Updated Baseline Human Health Risk Assessment

March 2011

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

CHESTER ENGINEERS

United Nuclear Corporation

Gallup, New Mexico

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Project No.: 11-6209-SC-111

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List of Acronyms and Abbreviations

ACL	alternate concentration limit
ALARA	as low as reasonably achievable
ARARs	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	chemical of potential concern
COC	chemical of concern
CRUMP	Church Rock Uranium Mining Project
CSF	cancer slope factor
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
FS	feasibility study
ft/yr	feet per year
gpm	gallons per minute
GWPS	NRC Source Materials License groundwater protection standards
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
IC	institutional control
IUR	inhalation unit risk
L/day	Liters per day
L/m^3	Liters per meters cubed
MCL	federal primary maximum contaminant level
m^3/hr	meters cubed per hour
m^3/day	meters cubed per day
mg/L	milligrams per liter
mg/kg-d	milligrams per kilogram per day
MNA	monitored natural attenuation
MOU	Memorandum of Understanding
NA	natural attenuation
NCP	National Contingency Plan
NMED	New Mexico Environment Department

List of Acronyms and Abbreviations

NNEPA	Navajo Nation Environmental Protection Agency
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
pCi/L	picocuries per liter
POC	point of compliance
POE	point of exposure
PLSS	public land survey system
PRG	preliminary remediation goals
RAGS	Risk Assessment Guidelines for Superfund
RAO	remedial action objective
RfD	reference dose
RME	reasonable maximum exposure
ROD	Record of Decision
SF	slope factor
SFS	supplemental feasibility study
SWSFS	site-wide supplemental feasibility study
SMCL	federal secondary maximum contaminant level
TDS	total dissolved solids
TTHMs	total trihalomethanes
TI	technical impracticability
UCL95	upper confidence limit on the mean at the 95% confidence level
UMTRCA	Uranium Mill Tailings Radiation Control Act
µg/L	micrograms per liter

Section 1

Introduction

On behalf of United Nuclear Corporation (UNC), Chester Engineers has prepared this updated baseline human health risk assessment (HHRA) for UNC's Church Rock Mill and Tailings Site (hereinafter the Site or Church Rock Site) near Gallup, New Mexico. The previous baseline risk assessment, called the Public Health Assessment (PHA), was completed as Chapter 4 of the original Feasibility Study (EPA, 1988b), to assess the potential hazards to public health associated with the release or threat of release of hazardous substances from the Site. Much of the content in this updated HHRA has been developed addressing specific sections of the Environmental Protection Agency's (EPA's) comment letter of September 2, 2010 (EPA, 2010a) and in accordance with the approach presented in a conference call held on November 1, 2010, with EPA, the United States Nuclear Regulatory Commission (NRC), the New Mexico Environment Department (NMED), and the Navajo Nation Environmental Protection Agency (NNEPA).

1.1 Site Location, Description, and Background

1.1.1 Site Location

The Church Rock Site is located approximately 17 miles northeast of Church Rock, McKinley County, New Mexico (see Figure 1). The Site comprises two Sections (i.e., as described using the Public Land Survey System [PLSS]) owned by UNC: Section 2 of New Mexico Township 16 North, Range 16 West (known hereinafter as Section 2) and Section 36 of New Mexico Township 17 North Range 16 West (known hereinafter as Section 36). Section 2 contains the former uranium ore processing mill facilities and a byproduct material (tailings) disposal site (hereinafter tailings impoundments or tailings site), which cover about 25 and 100 acres, respectively. Section 36 adjoins the southern border of the Navajo Reservation.

The area surrounding the Site is sparsely populated and the primary land use is grazing for sheep, cattle, and horses. Two underground uranium mines were formerly operated in the vicinity of the Site. UNC operated the former Northeast Church Rock (NECR) mine, which is located to the northwest and adjacent to the Site, and Quivira (formerly Kerr-McGee) operated a mine to the north of the Site (Figure 2).

1.1.2 Site Operational History

The UNC uranium mill was operated from 1977 to 1982. Uranium ore was processed at the facility using a combination of crushing, grinding, and acid-leach solvent extraction methods. The milling operation produced an acidic slurry of ground rock and fluid (tailings) that was pumped into the tailings impoundments, into which an estimated 3.5 million tons of tailings were disposed. Details of the Site operational history have been summarized in EPA (2008), N.A. Water Systems (2008d), and Chester Engineers (2011).

From approximately 1969 to 1986, large volumes of groundwater were pumped from the nearby NECR and Quivira mines to dewater the underground workings. This mine water was discharged to the local arroyo (known as Pipeline Arroyo), which runs through the Site. A portion of the mine discharge water infiltrated into the subsurface and significantly saturated the near-surface alluvium and Zone 1 and Zone 3 of the Upper Gallup Sandstone Formation. As designated in the Record of Decision (ROD; EPA, 1988c), this infiltrated water represents the background groundwater conditions for the Site (i.e., the groundwater present prior to tailings disposal which is known alternatively as (1) post-mining, pre-tailings water, (2) anthropogenic background groundwater, or (3) background groundwater).

Acidic tailing liquids from the tailings impoundments seeped into the Southwest Alluvium and the Zone 1 and Zone 3 bedrock units of the Upper Gallup Sandstone Formation. The tailings-impacted groundwater may have relatively low (acidic) pH and elevated concentrations of certain heavy metals, radionuclides, sulfate, and total dissolved solids (TDS).

1.1.3 Site Regulatory and Remediation History

EPA listed the Site on the National Priorities List (NPL) of Superfund sites in September 1983 and conducted a Site Remedial Investigation (RI) and Feasibility Study (FS) from 1984 through 1988. The RI report (EPA, 1988a) concluded that tailings seepage had contaminated the background water in the Southwest Alluvium, Zone 1, and Zone 3.

A Public Health Assessment (PHA) was completed as Chapter 4 of the FS (EPA, 1988b), to assess the potential hazards to public health associated with the release or threat of release of hazardous substances from the Site. Following the EPA's original PHA, this risk assessment addresses each hydrostratigraphic unit separately. The ROD (EPA, 1988c) indicates that although there was no exposure at that time to local residents from ingestion of groundwater in domestic and livestock wells within four miles of the site, EPA concluded that adverse health or environmental hazards could result in the future if no action was taken to prevent exposure to groundwater contaminants found at the Site. These conclusions were based on the assumed ingestion, of non-potable background and impacted well waters, having constituent concentrations measured during the 1985 RI sampling in Sections 1, 3, 36, and a few locations in Section 2. However, groundwater use beneath Sections 2 and 36 will be permanently precluded by the Uranium Mill Tailings Radiation Control Act (UMTRCA, discussed more below); groundwater use in Section 1 (Zone 1) is precluded by limited saturated thickness and non-potable quality; and groundwater use in Section 3 (Southwest Alluvium) is precluded by non-potable quality.

In the PHA, EPA indicated their analysis was conservative because dilution, dispersion, and natural attenuation were expected to reduce concentrations, from those assumed, if seepage continued to migrate downgradient from the Site (EPA, 1988b).

Under a 1988 Memorandum of Understanding (MOU) between EPA and the NRC (53 Fed. Reg. 37887 [September 28, 1988]), NRC is designated the lead federal agency responsible for regulating the reclamation and closure activities completed at the tailings impoundments pursuant to the NRC's Source Materials License SUA-1475 (License) and the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978, 42 U.S.C. §7901 et seq. Under the MOU, the NRC-regulated reclamation and source control actions are subject to EPA monitoring and review to ensure that such actions will allow attainment of the CERCLA requirements outside of the tailings impoundments. NRC assumes responsibility within the licensed area (within Section 2, containing the tailings disposal area); EPA assumes responsibility for groundwater offsite (outside of Section 2).

The remedy selected for the Site by EPA in the 1988 ROD was groundwater extraction and evaporation, along with groundwater monitoring. The ROD required groundwater extraction in the Southwest Alluvium, Zone 1, and Zone 3 hydrostratigraphic units to limit further migration of tailings-impacted water. Once the reclamation and remediation activities are complete, the tailings disposal impoundments and associated property will be transferred to the U.S. Department of Energy (DOE) for long-term control and surveillance monitoring.

Between 1999 and 2001, extraction well operation in Zone 1 was permanently stopped as declining groundwater levels reduced extraction efficiency to rates beneath the minimum needed for pumping as defined by the Source Materials License; it was temporarily stopped in Zone 3 because pumping was found to inadvertently accelerate contaminant transport away from the Site towards the northwest; and a natural attenuation test initiated in the Southwest Alluvium has continued to the present. Starting in 2005, extraction well pumping in Zone 3 was done under a revised pumping regime. UNC continues to revise and improve upon the Zone 3 remedial system and has recently installed the first injection well just downgradient of the northern edge of impact in Zone 3, to serve as a hydraulic barrier, and the injected water will be amended with alkalinity in order to stabilize the tailings-impacted water in situ. Pumping in Zone 3 continues to be characterized by very small, and diminishing, well yields. This results in limited ability to hydraulically control the groundwater flow that is governed by the dipping bedrock slope which controls the elevation heads.

There is a long history of remedy performance monitoring at the Site. The groundwater performance monitoring plan was originally described by the Corrective Action Plan (UNC, 1989a), Remedial Design Report (Canonie Environmental Services Corp. [Canonie], 1989a) and Remedial Action Plan (UNC, 1989b). The program has been modified over time, as described in the annual reports (Canonie, 1989b, 1990, 1991, 1992, 1993 and 1995; Smith Technology, 1995 and 1996; Rust, 1997; Earth Tech, 1998, 1999, 2000, 2002a and 2002b; USFilter, 2004a; N.A. Water Systems, 2004, 2005, 2007a, 2008a; Chester Engineers, 2009, 2010, and 2011), to adjust the monitoring requirements as the corrective action has progressed. The compliance monitoring program is required under Condition No. 30 of the NRC Source Materials License. Figure 2 is a Site map that shows the location of the performance monitoring wells, the decommissioned and temporarily idled extraction wells, the evaporation ponds, and the reclaimed tailings areas. Figure 2 also shows the Remedial Action Target Area for each hydrostratigraphic unit, where the impacts of tailings seepage were originally identified and corrective action was implemented (EPA, 1988c) (although the target areas shown for Zone 1 were refined on the basis of pH and isoconcentration mapping (Canonie, 1989a)).

Three CERCLA Five-Year Reviews have been completed to date; the most recent was issued in September 2008 (EPA, 2008). The third Five-Year Review concluded that the Site remedy is, ". . . currently considered protective of human health and the environment because there is no evidence that there is exposure;" however, ". . . there remains the question as to the long-term protectiveness of the Site ground-water operable remedy" (EPA, 2008, from the related Memorandum of Approval in the front of the report). For this reason, EPA has asked UNC to complete a Site-Wide Supplemental Feasibility Study (SWSFS) to review and develop potential remedial alternatives (including alternatives to restrict exposure to contaminated groundwater). EPA has also required that UNC prepare an updated baseline human health risk assessment (i.e., this HHRA document) to support the SWSFS remedy re-evaluation.

1.2 Scope of Risk Assessment

1.2.1 Site-Specific Risk Assessment Objectives

The objective of a human health risk assessment is to evaluate the likelihood of adverse effects occurring in human populations potentially exposed to contaminants released in the environment. As described in the EPA's September 2, 2010, comment letter (EPA, 2010a), the site-specific objectives for preparing an updated HHRA for the UNC Church Rock Mill and Tailings Site are the following:

1. Update the risk estimates for the Site using current risk assessment methods and information;
    - Comment 18 indicates that the "historic assessment may no longer provide adequate assessment of the risk under current Site conditions."
    - Comment 18 indicates that the "risk assessment needs to be updated to address the carcinogenic and non- carcinogenic risk posed by the COCs [Chemicals of Concern], including both radiologic and non-radiologic COCs. The updated assessment should include relevant Risk Assessment Guidance for Superfund (RAGS) revisions, applicable exposure pathways (e.g., dermal (RAGS E) and inhalation (RAGS F), and current toxicological information for each COC."
2. Support the reassessment of remediation levels;
    - Comment 17 states that "Part of the SWSFS is to reassess existing or baseline remediation standards or levels set forth in EPA's 1988 ROD and potential changes to those remediation levels that may be necessary to ensure the protectiveness of the remedy. Protection of human health should be discussed in terms of cancer and non-cancer risk associated with exposure to ground water."
3. Provide a basis for comparing remedial alternatives;
    - Comment 17 states that "Knowing the risk posed by ground water exposure will assist in the evaluation of alternatives with respect to demonstrating the potential

for achieving the RAOs [Remedial Action Objectives] and ground water protection standards established at the Site; protection of human health; long-term and short-term effectiveness; and reduction in toxicity, mobility, and volume."

4. Identify Point of Compliance (POC) and Point of Exposure (POE) concentrations in accordance with NRC requirements;
   - Comment 18 indicates that the exposure assessment component of the risk assessment should "determine the maximum permissible levels of COCs at the POC that are protective of human health and the environment at the POE."

The principal focus of the HHRA is the assumed future exposure to groundwater contaminants residing in all three of the hydrostratigraphic units. Because the hydrogeologic characteristics, COPCs, and remedial alternatives for each of the units are distinct, the risks of potential future exposure to groundwater in each of the units have been evaluated separately.

1.2.2 Risk Assessment Approach

This updated HHRA report has been prepared in the format of a baseline risk assessment in accordance with current EPA guidelines for risk assessment including relevant revisions to RAGS and statistical procedures (e.g., EPA 1989, 1991a, 2001b, 2004, 2007, 2009). According to EPA (1989), HHRAs comprise the following four principal steps:

1. Data Collection and Evaluation – gathering and analyzing the Site data relevant to the human health evaluation and identifying the substances that are the focus of the risk assessment process (i.e., the Chemicals of Potential Concern [COPCs]). For the Church Rock Site, much of this work had been previously completed and approved by EPA; however, additional screening was conducted to select the final list of contaminants for inclusion in the risk analysis.

2. Exposure Assessment – estimating the magnitude of the actual and/or potential human exposures, the frequency and duration of these exposures and the pathways by which humans are potentially exposed. The results of this assessment are quantitative pathway-specific intakes for exposures to individual substances. For the Church Rock Site, the exposure assessment focused on a potential future exposure to groundwater outside UNC-owned property (Sections 2 and 36), because there is no current exposure and no potential future exposure to groundwater contaminants on UNC-owned property.

3. Toxicity Assessment - The toxicity assessment component considers (1) the types of adverse health effects associated with chemical exposures, (2) the relationship between the magnitude of exposure and adverse effects, and (3) related uncertainties such as the weight of evidence of a particular chemical's carcinogenicity in humans. For the Church Rock Site, the toxicity assessment was based on existing toxicity information available from EPA and other sources, including information regarding carcinogenic and non-carcinogenic effects associated with radionuclide and non-radionuclide COPCs.

4. Risk Characterization - The risk characterization step summarizes and combines outputs of the exposure and toxicity assessments to characterize risk in a set of quantitative and qualitative statements. For the Church Rock Site, this includes the consideration of risks associated with background groundwater COPC concentrations and the uncertainties associated with the risk assessment process.

1.3 Report Organization

The rest of this HHRA report is organized in a manner that generally corresponds to the risk assessment steps described in Section 1.2.2:

Section 2 Identification of Chemicals of Potential Concern

Section 3 Exposure Assessment

Section 4 Toxicity Assessment

Section 5 Risk Characterization

Section 6 Uncertainty Analysis

Section 7 Risk Assessment Summary

Section 8 References

Risk assessment calculations have been prepared following the Risk Assessment Guidance for Superfund: Volume I: Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments; EPA, 2001b) and are documented using the RAGS Tables 1 to 10 format (i.e., the EPA RAGS Part D risk assessment summary tables) in Appendix A. Additionally, site-specific reference documents related to exposure assessment are provided on CD in Appendices B through D.

Section 2

Identification of Chemicals of Potential Concern

2.1 Overview of Site-Specific Data Evaluation Considerations

The principal focus of the Church Rock Site HHRA is the assumption of potential future exposure to seepage-impacted groundwater contaminants in each of the three hydrostratigraphic units (i.e., Southwest Alluvium, Zone 1, and Zone 3) at locations outside Section 2. However, groundwater use in Section 1 (Zone 1) is precluded by limited saturated thickness and non-potable quality, and groundwater use in Section 3 (Southwest Alluvium) is precluded by non-potable quality (discussed further below).

Because the hydrogeologic characteristics, contaminants, and remedial alternatives for each of the units are distinct, the risks of potential future exposure to groundwater in each of the units have been evaluated separately and COPCs have been selected for each unit. The COPCs are screened to derive the sets of COCs in Section 7 (Risk Assessment Summary).

2.2 Process to Select Chemicals of Potential Concern

A COPC selection process was used to focus the quantitative risk assessment on chemicals and radionuclides that pose the greatest risks to human health. Tabulated risk screening levels were used to evaluate groundwater performance monitoring data to select risk assessment COPCs for each of the hydrostratigraphic units.

The groundwater performance monitoring program was established at the Site on the basis of the Site Remedial Investigation/Feasibility Study (RI/FS) activities and NRC License conditions and has been ongoing, with approved modifications, for 22 years. Modifications have been made to the program over time, including the elimination of certain monitoring parameters that were no longer considered relevant to the remedy implementation (e.g., a set of trace metals plus iron); these historical monitoring parameters were not considered as potential COPCs for the quantitative risk estimates because (1) the data were not current and (2) EPA and NRC concurred with their deletion from the monitoring program. In contrast, the individual isotopes of uranium are of interest for risk calculations, but historically have not been part of the performance monitoring program. In this situation, simplifying assumptions were made so that exposure to the uranium isotopes could be evaluated in the HHRA and to reduce the chance that potential human health risk is underestimated. However, it should be acknowledged that these assumptions could result in an overestimation of risk because the actual uranium isotope activities are not known. The effects of these issues are considered in the discussion of uncertainties presented in Section 6.

For the Church Rock Site HHRA, it was necessary to identify a subset of the historic groundwater performance monitoring data that were representative of seepage-impacted groundwater under current Site conditions, had adequate data quality, and for which exposure point concentrations (EPCs) could be statistically estimated. This evaluation was performed by UNC at EPA's request in 2008 (N.A. Water Systems, 2008c) for each of the hydrostratigraphic units, and was subsequently approved by EPA. Comparable statistical estimates of background constituent concentrations were also made in a separate analysis (N.A. Water Systems, 2008b). The reports of these analyses are provided in Appendices A and B (on CD). Additional screening was subsequently conducted to select the risk assessment COPCs for inclusion in the Church Rock Site HHRA; this process is described below.

The following steps were used to select the risk assessment COPCs for each of the stratigraphic units.

1. Monitoring period selection, monitoring well selection, and statistical data evaluation. This data reduction step was completed in a 2008 report by UNC (N.A. Water Systems, 2008c).
   a. An eight-quarter period (July 2006 through April 2008 inclusive) of performance monitoring data was selected as representative of current conditions. This period comprised the most recent eight quarters of sampling available at the time of the calculations. The performance monitoring program COPCs included 23 analytes (Table 1 of this report).
   b. Monitoring data from the eight-quarter period were reviewed in each hydrostratigraphic unit to identify the wells in which tailings seepage-impacted groundwater was present. Groundwater that was representative of tailings seepage-impacted groundwater was discriminated from non-impacted (i.e., background) groundwater based on water quality including indicator parameter concentrations (e.g., pH or bicarbonate concentrations). The wells selected for each hydrostratigraphic unit are shown in Table 2 of this report.
   c. Statistical analyses were performed, using ProUCL (EPA, 2007) to calculate the 95th percentile upper confidence limit of the mean (UCL95) for the performance monitoring COPCs (Table 1) for tailings seepage-impacted groundwater in each of the three hydrostratigraphic units (N.A. Water Systems, 2008c). Many of the calculated UCL95 are utilized as EPCs for COPCs in the exposure assessment step of the HHRA. Statistical analyses were not completed for historical monitoring parameters comprising several trace metals and iron (Table 1). These historical monitoring parameters were eliminated from further consideration in the quantitative risk assessment. These parameters are characterized by very low concentrations and toxicities, and their potential effect with respect to risk calculation is addressed in the uncertainty analysis in Section 6.
2. Monitoring COPCs representing common ions (i.e., sulfate, chloride, nitrate-nitrogen), general chemistry parameters (i.e., total dissolved solids), and groups of multiple parameters (i.e., gross alpha, total radium) were eliminated from further consideration in the quantitative risk assessment calculations. The potential effect of these parameters with respect to risk calculation is addressed in the uncertainty analysis in Section 6.

3. Monitoring COPCs with no detected values during the eight quarter monitoring period were eliminated from further consideration in the quantitative risk assessment. The remaining monitoring COPCs were retained for further evaluation in the quantitative risk assessment and the EPC was estimated or assigned using other means.

4. Estimation of uranium isotope concentrations – total uranium mass concentrations are reported for groundwater samples, but there is no site-specific information regarding the abundance of the individual isotopes that can be used to evaluate the radioactive carcinogenic risk of uranium at the Site. Therefore, the activities of the three major uranium isotopes (U-234, U-235, and U-238) in groundwater within each hydrostratigraphic unit were estimated from the total uranium mass concentrations using the assumption that the isotopes were present in proportion to their natural abundance.

5. Screening process – Consistent with EPA risk assessment guidance (e.g., EPA, 2001b) a screening process was employed to further focus the COPC selection for quantitative evaluation in the risk assessment for each of the three hydrostratigraphic units. The screening process varied according to the contaminant type, as follows:

   a. Non-radionuclides

      - The non-radiologic, non-carcinogenic analytes with maximum concentrations exceeding 0.1 times the EPA Risk Screening Level (RSL) for the tapwater ingestion plus inhalation exposure pathways (i.e., a target hazard quotient (HQ) of 0.1) were retained as COPCs in the quantitative risk assessment. The use of a target HQ of 0.1 as a screening level accounts for the potential exposure to multiple constituents.

      - The non-radiologic carcinogenic analytes with maximum concentrations exceeding the EPA RSLs, compiled on the November 2010 EPA Risk Screening Level Table (EPA, 2010b) for the tapwater ingestion and inhalation exposure pathways (set at a target risk level of 1E-06), were retained as COPCs in the quantitative risk assessment.

      - All non-radiologic, non-carcinogenic analytes that were retained as COPCs for the tapwater ingestion exposure pathway were also retained for the dermal exposure pathway. This represents a conservative measure, because EPA guidance for the dermal-water exposure pathway requires only those chemicals which contribute a significant dose relative to the oral exposure pathway (EPA, 2004) be retained.

      - Non-radiologic analytes that were retained for the tapwater inhalation pathway were restricted to volatile organic compounds (i.e., organic compounds with a Henry's Law Constant greater than 1E-05 atm -

m^3/mole and a molecular weight of less than 200 g/mole (EPA, 2010b)). The only Site analyte that met these criteria was chloroform.

- Uranium has chemical toxicity as well as radiotoxicity and was retained as a non-carcinogenic COPC in the quantitative risk assessment in those hydrostratigraphic units where the maximum concentrations exceeded 0.1 times the RSL for the tapwater ingestion and dermal exposure pathways (i.e., a target HQ of 0.1).

b. Radionuclides

- All detected radiologic analytes were retained as COPCs in the quantitative risk assessment. In addition, the uranium isotopes for which activities were estimated from total uranium mass concentrations and were retained in as COPCs.
- The skin is generally an effective barrier against absorption of radionuclides and the dermal absorption exposure pathway is considered very minor with respect to other exposure routes, such as ingestion. Therefore, radionuclides were not retained as COPCs under the dermal exposure pathway.
- The only radiologic analytes that were retained for the tapwater inhalation pathway in the risk assessment were those for which EPA has included the inhalation pathway in the calculation of its radionuclide Preliminary Remediation Goals (PRGs). The only Site analyte that met this criterion was radium-226, for which the decay product is the gas radon-222.

A summary of the data evaluated and the COPCs selected for each hydrostratigraphic unit is provided in Section 2.4.

2.3 Relationship of Background COPC Concentrations to COPC Screening Process

The chemistry of the background groundwater in each of the hydrostratigraphic units is well known and is not considered suitable for use as a drinking water source. Sulfate and TDS, which are non-hazardous constituents, have exceeded New Mexico groundwater quality standards in the background water in each of the hydrostratigraphic units (Chester Engineers, 2011). Because the sulfate concentrations are controlled by geochemical equilibrium with gypsum (or anhydrite) and calcite, they are irreducible in the background water. Exceedances of these and other COPCs have been documented in the background water from each hydrostratigraphic unit.

Statistical estimates of upper confidence limits (UCL95s) for the population means of the background chemical concentrations have been calculated (N.A. Water Systems, 2008b) and approved by EPA. Background concentrations of some constituents equal or exceed concentrations in seepage-impacted groundwater. Where these background concentrations exceed applicable or relevant and appropriate requirements ARARs, background concentrations may be selected as cleanup levels. Additionally, a statistical evaluation of background water quality by NRC led to their recommendation that manganese, sulfate, and TDS should not be regulated site constituents and they should not be used as bases for corrective action (NRC, 1996). Consistent with EPA guidance regarding background concentrations (EPA, 2002), COPCs in seepage-impacted groundwater that are present in background groundwater have been included in the quantitative risk assessment calculations of the seepage-impacted groundwater. The resulting non-carcinogenic hazard and carcinogenic risk estimates (i.e., estimates which include background risk) may accurately quantify the total hazard and risk of exposure to groundwater, but may overestimate the risk associated with seepage-impacted groundwater. Therefore, background concentrations have been considered qualitatively and, in some cases, quantitatively in the risk characterization with respect to risk drivers and should be considered in any future reassessment of Site remediation levels. A discussion regarding uncertainties in the HHRA is presented in Section 6.

2.4 Summary of Selected Chemicals of Potential Concern

The wells included in the COPC selection evaluation for each hydrostratigraphic unit are listed in Table 2 and their locations are shown on Figure 2. For Zone 1 and Zone 3, wells that were within Section 2 were excluded from the calculations because Section 2 encompasses the tailings disposal area, which will eventually be transferred to the U.S. Department of Energy (DOE) for long-term care. This transfer will effectively eliminate the potential exposure to groundwater within this area. Furthermore, the high levels of seepage impact evident in Zone 1 and Zone 3 wells proximal to the tailings disposal cells are not expected to migrate and occupy areas outside of Section 2. This judgment is based on analysis of water-quality monitoring results from the past 22 years, and the conclusion that the tailings cells are no longer a source of measureable quantities of seepage fluid (USFilter, 2004b).

However, it was necessary to include data from seepage-impacted wells in Section 2 for the Southwest Alluvium dataset due to statistical limitations that were encountered when using only samples from outside Section 2.

The following subsections summarize the results of the EPC statistical analyses (N.A. Water Systems, 2008c) and the subsequent COPC screening process for each of the hydrostratigraphic units.

2.4.1 Southwest Alluvium COPCs

The HHRA COPCs for the Southwest Alluvium were selected as follows:

1. Seven monitoring parameters were eliminated from further consideration in the HHRA because they were not detected: beryllium, cadmium, lead, molybdenum, nickel, vanadium, and lead-210. Two parameters (cobalt and selenium) that were each detected only one time during the monitoring period were retained for further screening.

2. The remaining monitoring parameters were screened by comparing the maximum detected concentration against the toxicity screening values defined in Section 2.2. Aluminum and selenium were eliminated as risk assessment COPCs because their maximum concentrations were below the corresponding toxicity screening values. The results of the screening process are shown in Table 2.1 in Appendix A.

2.4.2 Zone 1 COPCs

The HHRA COPCs for Zone 1 were selected as follows:

1. Five monitoring parameters were eliminated from further consideration in the HHRA because they were not detected: beryllium, cadmium, lead, molybdenum, and lead-210. Two parameters (selenium and vanadium) that were each detected only one time during the monitoring period were retained for further screening.

2. The remaining monitoring parameters were screened by comparing the maximum detected concentration against the toxicity screening values defined in Section 2.2. Aluminum, nickel, selenium, and uranium were eliminated as risk assessment COPCs because their maximum concentrations were below the corresponding toxicity screening values. However, the uranium isotopes (for which activities are estimated from the uranium mass concentration) were retained for evaluation as radiologic carcinogens. The results of the screening process are shown in EPA risk assessment Table 2.1 in Appendix A.

2.4.3 Zone 3 COPCs

The HHRA COPCs for Zone 3 were selected as follows:

1. One monitoring parameter, lead, was eliminated from further consideration in the HHRA because it was not detected. Two parameters (selenium and vanadium) that were each detected only one time during the monitoring period were retained for further screening.

2. The remaining monitoring parameters were screened by comparing the maximum detected concentration against the toxicity screening values defined in Section 2.2. Selenium was eliminated as risk assessment COPC because its maximum concentration was below the corresponding toxicity screening value.

Section 3

Exposure Assessment

3.1 Characterization of Exposure Setting

The exposure assessment process is used to quantify the type and magnitude of the total exposure by potential receptors to COPCs across exposure pathway combinations. This section evaluates and documents the sources, receptors, exposure pathways, and exposure duration and frequency to quantify the human exposure to the Site risk assessment COPCs.

In their September 2, 2010 comments letter (EPA, 2010a), EPA stated that the updated risk assessment should include the following exposure assessment considerations:

- Information related to receptor population, expected land use, and ground water use in the vicinity of the Site (Comment 18).
- Relevant RAGS revisions, applicable exposure pathways (e.g., dermal (RAGS E) and inhalation (RAGS F)), and current toxicological information for each COC (Comment 18).
- A paragraph regarding the exposure routes and pathways [presented in SWSFS Part I], including potential exposure through the inhalation pathway associated with the evaporation ponds.

Each of the exposure assessment-related issues is addressed within this section of the report and the toxicological information is provided in Section 4.

3.1.1 Physical Setting

The Church Rock Site is located approximately 17 miles northeast of Church Rock, McKinley County, New Mexico. The local climate is arid, with approximately 10.6 inches of precipitation per year. The principal surface water feature in the vicinity of the Site is the Pipeline Arroyo (and Pipeline Canyon), which runs through the Site from northeast to southwest. Surface water flows in the arroyo seasonally and alluvium is present along the feature and its floodplain.

The Site is situated on alluvial valley fill, sandstone, and shale of Cretaceous age at the southern margin of the San Juan Basin. The stratigraphic units of interest at the Site are the three uppermost water-bearing units (i.e., hydrostratigraphic units) as follows (EPA, 2008):

1. Alluvium, which is located along Pipeline Arroyo, has a maximum thickness of approximately 150 ft and a maximum width of 4,000 ft;
2. Zone 3 (the uppermost stratigraphic unit of the Upper Gallup Sandstone, having a thickness of 70 to 90 ft in the area of the tailings impoundments); and
3. Zone 1 (the lowest stratigraphic unit of the Upper Gallup Sandstone, having a thickness of 80 to 90 ft in the area of the tailings impoundments).

There are three genetic classes of groundwater present in the vicinity of the Church Rock Site: (1) pre-mining water, (2) post-mining, pre-tailings water, and (3) tailings-seepage impacted groundwater. Pre-mining water is natural water that is present only in the Upper Gallup Formation north of UNC-owned property; this water does not underlie the Site and is not a focus of the HHRA. From approximately 1969 to 1986, large quantities of groundwater were pumped from the nearby NECR and Quivira mines to dewater the underground workings, and discharged to the Pipeline Arroyo. A portion of the mine discharge infiltrated into the alluvium and then into the Zone 3 and Zone 1 bedrock units. This water is referred to as the post-mining, pre-tailings water in the ROD which designated it as the background groundwater at the Site.

Seepage from the tailings, which were deposited in the impoundments beginning in 1977, subsequently impacted the Site background water. Impact from the tailings seepage has been observed in the alluvium to the west and southwest of the tailings impoundments (i.e., the Southwest Alluvium) and, because they are in contact with both the alluvium and the tailings in the vicinity of the impoundments, in Zone 3 and Zone 1 to the northeast and east of the impoundments (Figure 3).

3.1.2 Potentially Exposed Populations

Information related to the potential receptor population, current and expected land use, and groundwater use near the Church Rock Site has been used to identify potentially exposed populations and to develop and select exposure scenarios. Land use information is available in UNC's Annual Land Use Reports, which are prepared and submitted to NRC as a condition of UNC's NRC Source Materials License. The Annual Land Use Report for 2009 is provided in Appendix D (on CD).

Land use in the vicinity of the Site has not changed significantly in more than 30 years. The area surrounding the Site is sparsely populated and the primary land use is grazing for sheep, cattle, and horses. The 2009 Land Use Report indicates that there are a total of thirty-six home sites and eight wells within approximately two miles of the former mill site. Two of the wells listed in the 2009 Land Use Report are abandoned and two are used as monitoring wells. Only two of the wells are identified as having domestic use (including the Church Rock Site water supply well (the mill well, which is very deep and open to the Westwater Canyon Formation) and the Circle Wash Well (an alluvium well south of the Puerco River). Three wells, including the Circle Wash Well, the Friendship Well (14T-586) and Well 15K-303 are used for livestock watering, but due to their locations relative to hydraulic gradients, the first two wells cannot be impacted by seepage from the Church Rock Site. The Friendship well taps the Lower Gallup Formation. Well 15K-303, located more than two miles to the northeast of the mill Site, is the only local well known to tap the Upper Gallup Formation and is used for livestock watering; however, it is too distant to be impacted by seepage from the Church Rock Site, and the results of sampling (King, 2007) indicate the water has not been impacted by tailings seepage and it is unsuitable for human consumption. No residents have private wells for domestic water supply and many haul their own water from known (although often unregulated) sources for domestic supply and livestock watering. King (2007) cites the results of a 1999 survey by the Church

Rock Uranium Mining Project (CRUMP) which indicated that more than 80 percent of the nearby Churchrock Chapter residents haul water even when connected to a public water supply system. King (2007) also cites CRUMP groundwater monitoring data which indicate that the Friendship Well (Well 14T-586) was abandoned in 2003.

There is no current human exposure to groundwater at the Site (EPA, 2008) except during the quarterly groundwater sampling conducted by UNC personnel, and no potential future exposure to groundwater contaminants on UNC-owned property, because no groundwater supply wells drawing on any of the three hydrostratigraphic units will be allowed on UNC property, and the same restriction will apply once this property is turned over to the DOE for long-term surveillance monitoring.

Current potential effects on the ecology are mainly from the discharge of pumped water from Zone 3, and purged water from quarterly groundwater sampling, into the evaporation ponds on the South Cell. Illegally grazing stock have very rarely consumed water here but Site access is restricted according to the NRC License and key parts of the Site fencing have recently been physically strengthened, which has further decreased the rate of incursions.

Considering land ownership patterns and limited water availability, alternate future land use is unlikely, with the possible exception of additional mining-related activities such as in-situ leach mining. The assumed, potentially exposed populations to COPCs in groundwater, in the future residential exposure scenarios evaluated in this report, are those individuals that would use groundwater for domestic purposes from hypothetical wells overlying the seepage-impacted groundwater in locations just outside Section 2 (for the Southwest Alluvium and Zone 1) and just north of Section 36 (for Zone 3).

3.2 Identification of Exposure Pathways

Potential exposure pathways are identified to estimate the doses of contaminants to which populations may be exposed. The following four elements are necessary to identify a potentially complete exposure: (1) a source and mechanism of release of contaminants to the environment, (2) an environmental transport medium or mechanism of transfer of contaminants among environmental media, (3) a point of potential contact of humans to the contaminated medium, and (4) an identified route of exposure. An identified pathway indicates that the potential for exposure exists; it does not imply that exposures do or may actually occur.

3.2.1 Sources and Receiving Media

The source of the COPCs in the environment is the tailings impoundments and the only environmental medium impacted by the tailings is groundwater. Acidic tailings liquids seeped from the impoundments into the groundwater in the Southwest Alluvium, Zone 1, and Zone 3. The affected groundwater has relatively low (acidic) pH and elevated concentrations of certain heavy metals, radionuclides, sulfate, and total dissolved solids TDS. There is no local discharge of groundwater to surface water. Downdip to the north, the deep regional continuation of the Gallup Formation is inferred to leak upward and discharge to the San Juan River, which is approximately 150 miles from the Site (Stone, 1981; Raymondi and Conrad, 1983) and far beyond the potential reach of Site impacted groundwater). Source control and on-site surface reclamation activities conducted within Section 2 under the direction of the NRC (pursuant to the facility's NRC Source Materials License) have eliminated the potential COPC releases from the tailings impoundments to the atmosphere. Potential radionuclide emissions from the evaporation ponds are monitored within Section 2 under the direction of the NRC, pursuant to the facility's NRC Source Materials License, and are at acceptable levels.

3.2.2 Fate and Transport in Release Media

Seepage-impacted groundwater has slowly migrated from the tailings impoundments in each of three underlying affected hydrostratigraphic units (Southwest Alluvium, Zone 1, and Zone 3). The groundwater in the alluvium flows to the southwest beneath Pipeline Arroyo. The groundwater in both Zone 1 and 3 flows primarily in a north-northeasterly direction, following the direction of the bedrock dip. Therefore, tailings-seepage impact has been observed in the alluvium to the west and southwest of the tailings impoundments (i.e., the Southwest Alluvium) and in Zone 3 and Zone 1 to the northeast and east of the impoundments. The extent of seepage-impacted groundwater migration in October 2010 is shown in Figure 3 (Chester Engineers, 2011). Historically, the directions of groundwater flow in Zone 3 and Zone 1 were to the northeast and east, respectively, due to groundwater mounding in the overlying alluvium. These earlier flow directions are also reflected in the historical distribution of seepage impacts within these hydrostratigraphic units.

Currently, seepage impacts in the Southwest Alluvium extend beyond Section 2 into Sections 3 and 10, and seepage impacts in Zone 1 extend into Section 1. Seepage impacts in Zone 3 have been observed beyond Section 2 in Section 36, but have not migrated beyond the UNC property boundary to the north. Investigations are underway to explore the transport of seepage-impacted water beyond Section 36; for this risk assessment, it is presumed that seepage-impacted water could potentially migrate beyond the Section 36 boundary (so as to over-estimate possible risks). A portion of the Zone 3 seepage-impacted groundwater extends off the property into Section 1 (Figure 3); however, NRC has determined that this area is not a potential point-of-exposure (POE) because of limited and declining saturation (NRC, 1999).

Downgradient seepage-impacted water migration has been and is expected to continue to be limited by remediation activities and natural attenuation (Chester Engineers, 2011). In Zone 3, source control (neutralizing and later dewatering of the North Cell), neutralization of the seepage by natural attenuation, and active remediation have limited the migration of seepage impact. In Zone 1, COPC concentrations are attenuated by reactions between the bedrock matrix, and the tailings fluids. The natural system is successfully attenuating the seepage impacts by the processes of neutralization, precipitation, and adsorption. In Zone 1 and the Southwest Alluvium, natural geochemical attenuation has reduced COPC concentrations such that no hazardous constituents exceed Site standards (except for lead-210) outside the UNC property boundary within seepage-impacted water. An unexpectedly large number of detections and exceedances of lead-210 occurred in the laboratory analytical results for the samples collected in

October 2010 (further discussed in Chester Engineers, 2011). Off-site impacted groundwater in the Southwest Alluvium has quality that is equal to or better than the off-site background water quality; both types of groundwater are unsuitable for human consumption.

There is likely to be insufficient volumes of water available in Zones 1 and 3 for use as a potable water sources. In the ROD, EPA stated the following regarding the inaccessibility and unsuitability of Zone 1 for water supply wells: "EPA studies indicate that the physical characteristics of Zone 1 are such that sufficient quantities of water could not be pumped from the sandstone to support volumes required for domestic or livestock purposes. Therefore, Zone 1 would not be a good candidate for locating a domestic or livestock well even if there were no impacts from tailings seepage" (ROD, EPA 1988c, Appendix H [Responsiveness Summary], Response to Comment 9 in Section 2, p. 4). Recent studies related to the operation of the Zone 3 remediation pumping system indicate that the potential use of Zone 3 groundwater as a potable water source is also limited. Twenty-two years of remedial pumping have resulted in significant dewatering of Zone 3. The saturated thickness measured in Zone 3 wells has declined by 69 percent on average since the third quarter of 1989. Additionally, most of the Zone 3 pumping wells have reduced yields controlled by the following physical factors: (1) encrustation along the wellbore of iron oxyhydroxides, carbonates, and/or gypsum; (2) precipitation of amorphous aluminosilicates (e.g., well EPA 14); (3) alteration of feldspar to clays within the bedrock matrix; and (4) reduced saturated thicknesses (Chester Engineers, 2010). At some time in the future, there will be a balance between the tendency for the irreducible elevation head (caused by the bedrock dip) to promote the continuing northward migration of seepage-impacted water and the tendency for the seepage-induced permeability reductions (due to factor 3, listed above) to hold the groundwater in place. Moreover, the quantity of acidic tailings seepage water is fixed while the availability of alkalinity in Zone 3 is unlimited in comparison. It is inevitable that the tailings seepage will be fully neutralized by reactions with carbonate minerals in the Gallup Formation. The exact timing and location of the maximum extent of seepage-impacted water in Zone 3cannot be predicted with precision (e.g., Chester Engineers, 2011); however, it is reasonable to estimate that it would probably be on the order of hundreds of feet rather than thousands of feet. Therefore, setting a hypothetical groundwater exposure point immediately to the north of the Section 36 boundary represents the maximum potential exposure to Zone seepage-impacted groundwater.

3.2.3 Exposure Points and Exposure Routes

This section identifies the potential exposure points and exposure routes that make up the potential exposure pathways. As previously stated, groundwater is the only seepage-impacted medium, there is no current exposure to seepage-impacted groundwater (EPA, 2008) and there is no potential for future human exposure to groundwater in the property owned by UNC (Sections 2 and 36). Therefore, potential future exposure to seepage-impacted groundwater could occur only at exposure points outside Sections 2 and 36. Because each of the three hydrostratigraphic units have different water chemistries, likelihoods of exposure, and remedial alternatives, the following potential future groundwater exposure points at the UNC property boundary are selected for evaluation in the HHRA:

- Southwest Alluvium – a hypothetical future well located just west of the UNC property boundary in Section 3;
- Zone 1 – a hypothetical future well located just east of the UNC property boundary in Section 1; and
- Zone 3 – a hypothetical future well located just north of the UNC property boundary in Section 36.

It is unlikely that actual human exposure to seepage-impacted water using a domestic well will occur at any of the three hypothetical exposure points because both the background water and impacted water in each of the hydrostratigraphic units are not suitable for use as a primary drinking water source (e.g., due to sulfate and other chemicals that affect potability). Nonetheless, a hypothetical future residential land-use scenario represents the only conceivably possible exposure pathway to groundwater, given the current and anticipated future land use. The residential RME exposure scenario assumes that residents would construct residences and live adjacent to the UNC property boundary near the tailings impoundments for up to 30 years, and that residents would use seepage-impacted groundwater for all domestic water needs. Risk calculations based on this scenario will provide maximum estimates of the risk.

To assess the potential exposure of a hypothetical future resident, three exposure pathways were selected for evaluation:

- Ingestion of groundwater as the drinking water source;
- Direct dermal contact with groundwater through bathing; and
- Inhalation of volatile compounds in groundwater during showering exposure and other domestic tapwater uses.

A thirty year exposure period was evaluated, consistent EPA risk assessment guidance. A residential adult (aged 7-30) and a young child (aged 1 to 6) were selected as the potentially exposed populations for non-carcinogenic COPCs. A combined child/adult receptor was selected as the potentially exposed population for the carcinogenic COPCs, including radionuclides. EPA dermal risk assessment guidance (EPA, 2004) indicates that the age-adjusted child/adult receptor typically is the most sensitive receptor for cancer endpoints and the child typically is the most sensitive receptor for non-cancer endpoints. For non-carcinogenic compounds, groundwater exposure rates for children are higher than for adults because the ratio of intake rate to body weight is higher. For non-radionuclide carcinogens, the combined child/adult exposure scenario is conservative primarily because the combined intake for the child and adult (a larger intake than either a child or adult intake alone) is averaged over the lifetime of the receptor because of the assumption that cancer may develop even after actual exposure has ceased.

A second potential exposure scenario was considered: the hypothetical future secondary human exposure from consumption of meat or milk (i.e., food pathway) from livestock watered with groundwater that has been impacted by tailings seepage. This second scenario was excluded for the following reasons: (1) exposure would be insignificant compared to hypothetical use of impacted water as a domestic water supply; (2) the land use survey indicates it is not a current or anticipated future exposure pathway because there are no livestock watering wells that are currently, or anticipated to be, impacted by seepage, and (3) there is significant uncertainty related to exposure assumptions for this hypothetical exposure scenario (e.g., percentage of local consumption of local meat/milk products sourced from seepage-impacted area, likelihood that livestock would consume impacted water, and bioaccumulation factors). This determination was made with EPA during a teleconference on November 1, 2010.

3.3 Quantification of Exposure

3.3.1 Exposure Point Concentrations

Statistical analyses were performed using ProUCL (EPA, 2007) to verify the statistical distribution of COPC concentrations in groundwater in each of the hydrostratigraphic units and to estimate an EPC for each COPC. The statistical analyses are described in the EPA-approved submittal (N.A. Water Systems, 2008c), which is attached as Appendix B (on CD).

The EPC is the concentration term used in the exposure equations and represents the average COPC concentration that is contacted over the exposure period. Because of the uncertainty associated with estimating the true average COPC concentrations, the 95 percent upper confidence limit of the arithmetic mean (UCL95) is used to represent this variable when calculating the reasonable maximum exposure (RME) for selected exposure scenarios. As part of the analysis, the statistical distribution (i.e., normal, log-normal, or non-parametric) represented by the data was determined so that the proper statistical test could be applied to calculate the appropriate UCL95. The UCL95 provides reasonable confidence that the true Site average concentration will not be underestimated.

The EPCs calculated for the exposure scenarios for each hydrostratigraphic unit are shown on Table 3.1.RME and Table 3.2.RME in Appendix A. As described in Section 2.2, total uranium mass concentrations are analyzed and reported for Church Rock Site groundwater samples, but there is no site-specific data regarding the abundance of the individual uranium isotopes to evaluate the radioactive carcinogenic risk of uranium at the Site. Therefore, the EPCs shown for the three major uranium isotopes (U-234, U-235, and U-238) in groundwater (pCi/L) were estimated from the total uranium mass concentrations (mg/L) using the assumption that the isotopes were present in proportion to their natural abundance. The calculations are shown on supplemental Table 3.A.RME in Appendix A.

3.3.2 Estimation of Non-Radiological Chemical Intakes

Environmental medium-specific exposure algorithms were developed for each of the identified exposure route/pathways to estimate COPC intake of non-radiological COPCs by receptors (e.g., adult and young child residents) in potentially exposed populations. The exposure to radiological COPCs was assessed using similar algorithms and assumptions, but the total intake was calculated for the entire exposure period. Exposure to radiological COPCs is discussed in Section 3.3.3.

For each identified pathway, an RME scenario was assessed in which the exposure factors used are both average and upper-bound (90th to 95th percentile distribution) point estimates. The RME scenario is intended to represent the highest exposure that is reasonably expected to occur at a site (EPA, 1989).

The exposure factors and exposure algorithms to estimate intake of Site-related contaminants through the groundwater ingestion and dermal exposure pathways for potential future adult and young child residents are listed in Tables 4.1.RME and 4.2.RME in Appendix A. Details regarding the modeled intake methodologies for the dermal absorption exposure pathway are provided in supplemental Tables 7.A.RME and 7.B.RME in Appendix A. Details regarding the modeled intake methodology for the inhalation exposure pathway to non-radionuclides s are provided in supplemental Tables 7.C.RME and 7.D.RME in Appendix A. The exposure calculation methods are described in the following subsections.

3.3.2.1 Ingestion of Groundwater

A principal assumption of the future residential exposure scenario associated with the Church Rock Site was that groundwater would be used as the only water supply for all domestic needs. The chronic daily intake (CDI, mg/kg-d) of non-radiological, non-carcinogenic COPCs in groundwater due to ingestion was calculated by the following equations:

$$CDI = \frac{CW \times IR_W \times EF \times ED}{BW \times ATn}$$

where:

CDI = chronic daily intake of contaminants in groundwater (mg/kg-day)
CW = COPC concentration in groundwater (mg/L)
IR_W = ingestion rate of water (L/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
ATn = averaging time – non-carcinogenic effects (days).

The RME ingestion rates for drinking water were assumed to be two liters per day (2 L/day; EPA, 1989) for adults and 1 L/day for children (California EPA, 1994) over an exposure frequency of 350 days/ year for exposure durations of 6 and 24 years for a child and adult, respectively. The averaging times used for non-carcinogenic COPC effects were 2,190 days (6 years) for a child and 8,760 days (24 years) for an adult.

For carcinogenic exposure under the combined child/adult exposure scenario, an age-adjusted ingestion rate and corresponding intake equation was used:

$$CDI = \frac{CW \times IR_{Wadj} \times EF}{ATc}$$

And

$$IR_{Wadj} = \frac{EDc \times IRWc}{BWc} + \frac{EDa \times IRWa}{BWa}$$

where:

CDI = chronic daily intake of contaminants in groundwater (mg/kg-day)
CW = COPC concentration in groundwater (mg/L)
IR_{Wadj} = age-adjusted ingestion rate (1.09 L-year/kg-day)
IR_{Wa} = adult ingestion rate (2 L/day)
IR_{Wc} = child ingestion rate (1 L/day)
EF = exposure frequency (350 days/year)
EDc = child exposure duration (6 years)
EDa = adult exposure duration (24 years)
BWc = body weight (15 kg)
BWa = body weight (70 kg)
ATc = averaging time – carcinogenic effects (25,550 days [70 years]).

3.3.2.2 Dermal Contact With Groundwater

The dermal contact exposure pathway accounts for daily exposure to water while bathing. With respect to non-radionuclide COPCs, the dermal exposure pathway is important for many organic contaminants and some inorganic contaminants. Under EPA guidance for the dermal-water exposure pathway, only those chemicals which contribute a significant dose relative to the oral exposure pathway (i.e., more than 10% of the dose from drinking water ingestion) are required to be carried through the risk assessment (EPA, 2004). However, as a conservative measure, dermal exposure was evaluated for each of the non-radionuclide COPCs (i.e., those selected for the ingestion exposure pathway) in each of the hydrostratigraphic units.

The dermally absorbed dose (DAD) serves as the intake rate for non-radiologic COPCs in seepage impacted groundwater due to dermal absorption while bathing. DAD is calculated by the following formula:

$$DAD = \frac{DA_{event} \times EV \times ED \times EF \times SA}{BW \times ATn}$$

where:

DAD = dermally absorbed dose (mg/kg-day)

DA_{event} = absorbed dose per event (mg/cm2-event) – The calculation of DAevent is based on chemical-specific parameters and equations presented in EPA (2004) and shown in Table 4.1 in Appendix A and calculated in Tables 7.A.RME and 7.B.RME in Appendix A.
SA = surface area of exposed skin (cm2)
EV = event frequency (events/day)
EF = exposure frequency (days/yr)
ED = exposure duration (years)
BW = body weight (kg)
ATn = averaging time – noncarcinogenic effects (days).

Default RME exposure parameter values were obtained from EPA dermal guidance (EPA, 2004). Body surface area values are 18,000 cm2 for adults and 6,600 cm2 for a child. Bathing time values are assumed to be 0.58 hours for adults and one hour for a child per event and the event frequency was assumed to be one event (i.e., bath or shower) per day. The averaging times used for non-carcinogenic COPC effects were 2,190 days (6 years) for a child and 8,760 days (24 years) for an adult. For the combined child/adult risk exposure scenario for carcinogens, an age-adjusted DAD was calculated as follows:

$$DAD = \left(\frac{DA_{event-c} \times EV \times EDa \times EF \times SAc}{BWc} + \frac{DA_{event-a} \times EV \times EDc \times EF \times SAa}{BWa} \right) \times \frac{1}{ATc}$$

where:

DAD = dermally absorbed dose (mg/kg-day)
$DA_{event-c}$ = Absorbed dose per event-child (mg/cm2-event) - The calculation of DAevent is based on chemical-specific parameters and equations presented in EPA (2004).
$DA_{event-a}$ = absorbed dose per event-adult (mg/cm2-event) - The calculation of DAevent is based on chemical-specific parameters and equations presented in EPA (2004).
SAc = surface area of exposed skin - child (6,600 cm2)
SAa = surface area of exposed skin - adult (18,000 cm2)
EV = event frequency (1 events/day)
EF = exposure frequency (350 days/yr)
EDc = exposure duration (6 years)
EDa = exposure duration (24 years)
BWc = body weight - child (15 kg)
BWa = body weight - adult (70 kg)
ATc = averaging time – carcinogenic effects (25,550 days).

3.3.2.3 Inhalation of Groundwater

The inhalation of volatile organic compounds (VOCs) in groundwater while bathing was included as a potential exposure pathway under the future resident scenario. An exposure model developed by Foster and Chrostowski (1987) was used to estimate VOC exposure point concentrations in bathroom air during and after bathing (see supplemental risk assessment Tables 7.C.RME [for adult exposure] and 7.D.RME [for child exposure] in Appendix A). Chloroform, which is detected in groundwater at low concentrations, is the only non-radionuclide COPC that is sufficiently volatile to be included in the assessment of this pathway. The following equation was used to calculate the non-radionuclide COPC exposure concentration:

$$EC = \frac{CA \times EV \times ET \times EF \times ED}{CF \times AT}$$

where:

EC = Average Daily Exposure Concentration (mg/m^3)
CA = chemical concentration in air (mg/m^3) derived using Foster and Chrostowski shower model (1987)
EV = event frequency (1 event/day)
EF = exposure frequency (350 days/year)
ED = exposure duration (6 years child, 24 years adult)
ET = exposure event time (0.58 hours/event adult, 1 hour/event child)
AT = averaging time (2,190 days child, 8,760 days adult)
CF = conversion factor 24 hrs/day.

For the combined child/adult risk exposure scenario for carcinogens, an age-adjusted EC was calculated as follows:

$$EC_{adj} = \left(\frac{CA_a \times EVa \times ETa \times EDa \times EF}{CF \times AT}\right) + \left(\frac{CA_c \times EVc \times ETc \times EDc \times EF}{CF \times AT}\right)$$

where:

EC_{adj} = age-adjusted average daily exposure concentration (mg/m^3)
CAa = chemical concentration in air – adult (mg/m^3) (using Foster and Chrostowski, 1987)
CAc = chemical concentration in air – child (mg/m^3) (using Foster and Chrostowski, 1987)
EVa = event frequency - adult (1 event/day)
EVc = event frequency – child (1 event/day)
EF = exposure frequency (350 days/year)
EDa = exposure duration – adult (6 years)
EDc = exposure duration – child (24 years adult)
ETa = exposure event period - adult (0.58 hours/event)
ETc = exposure event period – child (1 hour/event)
AT = averaging time (25,550 days)

CF = conversion factor 24 hrs/day.

3.3.3 Estimation of Radiological Intakes

Generally, standardized default exposure equations for radionuclides are similar to those for non-radionuclides (EPA, 1991a). However, according to EPA (1991a), there are three principal differences:

- The equations utilize input quantities of activity (e.g., pCi/L) rather than mass (mg/L) because health effects due to radionuclide effects are directly related to the amount, type and energy of the radiation deposited in specific body tissues and organs;
- Radionuclide exposure equations consider only the carcinogenic effects of radionuclides; and
- Radionuclide exposure equations use cancer slope factors that are best estimates (i.e., median or 50th percentile values) of the age-averaged, lifetime excess total cancer risk per unit intake of a radionuclide. Radionuclide slope factors given in the EPA's Health Effects Assessment Summary Tables (HEAST, http://www.epa.gov/radiation/heast; EPA, 2001a) are calculated for individuals using a non-threshold, linear dose-response model that accounts for radionuclide absorption into and distribution throughout the body and also accounts for the age, sex and weight of an individual. The model then averages the risk over a lifetime exposure (i.e., 70 years). Consequently, radionuclide slope factors are not expressed as a function of body weight and time and do not require adjustments for gastrointestinal absorption or lung transfer efficiencies.

For the Church Rock Site HHRA, radionuclide COPC exposure was evaluated using the same potential future residential receptors as those evaluated for chemical COPCs. The exposure pathways evaluated included groundwater ingestion and inhalation of groundwater related to domestic water uses. The groundwater inhalation exposure pathway has been included for one COPC, radium-226, which has the radioactive gas radon-222 (Rn-222) as its decay product. This is consistent with EPA's inclusion of the inhalation pathway in its tapwater radionuclide PRG calculation for radium-226 (http://epa-prgs.ornl.gov/radionuclides/).

Dermal uptake is typically not an important exposure route for radionuclides and it has not been evaluated in this risk assessment. The skin is generally an effective barrier against absorption of radionuclides, which have small permeability constants (EPA, 1989), and the dermal absorption exposure pathway is considered very minor with respect to other exposure routes, such as ingestion and inhalation.

Other exposure pathways that are often considered in risk assessments with radionuclide COPCs include (1) inhalation of airborne particulates, and (2) external gamma radiation. As previously described, these exposure pathways also do not apply to the Church Rock Site, because (1) source control and on-site surface reclamation activities were conducted within Section 2 under the direction of the NRC, pursuant to the facility's NRC Source Materials License and (2) the operation of the evaporation ponds and the monitoring of potential radionuclide emissions are conducted within Section 2 under the direction of the NRC, pursuant to the facility's NRC Source Materials License.

Ingestion exposure to radionuclides was assessed using the same equations presented in the previous sections for chemical contaminants, except that the body weight and averaging time terms are omitted for reasons described previously. The result of these calculations is an estimate of total intake over the exposure duration, expressed in terms of activity (i.e., pCi/L), instead of a body weight normalized chronic daily intake (e.g., mg/kg-day). As with the carcinogenic chemical risk assessment, combined adult/child exposure assessment was completed for each of the selected exposure pathways for radionuclide COPCs.

3.3.3.1 Ingestion of Groundwater

The intake of radiological COPCs in groundwater due to ingestion was calculated for the child/adult receptor by the following formulas:

$$Intake = CW_R \times IR_{Wadj} \times EF \times ED$$

and

$$IR_{Wadj} = \left(IR_{Wc} \times EDc + IR_{Wa} \times EDa\right) \times \frac{1}{ED}$$

where:

Intake = intake of COPCs in groundwater (pCi)
CW_R = radionuclide activity in groundwater (pCi/L)
IR_{Wadj} = age-adjusted ingestion rate (1.8 L/day)
IR_{Wa} = adult ingestion rate (2 L/day)
IR_{Wc} = child ingestion rate (1 L/day)
EF = exposure frequency (350 days/year)
ED = exposure duration (30 years)
EDc = child exposure duration (6 years)
EDa = adult exposure duration (24 years).

3.3.3.2 Inhalation of Groundwater

Inhalation exposure to radium-226 in groundwater was assessed using a different method than that used for the chemical COPC chloroform. The Andelman volatilization factor K (Andelman, 1990), which is used by EPA in the development of its radionuclide PRGs and referenced in RAGS Part B (EPA, 1991a), was applied to calculate the fraction of radionuclide COPCs that are transferred from groundwater to the air through all uses of household water (e.g., showering, laundering, dishwashing). Residents are assumed to potentially be exposed to indoor air in their homes for 24 hours a day resulting in an exposure time ratio of 1. This is meant to be protective of sensitive populations who stay at home (i.e., young children or the elderly). Although radium is not considered to be volatile, radon has a Henry's Law constant approximately 30 times that of chloroform. Andelman's K (0.0005) is a unitless constant, but it is commonly given with a conversion factor of 1000 L/m^3 that is used so the resulting air concentration is expressed in units of pCi/m^3. The Andelman K represents an average transfer efficiency of 50 percent, in that half of the concentration of each chemical in water will be transferred into air by all water uses (e.g., a 10 pCi/L concentration in water will result in a 5 pCi/ m^3 concentration in air). EPA (1991a) indicates that the Andelman K is based primarily on experimental data from the volatilization of radon from water and cites assumptions used in the development of Andelman K to include (1) the volume of water used in a residence for a family of four is 720 L/day (approximately 190 gallons/day), (2) the volume of the dwelling is 150,000 L, and (3) the air exchange rate is 0.25 m^3/hr.

The intake of the radiological COPC radium-226 in groundwater through the inhalation pathway was calculated for the child/adult receptor by the following formulas (also see Table 7.E.RME in Appendix A):

$$Intake = CW_R \times IRA_{adj} \times EF \times ED \times ET \times K \times \frac{1}{CF}$$

and

$$IF_{adj} = (IRAc \times EDc + IRAa \times EDa) \times \frac{1}{ED}$$

Intake = intake of contaminants in groundwater (pCi)
CW_R = radionuclide activity in groundwater (pCi/L)
IRA_{adj} = age-adjusted inhalation rate (18 m^3/day)
IRA_a = adult inhalation rate (20 L/day)
IRA_c = child inhalation rate (10 L/day)
EF = exposure frequency (350 days/year)
ED = exposure duration (30 years)
ET = exposure time (24 hours/day)
EDc = child exposure duration (6 years)
EDa = adult exposure duration (24 years)
CF = conversion factor 24 hrs/day
K = volatilization factor of Andelman (0.5 L/m^3)

Section 4

Toxicity Assessment

The toxicity assessment component of the HHRA considers (1) the types of adverse health effects associated with chemical exposures, (2) the relationship between the magnitude of exposure and adverse effects, and (3) related uncertainties such as the weight of evidence of a particular chemical's carcinogenicity in humans. For the Church Rock Site, the toxicity assessment was based entirely on existing toxicity information available from EPA and other sources, including information regarding carcinogenic and non-carcinogenic effects associated with radionuclide and non-radionuclide COPCs.

Two categories of toxicological effects, cancer and non-cancer causing health effects, were evaluated in the toxicity assessment for each identified COPC for the Church Rock Site. Toxicity values are used to quantify the probability of observing cancer and non-cancer effects in a potentially exposed population. Several types of toxicity values are used to express a COPC's dose-response-effect relationship:

- Oral Reference Dose (RfD) – an RfD, expressed in mg/kg-day, is used for estimating potential non-carcinogenic effects through ingestion exposure, primarily from non-radiological contaminants. Oral RfDs are also used to calculate RfDs for dermal exposure to COPCs (i.e., absorbed RfD).
- Inhalation Reference Concentration (RfC) – RfCs are expressed in mg/m^3 and used for estimating potential non-carcinogenic effects though inhalation exposure, primarily from non-radiological contaminants.
- Oral and inhalation Slope Factor (SF) – an SF is used for estimating potential carcinogenic effects. An oral SF for non-radiological effects is expressed in the units of $(mg/kg\text{-}day)^{-1}$. The oral SFs are also used to calculate slope factors for dermal exposure to COPCs (i.e., absorbed cancer SF). An oral or inhalation SF for radiological COPCs is expressed in the units of $(pCi)^{-1}$ (i.e., risk/pCi) for radiological contaminants.
- Inhalation Unit Risk (IUR) – an IUR is used for estimating potential carcinogenic effects for non-radionuclides and is expressed in the units of $(\mu g/m^3)^{-1}$.

In their September 2, 2010 comment letter (EPA, 2010a), EPA requested that the risk assessment include updated toxicity factors. For the Church Rock Site HHRA, all toxicity factors were updated in accordance with EPA's Superfund program hierarchy of human health toxicity values (EPA, 2003), which is as follows:

- Tier 1 - EPA's IRIS - IRIS is the first tier of the recommended hierarchy as the generally preferred source of human health toxicity values. IRIS generally contains RfDs, RfCs, SFs, and IUR values that have gone through a peer review and EPA consensus review process.
- Tier 2 - EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs) – The Office of Research and Development/National Center for Environmental Assessment/Superfund

Health Risk Technical Support Center (STSC) develops PPRTVs on a chemical specific basis when requested by EPA's Superfund program.

- Tier 3 - Other Toxicity Values – Tier 3 includes additional EPA and non-EPA sources of toxicity information. Priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed.

Information on the non-carcinogenic toxicity factors and effects for the COPCs is listed in Tables 5.1 and 5.2 and carcinogenic toxicity effects for the COPCs (both non-radiological and radiological) are listed in Tables 6.1 and 6.2 in Appendix A. Sections 4.1 and 4.2 below summarize the development of toxicity information related to non-carcinogens and carcinogens, respectively.

4.1 Toxicity Information for Non-Carcinogens

Chronic RfD or RfCs are estimates of the daily exposure (intake) a human population (including any sensitive subpopulation) that is unlikely to cause an increased incidence of adverse health effects during a lifetime of exposure (i.e., a chronic exposure). Chronic RfD or RfC values are specifically developed to be protective for long-term exposure to a constituent. Subchronic RfDs and RfCs, which are used to evaluate the highest average daily exposure over shorter time periods (i.e., between 2 weeks and 7 years) that will not cause adverse health effects, have not been used in the Church Rock Site HHRA, because there are no short-term exposure pathways evaluated.

As discussed during the November 1, 2010, teleconference, the November 2010 EPA RSL Table (EPA, 2010b) was the primary source of most COPC toxicity values used within the Church Rock Site HHRA. The toxicity values used as "defaults" in the RSL table are selected by EPA in a manner consistent with their 2003 guidance regarding hierarchy of human health toxicity values (http://www.epa.gov/region9/superfund/prg). The original sources of the toxicity information used on the RSL Table, as well as other sources used for certain chemical COPCs, are noted on Tables 5.1 and 5.2 in Appendix A. Uranium is the only radionuclide COPC which has been determined to have chemical toxicity comparable to its radiotoxicity and for which an RfD has been included on the EPA RSL table to evaluate chemical toxicity. For the purposes of this HHRA, both effects (chemical toxicity and radiogenic cancer risk) are considered.

EPA guidance (EPA, 2004) was utilized to calculate dermal toxicity factors for the dermal contact with groundwater pathway. Dermal toxicity factors (RfDs) are based on absorbed dose (i.e., the amount of a chemical absorbed through the skin), while oral RfDs are based on an administered dose (i.e., the amount of a chemical ingested). Therefore, to obtain dermal RfDs from oral RfDs, the oral RfD is adjusted using an oral absorption efficiency values (ABS_{GI}), which represents the fraction of an orally administered dose of chemical that was absorbed by the gastrointestinal tract (i.e., the absorbed dose) in the critical study that was the basis of the oral RfD. The magnitude of toxicity factor adjustment is inversely proportional to the absorption fraction in the critical study (i.e., if the absorption efficiency value is high, the absorbed dose approaches the administered dose, resulting in little difference in a dermal RfD derived from an oral RfD). As absorption efficiency in the critical study decreases, the difference between the absorbed dose and administered dose increases, and the dermal RfD decreases with respect to the oral RfD. The ABS_{GI} values used to calculate the dermal RfDs were identified in EPA guidance (EPA, 2004 and EPA, 2010b). The ABS_{GI} value selected for vanadium was that for "vanadium and compounds" in the EPA RSL Table (ABS_{GI} = 1; EPA, 2010b), rather than the value in the EPA dermal risk assessment guidance (ABS_{GI} = 0.026, EPA, 2004) because this value corresponded with the selected oral RfD.

Certain inorganic groundwater contaminants at the Site do not have toxicity values established (e.g., sulfate, chloride). These contaminants have not been included in the quantitative risk assessment calculations, but are addressed qualitatively in the uncertainty analysis portion of the risk assessment (Chapter 6).

4.2 Toxicity Information for Carcinogens

Cancer risks are expressed as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., excess individual lifetime cancer risk). The SF and IUR toxicity values that define a quantitative relationship between dose and response are used to convert the estimated daily intakes averaged over a human lifetime of exposure directly to an incremental risk of an individual developing cancer. This approach assumes that the dose-response relationship is a linear relationship in the low-dose portion of the dose-response curve.

The Church Rock Site risk assessment considers cancer risk associated with both exposures to chemicals and radionuclides. For exposure to chemicals, slope factors typically represent an upper bound estimate or 95th percent confidence limit value that has been obtained from extrapolation from laboratory experiments (EPA, 1989). Cancer slope factors for radionuclides are central tendency estimates (i.e., median or 50th percentile values) of the age-averaged increased lifetime cancer risk that are based on epidemiological studies of radiogenic cancers in humans (EPA 1989).

As discussed with EPA in the November 1, 2010, teleconference, the November 2010 EPA RSL Table (EPA, 2010b) was used as the primary source of most chemical COPC slope factors and IURs. As with the non-carcinogenic toxicity values, the slope factors used in the RSL table are selected by EPA in a manner consistent with their 2003 guidance regarding hierarchy of human health toxicity values (RSL Table User's Guide, http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm). The original sources of the toxicity information used on the RSL Table, as well as other sources used for certain chemical COPCs are noted on Tables 6.1 and 6.2 in Appendix A. For the dermal groundwater exposure pathway, Table 6.1 shows the application of the oral absorption efficiency values (ABS_{GI}) to calculate the absorbed cancer slope factor; however, no adjustments to the oral SFs were necessary because the ABS_{GI} value was one (i.e., 100 percent) for each of the evaluated carcinogenic COPCs (EPA, 2004; EPA 2010b).

EPA has classified all radionuclides as known human carcinogens (Class A carcinogens) based on their property of emitting ionizing radiation in epidemiological studies of radiogenic cancers in humans. With the exception of uranium (see Section 4.1), the chemical toxicity of radionuclide COPCs is low in comparison to the carcinogenic risk; therefore chemical risk was not considered further in the risk assessment for radionuclides other than uranium.

Radionuclide cancer slope factors (i.e., risk coefficients for total cancer morbidity) were obtained from the EPA's HEAST (EPA, 2001a). The 2001 update of the HEAST for radionuclides incorporates slope factor values based on Federal Guidance Report No. 13 (EPA 1999), which incorporates state-of-the-art models and methods that take into account age and gender dependence of radionuclide intake, metabolism, dosimetry, radiogenic cancer risk, and competing risks. The EPA document "User's Guide: Radionuclide Carcinogenicity" (http://www.epa.gov/radiation/heast/) describes the derivation of the slope factors in the Radionuclide Table, information about the table, and contact information.

The User's Guide indicates that selected radionuclides and radioactive decay chain products are designated with the suffix "+D" (e.g., U-238+D, Ra-226+D) to indicate that cancer risk estimates for these radionuclides include the contributions from their short-lived decay products, assuming equal activity concentrations (i.e., secular equilibrium) with the principal or parent nuclide in the environment. The use of the "+D" designation can be important because some decay products can be more toxic than the parent isotope. For example, Ra-226, which has a half-life of 1600 years, decays to radon-222 (Rn-222, a noble gas) by alpha particle emission. However, Rn-222 and its daughters emit three additional alpha particles and two beta particles through the principle decay modes with a total half-life of less than four days. The User's Guide indicates that in the absence of site-specific data regarding secular equilibrium, the "+D" values for radionuclides should be used. For the Church Rock Site Risk Assessment, the cancer slope factors used for the following radionuclides had the "+D" designation: uranium-235+D, uranium-238+D, radium-226+D, radium-228+D, and lead-210+D (see Tables 6.1 and 6.2 in Appendix A).

Section 5

Risk Characterization

The risk characterization step of the HHRA process summarizes and combines outputs of the exposure and toxicity assessments to characterize risk in quantitative and qualitative statements. For the Church Rock Site HHRA, COPC intakes for RME exposure scenarios are combined with the toxicity values to estimate health hazards and cancer risks, as described in Sections 5.1 and 5.2. The RME exposure represents the highest exposure that is reasonably expected to occur at a site (EPA, 1989) and, therefore, the resulting risk estimate is conservative (i.e., well above the average case).

The only environmental medium affected by the tailings impoundments is groundwater. Because there is no current exposure to seepage-impacted groundwater, the HHRA does not evaluate past or current exposures. Following the EPA's original PHA (EPA, 1988b), this risk assessment addresses each hydrostratigraphic unit separately. Risk and hazard estimates are presented for each of the potential future exposure scenarios and are grouped by hydrostratigraphic unit (Sections 5.3 to 5.5) and the EPA RAGS Part D risk assessment summary tables (EPA, 2001) are provided in Appendix A.

The risk and hazard estimates for exposure to groundwater from each of the hydrostratigraphic units are based on the assumption that future residents will install wells and meet all their domestic water needs with seepage-impacted groundwater from one of the three affected hydrostratigraphic units. The risk and hazard estimates for the exposure scenarios within a selected hydrostratigraphic unit are considered to be additive because COPC exposure could occur independently through multiple scenarios in a residential setting (i.e., a receptor would likely be exposed both through groundwater ingestion and through dermal contact with groundwater during bathing). However, the risk and hazard estimates between hydrostratigraphic units are exclusive of one another because total daily groundwater exposure is limited to a receptor living at one location and using one groundwater source.

5.1 Method for Evaluating Non-Cancer Hazard

Risk estimates for non-cancer effects are calculated using the intake or exposure concentration calculated in the exposure assessment (Section 3) and toxicity benchmarks (i.e., RfDs or RfCs) that represent intake levels below which it is unlikely that a receptor will experience adverse health effects following a chronic exposure. The non-carcinogenic toxicity, or hazard, to an individual for a specific COPC, is the average daily intake divided by the RfD or RfC. This ratio is known as the hazard quotient (HQ):

$$HQ = \frac{CDI}{RfD} \text{ (for ingestion exposure)}$$

Or

$$HQ = \frac{EC}{RfC} \text{ (for inhalation exposure)}$$

where:
HQ = hazard quotient
CDI = chronic daily intake (mg/kg-day or mg/m^3)
EC = Exposure concentration (mg/m^3)
RfD = Reference Dose (mg/kg-day)
RfC = Reference Dose (mg/m^3)

The sum of the HQs for each COPC evaluated within an exposure scenario is known as the hazard index (HI). If the HI is less than one, it is generally assumed that no adverse impact to human health will occur as a result of the defined exposure scenario. EPA conservatively assumes dose and effect to be additive for non-carcinogenic effects; if the HI exceeds one for the exposure scenario, this provides an indication that the exposed receptor may be subject to an adverse health impact (EPA, 1989). However, EPA (1989) has also noted that adding all HQ or HI values may overestimate hazards, because the assumption of additivity is probably appropriate only for those chemicals having the same toxicological effect. Furthermore, the potential for adverse health effect does not necessarily increase linearly as an RfD is approached or exceeded because RfDs do not have equal accuracy or precision and are not based on the same severity of toxic effects.

Therefore, if the HI is greater than one as a consequence of summing several hazard quotients of similar value, it is appropriate to further evaluate the hazard calculations by segregating the compounds by target organ, toxicological effect, or toxic mechanism, and to derive separate hazard indices for each group (EPA 1989). If any segregated HI exceeds the target hazard level, this may indicate a potential adverse health impact. However, if all of the segregated HIs are less than the target hazard level, non-cancer health effects are unlikely to result from exposure to the COPCs included in the HI. In Sections 5.3 to 5.5, non-cancer health hazards based on chemical contaminants are presented for COPCs for each receptor population and for each exposure pathway and then summarized across all media and exposure pathways. Target organs for non-cancer health hazards are indicated, and organ-specific health hazards are also presented as applicable.

5.2 Method for Evaluating Cancer Risk

Risk estimates for cancer effects are expressed as an increased probability of contracting cancer (i.e., excess cancer risk). The EPA "target" acceptable excess cancer risk range (e.g., EPA, 1991a) is 1E-06 to 1E-04 (i.e., 1 in 1,000,000 to 1 in 10,000). Cancer risks above 1E-04 are generally considered unacceptable and warrant some form of remedial action. The risk calculation equation for non-radiological contaminants is as follows:

$$Risk = CDI \times SF$$

or

$$Risk = EC \times IUR$$

where:

Risk = probability (unitless) of an individual developing cancer over a lifetime
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
EC = cxposure concentration (µg/m^3)
SF = slope factor, expressed in (mg/kg-day)$^{-1}$
IUR = inhalation unit risk value, expressed in (µg/m^3)$^{-1}$.

The risk calculation equation for radiological contaminants is as follows:

$$Risk = Intake \times SF$$

where:

Risk = a unitless probability (e.g., 1E-06) of an individual developing cancer over a lifetime
Intake = total lifetime intake above background (pCi)
SF = slope factor, expressed in (pCi)$^{-1}$.

The excess cancer risk from exposure to multiple carcinogens is assumed to be additive. Therefore, the total cancer risk from radiological and non-radiological COPCs is calculated by summing the individual cancer risks for all COPCs across all exposure media and pathways. However, EPA (1989) also recommends that, due to differences in the way cancer toxicity values for radiological and chemical risk are developed, risk estimates for radiological and chemical risk should be tabulated separately in the final baseline risk assessment. In Sections 5.3 to 5.5, carcinogenic risks based on chemical and radiological contaminants are presented for COPCs for each receptor population and for each exposure pathway and then summarized across all media and exposure pathways.

5.3 Risk Characterization Results for the Southwest Alluvium

Potential future residents may be exposed to COPCs in Southwest Alluvium groundwater if they install a well in Section 3, west of the Section 2 boundary, and use seepage-impacted groundwater for drinking water and other domestic uses. Calculated hazards and risks associated with potential future exposure to seepage-impacted groundwater in the Southwest Alluvium are summarized in Tables 7.1.RME through 7.3.RME, 8.1.RME, and 9.1.RME through 9.3.RME (Appendix A). For the Southwest Alluvium, potential future non-carcinogenic hazards are associated primarily with the groundwater ingestion exposure pathway and excess carcinogenic risks are associated primarily with the ingestion and inhalation pathways.

5.3.1 Ingestion of Groundwater - Southwest Alluvium

The non-cancer chemical (i.e., non-radiological) hazard calculations are presented in Tables 7.1.RME and 7.2.RME for potential future adult and child residents, respectively. The child resident is a sensitive subpopulation and all COPC hazard quotients for the child resident receptors exceed those for adult resident receptors.

The HI for ingestion of Southwest Alluvium groundwater by a future child resident is 12.9 and for a future adult resident is 5.5. For the child, the HQs for manganese (7.5), uranium (2.7), and cobalt (2.1) exceed one. For the adult, the HQs for manganese (3.2) and uranium (1.2) exceed one. For both potential future residents, manganese accounts for more than half the hazard quotient associated with groundwater ingestion, and the sum of HQs for cobalt, manganese, and uranium represent over 95 percent of the health hazard, although the cobalt HQ is less than one (0.92) for the adult receptor.

The chemical (i.e., non-radiological) and radiological cancer risk associated with the ingestion of groundwater from the Southwest Alluvium was evaluated for a combined RME child/adult exposure. The results of the evaluation are summarized in Table 7.3.RME (Appendix A). Arsenic and chloroform are the only non-radionuclide, carcinogenic COPCs evaluated for the Southwest Alluvium. The results on Table 7.3.RME show that the chemical cancer risk is 5.9E-05, which is within the EPA acceptable risk range of 1E-04 to 1E-06. Arsenic accounts for more than 95 percent of the risk. The data used for the risk assessment show that average arsenic concentrations in impacted water (EPC UCL95, 0.00256 mg/L) are below the arsenic maximum contaminant level (MCL, 0.010 mg/L) and are similar to average background water concentrations (UCL95, 0.00116 mg/L). The range of detected concentrations was the same for both impacted and background water and the frequency of non-detected results for arsenic was 86.5 percent in impacted water and 93.1 percent in background water.

The radiological cancer risk associated with the ingestion of groundwater from the Southwest Alluvium is 1.5E-04, which exceeds the EPA acceptable risk range of 1E-04 to 1E-06 (Table 8.1.RME in Appendix A). None of the individual radionuclides exceeds the EPA acceptable risk range. Three radionuclides have individual risks greater than 1E-05: uranium-234 (5.8E-05), uranium-238+D (7.0E-05), and radium 228+D (1.7E-05). The sum of the risks associated with these three radionuclides represents more than 96 percent of the total radionuclide risk.

The risk associated with radionuclides due to ingestion of background groundwater in the Southwest Alluvium is likely to be slightly lower (i.e., near the high end of the acceptable risk range), based on the UCL95 concentrations of radionuclides reported in background groundwater (Appendix C).

5.3.2 Dermal Contact with Groundwater - Southwest Alluvium

The non-carcinogenic health effects of dermal contact with Southwest Alluvium groundwater through bathing was evaluated for potential future adult and child residents. The HI for dermal contact with groundwater by an adult is 0.43 and the HI for dermal contact with groundwater by a child is 1.3. Manganese contributes over 95 percent of the hazard for each receptor and the manganese HQ (1.2) exceeds one for the future child receptor.

The non-radiological cancer risk associated with the dermal contact with groundwater from the Southwest Alluvium was evaluated for a combined RME child/adult exposure. The results shown in Table 7.3.RME (Appendix A) indicate that the excess cancer risk is 4.7E-07, which is lower than the EPA target acceptable range of 1E-04 to 1E-06. As described in Section 3.3.3, dermal absorption is typically not an important exposure route for radionuclides and it has not been evaluated for radionuclides within this risk assessment.

5.3.3 Inhalation of Groundwater - Southwest Alluvium

The non-carcinogenic health effects of inhalation exposure to groundwater from the Southwest Alluvium through bathing were evaluated for potential future adult and child residents. Chloroform is the only volatile COPC that was evaluated in this scenario. The results, which are provided in Table 7.1.RME and 7.2.RME in Appendix A, show that the chloroform HQ (and the pathway HI) for the groundwater inhalation exposure pathway is below one for both an adult (0.0017) and a child (0.0041).

The non-radiological cancer risk associated with the inhalation exposure to groundwater from the Southwest Alluvium was evaluated for a combined RME child/adult exposure. The only volatile COPC evaluated in this scenario was chloroform and the results are provided in Table 7.3.RME (Appendix A). The cancer risk is 2.1E-06, which is within the EPA acceptable risk range of 1E-04 to 1E-06.

The radiological cancer risk associated with the inhalation exposure to groundwater through domestic tapwater use (bathing, dishwashing, laundry, etc.) from the Southwest Alluvium was evaluated for a combined RME child/adult exposure. Radium-226 is the only radiological COPC for which this exposure pathway is considered complete. The results presented in Table 8.1.RME (Appendix A) indicate that the excess cancer risk for radium-226 is 2.9E-04, which exceeds the EPA acceptable risk range of 1E-04 to 1E-06. However, the radium-226 EPC concentration in seepage-impacted groundwater (UCL95, 0.267 pCi/L) is approximately three times lower than the background groundwater concentration in the Southwest Alluvium (UCL95, 0.798 pCi/L). Therefore, the risk due to inhalation exposure to seepage-impacted Southwest Alluvium groundwater is within the range of background risk.

5.3.4 Hazard and Risk Summary - Southwest Alluvium

The total non-carcinogenic hazard and risks for future resident exposure to seepage-impacted groundwater in the Southwest Alluvium have been calculated. The HIs, based on RME exposure factors for future adult and child receptors and summed across all media and exposure pathways, are shown in Tables 9.1.RME and 9.2.RME (Appendix A). The total HI for an adult is 6.0 and for a child is 14.2, resulting mostly from the ingestion exposure pathway and from the COPCs manganese, cobalt, and uranium.

Several segregated total HIs exceed one for target organs or toxicological effect. The HIs based on central nervous system effects are 8.7 for the child and 3.6 for the adult, due to the ingestion of manganese in groundwater. The segregated HIs for kidney toxicity are 2.7 for the child and

1.2 for the adult, due to uranium. The segregated HI for thyroid toxicity is 2.1 for the child, based on the cobalt concentration. Hazard indices for other specific organs or targets are less than one.

Manganese is the most significant contributor to the total hazard in the Southwest Alluvium. Manganese is a trace nutrient; the Adequate Intake (i.e., for those nutrients that have not yet received enough scientific study to merit setting of an official Recommended Dietary Allowance, the AI represents an amount that appears to sustain good health) for manganese identified by the Institute of Medicine (2001) ranges from 1.2 mg/day for a child to 2.3 mg/day for an adult male. The RfD used in the HHRA for manganese was obtained from the EPA RSL table (EPA, 2010b) and was based on a modification of the IRIS RfD (0.14 mg/kg-day), which includes manganese from all sources, including diet. The RSL Table User's Guide (http://www.epa.gov/region9/superfund/prg/) indicates that the author of the IRIS assessment for manganese recommended that the dietary contribution from the normal United States diet (an upper limit of 5 mg/day) be subtracted when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. A modifying factor of three is also applied when calculating risks associated with non-food sources due to a number of uncertainties that are discussed in the IRIS file for manganese, leading to a RfD of 0.024 mg/kg-day.

The non-carcinogenic hazard associated with potential future residential exposure to background groundwater in the Southwest Alluvium would be lower than the impacted water, but would also exceed one for both the adult and child receptors. The hazard for ingestion of cobalt in seepage-impacted groundwater is based on one detected result out of 96 samples. Cobalt is more frequently detected in background groundwater in the Southwest Alluvium, at a slightly higher concentration (UCL95, 0.0121 mg/L) than the maximum detected concentration in seepage-impacted groundwater (0.01 mg/L) that was used as the EPC. Background manganese and uranium concentrations would also contribute to a background HI greater than 1 for both adult and child receptors.

The total radiological and chemical carcinogenic risk, summed across all media and exposure pathways, and based on RME exposure factors for the future child/adult receptor, is shown in Table 9.3.RME (Appendix A). The total risk for a combined adult/child receptor is 5.0E-04, resulting mostly from the ingestion and inhalation of radionuclide COPCs. The total radiological and chemical carcinogenic risk in background groundwater would also exceed the EPA target risk range, primarily due to inhalation exposure to radium-226, which has a background concentration (UCL95, 0.798 pCi/L) that is approximately three times the EPC (UCL95, 0.267 pCi/L) used for seepage-impacted groundwater in the Southwest Alluvium. Radium-228 and uranium would also contribute to background risk.

The selection of COCs from the COPCs, for all hydrostratigraphic units, is discussed in Section 7.2.

5.4 Risk Characterization Results for Zone 1

Potential future residents may be exposed to COPCs in Zone 1 groundwater if they install a well in Section 1, east of the Section 2 boundary, and use seepage-impacted groundwater for drinking water and other domestic uses. Calculated hazards and risks associated with potential future exposure to seepage impacted groundwater in Zone 1 are summarized Tables 7.4.RME through 7.6.RME, 8.2.RME, and 9.4.RME through 9.6.RME in Appendix A. For Zone 1, potential future non-carcinogenic hazards are associated primarily with the ingestion pathway and excess carcinogenic risks are associated primarily with the ingestion and inhalation pathways.

5.4.1 Ingestion of Groundwater - Zone 1

The non-cancer chemical (i.e., non-radiological) hazards are summarized in Tables 7.4.RME and 7.5.RME for potential future adult and child residents, respectively. The total HI for groundwater ingestion by a future child resident is 19.9 and the HI for a future adult resident is 8.5. For the child resident, the HQs for cobalt (11.9), manganese (5.2), and vanadium (2.6) exceed one. For the adult resident, the HQs for cobalt (5.1), manganese (2.2), and vanadium (1.1) also exceed one. For both the adult and child receptors, cobalt accounts for more than half the hazard quotient, and the sum of HQs for the cobalt, manganese, and vanadium represent over 98 percent of the health hazard. However, because the Zone 1 background manganese UCL95 concentration (2.519 mg/L) exceeds the manganese EPC concentration (UCL95, 1.95 mg/L) in seepage-impacted groundwater in Zone 1 (N.A. Water Systems, 2008b, 2008c), the background groundwater HI would also exceed one.

The chemical (i.e., non-radiological) and radiological cancer risk associated with the ingestion of groundwater from Zone 1 was evaluated for an RME combined child/adult exposure. Arsenic and chloroform are the only non-radionuclide, carcinogenic COPCs evaluated for Zone 1. The results provided in Table 7.6.RME (Appendix A) indicate that the chemical cancer risk is 3.3E-05, which is within the EPA acceptable risk range of 1E-04 to 1E-06. Arsenic accounts for more than 99 percent of the calculated excess risk for the ingestion exposure pathway. The arsenic EPC concentration for impacted water (UCL 95, 0.00145 mg/L) and the UCL95 for background water (0.00117 mg/L) are approximately equal and below the MCL (0.010 mg/L). The maximum result detected in Zone 1 background groundwater (0.004 mg/L) slightly exceeded the maximum detected in seepage-impacted groundwater (0.003 mg/L) (N.A. Water Systems, 2008b, 2008c).

The radiological cancer risk associated with the ingestion of groundwater from Zone 1 is 5.3E-05, which is within the EPA acceptable risk range of 1E-04 to 1E-06 (Table 8.2.RME in Appendix A). The only radionuclide with an excess risk exceeding 1 E-05 is radium 228+D (4.1E-05). The average radium 228 activity (UCL95, 2.946 pCi/L) in Zone 1 background groundwater exceeds the radium-228 activity in seepage-impacted water (EPC UCL95, 2.046 pCi/L); therefore, the risks associated with ingestion of background water would exceed those for impacted water.

5.4.2 Dermal Contact with Groundwater - Zone 1

The non-carcinogenic health effects of dermal contact with Zone 1 groundwater through bathing was evaluated for potential future adult and child residents. The hazard index (HI) for dermal contact with groundwater for an adult is 0.32 and for a child is 0.95. Manganese contributes 90 percent of the hazard for each receptor. These results are below the EPA target level of one for this pathway which indicates that adverse health effects are unlikely to be due to chronic dermal exposure. Furthermore, as described in Section 5.4.1, average Zone 1 background manganese concentration exceeds the EPC manganese concentration in impacted water; therefore non-carcinogenic hazard associated with the potential dermal exposure to manganese in background water exceeds that of the Zone 1 impacted water.

The non-radiological cancer risk associated with the dermal contact with groundwater from Zone 1 was evaluated for a combined RME child/adult exposure. The results, provided in Table 7.6.RME in Appendix A, show that the calculated cancer risk is 2.1E-07, which is lower than EPA acceptable risk range of 1E-04 to 1E-06.

5.4.3 Inhalation of Groundwater - Zone 1

The non-carcinogenic health effects of inhalation exposure to Zone 1 groundwater through bathing was evaluated for potential future adult and child residents. The only volatile COPC evaluated in this scenario was chloroform. The results, provided in Table 7.4.RME and 7.5.RME (Appendix A), show that the HI for the inhalation exposure pathway for an adult is 0.0003 and a child is 0.0008. These results are well below the EPA target level of one, which indicates that adverse health effects are unlikely as a result of chronic exposure to chloroform under the Zone 1 groundwater inhalation exposure scenario.

The non-radiological cancer risk associated with the inhalation exposure to groundwater from Zone 1 was evaluated for a combined RME child/adult exposure. As for the non-carcinogenic risk evaluation, the only volatile COPC evaluated in this scenario was chloroform. The results are provided in Table 7.6.RME (Appendix A). The cancer risks are 4.2E-07, which is below the EPA acceptable risk range of 1E-04 to 1E-06.

The radiological cancer risk associated with the inhalation exposure to Zone 1 groundwater through domestic tapwater use (e.g., bathing, dishwashing, laundry, etc.) was evaluated for a combined RME child/adult exposure. Radium-226 is the only radiological COPC for which this exposure pathway is considered complete. The results are provided in Table 8.2.RME (Appendix A). The calculated cancer risk for radium-226 is 1.3E-03, which exceeds the EPA acceptable risk range of 1E-04 to 1E-06. However, the radium-226 EPC concentration in Zone 1 seepage-impacted groundwater (1.213 pCi/L, based on the UCL95) is lower than the Zone 1 background groundwater radium-226 UCL95 (1.314 pCi/L). Therefore, the radiological cancer risk for seepage-impacted water is less than that of background water.

5.4.4 Hazard and Risk Summary - Zone 1

The total non-carcinogenic hazard and risks for future resident exposure to seepage-impacted groundwater in Zone 1 have been calculated. The HIs, summed across all media and exposure pathways and based on RME exposure factors for future adult and child receptors, are shown in Tables 9.4.RME and 9.5.RME (Appendix A). The total HI for an adult is 8.9 and for a child is 20.9, resulting mostly from the ingestion exposure pathway and from the COPCs cobalt, manganese, and vanadium.

Several segregated total HIs exceed one for target organs or toxicological effect. The HIs based on thyroid effects are 11.9 for the child and 5.1 for the adult, due mostly to the ingestion of cobalt in groundwater. The segregated HIs for the central nervous system are 6.1 for the child and 2.5 for the adult, due mostly to ingestion of manganese. The total HIs for the metabolic system (as indicated by decreased hair cystine) are 2.6 for the child and 1.1 for the adult, due to the ingestion of vanadium. Hazard indices for other specific organs or targets are less than one.

The non-carcinogenic hazard associated with background groundwater in Zone 1 would also exceed one for both the adult and child receptors. Although cobalt concentrations are lower in background groundwater than in Zone 1 seepage-impacted groundwater and vanadium is not detected in Zone 1 background groundwater, the Zone 1 background manganese concentration (UCL95, 2.519 mg/L) exceeds the manganese EPC concentration (UCL95, 1.95 mg/L) in seepage-impacted groundwater (N.A. Water Systems, 2008b, 2008c). Furthermore, certain other potential COPCs that could contribute to non-carcinogenic hazard (e.g., molybdenum, cadmium and lead) have been infrequently detected in background groundwater, but were not detected in Zone 1 seepage-impacted groundwater during the selected HHRA monitoring period (N.A. Water Systems, 2008b, 2008c).

The total radiological and chemical carcinogenic risk, summed across all media and exposure pathways and based on RME exposure factors for future adult and child receptors, is shown in Table 9.6.RME (Appendix A). The total risk for a combined adult/child receptor is 1.4E-03, resulting mostly from the inhalation of the radionuclide COPC radium-226. As was the case for Southwest Alluvium, total radiological and chemical carcinogenic risk in Zone 1 background groundwater would also exceed the EPA target risk range, primarily because the Zone 1 background groundwater radium-226 concentration (UCL95, 1.314 pCi/L) exceeds the Zone 1 seepage-impacted groundwater radium-226 EPC (UCL95, 1.213 pCi/L). The selection of COCs from the COPCs, for all hydrostratigraphic units, is discussed in Section 7.2.

5.5 Risk Characterization Results for Zone 3

Potential future residents may be exposed to COPCs in Zone 3 groundwater if the tailings seepage migrates beyond the northern Section 36 boundary and future residents were to install a well and use seepage-impacted groundwater as a drinking water and domestic source. Calculated hazards and risks associated with potential future exposure to seepage impacted groundwater in Zone 3 are summarized Tables 7.7.RME through 7.9.RME, 8.3.RME, and 9.7.RME through 9.9.RME (Appendix A). For Zone 3, potential future non-carcinogenic hazards are associated primarily with the ingestion pathway and excess carcinogenic risks are associated primarily with the ingestion and inhalation pathways.

5.5.1 Ingestion of Groundwater - Zone 3

The non-cancer chemical (i.e., non-radiological) hazards are summarized in Tables 7.7.RME and 7.8.RME for potential future adult and child residents, respectively. The HI for groundwater ingestion by a future child resident is 236 and the HI for a future adult resident is 101. For the child, the HQs for aluminum (2.5), arsenic (87.8), cadmium (8.0), cobalt (93.5), manganese (29.0), molybdenum (9.4), nickel (1.6), and vanadium (2.3) exceed the EPA target level of one. For the adult, the hazard quotients for aluminum (1.1), arsenic (37.6), cadmium (3.4), cobalt (40.1), manganese (12.4), molybdenum (4.0), and vanadium (1.0) equal or exceed one. For both potential future residents, the sum of the HQs for arsenic, cobalt, and manganese accounts for almost 90 percent of the health hazard.

Two non-carcinogenic Zone 3 COPCs (molybdenum and uranium) are present in Zone 3 background groundwater at concentrations that exceed Zone 3 seepage-impacted groundwater concentrations. The UCL95 molybdenum concentration in background water is 17.43 mg/L and the EPC UCL95 concentration in impacted water is 0.739 mg/L. The UCL95 uranium mass concentration in background water is 0.107 mg/L and the EPC (UCL95) in impacted water is 0.0431mg/L. For comparison, the HI for ingestion of Zone 3 background groundwater was calculated using the background concentrations of the COPCs selected for the seepage-impacted-water hazard calculation (see supplemental Tables 7.F.RME and 7.G.RME in Appendix A). The background HI calculation does not include hazard associated with constituents that have been detected in background groundwater but are not present in seepage-impacted groundwater at sufficient concentration to be evaluated as COPCs in the HHRA (e.g., lead). The results showed that the HI for ingestion of the background groundwater was higher than that for seepage-impacted groundwater for both a potential adult receptor (125) and a potential child receptor (292).

The risk associated with background groundwater ingestion is related primarily to molybdenum; individual HQs for background Zone 3 ground water that exceed one for a future child receptor are arsenic (37.3), cadmium (1.4), cobalt (18.7), manganese (9.2), molybdenum (223), and uranium (2.3). The individual HQs for background Zone 3 groundwater that exceed one for an adult receptor are arsenic (16.0), cobalt (8.0), manganese (3.9), and molybdenum (95.5).

The chemical (i.e., non-radiological) and radiological cancer risk associated with the ingestion of Zone 3 groundwater was evaluated for a combined RME child/adult exposure. The results of the evaluation are summarized in Table 7.9.RME (Appendix A). Arsenic and chloroform are the only non-radionuclide, carcinogenic COPCs evaluated for Zone 3. The results show that the chemical cancer risk is 9.2E-03, which exceeds the EPA acceptable risk range of 1E-04 to 1E-06. Arsenic accounts for almost 100 percent of the non-radionuclide cancer risk. Arsenic is also present in Zone 3 background groundwater at a UCL95 concentration of 0.175 mg/L, which is approximately 42 percent of the Zone 3 seepage-impacted groundwater EPC (UCL95, 0.412

mg/L). The chemical cancer risk associated with ingestion of Zone 3 background groundwater for a combined RME child/adult exposure is 3.9E-03, which also exceeds the EPA acceptable risk range of 1E-04 to 1E-06 (see supplemental Table 7.H.RME in Appendix A).

The radiological cancer risk associated with the ingestion of seepage-impacted Zone 3 groundwater for a combined RME child/adult is 5.3E-04, which exceeds the EPA target range of 1E-04 to 1E-06. The largest excess cancer risks are associated with the following individual radionuclides: radium-228+D (3.5E-04), uranium-234 (2.0E-05), uranium-238+D (2.4E-05), radium 226+D (8.1E-05) and lead-210+D (5.5E-05). The radiological cancer risk associated with the ingestion of Zone 3 background groundwater is 2.8E-04, which also exceeds the EPA target range of 1E-04 to 1E-06 (see supplemental Table 8.A.RME in Appendix A). The elevated risk in background is related primarily to uranium-234, uranium-238+D, radium-226+D, radium-228+D, and lead-210+D. The Zone 3 background uranium groundwater concentration (UCL95, 0.107 mg/L) is approximately 2.5 times higher than the uranium concentration in seepage-impacted groundwater (EPC UCL95, 0.0431 mg/L). The thorium-230 activity in background groundwater (UCL95, 1.426 pCi/L) also exceeds, by approximately 5.5 times, the thorium-230 EPC (UCL95, 0.259 pCi/L) in seepage-impacted groundwater. Radium-226, radium-228 and lead-210 activities (UCL95) in background groundwater are 25 to 70 percent of the corresponding activities (EPC, UCL95) in seepage-impacted Zone 3 groundwater.

