

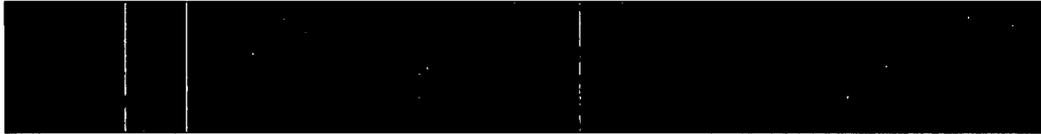
**Annual Review Report - 2009
Groundwater Corrective Action
Church Rock Site, Church Rock, New Mexico**

**United Nuclear Corporation
Gallup, New Mexico**

January 2010



"Tradition in Engineering Excellence Since 1910"



United Nuclear Corporation
Gallup, New Mexico

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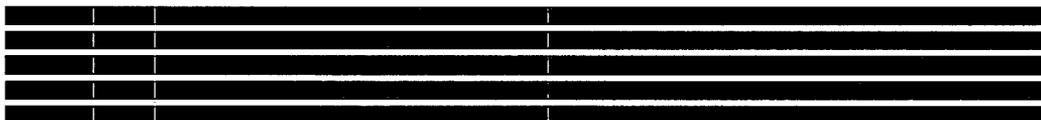


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List of Acronyms and Abbreviations

ACL	alternate concentration limit
ALARA	as low as reasonably achievable
ARARs	applicable or relevant and appropriate requirements
EPA	U.S. Environmental Protection Agency
FS	feasibility study
ft/yr	feet per year
gpm	gallons per minute
GWPS	NRC Source Materials License groundwater protection standards
IC	institutional control
MCL	federal primary maximum contaminant level
mg/L	milligrams per liter
MNA	monitored natural attenuation
NA	natural attenuation
NMED	New Mexico Environment Department
NNEPA	Navajo Nation Environmental Protection Agency
NRC	U.S. Nuclear Regulatory Commission
pCi/L	picocuries per liter
POC	point of compliance
POE	point of exposure
ROD	Record of Decision
SFS	supplemental feasibility study
SWSFS	site-wide supplemental feasibility study
SMCL	federal secondary maximum contaminant level
TDS	total dissolved solids
TTHMs	total trihalomethanes
TI	technical impracticability
UCL95	upper confidence limit on the mean at the 95% confidence level
µg/L	micrograms per liter

Section 1

Introduction

On behalf of United Nuclear Corporation (UNC), Chester Engineers has prepared this annual performance review of the groundwater corrective action at UNC's Church Rock Mill and Tailings Site near Gallup, New Mexico, pursuant to NRC Source Materials License 1475, Condition 30C. UNC has submitted an annual corrective action report at the end of each operating year since 1989. This report is the 21st in the series and includes groundwater quality analyses and groundwater elevations for the first quarter of 2009 through the fourth quarter of 2009.

This report focuses on both active remediation and the groundwater performance of the natural systems without active remediation. As indicated in the U.S. Environmental Protection Agency's (EPA's) First Five-Year Review Report (EPA, 1998) and by the approvals to decommission or temporarily shut off the three corrective action systems, the agencies recognized that those corrective action pumping systems had reached the limit of their effectiveness. EPA (1988b) recommended that Technical Impracticability (TI) Waivers, Alternate Concentration Limits (ACLs), and Monitored Natural Attenuation (MNA) be used to complete the corrective action program. Presentations and reports prepared to document the geochemical processes in the Southwest Alluvium (Earth Tech, 2000d and 2002c; Chester Engineers, 2009a) and the Zone 1 hydrostratigraphic unit (Earth Tech, 2000c; Chester Engineers, 2009a) showed that the natural geochemical mechanisms are at least as effective as the active remediation systems in controlling the migration of constituents of concern. This annual report describes how these natural processes are performing. This report updates active remediation efforts and investigations in Zone 3, including (1) the pumping of new extraction wells along the northern front of seepage impact (based on the UNC's hydrogeologic analysis and recommendations submitted to the agencies in N.A. Water Systems, 2008c); and (2) injection testing in Well NBL 2, which is located in background water to the west of the northern front of seepage impact (Chester Engineers, 2009d). 20 years of active remediation of Zone 3 by the extraction of impacted groundwater and constituent mass resumed with the Phase I hydrofracture study in 2005 and continued, with additional wells, through 2009.

UNC submitted an alternate concentration limits (ACL) application (N.A. Water Systems, 2008h) to the U.S. Nuclear Regulatory Commission (NRC). This focused ACL application proposed changing the NRC License groundwater protection standards in two point-of-compliance wells in Zone 1 within Section 2: Wells 604 (for nickel) and 614 (for total trihalomethanes [TTHMs]). This application is discussed further in this annual report in Section 4 Zone 1.

At the request of the NRC, UNC submitted to NRC a list of technical impediments (GE, 2009) to eventual Site closure at the Church Rock mill. UNC proposes that this list can serve as a framework for working with the NRC, and the other agencies, to map out the administrative and technical issues that need to be addressed for closure of Site corrective action.

EPA has directed UNC (EPA, 2006a) to provide a Site-Wide Supplemental Feasibility Study (SWSFS). Toward that objective, UNC submitted a statement of the preliminary proposed content of the SWSFS (N.A. Water Systems, 2006b) and a list of preliminary assembled remedial alternatives (N.A. Water Systems, 2006c). The latter document has been addressed by EPA comments (EPA, 2006b) developed with input from the NRC, the New Mexico Environment Department (NMED), and the Navajo Nation Environmental Protection Agency (NNEPA).

UNC and the agencies held a conference call on November 30, 2006 and agreed on the next step toward developing the SWSFS: UNC would reassess the provisional site cleanup goals (preliminary remediation goals, remedial action objectives, and Applicable or Relevant and Appropriate Requirements (ARARs)), following the original site Feasibility Study (EPA, 1988a) and the EPA Record of Decision (EPA, 1988b). The results of this work were reported to EPA during February 2007 as Part I of the SWSFS (N.A. Water Systems, 2007b). This submittal was the subject of EPA comments (EPA, 2008a) that included the requirement that UNC conduct extensive statistical analyses of the background and impacted waters. These analyses were completed and submitted in 2008 (N.A. Water Systems, 2008e; 2008f; 2008g). EPA approved these revised components of the SWSFS Part I and indicated that this first part of the SWSFS has been satisfactorily completed (EPA, 2009).

In July 2009, UNC submitted to EPA the revised Part II of the SWSFS (Chester Engineers, 2009b), which addresses the development and screening of remedial alternatives. EPA's Third Five-Year Review report (EPA, 2008b) emphasized the importance of the SWSFS for future CERCLA decision-making.

1.1 Site Location

The Church Rock Site ("Site") is located approximately 17 miles northeast of Church Rock, McKinley County, New Mexico (see Figure 1). Figure 2 is a Site map that shows the location of the decommissioned and temporarily idled extraction wells, the performance monitoring wells, the evaporation ponds, and the reclaimed tailings areas. Figure 2 also shows the Remedial Action Target Area for each hydrostratigraphic unit, where the impacts of tailings seepage were originally identified and corrective action was implemented (EPA, 1988a). Additional background information on Site facilities and activities is available in the previous annual reviews (Canonie Environmental Services Corp. [Canonie], 1989b, 1990, 1991, 1992, 1993 and 1995; Smith Technology Corporation, 1995 and 1996; Rust Environment and Infrastructure, 1997; Earth Tech, 1998, 1999, 2000e, 2002a and 2002d; USFilter, 2004a; N.A. Water Systems, 2004, 2005b, 2007a, and 2008a; and Chester Engineers, 2009a).

1.2 Corrective Action Systems

The corrective action systems for tailings seepage remediation were installed and began operating during the summer and fall of 1989. These systems have been decommissioned or, in the case of the Southwest Alluvium, temporarily shut off, and performance monitoring is

ongoing. The Zone 1 system was decommissioned in July 1999 in accordance with the letter from the NRC dated July 30, 1999 (NRC, 1999a).

Groundwater quality will be in full compliance with the NRC groundwater protection standards in Zone 1 upon NRC's approval of UNC's Zone 1 ACL application for nickel in Well 604 and TTHMs in Well 614.

The Zone 3 system was shut down in June 2000 for maintenance and repairs. Prior to the Zone 3 system being brought back on-line, the agencies agreed that the existing system should be decommissioned (NRC, December 29, 2000 License Amendment). This decision included a provision for UNC to submit a modified corrective action plan, an application for ACLs, or an alternative to the specific requirements of 10 CFR Part 40, Appendix A, if the License standards are not achievable. During 2006 UNC completed an extended pilot investigation to evaluate the suitability of hydrofracturing to enhance the extraction potential within the impacted area of this hydrostratigraphic unit (MACTEC, 2006). The hydrofracture study indicated that the new pumping configuration had achieved nearly complete capture of the northward-advancing impacted water, while causing a notable improvement in the water quality within the northern tracking wells. For these reasons, pumping in this part of Zone 3 continued during 2009 (discussed in Section 3 of this report).

Subsequent analyses indicated that the improvement of water quality in northern tracking wells was temporary and that there was a need for additional extraction wells to enhance groundwater capture. A new extraction well (RW A) was installed and started pumping on September 24, 2007. Based on UNC's hydrogeologic analysis and recommendations for the design of a new pumping system to intercept and recover impacted water (N.A. Water Systems, 2008c), five new extraction wells (the NW-series) were installed during September 2008. During February 2009, these extraction wells started pumping in the northernmost part of Zone 3. The pumping regime for these wells was re-optimized during November 2009 (Chester Engineers, 2009c). Pumping of all Zone 3 extraction wells removed almost 10 million gallons from 2005 through 2009. The pumped water is conveyed to an evaporation pond overlying part of the South Cell.

Groundwater quality in Zone 3 started to sharply degrade between May and December 2007 in several of the northern tracking wells (N.A. Water Systems, 2008b). Groundwater quality along the northern tracking wells has been oscillating between degrading and improving trends over the last seven years. Individual well water-quality trends of improvement and degradation have become collectively asynchronous since May 2007. During 2009, two of these wells (NBL 1 and PB 3) have shown highly variable groundwater quality reflecting mixing of impacted and background waters that accompanies pumping. The groundwater quality in the northern part of Zone 3 is discussed further in Section 3 of this report.

The Southwest Alluvium system was temporarily shut off in January 2001 to facilitate implementation of the Natural Attenuation (NA) test. The NA test was discussed and approved during the November 14 and 15, 2000, meeting in Santa Fe, New Mexico, and documented in the November 15, 2000, letter from the EPA. As requested by the EPA (2004a; and during meetings

in Santa Fe on February 26, 2004, and at Church Rock on May 5, 2005), UNC continues to acquire groundwater quality data from wells in the Southwest Alluvium to monitor the effectiveness of natural attenuation and compare its performance to that of previous remedial efforts.

Groundwater quality is in full compliance with the NRC groundwater protection standards in the Southwest Alluvium.

1.3 Performance Monitoring and Supplemental Sampling

1.3.1 Performance Monitoring

The groundwater performance monitoring plan is described by the Corrective Action Plan (UNC, 1989a), Remedial Design Report (Canonie, 1989a) and Remedial Action Plan (UNC, 1989b), and has been approved by the NRC and EPA. The program has been modified over time, as described in the annual reports (Canonie, 1989b, 1990, 1991, 1992, 1993 and 1995; Smith Technology, 1995 and 1996; Rust, 1997; Earth Tech, 1998, 1999, 2000e, 2002a and 2002d; USFilter, 2004a; N.A. Water Systems, 2004, 2005b, 2007a, 2008a; Chester Engineers, 2009a), to adjust the monitoring requirements as the corrective action has progressed. The NRC and EPA have approved all modifications.

In accordance with the EPA's request in 1999, UNC developed a revised monitoring program that began with the second quarter 2000 sampling event. The revised program is documented in the letters dated January 13, 2000 (Earth Tech, 2000a), and April 26, 2000 (Earth Tech, 2000b). Details of the revised monitoring program for each hydrostratigraphic unit are provided in the performance-monitoring portion of the following sections and in the appendices.

The field and laboratory data collected from the fourth quarter of 1989 through the fourth quarter of 2009 are tabulated in Appendices A (Southwest Alluvium), B (Zone 3), and C (Zone 1). These tables include the revised background standards for sulfate, nitrate, and total dissolved solids (TDS) recommended by the NRC in its report evaluating background for the Site (NRC, 1996) and supported by the New Mexico Environment Department (NMED) in its letter to the EPA dated January 6, 1998 (NMED, 1998). These revised standards are 2,125 milligrams per liter (mg/L) for sulfate, 190 mg/L for nitrate, and 4,800 mg/L for TDS. As part of the SWSFS background water statistical work, UNC has presented a comprehensive tabulation of contaminant-specific groundwater cleanup levels and other comparison values (N.A. Water Systems, 2008f, their Table 6; also provided in the SWSFS Part II, Chester Engineers, 2009b, Table 1).

Quarterly laboratory analytical data sheets for the 2009 operating year are included at the end of each appendix.

1.3.2 Supplemental Sampling

Following EPA's request on November 15, 2000 (meeting in Santa Fe), a new well was installed in the downgradient part of the Southwest Alluvium during 2004. This well (SBL 1) is not a formal requirement of the performance monitoring program; nonetheless, it is monitored, and the results are reported here.

Though not a formal requirement of the performance monitoring program, monthly measurements of select field parameters (pH, conductivity, chloride, and alkalinity (also called bicarbonate)) continued during 2009 in the tracking wells near the northern edge of the seepage-impact front in Zone 3. A new tracking well (NBL 2) was installed during August 2007. Starting in January 2008, monthly field parameter measurements have been made in Wells RW A and NBL 2, in addition to NBL 1, PB 2, PB 3, and PB 4; Well 504 B was dropped from this tracking program because the groundwater quality there has remained highly impacted for many years (see Table 11). Starting in June 2009, monthly field parameters have been measured in all five of the NW-series wells.

Though not a formal part of the performance monitoring program, in order to improve our understanding of the groundwater quality along the northern front of the impacted water in Zone 3, the following wells were sampled in 2009 for the full laboratory chemical parameter list: RW A, RW 11 (October only), NBL 1, NBL 2, PB 2, and PB 3. The planned October 2009 sample (for full laboratory analysis) from Well PB 4 could not be obtained. To serve as a check on the results of the monthly field parameter measurements, the following wells in the northern part of Zone 3 were sampled for laboratory analysis of bicarbonate, chloride, pH, and total dissolved solids (TDS): RW A, NBL 2, PB 2, and PB 3.

1.4 Southwest Alluvium

Active remediation of the Southwest Alluvium was suspended when the former extraction wells ceased being pumped in January 2001; those wells have remained idle while natural attenuation continues to be monitored. The NA test involved temporarily shutting off the pump-back wells and monitoring the water quality and water levels on a monthly basis. The results were presented in a "final" report submitted in November 2002 (Earth Tech, 2002c). The effectiveness of NA in the Southwest Alluvium was discussed by N.A. Water Systems in the 2004, 2005, 2006, and 2007 annual reports; in the 2008 annual report (Chester Engineers, 2009a); and in a presentation (2005a) at the annual, multi-agency meeting that was held at UNC's offices at Church Rock on May 5, 2005. This annual report presents a continuing assessment of the effectiveness of natural attenuation in the Southwest Alluvium.

1.5 Report Organization

This report presents each hydrostratigraphic unit in a separate section:

Section 2	Southwest Alluvium
Section 3	Zone 3

- Section 4 Zone 1
- Section 5 Conclusions and Recommendations
- Section 6 References

The monitoring data are contained in separate appendices for each hydrostratigraphic unit:

- Appendix A Southwest Alluvium Monitoring Data
- Appendix B Zone 3 Monitoring Data
- Appendix C Zone 1 Monitoring Data

The appendices to this report, unlike the report body, are printed and paginated double-sided.

Section 2

Southwest Alluvium

2.1 Corrective Action Summary

The Southwest Alluvium corrective action pumping system remained idle in 2009. Attenuation via natural geochemical processes has been shown to be at least as effective as pumping. No hazardous constituents exceed Site standards outside the UNC property boundary.

2.2 Mass of Chemical Constituents Removed

The mass of chemical constituents removed was calculated for the 12-year period from November 1989 through January 2001. These calculations were presented in the previous annual reviews, and the final summary was presented in the 2001 Annual Review (Earth Tech, 2002a).

2.3 Performance Monitoring Evaluation

The current performance monitoring program in the Southwest Alluvium is summarized in Table 1 and comprises quarterly monitoring of water levels in 16 wells and water quality in 14 wells. The monitoring well locations are shown on Figure 2 and Figure A-1 (Appendix A). A summary of constituents detected in the Southwest Alluvium in October 2009 is provided in Table 2, which shows that none of the Point of Compliance (POC) wells in the Southwest Alluvium had any exceedances of hazardous constituents. Historic groundwater quality and groundwater elevation data through October 2009 are provided in Appendix A (Table A.1).

2.3.1 Water Level Evaluation

Groundwater in the Southwest Alluvium in the vicinity of the tailings impoundments was created by the infiltration of pumped mine water that was discharged to the Pipeline Arroyo. This water percolated into the alluvium and created temporary saturation in the vicinity of the tailings impoundments. This temporary saturation caused by discharged mine water is the recognized Southwest Alluvium background water (EPA, 1988a; 1988b; 1998; 2008b). The level of saturation has been declining since the mine water discharge ceased in 1986. As a result, the flanks of the alluvial valley and the northern property boundary alluvium have completely desaturated and, by 2000, a 31 percent saturation loss had been observed further to the south (Earth Tech, 2000d). The October 2009 saturated thickness for each well in the performance monitoring program is provided in Table 3. During 2009, all wells have shown overall decreasing groundwater elevations (with small fluctuations), indicating that the groundwater flux continues to decline with the shrinking of the zone of saturation. The saturation measured in these wells has collectively declined by an average of 21 percent since 1989.

The Southwest Alluvium potentiometric surface map for October 2009 is shown in Figure 3A. This figure shows a local, eastward turn to the saturated alluvium, beneath the northwestern part of the South Cell, reflecting the presence of a relatively high area (bulge) in the bedrock surface between Wells 509 D and EPA 23. This bulge encompasses the area including the “Nickpoint”

along Pipeline Arroyo. The Nickpoint (Figure 3A) has been referred to in earlier reports. It is a local rim-like bedrock high along the arroyo, below which the streamway becomes incised and continues downgradient as Pipeline Canyon.

Figure 3B shows a contour map of saturated thickness in the Southwest Alluvium in October 2009. This map was developed by integrating the potentiometric surface with a structure contour map of the base of the alluvium (and thus does not involve directly contouring the posted values of saturated thickness). The distribution of the groundwater suggests the possibility that the northern portion of the groundwater system, upgradient of the Nickpoint and including Well 509 D, may have become “detached” or ponded (i.e., lost hydraulic continuity) from the groundwater to the south. Such detachment may occur along the local high in the top of bedrock that causes the saturated alluvium to jog to the east in the area of the Nickpoint (Figure 3B). The underlying data density is not sufficient to allow certainty on this issue. However, it is likely that this will eventually happen both to the north of the Nickpoint and in a large depression, along the top of bedrock, that is west of the South Cell and below the Nickpoint.

Figure 4 shows water levels over time in Southwest Alluvium wells, illustrating the overall long-term trend of decreasing levels as water continues to drain from the Southwest Alluvium. Note that in 2007, the water level in EPA 23 (below the Nickpoint) became higher than the level in 509 D (above the Nickpoint). The slope (rate) of decline above the Nickpoint (509 D) is greater than the rate of decline below the Nickpoint (EPA 23). These observations mean that alluvium groundwater above the Nickpoint no longer flows to the south.

Water levels in the vicinity of the pumping wells increased temporarily after they were turned off in January 2001 for the start of the NA test (see Figure 5). Water levels in the former pumping wells have since stabilized at elevations similar to those measured in nearby monitoring wells. These stable to declining water levels indicate that the hydraulic system has fully recovered from the effects of pumping (recovery was complete during approximately April to June 2002). A summary of operational data for the Southwest Alluvium extraction wells is provided in Table 4.

Southwest Alluvium groundwater flows to the southwest, along the Pipeline Arroyo. Based on calculations of the volume of background groundwater drainage through the valley in comparison to historic pumping rates, the drainage had exceeded the total pumping volume throughout the corrective action period by 30 percent or more (Earth Tech, 2000d). Groundwater pumping did not fully contain seepage-impacted water; however, it is important to realize that hydraulic containment is not a necessary feature of the corrective action program in the Southwest Alluvium because of the strong geochemical attenuation that occurs naturally. The SWSFS Part II has summarized the remedial alternatives appropriate to the Southwest Alluvium (Chester Engineers, 2009b, Table 4 and Figure 4).

2.3.2 *Water Quality Evaluation and Current Extent of Seepage-Impacted Water*

As discussed below, no hazardous constituents exceed Site standards outside the UNC property boundary within seepage-impacted water. Most constituents show time-series variations that have become “routine” in the context of 20 years of groundwater quality monitoring. Former

pumping did not improve the groundwater quality, nor would future pumping do so. During October 2009, no hazardous constituents exceeded Site standards within the UNC property boundary.

The area currently containing seepage-impacted groundwater in the Southwest Alluvium is shown on Figure 6. As explained more fully below, common ion geochemistry in the delineated area has been changed by the neutralization of tailings fluids migrating through the alluvium. The area of seepage impact extends southwest along the western margins of the North, Central, and South Cells, and continues approximately 1,400 ft across the southeastern corner of adjacent Section 3 and approximately 390 ft into the north-central portion of adjacent Section 10. The total length of the area is approximately 6,030 ft.

Historically, only two constituents, sulfate and TDS, exceed the Site standards in the Southwest Alluvium seepage-impacted groundwater outside the UNC property boundary in Sections 3 and 10. Sulfate and TDS, which are non-hazardous constituents, also exceed groundwater quality standards in the background water (Wells 627, EPA 28 and SBL 1). The majority of TDS is composed of sulfate; therefore, TDS concentrations mimic sulfate concentrations (Earth Tech, 2000d).

Historic sulfate concentrations through October 2009 are shown graphically in Figure 7. This figure shows that the long-term concentrations in most wells have remained approximately steady with the following exceptions: (1) the concentrations in Wells 801 and 509 D decreased in January 2000 and October 1999, respectively, and have since remained at these relatively lower levels; and (2) the concentrations in Wells GW 1 and GW 2 have shown overall increasing trends since the shutoff of pumping. The 20 light-gray data points in the upper right part of this chart represent the sulfate measurements from Well SBL 1 (post-mining/pre-tailings; i.e., background water quality). In October 2009, this well had the highest sulfate concentration (5,960 mg/L) of any well in the Southwest Alluvium (including all historic measurements of impacted wells), including the nearest, hydraulically upgradient Well 624 which is impacted by seepage and had a sulfate level in October 2009 of 1,960 mg/L.

Sulfate concentration increases in Wells GW 1 and GW 2 do not necessarily reflect the influence of the shutoff of pumps in January 2001. For example, the post-shutoff trend in GW 2 was approximately stable to October 2004 (2,570 mg/L), after which the increasing trend started (the concentration was 4,720 mg/L in October 2009). Increasing levels of common dissolved ions means that either (1) the diminishing saturation is being accompanied by increasing dissolved ion concentrations (consistent with the hypothesis developed by NRC, 1996), and/or (2) more of the alluvium minerals are being dissolved (also discussed by NRC, 1996). As shown by UNC's MINTEQ studies, the alluvium groundwater is generally saturated with respect to calcite, gypsum, and other soluble mineral salts.

Locally increasing trends in concentrations of common dissolved ions are unrelated to tailings seepage; they derive from the reaction of the anthropogenic recharge water with natural alluvium materials. Heterogeneous distribution of the soluble alluvium minerals is very likely to

be a significant factor affecting the intra-well variations in concentrations of common dissolved ions.

Figure 8 is a bicarbonate isoconcentration map of the Southwest Alluvium during October 2009. As explained in earlier annual reports and in the first natural attenuation evaluation (Earth Tech, 2002c), bicarbonate concentration is the main attribute by which the presence and extent of seepage-impacts can be evaluated. The seepage-impacted area has near-neutral pH values as a result of the high capacity of the alluvium to neutralize the acidic tailings seepage. The neutralization capacity has also prevented the migration of metals from the former tailings impoundments. The neutralization capacity is strongly tied to relatively large amounts of calcite (CaCO_3) in the alluvium that is available for buffering: Canonie (1987, Table 4.4) reported measured alluvium CaCO_3 fractions of 2.58 percent in a sample collected during drilling of Well EPA 23; 0.77 to 0.28 percent near the Pipeline Arroyo Nickpoint; and 0.02 to 12.6 percent elsewhere.

The bicarbonate isoconcentration contours shown in Figure 8 illustrate the zone of seepage impact with fine resolution. Prior to the 2004 annual report, the seepage impact zone was based on assumptions of seepage migration rates and delineated by a line encompassing estimated bicarbonate concentrations exceeding 1000 mg/L. It has since been recognized that there is a core of more significant impact (bicarbonate concentrations exceeding 2000 mg/L) surrounded by progressively less impacted groundwater (approximated by the 1000 mg/L contour).

The groundwater quality characteristics of the non-seepage-impacted water samples from Well SBL 1 differ in several important aspects from seepage-impacted water (refer to Figure 9 and Appendix A). Well 624 is the closest seepage-impacted well (500 ft) upgradient from Well SBL 1 (Figure 3A). Although the following observations compare these two wells in particular, they apply equally well to most, if not all, of the seepage-impacted wells:

- Well SBL 1 contains a magnesium-sulfate (Mg-SO_4) type water while Well 624 contains a calcium-sulfate (Ca-SO_4) type. The presence of much higher magnesium concentrations in SBL 1 is suggestive of the dissolution of magnesium-salts in the alluvium (for example, epsomite or magnesite) during the earlier flushes of mine discharge water down Pipeline Arroyo.
- The alkalinity (bicarbonate or HCO_3) of Well SBL 1 water is much less than the seepage-impacted water in Well 624 samples. As acidic tailings liquids seeped into the alluvium beneath the tailings impoundments, the acid was neutralized by dissolution of carbonate minerals. The reaction between the acidic water and carbonate-bearing minerals released bicarbonate in relatively high concentrations. Chloride concentrations in Well SBL 1 are also lower than those indicative of seepage-impacted groundwater (see Appendix A and the discussion below in Section 2.3.4).
- Geochemical speciation calculations using EPA's MINTEQ numeric modeling code confirm that several aluminum-hydroxide (Al-OH) salts are oversaturated in Well SBL 1 water while they are not in Well 624 water. Similar to the explanation given above for

the high magnesium concentrations, it is inferred that the water further downgradient than the seepage-impacted water may show signs of the dissolution of soluble salts associated with earlier flushes of the alluvium.

- Well SBL 1 water and seepage-impacted water are alike in that both appear to be in approximate equilibrium with an assemblage of Ca-SO₄ (as anhydrite or gypsum), magnesium-carbonate (Mg-CO₃, as magnesite or dolomite), and calcium-carbonate (CaCO₃, as calcite). MINTEQ simulations show that when acidic water (i.e., tailings liquid) is exposed to these mineral phases, there is a geochemical shift toward higher bicarbonate concentrations and lower sulfate concentrations (e.g., Well 624) than would occur in the absence of the acid (e.g., Well SBL 1). This type of re-equilibration is exactly the type of shift in water chemistry that is observed in seepage-impacted water compared to water that lies outside the zone of seepage impact. It is a natural consequence of the law of mass action whereby the releases of calcium and bicarbonate, in reaction to acidic tailings fluids, were accompanied by the precipitation of additional gypsum as the system tended to maintain constant calcium concentrations. The result is a tendency to increase bicarbonate, decrease sulfate, and maintain constant calcium concentrations as the seepage-impact front migrates. By the Phase Rule, the presence of two calcium-bearing phases forces the system to try to maintain constant aqueous calcium concentrations.

An interesting consequence of the migration of the seepage front should be that the ratio of sulfate to bicarbonate is at a minimum where the tailings seepage front meets and reacts with non-impacted areas in the alluvium. Sulfate concentrations are greater within the core of the seepage-impacted areas because sulfate concentrations in the tailings liquids were up to two orders-of-magnitude greater than the amount that remains in the seepage-impacted water. A significant amount of gypsum had to precipitate in proximity to the concentrated tailings liquids to cause the reduction of sulfate concentrations to levels that are in equilibrium with gypsum. Out in front of the seepage-impacted water, the dissolution of the alluvium gypsum (or anhydrite) produced sulfate in the background water at levels above the standard. The general areas where sulfate concentrations are lower than the Site standard of 2,125 mg/L are shown in Figure 8 with stippled pattern, and they confirm the expectation that sulfate concentrations should be lowest along the periphery of the tailings seepage front.

Figure 8 shows that the area comprising sulfate below the standard is relatively small and mostly confined to the area of impacted groundwater. Consequently, sulfate is expected to exceed the standard over an openly large area of background water, as well as within the core zone of seepage impact. The area depicting sulfate concentrations less than 2,125 mg/L in Figure 8 is elongated parallel to the bicarbonate isoconcentration contours. This area represents a migrating reaction zone separating two areas of relatively elevated sulfate: one due to seepage impact in the transport “wake” of the reaction zone, and the other downgradient (or side-gradient) in background water (post-mining/pre-tailings) that the reaction zone has not reached. The area of seepage-impact is very small in comparison to the area of background sulfate levels above the

standard; the latter condition is likely to persist downgradient within the alluvium for miles. This large area of background sulfate exceedances has an origin unrelated to the tailings impoundments and seepage impacts.

These same conceptual geochemical models, for both the earlier evolution of the background water chemistry and the later, progressive evolution of seepage-impacted water chemistry, can be constructively applied to consideration of the groundwater chemistry data shown in Figure 9. Figure 9 shows the primary components of TDS in the Southwest Alluvium in October 2009. The chart arrangement of the wells runs approximately from those located upgradient, on the left of the chart, to those downgradient on the right. Three background wells (627, EPA 28 and SBL 1) show relatively elevated sulfate combined with high ratios of sulfate to bicarbonate. Former background Well EPA 25 shows a relatively lower ratio of these two parameters in conjunction with relatively elevated calcium. The long-term geochemistry there (Appendix A) suggests that full seepage impact waters have been nearby, consistent with its hydraulically side-gradient location with respect to the bicarbonate isoconcentration map in Figure 8. Figure 9 shows the highest contribution of sulfate to the TDS is in Well SBL 1 (this also had the historically highest sulfate concentration of any Southwest Alluvium well), which also shows the lowest contribution from bicarbonate (HCO_3) and a very low contribution from chloride ("Cl" on the figure) and calcium (Ca). These observations and analysis confirm that the current extent of seepage-impacted water has not reached Well SBL 1.

The quality of both the seepage-impacted water and non-seepage-impacted water do not meet New Mexico water quality standards for TDS. There is a shift in the composition of the dissolved solids in each case, with magnesium and sulfate in higher concentrations in the non-seepage-impacted water and calcium and bicarbonate being higher in seepage-impacted water (Figure 9). There is no situation that can be envisioned in which the quality of alluvium background groundwater can be degraded by the migration of seepage-impacted water. In some respects, particularly regarding sulfate concentrations, the seepage-impacted water may be viewed as an improvement. Groundwater quality within the Southwest Alluvium is further discussed in Section 2.3.4.

Two other constituents are present at concentrations that historically have exceeded the Site standards primarily within the property boundary:

- Chloride – Chloride is a non-hazardous constituent. Chloride concentrations exceed the Site standard (250 mg/L) at Well 509 D. This well has exhibited an overall stable trend since 1996 with fluctuations ranging from 278 to 411 mg/L (see Figure 10). The chloride concentration at Well 632 has fluctuated about the standard with no discernible trend since 1990, and continued to do so during 2009 (Appendix A). Chloride has also fluctuated about the standard in Well GW 1 since January 2004 (Figure 10). Chloride concentrations are discussed more in Section 2.3.4.
- Chloroform – In August 2006 the NRC modified the Site License to change the former chloroform standard of 1 $\mu\text{g/L}$ to a total trihalomethanes (TTHMs) standard of 80 $\mu\text{g/L}$

(NRC, 2006b). Starting with the October 2006 sampling event, the laboratory has analyzed for TTHMs – all four component compounds (of which chloroform is one) are measured, and all Site groundwater samples (including the Southwest Alluvium) show that the TTHMs concentration equals the chloroform concentration (i.e., chloroform is the only TTHM compound present). In occasional discussion of “chloroform concentrations” in this report, the reader should bear in mind that the Site standard (and laboratory analysis) of relevance is now for TTHMs and not solely for chloroform as was previously the case. Table 2 shows that during October 2009 Southwest Alluvium TTHMs were detected at levels far below the Site standard of 80 µg/L in the following wells: 632, 801, 802, 803, 808, GW 1 and GW 2.

Well SBL 1 is located in front of the seepage-impacted water within background water (non-impacted water of post-mining/pre-tailings origin). Prior to the installation of Well SBL 1 and its first groundwater quality analysis in October 2004, the only historic exceedances of manganese (>2.6 mg/L) were within the Site boundary. Well SBL 1 has had multiple manganese exceedances and was above the Site standard at 3.15 mg/L in October 2009 (Table 2). Manganese exceedances (see Table 2 and Figure 11) occurred in onsite Wells EPA 23 (overall steady but fluctuating about an approximate level of 5 mg/L) and 801 (overall steady but fluctuating about an approximate level of 4 mg/L since 2004). Historically, the standard for manganese has occasionally been exceeded in Wells 802, 803, and 808 (Earth Tech, 2002c) (see Appendix A).

Long-term off-site seepage impacts to the groundwater have been limited to exceedances of the sulfate and TDS standards, both of which are non-hazardous constituents. Unlike Zone 1 and 3 impacted waters, the pH of the Southwest Alluvium impacted water is nearly neutral. Consequently, there are no exceedances of the metals or radionuclides standards within the seepage-impacted water, with the exception of the noted exceedances of manganese (a non-hazardous constituent) located well within the property boundary.

The non-impacted background water at downgradient Well SBL 1 showed October 2009 exceedances of nickel (0.07 mg/L) and manganese (3.15 mg/L), and occasional earlier exceedances of cobalt. These metals exceedances are unrelated to seepage impact to the groundwater because seepage-impacted water has not yet migrated to this location. Therefore, they should be viewed as a background condition, i.e., of post-mining/pre-tailings origin and age. The NRC’s statistical evaluation of background water quality led to their recommendation that manganese, sulfate, and TDS should not be regulated site constituents and they should not be used as bases for corrective action (NRC, 1996).

2.3.3 Rate of Seepage Migration

Earth Tech (2002c) analyzed concentration trends of chloride and bicarbonate to infer the rate of constituent migration. Seepage impacts were observed to have migrated beyond the Site property boundary by 1982, but the only constituents showing exceedances in the impacted water offsite have been sulfate and TDS. However, bicarbonate and chloride have been determined to

be the more effective indicators of seepage impact for reasons described in Section 2.3.2. Using chemical trends and estimates of hydraulic conductivity, hydraulic gradient, and effective porosity, Earth Tech calculated an average migration rate of 77 ft/yr beyond Well 624. Their transport rate was applied to the updated depiction of the inferred, southern edge of the impacted water during October 2003 (Figure 3 in USFilter, 2004a).

Subsequently, new groundwater velocity calculations have been made to estimate the rate of downgradient seepage-impact transport. These estimates are Darcy seepage velocities equal to the product of the hydraulic conductivity and the hydraulic gradient, divided by the effective porosity. The resultant groundwater velocities are upper-bound estimates of constituent transport velocities because no retardation or attenuation factors are applied.

Table 5 shows Southwest Alluvium groundwater velocities determined using hydraulic gradients based on the October 2009 measurements of groundwater elevations at Wells 805, 624, 627 and SBL 1. Upper and lower estimates of seepage velocity are based on a range of effective porosities adopted from Canonie (1989b) and Earth Tech (2002c). The average calculated velocities are effectively based on a median porosity estimate of 0.31. Application of the mean hydraulic conductivity value of 3.69×10^{-3} cm/sec formerly used by Earth Tech (2002c) results in the prediction that seepage impact should already have arrived at Well SBL 1, which is not the case. The hydraulic conductivity value used in this annual report is 2×10^{-3} cm/sec, which was determined to be an appropriate mean value based on an extensive review of relevant site reports (USFilter, 2004b). This same mean alluvium hydraulic conductivity value was used in the groundwater modeling accomplished as part of the Zone 3 Supplemental Feasibility Study (MWH, 2004).

The average calculated groundwater velocity from Well 624 to Well SBL 1 is 22 ft/yr. This is substantially lower than the velocities associated with the other two upgradient well pairs, because the hydraulic gradient from 624 to SBL 1 is significantly lower than that associated with the other pairs (Table 5). The downgradient limit (“nose”) of the 1,000 mg/L bicarbonate isoconcentration contour shown in Figure 8 is 22 ft farther to the southwest than it was in the comparable figure in the 2008 Annual Report. This mean velocity of 22 ft/yr (October 2009) is 31 percent lower than the mean velocity of 32 ft/yr that was calculated for October 2008. The lower value from October 2009 primarily reflects a reduction in the measured groundwater elevation in Well 624 (see Appendix A); future measurements will determine whether this lower groundwater level is anomalous.

The onset of persistent attainment of the “full impact threshold” values for bicarbonate (1000 mg/L) and chloride (150 mg/L) in Well 624 occurred in October 1996 (13 years prior to October 2009). Using the updated average groundwater flow rate from Wells 624 to SBL 1 of 22 ft/yr, it is inferred that the October 2009 location of the seepage-impact front is 395 ft downgradient from Well 624. This is consistent with the groundwater chemistry at Well SBL 1, which indicates no seepage impact. At the calculated velocity of 22 ft/yr, it would take approximately 5 years, or until 2014, for the seepage impact front to traverse the 105 ft from its present inferred position to Well SBL 1. This estimate assumes a constant seepage velocity, which may only be

approximately the case as saturation levels continue to decline. There are also uncertainties in the hydraulic parameters used to make this estimate. Therefore, the timing of the arrival of seepage impacts at SBL 1 is not subject to precise prediction.

Figure 8 shows the downgradient “nose” of the 1,000 mg/L bicarbonate isoconcentration line passing to the east of Well SBL 1. This depiction is based on the inference that the impacted water will locally take this southerly course to parallel the southerly turn in the edge of the cuesta nearby to the east. However, we expect that the area of alkalinity impact will eventually include Well SBL 1.

It took more than seven years of gradual concentration increases, from the start of monitoring in July 1989, for full seepage-impact levels of bicarbonate and chloride to develop at Well 624. Therefore, the start of future possible gradual increases in the bicarbonate and chloride levels in Well SBL 1 may be imminent. Continued monitoring of the water quality at this location should eventually allow back-calculation of the relevant rate of reaction front migration.

2.3.4 Continuing Assessment of Southwest Alluvium Natural Attenuation and Earlier Technical Impracticability Waiver Request

UNC conducted a scheduled natural attenuation test from February 2001 to July 2002 to determine whether shutting off the Southwest Alluvium extraction wells would adversely affect water quality. The Southwest Alluvium extraction wells were shut off in January 2001 for the duration of the test. The NA report was submitted to the EPA, NMED, and NRC on November 4, 2002 (Earth Tech, 2002c). The NA report concluded that turning off the extraction wells does not have an adverse effect on water quality and that the natural system is as effective as, or more effective than, pumping for controlling the migration of the constituents of concern. EPA has not reached the same conclusion based upon the Second Five-Year Review Report (EPA, 2003) and further comments on the NA report (EPA, 2004a), and so additional monitoring is being performed.

The Technical Impracticability (TI) evaluation in the NA report concluded that natural conditions maintain sulfate and TDS concentrations at non-impacted background concentrations, which are nonetheless greater than Site standards. Physical and geochemical processes that reduce the tailings-impacted groundwater concentrations to background (or lower than background) concentrations have operated since mine water discharge began. This is demonstrated by the sulfate concentrations from impacted wells that contain constituent concentrations equivalent to, or variously higher or lower than, the non-impacted background concentrations. (See Figures 7 and 8; compare background Wells 627, EPA 28, and SBL 1 with wells located within the area impacted by tailings seepage.) The same is true of TDS, for which historic concentrations are shown in Figure 12. Background Well 627 has fluctuated about the Site standard (4,800 mg/L); background Well EPA 28 has persistently exceeded the standard; and background (post-mining/pre-tailings) Well SBL 1 had the highest concentration of any well during October 2009 (9,000 mg/L). However, the sharply increasing TDS trend for impacted Well GW 2 (8,580 mg/L in October 2009) did reach the lower part of the range in Well SBL 1

during the last year. The increasing trends for sulfate and TDS in Well GW-2 are consistent with its location in the core area of the bicarbonate distribution mapped in Figure 8. However, it is important to recognize that the reaction of the alluvium water with the natural alluvium material causes the high TDS water – this is unrelated to the tailings seepage and would occur in any water placed into the formerly unsaturated alluvium.

