ENVIRON

June 19, 2014

Mr. Weiquan Dong, PE
Bureau of Corrective Actions, Special Projects Branch
Nevada Division of Environmental Protection
2030 E. Flamingo Rd., Suite 230
Las Vegas, Nevada 89119

Re: Errata to Remedial Investigation and Feasibility Study (RI/FS) Work Plan, Revision 1; and Response to NDEP Comments dated April 25, 2014, on the RI/FS Work Plan, Revision 1; Nevada Environmental Response Trust Site, Henderson, Nevada (NDEP Facility ID #H-000539)

Dear Mr. Dong,

On behalf of the Nevada Environmental Response Trust (Trust or NERT), please find attached annotated responses to Nevada Division of Environmental Protection (NDEP) comments dated April 25, 2014 on the *Remedial Investigation and Feasibility Study Work Plan, Revision 1*, dated January 10, 2014 (the "Work Plan") for the NERT Site in Henderson, Nevada. With NDEP concurrence, revisions to the Work Plan addressing NDEP's comments are provided in the errata transmitted with this letter and the response to comments. With the incorporation of this errata, the *Remedial Investigation and Feasibility Study Work Plan, Revision 2* is being submitted to NDEP.

The attached errata documentation are provided on 3-hole punched paper so these pages can be easily inserted into your hard copy of the Work Plan, provided previously. Please find attached the following errata documentation:

- Revised Report Text (Revision 2 of the Work Plan)
    - Updated cover page, certifications, and Table of Contents
    - Revisions to Section 5.2.2 to address NDEP Comment #1
    - Revisions to Section 5.4.2 to address NDEP Comment #4
    - Revisions to Section 4.3.2.1 to reflect GW-11's current use as an equalization basin.
    - Updated throughout for the current status of the RI/FS work plan process, for consistency with reports submitted since the submittal of Revision 1 of the RI/FS Work Plan, and to indicate the submittal of Revision 2 to the RI/FS Work Plan, with submittal of these errata.

- Revised Figure 4-1 to reflect GW-11's current use as an equalization basin.

- Revised Table 5-1 to address NDEP Comment #3

- Revised Figure 5-4 to address NDEP Comment #2

- Revised Figure 5-1 to address NDEP Comment #2 in their letter dated May 20, 2014 regarding the Baseline Health Risk Assessment Work Plan, Revision 0 for the NERT Site

- Revised Figure 7-1 to provide an updated anticipated RI/FS project schedule
- Revised Title Sheets for tables, figures, plates, and appendices with updated headers and footers for revision number and report date

Please replace the report text, title sheets, Table 5-1, and Figures 4-1, 5-1, 5-4, and 7-1 in your hard copy of the report with the pages attached. Also attached is a revised CD with the complete report (with these errata incorporated) in electronic format, to replace the CD you previously received.

Please contact John Pekala at (602) 734-7710 or Allan DeLorme at (510) 420-2565 if you have any comments or questions concerning this report.

Sincerely,

John M. Pekala, PG
Senior Manager
CEM #2347, expires 9/20/2014

Allan J. DeLorme, PE
Principal

Attachments

cc: BMI Compliance Coordinator, NDEP, BCA, Las Vegas
NDEP c/o Brian Giroux, McGinley and Associates, Reno

ec: James Dotchin, NDEP
Greg Lovato, NDEP
Nevada Environmental Response Trust
Tanya O'Neill, Foley & Lardner LLP
Joe McGinley, McGinley and Associate

Attachment A

Responses to NDEP Comments Dated April 25, 2014
Remedial Investigation and Feasibility Study Work Plan, Revision 1, Nevada Environmental Response Trust Site, Henderson, Nevada

Responses to NDEP Comments Dated April 25, 2014
Remedial Investigation and Feasibility Study Work Plan, Revision 1
Nevada Environmental Response Trust Site, Henderson, Nevada

NDEP Comment	Response
1. General Comment. Out-of-state MCLs should not be included in the RI/FS work plan for development of the RAOs. The NERT may consider the out-of-state MCLs as To-Be-Considered Standards (TBCs) for development of the RAOs.	Based on discussions with NDEP, section 5.2.2 of the Work Plan has been revised to include discussion of California and Arizona MCLs, and replacement pages of the text are provided in the errata submitted along with this response to comments.
2. Comment #76, NDEP requested clarification to Figure 5-4. In the response, ENVIRON agreed to revise Figure 5-4. However, the figure that was included in Revision 1 of the RI/FS Work Plan (January 10, 2014) is identical to the original figure.	A revised version of Figure 5-4 with language added to the figure to address NDEP's Comment #76, was provided in the revised Work Plan, dated January 10, 2014. We apologize if the copy of the work plan submitted to NDEP did not have the updated figure. The updated figure is provided in the errata.
3. Although not associated with an NDEP comment, ENVIRON made revisions to Table 5-1 which included the addition of several more footnotes. However, this inadvertently deleted the end of Footnote #1, which explains that arsenic contamination was compared to "a site-specific background concentration of 7.2 mg/Kg".	A corrected version of Table 5-1 is provided in the errata.
4. Section 5.4.2 Groundwater. It was noted that in the middle of the first paragraph on page 90 of the Revision 1, the text refers to wells EAST of the AWF. The wells are actually WEST of the AWF, as shown on Figure 5-12a.	This correction has been made in Section 5.4.2 of the Work Plan, and replacement pages of the text are provided in the errata.

Attachment B

Revised Work Plan Text
Remedial Investigation and Feasibility Study Work Plan, Revision 2,
Nevada Environmental Response Trust Site, Henderson, Nevada

Remedial Investigation and Feasibility Study Work Plan Revision 2

Nevada Environmental Response Trust Site; Henderson, Nevada

Prepared for:
Nevada Environmental Response Trust

Prepared by:
ENVIRON International Corporation
Emeryville, California

Date:
June 19, 2014

Project Number:
21-34800I

ENVIRON

Remedial Investigation and Feasibility Study Work Plan, Revision 2

Nevada Environmental Response Trust
(Former Tronox LLC Site)
Henderson, Nevada

Nevada Environmental Response Trust (Trust) Representative Certification

I certify that this document and all attachments submitted to the Division were prepared at the request of, or under the direction or supervision of the Trust. Based on my own involvement and/or my inquiry of the person or persons who manage the system(s) or those directly responsible for gathering the information or preparing the document, or the immediate supervisor of such person(s), the information submitted and provided herein is, to the best of my knowledge and belief, true, accurate, and complete in all material respects.

Office of the Nevada Environmental Response Trust

Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

not individually, but solely as President

Signature: [signature], not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Name: Jay A. Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Title: Solely as President and not individually

Company: Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Date: 6/18/14

Remedial Investigation and Feasibility Study Work Plan, Revision 2

Nevada Environmental Response Trust
(Former Tronox LLC Site)
Henderson, Nevada

Responsible Certified Environmental Manager (CEM) for this project

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.

June 19, 2014

John M. Pekala, PG
Senior Manager

Date

Certified Environmental Manager
ENVIRON International Corporation
CEM Certificate Number: 2347
CEM Expiration Date: September 20, 2014

The following individuals provided input to this document:

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Acronyms and Abbreviations

AECOM	AECOM, Inc.
AL	Action Levels
AMPAC	American Pacific Corporation
AOC	Administrative Order on Consent
AP	ammonium perchlorate
AP&CC	American Potash and Chemical Company
ARAR	applicable or relevant and appropriate requirements
AWF	Athens Road Well Field
BCL	basic comparison level
bgs	below ground surface
BHRA	baseline health risk assessment
BHC	benzene hexachloride (also known as hexachlorocyclohexane)
BMI	Black Mountain Industrial
BRC	Basic Remediation Company
Broadbent	Broadbent & Associates, Inc.
CAA	Clean Air Act
CAMU	Corrective Action Management Unit
CCAQR	Clark County Air Quality Regulations
CEM	Certified Environmental Manager
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIC	Community Involvement Coordinator
CIP	Community Involvement Plan
CO	Carbon monoxide
COPEC	chemicals of potential ecological concern
COH	City of Henderson
COPC	chemical of potential concern
CSTR	Continuously-Stirred Tank Reactors
CSM	conceptual site model
CWA	Clean Water Act
CZE	Capture Zone Evaluation
DAF	dilution attenuation factor

DBSA	Daniel B. Stephens & Associates, Inc
DDT	dichlorodiphenyltrichloroethane
DNAPLs	Dense Non-Aqueous Phase Liquids
DPE	Dual-Phase Extraction
DQO	data quality objective
DRO	diesel range organics
DTSC	Department of Toxic Substances Control
DVSR	Data Validation Summary Report
EC	electrical conductivity
ECA	Excavation Control Areas
EDDs	electronic data deliverables
ENSR	ENSR Corporation
Envirogen	Envirogen Technologies, Inc.
ENVIRON	ENVIRON International Corporation
ESTCP	Environmental Security and Technology Certification Program
Facility Area	The Site, excluding Parcels C, D, F, G, and H
FBR	Fluidized-Bed Reactor
FRTR	Federal Remediation Technology Roundtable
ft^3	cubic feet
ft/ft	feet per foot
ft/yr	feet per year
FS	Feasibility Study
FSP	Field Sampling Plan
GAC	Granular Activated Carbon
G&M	Geraghty & Miller, Inc
gpd/ft^2	gallons per day per square foot
gpm	gallons per minute
GRA	general response actions
GRO	gasoline range organics
GWETS	Groundwater Extraction and Treatment System
GWRTAC	Ground-Water Remediation Technologies Analysis Center
GWTP	Groundwater Treatment Plant

H+A	Hargis & Associates
HASP	Health and Safety Plan
HCB	hexachlorobenzene
HI	hazard index
HRA	health risk assessment
H2S	hydrogen sulfide
Integral	Integral Consulting Inc.
ISCO	In-Situ Chemical Oxidation (ISCO)
ISCR	In-Situ Chemical Reduction (ISCR)
ITRC	Interstate Technology & Regulatory Council
IWF	Interceptor Well Field
IX	ion exchange
KMCC	Kerr-McGee Chemical Corporation
LBCLs	Leaching-based Basic Comparison Levels
lbs	pounds
LOU	Letter of Understanding
LSSL	Leaching-Based, Site-Specific Levels
MCL	maximum contaminant level
MGD	million gallons per day
µg/L	micrograms per liter (parts per billion)
mg/L	milligrams per liter (parts per million)
MPE	Multi-Phase Extraction
mph	miles per hour
NAC	Nevada Administrative Code
NAPL	non-aqueous phase liquid
NCP	National Contingency Plan
NDEP	Nevada Division of Environmental Protection
NERT	Nevada Environmental Response Trust
NFA	No Further Action
Northgate	Northgate Environmental Management, Inc.
No_x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System

NRS	Nevada Revised Statute
OCHs	organochlorine herbicides
OCPs	organochlorine pesticides
O&M	operations and maintenance
OPA	Oil Pollution Act
OPPs	organophosphate pesticides
ORO	oil range organics
OSHA	Occupational Safety and Health Administration
OSSM	Olin Chlor-Alkali/Stauffer/Syngenta/Montrose (formerly POSSM)
PAHs	polycyclic aromatic hydrocarbons
Pb	Lead
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene (also referred to as perchloroethene)
PEL	permissible exposure limits
PEPCON	Pacific Engineering and Production Company of Nevada (former)
POTWs	Publicly Owned Treatment Works
PM_{10}	particulate matter
PRB	permeable reactive barrier
QA	quality assurance
QAPP	Quality Assurance Project Plan
Qal	Quaternary alluvium
QC	quality control
RAAs	remedial action alternatives (RAAs)
RAO	remedial action objective
RAW	removal action work plan
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RIB	Rapid Infiltration Basin
RSLs	Regional Screening Levels
RZ	remediation zone
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act

Site	Nevada Environmental Response Trust (NERT) Site
SLERA	Screening-Level Ecological Risk Assessment
SMP	Site Management Plan
SO_2	sulfur dioxide
SPCC	Spill Prevention, Control, and Countermeasure
SRC	Site-related chemical
SRG	soil remediation goal
SVE	Soil Vapor Extraction
SVOCs	semivolatile organic compounds
SWF	Seep Well Field
SWMU	solid waste management unit
TBC	to-be-considered
TCE	trichloroethene
TDS	total dissolved solids
TEFs	toxicity equivalent factors
Tetra Tech	Tetra Tech, Inc.
TEQ	toxic equivalents
TIMET	Titanium Metals Corporation
TOC	Total Organic Carbon
TPH	total petroleum hydrocarbons
TLP	Threshold Limit Values
Tronox	Tronox LLC
Trust	Nevada Environmental Response Trust
TSCA	Toxic Substances Control Act
UIC	Underground Injection Control
UMCf	Upper Muddy Creek Formation
UMCf-cg1	Upper Muddy Creek Formation, first coarse-grained facies
UMCf-cg2	Upper Muddy Creek Formation, second coarse-grained facies
UMCf-fg1	Upper Muddy Creek Formation, first fine-grained facies
UMCf-fg2	Upper Muddy Creek Formation, second fine-grained facies
USEPA	U.S. Environmental Protection Agency
VOCs	volatile organic compounds

WAPA	Western Area Power Administration
WBZ	water-bearing zone
WECCO	Western Electrochemical Company
Work Plan	Remedial Investigation and Feasibility Study Work Plan
xMCf	Transitional Muddy Creek Formation
yd^3	cubic yard

Executive Summary

This document comprises a work plan for a Remedial Investigation/Feasibility Study (RI/FS) at the Nevada Environmental Response Trust ("Trust") Site, located within the Black Mountain Industrial (BMI) Complex in unincorporated Clark County and surrounded by the City of Henderson, Nevada. This Work Plan has been prepared in accordance with the Interim Consent Agreement between the Nevada Division of Environmental Protection (NDEP) and the Trust, effective February 14, 2011, and is consistent with applicable U.S. Environmental Protection Agency (USEPA) RI/FS guidance (USEPA 1988), which states that the overall purpose of the RI/FS process is "to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site."

Background

The Site has been the location of industrial operations since 1942 when it was developed by the U.S. government as a magnesium plant to support World War II operations. Following the war, the Site continued to be used for industrial activities, including production of perchlorates, boron, and manganese compounds. Former industrial and waste management activities conducted at the Site, as well as those conducted at adjacent properties, resulted in contamination of environmental media, including soil, groundwater, and surface water. Tronox LLC (Tronox) leases a portion of the Site from the Trust, on which it operates a manufacturing facility producing manganese dioxide, batteries, and boron products. The northwestern portion of the Site contains groundwater treatment facilities, including a chromium groundwater treatment plant, a fluidized-bed reactor (FBR) process for perchlorate treatment, and a lined pond (GW-11) that receives extracted groundwater from one on-site and two off-site extraction well fields. In addition, a drainage ditch known as the Beta Ditch, traverses the Site from west to east and was historically used to convey storm water and process wastewater from the Site and neighboring facilities.

Removal Actions

The Site has been the subject of numerous investigations and removal actions beginning in 1979. The first investigation involved the installation of nine monitoring wells that identified elevated chromium concentrations in groundwater underlying the Site. In 1986-87, additional monitoring wells and 11 on-site extraction wells (known as the Interceptor Well Field [IWF]) were installed along with an on-site chromium treatment facility (the Groundwater Treatment Plant or "GWTP"). The IWF, which still operates at the Site in an expanded configuration, is located in the central portion of the property, approximately 2,400 feet north and downgradient of the central process area of the Site. Additional extraction wells were installed in the 1990s and early 2000s to increase groundwater capture at the IWF. In addition, a bentonite-slurry barrier wall (the "barrier wall") was installed on the downgradient side of the IWF in 2001.

In 1997, elevated concentrations of perchlorate were detected in the Colorado River, which was ultimately traced to groundwater plumes originating at the Site and another ammonium perchlorate manufacturing facility in Henderson. As an interim measure to address the perchlorate plume, a shallow water bearing zone (WBZ) extraction well was installed at Athens Road (approximately 8,200 feet north of the barrier wall and the IWF) in 1998. Groundwater from this well and the IWF was routed to an on-site holding pond, the GW-11 Pond which was constructed in late 1998, until the current perchlorate treatment system could be implemented.

In Spring 1999, hydrologists with the Southern Nevada Water Authority discovered an approximately 400 gpm seep discharging into Las Vegas Wash that contained over 100 mg/L of perchlorate. In 1999, a seep capture sump and temporary single-use resin ion exchange (IX) system were installed near the Las Vegas Wash to capture and treat the water discharging from the seep. In 2001, the Seep Well Field (SWF) was initially constructed near the seep with four extraction wells. Pumping from these wells began in July 2002 and the extracted groundwater was treated by a temporary IX system near the wash and later also by a second temporary single-use resin IX system located at the Site. Five additional extraction wells were installed in February 2003 and an additional extraction well was installed in December 2004 to complete the SWF. The 10 extraction wells in the SWF are situated over the deepest part of an alluvial channel, near the Las Vegas Wash.

To further address the perchlorate plume, in 2002, the Athens Well Field (AWF) was constructed, located approximately 8,200 feet north (downgradient) of the IWF and approximately 4,500 feet south (upgradient) of the SWF. The AWF was initially constructed as a series of 15 groundwater extraction wells screened in Quaternary alluvium (Qal) at eight locations[1] that span across two alluvial paleochannels located on either side of an Upper Muddy Creek Formation (UMCf) ridge. Another extraction well was added to the AWF in 2006.

The original IX treatment systems eventually proved to be unworkable and were abandoned in favor of a biological treatment system employing FBR technology in 2004 (ENSR 2005). An additional reactor was added to the FBR system in 2006 to manage the decommissioning of an on-site pond (AP-5) that contained high concentrations of perchlorate.

Interim Soil Removal Actions

Interim soil removal actions were conducted in response to NDEP's 2009 order to remove all impacted soil from the Site by the end of 2010 to minimize potential health risks associated with the continued presence of contaminated soil (NDEP 2009g). The main contaminated portions of the Site were divided into five separate remediation zones based on geographic groupings of elevated detections of contaminants and conceptual site model (CSM) considerations (Northgate Environmental Management, Inc. [Northgate] 2010g). For applicable remediation zones, the general removal action strategy consisted of excavation of soils within designated polygons, sampling of discolored soil, removal of discolored soil if above site-specific soil remediation goals (SRGs) or otherwise deemed appropriate to remove, and designation of Excavation Control Areas (ECAs) for inaccessible areas, including areas with chemicals of potential concern (COPCs) and/or discolored soil left in place. The removal activities and post-removal conditions at the Site are described in detail in the *Revised Interim Soil Removal Action Completion Report* (ENVIRON International Corporation [ENVIRON] 2012e), submitted to NDEP on September 28, 2012 and approved by NDEP on December 17, 2012 (NDEP 2012c).

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[1] The AWF wells are paired, with the well pairs acting in concert with one well pumping while the adjacent well (the so called "buddy" well) is used to measure water levels and monitor the effect of pumping on the aquifer.

Soil Gas Health Risk Assessment

Soil gas sampling results were evaluated and eight volatile organic compounds (VOCs) were retained as COPCs for quantitative evaluation in the draft *Site-wide Soil Gas Health Risk Assessment* (Soil Gas HRA) (Northgate 2010r). For the Soil Gas HRA (Northgate 2010r), the migration of COPCs in soil gas from the subsurface to indoor air was estimated using modeling.

Groundwater Removal Actions

Current operations at the Site include the continued operation of an on-site Groundwater Extraction and Treatment System (GWETS) that acts to remove hexavalent chromium and perchlorate from shallow groundwater beneath the Site and at downgradient locations along the existing contaminant plume. The GWETS has been in operation since 2006 and operates by capturing groundwater from three extraction well fields (the IWF, AWF, and SWF) and treating the captured groundwater via aboveground treatment facilities for subsequent discharge at the Las Vegas Wash. Perchlorate in extracted groundwater is treated in the on-site FBR process using ethanol as a carbon source. Chromium in extracted groundwater is treated via chemical reduction and precipitation using ferrous sulfate. The IWF currently consists of 23 active extraction wells located immediately upgradient (south) of the vertical barrier wall. The AWF currently consists of seven active extraction wells screened in the alluvium that span approximately 1,200 feet across two alluvial paleochannels. The SWF consists of 10 wells screened across the full thickness of the Quaternary alluvium at the deepest portion of an alluvial channel just south of the Las Vegas Wash. The two off-site well fields, the AWF and the SWF, are served by three lift stations that convey the captured groundwater to the aboveground treatment portions of the GWETS via underground pipelines.

The GWETS has been effective at removing and treating significant amounts of perchlorate and chromium in on-site and off-site groundwater. From July 2002 through June 2012, an estimated 3,093 tons of perchlorate and 19 tons of chromium have been removed and treated by the GWETS. Potential gaps in plume capture have been observed as evidenced by elevated concentrations (primarily perchlorate, but also chromium) at the ends of the IWF and downgradient of the AWF. To address potential gaps in capture and to increase the overall effectiveness of the existing GWETS, the Trust will conduct a GWETS Optimization Project (ENVIRON 2013c) that was approved by NDEP on December 3, 2013 (NDEP 2013e). As part of the GWETS Optimization Project, nine currently idle extraction wells will be activated, and the existing groundwater flow model will be refined and updated in order to estimate capture zones and perform other analyses to support the optimization of the GWETS extraction rates. The model will continue to be refined as part of the RI/FS.

Groundwater Monitoring Program

The current GWETS groundwater monitoring program consists of approximately 1,800 water level measurements and over 1,000 groundwater samples collected from groundwater wells each year. Samples are collected on monthly, quarterly, and annual schedules in accordance with monitoring requirements outlined in previous Consent Orders and an Administrative Order on Consent (AOC) and through subsequent regulatory correspondence. In an effort to improve and streamline the groundwater monitoring program, a long-term monitoring optimization study is planned and will be presented as part of the RI Report.

A work plan to characterize and remove the residual solids remaining in an on-site lined surface impoundment (the AP-5 pond) at the Site (ENVIRON 2012d) was approved by NDEP on February 4, 2013 (NDEP 2013a).

Initial Site Evaluation

Consistent with the RI/FS guidance (USEPA 1988), the initial site evaluation includes a detailed evaluation of historical information regarding the Site, including data generated from the numerous investigations previously conducted at the Site. The initial site evaluation: (1) summarizes the CSM, (2) identifies the preliminary remedial action objectives (RAOs) and applicable or relevant and appropriate requirements (ARARs), (3) describes the development of general response actions and screening of remedial technologies and process options, and (4) describes additional areas that require investigation to determine the nature and extent of COPCs at the Site.

Conceptual Site Model

The CSM for this Work Plan (see Section 5.1) is developed based on a current understanding of on-site and off-site environmental conditions that affect the Facility Area, which is comprised of the 265-acre portion of the Site excluding Parcels C, D, F, G, and H. This preliminary identification of sources, release mechanisms, exposure media, exposure routes, and receptors is based on a current understanding of on-site and off-site environmental conditions. As part of the CSM, potential contaminant sources and release mechanisms were identified and reviewed. NDEP has identified 70 source areas which include areas that are currently used for chemical production, areas that are no longer active, and/or areas where near surface soil contamination has previously been addressed. These current or former source areas include, but are not limited to:

- Unit buildings 1 through 6;
- Surface water impoundments (over 15 former and current surface water impoundments were identified as LOUs);
- Former and current surface and subsurface water conveyances (e.g., the Beta Ditch, Beta Ditch Extension, Northwest Ditch, drainage systems, sewers, piping);
- Leach Plant area;
- Acid drain system;
- Agricultural division plant;
- Ammonium perchlorate plant and associated buildings;
- Materials and product handling and storage areas;
- Waste handling and storage areas;
- Manganese tailings area;
- Stock pile areas; and
- Former hazardous waste landfill (LOU 10) and other hazardous waste storage areas.

Historical releases from potential source areas have been documented or inferred from field investigations that have identified chemically impacted on-site soils, soil gas, and groundwater.

Neighboring properties include the Olin property to the west of the Site, the unlined BMI landfill that received wastes from a number of operating entities, the Lhoist property that is surrounded by the Site on three sides and that contributed to flows to the Beta Ditch prior to 1979, and the Titanium Metals Corporation (TIMET) property to the east of the Site. These adjacent neighboring properties are considered potential former and/or current off-site sources of contaminants to Site groundwater, particularly from the west; surface soils and surface water (from off-site storm water entering the Site); and air (airborne particulates released from contaminated surface soils and buildings on these adjacent properties).

Considering the existing investigation results, completed removal action, and Site Management Plan (SMP) controls in place at the Facility Area, surface and near surface soils[2] were placed into one of four categories to inform the CSM, as well as identify data gaps and exposure pathways for evaluation in the RI and baseline health risk assessment (BHRA) to be conducted as part of the RI/FS. The four categories are identified as follows:

- Category 1 - Soils in ECAs
- Category 2 - Soil Remediation Goals [SRGs] Not Exceeded, Not in ECA
- Category 3 - SRGs Exceeded, Not in ECA
- Category 4 - Inadequate Characterization, Not in ECA.

The soil category classifications were utilized, along with worker activity patterns, for the identification of exposure units in the BHRA Work Plan submitted to NDEP on February 28, 2014 and approved on May 20, 2014 (ENVIRON 2014d). The approach for identifying soil COPCs for evaluating risk to human health was identified in the BHRA Work Plan. Based on our review of the data, soil COPCs will include chemicals (both inorganic and organic), asbestos, and radionuclides.

The potentially contaminated exposure media at the Facility Area and nearby vicinity include ambient and indoor air, soil, surface water, and groundwater. Consistent with the NDEP-approved 2010 HRA Work Plan (Northgate 2010d), current and future on-site receptors identified for evaluation in the BHRA include long-term indoor workers, long-term outdoor commercial or industrial workers, and short-term construction workers. Currently, over 100 full-time workers are employed at the Tronox facility and approximately seven workers are employed at the GWETS.

As part of this RI/FS Work Plan, ENVIRON conducted an updated screening of vadose zone soil concentrations against NDEP Leaching-based Basic Comparison Levels (LBCLs) or similar screening levels using a soil dataset that has been revised to incorporate changes resulting from the interim soil removal action. Preliminary leaching-based soil COPCs were selected using a frequency of detection approach and a complete list of COPCs based on leaching to

[2] Defined as 0-10 feet below the "new" ground surface. The "new" ground surface refers to the soil surface following excavation, backfilling, and grading associated with the 2011 interim soil removal action (ENVIRON 2012e).

groundwater was developed (Section 5.1.4.1). In addition to perchlorate and chromium, the list includes specific metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins/furans, organic acids, radionuclides, total petroleum hydrocarbons (TPH), and various general chemistry parameters. As part of the RI, ENVIRON will review available soil data to evaluate whether any revisions to this list are necessary.

Perchlorate and chromium are the primary Site-related chemicals detected in soil at the Site and in groundwater beneath and downgradient of the Site. Although there is no reported use of chloroform at the Site, chloroform is also detected in groundwater at the Site, at neighboring properties, and in downgradient areas. In addition to perchlorate and chromium, the groundwater CSM includes the transport of volatile chemicals present in the vadose zone to groundwater by infiltration and vapor-phase diffusion. In general, infiltration at the Site is limited due to portions of the Site being paved and the arid climate. However, sufficient water could be generated to mobilize Site-related chemicals during certain events including rainstorms of sufficient quantity and duration, utility pipeline leaks or breaks, or leaks from surface impoundments. Transport by diffusion can also occur if the vadose zone soils remain dry, which could result in transport of volatile chemicals in the vapor phase downward to the water table.

In addition to perchlorate and chromium, ENVIRON developed a list of other COPCs in groundwater that exceed screening criteria, based on analysis of data from several investigations performed since 2006, including the Phase A and Phase B investigations and others. COPCs in groundwater were selected using a frequency of detection approach and a complete list of COPCs in groundwater was developed (Section 5.1.4.2). In addition to perchlorate and chromium, COPCs in groundwater include specific metals, VOCs, pesticides, radionuclides, SVOCs, and general chemistry parameters. As part of the RI, available groundwater data will be reviewed to evaluate whether any revisions to the preliminary groundwater COPCs are necessary.

Remedial Action Objectives and Remedial Alternatives Evaluation

Preliminary RAOs and ARARs have been developed for use and further evaluation during the RI/FS. Short-term RAOs are anticipated to be met in less than 5 years and include: 1) mitigation of the discharge of COPCs originating at the Site to the Las Vegas Wash, 2) optimization of the current GWETS operation to ensure that maximum capture efficiency is being achieved for each of the three extraction well fields, and 3) prevention of human exposure to COPCs in soil that would pose an unacceptable health risk to on-site and off-site receptors. Long-term RAOs are those that address a longer time frame (i.e., greater than 5 years). These include: 1) downgradient aquifer restoration, 2) mitigation of the migration of COPCs from the Site to the area downgradient of the northern Site property boundary, and 3) mitigation of significant leaching of perchlorate and other Site COPCs from vadose zone soils to underlying groundwater.

Based on the identified ARARs and preliminary RAOs identified for the Site, general response actions (GRAs) have been developed (Section 5.3.1), and a comprehensive list of potentially applicable remedial technologies and process options has been compiled (Section 5.3.2). The technologies and process options have been evaluated and screened in this Work Plan resulting in the retention of implementable technologies that can be used in the development of remedial action alternatives (RAAs). Of the 119 discrete process options that were initially identified, 62 process options were screened out from further consideration on the basis of effectiveness, implementability, and cost. A total of 57 process options were retained from the screening process for remedial alternative development. The remedial technologies and process options will be further evaluated in the feasibility study (FS).

Based on the initial screening, the following general preliminary remedial action alternatives (RAA) have been identified as potentially practicable alternatives to address the COPCs in soil and groundwater at the Site: 1) no further action; 2) enhancement of groundwater containment, recovery, and aboveground treatment via upgrades to the existing GWETS; 3) enhancement of groundwater containment, recovery, and aboveground treatment via upgrades to the existing GWETS and on-site source control; and 4) enhanced groundwater containment and extraction at the IWF and AWF with in-situ treatment downgradient of the AWF. The preliminary RAAs are not meant to be comprehensive and specific with respect to retained process options. Rather, these RAAs represent general conceptual approaches that would address the primary COPCs and RAOs for the Site. Further analysis and screening conducted during the implementation of the RI are expected to identify numerous potentially applicable process options that can be evaluated for each of the preliminary RAAs identified. Treatability studies will also be used to evaluate certain remedial technologies for which additional information regarding their feasibility/performance under site-specific conditions is necessary. Treatability studies evaluating a permeable reactive barrier (PRB) and in-situ soil flushing have been proposed. Additional treatability studies may be identified as further information is developed during the RI/FS.

Data Gaps to be Evaluated in the RI

For the RI/FS, additional areas have been identified that require investigation to determine the nature and extent of COPCs in soil and groundwater at the Site. Many of these areas were previously identified by NDEP as areas requiring further study. For purposes of additional soil characterization, four main areas have been identified for collection of additional physical and chemical data from both shallow and deep soils. These areas include the AP-5 Pond area, the debris pile, soil in the area between the debris pile and AP-5 Pond, and the area west of Pond Mn-1. Also, additional data are needed to evaluate the Category 1 soil areas with limited soil characterization due to access constraints (e.g., soils beneath Unit buildings). These additional data needs will be addressed by the installation of shallow groundwater monitoring wells with soil samples collected continuously during drilling. Five monitoring wells are proposed in the area of the Unit Buildings 4, 5, and 6. In addition, directional drilling may be employed where feasible in order to obtain soil samples from beneath certain operating areas of the Site where high perchlorate concentrations are present in shallow wells. Soil and groundwater samples will be analyzed for COPCs in groundwater. Additional data review and groundwater investigations are also proposed to address the following data gaps: determination of background COPC concentrations, revision of the preliminary list of COPCs, COPC impact in the Middle Water-Bearing Zone/Muddy Creek Formation, the magnitude and extent of trespassing chemicals, the lateral and vertical extents of the downgradient plume, chloroform within the downgradient plume, and stream-aquifer interaction with the Las Vegas Wash. These data gaps will be addressed as part of the RI/FS.

RI/FS Tasks and Schedule

As specified within the RI/FS framework identified in USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988), the following tasks will be conducted as part of this RI/FS:

- Task 1: Project Planning;
- Task 2: Community Relations;
- Task 3: Groundwater Modeling;
- Task 4: Field Investigation;
- Task 5: Sample Analysis and Data Verification and Validation;
- Task 6: Data Evaluation;
- Task 7: Risk Assessment;
- Task 8: Treatability Studies;
- Task 9: Remedial Investigation Report;
- Task 10: Remedial Alternatives Development;
- Task 11: Detailed Analysis of Alternatives; and
- Task 12: Feasibility Study Report.

Further details regarding the scope of each of these tasks are provided in Section 6 of this Work Plan. This RI/FS Work Plan is being submitted to NDEP in June 2014, and follows the submittal in December 2013 and NDEP approval in February 2014 of an updated Community Involvement Plan (CIP) (ENVIRON 2013e). In addition, a Sampling and Analysis Plan (SAP) was submitted to NDEP in late January 2014, which contained a Field Sampling Plan (FSP) (ENVIRON 2014b), a Quality Assurance Project Plan (QAPP) (ENVIRON 2014c) and a health and safety plan (HASP) (ENVIRON 2014a) for the data gap field investigation. The BHRA Work Plan (ENVIRON 2014d) was submitted to NDEP in February 2014 and two revised treatability study work plans were submitted to NDEP in May 2014 (ENVIRON 2014f,g). NDEP approved the BHRA Work Plan and treatability studies in May 2014 (NDEP 2014e,f,g) and provided comments on the FSP, QAPP, and HASP (NDEP 2014b,c,d). It is anticipated that revised versions of the FSP, QAPP, and HASP will be submitted to NDEP in July 2014.

Field investigations to address data gaps, as outlined in the SAP, are anticipated to be performed between August 2014 and January 2015, after which the BHRA will be performed from approximately late February to September 2015. The soil flushing and permeable reactive barrier (PRB) treatability studies will be implemented concurrent with the data gap field investigation and continuing into 2015. The RI and BHRA reports are anticipated to be prepared from late March to September 2015, followed by completion of the treatability studies in mid-2015 to early 2016 and preparation of the FS report in 2016/2017. The anticipated RI/FS project schedule is provided in Section 7.2.

1.0 Introduction

In accordance with the Interim Consent Agreement between the Nevada Division of Environmental Protection (NDEP) and the Nevada Environmental Response Trust ("Trust"), effective February 14, 2011, ENVIRON International Corporation (ENVIRON) submits this Remedial Investigation (RI) and Feasibility Study (FS) Work Plan, Revision 2 (Work Plan) to the NDEP on behalf of the Trust. Prior RI/FS Work Plans were submitted to NDEP on December 17, 2012 and January 10, 2014. Comments on the December 2012 work plan were provided by NDEP to the Trust on June 27, 2013. On behalf of the Trust, ENVIRON provided a response to NDEP comments on October 4, 2013. On November 18, 2013, NDEP provided four comments based on their review of the October 4, 2013 response to comments document. As requested in NDEP's November 18, 2013 letter, a tabular summary providing revised annotated responses to NDEP's June 27, 2013 and November 18, 2013 comments is provided in Appendix A. In a letter dated April 25, 2014, NDEP provided comments on the January 10, 2014 RI/FS Work Plan, Revision 1, which have been addressed in this RI/FS Work Plan, Revision 2.

The Site comprises approximately 346 acres[3] located within the Black Mountain Industrial (BMI) Complex in unincorporated Clark County and is surrounded by the City of Henderson, Nevada (Figure 1-1). The property comprising the Site has a long, complex ownership and operational history, as summarized in Section 2. The Site has been the location of industrial operations since 1942 when it was developed by the U.S. government as a magnesium plant to support World War II operations. Following the war, the Site continued to be the location of industrial activities, including production of perchlorates, boron, and manganese compounds. Former industrial and waste management activities conducted at the Site, as well as those conducted at adjacent properties, resulted in contamination of environmental media at the Site, including soil, groundwater, and surface water.

Tronox LLC (Tronox) most recently owned and operated the Site until February 14, 2011, on which date the Trust took title to the Site in conjunction with the settlement of Tronox's bankruptcy proceeding. Tronox currently leases a portion of the Site from the Trust, on which it continues to operate its chemical manufacturing business. The exclusive purpose and functions of the Trust include (among others): "(i) own the (Site) for purposes of implementing the Settlement Agreement[4], (ii) carry out administrative and property management functions related to the (Site), (iii) manage and/or fund implementation of Environmental Actions for the Henderson Legacy Conditions (as defined in the Settlement Agreement) that are approved by (NDEP)."

The Site has been the subject of extensive environmental investigations and removal actions since the 1970s. The on-site Hazardous Waste Landfill was closed and capped in 1985. A groundwater treatment system for removal of hexavalent chromium from groundwater was

[3] Following the sale of Parcels A and B in December 2013 to TRECO, LLC, the Site comprises approximately 346 acres.

[4] Settlement Agreement shall mean that certain Consent Decree and Environmental Settlement Agreement, effective February 14, 2011, filed in the *Tronox Incorporated, et al.* Bankruptcy Case No. 09-10156 (ALG).

constructed in 1987. In 1994, NDEP identified 69 Letter of Understanding Potential Source Areas (NDEP 1994) (referred to in this and other reports as LOUs[5]). In 1997, perchlorate, later shown to originate, in part, from the Site, was detected in Las Vegas Wash and the Colorado River (NDEP 2011a), and in 1999, an additional groundwater treatment system for removal of perchlorate was constructed. At the end of 2010, Tronox excavated and disposed of the waste material from the onsite landfill. In 2010 and 2011, over 500,000 cubic yards (yd^3) of impacted soils and tailings were removed from the Site and disposed of at an off-site location.

Investigation and cleanup activities at the Site are being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended, and the Interim Consent Agreement[6] between NDEP and the Trust. In accordance with CERCLA, a Remedial Investigation/Feasibility Study (RI/FS) is being conducted to investigate the nature and extent of contamination at the Site and downgradient plume (Figure 1-2) and to develop remedial action alternatives, as appropriate. As stated in RI/FS guidance (U.S. Environmental Protection Agency [USEPA] 1988), the overall purpose of the RI/FS process is "to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site."

This Work Plan identifies additional activities within the RI/FS process that are proposed to address remaining contamination at the Site. The overall format of the Work Plan follows that recommended in USEPA guidance (USEPA 1988) for conducting an RI/FS, as follows:

- Section 1 presents a brief introduction, identifying the purpose of the RI/FS and the contents of this report.
- Section 2 presents background information about the Site including descriptions of the ownership and operational history, physical setting, climate, and geology and hydrogeology.
- Section 3 summarizes regulatory actions and historical and recent field investigations of soil, soil gas, indoor air, and groundwater.
- Section 4 summarizes interim removal actions conducted to date and risk assessments evaluating the potential adverse effects associated with exposures to chemicals in soils, indoor air, and groundwater.
- Section 5 presents the Initial Site Evaluation, which includes (1) a preliminary conceptual site model (CSM), (2) a preliminary identification of regulatory requirements and remedial action objectives (RAOs), (3) a screening of remedial technologies and process options, and (4) a preliminary identification of data gaps.
- Section 6 outlines RI/FS tasks described in USEPA guidance (USEPA 1988) and discusses the planned activities for each of these tasks.

[5] Appendix B includes a figure showing the locations of all LOUs (Figure B-1) and a comprehensive table (Table B-1) listing the LOUs, LOU name, and the soil and soil gas work plans and investigations conducted for the individual LOUs through October 2013.
[6] Interim Consent Agreement, effective February 14, 2011.

- Section 7 describes the project management structure and proposed schedule for completion of the RI/FS.
- Section 8 lists the references cited in this report.

Appendices to this Work Plan provide detailed analyses or supplementary information, as follows:

- Appendix A Response to NDEP Comments on the RI/FS Work Plan
- Appendix B Summary of Historical LOU Soil and Soil Gas Investigations
- Appendix C Soil Remediation Goals for the 2011 Interim Soil Removal Action
- Appendix D Background Data Set for Soils

2.0 Site Background

2.1 Operational History

The Site is located within the BMI[7] Complex, which consists of several facilities owned and operated by a number of chemical companies (Figure 2-1). The BMI Complex was first developed in 1942 by the U.S. government as a magnesium plant for World War II operations. Later, a part of the BMI Complex that would ultimately become the Site was leased by Western Electrochemical Company (WECCO). WECCO produced manganese dioxide, sodium chlorate, sodium perchlorate, and other perchlorates. WECCO also produced ammonium perchlorate (a powerful oxidizer) for the Navy during the early 1950s using a plant that was constructed on the Site by the Navy. WECCO merged with American Potash and Chemical Company (AP&CC) in 1956, and continued production of ammonium perchlorate for the Navy. In 1967, Kerr-McGee Chemical Corporation (KMCC) purchased AP&CC. KMCC began production of boron chemicals in the early 1970s. The production processes included elemental boron, boron trichloride (a colorless gas used as a reagent in organic synthesis), and boron tribromide (a colorless fuming liquid used in a variety of applications). The production of boron tribromide was discontinued in 1994, and the production of sodium chlorate and ammonium perchlorate was discontinued in 1997 and 1998, respectively. Perchlorate was reclaimed at the Site using existing equipment until early 2002.

In 2006, Tronox took ownership of the facility formerly operated by KMCC on the Site and operated it to produce electrolytic manganese dioxide for use in the manufacture of alkaline batteries; elemental boron for use as a component of automotive airbag igniters; and boron trichloride for use in the pharmaceutical and semiconductor industries and in the manufacture of high-strength boron fibers for products that include sporting equipment and aircraft parts. In 2009, Tronox filed for Chapter 11 bankruptcy. As previously noted in Section 1, the Trust took title to the Site on February 14, 2011, as a result of the settlement of Tronox's bankruptcy proceeding. Tronox currently has a long-term lease for approximately 114 acres of the Site (ENVIRON 2013d), where it continues its manufacturing operations (identified on Figure 2-2 as "Tronox-Leased Area").

2.2 Site Description

The Site is located approximately 13 miles southeast of the city of Las Vegas and is located in an area of unincorporated Clark County, Nevada, that is surrounded by the City of Henderson (Figure 1-1). It covers approximately 346 acres[8], and lies in Sections 12 and 13 of Township 22 S, Range 62 E (Figure 2-2).

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[7] The acronym "BMI" has been applied to several entities over the years. From 1941 until 1951 it referred to Basic Magnesium Incorporated; in 1951, a syndicate of tenants formed under the name of Basic Management, Inc. to provide utilities and other services at the complex; the group has also been known as Basic Metals, Inc., and at the present is called the Black Mountain Industrial complex.

