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Monticello Mill Tailings Site
Operable Unit III
Annual Groundwater Report
May 2016 Through April 2017

October 2017

U.S. DEPARTMENT OF ENERGY | Legacy Management

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Abbreviations

AOA	area of attainment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Difference
FFA	Federal Facility Agreement
FS	Feasibility Study
ft	feet
gpm	gallons per minute
Jm	Morrison Formation
Kbc	Burro Canyon Formation
Kd	Dakota Sandstone Formation
LM	Office of Legacy Management
µg/L	micrograms per liter
MMTS	Monticello Mill Tailings Site
MNA	monitored natural attenuation
OU	Operable Unit
pCi/L	picocuries per liter
PRB	permeable reactive barrier
RI	Remedial Investigation
ROD	Record of Decision
SOARS	System Operation and Analysis at Remote Sites
^{234}U	uranium-234
^{238}U	uranium-238
UDEQ	Utah Department of Environmental Quality
UMTRA	Uranium Mill Tailings Remedial Action (Project)
ZVI	zero-valent iron

Executive Summary

This report provides the annual analysis of water quality restoration progress, cumulative through April 2017, for Operable Unit (OU) III surface water and groundwater of the U.S. Department of Energy (DOE) Office of Legacy Management (LM) Monticello Mill Tailings Site (MMTS). The MMTS is a Comprehensive Environmental Response, Compensation, and Liability Act National Priorities List site located in and near the city of Monticello, San Juan County, Utah.

MMTS comprises the 110-acre site of a former uranium- and vanadium-ore processing mill (mill site) and 1700 acres of surrounding private and municipal property. Milling operations generated approximately 2.5 million cubic yards of waste (tailings) from 1942 to 1960. The tailings were impounded at four locations on the mill site. Dissolved inorganic constituents in the tailings fluid drained from the impoundments and contaminated local surface water (Montezuma Creek) and groundwater in the underlying alluvial aquifer. Mill tailings dispersed by wind and water also contaminated properties surrounding and downstream of the mill site.

Remedial actions to remove and isolate radiologically contaminated soil, sediment, and debris from the former mill site (OU I) and surrounding properties (OU II) were completed in 1999 with the encapsulation of the wastes in an engineered repository located on DOE property approximately 1 mile south of the former mill site. This effectively removed the primary source of groundwater contamination; however, contamination of groundwater and surface water remains within OU III at levels that exceed water quality protection standards. Uranium is the primary contaminant of concern.

LM implemented monitored natural attenuation with institutional controls as the OU III remedy in 2004. Because groundwater restoration proceeded more slowly than expected and did not meet performance criteria established in the OU III Record of Decision (dated June 2004), LM implemented a contingency action in 2009 with an Explanation of Significant Difference to include a pump-and-treat system using a single extraction well and treatment by zero-valent iron (ex situ treatment system). The contingency action was optimized in 2015 with the installation of 8 extraction wells and 16 monitoring wells in a focused area of the aquifer, the area of attainment (AOA). Contaminated water is treated by solar evaporation at an existing facility at the LM repository.

Findings for sitewide alluvial groundwater quality for the May 2016–April 2017 reporting period include:

- No anomalous monitoring results or site conditions that would identify a concern for contaminant source control or contaminant plume movement are noted.
- Uranium contamination remains at concentrations up to 31 times the remediation goal (30 micrograms per liter [µg/L]) within the AOA, and up to 16 times the remediation goal in other groundwater locations. The uranium groundwater contamination plume extends approximately 0.75 mile downgradient of the former mill site.

  Most regions of the aquifer are showing decreasing uranium concentrations; however, locations with sufficient water quality data in the farthest downgradient regions of the plume (Regions 4 and 5) show areas of both decreasing and increasing trends.

- Arsenic and vanadium concentrations are generally limited to locations upgradient of the permeable reactive barrier (PRB) and at concentrations that are less than twice the respective remediation goals.
- Manganese is limited to a few locations upgradient of the PRB and is present at levels up to 7 times the remediation goal.
- Molybdenum was detected above the remediation goal (100 µg/L) only in the AOA at a maximum concentration of 236 µg/L.
- Selenium was not detected above the remediation goal (50 µg/L) except downgradient of the AOA at one location (106 µg/L).
- Nitrate concentrations are currently at or below the respective restoration goal.

Findings for Burro Canyon groundwater quality for the May 2016–April 2017 reporting period include:

- The Burro Canyon aquifer is not contaminated by site-related contaminants: elevated concentrations of arsenic at one location and elevated concentrations of manganese at another location are attributed to natural sources.

Findings for surface water quality for the May 2016–April 2017 reporting period include:

- Uranium in Montezuma Creek remains below the remediation goal on the mill site and within about 0.75 mile downstream of the mill site until the Sorenson location. Although the uranium concentration at the Sorenson location (29 µg/L) did not exceed the restoration goal in April 2017, uranium concentrations at that location and downstream locations are typically above the OU III remediation goal for surface water.
- Seep 3 remains elevated in nitrate (39.7 mg/L) and selenium (64.3 µg/L) and Seep 6 remains elevated in uranium (2300 µg/L).
- Uranium exceeded the remediation goal (44 µg/L) in Wetland 3 (116 µg/L).
- No other contaminants exceed their remediation goals in surface water.

Findings for water quality restoration in the AOA for the May 2016–April 2017 reporting period include:

- The AOA remediation system operated without any unplanned shutdowns.
- Extraction well OR-04 was deactivated in April 2016 and extraction wells OR-1, OR-2, and OR-3 were deactivated in May 2016. This was done so that only the most productive wells for uranium recovery were operating and to manage the fill rate of Pond 4.
- During the review period, 4.5 million gallons of contaminated groundwater were extracted from the AOA. This equates to an annual extraction rate of 8.5 gallons per minute.
- Inflow to Pond 4 (extraction well inflow plus precipitation) was approximately balanced by annual evaporation in the pond after wells OR-1 through OR-4 were deactivated. Water contained in Pond 4 was relatively constant at approximately 7.3 million gallons, which is about one-half of the safe operating capacity (15.6 million gallons).

- Uranium concentrations of the extracted groundwater varied from 590 to 790 µg/L during the review period and averaged approximately 725 µg/L.
- Groundwater extraction removed approximately 30 pounds of uranium from the alluvial aquifer during the reporting period.
- The remediation system has removed approximately 12 million gallons of groundwater, equivalent to 6 pore volumes in the AOA.
- Uranium concentrations at monitoring wells in the AOA show a downward trend since the baseline period; however, they are currently more than 31 times the remediation goal (30 µg/L).
- Overall, the average uranium concentration in the AOA has decreased by approximately 25% since start of the groundwater remedy optimization system in January 2015.

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1.0 Introduction

This report provides the annual analysis of water quality restoration, cumulative through April 2017, for Operable Unit (OU) III surface water and groundwater of the U.S. Department of Energy (DOE) Office of Legacy Management (LM) Monticello Mill Tailings Site (MMTS). The MMTS is a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List site located in and near the city of Monticello, San Juan County, Utah (Figure 1). Water quality investigations under CERCLA began in 1992.

An alluvial aquifer and adjoining surface water became contaminated by dissolved inorganic constituents that drained from the former mill tailings impoundments from 1942 through source removal in 1999. The Record of Decision (ROD) for OU III (DOE 2004a) selected monitored natural attenuation (MNA) with institutional controls as the groundwater remedy. Contingency actions using pump-and-treat technology were implemented in 2005 and 2015 in a focused area of the aquifer because ROD-specific conditions for MNA performance were not attained.

2.0 Historical Information

2.1 Background Information

The MMTS was established as a CERCLA National Priorities List site in 1989 (CERCLIS ID Number UT3890090035). It comprises the 110-acre site of a former uranium- and vanadium-ore processing mill (mill site) and 1700 acres of surrounding private and municipal property. Ore processing generated 2.5 million cubic yards of tailings, a sandy waste product, during mill operation (1942 to 1960). The tailings were hydraulically emplaced to form four impoundments on the mill site (see Plate 1 for location of former mill tailings impoundments). Drainage of the process liquids and interaction with meteoric water resulted in the contamination of local surface water (Montezuma Creek) and the shallow alluvial aquifer by radioactive and other inorganic constituents in the tailings. Some mill tailings were dispersed by wind and some entered Montezuma Creek, which resulted in the contamination of properties surrounding and downstream of the mill site.

2.1.1 OU III Administrative History and Response Actions

The MMTS ROD, signed in August 1990, designated an OU for remediating radiologically contaminated soil, sediment, and debris on the mill site (OU I) and on the peripheral properties (OU II). Those remedial actions were completed during 1998 and 1999 and removed the primary source (mill tailings) of contamination to groundwater. All OU I and OU II wastes are encapsulated at the engineered repository located on DOE property 1 mile south of the former mill site. The MMTS ROD also designated OU III to address contaminated surface water and groundwater, stipulating that remedy selection would follow the completion of site characterization activities through a CERCLA Remedial Investigation (RI) and Feasibility Study (FS).

The RI report was issued in September 1998 (DOE 1998a); however, a companion FS report was not completed at that time because the effect of ongoing remedial actions on groundwater quality was uncertain. The U.S. Environmental Protection Agency (EPA) and the Utah Department of Environmental Quality (UDEQ) concurred with DOE to instead implement interim remedial

actions (DOE 1998b) and to complete the FS when site conditions had stabilized. Interim actions included implementing institutional controls in 1999 to restrict the use of contaminated groundwater, conducting a laboratory study of contaminant mobility in groundwater, and implementing passive remediation using an in situ permeable reactive barrier (PRB). Other interim actions included groundwater modeling and updating human health and ecological risk assessments. Interim remedial action findings and groundwater remedy evaluations are documented in the *Monticello Mill Tailings Site Operable Unit III Final Remedial Investigation Addendum/Focused Feasibility Study* (DOE 2004b). The findings were used to support selecting MNA with institutional controls as the OU III remedy (DOE 2004a).

By 2005, LM recognized that the PRB was becoming ineffective in treating the groundwater because internal mineral fouling resulted in a progressive loss of permeability. In response, LM installed an ex situ pump-and-treat system in 2005 using a single extraction well and zero-valent iron (ZVI)–based treatment vessels. This system was installed upgradient of the PRB where a mound of contaminated groundwater had developed. Neither the PRB nor ex situ treatment system was a formal component of the OU III ROD.

The OU III ROD provided specific criteria to evaluate MNA performance by comparing observed trends in uranium concentration over time at selected monitoring wells to those predicted by the OU III groundwater model (DOE 2004b). LM first identified in 2006 (DOE 2006a) that aquifer restoration progress was not meeting the performance criteria. This observation was confirmed in 2007 (DOE 2007) using a separate method of trend analysis.

On the basis of these findings, LM, EPA, and UDEQ concurred in March 2009 to augment the MNA remedy through an Explanation of Significant Difference (ESD; DOE 2009a) to implement a contingency remedy that formalized the ex situ treatment system as a remedy component and to include the PRB as a groundwater containment structure.

2.1.1.1 Current OU III Remedial Action

Although the ex situ system could be operated to extract and effectively treat contaminated groundwater, it was not designed to remediate a significant portion of the aquifer. As documented in previous annual groundwater reports, monitoring data indicated that this system did not accelerate restoration progress.

The contingency remedy was therefore optimized in 2015 by implementing an expanded pump-and-treat remediation approach that is referred to as the OU III groundwater contingency remedy optimization system. The conceptual design, objectives, and implementation plan for the remedy optimization system are documented in the *Groundwater Contingency Remedy Optimization Remedial Design/Remedial Action Work Plan for the Monticello Mill Tailings Site Operable Unit III, Monticello, Utah* (DOE 2014a).

Under that plan, groundwater is extracted in a focused area of the aquifer (referred to as the area of attainment, or AOA) and piped underground to a control/transfer building from where the water is conveyed through a buried water pipeline approximately 1 mile to the solar evaporation pond (Pond 4) at the LM repository for evaporative treatment. Figure 2 provides a plan view showing the main components of the remedy optimization system.

Construction of the remedy optimization system began in May 2014 and was completed in December 2014. The system became operational in January 2015. In concurrence with EPA and UDEQ, LM terminated operation of the ex situ treatment system in December 2014 when the new system was phased into operation

3.0 Site Description

3.1 Physical Setting

The MMTS is located in rural San Juan County at an elevation of approximately 7000 feet (ft), near and within the city of Monticello in southeastern Utah (see Figure 1). According to the 2010 U.S. Census, the population of Monticello is about 1970 residents. The MMTS occupies the valley of Montezuma Creek, a small stream that flows eastward from its origins in the Abajo Mountains, which rise to an elevation of 11,000 ft about 5 miles west of the site. The climate in the immediate site area is semiarid with four distinct seasons. Average annual precipitation is about 15 inches (WRCC 2014), most of which occurs during late summer and early fall storms. Potential evapotranspiration is on the order of 40 inches per year. Native woody vegetation is dominated by scrub oak, pinyon pine, juniper, sagebrush, and rabbitbrush. Phreatophytes, primarily willows, inhabit much of the riparian zone of Montezuma Creek.

The former mill site was restored with native and adapted grasses and forbs in 2000. Ownership of the former mill site was transferred to the City of Monticello in 2000 under a covenant deferral. The property is designated and maintained by the City as an open-space public park. Land use to about 1 mile east of the mill site is agricultural and sparse residential. From there, the valley transitions eastward to a rugged, undeveloped canyon.

3.2 Groundwater Contamination Plume

Uranium is the primary groundwater contaminant of concern (COC) in OU III because (1) compared to other site COCs, it is most widely distributed at higher concentration relative to the corresponding restoration goals, and (2) it is the primary contributor to potential risk to human health by way of the groundwater ingestion pathway. For these reasons, uranium is the focus of assessing aquifer restoration progress in this report.

Figure 3 depicts the uranium contamination plume in OU III groundwater based on 2009 monitoring data. This plume configuration illustrates the distribution of uranium in the alluvial aquifer based on the most comprehensive set of water quality monitoring data available before active groundwater remediation was implemented. Maximum concentrations at that time are shown to be approximately 1000 micrograms per liter (µg/L), coinciding with that portion of the alluvial aquifer immediately downgradient (east) of the former mill site.

The downgradient terminus of the uranium plume, occurring between wells 92-10 and 95-03 (see Plate 1 for well locations), coincides with a natural hydrologic boundary that prevents further downgradient movement of contamination. This boundary is formed by the discharge of uncontaminated groundwater from the underlying bedrock aquifer. This process both dilutes contamination in the alluvial aquifer and displaces it to Montezuma Creek.

3.3 Hydrogeologic Setting

The valley of Montezuma Creek is underlain by a shallow, thin aquifer composed of unconsolidated alluvial sand and gravel (alluvial aquifer). These granular materials are overlain by about 5 ft of flat-lying, fine-textured floodplain deposits. Bedrock beneath the valley floor is generally within 10–15 ft of ground surface, and the saturated thickness of the alluvial aquifer averages about 5 ft. Groundwater flow is west to east following the slope of the valley. A cross-sectional diagram of the Montezuma Creek valley near the PRB is provided as Figure 4.

Where contaminated, the alluvial aquifer is underlain by as much as 40 ft of low-permeability, variably saturated bedrock of the Dakota Sandstone Formation (DOE 1998a). The Dakota Sandstone comprises alternating beds of well-indurated, bioturbated sandstone with intervals of mudstone and carbonaceous sediments. This formation is considered to be an aquitard (DOE 1998a) that separates the alluvial aquifer in the area of contamination from the underlying Burro Canyon sandstone aquifer.

The Burro Canyon aquifer is a local source of municipal and domestic drinking water. This formation, approximately 100 ft thick, consists of fine- to medium-grained, well-indurated sand with intervals of large-scale cross beds. Erosion in the canyon has removed the Dakota Sandstone entirely about 0.6 mile downstream of the mill site.

Montezuma Creek forms at the confluence of North and South Creeks about 0.25 mile upstream of the mill site. Natural flow in Montezuma Creek is interrupted by water retention in the municipal reservoir (Loyds Lake; 3500 acre-feet capacity [UDWQ 2014]) located on South Creek about 0.5 mile upstream of the mill site, and by municipal diversions from North Creek in the Abajo Mountains. The locations of North Creek, South Creek, and Loyds Lake are shown in Figure 1 and Plate 1.

Montezuma Creek is typically dry where it enters the western boundary of the former mill site. Interaction between groundwater and surface water then accounts for gaining and losing reaches of Montezuma Creek in OU III. Some reaches are perennially flowing, whereas others become seasonally dry. The magnitude of base flow is on the order of 100–200 gallons per minute (gpm) in flowing reaches of the creek (DOE 1998a). Additional detail on aquifer–Montezuma Creek interaction is presented in Section 4.1.

3.3.1 Constructed Wetlands

Three wetland areas were constructed during mill site restoration to provide wildlife habitat (see Figure 5 for locations of Wetlands 1–3 and for additional site features and OU III monitoring locations). Water from Montezuma Creek enters each wetland through a subsurface infiltration gallery built into the upstream banks. Outlet channels return the captured water to Montezuma Creek. The wetlands were excavated to bedrock and thus fully penetrate the alluvial aquifer, establishing a hydraulic connection between the wetlands and the alluvial aquifer. Groundwater flows into the ponds, and surface water flows out of the ponds into the alluvium as a function of the difference between pond and adjacent groundwater levels.

Groundwater discharge to the wetlands is evident by the occurrence of seep zones along the banks of the wetlands. The eastern portion of Wetland 3 may be an area where surface water

recharges the aquifer. This is because the base of the wetland in this area is composed of native alluvium, and the water elevation in the wetland is greater than in nearby downgradient monitoring wells.

3.3.2 Groundwater Recharge and Discharge

The portion of the alluvial aquifer underlying the former mill site is recharged by groundwater underflow from the west and from anthropogenic sources along the northern margin of the valley. Underflow from the west is presumed to originate from stream loss from North and South Creeks below the Loyds Lake dam (refer to Figure 1 and Plate 1 that show site features and monitoring locations). Underflow from the west is approximately 10 gpm based on a Darcy's Law calculation with a hydraulic gradient of 0.01, hydraulic conductivity of 1×10^{-2} centimeter per second (28 ft/day), saturated thickness of 5 ft, and width of 300 ft.

Montezuma Creek is typically gaining through the mill site reach, often by as much as 100 gpm in wet years (DOE 2004b). This quantity of water presumably originates mainly from irrigation returns and leakage from municipal water utilities along the northern margin of the valley. Aquifer recharge from precipitation is probably minimal on the mill site because the steep topography and the fine-textured soil favor runoff rather than infiltration, and because the evaporation potential exceeds annual precipitation.

Crop irrigation (alfalfa and pasture grass) occurs in the valley east of the former mill site over a distance of about 0.5 mile east (downstream) of the mill site. This may contribute to seasonal recharge; however, the quantity of irrigation water that recharges the aquifer is unknown. Farther into the canyon, aquifer recharge occurs where Montezuma Creek has fully incised the Dakota Sandstone. Under an upward hydraulic gradient, groundwater in the Burro Canyon aquifer discharges to the alluvial aquifer and to Montezuma Creek in this reach (see Section 4.1). Through the entire reach of Montezuma Creek in OU III, dense growths of phreatophytes in the riparian zone likely consume significant quantities of groundwater during growing seasons.

3.3.3 Groundwater Use

UDEQ classifies alluvial aquifer groundwater within OU III as Class II, Drinking Water Quality Groundwater. Potential for exposure to contaminated groundwater at OU III is low because (1) the affected aquifer is low-yielding, (2) the aquifer has no record as a drinking water source, (3) municipal drinking water is available, and (4) DOE implemented institutional controls in 1999 to restrict use of the contaminated groundwater. The aquifer is not used for crop irrigation or livestock watering. There are several private domestic-use wells in the OU III area that produce from the Burro Canyon aquifer; however, none are located in the Groundwater Restricted Area, and the probability of a hydraulic connection with the alluvial aquifer is extremely remote.

The primary source of domestic-use water for Monticello area residents is surface water from the Abajo Mountains in the watershed of North Creek. Diversion systems in the mountains route the water to the municipal water treatment plant located on North Creek about 1.5 miles northwest (upstream) of the mill site. Loyds Lake is also connected to the municipal water treatment system. Historical MMTS activities and present-day conditions in OU III are not likely to impact the municipal water system because of hydrogeological isolation from the alluvial aquifer.

The City of Monticello historically distributed water from the Burro Canyon aquifer for nondomestic purposes (municipal and residential irrigation) until 2002, when the domestic supply was augmented with Burro Canyon groundwater (see Figure 6 for locations of the municipal wells). The probability of a hydraulic connection between the city wells and alluvial aquifer is extremely remote because the wells are located upgradient or cross-gradient of the alluvial aquifer and are outside of the alluvial valley.

3.3.3.1 Groundwater Use Restriction/Institutional Control

A restriction on the use of groundwater in OU III became effective through a groundwater management policy issued on May 21, 1999, which has since been administered by the Utah State Engineer's Office. The policy states that applications to appropriate water from the alluvial aquifer in the Groundwater Restricted Area for domestic purposes will not be approved by the State; however, construction of a suitable well in that area into the deeper bedrock formation may be possible (DOE 2004b).

3.3.4 Surface Water Use

Water quality in the segment of Montezuma Creek within OU III is protected by the State of Utah for domestic use with prior treatment (Class 1C), secondary contact recreation (Class 2B), warm water aquatic life (Class 3B), and agricultural use (Class 4) (UDAS 2014). There is no known use of Montezuma Creek water for human consumption. The creek has insufficient water for boating and swimming and does not support fish populations. Within OU III, Montezuma Creek is used for limited crop irrigation and livestock watering. Water is diverted from the creek near the center of the mill site to irrigate crops on private land immediately downstream of the mill site. Creek water is also diverted for irrigation about 1 mile east of the mill site. The creek is accessible for livestock watering at many locations in OU III. Upgradient of the mill site, water retained in the municipal reservoir (Loyds Lake; see Figure 1 and Plate 1 for location) is used for residential irrigation and for domestic use with prior treatment at the municipal treatment facility.

3.4 Groundwater Remediation Systems

3.4.1 Permeable Reactive Barrier

The PRB is a subsurface treatment system that was installed to immobilize uranium and other site contaminants (see Figure 2 and Figure 5 for PRB location) by passive groundwater flow through the treatment media. The PRB was installed in June 1999 about 750 ft east of the former mill site on private property. The PRB measures 103 ft long, north to south (perpendicular to flow), by about 13 ft below ground surface (height) by 8 ft wide (west to east) and is constructed of two treatment zones. The first treatment zone is 2 ft wide (upgradient) and consists of crushed gravel and 13% ZVI by volume. The second zone is 4 ft wide (center of PRB) and consists entirely of ZVI. A third zone, 2 ft wide (downgradient) and consisting entirely of crushed gravel, distributes the treated water to the aquifer. The ZVI consists of coarse iron filings generated as a byproduct of automobile manufacturing.

The PRB is keyed 1–2 ft into low-permeability mudstone bedrock. Low-permeability subsurface slurry walls constructed of bentonite-amended soil extend north and south from the PRB to divert groundwater to the treatment zones. The north slurry wall is 97 ft long; the south slurry wall is 240 ft long. Each is about 15 ft in height, 3–4 ft wide (west to east), and keyed into

bedrock. The top of the slurry wall excavations were backfilled with native soil to restore the land surface to its original contour.

The slurry walls do not fully extend to the margins of the aquifer, which causes some contaminated groundwater to bypass treatment. This condition was recognized soon after the installation of the PRB and was confirmed in the April 2009 groundwater investigation (DOE 2009b). The bypass zone at the end of the south slurry wall is about 40 ft long (north to south) and has a saturated thickness of about 2 ft. The bypass zone at the end of the north slurry is probably of similar dimensions. The extent of the north slurry wall was limited by landowner preference. The estimated quantity of bypass flow, less than 1 gpm, is further addressed in Section 6.2.1.

After 2 years of operation, groundwater flow through the PRB was estimated to be less than 10 gpm. Field and laboratory studies have since documented progressive loss of hydraulic conductivity of the ZVI by several orders of magnitude since installation (see DOE 2006b and 2006c) from the precipitation of calcium carbonate and iron oxide minerals in the ZVI media. Given this loss in hydraulic conductivity, the present total rate of groundwater flow through the PRB may be less than 1 gpm.

Water quality and water level monitoring at selected wells within and adjacent to the PRB continues as part of the routine, semiannual OU III monitoring program. PRB monitoring locations are shown in Figure 7. The current role of the PRB, as adopted in the ESD, is to act as a groundwater flow barrier. It also forms the downgradient boundary of the AOA.

3.4.2 Ex Situ Treatment System

An ex situ ZVI-based treatment system was installed in June 2005 as a technology demonstration alternative to the PRB. The system was expanded in March 2007 with the addition of a second treatment vessel. Each treatment cell was effective in removing uranium at an inflow rate of 4–5 gpm for about 1 year, at which time the ZVI was exchanged. Operation of the ex situ system was terminated in December 2014, being replaced by the more aggressive pump-and-treat approach that was implemented in the AOA as the groundwater contingency remedy optimization system (see Section 3.4.3).

The ex situ treatment system was operated by pumping groundwater through two cylindrical concrete cells that contained the treatment media (ZVI/gravel mixtures). The base of each cell is constructed of concrete. Each cell, serviceable from the ground surface, measures 6 ft in diameter by 6 ft in depth and is set approximately 4.5 ft into the ground.

Groundwater was extracted at a well located upgradient of the PRB (well EW-1 in Figure 5) and pumped upward, in parallel, through the cells. A third vault (rectangular in outline in Figure 5 and Figure 7) houses monitoring and control devices. The system discharged treated water to Montezuma Creek through an outfall pipe and to the aquifer by way of an infiltration trench located downgradient of the PRB. Discharge to the creek could not exceed 10 gpm with a concentration limit of 45.4 milligrams per liter for iron and pH between 6.5 and 9.0 (standard units) (DOE verbal communication with Utah Department of Water Quality, May 2008). The infiltration trench originally had the capacity to discharge about 4 gpm of treated water to the aquifer; however, the capacity diminished significantly over time, possibly by iron fouling.

3.4.3 Groundwater Remedy Optimization System

Active groundwater remediation was optimized in 2015 by replacing the ex situ system with an expanded pump-and-treat remediation in a focused area of the alluvial aquifer known as the AOA. The AOA comprises approximately 6.5 acres of private property that extends west to east along Montezuma Creek from the eastern boundary of the former mill site to the PRB.

Figure 8 is a photograph showing the AOA viewed to the northwest from a location on the former road that was used for transporting contaminated material from the former mill site to the repository (haul road). The AOA encompasses the flat-lying central area of the valley, as shown in Figure 8, and spans from left to right (west to east) a pasture (light brown area) and an alfalfa field (green area). Figure 9 shows the AOA in map view and includes the locations and identification of associated monitoring wells and extraction wells. The AOA shown in Figure 8 and Figure 9 corresponds to that area highlighted in red in Figure 2.

The AOA encompasses a subset of the entire uranium contamination plume. Excepting Seep 6 (see Figure 5 and Plate 1 for location), which does not emanate from the alluvial aquifer, the AOA generally contains the greatest concentrations of uranium and has well-defined hydrologic boundaries (described below). The conceptual approach of focused remediation in the AOA is not to remediate the entire aquifer but to meet remediation goals in the most contaminated region of the aquifer. Uranium concentrations in the AOA currently range between 89 and 940 µg/L and average about 450 µg/L. Baseline concentrations in the AOA ranged from 160 to 1400 µg/L (comparison to baseline concentrations is described further in Section 6.3).

Subsurface characterization was conducted in and near the now-defined AOA on multiple occasions: (1) during RI/FS activities starting in 1992 (DOE 1998a and DOE 2004a); (2) during the PRB design phase in 1998 and 1999 (DOE 1998b and DOE 1999a); (3) in 2000, to investigate the source of groundwater contamination in the southeast corner of the former mill site (DOE 2001); and (4) in April 2009 to evaluate the feasibility of active groundwater remediation in that area (DOE 2009b and DOE 2010).

The hydrogeologic boundaries of the AOA correspond to (1) underflow in the alluvial aquifer across the eastern boundary of the former mill site, both north and south of the creek, (2) the PRB (mainly a no-flow boundary), (3) low-permeability bedrock along the north and south margins of the aquifer (no-flow boundaries), and (4) Montezuma Creek, which represents an internal boundary for groundwater and surface water exchange. The base of the aquifer corresponds to the upper bedrock surface, typically within 15 ft of land surface. Depth to groundwater typically is within 10 ft of land surface.

Using these boundary definitions for a discrete area with relatively high concentrations of uranium, the AOA represents a feasible target with which to evaluate active groundwater remediation in a shallow alluvial aquifer setting. DOE described the conceptualization of the AOA boundaries in the Contingency Remedy Optimization Work Plan (DOE 2014a). DOE implemented additional studies in June 2017 to expand characterization of subsurface conditions and boundary definitions of the AOA in the area north of Montezuma Creek (see Section 3.4.3.2).

3.4.3.1 Remedy Optimization System Configuration

Eight vertical extraction wells were installed in the AOA to target the greatest saturated thickness and highest uranium concentrations in that area. Sixteen monitoring wells were installed within and surrounding the network of extraction wells to monitor contaminant concentration trends and water level responses to groundwater withdrawals. All AOA monitoring wells and extraction wells are equipped for real-time water level measurement through the LM System Operation and Analysis at Remote Sites (SOARS). The groundwater extraction system was designed for a total of 50 gpm from the extraction wells. Construction specifications for the remedy optimization system are documented in *Groundwater Remedy Optimization, Monticello Mill Tailings Site Monticello, Utah, Construction Specifications* (DOE 2014b).

The extracted groundwater is conveyed through buried pipes to the groundwater transfer building where it enters an aboveground holding tank. Instantaneous flow rate and cumulative volume per extraction well are metered in the transfer building. Water level sensors in the transfer tank activate and deactivate the transfer pump at high- and low-water–level set points. Water from the transfer tank is pumped to Pond 4 through a buried pipeline for evaporative treatment. The combined flow rate and cumulative volume from the transfer tank to Pond 4 are metered in the transfer building (see Figure 2 for a plan view of the main components of the groundwater optimization system).

Pond 4 and the groundwater extraction and transfer systems are instrumented to provide automated data collection of critical operating parameters (flow rates, line pressures, water levels, pump cycling, and water volume in the pond). Operational controls, metering, and data collection are integrated with the SOARS program. A comprehensive description of the operating parameters and as-built configuration of the remedy optimization system, including telemetry components, is provided in *Remedial Action Completion Report for Operable Unit III Groundwater Contingency Remedy Optimization System, Monticello Mill Tailings Site, Monticello, Utah* (DOE 2016).

3.4.3.2 New Monitoring Well Installation

The monitoring network was expanded in June 2017 with the installation of six monitoring wells in the area north of the creek between the mill site and PRB. The locations of these wells (MW-18 to MW-23) are shown in Plate 1. Monitoring data for these wells are not available for this report. These new wells will be instrumented with water-level transducers and will be sampled monthly with all other AOA monitoring wells for the next year. Information obtained from these wells will help define (1) aquifer boundaries (vertical and horizontal) north of the creek, (2) aquifer/creek interaction, and (3) the potential for groundwater flow in this area to affect water quality in the AOA south of the creek.

4.0 Hydrologic Monitoring

Hydrologic monitoring consists of periodic surface water flow measurement at established stations on Montezuma Creek and the measurement of groundwater levels in OU III monitoring wells. The data are used to assess surface water–aquifer interaction and to characterize flow

direction, hydraulic gradient, and responses to natural and imposed stresses on the alluvial aquifer and Burro Canyon sandstone aquifer.

4.1 Groundwater–Surface Water Interaction

Figure 10 presents a generalized depiction of gaining and losing conditions on Montezuma Creek based on field measurements and visual observations since 2000. Two prominent gaining reaches of the creek are recognized: the first spans the mill site between locations SW01-02 and SW00-02 and is attributed to discharge from the alluvial aquifer. In this reach, the alluvial aquifer receives recharge from anthropogenic sources (irrigation water and possibly from leaky municipal water utilities) that originate along the northern margin of the alluvial valley.

The potentiometric surface in the vicinity of the creek indicates that creek water is recharging the alluvial aquifer in the AOA. Flow measurements are routinely collected in the creek at upstream and downstream locations within the AOA to quantify bulk creek flow and creek losses. The quantity of stream loss may be limited by the fine-textured soil that was placed as the streambed material during site restoration in this area. Creek flow through the AOA is addressed further in Section 6.2.3.

A second gaining reach begins downstream of the AOA near the transition from the Dakota Sandstone ("Kd" in Figure 5 and Figure 10) to the Burro Canyon sandstone ("Kbc" in Figure 5 and Figure 10) in the valley floor (the approximate location of the Kd/Kbc contact is shown in Figure 10). In that reach, the Dakota Sandstone aquitard is absent, allowing groundwater in the Burro Canyon aquifer to discharge upward into both the alluvium and Montezuma Creek. Groundwater discharge to Montezuma Creek from the alluvial aquifer is also promoted by the narrowing of the canyon in this reach.

Numerous springs near the base of the Burro Canyon aquifer are direct evidence of Burro Canyon aquifer discharge in this reach. Upward hydraulic gradients observed at well pairs 95-01/95-02 and 95-03/95-04 in this part of the valley are also indicative of upward flow and discharge of groundwater from the Burro Canyon aquifer. This condition contributes to forming a natural hydrologic boundary that prevents eastward expansion of the contaminant plume. Alluvial groundwater is not contaminated downgradient of this boundary, as addressed in Section 5.6.1. The discharge of contaminated groundwater from the alluvial aquifer upgradient of this boundary may contribute to the uranium contamination in Montezuma Creek that is observed at the Sorenson location.

The canyon widens approximately 1.5 miles downstream of the mill site coincident with the transition to slope-forming mudstone of the Morrison Formation as the upper bedrock (see Figure 10 for the approximate location of the contact between the Burro Canyon sandstone and Morrison Formation ["Jm" in the figure]). In this wider reach of the canyon, a predominantly losing stream condition is evident. At the downstream boundary of OU III (Figure 1), the alluvial aquifer pinches out entirely in rugged canyon terrain. All alluvial groundwater presumably discharges to the creek by this point.

4.1.1 Stream Flow Measurements for April and October 2016

Creek flow was measured at three locations in April 2016 (SW00-02, Sorenson, and SW92-08). Aquatic and riparian vegetation and the lack of a defined flow channel prevented flow measurement at other OU III locations. At that time, flow was evident at the west end of the mill site. Measured flow at the east end of the mill site (location SW00-02) was approximately 230 gpm. Creek flow was measured at approximately 290 gpm and 240 gpm, respectively, at the downstream locations Sorenson and SW92-08.

Creek flow measurements in October 2016 (base flow conditions) confirmed a gaining stream condition through the mill site from approximately 60 gpm at location SW01-02 (west boundary of the mill site) to approximately 125 gpm at location SW00-02 (east boundary of the mill site). Creek flow downstream of the mill site was 160 gpm at the Sorenson location and 250 gpm at SW92-08. Creek flow measurements conducted in the AOA (at SW00-02 and the PRB) during the reporting period are addressed in Section 6.2.3.

4.2 Alluvial Aquifer Water Levels

4.2.1 Former Mill Site

Water level hydrographs for monitoring wells 82-20, MW00-01, and MW00-02 (Figure 11) indicate that the alluvial aquifer at the upgradient boundary of the former mill site is subject to water level fluctuations that vary from several feet to nearly 10 ft. These locations reflect water table conditions in the alluvial aquifer at the western inflow boundary of OU III (well 82-20 was decommissioned in September 2005). Within this range of water table fluctuation, the corresponding average saturated thickness of the aquifer across this boundary is about 4 ft.

On the mill site, water levels do not fluctuate as much as at the upgradient boundary (water level hydrographs for mill site monitoring wells completed in the alluvial aquifer are shown in Figure 12). The hydraulic connection between the aquifer, creek, and constructed wetlands may dampen the water level fluctuations from those evident at the upgradient boundary. Water levels at monitoring wells on the mill site have not shown strong upward or downward trends since 2000 (Figure 12). The saturated thickness of the alluvial aquifer on the mill site is about 5 ft.

4.2.2 PRB Area

Figure 13 shows water level hydrographs for selected monitoring wells (wells 92-11, 92-07, PW-18, 92-08, 92-09, 88-85, PW-17, MW00-06, and P92-06) located between the former mill site and the PRB. In this area, the effect of aquifer dewatering during mill site remediation is evident in the declining water levels at wells 92-11, 88-85, and 92-07 from mid-1998 through mid-1999, preceding installation of the PRB. To facilitate tailings removal during that time, engineering controls were in place to remove groundwater from the tailings excavations and later to dewater the aquifer using temporary interceptor trenches that were installed in the western portion of the mill site. These temporary trenches were backfilled during site restoration as tailings removal was completed.

Groundwater that was removed from the tailings excavations was treated by reverse osmosis at a temporary onsite treatment facility and returned to Montezuma Creek. Groundwater that was collected at the interceptor trenches was not contaminated and was routed to the creek where it crossed the east boundary of the mill site.

After dewatering ceased, the water table upgradient of the PRB, installed in summer 1999, rebounded within 6 months to levels that approached pre-remediation conditions (at wells 88-85 and 92-07, for example). Water level rebound was likely enhanced by flow convergence at the PRB. Water levels that are 2–3 ft higher in this area in April 2010 likely reflect the rapid runoff of an above-average mountain snowpack and releases from the reservoir. These data imply that the effects of hydrologic perturbations of this scale are recognizable within weeks to months at OU III monitoring wells.

4.2.2.1 Groundwater Levels at the PRB

Groundwater levels increased on the upgradient side of the PRB soon after it was installed. In Figure 14, the sharp water level decline observed at well 88-85 in 1998 is in response to the large-scale dewatering during the OU I remedial action. With the completion of this action, and following installation of the PRB (summer 1999), water levels in the near-upgradient area of the PRB rose through 2009 to exceed pre-PRB levels by about 4 ft (see water level hydrograph for well 88-85 in Figure 14). The rising water levels at well 88-85 was mimicked at alluvial aquifer well R1-M3 (Figure 14), located about 3 ft upgradient of the PRB, and at other PRB wells but was not observed to occur sitewide.

Groundwater level increases at the PRB is interpreted to result from (1) contrasting hydraulic conductivity between the alluvial aquifer (higher conductivity) and the interface with the PRB (lower conductivity) and (2) mineralization within the reactive media of the PRB. Once the PRB was installed, steep groundwater flow gradients developed between the alluvial aquifer and the PRB materials. Water levels in the alluvial aquifer within 10 ft of the PRB interface have remained 3 to 4 ft greater than within the PRB. A gradient of similar magnitude persists across the downgradient interface of the PRB, with water levels decreasing from the PRB to the aquifer.

The hydraulic gradient such as observed at the upgradient interface would not be expected if the hydraulic conductivity of the materials in the PRB equaled or exceeded that in the surrounding aquifer media. Development of this gradient is attributed to a suspected zone of low hydraulic conductivity at the upgradient alluvium–PRB interface. This zone may be the result of sediment compaction or smearing of fine-grained sediments during sheet piling installation and removal. Steepened hydraulic gradients and rising water levels at the upgradient alluvium-PRB interface may also result from progressive loss of hydraulic conductivity due to internal mineral precipitation (DOE 2006b and 2006c).

The effect of rising groundwater levels at the PRB has never compromised land-use (agricultural): there has been no crop damage or surface expression of groundwater on the property.

Effect of Ex Situ System on Local Water Levels

The water level hydrograph for well 88-85, located in the groundwater mound immediately upgradient of the PRB, indicated no apparent trend since the start of active remediation by the ex situ system in 2005 (see Figure 15). This suggests that groundwater extraction from well EW-1, sustained at approximately 10 gpm, did not reduce local water levels (water level declines in

2005 observed at well 88-85 is a regional effect and is unrelated to operation of the groundwater remediation system).