5.5.2 Dermal Contact with Groundwater - Zone 3

The non-carcinogenic health effects of dermal contact with Zone 3 groundwater used as tapwater for bathing were evaluated for potential future adult and child residents. The HQ for dermal contact with groundwater for an adult is 2.6 and the HQ for a child is 7.8. The individual HQs for dermal hazards associated with Zone 3 groundwater that exceed one for the potential child receptor are cadmium (1.1) and manganese (4.8). The only individual COPC HQ that exceeds one for dermal hazards associated with Zone 3 groundwater for the potential adult receptor is manganese (1.6).

The non-radiological cancer risk associated with the dermal contact with groundwater from Zone 3 was evaluated for a combined RME child/adult exposure. The results are provided in Table 7.3.RME in Appendix A. The cancer risks are 5.3E-05, which is within than EPA acceptable risk range of 1E-04 to 1E-06.

5.5.3 Inhalation of Groundwater - Zone 3

The non-carcinogenic health effects of inhalation exposure to Zone 3 groundwater through bathing was evaluated for potential future adult and child residents. The only volatile COPC evaluated in this scenario was chloroform. The results provided in Table 7.7.RME and 7.8.RME in Appendix A show that the HI for the inhalation exposure pathway for an adult is 0.0016 and a child is 0.0040. These results are well below the EPA target level of one which indicates that adverse health effects are unlikely following a chronic exposure under the groundwater inhalation exposure scenario.

The non-radiological cancer risk associated with the inhalation exposure to groundwater from Zone 3 was evaluated for a combined RME child/adult exposure. As for the non-carcinogenic risk evaluation, the only volatile COPC evaluated in this scenario was chloroform. The results are provided in Table 7.9.RME (Appendix A). The cancer risks are 2.0E-06, which is within the EPA acceptable risk range of 1E-04 to 1E-06.

The radiological cancer risk associated with the inhalation exposure to Zone 3 groundwater through domestic tapwater use (e.g., bathing, dishwashing, laundry, etc.) was evaluated for a combined RME child/adult exposure. Radium-226 is the only radiological COPC for which this exposure pathway is complete. The results are provided in Table 8.3.RME (Appendix A). The cancer risks for radium-226 are 1.2E-02, which exceeds the EPA acceptable risk range of 1E-04 to 1E-06.

However, Table 8.A.RME (Appendix A) indicates that the risk associated with radium-226 inhalation of Zone 3 background groundwater is 5.5E-03, which also exceeds the EPA acceptable risk range. The elevated background risk is the result of a Zone 3 background radium-226 activity (UCL95) of 4.996 pCi/L.

5.5.4 Hazard and Risk Summary - Zone 3

The total non-carcinogenic hazard and risks for future residential exposure to seepage-impacted groundwater in the Zone 3 have been calculated. The HIs summed across all media and exposure pathways, and based on RME exposure factors for future adult and child receptors, are shown in Tables 9.7.RME and 9.8.RME (Appendix A). The total HI for an adult is 104 and for a child is 244, resulting mostly from the ingestion exposure pathway and from the COPCs cobalt, arsenic, and manganese; however, the HIs for several individual COPCs exceed one. As can be determined from the description of the individual pathways in the preceding sections, the sum of non-carcinogenic hazard associated with background groundwater in Zone 3 across all media would also significantly exceed one for both the adult and child receptors.

Several segregated total HIs exceed or equal one for target organs or toxicological effect, as follows:

- The segregated HIs based on thyroid effects are 94.2 for the child and 40.3 for the adult, due mostly to the ingestion of cobalt in groundwater.
- The segregated HIs for skin toxicity are 88.4 for the child and 37.8 for the adult, due primarily to arsenic ingestion.
- The segregated HIs for central nervous system effects are 36.3 for the child and 15.1 for the adult due primarily to manganese ingestion.
- The segregated HIs for kidney effects are 19.5 for the child and 8.3 for the adult, due to molybdenum, cadmium and uranium. As described above, molybdenum and uranium are present in Zone 3 background groundwater at concentrations that exceed Zone 3 seepage-impacted groundwater concentrations.

- The segregated HIs for the metabolic system (as indicated by decreased hair cystine) are 2.3 for the child and 1.0 for the adult, due to the ingestion of vanadium.
- The segregated HI for reduced body and organ weights is 1.6 for the child receptor due to nickel.

Segregated hazard indices for liver and gastrointestinal effects for both the adult and the child are less than one. Additionally, the hazard index for reduced body and organ weights is less than one for the adult receptor.

The total radiological and chemical carcinogenic risk, summed across all media and exposure pathways, and based on RME exposure factors for future adult and child receptors are shown in Table 9.9.RME (Appendix A). The total risk for a combined adult/child receptor is 2.2E-02 resulting mostly from the inhalation of the radionuclide COPC radium-226. However, the risk associated with ingestion of arsenic and radium-228 also individually exceed the EPA target risk range. As was the case for the Southwest Alluvium and Zone 1, total radiological and chemical carcinogenic risk in Zone 3 background groundwater would also exceed the EPA target risk range, primarily due to inhalation exposure to radium-226. The selection of COCs from the COPCs, for all hydrostratigraphic units, is discussed in Section 7.2.

Section 6

Uncertainty Analysis

This section describes the uncertainties identified in the Church Rock Site HHRA. Uncertainty may relate to the variability of the available data or the variability in an estimate of a missing value for a parameter of interest (i.e., an EPC or exposure factor). This uncertainty analysis comprises a mostly qualitative assessment of assumptions used in the risk assessment and a discussion of whether the quantitative risk assessment process may have overestimated or underestimated the hazard and risk levels. The analysis presented in this section describes uncertainties related to the following:

- Exposure point concentrations and data;
- Exposure assessment;
- Toxicity assessment; and
- Risk characterization.

6.1 Exposure Point Concentrations and Data Uncertainties

The risk assessment process relies on the estimation of UCL95 EPCs in the exposure media to estimate risks and hazards. There is some bias associated with using an EPC to represent a receptor's exposure. There is also uncertainty associated with the sampled medium, including the numbers and locations of the sampling points (i.e., sampling bias), and possible measurement errors related to the sample collection and analysis. Our understanding of risk should include the context that allowable concentrations of constituents in public drinking water supplies (MCLs) sometimes exceed the risk range that EPA says must be used for baseline risk assessments (e.g., for arsenic).

The use of tailings-impacted groundwater concentrations representative of current conditions (e.g., current concentrations of impacted water in Section 36) is considered to be conservative for evaluation of future exposure scenarios, because future concentrations are anticipated to be attenuated or reduced by the natural processes (primarily adsorption and precipitation) that are known to occur in impacted groundwater at the Site. Furthermore, because it was necessary to include data from seepage-impacted wells in Section 2 for the Southwest Alluvium, the associated risks will be overestimated.

Regarding sampling bias, the assumption that a potential future receptor would be exposed only to impacted groundwater (in this case, tailings-impacted groundwater) would typically be considered conservative and likely to result in an overestimate of risk and hazard. In the case of the Church Rock Site, this uncertainty is not so important because the risk and hazard associated with background groundwater is similar to that of impacted water in many locations (see Section 5).

The uncertainty related with accurate sample collection and analysis of COPC concentrations is likely to be relatively low and could result in an overestimate or underestimate of the hazard and risk. However, the statistical process used to calculate the EPC (typically UCL95) is intended to minimize the chance that the average concentration is underestimated; therefore, it is likely that the result of the EPC estimation process results in an overestimate of risk and hazard. Additionally, the risk and/or hazard estimates are likely overestimated for each of the hydrostratigraphic units because certain monitoring parameters retained as COPCs were detected at very low frequency (i.e., less than 10 percent) in impacted groundwater. These COPCs include: cobalt in the Southwest Alluvium; vanadium in Zones 1 and 3 (vanadium has been detected only once in Zone 1 impacted water); and lead-210 and thorium-230 in Zone 3.

There is also some uncertainty related to missing data. The individual isotopes of uranium are of interest for radionuclide cancer risk calculations, but historically have not been part of the performance monitoring program. Therefore, a simplifying assumption was made that uranium isotope concentrations in groundwater are proportional to their natural abundance. Using this assumption improved the radiological cancer risk estimate relative to excluding the isotopes; however, because isotope activities in groundwater may not be proportional to natural concentrations, the calculated radiological risk due to uranium could be underestimated. For example, Rhodes et al. (2006) indicate that the activity ratio of uranium-234 to uranium-238 in groundwater increases with time due to the alpha particle recoil effect. A ratio higher than one-to-one would result in a lower calculated risk because the water cancer slope factor used for uranium-238+D is approximately 1.2 times higher than slope factor for uranium-234 (note however, that the U-234 slope factor is approximately 1.1 times the water cancer slope factor for U-238 without decay products).

There is low uncertainty associated with the missing data related to the elimination of monitoring parameters that were no longer considered relevant to the remedy implementation (i.e., a set of trace metals plus iron). These parameters were not included in the risk and hazard estimates because they were not analytes during the eight-quarter period (July 2006 through April 2008 inclusive) of performance monitoring data selected as representative of current conditions. These missing data are likely to represent a small underestimation of the hazard and risk; inclusion of a larger number of contaminants in the risk assessment is not likely to affect site decisions if the additional contaminants do not contribute significantly to the total risk. These parameters were eliminated from the monitoring program with EPA and NRC concurrence.

6.2 Exposure Assessment Uncertainties

Uncertainties associated with the exposure assessment for the Church Rock Site HHRA include (1) land use assumptions, (2) exposure factors, and (3) exposure models. The land use assumptions represent the most significant exposure assessment uncertainty, because the assumptions made about future exposure scenarios may result in either an overestimation or an underestimation of hazards and risks. In this case, the principal land use assumptions were as follows:

- Future residents would live adjacent to the Site and use seepage-impacted groundwater from one of the three hydrostratigraphic unit for drinking water.
- Other than the future use of impacted groundwater by future residents, land use would remain generally unchanged.

The likelihood that future residents will live adjacent to the Site and use impacted water for domestic use is believed to be very low; therefore the calculated risks and hazards represent an overestimation. The background water quality in the hydrostratigraphic units of interest in the vicinity of the Site is poor due to high concentrations of sulfate, chloride, TDS, metals, and radionuclides, and is not considered suitable for use as a drinking water source. Furthermore, there is unlikely to be sufficient saturated thickness available in Zone 1 for use as a potable water source. In the ROD, EPA stated that "the physical characteristics of Zone 1 are such that sufficient quantities of water could not be pumped from the sandstone to support volumes required for domestic or livestock purposes" and "Zone 1 would not be a good candidate for locating a domestic or livestock well even if there were no impacts from tailings seepage" (EPA, 1988c).

The assumption that future land use would remain generally unchanged is believed to be realistic; however, should future land use include exposures additional to the residential exposure scenario, the current risk and hazard estimates could be underestimated. Regarding exposure factors, an RME exposure was evaluated for the Church Rock Site HHRA and EPA default values were used for parameters such as groundwater ingestion rates, exposure duration, and event frequency. Because the RME represents the highest exposure that is reasonably expected to occur at a site (EPA, 1989), the resulting risk estimate is conservative (i.e., well above the average case and tends to overestimate exposure). However, it is possible that some of these exposure factors represent underestimates when considering the local population and, therefore, result in an underestimate of risk and hazard:

- A 30-year exposure duration may be low with respect to a local Navajo resident population because the Navajo resident population may be more likely to remain in one area than the general population (although it is also likely that there would be insufficient impacted water to use as a domestic supply for 30 years in Zones 1 and 3).
- A drinking water ingestion rate of two liters per day may be low with respect to a local population residing in a semi-arid environment.
- The assumption of a 350-day exposure frequency could be slightly low for the local population, but is bounded at 365 days, so the effect on risk would be expected to be minimal.

Conversely, it is possible that exposure factors related to the groundwater inhalation scenario represent overestimates when considering the local population and, therefore, result in an overestimate of risk and hazard. For example, 2000 census information posted on the Navajo Churchrock and Pinedale Chapters indicates that approximately 39 percent of the Chapter residents lack indoor plumbing and 38 percent lack kitchen facilities. Neither of these circumstances eliminate the potential exposure to groundwater contaminants through the inhalation pathway, however, the use of the Foster and Chrostowski shower model and the Andelman volatilization factor may overestimate potential risk for these potential receptors.

With respect to exposure models, there are two factors that contribute to uncertainty associated with the model utilized to calculate the exposure point concentration for radium-226 under the groundwater inhalation exposure pathway and to calculate the corresponding risk. This exposure pathway represents a significant percentage of the total risk calculated for each of the three hydrostratigraphic units and the model utilizes protective assumptions where measured radium concentrations are not available. However, the assumption that, in a domestic water supply, radium-226 becomes sufficiently airborne and inhaled to justify the use of the radium-226+D cancer slope factor instead of the slope factor for its gaseous decay product radon-222+D, appears to be conservative. The radium-226 cancer slope factor is approximately 650 times higher than the radium-226+D cancer slope factor, and consequently, the calculated risks would be proportionally lower. Secondly, the Andelman (1990) volatilization factor, which is used by EPA in the development of its radionuclide PRGs, appears very conservative for the non-volatile radium-226 because it assumes that half of the contaminant is transferred from the water through all domestic uses. At least one other source suggests that this transfer factor is too high for radon. In a United States Geological Survey Water-Resources Investigation Report, Lindsey and Ator (1996) indicate that well water radon concentrations equal to 10,000 pCi/L typically release approximately 1 pCi/L of radon to the air; this equals a transfer factor that is 20 percent of the Andelman factor.

The uncertainty associated with the use of the Foster and Chrostowski Model for inhalation exposure to chloroform is low because the chloroform concentrations are low when compared to other COPCs, resulting in lower risk and hazard. Similarly, the hazard and risk through the dermal exposure pathway for any of the hydrostratigraphic units represents a small proportion of the ingestion pathway (up to approximately 10 percent in the Southwest Alluvium).

6.3 Toxicity Assessment Uncertainties

The principal COPCs in groundwater at the Church Rock Site include radionuclides and metals including manganese, uranium, arsenic, cobalt, and molybdenum. The toxicity assessment portion of the Church Rock Site HHRA relied on existing toxicity information available from EPA and other sources, including information regarding carcinogenic and non-carcinogenic effects associated with radionuclide and non-radionuclide COPCs. The toxicity information is presented on Tables 5.1, 5.2, 6.1, and 6.2 (Appendix A).

The uncertainty associated with toxicity information varies depending on the COPC. EPA methodologies for both cancer and non-cancer toxicity evaluation (i.e., development of RfDs and cancer slope factors) are intentionally designed to be protective. In many cases, data are extrapolated from animals to sensitive humans by the application of uncertainty factors to an estimated No Observed Adverse Effect Levels (NOAELs) or Lowest Observed Adverse Effect

Levels (LOAELs) for non-cancer effects. It is likely in many cases that uncertainty factors overestimate the magnitude of differences that may exist between human and animals, and among humans. However, the extent to which toxicity values may overestimate toxic potency is not clear, and it is possible that the toxicity values for some compounds may not be adequately protective (e.g., where multiple COPCs are present or when the toxicity studies did not detect a sensitive adverse effect).

In addition, the derivation of cancer slope factors often involves linear extrapolation of effects at high doses to potential effects at lower doses commonly seen in environmental exposure settings. It is likely that the assumption of linearity is conservative and yields slope factors that are unlikely to lead to underestimation of risks for most carcinogens. It is also possible that the dose-response curves for individual carcinogens vary from the linear extrapolation in a way that leads to an underestimate of risk.

There is generally less uncertainty associated with carcinogenic risk from radionuclides than with non-radionuclides because of the method in which the toxicity numbers are typically developed. For exposure to chemicals, slope factors typically represent an upper bound estimate or 95th percent confidence limit value that has been obtained from extrapolation from laboratory experiments (EPA, 1989). Cancer slope factors for radionuclides are central tendency estimates (i.e., median or 50th percentile values) of the age-averaged increased lifetime cancer risk that are based on epidemiological studies of radiogenic cancers in humans.

There is significant uncertainty associated with the calculation of absorbed RfDs for the dermal exposure pathway, primarily in that the EPA guidance (2004) recommends the use of a 100 percent ABS_{GI} value for inorganics that have not otherwise been determined. This assumption may contribute to an underestimation of hazard or risk for those inorganics that are actually poorly absorbed in the gastrointestinal tract. As the ABS_{GI} value decreases, the contribution of the dermal pathway to overall risk increases, relative to the ingestion pathway.

Some of the COPCs evaluated in the HHRA, including manganese, uranium, and vanadium have special considerations associated with the toxicity values cited on the RSL table that may affect the uncertainty of the risk assessment. Manganese is a trace nutrient that has both a physiologically-required intake level and an intake level that is considered toxic. The "Adequate Intake" for manganese established by the National Research Council ranges from 1.2 mg/day for a child to 2.3 mg/day for an adult male (Institute of Medicine, 2001). The manganese RfD obtained from the EPA RSL table (0.024 mg/kg-d) incorporates an adjustment to the manganese RfD of 0.14 mg/kg-d listed on IRIS http://www.epa.gov/iris/subst/0373.htm. The RSL Table User's Guide (http://www.epa.gov/region9/superfund/prg/) indicates that the modifications were in accordance with a recommendation by the author of the IRIS assessment to subtract a normal United States dietary contribution (an upper limit of 5 mg/day) when evaluating non-food (e.g., drinking water or soil) exposures. The RSL Table User's Guide indicates that IRIS further recommends using a modifying factor of 3 when calculating risks associated with non-food sources, leading to the RfD of 0.024 mg/kg-day. The results of the risk calculations indicate that manganese is the most significant contributor to the total hazard in the Southwest Alluvium and also contributes significant hazard in Zones 1 and 3. These hazards may be overestimated due to the uncertainty, or conservatism, in the adjusted toxicity value for non-food manganese exposure.

The RfD used for uranium non-carcinogenic hazard was for "uranium - soluble salts," which appears appropriate for a drinking water exposure in which the potential receptor ingests salts dissolved in the drinking water. However, the use of this RfD may overestimate the calculated hazards slightly. IRIS references a 1949 study by Maynard and Hodge which indicates that soluble uranium salts are more toxic than the insoluble uranium salts (IRIS, http://www.epa.gov/iris/subst/0421.htm). Groundwater monitoring concentrations are reported for total uranium at the Church Rock Site (i.e., based on an unfiltered sample), rather than dissolved uranium (i.e., based on a filtered sample). Therefore, the reported concentrations could include insoluble uranium as well as soluble uranium. The overall affect of this uncertainty would be expected to be low. Non-carcinogenic uranium hazard was significant only in the Southwest Alluvium.

Vanadium HI values are above one for ingestion of impacted groundwater from Zones 1 and 3. EPA derived the oral RfD toxicity value for vanadium in the RSL Table from the IRIS RfD for vanadium pentoxide by factoring out the molecular weight of the oxide ion. It is not known whether this adjustment imparts any uncertainty into the risk calculations.

Toxicity values are not available for all COPCs. Therefore, health risks and hazards cannot be quantitatively assessed for all contaminants and the total risk or hazard for the site may be underestimated in such circumstances. At the Church Rock Site, monitoring COPCs representing common ions (i.e., sulfate, chloride, nitrate [measured as nitrate-nitrogen]) were eliminated from further consideration in the quantitative risk assessment calculations because with the exception of a nitrate RfD for formula ingestion by infants (0 to 3 months old), they do not have associated toxicity values. The nitrate RfD is 1.6 mg/kg-d for early clinical signs of methemoglobinemia for infants of age 0 to 3 months old. The exclusion of these parameters results in some uncertainty in the risk assessment as described below.

UCL95 chloride concentrations in seepage-impacted water at the Site exceed UCL95 background concentrations in each of the hydrostratigraphic units. However, the UCL95 chloride concentrations in seepage impacted water are below the secondary maximum contaminant level (SMCL, 250 mg/l) in each unit, and the maximum detected concentrations exceed the SMCL only in the Southwest Alluvium seepage-impacted water (374 mg/L, see (Appendix B). SMCLs are established by EPA only as guidelines to assist public water systems in managing their drinking water for aesthetic considerations (e.g., taste, color and odor) and EPA does not consider these contaminants to present a risk to human health at the SMCL. The chloride SMCL is established for a salty taste associated with chloride. Because the UCL95 concentrations in seepage impacted water are similar to or below the SMCL, chloride has little or no effect on uncertainty associated with the risk assessment.

Sulfate is a component of the tailings seepage fluid, and it is present in impacted water in the three hydrostratigraphic units with UCL95 values ranging from approximately 2,800 to 4,000 mg/L. However, sulfate is also present in the background groundwater and sulfate concentrations in the three hydrostratigraphic units are fixed by geochemical equilibrium with gypsum (or anhydrite) and calcite and are therefore unchangeable. Sulfate has an EPA SMCL of 250 mg/L based on a bitter, salty, or medicinal taste and higher concentrations have been associated with laxative effects. EPA proposed in 1994, but did not finalize, an MCL for sulfate of 500 mg/L based on the potential laxative or diarrheal health effects of sulfate in drinking water (59 Fed. Reg. 65578-65604). The New Mexico Water Quality Control Commission domestic water-supply standard for sulfate is 600 mg/L (New Mexico Administrative Code 20.6.2.3103). However, there is conflicting information regarding these potential effects: ATSDR (2010) cites two studies that have statements regarding the "laxative effect" with drinking water, wherein one study concluded that a laxative effect resulted from water containing 1 g sulfate/L, while a second study, using drinking water containing 1.2 g/L, found no "laxative effect." ATSDR (2010) also considered the effects of ingesting groundwater sulfate concentrations in Wyoming that are similar to those at the Church Rock Site. They state that drinking water from a well with sulfate concentrations of 3,640,000 µg/L (3,640 mg/L) would result in daily intakes of 7.3 g/day for an adult and 3.6 g/day for a small child and that both of these daily intake rates would exceed the intake rate associated with the gastrointestinal discomfort (2 g/day). Therefore, it is likely that a potential future receptor would become ill from ingestion of the seepage-impacted water (or background water) from the vicinity of the Church Rock Site. However, if a potential receptor is capable of ingesting water with a sulfate concentration that is ten times the taste-based SMCL, the effect on the hazard and risk estimates is almost certainly the opposite: due to the acute gastrointestinal effects, water with similar elevated concentrations of sulfate would not be drinkable for sufficient time to experience the ingestion-related chronic hazard and risk effects of the COPCs present in the water. In this situation, the calculated hazard and risk estimates would likely be substantial overestimates and actual risks would be related only to the inhalation and dermal exposures.

Nitrate has a Federal MCL of 10 mg/L (as nitrate-nitrogen). Infants below the age of six months who drink water containing nitrate in excess of the MCL are at particular risk of nitrate toxicity, which causes methemoglobinemia and can be fatal. According to the Ohio EPA (2005), healthy adults and older children can consume higher levels of nitrate than infants because of their fully developed digestive systems. Ohio EPA recommends that (1) women who are pregnant or nursing consult with their physicians about limiting nitrate consumption, and (2) people with medical conditions that may make them more susceptible to methemoglobinemia, such as reduced stomach acidity, should also consult their physicians. The Idaho Department of Environmental Quality (2001) summarized research on nitrate effects on human health, stating that studies have implicated nitrate exposure as a possible risk factor associated with non-Hodgkin's lymphoma, gastric cancer, hypertension, thyroid disorder and birth defects, but that it is difficult to demonstrate a link between nitrate in drinking water and cancer or birth defects. This is due, in part, to the widely variable exposure to nitrates from other sources. The National

Research Council (1995) stated that nitrate and nitrite have been tested for carcinogenicity in laboratory animals, and epidemiologic studies of human cancer rates among populations with high nitrate or nitrite exposure concentrations have been performed. The results have generally indicated that nitrate and nitrite are not carcinogenic in laboratory animals when administered in the absence of nitrosatable amines; but when nitrite and nitrosatable amines are administered together, carcinogenic nitrosamines can be formed in the stomach and lead to various tumors.

HEAST cancer slope factors for radionuclides were obtained from the EPA Radionuclide PRGs website (http://epa-prgs.ornl.gov/radionuclides/). Certain radionuclide COPCs (U-235, U-238, Ra-226, Ra-228 and Pb-210) are designated with the suffix "+D" (e.g., U-238+D, Ra-226+D) to indicate that cancer risk estimates for these radionuclides include the contributions from their short-lived decay products, assuming equal activity concentrations (i. e., secular equilibrium) with the principal or parent nuclide in the environment. The PRG Users Guide indicates that using the "+D" designation can be important because some decay products can be more toxic than the parent isotope. EPA states that in the absence of site-specific data regarding secular equilibrium, the "+D" values for radionuclides should be used; therefore, for the Church Rock Site HHRA, the cancer slope factors used for the following radionuclides had the "+D" designation: uranium-235+D, uranium-238+D, radium-226+D, radium-228+D, and lead-210+D(see Tables 6.1 and 6.2 in Appendix A).

There have been no site-specific determinations of secular equilibrium. Uncertainty associated with the use of these +D designations varies with COPC. For both of the radium isotopes, the difference in slope factor between the principal nuclide and the +D value is less than one percent. However, for uranium-235, the difference is approximately three percent; for uranium-238, the difference is 36 percent; and for lead-210, the difference is 44 percent. Therefore, the uncertainty related to the assumption of secular equilibrium is greater for uranium than radium and is in the range of three to 44 percent.

6.4 Risk Characterization Uncertainties

The risk characterization step of the HHRA process summarizes and combines outputs of the exposure and toxicity assessments to characterize risk in quantitative and qualitative statements. There is uncertainty in this process related to both non-carcinogenic and carcinogenic risk. For the non-carcinogenic hazard, there is uncertainty related to the significance of HQs greater than one and the process of summing individual HQs for multiple COPCs and across multiple exposure pathways. Because there is conservatism built into most toxicity numbers (i.e., RfDs) through uncertainty factors and modifying factors (e.g., the range of combined uncertainty and modifying factors shown in Table 5.1 is 3 to 1000), there is inherent conservatism in the HQ value calculated by dividing the estimated intake (which in turn may be conservative due to the use of conservative exposure factors) by the toxicity number.

Furthermore, EPA (1989) indicates that the potential for an adverse health effect does not necessarily increase linearly as an RfD is approached (i.e., an HQ of 1) or exceeded because RfDs do not have equal accuracy or precision and are not based on the same severity of toxic effects. This presents uncertainty when calculating the HI, which is the sum of the individual COPC HQs evaluated within an exposure scenario or across exposure scenarios. HIs are calculated in this HHRA first using the assumption that all the hazards are additive, and secondly by toxic effect or target organ. These HI calculations are important uncertainties in the risk characterization. The assumption that the risks are additive likely (but not always) would result in an overestimation of the hazard. It is unknown whether COPC interactions are synergistic, antagonistic, or additive or whether the severity of effects used to develop the RfDs are comparable. These uncertainties may be reduced by summing the COPCs by toxic effect or target organ; however, the hazard is likely still overestimated due to conservatism in the RfD development and RfDs that are based on toxic effects that are difficult to categorize (e.g., the reported effect for vanadium is "decreased hair cystine").

Another major source of uncertainty in the Church Rock HHRA, as well as for future risk management decisions, is the risk associated with background COPC concentrations. There are three principal situations under which unacceptable background hazard or risk is encountered at the Church Rock Site:

1. Background COPC concentrations higher than seepage-impacted waters – In this case, a hazard or risk driver is present at higher concentrations in background water than in seepage-impacted waters. An example of this is the groundwater inhalation exposure pathway for the Southwest Alluvium, where radium-226 concentrations represent more than half the total risk, and where radium-226 concentrations in background water are three times higher than in seepage impacted water.

2. Background COPC concentrations lower than seepage-impacted waters - In this case, a hazard or risk driver is present at lower concentrations in background water than in seepage-impacted waters, but the risk associated with background water exceeds the EPA acceptable range of 1E-04 to 1E-06. An example of this is the groundwater ingestion exposure pathway for Zone 3, where arsenic concentrations in impacted water are approximately 2.4 times the concentration in background water, but the non-radiological carcinogenic risk associated with both background and seepage-impacted water concentrations exceed the EPA acceptable range.

3. Different COPC distributions in seepage-impacted and background waters - In this case, the COPC distribution in background and seepage-impacted waters are different, but the risk or hazard associated with both waters exceed the applicable EPA acceptable range. An example of this is the non-carcinogenic groundwater ingestion exposure pathway for Zone 3, where the HI associated with seepage-impacted water for a child is estimated to be 236, due primarily to cobalt (93.5), arsenic (87.8), and manganese (29.0); whereas the background water ingestion exposure HI for a child is estimated to be 292 and is primarily due to molybdenum (222), arsenic (37.3), and cobalt (18.7).

Clearly, some of the hazards and risks that are calculated for the seepage-impacted water are overestimates because background hazards or risks either exceed or represent a large portion of the calculated hazard or risk. The variability of the background conditions results in some uncertainty in describing and quantifying the incremental risk due to seepage impacts, and will ultimately affect risk management decisions. For example, EPA guidance (2002) describes situations where COPCs with concentrations below natural or anthropogenic background concentrations are excluded from further consideration in the establishment of remediation goals. However, the application of this method to select individual COCs for each of the three hydrostratigraphic units may appear somewhat subjective when considering the background risks as a whole.

Section 7

Risk Assessment Summary

The objective of a human health risk assessment is to evaluate the likelihood of adverse effects occurring in human populations potentially exposed to contaminants released in the environment. This section summarizes the results of the Church Rock Site HHRA, including the risk calculations, the evaluation of uncertainty and the selection of chemicals of concern (COCs). The site-specific objectives for updating the Church Rock Site HHRA are the following:

1. Update the risk estimates for the Site using current risk assessment methods and information;
2. Support the reassessment of remediation levels;
3. Provide a basis for comparing remedial alternatives; and
4. Identify Point of Compliance (POC) and Point of Exposure (POE) concentrations in accordance with NRC requirements.

The following sections describe how the results of the HHRA have met, or can be used to meet, these objectives.

7.1 Hazard and Risk Summary

There is no current human exposure to groundwater at the Site (EPA, 2008) except during the quarterly groundwater sampling conducted by UNC personnel, and no potential future exposure to groundwater contaminants on UNC-owned property, because no groundwater supply wells drawing on any of the three hydrostratigraphic units will be allowed on UNC property, and the same restriction will apply once the license is transferred to the DOE for long-term surveillance monitoring.

Therefore, the focus of the Church Rock Site HHRA was the potential future exposure to seepage-impacted groundwater contaminants in one of the three hydrostratigraphic units (i.e., Southwest Alluvium, Zone 1, and Zone 3) at locations outside Section 2. A residential tapwater (i.e., groundwater) exposure scenario was selected. Because the hydrogeologic characteristics, contaminants, and remedial alternatives for each of the units are distinct, the risks of potential future exposure to groundwater at the following locations have been evaluated separately:

- Southwest Alluvium – a hypothetical future well located adjacent to the UNC property boundary in Section 3;
- Zone 1 – a hypothetical future well located adjacent to the UNC property boundary in Section 1; and
- Zone 3 – a hypothetical future well located to the north of and adjacent to the UNC property boundary in Section 36.

The residential tapwater exposure scenario assumes that residents would construct residences and live adjacent to the UNC property boundary near the tailings impoundments for up to 30 years, and that residents would use seepage-impacted groundwater for all domestic water needs. To assess the potential exposure of a hypothetical future resident, three exposure pathways were selected for evaluation:

- Ingestion of groundwater as the drinking water source;
- Direct dermal contact with groundwater through bathing; and
- Inhalation of volatile compounds in groundwater through showering exposure and, for radionuclides, through other domestic tapwater uses.

The non-carcinogenic hazard and carcinogenic risk to potential RME receptors were evaluated for each of the exposure pathways. A future resident adult and a future resident young child (aged 1 to 6) were selected as the potentially exposed populations for non-carcinogenic COPCs. A future resident combined child/adult receptor was selected as the potentially exposed population for the carcinogenic COPCs, including radionuclides.

The results of the risk assessment calculations are provided in the RAGS Part D tables in Appendix A and are summarized for the child and combined child/adult receptors as follows:

Hydrostratigraphic Unit	Exposure pathway	Total Non-carcinogenic Hazard Index (Child)	Chemical Carcinogenic Risk (Child/Adult)	Radionuclide Carcinogenic Risk (Child/Adult)	Total Carcinogenic Risk (Child/Adult)
Southwest Alluvium	Ingestion	12.9	5.9E-05	1.5E-04	2.1E-04
Southwest Alluvium	Dermal	1.3	4.7E-07	N/A	4.7E-07
Southwest Alluvium	Inhalation	0.0041	2.1E-06	*2.9E-04*	2.9E-04
Southwest Alluvium	**Total**	**14.2**	**6.2E-05**	**4.4E-04**	**5.0E-04**
Zone 1	Ingestion	19.9	3.3E-05	*5.3E-05*	8.6E-05
Zone 1	Dermal	0.95	2.1E-07	N/A	2.1E-07
Zone 1	Inhalation	0.0008	4.2E-07	*1.3E-03*	1.3E-03
Zone 1	**Total**	**20.9**	**3.4E-05**	**1.4E-03**	**1.4E-03**
Zone 3	Ingestion	*236*	9.2E-03	5.1E-04	9.7E-03
Zone 3	Dermal	7.8	5.3E-05	N/A	5.3E-05
Zone 3	Inhalation	0.0040	2.0E-06	1.2E-02	1.2E-02

Hydrostratigraphic Unit	Exposure pathway	Total Non-carcinogenic Hazard Index (Child)	Chemical Carcinogenic Risk (Child/Adult)	Radionuclide Carcinogenic Risk (Child/Adult)	Total Carcinogenic Risk (Child/Adult)
Zone 3	**Total**	**244**	**9.3E-03**	**1.3E-02**	**2.2E-02**

Notes:
N/A = Not applicable, radionuclides were not retained as COPCs under the dermal exposure pathway
Italics indicate that the hazard or risk shown for seepage-impacted groundwater is within background hazard or risk.

The summary table shows that there is significant total non-carcinogenic hazard and total risk associated with a hypothetical residential exposure scenario in each of the hydrostratigraphic units and that the highest hazard and risks are associated with Zone 3 groundwater. These calculations may accurately reflect the combined risk of exposure to seepage-impacted and non-seepage-impacted (i.e., background) groundwater, but likely overestimate the risk associated with seepage-impacted groundwater due the non-seepage-impacted COPC concentrations.

Total non-carcinogenic HI values exceed one in each of the hydrostratigraphic units. The ingestion exposure pathway is the most important for non-carcinogenic hazard, where total hazards exceed one for each of the hydrostratigraphic units. For the dermal exposure pathway, hazards exceed one for the Southwest Alluvium and Zone 3. The inhalation exposure pathway is not important with respect to non-carcinogenic hazard for any of the hydrostratigraphic units, because the only volatile non-radiologic compound present in seepage-impacted groundwater is chloroform at very low concentrations, and only at locations immediately adjacent the tailings impoundment. The hazard associated with the ingestion exposure scenario in background groundwater for Zone 3 exceeds that of the seepage-impacted water.

HIs segregated by target organ also exceed one within each of the hydrostratigraphic units as follows:

- For the Southwest Alluvium - The HIs based on central nervous system effects are 8.7 for the child and 3.6 for the adult, due to the ingestion of, and dermal contact with, manganese in groundwater. Segregated HIs for kidney effects are 2.7 for the future resident child and 1.2 for the future resident adult (due mostly to uranium ingestion) and the HI for thyroid effects is 2.1 for the child (due mostly to cobalt ingestion). Hazard indices for other specific organs or targets are less than one.

- For Zone 1 – Several segregated total HIs exceed one for target organs or toxicological effect. The HIs based on thyroid effects are 11.9 for the child and 5.1 for the adult (due mostly to the ingestion of cobalt in groundwater). Total HIs for the central nervous system are 6.1 for the child and 2.5 for the adult (due to manganese), and the total HIs for the metabolic system are 2.6 for the child and 1.1 for the adult (due to vanadium). Hazard indices for other specific organs or targets are less than one.

- For Zone 3 – The segregated HIs based on thyroid effects are 94.2 for the child and 40.3 for the adult, due mostly to the ingestion of cobalt in groundwater. Segregated HIs for skin toxicity are 88.4 for the child and 37.8 for the adult. Segregated HIs for the central nervous system are 36.3 for the child and 15.1 for the adult, and the segregated HIs for the kidney are 19.5 for the child and 8.3 for the adult. The segregated HIs for the metabolic system (as indicated by decreased hair cystine) are 2.3 for the child and 1.0 for the adult, due to the vanadium ingestion. Hazard indices for the liver, for both the adult and the child, are less than one. Additionally, the hazard index for gastrointestinal system effects and reduced body and organ weights is less than one for the adult receptor.

The summary table shows that total cancer risk exceeds EPA's target risk range of 1E-04 to 1E-06 for each of the hydrostratigraphic units. The radionuclide carcinogenic risk associated with inhalation exposure pathways for the Southwest Alluvium and Zone 1, and the radionuclide risk associated with the ingestion pathway for Zone 1, are below background risks for these pathways within these units. In each case, radium-226 and/or radium-228 activities in background water exceed those in seepage-impacted water.

There is significant uncertainty associated with the risk assessment results, primarily with respect to the following factors:

- Background COPC concentrations. Some of the hazards and risks that are calculated for the seepage-impacted water are overestimates because background hazards or risks either exceed or represent a large portion of the calculated hazard or risk.
- Background water quality is not considered suitable for use as a primary drinking water source (e.g., due to sulfate and other chemicals that affect potability);
- Toxicity numbers (particularly for non-radionuclides) are typically conservative due to the incorporation of uncertainty factors and modifying factors. Furthermore, summations of total hazards and total risks may or may not be appropriate.
- Inhalation risks may be overestimated for the following reasons:
    - The model for inhalation risk to radium-226 may not be appropriate because radium-226 is not volatile. The evaluation of exposure to the radium-226 decay product radon might be more appropriate, but measurements of radon in groundwater are not available. Furthermore, the use of the Andelman volatilization factor may be overly conservative for radium-226; a U.S. Geological Survey report (Lindsey and Ator, 1996) indicates that the typical transfer of radon from well water to residential air is 20 percent of that represented by the Andelman factor.
    - Inhalation exposure may be lower than estimated, because many local residents don't have running water in their homes and the models used to approximate RME intake may be inappropriate. However, some local residents may also haul

water from local wells and exposure factors for this potential exposure scenario have not been identified.

- Hazards and risks may be underestimated based on usage of the following exposure factors:
    - A 30-year exposure duration may be low with respect to a local resident population;
    - A drinking water ingestion rate of two liters per day may be low with respect to a local population residing in a semi-arid environment;
    - The assumption of a 350-day exposure frequency could be slightly low for the local population, but is bounded at 365 days.
- There is likely to be insufficient water available in Zone 1 for use as a potable water source for the exposure duration evaluated in the HHRA.
- Downgradient seepage impacts have been, and are expected to continue to be, limited by natural attenuation in all three hydrostratigraphic units.
- Assumptions that certain radionuclide decay products are at secular equilibrium with their parent nuclides.
- Assumption that uranium isotopes are present in proportion to natural abundance.

In summary, for the RME individual that meets assumptions made in this assessment with the established uncertainties, there is a potential for human health risk that exceeds the criteria established by the EPA for remedial action to be conducted.

7.2 Support the Reassessment of Remediation Levels and Provide a Basis for Comparing Remedial Alternatives

The results of this risk assessment, together with the background risk information and data from the three hydrostratigraphic units at the Site, can be used to support the reassessment of remediation levels within the SWSFS and provide a basis for comparing remedial alternatives.

Consistent with EPA risk assessment guidance regarding background concentrations (EPA, 2002), COPCs that are present in both impacted and background groundwater have been carried through the quantitative risk assessment calculations of the seepage-impacted groundwater. The resulting non-carcinogenic hazard and carcinogenic risk estimates (i.e., estimates which include background risk) may accurately quantify the total hazard and risk of exposure to groundwater, but may overestimate the excess risk associated with seepage-impacted groundwater due to the hazards or risk associated with background concentrations. Therefore, background concentrations should be considered in any future reassessment of Site remediation cleanup levels. Considerations may include the following:

- Where background concentrations exceed ARARs, background concentrations may be selected as remediation levels.
- Where background COPC concentrations exceed COPC concentrations in seepage impacted water, COPCs may be eliminated from further consideration as COCs.
- Where background water hazards or risks exceed EPA target levels, it would be more effective and appropriate to implement remediation alternatives that restrict exposure to contaminated groundwater as compared to the existing groundwater remedy.

COCs were identified using a two step process. First, COCs were identified using the following criteria:

- Those COPCs which contribute at least 1E-06 cancer risk to an exposure scenario (i.e., total risk) that exceeds EPA's target risk range of 1E-04 to 1E-06; or
- Those COPCs contributing an HQ of at least 0.1 to an HI (for a segregated total HI) of 1 for non-cancer effects.

COCs that meet these criteria are shown on Tables 10.1.RME to 10.9.RME. The second step was to compare COC concentrations for each of the hydrostratigraphic units against the corresponding background concentrations and background risks. The following table summarizes the selected COCs and the rationale used to select them.

Hydrostratigraphic Unit	COCs Identified in "Table 10s"	Non-carcinogen or Carcinogen	Selected as COC	COC Selection Rationale
Southwest Alluvium	Arsenic	Carcinogen	No	Similar to background concentrations; below MCL
Southwest Alluvium	Cobalt	Non-carcinogen	No	One detected result in impacted water; background concentrations higher than impacted water concentrations
Southwest Alluvium	Manganese	Non-carcinogen	Yes	HI = 8.7 (Child)
Southwest Alluvium	Uranium	Non-carcinogen	Yes	HI = 2.7 (Child)
Southwest Alluvium	Chloroform	Carcinogen	Yes	Risk = 1.7E-06 – Ingestion and dermal Risk = 2.1E-06 – Inhalation
Southwest Alluvium	Uranium isotopes	Carcinogen	Yes	Risk > 1E-04

Hydrostratigraphic Unit	COCs Identified in “Table 10s”	Non-carcinogen or Carcinogen	Selected as COC	COC Selection Rationale
Southwest Alluvium	Radium-226	Carcinogen	No	Background concentrations higher than impacted
Southwest Alluvium	Radium-228	Carcinogen	No	Background concentrations higher than impacted
Zone 1	Cobalt	Non-carcinogen	Yes	HI = 11.9 (Child)
Zone 1	Manganese	Non-carcinogen	No	Background concentrations higher than impacted
Zone 1	Vanadium	Non-carcinogen	No	Hazard based on only one historical detection in seepage impacted water
Zone 1	Arsenic	Carcinogen	No	Similar to background concentrations; below MCL
Zone 1	Radium-226	Carcinogen	No	Background concentrations higher than impacted water concentrations
Zone 1	Radium-228	Carcinogen	No	Background concentrations higher than impacted water concentrations
Zone 1	Thorium-230	Carcinogen	No	Risk = 1.1E-06, within background radiological risk
Zone 3	Aluminum	Non-carcinogen	Yes	HI = 2.5 (Child)
Zone 3	Arsenic	Carcinogen and Non-carcinogen	Yes	HI = 88.4 (Child) Risk 9.3E-03
Zone 3	Cadmium	Non-carcinogen	Yes	HI = 9.1 (Child)
Zone 3	Cobalt	Non-carcinogen	Yes	HI = 94.2 (Child)
Zone 3	Manganese	Non-carcinogen	Yes	HI = 33.8 (Child)
Zone 3	Molybdenum	Non-carcinogen	No	Background concentrations higher than impacted water concentrations
Zone 3	Nickel	Non-carcinogen	Yes	HI = 1.6 (Child)

Hydrostratigraphic Unit	COCs Identified in "Table 10s"	Non-carcinogen or Carcinogen	Selected as COC	COC Selection Rationale
Zone 3	Vanadium	Non-carcinogen	Yes	HI = 2.3 (Child)
Zone 3	Uranium	Non-carcinogen	No	Background concentrations higher than impacted water concentrations
Zone 3	Chloroform	Carcinogen	Yes	Risk = 1.6E-06 – Ingestion and dermal Risk = 2.0E-06 – Inhalation
Zone 3	Uranium Isotopes	Carcinogens	No	Background concentrations higher than impacted water concentrations
Zone 3	Radium-226	Carcinogen	Yes	Risk = 8.5E-05 – Ingestion Risk 1.2E-02 Inhalation
Zone 3	Radium-228	Carcinogen	Yes	Risk = 3.5E-04 – Ingestion
Zone 3	Lead-210	Carcinogen	Yes	Risk = 5.5E-05 – Ingestion

These COCs may require consideration for remedial action in the SWSFS. The SWSFS, which is currently underway, will consider the complicated nature of overlapping human health risks and hazards associated with seepage-impacted and background water. This information will be used to support any future CERLCA decision-making regarding remedy modification and, if necessary and appropriate, provide a basis for potentially waiving ARARs due to TI, consistent with the NCP and EPA TI waiver guidance.

7.3 Identify Point of Compliance (POC) and Point of Exposure (POE) Concentrations in Accordance with NRC requirements

The results of this risk assessment, together with the background risk information and data from the three hydrostratigraphic units at the Site, can be used outside of the CERCLA program to support the identification of NRC Point of Compliance (POC) and Point of Exposure (POE) concentrations (and associated risks) in accordance with NRC requirements.

The elements of the exposure assessment for the NRC are established in NRC guidance for review of reclamation plans (NRC, 2003, known as NUREG 1620), according to which:

- The POC is the location at which the groundwater is monitored to determine compliance with the groundwater protection standards. POCs have been established for each of the hydrostratigraphic units in the UNC's NRC Source Materials License.
- The POE is any location where people, wildlife, or other species could reasonably be exposed to hazardous constituents from groundwater contaminated by uranium mill tailings. The POE is generally located at the downgradient edge of land that will be transferred to either the Federal government or the state for long-term institutional control. For the Church Rock Site, the land to be transferred for administration by DOE includes Section 2, which comprises the tailings disposal site, and may also include Section 36, which is currently owned by UNC and adjoins Section 2 to the north.

With the exception of the previously mentioned, unexpected high frequency of lead-210 concentrations in October 2010, the Church Rock Site meets all NRC License ground water protection standards at the POCs for the Southwest Alluvium and, upon approval of the ACL application for nickel and chloroform in Zone 1, will meet all the NRC License compliance standards in Zone 1. (The first uranium exceedance (0.312 mg/L) in Southwest Alluvium POC well 509-D during October 2010 is an exception which UNC will monitor.)

The results of the risk assessment indicate that the there could potentially be unacceptable risk associated with using Zone 3 groundwater for residential use. Attenuation will occur in the Zone 3 plume, but it would likely be insufficient to reduce hazards and risks to potential receptors at a hypothetical POE that is established at the northern border of Section 36. NRC's NUREG 1620 (2003; section 4.3.3.2 Exposure Assessment) indicates that, using either empirical data or calculations, maximum permissible levels of COCs at a given POC should be determined and those levels should be protective of human health and the environment at the POE. UNC is presently evaluating the feasibility of conducting numerical groundwater modeling of Zone 3. The results of this task are pending and it is premature to define maximum permissible COC concentrations at a given POC. UNC will work with NRC to determine the most appropriate approach to these POC-POE issues.

The Zone 1 risk assessment evaluation in this report provides additional documentation to NRC that Zone 1 risks associated with chloroform and nickel are low at the proposed POE, and can be used in support of UNC's submitted ACL application (N.A. Water Systems, 2008d).

Section 8

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Tables

TABLE 1
Monitoring COPCs
Impacted Water Quality, July 2006 - April 2008
UNC Church Rock Mill and Tailings Site

Sampling and Analysis Plan Monitoring COPCs	
Aluminum	Chloride*
Arsenic	Sulfate*
Beryllium	Nitrate-Nitrogen*
Cadmium	Uranium
Cobalt	Chloroform
Lead	Total Dissolved Solids*
Manganese	Thorium-230
Molybdenum	Lead-210
Nickel	Gross Alpha*
Selenium	Radium (including Ra-226,
Vanadium	Ra-228, and total radium*)
Historical Monitoring Parameters - Trace Metals Plus Iron**	
Antimony	Mercury
Barium	Silver
Chromium	Thallium
Copper	Zinc
Iron	

* Common ion, general chemistry, and grouped parameters eliminated from consideration in the quantitative risk assessment calculations

** Previously dropped from the performance monitoring program. These parameters were eliminated from consideration in the quantitative risk assessment calculations

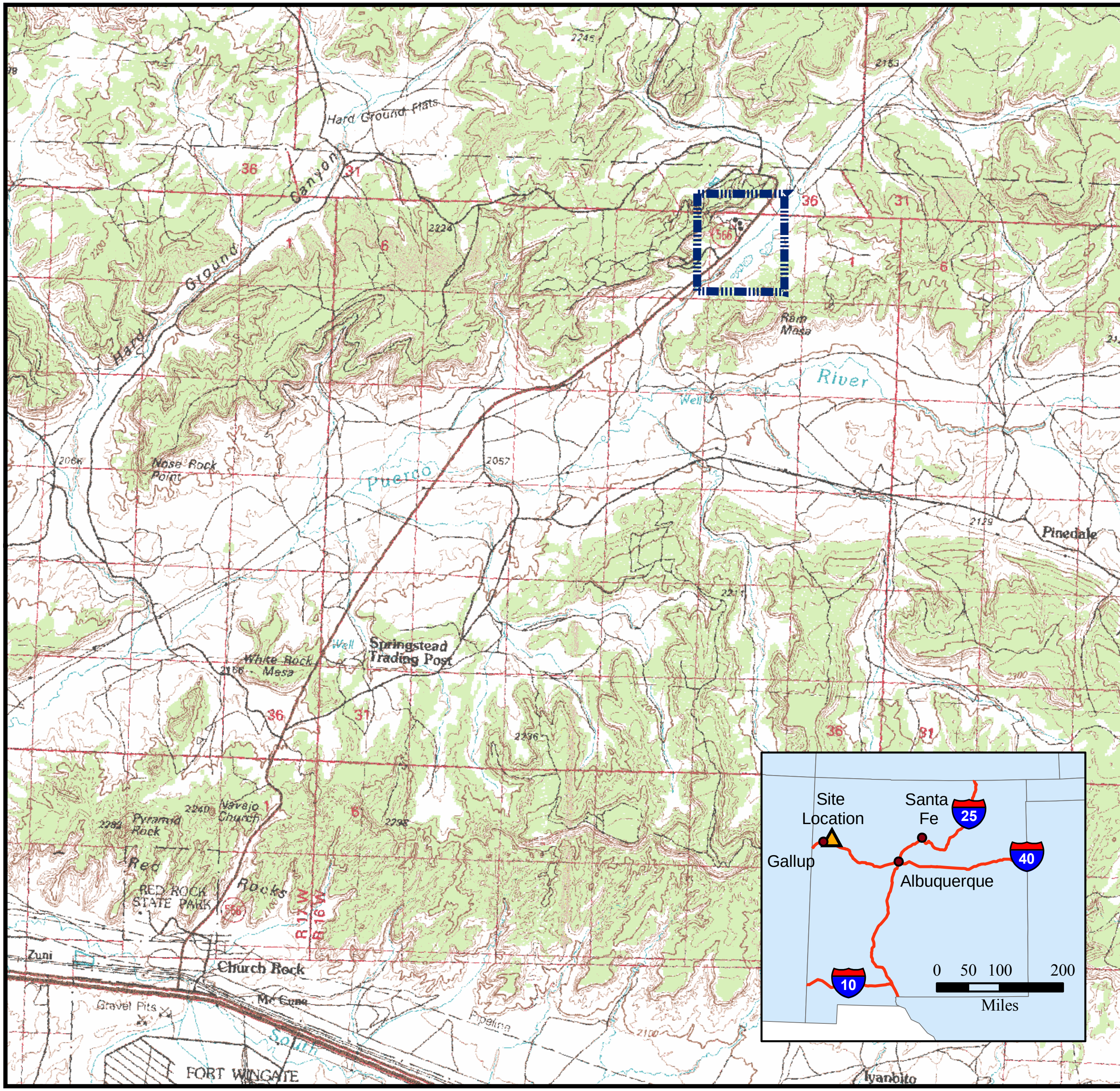
TABLE 2

Wells Having Samples Representative of
Impacted Water Quality, July 2006 - April 2008
UNC Church Rock Mill and Tailings Site

Southwest Alluvium	Zone 1	Zone 3
509 D (POC)	515 A*	504 B
624	604 (POC)*	517 (POC)
632 (POC)	614 (POC)*	613 (POC)*
801	EPA 5 (POC)	708 (POC)
802	EPA 7 (POC)	711 (POC)
803		717
808		719
EPA 23 (POC)		EPA 13
EPA 25		EPA 14
GW 1 (POC)		NBL 1
GW 2 (POC)		
GW 3 (POC)		

Notes:
* indicates well not included in the HHRA due to its location within Section 2
POC = NRC License Point-of-Compliance Well

Figures



N

LEGEND

Approximate Site Location

NEW MEXICO INSET LEGEND

Major City

Church Rock Site Location

Interstate Highway

State Boundary

Notes:

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

1 0.5 0 1

Miles

FIGURE 1

Site Location Map

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

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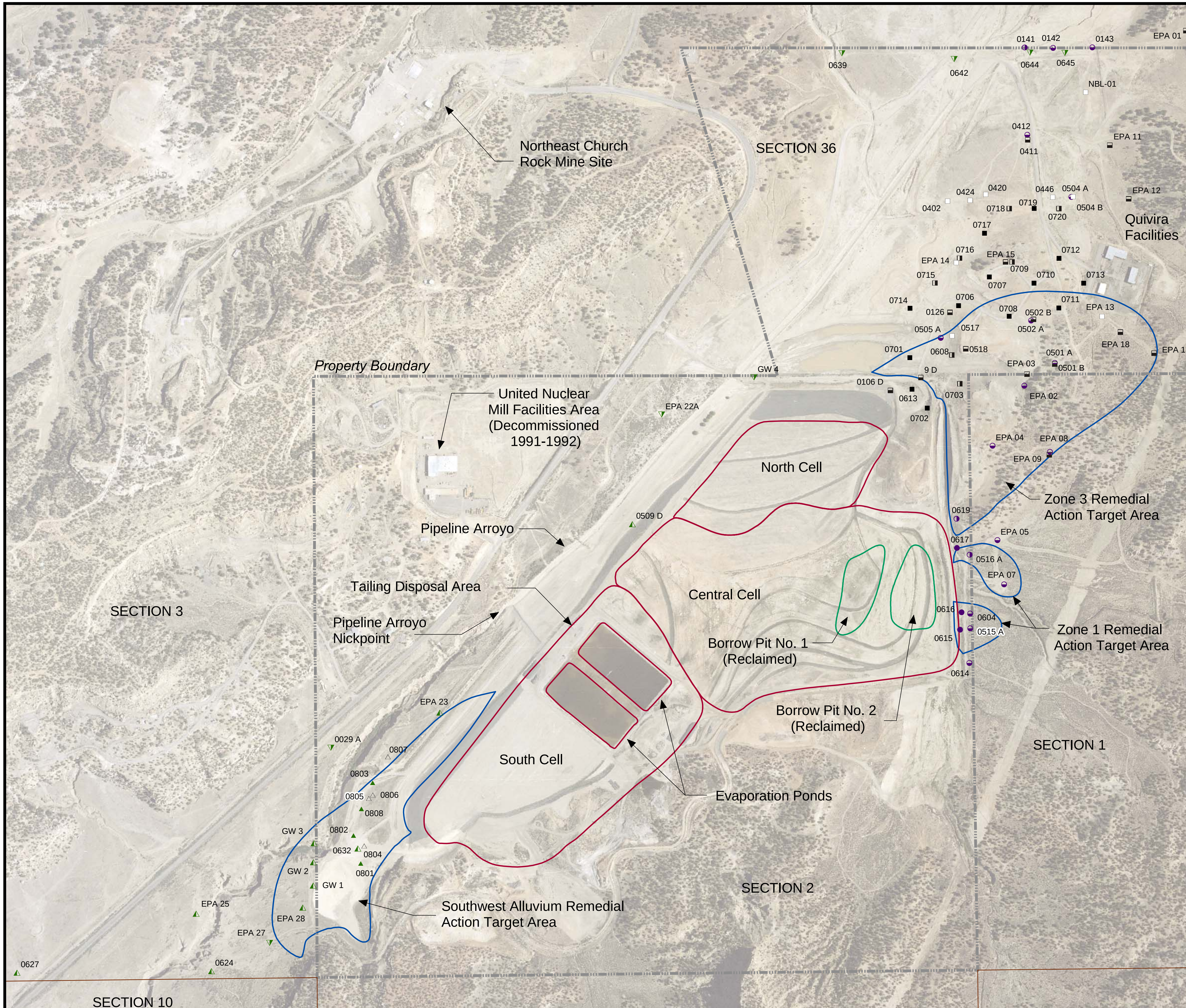

Legend

Southwest Alluvium

- Idled Extraction Well
- Monitoring Well
- Water Level Monitoring Well
- Dry Monitoring Well

Zone 3

- Idled Extraction Well Used for Monitoring
- Decommissioned or Idle Extraction Well
- Monitoring Well
- Dry or Decommissioned Monitoring Well

Zone 1

- Decommissioned Extraction Well
- Decommissioned Monitoring Well
- Monitoring Well

0 400 800 1,600
Feet

FIGURE 2

Site Layout and Performance
Monitoring Well Locations
2010 Operating Year

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

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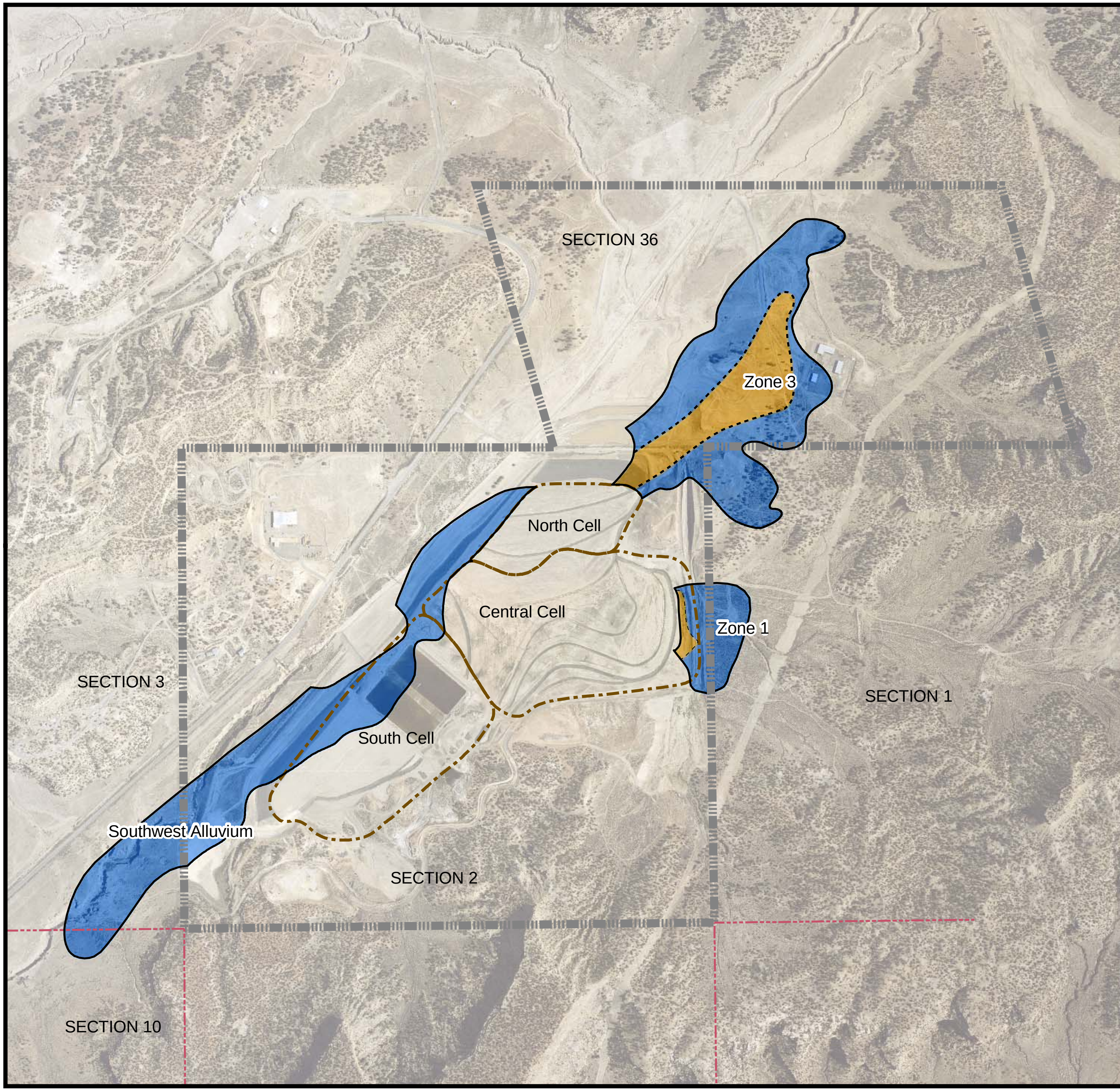

N

LEGEND

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

Aerial photo taken on
August 1, 1996.

0 750 1,500 3,000
Feet

FIGURE 3

Extent of Seepage-Impacted Groundwater, October 2010

United Nuclear Corporation Church Rock Site
Church Rock, New Mexico

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Appendices

APPENDIX A

EPA Risk Assessment Tables – Seepage Impacted Water

TABLE 0

SITE RISK ASSESSMENT IDENTIFICATION INFORMATION

UNC Church Rock Mill and Tailings Site

Site Name/OU:	UNC CHURCH ROCK MILL AND TAILINGS SITE
Region:	6
EPA ID Number:	NMD030443303
State:	New Mexico
Status:	RP Sitewide Supplemental Feasibility Study (ongoing)
Federal Facility (Y/N):	N
EPA Project Manager	Katrina Coltrain
EPA Risk Assessor:	Anna Milburn
Prepared by (Organization):	Chester Engineers
Prepared for (Organization):	United Nuclear Corporation
Document Title:	Human Health Risk Assessment for the UNC Church Rock Site
Document Date:	March 2011
Probabilistic Risk Assessment (Y/N):	N
Comments:	Groundwater at this site is impacted by seepage from uranium mill tailings disposal

TABLE 1

SELECTION OF EXPOSURE PATHWAYS

UNC Church Rock Mill and Tailings Site

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway(1)
Future	Groundwater - Southwest Alluvium	Groundwater	SW Alluvium Tapwater	Resident	Adult	Dermal	Quant	Future resident using domestic well in SW Alluvium
						Ingestion	Quant	Future resident using domestic well in SW Alluvium
					Child	Dermal	Quant	Future resident using domestic well in SW Alluvium
						Ingestion	Quant	Future resident using domestic well in SW Alluvium
					Adult/Child	Dermal	Quant	Future resident using domestic well in SW Alluvium
						Ingestion	Quant	Future resident using domestic well in SW Alluvium
		Air	Water Vapors from Showerhead / Domestic Uses	Resident	Adult	Inhalation	Quant	Future resident using domestic well in SW Alluvium
					Child	Inhalation	Quant	Future resident using domestic well in SW Alluvium
					Adult/Child	Inhalation	Quant	Future resident using domestic well in SW Alluvium
	Groundwater - Zone 1 Upper Gallup Fm	Groundwater	Zone 1 Tapwater	Resident	Adult	Dermal	Quant	Future resident using domestic well in Zone 1
						Ingestion	Quant	Future resident using domestic well in Zone 1
					Child	Dermal	Quant	Future resident using domestic well in Zone 1
						Ingestion	Quant	Future resident using domestic well in Zone 1
					Adult/Child	Dermal	Quant	Future resident using domestic well in Zone 1
						Ingestion	Quant	Future resident using domestic well in Zone 1
		Air	Water Vapors from Showerhead / Domestic Uses	Resident	Adult	Inhalation	Quant	Future resident using domestic well in Zone 1
					Child	Inhalation	Quant	Future resident using domestic well in Zone 1
					Adult/Child	Inhalation	Quant	Future resident using domestic well in Zone 1
	Groundwater - Zone 3 Upper Gallup Fm	Groundwater	Zone 3 Tapwater	Resident	Adult	Dermal	Quant	Future resident using domestic well in Zone 3
						Ingestion	Quant	Future resident using domestic well in Zone 3
					Child	Dermal	Quant	Future resident using domestic well in Zone 3
						Ingestion	Quant	Future resident using domestic well in Zone 3
					Adult/Child	Dermal	Quant	Future resident using domestic well in Zone 3
						Ingestion	Quant	Future resident using domestic well in Zone 3
		Air	Water Vapors from Showerhead / Domestic Uses	Resident	Adult	Inhalation	Quant	Future resident using domestic well in Zone 3
					Child	Inhalation	Quant	Future resident using domestic well in Zone 3
					Adult/Child	Inhalation	Quant	Future resident using domestic well in Zone 3

(1) All domestic well scenarios are based on the assumption that a potential future domestic well would be located outside UNC property (Sections 2 and 36) where tailings seepage has impacted existing background groundwater.

TABLE 2.1

OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier) (1)	Maximum Concentration (Qualifier) (1)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (4)	Background Value (5)	Screening Toxicity Value (N/C) (6)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag (Y/N)	Rationale for Selection or Deletion (7)
SW Alluvium	7429-90-5	Aluminum	0.1	0.3	mg/L	808	6 / 96	0.1 - 0.1	0.3	0.107	3.7 (N)	5	NMWQCC-I	N	BSL
Tapwater	7440-38-2	Arsenic	0.001	0.01	mg/L	632, 801, 803, 808, EPA23, EPA25, GW1, GW3	13 / 96	0.001 - 0.001	0.01	0.00116	0.000045 (C)	0.01	MCL	Y	ASL
	7440-48-4	Cobalt	0.01	0.01	mg/L	GW 3	1 / 96	0.01 - 0.01	0.01	0.0121	0.0011 (N)	0.05	NMWQCC-I	Y	ASL
	7439-96-5	Manganese	0.03	5.4	mg/L	EPA23	96 / 96	0.01 -0.01	5.4	0.414	0.088 (N)	0.2	NMWQCC-O	Y	ASL
	7782-49-2	Selenium	0.001	0.001	mg/L	EPA 23	1 / 96	0.001 - 0.001	0.001	0.00516	0.018 (N)	0.05	MCL	N	BSL
	7440-61-1	Uranium	0.0229	0.2460	mg/L	509D	96 / 96	0.0003 - 0.0004	0.246	0.0459	0.011 (N)	0.03	MCL	Y	ASL
	13966-29-5	Uranium-234	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	Y	DET
	15117-96-1	Uranium-235	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	Y	DET
	7440-61-1	Uranium-238	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	Y	DET
	67-66-3	Chloroform	0.00061	0.0155	mg/L	802	49 / 96	0.0005 -0.001	0.0155	ND	0.00019 (C)	0.08	MCL (TTHM)	Y	ASL
	13982-63-3	Radium-226 (3)	0.1	1	pCi/L	632	37 / 96	0.001 - 0.2	1	0.798	NA (C)	5	MCL (combined radium)	Y	DET
	15262-20-1	Radium-228 (3)	0.3	4.3	pCi/L	632	22 / 96	0.04 - 1	4.3	1.611	NA (C)	5	MCL (combined radium)	Y	DET
	14269-63-7	Thorium-230	0.2	1.6	pCi/L	632	10 / 96	0.2 - 0.2	1.6	0.509	NA (C)	15	MCL (gross alpha)	Y	DET
Zone 1	7429-90-5	Aluminum	0.2	1.3	mg/L	EPA07	7 / 16	0.1 - 0.1	1.3	0.117	3.7 (N)	5	NMWQCC-I	N	BSL
Tapwater	7440-38-2	Arsenic	0.001	0.003	mg/L	EPA07	4 / 16	0.001 - 0.001	0.003	0.00117	0.000045 (C)	0.01	MCL	Y	ASL
	7440-48-4	Cobalt	0.02	0.06	mg/L	EPA05	16 / 16	0.01 - 0.01	0.06	0.0112	0.0011 (N)	0.05	NMWQCC-I	Y	ASL
	7439-96-5	Manganese	0.95	2.96	mg/L	EPA07	16 / 16	0.01 - 0.01	2.96	2.519	0.088 (N)	0.2	NMWQCC-O	Y	ASL
	7440-02-0	Nickel	0.05	0.06	mg/L	EPA05	3 / 16	0.05 - 0.05	0.06	0.0602	0.073 (N)	0.2	NMWQCC-I	N	BSL
	7782-49-2	Selenium	0.001	0.001	mg/L	EPA05	1 / 16	0.001 - 0.001	0.001	0.00107	0.018 (N)	0.05	MCL	N	BSL
	7440-62-2	Vanadium	0.2	0.2	mg/L	EPA07	1 / 16	0.1 - 0.1	0.2	ND	0.018 (N)	NA	NA	Y	ASL
	7440-61-1	Uranium	0.0012	0.0022	mg/L	EPA07	16 / 16	0.0003 - 0.0004	0.0022	0.0255	0.011 (N)	0.03	MCL	N	BSL
	13966-29-5	Uranium-234	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	Y	DET
	15117-96-1	Uranium-235	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	Y	DET
	7440-61-1	Uranium-238	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	Y	DET
	67-66-3	Chloroform	0.0006	0.00076	mg/L	EPA07	2 / 16	0.0005 -0.001	0.00076	NBC	0.00019 (C)	0.08	MCL (TTHM)	Y	ASL
	13982-63-3	Radium-226 (3)	0.4	1.8	pCi/L	EPA05	13 / 16	0.2 - 0.2	1.8	1.314	NA (C)	5	MCL (combined radium)	Y	DET
	15262-20-1	Radium-228 (3)	1	4	pCi/L	EPA05	8 / 16	1.0 - 1.0	4	2.946	NA (C)	5	MCL (combined radium)	Y	DET
	14269-63-7	Thorium-230	0.6	0.7	pCi/L	EPA05	2 / 16	0.2 - 0.2	0.7	0.403	NA (C)	15	MCL (gross alpha)	Y	DET
Zone 3	7429-90-5	Aluminum	0.1	163	mg/L	EPA14	58 / 70	0.1 - 0.1	163	0.231	3.7 (N)	5	NMWQCC-I	Y	ASL
Tapwater	7440-38-2	Arsenic	0.001	2.5 D	mg/L	NBL-01	48 / 70	0.001 - 0.03	2.5	0.175	0.000045 (C)	0.01	MCL	Y	ASL
	7440-41-7	Beryllium	0.01	0.09	mg/L	EPA14	9 / 70	0.01 - 0.01	0.09	ND	0.0073 (N)	0.004	MCL	Y	ASL
	7440-43-9	Cadmium	0.005	1	mg/L	EPA14	16 / 70	0.005 - 0.005	1	0.0113	0.0018 (N)	0.005	MCL	Y	ASL
	7440-48-4	Cobalt	0.05	0.95 D	mg/L	EPA14	70 / 70	0.01 - 0.02	0.95	0.0877	0.0011 (N)	0.05	NMWQCC-I	Y	ASL
	7439-96-5	Manganese	3.33	23.7	mg/L	717	70 / 70	0.01 - 0.01	23.7	3.436	0.088 (N)	0.2	NMWQCC-O	Y	ASL
	7439-98-7	Molybdenum	0.1	5	mg/L	NBL-01	32 / 70	0.1 - 0.1	5	17.43	0.018 (N)	1	NMWQCC-I	Y	ASL
	7440-02-0	Nickel	0.11	0.89	mg/L	EPA14	70 / 70	0.05 - 0.05	0.89	0.14	0.073 (N)	0.2	NMWQCC-I	Y	ASL
	7782-49-2	Selenium	0.001	0.01	mg/L	NBL-01	3 / 70	0.001 - 0.001	0.01	0.00159	0.018 (N)	0.05	MCL	N	BSL
	7440-62-2	Vanadium	0.1	0.2	mg/L	517, 708, EPA13, EPA14, NBL-01	5 / 70	0.1 - 0.1	0.2	ND	0.018 (N)	NA	NA	Y	ASL
	7440-61-1	Uranium	0.0011	0.138	mg/L	NBL-01	70 / 70	0.0003 - 0.002	0.138	0.107	0.011 (N)	0.03	MCL	Y	ASL
	13966-29-5	Uranium-234	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	Y	DET
	15117-96-1	Uranium-235	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	Y	DET
	7440-61-1	Uranium-238	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	Y	DET
	67-66-3	Chloroform	0.00093	0.00676	mg/L	517	13 / 70	0.0005 -0.001	0.00676	NBC	0.00019 (C)	0.08	MCL (TTHM)	Y	ASL
	13982-63-3	Radium-226	2	27.6	pCi/L	EPA14	70 / 70	0.1 - 0.2	27.6	4.996	NA (C)	5	MCL (combined radium)	Y	DET
	15262-20-1	Radium-228	3.8	56.1	pCi/L	EPA14	70 / 70	1 - 1.4	56.1	4.509	NA (C)	5	MCL (combined radium)	Y	DET
	14269-63-7	Thorium-230	0.2	1.3	pCi/L	517	6 / 70	0.2 - 0.2	1.3	1.426	NA (C)	15	MCL (gross alpha)	Y	DET
	14255-04-0	Lead-210	1.8	8.1	pCi/L	719	6 / 70	1.0 - 1.0	8.1	1.618	NA (C)	4 mrem/y	MCL (gross beta)	Y	DET

Notes:

(1) Qualifier codes used for the "Minimum Concentration" and "Maximum Concentration":
D = the sample was diluted to facilitate analysis.

(2) Uranium isotopes not analyzed. Isotope concentrations esimated from total uranium mass concentration (see Table 3.A.RME).

(3) The summary statistics for Radium-226 and Radium-228 count the raw below-detection-limit values from the 2nd Quarter 2008 as detections, because they were treated as such in the calculation of EPC statistics using ProUCL.

(4) Maximum concentration used for screening chemicals. No screening was conducted for radionuclides. All radionuclides detected are selected as COPCs.

(5) Background values are mean (UCL95) calculated in N.A. Water Systems (2008b).

(6) All compounds were screened against the November 2010 USEPA Risk Screening Level Table (http://www.epa.gov/region9/superfund/prg/).
- For non-carcinogens: screening value = 0.1 x RSL tapwater value
- For carcinogens : screening value = RSL tapwater value

(7) Rationale Codes:

Selection Reason	Above Screening Level (ASL)
	Detected in seepage-impacted groundwater at Site (DET)
Deletion Reason	Below Screening Level (BSL)

Definitions:

NA = Not Applicable

ND = Not Detected

MCL = Maximum Contaminant level

SMCL = Secondary Maximum Contaminant level

NMWQCC = New Mexico Water Quality Control Commission Groundwater Standard

NMWQCC-I = New Mexico Water Quality Control Commission Irrigation Standard

NMWQCC-O = New Mexico Water Quality Control Commission Other Standard

C = Carcinogen

N = Noncarcinogen

TTHM = 0.080 mg/l is the MCL for total trihalomethanes, of which chloroform is a single compound.

NBC = No background concentration - chloroform was not detected frequently enough in Zone 1 and Zone 3 background samples (less than 1%) to calculate background concentration

TABLE 2.2

OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Air

Exposure Point	CAS Number	Chemical	Minimum Concentration (Qualifier) (1)	Maximum Concentration (Qualifier) (1)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (4)	Background Value (5)	Screening Toxicity Value (N/C) (6)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag (Y/N)	Rationale for Selection or Deletion (7)
SW Alluvium	7429-90-5	Aluminum	0.1	0.3	mg/L	808	6 / 96	0.1 - 0.1	0.3	0.107	3.7 (N)	5	NMWQCC-I	N	BSL
Water Vapors from Showerhead / Domestic Use	7440-38-2	Arsenic	0.001	0.01	mg/L	632, 801, 803, 808, EPA23, EPA25, GW1, GW3	13 / 96	0.001 - 0.001	0.01	0.00116	0.000045 (C)	0.01	MCL	N	NV
	7440-48-4	Cobalt	0.01	0.01	mg/L	GW 3	1 / 96	0.01 - 0.01	0.01	0.0121	0.0011 (N)	0.05	NMWQCC-I	N	NV
	7439-96-5	Manganese	0.03	5.4	mg/L	EPA23	96 / 96	0.01 -0.01	5.4	0.414	0.088 (N)	0.2	NMWQCC-O	N	NV
	7782-49-2	Selenium	0.001	0.001	mg/L	EPA 23	1 / 96	0.001 - 0.001	0.001	0.00516	0.018 (N)	0.05	MCL	N	BSL
	7440-61-1	Uranium	0.0229	0.2460	mg/L	509D	96 / 96	0.0003 - 0.0004	0.246	0.0459	0.011 (N)	0.03	MCL	N	NV
	13966-29-5	Uranium-234	NA (2)	NA (2)	pCi/L	NA (2)	NA (C)	NA (2)	NA	NA	NA (C)	NA	NA	N	NV
	15117-96-1	Uranium-235	NA (2)	NA (2)	pCi/L	NA (2)	NA (C)	NA (2)	NA	NA	NA (C)	NA	NA	N	NV
	7440-61-1	Uranium-238	NA (2)	NA (2)	pCi/L	NA (2)	NA (C)	NA (2)	NA	NA	NA (C)	NA	NA	N	NV
	67-66-3	Chloroform	0.00061	0.0155	mg/L	802	49 / 96	0.0005 - 0.001	0.0155	ND	0.00019 (C)	0.08	MCL (TTHM)	Y	ASL
	13982-63-3	Radium-226 (3)	0.1	1	pCi/L	632	37 / 96	0.001 - 0.2	1	0.798	NA (C)	5	MCL (combined radium)	Y	DET
	15262-20-1	Radium-228 (3)	0.3	4.3	pCi/L	632	22 / 96	0.04 - 1	4.3	1.611	NA (C)	5	MCL (combined radium)	N	NV
	14269-63-7	Thorium-230	0.2	1.6	pCi/L	632	10 / 96	0.2 - 0.2	1.6	0.509	NA (C)	15	MCL (gross alpha)	N	NV
Zone 1	7429-90-5	Aluminum	0.2	1.3	mg/L	EPA07	7 / 16	0.1 - 0.1	1.3	0.117	3.7 (N)	5	NMWQCC-I	N	BSL
Water Vapors	7440-38-2	Arsenic	0.001	0.003	mg/L	EPA07	4 / 16	0.001 - 0.001	0.003	0.00117	0.000045 (C)	0.01	MCL	N	NV
from	7440-48-4	Cobalt	0.02	0.06	mg/L	EPA05	16 / 16	0.01 - 0.01	0.06	0.0112	0.011 (N)	0.05	NMWQCC-I	N	NV
Showerhead /	7439-96-5	Manganese	0.95	2.96	mg/L	EPA07	16 / 16	0.01 - 0.01	2.96	2.519	0.088 (N)	0.2	NMWQCC-O	N	NV
Domestic Use	7440-02-0	Nickel	0.05	0.06	mg/L	EPA05	3 / 16	0.05 - 0.05	0.06	0.0602	0.073 (N)	0.2	NMWQCC-I	N	BSL
	7782-49-2	Selenium	0.001	0.001	mg/L	EPA05	1 / 16	0.001 - 0.001	0.001	0.00107	0.018 (N)	0.05	MCL	N	BSL
	7440-62-2	Vanadium	0.2	0.2	mg/L	EPA07	1 / 16	0.1 - 0.1	0.2	ND	0.018 (N)	NA	NA	N	NV
	7440-61-1	Uranium	0.0012	0.0022	mg/L	EPA07	16 / 16	0.0003 - 0.0004	0.0022	0.0255	0.011 (N)	0.03	MCL	N	BSL
	13966-29-5	Uranium-234	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (C)	NA	NA	NA (C)	NA	NA	N	NV
	15117-96-1	Uranium-235	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (C)	NA	NA	NA (C)	NA	NA	N	NV
	7440-61-1	Uranium-238	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (C)	NA	NA	NA (C)	NA	NA	N	NV
	67-66-3	Chloroform	0.0006	0.00076	mg/L	EPA07	2 / 16	0.0005 -0.001	0.00076	NBC	0.00019 (C)	0.08	MCL (TTHM)	Y	ASL
	13982-63-3	Radium-226 (3)	0.4	1.8	pCi/L	EPA05	13 / 16	0.2 - 0.2	1.8	1.314	NA (C)	5	MCL (combined radium)	Y	DET
	15262-20-1	Radium-228 (3)	1	4	pCi/L	EPA05	8 / 16	1.0 - 1.0	4	2.946	NA (C)	5	MCL (combined radium)	N	NV
	14269-63-7	Thorium-230	0.6	0.7	pCi/L	EPA05	2 / 16	0.2 - 0.2	0.7	0.403	NA (C)	15	MCL (gross alpha)	N	NV
Zone 3	7429-90-5	Aluminum	0.1	163	mg/L	EPA14	58 / 70	0.1 - 0.1	163	0.231	3.7 (N)	5	NMWQCC-I	N	NV
Water Vapors	7440-38-2	Arsenic	0.001	2.5 D	mg/L	NBL-01	48 / 70	0.001 - 0.03	2.5	0.175	0.000045 (C)	0.01	MCL	N	NV
from	7440-41-7	Beryllium	0.01	0.09	mg/L	EPA14	9 / 70	0.01 - 0.01	0.09	ND	0.0073 (N)	0.004	MCL	N	NV
Showerhead /	7440-43-9	Cadmium	0.005	1	mg/L	EPA14	16 / 70	0.005 - 0.005	1	0.0113	0.0018 (N)	0.005	MCL	N	NV
Domestic Use	7440-48-4	Cobalt	0.05	0.95 D	mg/L	EPA14	70 / 70	0.01 - 0.02	0.95	0.0877	0.0011 (N)	0.05	NMWQCC-I	N	NV
	7439-96-5	Manganese	3.33	23.7	mg/L	717	70 / 70	0.01 - 0.01	23.7	3.436	0.088 (N)	0.2	NMWQCC-O	N	NV
	7439-98-7	Molybdenum	0.1	5	mg/L	NBL-01	32 / 70	0.1 - 0.1	5	17.43	0.018 (N)	1	NMWQCC-I	N	NV
	7440-02-0	Nickel	0.11	0.89	mg/L	EPA14	70 / 70	0.05 - 0.05	0.89	0.14	0.073 (N)	0.2	NMWQCC-I	N	NV
	7782-49-2	Selenium	0.001	0.01	mg/L	NBL-01	3 / 70	0.001 - 0.001	0.01	0.00159	0.018 (N)	0.05	MCL	N	NV
	7440-62-2	Vanadium	0.1	0.2	mg/L	517, 708, EPA13, EPA14, NBL-01	5 / 70	0.1 - 0.1	0.2	ND	0.018 (N)	NA	NA	N	NV
	7440-61-1	Uranium	0.0011	0.138	mg/L	NBL-01	70 / 70	0.0003 - 0.002	0.138	0.107	0.011 (N)	0.03	MCL	N	NV
	13966-29-5	Uranium-234	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	N	NV
	15117-96-1	Uranium-235	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	N	NV
	7440-61-1	Uranium-238	NA (2)	NA (2)	pCi/L	NA (2)	NA (2)	NA (2)	NA	NA	NA (C)	NA	NA	N	NV
	67-66-3	Chloroform	0.00093	0.00676	mg/L	517	13 / 70	0.0005 -0.001	0.00676	NBC	0.00019 (C)	0.08	MCL (TTHM)	Y	ASL
	13982-63-3	Radium-226	2	27.6	pCi/L	EPA14	70 / 70	0.1 - 0.2	27.6	4.996	NA (C)	5	MCL (combined radium)	Y	DET
	15262-20-1	Radium-228	3.8	56.1	pCi/L	EPA14	70 / 70	1 - 1.4	56.1	4.509	NA (C)	5	MCL (combined radium)	N	NV
	14269-63-7	Thorium-230	0.2	1.3	pCi/L	517	6 / 70	0.2 - 0.2	1.3	1.426	NA (C)	15	MCL (gross alpha)	N	NV
	14255-04-0	Lead-210	1.8	8.1	pCi/L	719	6 / 70	1.0 - 1.0	8.1	1.618	NA (C)	4 mrem/y	MCL (gross beta)	N	NV

Notes:

(1) Qualifier codes used for the "Minimum Concentration" and "Maximum Concentration".
D = the sample was diluted to facilitate analysis.

(2) Uranium isotopes not analyzed. Isotope concentrations esimated from total uranium mass concentration (see Table 3.A.RME).

(3) The summary statistics for Radium-226 and Radium-228 count the raw below-detection-limit values from the 2nd Quarter 2008 as detections, because they were treated as such in the calculation of EPC statistics using ProUCL.

(4) Maximum concentration used for screening chemicals. No screening was conducted for radionuclides. All detected radionuclides considered volatile, or with volatile decay products, are selected as COPCs (i.e., only Ra-226).

(5) Background value calculated in N.A. Water Systems (2008b).

(6) All compounds were screened against the November 2010 USEPA Risk Screening Level Table (http://www.epa.gov/region9/superfund/prg/).
- For non-carcinogens: screening value = 0.1 x RSL tapwater value
- For carcinogens : screening value = RSL tapwater value

(7) Rationale Codes:

Selection Reason	Above Screening Level (ASL)
	Detected in seepage-impacted groundwater at Site (DET)
Deletion Reason	Below Screening Level (BSL)
	Not volatile (NV)

Definitions:

NA = Not Applicable
ND = Not Detected
MCL = Maximum Contaminant level
SMCL = Secondary Maximum Contaminant level
NMWQCC = New Mexico Water Quality Control Commission Groundwater Standard
NMWQCC-I = New Mexico Water Quality Control Commission Irrigation Standard
NMWQCC-O = New Mexico Water Quality Control Commission Other Standard
C = Carcinogen
N = Noncarcinogen
TTHM = 0.080 mg/l is the MCL for total trihalomethanes, of which chloroform is a single compound.
NBC = No background concentration - chloroform was not detected frequently enough in Zone 1 and Zone 3 background samples (less than 1%) to calculate background concentration

TABLE 3.1.RME

EXPOSURE POINT CONCENTRATION SUMMARY

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean (of Detected)	95% UCL (Distribution) (1)	Maximum Concentration (Qualifier) (3)	Exposure Point Concentration Value	Exposure Point Concentration Units	Exposure Point Concentration Statistic (4)	Exposure Point Concentration Rationale (5)
SW Alluvium Tapwater	Arsenic	mg/L	0.00885	0.00256 (NP)	0.01	0.00256	mg/l	95% UCL	KM (t)
	Cobalt	mg/L	NA	NA	0.01	0.01	mg/l	Max	(a)
	Manganese	mg/L	1.865	2.8 (O)	5.4	2.8	mg/l	97.5% UCL	Chebyshev, (b)
	Uranium	mg/L	0.104	0.128 (NP)	0.246	0.128	mg/l	95% UCL	Chebyshev
	Uranium-234 (2)	pCi/L	NA	NA	NA	4.37E+01	pCi/L	NA	(e)
	Uranium-235 (2)	pCi/L	NA	NA	NA	1.99E+00	pCi/L	NA	(e)
	Uranium-238 (2)	pCi/L	NA	NA	NA	4.27E+01	pCi/L	NA	(e)
	Chloroform	mg/L	0.00479	0.00338 (NP)	0.0155	0.00338	mg/l	95% UCL	KM (%)
	Radium-226	pCi/L	0.435	0.267 (N)	1	0.267	pCi/L	95% UCL	KM (%)
	Radium-228	pCi/L	1.786	0.86 (N)	4.3	0.86	pCi/L	95% UCL	KM (%)
	Thorium-230	pCi/L	0.69	0.29 (O)	1.6	0.29	pCi/L	95% UCL	KM (t)
Zone 1 Tapwater	Arsenic	mg/L	0.00175	0.00145 (N)	0.003	0.00145	mg/l	95% UCL	KM (t)
	Cobalt	mg/L	0.0363	0.0557 (NP)	0.06	0.0557	mg/l	95% UCL	Chebyshev
	Manganese	mg/L	1.656	1.95 (T)	2.96	1.95	mg/l	95% UCL	Modified t
	Vanadium	mg/L	NA	NA	0.2	0.2	mg/l	Max	(a)
	Uranium (f)	mg/L	0.00161	0.00174 (N)	0.0022	0.00174	mg/l	95% UCL	Modified t
	Uranium-234 (2)	pCi/L	NA	NA	NA	5.94E-01	pCi/L	NA	(e)
	Uranium-235 (2)	pCi/L	NA	NA	NA	2.71E-02	pCi/L	NA	(e)
	Uranium-238 (2)	pCi/L	NA	NA	NA	5.80E-01	pCi/L	NA	(e)
	Chloroform	mg/L	0.00068	0.000639 (NP)	0.00076	0.00068	mg/l	Mean	(c)
	Radium-226	pCi/L	1.138	1.213 (N)	1.8	1.213	pCi/L	95% UCL	KM (%)
	Radium-228	pCi/L	2.286	2.087 (N)	4	2.087	pCi/L	95% UCL	KM (t)
	Thorium-230	pCi/L	0.65	0.621 (NP)	0.7	0.65	pCi/L	Mean	(c)
Zone 3 Tapwater	Aluminum	mg/L	16.14	39.15 (NP)	163	39.15	mg/l	97.5% UCL	KM (Chebyshev), (b)
	Arsenic	mg/L	0.206	0.412 (NP)	2.5 D	0.412	mg/l	95% UCL	KM (Chebyshev), (b)
	Beryllium	mg/L	0.0589	0.0202 (N)	0.09	0.0202	mg/l	95% UCL	KM (t)
	Cadmium	mg/L	0.0713	0.0628 (NP)	1	0.0628	mg/l	95% UCL	KM (BCA)
	Cobalt	mg/L	0.381	0.439 (O)	0.95 D	0.439	mg/l	95% UCL	Gamma
	Manganese	mg/L	9.836	10.89 (NP)	23.7	10.89	mg/l	95% UCL	Modified t
	Molybdenum	mg/L	1.084	0.739 (NP)	5	0.739	mg/l	95% UCL	KM (BCA)
	Nickel	mg/L	0.377	0.489 (NP)	0.89	0.489	mg/l	95% UCL	Chebyshev
	Vanadium	mg/L	0.18	0.111 (NP)	0.2	0.18	mg/l	Mean	(d)
	Uranium	mg/L	0.0287	0.0431 (NP)	0.138	0.0431	mg/l	95% UCL	Chebyshev
	Uranium-234 (2)	pCi/L	NA	NA	NA	1.47E+01	pCi/L	NA	(e)
	Uranium-235 (2)	pCi/L	NA	NA	NA	6.71E-01	pCi/L	NA	(e)
	Uranium-238 (2)	pCi/L	NA	NA	NA	1.44E+01	pCi/L	NA	(e)
	Chloroform	mg/L	0.00441	0.00326 (N)	0.00676	0.00326	mg/l	95% UCL	KM (%)
	Radium-226	pCi/L	9.823	11.14 (O)	27.6	11.14	pCi/L	95% UCL	Gamma
	Radium-228	pCi/L	15.73	17.84 (O)	56.1	17.84	pCi/L	95% UCL	Gamma
	Thorium-230	pCi/L	0.533	0.259 (N)	1.3	0.259	pCi/L	95% UCL	KM (t)
	Lead-210	pCi/L	4.883	2.287 (N)	8.1	2.287	pCi/L	95% UCL	KM (t)

Notes:

(1) "95% UCL" term calculated using ProUCL ver 4.00.02 as described in N.A.Water Systems (2008c)

Codes describing the type of distribution for the "95% UCL" term.

N = Normal

T = Transformed (lognormal)

NP = Nonparametric

O = Other

(2) Uranium isotopes not analyzed. Isotope concentrations esimated from total uranium mass concentration (see Table 3.A.RME).

(3) Qualifier codes used for the "Maximum Concentration".

D = the sample was diluted to facilitate analysis.

(4) Codes describing the "EPC Statistic".

95% UCL = 95% UCL Statistic

97.5% UCL = 97.5% UCL Statistic

Max = Maximum Detected Concentration

Mean = Arithmetic Mean of Detected Concetnrations

Definitions:

NA = Not Applicable

(5) Codes describing the rationale the statistic is used to represent the EPC

KM (t) = UCL based upon Kaplan-Meier estimates using the Student's t-distribution cutoff value

KM (%) = UCL based upon Kaplan-Meier estimates using the percentile bootstrap method

Chebyshev = Chebyshev inequality-based UCL

Modified t = UCL based on the modified t statistic

KM (Chebyshev) = UCL based upon Kaplan-Meier estimates using the Chebyshev inequality

KM (BCA) = UCL based upon Kaplan-Meier estimates using bias-corrected accelerated bootstrap method

Gamma = 95% Approximate Gamma UCL

(a) Only one detection, 95% UCL not calculated, used maximum detected concentration.

(b) UCL calculated at 97.5% confidence level.

(c) Only two detections. 95% UCL of questionable reliability; used arithmetic mean of detected values.

(d) 95% UCL of questionable reliability; used arithmetic mean of detected values.

(e) Uranium isotopes not analyzed. Isotope concentrations esimated from total uranium mass concentration (see Table 3.A.RME)

(f) The total uranium mass concentration was screened out of the Zone 1 risk evaluation but appears in this table because it is the basis of the uranium isotope actitivies shown.

TABLE 3.2.RME

EXPOSURE POINT CONCENTRATION SUMMARY

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Air

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (Distribution) (1)	Maximum Concentration (Qualifier)	Exposure Point Concentration			
						Value	Units	Statistic (2)	Rationale (3)
SW Alluvium Water Vapors from Showerhead / Domestic Use	Chloroform	mg/L	0.00479	0.00338 (NP)	0.0155	0.00338	mg/l	95% UCL	KM (%)
	Radium-226	pCi/L	0.435	0.267 (N)	1	0.267	pCi/L	95% UCL	KM (%)
Zone 1 Water Vapors from Showerhead / Domestic Use	Chloroform	mg/L	0.00068	0.000639 (NP)	0.00076	0.00068	mg/l	Mean	(a)
	Radium-226	pCi/L	1.138	1.213 (N)	1.8	1.213	pCi/L	95% UCL	KM (%)
Zone 3 Water Vapors from Showerhead / Domestic Use	Chloroform	mg/L	0.00441	0.00326 (N)	0.00676	0.00326	mg/l	95% UCL	KM (%)
	Radium-226	pCi/L	9.823	11.14 (O)	27.6	11.14	pCi/L	95% UCL	Gamma

Notes:

(1) "95% UCL" term calculated using ProUCL ver 4.00.02 as described in N.A.Water Systems (2008c).

Codes describing the type of distribution for the "95% UCL" term:

N = Normal

NP = Nonparametric

O = Other

(2) Codes describing the "EPC Statistic":

95% UCL = 95% UCL Statistic

97.5% UCL = 97.5% UCL Statistic

Max = Maximum Detected Concentration

Mean = Arithmetic Mean of Detected Concetnrations

(3) Codes describing the rationale the statistic is used to represent the EPC:

KM (%) = UCL based upon Kaplan-Meier estimates using the percentile bootstrap method

Gamma = 95% Approximate Gamma UCL

(a) Only two detections. 95% UCL lower than arithmetic mean of detected and of questionable reliability; used arithmetic mean.

