					
5/14/2019 7:28	64080	89	15.86	2.79					
5/14/2019 7:29	64140	90	15.86	2.79					
5/14/2019 7:30	64200	91	15.86	2.79	17.7	2.75	0.7	626	
5/14/2019 7:31	64260	92	15.86	2.80					
5/14/2019 7:32	64320	93	15.87	2.80					
5/14/2019 7:33	64380	94	15.87	2.80					
5/14/2019 7:34	64440	95	15.88	2.81					
5/14/2019 7:35	64500	96	15.88	2.81					
5/14/2019 7:36	64560	97	15.88	2.81					
5/14/2019 7:37	64620	98	15.88	2.81					
5/14/2019 7:38	64680	99	15.89	2.82					
5/14/2019 7:39	64740	100	15.89	2.82					
5/14/2019 7:40	64800	101	15.89	2.82	17.73	2.78	1.5	641	
5/14/2019 7:41	64860	102	15.89	2.82					
5/14/2019 7:42	64920	103	15.89	2.82					
5/14/2019 7:43	64980	104	15.90	2.83					
5/14/2019 7:44	65040	105	15.90	2.83					
5/14/2019 7:45	65100	106	15.91	2.84					
5/14/2019 7:46	65160	107	15.92	2.85					
5/14/2019 7:47	65220	108	15.92	2.85					
5/14/2019 7:48	65280	109	15.91	2.84					
5/14/2019 7:49	65340	110	15.92	2.85					
5/14/2019 7:50	65400	111	15.93	2.86	17.75	2.8	1.7	658	
5/14/2019 7:51	65460	112	15.93	2.86					
5/14/2019 7:52	65520	113	15.93	2.86					
5/14/2019 7:53	65580	114	15.93	2.86					
5/14/2019 7:54	65640	115	15.93	2.86					
5/14/2019 7:55	65700	116	15.93	2.86					
5/14/2019 7:56	65760	117	15.94	2.87					
5/14/2019 7:57	65820	118	15.95	2.88					
5/14/2019 7:58	65880	119	15.94	2.88					
5/14/2019 7:59	65940	120	15.95	2.88					
5/14/2019 8:00	66000	121	15.95	2.88	17.79	2.84	1.5	673	
5/14/2019 8:01	66060	122	15.95	2.88					
5/14/2019 8:02	66120	123	15.96	2.89					
5/14/2019 8:03	66180	124	15.95	2.89					
5/14/2019 8:04	66240	125	15.96	2.89					
5/14/2019 8:05	66300	126	15.96	2.89					
5/14/2019 8:06	66360	127	15.97	2.90					
5/14/2019 8:07	66420	128	15.97	2.90					

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 8:08	66480	129	15.97	2.90					
5/14/2019 8:09	66540	130	15.98	2.91					
5/14/2019 8:10	66600	131	15.98	2.91	17.81	2.86	1.7	690	
5/14/2019 8:11	66660	132	15.98	2.91					
5/14/2019 8:12	66720	133	15.97	2.90					
5/14/2019 8:13	66780	134	15.98	2.91					
5/14/2019 8:14	66840	135	15.99	2.92					
5/14/2019 8:15	66900	136	15.99	2.92					
5/14/2019 8:16	66960	137	16.00	2.93					
5/14/2019 8:17	67020	138	16.00	2.93					
5/14/2019 8:18	67080	139	16.00	2.93					
5/14/2019 8:19	67140	140	16.00	2.93					
5/14/2019 8:20	67200	141	16.00	2.94	17.84	2.89	1.6	706	
5/14/2019 8:21	67260	142	16.01	2.94					
5/14/2019 8:22	67320	143	16.01	2.94					
5/14/2019 8:23	67380	144	16.01	2.94					
5/14/2019 8:24	67440	145	16.01	2.94					
5/14/2019 8:25	67500	146	16.02	2.95					
5/14/2019 8:26	67560	147	16.02	2.95					
5/14/2019 8:27	67620	148	16.02	2.95					
5/14/2019 8:28	67680	149	16.03	2.96					
5/14/2019 8:29	67740	150	16.02	2.95					
5/14/2019 8:30	67800	151	16.03	2.96	17.86	2.91	1.4	720	
5/14/2019 8:31	67860	152	16.02	2.95					
5/14/2019 8:32	67920	153	16.03	2.96					
5/14/2019 8:33	67980	154	16.02	2.95					
5/14/2019 8:34	68040	155	16.02	2.95					
5/14/2019 8:35	68100	156	16.03	2.96					
5/14/2019 8:36	68160	157	16.03	2.96					
5/14/2019 8:37	68220	158	16.04	2.97					
5/14/2019 8:38	68280	159	16.04	2.97					
5/14/2019 8:39	68340	160	16.04	2.97					
5/14/2019 8:40	68400	161	16.04	2.97	17.87	2.92	1.7	737	
5/14/2019 8:41	68460	162	16.04	2.97					
5/14/2019 8:42	68520	163	16.04	2.97					
5/14/2019 8:43	68580	164	16.04	2.97					
5/14/2019 8:44	68640	165	16.04	2.97					
5/14/2019 8:45	68700	166	16.05	2.98					
5/14/2019 8:46	68760	167	16.05	2.98					
5/14/2019 8:47	68820	168	16.06	2.99					
5/14/2019 8:48	68880	169	16.05	2.99					
5/14/2019 8:49	68940	170	16.05	2.98					
5/14/2019 8:50	69000	171	16.05	2.98	17.89	2.94	1.5	752	

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 8:51	69060	172	16.05	2.98					
5/14/2019 8:52	69120	173	16.06	2.99					
5/14/2019 8:53	69180	174	16.06	2.99					
5/14/2019 8:54	69240	175	16.06	2.99					
5/14/2019 8:55	69300	176	16.06	3.00					
5/14/2019 8:56	69360	177	16.06	2.99					
5/14/2019 8:57	69420	178	16.07	3.00					
5/14/2019 8:58	69480	179	16.07	3.00					
5/14/2019 8:59	69540	180	16.08	3.01					
5/14/2019 9:00	69600	181	16.08	3.01	17.9	2.95	1.5	767	
5/14/2019 9:01	69660	182	16.08	3.01					
5/14/2019 9:02	69720	183	16.08	3.01					
5/14/2019 9:03	69780	184	16.08	3.01					
5/14/2019 9:04	69840	185	16.08	3.01					
5/14/2019 9:05	69900	186	16.08	3.02					
5/14/2019 9:06	69960	187	16.08	3.01					
5/14/2019 9:07	70020	188	16.08	3.02					
5/14/2019 9:08	70080	189	16.08	3.01					
5/14/2019 9:09	70140	190	16.09	3.02					
5/14/2019 9:10	70200	191	16.09	3.02					
5/14/2019 9:11	70260	192	16.08	3.01					
5/14/2019 9:12	70320	193	16.10	3.03					
5/14/2019 9:13	70380	194	16.10	3.03					
5/14/2019 9:14	70440	195	16.10	3.03					
5/14/2019 9:15	70500	196	16.10	3.03					
5/14/2019 9:16	70560	197	16.10	3.03					
5/14/2019 9:17	70620	198	16.10	3.03					
5/14/2019 9:18	70680	199	16.11	3.04					
5/14/2019 9:19	70740	200	16.11	3.04					log cycle 1 - delta s = 0.90 ft
5/14/2019 9:20	70800	201	16.11	3.04					
5/14/2019 9:21	70860	202	16.10	3.03					
5/14/2019 9:22	70920	203	16.11	3.04					
5/14/2019 9:23	70980	204	16.11	3.04					
5/14/2019 9:24	71040	205	16.12	3.05					
5/14/2019 9:25	71100	206	16.11	3.04					
5/14/2019 9:26	71160	207	16.12	3.05					
5/14/2019 9:27	71220	208	16.11	3.04					
5/14/2019 9:28	71280	209	16.11	3.04					
5/14/2019 9:29	71340	210	16.12	3.05					
5/14/2019 9:30	71400	211	16.11	3.04	17.94	2.99	1.6	816	
5/14/2019 9:31	71460	212	16.12	3.05					
5/14/2019 9:32	71520	213	16.12	3.05					
5/14/2019 9:33	71580	214	16.12	3.05					

Table 2. Constant Rate Test Data (MW-66)

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 9:34	71640	215	16.12	3.06					
5/14/2019 9:35	71700	216	16.12	3.06					
5/14/2019 9:36	71760	217	16.13	3.06					
5/14/2019 9:37	71820	218	16.14	3.07					
5/14/2019 9:38	71880	219	16.14	3.07					
5/14/2019 9:39	71940	220	16.13	3.06					
5/14/2019 9:40	72000	221	16.13	3.06					
5/14/2019 9:41	72060	222	16.13	3.06					
5/14/2019 9:42	72120	223	16.13	3.06					
5/14/2019 9:43	72180	224	16.13	3.06					
5/14/2019 9:44	72240	225	16.13	3.06					
5/14/2019 9:45	72300	226	16.14	3.07					
5/14/2019 9:46	72360	227	16.13	3.06					
5/14/2019 9:47	72420	228	16.14	3.07					
5/14/2019 9:48	72480	229	16.14	3.07					
5/14/2019 9:49	72540	230	16.14	3.07					
5/14/2019 9:50	72600	231	16.14	3.07					
5/14/2019 9:51	72660	232	16.14	3.07					
5/14/2019 9:52	72720	233	16.15	3.08					
5/14/2019 9:53	72780	234	16.14	3.07					
5/14/2019 9:54	72840	235	16.15	3.08					
5/14/2019 9:55	72900	236	16.15	3.08					
5/14/2019 9:56	72960	237	16.15	3.08					
5/14/2019 9:57	73020	238	16.14	3.07					
5/14/2019 9:58	73080	239	16.15	3.08					
5/14/2019 9:59	73140	240	16.14	3.08					
5/14/2019 10:00	73200	241	16.14	3.07	17.97	3.02	1.6	863	
5/14/2019 10:01	73260	242	16.14	3.07					
5/14/2019 10:02	73320	243	16.15	3.08					
5/14/2019 10:03	73380	244	16.15	3.08					
5/14/2019 10:04	73440	245	16.15	3.08					
5/14/2019 10:05	73500	246	16.15	3.08					
5/14/2019 10:06	73560	247	16.15	3.08					
5/14/2019 10:07	73620	248	16.16	3.09					
5/14/2019 10:08	73680	249	16.16	3.09					
5/14/2019 10:09	73740	250	16.15	3.08					
5/14/2019 10:10	73800	251	16.16	3.09					
5/14/2019 10:11	73860	252	16.16	3.09					
5/14/2019 10:12	73920	253	16.15	3.09					
5/14/2019 10:13	73980	254	16.16	3.09					
5/14/2019 10:14	74040	255	16.16	3.09					
5/14/2019 10:15	74100	256	16.15	3.08					
5/14/2019 10:16	74160	257	16.16	3.09					

Table 2. Constant Rate Test Data (MW-66)

Well: MW-66 **Constant Rate Test Data**

Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 10:17	74220	258	16.16	3.09					
5/14/2019 10:18	74280	259	16.15	3.08					
5/14/2019 10:19	74340	260	16.15	3.09					
5/14/2019 10:20	74400	261	16.16	3.09					
5/14/2019 10:21	74460	262	16.16	3.09					
5/14/2019 10:22	74520	263	16.16	3.09					
5/14/2019 10:23	74580	264	16.15	3.08					
5/14/2019 10:24	74640	265	16.15	3.08					
5/14/2019 10:25	74700	266	16.17	3.10					
5/14/2019 10:26	74760	267	16.16	3.09					
5/14/2019 10:27	74820	268	16.17	3.10					
5/14/2019 10:28	74880	269	16.17	3.10					
5/14/2019 10:29	74940	270	16.16	3.10					
5/14/2019 10:30	75000	271	16.16	3.09	18	3.05	1.6	910	
5/14/2019 10:31	75060	272	16.17	3.10					
5/14/2019 10:32	75120	273	16.16	3.09					
5/14/2019 10:33	75180	274	16.17	3.10					
5/14/2019 10:34	75240	275	16.18	3.11					
5/14/2019 10:35	75300	276	16.18	3.11					
5/14/2019 10:36	75360	277	16.19	3.12					
5/14/2019 10:37	75420	278	16.18	3.11					
5/14/2019 10:38	75480	279	16.18	3.11					
5/14/2019 10:39	75540	280	16.17	3.10					
5/14/2019 10:40	75600	281	16.18	3.11					
5/14/2019 10:41	75660	282	16.18	3.11					
5/14/2019 10:42	75720	283	16.19	3.12					
5/14/2019 10:43	75780	284	16.19	3.12					
5/14/2019 10:44	75840	285	16.19	3.12					
5/14/2019 10:45	75900	286	16.19	3.12					
5/14/2019 10:46	75960	287	16.19	3.12					
5/14/2019 10:47	76020	288	16.18	3.12					
5/14/2019 10:48	76080	289	16.19	3.12					
5/14/2019 10:49	76140	290	16.18	3.11					
5/14/2019 10:50	76200	291	16.18	3.11					
5/14/2019 10:51	76260	292	16.17	3.10					
5/14/2019 10:52	76320	293	16.19	3.12					
5/14/2019 10:53	76380	294	16.19	3.12					
5/14/2019 10:54	76440	295	16.19	3.12					
5/14/2019 10:55	76500	296	16.20	3.13					
5/14/2019 10:56	76560	297	16.19	3.13					
5/14/2019 10:57	76620	298	16.20	3.13					
5/14/2019 10:58	76680	299	16.20	3.13					
5/14/2019 10:59	76740	300	16.20	3.13					

