Draft
Regional Groundwater Assessment of Impacts from Historic Releases of the NECR Mine and UNC Mill Facilities
Navajo Nation

September 2011

Prepared by:

U.S. Environmental Protection Agency, Region 9
75 Hawthorne Street
San Francisco, California 94105

and

ERRG

Engineering/Remediation Resources Group, Inc.
115 Sansome Street, Suite 200
San Francisco, California 94104

Table of Contents

List of Figures

List of Tables

List of Appendices

Acronyms and Abbreviations

a.k.a.	also know as
bgs	below ground surface
CDC	Center for Disease Control
CRUMP	Church Rock Uranium Monitoring Project
DO	dissolved oxygen
EE/CA	Engineering Evaluation/Cost Analysis
ERRG	Engineering/Remediation Resources Group, Inc.
HASL	Health and Safety Laboratory
MCL	Maximum Contaminant Limit
NECR	Northeast Church Rock Mine
NMEID	New Mexico Environmental Improvement Division
NNEPA	Navajo Nation Environmental Protection Agency
NPDES	National Pollution Discharge Elimination System
NRC	Nuclear Regulatory Commission
NURE	National Uranium Resource Evaluation Program
ORP	oxygen/reduction potential
TDS	total dissolve solids
UNC	United Nuclear Corporation
US EPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
ft^3	cubic feet
gpm	gallons per minute
mg/L	milligrams per liter
µg/L	micrograms per liter
pCi/L	picoCuries per liter

Section 1. Introduction

The purpose of this report is to summarize the impacts to groundwater due to historical mining and milling activities of the Northeast Church Rock, and the United Nuclear Corporation (UNC) Mill in the Church Rock area of the Navajo Nation.

The United States Environmental Protection Agency (US EPA) issued the "Engineering Evaluation/Cost Analysis, Northeast Church Rock (NECR) Mine Site, Gallup, New Mexico" (EE/CA) on May 30, 2009, which presented its preferred remedy for clean-up of waste material from the NECR Mine Site. The preferred remedy included excavation of approximately 871,000 cubic yards of waste material and placement in a disposal cell to be constructed on the United Nuclear Corporation (UNC) Mill Site tailings disposal cells located approximately 0.5 miles southeast of the NECR mine. The EE/CA specifically stated:

> "The scope of this EE/CA is to present alternatives for surface and near-surface soil removal actions only. A detailed groundwater characterization has not been performed at the NECR mine facility to date."

US EPA received numerous comments expressing concern that the EE/CA did not address groundwater. The local community and the Navajo Nation requested that further evaluation and understanding of the area-wide impacts to groundwater from local mining activities be conducted prior to the NECR surface soil cleanup. This groundwater assessment was conducted in response to the local community and the Navajo Nation's request to evaluate the potential groundwater impacts.

To determine aquifers that were likely to be impacted, this assessment analyzed the historic releases from the NECR mine and UNC mill sites, and the groundwater flow direction. Historical well data was reviewed to determine which wells were screened in potentially impacted aquifers, followed by review of historical and current groundwater chemistry data from representative wells.

The historical sources of potential groundwater contamination analyzed in this report include mine water discharges from the NECR and Quivira Mines, the 1979 spill due to the dam failure at the UNC Mill Site, ponding at the NECR Mine Site, historical seepage from the mill tailings, the dewatering of the Westwater Canyon Formation during mining operations and the placement of waste rock back into the Westwater Canyon Formation. The three local aquifers impacted by these releases include the Alluvium aquifer along the Rio Puerco, the Upper Gallup aquifer, and the Westwater Canyon aquifer. The historical releases from the mill cell tailings are the subject of a current investigation and enforcement action of US EPA Region 6.

Similarly, this report references and discusses the findings and conclusions of several other historical reports that examined the effects of releases of the mine water discharge and 1979 spill on the soils and groundwater along the Rio Puerco. However, this report focuses only on regional groundwater impacts of mining and milling in the local area.

Section 2. Geology

2.1. SAN JUAN BASIN GEOLOGY

The prominent geologic feature in northwestern New Mexico is the San Juan Basin, which encompasses over 26,000 square miles extending into southwestern Colorado (Figure 1). The central portion of the basin is a circular, bowl-shaped depression containing sedimentary rocks up to 14,400 feet thick and ranging in age from approximately 2 million to 570 million years old. The uplifted, folded, and faulted rocks of the adjacent mountain ranges define the margins of the San Juan Basin. (Brister and Hoffman, 2002).

The geologic description of the San Juan Basin was developed through observations of the subsurface rock outcrops at the basin margins and from wells and mines within the basin. The northern margin of the basin is defined by the San Juan uplift, La Plata Mountains, and Sleeping Ute Mountain of southern Colorado (Figure 1). The western margin is defined by the Carrizo and Chuska Mountains and the Defiance uplift (monocline). The southern margin of the San Juan Basin is defined by the Zuni Mountains (a result of the Zuni uplift), and the southeastern margin by the Lucero uplift and Ignacio monocline. The eastern margin is defined by the Nacimiento Mountains (uplift) and the Gallina-Archuleta arch. The mountains and highlands at the margins of the basin receive most of the rainfall and have more vegetation than the semiarid San Juan Basin (Brister and Hoffman, 2002).

Following the west, north, and east margins is the Hogback monocline, whose rocks dip steeply into the basin. Following the southern margin is the Chaco slope, a gently dipping platform with upper elevations approximately 2,500 feet above the central basin (Brister and Hoffman, 2002).

The basin terrain consists of mesas, canyons, and valleys eroded from nearly flat-lying Upper Cretaceous and Tertiary (approximately 95 to 2 million years ago) sedimentary rock units. In the early Paleocene epoch (approximately 65 million years ago), the mountains and hogbacks that define the basin boundary began to form (Brister and Hoffman, 2002).

The NECR mine is located on the Chaco slope adjacent to the Zuni uplift.

2.1.1. San Juan Basin Stratigraphy in the Zuni Uplift

The layers of sedimentary rock in the San Juan Basin slope down (dip) toward the center of the basin from the highlands at the margins. Older sedimentary rocks are exposed at the margins of the basin and are successively overlain by younger layers of rock toward the center, “similar to a set of nested bowls” (Figure 2) (Brister and Hoffman, 2002).

The oldest rocks in the San Juan Basin are the Precambrian basement rocks (approximately 1,500 to 1,750 million years old), which underlie all of the sedimentary rocks within the basin. Outcrops of the Precambrian rocks appear in uplifts along the basin margins, including the Nacimiento Mountains, the Zuni uplift, and the San Juan uplift in Colorado. Common Precambrian rock types in the area are Granite and quartzite (Brister and Hoffman, 2002).

Sedimentary deposition occurred in the San Juan Basin from the Pennsylvanian through Tertiary periods (from approximately 330 to 2 million years ago) when the basin went through cycles of marine, coastal, and nonmarine deposition. The Pennsylvanian and Permian formations (approximately 330 to 240 million years ago) also outcrop in the uplifts at the basin margins, prominently in the Zuni uplift east of Gallup. The Pennsylvanian and Permian rocks are marine and composed predominantly of limestone, shale, sandstone, and gypsum; and are fractured ground-water aquifers in the Zuni uplift region (Brister and Hoffman, 2002).

The Pennsylvanian and Permian rocks are overlain by nonmarine Triassic rocks (approximately 240 million years old) including sandstone, siltstone, and mudstone of the Chinle Group and the Rock Point Formation. These nonmarine deposits occurred mainly from rivers and streams that flowed into the area from the southeast (Brister and Hoffman, 2002).

This period of nonmarine deposition was followed by windblown sand dunes approximately 170 million years ago. These dunes were preserved as cross bedded layers of sand in the Middle Jurassic Entrada Sandstone (Brister and Hoffman, 2002).

During the Late Jurassic period (approximately 145 million years ago), stream-laid sands were deposited throughout the basin creating the Morrison Formation. The United States Geological Survey (USGS) recognizes four members of the Morrison Formation in the southern margin of the San Juan Basin (aka Grants uranium district): the Recapture Member (oldest), the Westwater Canyon Member, the Brushy Basin Member, and the Jackpile Sandstone Member (youngest). The Recapture Member is a grayish-red siltstone and claystone. The Westwater Canyon Member overlies the Recapture Member and consists principally of medium- to coarse-grained, arkosic sandstones interbedded with mudstone units of variable thicknesses. It is approximately 270 feet thick in NECR mine. The Brushy Basin Member overlies the Westwater Canyon member, is approximately 70 feet thick, and consists of mudstone formed from volcanic ash falls. The Jackpile Sandstone Member is the uppermost fluvial sandstone in the formation, and does not appear in the NECR area (Roca Honda Resources, 2009). The Morrison is one of several well-known uranium-bearing rock units in the mining districts along the southern flank of the basin (Brister and Hoffman, 2002).

The Late Jurassic period was followed by approximately 50 million years of no deposition and erosion, and no sediments were preserved in the San Juan Basin during the Early Cretaceous period (Brister and Hoffman, 2002).

The western U.S. was bisected by a large interior seaway during the Late Cretaceous (approximately 95 to 65 million years ago), which had a northwest-to-southeast-trending shoreline in northwest New Mexico. The shoreline migrated back and forth (northeastward and southwestward) across the basin, depositing approximately 6,500 feet of marine, coastal plain, and nonmarine sediments. The back and forth migration of the shoreline across the basin shifted the depositional environment from nonmarine to marine (transgression), and back to nonmarine (regression), until the seaway retreated from the basin and nonmarine deposits dominated the area at the end of the Cretaceous. The marine deposits in the area consist of sandstone, shale, and a few thin limestone beds; the coastal plain deposits include sandstone, mudstone, and coal; and nonmarine deposits include mudstone, sandstone, and conglomerate (Brister and Hoffman, 2002).

The transgression/regression sequence was repeated throughout the Late Cretaceous period and was preserved in the formations in the San Juan Basin. The Late Cretaceous rocks include the following units from the oldest to the youngest: the Dakota Sandstone, the Mancos Shale, the Mesa Verde Group (which includes the Gallup Sandstone, the Crevasse Canyon Formation, and the Point Lookout Sandstone), the Menefee Formation, the Cliffhouse Sandstone, the Lewis Shale, the Pictured Cliffs Sandstone, the Fruitland Formation, and the Kirtland Shale (Brister and Hoffman, 2002). The youngest rock outcrops in the NECR area are from the Mesa Verde Group (Canonie, 1988).

The Dakota Formation dates from the Late Cretaceous and consists of fine to medium grained, well sorted sandstone with siltstone and shale interbeds (Hilpert, 1963). The Formation is about 100 feet thick in the NECR mine (Canonie, 1988).

The Mancos Shale Formation dates from the Late Cretaceous and consists of three Members. The lowermost (oldest) Whitewater Arroyo Shale Member is about 60 feet thick, the middle Two Wells Sandstone Member is about 50 feet thick and the uppermost Mancos Shale Member is about 700 feet (Hilpert, 1963 and Canonie, 1988). The upper 200 feet of the Mancos Shale is interbedded with the lower Gallup sandstone of the Mesa Verde Group (Canonie, 1988).

In the NECR Mine, the Gallup formation occurs as the Lower Gallup Sandstone and the Upper Gallup Sandstone with the Lower Gallup Sandstone interbedded in the upper portion of the Mancos Shale (Figure 3 and Figure 4). The lower Gallup Sandstone is approximately 160 feet thick and the Upper Gallup Sandstone is approximately 150 feet thick. The Crevasse Canyon Formation overlies the Gallup Formation and includes the Dilco Coal Member, the Mulato Tongue, and the Dalton Sandstone Member. The basal unit of the Crevasse Canyon Formation is the Dilco Coal Member, which is approximately 100 feet thick and consists of interbedded sandstone, siltstone, shale and coal beds. The Mulatto Tongue is actually a member of the Mancos Shale but occurs between the Dilco Coal Member and the Dalton Sandstone in the Church Rock area and is included in the Crevasse Formation locally. The Mulatto Tongue consists of shale, siltstone, and marine sandstone and is approximately 70 feet thick. The Dalton Sandstone Member is above the Mulatto Shale and is approximately 90 feet thick at the top of the NECR

Mine. The Dalton Sandstone is a light gray very fine grained to fine grained marine sandstone. The Dalton Sandstone comprises the surface rocks at the NECR Mine (Canonie, 1988, and Brister and Hoffman, 2002) The Dalton Sandstone is non-producing formation in the vicinity of NECR, and as a consequence, there are no wells drawing from that formation.

Nonmarine deposition in stream channels, floodplains, lakes, and windblown sands were the dominant forms of sediments in the San Juan Basin from the end of the Cretaceous through the Tertiary (approximately 65 to 2 million years ago). These deposits are found primarily in the central basin area away from the margins (Brister and Hoffman, 2002).

2.2. HYDROGEOLOGY

There are two main sources of sources of water in the Churchrock area: surface water and groundwater.

2.2.1. Surface Water

Average annual precipitation in the area is approximately 12 to 16 inches and generally occurs as localized, short-duration, high-intensity thunderstorms from July to October causing streams in the area to be primarily ephemeral (EPA, 2007c). Water records from 1948 through 1962 indicate the annual evaporation rate is nearly 5 times the precipitation rate, which means more water is lost to the atmosphere than is absorbed by the ground, creating a semi-arid climate. Native vegetation consists of grasses, shrubs and trees, but is generally sparse in the region and provides minimal protection from surface erosion (Stone, 1981).

The dry conditions and high intensity rains cause the surface soils to quickly saturate and prevent precipitation from penetrating deeper below the ground surface and much of the rain fall in the canyons washes over the ground surface. During periods of increased precipitation the discharge rate in the streams increases allowing more sediment to be suspended in the river. Short-term, fast moving streams and arroyos are produced that cut-through the bedrock in the canyons and washes, carrying the sediments downstream, and depositing them as alluvium. Drainage ways and washes in the area tend to be long rectilinear channels following the direction of local fracture zones, suggesting influence from the underlying bedrock and regional uplift. This stream pattern is especially apparent where channels cross the Upper Gallup Sandstone (USGS, 1994).

The alluvium in the canyons and on valley floors consists of fine grained sand inter-fingered with silty clay layers deposited from eroded bedrock material. The alluvium directly overlies sedimentary bedrock in the Puerco River basin and aids in transferring surface water through the shallow groundwater zone in the alluvium to the deeper bedrock aquifers (Figure 5). The water table elevation in the area remains relatively constant through the year allowing the river channel to act as a zone of recharge, losing water downward through sediments when water is flowing in the river, and as zone of evaporation when water is not actively flowing in the channel (USGS, 1994). When surface water is present near the NECR mine, the flow direction is from northwest to southeast along unnamed arroyos and into the northeast- to southwest-trending Pipeline arroyo.

