DOE-EM/GJTAC3078

Moab UMTRA Project
2021 Groundwater Program Report

Revision 0

August 2022

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Revision 0

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Revision History

Revision	Date	Description
0	August 2022	Initial issue.

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Acronyms and Abbreviations

ALS	ALS Environmental
bgs	below ground surface
CA	Contamination Area
CF	configuration
CFR	Code of Federal Regulations
cfs	cubic feet per second
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ft	feet or foot
ft bgs	feet below ground surface
gal	gallon or gallons
gpm	gallons per minute
IA	interim action
kg	kilograms
lb	pound
µmhos/cm	micromhos per centimeter
mg/L	milligrams per liter
mil	million or millions
msl	mean sea level
TDS	total dissolved solids
UMTRA	Uranium Mill Tailings Remedial Action

1.0 Introduction

1.1 Purpose and Scope

The purpose of the annual Groundwater Program Report is to assess the groundwater interim action performance measures the U.S. Department of Energy (DOE) has taken at the Moab Uranium Mill Tailings Remedial Action (UMTRA) Project site. This report describes the Groundwater Program activities for the Moab Project during calendar year 2021 and evaluates the effectiveness of the remediation systems to remove contaminant mass from the groundwater system and protect endangered fish habitats that may develop in the Colorado River adjacent to the site.

1.2 Site History and Background

The Moab Project site is a former uranium ore-processing facility located approximately 3 miles northwest of the city of Moab in Grand County, Utah (Figure 1). The Moab mill operated from 1956 to 1984. When the processing operations ceased, an estimated 16 million (mil) tons of uranium mill tailings accumulated in an unlined impoundment. A portion of the impoundment is within the 100-year floodplain of the Colorado River. In 2001, ownership of the site was transferred to DOE. Since April 2009, tailings have been relocated by rail to a disposal cell 30 miles north, near Crescent Junction, Utah.

Site-related contaminants, primarily ammonia and uranium, have leached from the tailings pile into the shallow groundwater. Some of the more mobile constituents have migrated downgradient and are discharging into the Colorado River adjacent to the site.

In 2005, DOE issued the *Record of Decision for the Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah* (6450-01-P), which includes the cleanup alternative to continue and expand its ongoing active remediation of contaminated groundwater at the Moab site, as necessary. As an interim action (IA), DOE began limited groundwater remediation that involves extraction of contaminated groundwater from on-site remediation wells that is used for dust suppression inside the Contamination Area (CA). In addition, remediation activities also include the utilization of freshwater injection and surface water diversion systems.

2.0 Groundwater Program Description

The Groundwater Program at the Moab site is designed to limit ecological risk from contaminated groundwater discharging to potential endangered fish habitat areas along the Colorado River. This protection is accomplished by removing contaminant mass with groundwater extraction wells. In addition, freshwater injection between the river and the tailings pile creates a hydraulic barrier that reduces discharge of contaminated water to suitable habitat areas. When necessary, surface water diversion takes place in areas of the Colorado River adjacent to the IA well field when suitable habitats develop for endangered young-of-year fish.

Groundwater and surface water monitoring is performed in conjunction with injection and extraction operations and through groundwater elevation and analytical data.

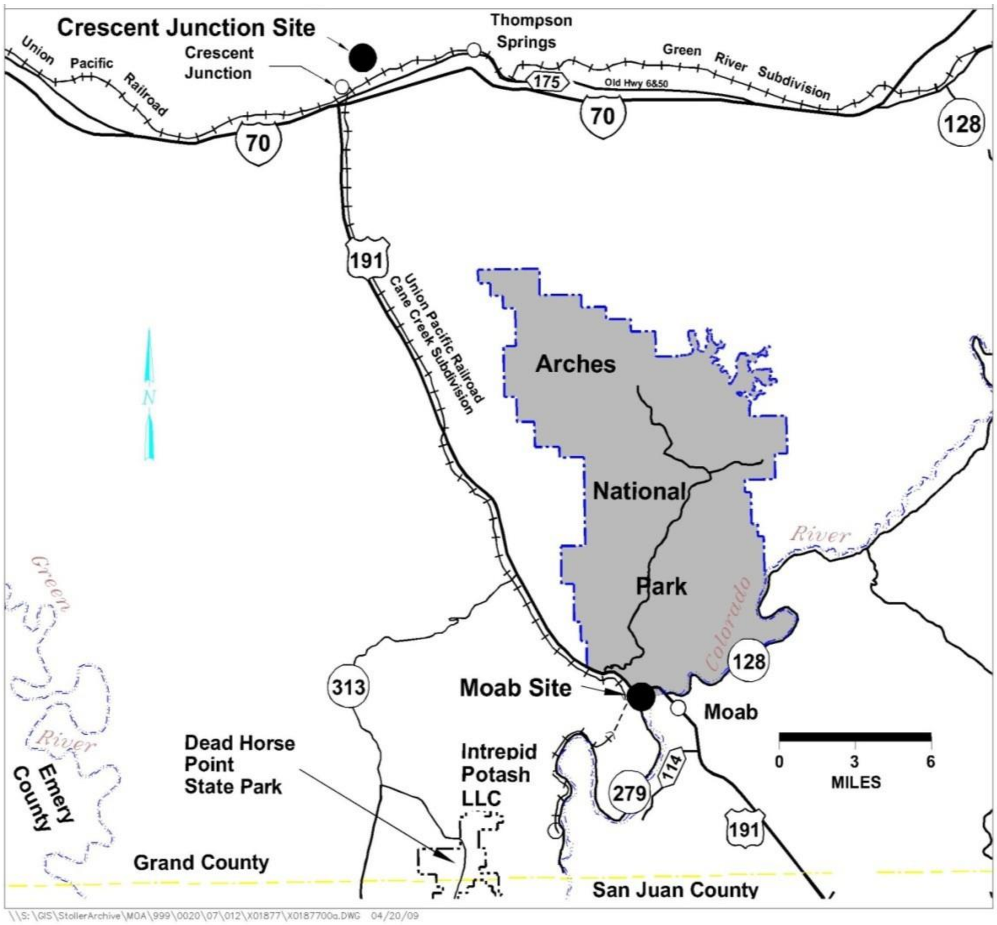

Figure 1. Location of the Moab Project Site

2.1 Interim Action Groundwater System

The Interim Action Groundwater System was installed and began operating the first of several configurations (CFs) of extraction/injection wells that comprise the IA groundwater system in 2003 (Figure 2).

The objectives of the IA system are to: 1) remove contaminant mass through groundwater extraction, 2) reduce the discharge of ammonia-contaminated groundwater to side channels that may be suitable habitat for endangered aquatic species, and 3) to provide performance data to select and design a final groundwater remedy. Contaminated groundwater from the shallow plume is extracted through a series of eight extraction wells (CF5). The IA system also includes injection of filtered river water into the underlying alluvium through remediation wells (CF4) located near the western bank of the river.

A surface water diversion system is designed to deliver fresh water to any area (primarily side channels) adjacent to the IA well field. This system is utilized when an area develops into a suitable habitat for endangered young-of-year fish species and is designed to reduce ammonia concentrations below either the acute or chronic criteria established U.S. Environmental Protection Agency (EPA). Monitoring wells are also part of the IA system for evaluation purposes. In 2021, CF4 wells were used for freshwater injection and extraction operations occurred through the CF5 extraction wells. In addition, the diversion system operated from late June through late August in 2021.

Figure 2. Location of IA Wells

2.2 Hydrology and Contaminant Distribution

The primary hydrogeologic unit present at the Moab site consists of alluvial valley fill deposits. The alluvium is mostly comprised of either the Moab Wash alluvium or the Colorado River basin-fill alluvium. Moab Wash alluvium is composed of fine-grained sand, gravelly sand, and detrital material that travels down the Moab Wash and is deposited along the northwestern boundary of the site with the Colorado River basin-fill alluvium.

The basin-fill alluvium is comprised of two distinct types of material. The upper unit consists mostly of fine sand, silt, and clay and ranges in thickness up to 15 feet (ft) near the saturated zone in some areas. This shallow unit is made of overbank deposits from the Colorado River.

The lower part of the basin-fill alluvium mostly consists of a gravelly sand and sandy gravel, with minor amounts of silt and clay. This deeper, coarse alluvium pinches out to the northwest along the subsurface bedrock contact and thickens to the southwest toward the river more than 450 ft near the deepest part of the basin. The upper silty-sand unit typically has a hydraulic conductivity that ranges from 100 to 200 ft/day.

Because of the conductive nature of the sands and gravels in the subsurface, any fluctuations in the Colorado River flows impact the groundwater surface elevations. Water table contour maps indicate the groundwater in this area discharges into the Colorado River under base flow conditions. Figure 3 is the groundwater surface contour map generated using data collected from May through June 2021, when the Colorado River flows ranged from 2,320 to 8,300 cubic feet per second (cfs).

Most groundwater beneath the site contains total dissolved solids (TDS) concentrations greater than 10,000 milligrams per liter (mg/L) (brackish water and brine). A brine interface naturally occurs beneath the Moab site that is delineated at a TDS concentration of 35,000 mg/L, which is equivalent to a specific conductance of approximately 50,000 micromhos per centimeter (µmhos/cm). The interface moves laterally and vertically during the course of each year in response to changes in river stage.

The tailings pile fluids contain TDS exceeding 35,000 mg/L, which allows this fluid sufficient density to vertically migrate downward in groundwater under previous operating conditions at the site. This former density-driven flow has created a legacy plume of dissolved ammonia that now resides below the brackish water/brine interface. The ammonia beneath the interface represents a potential long-term source of contamination to the upper alluvial groundwater system.

Since the cessation of milling operations at the site in 1984, the flux of relatively fresh water entering the site upgradient of the tailings pile may have diluted the ammonia concentrations in the shallow groundwater (Figure 4).

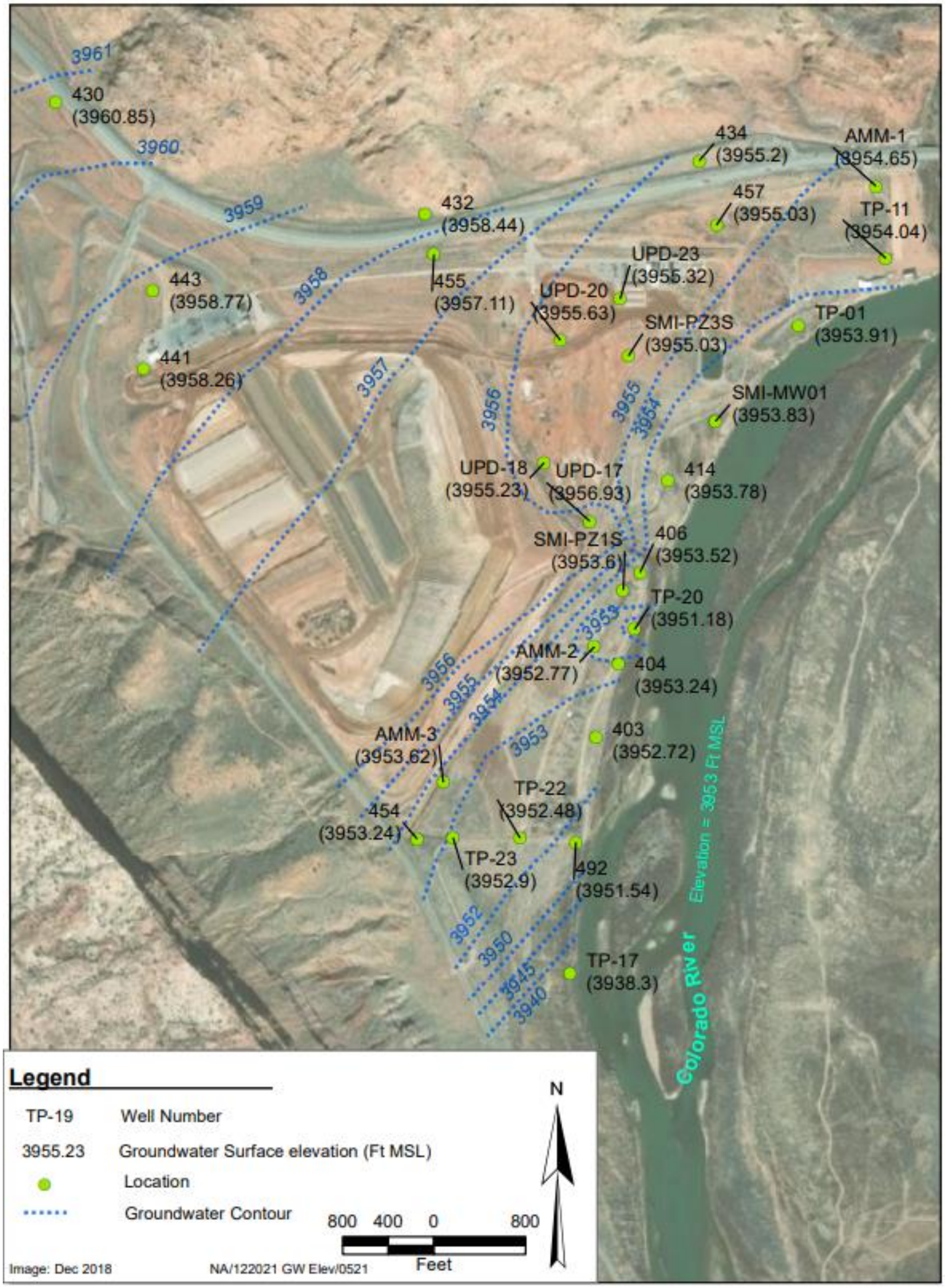

Figure 3. Site-wide Groundwater Elevations May/June 2021

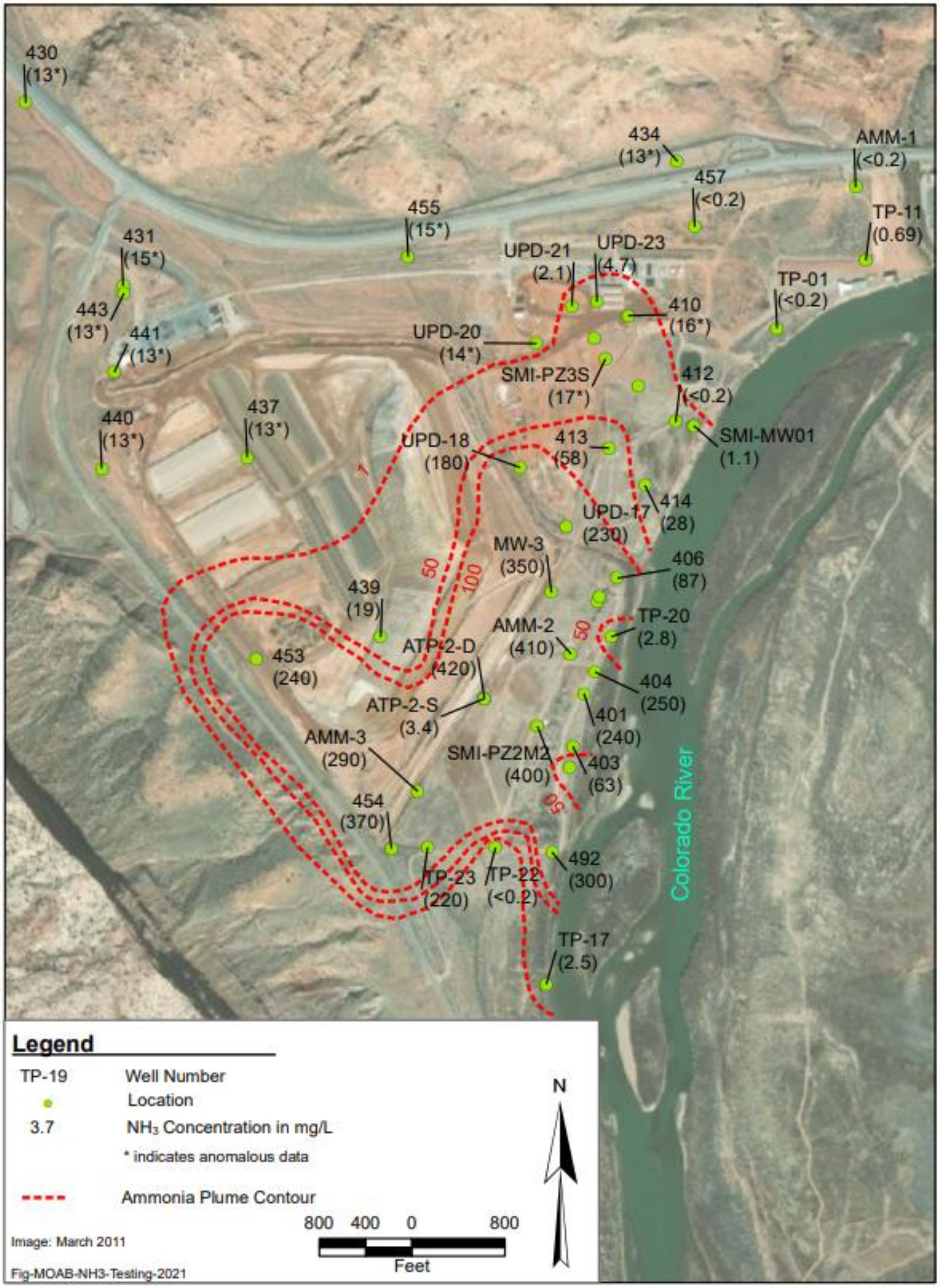

Figure 4. Ammonia Plume in Shallow Groundwater May/June 2021

Oxidation of ammonia to nitrate or nitrogen may also contribute to lower ammonia concentrations observed in the upgradient shallow groundwater beneath the tailings pile, where aerobic conditions are more likely; however, there is no flushing of the legacy plume by an advective flow of fresh water due to density stratification of the brine zone. Figure 4 shows the ammonia plume in May/June 2021.

Figure 5 shows the distribution of dissolved uranium in shallow groundwater in 2021. The uranium groundwater standard of 0.044 mg/L is based on Table 1 in Title 40 Code of Federal Regulations Part 192, Subpart A (40 CFR 192A), "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites."

2.3 Surface Water/Groundwater Interaction

Previous investigations have shown that Colorado River flows impact the groundwater elevations and contaminant concentrations in the well field. For the majority of the year, when the river is experiencing baseflow (less than 4,000 cfs), groundwater discharges into the river (river gaining conditions). As the river flow increases in response to the spring runoff, the river changes from gaining to losing conditions and a freshwater lens develops in the aquifer underlying the well field.

