Prepared for:
Tronox LLC
Henderson, Nevada

Upgradient Investigation Results
Tronox Facility
Henderson, Nevada

ENSR Corporation
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TRONOX

Susan Crowley
Staff Environmental Specialist

(702) 651-2234
Fax (405) 302-4607
Susan.crowley@tronox.com

September 27, 2007

Ms. Shannon Harbour, P.E.
Nevada Division of Environmental Protection
2030 East Flamingo Road, Suite 230
Las Vegas, Nevada 89119-0818

Subject: Revisions to the Upgradient Investigations Results Report
Tronox LLC, Henderson, Nevada

Dear Ms. Harbour:

Tronox LLC (Tronox) has undertaken an Environmental Conditions Assessment (ECA) as directed by the Nevada Division of Environmental Protection (NDEP). In response to the comments contained in the NDEP March 23, 2007 letter, Tronox has revised portions of the Upgradient Investigation Results report. As discussed Tronox is submitting the revised Executive Summary, revised Chapter 5, revised Figure 4-9, a new Appendix J, and a corrected CD with the new pages inserted. Please insert these revised sections into the appropriate sections of the Upgradient Investigation Results report. The NDEP March 23, 2007 letter and Tronox's annotated response to the comments are also included.

Please contact me at (702) 651-2234 if you have any comments or questions concerning this correspondence.

Sincerely,

SM Crowley

Susan M. Crowley
Staff Environmental Specialist

Overnight Mail

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Wilkinson	Craig	Timet		X	
Mack	Joel	Montrose Counsel			

Upgradient Investigation Results
Tronox Facility

Henderson, Nevada

Responsible CEM for this project

I hereby certify that all laboratory analytical data were generated by a laboratory certified by the NDEP for each constituent and method presented herein with the exceptions noted in Appendix G on Tables G-1 and G-2.

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state, and local statutes, regulations, and ordinances.

SMCrowley 9-24-07

Susan M. Crowley, CEM 1428 exp. date 3/8/09
Staff Environmental Specialist
Tronox LLC

Individuals who provided input to this document

Sally Bilodeau, ENSR

Brian Ho, ENSR

Elizabeth Perry, ENSR

Steve Heisler, ENSR

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APPENDIX

LIST OF FIGURES

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ABBREVIATIONS AND ACRONYMS

ANOVA	One-Way Analysis of Variance
AOC	Administrative Order on Consent
AP&CC	American Potash and Chemical Company
ASB	Analytical Services Branch
bgs	below ground surface
BMI	Basic Metals, Inc. also known as Basic Management Inc. and Black Mountain Industrial (Park)
BRC	Basic Remediation Company
CDDs	Chlorinated Dibenzo-p-Dioxins
CDFs	Chlorinated Dibenzofurans
CEC	Cation Exchange Capacity
COC	Chain-of-Custody
COH	City of Henderson
DRO	diesel range organics
DVSR	Data Validation Summary Report
EC	electrical conductivity
ECA	Environmental Conditions Assessment
EPA	U.S. Environmental Protection Agency
FB-1	field blank sample
Fm	Formation
FOD	Frequency of Detection
ft	feet
ft/ft	feet per foot
GC	Gas Chromatography
gpm	gallon per minute
GRO	gasoline range organics
ICP	Inductively coupled plasma
IQR	interquartile range
IX	Ion Exchange
Kerr-McGee	Kerr-McGee Chemical LLC
LCS	Laboratory control sample
LCSD	Laboratory control sample duplicate
LOU	Letter of Understanding
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols Manual
MBAS	methylene blue active substance

ABBREVIATIONS AND ACRONYMS

MCcg1	Muddy Creek Formation, upper, coarse grained facies
MCcg2	Muddy Creek Formation, lower, coarse grained facies
MCfg1	Muddy Creek Formation upper, fine grained facies
MCfg2	Muddy Creek Formation, lower, fine grained facies
MCL	Maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MS	Mass Spectrometry
MS/MSD	matrix spike/matrix spike duplicate
NAD83	North American Datum 1983
NDEP	Nevada Division of Environmental Protection
NPDES	National Pollutant Discharge Elimination System
OCPs	Organochlorine Pesticides
OPPs	Organophosphorous Pesticides
ORO	Oil range organics
PCB	polychlorinated biphenyls
PID	Photoionization detector
PPM	parts per million
PPE	Personal Protective Equipment
PRG	Preliminary Remediation Goal
PVC	polyvinylchloride
QA/QC	quality assurance/quality control
Qal	Quaternary Alluvium
QC	Quality Control
QAPP	Quality Assurance Project Plan
“R”	rejected
RPD	relative percent difference
SDGs	Sample Delivery Groups
SIM	Selected Ion Monitoring
SRC	Site Related Chemicals
SSL	Soil Screening Level
SVOCs	Semi-Volatile Organic Compounds
TCE	trichloroethylene
TOC	Total Organic Carbon
TPH	total petroleum hydrocarbons

ABBREVIATIONS AND ACRONYMS

Tronox	Tronox LLC
µg/kg	micrograms per kilogram
µg/l	micrograms per liter
USCS	Unified Soils Classification System
VOA	Volatile Organic Analysis
VOCs	volatile organic compounds
WECCO	Western Electrochemical Company
WRS	Wilcox Rank Sum

EXECUTIVE SUMMARY

This report describes the activities completed to assess upgradient soil and groundwater conditions at the Tronox (formerly Kerr-McGee) facility located at 8000 West Lake Mead Parkway in Henderson, Nevada. The facility is owned and operated by Tronox LLC (Tronox). The work was conducted by ENSR on behalf of Tronox under the supervision of the Nevada Division of Environmental Protection (NDEP). On March 23, 2006, the NDEP provided comments on the October 30, 2006 Upgradient Investigation Results report. Following discussions with the NDEP and in response to the comments, a revised Executive Summary, revised Chapter 5 - Conclusions, corrected Figure 4-9, and Appendix J - Additional Statistical Information and Interpretation have been prepared and inserted.

The upgradient investigation was conducted to characterize concentrations of specific constituents in the soil and groundwater in the upgradient (southern) portion of the Site, and to further develop the Conceptual Site Model. As appropriate, these data and information may be used in future evaluations at the Site. The following scope of work was conducted between March 13 and 24, 2006.

- Soil borings were drilled at six locations using sonic drilling techniques along the southern portion of the property and analyzed for perchlorate, metals, volatile organic compounds (VOCs) including fuel oxygenates, total petroleum hydrocarbons (TPH), chlorate, and radionuclides.
- Four of the soil borings (M-117, M-118, M-120, and M-121) were completed as 2-inch diameter groundwater monitoring wells. Wells M-120 and M-121 are about 100 feet (ft) deep and monitor the upper coarse-grained facies of the Muddy Creek Formation (MCcg1). Wells M-117 and M-118 are about 150 ft deep and monitor the lower fine-grained facies of the Muddy Creek Formation (MCfg2).
- Consistent with historical purging and sampling methods, bailers were used to collect groundwater samples from wells TR-7, TR-8, TR-9, TR-10, and M-103. These groundwater samples were analyzed for perchlorate, metals, VOCs including fuel oxygenates, TPH, pH, electrical conductivity (EC), alkalinity, carbonate, bicarbonate, water chemistry ions, and radionuclides.
- Dedicated micro-purge pumps were installed in the four new wells (M-117, M-118, M-120, and M-121) as well as five existing on-site wells (TR-7, TR-8, TR-9, TR-10, and M-103).
- Groundwater samples were collected using micro-purge methods from the nine wells and analyzed for perchlorate, metals, VOCs including fuel oxygenates, TPH, pH, EC, alkalinity, carbonate, bicarbonate, water chemistry ions, and radionuclides.
- Soil from 0.5, 10, and 30 ft below ground surface (bgs) in well M-120 as well as groundwater from M-120 were analyzed for the complete list of Site Related Chemicals (SRC) identified on Tables 1-1 and 3-1. The purpose of this sampling was to determine if there were potential issues regarding analytical methods, detection limits or data quality that could affect planning for subsequent sampling events.

Soil and groundwater data were used to characterize the upgradient conditions within the alluvium and Muddy Creek Formation. In addition, analytical data for inorganic constituents in soil have been compared to other background data collected for the City of Henderson (COH) and Basic Management Incorporated (BMI).

Data Quality. Soil and groundwater data were analyzed for the parameters specified in the Work Plan Addendum. All of the resulting laboratory data were reviewed and validated using standardized guidelines and procedures recommended by the U.S. Environmental Protection Agency (EPA) and NDEP. Based on this validation, 90% of the analytical results for this project were accepted as reported by the laboratory and should be considered valid for all decision making purposes. 8.9% of the total analytical results for this project were qualified as 'estimated' due to minor QC problems with precision or accuracy. These estimated results should be considered usable with the appropriate interpretation (e.g., consideration of the potential bias). 1.1% of the results were rejected as unusable due to more serious QC problems with spike recoveries and calibrations. The impact of the rejected results on the overall project goals was minimal. Qualified results were evaluated with respect to the data quality indicators and compared to the Quality Assurance Project Plan (QAPP) and Work Plan goals. Based on the results of data validation, the overall goals for data quality were achieved for this project.

Statistical Evaluation of Soil Data. The validated data from the upgradient soil samples were statistically evaluated to characterize the data and their respective subpopulations, to compare the data to the NDEP-approved background dataset, and to consider appropriate uses and limitations on future use of the data. In response to the NDEP March 23, 2007 comments, additional statistical evaluations were conducted (see Appendix J). The following conclusions are based on the statistical evaluation of the soil data. **Table ES-1** presents summary statistics for the datasets evaluated.

- A few of the metals were detected in only a small portion of the samples (e.g., selenium, boron, platinum, silver, etc). Because of the low frequency of detection, formal statistical calculations are strongly biased by the detection limits, and so are not appropriate. Therefore, the statistical use of these data is limited, although they may be used qualitatively.

- A statistically significant difference in concentrations of many metals was observed in samples from 0 to 20 ft deep compared to samples from greater than 20 ft. The concentrations of some metals are higher in the deeper soils, some lower. These differences are most likely associated with changes in geology (geologic unit, percent fines). The shallow samples (0-20 ft) represent the alluvium; the deeper samples (>20 ft), the Muddy Creek formation.

Statistical Comparison with Off-Site Data Sets: The Tronox shallow, upgradient soil data were compared to the COH and BRC/TIMET background data for metals, perchlorate, and radionuclides. As noted above, shallow soils (up to 20 ft) and deeper soils (>20 ft) have different geology and therefore different chemistry. The COH and BRC background samples were collected at depths up to 10 ft. Therefore, the comparisons were performed between the COH, BRC, and Tronox shallow samples only. Because there is no independent background dataset for the deeper Muddy Creek unit, no comparisons were performed using the deep upgradient samples.

The following conclusions are based on the comparisons performed:

- For many constituents, the formal statistical comparisons indicated statistically significant differences between the means/medians of the shallow Tronox upgradient data compared with the BRC and/or COH data. In most of these cases, the differences were due to the Tronox mean/median being less than COH and/or BRC. Where the Tronox mean/median was greater than COH, the concentrations were typically consistent with (not greater than) BRC concentrations.

- Comparisons for some of the constituents were not feasible due to the low frequency of detections (FODs) and variable detection limits. For these (silver, selenium, platinum, uranium-235, etc.), no conclusions can be developed comparing the datasets.

- For most of the constituents, the concentrations in the Tronox shallow, upgradient, soil samples appear representative of background conditions. These constituents include aluminum, arsenic, chromium, cobalt, calcium, magnesium, manganese, nickel, strontium, uranium, vanadium, zinc, radium (226 and 228), thorium (228, 230, and 232), and uranium (234 and 238), etc.

- For a small number of constituents, the concentrations in the Tronox shallow, upgradient soils appear to be elevated with respect to the NDEP-approved background data set. Perchlorate, boron, and possibly sodium and potassium are likely to be elevated potentially due to Tronox operations.

However, cadmium and copper are also elevated. As these are not associated with use and handling at the Tronox facility, the concentration, although elevated, are more likely to represent background conditions.

- For the deep (>20ft) Tronox upgradient samples, it seems likely that the concentrations for most of the constituents are representative of background, although this cannot be demonstrated quantitatively in the absence of an independent background dataset for the Muddy Creek formation. However, because of impacts to groundwater, the sodium, perchlorate, and chromium concentrations in deeper soils cannot be considered representative of background.

Upgradient Groundwater: Because of the absence of an independent, background dataset for groundwater, no formal comparisons were performed. However, it appears that many of the Tronox upgradient data reflect possible impacts, particularly with perchlorate and hexavalent chromium. Therefore, the Tronox upgradient groundwater data for these constituents are not representative of background conditions.

In addition, the Tronox upgradient wells are all screened in the Muddy Creek formation. Much of the shallow groundwater (that is, groundwater at and near the water table) beneath the remainder of the Tronox facility is present in the alluvium. As a result, even un-impacted upgradient wells might not be an appropriate background reference for groundwater in the alluvium.

Groundwater Sampling Method Comparison: Groundwater sampling methods were compared, including bailer and micro-purge methods for five sampled wells. The groundwater was redundantly sampled at each of the 6 wells using both methods, and then both sets of samples were analyzed for perchlorate, metals, VOCs including fuel oxygenates, TPH, pH, EC, alkalinity, carbonate, bicarbonate, water chemistry ions, and radionuclides. An RPD of 30% was identified as the objective for the precision between the two groundwater samples. For most of the parameters, there were insufficient data to measure RPD.

In general, the less soluble constituents appear to be affected more than the highly soluble constituents. This relationship is expected if the measured concentrations using different sampling techniques are a function of analyte solubility. The following conclusions were drawn regarding the two compared sampling methods:

- Based on the data, it appears that the bailer vs. micro-purge sampling method **does not** affect the analytical results for perchlorate, hexavalent chromium, boron, molybdenum, potassium, sodium, five radionuclides, and eight wet chemistry parameters.
- Based on the data, it appears that the bailer vs. micro-purge sampling method does affect the analytical results for aluminum, arsenic, barium, calcium, total chromium, copper, iron, lead, magnesium, manganese, titanium, uranium, vanadium, zinc, five radionuclides, and one wet chemistry parameter.
- Based on the data it appears that turbidity is affected by the sampling methods and that, in general, the lower the turbidity the less variation was observed in the paired results.

Evaluation for Analytical Methods for all SRCs: Soil and groundwater samples from M-120 were analyzed for expanded suites of compounds (SVOCs, OCPs, OPPs, PCBs, and dioxin/furans) in order to examine potential issues involving analytical methods, detection limits or matrix effects that could impact subsequent sampling events. The results of the evaluation showed that there were no interference for soil and water that significantly impacted the data nor resulted in the rejection of laboratory data or significant elevation of reporting limits for nondetects. Therefore, the analytical methods used for the Upgradient Investigation may continue to be used in future investigations.