Table 2. Constant Rate Test Data (MW-66)

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 11:00	76800	301	16.19	3.12	18.02	3.07	1.5	956	
5/14/2019 11:01	76860	302	16.20	3.13					
5/14/2019 11:02	76920	303	16.20	3.13					
5/14/2019 11:03	76980	304	16.21	3.14					
5/14/2019 11:04	77040	305	16.19	3.12					
5/14/2019 11:05	77100	306	16.20	3.13					
5/14/2019 11:06	77160	307	16.20	3.13					
5/14/2019 11:07	77220	308	16.20	3.13					
5/14/2019 11:08	77280	309	16.20	3.14					
5/14/2019 11:09	77340	310	16.20	3.14					
5/14/2019 11:10	77400	311	16.20	3.13					
5/14/2019 11:11	77460	312	16.20	3.13					
5/14/2019 11:12	77520	313	16.21	3.14					
5/14/2019 11:13	77580	314	16.21	3.14					
5/14/2019 11:14	77640	315	16.21	3.14					
5/14/2019 11:15	77700	316	16.20	3.13					
5/14/2019 11:16	77760	317	16.21	3.14					
5/14/2019 11:17	77820	318	16.20	3.13					
5/14/2019 11:18	77880	319	16.21	3.14					
5/14/2019 11:19	77940	320	16.20	3.14					
5/14/2019 11:20	78000	321	16.20	3.14					
5/14/2019 11:21	78060	322	16.20	3.13					
5/14/2019 11:22	78120	323	16.21	3.14					
5/14/2019 11:23	78180	324	16.21	3.14					
5/14/2019 11:24	78240	325	16.21	3.14					
5/14/2019 11:25	78300	326	16.20	3.14					
5/14/2019 11:26	78360	327	16.21	3.14					
5/14/2019 11:27	78420	328	16.21	3.14					
5/14/2019 11:28	78480	329	16.21	3.14					
5/14/2019 11:29	78540	330	16.22	3.15					
5/14/2019 11:30	78600	331	16.22	3.15	18.04	3.09	1.6	1005	Last totalizer reading -
5/14/2019 11:31	78660	332	16.22	3.15					Totalizer broke at or shortly
5/14/2019 11:32	78720	333	16.22	3.15					before this point
5/14/2019 11:33	78780	334	16.22	3.15					
5/14/2019 11:34	78840	335	16.22	3.15					Average Q = 1.5 gpm
5/14/2019 11:35	78900	336	16.22	3.15					
5/14/2019 11:36	78960	337	16.22	3.15					
5/14/2019 11:37	79020	338	16.21	3.14					
5/14/2019 11:38	79080	339	16.21	3.15					
5/14/2019 11:39	79140	340	16.21	3.15					
5/14/2019 11:40	79200	341	16.22	3.15					
5/14/2019 11:41	79260	342	16.22	3.15					
5/14/2019 11:42	79320	343	16.22	3.15					

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 11:43	79380	344	16.22	3.15					
5/14/2019 11:44	79440	345	16.22	3.15					
5/14/2019 11:45	79500	346	16.21	3.15					
5/14/2019 11:46	79560	347	16.21	3.14					
5/14/2019 11:47	79620	348	16.21	3.14					
5/14/2019 11:48	79680	349	16.22	3.15					
5/14/2019 11:49	79740	350	16.21	3.14					
5/14/2019 11:50	79800	351	16.21	3.14					
5/14/2019 11:51	79860	352	16.22	3.15					
5/14/2019 11:52	79920	353	16.22	3.15					
5/14/2019 11:53	79980	354	16.21	3.14					
5/14/2019 11:54	80040	355	16.21	3.14					
5/14/2019 11:55	80100	356	16.21	3.14					
5/14/2019 11:56	80160	357	16.21	3.14					
5/14/2019 11:57	80220	358	16.22	3.15					
5/14/2019 11:58	80280	359	16.22	3.15					
5/14/2019 11:59	80340	360	16.21	3.14					
5/14/2019 12:00	80400	361	16.18	3.11	18.05	3.1	1.5		The pumping rate from Minute 361 until the end of test is estimated
5/14/2019 12:01	80460	362	16.21	3.14					
5/14/2019 12:02	80520	363	16.23	3.16					
5/14/2019 12:03	80580	364	16.23	3.16					
5/14/2019 12:04	80640	365	16.24	3.17					
5/14/2019 12:05	80700	366	16.25	3.18					
5/14/2019 12:06	80760	367	16.23	3.16					
5/14/2019 12:07	80820	368	16.24	3.17					
5/14/2019 12:08	80880	369	16.24	3.17					
5/14/2019 12:09	80940	370	16.24	3.17					
5/14/2019 12:10	81000	371	16.24	3.17					
5/14/2019 12:11	81060	372	16.25	3.18					
5/14/2019 12:12	81120	373	16.25	3.18					
5/14/2019 12:13	81180	374	16.24	3.17					
5/14/2019 12:14	81240	375	16.25	3.18					
5/14/2019 12:15	81300	376	16.25	3.18					
5/14/2019 12:16	81360	377	16.25	3.18					
5/14/2019 12:17	81420	378	16.25	3.18					
5/14/2019 12:18	81480	379	16.24	3.17					
5/14/2019 12:19	81540	380	16.25	3.18					
5/14/2019 12:20	81600	381	16.25	3.19					
5/14/2019 12:21	81660	382	16.25	3.18					
5/14/2019 12:22	81720	383	16.25	3.18					
5/14/2019 12:23	81780	384	16.25	3.18					
5/14/2019 12:24	81840	385	16.24	3.17					
5/14/2019 12:25	81900	386	16.25	3.18					

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 12:26	81960	387	16.24	3.17					
5/14/2019 12:27	82020	388	16.24	3.17					
5/14/2019 12:28	82080	389	16.24	3.17					
5/14/2019 12:29	82140	390	16.24	3.17					
5/14/2019 12:30	82200	391	16.25	3.18	18.09	3.14	1.5		
5/14/2019 12:31	82260	392	16.24	3.18					
5/14/2019 12:32	82320	393	16.25	3.18					
5/14/2019 12:33	82380	394	16.24	3.17					
5/14/2019 12:34	82440	395	16.25	3.18					
5/14/2019 12:35	82500	396	16.24	3.17					
5/14/2019 12:36	82560	397	16.25	3.18					
5/14/2019 12:37	82620	398	16.25	3.18					
5/14/2019 12:38	82680	399	16.24	3.17					
5/14/2019 12:39	82740	400	16.25	3.18					log cycle 2 - delta s = 0.71 ft
5/14/2019 12:40	82800	401	16.26	3.19					
5/14/2019 12:41	82860	402	16.25	3.18					
5/14/2019 12:42	82920	403	16.26	3.19					
5/14/2019 12:43	82980	404	16.25	3.18					
5/14/2019 12:44	83040	405	16.25	3.18					
5/14/2019 12:45	83100	406	16.25	3.18					
5/14/2019 12:46	83160	407	16.25	3.18					
5/14/2019 12:47	83220	408	16.24	3.17					
5/14/2019 12:48	83280	409	16.25	3.18					
5/14/2019 12:49	83340	410	16.24	3.17					
5/14/2019 12:50	83400	411	16.24	3.18					
5/14/2019 12:51	83460	412	16.25	3.18					
5/14/2019 12:52	83520	413	16.25	3.18					
5/14/2019 12:53	83580	414	16.25	3.18					
5/14/2019 12:54	83640	415	16.25	3.18					
5/14/2019 12:55	83700	416	16.25	3.18					
5/14/2019 12:56	83760	417	16.24	3.17					
5/14/2019 12:57	83820	418	16.25	3.18					
5/14/2019 12:58	83880	419	16.25	3.18					
5/14/2019 12:59	83940	420	16.25	3.18					
5/14/2019 13:00	84000	421	16.25	3.18	18.09	3.14	1.5		
5/14/2019 13:01	84060	422	16.24	3.17					
5/14/2019 13:02	84120	423	16.25	3.18					
5/14/2019 13:03	84180	424	16.25	3.18					
5/14/2019 13:04	84240	425	16.25	3.18					
5/14/2019 13:05	84300	426	16.25	3.18					
5/14/2019 13:06	84360	427	16.25	3.18					
5/14/2019 13:07	84420	428	16.25	3.19					
5/14/2019 13:08	84480	429	16.25	3.19					

Table 2. Constant Rate Test Data (MW-66)

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 13:09	84540	430	16.26	3.19					
5/14/2019 13:10	84600	431	16.26	3.19					
5/14/2019 13:11	84660	432	16.27	3.20					
5/14/2019 13:12	84720	433	16.26	3.19					
5/14/2019 13:13	84780	434	16.25	3.18					
5/14/2019 13:14	84840	435	16.26	3.19					
5/14/2019 13:15	84900	436	16.25	3.18					
5/14/2019 13:16	84960	437	16.25	3.18					
5/14/2019 13:17	85020	438	16.25	3.18					
5/14/2019 13:18	85080	439	16.25	3.18					
5/14/2019 13:19	85140	440	16.25	3.18					
5/14/2019 13:20	85200	441	16.25	3.18					
5/14/2019 13:21	85260	442	16.24	3.17					
5/14/2019 13:22	85320	443	16.24	3.17					
5/14/2019 13:23	85380	444	16.25	3.18					
5/14/2019 13:24	85440	445	16.25	3.18					
5/14/2019 13:25	85500	446	16.25	3.18					
5/14/2019 13:26	85560	447	16.25	3.18					
5/14/2019 13:27	85620	448	16.25	3.18					
5/14/2019 13:28	85680	449	16.25	3.18					
5/14/2019 13:29	85740	450	16.25	3.18					
5/14/2019 13:30	85800	451	16.25	3.18	18.07	3.12	1.5		
5/14/2019 13:31	85860	452	16.24	3.17					
5/14/2019 13:32	85920	453	16.24	3.17					
5/14/2019 13:33	85980	454	16.23	3.16					
5/14/2019 13:34	86040	455	16.23	3.16					
5/14/2019 13:35	86100	456	16.22	3.15					
5/14/2019 13:36	86160	457	16.22	3.15					
5/14/2019 13:37	86220	458	16.23	3.16					
5/14/2019 13:38	86280	459	16.22	3.15					
5/14/2019 13:39	86340	460	16.22	3.15					
5/14/2019 13:40	86400	461	16.22	3.15					
5/14/2019 13:41	86460	462	16.22	3.15					
5/14/2019 13:42	86520	463	16.23	3.16					
5/14/2019 13:43	86580	464	16.22	3.15					
5/14/2019 13:44	86640	465	16.22	3.15					
5/14/2019 13:45	86700	466	16.22	3.15					
5/14/2019 13:46	86760	467	16.22	3.15					
5/14/2019 13:47	86820	468	16.21	3.14					
5/14/2019 13:48	86880	469	16.21	3.15					
5/14/2019 13:49	86940	470	16.23	3.16					
5/14/2019 13:50	87000	471	16.23	3.16					
5/14/2019 13:51	87060	472	16.23	3.16					