The remediation system did remove sulfate and TDS mass, but this is irrelevant because concentrations are dependent on the chemical equilibrium of gypsum with the water; therefore, they have been and will continue to remain similar to those achieved through geochemical processes within the groundwater system. Thus the concentrations are not dependent on continuing the former pump-and-evaporate corrective action program, but are instead controlled by natural geochemical reactions; in particular, the pervasive equilibrium between the groundwater and naturally occurring gypsum (or anhydrite).

Under the federal drinking water standards, sulfate and TDS are assigned secondary drinking water standards (SMCLs), which are non-enforceable guidelines regulating chemical constituents that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water (EPA, July 1992). EPA recommends secondary standards to water systems, but does not require those systems to comply. Under applicable New Mexico regulations (20 N.M.A.C.1101(TT)), TDS and sulfate are not defined as “toxic pollutants” for purposes of groundwater and surface water protection. Additionally, they are not included on NRC’s hazardous constituent list applicable to groundwater, nor were they assigned Site groundwater protection standards by NRC. The standards set for sulfate and TDS are not for the protection of human health. The secondary standards are not federally enforceable, but are intended as guidelines. Therefore, a TI Waiver has previously been deemed appropriate for sulfate and TDS (Earth Tech, 2002c; USFilter, 2004a; N.A. Water Systems, 2005a).

UNC believes that the earlier part of this report demonstrates an understanding of, as well as the distinctions between, background water and seepage-impacted water with respect to the character and evolution of their geochemistry. The concepts demonstrated above require a non-traditional view of a TI Waiver zone as it would apply to the Southwest Alluvium. Sulfate and TDS exceedances in the background water are unrelated to seepage impact. It is inappropriate to apply the TI zone concept to the extensive downgradient area of exceedances of sulfate and TDS. Instead, UNC is presenting the extrapolated location of the seepage-impacted water 195 years from now (shown in Figure 58), and has concluded that the area meets ALARA (as low as reasonably achievable) principles. This depiction derives from application of the average October 2004 groundwater velocity from Well 624 to Well SBL 1 (30 ft/yr) over a 200-year period; it assumes purely advective transport of seepage impacts with no retardation, dilution, or attenuation; and it assumes that sufficient hydraulic head will exist to drive the flow of impacted water (which may not be the case given the absence of significant recharge and the preceding observations regarding declining water levels). The extrapolated impact-area along the alluvium is predicted to advance by approximately 6,000 ft with the impact front of year 2204 located as shown in Figure 58. In conjunction with their review of the pending SWSFS, EPA must decide

whether to address sulfate and TDS with a TI Waiver, ACLs, or possibly Institutional Controls (ICs; EPA, 2008b).

2.3.5 *Reassessment of the Performance of the Natural System*

The NA report (Earth Tech, 2002c) used nonparametric trend analysis to determine whether increases in contaminant concentration occurred during the test and whether the changes were significant. Increases in upward trends were identified for bicarbonate, chloride, and TDS, although bicarbonate was evaluated as an indicator parameter only, not as a constituent of concern. These increases were attributed to the elimination of the partial capture provided by the extraction wells. No change in trend was observed for the sulfate concentrations because these are naturally equilibrated with gypsum. However, subsequent to the submittal of this report in 2002 and, as discussed earlier, Wells GW 2 and GW 1 have shown increasing sulfate trends; such increasing major ion concentrations reflect the influence of declining water levels and/or increased dissolution of the alluvium materials (NRC, 1996). The NA report (Earth Tech, 2002c) also concluded that there was no change in trend for manganese, chloroform, or uranium. It was concluded from these analyses that, although seepage-impacted water continues to migrate as shown by upward trends in bicarbonate, the migration of metals and radionuclides is arrested by attenuation processes (i.e., adsorption and precipitation). Continued groundwater quality monitoring through October 2009 supports this conclusion (with the possible exceptions of uranium in Wells GW 3 and EPA 25, discussed below).

Table 6 shows the predicted performance of natural attenuation in the Southwest Alluvium. Sulfate and TDS concentrations are not expected to meet Site standards within seepage-impacted areas because calcium availability and gypsum equilibrium in the groundwater limits reduction of sulfate concentrations. Sulfate and TDS concentrations within the background waters are unrelated to seepage impact and application of the Site standards is inappropriate. Entries in Table 6 are based on groundwater quality in background Well SBL 1, as well as our understanding of the geochemical systems associated with both background water and seepage-impacted water. Metals and radionuclides in seepage-impacted water are expected to meet the standards through attenuation by neutralization and adsorption. The individual indicator parameters and constituents of concern are discussed below.

Calcium and Bicarbonate

Calcium and bicarbonate are non-hazardous constituents. Figure 13 illustrates the long-term stability of calcium and bicarbonate concentrations at Wells 627 and EPA 28, which are examples of background wells that have not been impacted by tailings seepage. Calcium concentrations in these two wells have been essentially the same through time. Figure 13 shows that during the onset of seepage impact in Well 624 (indicated by the increasing bicarbonate), the calcium concentration increased by approximately 100 mg/L and then re-equilibrated at a concentration of 650 to 700 mg/L. Under changed groundwater quality flux, calcium concentrations remain fixed in the presence of calcite and gypsum by the Phase Rule; the long-term consistency of calcium concentrations in the Southwest Alluvium attests to the established

equilibrium between the groundwater and these minerals. In general, calcium concentrations do not vary appreciably anywhere in the groundwater flow system (see Figures 9 and 14).

Figure 15 shows the bicarbonate concentrations over the same period. Bicarbonate is a non-hazardous constituent that serves as the primary indicator of seepage impact in the Southwest Alluvium. Post-shutoff uptrends in GW 3 stabilized in approximately January 2003 and in GW 2 in approximately April 2005. GW 1 has shown an increasing trend post-shutoff to present. These observations indicate that neutralization and geochemical attenuation is still occurring naturally, and that dissolution of alluvial mineral salts into the alluvium groundwater is likely. Bicarbonate concentrations in Wells GW 2 and GW 3 may have achieved a chart “plateau” level of relatively constant values.

Sulfate and TDS

Sulfate and TDS are non-hazardous constituents. They do not have federal drinking water MCLs; they do have SMCLs. The provisional Site standards (2,125 mg/L for sulfate and 4,800 mg/L for TDS) derived from a background water quality analysis by the NRC (1996), with which NMED concurred (NMED, 1998).

Sulfate concentrations exceed the standard in both the seepage-impacted water and the background water in the Southwest Alluvium. Regardless of whether the extraction wells were operating, sulfate concentrations in the Southwest Alluvium are controlled by the system’s equilibrium with gypsum. Figure 16 shows sulfate concentrations from 1999 through October 2009; Figure 17 presents TDS concentrations over the same period. Well GW 3 shows long-term stability in the concentrations of sulfate and TDS that were not affected by pumping. However, Well GW 2 shows increasing trends in both sulfate and TDS since shutoff (the sulfate concentration of 4,720 mg/L in October 2009 is the highest value of any well except background Well SBL 1 (5,960 mg/L)). Full geochemical re-equilibration to the changed hydraulic conditions has apparently not been attained at GW 2. TDS in Well GW 1 stabilized in October 2004, but sulfate here has continued to increase since shutoff.

Concentrations of sulfate and TDS are lower within impacted waters than within non-impacted Well SBL 1, and they are not expected to rise above the values measured in SBL 1. Based on the results of the geochemical investigation presented by Earth Tech (2000d), sulfate is not expected to meet the clean-up standards in the Southwest Alluvium. As shown on Figure 9 (and consistent with Zone 1 and Zone 3), most of the TDS comprises sulfate. Accordingly, TDS concentrations are not expected to meet the clean-up standards.

Chloride

The Site standard for chloride derives from the New Mexico Water Quality Act; 250 mg/L is also the federal SMCL (this constituent does not have a federal primary MCL).

Figure 10 presents chloride concentrations from 1999 through October 2009. Well 509 D is the only location where chloride concentrations have persistently exceeded the standard (250 mg/L). Occasional, typically minor exceedances have occurred in the past at Wells 632, 801, and GW 1.

Figure 10 shows that during the 18 months after the pumping shutoff, there were small Site-wide increases in chloride, after which concentrations returned to their pre-shutoff levels. The small increases may have been (at least partially) an artifact of the more frequent, monthly water quality measurements that were made for the 18 months following shutoff (after which the frequency returned to quarterly monitoring). Pumping had no effect on chloride concentrations with the apparent exception of Well GW 1, where post-shutoff increases stabilized in January 2004 at concentrations that occasionally show very small exceedances.

Manganese

Manganese is non-hazardous constituent. It does not have a federal drinking water MCL; it does have a SMCL. The Site standard (2.6 mg/L) was cited as background water quality in the ROD (EPA, 1988b).

Figure 11 presents manganese concentrations from 1999 through October 2009. Manganese is the only metal that exceeds its current standard in seepage-impacted areas. Exceedances have occurred typically at three wells: 801, EPA 23, and 509 D. The concentration trends have been relatively flat at Well 801 since July 2004 and at Wells EPA 23 and 509 D since 2000. Well 509 D is an upgradient well that was not hydraulically influenced by the former downgradient extraction well pumping, and the changes of manganese concentrations are probably unrelated to previous pumping.

Two of the monitoring wells in proximity to the southwestern “nose” of the South Cell (802 and 808) continued to show low manganese concentrations during October 2009 that were below the standard. Nearby, Well 632 maintained a very gradual increasing concentration trend that started in December 2001 which appears to have stabilized in July 2008 at a concentration close to the standard. All three of the GW-series wells continued to show long-term stable trends below the Site standard.

These observations indicate that manganese natural attenuation continues effectively in much of the seepage-impacted waters. It is expected that concentrations will continue to be below the standard in most of the seepage-impacted wells; however, exceedances are expected to continue at Well EPA 23, and sporadic exceedances appear likely to continue in Well 509 D (both of these are POC wells located significant distances upgradient of the Section 2 property boundary). Based on long-term trends, modest exceedances may continue at Well 801.

The last nine quarters of sampling at background Well SBL 1 have shown minor exceedances of the manganese standard (Table 2 and Figure 11). Well SBL 1 has also shown nickel exceedances and relatively high concentrations of magnesium (Table 2; Figure 9; Appendix A). These characteristics do not reflect the presence of seepage-impacted water at this location. Rather, as explained earlier in Section 2.3.2, the geochemistry of groundwater at SBL 1 reflects background conditions that are very likely related to the dissolution of soluble alluvium minerals associated with the flux of discharged mine waters.

Uranium

Uranium concentrations do not exceed either of the current Site standards of 5 mg/L as listed in the ROD, or the NRC License standard of 0.3 mg/L. A summary of historic Southwest Alluvium uranium concentrations through October 2009 is provided in Appendix A and in the time-series charts discussed below.

The statistics included in the NA report (Earth Tech, 2000c) determined that there was not a significant increase in trend for uranium; however, the graphs of uranium concentration in several wells indicated a possible increase prior to and during the NA test. For this reason, UNC has continued to reassess the uranium trends as part of the Site annual reporting.

GE (2006) has evaluated the regulatory significance of the occurrence and distribution of dissolved uranium in the Southwest Alluvium. That report was prepared to assist EPA in deliberations about applying the current MCL for uranium (0.03 mg/L) as a formal cleanup criterion in the Southwest Alluvium. EPA has orally indicated that they are considering the adoption of the current MCL for uranium as their standard at Church Rock, although they have not yet proposed a formal modification to their current standard in the ROD (5 mg/L). Figures 18 through 34 (discussed below) show that most of both the impacted and background wells have long-term uranium concentrations exceeding 0.03 mg/L.

The concentration of dissolved uranium in seepage-impacted water is often a function of the bicarbonate concentration, and uranium has been empirically found to lie within the same concentration range as the background (post-mining/pre-tailings) water. The typical covariance of uranium and bicarbonate concentrations is an important observation for which some examples are provided below.

Graphs of uranium concentrations in all fourteen wells comprising the Southwest Alluvium water-quality performance monitoring program, through October 2009, are included as multi-well plots in Figures 18 and 19. These plots cover the period from April 1999 through October 2009, thus providing a visually expanded time (horizontal) scale spanning shutoff. Figure 18 shows only the seven POC wells; Figure 19 shows other select wells, including background water quality. Graphs of uranium concentrations are shown separately for each well in Figures 20 through 34. The plots indicate that uranium concentrations at each well have been below the NRC License standard. Furthermore, none of the time-series exhibit trends from which future exceedances might be predicted. These charts show the following additional key observations:

- **Well 509 D** (Figure 20): The uranium concentration in Well 509 D, which is located upgradient of the South Cell and the other Southwest Alluvium wells, increased one full year prior to the NA test starting in October 1999 (pumps were shut off in January 2001). Relatively large fluctuations have been characteristic since shutoff and during earlier periods. The concentration trend has been overall stable (i.e., approximately horizontal on the chart) since July 2000, at the higher end of the historic range. Well 509 D is located outside the zone of influence of the former pumping wells; it is not a good indicator of whether there is a benefit to pumping. However, if 509 D were postulated to

be in the zone of influence, then the uranium data would indicate that there is no benefit to pumping because the concentrations increased while the pumps were operating and stopped increasing when they were shut off.

- **Well 801** (Figure 21): The uranium concentration in Well 801 increased to its maximum just prior to shutdown and decreased through most of the NA test. The concentrations decreased and stabilized, approaching the long-term average concentration that had been extant during pumping. This indicates that although heterogeneous uranium-bearing waters may pass through the system, they will tend to approach a stable, average concentration whether or not the pumps are running.
- **Well 802** (Figure 22): Well 802 was a pumping well that was shut down on January 8, 2001. Subsequent concentrations increased through September 2001, were stable through October 2003, and then decreased through January 2008. If a long-term linear trend line were to be established for this well, it would seem that the discontinuance of pumping in 2001 had no discernible effect.
- **Well 803** (Figure 23): The uranium concentration in Well 803 spiked in the year 2000, more than one year before the NA test. Only one of the 41 samples collected since shutdown showed higher uranium concentrations than the two relatively high concentrations that were measured during 2000, before the shutdown. Post-shutoff concentrations increased through July 2002 to a similar value measured pre-shutoff during May and July 2000. Since July 2002, the trend has been decreasing and concentrations are consistent with the historic range. There is no discernible advantage to pumping based on well 803.
- **Well GW 1** (Figure 24): The uranium concentrations in Well GW 1 began to increase in 1999, well before the NA test, and therefore cannot be attributed to the cessation of pumping. Post-shutoff concentrations continued to increase at an accelerated rate through July 2002 and then decreased through January 2004, at which time they stabilized. Concentrations have since been stable at levels consistent with the early- to mid-1990s, but slightly above the lowest concentrations reached in the late 1990s. This chart also shows the bicarbonate concentrations over the entire history of monitoring. The covariance in uranium and bicarbonate concentrations is strong from 1989 through July 2002; subsequently, the trends of these two parameters have diverged. Since April 2008 the bicarbonate concentrations have undergone an upward step that amplifies the divergence versus the approximately stable uranium concentrations. The possible origin of this trend divergence is discussed later in this section.
- **Well GW 2** (Figure 25): Post-shutoff concentrations were stable through October 2002; then they increased to January 2005, after which they appear to have stabilized. The post-shutoff range concentrations have been lower than most historic concentrations and similar to concentrations that were achieved prior to the cessation of pumping.

- **Well GW 3** (Figure 26): Since shutoff the overall trend has been slightly upward; the concentrations have increased from 0.059 mg/L in February 2001 to 0.151 mg/L in October 2009, defining a linear rate of increase of +0.011 mg/L per year over this period of 8.7 years. Linear regression analysis over this same time period provides a coefficient of determination (R^2) of 0.8635, indicating a relatively high degree of correlation between concentrations and time. However, bicarbonate at this location has been overall stable to gradually decreasing since January 2003 and, as noted earlier, sulfate and TDS here have been stable since shutoff. GW 3 is the only Southwest Alluvium well to show a persistent increase in uranium since shutoff. The post-shutoff concentrations fall within the pre-cutoff historic range.

The gradual increasing trend of concentrations at GW 3 post-dates, for the most part, the shutoff. However, this does not necessarily indicate a causal relationship. For example, nearby Southwest Alluvium wells GW 1 and GW 2 have exhibited different concentration changes over the same time-frame. It is not clear what physical or chemical mechanism stemming from the shutoff could account for changes so heterogeneous in degree and timing over a relatively small downgradient area. Uranium concentrations in many Southwest Alluvium wells have shown that variously gradual to steep uptrends and downtrends are typical, whether they occur during pumping or in the absence of pumping.

- **Well 624** (Figure 27): Post-shutoff concentrations have been stable at the lower end of the historic range. There is no discernible advantage to pumping based on Well 624. This chart also shows the bicarbonate time series at this well. Unlike the long-term covariance between uranium and bicarbonate shown in Wells GW 1 and EPA 25, Well 624 conspicuously lacks covariance. This observation is discussed later in this section.
- **Well 632** (Figure 28): Post-shutoff concentrations have been stable at the lower end of the historic range (excluding a drop to nondetect in April 2004). There is no discernible advantage to pumping based on Well 632.
- **Well 627** (Figure 29): Post-shutoff concentrations have been stable along the historic trend that is associated with a low range. There is no discernible advantage to pumping based on Well 627.
- **Well 808** (Figure 30): This well was installed in conjunction with the planned shutoff of the extraction well system; it has no pre-shutoff history. The post-shutoff uranium concentration showed a large upward spike through September 2001; since then the trend was strongly downward through October 2002, subsequent to which the concentrations have stabilized.
- **Well EPA 23** (Figure 31): Post-shutoff concentrations have been stable at the lower end of the historic range that is associated with a low range. There is no discernible advantage to pumping based on Well EPA 23.

- **Well EPA 25** (Figure 32): Concentrations have been quite stable from July 1999 to January 2007. This chart also shows the covariance of uranium and bicarbonate concentrations over the entire history of monitoring. The onset of seepage impact at this well occurred during October 1995. An upward step in bicarbonate concentrations started in April 2006, while an apparent upward step in uranium concentrations started slightly later in January 2007 – these geochemical changes occurred many years after the shutoff of the pumps. Such covariance in uranium and bicarbonate concentrations is characteristic of most (but not all) wells in the Southwest Alluvium. This important relationship can be explained by the basic geochemical principles presented in GE (2006). EPA 25 is along the northwest flank of the bicarbonate impact area (see Figure 8).
- **Well EPA 28** (Figure 33): Concentrations have been quite stable since July 1989. There is no discernible advantage to pumping based on Well EPA 28.
- **Well SBL 1** (Figure 34): Concentrations at this newest, downgradient background well have varied from 0.0126 mg/L to 0.0332 mg/L.

This comprehensive review of historic uranium concentrations demonstrates that most of the seepage-impacted wells have shown overall stable to decreasing trends since shutoff. Overall, none of the wells have shown post-shutoff concentrations that exceed historic values, and many of the wells show that both gradual and sudden variations are common. UNC concludes that pumping would not result in improving groundwater quality with respect to uranium or any other constituent.

EPA (2008b) has stated (p. 53, Issue # 4):

“If the source of the uranium is the alluvial sediment, the increase in bicarbonate levels, as believed to be controlled by the shutoff, would be expected to influence the distribution and concentration of uranium. The bicarbonate levels are believed to determine whether or not the non-tailings-sourced uranium is dissolved, precipitated, or adsorbed. Thus, if the bicarbonate continues to migrate, then any uranium which could be sourced from the alluvium is expected to mimic the bicarbonate and migrate accordingly. In light of this, there remain questions regarding the effectiveness of the extraction wells to improve groundwater quality with respect to uranium.”

EPA (2008b) indicated that this and related statements in their third Five-Year Review report derived from their review of the 2007 Annual Review Report (N.A. Water Systems, 2008a) and GE (2006). UNC concurs that degrees of covariance between bicarbonate and uranium groundwater concentrations have been demonstrated in many Southwest Alluvium wells, and that the alkalinity of seepage-impacted water can be a strong determinant of how much uranium will be partitioned between the aqueous and (a typically surface-bound) solid phase (GE, 2006).

However, the potential heterogeneity of adsorbed uranium (of non-tailings origin) within the Southwest Alluvium sediments may inherently limit the degree to which one can predict the degree (or even presence) of such covariance. For example, Figure 24 indicates a degree of covariance between these two chemical parameters in Well GW 1. However, from July 2002 to October 2009 (a period of 7.25 years) the bicarbonate concentration in this well increased by +670 mg/L while the uranium concentration decreased by -0.024 mg/L.

Another example worth noting is provided by Well 624 (Figure 27). The increase in bicarbonate to a plateau starting in May 2000 is attributed to the migration of the bicarbonate “front” associated with tailings seepage-impact. However, this well shows no covariance between the bicarbonate and uranium concentrations. At least two interpretations are possible: (1) at this well location there is little to no adsorbed or precipitated uranium (i.e., solid phase) within the alluvial sediments; and (2) aqueous uranium that originated from upgradient tailings seepage impact has been strongly attenuated during transport and it has not reached this location.

None of the wells have shown exceedances of the uranium standards. *The time-concentration plots indicate that natural attenuation, by neutralization and adsorption, is at least equally as effective as a pumping remedy.* This conclusion is bolstered by earlier discussion indicating that in comparison to background water quality, the passage of the seepage-impact front presages an improvement in sulfate and TDS concentrations.

Section 3

Zone 3

3.1 Corrective Action Summary

3.1.1 Northeast Pump-Back and Stage I and II Remedial Action Systems

While operating, the corrective action system in Zone 3 performed as designed to enhance dewatering of the seepage-impacted area and remove constituent mass. Historic corrective action in Zone 3 consisted of pumping the three sets of extraction wells shown on Figure 35: (1) Northeast Pump-Back System (green triangles), (2) Stage I Remedial Action System (filled blue squares), and (3) Stage II Remedial Action System (empty black squares). The Northeast Pump-Back wells started operation in 1983; the Stage I and II wells were added later as part of the Remedial Action Plan (UNC, 1989b) implemented in 1989.

The numbers of operating extraction wells were reduced as Zone 3 dewatering caused sustainable pumping rates to drop below 1 gpm. The number and pumped volumes of the former extraction wells, during the period of Zone 3 corrective action from 1989 through 2000, have been summarized in Earth Tech (2002d, Figure 3-2). Pumping from the last three extraction wells ceased in 2000. The NRC amended the License (with approval from NMED and EPA) to shut off the three remaining wells (716, 717, and 718) in December 2000. This decision included a provision for UNC to submit a modified corrective action plan, an application for ACLs, or an alternative to the specific requirements of 10 CFR Part 40, Appendix A, if the License standards are not achievable.

3.1.2 2004 Supplemental Feasibility Study

At the request of the EPA (2004b), UNC conducted a Supplemental Feasibility Study (SFS) to evaluate all appropriate remedial options for Zone 3 (these options are being reviewed during the development of the SWSFS). Prior to reporting the SFS (MWH, 2004), UNC submitted (2004) a Technical Memorandum including a chronology of events that led to UNC's initiative to aggressively develop remedy modifications or enhancements that might improve the performance of the remedy in Zone 3. The SFS report presented (1) groundwater modeling of the Zone 3 sandstone unit and the locally overlying alluvium, (2) the pilot-hole hydrofracturing study results, (3) a remedial alternatives analysis, and (4) conclusions and recommendations for enhancing or optimizing remedies for Zone 3. The hydraulic modeling indicated that for most of the alternative remedies to be effective (excluding Alternative 6 – Cutoff/Containment Wells), the recharge from the alluvium to Zone 3 should be reduced or eliminated.

Two studies were conducted based on recommendations of the SFS. These were an in-situ alkalinity stabilization pilot study and the pilot and Phase I hydrofracture program. These studies are described below.

3.1.3 *In-Situ Alkalinity Stabilization Pilot Study*

UNC conducted an in-situ alkalinity stabilization pilot study to evaluate the potential to enhance the ongoing Zone 3 remediation through the use of alkalinity injection wells combined with carefully controlled extraction pumping at the Site. The proposed approach for the pilot study was presented in the In-Situ Alkalinity Stabilization Pilot Study (BBL, 2006), which was approved by EPA.

The pilot study was initially designed to test the injection of alkalinity-rich groundwater from a non-impacted part of the Southwest Alluvium into the Zone 3 aquifer. The injected water (so-called “fixiviant”) would flow through the Zone 3 formation to recovery wells where the fixiviant could be pumped to the surface for treatment and disposal. However, concerns were expressed by NMED that the groundwater from the Southwest Alluvium did not meet applicable groundwater standards for sulfate, total dissolved solids and manganese. Following the original submission of this pilot study (in October 2005) and subsequent discussions, NMED identified groundwater withdrawn from a formation below Zone 3 and the underlying Mancos Shale (the Westwater Canyon Formation), via the onsite Mill Well, as a potential alternative source of groundwater to use as the injection water. The pilot study approach was revised to include injection of the Mill Well water (amended with sodium bicarbonate to add alkalinity) into Zone 3, as described in the approved In-Situ Alkalinity Stabilization Pilot Study dated June 2006.

The pilot study was conducted from October 24, 2006, to February 15, 2007. The observed injection and extraction rates were unexpectedly low. As a result, the estimated travel time between the injection and extraction wells became prohibitively low and the pilot test was terminated. Data obtained as part of the pilot study indicated that the mineral feldspar in the Zone 3 arkosic sandstone had been altered by the acidic tailings liquids, generating kaolinitic clay that significantly clogged pore spaces and reduced hydraulic conductivity. The pilot study indicated that it would take 10 times longer to accomplish remedy goals than had been hypothesized. Using what had been envisioned as an approximate 5 year remedy enhancement could actually take 50 years or more. Based on these results, it was concluded that the use of alkalinity rich solutions to remediate the Zone 3 impacted groundwater in-situ was infeasible (ARCADIS BBL, 2007).

3.1.4 *Phase I Hydrofracture Program and Continuing Zone 3 Extraction Well Pumping*

Extraction of impacted groundwater from a new array of wells in the northern part of Zone 3 was tested in April 2005 as part of the Phase I (i.e., post-pilot) hydrofracture program (MACTEC, 2006). Continuous pumping of these wells began in May 2005. Phase I ended in January 2006; however, as discussed later in this section of the report, the pumping has been continued and supplemented by the installation of additional extraction wells. The locations of the Phase I pumping wells (RW 11, RW 12, RW 13, RW 16, RW 17, and PB 2) are shown on Figure 35 and Figure B-1 in Appendix B. Also shown is the location of a new extraction well, RW A, which started pumping on September 24, 2007. Due to fouling and/or insufficient yield, RW 12 and RW 13 have been taken off-line and are no longer pumping. Of this group, the pumping wells

that were operational during 2009 are PB 2, RW 11, RW 16, RW 17 (restarted after a hiatus) and RW A.

Based on UNC's hydrogeologic analysis and recommendations for the design of a new pumping system to intercept and recover impacted water (N.A. Water Systems, 2008c), five new extraction wells were installed during September 2008. These well locations are shown on Figure 35 and Figure B-1 (in the front of Appendix B) -- they are designated NW-1, NW-2, NW-3, NW-4, and NW-5. After an initial test period to determine that all five wells were pumping properly, three of the wells started pumping during February 2009 (NW-1, NW-2, and NW-3). NW-2 and NW-3 were each pumping at ~ 1 gpm; NW-1 has a very low recharge rate and the pumping there has been cycling off and on with a mean rate of ~ 0.10 gpm.

Approximately 9,972,100 gallons of groundwater have been pumped from this new Zone 3 extraction well network from January 2005 through the end of November 2009, and piped to the evaporation pond.

3.1.5 Evaluation of the Effects and Limitations of Zone 3 Extraction Well Pumping

Twenty years of remedial pumping have resulted in significant dewatering of Zone 3. One effect of this is that once the saturated thickness falls to approximately 25 ft or less, well efficiency declines and pumping rates fall to less than 1.0 gpm (Earth Tech, 2001). Table 7 presents the reductions in saturated thickness for Zone 3 monitoring wells between the third quarter of 1989 and the fourth quarter of 2009. Values of saturated thickness greater than 25 ft are shaded.

The saturated thickness measured in Zone 3 wells has declined by 69 percent on average since the third quarter of 1989. Only one well, EPA 14, had a saturated thickness greater than 25 ft in October 2009. Figure 35 shows that between 1989 and the fourth quarter of 2009, a very large portion of the Zone 3 Remedial Action Target Area has been desaturated (effectively dewatered). The eastern limit of Zone 3 saturation has shifted to the west-northwest over this time period (from the location of the wavy blue line, showing the saturation limit in 1989, to the dashed brown line showing the approximate October 2009 "zero" saturation limit).

The effects of both the former and the present-day, reconfigured remediation pumping in partially, locally dewatering Zone 3 are presented in Figure 36. The figure marks the start of recovery pumping from the new well array installed during the hydrofracture study in April 2005.

The in-situ alkalinity stabilization study unexpectedly found that the seepage-induced alteration of feldspathic minerals is reducing the bedrock permeability. This will tend to restrict the migration of tailings seepage. The main reason that the groundwater flows toward the north is that the Zone 3 bedrock unit dips toward the north. The hydraulic head that drives the flow comprises two components: the elevation head plus the pressure head. The long history of extraction pumping in Zone 3 has reduced the pressure head component of the total hydraulic head. However, it is not possible to reduce the slope-related elevation head – that is a driving force component that cannot be changed (N.A. Water Systems, 2008b). Continued pumping has

been helping in the short-term as Figure 36 shows; however, the saturated thicknesses in this hydrostratigraphic unit are quite low and there will eventually be no further possible reduction in the pressure head. UNC has been doing all that it can to counteract the overall hydraulic head. This is gradually approaching practical limits as the well yields decrease beneath the well decommissioning criteria. At some time in the future, there will likely be a balance between the tendency for the irreducible elevation head to promote the continuing northward migration of seepage-impacted water and the tendency for the seepage-induced permeability reductions to hold the groundwater in place. The exact timing and location of the development of this critical balance cannot be predicted – but such a condition should inevitably occur.

Another way to look at the inherent difficulty of extraction pumping in the northern part of the impacted water is to note that along a 1200-ft long, west-northwest trending line of cross section located between Wells NBL 1 and PB 3, the total groundwater flux (without any pumping) was calculated to be 512 ft³/day (2.7 gpm) during January 2005 (N.A. Water Systems, 2008c). This flux estimate will decrease with time approximately proportionally to the ongoing reduction of saturated thickness.

The revised Zone 3 pumping system has been declining in performance. Most of these wells have reduced yields that are below 0.5 gpm and RW 13 was taken off line due to low yields. The following physical factors controlled these declining yields: (1) encrustation along the wellbore of iron oxyhydroxides, carbonates, and/or gypsum; (2) precipitation of amorphous aluminosilicates (e.g., EPA 14); (3) alteration of feldspar to clays within the bedrock matrix; and (4) reduced saturated thicknesses.

Groundwater quality in Zone 3 started to sharply degrade between May and December 2007 in several of the northern tracking wells (N.A. Water Systems, 2008b). Groundwater quality along the northern tracking wells has been oscillating between degrading and improving trends over the last seven years. Individual well water-quality trends of improvement and degradation have become collectively asynchronous since May 2007.

UNC measures monthly field parameters in all five NW-series wells, and the alkalinity concentrations indicate the following: NW-1 is the most impacted and has the least saturated thickness; NW-4 shows lesser impact; NW-2 shows little to no impact; and NW-3 and NW-5 are pumping predominantly background water and have the greatest saturated thicknesses. Note that NW-1 and NW-4 are the easternmost of these five new wells, and NW-3 and NW-5 are the westernmost. These observations are consistent with our general understanding that the seepage-impacted water is most prevalent towards the eastern limit of saturation; moving westward the prevalence of non-seepage-impacted water increases as does the formation's saturated thickness.

Consistent with UNC's original recommendations (N.A. Water Systems, 2008c) and a more recent update (Chester Engineers, 2009c), UNC recently adjusted the pumping regime along the NW-series wells to attempt to: (1) minimize the withdrawal of background water; (2) minimize any tendency for impacted water to be drawn westward; and (3) maximize the withdrawal of impacted water. As always, the goal is to strike the best balance between containing the

seepage-impacted water while minimizing its transport to the more thickly saturated, but non-impacted parts of Zone 3. During November 9 and 10, 2009, the pumping regime was re-optimized as follows:

- NW-1 was left pumping at the current, maximum rate.
- NW-2 pumping rate was reduced by one-half to ~ 0.5 gpm.
- NW-3 was turned off.
- NW-5 remains off.
- NW-4 pumping was started at the maximum practicable rate.

All other non-NW-series pumping wells to the south will remain on. UNC continues to evaluate the chemistry and water levels in all these wells, which may result in further modifications to the pumping rates to iteratively re-optimize the extraction system operations.

3.1.6 Injection Well Feasibility Testing

On October 27 and November 4, 2009, UNC conducted injection testing in background well NBL 2 (the results and analysis were reported in Chester Engineers, 2000d). The primary objective of this test was to empirically assess the amount of water a well in the non-impacted, northern part of Zone 3 can accommodate by injection. A secondary objective was to determine an additional estimate of the hydraulic conductivity in this area.

The purpose of this test was to evaluate the potential for creating a hydraulic (or possibly an alkalinity) barrier, using multiple injection wells, to limit further northward advance of the seepage-impacted groundwater in the northern part of Section 36. This potential remedial option was retained in the SWSFS Part II (Chester Engineers, 2009b) with a caveat that the formation may not accept sufficient quantities of fluid to practicable, as occurred in the Zone 3 in-situ alkalinity stabilization test (ARCADIS BBL, 2007). The new injection test is located outside the influence of tailings seepage where secondary permeability restrictions, due to reaction of the bedrock with acidic tailings, are less likely.

Two tests were conducted. The first, falling-head test injected 1000 gallons over a period of 2 hrs and 25 min, with an average injection rate of ~ 8.3 gpm. A maximum, nearly constant head condition was obtained for a short period with ~ 55 ft of induced head. After 39 hrs and 52 min, the data logger collection was terminated and the water level had fully recovered.

The second, stepped-head test injected 3,226 gallons over a period of 6 hrs and 9 min. The rate of injection was adjusted throughout the test to regulate the water-level rise or pressure head induced in the well. The first pressure head of ~ 53 ft was obtained with an injection rate of 8.9 gpm; the second pressure head of ~ 49 ft required little adjustment from the average of 8.1 gpm. After injection was terminated, full hydraulic recovery occurred after 41 hrs. The Theis recovery method was used to analyze the recovery data. The resultant, calculated hydraulic conductivity is 0.87 ft/day, which is very close to the estimate of 0.84 ft/day previously made for this area of

Zone 3 (N.A. Water Systems, 2008c). Analysis of the head dependence on flow rate indicates that there is ample capacity to accommodate injection at rates similar to or less than those tested.

Based on the results of the injection test, UNC has proposed (Chester Engineers, 2008d) enhancement and testing of the potential remedial alternative comprising the injection of alkalinity-amended water through an array of new injection wells located to the north of the NW-series of extraction wells and south of the Section 36 property boundary. The first phase of the injection program would comprise a pilot phase with the installation of one new injection well (at a location suitable for the new well array) that will be subject to injection testing similar to that conducted at well NBL 2. There is likely to be spatial variation in the hydraulic conductivity and injection-take rates, and this pilot well will provide preliminary data on these hydraulic properties along the intended new well array.

This plan intends to neutralize and geochemically stabilize the impacted water; continue extracting impacted water flowing from the south; and to impede northward advance of the impacted water. The benefits from such a plan will be temporary (governed by the effective life spans of the new injection wells and the NW-series pumping wells) and should not be considered a permanent solution to meeting the groundwater protection standards throughout Zone 3.

Upon the agencies' approval of this proposed plan (Chester Engineers, 2009d), UNC will develop a remedial design report that will specify the proposed number and locations of new injection wells, their construction specifications and their design injection rates.

3.2 Mass of Chemical Constituents Removed

The mass of chemical constituents removed was calculated for the 12-year period from July 1989 through June 2000. These calculations were presented in the previous annual reviews, and the final summary is presented in the 2000 Annual Review (Earth Tech, 2000e).

As previously discussed, a relatively recent phase of extraction well pumping that originated with the hydrofracture program has continued to present. Table 8 shows the estimated mass removal by this pumping from December 2008 through November 2009 (the similar Table 8 in the 2008 Annual Report showed data through November 2008); the RW-series extraction wells (and converted pumping well PB 2), and the NW-series extraction wells, are shown on Figure 37 and Figure B-1 in Appendix B. The recovered masses were estimated by multiplying the volume of groundwater pumped by the estimated concentration of each constituent in the pumped water. The constituent concentrations were estimated from concentrations measured in groundwater samples taken from the extraction wells and nearby monitoring wells during October 2009.

3.3 Performance Monitoring Evaluation

The current Zone 3 performance monitoring program is summarized in Table 9 and comprises quarterly monitoring of water levels in 23 wells and water quality in 11 wells. This program went into effect in the second quarter of 2000 and was modified in the second quarter of 2001, at the request of the NRC, to include the following additional components:

- Water quality monitoring at Wells EPA 13, 717, and 719;
- Water level and water quality monitoring at Well 708; and
- Installation of Well NBL 1 (July 2001) as a new downgradient monitoring well.

The location of Well NBL 1 (see Figure 35) was selected to both bound the downgradient extent of the impacted water and function as a tracking well.

To supplement the performance monitoring program, four monitoring wells were installed (June 2002) between Wells 504 B and NBL 1: PB 1, PB 2, PB 3, and PB 4 (Figure 35). Drilling logs and well completion forms are included in Earth Tech (2002d, Appendix B). These wells serve to track the advance of the northernmost seepage-impact boundary. Well PB 1 was installed within impacted water and was thence excluded from monitoring of the advancing front.

During August 2007, a new tracking monitoring well (NBL 2; 187 ft deep) was installed approximately 400 ft to the west of NBL 1 (see Figure 35). Monthly water levels and general water quality analyses (pH, specific conductance, chloride, and alkalinity) have been collected from the tracking wells. Monthly field parameter monitoring of Well NBL 2 started in January 2008; at that time, Well 504 B was removed from the monthly tracking list because it has been fully impacted for many years. Well PB 2 was converted to an extraction well in November 2005 to complement the RW-series pumping wells in the northern area of the impacted water. Chloride and alkalinity are analysed with Hach field-testing kits. Quarterly samples from these boundary tracking wells are submitted to a laboratory to check the field results (the laboratory analyzes TDS in lieu of specific conductivity). Based on these comparisons, the field parameters provide a good indication of the migration of the seepage-impacted water. As discussed later in this section, the new pumping array had resulted in three beneficial effects: (1) capture of most if not all of the northward-advancing impacted water (i.e., partial hydrodynamic control); (2) marked groundwater quality improvement and recession of the seepage-impact front to the south; and (3) dewatering and mass removal. The groundwater quality improvement has proven to be temporary (discussed earlier in Section 3.1 Corrective Action Summary, and discussed further below). Pumping rates have declined and this is expected to continue because this has been the case for all other pumping wells in the past.

Two piezometers were installed in July 2004 to the base of Zone 3 just north of the northeastern boundary of the Central Cell (see Figure 35, piezometers Z3M-1 and Z3M-2). These installations were made following recommendations in UNC's investigation (USFilter, 2004b) of the potential for the covered tailings cells to continue to source seepage impact and recharge to the updip part of the Zone 3 hydrostratigraphic unit. The first two quarters of water-level monitoring showed that both piezometers were dry (excluding small amounts of drilling fluid). During October 2009, the height of the water column in Z3M-1 was 0.35 ft and Z3M-2 was dry (Table 10).

A new recovery well (RW A) started pumping during September 2007, approximately 400 ft to the southeast of NBL 2 (see Figure 37). This location was based on MACTEC's (2006) recommendation that fuller hydraulic containment was needed here (see their Figure 3.11).

As described earlier, five new recovery wells were completed along the northern front area of seepage impact (Wells NW-1 through NW-5; Figure 35). The rationale for these well locations was provided in UNC's hydrogeologic analysis and recommendations for new extraction well locations (N.A. Water Systems, 2008c), which was approved in letters from EPA, NRC, and NMED. Pumping of wells NW-1, NW-2, and NW-3 started in February 2009; in November 2009 the pumping regime was re-optimized, as discussed in the previous section of this report. Monthly field parameters and water levels have been measured in all five NW-series wells since June 2009.

To better characterize the groundwater quality in the northernmost area of seepage impact, starting in 2008 UNC has sampled the following additional wells for the full list of laboratory analytical parameters: PB 2, PB 3, PB 4 (October 2008 only), NBL 2, RW A, and RW 11. Such sampling occurred during January 2008 and October 2008; subsequent sampling occurred during October 2009 (although a sample from PB 4 could not be obtained).

3.3.1 Water Level Evaluation

Water level data from 1989 through the fourth quarter of 2009 are presented in Appendix B. Water levels from October 2009 are shown on the potentiometric surface map in Figure 37. These potentiometric contour lines indicate groundwater flows toward the north and northeast, approximately parallel with the eastern limit of Zone 3 saturation. This potentiometric field is similar to, though lowered from, those depicted for the fourth quarters of 2001 (Earth Tech, 2002a), 2002 (Earth Tech, 2002d), 2003 (USFilter, 2004a), 2004 (N.A. Water Systems, 2004), 2005 (N.A. Water Systems, 2005b), 2006 (N.A. Water Systems, 2007a), 2007 (N.A. Water Systems, 2008a), and 2008 (Chester Engineers, 2009a).