During higher flows, the groundwater gradient direction reverses adjacent to the river, and the groundwater contaminant concentrations are diluted. Once these flows subside, the river switches back from losing to gaining, and the groundwater gradient direction is re-established towards the river (to the southeast).

Figure 6 displays the groundwater elevation versus the elevation of the Colorado River in 2021. The elevation of the Colorado River was calculated using the river flows from the USGS Cisco gaging station and converting the flow to an elevation using the site rating curve included in the *Moab UMTRA Project Flood and Drought Mitigation Plan* (DOE-EM/GJTAC1640). The Colorado River Basin experienced a low water year in 2021 likely due to dry soil conditions despite an average snowpack.

Between January and May 2021, the Colorado River was under gaining conditions (when the groundwater elevation was higher than the river surface elevation). The river switched to losing conditions (groundwater elevation lower than the river surface elevation) in early May through mid-June. Monsoonal moisture impacted the river flow through the fall, but it is unlikely that the river switched to loosing conditions during the short-term flow fluctuations.

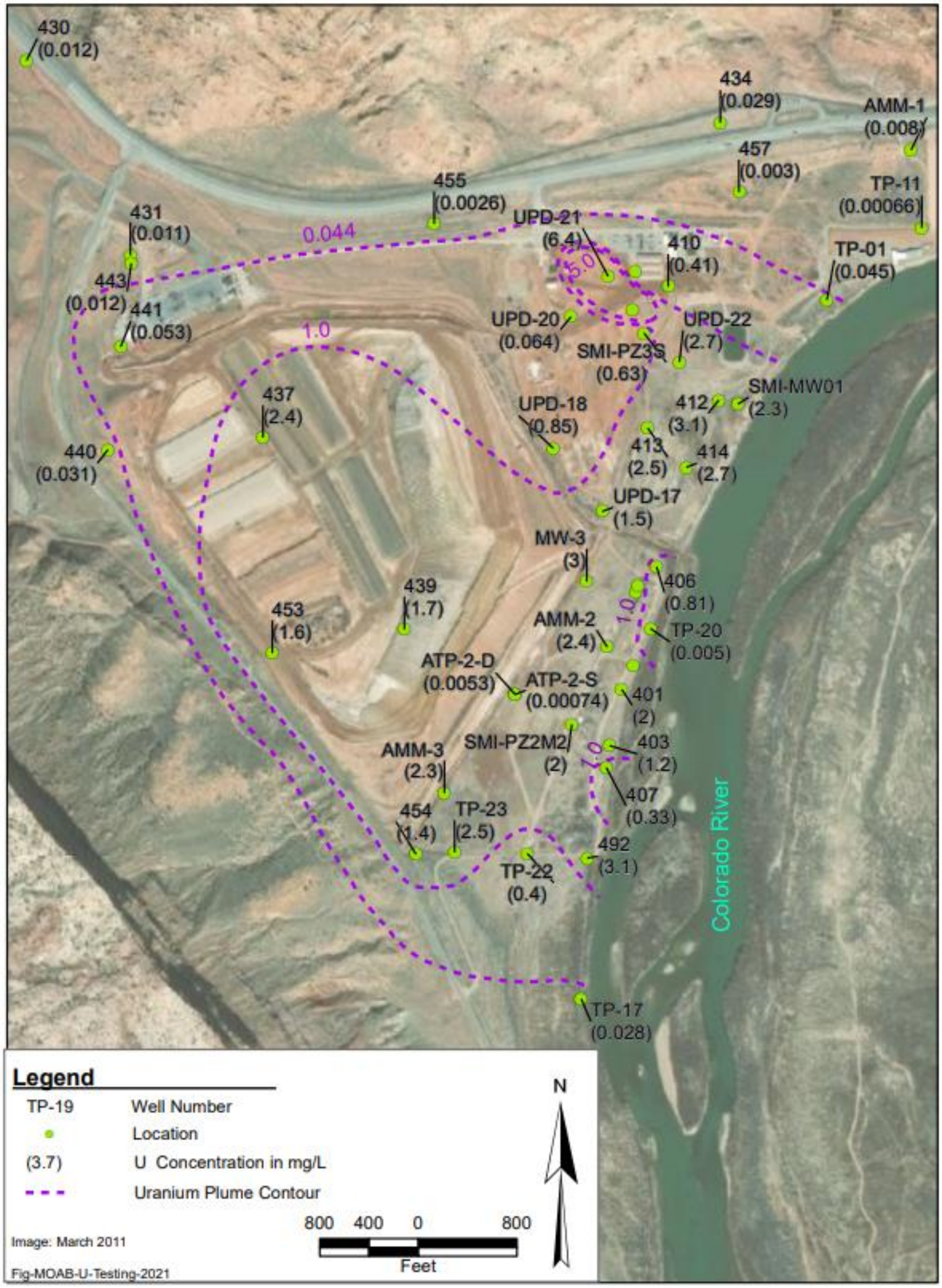

Figure 5. Uranium Plume in Shallow Groundwater May/June 2021

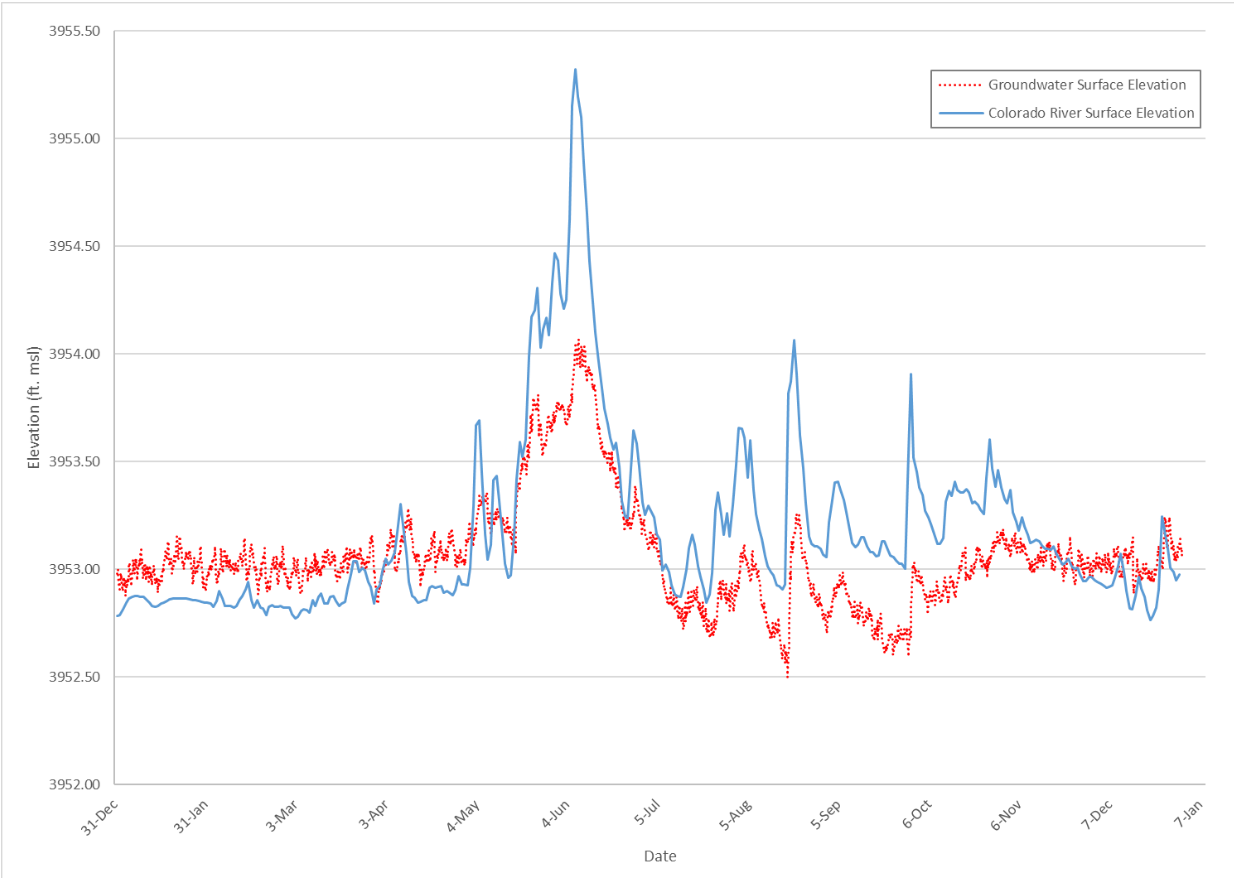

Figure 6. Groundwater Surface Elevation Compared to the Colorado River Surface Elevation 2021

3.0 Methods

Well field performance is assessed by measuring extraction/injection rates of remediation wells, measuring water levels, and the collection of samples from surface water locations, extraction wells, and monitoring wells for analytical analysis.

3.1 Remediation Well Extraction

Each extraction well contains a flow meter that displays the instantaneous flow rate in gallons (gal) per minute (gpm), the cumulative total volume extracted, and the net volume since the last reset of the internal memory. Flow meter readings are manually recorded on a weekly basis during extraction operations and are used in conjunction with water quality data to calculate the contaminant mass removal and evaluate the performance of the system.

This extracted groundwater is used as dust suppression in the CA. Any contaminants deposited as salts in the CA will eventually be removed for disposal with tailings and transported to the Crescent Junction disposal site.

3.2 Remediation Well Injection

Each injection well contains a flow meter that displays the instantaneous injection rate (in gpm) and the total volume. Flow meter readings are recorded manually on a weekly basis during injection operations. Water level data are used to calculate the elevation of freshwater mounding in response to the injection activities.

3.3 Water Levels

Groundwater levels are recorded in the IA well field on a weekly basis during injection operations to monitor groundwater drawdown and freshwater mounding. A water-level indicator is used to measure the depth to groundwater (below top of casing). Data logging equipment with pressure transducers are installed at various locations to measure water levels more frequently.

3.4 Water Quality

Select well and surface water locations are sampled at various times, depending on the purpose of the sampling event. Prior to collecting a sample, the field parameters (which include temperature, pH, and conductivity) are measured and recorded. Observation wells are primarily sampled with dedicated down-hole tubing and a peristaltic pump, while extraction wells are sampled with dedicated submersible pumps.

Water samples are collected from observation wells at various depths and locations to monitor the primary contaminants of concern, ammonia (as $NH\text{-}N_3$) and uranium. All sampling was performed in accordance with the *Moab UMTRA Project Surface Water/Groundwater Sampling and Analysis Plan* (DOE- EM/GJTAC1830). Samples were shipped overnight to ALS Environmental (ALS) in Fort Collins, Colorado, for analysis.

4.0 Groundwater Extraction System Operations and Performance

4.1 Interim Action Operations

This section provides information regarding the IA well field extraction performance during the 2021 pumping season. This section also includes a discussion of the total groundwater extraction rate, hydraulic control, mass removal, and water quality. Appendix A contains tables of well construction information (Table A-1), a chronology of 2021 activities (Table A-2), pumping volumes (Table A-3), and mass removal (Tables A-4 and A-5).

Groundwater extraction operations are controlled by an automated system, which utilize extraction wells that supply groundwater directly to two 21,000-gal holding tanks. The water is then pumped into a 12,000-gal Klein tank, where it transferred to water trucks and used for dust suppression in the CA.

Extraction operations are limited by how much water is needed for dust suppression in the CA and by weather conditions (wet weather leads to less extraction, and warm, windy weather leads to more extraction). The primary water truck used to disperse extraction water over the tailings was inoperable during July leading to limited extraction volumes through these warmer months and an overall decrease annually compared to 2020.

The 2021 extraction schedule was focused on optimizing ammonia and uranium mass removal and rotating through each of the eight CF5 remediation wells. In 2021, the extraction system was re-started in mid-March and operated consistently until the system was winterized in mid-November. Figure 7 provides a graphic summary of when the 8.0 mil gal of groundwater was extracted from CF5 in 2021. The figure also identifies the period the primary water truck was inoperable.

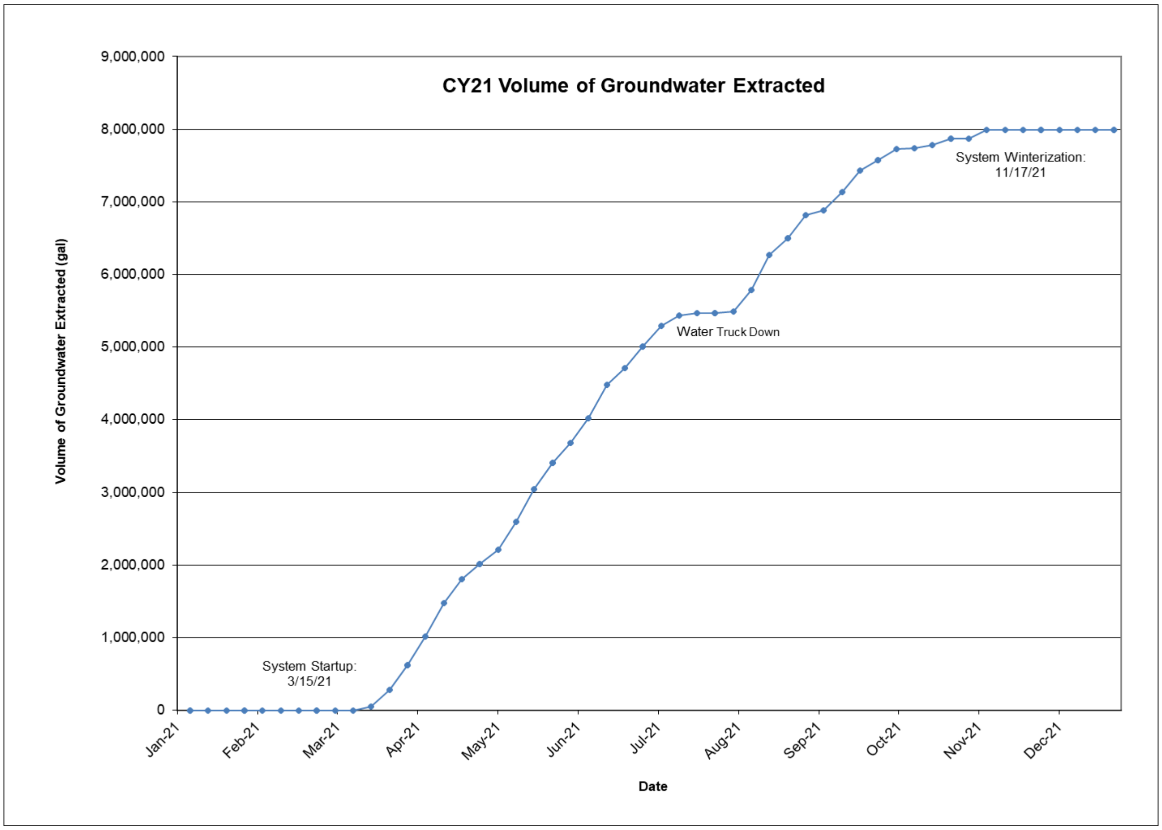

Figure 7. Cumulative Volume of Extracted Groundwater during 2021

4.2 CF5 Groundwater Volume Extracted and Contaminant Mass Removal

Monthly extraction volumes for each of the eight extraction wells are listed in Table A-3. The majority of the 2021 extracted water was removed from wells 0813 (1.93 mil gal) and 0816 (1.76 mil gal). The remaining CF5 wells extracted between approximately 365,000 and 1.07 mil gal in 2021. Extraction operations were maximized in June, when 1.60 mil gal of groundwater was extracted.

The 2021 ammonia and uranium mass removal is presented in Tables A-4 and A-5. These values are based on groundwater extraction volumes recorded by individual flow meters. The mass of ammonia and uranium removed from groundwater by the extraction wells was calculated by multiplying the extracted volume by the corresponding contaminant mass concentration measured in each well's discharge.

The concentrations used in these calculations were drawn from analytical data presented in Table 1. In 2021, a total of 16,123 pounds (lb) (7,329 kilograms [kg]) of ammonia and 152.0 lb (69.1 kg) of uranium were extracted from the groundwater system.

Table A-4 shows that extraction wells 0813 and 0816 removed the most ammonia mass at 4,460 lb (2,027 kg) and 3,063 lb (1,392 kg), respectively. Estimated mass withdrawals of uranium at CF5 extraction wells are presented in Table A-5, which shows the greatest mass of uranium was extracted from well 0813 (35.3 lb, or 16.0 kg).

4.3 Groundwater Chemistry

Groundwater samples were collected from the CF5 extraction wells in May and September 2021 (Table 1). Ammonia concentrations ranged from 71 mg/L (well 0814) to 400 mg/L (wells 0812 and SMI-PW02), and the uranium concentration ranged from 1.7 mg/L (well 0813) to 2.8 mg/L (well SMI-PW02). Specific conductance ranged from approximately 14,079 µmhos/cm at well 0813 (northern end of CF5) to 30,676 µmhos/cm at well 0810 (located at the southern end of CF5).

Figures 8 through 11 are time-versus-concentration trend plots that display trends of the CF5 extraction wells from 2010 through 2021, which represents the majority of the CF5 well field lifespan (extraction was started in April 2010). Figure 8 is the time versus ammonia concentration trend plot for extraction wells 0810 through 0813 and SMI-PW02, all of which are located along the CF5 southeastern boundary. Figure 9 displays the ammonia concentration trend plots for CF5 wells 0814 through 0816, which are located closer to the base of the tailings pile. Figures 10 and 11 are the time-versus-uranium concentration trend plots for the same sets of wells.

Taking into account all eight extraction wells, the ammonia concentrations continue to be significantly higher (in some cases twice as high) in the samples collected from wells located along the CF5 southeastern boundary compared to the wells located along the toe of the tailings pile. A similar trend is not apparent regarding the uranium concentrations, with both lines of wells having very similar results. In general, ammonia contaminant concentrations associated with samples collected from all CF5 have been gradually decreasing. Uranium concentration trends show little change over time. Most wells show a slight decrease in concentrations, whereas the northern most wells (well 0813 and 0816) show a slight upward trend.

The data from wells AMM-2 and SMI-PZ2M2 provide some insight on how the CF5 extraction wells are impacting the groundwater system. Well AMM-2 is located approximately 100 ft southeast of extraction well 0813, and well SMI-PZ2M2 is within the well SMI-PW02 cluster. Samples have been consistently collected from these locations at depths of 48 and 56 ft bgs, respectively.