Well: MW-66 **Constant Rate Test Data**

Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 13:52	87120	473	16.22	3.15					
5/14/2019 13:53	87180	474	16.23	3.16					
5/14/2019 13:54	87240	475	16.22	3.16					
5/14/2019 13:55	87300	476	16.23	3.17					
5/14/2019 13:56	87360	477	16.23	3.16					
5/14/2019 13:57	87420	478	16.23	3.16					
5/14/2019 13:58	87480	479	16.23	3.16					
5/14/2019 13:59	87540	480	16.22	3.15					
5/14/2019 14:00	87600	481	16.23	3.16	18.07	3.12	1.5		
5/14/2019 14:01	87660	482	16.23	3.17					
5/14/2019 14:02	87720	483	16.23	3.16					
5/14/2019 14:03	87780	484	16.24	3.17					
5/14/2019 14:04	87840	485	16.23	3.17					
5/14/2019 14:05	87900	486	16.23	3.16					
5/14/2019 14:06	87960	487	16.23	3.16					
5/14/2019 14:07	88020	488	16.23	3.16					
5/14/2019 14:08	88080	489	16.22	3.15					
5/14/2019 14:09	88140	490	16.23	3.16					
5/14/2019 14:10	88200	491	16.23	3.16					
5/14/2019 14:11	88260	492	16.22	3.15					
5/14/2019 14:12	88320	493	16.22	3.15					
5/14/2019 14:13	88380	494	16.22	3.15					
5/14/2019 14:14	88440	495	16.22	3.15					
5/14/2019 14:15	88500	496	16.22	3.15					
5/14/2019 14:16	88560	497	16.22	3.15					
5/14/2019 14:17	88620	498	16.22	3.15					
5/14/2019 14:18	88680	499	16.21	3.14					
5/14/2019 14:19	88740	500	16.23	3.16					
5/14/2019 14:20	88800	501	16.22	3.15					
5/14/2019 14:21	88860	502	16.22	3.15					
5/14/2019 14:22	88920	503	16.22	3.15					
5/14/2019 14:23	88980	504	16.22	3.15					
5/14/2019 14:24	89040	505	16.23	3.16					
5/14/2019 14:25	89100	506	16.23	3.16					
5/14/2019 14:26	89160	507	16.23	3.16					
5/14/2019 14:27	89220	508	16.23	3.16					
5/14/2019 14:28	89280	509	16.22	3.15					
5/14/2019 14:29	89340	510	16.23	3.16					
5/14/2019 14:30	89400	511	16.23	3.16	18.07	3.12	1.5		
5/14/2019 14:31	89460	512	16.23	3.16					
5/14/2019 14:32	89520	513	16.23	3.17					
5/14/2019 14:33	89580	514	16.23	3.16					
5/14/2019 14:34	89640	515	15.84	2.77					

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 14:35	89700	516	15.85	2.78					At 14:34, the generator powering
5/14/2019 14:36	89760	517	15.87	2.80					the pump shut down abruptly.
5/14/2019 14:37	89820	518	15.90	2.83					It was turned back on, but the
5/14/2019 14:38	89880	519	15.91	2.84					pumping rate after this point
5/14/2019 14:39	89940	520	15.91	2.84					is estimated.
5/14/2019 14:40	90000	521	15.92	2.85					
5/14/2019 14:41	90060	522	15.92	2.85					
5/14/2019 14:42	90120	523	15.93	2.86					
5/14/2019 14:43	90180	524	15.92	2.85					
5/14/2019 14:44	90240	525	15.92	2.85					
5/14/2019 14:45	90300	526	15.92	2.85					
5/14/2019 14:46	90360	527	15.93	2.86					
5/14/2019 14:47	90420	528	15.92	2.85					
5/14/2019 14:48	90480	529	15.92	2.85					
5/14/2019 14:49	90540	530	15.92	2.85					
5/14/2019 14:50	90600	531	15.91	2.85	17.8	2.85	1.5		
5/14/2019 14:51	90660	532	15.91	2.84					
5/14/2019 14:52	90720	533	15.92	2.85					
5/14/2019 14:53	90780	534	15.91	2.84					
5/14/2019 14:54	90840	535	15.92	2.85					
5/14/2019 14:55	90900	536	15.91	2.84					
5/14/2019 14:56	90960	537	15.91	2.84					
5/14/2019 14:57	91020	538	15.92	2.85					
5/14/2019 14:58	91080	539	15.91	2.84					
5/14/2019 14:59	91140	540	15.90	2.84					
5/14/2019 15:00	91200	541	15.91	2.84					
5/14/2019 15:01	91260	542	15.90	2.83					
5/14/2019 15:02	91320	543	15.90	2.83					
5/14/2019 15:03	91380	544	15.89	2.82					
5/14/2019 15:04	91440	545	15.91	2.84					
5/14/2019 15:05	91500	546	15.90	2.83					
5/14/2019 15:06	91560	547	15.91	2.84					
5/14/2019 15:07	91620	548	15.90	2.84					
5/14/2019 15:08	91680	549	15.90	2.83					
5/14/2019 15:09	91740	550	15.90	2.83					
5/14/2019 15:10	91800	551	15.90	2.83	17.74	2.79	1.5		
5/14/2019 15:11	91860	552	15.90	2.83					
5/14/2019 15:12	91920	553	15.89	2.82					
5/14/2019 15:13	91980	554	15.90	2.83					
5/14/2019 15:14	92040	555	15.90	2.83					
5/14/2019 15:15	92100	556	15.90	2.83					
5/14/2019 15:16	92160	557	15.90	2.83					
5/14/2019 15:17	92220	558	15.90	2.83					

Table 2. Constant Rate Test Data (MW-66)

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 15:18	92280	559	15.90	2.83					
5/14/2019 15:19	92340	560	15.90	2.83					
5/14/2019 15:20	92400	561	15.90	2.83					
5/14/2019 15:21	92460	562	15.90	2.83					
5/14/2019 15:22	92520	563	15.89	2.82					
5/14/2019 15:23	92580	564	15.89	2.82					
5/14/2019 15:24	92640	565	15.89	2.82					
5/14/2019 15:25	92700	566	15.89	2.82					
5/14/2019 15:26	92760	567	15.89	2.82					
5/14/2019 15:27	92820	568	15.89	2.82					
5/14/2019 15:28	92880	569	15.89	2.83					
5/14/2019 15:29	92940	570	15.89	2.82					
5/14/2019 15:30	93000	571	15.88	2.81	17.79	2.84	1.5		
5/14/2019 15:31	93060	572	15.89	2.82					
5/14/2019 15:32	93120	573	15.88	2.81					
5/14/2019 15:33	93180	574	15.89	2.82					
5/14/2019 15:34	93240	575	15.89	2.82					
5/14/2019 15:35	93300	576	15.90	2.83					
5/14/2019 15:36	93360	577	15.89	2.82					
5/14/2019 15:37	93420	578	15.89	2.83					
5/14/2019 15:38	93480	579	15.88	2.81					
5/14/2019 15:39	93540	580	15.89	2.82					
5/14/2019 15:40	93600	581	15.89	2.82					
5/14/2019 15:41	93660	582	15.89	2.82					
5/14/2019 15:42	93720	583	15.90	2.83					
5/14/2019 15:43	93780	584	15.89	2.83					
5/14/2019 15:44	93840	585	15.89	2.82					
5/14/2019 15:45	93900	586	15.90	2.83					
5/14/2019 15:46	93960	587	15.89	2.82					
5/14/2019 15:47	94020	588	15.88	2.81					
5/14/2019 15:48	94080	589	15.89	2.82					
5/14/2019 15:49	94140	590	15.89	2.83					
5/14/2019 15:50	94200	591	15.89	2.82	17.79	2.84	1.5		
5/14/2019 15:51	94260	592	15.90	2.83					
5/14/2019 15:52	94320	593	15.89	2.82					
5/14/2019 15:53	94380	594	15.89	2.82					
5/14/2019 15:54	94440	595	15.89	2.82					
5/14/2019 15:55	94500	596	15.89	2.82					
5/14/2019 15:56	94560	597	15.89	2.82					
5/14/2019 15:57	94620	598	15.89	2.82					
5/14/2019 15:58	94680	599	15.90	2.83					
5/14/2019 15:59	94740	600	15.89	2.82					
5/14/2019 16:00	94800	601	15.90	2.83					

Well: MW-66 **Constant Rate Test Data**

Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 16:01	94860	602	15.89	2.83					
5/14/2019 16:02	94920	603	15.89	2.82					
5/14/2019 16:03	94980	604	15.90	2.83					
5/14/2019 16:04	95040	605	15.89	2.82					
5/14/2019 16:05	95100	606	15.89	2.82					
5/14/2019 16:06	95160	607	15.89	2.82					
5/14/2019 16:07	95220	608	15.88	2.81					
5/14/2019 16:08	95280	609	15.89	2.82					
5/14/2019 16:09	95340	610	15.90	2.83					
5/14/2019 16:10	95400	611	15.89	2.82	17.78	2.83	1.5		
5/14/2019 16:11	95460	612	15.88	2.82					
5/14/2019 16:12	95520	613	15.89	2.83					
5/14/2019 16:13	95580	614	15.89	2.82					
5/14/2019 16:14	95640	615	15.88	2.82					
5/14/2019 16:15	95700	616	15.89	2.82					
5/14/2019 16:16	95760	617	15.90	2.83					
5/14/2019 16:17	95820	618	15.90	2.83					
5/14/2019 16:18	95880	619	15.90	2.83					
5/14/2019 16:19	95940	620	15.90	2.83					
5/14/2019 16:20	96000	621	15.90	2.83					
5/14/2019 16:21	96060	622	15.90	2.83					
5/14/2019 16:22	96120	623	15.89	2.82					
5/14/2019 16:23	96180	624	15.90	2.83					
5/14/2019 16:24	96240	625	15.90	2.83					
5/14/2019 16:25	96300	626	15.90	2.83					
5/14/2019 16:26	96360	627	15.89	2.82					
5/14/2019 16:27	96420	628	15.89	2.82					
5/14/2019 16:28	96480	629	15.90	2.83					
5/14/2019 16:29	96540	630	15.89	2.82					
5/14/2019 16:30	96600	631	15.89	2.82	17.79	2.84	1.5		
5/14/2019 16:31	96660	632	15.89	2.83					
5/14/2019 16:32	96720	633	15.91	2.84					
5/14/2019 16:33	96780	634	15.90	2.83					
5/14/2019 16:34	96840	635	15.90	2.84					
5/14/2019 16:35	96900	636	15.89	2.82					
5/14/2019 16:36	96960	637	15.89	2.82					
5/14/2019 16:37	97020	638	15.89	2.82					
5/14/2019 16:38	97080	639	15.89	2.82					
5/14/2019 16:39	97140	640	15.89	2.82					
5/14/2019 16:40	97200	641	15.90	2.83					
5/14/2019 16:41	97260	642	15.89	2.82					
5/14/2019 16:42	97320	643	15.89	2.82					
5/14/2019 16:43	97380	644	15.88	2.81					

Table 2. Constant Rate Test Data (MW-66)