2.2.2. Groundwater

The sandstone units in and near the NECR mine and the UNC Mill area mine overlying the basement faults show passive bending or draping as evidenced by fracturing in the sedimentary rock layers. The fracturing increases near the hinge of the folds over the basement faulting. Recharge for the aquifers primarily occurs where the water bearing strata are exposed at the ground surface or where they are in direct contact with potentially saturated alluvial deposits. The ability of the sandstone units to capture water increases as it is weathered from exposure, fractured from faulting, or chemically altered through dissolution. The main water bearing strata in the NECR mine and the UNC Mill area, from shallowest to deepest, are the alluvial deposits, the Upper Gallup Sandstone, the Lower Gallup Sandstones, and the Westwater Canyon Sandstone (Raymondi, R. & Conrad, R., 1983). Because of the northward dip of the rock units, each of these strata outcrop along the Pipeline Arroyo and the North Fork of the Puerco River with the deeper units appearing further south. The rock outcrops comprise a narrow east-to-west belt that forms the southern outline of the San Juan Basin along the north side of the Zuni Uplift. The narrow exposures dip northward locally from 3 to 30 degrees, and occur at elevations of approximately 6,500 feet above mean sea level. As stated previously, rainfall infiltrates into the shallow subsurface and become the alluvium groundwater moving southwesterly with the ground surface contours. Groundwater is transmitted to the underlying water bearing strata where the alluvium comes in contact. Once in the water bearing strata, the groundwater flows northward following the regional dip in the area (Kerr-McGee Corporation, 1976). A piezometric surface map for the Upper Gallup Sandstone shows a northeast flow direction following the regional dip in the area of the NECR Mines (EPA, 2010). Regional dip at the east end and south of the Zuni Uplift becomes nearly level and may not have much effect on groundwater flow direction (Stone, 1981).

Prior to mine dewatering a continuous shallow groundwater system in the alluvium was not likely present in Pipeline Arroyo area. The alluvium in the Pipeline canyon became saturated and generated an artificial groundwater system once dewatering of the mine began.

Measurements and calculations conducted by the USGS on water flowing in the Pipeline Arroyo from March through June 1981 estimated a daily water loss of 47,500 cubic feet (ft^3) of water per day. The areas of loss were evapotranspiration (5,000 ft^3/day), alluvial underflow (4,000 ft^3/day), absorbed by the Upper Gallup Sandstone[i] (32,000 ft^3/day), and absorbed by the Torrivio Sandstone[1] and Dilco Coal

[1] Raymondi and Conrad identified the Torrivio Sandstone Member as located just above the Upper Gallup Sandstone Member; however, subsequent geologic review of drilling logs and fieldwork found the Torrivio Sandstone Member cannot be distinguished from the underlying Upper Gallup Sandstone Member. This groundwater assessment report includes the Former Torrivio Sandstone Member as part of the Upper Gallup Sandstone Member.

Members (6,500 ft^3/day) (Raymondi, R. & Conrad, R., 1983). The amount was approximately 7% of the total flow in the arroyo and indicates substantial recharge occurred from surface precipitation along fractured sections of the bedrock.

According to a study conducted by Canonie, the alluvium sandstone layers within the Upper Gallup Sandstone Member are in direct contact with the tailings or tailings seepage. Figure 5 provides a conceptual model of how surface water and tailings can be transported to the shallow and deep aquifers in the region.

Section 3. Potential Location of Mining Impact

3.1. MINING HISTORY IN THE CHURCHROCK AREA

Uranium was mined near Church Rock from the 1950's until 1962, and to a greater extent from 1967 to 1986. The NECR Mine and the Quivira Mine (a.k.a. Kerr-McGee Mine) mined uranium ore form the Westwater Canyon member of the Morrison Formation from shafts between 1500 and 2000 feet below ground surface (bgs). Because the ore body was located below the groundwater table; large quantities of groundwater had to be pumped from the shafts to allow access to the ore. Prior to the mining and milling activities, no near-surface ground water system existed in the site area. During mining operations the Pipeline Arroyo had a steady flow of water from the mine water discharge.

Initially, mine water pumped from the shafts and mining works was discharged directly into an unnamed arroyo that feed into the Pipeline arroyo. In 1973, UNC applied for a National Pollution Discharge Elimination System (NPDES) permit for NECR Mine and in 1974, Kerr-McGee applied for the Quivira Mine. The permits granted effective January 1975, set the maximum uranium concentration of 2 milligrams per liter (mg/L) and dissolved radium-226 at 30 picocuries per liter (pCi/L). The dissolved radium-226 standard was subsequently lowered in 1977 to 3.3 pCi/L. Both mines used settling ponds followed by ion-exchange to meet the NPDES permit requirements. There were numerous daily exceedences during the mine discharge permit period. The USGS estimates that over the period of operations of the mines, a total of approximately 600 tons of uranium were released into the Pipeline Arroyo/Rio Puerco from the mine water discharges alone. The NECR mine ceased operations in 1982 and the Quivira Mine in 1986.

The mill facility at UNC was licensed to operate in May 1977. The mill used conventional acid leach, solvent extraction methods to extract uranium. The acid-waste tailings mix was pumped to three disposal cells located adjacent to the Pipeline Arroyo. Acidic waste water seeped into two underlying Gallup sandstone formations and the Alluvium material underneath the Pipeline Arroyo.

In July 1979, the dam on the south disposal cell failed and an estimated 94 million gallons and 18,000 tons of suspended solids were released into the Pipeline Arroyo, and ultimately in the Rio Puerco. Details of the release are presented in Section 4.2 Uranium Mine Releases.

In May 1982, the UNC Mill site was closed and in 1987, UNC submitted a reclamation plan for permanent closure to the Nuclear Regulatory Commission (NRC). A final Reclamation Plan was approved in 1991, which included dewatering of Borrow Pit #2, regrading and recontouring the tailings piles, dismantling the Mill buildings and equipment, and placing them in Borrow Pit #1 in compacted layers. A soil and rock cover was placed over the 100 acre tailings disposal cells. The final element for closure is groundwater corrective action program that is ongoing.

3.2. URANIUM MINE/MILL RELEASES

The releases that occurred as a result of uranium mining at NECR: mine water discharges from the NECR and Quivira Mines, the 1979 spill due to the dam failure at the UNC Mill Site, ponding at the NECR Mine Site, and historical seepage from the mill tailings cells. In addition, the dewatering during mining operation and the placement of waste rock back into the ore body may have impacted the Westwater Canyon formation. (Figure 6).

The largest historic release associated with mining in the area was the discharge of groundwater pumped from the uranium mines. Because the ore deposits were below the water table, groundwater was pumped from the mine workings to allow access to the ore bodies, tunnels, and shafts during operations. At its peak, mine water from NECR and neighboring Quivira Mine was discharged at 5,000 gallons per minute (gpm) to the unnamed arroyo which fed into the Pipeline Arroyo (Figure 7). Mine discharges began in 1967 but were not treated until after 1975 under an NPDES permit. The USGS estimates that approximately 140 million cubic meters of mine water discharge (37 billion gallons) and 600 tons of uranium was released into the Pipeline Arroyo/Rio Puerco from the discharges conducted from 1967 through 1985 when the UNC mining operations ceased.

In 1979, a catastrophic release occurred when the dam on the south tailings disposal cell at the UNC Mill facility failed and approximately 94 million gallons of acidic mine tailings were released into the Pipeline Arroyo. The release increased flows in the Rio Puerco and carried mine tailings as far as 80 miles downstream into the State of Arizona. The release left deposits of tailings sludge along the Pipeline Arroyo which contained radioactive thorium, uranium and other metals. Under oversight of the State of New Mexico (NMEID), UNC conducted a cleanup of tailings containing high levels of thorium-230 along approximately 8 miles on the Pipeline Arroyo and Rio Puerco downstream of the spill. Sediment samples collected after the cleanup indicated that most Thorium-230 levels were below NMEID standards. A comprehensive human health assessment of the spill was conducted by NMEID, NRC, and US EPA, and included water samples, sediment samples, air monitoring, and human and animal tissue analyses. The study found increased levels of radionuclides, specifically uranium, in animal tissue and bone radioactivity, although the high levels could not be directly associated with the 1979 spill, but may have been associated with the mine water discharges (Centers for Disease Control [CDC], 1980).

A sustained release in the form of seepage from the tailings disposal cells occurred, when UNC discharged an estimated 820 million gallons of acidic mine water and sludge into unlined tailings disposal cells located adjacent to the Pipeline Arroyo. Of the estimated 820 million discharged, an estimated 380 million gallons were lost to evaporation during this period and 94 million gallons were lost in the dam failure, leaving approximately 346 million gallons that seeped into the underlying formations or were retained in the tailings sludge. Whenever possible during closure of the tailings disposal cells, UNC removed excess liquid and mixed lime into the disposal pits in an attempt to neutralize the remaining acidic material. The Closure Report for the Mine Site stated that the tailings were no longer discharging into the underlying units. The contamination associated with the historic release is being cleaned up by UNC with oversight by US EPA Region 6 (UNC, 2011).

In response to a concern about the continued movement of the groundwater plumes, UNC conducted an assessment of the tailings to determine if contaminated liquids were still seeping into the formation aquifers below the site in 2004. The study included installation of piezometers near the former borrow area that had been the original source of acid seepage. Based on the field work and evaluation of historic data, the report concluded that the disposal cells had in fact stopped leaching to the aquifers. In 2011, in response to a request by US EPA, UNC modeled the saturation rate in the tailings over time and concluded that saturation exists in locations but the fluid is bound into the soil matrix.

There were also ponds on the NECR Mill site as part of the NPDES treatment process. The mine water pumped from the Westwater Canyon Formation was held for settlement prior to treatment and discharge into the Unnamed Arroyo. Theoretically, mine water could seep into the underlying formation that is located at the surface. The formation that outcrops at the NECR Mine is the Dalton sandstone which is a non-producing formation in the area.

The mining of uranium ore in the Westwater Canyon Formation at NECR involved sinking a shaft to the ore zone and dewatering since the ore resided below the top of the water table elevation. The dewatering, open shaft, tunnels, and stopes introduced air into the rock layers that were previously saturated. Opening of the underground through dewatering and exposure to air caused the geochemical setting to change from a reducing environment to an oxidizing environment. . After mining ended, the groundwater has been re-saturating the ore zones that were dewatered. The re-saturation is likely to have occurred slowly, but it would still trap some air that likely entered the ground water as dissolved oxygen. It would likely take a period before the geochemical condition of the ground water will change from an oxidizing to a reducing environment again. The oxidizing environment is more conducive to uranium solubilization and mobilization. At the end of mining and the beginning of closure, some parts of the NECR Mine were filled with washed tailings sands from the UNC mill using a slurry mixture that was pumped from the surface and down into the mine. After backfilling was completed, the NECR Mine was closed and sealed.

Section 4. Conceptual Model

Major releases uranium, radium and gross alpha that occurred in the NECR area are dewatering of the mine and discharges of mine water in to the unnamed Arroyo, catastrophic release from the tailings disposal cells, and seepage to the subsurface from water in the tailings disposal cells. These releases are discussed in more detail in Section 3.2. To assess the impact of all historic releases, wells that may have been impacted by the releases were selected. The wells were selected by reviewing the release, determining the movement of water from the release through in the subsurface, and identifying wells in the pathway.

The mine water discharges and the spill from the 1979 dam breach flowed south-southwesterly along the Pipeline Arroyo and into the Rio Puerco. The water infiltrated into the shallow groundwater unit in the Alluvium. The Alluvium beneath the Pipeline Arroyo is shallow and no wells were drilled in that part of the formation. However, shallow hand dug wells in the Alluvium beneath the Rio Puerco have been used in the area since before mining began.

To a lesser extent, mine water discharges would have also seeped through the Alluvium into the Upper Gallup formation where the Upper Gallup contacts the base of the Alluvium along the Pipeline Arroyo at the UNC Mill site. The Upper Gallup formation was unsaturated in the vicinity of the UNC Mill Site prior to mining operations, but became saturated once mine dewatering began (Canonie, 1988). Once mining operations ceased, the water levels in the Upper Gallup decreased.

Seepage from the tailings disposal cells infiltrated into the Upper Gallup Sandstone where it contacts the base of the Alluvium beneath the tailings disposal cells. Because groundwater flow in the Upper Gallup Sandstone Member is northerly at the UNC mill site, the closest well north of the site screened in the Upper Gallup Sandstone Member was selected for this assessment.

The Dalton Sandstone Member outcrop is present at the NECR Mine site where the historic holding ponds were operated for the NPDES permit compliance treatment before releasing into the Pipeline Arroyo. Theoretically, any seepage from the surface at the NECR Mine site would infiltrate into the Dalton Sandstone; however, the sandstone has been described in several wells logs in the area as dry or non-producing. A review of available well logs for the area at Navajo Nation Division of Natural Resources Department of Water Resources did not find any wells screened across the Dalton Sandstone Member in the vicinity of the site, further indicating that the sandstone does not produce water. The shallowest water producing formation at the NECR Mine site is the Upper Gallup.

The mining operations and subsequent closure may have impacted or altered the Westwater Canyon aquifer in the area of the mine. An oxidation/reduction environment is required for uranium to leach into the groundwater. Dewatering the mine workings and exposing the ore to air may have accelerated oxidation of the uranium ore, and once groundwater was allowed to fill the mine workings when the mine closed operations a larger oxidation/reduction environment may have been created than previously existed. In addition, waste rock from the mining and milling processes was placed in the mines to fill the workings and remove the waste rock from the surface. The waste rock also may have added oxidized and partially processed ore to the subsurface environment also increasing the oxidation/reduction environment in the mine area. Groundwater from the Westwater Canyon formation is used for drinking water up gradient in the aquifer (south of the mine) and near Crownpoint, New Mexico, approximately 40 miles cross gradient. The Westwater Canyon aquifer is too deep in the mine vicinity and wells for assessing water quality are limited to the NECR Mine Well (abandoned in 2004) and Mill Well[2].

Table 2 provides a summary of the rationale in selecting the wells used to assess groundwater quality for this assessment. The five historic releases are listed across the heading and the water bearing units are listed in the first column. If the water bearing unit had a potential impact from a specific release based on water flow in the area, the closest well to that impact was chosen. A review of the well locations in the Alluvium identified two old wells in the Rio Puerco Alluvium immediately down gradient of mouth of the Pipeline Arroyo. These wells would have been the first to see a potential impact from mine water discharges and 1979 spill. Two wells in the Upper Gallup formation north of the UNC Mill site and north of the NECR Mine Site were identified to assess impacts from the UNC Mill tailing seepage and the Mine water discharge historic releases. The UNC Mill well and the abandoned NECR Mine well are the only wells located in the Westwater Canyon aquifer in the area. There are no wells in the Dalton formation.

Figure 8 presents the well locations.

[2] Documents reviewed indicated that the Mill well is located in the Westwater Canyon member. However, one reference indicates that it might be located in the sandstone above the Westwater Canyon Member: the Dakota Sandstone.

