United Nuclear Corporation
Gallup, New Mexico

Annual Review Report – 2005
Groundwater Corrective Action
Church Rock Site, Church Rock, New Mexico

December 2005

NA WATERSYSTEMS

UNITED NUCLEAR CORPORATION
GALLUP, NEW MEXICO

ANNUAL REVIEW REPORT – 2005
GROUNDWATER CORRECTIVE ACTION
CHURCH ROCK SITE, CHURCH ROCK, NEW MEXICO

DECEMBER 2005

PREPARED BY:
MARK D. JANCIN, P. G.

APPROVED BY:
JAMES A. EWART, PH. D., P. G.

56003960

120 Radnor Road
State College, PA 16801
814-231-2170 phone
814-231-2174 fax

Annual Review Report – 2005
Groundwater Corrective Action
Church Rock Site, Church Rock, New Mexico
Table of Contents (continued)

Page No.

Section 1 Introduction **1**
1.1 Site Location 2
1.2 Corrective Action Systems 2
1.3 Performance Monitoring and Supplemental Sampling 3
1.3.1 Performance Monitoring 3
1.3.2 Supplemental Sampling 3
1.4 Southwest Alluvium 4
1.5 Report Organization 4

Section 2 Southwest Alluvium **6**
2.1 Corrective Action Summary 6
2.2 Mass Of Chemical Constituents Removed 6
2.3 Performance Monitoring Evaluation 6
2.3.1 Water Level Evaluation 6
2.3.2 Water Quality Evaluation and Current Extent of Seepage-Impacted Water 7
2.3.3 Rate of Seepage Migration 13
2.3.4 Continuing Assessment of Southwest Alluvium Natural Attenuation and Earlier Technical Impracticability Waiver Request 15
2.3.5 Reassessment of the Performance of the Natural System 16

Section 3 Zone 3 ..... **25**
3.1 Corrective Action Summary 25
3.2 Mass Of Chemical Constituents Removed 27
3.3 Performance Monitoring Evaluation 27
3.3.1 Water Level Evaluation 28
3.3.2 Water Quality Evaluation and Current Extent of Seepage-Impacted Water 30
3.3.3 Rate of Seepage Migration 34
3.3.4 Natural Attenuation System Performance Evaluation 34

Table of Contents (continued)

Page No.

Section 4 Zone 1 ..... **42**
4.1 Corrective Action Summary 42
4.2 Mass Of Chemical Constituents Removed 42
4.3 Performance Monitoring Evaluation 42
4.3.1 Water Level Evaluation 42
4.3.2 Water Quality Evaluation and Current Extent of Seepage-Impacted Water 43
4.3.3 Natural Attenuation System Performance Evaluation 45

Section 5 Conclusions And Recommendations **50**
5.1 Conclusions 50
5.2 Recommendations 52
5.2.1 Recommendations for Closure of Southwest Alluvium Remedial Action 52
5.2.2 Recommendations for Zone 3 Remedial Action 54
5.2.3 Recommendations for Closure of Zone 1 Remedial Action 54

Section 6 References **56**

Page No.

List of Tables

1 Southwest Alluvium Performance Monitoring Program, 2005 Operating Year
2 Detected Constituents in Southwest Alluvium, October 2005
3 Southwest Alluvium Saturated Thickness, October 2005
4 Summary of Operational Data, Southwest Alluvium Extraction Wells 1989 to 2001
5 Southwest Alluvium Groundwater Velocities, October 2005
6 Predicted Performance of Southwest Alluvium Natural Attenuation, 2005
7 Change in Zone 3 Saturated Thickness Over Time
8 Estimated Mass Removal by Extraction Well Pumping in Zone 3, 2005
9 Zone 3 Performance Monitoring Program, 2005 Operating Year
10 Zone 3 Saturated Thickness, October 2005
11 Zone 3 Field Parameter Measurements of Sentinel Wells Through October 2005
12 Zone 3 Seepage Migration Travel Time Calculations
13 Detected Constituents in Zone 3, October 2005
14 Zone 1 Performance Monitoring Program, 2005 Operating Year
15 Zone 1 Saturated Thickness, October 2005
16 Detected Constituents in Zone 1, October 2005
17 Predicted Performance of the Zone 1 Natural Attenuation System

List of Figures

1 Site Location Map
2 Site Layout and Performance Monitoring Well Locations, 2005 Operating Year
3 Southwest Alluvium Potentiometric Surface Map, October 2005
4 Southwest Alluvium Water Levels Over Time
5 Southwest Alluvium Pumping Well Water Levels Over Time
6 Extent of Seepage-Impacted Groundwater
7 Southwest Alluvium Sulfate Concentrations Over Time
8 Southwest Alluvium Bicarbonate Isoconcentration Map and Distribution of Sulfate Below 2125 mg/L, October 2005
9 Primary Components of TDS in Southwest Alluvium Groundwater
10 Southwest Alluvium TDS Concentrations Over Time
11 Calcium and Bicarbonate Concentrations in Selected Background and Seepage-Impacted Wells
12 Southwest Alluvium Calcium Concentrations From 1999 Through October 2005
13 Southwest Alluvium Bicarbonate Concentrations From 1999 Through October 2005
14 Southwest Alluvium Sulfate Concentrations From 1999 Through October 2005
15 Southwest Alluvium TDS Concentrations From 1999 Through October 2005
16 Southwest Alluvium Chloride Concentrations From 1999 Through October 2005
17 Southwest Alluvium Manganese Concentrations From 1999 Through October 2005
18 Uranium Concentrations in Selected Southwest Alluvium Wells
19 Uranium Concentrations in Selected Southwest Alluvium Wells
20 Uranium Concentrations in Well 509 D
21 Uranium Concentrations in Well 801
22 Uranium Concentrations in Well 802

List of Figures – continued

23 Uranium Concentrations in Well 803
24 Uranium Concentrations in Well GW 1
25 Uranium Concentrations in Well GW 2
26 Uranium Concentrations in Well GW 3
27 Uranium Concentrations in Well 624
28 Uranium Concentrations in Well 632
29 Uranium Concentrations in Well 627
30 Uranium Concentrations in Well 808
31 Uranium Concentrations in Well EPA 23
32 Uranium Concentrations in Well EPA 25
33 Uranium Concentrations in Well EPA 28
34 Uranium Concentrations in Well SBL 1
35 Zone 3 Approximate Extent of Seepage Impacts, October 2005
36 Zone 3 Locations of In-Situ Alkalinity Stabilization Pilot Study Wells for Remedy Enhancement, 2005
37 Effects of Past Pumping to Dewater Zone 3
38 Zone 3 Potentiometric Surface Map, October 2005
39 Zone 3 Saturated Thickness Map, October 2005
40 Zone 3 Sulfate Concentrations Over Time
41 Zone 3 Bicarbonate Concentrations Over Time
42 Zone 3 Impact Perimeter Bicarbonate Concentrations Over Time
43a Zone 3 Metals Concentrations Over Time
43b Zone 3 Metals Concentrations Over Time
44 Zone 3 Approximate Extent of Aluminum Exceeding 5.0 mg/L, October 2005
45 Zone 3 Uranium, Vanadium, And Radionuclides Over Time
46 Zone 3 Chloroform Concentrations Over Time
47 Zone 1 Potentiometric Surface Map, October 2005
48 Zone 1 Water Levels Over Time
49 Zone 1 Extent of Seepage Impacts, October 2005

List of Figures – continued

50 Zone 1 pH Over Time
51 Zone 1 Sulfate Concentrations Over Time
52 Zone 1 Approximate Extent of Sulfate Exceeding 2,125 mg/L, October 2005
53 Zone 1 Manganese Concentrations Over Time
54 Zone 1 Approximate Extent of Manganese Exceeding 2.6 mg/L, October 2005
55 Zone 1 Bicarbonate Concentrations Over Time
56 Zone 1 Cobalt and Nickel Concentrations Over Time
57 Zone 1 Approximate Extent of Cobalt and Nickel Exceeding 0.05 mg/L, October 2005
58 Zone 1 Combined Radium–226 and Radium–228 Over Time
59 Proposed Technical Impracticability Waiver for Zone 1 and Extrapolated Extent of Southwest Alluvium Seepage in 2204

List of Appendices

A Southwest Alluvium Monitoring Data (Table A.1) with Introductory Text; Figure A-1 (Southwest Alluvium Proposed Revised Monitoring Well Locations); and 2005 Laboratory Groundwater Analytical Reports.

B Zone 3 Monitoring Data (Table B.1) with Introductory Text; Figure B-1 (Zone 3 2005 Monitoring Well Locations); and 2005 Laboratory Groundwater Analytical Reports.

C Zone 1 Monitoring Data (Table C.1) with Introductory Text; Figure C-1 (Zone 1 2005 Monitoring Well Locations); and 2005 Laboratory Groundwater Analytical Reports.

List of Acronyms and Abbreviations

ACL	alternate concentration limit
ALARA	as low as reasonably achievable
EPA	U.S. Environmental Protection Agency
ft/yr	feet per year
gpm	gallons per minute
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
NRC	Nuclear Regulatory Commission
pCi/L	picocuries per liter
POC	point of compliance
POE	point of exposure
ROD	Record of Decision
SFS	Supplemental Feasibility Study
SMCL	federal secondary maximum contaminant level
TDS	total dissolved solids
THMs	trihalomethanes
TI	technical impracticability
µg/L	micrograms per liter

Section 1
Introduction

On behalf of United Nuclear Corporation (UNC), N.A. Water Systems 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 review report at the end of each operating year since 1989. This report is the seventeenth in the series and includes groundwater quality analyses and groundwater elevations for the first quarter of 2005 through the fourth quarter of 2005.

This report, similar to the 2004 report (N.A. Water Systems, 2004), focuses on 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 have reached the limit of their effectiveness. EPA (1988) 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; N.A. Water Systems, 2004 and 2005b) and the Zone 1 hydrostratigraphic unit (Earth Tech, 2000c; N.A. Water Systems, 2005b) 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. The ongoing hydrofractured extraction-well pilot study in Zone 3 is also updated in the report.

During 2005, General Electric Corporation (GE), on behalf of UNC, submitted two license amendment requests to the U.S. Nuclear Regulatory Commission (NRC): (1) a revised request for changing the site-wide chloroform groundwater protection standard (General Electric, 2005a); and (2) a request for changing the method by which compliance with the combined radium groundwater protection standard is evaluated in the Southwest Alluvium and Zone 1 (General Electric, 2005b; N.A. Water Systems, 2005b). Pending the approval of these license amendment requests, and as demonstrated by the groundwater quality reviewed in this report, UNC is very close to meeting the corrective action goals in the Southwest Alluvium and Zone 1. The remaining actions needed to meet those corrective action goals are discussed in this report.

UNC continues to investigate potential remedy enhancements in Zone 3 with an ongoing pilot study of hydrofractured extraction wells (MACTEC, 2003, rev. March 2004; MWH, 2004; MACTEC, 2005). A second, and distinct, pilot study work plan was submitted on October 12, 2005. The second study combines the injection of high alkalinity alluvial groundwater to neutralize and displace the acidic tailings seepage in Zone 3 towards recovery wells.

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. 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 [Smith Technology], 1995 and 1996; Rust Environment and Infrastructure [Rust], 1997; Earth Tech, 1998, 1999, 2000e, 2002a and 2002d; USFilter, 2004a; and N.A. Water Systems, 2004).

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). 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. UNC is conducting an ongoing, extended pilot investigation to evaluate the suitability of hydrofracturing to enhance the extraction potential within the impacted area of this hydrostratigraphic unit (MACTEC, 2003, rev. March 2004; MACTEC, 2005; MWH, 2004). The Southwest Alluvium system was temporarily shut off in January 2001 to allow implementation of the Natural Attenuation (NA) test, which 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.

1.3 Performance Monitoring and Supplemental Sampling

1.3.1 Performance Monitoring

The *Corrective Action Plan* (UNC, 1989a), *Remedial Design Report* (Canonie, 1989a) and *Remedial Action Plan* (UNC, 1989b), approved by the NRC and EPA, described the groundwater performance monitoring program. 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), 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 2005 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. Quarterly laboratory analytical data sheets for the 2005 operating year are included at the end of each appendix. Field and laboratory data for the period from 1989 to 2004 are included in the previous annual reviews.

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.

Wells NA 1 and NA 2 were installed in the alluvium close to the Zone 3 subcrop. Their original purpose was to be used for a pumping test to determine the hydraulic properties of the alluvium. The wells were installed in the alluvium located to the north of the North Cell outside of the seepage-impacted part of the alluvium. The water-type and common ion distribution between Well NA 2 and Well SBL 1 supports the conclusion that Well NA 2 is not impacted by tailings seepage. Analytical results are reported here.

1.4 Southwest Alluvium

The NA test assessment report was submitted during the 2002 reporting year. The 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 former extraction wells have continued to be idle since they were shut off in January 2001. The effectiveness of NA in the Southwest Alluvium was discussed by N.A. Water Systems in the 2004 annual report 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 2005. Attenuation via natural geochemical processes has been shown to be at least as effective as pumping.

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. A summary of constituents detected in the Southwest Alluvium in October 2005 is provided in Table 2. Historic groundwater quality and groundwater elevation data through October 2005 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, 1988; 1998). 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 de-saturated and, by 2000, a 31 percent saturation loss had been observed further to the south (Earth Tech, 2000d). The October 2005 saturated thickness for each well in the performance monitoring program is provided in Table 3. During 2005, all wells have shown overall decreasing groundwater elevations (with small fluctuations), indicating that the hydraulic gradient that

drives groundwater flow and constituent migration in the Southwest Alluvium continues to lessen.

The Southwest Alluvium potentiometric surface map for October 2005 is shown in Figure 3. 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 3) 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 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. 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 and would not do so in the future (Earth Tech, 2000d); 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.

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

The area currently containing seepage-impacted groundwater in the Southwest Alluvium is shown on Figure 6. As explained more fully below, the delineated area encompasses a region in which the common ion geochemistry 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 270 ft into the

north-central portion of adjacent Section 10. The total length of the area is approximately 5,010 ft.

Historically only two constituents, sulfate and TDS, exceed the Site standards in the Southwest Alluvium seepage-impacted groundwater outside the United Nuclear 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).

The October 2005 sample from Well GW 1 (a point-of-compliance (POC) well in Section 3) is an exception by having a chloride concentration of 267 mg/L, which exceeded the Site standard of 250 mg/L. Chloride is discussed later in this section of the report and in Section 2.3.5.

Historic sulfate concentrations through October 2004 are shown graphically in Figure 7. This figure shows that the long-term concentrations in most wells have remained approximately steady. However, 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. The four data points in the upper right part of this chart represent the sulfate measurements from new Well SBL 1. In October 2005, this well had the highest sulfate concentration (5,360 mg/L) of any well in the Southwest Alluvium (including all historic measurements), including the nearest, hydraulically upgradient Well 624 which is impacted by seepage and had a sulfate level in October 2005 of 2,170 mg/L.

Figure 8 shows a bicarbonate isoconcentration map of the Southwest Alluvium during October 2005. As explained in earlier annual reports and in the 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.

In Figure 8 of this annual report, we present bicarbonate isoconcentration contours throughout the seepage-impacted area. The advantage of showing isoconcentration contours is that the zone of seepage-impacted water can be

seen in finer resolution. The seepage-impacted zone was depicted in year 2003 and earlier annual reports as a "sharp-line" area based on assumptions of seepage migration rates and where bicarbonate concentrations exceeded 1000 mg/L. It can now be recognized to exhibit a core of more significant impact (bicarbonate concentrations exceeding 2000 mg/L) progressing outwards to less and less impact (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). The water from Well 624 is the closest known seepage-impacted water that is located upgradient from Well SBL 1. Well 624 lies 500 ft up the flow field from Well SBL 1 (Figure 3). 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 ($Mg\text{-}SO_4$) type water while Well 624 contains a calcium-sulfate ($Ca\text{-}SO_4$) 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 $Ca\text{-}SO_4$ (as anhydrite or gypsum), magnesium-carbonate ($Mg\text{-}CO_3$, as magnesite or dolomite), and calcium-carbonate ($CaCO_3$, 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-impacted water. It is a natural consequence of the law of mass action whereby the releases of calcium and bicarbonate that occurred, when acidic fluids were added to the alluvium, were accompanied by the tendency of the system to maintain constant calcium concentrations via the precipitation of additional gypsum. 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 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. Relatedly, 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 less than 2,125 mg/L in Figure 8 is elongate parallel to the bicarbonate isoconcentration contours. This area represents a migrating reaction zone separating relatively elevated sulfate due to seepage impact in its transport "wake," from relatively elevated sulfate downgradient (or side-gradient) in background water 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 2005. 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. 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.

The above observations and analysis confirm that Well SBL 1 has been placed further downgradient than the current extent of seepage-impacted water. They also confirm, as do the raw analytical data, that 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 natural quality of alluvium 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 only within the property boundary:

- Chloride – Chloride concentrations exceed the Site standard (250 mg/L) at Well 509 D. This well has exhibited gradual concentration increases at an average rate of approximately 11 mg/L per year since 1990. The chloride concentration at Well 632 has fluctuated about the standard with no discernible trend since 1990, and continued to do so during 2005 (Appendix A). Historically, chloride concentrations also exceeded the standard in Well 801, but a long-term, gradual decreasing trend (average -2 mg/L per year) has produced recent concentrations below the standard (see Appendix A). For the second time since the first exceedance in January 2004, chloride slightly exceeded the standard at Well GW 1 (POC well in Section 3) during

October 2005. Chloride concentrations (including Well GW 1) are discussed more in Section 2.3.4.

- Chloroform – Exceedances of chloroform (>0.001 mg/L) were measured in wells 632, 801, 802, 803, and 808 (Table 2). Concentrations in Wells 632 and 801 have fluctuated about respective averages of approximately 0.002 and 0.003 mg/L, with no discernible trend since 2001 (see Appendix A). Chloroform concentrations at Well 803 fluctuated about the standard from mid-2002 through the second quarter of 2003. Since then, the concentration has risen to 0.0026 mg/L. Prior to April 2002, the only detection (0.0017 mg/L) was in July 2000. A similar pattern of change, with different timing, occurred at Well 802. Chloroform was rarely detected prior to 1998, fluctuated about the standard from 1998 through 2001, and subsequently rose to 0.0106 mg/L by the fourth quarter of 2005. The record at Well 808 began in January 2001, but is indicative of a pattern similar to that at Wells 802 and 803. Chloroform concentrations above and below the standard were recorded in the first half of 2001. Thereafter, the concentrations increased, reaching 0.0073 mg/L in the fourth quarter of 2005 (see Appendix A). The chloroform concentrations measured in October 2005 are approximately ten times lower than the EPA's primary Maximum Contaminant Level (MCL; the federal drinking water standard) of 0.080 mg/L for total trihalomethanes (THMs). Chloroform is one of four THM compounds, and the license amendment request submitted to the NRC (General Electric, 2005a) proposes to analyze future groundwater samples for all four THMs.

Spatial clustering of the wells with chloroform detections indicates that the chloroform was probably derived from the western part of the South Cell (see Figures 2 and 8). The increasing chloroform concentration trends at former extraction Wells 802, 803, and 808 all post-date the cessation of pumping from the Southwest Alluvium in January 2001. These wells were also the more strongly influenced hydraulically by that event (see Figure 5), having experienced a more significant degree of resaturation than other wells. It is likely that the low-level increases noted in these wells are a localized phenomenon. During the same period concentrations in downgradient Wells 632 and 801 lacked any trend and there has been a continued absence of detections in the POC wells GW 1, GW 2, GW 3, and EPA 28 (see Appendix A).

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 had a manganese exceedance at 3.35 mg/L in October 2004 and was slightly below the Site standard at 2.25 mg/L in October 2005 (Table 2). Manganese exceedances (Table 2) occurred in onsite Wells EPA 23 (overall steady but fluctuating about an approximate level of 5

mg/L), and 801 (declining concentration trend since January 1993). 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. However, in October 2005 chloride slightly exceeded the standard at POC Well GW 1 (discussed more in Section 2.3.5). 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 located well within the property boundary. However, the non-impacted background water at downgradient Well SBL 1 showed October 2005 exceedance of nickel (0.08 mg/L), and one year earlier this well showed exceedances of manganese, cobalt, and nickel. 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.

2.3.3 Rate of Seepage Migration

Earth Tech (2002c) has previously 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).

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 2005 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 x 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 x 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 35 ft/yr. This is approximately half the velocities associated with the other two upgradient well pairs, because the hydraulic gradient from 624 to SBL 1 is approximately half that associated with the other pairs (Table 5). The average calculated groundwater velocity from 624 to SBL 1 in October 2004 was 30 ft/yr. Based on the mean of the October 2004 and 2005 estimates of groundwater velocity, the downgradient limit ("nose") of the 1,000 mg/L bicarbonate isoconcentration contour shown in Figure 8 is 32 ft farther to the southwest than it was in the comparable figure in the 2004 annual report.

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 (nine years prior to October 2005). Using the updated 2004/2005 average groundwater flow rate from Wells 624 to SBL 1 of 32 ft/yr, it is inferred that the October 2005 location of the seepage-impact front is 272 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 32 ft/yr, it would take approximately 7.1 years, or until 2012, for the seepage impact front to traverse the 228 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.

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 might occur as soon as approximately the first quarter of 2006. Continued monitoring of the water quality at this location should eventually allow back-calculation of the relevant, minimum average hydraulic conductivity.

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

UNC conducted a 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 test 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 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 10. Overall, ranges of TDS concentrations are no higher in impacted wells than in background wells. Background Well 627 has fluctuated about the Site standard (4,800 mg/L); background Well EPA 28 has persistently exceeded the standard; and background Well SBL 1 had the highest concentration of any well during October 2005 (excluding earlier measurements at SBL 1, the most recent concentration that exceeded this value was in impacted Well 801 during January 2000). The remediation system did remove sulfate and TDS mass, but this is irrelevant because concentrations are dependent on the chemical equilibrium of gypsum; therefore, they have been and will continue to remain similar to those previously achieved through geochemical processes that occur within the existing 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, equilibrium between the groundwater and naturally occurring gypsum (or anhydrite).

Furthermore, under the federal drinking water standards, sulfate and TDS are listed as the 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. 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).

UNC believes that the earlier part of this report demonstrates an understanding of, as well as the distinctions between, the geochemical evolution and characteristics of both background water and seepage-impacted water. The concepts demonstrated above require that a zone to be covered by a TI Waiver be viewed in a non-traditional manner. 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 199 years from now (shown in Figure 59), and has concluded that the area meets ALARA (as low as reasonably achievable) principles, and that Alternate Concentration Limits (ACLs) should be established by the NRC and applied to the management of this zone. 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, and it assumes purely advective transport of seepage impacts with no retardation, dilution, or attenuation. 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 59.