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: 24.5 ft

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 16:44	97440	645	15.89	2.82					
5/14/2019 16:45	97500	646	15.89	2.83					
5/14/2019 16:46	97560	647	15.89	2.83					
5/14/2019 16:47	97620	648	15.88	2.81					
5/14/2019 16:48	97680	649	15.88	2.81					
5/14/2019 16:49	97740	650	15.88	2.82					
5/14/2019 16:50	97800	651	15.90	2.83	17.76	2.81	1.5		
5/14/2019 16:51	97860	652	15.88	2.81					
5/14/2019 16:52	97920	653	15.88	2.82					
5/14/2019 16:53	97980	654	15.88	2.81					
5/14/2019 16:54	98040	655	15.89	2.82					
5/14/2019 16:55	98100	656	15.89	2.82					
5/14/2019 16:56	98160	657	15.89	2.82					
5/14/2019 16:57	98220	658	15.88	2.81					
5/14/2019 16:58	98280	659	15.87	2.80					
5/14/2019 16:59	98340	660	15.88	2.81					
5/14/2019 17:00	98400	661	15.88	2.81					
5/14/2019 17:01	98460	662	15.87	2.81					
5/14/2019 17:02	98520	663	15.87	2.80					
5/14/2019 17:03	98580	664	15.89	2.82					
5/14/2019 17:04	98640	665	15.88	2.81					
5/14/2019 17:05	98700	666	15.88	2.81					
5/14/2019 17:06	98760	667	15.88	2.81					
5/14/2019 17:07	98820	668	15.88	2.81					
5/14/2019 17:08	98880	669	15.88	2.81					
5/14/2019 17:09	98940	670	15.89	2.82					
5/14/2019 17:10	99000	671	15.86	2.79	17.78	2.83	1.5		
5/14/2019 17:11	99060	672	15.88	2.81					
5/14/2019 17:12	99120	673	15.87	2.80					
5/14/2019 17:13	99180	674	15.87	2.80					
5/14/2019 17:14	99240	675	15.88	2.81					
5/14/2019 17:15	99300	676	15.88	2.81					
5/14/2019 17:16	99360	677	15.87	2.80					
5/14/2019 17:17	99420	678	15.88	2.81					
5/14/2019 17:18	99480	679	15.88	2.81					
5/14/2019 17:19	99540	680	15.87	2.80					
5/14/2019 17:20	99600	681	15.88	2.81					
5/14/2019 17:21	99660	682	15.87	2.80					
5/14/2019 17:22	99720	683	15.89	2.82					
5/14/2019 17:23	99780	684	15.89	2.82					
5/14/2019 17:24	99840	685	15.88	2.81					
5/14/2019 17:25	99900	686	15.88	2.81					
5/14/2019 17:26	99960	687	15.87	2.80					

Well: MW-66 **Constant Rate Test Data**
Total Depth of Well: **24.5 ft**

Date and Time	Elapsed Time Seconds	Time Since Pump Started t - (minutes)	Sensor: Pres(G) 35ft SN#: 549696 Level Depth To Water (ft)	Drawdown (ft) (Static - Level Depth to Water)	Manual Water Level (ft)	Drawdown (ft) from Manual Measurement	Pump Rate (gpm)	Totalizer Reading (gallons)	Notes
5/14/2019 17:27	100020	688	15.89	2.82					
5/14/2019 17:28	100080	689	15.88	2.81					
5/14/2019 17:29	100140	690	15.88	2.81					
5/14/2019 17:30	100200	691	15.89	2.82	17.78	2.83	1.5		
5/14/2019 17:31	100260	692	15.88	2.81					
5/14/2019 17:32	100320	693	15.89	2.82					
5/14/2019 17:33	100380	694	15.88	2.81					
5/14/2019 17:34	100440	695	15.88	2.81					
5/14/2019 17:35	100500	696	15.89	2.82					
5/14/2019 17:36	100560	697	15.88	2.81					
5/14/2019 17:37	100620	698	15.87	2.80					
5/14/2019 17:38	100680	699	15.88	2.81					
5/14/2019 17:39	100740	700	15.88	2.81					
5/14/2019 17:40	100800	701	15.88	2.81					
5/14/2019 17:41	100860	702	15.88	2.81					
5/14/2019 17:42	100920	703	15.89	2.82					
5/14/2019 17:43	100980	704	15.87	2.80					
5/14/2019 17:44	101040	705	15.88	2.82					
5/14/2019 17:45	101100	706	15.88	2.81					
5/14/2019 17:46	101160	707	15.88	2.81					
5/14/2019 17:47	101220	708	15.88	2.81					
5/14/2019 17:48	101280	709	15.88	2.81					
5/14/2019 17:49	101340	710	15.89	2.82					
5/14/2019 17:50	101400	711	15.87	2.80	17.76	2.81	1.5		
5/14/2019 17:51	101460	712	15.95	2.88					
5/14/2019 17:52	101520	713	16.01	2.95					
5/14/2019 17:53	101580	714	16.06	2.99					
5/14/2019 17:54	101640	715	16.09	3.02					
5/14/2019 17:55	101700	716	16.12	3.05					
5/14/2019 17:56	101760	717	16.14	3.07					
5/14/2019 17:57	101820	718	16.16	3.09					
5/14/2019 17:58	101880	719	16.17	3.10					Average Q = 1.5 gpm
5/14/2019 17:59	101940	720	16.17	3.10					
5/14/2019 18:00	102000	721	16.18	3.11	18.09	3.11	1.5		**End Constant Rate Test**

FIGURES

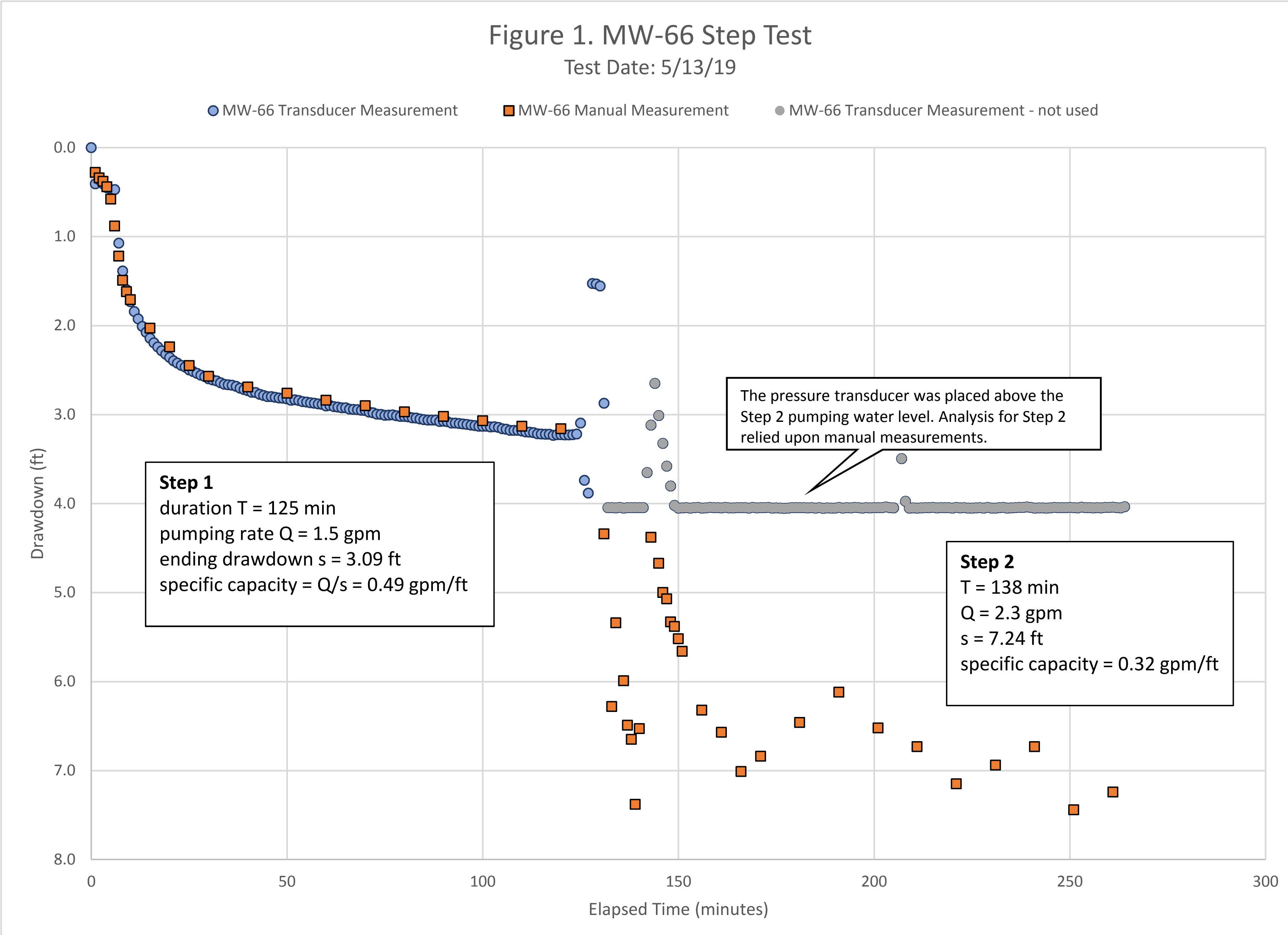
Figure 1. MW-66 Step Test
Test Date: 5/13/19
MW-66 Transducer Measurement
MW-66 Manual Measurement
MW-66 Transducer Measurement - not used
Drawdown (ft)
Elapsed Time (minutes)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
0
50
100
150
200
250
300
The pressure transducer was placed above the Step 2 pumping water level. Analysis for Step 2 relied upon manual measurements.
Step 1
duration T = 125 min
pumping rate Q = 1.5 gpm
ending drawdown s = 3.09 ft
specific capacity = Q/s = 0.49 gpm/ft
Step 2
T = 138 min
Q = 2.3 gpm
s = 7.24 ft
specific capacity = 0.32 gpm/ft

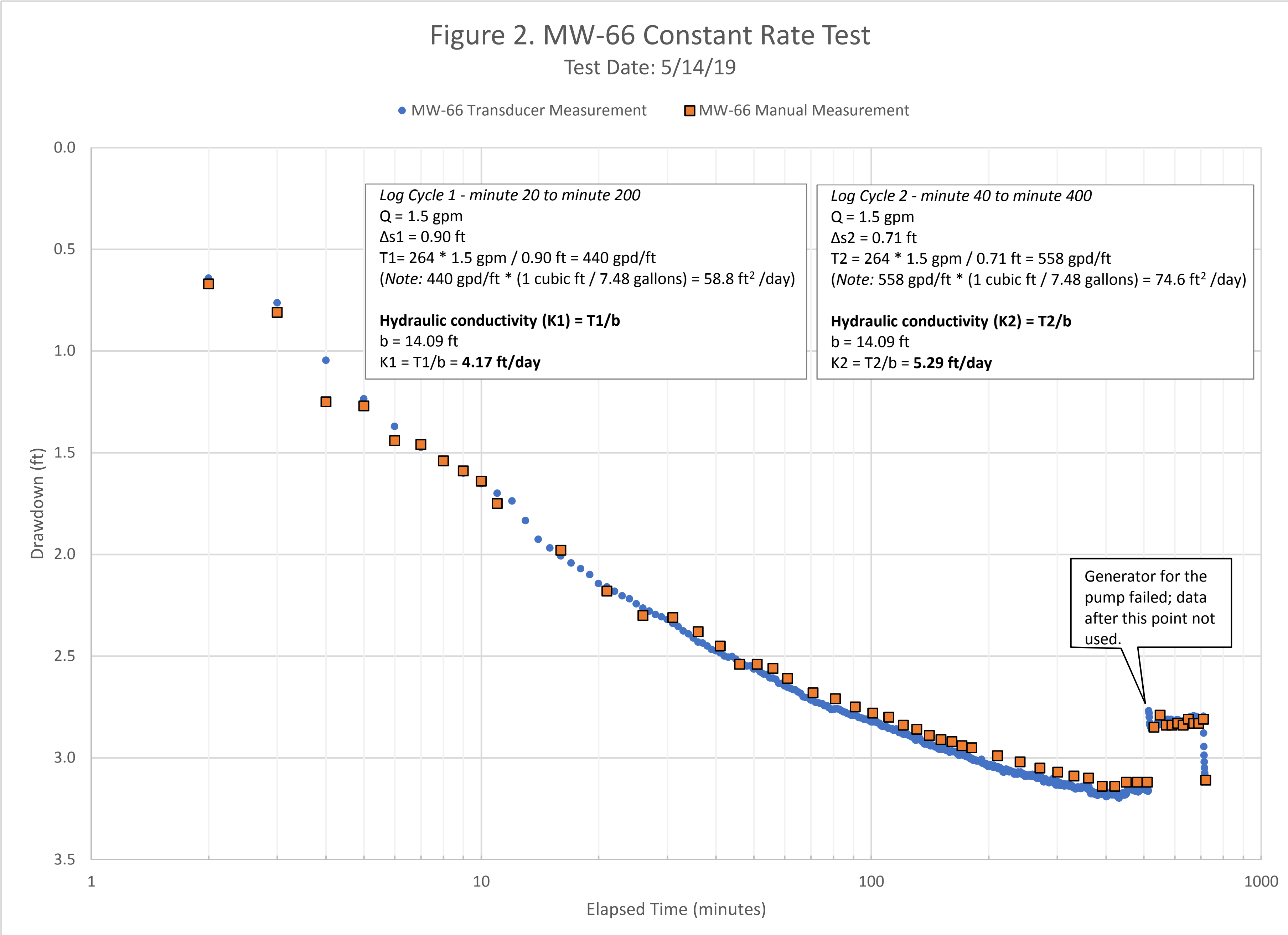
Figure 2. MW-66 Constant Rate Test
Test Date: 5/14/19
MW-66 Transducer Measurement
MW-66 Manual Measurement
Log Cycle 1 - minute 20 to minute 200
Q = 1.5 gpm
Δs1 = 0.90 ft
T1= 264 * 1.5 gpm / 0.90 ft = 440 gpd/ft
(Note: 440 gpd/ft * (1 cubic ft / 7.48 gallons) = 58.8 ft² /day)
Hydraulic conductivity (K1) = T1/b
b = 14.09 ft
K1 = T1/b = 4.17 ft/day
Log Cycle 2 - minute 40 to minute 400
Q = 1.5 gpm
Δs2 = 0.71 ft
T2 = 264 * 1.5 gpm / 0.71 ft = 558 gpd/ft
(Note: 558 gpd/ft * (1 cubic ft / 7.48 gallons) = 74.6 ft² /day)
Hydraulic conductivity (K2) = T2/b
b = 14.09 ft
K2 = T2/b = 5.29 ft/day
Generator for the pump failed; data after this point not used.
Drawdown (ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1
10
100
1000
Elapsed Time (minutes)