[8] Previous documents have identified an area of approximately 450 acres. Following the sale of Parcels I and J and a part of Parcel B in 2008, the Site comprised approximately 410 acres. Following the sale of Parcel A and the remaining portion of Parcel B in December 2013, the Site currently comprises approximately 346 acres.

The Site is located in an industrial land use area. The nearest residential areas are located just north (across North Boulder Highway) and south (across Lake Mead Parkway) of the Site (Figure 2-1). The Site is generally rectangular, but certain interior portions of the rectangle are owned and operated by other companies, specifically, Lhoist, Western Area Power Administration (WAPA), BMI, and Titanium Metals Corporation (TIMET). Facilities on the exterior borders of the Site are TIMET to the east, and Olin Chlor-Alkali to the west (formerly known as [1] Pioneer Americas LLC, which includes former Stauffer and Montrose Sites; [2] Olin Chlor-Alkali/Stauffer/Syngenta/Montrose [OSSM]; and [3] Pioneer/Olin Chlor-Alkali/Stauffer/Syngenta/ Montrose [POSSM]). Olin Chlor-Alkali is hereafter referred to as the Olin property. Certain remediation system components jointly operated by Olin Chlor-Alkali, Stauffer, Syngenta, and Montrose are referred to as being operated by OSSM. BMI is located mainly to the east of the Site, although a BMI-owned Corrective Action Management Unit (CAMU) is located immediately to the west. A summary of the neighboring properties, the ditches and other conveyances that are located on these properties, and their former property names are provided in Table 2-1. Areas referred to as Parcels A, B, I, and J, which were formerly part of the Site, were sold in 2008 and 2013, and now represent neighboring properties to the north (Figure 2-3).

An area within the northwestern portion of the Site consists of groundwater treatment facilities, which are operated on behalf of the Trust by an outside contractor, Envirogen Technologies, Inc. (Envirogen)[9]. Three lined ponds on the Site (known as WC-West, WC-East, and Mn-2 receive process-related wastewater discharges from ongoing Tronox facility operations, and an additional lined pond (known as GW-11) receives extracted groundwater from remediation activities. The Site is traversed (from west to east) by a drainage ditch known as the Beta Ditch that historically conveyed liquid wastes from the Site and from neighboring facilities located to the west. The Beta Ditch, which no longer discharges off-site to the east, has been re-graded, channelized, and now includes a retention basin as described in detail in Section 2.6. The west end of the Beta Ditch at the Site continues to receive storm water drainage from the neighboring property to the west. These Site features are shown in Figure 2-3.

The major buildings on the Site include Units 1 through 6, which are aligned in a row extending in a west-east direction across the southern portion of the Site (Figure 2-3). These buildings were constructed during World War II for magnesium production. Unit buildings 3 through 6 and the southern portions of Unit buildings 1 and 2 are within the boundaries of the Tronox-leased area. Tronox uses Units 5 and 6 for production of manganese dioxide; Unit 5 is also used for storage. Units 1, 2, and most of Unit 4 are no longer used and have been partially demolished. The remaining portion of Unit 4 has been retrofitted to house an advanced battery manufacturing process that started up in 2012. Tronox currently uses Unit 3 for office and storage activities. In addition, Tronox produces boron products within a Boron Plant to the north of Unit 4, and manganese sulfate solution (for use in the manganese dioxide production process) is produced within a Leach Plant north of Units 5 and 6. Other buildings present at the Site include an administration building, a change house, a laboratory building, a maintenance shop, a steam plant, and various storage buildings (Figure 2-3). The Site is crossed by asphalt

[9] Envirogen is referred to elsewhere in this report as the GWETS Contractor.

and concrete roads, dirt roads, active utility lines, a gaseous chlorine line, and railroad spurs. An extensive network of active and inactive underground utility lines is present under the roads and open areas at the Site.

In addition to the Tronox and Envirogen operations at the Site, Tronox has three subtenants within the Tronox-leased area, which provide various services to Tronox and other local businesses (Table 2-2). The locations of the tenant operations are shown in Figure 2-4. The Tronox subtenant operations are briefly described below:

- Industrial Supply: provides tools and supplies for manufacturing, construction, and utilities.
- Angelo & Newton: provides technical and managerial consulting services, specializing in chemical process plant safety compliance, regulatory compliance, and battery and energy systems.
- Pronto Constructors: provides construction services.

Within the boundaries of the Site, and as shown on Figure 2-3, are Parcels C, D, E, F, G, and H. The Parcels are at the edges of the Site, to the north, west, and south. Parcel E contains a portion of the OSSM groundwater treatment system. As noted above, Parcels I and J (and the eastern portion of Parcel B) were sold to Rolly Properties LLC (Parcels B and I) and Robert and Sandra Ellis (Parcels B and J) in 2008, and Parcel A and the remaining portion of Parcel B were sold to Treco in December 2013; these areas are no longer a part of the Site. Environmental investigations for all remaining Parcels except Parcel E (i.e., Parcels C, D, F, G, and H) have generally been conducted separate from investigations at other portions of the Site.[10] The field investigation work for these Parcels has been completed, and the health risk assessments and decision documents are in progress or completed, depending on the parcel. For these reasons, with the exception of Parcel E, the parcels are not included in this Work Plan and are not a part of the Site RI/FS process.

2.3 Physical Setting

Elevations across the Site range from 1,677 to 1,873 feet above mean sea level. The land surface across the Site generally slopes toward the north at a gradient of approximately 0.02 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. Further modifications to the Site were made as part of the Interim Soil Removal Action (ENVIRON 2012e) in which soils were typically excavated to depths of up to 10 ft below ground surface (bgs). In some cases, depths were extended to greater than 10 ft to remove discolored soils. Not all excavations were completely backfilled following excavation, resulting in some areas with depressions with 3:1 side slopes. Off-site to the north, the topographic surface continues at approximately the same gradient to approximately Sunset Road, at which point it flattens to a gradient of approximately 0.01 ft/ft to the Las Vegas Wash (ENSR 2005).

[10] The remaining portion of the Site excluding Parcels C, D, F, G, and H is herein after referred to as the “Facility Area.”

2.4 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. Winter storms generally produce low intensity rainfall over a large area. 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. Winds frequently blow from the south or northwest at a mean velocity of approximately 9 miles per hour (mph); however, velocities in excess of 50 mph are not atypical when weather fronts move through the area. During these windy events, dust, sand, and soil at the ground surface can become airborne and may travel several miles. Temperatures can rise to 120°F in the summer, and the average relative humidity is approximately 20%. The mean annual evaporation from lake and reservoir surfaces ranges from 60 to 82 inches per year (KMCC 1985).

2.5 Geology and Hydrogeology

The following subsections describe the regional geology, local geology, and local hydrogeology.

2.5.1 Regional Geology

The Site is located within the Las Vegas Valley, which 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 overlie Precambrian metamorphic and granitic rocks (ENSR 2007c).

In the Las Vegas Valley, eroded Tertiary and Quaternary sedimentary and volcanic rocks comprise the unconsolidated basin deposits, which can be up to 13,000 feet thick (ENSR 2007c). The valley floor consists of fluvial, paludal (swamp), playa, and lacustrine 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 their source and with decreasing elevation. The structure within the Quaternary and Tertiary-aged basin fill is characterized by a series of generally north-south trending fault scarps.

2.5.2 Local Geology

The local geology and hydrogeology are defined by data collected from more than 1,100 borings and wells that have been installed in the area. The following descriptions are summarized from the CSM report (ENSR 2005).

Alluvium. The Site is located on Quaternary alluvial deposits (Qal) 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 the 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 eroded into the surface of the Muddy Creek Formation during infrequent flood runoff periods. These deposits vary in thickness and are narrow and generally linear. These generally uniform 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 foot to more than 50 feet 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.

Transitional (or reworked) Muddy Creek Formation. Where present, Transitional Muddy Creek Formation (xMCf) is encountered at the base of the alluvium. The Transitional Muddy Creek Formation consists of reworked sediments derived from the Muddy Creek Formation, which is described below. Therefore, the xMCf appears similar to the Muddy Creek Formation, but it consists of reworked, less consolidated and indurated sediments.

Muddy Creek Formation. The Upper Muddy Creek Formation (UMCf) of Pleistocene age occurs in the 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. 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) interbedded with at least two thinner units of coarse-grained sediments of sand, silt, and gravel (the first and second coarse-grained facies). Except for the southernmost 1,000 feet adjacent to Lake Mead Parkway, the first fine-grained facies (UMCf-fg1) separates the first coarse-grained facies (UMCf-cg1) from the overlying Quaternary alluvium at the Site. Within the southern 1,000 feet of the Site, the Muddy Creek Formation's UMCf-fg1 pinches out along a roughly west-northwesterly trending line. South of this line, the UMCf-cg1 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 (UMCf-fg1) 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.

2.5.3 Local Hydrogeology

Background information is described in detail in the 2005 CSM report (ENSR 2005). Depth to groundwater ranges from about 27 to 80 ft bgs and is generally deepest in the southernmost portion of the Site, becoming shallower as it approaches the Las Vegas Wash to the north. A potentiometric surface map depicting shallow groundwater elevations during the May-June 2012 timeframe is presented on Plate 2 (ENVIRON 2012c). The groundwater gradient averages 0.015 to 0.02 ft/ft south of the Athens Road well field (AWF), flattening to 0.007 to 0.010 ft/ft north of the well field (Northgate Environmental Management, Inc. [Northgate] 2010m). The groundwater flow direction at the Site is generally north to north-northwesterly, whereas north of the Site the direction changes slightly to the north-northeast. This generally uniform flow pattern may be modified locally by subsurface alluvial channels cut into the underlying UMCf, the on-site bentonite-slurry groundwater barrier wall, on- and off-site artificial groundwater highs or “mounds” created around the on-site recharge trenches (not currently in use) and City of Henderson Water Reclamation Facility Bird Viewing Preserve Ponds, and by depressions created by the groundwater extraction wells at the three groundwater extraction well fields (Northgate 2010m).

NDEP has defined three water-bearing zones (WBZs) that are of interest in the BMI Complex: the Shallow WBZ, which is defined by the first occurrence of groundwater in either the Qal, xMCf, or the UMCf where the xMCf is missing, is unconfined to partially confined, and is considered the “water table aquifer”; the Middle WBZ, which extends from approximately 90 to 300 ft bgs; and the Deep WBZ, which is defined as the contiguous WBZ that is generally encountered between 300 to 400 ft bgs (NDEP 2009a). Environmental investigations at the Site have primarily focused on the Shallow WBZ, although recent investigations (Northgate 2010f, 2010i) have included a number of Middle WBZ wells to improve vertical delineation of hydrogeology and chemical constituent distribution. Plates 1a, 1b, and 1c show the locations of all former and current groundwater monitoring wells in the Shallow WBZ, Middle WBZ, and Deep WBZ, respectively.

At the Site, the Shallow WBZ is comprised of the saturated portions of the alluvium and the uppermost portion of the UMCf to depths of approximately 90 ft bgs. Beneath the northern portion of the Site, the first groundwater encountered occurs within the alluvium at depths of 30 ft bgs or more, 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. The results of a 1998 pump test in the Athens Road area indicate a permeability of 50 gallons per day per square foot (gpd/ft^2), a transmissivity of 1,300 gpd/ft, and a groundwater velocity of 220 feet per year (ft/yr) for groundwater in the alluvial aquifer (KMCC 1998b). However, significantly higher groundwater velocities, ranging from approximately 600 to 2,500 ft/yr, have been calculated based on alluvial well pumping and slug tests (KMCC 1998b), and a groundwater velocity of over 12,000 ft/yr was reported based on a tracer test conducted in the alluvial channel between the Athens Road area and the Las Vegas Wash (Errol Montgomery and Associates 2000).

Beneath the central portion of the Site, groundwater is first encountered within the Shallow Zone in the UMCf-fg1, and can be more than 50 ft bgs, as documented in historic water level measurements. South of where UMCf-fg1 pinches out, beneath the southern portion of the Site, the first groundwater encountered occurs within the UMCf-cg1 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 wells M-120 and M-121, which were installed as part of the upgradient investigation (ENSR 2007d). The gradient of the potentiometric surface in both UMCf-fg1 and UMCf-cg1 (south of where UMCf-fg1 pinches out) mimics the ground surface and the flow direction is to the north-northeast with minor variations. Both the horizontal and vertical hydraulic conductivities of the UMCf are one or more magnitudes of order less than those of the Qal (ENSR 2005).

Investigations of the Middle WBZ at the Site and surrounding sites indicate, with a few exceptions, a vertically upward gradient between the Middle and Shallow Zones that generally increases with depth. At the Site, the sediments within the Middle WBZ consist predominantly of the UMCf-fg1. The UMCf-cg2 occurs below the fine-grained unit at the base of the Middle WBZ, roughly between approximate depths of 280-300 ft bgs. The UMCf-cg2 unit has been defined below the western portion of the Site by six deep wells (TR-1, TR-5, TR-7, TR-9, TR-11, TR-12). The UMCf-cg2 unit is confined, as indicated by artesian groundwater elevations consistently measured in these wells.

Based on previous reports, there are no water supply wells reported within four miles of the Site that extract water from the regional Las Vegas Valley “shallow aquifer” (ENSR 2005). Businesses and residences located within or downgradient of the BMI Complex are connected to a municipal water supply. Under state policy, if there is a municipal connection at the property, the well should be plugged and abandoned unless there is a non-revocable permit associated with the well. The Nevada Division of Water Resources is the agency responsible for this enforcement.

According to information provided by NDEP, in 2007 NDEP conducted a survey of all identified owners of wells located downgradient of the BMI Complex. All owners responded that they had no information on any well that may have existed on their property except for two owners who could not be reached for follow up. The possible presence of wells on these two properties has not been verified. Based on information provided by NDEP, one well was identified by the Southern Nevada Water Authority at a business property near Boulder Highway northwest of the Site in September 2013. The agencies are evaluating follow up actions including possible referral to the Nevada Division of Water Resources for enforcement.

2.6 Surface Water

The Site is located in a very arid region with few natural surface water bodies; however, surface water is present at the Site, primarily in surface water impoundments receiving process wastewater. Surface water is also present following storm events. During the 2011 interim soil removal action, the Facility Area[11] was graded such that storm water would be retained on the Site. Due to existing roads, utility berms, and other site features, many areas at the Site have inward grades which keep storm water from flowing out of the Facility Area. Based on the surface areas and soil types, significant ponding is not expected to occur in these areas outside

[11] The term “Facility Area” represents the portion of the Site excluding Parcels C, D, F, G, and H.

of major storm events. In addition, two main designated retention basins and a drainage channel were constructed within the Facility Area, as shown on Figure 2-3, and described below:

- Central Retention Basin: Surface runoff from off-site areas and water collected in the majority of the storm sewer network within the Tronox-leased area is directed to the Central Retention Basin. Storm water also enters the Site from the west through surface flow, which is collected in an on-site conveyance trench that flows into the Central Retention Basin. This area has a design capacity of approximately 1,295,470 ft^3 (RCI Engineering 2010).

- Northern Retention Basin: Surface runoff from north of the former Beta Ditch is directed to the Northern Retention Basin. This basin also accepts overflow from the Central Retention Basin during major storm events through a channel constructed along the eastern side of the Site. This area has a design capacity of approximately 1,219,680 ft^3 of water (RCI Engineering 2010).

- Drainage Channel: A storm water conveyance channel is located east/northeast of the Central Retention Basin and conveys storm water from the Central Retention Basin (if necessary) and the eastern portion of the Site to the Northern Retention Basin.

Additionally, drainage and diversion structures have been constructed throughout and along the perimeters of the BMI Complex to channel surface water flow (ENSR 2005) as shown on Figure 2-1. The west end of the former Beta Ditch at the Site continues to receive storm water drainage from the neighboring property to the west during major storm events.

Surface water in the Downgradient Plume Area occurs infrequently as storm runoff in shallow washes and flows to the north toward Las Vegas Wash. Las Vegas Wash is a tributary to Lake Mead and it is the only channel through which the valley’s excess water flows to the lake. Lake Mead is a major reservoir on the Colorado River.

3.0 Regulatory Actions and Site Investigations

The Site has been the subject of numerous regulatory actions and environmental investigations since the early 1970s. The soil and groundwater investigations conducted through 2005 served as the basis of the first comprehensive CSM developed for the Site in 2005 by ENSR (ENSR 2005). A brief chronological summary of investigations conducted prior to 2005 is presented in Section 3.1.

Since development of the CSM in 2005 (ENSR 2005), additional investigations and interim removal actions have been conducted. For soil, soil gas, and groundwater, these investigations included primarily the Phase A and Phase B Source Area Investigations. These investigations (described in Section 3.2) and the interim soil removal action (described in Section 4) serve as the primary basis for the updated CSM presented in Section 5 of this report.

3.1 Overview of Regulatory Actions and Environmental Investigations: 1970 - 2005

This section provides a brief chronological summary of investigations conducted through 2005.

During the 1970s, the USEPA, the State of Nevada, and Clark County investigated potential environmental impacts from the BMI company operations, including atmospheric emissions, groundwater and surface water discharges, and soil impacts (ENSR 2007c).

Between 1971 and 1976, KMCC modified its manufacturing processes and constructed lined surface impoundments to recycle and evaporate industrial wastewater in response to the 1972 Federal Water Pollution Control Act (the Clean Water Act [CWA]). Ponds P-1 and Old P-2 were constructed in May through September 1972 for management of potassium-bearing process fluids. Pond S-1 was completed in October 1974 for management of chlorate process liquids. Ponds AP-1, AP-2, and AP-3 were completed by May 8, 1974 for management of ammonium perchlorate liquids, and Pond C-1 was completed by December 1974 for management of nonhazardous wastes including cooling tower liquids (Kleinfelder 1993). The facility achieved zero-discharge status in 1976 regarding industrial wastewater management, and in February 1977, KMCC obtained a National Pollutant Discharge Elimination System (NPDES) permit under the CWA authorizing up to 4 million gallons per day (MGD) discharge of non-contact cooling water to Las Vegas Wash. In 1980, the USEPA requested specific information from the BMI companies regarding their manufacturing and waste management practices by issuing a CWA Section 308 letter.

In July 1981, KMCC initiated a groundwater investigation to comply with federal Resource Conservation and Recovery Act (RCRA) standards for monitoring two existing on-site impoundments (Ponds S-1 and P-1). In December 1983, NDEP requested that KMCC investigate the extent of chromium impact in groundwater beneath the Site. Forty groundwater monitoring wells were installed and, in July 1985, KMCC submitted to NDEP a hydrogeological investigation report delineating a chromium plume within the “near surface groundwater” (KMCC 1985). A Consent Order between KMCC and NDEP was signed in September 1986 (NDEP 1986) that stipulated additional characterization and implementation of corrective action to address chromium in groundwater. Remediation of hexavalent chromium in groundwater began in mid-1987 when four extraction wells (or "interceptor" wells) were installed downgradient of the Ammonium Perchlorate (AP) Plant. The extracted water was pumped to a chromium treatment facility where hexavalent chromium was reduced to trivalent chromium that was then precipitated and removed. Treated water was subsequently reinjected at a series of recharge trenches downgradient of the interceptor well field (IWF).

In April 1991, KMCC was one of six past or present entities that had conducted business within the BMI Complex that entered into a Consent Agreement with NDEP (NDEP 1991) to conduct environmental studies to assess site-specific environmental conditions at individual company sites, the BMI Common Areas, and any off-site waste management areas that were the result of past and present industrial operations and waste disposal practices.

In April 1993, and in compliance with the 1991 Consent Agreement, KMCC submitted a Phase I Environmental Conditions Assessment report to NDEP (Kleinfelder 1993). The purpose of the report was to identify and document site-specific environmental impacts resulting from past or present industrial activities. The Phase I Environmental Conditions Assessment included a comprehensive assessment of the geologic and hydrologic setting, as well as historical manufacturing activities. The Environmental Conditions Assessment identified 31 solid waste management units (SWMUs), 20 areas of known or suspected releases or spills, and 14 miscellaneous areas where Site activities may have impacted the environment.

In 1994, NDEP issued a Letter of Understanding (LOU) to KMCC identifying 69 potential source areas or "items of interest" (LOU-1 through LOU-69) and specifying the level of environmental investigation to be conducted by KMCC (NDEP 1994). Subsequent to the issuance of the LOU, an additional potential source area, the former U.S. Vanadium site, was identified during planning for the Phase B 2008 investigation (NDEP 2011a). Although not formally designated as an LOU, the U.S. Vanadium site is hereafter referred to as LOU-70. A detailed discussion of the specific areas or items of interest identified in the LOUs, lists of the products made, years of production, and approximate waste volumes for WECCO, AP&CC, and Tronox, and actions taken for each LOU study item is presented in the 2005 CSM (ENSR 2005). The 70 LOUs are listed in Table B-1 of Appendix B to this Work Plan and the LOU locations are shown on Figure B-1.

In 1996, KMCC and the other parties at the BMI Complex entered into a Consent Agreement with NDEP to perform a Phase II Environmental Conditions Assessment and to conduct Remedial Alternative Studies (RAS), Interim Measures, or Additional Work (NDEP 1996). KMCC collected additional data in 1996 and 1997 as part of a Phase II Environmental Conditions Assessment (ENSR 1997) that addressed 12 LOUs identified for additional soil and groundwater characterization in the Phase II Work Plan (KMCC 1997).

In late 1997, perchlorate contamination was discovered in Las Vegas Wash and determined to have originated from the KMCC and former Pacific Engineering and Production Company of Nevada (PEPCON) facilities (NDEP 2011a). KMCC undertook a characterization study to identify the subsurface pathway(s) and characterize perchlorate concentrations in shallow groundwater downgradient of the Site to the Athens Road area in Henderson (about one-mile south of Las Vegas Wash) (KMCC 1997). KMCC installed extraction wells in the Athens Road area in September 1998 to remove perchlorate-bearing shallow groundwater (KMCC 1998a).

By late 1999, a water collection system and temporary ion exchange (IX) treatment process for perchlorate removal was installed at the Las Vegas Wash and began operating as a result of a 1999 Consent Agreement between KMCC and NDEP which defined initial removal requirements (NDEP 1999). Additional interceptor wells were installed in 1998 and early 1999 for continued capture of on-site groundwater for removal of hexavalent chromium (ENSR 2005). These interceptor wells, in combination with the interceptor wells installed in 1987 as a result of the 1986 Consent Order, continued to capture on-site groundwater for removal of hexavalent chromium; however, instead of re-injecting the treated groundwater, the treated water was impounded in a lined pond (GW-11, constructed in late 1998) and held for additional treatment for perchlorate.[12] Untreated Lake Mead water was reinjected into the groundwater system via the recharge trenches (NDEP 2011a).

Between 1999 and 2001, KMCC conducted a supplemental Phase II Environmental Conditions Assessment, the results of which were submitted to NDEP in April 2001 (ENSR 2001). In comments on the Supplemental Phase II Environmental Conditions Assessment report on February 11, 2004, NDEP (2004) required additional work to investigate and characterize the Site. Specifically, NDEP emphasized the importance of developing a CSM to identify all Site-related chemicals (SRCs), data gaps, and delineate the extent of groundwater contamination.

In 2001, an Administrative Order on Consent (AOC) (NDEP 2001) defined additional removal requirements that included a low-permeability barrier wall with an upgradient collection (interceptor) well field, the construction of the Athens Road groundwater collection well field, the construction of the seep area collection well field, and the development of a treatment process that removes chromium and perchlorate from the collected water and then discharges the water within limits set forth in an existing NPDES permit. The effectiveness of these systems at removing contaminant mass, reducing groundwater concentrations, and reducing contaminant mass flux into Las Vegas Wash is presented in annual and semi-annual monitoring reports (e.g., ENVIRON 2013b).

In response to this order, KMCC constructed a groundwater barrier wall along the downgradient side of the interceptor well line and installed additional groundwater extraction wells along the Athens Road Area and in the seep well field (SWF) area to enhance the recovery of perchlorate-contaminated groundwater. KMCC also constructed a biological fluidized-bed reactor (FBR) treatment system designed to remove perchlorate from recovered groundwater.

In 2005, an AOC (NDEP 2005) between NDEP and KMCC established a compliance schedule for treatment of the perchlorate residues of Pond AP-5 designed to reduce the amount of perchlorate in groundwater and surface water reaching the Las Vegas Wash and Lake Mead.

[12] NDEP (2011a) and other historical documents refer to GW-11 as an 11-acre pond. Recent review of available design drawings and topographic maps indicates the pond is approximately 14.8 acres at the top of the liner, and approximately 10.4 acres at the toe of the berm at the bottom of the pond.

Additionally, in 2005 as a follow up to the Phase I and Phase II activities completed by KMCC, a CSM report was prepared for the Site that integrated information from the soil and groundwater investigations conducted to date to document information on Site-specific sources, release mechanisms, transport pathways, exposure routes, and potential receptors (ENSR 2005). The 70 LOUs were subdivided into common potential contaminant groups for discussion. For reference, Appendix B includes a figure showing the locations of all LOUs (Figure B-1) and a comprehensive table (Table B-1) listing the LOUs, LOU name, and the soil and soil gas work plans and investigations and HRAs conducted for the individual LOUs through October 2013.

The 2005 CSM identified several data gaps related to soil characterization, including:

- Identification of background concentrations of metals and other naturally occurring chemicals of potential concern (COPCs) in the local area.
- Identification of other COPCs.
- Evaluation of historic data for usability for risk assessment purposes.
- Preparation of a risk assessment to evaluate risks posed by the Site to human receptors.

3.2 Regulatory Actions and Investigations: 2005 to Present

Site investigations conducted since completion of the 2005 CSM have included the Phase A and Phase B Source Area Investigations (Phase A and Phase B investigations) to further characterize soil, groundwater, and soil gas across the Site as described in the following sections. An indoor air study was also conducted at the operating Tronox facility to evaluate uncertainties in vapor intrusion models used in a soil gas health risk assessment.

3.2.1 Soil

The objectives of the Phase A and B investigations were to refine the 2005 CSM, further characterize site conditions, and provide data for future risk assessments. To identify and characterize the distribution of SRCs in soils, the investigation focused on soil conditions associated with the 192 SRCs identified in the 2005 CSM report and their suspected source areas. A total of 127 soil samples were collected from 27 suspected source area locations in November and December of 2007. The sample locations were selected based on results from past site investigations (ENSR 2005), information on chemical use at the Site, and the 70 LOU study areas identified by NDEP in 1994. In addition to the 192 SRCs previously identified, 44 additional parameters were analyzed and reported by the laboratory.

During the Phase A investigation, soil samples were collected at depths of 0.5 to 1 ft, and at 10-ft intervals thereafter, until groundwater was encountered (ENSR 2006). The samples were analyzed for metals; volatile organic compounds (VOCs), including fuel oxygenates; semivolatile organic compounds (SVOCs); polychlorinated biphenyls (PCBs); dioxins and furans; total petroleum hydrocarbons (TPH as gasoline, diesel, and oil range organics [GRO, DRO, and ORO]); organochlorine herbicides (OCHs); organochlorine pesticides (OCPs); and organophosphate pesticides (OPPs). In addition, analyses were conducted for radionuclides, asbestos (surface soil samples only), and wet chemistry constituents. Not all samples were analyzed for all analytes, and at some locations, samples were collected at more frequent depth intervals. In addition, samples were collected from the manganese ore and tailings stockpile for analysis of metals and radionuclides, and two near surface (1.5 to 3 ft bgs) soil samples were collected and analyzed for physical and geotechnical parameters.

The objective of the Phase B investigation was to further characterize and evaluate the LOUs in the Facility Area and their potential impact on soil conditions across the Facility Area, based on the results of the Phase A investigation. For the Phase B investigation, the Facility Area was subdivided into four areas for investigation activities: Areas I, II, III, and IV. Table B.1 (Appendix B) identifies the LOUs within the four investigation areas. Separate work plans describing the Area-specific scope of work were prepared as follows: Area I Work Plan (ENSR 2008b, approved by NDEP on May 6, 2008); Area II Work Plan (ENSR 2008c, approved by NDEP on July 21, 2008); Area III Work Plan (ENSR 2008e, approved by NDEP on July 21, 2008); and Area IV Work Plan (ENSR 2008d, approved by NDEP on June 18, 2008). In addition, a revised investigation work plan was prepared that was applicable to the four Investigation Areas (AECOM, Inc. [AECOM] 2008, approved by NDEP on January 16, 2009).

During the Phase B investigation, samples were collected at initial soil depths of 0.5 and 10 ft bgs, the capillary fringe, and the midpoint between the capillary fringe and 10 ft bgs, without exceeding 20 ft between each vertical sample (AECOM 2008). Judgmental samples were collected at 0.5 ft and 10 ft bgs in locations where certain surface features were noted, including minor stains or above ground pipelines.

The number of soil borings and samples varied across the investigation areas, as follows:

- **Area I:** 6,493 environmental samples and 1,369 field quality control (QC) samples were collected from 65 borings (Northgate 2010a).
- **Area II:** 7,697 environmental and 1,719 field QC samples were collected from 86 borings (Northgate 2010b).
- **Area III:** 2,990 environmental and 676 field QC samples were collected from 33 borings (Northgate 2010c).
- **Area IV:** 5,999 environmental and 1,266 field QC samples were collected from 54 borings (Northgate 2010e).

During the Phase B investigation, soil samples were analyzed for the following analytical groups and analytes: metals, VOCs, SVOCs, organic acids, PCBs and PCB congeners, dioxin/furans, OCPs, OPPs, TPH, chlorate, perchlorate, cyanide, hexavalent chromium, formaldehyde, and radionuclides. In addition, based on the findings of the Phase A investigation, samples were collected from 0 to 2 inches bgs and analyzed for asbestos fibers, and samples collected from 0 to 0.5 ft bgs were analyzed for dioxin/furans. Samples for wet chemistry and geotechnical parameters were also collected (Northgate 2010a,b,c,e).

Supplemental sampling of shallow soils was conducted in December 2009 in accordance with two Tronox memoranda, Scope for Additional Sampling of Area I and Area II (approved by NDEP on November 24, 2009 and December 14, 2009, respectively). A total of 129 soil samples were collected at Phase B locations where contaminants exceeded Nevada Basic

Comparison Levels (BCLs) to provide information for remediation planning and supplement post-excavation confirmation sampling (Neptune and Company 2010).

The results of the Phase A and B investigations identified a number of constituents within the upper 10 ft of soil with reported concentrations in excess of NDEP worker BCLs or modified risk-based goals (as agreed upon by NDEP), which are collectively referred to as “soil remediation goals” (SRGs). These constituents included metals; SVOCs, including hexachlorobenzene (HCB); PCBs; OCPs; dioxin toxic equivalents (TEQs), asbestos, and perchlorate.

Interim soil removal actions were conducted in Areas I through IV based on the results of the Phase A and B investigations, as described in Section 4. The SRGs utilized during the interim soil removal actions are described and listed Appendix C.

3.2.2 Soil Gas

The Phase B soil gas investigation involved collection of 75 soil gas samples across the Facility Area in May 2008. Details of the soil gas sampling are provided in the *Phase B Source Area Investigation Soil Gas Survey Work Plan* (Soil Gas Work Plan; ENSR 2008a, approved by NDEP in March 2008) and summarized in the draft *Site-wide Soil Gas Health Risk Assessment* (Soil Gas HRA) (Northgate 2010r). Soil gas sample locations were based on the following: (1) results of the Phase A investigation (ENSR 2007c), which identified the presence of several VOCs in soil and/or groundwater samples collected at the Site; (2) historic soil and groundwater data collected during prior investigations; and (3) an assessment of former chemical usage at the individual LOUs (18 LOUs were identified as potential sources of VOCs or in areas where VOCs had been detected in soil or groundwater)[13].

The objective of the soil gas survey was to evaluate the nature and extent of VOCs in soil gas in potential VOC source areas. From a review of historic information and Phase A investigation results, the following areas were identified in the Soil Gas Work Plan as potential sources of VOCs or areas where VOCs were detected in soil and/or groundwater (ENSR 2008a):

- Former Hardesty Chemical Company site (LOU 4)
- On-site portion of the Beta Ditch, including small diversion ditches (LOU 5)
- Old P-2, Old P-3, and New P-2 Ponds, and Ponds S-1 and P-1 (LOUs 7, 8, 9, 13, and 14)
- Ponds AP-1 through AP-5 (LOUs 16, 17, 18, and 19)
- Former Truck Emptying/Dumping Site (LOU 35)
- Satellite Accumulation Point/AP Maintenance Shop (LOU 39)

[13] A plume sourced at a neighboring property and carrying VOCs, non-aqueous phase liquid (NAPL), and other contaminants enters the site along the western boundary. The NAPL and COPCs in the dissolved phase are expected to affect soil gas. This area was not adequately sampled during the 2008 soil gas investigation. Additional soil gas samples were collected in this area, as described in *Soil Gas Investigation Report and Health Risk Assessment for Parcels C, D, F, G and H, Revision 0* (ENVIRON 2013a).

- Unit 4 Basement and Old Sodium Chlorate Plant Decommissioning (LOU 43)
- Diesel Storage Tank Area (LOU 45)
- AP Plant Area Change House/Laboratory Septic Tank (LOU 54)
- Acid Drain System (LOU 60)
- Former State Industries, including impoundments and catch basin (LOU 62)

A total of seventy-five soil gas samples were collected throughout the Facility Area, with one of these samples collected in Parcel E. Samples were collected at 5 ft bgs, with the exception of 4 samples collected in the vicinity of Unit 3, Unit 5, and Unit 6 at 20 ft bgs (SG-36, SG-37, SG-38, and SG-41) (Northgate 2010r). In a July 18, 2007 conference call (NDEP 2007a), NDEP and Tronox agreed that deeper soil gas samples would be collected from areas with higher chemical concentrations in groundwater, as well as from less impacted areas. Further, as specified in NDEP's March 26, 2008 approval (NDEP 2008b) of ENSR's *Phase B Source Area Investigation – Soil Gas Survey Work Plan* (ENSR 2008a), NDEP stated that samples in the vicinity of Unit 3 should be collected below the depth of the Unit 3 basement, which was occupied with engineering staff (Northgate 2010r). Based on these discussions, 20 ft bgs samples were collected as follows: SG-41, near Unit 3; SG-36, near an area of higher chloroform concentrations in groundwater (ENSR 2008a); and SG-37 and SG-38, near areas with relatively lower chloroform concentrations in groundwater (ENSR 2008a).

Results of the investigation indicated that chloroform, trichloroethene (TCE), chlorobenzene, carbon tetrachloride, and trichlorofluoromethane were detected at elevated concentrations in soil gas beneath the Site. Elevated concentrations of VOCs in soil gas appeared to be localized within specific areas, such as the western area, Unit 4, the Old P-3 Pond, Pond S-1, the former truck emptying/dumping site, the ammonium perchlorate laboratory building and former satellite accumulation point, and the former State Industries catch basin. Analytical results for samples collected during the soil gas survey were presented in a DVSR (ENSR 2008g) that was submitted to NDEP on October 13, 2008 and approved by NDEP on October 20, 2008.

The draft Soil Gas Health Risk Assessment (HRA) is summarized in Section 4.2.

3.2.3 Indoor Air

To assess the potential uncertainty associated with use of vapor intrusion models in the draft Soil Gas HRA, an indoor air quality study was conducted at the operating Tronox facility in 2010. The first round of indoor and outdoor air samples were collected at several locations throughout the facility in May 2010 (Northgate 2010o) and analyzed for chloroform, carbon tetrachloride, and TCE. The sampling results were presented in the *Spring 2010 Indoor Air Quality Sampling and Analysis Report* (Northgate 2010o, approved by NDEP on November 1, 2010). Chloroform and carbon tetrachloride were detected in all but one indoor air sample and all outdoor air samples. TCE was detected in all indoor air samples and some outdoor air samples; however, the detection limits in the outdoor samples were elevated due to sampling conditions (Northgate 2010o).

A second round of indoor and outdoor air sampling was performed in December 2010. The objective of the additional round of sampling was to identify the seasonal meteorological variations and the potential difference in the building operations and activities, and to collect additional data to supplement the indoor air modeling efforts and the uncertainty evaluation in the draft Soil Gas HRA. The sampling results were presented in the *December 2010 Indoor Air Quality Sampling and Analysis Report* (Northgate 2011a, approved by NDEP on March 21, 2011). A total of 32 indoor and 18 outdoor air samples were collected at the Tronox facility in Spring and December 2010. The samples were analyzed for three target analytes: chloroform, carbon tetrachloride, and TCE. Chloroform was detected in all but one indoor air sample and in all outdoor air samples, and carbon tetrachloride was detected in all but one indoor and one outdoor air sample. TCE was detected in approximately 80 percent of the samples. Northgate (2011a) reported that the maximum and mean indoor concentrations of the target analytes were significantly below their respective occupational exposure levels (specifically, Threshold Limit Values [TLVs]), and that mean indoor air concentrations were below risk-based commercial air concentrations corresponding to a 1×10^{-5} risk level. (It is noted that the NDEP point of departure for exposure to chemicals in indoor air resulting from Site-related releases is 1×10^{-6}.)

The results of the December 2010 indoor and outdoor air monitoring indicated that in general, the indoor chloroform concentrations were higher than ambient levels. However, based on the draft Soil Gas HRA, the modeled soil gas and groundwater chloroform concentrations do not entirely explain the measured indoor air concentrations, as the measured chloroform results are generally higher than the modeled values. Northgate (2011a) reported that the measured chloroform concentrations were below occupational levels and below the 1×10^{-5} risk level. (The NDEP point of departure for risk due to soil gas is 1×10^{-6}.)

3.2.4 Groundwater

As previously described for soils, in 2005, as a follow up to the Phase I and Phase II activities completed by KMCC, a CSM Report was prepared for the Site that integrated information from the soil and groundwater investigations conducted to date to document information on site-specific sources, release mechanisms, transport pathways, exposure routes, and potential receptors (ENSR 2005).

As described in the 2005 CSM, based on the results of the groundwater investigations conducted during the 1980s, the initial focus of the on-site groundwater remediation was containment and treatment of hexavalent chromium in shallow groundwater. Remediation of hexavalent chromium began in mid-1987, when four extraction wells were installed downgradient of the ammonium perchlorate plant.

In mid-1997, analytical methods were developed to detect low perchlorate concentrations (down to 0.004 milligrams per liter (parts per million) [mg/L]) and governmental and regulatory concern increased regarding health hazards of perchlorate in drinking water. Perchlorate was subsequently discovered in the Colorado River and traced upstream to Henderson and the location of two ammonium perchlorate manufacturing facilities, one of which was the Site. The other facility (American Pacific Corporation [AMPAC], formerly Pacific Engineering and Production Company of Nevada [PEPCON]) is located approximately 1.5 miles southwest of the Site.

In late 1997, KMCC undertook a perchlorate characterization study to determine the subsurface pathway(s) and the perchlorate concentrations in shallow groundwater downgradient from the Site to its discharge in Las Vegas Wash. Between March and June 1998, soil borings and monitoring wells were drilled and installed and the subsurface data was mapped and analyzed. The investigation results were presented in the Phase II Perchlorate Investigation Report (KMCC 1998a).

An outcome of this groundwater investigation report indicated that the perchlorate was generally confined to a Quaternary-age alluvial channel eroded into the underlying sediments. Subsurface mapping demonstrated that the deepest and best defined section of the channel lay beneath the Pittman Lateral (Athens Road) area, about one mile south of Las Vegas Wash. The north-trending perchlorate plume is displaced eastward from the main alluvial channel just north of the Site by a high total dissolved solids (TDS) plume that converges from the west and preferentially occupies the western part of the channel. The perchlorate plume eventually begins to merge and mix with the higher TDS plume at, and downgradient from, the Pittman Lateral. The Phase II investigation results provided the basis for installation of the first extraction well (PC-70) at the AWF in September 1998.

In the spring of 1999, hydrologists with the Southern Nevada Water Authority discovered a perchlorate-impacted seep on-trend with the buried alluvial channel, discharging into Las Vegas Wash. At the time of discovery, the seep was flowing at about 400 gallons per minute (gpm) and contained over 100 mg/L perchlorate. This led to another phase of off-site monitoring well installation, sampling, and groundwater characterization between March and September 2000. These results were presented in the *Seep Area Groundwater Characterization Report* (KMCC 2001). The report documented that groundwater was traveling at an average of 35 feet per day between Athens Road (now Galleria Drive) and the seep; that there were no other major downgradient sources of perchlorate along Las Vegas Wash; and that the entire saturated thickness of the alluvial channel contained perchlorate at varying concentrations.

Between 2001 and 2004, the SWF and the AWF were installed to mitigate perchlorate impacts. The on-site IWF was expanded in between 1998 and 2003 to include additional extraction wells to further address perchlorate and chromium impacts. In 2001, it was modified further by the addition of a groundwater barrier wall. The barrier wall was constructed along the downgradient side of the interceptor well line to a depth of 60 ft bgs.

The 2005 CSM identified several data gaps related to groundwater characterization, including:

- Background concentrations of metals and other naturally occurring COPCs in the local area.
- Configuration of the fine-grained facies of the Muddy Creek formation.
- Identification of other COPCs.
- Historic data need to be evaluated for their usability for human health and ecological risk assessment purposes.
- Risk assessment to evaluate risks posed by the Site to human and ecological receptors.

Investigations conducted since 2005 have addressed some of the identified data gaps related to groundwater characterization, as described below.

2006/2007 – Upgradient Investigation Results (ENSR). In March 2006, soil borings were drilled at six locations in the southern (upgradient) portion of the Site. Four of the borings were completed as 2-inch diameter monitoring wells (M-117, M-118, M-120, and M-121). The first saturated unit in this portion of the Site is the upper coarse-grained facies of the Muddy Creek Formation (UMCf-cg1). Wells M-120 and M-121 are about 100 feet deep and monitor the UMCf-cg1. Wells M-117 and M-118 are about 150 feet deep and monitor the lower fine-grained facies of the Muddy Creek Formation (UMCf-fg2). Groundwater samples were collected from the four new wells and six existing wells. The samples were analyzed for perchlorate, metals, VOCs including fuel oxygenates, TPH, pH, electrical conductivity (EC), alkalinity, carbonate, bicarbonate, water chemistry ions, and radionuclides. As part of the upgradient investigation, a comparison was performed to evaluate whether two sampling methods would yield significantly different analytical results. Two sets of groundwater samples were collected from nine of the wells, the first using bailers and the second using micro-purge sampling pumps. In general, the results yielded mixed results for metals and wet chemistry parameters. The results varied more for less soluble constituents than for the more highly soluble constituents.