Table ES-1
Summary Statistics, Inorganics in Soil
Upgradient Investigation, Tronox Facility - Henderson, Nevada

		Upgradient Shallow Soils (0-20 ft)					Background Dataset (BRC/Timet and COH combined)					
Analyte	units	n	FOD	Min	Max	Median	n	FOD	Min	Max	Median	p95
Aluminum (Al)	mg/kg	24	100%	6390	12100	8855	120	100%	3740	15300	8420	13300
Silver (Ag)	mg/kg	24	13%	0.106	0.29	0.27	120	13%	0.019	0.2609	0.2609	NA
Arsenic (As)	mg/kg	24	100%	2.11	5.2	3.385	120	100%	2.1	7.2	3.9	6.29
Boron (B)	mg/kg	24	33%	5.2	13.6	5.538	104	75%	3.2	11.6	4.25	8.75
Barium (Ba)	mg/kg	24	100%	120	272	183	120	100%	73	836	190	464
Beryllium (Be)	mg/kg	24	100%	0.394	0.758	0.554	120	100%	0.16	0.89	0.54	0.84
Calcium (Ca)	mg/kg	24	100%	11400	57350	27800	104	100%	8160	82800	23650	61300
Cadmium (Cd)	mg/kg	24	100%	0.284	0.729	0.446	120	13%	0.052	0.16	0.1291	NA
Perclorate (ClO4)	ug/kg	23	70%	20.75	3310	42.6	16	56%	9.35	402.5	28.8	NA
Cobalt (Co)	mg/kg	24	100%	5.88	8.57	7.008	120	100%	3.7	16.3	8.25	12.2
Chromium (Cr)	mg/kg	24	100%	6.53	13.5	9.133	120	100%	2.6	16.7	8.8	14.5
Chromium (Cr+6)	mg/kg	24	0%	NA	NA	NA	120	0%	NA	NA	NA	NA
Copper (Cu)	mg/kg	24	100%	13.65	367	26.3	120	100%	7.8	30.5	17.2	23.8
Iron (Fe)	mg/kg	24	100%	7390	14500	10350	120	100%	5410	19700	13050	18300
Potassium (K)	mg/kg	24	100%	1040	2630	2000	104	100%	625	3890	1535	3370
Magnesium (Mg)	mg/kg	24	100%	6420	14900	9125	120	100%	4580	17500	9425	14200
Manganese (Mn)	mg/kg	24	100%	252	710.5	349	120	100%	151	1090	419	640
Molybdenum (Mo)	mg/kg	24	79%	0.156	1.22	0.323	120	100%	0.17	2	0.475	1
Sodium (Na)	mg/kg	24	100%	376	1230	792.8	104	100%	111	1320	452	1040
Nickel (Ni)	mg/kg	24	100%	12.8	18.8	15.05	120	100%	7.8	30	15.35	22.1
Lead (Pb)	mg/kg	24	100%	5.81	50.8	7.86	120	100%	3	35.1	7.75	21
Lead (Pb212)	pCi/g	13	100%	1.445	2.13	1.83	16	100%	0.94	1.47	1.29	NA
Platinum (Pt)	mg/kg	24	4%	0.01	0.026	0.011	104	5%	0.0435	0.099	0.0435	NA
Radium (Ra226)	pCi/g	13	100%	0.891	1.335	0.986	119	100%	0.494	2.36	1.12	1.87
Radium (Ra228)	pCi/g	13	100%	1.295	1.92	1.86	100	100%	0.946	2.94	1.86	2.57
Antimony (Sb)	mg/kg	23	26%	0.11	0.303	0.265	120	41%	0	0.5	0.3298	0.4
Selenium (Se)	mg/kg	24	88%	0.123	0.278	0.184	120	43%	0	0.6	0.1579	0.39
Tin (Sn)	mg/kg	24	0%	NA	NA	NA	123	99%	0.200	1.000	0.500	0.73
Strontium (Sr)	mg/kg	24	100%	146	361	200	104	100%	69	808	186	494
Throium (Th228)	pCi/g	13	100%	1.32	3.04	1.79	120	100%	1.07	2.28	1.715	2.11
Throium (Th230)	pCi/g	13	100%	0.687	1.33	1.09	120	100%	0.66	3.01	1.19	2.14
Throium (Th232)	pCi/g	13	100%	1.05	2.42	1.73	120	100%	1.05	2.23	1.575	2.06
Titanium (Ti)	mg/kg	24	100%	241	820	590	120	100%	200	1010	503.5	857
Thallium (Tl)	mg/kg	24	25%	0.114	0.34	0.271	120	84%	0.1	1.8	0.5428	1.6
Uranium (U)	mg/kg	24	100%	0.619	1.48	0.989	103	100%	0.43	2.7	0.94	1.64
Uranium (U234)	pCi/g	13	100%	0.775	1.69	1.18	120	100%	0.47	2.84	0.99	2.06
Uranium (U235)	pCi/g	13	15%	0	0.197	0.048	120	45%	0	0.21	0.054	0.13
Uranium (U238)	pCi/g	13	100%	0.812	1.49	0.983	120	100%	0.45	2.37	1.02	1.95
Vanadium (V)	mg/kg	24	100%	17	36.3	25.93	120	94%	14.6	59.1	35.55	54.1
Tungsten (W)	mg/kg	24	25%	0.526	1.16	1.08	104	100%	0.49	2.5	1.05	2
Zinc (Zn)	mg/kg	24	100%	26.6	72.1	39.88	120	100%	15.4	121	37.2	52.4

Table ES-1
Summary Statistics, Inorganics in Soil
Upgradient Investigation, Tronox Facility - Henderson, Nevada

Analyte	units	Upgradient Deep Soils (>20 ft)					Background Dataset (BRC/Timet and COH combined)					
		n	FOD	Min	Max	Median	n	FOD	Min	Max	Median	p95
Aluminum (Al)	mg/kg	26	100%	6230	17000	11630	0	NA	NA	NA	NA	NA
Silver (Ag)	mg/kg	26	4%	0.119	0.411	0.296	0	NA	NA	NA	NA	NA
Arsenic (As)	mg/kg	26	100%	3.37	26.6	12.83	0	NA	NA	NA	NA	NA
Boron (B)	mg/kg	26	96%	5.3	27.4	13.35	0	NA	NA	NA	NA	NA
Barium (Ba)	mg/kg	26	100%	46	249	92.75	0	NA	NA	NA	NA	NA
Beryllium (Be)	mg/kg	26	100%	0.317	1.27	0.643	0	NA	NA	NA	NA	NA
Calcium (Ca)	mg/kg	26	100%	2440	170000	7575	0	NA	NA	NA	NA	NA
Cadmium (Cd)	mg/kg	26	100%	0.274	0.686	0.473	0	NA	NA	NA	NA	NA
Perclorate (ClO4)	ug/kg	26	19%	21.25	273	24.13	0	NA	NA	NA	NA	NA
Cobalt (Co)	mg/kg	26	100%	2.6	10.4	5.69	0	NA	NA	NA	NA	NA
Chromium (Cr)	mg/kg	26	100%	8	79.6	18.65	0	NA	NA	NA	NA	NA
Chromium (Cr+6)	mg/kg	26	0%	NA	NA	NA	0	NA	NA	NA	NA	NA
Copper (Cu)	mg/kg	26	100%	8.54	129.3	22.15	0	NA	NA	NA	NA	NA
Iron (Fe)	mg/kg	26	100%	5960	15900	11100	0	NA	NA	NA	NA	NA
Potassium (K)	mg/kg	26	100%	1410	4540	2995	0	NA	NA	NA	NA	NA
Magnesium (Mg)	mg/kg	26	100%	6140	34600	14650	0	NA	NA	NA	NA	NA
Manganese (Mn)	mg/kg	26	100%	100	481	186.8	0	NA	NA	NA	NA	NA
Molybdenum (Mo)	mg/kg	26	77%	0.222	1.12	0.419	0	NA	NA	NA	NA	NA
Sodium (Na)	mg/kg	26	100%	238	1350	776	0	NA	NA	NA	NA	NA
Nickel (Ni)	mg/kg	26	100%	8.85	31.5	14.95	0	NA	NA	NA	NA	NA
Lead (Pb)	mg/kg	26	100%	4.33	10.6	7.16	0	NA	NA	NA	NA	NA
Lead (Pb212)	pCi/g	4	100%	1.48	2.26	1.66	0	NA	NA	NA	NA	NA
Platinum (Pt)	mg/kg	26	8%	0.011	0.429	0.012	0	NA	NA	NA	NA	NA
Radium (Ra226)	pCi/g	4	100%	1.09	2.06	1.535	0	NA	NA	NA	NA	NA
Radium (Ra228)	pCi/g	4	100%	1.38	2.24	1.645	0	NA	NA	NA	NA	NA
Antimony (Sb)	mg/kg	22	14%	0.13	0.411	0.295	0	NA	NA	NA	NA	NA
Selenium (Se)	mg/kg	26	58%	0.124	0.411	0.197	0	NA	NA	NA	NA	NA
Tin (Sn)	mg/kg	26	0%	NA	NA	NA	0	NA	NA	NA	NA	NA
Strontium (Sr)	mg/kg	26	100%	78.2	393	179.5	0	NA	NA	NA	NA	NA
Throium (Th228)	pCi/g	4	100%	1.24	2.06	1.525	0	NA	NA	NA	NA	NA
Throium (Th230)	pCi/g	4	100%	1.13	1.85	1.66	0	NA	NA	NA	NA	NA
Throium (Th232)	pCi/g	4	100%	0.965	1.74	1.24	0	NA	NA	NA	NA	NA
Titanium (Ti)	mg/kg	26	100%	328	811	594.5	0	NA	NA	NA	NA	NA
Thallium (Tl)	mg/kg	26	62%	0.12	0.454	0.27	0	NA	NA	NA	NA	NA
Uranium (U)	mg/kg	26	100%	0.707	6.07	1.76	0	NA	NA	NA	NA	NA
Uranium (U234)	pCi/g	4	100%	0.914	2.36	2.07	0	NA	NA	NA	NA	NA
Uranium (U235)	pCi/g	4	25%	0.04	0.28	0.072	0	NA	NA	NA	NA	NA
Uranium (U238)	pCi/g	4	100%	0.905	2.02	1.68	0	NA	NA	NA	NA	NA
Vanadium (V)	mg/kg	26	100%	16.3	49.8	30.25	0	NA	NA	NA	NA	NA
Tungsten (W)	mg/kg	26	8%	0.669	1.64	1.16	0	NA	NA	NA	NA	NA
Zinc (Zn)	mg/kg	26	100%	19.1	136.9	38.9	0	NA	NA	NA	NA	NA

Notes:
n - number of results
FOD - frequency of detects; percentage of results reported as detected by the laboratory
Min - minimum value; Max - maximum value; Median - calculated median of all results
p95 - non-parametric 95th percentile of the background dataset (BRC and COH)
NA - Insufficient data, or insufficient data outside of detection limits, to calculate statistic.

1.0 INTRODUCTION

This upgradient investigation report describes activities conducted to characterize the upgradient soil and groundwater conditions at the Tronox LLC facility (the Site) located at 8000 West Lake Mead Parkway in Henderson, Nevada. The facility is owned and operated by Tronox LLC (formerly Kerr-McGee Chemical LLC), headquartered in Oklahoma City, Oklahoma (Tronox). The investigation was conducted under the supervision of the Nevada Division of Environmental Protection (NDEP).

In a letter dated February 11, 2004, the NDEP indicated that the existing background data of soil and groundwater conditions at the Tronox Henderson facility were insufficient and that additional data should be collected (NDEP 2004). A work plan to address this concern was submitted to the NDEP on March 29, 2005. The work plan was revised to respond to comments received from the NDEP dated May 6, 2005, and July 28, 2005, and resubmitted September 29, 2005. On October 6, 2005, additional comments were received from the NDEP. On February 20, 2006, Tronox provided a letter responding to the NDEP comments and issued the Upgradient Investigation Work Plan Addendum (ENSR 2006) on February 21, 2006. On February 22, 2006, the NDEP issued a letter approving the work plan with minor comments. **Appendix A** contains copies of the NDEP and Tronox correspondence.

The investigation focused on the southernmost part of the approximately 450-acre Tronox facility, an area representing the most upgradient limits of the Site. The location of the study area is depicted in **Figures 1-1, and 1-2**. The work was conducted consistent with the approved scope of work described in the Upgradient Investigation Work Plan Addendum (ENSR 2006). Deviations from the work plan are noted and discussed in the text below.

1.1 Upgradient Investigation Objectives

The objective of the upgradient investigation was to characterize the concentrations of specific constituents present in the alluvium, Muddy Creek Formation, and the groundwater located in the southern (upgradient) portion of the Site. These data will support the characterization of the Site and will be used for future comparisons with downgradient and off-site data.

Key elements of the investigation objectives were as follows.

- Develop a data set that is representative of the upgradient soil and groundwater conditions, and is suitable for use in evaluating downgradient conditions.
- Conduct a statistical evaluation of the upgradient data, including the following:
    - Determine how the Tronox site upgradient data compared with the background data generated by the City of Henderson (ENVIRON 2003) and BRC/TIMET (Tetra Tech 2005)
    - Determine if the on-site data represented one or more populations based on statistical testing and analysis.
    - Determine if the analytical data generated from samples collected from the on-site alluvium was significantly different from the samples collected from the underlying Muddy Creek Formation.
    - Determine if there were matrix effects that would affect the laboratory analytical methods or detection limits.
    - Refine the understanding of the Muddy Creek Formation.
    - Compare the precision of low-flow groundwater sampling and historical groundwater sampling methods.

1.2 Site Background

The following discussion presents background information regarding the Site. A brief physical description of the Site is provided followed by a summary of the history of the Site. The discussion concludes with a summary of the environmental conditions of the Site.

1.2.1 Site Description

The Site is approximately 450 acres in size and is located 13 miles southeast of Las Vegas in an unincorporated section of Clark County, Nevada (**Figure 1-1**). It is completely surrounded by the incorporated area comprising the City of Henderson. The Site is in Township 22 South, Range 62 East, and covers portions of Sections 1, 12, and 13. The approximate center of the Site is located at longitude 36°02'45" W and latitude 115°00'20" N. The specific area addressed in this upgradient investigation encompasses the southernmost limits of the Site, which comprises an area that extends from the Lake Mead Parkway on the south, northward, approximately 2,000 ft to Avenue H. The location of the study area is depicted on **Figure 1-1** and **Figure 1-2**.

1.2.2 Site History

The BMI complex has been the site of industrial operations since 1942 and was originally sited and operated by the U.S. government as a magnesium production plant in support of the World War II effort. Following the war, a portion of the complex was leased by Western Electrochemical Company (WECCO). By August 1952, WECCO had purchased several portions of the complex, including six of the large unit buildings, and produced manganese dioxide, sodium chlorate, and various perchlorates. In addition, in the early 1950s, pursuant to a contract with the U.S. Navy, WECCO constructed and operated a plant to produce ammonium perchlorate on land purchased by the Navy. In 1956, WECCO merged with American Potash and Chemical Company (AP&CC) and continued to operate the processes, with the Navy's continued involvement in the ammonium perchlorate process.

In 1962, AP&CC purchased the ammonium perchlorate plant from the Navy, but continued to supply the Navy, and its contractors, material from the operating process. AP&CC merged with Kerr-McGee Corporation (Kerr-McGee) in 1967. With this merger, boron production processes in California were moved to the Henderson facility. By the early 1970s, operations in Henderson included the production of elemental boron, boron trichloride, and boron tribromide.

In 1994, the boron tribromide process was shut down and dismantled. In 1997, the sodium chlorate process was shut down, and in 1998, production of commercial ammonium perchlorate ended as well. The ammonium perchlorate production equipment was used to reclaim perchlorate from impounded or stockpiled on-site materials until early 2002, when the equipment was permanently shut down. In 2005, Kerr-McGee Chemical LLC's name was changed to Tronox LLC. Processes currently operated by Tronox at the Henderson facility are for production of manganese dioxide, boron trichloride, and elemental boron.

Additional companies operate within the BMI complex; details regarding ownership and leases within the BMI complex are described in the 1993 Phase I Environmental Conditions Assessment (ECA) report (Kleinfelder 1993).

During the 1970s, the U.S. Environmental Protection Agency (EPA), the State of Nevada, and Clark County investigated potential environmental impacts from the BMI companies' operations, including atmospheric emissions, groundwater and surface water discharges, and soil impacts (E&E 1982). From 1971 to 1976, Tronox (then Kerr-McGee), modified their manufacturing process and constructed lined surface impoundments to recycle and evaporate industrial wastewater. In 1976, the facility achieved zero discharge status regarding industrial wastewater management. In 1980, the EPA requested specific information from the BMI companies regarding their manufacturing processes and their waste management practices by issuing Section 308 (Clean Water Act) information request letters. In 1994, the NDEP issued a Letter of Understanding (LOU) to Kerr-

McGee that identified 69 specific areas or items of interest on the Site and prescribed the level of environmental investigation they desired.

Tronox has undertaken environmental investigations to assess specific impacts on the Site and in the area as described below. A detailed discussion of the specific areas or items of interest identified in the LOU and summary of site conditions can be found in the Conceptual Site Model document (ENSR 2005).

1.2.3 Environmental Conditions Summary

Numerous investigations have been conducted to evaluate the nature, extent, and movement of contaminants on the Site and in downgradient and cross-gradient areas. A Consent Order between Tronox and NDEP prepared in September 1986 stipulated additional groundwater characterization and the implementation of remedial activities to address chromium in the groundwater. As a result of the 1986 Consent Agreement, monitor wells, groundwater interceptor wells, a groundwater treatment system for chromium reduction, and two treated-groundwater injection trenches were installed and the treatment of groundwater began in mid-1987. This treatment is on-going today.

In April 1991, Tronox was one of six companies entering into a Consent Agreement with the NDEP to conduct environmental studies to assess site-specific environmental conditions that are the result of past and present industrial operations and waste disposal practices. The six companies that entered into the Consent Agreement included those past or present entities that conducted business within the BMI complex. The Consent Agreement specified that, among other things, the companies identify, document, or address soil, surface water, groundwater, or air impacts and document measures that have been taken to address environmental impacts from their respective sites.

In April 1993, in compliance with the 1991 Consent Agreement, Tronox submitted the Phase I ECA to NDEP. The purpose of the report was to identify and document site-specific environmental impacts resulting from past or present industrial activities. The Phase I ECA included an assessment of the geologic and hydrologic setting as well as historical manufacturing activities. In 1994, the NDEP issued an LOU that identified 69 data gap areas that needed additional information, either in the form of additional document research or field sampling of site conditions.