Figure 37 shows the locations of pumping wells during October 2009, and monitoring wells. Measured groundwater elevations were used to develop this potentiometric map, which shows a 5-ft contour interval. The pumping in Wells RW A, RW 11, and RW 17 are associated with southwestward deflection of the contour lines, and a cone of depression is suggested by the 6835-ft contour line adjacent to RW 16.

Mine water discharge into Pipeline Arroyo ceased in 1986. Since then, Zone 3 groundwater flow directions became more generally north-northeasterly as recharge from, and groundwater mounding within, the alluvium to the southwest and west has decreased. The earlier east-to-northeast flow direction caused the distribution of groundwater impacts that was the original basis for delineation of the Zone 3 Remedial Action Target Area, as shown on Figure 35. Effects on the potentiometric surface from alluvium recharge (mine water discharge) have largely dissipated, and rates of water level change in Zone 3 are mostly very slow (excluding the influence of recent pumping). Variations from the depicted direction of groundwater flow are unlikely, except where flow may be locally redirected by the new pumping configuration. Since

cessation of mine water discharge, water levels have been declining. Pumping of extraction wells prior to January 2001 temporarily accelerated the local rates of water level decline until the saturated thickness was reduced to less than ~ 25 ft, after which the decline in levels slowed to natural rates of drainage. In October 2009, the collective average saturated thickness for all measured Zone 3 wells (Table 7) has reduced to approximately 14 feet.

Contours of saturated thickness during the fourth quarter of 2009 (Figure 38) show the combined effects of former pumping, current pumping, and natural drainage on Zone 3. This map was developed by evaluating the differences between two interpolated surfaces: the base of Zone 3 and the potentiometric surface for October 2009. The eastern extent of saturation has contracted to the west, so that the current boundary of saturation is approximately where the 25-ft saturated thickness contour was located in 1989 (for comparison, see Earth Tech, 2002d, Figure 3-1). Also, the wells located to the west, closer to the former recharge area, have lost substantial saturation. For example, Well EPA 14 had 76 ft of saturation in 1989 and 27 ft in the fourth quarter of 2009 (a 65 percent reduction in the saturated thickness; see Table 7). Table 10 shows the saturated thickness in each Zone 3 well during October 2009. From 2002 through 2009, most wells have shown overall decreasing groundwater elevations (usually with small fluctuations), indicating that the Zone 3 potentiometric field that drives groundwater flow and constituent migration continues to become lower as the groundwater further drains away. Pumping has removed almost 10 million gallons from 2005 through 2009.

The southwest part of Figure 35 shows the approximate contact area between the alluvium and the top of Zone 3. Former versions of this figure have shown an inferred area of saturation along this contact area (e.g., see Figure 35 in the 2008 annual report). The following lines of evidence suggest that this contact area is no longer saturated and no longer recharging Zone 3:

- N.A. Water Systems' (2008c) analysis of the groundwater flow through Zone 3 indicated little or no contribution from other sources (e.g., alluvium) than the ongoing self-drainage. There was very little flow crossing the southern, east-west directed cross section line near Well 613 (op cit, Figure 7), which is 1,642 ft long: the flux here in January 2005 was estimated to be 723 gallons per day (0.5 gpm).
- The elevation of the top of Zone 3 in the area of its contact with the alluvium is between 6910 and 6930 ft amsl. The closest alluvium well is 509 D (Figure 2) which had a water table elevation of 6872 ft amsl in October 2009, which is below the elevation of the relevant Zone 3 subcrop. Alluvium Well GW 4 (Figure 2) is much closer to the area of interest; this well went dry after July 1999 when it had a water elevation of 6909 ft amsl (which is very close to the well bottom). The alluvium groundwater then was very close to the lower part of the Zone 3 subcrop, suggesting that most of the alluvium/Zone 3 contact area was dry.
- Figure 35 shows that Wells 714 and 715 are not far downgradient from the alluvium/Zone 3 contact area. Table 7 indicates that in October 2009 these wells had saturated thicknesses of 17.3 ft and 10.4 ft, respectively. Compared to their saturated

thicknesses in 1991 (when the wells were installed), the October 2009 values represent decreases of -32.8 ft (-66%) and -37.2 ft (-78%), respectively. These reductions do not prove the absence of updip recharge from the alluvium, but they are consistent with the inference that little or no such recharge is occurring.

3.3.2 *Water Quality Evaluation and Current Extent of Seepage-Impacted Water*

The temporary saturation caused by the mine water discharge is considered the background water for Zone 3 (EPA, 1988a; 1988b; 1998). This background water was later impacted by acidic seepage from tailings in the North Cell. These seepage fluids contained elevated concentrations of metals, radionuclides, and major ions including sulfate and chloride. Source control (neutralizing and later dewatering of the North Cell), neutralization of the seepage by natural attenuation, and mixing with the background water have reduced constituent concentrations.

Seepage-impacted water, some of which exceeds Site standards, is contained within the property boundary in Section 36. The portion of the impacted water that extends off the property into Section 1 (Figures 6 and 35) was eliminated as a point-of-exposure (POE) because of limited saturation. The decision to eliminate this area as a POE is documented in a letter from the NRC (1999b).

It is important to recognize that exceedances of Site standards in some Site wells represent background water quality. For example, exceedances of the combined radium and sulfate standards in Well EPA 14 significantly pre-date the beginning of strong seepage impacts that were first observed at that well during 2000 (the water quality history of this well is discussed below). From 1989 through 1997, Well 411 showed long-term background exceedances in combined radium, cobalt, molybdenum, nickel, and sulfate. Background water quality is discussed further in the natural attenuation system performance evaluation. Statistical analysis of Site background water quality, using EPA's preferred ProUCL software, has been submitted by UNC (N.A. Water Systems, 2008f).

The following criteria have been used to distinguish background versus impacted groundwater quality in Zone 3:

- pH < 5 and bicarbonate < 100 and > 500 mg/L are useful (but not always definitive) indicators of seepage impact (see the Technical Memorandum (GE, 2000)). N.A. Water Systems (2008f, Figure 1) presented box-and-whiskers plots of bicarbonate and pH for the background wells. Impacted water with a pH < 5.0 has not yet migrated far enough to reach equilibrium, or to react sufficiently, with carbonate minerals in the Zone 3 strata (Canonie, 1987, Table 4-5 indicates a measured CaCO₃ content of 0.02 percent in the Zone 3 bedrock). A pH > 5.0 indicates either no seepage impact, or acid neutralization to varying degrees (usually a function of residence time and migration distance).

In non-impacted areas, background water has approximately reached equilibrium with the carbonate minerals resulting in bicarbonate concentrations ranging from approximately

100 to 500 mg/L. These threshold values reflect sequential chemical reactions. When acidic seepage-impacted water first entered Zone 3, it lacked bicarbonate. Once the seepage water migrates a short distance from its point of entry, bicarbonate is generated by reaction with calcite in the alluvium and/or bedrock. With increasing time of neutralization at a given location, the bicarbonate typically shows a gradual increase to levels above background (generally > 500 mg/L). Eventually, the neutralization capacity is exceeded and bicarbonate values may reduce to near zero. Further discussion of bicarbonate concentration trends is provided below.

- Time-series of these two indicator parameters are very helpful (sometimes essential). See N.A. Water Systems (2008f, Appendix A) for time-series of pH and bicarbonate for the background wells.
- The spatial context of well locations within the overall area impacted by seepage (e.g., see Figure 35).
- Time trends in the concentrations of major ions; in particular, decreasing ratios of Ca:Mg are associated with degrading groundwater quality (see Appendix B; e.g., Well EPA 14).
- Time trends in the concentrations of many metals and radionuclides will usually increase as the water quality degrades in Zone 3 (see Appendix B; e.g., Well EPA 15).

Invariably, some wells (or certain time spans at some wells) are difficult to classify because their groundwater chemistry tends to be gradational. For example, the geochemistry associated with Well 420 is “borderline” between background and impacted water quality.

Seepage-impact extent is primarily based on evaluation of pH and bicarbonate concentrations over time in (1) seepage-impacted wells (e.g., Wells 613, 518, and 517), (2) background and former background wells (e.g., Wells EPA 1 and 411), and (3) the northern tracking wells. Table 11 presents the monthly field parameter measurements for the northern tracking wells (from south to north: Wells RW A, PB 2, PB 4, PB 3, and NBL 2 and NBL 1). (The quarterly laboratory analytical results are provided in the back part of Appendix B.) Table 12 presents the monthly field parameter measurements for the new NW-series of wells (these measurements started in June 2009).

Bicarbonate time-series for all the Zone 3 wells are shown in Figure 39, while Figure 40 focuses on the northern tracking wells. Evaluation of these data indicates that bicarbonate concentrations at Well PB 4 have shown unusually large variations since December 2007 and since then the groundwater quality trend in PB 4 has overall been degrading; since February 2009, bicarbonate has been mostly nondetect, and pH < 3.

Historic groundwater quality data (see Appendix B) from fully impacted wells indicate that it takes from one to three years, from the onset of geochemical changes associated with the arrival of seepage-impacted groundwater, for full seepage-impact to develop (unless the constituent transport is effected by pumping). In discussing Table 11 in the 2005 annual report, it appeared that the development of full-stage seepage impact was imminent at Well PB 3 (i.e., it appeared

likely that bicarbonate would very soon fall to levels persistently below 50 mg/L, accompanied by a subsequent decrease of pH to below 5.0). This is shown on the bicarbonate time-series charts in Figures 39 and 40 (it should be noted that the bicarbonate values plotted in these charts are those derived from *laboratory* analyses of the quarterly monitoring samples; see the laboratory analytical summary sheets in the back of Appendix B). The northern limit of seepage impact on Figure 35 of the 2005 Annual Report was shown passing through Well PB 3, because of the duration of bicarbonate decrease at this location, culminating with the bicarbonate value of 51 mg/L in October 2005. Subsequently (see Table 11, which includes the monthly *field* bicarbonate measurements from the northern tracking wells), bicarbonate at this location decreased during November and December 2005, but then started to increase during January 2006 – it continued to increase to October 2007, and since then it has fluctuated while remaining overall stable. The sharp increase starting in January 2006 represents an abrupt reversal of the long-term declining bicarbonate concentrations at this location since well monitoring started in October 2002 (Table 11).

Since the beginning of the new Zone 3 pumping scheme in May 2005, bicarbonate in PB 2 started to decline in September 2007 and fell to 0 mg/L in January 2008. Since then it has fluctuated by ~ 150 mg/L (see Table 11 and Figure 40).

Since October 2007, Well NBL 1 has shown unusually large variations in bicarbonate concentrations that were overall downward through March 2008. Since then, the bicarbonate trend reversed slope and started to increase very sharply through March 2009 (306 mg/L), after which it dropped to 59 mg/L in September 2009. A similar range in bicarbonate concentrations in Well PB 3 occurred over this same time frame (though the large variations were sometimes asynchronous to those in NBL 1).

Collectively, these bicarbonate measurements in the northern tracking wells indicate that the groundwater quality is highly heterogeneous on the local scale of the related well array. The noted asynchronous changes of bicarbonate concentrations in the northern tracking wells indicates the local groundwater quality fluxes, near the seepage-impact front, due to the effects of pumping PB 2 (starting in September 2005), RW A (starting in September 2007), and NW-1, NW-2, and NW-3 (starting in February 2009).

Figure 35 shows the location of the northern edge of the seepage-impact front during October 2009 at Well NBL 1. As explained in the lower block of Table 13, full seepage impact has occurred at PB 4 since November 2008, but to the north of this well there is no unequivocal basis for selecting a single location representing the leading edge of moderate seepage impact. This reflects the influence of pumping. Table 13 explains the basis for selecting NBL 1 as the “end point well” of seepage impact shown in Figure 35.

Until the cessation of mine water discharge in 1986, seepage impacts in Zone 3 migrated to the east and northeast, due to groundwater mounding in the alluvium recharge area to the west. As the hydraulic head in the alluvium recharge area has decreased and then very likely ceased,

migration has been toward the north (in relatively southern locations) and northeast (in more northerly locations), subparallel to the eastern edge of saturation and the bedrock dip direction.

As predicted in the EPA's First Five-Year Review Report (EPA, 1998) and discussed in the Technical Memorandum (General Electric, 2000), continued pumping of the downgradient Stage II extraction wells caused the seepage-impacted waters to migrate to the northwest and north toward the pumping locations. For example, until May 2000, Wells 708 and 711 had pH values greater than 4.0, but after that time they dropped below 3.0.

The acidic "core" of the impacted water is shown in Figure 35 with the closed dashed red lines indicating the pH value of 4.0. The other red line shows the approximate location where the pH values are 5.0. Note that the pH shown for Well PB 2 (5.55) is significantly higher than that shown a short distance to the north for PB 4 (2.50); and a short distance to the north of PB 4, Well PB 3 had a pH of 6.26 in October 2009. This relatively large pH variation is inferred to be another effect of the pumping.

During 2009, Well EPA 14 has shown improving water quality (discussed further below; see Appendix B and Table 14), although relatively high concentrations were measured for manganese, aluminum, combined radium, and gross alpha. The EPA's Second Five-Year Review Report (EPA, 2003, Figure 6-7) presented Stiff diagrams for Well EPA 14 in annual "snapshots" of water quality from October 1998 through October 2002. Before October 2000, the calcium-to-magnesium (Ca/Mg) ratio was greater than one and the bicarbonate concentrations were elevated; from October 2000 to October 2002, the Ca/Mg ratio was less than one and bicarbonate was depleted. Modest exceedances of the aluminum and cobalt standards in Well EPA 14 began in 2000, when the bicarbonate concentration decreased suddenly and sharply. Figure 40 shows that the bicarbonate at this location fell sharply to nondetect (zero) in July 2001, then increased to 188 mg/L in October 2004, and then fell to nondetect again in October 2006. When the bicarbonate "comes off the floor" for either a short or extended period of time, this indicates flux in the geochemical conditions and a temporary (or extended) recovery in the groundwater systems' buffering capacity. However, since October 2006 the bicarbonate here has remained at nondetect levels.

The EPA (2003, Figure 6-8) also presented Stiff diagrams for ten Zone 3 wells based on October 2002 sampling. The following discussion refers to the Stiff diagrams shown in EPA's (2003) Figure 6-8, while also providing updates on specific changes in water quality through October 2009.

The first chemical measurements in Well NBL 1 were made in August 2001 (Appendix B), when the calcium-sulfate type of water was interpreted as representative of background water quality. Subsequently, early stage seepage impact was shown by the gradual reduction of the Ca/Mg ratio from 2001 through October 2005 (Appendix B) and the beginning of decreasing bicarbonate concentrations during approximately April 2004 (Appendix B, based on laboratory determinations of bicarbonate) and June 2004 (Table 11, based on field kit determinations of bicarbonate). However, as previously discussed, the period of gradually declining bicarbonate

trends at NBL 1 and the other northern tracking wells ended after October 2005 (see Table 11 and Figure 40). Subsequent heterogeneous and asynchronous fluctuations of bicarbonate concentrations at the northern tracking wells is attributed to the effects of extraction well pumping in their vicinity, which causes variations in the proportion of seepage-impacted versus non-impacted water that reaches the wells.

Samples from Well 420, located along the western edge of the impacted area in Figure 35, indicate a calcium-sulfate type of background water. Combined radium in this well has fluctuated above and below the Site standard from 1989 through October 2009 – this may reflect the flux of geochemically heterogeneous background water or impacted water (e.g., N.A. Water Systems, 2005b). Over the one-year period from April 2006 to April 2007, bicarbonate dropped relatively significantly from 781 mg/L to 237 mg/L. Since October 2007, uranium has persistently been greater than 0.27 mg/L for the first time in this well’s monitoring history (which started in 1989; see Appendix B). These observations are interpreted as indicating that the groundwater quality is “borderline” between background and impacted, that the seepage-impacted region is nearby, and that the groundwater quality may be degrading very gradually (though the magnesium concentrations have been approximately stable during the entire monitoring history).

Well 717, near the western edge of the seepage-impacted area in Figure 35, provides a third example of a calcium-sulfate type of water that was interpreted as predominantly background (largely non-impacted) in 2002, but has subsequently become increasingly impacted. Starting during 2006, exceedances for cobalt, nickel, and gross alpha have also occurred. Bicarbonate concentrations attained a maximum of 740 mg/L in July 2002, and subsequently decreased to nondetect during all four quarters of 2009 (Appendix B). This sharp decline is similar to that observed in Well EPA 14 (see Figure 40) and is interpreted to represent exhaustion of the local buffering capacity. The comparative water quality of 717 and EPA 14 are discussed further in Section 3.3.4.

The other seven wells depicted with Stiff diagrams (EPA, 2003, Figure 6-8) produce impacted magnesium-sulfate types of waters. For example, in October 2009 (see Appendix B) Well 613 (in the southwestern part of the impacted area shown in Figure 35) showed very high sulfate, a Ca/Mg ratio less than one, a nondetect for bicarbonate, a chloride concentration of 212 mg/L, a pH of 3.00, and exceedances for most parameters except several metals, lead, and some of the major ions. Well 613 is the most impacted Zone 3 well. Although some of the downgradient wells show significant impacts (e.g., Wells 708 and 719), they also show indications that neutralization accompanies migration from the waters’ source area.

3.3.3 Rate of Seepage Migration

Table 13 summarizes the key factors, locations, and criteria underpinning the past calculations of northward seepage travel times for Zone 3. As discussed in the 2006 annual report (N.A. Water Systems, 2007a), during that year the seepage-impact front was inferred to have receded from Well PB 4 to PB 2 as a consequence of dilution from pumping of RW 11, RW 12, RW 13, and

PB 2. In 2007 (N.A. Water Systems, 2008a), the location of the northern edge of seepage impact was inferred to have remained unchanged. In 2008 (Chester Engineers, 2009a), the leading edge of impact was inferred to have migrated from PB 4 to PB 2; as Table 13 shows, this same specific advance had previously occurred from April 2003 to February 2004. Such a repeated advance, covering the same ground locations, reflects the pumping-related hydraulic “tug of war” occurring in the vicinity of the northern tracking wells. With the advent of pumping from the northern, NW-series extraction wells in February 2009, the northern tracking wells became subject to influences from upgradient and downgradient extraction wells. The purpose of the upgradient wells (e.g., RW-series wells) is primarily to dewater and recover contaminant mass, while the purpose of the downgradient (e.g., NW-series wells) is to form a hydraulic barrier. The original purpose of calculating seepage-impact migration velocities for Table 13 equivalents, as a basis of predicting the progression of the impact reaction front, has been rendered moot by the designed actions of these extraction wells.

Since the beginning of field measurements in the PB-series northern tracking wells (October 2002), the inferred northern edge of full seepage impact had not shown a northward advance beyond Well PB 3 (refer to the related map depictions in Figure 35 the Annual Review Reports for 2002 through 2007) until 2009.

Figure 35 shows the location of the northern edge of the seepage-impact front during October 2009 at Well NBL 1. As explained in the lower block of Table 13, full seepage impact has occurred at PB 4 since November 2008, but to the north of this well there is no unequivocal basis for selecting a single location representing the leading edge of moderate seepage impact. This reflects the influence of pumping. Table 13 explains the basis for selecting NBL 1 as the “end point well” of seepage impact shown in Figure 35. The time-space variations in groundwater quality, especially the key bicarbonate and pH parameters, indicate that over the last year or more there is no clearly defined northern edge of seepage impact that is consistently advancing northward.

3.3.4 *Natural Attenuation System Performance Evaluation*

The Zone 3 natural attenuation system comprises the hydro-geochemical interactions between the bedrock matrix, the anthropogenic background waters (derived from former mine water discharge), and the tailings fluids. The natural system is attenuating the seepage impacts by the processes of neutralization, precipitation, adsorption, and mixing with the background waters.

Natural geochemical processes slow the migration of constituents associated with the acidic seepage in Zone 3 (as in the Southwest Alluvium and Zone 1). These processes neutralize the acidic seepage, which causes the precipitation and adsorption of metals and radionuclides. Evidence of this neutralization process includes: (1) increase in pH and corresponding decrease in concentrations of metals and radionuclides with increasing distance from the source area; and (2) gradual increase in bicarbonate for a few years followed by dramatic decreases in wells such as EPA 14 and 717, when acidic seepage begins migrating into a previously non-impacted (background water) area (Earth Tech, 2002d) and eventually overcomes the available buffering

capacity. Shutoff of the remaining Stage II wells in 2000 enhanced the effectiveness of the natural attenuation processes in many parts of the impacted area.

A summary of constituents detected in Zone 3 in October 2009 is provided in Table 14. Historic data are provided in Appendix B. These data indicate that the following constituents exceeded the Site standards in Zone 3:

- Sulfate and TDS;
- Metals (aluminum, beryllium, cadmium, cobalt, manganese, molybdenum, and nickel);
- Radionuclides (uranium, combined radium-226 and -228, thorium, vanadium, and gross alpha); and
- Total trihalomethanes (of which only chloroform was detected).

The geochemical processes influencing the migration of these constituents are discussed below.

Sulfate and TDS

Figure 41 is a graph of sulfate concentrations from 1989 through 2009. Concentrations are relatively high where seepage impacts have been greatest. However, as in the Southwest Alluvium, sulfate concentrations are controlled by geochemical equilibrium with gypsum (or anhydrite) and calcite. Although very high sulfate concentrations were present in the tailings fluids, such “primary” sulfate impact very rapidly attenuated downgradient. For example, compare the relatively elevated sulfate concentration in upgradient Well 613 (upper right, light blue line in Figure 41) with the much lower concentrations in all the other Zone 3 wells (grouped together in the lower part of Figure 41). Over the entire monitoring history since 1989, sulfate concentrations overall have remained within a range of approximately 5,000 to 1,800 mg/L (excluding Well 613). The upper part of this range is lower than the average background sulfate concentration in Well SBL 1 in the Southwest Alluvium (Figure 16).

Natural attenuation has reduced sulfate concentrations substantially from those reported in the tailings source area. Earth Tech (2002d, Figure 3-13) demonstrated that sulfate concentrations decreased by about 85 percent between the North Cell and the seepage-impacted water at Well 613. A similar comparison can be made using October 2009 sample data from the current northern portion of the impacted area: sulfate concentrations decrease 66 percent from Well 613 (8,690 mg/L) to the moderate-stage impacted water at Well NBL 1 (2,950 mg/L).

However, neither natural attenuation nor active remediation will reduce sulfate concentrations below the Site standard because the concentrations are controlled by groundwater equilibrium with the mineral gypsum (as in the Southwest Alluvium and Zone 1). For example, from 1989 through 1997, Well EPA 1 consistently had sulfate concentrations in the range of 2,500 mg/L to 3,000 mg/L. This well is located approximately 800 ft downgradient of the current northeastern edge of the seepage-impacted water (see Figure 35) and showed background water quality until this part of Zone 3 lost saturation. TDS also will continue to exceed the Site standard because sulfate comprises most of the TDS (as in the Southwest Alluvium and Zone 1).

Metals and Basis for Request for Revision of ROD Background Concentrations

Figures 42a and 42b are graphs of metals concentrations (from 1989 through 2009) that exceeded the Site standards: aluminum, beryllium, cadmium, cobalt, manganese, molybdenum, and nickel (the metals uranium and vanadium are discussed later with the radionuclides); the arsenic time series is included although there were no arsenic exceedances in any Site wells during the last three quarters of 2009. Arsenic, beryllium, and cadmium have MCLs under the federal Safe Drinking Water Act; aluminum and manganese have SMCLs and are non-hazardous; and cobalt, molybdenum, and nickel have neither MCLs or SMCLs.

UNC requests revision of the ROD background concentrations for arsenic, molybdenum, cobalt, and nickel (similar to the NRC revision in 1996 for the background standards for sulfate, nitrate, and TDS). The bases for this request are discussed below.

Arsenic and molybdenum exceed Site standards primarily in the background water. These two constituents have historically shown elevated concentrations in background Wells EPA 1 (now dry) and NBL 1, while very low to nondetect concentrations are found in most impacted wells, including Well 613 (see Table 14 and Figure 42b). Molybdenum has also shown long-term exceedances in impacted Well 504 B, but such occurrences may represent the local influence of background water that is mixed with impacted water.

The persistent exceedances of arsenic in NBL 1 (Figure 42b) did not occur during the last three quarters of 2009, when the values were nondetects, when the water was impacted. However, arsenic exceedances between approximately 0.5 and 1.0 mg/L from 2001 to 2004 were associated with background water – the seepage-impacted water here is better than non-impacted water regarding arsenic levels. Overall the fluctuating groundwater quality at NBL 1 during 2009 has shown degradation that included exceedances and uptrends in cobalt and nickel.

It is important to realize that background water quality is associated with metals exceedances. For example, from installation in August 2001 through mid-2004 (a period of background water quality), tracking Well NBL 1 exceeded the standards for molybdenum, nickel, and manganese. N.A. Water Systems (2008f) calculated background concentrations for all chemical parameters in all three hydrostratigraphic units through October 2007. For Zone 3 background arsenic, the UCL95 of the mean is 0.175 mg/L (the existing Site standard is 0.05 mg/L), based on 186 total data showing a range from nondetect to a maximum of 1.01 mg/L. (UCL95 refers to the upper confidence limit on the mean at the 95% confidence level.)

For Zone 3 background molybdenum, the UCL95 of the mean is 17.43 mg/L (the existing site standard is 1 mg/L), based on 184 total data showing a range from nondetect to a maximum of 75 mg/L. For Zone 3 background manganese, the UCL95 of the mean is 3.436 mg/L (the existing Site standard is 2.6 mg/L), based on 186 total data showing a range from nondetect to 7.5 mg/L. For Zone 3 background nickel, the UCL95 of the mean is 0.14 mg/L (the existing EPA Site standard is 2 mg/L, and the NRC standard is 0.05 mg/L), based on 186 total data

showing a range from nondetect to 0.67 mg/L. For Zone 3 background cobalt, the UCL95 of the mean is 0.0877 mg/L (the existing Site standard is 0.05 mg/L), based on 186 total data showing a range from nondetect to 0.53 mg/L). The metals exhibit a consistent pattern of higher concentrations in wells such as 613, 517, and 719, which have an acidic pH, and much lower concentrations where the pH is more neutral. This difference in concentrations is due to attenuation as the acidic seepage is neutralized along the groundwater flowpath.

Metals in Impacted Waters

Well 613 is located near the center of the impacted area, closest to the source area, where pH has ranged from 2.77 to 3.24 since this well was first monitored in 2000. This well shows the highest metals concentrations during October 2009 for cobalt, cadmium, beryllium, nickel, manganese, and aluminum.

During 2009 multiple metals showed increasing concentrations indicating water quality degradation in the following wells: 517, 708, 717, and 719. Figure 43 illustrates that the October 2009 distribution of aluminum exceedances was restricted to the southwestern part of the impacted area (this is a long-term distribution pattern).

During October 2009, all wells within the seepage-impacted area continued to show exceedances of manganese, cobalt, and nickel, except Well 420, near the northwestern edge, which shows borderline impacted/background water quality.

Attenuation has not stabilized the metals concentrations in some wells. In particular, the groundwater quality in Well 717 showed 2009 uptrends in beryllium, cobalt, nickel, and aluminum. The bicarbonate concentrations here have been falling sharply since July 2003 (Figure 39) and reached nondetect levels during all four quarters of 2009. In October 2009, the magnesium concentration was 548 mg/L, which is the highest value since well installation in 2001. Well 717 is 330 ft to the northeast of, and downgradient of, Well EPA 14, which started to show sharply degrading groundwater quality in 2000. Figure 39 shows that the rates of the sharp declines in bicarbonate concentrations are quite similar in both wells. In EPA 14 the sharp bicarbonate decline started during October 1999 (746 mg/L); in 717 it started in July 2003 (737 mg/L).

The time series of the metals (Figure 42) indicate the degree of impact at EPA 14 has recently been decreasing, while at 717 it has been increasing:

- EPA 14 decline in cobalt concentrations started in January 2009; at 717 cobalt is elevated and still increasing.
- EPA 14 decline in aluminum concentrations started in July 2008; at 717 aluminum is still elevated and steady.
- EPA 14 decline in manganese started in July 2008; at 717 manganese is still elevated and steady.

- EPA 14 decline in nickel started in July 2008; at 717 nickel is elevated and still increasing.
- EPA 14 decline in beryllium started in January 2009; at 717 beryllium is elevated and still increasing.
- EPA decline in cadmium started in July 2008; at 717 cadmium is still elevated and steady.
- EPA decline in cobalt started in January 2009; at 717 cobalt is elevated and still increasing.

Uranium, Vanadium, and Radionuclides

Figure 44 presents graphs of the concentrations of uranium, vanadium, combined radium, and thorium-230 from 1989 through 2009. Combined radium concentrations exceed the Site standard for Zone 3 (5 pCi/L) in the background water; consequently, radium concentrations in Zone 3 are never expected to reach the standard. This is exemplified by combined radium concentrations at well NBL 1 (Figure 44). From its installation in 2001 through approximately July 2005, combined radium concentrations at NBL-1 were approximately steady and above the Site standard; this period is interpreted as representing background water quality. Since that time and the onset of seepage impact, the overall trend has been increasing and the concentration of 31 pCi/L in October 2009 is the highest measurement here to date.

The License amendment request to change the combined radium standards (UNC, 2006), and the related NRC License amendment (NRC, 2006b), addressed only the Southwest Alluvium and Zone 1. However, the central fact underpinning the statistical analysis of background and impacted water quality (N.A. Water Systems, 2006a; technical analysis report in support of the License amendment request) is that background water, derived from the former mine water discharge into the alluvium, frequently exceeds the Site standard for radium. This fact also applies to Zone 3, which derived its background quality groundwater from the same source.

Historically, uranium, vanadium, and thorium-230 are typically present above the standards in Well 613, which has almost always had the most acidic pH (3.00 in October 2009). Downgradient toward the northeast, natural attenuation reduces the concentrations of these three radionuclides in Well 708 (pH of 3.58 in October 2009); however, since installation of this well in 1991 the concentration of uranium has been very gradually increasing. Much lower concentrations are reported where the pH is more neutral. These reductions are due to attenuation by neutralization, adsorption, or possibly precipitation. In October 2009, the only exceedances of these three constituents were in samples collected from Well 613 (see Table 14). The longer-term pattern of uranium at Well 613 has been fluctuating to approximately steady concentrations above the standard. The concentration in October 2009 (2.1 mg/L) was higher than the calculated UCL95 of the mean (0.107 mg/L; N.A. Water Systems, 2008f).

The uranium trends in NBL 1 (Figure 44) indicate a gross correlation between changing bicarbonate and uranium concentrations. The sharp upward spike in bicarbonate concentrations

here (Figure 40) appears to correspond to the relatively large increase in uranium concentrations from July 2008 (0.126 mg/L) to October 2008 (0.27 mg/L). This suggests that the geochemical covariance of uranium and bicarbonate has been occurring here (discussed earlier in the context of the Southwest Alluvium). However, since October 2008 the uranium concentrations at this location have been decreasing (0.0708 mg/L in October 2009; Figure 44), which was four months before a sharp decline in bicarbonate again occurred here (Table 11). Such disequilibrium, or dynamic variance, is likely due to mixing of distinct water types under the variable influence of extraction well pumping.

The historic amounts of gross alpha within the Zone 3 groundwater indicate that this parameter tends to fluctuate by approximately one order of magnitude in most of the impacted wells (except Well 613, which shows smaller fluctuations). The gross alpha Site standard of 15 pCi/L was exceeded in October 2009 in the following wells: 613 (long-term fluctuations), 504 B, 717, 708, EPA 14, NBL 1, and PB 2 (Table 14 and Appendix B). Since October 2004, Well 719 has remained below the standard. Well EPA 14 has demonstrated a distinctive pattern of gross alpha concentrations compared to all other impacted wells (see Appendix B). Since 1989, the values had consistently been below the standard until the last two quarters of 2003, when the values spiked upward by a factor of approximately ten. During these same two last quarters of 2003, the combined radium concentrations in this well also showed sharp upward spikes. The unusual (and singularly large) value for uranium in this well during July 2003 has been followed by the relatively large range in combined radium (Figure 44). The geochemistry of the background water (of post-mining/pre-tailings age) that seeped into the ground was heterogeneous, and it is often inherently difficult to unequivocally infer that impacted water, rather than high-concentration-bearing background water, is responsible for the pattern of exceedances at many locations. However, in either case, gross alpha concentrations in EPA 14 continued to decrease during 2009, as the seepage impact continued to wane.

Background Well NBL 2 showed an exceedance (0.3285 mg/L) of the uranium standard during its first monitoring event in July 2008.

In addition to the metals discussed earlier, declining groundwater quality at Well 717 was shown by uptrends with exceedances in uranium (0.55 mg/L in October 2009), gross alpha (35.6 pCi/L in October 2009), and combined radium (49 pCi/L in October 2009) (see Table 14).

Although neutralization of acidic seepage will continue to attenuate the radionuclides, the natural conditions will most likely prevent combined radium and gross alpha from being reduced to concentrations below the current Site standards.

Total Trihalomethanes (TTHMs)

The Site standard is no longer for chloroform per se, but rather for TTHMs pursuant to NRC License amendment 37 (NRC, 2006b). TTHMs (comprising only chloroform in all Site groundwater analyses) were detected above the Site standard in only Well 613 during October 2009 (see Figure 45). The concentrations in Well 613 have exceeded the TTHMs Site standard of 80 µg/L since October 2002, consistent with this well's proximity to the North Cell (see

Figure 35). Well 613 concentrations have shown long-term fluctuations but increased by approximately four times from July to October 2002 (166 µg/L). Since then the concentrations have shown relatively large fluctuations that are superimposed on an overall decreasing trend. For the first time since July 2002, Well 613 TTHMs fell below the Site standard in July 2009 (71.6 µg/L), and concentrations have remained below 100 µg/L since April 2008.

The only other Zone 3 locations with detected TTHMs are Wells 517 (4.72 µg/L chloroform in October 2009), EPA 14 (1.24 µg/L in October 2009), and 717 (0.55 µg/L in October 2009). Well 717 first showed chloroform detection in July 2008, and it showed detections during the last three quarters of 2009 (Appendix B). These are the first repeated detections of chloroform downgradient of Well EPA 14, and these observations once again support the inference that highly impacted water has migrated downgradient from EPA 14 to 717. Well 518 also consistently showed chloroform detections until it ceased being sampled in 2000 (Appendix B). All other Zone 3 wells have shown historic nondetects for chloroform and, since the fourth quarter of 2006, TTHMs. This indicates that groundwater to the northeast of Well 517 rapidly attenuates chloroform by degradation, dispersion, and dilution, to levels that are generally nondetect but are otherwise always far below the Site standard (which is equivalent to the primary drinking water standard).

Section 4

Zone 1

4.1 *Corrective Action Summary*

Zone 1 corrective action consisted of source remediation (neutralization and later dewatering of Borrow Pit No. 2) and pumping of a series of extraction wells from 1984 through 1999 (Earth Tech, 2002d). Well productivity in this hydrostratigraphic unit had always been very low. Earth Tech (2002d, Figure 4-1) summarized the pumping program for Zone 1, including the well systems pumped, the number of wells operating for each system, and the combined annual pumping rates. A maximum combined pumping rate of 14 gpm was achieved by the 17 East and North Cross-Dike Pump-Back wells. The productivity declined steadily over time, and by July 1999, when the system was decommissioned, the three remaining wells were yielding a combined annual average of 0.65 gpm. The three remaining Zone 1 wells (615, 616 and 617) were decommissioned at the end of July 1999 in accordance with a letter from NRC dated July 30, 1999 (Earth Tech, 2002a), with the concurrence of EPA.

4.2 *Mass of Chemical Constituents Removed*

The mass of chemical constituents removed was calculated for the 10-year period from July 1989 through July 1999. These calculations were presented in the previous annual reviews, and the final summary was presented in the 1999 Annual Review (Earth Tech, 1999).

4.3 *Performance Monitoring Evaluation*

The Zone 1 performance monitoring program is summarized in Table 15. The program consists of quarterly monitoring of water levels in 15 wells and water quality in eight wells and has been in effect since the second quarter of the 2000 operating year.

4.3.1 *Water Level Evaluation*

Historic water level data for Zone 1 wells through October 2009 are presented in Appendix C. Water levels for the fourth quarter of 2009 are shown on the potentiometric surface map in Figure 46. Water levels through time are shown on Figure 47. Saturated thicknesses calculated from the October 2009 measurements in Zone 1 are presented in Table 16. This table shows that the Zone 1 hydrostratigraphic unit remains completely saturated in most of the downdip wells: 505 A, 502 A, and 412 (in Section 36), and (TWQ)142 and (TWQ)143 (along the northern boundary of Section 36) (see Figure 46). However, during 2009, most of the wells continued to show overall decreasing piezometric elevations (usually with small fluctuations), indicating that the Zone 1 potentiometric field continues to lower as groundwater drains downdip into partially saturated parts of this bedrock stratigraphic unit.

Changes of piezometric elevations in updip and downdip wells indicate the broad pattern of the shift in the potentiometric field caused by groundwater drainage to the northeast in Zone 1. Groundwater levels in Well 504 A have risen gradually and may become fully saturated as

groundwater migrates to this portion of the confined Zone 1 hydrostratigraphic unit (see Table 16; Figures 46 and 47; and Appendix C). Similarly, the slowly rising groundwater levels at downdip Wells 142, 143, and 412 represent increasing potentiometric levels within these 100-percent saturated parts of the fully confined Zone 1 hydrostratigraphic unit. Long-term decreasing water levels updip to the south-southwest, at locations under less than fully saturated conditions, are a response to the continued flow of groundwater downdip into partially saturated parts of the system.

Earlier groundwater flow in Zone 1 was approximately eastward, reflecting groundwater mounding and recharge within the alluvium to the west. Since the dewatering of Borrow Pit No. 2 and termination of mine water discharge into Pipeline Arroyo, the former mounding has dissipated. Consequently, water levels in updip areas of Zone 1 have dropped significantly, though the rate of decline has reduced with the dissipation of recharge-induced mounding (see Figure 47). The rate of groundwater drainage is also limited by the unit's relatively low transmissivity, and the very low transmissivity of the underlying aquiclude.

UNC has submitted to NRC an ACL application for Zone 1 that presented a historic quantitative analysis of groundwater flow rates and directions (N.A. Water Systems, 2008h). In January 1983 the flow-direction azimuth (63°) had a strong easterly component. During later time periods the flow azimuth gradually rotated to the north, resulting in an azimuth of 24° during October 2007. This indicates that as the formerly higher groundwater mound has gradually continued to dissipate over the years, the northerly dip of the Zone 1 sandstone has exerted greater control on the flow direction. Darcy seepage velocities have gradually fallen through time. During January 1983, the groundwater velocity was 93 ft/yr, and by October 2007 the velocity had fallen to 40 ft/yr (a reduction of 57 percent).

4.3.2 Water Quality Evaluation and Current Extent of Seepage-Impacted Water

The temporary saturation created by the infiltration of former mine water discharges is considered the background water for Zone 1 (EPA, 1988b; 1998). This anthropogenic groundwater was later impacted by acidic seepage from Borrow Pit No. 2 in the Central Cell (compare Figure 2 and Figure 48). These seepage fluids contained elevated concentrations of metals, radionuclides, and major ions, including sulfate and chloride.

Source remediation (neutralization and subsequent dewatering of the borrow pit, and capping of the Central Cell), continued neutralization of the seepage by natural geochemical processes, and mixing with the background water have reduced concentrations of most constituents below the Site clean-up standards. However, as discussed below, exceedances of some constituents still occur in Zone 1. Appendix C provides historic constituent concentration data through October 2009. Table 17 summarizes the constituents detected in Zone 1 during October 2009.

It is important to realize that exceedances of Site standards in some wells represent background water quality. For example, since 1989 background Well EPA 4 (in Section 1) has persistently shown exceedances of sulfate, has generally shown exceedances of manganese, and has shown concentrations of combined radium that have fluctuated above and below the former Site

standard of 5 pCi/L (revised in 2006 to 9.4 pCi/L; NRC, 2006b). Background water quality is discussed further in the subsequent section entitled Natural Attenuation System Performance Evaluation.

Water quality has continued to improve since shutoff of the pumping wells, indicating that the degree of seepage impact is diminishing. Zone 1 seepage impacts have been delineated (Figure 48) by chloride concentrations greater than 50 mg/L (Earth Tech, 2000a). Well EPA 5 has shown a long-term, gradual reduction in chloride concentrations from a maximum of 289 mg/L in April 1992 to 48 mg/L in October 2009 (and six of the last seven quarters have values less than 50 mg/L – refer to Appendix C).

The zone of seepage impact has migrated predominantly toward the northeast. Further eastward components to migration are limited by the proximity of the eastern edge of saturation. The acidic “core” of the impacted zone is approximated by the area where pH is inferred to be less than 4.0 (orange area in Figure 48). Figure 49 shows historic field pH values for Zone 1 wells through October 2009. Well 604 has persistently shown the lowest pH; as discussed below, it also is the most highly impacted well. However, this well shows a long-term increasing trend in pH values (Figure 49). Figure 49 shows that starting in approximately 1990, acid neutralization and buffering resulted in substantial pH increases in Wells 515 A, 516 A, and EPA 7.