Section 5. Area-wide Groundwater Sampling Events

After mining operations began in the area, several sampling programs were instituted in response to increased community concern regarding the quality of the water for domestic and livestock purposes. This section describes these sampling programs and their findings in the area. Most of the programs were broader in scope than the impact of historic releases at the NECR Mine and the UNC Mill Site, and included wells that are not hydrogeologically connected to these sources.

The chemicals of concern in groundwater in the NECR mine area include radionuclides, TDS, nitrates, and arsenic. The primary contaminants are radium-226, radium-228, uranium, and TDS. The primary risk to human health and the environment from the chemicals of concern is through direct ingestion of contaminated groundwater or ingestion of meat from livestock that have ingested contaminated groundwater. The cleanup criteria for groundwater in the areas are the US EPA maximum contaminant levels (MCLs) for drinking water.

The US EPA established primary and secondary MCLs to protect public health and provide guidelines to state and local enforcement agencies. Primary MCLs are legally enforceable standards that apply to public water systems and were established to protect public health by limiting the levels of contaminants in drinking water. The secondary MCLs are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The US EPA recommends secondary standards to water systems but does not require systems to comply.

The MCLs for the contaminants of concern for NECR are:

Contaminants	Primary MCL	Secondary MCL
Gross Alpha	15 pCi/L	
Radium-226	not established	not established
Radium-228	not established	not established
Radium-226 + Radium-228	5 pCi/L	
Uranium	30 mg/L	
TDS	not established	500 mg/L
Nitrates	10 mg/L	
Arsenic	10 mg/L	
Sulfate	not established	250 mg/L
pH	Less than 6.5 greater than 8.5	

Water samples have been collected from many unregulated wells and springs throughout the Navajo Nation region under various investigations and programs. From 1977 to 1979, Los Alamos Scientific Laboratory collected samples in the Church Rock area as part of the National Uranium Resource Evaluation Program (NURE) during the hydrogeochemical and stream sediment reconnaissance phase. In July 2002, a water quality sample was collected from a domestic well in the Westwater Canyon Member in the area of the UNC Mill. In 2003 and 2004, Navajo Nation Environmental Protection Agency (NNEPA) collected samples under the Church Rock Uranium Monitoring Project (CRUMP). EPA collected additional samples in the Church Rock area from 2008 through 2010. Because the wells are unregulated sources of water, limited or no information on well development is available and groundwater samples were not collected regularly. Available analytical results summarized below are from limited grab groundwater samples.

5.1. NURE 1977 TO 1979 SAMPLING EVENT

From September 1977 to October 1979, NURE collected thirteen groundwater samples in the Church Rock area from twelve wells. Data from the samples were compiled and transferred to a database by USGS. Ten samples were collected in September 1977; one sample was collected in October 1978; and two samples were collected in October 1979 after the UNC Mill tailings spill in July 1979, including a resample of a well from the 1977 event (EPA, 2009d). Samples are identified in the database with unique identifiers; however, no information is available to correlate the samples with wells from other sampling events or specific aquifers in the area. Sample identification, dates collected, and uranium concentrations are presented below.

Sample ID	Date Collected	Uranium Concentration
1081950	9/20/1977	0.89
1081951	9/20/1977	0.22
1081952	9/20/1977	0.18
1081953	9/20/1977	0.64
1081954	9/20/1977	2.4
1081955	9/20/1977	1.24
1081956	9/20/1977	2.62
1081958	9/20/1977	0.44
1081962	9/20/1977	0.63
1082210	10/01/1978	1.46
1082328 (resample of 1081958)	10/17/1979	0.24
1082365	10/18/1979	0.95
1082366	10/18/1979	1007.4

Uranium concentrations in the samples ranged from 0.17 µg/L to 2.62 µg/L, except for sample 1082366 that had a uranium concentration of 1,007.4 µg/L, which exceeded the MCL of 30 µg/L. Sample 1082366 was collected from the drainage directly across Pipeline Arroyo from the UNC Mill .

5.2. 2002 UNC MILL SAMPLING EVENT

In July 2002, MWH collected a water quality sample from the Westwater Canyon Member in the area of the UNC Mill from a domestic well located in Section 2 of Township 16 north and Range 16 west. Dissolved uranium was detected at a concentration of 70 µg/L, and gross alpha activity was not detected at a level greater than the laboratory reporting limit of 1.0 pCi/L (MWH, 2003).

5.3. CHURCH ROCK URANIUM MONITORING PROJECT 2003 AND 2004 SAMPLING EVENTS

EPA and NNEPA collected water samples near the Church Rock and NECR Mines in October 2003 as part of the CRUMP. The pollutants and water quality parameters included in the analyses were concentrations of arsenic, iron, selenium, sulfate, pH, total hardness, fluoride, chloride, and total dissolved solids. Many of the wells sampled during the CRUMP October 2003 study were deemed unsuitable for human and domestic uses based on water quality parameters of the samples, and various pollutants detected. Thirteen wells were sampled in the area and analyzed for uranium (EPA, 2009):

- Well 14K-313 contained 0.05 µg/L of uranium
- Well 14K-586 contained 3 µg/Lof uranium
- Well 15T-303 (listed as 15K-303) contained 0.69 µg/L of uranium
- Well 16-4-10 contained 69.37 µg/L of uranium
- Well 16K-336 contained 0.57 µg/L of uranium
- Well 16K-340 contained 2.92 µg/L of uranium
- Well 16T-348 contained 0.29 µg/L of uranium
- Well 16T-534 contained 0.15 µg/L of uranium
- Well 16T-559 contained 0.09 µg/L of uranium
- Well 16T-606 contained 6.99 µg/L of uranium
- Well 16T-608 contained 5.76 µg/L of uranium
- Well Grey contained 14.84 µg/L of uranium
- Well Solar contained 0.24 µg/L of uranium

Of the 13 wells sampled during this sampling event, only the groundwater sample collected from well 16-4-10 contained uranium at a concentration greater than the MCL of 30 µg/L. Well 16-4-10 is a shallow well (less than 10 feet) and located approximately 6.5 miles downgradient of the UNC Mill site. It appears to be located in an outcrop of the Morrison Formation along a tributary drainage running northwest into the Rio Puerco.

5.4. EPA 2008 TO 2009 SAMPLING EVENT

EPA collected and analyzed water samples from 2008 to 2009 from the following wells:

- Well 15K-303 contained 0.38 µg/L of uranium
- Well 14T-586 contained 1.5 µg/L of uranium
- Well 14K-313 did not contained uranium at a concentration greater than or equal to the laboratory reporting limit
- Well Grey contained 5.2 µg/L of uranium
- Well 16-4-10 contained 260 µg/L of uranium
- Well 16-3-4 did not contained uranium at a concentration greater than or equal to the laboratory reporting limit
- Well 16T-513 did not contained uranium at a concentration greater than or equal to the laboratory reporting limit
- Becenti Trail Spring contained 110 µg/L of uranium

The uranium concentrations in the samples collected from well 16-4-10 in 2008 and the Becenti Trail Spring in 2009 exceeded the MCL of 30 µg/L. As mentioned earlier, Well 16-4-10 is downstream of the mines; however, it is along a different drainage running northwest into the Rio Puerco and therefore is not influenced by the releases analyzed in this report. Becenti Trail Spring is a shallow water source with an aquifer listed as 231CHNL, the Chinle Formation, although the spring depth does not correlate well with the expected formation depth. The measured depth to water at the Becenti Trail Spring was reported as 12 feet bgs. The spring may be an associated with the same source as Well 16-4-10.

5.5. EPA 2010 SAMPLING EVENT

EPA collected and analyzed water samples from the following wells on October 19, 2010:

- Well 15K-303 had uranium activity of 0.978 pCi/L
- Well 14T-586 had uranium activity of 2.474 pCi/L
- Well Mill Well had uranium activity of 5.604 pCi/L
- Well 16K-336 had uranium activity of 0.743 pCi/L
- Well 16K-340 had uranium activity of 1.812 pCi/L

- Mine Well was not sampled because it had previously been abandoned in place and filled with concrete.

Water from the wells were analyzed in the field for pH, temperature, conductivity, dissolved oxygen (DO), salinity, total dissolved solids (TDS), turbidity, and oxygen reduction potential (ORP). Samples were collected from each of the wells and analyzed for gross alpha, beta, and photon radioactivity by EPA Method 900, radium-226 by EPA Method 903.1, radium-228 by EPA Method 904.0, isotropic uranium by Health and Safety Laboratory (HASL) Method 300 U-01-RC mod, and thorium by HASL Method Th-01-RC mod. All wells met the maximum contaminant level (MCL) for radionuclides in drinking water, except 16K-336 that had a Radium (226 and 228) activity level of 5.78 pCi/L, which is greater than the MCL of 5 pCi/L. Groundwater samples from all wells exceeded the TDS secondary MCL of 500 mg/L. (Secondary MCLs are not health-based and for aesthetic considerations, such as taste, color and odor.) Wells 16K-340, 14K-586, 15T-303 and Mill Well had concentrations of sulfate greater than the secondary MCL of 250 mg/L. Well 16K-336 contained arsenic at a concentration of 11 mg/L, slightly greater than the MCL of 10 mg/L. A summary of the analytical results from the 2010 sampling event are presented in Table 1.

Section 6. Historical Groundwater Data for Select Wells

Water quality data including radionuclides and general chemistry were evaluated for the selected wells identified in Section 4. Table 3 summarizes data from the selected wells. Evaluation of the well data was problematic because:

- very few wells had groundwater data from before mining began,
- samples from different wells were rarely collected concurrently, making comparison of water quality parameters difficult,
- sampling methods and procedures could not be verified for most of the data,
- analytical procedures have modified and become more sensitive since sampling began,
- Infrequent sampling events providing a small data set.

The most recent laboratory analytical data for groundwater indicate that all wells met the federal standard for radionuclides contaminants, except 16K-336 that had a Radium (226 and 228) activity level of 5.78 pCi/L, which is greater than the MCL of 5 pCi/L. Well 16K-336 contained arsenic at a concentration of 11 mg/L, slightly greater than the MCL of 10 mg/L. Groundwater samples from all wells exceeded the Total Dissolved Solids (TDS) secondary MCL of 500 mg/L. Wells 16K-340, 14K-586, 15T-303 and Mill Well had concentrations of sulfate greater than the secondary MCL of 250 mg/L. The secondary MCLs are not health-based but established considering aesthetic qualities such as odor, taste and color. Primarily due to the high TDS concentrations, the water from the wells is considered poor quality for human consumption.

The data show indicates:

Alluvium wells:	• Decreases in the conductivity from >1,330 to 150 and >1,180 to 190
	• Decreases in nitrates from 13.02 mg/L to <7 mg/L, and >13.0 mg/L to 5.97 mg/L
	• A temporary increase in sulfate followed by decreasing concentrations, to concentrations approximately the same sulfate concentrations from the first sample event pre-mining. (368 mg/L and 118 mg/L)
Gallup Wells:	• Both wells exhibit increases in sulfate from 580.68 mg/L to 1,380 mg/L in well 14K-586 and 520 mg/L to 2,000 mg/L in well 15T-303.

Westwater Canyon:

- The Mill Well exhibited a decrease in uranium concentrations from 65 mg/L in 1984 to 3 mg/L in 2010. No radionuclide data was available for this well prior to 1984. However, the Mine well that draws water from the same formation had dissolved uranium concentrations between 0.725 mg/L and 3.71 mg/L in 1979
- The Mill Well showed an increase in TDS and sulfate from 335 mg/L to 2,300 mg/L and from 32 mg/L to 1,460 mg/L, respectively.

Section 7. Summary of Prior Groundwater Assessments

The US EPA and USGS conducted assessments of the groundwater in response to growing concern over the possible impact to the groundwater quality in the area around and down gradient of the NECR Mine.

7.1. WATER QUALITY IMPACTS OF URANIUM MINING AND MILLING ACTIVITIES IN THE GRANTS MINERAL BELT,

In 1975, at the request of NMEIA, US EPA Region 6 assessed the impacts of mining and mine water discharge in the Grants Mineral belt, specifically in relation to the applicable regulations and standards (US EPA, 1975). The water quality assessment evaluated discharges, potable water supply and limited stream data for the Ambrosia Lake, Church Rock and Jackpile-Paguate Mining areas. A representative sample of the mine discharge water could not be collected during the initial sampling event at the NECR Mine (referred to as United Nuclear Corporation Churchrcok Mine) because a power failure caused the mine to flood and mining operations were temporarily suspended for repairs. The report stated that even without a representative sample "Indications are that the present treatment facility is inadequate to meet existing NPDES permit conditions." NMEIA returned to the mine on March 14, 1975, and collected a sample after the mining operations had resumed. The concentration of radium-226 in the sample was 57 pCi/L, which exceed the NPDES permit condition of 30 pCi/L.

The assessment also found that concentrations of radium-226 and selenium in drinking water at the NECR Mine and mobile home area for workers and families exceeded the United States Public Health Service limits of 3 pCi/L and 0.01 mg/L, respectively. Radium was detected at concentrations of 12.6 pCi/L at the mine and 39.7 pCi/Lin a mobile home used by mine workers, and selenium was detected at a concentration of 0.06 mg/L in both locations. The US EPA recommended finding an alternate source of potable water for the workers and families of miners who use the wells (US EPA, 1975).

7.2. HISTORIC WATER QUALITY DATA, PUERCO RIVER BASIN, ARIZONA AND NEW MEXICO

In 1988, the USGS began a five-year study of the occurrence and movement of radionuclides and trace metals in the Puerco River basin in Northeastern Arizona and northwestern New Mexico (USGS, 1991). The report presented historical water quality data for select wells in the Puerco river basin and a bibliography of geology, hydrology, and water quality references. The purpose of the report was to summarize data for surface water and groundwater quality indicators in the Puerco River basin dating from before the mine tailings release up to 1988. The report included water quality information for 72 stream locations and 323 groundwater wells. Several of the 323 wells were located in the study area for this report, including wells 16K-340 and 16K-336. The historic stream water data presented several samples collected immediately after the July 16, 1979, tailings dam failure that contained high levels of thorium (54.6 pCi/L maximum result on August 4, 1979) and uranium (900 ug/L maximum result on July 26, 1979)

7.3. RADIOACTIVITIY IN THE ENVIRONMENT – A CASE STUDY OF THE PUERCO AND LITTLE COLOROADO RIVER BASINS, ARIZONA AND NEW MEXICO

The USGS presented a second study of the Puerco River basin to determine the distribution of radioactive elements (USGS, 1994). The second study included sampling surface water, sediment, and groundwater down to 150 feet bgs in the Puerco River basin. Nine surface water sampling stations were established in the basin: three on the Puerco River; three on the Little Colorado River, and three on tributaries not affected by mining (Black Creek, Zuni River, and the Little Colorado River at Woodruff). The groundwater strategy included sixty-nine wells along the Puerco and Little Colorado Rivers, including thirty-eight wells in ten well clusters. Each well cluster consisted of three to nine wells of varying depths and distances from the river channel to allow determination of vertical and horizontal extent of radioactive contamination. The screen lengths were typically short – from a foot screened interval to about 10 feet length. The USGS also sampled groundwater from wells on tributaries where no mining had occurred and wells screened in the underlying bedrock aquifers.