During the mid to late 1990s, Tronox collected additional data to fill the LOU-identified data gaps. This was done by investigating past operator records as well as through field sampling. Results of this work are described in the Phase II Written Response to the LOU, the Phase II ECA, and the Supplemental Phase II ECA, the latter two of which were reports describing the results of field sampling of groundwater and soils. Through this effort, potential environmental impacts associated with the 69 LOU areas were evaluated.

In 1997, perchlorate was discovered in the Las Vegas Wash vicinity, and this aspect of the ECA was placed on a remedial fast-track. Impact characterization and treatment methodology evaluation was on-going in the late 1990s with installation of a water collection system and temporary ion exchange (IX) process for perchlorate removal. This remedial process began operation in November 1999. Tronox and NDEP entered into a 1999 Consent Agreement, which defined remedial requirements and looked forward to a more permanent treatment process that would replace the temporary IX system. After considerable research and process development, a permanent treatment technology was developed. Tronox and NDEP entered into an October 2001 Administrative Order on Consent (AOC) defining the more permanent remedial requirements, which were installed and are operating today. To date, perchlorate remediation efforts have included the design, installation, and operation of groundwater extraction as well as surface water collection systems, along with development, design, installation, and operation of a permanent treatment process. These activities include:

- The on-site groundwater barrier wall together with an upgradient collection well field,
- The Athens Road groundwater collection well field,

- The seep area collection well field as well as a sump for collection of water in the area where groundwater surfaced, and
- A treatment system that removes chromium and perchlorate from the collected groundwater and then discharges the water in accordance with the limits set forth in the existing National Pollutant Discharge Elimination System (NPDES) permit.

The groundwater systems will continue to operate under the direction of the NDEP.

In February 2004, the NDEP provided a response to the Kerr-McGee, Supplemental Phase II ECA. NDEP indicated that additional work would be required including identification of all potential contaminants associated with the Site, background sampling, assessment of Site-specific action levels, and identification of data gaps.

Between February 2004 and March 2006, a comprehensive list of site-related chemicals (SRCs) was jointly developed by the NDEP and Tronox. **Table 1-1** presents an alphabetical list of the SRCs.

On March 29, 2005, the Background Investigation Work Plan was submitted by Kerr-McGee and on May 6, 2005, the NDEP provided comments on the document. Kerr-McGee met with the NDEP and discussed how they planned to address the comments. Kerr-McGee submitted a letter responding to the comments dated July 20, 2005. In a letter dated July 28, 2005, the NDEP provided additional comments and suggested that they be discussed in a meeting and then addressed in a revised work plan. The revised work plan was renamed the Upgradient Investigation Work Plan and was submitted September 29, 2005. In 2005 Kerr-McGee Chemical LLC was renamed Tronox LLC (Tronox). The NDEP submitted additional comments on October 6, 2005, and errata sheets were provided by Tronox on October 14, 2005. On February 20, 2006, Tronox provided a letter responding to the NDEP comments and issued the Upgradient Investigation Work Plan Addendum on February 21, 2006. The NDEP issued a letter February 23, 2006, approving the work plan with minor comments. Copies of the pertinent NDEP and Tronox correspondence are included in **Appendix A**.

The scope of work for the upgradient investigation was conducted from March 13 to 24, 2006, and included drilling and sampling six soil borings near the southern end of the property (**Figure 1-1**). Soil samples were analyzed for perchlorate, metals, volatile organic compounds (VOCs) including fuel oxygenates, total petroleum hydrocarbons (TPH), chlorate, and radionuclides. Four of the soil borings were completed as monitoring wells. Groundwater was collected from eight monitoring wells and analyzed for perchlorate, metals, VOCs including fuel oxygenates, TPH, pH, electrical conductivity (EC), alkalinity, carbonate, bicarbonate, water chemistry ions, and radionuclides. A comparison of the analytical results between bailer and micro-purge sampling methods was also conducted. In addition, soil from one boring (M-120) was analyzed for the full list of SRCs.

1.3 Report Organization

The upgradient investigation report is organized as follows:

- **Section 1** is the Introduction and describes the purpose of the upgradient investigation. The objectives of the investigation, along with a brief history of the Site, are presented, and the section concludes with a summary of the environmental conditions at the Site.
- **Section 2** discusses the physical setting of the Site, including site location, site topography, climate, regional and local geology/hydrogeology, and a brief summary of the results of background studies from adjacent areas.
- **Section 3** describes the upgradient investigation activities, including the field activities, sample handling and management, and a discussion of the procedures by which the laboratory data were evaluated.

- **Section 4** presents the results of the investigation, including a discussion of the geology encountered and the laboratory results for the soil and groundwater samples that were analyzed.
- **Section 5** presents the conclusions of the upgradient investigation.
- **Section 6** provides a bibliographic list for each of the references that were cited in this document.

Appendices included in this document are listed below.

- **Appendix A** contains the pertinent NDEP and Tronox correspondence regarding the upgradient investigation.
- **Appendix B** contains copies of the soil boring logs that were generated during drilling activities.
- **Appendix C** contains monitoring well construction diagrams.
- **Appendix D** contains copies of the groundwater sampling field data sheets.
- **Appendix E** presents the data validation memoranda.
- **Appendix F** contains the backup data that were generated as part of the statistical evaluation of the laboratory data.
- **Appendix G** is a compact disc containing copies of the laboratory certified analytical reports and chain-of-custody documentation.
- **Appendix H** contains the coordinates and elevations of the soil borings and new monitoring wells that were measured by the surveyor.
- **Appendix I** contains the evaluation of groundwater data generated using the micro-purge sampling methods as compared with the methods used to historically sample the wells.
- **Appendix J** contains the additional statistical information and interpretation.

2.0 PHYSICAL SETTING OF STUDY AREA

This section describes the physical setting of the Site and includes a brief description of the location of the Site, the topography of the Site, and the local and regional climate. This is followed by a discussion of the geology and hydrogeology of the area both from a regional and local perspective. Finally, this section concludes with a summary of the results of background or upgradient studies that have been performed in adjacent or nearby areas of Henderson.

2.1 Site Location

The Site is approximately 450 acres in size and is located 13 miles southeast of Las Vegas in an unincorporated section of Clark County, Nevada (**Figure 1-1**). It is completely surrounded by the incorporated City of Henderson. The Site is in Township 22 South, Range 62 East, and covers portions of Sections 1, 12, and 13. The approximate center of the Site is longitude 36°02'45" W and latitude 115°00'20" N. The specific area addressed in this upgradient investigation encompasses the southernmost limits of the Site, which comprises an area that extends from the Lake Mead Parkway on the south, northward, approximately 2,000 ft to Avenue H. The location of the study area is depicted on **Figure 1-1** and **Figure 1-2**.

2.2 Site Topography

Elevations across the Site range from 1,677 to 1,873 ft above mean sea level. The land surface across the Site slopes toward the north at a gradient of approximately 0.023 feet per foot (ft/ft). The developed portions of the Site have been modified by grading to accommodate building foundations, surface impoundments, and access roads.

2.3 Climate

The climate of the Las Vegas Valley is arid, consisting of mild winters and dry hot summers. Average annual precipitation as measured in Las Vegas from 1971 to 2000 was 4.49 inches. Precipitation generally occurs during two periods, December through March and July through September. The winter storms generally produce low intensity rainfall over a large area. The summer storms generally produce high intensity rainfalls over a smaller area for a short duration. These violent summer thunderstorms account for most of the documented floods in the Las Vegas area. Temperatures can rise to 120° F in the summer, and average relative humidity is 20%. The mean annual evaporation from lake and reservoir surfaces ranges from 60 to 82 inches per year.

Winds frequently blow from the southwest or northwest and are influenced by nearby mountains. Strong winds in excess of 50 miles per hour are experienced occasionally.

2.4 Geology and Hydrogeology

The following is a discussion of the regional geology and hydrogeology of the area as well as the local geology and hydrogeology encountered at the Site.

2.4.1 Regional Geology

The Las Vegas Valley occupies a topographic and structural basin trending northwest-southeast and extending approximately 55 miles from near Indian Springs on the north to Railroad Pass on the south. The valley is bounded by the Las Vegas Range, Sheep Range, and Desert Range to the north; by Frenchman and Sunrise Mountains to the east; by the McCullough Range and River Mountains to the south and southeast; and the Spring Mountains to the west. The mountain ranges bounding the east, north, and west sides of the valley consist primarily of Paleozoic and Mesozoic sedimentary rocks (limestones, sandstones, siltstones, and fanglomerates), whereas the mountains on the south and southeast consist primarily of Tertiary volcanic rocks (basalts, rhyolites, andesites, and related rocks) that lie directly on Precambrian metamorphic and granitic rocks (Bell 1981).

In the Las Vegas Valley, basin-fill consists of Tertiary and Quaternary sedimentary and volcanic rocks and unconsolidated deposits, which can be up to 13,000 ft thick (Langenheim et al. 1998). The valley floor consists of fluvial, paludal (swamp), and playa deposits surrounded by more steeply sloping alluvial fan aprons derived from erosion of the surrounding mountains. Generally, the deposits grade finer with increasing distance from the source area and with decreasing elevation. The structure within the Quaternary and Tertiary-age basin-fill is characterized by a series of generally north-south trending fault scarps. The origin of the faults is somewhat controversial; they may be tectonic in origin or may be the response to compaction and subsidence within the basin due to groundwater withdrawal.

A detailed discussion of the geology of the Site and surrounding area is found in the Conceptual Site Model document (ENSR 2005).

2.4.2 Local Geology

The local geology and hydrology are defined by data collected from the numerous borings and wells that have been installed in the area.

Alluvium. The Site is located on Quaternary-age alluvial deposits that slope north toward Las Vegas Wash. The alluvium consists of a reddish-brown heterogeneous mixture of well-graded sand and gravel with lesser amounts of silt, clay, and caliche. Clasts within the alluvium are primarily composed of volcanic material. Boulders and cobbles are common. Due to their mode of deposition, no distinct beds or units are continuous over the area.

A major feature of the alluvial deposits is the stream-deposited sands and gravels that were laid down within paleochannels that were eroded into the surface of the Muddy Creek Formation during infrequent flood runoff periods. These deposits are thickest within the paleochannel boundaries, which are narrow and linear. These sand and gravel deposits exhibit higher permeability than the adjacent, well-graded deposits. In general, these paleochannels trend northeastward.

The thickness of the alluvial deposits ranges from less than 1 ft to more than 50 ft beneath the Site. Soil types identified in on-site soil borings include poorly sorted gravel, silty gravel, poorly sorted sand, well sorted sand, and silty sand. The thickness of the alluvium, as well as the top of the underlying Muddy Creek Formation, was mapped to locate these paleochannels.

Muddy Creek Formation. The Muddy Creek Formation of Miocene and Pliocene (?) age occurs in Las Vegas Valley as valley-fill deposits that are coarse-grained near mountain fronts and become progressively finer-grained toward the center of the valley (Plume 1989). Where encountered beneath the Site, the Muddy Creek Formation is composed of at least two thicker units of fine-grained sediments of clay and silt (the first and second fine-grained facies, respectively) interbedded with at least two thinner units of coarse-grained sediments of sand, silt, and gravel (the first and second coarse-grained facies, respectively). Everywhere beneath the Site, except for the southernmost 1,000 ft adjacent to Lake Mead Parkway, the first fine-grained facies (MCfg1) separates the first coarse-grained facies (MCcg1) from the overlying Quaternary alluvium. Within the southern 1,000 ft of the Site, the Muddy Creek Formation's first fine-grained facies (MCfg1) pinches out along a generally west-northwesterly trending line. South of this line the coarse-grained facies (MCcg1) directly underlies the Quaternary alluvium.

The Muddy Creek Formation represents deposition in an alluvial apron environment from the Spring Mountains to the west grading into fluvial, paludal (swamp), playa, and lacustrine environments further out into the valley center. On the Site, the Muddy Creek does not crop out but instead subcrops beneath a veneer of Quaternary alluvium.

In on-site borings, the contact between the Quaternary alluvium and the Muddy Creek Formation (MCfg1) is typically marked by the appearance of a well-compacted, moderate brown silt-to-sandy silt or stiff clay-to-sandy clay, whereas near the Las Vegas Wash, the contact is marked by gray-green to yellow-green gypsiferous clays and silts.

2.4.3 Local Hydrogeology

Alluvial Aquifer. Beneath the northern portion of the Site, the first groundwater encountered occurs within the Quaternary-age alluvium at depths of more than 30 ft below ground surface (bgs) and shallows northward, occurring near the ground surface at Las Vegas Wash. In the alluvial aquifer, groundwater flows towards the north-northeast with minor variations, generally mimicking the slope of the ground surface.

Muddy Creek Aquifer. Beneath the central portion of the Site, the first groundwater encountered occurs within the first fine-grained facies of the Muddy Creek Formation (MCfg1) and can be more than 50 ft bgs, as documented in historical water-level measurements from well M-103. South of the MCfg1 pinch-out, beneath the southern portion of the Site, the first groundwater encountered occurs within the first coarse-grained facies of the Muddy Creek Formation (MCcg1) and can be more than 70 ft bgs as documented in historical water level measurements from well M-103 and further confirmed from water-level measurements from the new wells (M-120 and M-121) installed as part of this upgradient investigation. The gradient and flow direction of the potentiometric surface in both MCfg1 and MCcg1 (south of the pinch-out), mimics the ground surface and is to the north-northeast with minor variations.

At deeper depths beneath the Site and extending into the Las Vegas Valley, confined groundwater also occurs within the deeper coarse-grained facies of the Muddy Creek Formation. The flow direction of this deeper groundwater is more northeasterly than the shallow unconfined groundwater aquifer. Many deep wells drilled into the Muddy Creek Formation exhibit artesian conditions with some wells flowing at the surface. Most shallow wells drilled into the shallow Muddy Creek also demonstrate an upward hydraulic gradient.

2.5 Results of Other Background Studies

Assessments of background or upgradient conditions at adjacent or nearby sites have been performed by the City of Henderson (COH) and BRC/TIMET under the supervision of the NDEP. The following discussion summarizes the results of these two investigations.

2.5.1 Background Study Performed by the City of Henderson

Background soil conditions were evaluated by the COH as part of a risk assessment study (ENVIRON 2003) for the expansion of the City's Water Reclamation Facility. Field sampling was performed in April 2002 after the NDEP approved the sampling and analysis plan. The study was designed to obtain a data set that could be used to characterize the levels of the chemicals of interest that might be found in the BMI Common Areas in the absence of waste disposal activities or migration from the BMI Complex.

Several parameters were considered in finding a suitable area that was representative of background conditions in the Henderson area. These parameters included land use, topography, soil type, and local wind conditions. Ideally, undisturbed areas that were upgradient, upwind, and upstream of the BMI Common Areas were considered.

According to the report (ENVIRON 2003), background soil samples were collected from eight locations. These locations are roughly 3 to 4 miles east and southeast of the Tronox facility. The eight COH background locations are shown on **Figure 2-1**. At each location, two soil samples were collected for laboratory analyses.

Using a hand auger, the shallowest soil samples were collected from 0- to 1-ft depth; a second soil sample was collected from slightly deeper depths (between 2.5 and 4 ft bgs). Originally, the sampling and analysis plan called for the deeper soil sample to be collected from 4 to 5 ft bgs, but refusal was encountered below 4 ft due to the presence of caliche deposits.

A total of 16 soil samples were collected for the COH background study. All soil samples were analyzed for the following:

- Metals
- Radionuclides
- Perchlorate
- Dioxins/Furans
- Total Organic Carbon (TOC)
- Cation Exchange Capacity (CEC), and
- Soil Texture Classification

In addition, all surface (0- to 1-ft depth) soil samples were analyzed for pesticides. The results from the COH Background Study can be found in the “Risk Assessment for the Water Reclamation Facility Expansion Site, Henderson, Nevada” which was completed for the COH by ENVIRON International Corp. in October 2003 (ENVIRON 2003).

2.5.2 Background Study Performed for the BMI Common Areas and Complex

Background soil conditions were evaluated by BRC and TIMET (BRC/TIMET) for the BMI Common Areas and Complex (Tetra Tech ERM & MHW Americas 2006). Field activities were conducted according to the April 2005 Background Soil Sampling Workplan (Tetra Tech ERM 2005) that was approved by the NDEP. The goals of the study were to develop a representative background soil data set that could be used to evaluate whether concentrations of site-related chemicals detected in the BMI Common Areas soils statistically exceed concentrations of these chemicals in background soils. Summaries of the BRC/TIMET study data and results can be found in the May 15, 2006, document entitled, “Background Soil Summary Report, BMI Complex and Common Areas” (Tetra Tech & MWH Americas 2006).