Table 3.A.RME (SUPPLEMENTAL)
ESTIMATION OF URANIUM ISOTOPE CONCENTRATIONS
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Hydrostratigraphic Unit	Uranium Isotopes		Mass-Based Uranium EPC Concentration (mg/l)	Uranium Isotope Natural Abundance (%) (1)	Isotope Mass Concentration at EPC Concentration (mg/l)	Isotope Specific Activity (pCi/µg)	Isotope Activity (pCi/L) at Uranium EPC Concentration (2)
SWA	U-234	mg/L	0.128	0.000055	0.000007	6209	4.37E+01
SWA	U-235	mg/L	0.128	0.00720	0.00092	2.161	1.99E+00
SWA	U-238	mg/L	0.128	0.99270	0.12707	0.336	4.27E+01
Zone 1	U-234	mg/L	0.00174	0.000055	0.0000001	6209	5.94E-01
Zone 1	U-235	mg/L	0.00174	0.00720	0.00001	2.161	2.71E-02
Zone 1	U-238	mg/L	0.00174	0.99270	0.00173	0.336	5.80E-01
Zone 3	U-234	mg/L	0.0431	0.000055	0.0000024	6209	1.47E+01
Zone 3	U-235	mg/L	0.0431	0.00720	0.00031	2.161	6.71E-01
Zone 3	U-238	mg/L	0.0431	0.99270	0.04279	0.336	1.44E+01
Zone 3 (Background)	U-234	mg/L	0.107	0.000055	0.0000059	6209	3.65E+01
Zone 3 (Background)	U-235	mg/L	0.107	0.00720	0.00077	2.161	1.67E+00
Zone 3 (Background)	U-238	mg/L	0.107	0.99270	0.10622	0.336	3.57E+01

Notes:
(1) Source of natural abundance percentages: http://www.epa.gov/radiation/radionuclides/uranium.html
(2) Isotope activity (pCi/L) = Isotope Mass Concentration at EPC concentration (mg/L) x Isotope Specific Activity (pCi/µg) x Conversion Factor (1000 µg/mg)

TABLE 4.1.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference (1)	Intake Equation/ Model Name (2)
Ingestion	Resident	Adult	SW Alluvium	CW	Chemical Concentration in Water	See Table 3.1	mg/l	See Table 3.1	Chronic Daily Intake (CDI) (mg/kg/day) =
			Zone 1 and	IRw	Ingestion Rate of Water	2	l/day	EPA, 1991	CW x IRw x EF x ED x 1/BW x 1/(ATn)
			Zone 3	EF	Exposure Frequency	350	days/year	EPA, 1991	
			Tapwater	ED	Exposure Duration	24	years	EPA, 1991	
				BW	Body Weight	70	kg	EPA, 1991	
				ATn	Averaging Time - Non-Cancer	8,760	days	EPA, 1989	
		Child	SW Alluvium	CW	Chemical Concentration in Water	See Table 3.1	mg/l	See Table 3.1	CDI (mg/kg/day) =
			Zone 1 and	IRw	Ingestion Rate of Water	1	l/day	CalEPA, 1994	CW x IRw x EF x ED x 1/BW x 1/(ATn)
			Zone 3	EF	Exposure Frequency	350	days/year	EPA, 1991	
			Tapwater	ED	Exposure Duration	6	years	EPA, 1991	
				BW	Body Weight	15	kg	EPA, 1991	
				ATn	Averaging Time - Non-Cancer	2,190	days	EPA, 1989	
		Adult/Child	SW Alluvium	CW	Chemical Concentration in Water	See Table 3.1	mg/l	See Table 3.1	CDI (mg/kg/day) =
			Zone 1 and	IRwc	Ingestion Rate of Water - Child	1	l/day	CalEPA, 1994	CW x IRwadj x EF x 1/(ATc)
			Zone 3	IRwa	Ingestion Rate of Water - Adult	2	l/day	EPA, 1991	
			Tapwater	IRwadj	Ingestion Rate of Water - Age-Adjusted	1.09	[L*yr]/[kg*d]	Calculated	IRwadj ([L*yr]/[kg*d])=
				EF	Exposure Frequency	350	days/year	EPA, 1991	EDc x IRwc x (1/BWc) + EDa x IRwa x (1/BWa)
				EDc	Exposure Duration - Child	6	years	EPA, 1991	
				EDa	Exposure Duration - Adult	24	years	EPA, 1991	
				BW	Body Weight - Child	15	kg	EPA, 1991	
				BW	Body Weight - Adult	70	kg	EPA, 1991	
				ATc	Averaging Time - Cancer	25,550	days	EPA, 1989	
				CWR	Radionuclide Concentration in Water	See Table 3.1	pCi/l	See Table 3.1	Intake (pCi) = CWR x IRWadjR x EF x ED
				IRwadjR	Ingestion Rate of Water - Adjusted - Radionuclides	1.8	l/day	Calculated	
				IRwc	Ingestion Rate of Water - Child	1	l/day	CalEPA, 1994	IRwadjR (L/d)= [EDc x IRwc + EDa x IRwa]/ED
				IRwa	Ingestion Rate of Water - Adult	2	l/day	EPA, 1991	
				EF	Exposure Frequency	350	days/year	EPA, 1991	
				EDc	Exposure Duration - Child	6	years	EPA, 1991	
				EDa	Exposure Duration - Adult	24	years	EPA, 1991	
				ED	Exposure Duration	30	years	EPA, 1991	
Dermal	Resident	Adult	SW Alluvium	CW	Chemical Concentration in Water	See Table 3.1	mg/l	See Table 3.1	Dermally Absorbed Dose (DAD) (mg/kg-day) =
			Zone 1 and	DA-event	Absorbed Dose per Event	Chemical Specific	mg/cm2-event	Calculated	DA-event x EV x ED x EF x SA x 1/BW x 1/(ATn)
			Zone 3	FA	Fraction Absorbed Water	Chemical Specific	--	EPA, 2004	where, for organic compounds with t-event <= t*:
			Tapwater	Kp	Permeability Constant	Chemical Specific	cm/hr	EPA, 2004	Absorbed Dose per Event (DA-event) (mg/cm2-event) =
				SA	Skin Surface Area	18000	cm2	EPA, 2004	2 FA x Kp x CW x CF x SQRT{(6 x tau-event x t-event)/pi}
				tau-event	Lag time per event	Chemical Specific	hr/event	EPA, 2004	or
				t-event	Event Duration	0.58	hr/event	EPA, 2004	where, for organic compounds with t-event > t*:
				t*	Time to reach steady-state (hr)	Chemical Specific	hrs		DA-event = FA x Kp x CW x {(t-event/(1 + B)) +
				B	Ratio of permeability coefficient of a	Chemical Specific	--	EPA, 2004	2 x tau-event x ((1 + (3 x B) + (3 x B x B))/(1 + B)2)}
					compound through the stratum				and
					corneum relative to its permeability				where, for inorganic compounds,
					coefficient across the viable epidermis				DA-event = Kp x CW x CF x t-event
				EV	Event Frequency	1	events/day	EPA, 2004	(see Tables 7.A.RME and 7.B.RME)
				EF	Exposure Frequency	350	days/year	EPA, 2004	
				ED	Exposure Duration	24	years	EPA, 1991	
				CF	Volumetric Conversion Factor for Water	0.001	l/cm3	--	
				BW	Body Weight	70	kg	EPA, 2004	
				ATn	Averaging Time - Non-Cancer	8,760	days	EPA, 2004	
		Child	SW Alluvium	CW	Chemical Concentration in Water	See Table 3.1	mg/l	See Table 3.1	Dermally Absorbed Dose (DAD) (mg/kg-day) =
			Zone 1 and	DA-event	Absorbed Dose per Event	Chemical Specific	mg/cm2-event	Calculated	DA-event x EV x ED x EF x SA x 1/BW x 1/(ATn)
			Zone 3	FA	Fraction Absorbed Water	Chemical Specific	--	EPA, 2004	where, for organic compounds with t-event <= t*:
			Tapwater	Kp	Permeability Constant	Chemical Specific	cm/hr	EPA, 2004	Absorbed Dose per Event (DA-event) (mg/cm2-event) =
				SA	Skin Surface Area	6600	cm2	EPA, 2004	2 FA x Kp x CW x CF x SQRT{(6 x tau-event x t-event)/pi}
				tau-event	Lag time per event	Chemical Specific	hr/event	EPA, 2004	or
				t-event	Event Duration	1	hr/event	EPA, 2004	where, for organic compounds with t-event > t*:
				t*	Time to reach steady-state (hr)	Chemical Specific	hr	EPA, 2004	DA-event = FA x Kp x CW x {(t-event/(1 + B)) +
				B	Ratio of permeability coefficient of a	Chemical Specific	--	EPA, 2004	2 x tau-event x ((1 + (3 x B) + (3 x B x B))/(1 + B)2)}
					compound through the stratum				and
					corneum relative to its permeability				where, for inorganic compounds,
					coefficient across the viable epidermis				DA-event = Kp x CW x CF x t-event
				EV	Event Frequency	1	events/day	EPA, 2004	(see Tables 7.A.RME and 7.B.RME)
				EF	Exposure Frequency	350	days/year	EPA, 2004	
				ED	Exposure Duration	6	years	EPA, 2004	
				CF	Volumetric Conversion Factor for Water	0.001	l/cm3	--	
				BW	Body Weight	15	kg	EPA, 2004	
				ATn	Averaging Time - Non-Cancer	2,190	days	EPA, 2004	
		Adult/Child	SW Alluvium	CW	Chemical Concentration in Water	See Table 3.1	mg/l	See Table 3.1	Dermally Absorbed Dose (DAD) (mg/kg-day) =
			Zone 1 and	DA-event-a	Absorbed Dose per Event - Adult	Chemical Specific	mg/cm2-event	Calculated	[(DA-event-a x EV x EDa x EF x SAa x 1/Bwa) +
			Zone 3	DA-event-c	Absorbed Dose per Event - Child	Chemical Specific	mg/cm2-event	Calculated	[(DA-event-c x EV x EDc x EF x Sac x 1/Bwc)] x 1/(ATc)
			Tapwater	FA	Fraction Absorbed Water	Chemical Specific	--	EPA, 2004	where, for organic compounds with t-event <= t*:
				Kp	Permeability Constant	Chemical Specific	cm/hr	EPA, 2004	Absorbed Dose per Event (DA-event) (mg/cm2-event) =
				SAc	Skin Surface Area - Child	6600	cm2	EPA, 2004	2 FA x Kp x CW x CF x SQRT{(6 x tau-event x t-event)/pi}
				SAa	Skin Surface Area - Adult	18000	cm2	EPA, 2004	or
				tau-event	Lag time per event	Chemical Specific	hrs/event	EPA, 2004	where, for organic compounds with t-event > t*:
				t-event-a	Event Duration - Adult	0.58	hrs/event	EPA, 2004	DA-event = FA x Kp x CW x {(t-event/(1 + B)) +
				t-event-c	Event Duration - Child	1	hrs/event	EPA, 2004	2 x tau-event x ((1 + (3 x B) + (3 x B x B))/(1 + B)2)}
				t*	Time to reach steady-state (hr)	Chemical Specific	hr	EPA, 2004	and
				B	Ratio of permeability coefficient of a	Chemical Specific	--	EPA, 2004	where, for inorganic compounds,
					compound through the stratum				DA-event = Kp x CW x CF x t-event
					corneum relative to its permeability				(see Tables 7.A.RME and 7.B.RME)
					coefficient across the viable epidermis				
				EV	Event Frequency	1	events/day	EPA, 2004	Note: Adult and Child DA-event values are calculated using
				EF	Exposure Frequency	350	days/year	EPA, 2004	corresponding Adult or Child t-event value
				EDa	Exposure Duration - Adult	24	years	EPA, 2004	
				EDc	Exposure Duration - Child	6	years	EPA, 2004	
				CF	Volumetric Conversion Factor for Water	0.001	l/cm3	--	
				Bwa	Body Weight - Adult	70	kg	EPA, 2004	
				BWc	Body Weight - Child	15	kg	EPA, 2004	
				ATc	Averaging Time - Cancer	25,550	days	EPA, 2004	

Notes:

Dermal uptake is generally not an important route of uptake for radionuclides, which have small permeability constants (EPA, 1989a). Dermal uptake of radionuclides is not evaluated in this risk assessment.

(1) References:

California EPA (CalEPA). 1994. Preliminary Endangerment Assessment Guidance Manual, (PEA) Department of Toxic Substances Control, Sacramento, California.

EPA 1989: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual, Part A. OERR EPA/540/1-89/002.

EPA 1991: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual - Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER 9285.6-03.

EPA 2004: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final.

(2) Intake for adults and children combined/adjusted for cancer risk calculations based on exposure duration.

TABLE 4.2.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Air

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Inhalation (1)	Resident	Adult	Water Vapors From Showerhead	(1)	(1)	(1)	(1)	(1)	Foster and Chrostowski Model
Inhalation (1)	Resident	Child	Water Vapors From Showerhead	(1)	(1)	(1)	(1)	(1)	Foster and Chrostowski Model
Inhalation (1)	Resident	Child/Adult	Water Vapors From Showerhead	(1)	(1)	(1)	(1)	(1)	Foster and Chrostowski Model
Inhalation (2)	Resident	Child/Adult	Water Vapors From Showerhead and Other Domestic Uses	(2)	(2)	(2)	(2)	(2)	Andelman Volatilization Factor

Footnote Instructions:

(1) Refer to Tables 7.C.RME and 7.D.RME and the Risk Assessment text for details on the modeled intake methodology and parameters used to calculate modeled intake values for the Foster and Chrostowski Shower Model.

(2) Refer to the Table 7.E.RME and the Risk Assessment text for details on the modeled intake methodology and parameters used to calculate modeled intake values for the Andelman Volatilization Factor.

TABLE 5.1

NON-CANCER TOXICITY DATA -- ORAL/DERMAL

UNC Church Rock Mill and Tailings Site

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD		Oral Absorption Efficiency for Dermal (1)	Absorbed RfD for Dermal (2)		Primary Target Organ(s) Or Effects	Combined Uncertainty/Modifying Factors	RfD:Target Organ(s) (3)	
		Value	Units		Value	Units			Source(s)	Date(s) (MM/DD/YYYY)
Aluminum	Chronic	1.0E+00	mg/kg-day	1	1.0E+00	mg/kg-day	Central nervous system	100	PPRTV	12/13/2010
Arsenic	Chronic	3.0E-04	mg/kg-day	1	3.0E-04	mg/kg-day	Skin	3	IRIS	12/13/2010
Beryllium	Chronic	2.0E-03	mg/kg-day	0.007	1.4E-05	mg/kg-day	Gastrointestinal	300	IRIS	12/13/2010
Cadmium	Chronic	5.0E-04	mg/kg-day	0.05	2.5E-05	mg/kg-day	Kidney	10	IRIS	12/13/2010
Chloroform	Chronic	1.0E-02	mg/kg-day	1	1.0E-02	mg/kg-day	Liver	100	IRIS	12/13/2010
Cobalt	Chronic	3.0E-04	mg/kg-day	1	3.0E-04	mg/kg-day	Thyroid	1000	PPRTV	08/25/2008
Lead-210	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Manganese	Chronic	2.4E-02	mg/kg-day	0.04	9.6E-04	mg/kg-day	Central nervous system	3	RSL (4)	11/2010
Molybdenum	Chronic	5.0E-03	mg/kg-day	1	5.0E-03	mg/kg-day	Increased uric acid (kidney)	30	IRIS	12/13/2010
Nickel	Chronic	2.0E-02	mg/kg-day	0.04	8.0E-04	mg/kg-day	Reduced organ and body weights	300	IRIS	12/13/2010
Radium-226	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-228	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-230	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium	Chronic	3.0E-03	mg/kg-day	1	3.0E-03	mg/kg-day	Kidney	1000	IRIS	12/13/2010
Uranium-234	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	Chronic	5.0E-03	mg/kg-day	1	5.0E-03	mg/kg-day	Decreased hair cystine	100	RSL (5) (6)	12/13/2010

Notes:

(1) EPA 2004: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final, Section 4.2 and Exhibit 4-1, except for vanadium, which was based on the GIABS value listed in the EPA RSL Table for "Vanadium and Compounds".

(2) Absorbed RfD for Dermal calculated by multiplying Oral RfD by Oral Absorption Efficiency for Dermal.

(3) RfD Date: The date shown for IRIS values is the date IRIS was searched; for PPRTV values, the date of the PPRTV report; for RSL values, the date of the RSL Table.

(4) Manganese RfD obtained from November 2010 EPA RSL Table; based on IRIS assessment recommendation to subtract dietary contribution from IRIS RfD when evaluating non-food exposures (e.g., drinking water or soil).

(5) Vanadium oral RfD obtained from November 2010 EPA RSL Table for "Vanadium and Compounds"; derived from IRIS oral RfD for vanadium pentoxide by factoring out the molecular wt of the oxide ion.

(6) Vanadium oral RfD for decreased hair cystine interpreted to have a metabolic system endpoint.

Definitions:

NA = Not Applicable

IRIS = Integrated Risk Information System

RSL = Regional Screening Level Table

PPRTV = Provisional Peer Reviewed Toxicity Value, Superfund Health Technical Support Center

TABLE 5.2

NON-CANCER TOXICITY DATA -- INHALATION

UNC Church Rock Mill and Tailings Site

Chemical of Potential Concern	Chronic/ Subchronic	Inhalation RfC		Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	RfC : Target Organ(s) (1)	
		Value	Units			Source(s)	Date(s) (MM/DD/YYYY)
Chloroform	Chronic	9.80E-02	mg/m3	Liver	100	RSL/ATSDR	12-2010 / 09-1997
Radium-226	NA	NA	NA	NA	NA	NA	NA

Notes:

(1) RfC Date: The date shown for RSL values, the date of the RSL Table; for ATSDR values (MRLs), the date of the ATSDR report.

Definitions:

NA = Not Applicable

RSL = Regional Screening Level Table

ATSDR = Agency for Toxic Substances and Disease Registry

TABLE 5.3

NON-CANCER TOXICITY DATA -- SPECIAL CASE CHEMICALS

UNC Church Rock Mill and Tailings Site

Chemical of Potential Concern	Chronic/ Subchronic	Parameter			Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	Parameter:Target Organ(s)	
		Name	Value	Units			Source(s)	Date(s) (MM/DD/YYYY)
		NOT APPLICABLE						

TABLE 6.1

CANCER TOXICITY DATA - ORAL/DERMAL

UNC Church Rock Mill and Tailings Site

Chemical of Potential Concern	Oral Cancer Slope Factor		Oral Absorption Efficiency for Dermal	Absorbed Cancer Slope Factor for Dermal		Weight of Evidence/ Cancer Guideline Description	Oral CSF	
	Value	Units	(1)	Value (2)	Units		Source(s)	Date(s) (MM/DD/YYYY)
Aluminum	NA	NA	NA	NA	NA	NA	NA	NA
Arsenic	1.50E+00	$(mg/kg\text{-}day)^{-1}$	1	1.5E+00	$(mg/kg\text{-}day)^{-1}$	A	IRIS	12/12/2010
Beryllium	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	NA	NA	NA	NA
Chloroform	3.10E-02	$(mg/kg\text{-}day)^{-1}$	1	3.1E-02	$(mg/kg\text{-}day)^{-1}$	B2	CalEPA	09/01/1990
Cobalt	NA	NA	NA	NA	NA	NA	NA	NA
Lead-210+D (Water Ingestion)	1.27E-09	Risk/pCi	NA	NA	NA	A	HEAST	04/16/2001
Manganese	NA	NA	NA	NA	NA	NA	NA	NA
Molybdenum	NA	NA	NA	NA	NA	NA	NA	NA
Nickel	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226+D (Water Ingestion)	3.86E-10	Risk/pCi	NA	NA	NA	A	HEAST	04/16/2001
Radium-228+D (Water Ingestion)	1.04E-09	Risk/pCi	NA	NA	NA	A	HEAST	04/16/2001
Thorium-230 (Water Ingestion)	9.10E-11	Risk/pCi	NA	NA	NA	A	HEAST	04/16/2001
Uranium	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-234 (Water Ingestion)	7.07E-11	Risk/pCi	NA	NA	NA	A	HEAST	04/16/2001
Uranium-235+D (Water Ingestion)	7.18E-11	Risk/pCi	NA	NA	NA	A	HEAST	04/16/2001
Uranium-238+D (Water Ingestion)	8.71E-11	Risk/pCi	NA	NA	NA	A	HEAST	04/16/2001
Vanadium	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

(1) EPA 2004: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final, Section 4.2 and Exhib

(2) Absorbed Cancer Slope Factor for Dermal calculated by multiplying Oral Cancer Slope Factor by Oral Absorption Efficiency for Dermal.

(3) Oral CSF Date: The date shown for IRIS values is the date IRIS was searched; for CalEPA values, date of CalEPA document; for HEAST values, date of HEAST document.

Definitions:

NA = Not Applicable

CalEPA = California EPA (identified on EPA RSL Table)

HEAST = Health Effects Summary Tables

IRIS = Integrated Risk Information System

RSL = Regional Screening Level Table

A = Known human carcinogen

B2 = Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans

TABLE 6.2

CANCER TOXICITY DATA - INHALATION

UNC Church Rock Mill and Tailings Site

Chemical of Potential Concern	Unit Risk (1)		Inhalation Cancer Slope Factor (2)		Weight of Evidence/ Cancer Guideline Description	Unit Risk : Inhalation CSF	
	Value	Units	Value	Units		Source(s)	Date(s) (MM/DD/YYYY)
Chloroform	2.3E-05	$(\mu g/m^3)^{-1}$	8.1E-02	$(mg/kg\text{-}day)^{-1}$	B2	IRIS	12/13/2010
Radium-226+D	NA	NA	1.16E-08	risk/pCI	A	HEAST	04/16/2001

(1) Inhalation Unit Risk (IUR) values used in risk calculations for chloroform

(2) Inhalation cancer slope factor used in risk calculations for radium-226+D

Definitions:

NA = Not Applicable

HEAST = Health Effects Summary Tables

IRIS = Integrated Risk Information System

A = Known human carcinogen

B2 = Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans

TABLE 6.3

CANCER TOXICITY DATA - SPECIAL CASE CHEMICALS

UNC Church Rock Mill and Tailings Site

Chemical of Potential Concern	Parameters			Source(s)	Date(s) (MM/DD/YYYY)
	Name	Value	Units		
	NOT APPLICABLE				

TABLE 6.4

CANCER TOXICITY DATA - EXTERNAL (RADIATION)

UNC Church Rock Mill and Tailings Site

Chemical of Potential Concern	Cancer Slope Factor		Source(s)	Date(s) (MM/DD/YYYY)
	Value	Units		
	NOT APPLICABLE			

TABLE 7.1.RME

CALCULATION OF CHEMICAL NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
					(1)		Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater SW Alluvium	Groundwater	Tapwater	Ingestion	Arsenic	0.00256	mg/l	NA	NA	NA	NA	NA	7.01E-05	mg/kg/d	3.0E-04	mg/kg/d	0.23
				Cobalt	0.01	mg/l	NA	NA	NA	NA	NA	2.74E-04	mg/kg/d	3.0E-04	mg/kg/d	0.91
				Manganese	2.8	mg/l	NA	NA	NA	NA	NA	7.67E-02	mg/kg/d	2.4E-02	mg/kg/d	3.2
				Uranium	0.128	mg/l	NA	NA	NA	NA	NA	3.51E-03	mg/kg/d	3.0E-03	mg/kg/d	1.2
				Chloroform	0.00338	mg/l	NA	NA	NA	NA	NA	9.26E-05	mg/kg/d	1.0E-02	mg/kg/d	0.0091
			Exp. Route Total								NA					5.5
			Dermal	Arsenic	0.00256	mg/l	NA	NA	NA	NA	NA	3.7E-07	mg/kg/d	3.0E-04	mg/kg/d	0.0012
				Cobalt	0.01	mg/l	NA	NA	NA	NA	NA	1.4E-06	mg/kg/d	3.0E-04	mg/kg/d	0.0048
				Manganese	2.8	mg/l	NA	NA	NA	NA	NA	4.0E-04	mg/kg/d	9.6E-04	mg/kg/d	0.42
				Uranium	0.128	mg/l	NA	NA	NA	NA	NA	1.8E-05	mg/kg/d	3.0E-03	mg/kg/d	0.0061
				Chloroform	0.00338	mg/l	NA	NA	NA	NA	NA	8.4E-06	mg/kg/d	1.02E-02	mg/kg/d	0.0008
			Exp. Route Total								NA					0.43
		Exposure Point Total									NA					6.0
	Exposure Medium Total										NA					6.0
	Air	Water Vapors from Showerhead	Inhalation (1)	Chloroform	0.0070	mg/m3	NA	NA	NA	NA	NA	1.6E-04	mg/m3	9.8E-02	mg/m3	0.0017
			Exp. Route Total								NA					0.0017
		Exposure Point Total									NA					0.0017
	Exposure Medium Total										NA					0.0017
Groundwater Total - SW Alluvium											NA					6.0
							Total of Receptor Risks Across All Media				NA	Total of Receptor Hazards Across All Media				6.0

Notes:

(1) Inhalation EPC represents chemical air concentration (mg/m3) calculated from shower exposure model in Table 7.C.RME (Supplemental)

Definitions:

NA = Not Applicable

TABLE 7.2.RME

CALCULATION OF CHEMICAL NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value (1)	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater SW Alluvium	Groundwater	Tapwater	Ingestion	Arsenic	0.00256	mg/l	NA	NA	NA	NA	NA	1.64E-04	mg/kg/d	3.0E-04	mg/kg/d	0.55
				Cobalt	0.01	mg/l	NA	NA	NA	NA	NA	6.39E-04	mg/kg/d	3.0E-04	mg/kg/d	2.1
				Manganese	2.8	mg/l	NA	NA	NA	NA	NA	1.79E-01	mg/kg/d	2.4E-02	mg/kg/d	7.5
				Uranium	0.128	mg/l	NA	NA	NA	NA	NA	8.18E-03	mg/kg/d	3.0E-03	mg/kg/d	2.7
				Chloroform	0.00338	mg/l	NA	NA	NA	NA	NA	2.16E-04	mg/kg/d	1.0E-02	mg/kg/d	0.021
			Exp. Route Total								NA					12.9
			Dermal	Arsenic	0.00256	mg/l	NA	NA	NA	NA	NA	1.1E-06	mg/kg/d	3.0E-04	mg/kg/d	0.0036
				Cobalt	0.01	mg/l	NA	NA	NA	NA	NA	4.2E-06	mg/kg/d	3.0E-04	mg/kg/d	0.014
				Manganese	2.8	mg/l	NA	NA	NA	NA	NA	1.2E-03	mg/kg/d	9.6E-04	mg/kg/d	1.2
				Uranium	0.128	mg/l	NA	NA	NA	NA	NA	5.4E-05	mg/kg/d	3.0E-03	mg/kg/d	0.018
				Chloroform	0.00338	mg/l	NA	NA	NA	NA	NA	1.9E-05	mg/kg/d	1.02E-02	mg/kg/d	0.0019
			Exp. Route Total								NA					1.3
		Exposure Point Total									NA					14.2
	Exposure Medium Total										NA					14.2
	Air	Water Vapors from Showerhead	Inhalation	Chloroform	0.010	mg/m3	NA	NA	NA	NA	NA	4.1E-04	mg/m3	9.8E-02	mg/m3	0.0041
			Exp. Route Total								NA					0.0041
		Exposure Point Total									NA					0.0041
	Exposure Medium Total										NA					0.0041
Groundwater Total - SW Alluvium											NA					14.2
							Total of Receptor Risks Across All Media				NA	Total of Receptor Hazards Across All Media				14.2

Notes:

(1) Inhalation EPC represents chemical air concentration (mg/m3) calculated from shower exposure model in Table 7.D.RME (Supplemental)

Definitions:

NA = Not Applicable

TABLE 7.3.RME
CALCULATION OF CHEMICAL CANCER RISKS
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
					(1)		Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Tapwater	Ingestion	Arsenic	0.00256	mg/l	3.82E-05	mg/kg/d	1.5E+00	(mg/kg-day)-1	5.7E-05	NA	NA	NA	NA	NA
SW Alluvium				Cobalt	0.01	mg/l	1.49E-04	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Manganese	2.8	mg/l	4.18E-02	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Uranium	0.128	mg/l	1.91E-03	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Chloroform	0.00338	mg/l	5.05E-05	mg/kg/d	3.1E-02	$(mg/kg\text{-}day)^{-1}$	1.6E-06	NA	NA	NA	NA	NA
			Exp. Route Total								5.9E-05					NA
			Dermal	Arsenic	0.00256	mg/l	2.2E-07	mg/kg/d	1.5E+00	(mg/kg-day)-1	3.3E-07	NA	NA	NA	NA	NA
				Cobalt	0.01	mg/l	8.5E-07	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Manganese	2.8	mg/l	2.4E-04	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Uranium	0.128	mg/l	1.1E-05	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Chloroform	0.00338	mg/l	4.5E-06	mg/kg/d	3.1E-02	(mg/kg-day)-1	1.4E-07	NA	NA	NA	NA	NA
			Exp. Route Total								4.7E-07					NA
		Exposure Point Total									5.9E-05	NA	NA	NA	NA	NA
	Exposure Medium Total										5.9E-05					NA
	Air	Water Vapors from Showerhead	Inhalation	Chloroform	0.0076	mg/m3	9.1E-05	mg/m3	2.3E-05	(µg/m3)-1	2.1E-06	NA	NA	NA	NA	NA
			Exp. Route Total								2.1E-06					NA
		Exposure Point Total									2.1E-06					NA
	Exposure Medium Total										2.1E-06					NA
Groundwater Total - SW Alluvium											6.1E-05					NA
							Total of Receptor Risks Across All Media				6.1E-05	Total of Receptor Hazards Across All Media				NA

Notes:

(1) Inhalation EPC represents time weighted chemical air concentration (mg/m3) calculated from shower exposure model in Tables 7.C.RME Supplement C and 7.D.RME Supplement D (note that "Exposure Concentration" is calculated independently).

Definitions:

NA = Not Applicable

TABLE 7.4.RME

CALCULATION OF CHEMICAL NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value (1)	Units	Intake/Exposure Concentration Value	Intake/Exposure Concentration Units	CSF/Unit Risk Value	CSF/Unit Risk Units	Cancer Risk	Intake/Exposure Concentration Value	Intake/Exposure Concentration Units	RfD/RfC Value	RfD/RfC Units	Hazard Quotient
Groundwater Zone 1	Groundwater	Tapwater	Ingestion	Arsenic	0.00145	mg/l	NA	NA	NA	NA	NA	3.97E-05	mg/kg/d	3.0E-04	mg/kg/d	0.13
				Cobalt	0.0557	mg/l	NA	NA	NA	NA	NA	1.53E-03	mg/kg/d	3.0E-04	mg/kg/d	5.1
				Manganese	1.95	mg/l	NA	NA	NA	NA	NA	5.34E-02	mg/kg/d	2.4E-02	mg/kg/d	2.2
				Vanadium	0.2	mg/l	NA	NA	NA	NA	NA	5.48E-03	mg/kg/d	5.0E-03	mg/kg/d	1.1
				Chloroform	0.00068	mg/l	NA	NA	NA	NA	NA	1.86E-05	mg/kg/d	1.0E-02	mg/kg/d	0.0018
			Exp. Route Total								NA					8.5
			Dermal	Arsenic	0.00145	mg/l	NA	NA	NA	NA	NA	2.1E-07	mg/kg/d	3.0E-04	mg/kg/d	0.0007
				Cobalt	0.0557	mg/l	NA	NA	NA	NA	NA	8.0E-06	mg/kg/d	3.0E-04	mg/kg/d	0.027
				Manganese	1.95	mg/l	NA	NA	NA	NA	NA	2.8E-04	mg/kg/d	9.6E-04	mg/kg/d	0.29
				Vanadium	0.2	mg/l	NA	NA	NA	NA	NA	2.9E-05	mg/kg/d	5.0E-03	mg/kg/d	0.0057
				Chloroform	0.00068	mg/l	NA	NA	NA	NA	NA	1.7E-06	mg/kg/d	1.02E-02	mg/kg/d	0.0002
			Exp. Route Total								NA					0.32
		Exposure Point Total									NA					8.9
	Exposure Medium Total										NA					8.9
	Air	Water Vapors from Showerhead	Inhalation	Chloroform	0.0014	mg/m3	NA	NA	NA	NA	NA	3.3E-05	mg/m3	9.8E-02	mg/m3	0.0003
			Exp. Route Total								NA					0.0003
		Exposure Point Total									NA					0.0003
	Exposure Medium Total										NA					0.0003
Groundwater Total - Zone 1											NA					8.9
							Total of Receptor Risks Across All Media				NA	Total of Receptor Hazards Across All Media				8.9

Notes:

(1) Inhalation EPC represents chemical air concentration (mg/m3) calculated from shower exposure model in Table 7.D.RME (Supplemental)

Definitions:

NA = Not Applicable

TABLE 7.5.RME

CALCULATION OF CHEMICAL NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value (1)	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater Zone 1	Groundwater	Tapwater	Ingestion	Arsenic	0.00145	mg/l	NA	NA	NA	NA	NA	9.27E-05	mg/kg/d	3.0E-04	mg/kg/d	0.31
				Cobalt	0.0557	mg/l	NA	NA	NA	NA	NA	3.56E-03	mg/kg/d	3.0E-04	mg/kg/d	11.9
				Manganese	1.95	mg/l	NA	NA	NA	NA	NA	1.25E-01	mg/kg/d	2.4E-02	mg/kg/d	5.2
				Vanadium	0.2	mg/l	NA	NA	NA	NA	NA	1.28E-02	mg/kg/d	5.0E-03	mg/kg/d	2.6
				Chloroform	0.00068	mg/l	NA	NA	NA	NA	NA	4.35E-05	mg/kg/d	1.0E-02	mg/kg/d	0.0043
			Exp. Route Total								NA					19.9
			Dermal	Arsenic	0.00145	mg/l	NA	NA	NA	NA	NA	6.1E-07	mg/kg/d	3.0E-04	mg/kg/d	0.0020
				Cobalt	0.0557	mg/l	NA	NA	NA	NA	NA	2.4E-05	mg/kg/d	3.0E-04	mg/kg/d	0.078
				Manganese	1.95	mg/l	NA	NA	NA	NA	NA	8.2E-04	mg/kg/d	9.6E-04	mg/kg/d	0.86
				Vanadium	0.2	mg/l	NA	NA	NA	NA	NA	8.4E-05	mg/kg/d	5.0E-03	mg/kg/d	0.017
				Chloroform	0.00068	mg/l	NA	NA	NA	NA	NA	3.8E-06	mg/kg/d	1.02E-02	mg/kg/d	0.0004
			Exp. Route Total								NA					0.95
		Exposure Point Total									NA					20.9
	Exposure Medium Total										NA					20.9
	Air	Water Vapors from Showerhead	Inhalation	Chloroform	0.0020	mg/m3	NA	NA	NA	NA	NA	8.2E-05	mg/m3	9.8E-02	mg/m3	0.0008
			Exp. Route Total								NA					0.0008
		Exposure Point Total									NA					0.0008
	Exposure Medium Total										NA					0.0008
Groundwater Total - Zone 1											NA					20.9
										Total of Receptor Risks Across All Media	NA				Total of Receptor Hazards Across All Media	20.9

Notes:

(1) Inhalation EPC represents chemical air concentration (mg/m3) calculated from shower exposure model in Table 7.D.RME (Supplemental)

Definitions:

NA = Not Applicable

TABLE 7.6.RME

CALCULATION OF CHEMICAL CANCER RISKS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
					(1)		Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Tapwater	Ingestion	Arsenic	0.00145	mg/l	2.17E-05	mg/kg/d	1.5E+00	(mg/kg-day)-1	3.2E-05	NA	NA	NA	NA	NA
Zone 1				Cobalt	0.0557	mg/l	8.32E-04	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Manganese	1.95	mg/l	2.91E-02	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Vanadium	0.2	mg/l	2.99E-03	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Chloroform	0.00068	mg/l	1.02E-05	mg/kg/d	3.1E-02	(mg/kg-day)-1	3.1E-07	NA	NA	NA	NA	NA
			Exp. Route Total								3.3E-05					NA
			Dermal	Arsenic	0.00145	mg/l	1.24E-07	mg/kg/d	1.5E+00	(mg/kg-day)-1	1.9E-07	NA	NA	NA	NA	NA
				Cobalt	0.0557	mg/l	4.7E-06	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Manganese	1.95	mg/l	1.7E-04	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Vanadium	0.2	mg/l	1.7E-05	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Chloroform	0.00068	mg/l	9.1E-07	mg/kg/d	3.1E-02	(mg/kg-day)-1	2.8E-08	NA	NA	NA	NA	NA
			Exp. Route Total								2.1E-07					NA
		Exposure Point Total									3.3E-05					NA
	Exposure Medium Total										3.3E-05					NA
	Air	Water Vapors from Showerhead	Inhalation	Chloroform	0.0015	mg/m3	1.8E-05	mg/m3	2.3E-05	(µg/m3)-1	4.2E-07	NA	NA	NA	NA	NA
			Exp. Route Total								4.2E-07					NA
		Exposure Point Total									4.2E-07					NA
	Exposure Medium Total										4.2E-07					NA
Groundwater Total - Zone 1											3.3E-05					NA
									Total of Receptor Risks Across All Media		3.3E-05		Total of Receptor Hazards Across All Media			NA

Notes:

(1) Inhalation EPC represents time weighted chemical air concentration (mg/m3) calculated from shower exposure model in Tables 7.C.RME Supplement C and 7.D.RME Supplement D (note that "Exposure Concentration" is calculated independently.

Definitions:

NA = Not Applicable

TABLE 7.7.RME

CALCULATION OF CHEMICAL NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value (1)	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater Zone 3	Groundwater	Tapwater	Ingestion	Aluminum	39.15	mg/l	NA	NA	NA	NA	NA	1.07E+00	mg/kg/d	1.0E+00	mg/kg/d	1.1
				Arsenic	0.412	mg/l	NA	NA	NA	NA	NA	1.13E-02	mg/kg/d	3.0E-04	mg/kg/d	37.6
				Beryllium	0.0202	mg/l	NA	NA	NA	NA	NA	5.53E-04	mg/kg/d	2.0E-03	mg/kg/d	0.28
				Cadmium	0.0628	mg/l	NA	NA	NA	NA	NA	1.72E-03	mg/kg/d	5.0E-04	mg/kg/d	3.4
				Cobalt	0.439	mg/l	NA	NA	NA	NA	NA	1.20E-02	mg/kg/d	3.0E-04	mg/kg/d	40.1
				Manganese	10.89	mg/l	NA	NA	NA	NA	NA	2.98E-01	mg/kg/d	2.4E-02	mg/kg/d	12.4
				Molybdenum	0.739	mg/l	NA	NA	NA	NA	NA	2.02E-02	mg/kg/d	5.0E-03	mg/kg/d	4.0
				Nickel	0.489	mg/l	NA	NA	NA	NA	NA	1.34E-02	mg/kg/d	2.0E-02	mg/kg/d	0.67
				Vanadium	0.18	mg/l	NA	NA	NA	NA	NA	4.93E-03	mg/kg/d	5.0E-03	mg/kg/d	1.0
				Uranium	0.0431	mg/l	NA	NA	NA	NA	NA	1.18E-03	mg/kg/d	3.0E-03	mg/kg/d	0.39
				Chloroform	0.00326	mg/l	NA	NA	NA	NA	NA	8.93E-05	mg/kg/d	1.0E-02	mg/kg/d	0.0088
			Exp. Route Total								NA					101
			Dermal	Aluminum	39.15	mg/l	NA	NA	NA	NA	NA	5.6E-03	mg/kg/d	1.0E+00	mg/kg/d	0.0056
				Arsenic	0.412	mg/l	NA	NA	NA	NA	NA	5.9E-05	mg/kg/d	3.0E-04	mg/kg/d	0.20
				Beryllium	0.0202	mg/l	NA	NA	NA	NA	NA	2.9E-06	mg/kg/d	1.4E-05	mg/kg/d	0.21
				Cadmium	0.0628	mg/l	NA	NA	NA	NA	NA	9.0E-06	mg/kg/d	2.5E-05	mg/kg/d	0.36
				Cobalt	0.439	mg/l	NA	NA	NA	NA	NA	6.3E-05	mg/kg/d	3.0E-04	mg/kg/d	0.21
				Manganese	10.89	mg/l	NA	NA	NA	NA	NA	1.6E-03	mg/kg/d	9.6E-04	mg/kg/d	1.6
				Molybdenum	0.739	mg/l	NA	NA	NA	NA	NA	1.1E-04	mg/kg/d	5.0E-03	mg/kg/d	0.021
				Nickel	0.489	mg/l	NA	NA	NA	NA	NA	1.4E-05	mg/kg/d	8.0E-04	mg/kg/d	0.017
				Vanadium	0.18	mg/l	NA	NA	NA	NA	NA	2.6E-05	mg/kg/d	5.0E-03	mg/kg/d	0.0051
				Uranium	0.0431	mg/l	NA	NA	NA	NA	NA	6.2E-06	mg/kg/d	3.0E-03	mg/kg/d	0.0021
				Chloroform	0.00326	mg/l	NA	NA	NA	NA	NA	8.1E-06	mg/kg/d	1.0E-02	mg/kg/d	0.0008
			Exp. Route Total								NA					2.6
		Exposure Point Total									NA					104
	Exposure Medium Total										NA					104
	Air	Water Vapors from Showerhead	Inhalation	Chloroform	0.0068	mg/m3	NA	NA	NA	NA	NA	1.6E-04	mg/m3	9.8E-02	mg/m3	0.0016
			Exp. Route Total								NA					0.0016
		Exposure Point Total									NA					0.0016
	Exposure Medium Total										NA					0.0016
Groundwater Total - Zone 3											NA					104
							Total of Receptor Risks Across All Media				NA	Total of Receptor Hazards Across All Media				104

Notes:

(1) Inhalation EPC represents chemical air concentration (mg/m3) calculated from shower exposure model in Table 7.D.RME (Supplemental)

Definitions:

NA = Not Applicable

TABLE 7.8.RME

CALCULATION OF CHEMICAL NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
					(1)		Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Tapwater	Ingestion	Aluminum	39.15	mg/l	NA	NA	NA	NA	NA	2.50E+00	mg/kg/d	1.0E+00	mg/kg/d	2.5
Zone 3				Arsenic	0.412	mg/l	NA	NA	NA	NA	NA	2.63E-02	mg/kg/d	3.0E-04	mg/kg/d	87.8
				Beryllium	0.0202	mg/l	NA	NA	NA	NA	NA	1.29E-03	mg/kg/d	2.0E-03	mg/kg/d	0.65
				Cadmium	0.0628	mg/l	NA	NA	NA	NA	NA	4.01E-03	mg/kg/d	5.0E-04	mg/kg/d	8.0
				Cobalt	0.439	mg/l	NA	NA	NA	NA	NA	2.81E-02	mg/kg/d	3.0E-04	mg/kg/d	93.5
				Manganese	10.89	mg/l	NA	NA	NA	NA	NA	6.96E-01	mg/kg/d	2.4E-02	mg/kg/d	29.0
				Molybdenum	0.739	mg/l	NA	NA	NA	NA	NA	4.72E-02	mg/kg/d	5.0E-03	mg/kg/d	9.4
				Nickel	0.489	mg/l	NA	NA	NA	NA	NA	3.13E-02	mg/kg/d	2.0E-02	mg/kg/d	1.6
				Vanadium	0.18	mg/l	NA	NA	NA	NA	NA	1.15E-02	mg/kg/d	5.0E-03	mg/kg/d	2.3
				Uranium	0.0431	mg/l	NA	NA	NA	NA	NA	2.76E-03	mg/kg/d	3.0E-03	mg/kg/d	0.92
				Chloroform	0.00326	mg/l	NA	NA	NA	NA	NA	2.08E-04	mg/kg/d	1.0E-02	mg/kg/d	0.020
			Exp. Route Total								NA					236
			Dermal	Aluminum	39.15	mg/l	NA	NA	NA	NA	NA	1.7E-02	mg/kg/d	1.0E+00	mg/kg/d	0.017
				Arsenic	0.412	mg/l	NA	NA	NA	NA	NA	1.7E-04	mg/kg/d	3.0E-04	mg/kg/d	0.58
				Beryllium	0.0202	mg/l	NA	NA	NA	NA	NA	8.5E-06	mg/kg/d	1.4E-05	mg/kg/d	0.61
				Cadmium	0.0628	mg/l	NA	NA	NA	NA	NA	2.6E-05	mg/kg/d	2.5E-05	mg/kg/d	1.1
				Cobalt	0.439	mg/l	NA	NA	NA	NA	NA	1.9E-04	mg/kg/d	3.0E-04	mg/kg/d	0.62
				Manganese	10.89	mg/l	NA	NA	NA	NA	NA	4.6E-03	mg/kg/d	9.6E-04	mg/kg/d	4.8
				Molybdenum	0.739	mg/l	NA	NA	NA	NA	NA	3.1E-04	mg/kg/d	5.0E-03	mg/kg/d	0.062
				Nickel	0.489	mg/l	NA	NA	NA	NA	NA	4.1E-05	mg/kg/d	8.0E-04	mg/kg/d	0.052
				Vanadium	0.18	mg/l	NA	NA	NA	NA	NA	7.6E-05	mg/kg/d	5.0E-03	mg/kg/d	0.015
				Uranium	0.0431	mg/l	NA	NA	NA	NA	NA	1.8E-05	mg/kg/d	3.0E-03	mg/kg/d	0.0061
				Chloroform	0.00326	mg/l	NA	NA	NA	NA	NA	1.8E-05	mg/kg/d	1.0E-02	mg/kg/d	0.0018
			Exp. Route Total								NA					7.8
		Exposure Point Total									NA					244
	Exposure Medium Total										NA					244
	Air	Water Vapors from Showerhead	Inhalation	Chloroform	0.0098	mg/m3					NA	3.9E-04	mg/m3	9.8E-02	mg/m3	0.0040
			Exp. Route Total								NA					0.0040
		Exposure Point Total									NA					0.0040
	Exposure Medium Total										NA					0.0040
Groundwater Total - Zone 3											NA					244
							Total of Receptor Risks Across All Media				NA	Total of Receptor Hazards Across All Media				244

Notes:

(1) Inhalation EPC represents chemical air concentration (mg/m3) calculated from shower exposure model in Table 7.D.RME (Supplemental)

Definitions:

NA = Not Applicable

TABLE 7.9.RME

CALCULATION OF CHEMICAL CANCER RISKS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value (1)	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater Zone 3	Groundwater	Tapwater	Ingestion	Aluminum	39.15	mg/l	5.8E-01	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Arsenic	0.412	mg/l	6.2E-03	mg/kg/d	1.5E+00	(mg/kg-day)-1	9.2E-03	NA	NA	NA	NA	NA
				Beryllium	0.0202	mg/l	3.0E-04	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Cadmium	0.0628	mg/l	9.4E-04	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Cobalt	0.439	mg/l	6.6E-03	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Manganese	10.89	mg/l	1.6E-01	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Molybdenum	0.739	mg/l	1.1E-02	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Nickel	0.489	mg/l	7.3E-03	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Vanadium	0.18	mg/l	2.7E-03	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Uranium	0.0431	mg/l	6.4E-04	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Chloroform	0.00326	mg/l	4.9E-05	mg/kg/d	3.1E-02	(mg/kg-day)-1	1.5E-06	NA	NA	NA	NA	NA
			Exp. Route Total								9.2E-03					NA
			Dermal	Aluminum	39.15	mg/l	3.34E-03	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Arsenic	0.412	mg/l	3.51E-05	mg/kg/d	1.5E+00	(mg/kg-day)-1	5.3E-05	NA	NA	NA	NA	NA
				Beryllium	0.0202	mg/l	1.72E-06	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Cadmium	0.0628	mg/l	5.35E-06	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Cobalt	0.439	mg/l	3.74E-05	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Manganese	10.89	mg/l	9.28E-04	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Molybdenum	0.739	mg/l	6.30E-05	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Nickel	0.489	mg/l	8.33E-06	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Vanadium	0.18	mg/l	1.53E-05	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Uranium	0.0431	mg/l	3.67E-06	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Chloroform	0.00326	mg/l	4.35E-06	mg/kg/d	3.1E-02	(mg/kg-day)-1	1.3E-07	NA	NA	NA	NA	NA
			Exp. Route Total								5.3E-05					NA
		Exposure Point Total									9.3E-03					NA
	Exposure Medium Total										9.3E-03					NA
	Air	Water Vapors from Showerhead	Inahalation	Chloroform	0.0074	mg/m3	8.7E-05	mg/m3	2.3E-05	(µg/m3)-1	2.0E-06					NA
			Exp. Route Total								2.0E-06					NA
		Exposure Point Total									2.0E-06					NA
	Exposure Medium Total										2.0E-06					NA
Groundwater Total - Zone 3											9.3E-03					NA
									Total of Receptor Risks Across All Media		9.3E-03	Total of Receptor Hazards Across All Media				NA

Notes:

(1) Inhalation EPC represents time weighted chemical air concentration (mg/m3) calculated from shower exposure model in Tables 7.C.RME Supplement C and 7.D.RME Supplement D (note that "Exposure Concentration" is calculated independently.

Definitions:

NA = Not Applicable

TABLE 7.A.RME (SUPPLEMENTAL)

CALCULATION OF DAevent

FUTURE RESIDENT ADULT

UNC Church Rock Mill and Tailings Site

Hydrostratigraphic Unit	Chemical of Potential Concern (1)	Groundwater Concentration (CW) mg/L	Permeability Coefficient(2) (Kp) (cm/hr)	B(2) (dimensionless)	Lag Time(2) (τ_{event}) (hr)	t*(2) (hr)	Fraction Absorbed Water(2) (FA) (dimensionless)	Duration of Event(2) (tevent) (hr)	DAevent (mg/cm^2-event)
SW Alluvium	Arsenic (arsenite)	2.56E-03	1.0E-03	NA	NA	NA	NA	0.58	1.5E-09
SW Alluvium	Cobalt	1.00E-02	1.0E-03	NA	NA	NA	NA	0.58	5.8E-09
SW Alluvium	Manganese	2.80E+00	1.0E-03	NA	NA	NA	NA	0.58	1.6E-06
SW Alluvium	Uranium	1.28E-01	1.0E-03	NA	NA	NA	NA	0.58	7.4E-08
SW Alluvium	Chloroform	3.38E-03	6.8E-03	2.9E-02	5.0E-01	1.2E+00	1.0E+00	0.58	3.4E-08
Zone 1	Arsenic (arsenite)	1.45E-03	1.0E-03	NA	NA	NA	NA	0.58	8.4E-10
Zone 1	Cobalt	5.57E-02	1.0E-03	NA	NA	NA	NA	0.58	3.2E-08
Zone 1	Manganese	1.95E+00	1.0E-03	NA	NA	NA	NA	0.58	1.1E-06
Zone 1	Vanadium	2.00E-01	1.0E-03	NA	NA	NA	NA	0.58	1.2E-07
Zone 1	Uranium	1.74E-03	1.0E-03	NA	NA	NA	NA	0.58	1.0E-09
Zone 1	Chloroform	6.80E-04	6.8E-03	2.9E-02	5.0E-01	1.2E+00	1.0E+00	0.58	6.9E-09
Zone 3	Aluminum	3.92E+01	1.0E-03	NA	NA	NA	NA	0.58	2.3E-05
Zone 3	Arsenic (arsenite)	4.12E-01	1.0E-03	NA	NA	NA	NA	0.58	2.4E-07
Zone 3	Beryllium	2.02E-02	1.0E-03	NA	NA	NA	NA	0.58	1.2E-08
Zone 3	Cadmium (water)	6.28E-02	1.0E-03	NA	NA	NA	NA	0.58	3.6E-08
Zone 3	Cobalt	4.39E-01	1.0E-03	NA	NA	NA	NA	0.58	2.5E-07
Zone 3	Manganese	1.09E+01	1.0E-03	NA	NA	NA	NA	0.58	6.3E-06
Zone 3	Molybdenum	7.39E-01	1.0E-03	NA	NA	NA	NA	0.58	4.3E-07
Zone 3	Nickel	4.89E-01	2.0E-04	NA	NA	NA	NA	0.58	5.7E-08
Zone 3	Vanadium	1.80E-01	1.0E-03	NA	NA	NA	NA	0.58	1.0E-07
Zone 3	Uranium	4.31E-02	1.0E-03	NA	NA	NA	NA	0.58	2.5E-08
Zone 3	Chloroform	3.26E-03	6.8E-03	2.9E-02	5.0E-01	1.2E+00	1.0E+00	0.58	3.3E-08

Notes:

(1) Radionuclide COPCs not included in dermal evaluation because the ingested dose significantly outweighs the dermally absorbed dose.

(2) Values from EPA 2004, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final). EPA/540/R/99/005.
Per the guidance, the default Kp value of 1E-06 was assigned to inorganics without designated Kp values.

Definitions:

NA = Not Applicable

TABLE 7.B.RME (SUPPLEMENTAL)

CALCULATION OF DAevent

FUTURE RESIDENT CHILD

UNC Church Rock Mill and Tailings Site

Hydrostratigraphic Unit	Chemical of Potential Concern (1)	Groundwater Concentration (CW) mg/L	Permeability Coefficient(2) (Kp) (cm/hr)	B(2) (dimensionless)	Lag Time(2) (τ_{event}) (hr)	t*(2) (hr)	Fraction Absorbed Water(2) (FA) (dimensionless)	Duration of Event(2) (tevent) (hr)	DAevent (mg/cm^2-event)
SW Alluvium	Arsenic (arsenite)	2.56E-03	1.0E-03	NA	NA	NA	NA	1	2.6E-09
SW Alluvium	Cobalt	1.00E-02	1.0E-03	NA	NA	NA	NA	1	1.0E-08
SW Alluvium	Manganese	2.80E+00	1.0E-03	NA	NA	NA	NA	1	2.8E-06
SW Alluvium	Uranium	1.28E-01	1.0E-03	NA	NA	NA	NA	1	1.3E-07
SW Alluvium	Chloroform	3.38E-03	6.8E-03	2.9E-02	5.0E-01	1.2E+00	1.0E+00	1	4.5E-08
Zone 1	Arsenic (arsenite)	1.45E-03	1.0E-03	NA	NA	NA	NA	1	1.5E-09
Zone 1	Cobalt	5.57E-02	1.0E-03	NA	NA	NA	NA	1	5.6E-08
Zone 1	Manganese	1.95E+00	1.0E-03	NA	NA	NA	NA	1	2.0E-06
Zone 1	Vanadium	2.00E-01	1.0E-03	NA	NA	NA	NA	1	2.0E-07
Zone 1	Uranium	1.74E-03	1.0E-03	NA	NA	NA	NA	1	1.7E-09
Zone 1	Chloroform	6.80E-04	6.8E-03	2.9E-02	5.0E-01	1.2E+00	1.0E+00	1	9.0E-09
Zone 3	Aluminum	3.92E+01	1.0E-03	NA	NA	NA	NA	1	3.9E-05
Zone 3	Arsenic (arsenite)	4.12E-01	1.0E-03	NA	NA	NA	NA	1	4.1E-07
Zone 3	Beryllium	2.02E-02	1.0E-03	NA	NA	NA	NA	1	2.0E-08
Zone 3	Cadmium (water)	6.28E-02	1.0E-03	NA	NA	NA	NA	1	6.3E-08
Zone 3	Cobalt	4.39E-01	1.0E-03	NA	NA	NA	NA	1	4.4E-07
Zone 3	Manganese	1.09E+01	1.0E-03	NA	NA	NA	NA	1	1.1E-05
Zone 3	Molybdenum	7.39E-01	1.0E-03	NA	NA	NA	NA	1	7.4E-07
Zone 3	Nickel	4.89E-01	2.0E-04	NA	NA	NA	NA	1	9.8E-08
Zone 3	Vanadium	1.80E-01	1.0E-03	NA	NA	NA	NA	1	1.8E-07
Zone 3	Uranium	4.31E-02	1.0E-03	NA	NA	NA	NA	1	4.3E-08
Zone 3	Chloroform	3.26E-03	6.8E-03	2.9E-02	5.0E-01	1.2E+00	1.0E+00	1	4.3E-08

Notes:

(1) Radionuclide COPCs not included in dermal evaluation because the ingested dose significantly outweighs the dermally absorbed dose.

(2) Values from EPA 2004, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final). EPA/540/R/99/005.
Per the guidance, the default Kp value of 1E-06 was assigned to inorganics without designated Kp values.

Definitions:

NA = Not Applicable

TABLE 7.C.RME (SUPPLEMENTAL)

INHALATION EXPOSURE CONCENTRATIONS FROM FOSTER AND CHROSTOWSKI SHOWER MODEL

FUTURE RESIDENT ADULT

UNC Church Rock Mill and Tailings Site

Hydrostratigraphic Unit	Chemical of Potential Concern	Exposure Point Concentration Cwo (µg/L)	Molecular weight (MW) (g/mole)	Henry's Law Constant (H) (atm-m^3/mole)	Kg (VOC) (cm/hr)	Kl (VOC) (cm/hr)	KL (cm/hr)	Kal (cm/hr)	Cwd (µg/L)	S (µg/m^3 -min)	Ca (mg/m^3)
SW Alluvium	Chloroform	3.4E+00	119.38	3.67E-03	1.2E+03	1.2E+01	1.1E+01	1.5E+01	4.1E-01	3.4E-01	7.0E-03
Zone 1	Chloroform	6.8E-01	119.38	3.67E-03	1.2E+03	1.2E+01	1.1E+01	1.5E+01	8.2E-02	6.8E-02	1.4E-03
Zone 3	Chloroform	3.3E+00	119.38	3.67E-03	1.2E+03	1.2E+01	1.1E+01	1.5E+01	3.9E-01	3.3E-01	6.8E-03

Variables	Units	Exposure Assumptions
Kg(VOC) = gas-film mass transfer coefficient	cm/hr	Solved by Eq 1
Kl(VOC) = liquid-film mass transfer coefficient	cm/hr	Solved by Eq 2
KL = overall mass transfer coefficient	cm/hr	Solved by Eq 3
Kal = adjusted overall mass transfer coeff.	cm/hr	Solved by Eq 4
Tl = Calibration temp. of water	K (20C +273)	293
Ts = Shower water temperature	k (45C)	318
Us = water viscosity at Ts	centipoise	0.596
Ul = water viscosity at Tl	cp	1.002
Cwd = conc. leaving droplets after time sdt	µg/l	Solved by Eq 5
sdt = shower droplet drop time	sec	0.5
d = shower droplet diameter	mm	1
FR = shower water flow rate	l/min	10
SV = shower room air volume	m^3	12
S = indoor VOC generation rate	µg/m^3-min	Solved by Eq 6
VR = ventilation rate	l/min	13.8
BW = body weight	kg	70
Ds = duration of shower	min	35
Dt = total duration in shower room	min	60
R = Universal gas constant	atm-m3/mol-°K	8.20E-05
Rae = air exchange rate	min^{-1}	0.0083
Ca = indoor air concentration of VOCs	µg/m^3	Solved by Eq 7

Equation 1:	Kg(VOC) =	$3000 * (18 / MW)^{0.5}$
Equation 2:	Kl(VOC) =	$20 * (44 / MW)^{0.5}$
Equation 3:	KL =	$((1 / Kl(VOC)) + (0.024 / (Kg (VOC) * H)))^{-1}$
Equation 4:	Kal =	$(KL * (((Tl * Us) / (Ts * Ul))^{-0.5}))$
Equation 5:	Cwd =	(Cwo * (1-EXP((-1 * Kal * sdt)/(60 * d))))
Equation 6:	S =	(Cwd * FR / SV)
Equation 7:	Ca =	If t>Ds [(S / Rae) * (Ds + (EXP(-Rae * Dt) / Rae) -(EXP(Rae *(Ds - Dt)) / Rae)] / Dt * 1/1000

Notes:

Inhalation Exposure Concentrations calculated based on Foster, Sarah A., and Paul C. Chrostowski. 1987. Inhalation Exposures to Volatile Organic Contaminants in the Shower. *In* The Proceedings of the 80th Annual Meeting of the Air Pollution Control Association (APCA), June 21-26, New York. Air Pollution Control Association.

TABLE 7.D.RME (SUPPLEMENTAL)

INHALATION EXPOSURE CONCENTRATIONS FROM FOSTER AND CHROSTOWSKI SHOWER MODEL

FUTURE RESIDENT CHILD

UNC Church Rock Mill and Tailings Site

Hydrostratigraphic Unit	Chemical of Potential Concern	Exposure Point Concentration Cwo (µg/L)	Molecular weight (MW) (g/mole)	Henry's Law Constant (H) (atm-m^3/mole)	Kg (VOC) (cm/hr)	Kl (VOC) (cm/hr)	KL (cm/hr)	Kal (cm/hr)	Cwd (µg/L)	S (µg/m^3 -min)	Ca (mg/m^3)
SW Alluvium	Chloroform	3.4E+00	119.38	3.7E-03	1.2E+03	1.2E+01	1.1E+01	1.5E+01	4.1E-01	3.4E-01	1.0E-02
Zone 1	Chloroform	6.8E-01	119.38	3.7E-03	1.2E+03	1.2E+01	1.1E+01	1.5E+01	8.2E-02	6.8E-02	2.0E-03
Zone 3	Chloroform	3.3E+00	119.38	3.7E-03	1.2E+03	1.2E+01	1.1E+01	1.5E+01	3.9E-01	3.3E-01	9.8E-03

Variables	Units	Exposure Assumptions
Kg(VOC) = gas-film mass transfer coefficient	cm/hr	Calculated using Eq 1
Kl(VOC) = liquid-film mass transfer coefficient	cm/hr	Calculated using Eq 2
KL = overall mass transfer coefficient	cm/hr	Calculated using Eq 3
Kal = adjusted overall mass transfer coeff.	cm/hr	Calculated using Eq 4
Tl = Calibration temp. of water	K (20C +273)	293
Ts = Shower water temperature	k (45C)	318
Us = water viscosity at Ts	cp	0.596
Ul = water viscosity at Tl	cp	1.002
Cwd = conc. leaving droplets after time sdt	µg/l	Calculated using Eq 5
sdt = shower droplet drop time	sec	0.5
d = shower droplet diameter	mm	1
FR = shower water flow rate	l/min	10
SV = shower room air volume	m^3	12
S = indoor VOC generation rate	µg/m^3-min	Calculated using Eq 6
Ds = duration of shower	min	60
Dt = total duration in shower room	min	80
R = Universal gas constant	atm-m3/mol-°K	8.20E-05
Rae = air exchange rate	min^{-1}	0.0083
Ca = indoor air concentration of VOCs	µg/m^3	Calculated using Eq 7

Equation 1:	Kg(VOC) =	3000 * (18 / MW)$^{0.5}$	
Equation 2:	Kl(VOC) =	20 * (44 / MW)$^{0.5}$	
Equation 3:	KL =	((1 / Kl(VOC)) + (R*Tl / (Kg (VOC) * H)))$^{-1}$	
Equation 4:	Kal =	(KL * (((Tl * Us) / (Ts * Ul))$^{-0.5}$))	
Equation 5:	Cwd =	(Cwo * (1-EXP((-1 * Kal * sdt)/(60 * d))))	
Equation 6:	S =	(Cwd * FR / SV)	
Equation 7:	Ca =	If t>Ds	[(S / Rae) * (Ds + (EXP(-Rae * Dt) / Rae) -(EXP(Rae *(Ds - Dt)) / Rae)] / Dt * 1/1000

Notes:

Inhalation Exposure Concentrations calculated based on Foster, Sarah A., and Paul C. Chrostowski. 1987. Inhalation Exposures to Volatile Organic Contaminants in the Shower. *In* The Proceedings of the 80th Annual Meeting of the Air Pollution Control Association (APCA), June 21-26, New York. Air Pollution Control Association.

TABLE 7.E.RME (SUPPLEMENTAL)

CALCULATION OF INHALATION INTAKE USING ANDELMAN VOLATILIZATION FACTOR
FUTURE RESIDENT CHILD/ADULT
UNC Church Rock Mill and Tailings Site

Compound	Hydrostratigraphic Unit	EPC Activity pCi/L	Intake Through Vapor Inhalation pCi
Radium 226+D	SWA	0.267	2.52E+04
Radium 226+D	Zone 1	1.213	1.15E+05
Radium 226+D	Zone 3	11.14	1.05E+06

$$Intake(pCi) = CW_R(\frac{pCi}{L}) \times EF(\frac{350d}{y}) \times ED(30yr) \times IRAadj(\frac{18m3}{d}) \times ETr(\frac{24hr}{d}) \times (\frac{1d}{24h}) \times K(\frac{0.5L}{m3})$$

Name	Abbr	Value	Units
Radionuclide concentration (activity) in water	CW_R	Chem. specific	pCi/L
Exposure Frequency	EF	350	day/year
Exposure Duration	ED	30	year
Age-adjusted inhalation rate	IRAadj	18	m3/day
Andelman volatilization factor	K	0.5	L/day
Exposure Time-residential	ETr	24	hrs/day
Conversion	Constant (1 day/24 hours)	0.041666667	day/hours

Notes:

The inhalation exposure route is only calculated for Ra-226+D. Volatilization in the equation comes from household uses of water (e.g., showering, laundering, dishwashing)

TABLE 7.F.RME (SUPPLEMENTAL)

CALCULATION OF CHEMICAL NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC (1)		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Background	Groundwater	Tapwater	Ingestion	Aluminum	0.231	mg/l	NA	NA	NA	NA	NA	6.33E-03	mg/kg/d	1.0E+00	mg/kg/d	0.0063
Groundwater				Arsenic	0.175	mg/l	NA	NA	NA	NA	NA	4.79E-03	mg/kg/d	3.0E-04	mg/kg/d	16.0
Zone 3				Beryllium	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	2.0E-03	mg/kg/d	NC
				Cadmium	0.0113	mg/l	NA	NA	NA	NA	NA	3.10E-04	mg/kg/d	5.0E-04	mg/kg/d	0.62
				Cobalt	0.0877	mg/l	NA	NA	NA	NA	NA	2.40E-03	mg/kg/d	3.0E-04	mg/kg/d	8.0
				Manganese	3.436	mg/l	NA	NA	NA	NA	NA	9.41E-02	mg/kg/d	2.4E-02	mg/kg/d	3.9
				Molybdenum	17.43	mg/l	NA	NA	NA	NA	NA	4.78E-01	mg/kg/d	5.0E-03	mg/kg/d	95.5
				Nickel	0.14	mg/l	NA	NA	NA	NA	NA	3.84E-03	mg/kg/d	2.0E-02	mg/kg/d	0.19
				Vanadium	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	5.0E-03	mg/kg/d	NC
				Uranium	0.107	mg/l	NA	NA	NA	NA	NA	2.93E-03	mg/kg/d	3.0E-03	mg/kg/d	0.98
				Chloroform	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	1.0E-02	mg/kg/d	NC
			Exp. Route Total								NA					125
			Dermal	Aluminum	0.231	mg/l	NA	NA	NA	NA	NA	3.3E-05	mg/kg/d	1.0E+00	mg/kg/d	0.00003
				Arsenic	0.175	mg/l	NA	NA	NA	NA	NA	2.5E-05	mg/kg/d	3.0E-04	mg/kg/d	0.083
				Beryllium	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	1.4E-05	mg/kg/d	NC
				Cadmium	0.0113	mg/l	NA	NA	NA	NA	NA	1.6E-06	mg/kg/d	2.5E-05	mg/kg/d	0.065
				Cobalt	0.0877	mg/l	NA	NA	NA	NA	NA	1.3E-05	mg/kg/d	3.0E-04	mg/kg/d	0.042
				Manganese	3.436	mg/l	NA	NA	NA	NA	NA	4.9E-04	mg/kg/d	9.6E-04	mg/kg/d	0.51
				Molybdenum	17.43	mg/l	NA	NA	NA	NA	NA	2.5E-03	mg/kg/d	5.0E-03	mg/kg/d	0.50
				Nickel	0.14	mg/l	NA	NA	NA	NA	NA	4.0E-06	mg/kg/d	8.0E-04	mg/kg/d	0.0050
				Vanadium	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	5.0E-03	mg/kg/d	NC
				Uranium	0.107	mg/l	NA	NA	NA	NA	NA	1.5E-05	mg/kg/d	3.0E-03	mg/kg/d	0.0051
				Chloroform	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	1.0E-02	mg/kg/d	NC
			Exp. Route Total								NA					1.2
		Exposure Point Total									NA					126
	Exposure Medium Total										NA					126
	Air	Water Vapors from Showerhead	Inhalation	Chloroform	ND	mg/m3	NA	NA	NA	NA	NA	NC	mg/m3	9.8E-02	mg/m3	NC
			Exp. Route Total								NA					NC
		Exposure Point Total									NA					NC
	Exposure Medium Total										NA					NC
Groundwater Total - Zone 3											NA					126
							Total of Receptor Risks Across All Media				NA	Total of Receptor Hazards Across All Media				126

Notes:

(1) EPC concentration shown is "95% UCL" term for background groundwater calculated using ProUCL ver 4.00.02 as described in N.A.Water Systems (2008b). Chloroform is shown as not detected because it was detected in only one of 186 Zone 3 background samples.

Calculations do not include chemicals detected in background that are not COPCs in impacted water

Definitions:

NA = Not Applicable

NC = Not calculated, COPC was not detected in background water

ND = Not Detected; Shown where COPCs (for seepage-impacted water) were not detected in background water. HQs not calculated for these COPCs

TABLE 7.G.RME (SUPPLEMENTAL)

CALCULATION OF CHEMICAL NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC (1)		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Background	Groundwater	Tapwater	Ingestion	Aluminum	0.231	mg/l	NA	NA	NA	NA	NA	1.48E-02	mg/kg/d	1.0E+00	mg/kg/d	0.015
Groundwater				Arsenic	0.175	mg/l	NA	NA	NA	NA	NA	1.12E-02	mg/kg/d	3.0E-04	mg/kg/d	37.3
Zone 3				Beryllium	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	2.0E-03	mg/kg/d	NC
				Cadmium	0.0113	mg/l	NA	NA	NA	NA	NA	7.22E-04	mg/kg/d	5.0E-04	mg/kg/d	1.4
				Cobalt	0.0877	mg/l	NA	NA	NA	NA	NA	5.61E-03	mg/kg/d	3.0E-04	mg/kg/d	18.7
				Manganese	3.436	mg/l	NA	NA	NA	NA	NA	2.20E-01	mg/kg/d	2.4E-02	mg/kg/d	9.2
				Molybdenum	17.43	mg/l	NA	NA	NA	NA	NA	1.11E+00	mg/kg/d	5.0E-03	mg/kg/d	223
				Nickel	0.14	mg/l	NA	NA	NA	NA	NA	8.95E-03	mg/kg/d	2.0E-02	mg/kg/d	0.45
				Vanadium	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	5.0E-03	mg/kg/d	NC
				Uranium	0.107	mg/l	NA	NA	NA	NA	NA	6.84E-03	mg/kg/d	3.0E-03	mg/kg/d	2.3
				Chloroform	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	1.0E-02	mg/kg/d	NC
			Exp. Route Total								NA					292
			Dermal	Aluminum	0.231	mg/l	NA	NA	NA	NA	NA	9.7E-05	mg/kg/d	1.0E+00	mg/kg/d	0.0001
				Arsenic	0.175	mg/l	NA	NA	NA	NA	NA	7.4E-05	mg/kg/d	3.0E-04	mg/kg/d	0.25
				Beryllium	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	1.4E-05	mg/kg/d	NC
				Cadmium	0.0113	mg/l	NA	NA	NA	NA	NA	4.8E-06	mg/kg/d	2.5E-05	mg/kg/d	0.19
				Cobalt	0.0877	mg/l	NA	NA	NA	NA	NA	3.7E-05	mg/kg/d	3.0E-04	mg/kg/d	0.12
				Manganese	3.436	mg/l	NA	NA	NA	NA	NA	1.4E-03	mg/kg/d	9.6E-04	mg/kg/d	1.5
				Molybdenum	17.43	mg/l	NA	NA	NA	NA	NA	7.4E-03	mg/kg/d	5.0E-03	mg/kg/d	1.5
				Nickel	0.14	mg/l	NA	NA	NA	NA	NA	1.2E-05	mg/kg/d	8.0E-04	mg/kg/d	0.015
				Vanadium	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	5.0E-03	mg/kg/d	NC
				Uranium	0.107	mg/l	NA	NA	NA	NA	NA	4.5E-05	mg/kg/d	3.0E-03	mg/kg/d	0.015
				Chloroform	ND	mg/l	NA	NA	NA	NA	NA	NC	mg/kg/d	1.0E-02	mg/kg/d	NC
			Exp. Route Total								NA					3.6
		Exposure Point Total									NA					296
	Exposure Medium Total										NA					296
	Air	Water Vapors from Showerhead	Inhalation	Chloroform	ND	mg/m3					NA	NC	mg/m3	9.8E-02	mg/m3	NC
			Exp. Route Total								NA					NC
		Exposure Point Total									NA					NC
	Exposure Medium Total										NA					NC
Groundwater Total - Zone 3											NA					296
							Total of Receptor Risks Across All Media				NA	Total of Receptor Hazards Across All Media				296

Notes:

(1) EPC concentration shown is "95% UCL" term for background groundwater calculated using ProUCL ver 4.00.02 as described in N.A.Water Systems (2008b). Chloroform is shown as not detected because it was detected in only one of 186 Zone 3 background samples.

Calculations do not include chemicals detected in background that are not COPCs in impacted water

Definitions:

NA = Not Applicable

NC = Not calculated, COPC was not detected in background water

ND = Not Detected; Shown where COPCs (for seepage-impacted water) were not detected in background water. HQs not calculated for these COPCs

TABLE 7.H.RME (SUPPLEMENTAL)
CALCULATION OF CHEMICAL CANCER RISKS
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC (1)		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Background	Groundwater	Tapwater	Ingestion	Aluminum	0.231	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
Groundwater				Arsenic	0.175	mg/l	2.6E-03	mg/kg/d	1.5E+00	(mg/kg-day)-1	3.9E-03	NA	NA	NA	NA	NA
Zone 3				Beryllium	ND	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Cadmium	0.0113	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Cobalt	0.0877	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Manganese	3.436	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Molybdenum	17.43	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Nickel	0.14	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Vanadium	ND	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Uranium	0.107	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Chloroform	ND	mg/l	NC	mg/kg/d	3.1E-02	(mg/kg-day)-1	NC	NA	NA	NA	NA	NA
			Exp. Route Total								3.9E-03					NA
			Dermal	Aluminum	0.231	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Arsenic	0.175	mg/l	1.49E-05	mg/kg/d	1.5E+00	(mg/kg-day)-1	2.2E-05	NA	NA	NA	NA	NA
				Beryllium	ND	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Cadmium	0.0113	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Cobalt	0.0877	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Manganese	3.436	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Molybdenum	17.43	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Nickel	0.14	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Vanadium	ND	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Uranium	0.107	mg/l	NA	mg/kg/d	NA	NA	NA	NA	NA	NA	NA	NA
				Chloroform	ND	mg/l	NC	mg/kg/d	3.1E-02	(mg/kg-day)-1	NC	NA	NA	NA	NA	NA
			Exp. Route Total								2.2E-05					NA
		Exposure Point Total									3.9E-03					NA
	Exposure Medium Total										3.9E-03					NA
	Air	Water Vapors from Showerhead	Inahalation	Chloroform	ND	mg/m3	NC	mg/m3	2.3E-05	(µg/m3)-1	NC					NA
			Exp. Route Total								NC					NA
		Exposure Point Total									NC					NA
	Exposure Medium Total										NC					NA
Groundwater Total - Zone 3											3.9E-03					NA
							Total of Receptor Risks Across All Media				3.9E-03	Total of Receptor Hazards Across All Media				NA

Notes:

(1) EPC concentration shown is "95% UCL" term for background groundwater calculated using ProUCL ver 4.00.02 as described in N.A.Water Systems (2008b). Chloroform is shown as not detected because it was detected in only one of 186 Zone 3 background samples.

Calculations do not include chemicals detected in background that are not COPCs in impacted water

Definitions:

NA = Not Applicable

NC = Not calculated, COPC was not detected in background water

ND = Not Detected; Shown where COPCs (for seepage-impacted water) were not detected in background water. HQs not calculated for these COPCs

TABLE 7.I.RME (SUPPLEMENTAL)

CALCULATION OF DAevent

Future Resident Adult

UNC Church Rock Mill and Tailings Site

Hydrostratigraphic Unit	Chemical of Potential Concern (1)	Groundwater Concentration (CW) mg/L	Permeability Coefficient(2) (Kp) (cm/hr)	B(2) (dimensionless)	Lag Time(2) (τ_{event}) (hr)	t*(2) (hr)	Fraction Absorbed Water(2) (FA) (dimensionless)	Duration of Event(2) (tevent) (hr)	DAevent (mg/cm^2-event)
Zone 3 - Background	Aluminum	2.31E-01	1.0E-03	NA	NA	NA	NA	0.58	1.3E-07
Zone 3 - Background	Arsenic (arsenite)	1.75E-01	1.0E-03	NA	NA	NA	NA	0.58	1.0E-07
Zone 3 - Background	Beryllium	ND	1.0E-03	NA	NA	NA	NA	0.58	NC
Zone 3 - Background	Cadmium (water)	1.13E-02	1.0E-03	NA	NA	NA	NA	0.58	6.6E-09
Zone 3 - Background	Cobalt	8.77E-02	1.0E-03	NA	NA	NA	NA	0.58	5.1E-08
Zone 3 - Background	Manganese	3.44E+00	1.0E-03	NA	NA	NA	NA	0.58	2.0E-06
Zone 3 - Background	Molybdenum	1.74E+01	1.0E-03	NA	NA	NA	NA	0.58	1.0E-05
Zone 3 - Background	Nickel	1.40E-01	2.0E-04	NA	NA	NA	NA	0.58	1.6E-08
Zone 3 - Background	Vanadium	ND	1.0E-03	NA	NA	NA	NA	0.58	NC
Zone 3 - Background	Uranium	1.07E-01	1.0E-03	NA	NA	NA	NA	0.58	6.2E-08
Zone 3 - Background	Chloroform	ND	6.8E-03	2.9E-02	5.0E-01	1.2E+00	1.0E+00	0.58	NC

Notes:

(1) Radionuclide COPCs not included in dermal evaluation because the ingested dose significantly outweighs the dermally absorbed dose.

(2) Groundwater concentration shown is "95% UCL" term for background groundwater calculated using ProUCL ver 4.00.02 as described in N.A.Water Systems (2008b). Chloroform is shown as not detected because it was detected in only one of 186 Zone 3 background samples.

(3) Values from EPA 2004, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final). EPA/540/R/99/005. Per the guidance, the default Kp value of 1E-06 was assigned to inorganics without designated Kp values.

Definitions:

NA = Not Applicable

NC = Not calculated, COPC was not detected in background water

ND = Not Detected; Shown where COPCs (for seepage-impacted water) were not detected in background water. HQs not calculated for these COPCs

TABLE 7.J.RME (SUPPLEMENTAL)

CALCULATION OF DAevent

Future Resident Child

UNC Church Rock Mill and Tailings Site

Hydrostratigraphic Unit	Chemical of Potential Concern (1)	Groundwater Concentration (CW) mg/L	Permeability Coefficient(3) (Kp) (cm/hr)	B(3) (dimensionless)	Lag Time(3) (τ_{event}) (hr)	t*(3) (hr)	Fraction Absorbed Water(3) (FA) (dimensionless)	Duration of Event(3) (tevent) (hr)	DAevent (mg/cm^2-event)
Zone 3 - Background	Aluminum	2.31E-01	1.0E-03	NA	NA	NA	NA	1	2.3E-07
Zone 3 - Background	Arsenic (arsenite)	1.75E-01	1.0E-03	NA	NA	NA	NA	1	1.8E-07
Zone 3 - Background	Beryllium	ND	1.0E-03	NA	NA	NA	NA	1	NC
Zone 3 - Background	Cadmium (water)	1.13E-02	1.0E-03	NA	NA	NA	NA	1	1.1E-08
Zone 3 - Background	Cobalt	8.77E-02	1.0E-03	NA	NA	NA	NA	1	8.8E-08
Zone 3 - Background	Manganese	3.44E+00	1.0E-03	NA	NA	NA	NA	1	3.4E-06
Zone 3 - Background	Molybdenum	1.74E+01	1.0E-03	NA	NA	NA	NA	1	1.7E-05
Zone 3 - Background	Nickel	1.40E-01	2.0E-04	NA	NA	NA	NA	1	2.8E-08
Zone 3 - Background	Vanadium	ND	1.0E-03	NA	NA	NA	NA	1	NC
Zone 3 - Background	Uranium	1.07E-01	1.0E-03	NA	NA	NA	NA	1	1.1E-07
Zone 3 - Background	Chloroform	ND	6.8E-03	2.9E-02	5.0E-01	1.2E+00	1.0E+00	1	NC

Notes:

(1) Radionuclide COPCs not included in dermal evaluation because the ingested dose significantly outweighs the dermally absorbed dose.

(2) Groundwater concentration shown is "95% UCL" term for background groundwater calculated using ProUCL ver 4.00.02 as described in N.A.Water Systems (2008b). Chloroform is shown as not detected because it was detected in only one of 186 Zone 3 background samples.

(3) Values from EPA 2004, Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final). EPA/540/R/99/005. Per the guidance, the default Kp value of 1E-06 was assigned to inorganics without designated Kp values.

Definitions:

NA = Not Applicable

NC = Not calculated, COPC was not detected in background water

ND = Not Detected; Shown where COPCs (for seepage-impacted water) were not detected in background water. HQs not calculated for these COPCs

TABLE 8.1.RME

CALCULATION OF RADIATION CANCER RISKS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Radionuclide of Potential Concern	EPC		Risk Calculation Approach	Cancer Risk Calculations				
					Value (1)	Units		Intake/Activity		CSF		Cancer Risk
								Value	Units	Value	Units	
Groundwater SW Alluvium	Groundwater	Tapwater	Ingestion	Uranium-234	4.4E+01	pCi/l	USEPA RAGS	8.3E+05	pCi	7.1E-11	Risk/pCi	5.8E-05
				Uranium-235+D	2.0E+00	pCi/l	USEPA RAGS	3.8E+04	pCi	7.2E-11	Risk/pCi	2.7E-06
				Uranium-238+D	4.3E+01	pCi/l	USEPA RAGS	8.1E+05	pCi	8.7E-11	Risk/pCi	7.0E-05
				Radium-226+D	2.7E-01	pCi/l	USEPA RAGS	5.0E+03	pCi	3.9E-10	Risk/pCi	1.9E-06
				Radium-228+D	8.6E-01	pCi/l	USEPA RAGS	1.6E+04	pCi	1.0E-09	Risk/pCi	1.7E-05
				Thorium-230	2.9E-01	pCi/l	USEPA RAGS	5.5E+03	pCi	9.1E-11	Risk/pCi	5.0E-07
			Exp. Route Total									1.5E-04
		Exposure Point Total										1.5E-04
	Exposure Medium Total											1.5E-04
	Air	Water Vapors from Domestic Use	Inhalation	Radium-226+D	1.3E-01	pCi/m3	USEPA RAGS	2.5E+04	pCi	1.2E-08	Risk/pCi	2.9E-04
			Exp. Route Total									2.9E-04
		Exposure Point Total										2.9E-04
	Exposure Medium Total											2.9E-04
Medium Total												4.4E-04

Notes:

(1) Inhalation EPC represents the air concentration (pCi/m3) calculated using the Andelman volatilization factor K (0.5 L/m3)

Total of Receptor Risks Across All Media: 4.4E-04

TABLE 8.2.RME

CALCULATION OF RADIATION CANCER RISKS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Radionuclide of Potential Concern	EPC		Risk Calculation Approach	Cancer Risk Calculations				
					Value (1)	Units		Intake/Activity		CSF		Cancer Risk
								Value	Units	Value	Units	
Groundwater Zone 1	Groundwater	Tapwater	Ingestion	Uranium-234	5.9E-01	pCi/l	USEPA RAGS	1.1E+04	pCi	7.1E-11	Risk/pCi	7.9E-07
				Uranium-235+D	2.7E-02	pCi/l	USEPA RAGS	5.1E+02	pCi	7.2E-11	Risk/pCi	3.7E-08
				Uranium-238+D	5.8E-01	pCi/l	USEPA RAGS	1.1E+04	pCi	8.7E-11	Risk/pCi	9.6E-07
				Radium-226+D	1.2E+00	pCi/l	USEPA RAGS	2.3E+04	pCi	3.9E-10	Risk/pCi	8.8E-06
				Radium-228+D	2.1E+00	pCi/l	USEPA RAGS	3.9E+04	pCi	1.0E-09	Risk/pCi	4.1E-05
				Thorium-230	6.5E-01	pCi/l	USEPA RAGS	1.2E+04	pCi	9.1E-11	Risk/pCi	1.1E-06
			Exp. Route Total									5.3E-05
		Exposure Point Total										5.3E-05
	Exposure Medium Total											5.3E-05
	Air	Water Vapors from Domestic Use	Inhalation	Radium-226+D	6.1E-01	pCi/m3	USEPA RAGS	1.1E+05	pCi	1.2E-08	Risk/pCi	1.3E-03
			Exp. Route Total									1.3E-03
		Exposure Point Total										1.3E-03
	Exposure Medium Total											1.3E-03
Medium Total												1.4E-03

Notes:

(1) Inhalation EPC represents the air concentration (pCi/m3) calculated using the Andelman volatilization factor K (0.5 L/m3)

Total of Receptor Risks Across All Media: 1.4E-03

TABLE 8.3.RME

CALCULATION OF RADIATION CANCER RISKS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Radionuclide of Potential Concern	EPC		Risk Calculation Approach	Cancer Risk Calculations				
					Value (1)	Units		Intake/Activity Value	Intake/Activity Units	CSF Value	CSF Units	Cancer Risk
Groundwater Zone 3	Groundwater	Tapwater	Ingestion	Uranium-234	1.5E+01	pCi/l	USEPA RAGS	2.8E+05	pCi	7.1E-11	Risk/pCi	2.0E-05
				Uranium-235+D	6.7E-01	pCi/l	USEPA RAGS	1.3E+04	pCi	7.2E-11	Risk/pCi	9.1E-07
				Uranium-238+D	1.4E+01	pCi/l	USEPA RAGS	2.7E+05	pCi	8.7E-11	Risk/pCi	2.4E-05
				Radium-226+D	1.1E+01	pCi/l	USEPA RAGS	2.1E+05	pCi	3.9E-10	Risk/pCi	8.1E-05
				Radium-228+D	1.8E+01	pCi/l	USEPA RAGS	3.4E+05	pCi	1.0E-09	Risk/pCi	3.5E-04
				Thorium-230	2.6E-01	pCi/l	USEPA RAGS	4.9E+03	pCi	9.1E-11	Risk/pCi	4.5E-07
				Lead-210+D	2.3E+00	pCi/l	USEPA RAGS	4.3E+04	pCi	1.3E-09	Risk/pCi	5.5E-05
			Exp. Route Total									5.3E-04
		Exposure Point Total										5.3E-04
	Exposure Medium Total											5.3E-04
	Air	Water Vapors from Domestic Use	Inhalation	Radium-226+D	6E+00	pCi/m3	USEPA RAGS	1.1E+06	pCi	1.2E-08	Risk/pCi	1.2E-02
			Exp. Route Total									1.2E-02
		Exposure Point Total										1.2E-02
	Exposure Medium Total											1.2E-02
Medium Total												1.3E-02

Notes:

(1) Inhalation EPC represents the air concentration (pCi/m3) calculated using the Andelman volatilization factor K (0.5 L/m3)

Total of Receptor Risks Across All Media: 1.3E-02

TABLE 8.A.RME (SUPPLEMENTAL)

CALCULATION OF RADIATION CANCER RISKS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Radionuclide of Potential Concern	EPC (1)		Risk Calculation Approach	Cancer Risk Calculations				
					Value (2)	Units		Intake/Activity		CSF		Cancer Risk
								Value	Units	Value	Units	
Background Groundwater Zone 3	Groundwater	Tapwater	Ingestion	Uranium-234	3.7E+01	pCi/l	USEPA RAGS	6.9E+05	pCi	7.1E-11	Risk/pCi	4.9E-05
				Uranium-235+D	1.7E+00	pCi/l	USEPA RAGS	3.1E+04	pCi	7.2E-11	Risk/pCi	2.3E-06
				Uranium-238+D	3.6E+01	pCi/l	USEPA RAGS	6.7E+05	pCi	8.7E-11	Risk/pCi	5.9E-05
				Radium-226+D	5.0E+00	pCi/l	USEPA RAGS	9.4E+04	pCi	3.9E-10	Risk/pCi	3.6E-05
				Radium-228+D	4.5E+00	pCi/l	USEPA RAGS	8.5E+04	pCi	1.0E-09	Risk/pCi	8.9E-05
				Thorium-230	1.4E+00	pCi/l	USEPA RAGS	2.7E+04	pCi	9.1E-11	Risk/pCi	2.5E-06
				Lead-210+D	1.6E+00	pCi/l	USEPA RAGS	3.1E+04	pCi	1.3E-09	Risk/pCi	3.9E-05
			Exp. Route Total									2.8E-04
		Exposure Point Total										2.8E-04
	Exposure Medium Total											2.8E-04
	Air	Water Vapors from Showerhead	Inhalation	Radium-226+D	2.5E+00	pCi/m3	USEPA RAGS	4.7E+05	pCi	1.2E-08	Risk/pCi	5.5E-03
			Exp. Route Total									5.5E-03
		Exposure Point Total										5.5E-03
	Exposure Medium Total											5.5E-03
Medium Total												5.8E-03

Notes:

(1) Groundwater EPC represents UCL95 background water concentration per N.A. Water System (2008b)

(2) Inhalation EPC represents the air concentration (pCi/m3) calculated using the Andelman volatilization factor K (0.5 L/m3)

Total of Receptor Risks Across All Media	5.8E-03

TABLE 9.1.RME
SUMMARY OF RECEPTOR HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater SW Alluvium	Groundwater	Tapwater	Arsenic	--	--	--	--	--	Skin	0.23	--	0.0012	0.24
			Cobalt	--	--	--	--	--	Thyroid	0.91	--	0.0048	0.92
			Manganese	--	--	--	--	--	Central nervous system	3.2	--	0.42	3.6
			Uranium	--	--	--	--	--	Kidney	1.2	--	0.0061	1.2
			Chloroform	--	--	--	--	--	Liver	0.0091	--	0.0008	0.010
			Chemical Total	--	--	--	--	--		5.5	--	0.43	6.0
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total						--					6.0
	Exposure Medium Total							--					6.0
	Air	Water Vapors from Showerhead	Arsenic	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Uranium	--	--	--	--	--	--	--	--	--	--
			Chloroform	--	--	--	--	--	Liver	--	0.0017	--	0.0017
			Chemical Total					--			0.0017		0.0017
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total											0.0017
	Exposure Medium Total												0.0017
Medium Total													6.0
Receptor Total							Receptor Risk Total	--				Receptor HI Total	6.0

Total Skin HI Across All Media =	0.24
Total Thyroid HI Across All Media =	0.92
Total Central Nervous System HI Across All Media =	3.6
Total Kidney HI Across All Media =	1.2
Total Liver HI Across All Media =	0.012

TABLE 9.2.RME
SUMMARY OF RECEPTOR HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater SW Alluvium	Groundwater	Tapwater	Arsenic	--	--	--	--	--	Skin	0.55	--	0.0036	0.55
			Cobalt	--	--	--	--	--	Thyroid	2.1	--	0.014	2.1
			Manganese	--	--	--	--	--	Central nervous system	7.5	--	1.2	8.7
			Uranium	--	--	--	--	--	Kidney	2.7	--	0.018	2.7
			Chloroform	--	--	--	--	--	Liver	0.021	--	0.0019	0.023
			Chemical Total	--	--	--	--	--		12.9	--	1.3	14.2
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total						--					14.2
	Exposure Medium Total							--					14.2
	Air	Water Vapors from Showerhead	Arsenic	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Uranium	--	--	--	--	--	--	--	--	--	--
			Chloroform	--	--	--	--	--	Liver	--	0.0041	--	0.0041
			Chemical Total					--			0.0041		0.0041
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total											0.0041
	Exposure Medium Total												0.0041
Medium Total													14.2
Receptor Total							Receptor Risk Total	--				Receptor HI Total	14.2

Total Skin HI Across All Media =	0.55
Total Thyroid HI Across All Media =	2.1
Total Central Nervous System HI Across All Media =	8.7
Total Kidney HI Across All Media =	2.7
Total Liver HI Across All Media =	0.027

TABLE 9.3.RME
SUMMARY OF RECEPTOR RISKS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater SW Alluvium	Groundwater	Tapwater	Arsenic	5.7E-05	--	3.3E-07	--	5.8E-05	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Uranium	--	--	--	--	--	--	--	--	--	--
			Chloroform	1.6E-06	--	1.4E-07	--	1.7E-06	--	--	--	--	--
			Chemical Total	5.9E-05	--	4.7E-07	--	5.9E-05	--	--	--	--	--
			Uranium-234	5.8E-05	--	--	--	5.8E-05	--	--	--	--	--
			Uranium-235+D	2.7E-06	--	--	--	2.7E-06	--	--	--	--	--
			Uranium-238+D	7.0E-05	--	--	--	7.0E-05	--	--	--	--	--
			Radium-226+D	1.9E-06	--	--	--	1.9E-06	--	--	--	--	--
			Radium-228+D	1.7E-05	--	--	--	1.7E-05	--	--	--	--	--
			Thorium-230	5.0E-07	--	--	--	5.0E-07	--	--	--	--	--
			Radionuclide Total	1.5E-04	--	--	--	1.5E-04	--	--	--	--	--
		Exposure Point Total						2.1E-04					--
	Exposure Medium Total							2.1E-04					--
	Air	Water Vapors from Showerhead	Arsenic	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Uranium	--	--	--	--	--	--	--	--	--	--
			Chloroform	--	2.1E-06	--	--	2.1E-06	--	--	--	--	--
			Chemical Total		2.1E-06			2.1E-06	--	--	--		--
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	2.9E-04	--	--	2.9E-04	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	2.9E-04	--	--	2.9E-04	--	--	--	--	--
		Exposure Point Total						2.9E-04					--
	Exposure Medium Total							2.9E-04					--
Medium Total								5.0E-04					--
Receptor Total							Receptor Risk Total	5.0E-04				Receptor HI Total	--

TABLE 9.4.RME
SUMMARY OF RECEPTOR HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 1	Groundwater	Tapwater	Arsenic	--	--	--	--	--	Skin	0.13	--	0.0007	0.13
			Cobalt	--	--	--	--	--	Thyroid	5.1	--	0.027	5.1
			Manganese	--	--	--	--	--	Central nervous system	2.2	--	0.29	2.5
			Vanadium	--	--	--	--	--	Decreased hair cystine	1.1	--	0.0057	1.1
			Chloroform	--	--	--	--	--	Liver	0.0018	--	0.0002	0.0020
			Chemical Total	--	--	--	--	--		8.5	--	0.32	8.9
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total						--					8.9
	Exposure Medium Total							--					8.9
	Air	Water Vapors from Showerhead	Arsenic	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Vanadium	--	--	--	--	--	--	--	--	--	--
			Chloroform	--	--	--	--	--	Liver	--	0.0003	--	0.0003
			Chemical Total					--			0.0003		0.0003
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total											0.0003
	Exposure Medium Total												0.0003
Medium Total													8.9
Receptor Total							Receptor Risk Total	--				Receptor HI Total	8.9

Total Skin HI Across All Media =	0.13
Total Thyroid HI Across All Media =	5.1
Total Central Nervous System HI Across All Media =	2.5
Total Hair Cystine (Metabolic System) HI Across All Media =	1.1
Total Liver HI Across All Media =	0.0023

TABLE 9.5.RME
SUMMARY OF RECEPTOR HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 1	Groundwater	Tapwater	Arsenic	--	--	--	--	--	Skin	0.31	--	0.0020	0.31
			Cobalt	--	--	--	--	--	Thyroid	11.9	--	0.078	11.9
			Manganese	--	--	--	--	--	Central nervous system	5.2	--	0.86	6.1
			Vanadium	--	--	--	--	--	Decreased hair cystine	2.6	--	0.017	2.6
			Chloroform	--	--	--	--	--	Liver	0.0043	--	0.0004	0.0046
			Chemical Total	--	--	--	--	--		19.9	--	0.95	20.9
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total						--					20.9
	Exposure Medium Total							--					20.9
	Air	Water Vapors from Showerhead	Arsenic	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Vanadium	--	--	--	--	--	--	--	--	--	--
			Chloroform	--	--	--	--	--	Liver	--	0.0008	--	0.0008
			Chemical Total					--			0.0008		0.0008
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total											0.0008
	Exposure Medium Total												0.0008
Medium Total													20.9
Receptor Total							Receptor Risk Total	--				Receptor HI Total	20.9

Total Skin HI Across All Media =	0.31
Total Thyroid HI Across All Media =	11.9
Total Central Nervous System HI Across All Media =	6.1
Total Hair Cystine (Metabolic System) HI Across All Media =	2.6
Total Liver HI Across All Media =	0.0055

TABLE 9.6.RME
SUMMARY OF RECEPTOR RISKS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 1	Groundwater	Tapwater	Arsenic	3.2E-05	--	1.9E-07	--	3.3E-05	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Vanadium	--	--	--	--	--	--	--	--	--	--
			Chloroform	3.1E-07	--	2.8E-08	--	3.4E-07	--	--	--	--	--
			Chemical Total	3.3E-05	--	2.1E-07	--	3.3E-05	--	--	--	--	--
			Uranium-234	7.9E-07	--	--	--	7.9E-07	--	--	--	--	--
			Uranium-235+D	3.7E-08	--	--	--	3.7E-08	--	--	--	--	--
			Uranium-238+D	9.6E-07	--	--	--	9.6E-07	--	--	--	--	--
			Radium-226+D	8.8E-06	--	--	--	8.8E-06	--	--	--	--	--
			Radium-228+D	4.1E-05	--	--	--	4.1E-05	--	--	--	--	--
			Thorium-230	1.1E-06	--	--	--	1.1E-06	--	--	--	--	--
			Radionuclide Total	5.3E-05	--	--	--	5.3E-05	--	--	--	--	--
		Exposure Point Total						8.6E-05					--
	Exposure Medium Total							8.6E-05					--
	Air	Water Vapors from Showerhead	Arsenic	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Vanadium	--	--	--	--	--	--	--	--	--	--
			Chloroform	--	4.2E-07	--	--	4.2E-07	--	--	--	--	--
			Chemical Total		4.2E-07			4.2E-07	--	--	--		--
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	1.3E-03	--	--	1.3E-03	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	1.3E-03	--	--	1.3E-03	--	--	--	--	--
		Exposure Point Total						1.3E-03					--
	Exposure Medium Total							1.3E-03					--
Medium Total								1.4E-03					--
Receptor Total							Receptor Risk Total	1.4E-03				Receptor HI Total	--

TABLE 9.7.RME
SUMMARY OF RECEPTOR HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 3	Groundwater	Tapwater	Aluminum	--	--	--	--	--	Central nervous system	1.1	--	0.0056	1.1
			Arsenic	--	--	--	--	--	Skin	37.6	--	0.20	37.8
			Beryllium	--	--	--	--	--	Gastrointestinal	0.28	--	0.21	0.48
			Cadmium	--	--	--	--	--	Kidney	3.4	--	0.36	3.8
			Cobalt	--	--	--	--	--	Thyroid	40.1	--	0.21	40.3
			Manganese	--	--	--	--	--	Central nervous system	12.4	--	1.6	14.1
			Molybdenum	--	--	--	--	--	Increased uric acid (kidney)	4.0	--	0.021	4.1
			Nickel	--	--	--	--	--	Reduced organ and body weights	0.67	--	0.017	0.69
			Vanadium	--	--	--	--	--	Decreased hair cystine	1.0	--	0.0051	1.0
			Uranium	--	--	--	--	--	Kidney	0.39	--	0.0021	0.40
			Chloroform	--	--	--	--	--	Liver	0.0088	--	0.0008	0.01
			Chemical Total	--	--	--	--	--		101	--	2.6	104
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Lead-210+D	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total						--					104
	Exposure Medium Total							--					104
	Air	Water Vapors from Showerhead	Aluminum	--	--	--	--	--	--	--	--	--	--
			Arsenic	--	--	--	--	--	--	--	--	--	--
			Beryllium	--	--	--	--	--	--	--	--	--	--
			Cadmium	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Molybdenum	--	--	--	--	--	--	--	--	--	--
			Nickel	--	--	--	--	--	--	--	--	--	--
			Vanadium	--	--	--	--	--	--	--	--	--	--
			Uranium	--	--	--	--	--	--	--	--	--	--
			Chloroform	--	--	--	--	--	Liver	--	--	0.0016	0.0016
			Chemical Total					--					0.002
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Lead-210+D	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total											0.0016
	Exposure Medium Total												0.0016
Medium Total													104
Receptor Total							Receptor Risk Total	--				Receptor HI Total	104

Total Skin HI Across All Media =	37.8
Total Thyroid HI Across All Media =	40.3
Total Central Nervous System HI Across All Media =	15.1
Total Kidney HI Across All Media =	8.3
Total Liver HI Across All Media =	0.011
Total Gastrointestinal HI Across All Media =	0.48
Total Reduced Body and Organ Weights HI Across All Media =	0.69
Total Hair Cystine (Metabolic System) HI Across All Media =	1.0