Because radium and uranium adsorb to sediments, water samples were filtered so that the unfiltered water, filtered water, and sediment components of the sample could be assessed separately. Ninety-three of 95 filtered samples contained gross-alpha activity less than the federal drinking water standards of 15 pCi/L, and twenty out of twenty-three filtered samples contained uranium concentrations less than the proposed Federal standard in 1994 of 20 mg/L. In comparison to the filtered samples, unfiltered samples contained up to 10 times more uranium and generally exceeded Federal drinking-water standards for total uranium in 51 out of 54 samples, and exceeded total gross alpha standards in 82 out of 91 samples.

There was no significant difference in the radioactivity levels in sediments collected from areas that were potentially impacted by mining and in sediments collected from tributaries with no mining history. Differences in radioactivity in the sediments appeared to be related to the geology of the surrounding area and not proximity to uranium mines.

The groundwater study concluded that groundwater samples collected from shallow depths (less than 40 feet), closest to the abandoned uranium mines, and near the center of the riverbed had higher concentrations of dissolved uranium. In 1989, concentrations of dissolved uranium greater than 35 μg/L were detected in shallow groundwater samples from the mouth of the Pipeline Arroyo to the Arizona/New Mexico border. In 1990, the area containing concentrations of dissolved uranium greater than 35 μg/L only reached from the mouth of the Pipeline Arroyo to just East of Gallup, New Mexico

7.4. EFFECTS OF URANIUM-MINING RELEASES ON GROUND-WATER QUALITY IN THE PUERCO RIVER BASIN, ARIZONA AND NEW MEXICO

In 1997, the USGS published the "Effects of Uranium Mining Releases on Ground-Water Quality in Puerco River Basin, Arizona and New Mexico" to describe the water quality of the Rio Puerco Alluvium aquifer, the movement of water between the Puerco River and the underlying alluvial aquifer, and changes in the water quality of the alluvial and bedrock aquifers related to the mine releases. The report used the data presented in the previous USGS reports and additional previously published data to develop models and evaluate the geology and geochemistry of the Puerco River basin.

Reviewing historic stream gages and estimating evaporation rates, the USGS estimated that in 1990 the source of the almost half of the groundwater in the Alluvium between the mouth of the Pipeline Arroyo and the Nuria Monocline (approximately 3 miles east of Gallup) could have been mine water discharge. Background samples collected upstream of the mouth of the Pipeline Arroyo in the Rio Puerco contained tritium concentrations indicating recent source of water, and uranium concentrations between 6 and 13 ug/L. Groundwater samples downstream of the Pipeline Arroyo had tritium concentrations indicating an older source of water similar to the tritium concentrations from the mine water in the Westwater Canyon formation and uranium concentrations as high as 870 µg/L.

USGS reported groundwater concentrations of uranium ranged from 1 to 220 µg/L in 1990, which was less than the maximum uranium concentration of 870 µg/L detected in groundwater in 1989. The report also confirmed that higher concentrations were detected in shallow wells, close to the center of the riverbed, and closest to the abandoned mines. Water in the Alluvium was generally alkaline, with high concentrations of sulfate and TDS. All samples of radium-226 and radium-228 were less than federal standards.

The USGS assessed the fate of the uranium released through mine dewatering discharge and concluded that sorption of uranium on the sediment is the probable fate of the dissolved uranium. This conclusion was based on analyses of sediment samples for uranium and thorium isotopes. In most natural cases, the ratio of uranium activity to thorium activity should be close to one. If significant amount of uranium leached in to the environment or sorbed onto the sediments, the ratio would be greater than one. The calculated U/Th ratios for the sediment samples closer the centerline of the streambed were greater than one indicating uranium had been added to the sediments from mine releases. However, the changes were small because USGS could not distinguish between uranium concentrations in sediments containing mine water discharges and sediments without mine discharge water.

The USGS study determined that the groundwater and sediments in the Alluvium had been impacted by the mine water discharges. Concentrations of dissolved uranium had decreased over time but were still present in limited areas in 1990 at concentrations greater than 35 µg/L. Except for a few shallow samples in the center of the channel, gross alpha, uranium, and radium met federal standards downstream of Gallup. Groundwater samples east of Gallup showed improvement over the study period. As indicated in the analysis of the Alluvium aquifer, sorption on to the sediment is probably where the dissolved uranium resides. Isotope analyses of the sediments suggest that the concentrations of uranium in the sediments near the center of the channel are more likely to be associated with the mine water discharge than concentrations in the sediments away from the center.

Section 8. Conclusions

During the mining operations at NECR mines and the UNC Mill Site operations, dissolved uranium, radium, gross alpha and other contaminants were introduced into the groundwater in the area by several different releases: mine water discharges, the 1979 dam breach release, seepage from the tailings disposal cells at the UNC Mill site, dewatering of the ore body formation during mining, and disposal of waste rock back into the mine workings..

Surface water flowing in the Pipeline Arroyo and Rio Puerco seeps into the underlying Alluvium forming the shallow groundwater in the area. Groundwater in the Alluvium generally flows from northeast to southwest, in the same the direction as the Pipeline Arroyo and Rio Puerco. Groundwater can seep from the Alluvium into the underlying sandstone bedrock, such as the Upper Gallup Sandstone Member, where it contacts the Alluvium. Surface water can also seep directly into the sandstone formations where they outcrop at the surface. Groundwater in the sandstone formations flows northward following the regional dip in the area.

Based on the historic releases and the hydrogeology of the Area, three aquifers were identified as potentially impacted from the historic releases: the Alluvium aquifer, the Upper Gallup Sandstone Member aquifer, and the Westwater Canyon Formation aquifer.

8.1. IMPACTS TO THE ALLUVIUM AQUIFER

The Alluvium beneath the Rio Puerco is a source of groundwater for the neighboring communities. The largest impact on the Alluvium aquifer was from the mine water discharge where an estimated 37 billion gallons of water containing 600 tons of uranium was released into the Pipeline Arroyo/Rio Puerco over a 16 year period. The second major impact to the Alluvium Aquifer was the 1979 dam breach that released of approximately 94 million gallons of water containing radioactive mill tailings. While considered one of the largest radioactive spills in history, contamination from the 1979 spill occurred as a single event and had a brief period during which it could be absorbed into the underlying aquifers as it flowed down the Rio Puerco. Investigations conducted by USGS determined that the Alluvium beneath the Rio Puerco had been impacted by the mine water discharge and to a lesser extent by the 1979 dam breach. The USGS reports documented dissolved uranium in the Alluvium groundwater and indicated that the uranium had adsorbed on to the Alluvium sediments. The USGS investigations constructed numerous monitoring wells targeting zones in the Alluvium where groundwater impacts from the previous releases were expected (i.e. shallow, center of stream wells).

This groundwater assessment utilized data from wells installed prior to mining operations. This assessment of existing livestock wells found that mining in the area had a possible influence on secondary water quality constituents in the Alluvium groundwater, such as the decrease in TDS, and the spike and subsequent decrease in sulfate concentrations wells 16K-336 and 16K-340. The wells used in this assessment may not have shown impacts from uranium or radium 226/228 because they were not located in an optimal location relative to the center of the stream channel and the depth of screen, or they had an insufficient historical data.

TDS concentrations have remained consistent in the Alluvium groundwater wells from pre-mining to present. Pre-mining data indicate TDS concentrations ranged from 832 mg/L to 1,423 mg/L and data from October 2010 detected concentrations of TDS ranging from 1,000 mg/L to 1,200 mg/L. Concentrations of TDS in drinking water are regulated under the EPA's National Secondary Drinking Water Standards and is considered and aesthetic effect causing and undesirable taste or odor. The elevated concentrations of TDS detected in the Alluvium groundwater are considered poor water quality for human consumption.

Based on the limited data for wells in this assessment, the uranium concentrations in the Alluvium groundwater appears to have been consistent over the past 50 years and are below federal safe drinking water levels. The well furthermost from the NECR mine within the study area, 16K-336, had an anomalous concentration of 5.78 pCi/L of Radium-226/228 during the October 2010 sampling event, which exceeded the MCL of 5 pCi/L. Previous groundwater samples collected in 1989 and 1990 by the USGS were less than the MCL for of radium-226 and radium-228, as well as all other historic samples collected from the livestock wells in this assessment.

The Alluvium in the Pipeline Arroyo has also been impacted by historical tailing seepage. The lateral extent of this impact is approximately 2000 feet southeast of the UNC Mill Site; however, there are no livestock wells located in the Pipeline Arroyo Alluvium in the impacted area.

8.2. IMPACTS TO THE UPPER GALLUP SANDSTONE MEMBER AQUIFER

The Upper Gallup Sandstone Member wells may also have been affected by the mine water discharge but to a lesser extent because the mine water would have passed through the Alluvium before entering the Upper Gallup Sandstone Member. The Friendship well, 14K-586, and the Pipeline Canyon Well, 15T-303 showed an increase in sulfate concentrations but have not shown a subsequent decrease as seen in the Alluvium wells All other constituent's concentrations appear constant over the historic record.

Current groundwater in Upper Gallup Sandstone Member wells contains elevated concentrations of TDS ranging from 1,700 mg/L to 2,200 mg/L. Groundwater in the region that is not impacted by mining can also have high concentrations of TDS from dissolved formation material as groundwater passes through. Uranium and radium 226/228 concentrations in the groundwater in the livestock wells within the study area are less than federal safe drinking water levels, and based on the limited data; appear to have been fairly consistent over the past 33 years.

The greatest impact from releases of radionuclides and secondary contaminants on the quality of Upper Gallup Sandstone Member groundwater is at the UNC Mill Site, where the Upper Gallup Sandstone Member has been affected by the acidic seepage from the tailings disposal cells during mining operations. These releases are currently being remediated under oversight of US EPA Region 6 and the State of New Mexico. The extent of the release from the tailing seepage currently extends approximately 3000 feet in the Upper Gallup Sandstone Member.

8.3. IMPACTS TO THE WESTWATER CANYON AQUIFER

A large quantity of mine water was extracted from the Westwater Canyon Formation to allow access to ore during mining operations. This process introduced oxygen and temporarily changed the aquifer around the ore rock from anaerobic to aerobic. After mining operations ceased, groundwater around the ore returned to the original oxidation state. In addition, waste rock was disposed in the mine shafts and stopes as part of the mine closure.

The Westwater Canyon Sandstone Member Aquifer showed a decrease in water quality with elevated uranium concentrations occurring in the Mill well immediately following the cessation of mining, but has since declined to below federal levels. Radium-226 concentrations in the Mine well were high during mining operations but decreased to less than the MCL after mining ceased. Radionuclide concentrations appear to have improved, but secondary contaminant concentrations indicate a decrease in water quality in the Westwater Canyon Sandstone Member. The Mine well sample collected in 1973 and Mill well sample collected in 1976 contained high quality water with low TDS concentrations (300 mg/L to 400 mg/L). After mining ceased in 1986, the TDS concentrations increased to 2,258 mg/L in 1993 and have remained greater than the MCL of 500 mg/L.

Section 9. Summary

In response to concerns voiced by the community, US EPA evaluated the impacts to groundwater due to historical mining and milling activities of the Northeast Church Rock, and the UNC Mill in the Church Rock area of the Navajo Nation.

The prominent geologic feature in northwestern New Mexico is the San Juan Basin, which is a circular, bowl-shaped depression containing sedimentary rocks. The uplifted, folded, and faulted rocks of the adjacent mountain ranges define the margins of the San Juan Basin. The southern margin of the San Juan Basin, where NECR is located, is defined by the Zuni Mountains. The layers of sedimentary rock in the San Juan Basin slope down toward the center of the basin from the highlands at the margins. During the Late Jurassic period, stream-laid sands were deposited throughout the basin creating the Morrison Formation which includes the Westwater Canyon Sandstone Member. The Morrison is one of several well-known uranium-bearing rock units in the mining districts.

A prominent feature of the Late Cretaceous was northwest to southeast shoreline that migrated back and forth across the basin, depositing marine, coastal plain, and nonmarine sediments. The marine deposits in the area consist of sandstone, shale, and a few thin limestone beds. The Late Cretaceous rocks include the following units from the oldest to the youngest: the Dakota Sandstone, the Mancos Shale, the Mesa Verde Group (which includes the Upper Gallup Sandstone Member and the Crevasse Canyon Formation).

River deposited alluvium overlies the sedimentary bedrock in the Puerco River basin. The Alluvium consists of fine grained sand interfingered with silty clay layers. When surface water is present near the NECR mine, the flow direction is from northwest to southeast along unnamed arroyos, into the northeast-to southwest-trending Pipeline arroyo and into the Rio Puerco. Groundwater can seep from the Alluvium into the underlying sandstone bedrock, such as the Upper Gallup, where it contacts the Alluvium. Surface water can also enter the sandstone formations where the formation outcrops at the surface. Groundwater in the sandstone units flows to the north following the regional dip of bedrock.

During operations of the UNC Mill and the NECR Mine, the largest releases of uranium, radium and gross alpha were surface water discharges (water pumped from the mines, and the 1979 catastrophic release from the tailings disposal cells) whose impacts would first be observed in the Alluvium groundwater wells. The tailing disposal cells at the UNC Mill Site and the settlement ponds at the NECR Mill would affect groundwater by seeping into the underlying formations. The Upper Gallup Sandstone Member outcrops at the UNC Mill Site and the Dalton Sandstone Member outcrops at the NECR Mill site. The Dalton Sandstone Member is a non-producing sandstone in the NECR area; therefore, very little seepage would have passed through the Dalton into the groundwater. In addition, groundwater quality in the Westwater Canyon Sandstone Member Aquifer could have been affected by the disposal of waste rock in the mine workings and dewatering of the mine during operation.

Water samples have been collected from many unregulated wells and springs throughout region under various investigations and programs. From 1977 to 1979, Los Alamos Scientific Laboratory collected samples during the hydrogeochemical and stream sediment reconnaissance phase. In 2003 and 2004, Navajo Nation Environmental Protection Agency collected samples under the Church Rock Uranium Monitoring Project. EPA collected additional samples in the Church Rock area from 2008 through 2010. Uranium concentrations were greatest after the 1979 spill event in the Pipeline Arroyo. There also exceedences of federal standards for Uranium in wells within 15 miles of the area but were located in geologic formations or watersheds that would not have been impacted by releases at the NECR Mine or UNC Mill Site.

