Rio Algom Mining LLC

November 16, 2022

Mr. Doug Hansen
Utah Division of Environmental Quality
Division of Waste Management and Radiation Control (DWMRC)
195 North, 1950 West
Salt Lake City, Utah 84116

RE: Corrective Action Assessment Work Plan
Rio Algom Mining LLC Lisbon Facility, San Juan County, Utah
Radioactive Materials License Number UT 1900481

Rio Algom Mining LLC (RAML) respectfully submits the *Corrective Action Assessment Work Plan* (CAAWP) for the RAML Lisbon Facility (site) in San Juan County, Utah, for DWMRC review and comment. The CAAWP follows RAML's submittal and Utah Division of Waste Management and Radiation Control (DWMRC) review of the *Hydrogeological Supplemental Site Assessment, Phase 4 Report* (HSSA4 Report), which confirmed mill-related groundwater impacts beyond the preliminary long-term surveillance and maintenance (LTSM) boundary and uranium concentrations above Utah's drinking water standards at certain monitoring locations. This CAAWP has been prepared to fulfill Confirmatory Action 2 in a DWMRC letter dated 31 March 2022.

The CAAWP reflects RAML's shift in focus from characterizing site hydrogeology (i.e., the hydrogeological supplemental site assessment work culminating in the HSSA4 Report) to a focus on developing and implementing a Groundwater Corrective Action Plan (GCAP) in accordance with Utah Administrative Code (UAC) R317. The HSSA4 Report established that a new groundwater corrective action is necessary; the CAAWP presents RAML's roadmap to a DWMRC-approved GCAP (see CAAWP Figure 7.1) and describes the field and laboratory data collection needed to support this stage of corrective action planning.

To facilitate DWMRC's review of the CAAWP and further RAML's working relationship with DWMRC staff, this cover letter 1) summarizes the scope and purpose of the CAAWP; 2) outlines steps RAML is taking to expedite the CAAWP field program; and 3) explains RAML's vision for adaptive work plan implementation.

Scope and Purpose of the CAAWP

The CAAWP identifies data gaps for which field data must be obtained so that a diverse range of potential corrective action elements can be evaluated in a corrective action alternatives analysis. The data gaps are identified using the Lisbon conceptual site model (CSM) as a corrective action preliminary design tool, reflecting the shift in project focus from site characterization to planning corrective action. RAML anticipates that the corrective action ultimately selected for Site groundwater will be a comprehensive program that combines multiple elements, such as source control, groundwater treatment, and administrative and institutional controls.

In parallel with the field program described in the CAAWP, RAML will also research potential corrective action elements for which additional field data are not required. For example, RAML intends to research options for off-site disposal or re-processing of the tailing material, and modification of the proposed LTSM boundary. CAAWP Figure 4.1 is a flow chart that distinguishes between potential corrective action elements that require additional field data for proper screening (i.e., content in the CAAWP) versus elements for which the needed data are already available or can be obtained from desktop study (i.e,, not content in the CAAWP).

Data collection described in the CAAWP does not indicate a preference for, or bias against, any particular corrective action technology. Performance specifications for a hypothetical treatment technology (i.e., tailings cover material or groundwater extraction target rates) are intentionally avoided in the CAAWP as being premature. Field and laboratory data obtained from execution of the CAAWP field program will be used along with existing and new information to update the site CSM and groundwater flow and transport model. This body of knowledge will then be the basis for the corrective action assessment through which RAML will narrow down a diverse range of potential corrective action elements into one or more comprehensive corrective action alternatives that can then be evaluated in detail and/or advanced to pilot testing.

Section 4.3 of the CAAWP identifies criteria from UAC 317-6-6.15.E that RAML will consider in the future analysis of potential corrective action alternatives. RAML may incorporate additional criteria into the alternatives evaluation process, such as environmental stewardship and green remediation concepts. RAML's evaluation criteria will be provided to DWRMC for review and comment (anticipated to be in the Corrective Action Assessment Plan; see Figure 7.1 of the CAAWP) before RAML performs the corrective action alternatives analysis.

Steps to Expedite the Field Program

Based on experience from previous field programs at the site, RAML has identified several conditions that will affect the scope and schedule of the CAAWP field program. Specifically:

- Surface geophysical survey work must be performed early in the field program to identify geologic and hydrogeologic features, thereby informing the exact locations of later work streams (e.g., coreholes and monitoring wells).
- Much of the proposed work will occur on land that is not owned or controlled by RAML and therefore will require approval by private landowners or the Bureau of Land Management (BLM).
- Winter fieldwork is more difficult and less safe because of freezing conditions, shortened daylight hours, and potential inclement weather.

RAML is taking the steps described below to expedite the CAAWP field program while also performing field activities safely and in compliance with landowner requirements.

Prioritized Geophysical Surveys. The CAAWP describes 20 surface geophysical survey transects, results of which will refine the proposed corehole and monitoring well drilling locations. Prior to mobilization of the drilling program, RAML must also coordinate with landowners, construct access routes and drilling pads, and obtain environmental and cultural resource clearances. Pre-mobilization coordination can take several months after exact drilling locations are finalized. Thus, the geophysical surveys are the critical path in the CAAWP field program and should be completed as soon as practicable. To that end, RAML is initiating the geophysical surveys immediately and at-risk, with an anticipated field start date of 29 November 2022. Weather permitting, we anticipate completing the geophysical surveys in December 2022. The geophysical survey results will be available in early 2023 and used to finalize the proposed drilling locations so that RAML can proceed with pre-mobilization coordination for the drilling program. RAML recognizes that there is a scope risk involved with executing the geophysical surveys before receiving DWMRC's approval of the CAAWP. RAML believes the geophysical survey program is no-regrets work and the associated schedule gain of up to 6 months offsets the risk of scope changes following receipt of DWMRC's comments. RAML will work with DWMRC staff through adaptive work plan implementation (discussed below) if DWMRC determines through its review of the CAAWP that changes are required to the geophysical survey program as proposed.

Coordination with Private Landowners. Several geophysical surveys and proposed drilling locations are partially or entirely on private property not owned by RAML, as shown on CAAWP Figures 5.2, 6.1, and 6.3. RAML has established a relationship with the owners of these properties and is working with them to gain access for the field activities proposed in the CAAWP. At this time, RAML anticipates fieldwork on private property can progress without delay.

Coordination with BLM. Several geophysical surveys and proposed drilling locations are partially or entirely on public land administered by the BLM, as shown on CAAWP Figures 5.2, 6.1, and 6.3. Work on these lands requires approval from BLM; RAML has contacted the Moab BLM office and BLM staff indicated that due to resource limitations, it could take BLM two or more years to issue approvals for the full suite of fieldwork proposed in the CAAWP. Knowing this, RAML is taking the following steps to expedite field activities on BLM-administered land:

- RAML has proposed to perform the geophysical surveys on BLM-administered land using an approach that minimizes potential impacts to the land and resources. BLM staff have stated, on a preliminary basis, that RAML's proposed approach is consistent with a "casual use" activity and is therefore exempt from further review under the National Environmental Policy Act (NEPA). RAML is working with BLM to formalize the casual use determination within the next 1 to 2 weeks. Once formalized, RAML will be approved to conduct the geophysical surveys on BLM-administered land (see "Prioritized Geophysical Surveys" above).
- RAML has initiated cultural and completed biological resource surveys across a conservative area that includes the CAAWP field program area. BLM requires these surveys to evaluate RAML's proposed scope of work. Because biological resource surveys require seasonal field observations, RAML completed the surveys at-risk during the summer of 2022 with a resulting schedule gain of up to a year.

- RAML anticipates conducting one or more source control and/or groundwater treatment technologies in pilot- or full-scale implementation of a future GCAP and that these activities will require additional, and potentially significant, BLM review under NEPA. To streamline BLM approval for activity of this scale on public lands, RAML intends to seek programmatic NEPA review for these activities in 2023 with the objective of significantly reducing the required environmental review time for future GCAP field activities on BLM-administered land. Because the programmatic NEPA review will occur in parallel with CAAWP execution, the associated schedule gain for future GCAP field activities is up to three years.

Sequenced Fieldwork. RAML anticipates that the field program described in the CAAWP will require more than one field season (typically May through November) to complete. The first drilling mobilization will occur after DWMRC approval of the CAAWP and will be limited to work on private land and within the restricted area (i.e., on the tailing impoundments) if approval has not yet been received to proceed on BLM-administered lands. RAML expects to begin the second mobilization after BLM's review and approval of CAAWP work on BLM-administered land. Due to the dynamic and opportunistic nature of the field program, the CAAWP does not provide a calendar-referenced field schedule. RAML will communicate with DWMRC staff as the field schedule develops so DWMRC staff are aware of ongoing activities and can arrange oversight visits as desired.

Adaptive Work Plan Implementation

The purpose of the CAAWP is to resolve data gaps and support informed decision-making in the future corrective action alternatives analysis, i.e., to resolve the Principal Investigation Questions (PIQs) (see CAAWP Section 4.1 and Appendix A). To resolve the PIQs, the CAAWP presents an extensive field program that RAML proposes to execute via adaptive implementation. As described in Section 1.1 of the CAAWP, adaptive implementation uses real-time evaluation of data collected as the field program progresses to confirm that the information gained from field and laboratory work is useful in resolving the PIQs. If, during the field program, certain data collection efforts are identified as unnecessary for corrective action planning, these efforts may be modified or truncated to expedite completion of data collection and evaluation of the corrective action alternatives. The benefit of adaptive implementation is potential earlier completion of the field program, which will expedite the alternatives analysis timeline and reduce safety risks inherent in fieldwork by reducing time on site. Examples of adaptive work plan implementation decisions are provided in Section 1.1 of the CAAWP.

RAML will include DWMRC staff in adaptive work plan implementation decision-making. RAML proposes to formalize a process for collaborating with DWMRC staff on adaptive work plan implementation as part of the DWMRC review process for the CAAWP. Collaboration might include:

- Routine CAAWP field program update calls between RAML and DWMRC staff, such as on a monthly or quarterly basis during fieldwork; or,

- RAML notification to DWMRC staff of a proposed material adjustment to the field program, with response from DWMRC staff on an agreed timeline before the adjustment is implemented.

Closing

The CAAWP presents a comprehensive program to collect field and laboratory data that RAML will use to screen a diverse range of potential corrective action elements and assemble comprehensive groundwater corrective action alternatives for detailed evaluation. Findings from the CAAWP field program will be reported to DWMRC and will be used to update the CSM and groundwater flow and transport model, which will then be used in the corrective action alternatives analysis.

RAML anticipates entering one or more Stipulation and Consent Agreements (SCA) with DWMRC for the study and evaluation of potential corrective action alternatives, and ultimately a Stipulation and Consent Order to execute the approved GCAP. RAML anticipates the first SCA will follow DWMRC's review and approval of the CAAWP to formalize the work scope and roadmap presented in the CAAWP.

RAML would be pleased to host one or more meetings with DWMRC staff to discuss any questions about the content of the CAAWP. The timing and format of the meeting(s) will be arranged at DWMRC staff's convenience. We look forward to continuing our collaboration with DWMRC staff to address mill-related groundwater impacts at the site.

If you have any questions or need additional information, please do not hesitate to contact me at (916) 947-7637.