TABLE 9.8.RME

SUMMARY OF RECEPTOR HAZARDS FOR COPCs

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 3	Groundwater	Tapwater	Aluminum	--	--	--	--	--	Central nervous system	2.5	--	0.017	2.5
			Arsenic	--	--	--	--	--	Skin	87.8	--	0.58	88.4
			Beryllium	--	--	--	--	--	Gastrointestinal	0.65	--	0.61	1.3
			Cadmium	--	--	--	--	--	Kidney	8.0	--	1.1	9.1
			Cobalt	--	--	--	--	--	Thyroid	93.5	--	0.62	94.2
			Manganese	--	--	--	--	--	Central nervous system	29.0	--	4.8	33.8
			Molybdenum	--	--	--	--	--	Increased uric acid (kidney)	9.4	--	0.062	9.5
			Nickel	--	--	--	--	--	Reduced organ and body weights	1.6	--	0.052	1.6
			Vanadium	--	--	--	--	--	Decreased hair cystine	2.3	--	0.015	2.3
			Uranium	--	--	--	--	--	Kidney	0.92	--	0.0061	0.92
			Chloroform	--	--	--	--	--	Liver	0.020	--	0.0018	0.022
			Chemical Total	--	--	--	--	--		236	--	7.8	244
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Lead-210+D	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total						--					244
	Exposure Medium Total							--					244
	Air	Water Vapors from Showerhead	Aluminum	--	--	--	--	--	--	--	--	--	--
			Arsenic	--	--	--	--	--	--	--	--	--	--
			Beryllium	--	--	--	--	--	--	--	--	--	--
			Cadmium	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Molybdenum	--	--	--	--	--	--	--	--	--	--
			Nickel	--	--	--	--	--	--	--	--	--	--
			Vanadium	--	--	--	--	--	--	--	--	--	--
			Uranium	--	--	--	--	--	--	--	--	--	--
			Chloroform	--	--	--	--	--	Liver	--	--	0.0040	0.0040
			Chemical Total					--					0.0040
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	--	--	--	--	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Lead-210+D	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	--	--	--	--	--	
		Exposure Point Total											0.0040
	Exposure Medium Total												0.0040
Medium Total													244
Receptor Total							Receptor Risk Total	--				Receptor HI Total	244

Total Skin HI Across All Media =	88.4
Total Thyroid HI Across All Media =	94.2
Total Central Nervous System HI Across All Media =	36.3
Total Kidney HI Across All Media =	19.5
Total Liver HI Across All Media =	0.026
Total Gastrointestinal HI Across All Media =	1.3
Total Reduced Body and Organ Weights HI Across All Media =	1.6
Total Hair Cystine (Metabolic System) HI Across All Media =	2.3

TABLE 9.9.RME
SUMMARY OF RECEPTOR RISKS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 3	Groundwater	Tapwater	Aluminum	--	--	--	--	--	--	--	--	--	--
			Arsenic	9.2E-03	--	5.3E-05	--	9.3E-03	--	--	--	--	--
			Beryllium	--	--	--	--	--	--	--	--	--	--
			Cadmium	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Molybdenum	--	--	--	--	--	--	--	--	--	--
			Nickel	--	--	--	--	--	--	--	--	--	--
			Vanadium	--	--	--	--	--	--	--	--	--	--
			Uranium	--	--	--	--	--	--	--	--	--	--
			Chloroform	1.5E-06	--	1.3E-07	--	1.6E-06	--	--	--	--	--
			Chemical Total	9.2E-03	--	5.3E-05	--	9.3E-03		--	--	--	--
			Uranium-234	2.0E-05	--	--	--	2.0E-05	--	--	--	--	--
			Uranium-235+D	9.1E-07	--	--	--	9.1E-07	--	--	--	--	--
			Uranium-238+D	2.4E-05	--	--	--	2.4E-05	--	--	--	--	--
			Radium-226+D	8.1E-05	--	--	--	8.1E-05	--	--	--	--	--
			Radium-228+D	3.5E-04	--	--	--	3.5E-04	--	--	--	--	--
			Thorium-230	4.5E-07	--	--	--	4.5E-07	--	--	--	--	--
			Lead-210+D	5.5E-05	--	--	--	5.5E-05	--	--	--	--	--
			Radionuclide Total	5.3E-04	--	--	--	5.3E-04	--	--	--	--	
		Exposure Point Total						9.8E-03					--
	Exposure Medium Total							9.8E-03					--
	Air	Water Vapors from Showerhead	Aluminum	--	--	--	--	--	--	--	--	--	--
			Arsenic	--	--	--	--	--	--	--	--	--	--
			Beryllium	--	--	--	--	--	--	--	--	--	--
			Cadmium	--	--	--	--	--	--	--	--	--	--
			Cobalt	--	--	--	--	--	--	--	--	--	--
			Manganese	--	--	--	--	--	--	--	--	--	--
			Molybdenum	--	--	--	--	--	--	--	--	--	--
			Nickel	--	--	--	--	--	--	--	--	--	--
			Vanadium	--	--	--	--	--	--	--	--	--	--
			Uranium	--	--	--	--	--	--	--	--	--	--
			Chloroform	--	2.0E-06	--	--	2.0E-06	--	--	--	--	--
			Chemical Total					2.0E-06					--
			Uranium-234	--	--	--	--	--	--	--	--	--	--
			Uranium-235+D	--	--	--	--	--	--	--	--	--	--
			Uranium-238+D	--	--	--	--	--	--	--	--	--	--
			Radium-226+D	--	1.2E-02	--	--	1.2E-02	--	--	--	--	--
			Radium-228+D	--	--	--	--	--	--	--	--	--	--
			Thorium-230	--	--	--	--	--	--	--	--	--	--
			Lead-210+D	--	--	--	--	--	--	--	--	--	--
			Radionuclide Total	--	--	--	--	1.2E-02	--	--	--	--	
		Exposure Point Total						1.2E-02					--
	Exposure Medium Total							1.2E-02					--
Medium Total								2.2E-02					--
Receptor Total							Receptor Risk Total	2.2E-02				Receptor HI Total	--

TABLE 10.1.RME

RISK ASSESSMENT SUMMARY - NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater SW Alluvium	Groundwater	Tapwater	Cobalt	--	--	--	--	--	Thyroid	0.91	--	0.005	0.92
			Manganese	--	--	--	--	--	Central nervous system	3.20	--	0.42	3.6
			Uranium	--	--	--	--	--	Kidney	1.17	--	0.006	1.2
			Chemical Total	--	--	--	--	--		5.3	--	0.43	5.7
		Exposure Point Total						--					5.7
	Exposure Medium Total							--					5.7
Medium Total													5.7
Receptor Total							Receptor Risk Total	--				Receptor HI Total	5.7

Total Thyroid HI Across All Media =	0.92
Total Central Nervous System HI Across All Media =	3.6
Total Kidney HI Across All Media =	1.2

TABLE 10.2.RME

RISK ASSESSMENT SUMMARY - NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater SW Alluvium	Groundwater	Tapwater	Cobalt	--	--	--	--	--	Thyroid	2.1	--	0.014	2.1
			Manganese	--	--	--	--	--	Central nervous system	7.5	--	1.2	8.7
			Uranium	--	--	--	--	--	Kidney	2.7	--	0.018	2.7
			Chemical Total	--	--	--	--	--		12.3	--	1.3	13.6
		Exposure Point Total						--					13.6
	Exposure Medium Total												13.6
Medium Total													13.6
Receptor Total							Receptor Risk Total	--				Receptor HI Total	13.6

Total Thyroid HI Across All Media =	2.1
Total Central Nervous System HI Across All Media =	8.7
Total Kidney HI Across All Media =	2.7

TABLE 10.3.RME

RISK ASSESSMENT SUMMARY - CANCER RISKS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk: Ingestion	Carcinogenic Risk: Inhalation	Carcinogenic Risk: Dermal	Carcinogenic Risk: External (Radiation)	Carcinogenic Risk: Exposure Routes Total	Non-Carcinogenic Hazard Quotient: Primary Target Organ(s)	Non-Carcinogenic Hazard Quotient: Ingestion	Non-Carcinogenic Hazard Quotient: Inhalation	Non-Carcinogenic Hazard Quotient: Dermal	Non-Carcinogenic Hazard Quotient: Exposure Routes Total
Groundwater SW Alluvium	Groundwater	Tapwater	Arsenic	5.7E-05	--	3.3E-07	--	5.8E-05	--	--	--	--	--
			Chloroform	1.6E-06	--	1.4E-07	--	1.7E-06	--	--	--	--	--
			Chemical Total	5.9E-05	--	4.7E-07	--	5.9E-05	--	--	--	--	--
			Uranium-234	5.8E-05	--	--	--	5.8E-05	--	--	--	--	--
			Uranium-235+D	2.7E-06	--	--	--	2.7E-06	--	--	--	--	--
			Uranium-238+D	7.0E-05	--	--	--	7.0E-05	--	--	--	--	--
			Radium-226+D	1.9E-06	--	--	--	1.9E-06	--	--	--	--	--
			Radium-228+D	1.7E-05	--	--	--	1.7E-05	--	--	--	--	--
			Radionuclide Total	1.5E-04	--	--	--	1.5E-04	--	--	--	--	--
		Exposure Point Total						2.1E-04					--
	Exposure Medium Total							2.1E-04					--
		Water Vapors from Showerhead	Chloroform	--	2.1E-06	--	--	2.1E-06	--	--	--	--	--
			Chemical Total		2.1E-06			2.1E-06	--	--	--		--
			Radium-226+D	--	2.9E-04	--	--	2.9E-04	--	--	--	--	--
			Radionuclide Total	--	2.9E-04	--	--	2.9E-04	--	--	--	--	--
		Exposure Point Total						2.9E-04					--
	Exposure Medium Total							2.9E-04					--
Medium Total								5.0E-04					--
Receptor Total							Receptor Risk Total	5.0E-04				Receptor HI Total	--

TABLE 10.4.RME

RISK ASSESSMENT SUMMARY - NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 1	Groundwater	Tapwater	Cobalt	--	--	--	--	--	Thyroid	5.1	--	0.03	5.1
			Manganese	--	--	--	--	--	Central nervous system	2.2	--	0.3	2.5
			Vanadium	--	--	--	--	--	Decreased hair cystine	1.1	--	0.006	1.1
			Chemical Total	--	--	--	--	--		8.4	--	0.32	8.7
		Exposure Point Total						--					8.7
	Exposure Medium Total							--					8.7
Medium Total													8.7
Receptor Total							Receptor Risk Total	--				Receptor HI Total	8.7

Total Thyroid HI Across All Media =	5.1
Total Central Nervous System HI Across All Media =	2.5
Decreased Hair Cystine (Metabolic System) HI Across All Media =	1.1

TABLE 10.5.RME

RISK ASSESSMENT SUMMARY - NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 1	Groundwater	Tapwater	Cobalt	--	--	--	--	--	Thyroid	11.9	--	0.078	11.9
			Manganese	--	--	--	--	--	Central nervous system	5.2	--	0.86	6.1
			Vanadium	--	--	--	--	--	Decreased hair cystine	2.6	--	0.017	2.6
			Chemical Total	--	--	--	--	--		19.6	--	0.95	20.6
		Exposure Point Total						--					20.6
	Exposure Medium Total							--					20.6
Medium Total													20.6
Receptor Total							Receptor Risk Total	--				Receptor HI Total	20.6

Total Thyroid HI Across All Media =	11.9
Total Central Nervous System HI Across All Media =	6.1
Decreased Hair Cystine (Metabolic System) HI Across All Media =	2.6

TABLE 10.6.RME

RISK ASSESSMENT SUMMARY - CANCER RISKS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 1	Groundwater	Tapwater	Arsenic	3.2E-05	--	1.9E-07	--	3.3E-05	--	--	--	--	--
			Chemical Total	3.2E-05	--	1.9E-07	--	3.3E-05	--	--	--	--	--
			Radium-226+D	8.8E-06	--	--	--	8.8E-06	--	--	--	--	--
			Radium-228+D	4.1E-05	--	--	--	4.1E-05	--	--	--	--	--
			Thorium-230	1.1E-06	--	--	--	1.1E-06	--	--	--	--	--
			Radionuclide Total	5.1E-05	--	--	--	5.1E-05	--	--	--	--	--
		Exposure Point Total						8.4E-05					--
	Exposure Medium Total							8.4E-05					--
	Air	Water Vapors from Domestic Use	Radium-226+D	--	1.3E-03	--	--	1.3E-03	--	--	--	--	--
			Radionuclide Total	--	1.3E-03	--	--	1.3E-03	--	--	--	--	--
		Exposure Point Total						1.3E-03					--
	Exposure Medium Total							1.3E-03					--
Medium Total								1.4E-03					--
Receptor Total							Receptor Risk Total	1.4E-03				Receptor HI Total	--

TABLE 10.7.RME
RISK ASSESSMENT SUMMARY - NON-CANCER HAZARDS
REASONABLE MAXIMUM EXPOSURE
UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 3	Groundwater	Tapwater	Aluminum	--	--	--	--	--	Central nervous system	1.1	--	0.0056	1.1
			Arsenic	--	--	--	--	--	Skin	37.6	--	0.20	37.8
			Cadmium	--	--	--	--	--	Kidney	3.4	--	0.36	3.8
			Cobalt	--	--	--	--	--	Thyroid	40.1	--	0.21	40.3
			Manganese	--	--	--	--	--	Central nervous system	12.4	--	1.6	14.1
			Molybdenum	--	--	--	--	--	Increased uric acid (kidney)	4.0	--	0.021	4.1
			Nickel	--	--	--	--	--	Reduced organ and body weights	0.67		0.017	0.69
			Vanadium	--	--	--	--	--	Decreased hair cystine	1.0	--	0.0051	1.0
			Uranium	--	--	--	--	--	Kidney	0.39	--	0.0021	0.40
			Chemical Total	--	--	--	--	--		101	--	2.44	103
		Exposure Point Total						--					103
	Exposure Medium Total							--					103
Medium Total													103
Receptor Total							Receptor Risk Total	--				Receptor HI Total	103

Total Skin HI Across All Media =	37.8
Total Thyroid HI Across All Media =	40.3
Total Central Nervous System HI Across All Media =	15.1
Total Kidney HI Across All Media =	8.3
Total Reduced Body and Organ Weights HI Across All Media =	0.69
Decreased Hair Cystine (Metabolic System) HI Across All Media =	1.0

TABLE 10.8.RME

RISK ASSESSMENT SUMMARY - NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 3	Groundwater	Tapwater	Aluminum	--	--	--	--	--	Central nervous system	2.5	--	0.017	2.5
			Arsenic	--	--	--	--	--	Skin	87.8	--	0.58	88.4
			Cadmium	--	--	--	--	--	Kidney	8.0	--	1.1	9.1
			Cobalt	--	--	--	--	--	Thyroid	93.5	--	0.6	94.2
			Manganese	--	--	--	--	--	Central nervous system	29.0	--	4.8	33.8
			Molybdenum	--	--	--	--	--	Increased uric acid (kidney)	9.4	--	0.062	9.5
			Nickel	--	--	--	--	--	Reduced organ and body weights	1.6	--	0.052	1.6
			Vanadium	--	--	--	--	--	Decreased hair cystine	2.3	--	0.015	2.3
			Uranium	--	--	--	--	--	Kidney	0.9	--	0.0061	0.92
			Chemical Total	--	--	--	--	--		235.1	--	7.2	242
		Exposure Point Total						--					242
	Exposure Medium Total							--					242
Medium Total													242
Receptor Total							Receptor Risk Total	--				Receptor HI Total	242

Total Skin HI Across All Media =	88.4
Total Thyroid HI Across All Media =	94.2
Total Central Nervous System HI Across All Media =	36.3
Total Kidney HI Across All Media =	19.5
Total Reduced Body and Organ Weights HI Across All Media =	1.6
Decreased Hair Cystine (Metabolic System) HI Across All Media =	2.3

TABLE 10.9.RME

RISK ASSESSMENT SUMMARY - CANCER RISKS

REASONABLE MAXIMUM EXPOSURE

UNC Church Rock Mill and Tailings Site

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater Zone 3	Groundwater	Tapwater	Arsenic	9.2E-03	--	5.3E-05	--	9.3E-03	--	--	--	--	--
			Chloroform	1.5E-06	--	1.3E-07	--	1.6E-06	--	--	--	--	--
			Chemical Total	9.2E-03	--	5.3E-05	--	9.3E-03		--	--	--	--
			Uranium-234	2.0E-05	--	--	--	2.0E-05	--	--	--	--	--
			Uranium-238+D	2.4E-05	--	--	--	2.4E-05	--	--	--	--	--
			Radium-226+D	8.1E-05	--	--	--	8.1E-05	--	--	--	--	--
			Radium-228+D	3.5E-04	--	--	--	3.5E-04	--	--	--	--	--
			Lead-210+D	5.5E-05	--	--	--	5.5E-05	--	--	--	--	--
			Radionuclide Total	5.3E-04	--	--	--	5.3E-04	--	--	--	--	
		Exposure Point Total						9.8E-03					--
	Exposure Medium Total							9.8E-03					--
	Air	Water Vapors from Showerhead	Chloroform	--	2.0E-06	--	--	2.0E-06	--	--	--	--	--
			Chemical Total		2.0E-06			2.0E-06					--
			Radium-226+D	--	1.2E-02	--	--	1.2E-02	--	--	--	--	--
			Radionuclide Total	--	1.2E-02	--	--	1.2E-02	--	--	--	--	
		Exposure Point Total						1.2E-02					--
	Exposure Medium Total							1.2E-02					--
Medium Total								2.2E-02					--
Receptor Total							Receptor Risk Total	2.2E-02				Receptor HI Total	--

APPENDIX B

Revised Submittal – Estimated UCL95 Statistics and EPCs in Impacted Groundwater, UNC Church Rock Mill and Tailings Site, Church Rock, New Mexico. December 5, 2008

N.A. WATER SYSTEMS

December 5, 2008 **This Submittal Delivered by Email Only**

Ref. No. 56007746 GE Church Rock Project

Mr. Mark Purcell
Remedial Project Manager
U.S. Environmental Protection Agency
1445 Ross Ave., Suite 1200 (6SF-LP)
Dallas, TX 75202-2733

Re: Revised Submittal
Estimated UCL95 Statistics and EPCs in Impacted Groundwater
UNC Church Rock Mill & Tailings Site, Church Rock, New Mexico

Dear Mr. Purcell:

N.A. Water Systems (N.A.WS) is pleased to provide this revised report on the calculation of statistics for the estimation of exposure point concentrations (EPCs) in impacted groundwater at UNC's Church Rock Mill & Tailings Site in Church Rock, New Mexico. This report includes descriptions of the methods used to classify sample data, the statistical methods, and the estimation results.

The post-mining/pre-tailings water is referred to as background water, and the post-mining/post-tailings water is referred to as impacted water.

Introduction

Statistical analyses for the task of estimating exposure point concentrations (EPCs) have been completed for impacted groundwater in each of the three hydrostratigraphic zones at the Church Rock Site. Statistics were calculated for the 21 contaminants of potential concern (COPCs) included in the Church Rock Sampling and Analysis Plan. The estimates were made using the current version of the EPA's ProUCL software (ver. 4.00.02) as prescribed by the EPA and reiterated in the teleconference on June 27, 2008. The teleconference participants included representatives of U.S. Environmental Protection Agency (EPA), New Mexico Environment Department (NMED), and N.A.WS. The methodology is summarized by the following steps:

1. Classify sample data for the purpose of forming logical groupings for EPC estimation. The criteria used for these classifications include the sampled

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hydrostratigraphic unit (i.e. the Southwest Alluvium (SWA), Zone 1, and Zone 3), determination of unequivocal impact from seepage fluids, representation of recent conditions (i.e. the most recent eight quarters of sampling), and location relative to administrative boundaries.

2. Use ProUCL software to estimate the upper confidence limits (UCL95) for the population means of COPC concentrations from sample groups determined to be representative of impacted groundwater quality.

3. Estimate EPCs in impacted groundwater for those COPCs for which valid UCL95 statistics have been estimated.

Classification of Samples

Identification of Samples Representative of Impacted Groundwater Quality

With respect to water quality, three exclusive classes of groundwater samples are germane to the estimation of EPCs. Those classes are post-mining/pre-tailings (background), post-mining/post-tailings (impacted), and other. For present purposes, the "other" class is meant to represent any samples that are not clearly representative of either background or impacted quality. These may include water whose quality is interpreted to be transitional or that is representative of pre-mining conditions.

Samples representative of background groundwater quality were identified for the SWA and Zone 1 in the license amendment request for changing the Groundwater Protection Standard for radium (N.A. Water Systems, February 2006, *Technical Analysis Report in Support of License Amendment Request for Changing the Method of Determining Exceedances of the Combined Radium Groundwater Protection Standard in Source Materials License SUA-1475 (TAC LU0092), Groundwater Corrective Action Program, Church Rock Site, Church Rock, New Mexico*, pp. 3-6). The same methods were used to identify samples from Zone 3 that are representative of background water quality (N.A. Water Systems, October 17, 2008, letter to Mark Purcell (EPA), *Calculation of Background Statistics with Comparison Values, UNC Church Rock Mill & Tailings Site, Church Rock, New Mexico*).

The methods used to identify wells having background water quality for the February 2006 and October 2008 submittals had as their essential criterion the absence of evidence of seepage impact. By extension, the same methods may be used to identify evidence of seepage impact. Samples where evidence of seepage impact was equivocal or clearly absent were excluded from the calculations presented in this report.

The data sets used in calculations made for this report are from the period July 2006 through April 2008 inclusive, which represents the most recent eight quarters of sampling available at the time of the calculations. This time frame was selected to be representative of recent conditions, while providing at least the minimum recommended number of samples to satisfy the requirements of the statistical methods. For this reason, the estimation of UCL95 statistics and EPCs extend only to the 21 current COPCs and do not include trace metals (plus iron) that had previously been dismissed as COPCs (EPA, *August 1988, Draft Final Remedial Investigation, United Nuclear Church Rock Site*). Table 1 lists wells interpreted as having samples representative of impacted groundwater during the most recent 8 quarters.

Grouping of Samples by Hydrostratigraphic Zone and by Administrative Area

The data sets used to calculate statistics were subdivided by hydrostratigraphic zone and by geographic location. The three hydrostratigraphic zones by which sample data were grouped are the SWA, Zone 1, and Zone 3. The geographic grouping resulted in the elimination from Zone 1 and Zone 3 datasets of sample data from wells within Section 2 of Township 16 North, Range 16 West. This discrimination of Section 2 data was based on two considerations. One consideration is that Section 2 encompasses the tailings disposal area, which will eventually be administered by the U.S Department of Energy (DOE). As such, groundwater exposure within Section 2 will be prohibited by DOE controls. The second consideration is that the more extreme effects of seepage impact evident in Zone 1 and Zone 3 wells proximal to the tailings disposal cells are not expected to migrate and occupy areas outside of Section 2. This judgment is based on the following conclusions:

1. The tailings cells are no longer a source of measurable quantities of seepage fluid (US Filter, January 19, 2004, *Rationale and Field Investigation Work Plan to Evaluate Recharge and Potential Cell Sourcing to the Zone 3 Plume, Church Rock Site, Gallup, New Mexico*).

2. Reductions of saturated thickness and diminishment of porosity and hydraulic conductivity (by geochemical reactions) will continue to reduce groundwater flux across the boundary of Sections 2 and 36 to less than the 0.5 gallons per minute estimated to have occurred in January 2005 (N.A. Water Systems, April 25, 2008, *Recommendations and Summary of Hydrogeologic Analysis, Evaluation of Groundwater Flow in Zone 3 for the Design of a Pumping System to Intercept Impacted Groundwater, United Nuclear Corporation's Church Rock Tailings Site, Gallup, New Mexico*).

3. Evidence from groundwater sampling indicates that water quality in Zone 1 Point of Compliance Wells has been improving since the third quarter of 1989 (N.A. Water Systems, February 2006, *Technical Analysis Report in Support of License Amendment Request for Changing the Method of Determining Exceedances of the Combined Radium Groundwater Protection Standard in Source Materials License SUA-1475 (TAC LU0092), Groundwater Corrective Action Program, Church Rock Site, Church Rock, New Mexico*; and N.A. Water Systems, January 2008, *Annual Review Report 2007 – Groundwater Corrective Action, Church Rock Site, Church Rock, New Mexico*).

Results

Basic Statistics and Upper Confidence Limits for Means

Tables 2 through 4 list summary and UCL95 statistics for all COPCs calculated from the impacted data sets from wells in the SWA, Zone 1, and Zone 3. The data sets include only primary samples (i.e. no QA/QC samples). The samples were collected over the most recent eight quarters (July 2006 through April 2008) of data presently available. Eight quarters were selected as a compromise between the objective of representing current (or recent) conditions and the objective of having sample populations of sufficient size to estimate meaningful statistics. Probability (normal) plots of each dataset are provided in Appendix B.

All of the statistics were calculated using ProUCL software (Singh et al., April 2007, *ProUCL Version 4.00.02 User Guide*, EPA/600/R-07/038). The UCL95 estimates were selected from values recommended by the ProUCL software. One exception was made for a recommended UCL statistic (for nitrate as nitrogen, NO3_as_N, in Zone 1, see Table 3) that exceeded the maximum detected value. Summary tables of the output of UCL95 estimates are provided in Appendix A. In cases where two alternative estimates of UCL95 statistics are provided by ProUCL, the higher value was selected and is listed in Tables 2 through 4, except in those cases where the software issued a warning that the higher value may be unreliable (typically because of the limitations of bootstrap methods with small sample sizes). In one case (manganese, Mn, in Zone 1, see Tables 3, A.2) ProUCL recommended three alternative UCL statistics. In this case the highest value was not selected, because it was based on an assumption that the population followed a log-normal distribution. Prior testing of a much larger background sample data set indicated that this distributional assumption is probably incorrect. The higher values were selected as conservative estimates, consistent with the use of these same statistics as estimators of exposure point concentrations (EPCs).

The numbers of distinct detected values were too few to calculate UCL95 estimates for a significant fraction of COPCs: nine in the southwest alluvium (SWA, Table 2), seven in Zone 1 (Table 3), and one in Zone 3 (Table 4). UCL95 statistics also could not be estimated for any of the trace metals not included among the analytes in the past eight quarters of sample analyses. Current COPCs lacking sufficient data to estimate UCL95 statistics are summarized by hydrostratigraphic zone in Table 5. Table 6 summarizes current COPCs having UCL95 estimates whose reliability may be suspect, according to warnings issued by ProUCL. Such warnings typically apply to datasets having four or fewer distinct detected values.

Discussion

The constituents listed in Table 5 lack sufficient data (numbers of detections) to statistically quantify EPCs. The constituents listed in Table 6 have estimated UCL95 statistics that may not be sufficiently reliable to estimate EPCs. However, the constituents listed in Tables 5 and 6 either have not been detected in the past two years or have been detected infrequently and for the most part at concentrations below MCLs (or other applicable standards, if lacking MCLs). The exceptions are vanadium in Zone 1 (detected once at 0.2 mg/L), and vanadium in Zone 3 (detected four times at 0.2 mg/L). Therefore, the most of these constituents would be unlikely to present an unacceptable risk, even if there was a basis to quantify their EPC concentrations. Furthermore, with the few noted exceptions, these constituents would not be characterized as COPCs in their respective hydrostratigraphic zones if sampling data of the most recent two years were used to make such a determination.

Conclusion

This submittal provides estimates of UCL95 statistics for COPCs in impacted groundwater applicable to all areas in the SWA and to areas outside Section 2 in Zones 1 and 3. The estimated statistics provide a basis for estimating EPCs for those COPCs more likely to make a substantive contribution to quantifiable risk. Those COPCs for which UCL95 statistics cannot be reliably estimated were found, with few exceptions, to be unlikely to contribute substantively to quantifiable risk.

The UCL95 statistics provided in this submittal complement those submitted previously for background groundwater (N.A. Water Systems, October 17, 2008), which are bases for estimating EPCs in areas of the three hydrostratigraphic zones characterized as having background groundwater quality.

Very Truly Yours,

James Ewart, Ph.D., P.G.
Technical Consultant

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cc: Roy Blickwedel, GE
Larry Bush, UNC
Earle C. Dixon, NMED

Attachments

N.A. WATER SYSTEMS

Tables

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TABLE 1

Wells Having Samples Representative of Impacted Water Quality, July 2006 - April 2008

Southwest Alluvium	Zone 1	Zone 3
509 D (POC)	515 A	504 B
624	604 (POC)	517 (POC)
632 (POC)	614 (POC)	613 (POC)
801	EPA 5 (POC)	708 (POC)
802	EPA 7 (POC)	711 (POC)
803		717
808		719
EPA 23 (POC)		EPA 13
EPA 25		EPA 14
GW 1 (POC)		NBL 1
GW 2 (POC)		
GW 3 (POC)		

Notes:
POC = Point-of-Compliance Well.

TABLE 2

Summary Statistics for COPCs and Trace Metals in Southwest Alluvium Impacted Groundwater

Parameter	Units	Total Data	Percent Nondetect	Minimum Detected	Maximum Detected	Mean of Detected	Median of Detected	UCL95 of Mean
Al	mg/L	96	93.8%	0.1	0.3	0.167	0.15	**0.109**
As	mg/L	96	86.5%	0.001	0.01	0.00885	0.01	**0.00256**
Be	mg/L	96	100.0%	N/A	N/A	N/A	N/A	N/A
Cd	mg/L	96	100.0%	N/A	N/A	N/A	N/A	N/A
Co	mg/L	96	99.0%	0.01	0.01	N/A	N/A	N/A
Pb	mg/L	96	100.0%	N/A	N/A	N/A	N/A	N/A
Mn	mg/L	96	0.0%	0.03	5.4	1.865	1.83	**2.8**
Mo	mg/L	96	100.0%	N/A	N/A	N/A	N/A	N/A
Ni	mg/L	96	100.0%	N/A	N/A	N/A	N/A	N/A
Se	mg/L	96	99.0%	0.001	0.001	N/A	N/A	N/A
V	mg/L	96	100.0%	N/A	N/A	N/A	N/A	N/A
Cl	mg/L	96	0.0%	79	374	187.8	181	**199.6**
SO4	mg/L	96	0.0%	1510	4330	2745	2820	**2867**
NO3_as_N	mg/L	96	0.0%	0.3	160	65.08	76	**94.42**
U	mg/L	96	0.0%	0.0229	0.246	0.104	0.111	**0.128**
Chloroform	mg/L	96	49.0%	0.00061	0.0155	0.00479	0.00309	**0.00338**
Lab_TDS	mg/L	96	0.0%	3880	8250	6044	6245	**6250**
Rad-226	pCi/L	96	61.5%	0.1	1	0.435	0.4	**0.267**
Rad-228	pCi/L	96	77.1%	0.3	4.3	1.786	1.75	**0.86**
Rad_totl	pCi/L	96	57.3%	0.1	5.2	1.351	0.7	**0.828**
Th-230	pCi/L	96	89.6%	0.2	1.6	0.69	0.5	**0.29**
Pb-210	pCi/L	96	100.0%	N/A	N/A	N/A	N/A	N/A
Gross_Alpha	pCi/L	96	69.79%	1	2.4	1.317	1.2	**1.141**
Sb	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Ba	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Cr	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Cu	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Fe	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Hg	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Ag	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Tl	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Zn	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A

Notes:
N/A - insufficient data to make an estimate.
UCL95 statistics highlighted in yellow may be of questionable reliability.
Listed UCL statistics for Mn and NO3_as_N are at 97.5% confidence level

TABLE 3

Summary Statistics for COPCs and Trace Metals in Zone 1 Impacted Groundwater, Recent 8 Quarters 3rd Qtr. 2006 - 2nd Qtr. 2008, Excluding Samples from Section 2 Wells 0515 A, 0604, 0614

Parameter	Units	Total Data	Percent Nondetect	Minimum Detected	Maximum Detected	Mean of Detected	Median of Detected	UCL95 of Mean
Al	mg/L	16	56.3%	0.2	1.3	0.457	0.3	**0.44**
As	mg/L	16	75.0%	0.001	0.003	0.00175	0.0015	**0.00145**
Be	mg/L	16	100.0%	N/A	N/A	N/A	N/A	N/A
Cd	mg/L	16	100.0%	N/A	N/A	N/A	N/A	N/A
Co	mg/L	16	0.0%	0.02	0.06	0.0363	0.03	**0.0557**
Pb	mg/L	16	100.0%	N/A	N/A	N/A	N/A	N/A
Mn	mg/L	16	0.0%	0.95	2.96	1.656	1.47	**1.95**
Mo	mg/L	16	100.0%	N/A	N/A	N/A	N/A	N/A
Ni	mg/L	16	81.3%	0.05	0.06	0.0533	0.05	**0.0519**
Se	mg/L	16	93.8%	0.001	0.001	N/A	N/A	N/A
V	mg/L	16	93.8%	0.2	0.2	N/A	N/A	N/A
Cl	mg/L	16	0.0%	48	221	131.5	128.5	**214.3**
SO4	mg/L	16	0.0%	2960	4760	3778	3955	**4049**
NO3_as_N	mg/L	16	0.0%	16.2	200	80.5	72.75	**152***
U	mg/L	16	0.0%	0.0012	0.0022	0.00161	0.0015	**0.00174**
Chloroform	mg/L	16	87.5%	0.0006	0.00076	0.00068	0.00068	**0.00063873**
Lab_TDS	mg/L	16	0.0%	4620	7860	6208	6120	**6843**
Rad-226	pCi/L	16	18.8%	0.4	1.8	1.138	1.2	**1.213**
Rad-228	pCi/L	16	56.3%	1	4	2.286	1.9	**2.087**
Rad_totl	pCi/L	16	12.5%	0.6	5.2	2.2	1.6	**2.8**
Th-230	pCi/L	16	87.5%	0.6	0.7	0.65	0.65	**0.621**
Pb-210	pCi/L	16	100.0%	N/A	N/A	N/A	N/A	N/A
Gross_Alpha	pCi/L	16	18.8%	1.2	4.1	2.146	2	**2.319**
Sb	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Ba	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Cr	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Cu	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Fe	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Hg	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Ag	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Tl	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Zn	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

*95% Chebyshev (Mean, Sd) UCL chosen for NO3_as_N in lieu of ProUCL recommended UCL 99 statistic, which exceeded the maximum observed detection.

N/A - insufficient data to make an estimate.

UCL95 statistics highlighted in yellow may be of questionable reliability.

TABLE 4

Summary Statistics for COPCs and Trace Metals in Zone 3 Impacted Groundwater, Recent 8 Quarters
3rd Qtr. 2006 - 2nd Qtr. 2008, Exluding Samples from Section 2 Well 0613

Parameter	Units	Total Data	Percent Nondetect	Minimum Detected	Maximum Detected	Mean of Detected	Median of Detected	UCL95 of Mean
Al	mg/L	70	17.1%	0.1	163	16.14	2.45	**39.15**
As	mg/L	70	31.4%	0.001	2.5	0.206	0.025	**0.412**
Be	mg/L	70	87.1%	0.01	0.09	0.0589	0.06	**0.0202**
Cd	mg/L	70	77.1%	0.005	1	0.0713	0.0095	**0.0628**
Co	mg/L	70	0.0%	0.05	0.95	0.381	0.35	**0.439**
Pb	mg/L	70	100.0%	N/A	N/A	N/A	N/A	N/A
Mn	mg/L	70	0.0%	3.33	23.7	9.836	7.485	**10.89**
Mo	mg/L	70	54.3%	0.1	5	1.084	0.3	**0.739**
Ni	mg/L	70	0.0%	0.11	0.89	0.377	0.31	**0.489**
Se	mg/L	70	95.7%	0.001	0.01	0.00433	0.002	**0.0014**
V	mg/L	70	92.9%	0.1	0.2	0.18	0.2	**0.111**
Cl	mg/L	70	0.0%	14	98	43.66	37.5	**48.01**
SO4	mg/L	70	0.0%	2630	5260	3599	3545	**3717**
NO3_as_N	mg/L	70	61.4%	0.1	44.8	17.15	24	**16.09**
U	mg/L	70	0.0%	0.0011	0.138	0.0287	0.0219	**0.0431**
Chloroform	mg/L	70	81.4%	0.00093	0.00676	0.00441	0.00444	**0.00326**
Lab_TDS	mg/L	70	0.0%	3980	6680	5289	5290	**5441**
Rad-226	pCi/L	70	0.0%	2	27.6	9.823	7.9	**11.14**
Rad-228	pCi/L	70	0.0%	3.8	56.1	15.73	13.55	**17.84**
Rad_totl	pCi/L	70	0.0%	6.8	73.3	25.55	20.8	**29.14**
Th-230	pCi/L	70	91.4%	0.2	1.3	0.533	0.4	**0.259**
Pb-210	pCi/L	70	91.4%	1.8	8.1	4.883	4.9	**2.287**
Gross_Alpha	pCi/L	70	0.0%	2.4	35.2	12.62	10.55	**14.25**
Sb	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Ba	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Cr	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Cu	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Fe	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Hg	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Ag	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Tl	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Zn	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A

Notes:
N/A - insufficient data to make an estimate.
UCL95 statistics highlighted in yellow may be of questionable reliability.
Listed UCL statistics for Al, As, and NO3_as_N are at 97.5% confidence level

TABLE 5

COPCs Lacking Sufficient Data to Estimate UCL95 Statistics for Impacted Water Quality, July 2006 - April 2008

Southwest Alluvium	Zone 1	Zone 3
Be*	Be*	Pb*
Cd*	Cd*	
Co***	Pb*	
Pb*	Mo*	
Mo*	Se**	
Ni*	V	
Se**	Pb-210*	
V*		
Pb-210*		

Notes:
* no detected results in 8 quarters of sampling.
** one detected result at or below MCL in 8 quarters of sampling.
*** one detected result at or below New Mexico WQCC standard in 8 quarters of sampling.

TABLE 6

COPCs Having Estimated UCL95 Statistics of Questionable Reliability for Impacted Water Quality, July 2006 - April 2008

Southwest Alluvium	Zone 1	Zone 3
Al***	Ni** Chloroform* Th-230*	Se** V

Notes:

* 2 detected results at or below MCL or NRC compliance license standard in 8 quarters of sampling.

** 3 detected results at or below MCL or New Mexico WQCC standard in 8 quarters of sampling.

*** 6 detected results at or below New Mexico WQCC standard in 8 quarters of sampling.

N.A. WATER SYSTEMS

Appendix A

Summary Tables of Output from ProUCL for UCL95 Statistics

N.A. Water Systems, LLC
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Tel: 412-809-6000 ● Fax: 412-809-6075
Web site: www.nawatersystems.com

VEOLIA WATER
Solutions & Technologies

TABLE A1

UCL95 Statistics for Southwest Alluvium Impacted Data Sets with Non-Detects

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V
Total Number of Data	96	96	96	96	96	96	96	96	96	96	96
Number of Non-Detect Data	90	83	96	96	95	96	0	96	96	95	96
Number of Detected Data (or Distinct Obs. If zero nondetect)	6	13	0	0	1	0	79	0	0	1	0
Minimum Detected	0.1	0.001			0.01		0.03			0.001	
Maximum Detected	0.3	0.01			0.01		5.4			0.001	
Percent Non-Detects	93.75%	86.46%	100.0%	100.0%	99.0%	100.0%	0.00%	100.0%	100.0%	99.00%	100.0%
Minimum Non-detect	0.1	0.001	0.01	0.005	0.01	0.05		0.01	0.05	0.001	0.1
Maximum Non-detect	0.1	0.001	0.01	0.005	0.01	0.05		0.01	0.05	0.001	0.1
Mean of Detected Data	0.167	0.00885					1.865				
Median of Detected Data	0.15	0.01					1.83				
Variance of Detected Data	0.00667	0.000006141					2.151				
SD of Detected Data	0.0816	0.00248					1.467				
CV of Detected Data	0.49	0.28					0.787				
Skewness of Detected Data	0.86	-3.05					0.696				
Mean of Log-Transformed Detected Data	-1.888	-4.833					0.0407				
SD of Log-Transformed Detected Data	0.477	0.629					1.414				
Discernable Distribution (0.05) of Detected Data	normal	none					none				
Kaplan-Meier (KM) Method											
Mean	0.104	0.00206									
SD	0.0247	2.82E-03									
Standard Error of Mean	0.00276	3.00E-04									
95% KM (t) UCL	**0.109**	**0.00256**									
95% KM (z) UCL	0.109	0.00256									
95% KM (BCA) UCL	N/A	0.00908									
95% KM (Percentile Bootstrap) UCL	N/A	**0.00905**									
95% KM (Chebyshev) UCL	0.116	0.00337									
97.5% KM (Chebyshev) UCL	0.121	0.00394									
99% KM (Chebyshev) UCL	0.132	0.00505									
Datasets without Nondetects											
Student's-t UCL							2.113				
95% UCLs (Adjusted for Skewness)											
95% Adjusted-CLT UCL							2.122				
95% Modified-t UCL							2.115				
Non-Parametric UCLs											
95% CLT UCL							2.111				
95% Jackknife UCL							2.113				
95% Standard Bootstrap UCL							2.106				
95% Bootstrap-t UCL							2.121				
95% Hall's Bootstrap UCL							2.12				
95% Percentile Bootstrap UCL							2.104				
95% BCA Bootstrap UCL							2.129				
95% Chebyshev(Mean, Sd) UCL							2.517				
97.5% Chebyshev(Mean, Sd) UCL							**2.8**				
99% Chebyshev(Mean, Sd) UCL							3.354				
Potential UCL to Use											
95% KM (t) UCL	**0.109**	**0.00256**									
95% KM (z) UCL											
95% KM (BCA) UCL											
95% KM (Percentile Bootstrap) UCL		**0.00905**									
95% KM (Chebyshev) UCL											
97.5% KM (Chebyshev) UCL											
99% KM (Chebyshev) UCL											
95% Student's-t UCL											
95% Modified-t UCL											
95% Chebyshev(Mean, Sd) UCL											
97.5% Chebyshev(Mean, Sd) UCL							**2.8**				
95% Approximate Gamma UCL											
Notes	2	5	4	4	3	4	6	4	4	3	4

	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad-226	Rad-228	Rad_totl	Th-230	Pb-210	Gross_Alpha
Total Number of Data	96	96	96	96	96	96	96	96	96	96	96	96
Number of Non-Detect Data	0	0	0	0	47	0	59	74	55	86	96	67
Number of Detected Data (or Distinct Obs. If zero nondetect)	72	80	75	76	49	82	37	22	41	10	0	29
Minimum Detected	79	1510	0.3	0.0229	0.00061	3880	0.1	0.3	0.1	0.2		1
Maximum Detected	374	4330	160	0.246	0.0155	8250	1	4.3	5.2	1.6		2.4
Percent Non-Detects	0.0%	0.0%	0.00%	0.00%	48.96%	0.0%	61.46%	77.08%	57.29%	89.58%	100.0%	69.79%
Minimum Non-detect					0.0005		0.001	0.04	0.2	0.2	1	0.9
Maximum Non-detect					0.001		0.2	1	0.2	0.2	1	1
Mean of Detected Data	187.8	2745	65.08	0.104	0.00479	6044	0.435	1.786	1.351	0.69		1.317
Median of Detected Data	181	2820	76	0.111	0.00309	6245	0.4	1.75	0.7	0.5		1.2
Variance of Detected Data	4459	521381	2118	0.00299	1.5975E-05	1483184	0.0596	1.269	1.673	0.257		0.131
SD of Detected Data	66.78	722.1	46.03	0.0546	0.004	1218	0.244	1.126	1.293	0.507		0.363
CV of Detected Data	0.356	0.263	0.707	0.525	0.834	0.202	0.561	0.631	0.957	0.734		0.275
Skewness of Detected Data	0.78	0.05	-0.0574	0.632	1.28	-0.00205	0.536	0.449	1.12	1.09		1.52
Mean of Log-Transformed Detected Data	5.172	7.881	3.523	-2.427	-5.686	8.686	-1.019	0.316	-0.208	-0.607		0.245
SD of Log-Transformed Detected Data	0.364	0.275	1.569	0.619	0.881	0.208	0.67	0.829	1.085	0.729		0.244
Discernable Distribution (0.05) of Detected Data	gamma	none	none	none	none	none	normal	normal	none	gamma		none
Kaplan-Meier (KM) Method												
Mean					0.00275		0.229	0.693	0.634	0.251		1.096
SD					0.00351		0.221	0.799	1.039	0.216		0.244
Standard Error of Mean					0.00036246		0.0229	0.0866	0.107	0.0232		0.0254
95% KM (t) UCL					**0.00335**		**0.267**	**0.837**	0.813	**0.29**		**1.138**
95% KM (z) UCL					0.00334		0.267	0.835	0.811	0.289		1.138
95% KM (BCA) UCL					0.00338		0.272	0.895	**0.828**	0.501		1.143
95% KM (Percentile Bootstrap) UCL					**0.00338**		**0.267**	**0.86**	0.828	0.439		**1.141**
95% KM (Chebyshev) UCL					0.00433		0.329	1.07	1.102	0.352		1.206
97.5% KM (Chebyshev) UCL					0.00501		0.372	1.234	1.305	0.396		1.254
99% KM (Chebyshev) UCL					0.00635		0.457	1.555	1.703	0.482		1.348
Datasets without Nondetects												
Student's-t UCL	199.1	**2867**	72.88	0.113		**6250**						
95% UCLs (Adjusted for Skewness)												
95% Adjusted-CLT UCL	199.6	2866	72.78	0.114		6248						
95% Modified-t UCL	199.2	**2867**	72.88	0.113		**6250**						
Non-Parametric UCLs												
95% CLT UCL	199	2866	72.81	0.113		6248						
95% Jackknife UCL	199.1	2867	72.88	0.113		6250						
95% Standard Bootstrap UCL	198.9	2867	72.55	0.113		6246						
95% Bootstrap-t UCL	199.9	2864	73.19	0.113		6252						
95% Hall's Bootstrap UCL	199.9	2870	72.41	0.114		6257						
95% Percentile Bootstrap UCL	198.9	2866	72.69	0.114		6250						
95% BCA Bootstrap UCL	199.5	2862	72.77	0.114		6244						
95% Chebyshev(Mean, Sd) UCL	217.5	3066	85.56	**0.128**		6586						
97.5% Chebyshev(Mean, Sd) UCL	230.3	3205	**94.42**	0.139		6820						
99% Chebyshev(Mean, Sd) UCL	255.6	3478	111.8	0.16		7281						
Potential UCL to Use												
95% KM (t) UCL					**0.00335**		**0.267**	**0.837**		**0.29**		**1.138**
95% KM (z) UCL												
95% KM (BCA) UCL									**0.828**			
95% KM (Percentile Bootstrap) UCL					**0.00338**		**0.267**	**0.86**				**1.141**
95% KM (Chebyshev) UCL												
97.5% KM (Chebyshev) UCL												
99% KM (Chebyshev) UCL												
95% Student's-t UCL		**2867**				**6250**						
95% Modified-t UCL		**2867**				**6250**						
95% Chebyshev(Mean, Sd) UCL				**0.128**								
97.5% Chebyshev(Mean, Sd) UCL			**94.42**									
95% Approximate Gamma UCL	**199.6**											
Notes			6		1		1	1			4	1

Notes:

1. Data have multiple DLs - Use of KM Method is recommended.
2. Warning: There are only 3 Distinct Detected Values in this data set.
   The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
3. Warning: Only one distinct data value was detected! It is suggested to use alternative site specific values
   determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).
4. Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
5. Warning: There are only 4 Distinct Detected Values in this data. It should be noted that bootstrap calculations may not be reliable enough to draw conclusions.
6. Potential UCL to use is at 97.6% confidence level

TABLE A2

UCL95 Statistics for Zone 1 Impacted Data Sets with Non-Detects

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad-226	Rad-228	Rad_totl	Th-230	Pb-210	Gross_Alpha
Total Number of Data	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Number of Non-Detect Data	9	12	16	16	0	16	0	16	13	15	15	0	0	4	0	14	0	3	8	2	14	16	3
Number of Detected Data (or Distinct Obs. If zero nondetect)	7	4	0	0	4	0	15	0	3	1	1	15	16	12	8	2	15	13	8	14	2	0	13
Minimum Detected	0.2	0.001			0.02		0.95		0.05	0.001	0.2	48	2960	16.2	0.0012	0.0006	4620	0.4	1	0.6	0.6		1.2
Maximum Detected	1.3	0.003			0.06		2.96		0.06	0.001	0.2	221	4760	200	0.0022	0.00076	7860	1.8	4	5.2	0.7		4.1
Percent Non-Detects	56.25%	75.00%	100.0%	100.0%	0.00%	100.0%	0.00%	100.0%	81.25%	93.75%	93.8%	0.0%	0.0%	0.00%	0.00%	87.50%	0.0%	18.75%	50.00%	12.50%	87.50%	100.0%	18.75%
Minimum Non-detect	0.1	0.001	0.01	0.005		0.05		0.1	0.05	0.001	0.1					0.0005		0.2	1	0.2	0.2	1	1
Maximum Non-detect	0.1	0.001	0.01	0.005		0.05		0.1	0.05	0.001	0.1					0.001		0.2	1	0.2	0.2	1	1
Mean of Detected Data	0.457	0.00175			0.0363		1.656		0.0533			131.5	3778	80.5	0.00161	0.00068	6208	1.138	2.275	2.357	0.65		2.146
Median of Detected Data	0.3	0.0015			0.03		1.47		0.05			128.5	3955	72.75	0.0015	0.00068	6120	1.2	2.05	1.85	0.65		2
Variance of Detected Data	0.15	9.17E-07			0.000318		0.436		3.33E-05			5780	382536	4300	9E-08	1.28E-08	2099270	0.136	1.171	2.133	0.005		0.549
SD of Detected Data	0.387	0.000957			0.0178		0.66		0.00577			76.02	618.5	65.57	0.0003	0.00011314	1449	0.369	1.082	1.461	0.0707		0.741
CV of Detected Data	0.846	0.547			0.492		0.399		0.108			0.578	0.164	0.815	0.187	0.166	0.233	0.324	0.476	0.62	0.109		0.345
Skewness of Detected Data	2.25	0.86			0.33		0.649		1.73			0.02	0.02	0.259	0.948	N/A	0.0162	-0.491	0.718	0.75	N/A		1.60
Mean of Log-Transformed Detected Data	-0.996	-6.46			-3.436		0.433		-2.935			4.69	8.224	3.946	-6.449	-7.3	8.707	0.0661	0.723	0.668	-0.434		0.716
SD of Log-Transformed Detected Data	0.648	0.543			0.506		0.389		0.105			0.656	0.166	1.037	0.178	0.167	0.237	0.402	0.479	0.658	0.109		0.311
Discernable Distribution (0.05) of Detected Data	gamma	normal			none		lognormal		none			none	normal	none	normal	none	none	normal	normal	gamma	none		normal
Kaplan-Meier (KM) Method																							
Mean	0.313	0.00119							0.0506							0.00061143		1	1.638	2.138	0.606		1.969
SD	0.269	5.27E-04							0.00242							4.1206E-05		0.43	0.958	1.439	0.0242		0.741
Standard Error of Mean	0.0726	1.52E-04							7.41E-04							1.5575E-05		0.112	0.256	0.373	0.00856		0.193
95% KM (t) UCL	**0.44**	**0.00145**							**0.0519**							**0.00063873**		**1.196**	**2.087**	**2.792**	**0.621**		**2.307**
95% KM (z) UCL	0.432	0.00144							0.0518							0.00063705		1.184	2.059	2.752	0.62		2.286
95% KM (BCA) UCL	0.469	**N/A**							N/A							0.00076		1.238	2.388	2.813	N/A		2.394
95% KM (Percentile Bootstrap) UCL	0.45	N/A							**N/A**							**N/A**		**1.213**	**2.256**	**2.8**	**N/A**		**2.319**
95% KM (Chebyshev) UCL	0.629	0.00185							0.0539							0.00067932		1.488	2.754	3.765	0.644		2.809
97.5% KM (Chebyshev) UCL	0.766	0.00214							0.0553							0.00070869		1.699	3.237	4.469	0.66		3.172
99% KM (Chebyshev) UCL	1.035	0.0027							0.058							0.00076639		2.114	4.186	5.852	0.691		3.886
Datasets without Nondetects																							
Student's-t UCL					0.0441		**1.946**					164.8	**4049**	109.2	**0.00174**		**6843**						
95% UCLs (Adjusted for Skewness)																							
95% Adjusted-CLT UCL					0.044		1.956					162.9	4033	108.6	0.00175		6805						
95% Modified-t UCL					0.0441		**1.95**					164.8	4049	109.4	0.00174		**6843**						
Non-Parametric UCLs																							
95% CLT UCL					0.0436		1.928					162.8	4032	107.5	0.00173		6804						
95% Jackknife UCL					0.0441		1.946					164.8	4049	109.2	0.00174		6843						
95% Standard Bootstrap UCL					0.0432		1.92					161.1	4024	106.7	0.00172		6780						
95% Bootstrap-t UCL					0.0445		1.991					162.8	4043	110.7	0.00177		6828						
95% Hall's Bootstrap UCL					0.0431		1.923					160	4008	106.9	0.00175		6735						
95% Percentile Bootstrap UCL					0.0438		1.917					161.1	4018	107	0.00173		6760						
95% BCA Bootstrap UCL					0.0431		1.954					161.3	4018	109.1	0.00174		6764						
95% Chebyshev(Mean, Sd) UCL					**0.0557**		2.376					**214.3**	4452	**152**	0.00193		7787						
97.5% Chebyshev(Mean, Sd) UCL					0.0641		2.687					250.2	4744	182.9	0.00207		8470						
99% Chebyshev(Mean, Sd) UCL					0.0806		3.299					320.6	5317	**243.6**	0.00235		9812						
Potential UCL to Use																							
95% KM (t) UCL	**0.44**	**0.00145**							**0.0519**							**0.00063873**		**1.196**	**2.087**	**2.792**	**0.621**		**2.307**
95% KM (z) UCL																							
95% KM (BCA) UCL																							
95% KM (Percentile Bootstrap) UCL																		**1.213**	**2.256**	**2.8**			**2.319**
95% KM (Chebyshev) UCL																							
97.5% KM (Chebyshev) UCL																							
99% KM (Chebyshev) UCL																							
95% Student's-t UCL							**1.946**						**4049**				**6843**						
95% Modified-t UCL							**1.95**								**0.00174**		**6843**						
95% Chebyshev(Mean, Sd) UCL					**0.0557**							**214.3**		**152**									
97.5% Chebyshev(Mean, Sd) UCL																							
99% Chebyshev(Mean, Sd) UCL														243.6									
95% Approximate Gamma UCL																							
95% H-UCL							**2.02**																
Notes	**5**	**5**	**4**	**4**	**5**	**4**	**7**	**4**	**2, 5**	**3**	**3**			**6, 8**		**1, 2, 5**			**5**		**2, 5**	**4**	

Notes:

1. Data have multiple DLs - Use of KM Method is recommended.
2. There may not be adequate detected values to compute meaningful and reliable test statistics and estimates.
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
3. Warning: Only one distinct data value was detected! It is suggested to use alternative site specific values
   determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).
4. Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
5. Warning: There are less than 10 Distinct Detected Values in this data. It should be noted that bootstrap calculations may not be reliable enough to draw conclusions.
6. Recommended 99% Chebyshev(Mean, Sd) UCL exceeds the maximum observation (log transformed standard deviation of 1.037 barely exceeds the threshold of 1.0 for using the 99% Chebyshev UCL)
   95% Chebyshev(Mean, Sd) UCL chosen alternative
7. 95% Modified-t UCL selected instead of 95% H-UCL because of relatively small sample size and evidence from larger background Mn dataset that the population distribution may not be log-normal

TABLE A3

UCL95 Statistics for Zone 3 Impacted Data Sets with Non-Detects

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad-226	Rad-228	Rad_totl	Th-230	Pb-210	Gross_Alpha
Total Number of Data	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Number of Non-Detect Data	12	22	61	54	0	70	0	38	0	67	65	0	0	43	0	57	0	0	0	0	64	64	0
Number of Detected Data (or Distinct Obs. If zero nondetect)	58	48	9	16	46	0	64	32	31	3	5	39	58	27	63	13	60	58	59	61	6	6	62
Minimum Detected	0.1	0.001	0.01	0.005	0.05		3.33	0.1	0.11	0.001	0.1	14	2630	0.1	0.0011	0.00093	3980	2	3.8	6.8	0.2	1.8	2.4
Maximum Detected	163	2.5	0.09	1	0.95		23.7	5	0.89	0.01	0.2	98	5260	44.8	0.138	0.00676	6680	27.6	56.1	73.3	1.3	8.1	35.2
Percent Non-Detects	17.14%	31.43%	87.14%	77.14%	0.00%	100.0%	0.00%	54.29%	0.00%	95.71%	92.86%	0.0%	0.0%	61.43%	0.00%	81.43%	0.0%	0.00%	0.00%	0.00%	91.43%	91.43%	0.00%
Minimum Non-detect	0.1	0.001	0.01	0.005		0.05		0.1		0.001	0.1			0.1		0.0005					0.2	1	
Maximum Non-detect	0.1	0.001	0.01	0.005		0.05		0.1		0.001	0.1			0.1		0.001					0.2	1	
Mean of Detected Data	16.14	0.206	0.0589	0.0713	0.381		9.836	1.084	0.377	0.00433	0.18	43.66	3599	17.15	0.0287	0.00441	5289	9.823	15.73	25.55	0.533	4.883	12.62
Median of Detected Data	2.45	0.025	0.06	0.0095	0.35		7.485	0.3	0.31	0.002	0.2	37.5	3545	24	0.0219	0.00444	5290	7.9	13.55	20.8	0.4	4.9	10.55
Variance of Detected Data	1393	0.177	0.000586	0.0613	0.0572		27.12	1.533	0.0459	2.43E-05	0.002	468.3	349814	227.1	0.000764	3.3795E-06	585903	36.79	109.4	235.5	0.159	4.078	60.29
SD of Detected Data	37.32	0.421	0.0242	0.248	0.239		5.208	1.238	0.214	0.00493	0.0447	21.64	591.5	15.07	0.0276	0.00184	765.4	6.065	10.46	15.35	0.398	2.019	7.765
CV of Detected Data	2.312	2.04	0.411	3.473	0.627		0.529	1.142	0.568	1.138	0.248	0.496	0.164	0.879	0.964	0.417	0.145	0.617	0.665	0.601	0.747	0.414	0.615
Skewness of Detected Data	2.66	3.83	-0.65	4.00	0.68		1.079	1.40	1.13	1.652	-2.24	0.75	0.18	-0.0511	2.408	-0.39	-0.191	0.921	1.671	1.22	1.88	0.14	1.13
Mean of Log-Transformed Detected Data	0.9	-3.518	-2.966	-4.416	-1.206		2.163	-0.642	-1.119	-5.909	-1.748	3.656	8.175	1.277	-3.922	-5.539	8.563	2.091	2.561	3.078	-0.816	1.497	2.355
SD of Log-Transformed Detected Data	1.832	2.251	0.657	1.216	0.772		0.489	1.271	0.536	1.181	0.31	0.498	0.166	2.572	0.928	0.559	0.149	0.647	0.632	0.572	0.641	0.496	0.617
Discernable Distribution (0.05) of Detected Data	none	none	normal	none	gamma		none	none	none	normal	none	none	normal	none	none	normal	normal	gamma	gamma	lognormal	normal	normal	gamma
Kaplan-Meier (KM) Method																							
Mean	13.39	0.142	0.0163	0.0202				0.55		0.00114	0.106			6.677		0.00158					0.229	2.064	
SD	34.22	3.58E-01	1.83E-02	0.118				0.959		0.00107	0.0232			12.38		0.00155					0.142	1.018	
Standard Error of Mean	4.125	4.32E-02	2.32E-03	1.46E-02				0.116		1.57E-04	0.0031			1.508		0.00019315					0.0185	0.133	
95% KM (t) UCL	20.27	0.214	**0.0202**	0.0444				0.744		**0.0014**	**0.111**			9.191		**0.0019**					**0.259**	**2.287**	
95% KM (z) UCL	20.18	0.213	0.0201	0.0441				0.742		0.0014	0.111			9.157		0.00189					0.259	2.284	
95% KM (BCA) UCL	20.79	0.224	0.054	**0.0628**				**0.739**		N/A	N/A			9.191		0.00339					0.439	5.093	
95% KM (Percentile Bootstrap) UCL	20.16	0.22	**0.0529**	0.0486				0.747		N/A	N/A			9.246		**0.00326**					**0.421**	**4.941**	
95% KM (Chebyshev) UCL	31.37	0.33	0.0264	0.0836				1.058		0.00183	0.119			13.25		0.00242					0.309	2.645	
97.5% KM (Chebyshev) UCL	**39.15**	**0.412**	0.0308	0.111				1.277		0.00212	0.125			**16.09**		0.00278					0.344	2.897	
99% KM (Chebyshev) UCL	54.44	0.572	0.0394	0.165				1.709		0.00271	0.137			21.68		0.0035					0.413	3.39	
Datasets without Nondetects																							
Student's-t UCL					0.429		**10.87**		0.42			**47.97**	**3717**		0.0342		**5441**	11.03	17.81	28.61			14.17
95% UCLs (Adjusted for Skewness)																							
95% Adjusted-CLT UCL					0.431		10.95		0.423			48.16	3717		0.0351		5437	11.1	18.05	28.85			14.28
95% Modified-t UCL					0.429		**10.89**		0.421			**48.01**	3717		0.0343		5441	11.04	17.85	28.65			14.19
Non-Parametric UCLs																							
95% CLT UCL					0.428		10.86		0.419			47.91	3715		0.0341		5439	11.02	17.78	28.57			14.15
95% Jackknife UCL					0.429		10.87		0.42			47.97	3717		0.0342		5441	11.03	17.81	28.61			14.17
95% Standard Bootstrap UCL					0.428		10.85		0.42			47.86	3713		0.034		5438	10.97	17.74	28.53			14.12
95% Bootstrap-t UCL					0.432		10.95		0.424			48.63	3716		0.0361		5436	11.13	18.14	28.91			14.18
95% Hall's Bootstrap UCL					0.432		10.9		0.423			48	3719		0.0357		5447	11.14	18.31	29.03			14.29
95% Percentile Bootstrap UCL					0.429		10.84		0.418			47.96	3716		0.034		5432	11.04	17.81	28.53			14.16
95% BCA Bootstrap UCL					0.43		10.96		0.424			48.06	3710		0.0356		5442	11.05	17.99	28.56			14.24
95% Chebyshev(Mean, Sd) UCL					0.506		12.55		**0.489**			54.93	3907		**0.0431**		5688	12.98	21.18	33.54			16.67
97.5% Chebyshev(Mean, Sd) UCL					0.56		13.72		0.537			59.81	4040		0.0493		5860	14.35	23.53	37			18.42
99% Chebyshev(Mean, Sd) UCL					0.666		16.03		0.632			69.39	4302		0.0615		6199	17.04	28.16	43.8			21.85
Potential UCL to Use																							
95% KM (t) UCL			**0.0202**							**0.0014**	**0.111**					**0.0019**					**0.259**	**2.287**	
95% KM (z) UCL																							
95% KM (BCA) UCL				**0.0628**				**0.739**															
95% KM (Percentile Bootstrap) UCL			**0.0529**													**0.00326**					**0.421**	**4.941**	
95% KM (Chebyshev) UCL																							
97.5% KM (Chebyshev) UCL	**39.15**	**0.412**												**16.09**									
99% KM (Chebyshev) UCL																							
95% Student's-t UCL							**10.87**					**47.97**	**3717**				**5441**						
95% Modified-t UCL							**10.89**					**48.01**											
95% Chebyshev(Mean, Sd) UCL									**0.489**						**0.0431**								
97.5% Chebyshev(Mean, Sd) UCL																							
99% Chebyshev(Mean, Sd) UCL																							
95% Approximate Gamma UCL					**0.439**													**11.14**	**17.84**				**14.25**
95% H-UCL																				**29.14**			
Notes	**6**	**6**	**5**			**4**				**3, 5**	**2, 5**			**6**		**1**					**5**	**5**	

Notes:

1. Data have multiple DLs - Use of KM Method is recommended.
2. There may not be adequate distinct detected values to compute meaningful and reliable test statistics and estimates
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
3. Warning: There are only 3 Distinct Detected Values in this data set.
   The number of detected data may not be adequate enough to perform GOF tests, bootstrap, and ROS methods.
4. Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
5. Warning: There are less than 10 Distinct Detected Values in this data. It should be noted that bootstrap calculations may not be reliable enough to draw conclusions.
6. Potential UCL to use is at 97.6% confidence level

N.A. WATER SYSTEMS

Appendix B

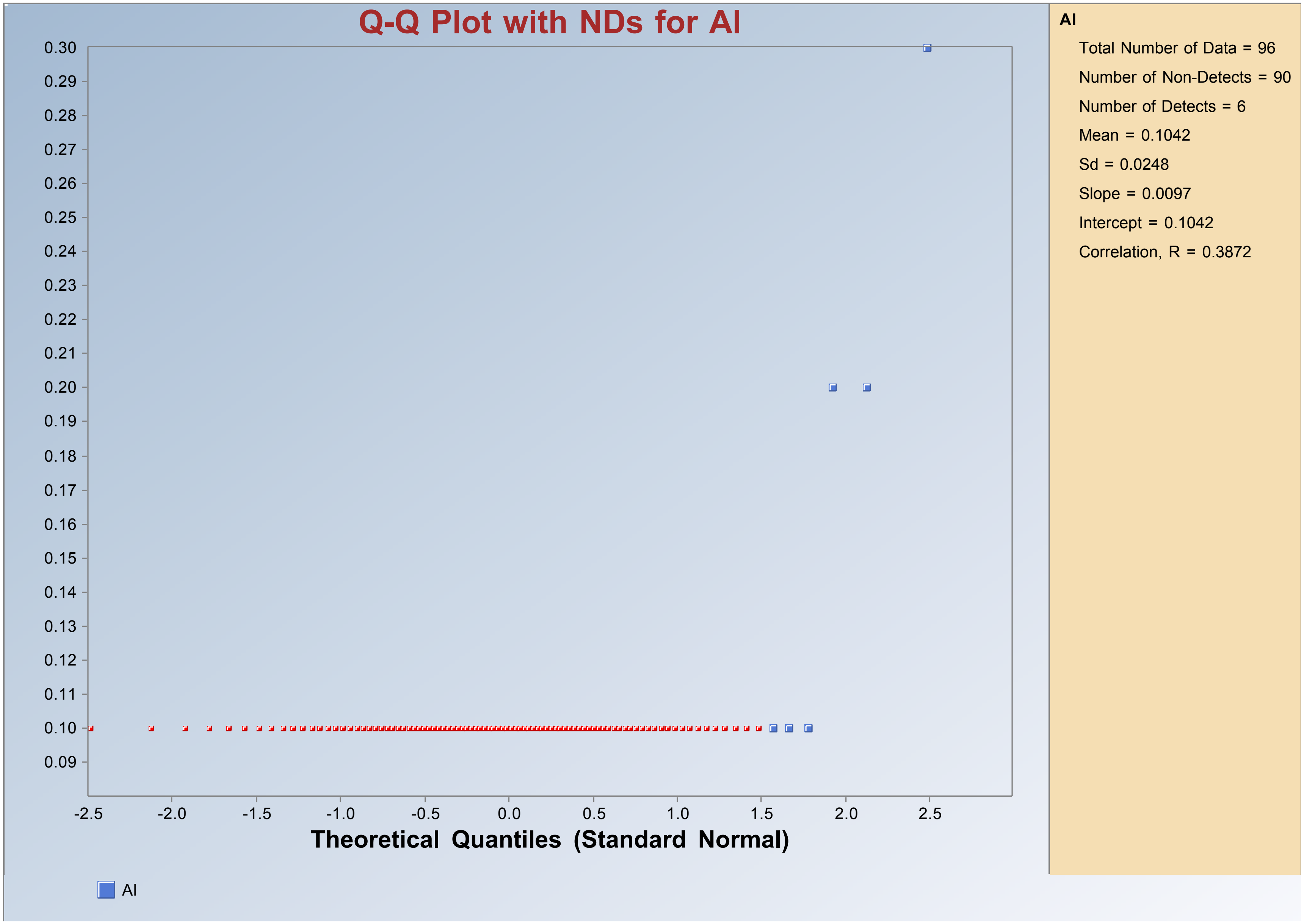
Probability Plots

N.A. Water Systems, LLC
Airside Business Park, 250 Airside Drive
Moon Township, Pennsylvania 15108-2793 USA
Tel: 412-809-6000 ● Fax: 412-809-6075
Web site: www.nawatersystems.com

VEOLIA WATER
Solutions & Technologies

GRAPH B 1.1

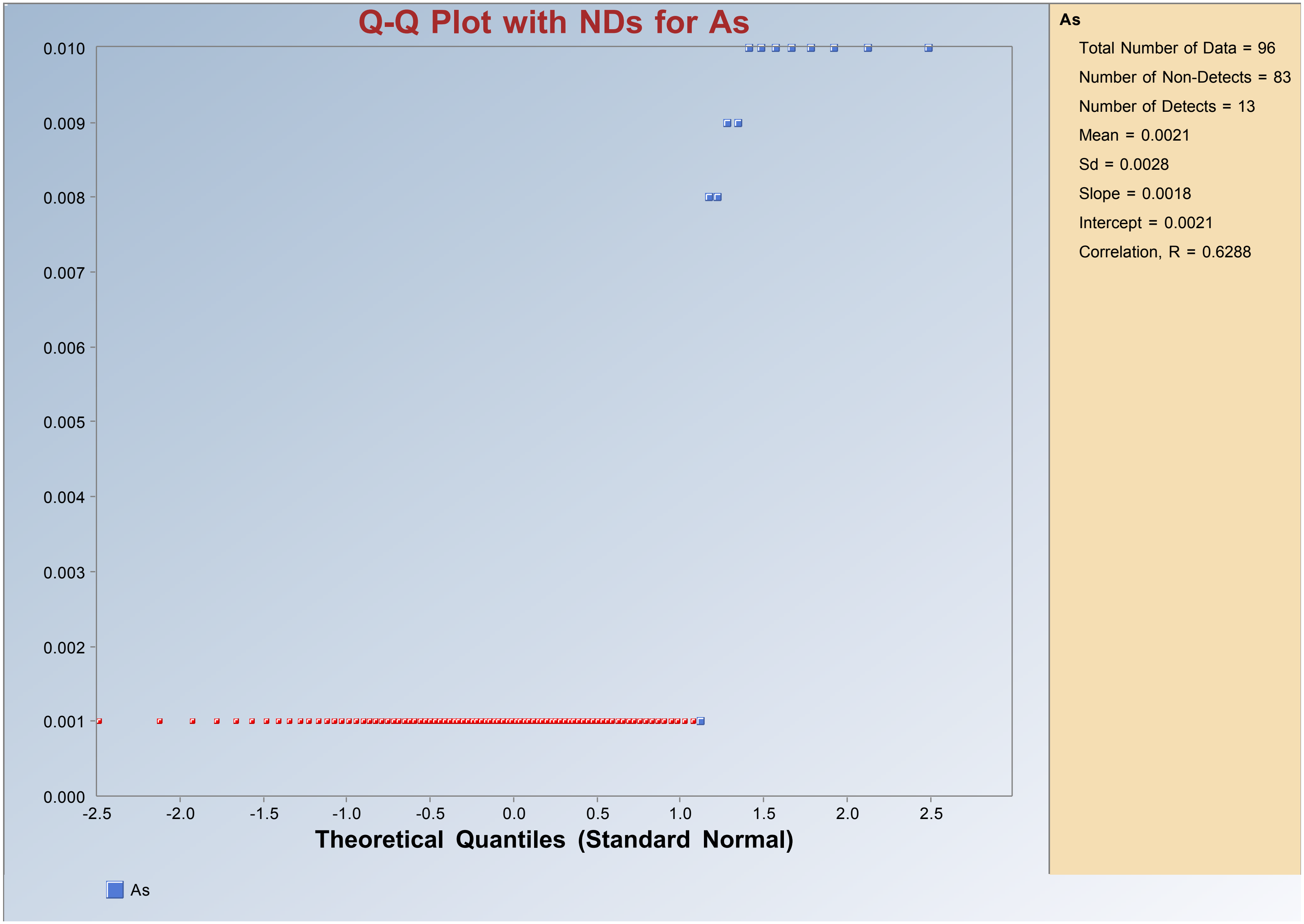
Probability Plot of Aluminum in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.2

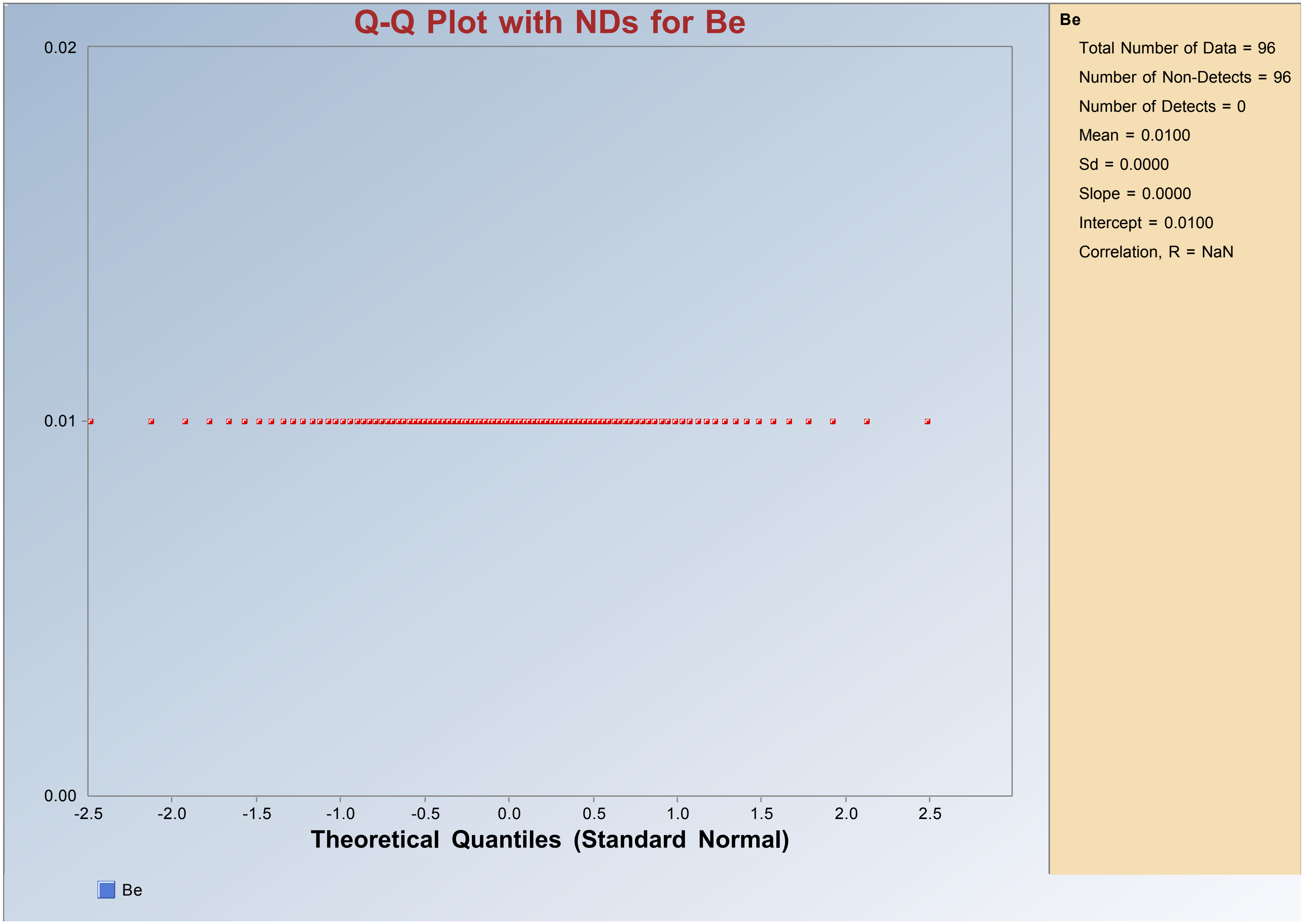
Probability Plot of Arsenic in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.3

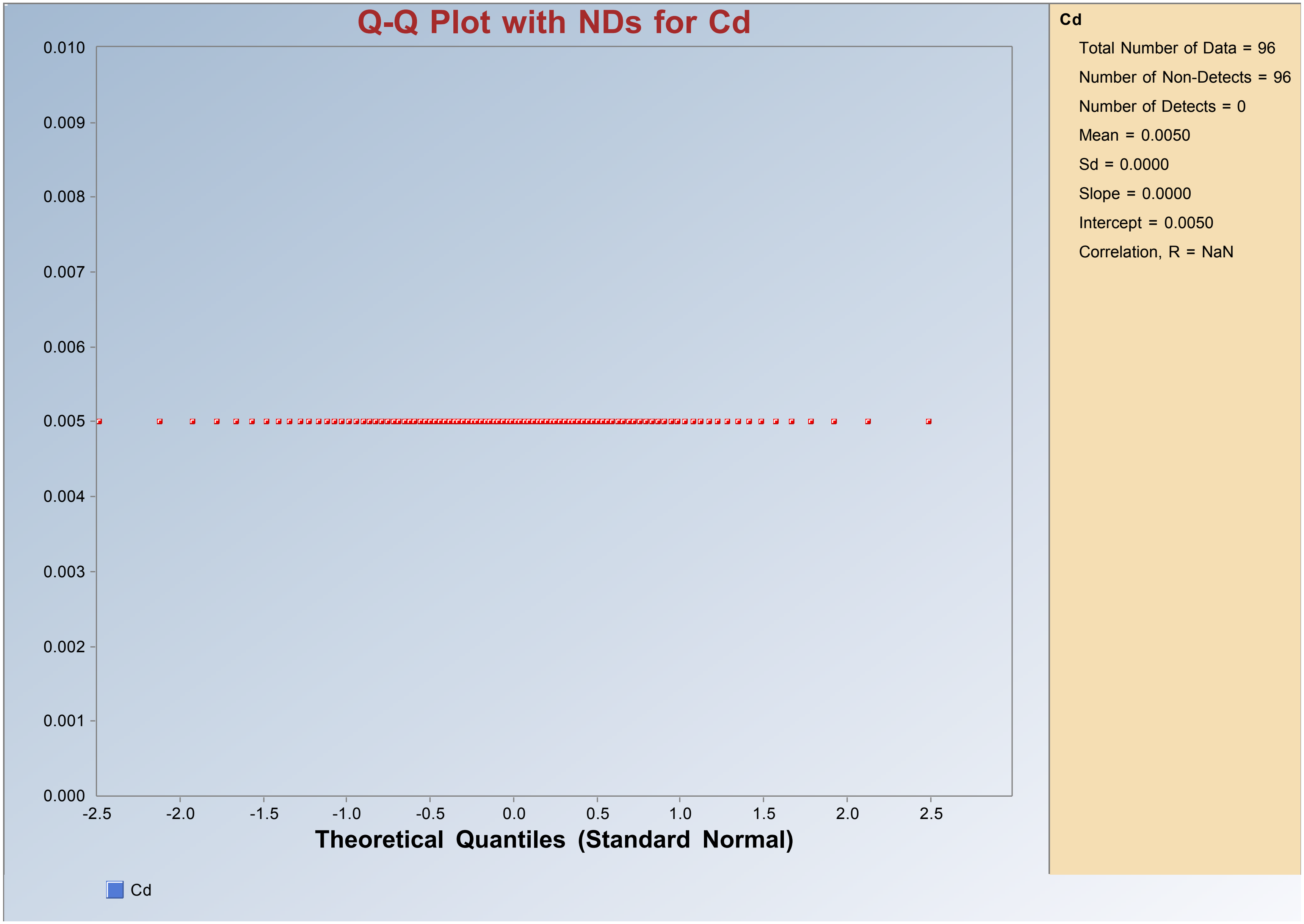
Probability Plot of Beryllium in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.4

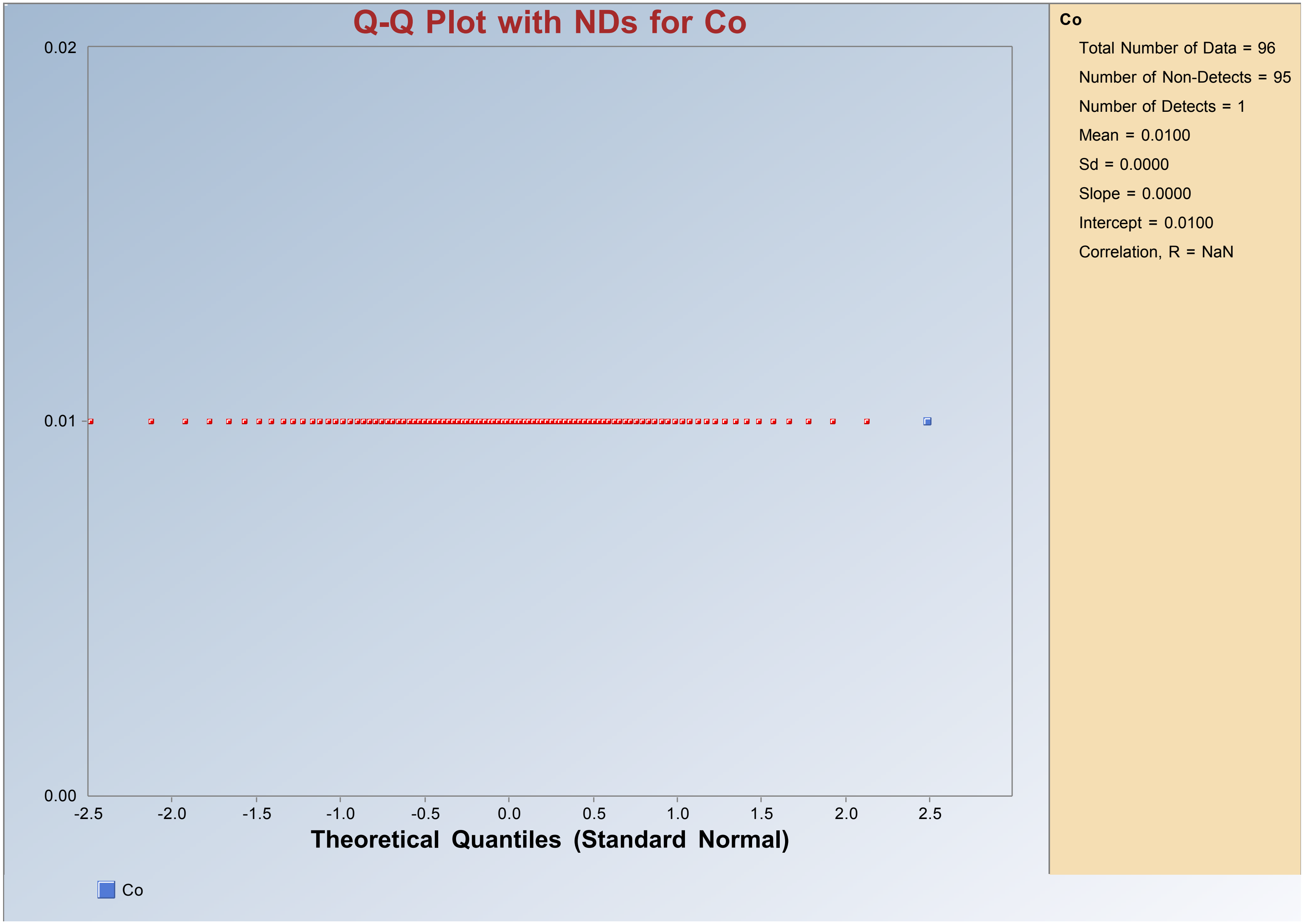
Probability Plot of Cadmium in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.5

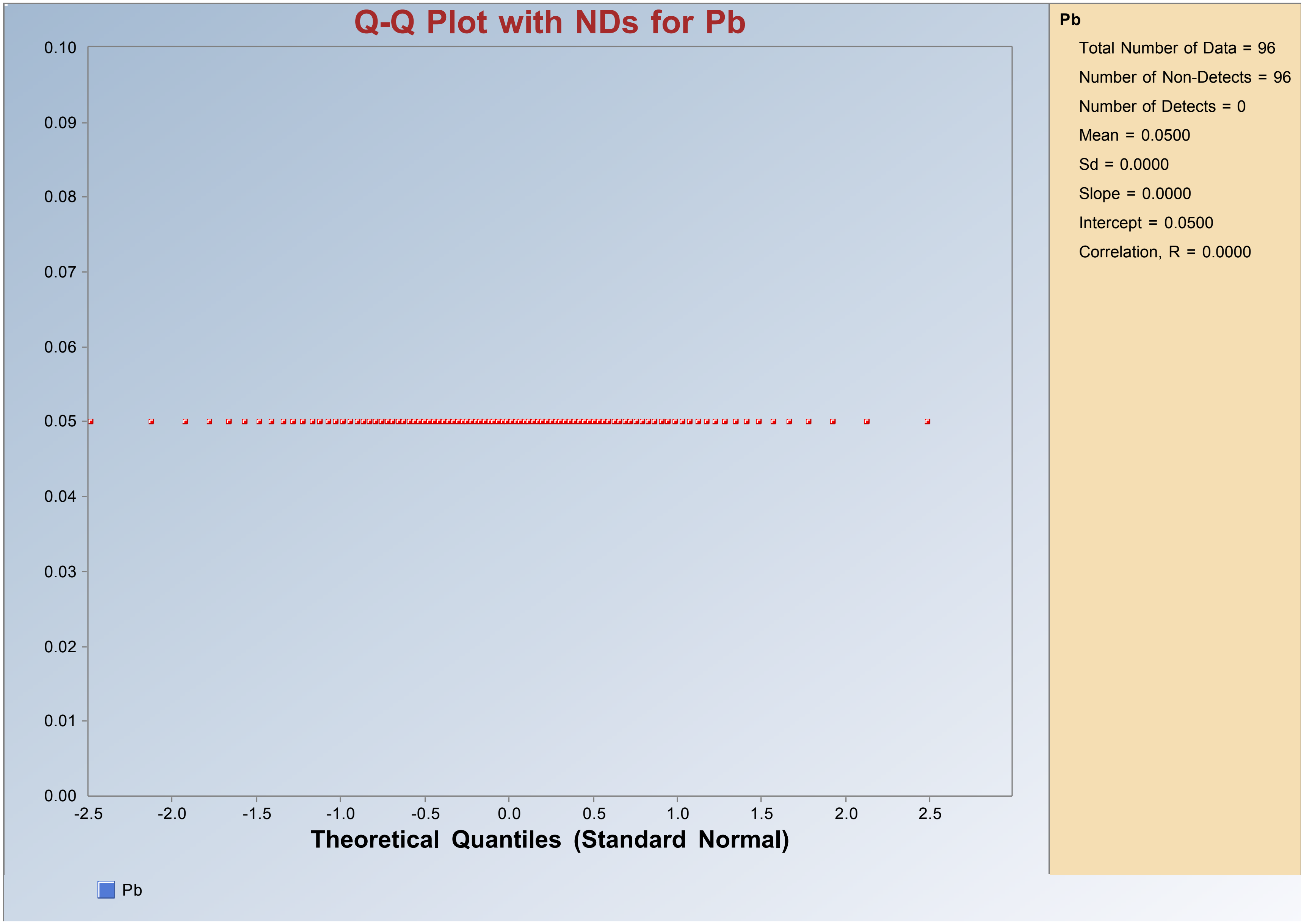
Probability Plot of Cobalt in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.6

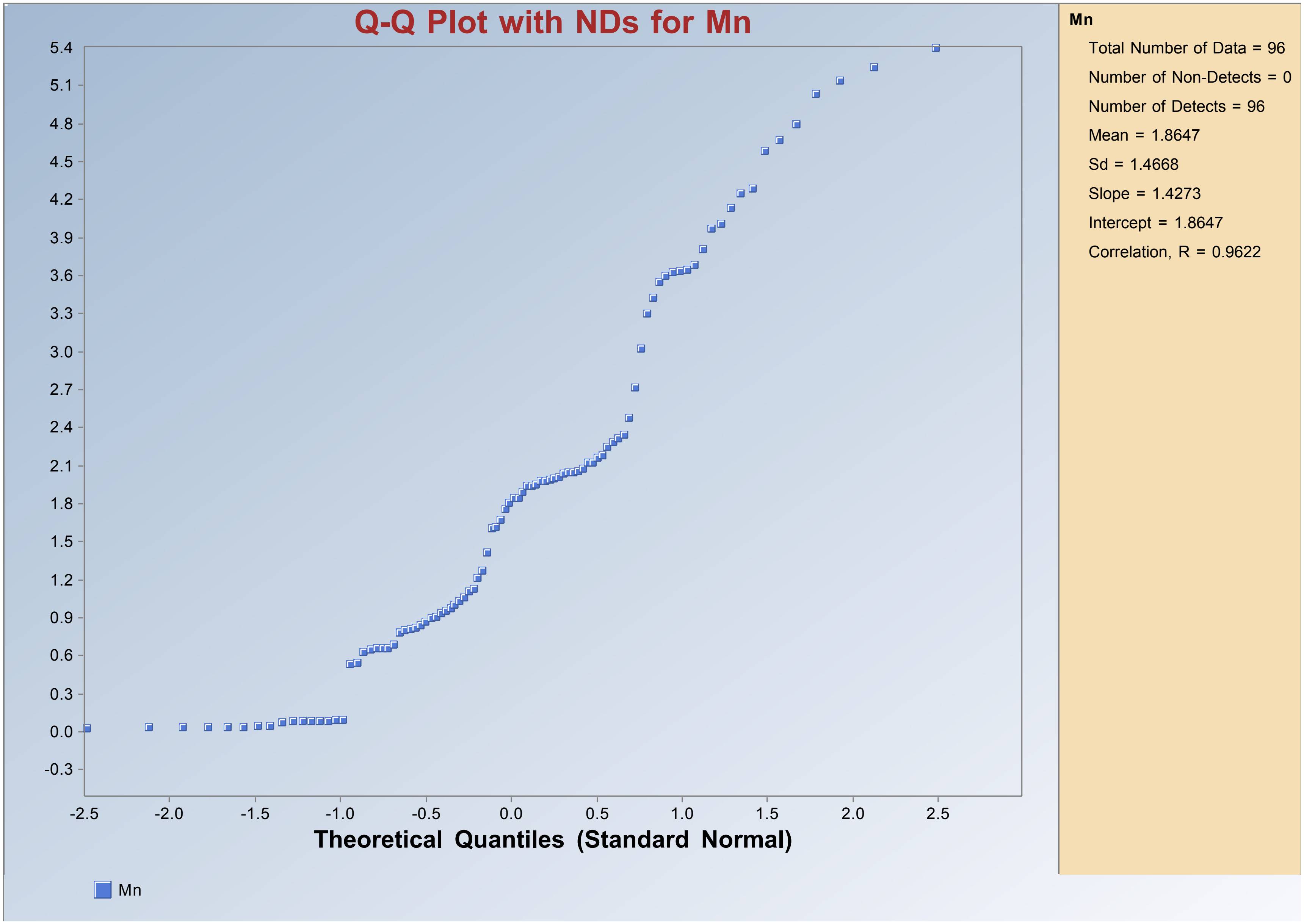
Probability Plot of Lead in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.7

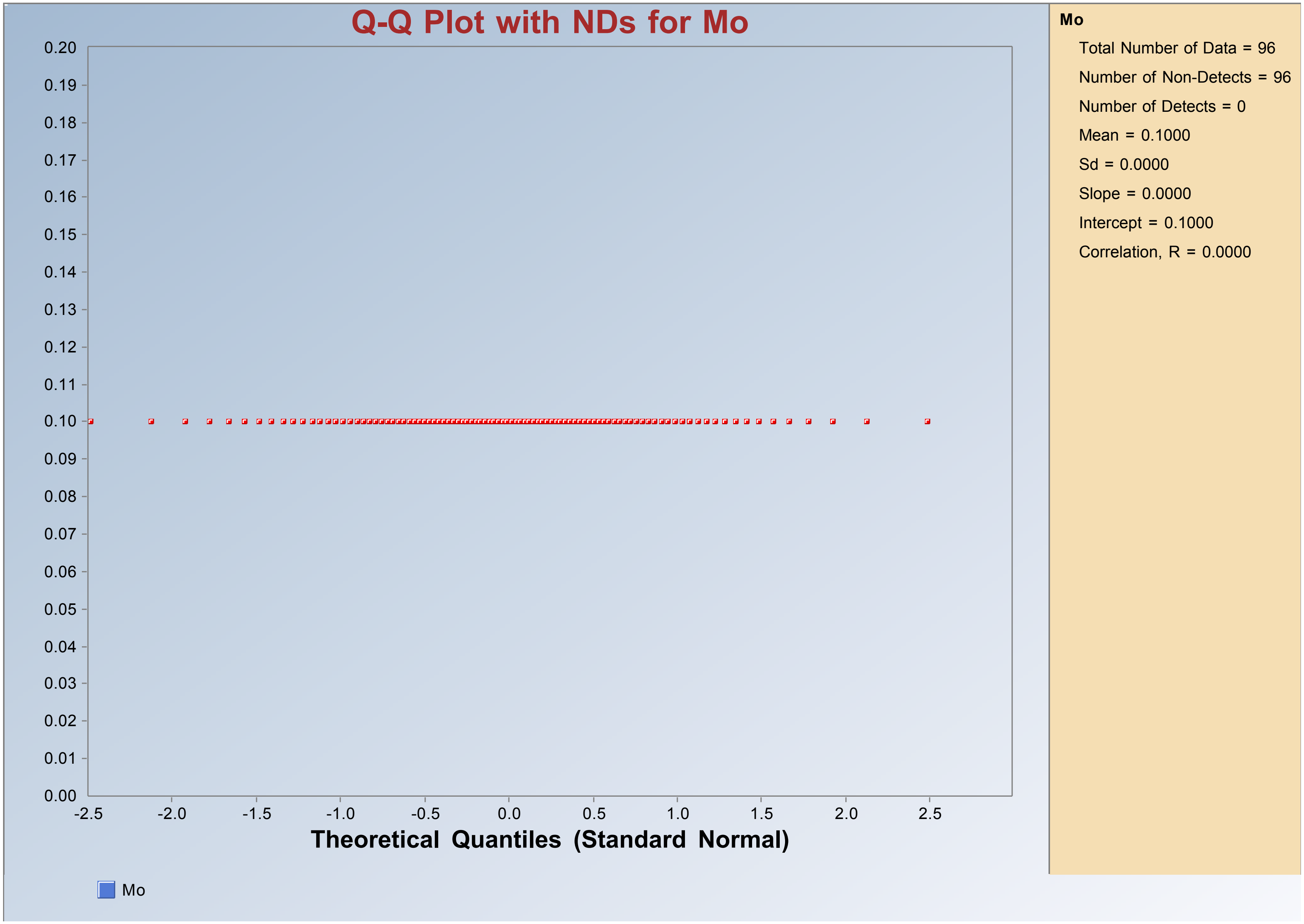
Probability Plot of Manganese in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

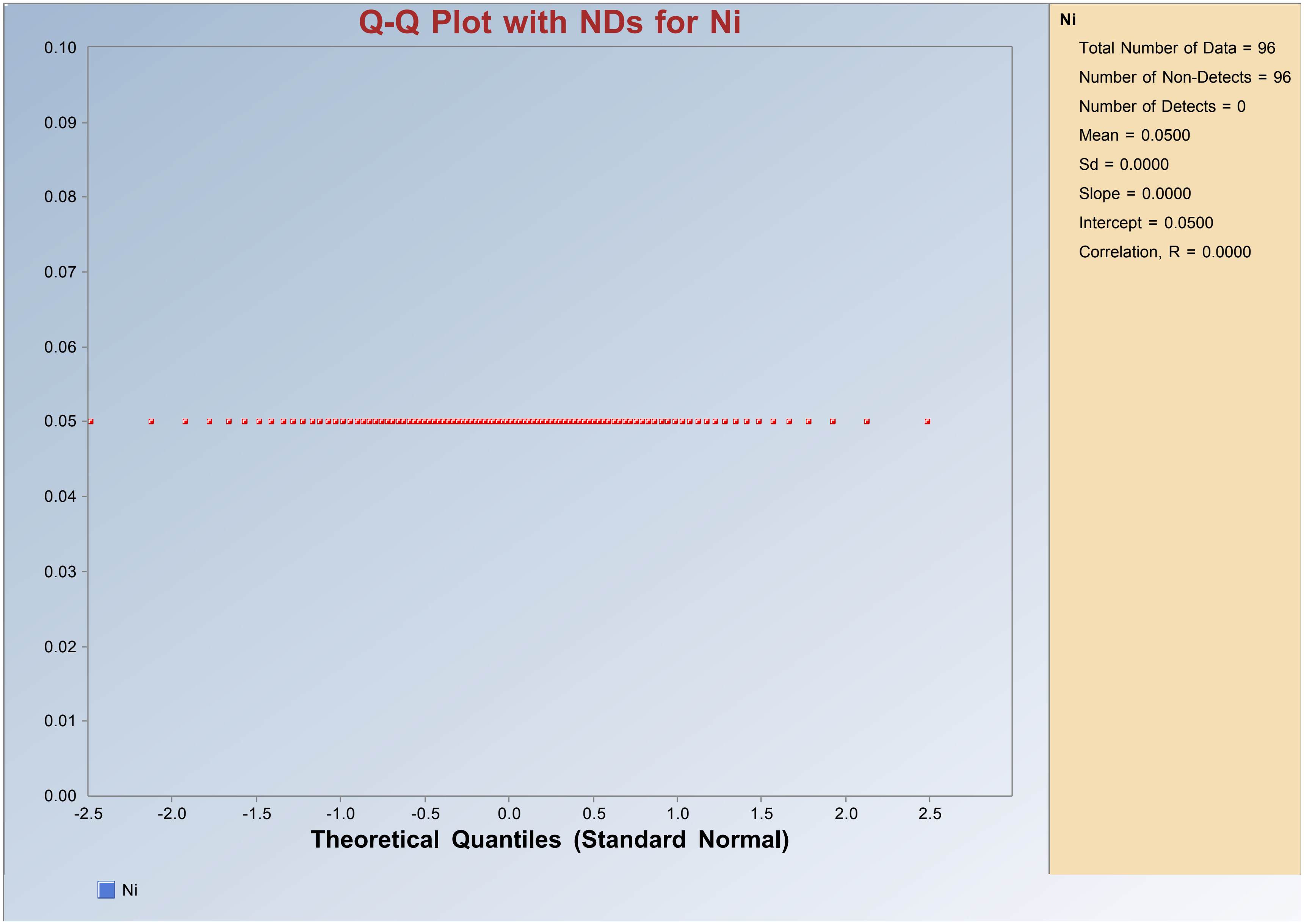
GRAPH B 1.8

Probability Plot of Molybdenum in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