Historical groundwater quality data including radionuclides and general chemistry were compiled for select wells. These select wells were identified after evaluating release and groundwater flow patterns to identify pre-mining wells closest to the releases. Generally, most Alluvium and Upper Gallup wells showed a general increase in secondary contaminant concentrations (such as sulfate and TDS) since mining had ceased. The Westwater Canyon Sandstone Member well, Mill Well 1, has shown improvement in quality for uranium concentrations but a worsening in quality for the secondary contaminants. The most recent laboratory analytical data for groundwater indicate that all wells met the federal standard for radionuclides contaminants, except the furthermost Alluvium well, 16K-336, had a Radium 226/228 activity level of 5.78 pCi/L. Groundwater samples from all wells exceeded the Total Dissolved Solids (TDS) secondary MCL of 500 mg/L and some wells had concentrations of sulfate greater than the secondary MCL of 250 mg/L.

Finally, a literature search was conducted and results summarized. The USGS conducted a detailed study of the Alluvium under the Rio Puerco between 1988 and 1991. Using short-screened, specifically-located monitoring wells in the Alluvium, the USGS documented that releases from the NECR Mine and the UNC Mill Site had resulted in increased uranium concentrations in the Alluvium groundwater. Concentrations of dissolved uranium decreased over time but were still present in limited areas in 1990 when the study was completed. The USGS assessed the fate of the uranium released through mine dewatering discharge and concluded that sorption of uranium on the sediment is the probable fate of the dissolved uranium; however, the changes in sediment concentrations were within the range of non-mining impact sediment concentrations.

In summary, the three major water sources in the NECR Mine and UNC Mill area, the Alluvium groudwater, the Upper Gallup Sandstone Member aquifer, and the Westwater Canyon Sandstone Member aquifer have shown impacts to water quality associated with the mining operations. Water quality in the groundwater has generally improved since cessation of mining operations. Current water quality is considered poor due to the TDS concentrations that are normal for the region. Uranium concentrations and Radium-226/228 are below federal health levels with the exception of an anomalous result from one Alluvium well, and the plume for the historical Tailing Disposal cells seepage, which is under investigation and enforcement by EPA Region 6.

Section 10. References

Brister and Hoffman, 2002. New Mexico's Energy, Present and Future: Policy, Production, Economics, and the Environment. Brian S. Brister and L. Greer Price editors. New Mexico Bureau of Geology and Mineral Resources.

Canonie Environmental, 1988. "Transmittal, Pre-Mining/Pre-Milling Water Level Data, United Nuclear Corporation's Church Rock Site, Gallup, New Mexico." July 26.

Canonie Environmental, 1988. "Reclamation Engineering Services: Geohydrologic Report, Church Rock Site, Gallup, New Mexico." May

Chronic Diseases Division, Bureau of Epidemiology, Memo: Biological Assessment After Uranium Mill Tailings Spill , Church Rock, New Mexico, December 24, 1980

Church Rock Uranium Monitoring Project (CRUMP), 2007. "Report of the Church Rock Uranium Monitoring Project, 2003-2007." Principal authors: C. Shuey and M. Ronca-Battista. Sponsored by Churchrock Chapter, Navajo Nation in collaboration with Southwest Research and Information Center and the Navajo Education and Scholarship Foundation. May.

Hilpert, 1963. "Uranium Resources of Northwestern New Mexico." Geological Survey Professional Paper 603. U.S. Department of the Interior.

Keller, J.C., 2007. "Jamie deLemos Takes on Toxins on the Navajo Nation." Profile for doctoral candidate at Tufts School of Engineering and member of Diné Network for Environmental Health. Tufts University E-News. September 4. Available Online at: <http://enews.tufts.edu/focus/18/2007/09/04/Jamie%20deLemosTakesonToxinsontheNavajoNation>.

MWH, 2003. "Northeast Church Rock Mine Site Assessment." Prepared for United Nuclear Corporation. July.

Raymondi, R & Conrad, R, 1983. "Hydrogeology of Pipeline Canyon, Near Gallup, New Mexico." Published in Volume 21, Number 2 of *Ground Water*. March - April

Roca Honda Resources, LLC, 2009. "Baseline Data Report, Roca Honda Mine." October.

Stone, 1981. "Hydrogeology of the Gallup Sandstone, San Juan Basin, Northwest New Mexico." Published in Volume 19 Number 1 of *Ground Water*. January-February

US EPA, 1975. "Water Quality Impacts of Uranium Mining and Milling Activities in the Grants Mineral Belt, New Mexico." September. Available on the internet at : <http://nepis.epa.gov/Simple.html>

United States Environmental Protection Agency (EPA). 2007c. "Abandoned Uranium Mines and the Navajo Nation, Navajo Nation AUM Screening Assessment Report and Atlas with Geospatial Data." August.

EPA, 2009d. Google Earth file from Linda Reeves with compilation of data from EPA and DWR. May 2.

EPA, 2010. E-mail and faxes containing historic Church Rock maps. From Cynthia Wetmore, EPA. To Robin L. Mock, ERRG. January.

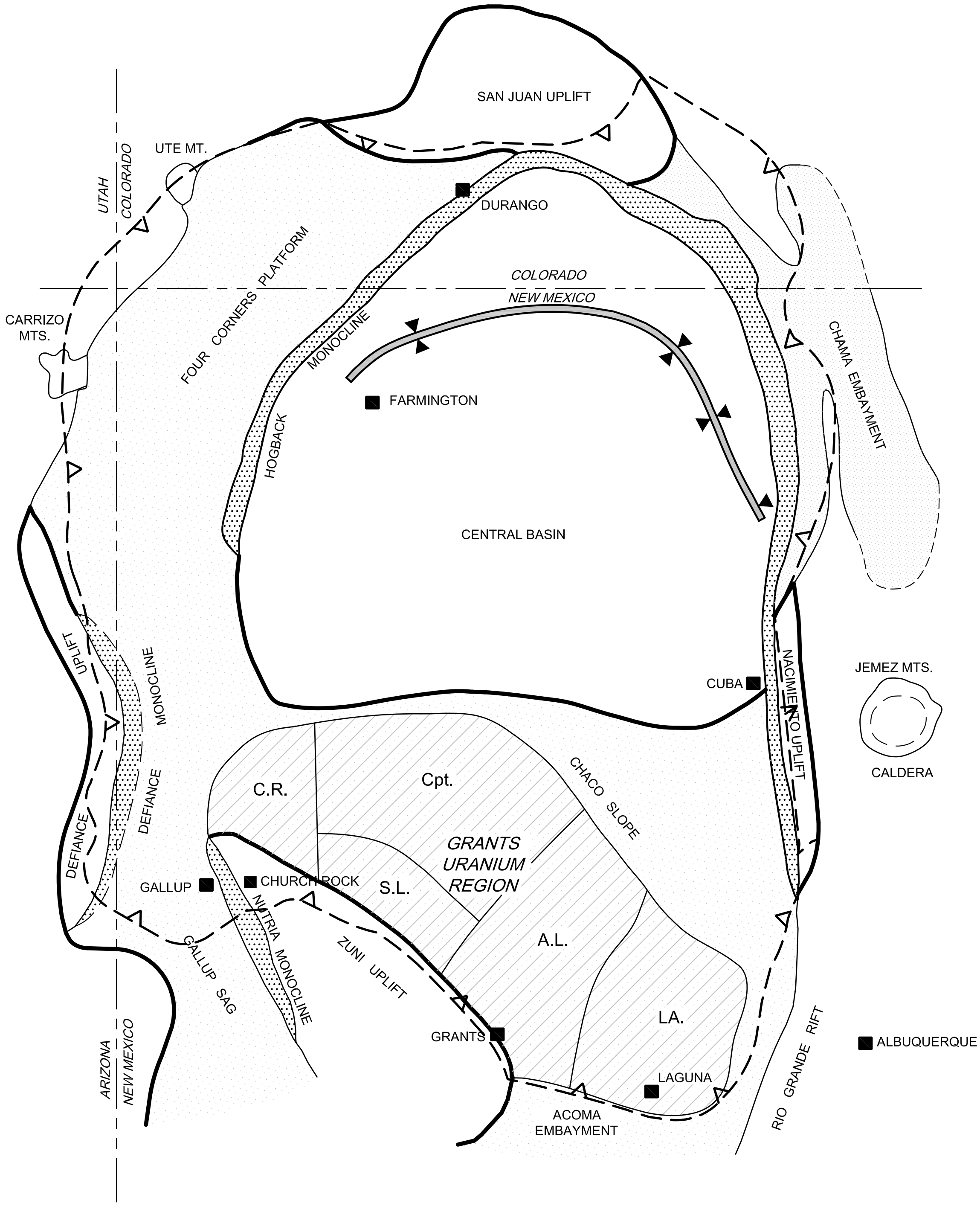
United States Geological Survey (USGS), 1991. "Historic Water Quality Data, Puerco River Basin, Arizona and New Mexico." Report 91-196 June Available on the internet at: http://pubs.er.usgs.gov/

USGS, 1994. "Radioactivity in the Environment – A Case Study of the Puerco and Little Coloroado River Basins, Arizona and New Mexico." Report 94-4192 Available on the internet at: < http://pubs.er.usgs.gov/>

USGS, 1997a. "Radioactivity in the Environment – A Case Study or the Puerco and Little Colorado River basins, Arizona and New Mexico." Open-File Report 94-4192.

USGS, 1997b. "Effects of Uranium-Mining Releases on Ground-Water Quality in the Puerco River Basin, Arizona and New Mexico." Water Supply Paper 2476 Available on the internet at: < http://pubs.er.usgs.gov/>

Figures



INDIVIDUAL DISTRICTS OF THE URANIUM REGION ARE OUTLINED. PRINCIPAL DISTRICTS: C.R.=CHURCH ROCK; Cpt.=CROWNPOINT; S.L.=SMITH LAKE - MARIANO LAKE; A.L.=AMBROSIA LAKE; LA.=LAGUNA. (AFTER SANTOS AND TURNER PETERSON 1986 BASED ON KELLY 1951) (REPRINTED BY PERMISSION OF AAPG).

N

0' 20 MI

APPROXIMATE SCALE: 1"=20 MI

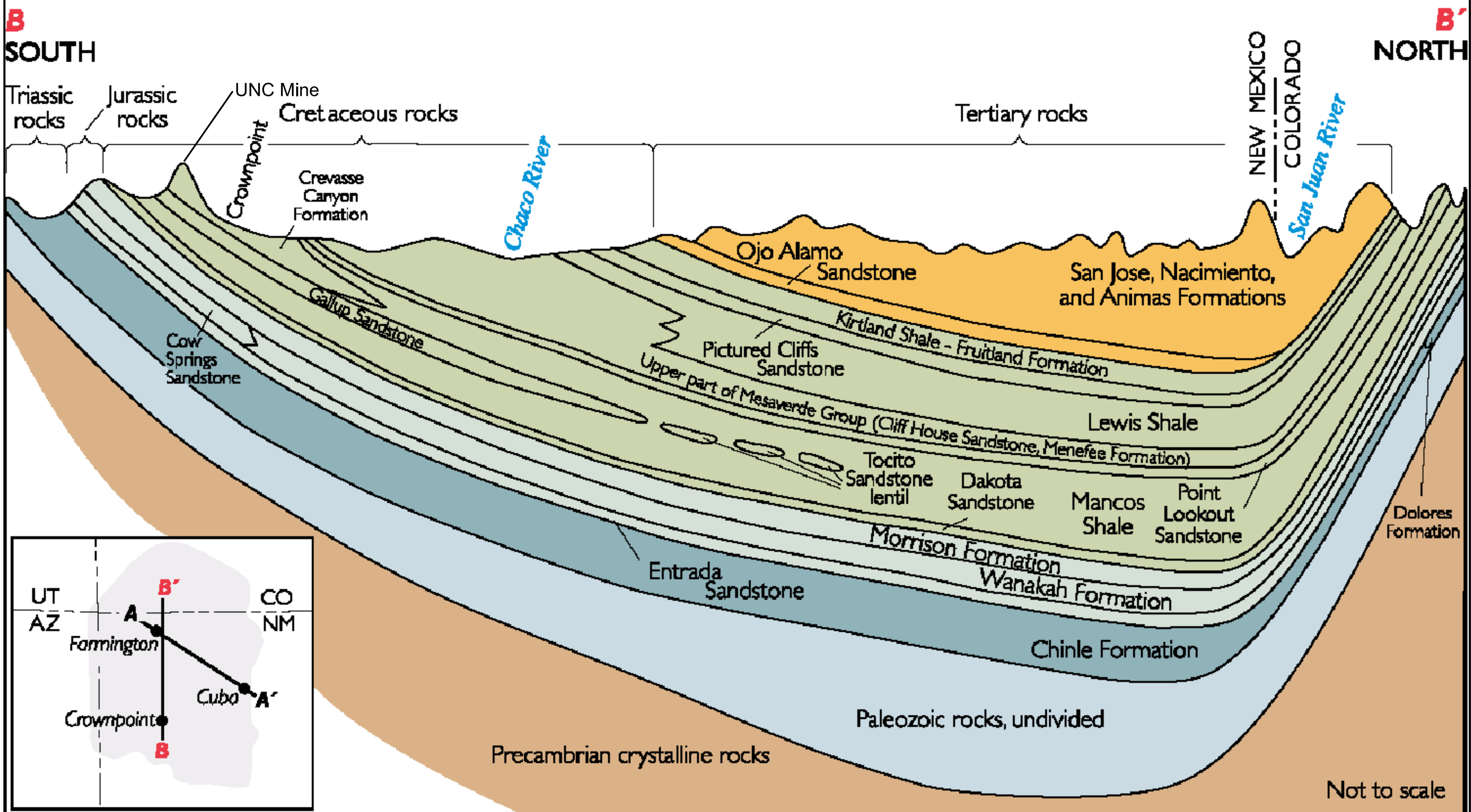
LEGEND:

BOUNDARY OF SAN JUAN STRUCTURAL BASIN

UPLIFT BOUNDARY

ERRG Engineering/Remediation Resources Group, Inc. 115 Sansome St., Suite 200 San Francisco, California 94104 (415) 395-9974	CLIENT: U.S. ENVIRONMENTAL PROTECTION AGENCY	GEOLOGIC FEATURES OF THE SAN JUAN BASIN			
	LOCATION: NEW MEXICO NAVAJO NATION	DRAWN BY: SC 08/08/11	CHECKED BY: MF 08/08/11	PROJECT NO. 2010-202	FIG NO. 1