Figure 12 presents the ammonia concentrations measured from these locations along with linear trend lines for each data set. As shown in this plot, the trend lines for both data sets are displaying a decreasing ammonia concentration since 2009. The trend line associated with well SMI-PZ2M2 exhibits a larger decrease in the concentrations, likely in response to this monitoring well’s proximity to an extraction well compared to AMM-2.

Figure 13 is a similar plot for the uranium concentrations. Both trend lines show the uranium concentrations are increasing. Also, samples collected during previous flooding conditions with lower concentrations than normal conditions may be affecting the slope of the data trends.

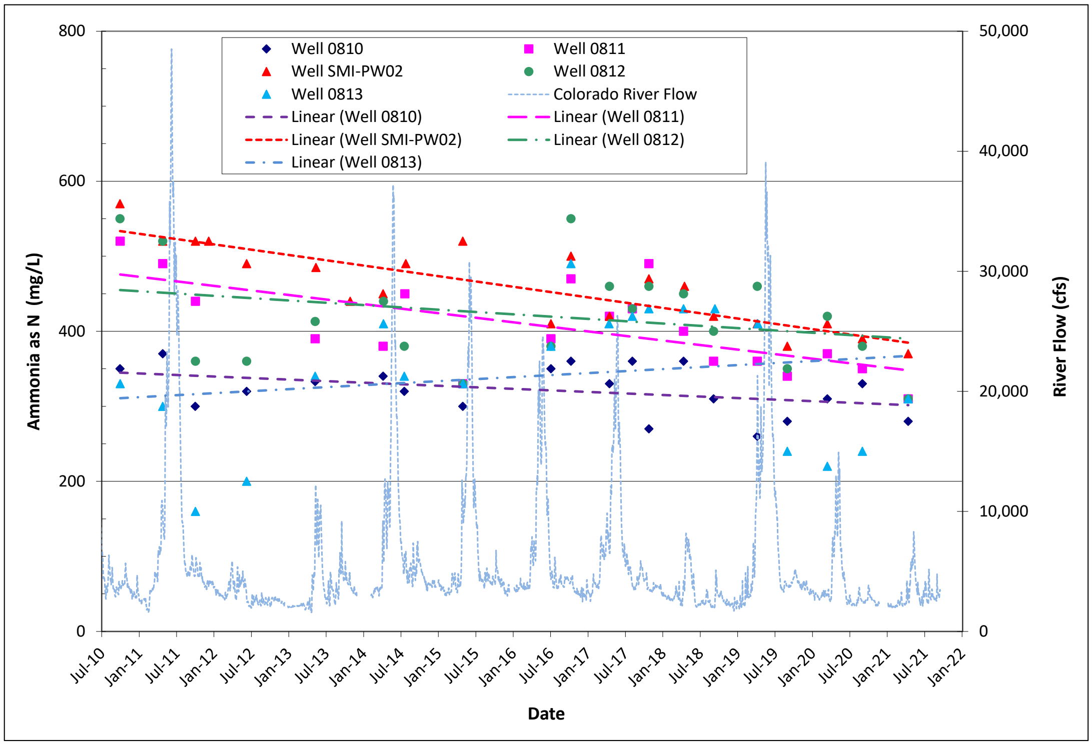

Figure 8. CF5 Extraction Wells 0810, 0811, 0812, 0813, and SMI-PW02 Time versus Ammonia Concentration Plot

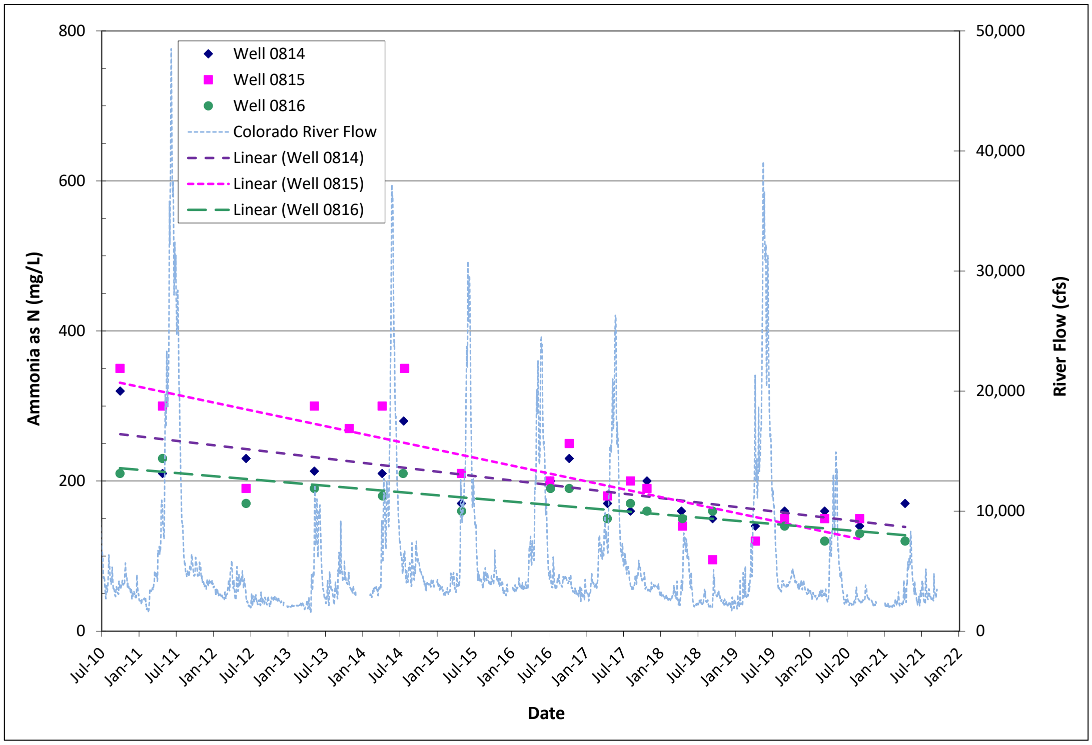

Figure 9. CF5 Extraction Wells 0814, 0815, and 0816 Time versus Ammonia Concentration Plot

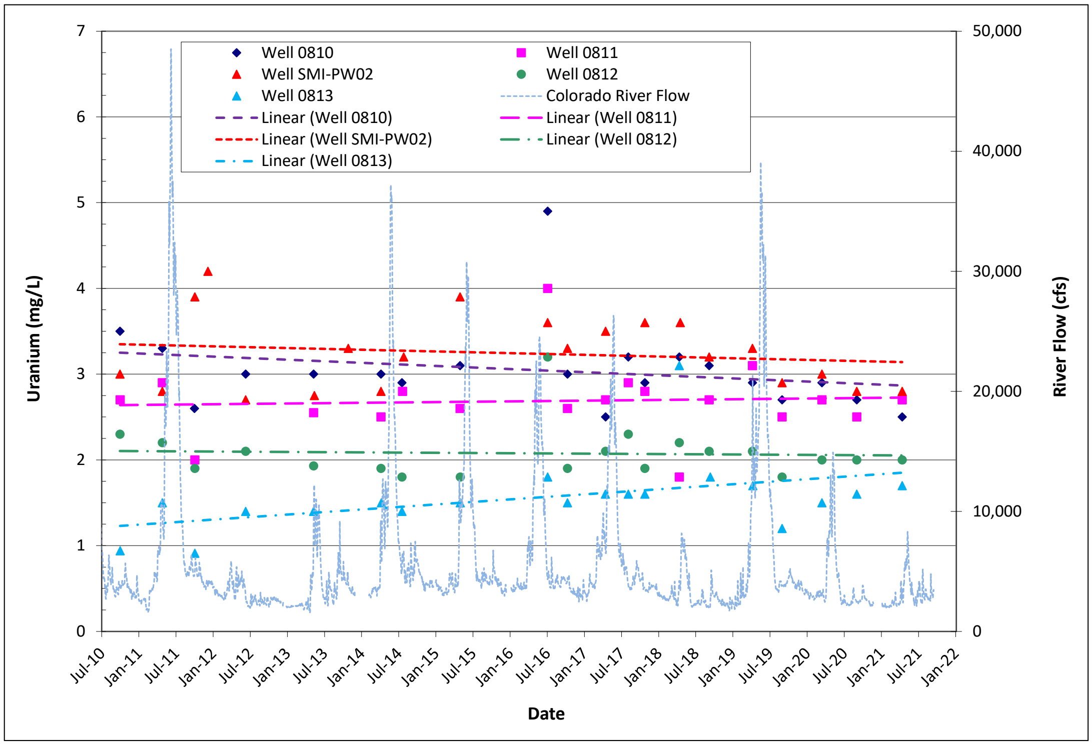

Figure 10. CF5 Extraction Wells 0810, 0811, 0812, 0813, and SMI-PW02 Time versus Uranium Concentration Plot

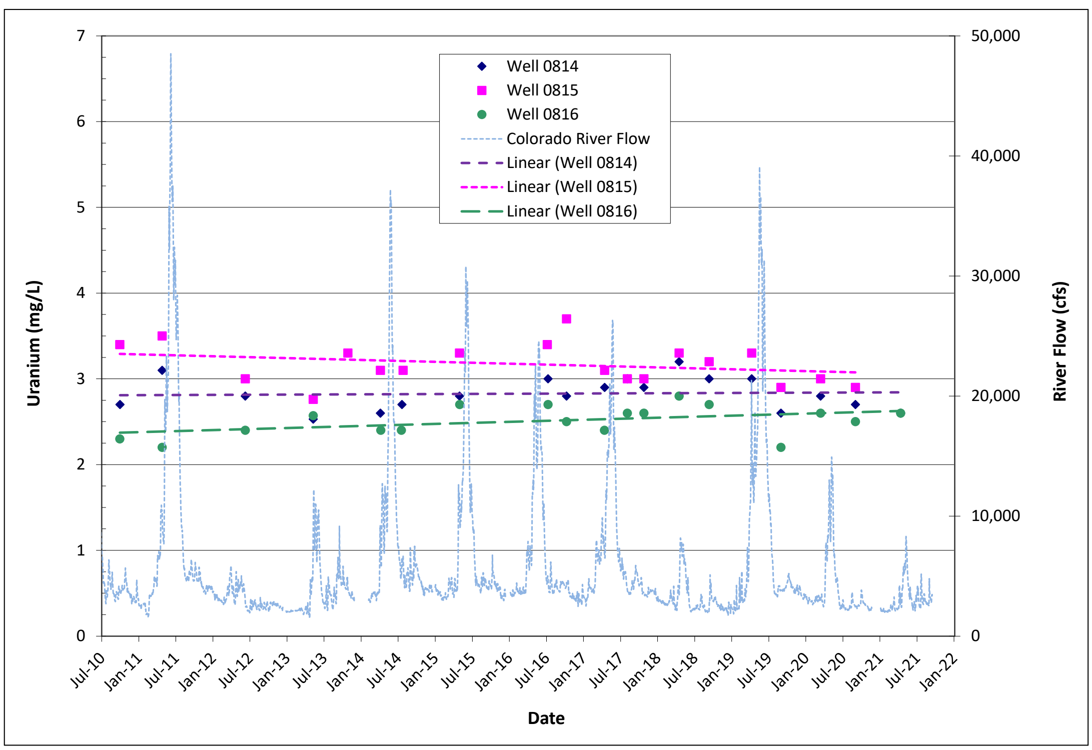

Figure 11. CF5 Extraction Wells 0814, 0815, and 0816 Time versus Uranium Concentration Plot

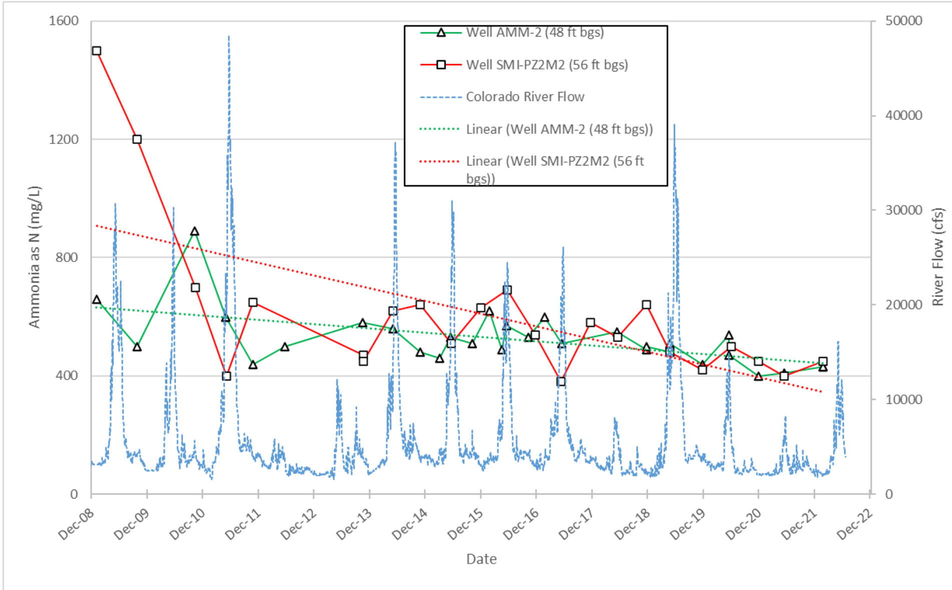

Figure 12. Monitoring Wells AMM-2 and SMI-PZ2M2 Time versus Ammonia Concentration Plot and Trend Lines

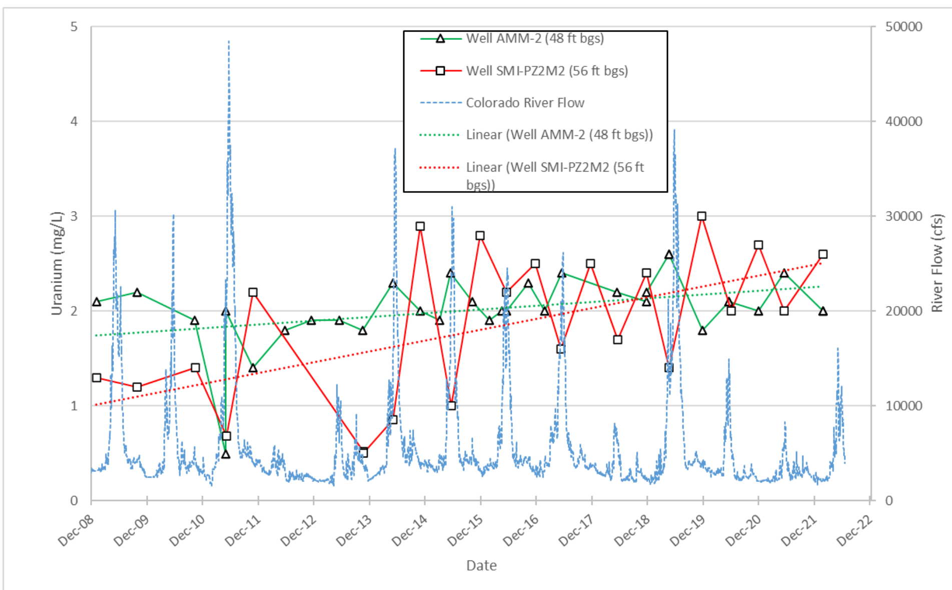

Figure 13. Monitoring Wells AMM-2 and SMI-PZ2M2 Time versus Uranium Concentration Plot and Trend Lines

Table 1. CF5 Ammonia, Uranium, and Specific Conductance Results 2021

Location	Date	Ammonia (mg/L)	Uranium (mg/L)	Specific Conductance (µmhos/cm)
0810	5/11/21	280	2.5	30,676
	9/15/21	260	2.6	25,757
0811	5/11/21	310	2.7	21,030
	9/15/21	270	2.0	16,897
0812	5/11/21	310	2.0	18,973
	9/15/21	400	2.0	16,519
0813	5/11/21	310	1.7	14,079
	9/15/21	300	1.8	14,395
0814	5/11/21	170	2.6	23,352
	9/15/21	71	2.5	19,660
0815	9/15/21	110	2.7	18,826
0816	5/11/21	120	2.6	21,468
	9/15/21	120	2.4	20,856
SMI-PW02	5/11/21	370	1.8	29,025
	9/15/21	400	2.8	23,948

5.0 Freshwater Injection System Operation and Performance

The main objective of freshwater injection is to form a hydrologic barrier between the tailings pile and the Colorado River side channel that potentially develops into a suitable young-of-year fish habitat. In addition, the contaminant concentrations are diluted prior to discharging into the river. The injection system uses Colorado River water that is diverted to the freshwater pond. This water is pumped through a sand and gravel media, and then through 1 to 5 micron bag filter prior to being injected into the CF4 remediation wells. Construction information for the CF4 wells can be found in Table B-1 of Appendix B. Table B-2 also contains a chronology of CF4 activities.

Configuration 4 is located in the southern portion of the IA wellfield adjacent to a prominent side channel the typically remains open to the main channel until the river flow drops below 3,000 cfs and a backwater (open at the bottom and closed off at the top) forms. During 2021, a suitable habitat was present from late June through late August.

5.1 Injection Performance

Freshwater injection into the CF4 wells occurred consistently April through December. Injection was off during February and March while the pump was being replaced. A new pump was installed March 30. In 2021, approximately 8.8 mil gal of freshwater were injected in CF4. Figure 14 provides a graphic summary of the cumulative volume of freshwater injected into CF4. The injection wells are typically developed annually to maintain efficiency. External factors prevented the redevelopment of the injection wells in 2021.

Factors that limited injection included sand filter operation issues, system pressure issues, leaks in the system, and replacing the pump. The injection system and the 75 HP irrigation system were utilized for surface water diversion into the backwater channel June 22 through August 25.