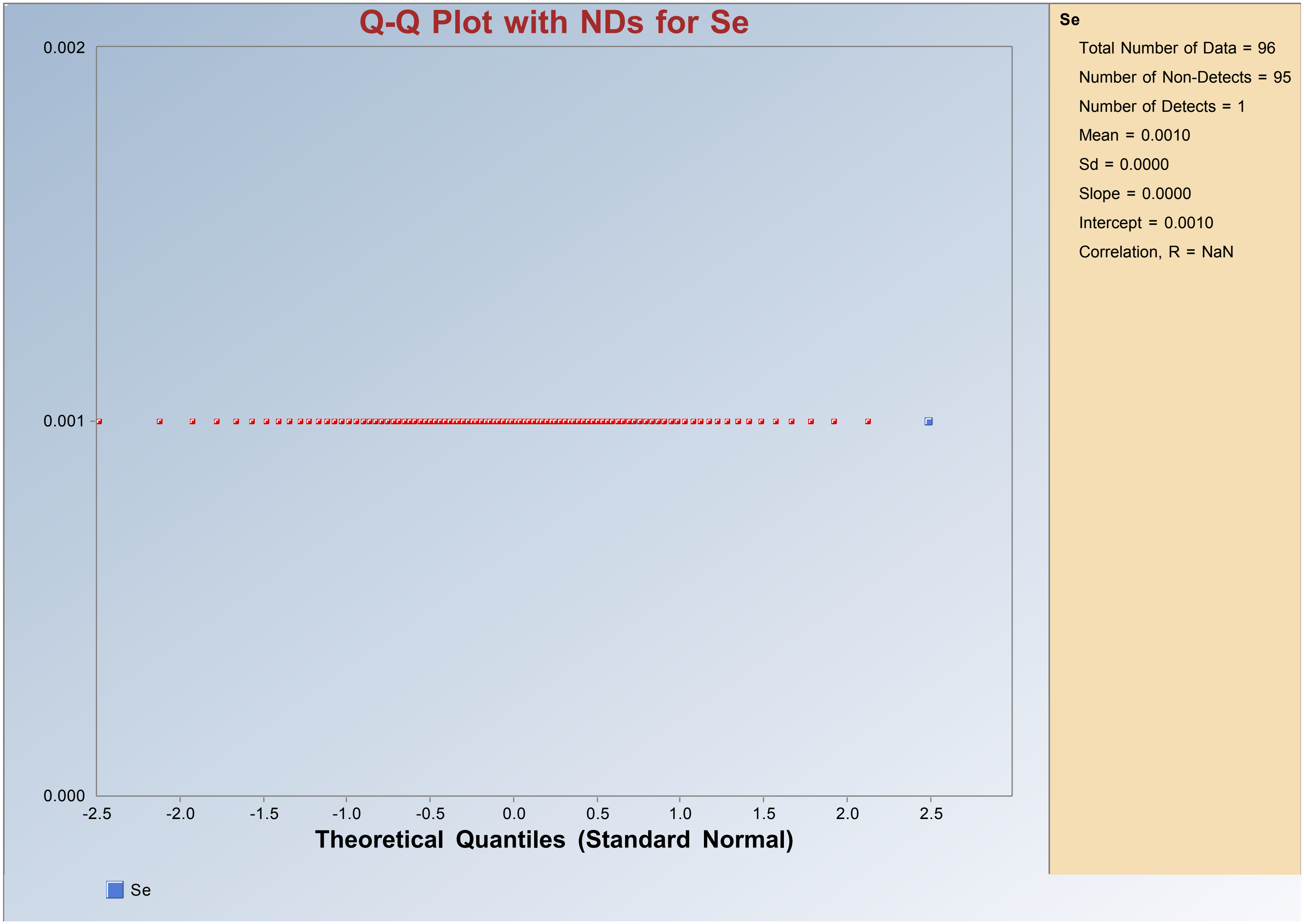
GRAPH B 1.9
Probability Plot of Nickel in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.10

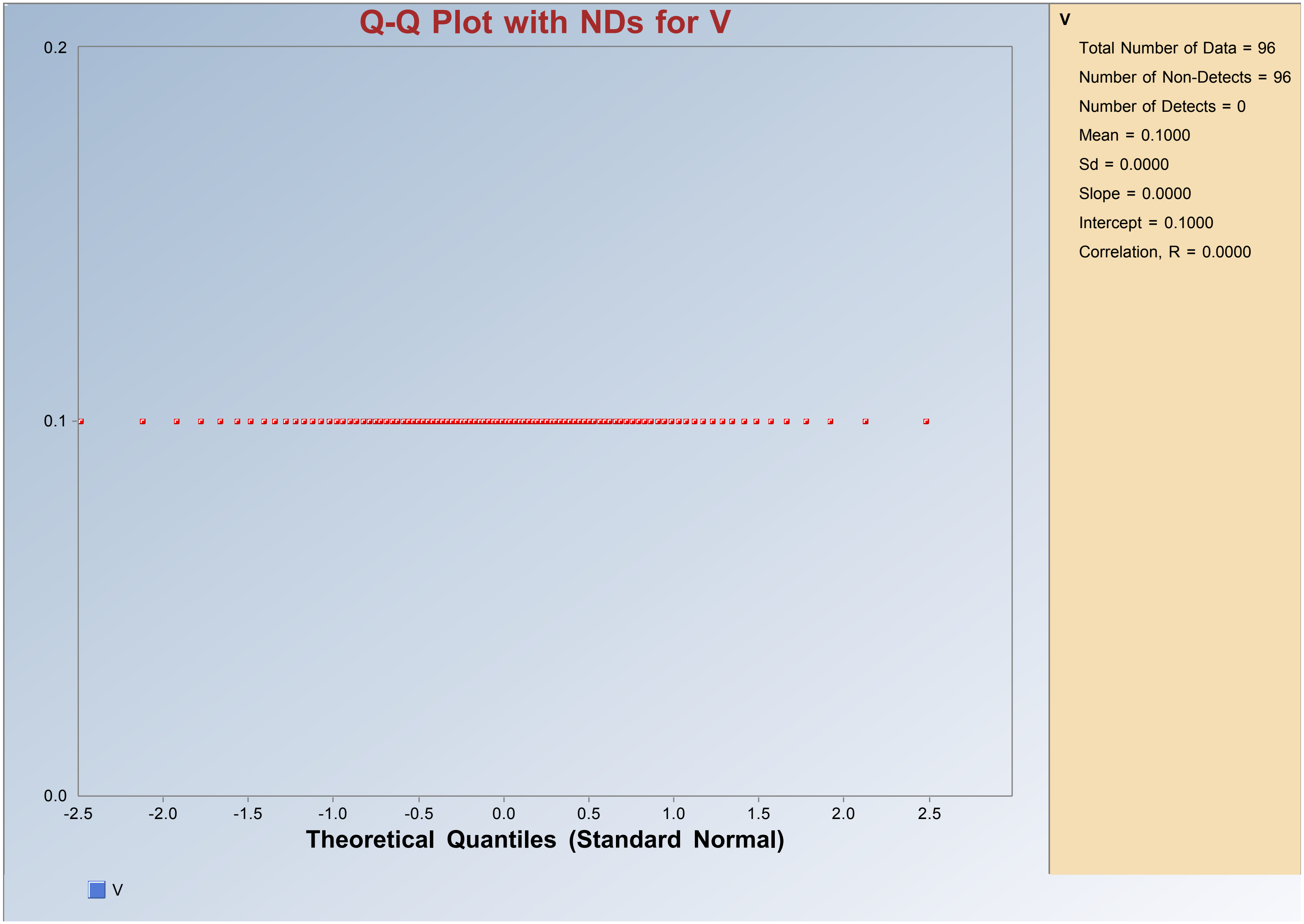
Probability Plot of Selenium in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

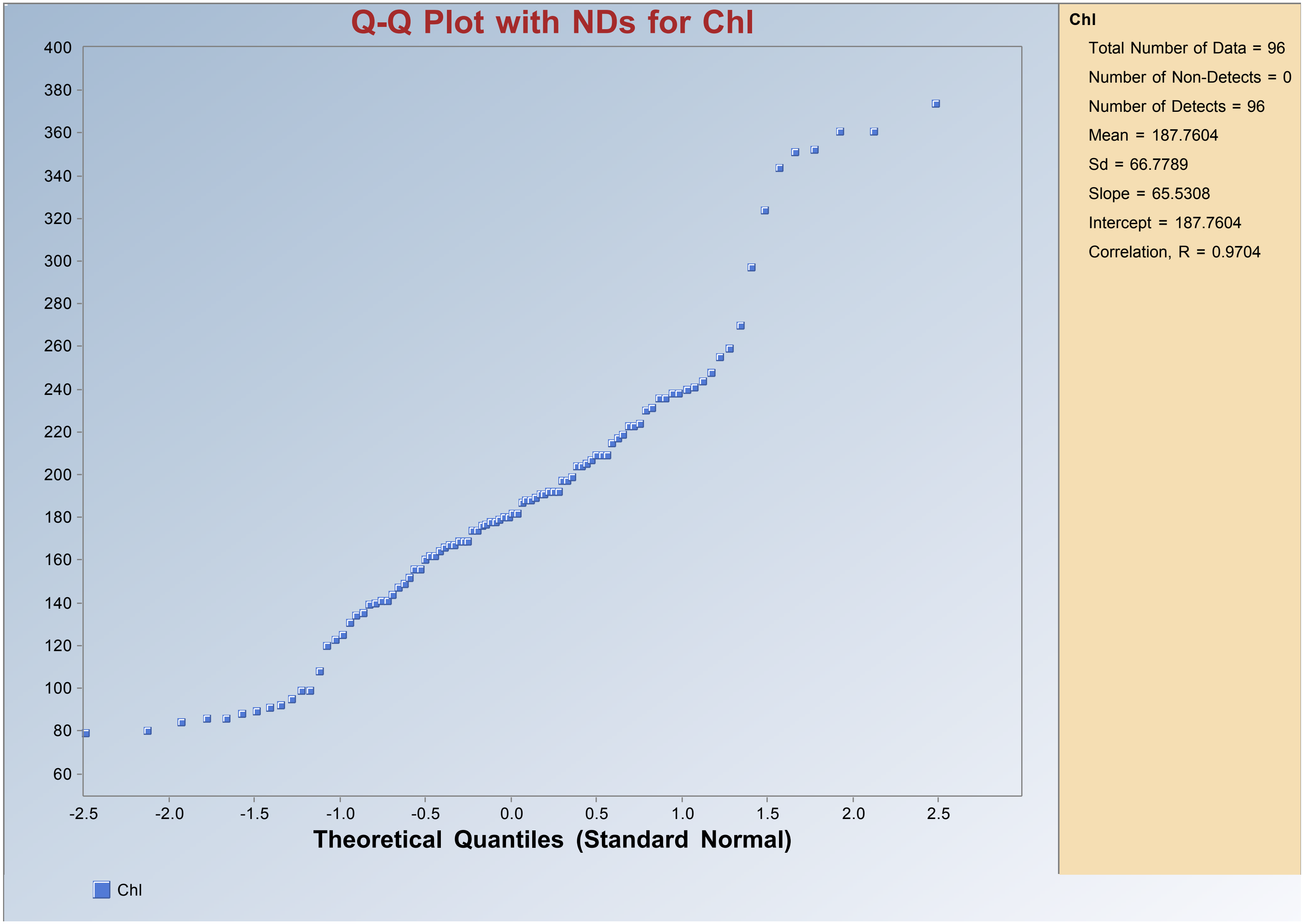
GRAPH B 1.11

Probability Plot of Vandadium in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

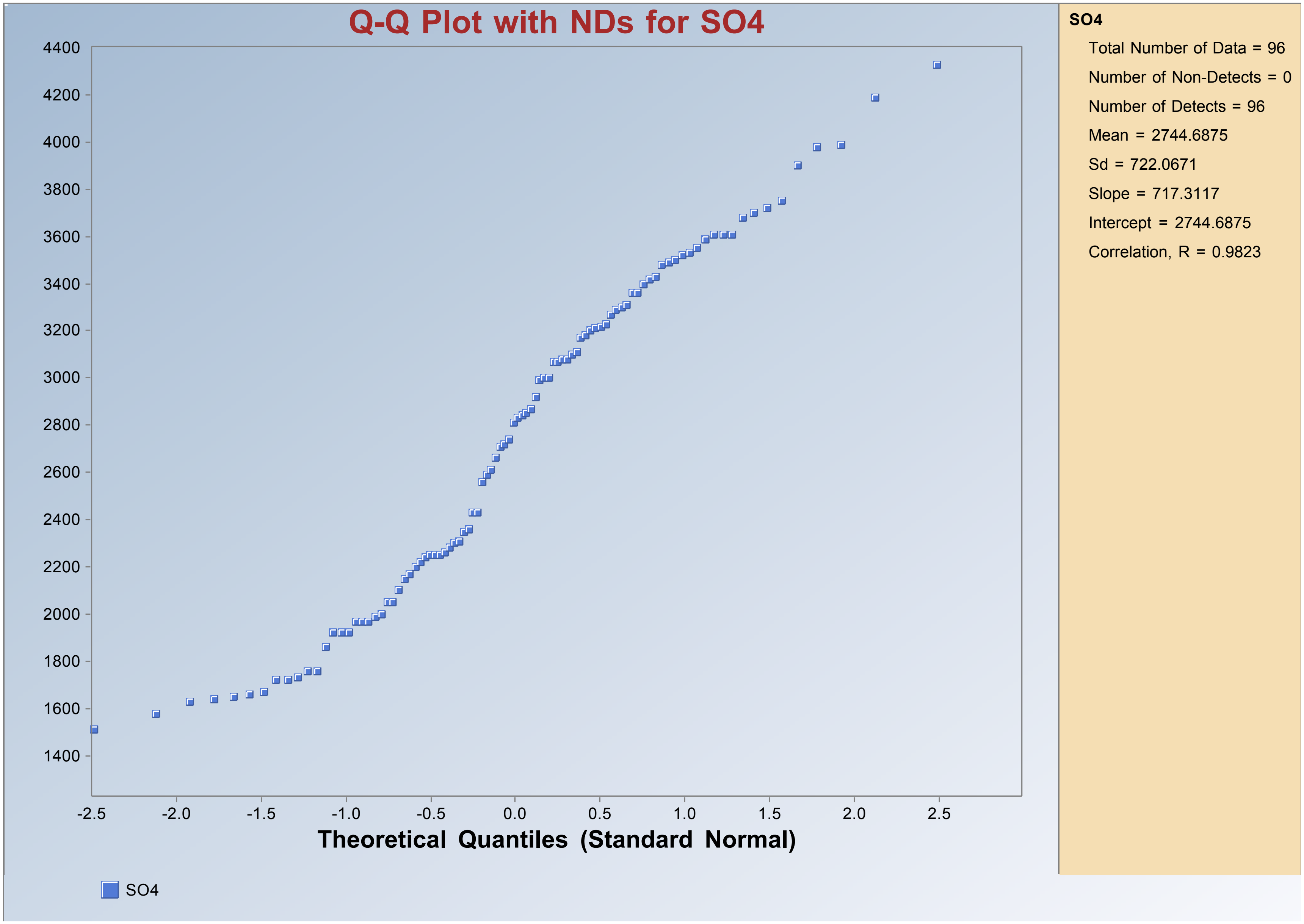
GRAPH B 1.12
Probability Plot of Chloride in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.13

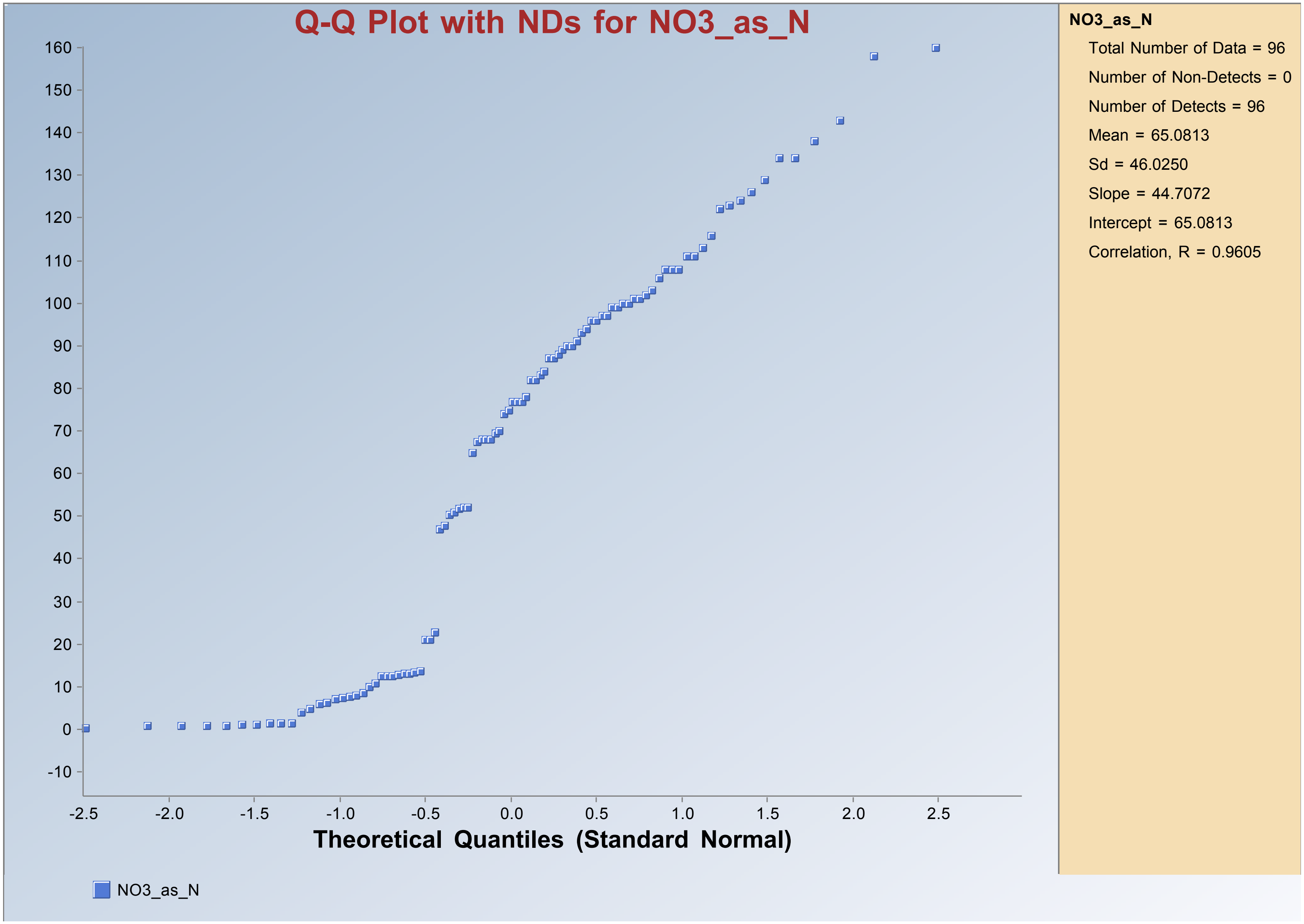
Probability Plot of Sulfate in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.14

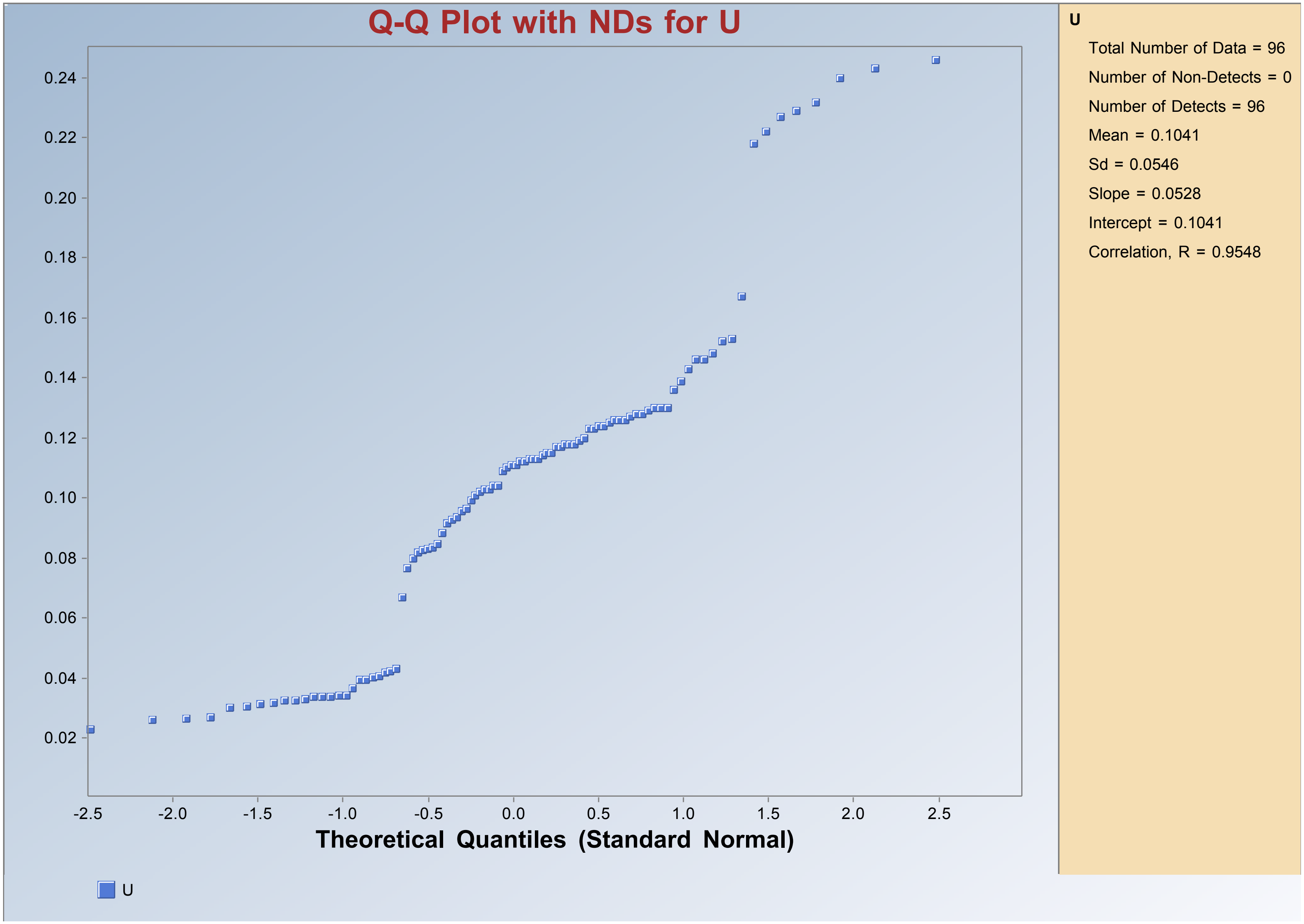
Probability Plot of Nitrate in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.15

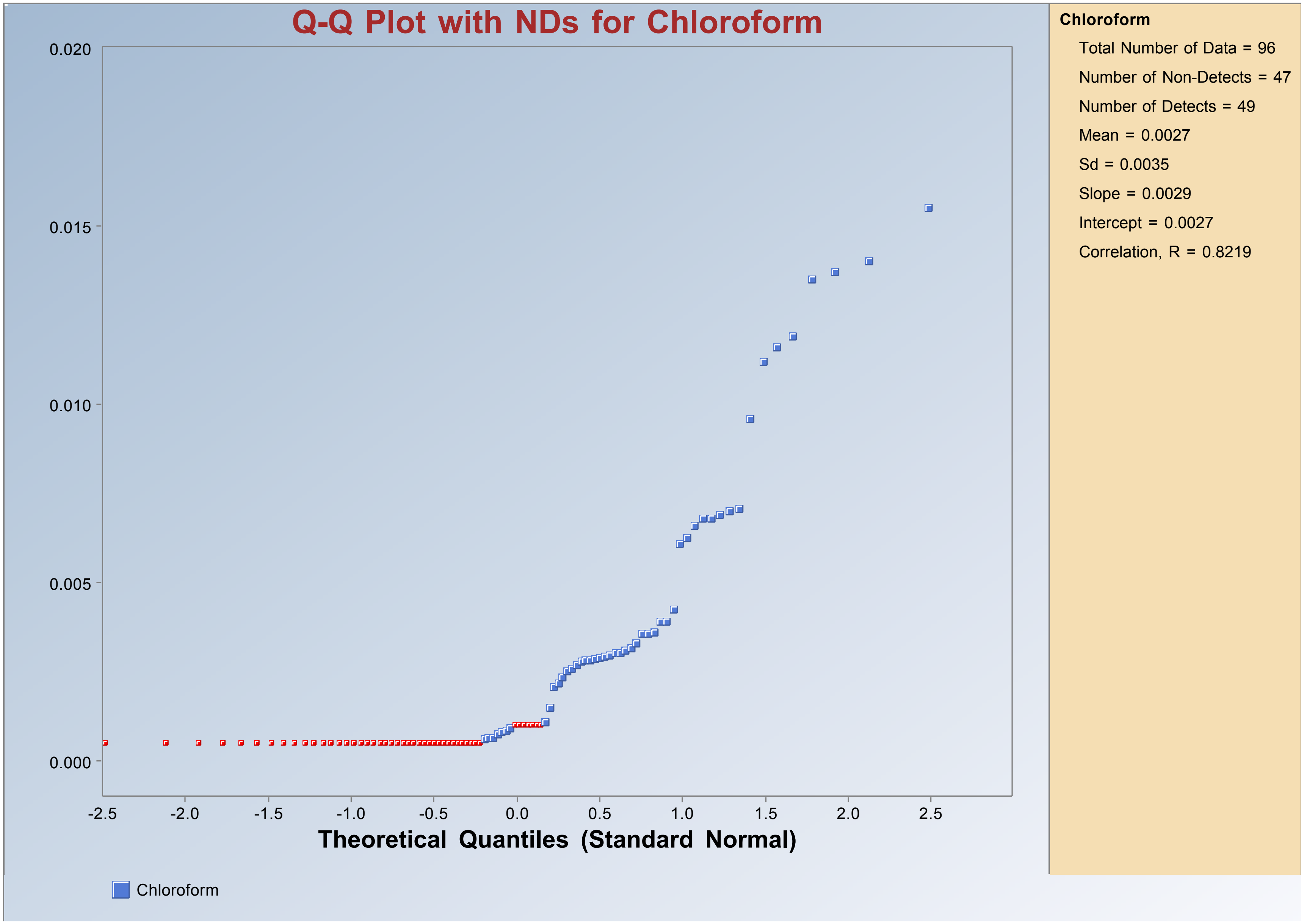
Probability Plot of Uranium in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.16

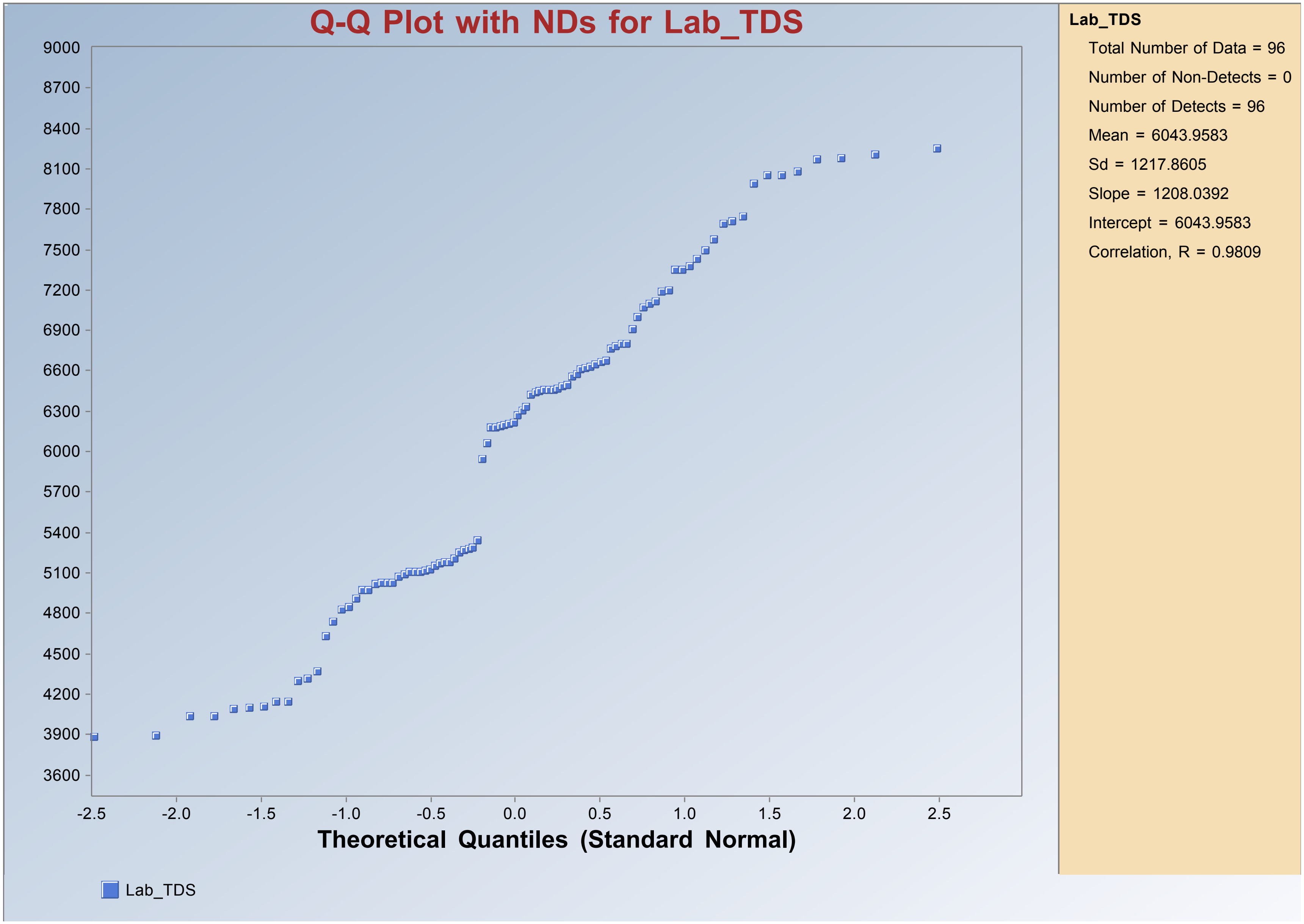
Probability Plot of Chloroform in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.17

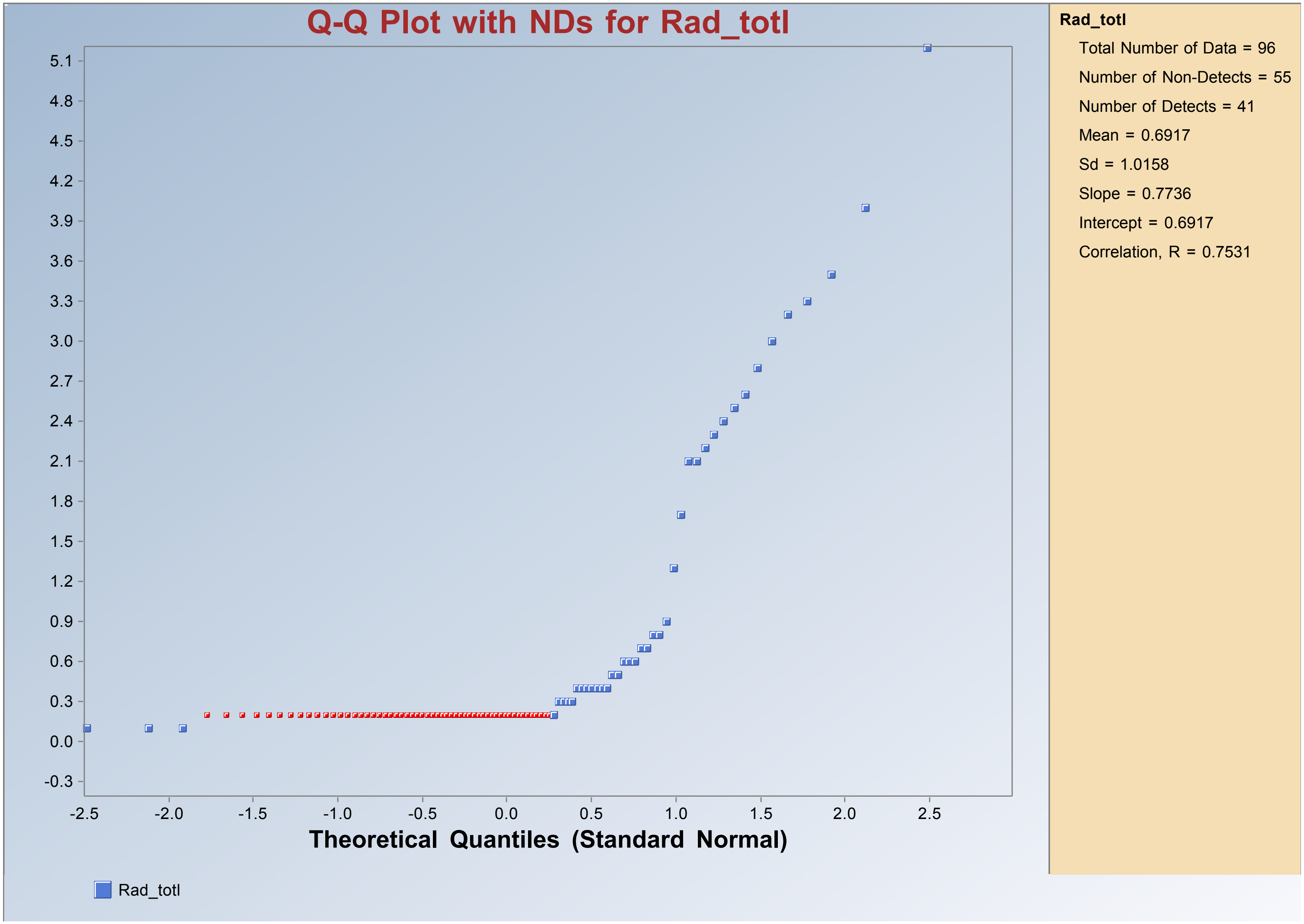
Probability Plot of Total Dissolved Solids in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 1.18

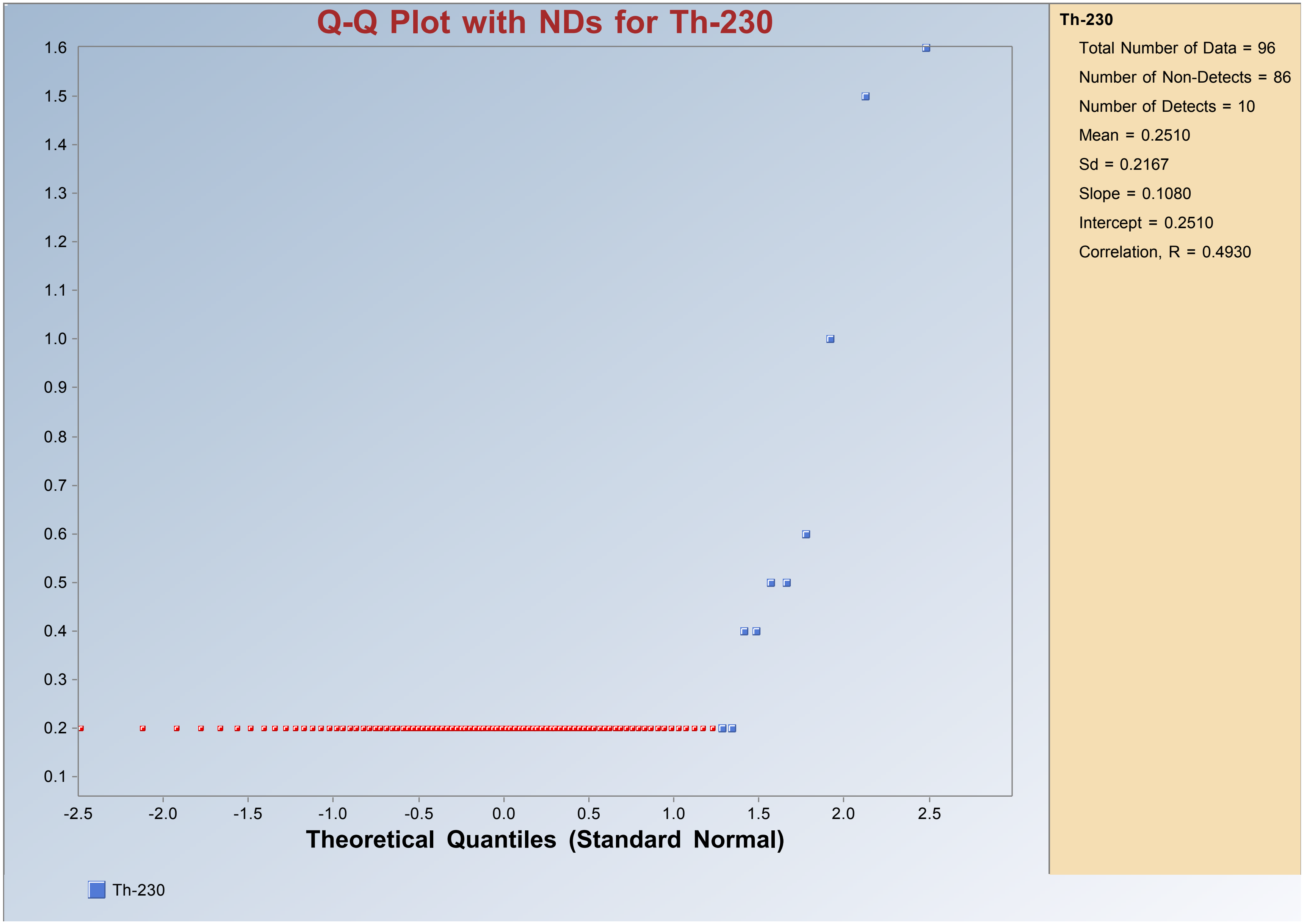
Probability Plot of Total Radium in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

GRAPH B 1.19

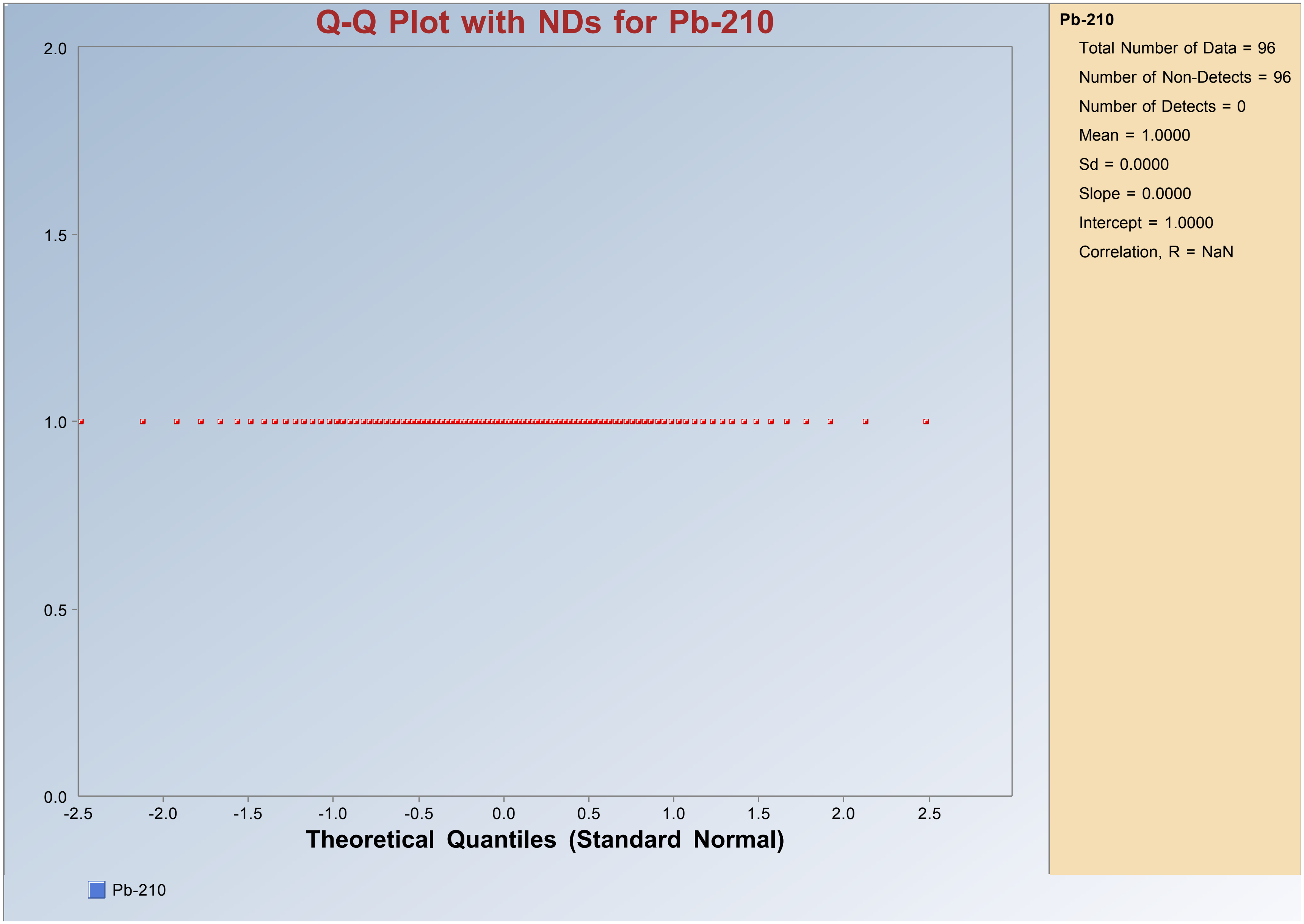
Probability Plot of Thorium-230 in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

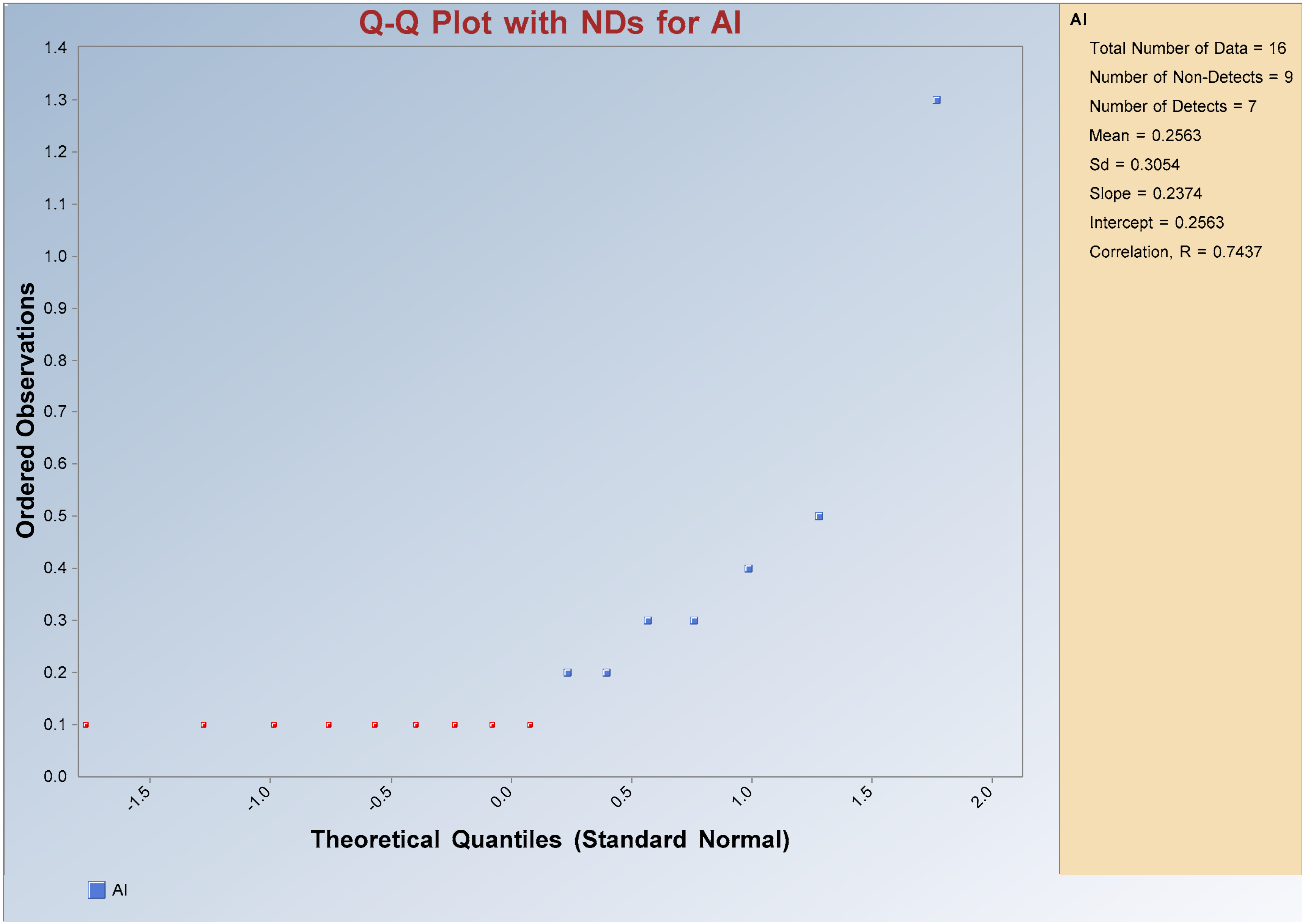
GRAPH B 1.20

Probability Plot of Lead-210 in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



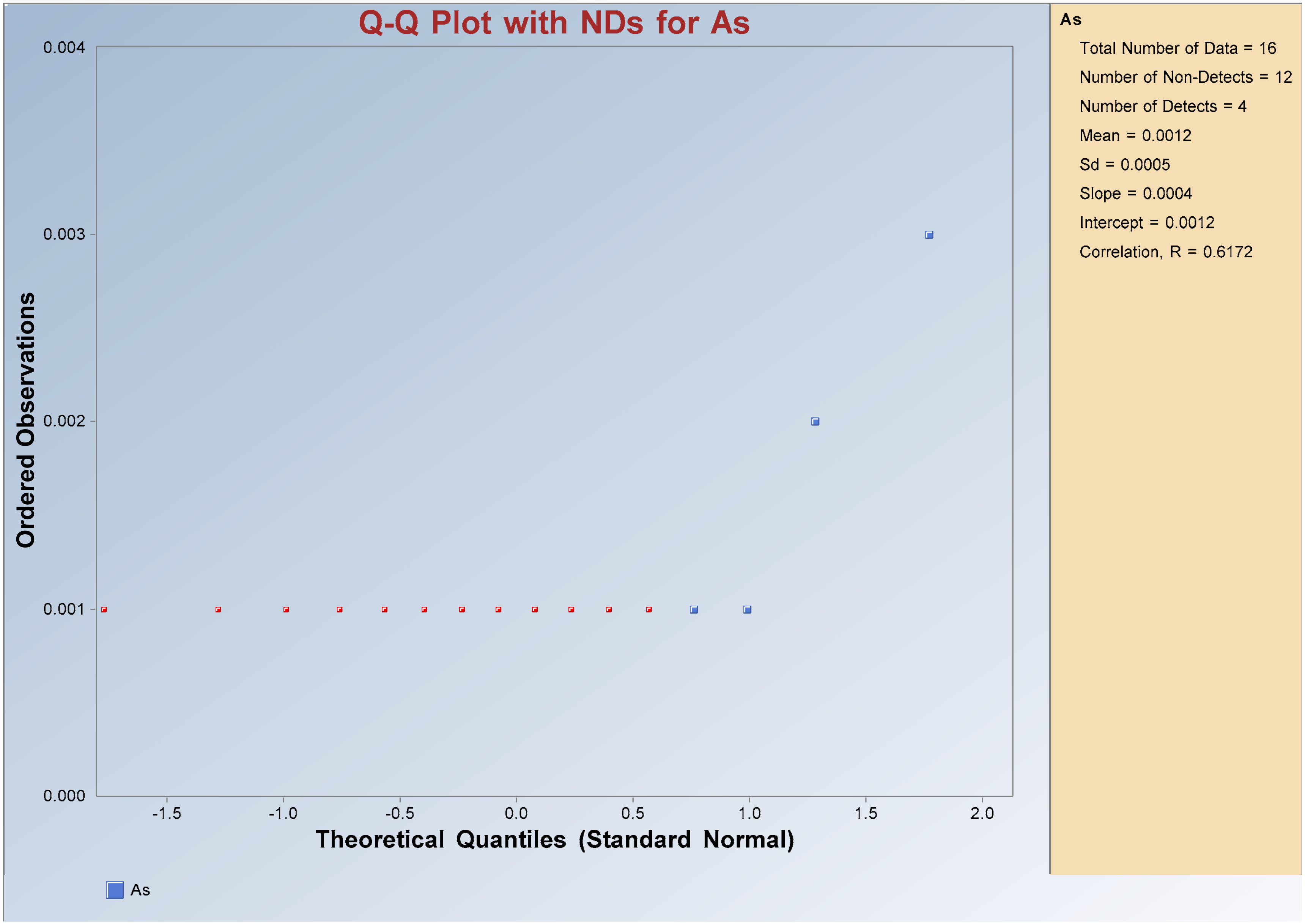
(concentrations in pico curies per liter)

GRAPH B 2.1
Probability Plot of Aluminum in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

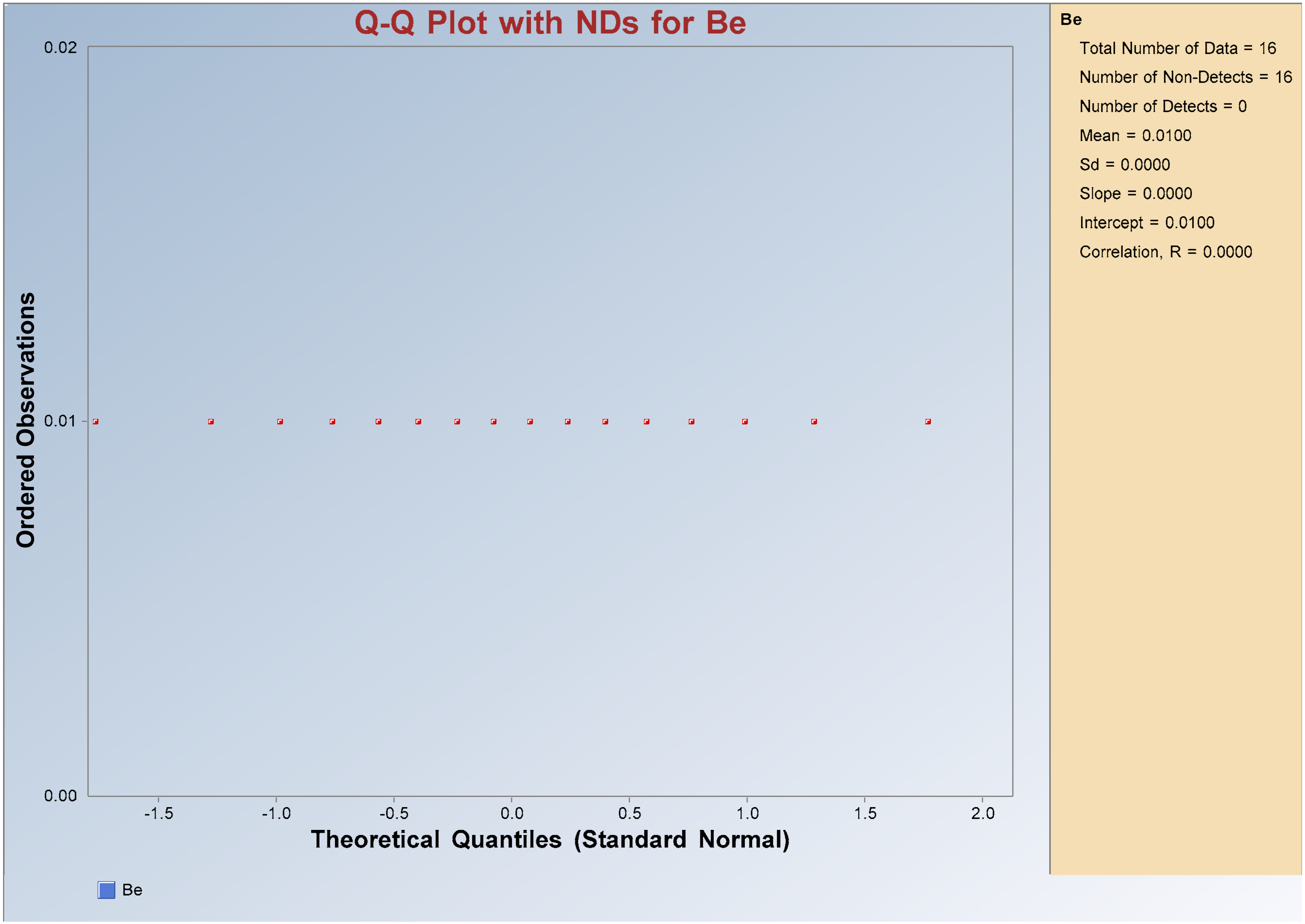
GRAPH B 2.2
Probability Plot of Arsenic in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

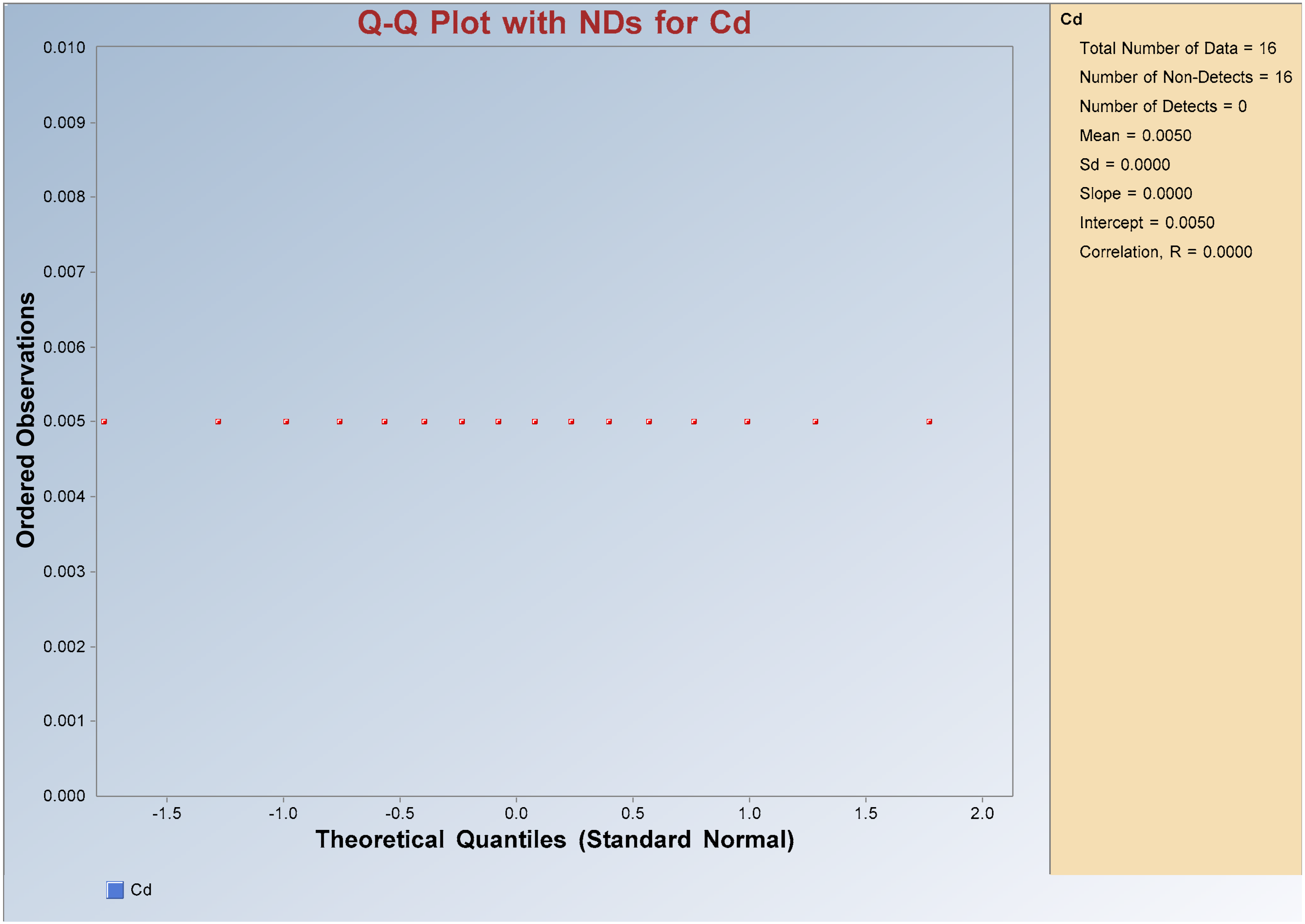
GRAPH B 2.3

Probability Plot of Beryllium in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

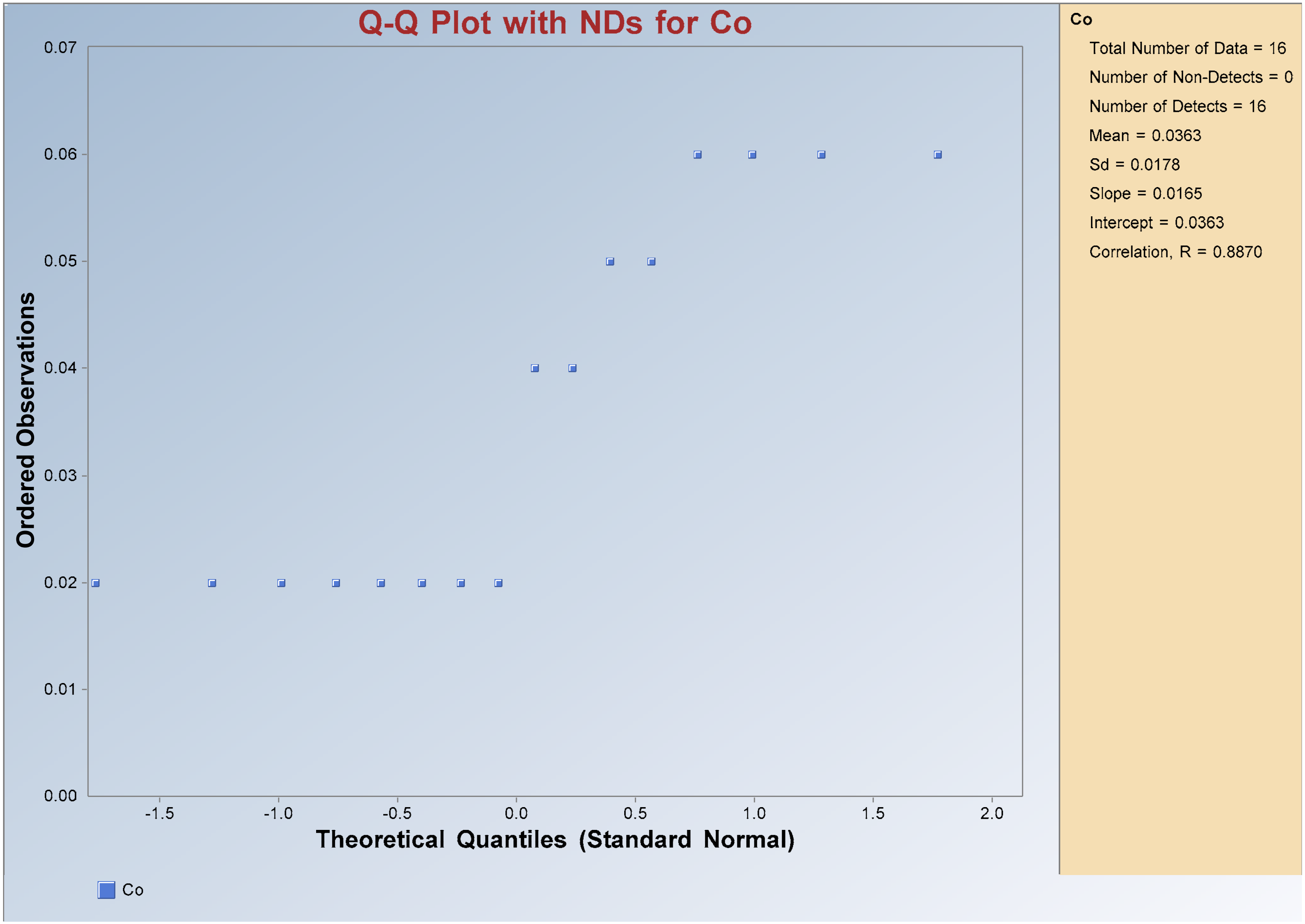
GRAPH B 2.4
Probability Plot of Cadmium in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.5

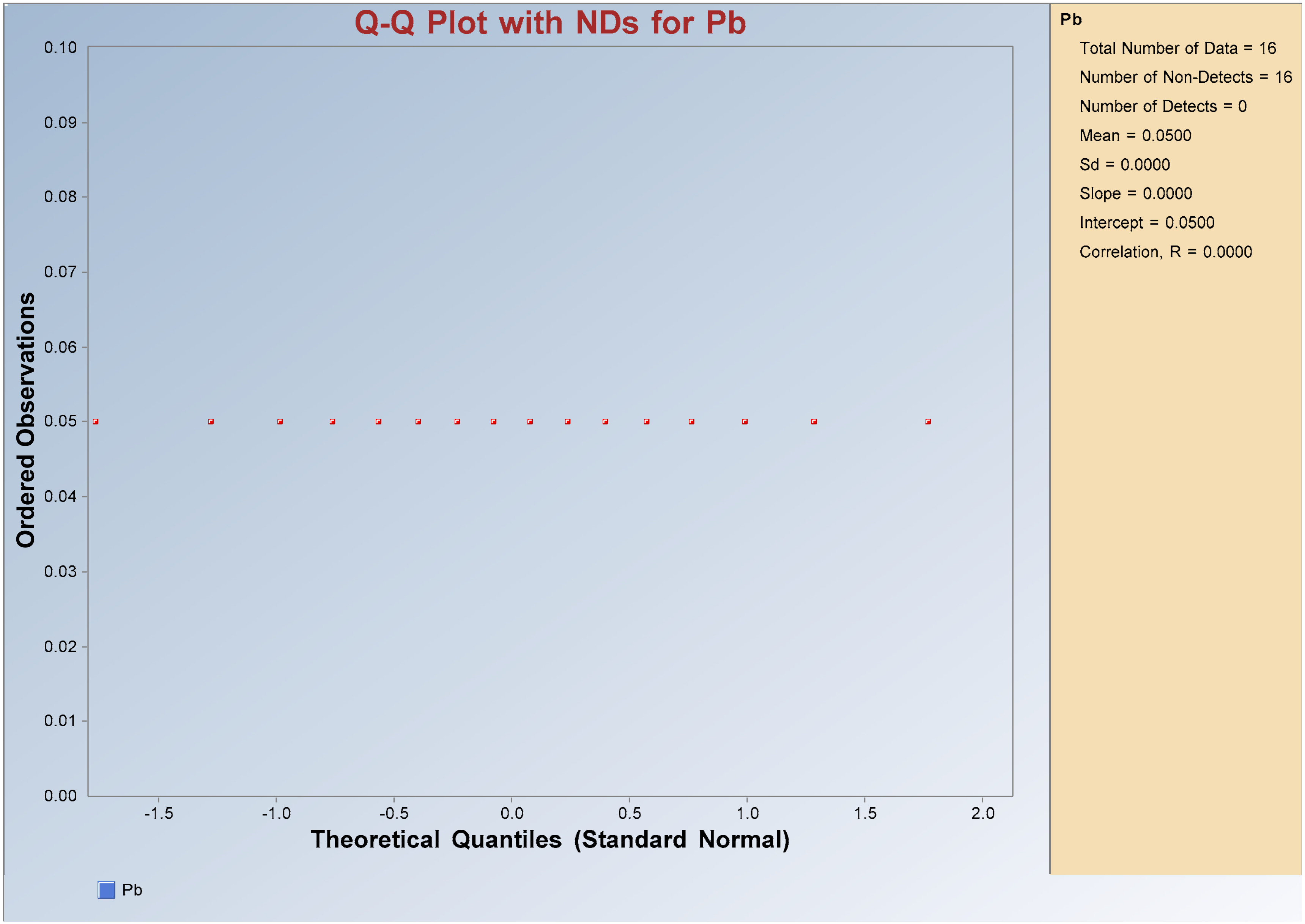
Probability Plot of Cobalt in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.6

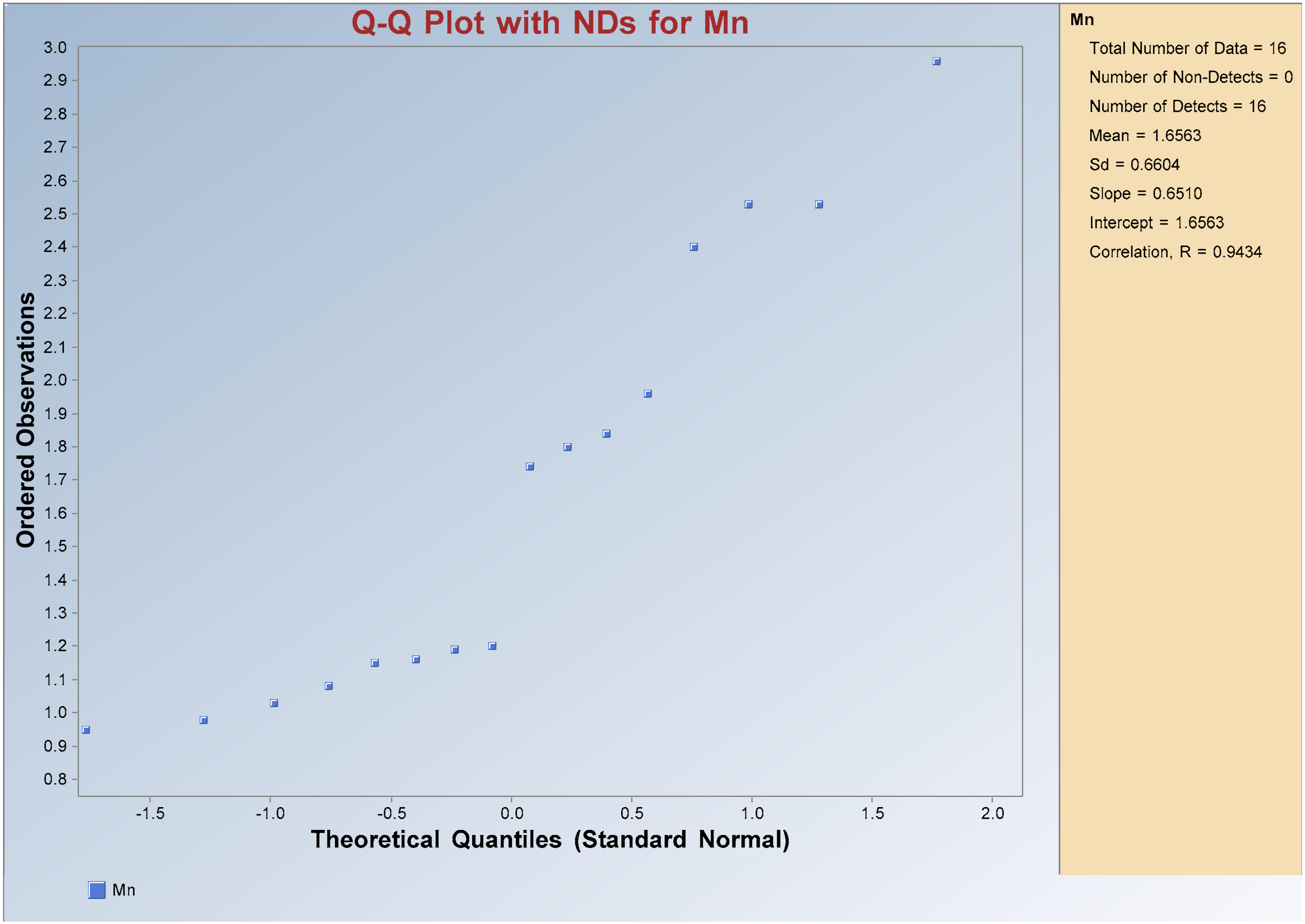
Probability Plot of Lead in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.7

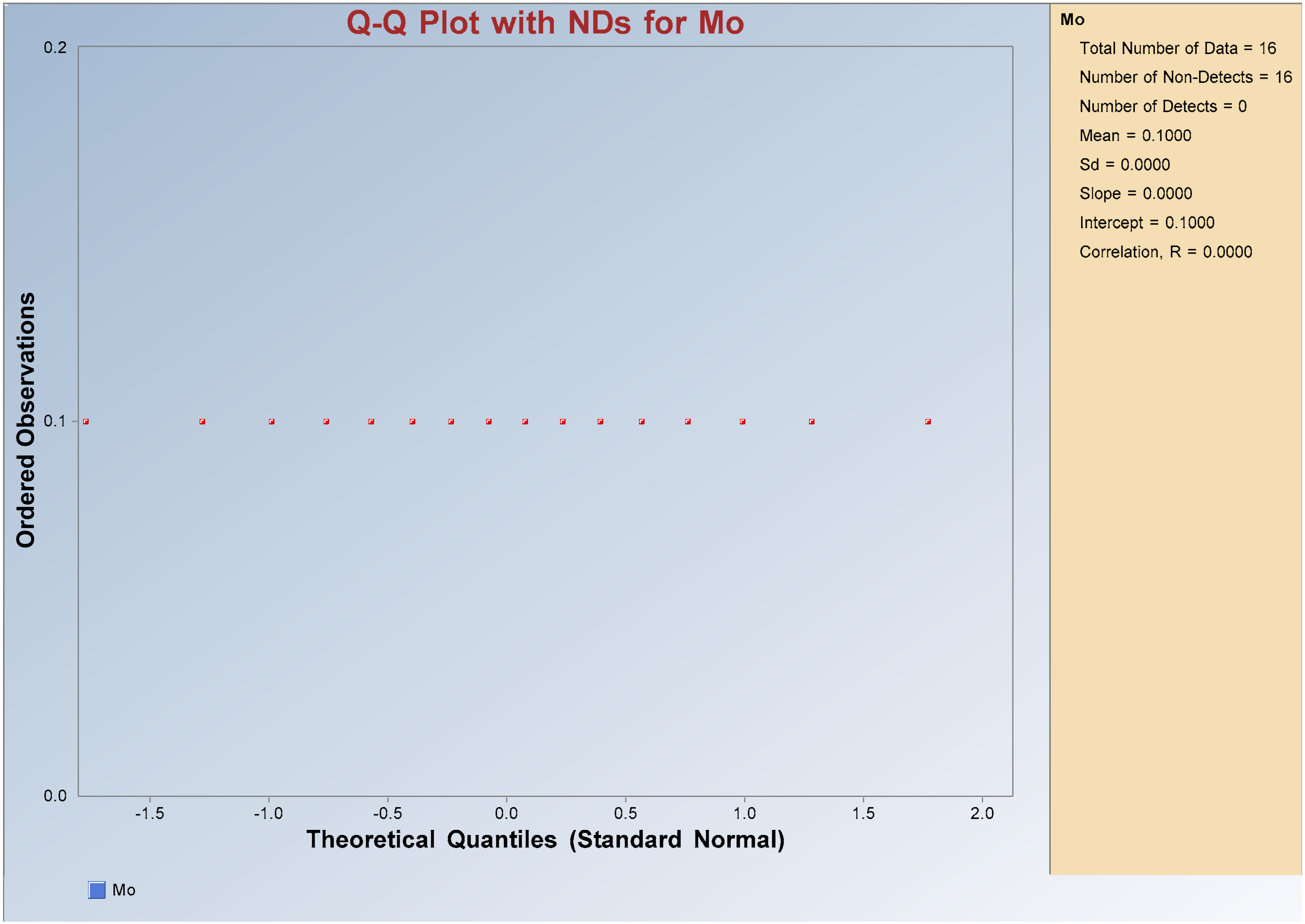
Probability Plot of Manganese in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.8

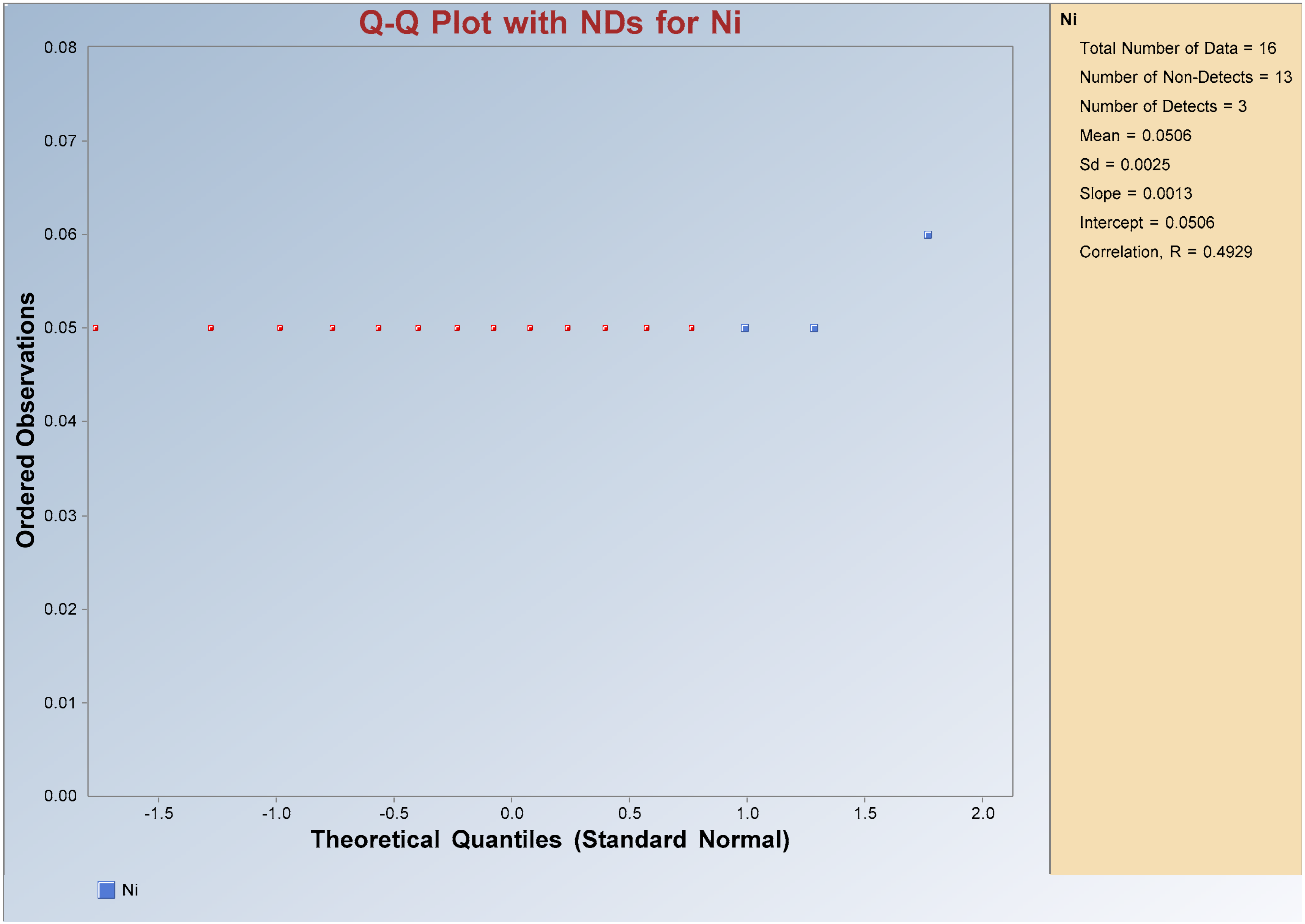
Probability Plot of Molybdenum in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.9

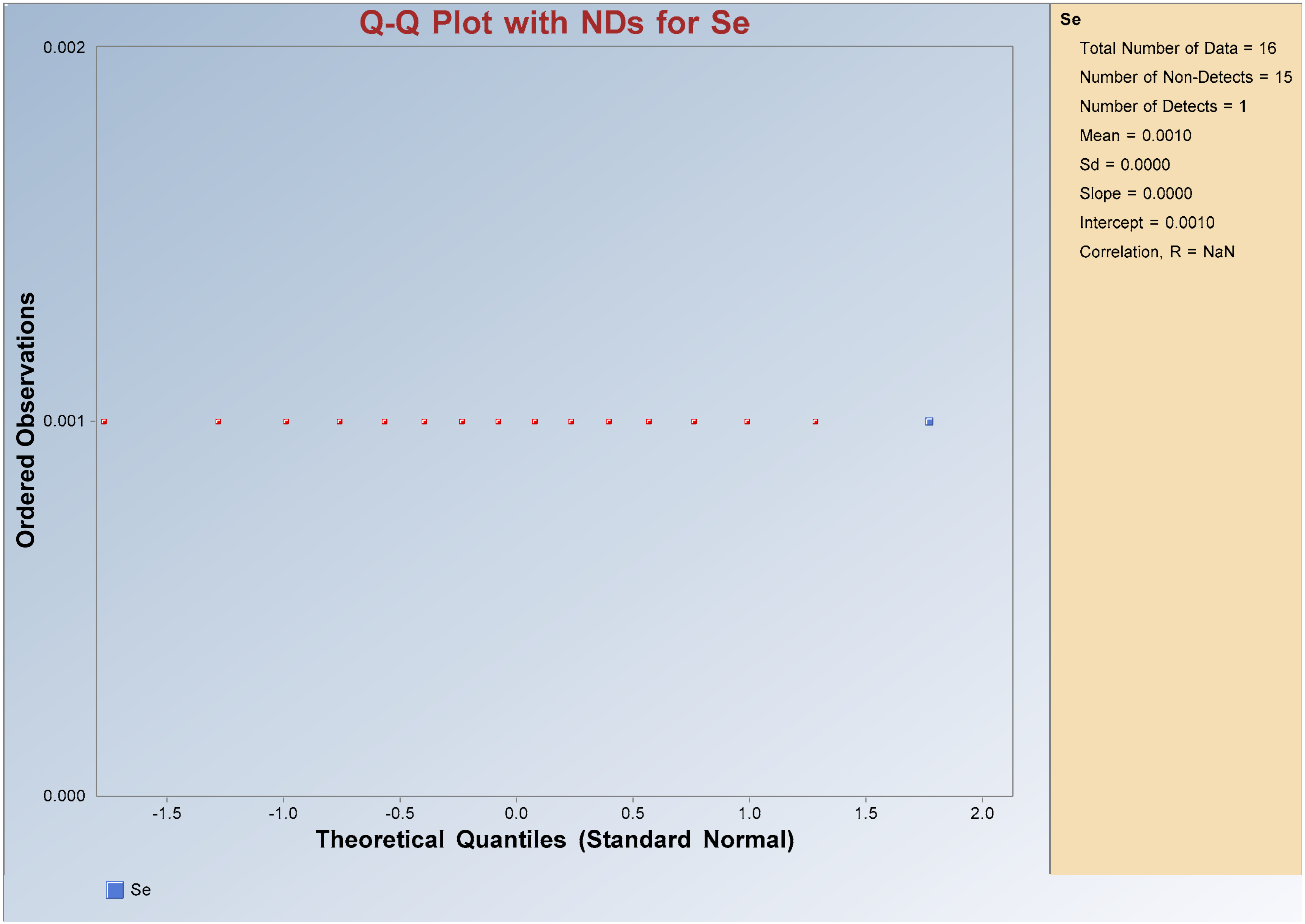
Probability Plot of Nickel in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.10

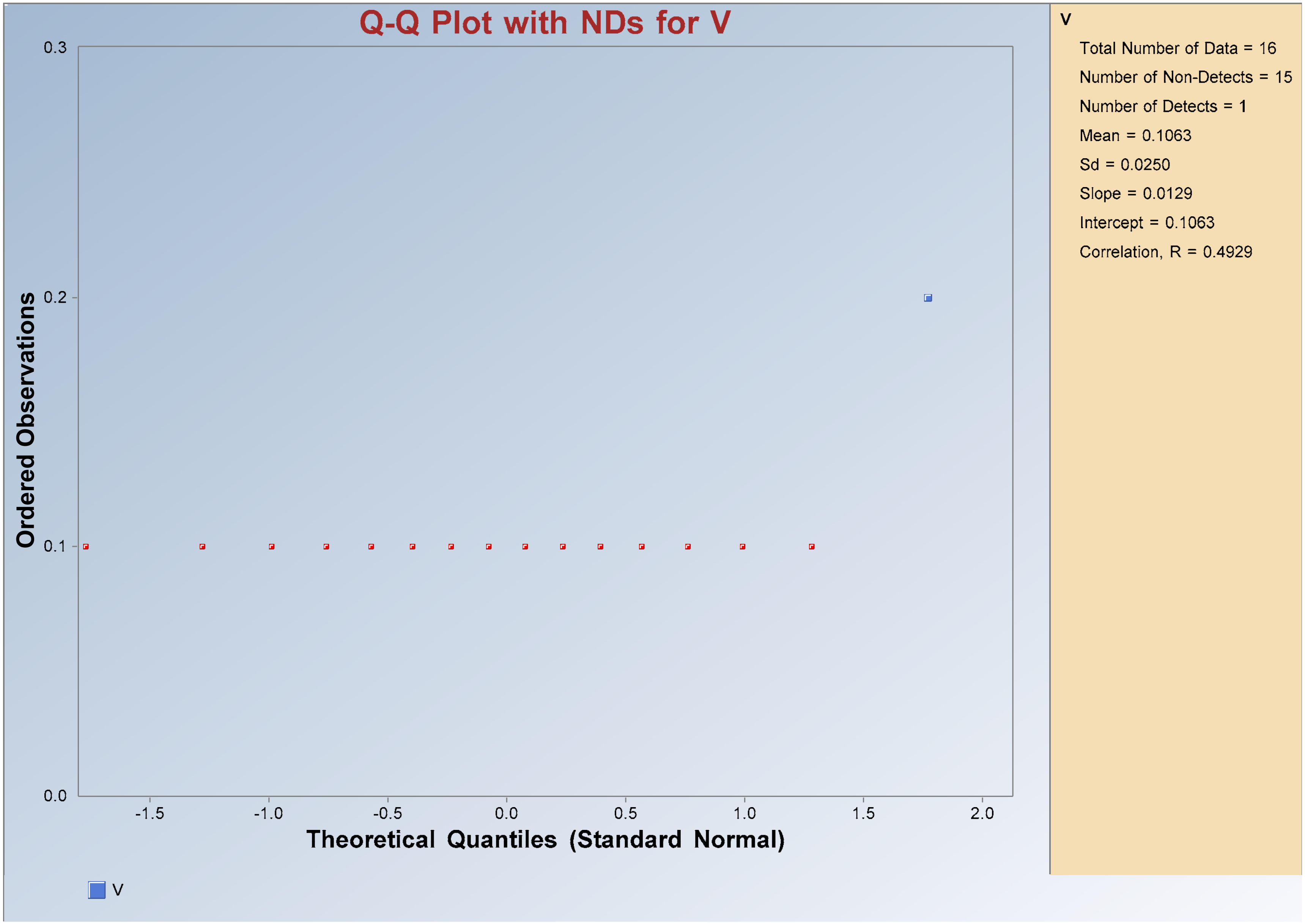
Probability Plot of Selenium in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.11

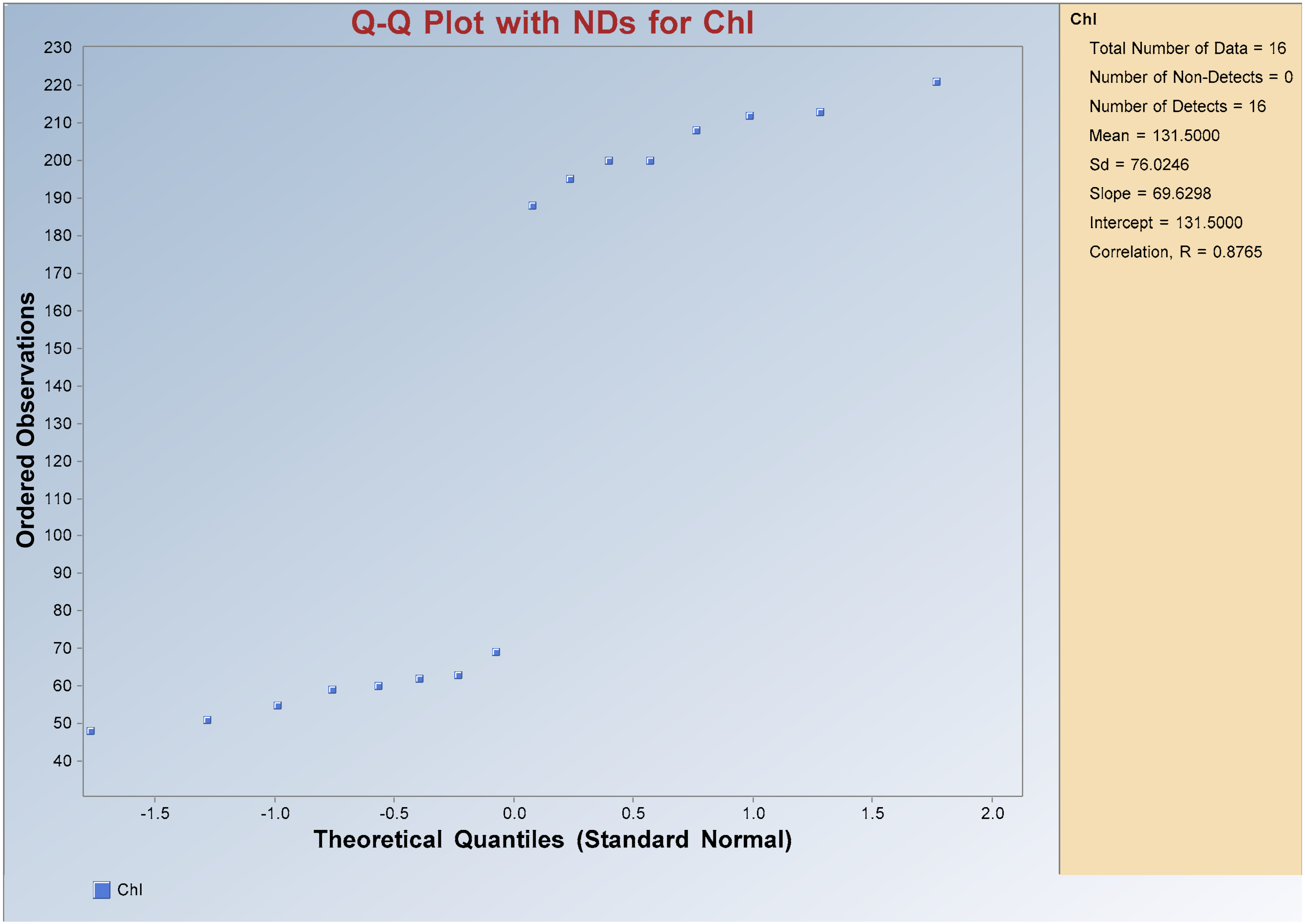
Probability Plot of Vanadium in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.12

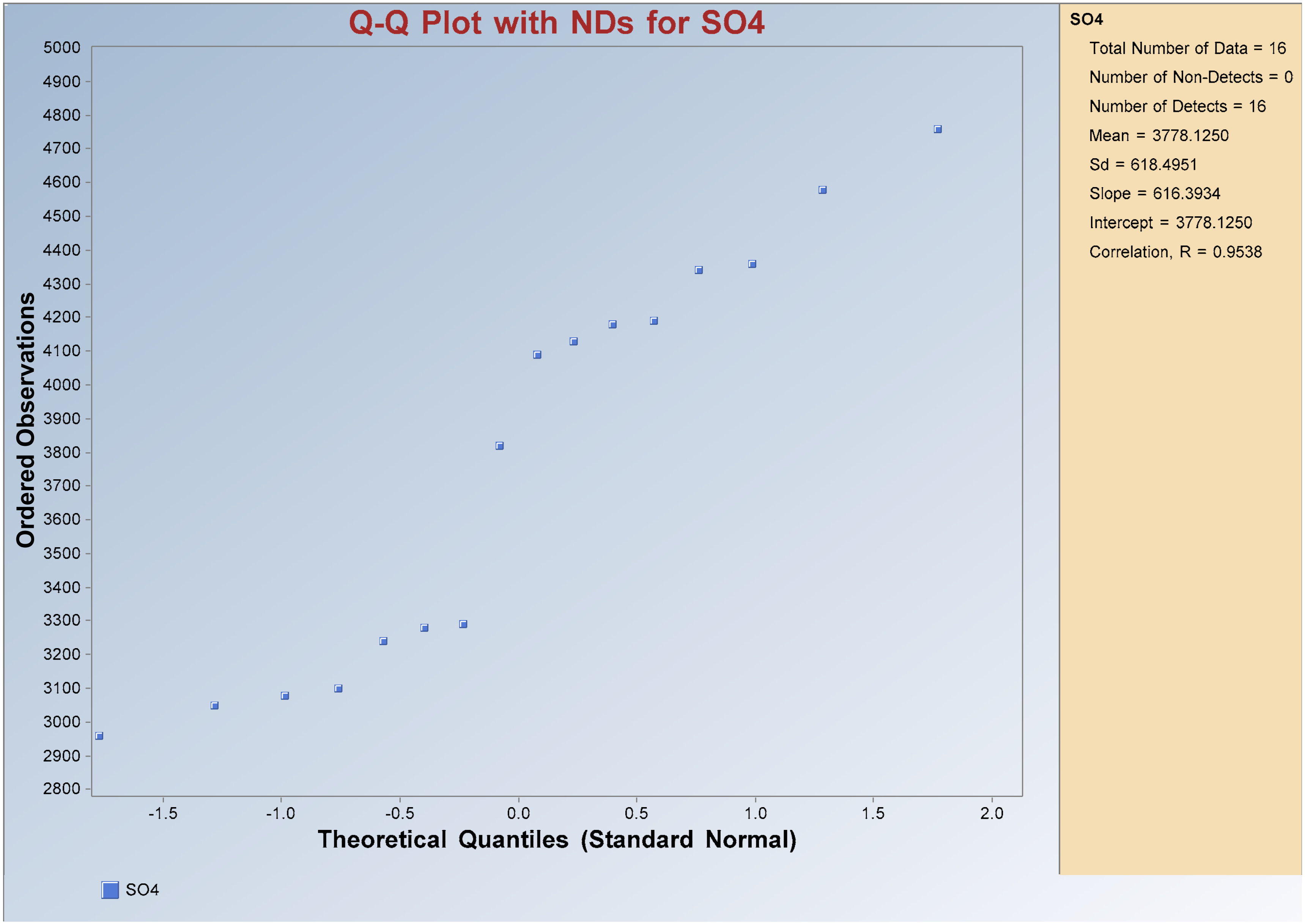
Probability Plot of Chloride in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.13

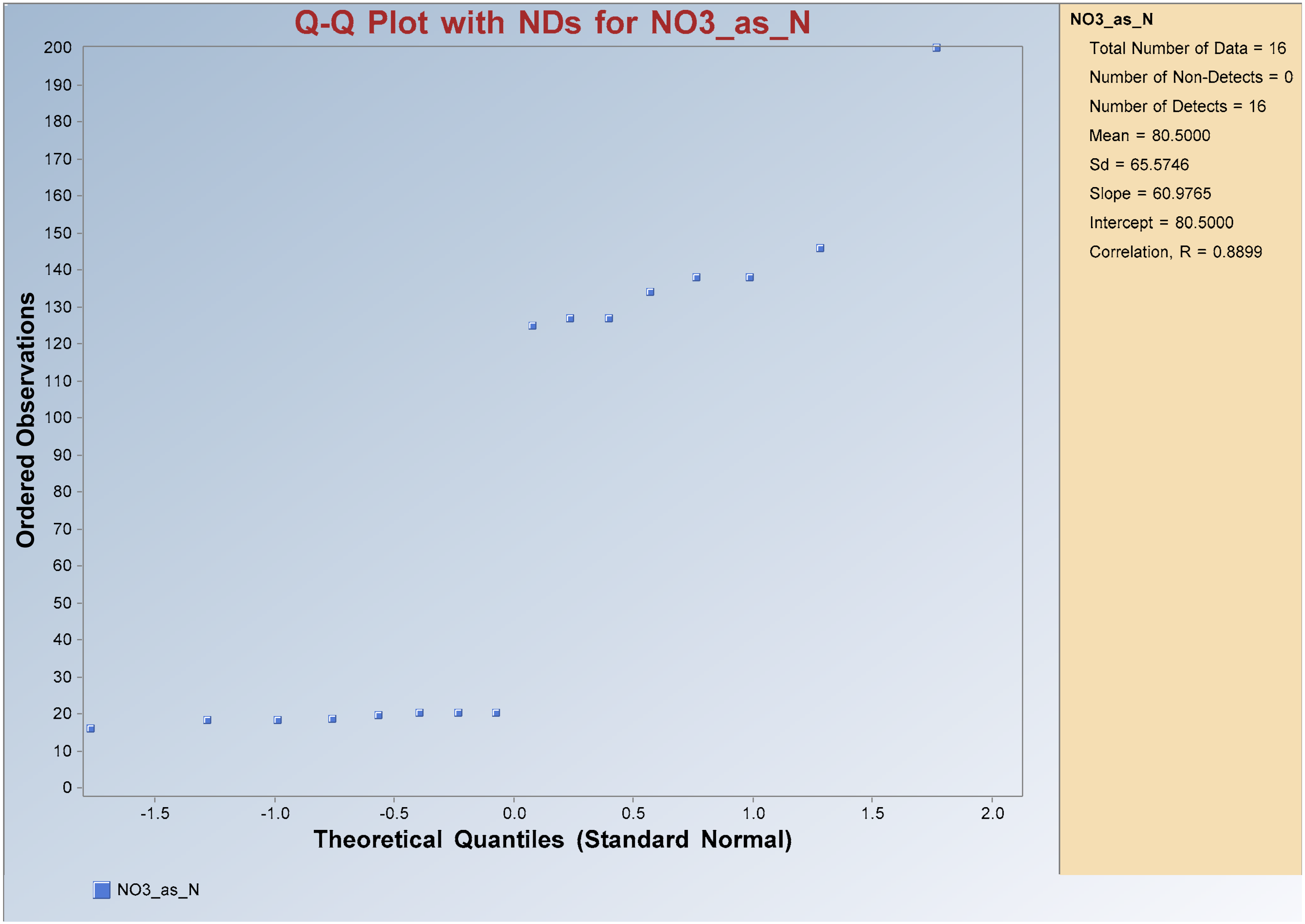
Probability Plot of Sulfate in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.14

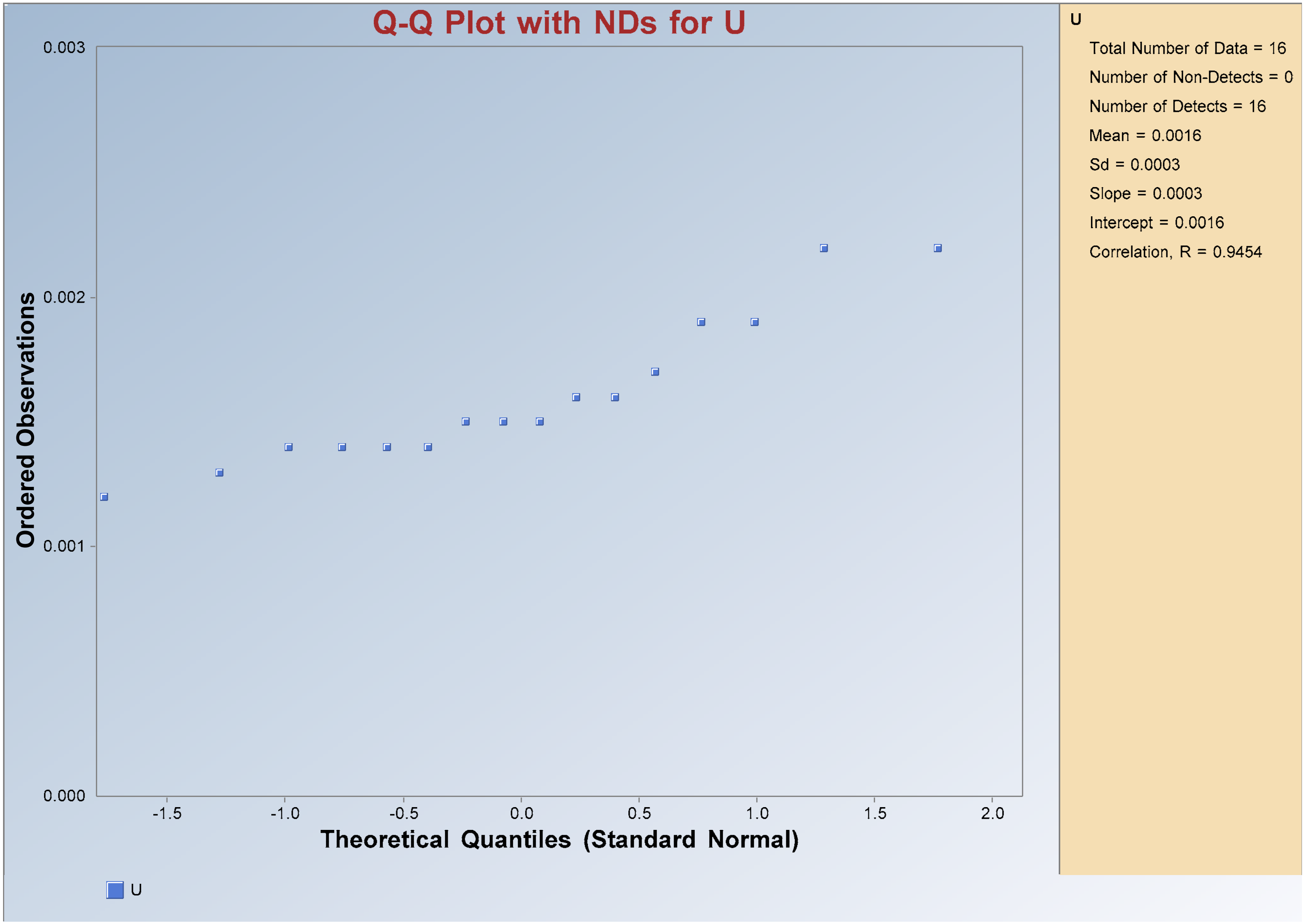
Probability Plot of Nitrate in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.15