Groundwater extraction from well EW-1 also had no apparent effect on water levels at monitoring wells 92-07 and PW-17 (Figure 15) located about 200 and 300 ft south, respectively, of the extraction well and near the end of the south slurry wall. A study conducted over a 4-month period in 2007 also concluded that the water level in the area surrounding well EW-1 was unaffected by groundwater extraction (DOE 2008). These results suggested that groundwater withdrawal at EW-1 did not decrease the quantity of groundwater flow around the south slurry wall (estimated to be less than 1 gpm prior to the start of pumping) but may have prevented increased bypass by stabilizing groundwater levels.

Section 6.0 presents a more comprehensive analysis of aquifer response to increased groundwater withdrawal associated with the remedy optimization system in the AOA.

4.2.3 Trends in Water Level Downgradient of the PRB

East of the PRB, the period of mill site dewatering can be discerned as a brief episode of a decline in alluvial aquifer water levels and subsequent recovery at several monitoring wells; for example, wells 92-08 and P92-06 (Figure 13). The effect of dewatering on the mill site diminished with distance from the mill site, with well 92-09 showing less change than adjacent wells 92-08 and P92-06. Overall, the water level data suggest a subtle decline (1 ft or less) in water levels downgradient of the PRB since 2000. Such a trend is not apparent for wells at the inflow boundary to OU III.

4.3 Vertical Flow Potential between the Burro Canyon and Alluvial Aquifers

4.3.1 Vertical Flow Potentials in the Far Downgradient Area

Well pairs 95-01/95-02 and 95-03/95-04 are the easternmost groundwater monitoring locations in OU III (see Figure 5 for well locations). Wells 95-01 and 95-03 are completed in the alluvial aquifer, and wells 95-02 and 95-04 are completed in the upper 20 ft of the Burro Canyon aquifer. Groundwater is not contaminated in either aquifer at the location of these well pairs. Ongoing water level monitoring at these wells is conducted to confirm that the natural upward flow potential between the Burro Canyon and alluvial aquifer in this part of the canyon continues, thus preventing downward migration of the plume. In addition, upward flow of groundwater from the Burro Canyon aquifer displaces alluvial groundwater to the creek, which also limits horizontal, downgradient plume migration.

Water levels at these well pairs have been relatively stable over time and demonstrate a consistent upward flow gradient from the Burro Canyon aquifer to the alluvial aquifer (Figure 16). The upward flow gradient is evidenced at each well pair by the water elevation in the Burro Canyon well that is higher than in the paired alluvial aquifer well. The direction (upward) and magnitude of this flow gradient were unchanged at these locations when the City of Monticello increased groundwater production from the Burro Canyon aquifer in 2002 and 2003 to meet residential demand.

4.3.2 Vertical Flow Potentials in Plume Area

Municipal well pumping did have an effect on water levels at some of the Burro Canyon monitoring wells that are located closer to the production wells. For example, about 15 ft of drawdown was observed at well 83-70 during years 2002–2004 (Figure 17). Well 83-70 is completed in the Burro Canyon aquifer at a location between the former mill site and the PRB (see Figure 5 and Plate 1 for well locations) where the overlying alluvial aquifer is contaminated. Despite this increase in the downward flow potential from the alluvial aquifer to the Burro Canyon aquifer, water quality in the Burro Canyon aquifer at this location has not been affected. It is interpreted that the Dakota Sandstone aquitard separates the aquifers and limits groundwater exchange at this location.[1]

4.3.3 Vertical Flow Potentials in Cross-Gradient Area

Burro Canyon well 95-08 is located on the mesa above well pair 95-03/95-04. The stable water table observed at well 95-08 (Figure 17) suggests that the drawdowns and subsequent declines in water levels observed at wells 93-205, 83-70, 93-01, and 95-06, which are much closer to the municipal production wells, may be related more to municipal well pumping rather than climatic factors (see Figure 6 for locations of municipal production wells and OU III Burro Canyon monitoring wells).

An additional feature of the hydrograph for well 95-08 is that the water level (nominally 6715 ft) is much higher than those at Burro Canyon wells 95-02 and 95-04 (nominally 6670 and 6675 ft, respectively, see Figure 16), which are located near well 95-08 but are in the canyon floor. The higher water level at well 95-08 (approximately 40 ft) is a measure of the hydraulic potential for groundwater to discharge from the Burro Canyon aquifer and be received by the creek and alluvial sediments within this reach of the canyon.

5.0 Water Quality Assessment

5.1 Groundwater Contamination Source Removal

OU I remedial actions, completed in 1999, removed the primary source of groundwater and surface water contamination (the mill tailings). All construction activities associated with OU I that would impact groundwater and surface water were completed by 2001; therefore, much of the current discussion regarding OU III water quality focuses on the period since the removal of the tailings (or "source removal") and site restoration. Despite effective removal of the primary source of groundwater contamination, a legacy contaminant plume remains in the dissolved phase that originated from the mill tailings. Desorption of tailings-derived uranium from the aquifer matrix, as a secondary source, may also contribute to sustaining the contaminant plume.

[1] Well 83-70 was transferred from DOE to private ownership in 2006. Water use quantity, schedule, and disposition since then are undocumented; however, the monitoring data do not indicate a drawdown in the alluvial aquifer subsequent to the transfer.

5.2 Contaminants of Concern and Remediation Goals

COCs for OU III surface water and groundwater are arsenic, manganese, molybdenum, nitrate, selenium, uranium, vanadium, and gross alpha and gross beta activity. Table 1 lists the remediation goals for these constituents in groundwater and surface water.

The groundwater goals correspond to either a maximum contaminant level as established by EPA, a maximum concentration limit from the Uranium Mill Tailings Remedial Action (UMTRA) Project, or a value derived from the OU III human health risk assessment (DOE 1998a), as indicated in Table 1.

Table 1. OU III Contaminants of Concern and Groundwater and Surface Water Remediation Goals

COC[a]	OU III Groundwater Remediation Goals[a]	Surface Water Remediation Goals[a,b]
Arsenic	10 µg/L[c]	10 µg/L
Manganese	880 µg/L[d]	--
Molybdenum	100 µg/L[e]	--
Nitrate (as nitrogen)	10,000 µg/L[c]	4000 µg/L
Selenium	50 µg/L[c]	5 µg/L
Uranium—metal toxicity	30 µg/L[c]	--
Vanadium	330 µg/L[d]	--
Uranium-234 plus Uranium-238—radiological dose	30 pCi/L[e]	30 pCi/L[b]
Gross alpha activity	15 pCi/L[c,f]	15 pCi/L[g]
Gross beta activity	--	--

Notes:
[a] From the OU III ROD (DOE 2004a).
[b] State of Utah's standard for surface water; Utah's uranium standard postdates the OU III ROD.
[c] EPA's maximum contaminant level.
[d] Based on OU III human health risk assessment.
[e] UMTRA's maximum concentration limit.
[f] Excluding uranium and radon.
[g] Excluding uranium and radon for MMTS OU III.

Abbreviation:
pCi/L = picocuries per liter

Surface water remediation goals correspond to water quality standards established by the State of Utah. Gross beta activity has no remediation goal because there is no activity-based standard for this constituent; risk factors to derive a risk-based goal are isotope-specific.

Analyses of uranium-234 (^{234}U) and uranium-238 (^{238}U) in groundwater and surface water were discontinued in 2006 with concurrence from EPA and UDEQ. The EPA groundwater remediation goal based on metal toxicity (30 µg/L) converts to approximately 20 picocuries per liter (pCi/L) as ^{234}U plus ^{238}U and so is more stringent than the radiation activity–based goal of 30 pCi/L. The 30 pCi/L Utah surface water standard converts to approximately 44 µg/L. Analyses for gross alpha and gross beta activity were also discontinued in 2006 with concurrence from EPA and UDEQ.

5.3 Monitoring Schedule, Frequency, and Network

OU III groundwater and surface water samples are collected for analysis of COCs and other geochemical parameters in April and October of each year. Water quality results for the current reporting period (May 2016 through April 2017) are tabulated in Appendixes A, B, and C for alluvial aquifer, bedrock aquifer, and surface water monitoring, respectively. Figure 5 shows the monitoring locations in the current monitoring network. This network is a subset of all locations monitored since January 2000; locations have changed as a consequence of revised data objectives or changing field conditions (Plate 1 in previous annual reports show all locations that have been monitored on one or more occasion since January 2000). Table 2 shows sampling frequencies for all locations sampled during the current reporting period.

Table 2. Sampling Frequency

Location ID	Semiannually[a]	Annually[b]	Every 5 Years
North Off-Site Wells			
93-205			X[c]
95-07			X[c]
Former Mill Site Wells			
93-01		X	
MW00-01	X		
T00-01		X	
T00-04		X	
T01-01	X		
T01-02	X		
T01-04	X		
T01-05	X		
T01-07	X		
T01-12	X		
T01-13		X	
T01-18		X	
T01-19	X		
T01-20		X	
T01-23		X	
T01-25		X	
T01-35	X		
Downgradient Wells			
82-08	X		
83-70		X	
88-85	X		
92-07	X		
92-08	X		
92-09	X		
92-10		X	
92-11	X		

Table 2: Sampling Frequency (continued)

Location ID	Semiannually[a]	Annually[b]	Every 5 Years
95-01		X	
95-03		X	
95-06			X[c]
0200	X		
0202	X		
MW00-06	X		
MW00-07		X	
P92-06	X		
PW-10	X		
PW-17	X		
PW-28	X		
PRB Wells			
R1-M3	X		
R1-M4	X		
R3-M2	X		
R3-M3	X		
R4-M3	X		
R4-M6	X		
R6-M3	X		
R6-M4	X		
R10-M1	X		
Former Mill Site Seeps and Wetland (W3) Locations			
Seep 1	X		
Seep 2	X		
Seep 3	X		
Seep 5	X		
Seep 6	X		
W3-03	X		
W3-04	X		
Surface Water Locations			
SW00–01	X		
SW00–02	X		
SW01–02	X		
SW01–03	X		
SW01–01	X		
Sorenson	X		
SW00–04	X		
SW92–08	X		
SW92–09	X		
SW94-01	X		

[a] Semiannual sampling occurs in April and October.
[b] Annual sampling occurs in October.
[c] 5-year sample collected during the current reporting period.

Sampling conducted in October is more comprehensive than that conducted in April; in April, several alluvial wells located beyond the extent of contamination and several bedrock wells are omitted from sample collection. Water levels are measured at all active monitoring wells during the April and October events. Excluding the PRB, water quality monitoring of the alluvial aquifer is conducted at 35 locations in October and at 22 locations in April. Three monitoring wells (83-70, 92-10, and 93-01) completed in the Burro Canyon aquifer are sampled in October only. Three other wells (93-205, 95-06, 95-07) completed in the Burro Canyon aquifer but at greater distance from the area of groundwater contamination are sampled every 5 years and were sampled during the current reporting period. Water quality monitoring is conducted in October and April each year at 10 surface locations in Montezuma Creek, at 5 groundwater seep locations, and at 2 locations in Wetland 3.

Water quality monitoring within the PRB typically occurs at four locations (R3-M2, R3-M3, R4-M3, and R4-M6) during the October and April events. R4-M3 had insufficient water during both sampling events during the current reporting period. Numerous other wells near the PRB were routinely sampled during earlier years of PRB operation, and, in this reporting period, additional PRB locations were sampled (R1-M3, R1-M4, R6-M4, and R10-M1; see Figure 7).

Hydrologic monitoring (Section 4.0) is conducted to measure water levels at monitoring wells and flow in Montezuma Creek. A visual inspection of groundwater seeps is also conducted. Appendix D contains the water level data collected in this reporting period. Water level and streamflow monitoring locations (streamflow sites generally coincide with water quality sampling locations on Montezuma Creek) are shown on Plate 1 and in Figure 5.

5.3.1 Groundwater Monitoring in the AOA

Water quality monitoring in the AOA is conducted separately from the general OU III monitoring events in April and October. Monitoring wells in the AOA are sampled at intervals when approximately 1 million gallons of water have been extracted from the AOA. Sampling of the transfer tank effluent is conducted monthly to estimate the mass of uranium that has been extracted from the aquifer and transferred to Pond 4 for evaporative treatment. Discretionary sampling of the extraction wells is conducted monthly (from sampling ports in the groundwater transfer building) to evaluate uranium capture performance for the individual extraction wells. The water samples collected from the monitoring wells are analyzed for the full suite of site COCs. Transfer tank and extraction wells samples are analyzed for uranium only. Detailed discussion of water quality restoration progress in the AOA, which includes additional monitoring locations specific to that area, is presented in Section 6.0 of this report.

5.4 Alluvial Aquifer Water Quality and Trends

Even-numbered graphics in Figure 18 through Figure 30 illustrate the current extent of contamination in the alluvial aquifer for arsenic, manganese, molybdenum, nitrate (as nitrogen), selenium, uranium, and vanadium, respectively. Posted results are from April 2017 unless the monitoring locations were only sampled in October 2016 (monitoring results from October 2016 are asterisked). Symbol coding identifies sample type (circles for groundwater and squares for surface water) and whether the remediation goal for the respective COC was exceeded (filled symbol) or not (open symbol) at the given location.

Odd-numbered graphics Figure 19 through Figure 31 illustrate time-varying concentrations of arsenic, manganese, molybdenum, nitrate (as nitrogen), selenium, uranium, and vanadium, respectively, at selected monitoring wells located along the axis of the groundwater plume. Ordering of the wells in the legend of these figures is from west (upgradient) to east (downgradient). Monitoring data since 1993 are included in the figures to show the effect of mill site cleanup (source removal), which is evidenced at many locations by the decrease in the concentration of many COCs in 1998 and 1999.

In the past year, all COCs were present in alluvial groundwater at one or more locations at a concentration that exceeded the respective remediation goal. The magnitude relative to remediation goals and spatial distribution of these COCs, except uranium, indicate only minor contamination. Alluvial aquifer water quality results for the reporting period are included as Appendix A on the attached CD.

Arsenic

Arsenic levels that exceeded the remediation goal were from sampling locations primarily between the eastern part of the mill site and the PRB; the maximum concentration (17 µg/L at location T01-04, Figure 18) has historically been at levels less than twice the remediation goal (10 µg/L).

In Figure 19, arsenic concentrations show no apparent trend since source removal at the selected alluvial aquifer wells. The low-level and localized arsenic contamination, persistent only at the eastern end of the former mill site, is remnant from the contaminant plume that developed before OU I remediation.

Manganese

Manganese exceeded the remediation goal (880 µg/L) at six locations in the western half of the mill site (excluding the AOA, which is discussed in Section 6.0) (Figure 20). This has been true since the OU I source removal, with manganese concentrations remaining consistently above the remediation goal at five of these locations (T01-13, T01-18, T01-19, T01-20, and T01-25). The sixth location, T01-01, has less consistently shown elevated levels of manganese. Previously, other sampling locations downgradient of the PRB have exceeded the remediation goal, attributed to ZVI corrosion within the PRB. However, during this reporting period, contamination in this area and downgradient of the mill site is not evident at any location.

Figure 21 shows that manganese concentrations at the selected alluvial aquifer wells remain stable below the remediation goal except at well T01-19. At that location, manganese concentrations vary widely and remain well above the remediation goal, although there is no apparent trend. Concentrations at that location range between about 4000 and 9000 µg/L (about 5–10 times the restoration goal of 880 µg/L).

Molybdenum

Molybdenum contamination since remediation of the mill site has been limited to a small area of the aquifer at the south end of the PRB slurry wall (Figure 22; excluding the AOA, which is discussed in Section 6.0). Molybdenum concentrations in groundwater did not exceed the remediation goal at any locations outside of the AOA for this reporting period.

Molybdenum concentrations in selected alluvial monitoring wells clearly show the effect of source removal in 1999 (Figure 23). Concentrations remain stable, all well below the remediation goal.

Nitrate

Nitrate contamination since the completion of mill site remediation has been limited to several locations along the north side of the mill site and immediately downgradient. The occasional occurrences of nitrate contamination in these areas could originate from nearby livestock feedlots. Nitrate concentrations in groundwater did not exceed the remediation goal (10,000 µg/L as nitrogen) at any location for this reporting period (Figure 24).

The increase in nitrate concentrations in groundwater from 1999 through 2001 (Figure 25) is attributed to fertilizer applications during restoration of the mill site. This pulse dissipated by 2004. In April 2005, 2008, and 2010, large increases again occurred at some locations, including the upgradient monitoring well (MW00-01, not shown). Those influxes possibly originated from the municipal golf course west of the former mill site and from livestock operations on the north side of the former mill site. No trend in nitrate concentrations is evident, and present concentrations are below the remediation goal.

Selenium

Selenium concentrations exceeded the remediation goal of 50 µg/L at location 0200, at 106 µg/L, during the reporting period (Figure 26).

Selenium concentrations in groundwater increased significantly following OU I remedial actions in 1999 (Figure 27), particularly in the eastern area of the mill site where the Dakota Sandstone was freshly exposed by the excavations. Naturally occurring selenium in the exposed shale and coal beds is presumed to have been mobilized by oxygenated groundwater that came in contact with these sediments. Locations where selenium concentrations increased in April 2005, 2008, and 2010 generally coincide with those of increased nitrate. This relationship, also apparent with the nitrate release in 1999, may be associated with the ability of nitrate to oxidize and mobilize naturally occurring selenium (Wright 1999; Wright and Butler 1993; Weres et al. 1990; see also DOE 2001). Selenium concentrations in groundwater have since decreased and remain relatively stable below the remediation goal.

Uranium

Uranium remains the most widespread contaminant in groundwater, extending about 0.75 mile (4000 ft) downgradient of the mill site, with concentrations that are up to 16 times the remediation goal (30 µg/L) at many locations (see Figure 28). The highest concentration outside of the AOA was at location P92-06 (466 µg/L). Concentration trends over time outside of the AOA are shown in Figure 29.

Inside the AOA, concentrations were up to 31 times the remediation goal (940 µg/L at location MW-11). Because uranium is the most widespread contaminant at OU III and contributes the most to potential human health risk, further analysis of concentration trending for uranium in groundwater is provided in Section 6.0.

Vanadium

Vanadium contamination in recent years has generally been limited to a few locations near the eastern boundary of the mill site at concentrations that only marginally exceed the remediation goal of 330 µg/L. Concentrations during the most recent monitoring event during this reporting period were below the remediation goal at all locations outside of the AOA except at wells 92-11 (343 µg/L) and R1-M3 (368 µg/L) (Figure 30).

Vanadium concentrations show the initial effect of source removal, particularly at the monitoring location nearest the former mill site (monitoring well 92-11; see Figure 31). Vanadium concentrations have slowly decreased since removal and remain just above the remediation goal at two locations.

5.4.1 Analysis of Uranium Restoration by Aquifer Region

The ROD for OU III stipulated performance metrics for comparing MNA progress to model-predicted rates of restoration progress. For that purpose, the aquifer was divided into five regions (Figure 32) for individual evaluation of restoration progress using selected monitoring wells, as identified in the ROD, within each region.

The ROD states that as of October 2004, if the model-predicted average for a given region is significantly less than the observed uranium concentrations over three consecutive sampling events, DOE is to implement contingency actions. Concentration trending was observed to significantly depart from the model predictions over three consecutive sampling events in 2005, (DOE 2006a). In accordance with the ROD, DOE subsequently conducted a second trend analysis of the groundwater concentration data. That analysis applied the Mann-Kendall test for trend detection (test method described in Gilbert 1987).

That analysis concluded that aquifer restoration by 2045 (42 years from 2002), as predicted by the groundwater model, was not likely (DOE 2007) under the MNA remedy. This prompted DOE to implement active remedial actions, as addressed in the ESD (DOE 2009a), which ultimately led to the current expansion of the active groundwater pump-and-treat system in the AOA.

Continued analysis of uranium trending in the five aquifer regions is no longer required by the ROD; however, Mann-Kendall test analyses are presented in this report for completeness in evaluating overall restoration progress as determined by the monitoring for selected wells in the individual aquifer regions. Region 3 of the aquifer (described below) encompasses the AOA; however, the selected wells used in the trend analysis differ from those used in the analysis of remediation system performance described in Section 6.0 of this report. The wells used for the analysis described in Section 6.0 had not yet been installed when the wells used in the analysis by region were selected.

In Figure 33 through Figure 37, the results of the Mann-Kendall trend test[2] for selected locations within the region are provided. For those wells with sufficient data, the nonparametric Mann-Kendall trend test is used to indicate whether uranium concentrations have a statistically

[2] ProUCL Version 5.1.002 Statistical Software for Environmental Applications for Data Sets with and Without Nondetect Observations was used to run the Mann-Kendall trend tests.

significant increasing or decreasing trend in the individual monitoring wells. A significance level (alpha, also known as the false positive error rate) of 0.05 was used for all tests.

- Region 1 encompasses the former mill site, much of which was overlain by mill tailings or occupied by mill facilities. Groundwater recharge occurs by underflow from the west and anthropogenic sources to the north. The alluvial aquifer and the course of Montezuma Creek were reconstructed during OU I remediation. Significant quantities of groundwater in this area are displaced to Montezuma Creek.

  Uranium concentrations in this region persist; however, they are relatively low (39 to 180 µg/L), with the exception of well T01-18 for which concentrations have historically remained around 300–400 µg/L. Subtle downward trending since 2001 is apparent at the wells in this region (Figure 33). Results of the Mann-Kendall test show statistically significant evidence of a decreasing trend at the locations selected to evaluate restoration progress in this aquifer region.

- Region 2 encompasses the area of Wetland 3 to the eastern boundary of the former mill site. All of Region 2 was formerly overlain by impounded mill tailings until OU I remedial actions were completed. Groundwater that flows across the eastern boundary of the former mill site passes through this region. Leakage of uncontaminated water from Wetland 3 is a source of groundwater recharge to Region 2.

  Uranium concentrations in Region 2 are relatively low (38–140 µg/L). Similar to that of Region 1, this range is consistent with the tailing effect observed in OU III column leach tests (DOE 2001[3]). Downward concentration trends observed between 2001 and 2005 (Figure 34) have since slowed. Results of the Mann-Kendall test show a subtle decreasing trend at locations selected to evaluate restoration progress within Region 2 of the aquifer.

  Contamination from Region 1 is not likely to impact Region 2 because most groundwater in Region 1 is thought to discharge to Montezuma Creek on the mill site. Leakage of water from Wetland 3 may locally dilute contaminant concentrations in the aquifer.

- Region 3 is the area between the former mill site and the PRB. Region 3 encompasses the AOA and the monitoring locations that are now in place as part of the groundwater remedy optimization; however, water quality restoration progress specific to the AOA is addressed in Section 6.0. Mann-Kendall trend analysis for the selected monitoring wells in Region 3, some of which are outside of the AOA, does not necessarily reflect the progress of restoration as evaluated for the monitoring wells strictly within the AOA (see Section 6.0).

  No portion of Region 3 was overlain by the mill tailings impoundments. The PRB is considered the downgradient boundary of this region because it forms a local groundwater flow barrier. Lateral boundaries coincide with the margins of the alluvial aquifer where it terminates against bedrock slopes. Region 3 (excluding the AOA) encompasses high concentrations of uranium in groundwater, with the highest concentration (409 µg/L) measured at well PW-17 during the current reporting period.

  Three of five of the selected wells in Region 3 (wells 92-11, 88-85, and PW-28) have exhibited a slight downward trend in uranium concentration since about 2008. Concentrations are relatively static at about 200 µg/L, similar to those of Region 1 and 2

[3] In this context, the concentration tailing effect refers to rapid contaminant desorption that progresses non-linearly to a quasi- steady-state concentration that persists through multiple volumes of pore water exchange with a contaminated sediment. The concentration 'tail' may exceed a remediation goal.

observations, and the concentrations may imply a tailing effect. Concentrations at wells 88-85 and 92-11 decreased significantly following mill site remediation.

Concentration trends at the remaining two of the selected wells in Region 3 (wells 92-07 and PW-17) contrast markedly with wells 92-11, 88-85 and PW-28 because concentrations were much greater and had also risen through 2007 up to 1400 µg/L (Figure 35). Possible reasons are that (1) wells 92-07 and PW-17 are farther from the creek and less influenced by dilution, (2) well 92-11 groundwater may by diluted by leakage from underflow from the mill site, and (3) the area south of Montezuma Creek may initially have been more contaminated.

The rise in concentrations at wells 92-07 and PW-17 does not imply the incomplete removal of mill tailings as a source of groundwater contamination but instead indicates plume movement in the area south of the creek toward the south end of the PRB slurry wall. The lack of downward-trending concentrations south of the creek may reflect flow stagnation at the PRB and limited groundwater underflow from Region 2 to the portion of Region 3 that is south of the creek.

The Mann-Kendall trend analysis for Region 3 was conducted at two different time intervals; 2000 to 2007 and 2008 to 2017 (Figure 35). This time period split was applied because of the record high concentrations that were measured in 2007, mainly at wells 92-07 and PW-17, and the implementation of an expanded active remediation system that may also be a contributing factor for the decline in concentrations following its implementation. During recent reporting periods, concentrations at these locations have continued to show a gradual decline and are now lower than those recorded during the 2000–2003 period.

Results of the Mann-Kendall test for the period from 2008 to 2017 show a statistically significant decreasing trend at all the selected locations in Region 3 (Figure 35). However, the wells selected for the Mann-Kendall test for Region 3 differ from those in the AOA, and so the trending results may differ from the evaluation of restoration progress presented in Section 6.0 for the AOA.

- Region 4 extends from the PRB approximately 750 ft east to the location of monitoring well 82-08. Water quality in this area is affected by agricultural irrigation, effluent from the PRB, suspected leakage from Montezuma Creek, and the flow of contaminated groundwater around the south end of the PRB. Uranium concentrations vary in this region from 86.9 µg/L at well R10-M1 to 360 µg/L at well MW00-06.

  Concentrations in wells MW00-06 and MW00-07 had increased since 2005 (Figure 36), although well MW00-07 did not yield sufficient water for sample collection during the last reporting period. The uranium concentration at well MW00-06 of 360 µg/L in April 2017 shows a decrease since peaking at 1100 µg/L in October 2012. Results of the Mann-Kendall test show a statistically significant decreasing trend at well 0202 and an increasing trend at wells MW00-06, MW00-07, and 82-08 (Figure 36).

  Uranium concentrations in Region 4 are expected to vary spatially and temporally because of (1) multiple water sources, (2) spatially variable initial uranium concentrations, and (3) plume movement, as exemplified at well MW00-06.

- Region 5 extends east of monitoring well 82-08 to the terminus of the uranium plume. Uranium concentrations in this region vary from several hundred micrograms per liter (location 92-09, 329 µg/L) to background concentrations at wells 95-01 and 95-03 near the hydrologic boundary condition described in Section 4.1.

Trending is not readily apparent at Region 5 wells (Figure 37); instead, except for well P92-06, concentrations remain relatively stable between about 200 and 500 µg/L. Uranium concentrations at well P92-06 increased to greater than 1000 µg/L during years 2008–2009 but have since decreased to approximately 450 µg/L. This event may represent movement of a pulse of contamination released during operation of the mill.

Uranium concentrations at well 92-09 may be increasing slightly over time at levels between approximately 300 and 500 µg/L. However, concentrations have been variable in that range over time, and levels were about 300 µg/L during the current reporting period.

Results of the Mann-Kendall test show a statistically significant decreasing trend at wells 92-08 and 0200 and an increasing trend at well 92-09. Plume migration beyond Region 5 is not expected because of the natural hydrologic boundary.

5.4.2 Plume Stability in the Alluvial Aquifer

The uranium contamination plume terminates between monitoring wells 92-09 and 95-03 (Figure 28); therefore, well 95-03 is regarded as a sentinel well to detect possible advancement of the plume past its current extent. The OU III groundwater model (DOE 2004a) predicted only slight increases in uranium concentrations east of the current extent of contamination but not to exceed the remediation goal at sentinel well 95-03 in the 50 years of simulated uranium transport.

Figure 38 illustrates that contaminant levels observed at well 95-03 are not increasing and that the plume is not expanding into uncontaminated regions of the aquifer. In this respect, the uranium contamination plume is considered to be stable. Plume expansion is prevented by prior source removal and by the natural hydrologic boundary described in Section 4.1. Further evidence of plume stability is the lack of increasing COC concentrations, indicating effective control of the primary source of groundwater contamination through OU I and OU II remedial actions (see Section 5.4.1 for additional discussion of COC trending).

Manganese concentrations at sentinel well 95-03 are not included in Figure 38 because they exceed the maximum scale of the chart (100 µg/L). Concentrations of manganese at well 95-03 remain steady between 300 and 400 µg/L. High manganese concentrations at this location are attributed to the discharge of Burro Canyon groundwater, which is naturally abundant in this element (historically between about 400 and 500 µg/L at paired location 95-04).

5.4.3 PRB Performance

Even-numbered graphics in Figure 18 through Figure 30 (see PRB insets in those figures) show that the PRB continues to effectively reduce contaminant concentrations to acceptable levels; however, the ability of the PRB to transmit a significant amount of water has been compromised by internal mineralization (DOE 2002 and DOE 2006c). There is no evidence of contaminant release from the PRB, except possibly for manganese at well R4-M6. At this location, manganese is seen to increase from less than 2 µg/L in the influent groundwater to 320 µg/L (below the restoration goal) at well R6-M4 in the alluvial aquifer immediately downgradient of the PRB (Figure 20). Manganese, a trace constituent of ZVI, is also observed to increase in the PRB relative to the influent groundwater. Manganese in the PRB effluent water is thought to be immobilized upon entry into the alluvial aquifer sediments because of contrasting geochemical conditions that promote precipitation or chemical sorption.

5.4.4 Ex Situ Treatment System

In concurrence with EPA and UDEQ, operation of the ex situ treatment system was suspended, effective December 29, 2014. The ex situ treatment system treated about 33 million gallons of groundwater and removed approximately 77 pounds of uranium from the alluvial aquifer cumulatively from June 2005 through December 2014. Performance of the ex situ treatment system and related effluent discharges to surface water were reported in quarterly Federal Facility Agreement (FFA) reports to EPA and UDEQ and in annual groundwater reports.

5.4.5 Remedy Optimization System Performance

A detailed analysis of water quality restoration within the AOA, as affected by operation of the remedy optimization system, is presented in Section 6.0. Performance of the remedy optimization system is also reported in quarterly FFA reports to EPA and UDEQ.

5.5 Burro Canyon Aquifer Water Quality

During the review period, six Burro Canyon aquifer wells were sampled in October 2016 (monitoring well locations are shown in Figure 5 and Plate 1). Well 93-01 provides background water quality data for the Burro Canyon aquifer; well 83-70 is completed a short distance downgradient of the former mill site where contamination in the alluvial aquifer is greatest; and well 92-10 is completed near the downgradient terminus of the uranium plume. Table 3 lists COC concentrations for these wells. Results indicate that site-related constituents have not contaminated the Burro Canyon aquifer at these locations. Bedrock aquifer water quality results for the reporting period are included as Appendix B on the attached CD.

Burro Canyon aquifer wells 93-205, 95-06, and 95-07 (monitoring well locations are shown in Figure 5 and Plate 1) have been sampled every 5 years since October 2006. The wells were sampled during the current reporting period in October 2016. Prior to 2006, these wells were sampled at least yearly since their installation in 1993 (well 93-205) and 1995 (wells 95-06 and 95-07). Table 3 shows the current sampling results for these wells and indicates that arsenic was detected at well 93-205 at a concentration (84 µg/L) that is above the remediation goal (10 µg/L). Arsenic has been detected above the remediation goal at this location since the well was installed and is attributed to sources not related to the mill (DOE 1998a). The uranium concentration detected at well 95-05 in October 2016 (29 µg/L) was less than the remediation goal (30 µg/L); however, the uranium concentration at that location has steadily decreased from a maximum of 64 µg/L detected in October 2001. The cumulative monitoring data to date for Burro Canyon monitoring wells indicate that the Burro Canyon aquifer is not contaminated by site-related constituents.

Table 3. COC Concentrations in Burro Canyon Groundwater, October 2016

Well	COC Concentration—October 2016 (µg/L)						
	Arsenic	Manganese	Molybdenum	Nitrate[a]	Selenium	Uranium	Vanadium
83-70	0.12	260	1	10U	0.66U	0.04	0.58U
92-10	0.12	800	1.4	10U	0.66U	0.08	0.58U
93-01	0.21	67	0.32U	10U	0.66U	0.11	0.58U
93-205	84	530	1.5	10U	0.66U	0.23	0.58U
95-06	0.31	310	1.8	10U	0.66U	29	0.58U
95-07	0.76	35	5.4	10U	0.66U	1	0.58U

Note:
[a] Nitrate as nitrogen.

Abbreviation:
U = Undetected at listed value

5.6 Surface Water Quality

5.6.1 Montezuma Creek Water Quality

Even-numbered graphics in Figure 18 through Figure 30 show the distribution of COCs in OU III surface water at the established monitoring locations. The results presented in these figures indicate that among the COCs only uranium was above a remediation goal (30 pCi/L, or approximately 44 µg/L) in April 2017 in samples collected from Montezuma Creek (seeps and wetland surface water samples are addressed separately in Sections 5.6.2 and 5.6.3.

Uranium remains below the remediation goal on the mill site and within about 0.75 mile downstream of the mill site until the Sorenson location. At that location, the uranium concentration was 110 µg/L (October 2016) compared to 9.1 µg/L (October 2016) at the nearest upstream location (SW01-01). Although the uranium concentration at the Sorenson location (29 µg/L) did not exceed the restoration goal in April 2017, uranium concentrations at that location and downstream locations are typically above the OU III remediation goal for surface water.

Because concentrations of uranium have historically been higher at the Sorenson location than at upstream locations, a study of possible causes for this occurrence was conducted in 2009 (reported in DOE 2009b and DOE 2010). The study concluded that the source of contamination to the creek was primarily from the discharge of contaminated groundwater from the alluvial aquifer between monitoring wells P92-06 and 92-09.

COCs that have no surface water standards (manganese, molybdenum, and vanadium) are present in Montezuma Creek at concentrations that are consistent with background levels or are less than the respective groundwater standards. Surface water quality results for the reporting period are included as Appendix C on the attached CD.

5.6.2 Water Quality at Seeps

Even-numbered graphics in Figure 18 through Figure 30 show the current distribution of COCs in samples collected at groundwater seeps.

Seep 1 is expressed in the northwest corner of Wetland 3 as discharge from the alluvial aquifer and leakage from the creek. Seep 2 is east of Seep 1 and is likely less influenced by creek water and so is more representative of local groundwater quality. Monitoring data for Seep 1 and Seep 2 are not available for this reporting period because water was insufficient for sample collection. Historically, selenium and uranium have occasionally exceeded the standard at Seeps 1 and 2.

Seeps 3, 5, and 6 are located along the northern margin of the mill site and are topographically higher than the alluvial aquifer. They originate from suspected anthropogenic sources above the valley of Montezuma Creek and are expressed near the contact between unconsolidated colluvium or fill and the Mancos Shale bedrock.

Nitrate, selenium, and uranium historically have been detected at one or more of these seeps in concentrations that exceeded a surface water remediation goal, but insufficient water was available for sample collection at Seep 5 during the reporting period. Contaminant levels at Seep 5 in recent years have been below remediation goals. Seep 3 remains elevated in nitrate (39,700 µg/L) and selenium (64.3 µg/L).

Seep 6 remains elevated in uranium (2300 µg/L); however, this uranium level is consistent with historical levels.

5.6.3 Water Quality at Wetland 3

Three wetlands were constructed as part of mill site restoration. Of those wetlands (Wetlands 1, 2, and 3), water quality monitoring continues only at Wetland 3 and occurs during the October and April sampling at two locations (W3-03 and W3-04). Uranium is the only COC that exceeded the surface water remediation goal (30 pCi/L, which converts to approximately 44 µg/L). In April 2017, the uranium concentration was 116 µg/L at W3-03. Water quality in Montezuma Creek is not likely affected by uranium in Wetland 3, as observed at location SW00-02, where the concentration was 7.83 µg/L in April 2017.

5.6.4 Concentration Trends in Montezuma Creek and Seeps

5.6.4.1 Trending in Montezuma Creek

Figure 39 and Figure 40 present selenium and uranium concentrations, respectively, in surface water samples collected from established monitoring sites along Montezuma Creek since April 2000. Ordering of the sampling sites in the legend of these figures is from west to east in the direction of creek flow. Selenium and uranium were selected for presentation because (1) selenium in surface water was particularly relevant to OU III biomonitoring (discontinued in 2012 in concurrence with EPA and UDEQ), and (2) these are the only COCs with in-stream concentrations above surface water standards.

Selenium concentrations in groundwater and in Montezuma Creek trended downward for about 5 years following OU I remedial actions. More recent increases in selenium concentrations (in 2009 and 2012–2014) in groundwater and surface water at some locations downgradient of the mill site (e.g., at SW00-04 and the Sorenson location) may be attributed to a greater proportion of contaminated groundwater entering the creek as base flow during dry periods. Otherwise, a trend is not apparent for selenium in Montezuma Creek surface water samples, and concentrations generally remain below the water quality standard.

Uranium concentrations in surface water show no apparent trend over the past 10 years; however, decreasing concentrations are evident over the past several years (Figure 40). At the locations where the remediation goal was exceeded during the current and past review periods (typically at Sorensen, SW00-04, SW92-08, SW92099, and SW94-01; Figure 40), higher concentrations occur during base flow conditions in the fall (October). Uranium concentrations are typically greatest at the Sorenson location.

5.6.4.2 Trending in Seeps

COC concentrations at Seep 1, Seep 2, and Seep 5 for this reporting period are not available due to an insufficient quantity of water during sampling.

High nitrate levels at seeps along the northern margin of the valley are attributed to known livestock operations. Nitrate concentrations at Seep 3 are persistently elevated, fluctuate widely, and have no apparent trend (Figure 41). Nitrate concentrations at Seep 6, which have exceeded the surface water goal in the past, were less than the surface water goal (4000 µg/L) during the current reporting period.

Selenium occurrence at Seep 3 (Figure 42) in both October 2016 (61 µg/L) and April 2017 (64.3 µg/L) was similar to previously reported concentrations, which have ranged between 47 µg/L and 100 µg/L since April 2003. Selenium concentrations at Seep 6 remain at low levels that are much less than the groundwater goal and below the surface water goal (5 µg/L).

Uranium concentrations remain elevated along the northern margin of the mill site at Seep 6 (approximately 2300 µg/L in April 2017; Figure 43). LM evaluated the source of water and uranium contamination expressed at Seep 6 and initially reported the findings in the 2009 annual groundwater report for OU III (DOE 2009b). The evaluation determined that uranium contamination at Seep 6 originates from tailings-contaminated soil in a municipal water utility corridor that contains sanitary sewer and secondary water lines. The contaminated soil in the utility corridor was identified during prior remedial actions. It was left in place for future management as supplemental standards material under the *Application for Supplemental Standards for City of Monticello Streets and Utilities* (DOE 1999c).

Water expressed at Seeps 3 and 5 (when flowing) persistently contains uranium concentrations between about 30 and 50 µg/L. Seep 5 is located in an area where former ore-milling activities were focused. Seep 3 is located east and outside of that area. The source of low-level uranium contamination at Seep 3 is uncertain. Concentration trends (increasing or decreasing) are not evident at either seep.

5.6.4.3 Seepage to Wetland 3

Seeps 1 and 2 are surface expressions of the local, moderately contaminated groundwater, and so concentration trends at these seeps are expected to mimic the groundwater trends. Water quality data for Seeps 1 and 2, which discharge directly to Wetland 3, are not available for this reporting period due to insufficient water for sample collection. There is a downward trend of selenium entering the wetland, similar to that at Seep 3. There is no apparent trend of uranium concentration at Seeps 1 and 2.