Background soil sample locations were selected based on their proximity to the BMI Common Areas, their upwind and upslope position relative to the BMI Common Areas, and their similarity to soils found on the BMI Common Areas. A total of 11 sampling locations were identified on undeveloped properties close to and upgradient from the BMI Common Areas. Three borings were advanced at all 11 locations, and three soil samples were collected from each at depths of 0 to 0.5 ft bgs, 4 to 6 ft bgs, and 9 to 11 ft bgs. Surface soil samples (0 to 0.5 ft) were collected by hand using a stainless steel shovel. Subsurface soil samples were collected using a hollow-stem auger rig. Each subsurface soil sample submitted for analysis was collected from a 2-ft interval of drill core that was homogenized in a stainless steel bowl.

An initial total of 99 soil samples were collected; however, one soil boring encountered refusal and was relocated, increasing the total number of samples to 104. All soil samples were analyzed for the following:

- Metals
- Anions (chloride, fluoride, sulfate, nitrate, and nitrite)
- Radionuclides
- Soil Texture Classification
- pH

- Conductivity
- CEC
- Salinity
- Total Organic Carbon (TOC), and
- Percent Moisture

2.5.3 Validation of COH and BRC/TIMET Background Data

In addition to the soil sampling activities, soil background data were validated from two events: BRC/TIMET (Tetra Tech ERM and MHW Americas 2006) and COH (ENVIRON 2003). Full and partial validations were conducted on the data sets. Data validation for the BRC/TIMET data set was conducted by the TIMET project team chemist and included 10% full validation and 90% partial validation. Partial validation was conducted by a project chemist with Neptune and Company Inc. (NDEP's contractor) on the COH background data set.

Results of the data validation conducted on the BRC/TIMET data set showed that 22 soil samples were rejected and qualified as "R" (rejected); however, the elimination of these rejected data did not adversely affect the data analysis used in this study. The overall objective of the data collection was met, with 98.5% of the data set validated as usable.

Neptune and Company inc's partial validation of the COH data set indicates that the results for the hexavalent chromium may not be accurate based on holding time exceedances. In addition, radium isotopes (224, 226, and 228) were also considered suspect due to high laboratory control sample recoveries and concerns that the results were biased high. For these reasons, NDEP's contractor recommended that these data be rejected and not used in the overall soil background data set. Except for hexavalent chromium and radium isotope data, the COH data set was considered usable for the intended purposes.

Background data for the McCullough Range and River Mountains were collected and analyzed in the BRC/TIMET and COH background studies. It appears that the northern McCullough Range is the primary source of material upslope of the BMI Complex. Mineral assemblages in these source rocks are thought to be the primary contributors to background concentrations of metals, radionuclides, and anions in the native soils. Soil samples collected down slope of the McCullough Range and River Mountains were evaluated statistically and validated as part of the background soil data set. With a few exceptions, the concentrations of metals and radionuclide from the McCullough Range and the River Mountains are similar.

The validated BRC/TIMET and COH background data sets discussed above were evaluated using statistical plots, calculation of summary statistics, and statistical tests. In addition, both data sets were compared to soils derived from the northern McCullough Range and River Mountains. The comparison of background data included an evaluation of the soil types and geology of for the McCullough Range and the River Mountains, as well as the sample results obtained from the BRC/TIMET and COH Background sample locations.

A comparison of the background soil samples from the BRC/TIMET study and the COH background study indicates that the two data sets are consistent with each other. The BRC/TIMET data set captures a wider range of natural variability than the COH data set because of the greater number of samples (104 vs. 16, respectively). The BRC/TIMET study further concluded that combining the two data sets would change mean concentrations only slightly for most analytes because the BRC/TIMET data set incorporates the variability of the COH data set.

The metal and radionuclide in soil results from the off-site studies have been compared with similar data generated by Tronox during the Upgradient Investigation. Statistical comparisons between the Tronox, BRC/TIMET, and COH data sets indicate that nearly all species represent different populations and should not be combined for subsequent analyses. The results of the comparisons are discussed in more detail in Sections 4.5.1 and 4.5.2.

3.0 UPGRADIENT INVESTIGATION ACTIVITIES

To assess Tronox upgradient soil conditions, soil borings were drilled at six locations and soil samples were collected at regular intervals for laboratory analyses. Monitoring wells were installed in four of the six borings; the wells were developed and dedicated pumps were installed. To assess upgradient groundwater conditions, water samples for laboratory analyses were collected from the four new wells plus six existing monitoring wells.

Field activities were performed following the measures described in the NDEP-approved Upgradient Investigation Work Plan (ENSR 2006) for this Site. Prior to the onset of drilling activities, the local Dig Alert service was contacted and each boring location was checked for the presence of underground utilities by representatives from The TBE Group, Inc., a local geophysical surveyor using electromagnetic surveying equipment.

For the four new wells that were installed, the drilling company (ProSonic Corporation) prepared and submitted to the State of Nevada an Affidavit of Intent to Abandon Monitoring Wells for these new wells as required under State law. A description of the field activities is presented below.

3.1 Soil Borings

Six soil borings (M-116, M-117, M-118, M-119, M-120, and M-121) were drilled near the southern boundary of the Site at the locations shown on **Figure 1-2**. The soil borings were drilled using sonic drilling technology from which continuous cores were obtained for lithologic examination and logging purposes.

Borings M-116 and M-119 were drilled to develop analytical data for the alluvium and to identify the southern extent of the MCfg1 unit. These borings were drilled through the Quaternary Alluvium until the MCfg1 unit was encountered – a depth of about 50 ft at both locations. The boreholes were backfilled with the unused core material and the surface restored to match the surrounding grade.

Borings M-117 and M-118 were drilled to develop analytical data for the alluvium, and the MCcg1 and MCfg2 units. They were drilled through the Quaternary Alluvium (Qal) and the underlying MCcg1 until the MCfg2 was encountered. These borings were converted into monitoring wells in order to sample groundwater from the MCfg2 unit. Borings M-117 and M-118 were drilled to depths of 155 ft bgs and 162 ft bgs, respectively.

Borings M-120 and M-121 were drilled to develop analytical data for the alluvium and the MCcg1 unit. They were drilled through the Qal and into the underlying the MCcg1. These borings were converted into monitoring wells in order to sample groundwater from the MCcg1 unit. Both M-120 and M-121 were drilled to depths of about 107 ft bgs.

During drilling operations, organic vapors were monitored with a Photovac™ microtip-photoionization detector (PID) and the readings were recorded on the soil boring logs. The Photovac™ used a 10.2 ev lamp. The following information was recorded on the boring logs: boring number and location; sample identification numbers; date and time; sample depth; lithologic description in accordance with the Unified Soils Classification System (USCS); and description of any noticeable evidence of soil contamination (i.e., odor, visual staining) in addition to the PID readings. Copies of the soil boring logs are presented in **Appendix B**.

The following section describes the soil sampling methods that were used at the Site.

3.2 Soil Sampling

When the drilling reached the target sample depth, a modified split-spoon sampler mounted to a steel pipe was inserted through the center of the hollow sonic drill pipe, and the split-spoon sampler was pushed 18-inches into the soil beneath the sonic drill bit in order to obtain samples of undisturbed soil for laboratory analyses. The split-spoon sampler was fitted with three 6-inch-long brass liners (sleeves). As the split-spoon was advanced downward, soil was driven into the sleeves.

As soon as the split-spoon sampler was removed from the borehole and disassembled, the sleeve corresponding to the target sample depth was chosen for laboratory analyses. Teflon™ sheets were placed on both ends of the sleeve; plastic end-caps were placed on the sleeve, and the sleeve was labeled and placed inside a chilled ice chest while awaiting delivery to the laboratory. In some instances, to ensure that the sample included a sufficient volume of soil for the specified analyses, additional soil (taken from the continuous core generated by the sonic core barrel) was placed in laboratory-supplied glass jars to augment the volume of soil in the brass sleeves. In all cases, the soil that was placed into glass jars were designated for analyses for non-volatile constituents (e.g., metals, radionuclides, etc.).

Samples for volatile constituent analyses: Soil samples designated for VOC, gasoline-range organics (GRO), and fuel alcohol analyses were collected from the chosen sleeve and preserved in the field as prescribed under EPA Method 5035. For each sample, aliquots of soil (roughly 5 grams) were placed into separate 40-milliliter (ml) volatile organic analysis (VOA) vials containing a solution of sodium bisulfate or methanol. When the samples reached the laboratory, soil in the sodium bisulfate-preserved vials was tested first; if elevated levels (>200 micrograms per kilogram [µg/kg]) of GRO and/or VOCs were detected, then the corresponding soil in the methanol-preserved vial would be analyzed in order to further quantify the GRO/VOC concentration.

As the soil samples were preserved in the field, it became apparent that sodium bisulfate could not be used as a field preservative. A strong chemical reaction (effervescence) occurred when soil from the Site came into contact with the sodium bisulfate preservative. The cause for the chemical reaction was likely the result of naturally occurring calcium carbonate in the soil (calcium carbonate effervesces upon contact with a solution containing sodium bisulfate). Since this chemical reaction could affect the analytical results, the vial was discarded and a new 5-gram aliquot of soil was placed into vials containing pre-measured laboratory-grade de-ionized water as the preservative. The substitution of de-ionized water in lieu of sodium bisulfate is acceptable under EPA Method 5035 in instances where excessive effervescence occurs.

Sample procedures for volatile constituent analyses: To collect a soil sample for GRO, VOC, or fuel alcohol analyses, a new, disposable syringe (T-handle) was used to collect 5-gram (approximate) aliquots directly from the sample sleeve. The aliquot was placed into 40-milliliter glass vials containing pre-measured amounts of de-ionized water or methanol. To analyze a soil sample for TPH and fuel alcohols, the following containers were filled:

- two vials of de-ionized water-preserved soil (for low-concentration GRO),
- one vial of methanol-preserved soil (for high-concentration GRO),
- four vials of de-ionized water-preserved soil (for fuel alcohol analyses), and
- soil in a brass sleeve (for heavy-end hydrocarbon [>C_{12}] analyses).

To analyze a soil sample for VOCs, the following containers were filled:

- two vials of de-ionized water-preserved soil (for low-concentration VOCs), and
- one vial of methanol-preserved soil (for high-concentration VOCs)

The sample ID number, date, time of sample collection, and analyses requested were then listed on the label. The vials were placed in Ziploc™ plastic bags and placed in a chilled cooler along with the rest of the samples pending delivery to the analytical laboratory. A new T-handle syringe was used to obtain 5-milligram (mg) aliquots of soil at each sample depth and then discarded to the trash.

Ambient Temperature Headspace Screening. After samples were removed from the core barrel, the remaining soil was used for lithologic description and screening for VOCs with a PID. For headspace analysis by the PID, approximately 200 grams of soil was removed from the sampling sleeve and placed in a Ziploc™ plastic bag. Once sealed in the bag, the soil was manually broken apart and allowed to come to ambient temperatures. The probe tip of the PID was then inserted into the plastic bag and a reading was obtained. The organic vapor readings were recorded on the boring logs by the field geologist. The PID was calibrated to 100 parts per million (ppm) isobutylene each day prior to its use.

3.2.1 Soil Analytical Testing Program

Soil samples were tested for the following suite of analytes:

- Perchlorate (EPA Method 314.0)
- TPH full carbon range (EPA Method 8015B/5035)
- Fuel Alcohols (EPA Method 8015B/5035)
- VOCs (EPA Method 8260B/5035)
- Metals (EPA Method 6010/6020/7000 series)
- Hexavalent Chromium (EPA Method 7199)
- Radionuclides (various methods)
- General Water Chemistry Parameters (various methods)
- Other miscellaneous parameters such as asbestos and surfactants (various methods)

In addition to the analytical suites listed above, soil samples from boring M-120 were also tested by additional methods including:

- Semi-Volatile Organic Compounds (SVOCs) (EPA Method 8270C)
- Organochlorine Pesticides (OCPs) (EPA Method 8081A)
- Polychlorinated Biphenyl (PCB) compounds (EPA Method 8082)
- Organophosphorous Pesticides (OPPs) (EPA Method 8141)
- Dioxins/Furans (Method SW 846 8290)

The broad suite of analyses was applied to the soil samples from boring M-120 to assess the presence and significance that potential matrix effects could cause on data quality. The analytical results indicated that, in general, the data quality was not impacted by matrix effects. Further details of the data validity are discussed in Section 4.0 and in the Data Validation Summary Report in Appendix E. The complete list of targeted analytes for the soil samples is presented in **Table 3-1.**

3.2.2 Soil Sample Handling and Laboratory Shipping

Soil samples for laboratory analyses were placed on wet ice inside ice chests for shipping to the laboratory. Each soil sample was logged on a Chain-of-Custody (COC) form, and the ice chests were taken to Federal Express for express overnight shipping to the laboratory. Copies of the COC forms are included in **Appendix G** (Laboratory-Certified Analytical Reports).

3.2.3 Borehole Abandonment

Two boreholes (M-116 and M-119) were abandoned once the target depth was reached and the necessary soil samples obtained. The boreholes were abandoned by backfilling each borehole with the unused portions of the soil core. The borehole was topped off with bentonite/neat cement grout to the ground surface. Since M-119 was located along the perimeter of an asphalt-paved parking lot, a surface plug consisting of concrete grout was placed from a depth of 1 ft to the ground surface.

3.3 Monitoring Well Installation

Four soil borings (M-117, M-118, M120, and M-121) were completed as groundwater monitoring wells. Each monitoring well was constructed of 2-inch diameter Schedule 40 polyvinylchloride (PVC) blank casing and screen (0.020-inch slot size). For each well, 5 ft of blank PVC casing was attached below the well screen to serve as a sediment trap. Above the sediment trap was 20 ft of well screen that was overlain by blank casing that extended to the ground surface.

The sand pack, bentonite seal, and sanitary (grout) seal were placed into the annular space using a tremie pipe. The filter pack material consisted of Lonestar # 3 sand that filled the annular space from the bottom of the borehole to a depth of roughly 5 ft above the top of the well screen. Following emplacement of the sand pack, a 5-ft-thick layer of bentonite pellets were placed on top of the sand pack. For wells M-120 and M-121, where the top of the sand pack was above the water table, the bentonite pellets were hydrated with potable water poured through the tremie pipe from the ground surface. For deep wells M-117 and M-118, where the top of the sand pack was at least 20 ft below the water table, the bentonite pellets were hydrated by the groundwater. After waiting at least 20 minutes for the bentonite to hydrate, a bentonite-cement grout was tremied on top of the bentonite seal to form a sanitary seal; the sanitary seal extended upwards to within 3 to 5 ft of the ground surface.

At each well location, the PVC well casing extended above the ground surface for 2 to 3 ft. To protect the well casing, a 6-inch diameter steel protective riser pipe (with locking steel lid) was set into the ground around the well casing and cemented in-place. A cement pad was placed on the ground surface around each of the four protective steel riser pipes. Construction details for all four monitoring wells are presented in **Appendix C** (Monitoring Well Construction Diagrams).

3.4 Monitoring Well Development

Each monitoring well was developed to remove sediments from the well, settle the annular filter pack, and to improve the hydraulic connection between the well and the aquifer formation. Well development activities were performed at least 24 hours after the wells were installed. A Schmeal™ rig was used to develop each well using the following procedures:

- The well screen was swabbed and surged by repeatedly raising and lowering the surge-block in 10-ft increments along the length of the 20-ft well screen; first the upper 10-ft of well screen was surged for 15 minutes, then the lower 10-ft of well screen was surged for 15 minutes. This entire process was then repeated a second time.
- After surging, the monitoring well was purged of 20 to 50 gallons using a bailer in order to remove coarse-grained sediment from the well.
- An electric submersible pump was then lowered into the well and groundwater was pumped from the well at a rate of about 1 gallon per minute (gpm) to remove fine-grained sediment.
- During pumping, specific conductivity and turbidity were monitored at periodic intervals. Pumping continued until the conductivity and turbidity stabilized or 2 hours had passed, whichever occurred first.

The water generated from well development activities was temporarily placed into a 400-gallon polyethylene tank mounted on a trailer. At the conclusion of well development activities, the water in the tank was discharged into the GW-11 holding pond for on-site treatment.

3.5 Groundwater Sampling

To evaluate upgradient groundwater conditions, groundwater samples were collected from ten wells (**Figure 1-2**). These include six existing upgradient wells (TR-7, TR-8, TR-9, TR-10, H-11, and M-103) and the four new wells (M-117, M-118, M-120, and M-121). Wells TR-7 and TR-8 form a well cluster (well cluster no. 1) with TR-7 screened from 260 to 290 ft bgs (completed within MCcg2 unit) and TR-8 screened from 63 to 93 ft bgs (completed in the MCcg1 unit). Similarly, wells TR-9 and TR-10 form well cluster no. 2, with TR-9 screened from 230 to 250 ft and TR-10 screened from 80 to 100 ft bgs. The rest of the wells are all screened in the MCcg1 unit, with the screen intervals ranging between 69.5 ft and 105 ft bgs. **Table 3-2** lists the screened intervals for the wells used in the upgradient investigation.