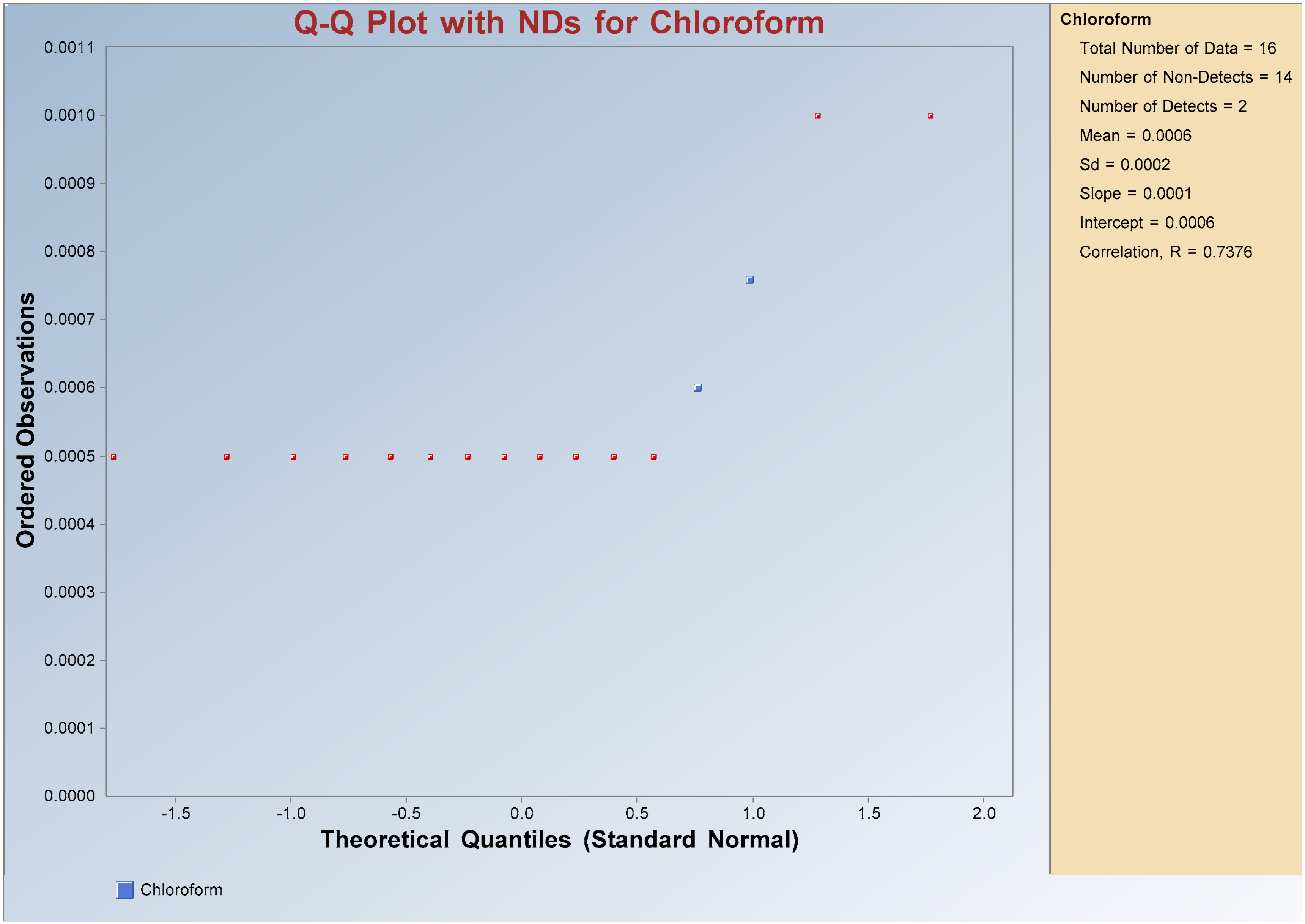
Probability Plot of Uranium in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.16

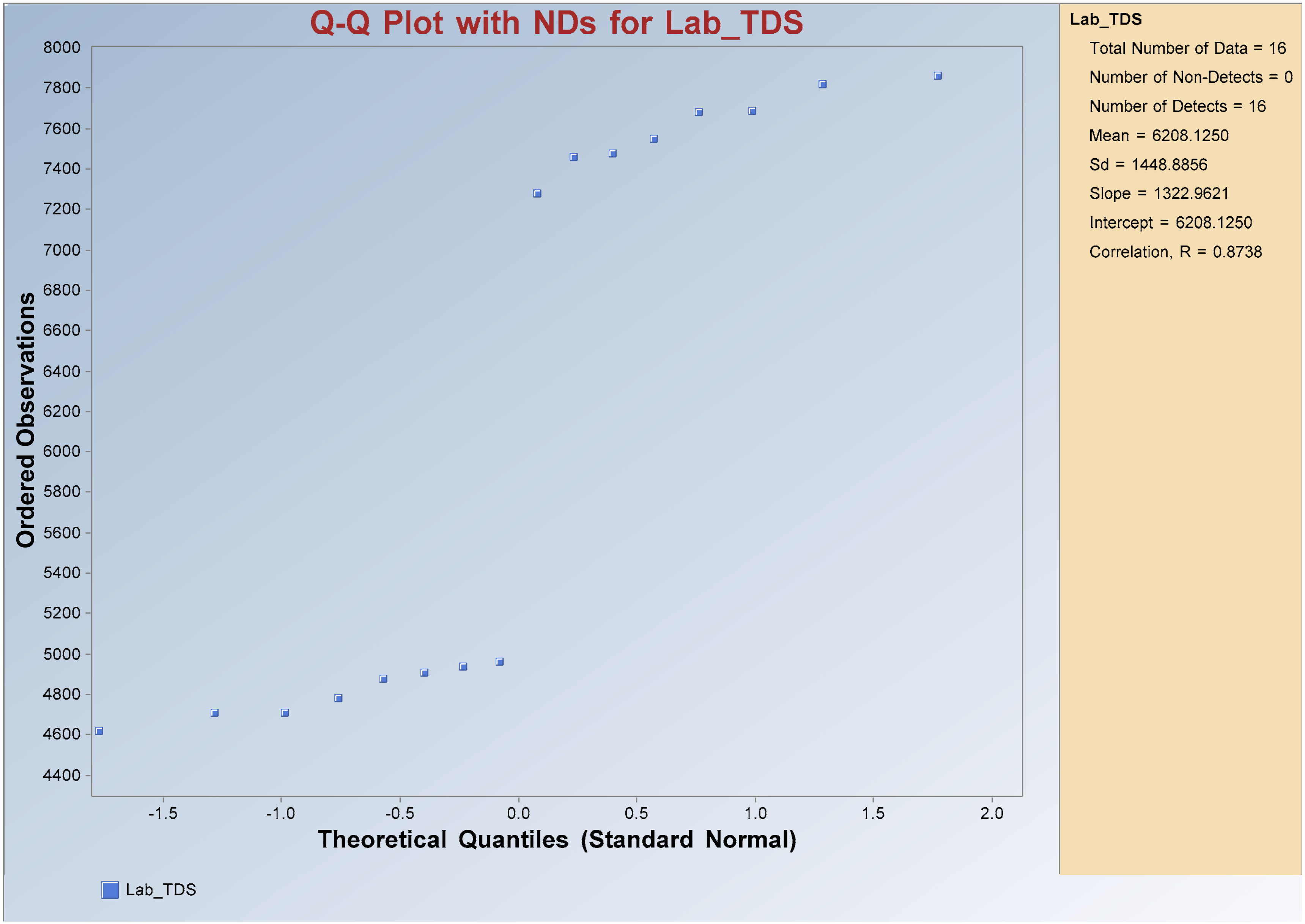
Probability Plot of Chloroform in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.17

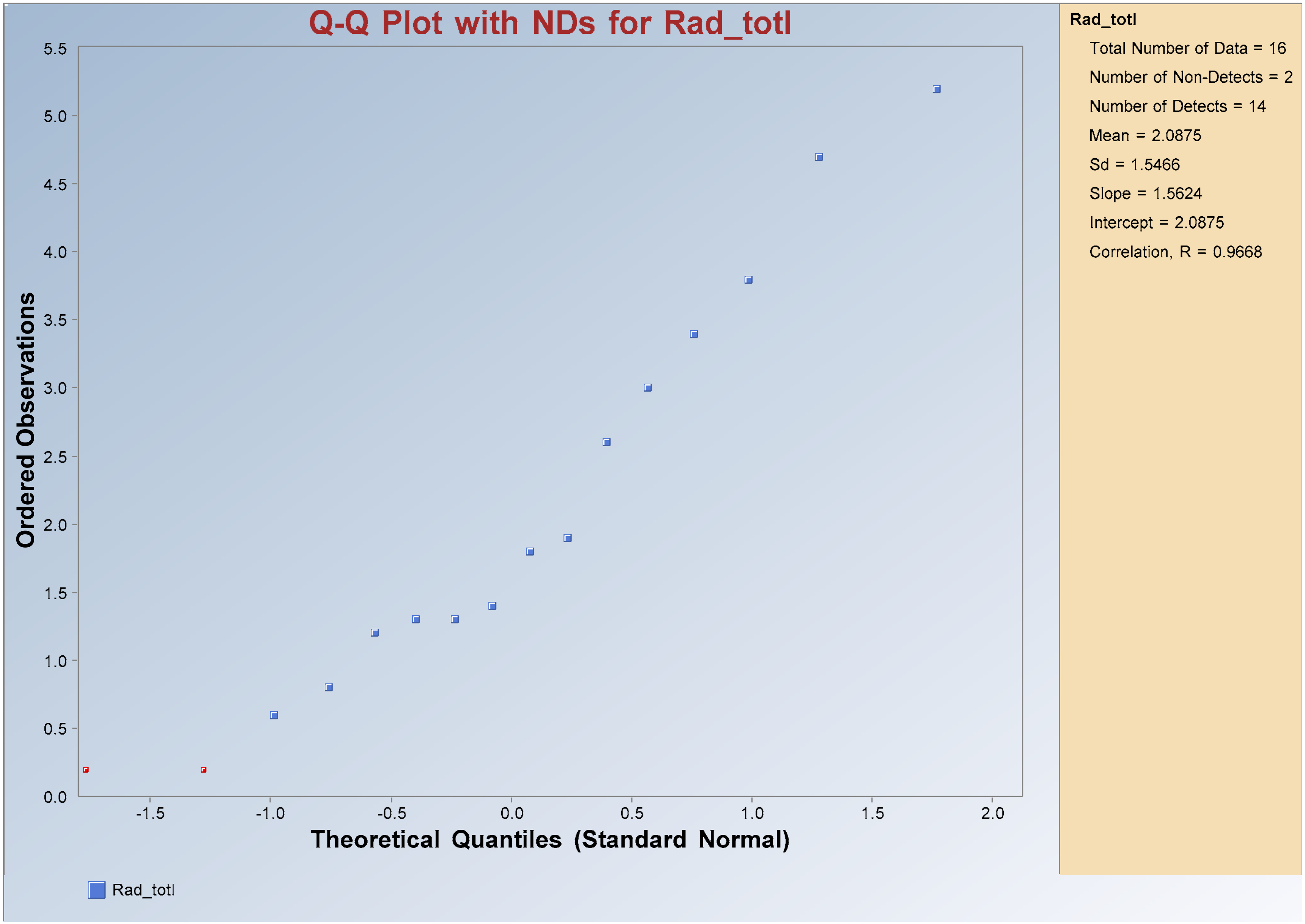
Probability Plot of Total Dissolved Solids in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 2.18

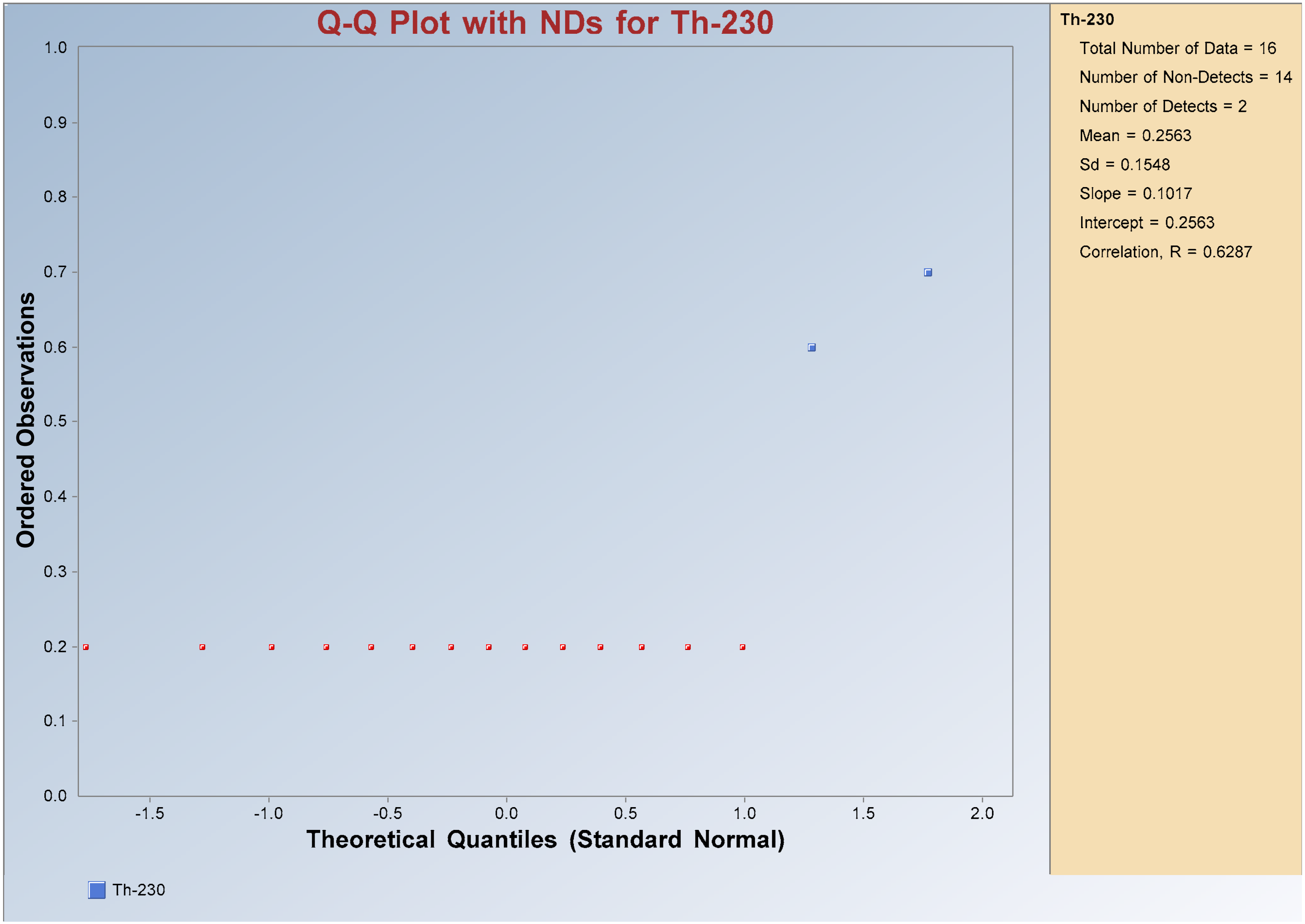
Probability Plot of Total Radium in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

GRAPH B 2.19

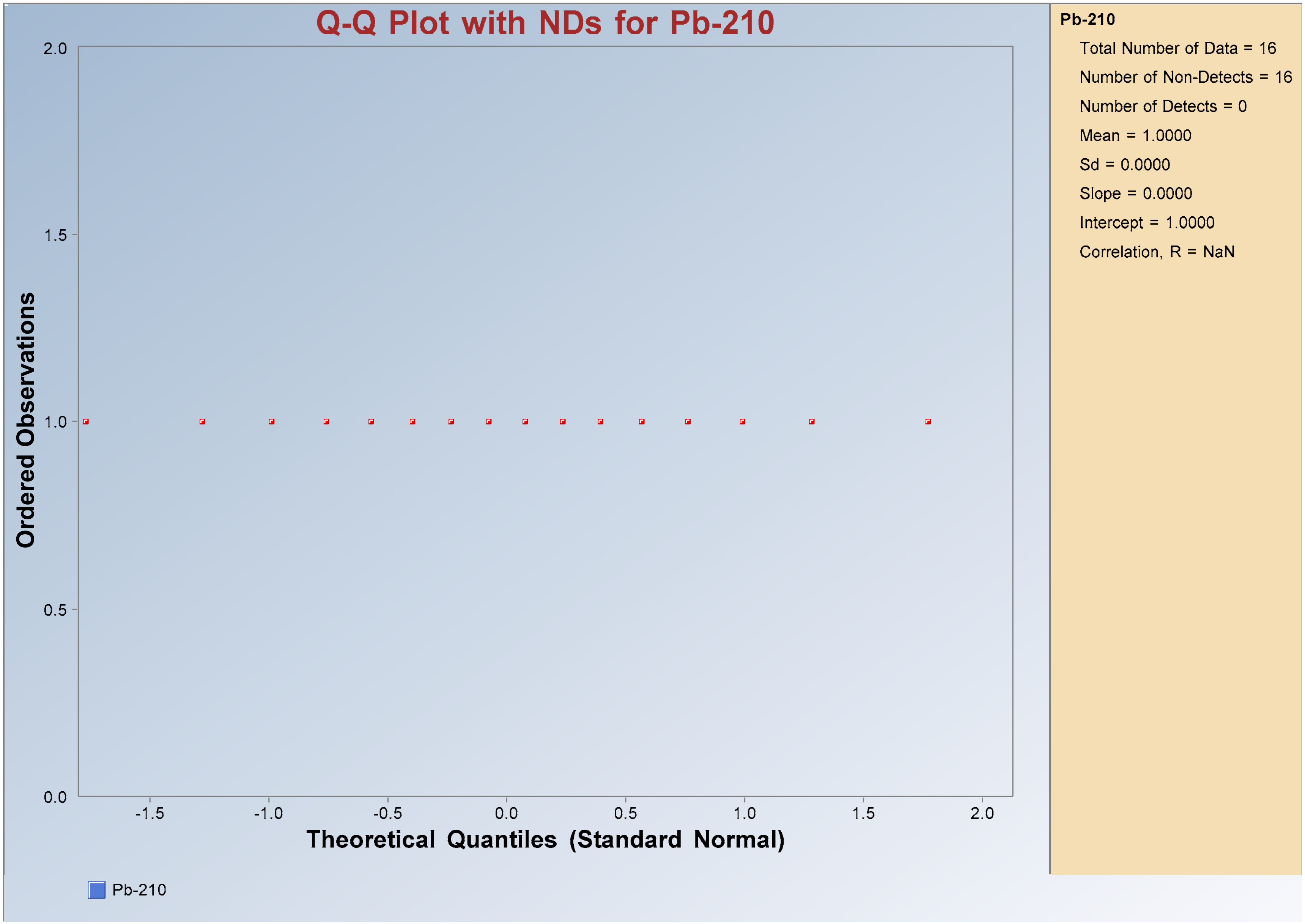
Probability Plot of Thorium-230 in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

GRAPH B 2.20

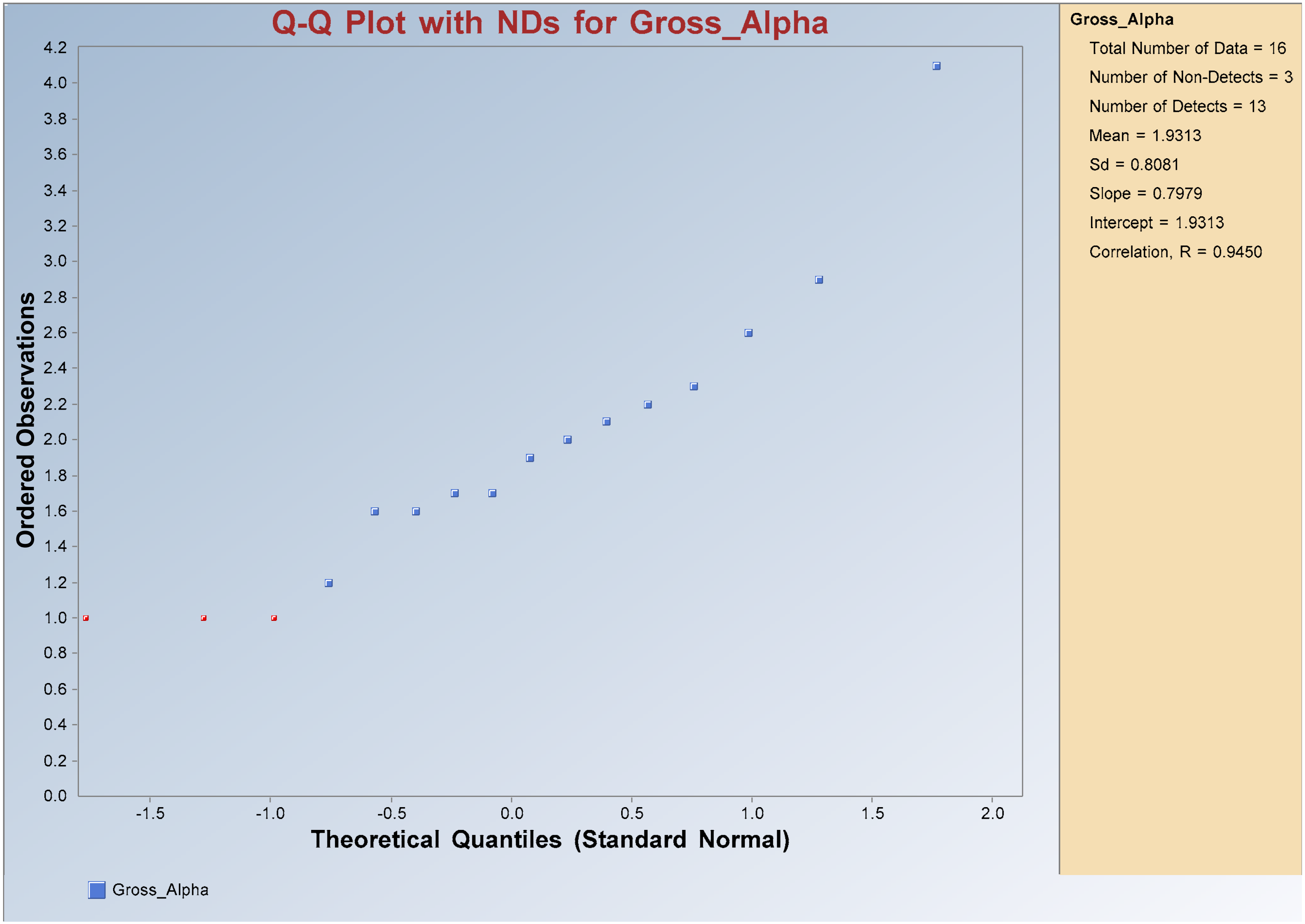
Probability Plot of Lead-210 in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

GRAPH B 2.21

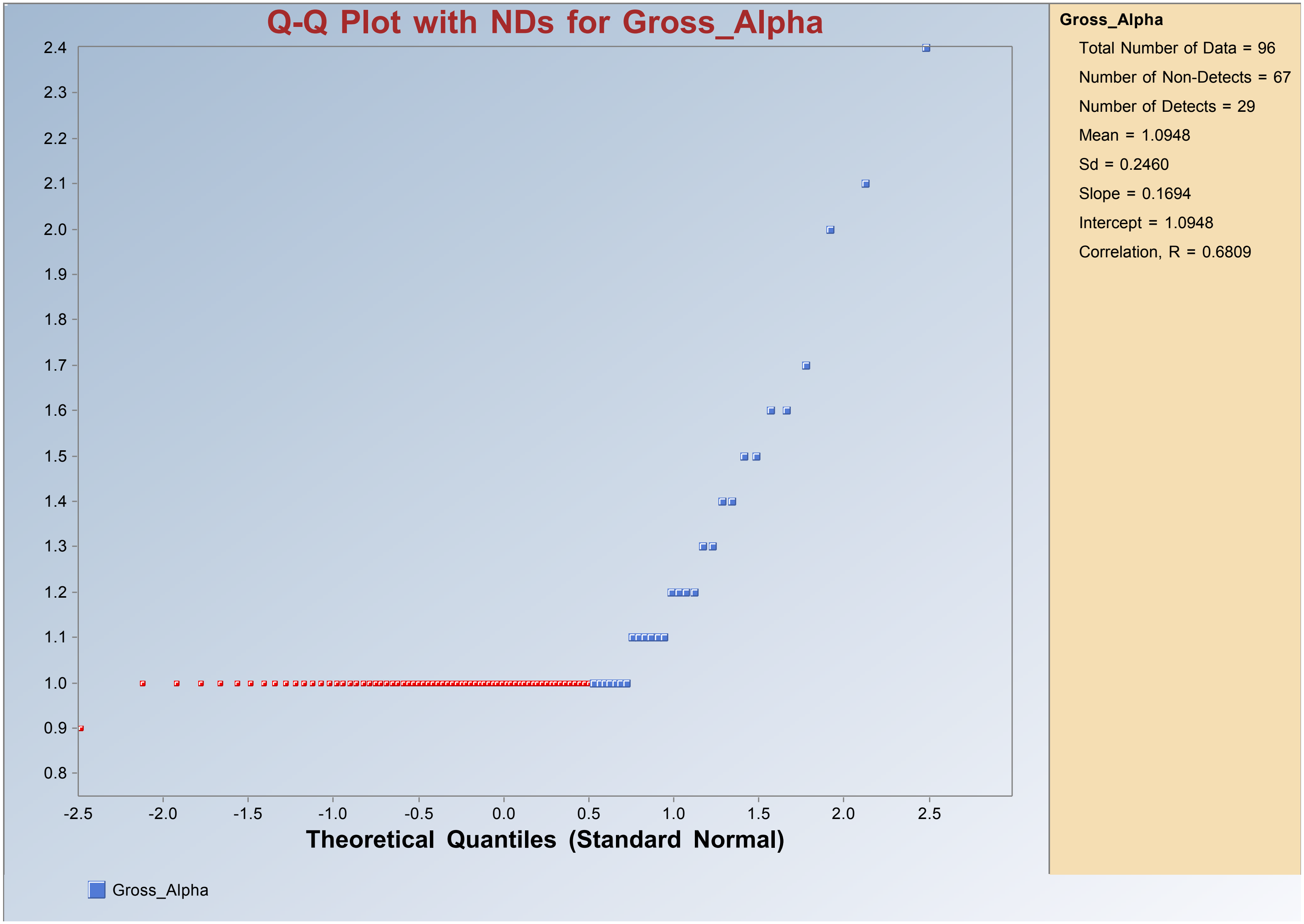
Probability Plot of Gross Alpha in Zone 1 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

GRAPH B 1.21

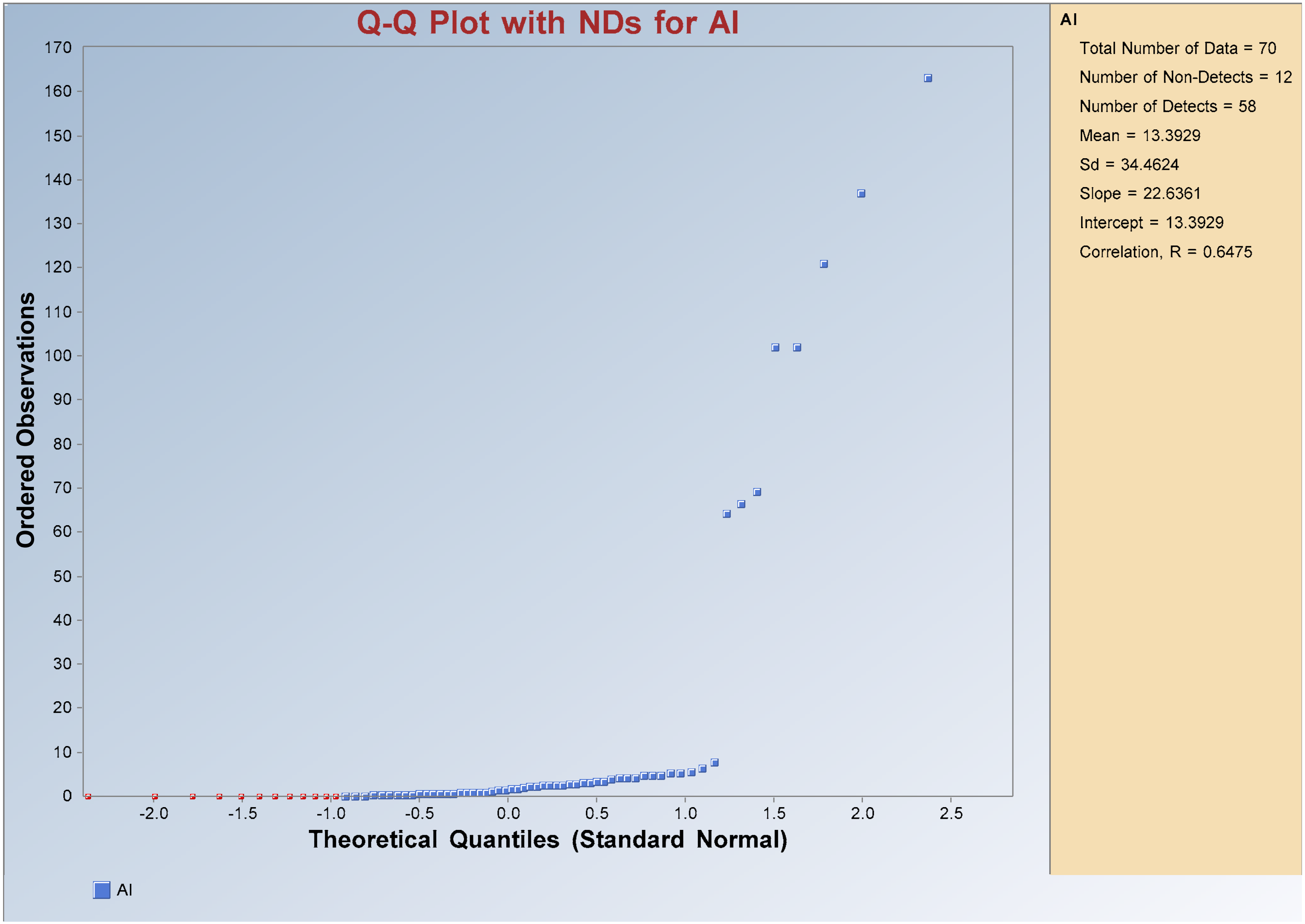
Probability Plot of Gross Alpha in Southwest Alluvium Impacted Groundwater, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

GRAPH B 3.1

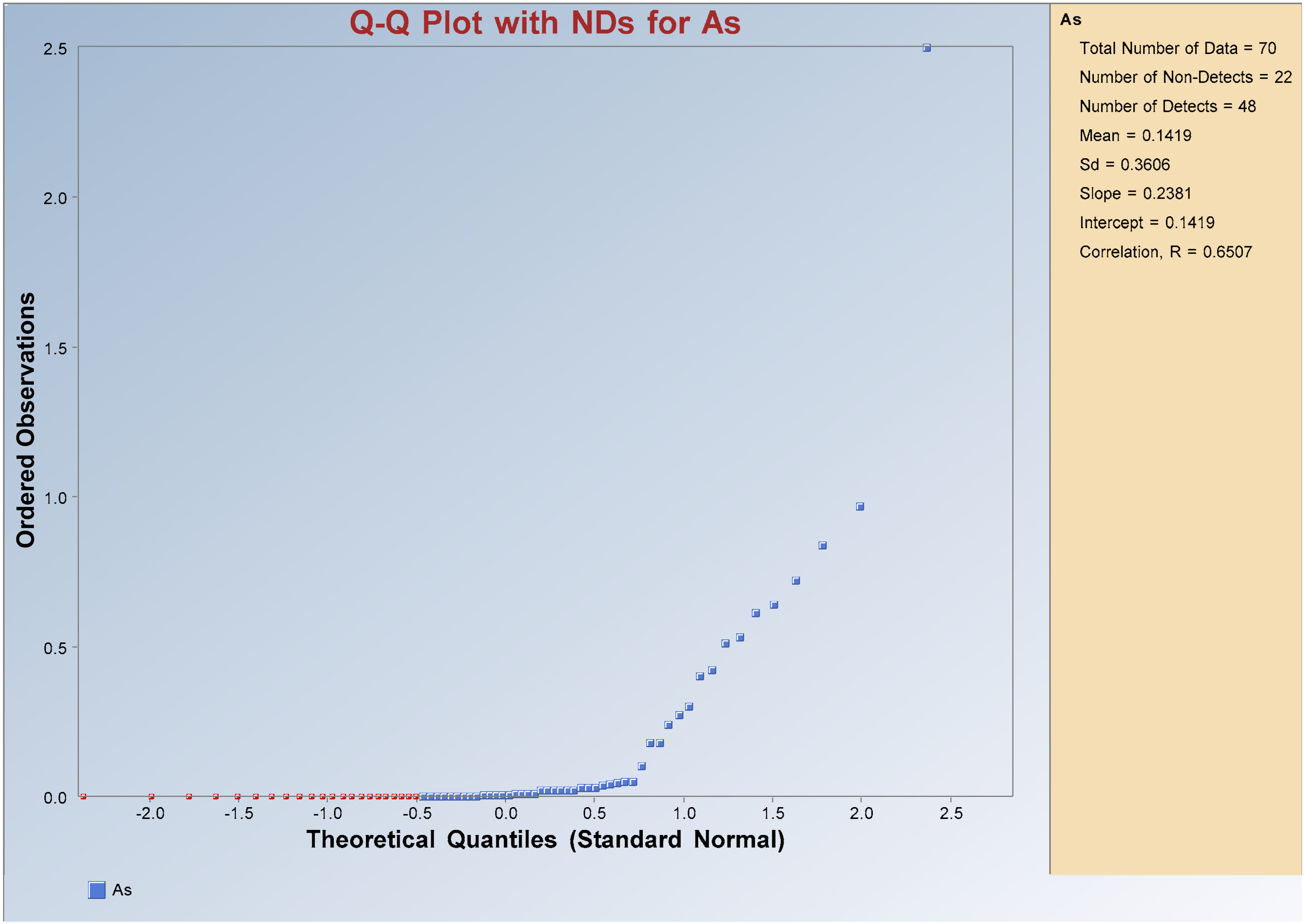
Probability Plot of Aluminum in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.2

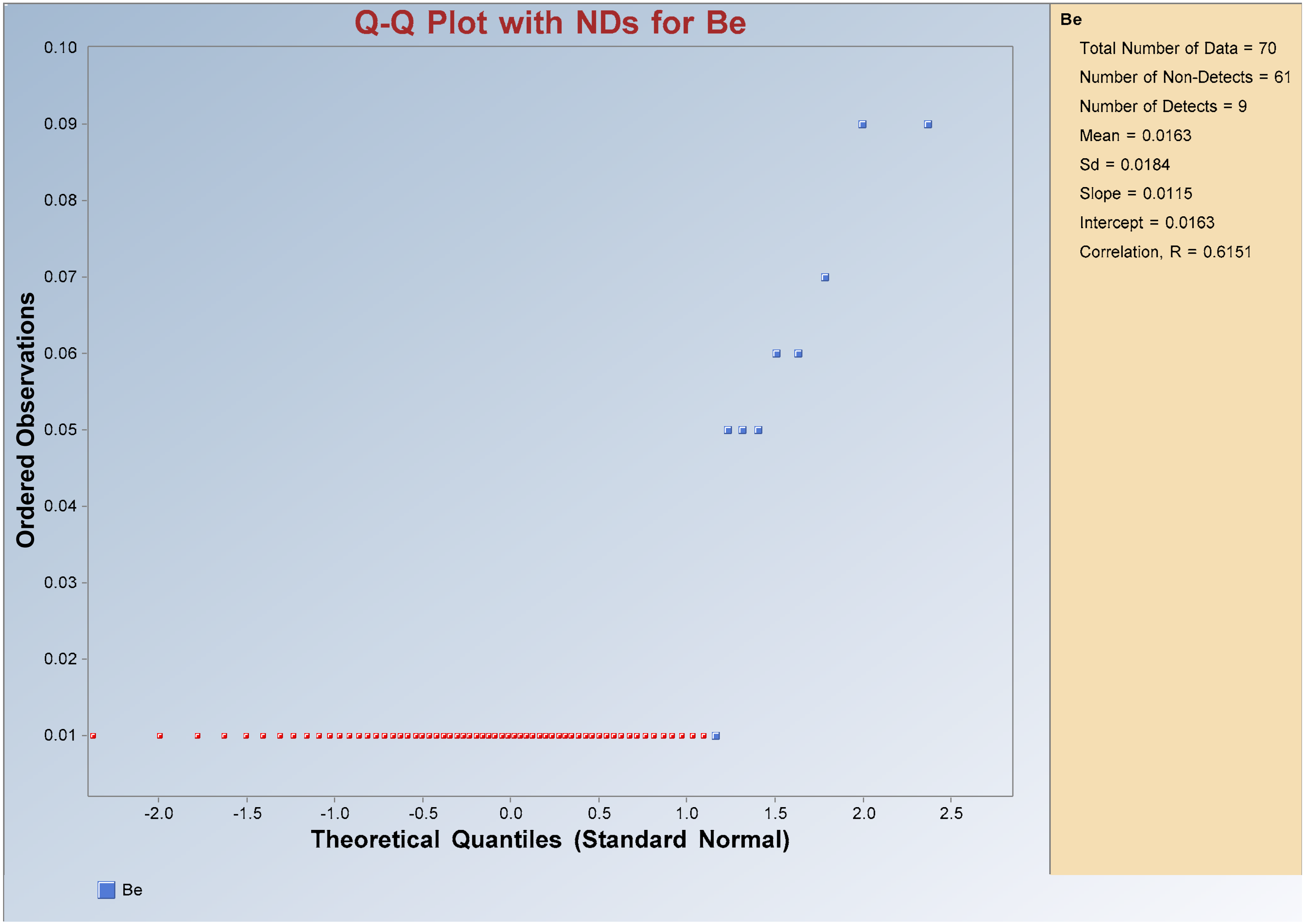
Probability Plot of Arsenic in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.3

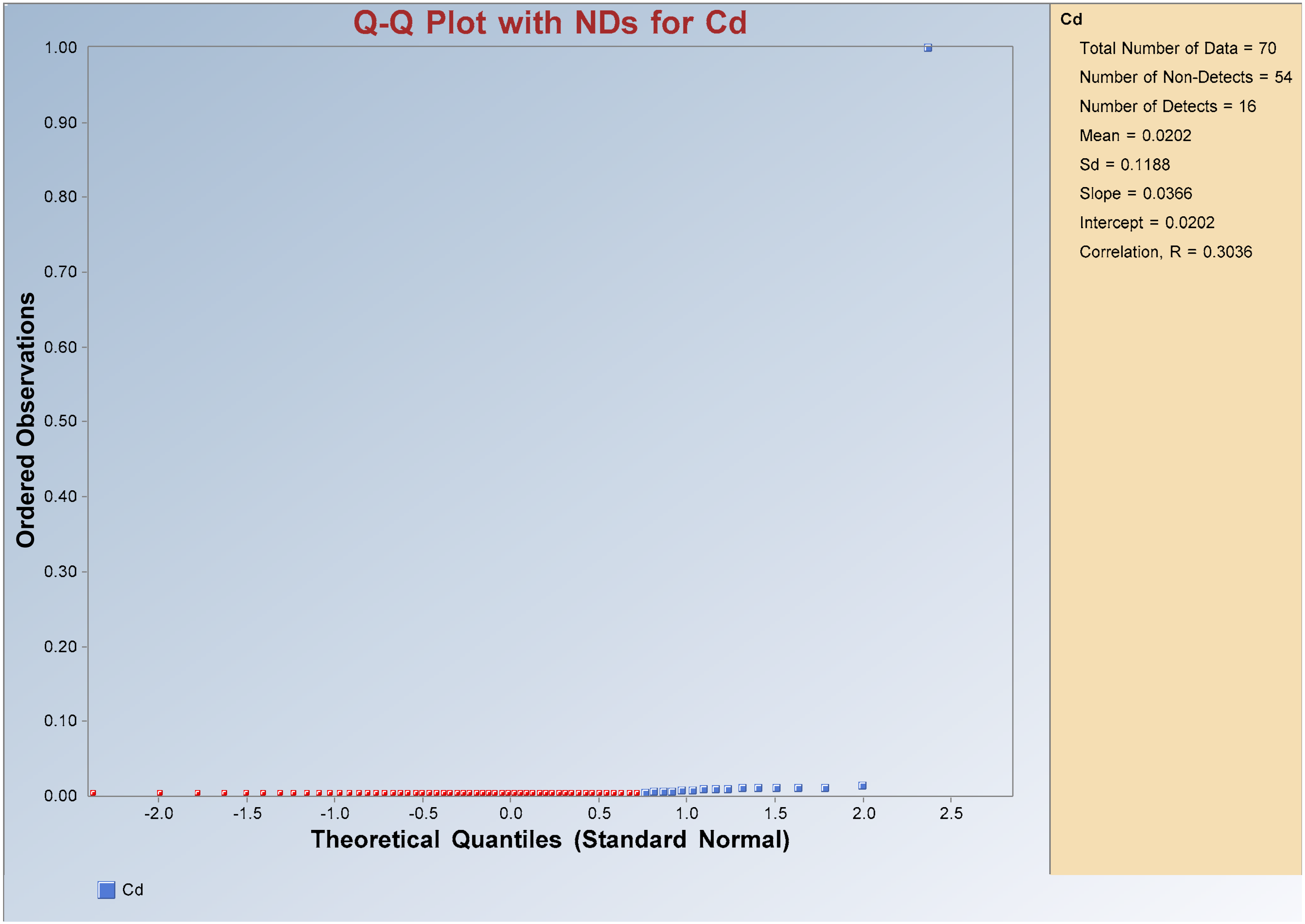
Probability Plot of Beryllium in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.4

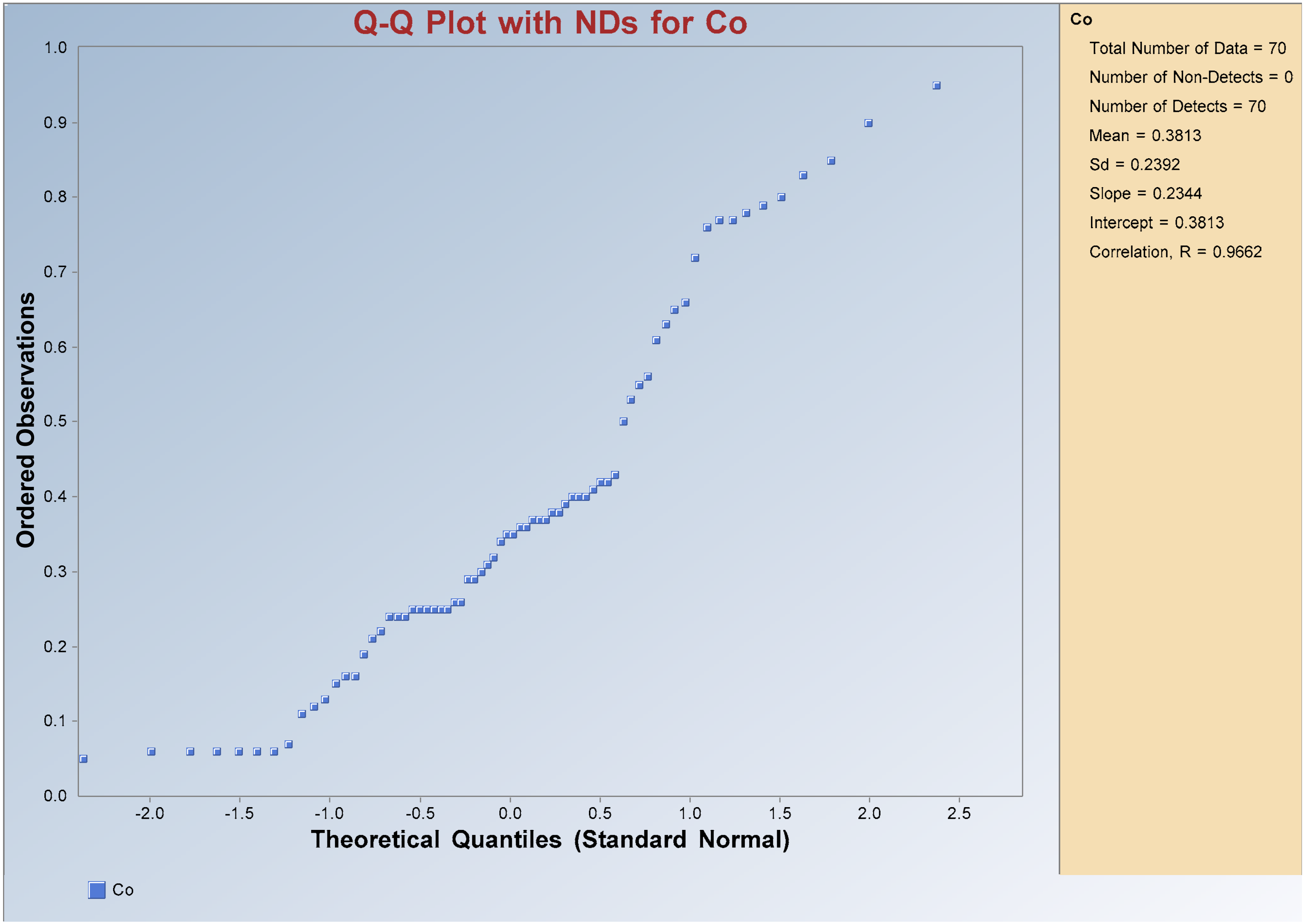
Probability Plot of Cadmium in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.5

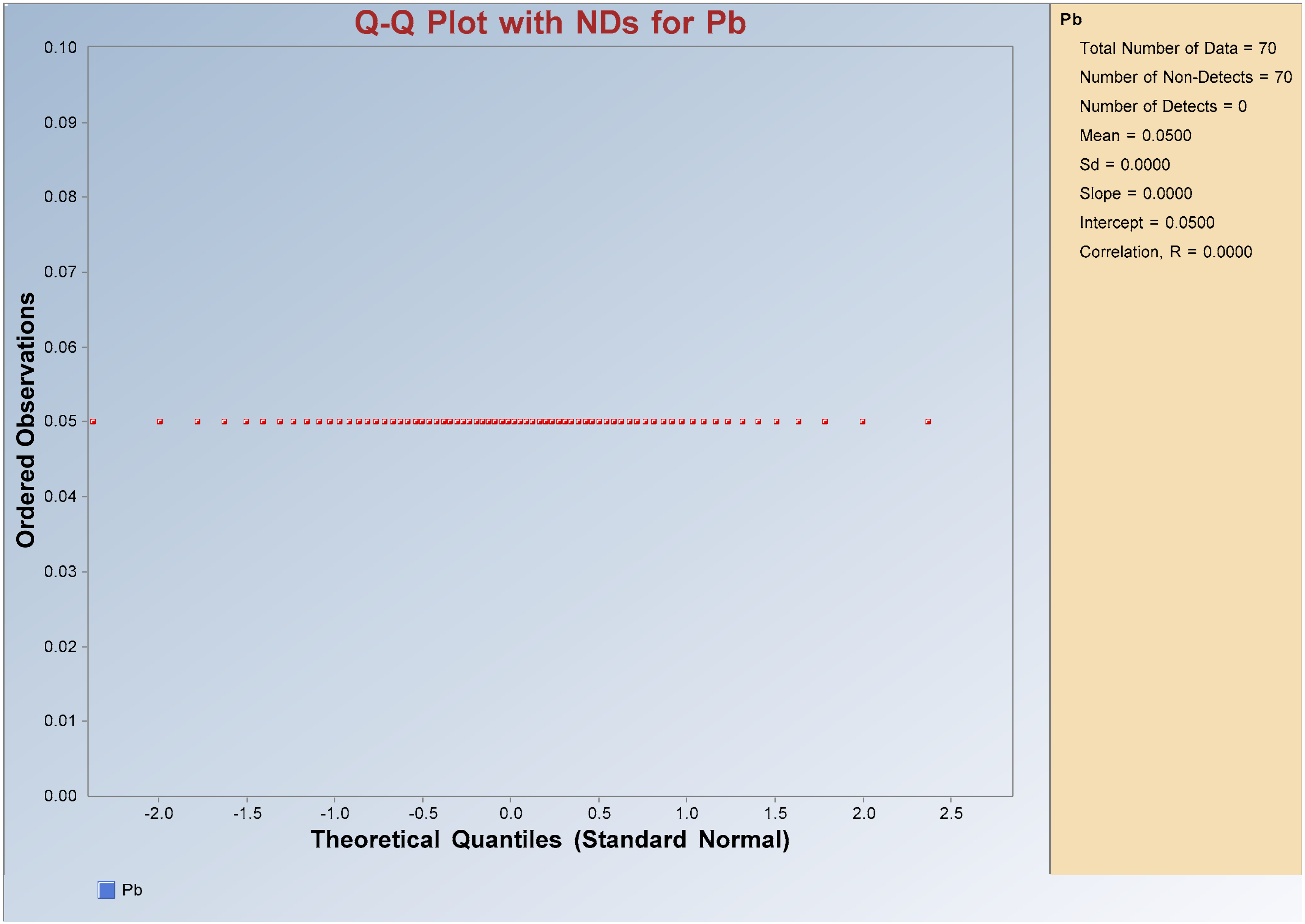
Probability Plot of Cobalt in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.6

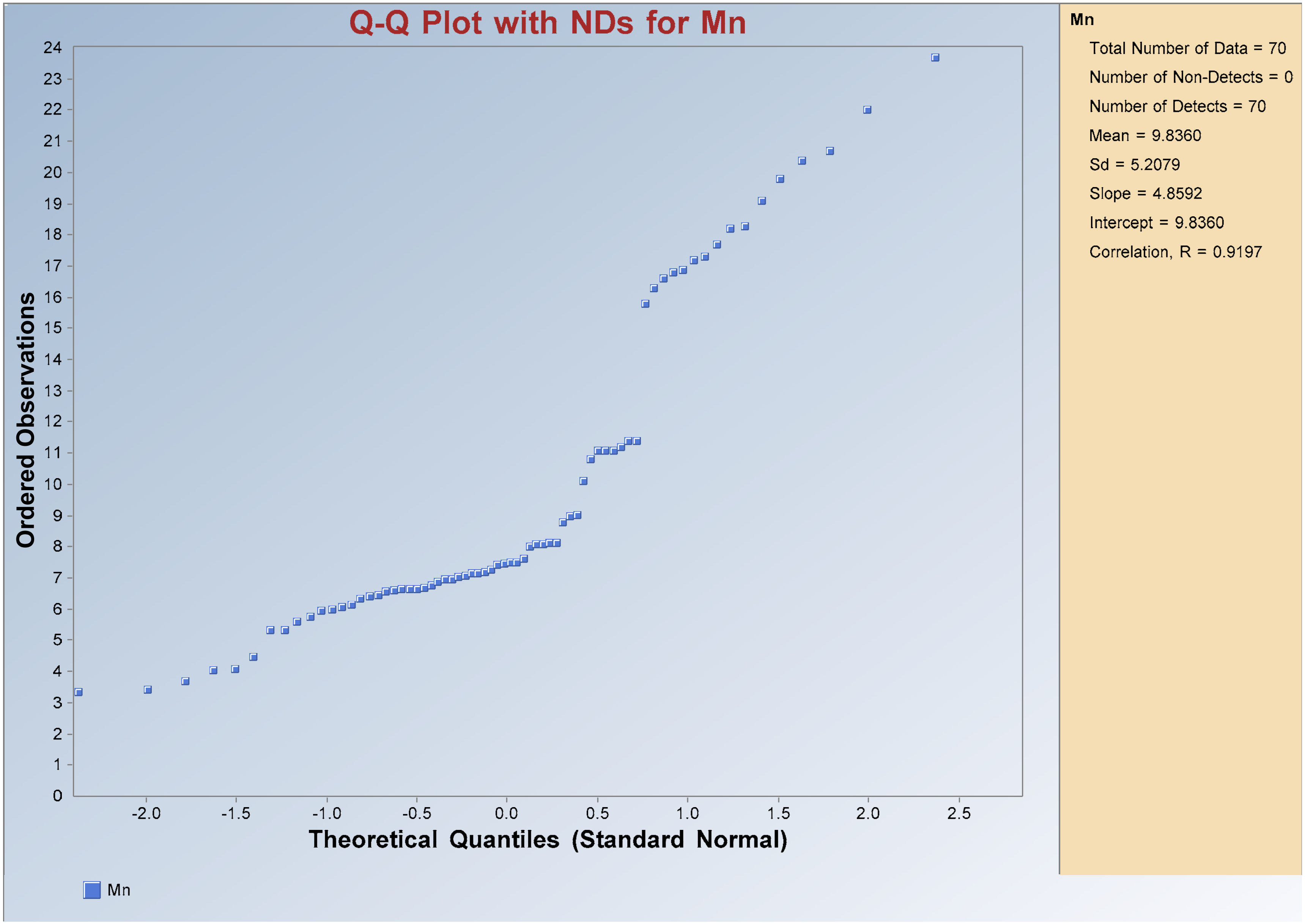
Probability Plot of Lead in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.7

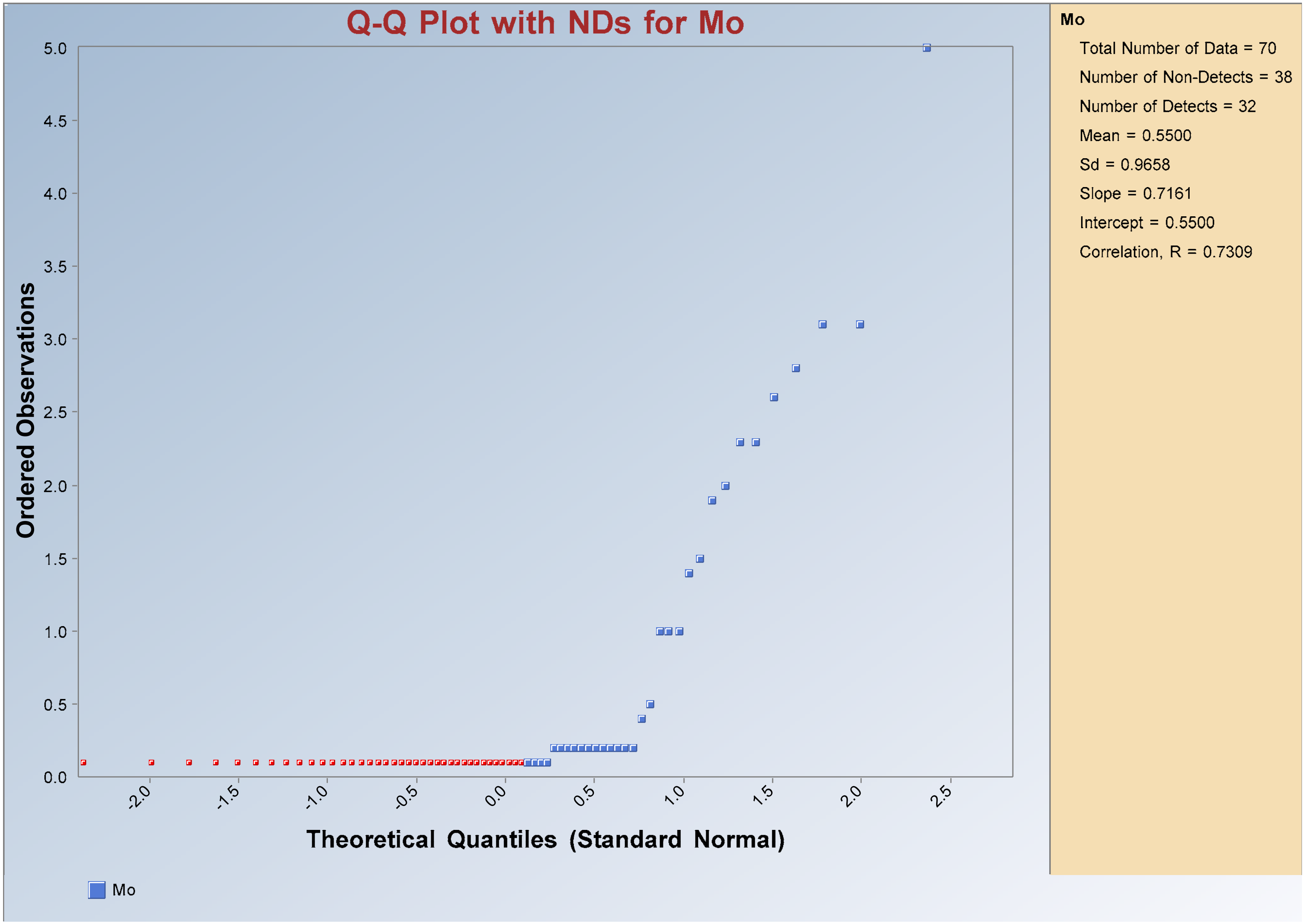
Probability Plot of Manganese in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.8

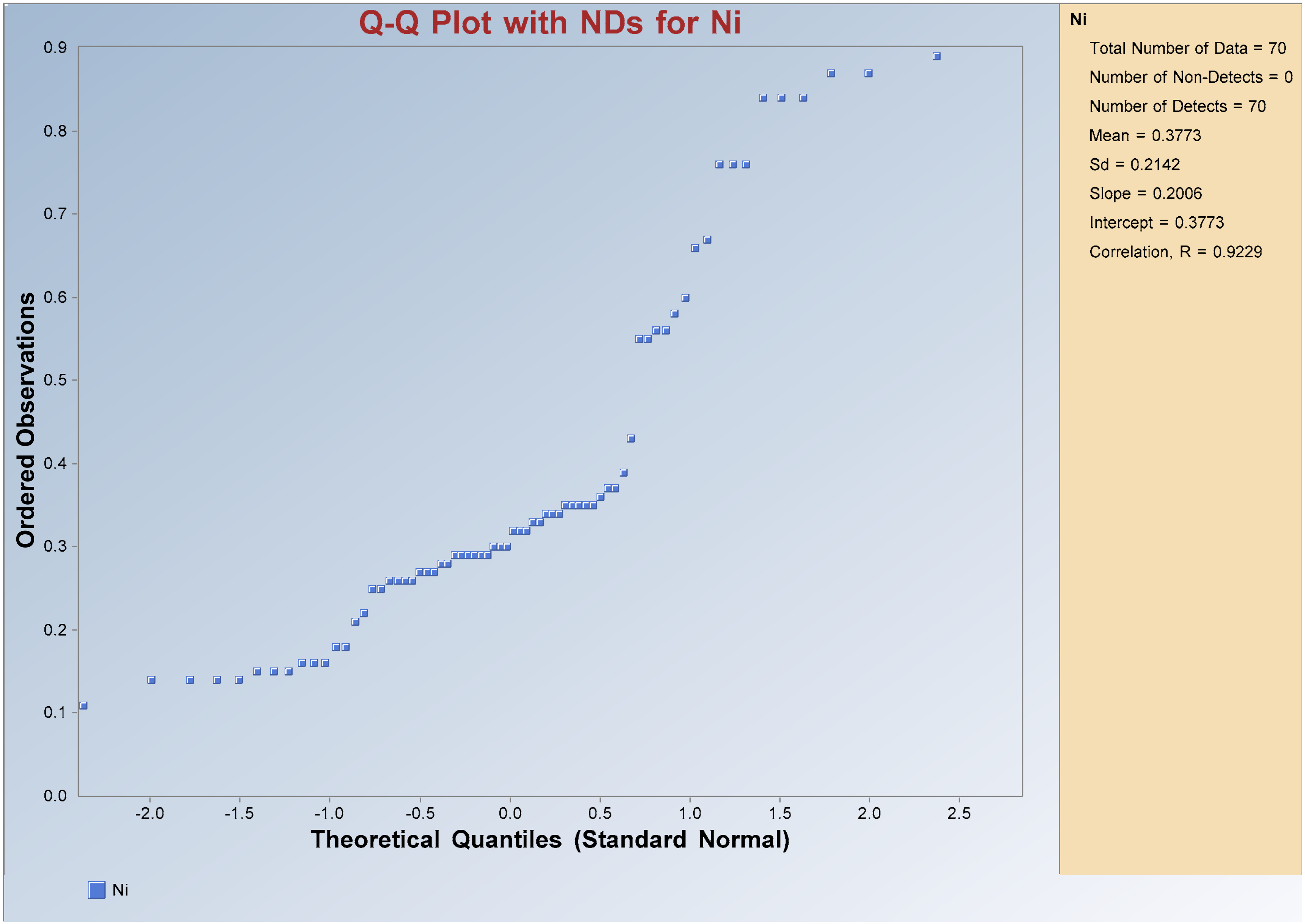
Probability Plot of Molybdenium in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.9

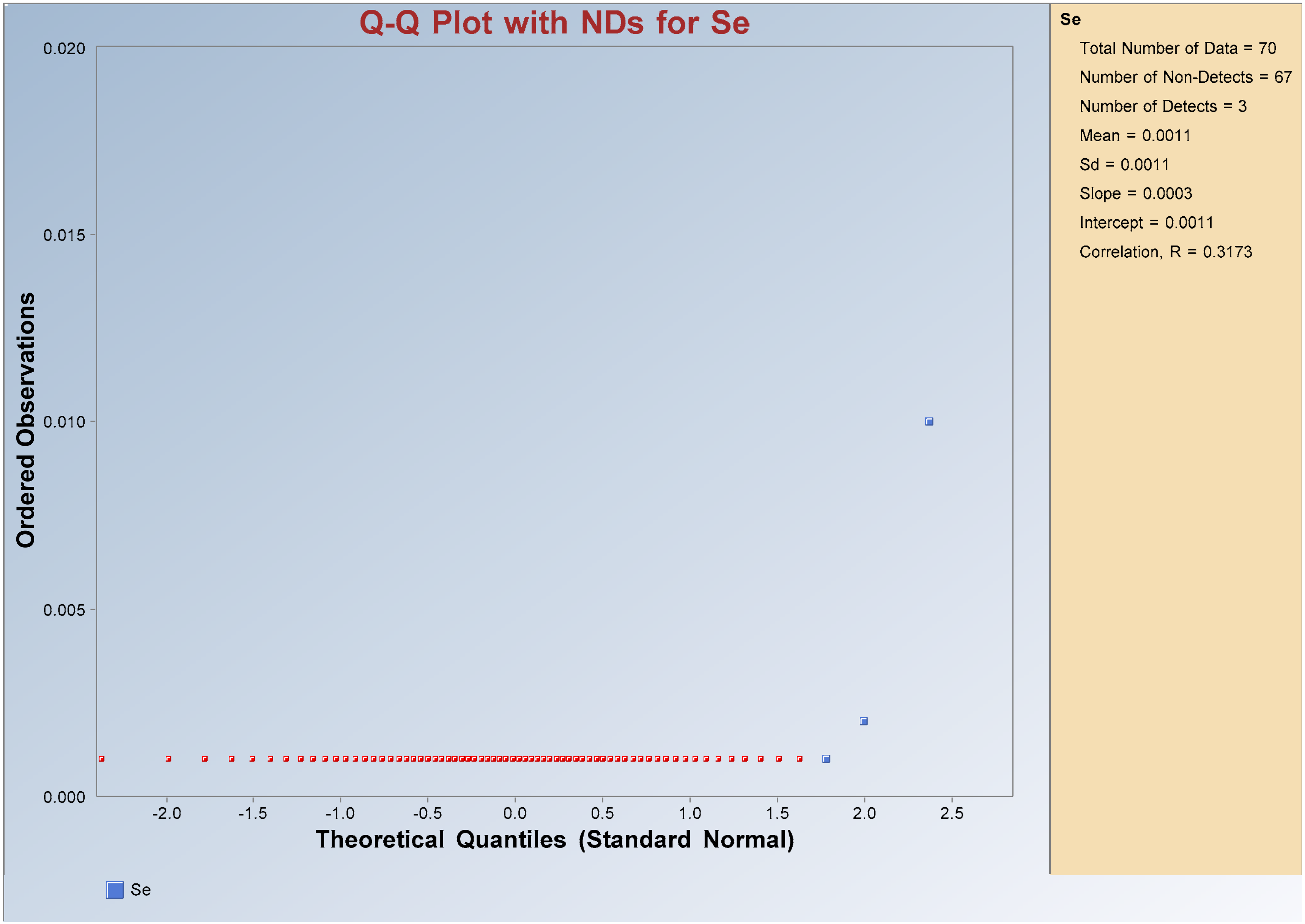
Probability Plot of Nickel in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.10

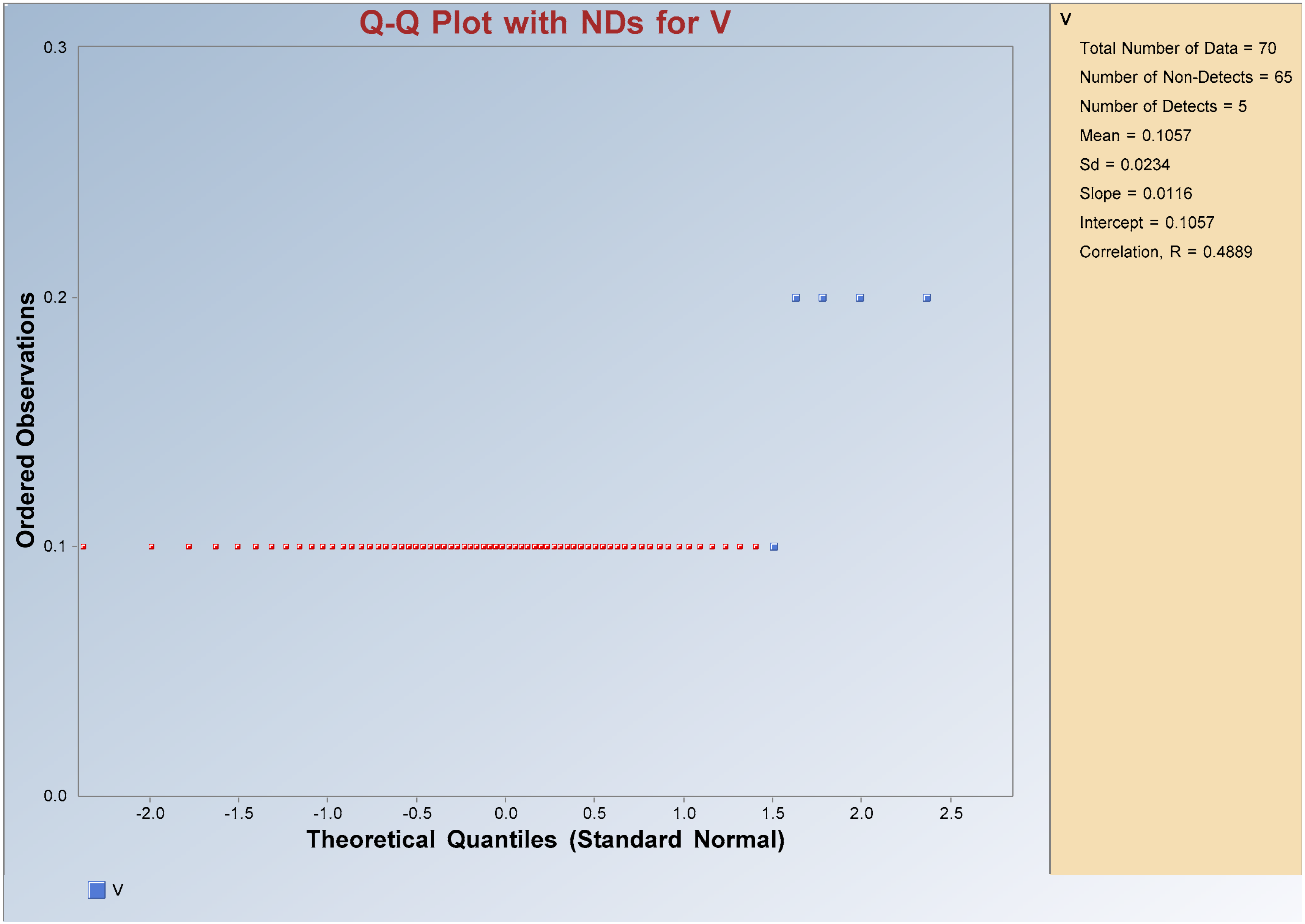
Probability Plot of Selenium in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.11

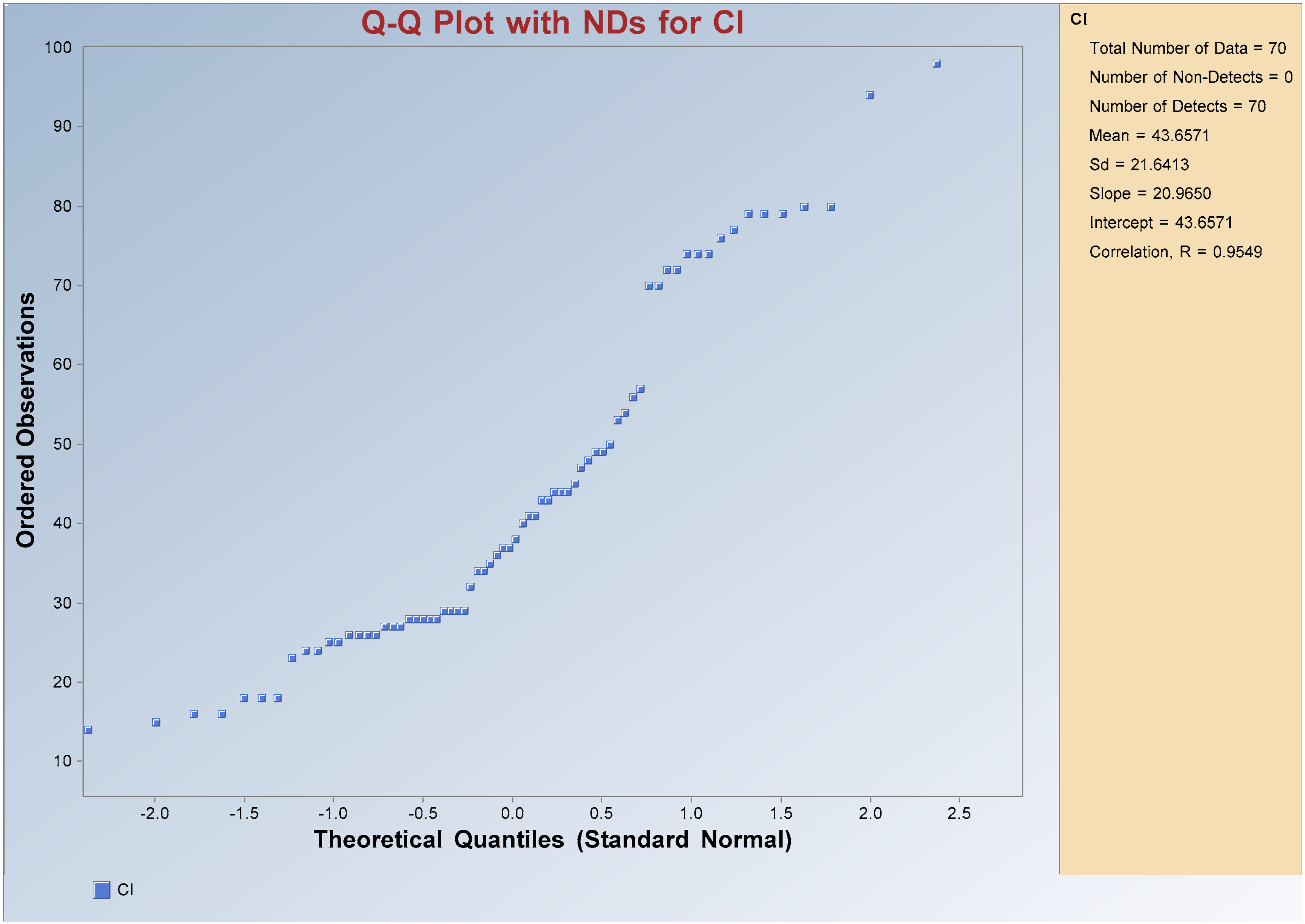
Probability Plot of Vanadium in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.12

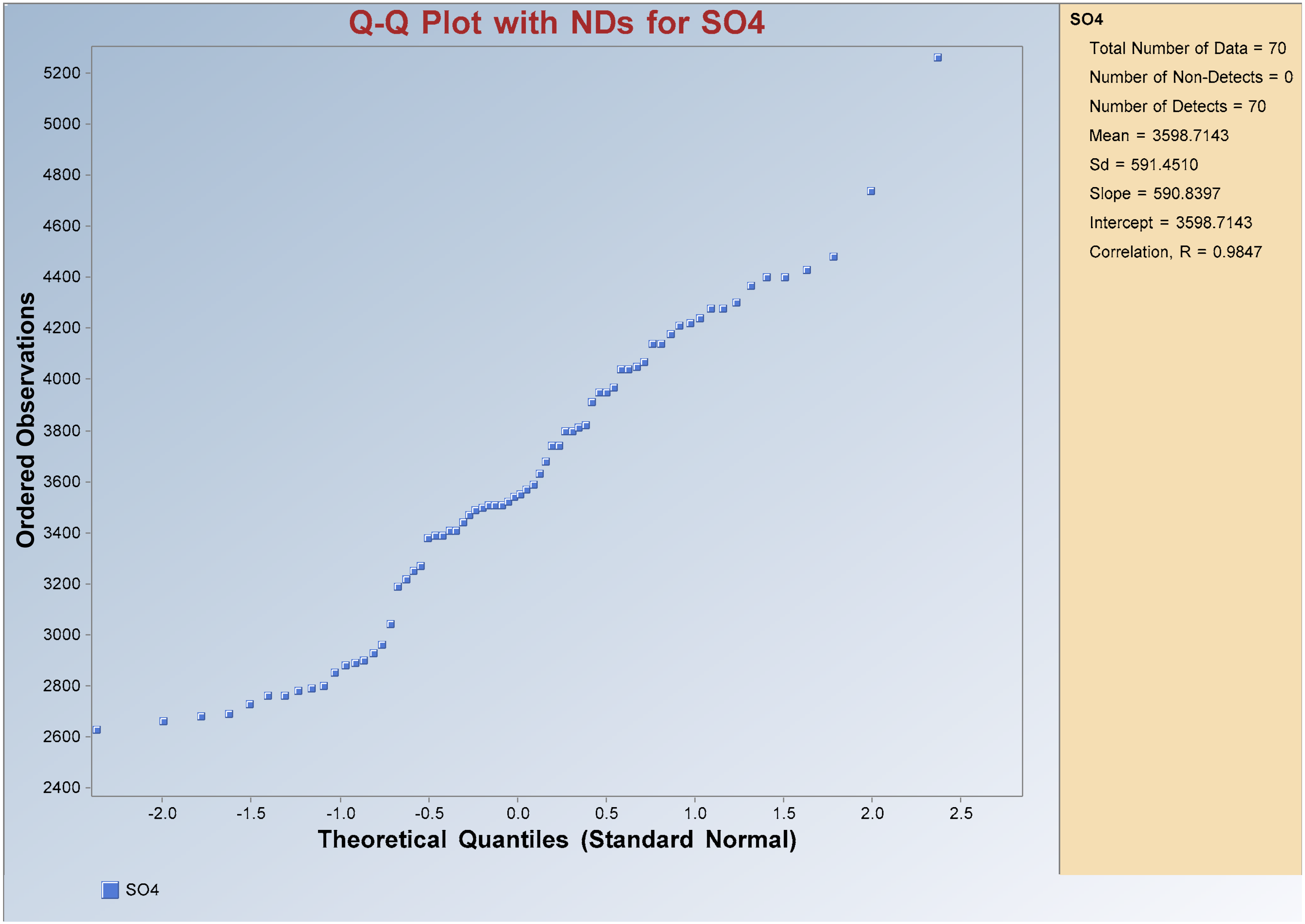
Probability Plot of Chloride in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.13

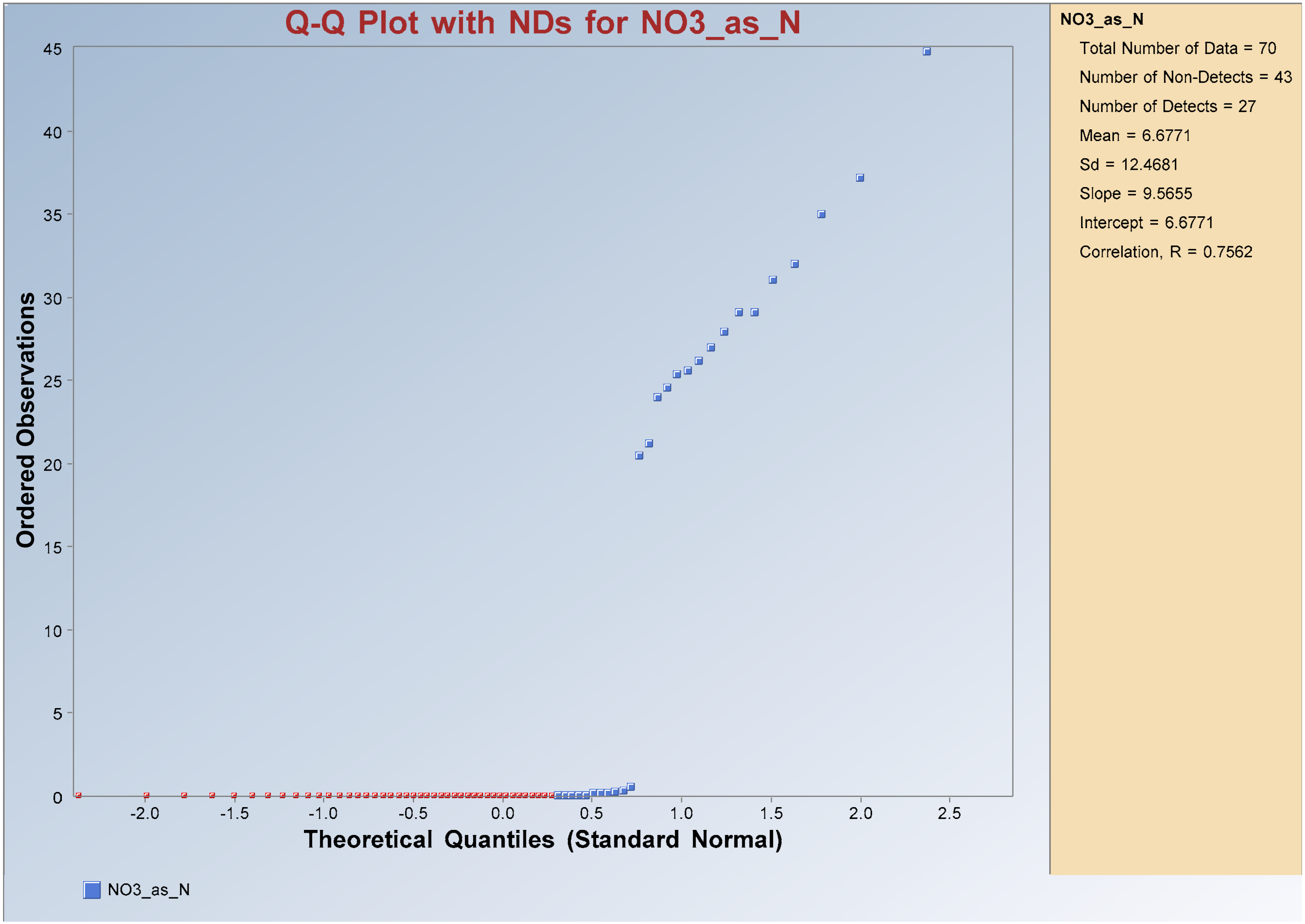
Probability Plot of Sulfate in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.14

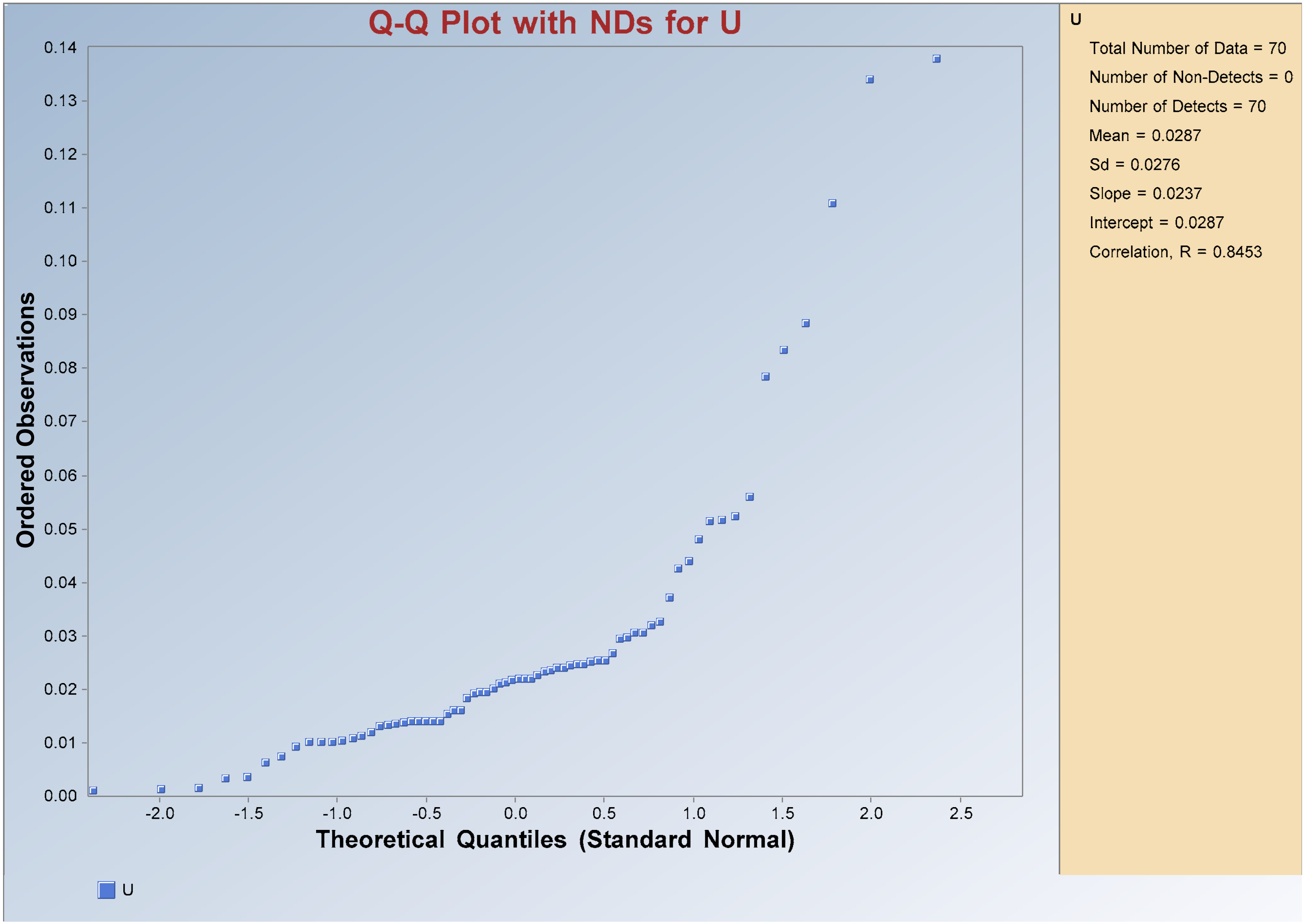
Probability Plot of Nitrate in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.15

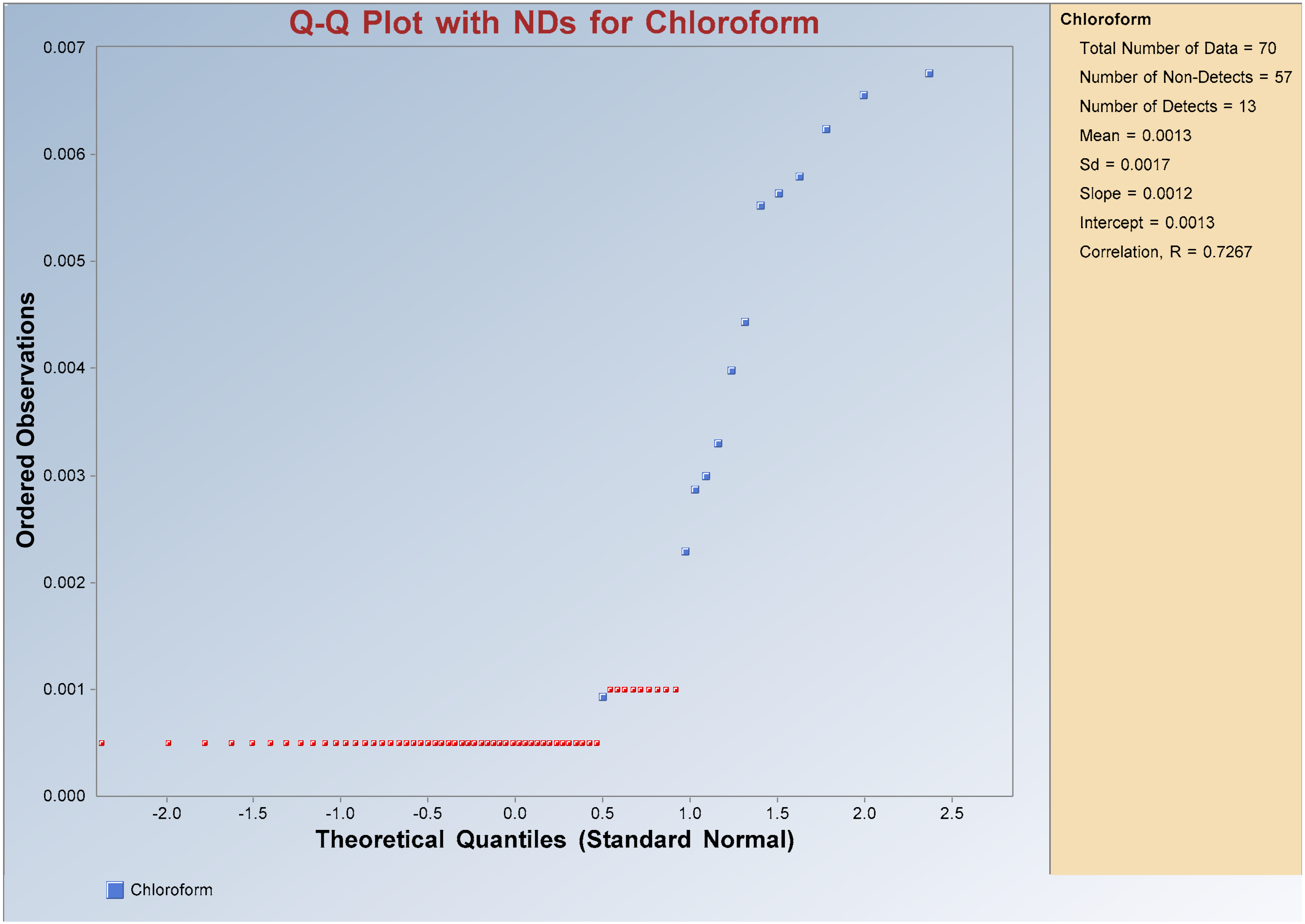
Probability Plot of Uranium in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.16

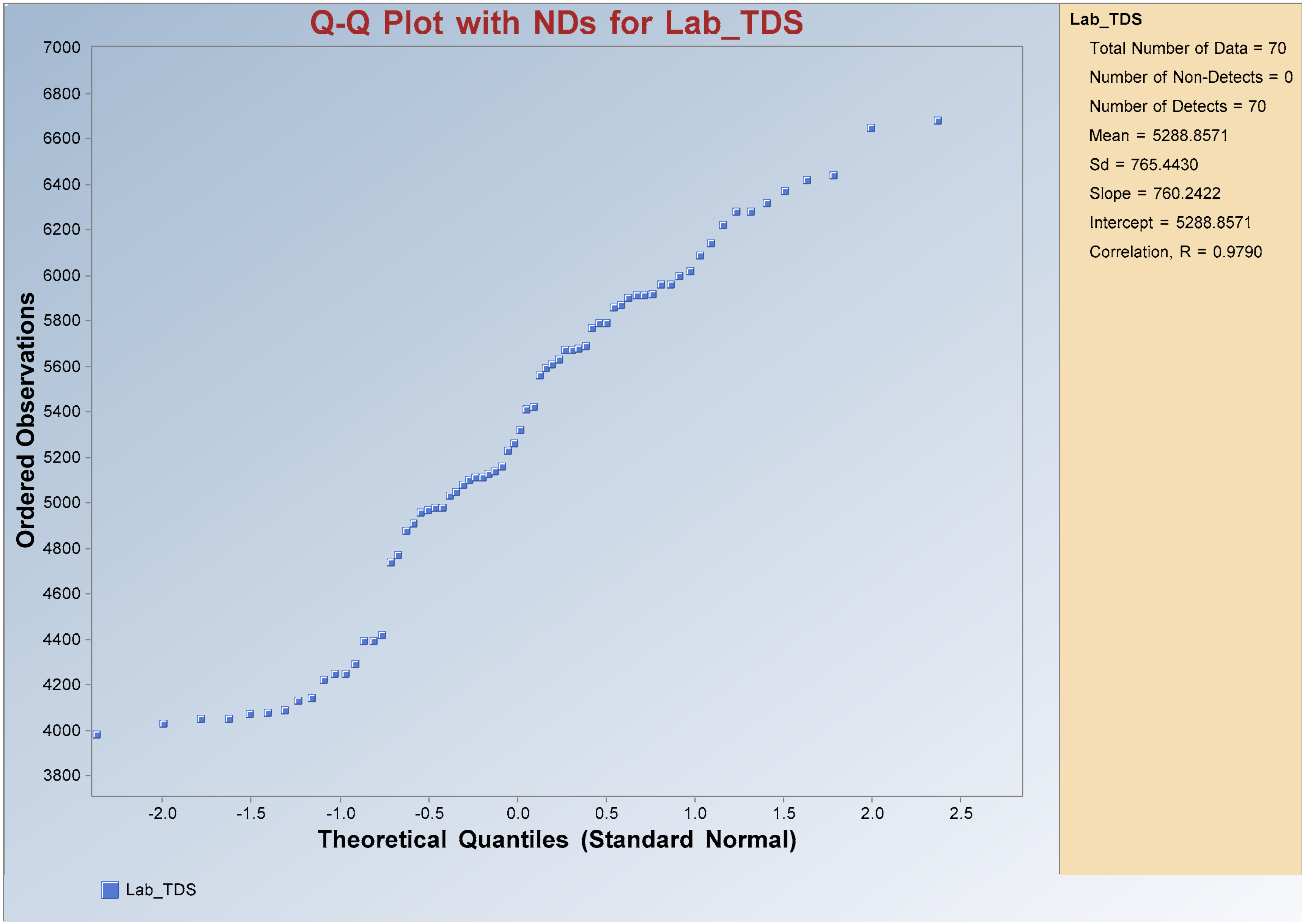
Probability Plot of Chloroform in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.17

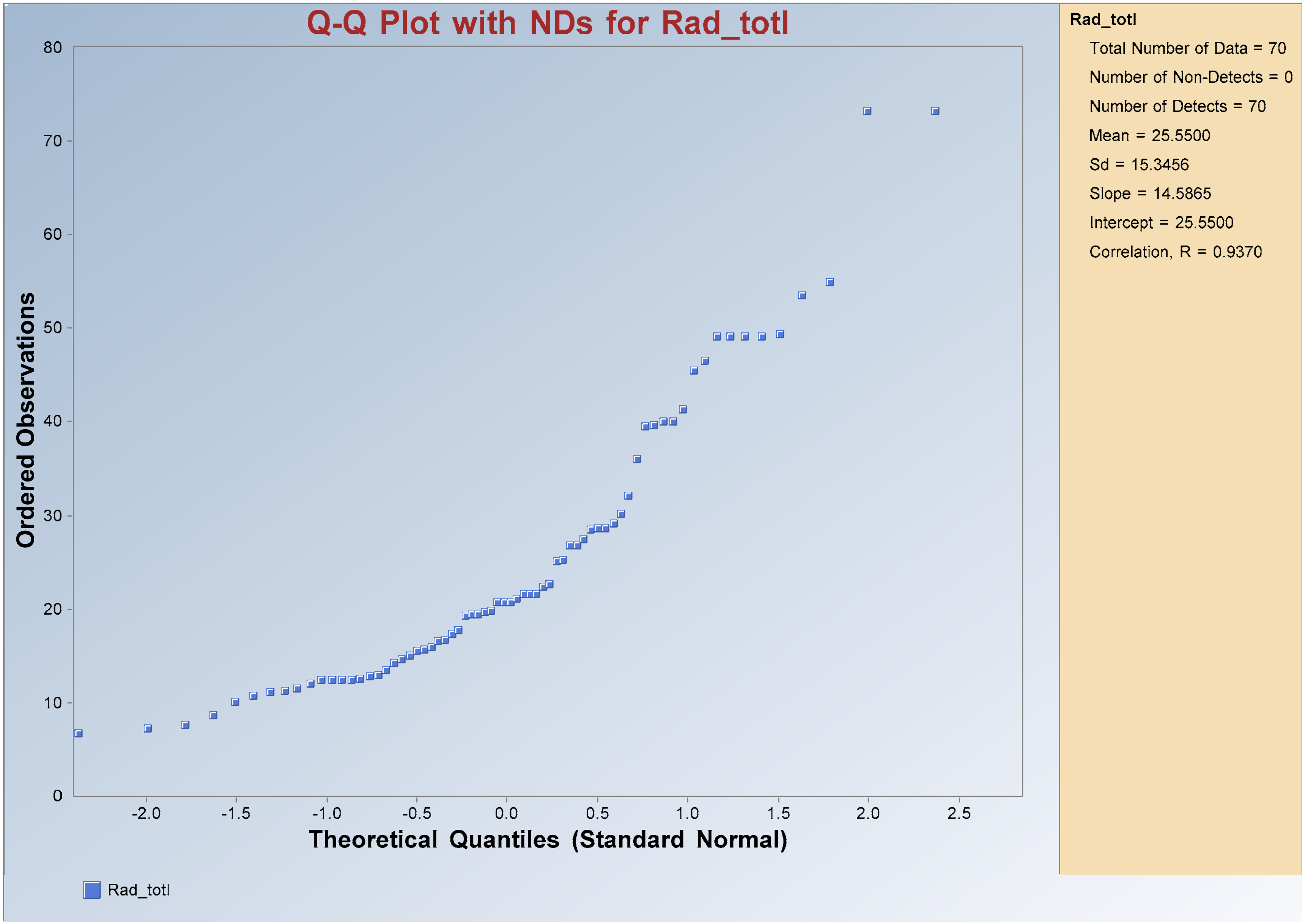
Probability Plot of Total Dissolved Solids in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in milligrams per liter)

GRAPH B 3.18

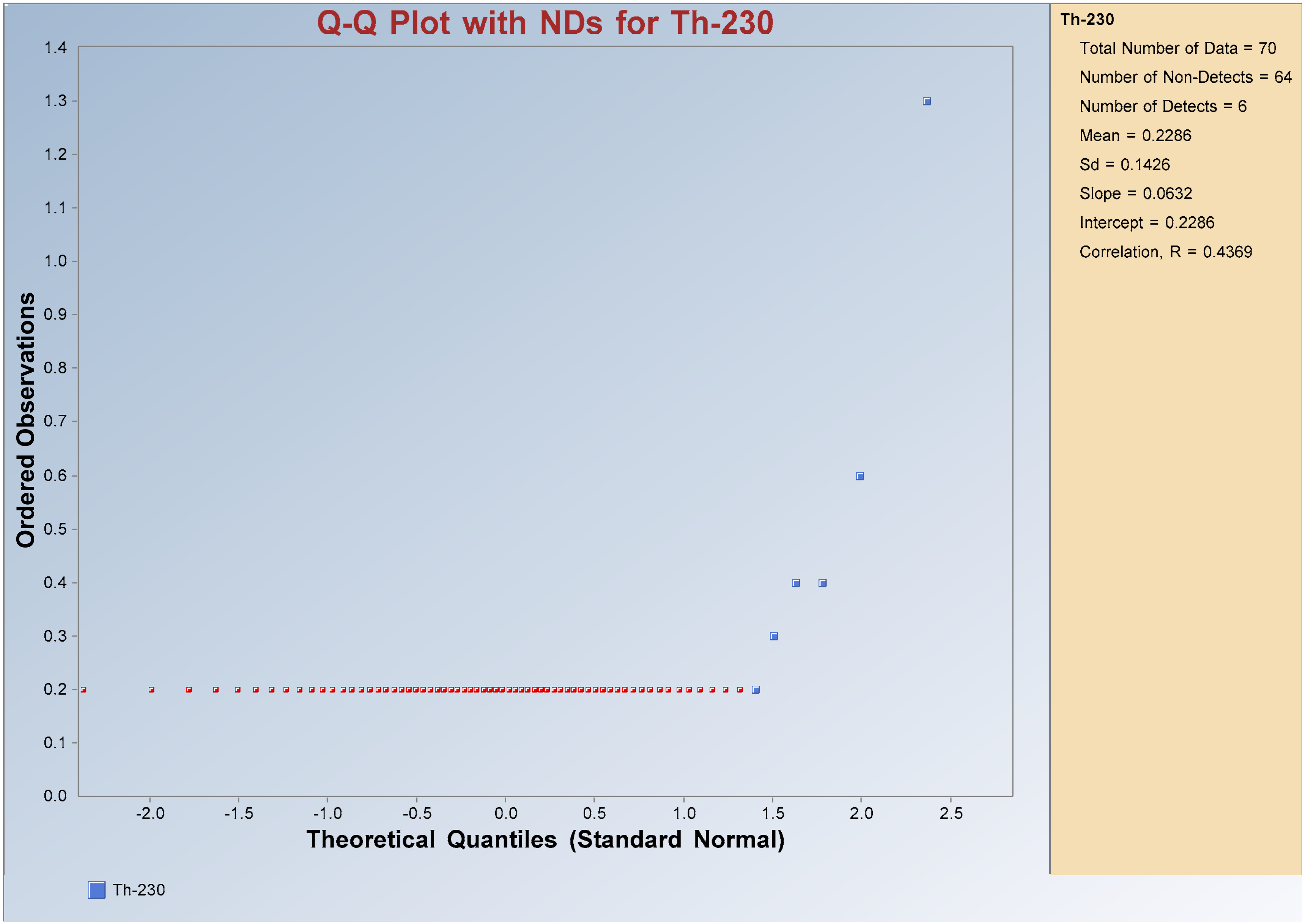
Probability Plot of Total Radium in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

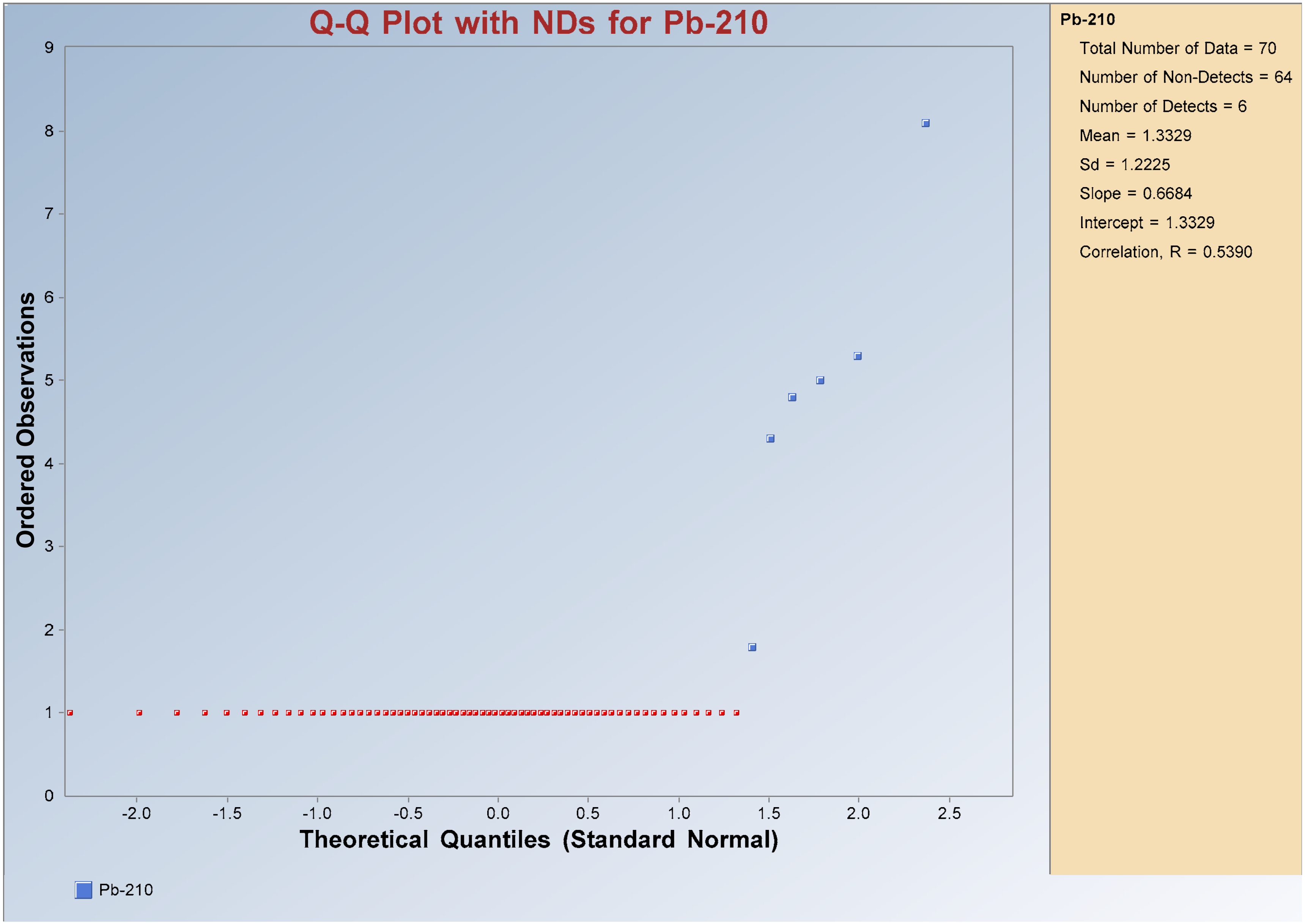
GRAPH B 3.19

Probability Plot of Thorium-230 in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

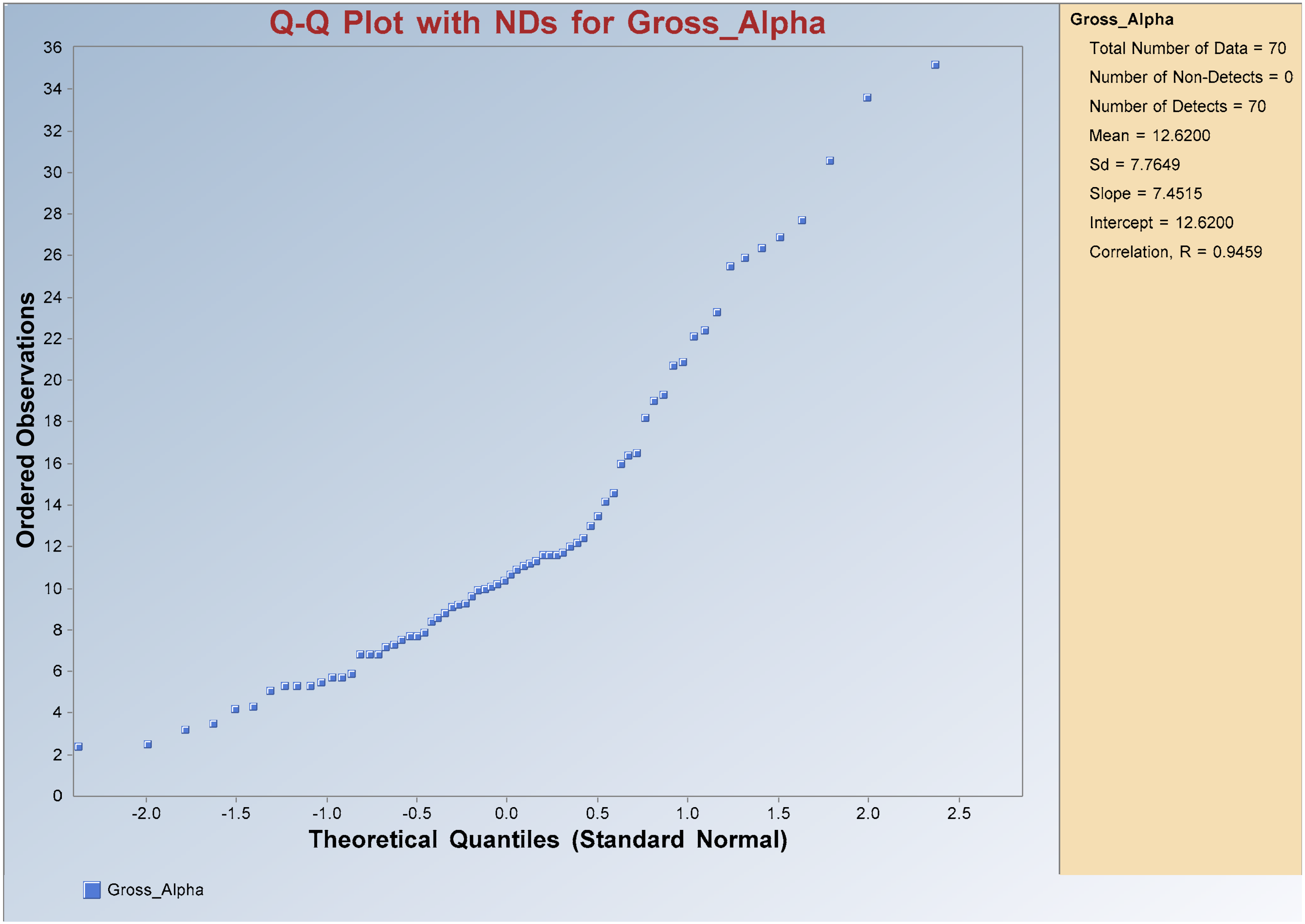
GRAPH B 3.20
Probability Plot of Lead-210 in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

GRAPH B 3.21

Probability Plot of Gross Alpha in Zone 3 Impacted Groundwater outside of Section 2, 3rd Qtr. 2006 - 2nd Qtr. 2008



(concentrations in pico curies per liter)

APPENDIX C

Revised Submittal – Calculation of Background Statistics with Comparison Values, UNC Church Rock Mill & Tailings Site, Church Rock, New Mexico. October 17, 2008

N.A. WATER SYSTEMS

This Submittal Delivered by Email Only

October 17, 2008

Ref. No: 56007746 GE Church Rock Project

Mr. Mark Purcell
Remedial Project Manager
U.S. Environmental Protection Agency
1445 Ross Ave., Suite 1200 (6SF-LP)
Dallas, TX 75202-2733

Re: Revised Submittal
Calculation of Background Statistics with Comparison Values
UNC Church Rock Mill & Tailings Site, Church Rock, New Mexico

Dear Mr. Mark Purcell:

N.A. Water Systems (N.A.WS) is pleased to provide this revised report regarding the calculation of background water statistics with comparison values for the UNC Church Rock Mill & Tailings Site in Church Rock, New Mexico. This report includes revisions to the August 26, 2008 submittal based on comments received from Dennis Beal of Science Applications International Corp. (Beal, SAIC, email communication, Sept. 19, 2008), and other reviewers (Mark Purcell, EPA, and Earle Dixon, NMED) during a teleconference of September 30, 2008.