The following constituents continue to exceed the Site standards outside the property boundary in Section 1:

- TDS – Wells EPA 5 and EPA 7
- Sulfate – Wells EPA 4, EPA 5, and EPA 7
- Manganese – Well EPA 4

TDS, sulfate, and manganese are non-hazardous constituents. All of these constituents have generally exceeded standards at the cited wells since 1989. As discussed earlier, during August 2006 the NRC groundwater protection standard for combined radium was revised to 9.4 pCi/L (NRC, 2006b). There were no exceedances of this standard in October 2009.

Within the Site property, the standards were exceeded for TDS, sulfate, and manganese (Table 17). Other constituents whose standards were exceeded onsite in October 2009 were: cobalt (Well 604), nickel (Wells 515 A and 604), and TTHMs (Well 614). During October 2009, Wells 515 A and 614 exceeded the chloride standard, as has frequently occurred at these locations since the start of monitoring during 1989.

The extent of seepage impacts, as delineated by a chloride concentration greater than 50 mg/L has diminished gradually over time (e.g., compare 2008 annual report Figures 48 and 49). Many other aspects of water quality have continued to improve since shutoff, confirming that the degree of seepage impact is diminishing. Natural attenuation processes include acid neutralization by (1) reaction with the Zone 1 bedrock (which has a calcite (calcium carbonate) component of 0.03 percent (Canonie, 1987, Table 4.5)); (2) mixing with the neutral background

water; (3) precipitation of metals and radionuclides; and (4) adsorption of metals (excluding manganese) and radionuclides. These processes attenuate pH, metals, and other seepage constituents. The relatively low transmissivity of Zone 1 slows migration and increases residence time for the attenuation processes.

Outside the UNC property boundary in Section 1, the post-pumping groundwater quality continues to improve overall (Tables 17 and 18). *During October 2009 there are no exceedances of hazardous constituents outside the UNC property boundary within seepage-impacted groundwater – in fact and more broadly, this is the case for all three hydrostratigraphic units.* The exceedances of sulfate and TDS in Wells EPA 5 and EPA 7 reflect geochemical equilibrium of the groundwater with gypsum; these constituents are also non-hazardous. All of these constituents are discussed more below.

4.3.3 Natural Attenuation System Performance Evaluation

The Zone 1 natural attenuation system comprises the hydro-geochemical interactions between the bedrock matrix, the anthropogenic background waters (derived from former mine water discharge), and the tailings fluids. The natural system is successfully attenuating the seepage impacts by the processes of neutralization, precipitation, adsorption, and mixing with the background waters. However, some constituents will remain at above-standard concentrations because of the inherent geochemical characteristics of the Zone 1 background water.

Table 18 shows the predicted geochemical performance of the Zone 1 natural attenuation system (revised from Earth Tech, 2002d). In summary, sulfate and TDS concentrations are not expected to meet Site standards because gypsum equilibrium in the groundwater prevents any further reduction in sulfate concentration. Manganese may meet the Site standards if sufficient bicarbonate is available for attenuation. The remaining metals and radionuclides are expected to meet the standards through attenuation by neutralization and adsorption. Outside of Section 2, TTHMs will meet the standard through attenuation by degradation, dilution, and dispersion. The individual constituents of concern are discussed below.

Sulfate and TDS

Sulfate concentrations exceed the Site standard in both the seepage-impacted water and the background water in Zone 1. Figure 50 shows historic sulfate concentrations through October 2009; Figure 51 shows the extent of sulfate exceedances during October 2009. The time-series indicate that the operation of extraction wells prior to July 1999 did not have a discernable influence on sulfate and TDS, because sulfate concentrations in Zone 1 are controlled by the system's equilibrium with gypsum. Based on the overall stable concentrations and the results of the geochemical investigation presented by Earth Tech (2000a), sulfate is not expected to meet the clean-up standards within Section 1. As in the Southwest Alluvium and Zone 3, most of the TDS comprises sulfate (although other dissolved solids contribute significantly to the TDS in Wells 614 and EPA 7; see Appendix C)). Accordingly, TDS concentrations are not expected to meet the clean-up standards in Section 1, although they should gradually decrease to background levels. The UCL95 of the mean sulfate concentration in Zone 1 background water was

determined to be 2,773 mg/L (N.A. Water Systems, 2008f); the ROD cleanup level is 2,160 (see multiple comparison values in op cit, Table 6).

Manganese

Manganese concentrations exceed the Site standard in both the seepage-impacted water and the background water (Well EPA 4) in Zone 1. Concentrations in the seepage-impacted water are usually higher (an exception being impacted well EPA 5). These concentrations have decreased over time as the acidic seepage has been neutralized, but the magnitude of the decrease is largely controlled by the bicarbonate concentrations (Earth Tech, 2000a). Historic manganese concentrations through October 2009 are shown on Figure 52 and tabulated in Appendix C. The extent of manganese that exceeded the Site standard during October 2009 is shown on Figure 53. Figure 52 shows that the long-term decreasing trend in manganese in Well EPA 7, which started in January 1998, for the first time fell below the standard in 2006 and it has remained below the standard to present (concentration of 2.22 mg/L in October 2009).

Bicarbonate concentrations in impacted wells are related to the waters' degree of neutralization of acidic seepage. Figure 54 shows historic bicarbonate concentrations through October 2009. As discussed above regarding Zone 3, marked declines of bicarbonate concentration are indicative of (sometimes temporary) exceedance of the local buffering capacity of the natural geochemical system (i.e., the flux of acidity (temporarily) exceeds the rate of buffering). The plunge of bicarbonate concentration in Well EPA 5 from January 2000 to May 2000 is such an example. By contrast, Well 614 (Figure 54) has never shown such a falloff in bicarbonate concentrations, which is consistent with its side-gradient location with respect to former Borrow Pit No. 2. A third example of historic bicarbonate trends is provided by Well EPA 7 (Figure 54), where formerly very low bicarbonate concentrations have increased step-wise beginning in July 1990, with additional upward steps in January 1994, again in October 1998, and again in May 2000. The rising concentrations indicated that the natural attenuation neutralization capacity has recovered in a similar step-wise manner at this location, and although the rate of recovery has slowed since July 2002 it is still increasing and the historically highest bicarbonate concentration in EPA 7 was measured in October 2009 (647 mg/L).

The seepage-impacted wells that have had bicarbonate concentrations greater than 1,000 mg/L (Wells 614, 516 A, and EPA 5) either have never had manganese exceedances or have had a decrease in manganese concentration to below the standard. In contrast, impacted wells with lower bicarbonate concentrations, such as Wells 515 A, 604 and EPA 7, have historically had manganese exceedances (including 515 A and 604 in October 2009). However, even among these wells the effect of bicarbonate on manganese concentrations is well illustrated by EPA 7. Since July 1991, increasing bicarbonate concentrations in Well EPA 7 (in Section 1) have exceeded 500 mg/L (Figure 54), and the manganese concentration steadily declined through October 2008 (Figure 52). The manganese concentration during 2009 appears to have stabilized below the Site standard.

In contrast to seepage-impacted wells, long-term manganese exceedances at Well EPA 4 represent background water quality. Similarly, Well EPA 8, located beyond the tailings-impacted zone in background water to the east of EPA 4, also showed persistent manganese exceedances through the termination of groundwater quality monitoring in January 2000. Most of the other constituents at EPA 8 had been fluctuating to steady since 1989 (Appendix C).

In summary, exceedance of the manganese standard within the property boundary will continue except where there is sufficient neutralization capacity to reduce the manganese concentrations. It is also important to realize that manganese exceeds the standard in the background water quality. Manganese is a non-hazardous constituent.

Cobalt and Nickel

Excluding manganese, there are no exceedances of metals outside the property boundary in Section 1. Other metals were attenuated within the property boundary. Exceedances of cobalt and nickel are now limited to the area within the property boundary where the acidic seepage has not been fully neutralized. Historic concentrations for these two constituents through October 2009 are presented graphically in Figure 55. The extent of cobalt and nickel exceeding the Site standard during October 2009 is shown in Figure 56.

Nickel has shown a continuous decline in Well EPA 5 since January 2002 (Figure 55). Since April 2007, the concentrations have been nondetects. Cobalt has shown a continuous decline in Well EPA 5 since April 2003 (Figure 55) and concentrations have been nondetects since October 2007.

Cobalt and nickel typically do not adsorb sufficiently to reduce their concentrations below their standards until the pH is approximately 6.5 or more (Earth Tech, 2002d). For example, cobalt and nickel concentrations in Well EPA 7 historically have fluctuated around the Site standard as the pH has increased to above 6.0. Continued neutralization in Well EPA 7 has been the geochemical impetus for reductions in concentrations to levels below the standards for cobalt in April 2002, and nickel in January 2003. Empirically (Appendix C) it appears that a pH of approximately 6.0 may promote adsorption sufficient for reduction of concentrations to below the standards for both parameters.

Combined Radium-226 and Radium-228

Similar to the metals, combined radium is attenuated by neutralization, precipitation, and adsorption. The highest concentrations of combined radium are within the property boundary where the pH is more acidic (Table 17). Historic concentrations for combined radium through October 2009 are presented in Figure 57. During October 2009, the NRC combined radium Zone 1 Site standard of 9.4 pCi/L (NRC, 2006b) was not exceeded in any well (Table 17; Appendix C).

Total Trihalomethanes (TTHMs)

Exceedance of the Site standard (80 µg/L; see NRC, 2006b) for TTHMs in October 2009 occurred only in Well 614 (92 µg/L), within the property boundary. For the first time since 1992-1993, during 2009 TTHMs in Well 515 A were below the Site standard for four successive quarters. UNC recently submitted an ACL application for TTHMs in POC Well 614 and nickel in POC Well 604, which is discussed next.

4.4 Alternate Concentration Limits Application

During December 2008 UNC submitted to NRC an ACL application (N.A. Water Systems, 2008h) for TTHMs in POC Well 614 and nickel in POC Well 604. Both of these wells are located along the eastern property boundary in Section 2 (see Figure 48). This document followed NRC's guidance for organizational content and included sections addressing hazard assessment, exposure assessment, and corrective action assessment (including an As Low As Reasonably Achievable (ALARA) demonstration).

In developing the proposed ACLs, UNC has conducted concentration trend analyses from the final shutoff of Zone 1 pumping wells in July 1999 through October 2007 (with the groundwater analytical data from the first three quarters of 2008 integrated into the analyses). In addition, historic groundwater quality has been reviewed for all monitoring wells in Zone 1. Based on these observations, UNC proposes the ACL of 0.4 mg/L for nickel at POC Well 604, and the ACL of 0.3 mg/L for TTHMs at POC Well 614.

The NRC Source Materials License for the Site has a groundwater protection standard (GWPS) for nickel of 0.05 mg/L. The New Mexico Water Quality Control Commission (NMWQCC) standard for nickel is 0.2 mg/L.

The License GWPS for TTHMs is 0.08 mg/L; this is the same value as the federal MCL. The NMWQCC standard for TTHMs is 0.1 mg/L.

Since the termination of pumping, constituent concentrations have progressively reduced through natural geochemical processes (as discussed in detail for all constituents in this 2009 Annual Review Report). Nickel and chloroform are being immobilized and will not migrate any further. The analysis presented in the ACL application confirms that the spatial extent of Zone 1 seepage impact is stable to diminishing, and that natural attenuation by neutralization (buffering) and adsorption is occurring for the metals (including nickel), and that attenuation by degradation, dilution, and dispersion is occurring for chloroform.

The 20-year history of continuous groundwater quality monitoring in Zone 1 (and Site-wide) provides a sound empirical basis for evaluating contaminant transport and attenuation. The key conclusions of the ACL application are summarized below:

- There is no nickel or chloroform at concentrations above standards in any Section 1 well

- The long monitoring history provides more than sufficient time to detect exceedances and to evaluate trends.
- Source area concentrations within Section 2 show decreasing long-term trends.
- Constituent concentrations progressively decrease downgradient.
- Hydraulic gradients and groundwater flow rates are diminishing over time.
- Groundwater quality is expected to continue its improvement at the proposed point-of-exposure (Wells EPA 5 and EPA 7) from levels already below Site standards.
- There are no Zone 1 exceedances of the License GWPS in Section 36 (UNC property) or Section 1 (Indian Trust Land property), nor are there exceedances of any hazardous constituents within impacted water outside of Section 2.
- A large part of Zone 1 in Section 1 is dry, and this hydrostratigraphic unit is physically and chemically non-viable for sourcing domestic or stock water supply wells. Treatment of either the impacted or background water, to potable quality, would be extremely expensive and is not feasible.
- The proposed Zone 1 remedy of No Further Action plus ACLs will be protective of human health and the environment.
- UNC has demonstrated ALARA conditions in Zone 1.

Section 5

Conclusions and Recommendations

This annual review evaluated the performance of the natural systems in all three Site hydrostratigraphic units and the active remediation in Zone 3. In the Southwest Alluvium and Zone 1, the natural systems have functioned as effectively as when active remediation took place. During 2009, part of Zone 3 underwent continued extraction well pumping that started during the hydrofracture program in 2005 – in addition, during February 2009, extraction started in the new NW-series wells located along the northernmost area of impact. The conclusions and recommendations of this evaluation are provided below.

5.1 Conclusions

- *There are no exceedances of hazardous constituents outside the UNC property within seepage-impacted groundwater – this is the case for all three hydrostratigraphic units.*
- *If NRC approves UNC's Zone 1 ACL application, then groundwater quality will be in full compliance with the NRC groundwater protection standards in Zone 1.*
- *Groundwater quality is in full compliance with the NRC groundwater protection standards in the Southwest Alluvium.*
- Groundwater levels in the Southwest Alluvium continued to decline in 2009, indicating that the artificially-recharged zone of saturation continues to become naturally dewatered as the groundwater drains down the arroyo. However, groundwater to the north of the Nickpoint apparently has become ponded and is no longer flowing to the southwest.
- Hydraulic containment is not a necessary feature of the corrective action program in the Southwest Alluvium because of the geochemical attenuation that occurs naturally. Furthermore, former pumping of extraction wells did not contain the constituents and would not do so in the future.
- Mapping of bicarbonate isoconcentration contours is the most meaningful method of delineating seepage-impacted water in the Southwest Alluvium.
- Evaluation and prediction of constituent concentrations in the Southwest Alluvium is predicated on understanding the geochemical evolution of both the background water quality and later changes associated with passage of the seepage-impact front. Hazardous constituents derived from seepage impact are effectively attenuated to acceptable concentrations within the Site boundary.
- Sulfate, TDS, and manganese are non-hazardous constituents that exceed standards outside the Site boundary in both seepage-impacted and background wells. Sulfate (the primary component of TDS) tends to temporarily fall below the standard in the migrating reaction zone associated with the front and northwestern flank of the migrating seepage-impacted groundwater in the Southwest Alluvium. Ahead of this migrating front, background concentrations for sulfate and TDS tend to exceed the standards but this

water quality is unrelated to seepage impact and application of the Site standards is inappropriate. Behind this migrating front, impacted groundwater quality offsite will tend to have sulfate and TDS levels approximately equal to, or lower than, those in the background water due to equilibration with the mineral gypsum. Ahead of the current seepage-impact front, downgradient background well SBL 1 has shown very high sulfate and TDS and minor exceedances of manganese, cobalt, and nickel that are not due to seepage impact. Similarly, background waters in the other two hydrostratigraphic units also have shown exceedances of Site standards. For example, in Zone 3, Well NBL 1 has shown background exceedances of arsenic, cobalt, molybdenum, nickel, and combined radium. In Zone 1, Well EPA 4 has shown background exceedances of sulfate, manganese, combined radium, and lead-210 (see Appendices A, B, and C).

- The upward trend in TDS at Well GW 2 can be explained by either declining saturation levels and/or continued dissolution of alluvium mineral salts. Heterogeneous distribution of the soluble alluvium minerals is very likely affects the inter-well variations in concentrations of common dissolved ions.
- Concentrations of uranium in the Southwest Alluvium are an indicator that natural attenuation is at least as effective a remedy as pumping. With the exception of POC Well GW 3, uranium concentrations and concentration time trends have either stabilized (e.g., Wells GW 1 and GW 2) or shown decreasing trends (e.g., Well 802) since the pumps were turned off. The gradual increasing trend of concentrations at GW 3 post-dates, for the most part, the shutoff. However, this does not necessarily indicate a causal relationship. For example, nearby Southwest Alluvium Wells GW 1 and GW 2 have exhibited different concentration changes over the same time-frame. It is not clear what physical or chemical mechanism stemming from the shutoff could account for changes so heterogeneous in degree and timing over a relatively small downgradient area. Many Southwest Alluvium wells have shown that variously gradual to steep uptrends and downtrends in uranium are typical, whether they occur during pumping or in the absence of pumping.
- Uranium concentrations in the Southwest Alluvium are not related to the migration of uranium in tailings fluids. In fact, tailings solutions are far more depleted in uranium than are background solutions. This is an important consideration for the Site-Wide Supplemental Feasibility Study (SWSFS, in preparation by UNC) because it means the following: (1) uranium in tailings-impacted water is not degrading the water quality, and (2) there is no further improvement in alluvial water quality that can be made with respect to uranium concentrations. The range of uranium concentrations in the background water has been empirically shown to be the same as the range within impacted water (GE, 2006). Uranium and bicarbonate concentrations are usually covariant in the Southwest Alluvium groundwater, i.e., when the concentration of the bicarbonate parameter changes, uranium changes with it provided that there is uranium available for dissolution or desorption in the sediments. This observation has held for

both the 11 years of active pumping and the 8.7 years of post-pumping monitoring, and is theoretically expected based on principles of aqueous chemistry.

- At downgradient Well 624 the increase in bicarbonate to a chart plateau starting in May 2000 is attributed to the migration of the bicarbonate “front” associated with tailings seepage-impact. However, this well shows no covariance between the bicarbonate and uranium concentrations. At least two interpretations are possible: (1) at this well location there is little to no adsorbed or precipitated uranium (i.e., solid phase) within the alluvial sediments; and (2) aqueous uranium that originated from upgradient tailings seepage impact has been strongly attenuated during transport and it has not reached this location.
- Both the Southwest Alluvium and Zone 1 natural systems are at least as effective as the former active remediation systems in attenuating the seepage-impacted water. Acidic seepage is being neutralized, resulting in attenuation of metals and radionuclides. Natural geochemical conditions related to gypsum equilibrium and bicarbonate availability will control sulfate and manganese concentrations in both hydrostratigraphic units, regardless of whether or not the extraction wells are operated.
- Groundwater levels in Zone 3 continued to decline in 2009, indicating that the artificially recharged zone of saturation continues to diminish as the groundwater drains down the dip of the bedrock layers. Pumping of extraction wells since 2005 has locally accelerated the rate of water level decline in Zone 3.
- Groundwater quality along the northern tracking wells in Zone 3 has been oscillating between degrading and improving trends over the last seven years. Individual well water-quality trends of improvement and degradation have become collectively asynchronous since May 2007, which approximately coincides with an increase in the size and rapidity of water-quality oscillations. The variations in water quality indicate that there has been local and variable degrees of mixing of impacted water with background water drawn in from the west. This is interpreted to have been a consequence of the designed actions of extraction wells upgradient and, since February 2009, downgradient of the northern tracking wells.
- Full seepage impact has occurred at Well PB 4 since November 2008 (based on bicarbonate concentrations < 50 mg/L) or January 2009 (based on pH < 5.0). To the north of this well, there is no unequivocal basis for picking a single location representing the leading edge of moderate seepage impact. However, based on specific (though oscillating) water quality trends, the northernmost edge of moderate impact is located along Well NBL 1.
- UNC installed five new extraction wells (the NW-series) north of Well NBL 1 during September 2008. Pumping of three of these wells began in February 2009, and the pumping regime was re-optimized during early November 2009. This remedy enhancement in Zone 3 is meant to intercept and extract impacted groundwater.

- During October and November 2009, Zone 3 northern background Well NBL 2 was subjected to injection testing, in order to determine the amount of water that non-impacted areas might accept. The results of this testing were reported in Chester Engineers (2009d), which included a proposal to install a new array of injection wells (with alkalinity-amended injection water) between the NW-series wells and the northern property boundary.
- The degree of seepage impact in Zone 1 is diminishing. Groundwater elevations in Zone 1 continued to decline in 2009, causing the saturated thickness that accommodates groundwater flow and constituent migration to diminish in the updip parts of this bedrock stratigraphic unit.
- Outside the UNC property boundary in Zone 1, the post-pumping groundwater quality continues to improve overall (Tables 17 and 18). The exceedances of sulfate and TDS in Wells EPA 5 and EPA 7 reflect geochemical equilibrium of the groundwater with gypsum; these constituents are non-hazardous.
- In Zone 1, the continuing improvement in offsite water quality, combined with the stability of onsite concentrations, leads to the conclusion that the Zone 1 groundwater corrective action program has achieved success. However, closure will require meeting the Site standards, which will require that ACLs be established for POC Wells 604 (aluminum, manganese, and nickel) and 614 (TTHMs and chloride). UNC has submitted an ACL application to NRC requesting revised groundwater protection standards for nickel in Well 604 and TTHMs in Well 614 (NRC's License does not have standards for aluminum, manganese, or chloride).
- *The screened and assembled remedial alternatives for the Site have been presented in the Revised SWSFS Part II (Chester Engineers, 2009b). The proposed Site remedy has been presented for the operable unit, while incorporating key factors for each of the three hydrostratigraphic units. UNC believes that the main requirements for achieving closure of corrective action are largely administrative in nature for the Southwest Alluvium and Zone 1. Zone 3 continues to be the focus of active Site remediation.*

5.2 Recommendations

5.2.1 Recommendations for Closure of Southwest Alluvium Remedial Action

Predicted performance of the Southwest Alluvium natural attenuation system is summarized on Table 6. The continuing assessment of natural attenuation in this annual report is the basis for the following recommendations for the Southwest Alluvium corrective action system:

1. Decommission the pumping wells. Attenuation via natural geochemical processes has been shown to be at least as effective as pumping. Implement a No Further Action remedial alternative.

2. Change performance monitoring from quarterly to an annual basis because the seepage-impacted water quality is largely stable, the offsite impacted water quality is not hazardous, and a yearly frequency is sufficient for tracking the migration of the seepage-impact front (estimated to be moving southwestward toward Well SBL 1 at an average rate of 22 ft per year).
3. EPA should consider adopting the revised NRC standards (NRC, 2006b) for chloroform (revised to a total trihalomethanes (TTHMs) Site-wide standard of 80 µg/L) and combined radium (revised to 5.2 pCi/L standard for the Southwest Alluvium). EPA should also consider (a) revising their current ROD uranium standard of 5 mg/L and adopting the NRC Site-wide standard of 0.3 mg/L (based on the review of dissolved uranium occurrences in the Southwest Alluvium presented by UNC (GE, 2006)), and (b) adopting the NRC (1996) standards for sulfate, TDS, and nitrate (throughout all three Site hydrostratigraphic units). Sulfate, TDS and manganese should be waived as constituents of concern based on NRC's (1996) background water quality analysis report and multiple reports by UNC (all of which are summarized in the SWSFS Part I; N.A. Water Systems, 2007b).
4. The Southwest Alluvium is in full compliance with the NRC groundwater protection standards. EPA's longstanding reluctance to issue a TI Waiver for sulfate and TDS is confusing because there are no known groundwater analyses anywhere in the Southwest Alluvium, seepage-impacted or not, that meet the New Mexico Standards for sulfate and TDS. In lieu of eliminating sulfate and TDS concentrations as ARARs, a TI Waiver for sulfate and TDS could best be applied in a non-traditional sense in that there would not be a classic TI zone. Instead, UNC proposes that the projected 200-year seepage front (as extrapolated during 2004) be used, which we understand to be compatible with NRC guidance. Background water quality has shown modest exceedances of manganese, cobalt, and nickel; it is appropriate that the EPA consider revising the ROD to recognize the historic background water quality for these constituents in the Southwest Alluvium. We now have available statistically derived background concentrations for all constituents (data permitting) in all three hydrostratigraphic zones (N.A. Water Systems, 2008f).
5. As first put forth by the NRC (1996), and further developed in several geochemistry (Earth Tech, 2000d and 2002c) and annual reports (Earth Tech, 2002d; N.A. Water Systems, 2004, 2005b, 2007a), there is quite simply no method to achieve the standards for sulfate, TDS and manganese -- short of dewatering the alluvium. The last drop of water left in the alluvium would exceed the standards for these parameters. UNC once again requests approval of a TI Waiver for sulfate and TDS to the extrapolated, downgradient impact zone in the year 2204 shown in Figure 58. The ongoing development of a SWSFS will formally evaluate and prioritize the most appropriate remedial course of action; however, the main actions required to meet closure are administrative.

5.2.2 Recommendations for Zone 3 Remedial Action

Continue Zone 3 remediation using the natural system to stabilize the seepage impacts, in conjunction with the current pumping system that provides capture of some of the downgradient migration of seepage-impacted water, and dewater the hydrostratigraphic unit.

UNC has recently proposed (Chester Engineers, 2009d) the installation of an array of injection wells in northern Zone 3 between the NW-series wells and the northern property boundary. Alkalinity-amended injection water will serve two purposes: to neutralize impacted groundwater, and to provide a hydraulic barrier to the northward advance of the impacted water. Some of the alkalinity-amended water will flow to the south toward extraction by the NW-series of wells, while some of the alkalinity-amended water will flow to the north onto Navajo land. The proposed injection array will lead to a mixing zone of impacted and non-impacted, amended waters along the NW-series wells. Non-impacted background water may also be drawn in locally from the west.

The proposed plan intends to neutralize and geochemically stabilize the impacted water; continue to extract impacted water flowing from the south; and to impede northward advance of the impacted water. The effective life-span of the NW-series of wells is hard to predict, although experience suggests that well fouling from multiple causes will limit the spans to several years. The life-span of the new injection wells is uncertain because such wells have no historic counterparts at the site to serve as examples; however, one should assume that fouling will eventually become an issue.

UNC recommends that the agencies approve the proposed injection well installation, and that this program be implemented as soon as practicable.

Declining yields from the current extraction-well array indicate that hydraulic control is temporary. This has always been the case for pumping in Zone 3. Zone 3 saturated thicknesses are quite low (especially considering well losses), and any future pumping to reduce the pressure head will obtain only limited short-term results. Because the bedrock slope drives groundwater flow to the north, there is an irreducible elevation head that cannot be decreased by pumping. Counteracting this force is the reduction of effective porosity by the seepage-induced chemical alteration of feldspar to clay. This reduces the bedrock permeability, which retards the migration of the seepage. Eventually, there will be a balance developed between the irreducible elevation head and the trapping of the seepage-impacted groundwater due to the diminished bedrock permeability. Although the timing and location of such a balance cannot be predicted, such a development is likely. UNC recommends that consideration be given to other regulatory tools to manage the inherent physical limitations to the Zone 3 bedrock-groundwater system. As with Zone 1 and the Southwest Alluvium, the tools might include: ACLs, TI Waivers, monitored natural attenuation, and ICs.

EPA should consider revision of the ROD background concentrations for the following metals in Zone 3: arsenic, molybdenum, nickel, cobalt and manganese. Uranium should also be addressed unless EPA adopts the NRC standard for uranium.

Sulfate, TDS and manganese should be waived as constituents of concern based on NRC's (1966) background water quality analysis report.

5.2.3 Recommendations for Closure of Zone 1 Remedial Action

Predicted performance of the Zone 1 natural attenuation system is summarized on Table 18. Implement the following recommendations toward closure of the Zone 1 corrective action system:

1. EPA should consider adopting the current NRC Site-wide groundwater protection standard of 80 µg/L for TTHMs (this group of compounds includes chloroform). This value is the current MCL.
2. EPA should consider adopting the current NRC standard of 9.4 pCi/L for combined radium in Zone 1. This value is based on background water quality statistical analysis that was done for NRC in 2006 (N.A. Water Systems, 2006a), as part of an approved License amendment.
3. The Zone 1 seepage-impacted area has attained ALARA goals. Toward completing the corrective action program for Zone 1, UNC has submitted to NRC an ACL application for nickel in POC Well 604 and TTHMs in POC Well 614.
4. As first put forth by the NRC (1996), and further developed in several geochemistry (Earth Tech, 2000c) and annual reports (Earth Tech, 2000e; N.A. Water Systems, 2004, 2005b, 2007a), there is no method to achieve the standards for sulfate and TDS, and Zone 1 has already been dewatered to the extent that is feasible (the final pumping wells were decommissioned in 1999 because their yields were less than the decommissioning limit). It is not appropriate to tie remediation progress to sulfate or TDS concentrations. Even the last drop of water left in Sections 1 and 2 of Zone 1 would exceed the standards for these parameters. The EPA should approve a TI Waiver for sulfate and TDS in the TI zone shown in Figure 58. Remedial alternatives to be presented in the final, complete SWSFS should be closely coordinated with the necessary TI Waiver(s), ACL applications, other potentially appropriate changes in Site remediation standards, or ICs (EPA, 2008b).

Section 6

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Tables

Figures

TABLE 1
 Southwest Alluvium Performance Monitoring Program, 2009 Operating Year
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

Well	Use ¹	Water Level	Water Quality	NRC POC	Purpose
509 D	Monitor	X	X	Y	Seepage extent
624	Monitor	X	X		Downgradient background, seepage extent
627	Monitor	X	X		Downgradient background, seepage extent
632	Monitor	X	X	Y	Seepage extent
801 ²	Pumping (idled)	X	X		Seepage and saturation extent
802	Pumping (idled)	X	X		Seepage and saturation extent
803	Pumping (idled)	X	X		Seepage and saturation extent
805	Monitor	X			Water level only
807	Monitor	X			Water level only
808 ³	Pumping (idled)	X	X		Seepage extent
EPA 23	Monitor	X	X	Y	Problematic completion
EPA 25	Monitor	X	X		Downgradient background, seepage extent
EPA 28	Monitor	X	X	Y	Seepage extent
GW 1	Monitor	X	X	Y	Seepage extent
GW 2	Monitor	X	X	Y	Seepage extent
GW 3	Monitor	X	X	Y	Downgradient background, seepage extent
Total		16	14		

Eliminated From Monitoring				Reason for Elimination
GW 4	X	X		Dry
EPA 22A			Y	Dry
29A				Dry
639				Dry
642				Dry
644				Dry
645				Dry
804				Not needed, use 632
806				Not needed, use 805
EPA 27				Dry

Notes:

- 1 Pumping wells turned off in January 2001 after final baseline samples were collected. Well 801 is the exception, see Note 2.
- 2 Well 801 was turned off at the end of July 1999 because it met decommissioning criteria. Sample collection ceased after the first quarter 2000. Well 801 water quality is included in the test program, therefore sampling recommenced January 2001 and has continued through 2003.
- 3 Well 808 was not included in the Performance Monitoring Program prior to the NA Test, therefore no data are available prior to January 2001.

TABLE 2
 Detected Constituents in Southwest Alluvium, October 2009
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

Chemical Name	Action Level	Unit	0509 D	0624	0627	0632	0801	0802	0803	0808	EPA 23	EPA 25
ALUMINUM	5	mg/l				0.1						
AMMONIA (AS N)		mg/l	4.30			0.64	4.0 D	0.07	3.09	0.16	2.04	
BICARBONATE (HCO3)		mg/l	2500	1490	583	1970	1510	2160	1820	1880	1220	1130
CALCIUM		pci/l	878 D	643 D	510	589 D	540 D	593 D	622 D	739 D	616	717
CHLORIDE	250	mg/l	367	187	44	258	215	208	159	169	98	88
COBALT	0.05	mg/l										
GROSS ALPHA	15	mg/l	1						0.9			
MAGNESIUM		mg/l	418	396	240	776	701	941	751	639	384	230
MANGANESE	2.6	mg/l	3.35	0.15	0.02	2.32	4.67	1.01	2.15	0.77	5.05	0.46
NICKEL	0.05	mg/l										
NITRATE (NO3)	190	mg/l	11.0	75 D	111 D	80 D	2.2	105 D	43 D	126 D	7.4	77 D
PH (FIELD)		su	6.44	6.44	6.93	6.24	6.47	6.51	6.43	6.34	6.58	6.70
PH (LAB)		su	7.16	7.17	7.67	7.37	7.10	7.13	7.09	7.09	7.22	7.53
POTASSIUM		mg/l	13	6	5	9	12	6	13	4	10	7
RADIUM-226		pci/l	0.69	0.56	0.36	0.99	0.91	0.67	0.47	0.61	0.42	0.13
RADIUM-226 plus 228	5	pci/l	1.58	1.35	1.17	3.59	2.11	1.45	1.77	0.31	1.62	0.34
SODIUM		mg/l	379 D	245 D	483	390 D	329 D	345 D	275 D	322	138	173
SULFATE (SO4)	2125	mg/l	1910 D	1960 D	2440 D	3610 D	3420 D	3700 D	3450 D	3180 D	2220 D	1820 D
TOTAL DISSOLVED SOLIDS	4800	mg/l	5600	4950	4530	7240	6530	7180	6950	6740	4610	4150
TOTAL TRIHALOMETHANES	80	ug/l				3.06	2.21	17.2	11.3	7.00		
URANIUM	0.3	mg/l	0.239	0.0315	0.0213	0.0764	0.0393	0.143	0.0780	0.123	0.0309	0.128

TABLE 2
 Detected Constituents in Southwest Alluvium, October 2009
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

Chemical Name	Action Level	Unit	EPA 28	EPA 28 Dup	GW 1	GW 2	GW 3	SBL-01
ALUMINUM	5	mg/l					1.5	0.1
AMMONIA (AS N)		mg/l			0.62			
BICARBONATE (HCO3)		mg/l	824	707	1870	2320	1430	446
CALCIUM		pci/l	515 D	514	717 D	599 D	889 D	469 D
CHLORIDE	250	mg/l	120	124	237	222	201	88
COBALT	0.05	mg/l				0.01		0.02
GROSS ALPHA	15	mg/l						
MAGNESIUM		mg/l	476	469	645	1060	281	1120
MANGANESE	2.6	mg/l	0.71	0.58	0.05	1.35	1.52	3.15
NICKEL	0.05	mg/l						0.07
NITRATE (NO3)	190	mg/l	34 D	30.1 D	97 D	13.9	124 D	43 D
PH (FIELD)		su	6.65		6.43	6.19	6.38	6.63
PH (LAB)		su	7.40	7.80	6.98	6.66	7.37	7.45
POTASSIUM		mg/l	11	11	7	13	8	13
RADIUM-226		pci/l	0.73	0.68	0.40	0.29	0.25	1.1
RADIUM-226 plus 228	5	pci/l	2.13	1.39	0.98	1.59	0.51	2.9
SODIUM		mg/l	209 D	218	385 D	374 D	283 D	285 D
SULFATE (SO4)	2125	mg/l	2850 D	2990 D	3340 D	4720 D	2240 D	5960 D
TOTAL DISSOLVED SOLIDS	4800	mg/l	5160	5060	6640	8580	5430	9000
TOTAL TRIHALOMETHANES	80	ug/l			2.08	3.57		
URANIUM	0.3	mg/l	0.0450	0.0406	0.104	0.0896 D	0.151	0.0142

Table 3
 Southwest Alluvium Saturated Thickness, October 2009
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

Well	Water Level Measurement Date	SW Alluvium Unsaturated Thickness	SW Alluvium Saturated Thickness	SW Alluvium Percentage Saturated
0509 D	10/5/09	75.95	34.05	31%
0624	10/5/09	50.39	24.61	33%
0627	10/6/09	57.79	13.21	19%
0632	10/6/09	42.65	24.35	36%
0801	10/5/09	47.88	12.62	21%
0802	10/5/09	45.78	35.72	44%
0803	10/5/09	60.61	57.39	49%
0805	10/14/09	48.05	71.95	60%
0807	10/14/09	53.64	46.36	46%
0808	10/6/09	47.43	84.57	64%
EPA 23	10/5/09	50.85	69.15	58%
EPA 25	10/6/09	50.70	19.30	28%
EPA 28	10/5/09	60.15	17.85	23%
GW 1	10/6/09	59.60	17.40	23%
GW 2	10/6/09	53.39	36.61	41%
GW 3	10/6/09	51.83	5.17	9%
SBL-01	10/5/09	47.38	17.62	27%

TABLE 4
 Summary of Operational Data
 Southwest Alluvium Extraction Wells 1989 to 2001
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

Well No.	Annual Average Pumping Rate (gallons per minute)												1990-2001
	1990 ⁽¹⁾	1991 ⁽²⁾	1992 ⁽³⁾	1993 ⁽⁴⁾	1994 ⁽⁵⁾	1995 ⁽⁶⁾	1996 ⁽⁷⁾	1997 ⁽⁸⁾	1998 ⁽⁹⁾	1999 ⁽¹⁰⁾	2000 ⁽¹¹⁾	2001 ⁽¹²⁾	
801 ⁽¹³⁾	1.2	0.5	0.4	0.2	0.2	0.1	0.1	0.1	0.08	0.08	0.00	0.00	0.25
802	11.1	12.5	11.9	9.0	9.8	9.7	9.1	10.1	11.02	9.62	9.31	5.80	9.91
803	2.0	2.6	2.5	3.0	3.2	3.5	3.1	2.9	3.84	3.56	3.83	3.68	3.14
808 ⁽¹⁴⁾		10.0	15.5	19.9	15.6	12.3	12.2	7.2	4.34	3.50	2.50	3.35	9.67
Total Pumping Rate	14.3	25.6	30.3	32.1	28.8	25.6	24.5	20.3	19.29	16.76	15.64	11.94	22.98
Volume Pumped (millions of gallons) ⁽¹⁵⁾	7.4	12.4	17.2	18.1	15.7	12.9	12.2	9.2	9.0	7.5	7.7	1.7	131.0

Notes:

1. Average pumping rate calculated for the period between October 13, 1989, and October 12, 1990.
2. Average pumping rate calculated for the period between October 13, 1990, and October 11, 1991, except Well 808, which calculated for the period between June 26, 1991 (i.e., well startup) and October 11, 1991.
3. Average pumping rate calculated for the period between October 12, 1991, and October 8, 1992.
4. Average pumping rate calculated for the period between October 9, 1992, and October 8, 1993.
5. Average pumping rate calculated for the period between October 9, 1993, and October 14, 1994.
6. Average pumping rate calculated for the period between October 15, 1994, and September 29, 1995.
7. Average pumping rate calculated for the period between September 30, 1995, and September 27, 1996.
8. Average pumping rate calculated for the period between September 28, 1996, and September 26, 1997.
9. Average pumping rate calculated for the period between September 27, 1997, and September 25, 1998.
10. Average pumping rate calculated for the period between October 02, 1998, and September 27, 1999.
11. Average pumping rate calculated for the period between September 28, 1999, and September 29, 2000.
12. Average pumping rate calculated for the period between September 30, 2000, and January 12, 2001.
13. Well 801 decommissioned at the end of July 1999.
14. Well 808 began operation on June 26, 1991.
15. Data obtained from system flowmeter.

Source: Earth Tech, December 2002, Figure 2.1

TABLE 5

Southwest Alluvium Groundwater Velocities, October 2009
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Well Pair 805 and 624

Groundwater Elevations: 6862.00 (Well 805) and 6847.77 (Well 624) ft amsl
Separation Distance: 1902 ft
Average Linear Horizontal Hydraulic Gradient: 0.0075
Velocity 1 = 59 ft/yr
Velocity 2 = 45 ft/yr
Average Velocity = 52 ft/yr

Well Pair 805 and 627

Groundwater Elevations: 6862.00 (Well 805) and 6834.02 (Well 627) ft amsl
Separation Distance: 3203 ft
Average Linear Horizontal Hydraulic Gradient: 0.0087
Velocity 1 = 67 ft/yr
Velocity 2 = 52 ft/yr
Average Velocity = 60 ft/yr

Well Pair 624 and SBL 1

Groundwater Elevations: 6847.77 (Well 624) and 6846.11 (Well SBL 1) ft amsl
Separation Distance: 500 ft
Average Linear Horizontal Hydraulic Gradient: 0.0033
Velocity 1 = 25 ft/yr
Velocity 2 = 19 ft/yr
Average Velocity = 22 ft/yr

Darcy seepage velocity calculation input values:

Mean hydraulic conductivity used = 2×10^{-3} cm/s (USFilter, 2004b).

Range of effective porosities = 27% (velocity 1) to 35% (velocity 2) (Canonie, 1989b; Earth Tech, 2002c).