For the upgradient investigation, groundwater samples were collected using dedicated micro-purge bladder pumps that were installed in nine out of the ten wells. H-11 was the lone exception. With the exception of H-11, the nine wells were purged and sampled using low-flow techniques.

(Well H-11 belongs to Pioneer Chemical, and for several years, a dedicated electric submersible pump was present and used to sample H-11. Well H-11 was planned to be purged and sampled using the dedicated pump; however, prior to the planned sampling, the pump had been removed by the land owner (Pioneer). As a result, groundwater samples were collected from H-11 using the alternative, historical methods, in which no purging was performed and laboratory-supplied sample bottles were filled using a bailer that was repeatedly lowered to the bottom of the well.)

Historical groundwater samples from the six existing wells (TR-7, TR-8, TR-9, TR-10, H-11, and M-103) had been collected with little or no well purging prior to sample collection. In the past, to collect groundwater samples, laboratory-supplied sample bottles were typically filled using a bailer that was lowered to the well bottom.

As part of the upgradient investigation, a comparison was performed to evaluate whether the two sampling strategies (low-flow purge and sample vs. bailer sample with no purging), when applied to the same well during the same sampling episode, would result in significantly different laboratory analytical results. The comparison of sampling methods yielded mixed results for metals and wet chemistry parameters. However, in general, the results varied more for the less soluble constituents than for the more highly soluble constituents. This evaluation is discussed in detail in **Appendix I** (Evaluation of Micro-purge Data Compared with Historical Sampling Methods).

3.5.1 Micro-purge/Low-Flow Groundwater Sampling

To collect groundwater samples from the nine wells (excluding H-11), the following procedures were used.

The depth-to-water in each well was first measured using an electric water-level meter. The micro-purge bladder pump was then placed approximately midway into the well's screened interval. The pumps were lowered slowly into each well to minimize disturbance of the formation, and the water level in each well was allowed to equilibrate prior to purging and sampling. Groundwater was purged at flow rates ranging between 100 to 500 ml per minute. During pumping, the water level was continually monitored using the water level meter to ensure that the water level was relatively stable (i.e., drawdown did not vary more than 0.3 ft).

During purging, water quality parameters were monitored using a Horiba U-22 water quality meter fitted with a flow-through cell. Parameters such as temperature, pH, electrical conductivity, turbidity, and dissolved oxygen were periodically measured until the parameters stabilized, at which time sample bottles could be filled.

Stabilization of water quality parameters was indicated when the following criteria were met in the final three consecutive readings: the pH varied less than 0.1 unit, temperature varied less than 1° Celsius, electrical conductivity varied less than 3%, and the dissolved oxygen and turbidity varied less than 5%. If field parameters did not stabilize within 30 minutes, the deviation was noted on the field sampling field sheet and a sample was collected. The field data were recorded onto data sheets that are included in **Appendix D** (Groundwater Sampling Field Data Sheets).

3.5.2 Sampling of Well H-11

Water samples from well H-11 were collected using historical sampling techniques, which consisted of a grab sample that was collected using a bailer, with no purging. Sampling H-11 in this manner was necessary since the landowner (Pioneer Chemical) had unexpectedly removed the dedicated submersible pump.

To collect the water sample from H-11, the depth-to-water was measured from the top-of-casing reference point to the nearest 0.01-ft using an electric water-level meter. The groundwater elevation was calculated by subtracting the measured depth-to-water from the surveyed elevation of the top of the well casing.

A clean PVC bailer, attached to a clean nylon rope, was then lowered to the bottom of H-11. The bailer was retrieved from the well, and water was slowly poured from the bailer into laboratory-supplied sample bottles. The bailer was repeatedly lowered and retrieved from the well bottom until all of the sample bottles were filled.

3.5.3 Groundwater Analytical Test Program

Groundwater samples from each well were tested for the following suite of analytes:

- Perchlorate (EPA Method 314.0)
- TPH full carbon range (EPA Method 8015B)
- Fuel Alcohols (EPA Method 8015B)
- VOCs (EPA Method 8260B)
- Metals (EPA Method 6010/6020/7000 series)
- Hexavalent Chromium (EPA Method 7199)
- Radionuclides (various methods)
- General Water Chemistry Parameters (various methods)
- Other miscellaneous parameters such as asbestos and surfactants (various methods)

In addition to the analytical suites listed above, groundwater samples from well M-120 were also tested for the following:

- SVOCs (EPA Method 8270C)
- OCPs (EPA Method 8081A)
- PCB compounds (EPA Method 8082)
- OPPs (EPA Method 8141)
- Dioxins/Furans (EPA Method 8290)

The complete list of targeted analytes for the groundwater samples is presented in **Table 3-1.**

3.6 Sample Handling and Management

For soil samples, as soon as the brass sleeves or glass jars were filled with soil, a label was affixed to these containers. The 40-ml vials that were used for TPH/VOC/fuel alcohol analyses were pre-labeled by the laboratory. For water samples, the sample containers were pre-labeled by the laboratory.

The labels were filled out on each container with the following information:

- Project number
- Site name
- Boring or well identification number
- Sample identification number
- Sampler's initials
- Date and time of collection
- Preservative used (if applicable)

Following collection and labeling, the samples were immediately placed on ice inside a sample cooler for temporary storage while awaiting shipping to the laboratory. The following protocol was followed for sample packaging:

- Sample containers were placed in leak-resistant clear plastic bags prior to placement in the ice chest. Screw caps were checked for tightness prior to placing the sample in the bag.
- Wet ice was placed in leak-resistant plastic bags in the coolers to keep samples at a chilled temperature during storage and transport to the analytical laboratory.
- The COC form was placed in a water-resistant plastic bag and placed inside of the cooler.
- Prior to shipping, each ice chest was sealed by placing multiple layers of tape around the ice chest, sealing the lid to the ice chest.

A temperature blank consisting of a 40-ml glass vial of distilled water was included in each cooler sent to the analytical laboratory. The purpose of the temperature blank was to allow the analytical laboratory to obtain a representative measurement of the temperature of samples enclosed in a cooler without disturbing the actual samples.

3.7 Sample Custody

COC records were used to document collection and shipment of samples to the laboratory for analyses. All sample shipments for analyses were accompanied by a COC record. When multiple coolers were sent to a single laboratory on a single day, separate COC forms were completed and sent (at least one COC form per cooler).

The COC record listed the contents of each shipment, and the record was used to document the custodial integrity of the samples. Generally, a sample is considered to be in someone's custody if it was either in someone's physical possession, in someone's view, locked up, or kept in a secured area that was restricted to authorized personnel.

3.8 Field Quality Control Samples

An integral part of the upgradient investigation field sampling was the collection of quality assurance/quality control (QA/QC) samples to ensure the reliability and compatibility of all data generated during this investigation. The following section describes the QA/QC samples that were collected as part of the upgradient investigation.

3.8.1 Field QA/QC Samples

Field QA/QC procedures were followed to ensure viability and integrity of sample analytical data. QA/QC procedures were adhered to in the field and included the following measures:

- Daily information regarding sample collection was recorded in field logbooks. Field data such as sample types (matrix), sample locations, sample depths, sample times, laboratory analyses requested, sample identification number, and sample locations were recorded on field summary sheets, field logbooks, and field diagrams.
- COC forms were used to document custody of every sample and to provide analytical instructions to the laboratory.
- Field duplicate samples were collected along with discrete samples and sent to the laboratory to assess the precision of the analytical methods employed by the laboratory.
- Equipment Blank samples were collected to evaluate the equipment cleaning procedures and to assess the potential for cross-contamination during field sampling activities.
- Trip blank samples were used to assess the potential for cross-contamination of discrete samples during shipping to the laboratory.
- A field blank sample was collected to assess the quality of the water used to clean soil sampling equipment.

3.9 Decontamination Procedures

Soil sampling equipment was cleaned prior to the beginning of each boring by steam cleaning in a designated area on-site. All non-disposable soil sampling equipment (e.g., split-spoon samplers, etc.) was disassembled and cleaned prior to the collection of each sample. This equipment was cleaned by either steam cleaning or by washing with a non-phosphate detergent solution (e.g., SimpleGreen™) followed by rinsing with distilled water.

Groundwater samples TR-7A, TR-8A, TR-9A, TR-10A, M-103A, and H-11 were collected using a non-disposable bailer as described in Section 3.5. Prior to sampling, the bailer was cleaned by washing with a solution of water and detergent (e.g., Simple Green™) followed by rinsing with distilled water. The remaining groundwater samples (TR-7, TR-8, TR-9, TR-10, M-103, M-117, M-118, M-120, and M-121) were collected using dedicated micro-purge bladder pumps and sample tubing that were installed in each well.

3.10 Investigation-Derived Wastes

Due to the nature of the sonic drilling method, the only excess soil that was generated during drilling activities was unused core from each soil boring. For soil borings M-116 and M-119, the excess soil was placed back into the borehole as part of the borehole abandonment. For the remainder of the soil borings, the plastic sleeve was removed and the excess soil was left on the Tronox property (at the direction of and with the prior approval of Tronox) and spread and leveled on the ground adjacent to the borehole. Other solid wastes consisted of used Personal Protective Equipment (PPE) and garbage, which was double-bagged in plastic trash bags and placed in on-site dumpsters that were disposed as municipal trash.

Liquid wastes (decontamination fluids, well development water and purged groundwater) were placed into a 400-gallon polyethylene tank that was mounted on a trailer. The tank was taken to the GW-11 holding pond within the main Tronox facility, and the liquids were discharged into the pond for on-site treatment by Tronox.

3.11 Surveying

Soil borings M-116 and M-119 along with the new monitoring wells M-117, M-118, M-120, and M-121 were surveyed by Stantec Surveying, Inc., to an accuracy of 0.01-ft vertical and 0.1-ft horizontal relative to North American Datum 1983 (NAD83) – Nevada East Plane. The survey data for each location are presented in Table H-1 in Appendix H.

3.12 Variances from the Approved Work Plan

As the field activities proceeded, several changes from the approved Work Plan were encountered. These changes are summarized below.

- According to Table 2 in the approved Work Plan, soil samples from borings M-117, M-118, M-120, and M-121 were to be collected to a maximum depth of 140 ft or until the water table was encountered, whichever came first. During the drilling activities, groundwater was consistently encountered at depths slightly deeper than 80 ft bgs. As a result, no soil samples were collected from depths deeper than 80 ft for this investigation.
- At boring M-119, the soil sample from a depth of 32 ft was collected for laboratory analyses (instead of 30 ft bgs as called for in the Work Plan) because the soil at 32 ft had a higher PID reading than the soil at 30 ft.
- At boring M-121, a soil sample from a depth of 70 ft was collected and sent to the laboratory for VOCs and TPH analyses because an elevated PID-reading was recorded in soils at this depth. Originally, no soil sample from this depth was planned for laboratory analysis, as described in the Work Plan.
- During the evaluation of Low-Flow Purge and Sample vs. Historical Groundwater Sampling (no purge, bailer grab sample) methods, well H-11 was replaced by well TR-10 as one of the five wells to be used in the comparison (along with wells TR-7, TR-8, TR-9, and M-103). The substitution of well TR-10 for H-11 was reasonable, and expected to yield comparable results, since both wells are screened in the same formation (Muddy Creek coarse-grained facies 1) and at similar depths (95 to 105 ft for H-11 and 80 to 100 ft for TR-10).
- During the course of developing well M-121, a small, 6-inch stainless steel weight separated from the bailer that was being used to remove sediment from the well and sank to the bottom of the well. Attempts to remove the weight were unsuccessful, and the weight was left at the bottom of M-121.
- Preliminary laboratory results indicated that methanol (a fuel alcohol) was detected in soil samples from multiple depths at five out of the six boring locations (M-119 being the exception) – despite the fact that GRO and diesel-range organics (DRO) were not detected in these soil samples. Methanol cross-contamination was suspected (i.e., the methanol was a carry-over from one of the liquids used to preserve the soil samples in the field – as required under EPA Method 5035.
- In order to confirm the significance of the methanol detections, a second set of soil samples (sampled at the 0.5- to 1-ft interval) were collected from boring locations M-116, M-117, M-117, M-120, and M-121 on March 24, 2006, and tested for fuel alcohols. Methanol was not detected in these samples, which confirmed that the initial methanol detections were likely an artifact of cross-contamination that occurred as the samples were shipped to the laboratory and that methanol was not actually present in the soil at depth.
- As the statistical evaluation of the upgradient data proceeded, the specific statistical tests employed were modified from the statistical tests that were listed in the approved-Work Plan (ENSR 2006). Section 5.1 of the Work Plan identified several statistical tests including the Gehan Modification of the Wilcox Rank Sum (WRS) Test, the Quantile Test, the Slippage Test and side-by-side plots as techniques that would be applied, as appropriate.

  The statistical analysis of the upgradient data was performed to determine the most appropriate way for the data, and the data subsets to be combined for future comparison with other on-site data. The statistical evaluation identified potential differences between data subsets by applying statistical tests to compare means, medians and standard deviations of the subsets.

The upgradient data were evaluated using the following statistical tests as specified in the work plan:

- the Gehan Modification of the WRS Test, and
- side-by-side box & whisker plots.

The Gehan modification to the WRS Test is a non-parametric test designed to compare the medians of two groups of data. The Gehan modification is most commonly used when some of the data are below detection limits and when the detection limits are not constant. When all values are above detection limits, or when the detection limits are constant, the WRS test, without the Gehan modification, is used.

The following additional statistical tests not specified in the work plan were also applied to the data:

- the t-test,
- the Shapiro-Wilk Test,
- the F-test,
- Analysis of Variance (ANOVA), and
- the Kruskal-Wallis Test.

The parametric t-test was used, as appropriate, to compare the means of two sets of data. The t-test is more powerful in detecting differences between two data sets than either of the non-parametric WRS Test or the Gehan modification to the WRS Test. The t-test assumes that the data follow a normal distribution or that the data can be transformed (such as by taking the logarithms of the data) to follow a normal distribution. Before the t-test is applied, the Shapiro-Wilk Test was used to evaluate whether the two datasets, or the logarithms of the two datasets, could be assumed to follow normal distributions. If the Shapiro-Wilk Test indicated that the data was either normal or lognormal, the t-test, rather than the WRS Test or the Gehan modification to the WRS Test, was used to compare the means of two datasets. The t-test also requires specifying if the standard deviations of the two datasets are the same or different. The F-test was applied to determine if the standard deviation could be considered to be the same.

The WRS Test, the Gehan modification to the WRS Test and the t-test compare two sets of data. When more than two sets of data were compared, such as when the concentrations of more than two soil borings were compared, the ANOVA and the Kruskal-Wallis tests were applied. ANOVA is a statistical test to compare the means of multiple datasets, and the Kruskal-Wallis Test is a non-parametric test to compare their medians.

The Slippage and Quantile tests were not performed as they are nonparametric tests that compare extreme values of data sets and were not required to meet the objectives of the statistical analysis of the upgradient data. However, these tests may be applied when the upgradient data are compared with subsequent data from future on-site investigations.

3.13 Data Evaluation

The data generated from the upgradient investigation were reviewed and evaluated to verify that the soil, groundwater, and QA/QC samples were collected in compliance with the specifications contained in the Work Plan (ENSR 2006). The laboratory-certified analytical data were reviewed through the data validation process to determine if analytical results were truly valid and reliable for use in decision-making applications such as statistical evaluations and risk assessments. The processes used to validate the data and statistically evaluate the data results are discussed in the following sections below.

3.13.1 Data Validation

The laboratory results for the upgradient investigation were subjected to formal data validation as described in the Upgradient Investigation Work Plan Addendum Section 5.1 (ENSR 2006) and following the guidance on data validation provided by NDEP for the BMI Plant Sites (NDEP 2006). A comprehensive ("full") data validation was performed on 9 of the 46 total laboratory Sample Delivery Groups (SDGs), and the remainder underwent a more limited validation as described below. The goal of 10% full validation that was established for the project was exceeded in order to cover the complete set of samples analyzed for the extended SRC list. This ensured that some data for every analytical method utilized during the upgradient investigation were subjected to full data validation. **Appendix E** contains the Data Validation Summary Report (DVSR).

Limited validation consisted of reviewing the following data elements to the level of summary data forms.

- Agreement of analyses conducted with COC requests
- Holding times and sample preservation
- Initial and continuing calibrations
- Laboratory blanks/equipment blanks/ field blanks
- Surrogate recoveries
- Laboratory control sample (LCS)/laboratory control sample duplicate (LCSD) results
- Matrix spike/matrix spike duplicate (MS/MSD) results
- Laboratory duplicate results
- Field duplicate results
- Quantitation limits and sample results

Full validation consisted of reviewing to the level of raw data all of the elements covered in the limited validation plus the following elements, where applicable, as defined by the analytical methods.