Introduction

Calculations of background statistics have been completed for the Church Rock project. These calculations were made using results for COPCs (Constituents of Potential Concern) in samples collected from July 1989 through October 2007, inclusive. Similar calculations were made for trace and major metal results obtained from samples collected from May 1988 through April 1989, inclusive. Methods used to calculate the statistics were consistent with those discussed by and agreed to in the teleconference on June 27, 2008. The teleconference participants included representatives of U.S. Environmental Protection Agency (EPA), New Mexico Environment Department (NMED), and N.A.WS. The methodology agreed to in that meeting is summarized by the following steps:

1. Use ProUCL software to estimate the upper confidence limits (UCL95) for the means of background populations of COPC concentrations from samples determined to be representative of background groundwater quality. (Background sample sets for the Southwest Alluvium and Zone 1 were established in the February 2006 license amendment request for changing the Groundwater Protection Standard (GWPS) for combined radium. Determination of background sample sets for Zone 3 and for the older trace metal data are presented below).
2. Determine which COPCs have higher median concentrations in background groundwater than the comparison values (these are presented below). The method of testing recommended during the June 27 teleconference by the expert consultant to the EPA (Dennis Beal of SAIC) was the single sample hypothesis test. Of the three nonparametric methods available in the ProUCL software, he recommended that the Wilcoxon Signed Rank test be used, rather than the Sign Test or the Test of Proportions.
3. Select for consideration as potential modifications to cleanup levels those background UCL95 statistics associated with COPCs that are determined (from single sample hypothesis tests) to have median concentrations equal or exceeding the comparison values. The selected UCL95 statistics (if adopted) would be single-valued standards that will be representative of background UCL95 (i.e., upper confidence limit on the mean at the 95% confidence level). Note that the UCL95 statistics presented in this document as candidates for consideration as modifications to cleanup levels are based solely on statistical calculations.

One of the conclusions of the June 27 teleconference was that the preferred method of comparing site samples to revised background-based cleanup levels is two-sample hypothesis testing (e.g., of a compliance data set against the background data set from which the revised cleanup level was derived). Therefore, one of the objectives of the current work is to define appropriate background data sets for those future comparisons.

Identification of Samples Representative of Background Groundwater Quality

The process used to identify samples representative of background groundwater quality was identical to that described in the license amendment request for changing the GWPS for radium (N.A. Water Systems, February 2006, *Technical Analysis Report in Support of License Amendment Request for Changing the Method of Determining Exceedances of the Combined Radium Groundwater Protection Standard in Source*

Materials License SUA-1475 (T AC LU0092), Groundwater Corrective Action Program , Church Rock Site, Church Rock, New Mexico , pp. 3-6). As such, the wells selected for the purposes of this report as having samples representative of background quality in Zone 1 and in the Southwest Alluvium are the same as those identified in the February 2006 report. One difference is that the data sets used in calculations made for this report are from the period July 1989 through October 2007 inclusive, whereas the February 2006 submittal only included samples collected through October 2005. The methods used to identify wells having background water quality for the February 2006 submittal were used to verify that the designation remained valid for samples collected through October 2007. Table 1 lists wells and sample dates representative of background.

A second difference from the February 2006 report is that the current calculations have been applied to all COPCs, as well as a group of trace metals (plus iron) that had previously been dismissed as COPCs (EPA, *August 1988, Draft Final Remedial Investigation, United Nuclear Church Rock Site*). The inclusion of former COPCs, which had not been a part of the site's approved Sampling and Analysis Plan, required that the much smaller pool of pre-plan (pre-July 1989) sample results be included in the statistical calculations for these metals. Well samples collected from May 1985 through 1989 (including those from the Remedial Investigation sampling) were evaluated for evidence of background water quality. This resulted in the addition of sample results for metals from wells GW-4 and 623 for the Southwest Alluvium and from well EPA-5 for Zone 1. Time series graphs of indicator parameters for wells GW-4, 623, and EPA-5 are included in Appendix A. Metals results from other background wells (identified in the February 2006 report) were also verified to have come from samples representative of background water quality. In other words, those wells identified as having background water quality subsequent to July 1989 (see Table 1) were found, as expected, to have had background water quality prior to July 1989.

Zone 3 groundwater was not a subject of the February 2006 report; therefore, the identification of samples representative of background water quality in Zone 3 is new to this report. Table 2 lists wells and sample dates representative of background in Zone 3. The following criteria have been used to distinguish background versus impacted groundwater quality in Zone 3:

- pH < 5 and bicarbonate < 100 and > 500 mg/L are useful (but not always definitive) indicators of seepage impact (e.g., see discussion of these empirically derived criteria in the 2007 annual review report). See Figure 1 for box-and-whiskers plots of bicarbonate and pH for the background wells.

- Time-series of these two indicator parameters are very helpful, sometimes essential. See Appendix A for time-series of pH and bicarbonate for the background wells.
- Well locations within the overall area impacted by seepage (e.g., see Figure 35 in the 2007 annual report).
- Time trends in the concentrations of major ions; in particular, decreasing ratios of Ca:Mg are associated with degrading groundwater quality (see Appendix B in the 2007 annual report; e.g. well EPA-14).
- Time trends in the concentrations of many metals and radionuclides will usually increase as the water quality degrades in Zone 3 (see Appendix B in the 2007 annual report; e.g. well EPA-15).

Invariably, some wells (or certain time spans at some wells) are difficult to classify because their groundwater chemistry tends to be gradational. For example, during the period of time of relevance for present purposes (1989 to October 2007), the geochemistry associated with well 420 is “borderline” – therefore, we have excluded it from the dataset associated with background water quality.

The time-series included in Appendix A show the inferred dates of the onset of seepage impact for those wells whose sampling regime spanned such a transition. Also shown on time series spanning the date is the May 3, 2000 transition to low-flow, unfiltered sampling from multiple-well-volume, purge-and-filter sampling. This transition date does not coincide with any of the inferred onset dates of seepage impact. However, May 2000 appears to coincide with changes of indicator parameter trends at two wells, EPA-5 and EPA-14. It is unlikely that the change of sampling method initiated the multi-year concentration trends noted at these two wells. Other groundwater parameter changes, post-filtration, can be gleaned from a review of the tabulated historic water quality data in the appendices of the 2007 annual review report (N.A. Water Systems, 2008), and these changes cannot be ascribed to the absence of field filtration.

The background sample sets used to make the current calculations have been revised by the removal of small numbers of sample results having unusually high reporting limits. This culling of data affected the sample data sets for each hydrostratigraphic zone. However, it involved less than approximately one percent of the sample data (typically no more than three data points for a particular COPC) and a relatively small number of COPCs. These data were removed because they were discovered to have undesirable consequences on the results of the single sample hypothesis tests (particularly with the recommended Wicoxon Signed Rank Tests). The causes of these problems and the rationale for removing these data were discussed with Dennis Beal by James Ewart. These problems and our solution for them are described below in the discussion of the results.

Results

Basic Statistics and Upper Confidence Limits for Means

Tables 3 through 5 list basic statistics for all COPCs and additional metals calculated from the background data sets from wells in the Southwest Alluvium, Zone 1, and Zone 3. The data sets include only primary samples (i.e. no QA/QC samples). Also listed are upper confidence limits at the 95% confidence level for the means (UCL95). All of the statistics were calculated using ProUCL software (Singh et al., April 2007, *ProUCL Version 4.00.02 User Guide*, EPA/600/R-07/038). The UCL95 estimates were selected from values recommended by the ProUCL software. Summary tables of the output of UCL95 estimates are provided in Appendix B. In cases where two alternative estimates of UCL95 statistics are provided by ProUCL, the higher value was selected and is listed in Tables 3 through 5. The higher values were selected as conservative estimates, consistent with the use of these same statistics as estimators of exposure point concentrations (EPCs).

Comparisons of Background COPC Concentrations with Comparison Values

Table 6 is a compilation of site cleanup goals (EPA, *September 1988, Record of Decision for the Church Rock Site*) at Church Rock and other more recently developed information sources and standards for COPCs and metals. Comparison values were selected from Table 6 (see the green highlighted values) in consultation with Mark Purcell (EPA). Tables 7 through 9 summarize the background concentrations versus comparison values for COPCs and metals in each of the three hydrostratigraphic zones. The results, as presented, deviate in one significant way from the methodology described in the three steps outlined in the Introduction. The selection of candidates for consideration as new background-based cleanup levels (shown in the last column of each table) was based solely on the estimated UCL95 statistics and comparison values (see column 6, titled UCL95>=CV?, meaning “is the UCL95 value greater than or equal to the comparison value?”). The results of single sample hypothesis testing, which are shown in the tables for information purposes, were not used in this determination. This methodological difference was based on an evaluation of the algorithms employed by the single sample hypothesis test methods (as implemented in ProUCL), and particularly how the accuracy of these methods are affected by the characteristics of the Church Rock datasets. Note that in the following discussion the term nondetect is used as a catchall for censored data, which in the case of the Church Rock data represents a result less than its reporting limit.

Datasets having the following characteristics tended to result in adverse consequences for the single sample hypothesis tests:

1. High percentages of results below reporting limits (nondetects).
2. Multiple values of reporting limits within datasets (i.e. for a particular COPC).
3. Nondetect results having values greater than other results reported as detected within a dataset.
4. Highly skewed distributions.

The Church Rock datasets for several COPCs commonly have one or more of these characteristics. The adverse consequences from characteristics 1 through 3 arise largely because of the handling of nondetect values by the algorithms employed by the single sample hypothesis tests in ProUCL. These consequences typically affected the results of the Wilcoxon Signed Rank Tests more than those of the Sign Tests. The reason for this is that the Wilcoxon Signed Rank Test replaces all nondetect results with a value equal to half the detection limit (or reporting limit). Furthermore, the method treats any result (detected or not) less than the highest nondetect result in a dataset as a nondetect result, and accordingly reduces its value by one half. Therefore, having even a single highly valued nondetect result can have a profound (and undesirable) affect on the outcome of the test. This is the reason that large nondetect results were removed from the datasets for these calculations.

In contrast to the Wilcoxon Signed Rank Test, the Sign Test retains nondetect values at their reported (reporting limit) value. The Sign Test also discards any nondetect result that exceeds the value of the comparison value, thereby typically avoiding the problems created by the handling of large nondetect values by the Wilcoxon Signed Rank Test. However, the Sign Test also resulted in questionable “Do Not Reject” outcomes in some cases where 100% of the data were nondetect results. (Note that the null hypothesis used in all the tests is that the median of the background dataset equals or exceeds the comparison value.)

For example, in cases where more than 50% of the results are nondetects and the reporting limit equals the comparison value, the Sign Test will fail to reject the null hypothesis even though the majority of the data are clearly less than the reporting limit (and the comparison value). This occurs because the Sign Test records a nondetect equaling the comparison value as a tie. The very different handling of nondetects by these two methods is illustrated by the significant differences of outcomes for the two tests shown in Tables 7 through 9. Finally, highly skewed distributions, a characteristic common to many of the Church Rock datasets, is described by the ProUCL documentation as a factor reducing the accuracy of the Wilcoxon Signed Rank Test.

The methodologies used by ProUCL for the Sign Test and Wilcoxon Signed Rank Test were tested by hand calculations. This was done using algorithms published in EPA statistical guidance (EPA, February 2006, *Data Quality Assessment: Statistical Methods for Practitioners*, EPA QA/G-9S, pp. 60-61). The same document is referenced by the ProUCL documentation as a source of its algorithms. The handling of nondetect results by ProUCL was determined to be faithful to the published algorithm for the Wilcoxon Signed Rank Test and numerically accurate. This procedure includes the substitution of values equal to one half of the detection limit (DL/2) for nondetects. The description of the Sign Test in EPA (February, 2006) does not explicitly mention any substitutions for nondetect results. However, the example calculation provided for the Sign Test (EPA, February 2006, Box 3-17, p. 63) indicates the use of the same DL/2 substitution used for the Wilcoxon Signed Rank Test. In this respect the authors of the ProUCL software may have misinterpreted the intentions of their source for the Sign Test algorithm, resulting in an inappropriate treatment of nondetects having the same value as the standard of comparison.

The solution of ignoring the single sample hypothesis tests in favor of direct comparisons of the estimated UCL95 statistics with comparison values avoids the problems described above, and has other additional advantages. Direct comparison of two values has the intuitive advantage of simplicity, and it also avoids the logical inconsistency of concluding (as would have been the case in some instances) that a UCL95 statistic should be considered lower than a comparison value when it obviously is not.

Equally important is the observation that the methodologies employed by the ProUCL software for estimating UCL95 statistics are highly advanced relative to the algorithms used by the single sample hypothesis tests. For example, a battery of more than 20 independent algorithms is employed by ProUCL to estimate UCL95 statistics. The software automatically sifts through these methods to recommend the better one or two estimates according to a variety of dataset characteristics, including number of samples, numbers and values of nondetect results, and shape of the distribution (including skewness). In particular, the handling of nondetect values by the Kaplan-Meier methods (for estimating UCL95 statistics) is more sophisticated than the methods used by the single sample hypothesis tests.

In the teleconference of September 30, 2008, it was agreed that this use of UCL95 statistics was an acceptable alternative to the single sample hypothesis test, for evaluating the background data sets versus the comparison values.

Note that direct evaluation of background UCL95 statistics versus comparison values are being made solely for the purpose of determining whether those statistics are numerically greater than the respective COPC comparison values. It would be inappropriate to use the same methodology for comparisons of compliance samples to cleanup levels, because of the much smaller size of compliance well sample sets (relative to background sample sets). For such comparisons single- or two-sample hypothesis testing is preferable.

Conclusion

We have concluded that direct evaluation of UCL95 statistics versus comparison values is the preferable method of determining which UCL95 statistics should be selected as candidates for consideration for modifying cleanup levels to reflect background concentrations. The UCL95 statistics presented in this document as candidates for consideration as modified cleanup levels are based solely on statistical calculations. One of the conclusions of the June 27, 2008, teleconference was that the preferred method of comparing compliance samples to background-based cleanup levels is two-sample hypothesis testing (e.g. of a compliance data set against the defined background data set). Therefore, one of the objectives of the current work has been to define appropriate background data sets for those future comparisons.

Very Truly Yours,

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Attachments

N.A. WATER SYSTEMS

This Submittal Delivered by Email Only

Figures and Tables

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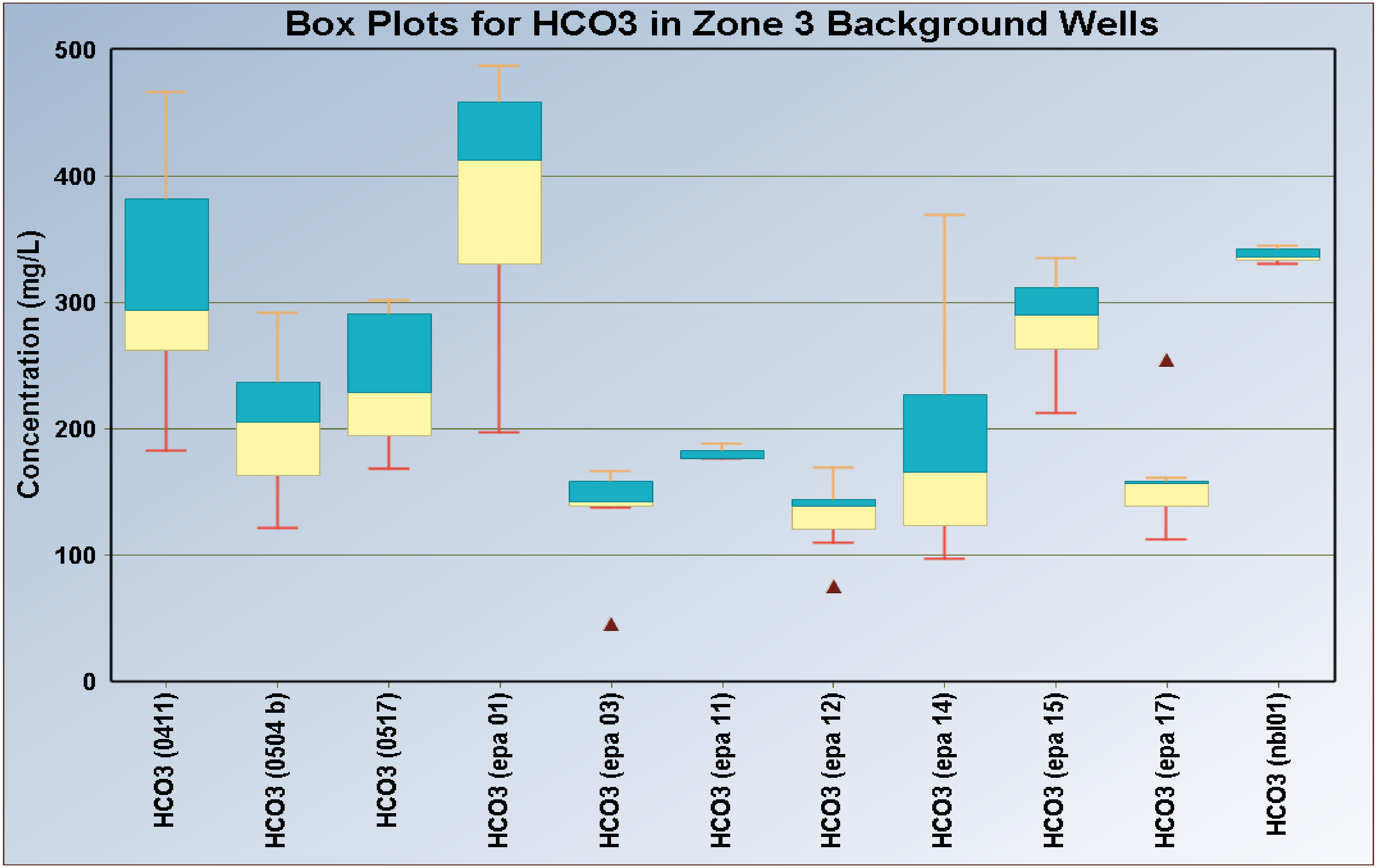
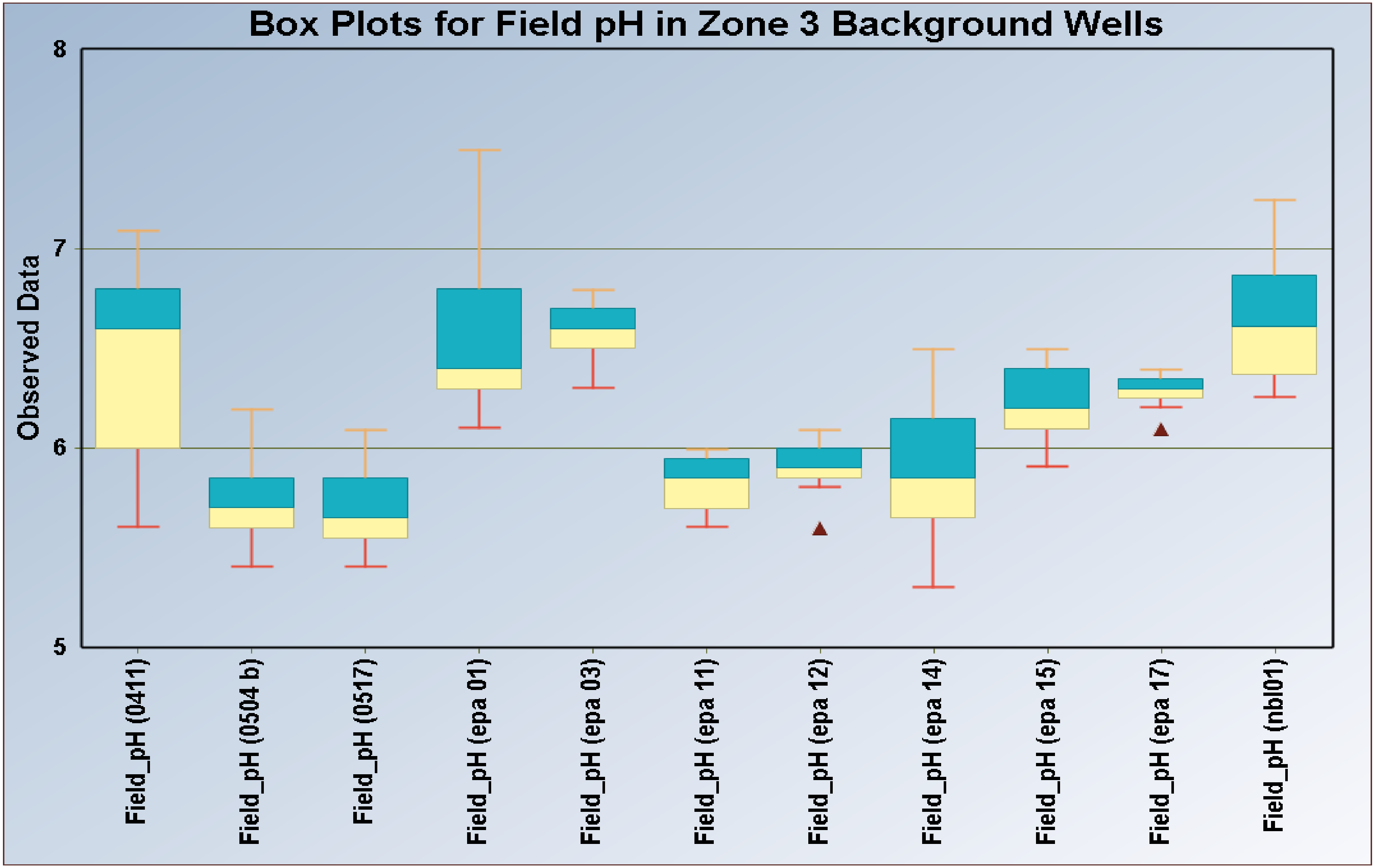
FIGURE 1A



Box Plots for HCO3 in Zone 3 Background Wells
Concentration (mg/L)
0
100
200
300
400
500
HCO3 (0411)
HCO3 (0504 b)
HCO3 (0517)
HCO3 (epa 01)
HCO3 (epa 03)
HCO3 (epa 11)
HCO3 (epa 12)
HCO3 (epa 14)
HCO3 (epa 15)
HCO3 (epa 17)
HCO3 (nbl01)

FIGURE 1B



Box Plots for Field pH in Zone 3 Background Wells
Observed Data
8
7
6
5
Field_pH (0411)
Field_pH (0504 b)
Field_pH (0517)
Field_pH (epa 01)
Field_pH (epa 03)
Field_pH (epa 11)
Field_pH (epa 12)
Field_pH (epa 14)
Field_pH (epa 15)
Field_pH (epa 17)
Field_pH (nbl01)

TABLE 1

Southwest Alluvium and Zone 1 Wells
Having Samples Representative of Background Water Quality

Southwest Alluvium	Zone 1
29 A	619
624 (Jul 89 - Oct 95)	EPA 2
627	EPA 4 (POC)
639	EPA 8
642	
645	
EPA 22 A	
EPA 25 (Jul 89 - Oct 95)	
EPA 27	
EPA 28 (POC)	
SBL 1	

Notes:

POC = Point-of-Compliance Well.

The following wells were included only for the pre-July 1989 metals results:

GW 4 and 623 (SWA)

EPA 5 (Zone 1)

TABLE 2

Zone 3 Wells Having Samples Representative of Background Water Quality

Well	Sampled Time Period
411	Jul 89 - Jan 98
504 B	Jul 89 - Apr 92
517 (POC)	Jul 89 - Apr 91
EPA 01	Jul 89 - Oct 97
EPA 03	Jul 89 - Oct 91
EPA 11	Jul 89 - Apr 90
EPA 12	Jul 89 - Apr 92
EPA 14	Jul 89 - Apr 95
EPA 15	Jul 89 - Apr 95
EPA 17	Jul 89 - Apr 92
NBL-01	Aug 01 - Jan 04

Note: POC = Point-of-Compliance well.

TABLE 3
Summary Statistics for COPCs and Trace Metals in Southwest Alluvium Background Groundwater

Parameter	Units	Total Data	Percent Nondetect	Minimum Detected	Maximum Detected	Mean of Detected	Median of Detected	UCL95 of Mean
Al	mg/L	391	94.6%	0.1	0.6	0.182	0.14	0.107
As	mg/L	391	93.1%	0.001	0.01	0.00237	0.001	0.00116
Be	mg/L	389	100.0%	N/A	N/A	N/A	N/A	N/A
Cd	mg/L	391	96.9%	0.006	0.07	0.0255	0.01	0.0108
Co	mg/L	391	81.6%	0.01	0.06	0.0186	0.02	0.0121
Pb	mg/L	388	99.5%	0.05	0.07	0.06	0.06	0.0502
Mn	mg/L	389	11.8%	0.01	3.35	0.339	0.13	0.414
Mo	mg/L	391	99.5%	0.03	0.03	N/A	N/A	N/A
Ni	mg/L	391	96.4%	0.05	0.17	0.08	0.08	0.0613
Se	mg/L	390	50.5%	0.001	0.195	0.00708	0.003	0.00516
V	mg/L	391	100.0%	N/A	N/A	N/A	N/A	N/A
Cl	mg/L	391	0.0%	9.8	169	74.82	67.8	83.72
SO4	mg/L	391	0.0%	605	5830	2401	2420	2468
NO3_as_N	mg/L	391	1.3%	0.09	1225	99.54	74.1	137.4
U	mg/L	390	0.3%	0.001	0.367	0.0419	0.031	0.0459
Chloroform	ug/L	391	100.0%	N/A	N/A	N/A	N/A	N/A
Lab_TDS	mg/L	390	0.0%	1310	10530	4630	4795	4745
Rad-226	pCi/L	391	34.3%	0.2	9.4	0.979	0.6	0.798
Rad-228	pCi/L	391	67.8%	1	7	2.55	2.2	1.611
Rad_totl	pCi/L	391	25.3%	0.2	12	1.9	1.3	1.621
Th-230	pCi/L	391	91.8%	0.2	14.3	2.841	1.6	0.509
Pb-210	pCi/L	391	78.3%	1	14.2	2.845	2.2	1.513
Gross_Alpha	pCi/L	391	70.6%	0.4	17.8	3.35	2.1	1.693
Sb	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Ba	mg/L	26	100.0%	N/A	N/A	N/A	N/A	N/A
Cr	mg/L	37	97.3%	0.29	0.29	N/A	N/A	N/A
Cu	mg/L	13	84.6%	0.01	0.01	N/A	N/A	N/A
Fe	mg/L	19	79.0%	0.06	1.4	0.418	0.105	0.275
Hg	mg/L	8	100.0%	N/A	N/A	N/A	N/A	N/A
Ag	mg/L	21	100.0%	N/A	N/A	N/A	N/A	N/A
Tl	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Zn	mg/L	25	40.0%	0.02	0.429	0.0891	0.05	0.0949

TABLE 4
Summary Statistics for COPCs and Trace Metals in Zone 1 Background Groundwater

Parameter	Units	Total Data	Percent Nondetect	Minimum Detected	Maximum Detected	Mean of Detected	Median of Detected	UCL95 of Mean
Al	mg/L	234	86.8%	0.1	0.6	0.185	0.14	0.117
As	mg/L	234	83.8%	0.001	0.004	0.00174	0.002	0.00117
Be	mg/L	234	100.0%	N/A	N/A	N/A	N/A	N/A
Cd	mg/L	234	98.7%	0.005	0.01	0.00733	0.007	0.0051
Co	mg/L	234	89.7%	0.01	0.06	0.0171	0.01	0.0112
Pb	mg/L	234	99.6%	0.05	0.05	N/A	N/A	N/A
Mn	mg/L	234	0.4%	0.66	4.15	2.434	2.65	2.519
Mo	mg/L	234	97.9%	0.03	0.27	0.12	0.13	0.132
Ni	mg/L	230	98.7%	0.06	0.07	0.0667	0.07	0.0602
Se	mg/L	234	95.7%	0.001	0.004	0.0019	0.0015	0.00107
V	mg/L	234	100.0%	N/A	N/A	N/A	N/A	N/A
Cl	mg/L	234	0.0%	19.4	252	37.13	37.9	39.03
SO4	mg/L	234	0.0%	1410	3882	2703	2952	2773
NO3_as_N	mg/L	233	71.7%	0.01	51.8	1.767	0.16	1.754
U	mg/L	233	16.7%	0.0004	0.975	0.00862	0.0013	0.0255
Chloroform	ug/L	234	99.6%	0.91	0.91	N/A	N/A	N/A
Lab_TDS	mg/L	234	0.0%	2490	5610	4225	4569	4319
Rad-226	pCi/L	233	1.7%	0.2	5.4	1.269	1.2	1.314
Rad-228	pCi/L	234	29.9%	1	13.8	3.457	3.1	2.946
Rad_totl	pCi/L	234	0.9%	0.2	14.8	3.618	3.35	3.841
Th-230	pCi/L	234	91.9%	0.2	4.9	0.974	0.7	0.403
Pb-210	pCi/L	234	80.8%	1.1	9.1	2.58	2.1	1.579
Gross_Alpha	pCi/L	234	35.0%	0.9	14	2.757	2	2.361
Sb	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Ba	mg/L	14	78.6%	0.079	0.091	0.0847	0.084	0.091
Cr	mg/L	11	100.0%	N/A	N/A	N/A	N/A	N/A
Cu	mg/L	4	75.0%	0.026	0.026	N/A	N/A	N/A
Fe	mg/L	12	8.3%	0.25	14	6.386	6.2	8.701
Hg	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Ag	mg/L	11	100.0%	N/A	N/A	N/A	N/A	N/A
Tl	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Zn	mg/L	16	56.3%	0.01	5	0.784	0.046	3.583

TABLE 5
Summary Statistics for COPCs and Trace Metals in Zone 3 Background Groundwater

Parameter	Units	Total Data	Percent Nondetect	Minimum Detected	Maximum Detected	Mean of Detected	Median of Detected	UCL95 of Mean
Al	mg/L	186	68.28%	0.1	1.68	0.422	0.31	0.231
As	mg/L	186	26.88%	0.001	1.01	0.121	0.0235	0.175
Be	mg/L	186	100.00%	N/A	N/A	N/A	N/A	N/A
Cd	mg/L	186	95.16%	0.01	0.09	0.02	0.01	0.0113
Co	mg/L	186	9.14%	0.01	0.53	0.0835	0.06	0.0877
Pb	mg/L	185	97.84%	0.05	0.08	0.065	0.065	0.0701
Mn	mg/L	186	0.54%	0.42	7.5	3.25	3.3	3.436
Mo	mg/L	184	14.13%	0.02	75	11.88	3.76	17.43
Ni	mg/L	186	39.25%	0.05	0.67	0.173	0.12	0.14
Se	mg/L	186	77.42%	0.001	0.015	0.0026	0.001	0.00159
V	mg/L	186	100.00%	N/A	N/A	N/A	N/A	N/A
Cl	mg/L	186	0%	15	66	31.62	30.85	32.65
SO4	mg/L	186	0%	1319	4674	2588	2651	2674
NO3_as_N	mg/L	186	17.20%	0.01	61	11.34	4.785	15.61
U	mg/L	186	1.08%	0.0007	0.38	0.0791	0.039	0.107
Chloroform	ug/L	186	99.46%	1.1	1.1	N/A	N/A	N/A
Lab_TDS	mg/L	186	0%	2244	6930	4115	4237	4239
Rad-226	pCi/L	186	11.83%	0.2	23.7	5.01	4.5	4.996
Rad-228	pCi/L	185	29.19%	1	22.3	5.34	4.3	4.509
Rad_totl	pCi/L	185	9.73%	0.2	40.9	9.099	7.9	10.66
Th-230	pCi/L	186	89.78%	0.2	57	6.705	2.3	1.426
Pb-210	pCi/L	186	69.35%	1	11	2.549	2	1.618
Gross_Alpha	pCi/L	186	15.59%	1	69	8.191	5.4	8.217
Sb	mg/L	1	100.0%	N/A	N/A	N/A	N/A	N/A
Ba	mg/L	36	94.4%	0.54	0.54	N/A	N/A	N/A
Cr	mg/L	37	100.0%	N/A	N/A	N/A	N/A	N/A
Cu	mg/L	13	76.9%	0.028	0.06	0.042	0.038	0.06
Fe	mg/L	23	39.1%	0.03	67	9.682	1.45	12.16
Hg	mg/L	4	100.0%	N/A	N/A	N/A	N/A	N/A
Ag	mg/L	29	100.0%	N/A	N/A	N/A	N/A	N/A
Tl	mg/L	0	N/A	N/A	N/A	N/A	N/A	N/A
Zn	mg/L	31	19.4%	0.02	6.859	0.766	0.193	3.539

TABLE 6

Contaminant-Specific Groundwater Cleanup Levels and Other Comparison Values

United Nuclear Corporation, Church Rock Site

Church Rock, New Mexico

Source	ROD (September 1988) Derived Standards Used for 2nd 5-Year Review (September 2003, Table 3-1)				NRC Source Materials	Post-ROD Promulgated ARARs					Standard Compared to in 2007 Annual Review		Current Health-Based Criteria (+)		
Contaminant	New Mexico WQCC Standards	Health-based	Maximum Concentration Limit (MCL)	Background Level	License Compliance Standards	NRC Appendix List*	New Mexico WQCC Standards		EPA Drinking Water MCL	EPA Drinking Water Other**	EPA	NRC	Health-Based Criterion	Source	
Sulfate				2160			2125***				2125***				SO4
Total Dissolved Solids				3170			4800***				4800***				TDS
NO3 as N				30			190***		10		190***		10	R6HHSL, MCL	NO3
Manganese				2.6			0.2	O			2.6		1.7	R6HHSL	Mn
Chloride	250						250	O			250				Cl2
Aluminum	5						5	I			5		37	R6HHSL	Al
Antimony		0.014							0.006				0.006	MCL	Sb
Arsenic			0.05		0.05	0.05	0.1	HH	0.01		0.05	0.05	0.01	MCL	As
Barium	1		1			1	1	HH	2				2	MCL	Ba
Beryllium		0.017			0.05				0.004		0.017	0.05	0.004	MCL	Be
Cadmium	0.01		0.01		0.01	0.01	0.01	HH	0.005		0.01	0.01	0.005	MCL	Cd
Chromium	0.05		0.05			0.05	0.05	HH	0.1				0.1	MCL	Cr
Cobalt	0.05						0.05	I			0.05		0.73	R6HHSL	Co
Copper	1						1	O	1.3	MCLG & TT			1.3	MCL	Cu
Iron				5.5			1	O					26	R6HHSL	Fe
Lead	0.05		0.05		0.05	0.05	0.05	HH	0.015	MCLG & TT	0.05	0.05	0.015	MCL	Pb
Mercury	0.002		0.002			0.002	0.002	HH	0.002				0.002	MCL	Hg
Molybdenum	1						1	I			1		0.18	R6HHSL	Mo
Nickel	0.2				0.05		0.2	I			0.2	0.05	0.73	R6HHSL	Ni
Selenium			0.01		0.01	0.01	0.05	HH	0.05		0.01	0.01	0.05	MCL	Se
Silver	0.05		0.05			0.05	0.05	HH					0.18	R6HHSL	Ag
Thallium		0.014							0.002	MCLG = 0.0005			0.002	MCL	Tl
Vanadium		0.7			0.1						0.7	0.1	0.18	R6HHSL	Zn
Zinc	10						10	O					11	R6HHSL	V
TTHMs****					0.08		0.1	HH	0.08	MCLG = 0.07****		0.08	0.08	MCL	TTHMs
Uranium	5				0.3		0.03	HH	0.03		5	0.3	0.03	MCL	U
Radium 226 and 228			5 pCi/l		*****	5 pCi/l	30 pCi/l	HH	5 pCi/l		5 pCi/l	*****	5 pCi/l	MCL	comb Ra
Lead-210					1 pCi/l							1 pCi/l	0.0541 pCi/l	PRG	Pb-210
Thorium-230			15 pCi/l		5 pCi/L							5 pCi/l	0.523 pCi/l	PRG	Th-230
Gross Alpha			15 pCi/l		15 pCi/l	15 pCi/l			15 pCi/l		15 pCi/l	15 pCi/l	15 pCi/l	MCL	GA

Notes:

Units = mg/L unless otherwise noted

Yellow or shaded cells = constituents not analyzed since site active remediation started in 1989, per EPA FS (August 1988) and ROD (September 1988)

* 10 CFR Appendix A to Part 40

** "Other" includes non-zero Maximum Contaminant Level Goals (MCLG) or Treatment Technology Action Levels (TT)

*** New Mexico Environment Department recommended background values (letter to EPA of January 6, 1998); EPA has not formally adopted these revisions

**** TTHMs (total trihalomethanes) include chloroform; TTHMs MCL = 0.08 mg/L; in addition, chloroform has an MCLG = 0.07 mg/L

***** Combined radium NRC Site Groundwater Protection Standards are 5.0 pCi/L for Zone 3; 5.2 pCi/L for Southwest Alluvium (background); and 9.4 pCi/L for Zone 1 (background)

(+) Sources of health-based criteria include EPA Region 6 Human Health Medium-Specific Screening Levels (R6HHSL) and EPA Preliminary Remediation Goals for Radionuclides (PRGs). For those contaminants with federal MCLs, the MCL is shown as the health-based screening level, per January 25, 2008 letter from EPA to UNC (General Comment 5).

HH = Human Health Standard

I = Irrigation Standard

O = Other Standards for domestic water supply

"Comparison Values" column in N.A. Water Systems report: Calculation of Background Statistics with Comparison Values (Tables 7 to 9)

TABLE 7

Summary comparisons of Parameter Concentrations in Southwest Alluvium Background Groundwater to Comparison Values

Parameter	Units	Comparison Value[1]	Max RL[2]	UCL95	UCL95>CV?	Max RL>=CV?	Percent < RL	Single Sample Hypothesis Test[3] H0: Site Median >= CV — Sign Test	Single Sample Hypothesis Test[3] H0: Site Median >= CV — Wilcoxon Signed	Potential Background Level
Al	mg/L	5	0.1	0.107	NO	NO	95%	**Reject**	**Reject**	
As	mg/L	0.01	0.001	0.00116	NO	NO	93%	**Reject**	**Reject**	
Be	mg/L	0.004	0.1	NA	N/A	**YES**	100%	**N/A**	**N/A**	
Cd	mg/L	0.005	0.01	0.0108	**YES**	**YES**	97%	**Do not Reject**	**Reject**	**0.0108**
Co	mg/L	0.05	0.01	0.0121	NO	NO	82%	**Reject**	**Reject**	
Pb	mg/L	0.05	0.05	0.0502	**YES**	**YES**	99%	**Do not Reject**	**Reject**	**0.0502**
Mn	mg/L	0.2	0.01	0.414	**YES**	NO	12%	**Reject**	**Reject**	**0.414**
Mo	mg/L	1	0.1	NA	N/A	NO	99%	**Reject**	**Reject**	
Ni	mg/L	0.2	0.05	0.0613	NO	NO	96%	**Reject**	**Reject**	
Se	mg/L	0.05	0.001	0.00516	NO	NO	51%	**Reject**	**Reject**	
V	mg/L	0.1	0.1	NA	N/A	**YES**	100%	**N/A**	**N/A**	
Cl	mg/L	250	N/A	83.72	NO	N/A	0%	**Reject**	**Reject**	
SO4	mg/L	2125	N/A	2468	**YES**	N/A	0%	**Do not Reject**	**Do not Reject**	**2468**
NO3_as_N	mg/L	30	0.1	137.4	**YES**	NO	1%	**Do not Reject**	**Do not Reject**	**137.4**
U	mg/L	0.03	0.0003	0.0459	**YES**	NO	0%	**Do not Reject**	**Do not Reject**	**0.0459**
Chloroform	ug/L	80	1	NA	N/A	NO	100%	**N/A**	**N/A**	
Lab_TDS	mg/L	3170	N/A	4745	**YES**	N/A	0%	**Do not Reject**	**Do not Reject**	**4745**
Rad_totl	pCi/L	5	0.2	1.621	NO	NO	25%	**Reject**	**Reject**	
Th-230	pCi/L	5	0.2	0.509	NO	NO	92%	**Reject**	**Reject**	
Pb-210	pCi/L	1	1	1.513	**YES**	**YES**	78%	**Do not Reject**	**Reject**	**1.513**
Gross_Alpha	pCi/L	15	1	1.693	NO	NO	71%	**Reject**	**Reject**	
Sb	mg/L	0.006	N/A	NA	N/A	N/A	N/A	**no data**	**no data**	
Ba	mg/L	2	0.1	NA	N/A	NO	100%	**Reject**	**Reject**	
Cr	mg/L	0.05	0.05	NA	N/A	**YES**	97%	**Reject**	**Reject**	
Cu	mg/L	1	0.02	NA	N/A	NO	85%	**Reject**	**Reject**	
Fe	mg/L	1	0.1	0.275	NO	NO	79%	**Reject**	**Reject**	
Hg	mg/L	0.002	0.001	NA	N/A	NO	100%	**N/A**	**N/A**	
Ag	mg/L	0.05	0.05	NA	N/A	**YES**	100%	**N/A**	**N/A**	
Tl	mg/L	0.002	N/A	NA	N/A	N/A	N/A	**no data**	**no data**	
Zn	mg/L	10	0.1	0.0949	NO	NO	40%	**Reject**	**Reject**	

Note:

1. See Table 6 for sources of Comparison Values (CV)
2. RL is an abbreviation of reporting limit
3. Single sample hypotheses tests are not applicable to datasets having 100% censored data

TABLE 8
Summary Comparisons of Parameter Concentrations in Zone 1 Background Groundwater to Comparison Values

Parameter	Units	Comparison Value[1]	Max RL[2]	UCL95	UCL95>CV?	Max RL>=CV?	Percent < RL	Single Sample Hypothesis Test[3] H0: Site Median >= CV Sign Test	Single Sample Hypothesis Test[3] H0: Site Median >= CV Wilcoxon Signed	Potential Background Level
Al	mg/L	5	0.1	0.117	NO	NO	87%	**Reject**	**Reject**	
As	mg/L	0.01	0.001	0.00117	NO	NO	84%	**Reject**	**Reject**	
Be	mg/L	0.004	0.05	N/A	N/A	YES	100%	**N/A**	**N/A**	
Cd	mg/L	0.005	0.01	0.0051	YES	YES	99%	**Do not Reject**	**Reject**	**0.0051**
Co	mg/L	0.05	0.01	0.0112	NO	NO	90%	**Reject**	**Reject**	
Pb	mg/L	0.05	0.05	N/A	N/A	YES	100%	**N/A**	**N/A**	
Mn	mg/L	0.2	0.01	2.519	YES	NO	0%	**Do not Reject**	**Do not Reject**	**2.519**
Mo	mg/L	1	0.1	0.132	NO	NO	98%	**Reject**	**Reject**	
Ni	mg/L	0.2	0.05	0.0602	NO	NO	99%	**Reject**	**Reject**	
Se	mg/L	0.05	0.001	0.00107	NO	NO	96%	**Reject**	**Reject**	
V	mg/L	0.1	0.1	N/A	N/A	YES	100%	**N/A**	**N/A**	
Cl	mg/L	250	N/A	39.03	NO	N/A	0%	**Reject**	**Reject**	
SO4	mg/L	2125	N/A	2773	YES	N/A	0%	**Do not Reject**	**Do not Reject**	**2773**
NO3_as_N	mg/L	30	0.1	1.754	NO	NO	72%	**Reject**	**Reject**	
U	mg/L	0.03	0.0004	0.0255	NO	NO	17%	**Reject**	**Reject**	
Chloroform	ug/L	80	1	N/A	N/A	N/A	100%	**N/A**	**N/A**	
Lab_TDS	mg/L	3170	N/A	4319	YES	N/A	0%	**Do not Reject**	**Do not Reject**	**4319**
Rad_totl	pCi/L	5	0.2	3.841	NO	NO	1%	**Reject**	**Reject**	
Th-230	pCi/L	5	0.2	0.403	NO	NO	92%	**Reject**	**Reject**	
Pb-210	pCi/L	1	1	1.579	YES	YES	81%	**Do not Reject**	**Reject**	**1.579**
Gross_Alpha	pCi/L	15	1	2.361	NO	NO	35%	**Reject**	**Reject**	
Sb	mg/L	0.006	N/A	N/A	N/A	N/A	N/A	**no data**	**no data**	
Ba	mg/L	2	0.1	0.091	NO	NO	79%	**Reject**	**Reject**	
Cr	mg/L	0.05	0.05	N/A	N/A	YES	100%	**N/A**	**N/A**	
Cu	mg/L	1	0.02	N/A	N/A	NO	75%	**Do not Reject**	**Do not Reject**	
Fe	mg/L	1	0.1	8.701	YES	NO	8%	**Do not Reject**	**Do not Reject**	**8.701**
Hg	mg/L	0.002	N/A	N/A	N/A	N/A	N/A	**no data**	**no data**	
Ag	mg/L	0.05	0.05	N/A	N/A	N/A	100%	**N/A**	**N/A**	
Tl	mg/L	0.002	N/A	N/A	N/A	N/A	N/A	**no data**	**no data**	
Zn	mg/L	10	0.1	3.583	NO	NO	56%	**Reject**	**Reject**	

Note:
1. See Table 6 for sources of Comparison Values (CV)
2. RL is an abbreviation of reporting limit
3. Single sample hypotheses tests are not applicable to datasets having 100% censored data

TABLE 9
Summary Comparisons of Parameter Concentrations in Zone 3 Background Groundwater to Comparison Values

Parameter	Units	Comparison Value[1]	Max RL[2]	UCL95	UCL95>CV?	Max RL>=CV?	Percent < RL	Single Sample Hypothesis Test[3] H0: Site Median >= CV — Sign Test	Single Sample Hypothesis Test[3] H0: Site Median >= CV — Wilcoxon Signed	Potential Background Level
Al	mg/L	5	0.1	0.231	NO	NO	68%	Reject	Reject	
As	mg/L	0.01	0.001	0.175	YES	NO	27%	Do Not Reject	Do Not Reject	0.175
Be	mg/L	0.004	0.05	N/A	N/A	YES	100%	N/A	N/A	
Cd	mg/L	0.005	0.01	0.0113	YES	YES	95%	Do Not Reject	Reject	0.0113
Co	mg/L	0.05	0.01	0.0877	YES	NO	9%	Do Not Reject	Do Not Reject	0.0877
Pb	mg/L	0.05	0.05	0.0701	YES	YES	98%	Do Not Reject	Reject	0.0701
Mn	mg/L	0.2	0.01	3.436	YES	NO	1%	Do Not Reject	Do Not Reject	3.436
Mo	mg/L	1	0.1	17.43	YES	NO	14%	Do Not Reject	Do Not Reject	17.43
Ni	mg/L	0.2	0.05	0.14	NO	NO	39%	Reject	Reject	
Se	mg/L	0.05	0.001	0.00159	NO	NO	77%	Reject	Reject	
V	mg/L	0.1	0.1	N/A	N/A	YES	100%	N/A	N/A	
Cl	mg/L	250	N/A	32.65	NO	N/A	0%	Reject	Reject	
SO4	mg/L	2125	N/A	2674	YES	N/A	0%	Do Not Reject	Do Not Reject	2674
NO3_as_N	mg/L	30	0.1	15.61	NO	NO	17%	Reject	Reject	
U	mg/L	0.03	0.0003	0.107	YES	NO	1%	Do Not Reject	Do Not Reject	0.107
Chloroform	ug/L	80	1	N/A	N/A	NO	99%	Reject	Reject	
Lab_TDS	mg/L	3170	N/A	4239	YES	N/A	0%	Do Not Reject	Do Not Reject	4239
Rad_totl	pCi/L	5	0.2	10.66	YES	NO	10%	Do Not Reject	Do Not Reject	10.66
Th-230	pCi/L	5	0.2	1.426	NO	NO	90%	Reject	Reject	
Pb-210	pCi/L	1	1	1.618	YES	YES	69%	Do Not Reject	Reject	1.618
Gross_Alpha	pCi/L	15	1	8.217	NO	NO	16%	Reject	Reject	
Sb	mg/L	0.006	0.05	N/A	N/A	YES	100%	N/A	N/A	
Ba	mg/L	2	0.1	N/A	N/A	NO	94%	Reject	Reject	
Cr	mg/L	0.05	0.1	N/A	N/A	YES	100%	Reject	Reject	
Cu	mg/L	1	0.02	0.06	NO	NO	77%	Reject	Reject	
Fe	mg/L	1	0.1	12.16	YES	NO	39%	Do not Reject	Do not Reject	12.16
Hg	mg/L	0.002	0.0002	N/A	N/A	NO	100%	N/A	N/A	
Ag	mg/L	0.05	0.05	N/A	N/A	YES	100%	N/A	N/A	
Tl	mg/L	0.002	N/A	N/A	N/A	N/A	N/A	no data	no data	
Zn	mg/L	10	0.1	3.539	NO	NO	19%	Reject	Reject	

Note:
1. See Table 6 for sources of Comparison Values (CV)
2. RL is an abbreviation of reporting limit
3. Single sample hypotheses tests are not applicable to datasets having 100% censored data

N.A. WATER SYSTEMS

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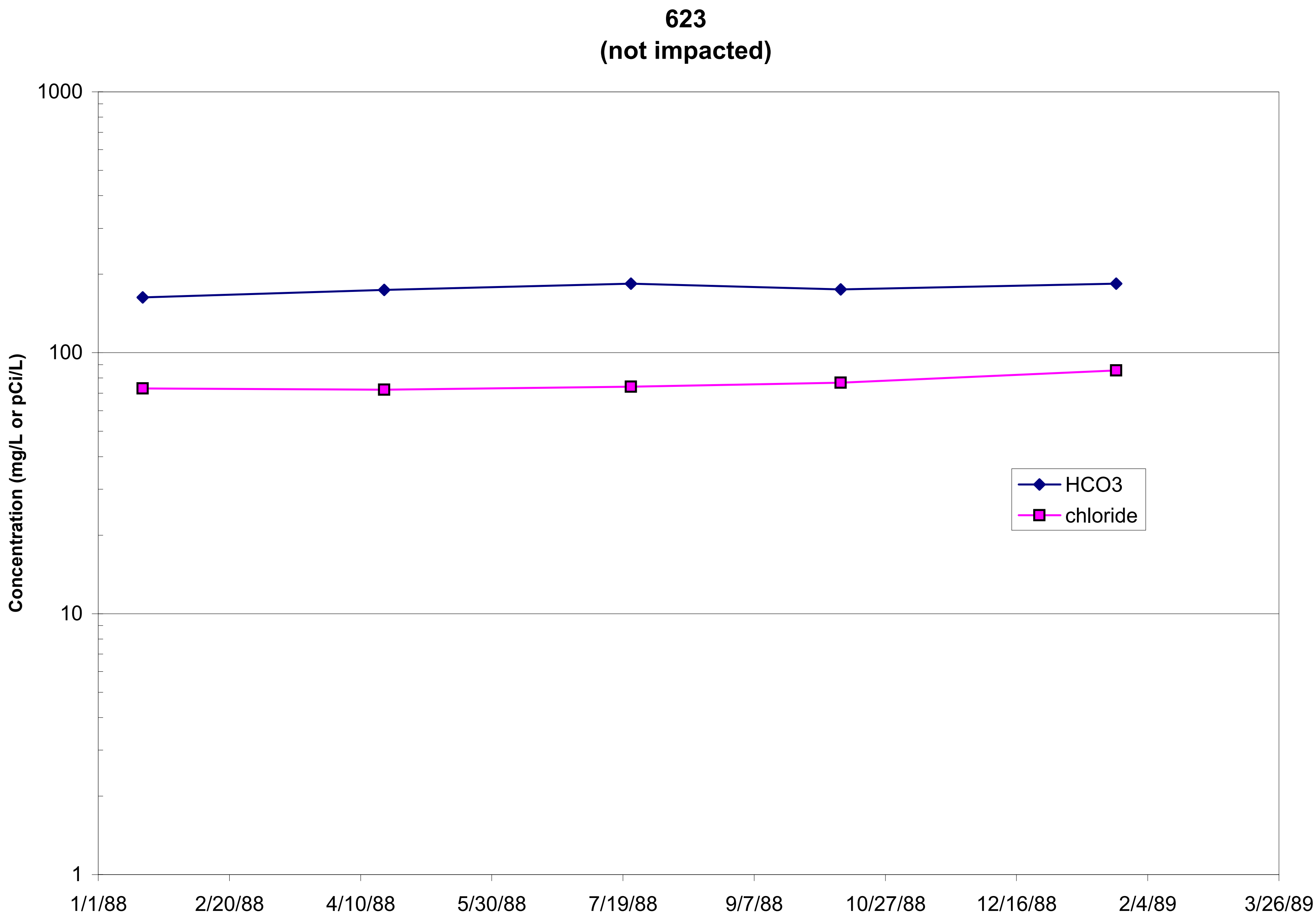
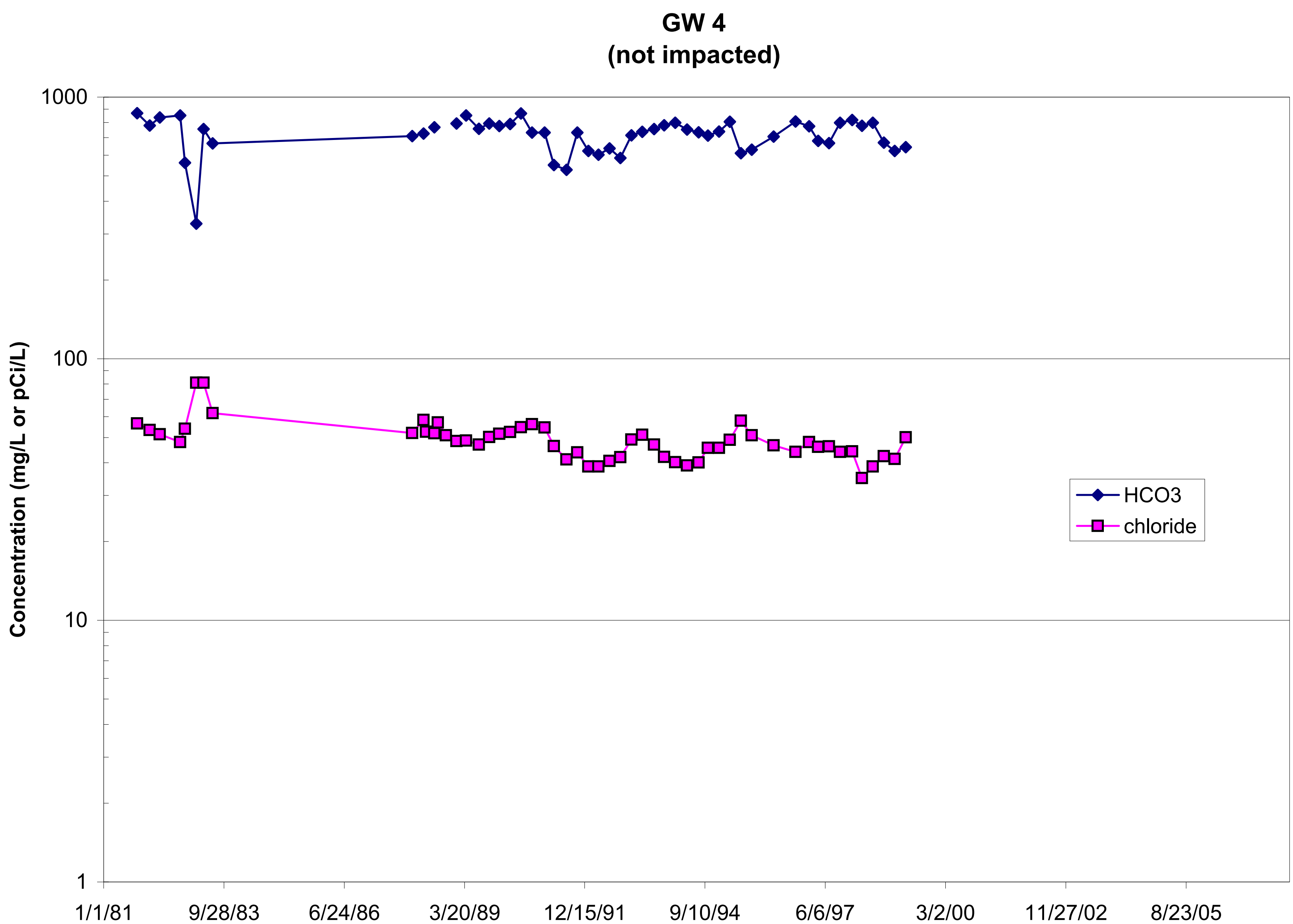
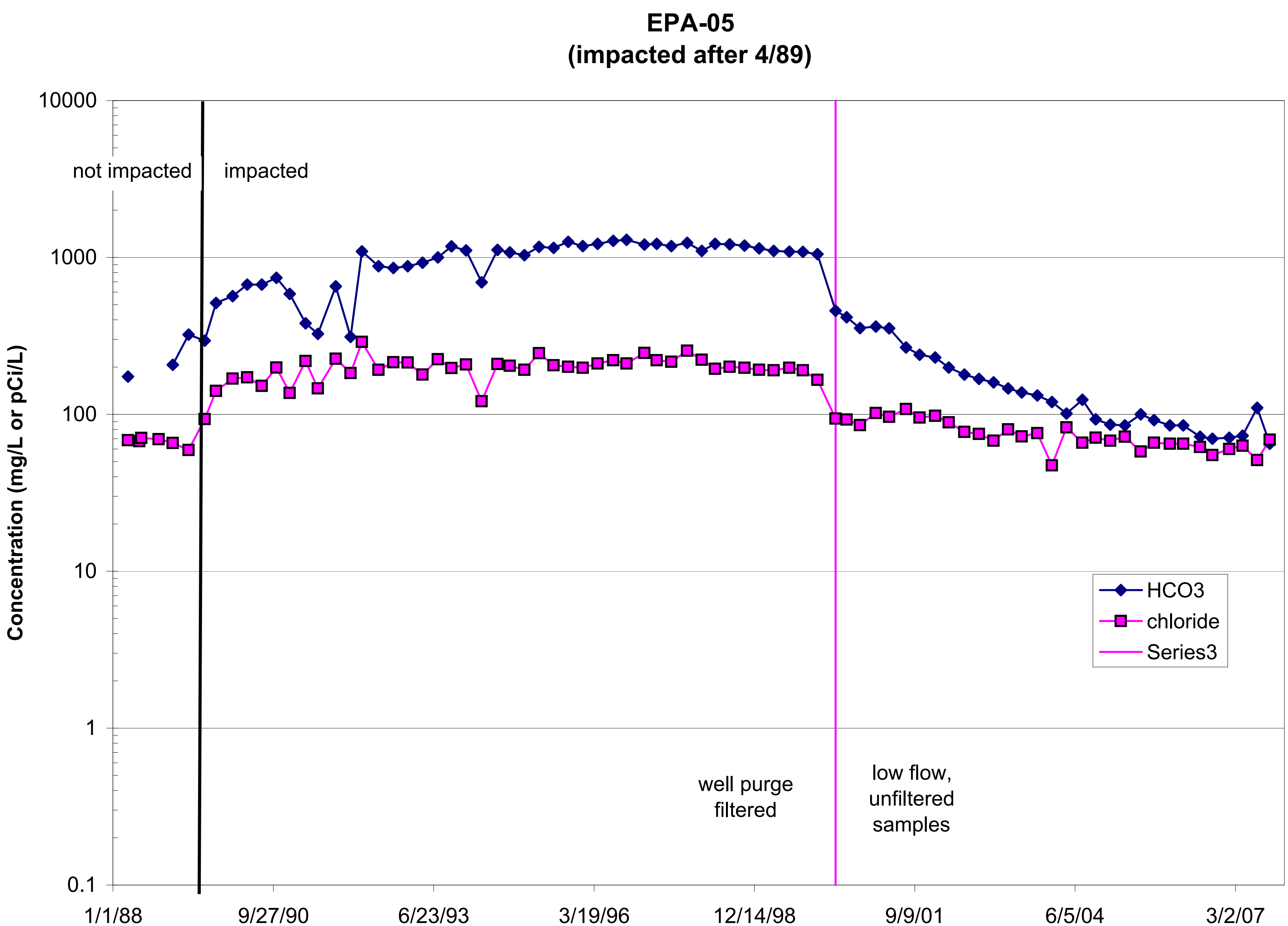
Appendix A
Time Series Graphs of Indicator Parameters

N.A. Water Systems, LLC
Airside Business Park, 250 Airside Drive
Moon Township, Pennsylvania 15108-2793 USA
Tel: 412-809-6000 ● Fax: 412-809-6075
Web site: www.nawatersystems.com

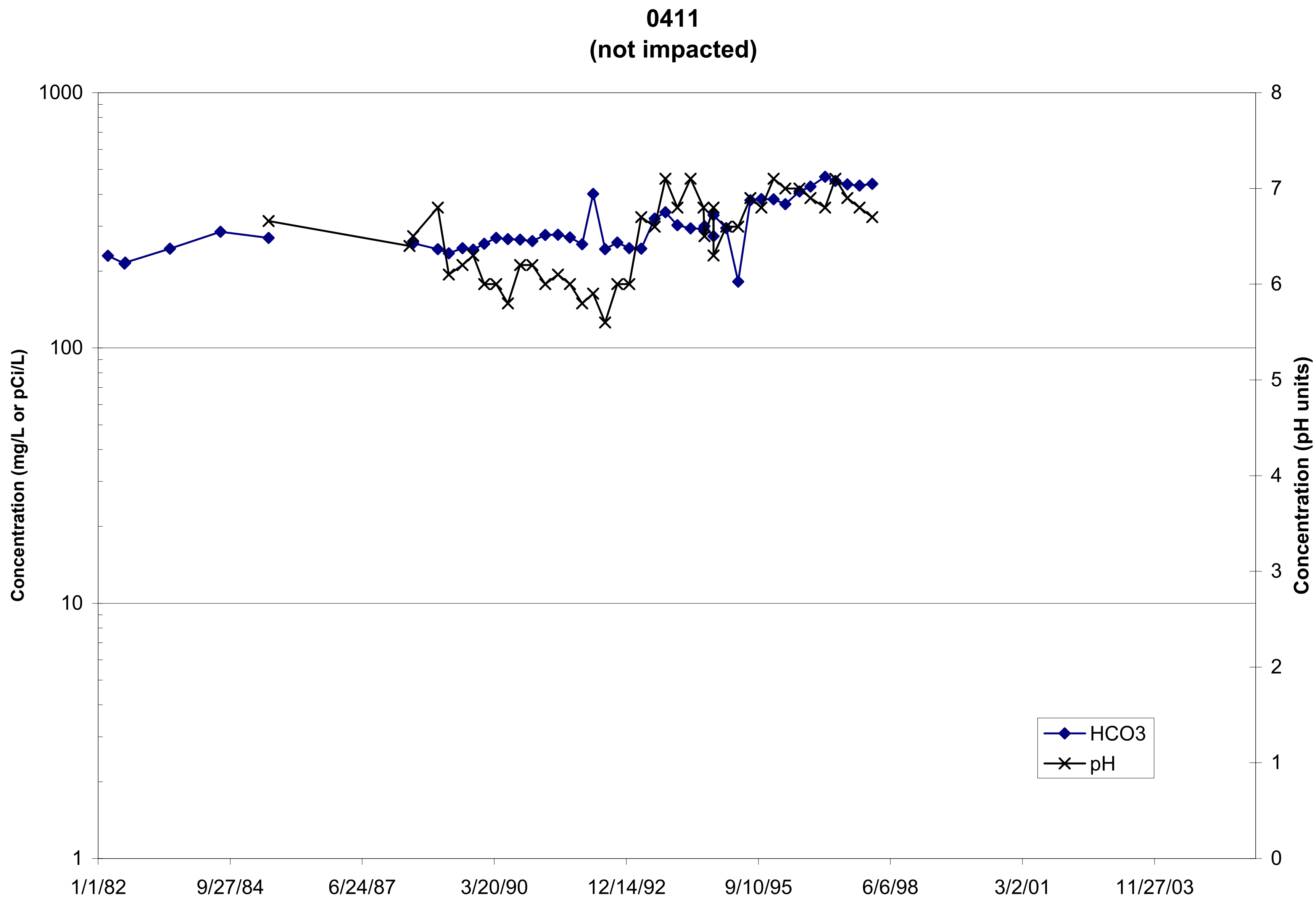
VEOLIA WATER
Solutions & Technologies


623
(not impacted)
1000
100
10
1
Concentration (mg/L or pCi/L)
HCO3
chloride
1/1/88
2/20/88
4/10/88
5/30/88
7/19/88
9/7/88
10/27/88
12/16/88
2/4/89
3/26/89


GW 4
(not impacted)
Concentration (mg/L or pCi/L)
1000
100
10
1
1/1/81
9/28/83
6/24/86
3/20/89
12/15/91
9/10/94
6/6/97
3/2/00
11/27/02
8/23/05
HCO3
chloride

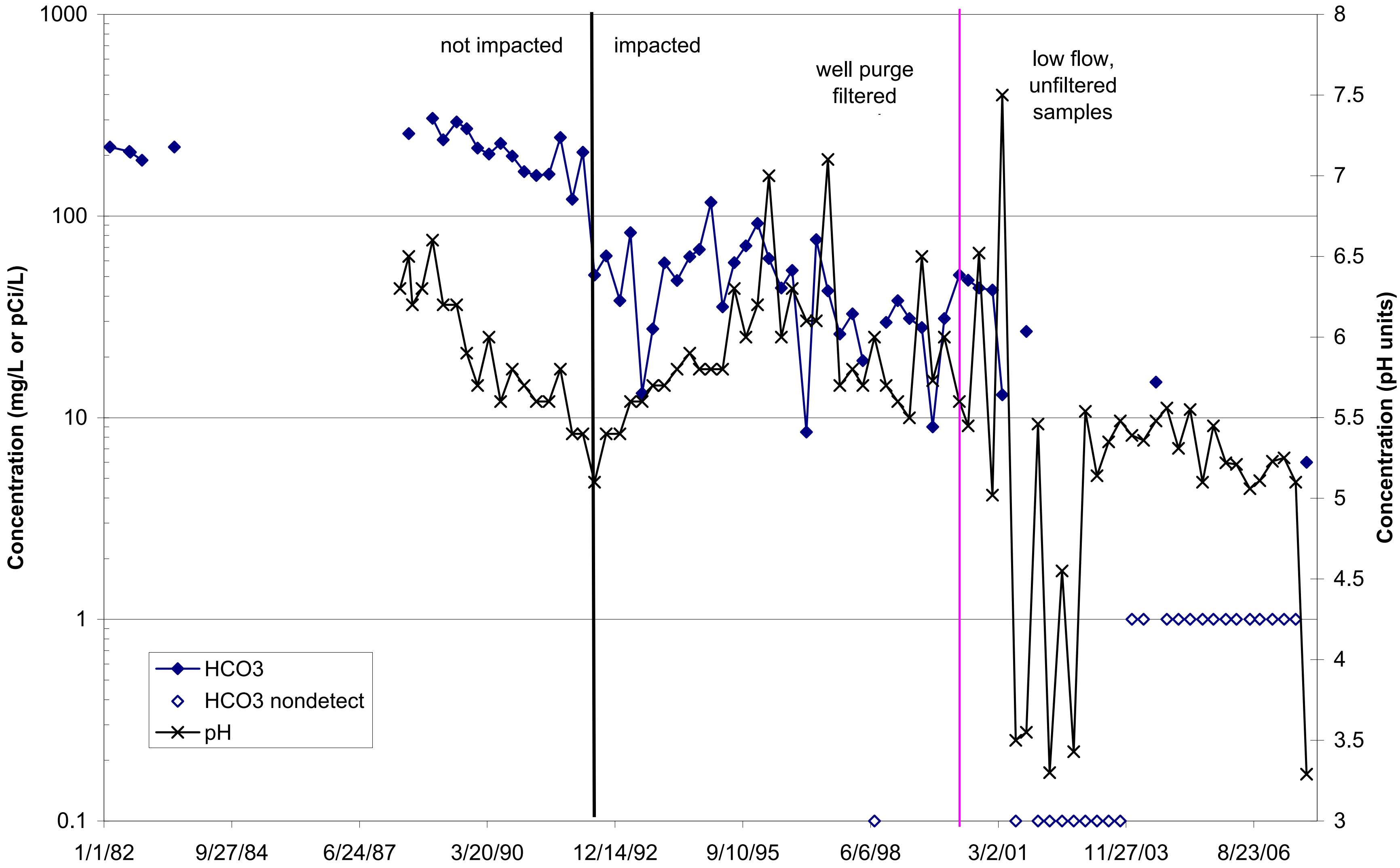


EPA-05
(impacted after 4/89)
10000
1000
100
10
1
0.1
Concentration (mg/L or pCi/L)
not impacted
impacted
well purge filtered
low flow, unfiltered samples
HCO3
chloride
Series3
1/1/88
9/27/90
6/23/93
3/19/96
12/14/98
9/9/01
6/5/04
3/2/07

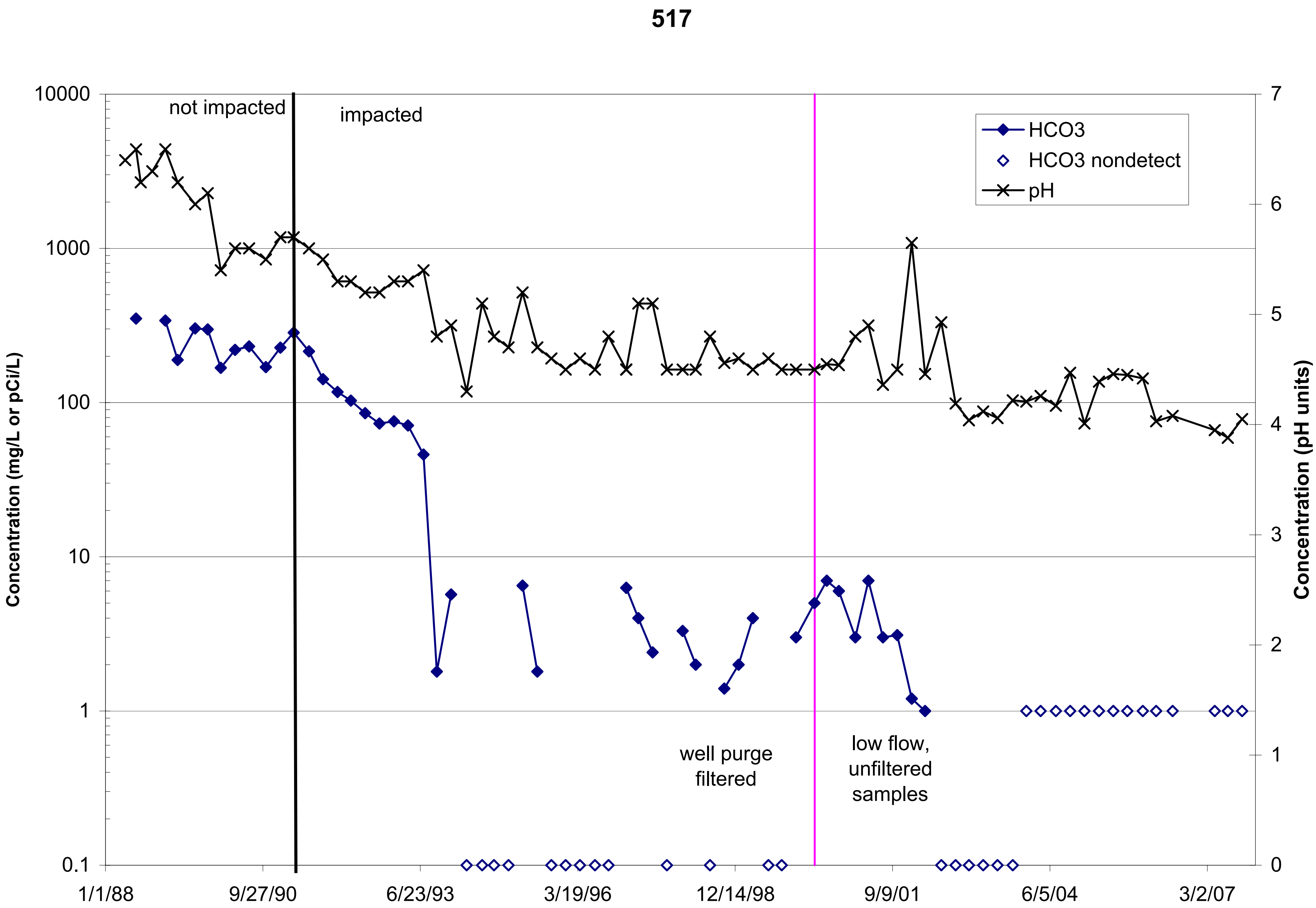


0411
(not impacted)
1000
100
10
1
8
7
6
5
4
3
2
1
0
Concentration (mg/L or pCi/L)
Concentration (pH units)
1/1/82
9/27/84
6/24/87
3/20/90
12/14/92
9/10/95
6/6/98
3/2/01
11/27/03
HCO3
pH

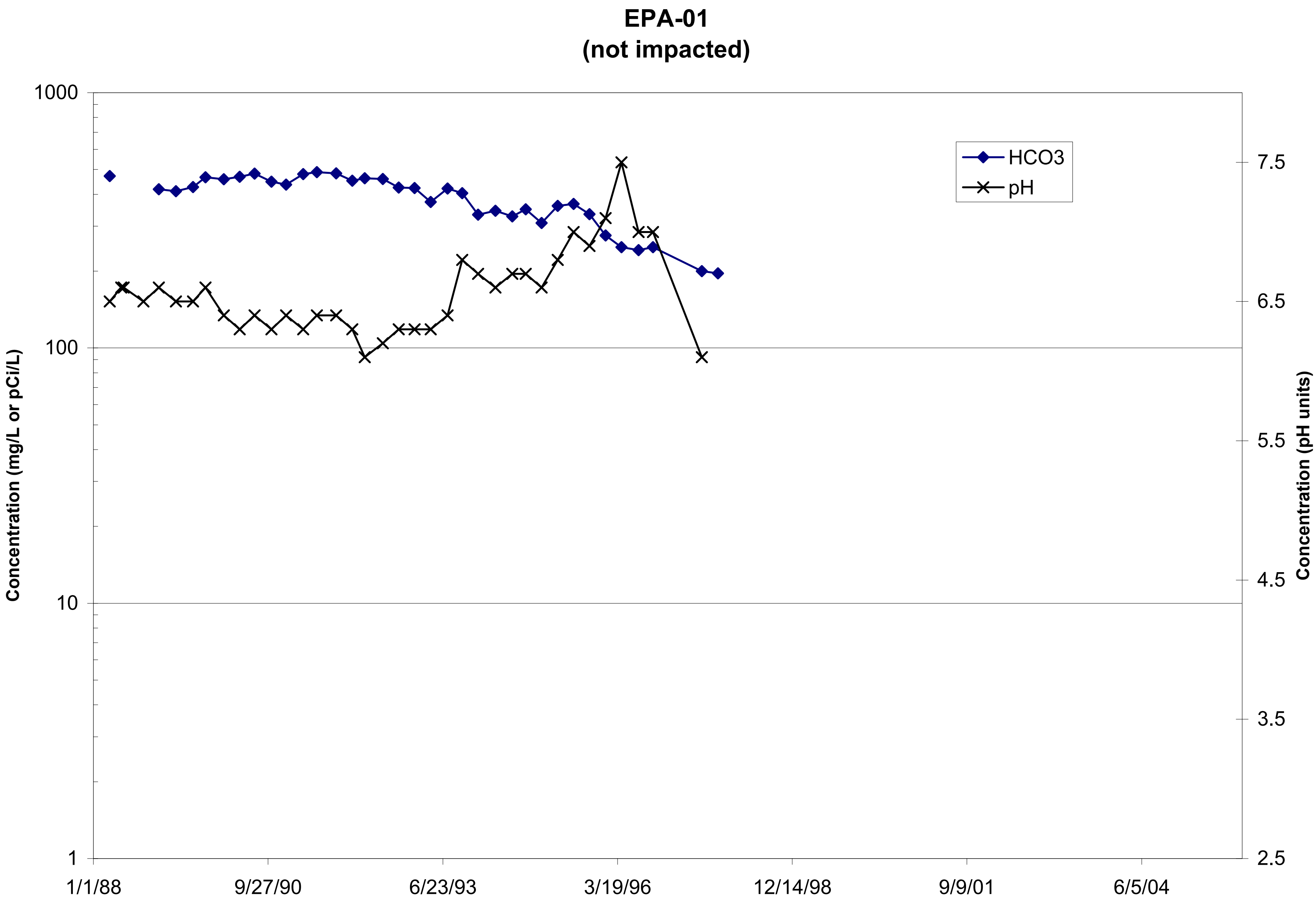
504 B



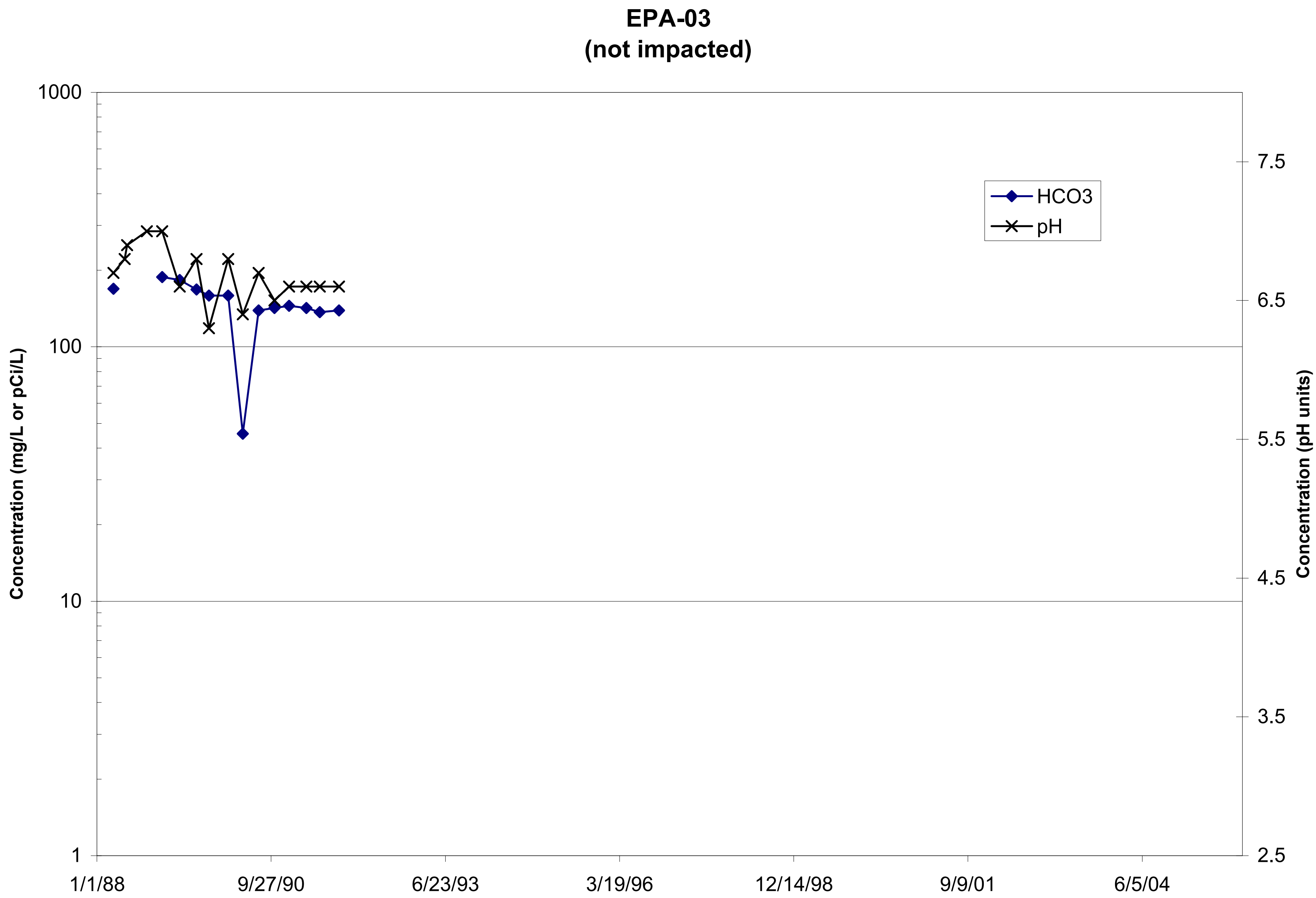
1000
100
10
1
0.1
Concentration (mg/L or pCi/L)
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
Concentration (pH units)
1/1/82
9/27/84
6/24/87
3/20/90
12/14/92
9/10/95
6/6/98
3/2/01
11/27/03
8/23/06
not impacted
impacted
well purge
filtered
low flow,
unfiltered
samples
HCO3
HCO3 nondetect
pH



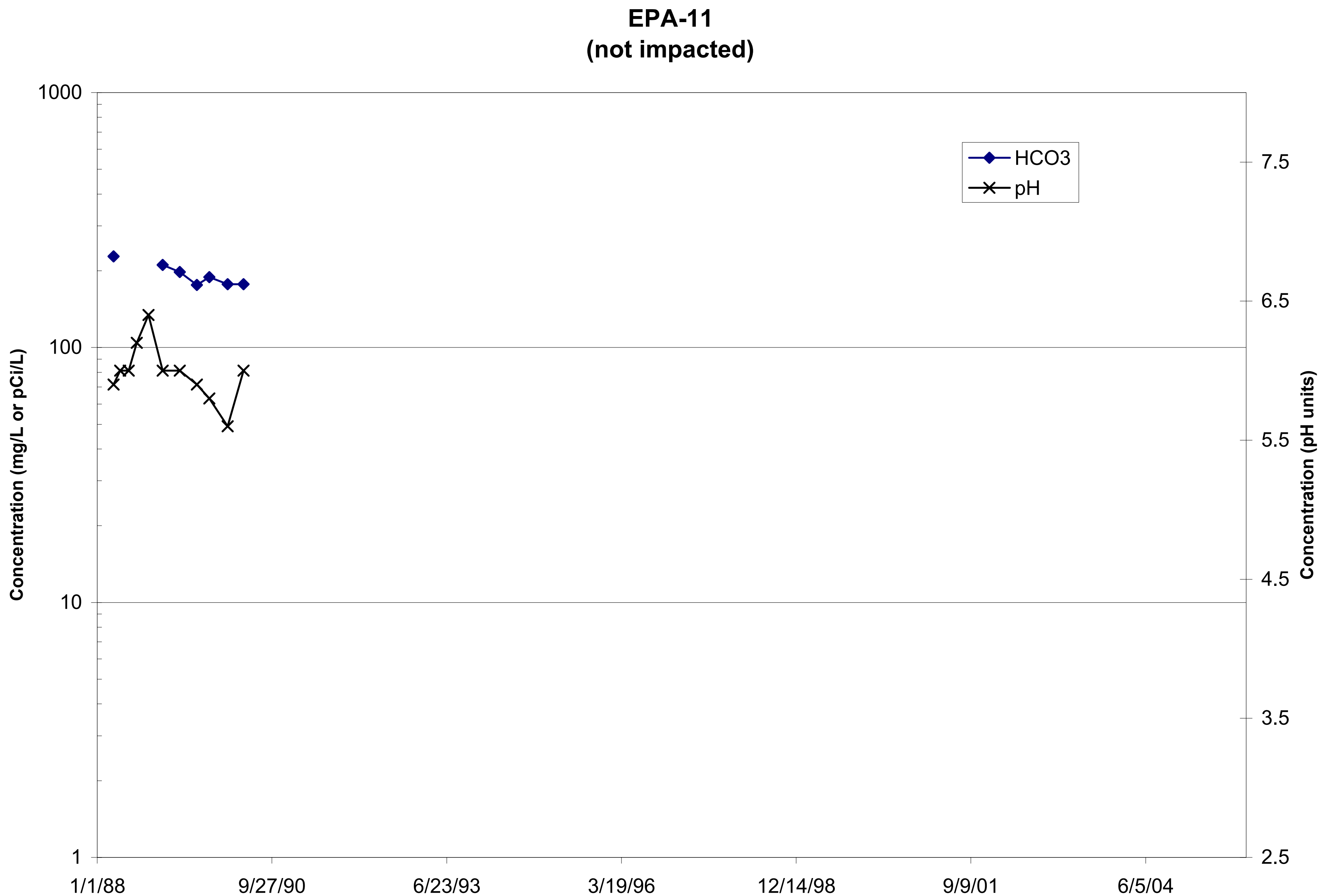
517
not impacted
impacted
HCO3
HCO3 nondetect
pH
well purge filtered
low flow, unfiltered samples
Concentration (mg/L or pCi/L)
Concentration (pH units)
10000
1000
100
10
1
0.1
7
6
5
4
3
2
1
0
1/1/88
9/27/90
6/23/93
3/19/96
12/14/98
9/9/01
6/5/04
3/2/07



EPA-01
(not impacted)
Concentration (mg/L or pCi/L)
Concentration (pH units)
HCO3
pH
1000
100
10
1
7.5
6.5
5.5
4.5
3.5
2.5
1/1/88
9/27/90
6/23/93
3/19/96
12/14/98
9/9/01
6/5/04

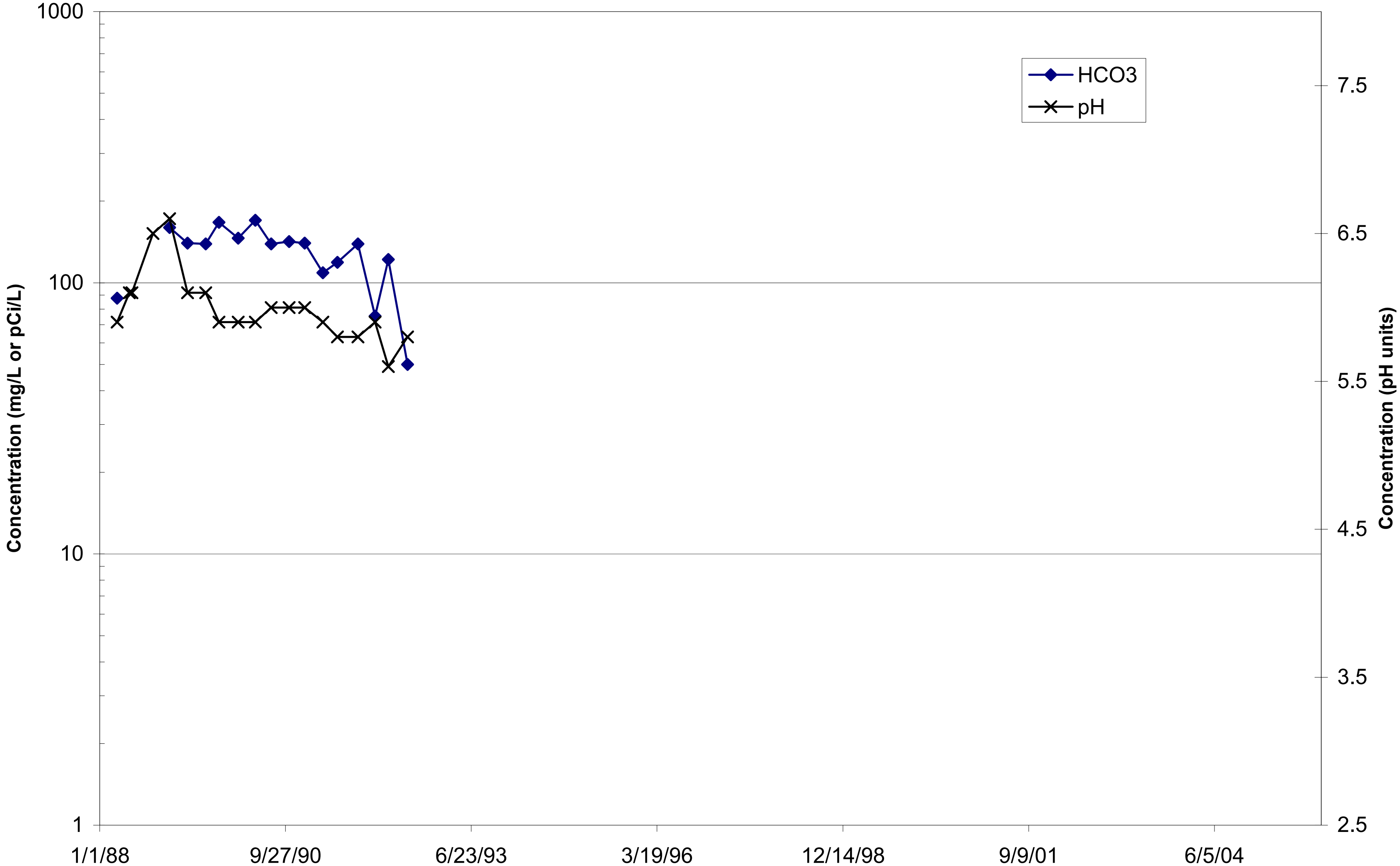


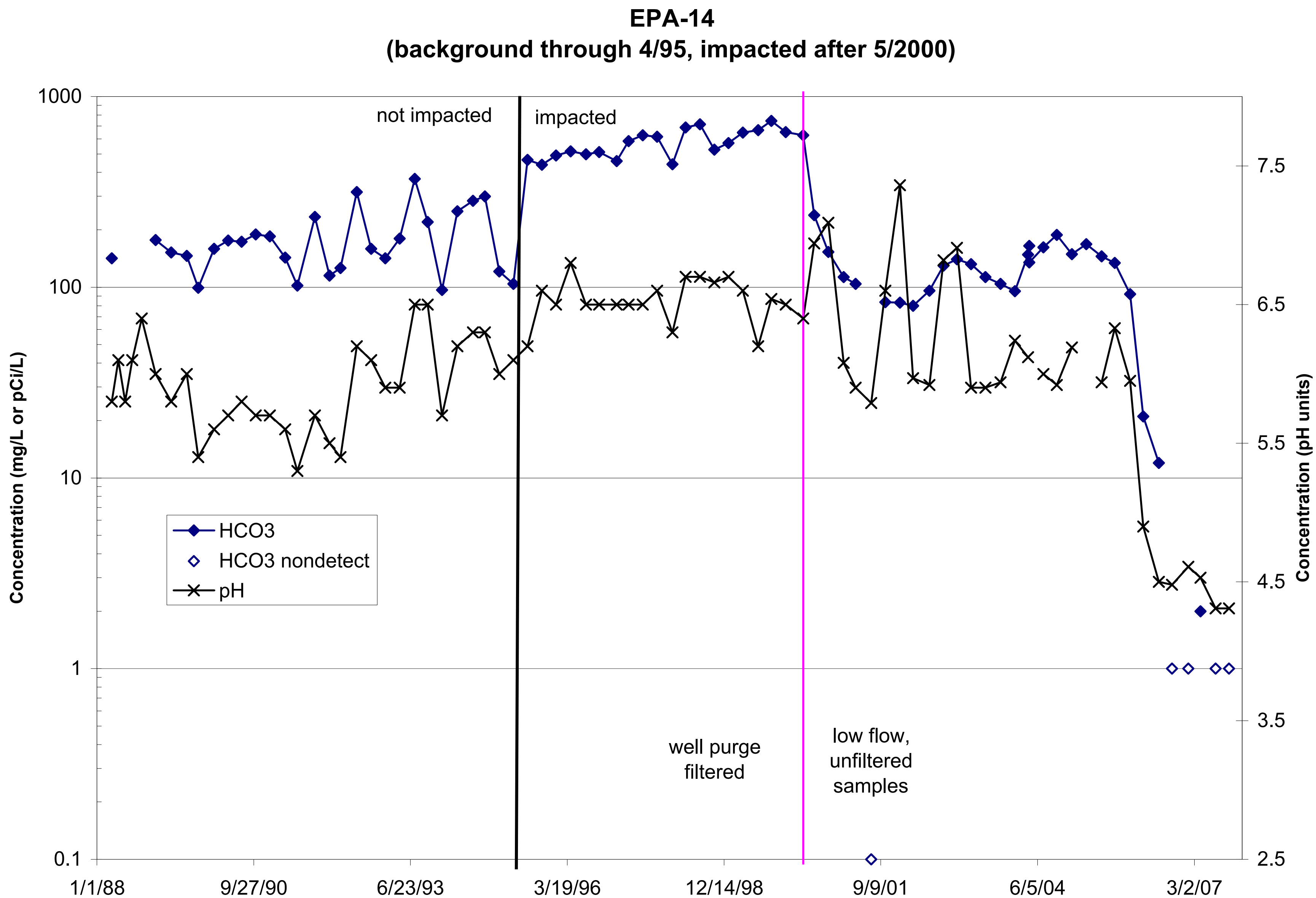
EPA-03
(not impacted)
1000
100
10
1
Concentration (mg/L or pCi/L)
7.5
6.5
5.5
4.5
3.5
2.5
Concentration (pH units)
HCO3
pH
1/1/88
9/27/90
6/23/93
3/19/96
12/14/98
9/9/01
6/5/04