In the wells sampled for this upgradient investigation, chromium was detected at concentrations up to 0.054 mg/L. None of the chromium detections were above the maximum contaminant level (MCL) for chromium of 0.1 mg/L. In shallow groundwater wells M-120 and M-121 at the southern (upgradient) Site boundary, perchlorate was detected at concentrations of 0.55 mg/L and 2 mg/L, respectively. These results indicate that perchlorate is migrating onto the Site from upgradient locations.

Soil samples collected during this investigation were analyzed for a broad suite of SRCs. The validated data were compared statistically to the City of Henderson (COH) and Basic Remediation Company (BRC)/TIMET background data (BRC/TIMET 2007) to assess whether they represented similar populations and could be combined for subsequent analyses. The statistical comparisons indicated that for arsenic and iron, the COH data set could be combined with the Site upgradient area data from depths of 20 feet or less. For calcium and lead, the BRC/TIMET data set could be combined with the Site upgradient area data from depths of 20 feet or less. For the radionuclides thorium-228, thorium-230, and uranium-235, the COH data set could be combined with the Site upgradient area data from depths up to 5 feet. For uranium-238, the BRC/TIMET data set could be combined with the Site upgradient area data from depths up to 5 feet. All other chemicals represented different populations and should not be combined for subsequent analyses (BRC/TIMET 2007).

2007-2009 – Phase A and Phase B Investigations. In conjunction with the soil samples collected during the Phase A and Phase B investigations described in Section 3.2.1, one-time groundwater samples were collected from many of the deeper soil borings. In addition, groundwater samples were collected from new and existing monitoring wells during several sampling events.

The objectives of the Phase A groundwater investigation were to (1) characterize SRCs in groundwater at 27 suspected source areas at the Site and (2) characterize groundwater chemistry upgradient and downgradient of the Site (ENSR 2006). As part of the Phase A investigation, groundwater samples were collected from 20 shallow groundwater monitoring wells and one groundwater interceptor well (I-AR), and groundwater grab samples were collected from open boreholes at 6 locations where nearby wells either did not exist or were not functional. The wells were sampled in November/December 2006 using micro-purge/low-flow sampling techniques. All groundwater samples were analyzed for inorganic compounds (metals and cyanide), fuel alcohols, OCPs, PCBs, radionuclides, OPPs, OCHs, VOCs and SVOCs. Of the 210 SRCs analyzed, 125 SRCs were not detected (ENSR 2007c).

The same 20 monitoring wells plus well M-98 were sampled again in May 2007 to assess the potential for analytical bias of metals and radionuclides in groundwater results based on high turbidity levels associated with sampling methodology. An addendum to the Phase A Work Plan was submitted on May 1, 2007 (ENSR 2007a, approved by NDEP the same day) to evaluate potential analytical bias in the results reported for metals and radionuclides for the November/December 2006 sampling. On two sampling events conducted in May 2007, three samples were collected from each of the 21 monitoring wells to assess the effect of turbidity on groundwater results for metals and radionuclides. Two unfiltered samples were collected from each well using two different low-flow rates to evaluate the effect of pump rates on turbidity levels, and a third sample was collected and field filtered to provide a baseline from which comparisons between filtered and unfiltered analytical results could be made (ENSR 2007a). Based on an evaluation of the results, and as reported in the NDEP approved Phase A investigation report, ENSR (2007c) concluded that analytical results appropriate for evaluation of metals and radionuclides in groundwater include the following:

- Unfiltered low-flow samples collected in May 2007.
- Filtered grab samples collected during the November/December 2006 sampling.
- For hexavalent chromium, results from all samples could be used (the analytical method employed for this constituent was essentially a filtered method).
- Analytical results for metals and radionuclides from the unfiltered water samples collected during the November/December 2006 sampling event were found to be biased high due to elevated turbidity levels and should be excluded (ENSR 2007c).

Fourteen new on-site monitoring wells were installed during the Phase B investigation and an extensive focused sampling program was conducted. As described in Section 3.2.1, Phase B work plans were developed for each of the four investigation areas (i.e., Areas I, II, III, and IV). The objective of the groundwater portion of the Phase B investigation was to characterize the presence of SRCs in specific LOU source areas. The locations of the new monitoring wells were selected to allow for further delineation of SRCs detected in Phase A investigation grab samples (ENSR 2007c).

Samples were collected from 109 existing and new groundwater monitoring wells in Areas I, II, III, and IV, and wells north (downgradient), east, and west of Area I. The groundwater samples were collected and analyzed in accordance with the *Revised Phase B Investigation Work Plan*

(AECOM 2008) and the *Revised Phase B Quality Assurance Project Plan* (AECOM-Northgate 2009). Samples were analyzed for metals, VOCs, SVOCs, PCBs, OCPs, OPPs, organic acids, perchlorate, hexavalent chromium, and total cyanide. In addition, analyses were conducted for radionuclides and wet chemistry constituents. Not all wells were sampled for all analytes. The Phase B sampling investigation resulted in 2,817 groundwater analyses and 746 field QC sample analyses. The validated data from this extensive groundwater sampling program is available for use in the RI to identify the COPCs in groundwater that will be evaluated further during the RI/FS process.

2008-2010 – Investigations in Support of Capture Zone Evaluations. In order to support an evaluation of the capture zones of the three well fields, field work consisting of well installation, geotechnical sampling, and well testing was performed in early 2008. A capture zone evaluation was submitted as Appendix B of the 2008 Annual Remedial Performance Report (ENSR 2008f). Additional drilling of two soil borings and completion of one recovery well (I-AB) at the west end of the barrier wall was proposed, and was completed in mid-2009. In response to NDEP comments, eight deeper UMCf monitoring wells were installed in September and October 2009 to evaluate the vertical extent of contaminant plumes and vertical head differences. The data collected from the new wells was incorporated into an interim evaluation of the capture zones established by operation of the IWF and the AWF (Northgate 2010f).

As proposed in the *Capture Zone Evaluation Work Plan* prepared by Northgate (2010i, approved by NDEP on May 24, 2010), an additional 41 new monitoring and recovery wells and 8 replacement monitoring wells were installed at the IWF and AWF during April-July 2010. Based on the new data and in response to NDEP comments, the *Capture Zone Evaluation (CZE) Report* provided an evaluation of the capture zones of all three well fields (Northgate 2010s). In Appendix E of the *CZE Report*, Northgate described a numerical groundwater flow model that was developed for use in evaluating capture zones. Although the *CZE Report* itself has not been approved by NDEP, this initial groundwater model was approved by NDEP on April 4, 2013 for use in capture zone evaluation.

As part of the 2013 Groundwater Extraction and Treatment System (GWETS) Optimization Project, which is described in more detail in Section 4.3.3, the initial groundwater model will be updated and revised and used to estimate capture zones and perform other analyses to support the optimization of the existing groundwater extraction system.

4.0 Interim Removal Actions and Health Risk Assessments

Sections 4.1 and 4.2 describe soil removal actions and HRAs conducted at the Facility Area. Section 4.3 describes on-site and downgradient groundwater removal actions performed previously and currently in place. Section 4.4 describes the current groundwater monitoring program.

Since the Trust assumed ownership of the Site in February 2011, all analytical data collected by ENVIRON and used for data analysis and decision making (except for FBR influent and effluent monitoring data) were validated in accordance with NDEP's data validation requirements at the time. This data includes monitoring well data, extraction well data, and soil data contained in a relational database maintained by ENVIRON. In addition, data compiled from NDEP's regional database[14] collected by neighboring properties has been used for analyzing off-site areas and historical data. It is our understanding that data from NDEP's regional database were validated according to NDEP guidance current at the time of sampling.

4.1 Interim Soil Removal Actions and Health Risk Assessments at the Facility Area

As previously described in Section 3.2.1, the results of the Phase A and B source investigations identified a number of constituents within the upper 10 ft of soil in excess of SRGs. On December 14, 2009, NDEP issued to Tronox a Finding of Alleged Violation and Order requiring Tronox to comply with the obligations pertaining to the Henderson facility under the various Consent Agreements previously issued for the Site, and setting forth a specified schedule for compliance (the "2009 Division Order") (NDEP 2009g). At a meeting on February 22, 2010, NDEP and Tronox discussed the conceptual scope and implementation of a soil remediation program to comply with the 2009 Division Order requiring the removal of all impacted soil from the Site by the end of 2010 to minimize potential health risks associated with the continued presence of contaminated soil. A detailed scope of work for the soil removal was presented in the *Removal Action Work Plan for Phase B Soil Remediation of Remediation Zones RZ-B through RZ-E* (the "RAW") (Northgate 2010j, approved by NDEP on August 20, 2010).

For purposes of soil excavation activities, the main contaminated portions of the Site were divided into five separate remediation zones (RZs) roughly based on geographic groupings of elevated detections of contaminants and CSM considerations (Northgate 2010g). The RZs are listed below:

- RZ-A: the area on the southern portion of the Site
- RZ-B: the area around the Units
- RZ-C: the ammonium perchlorate production area, Koch Materials area, pond and diesel storage tank area, and manganese tailings area
- RZ-D: the former Trade Effluent ponds and ammonium perchlorate pad/drum recycling area (including the former hazardous waste landfill)

[14] The NDEP regional database is available at: http://ndep.neptuneinc.org/ndep_gisdt/home/index.xml.

- RZ-E: the Beta Ditch

For RZ-A, the results of a soil HRA (Northgate 2010k, approved by NDEP on August 20, 2010) indicated that exposures to residual chemicals in the upper 10 ft of soil in RZ-A were below NDEP's point of departure for noncancer effects (hazard index [HI] of 1) and cancer risks (1×10^{-6}) for indoor commercial workers, outdoor commercial/industrial workers, and construction workers. The upper-bound estimated risks for death from lung cancer or mesothelioma for asbestos exposures to outdoor commercial/industrial workers were less than or equal to 1×10^{-6} for chrysotile and amphibole fibers. The best estimate and upper-bound estimates for asbestos exposures to construction workers were less than or equal to 1×10^{-6} for chrysotile fibers and ranged from zero to 6×10^{-5} for amphibole fibers. Since the risks estimated from asbestos exposures were evaluated based on constant lifetime exposures, not short-term exposures such as construction activities, the results indicate that exposures to asbestos in soil should not result in unacceptable risks for the aforementioned receptors. Based on HRA results, RZ-A was not included in the removal program (Northgate 2010k).

For RZ-B through RZ-E, Voronoi/Thiessen polygons were generated for each RZ to define areas with SRG exceedances (Northgate 2010j). The general remediation strategy consisted of excavation of soils within designated polygons, sampling of discolored soil, removal of discolored soil if above SRGs or otherwise deemed appropriate to remove, and designation of Excavation Control Areas (ECAs) for inaccessible areas, including areas with COPCs and/or discolored soil left in place.

To further define the polygons of areas identified for excavation, pre-confirmation sampling was conducted in Spring 2010 in accordance with a pre-confirmation sampling work plan (Northgate 2010g, approved by NDEP on March 30, 2010). Two types of borings were advanced during the pre-confirmation sampling program, including (1) 84 borings at existing locations (adjacent to Phase A and B sampling locations) and (2) 91 borings at new locations. Data from "existing locations" were used to establish polygon depths, while data from "new locations" were used to define the horizontal extent and vertical delineation of excavation of near-surface soils (0 to 10 ft bgs). Results from the Phase A, Phase B, and pre-confirmation sampling events are presented in Appendix A of the Excavation Plans for Phase B Soil Remediation for each RZ (RZ-B, Northgate 2010l; RZ-C, Northgate 2010n; RZ-D, Northgate 2010p; and RZ-E, Northgate 2010q).

Discolored soil was encountered in various locations during removal activities. Based on the location of the discolored soil, available nearby analytical results, the anticipated extent of discolored soil, and the excavation activities currently in progress, some areas of discolored soil were removed. Other areas of discolored soil were sampled and evaluated to determine if the soil should be removed or left in place in accordance with the *Work Plan for Evaluation of Discolored Soil and Confirmation Soil Sampling in Visually-Impacted Areas* (ENVIRON 2011b, approved by NDEP on May 12, 2011). Following the removal of discolored soil, confirmation soil samples were collected to verify that remaining COPC soil concentrations were below SRGs. If the analytical results indicated that concentrations were above SRGs, additional soil was typically removed and additional confirmation soil sampling performed.

As presented in Northgate's Manganese Tailings Removal Technical Memorandum (Northgate 2012) approved by NDEP February 21, 2013, the manganese tailings pile area removal actions were initiated on April 29, 2010 and completed on July 19, 2010. The manganese tailings pile area, located north of the Manganese Leach Plant and south of Mn-1 Pond (Figure 2-3), is approximately 8.6 acres in size and was used from 1975 through 2004 for the disposal of manganese tailings from the leach plant process which included the leach beds (the historic manganese tails). This material is a non-hazardous solid waste product generated in the production of electrolytic-grade manganese dioxide. Manganese tailings material from all locations at the Site were consolidated to this location and covered with soil sometime prior to 1985. The tailings pile was periodically graded to maintain the desired shape and drainage. Since 2004, manganese tailings from the Tronox operations (current tailings production) have been shipped to an appropriate off-site landfill.

A total of 284,232 tons of tailings and minor debris were removed from the manganese tailings pile. In accordance with a request by the NDEP, a confirmation sampling program was implemented subsequent to tailings removal. Based on the results of the confirmation sampling program, additional shallow soil excavation was conducted concurrent with Phase B soil remediation in accordance with the *Removal Action Work Plan* (Northgate 2010j), and the *Revised Excavation Plan for Phase B Soil Remediation of RZ-C Addendum to the Remedial Action Work Plan* (Northgate 2010n). The post-confirmation sampling excavation was conducted to address soil that contained concentrations of manganese, arsenic, cobalt, and/or asbestos that exceeded screening criteria.

The removal activities and post-removal conditions at the Site are described in detail in the *Revised Interim Soil Removal Action Completion Report* (ENVIRON 2012e), submitted to NDEP on September 28, 2012 and approved by NDEP on December 17, 2012 (NDEP 2012c). Post-removal soil conditions are described in Section 5.1.3.

4.2 Site-wide Health Risk Assessment for Soil Gas

The soil gas sampling results and data usability evaluation were also presented in the draft Soil Gas HRA (Northgate 2010r). The objective of the draft Soil Gas HRA was to evaluate the potential for adverse health impacts associated with potential exposure by future indoor commercial workers to chemicals in soil gas that may migrate to indoor and outdoor air. As described in the draft Soil Gas HRA, 65 of the 71 VOCs analyzed were detected in one or more samples during the Phase B soil gas survey. Based on a multi-step COPC selection process, including toxicity screen evaluation, frequency of detection, and CSM considerations, eight VOCs (benzene, bromodichloromethane, carbon tetrachloride, chloroform, hexachlorobutadiene, naphthalene, tetrachloroethene [PCE], and TCE) detected in soil gas were retained as COPCs for quantitative evaluation in the HRA.

For the HRA, the migration of COPCs in soil gas from the subsurface to indoor air was estimated using the USEPA vapor intrusion model (2004a) based on Johnson and Ettinger (1991). Cancer risks and hazard indices were quantified on a sample-by-sample basis. Non-cancer hazard indices associated with inhalation of vapors in indoor and outdoor air and theoretical excess cancer risks associated with inhalation of vapors in outdoor air were below NDEP's point of departure for indoor and outdoor commercial workers. Theoretical excess cancer risks associated with inhalation of vapors in indoor air under hypothetical future site conditions range from 2×10^{-9} (SG94, located in RZ-C) to 1×10^{-4} (SG32, also located in RZ-C). The results of the draft Soil Gas HRA indicate that at most locations evaluated, chloroform contributes up to 99% of the overall cancer risk from inhalation of vapors in indoor air, with carbon tetrachloride the only other VOC for which a cancer risk was above 1×10^{-5}. None of the other COPCs had cancer risk estimates greater than 1×10^{-6} (Northgate 2010r). NDEP has not reviewed or approved the Soil Gas HRA.

4.3 Interim Groundwater Removal Actions

The following subsections describe on-site and downgradient groundwater removal actions performed previously (Section 4.3.1) and those that are currently in place (Section 4.3.2).

4.3.1 Historical Groundwater Removal Actions

Groundwater remediation has been conducted at the Site dating back to the mid-1980s. This subsection summarizes historical groundwater removal actions conducted at the Site to address chromium (Section 4.3.1.1) and perchlorate (Section 4.3.1.2).

4.3.1.1 Chromium Removal and the Interceptor Well Field

A groundwater investigation was initiated by KMCC in July 1981 to comply with federal RCRA standards associated with certain on-site impoundments. This investigation involved the installation of nine monitoring wells and identified elevated chromium concentrations in groundwater underlying the Site. In 1986, KMCC and NDEP entered into a Consent Order, which required additional groundwater characterization activities and the implementation of removal activities to address elevated concentrations of chromium in groundwater (NDEP 1986). Pursuant to the Consent Order, KMCC installed an additional 43 monitoring wells and a groundwater interceptor well field (the IWF) consisting of 11 groundwater extraction wells (I-A[15] through I-K) in the shallow WBZ in late 1986 (ENSR 2005).

The 11 extraction wells initially were capable of producing a cumulative extraction rate of approximately 100 gpm; however, this level of extraction was not sustainable over the long term (see additional discussion below). The extracted groundwater was conveyed to a chromium treatment facility (called the Groundwater Treatment Plant or “GWTP”), constructed in 1986-87 along with the IWF, where hexavalent chromium was electrolytically reduced to trivalent chromium and then co-precipitated with iron oxide. The treated water was subsequently re-injected through two parallel recharge trenches located approximately 250 feet downgradient (north) of the IWF line of wells. The IWF, which still operates at the Site in an expanded configuration, is located in the central portion of the Site, approximately 2,400 feet north and downgradient of the central process area of the Site. From initiation of removal activities through 1993, the IWF and GWTP had captured and treated over 200 million gallons of groundwater and removed an estimated 8,500 pounds of chromium from the environment (ENSR 2005).

[15] Interceptor well I-A has since been plugged and abandoned.

Over the course of the next several years, additional groundwater monitoring wells were installed to evaluate the effectiveness of the IWF, GWTP and recharge trenches. Between 1986 and 1993 approximately 47 additional monitoring wells were installed at the Site. All of these wells were installed in the Shallow WBZ, some being entirely screened within the Qal, some being screened within the transition to the UMCf, and some entirely within the UMCf.

Evaluations of Site conditions in 1991 and 1993 concluded that the extensive dewatering of the Qal in the vicinity of the IWF and the localized groundwater flow in discrete channels in the UMCf were contributing to a decline in recovery volumes (ENSR 2005). Based on these findings, KMCC installed four additional extraction wells in 1993 (I-L, I-M, I-N, and I-O) to improve capture in the discrete channel flow areas. Over the next several years, additional extraction wells were installed as part of continued efforts to increase groundwater capture at the IWF. Two extraction wells (I-P and I-Q) were installed in 1998; five more wells (I-R, I-S, I-T, I-U, and I-V) were installed in early 1999; and a large diameter well (I-AR) located upgradient of the IWF was installed in April 2000. To further enhance groundwater capture, a bentonite-slurry barrier wall (the “barrier wall”) was installed on the downgradient side of the IWF in 2001. The barrier wall, which is still in place, is approximately 1,600 feet in length and 60 feet deep and constructed to tie vertically into the uppermost 30 feet of the UMCf. By November 2001, cumulative extraction from the IWF had increased from approximately 23 gpm to over 50 gpm.

4.3.1.2 Perchlorate Removal and the Athens Road and Seep Well Fields

In 1997, elevated concentrations of perchlorate were detected in the Colorado River, the source of which was ultimately traced to the Site and another ammonium perchlorate manufacturing facility in Henderson. Groundwater perchlorate investigations completed in 1997 and 1998 identified perchlorate concentrations ranging from 1,500 mg/L at the northern Site boundary to around 100 mg/L between the City of Henderson former Rapid Infiltration Basins (RIBs) and the Las Vegas Wash (ENSR 2005). The investigations concluded that Quaternary-age alluvial channels eroded into the underlying sediments were significant transport pathways for downgradient perchlorate migration. Subsurface mapping indicated that the deepest and best defined section of the channel believed primarily responsible for transport of perchlorate from the Site lay beneath the Pittman Lateral area at Athens Road (now Galleria Drive) about one mile south of Las Vegas Wash (ENSR 2005). As an interim measure to address the perchlorate plume, a Shallow WBZ extraction well (PC-70) was installed at Athens Road (approximately 8,200 feet north of the barrier wall and the IWF) in September 1998. Groundwater extracted from this extraction well, as well as groundwater extracted from the IWF, was routed to the GW-11 Pond, which commenced operation in late 1998. The extracted groundwater was held in GW-11 until the current perchlorate treatment system could be implemented.

In Spring 1999, hydrologists with the Southern Nevada Water Authority discovered an approximately 400 gpm seep discharging into Las Vegas Wash that contained over 100 mg/L of perchlorate. Following investigation of this seep, KMCC entered into a Consent Agreement with NDEP (dated July 26, 1999) to initiate removal measures to intercept and treat the seep discharge. Later in 1999, a seep capture sump and temporary single-use resin ion exchange (IX) system were installed near the Las Vegas Wash to capture and treat the water discharged from the seep. After additional investigation of the seep was completed, in 2001 KMCC constructed four extraction wells in the seep vicinity (PC-99R2, PC-99R3, PC-115, and PC-

116)[16], from which extracted groundwater was treated by the temporary IX system near the wash and later also by a second temporary single-use resin IX system located on-site. The pumping from these additional wells began in July 2002.

Another AOC, entered into by KMCC and NDEP on October 8, 2001, further defined removal requirements necessary to address the perchlorate contamination. Pursuant to this AOC, KMCC commenced construction of the existing off-site AWF, the off-site SWF, and an on-site perchlorate treatment system.

The AWF was initially constructed as a series of 15 groundwater extraction wells screened in the Qal at seven paired well locations (with one standalone well) that span approximately 1,200 feet across two alluvial paleochannels located on either side of an UMCf ridge. Construction of the AWF was completed in March 2002[17] and continuous pumping began in mid-October of that year. The well pairs act in concert with one well pumping while the adjacent well (the so called “buddy” well) is used to measure water levels and monitor the effect of pumping on the aquifer. In September 2006, another standalone well screened deeper into the alluvial channel on the east side of the AWF, ART-9, began full-time operation replacing ART-6A after groundwater elevations at the AWF dropped below a level where ART-6/6A could be effective.

The SWF is located approximately 4,500 feet north (downgradient) of the AWF near the Las Vegas Wash. As discussed above, when pumping began in July 2002, the SWF consisted of four extraction wells situated over the deepest part of the alluvial channel and a seep capture sump. Five additional wells (PC-117 to PC-121) were installed in February 2003 and an additional well (PC-133) was installed in December 2004 to complete the SWF.

With regard to the perchlorate treatment system, KMCC initially designed and constructed an 825 gpm regenerable resin IX (ISEP®/catalytic destruction process) treatment plant. Due to difficulties in commissioning the regenerable resin IX system, a temporary single-use resin IX system was placed in service on-site to supplement the seep area temporary IX system (ENSR 2005). The permanent on-site ISEP/catalytic destruction process treatment system eventually proved to be unworkable and was abandoned in favor of a biological treatment system employing FBR technology (ENSR 2005). Construction of a 1,000 gpm (peak flow) biological treatment plant was completed in early 2004. Optimization of the plant operations continued into the fourth quarter of 2004. The temporary IX system at Las Vegas Wash near the SWF was shut down in June 2004 and the on-site temporary IX system was shut down in the first quarter of 2004.

Pursuant to the April 12, 2005 AOC, an additional reactor was added to the FBR system in 2006 to manage the decommissioning of an on-site impoundment, the AP-5 pond, which contained

[16] PC-99R2 (a 6-inch diameter well) and PC-99R3 (an 8-inch diameter well) were combined into one extraction well. PC-115 and PC-116 (6-inch diameter wells) were subsequently replaced by PC-115R and PC-116R (8-inch diameter wells) to improve performance.

[17] Eight extraction wells (ART-1 through ART-8) were completed between October 2001 and January 2002 allowing pumping to begin from these wells in March 2002. Seven additional extraction wells (ART-1A, 2A, 3A, 4A, 6A, 7A, and 8A) were installed in February through March 2003. ART-5 does not have a buddy well.

high concentrations of perchlorate. In August 2006, pumping of AP-5 pond water to the on-site treatment system commenced as part of the decommissioning process. After initial dewatering of the AP-5 pond, stabilized Lake Mead water was periodically pumped to the pond to solubilize residual ammonium perchlorate in the pond solids. The last of these transfers occurred in December 2012. The resulting water was discharged to the treatment plant in batches via the GW-11 pond. Since the AP-5 pond pumping operation began in 2006, an estimated 1,176 tons of perchlorate were removed from the AP-5 pond and treated on-site.[18]

Since the discovery of perchlorate in on-site and downgradient groundwater in 1997-1998 to the full-scale treatment of perchlorate via the biological perchlorate reduction FBR plant in 2005, over 220 additional groundwater monitoring wells have been installed on-site and at downgradient locations by KMCC. Some of these groundwater wells, as well as those previously installed as part of the various chromium investigations, have been plugged and abandoned; however, the majority of wells remain part of the active groundwater monitoring well network for use in evaluating the performance of the groundwater removal actions. The current groundwater monitoring program utilizing these wells, and others installed after 2005, is discussed in Section 4.4.

4.3.2 Current Groundwater Removal Actions

Current operations at the Site include the continued operation of an on-site GWETS that removes hexavalent chromium and perchlorate from shallow groundwater beneath the Site and at downgradient locations along the existing contaminant plume. This section describes the current system (Section 4.3.2.1) and discusses its performance (Section 4.3.2.2).

4.3.2.1 Description of the Current Groundwater Extraction and Treatment System

The GWETS has been in place in essentially its current configuration since 2006. The GWETS operates by capturing groundwater from three extraction well fields and treating the captured groundwater via aboveground treatment facilities for subsequent discharge at the Las Vegas Wash. Perchlorate in extracted groundwater is treated in the on-site FBR process using ethanol as a carbon source. Chromium in extracted groundwater is treated via chemical reduction and precipitation using ferrous sulfate. A process flow diagram for the GWETS is included as Figure 4-1, and a location map covering the area from the Site to the Las Vegas Wash showing the primary components of the GWETS is included as Figure 4-2. Design specifications for the various pipelines and pumps used within the GWETS, including all extraction well pumps, are presented in Tables 4-1 and 4-2, respectively.

Groundwater is captured from a system of extraction wells installed into the Shallow WBZ at three strategic locations described previously in Section 4.3.1: (1) on-site at the IWF; (2) approximately 8,200 feet downgradient of the IWF at the AWF; and (3) approximately 4,500

[18] The estimate of perchlorate removed from AP-5 was calculated from monthly flow volumes to GW-11 from AP-5 and perchlorate data provided by Veolia Water North America (Veolia), for the period from September 2006 to June 2011. Data from GW-11 was used since it has received the water pumped from AP-5. Based on the monthly flow and concentration data, the mass of perchlorate was calculated for each month and was summed to obtain the estimate of 1,176 tons. A previous estimate of perchlorate removal from AP-5 found that a total of 1,295 tons were removed between 2006 and 2012 (Tronox 2010). This estimate was prepared by Northgate on behalf of Tronox and also reportedly used flow and concentration data, although the exact methodology is not known.

feet beyond the AWF near the Las Vegas Wash at the SWF. The locations of the three well fields are shown on Figure 4-2 in relation to other GWETS features.

The IWF currently consists of 23 active extraction wells[19] located immediately upgradient (south) of the vertical barrier wall constructed in 2001. The IWF pumps at a cumulative extraction rate of between 60 and 73 gpm (ENVIRON 2012c) and captures the highest concentrations of both chromium and perchlorate (as compared with the downgradient well fields). From May 2011 through June 2012, chromium concentrations in the IWF pumping wells ranged from 0.16 to 31 mg/L, while perchlorate concentrations ranged from 96 to 2,300 mg/L during this same time period (ENVIRON 2012c). The highest concentrations of chromium observed are in the middle of the IWF well line around I-T (28-31 mg/L during quarterly sampling from May 2011 through June 2012) and decrease to below 1.0 mg/L at the western end of the IWF and to 1.3 mg/L at I-K at the eastern end of the IWF over this same time period. Higher perchlorate concentrations are observed in two areas of the IWF: on the western side of the IWF around I-AR (2,100-2,300 mg/L during quarterly sampling from May 2011 through June 2012) and on the eastern side around I-U (1,600-1,900 mg/L over the same time period).

The AWF currently consists of 7 active extraction wells[20] screened in the alluvium that span approximately 1,200 feet across two alluvial paleochannels located on either side of an UMCf ridge. The AWF cumulatively pumps at a rate of between approximately 250 and 273 gpm (ENVIRON 2012c) and captures chromium and perchlorate at concentrations significantly lower than those observed at the IWF. From May 2011 through June 2012, chromium concentrations in the AWF pumping wells have ranged from below laboratory quantitation limits (0.00088-0.0020 mg/L) to 1.5 mg/L, while perchlorate concentrations have ranged from 1.3 to 420 mg/L during this same time period (ENVIRON 2012c). The highest concentrations of chromium are at the east side of the AWF well line around ART-9 (1.2-1.5 mg/L during quarterly sampling from May 2011 through June 2012) and decrease to below laboratory quantitation limits (0.00088-0.0020 mg/L) at the eastern end of the AWF at ART-1. Higher perchlorate concentrations are observed in two areas of the AWF: on the western side of the AWF around ART-4 (330-420 mg/L during monthly sampling from May 2011 through June 2012) and on the eastern side around ART-9 (300-330 mg/L during the same time period). The locations of ART-4 and ART-9 correspond with two alluvial sub-channels that intersect the AWF. It is believed that these channels represent primary transport pathways for contaminated groundwater from the Site.

[19] Seven additional extraction wells (I-AA, I-AB, I-AC, I-AD, I-W, I-X, and I-Y) were installed between December 2007 and June 2010 and connected to the IWF in 2010-2011; initial extraction from these wells has been implemented as part of the 2013 GWETS Optimization Project, as described in Section 4.3.3. The 2012 Annual Remedial Performance Report presented an evaluation of these new extraction wells and proposed a plan to operate these new wells (ENVIRON 2012c).

[20] In June/July 2010, additional groundwater wells were installed in the AWF including four large diameter monitoring wells that could be used as additional extraction wells (ART-7B, PC-148, PC-149, and PC-150). The 2012 Annual Remedial Performance Report presented an evaluation of these new wells and proposed a plan to operate them as extraction wells (ENVIRON 2012c). Startup of two of these wells (ART-7B and PC-150) is being performed under the 2013 GWETS Optimization Project, as described in Section 4.3.3.

The SWF consists of 10 wells[21] screened across the full thickness of the Qal at the deepest portion of an alluvial channel just south of the Las Vegas Wash. The SWF cumulatively pumps at a rate of between approximately 510 and 622 gpm (ENVIRON 2012c). Chromium concentrations in the SWF pumping wells are below laboratory quantitation limits (0.00088-0.0020 mg/L). Perchlorate concentrations in the SWF pumping wells from May 2011 through June 2012 ranged from 0.31 to 14 mg/L (ENVIRON 2012c). The highest perchlorate concentrations are generally observed in PC-99R2/R3 in the center of the SWF.

The two off-site well fields, the AWF and the SWF, are served by three lift stations that convey the captured groundwater to the aboveground treatment portions of the GWETS via underground pipelines. The locations of these lift stations and pipelines are shown on Figure 4-2. Lift Station 1, located at the Las Vegas Wash, conveys groundwater extracted by the SWF to Lift Station 2 located on Pabco Road just south of Galleria Drive (formerly Athens Road). Lift Station 3, located within the AWF well line along Galleria Drive, conveys groundwater extracted by the AWF to Lift Station 2. Lift Station 2 pumps the combined flows from Lift Stations 1 and 3 to the on-site equalization area for treatment. A small ferrous sulfate drip system is located at the AWF lift station (Lift Station 3) to treat the lower concentrations of chromium present in groundwater extracted by the AWF. Because the concentrations of total chromium within extraction wells at the SWF are well below the GWETS effluent discharge limitation of 0.1 mg/L (7-day average), groundwater extracted from the SWF is not treated specifically to remove chromium. However, based on FBR influent and effluent monitoring data some incidental chromium removal is achieved in the FBRs (ENVIRON 2013b).

The aboveground treatment system consists of two series-linked systems: (1) a hexavalent chromium treatment system that treats extracted groundwater from the IWF using ferrous sulfate to reduce hexavalent chromium to trivalent chromium, which is then removed from solution via chemical precipitation, and (2) the FBR process that treats extracted groundwater from the IWF, AWF, and SWF.[22] Effluent from the chromium treatment system, historically referred to as the GWTP, is pumped into an approximately 15-acre double-lined pond, referred to as GW-11,[23] where it is combined with water from the off-site well fields and acts as an equalization area. The current configuration of the GWTP has a reported design maximum capacity of 75 gpm at a maximum hexavalent chromium concentration of 15 mg/L. According to

[21] Two of the extraction wells at the SWF (PC-99R2 and 99R3) are connected and operate as one combined extraction well and are also sampled as one.

[22] The FBRs are part of a biological treatment system that includes five 33,000-gallon primary reactors, four 28,800-gallon secondary reactors, and ancillary systems. See Figure 4-1 for a process flow diagram. For brevity, the system as a whole is often referred to as the “FBRs” or the “FBR Plant”.

[23] GW-11 began operating as an equalization basin in March 2014 and also holds off-specification effluent and feed bypass during treatment system maintenance. Tetra Tech, Inc. (Tetra Tech) is conducting an evaluation of the long-term use of GW-11 as an equalization basin. The GW-11 pond has been referred to in historical documents as being approximately 11 acres in size. Recent review of available design drawings and topographic maps indicates the pond is approximately 14.8 acres at the top of the liner, and approximately 10.4 acres at the toe of the berm at the bottom of the pond.

original design drawings, the FBR design hydraulic flow is 1,000 gpm (at a contaminant loading of 1,893 equivalent pounds per day).[24]

From GW-11, the water moves through a series of tanks[25] prior to reaching activated carbon beds that remove organic compounds. The water is then filtered and pumped to the FBRs for removal of perchlorate, chlorate, and nitrate.[26] Chromium that is precipitated out of solution from the AWF (via the ferrous sulfate drip in Lift Station 3) is retained in activated carbon beds and subsequently backwashed into the GW-11 pond using stabilized Lake Mead water. During backwash events, the carbon remains in the vessels and is reused until the absorptive capacity of the carbon is ultimately spent. The effluent from the FBRs is discharged to an outfall located at the Las Vegas Wash via an underground pipeline. Solids from the GWTP and the FBRs are conditioned and dewatered prior to being disposed off-site. The maximum operating capacity of the GW-11 pond is approximately 62.4 million gallons (Mgal) with an allowed three feet of freeboard, corresponding to a maximum operating water elevation of 1,747 feet above mean sea level (amsl). As of June 1, 2014, the current water elevation in GW-11 is 1742.05 feet amsl, corresponding to a water volume of approximately 40.8 Mgal. A perchlorate concentration of 99 mg/L was detected in the most recent sample collected from GW-11 (June 2, 2014). GW-11 has been sampled on a monthly basis since May 2013. Perchlorate concentrations in GW-11 have varied between 24 mg/L and 190 mg/L during this period.

There are some former components of the GWETS that are no longer operating. Groundwater recharge trenches formerly located downgradient (north) of the IWF and barrier wall were originally installed to receive extracted and treated groundwater, but have been used in the recent past to inject stabilized Lake Mead water into the subsurface to replace water extracted by the IWF. Reinjection ceased in September 2010, when the recharge trenches were partially removed to accommodate soil excavation activities at the Site. Also, a seep capture sump located north of the SWF was formerly used to capture groundwater before it surfaced and flowed to the Las Vegas Wash; however, the seep has not flowed since April 2007.

4.3.2.2 Performance of the Current Groundwater Extraction and Treatment System

The GWETS has been effective at removing and treating large amounts of perchlorate and chromium in on-site and off-site groundwater. From July 2002[27] through June 2012 the estimate

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[24] Equivalent pounds per day is calculated with the following formula:
Equivalent Load (lbs/day) = [(0.90 x NO3-N) + (0.17 x ClO3) + (0.18 x ClO4)] x Q x 1440 x 8.34 / 1,000,000

Where:
NO3-N = Nitrate-nitrogen concentration, (mg/L as N)
ClO3 = Chlorate concentration, (mg/L)
ClO4 = Perchlorate concentration, (mg/L)
Q = Influent flow (gpm)

[25] Prior to March 2014 these tanks operated as the GWETS equalization area.

[26] Envirogen anticipates utilizing the GW-11 pond as an equalization basin and is currently in the process of making the required modifications.

[27] July 2002 was used as the start date for this performance evaluation since the extraction before this time was limited. This date corresponds to the time period when the AWF and SWF well fields were being installed and downgradient extraction from these well fields began.

of perchlorate mass removed and treated by the GWETS is approximately 6,185,000 pounds (approximately 3,093 tons). The current estimate of chromium mass removed and treated during this same time period is approximately 38,000 pounds (approximately 19 tons).

Figures 4-3 and 4-4 present estimated monthly mass removals based on well extraction rates and individual well concentrations from July 2002 through June 2012 for perchlorate and chromium, respectively. This represents the time period where all three of the well fields were operating; however, as discussed in previous sections, the well fields have been expanded significantly during this time.

As shown in Figure 4-3, system-wide perchlorate mass removals have declined since the middle of 2003 primarily due to the sharp decline in perchlorate mass removal at the SWF. The decreased mass removal rates from the SWF result from decreased concentrations of perchlorate at the Las Vegas Wash, which is likely due to operation of the upgradient extraction well fields. In contrast, the perchlorate mass removals at the IWF and AWF have only marginally decreased during this time period.

Since July 2002, the maximum monthly perchlorate mass removal occurred in June 2003 when a total of approximately 76,300 pounds were removed and treated. At this time the percentages of perchlorate mass removal attributed to the IWF, AWF, and SWF were 39, 36, and 25 percent, respectively. Since then, the perchlorate mass removed from the SWF has diminished significantly. Recently, in June 2012, the total monthly perchlorate mass removal was 37,600 pounds with the IWF and AWF accounting for 51 and 45 percent, respectively, while the SWF accounted for only 3 percent.

As shown on Figure 4-4, the IWF is responsible for the majority of chromium mass removal with the AWF responsible for a significantly smaller amount. As mentioned above, because concentrations of chromium at the SWF are consistently below laboratory quantitation limits (0.00088-0.0020 mg/L), the chromium mass removal at the SWF is negligible, and therefore, is not shown on Figure 4-4. The figure shows that chromium mass removal at the IWF has been decreasing since around the end of 2008, while chromium mass removal from the AWF has been slowly increasing during this same period. In fact, chromium mass removed at the AWF has slowly, but steadily increased since the end of 2003. This increase of chromium mass removal at the AWF is also evident in Figure 4-5, which presents a side-by-side comparison of extraction rates and chromium and perchlorate mass removal estimates for each of the three well fields.

Since July 2002, the maximum monthly chromium mass removal occurred in January 2005 when a total of approximately 366 pounds were removed and treated. At this time the percentages of chromium mass removal attributed to the IWF and AWF were 96 and 4 percent, respectively. Recently, in June 2012 the total monthly chromium mass removal was 243 pounds with the IWF and AWF accounting for 84 and 16 percent, respectively,

Figure 4-5 illustrates the relative efficiencies of the three extraction well fields based on the amount of perchlorate and chromium mass removed and the overall extraction rates. Figure 4-5 illustrates that although the IWF has a relatively low overall extraction rate, it is responsible for the majority of chromium removal and about half of the perchlorate removal of the entire GWETS. The AWF is responsible for a relatively small amount of chromium removal and slightly less than half of the perchlorate removal. The SWF has by far the highest extraction rate, but negligible chromium removal and a relatively small percentage of the overall perchlorate removal (three percent in June 2012).

Estimates of perchlorate mass remaining in the subsurface were originally presented within an attachment to the 2013 annual performance report (ENVIRON 2013b). Three different methodologies (kriging, spline, and contour interpolation) were used to generate a range of estimated masses for the years 2012, 2006, and 2002 as summarized in Table 4-3. For 2012, estimated perchlorate mass remaining within the plume boundary ranged between 2,674 and 3,728 metric tons. In 2006, the remaining perchlorate mass was estimated between 3,724 to 4,199 metric tons. In 2002, the mass was estimated between 5,514 to 6,893 metric tons.

Although mass removal is an important measure of performance, the degree that the GWETS captures Site contaminants, thereby mitigating migration of contaminants downgradient, is the ultimate measure of effectiveness. Northgate conducted a capture zone evaluation (CZE) to evaluate the efficacy of the GWETS in 2010. In conjunction with the CZE, a calibrated groundwater flow model was developed for the Site and additional monitoring and potential extraction wells were installed (Northgate 2010f and 2010s). The groundwater flow model was approved by NDEP on April 4, 2013. The model will be updated and refined as described in Section 4.3.3.2 and then used to further evaluate the performance of the GWETS.

As discussed in the 2012 annual performance report (ENVIRON 2012c), potential gaps in plume capture have been observed as evidenced by elevated concentrations (primarily of perchlorate, but also chromium) at the ends of the IWF and downgradient of the AWF. The gaps are generally consistent with capture gaps identified in the 2010 CZE Report, and therefore, some of the potential new extraction wells installed previously could be utilized to enhance capture in these areas. The 2013 GWETS Optimization Project, described in the next section, was developed to address these capture zone gaps.

4.3.3 2013 GWETS Optimization Project

As discussed above, potential gaps in plume capture have been observed as evidenced by elevated concentrations (primarily of perchlorate, but also chromium) at the ends of the IWF and downgradient of the AWF. The 2013 GWETS Optimization Project is designed to address potential gaps in plume capture that have been observed as evidenced by elevated concentrations (primarily perchlorate, but also chromium) at the ends of the IWF and downgradient of the AWF, as well as to increase the overall effectiveness of the existing GWETS. A revised work plan describing the project (ENVIRON 2013c) was submitted to NDEP on November 22, 2013, and approved by NDEP on December 3, 2013 (NDEP 2013e). The primary goal of the 2013 GWETS Optimization Project is to optimize mass removal rates and capture zones of the three well fields comprising the GWETS.