Sincerely,
Rio Algom Mining LLC

Sandra L. Ross
Manager US Legacy Assets

Attachment: *Corrective Action Assessment Work Plan* (2 hard copies)

cc: Phil Goble, DWMRC (electronic only)
Jason Nguyen, LM DOE (electronic only)

CORRECTIVE ACTION ASSESSMENT WORK PLAN

Lisbon Facility, Rio Algom Mining LLC

Radioactive Material License Number UT 1900481
San Juan County, Utah

Prepared for:

Rio Algom Mining LLC
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Grants, NM 87020

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November 16, 2022

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ACRONYMS AND ABBREVIATIONS

ACACL	alternative corrective action concentration limit
ACL	Alternate Concentration Limits
Background Report	Background Groundwater Quality Report (INTERA, 2021d)
BART	biological activity reaction test
BCA	Burro Canyon aquifer
bgs	below ground surface
BLM	Bureau of Land Management, United States
Brushy Basin	Brushy Basin Member of the Morrison Formation
Burro Canyon	Burro Canyon Formation
CAA	Corrective Action Assessment
CAAP	Corrective Action Assessment Plan
CAA Report	Corrective Action Assessment Report
CAAWP	Corrective Action Assessment Work Plan
CAP	1990-2004 Corrective Action Program
COC	constituent of concern
CSM	Conceptual Site Model
DEQ	Utah Department of Environmental Quality
DRC	Utah Division of Radiation Control
DTM	digital terrain model
DWMRC	Utah Division of Waste Management and Radiation Control
EC	electrical conductivity
EPA	United State Environmental Protection Agency
ERM	Electrical Resistivity Mapping
ERT	Electrical Resistivity Tomography
ft	foot *or* feet
ft/d	feet per day
GCAP	Groundwater Corrective Action Plan
HSA	hollow stem auger
HSSA3	Hydrogeological Supplemental Site Assessment Phase 3
HSSA4	Hydrogeological Supplemental Site Assessment Phase 4
HSSA4 Report	Hydrogeological Supplemental Site Assessment Phase 4 Report
INTERA	INTERA Incorporated
ISBR	in situ biological reduction
ISCR	in situ chemical reduction
ISGR	in situ gaseous reduction
License	Radioactive Materials License UT 1900481
LiDar	laser imaging, detection, and ranging
Lisbon Mill	Rio Algom Mining LLC Lisbon former uranium mill Facility
LTGMP	Long-Term Groundwater Monitoring Plan
LTI	Lower Tailing Impoundment
LTSM	Long-Term Surveillance and Maintenance

LVF	Lisbon Valley Fault
mg/L	milligram per liter
MMR	magnetometric resistivity
MNA	Monitored Natural Attenuation
MPO	Mine Plan of Operations
Navajo	Navajo Sandstone
NBCA	North Burro Canyon aquifer
NR-WB	Natural Recharge-Water Balance
NR-WB Report	Natural Recharge and Water Balance Modeling Report
OOC	Out-of-Compliance
PCA	principal components analysis
PCR	polymerase chain reaction
PIQ	Principal Investigation Question
PneuSine	pneumatic sinusoidal
POC	Point of Compliance
POE	Point of Exposure
RAI	Request for Additional Information
RAML	Rio Algom Mining LLC
RAP	resonance acoustic profiling
RWP	Radiation Work Permit
s.u.	pH standard units
SBCA	South Burro Canyon aquifer
SCA	Stipulation and Consent Agreement
Site	Rio Algom Mining LLC Lisbon former uranium mill facility and the monitoring well network
SP	spontaneous potential
SSA1	Phase 1 Supplemental Site Assessment (Montgomery & Associates, 2013)
SSA2	Phase 2 Supplemental Site Assessment (Montgomery & Associates, 2014)
SWPPP	Storm Water Pollution Prevention Plan
TAL	Target Action Limits
TDS	total dissolved solids
Tertiary Anticline	the Tertiary Lisbon Valley Anticline
TSF	tailings storage facility
UAC	Utah Administrative Code
USCS	Unified Soil Classification System
UTI	Upper Tailing Impoundment
WCW	West Coyote Wash
ZVI	zero valent iron

1.0 INTRODUCTION

Groundwater conditions at the Rio Algom Mining LLC (RAML) former Lisbon Mill (Site) in southeast Utah (**Figure 1.1**) are not meeting the established performance standards, so corrective action is necessary. This Corrective Action Assessment Work Plan (CAAWP) provides the basis for collecting additional field data to support a groundwater corrective action alternative analysis. The groundwater corrective action alternative analysis will provide the basis to select a preferred groundwater corrective action, which RAML will propose in a Groundwater Corrective Action Plan (GCAP) for review and approval by the Utah Division of Waste Management and Radiation Control (DWMRC) in accordance with Utah Administrative Code (UAC) R317. The GCAP will address the presence and migration of uranium and other constituents of concern (COCs) in groundwater associated with the former mill.

As a step towards evaluating and selecting a comprehensive GCAP, the primary objectives of the CAAWP are to:

1) Identify data gaps for which field data must be obtained using the preliminary Design Conceptual Site Model (CSM) (see Section 3.2) so that a diverse range of potential corrective action elements can be evaluated in a corrective action alternatives analysis (see Sections 4.1, 4.2, and 4.3).
2) Describe the field program to resolve the identified field data gaps (see Section 5.0 and Section 6.0).
3) Present a road map to implementation of a DWMRC-approved GCAP for the Site (see Section 8.0).

1.1 Adaptive Work Plan Implementation

This CAAWP proposes an extensive field investigation that will be adaptively implemented to fulfill the project objectives. As the field program progresses, the data collected will be evaluated to confirm they are useful in satisfying the project objectives and resolving the data gaps. The results of these ongoing evaluations will inform progression of remaining CAAWP field program elements. Data collection efforts that are not found to be informative for the CSM may be modified or truncated to expedite completion of data collection and evaluation of the corrective action alternatives. The benefit of adaptive implementation is potentially earlier completion of the field program, which will expedite the alternatives analysis timeline and reduce safety risks inherent in fieldwork by reducing time on-site.

Adaptive implementation is demonstrated in the flow charts introduced in Sections 5.0 and 6.0, indicating conditions under which certain technologies will be used for bench-scale treatability studies. Technologies that are unlikely to be successful based on specific site conditions will not be subjected to time- and resource-consuming treatability studies.

Additional hypothetical examples of adaptive implementation include the following:

- If magnetometric resistivity (MMR) and resonance acoustic profiling (RAP) survey technology (see Section 6.1.1) provide inconclusive results after completing several transects, the remaining MMR and RAP surveys may be cancelled.
- If sequential extraction testing shows consistent results for several drill core samples, the results may be extrapolated to additional samples with similar characteristics (i.e., lithology, mineralogy, and total metals content) without performing additional sequential extraction testing.

The process for adaptive implementation decision-making will be established between RAML and DWMRC before being applied during the CAAWP field program.

1.2 Work Plan Organization

This CAAWP is organized as follows:

Section 2.0 Background – describes the Site setting, brief Site history, previous work, and the regulatory framework.

Section 3.0 Conceptual Site Model – describes the development and evolution of the CSM for the Site. The CSM is used to identify the corrective action data gaps that are the focus of this CAAWP. The data obtained through implementation of the CAAWP will be used to refine and evolve the Characterization CSM to a Design CSM and support the corrective action alternatives analysis.

Section 4.0 Work Plan Development Approach – describes the approach to development of the CAAWP and the determination of what laboratory and field data are needed to conduct the corrective action alternatives analysis. Drawing from the corrective action data gaps identified in the preliminary Design CSM, this section presents the Principal Investigation Questions (PIQs) that drive the proposed field work. This section also identifies key criteria that will be used to evaluate potential corrective action elements in the alternatives analysis and a proposed approach for conducting the alternatives analysis. This section concludes with a discussion of the implementation steps required before field work can be conducted.

Section 5.0 Source Area Proposed Field Investigations – describes the field program to answer the PIQs associated with the Source Area (**Appendix A; Table A.1a** and **Table A.1b**). The Source Area section describes the work required to understand the Source Area contribution of COCs to groundwater and which technologies could mitigate COC migration away from the Source Area.

Section 6.0 Groundwater Proposed Field Investigations – describes the field and laboratory work to evaluate whether Site conditions are conducive to different forms of treatment or attenuation of COCs in the groundwater system, and to understand where such concepts might be employed most effectively (**Appendix A; Table A.2, Table A.3,** and **Table A.4**).

Section 7.0 Documentation and Reporting – describes how the results from the field investigation will be compiled and reported to DWRMC.

Section 8.0 Groundwater Corrective Action Schedule – describes the sequencing and milestones for implementing the CAAWP field program and the subsequent steps leading to the selection and approval of a GCAP.

Throughout the CAAWP, the term “corrective action elements” is used when referring broadly to a range of technological, administrative, and institutional control concepts that may be components of a comprehensive corrective action. The term “corrective action technology” is used when referring more specifically to concepts that use scientific or engineering principles to treat, extract, isolate, or immobilize COCs or impacted media.

2.0 BACKGROUND

This section describes the Site setting, provides a brief Site history, summarizes previous work, and outlines the relevant regulatory framework.

2.1 Site Setting

The Site is located within the Paradox Basin of Colorado and Utah, at the north end of Lisbon Valley. Extensive folding, faulting, and mineralization have occurred in the area in response primarily to thick salt deposit migration at depth in the Paradox Basin. The key geologic units of interest in the investigation area are interbedded sandstones, siltstones, and shales of the Cretaceous Burro Canyon Formation (Burro Canyon) and the Brushy Basin Member of the Jurassic Morrison Formation (Brushy Basin) as well as the Jurassic Navajo Sandstone (Navajo). The structural geology of the Site is dominated by the Lisbon Valley Fault (LVF) and the Tertiary Lisbon Valley Anticline (the Tertiary Anticline) (**Figure 1.1**), which have direct influences on the occurrence and direction of groundwater flow at the Site.

Lisbon Valley is a northwest-to-southeast trending valley and is one of the many northwest-trending stream valleys formed along salt anticlines in the Paradox Basin of the Colorado Plateau. Topography varies throughout the investigation area, with elevations ranging from approximately 6,400 feet (ft) in the low-lying areas in Lisbon Valley to 8,000 ft in the upper reaches of mountainous terrain to the northeast where the La Sal Mountains are located. Average monthly precipitation in the area ranges from 0.7 inches in June to 1.6 inches in September with a mean total annual precipitation of 12.6 inches. Average potential evaporation ranges from 0.9 inches in December to 10.8 inches in June, with a mean total annual potential evaporation of 58.6 inches. Summer precipitation follows a monsoonal pattern typical of the high desert Colorado Plateau, while winter precipitation, typically occurring from October through April, falls primarily as snow. Vegetation consists of sagebrush, juniper, and piñon in the hills and steeper slopes, while desert grasses, rubber rabbitbrush, and sagebrush cover the Lisbon Valley floor.

For the CAAWP, the Site has been divided into seven key investigation areas (**Figure 2.1**), consisting of the following:

- Source Area (the tailings storage facilities [TSFs] and vadose zone below the TSFs),
- North Near-Field Area,
- South Near-Field Area,
- Far-Field Area,
- North Area,
- Northwest Area, and
- LVF Area.

The terms "near-field" and "far-field" result from locations being closer to and farther from the Source Area, respectively. The distinction between the North Near-Field and Far-Field Areas has been made based on notable changes in geologic structures, groundwater elevations and flow pathways, and groundwater chemistry (INTERA, 2021b). The details of the boundary between the north Near-Field and Far-Field areas may change in the future as more information is gathered during the planned Corrective Action Assessment (CAA) work. The investigation questions, goals, and approaches for the North Near-Field, South Near-Field, and Far-Field are similar, but the information gathered from each of these areas could differ and result in different corrective action strategies for each of these areas (**Figure 2.1**).