- Mass spectrometer tuning
- Gas chromatography/Mass Spectrometry (GC/MS) performance checks
- Interference check sample results
- Inductively coupled plasma (ICP) serial dilution results
- Internal standard performance
- Compound or element identification
- Peak integration and mass spectral matches
- Chemical Yield (Tracers and Carriers)
- Calculation and transcription verifications

Analytical data were evaluated with reference to the National Functional Guidelines (EPA 1999, 2004) and other method-appropriate validation guidance documents, as well as the Region 9 Superfund Data Evaluation/ Validation Guidance (EPA 2001), the above-mentioned NDEP Guidance on Data Validation (NDEP 2006), and the quality control (QC) criteria specified in the Quality Assurance Project Plan (QAPP; ENSR in press) and Work Plan (ENSR 2006). The Regional and National Functional Guidelines were modified to accommodate the non-Contract Laboratory Program methodologies. The specific guidelines used for the various methods are listed below:

- Inorganic analytical data were evaluated with reference to "USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review" (October 2004)
- Organic analytical data were evaluated with reference to the "USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review" (October 1999)
- Dioxin data were evaluated with reference to "USEPA Analytical Services Branch (ASB) National Functional Guidelines for Chlorinated Dibenzo-p-Dioxins (CDDs) and Chlorinated Dibenzofurans (CDFs) Data Review," EPA-540-R-05-001 (September 2005)

Radiochemical analytical data were evaluated with reference to the Department of Energy "Evaluation of Radiochemical Data Usability" (1997) and the "Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP)," (July 2004).

3.13.2 Statistical Evaluation

The analytical data were analyzed and evaluated to:

- Prepare statistical summaries of the analytical data.
- Evaluate whether the upgradient data for each chemical species should be subdivided into subsets for future comparisons with on-site data, or if the upgradient results can be used as a single data set for future comparisons. If there are differences in the upgradient results associated with factors such as geological formation or boring depth, and the differences are not taken into account when the upgradient data are compared with on-site data, incorrect conclusions may be reached from the comparisons. For example, suppose that arsenic concentrations in the Quaternary Alluvium soil typically exceed the arsenic concentrations in Muddy Creek Formation soil. If all of the upgradient arsenic soil data are indiscriminately combined without accounting for the difference by geological formation, the resulting average arsenic concentration will not be representative of either the Muddy Creek Formation or the Quaternary Alluvium.

  Comparisons were made according to depth and geological formation for metals and perchlorate in soil samples, and only according to depth for radionuclides in soil samples (the comparisons for radionuclides was limited because only a small number of radionuclide analyses were conducted below the Quaternary Alluvium).
- Compare concentrations measured during this study with the background concentrations previously measured by the COH and BRC/TIMET to determine if results from the studies are statistically similar enough to allow being combined for subsequent analyses.

Prior to conducting the statistical analyses, concentrations of metals and perchlorate below method detection limits were set to one-half the laboratory quantitation limit. Concentrations of radionuclides were used as reported. Additionally, results from duplicate samples were averaged, and the average concentrations were used in the subsequent analyses. Averaging the results from duplicate samples is a standard statistical procedure employed to avoid providing more weight to the duplicate samples from a single location than to single samples from other locations.

Statistical summaries for each chemical species include the number of samples, the number of results that exceeded the laboratory detection limit, the minimum and maximum laboratory quantitation limits for species that were below the detection limit, the average concentration, the standard deviation, the coefficient of variation, the minimum and maximum concentrations, the median, the 5th, 25th, 75th and 95th percentile concentrations, and the 95 percent upper confidence interval for the mean.

A box and whisker plot was also prepared for all results for each chemical to illustrate the distribution of all of the data. These plots are described in Section 4.5.

Various statistical tests were employed to evaluate the data, and to confirm that the data are meaningful and representative in describing the various sampled media.

Statistical tests were used because the samples that were collected only represent a portion of the entire surface and subsurface materials from which they were collected.

For example, statistical evaluation was employed to determine if there is a significant difference between the mean arsenic concentrations within the Quaternary Alluvium and the Muddy Creek Formation. Arsenic was measured in 34 soil samples collected from the Quaternary Alluvium and in 16 soil samples from the Muddy Creek Formation. Because there is natural variability in the arsenic concentration within these geological formations, there are differences among the arsenic concentrations measured in the soil samples from each formation. Because of this expected variability, and because the entire volume of formation material was neither sampled nor analyzed for arsenic, the average arsenic concentration in the samples from each formation is an approximation of the true mean concentration within the entire formation. Because the average concentrations are only approximations of the true means, differences between the average concentrations are expected to occur even if the mean arsenic concentrations are the same in both formations. Therefore, determining whether the mean concentrations are the same can not be accomplished by simple comparison. Instead, statistical tests can be applied to determine with reasonable confidence if the measured concentrations came from two separate formations, even if the mean arsenic concentrations are the same or similar.

Statistical testing determines whether the data are convincing beyond a reasonable doubt that a specified null hypothesis is false and should be rejected in favor of a specified alternative hypothesis that is true and should be accepted. For example, when comparing arsenic concentration in soil samples collected within the two geological formations, the null hypothesis could be that the mean arsenic concentrations in the two geological formations are the same, and the alternative hypothesis would be that the mean concentrations are not the same. An appropriate statistical test could be conducted to determine the probability that the null hypothesis is true. The statistical test provides what is called a p-value, which is the probability that we would be incorrect in rejecting the null hypothesis. For example, if the p-value were less than 0.05 (5%), we could conclude that the mean concentrations are not the same, at a 95 percent confidence level.

Statistical tests are grouped as either parametric or nonparametric. Parametric tests assume specific probability distributions for the investigated variable. For example, the two-sample t-test assumes that the mean concentrations of the investigated datasets are normally distributed. In contrast, nonparametric tests can be applied to any dataset regardless of the distributions.

Box and whisker plots of the data within each data subset were prepared to provide a graphical comparison between the subsets. These plots are described in Section 4.5.

Prior to conducting each statistical comparison between two subsets of data, the distributions of the concentrations were tested for normality using the Shapiro-Wilk test. If the p-value from the Shapiro-Wilk test was less than 0.05, it was concluded that the data do not follow a normal distribution, and if the p-value was 0.05 or larger, the data were assumed to have come from a normal distribution. When the p-value was less than 0.05, the Shapiro Wilk test was applied to the logarithms of the data to determine if the data came from a lognormal distribution. Again, if the p-value was 0.05 or larger, the data were assumed to be from a lognormal distribution. These tests were also applied to all of the data for each chemical to determine if the entire data set follows a normal distribution, a lognormal distribution, or neither.

Figure 3-1 is a flow chart illustrating the procedures for comparing two subsets of data. The statistical tests that were subsequently conducted to compare two subsets of data depended on whether the data subsets were both from normal distributions, both from lognormal distributions, or from two different distributions.

If both subsets of data were assumed to follow normal distributions, the parametric F-test was conducted to evaluate if the standard deviations are equal. If the result of the F-test indicated that the standard deviations are probably the same, the t-test was conducted assuming equal standard deviations to test the null hypothesis that the means of the two subsets are equal. If the result of the F-test indicated that the standard deviations are probably not the same, the t-test was conducted assuming unequal standard deviations. If the p-value from the t-test was less 0.05, it was concluded that there are statistically significant differences in the means of the two subsets and that the two subsets should not be combined for future evaluations. If both subsets of data were assumed to follow lognormal distributions, this procedure was used with the logarithms of the data. If the distributions of the two subsets of data were not the same (i.e., one normal and one lognormal or either one or both neither normal or lognormal), the nonparametric WRS Test or the Gehan modification to the WRS was conducted to test the null hypothesis that the medians of the two subsets are the same. The Gehan modification was used when the data included values less than detection limits and the detection limits were variable. Otherwise, the WRS test was used. If the p-value from the test was less than 0.05, it was concluded that there is a statistically significant difference in the medians of the two subsets, and that the two subsets should not be combined in subsequent evaluations.

Differences among borings were evaluated using a parametric ANOVA to test the null hypothesis that the mean concentrations from all of the borings are the same and using a non-parametric Kruskal-Wallis test to test the null hypothesis that the median concentrations from all of the borings are the same. When the p-value was less than 0.05, it was concluded that either the means or the medians are not all the same.

The statistical analyses were conducted using the STATGRAPHICS® Centurion XV software.

A discussion of the findings of the statistical evaluation is discussed in the following sections.

4.0 FINDINGS

The results of the upgradient investigation are discussed in this section.

4.1 Lithologic Interpretation

The stratigraphy beneath the southern portion of the Site is depicted in **Figures 4-1, 4-2, and 4-3**, which represent east-west and north-south geologic cross-sections. From the numerous soil borings and monitoring wells that have previously been drilled across the Site, the stratigraphic sequence of sediments underlying the Site consists predominantly of the following:

1. Quaternary Alluvium (Younger)
2. Muddy Creek Formation (Fm)
    a. Fine-Grained Facies # 1 (MCfg1)
    b. Coarse-Grained Facies # 1 (MCcg1)
    c. Fine-Grained Facies # 2 (MCfg2)
    d. Coarse-Grained Facies # 2 (MCcg2) (Older)

Quaternary Alluvium. Along the southern boundary of the Site, the Quaternary Alluvium consists of unconsolidated silty sands, gravelly sands, and clayey sands. In places, this unit contains interbeds of sandy gravel and gravel with cobbles. With increasing depth, weakly cemented (calichified) sediments become more common in the Quaternary Alluvium, with caliche nodules present at the base of the alluvium as shown in **Figure 4-1**. In total, the Quaternary Alluvium is approximately 45 to 52 ft thick along the southern boundary of the Site.

Muddy Creek Formation – Fine-Grained Facies #1 (MCfg1). The MCfg1 unit consists of silt and sandy silt that grades to sandy clay farther north. MCfg1 was not encountered in boreholes M-117, M-118, M-120, and M-121, but was encountered in boreholes M-116 and M-119 at depths of 29 to 32 ft, forming a layer approximately 12 to 14 ft thick (see **Figures 4-2** and **4-3**). The finer-grained lithologies of the Muddy Creek subunits normally contain varying amounts of sand-size caliche nodules which help in differentiating the Muddy Creek from the Alluvium. The MCfg1 pinches out in the southern part of the Site, and is not present beneath the southern boundary of the Site.

Muddy Creek Formation – Coarse-Grained Facies #1 (MCcg1). The MCcg1 unit consists of unconsolidated silty sands, silty clayey sands, and gravelly sands. Locally, MCcg1 contains silty gravel lenses and zones of caliche nodules (up to 1-inch diameter). MCcg1 gravels are predominately pea-gravel size and do not contain volcanic cobbles and boulders similar in size to those in the overlying Alluvium. MCcg1 was encountered at depths ranging from 40 to 62 ft, and at M-118, this unit is 74 ft thick. As shown in **Figures 4-1, 4-2, and 4-3**, the MCcg1 unit directly underlies the Quaternary Alluvium along the southern boundary of the Site.

Muddy Creek Formation – Fine-Grained Facies #2 (MCfg2). The MCfg2 unit consists predominantly of silt and sandy silt, with silty clay present locally. MCfg2 underlies MCcg1 and was encountered at depths ranging from 102 to 126 ft bgs. At well TR-9, this unit was 112 ft thick.

Muddy Creek Formation – Coarse-Grained Facies #2 (MCcg2). This unit consists of gravel and sandy gravel, and has been encountered only in the boreholes for the deepest wells (TR-9 and TR-7) at depths of 214 to 217 ft bgs.

4.2 Analytical Results

The following subsections discuss the results of the laboratory analyses that were performed on the soil and groundwater samples. Constituents that were detected in the soil and groundwater samples are summarized in a series of tables (**Tables 4-1 through 4-24**). A comprehensive list of targeted analytes for soil and groundwater samples is shown in **Table 3-1**. **Appendix G** contains the laboratory-certified analytical reports and COC documentation.

4.2.1 Metals

Soil samples from all six boring locations and groundwater samples from all 10 wells were analyzed for 30 different metals including hexavalent chromium. In addition, three soil samples from boring M-120 were analyzed for methyl mercury, silicon, strontium, and tin. The three samples from M-120 were collected from depths of 0.5, 10, and 20 ft, and correspond with samples M120-0.5, M120-10, and M120-20. The groundwater sample from well M-120 was similarly analyzed for additional parameters, including methyl mercury, silicon, strontium, and tin.

Of the metals measured in soil, only arsenic and magnesium had detections exceeding industrial Preliminary Remediation Goals (PRGs). Of the metals measured in groundwater, only arsenic and manganese exceeded either the industrial PRG or the EPA maximum contaminant level (MCL).

Analytical results for metals in soil and groundwater are summarized in **Table 4-1** and **Table 4-2**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.2 Perchlorate

Soil samples from all six boring locations and groundwater samples from all 10 wells were analyzed for perchlorate using EPA Method 314.0. In general, perchlorate was detected in soils to depths of up to roughly 20 ft and again at approximately 80 ft bgs – a depth corresponding closely to the water table. For groundwater samples, perchlorate concentrations ranged from non-detect in several wells to 2,000 micrograms per liter (µg/L) in well M-121.

Analytical results for perchlorate in soil and groundwater are summarized in **Table 4-3** and **Table 4-4,** respectively.

Perchlorate has been the focus of much attention and significant remedial action at the Site. In an effort to better understand the distribution and mechanisms of perchlorate migration in the vadose zone, the areal and vertical extent of perchlorate in the subsurface are depicted in **Figures 4-4, 4-5,** and **4-6**. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.3 Total Petroleum Hydrocarbons and Fuel Alcohols

Soil samples from all six boring locations and groundwater samples from all 10 wells were analyzed for TPH and fuel alcohols (methanol, ethanol, and ethylene glycol) using EPA Method 8015B. DRO ($C_{11} – C_{28}$) and oil range organics (ORO; $C_{28} – C_{38}$) were detected in the near surface (0.5-ft depth) soil sample from boring M-121 at 290 and 800 milligrams per kilogram (mg/kg), respectively. Otherwise, TPH was not detected at concentrations above the laboratory quantitation limit in the rest of the soil samples.

Except for well H-11, TPH was not detected in the groundwater samples at concentrations above the laboratory quantitation limit. In the groundwater sample from H-11, GRO and DRO were reported at concentrations of 0.083 milligrams per liter (mg/L) and 0.18 mg/L, respectively.

Methanol was detected in soil samples from several borings. As discussed in Section 3.12, the presence of the methanol in the soil samples combined with the absence of GRO/DRO in the soil samples suggested that the methanol was the product of cross-contamination from the methanol preservative that was used in the field to preserve the soil samples. When the near surface soil (0.5 ft deep) was resampled on March 24, 2006, and analyzed for methanol, no detectable concentrations of methanol were reported in the samples. This confirmed that the methanol that was reported in the initial near-surface soil samples was the product of cross-contamination. As a result, the methanol data for the initial 0.5-ft samples were rejected and assigned an "R" qualifier as shown on **Table 4-5**. The analytical results for those samples that were re-sampled (designated with an "R" in the sample name – e.g., M120-0.5R) are shown on **Table 4-5**. The methanol results for the deeper soil samples (for which confirmation samples could not be collected) were qualified with a "Z" to indicate that the analytical result is likely the product of cross-contamination. No fuel alcohols were detected in the water samples at concentrations above the laboratory quantitation limit.

Analytical results for TPH and fuel alcohols in soil and groundwater are summarized in **Table 4-5** and **Table 4-6**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.4 Volatile Organic Compounds

Soil samples from all six boring locations and groundwater samples from all 10 wells were analyzed for 68 different VOCs using EPA Method 8260B. Only four VOCs were detected in soil samples: 2-butanone, acetone, methylene chloride, and trichlorofluoromethane, none of which exceeded the industrial PRGs for soil. Four VOCs were detected in the groundwater samples: acetone, chloroform, toluene, and trichloroethylene (TCE), none of which exceeded their respective industrial PRGs or the EPA MCLs.

Analytical results for VOCs in soil and groundwater are summarized on **Table 4-7** and **Table 4-8**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.5 Semi-Volatile Organic Compounds

Three soil samples, all from boring M-120, and the groundwater sample from well M-120 were tested for 67 different SVOCs using EPA Methods 8270C/8270C selected ion monitoring (SIM). No SVOCs were detected in the soil or groundwater samples at concentrations above the laboratory's quantitation limit. The three samples from M-120 were collected from depths of 0.5, 10, and 20 ft, and correspond with samples M120-0.5, M120-10, and M120-20. Soil samples from the other soil borings and groundwater samples from the nine other wells were not analyzed for SVOCs as per the NDEP-approved Upgradient Investigation Work Plan (ENSR 2006).