To support the optimization, the following work will be performed in 2014:

- Test and activate nine currently idle extraction wells located in the IWF and AWF,

- Perform additional well testing to further characterize hydraulic properties of the major geologic units at the IWF and AWF,
- Characterize the stream-aquifer interaction at the SWF, and
- Update and refine the existing groundwater model.

Following completion of these tasks, extraction rates at each of the three well fields will be optimized using the results of data analysis and groundwater modeling. Detailed information is provided in the 2013 GWETS Optimization Project Work Plan (ENVIRON 2013c).

4.3.3.1 Performance Metrics

As described in the work plan, the optimization of the GWETS will be informed by the analysis of several performance metrics. The performance metrics include the metrics requested by NDEP, as well as additional metrics identified by ENVIRON that are consistent with the objectives of the 2013 GWETS Optimization Project and future optimization efforts.

The metrics include those identified by NDEP in the October 10, 2013 letter commenting on the 2013 Annual Remedial Performance Report (ENVIRON 2013b) as well as the April 9, 2014 letter commenting on the 2013 Semi-Annual Remedial Performance Report (ENVIRON 2014e) as outlined below:

- The concentrations at which NERT is achieving 90% and 99% capture of perchlorate and chromium;
- Monthly perchlorate and chromium mass removal rates from the IWF, AWF, and SWF;
- Perchlorate and chromium capture efficiency of IWF, AWF, and SWF;
- Perchlorate and chromium plume mass estimates;
- Mass loading of perchlorate and chromium in the Las Vegas Wash at Northshore Road and;
- Water elevation, volume, chemical concentration[28], and flow rate information for the GW-11 pond.

Additional metrics identified by ENVIRON include the following:

- The amount of surface water from Las Vegas Wash and the COH Birding Ponds that is being extracted by the SWF;
- The fraction of mass loading in Las Vegas Wash at Northshore Road that originates from the NERT Site; and
- The environmental footprint of the GWETS with a focus on energy use.

A description of ENVIRON's proposed approach for determining the performance metrics is as follows:

[28] Monthly GW-11 pond samples will be collected by Envirogen and analyzed for perchlorate, chlorate, nitrate, chloride, sulfate, ammonia, phosphorus, calcium, iron, total chromium, hexavalent chromium, TDS, TSS, and pH.

- In order to calculate several of the metrics, study area boundaries must be defined. For this purpose, ENVIRON will use the plume mass estimate boundaries presented in Appendix A of the recent Annual Remedial Performance Report (ENVIRON 2013b).
- The total mass flux within the study area being transported by groundwater flow across hypothetical east-west lines passing through the IWF, AWF, and SWF will be estimated using modeled groundwater flow rates and interpolated concentrations.
- The fraction of the total mass flux being captured by the IWF, AWF, and SWF will be estimated using capture zones from the groundwater model. Capture efficiency is the ratio of captured mass flux to total mass flux.
- Target capture zones that represent 90% and 99% capture efficiency will be shown on a figure and compared to the actual capture zones achieved by well fields as estimated by the groundwater model.
- Future estimates of perchlorate and chromium plume mass will follow the general approach used in the recent Annual Remedial Performance Report (ENVIRON 2013b).
- Mass loading at Northshore Road will be calculated as the product of the flow rate at the Northshore Road stream gage and perchlorate concentrations measured in Las Vegas Wash near the stream gage.

A presentation of the draft metrics was provided to NDEP on October 31, 2013. No comments were received from NDEP on this deliverable. These metrics will be used during the optimization of the GWETS and incorporated into future deliverables such as the Annual and Semi-Annual Remedial Performance Reports as well as the RI/FS. The evaluation of GWETS performance using the metrics will be consistent with the USEPA guidance on evaluating capture zones for groundwater pump and treat systems (USEPA 2008).

4.3.3.2 Groundwater Modeling

As part of the 2013 GWETS Optimization Project, the existing groundwater flow model will be refined and updated. The updated and refined model will be used to estimate capture zones and perform other analyses to support the optimization of the GWETS extraction rates. The model will continue to be refined as part of the RI/FS, as described in Section 6.3.

The existing model was developed by Northgate and documented in the Capture Zone Evaluation Report (Northgate 2010s). On April 4, 2013, the groundwater model was approved by NDEP for use in capture zone evaluation. The current model is a steady-state model calibrated to Site conditions existing during 2008/2009. In order to optimize the current GWETS, the model will be updated to current conditions and refined to better represent groundwater flow in the vicinity of the three extraction well fields. The model update and refinement will be performed in two phases as described below.

Phase I. The model will be updated to reflect the current configuration and pumping and injection rates of the GWETS, AMPAC, and OSSM remediation systems. A regional water balance will be prepared in order to confirm that the model is generally consistent with observed conditions. An initial evaluation of the stream-aquifer interaction in the vicinity of the SWF will also be conducted. This updated version of the model and the stream-aquifer interaction evaluation will be used to support the development of performance metrics described in Section 4.3.3.1.

Phase II. The model will be refined in order to incorporate the results of aquifer testing performed as part of the 2013 GWETS Optimization Project, the regional water balance, and the study of stream-aquifer interaction. As part of this phase, the model boundary conditions and hydraulic properties will be recalibrated to more accurately represent groundwater flow and evaluate the effectiveness of the GWETS. The updated and refined model will then be used to evaluate the performance of alternative extraction rates at the three well fields. Optimum extraction rates using the identified performance metrics will be identified and recommended for future implementation.

4.3.3.3 Future Work

Currently, there are certain limitations to operation of the existing GWETS that may require upgrades if expansion of the groundwater extraction network is deemed necessary. The treatment system is operating near its design average annual hydraulic loading of 950 gpm at the FBRs (the design 30-day average maximum flow is 1,000 gpm). The GWTP is operating near its current operational maximum hydraulic loading of 75 gpm (including 8-10 gpm of required recycle). Lift Station 3, which conveys extracted water from the AWF to Lift Station 2, is pumping at close to its maximum sustainable flow of 290 gpm. The pumping at Lift Station 2, which conveys water from the SWF and the AWF to the on-site treatment plant is also limited — it has a maximum sustainable flow of 900 gpm — but since Lift Station 2 is downstream of Lift Station 3, it is not directly limiting the flow from the AWF. A full evaluation of the GWETS, including the issues noted above, will be performed as part of the RI/FS.

4.4 Groundwater Monitoring Program

Pursuant to the aforementioned NDEP Orders, KMCC and then Tronox conducted groundwater monitoring and remediation system monitoring. In conjunction with the settlement of Tronox's bankruptcy proceeding, the Trust took title to the Site and the GWETS and continued the GWETS monitoring program.

The GWETS monitoring program consists of about 8,000 analyses per year including various and wide-ranging analytical methods from samples collected from the treatment processes, as well as from groundwater wells. Performance and compliance samples are collected and analyzed throughout the year including during weekly, bi-weekly, monthly, quarterly, and annual sampling events. However, the remainder of this section focuses on the groundwater monitoring program that is used to evaluate the overall effectiveness of the GWETS rather than monitoring related to permit compliance.

Currently, approximately 1,800 water level measurements and over 1,000 groundwater samples are collected from groundwater wells each year as part of the remediation monitoring program. Samples are collected on monthly, quarterly, and annual schedules in accordance with monitoring requirements outlined in the previous Consent Orders and AOC and through subsequent regulatory correspondence. One monitoring well, M-10, is sampled on a quarterly basis in compliance with the Site's NPDES permit. The wells sampled as part of the monitoring program are shown on Figure 4-6. The current monitoring program is summarized in Table 4-4 and as follows (numbers referenced are from the 2011 monitoring year, but will vary slightly due to well access and status):

- **Monthly Sampling** – On a monthly basis, groundwater samples and water level measurements are collected from most active monitoring wells in the AWF, SWF, and within the plume between these two well fields. Samples are analyzed for perchlorate and TDS.[29] Data are used to calculate the mass of perchlorate removed by the well fields and to provide groundwater level and quality data in the northern portion of the plume downgradient of the AWF. Water level measurements only are collected monthly from the IWF extraction wells and approximately 45 monitoring wells located within or adjacent to the NERT facilities to characterize the groundwater levels and flow directions.
- **Quarterly Sampling** – Expanded monitoring events are conducted in the first, third, and fourth quarters and consist of collecting 138 groundwater samples and 163 water level measurements (inclusive of monthly monitoring activities described above). Groundwater samples are collected from wells screened in the Shallow WBZ located throughout the plume. Samples are analyzed for perchlorate, chromium, TDS, and pH. A small subset of wells is also sampled for hexavalent chromium for compliance with the Site's Underground Injection Control (UIC) permit #UNEV94218. One monitoring well, M-10, is sampled on a quarterly basis in compliance with the Site's NPDES permit.
- **Annual Sampling** – Annually, a comprehensive monitoring event is conducted in the second quarter, and consists of 262 groundwater samples and 294 water level measurements collected from wells screened in the Shallow, Middle, and Deep WBZs. These wells include 29 wells that are owned by entities other than NERT including the City of Henderson, BMI, Olin, TIMET, and others. In addition to the analytes above, a subset of wells are analyzed for chlorate and nitrate.

Initially, separate quarterly progress reports were submitted for the chromium and perchlorate removal programs. In 2006, reporting for the two programs was combined, and since then the monitoring reports have been submitted semi-annually. The current semi-annual reports consist of text, tables, and figures documenting the status of remediation efforts, with appendices containing laboratory data reports, data validation reports, field documentation, and electronic data deliverables. An annual report submitted following the comprehensive second quarter monitoring event also includes a potentiometric surface map for the plume area and isoconcentration maps for the monitored constituents.

As described in Section 3, numerous groundwater investigations were conducted dating back to the early 1980s to characterize potential impacts to groundwater primarily related to chromium, and later, perchlorate. These investigations involved the installation of borings and groundwater wells to investigate specific data gaps; however, a systematic and critical evaluation of the groundwater monitoring network does not appear to have ever been performed. According to

[29] Chromium and pH are analyzed on a quarterly and annual basis and are not regularly analyzed as part of the monthly sampling events.

the NDEP's All Wells Database for the BMI Complex (September 2012 version) over 700 borings have been installed at the Site and downgradient of the Site by KMCC/Tronox including 390 that were constructed as groundwater wells. Of these 390 wells, it appears 103 were plugged and abandoned leaving 287 active wells at the Site. As noted above, most of these wells, and an additional 27 wells owned by others, are currently gauged and/or sampled as part of the groundwater monitoring program. In an effort to improve and streamline the groundwater monitoring program, a long-term monitoring optimization study is planned and will be presented as part of the RI Report.

4.4.1 AP-5 Pond Solids Characterization and Disposal

A work plan to characterize and remove the residual solids remaining in an on-site lined surface impoundment (the AP-5 pond) at the Site (ENVIRON 2012d) was submitted to NDEP on September 28, 2012 and approved by NDEP on February 4, 2013. The objective of this work plan is to methodically and efficiently characterize the solids to facilitate proper handling, management, and disposal.

This plan was prepared in response to NDEP's approval letter dated June 28, 2012 to implement a *Proposal to Discontinue Treatment of AP-5 Pond Water at NERT Facility*, dated March 30, 2012 (ENVIRON 2012a). The proposal recommended implementation of the following four steps:

1. Permanently close the valve that allows flow of Lake Mead water into the AP-5 pond.
2. Pump all remaining water present in the AP-5 pond to the GW-11 pond and from there to the on-site groundwater treatment plant.
3. Characterize residual solids in the AP-5 pond for off-site disposal.
4. Remove residual solids from the AP-5 pond for disposal at an appropriately permitted off-site disposal facility.

To date, step one has been implemented and step two has been completed to the extent possible utilizing the existing AP-5 pond pumping system. Characterization of the solids in the AP-5 pond (step three) is currently in progress. Data collected from characterization sampling will inform removal and disposal methods to be implemented during step four. A Work Plan providing closure procedures for AP-5, prepared by Tetra Tech, was submitted to NDEP on May 22, 2014 (Tetra Tech 2014) and approved by NDEP on June 18, 2014 (NDEP 2014h). All subsequent decommissioning work regarding the AP-5 pond (e.g., liner removal, underlying soil sampling, remediation as necessary) will be undertaken as part of the RI/FS.

5.0 Initial Site Evaluation

Consistent with RI/FS guidance (USEPA 1988), the initial site evaluation: (1) summarizes the CSM, (2) identifies the preliminary RAOs and applicable or relevant and appropriate requirements (ARARs), (3) describes the development of general response actions and screening of remedial technologies and process options, and (4) describes additional areas that require investigation to determine the nature and extent of COPCs in groundwater and soil at the Site.

Since the Trust assumed ownership of the Site in February 2011, all analytical data collected by ENVIRON and used for data analysis and decision making (except for FBR influent and effluent monitoring data) were validated in accordance with NDEP's data validation requirements current at the time of sampling. This data includes monitoring well data, extraction well data, and soil data contained in a relational database maintained by ENVIRON. In addition, data compiled from NDEP's regional database[30] collected by neighboring properties has been used for analyzing off-site areas and historical data. It is our understanding that data from NDEP's regional database were validated according to NDEP guidance current at the time of sampling.

5.1 Conceptual Site Model

This preliminary identification of sources, release mechanisms, exposure media, exposure routes, and receptors is based on a current understanding of on-site and off-site environmental conditions. The CSM will be revised, as appropriate, based on further evaluation of available on-site and off-site characterization data and additional environmental data collected during the RI.

The CSM for this RI/FS Work Plan is developed for the Facility Area. Information from the parcel investigations will be reviewed and considered within the context of an evaluation of the nature and extent of historical soil and groundwater contamination, but the BHRA will not include the evaluation of health risks for Parcels C, D, F, G, or H. As noted in Section 2.2, the parcels have generally been evaluated on a separate timeframe from that of the Facility Area and are not included in the RI/FS process.

A comprehensive *Environmental Conditions Assessment* report was prepared for the Site in 1993 (Kleinfelder 1993). The report provided detailed summaries of processes and operations conducted during the periods of operation by the U.S. government and subsequent occupants of the Site and identified locations of former operations and associated support structures. Based on information from historical investigations and the 1993 *Environmental Conditions Assessment*, NDEP identified 70 LOUs as potential source areas (or areas requiring additional information, either in the form of further historical research or additional field sampling) in 1994 (NDEP 1994).

The 2005 CSM (ENSR 2005) presented detailed information on the LOU source areas identified by NDEP, including information on products made, years of production, and approximate waste volumes and actions taken to date. Available analytical results for each LOU were summarized

[30] The NDEP regional database is available at: http://ndep.neptuneinc.org/ndep_gisdt/home/index.xml.

and SRCs were identified based on a review of the activities and/or processes associated with each LOU. Potential contaminant migration pathways and receptors were also described. The 70 LOUs are listed in Table B-1 of Appendix B and the LOU locations are shown on Figure B-1.[31]

Since 2005, the Site has been the subject of additional field investigations and interim removal actions have been implemented. For Facility Area soils, the investigations and interim removal actions included mainly the Phase A and Phase B Source Area Investigations and soil removal actions in RZ-B through RZ-E, as described in Sections 3 and 4 of this Work Plan and tabulated in Table B-1 of Appendix B. The design of the Phase A and Phase B investigations was based on knowledge of historical Site operations (including consideration of all NDEP-identified LOUs), and all work plans were reviewed and approved by NDEP. This resulting data set was then used to inform the soil interim removal action (completed in 2011) during which over 500,000 yd^3 of soil were removed from the Site.

Based on the Phase A, Phase B, and other historical data, an HRA was completed for soils in RZ-A (Northgate 2010k). As summarized in Section 4.1, estimated cancer risks and noncancer hazards for RZ-A soils were less than NDEP's point of departure and these soils were not included in the removal program (Northgate 2010k). As a result of this finding, soils were not removed from RZ-A, and the RZ-A soil data set has been used as a background data set for soils in the remaining RZs, as directed by NDEP in August 2010 (NDEP 2010b).

The following sections provide an updated CSM based on current conditions at the Site, incorporating information from the recent investigations, removal actions, and HRAs. Background information described in Section 2 of this Work Plan — site history, physical setting and climate, geology, and hydrogeology — was taken into consideration in the development of the CSM. Information from previous sections of this report is summarized below, as appropriate, for clarity in the development of the CSM. A schematic of the CSM is shown on Figure 5-1.

5.1.1 Potential Contaminant Sources and Release Mechanisms

The 5,000-acre BMI Complex (of which the Facility Area comprises 265 acres) has been used for industrial activities since 1942, when the complex was sited and operated for the U.S. government as a wartime magnesium production plant (Kleinfelder 1993). During the period of government operations, the magnesium production operations consisted of the following major facilities, some of which were located on the area that is now the Site:

- A brine purification facility that dissolved solar salt and removed calcium, potassium, strontium, sulfate, and bicarbonate impurities via a precipitation and filtering process.
- A chloralkali plant to produce sodium hydroxide and chlorine gas from the electrolysis of purified sodium chloride brine.

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[31] Additional information for the LOUs can be found in "LOU Packets," provided on a compact disc accompanying the *Site Management Plan (SMP)* (ENVIRON 2013d, 2012b).

- A plant that created pellets of magnesium oxide and a carbon source.
- Ten identical, large buildings (Units 1 through 10), each of which contained chlorinators (furnaces) that created molten magnesium chloride by reacting the magnesium oxide/carbon pellets with chlorine gas at high temperature and banks of electrolytic cells that produced magnesium metal by electrochemical reduction of the molten magnesium chloride.
- An extensive system of surface impoundments that were used to receive process effluent for evaporative disposal. This system originally included the Trade Effluent Ponds, and later included the Upper and Lower BMI Ponds, and the associated Alpha, Beta, and Northwest Ditches used to transport effluent to the Ponds. Additionally, storm water and waste water originating from the former Stauffer and Montrose operations areas were diverted from the Lower to the Upper Ponds through the Beta Ditch Extension, which extends onto the Site and connects with the Beta Ditch.
- Associated support buildings for the storage and transport of raw materials and the purification and processing of magnesium metal into ingots.

During the period of government operations, extensive volumes of liquid wastes were discharged to four unlined Trade Effluent Settling Ponds (Figure 5-2)[32]. These liquids were generally composed of acid effluent and waste caustic liquor containing high levels of TDS, dissolved metals, and to a lesser degree, chlorinated organic compounds (Kleinfelder 1993). Solid materials were placed in an open area south of the Trade Effluent Settling Ponds and north of the caustic settling ponds (Kleinfelder 1993). Waste water originating from the various production processes was discharged to a storm sewer system that emptied into unlined drainage ditches (e.g., the Alpha, Beta, and Northwest Ditches). The unlined drainage ditches routed waste water to a system of unlined ponds currently referred to as the Upper and Lower BMI ponds. The unlined surface conveyances and subsurface piping served to move waste water and chemicals across the BMI Complex (with the potential for releases to soil) and impoundments allowed process effluents to infiltrate into soil and to groundwater in areas throughout the BMI Complex. Additionally, storm water and waste water originating from the former Stauffer and Montrose operations areas were diverted from the Lower to the Upper Ponds through the Beta Ditch Extension (BRC 2007).

Following the end of magnesium production in 1944, the BMI Complex was subdivided into three primary production areas. Features located on what is now the Site include (Kleinfelder 1993):

- Six metal process Unit buildings (Units 1 through 6) and the attached chlorination buildings, rectifier buildings, motor generator buildings, and bridges.
- A flux plant.
- Peat storage areas.

[32] Figure 5-2 identifies former and current surface water impoundments and conveyances located on the Site. The Alpha Ditch and Upper and Lower BMI Ponds, mentioned in this paragraph, were not located on the area currently occupied by the Site.

- An area with a salt storage building, pulverizer building, tunnel kiln building, rotary kiln building, pellet storage building, and magnesite silos.
- Various other buildings and open storage areas.
- An area occupied by approximately two and one-fifth of the original four Trade Effluent Ponds (Figure 5-2) that were used for management of liquid waste generated by the U.S. government operations.
- The Beta Ditch (specifically, the section crossing the Site), the Beta Ditch Extension, and the Northwest Ditch.
- As described previously in Section 2, chemical manufacturing operations have continued at the Site since 1945, including production of chlorate and perchlorate compounds, boron and boron-related compounds, and refined manganese oxide.

5.1.1.1 Source Areas

The 70 source areas identified by NDEP include areas that are currently used for chemical production (e.g., some Unit buildings), areas that are no longer active, and/or where near surface soil contamination has been addressed (e.g., former surface water impoundments that have been closed). These current or former source areas include, but are not limited to:

- Unit buildings 1 through 6
- Surface water impoundments (over 15 former and current surface water impoundments were identified as LOUs)
- Former and current surface and subsurface water conveyances (e.g., the Beta Ditch, Beta Ditch Extension, Northwest Ditch, drainage systems, sewers, piping)
- Leach Plant area
- Acid drain system
- Agricultural division plant
- Ammonium perchlorate plant and associated buildings
- Materials and product handling and storage areas
- Waste handling and storage areas
- Manganese tailings area
- Stock pile areas
- Former hazardous waste landfill (LOU 10) and other hazardous waste storage areas

Historical releases from potential source areas have been documented or inferred from field investigations that have identified chemically impacted on-site soils, soil gas, and groundwater.

Specific examples of reported releases include process chemicals leaking to soil through cracks in the basements of Units 4 and 5 (LOUs 43 and 61) and the basement of Unit 6 (LOU 44). The concrete basements served as sumps to collect process liquor, spillage, and wash water. Removal activities were undertaken in the Unit 6 basement in 1987 to remove the cracked concrete floor, followed by recontouring of the underlying soil and installation of a liner system. Other process leaks and spills (associated with the Unit buildings) to soils have been documented. The Unit process effluents contained high levels of TDS, perchlorate, and to a lesser degree, hexavalent chromium (Kleinfelder 1993).

From 1945 until the mid-1970s, process effluents from the chlorate, perchlorate, and boron-related production processes were sent to the unlined Upper and Lower BMI Ponds via the Beta Ditch (LOU 5) and manganese-related wastes were disposed of in on-site leach beds (LOU 24). In addition, other BMI companies used these same ditches for conveying wastes, providing an historical source of contaminants (from neighboring properties) unrelated to former Site operations to be present in Site environmental media. In the early 1970s, under the federal NPDES program, the industries at the BMI Complex curtailed waste discharges to the Upper and Lower BMI Ponds. KMCC achieved zero-discharge status in 1976, at which time process effluents were sent to on-site, lined surface impoundments. Over time, several of these lined surface impoundments reported known releases and liner failures; these early impoundments were eventually replaced with more effective double-lined systems.

Investigations of areas potentially impacted as a result of former tenant operations were addressed through NDEP's identification of LOUs and the Phase A and B investigations conducted at the LOUs. RI/FS planning will take into consideration the presence of current tenants (as described in Section 2.2); soil investigations conducted to date have been impeded by current building footprints and associated infrastructure, leaving data gaps in the investigation. Tenant buildings and associated infrastructure will also be considered in evaluating possible remedial alternatives. In conducting any remedial action, potential exposures/risks associated with the inhalation pathway (and any other relevant pathways) for tenants (and off-site receptors) will be considered.

5.1.1.2 Neighboring Properties

The Olin property to the west of the Site (formerly referred to as POSSM, Figure 2-1) occupies the location of the former BMI Complex chloralkali production facility. Post-1945 process activities on the property included operation of a chloralkali facility to produce chlorine gas, hydrochloric acid, and sodium hydroxide. In 1947, additional manufacturing facilities were constructed to produce pesticides and chlorinated organic compounds. Production of pesticides and organic compounds ceased in 1983, and production facilities were demolished and removed from the Olin property in 1984. Operation of the chloralkali facility is ongoing (Integral Consulting Inc. [Integral] 2009). Over time, extensive volumes of process effluents and solid wastes were disposed of in unlined ponds and buried on the Olin property. These wastes contained high levels of TDS, chlorinated organic compounds, and extensive amounts of phosphoric acid. Prior to 1976, certain process effluents were routed to the Upper and Lower BMI Ponds. These waste streams included large volumes of sulfuric and hydrochloric acid, as well as sulfonated metabolites of dichlorodiphenyltrichloroethane (DDT) (Hargis & Associates [H+A] 2008). The unlined Beta Ditch transported contaminants from these western properties through the Site. Also to the west is the BMI CAMU (Figure 2-1). Both the Olin and BMI properties have been the subject of extensive environmental investigations, which have documented significant chemical impact to environmental media at the properties. It is noted that significant volumes of organochlorine pesticide and asbestos wastes were disposed of at what is now the Olin property.

The BMI landfill (also referred to as the BMI dump) is located within the BMI CAMU area in the western portion of the BMI Complex in an area formerly used as a Trade Effluent pond; the landfill began operating in 1942. The BMI landfill is unlined and consists of a northern and southern lobe, referred to as the North Landfill Lobe and the South Landfill Lobe, as shown on Figure 2-1. The North Landfill Lobe occupies a 51.7-acre rectangular-shaped area of land from the northern boundary of the CAMU Area south to approximately the northern edge of the Slit Trench Area (Daniel B. Stevens & Associates, Inc. [DBSA] 2007). The South Landfill Lobe occupies an 8.2-acre polygonal-shaped area that abuts the eastern boundary of the CAMU area in the southern portion of the property.

A number of different operating companies, including KMCC, sent solid and liquid wastes to the BMI landfill. KMCC sent primarily the following types of wastes: housekeeping wastes (e.g., paper, cartons, bags, pallets, drums, and plastics), asbestos-containing material, elemental carbon powder (from boron operations), filter cake from the sodium chlorate operations, and dried residues from the cleaning of Ponds P-1 and AP-2 (ENVIRON 2011a). Other materials disposed of in the North Landfill Lobe included: DDT paper bag packaging, carbon tetrachloride liquid waste, high paraffin fuel oil, polychlorinated benzene still bottom residues, and chlorine liquefaction sludge (DBSA 2007). Prior to 1970, solid wastes were reportedly periodically disposed of in the BMI North Landfill Lobe and burned (Geraghty & Miller, Inc. [G&M] 1993, as cited by DBSA 2007). BRC has estimated that the North and South Landfill Lobes received between 500,000 and 1,000,000 cubic yards of materials from 1942 until 1980. From 1972 to 1979, KMCC used the BMI landfill for disposal of certain boron compound wastes and from 1975 to 1980, for disposal of chlorate wastes. In 1979, the boron compound wastes were disposed of off-site (Kleinfelder 1993). Between 1980 (when the BMI landfill closed) and 1983, the chlorate wastes were disposed of at an on-site hazardous waste landfill (LOU 10, subsequently closed). Between 1967 and 1975, manganese dioxide wastes were disposed of through on-site leach beds; subsequently, these wastes were disposed of at an on-site nonhazardous waste pile and more recently, off-site. It is believed that the South Landfill Lobe received similar wastes during similar time frames as the North Landfill Lobe, except there were no effluent ponds located in the footprint of the South Landfill Lobe nor was the waste burned (DBSA 2007).

In February 1980, the BMI landfill was closed and capped (BRC 2012b and Weston 1993, as cited by BRC 2007). Historical manufacturing operations in the production areas upgradient of the BMI Landfill have significantly impacted groundwater quality in the vicinity of the CAMU area, as well as further downgradient (DBSA 2007). More recently, BRC covered and capped buried waste in the North and South Landfill Lobes, and surface liquids were removed from ditches to reduce the potential for chemical leachate in the CAMU area to migrate to and impact groundwater (DBSA 2007 and BRC 2012a). Due to the direction of groundwater flow in the region (generally north to northeasterly), a groundwater contaminant plume has migrated onto the Site from the Olin property. Contaminants include VOCs, non-aqueous phase liquid (NAPL), and pesticides. The responsible parties for this plume are currently operating a groundwater treatment system and performing groundwater monitoring under NDEP oversight (ENVIRON 2011a).

The Lhoist property (formerly Chemstar, a lime producer) is surrounded by the Site on three sides. Lhoist operations contributed to flows to the Beta Ditch prior to 1979. Lime production processes encompass mining and rock preparation, calcining to convert carbonate rock to calcium and/or magnesium oxides (quicklime), and hydrating the quicklime to hydroxides. The storm sewer system historically conveyed effluent from the Lhoist, Stauffer, and TIMET properties (Kleinfelder 1993).

The TIMET property to the east of the Site includes four former BMI process units (Units 7 through 10) and refinery buildings. Activities conducted on what is now the TIMET site from 1951 to present included production of magnesium ingot, titanium tetrachloride, titanium sponge, and titanium ingot (TIMET 2007). From 1951 until 1972, TIMET disposed of its caustic waste, leach liquor, and other process waste streams to the Upper BMI Ponds via the Beta Ditch. From 1970 to 1971, Stauffer and Montrose conveyed storm water and wastewaters from the Lower to the Upper BMI Ponds via the Beta Ditch Extension (BRC 2007). Additionally the Northwest Ditch (LOU 6), which originates near the Beta Ditch and crosses the northern portion of the Site (Kleinfelder 1993), received and conveyed process waste streams from the BMI Complex facilities to the BMI Common Area and was identified under the Phases I and II BMI Common Area Consent Agreement as a BMI Common Areas issue (ENSR 2005, Broadbent & Associates, Inc. [Broadbent] 2011). From 1976 to 1982, TIMET built 31 lined surface impoundments on top of the southwestern portion of the Upper Ponds where its process waste streams were discharged. Several of the lined ponds reported liner failures and were upgraded to double-lined systems. In 2005, a water conservation facility went online and discharge to the ponds ceased. The TIMET process waste streams contained high levels of TDS and dissolved metal chlorides (LAW Engineering 1993).

These adjacent neighboring properties are considered potential former and/or current “off-site” sources of contaminants to Site groundwater (as noted above), particularly from the west; surface soils and surface water (from off-site storm water entering the Site); and air (airborne particulates released from contaminated surface soils and buildings on these adjacent properties).

5.1.2 Release Mechanisms and Potential Migration Pathways

Environmental media at the Site, including air, soil, soil gas, surface water, and groundwater, have been impacted, as shown through a review of historical records or confirmed through field investigations. The fate and transport of Site contaminants released from on-site (and off-site) sources was assessed to identify the environmental media potentially impacted by releases. The primary historical and/or current release mechanisms and impacted environmental media at the Site are identified as follows:

- Wind dispersal of fugitive dust from contaminated surface soils.
- Following precipitation events, contaminants adsorbed to surface soils and sediments can be transported via surface water to other on-site soils and on-site surface

impoundments. (As discussed in Section 2.6, the Site has been graded to retain surface water runoff in order to minimize transport of contaminants to off-site areas.)

- Overflow of surface impoundments.
- Leaching from surface impoundments and surface and subsurface conveyances through subsurface soils to groundwater.
- Leaching from contaminated surface and near surface soils to deep soils and migration to groundwater.
- Migration of VOCs from subsurface sources (groundwater or soil) through the vadose zone to ambient or indoor air.
- For NAPL (a trespassing contaminant), formation of smear zones due to fluctuations in the water table and subsequent migration of the more volatile constituents through the vadose zone to ambient or indoor air.
- Surfacing of groundwater or groundwater discharges to drainages or lakes, such as Las Vegas Wash or Lake Mead.

5.1.3 Categorization of Soils

As described in Section 4.1, an interim soil removal action was completed for the Facility Area (RZs B through E) in November 2011, in which accessible soils with COPC concentrations greater than worker SRGs were removed. Inaccessible soils (with COPC concentrations greater than SRGs) and incompletely characterized soils (due to access issues) were assigned to one of 38 ECAs established following the remediation program (7 in RZ-B, 18 in RZ-C, 10 in RZ-D, and 3 in RZ-E).

Considering the investigations, removal action, and Site Management Plan (SMP) controls in place at the Facility Area, surface and near surface soils (0-10 ft below the “new” ground surface[33]) were placed into one of four categories to help inform the CSM, as well as identify data gaps and exposure pathways for evaluation in the RI and BHRA. The four categories are identified as follows:

- **Category 1 (Soils in ECAs)**: Includes all soils in ECAs. Due to access or other constraints that precluded soil excavation, soils in ECAs with COPC concentrations exceeding SRGs were left in place. ECAs also include 0 to 10 ft bgs soils that have not been fully characterized due to access or other restrictions. Soils in approximately 85 acres of the Facility Area (total area of 265 acres) are identified as ECAs (ENVIRON 2013d).

  Deeper Category 1 soils (greater than 10 ft bgs) with no or limited sampling data due to access constraints (e.g., soils beneath Unit buildings or active ponds), are being evaluated to identify data gaps and strategies for sampling, containment, and/or remediation as described in Section 5.4.

[33] The “new” ground surface refers to the soil surface following excavation, backfilling, and grading associated with the 2011 interim soil removal action (ENVIRON 2012e). In Sections 5 and 6, the 0 to 10 ft depth interval refers to the post-excavation soil horizon unless otherwise stated.

- **Category 2 (SRGs Not Exceeded, Not in ECA)**: Includes soils with COPC concentrations less than SRGs within the 0-10 ft post-excavation depth interval. These soils are in areas that (1) were not identified for remediation because COPC concentrations were less than SRGs based on results of the Phase A and Phase B source investigations (or other investigations completed since 2006) or (2) where soils exceeding SRGs in the 0-10 ft depth interval have been removed, either in 2011 during the interim soil removal action or during other actions (e.g., closure of surface water impoundments).

  2A: Category 2A soils include soils for which analytical data representative of the 0 to 10 ft depth interval remaining post-excavation are available (excluding RZ-A). Category 2A soils comprise approximately 29 acres (11% of the Facility Area).

  2B: Category 2B soils correspond to RZ-A. As previously noted, an HRA was completed and approved by NDEP for RZ-A. Category 2B soils comprise approximately 134 acres (51% of the Facility Area).

- **Category 3 (SRGs Exceeded, Not in ECA)**: Includes soils with COPC concentrations greater than SRGs within the 0-10 ft post-excavation depth interval that are not in ECAs. Category 3 soils comprise approximately 8 acres.

  Category 3 soils were identified during a comprehensive review of residual soil concentrations following completion of the 2011 interim soil removal action (ENVIRON 2012e, approved by NDEP on December 17, 2012). The 12 areas identified as Category 3 soils are shown on Figure 5-3 (numbers 1-12) and information about each area is provided in Table 5-1, including sample location, sample depth interval, chemicals exceeding their respective SRG, detected concentrations, and SRGs. The chemicals detected in one or more of these areas at concentrations above their respective SRG are arsenic, perchlorate, dioxin TEQs, benzo(a)pyrene TEQs, and hexachlorobenzene.

  Soils in Category 3 areas are being evaluated to identify data gaps, although in general, it is anticipated that sufficient post-remediation samples are available to evaluate potential risks to human health associated with exposures to soils in these areas.

- **Category 4 (Inadequate Characterization, Not in ECA)**: Includes soils that are inadequately characterized that are not in ECAs. One of the Category 4 areas — the debris pile — has been identified for further evaluation (shown on Figures 2-2 and 5-3). Materials in the debris pile (e.g., concrete) have not been characterized and soils have not been sampled; sampling in this area is identified as a data gap in Section 5.4. The debris pile covers approximately 10 acres.

The approach for identifying soil COPCs (for evaluating risk to human health) was identified in the ENVIRON BHRA Work Plan submitted to NDEP in February 2014 and approved on May 20, 2014 (ENVIRON 2014d). Based on our review of the data, soil COPCs will include chemicals (both inorganic and organic), asbestos, and radionuclides. The BHRA Work Plan also described the approach for dividing the Facility Area into exposure units. The primary factors that will be considered in the identification of exposure units include soil category (as defined above) and worker activity patterns. Section 5.1.5 identifies the receptors and exposure pathways that will be evaluated in the BHRA and Section 6.7 provides additional information on the BHRA task.

The 2011 interim soil removal action addressed mainly soils in the 0 to 10 ft pre-excavation horizon (with some exceptions, as noted above). The primary concern with contamination in deeper soils (greater than 10 ft bgs) is the potential for leaching to groundwater, as discussed in the following section.

5.1.4 Summary of the Groundwater CSM

The 2005 CSM presented a CSM for groundwater based on data collected at the Site and Site vicinity since 1986 (ENSR 2005). An updated version of a generalized conceptual diagram of potential contaminant source areas, contaminant pathways, and potential receptors is presented on Figure 5-4.

As noted in the 2005 CSM, vadose zone transport of non-volatile chemicals is a function of having the necessary chemical environment and sufficient infiltration to mobilize the chemical through the unsaturated zone to underlying groundwater. Portions of the Site are paved or covered, which prevents infiltration of water. Given the arid climate and the current physical condition of the Site, there are only a few specific occurrences that can generate sufficient water to mobilize Site-related chemicals that are present in the subsurface following the remediation of impacted soils in the upper surface and near surface (typically, 0-10 feet). These occurrences can include a rainstorm of sufficient quantity and duration to saturate the soil beyond its field capacity; a water supply pipeline break that discharges water to a specific area which then infiltrates to groundwater; or developing a leak in or beneath a synthetically lined pond that releases sufficient water to reach the water table (ENSR 2005).

Volatile chemicals present in the vadose zone can also be transported to groundwater by vapor-phase diffusion, in addition to being transported by infiltration. If infiltration is limited, vadose zone soils will remain generally dry, which will allow diffusion of volatile chemicals in the vapor phase downward to the water table. Volatile chemicals that are soluble will dissolve in groundwater and may be transported downgradient through groundwater transport.

5.1.4.1 Leaching-Based Soil COPCs

Perchlorate and chromium are the primary chemicals present in soil that may impact groundwater. An initial screening of chemicals present in on-site soils (RZ-A through RZ-E) for leaching potential was presented in the *Revised Technical Memorandum: Calculation of Leaching-Based, Site-Specific Levels (LSSLs) for the Soil-to-Groundwater Pathway using NDEP Guidance* by Northgate (2011b) dated May 9, 2011. This document has not been approved by NDEP. This initial screening was conducted prior to the soil removal action, so the screening included soil results from locations that were excavated as part of the soil removal action and did not include soil results from confirmation samples collected as part of the removal action. Therefore, the initial screening by Northgate will not be revised and resubmitted to NDEP, nor will it be used in future evaluations.

As part of this RI/FS Work Plan, ENVIRON conducted an updated screening of vadose zone soil concentrations against NDEP Leaching-based Basic Comparison Levels (LBCLs) or similar screening levels using a soil dataset that has been revised to incorporate changes resulting from the interim soil removal action. The revised leaching-based screening was conducted on all vadose zone soil samples collected within the alluvium in the Facility Area since 2006 that were not excavated. For this screening, a default dilution attenuation factor (DAF) of 1 was used. If warranted, ENVIRON may in the future calculate site-specific screening levels or perform unsaturated zone transport modeling to further refine the list of soil COPCs that may pose a leaching concern.

ENVIRON used the most recent version of the LBCLs from August 2013 for non-radionuclides (NDEP 2013d) and from February 2009 for radionuclides (NDEP 2009b). For chemicals detected in soil that do not have a LBCL, screening criteria were based on the USEPA Regional Screening Levels (RSLs) for groundwater protection (USEPA 2013a), with the MCL-based screening levels selected over the risk-based screening levels, if available. For the seven Aroclors and 12 dioxin-like co-planer PCB congeners, individual risk-based screening levels in the USEPA RSL table were used; for all other individual or mixtures of PCBs, MCL-based screening levels for low-risk PCBs were used. For radionuclides without NDEP LBCLs, screening criteria were based on USEPA screening levels (USEPA 2000b). Finally, for chemicals with no published NDEP or USEPA screening levels, a generic LBCL was calculated using the approach presented in NDEP guidance (NDEP 2013d).

Leaching-based soil COPCs were selected as follows. For chemicals with a site-wide detection frequency in soil greater than 5%, the chemical was considered a COPC if there was at least one detected concentration exceeding the screening level. For chemicals with a detection frequency between 0 and 5%, the chemical was considered a COPC if the maximum concentration was greater than a factor of 20 over the screening level or if the number of samples exceeding the screening level was greater than 10. Chemicals with no screening levels were retained as COPCs. The 16 dioxin and furan congeners other than 2,3,7,8-tetrachlorodibenzo-p-dioxin with toxicity equivalent factors (TEFs) defined by the World Health Organization (Van den Berg et al. 2006) were retained as COPCs in this initial screening, but will be evaluated further in the future. Consistent with USEPA guidance, the essential nutrients calcium, potassium, and sodium were not included as COPCs.

In the following list of COPCs in soil, an asterisk indicates that no comparison screening criterion was available:

Preliminary Contaminants of Potential Concern (COPCs) in Soil Based on Leaching to Groundwater		
Chlorates	Perchlorate	Chlorate
Metals	Aluminum Antimony Arsenic Barium Boron Cadmium Chromium Cobalt Copper Iron Lead Magnesium Manganese	Mercury Molybdenum Nickel Niobium Palladium* Selenium Silver Strontium Thallium Tungsten Zinc Zirconium
VOCs	Benzene 2-Butanone Carbon Tetrachloride Chlorobenzene Chloroform 1,2-Dichlorobenzene 1,4-Dichlorobenzene 1,2-Dichloroethane 1,1-Dichloroethene	1,1-Dichloropropene* 1,4-Dioxane Ethyl tert-butyl ether* Methylene Chloride Tetrachloroethene 1,2,3-Trichlorobenzene Trichloroethene 1,2,3-Trichloropropane 1,2,4-Trimethylbenzene
SVOCs	Dimethylphthalate* Formaldehyde 1-Methylnaphthalene	2-Methylnaphthalene Octachlorostyrene*
Organophosphorus Pesticides	Dimethoate	Stirphos*
Organochlorine Pesticides	alpha-BHC beta-BHC gamma-BHC 2,4’-DDE* 4,4'-DDE 4,4'-DDT	Dieldrin Endosulfan I* Endosulfan Sulfate* Endrin Ketone* Hexachlorobenzene

Preliminary Contaminants of Potential Concern (COPCs) in Soil Based on Leaching to Groundwater		
Polycyclic Aromatic Hydrocarbons (PAHs)	Acenaphthylene Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene	Benzo(g,h,i)perylene* Indeno(1,2,3-cd)pyrene Phenanthrene
Polychlorinated Biphenyls (PCBs)	Aroclor-1260 PCB-081 PCB-118 PCB-126	PCB-169 PCB-209 Total PCBs
Dioxins/Furans	2,3,7,8-tetrachlorodibenzo-p-dioxin Other 16 congeners with TEFs*	
Organic Acids	Phthalic Acid*	
Radionuclides	Radium-226 Radium-228 Thorium-228 Thorium-230 Thorium-232	Uranium-234 Uranium-235 Uranium-238 Uranium
Total Petroleum Hydrocarbons (TPH)	TPH-diesel* TPH-gasoline*	TPH-oil*
General Chemistry	Ammonia* Bromide* Carbonate* Chloride* Nitrate	Nitrite* Phosphorus (total) Ortho-Phosphate* Silicon* Sulfate* Sulfur*

For metals and radionuclides, the Site soil concentrations will be compared to background datasets to determine whether the concentrations found on-site are consistent with background. The background comparisons will be done using the background datasets described in Appendix D and consistent with the statistical approach presented in NDEP guidance (NDEP 2009f). As part of the RI, ENVIRON will review available soil data to evaluate whether any revisions to this list are necessary.