009882

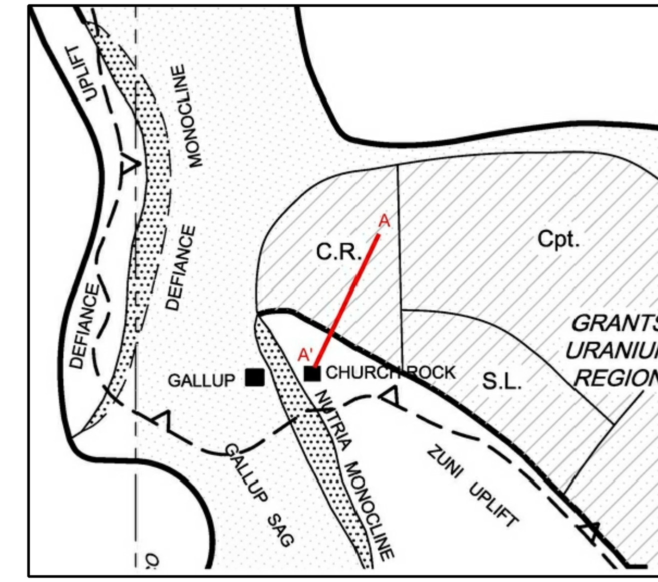


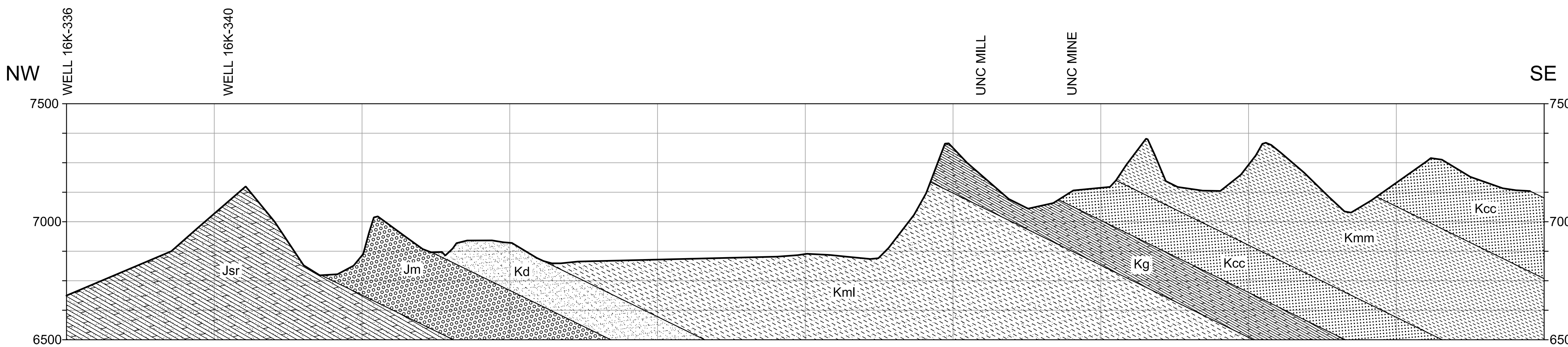
Source:
Brister and Hoffman, 2002. New Mexico's Energy, Present and Future: Policy, Production, Economics, and the Environment. Brian S. Brister and L. Greer Price editors. New Mexico Bureau of Geology and Mineral Resources.

ERRG Engineering/Remediation Resources Group, Inc. 115 Sansome St., Suite 200 San Francisco, California 94104 (415) 395-9974	CLIENT: U.S. ENVIRONMENTAL PROTECTION AGENCY	GEOLOGIC CROSS–SECTION OF THE SAN JUAN BASIN
	LOCATION: CHURCH ROCK AREA NEW MEXICO, NAVAJO AREA	DRAWN BY: SC 08/08/11 / CHECKED BY: MHF 08/08/11 / PROJECT NO. 2010–202 / FIG NO. 2

FILE NAME: N:\Projects\2010 Projects\2010-202_EPA_NEChurchRock_GWResearch\N_Maps&Dwgs\Figs_1_2_3.dwg LAYOUT NAME: 2 PLOTTED: Monday, August 08, 2011 - 7:58am

009883





CROSS SECTION VIEW WITH EXAGGERATED VERTICAL SCALE

0' 1000'

HORIZONTAL SCALE: 1"=5000'
VERTICAL SCALE: 1"=500'

LEGEND:

- Trc - CHINLE GROUP
- Jsr - SAN RAFAEL FROUP (ENTRADA; TODILTO; SUMERVILLE)
- Jm - MORRISON GROUP
- Kd - DAKOTA
- Kml - MANCOS SHALE
- Kg - GULLOP SANDSTONE
- Kcc - CREVASSE CANYON
- Kmm - MULATTO TONGUE OF MANKOS

ERRG Engineering/Remediation Resources Group, Inc.
115 Sansome St., Suite 200
San Francisco, California 94104
(415) 395-9974

CLIENT: U.S. ENVIRONMENTAL PROTECTION AGENCY	GEOLOGIC CROSS SECTION CHURCH ROCK AREA			
LOCATION: CHURCH ROCK AREA NEW MEXICO, NAVAJO AREA	DRAWN BY: SC 09/08/11	CHECKED BY: MHF 09/08/11	PROJECT NO. 2010-202	FIG NO. 3

FILE NAME: N:\Graphics\2010\2010-202 US EPA Navajo Nation\Fig3_Geolg-xsect.dwg LAYOUT NAME: 3 PLOTTED: Thursday, September 08, 2011 - 2:08pm

009884

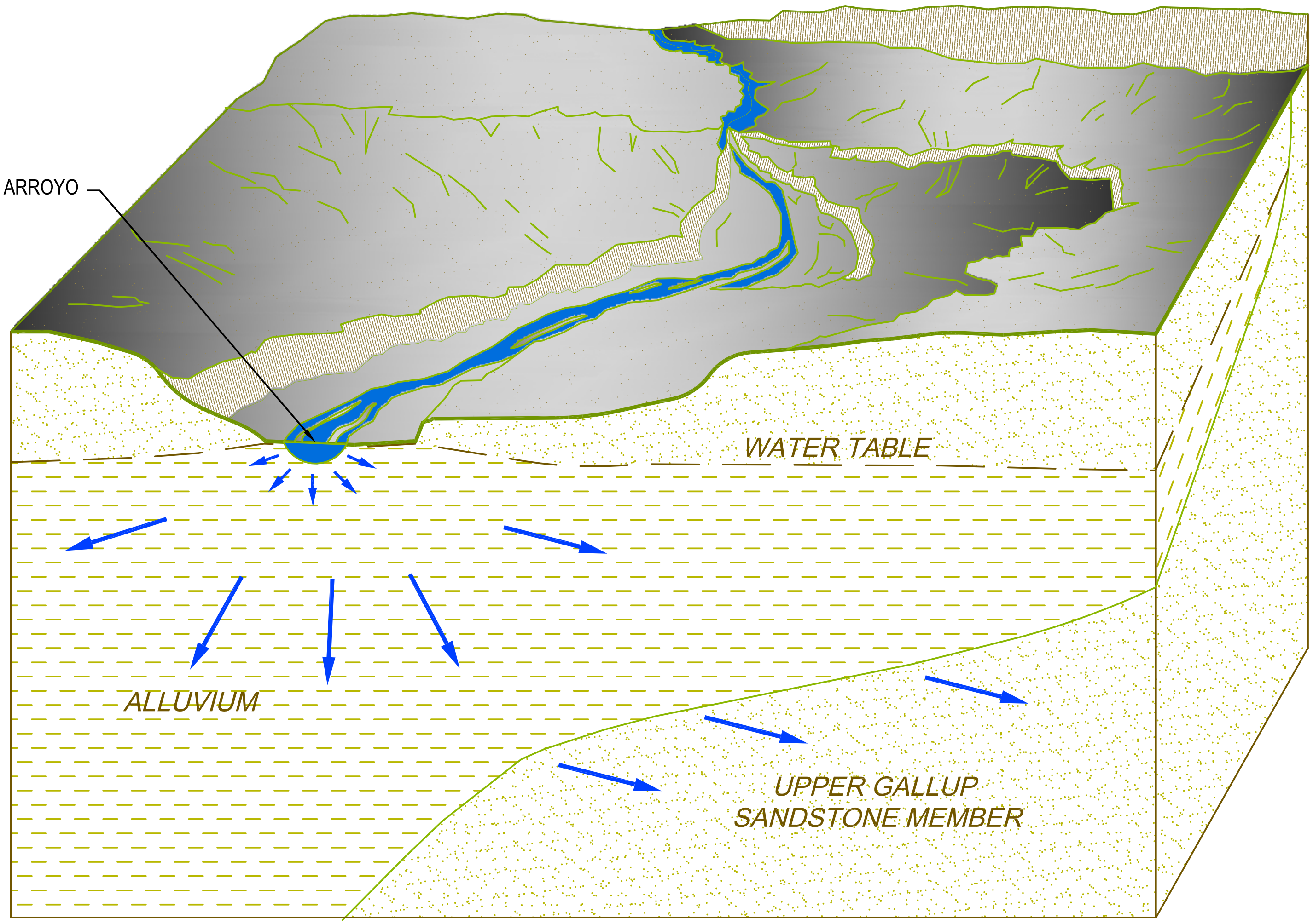
FILE NAME: N:\Projects\2010 Projects\2010-202_EPA_NEChurchRock_GWResearch\N_Maps&Dwgs\Figs_1_2_3.dwg LAYOUT NAME: 4 PLOTTED: Tuesday, August 02, 2011 - 8:37am

GEOLOGIC TIME			ROCK UNIT		DESCRIPTION
LATE CRETACEOUS PERIOD	MESA VERDE GROUP	CREVASSE CANYON FORMATION	DALTON SANDSTONE MEMBER	7092	Massive clean white to buff, medium to coarse-grained sandstone. This sand outcrops at the site, forms cap of Ram Mesa. Regressive coastal barrier sand. Gradational with Mulatto Tongue.
LATE CRETACEOUS PERIOD	MESA VERDE GROUP	CREVASSE CANYON FORMATION	MULATTO TONGUE	6962	Chiefly dark gray mudstone and silty sandstone with scattered thin beds of sandstone. Disconformable with Dilco Coal. Offshore marine deposit.
LATE CRETACEOUS PERIOD	MESA VERDE GROUP	CREVASSE CANYON FORMATION	DILCO COAL MEMBER	6882	Paludal and fluvial deposits. Chiefly irregular buff to gray medium-grained sandstone, light gray clay and lenticular coal beds and carbonaceous shales. Interfingered with underlying Gallup Sandstone. Mill site complex lies in this member.
LATE CRETACEOUS PERIOD	MESA VERDE GROUP		UPPER GALLUP SANDSTONE MEMBER	6780	Predominantly a gray to tan, fine to coarse-grained sandstone interbedded with gray siltstone and mudstone, and minor amounts of coal Coastal barrier deposit.
LATE CRETACEOUS PERIOD	MANCOS SHALE FORMATION		CROSS TONGUE	6630	Sandy marine shales and thin lenticular sandstone. Transgressive marine deposits.
LATE CRETACEOUS PERIOD	MANCOS SHALE FORMATION		LOWER GALLUP SANDSTONE MEMBER	6500	Interbed of Gallap Sandstone. Generally gray to tan, fine-grained and silty becoming gradually finer grained towards the base merging with the rather thick transition zone which comprises the upper 100 ft. of the underlying Mancos Shale Regressive, littoral or nearshore deposits.
LATE CRETACEOUS PERIOD	MANCOS SHALE FORMATION		MANCOS SHALE MEMBER	6340	Fissile shale with calcareous zone. Thin sandstone and/or siltstone beds Late Cretaceous subregional marine transgression. Limey medium gray to black marine shale interbedded with platey laminated light gray to grayish yellow to white limestone and gypsum.
LATE CRETACEOUS PERIOD	MANCOS SHALE FORMATION		TWO WELLS SANDSTONE MEMBER	5900	Tongue of Dakota Sandstone; soft white and light-gray sandstone with irregular, hard, brown, indurated masses.
LATE CRETACEOUS PERIOD	MANCOS SHALE FORMATION		WHITE ARROYO SHALE MEMBER	5845	
LATE CRETACEOUS PERIOD			DAKOTA FORMATION	5770	Continental and marginal marine uniformly fine to medium grained well sorted gray to pure white sandstone, with some interbedded siltstone and coal.
Unconformity between the Dakota Formation and Morrison Formation. No deposit during Early Cretaceous Period.					
LATE JURASSIC PERIOD	MORRISON FORMATION		BRUSHY BASIN MEMBER	5705	A green to grayish-green mudstone of continental deposition, split occasionally by discontinuous sandstone lenses.
LATE JURASSIC PERIOD	MORRISON FORMATION		WEST WATER CANYON SANDSTONE MEMBER	5630	Gray to light grayish-red to yellowish-gray, locally conglomeratic fine to coarse-grained sandstone characterized by scour-and-fill crossbedding and by angular grains of unweathered feldspar. Discontinuous lenses of grayish-green sandy mudstone are present.
LATE JURASSIC PERIOD	MORRISON FORMATION		COWSPRING SANDSTONE MEMBER	5362 5330	Chiefly gray to light yellowish-gray, fine to medium-grained sandstone with some interbedded siltstone.

Source:
Canonie Environmental, 1988. "Transmittal, Pre-Mining/Pre-Milling Water Level Data, United Nuclear Corporation's Church Rock Site, Gallup, New Mexico." July 26.
Specific source for Two Wells SS - Cobban, W.A., and Hook, S.C., 1989, Mid-Cretaceous molluscan record from west-central New Mexico, IN Anderson, O.J., and others, eds., Southeastern Colorado Plateau: New Mexico Geological Society Guidebook, no. 40, p. 247-264

ERRG Engineering/Remediation Resources Group, Inc. 115 Sansome St., Suite 200 San Francisco, California 94104 (415) 395-9974	CLIENT: U.S. ENVIRONMENTAL PROTECTION AGENCY	NORTHEAST CHURCH ROCK MINE SITE STRATIGRAPHIC COLUMN			
	LOCATION: CHURCH ROCK AREA NEW MEXICO, NAVAJO NATION	DRAWN BY: SC 08/03/11	CHECKED BY: MHF 08/03/11	PROJECT NO. 2010-202	FIG NO. 4

009885



LEGEND:

Ground Water Recharge

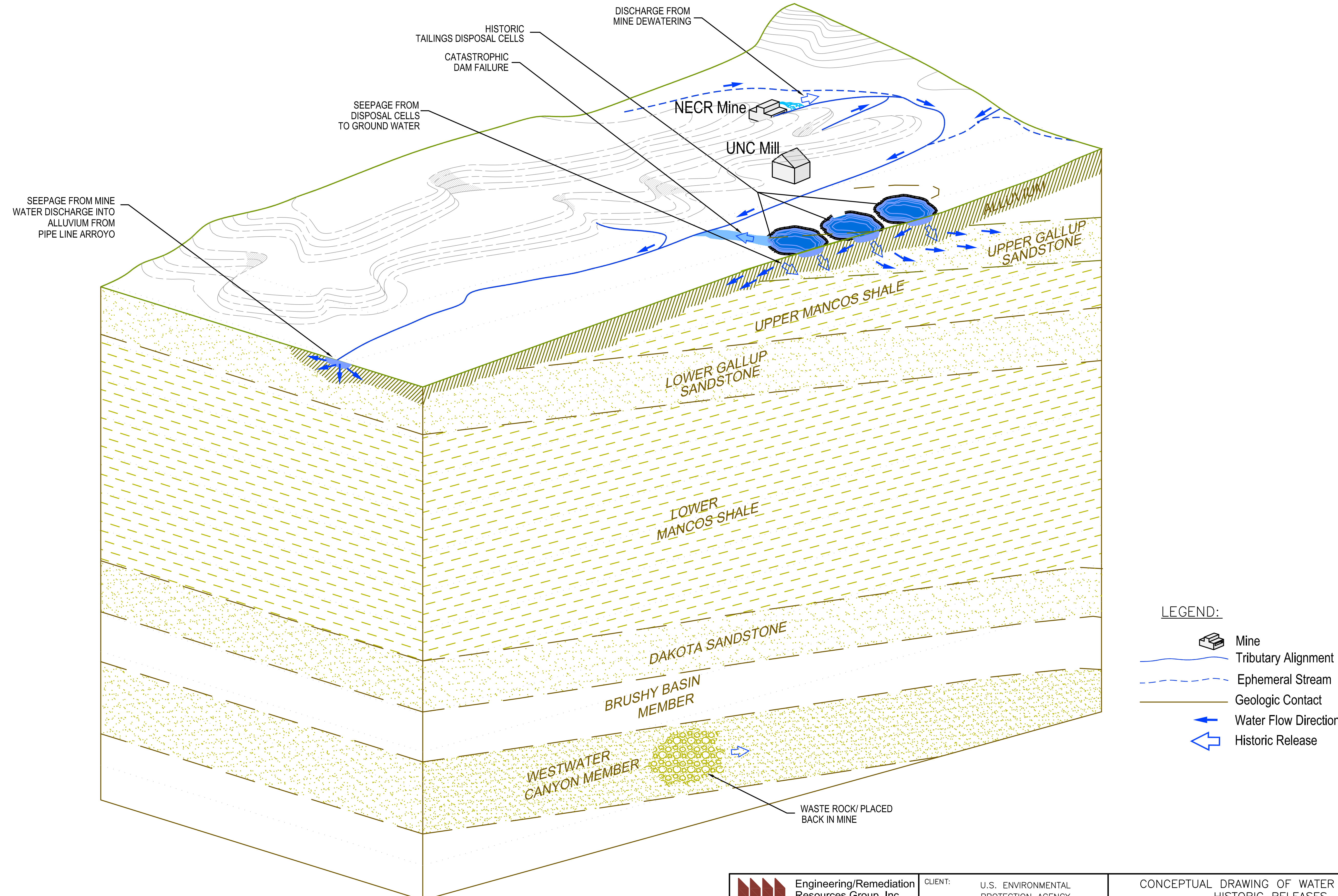
NOT TO SCALE

Engineering/Remediation Resources Group, Inc.
115 Sansome St., Suite 200
San Francisco, California 94104
(415) 395-9974
ERRG

CLIENT: U.S. ENVIRONMENTAL PROTECTION AGENCY		CONCEPTUAL DRAWINGS OF GROUNDWATER RECHARGE FROM STREAM FLOW		
LOCATION: CHURCH ROCK AREA NAVAJO NATION	DRAWN BY: SC 09/08/11	CHECKED BY: MF 09/08/11	PROJECT NO. 2010–202	FIG NO. 5

FILE NAME: N:\Graphics\2010\2010–202 US EPA Novajo Nation\Fig5_sectionVIEW.dwg LAYOUT NAME: 5 PLOTTED: Friday, September 09, 2011 – 10:50am

009886

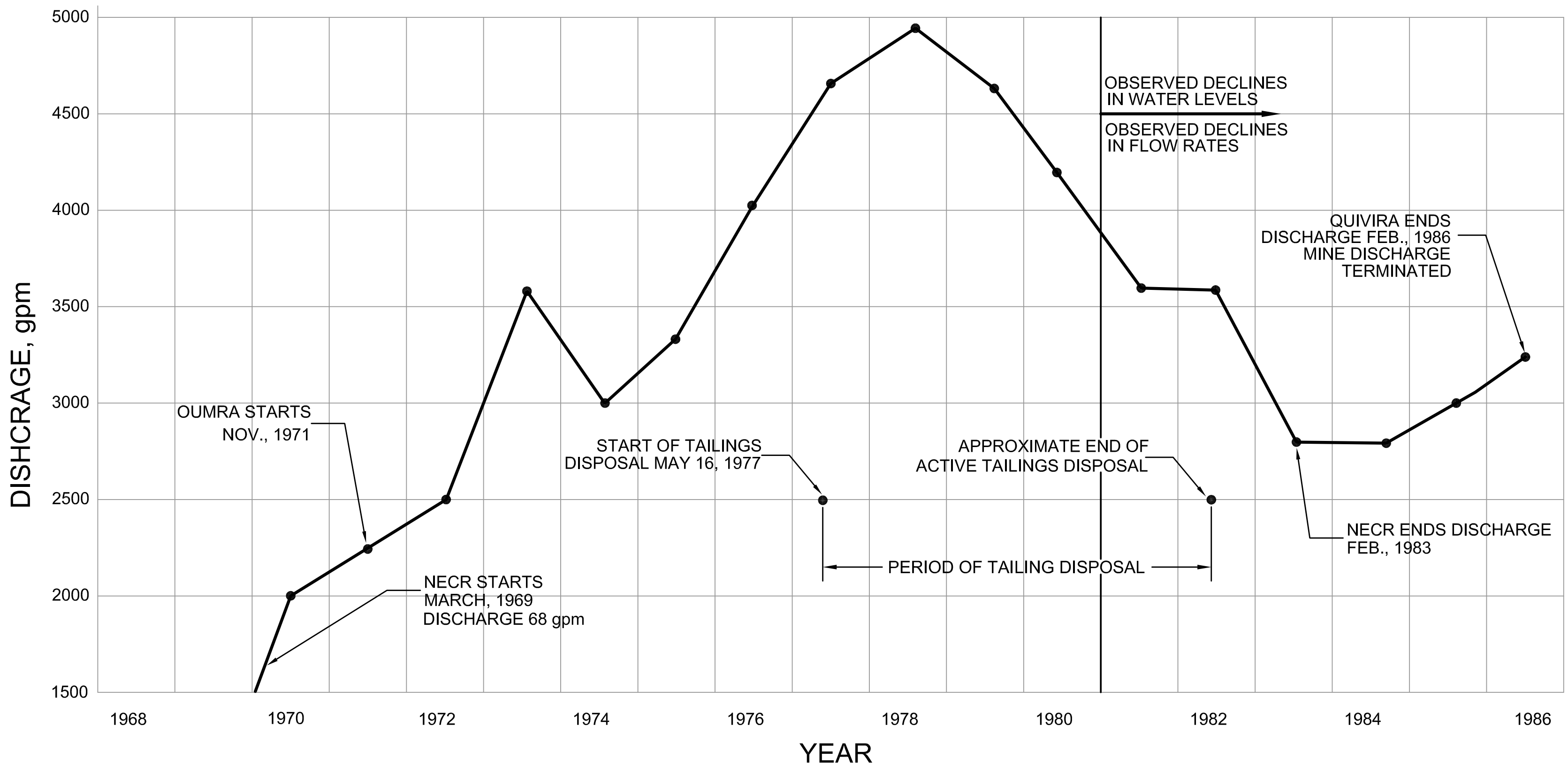


NOT TO SCALE

ERRG Engineering/Remediation Resources Group, Inc. 115 Sansome St., Suite 200 San Francisco, California 94104 (415) 395-9974	CLIENT: U.S. ENVIRONMENTAL PROTECTION AGENCY	CONCEPTUAL DRAWING OF WATER FLOW AND HISTORIC RELEASES
	LOCATION: CHURCH ROCK AREA NAVAJO NATION	DRAWN BY: SC 09/08/11 — CHECKED BY: MF 09/08/11 — PROJECT NO. 2010-202 — FIG NO. 6

FILE NAME: N:\Graphics\2010\2010-202 US EPA Navajo Nation\Fig6_uranium-release.dwg LAYOUT NAME: 6 PLOTTED: Friday, September 09, 2011 - 12:58pm

009887



NOTES:

1. MINE WATER WAS DISCHARGED FROM BOTH THE NORTHEAST CHURCH ROCK MINE AND THE QUIVA MINE.
2. SOURCE OF OBSERVED DATA: UNC MINING AND MILLING MEMORANDUM DATED SEPTEMBER 30, 1986.

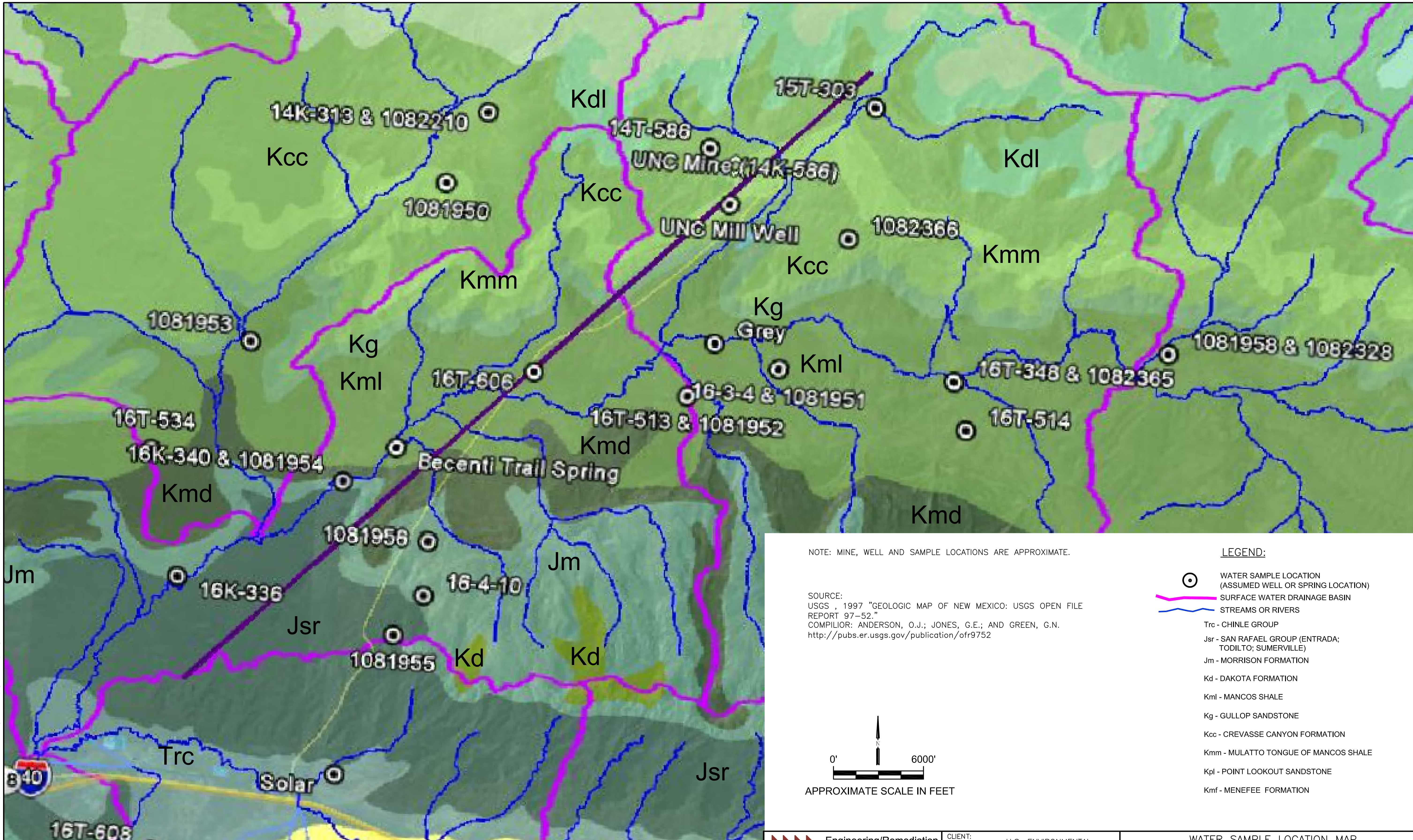
SOURCE: "CANONIE ENVIRONMENTAL, 1991. TAILING RECLAMATION PLAN AS APPROVED BY NRC MARCH 01,1991, LICENSE NO. SUA-1475."

NOT TO SCALE

ERRG
Engineering/Remediation Resources Group, Inc.
115 Sansome St., Suite 200
San Francisco, California 94104
(415) 395-9974

CLIENT: U.S. ENVIRONMENTAL PROTECTION AGENCY	AVERAGE YEARLY MINE WATER DISCHARGE			
LOCATION: CHURCH ROCK AREA NEW MEXICO, NAVAJO AREA	DRAWN BY: SC 08/03/11	CHECKED BY: MHF 08/03/11	PROJECT NO. 2010-202	FIG NO. 7

FILE NAME: N:\Graphics\2010\2010-202 US EPA Novajo Nation\Fig7_yearly_dschrg.dwg LAYOUT NAME: 7 PLOTTED: Thursday, September 08, 2011 - 1:57pm



NOTE: MINE, WELL AND SAMPLE LOCATIONS ARE APPROXIMATE.