2.3.5 Reassessment of the Performance of the Natural System

The natural attenuation evaluation report (Earth Tech, 2002c) included 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. The natural attenuation evaluation (Earth Tech, 2002c) also

concluded that there was no change in trend for manganese, chloroform, or uranium (however, as discussed above in Section 2.3.2, groundwater quality data through October 2005 indicate increasing post-shutoff chloroform concentration trends at former extraction Wells 802, 803, and 808). It was concluded from these analyses that, athough 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 2005 supports this conclusion.

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. Groundwater quality in background Well SBL 1, and our understanding of the geochemical systems associated with both background water and seepage-impacted water, have been incorporated into the entries in Table 6. Within seepage-impacted water the metals and radionuclides 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

Figure 11 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 Wells 627, EPA 28, and 624 have been essentially the same through time. In general, calcium concentrations do not vary appreciably anywhere in the groundwater flow system (e.g., Figure 9). Figure 12 shows calcium concentrations from 1999 through October 2005, and includes a vertical line indicating when the extraction pumps were shutoff in January 2001. Wells GW 1, GW 2, and GW 3 show moderate increases in calcium concentrations since shutoff that fluctuate but appear to have stabilized. Figure 13 shows the bicarbonate concentrations over the same period. The bicarbonate concentration trends in these same three wells are conspicuously upward since shutoff (especially in GW 2). These observations indicate an increased degree of seepage impact has been reaching the GW-series wells since shutoff, and that neutralization and geochemical attenuation is still occurring naturally. Calcium concentrations in these wells will re-equilibrate under changed groundwater quality flux, becoming relatively quickly fixed in the presence

of calcite and gypsum by the Phase Rule, and their long-term consistency in the Southwest Alluvium attests to the established equilibrium between the groundwater and these minerals. Bicarbonate concentrations in these wells are expected to eventually achieve a chart "plateau" level of relatively constant values, once the natural neutralization processes have attained readjusted equilibrium (for example, see Well 624 bicarbonate in Figure 11). This appears to already be the case in Well GW 3, starting in January 2003, and it may also be the case for GW 1 starting at the same time.

Sulfate and TDS

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 14 shows sulfate concentrations from 1999 through October 2005; Figure 15 presents TDS concentrations over the same period. Figure 14 shows that sulfate concentrations in Well GW 1 increased modestly after shutoff until January 2002; since then this parameter has been stable. TDS in Well GW 1 has shown an increasing trend since shutoff. Before July 1997 and since July 2001, TDS has exceeded the standard (4,800 mg/L) in this well. The TDS value of 6,420 mg/L measured in October 2005 may represent part of a stabilizing trend here subsequent to the highest concentration of 6,800 mg/L that was measured in October 2004. The TDS value of 6,420 mg/L measured in October 2005 represents a decline from the historic high concentration of 6,800 mg/L measured in October 2004.

Well GW 2 sulfate has fluctuated but remained overall stable over the chart period of Figure 14, which spans shutoff. Since 1989, sulfate and TDS here have exceeded the standards. TDS concentrations in this well have increased since approximately March 2002. The TDS concentration of 6,730 mg/L in October 2005 is the highest value measured in this well since its installation in 1989. However, as with GW 1, the chart indicates that the rate of TDS concentration change has declined since October 2004.

Sulfate in Well GW 3 has generally been below the standard, but since shutoff the concentration has increased modestly to levels fluctuating about the standard. Since April 2001, the TDS concentration has been trending upward in this well; however, as with the other two GW-series wells, TDS in GW 3 appears to have approximately stabilized since

October 2004. The October 2005 TDS concentration of 5,270 mg/L is less than the highest level that was measured in July 1992.

Of these three wells, post-shutoff increases of sulfate and TDS have been greatest in GW 1. Increasing TDS in all three wells corresponds with the generally increasing concentrations of bicarbonate and calcium, and to varying degrees sulfate and magnesium (typically the largest components of TDS; see Figure 9). TDS concentrations over the last year in these locations suggest the possibility that seepage-impact neutralization reactions are converging toward post-shutoff geochemical equilibrium.

By comparison, the TDS and sulfate concentrations have been approximately constant in idled extraction wells 801, 803, and 808 (Figures 14 and 15). Well 802 experienced moderate, increasing trends for TDS (Figure 15), sulfate (Figure 14), and bicarbonate (Figure 13). Rates of concentration increase in each of these trends diminished significantly after mid-2003.

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). Chloride is chemically nonreactive and serves as a geochemically passive tracer of tailings fluid impact.

Figure 16 presents chloride concentrations from 1999 through October 2005. Chloride concentrations have persistently exceeded the standard (250 mg/L) at Well 509 D, and Well 632 has fluctuated about the standard since well installation in 1989.

Since shutoff, upward chloride concentration trends are shown for Wells GW 1, GW 2, and GW 3. GW 2 briefly exceeded the standard with a concentration of 260 mg/L in January 2004 but appears to have subsequently stabilized below the standard. The only other exceedances of chloride within the Southwest Alluvium and outside the UNC property boundary occurred in Well GW 1 in October 2005 (267 mg/L; see Appendix A and Figure 16) and January 2004 (252 mg/L). Chloride concentrations have been rising in Well GW 1 since the shutoff of pumps

in January 2001. As with the post-shutoff increases in TDS and bicarbonate in these same wells, the increased levels of chloride indicate that an increased degree of seepage impact has been reaching these wells.

By comparison, the chloride levels in former pumping wells 801, 802, 803, and 808 have remained approximately constant over the entire time period shown in Figure 16.

Manganese

Figure 17 presents manganese concentrations from 1999 through October 2005. Manganese is the only metal that exceeds its current standard in seepage-impacted areas. Exceedances continue to occur at Well 801, although the post-shutoff downward concentration trend continues. Exceedances also continue at Well EPA 23 where concentrations have been fluctuating about the level of 5 mg/L since May 2000. Concentrations at Well 509 D have been fluctuating about the standard since approximately the time of shutoff; prior to this manganese concentrations had been increasing in Well 509 D. 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. Manganese was temporarily at concentrations exceeding the standard in Wells 802, 803, and 808 in early 2001, but they have since reduced below the standard. These observations indicate that manganese natural attenuation continues effectively in the seepage-impacted waters. It is expected that concentrations will continue to diminish to below the standard in all seepage-impacted wells.

There was an exceedance of the manganese standard at Well SBL 1 in October 2004 (Figure 17), but the following four measurements have all been slightly below the standard (2.25 mg/L in October 2005). Well SBL 1 has also had exceedances of cobalt and nickel and relatively high concentrations of magnesium (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 earlier alluvium flushing associated with the discharge of mine waters.

Uranium

Uranium concentrations do not exceed the current Site standard 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 2005 is provided in Appendix A.

The statistics included in the NA report 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. Graphs showing uranium concentrations through October 2003 were presented in the 2003 annual report (USFilter, 2004a).

Graphs of uranium concentrations in all fourteen wells comprising the Southwest Alluvium water-quality performance monitoring program, through October 2005, are included as multi-well plots in Figures 18 and 19. These plots cover the period from April 1999 through October 2005, 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. These plots show the entire historic record for each well, from 1989 through October 2005. These charts show the following 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; Well 509 D is not a good indicator of whether there is a benefit to pumping. However, if Well 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 slugs of uranium-bearing water 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 have been decreasing since then. The decreasing trend since October 2003 is within the upper part of the historic range. The October 2005 concentration (0.018 mg/L) is the lowest value since May 2001 (also 0.018 mg/L). If a long-term linear trend line were to be established for this well, it would seem that the discontinuance of pumping in 2001 would have no discernible effect on the long-term trend.
- **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 29 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 statistically 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, then decreased through January 2004. 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.
- **Well GW 2** (Figure 25): Post-shutoff concentrations were stable through October 2002; since then the trend has been increasing. 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. October 2005 showed the highest concentration (0.013 mg/L) since shutoff.
- **Well GW 3** (Figure 26): Post-shutoff concentrations were stable through October 2002; since then the trend has been increasing. 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. October 2005 showed the highest concentration (0.118 mg/L) since shutoff.
- **Well 624** (Figure 27): Post-shutoff concentrations have been stable at the lower end of the historic range. There is no statistically discernible advantage to pumping based on Well 624.

- **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 statistically discernible advantage to pumping based on Well 632. However, October 2005 showed the highest concentration (0.088 mg/L) since shutoff.
- **Well 627** (Figure 29): Post-shutoff concentrations have been stable along the historic trend that is associated with a low range. There is no statistically 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 statistically discernible advantage to pumping based on Well EPA 23.
- **Well EPA 25** (Figure 32): Concentrations have been quite stable since July 1999 along the upper part of the historic range. There is no statistically discernible advantage to pumping based on Well EPA 25.
- **Well EPA 28** (Figure 33): Concentrations have been quite stable since July 1989. There is no statistically discernible advantage to pumping based on Well EPA 28.
- **Well SBL 1** (Figure 34): Concentrations at this newest, downgradient background well have varied from 0.024 mg/L to 0.033 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. The two exceptions through October 2005 are Wells GW 2 and GW 3, where post-shutoff trends were stable through October 2002 and have since been increasing. However, none of the concentrations measured in these wells have exceeded higher historic concentrations that were measured for very extended periods at these wells; these extended periods included significant spans of extraction time. 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.

None of the wells have shown exceedances of the 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.

UNC (General Electric, 2005a) has briefly discussed the observation that a semi-log plot of recent Southwest Alluvium concentrations of bicarbonate (alkalinity) versus the log of uranium concentrations defines an approximately linear correlation, especially at seepage-impacted wells. This is explained as a consequence of increased alkalinity tending to increase the stability of uranium in groundwater solutions.

The present-day MCL for uranium is 0.03 mg/L; this is ten times lower than the current Site standard. EPA has orally indicated that they intend to adopt the present-day MCL for uranium as the standard at Church Rock, although they have not yet proposed a formal modification. Figures 18 through 34 show that, regardless of the former pumping in the Southwest Alluvium, most of the POC wells (collectively shown in Figure 18) have exceeded the present-day MCL; the only exception is side-gradient impacted POC Well EPA 23 (for example, the October 2005 concentration was slightly below the MCL at 0.026 mg/L). Figure 19 includes three background wells, which showed the following uranium concentrations in October 2005: Well EPA 25, 0.102 mg/L (exceeds the MCL); Well 627, 0.027 (slightly below the MCL); and Well SBL 1 (has fluctuated above and below the MCL during the five quarterly measurements). The single background well that is also a POC is EPA 28 (Figure 18), which had a concentration of 0.041 mg/L in October 2005 (exceeds the MCL).

These observations suggest that, if the Site standard for uranium were changed to the current MCL, the only way in which the background and impacted groundwater could meet this presumptive standard would be to dewater the Southwest Alluvium. There are no other remedial options that could be applied that would lead to the attainment of the standard. It would be pointless to initiate a feasibility analysis. This is also true as long as the current standards for sulfate, TDS and manganese are not waived as presented in other parts of this report. Alternatively, EPA could adopt an Alternate Concentration Limit (ACL) application or employ a Technical Impracticability Waiver Zone that would address the impacted water. Exceedances of the uranium MCL in background waters are unrelated to seepage impact. UNC is currently conducting an analysis of historic uranium concentrations in the Southwest Alluvium and statistically comparing the background water quality to the impacted water quality.

Section 3
Zone 3

3.1 Corrective Action Summary

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.

Eighteen years of remedial pumping have shown 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 wells between the third quarter of 1989 and the fourth quarter of 2005. Values of saturated thickness greater than 25 ft are shaded. 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).

The saturated thickness in Zone 3 has declined substantially. As discussed in the "Technical Memorandum, Change in Zone 3 Saturated Thickness" (Earth Tech, 2001) submitted to the NRC on April 23, 2001, the loss of saturated thickness over time resulted in a decrease in the efficiency of the extraction wells to the point that only three of the total 24 wells were still pumping at rates greater than 1.0 gpm in June 2000. UNC's May 2000 License amendment request to shut off remaining Zone 3 pumping wells (Earth Tech, 2000b) concluded that operation of these pumping wells accelerated the rate of downgradient constituent migration. UNC requested that these extraction wells be shut off to reduce the migration rate, allowing more time for the background water to neutralize the seepage and attenuate the hazardous constituents. Additionally, these wells were pumping background-quality water and served no purpose in reducing contaminant mass in seepage-impacted waters. 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.

At the request of the EPA (2004b), UNC has conducted a Supplemental Feasibility Study (SFS) to evaluate all appropriate remedial options for Zone 3. 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.

The work leading up to the submittal of SFS report, and related recommendations made in that report, were developed into a formal work plan (MACTEC, December 2003; revised by letter March 2004; approved by EPA in letter of May 21, 2004). UNC is conducting an ongoing, extended pilot program to determine the efficacy of hydrofracturing in enhancing extraction potential along the basal part of Zone 3 to contain the advancing seepage-impacted water. The pilot program was proposed to operate over a period of approximately one year. Approximately 2,904,000 gallons of groundwater has been pumped from this new Zone 3 extraction well network from January 2005 to November 2005, and piped to the evaporation ponds. This ongoing work is still being reviewed and analyzed by MACTEC and submittal of a report is anticipated near the end of the first quarter of 2006.

During October 2005, UNC proposed (Blasland, Bouck & Lee, 2005) an in-situ alkalinity stabilization pilot study comprising an additional, aggressive approach to enhancing the remedy in Zone 3. The planned work proposes to test the injection of alkalinity (bicarbonate) rich groundwater obtained from a nonimpacted part of the alluvium, into Zone 3. The injected water will flow through the bedrock hydrostratigraphic unit to recovery wells where it will be pumped for treatment. Figure 36 shows the approximate locations of the proposed injection and extraction wells; Well NA 2 is a well in the nearby alluvium that will supply the relatively bicarbonate-rich injection water. This proposed pilot program will determine whether the following, potentially beneficial effects occur in the affected area of Zone 3: (1) pH increase (buffering); (2) changes in aqueous/solid partitioning and precipitation reactions that would reduce or eliminate the migration potential for certain constituents of concern; and (3) extraction of uranium, radium and other metals that exceed the ROD's cleanup objectives, and piping of the pumped water to the evaporation ponds.

The former remediation system wells (the last three of which were shut off in 2000) accelerated the process of natural drainage of the water from Zone 3. In this sense, "natural" drainage refers to the reduction of saturated thickness and potential energy by gravity flow and dissipation into the contiguous unsaturated parts of the Zone 3 hydrostratigraphic unit. Figure 35 shows that between 1989 and the fourth quarter of 2005, 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 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 2005 "zero" saturation limit). The effects of former remediation pumping in partially, locally dewatering Zone 3 are presented in Figure 37.

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).

Extraction well pumping occurred during 2005 as part of the ongoing pilot study of Zone 3 permeability enhancement using hydrofracturing. Table 8 shows the estimated mass removal by this pumping from January through November 2005; the RW-series extraction wells are shown on 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 other Zone 3 wells during October 2005 (water quality analyses were not determined for the actual pumped water). These estimates were made using the method of kriging to spatially interpolate the measured concentrations, in a way analogous to that used to produce contour maps.

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 sentinel 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. During 2005, monthly water levels and water quality data were collected from two of these wells: PB 3 and PB 4. (Well PB 1 was installed within impacted water and has been excluded from further monitoring that is intended to track the advancing front. Well PB 2 showed full seepage impact in February 2004 and from August through November 2005 it has been used as an extraction well in conjunction with the hydrofractured-well pilot program.) Water quality analyses conducted monthly include field measurements of pH, specific conductivity, bicarbonate, and chloride. The latter two analyses are performed using Hach field testing kits. Quarterly samples from these three boundary "sentinel" 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 impacted water.

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 hydrostatigraphic unit. The first two quarters of water-level monitoring showed that both piezometers were dry (excluding small amounts of drilling fluid). Therefore, the piezometers are no longer monitored.

3.3.1 Water Level Evaluation

Water level data from 1989 through the fourth quarter of 2005 are presented in Appendix B. Water levels from October 2005 are shown on the potentiometric surface map in Figure 38. Groundwater levels clearly affected by pumping during October 2005 were excluded in developing Figure 38, because a more definitive analysis of the influence of this pumping will be made in a forthcoming report. 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), and 2004 (N.A. Water Systems, 2004).

Mine water discharge into Pipeline Arroyo ceased in 1986. Since then, Zone 3 groundwater flow directions have shifted from easterly-to-northeasterly to north-northeasterly-to-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) and former extraction-well pumping drawdowns 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 hydrofractured well pilot test. 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. Since about 1997, the water level trends in Zone 3 have been approximately proportional to the log of time and appear to asymptotically flatten when plotted on an arithmetic scale, as in Figure 37.

Contours of saturated thickness during the fourth quarter of 2005 (Figure 39) show the combined effects of former 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 2005. 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 recharge area, have lost substantial saturation. For example, Well EPA 14 had 76 ft of saturation in 1989 and 33 ft in the fourth quarter of 2005. Table 10 shows the saturated thickness in each Zone 3 well during October 2005. From 2002 through 2005, 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. Hydrofractured extraction well pumping has removed approximately 2.9 million gallons during 2005.

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

Figure 35 shows the approximate recharge area, located to the north and northeast of the North Cell, where mine water in the alluvium percolated into the underlying Zone 3 hydrostratigraphic unit. This figure shows the saturated portion of the alluvium/Zone 3 contact as well as the unsaturated portion of this same contact zone. The temporary saturation caused by the mine water discharge is considered the background water for Zone 3 (EPA, 1988; 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 has 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 there is now less than 5 ft of saturation, which is projected to drain out in about 10 years. 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.

Delineation of the extent of the seepage-impacted water in Zone 3 (Figure 35) is based primarily on the values of two parameters: pH and bicarbonate concentrations. The following threshold or bracketing values for pH and bicarbonate, which indicate seepage impact to the water, have been discussed in the Technical Memorandum (General Electric, 2000):

- A pH <5.0 indicates seepage impact. Such impacted water 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 $CaCO_3$ 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).

- Bicarbonate (HCO_3) concentrations <100 mg/L and >500 mg/L indicate seepage impact. 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 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 reduce to near zero. Further discussion of bicarbonate concentration trends is provided below.

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, 411, and 420), and (3) the new boundary wells PB 2 through PB 4. Table 11 presents the monthly field parameter measurements for the boundary sentinel wells (from south to north, Wells 504 B, PB 2, PB 4, PB 3, and NBL 1). (The quarterly laboratory analytical results are provided in the back part of Appendix B.) Evaluation of these data indicates that bicarbonate concentrations at Well PB 4 have decreased since February 2003, and the pH has fluctuated while showing an overall decrease. The bicarbonate concentration continued to decline in 2005 to below the detection limit (recorded as a value of 0 mg/L) from May through October.

By comparison (Table 11), Well PB 3 has also shown overall decreasing bicarbonate concentrations since February 2003, attaining a lowest value of 51 mg/L in October 2005. Over this same time period the pH at Well PB 3 has fluctuated between a low of 5.77 in June 2005 to a high of 7.51 in January 2004 (Table 11). It appears that the arrival of full-stage seepage impact is imminent at Well PB 3 (i.e., it is likely that bicarbonate will very soon fall to levels persistently below 50 mg/L, accompanied by a subsequent decrease of pH to below 5.0). The northern limit of seepage impact on Figure 35 is 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. However, confirmation of this interpretation is contingent on continued decreases in the bicarbonate concentration demonstrated by water quality monitoring. As discussed more below, historic groundwater quality data (see Appendix B) from fully impacted wells indicate that precursory geochemical changes can occur for approximately one to three years prior to the arrival of seepage-impacted groundwater.

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, 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 line indicating the pH value of 4.0. The other red line shows the approximate location where the pH values are 5.0.

During 2005, Well EPA 14 continued to show impacted water quality (Appendix B). For example, high concentrations were measured for manganese, aluminum, combined radium, and gross alpha, and lead-210 varied from 22 pCi/L in January to nondetect in the subsequent three quarters. The EPA's *Second Five-Year Review Report* (USEPA, 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 this well began in 2000, when the bicarbonate concentration decreased suddenly and sharply.

The EPA (2003, Figure 6-8) also presented Stiff diagrams for ten Zone 3 wells based on October 2002 sampling. The major ion concentrations measured in these wells during 2005 indicate that their Stiff diagram representations would be extremely similar (virtually identical) to those previously presented for October 2002. For this reason, new Stiff diagrams have not been produced for October 2005, and the following discussion refers to the Stiff diagrams shown in EPA's (2003) Figure 6-8.

Well NBL 1, to the north of the present edge of the seepage impact, contains a calcium-sulfate type of water and is representative of background water quality that appears transitional to early-stage impact. The latter interpretation is based on 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).

Well 420, located along the western edge of the impacted area in Figure 35, contains a calcium-sulfate type of water that is predominantly background (largely non-impacted). Combined radium in this well has fluctuated above and below the Site standard from 1989 through October 2005 – this may reflect the flux of geochemically heterogeneous background water or impacted water (e.g., N.A. Water Systems, 2005b). In July 2004, water collected from Well 420 contained the highest recorded bicarbonate concentration of 684 mg/L; subsequent bicarbonate concentrations have been lower (see Appendix B). These observations are interpreted as indicating that the seepage-impacted region is nearby.

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 is interpreted as predominantly background (largely non-impacted). From 2001 and through October 2005 (the time period for which water quality data are available), only combined radium has been persistently detected at concentrations above its standard. However, given the relatively short time period for which groundwater quality data are available at this well, the combined radium exceedances may reflect the flux of geochemically heterogeneous background water or impacted water. Bicarbonate concentrations attained a maximum of 740 mg/L in July 2002, and subsequently decreased to 518 mg/L in October 2005 (Appendix B). Since 2001, the concentrations of manganese, sulfate, and TDS have gradually increased through October 2005; but again, the magnitude and covariance of these concentrations do not unequivocally show the influence of impacted water versus nonimpacted water. The bicarbonate concentrations are interpreted as indicators of an increasing degree of seepage impact at this location.

The other seven wells depicted with Stiff diagrams (EPA, 2003, Figure 6-8) contain impacted magnesium-sulfate types of waters. For example, in October 2005 (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 non-detect for bicarbonate, a chloride concentration of 156 mg/L, a pH of 3.02, and exceedances for most parameters except several metals, lead, and some of the major ions. Well 613 is the most impacted of any of the wells. 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.

The EPA (2003, Figures 6-9 through 6-12, and 6-6) has presented annual "snapshots" of the Zone 3 seepage-impacted area from October 1998 through

October 2002. Viewed together with the seepage-impact maps from October 2003 (USFilter, 2004a) and October 2005 (Figure 35), these seven maps indicate that the constituents have migrated both northward and westward at various times during the last eight years. During this time period, the eastern limit of Zone 3 saturation gradually shifted to the northwest under the influences of extraction well pumping (terminated previously in 2000) and natural drainage.