Analytical results for SVOCs in soil and groundwater are summarized on **Table 4-9** and **Table 4-10**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.6 Radionuclides

Soil samples from all six boring locations and groundwater samples from all 10 monitoring wells were tested for 16 different radionuclides, of which 13 radionuclides were detected in both soil and groundwater samples. The radionuclides that were detected in soil samples include the following:

- Actinium-228
- Bismuth-212
- Gross Alpha
- Lead -212
- Radium-226
- Radium-228
- Polonium-210
- Thorium-228
- Thorium-230
- Thorium-232
- Uranium-234
- Uranium-238
- Uranium (natural)

None of the radionuclide detections in soil in samples collected exceeded the industrial PRGs.

For any one sample, all of the radionuclide results from the HASL-300 analyses are internally consistent. Therefore, the results demonstrate that the soil samples exhibit secular equilibrium throughout both the natural uranium series and natural thorium series radionuclides. That is, within the laboratory's analytical uncertainty:

- The Ra-226 = Th-230 = U-234 = U-238 for each sample, and
- The Ac-228/Ra-228 = Bi-212 = Pb-212 = Th-228 = Th-232 for each sample. (By recognized protocol, GEL sets Ac-228 = Ra-228)

The radionuclides that were detected in groundwater samples include the following:

Gross Alpha
Radium-228
Uranium (total)
Uranium (natural)
Lead 210
Thorium-228
Uranium-234
Radon-222
Thorium-230
Uranium-235
Radium-226
Thorium-232
Uranium-238

Of the radionuclide detections in groundwater, only Radium-226 and -228, natural Uranium, and Uranium-234, -235 and -238 exceeded industrial PRGs. Because of very large differences in aqueous solubility of the various radionuclides, secular equilibrium throughout the natural uranium series or natural thorium series does not occur in groundwater.

Analytical results for radionuclides in soil and groundwater are summarized on **Table 4-11** and **Table 4-12**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.7 Organochlorine Pesticides

Three soil samples, all from boring M-120 and the groundwater sample from well M-120, were tested for 22 different organochlorine pesticides (OCPs) using EPA Method 8081A. No OCPs were detected in the soil or groundwater samples at concentrations above the laboratory's quantitation limit. The three samples from M-120 were collected from depths of 0.5, 10, and 20 ft, and correspond with samples M120-0.5, M120-10, and M120-20. Soil samples from the other soil borings and groundwater samples from the nine other wells were not analyzed for OCPs as per the NDEP-approved Upgradient Investigation Work Plan (ENSR 2006).

Analytical results for OCPs in soil and groundwater are summarized on **Table 4-13** and **Table 4-14**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.8 Organophosphorous Pesticides

Three soil samples, all from boring M-120, and the groundwater sample from well M-120 were tested for 28 different organophosphorous pesticides (OPPs) using EPA Method 8141. No OPPs were detected in the soil or groundwater samples at concentrations above the laboratory's quantitation limit. The three samples from M-120 were collected from depths of 0.5, 10, and 20 ft, and correspond with samples M120-0.5, M120-10, and M120-20. Soil samples from the other soil borings and groundwater samples from the nine other wells were not analyzed for OPPs as per the NDEP-approved Upgradient Investigation Work Plan (ENSR 2006).

Analytical results for OPPs in soil and groundwater are summarized on **Table 4-15** and **Table 4-16**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.9 Polychlorinated Biphenyl Compounds

Three soil samples, all from boring M-120, and the groundwater sample from well M-120 were tested for seven different polychlorinated biphenyl (PCB) compounds using EPA Method 8082. No PCB compounds were detected in the soil or groundwater samples at concentrations above the laboratory's quantitation limit. The three samples from M-120 were collected from depths of 0.5, 10, and 20 ft, and correspond with samples M120-0.5, M120-10, and M120-20. Soil samples from the other soil borings and groundwater samples from the nine other wells were not analyzed for PCBs as per the NDEP-approved Upgradient Investigation Work Plan (ENSR 2006).

Analytical results for PCBs in soil and groundwater are summarized on **Table 4-17** and **Table 4-18**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.10 Dioxins and Dibenzofurans

Three soil samples, all from boring M-120, and the groundwater sample from well M-120 were tested for 17 different dioxin/furan cogeners using EPA Method 8290. The three samples from M-120 were collected from depths of 0.5, 10, and 20 ft bgs, and correspond with samples M120-0.5, M120-10, and M120-20. Analyses for dioxin/furans were limited to soil and water collected from M-120 in compliance with the NDEP-approved Upgradient Investigation Work Plan (ENSR 2006).

Of the Dioxin/Furan results in soil, the only detections to exceed the industrial PRGs were collected from the shallowest 0.5-ft depth. Detections in groundwater exceeded the industrial PRGs.

Analytical results for Dioxins and Furans in soil and groundwater are summarized on **Table 4-19** and **Table 4-20**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.11 General Chemistry Parameters

General chemistry parameters were measured in soil and groundwater samples from all six boring locations. Analytical results for the general chemistry parameters in soil and groundwater **Table 4-21** and **Table 4-22**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.2.12 Other Parameters

Three soil samples from boring M-120 and the groundwater sample from well M-120 were analyzed for other constituents or parameters including chlorate, cyanide (total), surfactants (methylene blue active substances [MBAS]), ignitability (flashpoint), and asbestos. Soil samples collected from depths of 0.5, 10, and 30 ft were tested for these constituents/ parameters. The results of these analyses in soil and groundwater are summarized in **Table 4-23** and **Table 4-24**, respectively. Copies of the laboratory reports listing the results of the analysis are provided in **Appendix G.**

4.3 Evaluation of Groundwater Sampling Methods: Historical Sampling Methods vs. Low-Flow Sampling Methods

The evaluation of historical sampling methods vs. low-flow sampling methods was done to evaluate which method yielded the most representative samples from the site. As part of the upgradient investigation, groundwater samples were collected on March 13, 14, and 20, 2006, from a subset of five wells (TR-7, TR-8, TR-9, TR-10, and M-103) using groundwater sampling methods that have been used during previous groundwater sampling events at the Tronox facility. Specifically, the wells were not purged prior to sample collection, and the sample bottles were filled using a PVC bailer that was lowered to within the screened interval of each well. Following collection of the bailer samples, dedicated micro-purge bladder pump systems (pump and tubing) were installed in the same five monitoring wells (TR-7, TR-8, TR-9, TR-10, and M-103), and the wells were redundantly sampled using micro-purge techniques. The micro-purge groundwater samples were collected March 20 through 23, 2006.

For many of the parameters, there were insufficient data to measure the precision or relative percent difference (RPD). However, some observations can be drawn from the comparison, as follows:

- Perchlorate, hexavalent chromium, boron, molybdenum, potassium, sodium, five radionuclides, and eight wet chemistry parameters demonstrated acceptable precision through meeting an RPD of 30% or lower. Based on the data, it appears that the bailer vs. micro-purge sampling method does not affect the analytical results for these parameters.

- Aluminum, arsenic, barium, calcium, total chromium, copper, iron, lead, magnesium, manganese, titanium, uranium, vanadium, zinc, five radionuclides, and one wet chemistry parameter did not meet the acceptable precision objective of RPD 30% or lower. Based on the data, it appears that the bailer vs. micro-purge sampling method affects the analytical results for these parameters.

In general, the less soluble constituents appear to be affected more than the highly soluble constituents.

Appendix I contains additional details regarding the comparison of bailer vs. micro-purge sampling methods and a discussion of the evaluation follows.

Precision of the bailer method vs. the micro-purge method was measured through the calculation of RPD. Precision is a measure of the degree to which two or more measurements are in agreement. The objectives for precision RPDs for this study are 30% or less for aqueous samples. An RPD greater than 30% represents a statistically significant difference in duplicate water samples. Below is a comparison of the analytical laboratory results and RPDs between the groundwater samples collected with the bailer vs. the micro-purge methods. A summary of the data is presented in **Appendix I (Table I-1 and Table I-2)**.

- Five groundwater wells were included in the comparison study. In addition, a duplicate sample (TR-8D) was also used for comparison purposes within a single well. Perchlorate was detected in four of the wells where RPD could be calculated. These samples met the precision objective of 30% RPD or lower.
- RPD was calculated for hexavalent chromium for four of the data sets. These data met the precision objective of 30% RPD or lower.
- TPH was not detected above the laboratory quantitation limits for groundwater samples collected; therefore, RPD can not be calculated and a comparison of the two sampling techniques is inconclusive.
- Fuel alcohols (methanol, ethanol, and ethylene glycol) were not detected above the laboratory quantitation limits for the groundwater samples; therefore, RPD can not be calculated and a comparison of the two sampling techniques is inconclusive.
- VOCs were not detected in the groundwater samples during this sampling event; therefore, RPD can not be calculated and a comparison of the two sampling techniques is inconclusive.
- Of the metals analyzed, 19 were detected in two or more samples where RPD could be calculated. Of the 19 metals where RPD was calculated, 14 exhibited an RPD greater than 30%. These data are presented in **Appendix I (Table I-2).**
- Of the radionuclides analyzed, 10 were detected in two or more samples where RPD could be calculated. Of the 10 radionuclides where RPD was calculated, five met the RPD precision objective of 30% and five exhibited an RPD greater than 30%.
- Of the chemistry parameters analyzed, nine were detected in two or more samples where RPD could be calculated. Of the nine wet chemistry parameters where RPD was calculated, eight met the precision objective of 30% RPD or lower and one exhibited an RPD greater than 30%.

In Well Cluster 1 (TR-7 and TR-8), higher analytical values were generally observed in the wells sampled using the micro-purge method. The opposite was observed in the analytical values for wells in Well Cluster 2 (TR-9A and TR-10A) and M-103A, with higher analytical values detected in the wells sampled using the bailer method. The greatest difference between the two methods was observed in M-103A and M-103.

4.4 Data Validation Results Summary

Details regarding the data validation, including the data validation summary report (DVSR), data validation memoranda, and the summary tables, are included in **Appendix E**.

4.5 Statistical Evaluation Results Summary

The results of the statistical evaluation of the constituents in soil samples are discussed below. Detailed results of the statistical tests are in **Appendix F**. Soil and groundwater samples from M-120 were analyzed for expanded suites of compounds (SVOCs, OCPs, OPPs, PCBs, and dioxin/furans) from other locations in order to examine potential issues involving detection limits or matrix effects that could impact subsequent sampling events. The results of the evaluation showed that soil and water matrix interferences did not result in the rejection of laboratory data or significant elevation of reporting limits for nondetects. This issue is discussed in further detail in the DVSR in **Appendix E**.

4.5.1 Metals and Perchlorate in Soil Samples

Summary statistics for the concentrations of metals and perchlorate measured in soil samples from the Tronox data are contained in **Table 4-25**. All of the metals, except methyl mercury, silica, antimony, and perchlorate, were measured in 50 samples. Only three samples were analyzed for methyl mercury and silica, antimony was measured in 45 samples, and perchlorate was measured in 49 samples. Most metals were above the detection limit in all samples. The exceptions were methyl mercury (detected in 1 of 3), antimony (9 of 45), boron (33 of 50), molybdenum (39 of 50), platinum (3 of 50), selenium (36 of 50), silver (4 of 50), thallium (22 of 50), tungsten (8 of 50), and perchlorate (21 of 49). **Table 4-25** also indicates whether the data are assumed to follow a normal distribution, a lognormal distribution, or neither. Seven of the metals are assumed to follow a normal distribution (barium, cadmium, iron, potassium, sodium, titanium, and vanadium); eight follow a lognormal distribution (aluminum, beryllium, calcium, manganese, molybdenum, nickel, strontium, and zinc), and the remaining 14 metals (antimony, arsenic, boron, chromium, cobalt, copper, lead, magnesium, platinum, selenium, silver, thallium, tungsten, and uranium) and perchlorate do not follow either distribution.

– Box and Whisker Plots

Box and whisker plots of the data for each metal and for perchlorate in the soil samples are presented in **Figure 4-7**. Box and whisker plots provide a method for comparing data groupings or data sets side-by-side. Box and whisker plots simultaneously display the full range of data, as well as key summary statistics, such as the mean, median (half the values are above and half are below the median), 25th and 75th percentiles (25% of the values are below the 25th percentile and 25% are above the 75th percentile), minimum and maximum values, and outliers. A box and whisker plot is a box (a rectangle) with lines. The length of the box is the interquartile range (IQR); therefore, the box represents the middle 50% of the data. The top and bottom of the box are the 25th and 75th percentiles of the data. The width of the box is arbitrary. The horizontal line in the box depicts the median value of the data, and the "+" in the box represents the mean. Open points above or below the box are individual values that are more than 1.5 times but less than 3 times the IQR range above or below the box. The whiskers extend to the largest and smallest values that are not more then 1.5 times the IQR range above or below the box. Points with "+" signs inside them are individual values that are more than 3 times the interquartile range above or below the box. These plots show the symmetry of the data set, the range of data, and a measure of the central tendency (median).

Box and whisker plots for metals and perchlorate grouped by boring are presented in **Figure 4-8**. The results of the ANOVA tests to compare the mean concentrations and the Kruskal-Wallis tests to compare the medians indicated that there are statistically significant differences by boring for antimony, cadmium, molybdenum, sodium, and tungsten.

Box and whisker plots grouped by sample depth are presented in **Figure 4-9**. As seen in the figure, there is a difference in concentrations for many of the metals between the samples collected at depths of 20 ft or less and the samples collected at depths of 30 ft or more. Box and whisker plots grouped by these two depth ranges are presented in **Figure 4-10**. Based on the apparent differences in concentrations between these two depths, statistical tests were conducted to compare subsets of the data in these two depth ranges.

Box and whisker plots grouped by geological formation are presented in **Figure 4-11**. Because only three samples were collected from the Muddy Creek fine-grained facies, data from these three samples were grouped with the data from the samples collected in the Muddy Creek coarse-grained facies for the evaluations. Statistical tests were conducted to compare the concentrations in Quaternary Alluvium with the concentrations in the Muddy Creek Formation.

The results from the statistical comparisons by depth range and by geological formation are summarized in **Table 4-26**. The table summarizes which of the identified differences are statistically significant at the 95 percent confidence level. Differences were not statistically significant for either depth or geological formation for 15 of the 30 metals: antimony, beryllium, cadmium, copper, iron, lead, molybdenum, nickel, platinum, silver, sodium, thallium, titanium, tungsten and zinc. All of the upgradient data for these metals can be combined to represent the upgradient data for future comparisons.

Differences were statistically significant by depth range but not by geological formation for two chemicals: tungsten, vanadium, and perchlorate. As a result, vanadium and perchlorate data from samples collected at depths of 20 ft or less should not be combined with data from samples collected at 30 ft or more for future investigations on the site.

Differences were statistically significant by geological formation but not by depth range for strontium, and data for strontium from samples collected from alluvium and from the Muddy Creek Formation should not be combined for future investigations.

Differences were statistically significant by both depth range and geological formation for 12 of the 30 metals: aluminum, arsenic, barium, boron, calcium, chromium, cobalt, magnesium, manganese, potassium, selenium, and uranium. The data for these metals should be separated by either depth range or by geological formation for future investigations.

Subsets of the data recommended for use in future comparisons with on-site data were determined as follows:

- If differences were not statistically significant by depth range or by geological formation, all data are combined.
- If differences were statistically significant by depth range but not by geological formation, two subsets were defined as data from samples collected at depths of 20 ft or less and from samples collected at depths of 30 ft or more.
- If differences were statistically significant by geological formation but not by depth range, two subsets were defined as data from samples collected in alluvium and from samples collected in the Muddy Creek Formation.
- If differences were statistically significant by both depth range and geological formation, preference was given to the categorization (i.e., by depth range or by geological formation) that resulted in subsets of the data that followed either normal or lognormal distributions. This selection was made to provide subsets of the data that could be used in parametric statistical tests for future comparisons. If

both categorizations led to subsets that followed normal or lognormal distributions, the data were categorized by geological formation. Similarly, if neither categorization led to subsets that followed normal or lognormal distributions, the data were also categorized by geological formation.

The resulting subsets recommended for future comparisons with on-site data are summarized in **Table 4-27**. The table indicates the definitions of the subsets for each chemical and the probability distribution followed by the data in each subset. Summary statistics for the subsets for each chemical are in **Table 4-28**.

– Upgradient Data vs. Background Data

Box plots of the concentrations of metals and perchlorate in soil samples grouped by dataset (i.e., Tronox, COH, and BRC/TIMET) are in **Figure 4-12.** The results of statistical comparisons of the data from samples collected at depths of 20 ft or less from the Tronox upgradient data with the COH and BRC/TIMET data are summarized in **Table 4-29**.

Differences between the Tronox and COH data are statistically significant for all but five (arsenic, iron, selenium, thallium and zinc) of the 21 analytes that were measured in both studies. The data for arsenic, iron and thallium from the two data sets could probably be combined for future evaluations because they follow the same distribution in both data sets and differences between the standard deviations are not statistically significant. However, zinc follows a lognormal distribution in the Tronox data set, but it does not follow either a normal or lognormal distribution in the COH dataset. Therefore, the zinc data from the two datasets should not be combined. The data for the 18 other analytes from the two studies should not be combined for future evaluations.