2.2 History

A thorough summary of past mine- and mill-related activities is provided in the *Hydrogeological Supplemental Site Assessment Phase 4* (HSSA4) *Report* (HSSA4 Report, INTERA, 2021b). Impacts from historical milling activities, including TSFs, water storage, and treatment ponds at the Site, are referred to as mill-related impacts throughout this CAAWP. Mine and mill construction at the Site started in 1970, and mining commenced in 1972. Milling started in May 1972 with a conventional alkaline carbonate-leach process to extract uranium oxide from ore mined from the Moss Back Member of the Triassic Chinle Formation, located approximately 2,750 ft below ground surface (bgs). The Moss Back Member deposit is much deeper in the geologic section than the geologic units that are the focus of this CAAWP.

During operations, tailings from the mill were pumped via a pipeline from the mill to two TSFs located west of the mill site. The Lower Tailing Impoundment (LTI) was constructed in 1971 and used for all tailings discharge until 1974, when the Upper Tailing Impoundment (UTI) was constructed (**Figure 1.1**). Neither the UTI nor the LTI has a constructed liner. Each of the TSFs covers an area of approximately 50 acres. In October 1988 mining operations discontinued, and in early 1989 milling operations at the Lisbon mill discontinued.

As early as 1973, it was determined that seepage from the bottom of the TSFs resulted in rising groundwater levels and impacts to groundwater below the TSFs (Lewis, 2001). The groundwater impacted below the TSFs is within the Burro Canyon, the bedrock formation below the TSFs. Various corrective actions were attempted starting in 1982, and a Corrective Action Program (CAP) was conducted from 1990 through 2004, which consisted of pumping mill-impacted groundwater from the Burro Canyon aquifer (BCA) and placing it in evaporation ponds constructed on the TSFs. More detail about the remedial actions and the CAP is provided in the HSSA4 Report (INTERA, 2021b).

2.3 Previous Work

Consecutive detections of uranium concentrations greater than Target Action Limits (TALs) in trend wells RL-1 and EF-8 were first observed in 2008 and 2011, respectively. In a letter dated February 7, 2011, the Utah Division of Radiation Control (DRC, now DWMRC) issued an Out-of-Compliance (OOC) Notice for RL-1 and EF-8 and requested RAML to conduct a hydrogeologic assessment (DRC, 2011). In response to DWMRC's letter and subsequent requests for more information from DWMRC, four phases of Site characterization work were conducted and documented in supplemental site assessment reports, as summarized in the HSSA4 Report (INTERA, 2021b).

The most recent phase of supplemental site assessment was submitted to DWMRC on October 29, 2021, and consisted of the HSSA4 Report (INTERA, 2021b), the *Natural Recharge and Water Balance Modeling Report* (NR-WB Report, INTERA, 2021c), and the *Background Groundwater Quality Report* (Background Report, INTERA, 2021d). DWMRC responded to the HSSA4, NR-WB, and Background reports in a letter dated March 31, 2022, with no additional requests for information and confirmed that RAML will provide a Draft CAAWP to fill existing data gaps for the evaluation of corrective action technologies for the Site (DWMRC, 2022).

RAML has been bound by a series of Stipulation and Consent Agreements (SCA) with DWMRC to conduct hydrogeological supplemental site investigations and address OOC status of wells regulated under Radioactive Materials License UT 1900481 (the License, most recently, DWMRC, 2019). The HSSA4 Report identified that monitored natural attenuation (MNA) of COCs, as currently designed, has not been successful in meeting Alternative Concentration Limits (ACLs) and TALs for the Site (INTERA, 2021b). Therefore, corrective action must be taken to address groundwater impacts. An effective corrective action requires a robust GCAP informed by an evaluation of a diverse range of potential corrective action alternatives. This CAAWP directs the collection of field data needed to assemble and evaluate the potential corrective action alternatives. DWMRC agreed with RAML's proposal to prepare the CAAWP and confirmed that the CAAWP activities and dates will be reviewed by DWMRC before approval (DWMRC, 2022).

2.4 Regulatory Framework

The scope of this CAAWP is to collect additional field and laboratory data to evaluate corrective action elements that will address mill-impacted groundwater, and ongoing constituent mass loading to the groundwater regulated by DWMRC pursuant to its authorities under the Atomic Energy Act. For the sake of this CAAWP, the mill-related impacts to groundwater will be referred to as impacted groundwater, plume, or COCs in groundwater. License Amendment 7 (DWMRC, 2021) authorizes RAML to transfer, receive, possess, and use radioactive material as designated in the License. License Condition 29 requires RAML to implement a groundwater compliance monitoring program that includes:

- Compliance with maximum groundwater concentrations for distinct parameters listed as background concentrations (applicable to background wells only),
- ACLs (applicable to point of compliance [POC] wells and point of exposure [POE] wells), and
- TALs (applicable to trend wells) (**Figure 1.1**) (DWMRC, 2021).

Among the License parameters, arsenic, molybdenum, selenium, and uranium have compliance limits defined in the License. In previous reports (e.g., Lewis, 2001; Komex, 2004; Montgomery & Associates, 2013, 2014; INTERA, 2021a, 2021b, 2021d), arsenic, molybdenum, selenium, and uranium have been referred to as COCs. In an addendum to the Background Report, total nitrate/nitrite was proposed to be added to the COC list for the Site (INTERA, 2022). DWMRC concurred with the addition of total nitrate/nitrite to the COC list (DWMRC, 2022), and so COC in this CAAWP applies to arsenic, molybdenum, selenium, uranium, and total nitrate/nitrite.

3.0 CONCEPTUAL SITE MODEL

A CSM is a representation of the Site system that consists of source areas, geology and hydrogeology, relevant materials, processes, and mechanisms underlying and controlling movement of surface water and groundwater and chemical migration, as well as the extent and magnitude of COCs in source areas, in surface and groundwater, migration pathways, and receptors. A CSM typically evolves through time as additional field data are collected and data interpretation is updated. A CSM is a tool to synthesize complex information to support evaluation and testing of corrective actions, and has a life cycle for environmental cleanup projects (EPA, 2011) that has been adapted to the Utah corrective action process and the Lisbon groundwater program using the following six (6) stages:

1) Preliminary CSM – The Preliminary CSM is a systematic planning CSM that provides an initial overview of the site, source areas, chemicals of concern, historical processes, geology and hydrogeology, and historical environmental impact information, based on site-related relevant documents available early in a program and limited studies. The Preliminary CSM can serve as a starting point for compiling and synthesizing existing information to support building stakeholder consensus, identifying data gaps and uncertainties, and determining subsequent data needs. Though they were not presented as such at the time, the following documents from the initial stages of investigating the Site groundwater plume and developing the original CAP for the Site reflect a Preliminary CSM:

- Groundwater Geohydrology and Seepage Evaluation (Dames and Moore, 1973)
- Groundwater Investigations (Dames and Moore, 1981)
- Groundwater Investigations (Earthfax, 1984a)
- Remedial-Action Plan (Earthfax, 1984b)
- Recommended Corrective-Action Plan (Earthfax, 1989)
- Evaluation of the Groundwater Corrective Action Program (Medlock, 1998)

2) Baseline CSM – The Baseline CSM is an improved, more informed version of the preliminary CSM used to identify data gaps and needs, and as the basis for designing data gap studies to reduce characterization uncertainties. The Baseline CSM for the Site was developed through iterative rounds of data gap identification and fieldwork to fill those gaps as documented in these reports:

- ACL Application (Lewis, 2001)
- Request for Additional Information (RAI) on the ACL Application (Komex, 2003)
- Long-Term Groundwater Monitoring Plan (LTGMP) (Komex, 2004)

3) Characterization CSM – The Characterization CSM builds on the Baseline CSM iteratively and addresses principal study questions about elements such as the nature and extent of contamination, or identification of key geologic/hydrogeologic features controlling flow and transport processes. Characterization CSM components capture and synthesize data that can be used to identify immediate risks to human health and the environment. Collection, evaluation, and synthesis of data used in the Characterization CSM supports the development of corrective action goals and intermediate decisions such as the need for an interim action. The Characterization CSM for the Site has now been completed and is summarized in Section 3.1. The Characterization CSM was developed through the following studies:

- Phase 1 Supplemental Site Assessment (SSA1) (Montgomery & Associates, 2013)
- Phase 2 Supplemental Site Assessment (SSA2) (Montgomery & Associates, 2014)
- HSSA3 (INTERA, 2021a)
- HSSA4 (INTERA, 2021b)
- NR-WB Report (INTERA, 2021c)
- Background Report (INTERA, 2021d)
- Addendum Background Report (INTERA, 2022)

4) Design CSM – The Design CSM will directly support the design basis for implementation of potential pilot studies, interim actions, and corrective actions. The Design CSM will be informed by the results of the CAAWP field program. As a tool, it will support evaluation of important design considerations for potential corrective action elements such as, by way of example, radius of influence for pump-based or in situ treatment systems, aquifer geochemical characteristics, locations for placement of reactive barriers, and isolation, stabilization, or relocation of impacted solid materials.

5) Corrective Action CSM – The Corrective Action CSM will be used to guide corrective action and mitigation efforts such as directing excavation activities, managing phased corrective action programs, responding to changed conditions, and optimizing treatment system implementation. This stage also includes operation and maintenance and long-term monitoring activities. The Corrective Action CSM will be developed and updated during corrective action implementation and monitoring to evaluate the attainment of corrective action goals.

6) Post-Remedy CSM – The Post-Remedy CSM will provide integrated and synthesized information to support Site transition to the U.S. Department of Energy for long-term care and maintenance after the License is terminated.

3.1 Lisbon Characterization CSM

The Lisbon Characterization CSM outlines the nature and extent of mill-related groundwater impacts and identifies key geologic, hydrogeologic, and geochemical features controlling flow and transport processes (**Figure 3.1**). The Characterization CSM was updated and refined during each phase of hydrogeological supplemental site assessments (Montgomery & Associates, 2013, 2014; INTERA, 2021a, 2021b). The Characterization CSM identifies the TSFs as primary sources of mill-related constituents to groundwater, and assumes constituent mass in the vadose zone beneath the TSFs as a potential secondary source. The Characterization CSM explains where mill-related constituents are present in the groundwater system, and that the constituent mass is migrating downgradient along flow paths that are influenced by faults, folds, and stratigraphy in the bedrock. As noted above, the COCs associated with the UTI and LTI, and for which compliance limits are established in the License, are arsenic, molybdenum, selenium, uranium, and, pending an anticipated License amendment, total nitrate/nitrite. Groundwater receptors are understood to be domestic users of the East and West Well on Rattlesnake Ranch, and domestic users, wildlife, and potential sensitive habitats exposed to water discharged from Coyote Wash Spring (CWS-1) and Rattlesnake Spring (**Figure 2.1**).