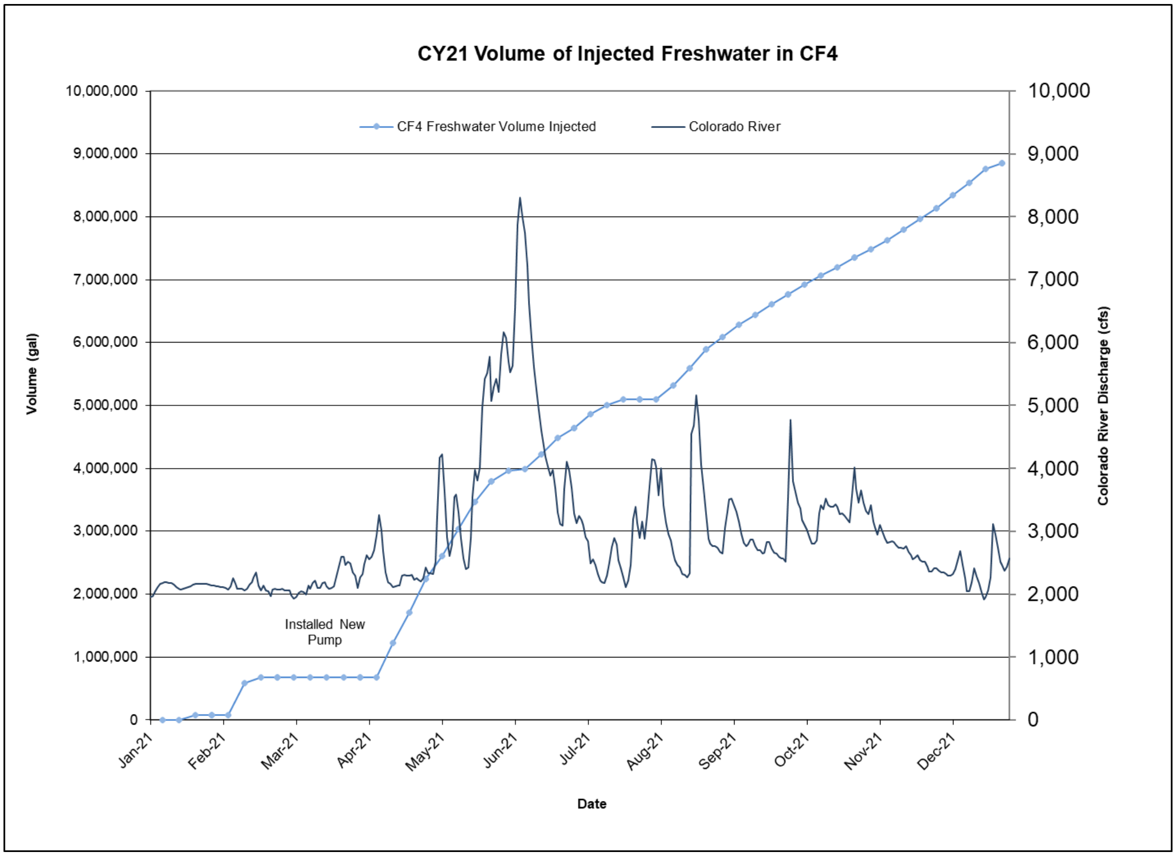

Figure 14. Cumulative Volume of Injected Freshwater during 2021

5.2 Observation Well Chemical Data Summary

Groundwater samples were collected from the CF4 observation wells during January, May, and September 2021 to assess the effectiveness of the system (Table B-3). The January samples were collected during baseflow, the May samples were collected during high river flow, and the September samples were collected after a small late season peak.

Table 2. CF4 Observation Well Ammonia Concentrations, January, May, and September 2021

Location	Sample Depth (ft bgs)	Relative Location to Injection Wells	January 2021 Concentration (mg/L)	May 2021 Concentration (mg/L)	September 2021 Concentration (mg/L)
0780	28	Upgradient	250	26	5.2
0781	46	Upgradient	1200	850	900
0782	33	Upgradient	290	100	310
0783	18	Upgradient	60	41	1.4
0784	18	Downgradient	5.1	0.2#	0.2#
0785	18	Downgradient	88	0.77	0.2#
0786	28	Downgradient	450	3.6	19
0787	36	Downgradient	1200	440	660

ft bgs = feet below ground surface, # = the result was below the detection limit

The CF4 wells are screened to deliver freshwater into the subsurface from 15 to 35 feet below ground surface (ft bgs). Samples collected from observation wells 0780, 0783, 0784, 0785, and 0786 are all screened within this shallow zone, and represent the ammonia concentrations directly impacted by the freshwater injection. Wells 0781, 0782, and 0787 represent the conditions near the bottom of the zone where the CF4 injection wells deliver freshwater into the subsurface when the system is active. Samples collected from these locations typically have the highest concentrations.

When the samples were collected in January, the system had been inactive for 6 months. The May samples were collected after one month of the system running where the September samples were collected after the system had been active for 5 months. The ammonia concentrations are provided in Table 2 and are graphically displayed in Figure 15 for the upgradient observation wells and Figure 16 for the downgradient observation wells. Included in these plots are the volume of freshwater injected on a weekly basis in 2021.

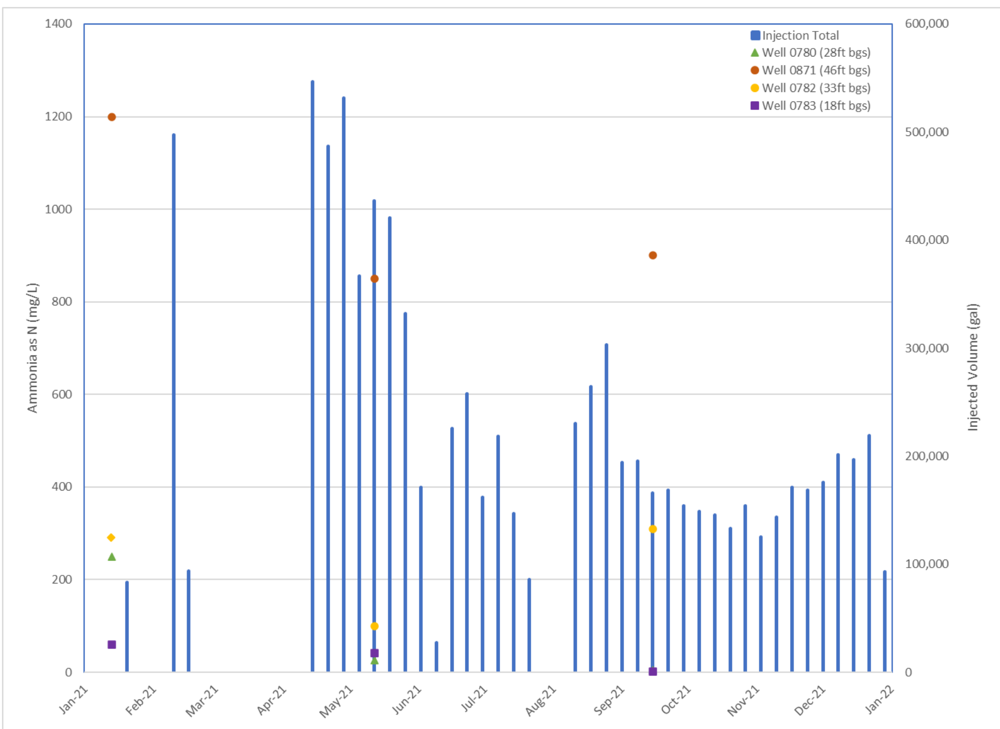

Figure 15. CF4 Upgradient Observation Wells 2021 Ammonia Concentrations

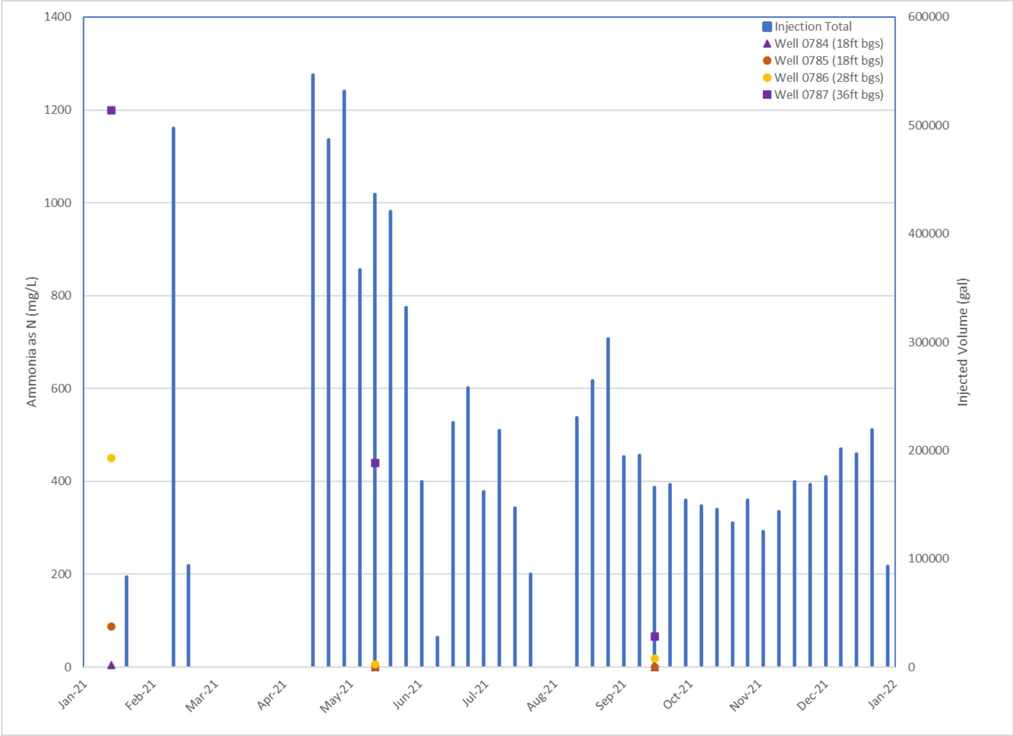

Figure 16. CF4 Downgradient Observation Wells 2021 Ammonia Concentrations

5.3 Freshwater Mounding

Water levels were collected on a regular basis during injection operations. To determine the amount of freshwater mounding in each well, the water level data were plotted against the levels measured in the background well 0405.

The water levels in each well were adjusted to match well 0405 during non-pumping baseflow conditions. Tables 3 and 4 summarize the mounding data that are shown in Figures B-1 to B-10 (Appendix B) for the injection wells. Mounding data were collected when the injection system was operating and not undergoing maintenance. Figures B-11 through B-18 illustrate the mounding data in CF4 observation wells.

Figure 17 displays the CF4 groundwater elevations in monitoring and injection wells in August 2021 during injection operations. The highest freshwater mounding occurs within 30 ft of the injection system. The amount of mounding was dependent on the individual well’s efficiency and the corresponding injection rate.

Table 3 presents the maximum mounding measured in each of the injection wells and the corresponding injection rate. The maximum mounding in the CF4 observation wells is presented in Table 4 and varied from 0.65 to 3.40 ft in the upgradient wells and from 0.66 to 1.91 ft in the down gradient wells.

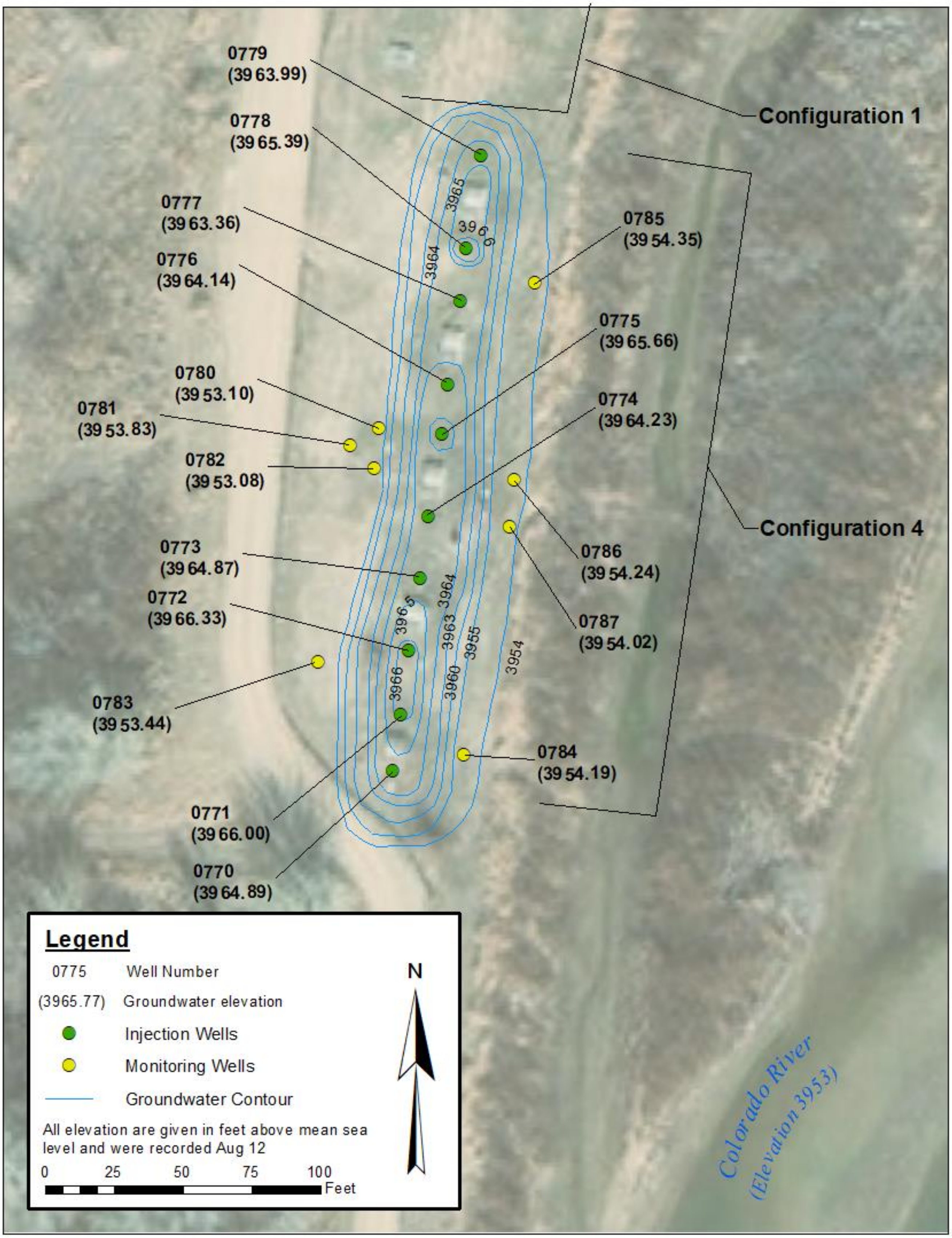

Figure 17. Freshwater Mounding at CF4 during Injection Operations August 2021

Table 3. Maximum Mounding Observed in CF4 Injection Well, 2021

Well	Date	Type	Maximum Mounding (ft)	Injection Rate (gpm)
0770	8/18/21	Injection Well	13.00	3.59
0771	8/18/21	Injection Well	13.44	4.16
0772	4/21/21	Injection Well	13.76	3.75
0773	5/5/21	Injection Well	13.58	>0.00
0774	10/6/21	Injection Well	12.90	6.49
0775	8/12/21	Injection Well	13.30	7.33
0776	5/5/21	Injection Well	13.09	6.43
0777	5/26/21	Injection Well	12.83	3.27
0778	8/18/21	Injection Well	13.13	4.05
0779	2/17/21	Injection Well	13.47	2.70

Table 4. Freshwater Mounding Observed in CF4 Observation Wells, 2021

Well	Date	Location	Maximum Mounding (ft)	Distance from Injection Source (ft)
0780	5/24/21	Upgradient	1.78	25
0781	5/24/21	Upgradient	1.15	30
0782	5/24/21	Upgradient	0.65	25
0783	2/8/21	Upgradient	3.40	30
0784	5/24/21	Downgradient	0.66	30
0785	5/24/21	Downgradient	0.82	25
0786	5/24/21	Downgradient	1.12	30
0787	11/1/21	Downgradient	1.91	30

6.0 Surface Water Monitoring

Surface water monitoring occurs during the site-wide sampling event, when samples are collected upgradient of the site, on site, and downgradient of the site. The backwater channel adjacent to CF4 is monitored from June to September to determine if and when it becomes a suitable habitat for young-of-year fish. By late June in 2021, the high waters had receded enough for the side channel to be considered a viable habitat. On August 25, the river flow had decreased to below 3,000 cfs and the backwater habitat was no longer considered suitable because the channel was full of sediment.

6.1 Site-wide Surface Water Monitoring

Site-wide surface water sampling was conducted adjacent to the well field in May 2021 (locations are shown on Figure 18). The results of this sampling event can be found in the *Moab UMTRA Project Groundwater and Surface Water Monitoring January through June 2021* (DOE-EM/GJTAC3060) and the results are presented in Table 5.

The ammonia concentrations measured during this event w mostly below the detection limit, and location 0226 had a concentration of 4 mg/L, which is above the Environmental Protection Agency (EPA) acute and chronic criteria. This location was not considered a suitable endangered fish habitat at the time and no dead or distressed fish were noted.