5.1.4.2 Groundwater COPCs

Perchlorate and chromium are the primary Site-related chemicals detected in groundwater downgradient of the Site. Although there is no reported use of chloroform at the Site, chloroform is also detected in groundwater at the Site, at neighboring properties, and in downgradient areas. ENVIRON developed a list of other COPCs in groundwater that exceed screening criteria. Groundwater screening criteria were selected according to the following hierarchy: 1) primary MCLs, 2) residential water BCLs (NDEP 2013d), 3) tap water RSLs (USEPA 2013a), 4) secondary MCLs, and 5) risk-based target activities for thorium isotopes from NDEP (2009b) and uranium isotopes from USEPA (2013b).

The screening for groundwater COPCs was based on analysis of data from the Phase A investigation (low-flow samples only) conducted in May 2007 (ENSR 2007a,c), Phase B investigations conducted from 2008 to 2009 (Northgate 2010h), the Upgradient Investigation (ENSR 2007d), the Capture Zone Evaluation data gaps investigation conducted in September 2010 (Northgate 2010s), and other groundwater sampling data collected since 2006. The analysis was limited to unfiltered samples for this initial screening. Groundwater samples were analyzed for metals, VOCs, SVOCs, pesticides, herbicides, dioxins, furans, radionuclides, organic acids, and other general chemistry parameters.

Groundwater COPCs were defined as follows. For chemicals with a site-wide detection frequency in groundwater greater than 5%, the chemical was considered a COPC if there was at least one detected concentration exceeded the screening level. For chemicals with a detection frequency between 0 and 5%, the chemical was considered a COPC if the maximum concentration was greater than a factor of 20 over the screening level or if the number of samples exceeding the screening level was greater than 10. If no screening criterion was available, the chemical was retained as a COPC in this initial screening, but will be evaluated further in the future. Consistent with USEPA guidance, the essential nutrients calcium, potassium, and sodium were not included as COPCs. Also in a future evaluation during the RI, metals, radionuclides, and TDS concentrations in groundwater will be compared to background concentrations to determine whether they are statistically different.

In the following list of COPCs in groundwater, an asterisk indicates that no comparison screening criterion was available:

Preliminary Contaminants of Potential Concern (COPCs) in Groundwater		
Chlorates	Perchlorate	Chlorate
Metals	Aluminum Arsenic Boron Chromium VI Chromium (total) Cobalt	Iron Lead Magnesium Manganese Strontium Tungsten
VOCs	Benzene Bromodichloromethane Bromoform 1,2-Dichlorobenzene 1,4-Dichlorobenzene 1,1-Dichloroethane 1,2-Dichloroethane 1,1-Dichloroethene 1,4-Dioxane	Carbon Tetrachloride Chlorobenzene Chloroform Chloromethane Dibromochloromethane Methylene Chloride Tetrachloroethene Trichloroethene 1,2,3-Trichloropropane
Organochlorine Pesticides	alpha-BHC	Heptachlor epoxide
Radionuclides	Radium-226 and -228 Thorium-228 Thorium-230	Thorium-232 Uranium-238 Uranium
SVOCs	bis(2-Ethylhexyl)phthalate	
General Chemistry	Ammonia Bromide* Chloride Cyanide (total) Nitrate	Nitrite Phosphorus (total) Sulfate Total Dissolved Solids
Organic Acids	4-Chlorobenzenesulfonic acid	

As part of the RI, ENVIRON will review available groundwater data to evaluate whether any revisions to this list are necessary.

5.1.5 Land Use, Exposed Populations, and Exposure Pathways

The following sections identify current and future land use at the Site and potentially exposed populations. Potential exposure pathways for evaluation in the BHRA are discussed.

5.1.5.1 Land Use and Exposed Populations

The Site is situated within an area zoned for industrial use and as discussed previously, Tronox currently has a long-term lease for approximately 114 acres of the Site where it conducts its manufacturing operations. Parcels C, D, F, G, and H (not evaluated as part of the RI/FS process, as discussed in Section 2.2) are currently subject to an option to purchase by a third party. Parcel E (part of the Facility Area) contains a portion of the OSSM groundwater treatment system.

Surrounding land use is predominantly industrial. The nearest residential developments are located north and south of the Site, with residential developments to the east and west located at a greater distance. Given the highly industrialized nature of the 5,000-acre BMI Complex (which includes the Facility Area and adjacent facilities), and the long-term lease with Tronox, future use of the Facility Area is expected to remain industrial.

Potentially exposed populations (receptors) were identified considering current and expected future land use. Consistent with the NDEP-approved 2010 HRA Work Plan (Northgate 2010d), current and future on-site receptors identified for evaluation in the BHRA include long-term indoor workers, long-term outdoor commercial or industrial workers, and short-term construction workers. Currently, over 100 full-time workers are employed at the Tronox facility and approximately 7 workers are employed at the GWETS.

Other potential on-site receptors include visitors and trespassers. However, as discussed in USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA 2002), evaluation of exposures to members of the public entering an operating facility is generally not warranted for two reasons: (1) public access is restricted or controlled at industrial sites, and (2) while the public may have access to a property, exposures of an on-site worker would be much higher than those of a visitor because workers spend substantially more time at a site. Accordingly, on-site visitors and trespassers will not be quantitatively evaluated in the risk assessment. These receptors were also excluded in the NDEP-approved 2010 HRA Work Plan (Northgate 2010d). Potential off-site receptors include workers, residents, and recreational users.

5.1.5.2 Exposure Media and Pathways

The potentially contaminated exposure media at the Facility Area and nearby vicinity include ambient and indoor air, soil, surface water, and groundwater. Potentially complete exposure pathways for each on-site and off-site receptor and exposure medium are discussed in the following sections and identified on the preliminary CSM diagram (Figure 5-1) and in Tables 5-2a and 5-2b.

The Facility Area was divided into subareas (exposure units) in the BHRA Work Plan. The exposure units were identified considering current and anticipated future land use and the soil category (i.e., Category 1, 2, 3, or 4 soils). The BHRA Work Plan also included preliminary summary statistics for the post-removal data set for the Facility Area as a whole and by exposure unit. Applicable elements from the 2010 HRA Work Plan were incorporated into the BHRA Work Plan and the general risk assessment methodology, including exposure equations, toxicity values, and risk equations, presented in the NDEP-approved 2010 HRA Work Plan (Northgate 2010d), will be adopted in the BHRA.

Air. Chemicals detected in soil or soil gas can be transported into air through two primary mechanisms. Soil-bound chemicals can be released to air if impacted surface soils are subjected to wind erosion and/or mechanical disturbance. Volatile chemicals in soil gas can migrate through the unsaturated zone to ambient and indoor air.

- For on-site receptors, potential exposure pathways include inhalation of airborne particulates in ambient and indoor air and inhalation of VOCs in ambient and indoor air, with inhalation of VOCs in indoor air higher than those estimated for ambient air. If the cancer risk is greater than 1×10^{-6} or the HI is greater than 1 for the indoor air pathway, the potential risks to on-site outdoor workers will also be quantified. In the absence of monitoring data following soil removal activities in the Facility Area, potential airborne concentrations of COPCs resulting from Site releases will be modeled.[34] The specific models to be used were identified in the BHRA work plan. Inhalation pathways (airborne particulates and the vapor intrusion pathway) will be evaluated for all soil categories except Category 2 soils (i.e., soils for which COPC concentrations are less than BCLs). Potential exposures of current tenants will be considered in evaluating this pathway.
- For off-site receptors, inhalation exposures to airborne particulates or VOCs released from the Facility Area would be substantially lower than the exposures of on-site outdoor workers. These pathways will be evaluated if cancer risks for on-site receptors exceed 1×10^{-6} or the HI is greater than one. However, the vapor intrusion pathway for VOCs in the downgradient plume is considered a potentially complete exposure pathway for off-site receptors (indoor worker and residents). The importance of this pathway and need for quantitative assessment is under evaluation. The evaluation will consider the effectiveness of the current groundwater mitigation systems, depth of groundwater in the downgradient area, and contaminant (VOC) concentrations in downgradient groundwater.

Soil. Individuals may ingest soil inadvertently, by transfer of soil on fingers to the mouth, for example. Individuals may also be exposed to COPCs in soil through dermal contact and external gamma radiation.

- For on-site receptors, three complete exposure pathways for outdoor workers will be evaluated: (1) incidental ingestion of soil, (2) dermal contact with soil, and (3) external gamma exposure from radionuclides in soil. For the indoor worker, only the soil ingestion pathway will be evaluated quantitatively. Although the dermal pathway is considered complete for the indoor worker, exposures for this pathway would be negligible relative to the ingestion pathways; consistent with USEPA guidance (USEPA 2002) and the NDEP-approved HRA work plan (Northgate 2010d), this pathway

[34] As noted in response-to-comment #41a (see Appendix A), ENVIRON's review of an ambient air data set collected by BMI and provided to ENVIRON by NDEP indicates that the data are not representative of current conditions at the NERT site. For this reason, ambient air concentrations will be modeled.

will not be evaluated quantitatively. Inhalation of airborne soil particulates and VOCs released from soil was discussed above in the "Air" exposure medium section.

- For the ingestion, dermal contact, and external gamma exposure pathways, exposures will be evaluated for Category 3 and 4 soils. For Category 1 soils, exposures for direct contact pathways (soil ingestion and dermal contact) will be managed through the SMP (ENVIRON 2013d). The ingestion and dermal contact pathways for Category 2 soils, for which COPC concentrations are less than SRGs, will not be evaluated quantitatively.
- For off-site receptors, deposition of airborne particulates released from the Site is a potential transport mechanism. However, potential exposures of off-site receptors to deposited particulates would be negligible.

Surface Water. As previously discussed in Section 2.6, the Site is located in a very arid region with few natural surface water bodies; however, surface water is present at the Site, primarily in surface water impoundments receiving process wastewater. Surface water is also present following storm events, during which COPCs in contaminated surface soils can dissolve. Based on the surface grade and soil types, significant ponding is not expected to occur outside of major storm events.

- For on-site receptors, exposures of outdoor workers to COPCs in storm water runoff during the few yearly precipitation events would be insignificant and worker maintenance activities at the surface water impoundments and associated conveyances would be covered under regulations put forward by the Occupational Safety and Health Administration (OSHA). Based on these considerations, potential worker exposures to surface water are not identified for quantitative evaluation.

- For off-site receptors, exposure to SRCs in surface water represents a potentially complete exposure pathway. As discussed in Section 3.2.4, impacted groundwater discharges to surface water at Las Vegas Wash, which empties into Lake Mead. Lake Mead is the source of approximately 90 percent of the drinking water in Southern Nevada (Las Vegas Water District 2012). Further, Lake Mead and the downstream Colorado River serve as municipal and agricultural water sources for areas of California, Arizona, and Mexico. The existing GWETS was designed to mitigate this exposure pathway and the three extraction well fields in the system have reduced the amount of perchlorate entering Las Vegas Wash by approximately 90 percent (Las Vegas Water District 2012). Nevertheless, exposures to SRCs present in Las Vegas Wash and Lake Mead represent potentially complete exposure pathways for off-site recreational users and residents serviced by the Las Vegas Water District, as well as recreational users and residents in California, Arizona, and Mexico served by Lake Mead and the Colorado River.

Groundwater. Businesses and residences located within or downgradient of the BMI Complex are connected to a municipal water supply. NDEP has conducted a survey of identified private well owners in the area downgradient of the BMI Complex to confirm that the wells are no longer present, and none were identified. NDEP is coordinating with the Southern Nevada Water Authority to investigate the status of a private well identified at a business property within the municipal hookup area in September 2013. Based on the available information, groundwater is not currently used as a source of drinking water, and given the high concentrations of TDS, will not be used in the future as a drinking water source. The only potential for direct contact with groundwater is associated with intrusive subsurface activities.

- For on-site receptors, direct contact with groundwater (i.e., incidental ingestion or dermal contact) during construction activities is considered to be an incomplete exposure pathway. Depth to groundwater ranges from about 27 to 80 ft bgs, deeper than excavations typically associated with construction activities. Further, potential exposures of workers (e.g., construction or utility workers) associated with activities at depths greater than 10 ft bgs are managed through the SMP (ENVIRON 2013d). Specifically, the SMP presents risk management measures and procedures to be implemented during construction to mitigate potential risks to human health and the environment from potential exposure to COPCs, and to manage soil and groundwater during construction activities.

  Potential exposures of current and future indoor receptors will be evaluated for the vapor intrusion pathway (with groundwater as the source of VOCs) for all areas of the Site where data indicate that groundwater is contaminated with VOCs. If risks or HIs exceed 10^{-6} or 1, respectively, for the on-site indoor commercial/industrial worker, then potential risks to on-site outdoor commercial/industrial workers will also be quantified.

- For off-site receptors, although depth to groundwater can be less than 20 ft in the downgradient area, potential exposures of construction workers to groundwater are considered negligible. Direct contact with groundwater (incidental ingestion or dermal contact) would be intermittent and standard engineering controls such as dewatering of excavations, minimize worker exposures. Indirect pathways (specifically, the vapor intrusion pathway) will be evaluated in off-site areas with site-related VOC concentrations greater than screening levels.

5.1.6 Screening-Level Ecological Risk Assessment

A screening-level ecological risk assessment (SLERA) will be conducted for the Site. The SLERA will involve a field survey by a certified ENVIRON biologist/ecologist to assess the environmental setting and identify potential habitat in and around the Site. If there is no indication that threatened or endangered species are present at the Site and that the Site does not provide any functional habitat for wildlife populations, further evaluation of ecological risks will not be completed. In the event that potential exposure pathways are present, the SLERA will follow USEPA’s (1997a) approach to identify chemicals of potential ecological concern (COPECs). If warranted, the risk evaluation may include the refinement of COPECs to identify those receptors and chemicals that may require further consideration in a baseline ecological risk assessment. A separate work plan will be submitted to NDEP in July 2014 for the SLERA and refinement of COPECs.

5.2 Remedial Action Objectives and ARARs

RAOs are media-specific (e.g., soil or groundwater) objectives designed to protect human health and the environment from releases and exposures to hazardous substances. RAOs incorporate information regarding the specific setting, COPCs, potential future uses of the Site, and human health and ecological risk-based criteria. The RAOs reflect a preference for permanent solutions, incorporating approaches, where feasible and appropriate, that will reliably reduce contaminant toxicity, mobility, or volume.

Applicable or relevant and appropriate requirements (ARARs) are considered during the development of RAOs. Applicable requirements are those federal and state cleanup standards, standards of control, and other environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site. If a requirement is not applicable, it may still be relevant and appropriate. A relevant and appropriate requirement addresses problems or situations that are substantially similar to those encountered at a similar site.

5.2.1 Identification and Selection of Applicable or Relevant and Appropriate Requirements

It is not unusual that multiple federal and/or state requirements are initially identified as being relevant, even though the requirements address similar issues or circumstances. USEPA ARAR guidance provides for screening of the "relevant" requirements to determine which requirements are "appropriate" and hence, an ARAR. "Relevant" requirements would not be considered "appropriate" when:

- "...another requirement is available that more fully matches the circumstances at the site," or
- "...another requirement is available that has been designed to apply to that specific situation, reflecting an explicit decision about the requirements appropriate to that situation."

For a state requirement to qualify as an ARAR, it must be promulgated, legally enforceable, more stringent than any corresponding federal requirement, consistently applied, and identified in a timely manner.

ARARs fall into one of three identified categories: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs are health- or risk-based numerical limitations or standards that apply to site-specific conditions. Location-specific ARARs are restraints placed on activities conducted in a specific location. Action-specific ARARs are technology- or activity-based requirements or limitations on actions taken with respect to hazardous waste or site remediation activities.

In addition to chemical-, location-, and action-specific ARARs, advisories, criteria, and guidance developed by USEPA or other federal or state agencies may, as appropriate, be considered in developing remediation alternatives. These criteria are referred to as "to-be-considered" (TBC) criteria.

5.2.1.1 Potential Chemical-Specific ARARs and TBC Criteria

As discussed in the July 2011 NDEP Action Memorandum, federal chemical-specific ARARs determined to be practicable for the Site are as follows:

- Safe Drinking Water Act (SDWA) under 40 CFR 142;
- Toxic Substances Control Act (TSCA); and
- OSHA Standard 29 CFR 1910 Subpart Z (Toxic and Hazardous Substances). Subpart Z provides permissible exposure limits (PELs), communication guidelines, and chemical specific information for hazardous substances.

State chemical-specific ARARs determined to be applicable for the Site are as follows:

- Nevada Administrative Code (NAC) 445A.200 - 201 (Las Vegas Wash Beneficial Use Standards for Confluence of Las Vegas Wash with Lake Mead to Telephone Line Road); and
- NAC 445A.121 - 122, and 445A.1236 (Standards for Water Quality).

The following federal chemical-specific TBC criteria were identified for perchlorate in groundwater:

- "Interim Drinking Water Health Advisory for Perchlorate" prepared by USEPA Office of Science and Technology, Office of Water, EPA 822-R-08-025 dated December 2008 (USEPA 2008); and,
- "Revised Assessment Guidance for Perchlorate", Memorandum prepared by USEPA Office of Solid Waste and Emergency Response dated January 8, 2009 (USEPA 2009a).

The following state chemical-specific TBC criteria were identified for groundwater, soil, or surface water. These values are generally risk-based concentrations that are to be used as guidelines for preliminary screening evaluations:

- Under NAC 445A.226 – 22755, Action Levels (ALs) for contaminated sites are derived. BCLs are risk-based media concentrations for use in an initial screening evaluation to assist in risk assessment components such as the evaluation of data usability, determination of extent of contamination, identification of COPCs, and identification of preliminary remediation goals. The BCL values are derived as specified in NAC 445A.2272 and using equations from USEPA guidance, USEPA toxicity criteria, and USEPA exposure factors.

5.2.1.2 Potential Location-Specific ARARs

Location-specific ARARs are restraints placed on activities to be conducted in specific locations. Types of location-specific ARARs include requirements restricting actions or protecting floodplains, wetlands, historic places, archeological sites, and sensitive ecosystems. Potential federal location-specific ARARs at the Site are:

- Clean Water Act (CWA) 40 CFR 131, 404 and 33 CFR Part 330 (Dredge and Fill Material Discharge into Waterways);
- Federal Migratory Bird Treaty Act (Federal Protection of Migratory Birds);

- Federal Endangered Species Act of 1973 (Conservation of Threatened and Endangered Plants and Animals and the Habitats); and
- The National Historic Preservation Act of 1966, as amended in 2006, 16 U.S.C. 470 (NHPA) 36 CFR 65, 68, and 800 (Standards for the Designation, Treatment, and Protection of Historic Properties). These codes are applicable if a portion of the Site is deemed to be a "historic property."

Potential State location-specific ARARs at the Site are:

- Nevada Revised Statute (NRS) 535 (Dams and Other Obstructions); and
- NAC 534 (Underground Water and Wells).

5.2.1.3 Potential Action-Specific ARARs

Action-specific ARARs are technology- or activity-based requirements or standards that apply to specific remedial activities conducted as part of a selected remedy. Potential federal action-specific ARARs are:

- Resource Conservation and Recovery Act (RCRA), as amended by the 1984 Hazardous Solid Waste Amendments:
  - 42 USC Chapter 82 Section 6901 - 6991 (Solid Waste Disposal);
  - 40 CFR 261 (Identification and Listing of Hazardous Waste);
  - 40 CFR 262 (Standards Applicable to Generators of Hazardous Waste); and
  - 40 CFR 263 (Standards Applicable to Transporters of Hazardous Waste).
- National Pollution Discharge Elimination System (NPDES) Permits issued under the CWA 40 CFR 122-125 (Discharge of Treated Groundwater to Surface Water);
- National Pretreatment Standards for Discharges to Public Owned Treatment Works (POTWs) under the CWA 40 CFR 403 (Discharge of Wastewater and Treated Groundwater to Sewers);
- CWA and Oil Pollution Act (OPA) 40 CFR 112 (Oil Pollution Prevention):
  - 40 CFR 112 Subpart A (General Applicability and Requirements);
  - 40 CFR 112.8 (Spill Prevention, Control, and Countermeasure (SPCC) Plan Requirements for Onshore Facilities); and
  - 40 CFR 112 Subpart D (Response Requirements).
- SDWA 40 CFR 144 (Groundwater Injection);
- Clean Air Act (CAA) 40 CFR 51 (New Source Review/Prevention of Significant Deterioration Rules for Nonfugitive Major Emission Sources);
- CAA 40 CFR 61 (National Emission Standards for the Hazardous Air Pollutants);
- Hazardous Materials Transportation Act 40 CFR 171-178 (Transportation of Hazardous Materials);

- Federal Hazardous Materials Transportation Law (49 U.S.C. 5101 et seq.) 49 CFR 171 and 172 (General Information, Regulations, Definitions, Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans); and
- OSHA 29 CFR 1910.20 (Worker Training for Remediation Activities at Hazardous Waste Remediation Sites).

Potential State action-specific ARARs are:

- NAC 459.970 - 9729 (Certification of Certain Consultants and Contractors);
- NAC 445A.121 - 122, and 445A.1236 (Standards for Water Quality);
- NAC 445A.228 - 263 (Discharge Permits);
- NAC 444.965 - 976 (Disposal of Asbestos);
- NAC 445A.810 - 925 (Underground Injection Control);
- NRS 533.437 - 4377 (Groundwater Appropriations — Environmental Permits);
- Clark County Air Quality Regulations (CCAQRs) Section 12.0 - 12.13 (Stationary Source Permitting). CCAQRs require permits for source facilities based on emission rates of the following: particulate matter (PM_{10}), carbon monoxide (CO), VOCs, nitrogen oxides (NO_x), sulfur dioxide (SO_2), Lead (Pb), total reduced sulfur, and hydrogen sulfide (H_2S);
- CCAQR Section 26 (Emission of Visible Air Contaminants);
- CCAQR Section 40 (Prohibitions of Nuisance Conditions);
- CCAQR Sections 41 and 90 - 93 (Fugitive Dust);
- CCAQR Section 45 (Idling of Diesel Powered Motor Vehicles);
- CCAQR Sections 50 and 51 (Storage and Loading of Petroleum Products); and
- CCAQR Section 94 (Permitting and Dust Control for Construction Activities). Requires permits for construction activities including, but not limited to, soil excavation, grading, and mechanized trenching.

5.2.2 Potential RAOs for the Site

For consistency with the National Oil and Hazardous Substances Contingency Plan (NCP, 40 CFR 300), RAOs proposed for the Site must be technically feasible and comply with ARARs (40 CFR 300.430). As discussed above and in the NDEP Action Memorandum dated July 21, 2011 (NDEP 2011a), the primary chemical-specific ARARs that apply to groundwater at the Site include:

- SDWA USEPA Maximum Contaminant Levels (MCLs) under 40 CFR 142;
- Nevada Water Quality Standards under NAC 445A.200 - 201 which include Las Vegas Wash Beneficial Use Standards for Confluence of Las Vegas Wash with Lake Mead to Telephone Line Road.

In addition, TBC criteria would include the BCLs discussed above. With respect to perchlorate, the TBC criteria include the Nevada Interim Action Level (AL) for perchlorate in drinking water of 18 µg/L (NDEP 2011a,b) and the Interim Drinking Water Health Advisory and federal PRG of 15 µg/L (USEPA 2008 and USEPA 2009a).

The proposed RAOs for groundwater have been selected to incorporate the following chemical-specific ARARs/TBCs:

- Perchlorate: Because there are no chemical-specific ARARs for perchlorate, the most applicable and relevant TBC for perchlorate that is protective of human health is the Interim Drinking Water Health Advisory and federal PRG of 15 µg/L (USEPA 2008 and USEPA 2009a), chosen over the Nevada Interim AL of 18 µg/L since it is the lower of the two values.

- Other Site COPCs: The most prevalent COPC detected in groundwater at the Site other than perchlorate is chromium. The chemical-specific ARAR for chromium is the federal MCL of 100 µg/L, which the State of Nevada has adopted by reference (NAC 445A). For other Site COPCs, the chemical-specific ARARs/TBCs discussed above will be evaluated based on the results of a site-specific risk assessment and incorporated into the Site FS.

In addition, while acknowledging that other sites are contributing COPCs to Las Vegas Wash and Lake Mead (including sites within the BMI Complex, as well as upgradient and downgradient sources), both short- and long-term remedial actions selected at this Site shall help achieve at downstream state boundaries out-of-state MCLs: namely, California's MCL for perchlorate of 6 µg/L (California Code of Regulations [CCR] Title 22, Section 64431) and other MCLs for COPCs originating at the Site (CCR Title 22, Division 4, Chapter 15), and Arizona Administrative Code [AAC] Title 18, R-18-4-104, R-18-109).

5.2.2.1 Short-Term Remedial Action Objectives

Short-term RAOs for the Site are those RAOs that are projected to be met in less than 5 years at the Site.

- **Off-Site Groundwater and Las Vegas Wash:** To meet the primary CERCLA objective of being protective of human health and the environment, discharge of COPCs originating at the Site to the Las Vegas Wash will be mitigated to help achieve chemical-specific ARARs/TBCs within the Wash. This RAO is currently being achieved, in part, and (in the short-term) will be met via continued operation of the SWF, the AWF, and the IWF and Barrier Wall System. RAOs associated with on-site soils and groundwater (described below) will be consistent with meeting this objective in the long-term.

- **Optimization/Enhancement of Groundwater Extraction and Treatment System:** Consistent with the short-term RAO regarding off-site groundwater and Las Vegas Wash (described above), the current groundwater extraction and treatment system will be investigated with the objective of optimizing operation and enhancing performance of the system, including pumping at all three extraction well fields. The current system has been effective in reducing the concentrations of perchlorate in Las Vegas Wash. In 2011, annual average perchlorate concentrations in Las Vegas Wash were 14.8 µg/L at Pabco Road and 44.8 µg/L at Northshore Road (USBOR 2012). In Lake Mead, perchlorate concentrations in 2011 at site CR 346.4 were generally below 3 µg/L (LVWCC 2013). The optimization program will investigate current groundwater pumping schemes and the system configuration to ensure that maximum capture efficiency is being achieved at each of the three extraction well fields and to evaluate whether alternatives could be used to enhance such efficiency and improve cost-effectiveness.

- **Shallow Soil:** Prevent human exposure to COPCs in soil that would pose an unacceptable health risk to on-site and off-site receptors under current and future land uses.

5.2.2.2 Long-Term Remedial Action Objectives

Long-term RAOs for the Site are those RAOs that will focus on achieving restoration of downgradient groundwater over a long time frame (i.e., greater than 5 years).

- **Downgradient Aquifer Restoration:** The overall RAO for groundwater downgradient of the Site is to restore the alluvial aquifer and UMCf to meet ARARs/TBCs. This RAO will be achieved incrementally by first focusing on the control of off-site migration of COPCs at the downgradient boundary of the Site (see below).

- **On-Site Groundwater Control:** To achieve the overall long-term RAO of downgradient aquifer restoration, the migration of COPCs present in groundwater at the Site will be mitigated. Specifically, groundwater immediately downgradient of the northern property boundary of the Site will meet ARARs/TBCs likely through a combination of the implementation of on-site vadose zone source control and the implementation (as required) of barrier groundwater control options (e.g., extraction, hydrogeologic barriers, or in-situ treatment).

- **Vadose Zone Source Control:** To be consistent with the preference for permanent remedies, incorporating approaches that will reliably reduce contaminant toxicity, mobility, or volume through treatment, this RAO will address the mitigation of significant leaching of perchlorate and other Site COPCs from vadose zone soils to underlying groundwater. In addition, vadose zone source control will also reduce direct contact with COPCs present in soil. The effectiveness and implementability of this RAO could be limited by the presence of existing operating units at the Site and therefore, will be evaluated in conjunction with on-site groundwater control alternatives to ensure that ARARs/TBCs will be achieved at the downgradient Site boundary. It is also anticipated that additional areas of vadose zone source control will be identified in the future as Site operations and Unit buildings are altered and/or decommissioned.

5.3 Development of General Response Actions and Screening of Remedial Technologies and Process Options

Under USEPA RI/FS guidance (USEPA 1988), a preliminary range of remedial action alternatives and associated technologies should be identified. This identification is not meant to be a detailed investigation of alternatives. Rather, it is intended to be a more general classification of potential remedial actions based upon the RAOs. To accomplish this, as described in this section, general response actions (GRAs) were developed for the Site. Following the identification of GRAs, and in accordance with USEPA RI/FS guidance, remedial technologies and process options were identified and initially screened. Following the initial screen, the process options retained for further analysis were further evaluated and screened. Process options were eliminated from further consideration if other process options within the same technology type offer significant relative advantages. The purpose of this screening step is to minimize the number of process options that must be considered in the development of alternatives without limiting the flexibility of the remedial design.

5.3.1 General Response Actions

GRAs are media-specific actions that satisfy RAOs that have been developed for the Site. The GRAs that have been developed for groundwater and associated source areas at the Site are summarized below.

- **No Further Action (NFA).** Evaluation of a "no action" alternative, or a no further action alternative if removal or remedial actions have already been implemented, is required under the NCP (40 CFR §300.430). For this GRA, it is assumed that no further removal or remedial actions, other than those removal actions that have already been implemented at the Site, would be performed.
- **Institutional Controls.** Institutional controls are legal or physical means to prevent potential exposures to COPCs by limiting the use of contaminated property (e.g., limiting groundwater use).
- **Groundwater Monitoring.** Impacted groundwater may be monitored on a periodic basis to ensure that chemical concentrations do not increase such that there is an unacceptable risk to human health or the environment.
- **Monitored Natural Attenuation.** Monitored natural attenuation relies on natural processes to achieve site-specific remedial objectives and routine monitoring to measure progress toward those objectives. The "natural attenuation processes" include physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentrations of contaminants in groundwater.
- **Containment Actions.** These response actions reduce the mobility of COPCs, eliminate exposure pathways, and prevent the migration and transport of COPCs to unaffected media.
- **Groundwater Extraction.** These response actions provide for extracting groundwater prior to ex-situ treatment.
- **Ex-Situ Groundwater Treatment Actions.** These response actions provide for treatment of extracted groundwater prior to discharge/disposal.
- **Excavation.** These response actions provide for excavation of source areas, prior to ex-situ treatment or disposal.

- **Ex-Situ Source Area Treatment Actions.** These response actions provide for treatment of excavated source area soils.
- **In-Situ Groundwater Treatment Actions.** These response actions reduce the mobility of COPCs, eliminate exposure pathways and prevent the migration and transport of COPCs to unaffected media.
- **In-Situ Source Area Treatment Actions.** These response actions are intended to reduce the concentrations of COPCs within vadose zone source areas in order to reduce the toxicity, mobility, or volume of contamination and also to aid in the attainment of RAOs at downgradient locations.
- **Discharge of Water from Ex-Situ Groundwater Treatment Actions.** These response actions provide for the disposal of treated liquids resulting from groundwater extraction and treatment operations.
- **Ex-Situ Vapor/Air Emissions Treatment Actions.** These response actions provide for the ex-situ treatment of vapors or other air emissions resulting from other in-situ or ex-situ treatment operations.

5.3.2 Initial Screening of Remedial Technologies and Process Options

A list of potentially applicable technology types and process options has been identified, evaluated, and screened for each GRA that has been developed for the Site. The term "technology types" refers to general categories of remedial technologies, and the term "process options" refers to specific processes within each of the technology types. The technology types and process options that have been considered and evaluated in this section are based upon ENVIRON's experience at similar sites and readily available technical information from government, industry, and academia including the following sources:

- Department of Toxic Substances Control (DTSC), 2004. Perchlorate Contamination Treatment Alternatives. January.
- Evanko, C.R. and Dzombak, D.A., 1997. Technology Evaluation Report TE-97-01: Remediation of Metals-Contaminated Soils and Groundwater. Ground-Water Remediation Technologies Analysis Center (GWRTAC). October.
- Federal Remediation Technology Roundtable (FRTR). 2012. www.frtr.gov.
- Interstate Technology & Regulatory Council (ITRC), 2000. Technology Overview: Dense Non-Aqueous Phase Liquids (DNAPLs): Review of Emerging Characterization and Remediation. Interstate Technology & Regulatory Council. June.
- ITRC, 2007. Remediation Technologies for Perchlorate Contamination in Water and Soil. PERC-2. Interstate Technology & Regulatory Council, Perchlorate Team. www.itrcweb.org.
- Sale, T. and Newell, C., 2011. A Guide for Selecting Remedies for Subsurface Releases of Chlorinated Solvents, U.S. Department of Defense, Environmental Security and Technology Certification Program (ESTCP) Project ER-200530. March.

- Urbansky, E. T, 1998. Perchlorate chemistry: implications for analysis and remediation. Bioremediation Journal 2, 81–95.
- USEPA, 1986. Grouting Techniques in Bottom Sealing of Hazardous Waste Sites. (EPA/600/2-86/020).
- USEPA, 1997b. Engineering Bulletin: Technology Alternatives for the Remediation of Soils Contaminated with As, Cd, Cr, Hg, and Pb. (EPA/540/S-97/500). August.
- USEPA, 2000a. In-Situ Treatment of Soil and Groundwater Contaminated with Chromium, Technical Resource Guide. (EPA/625/R-00/005). October.
- USEPA, 2004b. In-Situ Thermal Treatment of Chlorinated Solvents: Fundamentals and Field Applications. (EPA/542/R-04/010). March.
- USEPA, 2004c. DNAPL Remediation: Selected Projects Approaching Regulatory Closure. (EPA 542-R-04-016). December.
- USEPA, 2005. Perchlorate Treatment Technology Update, Federal Facilities Forum Issue Paper. (EPA/542/R-05/015). May.
- USEPA, 2009b. DNAPL Remediation: Selected Projects Where Regulatory Closure Goals Have Been Achieved. (EPA 542/R-09/008). August.
- USEPA, 2012. Contaminated Site Clean-up Information Website. http://www.clu-in.org/.

According to USEPA guidance (USEPA 1988), technology types and process options are screened to retain implementable technologies that can be used in the development of remedial alternatives. During this initial screening step, process options are eliminated from further consideration on the basis of technical implementability (either as a stand-alone remedy or as a component of an overall remedial option). Readily available data concerning Site characteristics and chemical distributions are used to screen out technologies and process options that cannot be effectively implemented at the Site.

Because the Site covers a relatively large area, consists of variable geological features, and contains a number of different classes of contaminants, the relatively broad spectrum of technologies evaluated herein was required to fully evaluate technologies with potential applicability at the Site.

The results of the initial screening of remedial technologies and process options for the Site are summarized in Table 5-3. Table 5-3 lists GRAs, remedial technologies and process options that were considered during the initial screening process, descriptions of process options, and screening comments that support conclusions concerning the technical implementability of the various process options. Process options that were retained for secondary screening are shaded, while process options that were eliminated from further consideration are unshaded.

A total of 119 discrete process options were included in the initial screening matrix for the Site. Of these, 10 process options were eliminated from further consideration based on a lack of technical implementability, leaving 109 process options that were retained for further analysis.

5.3.3 Secondary Screening of Process Options

During this stage of the screening process, the process options that were retained within the initial screening process were further evaluated and screened on the basis of effectiveness, implementability, and relative cost.

5.3.3.1 Process Option Screening Criteria

As noted above, process options were screened in this step on the basis of effectiveness, implementability, and cost. These screening criteria are discussed below.

- **Effectiveness**: The effectiveness of process options that are considered to be technically implementable is evaluated relative to other processes within the same technology type. This evaluation focuses upon: (1) the potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the remediation goals identified in the RAOs; (2) the potential impacts to human health and the environment during the construction and implementation phase; and (3) how proven and reliable the process is with respect to the contaminants and conditions at the Site.

- **Implementability**: Implementability encompasses both the technical and administrative feasibility of implementing a process option. Since technical implementability is used as a screening criterion during initial screening to eliminate technology types and process options, this secondary screening process places more emphasis on the institutional aspects of implementability such as the ability to obtain necessary permits, the availability of treatment, storage, and disposal facilities, and the availability of equipment and skilled workers necessary to implement the process option.

- **Cost:** At this early stage in the RI/FS process, relative capital and operations and maintenance (O&M) costs are qualitatively compared using engineering judgment. Each process is evaluated as to whether costs are high, moderate, or low relative to other process options in the same technology type. Life cycle costs have been considered, though not explicitly, in the relative cost comparisons in the initial screening process.

5.3.3.2 Preliminary Selection of Feasible Technologies

Results of secondary screening of process options on the basis of effectiveness, implementability, and cost are summarized in Table 5-4. Of the 109 process options that were retained for further evaluation after the initial screening step, an additional 46 process options were screened out from further consideration in this step. A total of 63 process options were retained from the secondary screening process for remedial alternative development. A general summary of the process options retained for further analysis in the RI/FS is provided below.

No Further Action

This option is required under the NCP for comparison purposes. This option stipulates that no actions are to be taken beyond the previous and current interim removal actions described in Section 4 of this Work Plan, including the interim soil removal actions and health risk assessments described in Sections 4.1 and 4.2, the historical and current groundwater removal actions described in Section 4.3 (i.e., the construction and operation of the GWETS), and the groundwater monitoring described in Section 4.4.

Management Options

Management options include those which limit exposures to COPCs through the use of institutional controls and other administrative instruments implemented at the Site. Examples of management options that have been retained for further evaluation include the following:

- Groundwater Use Restrictions;
- Site Access Restrictions;
- SMP to manage risk to Site occupants and workers by identifying remaining COPCs left in place and the appropriate risk management measures to follow when encountering/ disturbing media containing COPCs;
- Legal Restrictions to Land Use; and
- Deed Restrictions.

Monitoring Options

Monitoring options include those to limit exposures to COPCs through the methodic and routine observation, measurement, and/or sample collection/analysis of environmental media. Monitoring options are used to ensure that levels of COPCs do not exceed certain health or environmental standards and to alert site managers to changing conditions that may lead to such an exceedance in the future, so that preventative measures can be implemented. In the case of monitored natural attenuation, monitoring is used to measure the progress of natural processes to reduce the mass, mobility, and/or toxicity of COPCs. Examples of monitoring options that have been retained for further evaluation include the following:

- Groundwater Sampling and Monitoring; and
- Monitored Natural Attenuation of Groundwater.

Source Control Options

Source control options include those which restrict or mitigate the transport of COPCs from source areas to downgradient groundwater and off-site receptors. Contaminant discharge from sources can be reduced via containment and/or depletion. Some process options can perform both functions depending on how they are implemented (e.g., groundwater extraction). Examples of source control options employing a containment approach that have been retained for further evaluation include the following:

- Groundwater Extraction/Hydraulic Containment (including applicable ex-situ groundwater treatment options);
- Slurry Walls;
- Single-Layer Synthetic Membrane Cap;
- Multi-Layered Cap System; and

- Asphalt/Concrete Paving.

Examples of source control options employing a source depletion approach that have been retained for further evaluation include the following:

- Groundwater Extraction (including applicable ex-situ groundwater treatment options);
- Soil Flushing;
- Soil Excavation;
- Enhanced Reductive Bioremediation;
- In-Situ Chemical Reduction (ISCR);
- In-Situ Chemical Oxidation (ISCO);
- Soil Vapor Extraction (SVE) (including applicable ex-situ vapor treatment options);
- Dual-Phase Extraction (DPE) (including applicable ex-situ vapor and groundwater treatment options);
- Multi-Phase Extraction (MPE) (including applicable ex-situ vapor, groundwater, and DNAPL treatment options);
- Air Sparging (including applicable ex-situ vapor treatment options); and
- In-Situ Well Stripping (including applicable ex-situ vapor treatment options).

Downgradient Plume Options

Downgradient plume options include those which restrict or mitigate the transport of off-site COPCs to further downgradient groundwater and off-site receptors. Ultimately, in keeping with the long-term RAOs, the downgradient plume options are those capable of also restoring off-site groundwater in the alluvial aquifer and UMCf to meet ARARs/TBCs. Examples of downgradient plume options that have been retained for further evaluation include the following:

- Groundwater Extraction (including applicable ex-situ groundwater treatment options);
- ISCR;
- Enhanced Reductive Bioremediation – Mobile Amendments;
- Enhanced Reductive Bioremediation – Fixed Biobarriers; and
- Slurry Walls or Other Containment Options.

In-Situ Process Enhancement Options

In-situ process enhancement options include those which can enhance the performance of the source control and downgradient plume options. These options can be employed within low-permeability formations to enhance either the yield of groundwater and/or vapor extraction process options or increase distribution of substrates or other subsurface amendments for enhancing the performance or longevity of in-situ biological/chemical options. Examples of in-situ process enhancement options that have been retained for further evaluation include the following:

- Pneumatic Fracturing;
- Hydraulic Fracturing;
- Funnel and Gate;
- Directional Wells;
- Soil Flooding; and
- Bioremediation.

Ex-Situ Groundwater Treatment

Ex-situ groundwater treatment options include those which can reduce the mass, mobility, and/or toxicity of COPCs in extracted groundwater from on-site and off-site groundwater extraction facilities. Examples of ex-situ groundwater treatment options that have been retained for further evaluation include the following:

- Air Stripping;
- Liquid-Phase Carbon Adsorption Using Granular Activated Carbon (GAC);
- Chemical Oxidation;
- Chemical Precipitation;
- Coagulation/Flocculation;
- IX Using Single-Use Resins;
- Anaerobic FBRs; and
- Anaerobic Continuously-Stirred Tank Reactors (CSTRs).