TABLE 6
 Predicted Performance of Southwest Alluvium Natural Attenuation, 2009
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

Constituent	Will Standards Be Met?			Remarks
	Section 2	Section 3	Section 10	
Manganese	No	Yes?	No	Section 2 includes onsite seepage impact; Section 3 includes offsite seepage impact with Mn attenuated and known background water with Mn below standard; Section 10 includes advancing front of seepage impact with Mn below standard but Mn slightly above standard occasionally in background Well SBL 1 (see Table 2 and Table A.1 in Appendix A)
Sulfate	No	No	No	Seepage impact areas limited by calcium availability; background waters characterized by exceedances unrelated to seepage impact; highest sulfate concentrations occur in background Well SBL 1 but note increases in impacted Well GW 2 (see Figures 9 and 14)
TDS	No	No	No	Governed by sulfate concentration; highest TDS concentrations occur in background Well SBL 1 but note increases in impacted Well GW 2 (see Figure 17)
Metals	Yes	Yes?	No	Attenuation by neutralization and adsorption. Section 2 includes onsite seepage impact with no exceedances; Section 3 includes offsite seepage impact and known background water with no exceedances; Section 10 includes advancing front of seepage impact with no exceedances but small exceedances of nickel in background Well SBL 1 continued during 2009 (see Table 2)
Radionuclides	Yes	Yes	Yes	Attenuation by neutralization and adsorption
TTHMs	Yes	Yes	Yes	Attenuated by degradation, dilution, dispersion

TABLE 7
Change in Zone 3 Saturated Thickness Over Time
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

Well Number ¹	Saturated Thickness		Change (feet)	Change
	3rd Quarter 1989	4th Quarter 2009		
402	--	19.34	--	--
411	62.5	--	--	--
420	56.3	8.36	-47.9	-85%
424	--	20.79	--	--
446	--	7.32	--	--
501 B	20.2	--	--	--
502 B	48.5	--	--	--
504 B	40.1	6.38	-33.7	-84%
517	42.7	11.67	-31.0	-73%
518 ²	37.2	--	--	--
613 ³	67.2	19.36	-47.8	-71%
EPA 01	14.7	--	--	--
EPA 03	8.3	--	--	--
EPA 09	8.1	3.60	-4.5	-56%
EPA 11	30.8	--	--	--
EPA 12	10.7	--	--	--
EPA 13	24.8	8.49	-16.3	-66%
EPA 14	76.3	27.00	-49.3	-65%
EPA 15	60.8	--	--	--
EPA 17	1.4	--	--	--
EPA 18	2.5	--	--	--
701	46.1	16.34	-29.8	-65%
702	24.1	9.01	-15.1	-63%
703	32.6	19.22	-13.4	-41%
705	--	--	--	--
706	--	17.03	--	--
707	58.8	14.60	-44.2	-75%
708	49.8	15.70	-29.8	-60%
709	56.1	14.23	-41.9	-75%
710	45.5	13.23	-32.3	-71%
711	43.7	19.30	-24.4	-56%
712	39.1	6.34	-32.8	-84%
713	34.2	9.56	-24.6	-72%
714 ⁴	50.1	17.26	-32.8	-66%
715 ⁴	47.6	10.38	-37.2	-78%
716 ⁴	58.3	18.99	-39.3	-67%
717 ⁴	57.6	21.01	-36.6	-64%
718 ⁴	51.1	17.78	-33.3	-65%
719 ⁴	39.9	8.83	-31.1	-78%
720 ⁴	33.1	3.36	-29.7	-90%
NBL-01 ⁵	--	13.55	--	--
Average	37.3	13.73	-31.6	-69%

Notes:

- ¹ Wells 9 D and 106 D were not included because they appear to be completed above the bottom of Zone 3. Measurements of saturated thickness in these wells may be less than actual conditions. Well 126 was not included because it was completed above the bottom of Zone 3. Measurements of saturated thickness in this well are less than actual conditions. Wells 600, 610 and 672 were not included because they were used solely as pumping wells, therefore no water level data are available. Well 608 was not included because no water level data were available in 1989 and the last water level measurement was in February 2000.
 - ² Water level for Well 518 last measured in January 2000.
 - ³ Water level for Well 613 measured in 1983 before pumping started. Water level data for 1989 are not available because the well was pumping.
 - ⁴ Water levels for the Stage II wells were measured June 1991 when wells were installed. Not included in 1989 average saturated thickness calculation.
 - ⁵ Well NBL-01 installed in July 2001 and first water level measured in August 2001.
- Shading indicates saturated thickness greater than 25 feet.
"--" indicates that no data is available.

TABLE 8
 Estimated Mass Removal by Extraction Well Pumping in Zone 3, December 2008 Through November 2009
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

Well	Water Pumped (gallons)	SO4 (kg)	NO3 as N (kg)	Chloroform (g)	Al (kg)	As (g)	Be (g)	Co (g)	Pb (g)	Mn (kg)	Mo (g)	Ni (g)	U (g)	Total Radium (mci)	Pb-210 (mci)	Gross Alpha (mci)
RW-11	324,102	3,104	0.1	0.3	0.1	5	1	196	31	5	245	221	164	27	0.49	12
RW-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0
RW-13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0
RW-15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0
RW-16	193,494	3,310	19.2	0.4	106	0.4	81	725	18	17	37	644	0.4	36	0.07	26
RW-17	263,405	3,948	0.05	0.2	2	0.5	5	608	25	6	50	668	23	12	1.00	4
PB-2	195,677	2,466	0.04	0.2	1	0.4	4	281	19	4	370	363	50	21	1.19	14
RW-A	230,664	2,305	0.17	0.2	0.0	0.4	4	140	22	4	175	157	97	28	0.87	11
NW-1	19,770	221	0.00	0.0	0.0	0.0	0	31	2	1	75	31	5	2	0.06	2
NW-2	359,268	4,011	0.07	0.3	0.3	0.7	7	558	34	11	1,360	558	96	42	1.09	34
NW-3	366,988	4,098	0.07	0.3	0.3	0.7	7	570	35	11	1,389	570	98	43	1.11	35
NW-4	23,434	262	0.00	0.0	0.0	0.0	0	36	2	1	89	36	6	3	0.07	2
NW-5	35,358	395	0.01	0.0	0.0	0.1	1	55	3	1	134	55	9	4	0.11	3
Total	2,012,159	24,120	20	2	111	8	109	3,200	190	61	3,923	3,302	550	219	2	145

Notes:

Wells are located on Figure 38 of the *2009 Annual Review Report*.

Wells RW-12, RW-13, and RW-15 were not pumped, because of negligible capacity.

Units for radionuclides (mci) are not mass units proper; mci are milli-Curies, or thousandths of Curies.

In developing this table, masses were estimated from analyses of October 2009 samples, except for RW-16 and RW-17 where concentrations were based on the samples from nearby wells 717 and 719.

Nonradiological nondetects were assigned values of one-half the reporting limit.

Radiological results were assigned as reported (even if negative).

TABLE 9
 Zone 3 Performance Monitoring Program, 2009 Operating Year
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

Well	Water Level	Water Quality	NRC POC	Purpose
Continue Monitoring				
420	X	X		Postmining-pretailings background, track plume.
711	X	X	Y	Track saturation and plume, replace 502 B based on results of low flow purge testing performed in January 2000.
504 B	X	X		Track saturation and plume, extensive data set.
517	X	X	Y	Track plume, extensive data set.
EPA 9	X			Extent of saturation, water quality not necessary.
EPA 13	X	X		Extent of saturation. Water quality added 2nd quarter 2001.
EPA 14	X	X		Postmining-pretailings background, track plume.
702	X			Water level only, track saturation.
710	X			Water level only.
712	X			Water level only.
713	X			Water level only.
714	X			Water level only.
613	X	X	Y	Extensive data set, track saturation and source.
701	X			Water level only (decommissioned pumper).
706	X			Water level only (decommissioned pumper).
707	X			Water level only (decommissioned pumper).
708	X	X	Y	Added to program 2nd quarter 2001.
717	X	X		Water level. Water quality added 2nd quarter 2001.
719	X	X		Water level. Water quality added 2nd quarter 2001.
Additional Wells, Not Included In Original Performance Monitoring Program				
402	X			Long-term water level for migration path.
424	X			Long-term water level for migration path.
446	X			Long-term water level for migration path.
NBL-01	X	X		Well drilled and installed June 2001. Water level and water quality to track downgradient extent of seepage.
Total	23	11		

Eliminated From Monitoring			Reason For Elimination
9 D			Dry
106 D			Dry
411			Oil, cannot get water level or sample.
501 B		Y	Dry
EPA 1			Dry
EPA 3		Y	Dry
EPA 11			Unuseable since 1990 - water level below pump, pump cemented in well.
EPA 12			Dry
EPA 15			Dry
EPA 17			Dry
EPA 18			Dry
126			Dry
502 B			Failed low-flow test, use 711
518		Y	Failed low-flow test, use 517
608			Not needed (formerly water level only)
703			Not needed (formerly water level only)
715			Not needed (formerly water level only)
709			Not needed (decommissioned pumper)
716			Not needed (pumper)
718			Not needed (pumper)
720			Not needed (decommissioned pumper)

Notes:

NRC POC = Nuclear Regulatory Commission Point of Compliance well

Source: Earth Tech, December 2002, Table 3.2

TABLE 10

Zone 3 Saturated Thickness, October 2009
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

Well	Water Level Measurement Date	Zone 3 Unsaturated Thickness	Zone 3 Saturated Thickness	Zone 3 Percentage Saturated
0402	10/15/09	43.66	19.34	31%
0420	10/13/09	42.64	8.36	16%
0424	10/15/09	52.21	20.79	28%
0446	10/15/09	57.68	7.32	11%
0504 B	10/13/09	59.62	6.38	10%
0517	10/12/09	50.33	11.67	19%
0613	10/7/09	48.64	19.36	28%
0701	10/14/09	47.66	16.34	26%
0702	10/14/09	71.99	9.01	11%
0703	10/14/09	72.78	19.22	21%
0706	10/14/09	60.97	17.03	22%
0707	10/14/09	73.40	14.60	17%
0708	10/12/09	69.30	15.70	18%
0709	10/15/09	62.77	14.23	18%
0710	10/14/09	67.77	13.23	16%
0711	10/12/09	65.70	19.30	23%
0712	10/14/09	79.66	6.34	7%
0713	10/14/09	63.44	9.56	13%
0714	10/14/09	20.74	17.26	45%
0715	10/15/09	24.62	10.38	30%
0716	10/15/09	45.01	18.99	30%
0717	10/13/09	49.99	21.01	30%
0718	10/15/09	29.22	17.78	38%
0719	10/13/09	36.17	8.83	20%
0720	10/15/09	50.14	3.36	6%
EPA 09	10/12/09	46.40	3.60	7%
EPA 13	10/13/09	55.51	8.49	13%
EPA 14	10/6/09	46.00	27.00	37%
MW-2	10/15/09	46.88	13.55	22%
MW-3	10/21/09	45.34	15.58	26%
MW-4	10/21/09	48.58	0.14	0%
MW-5	10/21/09	40.48	3.72	8%
NBL-01	10/13/09	29.26	15.05	34%
NBL-02	10/13/09	48.67	28.90	37%
NW-1	10/13/09	41.32	2.97	7%
NW-2	10/13/09	30.91	20.21	40%
NW-3	10/13/09	30.42	27.39	47%
NW-4	10/13/09	32.97	17.39	35%
NW-5	10/13/09	30.20	27.81	48%
PB-02	10/13/09	35.21	12.39	26%
PB-03	10/13/09	30.11	16.86	36%
RW-11	10/13/09	49.26	12.58	20%
RW-15	10/15/09	45.50	25.44	36%
RW-16	10/15/09	55.33	7.77	12%
RW-17	10/15/09	70.86	2.37	3%
RW-A	10/13/09	62.22	5.65	8%
Z3 M-01	10/14/09	42.83	0.35	1%
Z3 M-02	10/14/09	43.54	0.00	0%

TABLE 11
 Zone 3 Field Parameter Measurements of Tracking Wells, Through October 2009
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

Date	Bicarbonate (mg/L)						Conductivity (umhos/cm)						pH (s.u.)						Chloride (mg/L)									
	0504 B	PB-02	PB-04	PB-03	NBL-01	NBL-2	RW-A	0504 B	PB-02	PB-04	PB-03	NBL-01	NBL-2	RW-A	0504 B	PB-02	PB-04	PB-03	NBL-01	NBL-2	RW-A	0504 B	PB-02	PB-04	PB-03	NBL-01	NBL-2	RW-A
Oct-02	0	58	194	224	330			5,010	4,040	3,730	3,670	3,160			5.06	7.09	7.10	7.10	7.18			NA	25.3	23.8	113.0	NA		
Nov-02	0	41	188	299	285			4,930	3,080	2,860	2,510	3,120			5.30	5.95	6.47	6.60	6.51			14.0	26.5	24.3	23.8	21.0		
Dec-02	22.9	57	178	283	NA			5,040	4,120	3,950	3,330	NA			5.40	5.75	6.40	6.68	NA			22.9	26.2	23.2	25.7	NA		
Jan-03	0	34	148	239	311			5,180	3,930	3,716	3,460	3,300			5.54	4.97	6.92	6.41	6.43			NA	NA	22.9	22.8	NA		
Feb-03	0	58	193	324	328			3,620	2,910	2,660	2,570	2,300			3.52	5.57	6.96	6.92	6.53			26.7	30.1	30.4	28.5	21.5		
Mar-03	NA	60	188	311	326			4,000	3,090	2,890	2,680	2,500			3.49	5.59	6.71	6.95	6.73			26.4	30.1	29.7	29.7	22.1		
Apr-03	NA	34	172	310	321			4,210	4,460	4,220	3,820	2,650			5.14	5.46	5.94	6.26	6.87			26.6	30.5	30.0	30.1	21.6		
May-03	0	34	167	293	322			5,510	4,460	4,210	3,820	3,390			5.01	5.36	5.99	6.31	6.37			28.0	31.0	30.2	31.9	32.7		
Jun-03	0	21	129	267	316			5,470	4,480	4,060	3,820	3,380			4.28	5.15	6.17	6.20	6.36			27.7	30.8	29.6	30.6	28.0		
Jul-03	NA	32	126	257	311			5,480	4,560	4,330	3,920	3,500			5.35	5.28	5.85	6.32	6.29			26.5	30.6	29.7	31.1	25.8		
Aug-03	NA	5	100	234	307			5,210	4,280	3,960	3,630	3,230			5.14	5.18	5.76	6.18	6.28			27.0	30.4	29.7	31.1	23.1		
Sep-03	NA	7	91	218	295			5,260	4,400	4,160	3,770	3,340			4.68	5.23	5.79	6.28	6.39			28.0	30.5	29.3	31.5	26.7		
Oct-03	NA	0	65	211	295			5,360	4,450	4,210	3,860	3,410			5.48	5.18	5.81	6.34	6.41			27.7	21.0	30.0	32.7	26.8		
Nov-03	NA	0	73	197	285			5,290	4,510	4,210	3,880	3,490			5.09	5.25	5.81	6.24	6.42			27.3	30.6	30.2	32.1	24.8		
Dec-03	NA	NA	41	166	265			5,370	4,540	4,290	3,910	3,510			4.41	5.14	5.77	6.76	6.48			27.7	30.2	29.8	31.5	25.2		
Jan-04	NA	NA	73	194	327			5,340	4,610	4,310	4,030	3,550			5.39	5.16	5.82	7.51	6.50			32.5	30.5	29.5	32.6	26.8		
Feb-04	NA	NA	50	190	323			5,410	4,630	4,260	3,970	3,590			3.40	3.81	5.99	6.25	6.40			28.0	30.1	30.3	32.7	26.6		
Mar-04	NA	15	48	179	316			5,560	4,730	4,500	4,130	3,780			3.89	4.75	5.70	6.31	6.29			27.5	30.1	30.2	33.3	25.9		
Apr-04	NA	15	48	174	315			5,370	4,560	4,380	4,010	3,630			5.36	5.08	5.52	6.03	6.34			28.1	32.1	32.3	36.2	31.1		
May-04	NA	0	27	166	312			6,190	4,390	4,160	3,870	3,510			3.26	5.02	5.34	5.88	6.23			28.4	33.2	32.8	38.1	31.9		
Jun-04	NA	0	22	152	294			5,510	4,530	4,400	4,040	3,750			4.48	4.92	5.46	6.05	6.40			28.2	32.6	32.9	37.7	34.1		
Jul-04	NA	0	20	140	274			5,450	4,510	4,420	4,000	3,740			5.48	5.04	5.58	6.05	6.45			27.8	31.9	32.8	36.9	34.1		
Aug-04	NA	0	17	124	272			5,500	4,450	4,380	4,040	3,710			3.77	4.26	5.45	5.98	6.39			28.3	31.0	32.3	36.2	33.7		
Sep-04	0	0	20	117	251			5,480	4,500	4,430	4,030	3,790			4.04	4.46	5.48	6.05	6.45			28.5	30.9	32.5	36.0	34.0		
Oct-04	0	0	18	102	245			5,520	4,540	4,560	4,110	3,940			5.56	5.15	5.62	6.08	6.47			27.8	31.5	32.0	30.2	33.2		
Nov-04	0	0	17	98	245			5,370	4,400	4,340	3,950	3,840			4.46	4.23	5.47	5.99	6.37			28.8	31.4	32.3	35.6	32.0		
Dec-04	0	0	13	87	207			5,290	4,340	4,290	3,920	3,790			4.46	4.28	5.44	5.95	6.36			28.3	31.2	31.0	34.0	30.0		
Jan-05	11	0	32	79	198			5,700	4,610	4,520	4,110	4,080			5.31	3.92	5.46	6.03	6.29			29.1	31.3	31.3	33.8	34.2		
Feb-05	0	0	7	68	196			5,680	4,720	4,550	4,130	3,980			3.92	3.24	5.31	5.98	6.37			28.0	31.5	31.3	33.4	30.0		
Mar-05	0	0	0	60	169			5,540	4,510	4,350	3,990	3,960			3.84	3.72	5.32	5.93	6.27			24.5	31.3	32.0	33.7	35.2		
Apr-05	8	0	29	70	154			5,350	4,300	4,340	3,980	3,890			4.46	4.25	5.56	5.88	6.31			27.8	32.4	32.2	34.0	35.1		
May-05	0	0	0	67	150			5,300	4,290	4,170	3,840	3,810			4.33	3.78	4.53	5.85	6.30			28.5	32.6	30.6	33.4	34.6		
Jun-05	0	0	0	65	138			5,400	4,330	4,280	3,980	3,910			4.06	3.93	4.63	5.77	6.15			28.1	32.1	31.0	33.6	34.7		
Jul-05	0	0	0	67	123			5,020	4,150	4,100	3,780	3,640			5.10	3.55	4.04	5.58	5.88			27.9	31.2	31.9	33.1	34.3		
Aug-05	0	0	0	57	122			5,270	4,320	4,360	3,880	3,730			3.40	3.39	3.29	5.89	6.62			28.4	31.5	31.6	34.2	34.2		
Sep-05	0	NA	0	54	111			5,430	NA	4,230	3,920	3,830			3.58	NA	4.15	5.80	6.24			28.4	NA	31.3	33.2	34.1		
Oct-05	0	NA	0	51	107			5,630	NA	4,410	4,220	4,030			5.45	NA	4.99	6.00	6.26			28.3	NA	31.3	33.6	34.0		
Nov-05	0	NA	5	48	96			5,550	NA	4,180	4,080	3,940			3.75	NA	5.45	5.76	6.25			28.7	NA	33.0	34.2	34.2		
Dec-05	0	NA	22	44	77			5,670	NA	4,190	4,060	3,950			3.38	NA	5.92	5.97	6.43			33.3	NA	35.6	34.1	31.6		
Jan-06	0	NA	28	89	128			5,720	NA	4,110	4,330	4,250			5.22	NA	6.30	6.36	6.47			29.4	NA	45.0	35.2	32.2		
Feb-06	0	NA	101	117	126			5,670	NA	4,350	4,250	4,040			3.83	NA	6.19	6.14	6.38			27.5	NA	41.3	37.5	49.0		
Mar-06	0	NA	190	133	132			5,850	NA	4,290	4,310	4,060			4.14	NA	6.19	6.18	6.18			27.6	NA	43.7	39.9	38.8		
Apr-06	0	NA	244	139	119			5,710	NA	4,280	4,310	5,710			5.21	NA	6.24	6.17	6.10			28.9	NA	44.3	41.0	34.0		
May-06	0	NA	246	138	112			5,740	NA	4,180	4,290	4,130			4.12	NA	6.16	6.02	6.01			28.3	NA	45.1	42.0	33.9		
Jun-06	0	104	249	138	130			5,680	4,280	4,160	4,450	4,080			4.12	5.86	6.14	6.08	6.02			29.0	44.3	45.8	42.0	32.8		
Jul-06	0	134	230	217	138			5,140	4,020	3,750	4,060	3,810			5.06	5.90	6.13	6.14	6.06			29.4	40.7	45.0	50.5	37.0		
Aug-06	0	160	232	227	137			5,340	4,050	3,860	4,140	3,850			3.89	6.04	6.17	6.34	6.24			27.6	43.1	47.2	50.0	37.8		
Sep-06	0	137	235	278	155			5,350	3,960	3,740	3,980	3,870			3.41	6.00	6.16	6.45	6.49			27.8	38.7	27.8	50.5	41.2		
Oct-06	0	141	279	323	133			5,230	4,040	3,810	4,000	4,000			5.11	6.02	6.24	6.42	6.21			29.9	39.0	47.3	51.4	35.0		
Nov-06	0	159	229	304	155			5,390	4,180	3,840	4,020	4,020			3.64	6.01	6.96	6.46	6.59			27.8	38.7	46.2	53.1	44.0		

TABLE 11
 Zone 3 Field Parameter Measurements of Tracking Wells, Through October 2009
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

Date	Bicarbonate (mg/L)							Conductivity (umhos/cm)							pH (s.u.)						Chloride (mg/L)								
	0504 B	PB-02	PB-04	PB-03	NBL-01	NBL-2	RW-A	0504 B	PB-02	PB-04	PB-03	NBL-01	NBL-2	RW-A	0504 B	PB-02	PB-04	PB-03	NBL-01	NBL-2	RW-A	0504 B	PB-02	PB-04	PB-03	NBL-01	NBL-2	RW-A	
Dec-06	0	151	233	328	183			5,680	4,290	4,090	4,230	4,360			3.42	6.18	7.05	6.67	6.44			28.6	38.8	47.1	54.0	48.3			
Jan-07	0	149	243	335	196			5,310	4,170	3,920	4,010	4,220			5.23	6.13	6.70	6.56	6.36			29.0	37.0	48.0	53.0	49.0			
Feb-07	0	144	205	272	178			5,340	4,150	3,800	3,900	4,160			4.16	6.50	6.64	6.62	6.43			28.0	37.0	49.0	53.0	51.0			
Mar-07	0	NA	258	310	210			5,500	NA	3,970	4,120	4,200			3.84	NA	6.99	6.92	6.56			29.0	NA	50.0	53.0	50.0			
Apr-07	0	161	302	345	217			5,210	3,990	3,830	3,950	4,060			5.25	6.01	6.33	6.44	6.18			28.0	38.0	46.0	44.0	52.0			
May-07	0	173	288	317	223			5,260	3,980	3,750	3,850	3,860			3.91	6.05	6.48	6.52	6.61			28.0	36.0	48.0	52.0	54.0			
Jun-07	0	169	310	311	191			4,200	3,230	3,020	2,980	3,030			3.38	6.03	6.86	6.85	6.44			28.0	35.0	50.0	51.0	52.0			
Jul-07	0	156	293	322	199			4,750	3,400	3,530	3,410	3,520			5.10	6.16	6.37	6.51	6.40			29.0	36.0	51.0	49.0	54.0			
Aug-07	0	171	293	306	150			4,860	3,770	3,550	3,570	3,650			3.92	5.91	6.45	6.41	6.06			28.0	36.0	53.0	52.0	55.0			
Sep-07	0	184	307	304	135			4,940	3,610	3,570	3,660	3,720			3.58	6.09	6.60	6.46	6.77			29.0	35.0	54.0	53.0	57.0			
Oct-07	20	161	329	307	185			4,630	3,300	3,170	3,200	3,350			3.29	6.39	6.51	6.64	6.20			29.0	36.0	55.0	52.0	50.0			
Nov-07	0	159	295	258	109			4,400	3,530	3,170	3,160	3,350			3.69	5.88	6.94	6.52	6.20			29	36	53	50	53			
Dec-07	0	148	316	290	55			5,440	3,990	3,890	3,980	4,110			3.49	6.04	6.80	6.65	6.05			29	34	51	51	53			
Jan-08	NA	NA	289	294	107	302	350	NA	NA	4,190	4,220	4,470	3,720	3,870	NA	NA	6.41	6.37	5.88	6.69	6.27	NA	NA	54	54	50	37	43	
Feb-08	NA	NA	189	299	13	313	NA	NA	NA	3,900	4,050	4,280	3,710	NA	NA	NA	6.80	7.00	5.34	6.64	NA	NA	NA	57	49	53	36	NA	
Mar-08	NA	143	139	323	0	312	602	NA	4,220	3,900	4,060	4,370	3,630	3,870	NA	NA	6.20	6.45	6.82	5.16	6.92	6.30	NA	32	57	50	57	35	50
Apr-08	NA	116	156	362	96	306	NA	NA	3,800	3,590	3,680	3,840	3,260	NA	NA	NA	5.86	6.18	6.58	5.83	6.51	NA	NA	32	58	50	49	36	NA
May-08	NA	NA	169	337	29	312	406	NA	NA	3,900	4,040	3,950	3,690	3,980	NA	NA	6.21	6.50	5.97	6.29	6.47	NA	NA	58	53	51	36	37	
Jun-08	NA	0	293	287	133	302	453	NA	4,570	3,890	3,990	3,940	3,640	3,880	NA	3.84	6.40	6.53	6.12	6.26	6.15	NA	35	54	54	48	35	37	
Jul-08	NA	0	268	302	162	313	228	NA	4,140	3,740	3,770	3,850	3,450	3,730	NA	5.94	6.39	7.28	6.33	6.54	6.38	NA	36	49	53	50	33	41	
Aug-08	NA	99	201	289	208	316	349	NA	4,230	3,800	3,840	3,790	3,620	3,810	NA	5.83	6.42	6.88	6.46	6.50	6.35	NA	35	52	51	48	34	40	
Sep-08	NA	106	211	290	244	310	327	NA	4,170	3,650	3,720	3,340	3,510	3,740	NA	5.86	6.89	7.18	7.09	6.39	6.32	NA	37	42	48	46	35	38	
Oct-08	NA	98	84	301	294	321	337	NA	4,080	4,000	3,770	3,820	3,560	3,760	NA	5.74	5.85	6.69	6.31	6.54	6.37	NA	30	50	55	48	38	38	
Nov-08	NA	80	50	127	246	335	338	NA	4,120	3,570	3,900	3,730	3,560	3,750	NA	5.55	5.87	6.16	6.41	6.43	6.24	NA	32	53	57	46	34	35	
Dec-08	NA	85	39	79	248	351	346	NA	3,990	3,500	4,040	3,660	3,530	3,700	NA	6.05	5.68	5.76	6.86	6.48	6.26	NA	34	52	57	44	36	38	
Jan-09	NA	63	10	15	295	351	344	NA	4190	3690	4100	3860	3580	3800	NA	5.41	4.02	5.41	6.24	6.55	6.25	NA	30	50	57	43	40	39	
Feb-09	NA	74	0	16	268	344	361	NA	4200	4220	3910	3420	3580	3730	NA	5.64	3.03	5.00	6.55	6.43	6.35	NA	29	51	58	43	39	40	
Mar-09	NA	89	12	0	306	343	351	NA	4170	3430	3850	3750	3580	3750	NA	5.74	4.56	4.87	7.29	6.44	6.30	NA	31	39	58	40	38	37	
Apr-09	NA	55	0	174	271	338	385	NA	4010	4960	3900	3560	3600	3710	NA	5.31	2.88	6.21	6.80	6.43	6.36	NA	29	42	53	40	38	38	
May-09	NA	83	0	205	258	337	332	NA	4250	4980	3800	3600	3530	3820	NA	5.8	2.51	6.35	6.99	6.41	6.31	NA	28	51	50	44	36	36	
Jun-09	NA	83	0	287	235	334	318	NA	4010	4410	3520	3400	3410	3660	NA	5.6	2.52	7.32	6.98	6.43	6.98	NA	29	51	48	37	39	44	
Jul-09	NA	77	0	244	227	328	308	NA	4030	4540	3680	3370	3470	3660	NA	5.68	2.5	6.45	7.16	7.91	6.30	NA	29	40	48	50	40	38	
Aug-09	NA	50	0	226	85	312	293	NA	4440	5200	3760	3640	3490	3860	NA	5.33	2.51	6.62	6.64	6.58	6.21	NA	29	40	48	51	41	37	
Sep-09	NA	65	NA	51	59	306	277	NA	4370	NA	3570	3720	3390	3910	NA	5.39	NA	6.18	6.60	6.44	6.30	NA	29	NA	49	59	43	37	
Oct-09	NA	94	NA	111	178	335	280	NA	3980	NA	3530	3960	3360	3470	NA	5.55	NA	6.26	5.65	6.41	5.80	NA	28	NA	42	48	41	36	

Notes:

Parameter monitoring of wells NBL-2 and RW-A started in January 2008.

NA = not available (parameters not measured).

TABLE 12
 Zone 3 Field Parameter Measurements of NW-Series Wells, Through October 2009
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

Date	Bicarbonate (mg/L)					Conductivity (umhos/cm)					pH (s.u.)					Chloride (mg/L)				
	NW-1	NW-2	NW-3	NW-4	NW-5	NW-1	NW-2	NW-3	NW-4	NW-5	NW-1	NW-2	NW-3	NW-4	NW-5	NW-1	NW-2	NW-3	NW-4	NW-5
Jun-09	137	351	484	196	502	4,170	3,640	3,350	4,270	3,450	5.93	6.27	6.52	6.15	6.52	26	39	40	31	45
Jul-09	127	333	483	212	577	4,270	3,660	3,380	4,400	3,440	6.25	6.15	6.40	6.64	6.30	27	39	37	32	45
Aug-09	106	319	458	220	563	4,460	3,820	3,530	4,460	3,670	5.91	6.16	6.40	6.30	6.51	26	37	36	33	46
Sep-09	112	328	457	232	511	4,420	3,850	3,570	4,530	3,650	6.00	6.35	6.51	6.55	6.88	26	37	37	32	46
Oct-09	146	341	490	243	597	4,060	3,480	3,250	4,080	3,340	7.01	6.73	6.91	6.59	7.15	25	36	36	29	48

Note:
 Parameter monitoring of these five wells started in June 2009.

TABLE 13
 Zone 3 Seepage Migration Evaluation, 2009
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

End Point Well	Starting Point	Distance Between Both Points (ft)	Time for Onset		Travel Time (ft/yr)	Basis for Determining Onset Date for Seepage Impacts At Selected Points
			Seepage Impacts at Starting Point (date)	Seepage Impacts at End Point (date)		
420	North Cell	2,100	1980	Oct-02	95	Bicarbonate concentration greater than 500 mg/L
504 B	North Cell	2,450	1980	Jul-92	204	Bicarbonate concentration less than 100 mg/L
EPA 14	North Cell	1,520	1980	Apr-96	95	Bicarbonate concentration greater than 500 mg/L
PB 2	North Cell	3,080	1980	Oct-02	140	Bicarbonate concentrations first declining to 50 mg/L at Well PB 2
PB 2	504 B	630	Jul-92	Oct-02	61	Bicarbonate concentrations first declining to 50 mg/L at each well
PB 4	PB 2	52	Apr-03	Feb-04	60	Bicarbonate concentrations first persistently at or below 50 mg/L at each well
PB 4	PB 2	52	Jan-08	Nov-08	58	Bicarbonate concentrations again declined to below 50 mg/L at each well
			Geometric Mean		92	

End Point Well	Starting Point Well	Distance Between Both Points (ft)	Time for Onset		Net Migration Distance (ft)	Basis for Determining Onset Date for Seepage Impacts At Selected Points
			Seepage Impacts at Starting Point (date)	Seepage Impacts at End Point (date)		
NBL 1	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Since December 2005, water quality in the northern tracking wells (including NBL 1) has varied significantly (for example, see the field bicarbonate measurements in Table 11 and the lab bicarbonate measurements shown in Figure 40). This reflects the influence of pumping systems (which have changed over time) and variable mixing of impacted water with background water drawn in from the west. Full seepage impact has occurred at PB 4 since Nov-08 (bicarbonate < 50 mg/L) or Jan-09 (pH < 5.0). To the north of this well, there is no unequivocal basis for picking a single location representing the leading edge of moderate seepage impact. However, NBL 1 first showed bicarbonate < 50 mg/L in Feb-08 (succeeded by, for example, 306 mg/L in Mar-09, 59 mg/L in Sept-09, and 111 mg/L in Oct-09); pH here during 2009 varied from 7.29 (Feb-09) to 5.65 (Oct-09)). Constituent exceedances at NBL 1 during Oct-09 (see Table 14) indicate a moderate degree of impact; the water quality here has shown sharp fluctuations since Oct-07.

TABLE 14
 Detected Constituents in Zone 3, October 2009
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

Chemical Name	Action Level	Unit	NBL-01	NBL-02	NW-1	NW-2	NW-3	NW-4	NW-5	PB-02	PB-03	RW-11	RW-A
ALUMINUM	5	mg/l	0.5		no data	1.9	1.9						
AMMONIA (AS N)		mg/l	6.7 D		no data	1.00	5.79	2.99	3.06				
ARSENIC	0.05	mg/l			no data								
BERYLLIUM	0.017	mg/l			no data								
BICARBONATE (HCO3)		mg/l	65	345	136	355	501	226	612	72	32	238	281
CADMIUM	0.01	mg/l			no data								
CALCIUM		mg/l	618	620	no data	575 D	588	547	607				
CHLORIDE	250	mg/l	49	49	25	41	44	32	58	28 H	39 H	32	46
COBALT	0.05	mg/l	0.41	0.04	no data	0.38	0.24	0.16	0.16				
GROSS ALPHA	15	pci/l	25.1	7.2	no data	19.4	14.0	10	13.1				
LEAD-210	1	pci/l			no data								
MAGNESIUM		mg/l	274	183	no data	408	236	259	254				
MANGANESE	2.6	mg/l	7.92	1.38	no data	5.49	5.75	4.27	4.70				
MOLYBDENUM	1	mg/l	1.0	0.3	no data	0.5	0.2	0.2	0.2				
NICKEL	0.05	mg/l	0.41	0.05	no data	0.49	0.26	0.18	0.18				
NITRATE (NO3)	190	mg/l		19.4	no data				0.2				
PH (FIELD)		su	5.65	6.41	7.01	6.73	6.91	6.59	7.15	5.55	6.26	5.90	5.80
PH (LAB)		su	6.26	7.19	6.76 H	7.09 H	7.28 H	6.89 H	7.45 H	6.33	6.65	7.45	6.99
POTASSIUM		mg/l	13	7	no data	11	10	10	10				
RADIUM-226		pci/l	15	6.4	no data	14	14	9.3	14				
RADIUM 226 & 228	5	pci/l	31	17.4	no data	29	27	22.3	32				
SELENIUM	0.01	mg/l			no data								
SODIUM		mg/l	142	144	no data	131 D	133	130	135				
SULFATE (SO4)	2125	mg/l	2950 D	2100 D	no data	3330 D	2460 D	2530 D	2640 D				
THORIUM-230	5	pci/l			no data	1.5	2.4						
TOTAL DISSOLVED SOLIDS	4800	mg/l	4330 H	3550 H	4780 H	3890 H	3470 H	4680 H	3630 H	4760 H	3910 H	3800 H	3950 H
TOTAL TRIHALOMETHANES	80	ug/l			no data								
URANIUM	0.3	mg/l	0.0708	0.206	no data	0.0680	0.113	0.134	0.111				
VANADIUM	0.1	mg/l			no data								

TABLE 15
 Zone 1 Performance Monitoring Program, 2009 Operating Year
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

Well ¹	Water Level ²	Water Quality ²	NRC POC	Purpose
Continue Monitoring				
515 A	X	X		Track transition area
604	X	X	Y	Track center of seepage
614	X	X	Y	Track transition area
EPA 2	X	X		Postmining-pretailings background water quality
EPA 4	X	X	Y	Postmining-pretailings background water quality
EPA 5	X	X	Y	Track transition area
EPA 7	X	X	Y	Track transition area, edge of saturation
EPA 8	X			Track edge of saturation
142	X	X		Premining background
143	X			Water level only, use 142
Additional Wells, Not Included In Original Performance Monitoring Program				
505 A	X			Long-term water level for migration path
502 A	X			Long-term water level for migration path
501 A	X			Long-term water level for migration path
504 A	X			Long-term water level for migration path
412	X			Long-term water level for migration path
Total	15	8		

Eliminated From Monitoring			Reason For Elimination
141			No longer useable, plugged during arroyo flooding
516 A		Y	Failed low-flow testing
619			Anomalous water quality and water level
615			Decommissioned pumper, not needed - use 515 A
616			Decommissioned pumper, not needed - use 604
617			Decommissioned pumper, not needed

Notes:

1. No wells within the tailings reclamation cap were included.
2. Water level and water quality monitored on a quarterly basis.