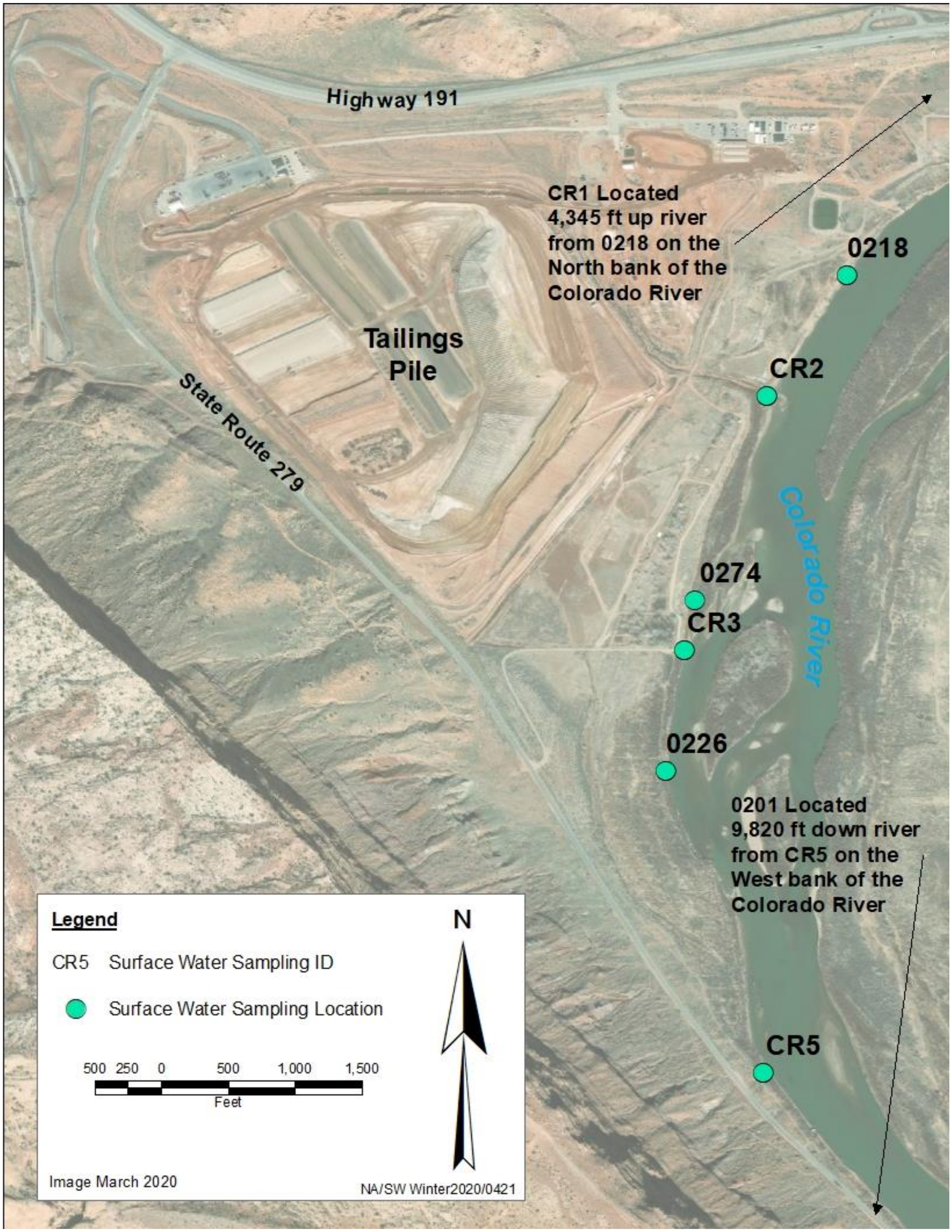

Figure 18. 2021 Site-wide Surface Water Sampling Locations

Table 5. May Through July 2021 Site-wide Surface Water Ammonia Concentrations and Comparisons to EPA Acute and Chronic Criteria

Location	Date	Temp (ºC)	pH	June 2021 Ammonia as N (mg/L)	EPA - Acute Total as N (mg/L)*	EPA - Chronic Total as N (mg/L)**
0201	6/10/21	20.72	7.4	<2	9.8	1.4
0218	6/10/21	20.83	7.54	<2	8.5	1.3
0226	6/10/21	24.33	8.32	4	1.6	0.38
0274	6/10/21	25.70	8.08	N/A***	2.0	0.46
CR1	6/10/21	21.34	7.47	<2	8.5	1.3
CR2	6/10/21	21.59	7.62	<2	6.7	1.1
CR3	6/10/21	23.86	7.76	<0.2	4.0	0.79
CR5	6/10/21	21.77	7.49	<2	7.8	1.2

*U.S. EPA Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater State (Effective April 2013), Table N.4., Temperature and pH-Dependent Values, Acute Concentration of Total Ammonia as N (mg/L)
**U.S. EPA Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater State (Effective April 2013), Table 6. Temperature and pH-Dependent Values, Chronic Concentration of Total Ammonia as N (mg/L)
*** A laboratory error prevented accurate analysis from location 0274

6.2 Surface Water/Habitat Monitoring

Surface water monitoring adjacent to CF4 is typically conducted after the spring peak river flow begins to recede and a suitable habitat develops. The purpose is to monitor the water quality and protect young-of-year endangered fish species (e.g., Colorado pikeminnow, razorback sucker) from elevated ammonia concentrations. In 2021, the side channel adjacent to CF4 was identified as suitable habitat on June 22 and surface water diversion operation was initiated.

Samples were collected in the backwater channel four times between late June and mid-July with a Hach Sense-Ion ® probe. None of the samples exceeded the EPA acute criteria, however eight of the twenty-two samples that were collected exceed the chronic criteria by up to 0.7 mg/L. No dead or distressed fish were noted.

The efficacy of the surface water diversion system and the ammonia concentrations in the habitat are calculated monthly averages based on Table 6 of the *EPA Aquatic Life Ambient Water Quality Criteria for Ammonia.* At each location, the chronic criteria for a given month derived from the table are averaged and then multiplied by 2.5 to determine the four-day limit. This four-day limit represents the ammonia concentrations that shall not be exceeded at that location in that month. Table 6 shows the chronic criteria calculation for the 2021 sample locations.

The habitat sampling results were collected to confirm the surface water diversion system was effective in lowering the ammonia concentrations below the acute and chronic concentrations. The sample results are also an effective tool for staff to determine the best placement of surface water diversion manifolds.

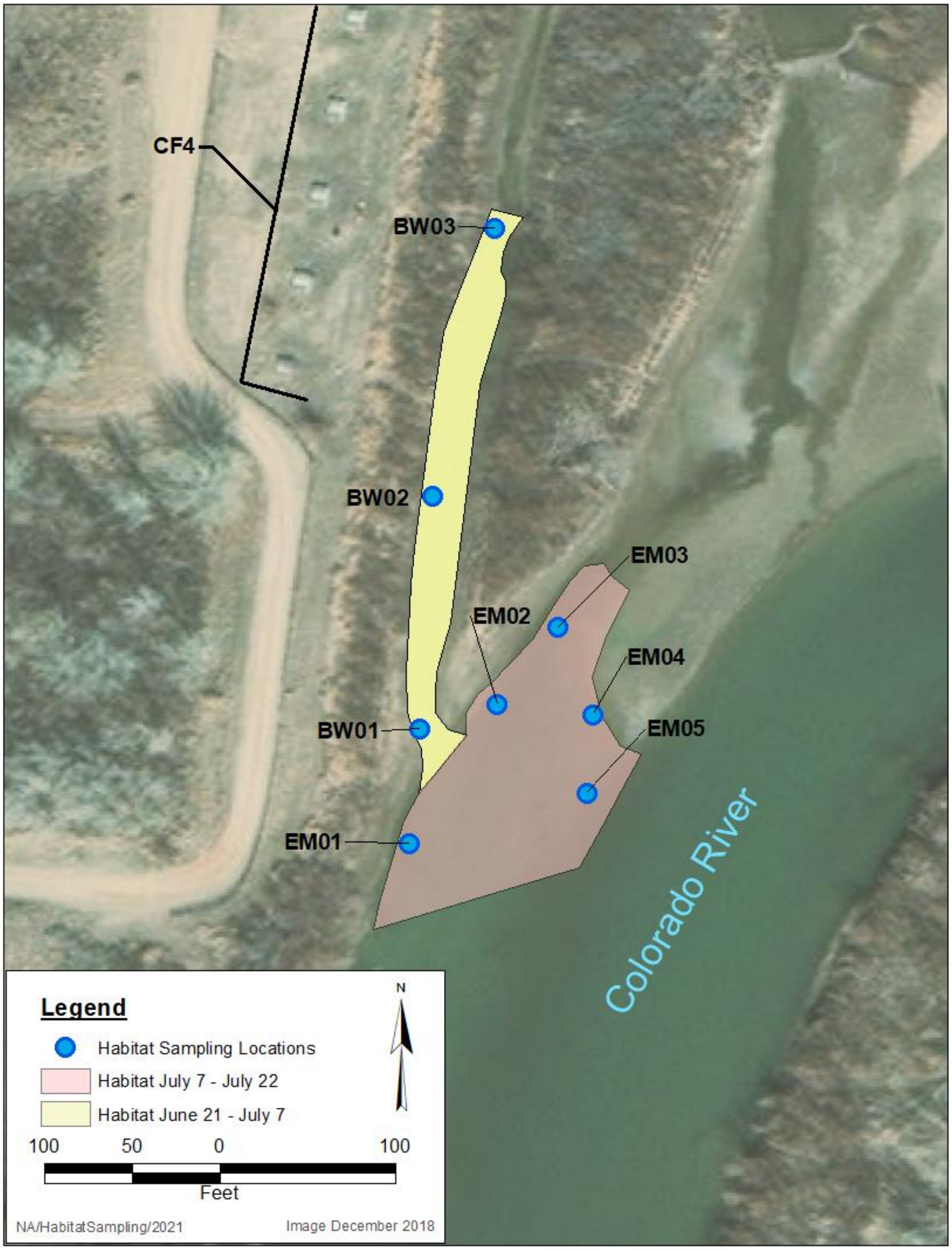

Figure 19. 2021 Habitat Area Sampling Locations

Table 6. 2021 Habitat Area Surface Water Ammonia Chronic Criteria

Location	June 4-Day limit (mg/L)	July 4-Day limit (mg/L)	Comments
BW01	2.52	2.62	All sample concentrations were below the 4-day limit during June and July
BW02	3.07	2.42	One sample in June exceeded the 4-day limit (9.25 mg/L) but the sample collected from BW02 seven days later was 0.18 mg/L
EM01	N/A	2.47	All sample concentrations were below the 4-day limit during June and July
EM02	N/A	2.87	
EM03	N/A	3.12	
EM04	N/A	3.25	
EM05	N/A	2.75	

6.3 Surface Water Monitoring Summary

This system was operational from June 22 to August 25 and pumped a total of 4.6 mil gal of fresh water through the suitable habitat. Ammonia sampling efforts showed that the surface water diversion system was effective in diluting the critical habitat to compliant levels, and no dead fish were observed.

7.0 Investigations

In addition to the operation of the groundwater extraction, freshwater injection, and surface water diversion systems, Crescent Junction wells 0202 and 0205 were also monitored.

7.1 Crescent Junction Wells 0202 and 0205 Sampling and Recharge Monitoring

The placement of the cell cover has significantly altered the surface runoff/hydrology of the vicinity of well 0205. Before the installation of the cell cover, most of the precipitation would evaporate with larger storm events producing surface runoff, with a very small portion slowly infiltrating over a much larger area. With the cover material in place, there is often less evaporation and more surface runoff that tends to accumulate in discrete areas of the site and provides a longer-term source of infiltration.

Water was first encountered in well 0205 in late June 2015 and has been present in the well since. Observations show that after a significant event or multiple precipitation events, the runoff collects into the retention ditch at the toe of the cell. As this water infiltrates into the subsurface, it likely intercepts a fracture system that is in part connected to the fracture observed inside well 0205 and eventually flows into the well. A sample was collected from well 0205 in September 2021, with the results presented in Table 7.

Between the March and late June 2019 quarterly monitoring events, water was first encountered in well 0202, located to the west of the completed portion of the disposal cell (Figure 20). Samples of this water were also collected in September 2021 and was submitted to the analytical lab for the same analyte suite as that of samples collected from well 0205. The results of the analysis of the water sample collected from well 0202 is also presented in Table 7.

A short-term recovery test was completed in December 2021 on well 0205, and the recharge rate measured at 0.003 gpm. The submersible pump experienced a failure, and the well could not be drawn down to a level below the identified fracture (~60ft below top of casing). This really limited the recharge rate, and the value is not comparable to previous tests. Also, the meteorological station was not in operation from January 11 to August 18 and no manual precipitation records were kept.

The way well 0205 water elevation responds to the site precipitation is graphically displayed on Figure 21, and the fluctuation of the recharge rate in response to precipitation is shown on Figure 22.

Table 7. 2021 Crescent Junction Wells 0202 and 0205 Analyte Concentrations

Analyte	**Analyte Concentration**	
	Well 0202	**Well 0205**
	9/22/21	**9/22/21**
Ammonia as N	8.9	11
Arsenic	0.039#	0.087J
Bicarbonate as $CaCO_3$	980	910
Boron	1,300	1,100
Bromide	40#	40#
Cadmium	0.0033#	0.0033#
Calcium	370	280
Carbonate as $CaCO_3$	20#	20#
Chloride	1,200	3,100
Chromium	0.0051#	0.0051#
Cobalt	0.0045#	0.0045#
Copper	0.0097#	0.0097#
Fluoride	20#	20#
Iron	0.049#	0.049#
Lead	0.013#	0.013#
Magnesium	690	730
Manganese	0.5	0.29
Molybdenum	11#	11#
Nitrate/Nitrite as N	1000	590
Selenium	0.027#	2.6
Sodium	8,800	7,400

Table 7. 2021 Crescent Junction Wells 0202 and 0205 Analyte Concentrations (continued)

Sulfate	2,400	24,000
Total Alkalinity as $CaCO_3$	980	910
Total Dissolved Solids	40,000	38,000
Uranium $_{234}$	36.2 +/- 6.30 pCi/L	35.7 +/- 6.4 pCi/L
Uranium $_{235}$	0.74 +/- 0.38 pCi/L	0.63 +/- 0.38 pCi/L
Uranium $_{238}$	8.6 +/- 1.8 pCi/L	10.7 +/- 2.2 pCi/L
Uranium	0.022	0.022

# = Concentration at or below the detection limit, Note: All concentrations in mg/L, except where noted
J = Concentration is estimated.

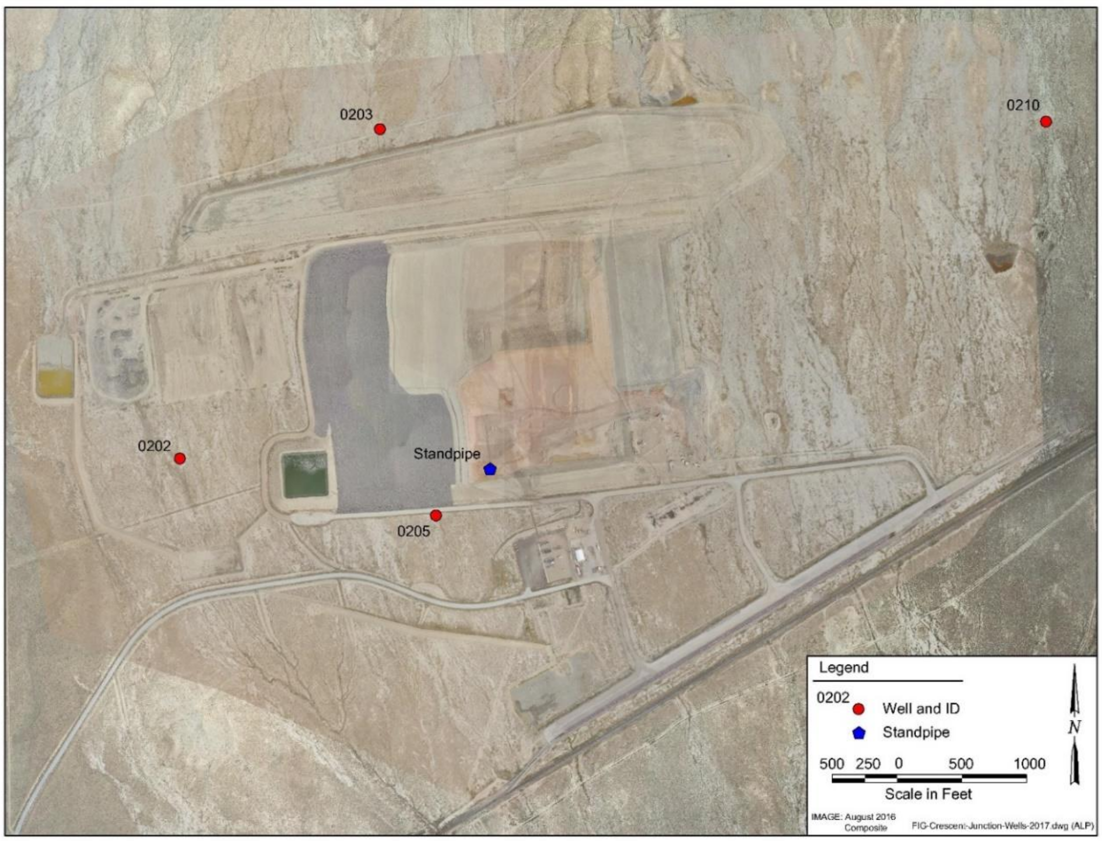

Figure 20. Crescent Junction Well Location Map

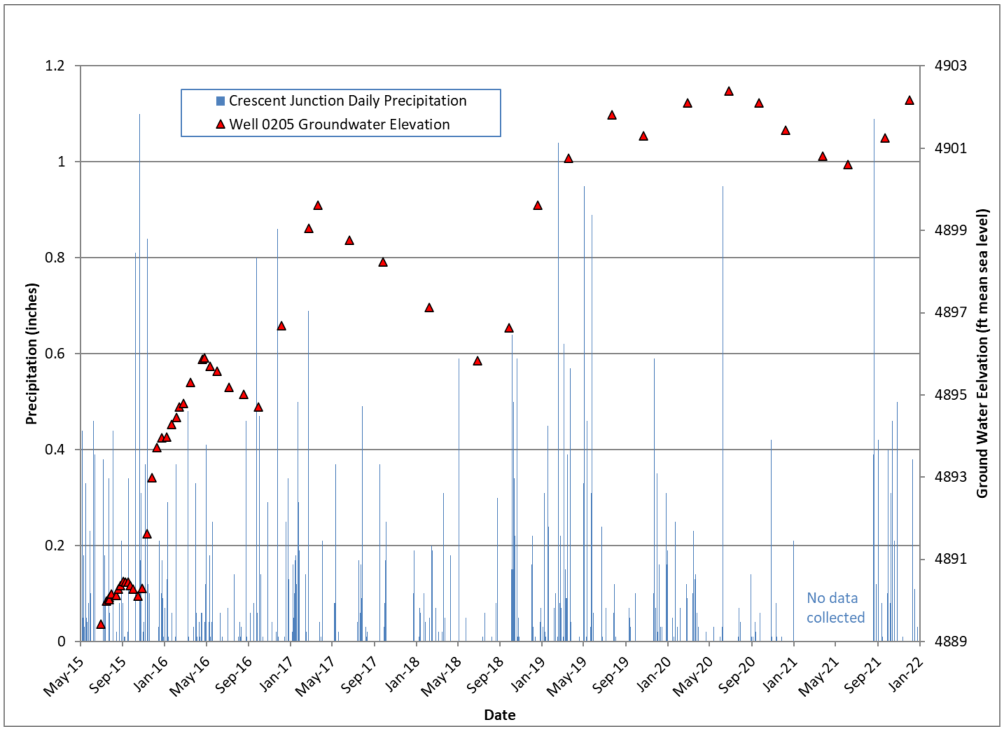

Figure 21. Crescent Junction Well 0205 Water Level Changes in Response to Precipitation through 2021

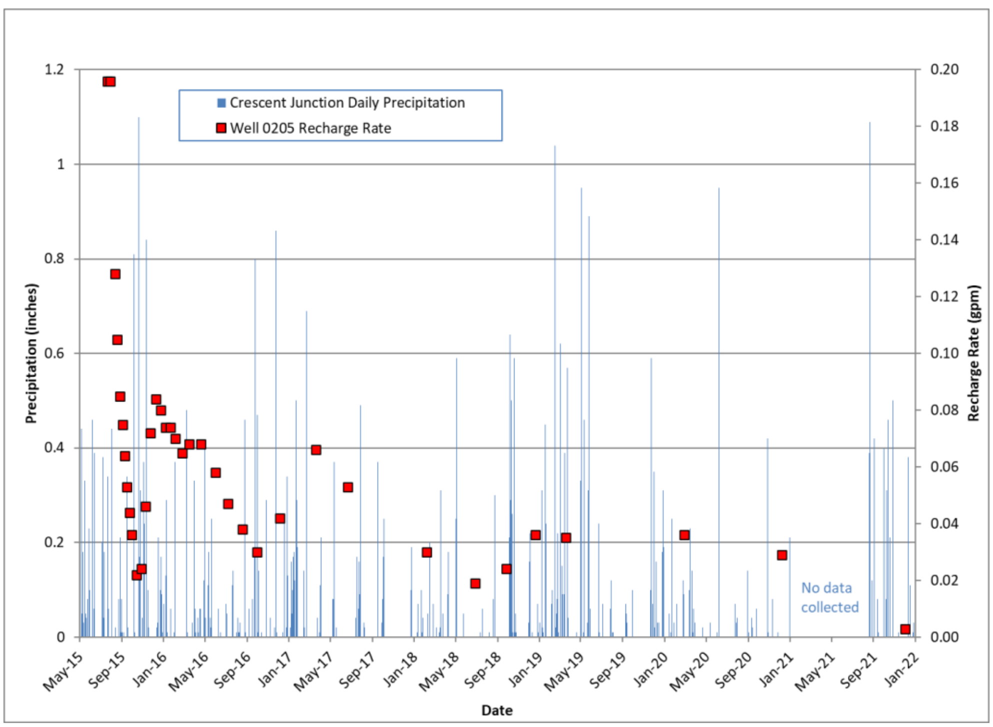

Figure 22. Crescent Junction Well 0205 Recharge Rate Changes in Response to Precipitation through 2021

8.0 Summary and Conclusions

In 2021, the IA operations focused on groundwater extraction (CF5) and freshwater injection (CF4); the surface water diversion system was operational from late June through late August in an area located to the east of the CF4 side channel.