6.0 Groundwater Remedy Optimization System Performance

6.1 Operations Summary

The groundwater remedy optimization system began operation in January 2015. The system operated continuously through the current reporting period (May 2016–April 2017) except for brief interruptions for water sampling (72 hours or less) or for maintenance. In the previous review period (May 2015–April 2016), operation of the system was interrupted from May 31, 2015, through July 27, 2015, to repair or replace equipment in the groundwater transfer building. System operation was again suspended from December 1, 2015, through March 7, 2016, also for mechanical repairs in the groundwater transfer building.

Operation of the remedy optimization system was initially planned for cyclic periods of active pumping and water level recovery (no pumping). This approach presumed that contaminant recovery would benefit from a concentration rebound effect while lessening the long-term volume of extracted groundwater. Concentration rebounding was evaluated during the unplanned December 2015 to March 2016 shutdown (refer to Section 6.3.3.1) and will again be evaluated during well field testing in August and September 2017.

Quarterly reports prepared by LM provide summaries of the remedy optimization system operation that include monthly and cumulative quantity of groundwater and mass of uranium extracted and general operating conditions (e.g., flow rates, downtime); see *Monticello, Utah, National Priorities List Sites Federal Facilities Agreement (FFA) Quarterly Report: January 1−March 31, 2017* (DOE 2017).

6.1.1 Modifications to System Operation

To maximize uranium recovery from the AOA and preserve operating capacity in Pond 4, extraction well OR4 was deactivated on April 21, 2016. This well was capable of extracting groundwater at a rate of approximately 10 gpm, which is the highest production rate among the extraction wells. However, uranium concentrations captured at this well (approximately 300 to 400 µg/L) ranked as the lowest. A similar analysis led to indefinitely deactivating wells OR1, OR2, and OR3 on May 12, 2016.

Deactivating these wells reduced flow into Pond 4 by about one-half (from about 15 to 20 gpm to less than 10 gpm) but did not significantly reduce uranium concentrations in the extracted groundwater since September 2015 when all extraction wells were active. Because it takes longer

to pump a million gallons due to reduced extraction rate, the mass of uranium removed per time has decreased compared to the initial pumping schedule.

6.1.2 Annual Groundwater Production from the AOA

The volume of groundwater extracted during the review period is approximately 4.5 million gallons. With this volume and an elapsed time of 365 days, the calculated rate of groundwater extraction for the year was approximately 8.5 gpm. This rate was relatively steady after wells OR1–OR4 were deactivated in April and May 2016. The monthly rate of groundwater extraction is shown in Figure 44.

The cumulative volume of groundwater extracted by the remedy optimization system through April 30, 2017, is approximately 12.4 million gallons. This volume equates to the extraction of approximately 6 pore volumes of groundwater in the AOA (one pore volume in the AOA is estimated to be approximately 2 million gallons[4]). Although there is no presumption of a complete pore volume turnover induced by pumping, the quantity of groundwater extracted to date indicates significant capture of contaminated groundwater in the AOA.

6.1.3 Evaporative Treatment

The operating capacity of Pond 4 for the remedy optimization system is 15.6 million gallons, corresponding to the water level that is 3 ft below the overflow pipe and approximately 17 ft above the floor of the pond. The water level in Pond 4 is monitored by a pressure transducer, which is in the northeast corner of the pond and connected to SOARS. The water level is monitored to ensure that the operating capacity of the pond is not exceeded and to provide input for computing the volume of water stored in the pond (an automated calculation done in SOARS).

Monitoring the water level and the volumetric change in Pond 4 storage over time also provides input to determine the evaporation rate from the pond. This is an important parameter in managing the fill rate of the pond while maintaining its desired operating level (maximum of 7 to 8 million gallons).

6.1.3.1 Pond 4 Evaporation Rate

Flow metering within the groundwater transfer building indicates that approximately 12.4 million gallons of groundwater were extracted from the AOA and transferred to Pond 4 from inception (January 2015) through April 2017. During that time, the volume of water contained in Pond 4 has never exceeded approximately 7.4 million gallons. Cumulatively, these data indicate that evaporation at Pond 4 exceeded the combined inflow from the extraction wells and precipitation. Groundwater extraction approached 20 gpm early during system operation, which exceeded evaporation, thus allowing the pond level to temporarily increase.

To further this analysis, annual evaporation from Pond 4 was estimated based on the difference between the total inflow to Pond 4 and the change in volume of contained water between May 1, 2016, and April 30, 2017. At those times the pond contained approximately 6.1 million gallons and 7.4 million gallons, respectively. Over this 1-year period, the pond received

[4] Estimate based on AOA dimensions of 700 ft by 250 ft by 5 ft thick, and porosity of 0.30.

approximately 4.5 million gallons of water from the extraction wells and approximately 1.2 million gallons from precipitation (precipitation data is from the onsite meteorological monitoring station). The change of contained water in the pond (an increase of 1.3 million gallons) is less than the total inflow (5.7 million gallons). This difference of 4.4 million gallons equates to 8.4 gpm of evaporation from Pond 4 for this 1-year period.

With the same measurement data the seasonal (quarterly) evaporation from Pond 4 was calculated (see Table 4 for results). For this review period, the maximum rate of evaporation was 15.5 gpm (from midsummer to late summer) and the minimum rate was 1.1 gpm in late winter. Spring and fall months were equal at approximately 8.1 gpm. The evaporation rate from Pond 4 averaged over the seasons for this reporting period is 8.2 gpm.

Table 4. Monticello Site Pond 4 Seasonal Evaporation Rates

Date/Quarter	System Operation	Well Inflow (gpm)	Precipitation Inflow (gpm)	Quarterly Evaporation (gpm)
April through June 2016	On	14.7	1.3	8.1
July through September 2016	On	8.5	3.1	15.5
October through December 2016	On	8.1	2.4	8.1
January through March 2017	On	8.4	1.9	1.1
Average	--	10	2.2	8.2

6.2 Groundwater Flow in the AOA

6.2.1 Baseline Water Table

The potentiometric surface (water table) for the baseline period (Figure 45) shows that groundwater flow was generally directed to the east and southeast through the AOA with a subtle groundwater divide between the north and south portions of the AOA. These observations are consistent with groundwater elevations measured in this area before the PRB was installed (documented in DOE 1998c and DOE 1999b).

Although Montezuma Creek was dry in July 2014 when baseline conditions were evaluated, other measurement data indicate a losing stream potential (aquifer recharge) in the western portion of the AOA and a gaining stream potential near the PRB (aquifer discharge) (e.g., in the October 2015 annual groundwater report [DOE 2015]). Figure 45 also shows a local, steep hydraulic gradient across the PRB. This gradient and the gaining stream potential near the PRB are likely effects of flow restriction through the PRB.

Converging flow to the southern extremity of the south slurry wall of the PRB results from incomplete groundwater capture in this area because the slurry wall does not intercept the full extent (north to south) of the aquifer. The amount of bypass flow is estimated to be approximately 0.5 gpm (96 ft^3/day) based on a Darcy's Law calculation with a hydraulic gradient of 0.044, hydraulic conductivity of 1×10^{-2} centimeter per second (28 ft/day), saturated thickness of 2 ft, and length of 40 ft. Borehole information used to define the cross-sectional area and hydraulic gradient in this calculation is documented in an annual groundwater report

(DOE 2009b). The hydraulic conductivity used in this calculation is at the high end of hydraulic testing results documented in the OU III RI Addendum (DOE 2004b).

The potentiometric surface of the alluvial aquifer in the AOA may be affected by the presence of non-native backfill present in the former channel of Montezuma Creek. As reported in the October 2009 annual groundwater report (DOE 2009b), fine-textured soil, presumably of lower hydraulic conductivity than that of the surrounding native alluvium, was used to backfill the remediated creek channel from ground surface to bedrock in this area. This material may serve as a flow barrier within the AOA and thus account for the generally dry conditions observed downgradient of this feature (Figure 45 and Figure 46) during characterization activities completed in 2009 (DOE 2009b).

6.2.2 Aquifer Response to Pumping

A groundwater elevation contour map was developed to illustrate the potentiometric surface of the alluvial aquifer in the AOA in April 2017, following approximately 1 year of relatively constant and uniform pumping at approximately 8.5 gpm (Figure 46). As with the baseline potentiometric surface shown in Figure 45, the contours were generated using the spline interpolation method with barrier settings to represent a condition of no flow through the PRB slurry walls.

Compared to the baseline potentiometric surface, that observed in April 2017 shows a depression in the area of the extraction wells. Convergent flow to an extraction well is particularly evident at location OR-06 (the magnitude of water level drawdown relative to the baseline water table is described in the next section). Two features of the April 2017 potentiometric surface are similar to that of the baseline period: (1) an apparent east-to-west groundwater flow divide that separates southeast flow to the south slurry wall of the PRB from the more easterly flow to the reactive media portion of the PRB, and (2) a steep hydraulic gradient across the PRB.

The April 2017 potentiometric surface map includes stage elevations for Montezuma Creek (locations T-Post West, T-Post East, and PRB Culvert West in Figure 45 and Figure 46). Measurement data for these locations were used to develop the potentiometric surface map on the assumption of a saturated hydraulic connection between the creek and the underlying aquifer. A losing stream potential is indicated in the western portion of the AOA, and neither gain nor loss is indicated at the PRB.

6.2.2.1 Water Level Drawdown and Saturated Thickness

The difference in groundwater elevation at AOA monitoring and extraction wells from July 2014 to April 2017 is displayed in Figure 47, where negative values indicate that the water table has risen at the given location and positive values imply a lower water table. The groundwater elevation data used to develop this drawdown plot were also used for the potentiometric surface maps. Drawdowns of approximately 1 to 3 ft are observed at the active extraction wells.

Aquifer drawdown in the area surrounding the active extraction wells reaches approximately 1 ft at a distance of 150 ft (e.g., at in active extraction wells OR-01 to OR-04). A slight rise in the water elevation (up to approximately 0.2 ft) is evident among the row of monitoring wells closest to the creek. This may be explained by a higher creek stage in April 2017 (when the creek was

flowing) compared to the baseline monitoring event in July 2014 when the creek was dry. The rise in the water table nearest the creek suggests aquifer recharge from the creek. Water level monitoring data from six wells installed immediately north of Montezuma Creek in June 2017 will assist the evaluation of groundwater underflow from the north to the AOA.

The saturated thickness of the alluvial aquifer in the AOA is presently between about 1 and 6 ft, with the greatest thickness encompassed by the AOA extraction wells. As reported in the Groundwater Remedy Optimization Work Plan (DOE 2014a), the maximum saturated thickness that was measured before the start of pumping was approximately 10 ft, occurring in the central area of the AOA. The saturated thickness decreased to between 1 and 2 ft to the west toward the former mill site. In the area between the former creek channel and the PRB, there was no evidence of groundwater saturation (DOE 2009b).

6.2.2.2 Water Level Trending in AOA

Water level hydrographs for monitoring wells located in the AOA are shown in Figure 48 and Figure 49. The figures group the wells according to geographic location, north and south, in the AOA. In these figures, water levels at individual wells are seen to have risen by several feet from the baseline period to the start of pumping. Since then, a general decrease in groundwater elevation of the same magnitude is apparent, although large fluctuations of several feet are observed during that time. These fluctuations do not appear to be related to variable underflow from the west, because similar fluctuations are not observed at the monitoring wells located across the east boundary of the mill site (not shown in these figures). This difference in behavior suggests a greater sensitivity to recharge (creek flow, irrigation, and precipitation) and to groundwater pumping in the AOA than farther west.

6.2.2.3 Aquifer Response to Temporal Stress

Cyclic operation of the remediation system as a remediation strategy depends in part on the time for the aquifer to recover from imposed stresses. In this context, continuous water level data collected from SOARS for AOA monitoring wells were reviewed to estimate the water level equilibration from December 1, 2015, to March 9, 2016, when the remediation system was not in operation. The continuous monitoring data indicate that water levels stabilized within 2 weeks of flow cessation. This followed a period (months) of sustained groundwater extraction.

6.2.2.4 Steady-State Groundwater Inflow to AOA

With sustained groundwater extraction over the past year, the yield of the aquifer may be approaching a steady-state condition whereby groundwater pumping is balanced by the rate of recharge to the AOA, and release from storage is minimal. The steady-state inflow of groundwater across the eastern boundary of the former mill site is estimated to be 5 gpm (based on an estimated cross section area of 3750 square ft (750 ft in length by 5 ft of saturated thickness), hydraulic gradient of 0.01, and hydraulic conductivity of 28 ft/day). This quantity is of importance in quantifying the water budget for the AOA and water management at Pond 4.

6.2.3 Stream Flow in AOA

Measurement of surface water flow was initiated in July 2016 specifically to gage flow in Montezuma Creek through the AOA. The upstream station is located at the eastern boundary of the mill site coincident with monitoring location SW00-02, and the downstream station is located immediately upstream of the north slurry wall of the PRB. Measurements were conducted every 2 to 4 weeks, as permitted by weather (freezing) and runoff conditions. Flow was measured by the velocity/area method using a portable flume and rotating element velocity meter.

Measurements of creek flow through the AOA during this review period, taken while remediation pumping was occurring, indicate that typical base flow (no runoff) is on the order of 130 gpm (approximately 0.28 cubic feet per second). Average flow at the upstream and downstream locations was 134 and 129 gpm, respectively. This difference is probably insignificant compared to the uncertainty associated with the method of open-channel flow measurement, and so a net gaining or losing stream condition in this reach cannot be resolved.

6.3 Restoration Progress in the AOA

6.3.1 Uranium Mass Removal

The remedy optimization system removed approximately 77 pounds of uranium from the alluvial aquifer in the AOA from January 2015 (system startup) through April 6, 2017, when the transfer tank was last sampled during the review period. Approximately 30 pounds of uranium were removed during the current reporting period.

By comparison, the ex situ treatment system removed about the same amount—an estimated 77 pounds of uranium—cumulatively during its 9.5 years of operation. The total mass of uranium (dissolved and sorbed phases) in the AOA before the start of active remediation is estimated to be 350 pounds. This estimate was determined under laboratory conditions using mild acid leaching of sediments that were collected from within the OU III contaminant plume (DOE 2001).

The cumulative mass of uranium removed from the aquifer by the groundwater contingency remedy optimization system is displayed by month in Figure 50. In this plot, the rate of uranium removal appears to be slightly decreasing over time due to a reduction in pumping rates starting in May 2016. The monthly rate of uranium removal (pounds per month) and the monthly pumping rate are shown in Figure 51. This figure shows that the rate of uranium extraction decreased from approximately 4 pounds per month in May and June 2016 to a relatively constant extraction rate of approximately 2.3 pounds per month. Uranium concentration of the extracted groundwater varied from 590 to 790 µg/L during the review period and averaged approximately 725 µg/L. These estimates are from monthly analysis of the contents of the transfer tank in the groundwater transfer building.

Another metric of uranium mass removal during the review period equates to approximately 6 pounds of uranium removed per million gallons of water extracted (not shown) at the average annual pumping rate (approximately 8.5 gpm).

6.3.2 Uranium Concentrations in AOA

The distribution of uranium in groundwater at extraction and monitoring wells in the AOA for July 2014 (prior to groundwater pumping) is shown in Figure 52. At that time, concentrations nearest the creek ranged from 280 to 930 µg/L and increase up to 1400 µg/L with distance from the creek.

Figure 53 shows uranium distribution at AOA monitoring wells for April 2017, coincident with the cumulative extraction of approximately 12 million gallons of groundwater from the AOA (extraction wells were not sampled on million-gallon intervals). Concentrations are observed to generally increase with distance from Montezuma Creek, with maximum concentrations currently at more than 31 times the remediation goal. The highest uranium concentration (940 µg/L) is observed at monitoring well MW-11.

The changes in uranium concentration at individual monitoring wells from baseline values (July 2014) to April 2017 show concentrations declining by approximately 60 to 600 µg/L in the AOA (Figure 54).

6.3.2.1 Water Quality Entering the AOA

Groundwater that enters the AOA from the west contains relatively low concentrations of uranium (e.g., 82 µg/L at well T00-04 and 139 µg/L at well 92-11 in April and October 2017; see Figure 28). The origin of uranium contamination at these locations is attributed to secondary sources (sorbed phases) in the alluvial sediments that were in contact with the legacy contaminant plume that developed before OU I remedial actions removed the primary source of contamination (mill tailings).

Surface water entering the AOA is also low in uranium (7.8 µg/L at location SW00-02). These data indicate that the high concentrations of uranium observed in the AOA are not from an upgradient source of higher contamination.

6.3.3 Temporal Variation of Uranium Concentration in the AOA

Figure 55 and Figure 56 depict uranium concentrations in groundwater over time at individual AOA monitoring wells and the average concentration for each monitoring event. Monitoring wells in the AOA are divided into two groups: north (Figure 55) and south (Figure 56), with the northern group closest to Montezuma Creek. The time-varying average concentration depicted in the figures corresponds to that computed for all of the AOA monitoring wells and not only for those shown in the individual figure.

The figures reveal discrete periods of uranium concentration variation, which are (1) a general decrease from baseline values with the onset of groundwater extraction through November 2015, (2) a concentration rebound during the subsequent shutdown period, (3) a rapid decrease in concentration following the system restart in March 2016, and (4) a general downward trend since that time. The figures also show that compared to the average concentration of uranium in the AOA, concentrations are generally lower in the north portion of the AOA (nearer the creek) than in the south portion.

The information presented in Figure 55 and Figure 56 is condensed into slope graphs (Figure 57 and Figure 58) for simplified representations of uranium concentration trending using two data end points. The uranium concentration in samples collected in March 2015 (soon after the start of pumping) and May 2017 (current) are presented in Table 5 and Figure 57. Over this period, the average uranium concentration went from 606 µg/L to 456 µg/L**,** a decrease of 24.7 percent. On the basis of this analysis, a general downward trend in uranium concentration is apparent at AOA monitoring wells.

Table 5. Change in Uranium Concentration in AOA Wells

Well Number	Uranium (µg/L)		Percent Change
	3/31/2015	5/24/2017	
MW-01	630	530	−15.9
MW-03	410	220	−46.3
MW-04	860	500	−41.9
MW-05	270	170	−37.0
MW-06	770	550	−28.6
MW-07	660	630	−4.5
MW-08	860	750	−12.8
MW-09	600	450	−25.0
MW-10	1100	940	−14.5
MW-11	1100	900	−18.2
MW-12	330	210	−36.4
MW-13	520	380	−26.9
MW-14	710	400	−43.7
MW-15	160	140	−12.5
MW-16	270	200	−25.9
MW-17	440	330	−25.0
Average	**606**	**456**	**−24.7**

6.3.3.1 Uranium Concentration Rebound in the AOA

The endpoints in Figure 58 correspond to November 9, 2015, when the wells were last sampled before the December 1 shutdown, and March 10, 2016, coincident with restarting the system.

Concentration rebounding is evident in this plot (indicated by the positive slope due to concentrations that were higher in March 2016 than they were in November 2015). The average increase in uranium concentration was approximately 130 µg/L. Concentrations did not rebound to baseline levels but generally did approach those measured before the December 2015 shutdown. As displayed in Figure 55 and Figure 56, the concentration rebound effect was largely diminished within about 1 month of restarting the remediation system.

6.3.4 Summary of Groundwater Restoration Progress in the AOA

A summary of groundwater restoration progress in the AOA since the groundwater remedy optimization system was implemented is shown in Figure 59. That figure displays the average

uranium concentration at AOA monitoring wells over time (the red line that should be read using the left vertical axis) and the cumulative volume of groundwater extracted (the gray dashed line that should be read using the right vertical axis). These performance metrics are shown in comparison to the estimated pore volume of groundwater contained in the AOA (the yellow horizontal line) and the black dashed line marking the uranium remediation goal.

Overall, the information presented in Figure 59 indicates that average AOA uranium groundwater concentrations have declined since extraction system pumping began from about 600 µg/L to 450 µg/L (a reduction of 25% in the average concentration). This reduction includes the December 2015 to March 2016 shutdown period when average AOA uranium groundwater concentrations increased (rebounded) until pumping resumed. As of the end of this reporting period (April 30, 2017) approximately 12 million gallons of groundwater have been extracted from the AOA, equivalent to 6 pore volumes within that area. However, the average uranium concentration (approximately 450 µg/L) remains above the remediation goal (30 µg/L).

7.0 Year-in-Review Summary

Findings for sitewide alluvial groundwater quality for the May 2016–April 2017 reporting period include:

- No anomalous monitoring results or site conditions that would identify a concern for contaminant source control or contaminant plume movement are noted.
- Uranium contamination remains at concentrations up to 31 times the remediation goal (30 µg/L) within the AOA, and up to 16 times the remediation goal in other groundwater locations. The uranium groundwater contamination plume extends approximately 0.75 mile downgradient of the former mill site.

  Most regions of the aquifer are showing decreasing uranium concentrations; however, locations with sufficient water quality data in the farthest downgradient regions of the plume (Regions 4 and 5) show areas of both decreasing and increasing trends.
- Arsenic and vanadium concentrations are generally limited to locations upgradient of the PRB and at concentrations that are less than twice the respective remediation goals.
- Manganese is limited to a few locations upgradient of the PRB and is present at levels up to 7 times the remediation goal.
- Molybdenum was detected above the remediation goal (100 µg/L) only in the AOA at a maximum concentration of 236 µg/L.
- Selenium was not detected above the remediation goal (50 µg/L) except downgradient of the AOA at one location (106 µg/L).
- Nitrate concentrations are currently at or below the restoration goal.

Findings for Burro Canyon groundwater quality for the May 2016–April 2017 reporting period include:

- The Burro Canyon aquifer is not contaminated by site-related contaminants: elevated concentrations of arsenic at one location and elevated concentrations of manganese at another location are attributed to natural sources.

Findings for surface water quality for the May 2016–April 2017 reporting period include:

- Uranium in Montezuma Creek remains below the remediation goal on the mill site and within about 0.75 mile downstream of the mill site until the Sorenson location. Although the uranium concentration at the Sorenson location did not exceed the restoration goal in April 2017 (29 µg/L), uranium concentrations at that location and downstream locations are typically above the OU III remediation goal for surface water.
- Seep 3 remains elevated in nitrate (39.7 mg/L) and selenium (64.3 µg/L), and Seep 6 remains elevated in uranium (2300 µg/L).
- Uranium exceeded the remediation goal (44 µg/L) in Wetland 3 (116 µg/L).
- No other contaminants exceed their remediation goals in surface water.

Findings for water quality restoration in the AOA for the May 2016–April 2017 reporting period include:

- The AOA remediation system operated without any unplanned shutdowns.
- Extraction well OR-04 was deactivated in April 2016, and extraction wells OR-1, OR-2, and OR-3 were deactivated in May 2016. This was done so that only the most productive wells for uranium recovery were operating and to manage the fill rate of Pond 4.
- During the review period, 4.5 million gallons of contaminated groundwater were extracted from the AOA. This equates to an annual extraction rate of 8.5 gpm.
- Inflow to Pond 4 (extraction well inflow plus precipitation) was approximately balanced by annual evaporation in the pond after wells OR-1 through OR-4 were deactivated. Water contained in Pond 4 was relatively constant at approximately 7.3 million gallons, which is about one-half of the safe operating capacity (15.6 million gallons).
- Uranium concentration of the extracted groundwater varied from 590 to 790 µg/L during the review period and averaged approximately 725 µg/L.
- Groundwater extraction removed approximately 30 pounds of uranium from the alluvial aquifer during the reporting period.
- The remediation system has removed approximately 12 million gallons of groundwater, equivalent to 6 pore volumes in the AOA.
- Uranium concentrations at monitoring wells in the AOA show a downward trend since the baseline period; however, they are currently more than 31 times the remediation goal (30 µg/L).
- Overall, the average uranium concentration in the AOA has decreased by approximately 25% since start of the groundwater remedy optimization system in January 2015.

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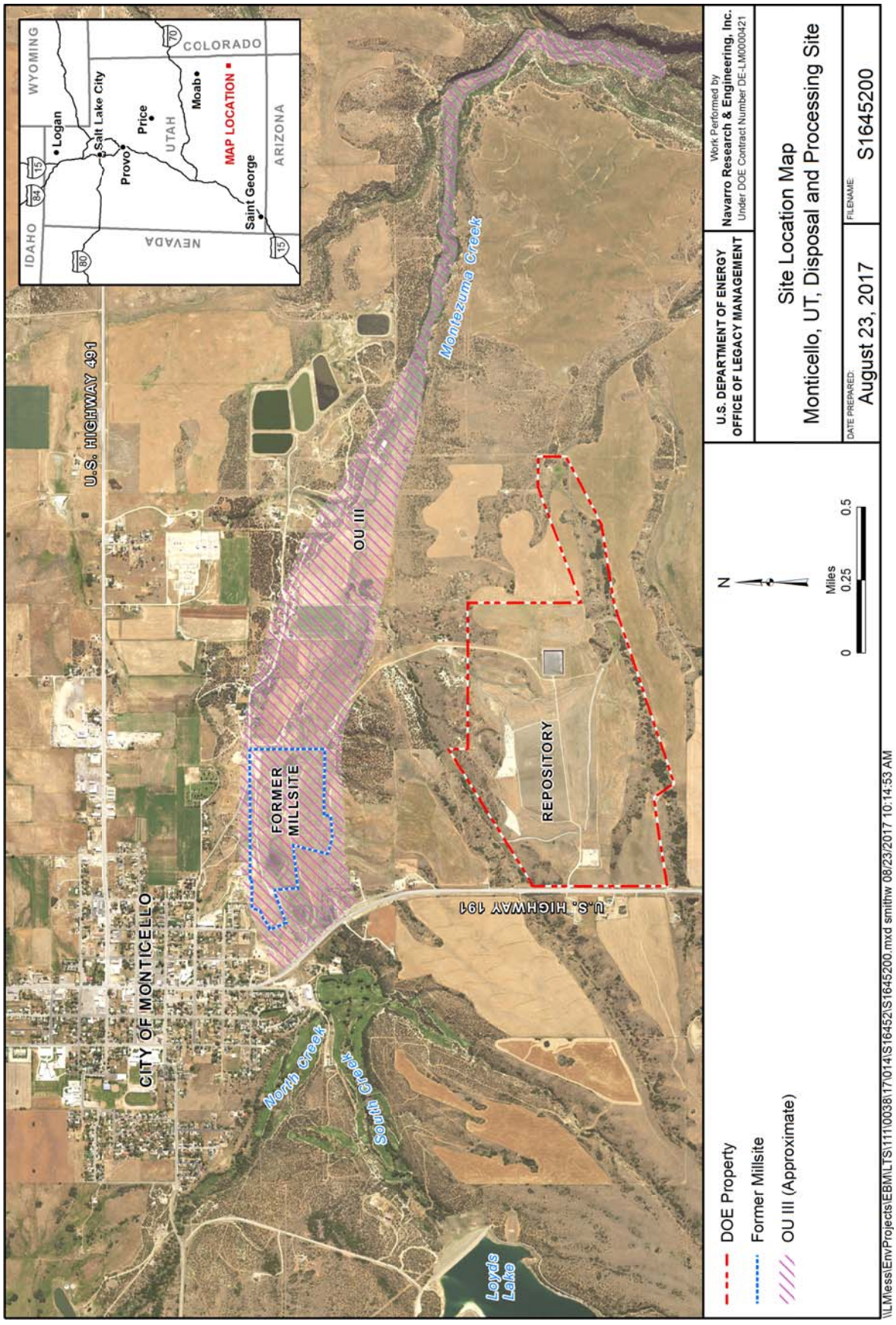

Figure 1. Location of the Monticello Mill Tailings Site

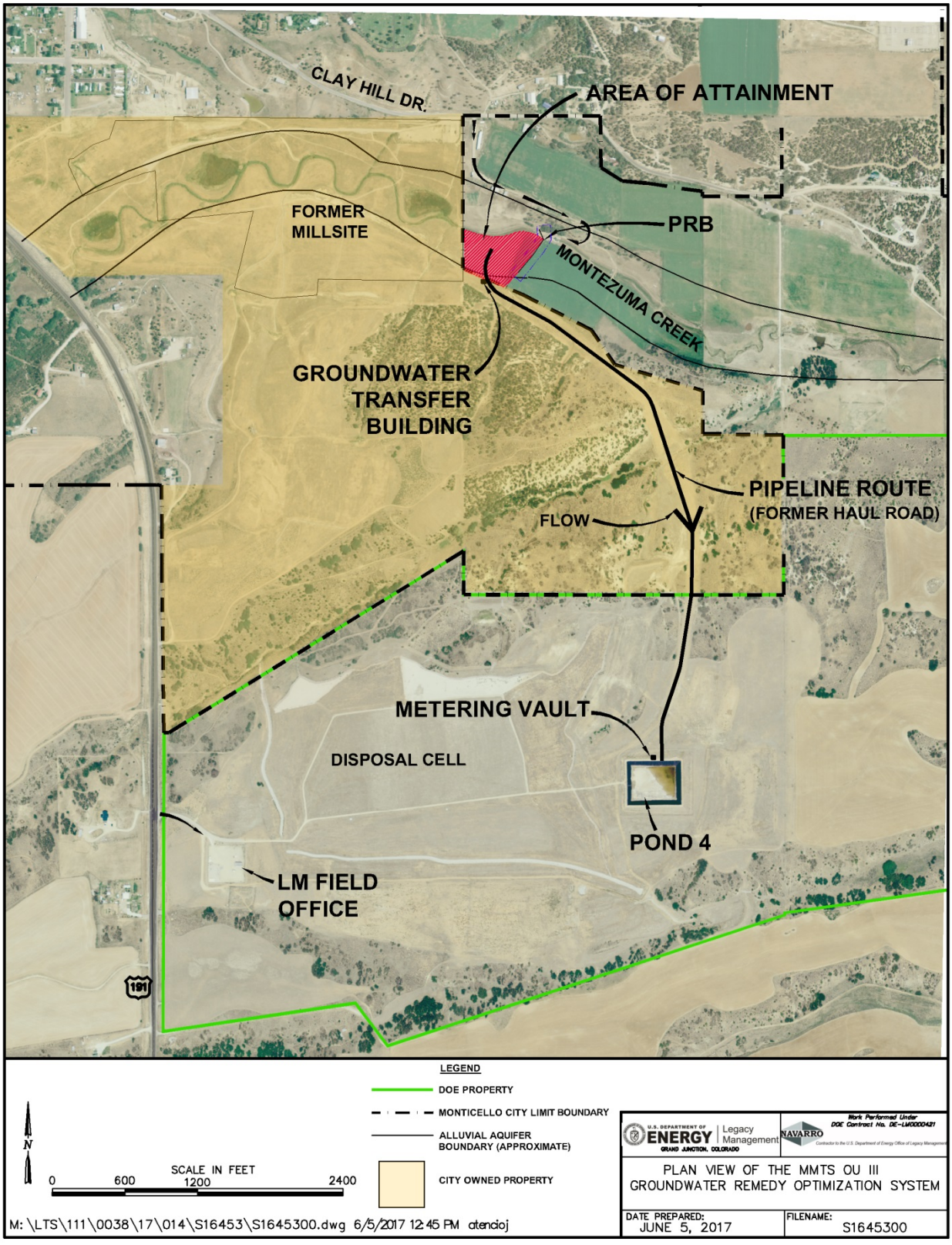

Figure 2. Plan View of the MMTS OU III Groundwater Remedy Optimization System

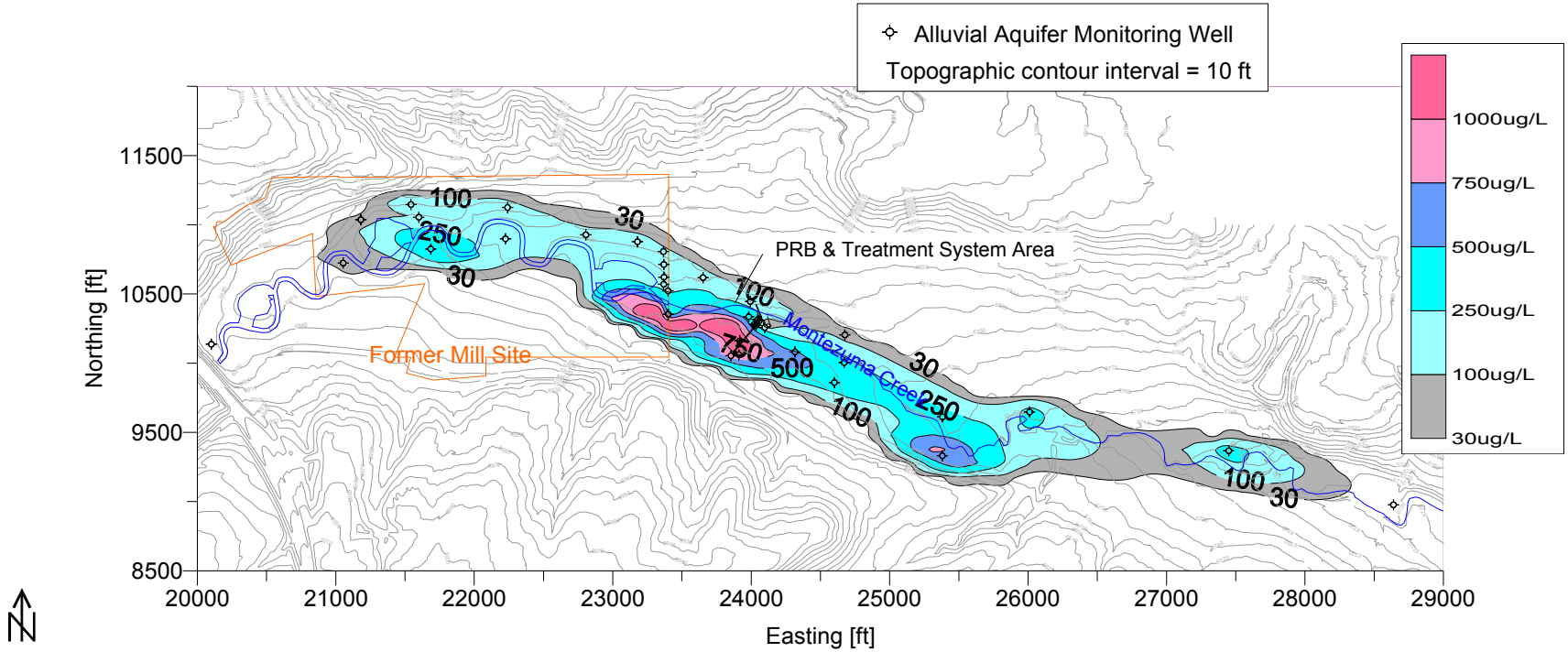

Figure 3. Estimated MMTS OU III Uranium Groundwater Plume, 2009
(includes data from special groundwater investigation, April 2009)