Groundwater flows from recharge areas in the La Sal Mountains towards the Site and from local recharge to the Lisbon Valley to the west of the Tertiary Anticline (**Figure 3.1** and **Figure 3.2**). As groundwater enters the Site, structural features influence the local groundwater flow patterns. The Tertiary Anticline uplifts a portion of the Burro Canyon above the regional water table, creating the unsaturated BCA zone. The local groundwater flow in the BCA is naturally divided into two separate pathways, with one pathway along the northern side of the unsaturated BCA and the other pathway along the southwestern side of the unsaturated BCA, as represented by the purple arrows in **Figure 3.1**. The approximate location of this region of the Burro Canyon is indicated as the unsaturated BCA in **Figure 3.3**. The Burro Canyon is heterogeneous with layers of limestone, conglomerate, shale, and siltstone occurring within the sandstone formation. The fluvial depositional environment of the Burro Canyon and the presence of the Tertiary Anticline result in large spatial variability of the subunits within the Burro Canyon. The Burro Canyon-Brushy Basin contact dips to the northwest, and near MW-119 enough saturated Burro Canyon is present in this area to allow groundwater to flow from the North Burro Canyon aquifer (NBCA) across the Tertiary Anticline toward MW-124 in the northwest (**Figure 3.3**). Groundwater flow along the southwestern side of the unsaturated BCA flows from the southeast to northwest, following the Lisbon Valley (**Figure 3.3**). The LVF, a normal fault with 1,500 to 2,000 vertical ft of offset in the area, acts as a barrier to flow throughout much of the Site and restricts groundwater from flowing to the west into the Wingate Formation or Chinle Formation (**Figure 3.1**).

The groundwater flow pathways from either side of the unsaturated BCA converge to the northwest towards the northern edge of the preliminary Long-Term Surveillance and Maintenance (LTSM) boundary (**Figure 3.3**). Near the preliminary LTSM boundary, a fine-grained layer within the BCA (the Burro Canyon Fines 2) hydraulically separates the shallow, unconfined groundwater from the deep, confined zones in the aquifer (**Figure 3.4**). West Coyote Wash (WCW) just north of the preliminary LTSM boundary is largely fed by Coyote Wash Spring (CWS-1, **Figure 3.2**). Near the intersection of the LVF and WCW, the LVF is not a barrier to shallow groundwater flow, and shallow BCA groundwater is in hydraulic connection with the Navajo west of the LVF. The potential local groundwater flow pathways from the vicinity of the LVF and WCW are to the northwest, toward Rattlesnake Spring and surface water further north, and westward into the Navajo where two domestic private wells (East Well and West Well) are located (**Figure 3.5**).

The geochemical conditions in the BCA near the TSFs are not favorable for attenuation of molybdenum, selenium, uranium, and total nitrate/nitrite (INTERA, 2021b). The drilling program associated with the HSSA4 Report found that mill-related COCs in groundwater have migrated outside the preliminary LTSM boundary in the lower BCA, impacting wells MW-138S and MW-138D (INTERA, 2021b). The flow and transport groundwater model developed as part of the HSSA4 work demonstrated the potential for uranium in the groundwater to migrate beyond the preliminary LTSM boundary and impact potential receptors, defined as the human or animal users or affected habitats for water from the East Well, West Well, and surface water in WCW near Rattlesnake Spring, in approximately 70 years (INTERA, 2021b). Similarly, impacts to these potential receptors from elevated molybdenum concentrations could occur within approximately 200 years, based on the predictive model results (INTERA, 2021b). The HSSA4 groundwater model demonstrated that MNA of COCs is not meeting ACLs and TALs.

3.2 Lisbon Design CSM

The Characterization CSM, as summarized above based on the body of work culminating in the HSSA4 Report, established that a new corrective action is needed to address COCs in groundwater. While the Characterization CSM (**Figure 3.1**) explains the COC sources, migration pathways, and potential receptors, it has gaps in information and level of detail needed to screen, evaluate, and select a comprehensive corrective action program to address COCs in groundwater. As a step towards selecting and implementing a new corrective action, a preliminary Design CSM (**Figure 3.6a** and **Figure 3.6b**) has been developed for the Site. **Appendix B** also provides a summary of the preliminary Design CSM. In addition to the cross sections depicted in **Figure 3.6a** and **Figure 3.6b**, **Appendix B** shows recent uranium concentration contours, which are also shown in **Figure 2.1** and discussed in detail by INTERA (2021b, 2021d). **Appendix B** also shows multivariate statistical analysis of recent concentrations of multiple constituents (alkalinity, molybdenum, arsenic, uranium, selenium, sulfate, and magnesium) measured Site-wide in BCA wells in a Principal Components Analysis (PCA) biplot. The results from PCA show that mill-impacted groundwater has a distinct geochemical signature compared to unimpacted and fault-impacted groundwater.

A goal of the work described in this CAAWP is to collect additional data to address data gaps and refine the preliminary Design CSM as the project advances into the design stage with a focus on specific areas and conditions at the Site that are most relevant to implementing corrective action. The following subsections describe the focus areas and identify field data gaps, from a preliminary Design CSM perspective, that currently are limitations to performing an alternatives analysis of potential corrective action elements.

3.2.1 Source Area

The Characterization CSM recognizes two primary sources of COCs to groundwater: (1) the TSFs and (2) constituent mass that is conceptualized to reside in the vadose zone below the TSFs (associated with mass transfer from the TSFs) (**Figure 3.1**). Characterization of tailings indicates the TSFs are close to saturation, based on the measured moisture content. Seepage rates from the TSFs are predicted to be nearly constant if the current configurations and materials remain as they are today. The rate of seepage from the LTI and UTI into the underlying Burro Canyon has not been directly measured; therefore, characterization of natural recharge and TSF material properties and vegetation was used to inform the water balance modeling and estimate seepage rates from the TSF as part of the HSSA3 and HSSA4 investigations (INTERA, 2021a, 2021b, 2021c). Since the TSFs have not significantly changed in surface area, volume, or cover materials since the end of mining in 1989, it is assumed that the seepage rates estimated from water balance modeling (INTERA, 2021c) are representative of the rates starting in 1989. Seepage rates prior to 1989 would have depended on the amount of tailings in each impoundment, the extent of ponding on the surface of each impoundment, hydraulic properties of the tailings, and the precipitation and subsequent seepage through tailings along slopes outside the ponded areas. Ponding on the TSFs occurred during mining, when slurry tailings were being discharged to the TSFs, and from discharge of pumped water to evaporation ponds constructed on the TSFs during the CAP from 1990 To 2004 (INTERA, 2021b). The volume of tailings in each impoundment is estimated from historical topographic maps of the TSF area (Dames and Moore, 1973) and cross sections developed from borings in the area of the TSFs.

The concentrations of COCs in the TSF seepage have been estimated using pore water data collected from lysimeters installed in the UTI (UTY-2) and LTI (LTY-3 and LTY-4). Water quality data were collected from 2016 to 2018 for the UTI and from 2020 to 2022 for the LTI (**Table 3.1**). The water quality data in **Table 3.1** indicate that the UTI pore water is generally more concentrated in dissolved constituents than the LTI pore water. Maximum concentrations of total dissolved solids (TDS), dissolved uranium, and pH are 46,800 milligrams per liter (mg/L), 268 mg/L, and 10.4 standard units (s.u.), respectively, in the UTI pore water (**Table 3.1**). In the LTI pore water, concentrations are variable between LTY-3 and LTY-4; and maximum concentrations of TDS, uranium, and pH range from 21,400 to 27,300 mg/L, 94 to 194 mg/L, and 8.8 to 10.3 s.u., respectively (**Table 3.1**). These notably high solute concentrations have an influence on groundwater density and flow directions that will need to be considered when evaluating corrective action elements.

Groundwater impacts were detected near the TSFs as early as 1973 (Lewis, 2001) indicating that seepage from the TSFs was impacting both the vadose zone as well as the groundwater underlying the TSFs soon after mining began (**Figure 3.6a**).

Review of the preliminary Design CSM identified the following data gaps in the Source Area for which additional field data is needed to inform the screening and evaluation of potential corrective action elements:

- Ongoing constituent mass loading from the tailings material to groundwater has not been directly measured or quantified.
- Ongoing constituent mass loading from the vadose zone has not been directly measured or quantified.

These Source Area data gaps, presented as investigation questions, are summarized in Section 4.1. The field and laboratory data programs to address these Source Area data gaps are described in Section 5.0 and **Appendix A, Table A.1a** and **Table A.1b**.

3.2.2 Near-Field and Far-Field Areas

Evaluation of corrective action technologies to effectively mitigate COCs will require detailed knowledge of the flow and transport properties of the aquifer material at the scale of each target zone in the Near-Field and Far-Field Areas. The target zones are illustrated in **Figure 3.7** with yellow rectangles, representing areas within which data (e.g., groundwater wells, core samples and/or geophysical surveys) will be collected. The Near-Field and Far-Field Areas are defined spatially in relation to the LTI and the UTI (**Figure 2.1**). The Near-Field Area of the north plume extends from the UTI to where the plume migrates across the axis of the Tertiary Anticline into Lisbon Valley near well MW-119. The Near-Field Area of the south plume extends from the area below the LTI to the northwest along the axis of Lisbon Valley. The Far-Field Area consists of the area adjacent to the northwest preliminary LTSM boundary near wells MW-124 and MW-138 S/D (**Figure 2.1**). The Far-Field Area is currently only impacted by the north plume after the plume has crossed the anticline and entered Lisbon Valley. Based on modeling results in the HSSA4 Report (INTERA, 2021b), the south plume is predicted to continue migrating to the northwest and eventually merge with the north plume in the Far-Field Area.

Material properties that control groundwater flow at the Site include hydraulic conductivity and aquifer storage. Hydraulic conductivity is an important detail for evaluating several types of potential corrective action technologies, including in situ treatment, groundwater extraction systems, and hydraulic barriers. Hydraulic conductivity has been estimated at the Site from a total of 97 aquifer tests (INTERA, 2021b). Aquifer tests conducted at the Site include traditional slug tests, pumping tests, and a method that stresses the aquifer pneumatically in the form of pneumatic slug tests and pneumatic sinusoidal tests. Results of the aquifer tests show that the hydraulic conductivity of the BCA was found to vary over approximately four orders of magnitude, ranging from 0.01 feet per day (ft/d) to 798 ft/d (INTERA, 2021b). Based on the locations of wells exhibiting high hydraulic conductivities from aquifer tests, the Tertiary Anticline is conceptualized as a more faulted and fractured region of the BCA. This observation may be a key component of the Design CSM.

Hydraulic conductivity estimates based on pumping and pneumatic tests are considered more reliable than traditional slug tests, particularly for understanding constituent transport with or without corrective action. Of the 97 tests conducted, 34 were conducted using pumping or pneumatic methods. In the Near-Field Area of the South BCA (SBCA), two wells were below the LTI tailings dam were tested with a pumping test (MW-1 and MW-2) one well was tested using pneumatic methods (MW-136). In the Near-Field Area of the NBCA, two wells were tested with pumping tests near the target zone closest to the UTI (OW-UT-9 and H-48). In the Far-Field target zone, the three existing wells in that zone were tested using pneumatic methods (MW-124, MW-138S, and MW-138D). Matrix porosity has been measured in the laboratory for core samples taken from four cores and a total of 9 1-foot core intervals. Only two cores have been sampled within a Near-Field target zone (coreholes at MW-109 and MW-117), and no cores have been sampled for the Far-Field target zone. Porosity measurements range between 9% to 24% (Montgomery & Associates, 2013).