A total of 8.0 mil gal of water was extracted from CF5 in 2021. The extraction rate peaked in June, and operations continued through the fall. Each of the eight extraction wells were utilized in 2021. Figure 23 shows the ammonia and uranium mass removed and the volume of groundwater extracted from the CF5 extraction wells from 2003 through 2021.

The volume of extracted groundwater and removed contaminant mass were lower in 2021 than in 2020. This was likely a result of the primary water truck needing service during July when the extraction rate is typically highest. Still, a total 8.0 mil gal of groundwater, which included 16,123 lbs of ammonia and 152.0 lbs of uranium, was removed from the groundwater system in 2021.

Approximately 8.8 mil gal of freshwater was injected into CF4 in 2021. Laboratory data from the CF4 observation wells during injection operations indicate the system is effective at diluting ammonia concentrations, especially from the groundwater surface down to a depth of 28 ft bgs. However, the injection system was used to divert freshwater into the critical habitat rather than inject into the wells for part of the year. Ammonia concentrations generally increased while injection system operations were suspended, further indicating the effectiveness of the injection. Site-wide surface water samples indicated the contaminants do not extend past the site boundary.

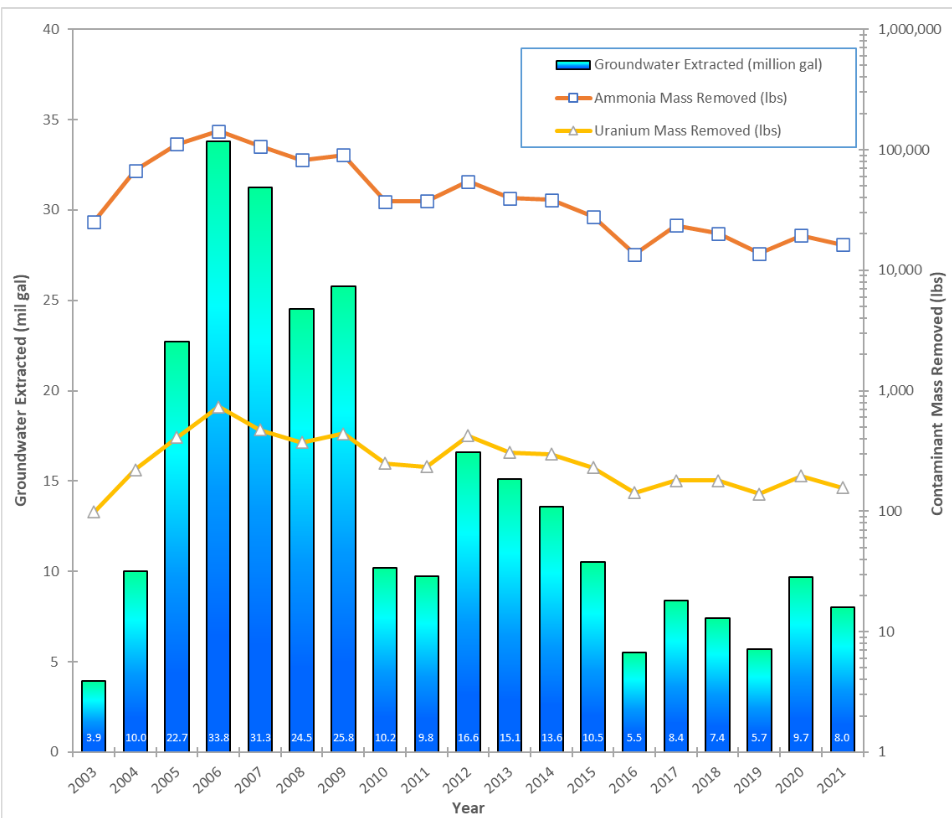

Figure 23. Groundwater Extracted Volume and Contaminant Mass Removal, 2003 through 2021

9.0 References

40 CFR 192A (U.S. Code of Federal Regulations), "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites."

DOE (U. S. Department of Energy), *Moab UMTRA Project Flood and Drought Mitigation Plan* (DOE-EM/GJTAC1640).

DOE (U.S. Department of Energy), *Moab UMTRA Project Groundwater and Surface Water Monitoring January through June 2021* (DOE-EM/GJTAC3060).

DOE (U.S. Department of Energy), *Moab UMTRA Project Groundwater and Surface Water Monitoring July through December 2021* (DOE-EM/GJTAC3072).

DOE (U.S. Department of Energy), *Moab UMTRA Project Surface Water/Groundwater Sampling and Analysis Plan* (DOE-EM/GJTAC1830).

DOE (U.S. Department of Energy), *Record of Decision for the Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah* (6450-01-P).

Appendix A.

Tables and Data for 2021 Groundwater Extraction

Appendix A. Tables and Data for 2021 Groundwater Extraction

Table A-1. Well Construction for CF5 Extraction Wells

Well	Well Type	Diameter (in.)	Ground Surface Elevation (ft above msl)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0810	Extraction	8	3,966.56	10.4 – 40.4	40.4
0811	Extraction	8	3,966.59	8.8 – 38.6	38.6
0812	Extraction	8	3,966.62	14.2 – 44.2	44.2
0813	Extraction	8	3,966.67	14.4 – 44.4	44.4
0814	Extraction	8	3,967.02	12.4 – 42.4	42.4
0815	Extraction	8	3,967.13	21.7 – 51.7	51.7
0816	Extraction	8	3,967.38	20.9 – 50.9	50.9
SMI-PW02	Extraction	4	3,965.60	20.0 – 60.0	60.3

In. = inch

Table A-2. 2021 Chronology of CF5 Activities

Date	Activity
January	System winterized.
February	System winterized.
March	Restarted extraction system on March 15.
April	Extraction system operation in automatic mode.
May	Extraction system operation in automatic mode. Samples collected on May 11.
June	Extraction system operation in automatic mode. Submersible pump in well 0815 was replaced on June 24.
July	Extraction system operation in automatic mode. Water truck under repair and limited water was used from July 21 – Aug 4.
August	Extraction system operation in automatic mode.
September	Extraction system operation in automatic mode. Samples collected on Sept 15.
October	Extraction system operation in automatic mode.
November	Submersible pump in well 0814 faulted and quite running the week of Nov 10. Winterization of the extraction system (well vaults, pump house, and storage tanks) occurred on Nov 16 and 17.
December	System winterized.

Appendix A. Tables and Data for 2021 Groundwater Extraction (*continued*)

Table A-3. CF5 Extraction Volumes 2021

Well	Extraction Volumes Removed (gal)												
	Jan-21	**Feb-21**	**Mar-21**	**Apr-21**	**May-21**	**Jun-21**	**Jul-21**	**Aug-21**	**Sep-21**	**Oct-21**	**Nov-21**	**Dec-21**	**Well Total**
0810	0	0	93,576	198,969	130,119	217,554	67,518	119,314	110,677	2,407	5,856	0	**945,990**
0811	0	0	33,925	73,003	70,962	62,678	19,244	54,952	39,702	5,720	4,629	0	**364,815**
0812	0	0	107	5,339	126,993	133,978	46,226	69,433	78,568	17,417	10,870	0	**488,931**
0813	0	0	158,229	367,926	350,488	373,631	133,085	203,618	230,576	76,859	31,238	0	**1,925,650**
0814	0	0	90,524	200,539	205,003	206,195	55,240	112,769	133,433	38,920	0	0	**1,042,623**
0815	0	0	3,447	0	0	30,601	50,733	108,817	139,013	41,183	16,880	0	**390,674**
0816	0	0	149,531	344,070	335,816	354,049	40,046	222,158	211,761	71,515	29,174	0	**1,758,120**
SMI-PW02	0	0	92,064	207,150	168,775	222,276	49,970	133,457	137,216	42,920	17,414	0	**1,071,242**
Monthly Total	**0**	**0**	**621,403**	**1,396,996**	**1,388,156**	**1,600,962**	**462,062**	**1,024,518**	**1,080,946**	**296,941**	**116,061**	**0**	
Annual Total													7,988,045

Table A-4. CF5 Ammonia Mass Removal 2021

Well	Ammonia Mass Removed (lbs)												
	Jan-21	**Feb-21**	**Mar-21**	**Apr-21**	**May-21**	**Jun-21**	**Jul-21**	**Aug-21**	**Sep-21**	**Oct-21**	**Nov-21**	**Dec-21**	**Well Total**
0810	0	0	257	547	358	0	56	99	92	2	5	0	**1,416**
0811	0	0	99	213	207	78	24	69	50	7	6	0	**752**
0812	0	0	0	17	402	346	119	179	203	45	28	0	**1,339**
0813	0	0	316	735	700	964	344	526	595	198	81	0	**4,460**
0814	0	0	106	234	239	567	152	310	367	107	0	0	**2,080**
0815	0	0	4	0	0	38	63	136	174	51	21	0	**488**
0816	0	0	162	372	364	825	93	518	494	167	68	0	**3,063**
SMI-PW02	0	0	299	673	548	370	83	222	229	71	29	0	**2,524**
Monthly Total	**0**	**0**	**1,243**	**2,791**	**2,817**	**3,189**	**935**	**2,059**	**2,202**	**649**	**237**	**0**	
Annual Total													**16,123**

Appendix A. Tables and Data for 2021 Groundwater Extraction (*continued*)

Table A-5. CF5 Uranium Mass Removal 2021

Well	Uranium Mass Removed (lbs)												
	Jan-21	**Feb-21**	**Mar-21**	**Apr-21**	**May-21**	**Jun-21**	**Jul-21**	**Aug-21**	**Sep-21**	**Oct-21**	**Nov-21**	**Dec-21**	**Well Total**
0810	0.0	0.0	2.1	4.5	2.9	0.0	1.4	2.5	2.3	0.1	0.1	0.0	**15.9**
0811	0.0	0.0	0.7	1.5	1.5	1.4	0.4	1.2	0.9	0.1	0.1	0.0	**7.9**
0812	0.0	0.0	0.0	0.1	2.1	3.6	1.2	1.9	2.1	0.5	0.3	0.0	**11.7**
0813	0.0	0.0	2.1	4.9	4.7	8.4	3.0	4.6	5.2	1.7	0.7	0.0	**35.3**
0814	0.0	0.0	2.0	4.5	4.6	3.6	1.0	2.0	2.3	0.7	0.0	0.0	**20.7**
0815	0.0	0.0	0.1	0.0	0.0	0.7	1.2	2.6	3.4	1.0	0.4	0.0	**9.4**
0816	0.0	0.0	3.1	7.2	7.0	5.3	0.6	3.3	3.2	1.1	0.4	0.0	**31.2**
SMI-PW02	0.0	0.0	2.1	4.8	3.9	3.3	0.7	2.0	2.1	0.6	0.3	0.0	**20.0**
Monthly Total	**0.0**	**0.0**	**12.3**	**27.5**	**26.7**	**26.4**	**9.6**	**20.1**	**21.4**	**5.8**	**2.3**	**0.0**	
Annual Total													**152.0**

Appendix B.

Tables and Data for 2021 Freshwater Injection

Appendix B. Tables and Data for 2021 Freshwater Injection

Table B-1. CF4 Well Construction Details

Well	Well Type / Relative Depth	Diameter (in)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0770	Remediation/Deep	6	14.9 – 34.8	35.2
0771	Remediation/Deep	6	15.0 – 34.9	35.3
0772	Remediation/Deep	6	15.2 – 35.1	35.5
0773	Remediation/Deep	6	15.2 – 35.1	35.5
0774	Remediation/Deep	6	15.5 – 35.4	35.8
0775	Remediation/Deep	6	15.1 – 35.0	35.4
0776	Remediation/Deep	6	15.2 – 35.1	35.5
0777	Remediation/Deep	6	15.3 – 35.2	35.6
0778	Remediation/Deep	6	15.1 – 35.0	35.4
0779	Remediation/Deep	6	15.7 – 35.6	36.0
0780	Observation/Shallow	6	20.3 – 30.1	30.5
0781	Observation/Deep	6	44.8 – 54.5	55.0
0782	Observation/Deep	6	31.0 – 40.8	41.2
0783	Observation/Shallow	2	8.6 – 18.6	19.1
0784	Observation/Shallow	2	9.4 – 19.4	19.9
0785	Observation/Shallow	2	9.6 – 19.6	19.9
0786	Observation/Shallow	6	20.5 – 30.3	30.7
0787	Observation/Deep	6	35.4 – 45.2	45.7

Table B-2. 2021 Chronology of CF4 Activities

Month	Activity
January	Injection system modified to use 15 HP irrigation system. System operation 1/11 - 1/14. System shut down due multiple leaks. Samples collected.
February	System repaired 2/3 and restarted 2/4. Operational 2/4 - 2/11, 2/17 -2/19. Issues with pressure prevented continual operation.
March	Old pump removed by Rhino Pumps 3/2. New pump installed 3/30.
April	System restarted 4/7 and operational all month.
May	System operational. Shut down on 5/29 due to break in line. Samples collected.
June	System restarted 6/8. System operational with minor repair. Freshwater diversion to fish habitat began on 6/22.
July	System operational 7/1 - 7/21. Backflush valve replaced 7/26.
August	System restarted 8/4. System operational with minor repair. Freshwater diversion stopped 8/25 (habitat no longer present).
September	System operational. Samples collected.
October	System operational.
November	System operational.
December	System shut down 12/29.

Table B-3. CF4 Observation Well Analytical Sample Results 2021

Location	Location from Injection	Sample Depth (ft bgs)	Date	Ammonia as N (mg/L)	Uranium (mg/L)	Specific Conductance (µmhos/cm)
0780	Upgradient	28	1/12/2021	250	2.6	21,612
			5/10/2021	26	0.19	2,362
			9/14/2021	5.2	0.037	1,383
0781	Upgradient	46	1/12/2021	1200	2.9	67,575
			5/10/2021	850	3.4	47,880
			9/14/2021	900	3.2	55,820
0782	Upgradient	33	1/12/2021	290	2.8	20,131
			5/10/2021	100	0.44	4,490
			9/14/2021	310	1.8	15,475
0783	Upgradient	18	1/13/2021	60	1.6	14,361
			5/10/2021	41	0.27	1,372
			9/14/2021	1.4	0.068	1,430
0784	Downgradient	18	1/11/2021	5.1	0.27	3,096
			5/10/2021	0.2	0.011	1,202
			9/14/2021	0.2	0.0096	1,232
0785	Downgradient	18	1/12/2021	88	1.5	13,444
			5/11/2021	0.77	0.028	1,225
			9/14/2021	0.2	0.017	1,307
0786	Downgradient	28	1/7/2021	450	3.1	28,597
			5/11/2021	3.6	0.065	1,286
			9/14/2021	19	0.052	1,364
0787	Downgradient	36	1/7/2021	1200	2.2	80,723
			5/11/2021	440	2.5	20,552
			9/14/2021	660	2.2	38,070