3.3.3 Rate of Seepage Migration

Table 12 summarizes the key factors, locations, and criteria underpinning the calculations of seepage travel times for Zone 3. This most recently determined travel time in this table includes the first arrivals of full seepage impact at boundary wells PB 2 and PB 4, as determined by the first and persistent attainment of bicarbonate concentrations equal to, or lower than, 50 mg/L (see Table 11). The impact source starting location was assumed to be the northeastern corner of the North Cell in 1980. The calculated rates vary from 60 ft/yr to 204 ft/yr, with a geometric mean of 99 ft/yr. Extrapolating the migration rate of 60/yr derived from PB 2 to PB 4, full seepage impact is predicted to arrive at sentinel Well NBL 1 in approximately June 2006.

The approximate October 2005 location of the northern edge of full seepage impact, shown on Figure 35, passes through Well PB 3. However, as discussed earlier, this location has not yet shown the persistent reduction of bicarbonate concentrations to 50 mg/L or less. Continued water quality monitoring here, during 2006, may demonstrate sequential bicarbonate values below the 50 mg/L generalized threshold. Based on the 2005 water quality data, no update for quantitative seepage migration rates is merited. Regardless, the PB-series wells and NBL 1 are very useful for tracking the advance of the seepage impact.

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, 420, 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 has enhanced the effectiveness of the natural attenuation processes in many parts of the impacted area. However, Zone 3 has not yet fully stabilized. For this reason, UNC is currently conducting an extended pilot study assessment of the effectiveness of hydrofracturing to enhance extraction rates along the leading edge of the seepage impact, to cutoff and contain the advancing impact front. In addition and pending agency approval, UNC is prepared to start the proposed in-situ alkalinity stabilization pilot study (Blasland, Bouck & Lee, 2005).

A summary of constituents detected in Zone 3 in October 2005 is provided in Table 13. 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, arsenic, beryllium, cadmium, cobalt, lead, manganese, molybdenum, and nickel);
- Radionuclides (lead-210, uranium, combined radium-226 and –228, thorium, vanadium, and gross alpha); and
- Chloroform.

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

Sulfate and TDS

Figure 40 is a graph of sulfate concentrations from 1989 through 2005. Concentrations are relatively high where seepage impacts have been greatest. Well 420 (located near the northwestern edge of the impacted area) was the only well having a sulfate concentration below the standard in October 2005. Background to early-stage impacted water in Well NBL 1 exhibited sulfate concentrations below the standard in October 2002 (2,070 mg/L) and October 2003 (1,940 mg/L), but in 2004 concentrations gradually increased to above the standard and continued to increase moderately in 2005.

Although bicarbonate is not a constituent of concern, its concentration in impacted wells is related to the degree of acidic seepage neutralization that has occurred in the impacted groundwater. Although strongly subordinate to sulfate, bicarbonate is still a significant component of the TDS. Figure 41 shows historic bicarbonate concentrations through

October 2005. The increasing concentration trend in Well EPA 14 that started in July 2002 appears to have stabilized during 2005. Figure 42 shows historic bicarbonate concentrations for wells located near the present impact-zone perimeter, plus the boundary sentinel wells used to track the northward advance of the constituents (it should be noted that the bicarbonate values plotted in this chart are those derived from laboratory analyses; see the laboratory analytical summary sheets in the back of Appendix B). The bicarbonate concentrations in Well PB 4 "bottomed out" at nondetect levels (shown as zero concentration) starting in April 2005.

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 2005 sample data from the current northern portion of the impacted area: sulfate concentrations decreased 71 percent from Well 613 (9,040 mg/L) to the early-stage impacted water at Well NBL 1 (2,640 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 Zone1).

Metals

Figures 43a and 43b are graphs of metals concentrations (from 1989 through 2005) that exceeded the Site standards: aluminum, arsenic, beryllium, cadmium, cobalt, manganese, molybdenum, and nickel (the metals uranium and vanadium are discussed later with the radionuclides). UNC requests revision of the ROD background concentrations for arsenic, molybdenum, cobalt, and nickel (similar to the ROD 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 non-detect concentrations are found in most impacted wells, including Well 613 (see Table 13 and Figure 43b). Previously, the only exception was impacted Well 504 B, where the molybdenum standard (1 mg/L) had been exceeded. However, the molybdenum concentration at Well 504 B fell below the standard in July 2005 for the first time since April 1997, in line with a downward trend that started in October 1999.

Similarly, the concentration of molybdenum in Well NBL 1 also fell below the standard for the first time in July 2005, following a more gradual downward trend. However, unlike the reduction in fully impacted Well 504 B, due to natural attenuation, the reduction in NBL 1 is interpreted to have resulted from the changing of water quality from background to early-stage impact. The persistent exceedances of arsenic in NBL 1 (Figure 43b) showed a very sharp falloff from July 2005 (0.82 mg/L) to October 2005 (0.06 mg/L, close to the standard of 0.05 mg/L). Arsenic in Well EPA 13 continued an overall decreasing trend since April 1999 and was below the standard in October 2005 (see Appendix B). These patterns of exceedances are the opposite of what is expected for metals associated with the seepage impact and they indicate that, for at least arsenic and molybdenum, the primary source is the background water.

Many of the other metals exceed the Site standards in at least one background well, usually EPA 1. The changing water quality at Well NBL 1 is again instructive on this count. During 2005 nickel and cobalt both trended upward in NBL 1, from "baseline" background water concentrations equal to or slightly exceeding the Site standard for cobalt (Figure 43a) and concentrations slightly above the standard for nickel. Therefore, although neutralization of the acidic seepage will continue to reduce metals concentrations at many of the impacted wells, the natural Site conditions (i.e., background) may prevent them from being reduced below the current Site standards (Earth Tech, 2002d).

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.

Figures 43a and 43b show that attenuation occurs throughout the seepage-impacted area, including areas where the pH is less than 4.0.

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. On graphs for five of the eight constituents, this well shows the highest metals concentrations during October 2005. The effectiveness of natural attenuation and seepage impact mitigation is shown by the metals concentrations at Well 719. In October 2005, this well had a pH (3.73) only moderately higher than that measured in Well 613 (3.02); however, the concentrations of metals are generally much lower in Well 719. In fact, the concentrations in Well 719 are similar to those in other wells located further downgradient, and in October 2005 they were either below the standards (arsenic, cadmium, beryllium, and aluminum) or they were exceedances that continue to show decreasing trends (cobalt and nickel; manganese showed a modest increase from July to October). These decreasing trends suggest that since the pumping wells were shut off, the downgradient seepage migration is slowing and the natural system is becoming more effective in attenuating seepage impacts. Figure 44 illustrates that the October 2005 distribution of aluminum exceedances was restricted to the southwestern part of the impacted area and an outlier (Well 504 B).

Starting in October 2003 and through October 2004, aluminum (Figure 43a) and beryllium (Figure 43b) concentrations had increased sharply in Well EPA 14. The first detections of lead in this well were exceedances starting in January 2004 (Appendix B). From July 2004 to October 2004, both manganese and nickel increased (Appendix B). This was interpreted as a slug of more impacted water moving through the location of Well EPA 14. However, during 2005 aluminum and beryllium showed very sharp declines and lead decreased to nondetect levels. Relatively steady pH and the increased concentrations of bicarbonate since 2001 suggest that the groundwater at EPA 14 is successfully buffering the pH and undergoing neutralization reactions.

Certain metals, such as manganese, continue to be present at higher concentrations at more neutral pH values (e.g., Well 717, which has shown gradually increasing exceedances since January 2004). Cobalt and nickel have patterns of exceedances similar to manganese. These two metals generally do not attenuate until the pH is about 6.5 or more (e.g., Earth Tech, 2002d). However, cobalt and nickel have shown modest reductions during 2005. During October 2005, all wells within the seepage-impacted area continued to show exceedances of manganese, cobalt, and nickel, except two wells near the northwestern edge: 420 (pH of 6.65) and 717 (pH of 6.49, but has shown minor exceedances of manganese during 2004 and 2005). The pH values of these two wells

were the highest among the impacted group of wells (Figure 35). It is important to realize that background water quality is associated with metals exceedances. For example, from installation in August 2001 through mid-2004 (background water quality), sentinel Well NBL 1 exceeded the standards for molybdenum, nickel, and manganese. Since mid-2004 and accompanying the onset of early-stage impact here, the concentrations of nickel and manganese have been increasing. On the other hand, from 2001 through 2005 the molybdenum concentrations have been decreasing and were below the standard during July 2005.

Uranium, Vanadium, and Radionuclides

Figure 45 presents graphs of the concentrations of uranium, vanadium, and the two radionuclides (combined radium and thorium-230) from 1989 through 2005. Combined radium concentrations exceed the Site standard (5 pCi/L) in the background water; consequently, radium concentrations in Zone 3 may never reach the standard.

Historically, uranium, vanadium, and thorium-230 are typically present above the standards in Well 613, which has the most acidic pH (3.02 in October 2005). Downgradient toward the northeast, natural attenuation reduces the concentrations of these three radionuclides in Well 708 (pH of 3.94 in October 2005) to nondetect (vanadium and thorium-230) or below the standard (uranium). 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 2005, the only exceedances of these three constituents were in samples collected from Well 613.

Most wells show uranium concentrations below the Site standard of 0.3 mg/L. However, the exceedance of the uranium standard continued in Well 613 during 2005 (the longer-term pattern shows fluctuating to approximately steady concentrations above the standard). The "spikey" uranium concentrations at Well EPA 14, which started during April 2003, reduced to below the Site standard during April 2005 (Figure 45 and Appendix B); in October 2005 the uranium concentration was 0.054 mg/L. Time correlative, large swings in other constituent concentrations (e.g., combined radium [Figure 45], gross alpha, and aluminum [Appendix B]) also showed sharp declines during 2005, suggesting the possibility that a slug of highly impacted water may be exiting this location.

In 2005, combined radium concentrations continued to exceed Site standard (5 pCi/L) in the water at well NBL 1 (Figure 45). Since well installation, the combined radium here has fluctuated but remained

approximately steady, indicating the presence of the constituent radionuclides at this location is unrelated to seepage impact. In Well 420, the long-term fluctuations about the Site standard continued during 2005. During October 2005, this well had the lowest concentration of combined radium (6.2 pCi/L). The submitted license amendment request to change the method by which compliance with the groundwater protection standard for combined radium is determined (General Electric, 2005b; N.A. Water Systems, 2005b) addressed only the Southwest Alluvium and Zone 1. However, the accompanying statistical analysis of background and impacted water quality presents an implication that is at least qualitatively applicable to Zone 3: the background water, derived from the former mine water discharge into the alluvium, frequently exceeds the Site standard for radium.

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 2005 in the following wells: 504 B (concentrations stable during 2005), 517 (fluctuated during 2005), 613 (long-term fluctuations), and EPA 14 (fluctuated during 2005). Since October 2004, Well 719 has remained below the standard. During 2004 and 2005, Well EPA 14 concentrations fluctuated by a factor of approximately five, from 254 pCi/L in January 2004 to a minimum of 19.7 pCi/L in April 2005. 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 have 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, and the relatively large range in combined radium since July 2003, indicate that a slug of radioactive water migrated into this well location during approximately mid-year 2003. Earlier discussion presented the evidence for concluding that this slug of highly impacted water may be exiting this location; this inference is bolstered by noting that during the last three quarters of 2005, the gross alpha measurements were the lowest since July 2003 (Appendix B). However, the geochemistry of the background water (from mine discharges) that seeped into the ground was heterogeneous, and it is often inherently difficult to unequivocally infer that impacted water, rather than a high-concentration-

bearing slug of background water, is responsible for the pattern of exceedances at many locations.

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.

Chloroform

Historic chloroform concentrations through October 2005 are shown in Figure 46. Chloroform was detected above the Site standard in two wells during 2005: 613 and 517. The concentrations in Well 613 have always exceeded those in Well 517, consistent with the former being located closer 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 ug/L). Since then the concentration has fluctuated but remained overall steady through October 2005.

All other Zone 3 wells have shown historic non-detects for chloroform. This indicates that the groundwater to the northeast of Well 517 rapidly attenuates chloroform.

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 has 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 14. 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 2005 are presented in Appendix C. Water levels for the fourth quarter of 2005 are shown on the potentiometric surface map in Figure 47. Water levels through time are shown on Figure 48. Saturated thicknesses calculated from the October 2004 measurements in Zone 1 are presented in Table 15. 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 47). However, during 2005, most of the wells continued to show overall decreasing piezometric elevations (usually with small fluctuations), indicating that the Zone 1 potentiometric field continues to become lower as the groundwater further dissipates into unsaturated 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 15; Figures 47 and 48; 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, represent the slow dissipation of head levels there as groundwater continues to flow downdip toward the fully 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 48). The rate of groundwater drainage is also limited by the unit's relatively low transmissivity, and the very low transmissivity of the underlying aquiclude.

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

In the absence of naturally occurring groundwater in this part of Zone 1, the temporary saturation created by the infiltration of former mine water discharges is considered the background water for Zone 1 (EPA, 1988; 1998). This anthropogenic groundwater was later impacted by acidic seepage from Borrow Pit No. 2 in the Central Cell (compare Figure 2 and Figure 49). 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), 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 2005. Table 16 summarizes the constituents detected in Zone 1 during October 2005.

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 standard. 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 stable to diminishing. Zone 1 seepage impacts have been delineated by chloride concentrations greater than 50 mg/L (Earth Tech, 2000a). Figures 6 and 49 show the extent of seepage impacts in October 2005. 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 49). Figure 50 shows historic pH values for Zone 1 wells through October 2005. Well 604 has persistently shown the lowest pH; as discussed below, it also is the most highly impacted well. Figure 50 shows that starting in approximately 1993, 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
- Metals – Wells EPA 4 (manganese), EPA 5 (cobalt and nickel), and EPA 7 (manganese)

All of these constituents have generally exceeded standards at the cited wells since 1989. In addition, Well EPA 4 was just below the combined radium standard in October 2005 (4.7 pCi/L). Well EPA 4 is located approximately 220 ft to the north of the current edge of the impacted area, within an area of background water quality.

Within the Site property, the standards for TDS, sulfate, and the above noted metals were also exceeded. Other constituents whose standards were exceeded

in October 2005 were: nickel (Wells 515 A, 604), aluminum (Well 604), chloroform (Wells 515 A, 604, and 614), and combined radium (Well 604).

The extent of seepage impacts, as delineated by a chloride concentration greater than 50 mg/L, has not changed perceptibly in the past eight years, including the period since the shutoff of the extraction wells. Nonetheless, water quality has continued to improve since shutoff, indicating that the degree of seepage impact is stable to diminishing. Natural attenuation processes include acid neutralization by (1) reaction with the Zone 1 bedrock (which has a calcite (calcium carbonate) fraction 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.

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 17 shows the predicted geochemical performance of the Zone 1 natural attenuation system (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. 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 51 shows historic sulfate concentrations through October 2005; Figure 52 shows the extent of sulfate exceedances during October 2005. 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. Accordingly, TDS concentrations are not expected to meet the clean-up standards in Section 1, although they should gradually decrease to background levels.

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 2005 are shown on Figure 53 and tabulated in Appendix C. The extent of manganese that exceeded the Site standard during October 2005 is shown on Figure 54. Figures 53 and 54 show that the general decreasing trend of manganese concentrations at impacted Well EPA 7 reached a concentration very close to the standard.

Bicarbonate concentrations in impacted wells are related to the waters' degree of neutralization of acidic seepage. Figure 55 shows historic bicarbonate concentrations through October 2005. As discussed above regarding Zone 3, marked declines of bicarbonate concentration are indicative of (sometimes temporary) exhaustion of the local neutralization capacity of the natural geochemical system. The plunge of bicarbonate concentration in Well EPA 5 from January 2000 to May 2000 is such an example. By contrast, Well 614 (Figure 55) 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 55), 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 2005.

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 in October 2005). 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 55), and the manganese concentration has steadily declined (Figure 53). The decreasing manganese trend continued through October 2005, albeit with a small increase in October. If these trends continue the manganese concentration at EPA 7 is expected to decrease below the Site standard within the next two or three quarters.

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 have been fluctuating to steady since 1989 (Appendix C).

In summary, exceedance of the manganese standard within the property boundary will continue unless sufficient neutralization capacity to reduce the manganese concentrations. It is also important to realize that manganese exceeds the standard in the background water quality.

Cobalt and Nickel

The only metals other than manganese that exceed Site standards in Section 1 are cobalt and nickel (Well EPA 5 showed slight exceedances of both constituents during 2005; see Table 16 and Appendix C). Other metals were attenuated within the property boundary. Exceedances of cobalt and nickel are primarily 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 2005 are presented graphically in Figure 56. The extent of cobalt and nickel exceedances during October 2005 is shown in Figure 57.

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 standards as the

pH has increased to above 6.0. During October 2005 (Figure 56), the cobalt concentration in this well was less than the Site standard (0.05 mg/L), and nickel was non-detect. 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.

Combined Radium-226 and Radium–228

Similar to the metals, combined radium is attenuated by neutralization, precipitation, and adsorption. The primary exceedances of combined radium are within the property boundary where the pH is more acidic. Historic concentrations for combined radium through October 2005 are presented in Figure 58. During October 2005, the combined radium Site standard was exceeded within the property boundary in Well 604 (where it has fluctuated about the standard since October 2003). Outside the property boundary, Well EPA 2 showed a slight exceedance in October 2005.

Historically, the combined radium standard has been exceeded in all three background wells (EPA 2, EPA 4, and EPA 8). The combined radium concentrations are expected to decrease to at least the background levels, and possibly to below the standard, with continued natural attenuation.

As part of UNC's submitted license amendment request to change the method by which compliance with the groundwater protection standard for combined radium is determined in the Southwest Alluvium and Zone 1 (General Electric, 2005b), N.A. Water Systems (2005b) conducted statistical analyses of the historic combined radium concentrations in both background and POC wells. Because exceedences of the combined radium standard occur in the background and seepage-impacted water, UNC proposed that should the standard be exceeded during the quarterly results from any POC monitoring well within that hydrostratigraphic unit, then the Two Sample Test of Proportions and the Kruskal-Wallis test (both of these are statistical tests) should be applied to determine if the concentration is a valid and meaningful exceedance of the Site standard. The Two Sample Test of Proportions is proposed to be applied to quarterly compliance data, while the Kruskal-Wallis test will be applied to compliance data lumped from the most recent six quarters in Zone 1.

Chloroform

Exceedances of the Site standard (1 ug/L) for chloroform in October 2005 occurred only in wells within the property boundary: 515 A, 604, and 614.

Wells 515 A and 614 have long-term concentrations in the low hundreds of µg/L; Wells 604 and EPA 7 have shown long-term fluctuations between non-detects and concentrations to approximately four times the standard. The occasional exceedances in Well EPA 7 and the historic absence of detections in all wells farther to the north indicate that chloroform rapidly attenuates over relatively short distances of groundwater flow.

Section 5
Conclusions and Recommendations

This annual review evaluated the performance of the natural systems in all three Site hydrostratigraphic units. In the Southwest Alluvium and Zone 1, the natural systems have functioned as effectively as when active remediation took place. During 2005, part of Zone 3 underwent extraction well pumping as part of the ongoing pilot study of permeability enhancement by hydrofracturing. The conclusions and recommendations of this evaluation are provided below.

5.1 Conclusions

- Groundwater levels in the Southwest Alluvium continued to decline in 2005, indicating that the saturated thickness, which accommodates groundwater flow and constituent migration, continues to diminish as the groundwater drains down the arroyo.
- 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 and almost entirely contained within the Site boundary.
- Sulfate, TDS, and manganese, which exceed standards outside the Site boundary, do so 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. Ahead of the current seepage-impact front,

downgradient background well SBL 1 has shown very high sulfate and minor exceedances of manganese, cobalt, and nickel that are not due to seepage impact.

- Since shutoff of the Southwest Alluvium extraction pumping, chloride concentrations have risen in POC Wells GW 1 and GW 2. During October 2005, Well GW 1 exceeded the Site chloride standard by 17 mg/L. Continued monitoring here will demonstrate whether such exceedance becomes persistent, or if the chloride level will stabilize below the standard of 250 mg/L. Under federal drinking water standards, chloride does not have a primary MCL; the secondary MCL is 250 mg/L (the same value as in the New Mexico Water Quality Act).

- Concentrations of uranium in the Southwest Alluvium indicate that natural attenuation is at least as effective a remedy as pumping. The uranium concentrations and concentration-time trends have been mostly stable to decreasing since the pumps were turned off. The main exceptions are increasing concentration trends in POC wells GW 2 and GW 3. However, the highest post-shutoff concentrations in these wells are below the upper values of historic ranges and well below the standard. The historic and recent records of uranium concentrations in the Southwest Alluvium show that within impacted water, both gradual and sudden variations are characteristic and unrelated to former extraction pumping.

- Following the long-term trends in the Southwest Alluvium, there are no exceedances of the Site uranium standard of 0.3 mg/L. If the Site standard is reduced to the present-day uranium MCL of 0.03 mg/L, it is likely that all of the POC wells (possibly excluding EPA 23) will show exceedances openly forward in time; background Wells EPA 25 and EPA 28 would exceed the MCL; and background Wells 627 and SBL 1 would fluctuate above and below the MCL openly forward in time.

- Both the Southwest Alluvium and Zone 1 natural systems are at least as effective as the former remediation systems in attenuating the seepage-impacted water. Acidic seepage is being neutralized, resulting in attenuation of metals and radionuclides. Geochemical conditions related to gypsum equilibrium and bicarbonate availability will limit the reduction of sulfate and manganese concentrations in both hydrostratigraphic units, regardless of whether or not the extraction wells are operated.

- Groundwater levels in the Zone 3 continued to decline in 2005, indicating that the saturated thickness, which accommodates groundwater flow and constituent migration, continued to diminish. The effects of former

downgradient Stage II pumping have dissipated as the groundwater drains down the dip of the bedrock layers.

- 2005 water quality data from Well PB 3 suggests that full seepage impact may have arrived at this location during the latter part of 2005 (full impact reached Well PB 4, just to the south, during 2004); continued monitoring during 2006 will demonstrate if this is the case. The boundary well array is successfully allowing tracking of the northward migration of the seepage impact.
- UNC is conducting an ongoing, expanded pilot study toward evaluating the effectiveness of hydraulic fracturing to enhance the remedy of cutoff and containment of the seepage-impact front. From January through November 2005, approximately 2.9 million gallons of Zone 3 water was extracted as part of this pilot study and pumped to the evaporation ponds. In addition, UNC is prepared to implement the proposed in-situ alkalinity stabilization pilot study toward further, aggressive enhancement of the Zone 3 remedy.
- The degree of seepage impact in Zone 1 is stable to diminishing. The potentiometric field in Zone 1 continued to decline in 2005, causing the saturated thickness that accommodates groundwater flow and constituent migration to diminish in parts of this bedrock stratigraphic unit.