Matrix horizontal hydraulic conductivities obtained from the nine laboratory BCA core measurements range from 0.004 ft/d to 2 ft/d (Montgomery & Associates, 2013). These matrix hydraulic conductivity values fall at or below the lower end of hydraulic conductivities estimated from aquifer tests. Hydraulic conductivities from aquifer tests that are of the same magnitude as the values from laboratory core measurements indicate that fracturing is limited at that location and flow is controlled by the rock matrix properties. Hydraulic conductivities from aquifer tests that are higher than the values from laboratory core measurements indicate that flow may be controlled by fractures. In areas of the BCA where fracturing occurs, a dual-domain system exists where flow and constituent transport preferentially occurs in the more highly mobile domain of the fractures but, due to the relatively high porosity of the rock matrix, dissolved constituent mass can migrate into the matrix. In this way, the matrix can act to store constituent mass that can be released slowly after mass in the fractures has been removed. This process may play an important role in the success of potential corrective action technologies and is an important component of the Design CSM.

The water quality and composition of the BCA is reasonably well understood in the main groundwater flow pathway of the Near-Field and Far-Field northern plume and the Near-Field southern plume, as well as along the LVF and in the Northwest Area immediately beyond the preliminary LTSM boundary (**Figure 2.1**). The solid phases that host uranium and other COCs in the Burro Canyon have been characterized to some extent for locations in the Far-Field of the northern plume (near MW-124 and MW-138D), the Near-Field of the southern plume (near MW-136), and the characterized region of the Northwest Area (INTERA, 2021b).

Review of the preliminary Design CSM identified the following data gaps at the Near-Field and Far-Field Areas for which additional field data is needed to inform the screening and evaluation of potential corrective action elements:

- The lateral margins of the north and south plumes and the depth of the Burro Canyon-Brushy Basin contact are not currently defined in the target zones with the resolution need to evaluate the feasibility of potential corrective action technologies.
- The degree to which the bedrock matrix and fractures create a dual-domain system for storage of water and constituent mass is not currently understood well enough to evaluate the feasibility of potential corrective action technologies.
- Flow pathways and hydraulic properties of the BCA are not currently defined in certain areas at the resolution needed to evaluate the feasibility of potential corrective action technologies.
- A better understanding of the solid-phase hosts and labile fractions of uranium and other COCs in the target zones is needed to predict rates of COC leaching, sorption, and desorption under ambient and potential treatment conditions.

The Near-Field and Far-Field Area data gaps, presented as investigation questions, are summarized in Section 4.1. The field and laboratory data programs proposed to address the data gaps are described in Section 6.0 and **Appendix A, Table A.2** and **Table A.3**.

3.2.3 North, Northwest, and LVF Areas

The North, Northwest, and LVF Areas are beyond the mill-impacted Near-Field and Far-Field Areas (**Figure 2.1**) and are downgradient or cross-gradient from the mill-impacted groundwater plumes. The North Area focuses on the general area to the north of wells RL-4, RL-5, and MW-101 northward to WCW and westward to the Spring Fault. The Northwest Area refers to Lisbon Valley and the area across the LVF to the west in the Navajo (**Figure 2.1** and **Figure 3.1**). The LVF Area refers to a narrow band along the footwall side of the LVF from the northern preliminary LTSM boundary near wells MW-131ALL/S to the southeast near well MW-128 (**Figure 2.1**).

3.2.3.1 North Area

The North Area is north of the current plume and is understood to be unimpacted by mill-related COCs (**Figure 2.1**). The Characterization CSM shows the plume migrating west across the axis of the Tertiary Anticline near well MW-119 where only a thin portion of the BCA is saturated above the Burro Canyon-Brushy Basin contact. If Site or regional groundwater levels were to decline due to climate change, groundwater extraction, or other causes, the north plume could conceivably shift further northward, flowing parallel to the northwest-trending plunge of the Tertiary Anticline before flowing westward across the anticline into Lisbon Valley. This theoretical alteration of the current groundwater flow path could shift the north plume into the North Area, where the hydrogeology and geochemistry have not previously been studied.

Review of the preliminary Design CSM identified the following data gap in the North Area, for which additional field data is needed to inform the screening and evaluation of potential corrective action elements:

- The groundwater flow path in the North Area, north of RL-4, RL-5, and MW-101, is not currently understood well enough to effectively evaluate and design a potential hydraulic control or COC removal approach if needed for this area, particularly if climate conditions vary (e.g., different groundwater recharge conditions).

The North Area data gap, presented as an investigation question, is summarized in Section 4.1. The field and laboratory data programs proposed to address the data gaps are described in Section 6.0 and **Appendix A, Table A.4**.

3.2.3.2 Northwest and LVF Areas

In the Northwest Area of the Site in Lisbon Valley, four fine-grained units within the Burro Canyon identified during drilling act as aquitards (**Figure 3.4**). Burro Canyon Fines 2 acts as the most significant aquitard, effectively creating a deep confined aquifer zone (deep zone BCA) and a shallow unconfined aquifer zone (shallow zone BCA). Due to the northwesterly dip of the fine-grained units, and the erosion of the fine-grained units in the area of the anticline, Burro Canyon Fines 2 was not encountered at well MW-130 near the Spring Fault, indicating that the deep zone

BCA is no longer confined in that area and may be in direct hydraulic connection with the shallow zone BCA (**Figure 3.8**). The area where the Burro Canyon Fines 2 is missing represents a potential groundwater flow pathway for the plume in the deep zone BCA to migrate into the shallow zone and ultimately across the LVF into the Navajo. The dip of the Burro Canyon Fines 2 to the northwest suggests that it may eventually reappear adjacent to, and intersect with the Spring Fault, thus re-establishing the confined deep zone BCA further northwest. However, the extent and orientation of the Spring Fault along the northeast side of Lisbon Valley (**Figure 3.1** and **Figure 3.2**) has not been characterized northwest of the area where it was mapped near wells MW-130 and MW-135.

Groundwater flow in the deep zone BCA is hypothesized to continue migrating to the northwest in the general direction of WCW and Rattlesnake Spring (**Figure 3.3** and **Figure 3.5**). South of Rattlesnake Spring and WCW, a splay of the LVF extends northward east of Rattlesnake Spring (**Figure 3.2**). In the HSSA4 Report, the hydrogeologic data were interpreted to imply that the deep BCA groundwater, and eventually the plume, discharges to WCW near Rattlesnake Spring (INTERA, 2021b). The hydrogeology of the BCA represents a data gap in this area; and until further data is collected, it is not clear what effect the splay fault has on groundwater flow. It is unclear if Rattlesnake Spring represents discharge of deep zone BCA groundwater in Lisbon Valley or if Rattlesnake Spring is discharge of groundwater flowing from the La Sal area to the east, or both. It is also unclear if groundwater in Lisbon Valley discharges directly to WCW near Rattlesnake Spring.

The LVF strongly influences the movement of groundwater in Lisbon Valley. Several wells and boring B-2 (**Figure 3.3**) previously drilled into formations on the footwall side of the LVF did not intercept groundwater, indicating that the LVF southeast of WCW (LVF Area, **Figure 2.1**) acts as a barrier to groundwater flow across the fault (INTERA, 2021a, 2021b) over most of the study area. Boring B-2 is located near the southeastern extent of the Navajo (**Figure 3.3**) and was dry during drilling in 2013 where it intercepted the Navajo, Kayenta Formation, and Wingate Formation. The Navajo northwest of boring B-2 contains groundwater, as evidenced by monitoring well MW-132S and domestic wells East Well and West Well (**Figure 3.9** and **Figure 3.6b**). Sources of groundwater in the Navajo west of the LVF include vertical recharge and lateral flow across the LVF from the BCA on the hanging-wall side of the fault. Vertical recharge may be in the form of diffuse recharge from precipitation or from seepage from a short reach of WCW where it discharges from a diversion pipe (being routed into a weir box further upstream) to where it crosses the LVF further north (**Figure 3.9**).

In the Northwest Area, where WCW crosses the LVF (**Figure 3.9**), flow across the LVF from the hanging-wall side of the fault is conceptualized to occur within both the alluvial aquifer and the shallow bedrock on each side of the LVF in this area (**Figure 3.6b** and **Figure 3.10**). Saturated alluvium exists on both sides of the fault in this area and provides a hydraulic pathway up to approximately 15 ft thick over the top of the LVF (INTERA, 2021b). The alluvial thickness at wells MW-132ALL and MW-133ALL is 30 ft and 20 ft, respectively, which agrees with the estimated thickness of the alluvium above the LVF from seismic surveys conducted across the LVF (INTERA, 2021b). Groundwater flow through the upper part of the LVF is supported by aquifer test results from wells MW-132ALL and MW-132S, on the footwall side of the fault, and wells MW-133ALL and MW-133S on the hanging-wall side of the fault (**Figure 3.10**), indicating that the upper part of the LVF is permeable. The depth of the LVF over which there is increased hydraulic conductivity has not been established by aquifer testing or other direct measurements. However, the area where groundwater is flowing across the LVF is suspected to be limited to the area around the intersection of WCW and the LVF based on the dry borehole, B-2, to the south (**Figure 3.9**).

Groundwater flow and transport modeling presented in the HSSA4 Report (INTERA, 2021b) assumed that the increased hydraulic conductivity of the shallow LVF extends to a depth of approximately 70 ft. Aquifer test data for wells across the LVF below this depth were not collected as no deeper well pairs were installed on each side of the fault as was done with wells MW-132S and MW-133S. However, data for interpreting the deep part of the LVF as impermeable is based on the observation that wells and bores drilled in the footwall side of the fault to the southeast of WCW did not encounter saturated conditions as would be expected if the LVF were permeable. Additionally, the presence of fault gouge within the LVF observed from cores collected during earlier investigations (INTERA, 2021a) is supporting evidence that the LVF is effectively impermeable (INTERA, 2021b).

Boring B-2 and core C-132D (drilled near MW-132) (**Figure 3.9**) are both interpreted as having intersected the Kayenta Formation at the base of the Navajo, and both were drilled close to and in the footwall of the LVF. Lithologic logs of the domestic wells on Rattlesnake Ranch property are not available, and it is unknown if they intersect the Navajo-Kayenta contact. Other data indicating the elevation of the top and bottom of the Navajo is from mapped outcrop approximately 2.5 miles southwest of the LVF (Doelling, 2004).

Review of the preliminary Design CSM identified the following data gaps in the Northwest and LVF Areas, for which additional field data is needed to inform the screening and evaluation of potential corrective action elements:

- The hydraulic connection between the deep zone BCA and shallow zone BCA near the Spring Fault is not currently understood well enough to confidently predict groundwater flow and COC migration towards potential future receptors, and the extent to which potential corrective action elements could protect the receptors.
- Groundwater modeling presented in the HSSA4 Report predicts future impacts to Rattlesnake Spring and the East Well and West Well, but the model relies on assumptions about hydrogeology, geologic structure, and groundwater flow patterns that should be verified to reduce uncertainty in the predictive modeling and evaluate potential corrective action elements.

The Northwest Area and LVF Area data gaps, presented as investigation questions, are summarized in Section 4.1. The field and laboratory data programs proposed to address the data gaps are described in Section 6.0 and **Appendix A, Table A.4**.