APPENDIX B

GROUNDWATER MODEL DOCUMENTATION FOR THE URS CORRECTIVE MEASURES ASSESSMENT

Technical Memorandum

To:	Michele Robertson, RG Pamela Norris	**File No:**	14-2018-2068
From:	Jake Perry Devin Politoske	**Reviewed by:**	Emily LoDolce, PE Natalie Chrisman Lazarr, PE
Date:	June 14, 2019		
Subject:	**GROUNDWATER MODEL DOCUMENTATION FOR THE URS CORRECTIVE MEASURES ASSESSMENT Arizona Public Service Four Corners Power Plant – Fruitland, New Mexico**		

1.0 INTRODUCTION

This technical memorandum (memo) documents the development, calibration, and use of a three-dimensional (3-D) groundwater flow and transport model representing near surface hydrogeologic conditions in the vicinity of the former Upper Retention Sump (URS), a coal combustion residuals (CCR) unit at the Arizona Public Service (APS) Four Corners Power Plant in Fruitland, New Mexico (the Site) The memo is an appendix to a report documenting an *Assessment of Corrective Measures for Multiunit 1 and the URS* prepared by Wood Environment & Infrastructure Solutions, Inc. (Wood).

The model was developed to serve as a scientific tool to evaluate potential corrective measures to address the elevated concentrations of fluoride, a CCR Rule constituent observed in the Pictured Cliffs Sandstone hydrostratigraphic unit downgradient of the former URS. This memo presents the data and specifications for the Four Corners Power Plant URS Groundwater Model (the model), including modeling platform, structure, parameters, and calibration data.

2.0 MODELING PLATFORM

Wood developed the model using MODFLOW 2005 (Harbaugh, 2005), a standard and widely-used USGS modeling code, with the PCG2 solver. Contaminant transport was simulated using MT3DMS (Zheng and Wang, 1999) with the finite difference solver, which has the advantage of being mass conservative. Groundwater Vistas version 7.24 was used as a graphical user interface to facilitate modeling and visualization.

MODFLOW is a program that uses the finite difference method to solve a 3-D groundwater flow equation. The groundwater flow equation uses transmissivity (in unconfined aquifers, this is the product of hydraulic conductivity and saturated thickness), volumetric flux of water, and storage to solve for the change in head over time. MODFLOW solves the groundwater flow equation numerically by dividing the model domain into grid cells and calculating the head at the center of each cell. A complete discussion of the equations used in MODFLOW is available in the USGS open-file report 00-92, "MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process".

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MT3DMS is a program for simulating advection, dispersion/diffusion, and chemical reactions of contaminants in groundwater flow systems under general hydrogeologic conditions. The advection-dispersion equation uses porosity, dispersivity, and groundwater velocity to solve for the change in concentration over time. MT3DMS solves the advection-dispersion equation numerically using the groundwater flow field from the MODFLOW simulation and a finer discretization of time than what is used in the groundwater flow model to calculate the concentration in the center of each cell at each time step.

Groundwater Vistas (Environmental Simulations, Inc., 2017) is a proprietary graphical user interface that facilitates the modeling process by generating the input files required by MODFLOW 2005 and MT3DMS, and by displaying the modeling environment graphically. While this software is not required to run the model, the pre- and post-processing tools within this software package allow flow and transport models to be quickly constructed, run, and processed for evaluation. Additional tools for processing and visualizing model input and output data include Microsoft Excel and the ArcGIS (version 10.4 [ESRI, 2015]) suite of programs, specifically ArcMap.

2.1 Modeling Approach

The approach to modeling the groundwater system in the vicinity of the former URS at the Site was to first develop and calibrate a steady state groundwater flow model using groundwater elevations from Site monitoring wells as calibration data. The calibrated steady state flow model formed the basis for a transient model that was used to simulate groundwater flow and contaminant transport. Concentrations in the transient model were initialized using site-specific observations and then simulated into the future to evaluate potential impacts of corrective measures for the URS.

2.2 Model Structure

To solve the groundwater flow equation, it is necessary to define the extent of the area of interest. This section discusses the geometry of the groundwater model, which can be thought of as a 3-D box that is cut out of the earth and isolated. The domain (edges of the box), cell size (partitions within the box), and layering (levels within the box) were developed by Wood in consultation with APS.

2.2.1 Model Domain

The model encompasses 0.8 square miles around the former URS at the Site. General goals for model boundaries were to encompass the sandstone aquifer in the vicinity of the URS and to minimize the impact of model boundaries on the areas of potential corrective measures. Where feasible, this was done by extending the model to the nearest natural boundary to groundwater flow (e.g., Morgan Lake). Where no natural boundaries are present, the model domain is extended sufficiently beyond the area of interest to minimize boundary effects, as described in **Section 2.4**. **Figure 1** presents an overview of the model domain, grid, and boundaries.

2.2.2 Grid Size, Orientation, and Layering

The model contains 154 rows and 127 columns. Model grid cells within an area of 5,000 square feet immediately surrounding the URS have dimensions of 10 feet (ft) by 10 ft. Grid cell size increases steadily outside this area, reaching a maximum value of 100 ft by 100 ft at the edges of the model domain. The grid is rotated 33 degrees from north to align with the primary direction of groundwater flow in the area of interest, i.e., cross- and down-gradient of the former URS. The model consists of one layer with model cell thickness varying in accordance to local hydrogeologic stratification on a cell by cell scale.

Layer 1 is unconfined and comprised of sandstone. Ground surface elevation (the top of Layer 1) was defined using 10-meter (m) Digital Elevation Model files (DEMs) from the USGS (USGS, 2017). These are raster files that are a product of satellite imagery, produced at a 10-m resolution. Using mapping and spatial analysis tools in ArcMap, Wood intersected the DEM data with the model grid cells and calculated an approximate surface elevation for each grid cell. The model assumes there is no downward flow from the sandstone layer at the site into the underlying Lewis Shale formation.

The bottom of Layer 1 is based primarily on boring logs of drilling activities undertaken in the vicinity of the former URS. Due to the limited quantity of boring data in the southern portion of the model domain, three extrapolated data points were added to the bottom row of the model based on the trend of the ground surface elevation, e.g., if the ground surface elevation increases, the Layer 1 bottom surface elevation increases accordingly. ArcMap was used to calculate an average bottom elevation per model cell and assign it to the model grid.

2.2.3 <u>Boundary Conditions</u>

Constant head boundary conditions and general head boundary (GHB) conditions were used within the model domain and calibrated to match available site data. Boundary condition development is described in more detail below.

Constant head boundary cells were used to represent Morgan Lake. This body of surface water comprises the upper right corner and top row of the model domain. A constant head value of 5,330 feet above North American Vertical Datum of 1988 (ft NAVD 88) was set based on the DEM data from the USGS.

GHB cells were added to the borders of the model domain where a constant head boundary was not present. The value chosen for a given GHB cell is a linear extrapolation of measured groundwater elevations from nearby monitoring wells. For example, if the ground surface elevation at a boundary cell is three feet higher than that of the cell containing the monitoring well, then the value assigned to the GHB would be specified three feet higher than the observed water level in the monitoring well. This estimation was performed to compensate for the limited amount of groundwater elevation data near the boundaries of the model domain. The GHB cells were adjusted during model calibration until modeled heads satisfactorily simulated observed heads in nearby monitoring wells.

The resulting GHBs have a maximum value of 5,335.8 ft NAVD 88 in the lower right corner of the model. The GHB elevation decreases from 5,335.8 ft NAVD 88 to 5,330.1 ft NAVD 88 at the junction with the constant head boundary representing Morgan Lake. Moving along the bottom row of the model, the GHB decreases steadily from 5,335.8 ft NAVD 88 in the lower right corner to 5,333 ft NAVD 88 in the lower left corner of the model domain. From the lower left corner, the GHB decreases from 5,333 ft NAVD 88 to 5330.1 ft NAVD 88 at the constant head boundary representing Morgan Lake (**Figure 1**).

3.0 MODEL PARAMETERS

Model parameters used to describe the geology are hydraulic conductivity, specific yield (unconfined layers), and porosity. Parameter values used in this model are derived from the following sources:

- Slug tests of MW-67, MW-68 and MW-71 (AECOM, 2016)
- Pumping test of MW-66 (Appendix A of the Main Report)
- Literature values (Freeze and Cherry, 1979; Fetter, 1994)

Recharge, a common parameter in groundwater models, was not included in the model because the plant location is an arid, high-elevation plateau, and what little precipitation occurs is not expected to have a notable recharge effect on model results for their intended purpose. For this same reason evapotranspiration was also not simulated.

3.1 Hydraulic Conductivity

Hydraulic conductivity (K) is a measure of how freely groundwater can move through a geologic formation. Site-specific data from aquifer testing at MW-66, MW-67, MW-68, and MW-71 were compiled and used to inform the calibration of K in the model. Aquifer test results are shown in **Table 1**.

Table 1 – Sandstone Aquifer Test Results

Monitoring Well	Test Date	Activity	K (ft/day)
MW-66	5/14/2019	Constant Rate Test	4.17 to 5.29
MW-67	3/5/2016	Slug Test	1.3
MW-68	3/5/2016	Slug Test	1.4
MW-71	3/5/2016	Slug Test	5.4

These data points were used in conjunction with literature values for K in sandstone (Freeze and Cherry 1979, Fetter 1994) to generate a distribution of hydraulic conductivity zones within the model domain. K values were adjusted during the model calibration until the modeled heads satisfactorily approximated the observed heads. The ratio of horizontal to vertical hydraulic conductivity was fixed at 10:1. **Figure 2** shows the distribution and corresponding K values by zone. (Note that **Figure 2** shows two values for each K zone; this is discussed in **Section 6**.)

3.2 Porosity

Porosity is an advective transport parameter that is part of the calculation of groundwater velocity. The porosity value used in the model is 0.3 (dimensionless). This was obtained from literature values for sandstone (Freeze and Cherry 1979, Fetter 1994).

4.0 CALIBRATION

Model calibration is performed so that simulated hydraulic heads satisfactorily approximate real-life observations. A model is considered calibrated when the difference between the observed and modeled heads is sufficiently small. Pre-determined calibration criteria for the model are as follows:

- Normalized root-mean-square-error (RMSE) less than 10% (industry standard)
- R^2 greater than 0.9
- General direction of groundwater flow in the model matches observations
- General hydraulic gradient (change in head over distance) of groundwater in the model matches observations

4.1 Head Targets

The data used for calibration of the model are groundwater elevations measured at 16 monitoring wells that fall within the model domain. The dataset was limited to elevations monitored in November 2018 and March 2019 since new wells were installed in November 2018 (MW-83, MW-84, MW-85, and MW-86) and the November 2018 event was the first round where water level mounding due to the presence of the URS was limited (the URS was demolished between June and December 2018).