Table 16
 Zone 1 Saturated Thickness, October 2009
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

Well	Water Level Measurement Date	Zone 1 Unsaturated Thickness	Zone 1 Saturated Thickness	Zone 1 Percentage Saturated
TWQ-142	10/13/2009	0.00	55.00	100%
TWQ-143	10/15/2009	0.00	52.00	100%
412	10/15/2009	0.00	76.00	100%
501-A	10/14/2009	9.58	55.42	85%
502-A	10/14/2009	0.00	59.00	100%
504-A	10/14/2009	7.51	60.49	89%
505-A	10/14/2009	0.00	46.00	100%
515-A	10/7/2009	26.65	14.35	35%
604	10/6/2009	24.28	20.72	46%
614	10/7/2009	22.32	22.68	50%
EPA-02	10/12/2009	20.17	29.84	60%
EPA-04	10/12/2009	17.60	37.40	68%
EPA-05	10/12/2009	28.60	20.40	42%
EPA-07	10/12/2009	29.15	53.85	65%
EPA-08	10/12/2009	27.43	38.57	58%

TABLE 17

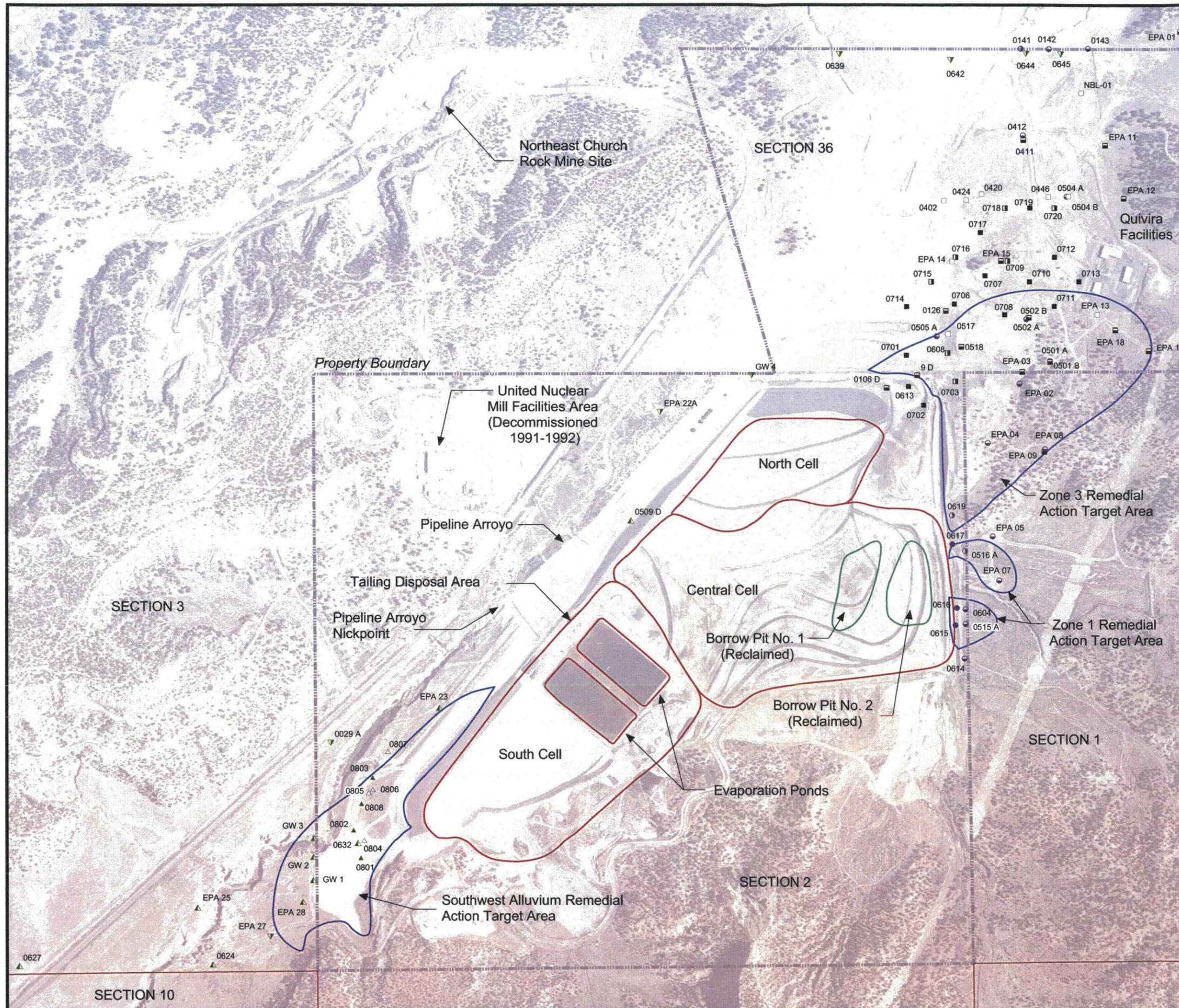
Detected Constituents in Zone 1, October 2009
 United Nuclear Corporation, Church Rock Site
 Church Rock, New Mexico

Chemical Name	Action Level	Unit	0142	0515 A	0604	0614	EPA 02	EPA 02 DUP	EPA 04	EPA 05	EPA 07
ALUMINUM	5	mg/l		0.6	2.8						0.4
AMMONIA (AS N)		mg/l	0.28	10.0 D	0.14	76 D	0.42	0.45	0.76	11.0 D	0.14
BICARBONATE (HCO3)		mg/l	281	200	10	1410	318	331	161	65	647
CALCIUM		mg/l	43	471 D	436 D	576 D	360	351	540	469	486 D
CHLORIDE	250	mg/l	19	258	60	343	21	24	42	48	208
COBALT	0.05	mg/l		0.04	0.19					0.04	0.03
GROSS ALPHA	15	pci/l	0.9	2.6	2.6	1.3	2.0	2.0	1.6	2.3	1.1
MAGNESIUM		mg/l	22	831	808	652	158	164	364	488	1050
MANGANESE	2.6	mg/l	0.06	18.4	8.55	0.57	1.44	1.49	3.48	1.21	2.22
NICKEL	0.05	mg/l		0.29	0.26						
NITRATE (NO3)	190	mg/l		64 D	72 D	101 D				12.4	127 D
PH (FIELD)		su	7.76	6.32	5.12	6.94	6.77		6.73	5.94	6.00
PH (LAB)		su	7.81	6.90	5.79	7.60	7.31	7.20	7.07	6.54	6.77
POTASSIUM		mg/l	4	15	12	12	6	6	9	8	8
RADIUM-226		pci/l	0.28	0.91	1.3	0.37	1.1	1.1	1.2	1.7	0.44
RADIUM 226 & 228	5	pci/l	1.23	3.81	6.1	2.77	4.2	4.1	4.6	5	5.44
SODIUM		mg/l	335	434 D	286 D	477 D	192	198	183	115	366 D
SULFATE (SO4)	2125	mg/l	624 D	4960 D	4360 D	2980 D	1670 D	1620 D	3010 D	3170 D	4300 D
TOTAL DISSOLVED SOLIDS	4800	mg/l	1180 H	7800	7090	6650	2830 H	2790	4640	4850	8750 H
TOTAL TRIHALOMETHANES	80	ug/l		46.4	6.80	92.0					0.65
URANIUM	0.3	mg/l		0.0008	0.0009	0.0512	0.0019	0.0016	0.0004	0.0015	0.0020

TABLE 18

Predicted Performance of the Zone 1 Natural System
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Constituent	Will Standards Be Met?		Remarks
	Section 1	Section 36	
Manganese	Maybe	Maybe	Dependent on bicarbonate availability
Sulfate	No	No	Limited by calcium availability
TDS	No	No	Governed by sulfate concentration
Metals	Yes	Yes	Attenuated by neutralization and adsorption
Radionuclides	Yes	Yes	Attenuated by neutralization and adsorption
TTHMs	Yes	Yes	Attenuated by degradation, dilution, dispersion



Legend

- Southwest Alluvium**
 - ▲ Idled Extraction Well
 - ▲ Monitoring Well
 - △ Water Level Monitoring Well
 - ▽ Dry Monitoring Well
- Zone 3**
 - Idled Extraction Well Used for Monitoring
 - Decommissioned or Idle Extraction Well
 - Monitoring Well
 - Dry or Decommissioned Monitoring Well
- Zone 1**
 - Decommissioned Extraction Well
 - Decommissioned Monitoring Well
 - Monitoring Well

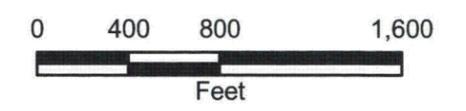
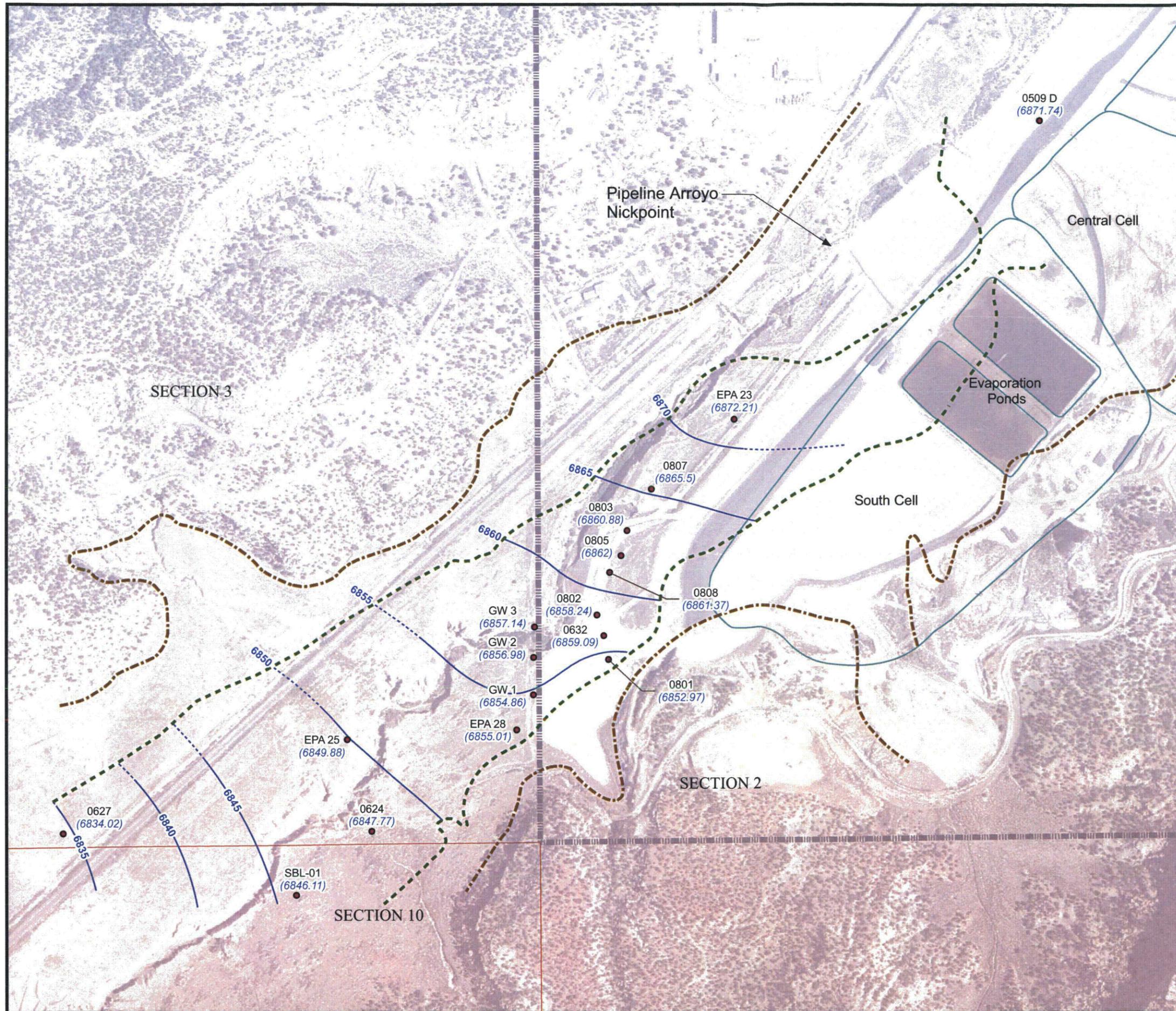


FIGURE 2
 Site Layout and Performance
 Monitoring Well Locations
 2009 Operating Year
 United Nuclear Corporation Church Rock Site,
 Church Rock, New Mexico





Legend

- Southwest Alluvium Monitoring Well
- Groundwater Elevation Contour
- - - - Inferred Groundwater Elevation Contour
- - - - Approximate Extent of Alluvium
- - - - Approximate Extent of Saturated Alluvium
- ▤ Property Boundary
- Section Boundary
- Cell Boundary

Notes:

1. Groundwater elevation values are displayed in feet above mean sea level.
2. Well names are displayed with black text.
3. Groundwater elevations are shown with blue text and enclosed in parentheses.
4. Aerial photo taken on August 1, 1996.

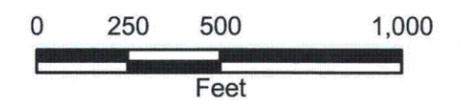
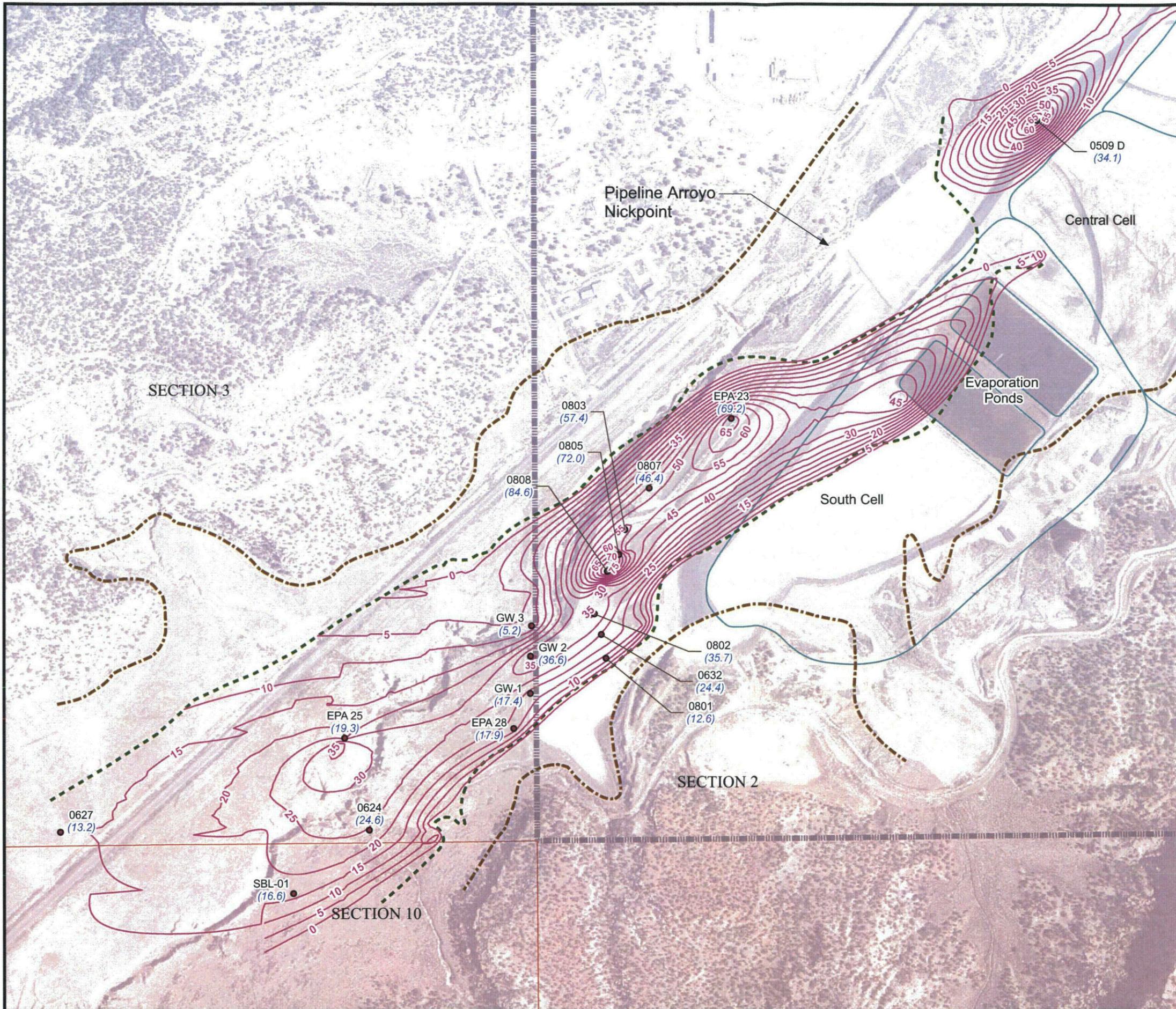


FIGURE 3A
 Southwest Alluvium
 Potentiometric Surface Map
 October 2009

United Nuclear Corporation Church Rock Site,
 Church Rock, New Mexico





Legend

- Southwest Alluvium Monitoring Well
- Approximate Extent of Alluvium
- - - Approximate Extent of Saturated Alluvium
- ▬ Property Boundary
- ▬ Section Boundary
- ▬ Cell Boundary
- ▬ Saturated Thickness Contours (feet)

Notes:

1. Well names are displayed with black text.
2. Saturated thicknesses (feet) are shown with blue text and enclosed in parentheses.
3. Aerial photo taken on August 1, 1996.
4. The posted value of saturated thickness at well 0509 D derives from reference to the screen bottom. The alluvium extends as much as 38 feet below this depth in the vicinity of this well.

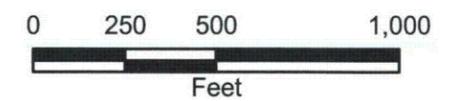


FIGURE 3B
 Southwest Alluvium
 Saturated Thickness Map
 October 2009

United Nuclear Corporation Church Rock Site,
 Church Rock, New Mexico



FIGURE 4
 Southwest Alluvium Water Levels Over Time
 United Nuclear Corporation, Church Rock Site, Church Rock New Mexico

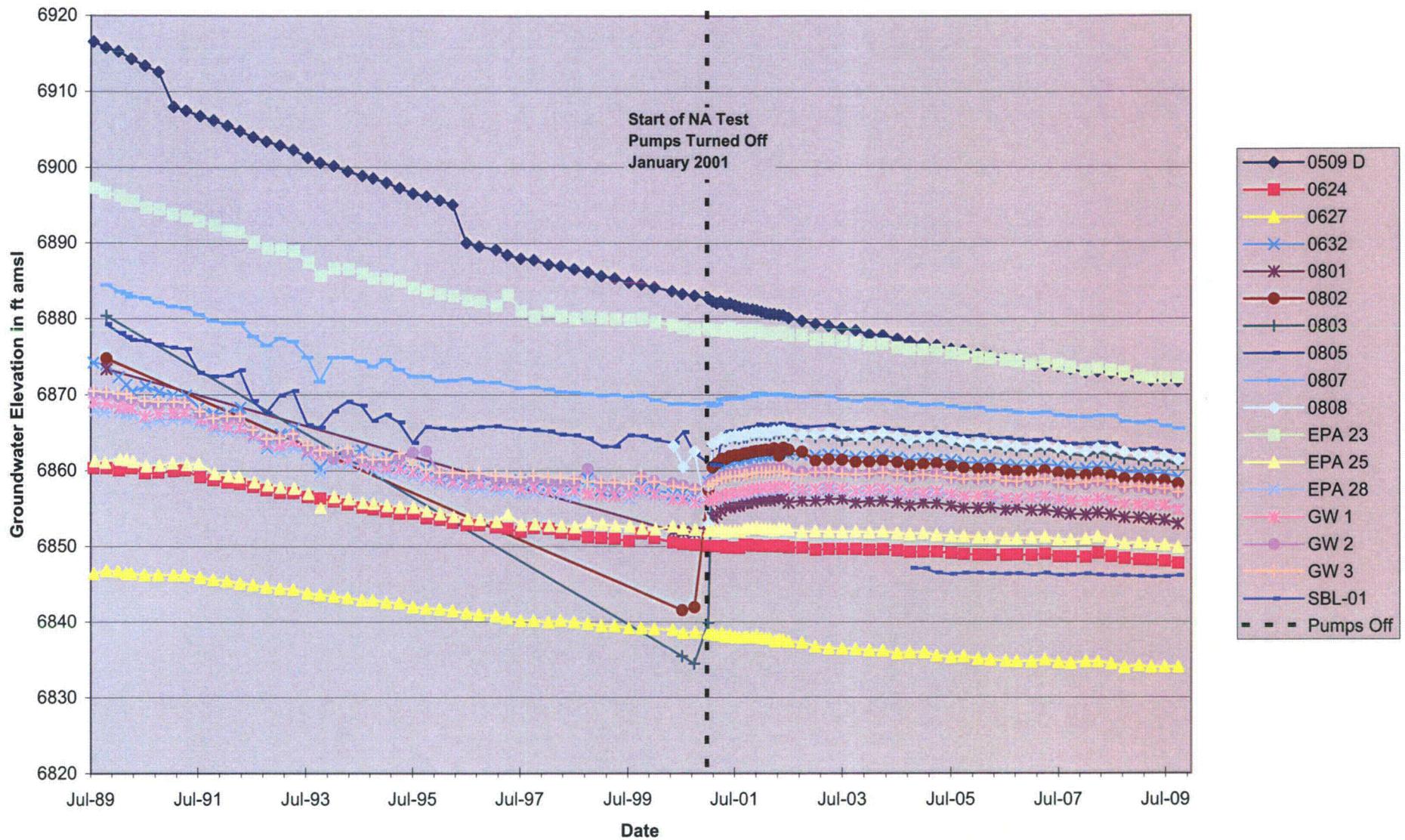
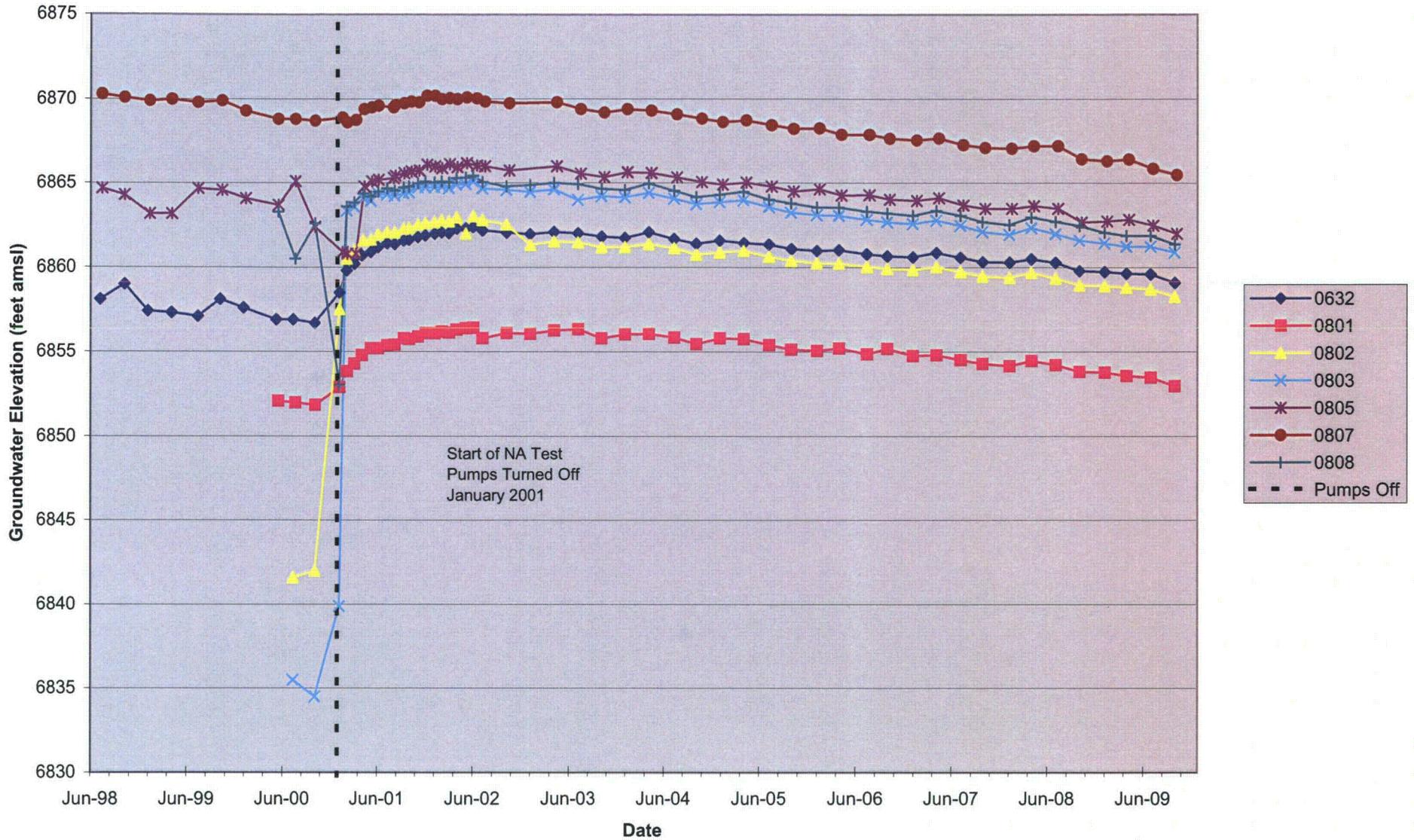
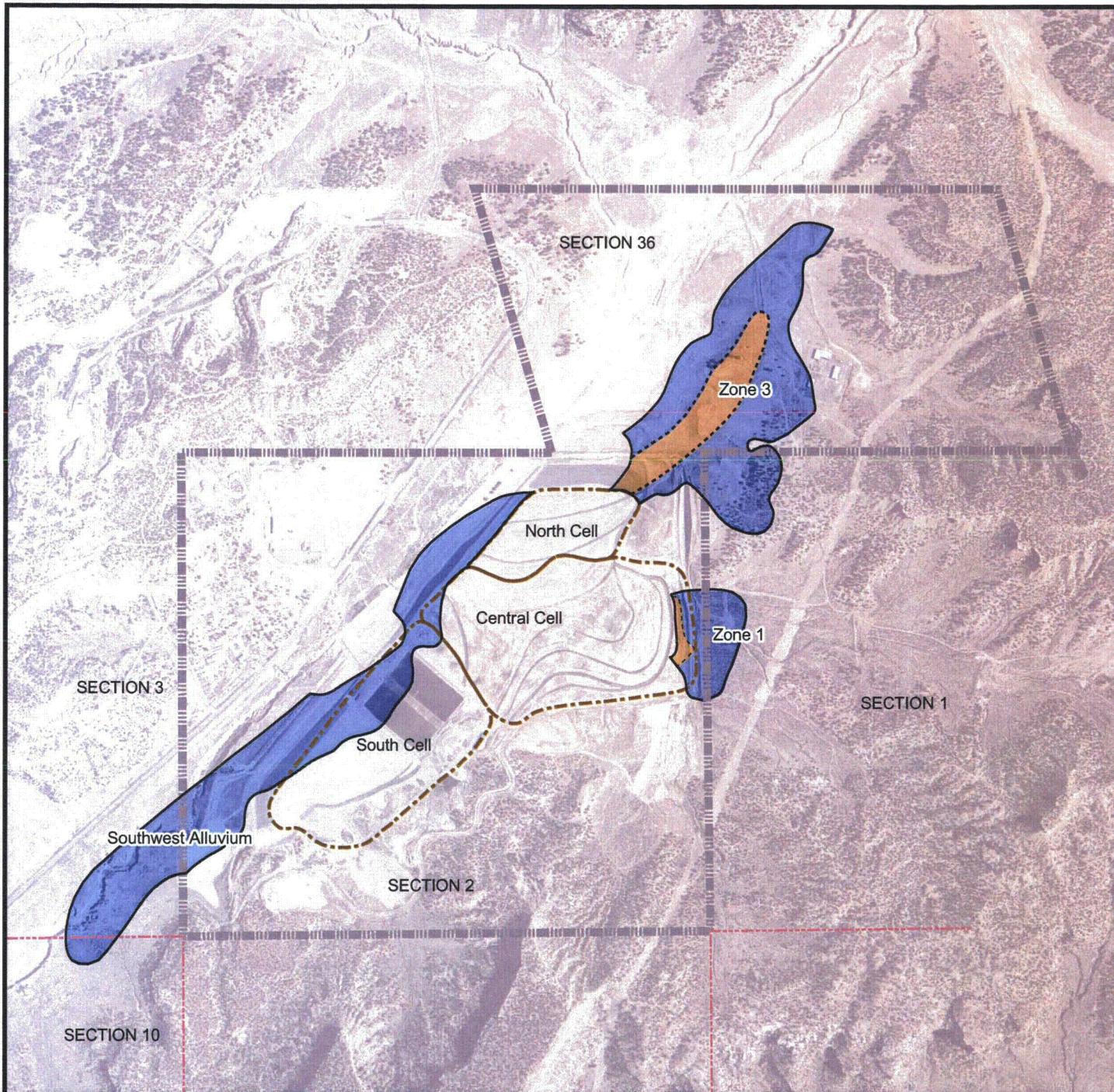


FIGURE 5
 Southwest Alluvium Pumping Well Water Levels Over Time
 United Nuclear Corporation, Church Rock Site, Church Rock New Mexico





LEGEND

-  Section Boundary
-  Property Boundary
-  Tailings Pond
-  Groundwater with pH ≤ 4
-  Seepage-Impacted Groundwater

Aerial photo taken on August 1, 1996.

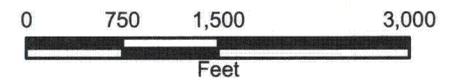


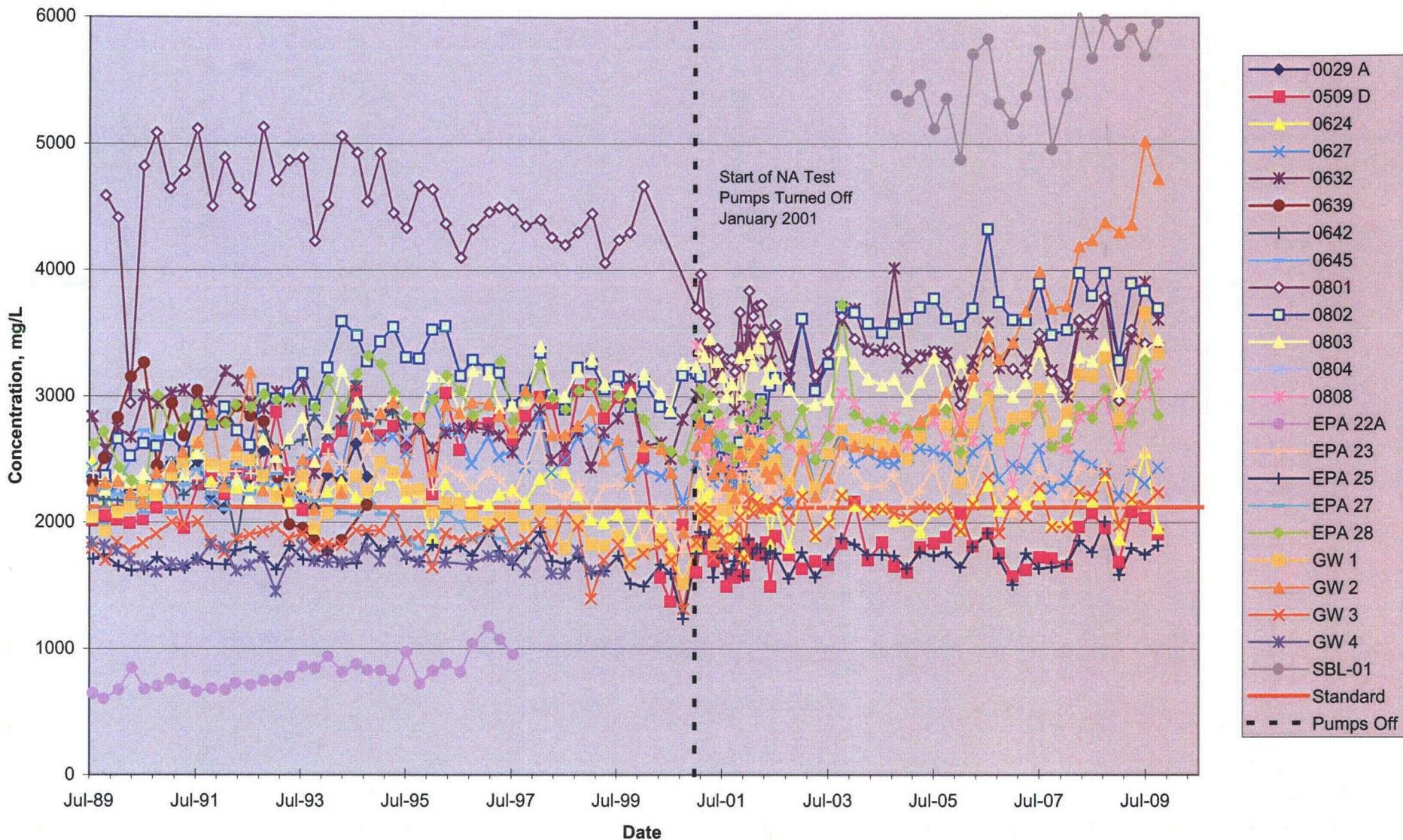
FIGURE 6

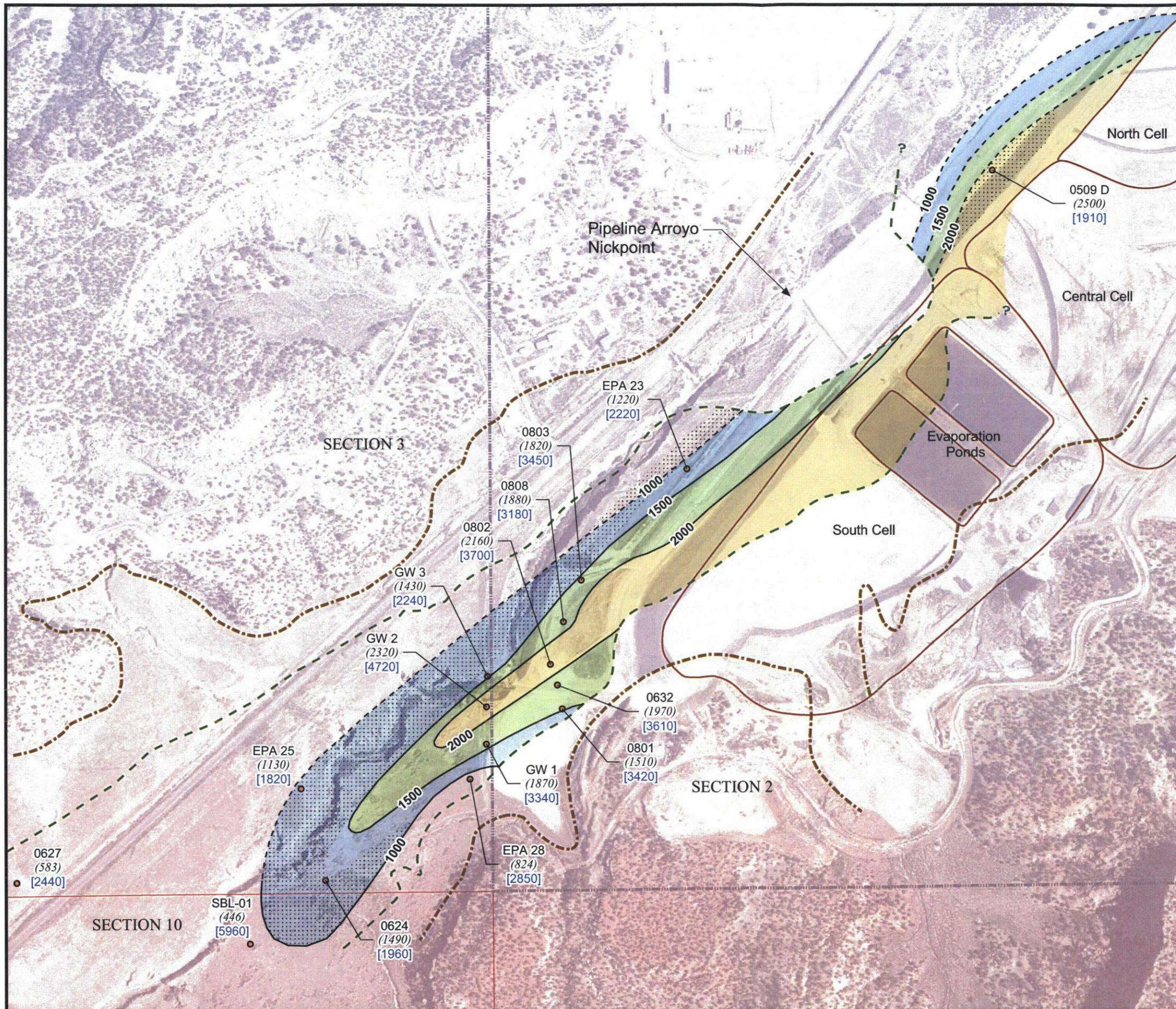
Extent of Seepage-Impacted Groundwater, October 2009

United Nuclear Corporation Church Rock Site
Church Rock, New Mexico



FIGURE 7
 Southwest Alluvium Sulfate Concentrations Over Time
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico





Legend

- Southwest Alluvium Well
 - - - Approximate Extent of Saturated Alluvium
 - ⋯ Approximate Extent of Alluvium
 - Bicarbonate Isoconcentration Contour in mg/L
 - - - Inferred Bicarbonate Isoconcentration Contour in mg/L
- Bicarbonate Concentrations (mg/L)**
- 1000 - 1500
 - 1500 - 2000
 - >2000
- ⋯ Property Boundary
 - Section Boundary
 - Tailings Pond
 - ⋯ Sulfate Below 2125 mg/L
- (2350) Bicarbonate result in mg/L
[3580] Sulfate result in mg/L

Notes:

1. Well names are displayed with black text.
2. Aerial photo taken on August 1, 1996.

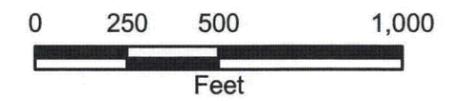


FIGURE 8
 Southwest Alluvium Bicarbonate Isoconcentration Map and Distribution of Sulfate Below 2125 mg/L, October 2009

United Nuclear Corporation Church Rock Site,
 Church Rock, New Mexico



FIGURE 10
 Southwest Alluvium Chloride Concentrations From 1999 Through October 2009
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

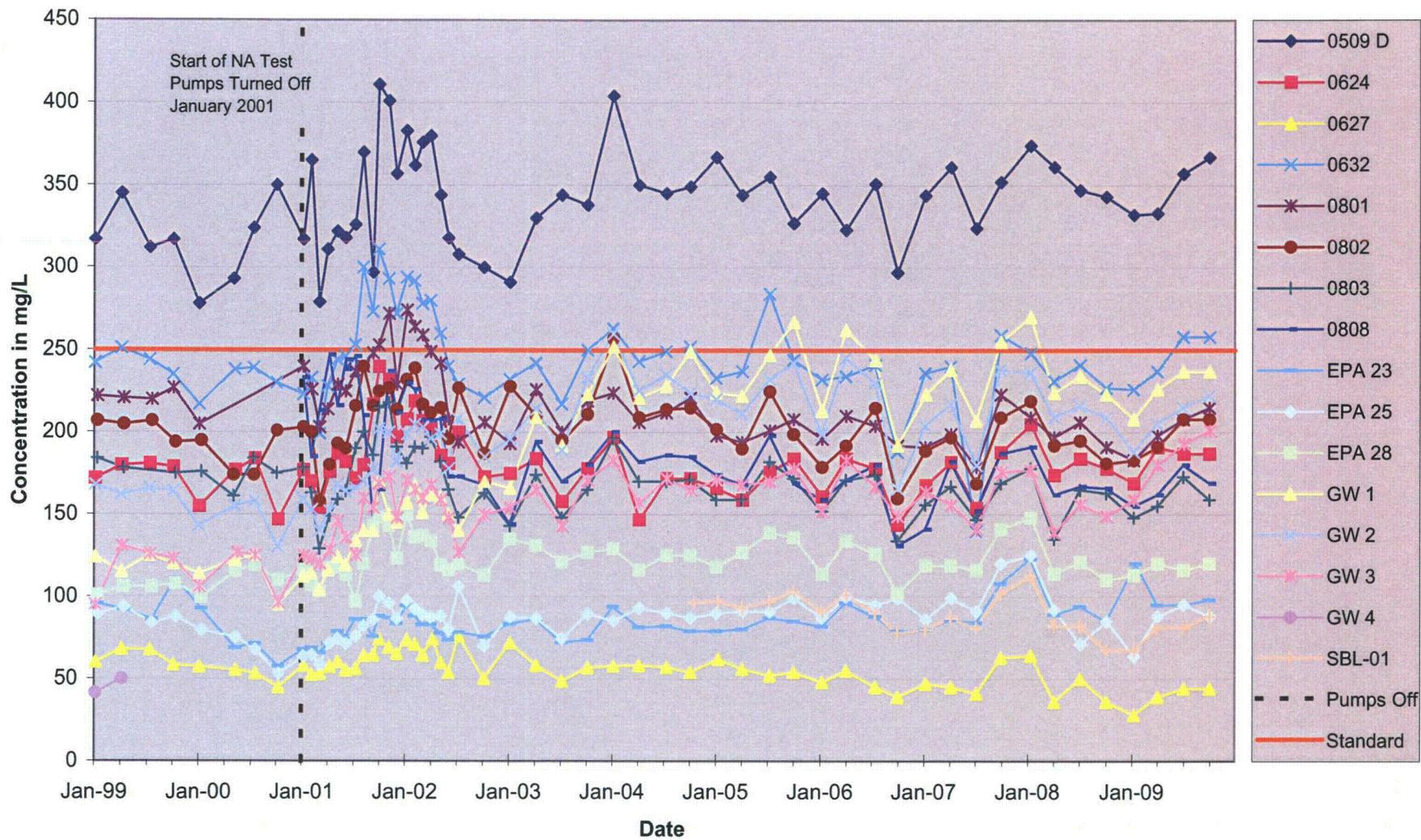


FIGURE 11

Southwest Alluvium Manganese Concentrations From 1999 Through October 2009
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

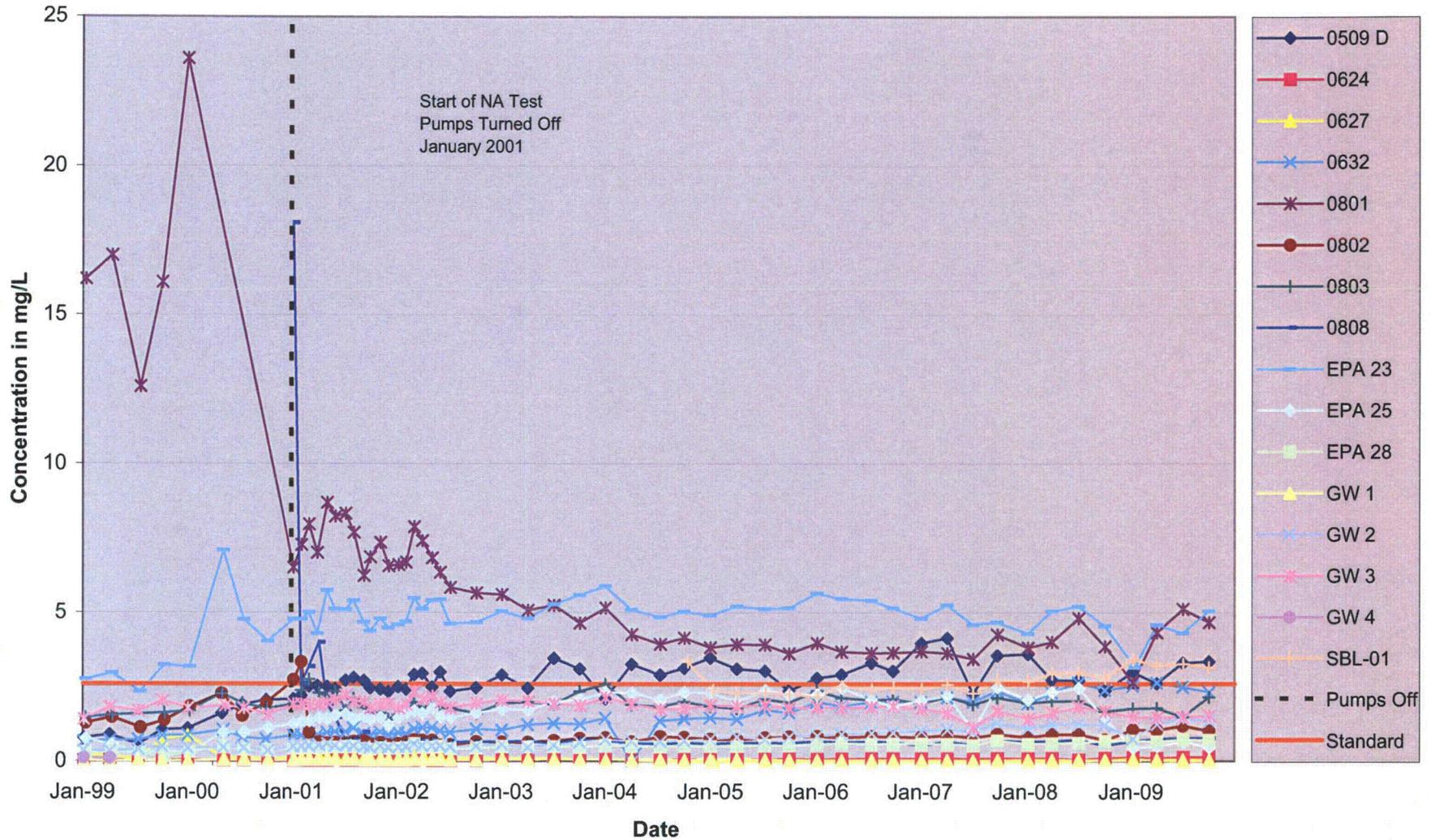


FIGURE 12
 Southwest Alluvium Total Dissolved Solids Concentrations Over Time
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