4.0 WORK PLAN DEVELOPMENT APPROACH

A preliminary screening of potential source control and treatment technologies was completed as part of the HSSA4 (INTERA, 2021b; see Section 7.0 and Table 7-1). That evaluation focused on treatment options but stated that a future corrective action plan at the Lisbon Facility should consider a multi-element approach, potentially consisting of source control measures, groundwater treatment, and institutional controls. An updated list of potential elements of a Lisbon groundwater corrective action program is provided herein as **Table 4.1**, including consideration of the preliminary treatment options identified in HSSA4 Table 7.1. As shown on **Table 4.1**, a wide range of corrective action elements are being considered and are categorized as (1) data needed to conduct a screening-level alternatives analysis that are available or can be obtained from desktop study, or (2) requiring additional field or laboratory data to conduct a screening-level alternatives analysis (**Figure 4.1**). This CAAWP presents the scope of work to fill the data gaps associated with corrective action elements that require additional field data before an alternatives analysis. **Figure 4.1** provides a decision flow chart illustrating which corrective action elements need additional field data inputs to update the preliminary Design CSM (**Appendix B**) and conduct the alternatives analysis. Though some corrective action elements may not need additional field data, all elements listed in **Table 4.1** (and potentially others) will be considered in a future screening-level alternatives analysis. Field data collection as proposed in the CAAWP is not an indication of preference or dismissal of specific technologies, but rather an approach to address preliminary Design CSM data gaps that are best resolved through field study. The sections below describe the approach developed to identify the field data required to evaluate the corrective action elements through development of PIQs, a preliminary approach for evaluating the corrective action elements and conducting the screening-level alternatives analysis, and a framework for implementing the field program to collect the data needed for evaluation of the corrective action elements.

4.1 Principal Investigation Questions

PIQs are defined here to guide the collection and use of data for the CAA. The PIQs were identified for the key investigation areas (**Figure 2.1**) and are the following:

- What corrective action technology(s) could effectively mitigate mill-related COC migration to groundwater from the Source Area (TSFs) (**Appendix A**, **Table A.1a**)?
- What corrective action technology(s) could effectively mitigate mill-related COC migration to groundwater from the Source Area (vadose zone below the TSFs) (**Appendix A**, **Table A.1b**)?
- What corrective action technology(s) could effectively mitigate mill-related COCs in groundwater in the Near-Field Area (**Appendix A**, **Table A.2**)?
- What corrective action technology(s) could effectively mitigate mill-related COCs in groundwater in the Far-Field Area (**Appendix A**, **Table A.3**)?

- How will the hydrogeology of the groundwater exposure pathways to potential receptors in the North, Northwest, and LVF Areas impact the evaluation and selection of a corrective action(s) (**Appendix A**, **Table A.4**)?

The objectives outlined for each key investigation area consist of the following:

1) the investigation sub-questions that need to be addressed to allow evaluation of a diverse range of corrective action elements for the given area;
2) the goals for addressing each of the investigation questions;
3) the approach to addressing each of the investigation questions;
4) the specific areas where the investigation questions will be addressed; and
5) the performance and acceptance criteria for determining whether the investigation goals have been met.

The investigation sub-questions identified for each of the PIQs and their respective key investigation area further define the data gaps in the preliminary Design CSM (**Appendix B**) that need to be answered to evaluate and screen the corrective action elements (**Appendix A**). The investigation sub-questions, or data gaps, pertaining to the Source Area TSFs are provided in **Appendix A**, **Table A.1a** and are the following:

- How much of the existing mass of COCs in the tailings solids is leachable and can potentially contribute to the vadose zone and groundwater below the TSFs?
- What potential in situ treatment technologies are feasible for reduction or immobilization of COCs within the TSFs? In the CAAWP, the term immobilization refers to restricting the movement of constituents dissolved in water by various methods, such as sequestration (e.g., transforming mobile dissolved constituents into a relatively immobile solid phase through sorption or precipitation), emplacing physical or reactive barriers, or removal from the system.
- Are there engineering solutions that can physically isolate tailings in situ and eliminate or reduce COC migration from the TSFs?
- What are the chemical, physical, and geotechnical properties of the tailings that might impact tailings removal?
- Are there areas on or near the Site that may warrant consideration for a new waste repository?
- What are the chemical and physical properties of soil near the Site for possible use as borrow material, and how much material is available?

The proposed field work to address these questions is provided in detail in Section 5.0.

Little information is available for the vadose zone below the TSFs, though it is anticipated that COCs will be present through the entire vertical extent of the vadose zone in the BCA below the TSFs. The investigation sub-questions, or data gaps, pertaining to the Source Area vadose zone are provided in **Appendix A**, **Table A.1b** and are the following:

- The TSFs are unlined and contributed seepage to the vadose zone and groundwater soon after they were constructed in the 1970s. What is the extent of mill-related impacts in the vadose zone below the TSFs? What are the primary controls on transport to the groundwater?
- If the TSFs are to be removed, is it also feasible to remove the impacted vadose zone material underneath the TSFs to reduce COC migration from the vadose zone beneath the TSFs?
- What potential in situ treatment technologies are feasible for reduction or immobilization of COCs within the vadose zone?
- Are there engineering solutions that can physically isolate the vadose zone and reduce or eliminate COC migration from the vadose zone?

The approach to addressing these questions is provided in detail in Section 5.0.

Many of the data gaps and investigation sub-questions identified in the Near-Field and Far-Field Areas are similar as discussed in Section 3.2.2. The investigation sub-questions, or data gaps, for the Near-Field and Far-Field Areas are provided in **Appendix A**, **Table A.2** and **Table A.3** and are the following:

- What are the most promising locations within the Near-Field and Far-Field Areas where groundwater treatment technologies may be feasible?
- Are groundwater extraction or injection of treatment solutions feasible for reducing or removing COCs from groundwater with the site-specific hydrologic conditions?
- What are the physical and hydrologic properties in target zones of the heterogenous BCA that are needed to resolve data gaps and enhance the preliminary Design CSM?
- What are the solid phase distributions of uranium and other COCs within the Near-Field and Far-Field Areas of the BCA and how do these phases impact the current groundwater concentration and potential treatment technologies?
- Is in situ treatment feasible for reduction or immobilization of COCs within the BCA?

The approach to addressing these questions is provided in detail in Section 6.0.

Groundwater and surface water north and northwest of the preliminary LTSM boundary and on the west side of the LVF are not known to be impacted by historical milling activities, except for the leading edge of the northern plume (e.g., MW-138D/S). Because these areas contain possible future groundwater exposure pathways, additional detail about the hydraulics and geochemistry along the groundwater flow path is needed to inform the Design CSM and evaluate potential corrective action elements and contingency measures. The investigation sub-questions, or data gaps, for the North, Northwest, and LVF Areas are provided in **Appendix A**, **Table A.4** and are the following:

- Is deep BCA groundwater upwelling into the shallow BCA and alluvium near the intersection of the Spring Fault and WCW?
- Is deep BCA groundwater flowing across the LVF into the Navajo or other formations?
- What is the groundwater flow direction in the Navajo northwest of the preliminary LTSM boundary?
- What is the flow pathway of groundwater in the BCA in the Northwest Area, downgradient of existing wells? Does the northern splay of the LVF create a flow boundary or will BCA groundwater discharge at Rattlesnake Spring or WCW?
- How might the northern plume groundwater flow pathway change under variable climate conditions (e.g., more, or less recharge)?

The approach to addressing these questions is provided in detail in Section 6.0.

4.2 Corrective Action Assessment Approach

All data collection, analyses, and treatability studies proposed in this CAAWP are for updating the preliminary Design CSM (**Appendix B**) and to support assessment of corrective action technologies that can treat or mitigate the COCs in or potentially entering the groundwater system. As described in Section 1.1, an adaptive work plan implementation approach will be employed. For example, some of the findings from the initial treatability tests may apply to other key investigation areas (e.g., Source Area, Near-Field, and Far-Field Areas) and may not necessarily require testing for all areas. A comprehensive range of potential corrective action elements, including but not limited to active or construction-based technologies (**Figure 4.1**), will be included in the assessment approach and the future alternatives analysis. A summary of key criteria that will be used for the corrective action alternatives analysis are presented below in Section 4.3.

A general approach for assessing the corrective action elements will progress with the following steps (with bold font indicating the steps that are covered under this CAAWP and non-bold font indicating the steps for future work scopes):

1. **Collect the field and laboratory data identified in the CAAWP as necessary to:**
    a. **Enhance the preliminary Design CSM and the groundwater flow and transport model for use as corrective action alternative planning and evaluation tools.**
    b. **Resolve data gaps that currently limit RAML's ability to conduct an initial screening of a diverse range of potential corrective action elements.**

2. **Prepare a Field Investigation Report to document the field work described in the CAAWP.**
3. Prepare iterative updates to the Design CSM and groundwater flow and transport model.
4. Conduct the corrective action alternatives analysis to identify a preferred alternative, a process that may involve field-scale pilot testing.
5. Prepare a GCAP for DWMRC review and approval.

The steps associated with the CAAWP and the overall CAA process are discussed further in Section 8.0.

4.3 Evaluation of Corrective Action Elements

A preliminary evaluation of corrective action technologies for the Site was included in the HSSA4 Report (INTERA, 2021b). The technologies reviewed in the HSSA4 Report included those technologies discussed by Lewis (2001) in the original ACL application and were categorized as source control, groundwater treatment, and other treatment options (INTERA, 2021b). The preliminary screening of potential treatment technologies in the HSSA4 Report identified that the Site's physical setting may affect the implementability or effectiveness of specific technologies. For example, large-scale fracturing or lower permeability areas in the BCA may make some types of barriers impracticable. In 1982, a grout curtain was attempted north of the UTI; however, proper sealing of the curtain was not successfully established due to the "consolidated and fractured nature of the Burro Canyon aquifer," and so the program was discontinued (Lewis, 2001).

In addition, the preliminary screening in the HSSA4 Report revealed that additional site-specific data are required to effectively evaluate the corrective action technologies. The work proposed in this CAAWP is designed to gather the data needed to assess the feasibility of and rank a wide range of potential corrective action technologies for the groundwater corrective action. The field and laboratory data collected and analyzed will inform the preliminary Design CSM (**Appendix B**) and provide the technical basis for evaluating and testing the corrective action technologies. The criteria used for a future alternatives analysis of all corrective action elements will include the criteria identified for evaluation of a proposed GCAP, as listed in UAC R317-6-6.15.E, which in addition to completeness and accuracy of the GCAP, include the following:

- Protects public health and the environment (including impacts as a result of any off-site activities such as transport or disposal of contaminated materials at an off-site facility),
- Meets applicable concentration limits,
- Produces a permanent effect, and
- May use other additional measures to ensure that the criteria and factors specified in R317-6-6.15.E are met.

RAML may add other criteria to complete the future corrective action alternatives analysis and will develop these additional criteria at appropriate times in the corrective action planning process and in consultation with DWMRC.

4.4 Implementation

Prior to implementing the field work and laboratory testing proposed in this CAAWP, a number of planning steps will need to take place, including, but not limited to, permitting (including environmental and cultural resource clearances), contracting work scopes, and reviewing regulatory requirements. The section below outlines the steps that need to happen before field work or laboratory testing can proceed.

4.4.1 Field Work Preparation

Before intrusive field activities such as drilling can occur, the appropriate regulatory approvals and permits must be obtained. Before implementation of the CAAWP field work, a review of the regulatory requirements will occur. A number of regulatory requirements from both State and Federal regulations apply to the proposed CAAWP field program. The following requirements must be met before field work can begin:

- Biological (wildlife and vegetation) and cultural surveys completed on areas of proposed land disturbance and submitted to the Bureau of Land Management (BLM) and/or Utah State Historic Preservation Office,
- Lisbon Mine Plan of Operations (MPO) amended and submitted to the BLM for land disturbance activities on BLM-managed land and approvals obtained,
- Stormwater Pollution Prevention Plan (SWPPP) submitted to the United States Environmental Protection Agency (EPA) and Utah Department of Environmental Quality (DEQ),
- Utility (underground and overhead) clearance,
- Well Construction Permits for construction of new monitoring wells submitted and Start Cards obtained from the Utah Division of Water Rights, and
- License-required Radiation Work Permits (RWPs) developed by the Site Radiation Safety Officer for non-routine activities that may result in worker exposure to licensed material.