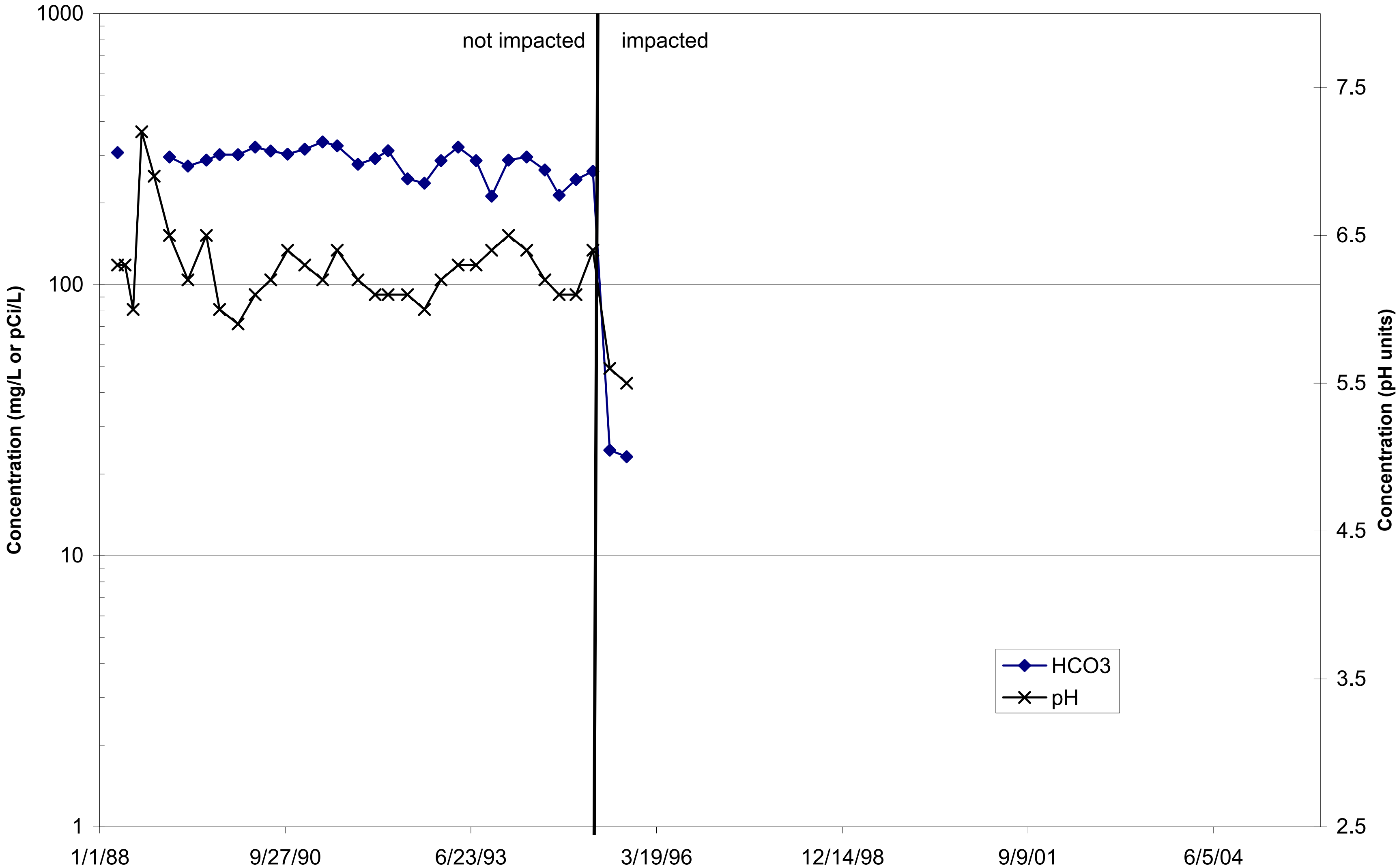
EPA-11
(not impacted)
1000
100
10
1
Concentration (mg/L or pCi/L)
7.5
6.5
5.5
4.5
3.5
2.5
Concentration (pH units)
HCO3
pH
1/1/88
9/27/90
6/23/93
3/19/96
12/14/98
9/9/01
6/5/04

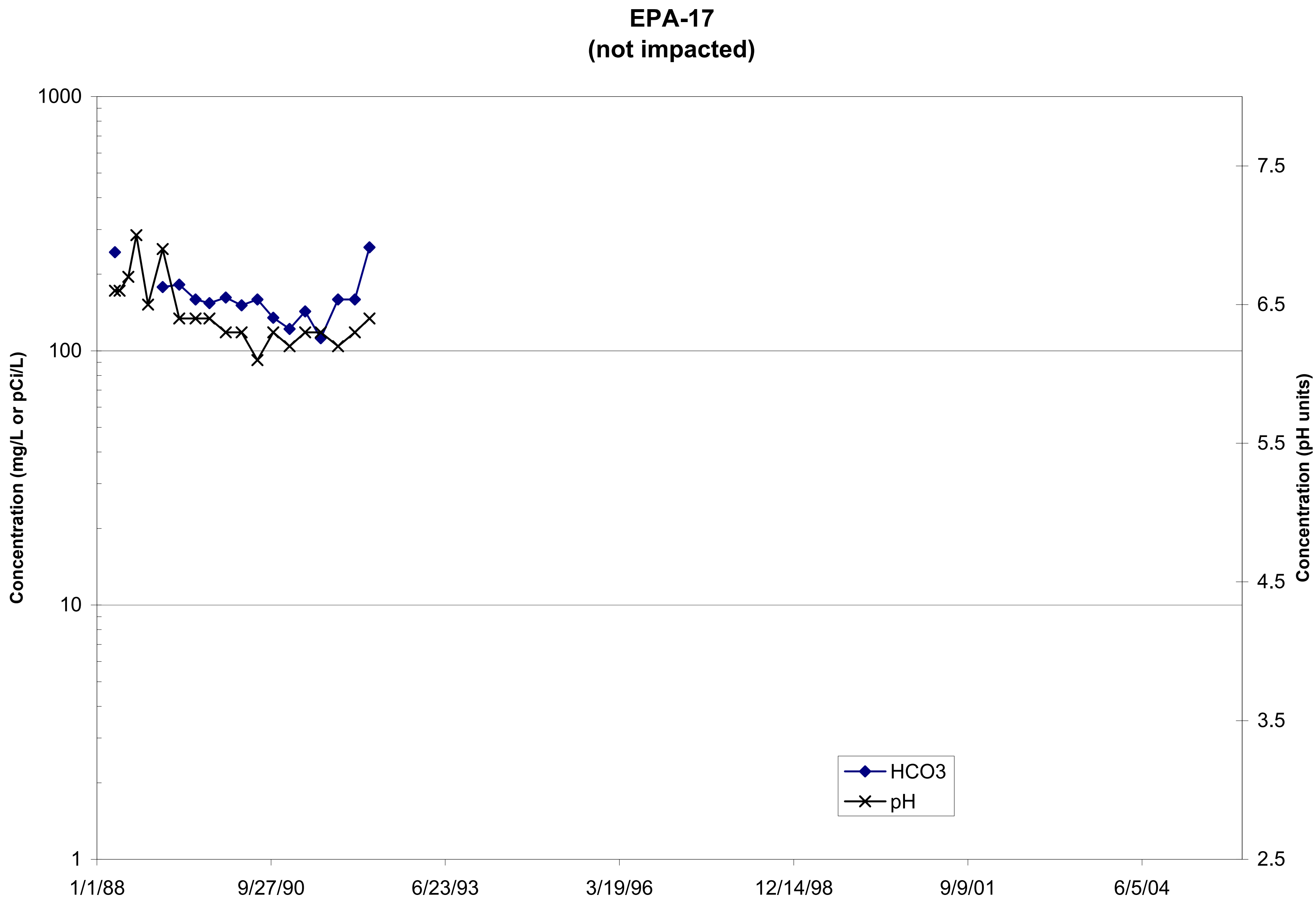
EPA-12
(not impacted)



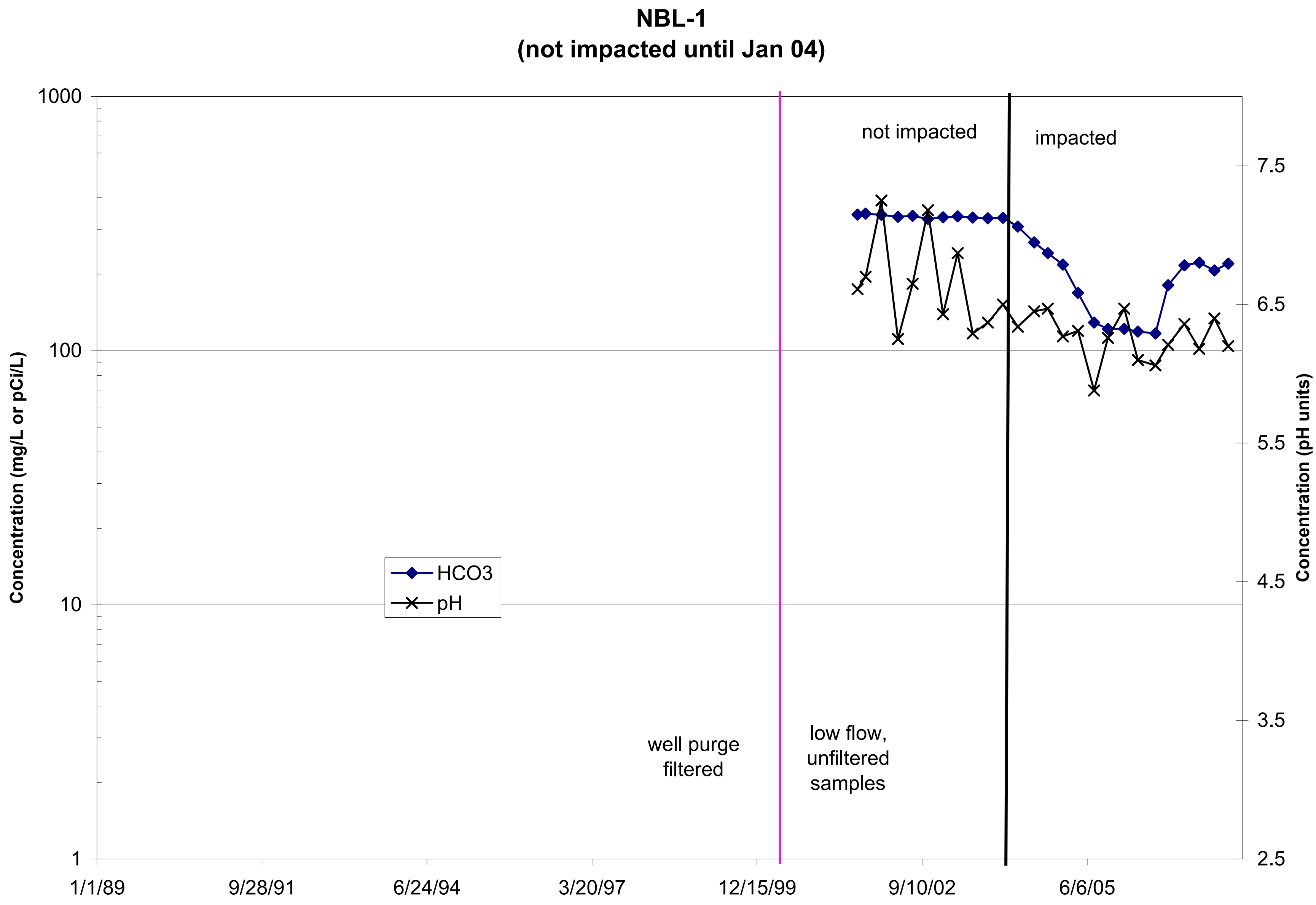

EPA-14
(background through 4/95, impacted after 5/2000)
not impacted
impacted
well purge
filtered
low flow,
unfiltered
samples
HCO3
HCO3 nondetect
pH
Concentration (mg/L or pCi/L)
Concentration (pH units)
1000
100
10
1
0.1
7.5
6.5
5.5
4.5
3.5
2.5
1/1/88
9/27/90
6/23/93
3/19/96
12/14/98
9/9/01
6/5/04
3/2/07

EPA-15
(not impacted through 4/95)





EPA-17
(not impacted)
1000
100
10
1
7.5
6.5
5.5
4.5
3.5
2.5
Concentration (mg/L or pCi/L)
Concentration (pH units)
1/1/88
9/27/90
6/23/93
3/19/96
12/14/98
9/9/01
6/5/04
HCO3
pH


NBL-1
(not impacted until Jan 04)
1000
100
10
1
7.5
6.5
5.5
4.5
3.5
2.5
Concentration (mg/L or pCi/L)
Concentration (pH units)
1/1/89
9/28/91
6/24/94
3/20/97
12/15/99
9/10/02
6/6/05
not impacted
impacted
HCO3
pH
well purge
filtered
low flow,
unfiltered
samples

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Appendix B
Summary Tables of Output from ProUCL
For UCL95 Statistics and Single Sample Hypothesis Tests

N.A. Water Systems, LLC
Airside Business Park, 250 Airside Drive
Moon Township, Pennsylvania 15108-2793 USA
Tel: 412-809-6000 ● Fax: 412-809-6075
Web site: www.nawatersystems.com

Nonparametric Background Statistics for Southwest Alluvium Data Sets with Non-Detects

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad-226	Rad-228	Rad_totl	Th-230	Pb-210	Gross_Alpha
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L
Total Number of Data	391	391	389	391	391	388	389	391	391	390	391	391	391	391	390	391	390	391	391	391	391	391	391
Number of Non-Detect Data	370	364	389	379	319	386	46	389	377	197	391	0	0	5	1	391	0	134	265	99	359	306	276
Number of Detected Data (or Distinct Obs. If zero nondetect)	21	27	0	12	72	2	343	2	14	193	0	262	306	386	389	0	307	257	126	292	32	85	115
Minimum Detected	0.1	0.001	N/A	0.006	0.01	0.05	0.01	0.03	0.05	0.001	N/A	9.8	605	0.09	0.001	N/A	1310	0.2	1	0.2	0.2	1	0.4
Maximum Detected	0.6	0.01	N/A	0.07	0.06	0.07	3.35	0.03	0.17	0.195	N/A	169	5830	1225	0.367	N/A	10530	9.4	7	12	14.3	14.2	17.8
Percent Non-Detects	94.6%	93.1%	100.0%	96.9%	81.6%	99.5%	11.83%	99.5%	96.4%	50.51%	100.0%	0.0%	0.0%	1.28%	0.26%	100.0%	0.0%	34.27%	67.77%	25.32%	91.8%	78.3%	70.6%
Minimum Non-detect	0.1	0.001		0.005	0.01	0.05	0.01	0.1	0.05	0.001	0.1	N/A	N/A	0.01	0.0003	0.001	N/A	0.02	1	0.2	0.2	1	1
Maximum Non-detect	0.1	0.001		0.01	0.01	0.05	0.01	0.1	0.05	0.001	0.1	N/A	N/A	0.1	0.0003	1	N/A	0.2	1	0.2	0.2	1	1
Mean of Detected Data	0.182	0.00237		0.0255	0.0186	0.06	0.339		0.08	0.00708		74.82	2401	99.54	0.0419		4630	0.979	2.55	1.9	2.841	2.845	3.35
Median of Detected Data	0.14	0.001		0.01	0.02	0.06	0.13		0.08	0.003		67.8	2420	74.1	0.031		4795	0.6	2.2	1.3	1.6	2.2	2.1
SD of Detected Data	0.123	0.00259		0.0242	0.0104	0.0141	0.536		0.0291	0.0168		40.39	808	124.1	0.0448		1377	1.149	1.369	1.783	2.912	2.07	2.927
Mean of Log-Transformed Detected Data	-1.848	-6.402		-4.04	-4.106	-2.827	-1.973		-2.572	-5.705		4.115	7.72	3.891	-3.431		8.386	-0.354	0.813	0.23	0.58	0.871	0.911
SD of Log-Transformed Detected Data	0.51	0.757		0.868	0.481	0.238	1.392		0.299	1.067		0.705	0.385	1.632	0.659		0.358	0.73	0.487	0.931	1.02	0.558	0.757
Discernable Distribution (0.05)	none	none	N/A	none	none	none	none	N/A	none	none	N/A	none	none	none	none	N/A	none	none	none	none	Gamma	Lognormal	none
Skewness of Detected Data	2.38	2.06	N/A	1.24	1.99	N/A	2.931	N/A	2.45	8.339	N/A	0.14	1.04	4.762	4.177	N/A	0.40	3.919	1.342	1.80	2.87	2.21	2.09
Kaplan-Meier (KM) Method																							
Mean	0.104	0.00109		0.0066	0.0116	0.0501	0.3		0.0511	0.00401		74.82	2401	98.27	0.0418		4630	0.712	1.499	1.47	0.416	1.401	1.494
SD	0.0334	7.53E-04		0.00527	0.00554	0.00101	0.514		0.00769	0.0122		40.34	806.9	123.6	0.0448		1375	1	1.06	1.707	1.094	1.225	1.99
Standard Error of Mean	0.00173	3.88E-05		2.78E-04	2.82E-04	7.28E-05	0.0261		4.04E-04	6.18E-04		2.043	40.86	6.261	0.00227		69.71	0.0507	0.0538	0.0865	0.0562	0.0623	0.119
95% KM (t) UCL	0.107	0.00116		0.00706	0.0121	0.0502	0.343		0.0517	0.00503		78.18	2468	108.6	0.0455		4744	0.796	1.588	1.612	0.509	1.504	1.689
95% KM (z) UCL	0.107	0.00116		0.00706	0.0121	0.0502	0.343		0.0517	0.00503		78.18	2468	108.6	0.0455		4744	0.795	1.588	1.612	0.509	1.503	1.689
95% KM (BCA) UCL	0.107	0.00117		0.0109	0.012	N/A	0.347		0.0706	0.00516		77.94	2465	108.4	0.0459		4750	0.798	1.624	1.621	0.812	1.532	1.687
95% KM (Percentile Bootstrap) UCL	0.107	0.00116		0.0108	0.0121	N/A	0.343		0.0613	0.00511		78.25	2470	109	0.0456		4740	0.797	1.611	1.61	0.71	1.513	1.693
95% KM (Chebyshev) UCL	0.112	0.00126		0.00781	0.0128	0.0504	0.414		0.0528	0.0067		83.72	2579	125.6	0.0517		4933	0.933	1.734	1.847	0.661	1.673	2.011
97.5% KM (Chebyshev) UCL	0.115	0.00134		0.00834	0.0133	0.0505	0.463		0.0536	0.00787		87.57	2656	137.4	0.056		5065	1.029	1.836	2.01	0.767	1.79	2.234
99% KM (Chebyshev) UCL	0.122	0.00148		0.00937	0.0144	0.0508	0.56		0.0551	0.0102		95.14	2807	160.6	0.0644		5323	1.216	2.035	2.33	0.975	2.021	2.674
Datasets without Nondetects																							
Student's-t UCL												78.18	2468				4744						
95% UCLs (Adjusted for Skewness)																							
95% Adjusted-CLT UCL												78.19	2470				4746						
95% Modified-t UCL												78.19	2468				4745						
Non-Parametric UCLs																							
95% CLT UCL												78.18	2468				4744						
95% Jackknife UCL												78.18	2468				4744						
95% Standard Bootstrap UCL												78.21	2468				4743						
95% Bootstrap-t UCL												78.3	2474				4743						
95% Hall's Bootstrap UCL												78.15	2470				4743						
95% Percentile Bootstrap UCL												78.25	2467				4739						
95% BCA Bootstrap UCL												78.23	2469				4751						
95% Chebyshev(Mean, Sd) UCL												83.72	2579				4933						
97.5% Chebyshev(Mean, Sd) UCL												87.57	2656				5065						
99% Chebyshev(Mean, Sd) UCL												95.14	2807				5323						
Potential UCL to Use																							
95% KM (t) UCL	0.107	0.00116		0.00706	0.0121	0.0502			0.0517										1.588		0.509	1.504	1.689
95% KM (z) UCL																							
95% KM (BCA) UCL										0.00516					0.0459			0.798		1.621			
95% KM (Percentile Bootstrap) UCL	0.107	0.00116		0.0108	0.0121				0.0613										1.611			1.513	1.693
95% KM (Chebyshev) UCL							0.414																
97.5% KM (Chebyshev) UCL														137.4									
99% KM (Chebyshev) UCL																							
95% Student's-t UCL													2468				4744						
95% Modified-t UCL													2468				4745						
95% Chebyshev(Mean, Sd) UCL												83.72											
Notes			4	1		2		3			4			1		4		1					

Note:

1. Data have multiple DLs - Use of KM Method is recommended
2. There may not be adequate detected values to compute meaningful and reliable test statistics and estimates
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
3. Warning: Only one distinct data value was detected! It is suggested to use alternative site specific values
   determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).
4. Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Nonparametric Background Statistics for Trace Metal Data Sets with Non-Detects in the Southwest Alluvium

	Sb	Ba	Cr	Cu	Fe	Hg	Ag	Tl	Zn
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Total Number of Data	0	26	37	13	19	8	21	0	25
Number of Non-Detect Data		26	36	11	15	8	21		10
Number of Detected Data (or Distinct Obs. If zero nondetect)		0	1	2	4	0	0		15
Minimum Detected					0.06				0.02
Maximum Detected					1.4				0.429
Percent Non-Detects		100.00%	97.30%	84.60%	78.95%	100.00%	100.00%		40.00%
Minimum Non-detect					0.05				0.01
Maximum Non-detect					0.1				0.1
Mean of Detected Data					0.418				0.0891
Median of Detected Data					0.105				0.05
SD of Detected Data					0.656				0.109
Mean of Log-Transformed Detected Data					-1.761				-2.889
SD of Log-Transformed Detected Data					1.434				0.936
Discernable Distribution (0.05)					Gamma				Gamma
Skewness of Detected Data					1.988				2.519
Kaplan-Meier (KM) Method for Datasets with Nondetects									
Mean					0.138				0.0636
SD					0.298				0.0879
Standard Error of Mean					0.079				0.0183
95% KM (t) UCL					**0.275**				**0.0949**
95% KM (z) UCL					0.268				0.0937
95% KM (BCA) UCL					1.4				0.1
95% KM (Percentile Bootstrap) UCL					0.342				0.0951
95% KM (Chebyshev) UCL					0.482				0.143
97.5% KM (Chebyshev) UCL					0.631				0.178
99% KM (Chebyshev) UCL					0.924				24.60%
Datasets without Nondetects									
Student's-t UCL									
95% UCLs (Adjusted for Skewness)									
95% Adjusted-CLT UCL									
95% Modified-t UCL									
Non-Parametric UCLs									
95% CLT UCL									
95% Jackknife UCL									
95% Standard Bootstrap UCL									
95% Bootstrap-t UCL									
95% Hall's Bootstrap UCL									
95% Percentile Bootstrap UCL									
95% BCA Bootstrap UCL									
95% Chebyshev(Mean, Sd) UCL									
97.5% Chebyshev(Mean, Sd) UCL									
99% Chebyshev(Mean, Sd) UCL									
Potential UCL to Use									
95% KM (t) UCL					**0.275**				**0.0949**
95% KM (z) UCL									
95% KM (BCA) UCL									
95% KM (Percentile Bootstrap) UCL									
95% KM (Chebyshev) UCL									
97.5% KM (Chebyshev) UCL									
99% KM (Chebyshev) UCL									
95% Student's-t UCL									
95% Modified-t UCL									
Notes		**5**	**4**	**4**	**1, 3**	**5**	**5**		**1**

Note:

1. Data have multiple DLs - Use of KM Method is recommended
2. UCL recommendation based on guidance (table 16). None provided by software.
3. There may not be adequate detected values to compute meaningful and reliable test statistics and estimates
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
4. Warning: Only one distinct data value was detected! It is suggested to use alternative site specific values
   determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).
5. Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
6. Insufficent Number of Observations to produce Meaningful Statistics.

Comparisons of Background Sample Distributions to Comparison Values for Contaminants of Concern in the Southwest Alluvium

Single Sample Sign Test

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Raw Statistics													
Number of Valid Data	391	391	389	391	391	388	389	391	391	390	391	391	391
Number of Distinct Data	8	6	3	7	5	2	90	2	6	28	1	262	306
Number of Non-Detect Data	370	364	389	379	319	386	46	389	377	197	391	0	0.00%
Number of Detected Data	21	27	0	12	72	2	343	2	14	193	0	391	391
Percent Non-Detects	94.63%	93.09%	100.00%	96.93%	81.59%	99.48%	11.83%	99.49%	96.42%	50.51%	100.00%	0.00%	0.00%
Minimum Non-detect	0.1	0.001	0.01	0.005	0.01	0.05	0.01	0.1	0.05	0.001	0.1	N/A	N/A
Maximum Non-detect	0.1	0.001	0.1	0.01	0.01	0.05	0.01	0.1	0.05	0.001	0.1	N/A	N/A
Minimum Detected	0.1	0.001	N/A	0.006	0.01	0.05	0.01	0.03	0.05	0.001	N/A	9.8	605
Maximum Detected	0.6	0.01	N/A	0.07	0.06	0.07	3.35	0.03	0.17	0.195	N/A	169	5830
Mean of Detected Data	0.182	0.00237	N/A	0.0255	0.0186	0.06	0.339	0.03	0.08	0.00708	N/A	74.82	2401
Median of Detected Data	0.14	0.001	N/A	0.01	0.02	0.06	0.13	0.03	0.08	0.003	N/A	67.8	2420
SD of Detected Data	0.123	0.00259	N/A	0.0242	0.0104	0.0141	0.536	0	0.0291	1.68%	N/A	40.39	808
Number Above Limit	0	0	0	12	2	1	144	0	0	2	0	0	292
Number Equal Limit	0	1	0	36	0	387	3	0	0	0	391	0	0
Number Below Limit	391	390	0	0	389	0	242	391	391	388	0	391	99
Number Observations Discarded			389	379		387					391	0	0
H0: Site Median >= Comparison Value (Form 2)	**5**	**0.01**	**0.004**	**0.005**	**0.05**	**0.05**	**0.2**	**1**	**0.2**	**0.05**	**0.1**	**250**	**2125**
Test Value	-19.77	-19.75	0	12	-19.57	1	-4.988	-19.77	-19.77	-19.55	0	-19.77	9.76
Lower Critical Value (0.05)	-1.645	-1.645	-1	2	-1.645	-1	-1.645	-1.645	-1.645	-1.645	-1	-1.645	-1.645
P-Value	0	0	1	1	0	1	3.05E-07	0	0	0	1	0	1
Obsevations below max detection limit = non-detects[1]				0.01				0.1					
Conclusion with Alpha = 0.05	**Reject**	**Reject**	Do not Reject	**Do not Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Do not Reject**	**Reject**	**Do not Reject**
Notes			2, 4	1, 3		3		1			2, 4		

	NO3_as_N	U	Chloroform	Lab_TDS	Rad_totl	Th-230	Pb-210	Gross_Alph	Sb	Ba	Cr	Cu	Fe	Hg	Ag	Tl	Zn
Concentration Units	mg/L	mg/L	ug/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L
Raw Statistics																	
Number of Valid Data	391	390	391	390	391	391	391	391		26	37	13	19	8	21		25
Number of Distinct Data	279	189	3	307	61	24	38	59		3	4	2	6	2	2		12
Number of Non-Detect Data	5	1	391	0	99	359	306	276		26	36	11	15	8	21		10
Number of Detected Data	386	389	0	390	292	32	85	115		0	1	2	4	0	0		15
Percent Non-Detects	1.28%	0.26%	100.00%	0.00%	25.32%	91.82%	78.26%	70.59%		100%	97.30%	84.62%	78.95%	100.00%	100.00%		40.00%
Minimum Non-detect	0.01	0.0003	0.001	N/A	0.2	0.2	1	1		0.001	0.001	0.01	0.05	0.0002	0.01		0.01
Maximum Non-detect	0.1	0.0003	1	N/A	0.2	0.2	1	1		0.1	0.05	0.02	0.1	0.001	0.05		0.1
Minimum Detected	0.09	0.001	N/A	1310	0.2	0.2	1	0.4		N/A	0.029	0.01	0.06	N/A	N/A		0.02
Maximum Detected	1225	0.367	N/A	10530	12	14.3	14.2	17.8		N/A	0.029	0.01	1.4	N/A	N/A		0.429
Mean of Detected Data	99.54	0.0419	N/A	4630	1.9	2.841	2.845	3.35		N/A	0.029	0.01	0.418	N/A	N/A		0.0891
Median of Detected Data	74.1	0.031	N/A	4795	1.3	1.6	2.2	2.1		N/A	0.029	0.01	0.105	N/A	N/A		0.05
SD of Detected Data	124.1	0.0448	N/A	1377	1.783	2.912	2.07	2.927		N/A	N/A	0	0.656	N/A	N/A		0.109
Number Above Limit	322	197	0	351	19	6	82	1		0	0	0	1	0	0		0
Number Equal Limit	1	3	0	0	0	0	309	0		0	26	0	0	0	17		0
Number Below Limit	68	190	391	39	372	385	0	390		26	11	13	18	8	4		25
Number Observations Discarded				0			309				26				17		
H0: Site Median >= Comparison Value (Form 2)	**30**	**0.03**	**80**	**3170**	**5**	**5**	**1**	**15**	**0.006**	**2**	**0.05**	**1**	**1**	**0.002**	**0.05**		**10**
Test Value	12.86	0.356	-19.77	15.8	-17.85	-19.17	9.055	-19.67		0	0	0	1	0	0		0
Lower Critical Value (0.05)	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645		8	2	3	5	1	-1		7
P-Value	1	0.639	0	1	0	0	1	0		1.49E-08	4.88E-04	1.22E-04	3.81E-05	0.00391	0.0625		2.98E-08
Obsevations below max detection limit = non-detects[1]	0.1							1			0.05	0.02	0.1				**0.1**
Conclusion with Alpha = 0.05	**Do not Reject**	**Do not Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Do not Reject**	**Reject**	**no data**	**Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Do not Reject**	**no data**	**Reject**
Notes	1		4				3	1	5	4	1, 3	1	1	4	3, 4, 6	5	1

1. Values lower than listed maximum nondetect value are treated by ProUCL as nondetects in single sample hypotheses tests
2. All detection limits equal or higher than ARAR, all data rejected
3. Nondetects equal or higher than ARAR rejected
4. All values nondetects
5. No data
6. Erroneous conclusion by ProUCL

Comparisons of Background Sample Distributions to Comparison Values for Contaminants of Concern in the Southwest Alluvium

Single Sample Wilcoxon Signed Rank Test

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad_totl	Th-230	Pb-210	Gross_Alph	Sb	Ba	Cr	Cu	Fe	Hg	Ag	Tl	Zn
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L
Raw Statistics																														
Number of Valid Data	391	391	389	391	391	388	389	391	391	390	391	391	391	391	390	391	390	391	391	391	391	0	26	37	13	19	8	21	0	25
Number of Distinct Data	8	6	3	7	5	2	90	2	6	28	1	262	306	279	189	3	307	61	24	38	59		3	4	2	6	2	2		12
Number of Non-Detect Data	370	364	389	379	319	386	46	389	377	197	391	0	0	5	1	391	0	99	359	306	276		26	36	11	15	8	21		10
Number of Detected Data	21	27	0	12	72	2	343	2	14	193	0	391	391	386	389	0	390	292	32	85	115		0	1	2	4	0	0		15
Percent Non-Detects	94.63%	93.09%	100.00%	96.93%	81.59%	99.48%	11.83%	99.49%	96.42%	50.51%	100.00%	0.00%	0.00%	1.28%	0.26%	100.00%	0.00%	25.32%	91.82%	78.26%	70.59%		100.00%	97.30%	84.62%	78.95%	100.00%	100.00%		40.00%
Minimum Non-detect	0.1	0.001	0.01	0.005	0.01	0.05	0.01	0.1	0.05	0.001	0.1	N/A	N/A	0.01	0.0003	0.001	N/A	0.2	0.2	1	1		0.001	0.001	0.01	0.05	0.0002	0.01		0.01
Maximum Non-detect	0.1	0.001	0.1	0.01	0.01	0.05	0.01	0.1	0.05	0.001	0.1	N/A	N/A	0.1	0.0003	1	N/A	0.2	0.2	1	1		0.1	0.05	0.02	0.1	0.001	0.05		0.1
Minimum Detected	0.1	0.001	N/A	0.006	0.01	0.05	0.01	0.03	0.05	0.001	N/A	9.8	605	0.09	0.001	N/A	1310	0.2	0.2	1	0.4		N/A	0.029	0.01	0.06	N/A	N/A		0.02
Maximum Detected	0.6	0.01	N/A	0.07	0.06	0.07	3.35	0.03	0.17	0.195	N/A	169	5830	1225	0.367	N/A	10530	12	14.3	14.2	17.8		N/A	0.029	0.01	1.4	N/A	N/A		0.429
Mean of Detected Data	0.182	0.00237	N/A	0.0255	0.0186	0.06	0.339	0.03	0.08	0.00708	N/A	74.82	2401	99.54	0.0419	N/A	4630	1.9	2.841	2.845	3.35		N/A	0.029	0.01	0.418	N/A	N/A		0.0891
Median of Detected Data	0.14	0.001	N/A	0.01	0.02	0.06	0.13	0.03	0.08	0.003	N/A	67.8	2420	74.1	0.031	N/A	4795	1.3	1.6	2.2	2.1		N/A	0.029	0.01	0.105	N/A	N/A		0.05
SD of Detected Data	12.30%	0.26%	N/A	0.0242	0.0104	0.0141	0.536	0	0.0291	0.0168	N/A	40.39	808	124.1	0.0448	N/A	1377	1.783	2.912	2.07	2.927		N/A	N/A	0	0.656	N/A	N/A		0.109
Number Above Limit	0	0	389	11	2	1	144	0	0	2	0	0	292	322	197	0	351	19	6	82	1		0	0	0	1	0	0		0
Number Equal Limit	0	1	0	343	0	1	3	0	0	0	0	0	0	1	3	0	0	0	0	3	0		0	0	0	0	0	0		0
Number Below Limit	391	390	0	37	389	386	242	391	391	388	391	391	99	68	190	391	39	372	385	306	390		26	37	13	18	8	21		25
T-plus	0	0	75855	473	3	1	32515	0	0	458	0	0	56328	67525	45502	0	70816	1241	424.5	23905	2		0	0	0	1	0	0		0
T-minus	76636	76245	0	703	76633	75077	42177	76636	76636	75787	76636	76636	20309	8721	29577	76636	5429	75396	76212	51561	76634		351	703	91	189	36	231		325
H0: Site Median >= Comparison Value (Form 2)	**5**	**0.01**	**0.004**	**0.005**	**0.05**	**0.05**	**0.2**	**1**	**0.2**	**0.05**	**0.1**	**250**	**2125**	**30**	**0.03**	**80**	**3170**	**5**	**5**	**1**	**15**	**0.006**	**2**	**0.05**	**1**	**1**	**0.002**	**0.05**	**0.002**	**10**
Large Sample z-Test Value	-19.29	-19.26	18.47	-409.8	-18.43	-19.75	-2.468	-19.72	-19.44	-17.19	-19.77	-17.14	8.054	13.11	3.351	-18.98	14.68	-16.62	-18.86	-6.968	-17.94		-4.751	-5.541	0	1	0	-4.272		-4.38
Critical Value (0.05)	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645		-1.645	-1.645	21	53	5	-1.645		-1.645
P-Value	0	0	1	0	0	0	0.00679	0	0	0	0	0	1	1	1	0	1	0	0	1.60E-12	0		1.01E-06	1.51E-08	1.00E-04	0	0.0039	9.67E-06		5.95E-06
Obsevations below max detection limit = non-detects[1]			0.1	0.01				0.1						0.1							1			0.05	0.02	0.1				0.1
Conclusion with Alpha = 0.05	**Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Do not Reject**	**Do not Reject**	**Do not Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**no data**	**Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**no data**	**Reject**
Notes			1,2, 4	1, 2, 3, 6		3		1			3, 4			1		4				3	1	5	4	1, 3	1	1	2, 4	3, 4	5	1

1. Values lower than listed maximum nondetect value are treated by ProUCL as nondetects in single sample hypotheses tests
2. Detection limit higher than ARAR
3. Detection limit equals ARAR
4. All data nondetects
5. No data
6. Erroneous conclusion by ProUCL

Nonparametric Background Statistics for Zone 1 Data Sets with Non-Detects

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad-226	Rad-228	Rad_totl	Th-230	Pb-210	Gross_Alpha
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L
Total Number of Data	234	234	234	234	234	234	234	234	230	234	234	234	234	233	233	234	234	233	234	234	234	234	234
Number of Non-Detect Data	203	196	234	231	210	233	1	229	227	224	234	0	0	167	39	233	0	4	70	2	215	189	82
Number of Detected Data (or Distinct Obs. If zero nondetect)	31	38		3	24	1	233	5	3	10		156	187	66	194	1	186	229	164	232	19	45	152
Minimum Detected	0.1	0.001		0.005	0.01		0.66	0.03	0.06	0.001		19.4	1410	0.01	4.00E-04	0.91	2490	0.2	1	0.2	0.2	1.1	0.9
Maximum Detected	0.6	0.004		0.01	0.06		4.15	0.27	0.07	0.004		252	3882	51.8	0.975	0.91	5610	5.4	13.8	14.8	4.9	9.1	14
Percent Non-Detects	86.75%	83.76%	100.0%	98.72%	89.74%	99.6%	0.43%	97.86%	98.70%	95.73%	100.0%	0	0	71.67%	16.74%	99.57%	0	1.72%	29.91%	0.85%	91.88%	80.77%	35.04%
Minimum Non-detect	0.1	0.001	0.01	0.005	0.01	0.05	0.01	0.01	0.05	0.001	0.1	NA	NA	0.01	3.00E-04	0.5	NA	0.2	1	0.2	0.02	1	1
Maximum Non-detect	0.1	0.001	0.05	0.01	0.01	0.05	0.01	0.1	0.05	0.001	0.1	NA	NA	0.1	4.00E-04	1	NA	0.2	1	0.2	0.2	1	1
Mean of Detected Data	0.185	0.00174		0.00733	0.0171		2.434	0.12	0.0667	0.0019		37.13	2703	1.767	0.00862		4225	1.269	3.457	3.618	0.974	2.58	2.757
Median of Detected Data	0.14	0.002		0.007	0.01		2.65	0.13	0.07	0.0015		37.9	2952	0.16	0.0013		4569	1.2	3.1	3.35	0.7	2.1	2
SD of Detected Data	0.107	7.60E-04		0.00252	0.0112		0.814	0.099	0.00577	0.0011		16.53	649.3	7.961	0.0701		868.8	0.612	1.946	2.332	1.114	1.594	2.092
Mean of Log-Transformed Detected Data	-1.804	-6.446		-4.955	-4.208		0.824	-2.466	-2.711	-6.411		3.567	7.868	-1.745	-6.263		8.324	0.132	1.111	1.044	-0.388	0.822	0.82
SD of Log-Transformed Detected Data	0.458	0.429		0.347	0.497		0.38	0.992	0.089	0.56		0.286	0.275	1.586	1.142		0.23	0.481	0.501	0.76	0.801	0.472	0.579
Discernable Distribution (0.05)	none	none		Normal	none		none	Normal	none	none		none	none	none	none		none	none	Gamma	none	Lognormal	none	none
Skewness of Detected Data	2.288	0.882		0.586	2.65		-0.224	0.827	-1.732	0.863		9.472	-0.673	5.661	13.74		-0.723	2.292	2.015	1.103	2.897	2.492	2.318
Kaplan-Meier (KM) Method for Datasets with Nondetects																							
Mean	0.111	0.00112		0.00504	0.0107		2.426	0.0319	0.0601	0.00104				0.524	0.00724			1.25	2.722	3.589	0.263	1.385	2.106
SD	0.0479	4.06E-04		3.82E-04	0.00412		0.819	0.0184	9.28E-04	2.82E-04				4.277	0.0638			0.621	1.976	2.338	0.374	0.904	1.9
Standard Error of Mean	0.00318	2.69E-05		3.59E-05	2.75E-04		0.0537	0.00134	7.50E-05	1.95E-05				0.282	0.00419			0.0408	0.13	0.153	0.0251	0.0598	0.125
95% KM (t) UCL	0.116	0.00116		0.0051	0.0112		2.515	0.0341	0.0602	0.00107				0.99	0.0142			1.318	2.936	3.842	0.304	1.483	2.312
95% KM (z) UCL	0.116	0.00116		0.0051	0.0112		2.514	0.0341	6.02E-02	0.00107				0.988	0.0141			1.317	2.935	3.841	0.304	1.483	2.311
95% KM (BCA) UCL	0.118	0.00116		N/A	0.0112		2.519	0.142	N/A	0.00107				1.129	0.0156			1.314	2.962	3.841	0.462	1.622	2.361
95% KM (Percentile Bootstrap) UCL	0.117	0.00117		N/A	0.0112		2.512	0.132	N/A	0.00107				1.043	0.0155			1.32	2.946	3.849	0.403	1.579	2.321
95% KM (Chebyshev) UCL	0.125	0.00124		0.0052	0.0119		2.66	0.0378	0.0604	0.00112				1.754	0.0255			1.428	3.287	4.257	0.372	1.645	2.649
97.5% KM (Chebyshev) UCL	0.131	0.00129		0.00527	0.0124		2.761	0.0403	0.0606	0.00116				2.287	0.0334			1.505	3.531	4.546	0.42	1.758	2.884
99% KM (Chebyshev) UCL	0.143	0.00139		0.0054	0.0135		2.96	0.0453	0.0608	0.00123				3.333	0.049			1.656	4.011	5.113	0.513	1.979	3.346
Datasets without Nondetects																							
Student's-t UCL												38.92	2773				4319						
95% UCLs (Adjusted for Skewness)																							
95% Adjusted-CLT UCL												39.62	2770				4316						
95% Modified-t UCL												39.03	2772				4318						
Non-Parametric UCLs																							
95% CLT UCL												38.91	2772				4319						
95% Jackknife UCL												38.92	2773				4319						
95% Standard Bootstrap UCL												38.84	2773				4318						
95% Bootstrap-t UCL												40.09	2771				4317						
95% Hall's Bootstrap UCL												47.29	2771				4318						
95% Percentile Bootstrap UCL												39.23	2772				4319						
95% BCA Bootstrap UCL												39.98	2771				4317						
95% Chebyshev(Mean, Sd) UCL												41.84	2888				4473						
97.5% Chebyshev(Mean, Sd) UCL												43.88	2968				4580						
99% Chebyshev(Mean, Sd) UCL												47.88	3125				4790						
Potential UCL to Use																							
95% KM (t) UCL	0.116	0.00116		0.0051	0.0112			0.0341	0.0602	0.00107											0.304	1.483	
95% KM (z) UCL																							
95% KM (BCA) UCL							2.519											1.314		3.841			2.361
95% KM (Percentile Bootstrap) UCL	0.117	0.00117			0.0112			0.132		0.00107									2.946		0.403	1.579	
95% KM (Chebyshev) UCL														1.754	0.0255								
97.5% KM (Chebyshev) UCL																							
99% KM (Chebyshev) UCL																							
95% Student's-t UCL												38.92	2773				4319						
95% Modified-t UCL												39.03	2772				4318						
Notes		3	5	1, 3	3	4		1, 3	3	3	5			1	1	4							

Note:

1. Data have multiple DLs - Use of KM Method is recommended
2. UCL recommendation based on guidance (table 16). None provided by software.
3. There may not be adequate detected values to compute meaningful and reliable test statistics and estimates
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
4. Warning: Only one distinct data value was detected! It is suggested to use alternative site specific values
   determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).
5. Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Nonparametric Background Statistics for Zone 1 Trace Metal Data Sets with Non-Detects

	Sb	Ba	Cr	Cu	Fe	Hg	Ag	Tl	Zn
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Total Number of Data	0	14	11	4	12	0	11	0	16
Number of Non-Detect Data		11	11	3	1		11		9
Number of Detected Data (or Distinct Obs. If zero nondetect)		3	0	1	11		0		7
Minimum Detected		0.079		0.026	0.25				0.01
Maximum Detected		0.091		0.026	14				5
Percent Non-Detects		78.57%	100.00%	75.0%	8.33%		100.00%		56.25%
Minimum Non-detect		0.05	0.01	0.02	0.1		0.01		0.01
Maximum Non-detect		0.1	0.05	0.02	0.1		0.05		0.1
Mean of Detected Data		0.0847			6.386				0.784
Median of Detected Data		0.084			6.2				0.046
SD of Detected Data		0.00603			5.381				1.862
Mean of Log-Transformed Detected Data		-2.471			1.169				-2.488
SD of Log-Transformed Detected Data		0.0709			1.495				2.093
Discernable Distribution (0.05)		Normal			Normal				Lognormal
Skewness of Detected Data		0.492			0.0576				2.626
Kaplan-Meier (KM) Method for Datasets with Nondetects									
Mean		0.0833			5.875				0.351
SD		0.00492			5.197				1.203
Standard Error of Mean		0.00301			1.573				0.325
95% KM (t) UCL		**0.0886**			**8.701**				0.921
95% KM (z) UCL		0.0882			8.463				0.886
95% KM (BCA) UCL		0.091			8.418				0.995
95% KM (Percentile Bootstrap) UCL		**0.091**			**8.346**				0.968
95% KM (Chebyshev) UCL		0.0964			12.73				1.767
97.5% KM (Chebyshev) UCL		0.102			15.7				2.379
99% KM (Chebyshev) UCL		0.113			21.53				**3.583**
Datasets without Nondetects									
Student's-t UCL									
95% UCLs (Adjusted for Skewness)									
95% Adjusted-CLT UCL									
95% Modified-t UCL									
Non-Parametric UCLs									
95% CLT UCL									
95% Jackknife UCL									
95% Standard Bootstrap UCL									
95% Bootstrap-t UCL									
95% Hall's Bootstrap UCL									
95% Percentile Bootstrap UCL									
95% BCA Bootstrap UCL									
95% Chebyshev(Mean, Sd) UCL									
97.5% Chebyshev(Mean, Sd) UCL									
99% Chebyshev(Mean, Sd) UCL									
Potential UCL to Use									
95% KM (t) UCL		**0.0886**			**8.701**				
95% KM (z) UCL									
95% KM (BCA) UCL									
95% KM (Percentile Bootstrap) UCL		**0.091**			**8.367**				
95% KM (Chebyshev) UCL									
97.5% KM (Chebyshev) UCL									
99% KM (Chebyshev) UCL									**3.583**
95% Student's-t UCL									
95% Modified-t UCL									
Notes		**1, 3**	**5**	**6**			**5**		**1, 3**

Note:

1. Data have multiple DLs - Use of KM Method is recommended
2. UCL recommendation based on guidance (table 16). None provided by software.
3. There may not be adequate detected values to compute meaningful and reliable test statistics and estimates
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
4. Warning: Only one distinct data value was detected! It is suggested to use alternative site specific values
   determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).
5. Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
6. Insufficent Number of Observations to produce Meaningful Statistics.

Comparisons of Background Sample Distributions to Comparison Values for Contaminants of Concern in Zone 1
Single Sample Sign Test

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad_totl	Th-230	Pb-210	Gross_Alpha	Sb	Ba	Cr	Cu	Fe	Hg	Ag	Tl	Zn
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Raw Statistics																														
Number of Valid Data	234	234	234	234	234	234	234	234	230	234	234	234	234	233	233	234	234	234	234	234	234	0	14	11	4	12	0	11	0	16
Number of Distinct Data	15	4	2	3	4	1	152	6	3	4	1	156	187	35	56	3	186	72	13	27	49		5	2	2	12		2		9
Number of Non-Detect Data	203	196	234	231	210	233	1	229	227	224	234	0	0	167	39	233	0	2	215	189	82		11	11	3	1		11		9
Number of Detected Data	31	38	0	3	24	1	233	5	3	10	0	234	234	66	194	1	234	232	19	45	152		3	0	1	11		0		7
Percent Non-Detects	86.75%	83.76%	100.00%	98.72%	89.74%	99.57%	0.43%	97.86%	98.70%	95.73%	100.00%	0.00%	0.00%	71.67%	16.74%	99.57%	0.00%	0.85%	91.88%	80.77%	35.04%		78.57%	100.00%	75.00%	8.33%		100.00%		56.25%
Minimum Non-detect	0.1	0.001	0.01	0.005	0.01	0.05	0.01	0.01	0.05	0.001	0.1	N/A	N/A	0.01	0.0003	0.5	N/A	0.2	0.02	1	1		0.05	0.01	0.02	0.1		0.01		0.01
Maximum Non-detect	0.1	0.001	0.05	0.01	0.01	0.05	0.01	0.1	0.05	0.001	0.1	N/A	N/A	0.1	0.0004	1	N/A	0.2	0.2	1	1		0.1	0.05	0.02	0.1		0.05		0.1
Minimum Detected	0.1	0.001	N/A	0.005	0.01	0.05	0.66	0.03	0.06	0.001	N/A	19.4	1410	0.01	0.0004	0.91	2490	0.2	0.2	1.1	0.9		0.079	N/A	0.026	0.25		N/A		0.01
Maximum Detected	0.6	0.004	N/A	0.01	0.06	0.05	4.15	0.27	0.07	0.004	N/A	252	3882	51.8	0.975	0.91	5610	14.8	4.9	9.1	14		0.091	N/A	0.026	14		N/A		5
Mean of Detected Data	0.185	0.00174	N/A	0.00733	0.0171	0.05	2.434	0.12	0.0667	0.0019	N/A	37.13	2703	1.767	0.00862	0.91	4225	3.618	0.974	2.58	2.757		0.0847	N/A	0.026	6.386		N/A		0.784
Median of Detected Data	0.14	0.002	N/A	0.007	0.01	0.05	2.65	0.13	0.07	0.0015	N/A	37.9	2952	0.16	0.0013	0.91	4569	3.35	0.7	2.1	2		0.084	N/A	0.026	6.2		N/A		0.046
SD of Detected Data	0.107	7.60E-04	N/A	0.00252	0.0112	N/A	0.814	0.099	0.00577	0.0011	N/A	16.53	649.3	7.961	0.0701	N/A	868.8	2.332	1.114	1.594	2.092		0.00603	N/A	N/A	5.381		N/A		1.862
Number Above Limit	0	0	0	2	1	0	233	0	0	0	0	1	178	2	3	0	183	54	0	45	0		0	0	0	7		0		0
Number Equal Limit	0	0	0	97	0	234	0	0	0	0	234	0	0	0	0	0	0	5	0	189	0		0	7	0	0		10		0
Number Below Limit	234	234	0	0	233	0	1	234	230	234	0	233	56	231	230	234	51	175	234	0	234		14	4	4	5		1		16
Number Observations Discarded	0	0	234	232	0	234	0	0		0	234	0	0			0	0		0	189				7				10		
H0: Site Median >= Comparison Value (Form 2)	**5**	**0.01**	**0.004**	**0.005**	**0.05**	**0.05**	**0.2**	**1**	**0.2**	**0.05**	**0.1**	**250**	**2125**	**30**	**0.03**	**80**	**3170**	**5**	**5**	**1**	**15**	**0.006**	**2**	**0.05**	**1**	**1**	**0.002**	**0.05**	**0.002**	**10**
Test Value	-15.3	-15.3	0	2	-15.17	0	15.17	-15.3	-15.17	-15.3	0	-15.17	7.975	-15	-14.87	-15.3	8.629	-7.996	-15.3	6.708	-15.3		0	0	0	7		0		0
Lower Critical Value (0.05)	-1.645	-1.645	-1	-1	-1.645	-1	-1.645	-1.645	-1.645	-1.645	-1	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645		3	-1	-1	2		-1		4
P-Value	0	0	1	1	0	1	1	0	0	0	1	0	1	0	0	0	1	6.43E-16	0	1	0		6.10E-05	0.0625	0.0625	0.806		0.5		1.53E-05
Conclusion with Alpha = 0.05	**Reject**	**Reject**	**Do not Reject**	**Do not Reject**	**Reject**	**Do not Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Do not Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Do not Reject**	**Reject**		**Reject**	**Do not Reject**	**Do not Reject**	**Do not Reject**		**Do not Reject**		**Reject**
Obsevations below max detection limit = non-detects[1]			0.05	0.01				0.1																						
Notes			1, 2	1,3		2		1			2									3				3,4	4			3,4		

1. Values lower than listed maximum nondetect value are treated by ProUCL as nondetects in single sample hypotheses tests
2. All detection limits equal or higher than ARAR, all data rejected
3. Nondetects equal or higher than ARAR rejected
4. Erroneous conclusion by ProUCL

Comparisons of Background Sample Distributions to Comparison Values for Contaminants of Concern in Zone 1

Single Sample Wilcoxon Signed Rank Test

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Raw Statistics											
Number of Valid Data	234	234	234	234	234	234	234	234	230	234	234
Number of Distinct Data	15	4	2	3	4	1	152	6	3	4	1
Number of Non-Detect Data	203	196	234	231	210	233	1	229	227	224	234
Number of Detected Data	31	38	0	3	24	1	233	5	3	10	0
Percent Non-Detects	86.75%	83.76%	100.00%	98.72%	89.74%	99.57%	0.43%	97.86%	98.70%	95.73%	100.00%
Minimum Non-detect	0.1	0.001	0.01	0.005	0.01	0.05	0.01	0.01	0.05	0.001	0.1
Maximum Non-detect	0.1	0.001	0.05	0.01	0.01	0.05	0.01	0.1	0.05	0.001	0.1
Minimum Detected	0.1	0.001	N/A	0.005	0.01	0.05	0.66	0.03	0.06	0.001	N/A
Maximum Detected	0.6	0.004	N/A	0.01	0.06	0.05	4.15	0.27	0.07	0.004	N/A
Mean of Detected Data	0.185	0.00174	N/A	0.00733	0.0171	0.05	2.434	0.12	0.0667	0.0019	N/A
Median of Detected Data	0.14	0.002	N/A	0.007	0.01	0.05	2.65	0.13	0.07	0.0015	N/A
SD of Detected Data	0.107	7.60E-04	N/A	0.00252	0.0112	N/A	0.814	0.099	0.00577	0.0011	N/A
Number Above Limit	0	0	234	1	1	0	233	0	0	0	0
Number Equal Limit	0	0	0	135	0	1	0	0	0	0	0
Number Below Limit	234	234	0	98	233	233	1	234	230	234	234
T-plus	0	0	27495	99	1	0	27494	0	0	0	0
T-minus	27495	27495	0	4851	27494	27261	1	27495	26565	27495	27495
H0: Site Median >= Comparison Value (Form 2)	**5**	**0.01**	**0.004**	**0.005**	**0.05**	**0.05**	**0.2**	**1**	**0.2**	**0.05**	**0.1**
Large Sample z-Test Value	-14.49	-14.35	14.64	-54.34	-14.64	-15.39	13.26	-15.05	-15.07	-15	-15.3
Critical Value (0.05)	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645
P-Value	0	0	1	0	0	0	1	0	0	0	0
Conclusion with Alpha = 0.05	**Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Reject**
Obsevations below max detection limit = non-detects[1]			0.05	0.01				0.1	0.5		
Notes			1, 2	1		3		1	1		3

	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad_totl	Th-230	Pb-210	Gross_Alph	Sb	Ba	Cr	Cu	Fe	Hg	Ag	Tl	Zn
Concentration Units	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Raw Statistics																			
Number of Valid Data	234	234	233	233	234	234	234	234	234	234	0	14	11	4	12	0	11	0	16
Number of Distinct Data	156	187	35	56	3	186	72	13	27	49		5	2	2	12		2		9
Number of Non-Detect Data	0	0	167	39	233	0	2	215	189	82		11	11	3	1		11		9
Number of Detected Data	234	234	66	194	1	234	232	19	45	152		3	0	1	11		0		7
Percent Non-Detects	0.00%	0.00%	71.67%	16.74%	99.57%	0.00%	0.85%	91.88%	80.77%	35.04%		78.57%	100.00%	75.00%	8.33%		100.00%		56.25%
Minimum Non-detect	N/A	N/A	0.01	0.0003	0.5	N/A	0.2	0.02	1	1		0.05	0.01	0.02	0.1		0.01		0.01
Maximum Non-detect	N/A	N/A	0.1	0.0004	1	N/A	0.2	0.2	1	1		0.1	0.05	0.02	0.1		0.05		0.1
Minimum Detected	19.4	1410	0.01	0.0004	0.91	2490	0.2	0.2	1.1	0.9		0.079	N/A	0.026	0.25		N/A		0.01
Maximum Detected	252	3882	51.8	0.975	0.91	5610	14.8	4.9	9.1	14		0.091	N/A	0.026	14		N/A		5
Mean of Detected Data	37.13	2703	1.767	0.00862	0.91	4225	3.618	0.974	2.58	2.757		0.0847	N/A	0.026	6.386		N/A		0.784
Median of Detected Data	37.9	2952	0.16	0.0013	0.91	4569	3.35	0.7	2.1	2		0.084	N/A	0.026	6.2		N/A		0.046
SD of Detected Data	16.53	649.3	7.961	0.0701	N/A	868.8	2.332	1.114	1.594	2.092		0.00603	N/A	N/A	5.381		N/A		1.862
Number Above Limit	1	178	2	3	0	183	54	0	45	0		0	0	0	7		0		0
Number Equal Limit	0	0	0	0	0	0	5	0	0	0		0	0	0	0		0		0
Number Below Limit	233	56	231	230	234	51	175	234	189	234		14	11	4	5		11		16
T-plus	1	24822	3	470	0	25771	4650	0	8028	0		0	0	0	63		0		0
T-minus	27494	2673	27258	26791	27495	1724	21686	27495	19467	27495		105	66	10	15		66		136
H0: Site Median >= Comparison Value (Form 2)	**250**	**2125**	**30**	**0.03**	**80**	**3170**	**5**	**5**	**1**	**15**	**0.006**	**2**	**0.05**	**1**	**1**	**0.002**	**0.05**	**0.002**	**10**
Large Sample z-Test Value	-13.26	10.68	-13.76	-12.79	-15	11.6	-9.065	-14.73	-5.932	-13.33		0	0	0	63		0		0
Critical Value (0.05)	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645		25	13	-1	17		13		35
P-Value	0	1	0	0	0	1	6.21E-20	0	1.50E-09	0		1.00E-04	5.00E-04	N/A	0.968		5.00E-04		0
Conclusion with Alpha = 0.05	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**no data**	**Reject**	**Reject**	**Do not Reject**	**Do not Reject**	**no data**	**Reject**	**no data**	**Reject**
Obsevations below max detection limit = non-detects[1]			1	0.003	1		1	0.2		1		0.1	0.05				0.05		0.1
Notes			1	1	1		1	1	3	1	4	1	1,3	5			1,3		1

1. Values lower than listed maximum nondetect value are treated by ProUCL as nondetects in single sample hypotheses tests
2. Detection limits higher than ARAR
3. Detection limits equal ARAR
4. No data
5. Erroneous conclusion by ProUCL

Background Statistics for Zone 3 Data Sets with Non-Detects

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad-226	Rad-228	Rad_totl	Th-230	Pb-210	Gross_Alpha
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L
Total Number of Data	186	186	186	186	186	185	186	184	186	186	186	186	186	186	186	186	186	186	185	185	186	186	186
Number of Non-Detect Data	127	50	186	177	17	181	1	26	73	144	186	0	0	32	2	185	0	22	54	18	167	129	29
Number of Detected Data (or Distinct Obs. If zero nondetect)	59	136		9	169	4	185	158	113	42		138	175	154	184	1	178	164	131	167	19	57	157
Minimum Detected	0.1	0.001		0.01	0.01	0.05	0.42	0.02	0.05	0.001		15	1319	0.01	0.0007	1.1	2244	0.2	1	0.2	0.2	1	1
Maximum Detected	1.68	1.01		0.09	0.53	0.08	7.5	75	0.67	0.015		66	4674	61	0.38	1.1	6930	23.7	22.3	40.9	57	11	69
Percent Non-Detects	68.28%	26.88%	100.00%	95.16%	9.14%	97.84%	0.54%	14.13%	39.25%	77.42%	100.00%	0%	0%	17.20%	1.08%	99.46%	0%	11.83%	29.19%	9.73%	89.78%	69.35%	15.59%
Minimum Non-detect	0.1	0.001		0.005	0.01	0.05	0.01	0.1	0.05	0.001				0.01	0.0003	1		0.2	1	0.2	0.2	1	1
Maximum Non-detect	0.1	0.001		0.01	0.01	0.05	0.01	0.1	0.05	0.001				0.1	0.0003	1		0.2	1	0.2	0.2	1	1
Mean of Detected Data	0.422	0.121		0.02	0.0835	0.065	3.25	11.88	0.173	0.0026		31.62	2588	11.34	0.0791		4115	5.01	5.34	9.099	6.705	2.549	8.191
Median of Detected Data	0.31	0.0235		0.01	0.06	0.065	3.3	3.76	0.12	0.001		30.85	2651	4.785	0.039		4237	4.5	4.3	7.9	2.3	2	5.4
Variance of Detected Data	0.11	0.0443		0.0007	0.00803	0.000167	2.724	266.4	0.0197	1.113E-05		72.59	504851	200.6	0.00792		1049301	17.13	14.78	55.58	170.2	2.889	91.4
SD of Detected Data	0.332	0.211		0.0265	0.0896	0.0129	1.65	16.32	0.141	0.00334		8.52	710.5	14.16	0.089		1024	4.139	3.845	7.455	13.05	1.7	9.56
CV of Detected Data	0.786	1.744		1.323	1.073	0.199	0.508	1.374	0.813	1.285		0.269	0.275	1.249	1.125		0.249	0.826	0.72	0.819	1.946	0.667	1.167
Skewness of Detected Data	1.636	2.409		2.916	2.85	0	0.313	1.631	1.75	2.646		1.052	0.557	1.16	1.255		0.607	2.032	1.985	1.86	3.549	2.725	3.849
Mean of Log-Transformed Detected Data	-1.125	-3.512		-4.284	-2.866	-2.749	1.008	1.176	-2.013	-6.38		3.42	7.821	0.277	-3.329		8.292	1.28	1.464	1.835	0.85	0.784	1.712
SD of Log-Transformed Detected Data	0.726	1.816		0.74	0.86	0.202	0.648	1.934	0.692	0.798		0.26	0.28	2.849	1.416		0.25	0.892	0.652	1.001	1.465	0.525	0.851
Discernable Distribution (0.05) of Detections	Gamma	lognormal		none	lognormal	normal	normal	none	none	none		gamma	none	none	none		none	none	lognormal	none	gamma	gamma	lognormal
Kaplan-Meier (KM) Method for Datasets with Nondetects																							
Mean	0.202	0.0886		0.0105	0.0768	0.0503	3.234	10.21	0.125	0.00136				9.391	0.0782			4.441	4.073	8.234	0.865	1.475	7.07
SD	0.238	0.187		0.00589	0.0878	0.00273	1.655	15.63	0.124	0.0017				13.54	0.0886			4.175	3.779	7.538	4.512	1.175	9.136
Standard Error of Mean	0.0176	0.0138		0.000458	0.00646	0.000232	0.122	1.156	0.00916	0.0001263				0.996	0.00652			0.307	0.279	0.556	0.34	8.69%	0.672
95% KM (t) UCL	**0.231**	0.111		**0.0112**	0.0875	**0.0507**	**3.435**	12.12	0.14	**0.00157**				11.04	0.089			4.949	4.534	9.153	**1.426**	**1.618**	8.181
95% KM (z) UCL	0.231	0.111		0.0112	0.0874	0.0507	3.434	12.11	0.14	0.00157				11.03	0.089			4.946	4.532	9.148	1.424	1.618	8.175
95% KM (BCA) UCL	0.238	0.113		0.0113	**0.0877**	0.0701	3.445	12.19	**0.14**	0.00159				11.14	0.0908			**4.996**	**4.509**	9.196	1.881	1.697	**8.217**
95% KM (Percentile Bootstrap) UCL	0.234	0.112		**0.0113**	0.0876	**0.0701**	**3.436**	12.06	0.14	**0.00159**				10.92	0.0895			4.98	4.537	9.158	1.625	1.655	8.186
95% KM (Chebyshev) UCL	0.279	0.149		0.0125	0.105	0.0513	3.765	15.25	0.165	0.00191				13.73	**0.107**			5.78	5.289	**10.66**	2.346	1.854	9.999
97.5% KM (Chebyshev) UCL	0.312	**0.175**		0.0133	0.117	0.0518	3.994	**17.43**	0.182	0.00215				**15.61**	0.119			6.359	5.815	11.71	2.987	2.017	11.27
99% KM (Chebyshev) UCL	0.378	0.226		0.015	0.141	0.0526	4.445	21.71	0.216	0.00262				19.3	0.143			7.496	6.848	13.76	4.246	2.339	13.76
Datasets without Nondetects																							
Student's-t UCL												32.66	**2674**				**4239**						
95% UCLs (Adjusted for Skewness)																							
95% Adjusted-CLT UCL												32.7	2676				4242						
95% Modified-t UCL												32.66	**2674**				**4239**						
Non-Parametric UCLs																							
95% CLT UCL												32.65	2674				4238						
95% Jackknife UCL												32.66	2674				4239						
95% Standard Bootstrap UCL												32.68	2673				4237						
95% Bootstrap-t UCL												32.75	2675				4249						
95% Hall's Bootstrap UCL												32.66	2676				4252						
95% Percentile Bootstrap UCL												32.71	2670				4237						
95% BCA Bootstrap UCL												32.65	2673				4235						
95% Chebyshev(Mean, Sd) UCL												34.35	2815				4442						
97.5% Chebyshev(Mean, Sd) UCL												35.53	2913				4584						
99% Chebyshev(Mean, Sd) UCL												37.84	3106				4862						
Potential UCL to Use																							
95% KM (t) UCL	**0.231**			**0.0112**		**0.0507**	**3.435**			**0.00157**											**1.426**	**1.618**	
95% KM (z) UCL																							
95% KM (BCA) UCL					**0.0877**				**0.14**									**4.996**	**4.509**				**8.217**
95% KM (Percentile Bootstrap) UCL				**0.0113**		**0.0701**	**3.436**			**0.00159**													
95% KM (Chebyshev) UCL															**0.107**					**10.66**			
97.5% KM (Chebyshev) UCL		**0.175**						**17.43**						**15.61**									
99% KM (Chebyshev) UCL																							
95% Student's-t UCL													**2674**				**4239**						
95% Modified-t UCL													**2674**				**4239**						
95% Approximate Gamma UCL												**32.65**											
Notes			5	1, 3		3					5			1		4							

Note:

1. Data have multiple DLs - Use of KM Method is recommended
2. UCL recommendation based on guidance (table 16). None provided by software.
3. There may not be adequate distinct detected values to compute meaningful and reliable test statistics and estimates
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
4. Warning: Only one distinct data value was detected! It is suggested to use alternative site specific values
determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).
5. Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).

Nonparametric Background Statistics for Trace Metal Data Sets with Non-Detects in Zone 3

	Sb	Ba	Cr	Cu	Fe	Hg	Ag	Tl	Zn
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Total Number of Data	1	36	37	13	23	4	29	0	31
Number of Non-Detect Data	1	34	37	10	9	4	29		6
Number of Detected Data (or Distinct Obs. If zero nondetect)	0	2	0	3	14	0	0		25
Minimum Detected		0.54		0.028	0.03				0.02
Maximum Detected		0.54		0.06	67				6.859
Percent Non-Detects	100.0%	94.40%	0.00%	76.92%	39.13%	100.00%	100.00%		19.35%
Minimum Non-detect				0.01	0.1				0.02
Maximum Non-detect				0.02	0.1				0.1
Mean of Detected Data				0.042	9.682				0.766
Median of Detected Data				0.038	1.45				0.193
SD of Detected Data				0.0164	17.88				1.787
Mean of Log-Transformed Detected Data				-3.22	0.439				-1.622
SD of Log-Transformed Detected Data				0.384	2.354				1.511
Discernable Distribution (0.05)				Normal	Gamma				Lognormal
Skewness of Detected Data				1.034	2.879				3.177
Kaplan-Meier (KM) Method for Datasets with Nondetects									
Mean				0.0312	5.905				0.622
SD				0.00872	14.24				1.599
Standard Error of Mean				0.00296	3.082				0.293
95% KM (t) UCL				**0.0365**	11.2				1.12
95% KM (z) UCL				0.0361	10.97				1.105
95% KM (BCA) UCL				0.06	11.63				1.245
95% KM (Percentile Bootstrap) UCL				**0.06**	**11.44**				1.123
95% KM (Chebyshev) UCL				0.0441	19.34				1.9
97.5% KM (Chebyshev) UCL				0.0497	25.15				2.453
99% KM (Chebyshev) UCL				0.0607	36.57				**3.539**
Datasets without Nondetects									
Student's-t UCL									
95% UCLs (Adjusted for Skewness)									
95% Adjusted-CLT UCL									
95% Modified-t UCL									
Non-Parametric UCLs									
95% CLT UCL									
95% Jackknife UCL									
95% Standard Bootstrap UCL									
95% Bootstrap-t UCL									
95% Hall's Bootstrap UCL									
95% Percentile Bootstrap UCL									
95% BCA Bootstrap UCL									
95% Chebyshev(Mean, Sd) UCL									
97.5% Chebyshev(Mean, Sd) UCL									
99% Chebyshev(Mean, Sd) UCL									
Potential UCL to Use									
95% KM (t) UCL				**0.0365**					
95% KM (z) UCL									
95% KM (BCA) UCL					**12.16**				
95% KM (Percentile Bootstrap) UCL				**0.06**					
95% KM (Chebyshev) UCL									
97.5% KM (Chebyshev) UCL									
99% KM (Chebyshev) UCL									**3.539**
95% Student's-t UCL									
95% Modified-t UCL									
Notes	**6**	**4**	**5**	**1, 3**		**6**	**5**		**1**

Note:
1. Data have multiple DLs - Use of KM Method is recommended
2. UCL recommendation based on guidance (table 16). None provided by software.
3. There may not be adequate detected values to compute meaningful and reliable test statistics and estimates
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
4. Warning: Only one distinct data value was detected! It is suggested to use alternative site specific values
   determined by the Project Team to estimate environmental parameters (e.g., EPC, BTV).
5. Warning: All observations are Non-Detects (NDs), therefore all statistics and estimates should also be NDs!
   The Project Team may decide to use alternative site specific values to estimate environmental parameters (e.g., EPC, BTV).
6. Insufficent Number of Observations to produce Meaningful Statistics.

Comparisons of Background Sample Distributions to Comparison Values for Contaminants of Concern in Zone 3

Single Sample Sign Test

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4	NO3_as_N	U	Chloroform	Lab_TDS	Rad_totl	Th-230	Pb-210	Gross_Alpha	Sb	Ba	Cr	Cu	Fe	Hg	Ag	Tl	Zn
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Raw Statistics																														
Number of Valid Data	186	186	186	186	186	185	186	184	186	186	186	186	186	186	186	186	186	185	186	186	186	1	36	37	13	23	4	29	0	31
Number of Distinct Data	38	84	3	4	29	4	148	132	34	9	2	138	175	102	141	2	178	113	17	30	92	1	3	3	5	13	1	3		22
Number of Non-Detect Data	127	50	186	177	17	181	1	26	73	144	186	0	0	32	2	185	0	18	167	129	29	1	34	37	10	9	4	29		6
Number of Detected Data	59	136	0	9	169	4	185	158	113	42	0	186	186	154	184	1	186	167	19	57	157	0	2	0	3	14	0	0		25
Percent Non-Detects	68.28%	26.88%	100.00%	95.16%	9.14%	97.84%	0.54%	14.13%	39.25%	77.42%	100.00%	0.00%	0.00%	17.20%	1.08%	99.46%	0.00%	9.73%	89.78%	69.35%	15.59%	100.00%	94.44%	100.00%	76.92%	39.13%	100.00%	100.00%		19.35%
Minimum Non-detect	0.1	0.001	0.001	0.005	0.01	0.05	0.01	0.1	0.05	0.001	0.01	N/A	N/A	0.01	0.0003	1	N/A	0.2	0.2	1	1	0.05	0.05	0.01	0.01	0.1	2.00E-04	0.005		0.02
Maximum Non-detect	0.1	0.001	0.05	0.01	0.01	0.05	0.01	0.1	0.05	0.001	0.1	N/A	N/A	0.1	0.0003	1	N/A	0.2	0.2	1	1	0.05	0.1	0.1	0.02	0.1	2.00E-04	0.05		0.1
Minimum Detected	0.1	0.001	N/A	0.01	0.01	0.05	0.42	0.02	0.05	0.001	N/A	15	1319	0.01	0.0007	1.1	2244	0.2	0.2	1	1	N/A	0.054	N/A	0.028	0.03	N/A	N/A		0.02
Maximum Detected	1.68	1.01	N/A	0.09	0.53	0.08	7.5	75	0.67	0.015	N/A	66	4674	61	0.38	1.1	6930	40.9	57	11	69	N/A	0.054	N/A	0.06	67	N/A	N/A		6.859
Mean of Detected Data	0.422	0.121	N/A	0.02	0.0835	0.065	3.25	11.88	0.173	0.0026	N/A	31.62	2588	11.34	0.0791	1.1	4115	9.099	6.705	2.549	8.191	N/A	0.054	N/A	0.042	9.682	N/A	N/A		0.766
Median of Detected Data	0.31	0.0235	N/A	0.01	0.06	0.065	3.3	3.76	0.12	0.001	N/A	30.85	2651	4.785	0.039	1.1	4237	7.9	2.3	2	5.4	N/A	0.054	N/A	0.038	1.45	N/A	N/A		0.193
SD of Detected Data	0.332	0.211	N/A	0.0265	0.0896	0.0129	1.65	16.32	0.141	0.00334	N/A	8.52	710.5	14.16	0.089	N/A	1024	7.455	13.05	1.7	9.56	N/A	0	N/A	0.0164	17.88	N/A	N/A		1.787
Number Above Limit	0	97	0	9	87	3	185	112	30	0	0	0	135	18	104	0	151	121	5	56	19	0	0	0	0	7	0	0		0
Number Equal Limit	0	3	0	12	19	182	0	0	3	0	185	0	0	0	1	0	0	1	0	130	0	0	0	21	0	1	0	23		0
Number Below Limit	186	86	1	0	80	0	1	72	153	186	1	186	51	168	81	186	35	63	181	0	167	0	36	13	13	15	4	6		31
Number Observations Discarded			185	177		182					185	0	0				0			130		1		24				23		
H0: Site Median >= Comparison Value (Form 2)	**5**	**0.01**	**0.004**	**0.005**	**0.05**	**0.05**	**0.2**	**1**	**0.2**	**0.05**	**0.1**	**250**	**2125**	**30**	**0.03**	**80**	**3170**	**5**	**5**	**1**	**15**	**0.006**	**2**	**0.05**	**1**	**1**	**0.002**	**0.05**	**0.002**	**10**
Test Value	-13.64	0.813	0	9	0.542	3	13.49	2.949	-9.092	-13.64	0	-13.64	6.159	-11	1.691	-13.64	8.506	4.276	-12.9	7.483	-10.85	0	0	0	0	7	0	0		0
Lower Critical Value (0.05)	-1.645	-1.645	-1	1	-1.645	-1	-1.645	-1.645	-1.645	-1.645	-1	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1	12	3	3	6	-1	0		10
P-Value	0	0.792	0.5	1	0.706	1	1	0.998	4.84E-20	0	0.5	0	1	1.94E-28	0.955	0	1	1	0	1	9.77E-28	1	1.46E-11	1.22E-04	1.22E-04	0.0669	0.0625	0.0156		4.66E-10
Obsevations below max detection limit = non-detects[1]								0.1						0.1									0.1			0.1				0.1
Conclusion with Alpha = 0.05	**Reject**	**Do Not Reject**	**Do Not Reject**	**Do Not Reject**	**Do Not Reject**	**Do Not Reject**	**Do Not Reject**	**Do Not Reject**	**Reject**	**Reject**	**Do Not Reject**	**Reject**	**Do Not Reject**	**Reject**	**Do Not Reject**	**Reject**	**Do Not Reject**	**Do Not Reject**	**Reject**	**Do Not Reject**	**Reject**	**Do not Reject**	**Reject**	**Reject**	**Reject**	**Do not Reject**	**Do not Reject**	**Reject**	**no data**	**Reject**
Notes			3, 4	3		3		1			3, 4			1						3		2, 4	1			1, 4	4			1

1. Values lower than listed maximum nondetect value are treated by ProUCL as nondetects in single sample hypotheses tests
2. All detection limits equal or higher than ARAR, all data rejected
3. Nondetects equal or higher than ARAR rejected
4. Erroneous conclusion by ProUCL

Comparisons of Background Sample Distributions to Comparison Values for Contaminants of Concern in Zone 3
Single Sample Wilcoxon Signed Rank Test

	Al	As	Be	Cd	Co	Pb	Mn	Mo	Ni	Se	V	Cl	SO4	NO3_as_N	U
Concentration Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Raw Statistics															
Number of Valid Data	186	186	186	186	186	185	186	184	186	186	186	186	186	186	186
Number of Distinct Data	38	84	3	4	29	4	148	132	34	9	2	138	175	102	141
Number of Non-Detect Data	127	50	186	177	17	181	1	26	73	144	186	0	0	32	2
Number of Detected Data	59	136	0	9	169	4	185	158	113	42	0	186	186	154	184
Percent Non-Detects	68.28%	26.88%	100.00%	95.16%	9.14%	97.84%	0.54%	14.13%	39.25%	77.42%	100.00%	0.00%	0.00%	17.20%	1.08%
Minimum Non-detect	0.1	0.001	0.001	0.005	0.01	0.05	0.01	0.1	0.05	0.001	0.01	N/A	N/A	0.01	0.0003
Maximum Non-detect	0.1	0.001	0.05	0.01	0.01	0.05	0.01	0.1	0.05	0.001	0.1	N/A	N/A	0.1	0.0003
Minimum Detected	0.1	0.001	N/A	0.01	0.01	0.05	0.42	0.02	0.05	0.001	N/A	15	1319	0.01	0.0007
Maximum Detected	1.68	1.01	N/A	0.09	0.53	0.08	7.5	75	0.67	0.015	N/A	66	4674	61	0.38
Mean of Detected Data	0.422	0.121	N/A	0.02	0.0835	0.065	3.25	11.88	0.173	0.0026	N/A	31.62	2588	11.34	0.0791
Median of Detected Data	0.31	0.0235	N/A	0.01	0.06	0.065	3.3	3.76	0.12	0.001	N/A	30.85	2651	4.785	0.039
SD of Detected Data	0.332	0.211	N/A	0.0265	0.0896	0.0129	1.65	16.32	0.141	0.00334	N/A	8.52	710.5	14.16	0.089
Number Above Limit	0	97	185	9	87	3	185	112	30	0	0	0	135	18	104
Number Equal Limit	0	3	0	165	19	1	0	0	3	0	0	0	0	0	1
Number Below Limit	186	86	1	12	80	181	1	72	153	186	186	186	51	168	81
T-plus	0	11532	17264	153	8396	187	17390	13885	2603	0	0	0	14409	675.5	12127
T-minus	17391	5304	127	78	5632	16833	1	3135	14234	17391	17391	17391	2982	16716	5079
H0: Site Median >= Comparison Value (Form 2)	**5**	**0.01**	**0.004**	**0.005**	**0.05**	**0.05**	**0.2**	**1**	**0.2**	**0.05**	**0.1**	**250**	**2125**	**30**	**0.03**
Large Sample z-Test Value	-12.32	3.964	12.18	-304.9	-0.478	-13.31	11.83	7.433	-8.559	-12.58	-13.6	-11.83	7.772	-10.91	4.705
Critical Value (0.05)	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645
P-Value	3.42E-35	1	1	0	0.316	0	1	1	5.69E-18	1.43E-36	0	1.43E-32	1	5.12E-28	1
Conclusion with Alpha = 0.05	**Reject**	**Do Not Reject**	**Do Not Reject**	**Reject**	**Do Not Reject**	**Reject**	**Do Not Reject**	**Do Not Reject**	**Reject**	**Reject**	**Reject**	**Reject**	**Do Not Reject**	**Reject**	**Do Not Reject**
Obsevations below max detection limit = non-detects[1]								0.1						0.1	
Notes			2, 4	2, 3		3		1			3, 4			1	

	Chloroform	Lab_TDS	Rad_totl	Th-230	Pb-210	Gross_Alpha	Sb	Ba	Cr	Cu	Fe	Hg	Ag	Tl	Zn
Concentration Units	ug/L	mg/L	pCi/L	pCi/L	pCi/L	pCi/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Raw Statistics															
Number of Valid Data	186	186	185	186	186	186	1	36	37	13	23	4	29	0	31
Number of Distinct Data	2	178	113	17	30	92	1	3	3	5	13	1	3		22
Number of Non-Detect Data	185	0	18	167	129	29	1	34	37	10	9	4	29		6
Number of Detected Data	1	186	167	19	57	157	0	2	0	3	14	0	0		25
Percent Non-Detects	99.46%	0.00%	9.73%	89.78%	69.35%	15.59%	100.00%	94.44%	100.00%	76.92%	39.13%	100.00%	100.00%		19.35%
Minimum Non-detect	1	N/A	0.2	0.2	1	1	0.05	0.05	0.01	0.01	0.1	2.00E-04	0.005		0.02
Maximum Non-detect	1	N/A	0.2	0.2	1	1	0.05	0.1	0.1	0.02	0.1	2.00E-04	0.05		0.1
Minimum Detected	1.1	2244	0.2	0.2	1	1	N/A	0.054	N/A	0.028	0.03	N/A	N/A		0.02
Maximum Detected	1.1	6930	40.9	57	11	69	N/A	0.054	N/A	0.06	67	N/A	N/A		6.859
Mean of Detected Data	1.1	4115	9.099	6.705	2.549	8.191	N/A	0.054	N/A	4.20%	9.682	N/A	N/A		0.766
Median of Detected Data	1.1	4237	7.9	2.3	2	5.4	N/A	0.054	N/A	0.038	1.45	N/A	N/A		0.193
SD of Detected Data	N/A	1024	7.455	13.05	1.7	9.56	N/A	0	N/A	0.0164	17.88	N/A	N/A		1.787
Number Above Limit	0	151	121	5	56	19		0	0	0	7	0	0		0
Number Equal Limit	0	0	1	0	1	0		0	3	0	1	0	0		0
Number Below Limit	186	35	63	181	129	167		36	34	13	15	4	29		31
T-plus	0	15898	12007	740	6821	1331		0	0	0	121	0	0		0
T-minus	17391	1493	5013	16651	10385	16060		666	595	91	132	10	435		496
H0: Site Median >= Comparison Value (Form 2)	**0.05**	**3170**	**5**	**5**	**1**	**15**	**0.006**	**2**	**0.05**	**1**	**1**	**0.002**	**0.05**	**0.002**	**10**
Large Sample z-Test Value	-13.6	9.797	4.707	-11.94	-2.688	-10.02		-5.549	-6.221	0	-0.54	0	-4.999		-4.855
Critical Value (0.05)	-1.645	-1.645	-1.645	-1.645	-1.645	-1.645		-1.645	-1.645	21	-1.645	-1	-1.645		-1.645
P-Value	0	1	1	3.463E-33	3.59E-03	6.16E-24		1.44E-08	2.47E-10	1.00E-04	0.295	N/A	2.88E-07		6.02E-07
Conclusion with Alpha = 0.05	**Reject**	**Do Not Reject**	**Do Not Reject**	**Reject**	**Reject**	**Reject**		**Reject**	**Reject**	**Reject**	**Do not Reject**	**Do not Reject**	**Reject**		**Reject**
Obsevations below max detection limit = non-detects[1]								0.1							
Notes					3		2, 4	1	2				3	5	

1. Values lower than listed maximum nondetect value are treated by ProUCL as nondetects in single sample hypotheses tests
2. Detection limits higher than ARAR
3. Detection limits equal ARAR
4. All data are below detection limits
5. No data

APPENDIX D

Annual Land Use Report for 2009

UNC CHURCH ROCK

~~REPT 07~~
COAG '08

UNITED NUCLEAR CORPORATION

UNC

P.O. Box 3077
Gallup, New Mexico 87305-3077

Telephone: (505) 905-6651
Fax: (505) 905-6654

March 17, 2010

Mr. Keith I. McConnell, Deputy Director
Decommissioning and Uranium Recovery Licensing Directorate
Division of Waste Management and Environmental Protection
Office of Federal and State Materials and Environmental Management
Programs
U.S. Nuclear Regulatory Commission
11545 Rockville Pike
#2 White Flint, Mail Stop T7 E-18
Rockville, MD 20852-2738

Re: Annual Land Use Report for 2009

Dear Mr. McConnell:

The above report is submitted, pursuant to our NRC Source Materials License No. SUA-1475, Condition 31.

Sincerely,

Max Chischilly Jr.

Max Chischilly, Jr.
Radiation Safety Officer

DY:

Enclosure

Cc: Jack E. Whitten, NRC Region IV
Steve Hill, GE
Roy Blickwedel, GE
Yolande Norman, NRC

ANNUAL LAND USE SURVEY REPORT FOR 2009

UNITED NUCLEAR CORPORATION

LICENSE NO. SUA – 1475

CONDITION NO. 31

MARCH 16, 2010

SURVEY OF LAND OWNERSHIP AND USE WITHIN TWO-MILE RADIUS OF MILL SITE

UNITED NUCLEAR CORPORATION
License No. SUA-1475
Condition No. 31

1.0 Introduction

This report has been prepared pursuant to License Condition 31 of United Nuclear Corporation's License No. SUA – 1475. The information submitted in this report was acquired from the master title plate published by the Bureau of Land Management. United Nuclear Corporation maintains the surface ownership records. The map is a copy of the USGS Quadrangle of Hardground Flats, Oak Springs, and Churchrock, the photo revised in 1979. United Nuclear Corporation's Radiation Safety Officer performed the land use survey.

2.0 Area Ownership and Use

Reference the attached map (figure 1) for location in regards to Mill Site.

Area:	Owner:	Usage:
Section 1	Navajo Tribe	Grazing and well monitoring
Section 2*	United Nuclear	Mill & Tailings site, one employee homesite and well monitoring.
Section 3	Navajo Tribe	Grazing and well monitoring
Section 4	Indian Allotted	Grazing
Section 6	Indian Allotted	Grazing
Section 9	Navajo Tribe	Grazing
Section 10	Indian Allotted	Grazing, eleven homesite, and well monitoring
Section 11	Navajo Tribe	Grazing
Section 12	BLM, A, Etah, Etal	Grazing
Section 13	Navajo Tribe	Grazing
Section 14	Indian Allotted	Grazing
Section 15	Navajo Tribe	Grazing

Area:	Owner:	Usage:
Section 33	Navajo Tribe	Grazing
Section 34	BLM (western portion) United Nuclear (eastern portion)	Grazing
Section 35	Indian Trust for Navajo Tribe	Grazing and UNC'S Reclaimed Northeast Churchrock Mine Site is located in this section.
Section 36	United Nuclear	Unauthorized grazing and well monitoring.
Map Northern Portion of 2 mile radius	Navajo Reservation	Grazing, 24 home sites, and Quivira's reclaimed Church-Rock Mine site is located in this area.
Section 31	Indian Allotted	Grazing

*Additional Note for Section 2:

The Mill has been decommissioned and has been cleaned to meet releasable standards for unrestricted use. Final reclamation activity on the tailings area was completed in 1996 with the exception of evaporation pond area, currently used for ground water remediation. Final cover radon flux test result was reported in the "Report On Radon Emanation Testing Of Final Radon Cover Over UNC'S Church Rock Tailings Site, Docket No. 40-80907" submitted on January 3, 1997.

3.0 Current ongoing groundwater tailings seepage remediation activity

1) Sample/monitor wells on Sec. 2 and 36 (UNC), Sec. 1 and 3 (Navajo Tribe) and Sec. 10 (Indian Allotted) on a quarterly basis.

2) Continual pumping/extraction of wells RW-11, RW-16, RW-17, RW-A, PB-2, NW-1 NW-2, NW-3 (pumping since Feb. 2009 and turned off on Nov. 2009) and NW-4 (pumping started on Nov. 2009). These wells are on UNC's Sec. 36 to enhance the remedy for cut off and containment of the migrating Zone 3 seepage impacted water.

3) Monthly monitoring (i.e. measure field parameters, in-house bicarbonate and chloride titration test) of wells NBL-1, NBL-2, PB-2, PB-3, PB-4, RW-A and NW series 1 thru 5 to track the northern most migration of the seepage impacted water in Zone 3, Sec. 36.

4.0 Well ID, Use, Location and Formation

Well ID:	Use:	Location:	Formation:
United Nuclear	Domestic	Sec. 2-Mill Site	Westwater
Circle Wash	Domestic/ Livestock	Section 14	Alluvium
Unknown ID Abandoned	No Known Use	Section 11	Alluvium
J.E. Soper#1 Abandoned	No Known Use	Section 1	Two Wells- Members Mancos
BLM – 2	Monitor	Section 12	Alluvium
14T – 586 (Friendship well # 1)	Livestock	N.I.R. N Part of map	Lower Gallup
NR – 1	Monitor/ Inactive	N.I.R. N Part of map	Alluvium
15K – 303	Livestock	N.I.R. NE Part of Map	Upper Gallup

5.0 Significant changes or events which took place in 2009 are as follows:

1) No change under item 2.0 (Area ownership and Use) and item 4.0 (Well ID, Use, Location and Formation). Total current homesite is thirty-six within the two mile radius of mill site.

2) Pumping started during February 2009 for wells NW-1, NW-2 and NW-3 also a new pumping regime was implemented during the second week of November 2009, whereby NW-3 was turned off and pumping started for NW-4 in Sec. 36. All the pumped ground water is discharged into the tailings North Evaporation Pond in Sec. 2.

3) On August 18, 2009 remedial construction activity (i.e. Interim Removal Action) involving various agencies and contractors (i.e. USEPA, NNEPA, MWH, MACTEC, AVM and UNC) started on UNC's inactive Northeast Church Rock Mine Site in Sec. 35 (Indian Trust Land) and the nearby adjacent Navajo Reservation Land. The work ceased on January 11, 2010 due to winter weather conditions and will resume during the spring of 2010. Also, three households were temporarily relocated to an off – site housing complex for about five months due to the residents in close proximity to or within the construction activity area.

4) As requested by Chester Engineers, an injection test was performed during October 30, 2009 and November 4, 2009 in well NBL-2 (background monitor well in Zone 3, Sec. 36) by MACTEC and UNC as part of a potential remedial option for the on going SWSFS (site – wide supplemental feasibility study). The objective and result of this test is reported on pg. 29 of Chester Engineers 2009 Ground water Corrective Action Annual Review Report for UNC.

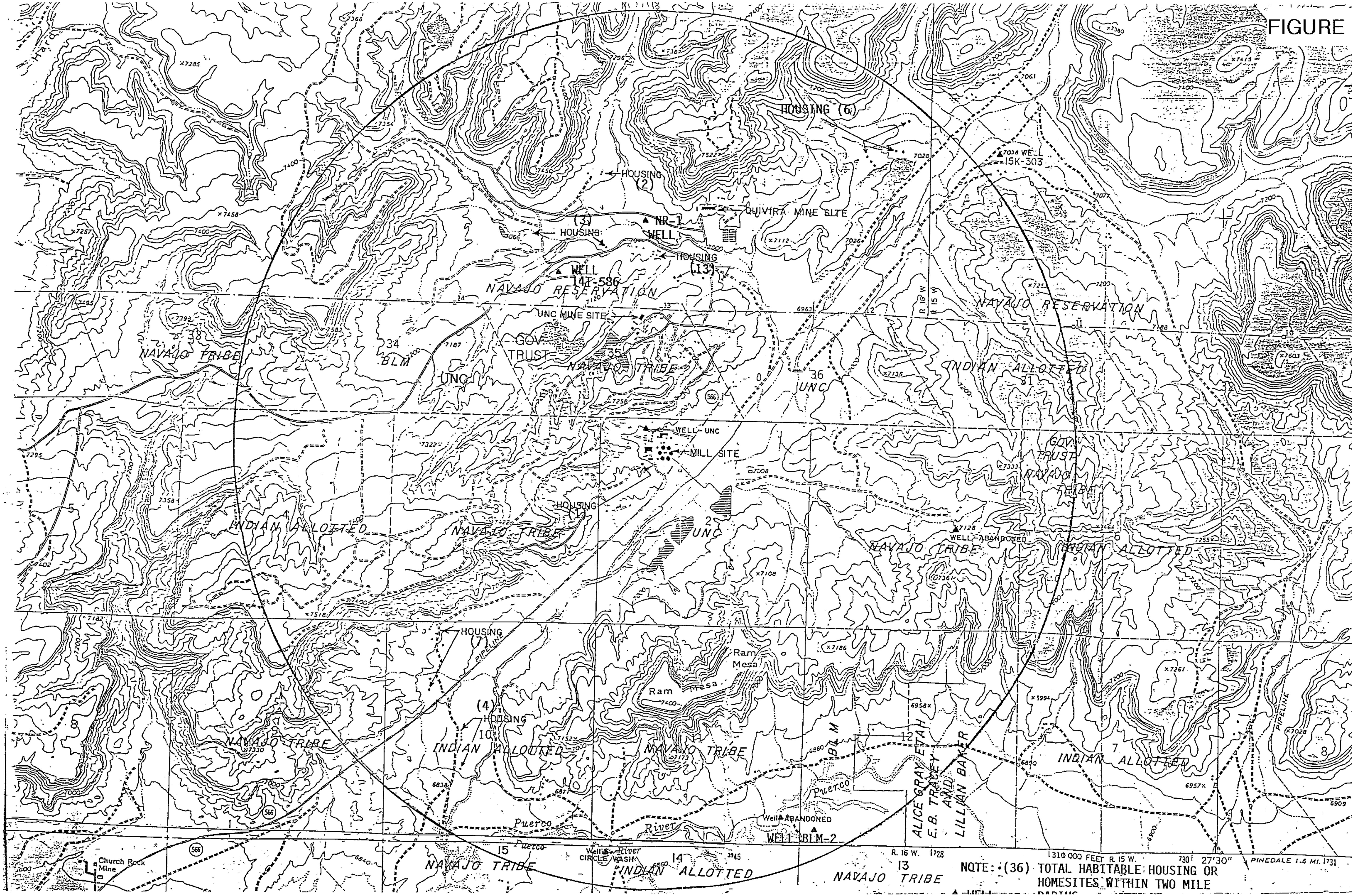
HOUSING (6)
HOUSING (2)
QUIVIRA MINE SITE
(3) HOUSING
NR-1 WELL
HOUSING (13)
WELL 14T-586
NAVAJO RESERVATION
UNC MINE SITE
GOV TRUST
BLM
UNC
NAVAJO TRIBE
NAVAJO RESERVATION
INDIAN ALLOTTED
WELL 15K-303
WELL-UNC
MILL SITE
HOUSING (1)
INDIAN ALLOTTED
NAVAJO TRIBE
UNC
NAVAJO TRIBE
WELL-ABANDONED
INDIAN ALLOTTED
GOV TRUST NAVAJO TRIBE
HOUSING (7)
PIPELINE
Ram Mesa
Ram Mesa
(4) HOUSING
INDIAN ALLOTTED
NAVAJO TRIBE
NAVAJO TRIBE
BLM
ALICE GRAY EVAH
E.B. TRACEY AND
LILLIAN BAKER
INDIAN ALLOTTED
PIPELINE
Puerco River
Well-ABANDONED
WELL BLM-2
Church Rock Mine
CIRCLE WASH
NAVAJO TRIBE
INDIAN ALLOTTED
NAVAJO TRIBE
R. 16 W.
R. 15 W.
310 000 FEET
27'30"
PINEDALE 1.6 MI.
NOTE: (36) TOTAL HABITABLE HOUSING OR HOMESITES WITHIN TWO MILE RADIUS

FIGURE 1