Discharge Options

Discharge options include those allowing discharge of extracted groundwater. Examples of discharge options that have been retained for further evaluation include the following:

- Surface Water Discharge;
- Sewer Discharge;
- Water Reuse;
- Subsurface Water Discharge;
- Pittman Bypass Pipeline; and
- Zero Discharge (i.e., enhanced evaporation mechanisms).

Ex-Situ Vapor/Air Emissions Treatment

Ex-Situ vapor/air emissions treatment options include those which remove COPCs from vapor or air emissions resulting from other process options. Examples of ex-situ vapor/air emissions options that have been retained for further evaluation include the following:

- Vapor Phase Carbon Adsorption;

- Advanced Oxidation;
- Catalytic Oxidation;
- Thermal Oxidation; and
- Biofiltration.

Following completion of site characterization, risk assessment, and treatability study tasks in the RI/FS, the above process options will be evaluated to determine their applicability in relevant regions of the Site. Following this evaluation, the process options will be assembled into several remedial alternatives for further evaluation in the FS.

5.3.4 Preliminary Remedial Action Alternatives

From the preliminary screening evaluation, a number of practicable remedial technologies and process options to address the COPCs in soil and groundwater at the Site were retained based on readily available Site information and professional experience. From this list of retained technologies and process options, the following preliminary remedial action alternatives (RAAs) were developed for further evaluation. ENVIRON notes that the RAAs presented here are not meant to be comprehensive and specific with respect to the retained process options to be evaluated in each. Rather, we have identified conceptual RAAs that would address the primary COPCs and RAOs identified for the Site. It is anticipated that numerous variations on each conceptual RAA identified below will be included for analysis in the FS. As information is obtained in the RI to address data gaps, additional RAAs may be identified and included in future analyses. Short-term and long-term RAOs, which must be technically feasible and comply with ARARs, will be used to evaluate the acceptability of each of RAA. Alternatives that meet both short-term and long-term RAOs will be ranked higher than RAAs that meet only short-term or long-term RAOs. The criteria used to evaluate RAAs are discussed in more detail in Section 6.11.

The conceptual remedial alternatives developed from the preliminary screening include:

RAA-1 – No Further Action

The No Further Action alternative involves no remedial actions beyond the interim measures currently in place, and represents a baseline for comparison of the remaining remedial alternatives. The No Further Action alternative is not expected to meet RAOs defined for the Site.

RAA-2 – Enhancement of Groundwater Containment, Recovery, and Aboveground Treatment via Upgrades to the Existing GWETS

This alternative would include use of the existing GWETS as a primary component for both on-site containment of COPCs and for downgradient groundwater restoration. Enhancements to the existing GWETS would likely be required to meet RAOs and could include the installation of additional extraction wells to improve horizontal and vertical capture. Groundwater modeling would be used to optimize groundwater extraction using the new wells. Upgrades to the treatment system could be necessary to handle increased hydraulic and/or mass loading.

Groundwater treatment process options and discharge options retained in the screening process described above would be considered for this purpose.

RAA-3 – Enhancement of Groundwater Containment, Recovery, and Aboveground Treatment via Upgrades to the Existing GWETS and On-site Source Control

This alternative would employ the same upgrades to the existing GWETS identified in RAA-2 and also examine the potential effectiveness of employing source control alternatives to mitigate the migration of COPCs from on-site vadose zone source area soils to groundwater. The methods of source control could include containment and/or source depletion options. Source control process options to be examined in this alternative would include capping, soil flushing, and in-situ treatment options. Treatability/pilot testing of soil flushing, which appears to be particularly promising as a source control option for perchlorate based on preliminary screening, was proposed in a revised work plan submitted to NDEP on May 9, 2014 and approved on May 20, 2014 (ENVIRON 2014g).

RAA-4 – Enhanced Groundwater Containment and Extraction at the IWF and AWF with In-Situ Treatment Downgradient of the AWF

This alternative would employ some of the same upgrades to the existing GWETS identified in RAA-2 or RAA-3 with the implementation of an in-situ treatment (e.g., enhanced bioremediation via a permeable reactive barrier) downgradient of the AWF. Depending on the demonstrated effectiveness of the in-situ treatment system, this alternative could ultimately include reducing (or eliminating) the operation of the SWF. Treatability/pilot testing of enhanced in-situ bioremediation was proposed in a revised work plan submitted to NDEP on May 9, 2014 and approved on May 20, 2014 (ENVIRON 2014f).

5.4 Data Gaps

As discussed in Section 3, the Site has been the subject of numerous regulatory actions and environmental investigations since the early 1970s. The soil and groundwater investigations conducted through 2005 served as the basis of the first comprehensive CSM developed for the Site in 2005 (ENSR 2005). Since then, additional soil and groundwater investigations and interim removal actions (described in Section 4) have been conducted. For the RI/FS, additional areas have been identified that require investigation to determine the nature and extent of COPCs in soil and groundwater at the Site. Many of these areas were previously identified by NDEP as areas requiring further study.

5.4.1 Soil

The purpose of soil investigations conducted during the RI phase is to complete characterization activities (i.e., to address data gaps) at the Facility Area and ensure that adequate data is available to: (1) conduct the BHRA, (2) identify and evaluate potential sources of COPCs in groundwater, and (3) support the development and evaluation of remedial alternatives.

All analytical results for soil samples in areas not removed during the interim soil removal action and that remain representative of current conditions at the Facility Area are being reviewed for usability in the BHRA. For many analytes, the post-remediation data set for 0-10 ft depth interval includes results at over 500 sampling locations, although for other analytes (particularly those not expected to be Site related) the analytical data set is much more limited. The ongoing data gap evaluation considers spatial coverage for the preliminary list of soil COPCs and the exposure units that were identified in the BHRA work plan (see Section 6.7 for additional information on the BHRA work plan). For the evaluation of potential groundwater sources, the analytical results from both shallow and deep soils are being reviewed for spatial coverage, considering the current understanding of groundwater contamination.

5.4.1.1 Soil Data Gaps

Several data gaps have been identified based on the review of the post-removal soil data set completed to date. As shown on Figure 5-5a, additional physical and chemical data are needed in both shallow and deep soils in at least four main areas.

These areas, and the general nature of the investigation in each area, can be described as follows:

- **Pond AP-5.** Relatively high concentrations of perchlorate and chromium have been detected in groundwater in the AP-5 pond area. NDEP previously identified Pond AP-5 as a potential source of metals, hexavalent chromium, perchlorate, chlorate, and ammonium (NDEP 2011a). As discussed in Section 4.4.1, draining and removal of residual solids from the pond has been proposed to NDEP. Following draining and residual solids removal, approximately 6 to 8 soil borings are anticipated to be installed in the area of the former Pond AP-5. The exact number of these borings are identified in the SAP and soil boring locations will be designated following pond decommissioning.
- **Debris pile.** Data are needed to evaluate the nature of the debris in the debris pile and the chemical and physical characteristics of the soil within and below the debris pile, as well as soil to the area south of the debris pile. NDEP has previously requested that this area be investigated during the RI. It is anticipated that three exploratory trenches/test pits will be constructed within the debris pile to observe the materials in the debris pile. Visual evidence of subsurface soil and debris along with field instrument readings will be used during exploratory trenching to track visual evidence of contamination from the debris in the waste pile. Up to 5 grab soil samples or debris samples will be collected for analysis from each of the exploratory trenches to determine if the materials in the debris pile are a source of COPCs at the Site. In addition, approximately 4 to 6 soil borings will be installed around the perimeter of the debris pile. The specific location of the exploratory trenches/test pits, the number of grab samples, and the exact number and location of perimeter borings are identified in the SAP.
- **Soil in the area between the debris pile and Pond AP-5.** Relatively high concentrations of perchlorate and chromium have been detected in groundwater in this area. Approximately 12 to 15 soil borings are anticipated to be installed in this area. The exact number and location of these borings are identified in the SAP.
- **Area West of Pond Mn-1.** Relatively high concentrations of perchlorate, chromium and chloroform have been identified in groundwater in this area. Approximately 6 to 8 soil borings are anticipated to be installed in this area. The exact number and location of these borings are identified in the SAP.

Additional characterization of Category 3 soils may be identified as a data gap in conjunction with the ongoing review of available soil data for the BHRA. Further, additional characterization of soil gas is a possible data gap. However, given that groundwater has been identified as a source of VOCs in soil gas, review and identification of data gaps in the existing soil gas dataset will be completed following investigation of trespassing VOCs in groundwater from neighboring properties, as discussed in Section 5.4.2.

The specific scope and DQOs for the additional soil investigation areas were described in detail in the SAP, which was submitted separately from this RI/FS Work Plan in January 2014 (ENVIRON 2014a,b,c). Conceptually, soil borings will be installed in the four areas shown on Figure 5-5a to a depth of first encountered groundwater. Soil samples will be collected continuously and analyzed for COPCs in groundwater. Soil samples will also be analyzed, at a minimum, for: redox potential, total organic carbon (TOC), pH, ferrous iron, ferric iron, chloride, nitrate, nitrite, pH, sulfide, sulfate, calcium, potassium, and sodium. In addition to a discussion of the nature and extent of soil investigation activities and DQOs for the areas of investigation, the SAP includes the FSP, QAPP, and HASP (ENVIRON 2014a,b,c).

5.4.1.2 Unit Buildings Investigation Approach

In addition to the four areas discussed in Section 5.4.1.1, data are needed to evaluate the Category 1 soil areas with limited soil characterization due to access constraints (e.g., soils beneath Unit buildings). As discussed in Section 2.2, the major buildings on the Site include Units 1 through 6, which are aligned in a row extending in a west-east direction across the southern portion of the Site as shown on Figure 5-5a. These buildings were constructed during World War II for magnesium production. Unit buildings 3 through 6 and the southern portions of Unit buildings 1 and 2 are within the boundaries of the Tronox-leased area. Tronox uses Units 5 and 6 for production of manganese dioxide; Unit 5 is also used for storage. Units 1, 2, and most of Unit 4 are no longer used and have been partially demolished. The remaining portion of Unit 4 has been retrofitted to house an advanced battery manufacturing process that started up in 2012. Tronox currently uses Unit 3 for office and storage activities. In addition, Tronox produces boron products within a Boron Plant to the north of Unit 4, and manganese sulfate solution (for use in the manganese dioxide production process) is produced within a Leach Plant north of Units 5 and 6. This area of the Site is crossed by asphalt and concrete roads, dirt roads, active utility lines, a gaseous chlorine line, and railroad spurs. An extensive network of active and inactive underground utility lines is present under the roads and open areas in this area of the Site.

As discussed in Section 5.1.1.1, historic reported releases at the Site include process chemicals leaking to soil through cracks in the central basements of Units 4 and 5 (LOUs 43 and 61) and the basement of Unit 6 (LOU 44). The concrete basements served as sumps to collect process liquor, spillage, and wash water. Removal activities were undertaken in the Unit 6 basement in 1987 to remove the cracked concrete floor, followed by recontouring of the underlying soil and installation of a liner system. Other process leaks and spills (associated with the Units) to soils have been documented. The Unit process effluents contained high levels of TDS, perchlorate, and to a lesser degree, hexavalent chromium (Kleinfelder 1993).

Review of Available Data

During previous investigations, approximately 81 deep soil borings were drilled in the immediate vicinity of the Unit buildings and surrounding area. The majority of these borings were drilled between September-November 2009, with a few earlier borings advanced in 2006 and 2007. Generally, two (sometimes three) soil samples were collected between 0 and 12.5 feet bgs, with two (sometimes three) deeper samples collected at depths between 20 and 45 feet. In addition, nine shallow borings were drilled to depths between 5.5 and 11.5 feet in 2010, and one additional shallow boring was drilled in this area in 2011.

To better assess data gaps associated with the Unit buildings, the existing soil data were evaluated along with the May-June 2012 groundwater data to identify areas of impacted soil and groundwater around and downgradient of the Unit buildings. Due to its high solubility, perchlorate distribution was evaluated as the primary indicator of areas where perchlorate remaining in deep soils may be a continuing source to underlying groundwater and where additional investigation of the deep soils may be needed.

Perchlorate concentrations in shallow groundwater below the Unit buildings at the Site are shown on Figure 5-5b. Three monitoring wells are located downgradient of the three Unit buildings that had reported releases through cracks in central basement concrete floors. Well M-12A is located downgradient of Unit 4 and the Boron Plant, well M-11 is located downgradient of Unit 5, and well M-29 is located downgradient of Unit 6. The highest perchlorate concentration was detected downgradient of Unit 4 in well M-12A, where the perchlorate concentration was 200 mg/L. In contrast, the perchlorate concentration downgradient of Unit 5 in well M-11 was 29 mg/L. Downgradient of Unit 6, the perchlorate concentration at well M-29 was 4.4 mg/L in May 2011 (this well was not sampled in 2012). These downgradient groundwater concentrations suggest that, if present, deep soils impacted by past releases are most likely to be present beneath Unit 4, followed by Unit 5. As noted above, the basement floor in Unit 6 has been replaced with a new concrete slab and an underlying liner. Given the comparatively low perchlorate concentration in downgradient well M-29, investigation of deep soil sources beneath Unit 6 does not appear warranted at this time.

As also shown on Figure 5-5b, higher perchlorate concentrations were detected in wells located within and downgradient of the Leach Plant (M-52, 570 mg/L; M-141, 630 mg/L; M-31A, 1,100 mg/L), suggesting a potential for deep impacted soil to be present in the Leach Plant area downgradient of the Unit buildings.

Additional information on perchlorate in shallow groundwater can be inferred from the deep soil borings drilled around the Unit buildings in 2009. Based on groundwater levels measured in May 2013, the depth to water ranges from approximately 34 to 45 feet bgs in the existing shallow wells near the Unit buildings. The deepest soil sample depths at each of the 81 deep borings were compared to the groundwater depth in the nearest shallow groundwater well. Based on this comparison, the deepest soil samples in 75 of the borings were collected from just below the water table or within the capillary fringe zone just above it. In addition, the deepest soil samples at many of these borings had higher concentrations than the shallow soil samples above them, further indicating that the pore water in the deepest samples contained perchlorate concentrations that are reflective of underlying groundwater.

To provide a more comprehensive screening level assessment of perchlorate distribution, the soil perchlorate concentrations were converted to equivalent groundwater concentrations. For those soil samples below the water table depth or close enough to be in the capillary fringe, an equivalent groundwater concentration was calculated from the soil perchlorate results.[35] These one-time equivalent groundwater concentrations are posted along with the May and June 2012 groundwater monitoring results on Figure 5-5c. Together, these concentrations provide a more complete screening level "snapshot" of areas of higher concentration that may warrant further investigation outside the Unit building footprints.

As shown on Figure 5-5c, equivalent groundwater perchlorate concentrations >1,000 mg/L were present in the deep soil borings located west of Unit 4, between Units 4 and 5, and between Units 5 and 6. Based on these results, three shallow groundwater monitoring wells will be installed at these locations. Two additional shallow wells will be installed upgradient of Units 4 and 5 to provide better delineation in the area south of the buildings.

Methods for obtaining deep soil samples directly beneath the Unit 4 and 5 buildings will be affected by factors including worker safety issues, severe access constraints for drilling equipment within the operating Unit buildings, low ceiling heights in the basements, and limited access to the basement levels. Based on discussions with Tronox, historically the southern portion of each building consisted of a substation with two basement levels. The central portion was occupied by electrolytic cells with one basement level (this is the portion of the Unit 4, 5, and 6 buildings where historic releases were reported). The northern portion was a four-story chlorination unit above ground level with limited ceiling height.

In Unit 4, the southern portion of the building is now used for advanced battery manufacturing. The central cell area has been demolished to floor level; however, the condition of the floor slab is very poor and would not support more than occasional foot traffic. Access to the basement beneath the unstable floor slab is unsafe in its current condition. The northern portion is occupied by an air compressor and storage. In Unit 5, active operations conducted in the southern and central portions of the building and the presence of closely spaced equipment would prevent access to the basements. The northern portion of Unit 5 is unused, but access is limited by low ceiling height on the ground floor level. Based on these building conditions, vertical drilling through the Unit 4 and 5 basement floors will not be feasible even with limited access equipment.

Directional drilling may be feasible, subject to several limitations. To achieve the target sampling depth, a 5:1 setback is required. For example, a target sampling depth of 20 feet below grade would require that the rig be positioned 100 feet away from the first soil sampling location. Soil samples are typically collected at 20 to 30 feet intervals along the horizontal drill path. The drill bit is maintained on course by tracking with an above ground instrument that detects signals transmitted from the drill bit. The detection instrument is operated by a worker

[35] The equivalent groundwater concentration was calculated by multiplying the saturated soil concentration by the bulk density (assumed to be 1.2 grams per cubic centimeter) and dividing by the porosity (assumed to be 0.6). The saturated soil samples were collected from the UMCf, so values of bulk density and porosity generally representative of the UMCf were selected.

who walks on the paved or unpaved ground surface directly above the bit. Based on discussions with Tronox, this will not be possible in the basement of Unit 4 due to safety issues and may not be possible in Unit 5 due to the density of operating equipment. In addition, the detection instrument is affected by interference from electrical equipment and electric fields, which may be an issue in Unit 5. However, it may be feasible to use directional drilling to obtain soil samples from beneath the western portion of the Leach Plant where higher perchlorate concentrations are present in shallow wells.

Proposed Investigation Approach

The specific scope and DQOs for the additional Unit building investigation is described in detail in the SAP, submitted separately from this Work Plan in January 2014. Conceptually, five shallow groundwater monitoring wells will be installed at the locations shown on Figure 5-5c. Soil samples will be collected continuously during drilling. The feasibility of directional drilling beneath Unit buildings 4 and 5 and beneath the western portion of the Leach Plant was evaluated by an experienced directional drilling contractor prior to submittal of the SAP. The investigation results will provide additional data to evaluate whether perchlorate and other site related chemicals may be present in soil beneath the Unit buildings or Leach Plant at concentrations of potential concern with respect to transport to underlying groundwater. For this transport to occur, sufficient water would need to percolate the ground surface, contact COPCs currently bound to soils, and transport the COPCs in the aqueous phase through the entire vadose zone. If current operations at the Unit buildings and Leach Plant are managed to minimize sources of infiltrating water, COPCs present in the vadose zone from historic releases would remain in place in the absence of a transporting fluid.

Soil and groundwater samples will be analyzed for COPCs in groundwater. Selected soil samples will also be analyzed for general characterization parameters including redox potential, total organic carbon (TOC), pH, ferrous iron, ferric iron, chloride, nitrate, nitrite, pH, sulfide, sulfate, calcium, potassium, and sodium. The detailed sampling plans for this investigation are provided in the FSP (ENVIRON 2014b).

5.4.2 Groundwater

The Site has been studied extensively; over 1,000 wells and borings have been drilled in and around the BMI Complex to characterize subsurface conditions. Groundwater and surface water impacts have been monitored and evaluated, and removal actions have been implemented to partially mitigate chromium and perchlorate impacts.

As discussed in Section 2.5, lateral transport of shallow groundwater is primarily within paleochannels incised within the Muddy Creek Formation. In addition, infiltration of surface water from the COH ponds in the Bird Viewing Preserve and from Las Vegas Wash near the SWF affect groundwater flow in the northern portion of the downgradient plume. Figure 5-6 shows the May-June 2012 potentiometric surface in shallow groundwater, along with the paleochannels and major surface water features. As can be seen on Figure 5-6, the on-site barrier wall and IWF, the off-site downgradient AWF, and the SWF adjacent to Las Vegas Wash operated by the Trust, as well as the extraction well systems operated by OSSM and AMPAC, are positioned across the preferential flow pathways formed by the paleochannels.

Perchlorate is the primary Site-related chemical detected in groundwater downgradient of the Site. Figure 5-7 presents the May-June 2012 perchlorate shallow groundwater isoconcentration contour map along with the paleochannels and locations of the on-site barrier wall/IWF, the off-site downgradient AWF, and the SWF adjacent to Las Vegas Wash. The May-June 2012 isoconcentration contour maps for total chromium and total dissolved solids are presented on Figures 5-8 and 5-9, respectively. The detailed maps showing the data for these schematic figures are presented on Plates 2 through 5. In addition, an isoconcentration contour map for chloroform in shallow groundwater is presented on Figure 5-10, and a detailed map is presented on Plate 6. Chloroform was tested for during the Phase B Site investigation conducted in 2008-2009. To provide the most complete data set, Figure 5-10 is based on the Site data and off-site data collected during that time period.

The following data gaps for groundwater have been identified:

- **Background Determination.** As described in the 2005 CSM, although regional information is available, background concentrations of metals and other naturally occurring compounds of concern in soil and groundwater have not been determined for the localized area. This issue is being jointly evaluated by BMI Complex members. An outline for a Background Study Work Plan was submitted to NDEP by Tronox in 2008 (Tronox 2008). For purposes of this RI/FS, naturally occurring compounds will be compared to upgradient concentrations in four wells located on the upgradient (southern) Site boundary. These include Shallow WBZ wells M-120 and M-121 (screened in UMCf-cg1) and Middle WBZ wells M-117 and M-118 (screened in UMCf-fg1). The alluvium is unsaturated at the upgradient Site boundary.

- **Chemicals of Potential Concern.** In Section 5.1.4.2, a preliminary list of groundwater COPCs is presented based on screening of groundwater data collected since 2006. As part of the RI, ENVIRON will review available groundwater data to determine whether any revisions to this list are necessary.

- **Middle Water-Bearing Zone/Muddy Creek Formation.** There are currently 23 on-site monitoring wells completed in the Middle WBZ. Three of these wells (MC-MW-18, MC-MW-39, MC-MW-42) are owned by Montrose and were installed to assess the extent of DNAPL originating at the OSSM property west of the Site. The DNAPL is a trespassing chemical and is discussed further below.

  At the Site, the soils within the Middle WBZ consist predominantly of the UMCf-fg1. The UMCf-cg2 occurs below the fine-grained unit at the base of the Middle WBZ. The top of the UMCf-cg2 unit varies depending on location; it has been encountered at depths ranging from 175 ft bgs to as deep as 272 ft bgs. The UMCf-cg2 unit has been defined below the western portion of the Site by six deep wells (TR-1, TR-5, TR-7, TR-9, TR-11, TR-12) and below the northern portion of the Site by two deep wells (M-154 and M-155). The UMCf-cg2 unit is confined, as indicated by artesian groundwater elevations consistently measured in these wells. These eight wells were sampled for perchlorate and chromium in May 2012. Perchlorate was not detected (ND<0.254 μg/L) in any of the wells. Total chromium concentrations were all below the MCL of 100 μg/L; the detected chromium concentrations ranged from 13 to 48 µg/L. These results indicate that the UMCf-cg2 unit at the base of the Middle WBZ is not impacted by Site-related chemicals.

Vertical Extent of Site-related Chemicals in the UMCf Fine-grained Unit – The vertical extent of Site-related chemicals in the UMCf-fg1 unit has been partially defined by recent deeper wells installed in the central portion of the Site and in the vicinity of the IWF. Installation of deeper wells to further delineate vertical extent is recommended at three Site locations to add one or more deeper wells to existing well clusters:

- Adjacent to Middle WBZ monitoring well M-186 located on the eastern Site boundary.
- Adjacent to Middle WBZ monitoring well M-161 located on the north-central side of the barrier wall and IWF.
- Adjacent to Middle WBZ monitoring well M-162 located on the north side of the barrier wall and IWF at its western end.

The recommended additional well locations are shown on Figure 5-11.

Additional Hydraulic Characterization – In order to better characterize hydraulic properties in the Middle WBZ UMCf fine-grained unit, slug tests will be conducted in all the existing and new Trust-owned wells completed in this unit. These data will be incorporated into the numerical model developed to assess remedial alternative extraction scenarios for Site groundwater. While the majority of groundwater flow and transport occurs in the shallow alluvial deposits, evaluation of flow rates and mass transport in the deeper Muddy Creek formation will be conducted as part of the FS assessment of the IWF effectiveness.

Evaluation of Vertical Head Differences – Previous investigations of the Middle WBZ at the Site and surrounding sites indicate, with a few exceptions, a vertically upward gradient between the Middle and Shallow Zones that generally increases with depth. Following installation of the recommended new Middle WBZ wells, the previous evaluations of vertical head differences will be updated with current data.

- **Trespassing Chemicals.** The Site is situated in between two other operating facilities that are part of the BMI Complex. The Site is bordered by TIMET on the east and the Olin property on the west. All three facilities released wastewater into the former Beta Ditch for transport to former ponds in the BMI Common Area (see Figure 2-3 for the location of the former Beta Ditch). During the past decades of operation, chemicals released to groundwater at the individual facilities have become commingled, particularly in the areas near the property boundaries, below the unlined Beta Ditch, and in downgradient plume areas.

  At the Olin property, Montrose is conducting an investigation of DNAPL that has been detected in several wells completed in the Middle WBZ. As shown on Figure 5-11, DNAPL has also been found in well MC-MW-18 located on the Site. The DNAPL has been tested, and it contains several VOCs (primarily benzene, dichlorobenzenes, and chloroform), pesticides, and herbicides. The most recent phase of Montrose's investigation is an assessment of DNAPL mobility for recovery purposes.

The Trust provides access to Montrose and its consultants for their ongoing monitoring and investigations. To further assess the extent of impact by dissolved VOCs from this adjacent site, VOCs will be added to the Trust's groundwater sampling program as discussed in Section 5.4.2.1.

- **Downgradient Plume – Lateral Extent.** As a result of its high solubility, perchlorate is the primary Site-related chemical detected in groundwater downgradient of the Site. The Interim Drinking Water Health Advisory and federal PRG of 15 µg/L for perchlorate will be used as the basis to delineate the boundaries of the area-wide BMI Complex commingled groundwater plume. However, within the area of commingled groundwater, a different approach is needed to define the Study Area to be addressed in the RI/FS. Based on the existing data, a 1 mg/L perchlorate concentration is assumed for separation between the Trust plume and the AMPAC plume to the west.

  As illustrated on Figure 5-7, the lateral extent of the Site downgradient perchlorate plume can be delineated by the 1 mg/L isoconcentration contour on its western side. As discussed in Section 3.2.4, perchlorate was also released to groundwater from the AMPAC facility located approximately 1.5 miles southwest of the Site. The downgradient AMPAC perchlorate plume is located west of the Site-related downgradient plume. The AMPAC extraction and re-injection systems and the northern portion of the AMPAC perchlorate plume are shown on Figure 5-7. However, the separation between the two plumes is based on reasonable extrapolation of 1 mg/L contours. In order to confirm this interpretation, additional sampling will be conducted along Galleria Road west of the AWF. As shown on Figure 5-12a, three existing wells (L637, L639, L641) are located along the road in this area. These wells will be evaluated for sampling. Assuming access can be obtained from the well owner, one additional new shallow well will be installed west of L645. If the three existing wells are not suitable for sampling, or if access cannot be obtained, 2-3 additional new shallow wells will be installed nearby. In addition, 2-3 new shallow monitoring wells will be installed along Sunset Road in the area between the Site-related downgradient plume and the AMPAC downgradient plume. The recommended well locations are shown on Figure 5-12a.

  On the east side, commingling between the Trust plume and the BMI Common Areas plume is more extensive. The BMI Common Area pond complex, located to the east, appears to represent a separate and distinct source of perchlorate to shallow groundwater. As illustrated on Figure 5-13, perchlorate concentrations in wells located on the western portion of the BMI Common Areas property below former unlined ponds contain perchlorate at concentrations higher than 1 mg/L. The most recent data available in the BMI Complex database shows concentrations ranging from 3.6 to 9.6 mg/L in wells located east of Pabco Road. Based on this preliminary evaluation, separation between the Site downgradient plume and the BMI Common Area plume may need to be defined by a 5 or 10 mg/L contour. A more thorough evaluation of groundwater conditions and current data in wells along the east side of Pabco Road will be conducted during the RI. However, as previously discussed with NDEP, a geographic boundary (Pabco Road), will be used to delineate the eastern boundary of the Trust plume for purposes of the RI/FS.

- **Downgradient Plume – Vertical Extent.** The vertical extent of perchlorate in the Muddy Creek Formation beneath the AWF extraction wells has not been fully delineated. Existing wells PC-134A and PC-137 are screened in the UMCf. In May 2012, perchlorate concentrations were 32 mg/L in PC-134A and 0.27 mg/L in PC-137. Deeper monitoring wells will be installed adjacent to these two existing wells to define the vertical extent of perchlorate-impacted groundwater. The recommended well locations are shown on Figure 5-12a.

- **Downgradient Plume – Chloroform.** Eight shallow groundwater wells located between the Site and the Athens Road Well Field will be sampled for VOCs to assess current chloroform concentrations in shallow groundwater. The well locations (AA-11, BHE1-10, PC-24, PC-28, PC-64, PC-65, PC-66, PC-67) are shown on Figure 5-12b. Six of these wells have been sampled previously for chloroform. The most recent concentrations have ranged between 3.2 µg/L (PC-64) and 860 µg/L (PC-67) (see Plate 6). After the planned groundwater sampling is completed, the data will be reviewed along with previous available sampling results. If the current chloroform concentrations are above the chloroform RBCs for vapor intrusion established for the Sale Parcels, soil gas samples will be collected at two depths adjacent to the three wells with the highest concentrations. This information will be used to establish the relationship between groundwater and soil gas concentrations in this area of the downgradient plume and to develop a chloroform groundwater RBC for vapor intrusion.

- **Stream-Aquifer Interaction with Las Vegas Wash.** An initial evaluation of stream-aquifer interaction is being conducted as part of the 2013 GWETS Optimization Project (ENVIRON 2013c). Comparison of the water levels in Las Vegas Wash at the Pabco Road stream gage with the water levels in the groundwater monitoring wells at the SWF indicate that some amount of surface water from Las Vegas Wash is flowing into the extraction wells of the SWF. Additional wells between the SWF and Las Vegas Wash are proposed in order to better quantify the amount of surface water being extracted by the SWF and to better delineate the extent of the area in which the SWF is causing a reversal of groundwater flow. Near the proposed new wells are two existing wells owned by SNWA (WMW6.15S and WMW6.55S) that would be useful to include in the evaluation. Water levels are measured in these SNWA wells periodically; however, a surveyed measuring point is reportedly not available to determine absolute water table elevation. In order to allow comparisons of water table elevations among the wells near the Wash and the stream gage elevation, it is recommended that the existing SNWA wells and the Pabco Road stream gage be surveyed to a standard vertical datum. The proposed well locations are shown on Figure 5-12a.

The specific nature, extent and the DQOs for the elements of the additional groundwater investigation are described in detail in the SAP.

5.4.2.1 Groundwater Analytical Program

As part of the ongoing groundwater monitoring program, groundwater samples from designated Site wells are analyzed for chlorate, chromium, hexavalent chromium, perchlorate, and TDS. It is proposed that for 2014, to address data gaps as part of the RI/FS, groundwater samples will be analyzed for the list of chemicals presented in Section 5.1.4.2 identified as a preliminary list of groundwater COPCs that exceed USEPA MCLs, NDEP BCLs, or other criteria. The SAP details the proposed subset of wells and analytes and sampling frequency.

In addition, to gain a better understanding of Site geochemistry and how redox conditions may control the mobility of hexavalent chromium in groundwater, groundwater samples will be analyzed for: dissolved oxygen, redox potential, TOC, pH, alkalinity, ferrous iron, ferric iron, chloride, nitrate, nitrite, pH, sulfide, sulfate, calcium, potassium, and sodium. The SAP will present the details of the analytical program to be included following NDEP approval of this Work Plan.

6.0 Remedial Investigation/Feasibility Study Tasks

The following sections describe key tasks within the RI/FS framework identified in USEPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988).

6.1 Task 1: Project Planning

The contents of this Work Plan and associated supporting documents – i.e., task-specific sampling and analysis plans, a health and safety plan, and the Community Involvement Plan (CIP) (ENVIRON 2013e) – describe planning activities for the project. Activities under this task include:

- Collecting and evaluating available information on the Site, including information on historical operations, historical characterization data and analyses, regulatory actions, and removal actions completed to date (Sections 2 through 4);
- Developing a CSM on the basis of available information (Section 5.1);
- Identifying data needs (data gaps are identified in Section 5.4, and DQOs have been developed in the SAP);
- Identifying ARARs (Section 5.2.1);
- Identifying preliminary RAOs (Section 5.2.2);
- Screening of preliminary remedial technologies and process options, and identifying potential remedial alternatives (Section 5.3);
- Treatability studies (identified in individual treatability study work plans; ENVIRON 2014f,g);
- Identifying projection organization and project management (Section 7.1); and
- Developing schedules for completion of major project elements (Section 7.2).

All of these elements are included in this Work Plan and associated supporting documents (e.g., the SAP). Many elements are summaries of more comprehensive documents or identify the document in which the element is provided. Each of the summaries provided in this Work Plan reflects the current status of the respective tasks, with some tasks at the preliminary planning stage and others completed or nearing completion.

6.2 Task 2: Community Relations

Task 2 incorporates all efforts related to the preparation and implementation of the CIP for the Site. A draft CIP was submitted to NDEP on April 30, 2012 and NDEP provided comments on the draft CIP on June 18, 2013. On behalf of the Trust, ENVIRON responded to NDEP's comments on October 4, 2013. A revised CIP was submitted to NDEP on December 27, 2013 and approved by NDEP on February 19, 2014 (ENVIRON 2013e).

The CIP was developed in accordance with the NCP (40 CFR 300) to guide the facilitation of communication between the community surrounding the Site with NDEP and the Trust and to encourage community involvement in Site activities. The CIP provides a Site description; a community profile and history of community involvement; information on community relations and community concerns; communication needs and strategies; lists of contacts and interested parties; and a description of activities the Trust is undertaking to ensure full public participation at the Site, as listed below. As required by the NCP, the CIP identifies local information repositories, describes the maintenance of the administrative record, and summarizes the community interviews and community relations activities, which have provided opportunities for public involvement, review, and comment. As described in the CIP, the administrative record was established and is maintained at NDEP's Las Vegas office. A second location will be established at the James I. Gibson Library in Henderson, Nevada. NDEP will continue to be responsible for maintaining the two sets of the administrative record following approval of the revised CIP. A previous CIP (ENSR 2007b) was implemented for the Site by Tronox, and NDEP has maintained a public website with various Site-related documents and related information since 2006. For the draft 2012 CIP, the Trust drew from multiple sources, including community input (through stakeholder calls and meetings; community interview meetings and questionnaires; and open communications with interested parties, such as local residents, business owners, schools, local industries, and municipal programs) and through reviews of public information and Site files to develop the plan. The major community involvement activities associated with this plan are identified below:

- Designate the Community Involvement Coordinator (CIC), the primary liaison between the community, NDEP, and the Trust. The CIC was previously designated as Shannon Harbour in April 2012, and a new CIC was designated in the December 2013 CIP as James Dotchin of NDEP;
- Prepare and distribute fact sheets and technical summaries;
- Maintain a mailing list for the Site;
- Establish and maintain information repositories;
- Provide key resources for both general and specific information about the Site;
- Establish and maintain the Administrative Record;
- Hold public meetings or public availability sessions; and
- Revise the CIP as community input warrants or at least every three years until the Site is closed out.

To date, information related to Site activities has been provided to the public through NDEP's *Remediation of the BMI Complex* website available at http://ndep.nv.gov/bmi/tronox.htm, fact sheets and technical summaries, public meetings, and briefings. The Trust will continue to use these public mechanisms to inform the public regarding activities at the Site. In addition, the public has access to documentation related to the RI/FS process for the Site at the NDEP office in Las Vegas, Nevada, as well as at a local information repository at the James I. Gibson Library on Lake Mead Parkway in Henderson, Nevada.

6.3 Task 3: Groundwater Modeling

Task 3 includes the on-going development of the groundwater flow model, including the development of a transient model. As part of the 2013 GWETS Optimization Project, the initial steady-state groundwater model developed by Northgate is being updated to early 2012 conditions and revised to include additional information about aquifer properties and boundary conditions. This updated model will be used to make recommendations about how to optimize the existing GWETS. These initial recommendations will be based on the steady-state model.

Under Task 3, a transient groundwater model will be developed that builds upon the steady-state model. A transient model is needed in order to predict how changing groundwater conditions will affect the effectiveness of GWETS and to evaluate potential remedial alternatives considered in the FS. In addition, a contaminant transport model will be developed in order to estimate aquifer clean-up times for various remedial alternatives.

6.4 Task 4: Field Investigation

Task 4 involves field investigation activities to be undertaken during the RI phase to complete characterization activities (i.e., to address data gaps) at the Facility Area and ensure that adequate data is available to conduct the BHRA and support the development and evaluation of remedial alternatives.[36]

As presented in Section 5.4, the following data gaps are to be addressed during field investigation activities:

- Additional characterization of shallow and deep soils to determine whether these areas serve as potential sources of COPCs in groundwater;
- Additional characterization of Category 3 soils, as needed, to provide a sufficient data set for risk assessment;
- Characterization of the Debris Pile (Category 4 area);
- Investigation of soil and groundwater in the vicinity of the Unit buildings;
- Additional characterization of groundwater, to include (1) a background determination, (2) identification of groundwater COPCs, (3) further investigation of the Middle WBZ/Muddy Creek formation, (4) further investigation of trespassing chemicals from neighboring properties, (5) further investigation of the lateral and vertical extent of the downgradient plume, and (6) further investigation of concentrations of chloroform in the downgradient plume[37].
- An initial evaluation of stream-aquifer interaction in the vicinity of the SWF and Las Vegas Wash.
- Additional characterization of soil gas, as needed, to address possible data gaps. However, given that groundwater has been identified as a source of VOCs in soil gas, review and identification of data gaps in the existing soil gas dataset will be completed following investigation of trespassing VOCs in groundwater from neighboring properties.

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[36] As noted previously in Section 2.2, Parcels C, D, F, G, and H are not being addressed in the RI. Environmental investigations for these parcels have been completed and risk assessments have been completed or are in progress.

[37] Depending on the results of testing groundwater for chloroform, soil gas sampling in the downgradient plume area may also be performed.

For risk assessment purposes, it is anticipated that indoor and outdoor air concentrations of airborne particulates and VOCs will be estimated based on modeling and not measured concentrations. Additional data gaps may be identified following further review and evaluation of existing data and data collected as part of the RI.

A detailed SAP has been developed to address the data gaps and was submitted to NDEP as a separate deliverable in January 2014 (ENVIRON 2014a,b,c).. The SAP includes the FSP, a QAPP, and a site-specific HASP. Information related to DQOs, methods for sample collection and analysis, methods for data evaluation and quality assurance, and other components were included in the FSP. The QAPP describes the quality assurance procedures, quality control specifications, and other technical activities that must be implemented to ensure that the results of the project or task performed during the RI/FS process will meet project specifications. The SAP was submitted to NDEP on January 24, 2014 (ENVIRON 2014a,b,c) and NDEP comments were received on May 20, 2014 (NDEP 2014b,c,d). Upon NDEP and Trust approval of the SAP, subcontractors will be mobilized for field investigations. The following typical activities are anticipated to be conducted as part of Task 4:

- Mobilization of field activities;
- Exploratory trenching;
- Grab soil sampling;
- Soil boring installation and sampling;
- Well Installation, development and sampling;
- Laboratory analysis of soil and groundwater samples;
- Aquifer testing;
- Field measurements;
- Site surveys; and
- Task management and quality control.

All field investigations will be conducted in accordance with the SAP (including the FSP, QAPP, and HASP).

6.5 Task 5: Sample Analysis and Data Verification and Validation

Under Task 5, samples collected during the field investigations will be reviewed in accordance with the DQOs established for the specific field activity, as detailed in the SAP. Data validation will be conducted in accordance with NDEP's *Supplemental Guidance on Data Validation* (NDEP 2009d) and *Guidance on Validation for Asbestos Data in Soils for the BMI Plant Sites and Common Areas Projects* (NDEP 2012b). Electronic data deliverables (EDDs) will be prepared in accordance with the NDEP's *Guidance* on *Unified Chemical Electronic Data Deliverable Format* (NDEP 2013b) and submitted to NDEP for uploading to the NDEP Site-Wide Database. The SAP provides details regarding how sample analysis and data validation will be conducted for the data gap field investigation, including:

- COPCs, media, and associated analytical methods;
- Laboratories that will analyze samples and required detection limits;
- The entity who will perform data validation; and
- Procedure(s) for establishing data quality criteria.

6.6 Task 6: Data Evaluation

The data evaluation task includes the data usability evaluation, data analysis, and the data quality assessment. USEPA states in its *Data Usability Guidance* (USEPA 1992a) that "data usability is the process of assuring or determining that the quality of data generated meets the intended use," and that when risk assessment is the intended use, USEPA's guidance "provide[s] direction for planning and assessing analytical data collection activities for the HRA…" The analytical data set identified for the BHRA will be evaluated using the six USEPA data usability criteria, as modified by NDEP (2010c).

As described by NDEP (2010c), the purpose of the data analysis step is to "use simple exploratory data analysis to compare data to the expectations of the CSM, to determine if the data adequately represent the source terms and exposure areas or evaluation areas." Consistent with guidance, summary statistics, simple data plots, and spatial plots of the data will be included in the BHRA. Finally, the data quality assessment is conducted following completion of the risk assessment to evaluate whether the data meet the desired DQOs.

The data usability evaluation, data analysis, and the data quality assessment will be completed consistent with the following guidance documents from USEPA:

- *Data Usability Guidance* (USEPA 1992a).
- *Guidance for Data Usability in Risk Assessment (Parts A and B)* (USEPA 1992a,b).

and NDEP:

- *Guidance on the Development of Summary Statistic Tables at the BMI Complex and Common Areas in Henderson, Nevada* (NDEP 2008e).
- *Significance Levels for The Gilbert Toolbox of Background Comparison Tests for the BMI Plant Sites and Common Areas Projects* (NDEP 2009f).
- *NDEP Supplemental Guidance for Assessing Data Usability for Environmental Investigations at the BMI Facility in Henderson, NV* (NDEP 2010c).

It is anticipated that the Facility Area will be divided into two or more subareas (exposure units) for evaluation in the BHRA. The proposed subareas were identified in the BHRA Work Plan submitted to NDEP. In the BHRA, the data usability evaluation, data analysis, and the data quality assessment will be conducted for each subarea identified.

Other NDEP guidance, available on NDEP's Technical Topics website,[38] will be consulted, as appropriate to the intended use of the data, including NDEP's guidance for data processing (NDEP 2008c,d, 2012a) and evaluating radionuclide data (NDEP 2007b, 2008a, 2009b,c,e).