In addition, any disturbances that may occur on private land not belonging to RAML will need to be approved by the impacted landowner. A plan will be developed for the proper handling of investigation-derived waste from both the drilling operations as well as waste generated during the testing proposed in this CAAWP. Any investigation-derived waste that is or may be licensed material must follow the handling requirements listed in UAC R313-15-801 and UAC R313-15-901 to 905. Additional regulations or requirements may also be identified, and a review of the requirements necessary for field implementation will be conducted before field work starts.

4.4.2 Laboratory Testing

Laboratory testing of water and solid samples is planned for the CAAWP. The two main categories of laboratory testing are (1) hydrologic, geochemical, and physical properties of samples; and (2) treatability testing of groundwater, tailings solids, and bedrock solids. Many of the anticipated sample locations and media (e.g., tailings solids, tailings pore water, mill-impacted groundwater, and mill-impacted aquifer solids) are expected to require that the contracted laboratory holds a radioactive materials license to handle 11e.(2) byproduct material.

5.0 SOURCE AREA PROPOSED FIELD INVESTIGATIONS

The purpose of the Source Area investigation is to gather the field data needed to evaluate potential corrective action elements that could decrease or eliminate migration of mill-related COCs from the Source Area (i.e., TSFs and vadose zone) (**Figure 4.1**) into the groundwater system, such as:

- Reduce, immobilize, or isolate COCs in tailings and/or mill-impacted vadose zone.
- Remove the tailings and mill-impacted vadose zone material to a new on-site/nearby repository or an existing repository (i.e., an appropriately permitted landfill).
- Reduce or eliminate COC migration to groundwater from the tailings and/or vadose zone.

The data needs for the Source Area are identified, along with the goals, approach, and performance criteria, in **Appendix A**, **Table A.1a** and **Table A.1b**.

5.1 Evaluation of Borrow Areas

This section of the CAAWP addresses the availability of borrow materials near the Site that could be used in the future for potential construction of mitigation elements, including but not limited to final cover, disposal cell embankments, erosion protection, general site fill, and liner material for a new on-site repository. These potential corrective action elements target the decrease of mass loading of COCs into the groundwater. **Appendix A, Table A1a** (investigation sub-question 6) outlines the PIQs for borrow area evaluation.

The approach to evaluating borrow materials consists of the following: (1) identification of candidate borrow areas near the Site; (2) field investigation to collect representative samples of soil and rock materials; (3) laboratory analyses to determine engineering properties of the soil and rock for use as construction materials, and (4) estimation of the volume of suitable materials in the borrow area(s) to determine if it is adequate to meet proposed construction criteria. The performance and acceptance criterion for the selected borrow areas and their respective materials, as characterized through field investigation and laboratory tests, is whether the borrow materials are suitable for use as construction materials in a range of applications. Results of the evaluation of borrow areas will be provided as a ranking of the four areas from the most suitable to the least suitable for the range of applications considered.

5.1.1 Candidate Borrow Area(s)

A preliminary evaluation of the surface geology and soils in the vicinity of the Site indicates that suitable materials for borrow/purchase are likely within a 5-mile radius of the Site. For the purpose of identifying candidate borrow area for this CAAWP, the generalized materials (textural classes) under consideration, consistent with various possible construction needs, are the following:

- Rock (durable for erosion protection).
- Silty sand/sandy silt (granular and non-plastic for various applications).
- Clay (low hydraulic conductivity for restricting water movement).

In combination, these materials may be used for any potential new cover(s) or modifications of the current, as-constructed covers; for embankment fill associated with new disposal cell construction; erosion protection; and/or liner material for a new on-site repository. The methodology for proposed data collection and laboratory testing is discussed in more detail in **Appendix C** and **Appendix D**. The proposed laboratory testing of the materials will characterize their engineering, hydraulic, and agronomic properties.

Additional considerations for identification of candidate borrow areas include proximity to the Site; land ownership; access; existing, developed quarry or pit, and conditions of use; and possible (estimated) volume of suitable materials. Based upon the criteria described above, **Figure 5.1** shows four candidate borrow areas selected for investigation as part of this CAAWP, superimposed on the Site area soils. Each of the borrow areas is within a 5-mile haul distance to the Site on existing paved and dirt roadways. Area 2 is on RAML property and areas 1, 3, and 4 are on BLM-managed land. Area 1 encompasses all or a portion of an existing quarry or pit. Area 4 is adjacent to the former borrow areas used for construction of the clay radon barrier of the existing, as-constructed covers on the TSFs. Area 2 is also within the area under consideration for possible disposal of tailings as described in Section 5.2.

Each of the four candidate borrow areas are characterized by unconsolidated Quaternary-age materials (**Figure 3.2**). Throughout the area, all these deposits may be relatively thin and contain interbedded layers of poorly sorted materials (clay, silt, sand, and gravel/cobbles). The soils within the borrow areas are described as fine sandy loam, gravelly fine sandy loam, and very stony fine sandy loam (Area 1); fine sandy loam (Areas 3 and 4); and loam, and very fine sandy loam (Area 2) (**Figure 5.1**).

The size (investigation footprints) and number of the candidate borrow areas were developed from the following assumptions:

- The material characteristics (gradation and sorting) within the larger area surrounding the Site, inclusive of the four candidate borrow areas, indicate that all the materials required for suitable construction materials are present, but they are likely in relative thin layers, are interbedded, and are poorly sorted.
- The total thicknesses of unconsolidated materials available for borrow from alluvial sources are, for the most part, relatively thin (a few feet to 20 ft).
- It is likely that either more than one borrow area will be required or the extent of a given area may need to be increased to provide the required volumes.

The area, surface geology and soils, as well as the proposed auger borings are summarized for each borrow area in **Appendix C, Table C.3**. Collection of field samples from the borrow areas is described in **Appendix C**. The laboratory tests proposed for the samples collected from the borings are provided in **Appendix D**.

5.2 Tailings Removal and Off-Site Disposal

This section of the CAAWP addresses tailings removal as a possible corrective action element. Removing tailings material from the TSFs would remove the original source of tailings and related fluid with the goal of eliminating solute loading into underlying groundwater. Several options may exist for removal of the tailings, including relocating to an existing permitted disposal facility, a new disposal facility, or other processing facilities. Any new or existing disposal facilities would meet modern-day requirements of a fully-lined facility with leak detection and modern cover design. Relocation of the tailings to a new disposal cell within the immediate area of the Site is being considered and related collection of data to conduct a preliminary evaluation of options is proposed herein.

Further discussion of tailings removal from the TSFs and relocation to an off-site location(s) for disposal is provided in **Appendix A, Table A.1a** (columns 4 and 5). The data needs include geotechnical and hydrogeochemical data of the TSF material itself to determine if removal is feasible and if an existing facility might accept the material, as well as geotechnical data of potential new disposal area(s) (**Figure 4.1**).

A significant database of geotechnical data exists for the TSFs at the Site, including engineering properties of the tailings and dam embankments (index, strength, and hydraulic properties). Additionally, RAML has developed a conceptual model of the TSFs which includes a digital terrain model (DTM) of the TSFs and surrounding areas from recent laser imaging, detection, and ranging (LiDar) data, and AutoCAD drawings of the TSFs in plan and section illustrating best knowledge of the TSFs geometry and materials encountered. The database of geotechnical information has been developed from both previous hollow-stem auger (HSA) drilling and sampling and sonic core drilling of the impoundments and dams. In addition, this CAAWP proposes sampling the TSF material for hydrogeochemical evaluations, which will provide more information needed to determine disposal options. The drilling and the hydrogeochemical evaluations proposed for the TSF material are described in Section 5.3.1 and Section 5.3.2, respectively.

For the purposes of this CAAWP, a very preliminary screening of candidate locations within a 5-mile radius of the Site was conducted. In general, there appear to be potentially suitable areas for a tailings disposal site. The half-square-mile section of land immediately north of the existing TSFs on RAML property was selected for further consideration as a possible disposal area. Data collection for evaluation of the possible disposal area coincides with Borrow Area 2 and relies on the same data collected for evaluation of Borrow Area 2 (Section 5.1; **Appendix C**). Collection of field samples from the repository area is described in **Appendix C**.

5.3 Migration of Mill-Related Constituents

This section describes the proposed data collection needed from the Source Area (the TSFs and the vadose zone) to inform the Design CSM for the purpose of evaluating potential corrective action elements to mitigate seepage of COCs from the TSFs and vadose zone into the groundwater system. The data collection proposed in this section may also be used to refine the tailings water balance model for the TSFs. The data needs and accompanying PIQs for the migration of COCs from the TSFs (Source Area) are summarized in PIQ1a, investigation sub-questions 1, 2, and 3 (**Appendix A, Table A.1a**). The data needs and accompanying PIQs for the migration of COCs from the vadose zone (Source Area) are summarized in PIQ1b, investigation sub-questions 6, 7, 8, and 9 (**Appendix A, Table A.1b**). The sections below describe the hydrogeological field investigations, the hydrogeochemical investigations, and the treatability studies that will provide the field data required to evaluate the effect of the loading to groundwater from the Source Area and corrective action technologies to mitigate COC migration to groundwater from the Source Area (**Appendix A, Table A.1a** and **Table A.1b**). The corrective action technologies currently under consideration for the Source Area include passive hydraulic barriers, passive reactive barriers, and technologies to reduce, immobilize or isolate COCs in the tailings and/or vadose zone (**Figure 4.1**).

5.3.1 Hydrogeological Field Investigations

Very little geochemical, physical, and hydraulic data are available for the vadose zone below the TSFs. Additional information is also needed for the TSF material to effectively evaluate potential corrective action technologies (**Appendix A, Table A.1b**). Therefore, it is necessary to drill additional coreholes into and through the TSFs to collect a representative set of samples from both the TSF material and the underlying vadose zone. Data is also needed to assess the potential for enhanced recharge to occur along the edges of the impoundments. The approach to collecting hydrogeological data from the TSF and vadose zone Source Areas will consist of the following:

- Conduct geophysical surveys to help delineate stratigraphy and to potentially identify zones of enhanced seepage from the TSFs.
- Drill coreholes into the TSFs and underlying Burro Canyon to collect core samples for physical and geochemical analysis of solids.
- Install wells in the BCA underlying the TSFs at locations where groundwater is encountered during coring.
- Instrument the TSF material with soil moisture sensors at locations near the edge of the TSFs where enhanced recharge may occur resulting from surface water flows originating outside of the impoundment footprint.

Geophysical surveys (**Figure 5.2**) will consist of Electrical Resistivity Tomography (ERT) and seismic refraction. Seismic refraction surveys will provide data that will help delineate the base of the TSF and the Burro Canyon-Brushy Basin contact. The ERT surveys may provide information about the spatial variability of seepage in the TSF and underlying vadose zone. Results of the seismic refraction and ERT surveys will be used to refine anticipated drilling depths of coreholes and borings.