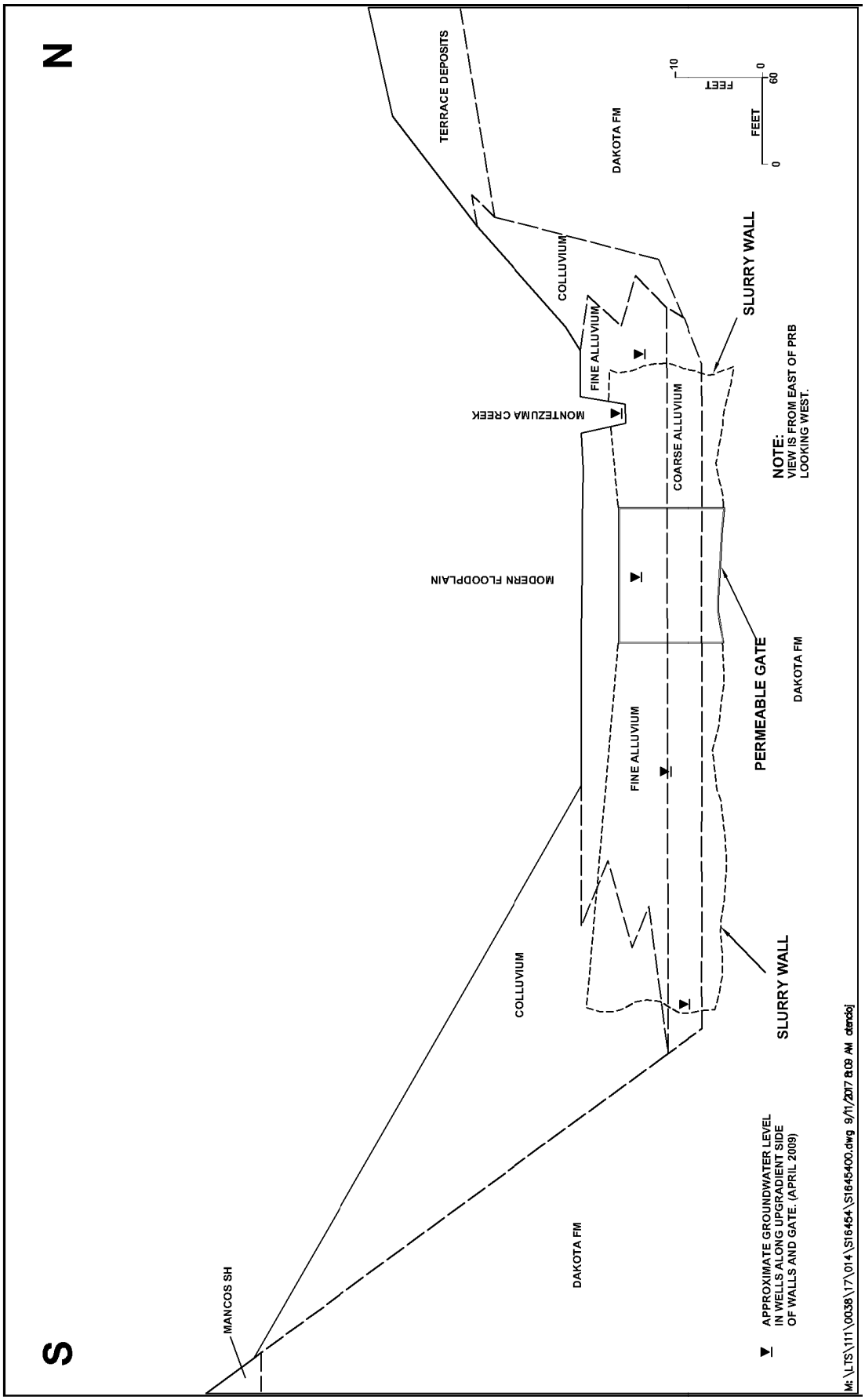

Figure 4. Hydrogeologic Cross Section of Montezuma Creek Valley at the PRB

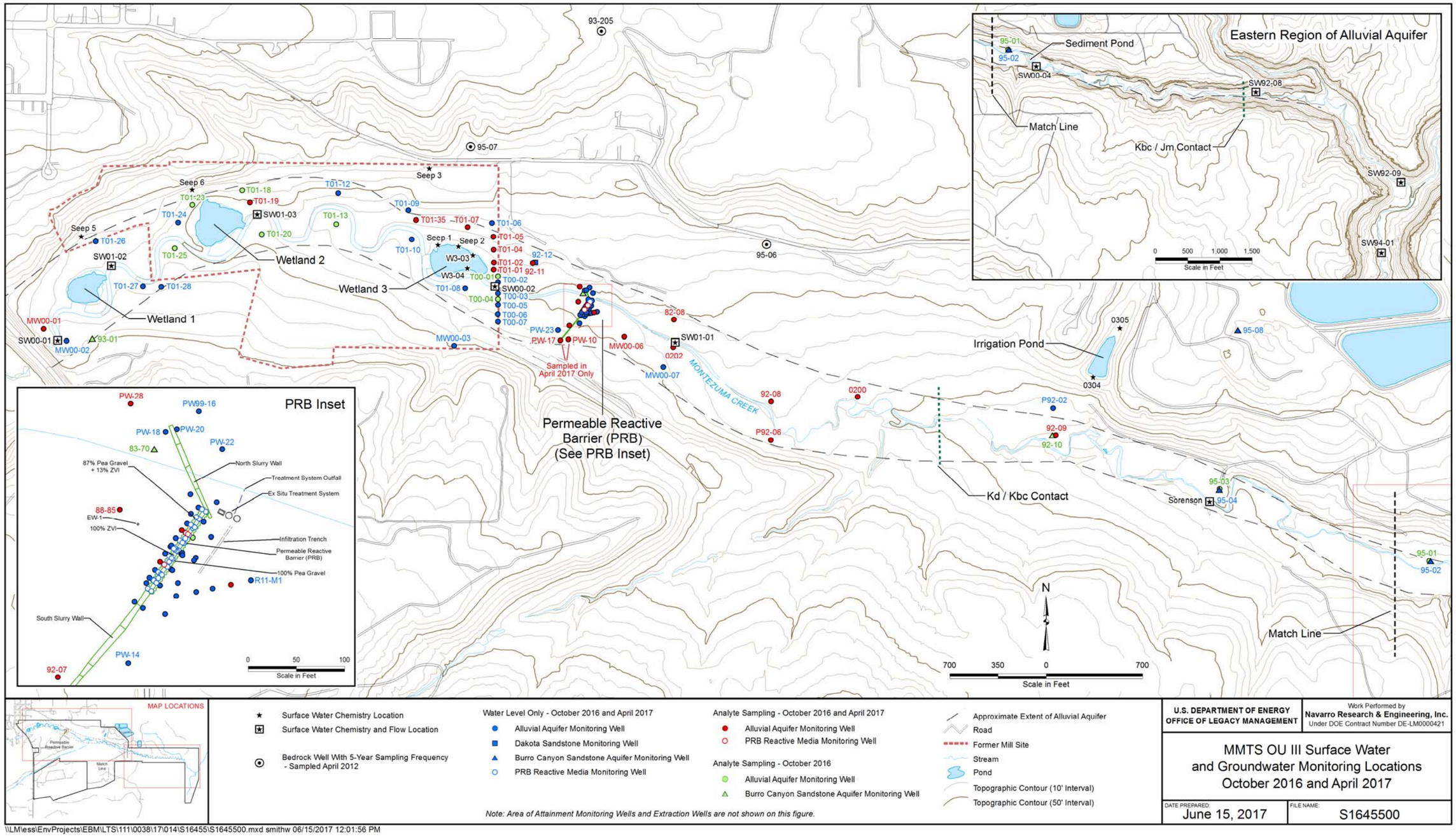

Figure 5. Reference Map for MMTS OU III Water Quality Monitoring Locations

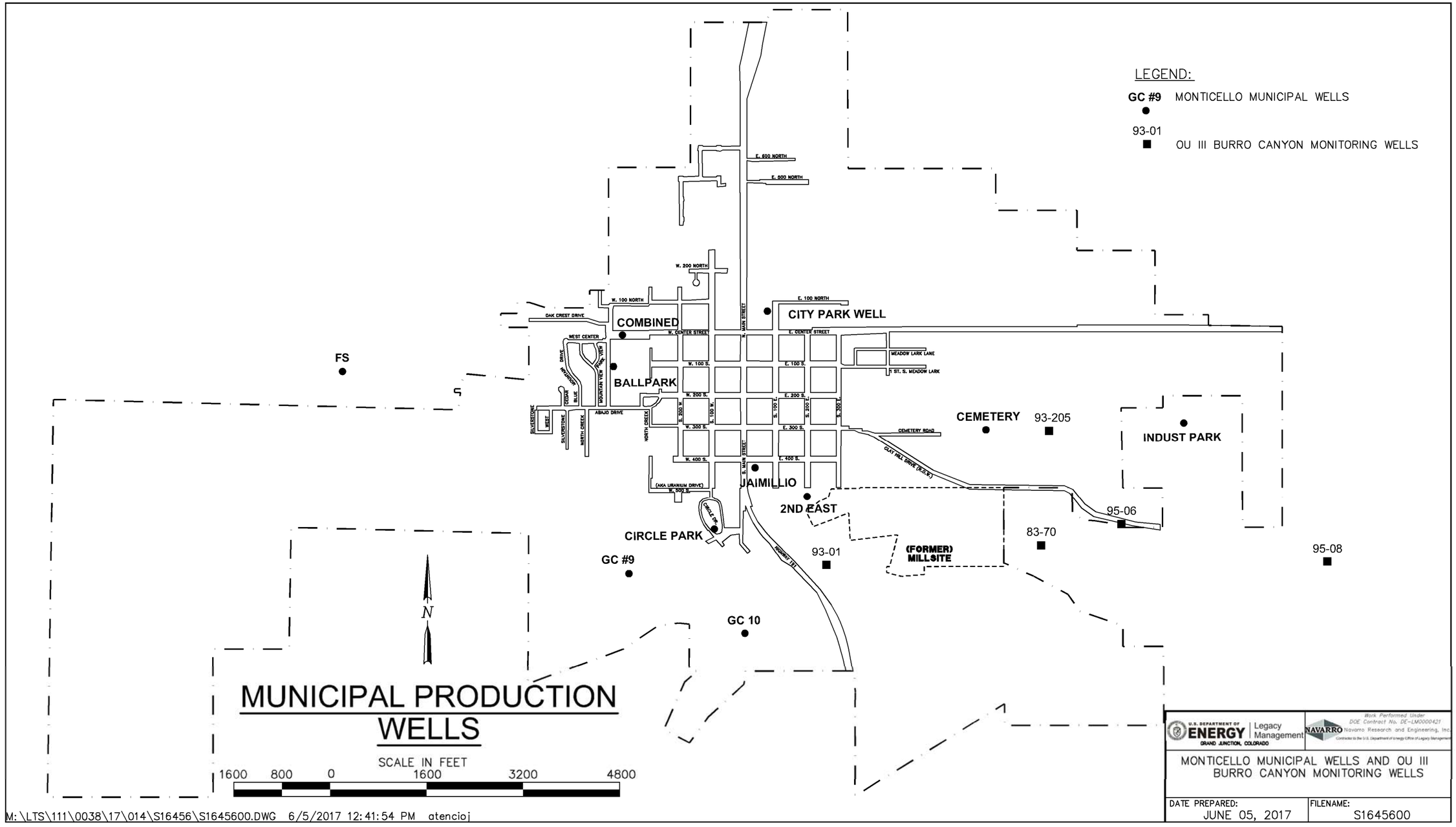

Figure 6. Monticello Municipal Wells and OU III Burro Canyon Monitoring Wells

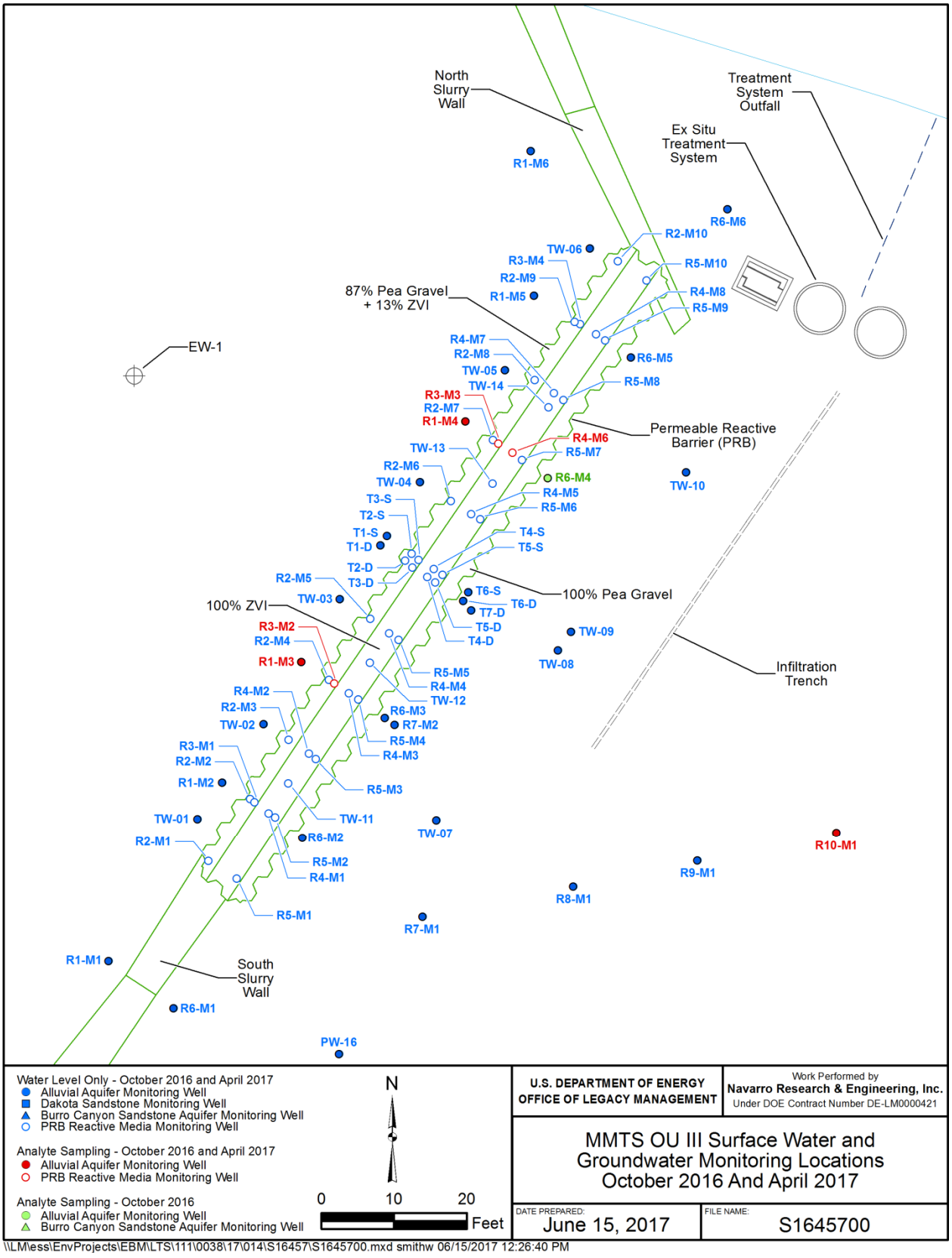

Figure 7. MMTS OU III Surface Water and Groundwater Monitoring Locations at the PRB Area

Figure 8. Northwest View Overlooking the AOA from the Former Haul Road

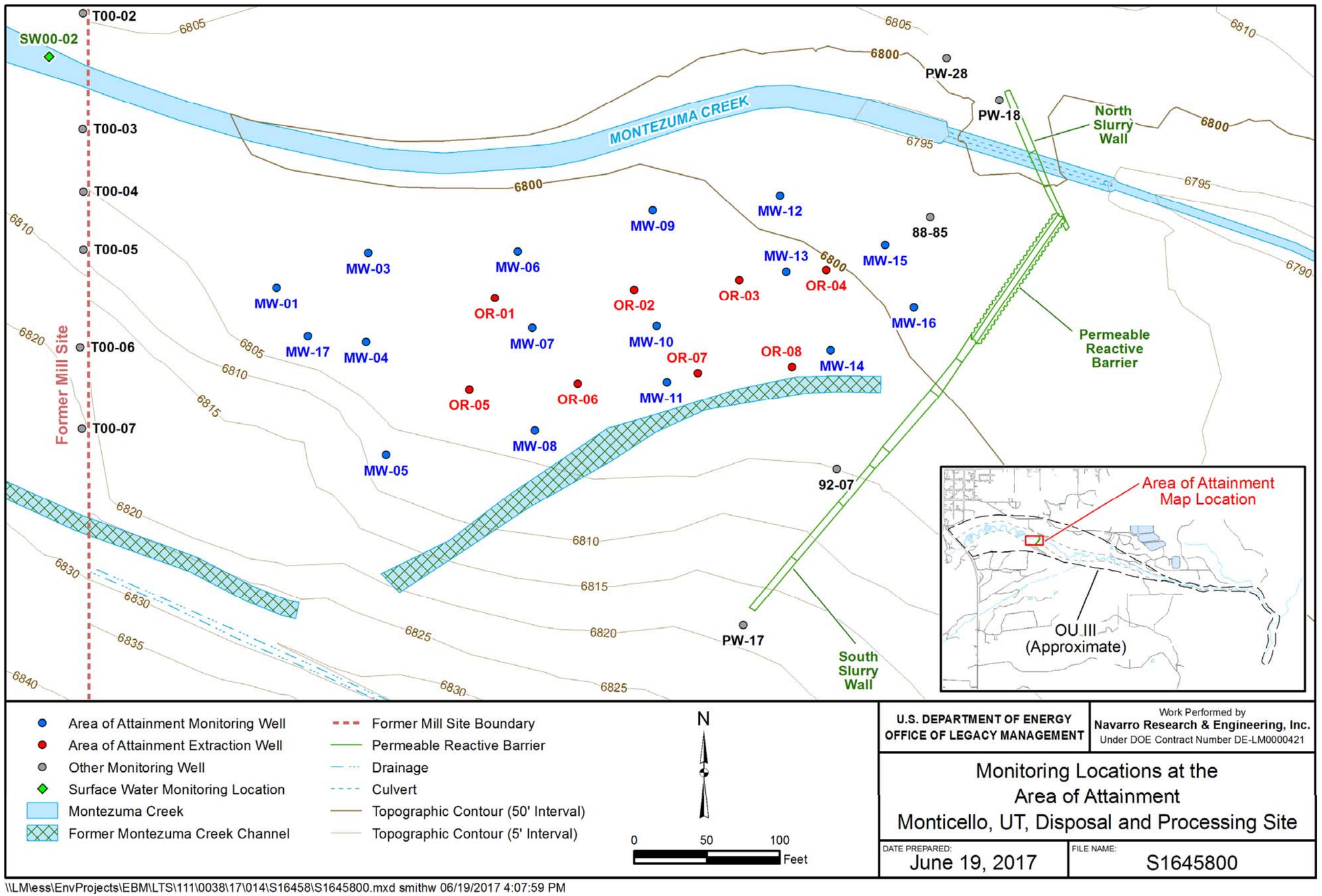

Figure 9. MMTS OU III Area of Attainment Monitoring Locations

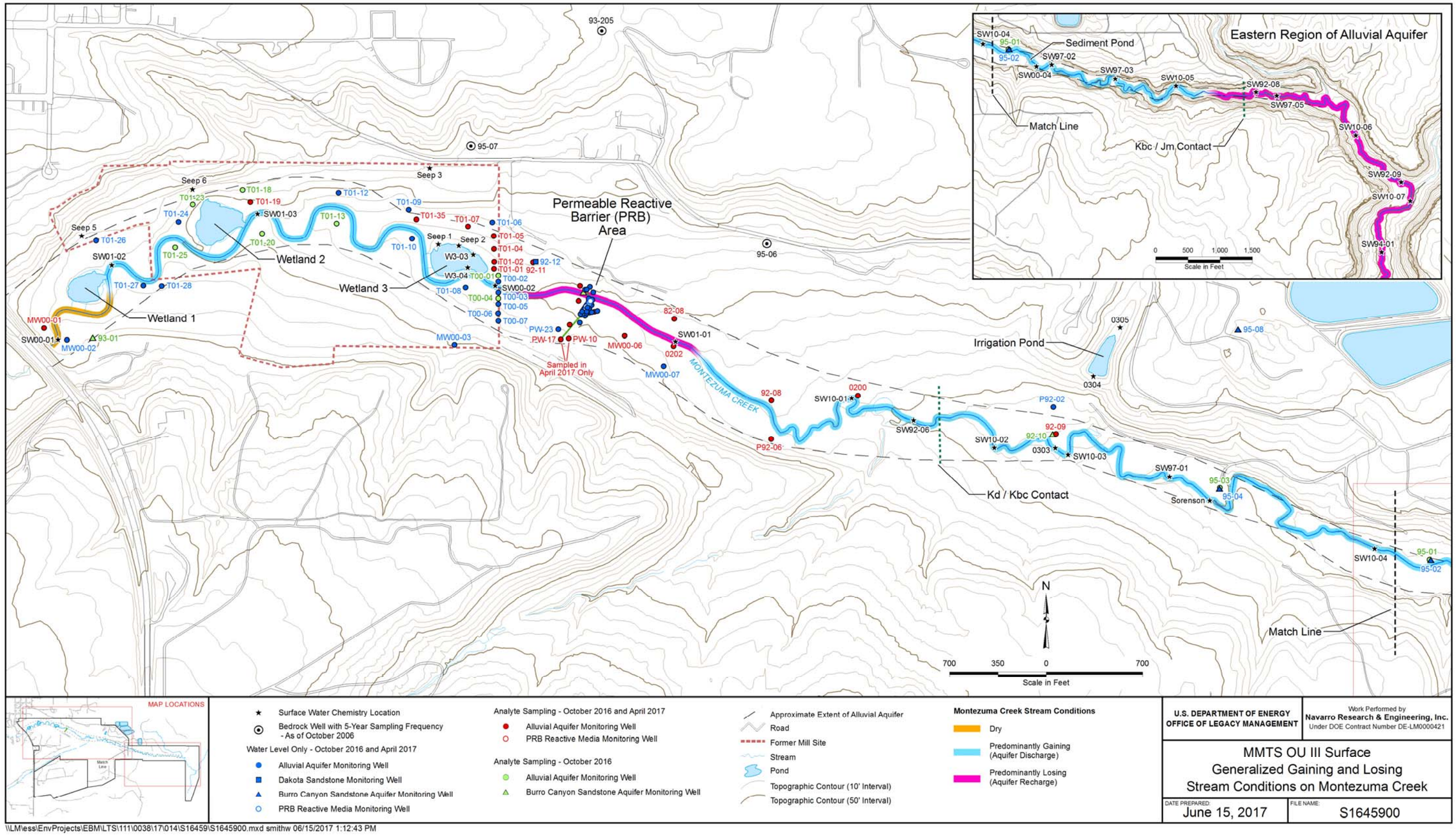

Figure 10. *Generalized Gaining and Losing Stream Conditions on Montezuma Creek*

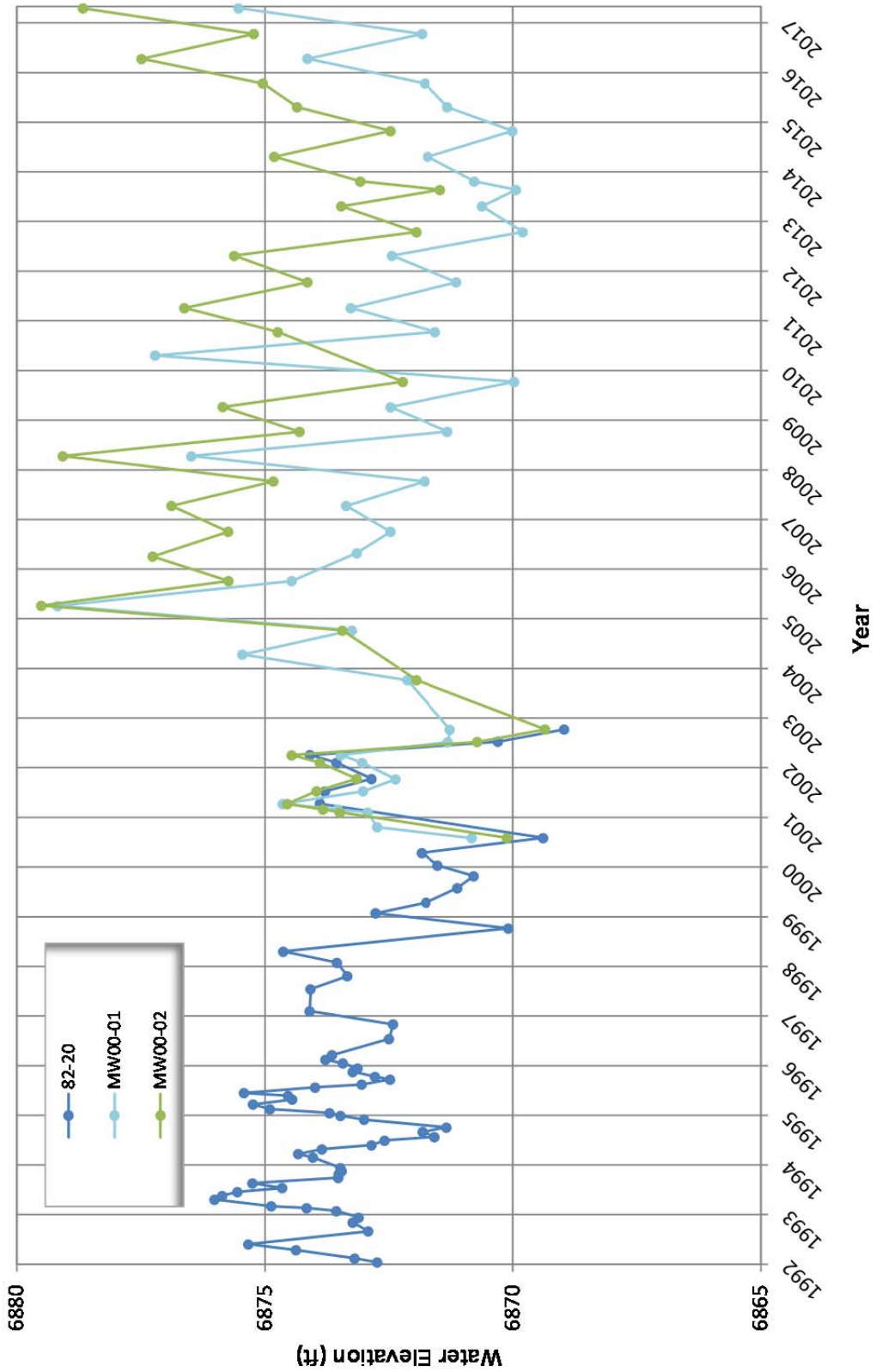

Figure 11. Water Level Hydrographs for Alluvial Wells at Western Boundary of Former Mill Site

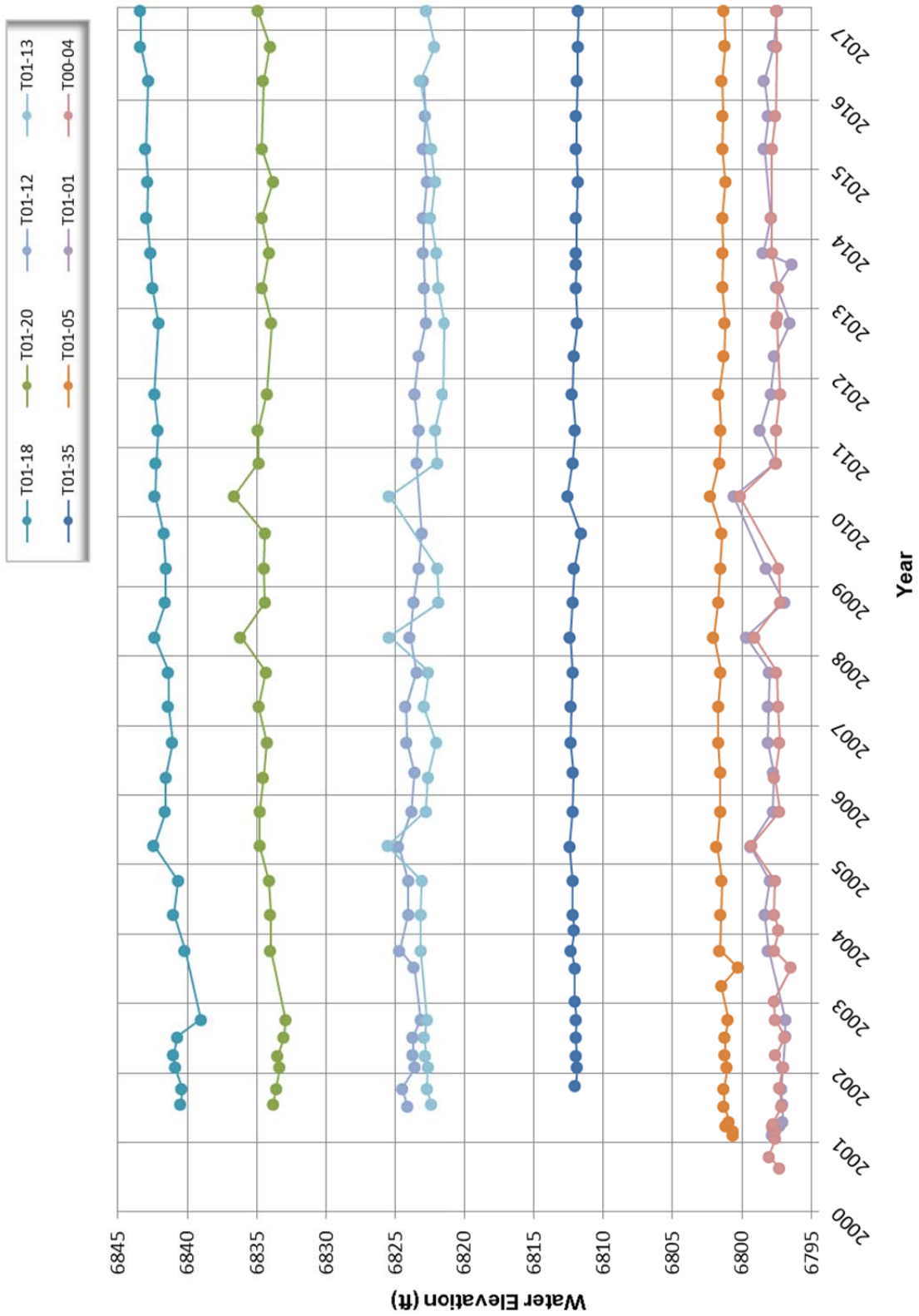

Figure 12. Water Level Hydrographs for Selected Mill Site Alluvial Wells

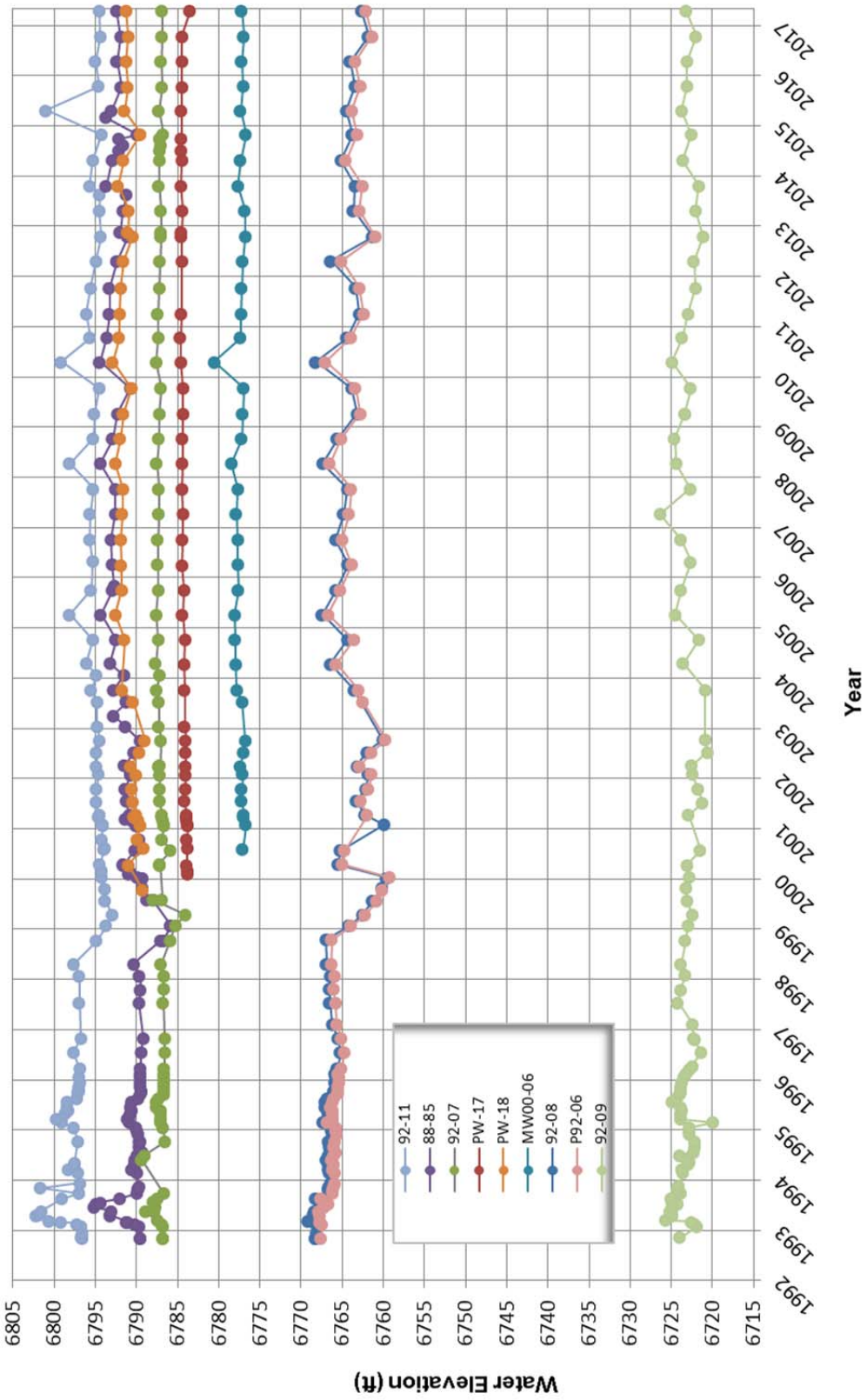

Figure 13. Water Level Hydrographs for Alluvial Wells Downgradient of the Former Mill Site, West to East

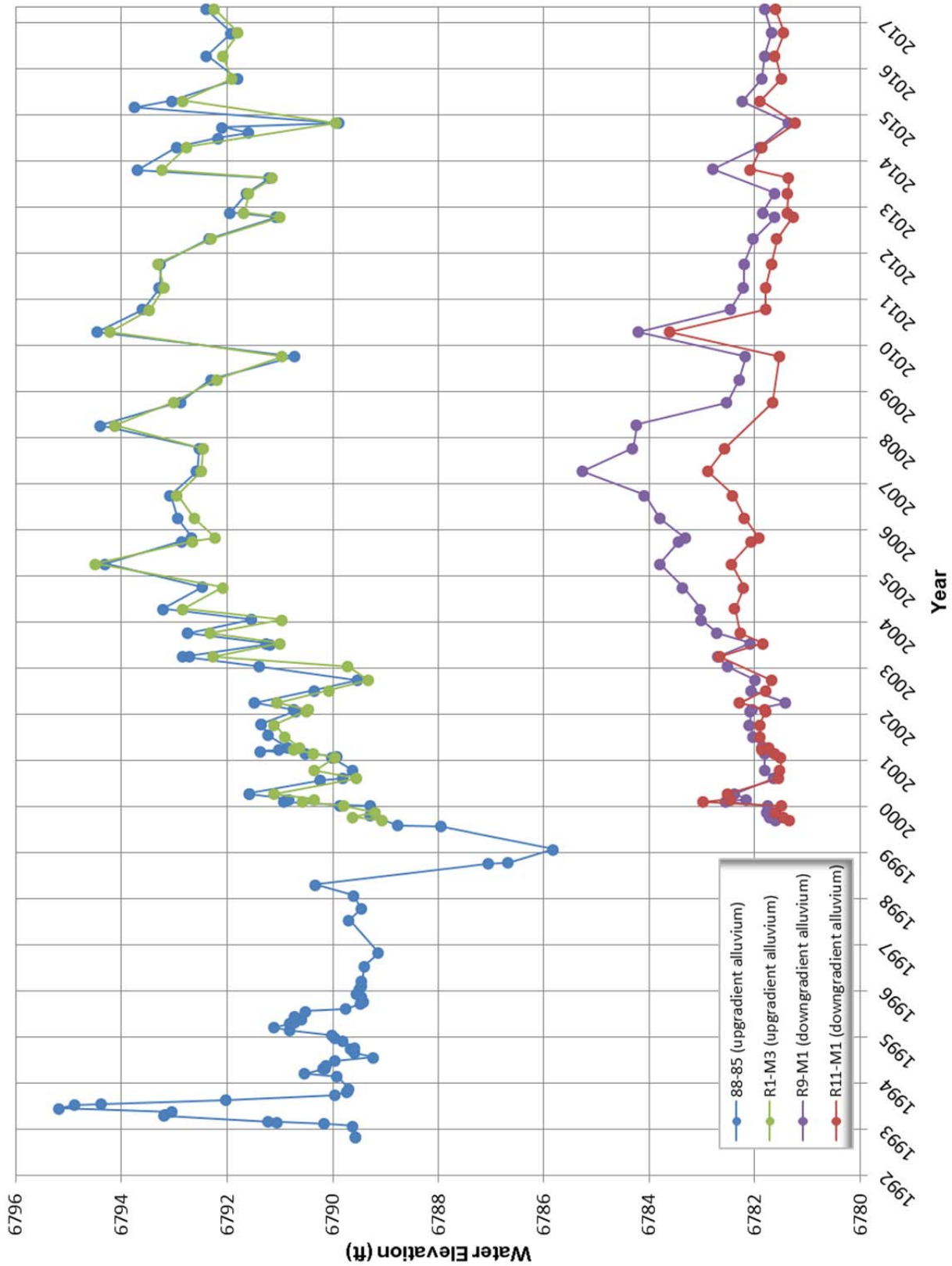

Figure 14. Water Level Hydrographs for Wells at PRB

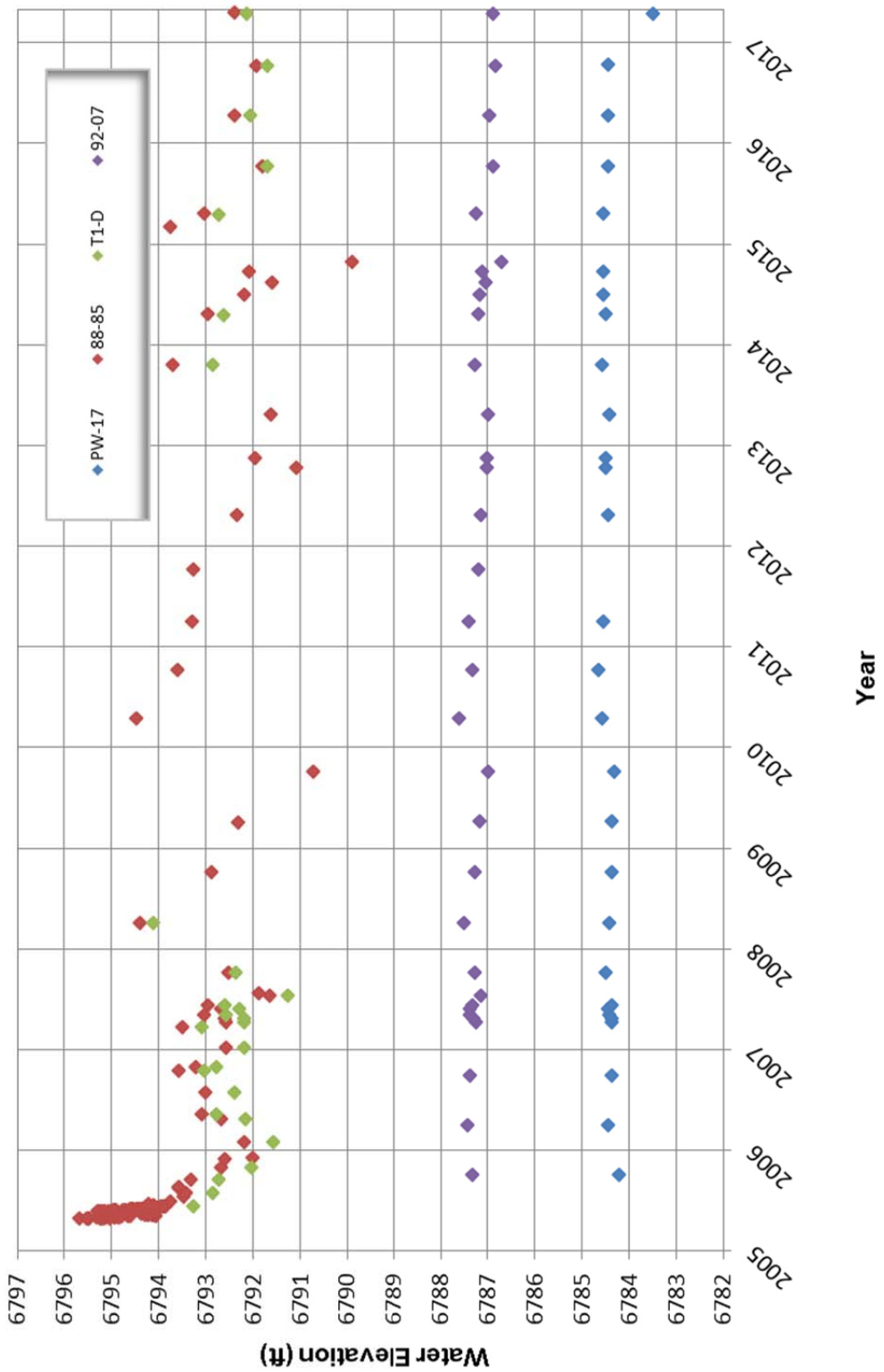

Figure 15. Water Level Trends near the PRB After Installation of Ex Situ System in June 2005

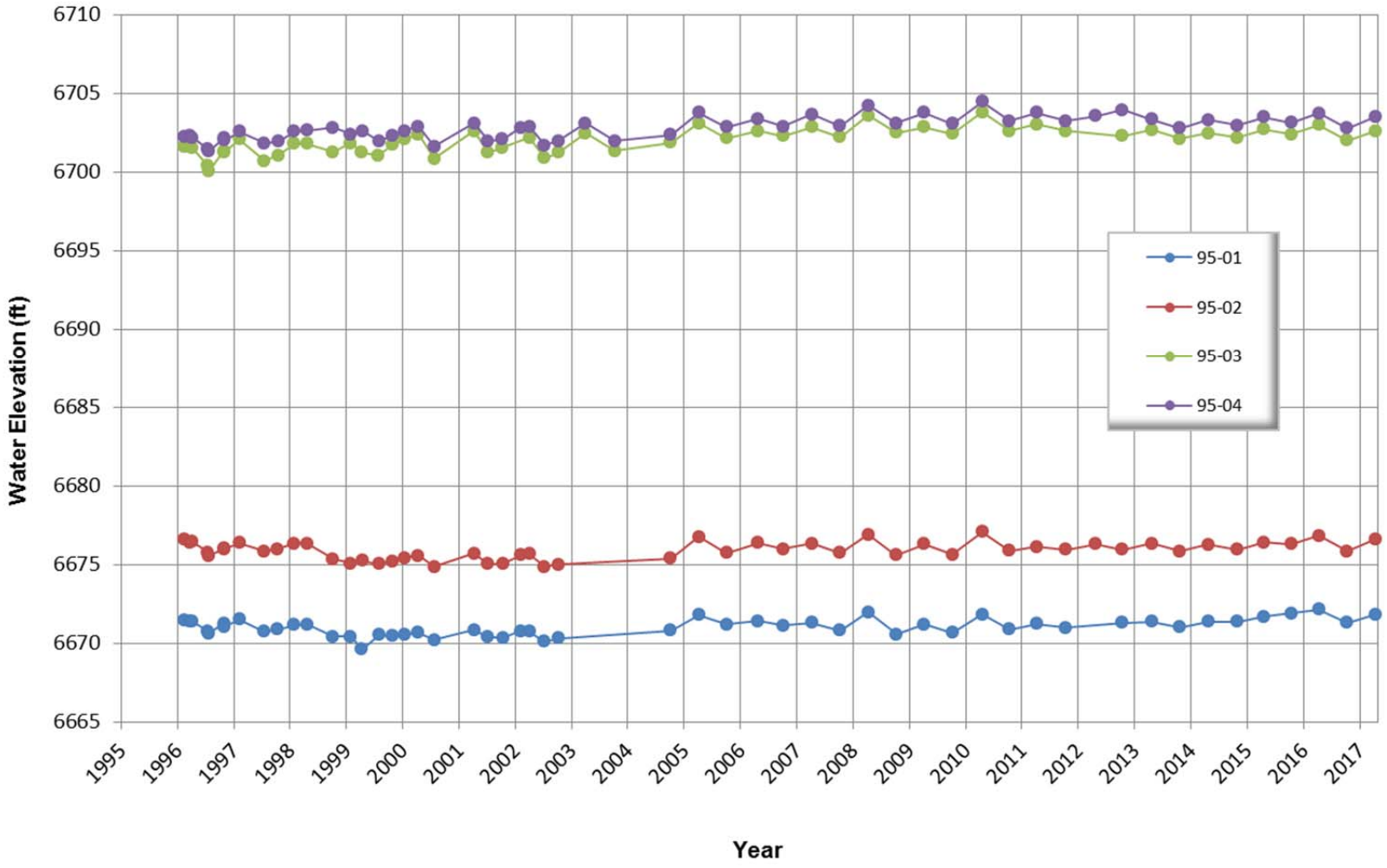

Figure 16. Water Level Hydrographs for Alluvial/Burro Canyon Well Pairs 95-01/95-02 and 95-03/95-04