6.7 Task 7: Risk Assessment

Task 7 includes preparation of the BHRA work plan and BHRA. As part of Task 7, ENVIRON reviewed the NDEP-approved HRA work plan prepared by Northgate and dated March 9, 2010 (Northgate 2010d). ENVIRON adopted the general risk assessment methodology, including exposure equations, toxicity values, and risk equations, outlined in the Northgate 2010 HRA work plan. However, some elements of the 2010 work plan lacked sufficient detail for implementation or do not account for the soil removal action completed in 2011. The ENVIRON BHRA work plan updated background information for the Facility Area and described the approach for dividing the Facility Area into exposure units. The BHRA work plan also included preliminary summary statistics for the post-removal data set. Applicable elements from the 2010 HRA work plan were incorporated by reference, and, for completeness, the 2010 HRA was included as an attachment to the ENVIRON BHRA work plan. The BHRA work plan was submitted to NDEP on February 21, 2014 and approved on May 20, 2014 (ENVIRON 2014d).

ENVIRON also reviewed the 2010 *Site-Wide Soil Gas Human Health Risk Assessment* (Northgate 2010r), which has been submitted to, but not reviewed by, NDEP. The soil gas HRA evaluated risks associated with soil gas in Parcels A, B, C, D, F, G, and H and in the Facility Area. The available soil gas data for the Facility Area included in the 2010 soil gas HRA will be reviewed in the context of our current understanding of groundwater VOC contamination. However, given that investigation of trespassing chemicals (primarily VOCs) from neighboring properties has been identified as a groundwater data gap (see Section 5.4.2 and Task 4, above), it is anticipated that identification of data gaps for the existing soil gas data within the Facility Area can be completed only following the collection of additional groundwater samples and the review of the soil gas sampling locations relative to an updated understanding of groundwater VOC contamination. Depending on the need to collect additional soil gas samples within the Facility Area, an updated soil gas evaluation will be submitted either as part of the soil BHRA or as a separate deliverable.

The BHRA will evaluate the potential for adverse human health effects associated with exposures to impacted environmental media under current and anticipated future land-use conditions. The BHRA will take into consideration all removal actions completed at the time the BHRA is prepared. The results of the BHRA will be used to support activities related to the screening of remedial alternatives and development of cleanup goals for impacted media. The elements of the BHRA report will include (1) data evaluation (as described under Task 6, above); (2) identification of Site-related COPCs (including chemical and radiological contaminants and asbestos); (3) exposure assessment, including fate and transport modeling; (4) toxicity assessment; and (5) risk characterization. Cumulative risks will be presented for COPCs and radionuclides, combined, and risks will be presented separately for asbestos. Uncertainties associated with the risk characterization will be discussed.

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[38] http://ndep.nv.gov/bmi/technical.htm

The NDEP-approved 2010 work plan (Northgate 2010d) noted that an ecological risk assessment would not be conducted for the Facility Area. However, based on communications with NDEP in 2014 and as noted in Section 5.1.6, a SLERA will be conducted at the Site as part of the RI/FS. A separate work plan for the SLERA is in progress, and is anticipated to be submitted to NDEP in July 2014. In addition, following aquifer restoration, an ecological risk assessment will be conducted for impacted areas downgradient of the Facility Area (which includes Las Vegas Wash), consistent with NDEP comments (NDEP 2013c) on the 2012 RI/FS work plan (ENVIRON 2012f).

6.8 Task 8: Treatability Studies

Under Task 8, information needs are identified and studies conducted to support the further development of the preliminary remedial action alternatives for evaluation during the RI/FS process. Treatability studies can provide data important to an adequate evaluation of certain technologies for a given response action – including information on performance, operating parameters, and cost – in sufficient detail to support the remedy selection process and subsequent design activities. This task can involve efforts for bench-scale or pilot-scale tests, including associated procurement activities. Treatability studies can be identified at different times during the RI/FS (e.g., from the scoping stage through the screening of preliminary alternatives).

Revised work plans for the following treatability studies were submitted to NDEP on May 9, 2014 and approved on May 20, 2014:

- PRB Treatability Study Work Plan (ENVIRON 2014f); and
- In-Situ Soil Flushing Treatability Study Work Plan (ENVIRON 2014g).

Additional treatability studies may be identified as further information is developed during the RI.

6.9 Task 9: Remedial Investigation Report

Task 9 includes all activities undertaken to prepare and complete the RI report for the Site. This report will include the following:

- A comprehensive description of the area that comprises the Site;
- A brief Site history and discussion of the origin of contamination to provide rationale for the characterization activities completed;
- Summaries of field investigations and relevant Site characterization data, including historical data used to support the CSM and evaluation of remedial alternatives;
- A synthesis of previous groundwater investigations that will also incorporate the results of additional work conducted for the RI. As has been discussed previously, the Shallow WBZ has been well characterized, particularly with respect to the distribution of chromium, TDS, and perchlorate. However, additional evaluation of the lateral extent of the downgradient perchlorate plume will be conducted during the RI. The RI report will also present an evaluation of the presence and extent of other Site-related COPCs identified for groundwater. The RI report will include an evaluation of the nature and

extent of COPC impacts to groundwater in the Middle WBZ, both from Site-related COPCs and trespassing chemicals. Existing and new information on aquifer properties will be compiled that will include estimates of groundwater gradient, flow velocities, and an evaluation of vertical head differences at well cluster locations;

- An updated CSM for the Site, revised to incorporate additional information obtained through the RI process; and
- A summary of the BHRA and SLERA performed for the Site. A separate report will be prepared to present the analysis and results of the BHRA and SLERA based on the updated CSM.

6.10 Task 10: Remedial Alternatives Development

Task 10 involves the initial development and preliminary screening of remedial alternatives; the preliminary alternatives are then fully evaluated under Task 11. The objective of the screening process is to narrow the number of alternatives that undergo detailed evaluation. The screening process begins with identification of RAOs, then proceeds through narrowing of the potential technologies on the basis of applicability, effectiveness, implementability, and cost. From this list of retained technologies and process options a list of RAAs is developed for further evaluation. Each RAA may involve application of a single technology or a combination of two or more technologies. Task 10 consists of the following activities:

- Identifying RAOs and ARARs (Section 5.2);
- Listing potential remedial technologies (Section 5.3);
- Screening remedial technologies and process options based on Site-specific criteria (initial screening performed in Section 5.3);
- Assembling potential RAAs from the screened technologies and process options (preliminary conceptual RAAs are provided in Section 5.3.4); and
- Evaluating potential RAAs on the basis of screening criteria (i.e., effectiveness, implementability, and cost).

Identifying candidate remedial action alternatives for detailed evaluation is described under Task 11.

6.11 Task 11: Detailed Analysis of Alternatives

Under Task 11, the candidate RAAs that passed the screening process in Task 10 will be evaluated in detail. The following criteria, identified in USEPA guidance (USEPA 1988), will be used for evaluating the alternatives:

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;

- Implementability;
- Cost;
- Acceptance by the state; and
- Acceptance by the community.

A summary of each alternative, including the no-action alternative, will be prepared on the basis of these nine criteria, consistent with the NCP. The first two criteria (i.e. overall protection of human health and the environment and compliance with ARARs) are categorized as threshold criteria that every alternative must meet in order to be considered for implementation. The next five criteria (i.e. long-term effectiveness and permanence; reduction of toxicity, mobility and volume; short-term effectiveness; implementability; and cost) are so-called balancing criteria used during the analysis process. The final two criteria (acceptance by the state and community) are evaluated during the final decision-making process and after the RI/FS report is complete.

As described in USEPA guidance (1988), long-term effectiveness will be evaluated to ensure the magnitude of residual risks are understood for each RAA. For some COPCs this may include estimates of contaminant volume or concentrations that are anticipated to remain at the Site following implementation. The reliability and/or expected life cycle of each RAA will also be incorporated into evaluations of long-term effectiveness. Understanding the long-term effectiveness of a particular RAA is critical to meeting the Site's long-term RAOs.

Short-term effectiveness is described in USEPA guidance (1988) as the impact of each RAA during the initial construction and/or implementation phase and lasts until cleanup criteria are achieved. RAAs will therefore be evaluated for potential risks to the local community, on-site workers, and the environment during the implementation period. Measures used to mitigate potential short-term impacts will be evaluated for their reliability and effectiveness. This section will also evaluate the anticipated time for each RAA to achieve the Site's RAOs.

According to USEPA guidance (1988), there is a statutory preference for the selection of RAAs that result in a significant reduction in the toxicity, mobility, and volume of hazardous substances in the environment (USEPA 1988). Alternatives should therefore be evaluated based on factors such as the quantity of COPCs treated and the irreversibility of treatment techniques. Alternatives that satisfy this statutory preference will be favored over those that do not include treatment as a primary element. In the case of on-site contamination, RAAs will be evaluated based on their ability to eliminate COPCs from the Site. As an example, source depletion of perchlorate would have the effect of reducing the volume of hazardous materials, the benefits of which would be compared with containment alternatives.

Understanding the implementability of each RAA involves an evaluation of the technical and administrative feasibility of each alternative. An evaluation of technical feasibility will examine the reliability of existing technologies and unknowns of emerging technologies, the impacts of any interim actions on possible future Site activities, and any monitoring associated with a particular RAA. An evaluation of administrative feasibility will consider coordination with various agencies, the availability of services (e.g., disposal services, treatment facilities), or additional resources such as specialized knowledge or equipment. When evaluating on-site groundwater control options, various RAAs will be ranked based on the anticipated administrative effort and technical knowledge. For example, the potential benefits of a technology that requires a pilot study prior to implementation will need to be balanced with the need to meet short-term RAOs.

The comparative analysis of RAAs will include development of both direct and indirect capital costs, as well as annual/periodic O&M costs. The comparative analysis of alternatives will include a present-value analysis of capital and O&M costs consistent with USEPA guidance (USEPA 1988). Life cycle costs will also be considered in evaluation of the RAAs. Optimization/enhancement of the groundwater extraction and treatment system, which is a short term RAO for the Site, will be evaluated using a cost comparison framework specifically designed for optimizing the operation of pump and treat systems. The revised groundwater model will be used as appropriate to quantitatively evaluate the effectiveness of the alternatives.

6.12 Task 12: Feasibility Study Report

Task 12 involves the coordination and preparation of the FS report. The report will contain descriptions of the activities, results, and associated conclusions of the entire RI/FS process. The report will include a description of the screening process and a detailed evaluation of RAAs (from Tasks 10 and 11). A RAA will be recommended for implementation.

7.0 Project Schedule and Project Management

The following sections present the schedule for the RI/FS project tasks and outline the project organization and responsibilities.

7.1 Project Organization and Responsibilities

Mr. Weiquan Dong, PE is the NDEP Project Manager for the Site and handles all Site-related correspondence. Mr. James Dotchin has responsibility for overall supervision of all projects in the NDEP Bureau of Corrective Actions Special Projects Branch. All Site characterization activities and remedial actions carried out by the Trust for the Site are subject to NDEP oversight under the Settlement Agreement, effective February 14, 2011.

The responsibilities of the two major organizations under contract to the Trust are as follows:

- ENVIRON
  - Provide overall project management support for the Trust's remediation of the Site. This support includes implementation and documentation of activities related to health and safety requirements, cost control procedures, sample and data management, and project schedule tracking.
  - Administer procurement and quality assurance functions.
  - Perform general administrative functions.
  - Assist with maintaining compliance with environmental permits and regulations.
  - Direct all engineering activities.
  - Provide technical input to the preparation of environmental documents.
  - Perform community relations duties.
- Envirogen[39]
  - Operate the groundwater treatment facilities as described in Section 4.3.2.1.

The ENVIRON project manager and task leaders working on this project include:

- Project Manager, **Allan J. DeLorme, PE** – The Project Manager is responsible for the overall technical and policy decisions involving the project, including interaction and coordination with ENVIRON project staff, the GWETS operator, the Trust, and NDEP.
- Task Leader, **John M. Pekala, PG, CEM** – This Task Leader is responsible for the overall development and implementation of ENVIRON's remediation strategy as approved by NDEP.
- Task Leader, **Jessica E. Donovan, PG** – This Task Leader is responsible for the overall execution of the approved Work Plan. She will work with the Project Manager and

[39] The operation of the groundwater treatment facilities was transitioned from Veolia to Envirogen on July 24, 2013, following an approximately 5 month transition period from February 15 to July 24, 2013.

Quality Assurance (QA) Officer to ensure that work is conducted in compliance with project-specific objectives and applicable QA procedures.

- Task Leader, **Lynne Haroun, MPH** – This Task Leader is responsible for executing the health risk assessment components of the approved Work Plan. She will work with the Project Manager and QA Officer to ensure that work is conducted in compliance with project-specific objectives and applicable QA procedures.
- Project (QA) Officer, **John M. Pekala, PG, CEM –** The QA Officer is responsible for reviewing the project QA program as it relates to the collection and completeness of data from field and laboratory programs.
- Data Manager, **Craig J. Knox** – The data manager is responsible for management of the applicable databases, including updating and maintaining the databases as needed.

7.2 Project Schedule

The overall schedule for the RI/FS process at the Site is shown on Figure 7-1. The schedule identifies the primary RI/FS tasks, beginning with the submittal of this Work Plan and continuing through preparation and NDEP approval of the Site RI and FS reports. The projected durations of each task are provided, as well as the relationships between the various tasks.

The following major elements of the RI/FS process are identified in the schedule:

- Preparation of the CIP (ENVIRON 2013e) and NDEP approval of the CIP in February 2014.
- Preparation of the BHRA work plan in February 2014 and NDEP approval of the BHRA work plan in May 2014.
- Preparation and NDEP approval of two revised treatability study work plans (ENVIRON 2014f,g) in May 2014.
- NDEP review and approval of this RI/FS Work Plan (June – July 2014).
- Preparation and NDEP approval of a revised SAP (including the FSP, QAPP, and HASP), addressing NDEP comments on the SAP received in May 2014 (June – July 2014).
- Preparation and NDEP approval of the SLERA Work Plan (June – July 2014).
- Implementation of additional field investigation activities to address the data gaps and the fieldwork outlined in the SAP (August 2014 – January 2015).
- Preparation of the BHRA and SLERA (March – September 2015).
- Implementation of the soil flushing treatability study (January – September 2015).
- Preparation and submittal of the soil flushing treatability study report (October – November 2015).
- Implementation of the PRB treatability study (May 2015 – April 2016).
- Preparation and submittal of the PRB treatability study report (April – June 2016).

- Preparation of the RI and BHRA reports (March – September 2015).
- FS Analysis and Preparation of the FS report (July 2016 – January 2017).
- NDEP review and approval of the treatability study, RI, and FS reports (within 4 months following completion of each report; anticipated completion in mid 2017).

All listed documents include document submittal to NDEP for review, document revisions to address NDEP comments, and final NDEP approval. Figure 7-1 provides the anticipated RI/FS schedule based on currently available information and is subject to revision based on NDEP comments on work plans, contractor availability, and other factors.

This RI/FS Work Plan has been prepared in accordance with CERCLA, as amended, and the Interim Consent Agreement between NDEP and the Trust to investigate the nature and extent of contamination at the Site and downgradient plume and to develop remedial action alternatives, as appropriate. This Work Plan follows USEPA (1988) *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* as well as other relevant USEPA and NDEP guidance. Subsequent work plans (including the BHRA Work Plan, FSP, QAPP, and HASP) have been prepared at the direction of NDEP and the Trust; subsequent deliverables (including the treatability study reports, RI report, and FS report) will continue to be prepared at the direction of NDEP and the Trust.

8.0 References

AECOM, Inc. (AECOM), 2008. Revised Phase B Site Investigation Work Plan for Areas I, II, III and IV, Tronox LLC Facility, Henderson, Nevada. December. NDEP approved Response to Comments (dated January 16, 2009) January 16, 2009.

AECOM and Northgate Environmental Management, Inc. (AECOM-Northgate), 2009. Revised Phase B Quality Assurance Project Plan, Tronox LLC Facility, Henderson, Nevada, Revision. July. NDEP approved January 16, 2009.

Basic Remediation Company (BRC), 2007. BRC Closure Plan, BMI Common Areas, Clark County, Nevada. May. NDEP conditionally approved July 16, 2007.

BRC, 2012a. CAMU 2010/2011 Groundwater Monitoring Report, BRC Corrective Action Management Unit (CAMU) Area, Clark County, Nevada. March.

BRC, 2012b. Remedial Action Plan (RAP) Renewal Permit Application for Corrective Action Management Unit (CAMU), Henderson, Nevada. May.

BRC and Titanium Metals Corporation (BRC/TIMET), 2007. Background Shallow Soil Summary Report, BMI Complex and Common Areas Vicinity. March 16. NDEP commented May 31, 2007 requested errata pages; Errata submitted June 28, 2007; NDEP approved July 3, 2007; Addendum submitted July 22, 2007. NDEP approved July 26, 2007.

Broadbent & Associates, Inc. (Broadbent), 2011. Quarterly Status Report for the 1st Quarter of 2011. Titanium Metals Corporation, Henderson, Nevada Facility, Facility ID #H000537. April 15.

Daniel B. Stephens & Associates, Inc. (DBSA), 2007. Conceptual Site Model, Proposed CAMU Site, Henderson, Nevada. February 16. Department of Toxic Substances Control (DTSC), 2004. Perchlorate Contamination Treatment Alternatives. January.

Department of Toxic Substances Control (DTSC), 2004. Perchlorate Contamination Treatment Alternatives. January.

Evanko, C.R. and Dzombak, D.A., 1997. Technology Evaluation Report TE-97-01: Remediation of Metals-Contaminated Soils and Groundwater. Ground-Water Remediation Technologies Analysis Center (GWRTAC). October.

ENSR Corporation (ENSR), 1997. Kerr-McGee Chemical Corporation, Phase II Environmental Conditions Assessment Located at Kerr-McGee Chemical Corporation, Henderson, Nevada. NDEP approved June 10, 1998.

ENSR, 2001. Supplemental Phase II Environmental Conditions Assessment. April 2001.

ENSR, 2005. Conceptual Site Model, Kerr-McGee Facility, Henderson, Nevada. February. NDEP requested response to comments during the next monthly meeting October 22, 2005.

ENSR, 2006. Phase A Source Area Investigation Work Plan, Tronox LLC Facility, Henderson, Nevada. September. NDEP conditionally approved October 26, 2006.

ENSR, 2007a. Addendum to the Phase A Source Area Investigation Work Plan, Tronox LLC Facility, Henderson, Nevada. May. NDEP approved May, 2007 per email from Keith Bailey May 7, 2007.

ENSR, 2007b. Community Involvement Plan for Tronox LLC, Henderson, Nevada. August 28. NDEP. NDEP approved September 18, 2007.

ENSR, 2007c. Phase A Source Area Investigation Results Report, Tronox LLC Facility, Henderson, Nevada. September. NDEP approved November 30, 2007.

ENSR, 2007d. Upgradient Investigation Results, Tronox Facility, Henderson, Nevada. Revised September. NDEP commented March 4, 2008; no revised submittal or response to comments requested.

ENSR, 2008a. Phase B Source Area Investigation, Soil Gas Survey Work Plan, Tronox LLC Facility, Henderson, Nevada. March. NDEP approved March 26, 2008.

ENSR, 2008b. Phase B Source Area Investigation Work Plan, Area I (Northern LOUs), Tronox LLC Facility, Henderson, Nevada. April. NDEP conditionally approved May 6, 2008.

ENSR, 2008c. Phase B Source Area Investigation Work Plan, Area II (Central LOUs), Tronox LLC Facility, Henderson, Nevada. May. NDEP conditionally approved July 21, 2008.

ENSR, 2008d. Phase B Source Area Investigation Work Plan, Area IV (Western and Southern LOUs), Tronox LLC Facility, Henderson, Nevada. May. NDEP conditionally approved June 18, 2008.

ENSR, 2008e. Phase B Source Area Investigation Work Plan, Area III (Eastern LOUs), Tronox LLC Facility, Henderson, Nevada. June. NDEP conditionally approved July 21, 2008.

ENSR, 2008f. Annual Remedial Performance Report for Chromium and Perchlorate, July 2007 through June 2008, Tronox LLC, Henderson, Nevada. August 25. NDEP commented October 6, 2008 and requested response to comments as part of the next annual report.

ENSR, 2008g. Revised Data Validation Summary Report Phase B Source Area Investigation Soil Gas Survey - Tronox LLC Facility Henderson, Nevada. October. NDEP approved October 20, 2008.

ENVIRON International Corporation (ENVIRON), 2011a. Phase I Environmental Site Assessment of Tronox LLC, Clark County, Nevada. January.

ENVIRON, 2011b. Workplan for Evaluation of Discolored Soil and Confirmation Soil Sampling in Visually-Impacted Areas. April 18. NDEP approved May 12, 2011.

ENVIRON, 2012a. Memorandum to Shannon Harbour, NDEP, re: Proposal to Discontinue Treatment of AP-5 Pond Water at NERT Facility. March 30. NDEP approved June 28, 2012.

ENVIRON, 2012b. Site Management Plan, Nevada Environmental Response Trust Site, Clark County, Nevada. Revised April 2012 with May 2012 Errata. NDEP approved June 1, 2012.

ENVIRON, 2012c. Annual Remedial Performance Report for Chromium and Perchlorate, Nevada Environmental Response Trust Site, Henderson, Nevada, July 2011 - June 2012. August 31. NDEP approved July 2, 2013.

ENVIRON, 2012d. AP-5 Pond Solids Characterization and Disposal Work Plan, Nevada Environmental Response Trust Site, Henderson, Nevada. September 28. NDEP approved February 4, 2013.

ENVIRON, 2012e. Interim Soil Removal Action Completion Report, Nevada Environmental Response Trust Site, Henderson, Nevada, August 2010 – November 2011. January. Revised September 28. NDEP approved December 17, 2012.

ENVIRON, 2012f. Remedial Investigation and Feasibility Study Work Plan, Nevada Environmental Response Trust Site, Henderson, Nevada. December 17. NDEP commented June 27, 2013 and November 18, 2013.

ENVIRON, 2013a. Soil Gas Investigation Report and Health Risk Assessment for Parcels C, D, F, G, and H, Revision 0, Nevada Environmental Response Trust Site, Henderson, Nevada. July 25. NDEP commented September 30, 2013.

ENVIRON, 2013b. Annual Remedial Performance Report for Chromium and Perchlorate, July 2012-June 2013; Nevada Environmental Response Trust Site, Henderson, Nevada. August 30, 2013. NDEP approved October 10, 2013.

ENVIRON, 2013c. 2013 GWETS Optimization Project Work Plan, Revision 1, Nevada Environmental Response Trust Site, Henderson, Nevada. November 22. NDEP approved December 3, 2013.

ENVIRON, 2013d. Site Management Plan, Revision 1, Nevada Environmental Response Trust Site, Henderson, Nevada. October 31. NDEP approved November 7, 2013.

ENVIRON, 2013e. Community Involvement Plan, Nevada Environmental Response Trust Site (Formerly Tronox Henderson Site), Henderson, Nevada. December 27. NDEP approved February 19, 2014.

ENVIRON, 2014a. Health and Safety Plan for Remedial Investigation and General Site Activities, Nevada Environmental Response Trust Site, Henderson, Nevada. January 24. NDEP commented May 20, 2014.

ENVIRON, 2014b. Field Sampling Plan Revision 0, Nevada Environmental Response Trust Site, Henderson, Nevada. January 24. NDEP commented May 20, 2014.

ENVIRON, 2014c. Quality Assurance Project Plan, Revision 0, Nevada Environmental Response Trust Site, Henderson, Nevada. January 24. NDEP commented May 8, 2014.

ENVIRON, 2014d. Baseline Health Risk Assessment Work Plan, Nevada Environmental Response Trust Site, Henderson, Nevada. February 28. NDEP approved May 20, 2014.

ENVIRON, 2014e. Semi-Annual Performance Report for Chromium and Perchlorate, Nevada Environmental Response Trust Site, Henderson, Nevada, July – December 2013. NDEP commented April 9, 2014.

ENVIRON, 2014f. Treatability Study Work Plan In-Situ Soil Flushing Pilot, Revision 2, Nevada Environmental Response Trust Site, Henderson, Nevada. May 9. NDEP approved May 20, 2014.

ENVIRON, 2014g. Treatability Study Work Plan Permeable Reactive Barrier Pilot, Revision 2, Nevada Environmental Response Trust Site, Henderson, Nevada. May 9. NDEP approved May 20, 2014.

Errol Montgomery & Associates, 2000. Analysis of Rate of Groundwater Movement Based on Results of Tracer and Hydraulic Tests Conducted Between Pittman Lateral and Seep Area.

Federal Remediation Technology Roundtable (FRTR), 2012. www.frtr.gov.

Geraghty & Miller, Inc., 1993. Phase I Environmental Conditions Assessment for BMI Complex – Clark County, Nevada. April.

Hargis & Associates (H+A), 2008. Conceptual Site Model, Former Montrose and Stauffer Facilities and Downgradient Areas to Las Vegas Wash, Henderson, Clark County, Nevada. July.

Integral Consulting Inc. (Integral), 2009. Draft Risk Assessment Work Plan, Former Montrose and Stauffer Facilities, Henderson, Nevada. May. NDEP commented November 9, 2009.

ITRC (Interstate Technology & Regulatory Council), 2000. Technology Overview: Dense Non-Aqueous Phase Liquids (DNAPLs): Review of Emerging Characterization and Remediation. Interstate Technology & Regulatory Council. June.

ITRC, 2007. Remediation Technologies for Perchlorate Contamination in Water and Soil. PERC-2. Interstate Technology & Regulatory Council, Perchlorate Team. www.itrcweb.org.

Johnson and Ettinger, 1991. Model for Subsurface Vapor Intrusion into Buildings.

Kerr-McGee Chemical Corporation (KMCC), 1985. Hydrogeological Investigation, Kerr-McGee Chemical Corporation Henderson Facility. July. NDEP commented February 26, 1986.

KMCC, 1997. Phase II Work Plan. April. NDEP approved February 4, 1997.

KMCC, 1998a. Phase II Groundwater Perchlorate Investigation Report. July 15.

KMCC, 1998b. Preliminary Report on a Hydrologic Investigation of Channel-Fill Alluvium at the Pittman Lateral, Henderson, Nevada. October 19.

KMCC, 2001. Seep Area Groundwater Characterization Report, Kerr-McGee Chemical LLC, Henderson, Nevada. January 18.

Kleinfelder, 1993. Environmental Conditions Assessment, Kerr-McGee Chemical Corporation, Henderson, Nevada. April.

Las Vegas Wash Coordinating Committee (LVWCC), 2013. 2008-2012 Year-End Report.

Las Vegas Water District, 2012. Perchlorate. http://www.lvvwd.com/wq/facts_perchlorate.html.

LAW Engineering, 1993. Final Report of Phase I Environmental Conditions Assessment, Volume 1: Text, Titanium Metals Corporation (TIMET), Henderson, Nevada. April 15.

National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 1990. 55 FR 8666. March 8. (Codified at 40 CFR 300.1-300.920).

Neptune and Company, 2010. Revised Data Validation Summary Report for Shallow Supplemental Soil Sampling in Areas I and II. July 21. NDEP approved July 28, 2010.

Nevada Division of Environmental Protection (NDEP), 1986. Consent Order between NDEP and Kerr-McGee. September 9.

NDEP, 1991. Consent Agreement, Phase I Environmental Conditions Assessment. April 25.

NDEP, 1994. Phase II Letter of Understanding between NDEP and Kerr-McGee. August 15.

NDEP, 1996. Consent Agreement, Phase II Environmental Conditions Investigation. August 1.

NDEP, 1999. Consent Agreement between NDEP and Kerr-McGee. July 26.

NDEP, 2001. Administrative Order on Consent between NDEP and Kerr-McGee. October 8.

NDEP, 2004. NDEP Response to: *Supplemental Phase II Report – Environmental Conditions Assessment*. February 11.

NDEP, 2005. Administrative Order on Consent between NDEP and Kerr-McGee. April 12.

NDEP, 2006. BMI Plant Sites and Common Areas Projects, Henderson, Nevada Hydrogeologic and Lithologic Nomenclature Unification. January 2006.

NDEP, 2007a. Phase A Report and Phase B Work Plan Meeting Minutes, Tronox. July 18.

NDEP, 2007b. Advisement Regarding Radionuclide Analyses for Uranium, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. December 7.

NDEP, 2008a. Advisement Regarding Radionuclide Analyses, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. January 29.

NDEP, 2008b. NDEP Response to: *Phase B Source Area Investigation – Soil Gas Survey Work Plan, Tronox LLC, Henderson, Nevada, Dated: March 20, 2008*. March 26.

NDEP, 2008c. Statistical Analysis Recommendations for Field Duplicates and Field Splits, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. November 14.

NDEP, 2008d. Detection Limits and Data Reporting, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. December 3.

NDEP, 2008e. Guidance on the Development of Summary Statistics Tables, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. December 10.

NDEP, 2009a. BMI Plant Sites and Common Areas Project, Henderson, Nevada: Hydrogeologic and Lithologic Nomenclature Unification. January 6.

NDEP, 2009b. Guidance for Evaluating Radionuclide Data, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. February 6.

NDEP, 2009c. Guidance for Evaluating Secular Equilibrium at the BMI Complex and Common Areas, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. February 6.

NDEP, 2009d. Supplemental Guidance on Data Validation, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. April 13.

NDEP, 2009e. Supplement to the Guidance for Evaluating Radionuclide Data for the BMI Plant Sites and Common Areas Projects dated February 6, 2009, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. April 29.

NDEP, 2009f. Significance Levels for The Gilbert Toolbox of Background Comparison Tests for the BMI Plant Sites and Common Areas Projects, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. July 9.

NDEP, 2009g. Finding of Alleged Violation and Order. December 14.

NDEP, 2010a. NDEP Response to: *Results of Bioaccessibility Study for Dioxin/Furans in Soil, Tronox LLC, Henderson, Nevada (Revised), Dated: May 24, 2010*. May 25.

NDEP. 2010b. Letter to Mr. Matt Paque, Tronox LLC, from Ms. Shannon Harbour, regarding NDEP Response to *Background Issues and Determination of Background Dataset for TRX*. August 17.

NDEP, 2010c. Supplemental Guidance for Assessing Data Usability for Environmental Investigations at the BMI Complex and Common Areas in Henderson, Nevada. September 1.

NDEP, 2011a. Action Memorandum: Removal Actions, Nevada Environmental Response Trust Site, Clark County, Nevada. July 21.

NDEP, 2011b. Defining a Perchlorate Drinking Water Standard. http://ndep.nv.gov/bca/perchlorate02_05.htm

NDEP, 2012a. Revised Guidance on Qualifying Data due to Blank Contamination for the BMI Complex and Common Areas, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. January 5.

NDEP, 2012b. Guidance on Validation for Asbestos Data in Soils, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. July 24.

NDEP, 2012c. NDEP Response to: *Interim Soil Removal Action Completion Report, Nevada. Environmental Response Trust Site, Henderson, Nevada, August 2010 - November 2011, Dated: September 2012 (Revised) and Response to NDEP Comments on the Interim Soil Removal Action. Completion Report, Nevada Environmental Response Trust Site, Henderson, Nevada, Dated: September 28, 2012*. December 17.

NDEP, 2013a. NDEP Response to: *AP-5 Ponds Solids Characterization and Disposal Work Plan, Nevada Environmental Response Trust Site, Henderson, NV, Dated: September, 2012*. February 4.

NDEP, 2013b. Guidance on Unified Chemical Electronic Data Deliverable Format, BMI Plant Sites and Common Areas Projects, Henderson, Nevada. June 5.

NDEP, 2013c. NDEP Response to: *Remedial Investigation and Feasibility Study Work Plan, Nevada Environmental Response Trust Site, Henderson, Nevada, Dated: December 17, 2012*. June 27.

NDEP, 2013d. User's Guide and Background Technical Document for NDEP Basic Comparison Levels (BCLs) for Human Health for the BMI Complex and Common Areas. Revision 12, August.

NDEP, 2013e. NDEP Response to: *2013 GWETS Optimization Project Work Plan, Revision 1, Dated: November, 22, 2013*. December 3.

NDEP, 2014a. NDEP Response to: *Semi-Annual Remedial Performance Report for Chromium and Perchlorate, Nevada Environmental Response Trust Site, Henderson, Nevada; July – December 2013. Dated: February 28, 2014.* April 9.

NDEP, 2014b. NDEP Response to: *Quality Assurance Project Plan, Revision 0, Nevada Environmental Response Trust Site, Henderson, Nevada, Dated: January 24, 2014*. May 8.

NDEP, 2014c. NDEP Response to: *Health and Safety Plan for Remedial Investigation and General Site Activities, Nevada Environmental Response Trust Site, Henderson, Nevada. Dated: January 24, 2014.* May 20.

NDEP, 2014d. NDEP Response to: *Field Sampling Plan Revision 0, Nevada Environmental Response Trust Site, Henderson, Nevada. Dated: January 24, 2014*. May 20.

NDEP, 2014e. NDEP Response to: *Baseline Health Risk Assessment Work Plan, Revision 0, Nevada Environmental Response Trust Site, Henderson, Nevada. Dated: February 28, 2014.* May 20.

NDEP, 2014f. NDEP Response to: *Treatability Study Work Plan Permeable Reactive Barrier Pilot, Revision 2, Nevada Environmental Response Trust Site, Henderson, Nevada, and Response to NDEP Comments Dates March 17, 2014, Treatability Study Work Plan Permeable Reactive Barrier Pilot, Revision 1, Nevada Environmental Response Trust Site, Henderson, Nevada. Dated: May 9, 2014.* May 20.

NDEP, 2014g. NDEP Response to: *Treatability Study Work Plan In-Situ Soil Flushing Pilot, Revision 2, Nevada Environmental Response Trust Site, Henderson, Nevada, and Response to NDEP Comments Dates March 18, 2014, treatability Study Work Plan In-Situ Soil Flushing Pilot, Revision 1, Nevada Environmental Response Trust Site, Henderson, Nevada. Dated: May 9, 2014.* May 20.

NDEP, 2014h. NDEP Response to: *AP-5 Closure Work Plan 1: Develop Closure Procedures for the AP-5 Pond, Henderson, Nevada. Dated: May 27, 2014.* June 18.

Northgate, 2010a. Revised Data Validation Summary Report, Phase B Investigation Area I Soil, Tronox LLC, Henderson, Nevada. January 15. NDEP approved January 20, 2010.

Northgate, 2010b. Data Validation Summary Report, Phase B Investigation Area II Soil, Tronox LLC, Henderson, Nevada. February 12. NDEP approved February 18, 2010.

Northgate, 2010c. Data Validation Summary Report, Phase B Investigation Area III Soil, Tronox LLC, Henderson, Nevada. February 18. NDEP approved March 17, 2010.

Northgate, 2010d. Health Risk Assessment Work Plan, Tronox LLC Facility, Henderson, Nevada. March 9. NDEP approved March 16, 2010.

Northgate, 2010e. Revised Data Validation Summary Report, Phase B Investigation Area IV Soil, Tronox LLC, Henderson, Nevada. March 19. NDEP approved March 29, 2010.

Northgate, 2010f. Interim Groundwater Capture Evaluation and Vertical Delineation Report, Tronox LLC, Henderson, Nevada. March 23. ENVIRON resubmitted the NERT Site groundwater model on February 21, 2013. NDEP approved April 4, 2013.

Northgate, 2010g. Final Revised Pre-Confirmation Sampling Work Plan Remediation Zones RZ-A through RZ-E Phase B Investigation, Tronox Facility, Henderson, Nevada. March 25. NDEP approved March 30, 2010.

Northgate, 2010h. Revised Data Validation Summary Report, Phase B Investigation Groundwater, Tronox LLC, Henderson, Nevada. April 7. NDEP approved April 14, 2010.

Northgate, 2010i. Capture Zone Evaluation Work Plan, Tronox LLC, Henderson, Nevada. May 13. NDEP approved May 24, 2010.

Northgate, 2010j. Removal Action Work Plan for Phase B Soil Remediation of Remediation Zones RZ-B through RZ-E, Tronox LLC, Henderson, Nevada. Revised June 22; Errata submitted August 13. NDEP approved Errata August 20, 2010.

Northgate, 2010k. Revised Human Health Risk Assessment for Remediation Zone A, Tronox LLC, Henderson, Nevada. July 23. NDEP approved August 20, 2010.

Northgate, 2010l. Appendix A of the Excavation Plan for Phase B Soil Remediation of RZ-B, Addendum to the Removal Action Work Plan. August 20. NDEP approved September 3, 2010.

Northgate, 2010m. Annual Remedial Performance Report for Chromium and Perchlorate, Tronox LLC, Henderson, Nevada, July 2009-June 2010. August 27.

Northgate, 2010n. Appendix A of the Revised Excavation Plan for Phase B Soil Remediation of RZ-C, Addendum to the Removal Action Work Plan. September 1. NDEP conditionally approved December 1, 2010.

Northgate, 2010o. Spring 2010 Indoor Air Quality Sampling and Analysis Report, Tronox LLC, Henderson, Nevada. September 22. NDEP approved November 1, 2010.

Northgate, 2010p. Appendix A of the Excavation Plan for Phase B Soil Remediation of RZ-D, Addendum to the Removal Action Work Plan. October 18. NDEP approved November 8, 2010.

Northgate, 2010q. Appendix A of the Excavation Plan for Phase B Soil Remediation of RZ-E, Addendum to the Removal Action Work Plan. November 3. NDEP conditionally approved November 29, 2010.

Northgate, 2010r. Site-Wide Soil Gas Human Health Risk Assessment, Tronox LLC, Henderson, Nevada. November 22. Not reviewed by NDEP.

Northgate, 2010s. Capture Zone Evaluation Report, Tronox LLC. Henderson, Nevada. December 10. ENVIRON resubmitted the NERT Site groundwater model on February 21, 2013. NDEP approved April 4, 2013.

Northgate, 2011a. December 2010 Indoor Air Quality Sampling and Analysis Report, Tronox LLC, Henderson, Nevada. February 3. NDEP approved March 21, 2011.

Northgate, 2011b. Revised Technical Memorandum: Calculation of Leaching-Based Site-Specific Levels for the Soil-to-Groundwater Pathway Using NDEP Guidance, Tronox LLC, Henderson, Nevada. May 9.

Northgate, 2012. Manganese Tailings Removal Technical Memorandum, Nevada Environmental Response Trust, Henderson, Nevada. November 9. NDEP approved February 21, 2013.

RCI Engineering, 2010. Technical drainage study for Tronox soil remediation treatment basins. RCI Engineering, Las Vegas, NV, October 2010.

Sale, T. and Newell, C, 2011. A Guide for Selecting Remedies for Subsurface Releases of Chlorinated Solvents, U.S. Department of Defense, Environmental Security and Technology Certification Program (ESTCP) Project ER-200530. March.

Tetra Tech, 2014. AP-5 Closure Work Plan 1: Develop Closure Procedures for the AP-5 Pond, Henderson, Nevada. May 22. NDEP approved June 18, 2014.

TIMET, 2007. Conceptual Site Model, Titanium Metals Corporation Facility, Henderson, Nevada. April 25. NDEP issued final response August 14, 2008.

Tronox LLC (Tronox), 2008. Outline Proposal to Assess Background Water Quality, Tronox, LLC, Henderson Nevada. Letter, dated December 18, 2008, from Susan M. Crowley, Staff Environmental Specialist, to Shannon Harbour, P.E., NDEP. NDEP commented January 6, 2008; no revised submittal or response to comments requested.

Tronox, 2010. Letter to Ms. Shannon Harbour, P.E., re: Response to Nevada Division of Environmental Protection (NDEP) letter RE: Pond AP-5, dated November 30, 2010. December 10.

Urbansky, E. T. 1998. Perchlorate chemistry: implications for analysis and remediation. Bioremediation Journal 2, 81–95.

U.S. Bureau of Reclamation (USBOR), 2012. Las Vegas Wash Water Quality Monitoring Program 2011 Report. A Water Quality Assessment. July.

U.S. Environmental Protection Agency (USEPA), 1986. Grouting Techniques in Bottom Sealing of Hazardous Waste Sites. (EPA/600/2-86/020).

USEPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final. October.

USEPA, 1992a. Guidance for Data Usability in Risk Assessment (Part A), Final. Office of Emergency and Remedial Response, April. http://www.epa.gov/oswer/riskassessment/datause/parta.htm.

USEPA, 1992b. Guidance for Data Usability in Risk Assessment (Part B), Final. Office of Emergency and Remedial Response, April. http://www.epa.gov/oswer/riskassessment/datause/partb.htm

USEPA, 1997a. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final. (EPA 540/R-97/006). June.

USEPA, 1997b. Engineering Bulletin: Technology Alternatives for the Remediation of Soils Contaminated with As, Cd, Cr, Hg, and Pb. (EPA/540/S-97/500). August. USEPA, 2000a. In-Situ Treatment of Soil and Groundwater Contaminated with Chromium, Technical Resource Guide. (EPA/625/R-00/005). October.

USEPA, 2000b. Soil Screening Guidance for Radionuclides: User’s Guide. OSWER Directive 9355.4-16A. October.

USEPA, 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Office of Solid Waste and Emergency Response, Washington, DC. OSWER 9355.4-24. December.

USEPA, 2004a. User’s Guide for Evaluating Subsurface Vapor Intrusion into Buildings. February 22.

USEPA, 2004b. In-Situ Thermal Treatment of Chlorinated Solvents: Fundamentals and Field Applications. (EPA/542/R-04/010). March

USEPA, 2004c. DNAPL Remediation: Selected Projects Approaching Regulatory Closure. (EPA 542-R-04-016). December.

USEPA, 2005. Perchlorate Treatment Technology Update, Federal Facilities Forum Issue Paper. (EPA/542/R-05/015). May.

USEPA. 2008. “Interim Drinking Water Health Advisory for Perchlorate,” EPA Office of Science and Technology, Office of Water. (EPA 822-R-08-025). December.

USEPA, 2009a. “Revised Assessment Guidance for Perchlorate”, Memorandum prepared by USEPA Office of Solid Waste and Emergency Response January 8.

USEPA, 2009b. DNAPL Remediation: Selected Projects Where Regulatory Closure Goals Have Been Achieved. (EPA 542/R-09/008). August.

USEPA, 2012. Contaminated Site Clean-up Information Website. http://www.clu-in.org/.

USEPA, 2013a. Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites. November.