Differences between the means or medians of Tronox and BRC/TIMET data are not statistically significant for 11 of the 27 chemicals that were measured in both studies. The data for lead from the two data sets could probably be combined for future evaluations because the data in neither dataset follows a normal or lognormal distribution. The calcium data could probably be combined because they follow a lognormal distribution in both datasets and the differences in the standard deviations are not statistically significant. The data for the 25 other chemicals from the two studies should not be combined for future evaluations.

4.5.2 Radionuclides in Soil

As discussed previously, radionuclides were measured in the 0.5-ft (6 inches) and 5-ft bgs samples from all six borings. Because samples from lower depths were analyzed for only three borings (the 50-ft sample from M-119; the 10-, 30- and 50-ft samples from M-120; and the 80-ft sample from M-121), the statistical evaluations of the radionuclide data for soil samples only included the 0.5- and 5-ft sample results. Because data are only available for two samples from each boring, concentrations were not compared by boring. Additionally, because the 0.5- and 5-ft samples from all six borings were in the Quaternary Alluvium, comparisons could not be made by geological formation.

Summary statistics for the concentrations of radionuclides measured in soil samples from the Tronox data are contained in **Table 4-30**. All of the radionuclides were measured in all 12 samples. All of the radionuclides, except uranium 235, were above the detection limit in all samples. Uranium 235 was only detected in three samples. The data for six of the radionuclides (lead 212, thorium 228, thorium 230, thorium 232, uranium 234 and uranium 235) follow a normal distribution, and the data for one of the radionuclides (uranium 238) follows a lognormal distribution. The data for the other three radionuclides (uranium total, radium 226, and radium 238) do not follow either a normal or a lognormal distribution. Box and whisker plots for the individual radionuclides are presented in **Figure 4-13**.

Box and whisker plots for the activities by sample depth are presented in **Figure 4-14**, and the results of the statistical comparisons by sample depth are summarized in **Table 4-31**. The differences by sample depth were statistically significant for 2 of the 10 radionuclides (thorium 228 and uranium 234), and the 0.5- and 5-ft data for these radionuclides should not be combined for comparisons with on-site data.

– Upgradient Data vs. Background Data

Box and whisker plots for the activities by dataset are presented in **Figure 4-15**, and the results of the statistical comparisons by dataset are summarized in **Table 4-32**. Differences were not statistically significant for four of the nine radionuclides measured in the Tronox and COH datasets (thorium 228, thorium 230, thorium 232, and uranium 235). The data for thorium 228, thorium 230, and thorium 232 from the two datasets can probably by combined for future evaluations because the data from both datasets follow the same distribution and differences between the standard deviations are not statistically significant. However, uranium 235 data are consistent with a lognormal distribution in the Tronox data set and with a normal distribution in the COH data set. Therefore, the uranium 235 data from the two data sets should not be combined.

Differences in the mean or median activities were not statistically significant for all of the eight radionuclides measured in both datasets. However, only the data for thorium 230 and uranium 238 followed the same distribution in both data sets and did not have statistically significant differences in the standard deviations. Therefore, only the data for thorium 230 and uranium 238 could probably be combined for future evaluations

4.6 Field Quality Control Sample Results Summary

Field QC samples consisting of equipment blanks, a field blank, trip blanks, and MS/MSD samples were collected for the upgradient investigation. The laboratory results from these samples are discussed in the following subsections.

4.6.1 Field Duplicates

During the soil sampling activities, six duplicate soil samples were collected as specified in the Upgradient Investigation Work Plan Addendum Table 2 (ENSR 2006) and tested for the same suite of analytes as the parent samples. These soil field duplicates represent 11% of the soil samples collected for analyses that meet the work plan goal of one field duplicate for every 10 samples. During the groundwater sampling, one duplicate sample was collected from well TR-8 as specified in the work plan and tested for the same suite of analytes as the parent sample. This groundwater sample field duplicate represents 10% of the well locations samples, and this meets the work plan goal one field duplicate for every 10 samples. Evaluation of the field duplicate results is discussed in Sections 3.9 and 4.1 of the DVSR in **Appendix E** and displayed in Table E-13. In general, the field duplicate precision met the established acceptance RPD limits of 30% for aqueous samples and 50% for solid samples. A limited number of metals results, representing only 1.3% of the total data points, exceeded the acceptance limits and were qualified as estimated but usable. No data were rejected based on field duplicate precision problems.

4.6.2 Equipment Blank Samples

Three equipment blank samples (EB-1, EB-2, and EB-3) were collected for the upgradient investigation. Samples EB-1 and EB-2 were samples of rinse water (distilled water) collected from soil sampling equipment after the equipment had been decontaminated. Sample EB-3 was rinse water from the PVC bailer that was used to collect the groundwater samples that were part of the historical groundwater sampling (i.e., no purge/bailer groundwater grab sample) vs. low-flow purge/sample study. EB-3 was collected after the bailer had been cleaned by washing with phosphate-free detergent and rinsing with distilled water.

Samples EB-1 and EB-2 were tested for VOCs, TPH, fuel alcohols, metals, perchlorate, and radionuclides. Sample EB-3 was tested for metals, TPH, fuel alcohols, perchlorate, radionuclides, SVOCs, PCBs, OCPs, and general chemistry parameters.

Several constituents were detected in the equipment blank samples for soil samples and for those groundwater samples that were collected with a bailer (i.e., samples H-11, TR-7A, TR-8A, TR-9A, TR-10A, and M-103A). The equipment blank sample EB-3 is not applicable to the remaining groundwater samples

(TR-7, TR-8, TR-9, TR-10, M-103, M-117, M-118, M-120, and M-121) because these samples were collected using dedicated bladder pumps.

Evaluation of the equipment blank contaminants and their concentrations in relation to the associated field samples is discussed in Sections 3.4 and 4.2 of the DVSR and displayed in Table E-8 (**Appendix E**). Results for radium-226 in two groundwater samples and acetone in 16 soil samples were negated (qualified "U" for nondetected) based on the associated equipment blank results. Results for zinc in one soil sample and barium and cobalt in two groundwater samples were qualified as estimated and possible biased high due to contamination in the associated equipment blanks. These qualified data points represent less than 0.5% of the total data points collected. No data were rejected during validation based on equipment blank results.

4.6.3 Field Blank Samples

One field blank sample (FB-1) was collected from the decontamination water used to clean the soil sampling equipment. The source of this water was a fire hydrant on Site. FB-1 was analyzed for metals, perchlorate, and radionuclides. The results confirm that the decontamination water source did not adversely affect the data. As the source of this field blank was not the rinsate source water used to prepare the equipment blanks, the results of this field blank analysis were used for informational purposes only and were not used to qualify sample results during validation.

4.6.4 Trip Blank Samples

Trip blank samples were placed in an ice chest whenever at least two samples for VOC and/or TPH analyses were placed in the same ice chest bound for the laboratory. Trip blank samples were tested for either VOCs and/or gasoline-range organics. Trip blank results were evaluated during data validation, and no sample results were qualified or rejected based on the trip blank data. No target analytes were detected in any of the trip blanks.

4.6.5 Matrix Spike and Matrix Spike Duplicate Samples

Additional sample volume was collected at three soil boring locations and one well, and designated on the COC forms for MS/MSD analyses for the same suite of analytes as the parent samples. These six matrix spikes for soil and two matrix spikes for groundwater represent 12% and 18% of the soil and groundwater samples, respectively, collected for this project (excluding QC samples and samples collected for field sampling method comparison purposes). The frequencies of matrix spike collection for both soil and groundwater met the work plan goal of analyzing matrix spikes at a frequency of 10%.

Data from the matrix spike analyses were evaluated during data validation with respect to the associated samples. In general, the accuracy and precision acceptance criteria were met, with less than 3% of the total data points qualified as estimated and usable on the basis of accuracy and less than 1% qualified as estimated and usable on the basis of precision. Six results for antimony (representing 0.09% of the total data points) were rejected due to extremely low recoveries. The specific analytes and samples that were rejected or qualified as estimated on the basis of recoveries and/or duplicate precision are discussed in Sections 3.6, 4.1, and 4.2 of the DVSR and displayed in Table E-10 and E-12 (**Appendix E**).

5.0 CONCLUSIONS

The upgradient investigation was conducted to characterize concentrations of specific constituents in the soil and groundwater in the upgradient (southern) portion of the Site, and to further develop the conceptual site model. As appropriate, these data and information may be used in future evaluations at the Site. The Executive Summary and Conclusions (Section 5) sections of this report have been revised in response to the March 23, 2006 NDEP letter containing comments on the October 2006 version of this report. In addition, Appendix J - Additional Statistical Information and Interpretation, has been prepared and inserted.

Geologic Findings: The planned six borings achieved their target depths and the planned soil and groundwater samples were obtained as described in the Work Plan Addendum (ENSR 2006). The sonic drilling technique was effective in drilling through both the alluvium and Muddy Creek Formations, and the resulting continuous core allowed the necessary direct observation to adequately describe subsurface lithologies and differentiate between the alluvium and the Muddy Creek Formation subunits. Further, the lithologic data improved the understanding of the location and nature of the MCfg1 pinchout beneath the overlying alluvium. In particular, the lithologic data confirm that along the Site's southern boundary, the MCfg1 unit is absent, and that in this same area the alluvium directly overlies the MCcg1 unit.

Data Validation: Soil and groundwater data were analyzed for the parameters specified in the Work Plan Addendum (ENSR 2006). The resulting laboratory data were reviewed and validated using standardized guidelines and procedures recommended by EPA and NDEP. Based on this validation, 90% of the analytical results for this project were accepted as reported by the laboratory and should be considered valid for all decision making purposes. 8.9% of the results were qualified as estimated due to minor QC problems with precision and accuracy. These estimated results should be considered usable with the appropriate interpretation (e.g., consideration of the potential bias). 1.1% of the results were rejected as unusable due to more serious QC problems with spike recoveries and calibrations. The impact of the rejected results on the overall project goals was minimal. Of the rejected data points, only 11 results involved designated Site Related Chemicals, 5 results for methanol in soil and 6 results for antimony in soil. The methanol data were replaced by acceptable results from resampling and reanalysis. The rejected results for antimony were all from a single boring that also had usable data for antimony at other depths indicating the concentrations were orders of magnitude below the industrial PRG value. All qualified results were evaluated with respect to the data quality indicators and compared to the QAPP and Work Plan goals. Based on the results of data validation the overall goals for data quality were achieved for this project.

Data comparability for the Upgradient Investigation was deemed adequate by Tronox because no historical data had been acquired by Tronox for most of the analytes and only approved EPA methods were used for sample analysis of the new analytes. Methods used to determine analytes previously characterized as a part of the routine monitoring program were either identical or judged to be highly comparable based on a comparison of the CWA and equivalent RCRA method details. Comparability with the BRC/TIMET and COH background datasets was verified by comparing the method lists in the BRC/TIMET database and the COH data risk assessment by Environ. The cited methods were identical or essentially equivalent to those used in the Tronox Upgradient investigation. Representativeness was ensured by proper study design, proper location and number of samples collected, correct field techniques and a combination of field and lab QC measurements to verify adequate precision was achieved for both sampling and analysis.

Statistical Evaluation of Soil Data: The validated data from the upgradient soil samples were statistically evaluated to characterize the data and their respective subpopulations, to compare the data to the NDEP-approved background dataset, and to consider appropriate uses and limitations on future use of the data. The following conclusions are based on the statistical evaluation of the soil data.

- A few of the metals were detected in only a small portion of the samples (e.g., selenium, boron, platinum, silver, etc). Because of the low frequency of detection, formal statistical calculations are strongly biased by the detection limits, and so are not appropriate. Therefore, the statistical use of these data is limited, although they may be used qualitatively.
- A statistically significant difference in concentrations of many metals was observed in samples from 0 to 20 ft deep compared to samples from greater than 20 ft. The concentrations of some metals are higher in the deeper soils, some lower. These differences are most likely associated with changes in geology (geologic unit, percent fines). The shallow samples (0-20 ft) represent the alluvium; the deeper samples (>20ft), the Muddy Creek formation.

Statistical Comparison with Off-Site Data Sets: The shallow Tronox upgradient soil data were compared to the COH and BRC/TIMET background data for metals, perchlorate, and radionuclides. As noted above, shallow soils (up to 20 ft) and deeper soils (>20 ft) have different geology and therefore different chemistry. The COH and BRC background samples were collected at depths up to 10 ft. Therefore, the comparisons were performed between the COH, BRC, and Tronox shallow samples only. Because there is no independent background dataset for the deeper Muddy Creek unit, no comparisons were performed using the deep upgradient samples.

The following conclusions are based on the comparisons performed:

- The formal statistical comparisons indicated statistically significant differences between the means/medians of the shallow Tronox upgradient data compared with the BRC and/or COH data. In most of these cases, the differences were due to the Tronox mean/median being less than COH and/or BRC. Where the Tronox mean/median was greater than COH, the concentrations were typically consistent with (not greater than) BRC concentrations.
- Comparisons for some of the constituents were not feasible due to the low FODs and variable detection limits. For these (silver, selenium, platinum, uranium-235, etc.), no conclusions can be developed comparing the datasets.
- For most of the constituents, the concentrations in the Tronox shallow, upgradient samples appear representative of background conditions. These constituents include aluminum, arsenic, chromium, cobalt, calcium, magnesium, manganese, nickel, strontium, uranium, vanadium, zinc, radium (226 and 228), thorium (228, 230, and 232), and uranium (234 and 238), etc.
- For a small number of constituents, the concentrations in the Tronox shallow, upgradient soils appear to be elevated with respect to the NDEP-approved background data set. Perchlorate, boron, and possibly sodium and potassium may be elevated due to Tronox operations. However, cadmium and copper are also elevated. As these are not associated with use and handling at the Tronox facility, the concentration, although elevated, are more likely to represent background conditions.
- For the deep (>20ft) Tronox upgradient samples, it seems likely that the concentrations for most of the constituents are representative of background, although this cannot be demonstrated quantitatively in the absence of an independent background dataset for the Muddy Creek formation. However, because of impacts to groundwater, the sodium, perchlorate, and chromium concentrations in deeper soils cannot be considered representative of background.

Upgradient Groundwater: Because of the absence of an independent, background dataset for groundwater, no formal comparisons were performed. However, it appears that many of the Tronox upgradient groundwater data reflect possible impacts, particularly with perchlorate and hexavalent chromium. Therefore, the Tronox upgradient groundwater data for these constituents are not representative of background conditions.

In addition, the Tronox upgradient wells are all screened in the Muddy Creek formation. Elsewhere on the Tronox facility the shallow groundwater (that is, groundwater at and near the water table) is present in the alluvium. As a result, even un-impacted upgradient wells might not be an appropriate background reference for groundwater in the alluvium.

Groundwater Sampling Comparison: Groundwater sampling methods were compared, including bailer and micro-purge methods for five sampled wells. The groundwater was redundantly sampled at each of the 6 wells using both methods, and then both sets of samples were analyzed for perchlorate, metals, VOCs including fuel oxygenates, TPH, pH, EC, alkalinity, carbonate, bicarbonate, water chemistry ions, and radionuclides. An RPD of 30% was identified as the objective for the precision between the two groundwater samples. For most of the parameters, there were insufficient data to measure RPD.

In general, the less soluble constituents appear to be affected more than the highly soluble constituents. This relationship is expected if the measured concentrations using different sampling techniques are a function of analyte solubility. The following conclusions were drawn regarding the two compared sampling methods:

- Based on the data, it appears that the bailer vs. micro-purge sampling method **does not** affect the analytical results for perchlorate, hexavalent chromium, boron, molybdenum, potassium, sodium, five radionuclides, and eight wet chemistry parameters.
- Based on the data, it appears that the bailer vs. micro-purge sampling method does affect the analytical results for aluminum, arsenic, barium, calcium, total chromium, copper, iron, lead, magnesium, manganese, titanium, uranium, vanadium, zinc, five radionuclides, and one wet chemistry parameter.
- Based on the data it appears that turbidity is affected by the sampling methods and that, in general, the lower the turbidity the less variation was observed in the paired results.

Evaluation for Matrix Effects: Soil and groundwater samples from M-120 were analyzed for expanded suites of compounds (SVOCs, OCPs, OPPs, PCBs, and dioxin/furans) in order to examine potential issues involving detection limits or matrix effects that could impact subsequent sampling events. The results of the evaluation showed that there were no interference for soil and water that significantly impacted the data nor resulted in the rejection of laboratory data or significant elevation of reporting limits for nondetects Therefore, the analytical methods used for the Upgradient Investigation may continue to be used in future investigations.

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