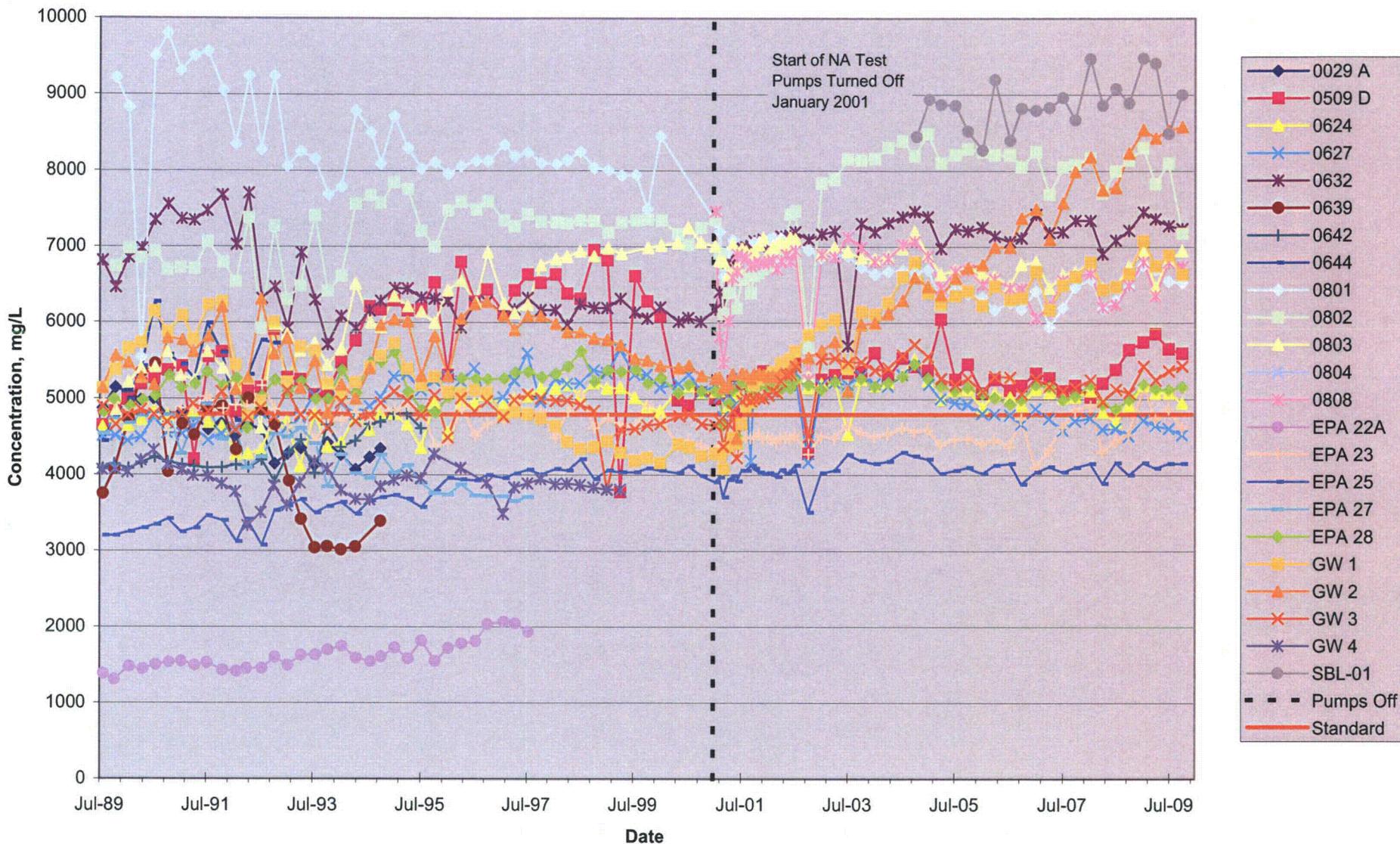


FIGURE 13

Calcium and Bicarbonate Concentrations in Selected Background and Seepage-Impacted Wells
United Nuclear Corporation Church Rock site, Church Rock, New Mexico

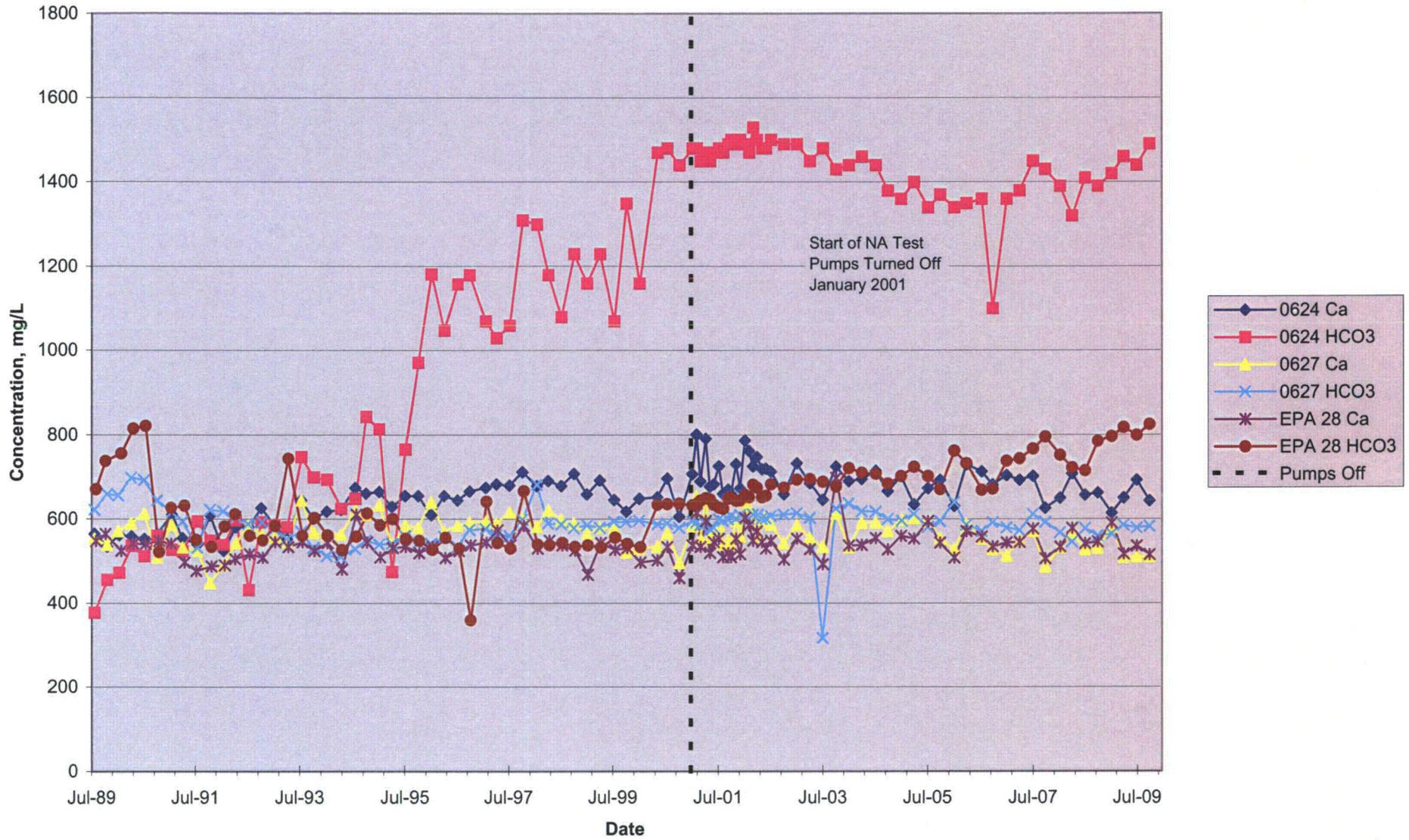


FIGURE 14

Southwest Alluvium Calcium Concentrations From 1999 Through October 2009
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

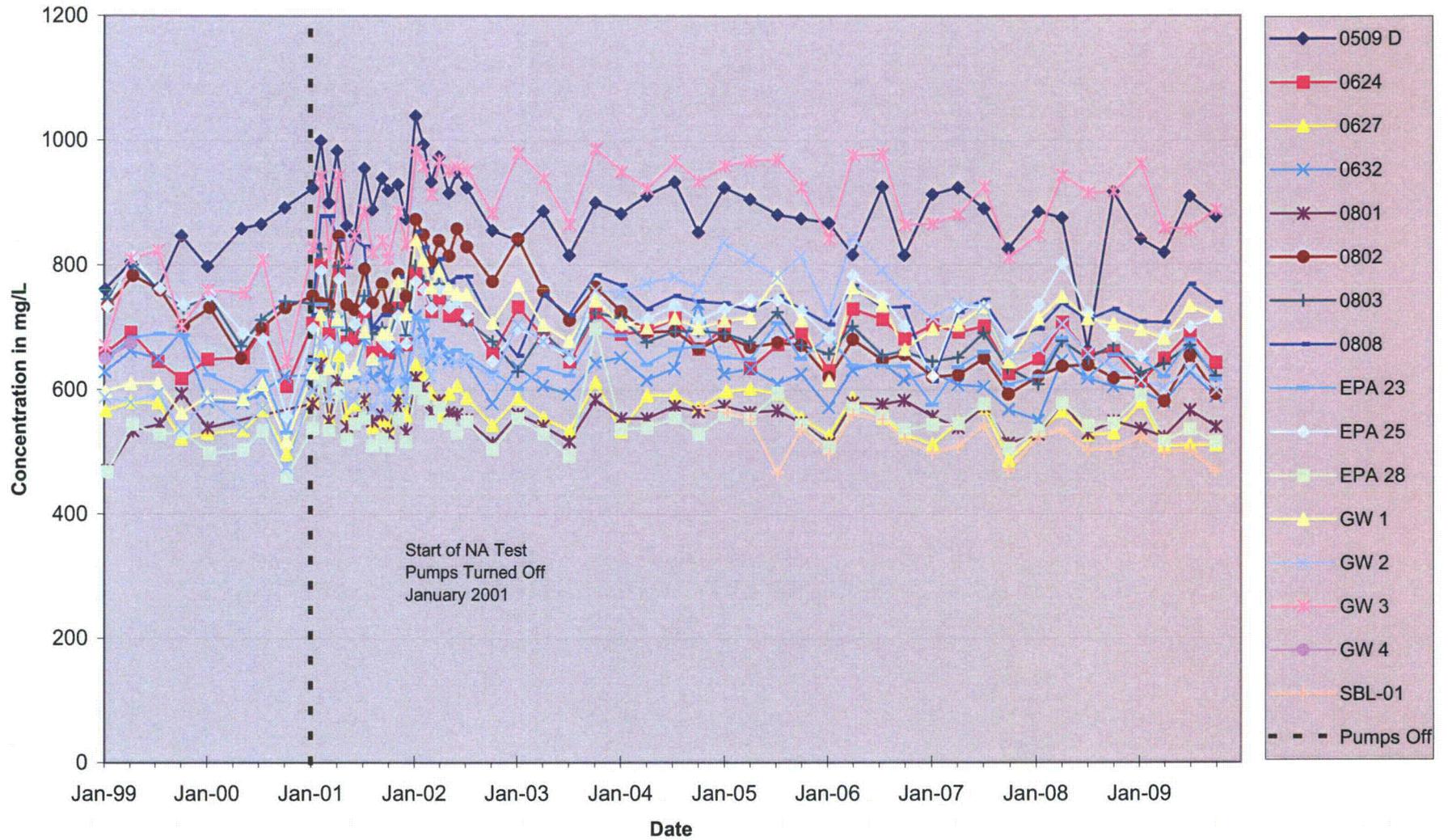


FIGURE 15
 Southwest Alluvium Bicarbonate Concentrations From 1999 Through October 2009
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

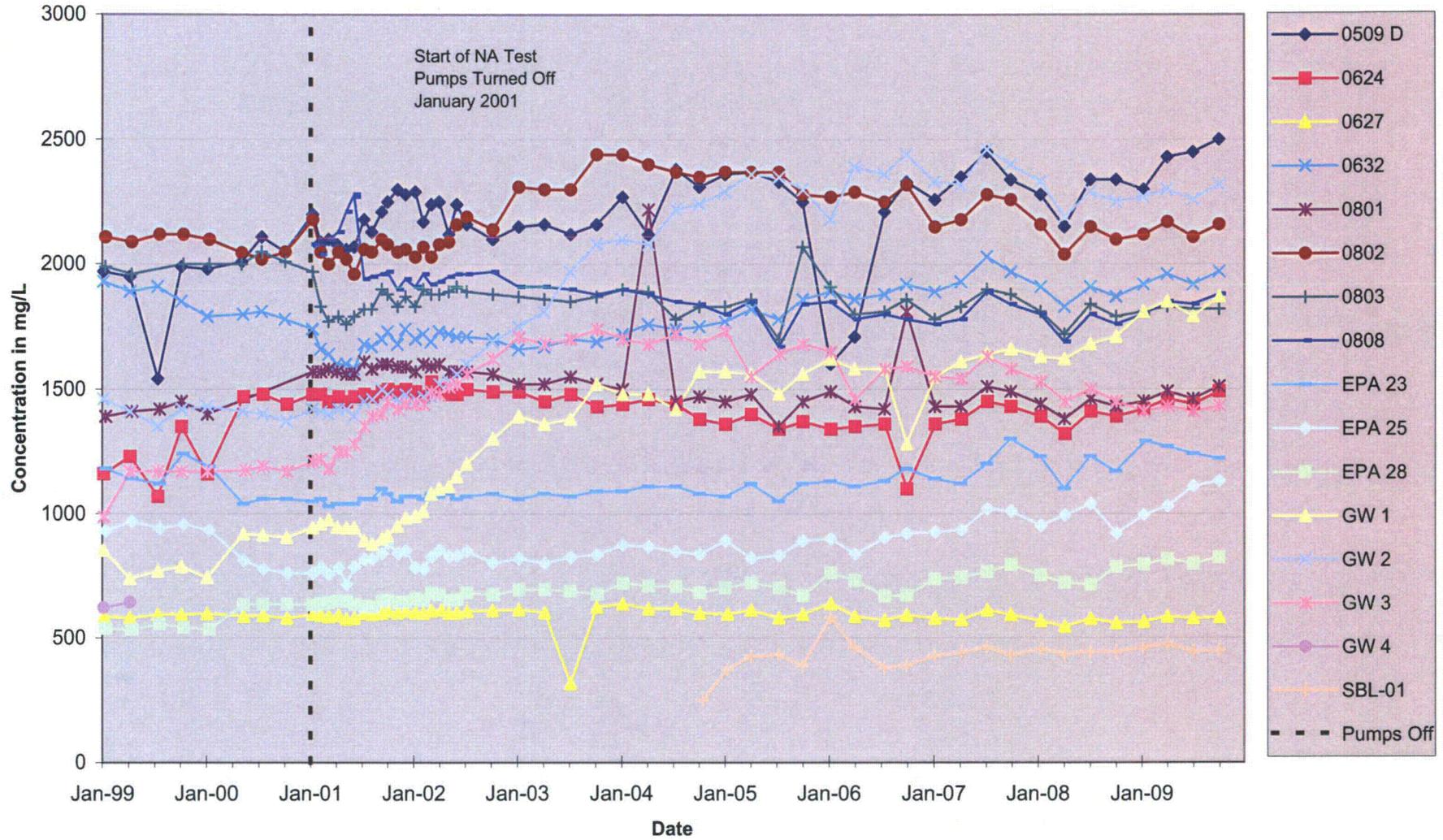


FIGURE 16

Southwest Alluvium Sulfate Concentrations From 1999 Through October 2009
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

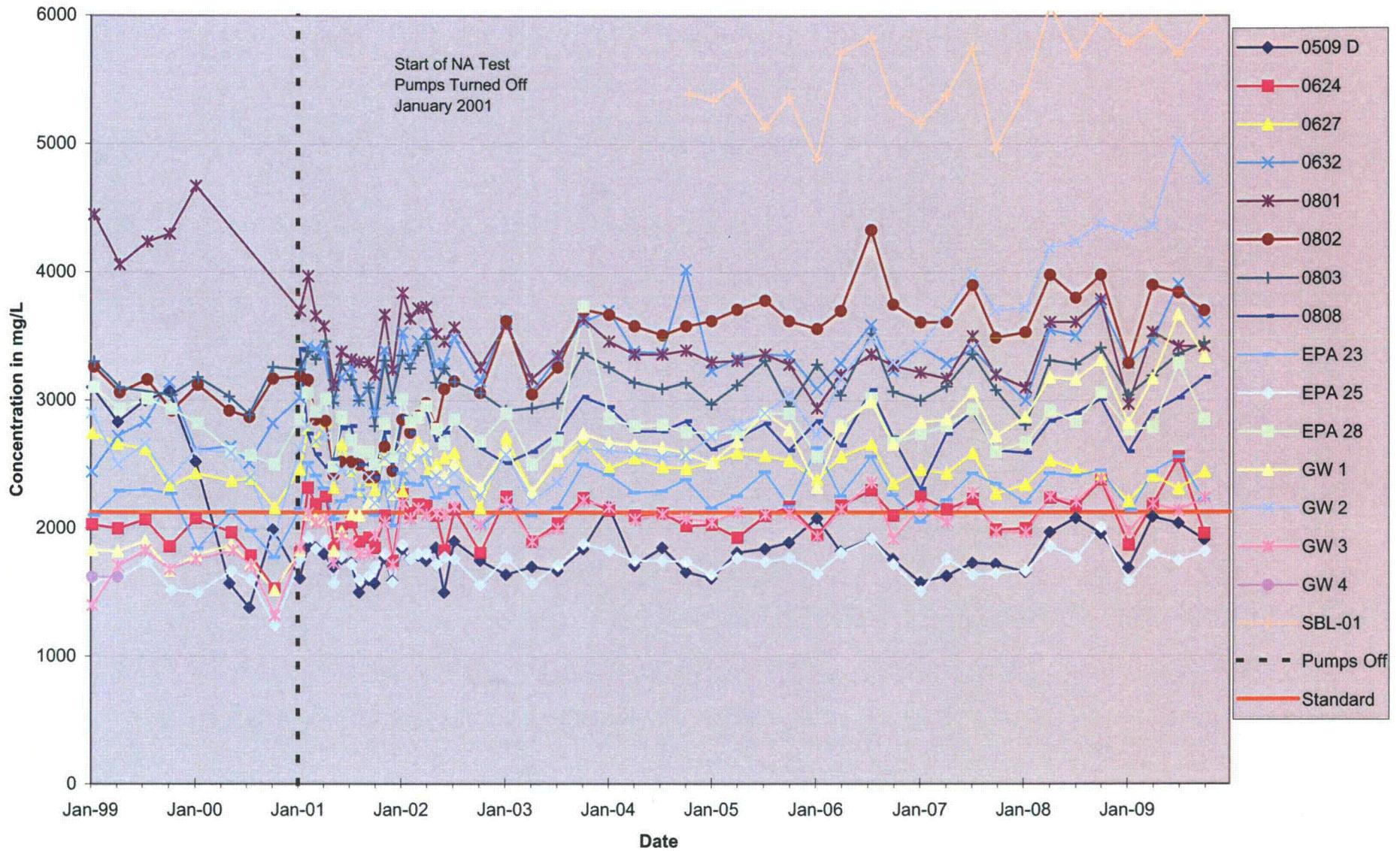


FIGURE 17
 Southwest Alluvium Total Dissolved Solids Concentrations From 1999 Through October 2009
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

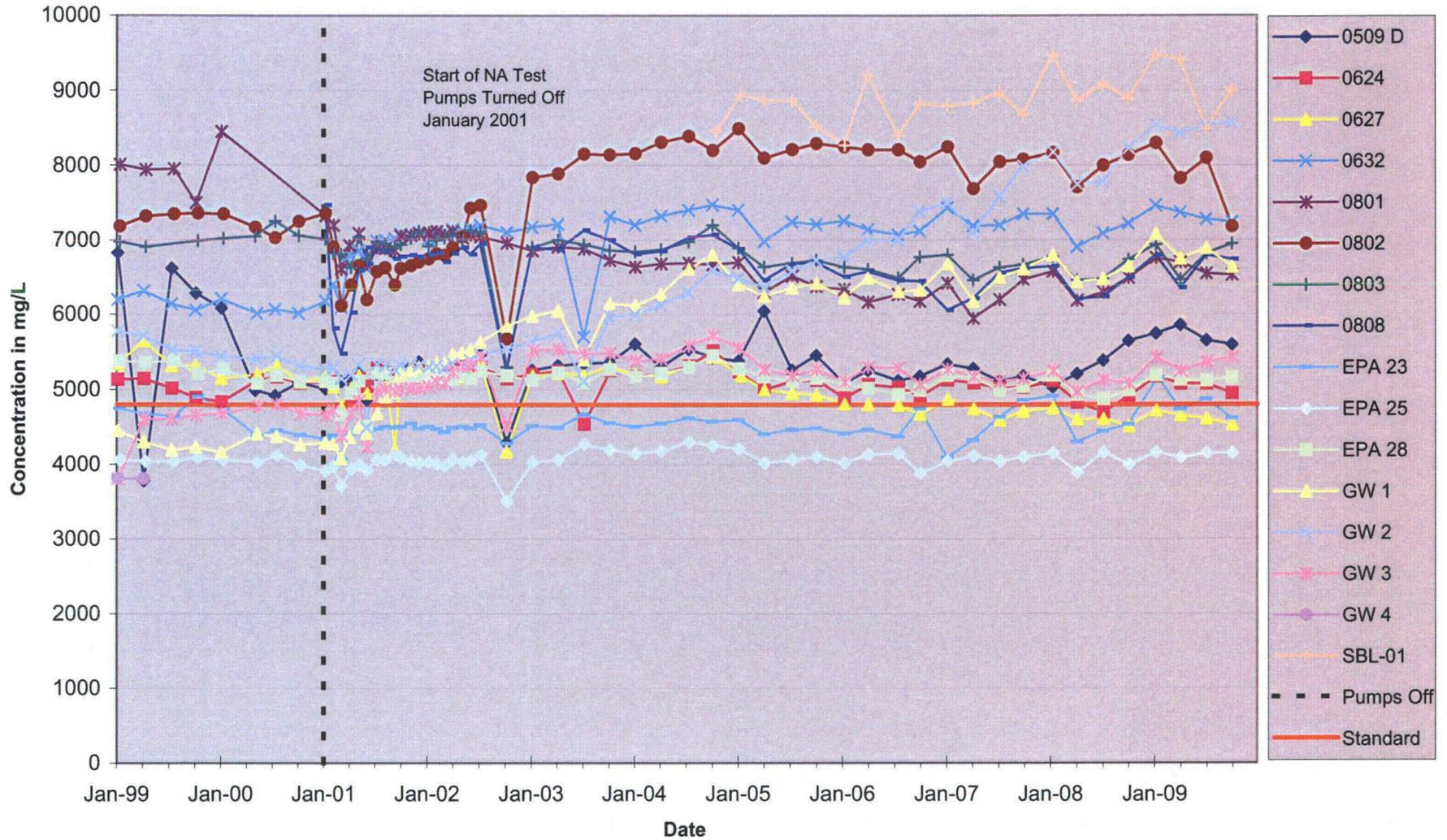


FIGURE 18

Uranium Concentrations in Selected Southwest Alluvium Wells
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

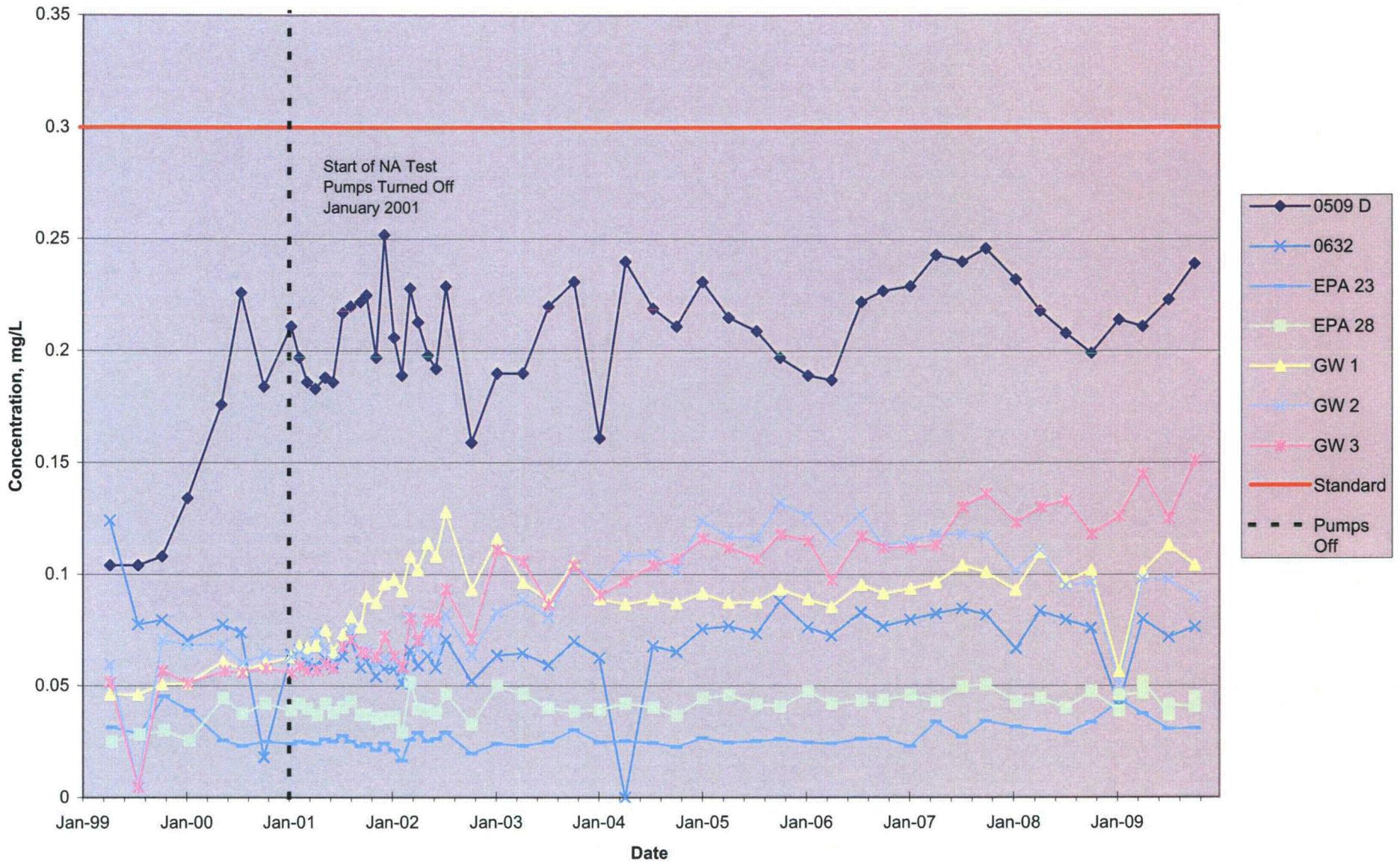


FIGURE 19
 Uranium Concentrations in Selected Southwest Alluvium Wells
 United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

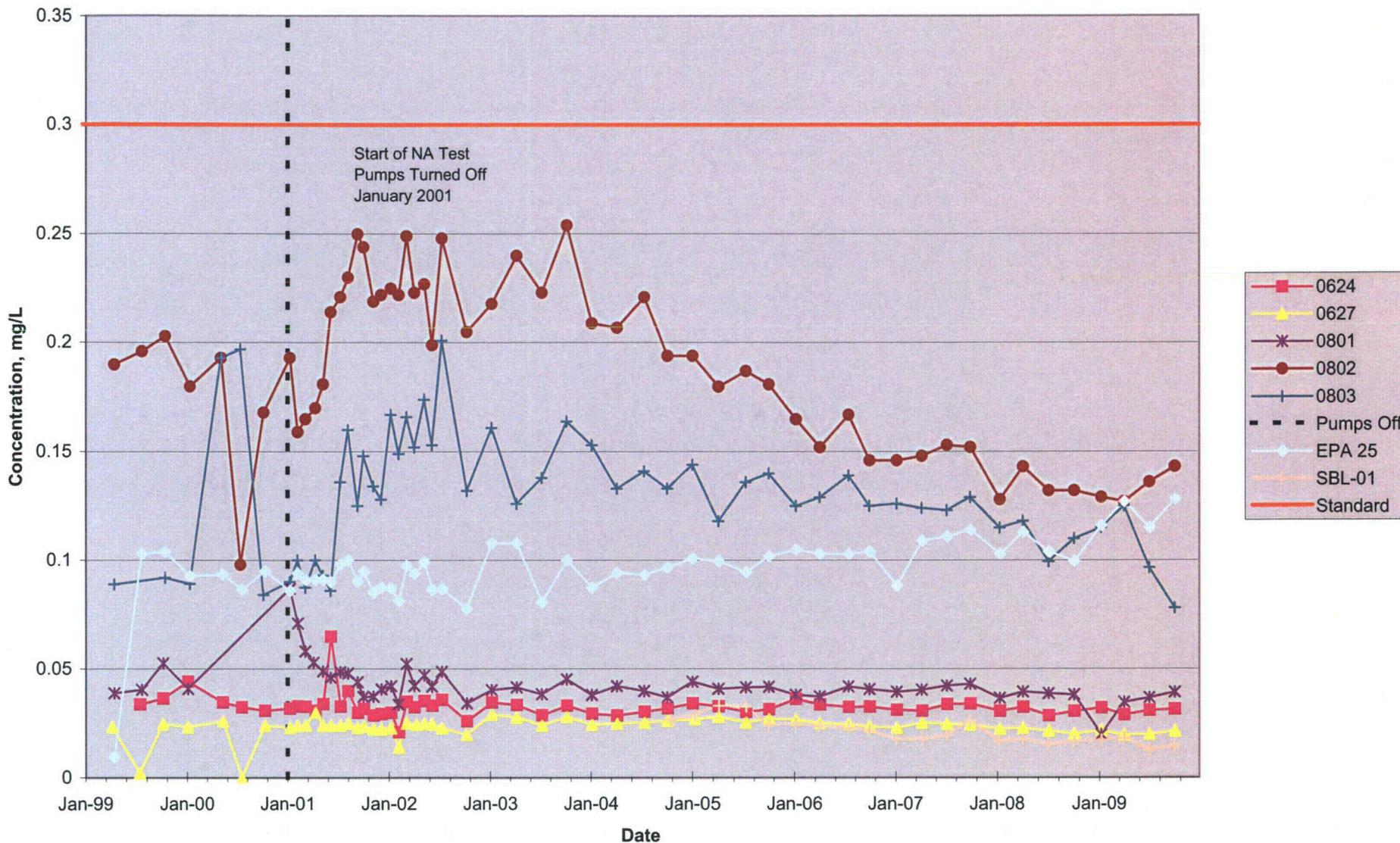
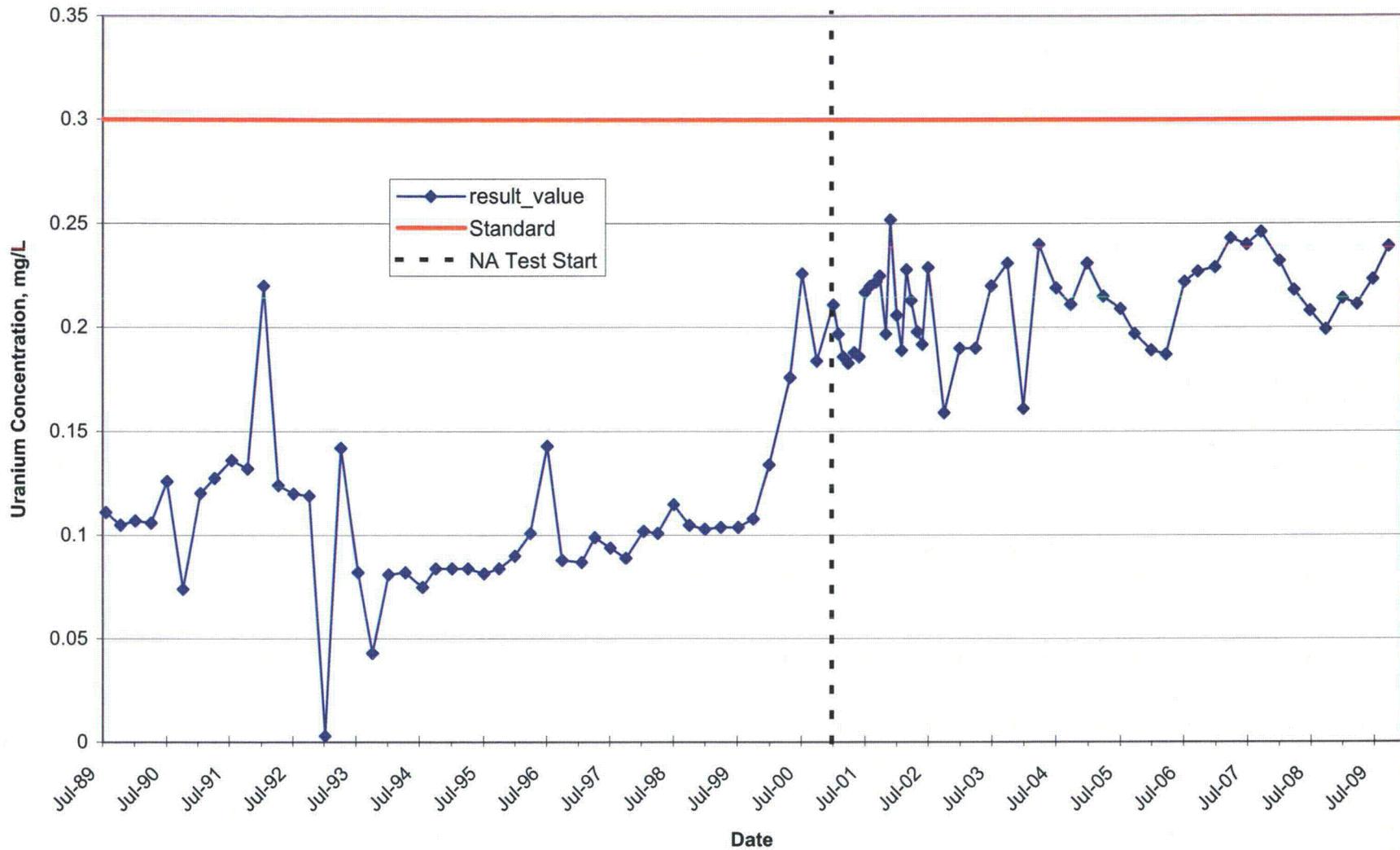
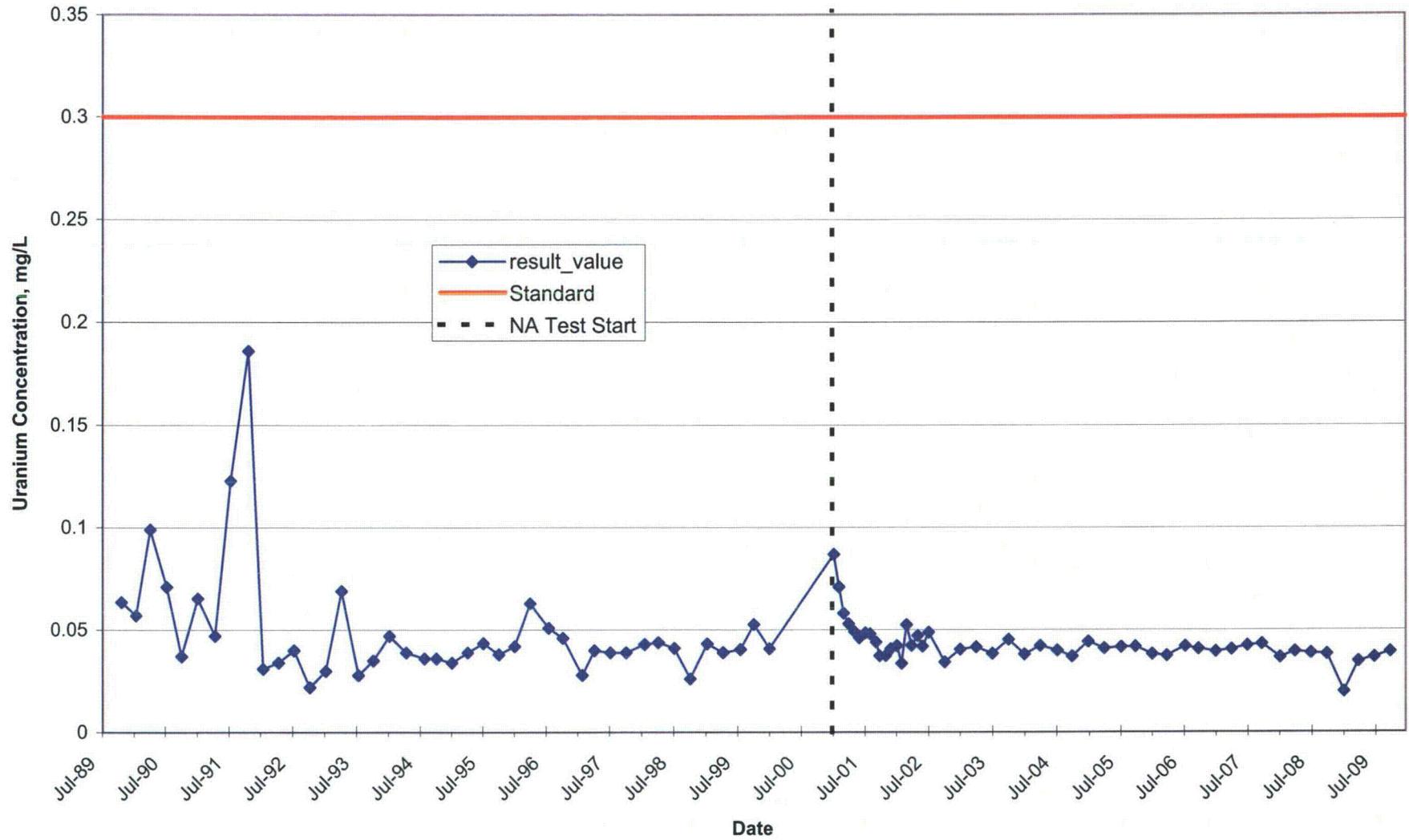


FIGURE 20
Uranium Concentration in Well 0509 D
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



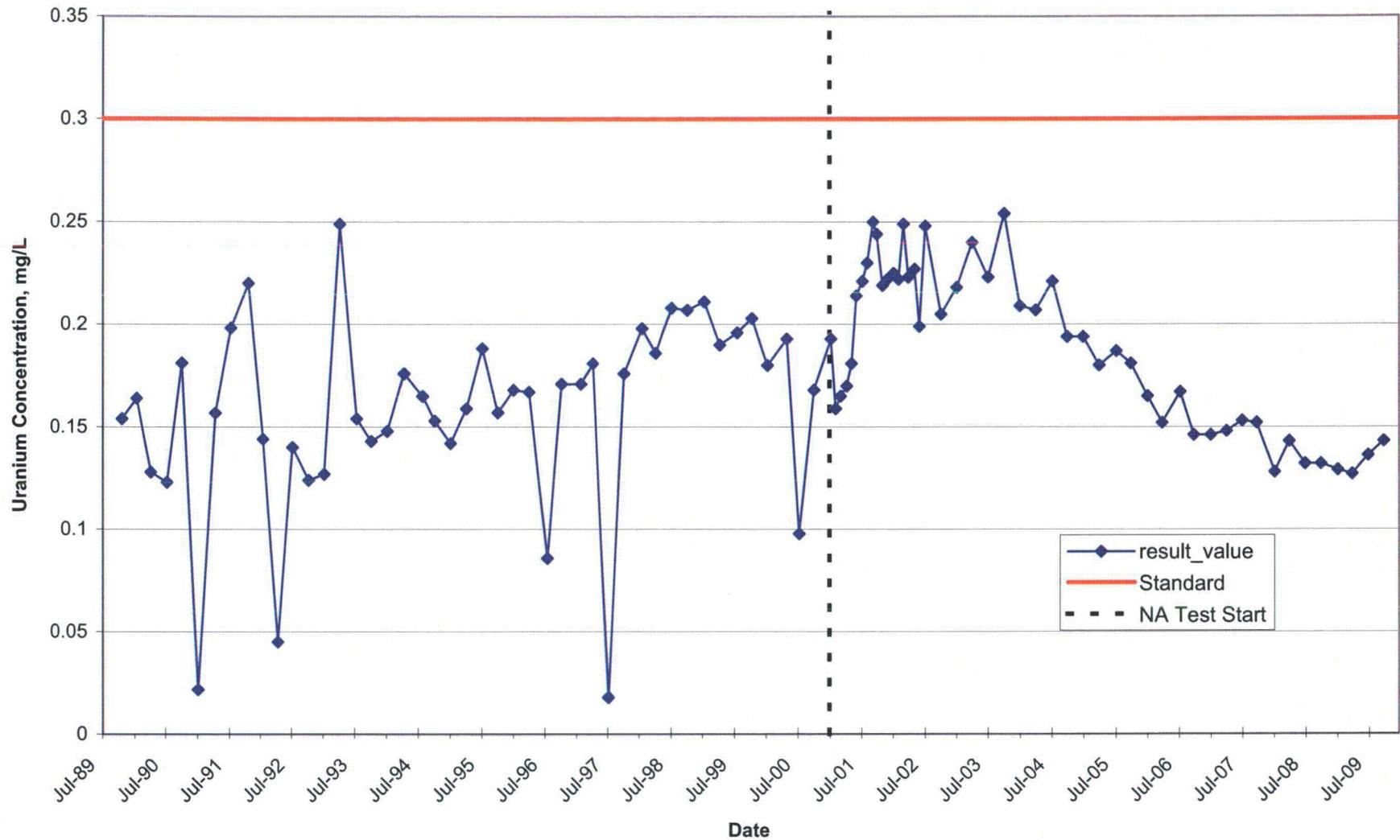
Red line indicates uranium standard (0.3 mg/L).