USEPA, 2013b. Preliminary Remediation Goals for Radionuclides. On-line calculator. http://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search

Van den Berg, M. et al, 2006. The 2005 World Health Organization re-evaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicological Sciences 93(2), 223-241.

Weston, 1993. Site Conceptual Model, Stauffer/Pioneer/Montrose Site, Henderson, Nevada. September.

Attachment C

Revised Table 5-1
Remedial Investigation and Feasibility Study Work Plan, Revision 2,
Nevada Environmental Response Trust Site, Henderson, Nevada

TABLE 5-1. CATEGORY 3 AREA INFORMATION
Nevada Environmental Response Trust Site; Henderson, Nevada

AREA #	DESCRIPTION	SAMPLE INFORMATION					
		SAMPLE LOCATION	DEPTH INTERVAL (feet bgs)	CHEMICAL [1]	RESULT [2]	BCL or SRG [3]	Unit
1	Dioxin TEQ > BCL at two locations at ground surface (0-1.5 ft). Northgate did not define a soil removal polygon for this area and soil was not removed. RSAI7 is slightly north of an existing ECA and along fenceline where removal of the BMI Haul Road is anticipated. TSB-CJ-09 is just north of this area.	RSAI7	0 - 0.5	Dioxin TEQ	31,000	2,700	pg/g
		TSB-CJ-09	0 - 1.5	Dioxin TEQ	3,900	2,700	pg/g
2	Dioxin TEQ and HCB > BCL originally at ground surface and is now buried by approximately 2 ft of soil. Northgate did not define a soil removal polygon for this area and soil was not removed.	SSAK3-05	2.5 - 3	Hexachlorobenzene	4.7	1.2	mg/kg
			2.5 - 3	Dioxin TEQ	11,000	2,700	pg/g
3	Hexachlorobenzene > BCL at 1.5-2 ft deep. Northgate did not define a soil removal polygon for this area and soil was not removed.	RSAK4	1.5 - 2	Hexachlorobenzene	2.1	1.2	mg/kg
4	Arsenic slightly > background at 2-5 ft deep. These samples were originally collected at 10-13 ft deep. Polygon excavation was planned to 4 ft, but actual soil excavation was to ~8 ft (due to discolored soil or grading).	BDT-2-S-5	2 - 3	Arsenic	10	7.2	mg/kg
			4 - 5	Arsenic	7.7	7.2	mg/kg
			4 - 5	Arsenic	9.0	7.2	mg/kg
5	Perchlorate > BCL at various locations at and near ground surface (within retention basin). These samples were originally collected at 10-12 ft deep. Polygon excavation was performed to 10 ft. In consultation with NDEP, grading was performed to construct retention basin in this area. Also, perchlorate is present at >9 ft below "new" ground surface in this area.	RSAM5	1 - 2.5	Perchlorate	2,620	795	mg/kg
		SA15	0 - 0.5	Perchlorate	1,160	795	mg/kg
			0 - 0.5	Perchlorate	1,210	795	mg/kg
			9 - 10.5	Perchlorate	943	795	mg/kg
		SA65	surface	Perchlorate	1,690	795	mg/kg
			8.5 - 10	Perchlorate	984	795	mg/kg
6	Arsenic slightly > background at 6-7 ft deep. These samples were originally collected at 5-6 ft deep. Polygon excavation was planned and performed to 1 ft, with approximately 1 ft of backfill in this area. Soil removal polygons were not originally designed to excavate this deep, presumably since the concentration of arsenic was only slightly above the arsenic background concentration.	SA63	6 - 7	Arsenic	7.5	7.2	mg/kg
7	Arsenic slightly > background at ~4 ft deep. After polygon excavation to 1 ft and additional discolored soil excavation, a confirmation sample was collected which indicated that arsenic was slightly above background. In consultation with NDEP and because arsenic concentrations were only slightly above background, no further excavation was performed in this area and the area was backfilled with approximately 4 ft of soil.	CS-D31A-1	4	Arsenic	8.1	7.2	mg/kg
8	Perchlorate > BCL at ~8.5-18 ft deep. These samples were originally collected at 12-21.5 ft deep. Polygon excavation was performed to 10 ft, then area partially backfilled.	SA106	8.5 - 10	Perchlorate	1,050	795	mg/kg
9	Arsenic > background at surface. After soil removal and cleanup following stockpile staging area use in this area, a confirmation sample (DS-C45-2) was collected which indicated arsenic was slightly above background. In consultation with NDEP and because arsenic concentrations were only slightly above background, no further excavation was performed in this area.	DS-C45-2	surface	Arsenic	10	7.2	mg/kg
			surface	Arsenic	12	7.2	mg/kg
10	Arsenic > background at ~8 ft deep. After polygon excavation and additional discolored soil removal to ~8 ft, a confirmation sample was collected which indicated arsenic was slightly above background. In consultation with NDEP and because the arsenic concentration was only slightly above background, no further excavation was performed in this area and the area was backfilled with approximately 8 ft of soil.	CS-C27-1	8	Arsenic	11	7.2	mg/kg
11 [4]	Arsenic > background at 2-3.5 ft. After soil removal and cleanup following stockpile staging area use in this area, a confirmation sample (DS-C45-2) was collected which indicated arsenic was slightly above background. In consultation with NDEP and because arsenic concentrations were only slightly above background, no further excavation was performed in this area.	SA149	2 - 3.5	Arsenic	25	7.2	mg/kg
			2 - 3.5	Arsenic	21	7.2	mg/kg
12	Arsenic slightly > background in upper 3.5 ft. This sample appears to have been collected on the neighboring property (Lhoist), so soil removal was not planned in this area.	RSAQ5	1 - 2.5	Arsenic	7.4	7.2	mg/kg
			1.5 - 2.5	Arsenic	8.7	7.2	mg/kg
			2.5 - 3.5	Arsenic	7.7	7.2	mg/kg

TABLE 5-1. CATEGORY 3 AREA INFORMATION
Nevada Environmental Response Trust Site; Henderson, Nevada

Notes:

Samples and analytical results listed on this table are from samples presently within 10 ft of the "new" ground surface. Analytical results for deeper samples are not provided on this table.

[1] An NDEP approved site-specific BCL is used as the SRG for dioxins/furans, i.e., dioxin TEQ of 2,700 mg/kg (NDEP 2010a). For arsenic, "contaminated" soil is defined as concentrations greater than a site-specific background concentration of 7.2 mg/kg.

[2] One sample result (dioxin TEQ result of 29,000 pg/g collected at soil boring location RSAI7 from 0 to 0.5 ft bgs) in Category 3 area 1 was removed from Table 5-1 presented in the December 17, 2012 report (ENVIRON 2012f). Following further review of the data, it was determined that this sample was a screening result for the same sample that was detected at 31,000 pg/g.

[3] The BCL for white phosphorus was not compared to the analytical results for phosphorus because the site history does not suggest that white phosphorus is present on-site.

[4] This sample was previously listed in category area #9.

Abbreviations:

bgs = below ground surface
BCL = Basic Comparison Level
BMI = Black Mountain Industrial
ECA = Excavation Control Area
ft = foot or feet
mg/kg = milligrams per kilogram
NDEP = Nevada Division of Environmental Protection
pg/g = picograms per gram
SRG = Soil Remediation Goal
TEQ = toxicity equivalent
TIMET = Titanium Metals Corporation

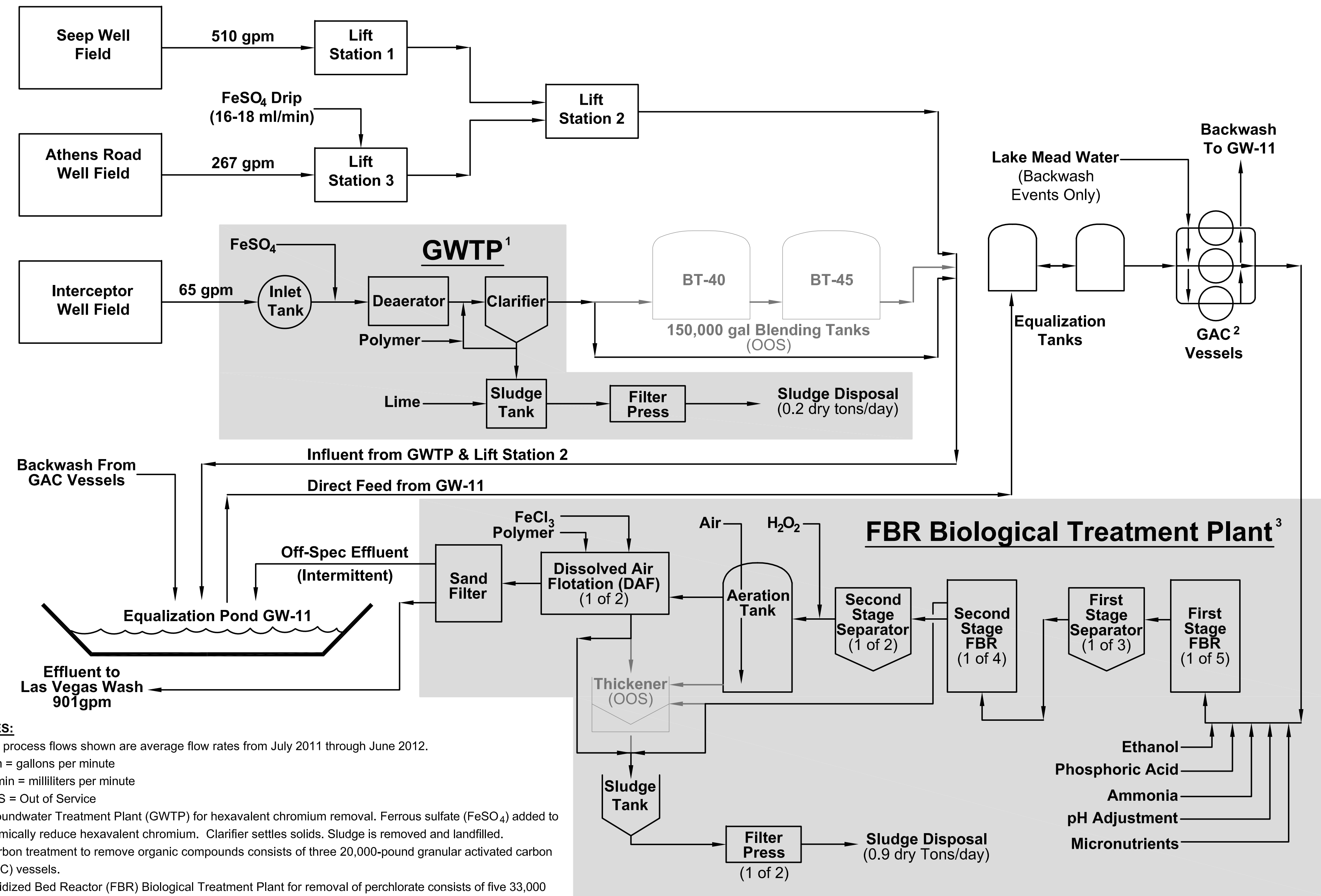
References:

ENVIRON, 2012f. Remedial Investigation and Feasibility Study Work Plan, Nevada Environmental Response Trust Site; Henderson, Nevada. December 17.

Nevada Division of Environmental Protection (NDEP), 2010a. NDEP Response to: *Results of Bioaccessibility Study for Dioxin/Furans in Soil, Tronox LLC, Henderson, Nevada (Revised) Dated: May 24, 2010.* May 25.

Attachment D

Revised Figures,
Remedial Investigation and Feasibility Study Work Plan, Revision 2,
Nevada Environmental Response Trust Site, Henderson, Nevada



NOTES:

The process flows shown are average flow rates from July 2011 through June 2012.

gpm = gallons per minute

ml/min = milliliters per minute

OOS = Out of Service

1) Groundwater Treatment Plant (GWTP) for hexavalent chromium removal. Ferrous sulfate ($FeSO_4$) added to chemically reduce hexavalent chromium. Clarifier settles solids. Sludge is removed and landfilled.

2) Carbon treatment to remove organic compounds consists of three 20,000-pound granular activated carbon (GAC) vessels.

3) Fluidized Bed Reactor (FBR) Biological Treatment Plant for removal of perchlorate consists of five 33,000 gallon first-stage FBRs, four 28,800 gallon second-stage FBRs, aeration (air and hydrogen peroxide, H_2O_2), dissolved air flotation (DAF), two plate and frame filter presses, and a sand filter.

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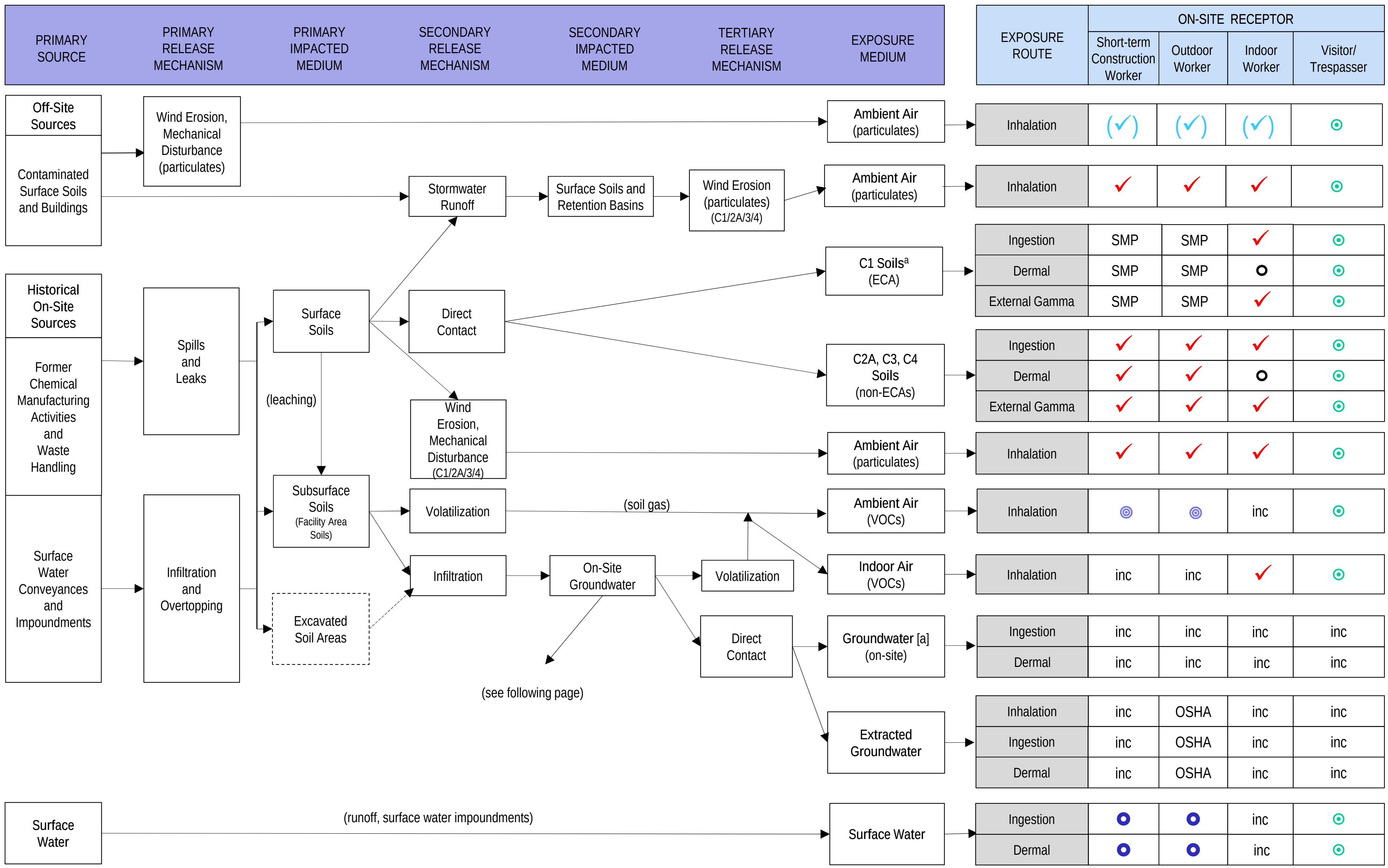
Groundwater Extraction and Treatment System (GWETS) Flow Diagram
Nevada Environmental Response Trust (NERT)
Henderson, Nevada

Figure **4-1**

Drafter: RS | Date: 6/17/14 | Contract Number: 21-29100I | Approved: | Revised:



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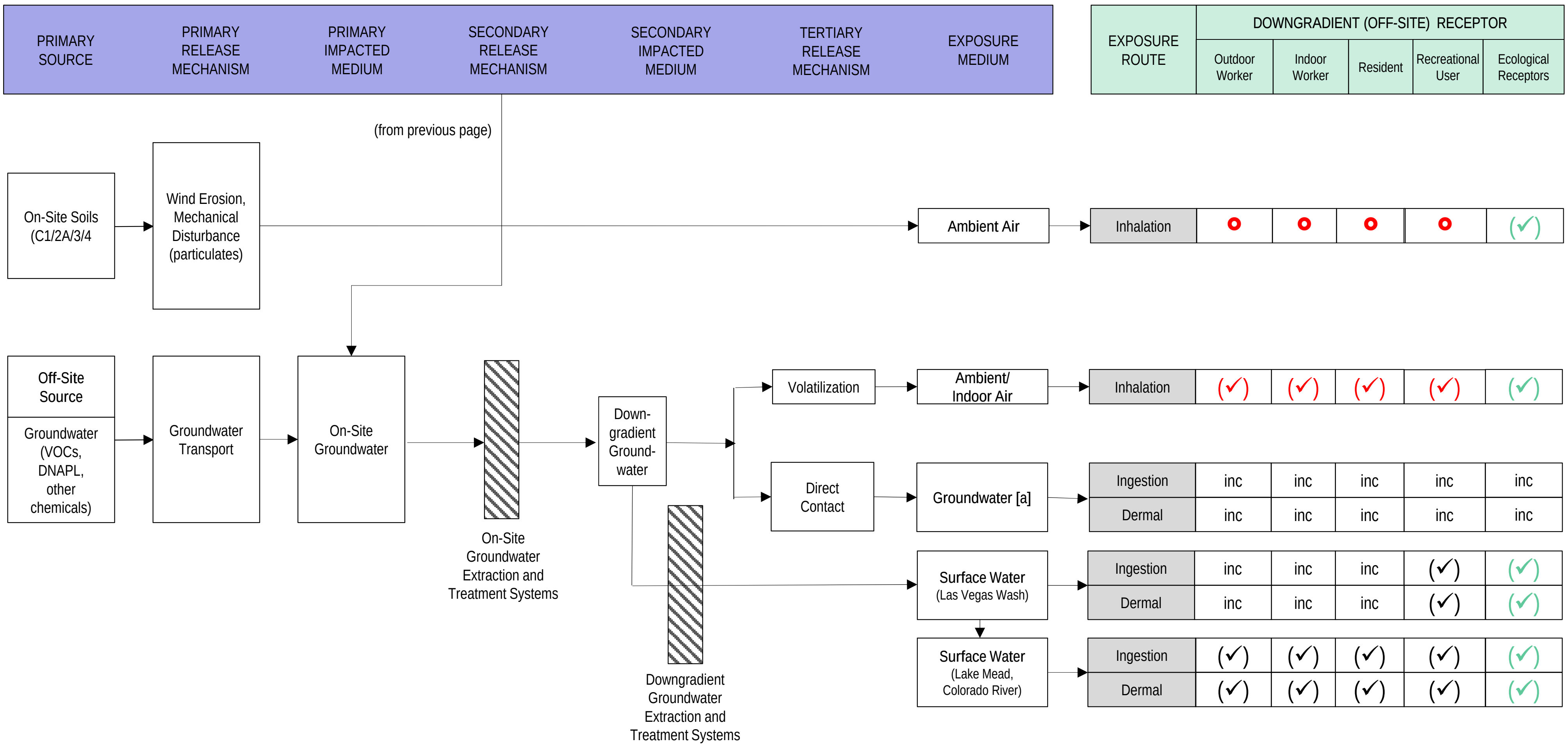
Conceptual Site Model Diagram: Facility Area and Downgradient Plume
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure
5-1

Drafter: EL | Date: 2/21/2014 | Contract Number: 21-34800I | Approved by: | Revised:



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Conceptual Site Model Diagram: Facility Area and Downgradient Plume
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure
5-1

Drafter: EL | Date: 2/21/2014 | Contract Number: 21-34800I | Approved by: | Revised:

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Note:

This preliminary CSM, including the identification of sources, release mechanisms, exposure media, exposure routes, and receptors is based on current understanding of on-site and off-site environmental conditions. The CSM will be revised, as appropriate, based on evaluation of additional environmental data collected during the RI.

[a] Groundwater is not and will not be used as a source of drinking water. Incidental ingestion and dermal contact with groundwater by on-site construction workers are considered to be incomplete exposure pathways because depth to groundwater is >20 ft bgs. For off-site workers, depth to groundwater in some areas is <20 feet; however, the intermittent exposures of a construction worker to groundwater would be negligible.

Key:

C1, C2A, C3, C4	Category 1, 2A, 3, and 4 soils, where C1 = soils 0 – 10 feet bgs in ECAs; C2A = soils 0 – 10 feet bgs (excluding remediation zone A) with concentrations <BCLs; C3 = soils 0 – 10 feet bgs with concentrations >BCLs; C4 = soils 0 – 10 feet bgs not previously sampled or available information considered inadequate. C2B soils (not shown on this CSM) are soils 0 – 10 feet bgs with concentrations <BCLs in remediation zone A.
inc	Incomplete exposure pathway
OSHA	Workers at the groundwater extraction and treatment facility could potentially be exposed to contaminants in extracted groundwater. However, potential exposures will not be evaluated quantitatively because the workers are regulated by the Occupational Safety and Health Administration (OSHA) and a comprehensive worker health and safety plan (HASP) is in place to mitigate potential exposures.
SMP	Site Management Plan -- potential exposures for direct-contact pathways will be managed through the SMP.
✓	Complete exposure pathway; evaluated quantitatively in the BHRA.
(✓)	Potentially complete exposure pathway for off-site receptors. For indoor and outdoor air; pathway will be evaluated quantitatively using analytical results for soil gas and/or groundwater depending on receptor location and data availability. The specific receptors and pathways (i.e., indoor and outdoor exposures) that will be evaluated quantitatively will depend on various factors, including the results from additional sampling for VOCs in the downgradient groundwater plume and/or results from off-site soil gas investigations.
(✓)	Complete exposure pathway. ENVIRON understands that exposures of on-site receptors to airborne releases from neighboring properties would be evaluated in the risk assessments being prepared for those properties, under the oversight of NDEP. Pathway will be discussed quantitatively in the BHRA using results of risk assessments prepared by the neighboring properties, or qualitatively, if risk assessments are not available.
(✓)	Complete exposure pathway for perchlorate and possibly other site-related chemicals; for perchlorate, pathway will be evaluated by comparing surface water concentrations to the Nevada Provisional Action Level for perchlorate (NDEP 2011b).
(✓)	Complete exposure pathway; as discussed in Section 1.2.3, the ecological risk assessment will be conducted following aquifer restoration.
○	Complete, but insignificant exposure pathway. Consistent with USEPA guidance (USEPA 2002b) and the NDEP-approved 2010 HRA work plan (Northgate and Exponent 2010a), potential exposures of indoor workers to soil from dermal exposure are not evaluated quantitatively, but will be discussed qualitatively.
◎	Exposures of outdoor workers via inhalation of soil or groundwater vapors would be less than exposures of indoor workers; inhalation of vapors in outdoor air will be evaluated only if estimated risks for the vapor intrusion (indoor) pathway are >1E-06 or the hazard index is >1.
○	Exposures of all off-site receptors via inhalation of airborne soil particulates would be significantly less than exposures of on-site workers; inhalation of particulates will be evaluated for off-site receptors only if estimated risks for on-site receptors are >1E-06 or the hazard index is >1.
○	For on-site receptors, potentially complete, but insignificant exposure pathway; not evaluated quantitatively because potential exposures would be intermittent and of short duration or regulated under OSHA; surface water pathways will be discussed qualitatively.
⊙	Potentially complete exposure pathway; not evaluated quantitatively because potential exposures of a visitor/trespasser would be less than exposures of an on-site worker; the visitor/trespasser will be discussed qualitatively.

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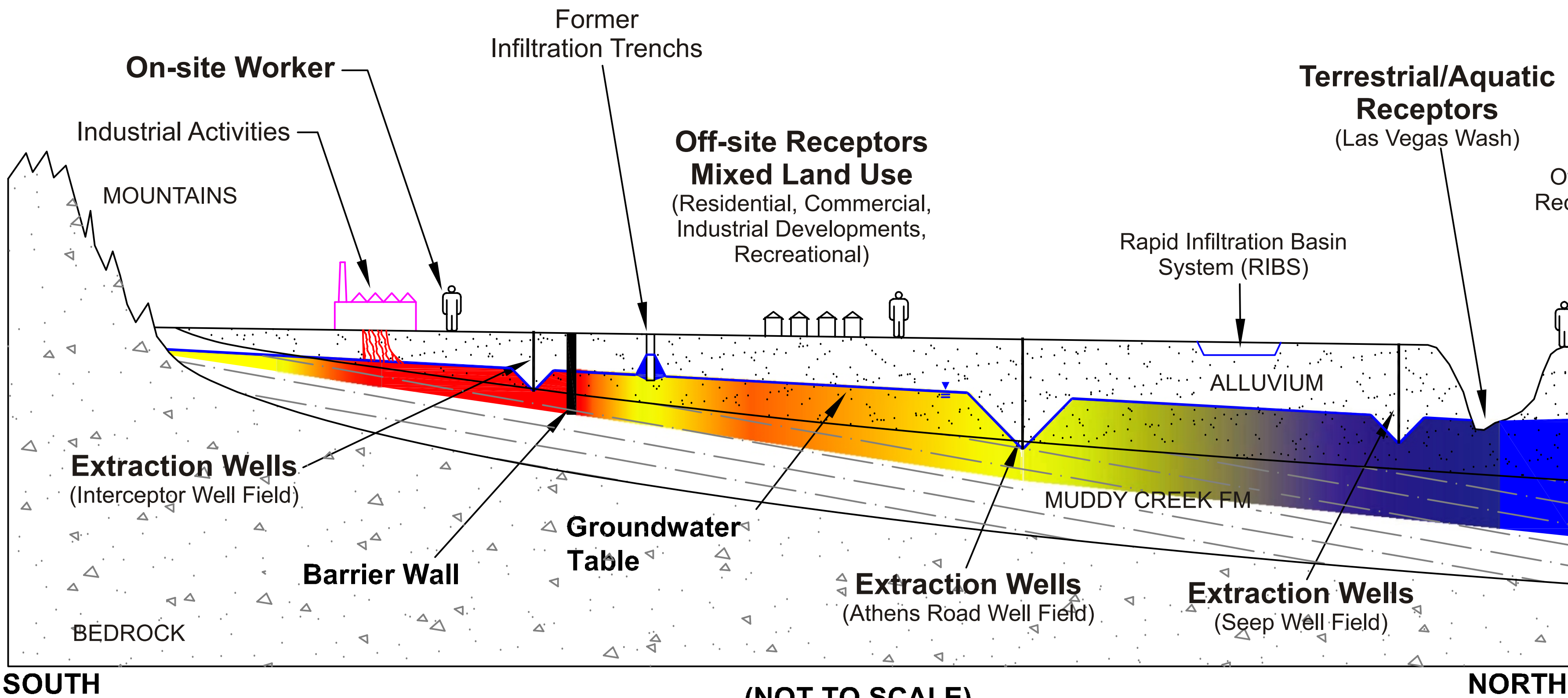
Conceptual Site Model Diagram: Facility Area and Downgradient Plume
Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **5-1**

Drafter: EL Date: 2/21/2014 Contract Number: 21-34800I Approved by: Revised:



(NOT TO SCALE)

Explanation:
Relative Groundwater Impact
Compared to Regulatory Criteria

Sources: ENSR|AECOM, 2007.
Northgate 2010.

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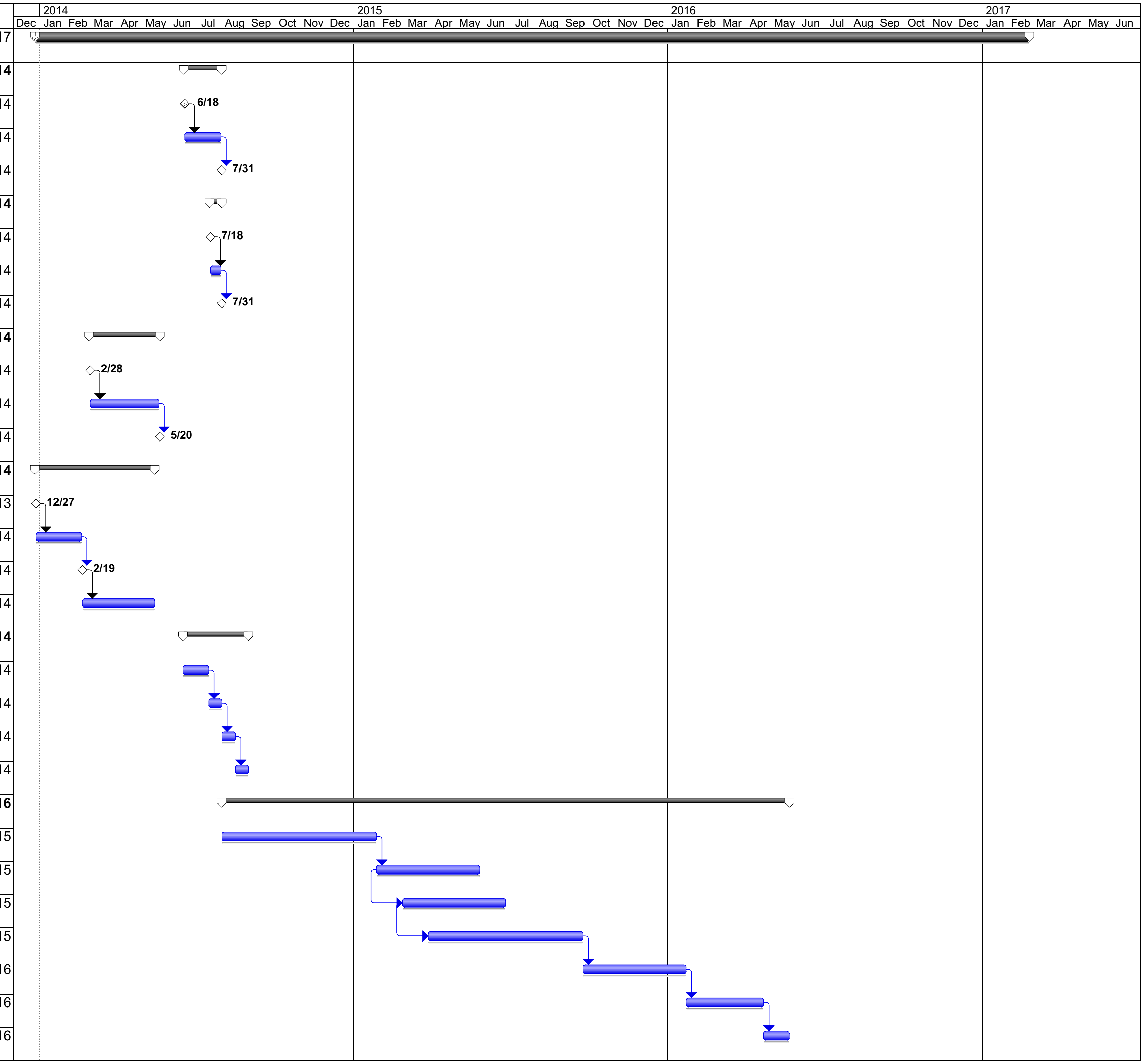
Preliminary Conceptual Site Model Illustration
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
5-4

Drafter: RS | Date: 11/14/12 | Contract Number: 21-32100I | Approved: | Revised:

ID	Task Name	Calendar Days	Start	Finish
1	**REMEDIAL INVESTIGATION/FEASIBILITY STUDY (RI/FS)**	1156 days	12/27/13	2/24/17
2	**RI/FS Work Plan**	**44 days**	**6/18/14**	**7/31/14**
3	Submit RI/FS Work Plan to NDEP	1 day	6/18/14	6/18/14
4	NDEP Review of RI/FS Work Plan	42 days	6/19/14	7/30/14
5	NDEP Approval of RI/FS Work Plan	1 day	7/31/14	7/31/14
6	**SAP, QAPP, and HASP**	**14 days**	**7/18/14**	**7/31/14**
7	Submit SAP, QAPP, and HASP to NDEP	1 day	7/18/14	7/18/14
8	NDEP Review of SAP, QAPP, and HASP	12 days	7/19/14	7/30/14
9	NDEP Approval of SAP, QAPP, and HASP	1 day	7/31/14	7/31/14
10	**Baseline Health Risk Asessment (BHRA) Work Plan**	**82 days**	**2/28/14**	**5/20/14**
11	Submit BHRA Work Plan to NDEP	1 day	2/28/14	2/28/14
12	NDEP Review of BHRA Work Plan	80 days	3/1/14	5/19/14
13	NDEP Approval of BHRA Work Plan	1 day	5/20/14	5/20/14
14	**Community Involvement Plan (CIP)**	**139 days**	**12/27/13**	**5/14/14**
15	Submitted CIP to NDEP	1 day	12/27/13	12/27/13
16	NDEP Review of CIP	53 days	12/28/13	2/18/14
17	NDEP Approval of Final CIP	1 day	2/19/14	2/19/14
18	Establish Additional Information Repository at Henderson Library	84 days	2/20/14	5/14/14
19	**Screening Level Ecological Risk Assessment (SLERA) Work Plan**	**76 days**	**6/17/14**	**8/31/14**
20	Prepare SLERA Work Plan	30 days	6/17/14	7/16/14
21	NDEP Review of SLERA Work Plan	15 days	7/17/14	7/31/14
22	Address NDEP Comments/Finalize SLERA Work Plan	16 days	8/1/14	8/16/14
23	NDEP Approval of SLERA Work Plan	15 days	8/17/14	8/31/14
24	**Remedial Investigation (RI), BHRA, and SLERA**	**660 days**	**8/1/14**	**5/21/16**
25	Data Gap Field Investigation(s)	180 days	8/1/14	1/27/15
26	Evaluate Additional Data Collected	120 days	1/28/15	5/27/15
27	Perform BHRA and SLERA	120 days	2/27/15	6/26/15
28	Preparation of the RI, BHRA, and SLERA Reports	180 days	3/29/15	9/24/15
29	NDEP Review of the RI, BHRA, and SLERA Reports	120 days	9/25/15	1/22/16
30	Address NDEP Comments and Finalize RI, BHRA, and SLERA Reports	90 days	1/23/16	4/21/16
31	NDEP Approval of RI, BHRA, and SLERA Reports	30 days	4/22/16	5/21/16



Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

Schedule subject to change based on NDEP and contractor input.

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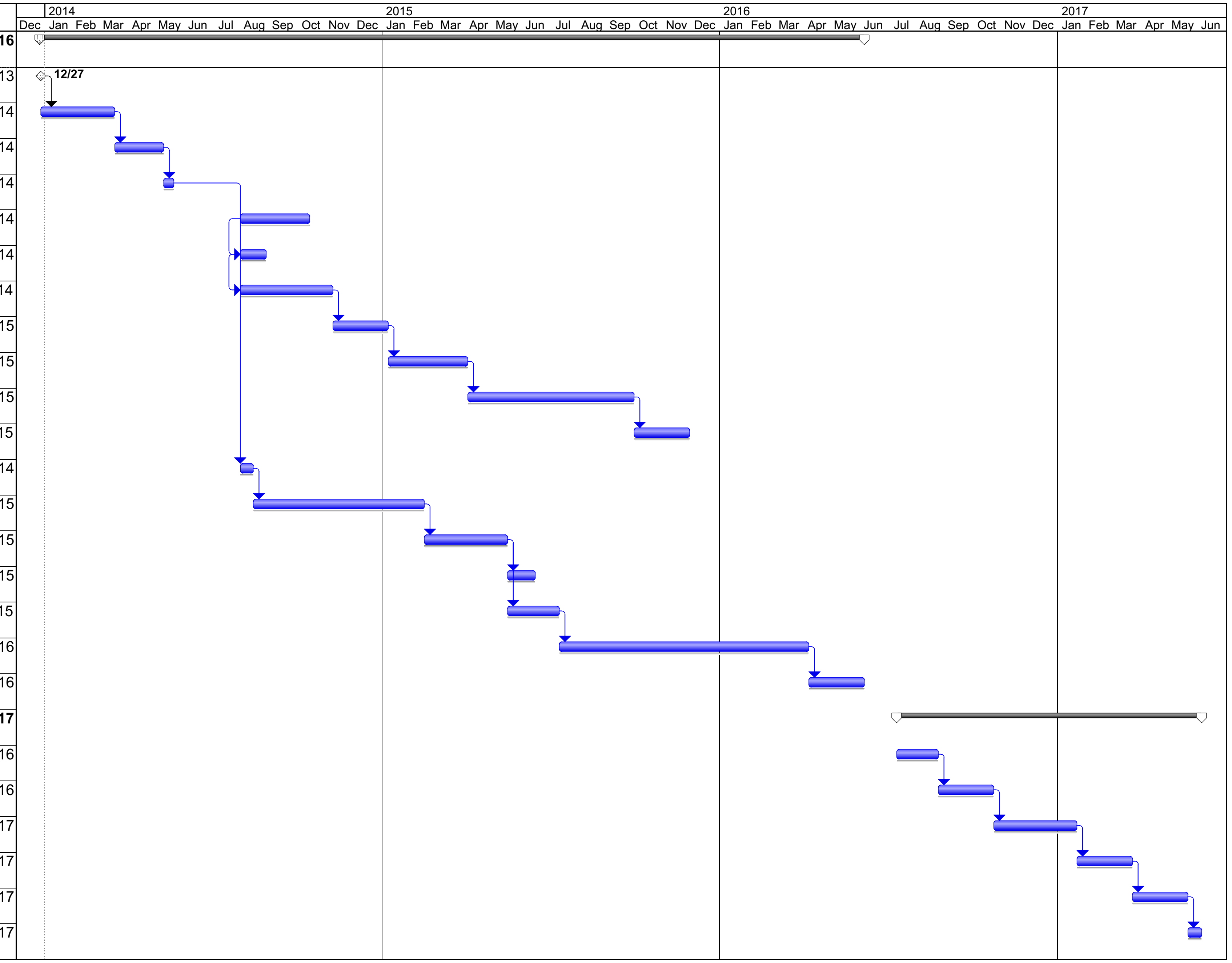
Remedial Investigation and Feasibility Study Schedule

Nevada Environmental Response Trust Site
Henderson, Nevada

Figure **7-1**

Drafter: KPL | Date: 6/17/2014 | Contract Number: 21-34800I | Approved by: | Revised:

ID	Task Name	Calendar Days	Start	Finish
32	**Treatability Study (TS)**	**892 days**	**12/27/13**	**6/5/16**
33	Submitted TS Work Plans to NDEP	1 day	12/27/13	12/27/13
34	NDEP Review of TS Work Plans	80 days	12/28/13	3/17/14
35	Respond to NDEP Comments / Finalize TS Work Plans	53 days	3/18/14	5/9/14
36	NDEP Approval of TS Work Plans	11 days	5/10/14	5/20/14
37	Apply for and Obtain Permits	75 days	8/1/14	10/14/14
38	Soil Flushing Pilot Preliminary Field Testing	28 days	8/1/14	8/28/14
39	Soil Flushing Field-Scale Pilot Design	100 days	8/1/14	11/8/14
40	NDEP Review and Approval of Soil Flushing Field-Scale Pilot Design	60 days	11/9/14	1/7/15
41	Soil Flushing Field-Scale Pilot Construction	86 days	1/8/15	4/3/15
42	Soil Flushing Field-Scale Pilot Operation	180 days	4/4/15	9/30/15
43	Soil Flushing Treatability Study Report Preparation	60 days	10/1/15	11/29/15
44	PRB Field-Scale Pilot Preliminary Field Activities	14 days	8/1/14	8/14/14
45	PRB Dilution Testing and ISM Studies	185 days	8/15/14	2/15/15
46	PRB Field-Scale Pilot Design	90 days	2/16/15	5/16/15
47	NDEP Review and Approval of PRB Field-Scale Pilot Design	30 days	5/17/15	6/15/15
48	PRB Field-Scale Pilot Construction	56 days	5/17/15	7/11/15
49	PRB Field-Scale Pilot Operation	270 days	7/12/15	4/6/16
50	PRB Treatability Study Report Preparation	60 days	4/7/16	6/5/16
51	**Feasibility Study (FS)**	**330 days**	**7/11/16**	**6/5/17**
52	Remedial Alternatives Development	45 days	7/11/16	8/24/16
53	Detailed Analysis of Alternatives	60 days	8/25/16	10/23/16
54	Prepare FS Report	90 days	10/24/16	1/21/17
55	NDEP Review of FS Report	60 days	1/22/17	3/22/17
56	Address NDEP Comments / Finalize FS Report	60 days	3/23/17	5/21/17
57	NDEP Approval of FS Report	15 days	5/22/17	6/5/17



Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

Schedule subject to change based on NDEP and contractor input.

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2200 Powell St., Suite 700, Emeryville, CA 94608

Remedial Investigation and Feasibility Study Schedule
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
7-1

Drafter: KPL | Date: 6/17/2014 | Contract Number: 21-34800I | Approved by: | Revised:

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Attachment E

Revised Tables, Figures, Plates, and Appendices Title Sheets
Remedial Investigation and Feasibility Study Work Plan, Revision 2,
Nevada Environmental Response Trust Site, Henderson, Nevada

Tables

Figures

Plates

Appendix A

Response to NDEP Comments on RI/FS Work Plan

Appendix A-1

Response to NDEP Comments on RI/FS Work Plan, Dated June 27, 2013

Appendix A-2

Response to NDEP Comments on RI/FS Work Plan, Dated November 18, 2013

Appendix B

Summary of Historical LOU Soil and Soil Gas Investigations

Appendix C

Soil Remediation Goals for the 2011 Interim Soil Removal Action

Appendix D

Background Data Set for Soils

Attachment F

Revised CD with Complete Report Copy (Including Errata)
Remedial Investigation and Feasibility Study Work Plan, Revision 2,
Nevada Environmental Response Trust Site, Henderson, Nevada