Two monitoring wells from the March 2019 event had potentially anomalous measurements. The groundwater elevation at MW-67 was reported to increase by 4 feet relative to the previous sampling event in November 2018 (from 5,330.5 to 5,334.5 ft NAVD 88) and the MW-71 groundwater elevation was reported to decrease by 1.9 feet relative to the November 2018 sampling event (from 5,330.8 to 5,328.9 ft NAVD 88). Measurements from the neighboring wells (MW-66, MW-68, MW-69, MW-70, and MW-72) did not show this magnitude of fluctuation. As it was ultimately not possible to calibrate the model in a satisfactory manner matching these two groundwater elevation data, head targets for calibration contain a combination of groundwater elevation measurements from November 2018 and March 2019. **Table 2** summarizes the calibration targets and modeled residuals, and **Table 3** presents calibration statistics.

Table 2 – Summary of Calibration Targets and Results

Well Name	Easting (ft) X	Northing (ft) Y	Date of Groundwater Measurement	Observed Head (ft NAVD 88)	Computed Head (ft NAVD 88)	Residual
MW-62	2534533	2071563	11/2/2018	5330.16	5330.26	-0.10
MW-63	2534982	2071997	11/2/2018	5329.96	5330.03	-0.07
MW-64	2535675.131	2071564.6	11/2/2018	5330.5	5330.16	0.34
MW-65	2535315.836	2071367.4	11/2/2018	5330.65	5330.54	0.11
MW-66	2534260.177	2070329.4	11/2/2018	5330.22	5330.97	-0.75
MW-67	2534124.252	2070194.4	11/2/2018	5330.5	5331.01	-0.51
MW-68	2534176.268	2070059.5	11/2/2018	5331.27	5331.21	0.06
MW-69	2534353.918	2069878	11/2/2018	5332.08	5331.59	0.49
MW-70	2534558.226	2070090.6	11/2/2018	5331.99	5331.52	0.47
MW-71	2533344.718	2069273.3	11/2/2018	5330.82	5331.26	-0.44
MW-72	2534270.977	2069248.1	11/2/2018	5331.56	5332.03	-0.47
MW-73	2531266.172	2070658	11/2/2018	5329.06	5330.01	-0.95
MW-83	2533647.781	2071872.3	3/13/2019	5329.75	5330.03	-0.28
MW-84	2534044.644	2070510.1	3/13/2019	5330.38	5330.74	-0.36
MW-85	2533808.627	2070175.6	3/13/2019	5330.62	5330.89	-0.27
MW-86	2534508.885	2070725	3/13/2019	5330.23	5330.84	-0.61

Table 3 – Calibration Statistics

Statistic	Head Targets
Residual Mean	-0.21
Absolute Residual Mean	0.39
Residual Standard Deviation	0.41
Sum of Squares	3.42
RMS Error	0.46
Min. Residual	-0.95
Max. Residual	0.49
Number of Observations	16
Range in Observations	3.02
Scaled Residual Standard Deviation	0.14
Scaled Absolute Residual Mean	0.13
Scaled RMS Error	15.31%
Scaled Residual Mean	-0.07
R^2	0.72

4.2 Commentary on the Steady State Flow Calibration

The model does not meet the pre-determined statistical RMSE and R^2 calibration criteria specified for a well-calibrated model, with a RMSE of 15.31% and an R^2 of 0.72. This is possibly due to the relatively high number of observations clustered within a limited spatial area, resulting in many observations in a small portion of the model area and no observations in the larger model area. Groundwater elevations from future monitoring events as well as future aquifer testing data (as applicable) could serve to provide supplemental data that would likely improve model calibration. The uncertainty regarding K values in the model is addressed using two versions of the model to evaluate potential corrective measures, thus providing a range of values rather than a single solution (**Section 6**).

The model successfully approximates observed groundwater flow direction and gradient. While there is uncertainty regarding specific properties that could potentially improve the match to observed head data, the model is considered a suitable flow model for use with the transient transport simulations.

5.0 TRANSLATION TO TRANSIENT WITH CONTAMINANT TRANSPORT

The calibrated steady-state model was modified to operate in transient mode to simulate the time-varying aspects of contaminant fate and transport. Details of this transformation are provided below:

Stress Period/Time Steps – The transient model has one stress period simulating a forecast period of 30 years. The time step length for the transient model begins at 0.1 days. The model uses a 1.2 times multiplier to increase the amount of time between each successive time step, reaching a maximum value of 100 days. There are a total of 143 time steps.

Initial Concentrations – Fluoride concentrations measured in Site monitoring wells in November/ December 2018 were input into ArcMap as datapoints. These were used to generate a distribution of fluoride concentrations within the model domain. The initial fluoride concentration ranges from a high of 22.52 mg/L at MW-66 to a low of 0 mg/L in areas more distant from the URS (**Figure 3**).

The following observations pertain to the transient contaminant transport model:

- The source of fluoride at the URS has been removed (i.e., the former URS has been replaced with an above ground tank), and as such, the initial concentrations specified at the beginning of the model simulation period are the only source of contaminant mass in the aquifer. Because the initial concentrations in the model are directly based on observations from Site monitoring wells, there is a high level of confidence that the appropriate amount of contaminant mass is simulated in the aquifer.
- The flow model correctly simulates the observed groundwater flow direction and gradient, suggesting that the direction of contaminant transport will be approximated accurately by the model.
- The hydraulic conductivities in the flow model are based on Site-specific values and fit within the range of literature values for the aquifer matrix (sandstone). This increases confidence that the rate of contaminant transport will be reasonably approximated by the model.

These factors support the use of the transient model for corrective measures evaluation.

6.0 SENSITIVITY ANALYSIS

A sensitivity analysis on horizontal hydraulic conductivity was conducted to evaluate:

- Flow model sensitivity to increased K; and
- Advective transport sensitivity to increased K.

The "base", or "one times K (1xK)" model refers to the version of the model with the original calibrated K values (**Figure 2**). Based on the results of a constant rate aquifer test conducted at MW-66 on May 14, 2019 (**Appendix A** of Main Report), which estimated K at MW-66 to be between 4.17 feet per day (ft/day) and 5.29 ft/day, the K values in the 1xK model were increased by a factor of four (**Figure 2**). This model is referred to as the "four times K (4xK)" model. The 1xK model has K at MW-66 equal to 1.8 ft/day. The 4xK model has K at MWM-66 equal to 7.4 ft/day.

The steady state flow model was run using both the 1xK and the 4xK versions. The resulting calibration statistics were identical, indicating that the modeled heads are not sensitive to scale changes in K. This suggests that the boundary conditions as well as the specified zones of K are dominating the head solution in the model. Recommendations for future model refinements are included in **Section 8**.

To evaluate the impact of the increased K on contaminant transport, the initial concentrations of fluoride (**Section 5**) were modeled in the vicinity of the former URS and allowed to attenuate. The results of this analysis are shown in **Figure 4**, which indicates the higher K model produced a higher flow velocity and subsequent increased transport of contaminant in the aquifer.

Both models (1xK and 4xK) were used to evaluate the fluoride plume movement due the degree of model parameter uncertainty. The use of two models produces a range of potential timelines for corrective measures to lend confidence to planning efforts.

7.0 CORRECTIVE MEASURES EVALUATIONS

This section summarizes the model runs used to evaluate potential groundwater corrective measures and their resultant effect on the groundwater resource. The general approach to evaluating the efficacy of the corrective measures alternatives is to evaluate the differences between the active management alternatives and a natural attenuation alternative, which can be thought of as a "limited response action" look into the future. Potential corrective measures goals for the Site include:

- Water removal at a rate that is low enough to be reasonably sustained by the sandstone aquifer and high enough to create a sufficient radius of influence so as to effectuate remediation of the aquifer beyond what is seen in the natural attenuation alternative (generally 1 gpm, based on the results of the aquifer test at MW-66); and
- Remediation of the aquifer to levels below the applicable Groundwater Protection Standard (GWPS) within 30 years.

Alternatives addressing these goals were developed and compared to results from the natural attenuation alternative for the URS. In the following section, the structure, details, and results of the natural attenuation alternative and two active management alternatives are presented.

7.1 Alternative 1– Natural Attenuation

URS Alternative 1 corresponds to a transient model run representing the attenuation of fluoride in the aquifer downgradient from the former URS. The model run is used to estimate when the concentrations will attenuate to less than the GWPSs given:

- Replacement of the URS with an above ground tank, effectively removing the source of mass to the aquifer;
- Removal of the localized hydraulic head from the former URS; and
- Water levels at Morgan Lake and surrounding GHB cells remain constant.

In Alternative 1, the model was run for 30 years (from 2019 to 2048). **Figure 4** presents the results of the natural attenuation scenario at the URS. The maximum concentration of fluoride in groundwater at a given time tends to track with concentrations in MW-66. When the maximum concentration is less than the respective GWPS, the groundwater is considered remediated for the purposes of this analysis.

The model results in Alternative 1 indicate that concentrations of fluoride in groundwater will attenuate below the GWPS by 2036 (17 years from present) or beyond 2048 (over 30 years from present), for the 4xK and 1xK models, respectively.

7.2 Alternative 2 – One Extraction Well (EXT-1)

URS Alternative 2 consists of the conditions listed in Alternative 1, plus:

- One extraction well (EXT-1) placed near MW-66 pumping at a rate of 1 gpm for the 30-year duration of the simulation.

The location of EXT-1 is shown in **Figure 3-3** in the Main Report. The time to remediate estimated by the 1xK and 4xK distribution versions of the transient model is shown in **Figure 5**. The model results for Alternative 2 indicate that concentrations of fluoride in the aquifer will attenuate below the GWPS by 2028

(9 years 1 month from present) or 2032 (12 years 11 months from present), for the 4xK and 1xK models, respectively.

7.3 Alternative 3 – Two Extraction Wells (EXT-1 and EXT-2)

URS Alternative 3 consists of the conditions listed in Alternative 1, plus:

- Two extraction wells (EXT-1 and EXT-2) placed near MW-66 and MW-68, respectively, both pumping at a rate of 1 gpm for the 30-year duration of the simulation.

The locations of EXT-1 and EXT-2 are shown in **Figure 3-3** in the Main Report. The time to remediate the groundwater to the GWPS estimated by the 1xK and 4xK distribution versions of the transient model is shown in **Figure 6**. The model results for Alternative 3 indicate that concentrations of fluoride in the aquifer will attenuate below the GWPS by 2025 (5 years 9 months from present) or 2026 (6 years 10 months from present), for the 4xK and 1xK distributions, respectively.

8.0 MODEL LIMITATIONS AND RECOMMENDATIONS FOR FUTURE IMPROVEMENT

The objective of the groundwater model was to provide a planning tool for better understanding the fate and transport of contamination in groundwater underlying the former URS at the Four Corners Power Plant, specifically as it relates to future attenuation or remediation of fluoride. The uppermost aquifer (sandstone) is the area of interest and focus of the groundwater model, which is necessarily a simplification of the aquifer system at the Site. Given the scale and complexity of the geology at the Site, there are uncertainties in the modeled hydrogeologic properties. The model in its present state is appropriate for estimating order-of-magnitude transport/remediation times. Several areas of refinement have been identified that could reduce model uncertainty for future use:

- **Calibration data** – The steady state flow model calibration to observed heads did not meet some of the pre-determined calibration criteria. This could possibly be improved by incorporating additional groundwater elevation observations in a transient simulation and calibrating the K field to these data.
- **Boundary conditions** – The model is constrained on all four sides by specified head or specified gradient boundary cells. It is possible that this conceptualization does not allow for variation in simulated water levels (e.g. through the variation of K values). Future sensitivity analyses with the model could explore this hypothesis and potentially arrive at a set of boundary conditions that result in a better calibration to observed heads.