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.
2. Continue to perform monitoring on an annual basis (except for specific POC wells as noted next) 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 32 ft per year). However, uranium concentrations at POC Wells GW 2 and GW 3 have not yet stabilized, and continued quarterly monitoring is recommended at POC Wells GW 1, GW 2, GW 3, and EPA 28, which are located just outside the UNC property boundary. Also, chloride

concentrations at GW 1 have not yet stabilized and the standard was exceeded for the second time during October 2005.

3. Approve UNC's license amendment requests (submitted to the NRC in 2005 for chloroform and combined radium) to modify the way that chloroform and radium are compared to the Site standards. UNC will analyze samples for total trihalomethanes (including chloroform) and apply statistical analyses to all POC exceedances of combined radium utilizing a method that incorporates the historic background water quality. It is expected that the revised approach will demonstrate attainment of the remedial standards for chloroform and radium.

4. The Southwest Alluvium seepage-impacted area has attained ALARA goals. In the future, it will have to be either completely dewatered or managed via ACLs established by NRC and/or TI Waiver. A TI Waiver for sulfate and TDS would be non-traditional in the sense 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 ROD be revised to recognize the historic background water quality for these constituents in the Southwest Alluvium. A TI Waiver should include these metals.

5. EPA has expressed some interest in initiating a Site-wide feasibility study, with the objective of evaluating technologies that will enable the achievement of the current ROD cleanup standards. UNC does not recommend this course of action for the Southwest Alluvium. As first put forth by the NRC (1996), and further developed in several geochemistry (Earth Tech, 2000d and 2002c) and annual (Earth Tech, 2002d; N.A. Water Systems, 2004) reports, 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. If a feasibility study becomes EPA's preferred approach to affect remedy modification, then it should be closely coordinated with the necessary TI waivers, and other changes in Site remediation standards, and it should be focused on institutional controls, monitored natural attenuation, and other passive measures to protect human health and the environment. It may well be that a feasibility study would not be needed to formally change the remedy once the proposed waivers and standard revisions are adopted because the proposals would likely result in the attainment of all objectives.

6. Complete the statistical comparison of uranium in background and in seepage-impacted water to assist EPA in determining whether or not it makes

sense to adopt the present-day MCL for uranium. Should EPA elect to pursue the modification, then the analysis could be used to develop a reasonable approach to evaluate uranium; it will likely require the development of an ACL or a TI waiver similar to sulfate, TDS, and manganese.

5.2.2 Recommendations for Zone 3 Remedial Action

Continue Zone 3 remediation using the natural system to stabilize the seepage impacts, and continue the current pilot pumping system to retard the downgradient migration of seepage-impacted water. The revised monitoring program requested by the NRC and implemented in 2001, combined with the boundary wells that UNC installed in 2002, have proven to be very useful for evaluating the migration of the seepage and the performance of the natural system in attenuating constituents.

1. Implement the in-situ alkalinity stabilization pilot study that has been proposed by UNC.
2. UNC recommends revision of the ROD background concentrations for Zone 3 metals, as was done in 1996 for sulfate, nitrate, and TDS in all three hydrostratigraphic units. The background metals of relevance include arsenic, molybdenum, nickel, cobalt and manganese.

5.2.3 Recommendations for Closure of Zone 1 Remedial Action

Predicted performance of the Zone 1 natural attenuation system is summarized on Table 17. Implement the following recommendations for the Zone 1 corrective action system:

1. Close the Zone 1 corrective action program using MNA for metals and radionuclides.
2. Approve UNC's license amendment requests (submitted to the NRC in 2005 for chloroform and combined radium) to modify the way that chloroform and radium are compared to the Site standards. UNC will analyze samples for total trihalomethanes (including chloroform) and apply statistical analyses to all POC exceedances of combined radium utilizing a method that incorporates the historic background water quality. It is expected that the revised approach will demonstrate attainment of the remedial standards for chloroform (excluding Well 614; see item 6, below) and radium.
3. Approve a TI Waiver for sulfate, TDS, and manganese in the TI zone shown on Figure 59.

4. EPA has expressed some interest in initiating a Site-wide feasibility study, with the objective of evaluating technologies that will enable the achievement of the current ROD cleanup standards. UNC does not recommend this course of action for Zone 1. As first put forth by the NRC (1996), and further developed in several geochemistry (Earth Tech, 2000c) and annual (Earth Tech, 2000e; N.A. Water Systems, 2004) reports, 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 (all pumping wells were decommissioned in 1999 because their yields were less than the decommissioning limit). The last drop of water left in Sections 1 and 2 of Zone 1 would exceed the standards for these parameters. If a feasibility study becomes EPA's preferred approach to affect remedy modification, then it should be closely coordinated with the necessary TI waivers, and other changes in Site remediation standards, and it should be focused on institutional controls and other passive measures to protect human health and the environment. It may well be that a feasibility study would not be needed to formally change the remedy once the proposed waivers and standard revisions are adopted because the proposals would likely result in the attainment of all objectives.

5. UNC should submit an ACL for chloroform in Well 614 (POC located within the property boundary). With the vast amount of spatial and temporal monitoring data in Zone 1, it is a straightforward exercise to empirically demonstrate that chloroform attenuates to below the proposed standard everywhere off of UNC property.

Section 6
References

Blasland, Bouck & Lee, 2005, Inc., UNC Church Rock Site In-Situ Alkalinity Stabilization Pilot Study; October 2005.

Canonie Environmental Services Corp., 1995, EPA Remedial Action and NRC Ground Water Corrective Action, Five-Year Review (1989-1994). January.

Canonie Environmental Services Corp., 1993, Ground Water Corrective Action, Annual Review - 1993, Church Rock Site, Gallup, New Mexico. December.

Canonie Environmental Services Corp., 1992, Ground Water Corrective Action, Annual Review - 1992, Church Rock Site, Gallup, New Mexico. December.

Canonie Environmental Services Corp., 1991, Ground Water Corrective Action, Annual Review - 1991, Church Rock Site, Gallup, New Mexico. December.

Canonie Environmental Services Corp., 1990, Ground Water Corrective Action, Annual Review - 1990, Church Rock Site, Gallup, New Mexico. December.

Canonie Environmental Services Corp., 1989a, Remedial Design Report, Church Rock Site, Gallup, New Mexico. April.

Canonie Environmental Services Corp., 1989b, Ground Water Corrective Action, Annual Review - 1989, Church Rock Site, Gallup, New Mexico. December.

Canonie Environmental Services Corp., 1987, Geohydrologic Report, Church Rock Site, Gallup, New Mexico. May.

Earth Tech, Inc., 2002a, Ground Water Corrective Action, Annual Review - 2001, Church Rock Site, Gallup, New Mexico. January.

Earth Tech, 2002b, Presentation – "Status Update for Southwest Alluvium, Zone 1 and Zone 3 Remedial Action." Presented to EPA, NRC, NMED and Navajo Superfund. Santa Fe, New Mexico. March 7.

Earth Tech, 2002c, Final Report and Technical Impracticability Evaluation – Southwest Alluvium Natural Attenuation Test, Church Rock Site. Prepared for United Nuclear Corporation. November.

Earth Tech, 2002d, Annual Review Report – 2002 – Groundwater Corrective Action, Church Rock Site, Gallup, New Mexico. December.

Earth Tech, 2001, "Technical Memorandum – Change in Zone 3 Saturated Thickness, United Nuclear Church Rock Site, Gallup, New Mexico." April.

Earth Tech, 2000a, Letter to John J. Surmeier, Subject: "Source Materials License SUA-1475, Technical Support for Proposed License Amendments", January 13.

Earth Tech, 2000b, Letter to Greg Lyssy, Subject: "Response to Agency Comments on the January 13, 2000, Letter titled 'Source Materials License SUA-1475, Technical Support for Proposed License Amendments', for United Nuclear Corporation Church Rock Site", April 26.

Earth Tech, 2000c, Zone 1 Groundwater Geochemistry, Church Rock Site, Gallup, New Mexico. May.

Earth Tech, 2000d, Southwest Alluvium Groundwater Geochemistry Report, Church Rock Site, Gallup, New Mexico. June.

Earth Tech, Inc., 2000e, Ground Water Corrective Action, Annual Review - 2000, Church Rock Site, Gallup, New Mexico. December.

Earth Tech, Inc., 1999, Ground Water Corrective Action, Annual Review - 1999, Church Rock Site, Gallup, New Mexico. December.

Earth Tech, Inc., 1998, Ground Water Corrective Action, Annual Review - 1998, Church Rock Site, Gallup, New Mexico. December.

General Electric Corporation, 2000, "Technical Memorandum – Support for Shutting Off Remaining Zone 3 Pumping Wells." May.

General Electric Corporation, 2005a, Letter Submittal to Gary Janosko (NRC), "Revised License Amendment Request for Changing the Chloroform Ground Water Protection Standard in Source Materials License SUA-1475 (TAC LU0092) Groundwater Corrective Action Program;" July 14, 2005 (Revision of May 26, 2005 Submittal).

General Electric Corporation, 2005b, Letter Submittal to Gary Janosko (NRC), "License Amendment Request for Changing Ground Water Protection Standard for Radium in Source Materials License SUA-1475 (TAC LU0092) Groundwater Corrective Action Program;" September 30, 2005.

General Electric Corporation, 2005c, *Presentation*: Uranium Geochemistry; *Meeting at Church Rock, May 5, 2005.*

MACTEC Engineering and Consulting, Inc., 2003, Final Report Hydraulic Fracturing Pilot Test Results and Preliminary Full Scale Design, United Nuclear Church Rock Facility, Gallup, New Mexico. December 23, 2003 (revised by letter, March 2004).

MACTEC, 2005, *Presentation*: Zone 3 Remedy Update; *Meeting at Church Rock, May 5, 2005.*

MWH, 2004, Supplemental Feasibility Study, Zone 3 Hydrostratigraphic Unit, Church Rock, Uranium Mill Tailing Site; October 2004.

N.A. Water Systems, 2004, Annual Review Report 2004 – Groundwater Corrective Action, Church Rock Site, Church Rock, New Mexico; December 30, 2004.

N.A. Water Systems, 2005a, *Presentation*: 2004 Corrective Action, Keypoints and Rationale for Changes to Standards; *Meeting at Church Rock, May 5, 2005.*

N.A. Water Systems, 2005b, Technical Analysis Report in Support of License Amendment Request for Changing the Method of Determining Exceedances of the Combined Radium Groundwater Protection Standard in Source Materials License SUA-1375 (TAC LU0092), Groundwater Corrective Action Program, Church Rock Site, Church Rock, New Mexico; September 2005.

New Mexico Environment Department, 1998, Letter to Greg Lyssy from Maura Hanning, Subject: "Revision of Postmining, Pretailings Concentrations at the UNC Church Rock Site." January 6.

Nuclear Regulatory Commission, 1999a, Letter to Roy Blickwedel from John Surmeier, Subject: "Discontinuing of Pumping of Selected Wells at Church Rock Site, Materials License SUA-1475." July 30.

Nuclear Regulatory Commission, 1999b, Letter to Roy Blickwedel from John Surmeier, Subject: "Consideration of Temporary Saturation of a portion of Zone 3 at the Church Rock Site." September 16.

Nuclear Regulatory Commission, 1996, Evaluation of the Statistical Basis for Establishing Background Levels and Remediation Standards at the United Nuclear Corporation Church Rock Uranium Mill Tailings Disposal Facility, Gallup, New Mexico. June.

Rust Environment and Infrastructure, 1997, Ground Water Corrective Action, Annual Review - 1997, Church Rock Site, Gallup, New Mexico. December.

Smith Technology Corporation (Smith Environmental Technologies Corporation), 1995, *Ground Water Corrective Action, Annual Review - 1995, Church Rock Site, Gallup, New Mexico*. December.

Smith Technology Corporation, 1996, Ground Water Corrective Action, Annual Review - 1996, Church Rock Site, Gallup, New Mexico. December.

United Nuclear Corporation, 2004, Letter regarding "Supplemental Feasibility Study, United Nuclear Superfund Site, Church Rock, NM, Administrative Order Docket No. CERCLA 6-11-89;" April 15, 2004.

United Nuclear Corporation, 1989a, Corrective Action Plan, Church Rock Uranium Mill Tailings Facility. April.

United Nuclear Corporation, 1989b, Remedial Action Plan, Church Rock Uranium Mill Tailings Facility. April.

U.S. Environmental Protection Agency (EPA), 2004b, Letter on "Hydraulic Fracturing for Zone 3 and Supplemental Feasibility Study, United Nuclear Corporation Church Rock Superfund Site, Administrative Order (Docket No. CERCLA 6-11-89);" March 10, 1994, with additional comments on March 19, 2004.

U.S. Environmental Protection Agency (EPA), 2004a, EPA Comments on the Technical Impracticability Evaluation and Southwest Alluvium Natural Attenuation Test, United Nuclear Corporation Church Rock Superfund Site; February 13, 2004.

U.S. Environmental Protection Agency (EPA), 2003, *Five-Year Review Report – Second Five-Year Review Report.* September.

U.S. Environmental Protection Agency (EPA), 1998, *Five-Year Review Report.* September.

U.S. Environmental Protection Agency (EPA), 1992, *Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals;* EPA 810/K-92-01. July.

U.S. Environmental Protection Agency (EPA), 1988, *Record of Decision, United Nuclear Corporation, Ground Water Operable Unit, McKinley County, New Mexico.* U.S. Environmental Protection Agency, Region VI, Dallas, Texas, September.

USFilter, 2004a, Annual Review Report 2003 – Groundwater Corrective Action, Church Rock Site, Church Rock, New Mexico; January 14, 2004.

USFilter, 2004b, Rationale and Field Investigation Work Plan to Evaluate Recharge and Potential Cell Sourcing to the Zone 3 Plume, Church Rock Site, Gallup, New Mexico; January 19, 2004.

TABLE 1
Southwest Alluvium Performance Monitoring Program, 2005 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 2005
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Chemical Name	Unit	Action Level	0509 D	0624	0627	0632	0801	0802	0803	0808	EPA 23	EPA 25	EPA 28	GW 1	GW 2	GW 3	SBL-01
ALUMINUM	mg/l	5															0.1
AMMONIA (AS N)	mg/l		3.93			0.49	2.9 D	0.09	1.19	0.13	1.11	0.09		0.23	0.08	0.11	0.17
BICARBONATE	mg/l		2250	1370	595	1860	1450	2280	2070	1840	1120	891	671	1560	2300	1680	387
CALCIUM	mg/l		875 D	693 D	554 D	626 D	547 D	672 D	672 D	730 D	650 D	727 D	544 D	711 D	815 D	926 D	537 D
CHLORIDE	mg/l	250	327	184	54	244	208	199	172	169	85	99	136	267	242	178	103
CHLOROFORM	ug/l	1				2.9	2.9	10.6	2.6	7.3							
COBALT	mg/l	0.05														0.01	0.03
GROSS ALPHA	pci/l	15				2.4	1.0	1.2				1.4	1.4				
MAGNESIUM	mg/l		430 D	436 D	284 D	792 D	676 D	1050 D	768 D	695 D	408 D	231 D	513 D	595 D	638 D	314 D	981 D
MANGANESE	mg/l	2.6	2.36	0.08		1.62	3.62	0.82	1.96	0.61	5.15	2.23	0.52	0.05	0.81	1.78	2.25
NICKEL	mg/l	0.05															0.08
NITRATE (NO3)	mg/l	190	14.9 D	75 D	108 D	58 D	0.2	90 D	49.2 D	120 D	0.4	84 D	28 D	85 D	7.6 D	78 D	41.4 D
PH (LAB)	SU		7.01	7.21	7.60	7.03	7.05	7.17	7.08	7.09	7.21	7.46	7.30	7.24	7.02	7.26	7.25
POTASSIUM	mg/l		13.7	6.2	5.2	9.2	12.2	6.8	11.6	4.8	10.2	7.9	12.2	6.3	12.3	8.6	12.6
RADIUM-226	pci/l				0.3	0.6							0.4				
RADIUM-228	pci/l		1.7	2.9	1.4	3.3	2.4			1.7	1.2	2.0	1.4			1.4	3.5
RADIUM 226 & 228	pci/l	5	1.7	2.9	1.7	3.9	2.4			1.7	1.2	2	1.8			1.4	3.5
SODIUM	mg/l		323	241	495	399	355	366	271	306	130	170	215	352	376	275	357
SULFATE (SO4)	mg/l	2125	1890 D	2170 D	2530 D	3350 D	3280 D	3620 D	2950 D	2610 D	2170 D	1770 D	2900 D	2770 D	3040 D	2120 D	5360 D
TDS	mg/l	4800	5460	5130	4930	7210	6380	8290	6730	6700	4480	4100	5150	6420	6730	5270	8520
URANIUM	mg/l	0.3	0.197	0.0316	0.0271	0.0880 D	0.0419	0.181 D	0.140	0.134	0.0261	0.102	0.0408	0.0934	0.132	0.118	0.0241 D

TABLE 3
Southwest Alluvium Saturated Thickness, October 2005
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
509-D	10/3/05	71.85	38.15	35%
624	10/4/05	49.14	25.86	34%
627	10/4/05	56.33	14.67	21%
632	10/4/05	40.63	26.37	39%
801	10/3/05	45.70	14.80	24%
802	10/3/05	43.61	37.89	46%
803	10/3/05	58.22	59.78	51%
805	10/12/05	45.52	74.48	62%
807	10/12/05	50.91	49.09	49%
808	10/3/05	44.98	87.02	66%
EPA-23	10/3/05	47.65	72.35	60%
EPA-25	10/4/05	49.23	20.77	30%
EPA-28	10/4/05	58.63	19.37	25%
GW-1	10/4/05	57.86	19.14	25%
GW-2	10/3/05	51.47	38.53	43%
GW-3	10/4/05	50.07	6.93	12%
SBL-01	10/4/05	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 (gpm)												
	1990 (1)	1991 (2)	1992 (3)	1993 (4)	1994 (5)	1995 (6)	1996 (7)	1997 (8)	1998 (9)	1999 (10)	2000 (11)	2001 (12)	1990-2001
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.

gpm = gallons per minute
Source: Earth Tech, December 2002, Figure 2.1

TABLE 5
Southwest Alluvium Groundwater Velocities, October 2005
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Well Pair 805 and 624

Groundwater Elevations: 6864.53 (Well 805) and 6849.02 (Well 624) ft amsl
Separation Distance: 1902 ft
Average Linear Horizontal Hydraulic Gradient: 0.0083
Velocity 1 = 64 ft/yr
Velocity 2 = 49 ft/yr
Average Velocity = 57 ft/yr

Well Pair 805 and 627

Groundwater Elevations: 6864.53 (Well 805) and 6835.48 (Well 627) ft amsl
Separation Distance: 3203 ft
Average Linear Horizontal Hydraulic Gradient: 0.0091
Velocity 1 = 70 ft/yr
Velocity 2 = 54 ft/yr
Average Velocity = 62 ft/yr

Well Pair 624 and SBL 1

Groundwater Elevations: 6849.02 (Well 624) and 6846.49 (Well SBL 1) ft amsl
Separation Distance: 500 ft
Average Linear Horizontal Hydraulic Gradient: 0.00506
Velocity 1 = 39 ft/yr
Velocity 2 = 30 ft/yr
Average Velocity = 35 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, 2005
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 and Mn slightly below standard in background Well SBL 1
Sulfate	No	No	No	Seepage impact areas limited by calcium availability; background waters characterized by exceedances unrelated to seepage impact
TDS	No	No	No	Governed by sulfate concentration
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 new background Well SBL 1
Radionuclides	Yes	Yes	Yes	Attenuation by neutralization and adsorption

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 2005		
402	–	25.89	–	–
411	62.5	–	–	–
420	56.3	16.41	-39.9	-71%
424	–	28.25	–	–
446	–	9.52	–	–
501 B	20.2	–	–	–
502 B	48.5	–	–	–
504 B	40.1	11.57	-28.6	-71%
517	42.7	12.50	-30.2	-71%
518[2]	37.2	–	–	–
613[3]	67.2	20.01	-47.2	-70%
EPA 01	14.7	–	–	–
EPA 03	8.3	–	–	–
EPA 09	8.1	4.25	-3.8	-47%
EPA 11	30.8	–	–	–
EPA 12	10.7	–	–	–
EPA 13	24.8	10.78	-14.1	-57%
EPA 14	76.3	33.40	-42.9	-56%
EPA 15	60.8	–	–	–
EPA 17	1.4	–	–	–
EPA 18	2.5	–	–	–
701	46.1	15.85	-30.2	-66%
702	24.1	9.96	-14.1	-59%
703	32.6	–	–	–
705	–	–	–	–
706	–	18.47	–	–
707	58.8	18.82	-40.0	-68%
708	49.8	18.98	-29.8	-60%
709	56.1	–	–	–
710	45.5	16.17	-29.3	-64%
711	43.7	20.66	-23.0	-53%
712	39.1	8.64	-30.5	-78%
713	34.2	11.33	-22.9	-67%
714[4]	50.1	18.37	-31.7	-63%
715[4]	47.6	–	–	–
716[4]	58.3	–	–	–
717[4]	57.6	26.66	-30.9	–
718[4]	51.1	–	–	–
719[4]	39.9	14.51	-25.4	-64%
720[4]	33.1	–	–	–
NBL-01[5]	–	22.32	–	–
Average	37.3	17.10	-28.6	-64%

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 2001and 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, January Through November 2005
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	564,454	5,662	10	1,068	7	48	11	363	53	10	1,282	470	160	27.77	1.07	19.23
RW-12	303,718	3,276	2	575	7	26	6	264	29	5	632	310	57	20.69	0.57	13.22
RW-13	421,303	4,545	0	797	10	44	8	399	40	8	877	446	44	36.68	0.80	20.73
RW-15	728,068	7,440	65	1,378	96	6	55	220	69	16	138	207	158	63.38	1.38	49.60
RW-16	331,766	3,767	23	628	6	3	7	188	31	7	377	138	69	18.84	0.63	11.30
RW-17	271,712	3,805	5	514	9	2	6	267	26	7	566	257	57	17.48	0.51	10.28
PB-2	273,238	2,792	0	517	3	47	5	269	26	5	827	310	26	17.06	0.52	11.89
Total	2,894,258	31,288	104	5,477	139	174	97	1,971	274	59	4,699	2,139	572	201.91	5.48	136.26

Notes:

RW-series wells are located on Figure B-1 in Appendix B of this *2005 Annual Review Report*.

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

The location of extraction Well MW-5 was unknown while developing this table; however, its contribution was negligible.

Total pumped amount excludes Well MW-5; actual total amount pumped including MW-5 is estimated to be approximately 2,904,000 gallons.

In developing this table, analytical nondetects were assigned values of one-half the detection limit.