Note: µmhos/cm = micromhos per centimeter

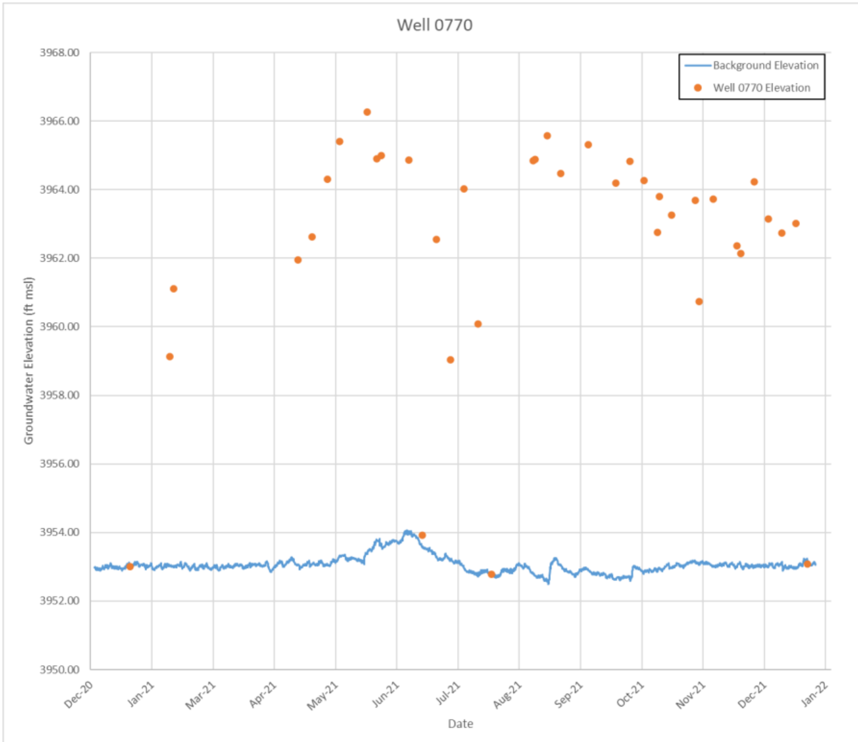

Figure B-1. Freshwater Mounding in Remediation Well 0770 during Injection

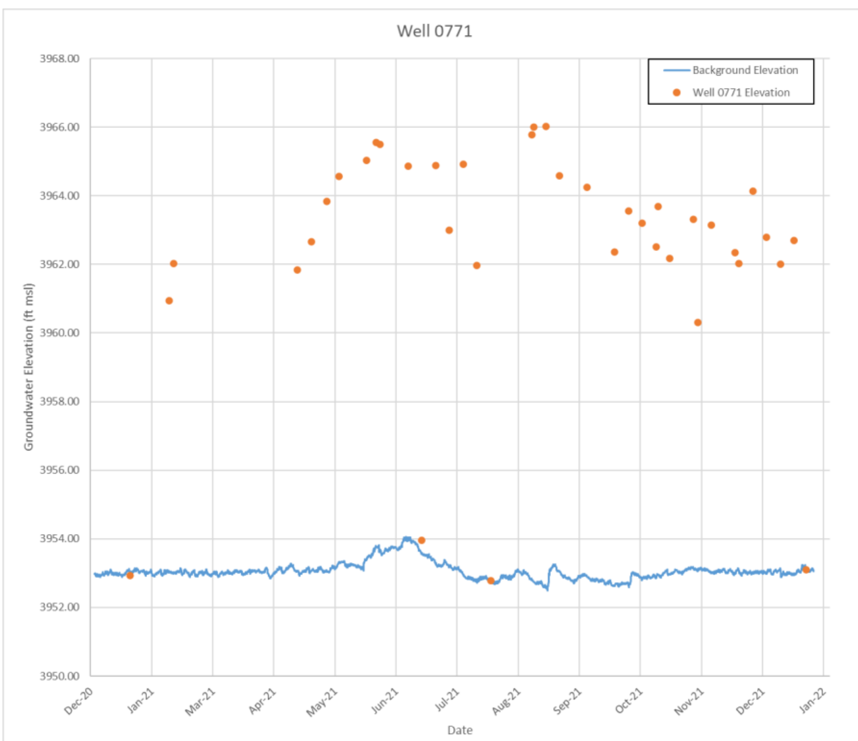

Figure B-2. Freshwater Mounding in Remediation Well 0771 during Injection

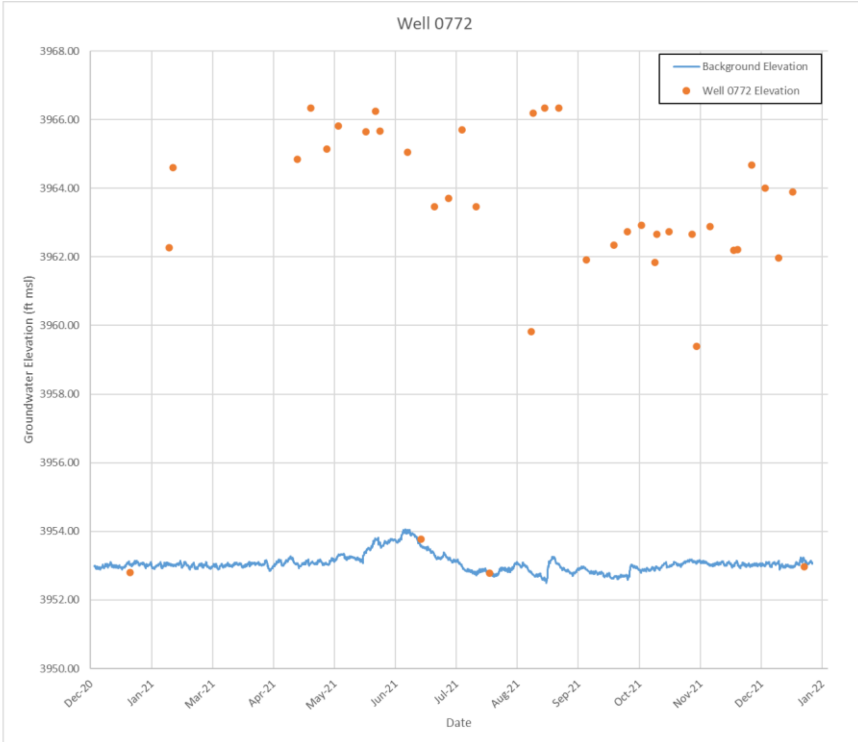

Figure B-3. Freshwater Mounding in Remediation Well 0772 during Injection

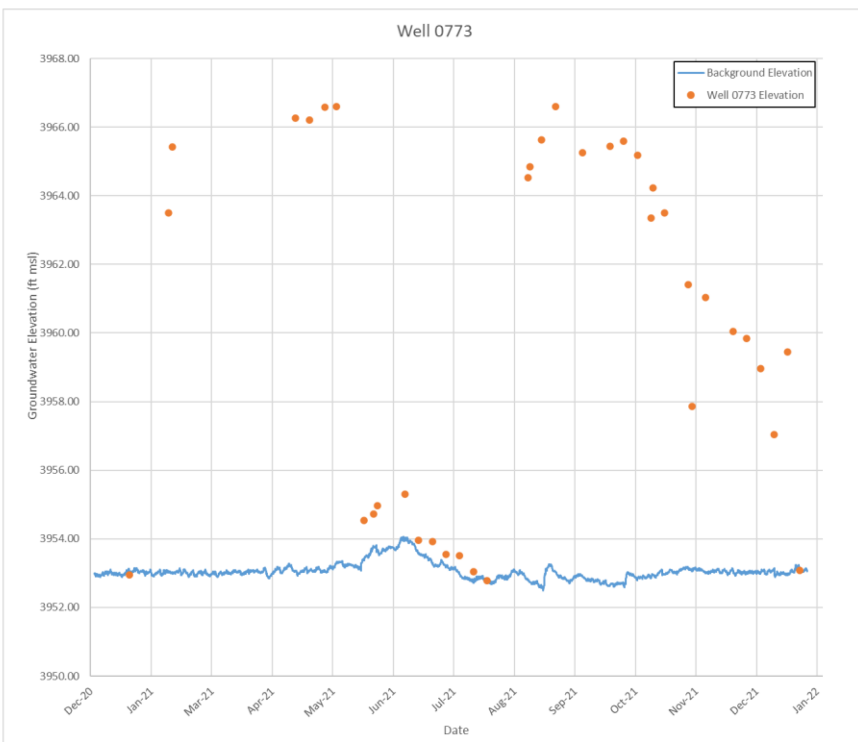

Figure B-4. Freshwater Mounding in Remediation Well 0773 during Injection

Appendix B. Tables and Data for 2021 Freshwater Injection (*continued*)