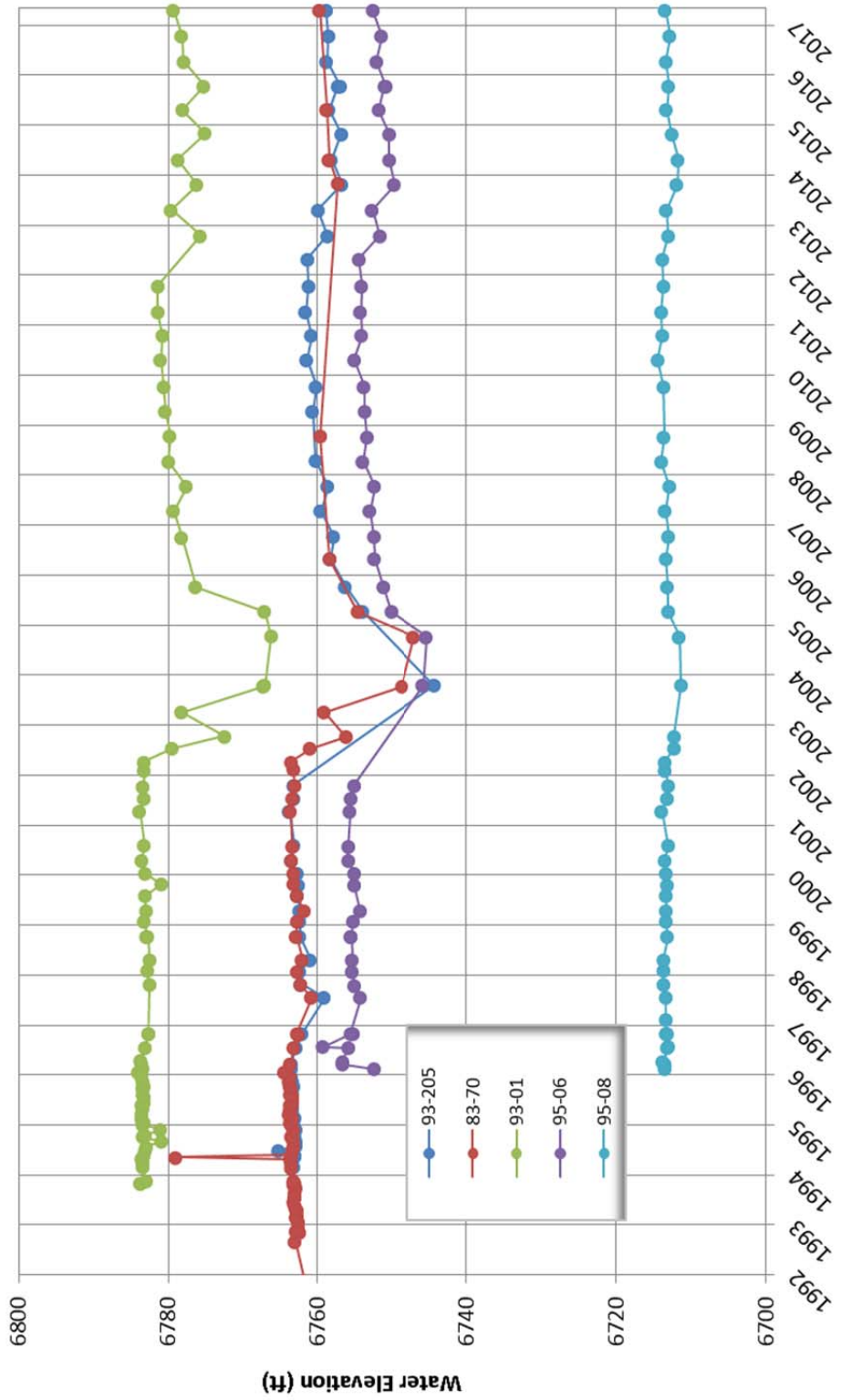

Figure 17. Water Level Hydrographs for Selected Burro Canyon Aquifer Wells

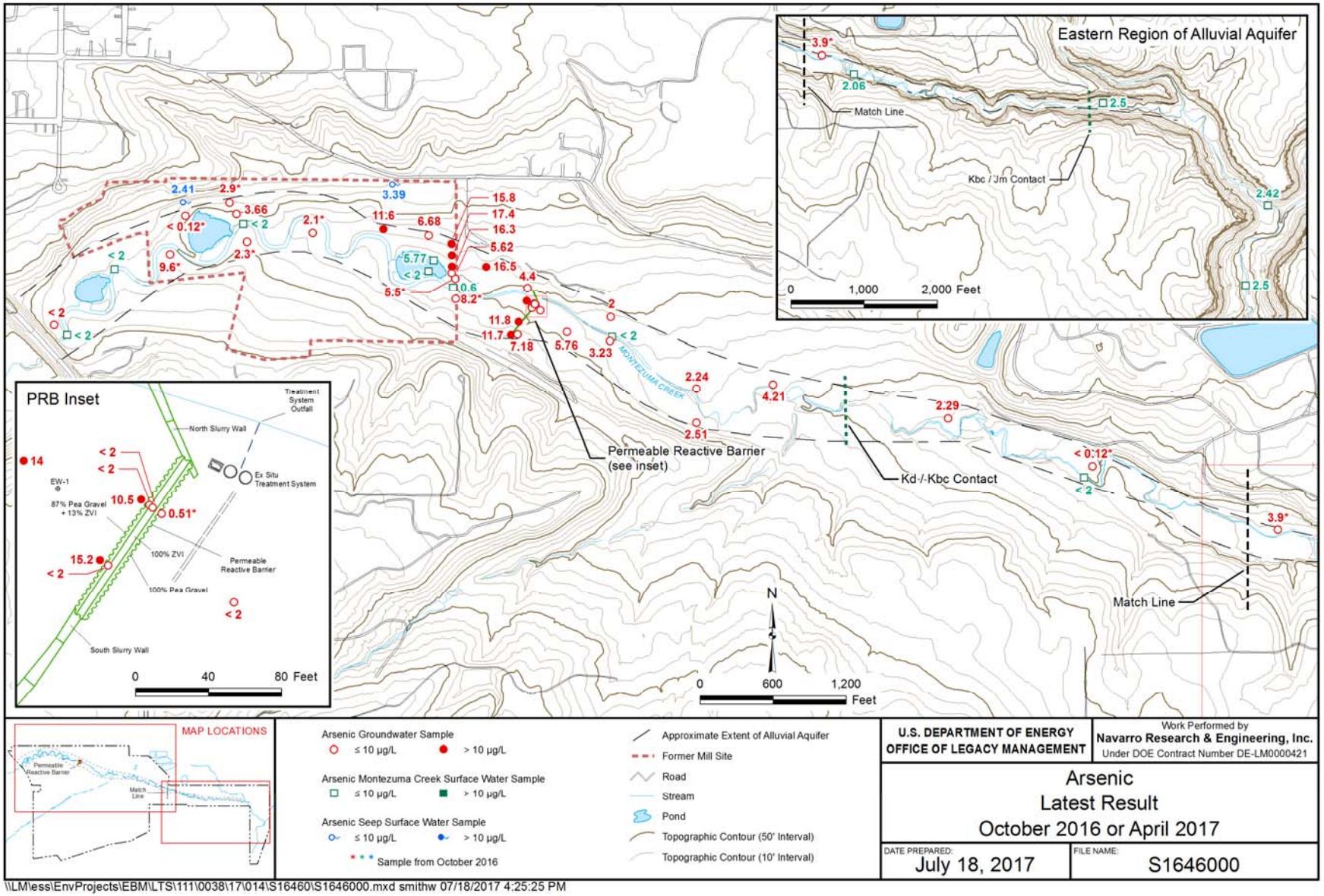

Figure 18. Distribution of Arsenic in Surface Water and Alluvial Aquifer Groundwater, Current Reporting Period

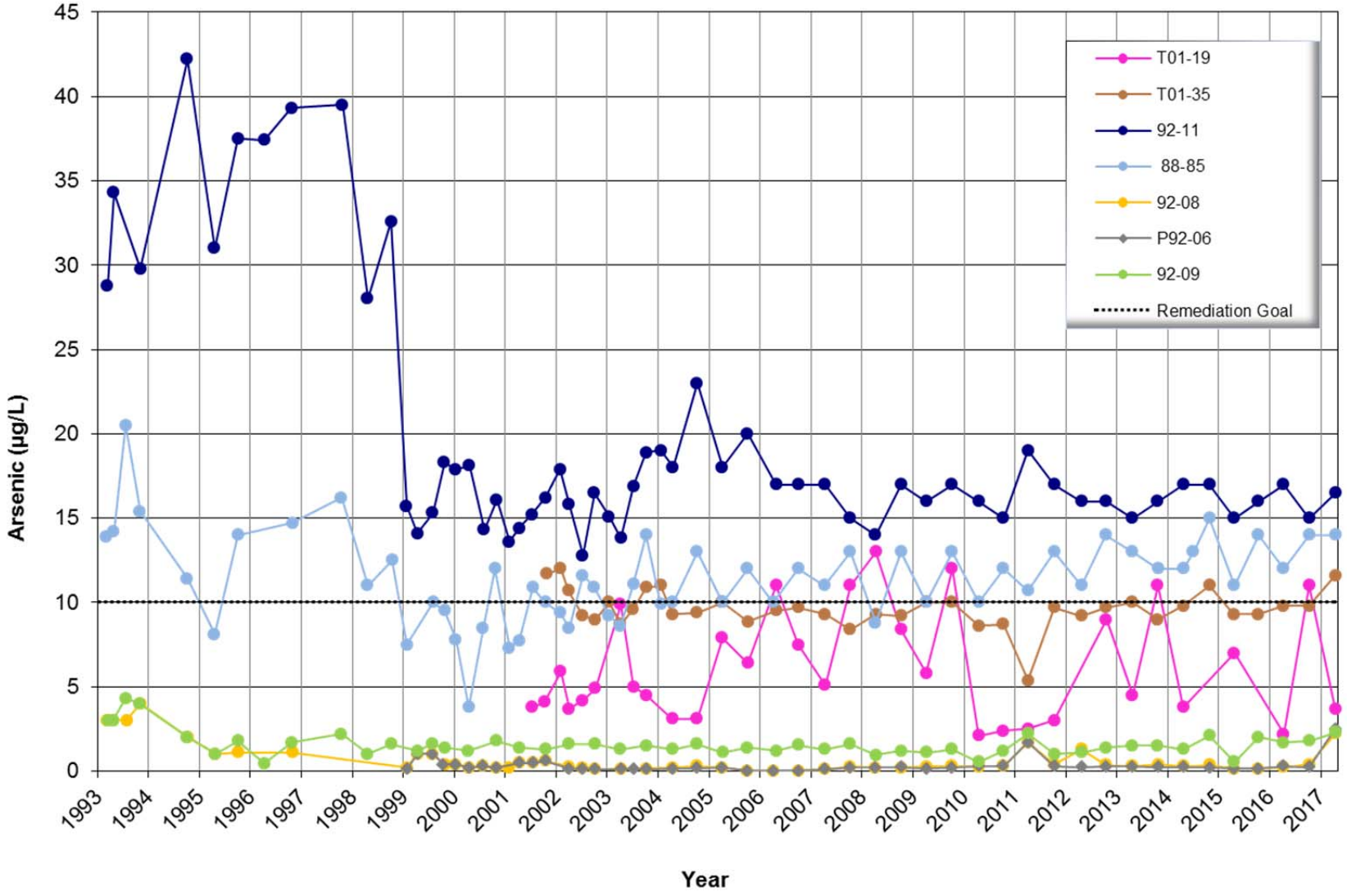

Figure 19. Arsenic Concentration over Time at Selected Alluvial Aquifer Monitoring Wells

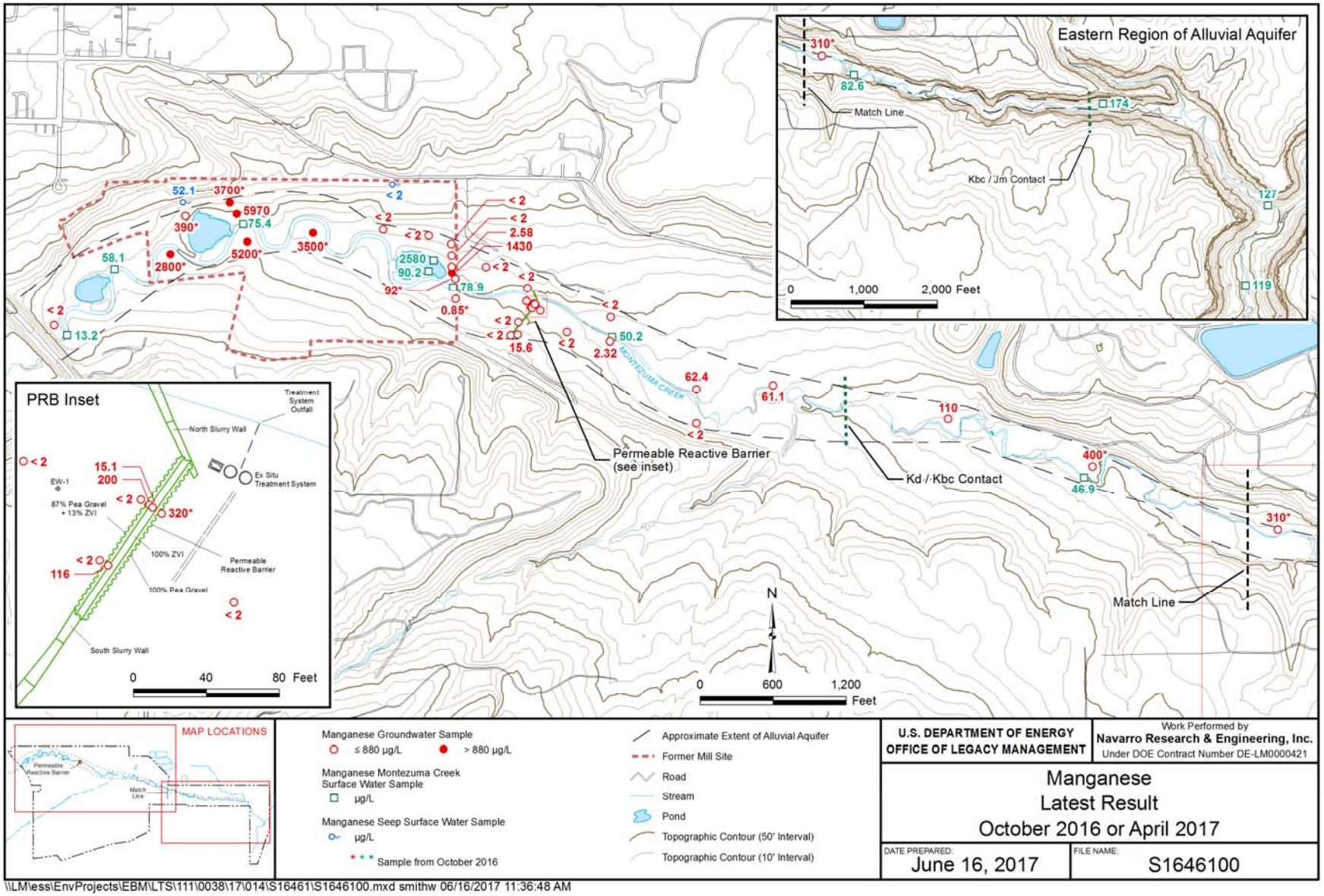

Figure 20. Distribution of Manganese in Surface Water and Alluvial Aquifer Groundwater, Current Reporting Period

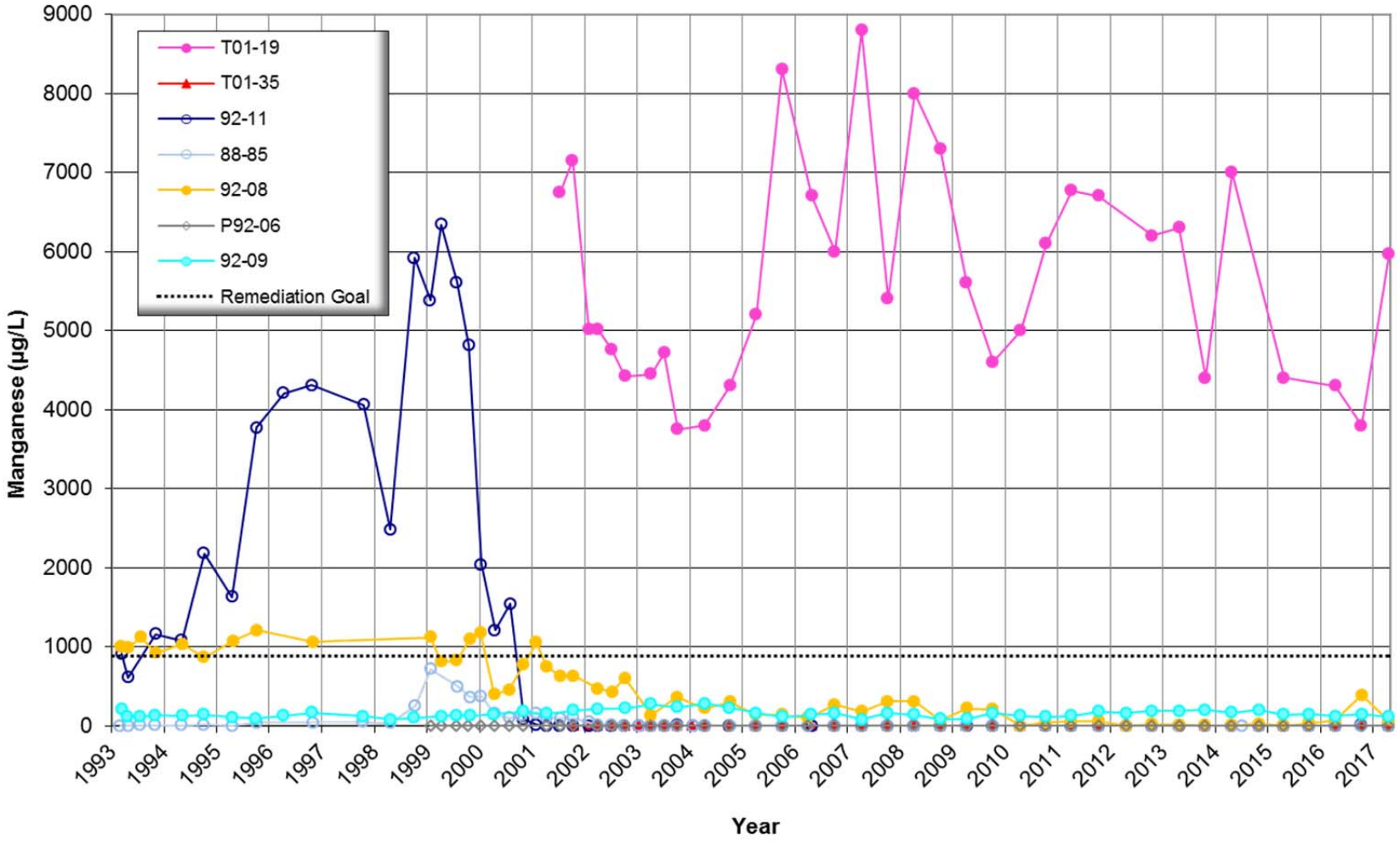

Figure 21. Manganese Concentration over Time at Selected Alluvial Aquifer Monitoring Wells

Figure 22. Distribution of Molybdenum in Surface Water and Alluvial Aquifer Groundwater, Current Reporting Period

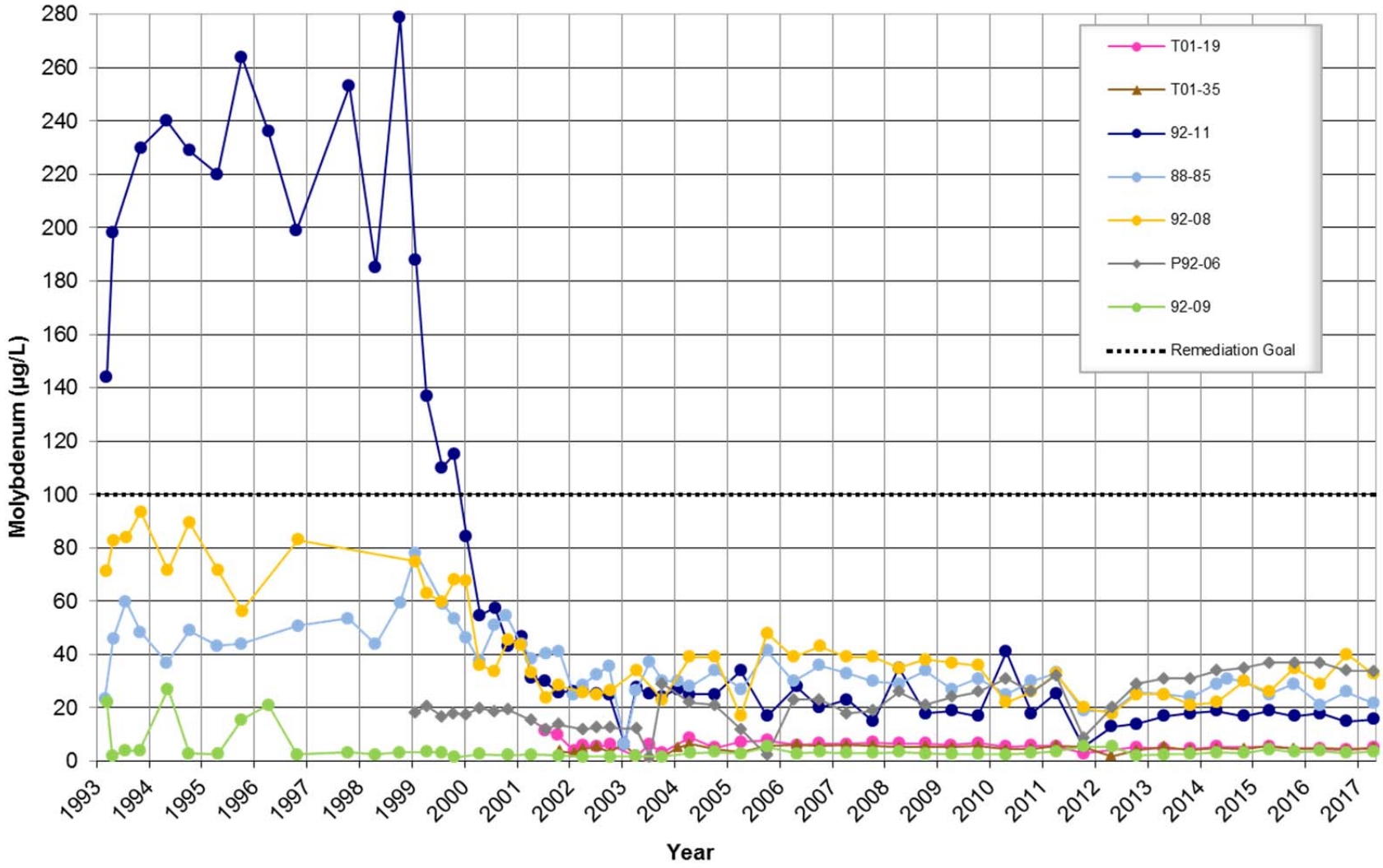

Figure 23. Molybdenum Concentration over Time at Selected Alluvial Aquifer Monitoring Wells

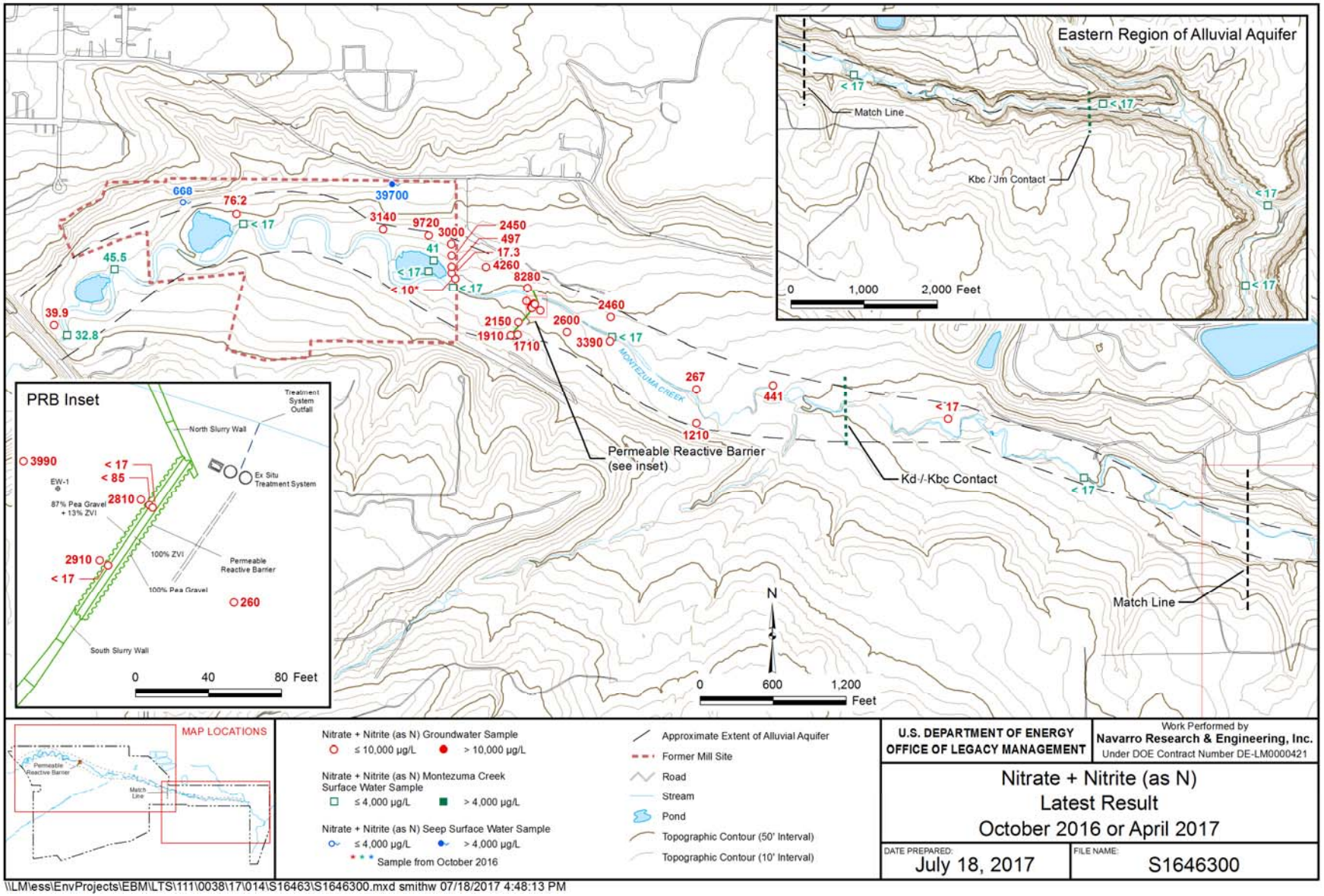

Figure 24. Distribution of Nitrate (as Nitrogen) in Surface Water and Alluvial Aquifer Groundwater, Current Reporting Period

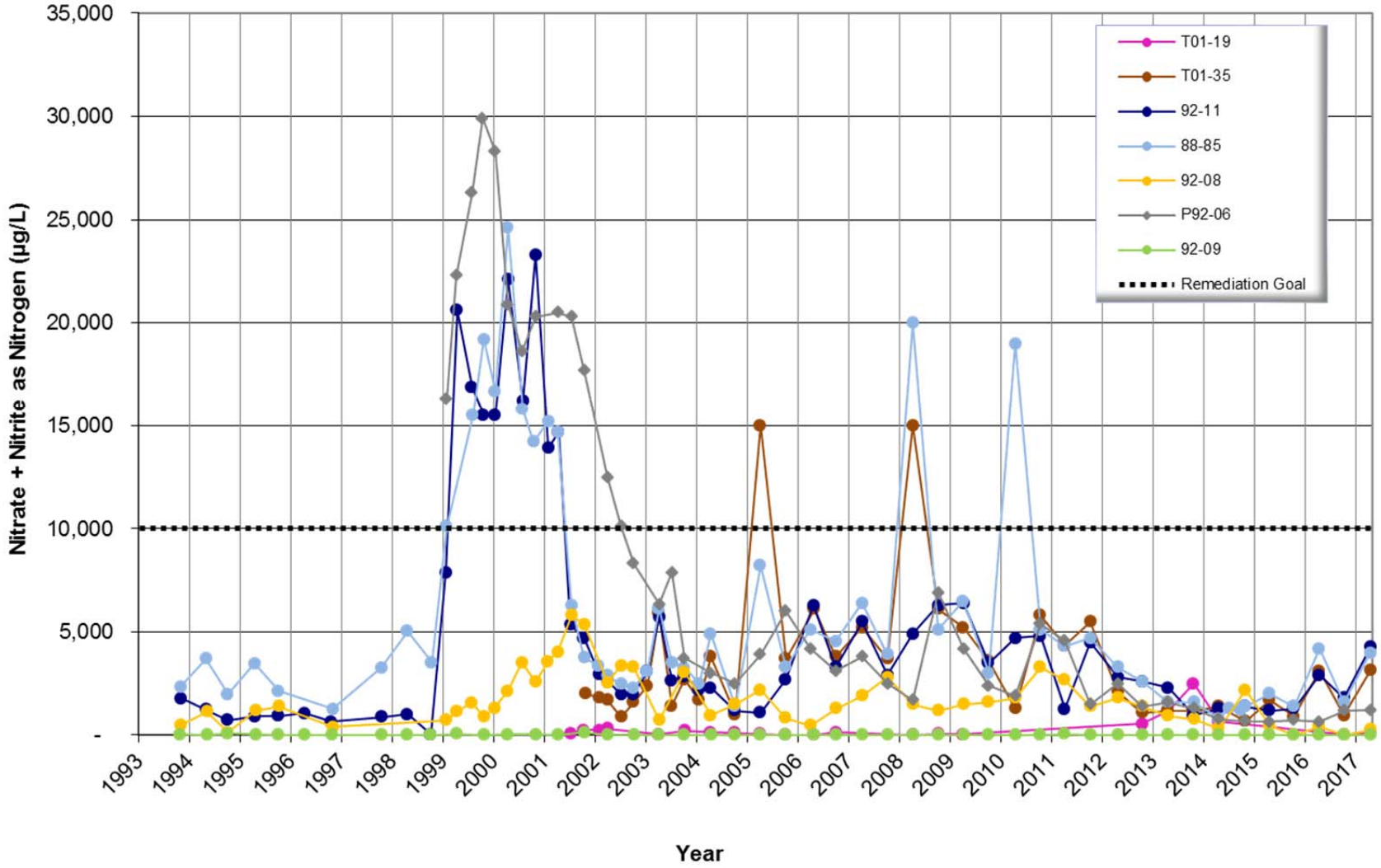

Figure 25. Nitrate + Nitrite (as Nitrogen) Concentration over Time at Selected Alluvial Aquifer Monitoring Wells

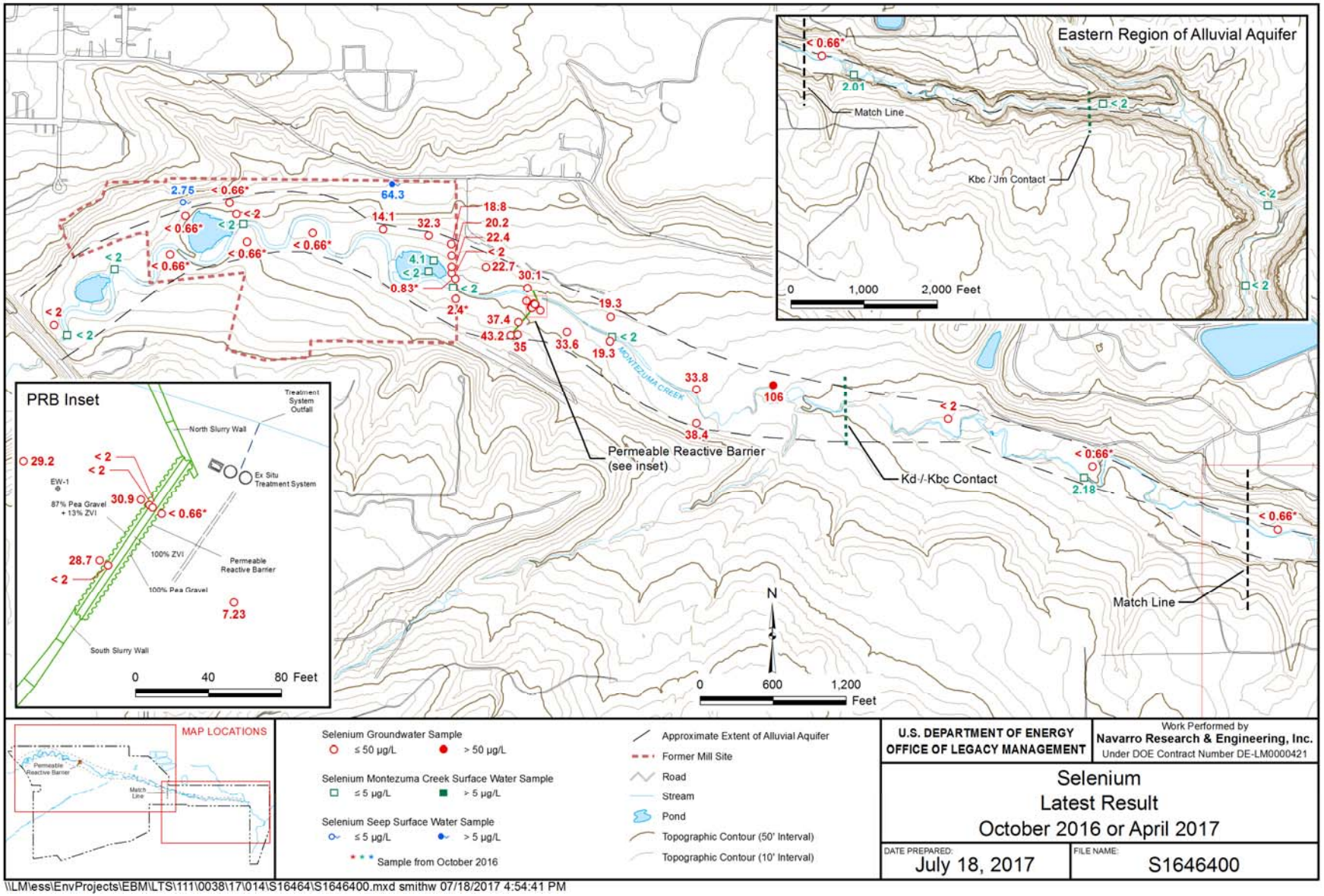

Figure 26. Distribution of Selenium in Surface Water and Alluvial Aquifer Groundwater, Current Reporting Period

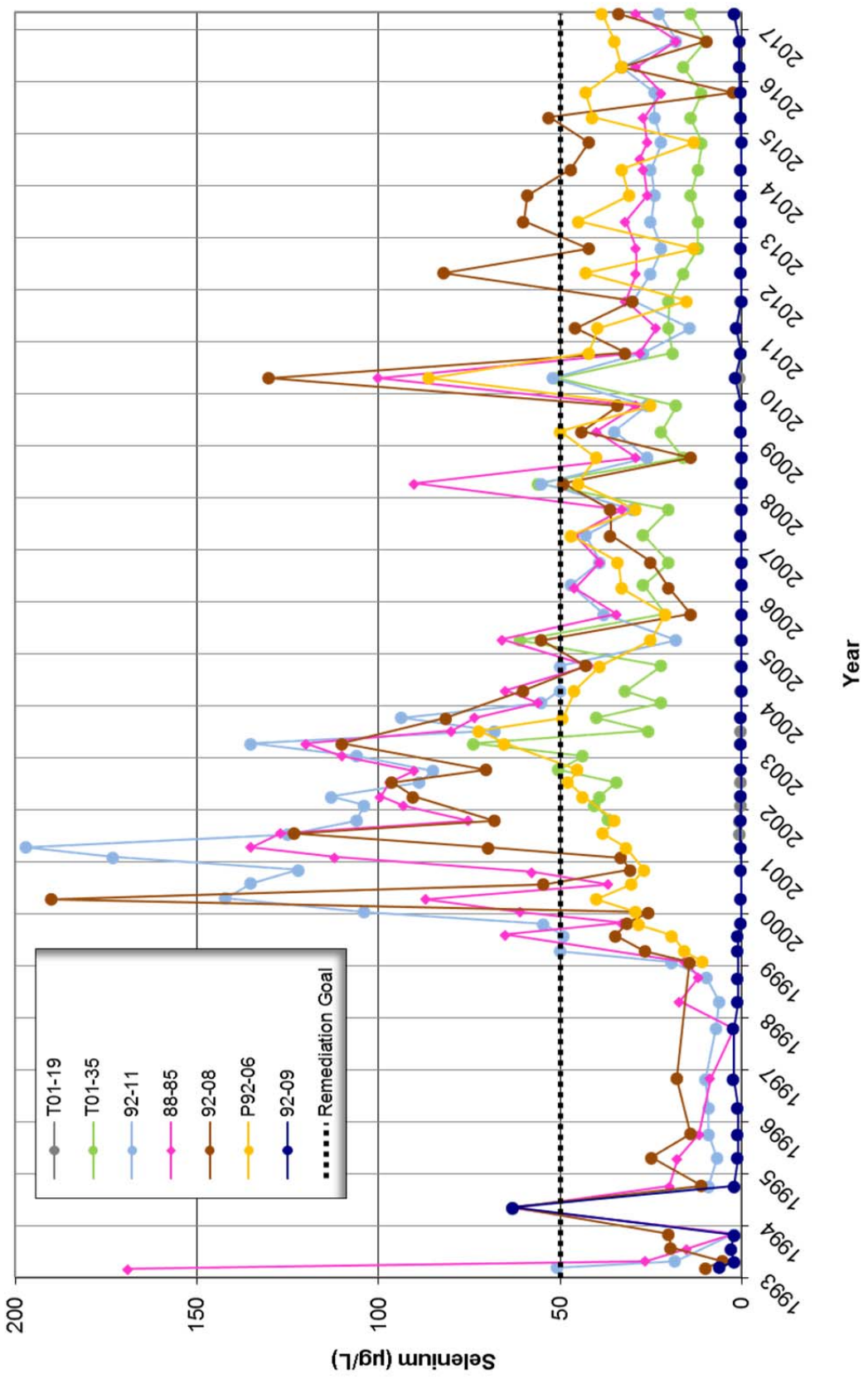

Figure 27. Selenium Concentration over Time at Selected Alluvial Aquifer Monitoring Wells