TABLE 9
Zone 3 Performance Monitoring Program, 2005 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 2005
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
402	10/12/05	37.11	25.89	41%
420	10/10/05	34.59	16.41	32%
424	10/12/05	44.75	28.25	39%
446	10/12/05	55.48	9.52	15%
504-B	10/10/05	54.43	11.57	18%
517	10/10/05	49.50	12.50	20%
613	10/5/05	47.99	20.01	29%
701	10/12/05	48.15	15.85	25%
702	10/12/05	71.04	9.96	12%
706	10/12/05	59.53	18.47	24%
707	10/12/05	69.18	18.82	21%
708	10/11/05	66.02	18.98	22%
710	10/12/05	64.83	16.17	20%
711	10/11/05	64.34	20.66	24%
712	10/12/05	77.36	8.64	10%
713	10/12/05	61.67	11.33	16%
714	10/12/05	19.63	18.37	48%
717	10/10/05	44.34	26.66	38%
719	10/10/05	30.49	14.51	32%
EPA-09	10/11/05	45.75	4.25	8%
EPA-13	10/11/05	53.22	10.78	17%
EPA-14	10/10/05	39.60	33.40	46%
NBL-01	10/10/05	11.68	22.32	66%
PB-03	10/10/05	22.16	26.84	55%
PB-04	10/10/05	15.16	21.84	59%

TABLE 11

Zone 3 Field Parameter Measurements of Sentinel Wells, Through October 2005
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

	Month	Bicarbonate (mg/L)					Conductivity (umhos/cm)					pH (s.u.)					Chloride (mg/L)				
		504B	PB-2	PB-4	PB-3	NBL-01	504B	PB-2	PB-4	PB-3	NBL-01	504B	PB-2	PB-4	PB-3	NBL-01	504B	PB-2	PB-4	PB-3	NBL-01
1	Jun-02	NA	141	270	341	339	NA	3950	3660	3400	NA	4.55	6.18	6.38	6.23	6.65	NA	29.9	21.8	2.0	NA
3	Aug-02	NA	94	211	311	NA	4900	3780	3540	3200	3140	NA	5.93	6.77	6.68	NA	NA	26.0	24.5	4.0	NA
4	Sep-02	NA	105	178	327	NA	NA	3930	3770	3330	NA	NA	5.95	6.80	6.56	NA	NA	24.1	24.5	24.7	NA
5	Oct-02	NA	58	194	224	330	5010	4040	3730	3670	3160	5.06	7.09	7.10	7.10	7.18	NA	25.3	23.8	113.0	NA
6	Nov-02	0	41	188	299	285	4930	3080	2860	2510	3120	NA	5.95	6.47	6.60	6.51	14.0	26.5	24.3	23.8	21.0
7	Dec-02	NA	57	178	283	NA	5040	4120	3950	3330	NA	5.40	5.75	6.40	6.68	NA	22.9	26.2	23.2	25.7	NA
8	Jan-03	NA	34	148	239	311	5180	3930	3716	3460	3300	5.54	4.97	6.92	6.41	6.43	NA	NA	22.9	22.8	NA
9	Feb-03	NA	58	193	324	328	3620	2910	2660	2570	2300	3.52	5.57	6.96	6.92	6.53	26.7	30.1	30.4	28.5	21.5
10	Mar-03	NA	60	188	311	326	4000	3090	2890	2680	2500	3.49	5.59	6.71	6.95	6.73	26.4	30.1	29.7	29.7	22.1
11	Apr-03	NA	34	172	310	321	4210	4460	4220	3820	2650	5.14	5.46	5.94	6.26	6.87	26.6	30.5	30.0	30.1	21.6
12	May-03	0	31	167	293	322	5510	4460	4210	3820	3390	5.01	5.36	5.99	6.31	6.37	28.0	31.0	30.2	31.9	32.7
13	Jun-03	0	21	129	267	316	5470	4480	4060	3820	3380	4.28	5.15	6.17	6.20	6.36	27.7	30.8	29.6	30.6	28.0
14	Jul-03	0	32	126	257	311	5480	4560	4330	3920	3500	5.35	5.28	5.85	6.32	6.29	26.5	30.6	29.7	31.1	25.8
15	Aug-03	NA	5	100	234	307	5210	4280	3960	3630	3230	5.14	5.18	5.76	6.18	6.28	27.0	30.4	29.7	31.1	23.1
16	Sep-03	NA	7	91	218	295	5260	4400	4160	3770	3340	4.68	5.23	5.79	6.28	6.39	28.0	30.5	29.3	31.5	26.7
17	Oct-03	NA	0	65	211	295	5360	4450	4210	3390	3390	5.27	5.18	5.81	6.34	6.41	27.7	21.0	30.0	32.7	26.8
18	Nov-03	NA	0	73	197	285	5290	4510	4210	3880	3490	5.09	5.25	5.81	6.24	6.42	27.3	30.6	30.2	32.1	24.8
18	Dec-03	NA	NA	41	166	265	5370	4540	4290	3910	3510	4.41	5.14	5.77	6.76	6.48	27.7	30.2	29.8	31.5	25.2
19	Jan-04	NA	NA	73	194	327	5340	4610	4310	4030	3550	5.39	5.16	5.82	7.51	6.50	32.5	30.5	29.5	32.6	26.8
20	Feb-04	NA	NA	50	190	323	5410	4630	4260	3970	3590	3.40	3.81	5.99	6.25	6.40	28	30.1	30.3	32.7	26.6
21	Mar-04	NA	15	48	179	316	5560	4730	NA	4130	3780	3.89	4.75	5.70	6.31	6.29	27.5	30.1	30.2	33.3	25.9
22	Apr-04	NA	15	48	174	315	5370	4560	NA	4010	3630	5.36	5.08	5.52	6.03	6.34	28.1	32.1	32.3	36.2	31.1
23	May-04	NA	0	27	166	312	6190	4390	NA	3870	3510	3.26	5.02	5.34	5.88	6.23	28.4	33.2	32.8	38.1	31.9
24	Jun-04	NA	0	22	152	294	5510	4530	NA	4040	3750	4.48	4.92	5.46	6.05	6.40	28.2	32.6	32.9	37.7	34.1
25	Jul-04	NA	0	20	140	274	5450	4510	NA	4000	3740	5.48	5.04	5.58	6.05	6.45	27.8	31.9	32.8	36.9	34.1
26	Aug-04	NA	0	17	124	272	5500	4450	NA	4040	3710	3.77	4.26	5.45	5.98	6.39	28.3	31.0	32.3	36.2	33.7
27	Sep-04	0	0	20	117	251	5480	4500	NA	4030	3790	4.04	4.46	5.48	6.05	6.45	28.5	30.9	32.5	36.0	34.0
28	Oct-04	0	0	18	102	245	5520	4540	NA	4110	3940	5.56	5.15	5.62	6.08	6.47	27.8	31.5	32.0	30.2	33.2
29	Nov-04	0	0	17	98	245	5370	4400	4340	3950	3840	4.46	4.23	5.47	5.99	6.37	27.8	31.4	32.3	35.6	32
30	Dec-04	0	0	13	87	207	5290	4340	4290	3920	3790	4.46	4.28	5.44	5.95	6.36	27.8	31.2	31	34	30
31	Jan-05	11	0	32	79	198	5700	4610	4520	4110	4080	4.46	3.92	5.46	6.03	6.27	27.8	31.3	31.3	33.8	34.2
32	Feb-05	0	0	7	68	196	5680	4720	4550	4130	3980	4.46	3.24	5.31	5.98	6.37	27.8	31.5	31.3	33.4	30
33	Mar-05	0	0	0	60	169	5540	4510	4350	3990	3960	4.46	3.72	5.32	5.93	6.27	27.8	31.3	32	33.7	35.2
34	Apr-05	8	0	29	70	154	5350	4300	4340	3980	3890	4.46	4.25	5.56	5.88	6.31	27.8	32.4	32.2	34	35.1
35	May-05	0	0	0	67	150	5300	4290	4170	3840	3810	4.46	3.78	4.53	5.85	6.30	27.8	32.6	30.6	33.4	34.6
36	Jun-05	0	0	0	65	138	5400	4330	4280	3980	3910	4.46	3.93	4.63	5.77	6.15	27.8	32.1	31	33.6	34.7
37	Jul-05	0	0	0	67	123	5020	4150	4100	3780	3640	4.46	3.55	4.04	5.58	5.88	27.8	31.2	31.9	33.1	34.3
38	Aug-05	0	0	0	57	122	5270	4320	4360	3880	3730	4.46	3.39	3.29	5.89	6.62	27.8	31.5	31.6	34.2	34.2
39	Sep-05	0	NA	0	54	111	5430	NA	4230	3920	3830	4.46	NA	4.15	5.80	6.24	27.8	NA	31.3	33.2	34.1
40	Oct-05	0	NA	0	51	107	5630	NA	4410	4220	4030	4.46	NA	4.99	6.00	6.26	27.8	NA	31.3	33.6	34

Note: NA indicates not analyzed

TABLE 12
Zone 3 Seepage
Migration Travel Time Calculations
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Well	Measuring Point	Distance From Measuring Point (ft)	Time for Seepage Impacts at Measuring Point (date)	Time for Seepage Impacts at End Point (date)	Travel Time (ft/yr)	Basis for Determining Date for "Seepage Impacts At End Point"
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 reaching @ 50 mg/L at Well PB-02
PB 2	504 B	630	Jul-92	Oct-02	61	Bicarbonate concentrations first reaching @ 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
			Geometric Mean		99	

TABLE 13
Detected Constituents in Zone 3, October 2005
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Chemical Name	Action Level	Unit	0420	0504 B	0517	0613	0708	0711	0717	0719	EPA 13	EPA 14	NBL-01
ALUMINUM	5	mg/l		13.7	4.8	712 D	2.6	0.8		0.2		57.9	
AMMONIA (AS N)		mg/l	0.20	0.93	8.6 D	253 D	1.84	0.82	6.6 D	1.25	0.79	10.5 D	0.52
ARSENIC	0.05	mg/l	0.006				0.001	0.04		0.02	0.03	0.004	0.06
BERYLLIUM	0.017	mg/l				0.21				0.01		0.03	
BICARBONATE		mg/l	586						518		82	134	122
CADMIUM	0.01	mg/l			0.007	0.036							
CALCIUM		mg/l	713 D	525 D	502 D	431 D	458 D	492 D	712 D	494 D	475 D	594 D	613 D
CHLORIDE	250	mg/l	73	29	46	156	31	21	72	30	42	60	34
CHLOROFORM	1	ug/l			3.4	136 D							
COBALT	0.05	mg/l		0.27	0.78	2.38	0.35	0.44	0.03	0.26	0.06	0.1	0.28
GROSS ALPHA	15	pci/l	5.2	16.8	16.7	48.5	9.4	12.4	9.2	6.4	7.7	25.1	10.5
MAGNESIUM		mg/l	147	415 D	467 D	744 D	591 D	526 D	319 D	709 D	788 D	427 D	319 D
MANGANESE	2.6	mg/l	2.37	5.02	7.49	62.9	10.3	7.3	4.5	7.12	6.44	7.25	5.37
MOLYBDENUM	1	mg/l	0.1							1.3	0.1		1.0
NICKEL	0.05	mg/l		0.28	0.68	2.21	0.33	0.36		0.3	0.14	0.12	0.34
NITRATE (NO3)	190	mg/l	15.1 D		0.4	10.7 D			26.4 D			21.1 D	
PH (FIELD)		pH units	6.65		4.45	3.02	3.94	4.51	6.49	3.73	6.06	6.33	
PH (LAB)		pH units	7.22	5.07	3.86	3.15	3.62	3.62	7.00	3.82	6.56	6.40	6.69
POTASSIUM		mg/l	6.9	10	10		12.6	10.8	11.9	12.5	11.9	11.1	7.3
RADIUM-226		pci/l	3.8	14.8	10.3	8.2	8.6	7.3	7.2	4.3	6.0	16.2	9.2
RADIUM-228		pci/l	2.4	14.5	12.2		8.7	15.3	8.5	5.4	3.8	13.2	4.7
RADIUM 226 & 228	5	pci/l	6.2	29.3	22.5	8.2	17.3	22.6	15.7	9.7	9.8	29.4	13.9
SODIUM		mg/l	154	126	146	284	116	99.8	152	157	140	171	133
SULFATE (SO4)	2125	mg/l	1780 D	3040 D	3260 D	9040 D	3960 D	3560 D	2520 D	4160 D	4360 D	3020 D	2640 D
THORIUM-230	5	pci/l				254							
TDS	4800	mg/l	3510	4250	4880	13400	5900	5240	4500	4540	6270	4820	4090
URANIUM	0.3	mg/l	0.113	0.0190	0.0447	1.68 D	0.0214	0.0302	0.0536	0.0994	0.0129	0.0538	0.0202
VANADIUM	0.1	mg/l				3.3							

TABLE 14
Zone 1 Performance Monitoring Program, 2005 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 15
Zone 1 Saturated Thickness, October 2005
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

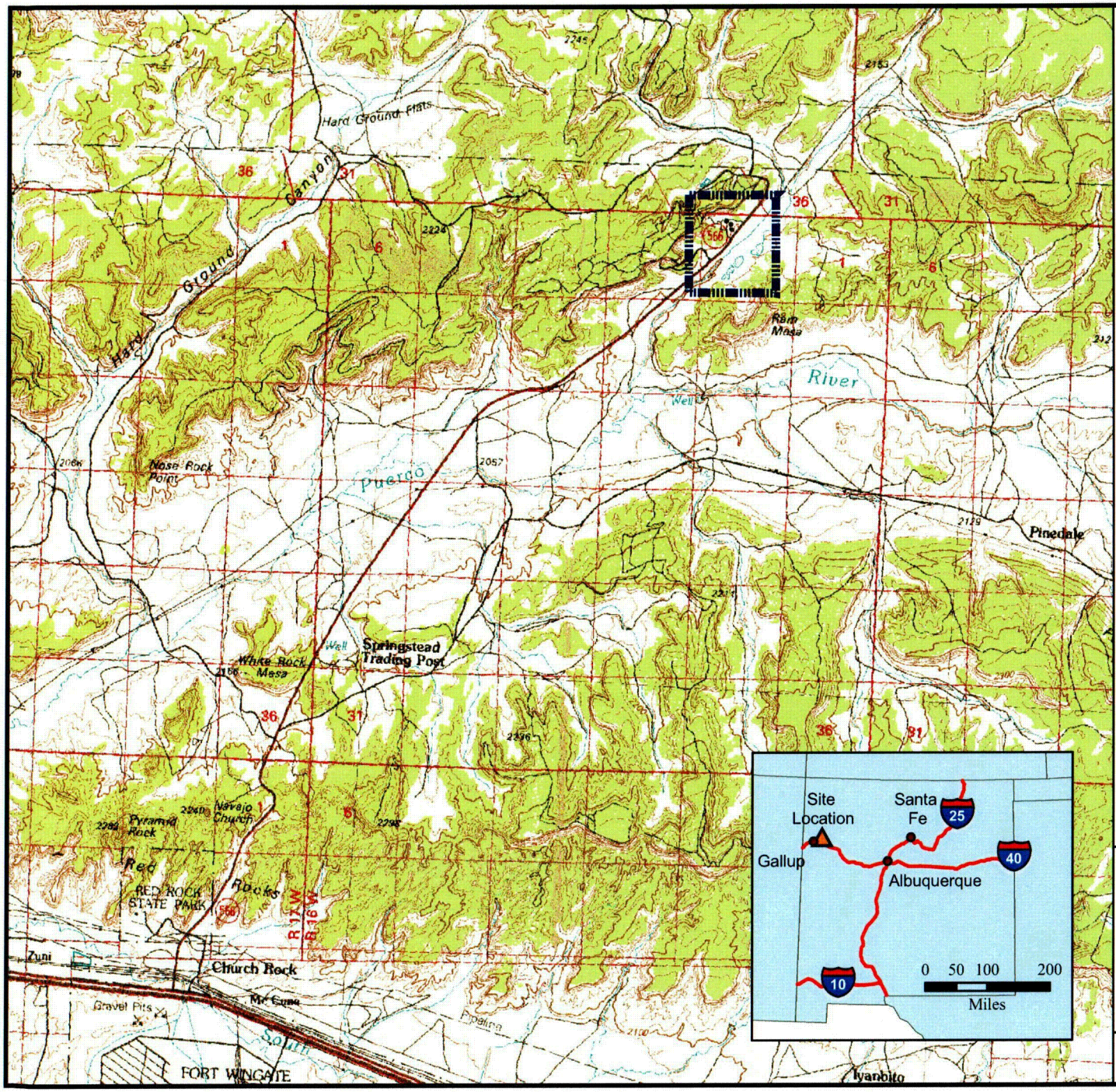
Well	Water Level Measurement Date	Zone 1 Unsaturated Thickness	Zone 1 Saturated Thickness	Zone 1 Percentage Saturated
TWQ-142	10/10/2005	0.00	55.00	100%
TWQ-143	10/12/2005	0.00	52.00	100%
412	10/12/2005	0.00	76.00	100%
501-A	10/12/2005	8.64	56.36	87%
502-A	10/12/2005	0.00	59.00	100%
504-A	10/12/2005	7.75	60.25	89%
505-A	10/12/2005	0.00	46.00	100%
515-A	10/5/2005	24.60	16.40	40%
604	10/5/2005	21.83	23.17	51%
614	10/5/2005	20.45	24.55	55%
EPA-02	10/11/2005	18.63	31.37	63%
EPA-04	10/11/2005	15.28	39.72	72%
EPA-05	10/11/2005	26.40	22.60	46%
EPA-07	10/11/2005	27.00	56.00	67%
EPA-08	10/11/2005	26.08	39.92	60%

TABLE 16
Detected Constituents in Zone 1, October 2005
United Nuclear Corporation, Church Rock Site
Church Rock, New Mexico

Chemical Name	Action Level	Unit	0142	0515 A	0604	0614	EPA 02	EPA 04	EPA 05	EPA 07
ALUMINUM	5	mg/l		1.3	9.5					0.3
AMMONIA (AS N)		mg/l		4.15	0.46	50 D	0.47	0.77	7.8 D	0.54
ARSENIC	0.05	mg/l				0.001				
BICARBONATE (HCO3)		mg/l	250	209	12	1440	284	174	92	564
CALCIUM		mg/l	22.8	455 D	450 D	584 D	352 D	544 D	466 D	494 D
CHLORIDE	250	mg/l	19	242	58	324	23	39	66	203
CHLOROFORM	1	ug/l		161 D	2.8	202 D				
COBALT	0.05	mg/l		0.07	0.27				0.08	0.02
GROSS ALPHA	15	pci/l		3.1	4.0		1.1	1.6	4.0	2.8
MAGNESIUM		mg/l	10.3	875 D	854 D	659 D	163 D	382 D	538 D	896 D
MANGANESE	2.6	mg/l		15.4	11.1	0.30	1.28	3.24	1.23	2.8
NICKEL	0.05	mg/l		0.25	0.34				0.06	
NITRATE (NO3)	190	mg/l		52 D	60 D	61 D			22.4 D	125 D
PH (FIELD)		su	7.53	5.53	4.93	6.48	6.79	6.65	5.87	6.03
PH (LAB)		su	7.94	6.10	4.85	7.05	7.26	7.02	6.51	6.78
POTASSIUM		mg/l	3.2	14.3	12.4	10.5	6.4	8.9	10.6	8.0
RADIUM-226		pci/l		1.9	2.2	0.6	1.6	1.4	1.7	1.1
RADIUM-228		pci/l		1.3	5.7	1.6	3.7	3.3	1.6	1.4
RADIUM 226 & 228	5	pci/l		3.2	7.9	2.2	5.3	4.7	3.3	2.5
SODIUM		mg/l	322	427	286	460	199	190	138	333
SULFATE (SO4)	2125	mg/l	562	4540 D	4600 D	2910 D	1560 D	2880 D	3120 D	4100 D
TOTAL DISSOLVED SOLIDS	4800	mg/l	1050	7710	7260	6550	2640	4580	5120	7790
URANIUM	0.3	mg/l		0.0009 D	0.0015	0.0498 D	0.0011	0.0005	0.0014	0.0018 D

TABLE 17
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



N

LEGEND

Approximate Site Location

NEW MEXICO INSET LEGEND

- Major City
- Church Rock Site Location
- Interstate Highway
- State Boundary

Notes:

1. Topographic basemap taken from the United States Geologic Survey 30x60 minute, 1:100,000 scale, Gallup, New Mexico Topographic Map, 1981.
2. Data for New Mexico Inset map taken from ESRI Data & Maps 2002 CD-ROM set.