FIGURE 21
Uranium Concentration in Well 0801
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



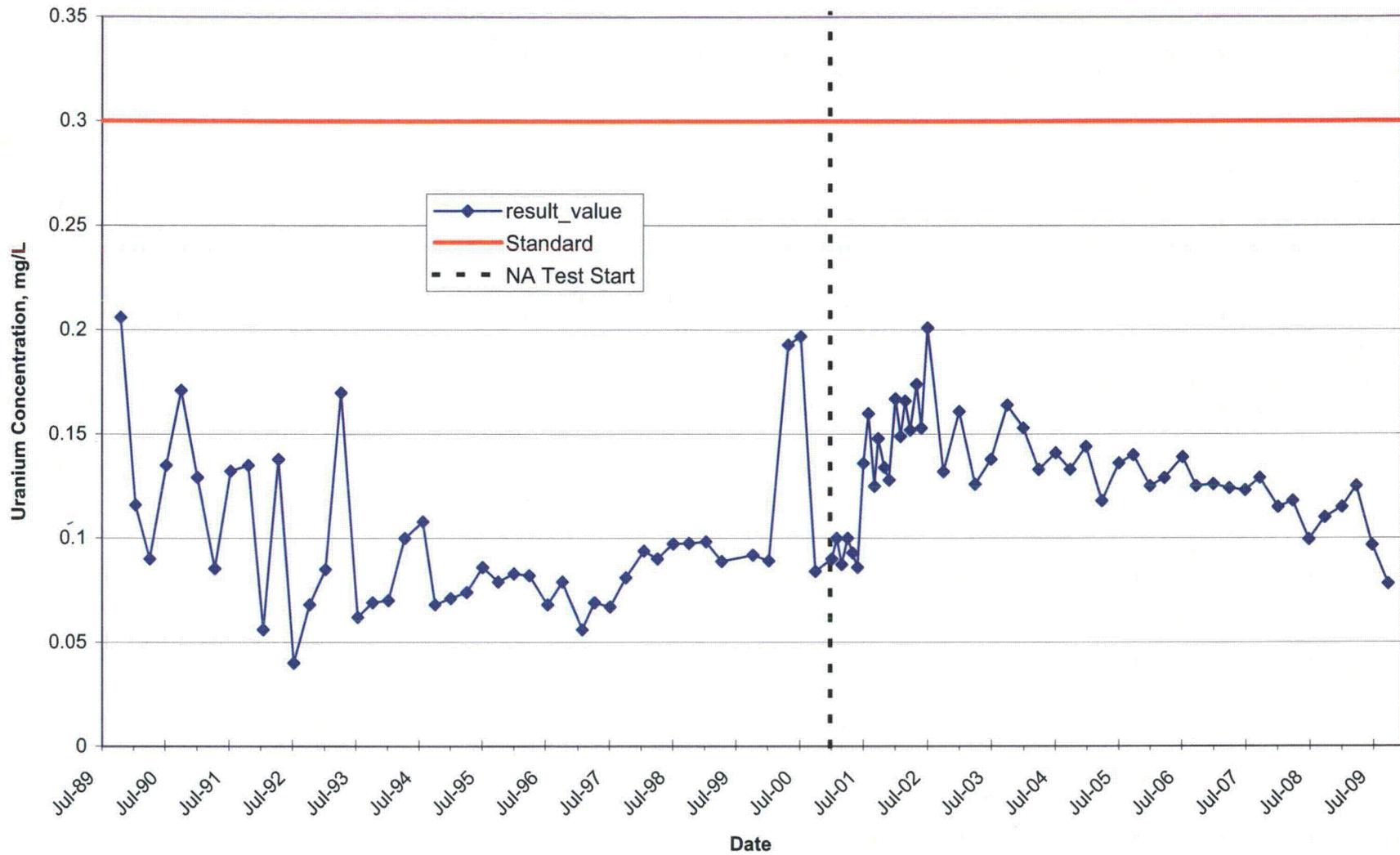
Red line indicates uranium standard (0.3 mg/L).

FIGURE 22
Uranium Concentration in Well 0802
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



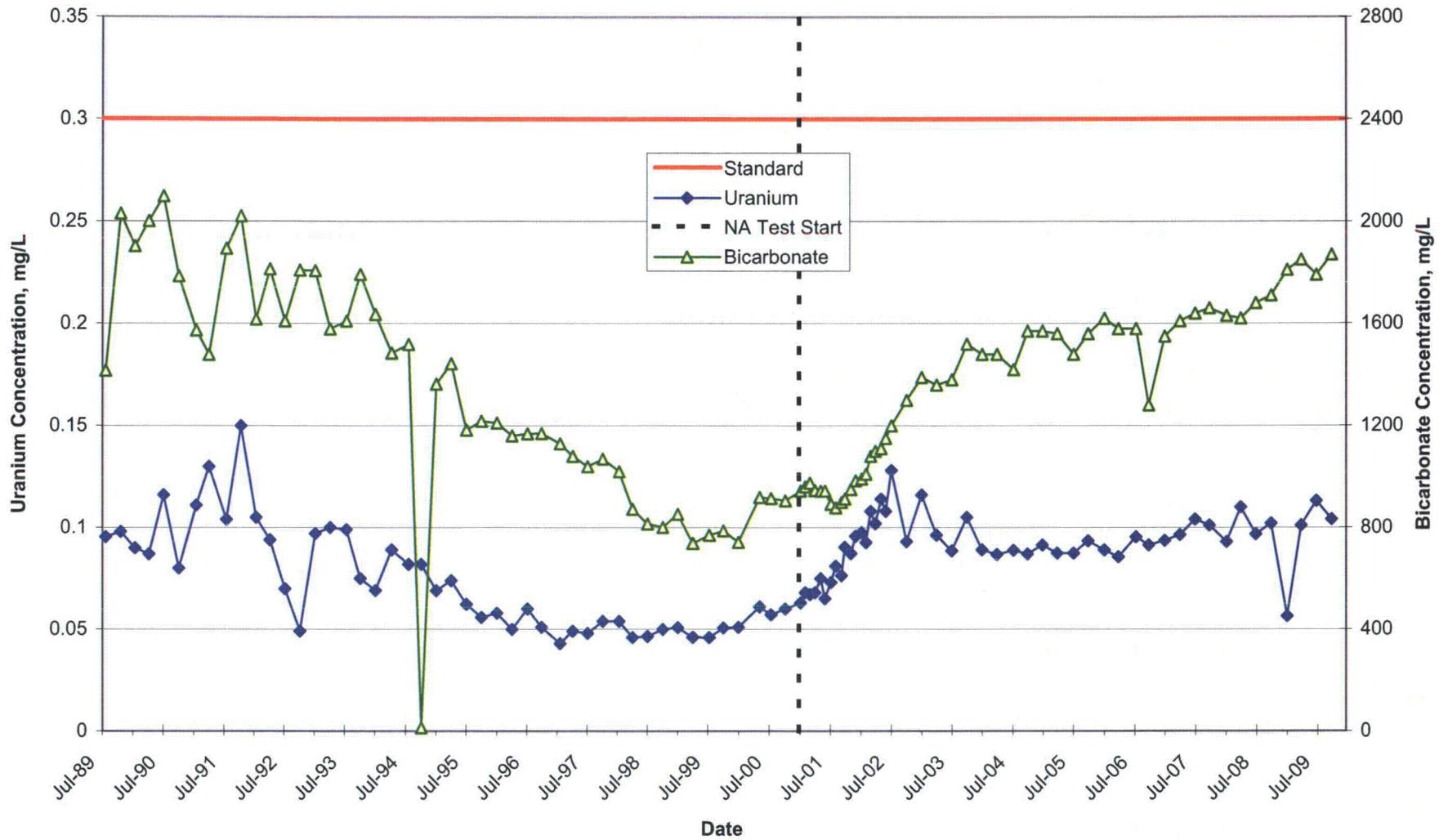
Red line indicates uranium standard (0.3 mg/L).

FIGURE 23
Uranium Concentration in Well 0803
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



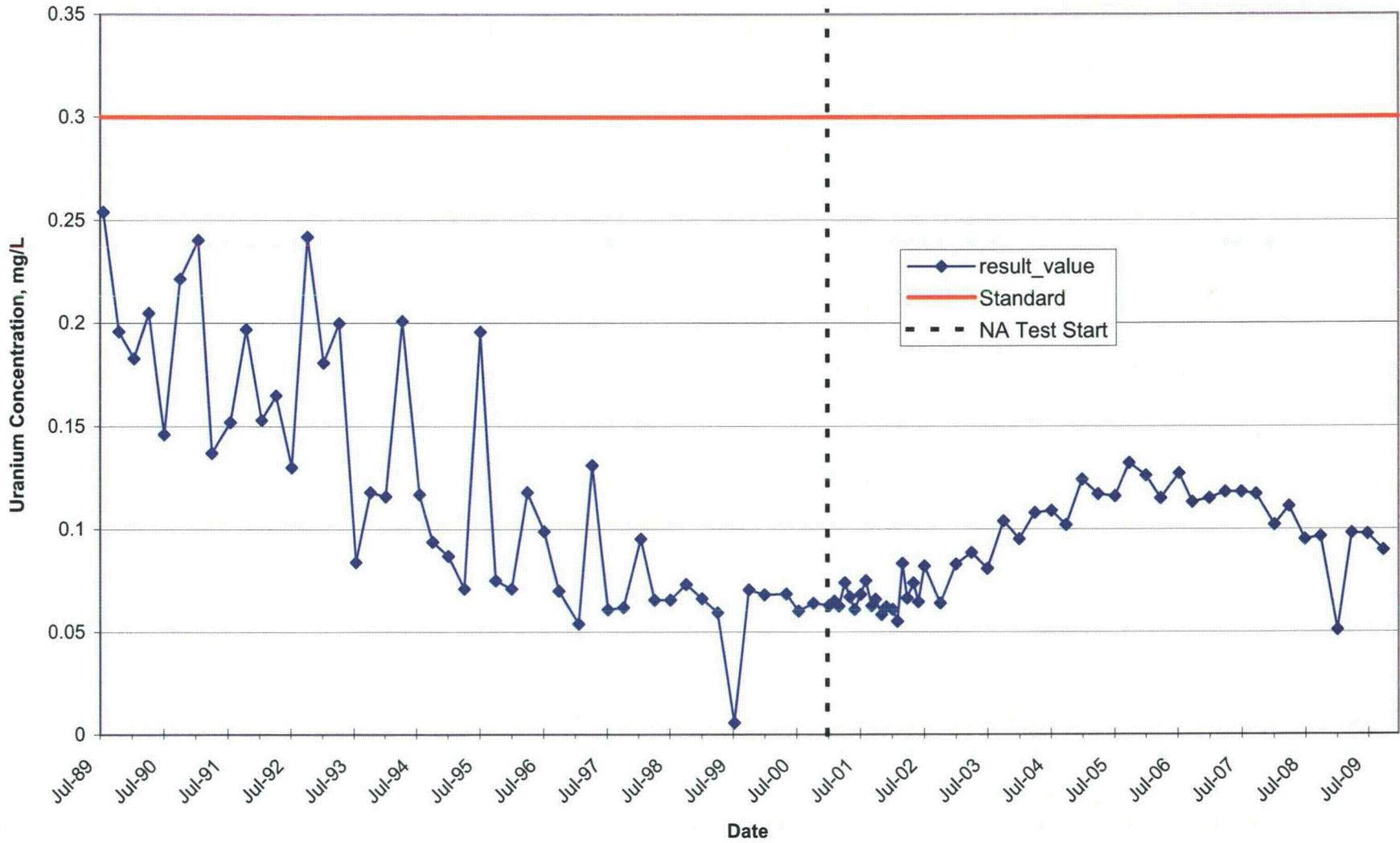
Red line indicates uranium standard (0.3 mg/L).

FIGURE 24
 Uranium and Bicarbonate Concentrations in Well GW 1
 United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



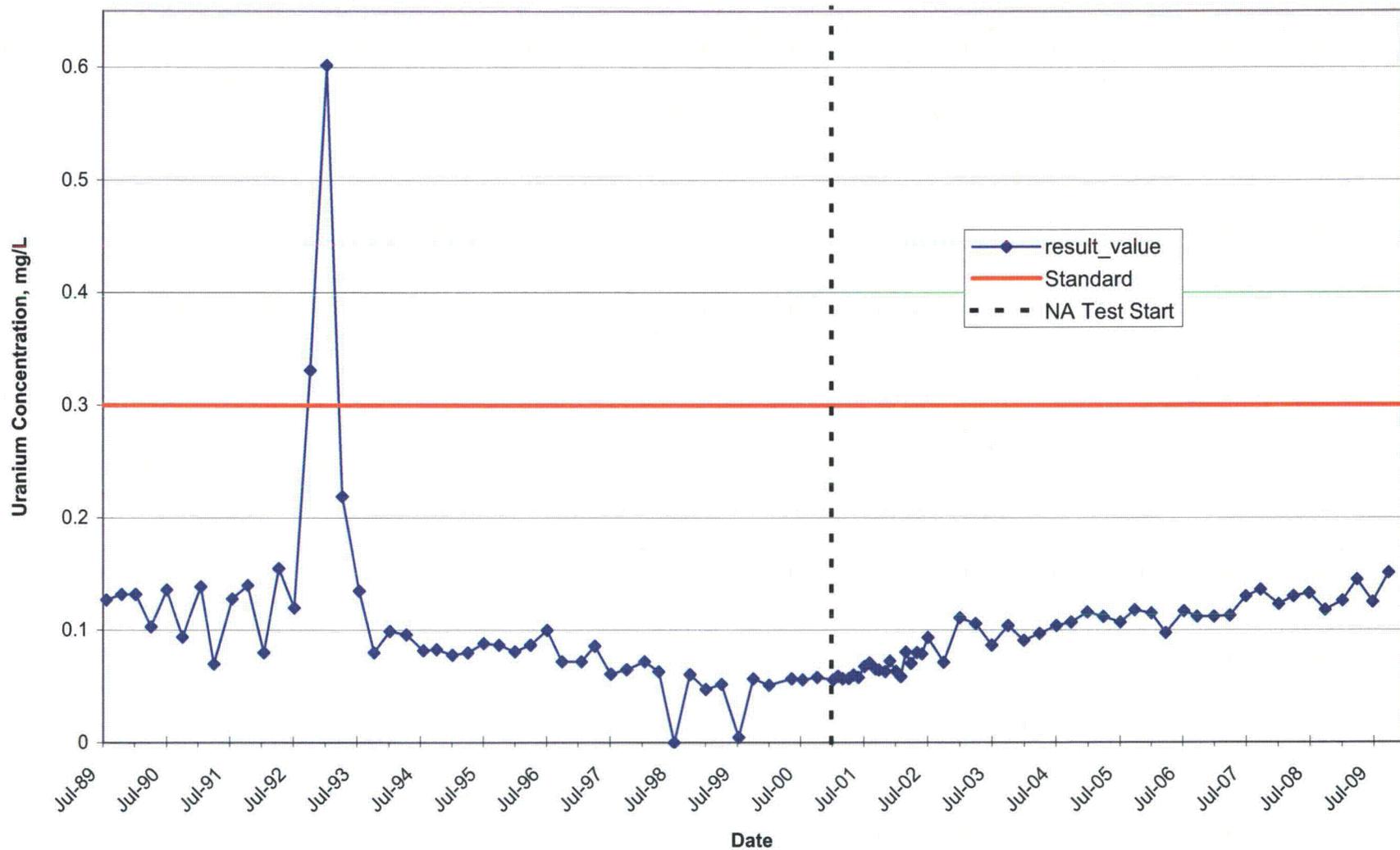
Red line indicates uranium standard (0.3 mg/L).

FIGURE 25
Uranium Concentration in Well GW 2
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



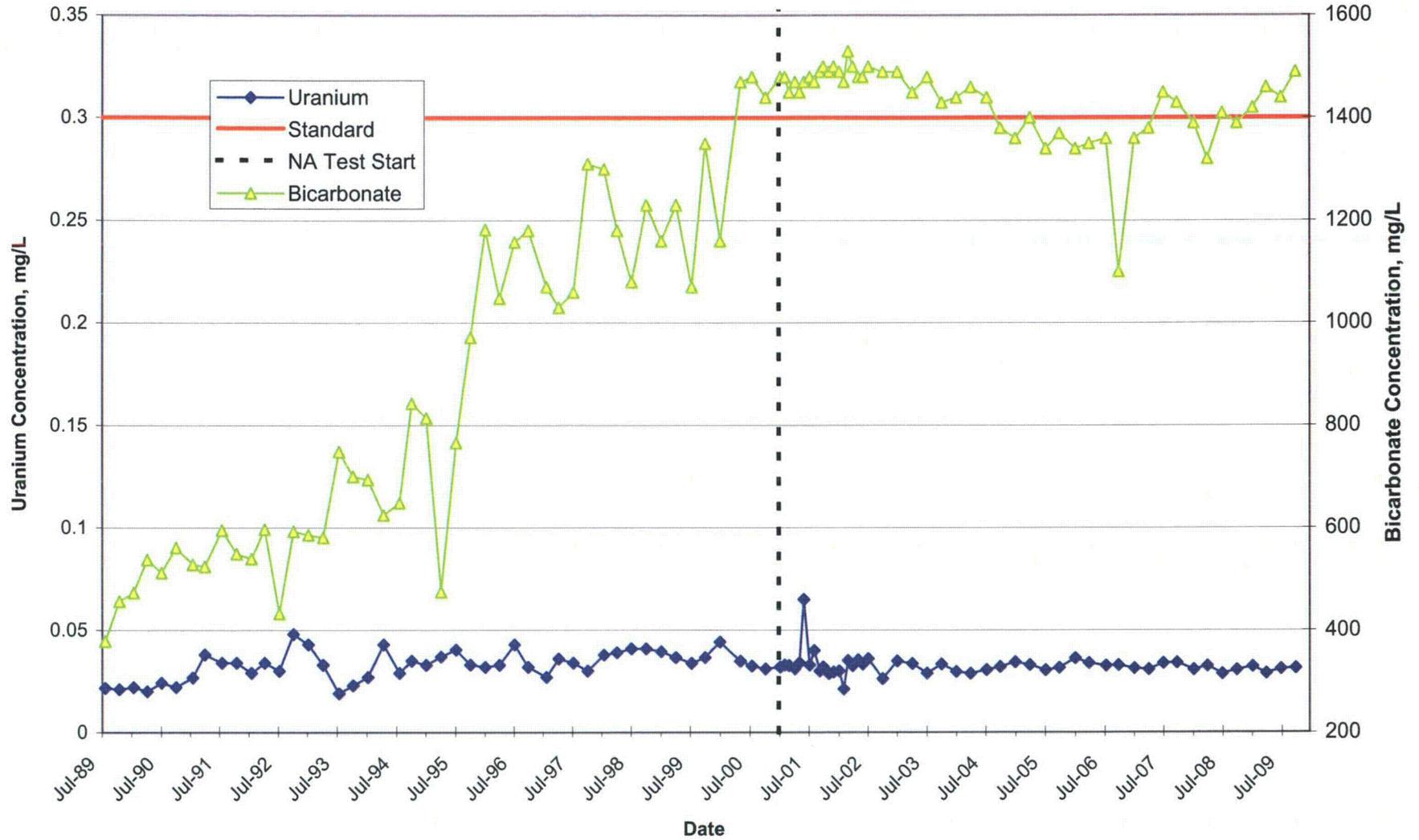
Red line indicates uranium standard (0.3 mg/L).

FIGURE 26
Uranium Concentration in Well GW 3
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



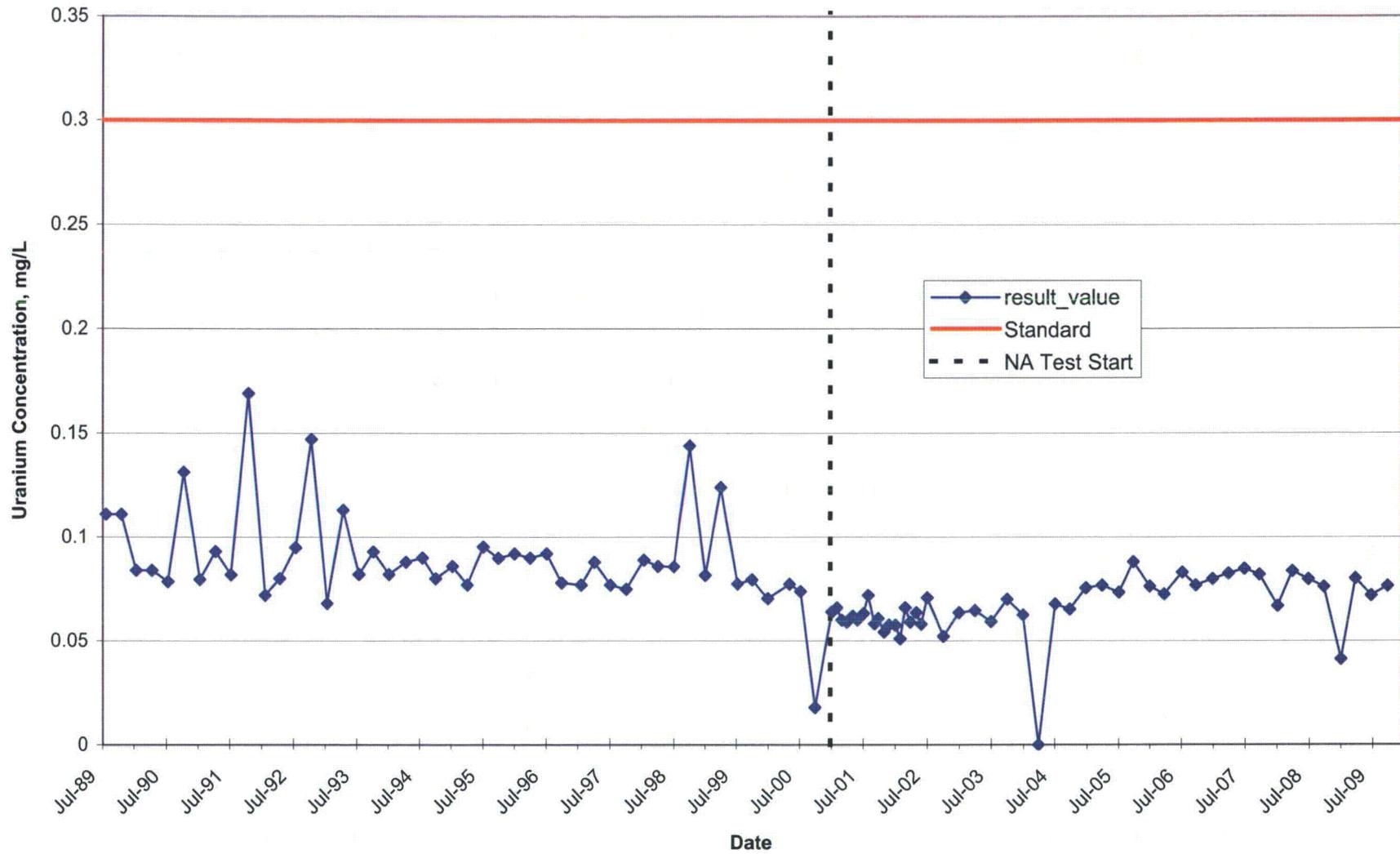
Red line indicates uranium standard (0.3 mg/L).

FIGURE 27
 Uranium and Bicarbonate Concentrations in Well 0624
 United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



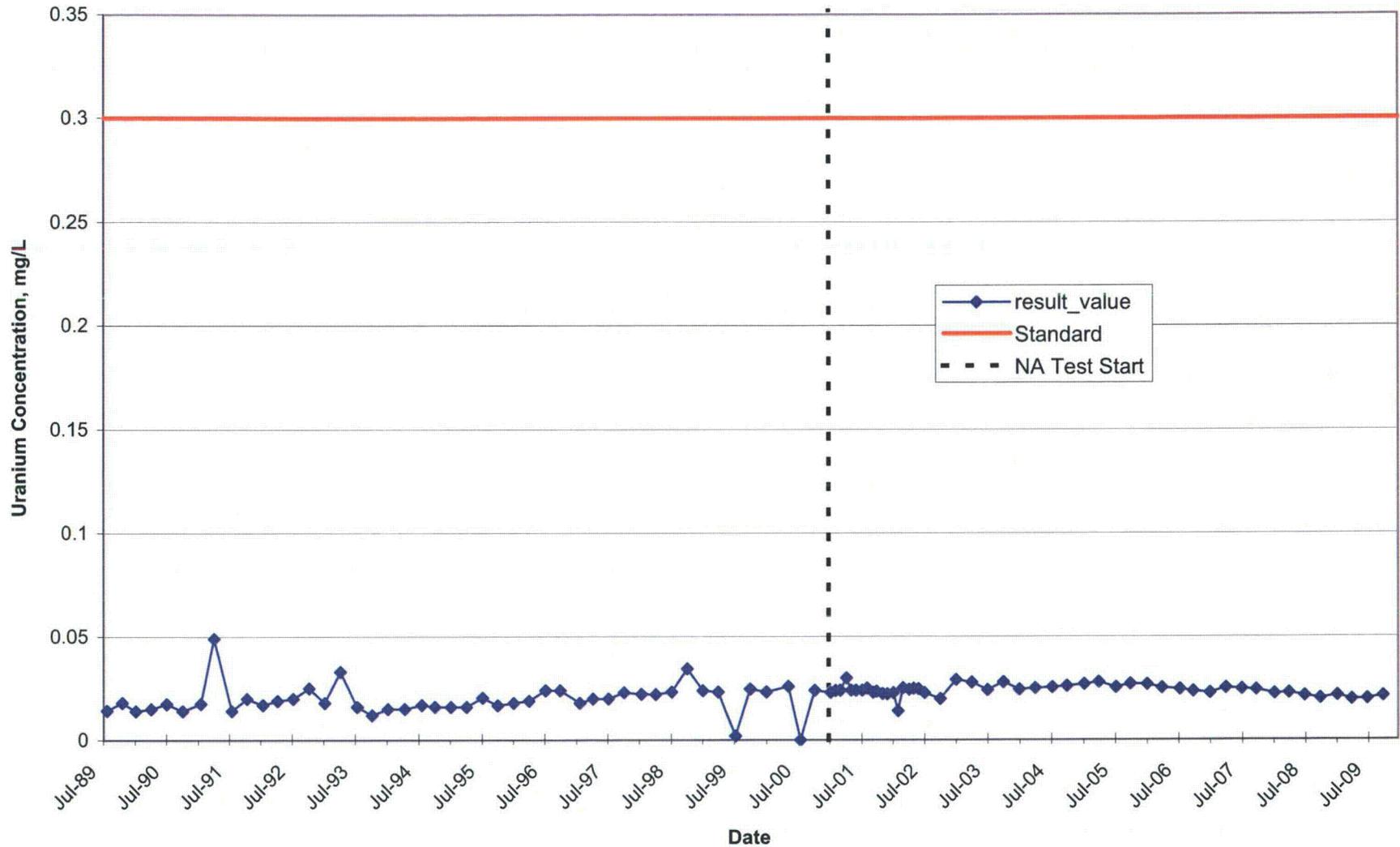
Red line indicates uranium standard (0.3 mg/L).

FIGURE 28
Uranium Concentration in Well 0632
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



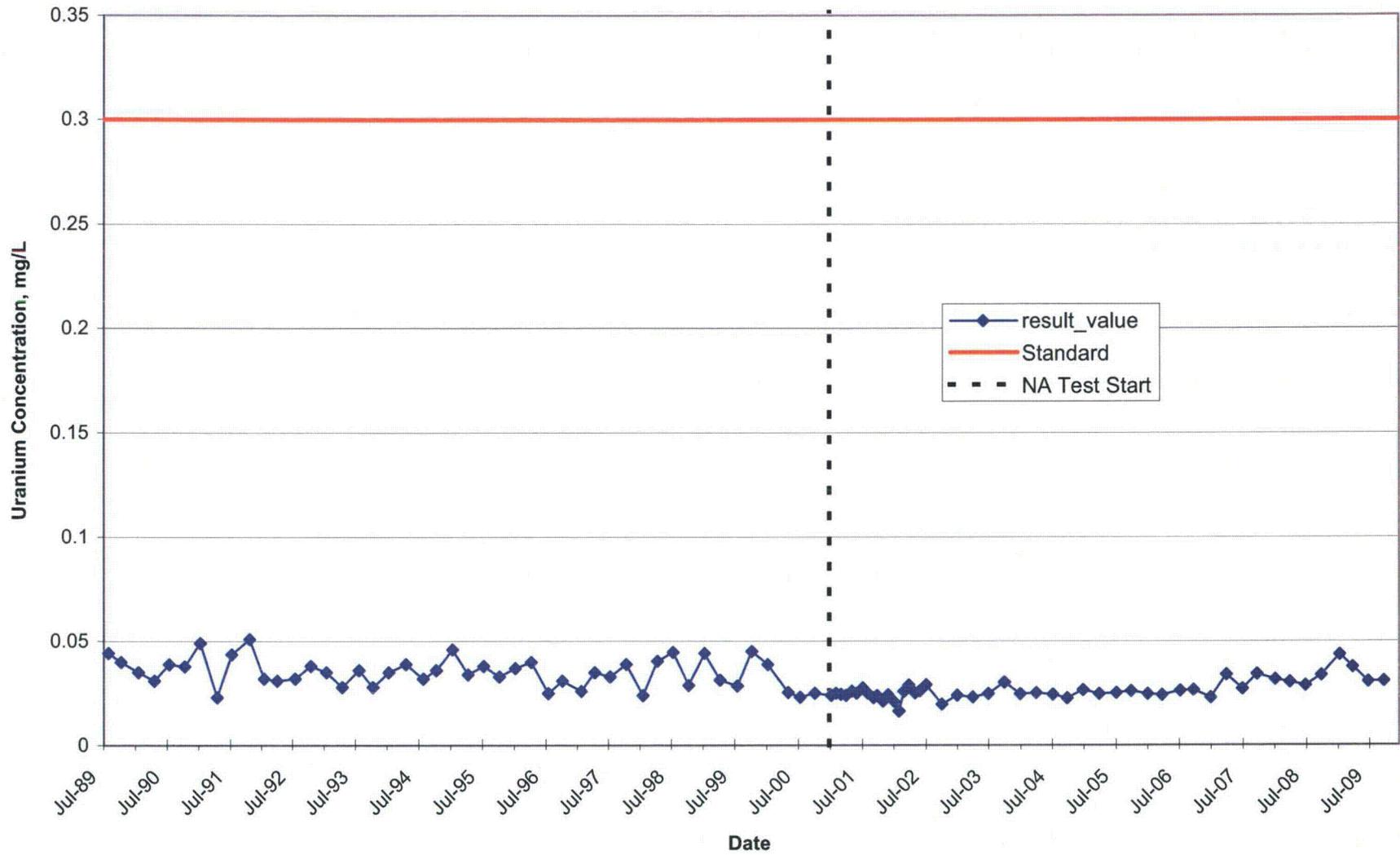
Red line indicates uranium standard (0.3 mg/L).

FIGURE 29
Uranium Concentration in Well 0627
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



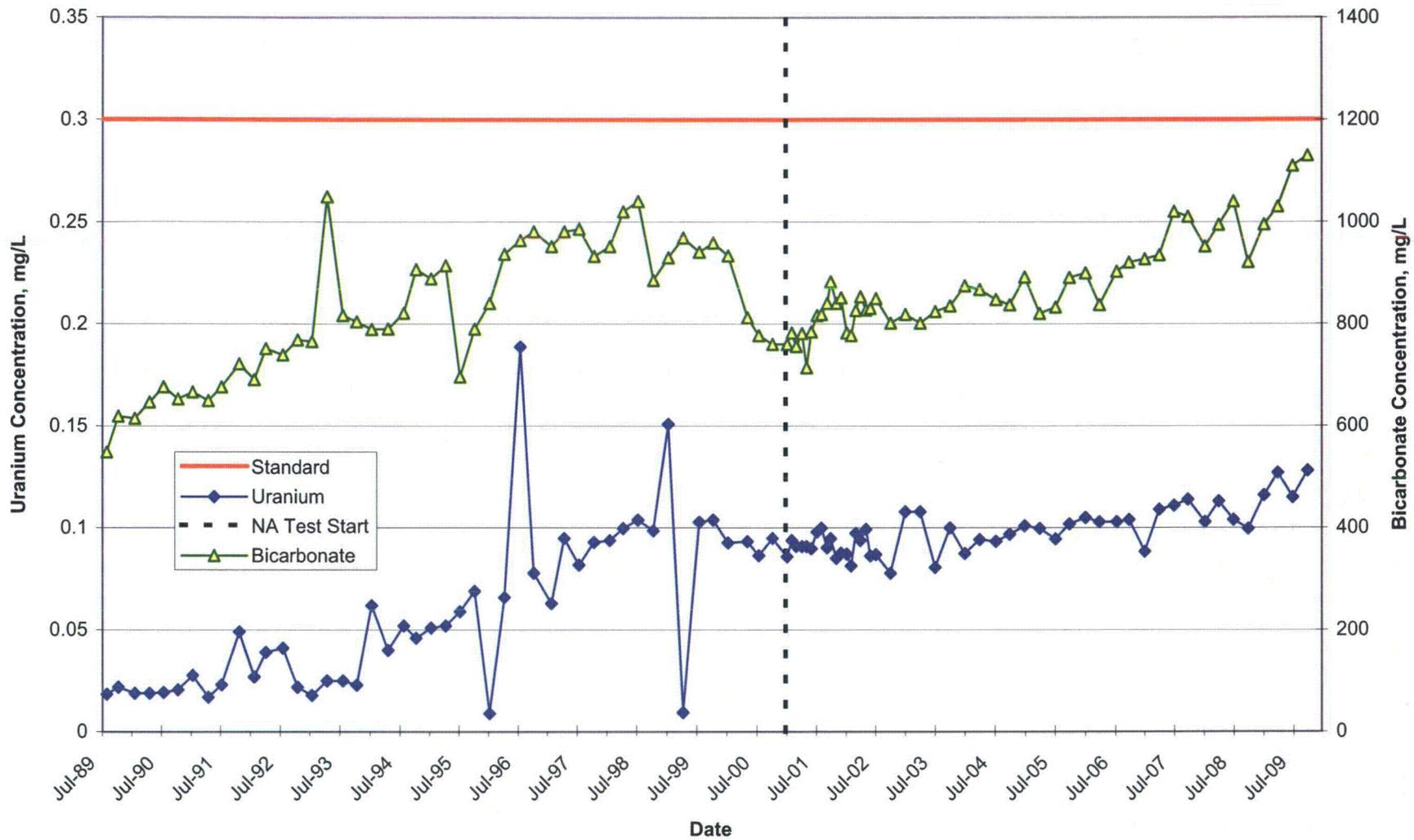
Red line indicates uranium standard (0.3 mg/L).

FIGURE 31
Uranium Concentration in Well EPA 23
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



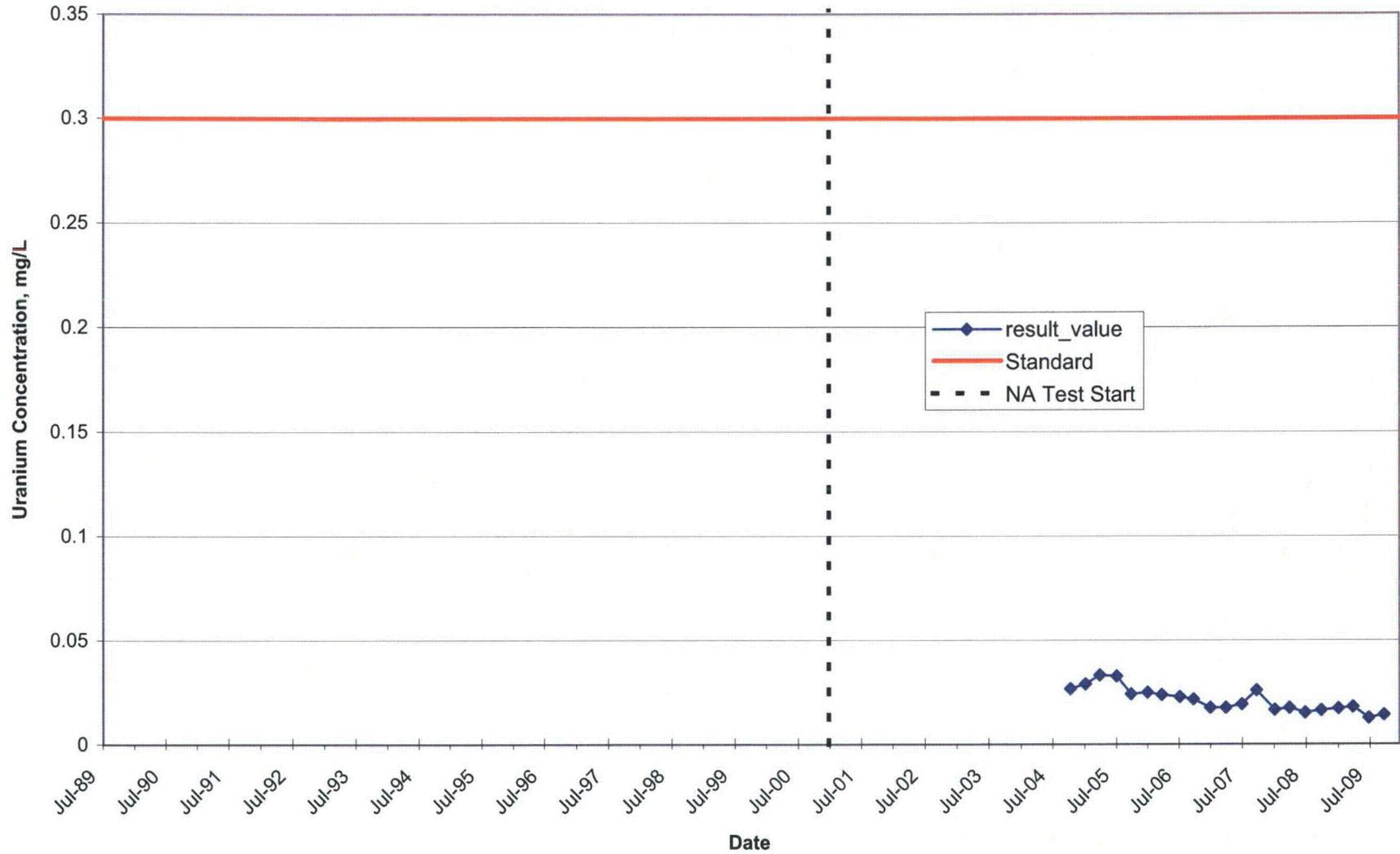
Red line indicates uranium standard (0.3 mg/L).

FIGURE 32
 Uranium and Bicarbonate Concentrations in Well EPA 25
 United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



Red line indicates uranium standard (0.3 mg/L).

FIGURE 34
Uranium Concentration in Well SBL-01
United Nuclear Corporation Church Rock Site, Church Rock, New Mexico



Red line indicates uranium standard (0.3 mg/L).