9.0 REFERENCES

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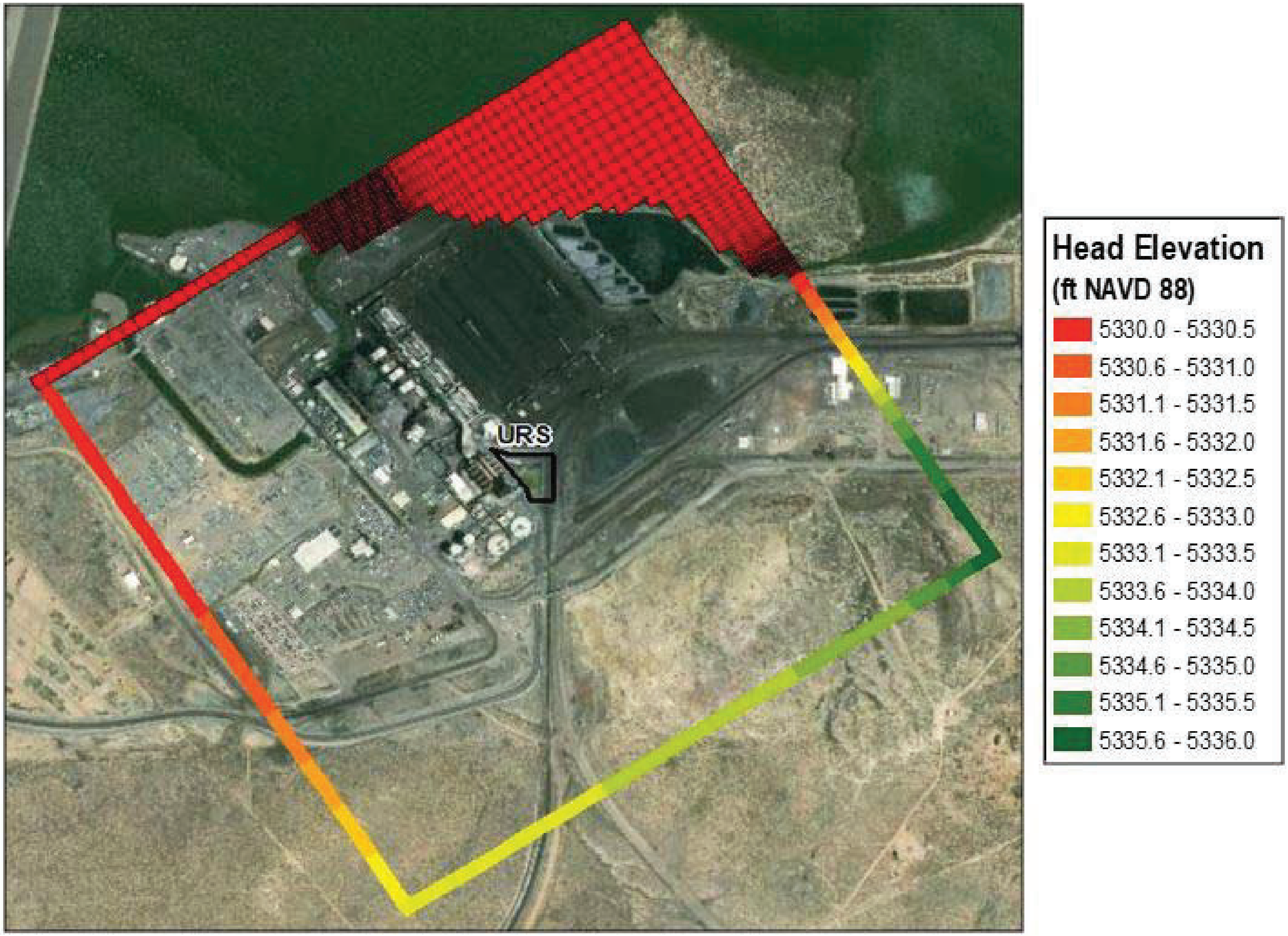
FIGURES



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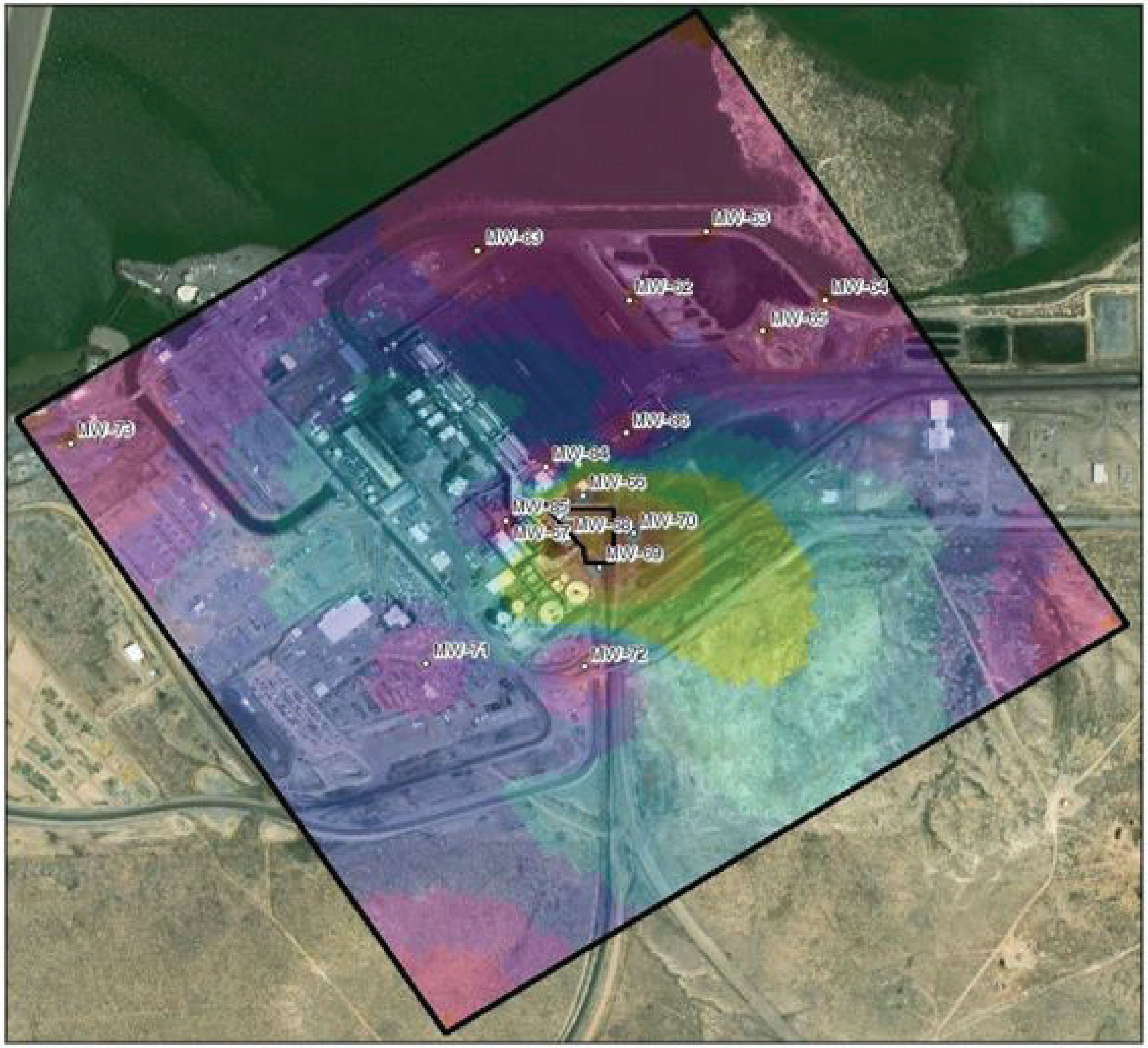
Overview of Model Domain and Head Boundaries

FIGURE
1

wood.



Zone	1x K (ft/day)	4x K (ft/day)
1	1.4	5.6
2	1.6	6.2
3	1.8	7.4
4	2.2	8.8
5	2.5	9.8
6	2.8	11.2
7	3.3	13
8	3.6	14.3
9	4	15.8
10	4.4	17.5
11	4.9	19.6
12	5.4	21.5
13	6	24

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Distribution of Hydraulic Conductivity by Zone within the Model Domain

FIGURE **2**

wood.

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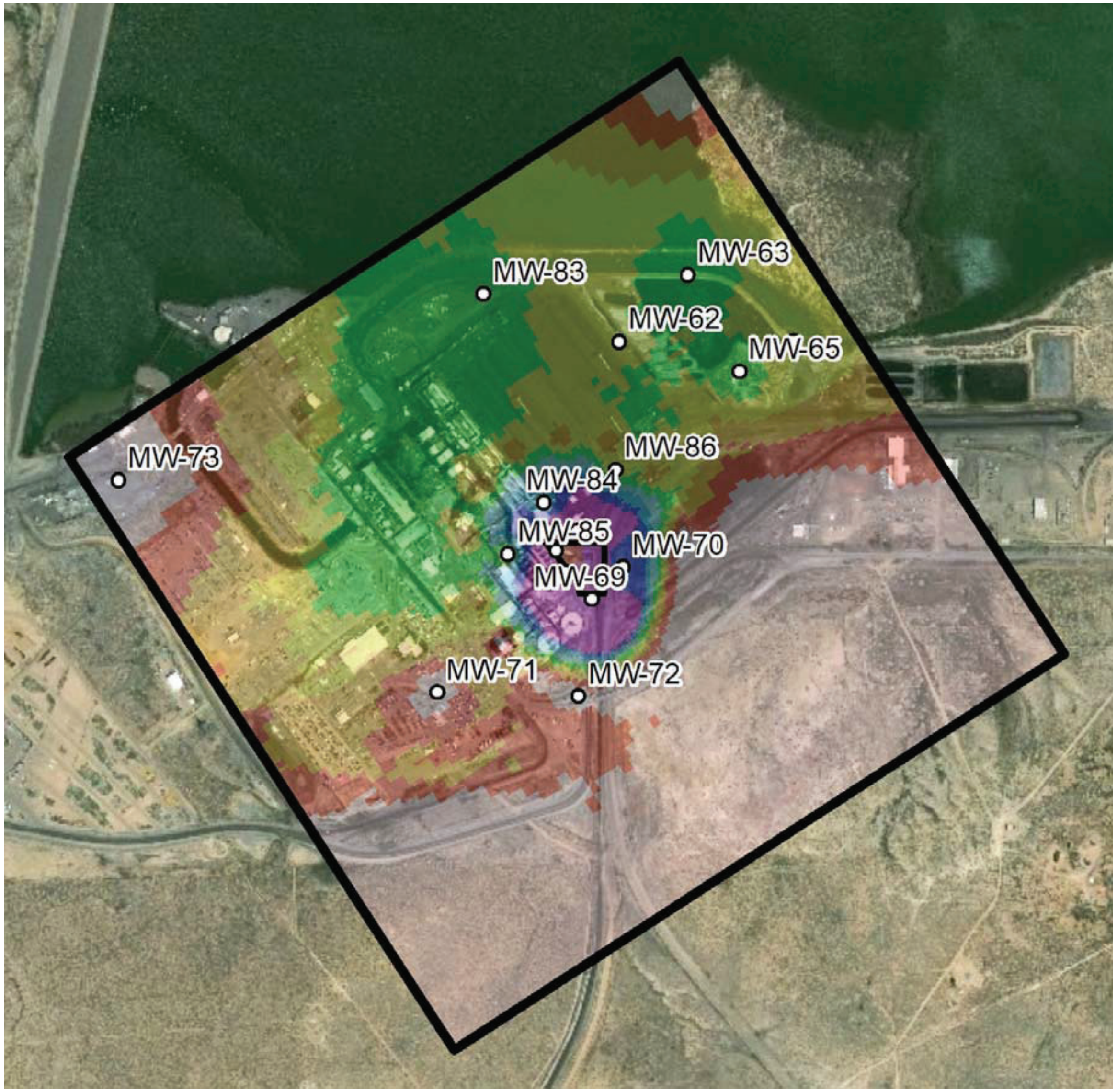

Zone	Initial Fluoride (mg/L)
1	0 - 0.27
2	0.28 - 0.69
3	0.70 – 1.13
4	1.14 – 1.55
5	1.56 – 2.10
6	2.11 – 2.77
7	2.78 – 3.41
8	3.42 – 3.98
9	3.99 – 7.13
10	7.14 – 22.52

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Initial Concentrations of Fluoride at the URS