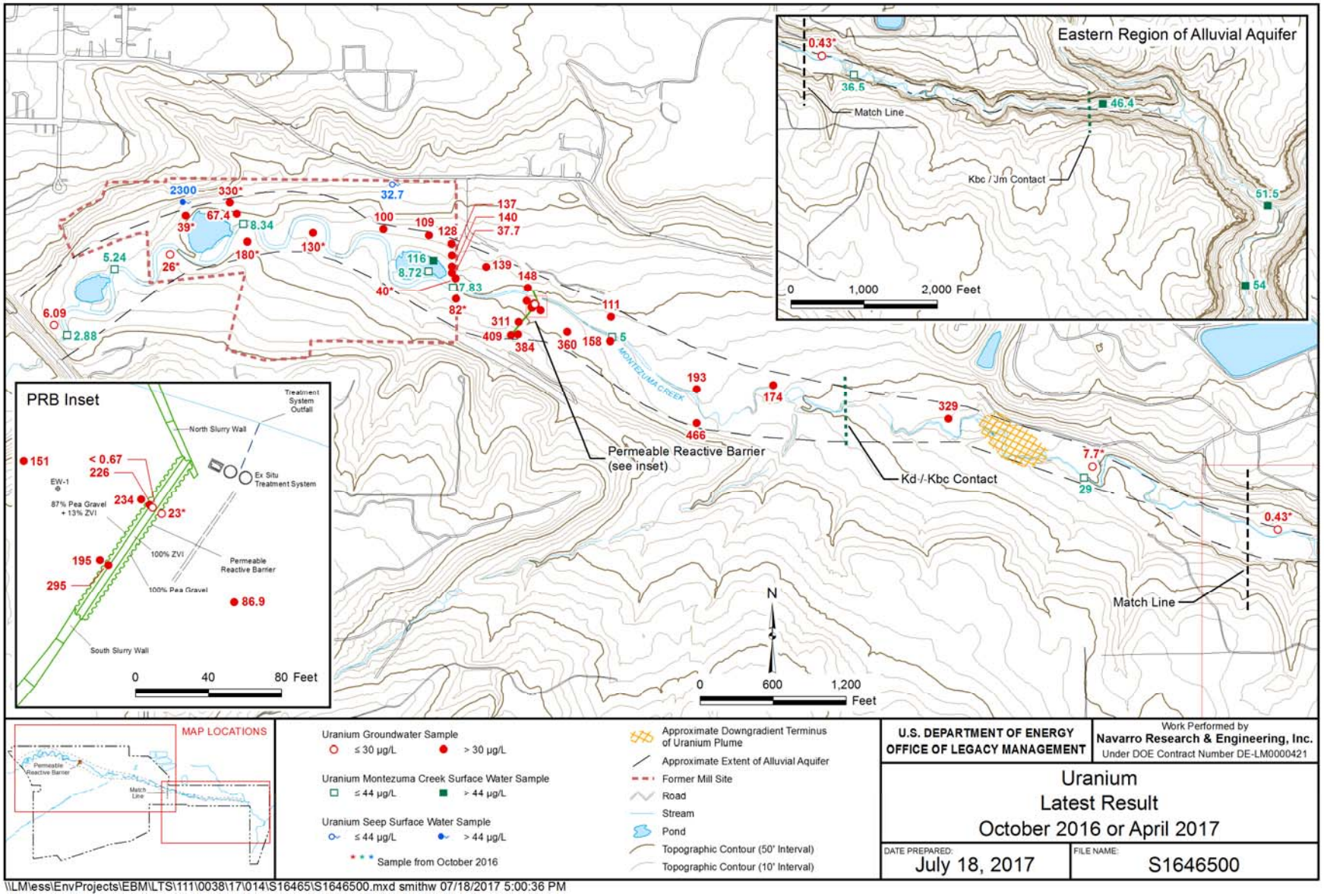

Figure 28. Distribution of Uranium in Surface Water and Alluvial Aquifer Groundwater, Current Reporting Period

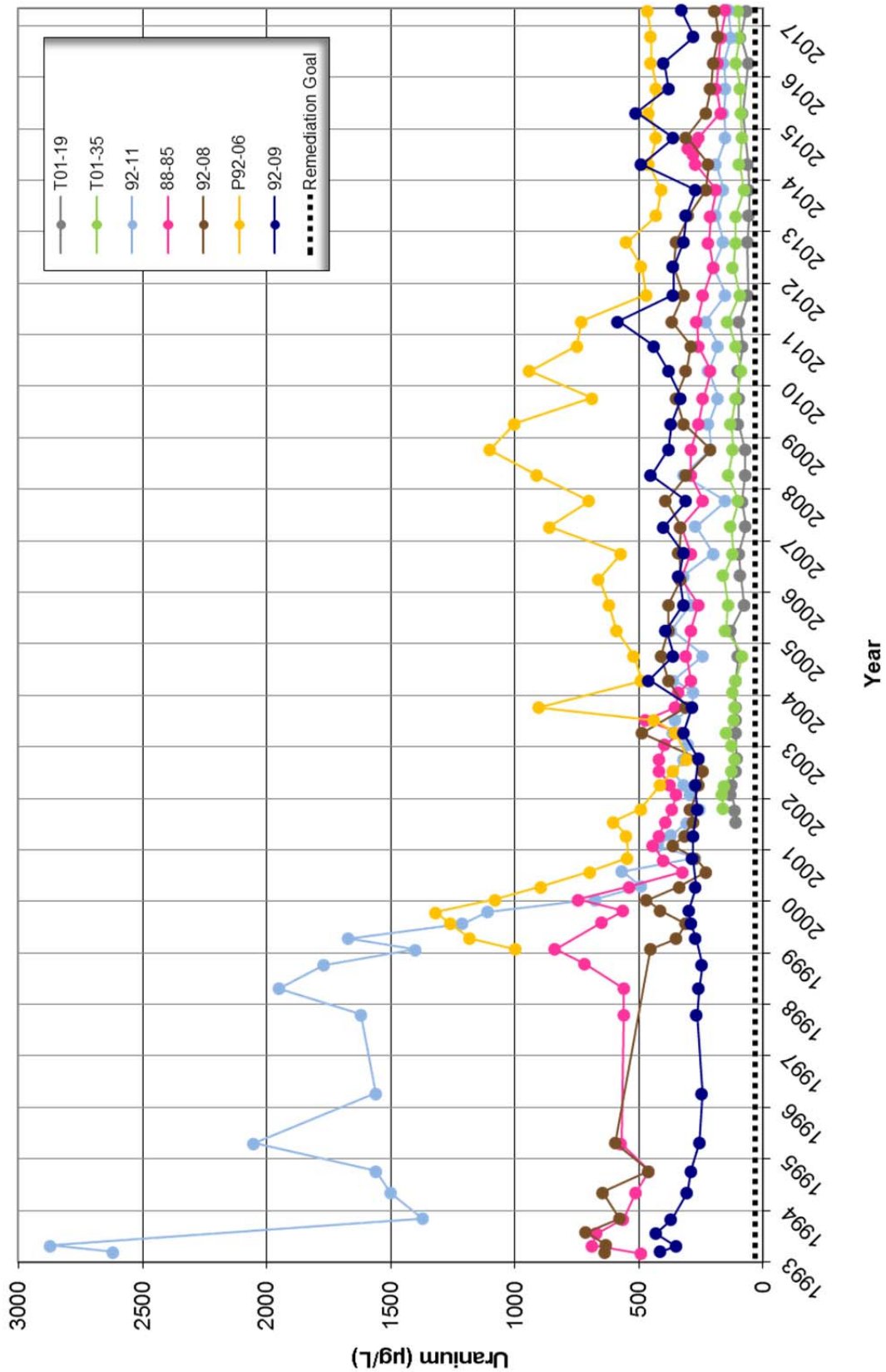

Figure 29. Uranium Concentration over Time at Selected Alluvial Aquifer Monitoring Wells

Figure 30. Distribution of Vanadium in Surface Water and Alluvial Aquifer Groundwater, Current Reporting Period

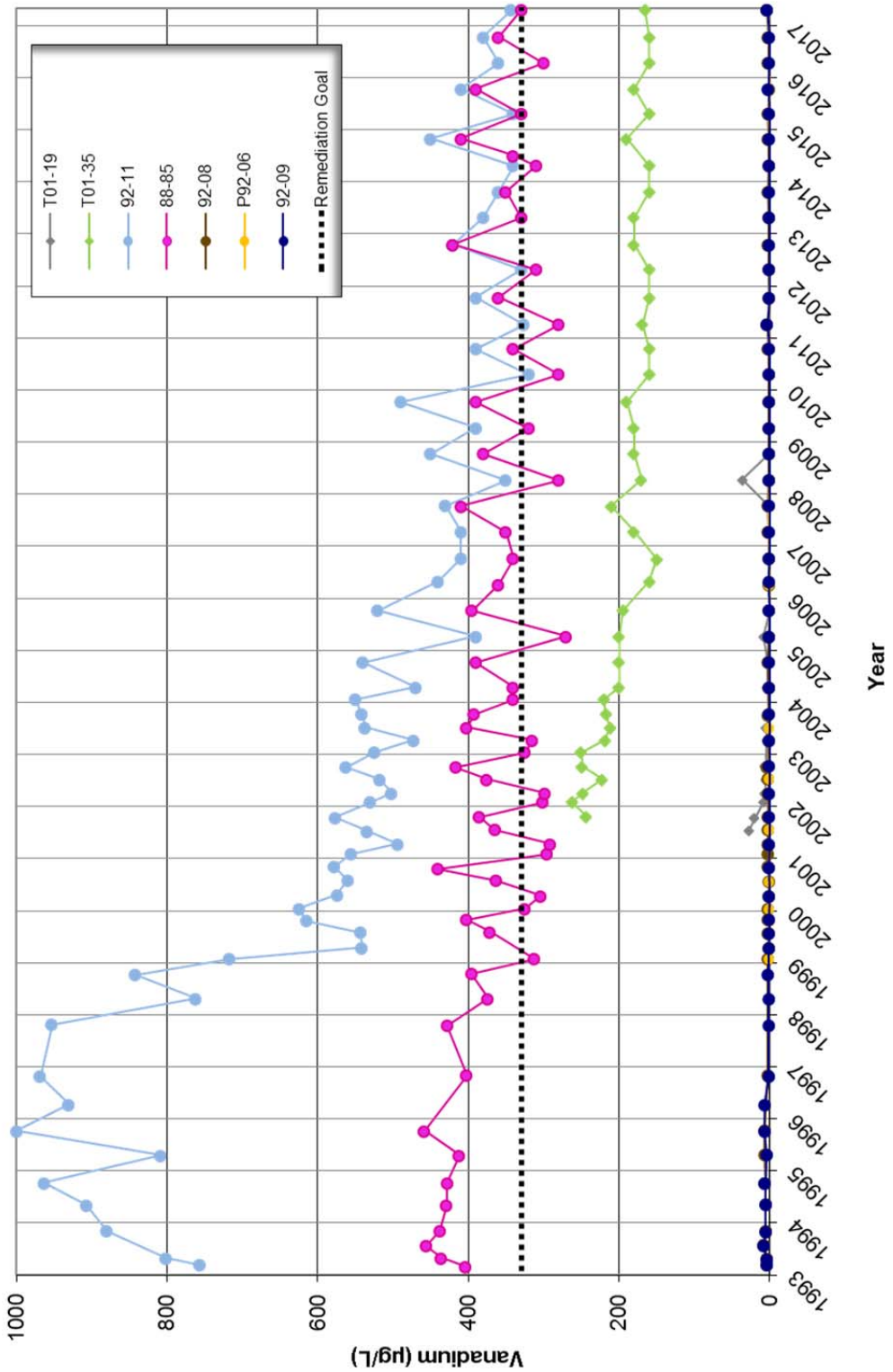

Figure 31. Vanadium Concentration over Time at Selected Alluvial Aquifer Monitoring Wells

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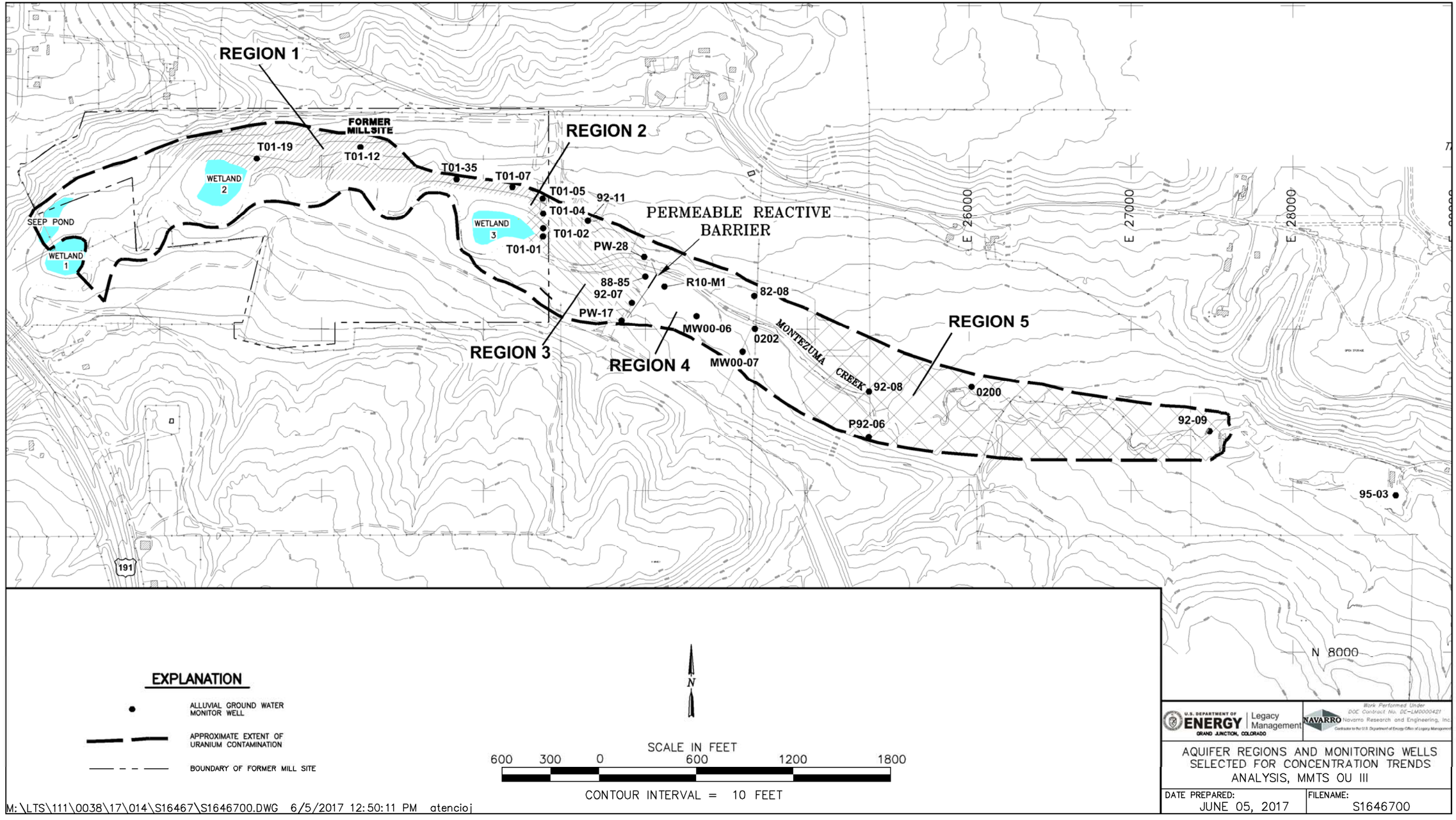

Figure 32. Aquifer Regions and Monitoring Wells Selected for Concentration Trend Analysis, MMTS OU III

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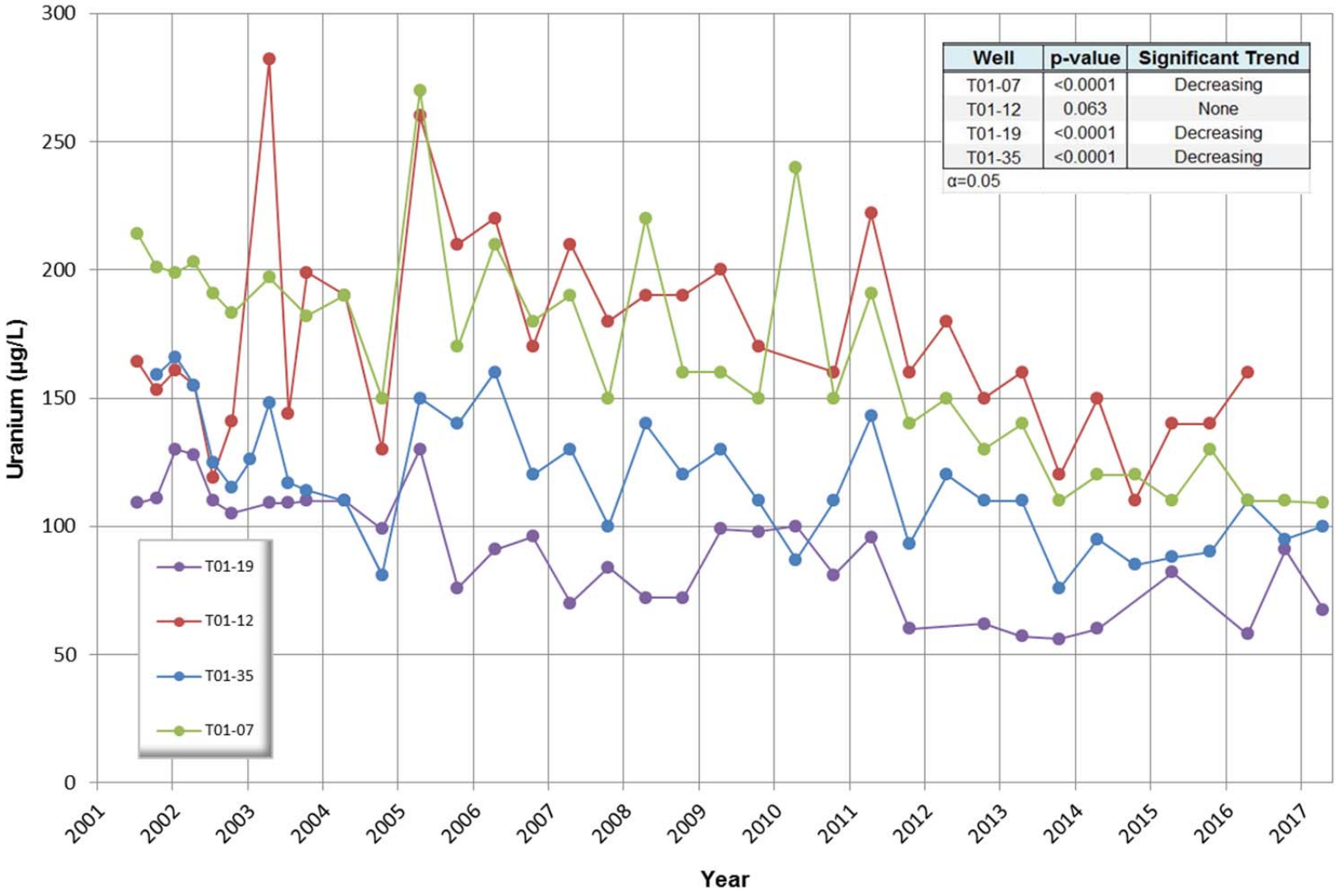


Figure 33. Region 1 Uranium Concentration Trends in Alluvial Groundwater

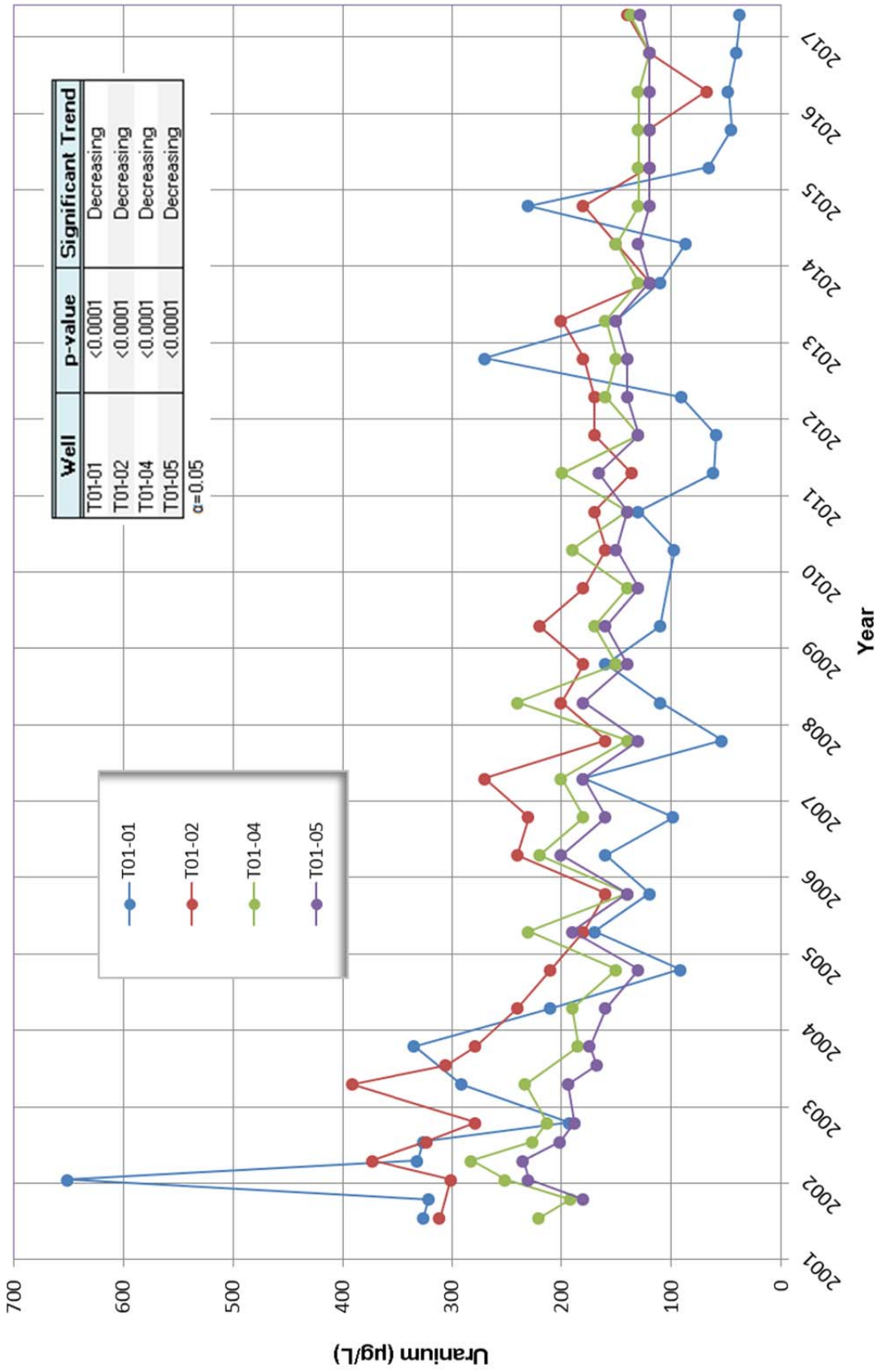
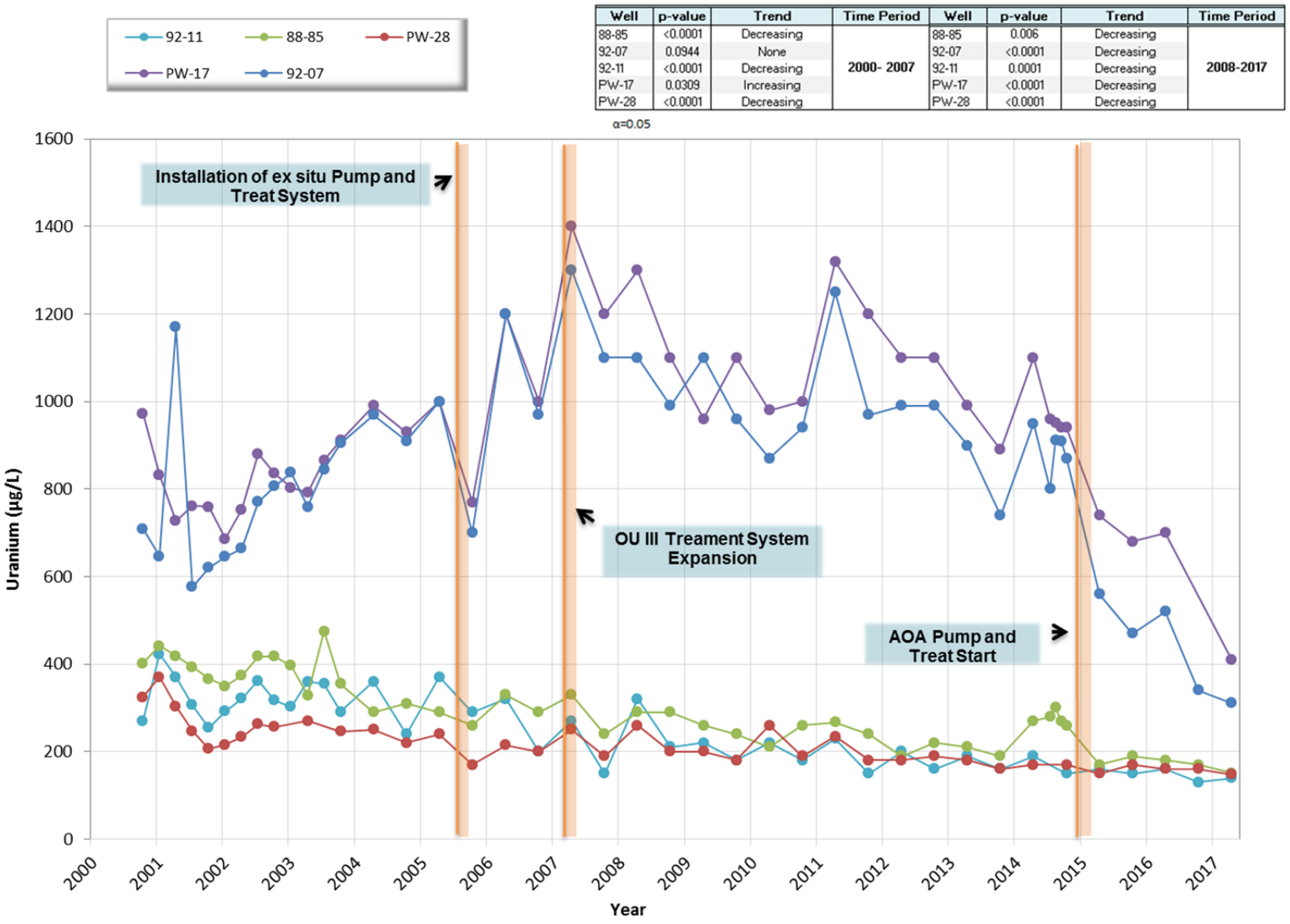


Figure 34. Region 2 Uranium Concentration Trends in Alluvial Groundwater



Well	p-value	Trend	Time Period
88-85	<0.0001	Decreasing	2000- 2007
92-07	0.0944	None	
92-11	<0.0001	Decreasing	
PW-17	0.0309	Increasing	
PW-28	<0.0001	Decreasing	

Well	p-value	Trend	Time Period
88-85	0.006	Decreasing	2008-2017
92-07	<0.0001	Decreasing	
92-11	0.0001	Decreasing	
PW-17	<0.0001	Decreasing	
PW-28	<0.0001	Decreasing	