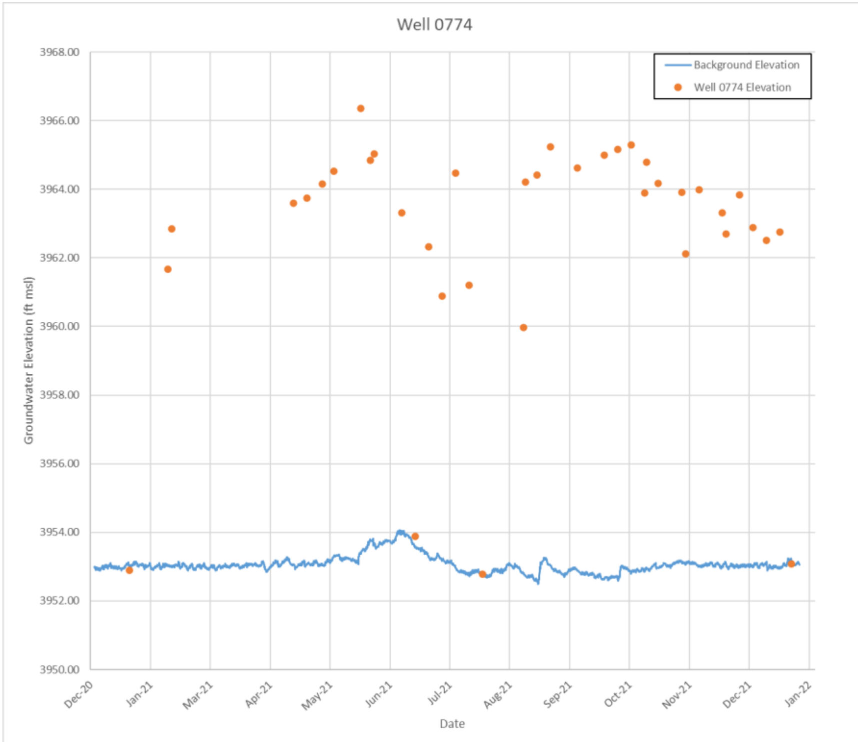

Figure B-5. Freshwater Mounding in Remediation Well 0774 during Injection

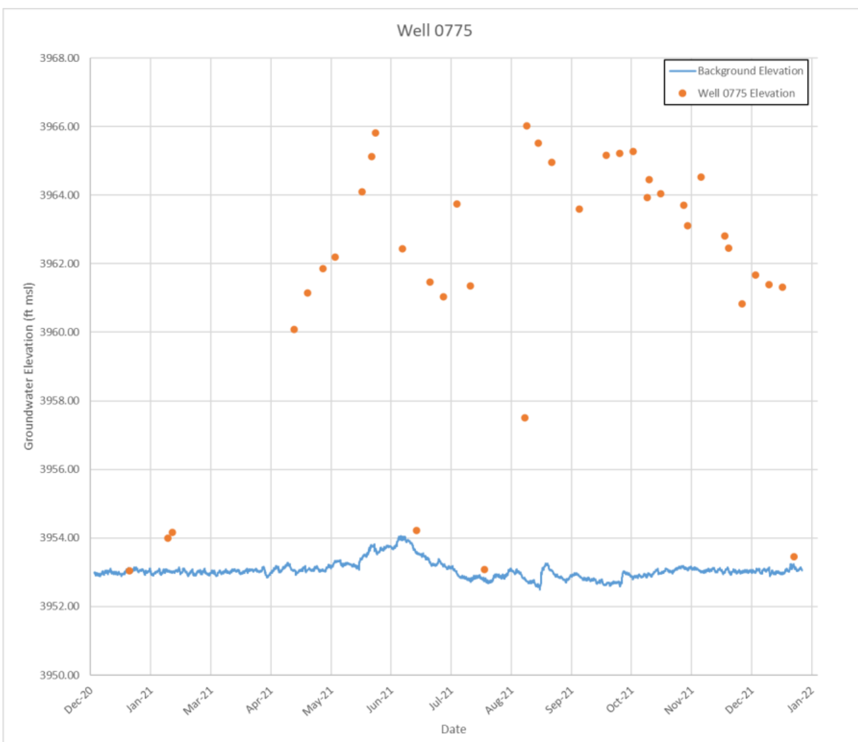

Figure B-6. Freshwater Mounding in Remediation Well 0775 during Injection

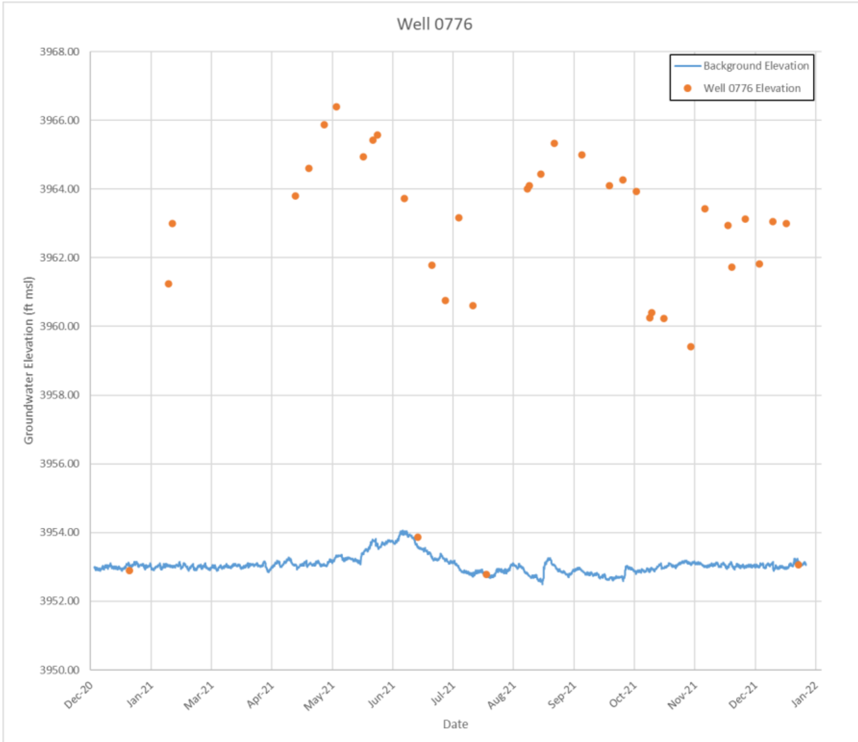

Figure B-7. Freshwater Mounding in Remediation Well 0776 during Injection

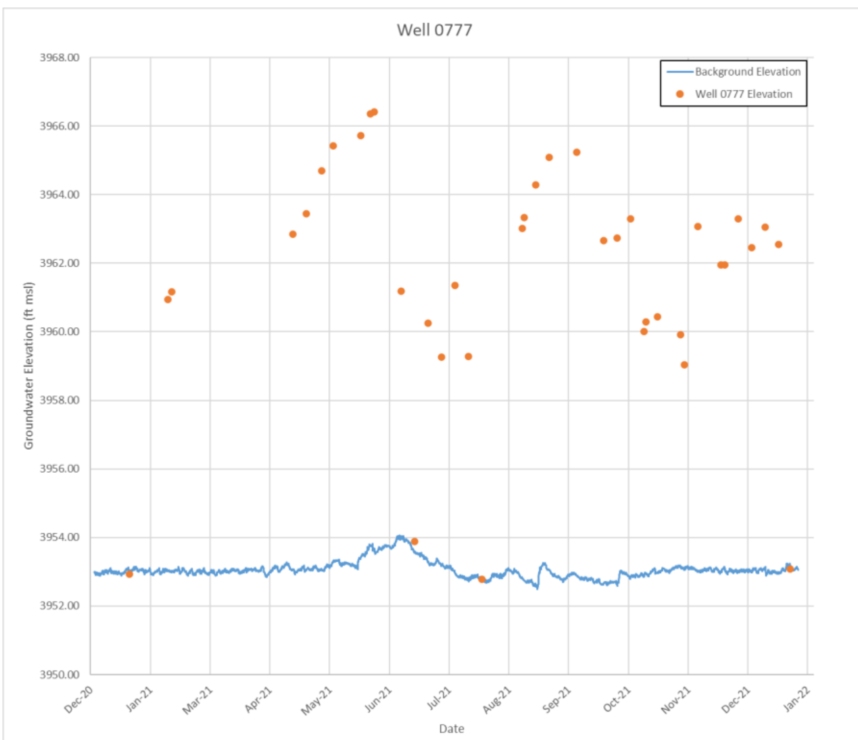

Figure B-8. Freshwater Mounding in Remediation Well 0777 during Injection

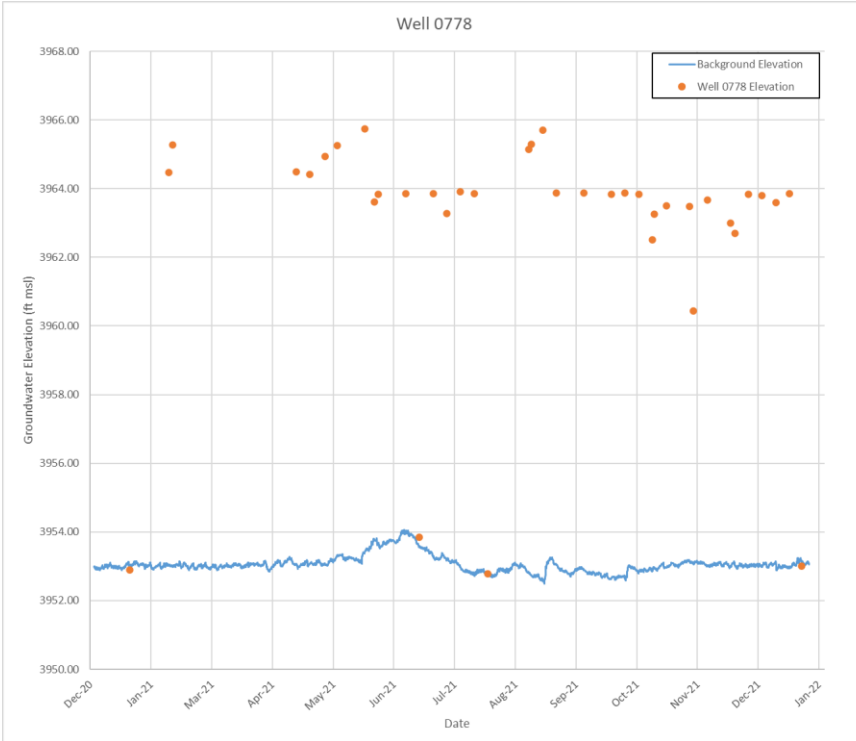

Figure B-9. Freshwater Mounding in Remediation Well 0778 during Injection

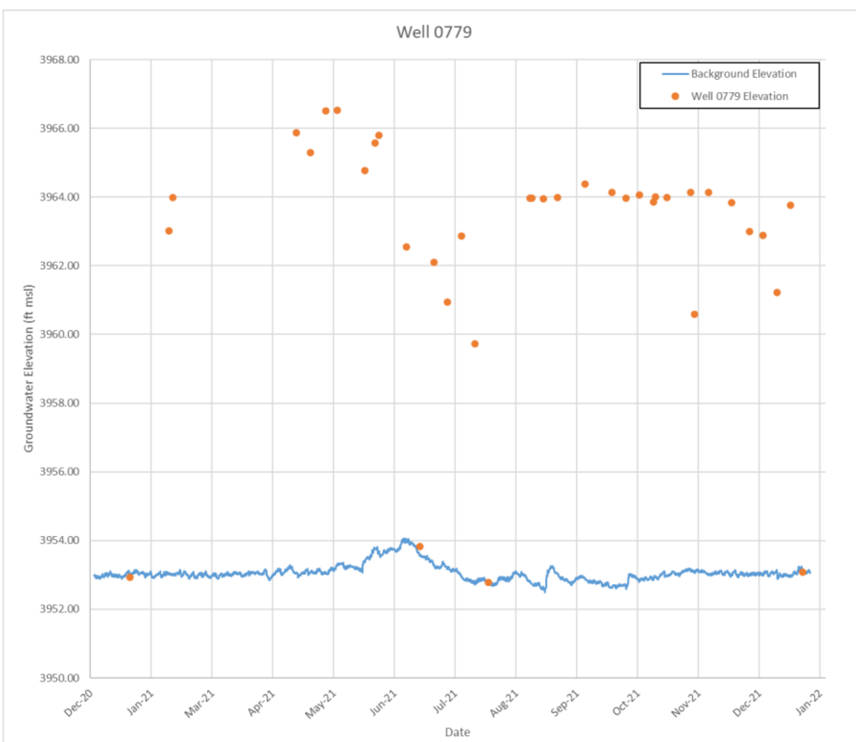

Figure B-10. Freshwater Mounding in Remediation Well 0779 during Injection

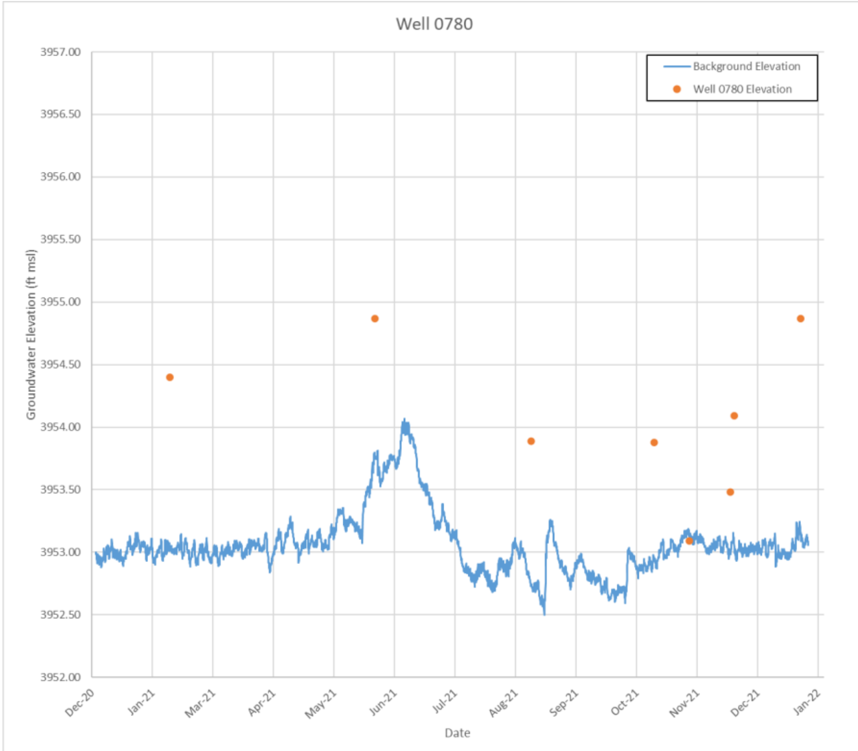

Figure B-11. Freshwater Mounding in Observation Well 0780

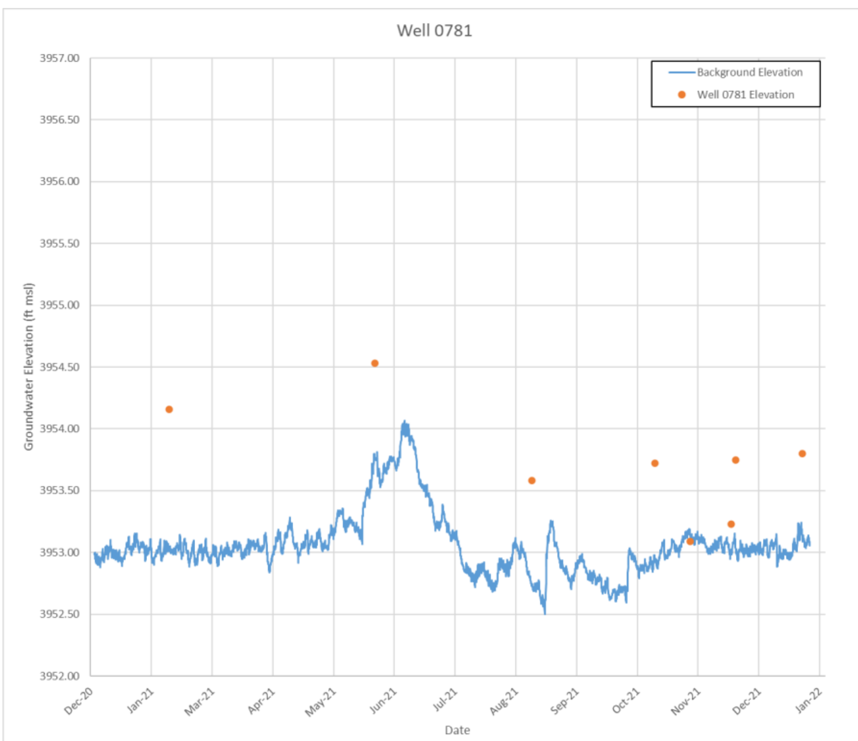

Figure B-12. Freshwater Mounding in Observation Well 0781

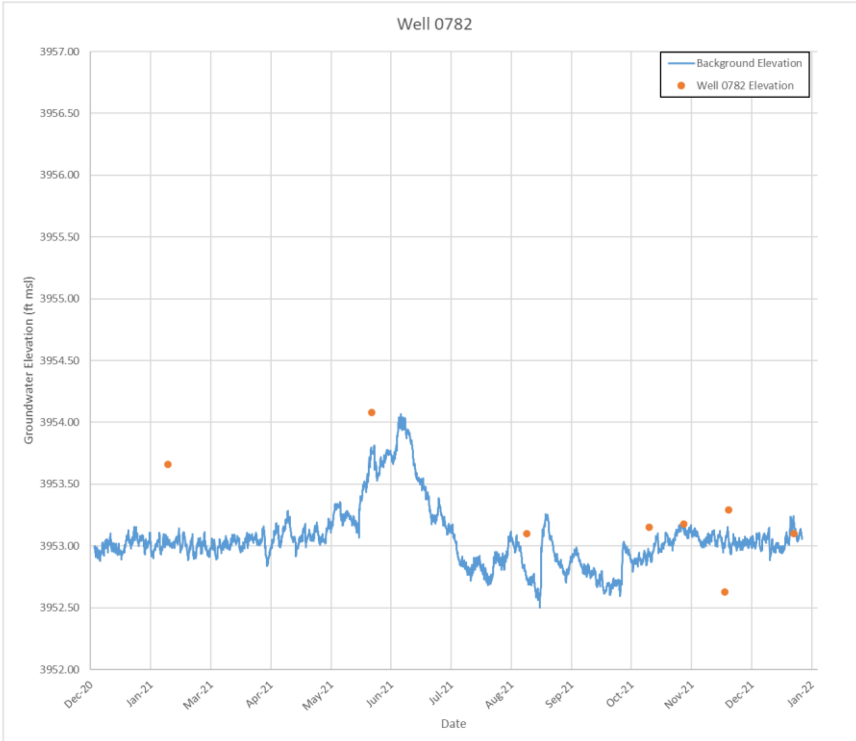

Figure B-13. Freshwater Mounding in Observation Well 0782

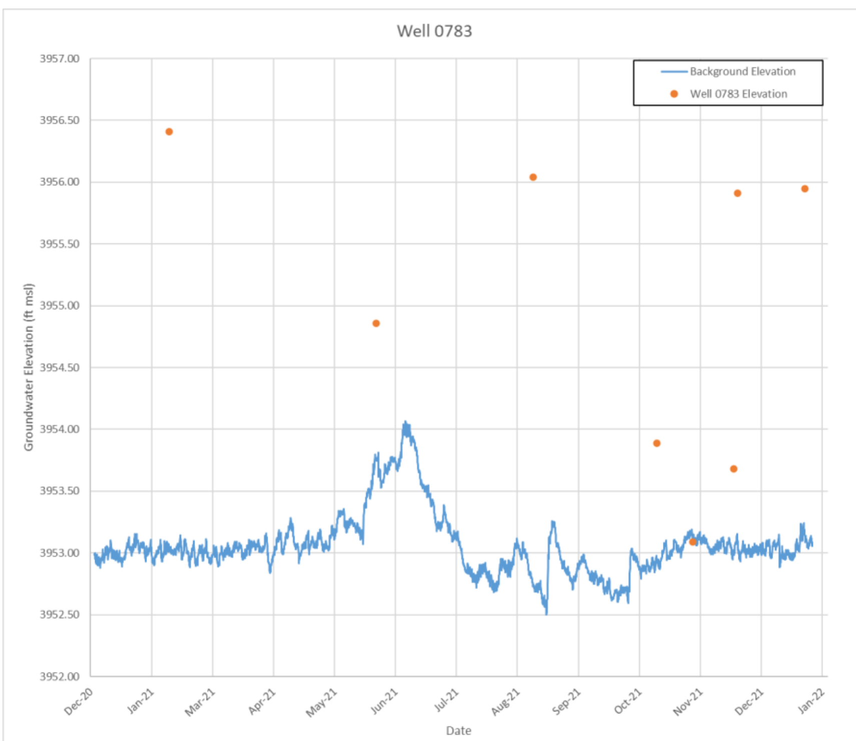

Figure B-14. Freshwater Mounding in Observation Well 0783

Appendix B. Tables and Data for 2021 Freshwater Injection (*continued*)

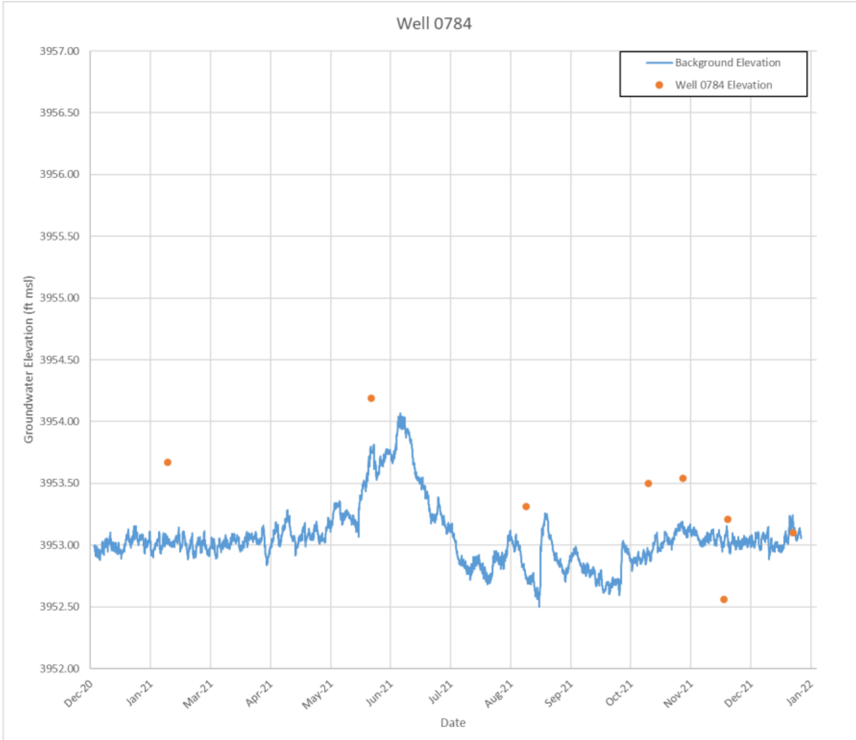

Figure B-15. Freshwater Mounding in Observation Well 0784

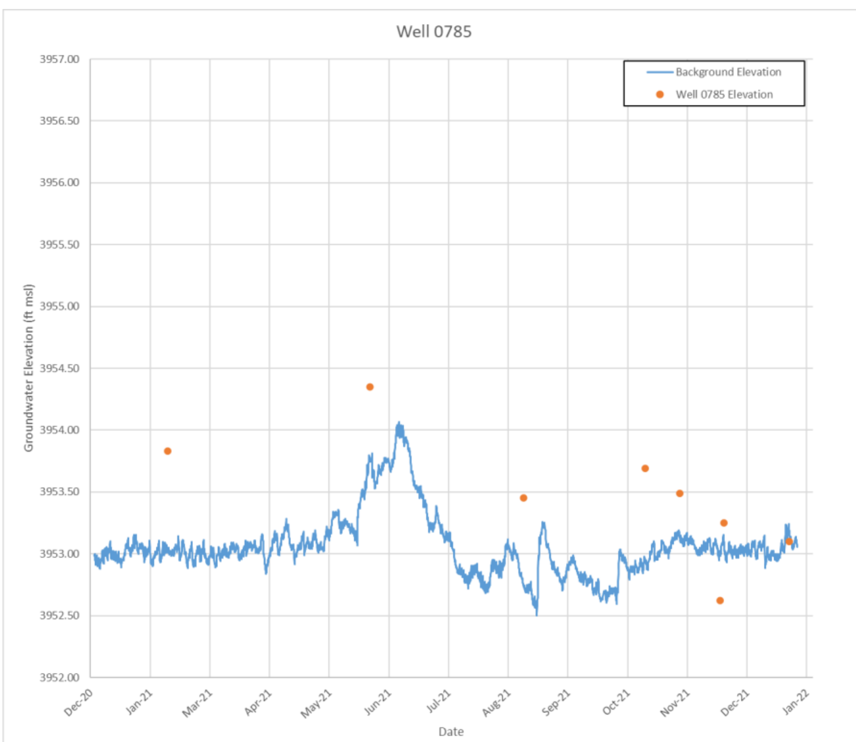

Figure B-16. Freshwater Mounding in Observation Well 0785

Appendix B. Tables and Data for 2021 Freshwater Injection (*continued*)

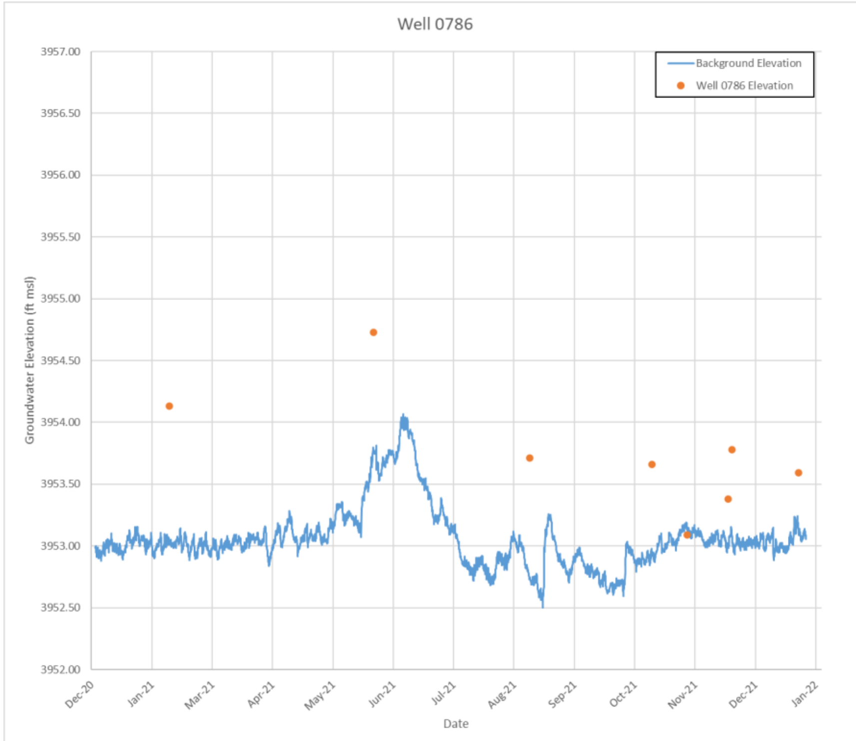

Figure B-17. Freshwater Mounding in Observation Well 0786

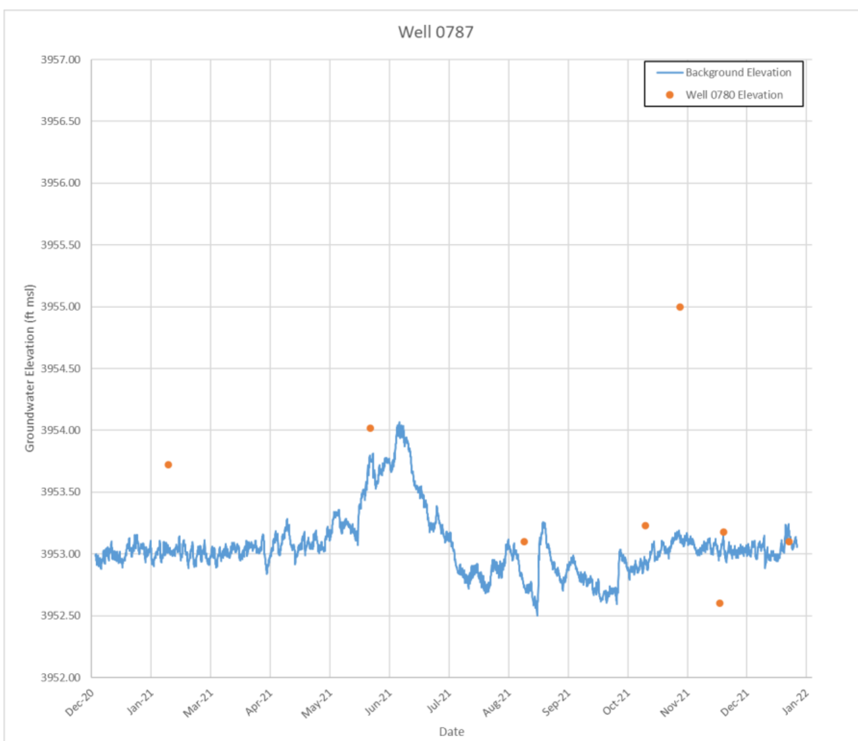

Figure B-18. Freshwater Mounding in Observation Well 0787