1 0.5 0 1
Miles

FIGURE 1

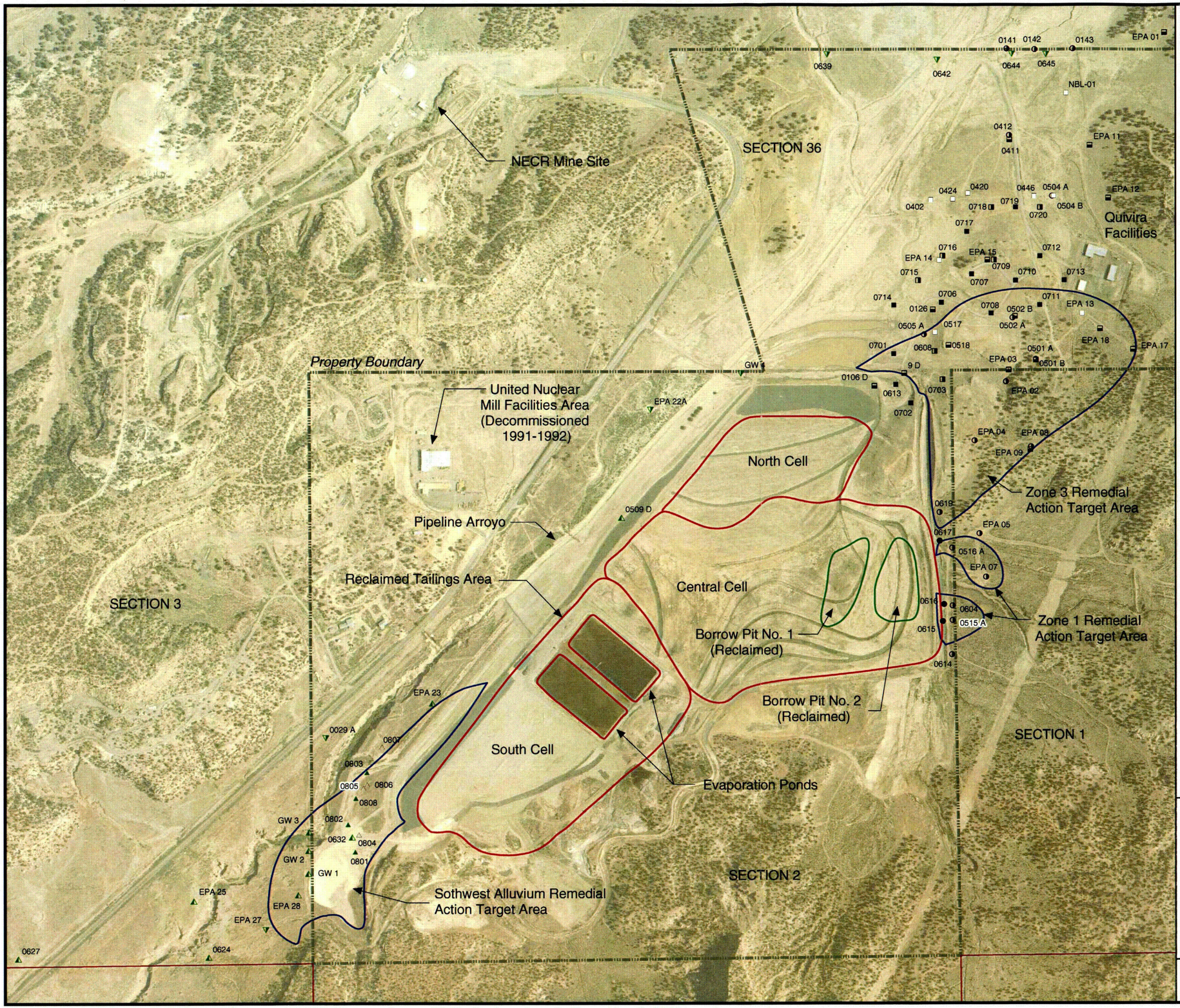
Site Location Map

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

NA WATERSYSTEMS

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2005_annual_report\f01_site_location.mxd; December 9, 2005

C-01



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

0 400 800 1,600
Feet

FIGURE 2

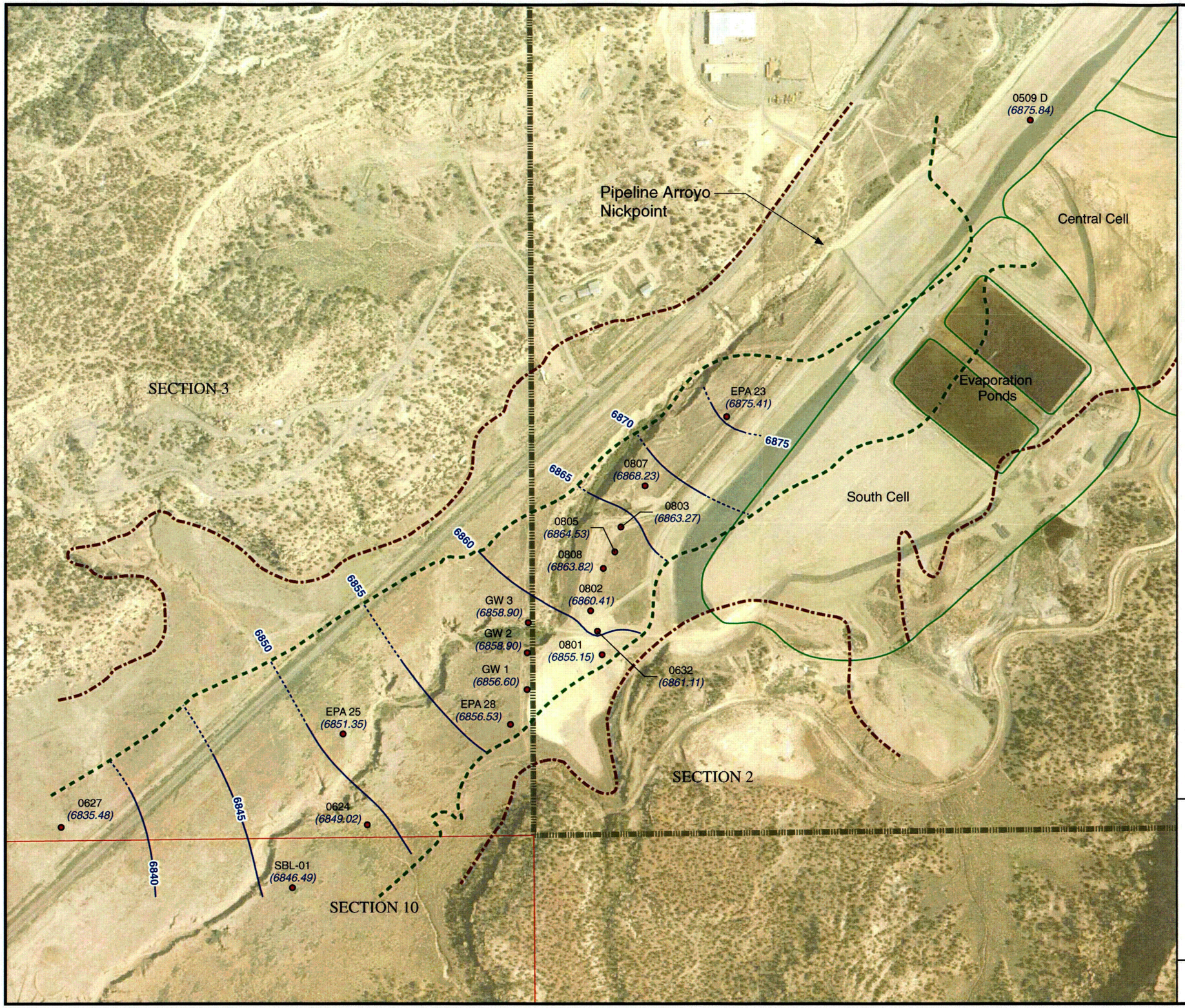
Site Layout and Performance Monitoring Well Locations 2005 Operating Year

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

NA WaterSystems

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2005_annual_report\f02_site_layout.mxd; December 9, 2005

C-02



N

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.

0 250 500 1,000
Feet

FIGURE 3

Southwest Alluvium
Potentiometric Surface Map
October 2005

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

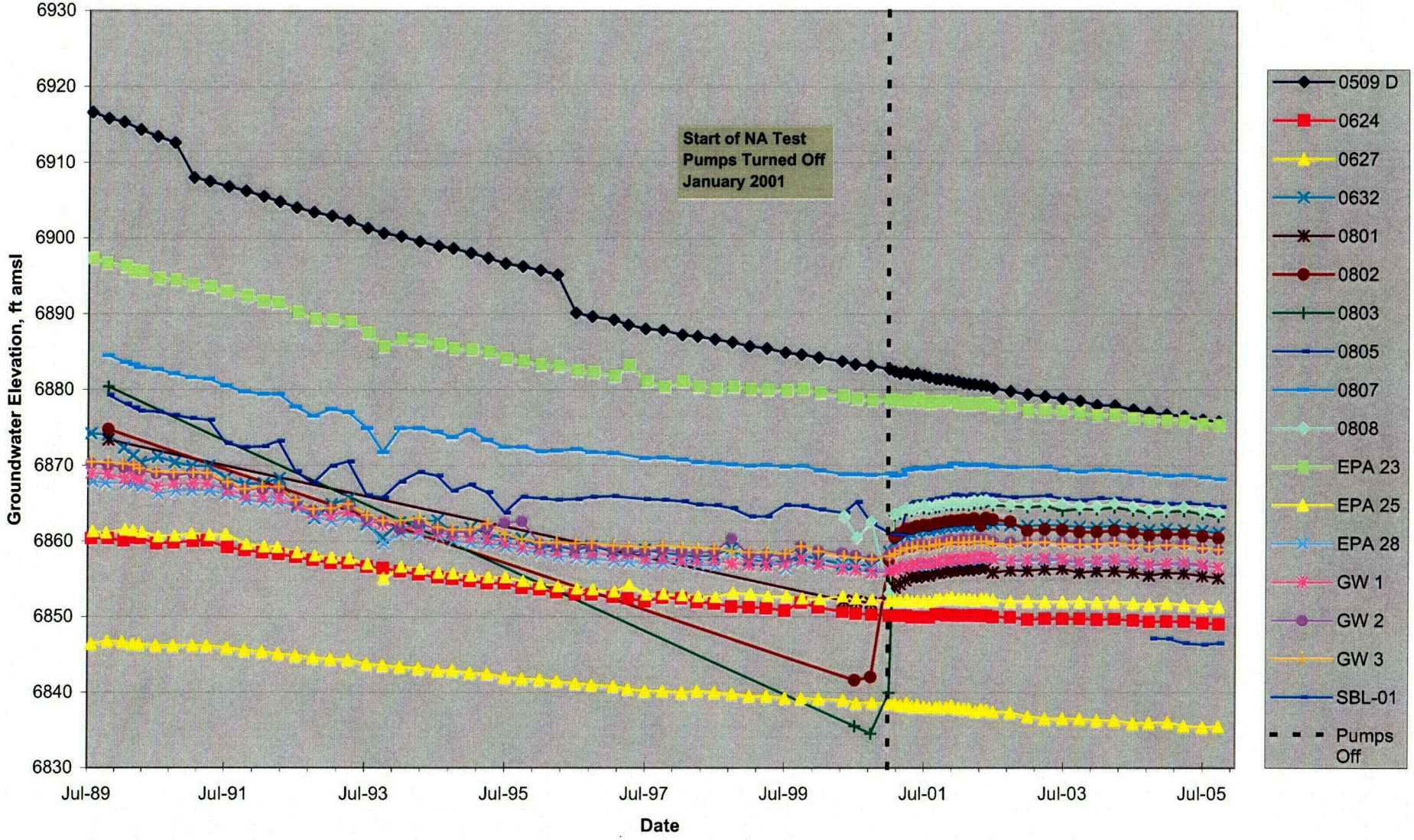
NA WaterSystems

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2005_annual_report\f03_swa_piezo.mxd; December 9, 2005

FIGURE 4

Southwest Alluvium Water Levels Over Time

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



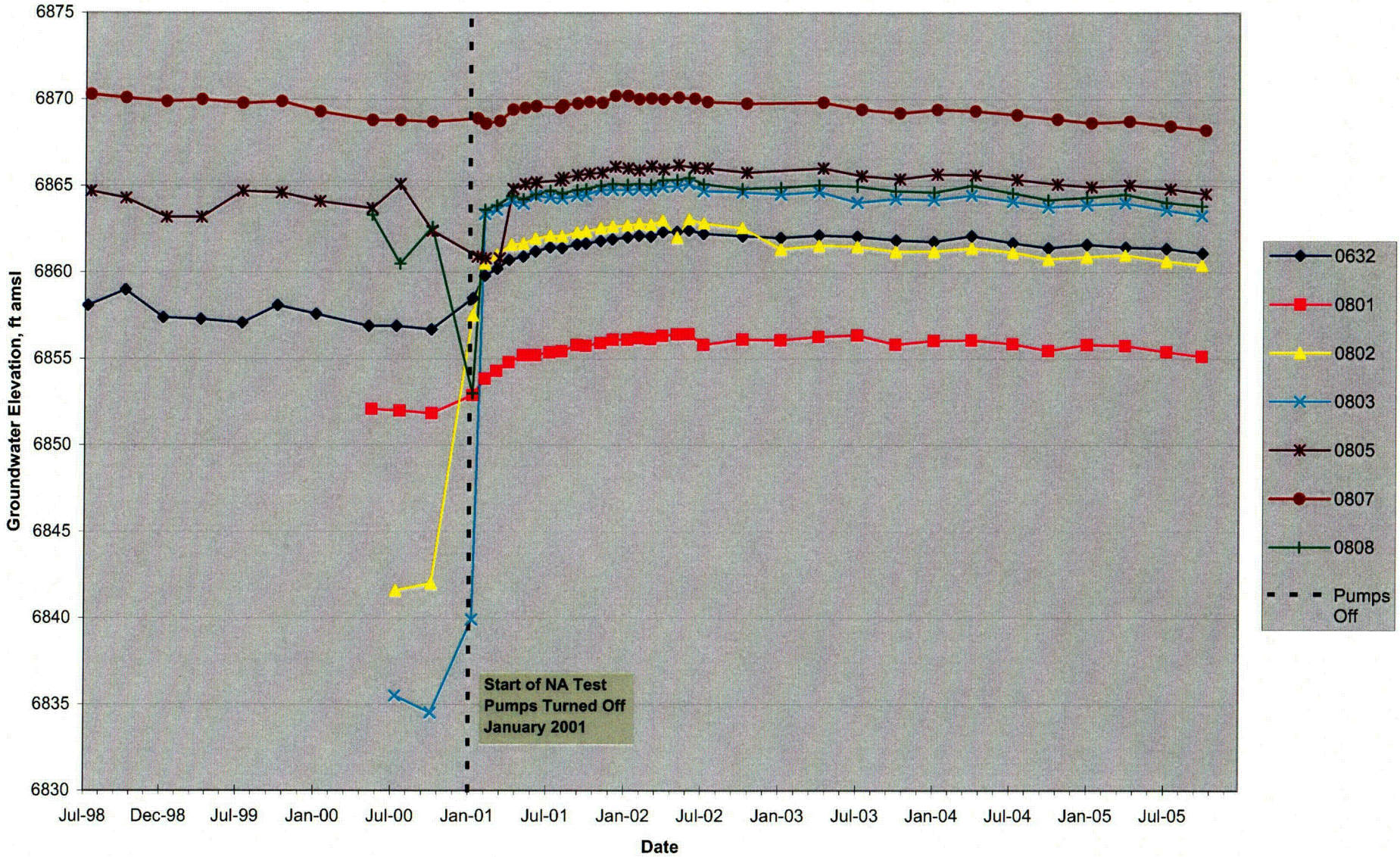
dll-1200

N.A. Water Systems

FIGURE 5

Southwest Alluvium Pumping Well Water Levels Over Time

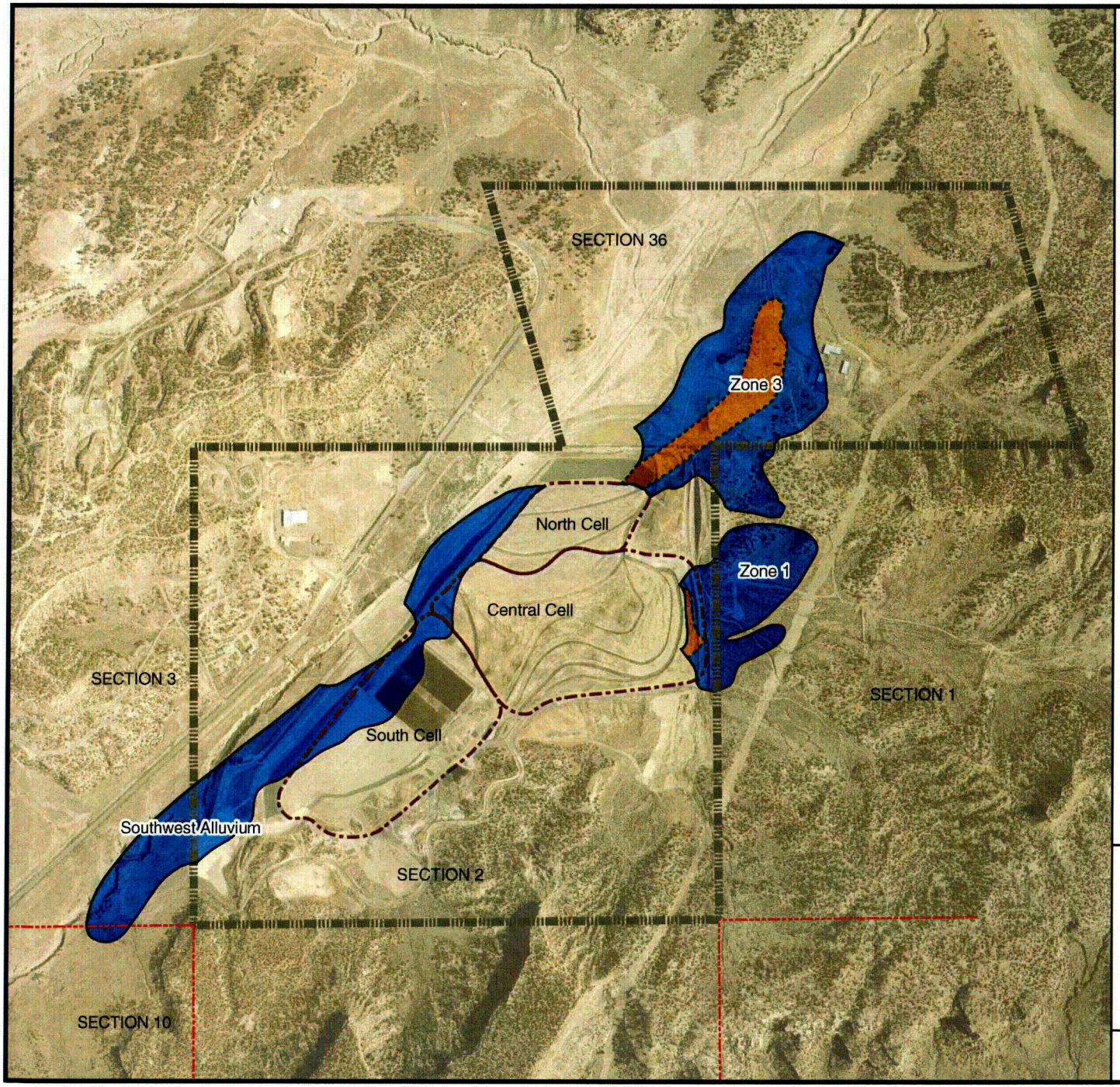
United Nuclear Corporation, Church Rock Site, Church Rock New Mexico



C-05

dll-1200

N.A. Water Systems



N

LEGEND

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

Aerial photo taken on August 1, 1996.

0 750 1,500 3,000
Feet

FIGURE 6

Extent of Seepage-Impacted Groundwater

United Nuclear Corporation Church Rock Site
Church Rock, New Mexico

NA WaterSystems

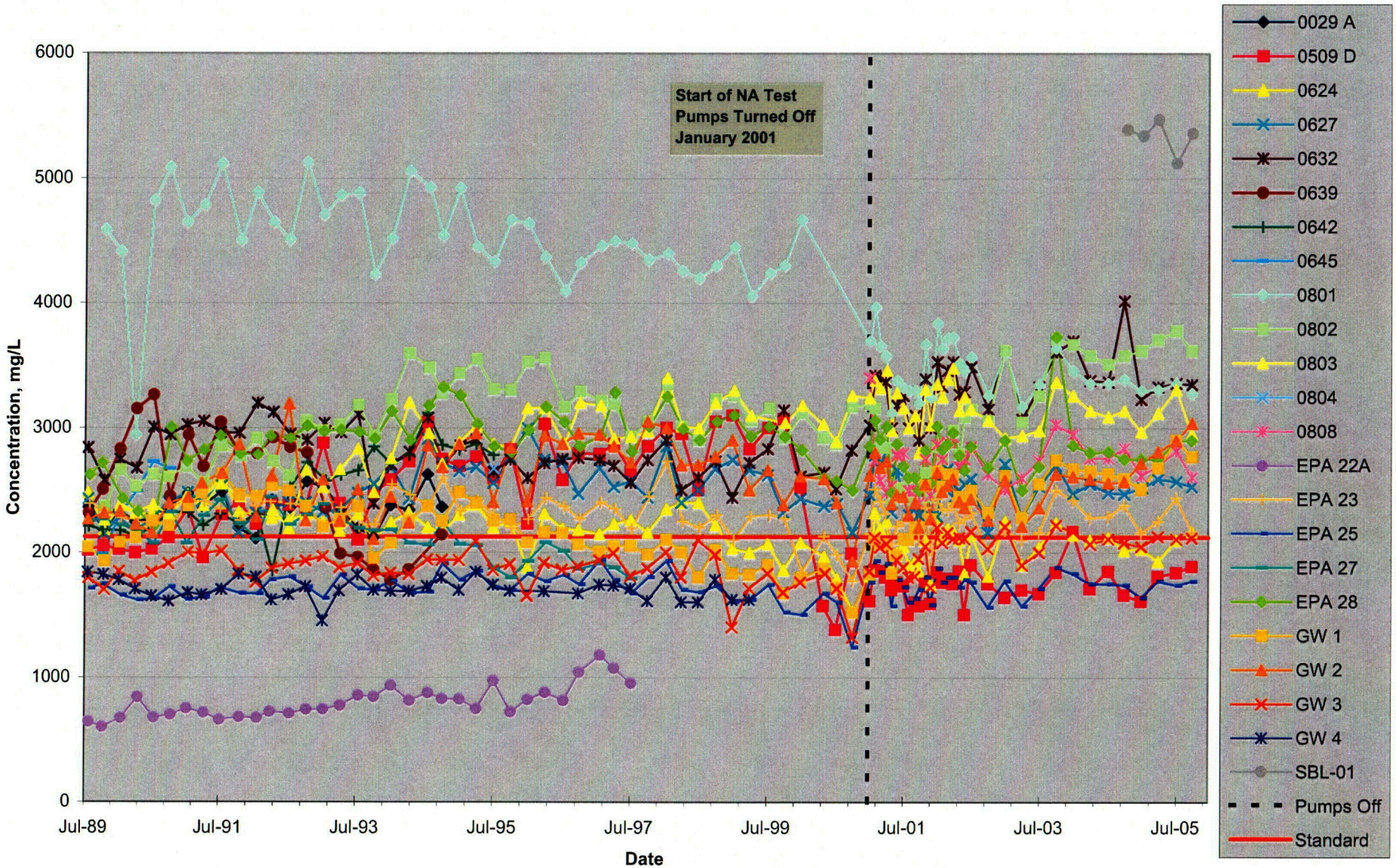
Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2005_annual_report\f06_seepage_extents.mxd; December 12, 2005

C-06

FIGURE 7

Southwest Alluvium Sulfate Concentraions Over Time

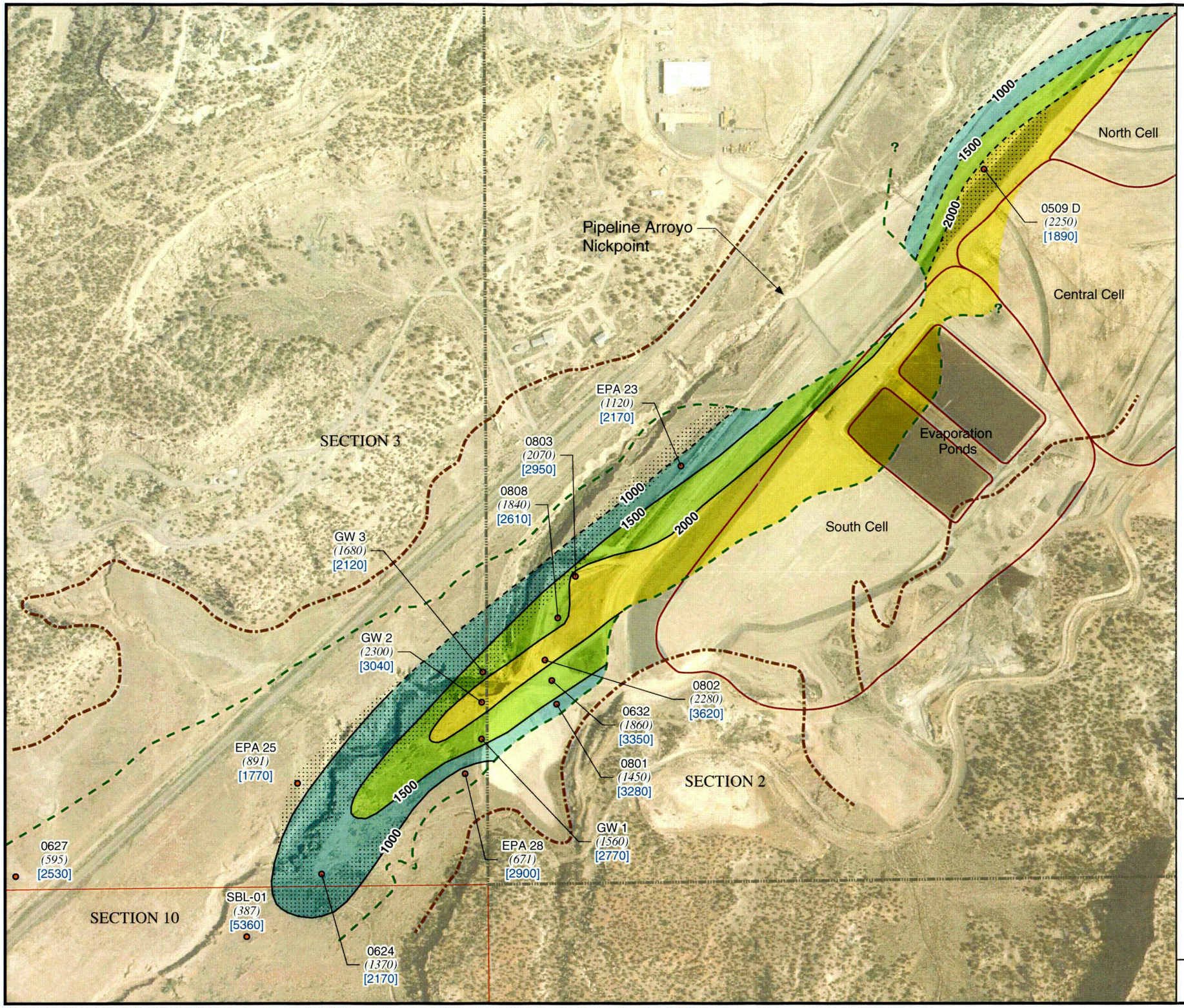
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico



dll-1200

N.A. Water Systems

C-07



N

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.