Figure 35. Region 3 Uranium Concentration Trends in Alluvial Groundwater

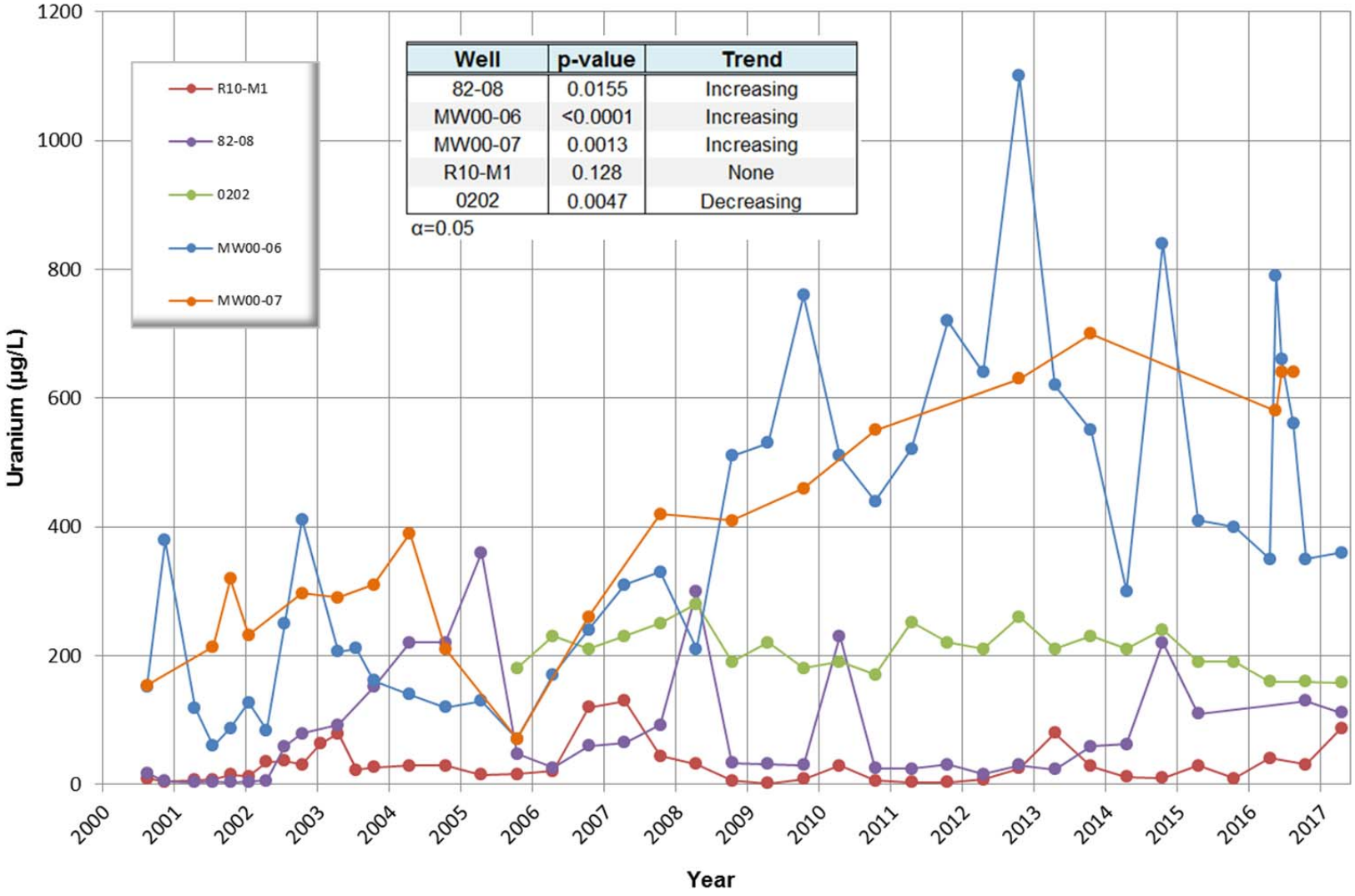


Figure 36. Region 4 Uranium Concentration Trends in Alluvial Groundwater

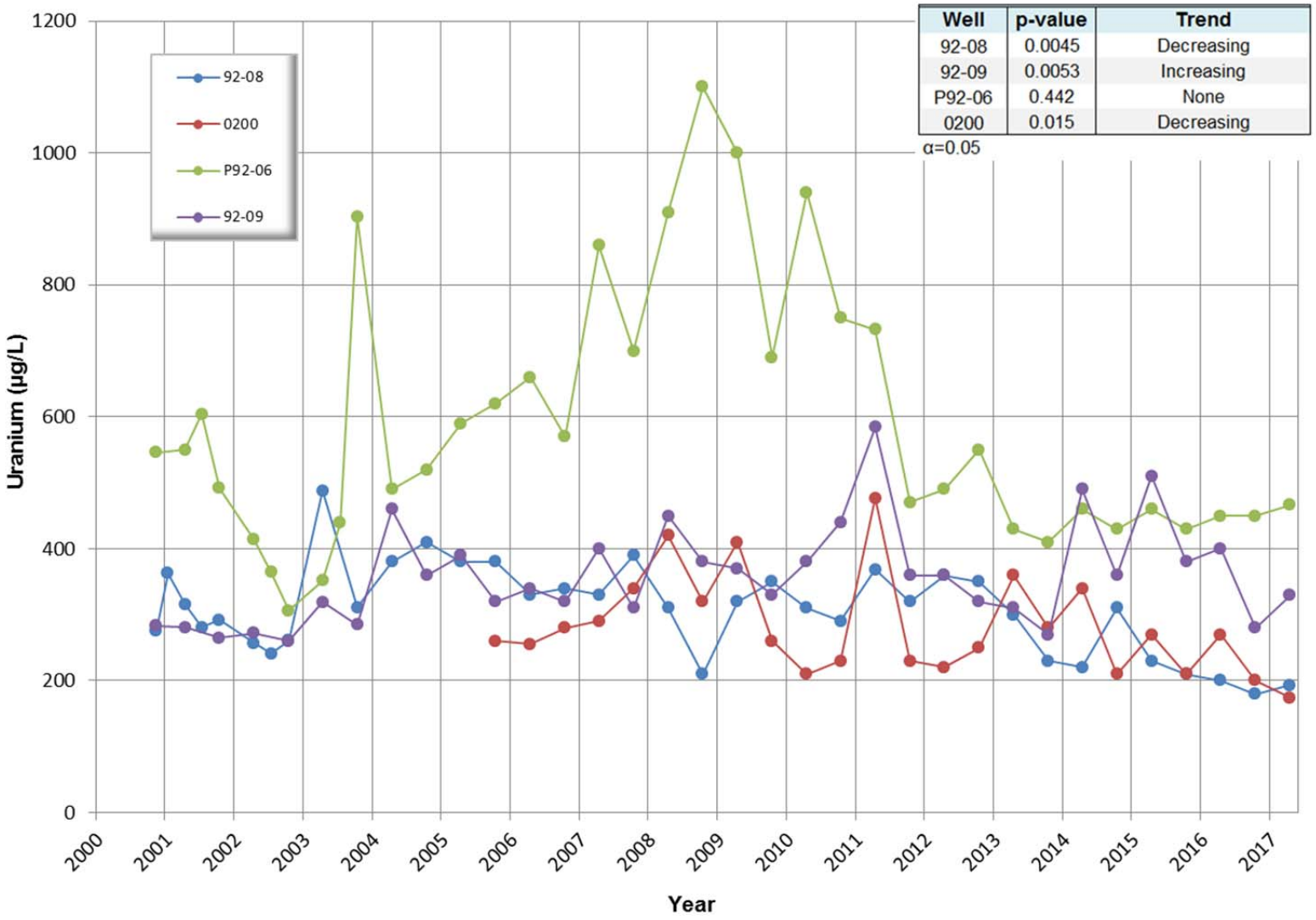


Figure 37. Region 5 Uranium Concentration Trends in Alluvial Groundwater

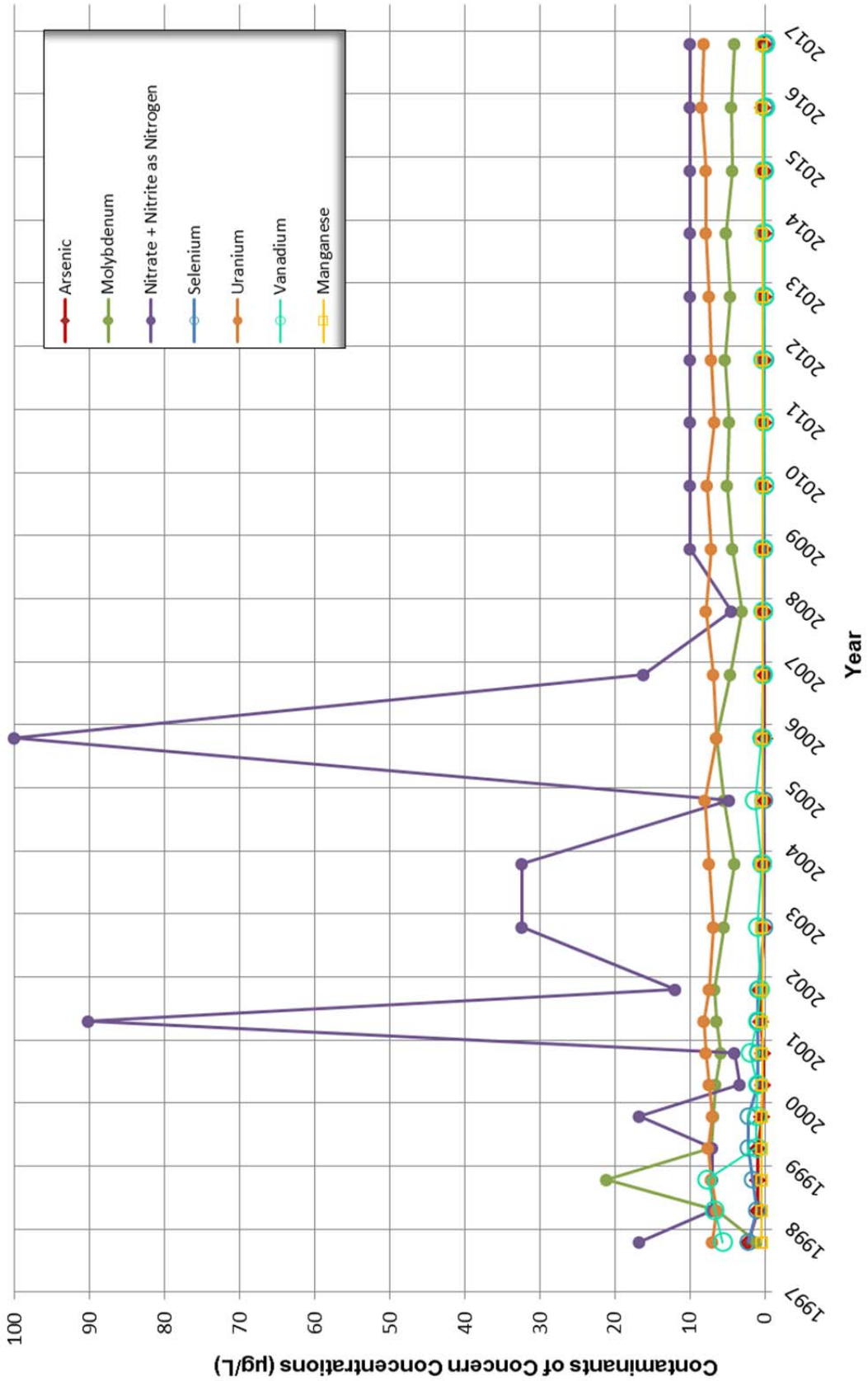


Figure 38. Contaminant Concentrations over Time at Sentinel Well 95-03

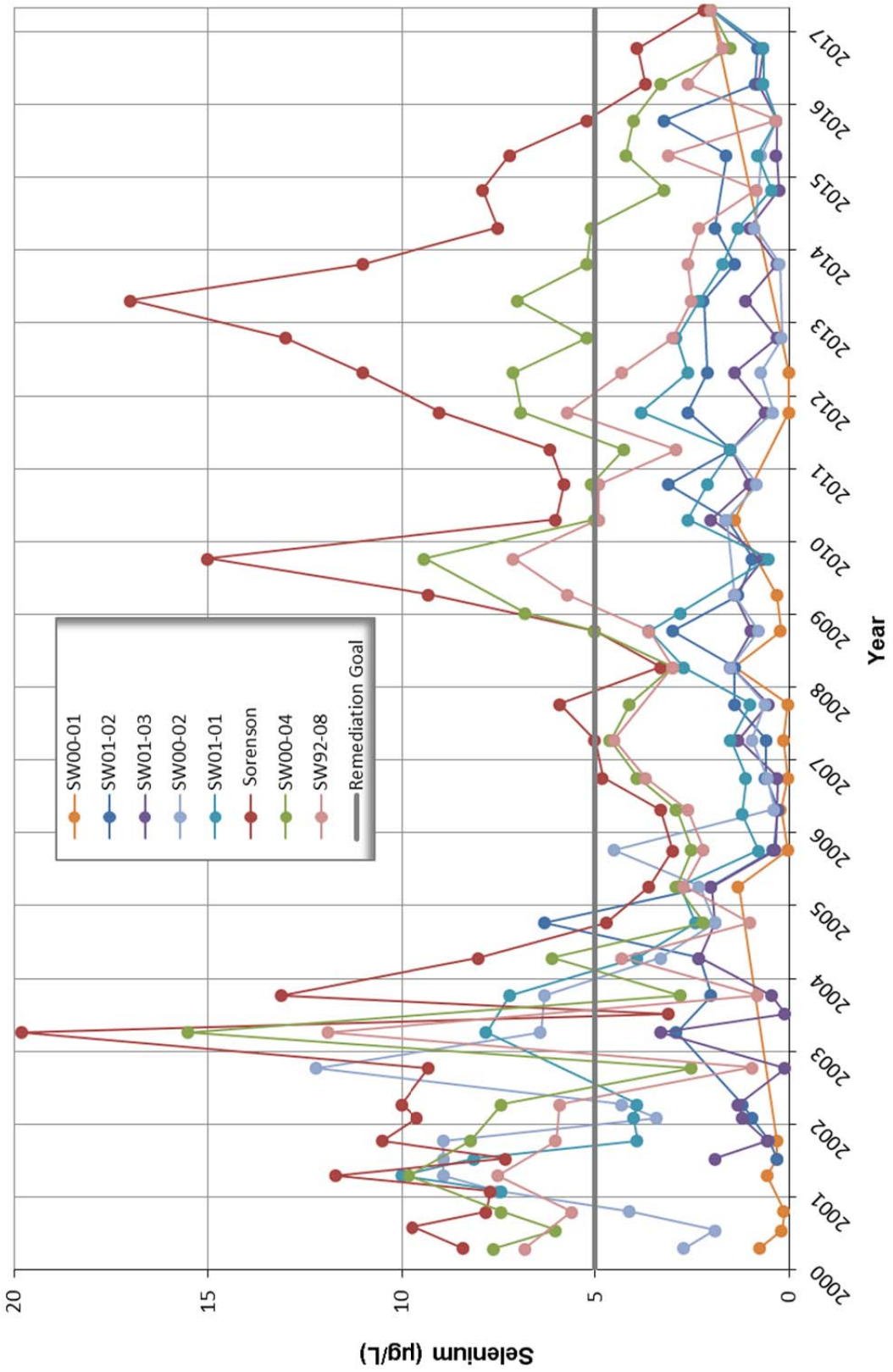


Figure 39. Selenium Concentration over Time in Montezuma Creek

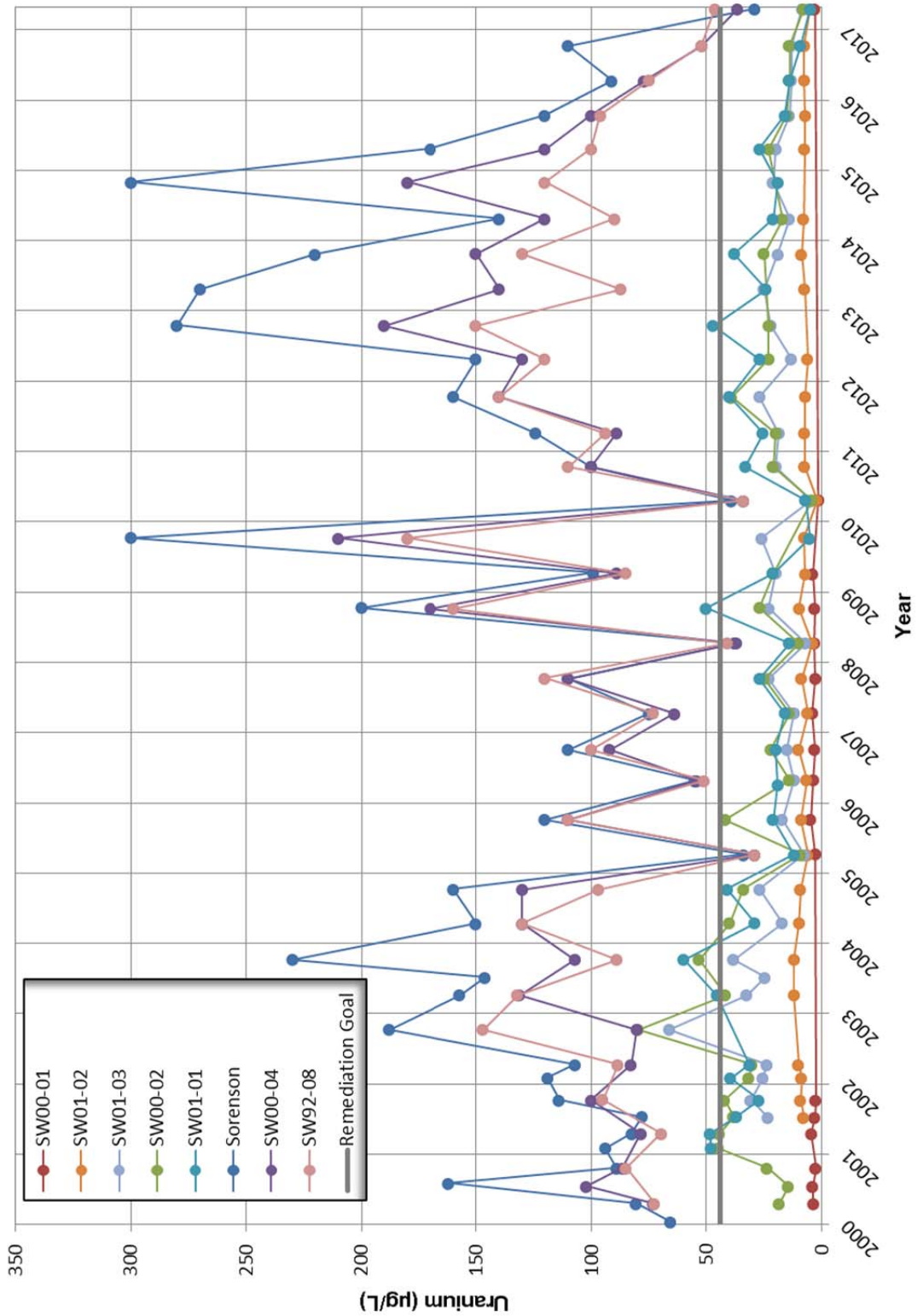


Figure 40. Uranium Concentration over Time in Montezuma Creek

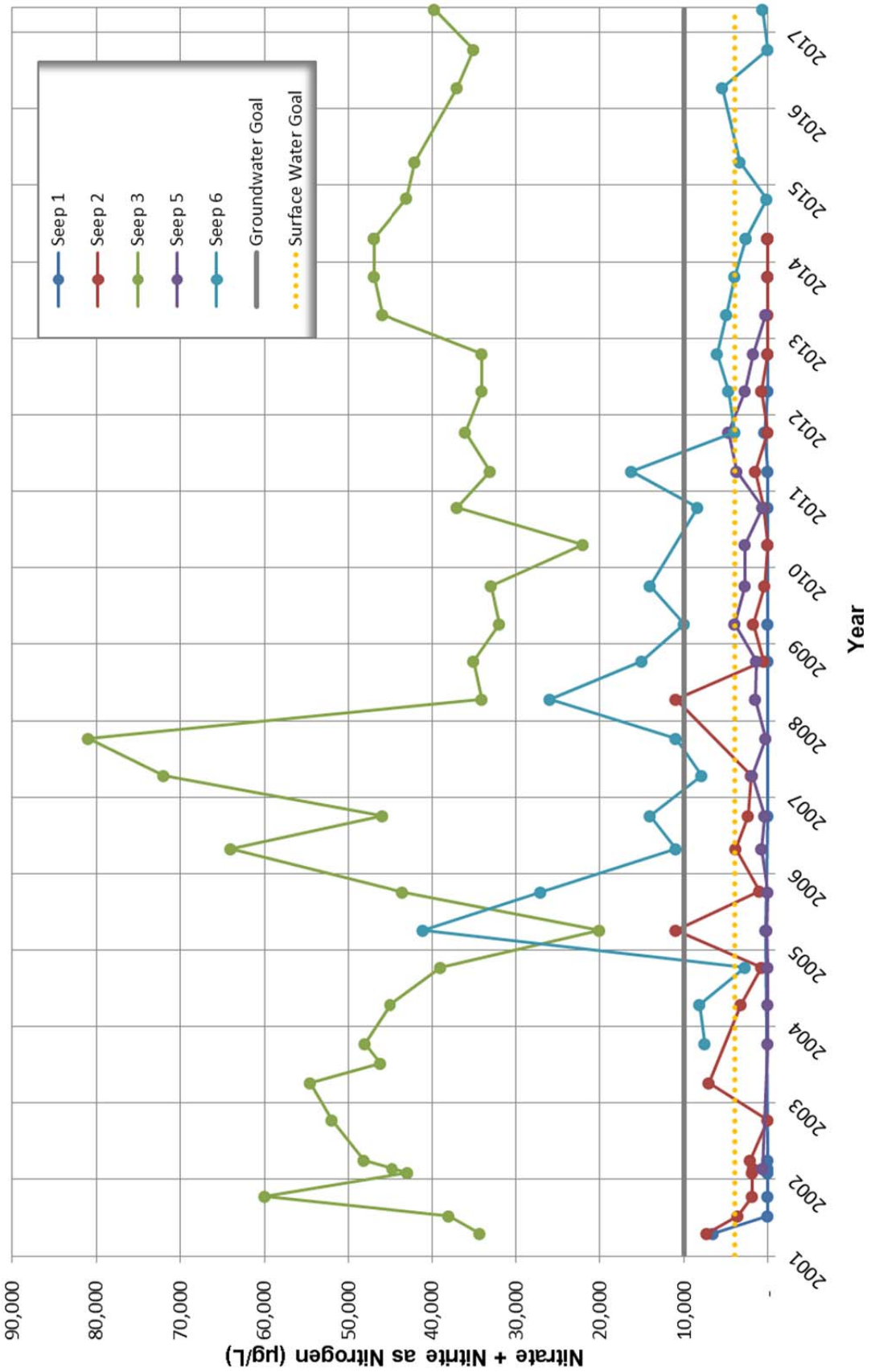


Figure 41. Nitrate + Nitrite (as nitrogen) Concentration over Time at Selected Seep Locations

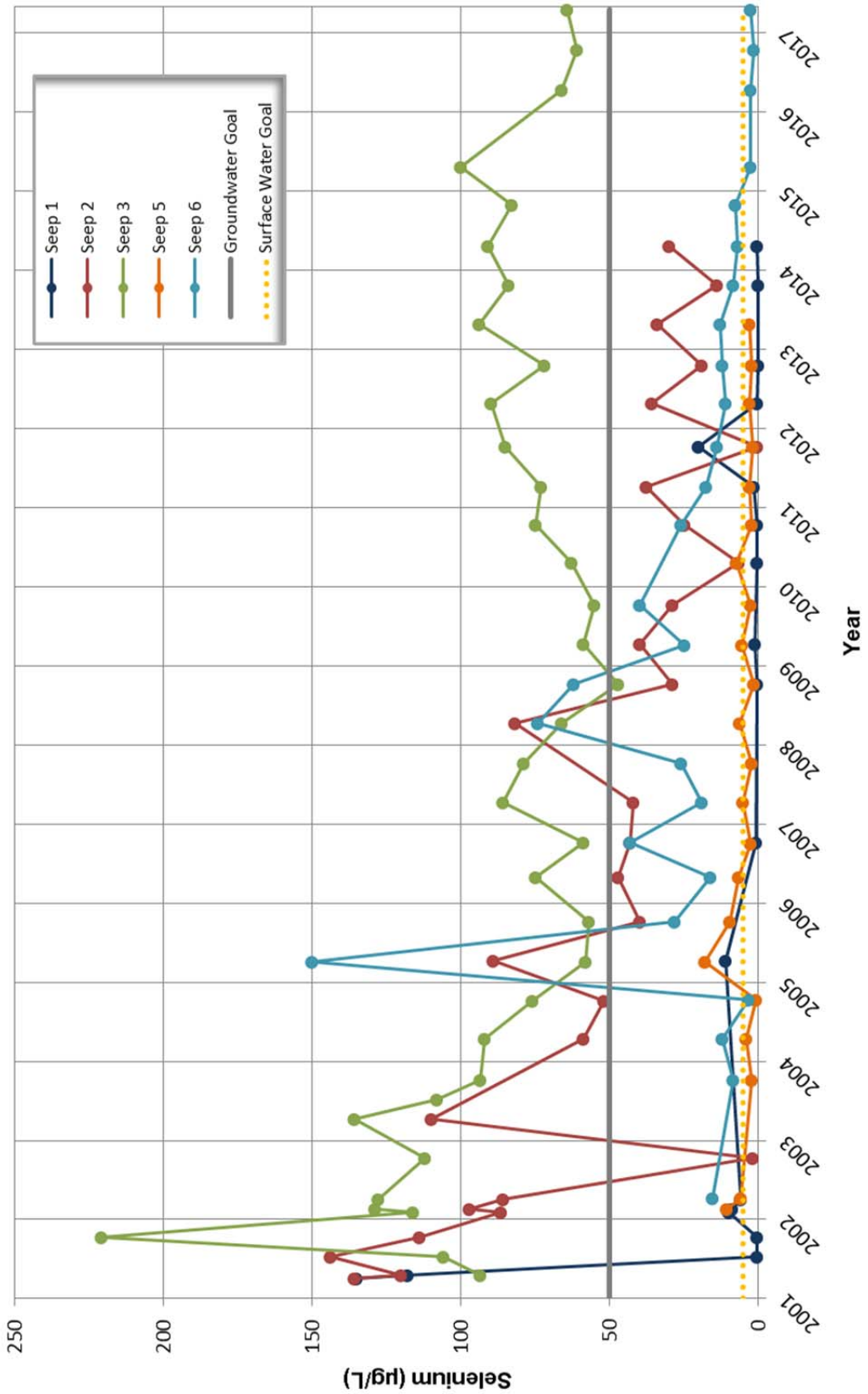


Figure 42. Selenium Concentration over Time at Selected Seep Locations

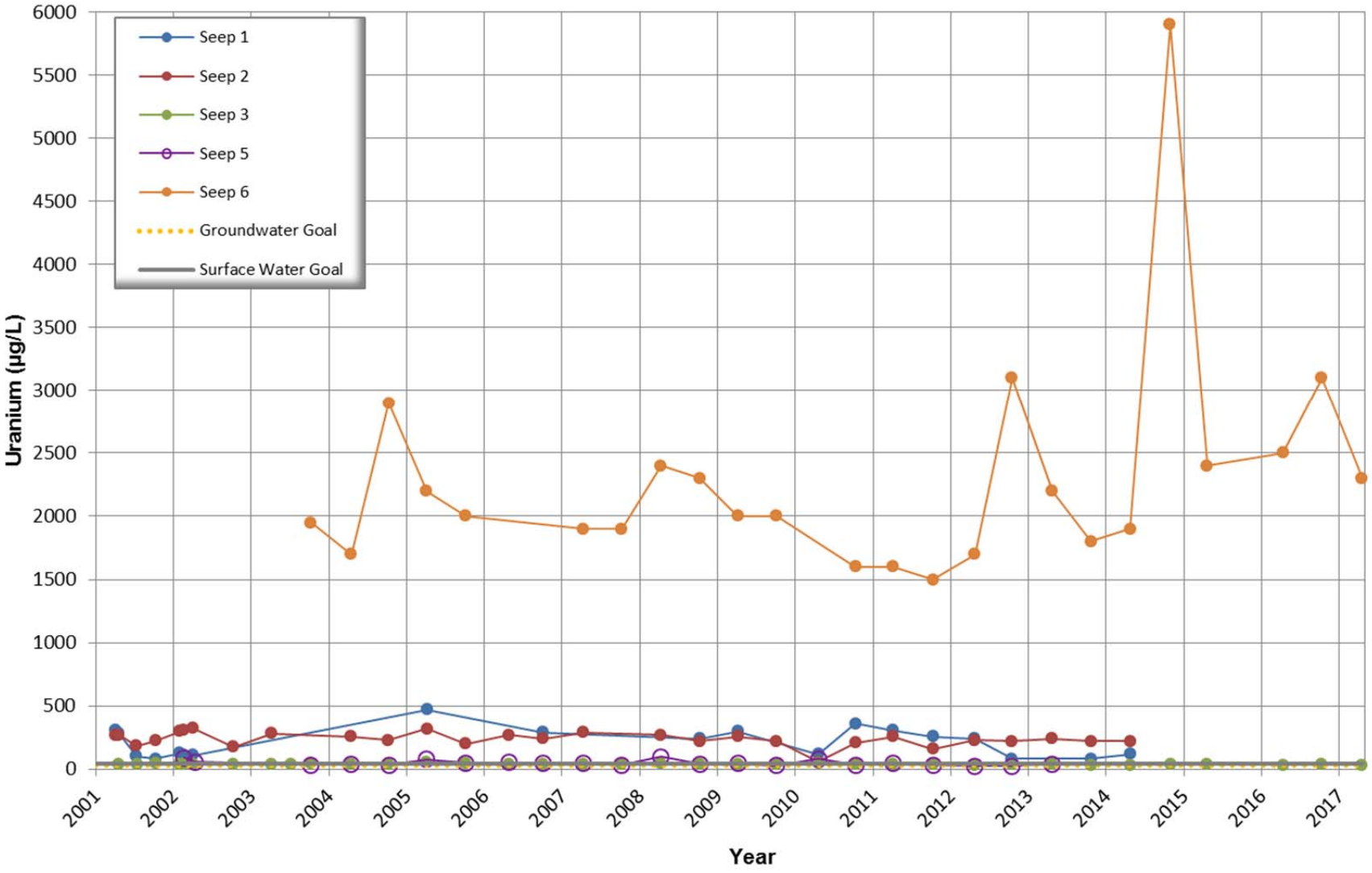


Figure 43. Uranium Concentration over Time at Selected Seep Locations

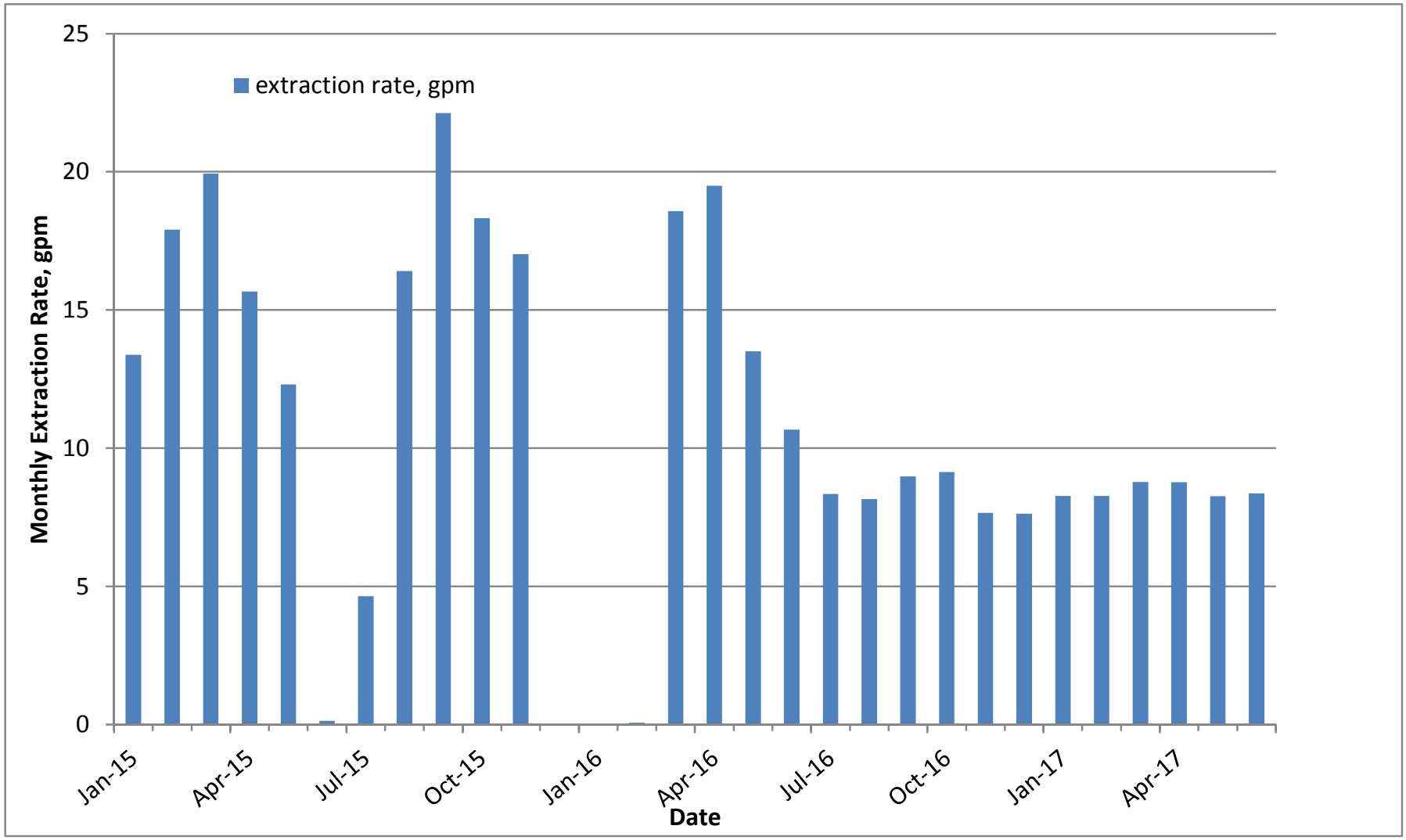


Figure 44. Monthly Rate of Groundwater Extraction from the AOA, MMTS OU III

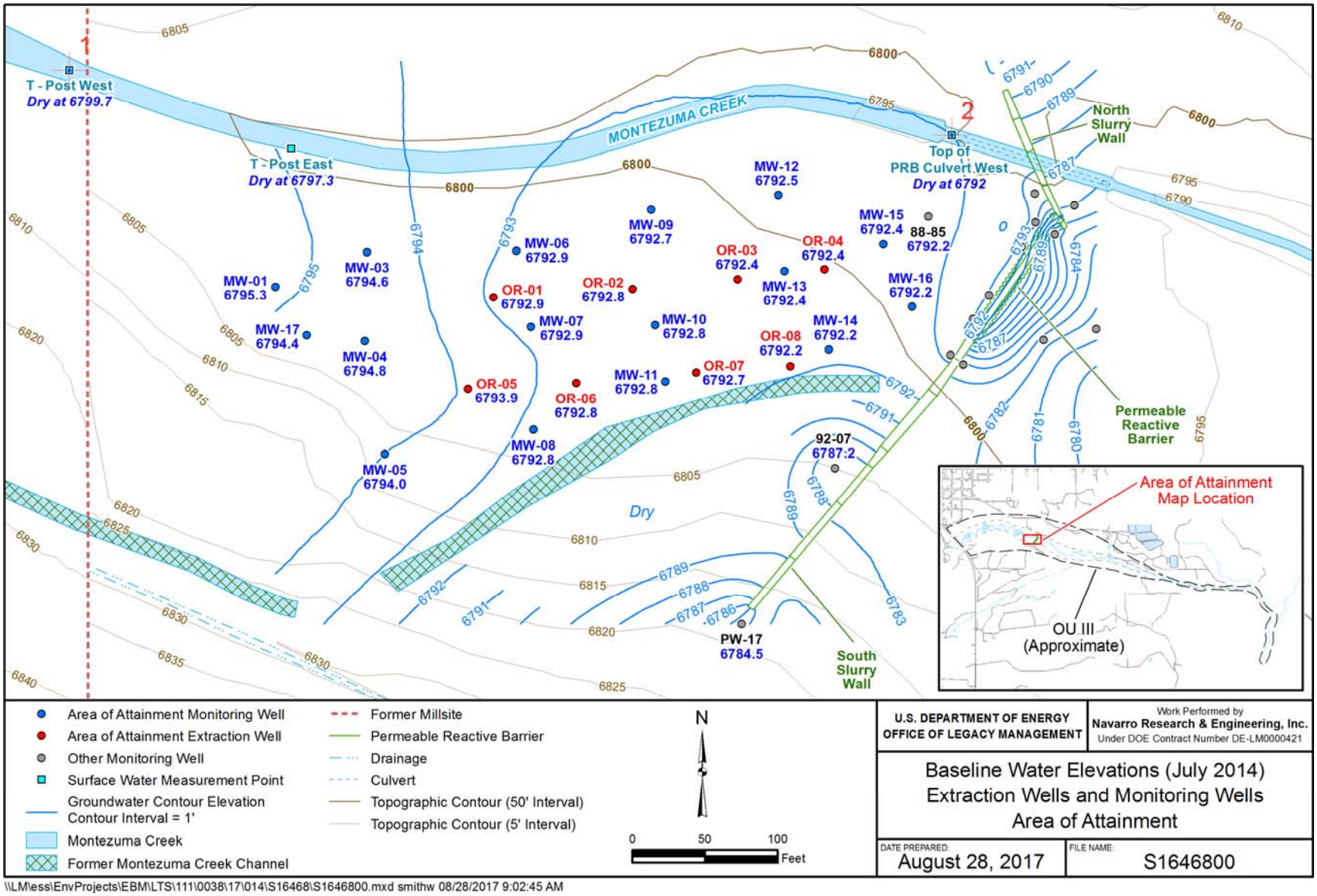


Figure 45. Alluvial Groundwater Elevation Contour Map in the AOA During Baseline Conditions

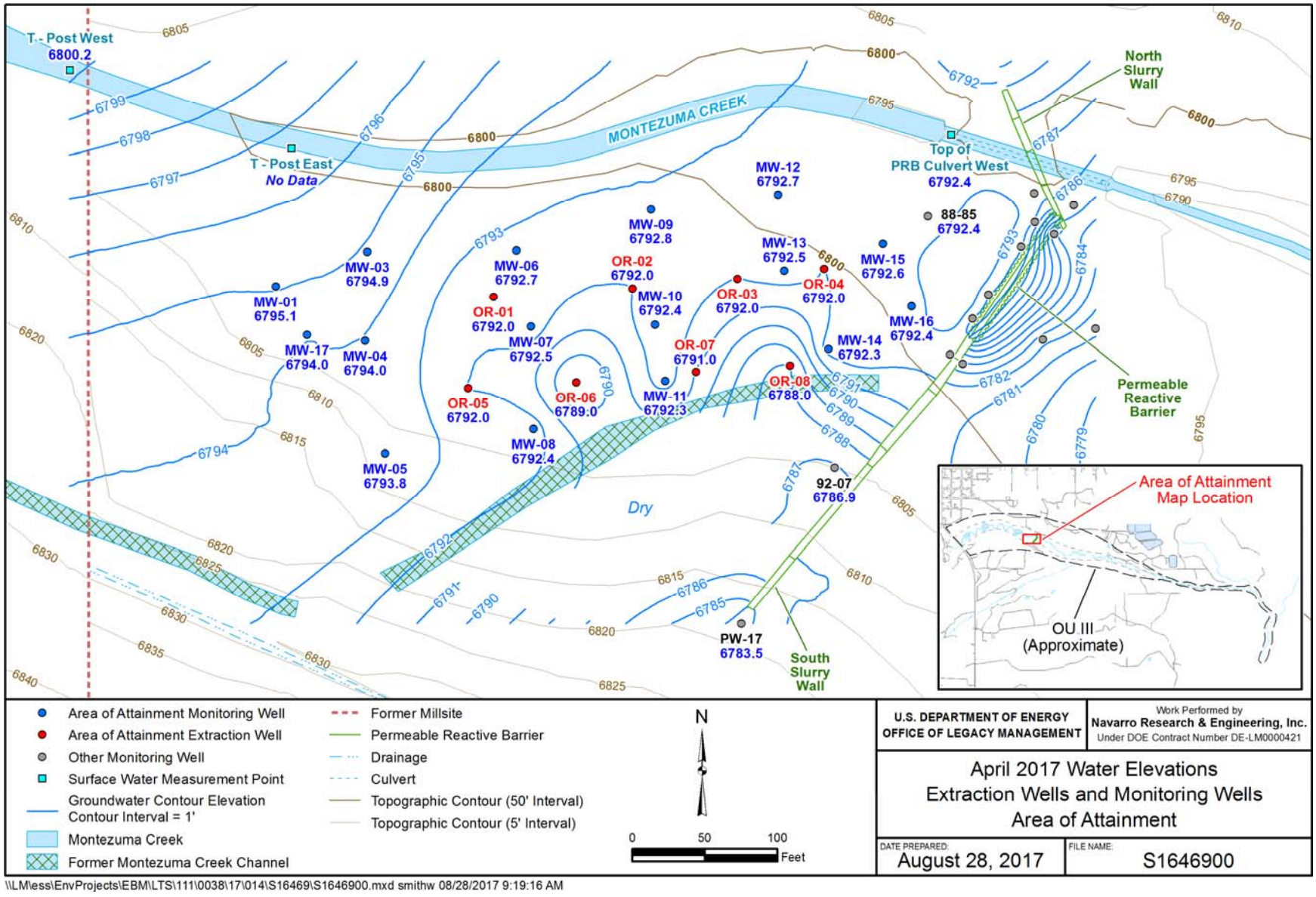


Figure 46. Alluvial Groundwater Elevation Contour Map in the AOA During April 2017

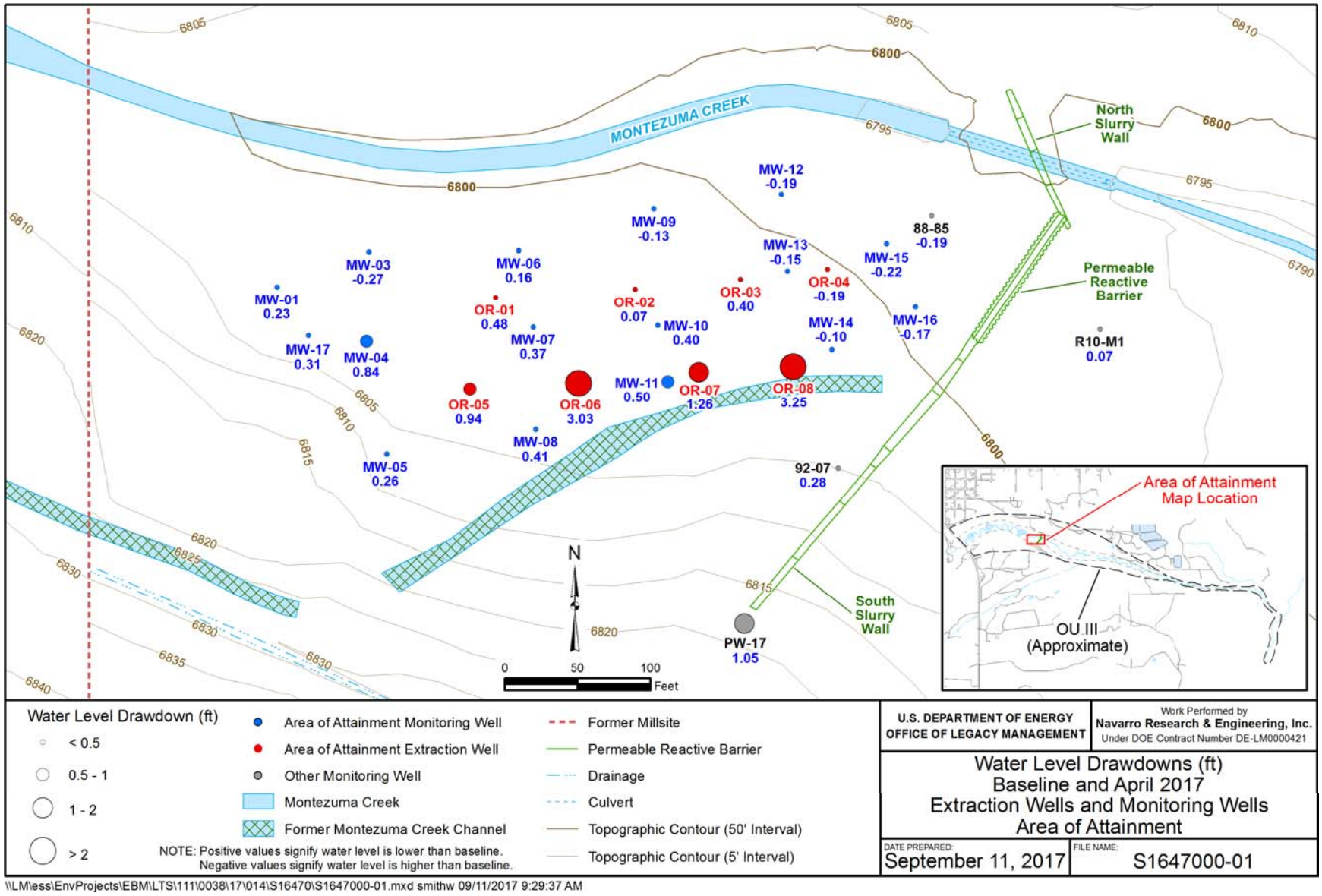


Figure 47. Water Level Drawdowns in AOA: July 2014 (baseline) to April 2017

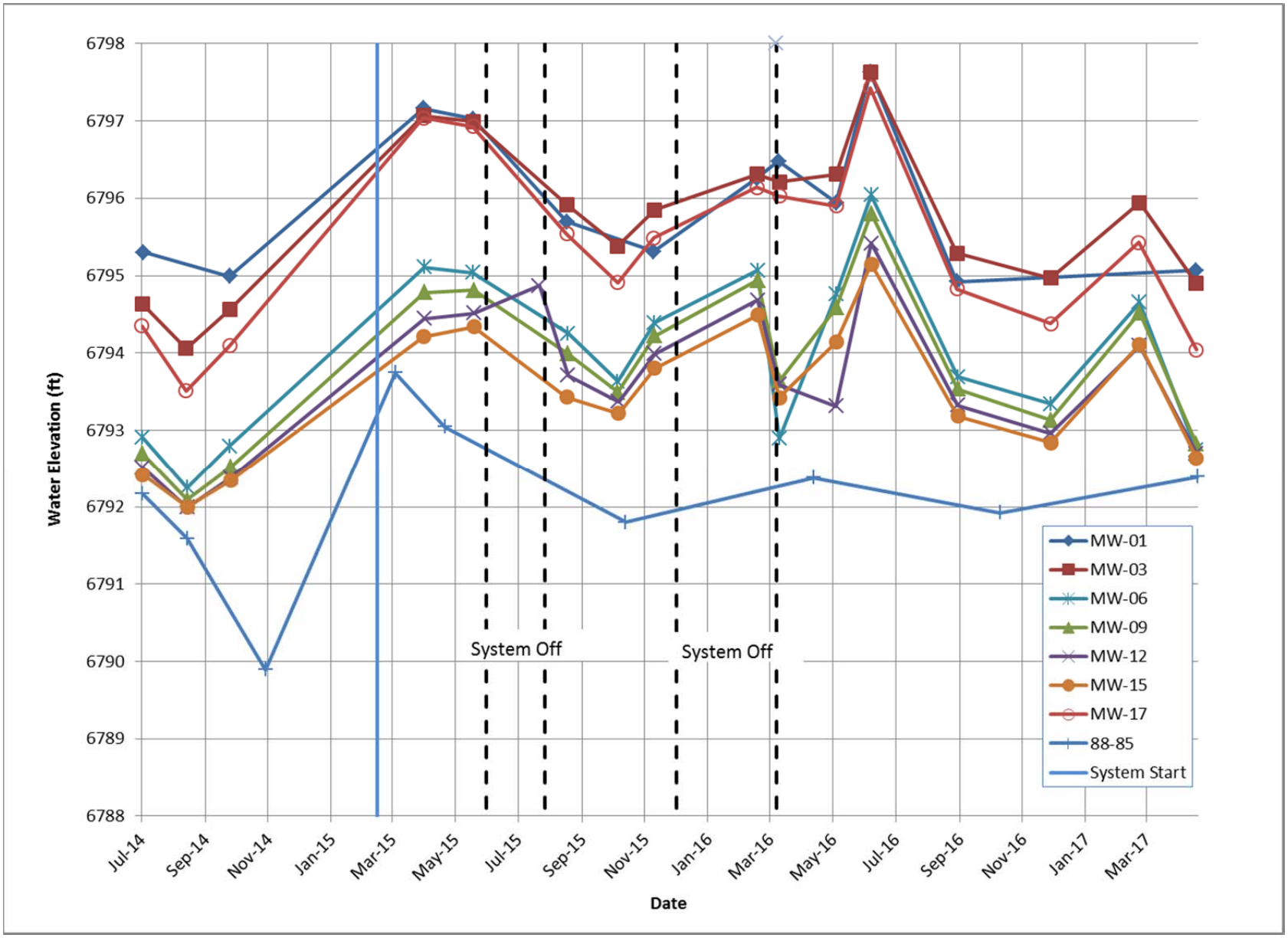


Figure 48. Water Level Hydrographs for Monitoring Wells in the North Portion of the AOA

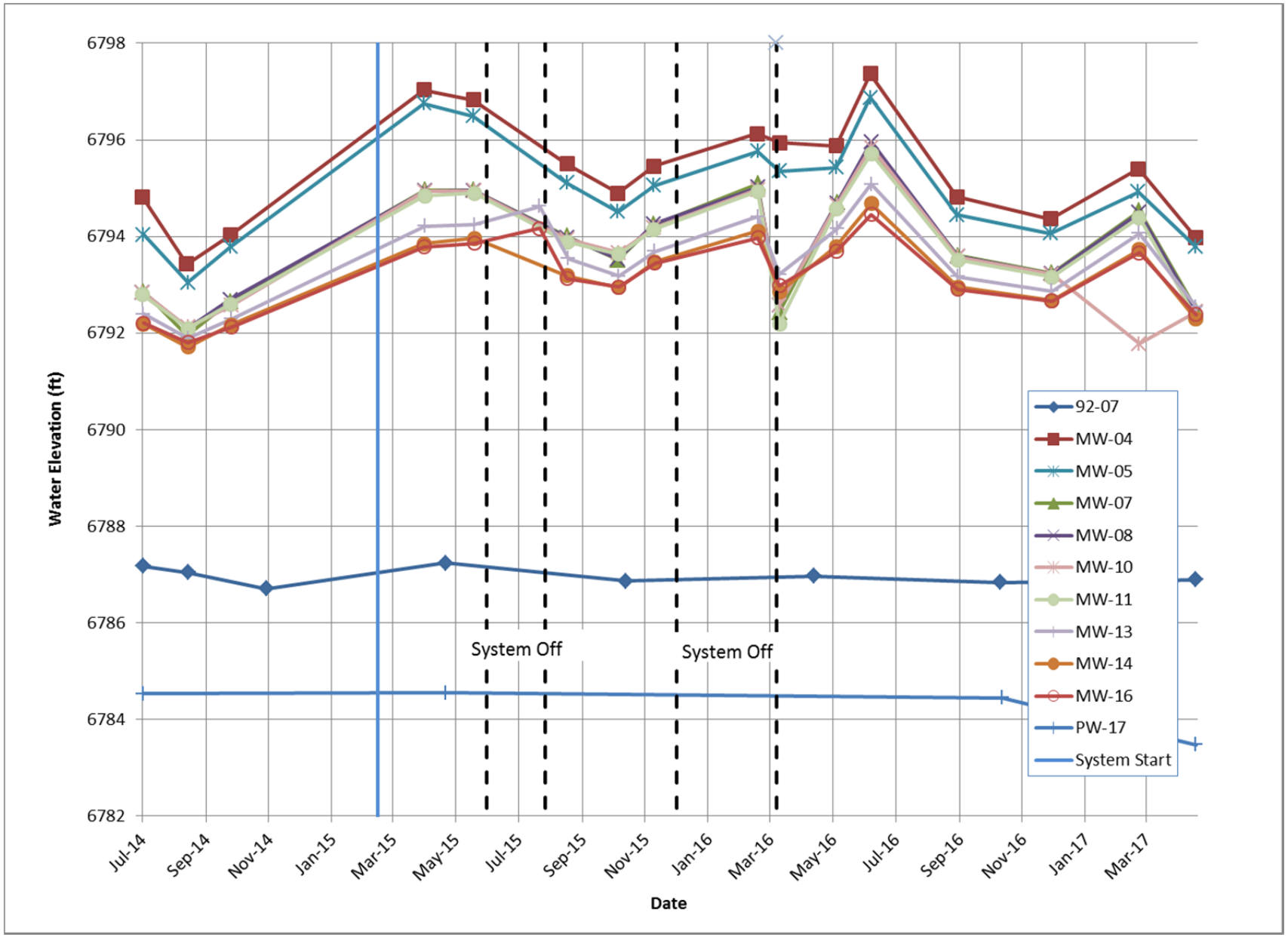


Figure 49. Water Level Hydrographs for Monitoring Wells in the South Portion of the AOA