FIGURE 3

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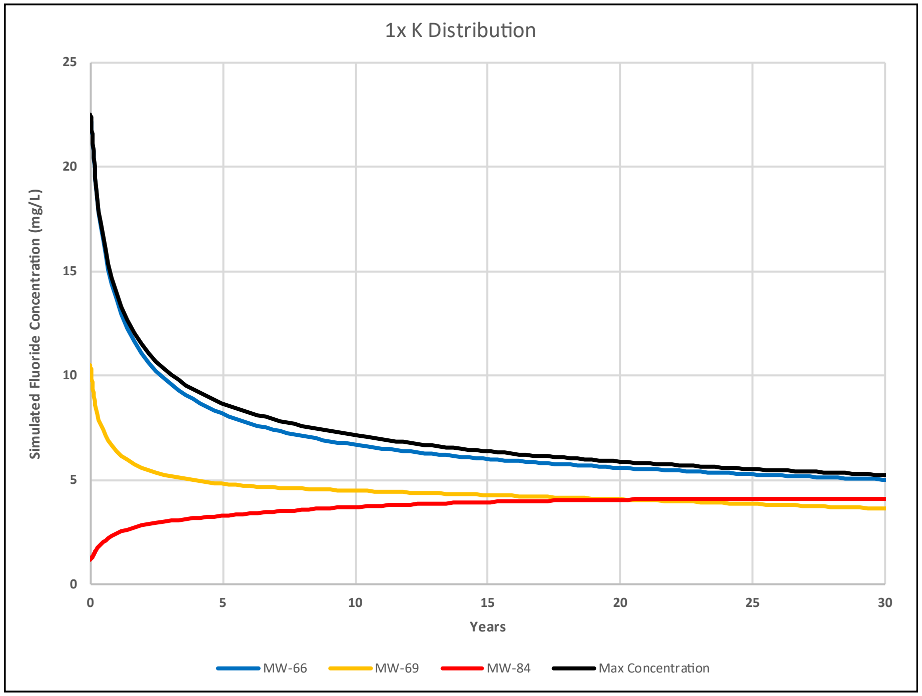

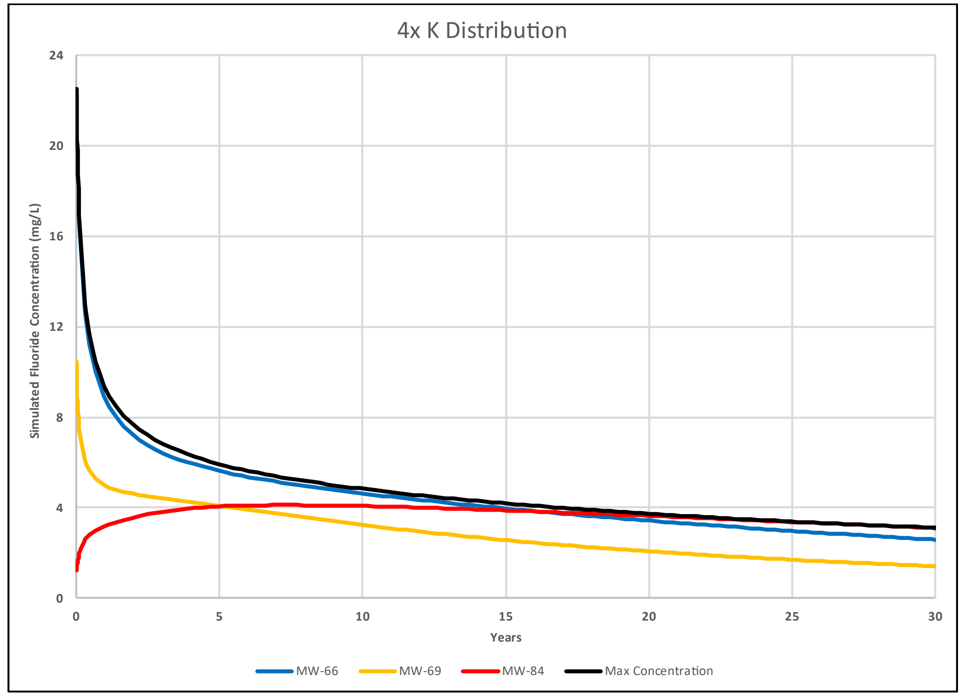

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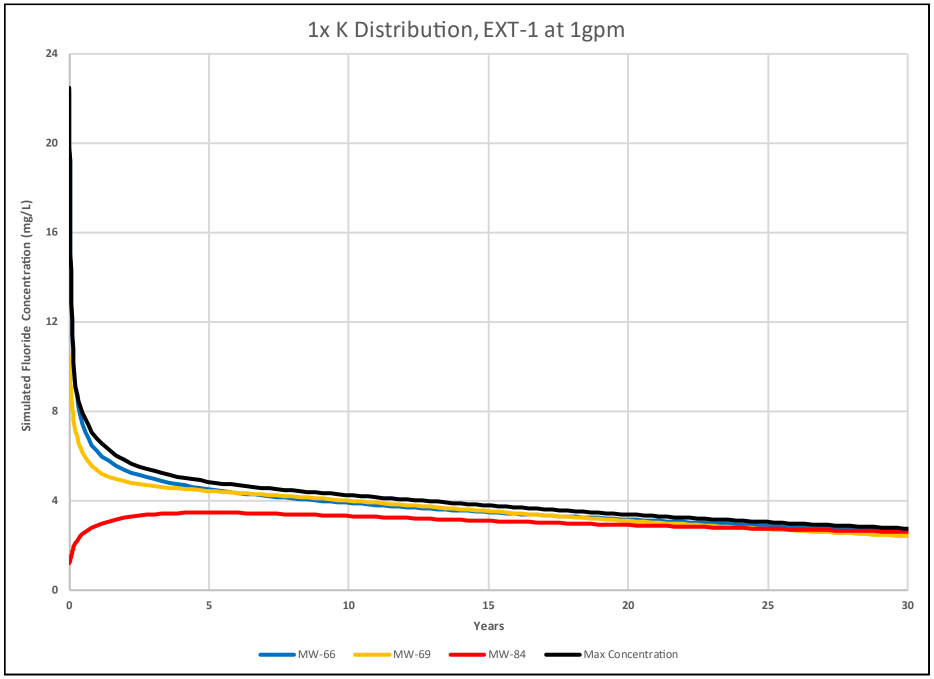
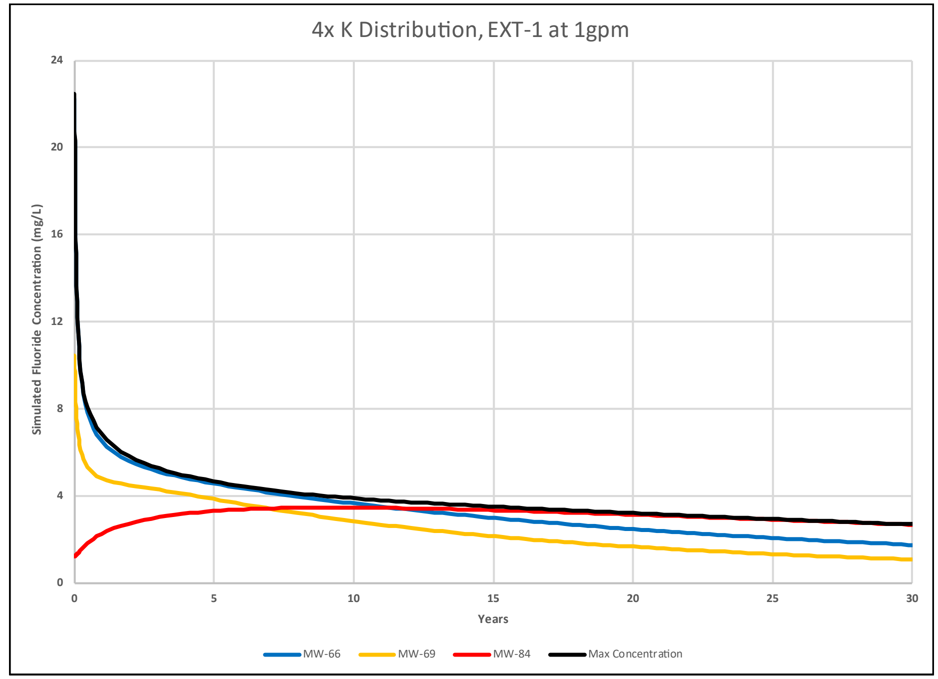
Alternative 1 Simulated Concentrations of Fluoride at Select Wells

FIGURE
4





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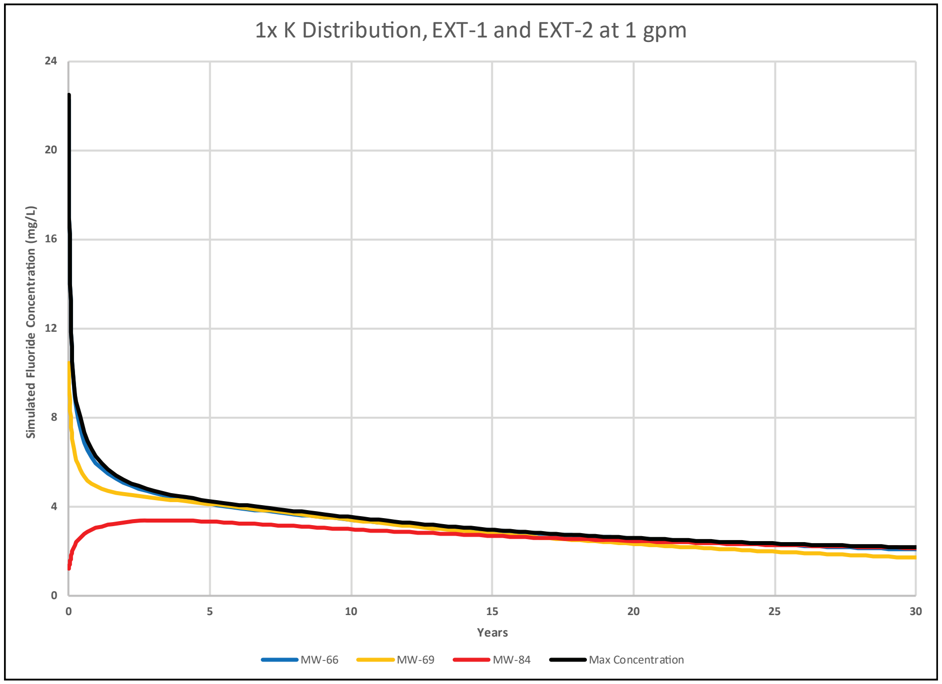
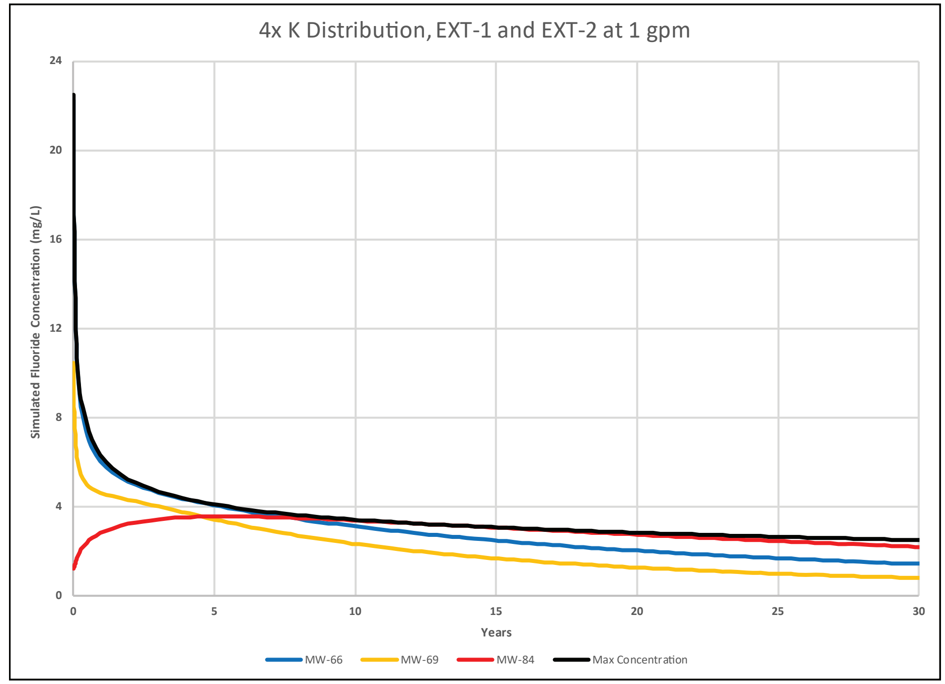
Alternative 2 Simulated Concentrations of Fluoride at Select Wells

FIGURE
5





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Alternative 3 Simulated Concentrations of Fluoride at Select Wells

FIGURE
6

wood.