0 250 500 1,000
Feet

FIGURE 8

Southwest Alluvium Bicarbonate Isoconcentration Map and Distribution of Sulfate Below 2125 mg/L, October 2005

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

NA WaterSystems

Z:\databases\6209_GE_CR\GISDATA\arcmap_doc\2005_annual_report\f08_swa_sulfate.mxd; December 11, 2005

FIGURE 9

Primary Components of Total Dissolved Solids in the Southwest Alluvium, October 2005
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

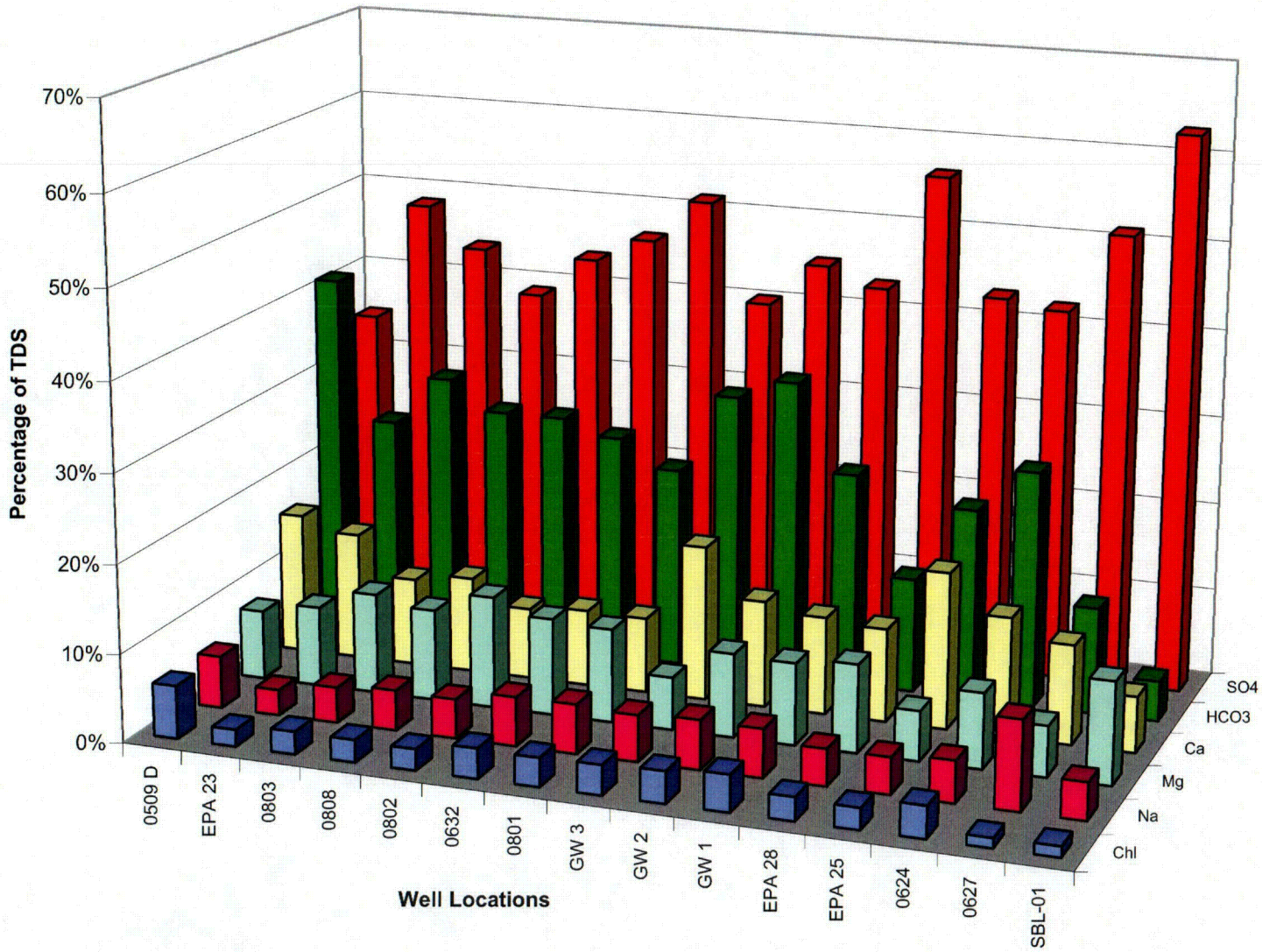
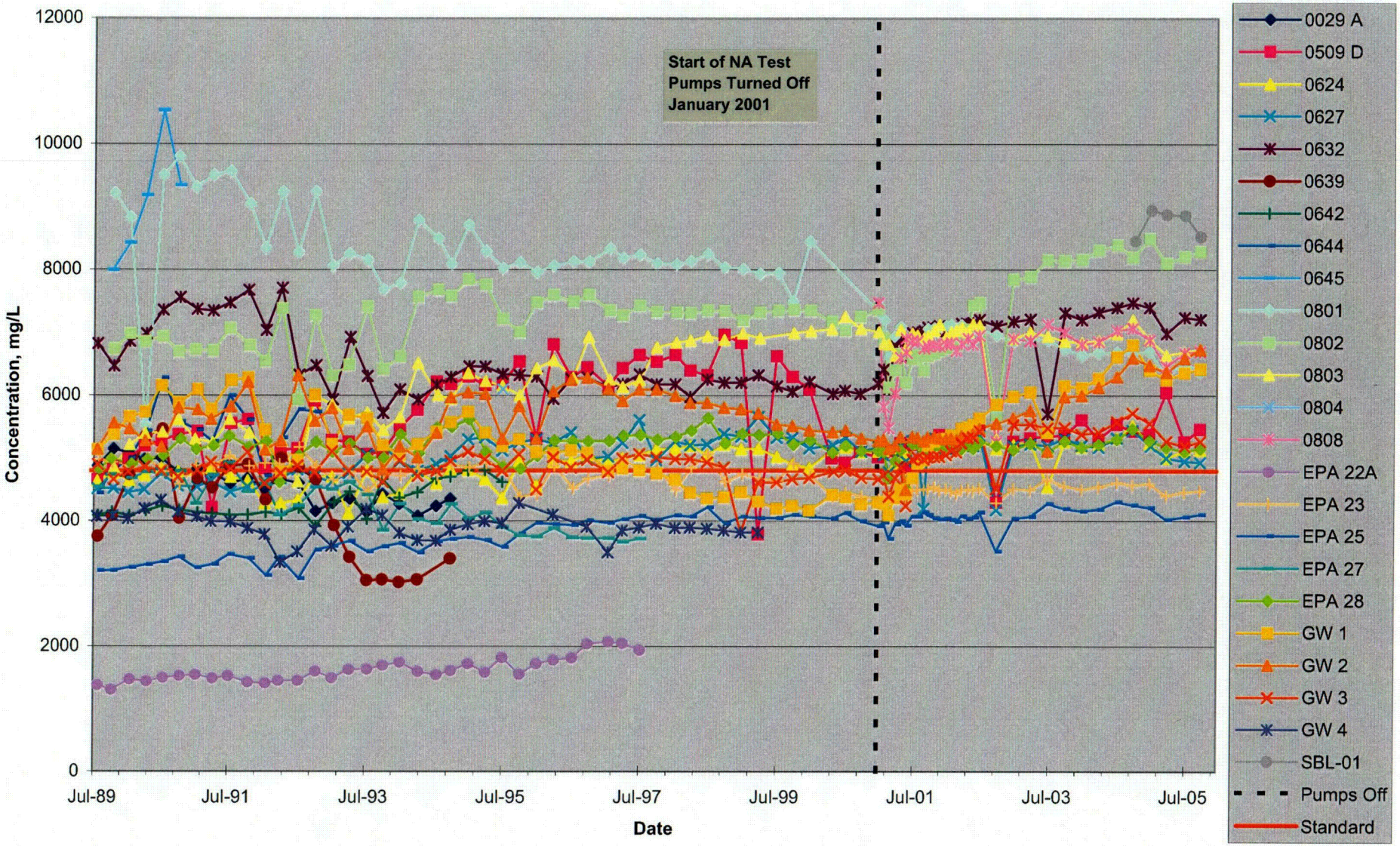


FIGURE 10

Southwest Alluvium Total Dissolved Solids Concentrations Over Time

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



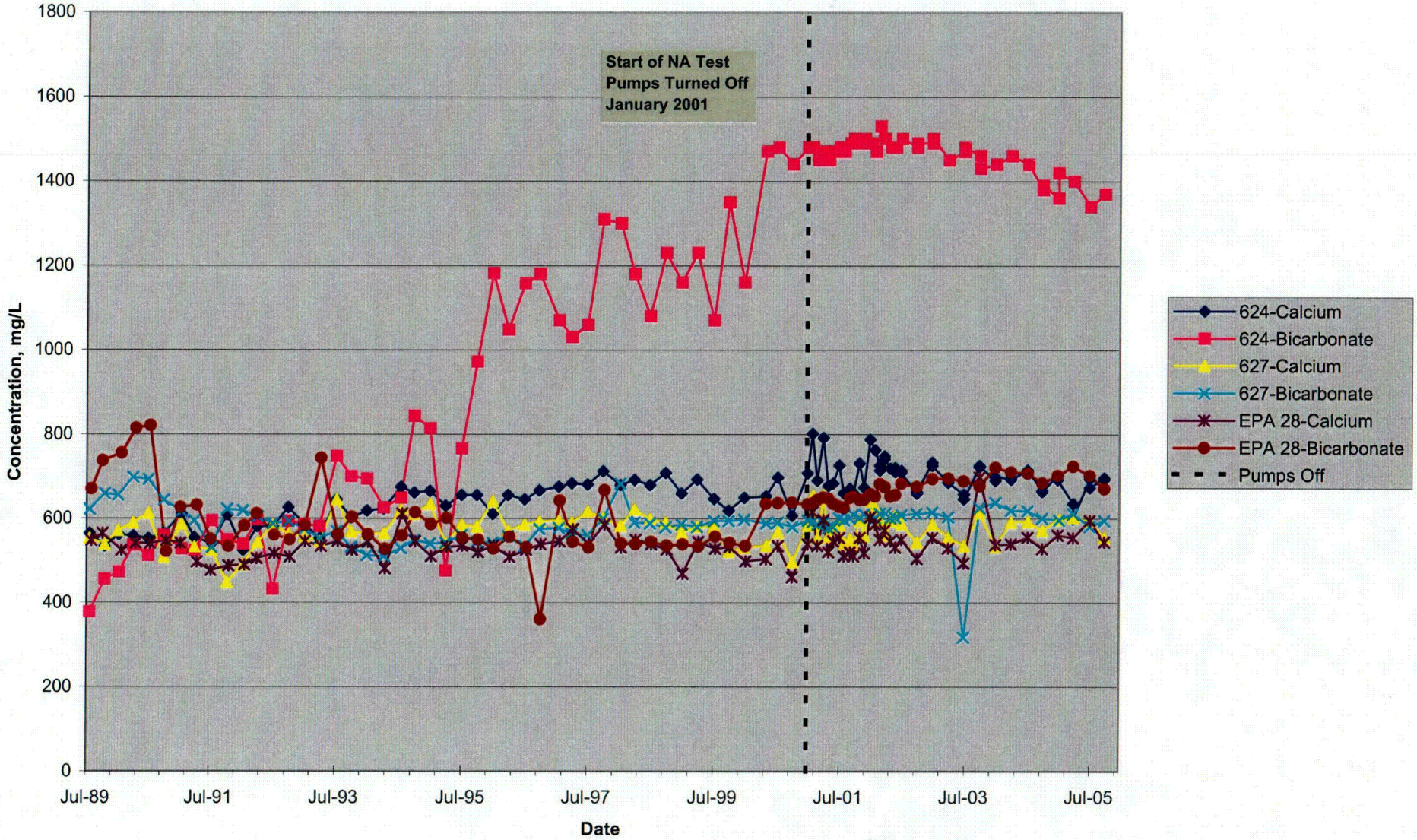
C-10

dll-1200

N.A. Water Systems

FIGURE 11

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



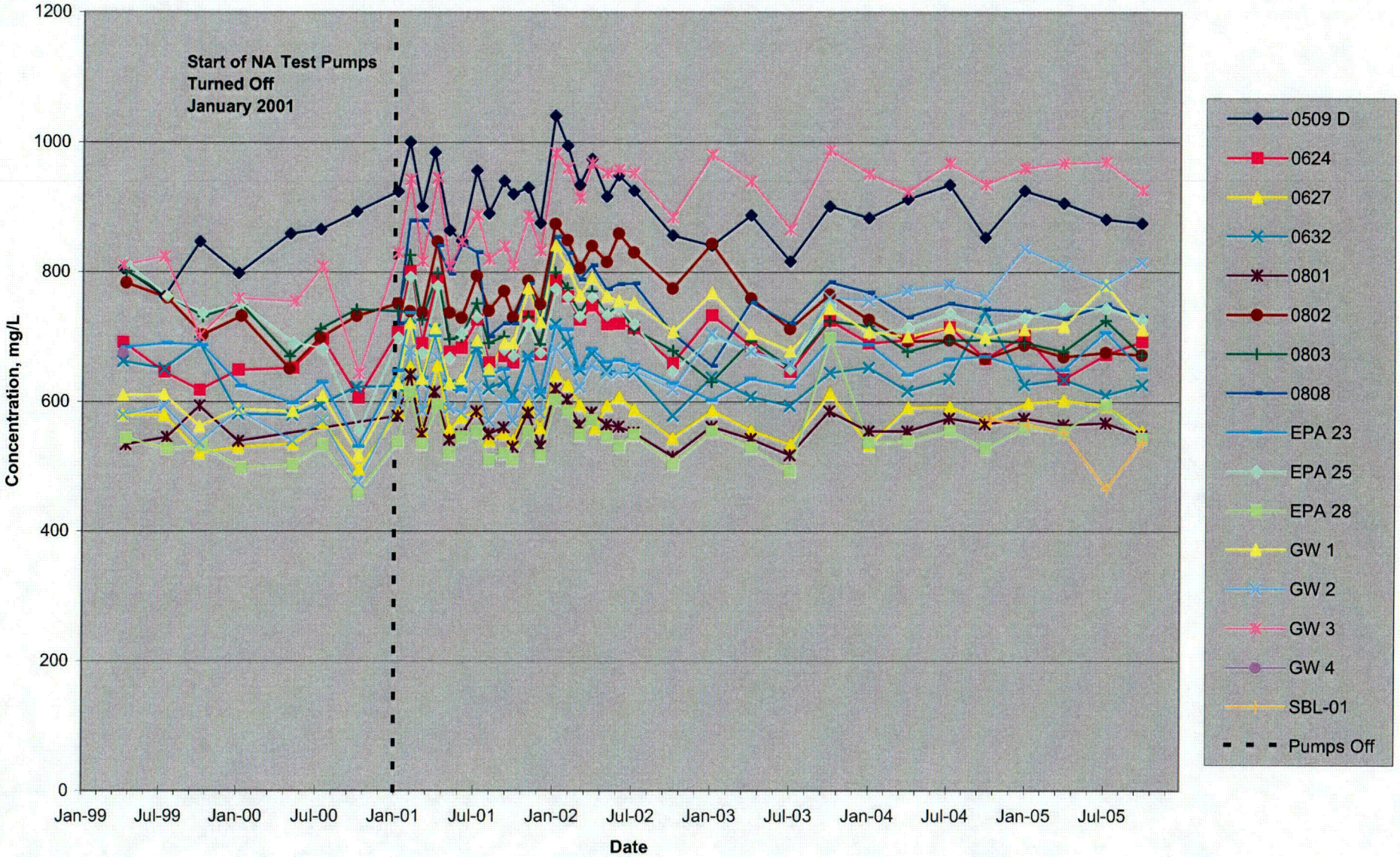
C-11

dll-1200

N.A. Water Systems

FIGURE 12

Southwest Alluvium Calcium Concentrations From 1999 Through October 2005
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

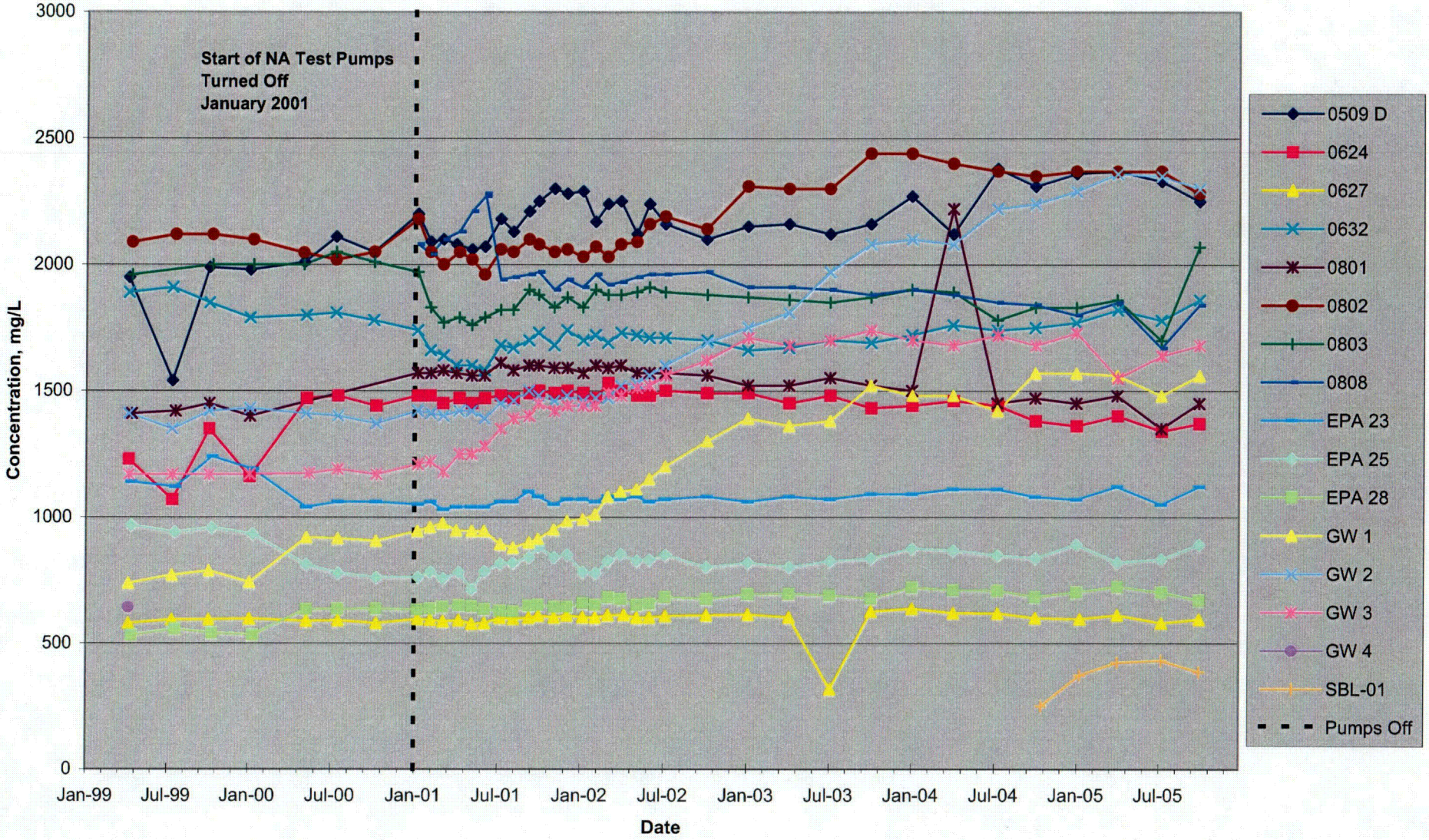


C-12

dll-1200

N.A. Water Systems

FIGURE 13
Southwest Alluvium Bicarbonate Concentrations From 1999 Through October 2005
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico



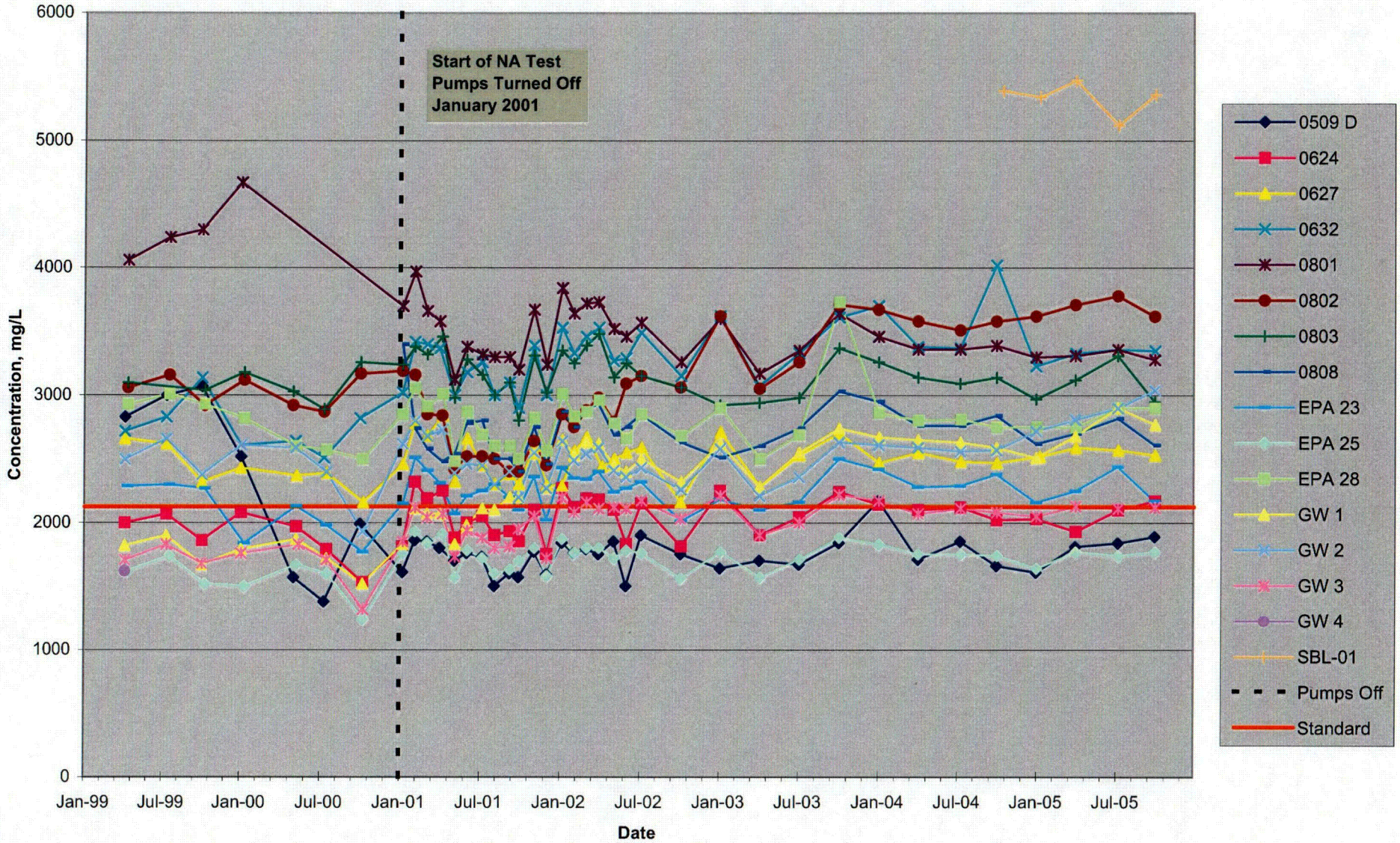
C-13

dll-1200

N.A. Water Systems

FIGURE 14

Southwest Alluvium Sulfate Concentrations From 1999 Through October 2005
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico



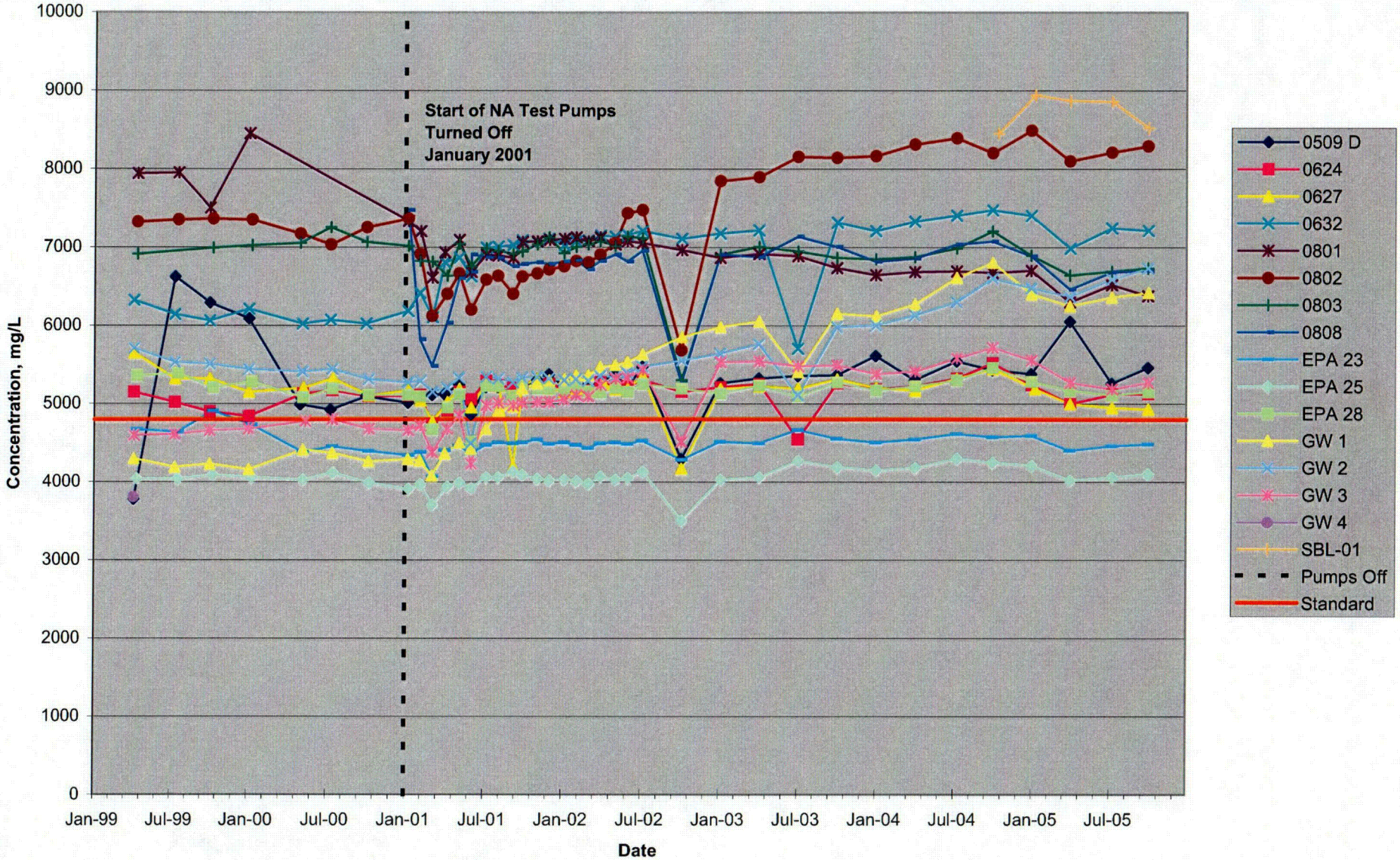
C-14

dll-1200

N.A. Water Systems

FIGURE 15

Southwest Alluvium Total Dissolved Solids (TDS) Concentrations From 1999 Through October 2005
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

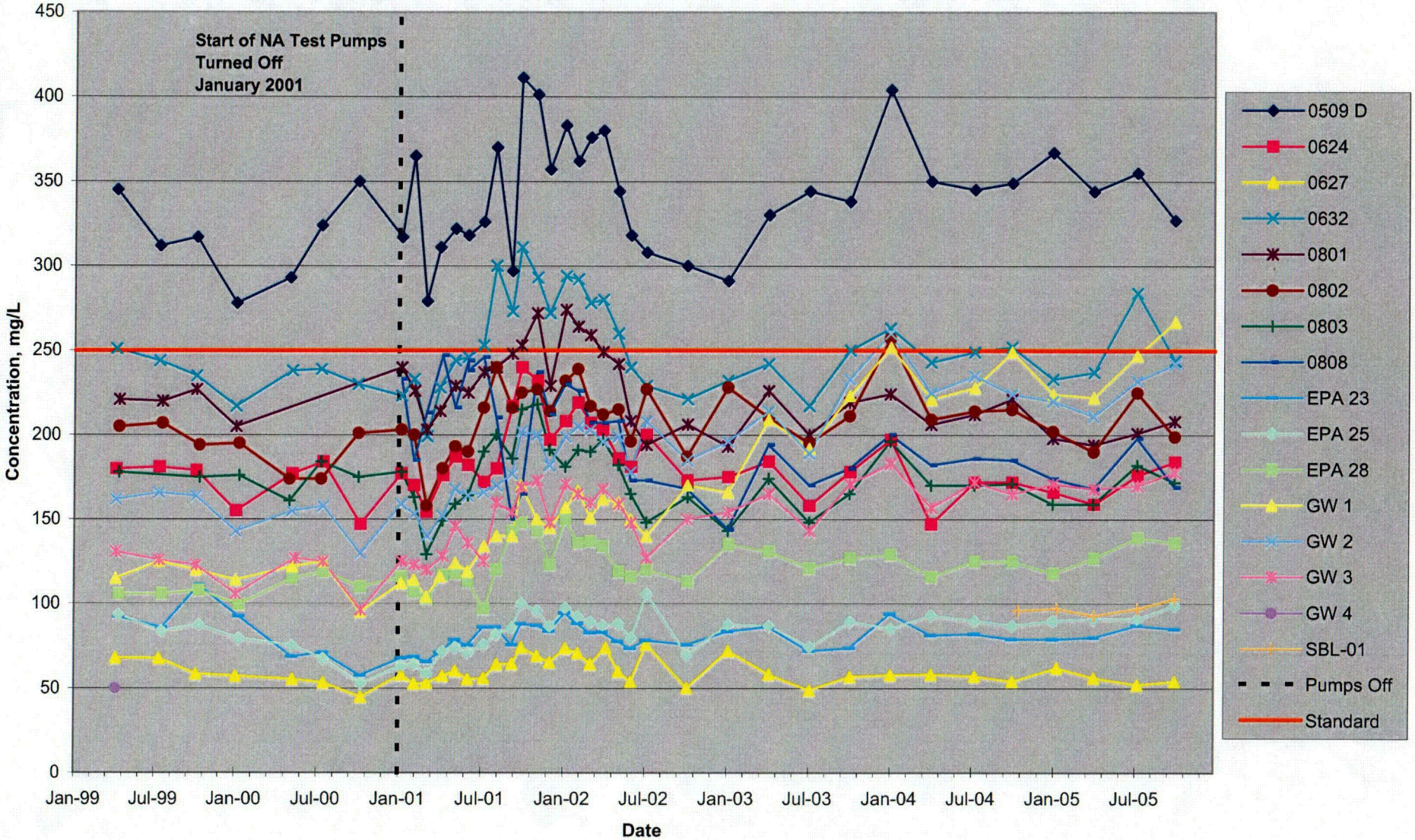


C-15

dll-1200

N.A. Water Systems

FIGURE 16
Southwest Alluvium Chloride Concentrations From 1999 Through October 2005
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico



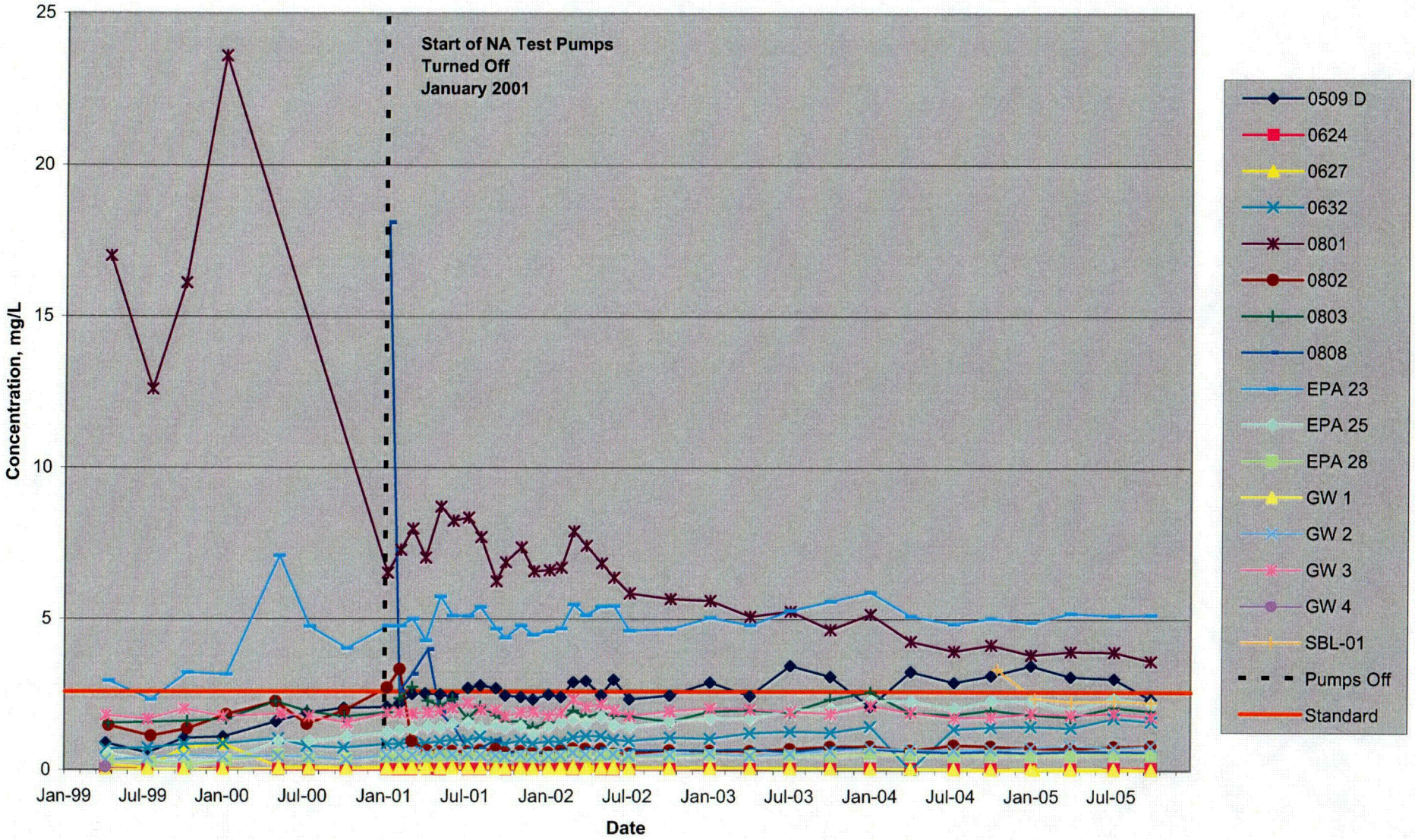
C-16

dll-1200

N.A. Water Systems

FIGURE 17

Southwest Alluvium Manganese Concentrations From 1999 Through October 2005
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

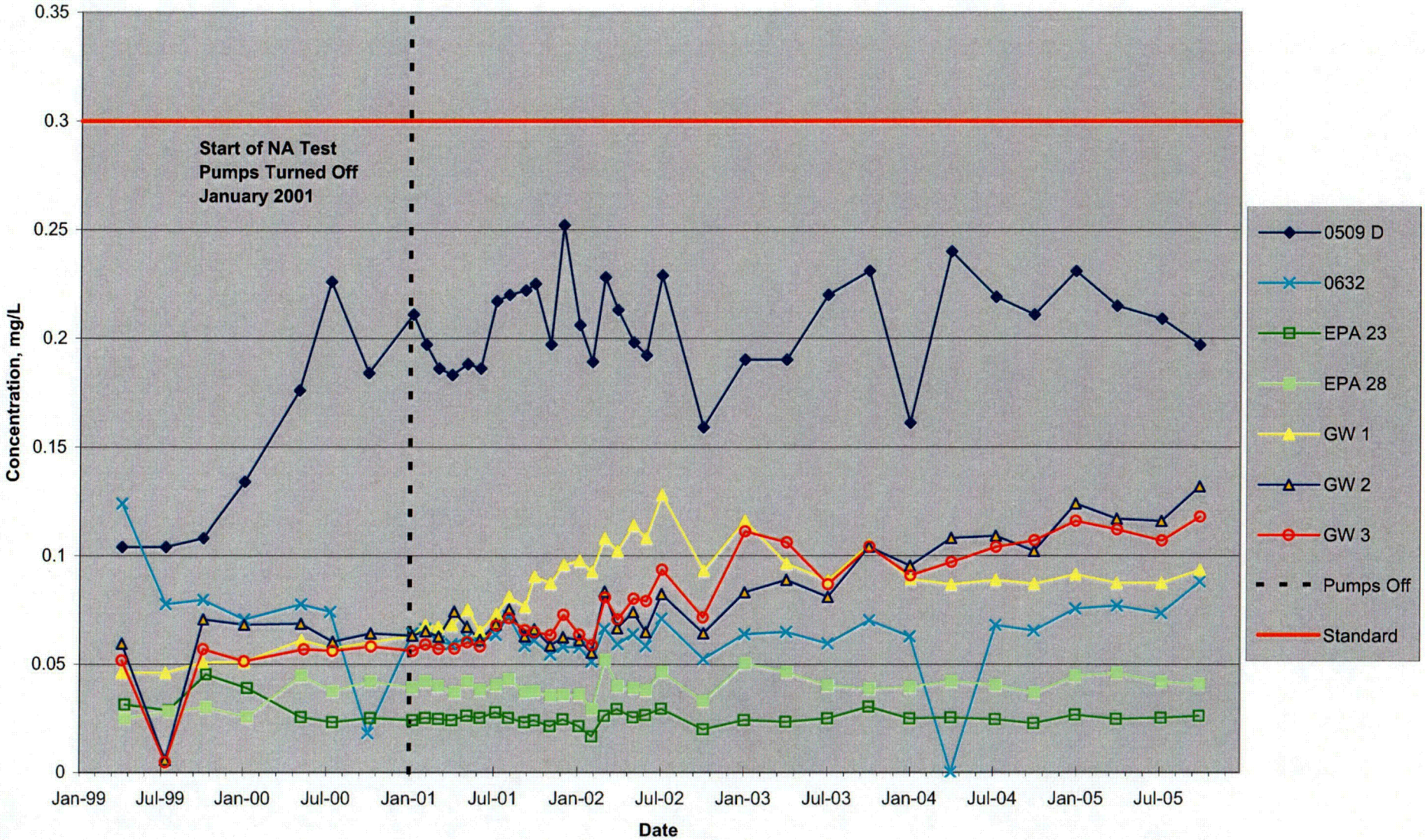


C-17

dll-1200

N.A. Water Systems

FIGURE 18
Uranium Concentrations in Selected Southwest Alluvium Wells
United Nuclear Corporation, Church Rock Site, Church Rock, New Mexico

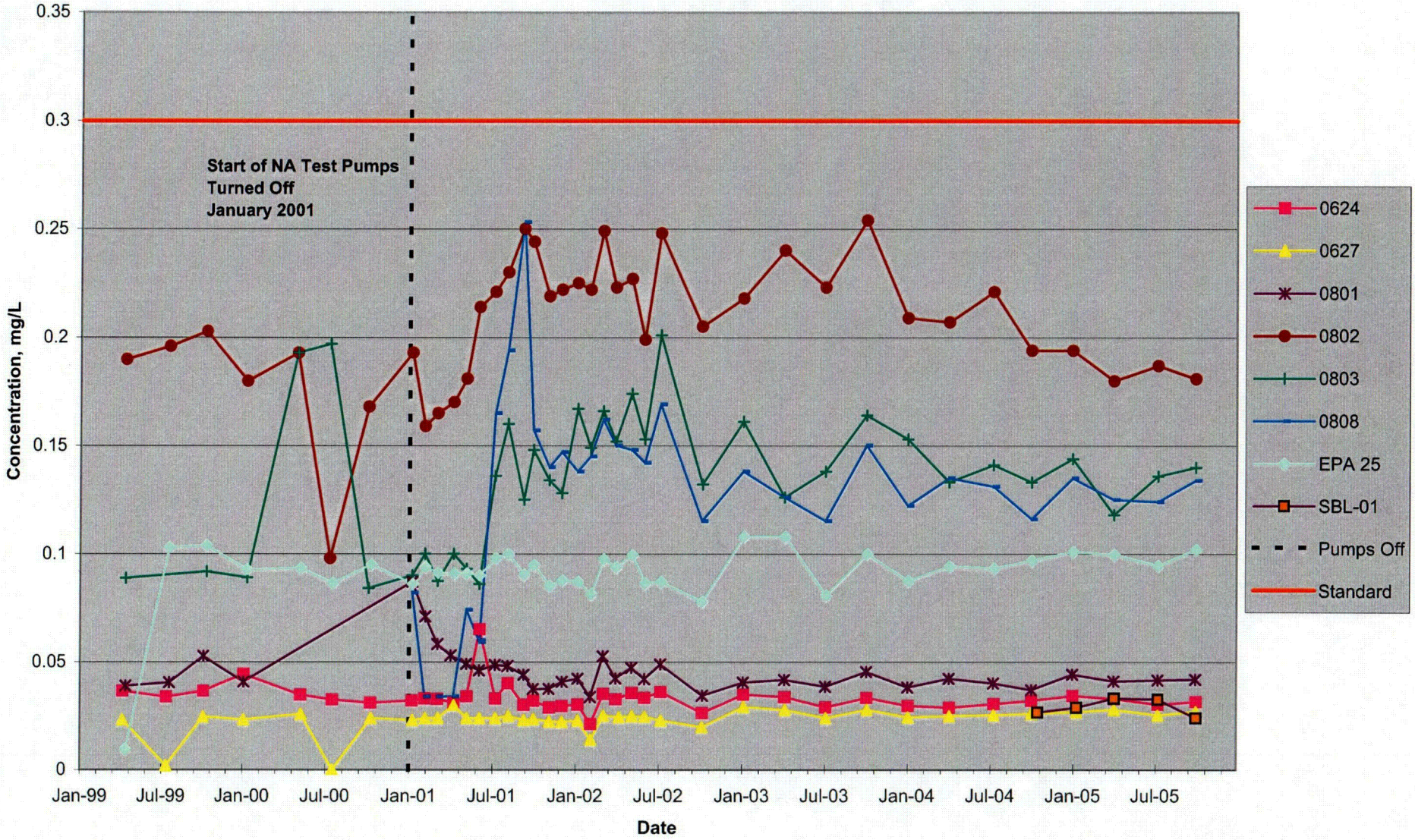


C-18

dll-1200

N.A. Water Systems

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



C-19

dll-1200

N.A. Water Systems