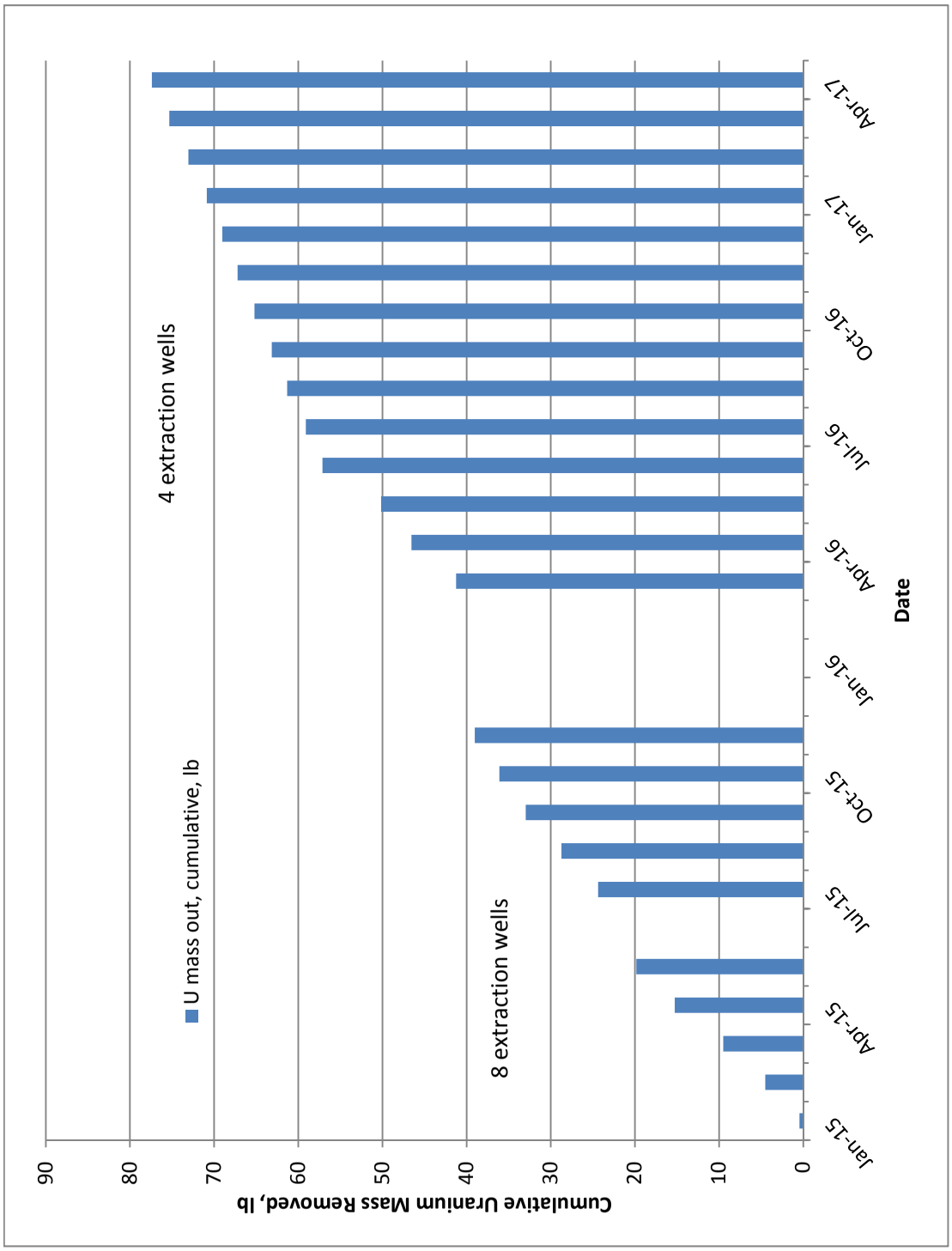


Figure 50. Cumulative Mass of Uranium Removed by the Groundwater Contingency Remedy Optimization System from the Alluvial Aquifer in the AOA

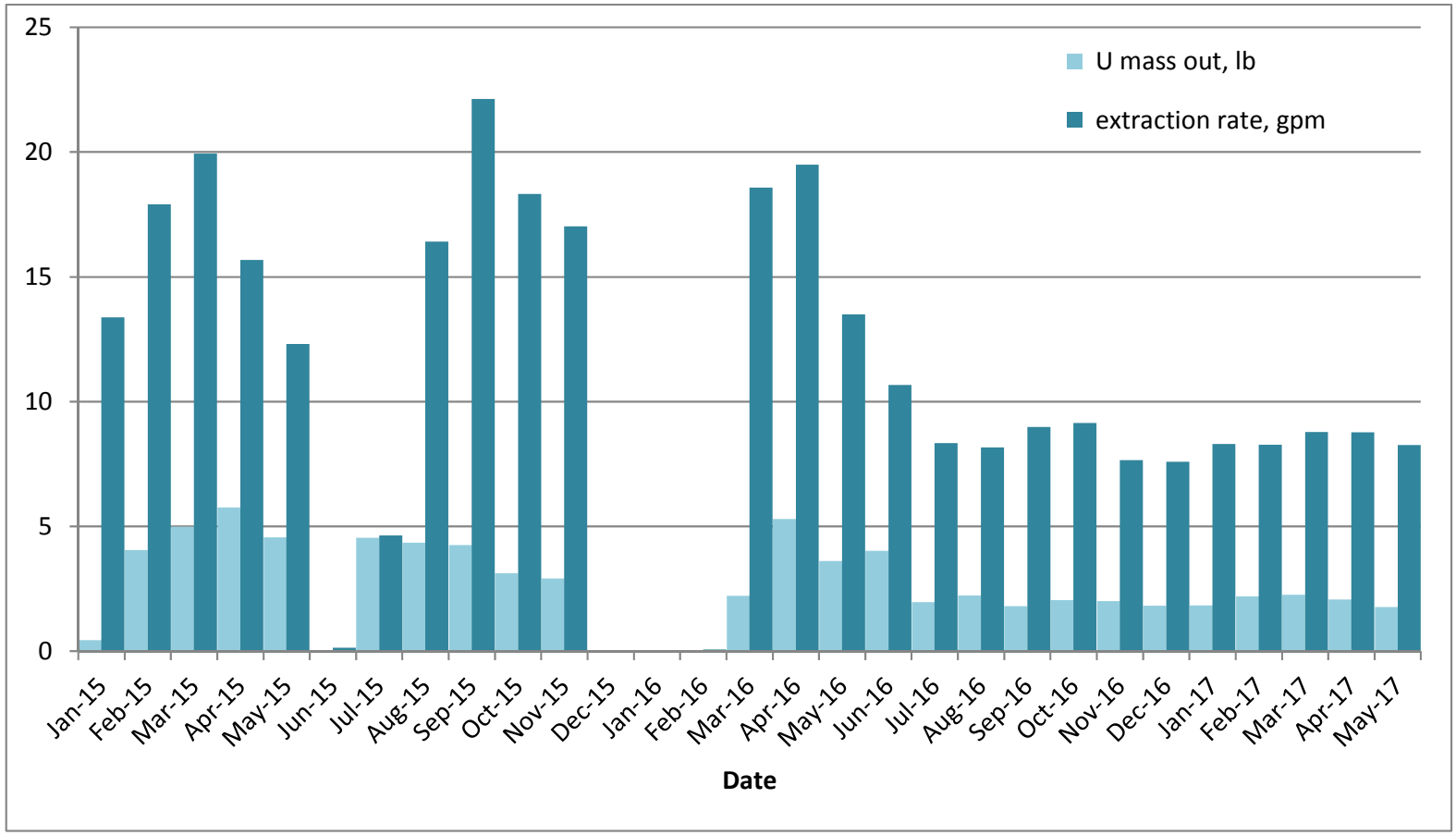


Figure 51. Monthly Groundwater Pumping and Uranium Mass Extraction Rates

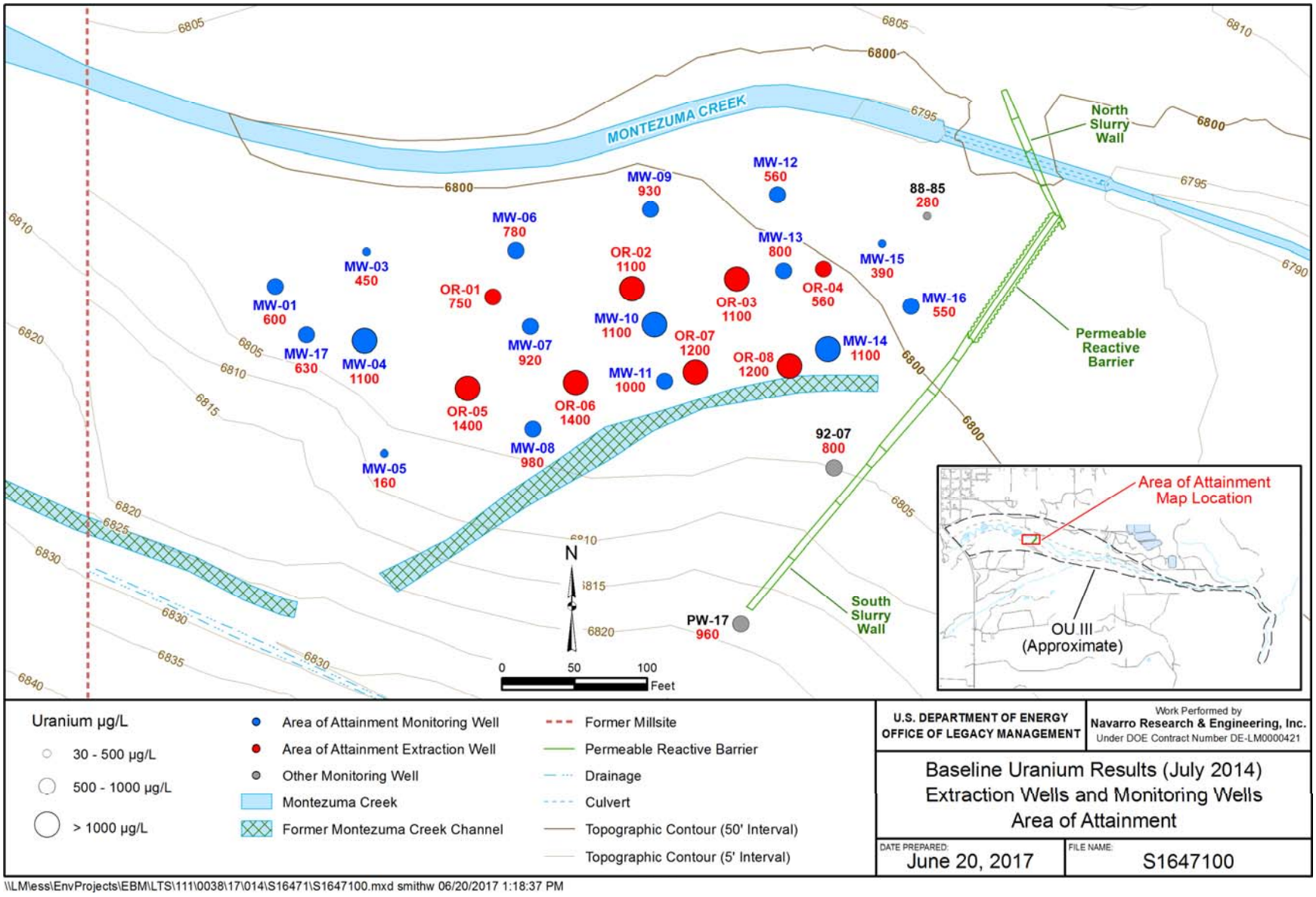


Figure 52. Uranium Concentrations in AOA Monitoring Wells and Extraction Wells in July 2014 (Baseline Condition)

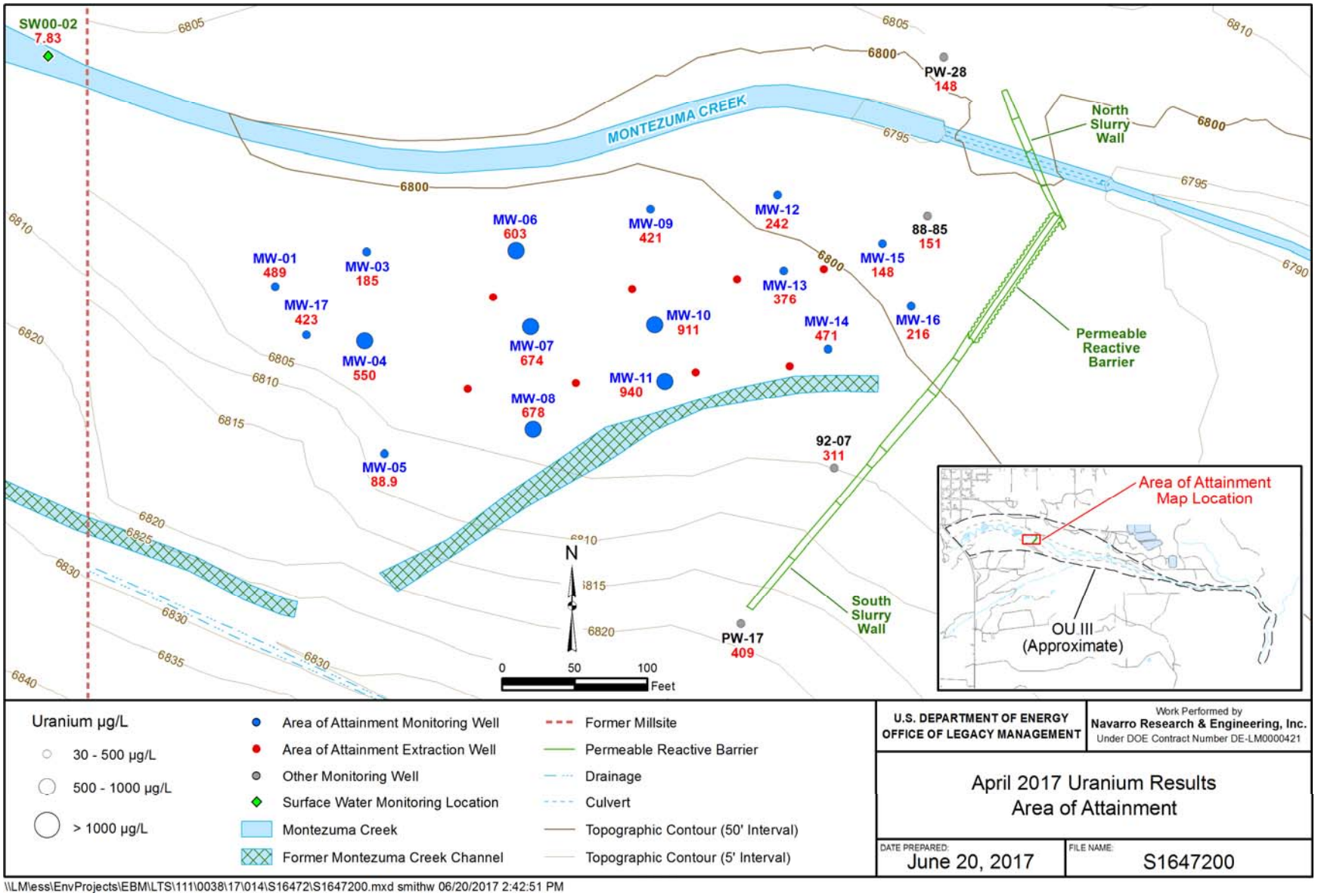


Figure 53. Uranium Concentrations in AOA in April 2017

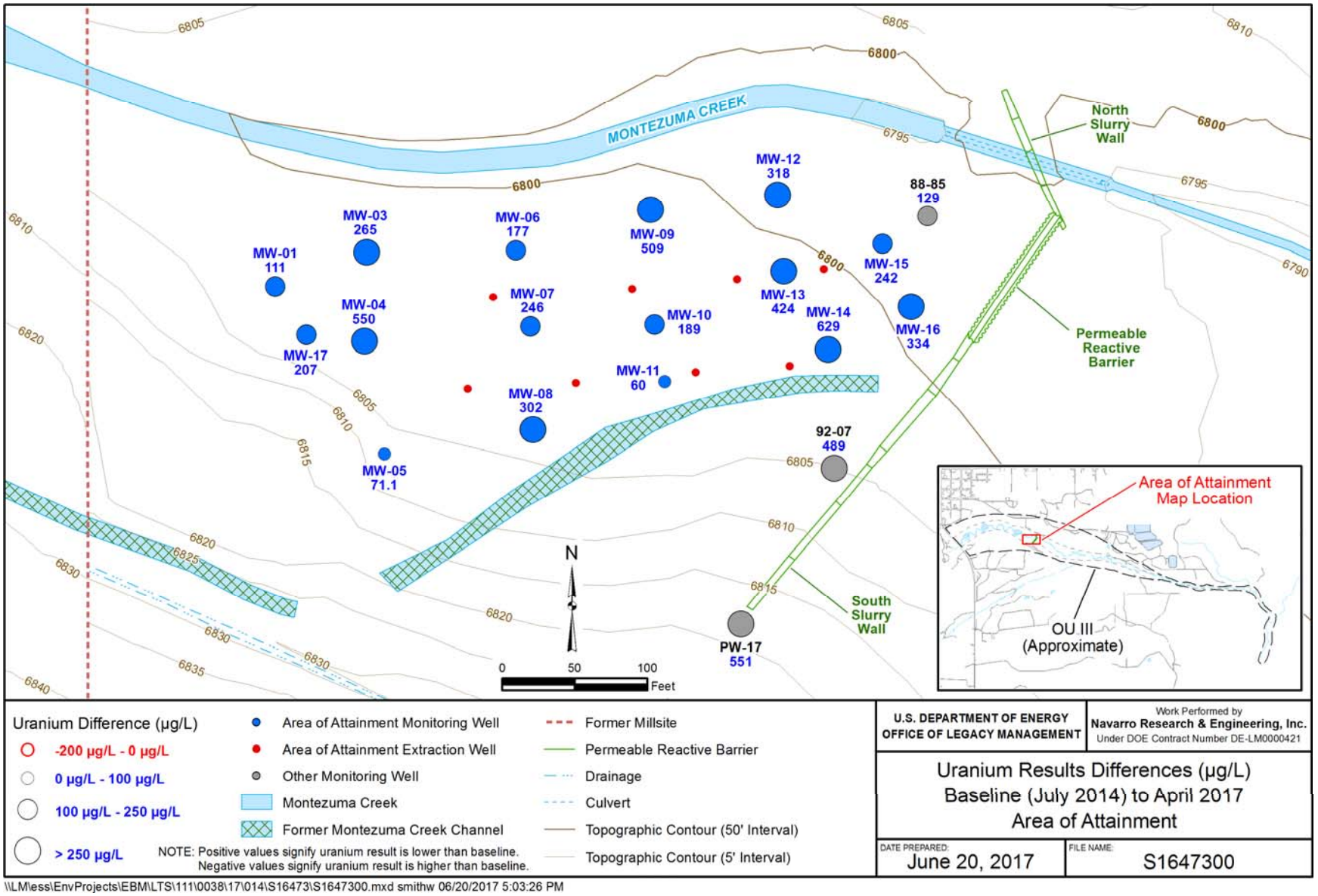


Figure 54. Uranium Concentration Difference Between Baseline in July 2014 and April 2017

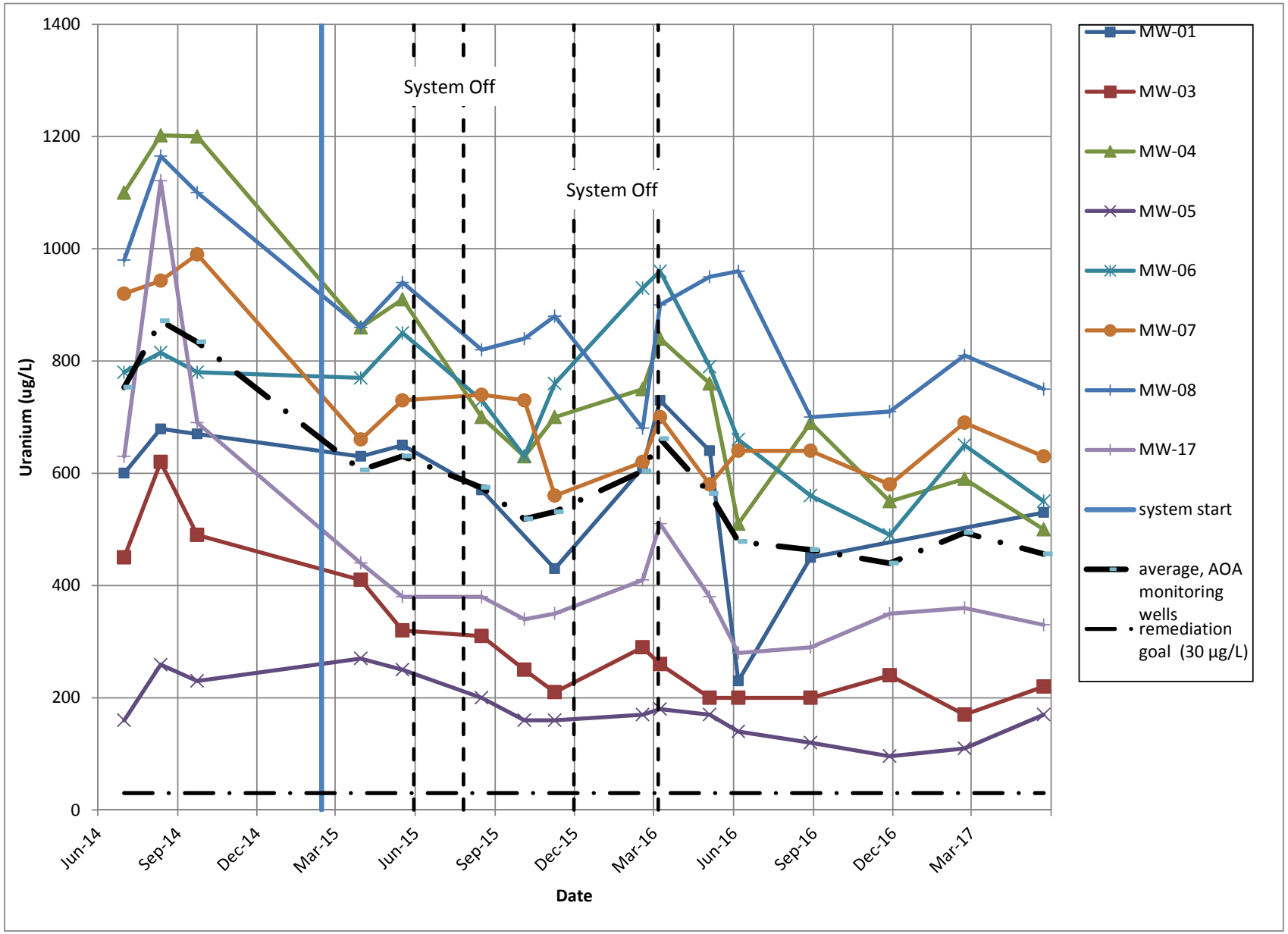


Figure 55. Time Series Uranium Concentrations in Monitoring Wells, North Half of AOA

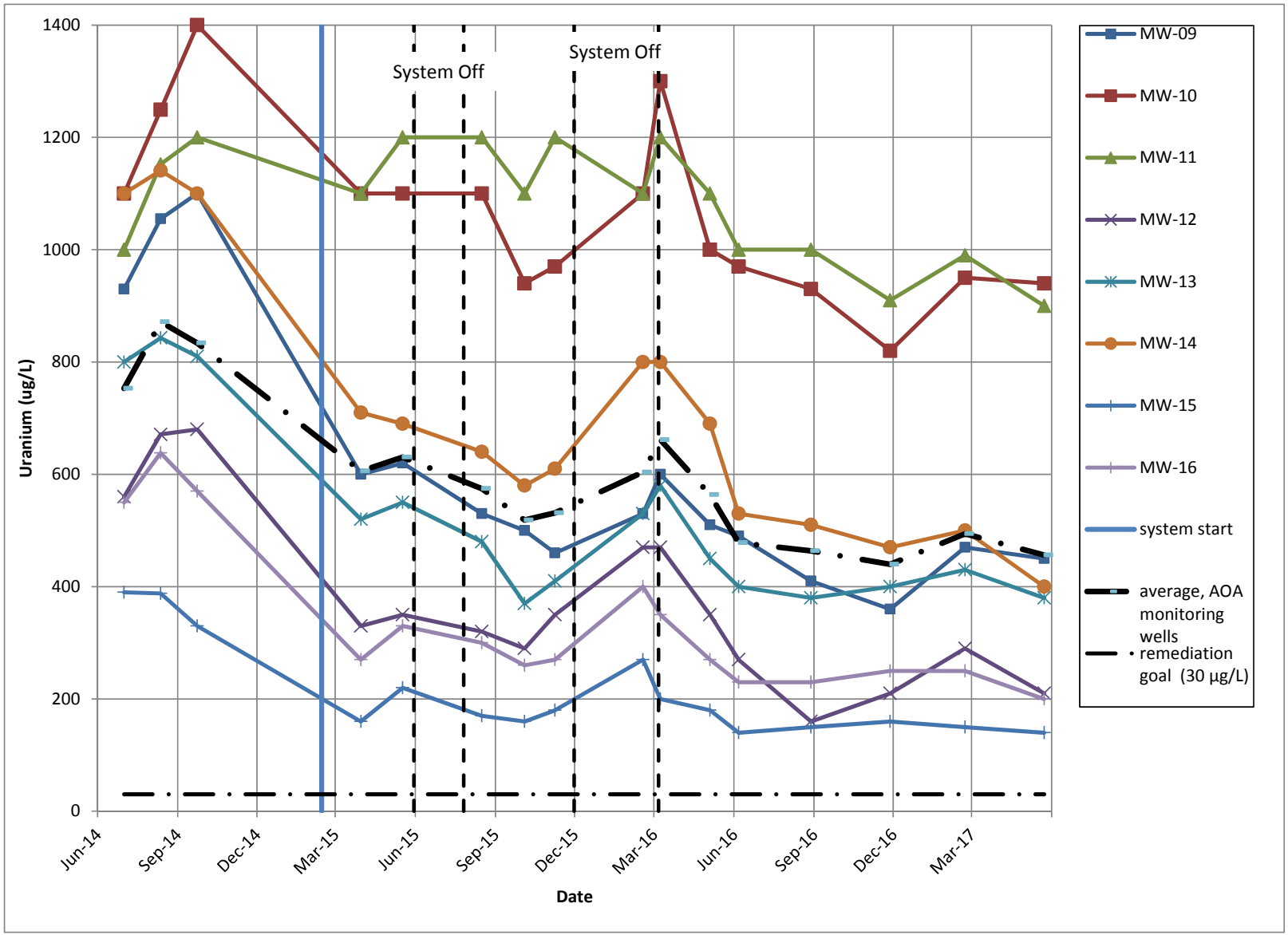


Figure 56. Time Series Uranium Concentrations in Monitoring Wells, South Half of AOA

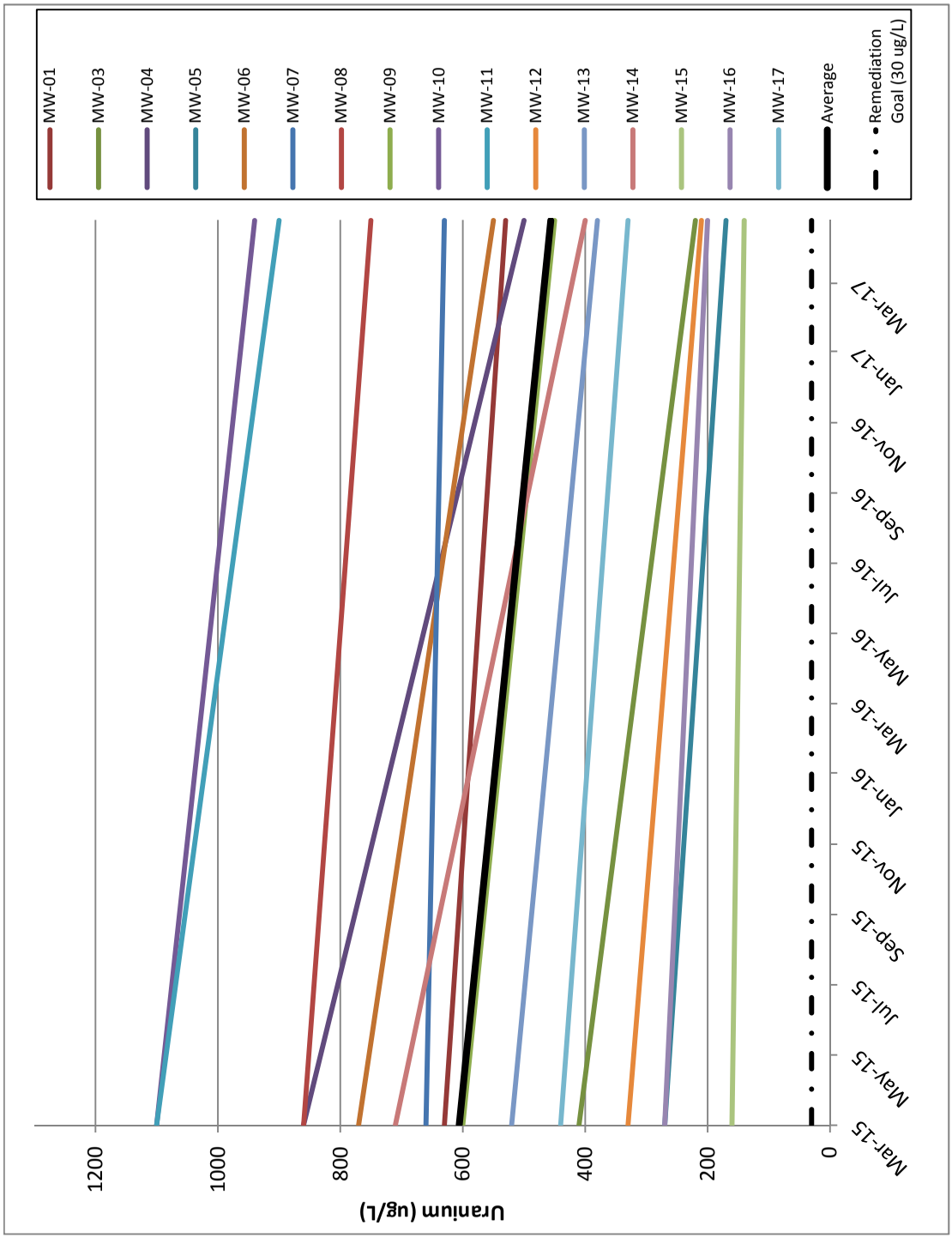


Figure 57. Slope Graphs of Uranium Concentrations in AOA Monitoring Wells: March 2015 and May 2017 Endpoints

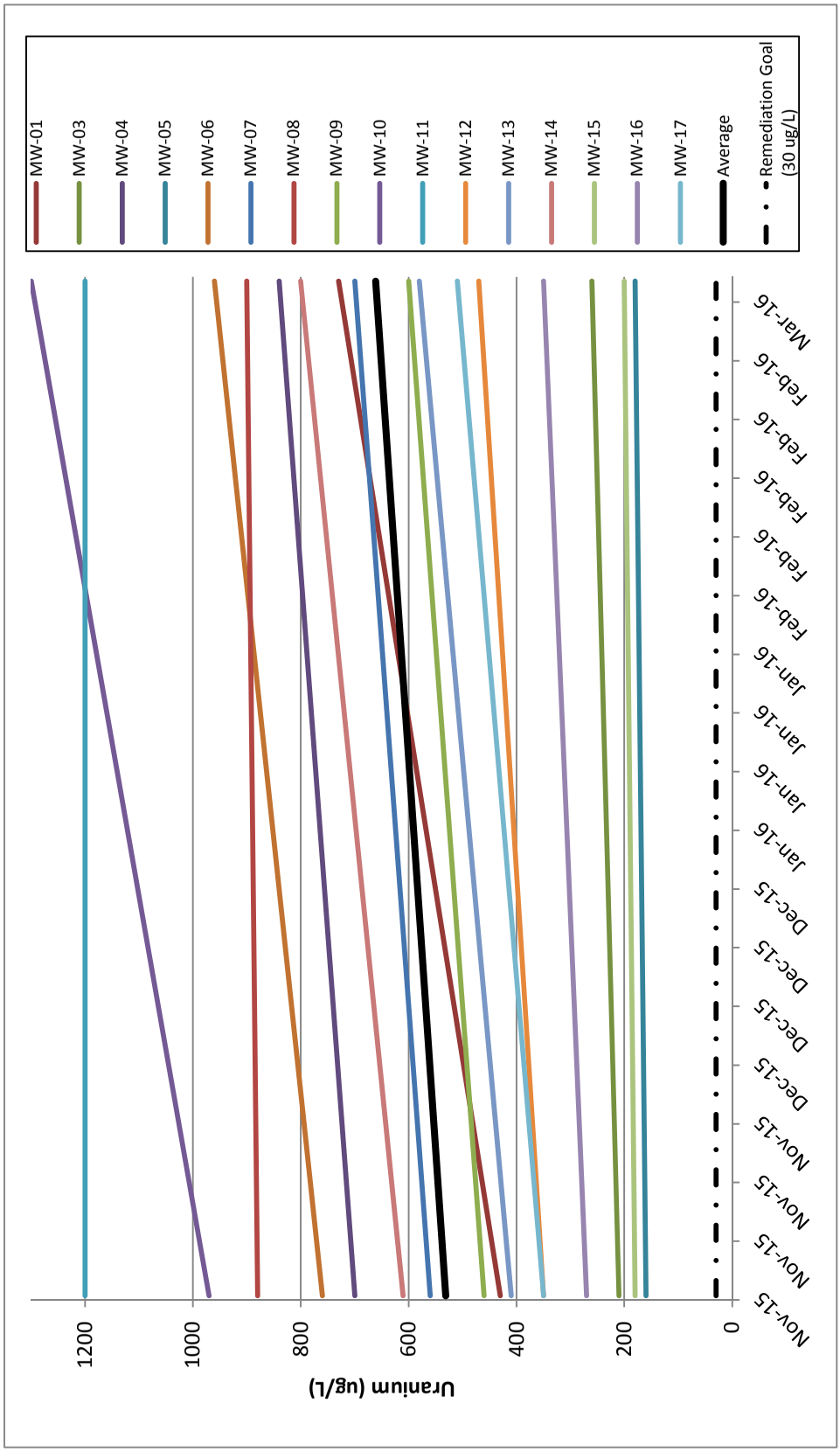


Figure 58. Slope Graphs of Uranium Concentrations in AOA Monitoring Wells: November 2015 and March 2016 Endpoints (Shutdown Period)

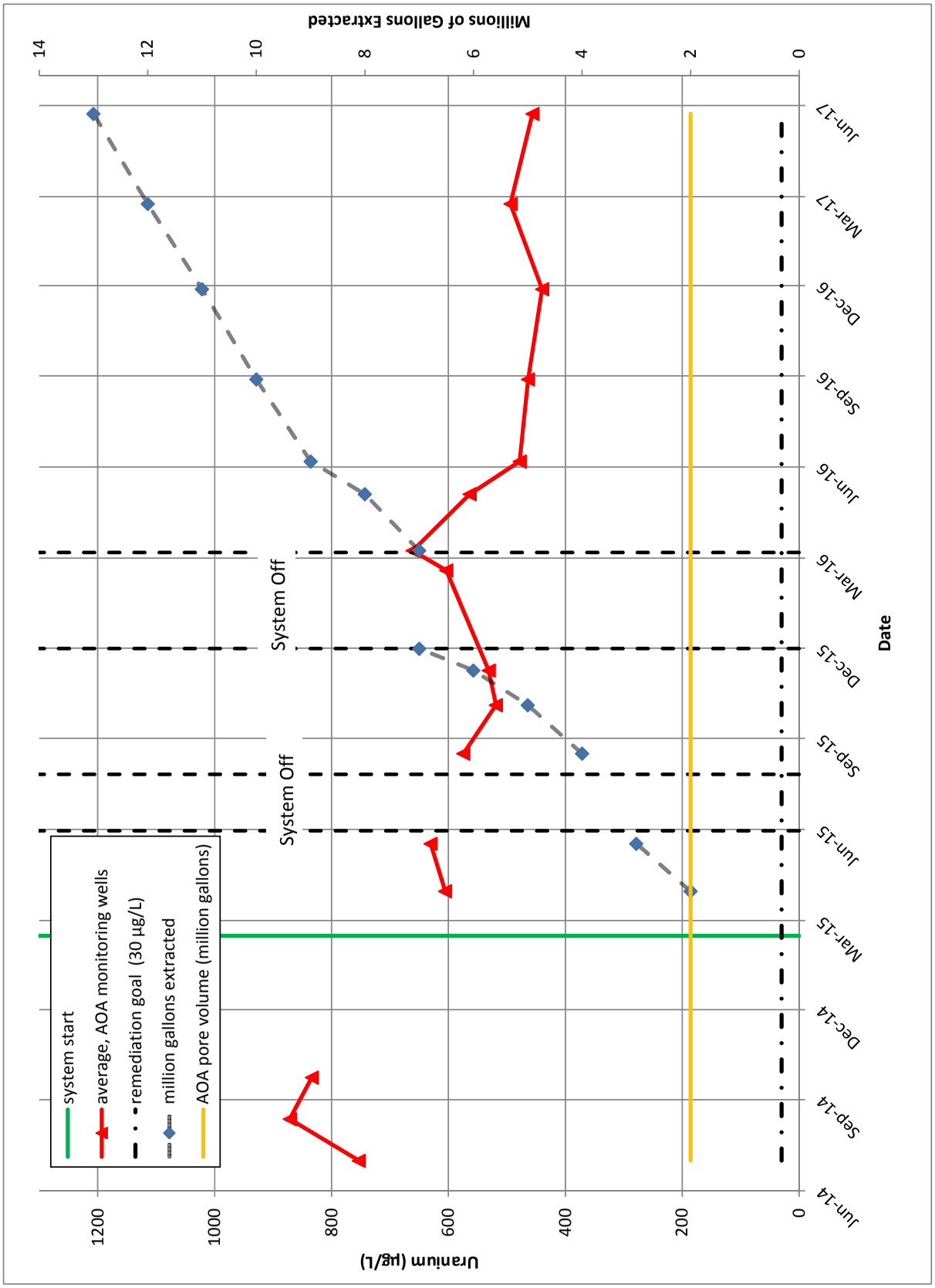


Figure 59. Graphical Summary of Uranium Restoration Progress in the AOA

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