SOURCE:
USGS , 1997 "GEOLOGIC MAP OF NEW MEXICO: USGS OPEN FILE REPORT 97-52."
COMPILIOR: ANDERSON, O.J.; JONES, G.E.; AND GREEN, G.N.
http://pubs.er.usgs.gov/publication/ofr9752

0' 6000'
APPROXIMATE SCALE IN FEET

LEGEND:

- WATER SAMPLE LOCATION (ASSUMED WELL OR SPRING LOCATION)
- SURFACE WATER DRAINAGE BASIN
- STREAMS OR RIVERS
- Trc - CHINLE GROUP
- Jsr - SAN RAFAEL GROUP (ENTRADA; TODILTO; SUMERVILLE)
- Jm - MORRISON FORMATION
- Kd - DAKOTA FORMATION
- Kml - MANCOS SHALE
- Kg - GULLOP SANDSTONE
- Kcc - CREVASSE CANYON FORMATION
- Kmm - MULATTO TONGUE OF MANCOS SHALE
- Kpl - POINT LOOKOUT SANDSTONE
- Kmf - MENEFEE FORMATION

ERRG Engineering/Remediation Resources Group, Inc.
115 Sansome St., Suite 200
San Francisco, California 94104
(415) 395-9974

CLIENT: U.S. ENVIRONMENTAL PROTECTION AGENCY	WATER SAMPLE LOCATION MAP NORTHEAST CHURCH ROCK AREA			
LOCATION: CHURCH ROCK AREA NEW MEXICO, NAVAJO AREA	DRAWN BY: SC 09/08/11	CHECKED BY: MHF 09/08/11	PROJECT NO. 2010-202	FIG NO. 8

FILE NAME: N:\Graphics\2010\2010-202 US EPA Navajo Nation\Fig8_wellmap.dwg LAYOUT NAME: 8 PLOTTED: Friday, September 09, 2011 - 7:24am

009889

Tables

Table 1. NECR Water Well Sampling Data – EPA START October 2010

Analyte	Units	MCL	Well Name					
			14T-586	14T-586 100(dup)	15T-303	16K-336	16K-340	Mill Well
Water Quality								
pH			7.1	7.1	6.8	7.4	7.6	7.4
Conductivity	S/m		0.26	0.26	0.35	0.15	0.19	0.36
Turbidity	NTU		10.1	10.1	10.1	29.9	5.5	14.7
Dissolved Oxygen	mg/L		6.30	6.30	7.99	3.05	5.26	6.39
Temperature	°C		7.6	7.6	12.1	15.5 °C	Temperature	
Salinity	%		0.1	0.1	0.2	0.1	0.1	0.2
Total Dissolved Solids	g/L		1.7	1.7	2.2	1	1.2	2.3
Oxidation Reduction Potential	mV		100	100	mV	86	76	-127
Metals								
Aluminum	μg/L		220	82	68.0	229	126	68.0
Antimony	μg/L	6	3.00	7.34	6.83	3.00	3.00	3.00
Arsenic	μg/L	10	5.00	5.00	7.54	11	8.53	5.00
Barium	μg/L	2,000	13.1	13.4	8.24	450	140	1.64
Beryllium	μg/L	4	1.00	1.00	1.00	1.00	1.00	1.00
Bromide	μg/L		0.200	0.200	0.200	0.234	0.295	0.361
Cadmium	μg/L	5	1.00	1.00	1.17	1.00	1.00	1.00
Calcium	μg/L		270000	281000	373000	76800	99800	2420
Chromium	μg/L	100	13.9	1.00	1.16	1.00	1.03	1.43
Cobalt	μg/L		1.13	1.00	1.00	1.00	1.00	1.00
Copper	μg/L	1,300	3.00	3.00	3.00	29.7	3.00	20.4
Iron	μg/L		482	468	685	2720	181	9870
Lead	μg/L	15	3.30	3.30	3.30	3.58	3.30	3.74
Magnesium	μg/L		119000	122000	144000	20600	43500	470
Manganese	μg/L		320	319	162	95.9	122	51
Mercury	μg/L	2	0.066	0.066	0.066	0.066	0.066	0.066
Nickel	μg/L		71.3	1.51	1.50	1.50	1.50	2.38
Potassium	μg/L		7430	7690	5650	2540	3940	3200
Selenium	μg/L	50	7.7	37.7	43.8	10.2	5.00	26.7
Silver	μg/L		1.00	1.00	1.00	1.00	1.00	1.00
Sodium	μg/L		135000	140000	188000	202000	233000	694000
Thallium	μg/L	2	5.00	5.00	8.9	5.00	5.00	6.45
Vanadium	μg/L		1.00	1.00	1.00	1.00	1.00	1.00
Zinc	μg/L		338	355	839	153	148	659
Radionuclides								
ALPHA	pCi/L	15	2.62	5.80	-0.526	0.129	5.46	9.79
BETA	pCi/L	ne	6.58	6.02	2.62	4.99	2.37	2.72
Pct Uranium-235	percent	ne	0.00	0.00	0.00	0.00	0.00	0.00
Radium-226	pCi/L		0.880	0.540	1.18	1.20	0.464	0.639
Radium-228	pCi/L		3.41	3.71	3.34	4.58	0.747	1.77
Radium 226 + 228	pCi/L	5	4.29	4.25	4.52	5.78	1.211	2.409

Table 1. NECR Water Well Sampling Data – EPA START October 2010 (continued)

Analyte	Units	MCL	Well Name					
			14T-586	14T-586 100(dup)	15T-303	16K-336	16K-340	Mill Well
Thorium-228	pCi/L		-0.0147	0.155	-0.139	0.298	-0.0682	0.139
Thorium-230	pCi/L		-0.185	0.818	-0.158	-0.524	0.0264	0.480
Thorium-232	pCi/L		-0.133	-0.0195	-0.0195	-0.0195	-0.0722	-0.0195
Uranium-233/234	pCi/L		1.16	1.73	0.317	-0.171	0.297	2.61
Uranium-235/236	pCi/L		0.114	0.0569	0.219	0.181	0.115	0.174
Uranium-238	pCi/L		1.20	0.790	0.442	0.392	1.40	2.82
Uranium[1]	μg/L	30	3.69	3.85	1.46	0.60	2.70	8.36
Anions								
Chloride	mg/L		14.0	14.1	10.5	18.8	22.1	154
Nitrate	mg/L		0.267	0.266	0.100	2.89	5.97	0.100
Nitrite	mg/L		0.100	0.100	0.100	0.100	0.100	0.100
Ortho-phosphate	mg/L		0.200	0.200	2.00	0.291	0.163	2.00
Sulfate	mg/L	250[2]	1380	1310	2000	118	368	1460
Fluoride	mg/L		1.19	1.24	1.52	0.861	0.483	1.73
Miscellaneous								
$\delta D\ H_2O$	%		-80.8	-81.2	-73.1	-91.4	-82.6	-107.3
$\delta^{18}O\ H_2O$	%		-10.44	-10.53	-8.56	-12.04	-11.01	-14.14

Notes:

1. Uranium in μg/L was calculated by summing the pCi/l for uranium 233 through 238 and multiplying by a conservative conversion factor of 0.67 pCi/μg.
2. Secondary drinking water standard for sulfate is presented in the table.

MCL – maximum contaminant level for EPA drinking water standards

S/m – Siemens per meter

NTU – Nephelometric Turbidity Units

mg/L – milligram per liter

°C – degrees Celsius

g/L – grams per liter

mV – millivolts

μg/L – micrograms per liter

pCi/L – picoCuries per liter

% - percent

ne – not established

Table 2. Summary of NECR Aquifer Formations and Associated Wells

		Mine Site			UNC Mill Site	
Geologic Unit	**Description**	**Mine Dewatering**	**Waste placed back in ore body**	**Pond/ Waste Seepage**	**Tailings Seepage**	**1979 Spill**
Alluvium	Shallow water bearing zone in under Pipeline Arroyo and Rio Puerco	Majority of water infiltrated into Alluvium. **16K-336** **16K-340**			Under Region 6, GE is addressing plume from tailings remanating about 1400 feet d/g from tailings pile.	Dam breached resulted in thorium-230 contamination in Pipeline Arroyo sediments. Clean-up was completed. **16K-336** **16K-340**
Dalton Sandstone Member	Non- producing sandstone/shale			No wells. Formation not a large producer		
Upper Gallup Sandstone Member	First producing sandstone in are	Fraction of Mine water may infiltrate from Alluvium into Gallup and back under Mine Site **14K-586**			Two areas impacted : Zone 1 – Plume stable, remedy suspended; MNA proposed and Zone 3 – Plume migrating towards north **15T-303**	
Westwater Canyon Sandstone Member	Ore body aquifer	Large radius of influence may have resulted in change of geochemistry which could increase Uranium dissolution rates **NECR Mine Well; Mill Well**	Waste placed back in ore body **NECR Mine Well; Mill Well**			

Table 3. Summary of Groundwater Sampling Results

Geologic Formation	Well ID/ Sample ID	Sample Date**	Radionuclides: Total Uranium (pCi/L)	Uranium (mg/L)	Radium-226 (pCi/L)	Radium-228 (pCi/L)	Radium-226 + Radium 228 (pCi/L)	Gross Alpha (pCi/L)	Gross Alpha excluding U (pCi/L)	General Chemistry: TDS (mg/L)	Conductivity	Field pH	pH	Arsenic (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)
Alluvium	16K-336 (Puerco North Fork; Superman 2)	Sep-53	--	--	--	--	--	--	--	832	1,330	--	--	--	91	0.3
		26-Mar-74	--	--	--	--	--	--	--	892	1,380	--	8.2	<10 (trace)	136.41	**13.02**
		29-Oct-03	0.38	0.57	0.83	0.30	1.13	5.9	--	888	--	8.05	--	6	122.0	--
		01-Oct-08	--	0.80	0.40	0.67	1.07	--	--	904	--	--	--	--	158.0	7
		09-Oct-10	0.402		1.20	4.58	**5.78**	0.129		1,000	150		7	**11**	118	2.89
	16K-340 (1081954)	22-Jun-54									1,810				310	**13**
		02-May-72	--	--	--	--	--	--	--	1,423	2,190	--	8.3	--	490	**20**
		26-Mar-74									2,100	8			500	**20**
		06-Oct-76		2.1	0.52			<18			**2,300**				**520**	
		20-Sep-77	--	2.4	--	--	--	--	--	--	2,150	--	7.1	--	--	--
		01-Aug-79		<5.0				<5.4			2,130	7.30		<5	460	
		24-Mar-82		<5.0							1,850	7.40	8.3	26.00	550	
		09-Dec-82		<5.0				4.70			2,020	7.90		12.00	580	
		29-Oct-03	1.96	2.92	0.40	0.40	0.80	nd	--	1,469	--	8.16	--	<5	419	--
		Oct-09[b]	--	2.20	--	0.34	--	--	--	--	--	--	--	--	--	--
		09-Oct-10	1.812		0.464	0.747	1.2	5.46		1200	190		7.6	8.5	368	5.97
Gallup	14K-586 (Friendship-1; 14T-586)	12-Apr-76	--	--	--	--	--	--	--	4,890	1,690	--	8.0	--	581	trace
		17-May-78	--	2 [a]	1.2 [a]	2 [a]	3.2 [a]	--	--	--	--	--	--	--	--	--
		06-Mar-79	--	--	--	--	--	<17	--	--	--	--	--	<5	--	0.5
		31-Jul-79	--	--	--	--	--	<5	--	--	--	--	--	--	--	--
		07-Nov-79	--	--	--	--	--	<3	--	--	--	--	--	--	--	--
		11-Feb-80	--		--	--		<4	--	--	2,134	--	7.87	--	887	--
		30-May-85	--	--	--	--	--	--	--	922	--	7	7.3	**23.9**	1042	0.42
		18-Jul-85	--	--	--	--	--	<2	--	--	--	--	--	--	--	--
		17-Mar-88	--	--	--	--	--		--	--	--	--	--	--	886	--
		05-Aug-03	--	3	2.60	--	--	10.80	--	2,136	--	8.07	--	8	1097	--
		Feb - Mar 2008	--	2	1.19	2	3.44	7.85	7	1,810	2,250	6.98	8	1	--	<0.3
		09-Oct-10	2.474		0.88	3.41		2.62		1,700	2,600		7.1	5.00	1380	0.267
	15T-303* (Pipeline Cyn.)	Jun-55								2,450	3,120				520	0.6
		24-Sep-87	--	--	1.6 ± 0.1	0 ± 1	--	-5.1 ± 3.2	--	2,593	1910	8.00	7.20	<5	1770	0.24
		28-Oct-03	0.46	0.69	0.47	1.50	--	4.0	--	3,043	--	8.13	--	<5	1940	--
		Feb - Mar 2008	--	0.38	1.19	3.73	4.9	0.9	1	2,528	2,890	7.20	7	1	--	<0.3
		09-Oct-10	0.978		1.18	3.34	4.52	-0.526		2,200	3,500		6.8	7.54	2000	0.100

N:\Projects\2010 Projects\2010-202_EPA_NEChurchRock_GWResearch\B_Originals\Table 3.xls

ERRG

Table 3. Summary of Groundwater Sampling Results

Geologic Formation	Well ID/ Sample ID	Sample Date**	Radionuclides							General Chemistry						
			Total Uranium (pCi/L)	Uranium (mg/L)	Radium-226 (pCi/L)	Radium-228 (pCi/L)	Radium-226 + Radium 228 (pCi/L)	Gross Alpha (pCi/L)	Gross Alpha excluding U (pCi/L)	TDS (mg/L)	Conductivity	Field pH	pH	Arsenic (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)
Westwater Canyon Member	Mine Well Mine Wtaer	Nov-73	--	--	--	--	--	--	--	412	663	--	--	--	110	--
		13-Feb-79		1.25	76.7	1				552			8.4	10	77	0.7
		14-Feb-79		0.725	103	1				421			8.4	<10	79	1.2
		16-Feb-79		2.07	0.6	5				415			7.98	<10	81	0.7
		17-Feb-79		2.1	49.3	<1				483			8.2	<10	76	0.5
		21-Feb-79		0.96	82	<1				386			8.19	<10	73	0.4
		27-Feb-79		3.71	155	<1				383			7.42	<10	70	0.5
		14-Mar-79		1.57	67	<1				386			7.2	<10	70	0.5
		27-Mar-79		1.53	89.8	2				404			8	<10	76	0.5
		11-Apr-79		2.29	22	5				380.5			7.59	<10	75.8	**13**
		2-May-79		1.7	11.2	--				370.5			8.45	--	73.3	1.0
		11-Jun-79		3.62	36.1	5.2				449.6			7.94	**11.8**	111.5	<0.1
		30-Apr-80		2.84	490	<1				381.0			8		71	
		16-Jul-80		2.7	86.1	1.3				538			6.7		272	
		2-Jun-81		1.9												
		17-May-04		0.1	2.4	<1		**93**		1,150			**9.9**	<10	450	
	Mill Well I	12-Aug-76	--							335			7.98	1	32	5
		9-Oct-84	--	**65**	1.8	--	--	**43**	--	228	--	--	8.49	1	17.7	--
		23-Apr-92	--	0.576	0.4	2		2		292			**8.83**	4	33.3	0.1
		28-Jul-93	--	2	1.6	1.4	3	1.8	--	2258	--	--	8.5	1.0	1260.0	0.1
		3rd Quarter 1998	--	**65**	--	--	<0.2	--	--	--	--	--	--	--	--	--
		4th Quarter 1998	--	1	--	--	<0.2	--	--	--	--	--	--	--	--	--
		1st Quarter 1999	--	**48**	--	--	<0.2	--	--	--	--	--	--	--	--	--
		2nd Quarter 1999	--	**33**	--	--	<0.2	--	--	--	--	--	--	--	--	--
		18-Jun-02	--	**70**	0.7	2.7	3.4	1	--	2,090	--	--	8.34	1	1,100	0.1
		Feb-06	--	8.1	--	--	2.4	--	--	--	--	--	--	--	--	--
		Sep-10	--	3	0.92	1.7	2.6	--	1.7	2240	--	--	**8.8**	<1	1270	<0.1
		09-Oct-10	5.604		0.639	1.77		9.79		2,300	360		7.4	5.0	1,460	0.100
MCLs			ne	30	ne	ne	5	15	15	500[b]	ne	6.5 to 8.5	6.5 to 8.5	10	250[b]	10

Notes:

a = Radio isotope data for Well 14K-586 is a compilation of data from the same formation former nearby wells.
b = secondary MCL
Values in **bold** exceed MCLs.
MCLs = maximum contaminant levels
mg/L = milligrams per liter

nd = non-detect (detection limit not available)
pCi/L = picoCuries per liter
TDS = total dissolved solids
-- = not analyzed for
<0.5 = not detected at concentrations greater than the laboratory reporting limit of 0.5 µg/L.
µg/L = micrograms per liter

Appendix A. Historic Select Well Groundwater Data