Eight locations for coreholes are proposed for the TSF and vadose zone below with four coreholes in the UTI (UPC-1 to UPC-4) and four coreholes in the LTI (LPC-5 to LPC-8 (**Figure 5.2**). Actual corehole locations may be determined based on geophysical electrical resistivity and seismic refraction surveys. Continuous core will be collected from the proposed coreholes, and samples will be collected at least every 5 ft, including at noteworthy changes in the material, alluvium, or geology. The anticipated depth of coring is 10 to 15 ft below the Burro Canyon-Brushy Basin contact.

Coreholes drilled into bedrock will be used to identify lithology and extent of fracturing. Downhole geophysical surveys (caliper, temperature, spontaneous-potential (SP), natural gamma ray, 16 inch and 64-inch normal resistivity, single point resistance), will be performed to evaluate moisture content profile, uranium distribution, and fracture density. Borehole flow logging and electrical conductivity logging will be conducted to help identify zones of increased groundwater flow adjacent to the borehole.

Core samples will be analyzed for geochemical and physical properties (Section 5.3.2) and for laboratory evaluation of the effectiveness of corrective action technologies (Section 5.3.3). Select core samples will also be submitted for laboratory analysis of soil moisture retention curves that represent the constitutive relations between hydraulic conductivity and moisture content with matric potential. The resulting parameterization can be used to conduct additional water balance modeling, as was done in the HSSA4 investigation (INTERA, 2021b, 2021c), to refine estimates of recharge to the TSFs and seepage out the bottom of the TSFs. Guidance for implementation of the hydrogeological field investigations is provided in **Appendix C**, Field Implementation Guidelines.

If coreholes advanced into the Burro Canyon intercept groundwater, a monitoring well will be installed at that location. The monitoring well will be used to provide water levels and samples for geochemical analysis. Electrical conductivity (EC) and flow logging will also be conducted at these wells. Some of the wells (e.g., UPW-4 and LPW-8) installed in the BCA may also be used in MMR surveys to help delineate preferential pathways of COCs from beneath the TSFs (this evaluation is considered part of the Near-Field Area investigation, Section 6.1.1).

As part of evaluation of recharge through the TSF to support flow and transport modeling for the HSSA4 investigation (INTERA, 2021b), estimates of recharge were assumed to be uniform across the impoundment footprints. This approach did not consider the potential for recharge to occur from surface flows along the lateral margins of the impoundments. Surface flows may occur from runoff during precipitation events where the runoff can interact with the TSFs by (1) contributing to run-on to the TSF cover material with subsequent vertical recharge, or (2) seepage along the interface between the TSF material (cover, tailings, etc.) and the underlying unconsolidated material or bedrock with the potential for seepage to flow into the tailings material as recharge. The seepage along the interface on the north side of the LTI and UTI would originate from adjacent slopes runoff. The seepage occurring on the south side of the impoundments would originate from runoff associated with surface water in the diversion channel adjacent to the impoundments (**Figure 5.2**). To evaluate the occurrence of either of these potential sources of recharge, soil moisture sensors will be installed at several locations near the margin of the impoundments (**Figure 5.2**). Time series of soil moisture levels measured along transects of sensors will be compared to precipitation at the Site to qualitatively assess recharge into the tailings and to determine if these recharge mechanisms warrant further evaluation as part of corrective action assessment.

5.3.2 Hydrogeochemical Investigations

The goals of the hydrogeochemical evaluation of TSF materials are to provide information that can be used to assess the COC mass flux from the TSFs and determine if isolation of COCs in place is possible and would eliminate or reduce seepage of COCs from the TSFs (**Appendix A**, PIQ1 in **Table A.1a**). Samples for analysis will be collected from borings into the TSFs. Proposed coreholes will be drilled in the preliminary locations indicated in **Figure 5.2**. Tailings solid samples will be collected at a frequency of at least 5-ft intervals. These tailings solid samples will be analyzed along with any available tailings samples collected during the 2019 drilling program (INTERA, 2021c).

Tailings solids will be analyzed for the following:

1. solid phases that host uranium and other COCs,
2. sequential extraction tests for uranium and other COCs, major ions, and economic commodities (e.g., rare earth elements),
3. batch and flow-through column leach tests (including stop-flow events) for uranium, other COCs, and major ions using simulated pore water over multiple pore volumes,
4. total and effective porosity,
5. moisture content, including samples collected above the water table,
6. bulk density,
7. particle size distribution, and
8. specific surface area (**Appendix A**, PIQ1 Investigation Approach in **Table A.1a**).

The methods used to obtain this information will be the same as or similar to those listed in **Table D.1** (**Appendix D**). More detail about these methods is provided in **Appendix D**.

The goals of the hydrogeochemical evaluation of the vadose zone below the TSFs are to provide information that can be used to assess the mass flux of uranium and other COCs from the vadose zone to the BCA, the efficacy of uranium and other COCs removal from or immobilization within the vadose zone, and the feasibility of placing physical barriers within the vadose zone to eliminate or minimize COC loading to the aquifer (**Appendix A**, PIQ1b in **Table A.1b**). Samples for analysis will be collected from borings into the vadose zone. Proposed coreholes will be drilled into the vadose zone in the preliminary locations indicated in **Figure 5.2**. Core samples will be collected from intervals within the Burro Canyon that show differing rock type, mineralogy, textures, and physical disturbance such as fracturing. Subsamples of cores will be collected at a frequency of at least 5-ft intervals, including at noteworthy changes in the material or geology. The anticipated depth of coring is 10 to 15 ft below the Burro Canyon-Brushy Basin contact. New core samples will be analyzed along with core collected in 2019 (INTERA, 2021c) from LDB-4, UDB-4, and UDB-5 (**Figure 5.2**). The planned hydrologic, geochemical, and physical data collection will be same as that outlined for tailings solid samples, with the addition of matric potential, as described in **Appendix A** (PIQ1b Investigation Approach in **Table A.1b**). The methods used to obtain this information will be the same as or similar to those listed in **Table D.1** (**Appendix D**). More detail about these methods is provided in **Appendix D**.

5.3.3 Source Area Treatability Tests

The goals for the treatability tests for the Source Area will be to evaluate the applicability and capacity of corrective action technologies to either reduce or immobilize uranium and other COCs in the TSF material and the vadose zone directly beneath the TSFs. There are numerous reagents, slurries, or injectates that can be tested for the treatment of uranium species and the other COCs for the purpose of immobilization from further vertical migration through the base layer of the TSFs and the underlying vadose zone into the BCA. Selection of the treatability tests will be based on the results from laboratory analyses that will be conducted on tailings solid and bedrock core samples, as described in Section 5.3.2, that will be obtained from the proposed Source Area drilling locations depicted on **Figure 5.2**. Samples will be collected from each Source Area location and screened based on field and preliminary laboratory results prior to use in treatability tests for sequestration of uranium and other COCs. A subset of solid samples will undergo treatability tests that represent the range in observed hydrogeologic and hydrogeochemical conditions, including COC concentrations. The decision-support tool provided in **Figure 5.3** will be used to select the treatability tests that are best suited to treat given known hydrogeochemical parameters of the Source Area. The in situ treatability tests under consideration are:

- In situ gaseous reduction (ISGR) of uranium and other COCs via the injection of reducing gases such as hydrogen sulfide (Deng, 2004) or gaseous ammonia. This treatability test will only be applied to samples of the vadose zone below the TSFs.
- Grout slurry injection to assess the potential for engineered subsurface barriers such as a grout curtain to isolate uranium and other COCs within the TSF, vadose zone, or saturated zone (EPA, 1998).
- In situ phosphate tests by addition of polyphosphate chain formulations (Wellman et al., 2009; Vermeul et al., 2009; Mehta, 2017) and addition of an organophosphate to enhance microbially induced sequestration of uranium into a phosphate mineral (Newsome et al., 2015).
- In situ chemical reduction (ISCR) of uranium and other COCs via the injection of chemical reductants such as zero-valent iron (ZVI), calcium polysulfide, dithionite, or ferrous sulfate (Li et al., 2015; Kornilovych et al., 2018).

- In situ biological reduction (ISBR) of uranium and other COCs via the injection of carbon substrates that act as electron donors such as sodium lactate, molasses, and emulsified oil (Watson et al., 2013).

Before, during, and after treatability tests, samples will be characterized for hydrologic, geochemical, and physical properties using the methods outlined in **Appendix D**. The flow-through leach tests described in **Appendix D** will be conducted on solid samples to assess the sorption-desorption rates and reaction kinetics of sequestering uranium and other COCs. These rates will also provide a means of comparing the efficacy of each type of treatability test. These treatability tests have a primary focus on uranium sequestration because uranium is the most mobile among the COCs at the Site (INTERA, 2021b). Additionally, the mass of uranium currently in the northern and southern plumes may warrant treatment regardless of the corrective action elements that may be applied to the Source Area. The treatment solutions are optimized for uranium but will also likely sequester other COCs to some degree. The efficacy of each type of treatment will be assessed and documented for all COCs as part of this investigation. If any treatability tests appear to make any one of the COCs more mobile, then that information will be considered in the alternatives analysis.

It is anticipated that any treatability tests where the main mechanism is reduction of dissolved uranium (U[VI]) to solid uranium (U[IV]) may release arsenic at the benefit of sequestering uranium. This phenomenon is observed in cases where oxidized iron minerals are present and get reduced and dissolved along with uranium reduction, resulting in the release of any metals associated with the iron minerals. Arsenic is well known for associating with oxidized iron minerals through sorption and coprecipitation (Hem, 1985; Bowell, 1994). The common association of arsenic with oxidized iron minerals is likely one of the reasons why arsenic is the least mobile among the COCs at the Site (INTERA, 2021b, 2021d). Increased mobility of iron and associated metals during uranium reduction has been documented during the ISBR process (e.g., Gihring et al., 2011; Stucker et al., 2013). Particular attention will be given to the possible increased mobility of arsenic during treatability tests. Increased mobility of arsenic will not necessarily preclude a given treatment option if it can be demonstrated that arsenic could be naturally attenuated at the Site within the preliminary LTSM boundary in the same manner that is observed currently (INTERA, 2021b).

Microorganisms are capable of sequestering uranium through various bioremediation processes referred to specifically as biosorption, biomineralization, bioreduction, and bioaccumulation (Banala et al., 2020). One of the more common ISBR strategies applied to uranium-contaminated sites is the combination of bioreduction and biomineralization, where dissolved U(VI) is reduced to solid U(IV) by various microorganisms, such as iron- and sulfate-reducing bacteria (e.g., Gihring et al., 2011; Stucker et al., 2013; Watson et al., 2013; Newsome et al., 2015). Pilot-scale studies of such ISBR strategies have shown varying levels of success. For example, when fast-release electron donors such as hydrogen gas, acetate, lactate, ethanol, methanol, and glucose have been added to the system to stimulate uranium bioreduction/biomineralization, the process generally lasts only during active injection, and the injection well may become clogged with biomass and require frequent cleaning (Wu et al., 2006, 2007). Alternatively, when a slow-release electron donor, in this case emulsified vegetable oil, was added to stimulate uranium bioreduction/biomineralization, the sequestration of uranium was shown to last for over a year with just a 2-hour injection (Watson et al., 2013). The slow-release electron donor substrates injected during pilot-scale studies typically break down into fast-release electron donor substrates (e.g., Watson et al., 2013). Considering that ISBR treatability tests with slow-release electron donors may take a relatively long time to generate results during benchtop-scale laboratory screening tests, treatability tests with both fast-release and slow-release electron donors will be conducted in this investigation.

The exact form of the bioreduced/biomineralized uranium product appears to play a role in the long-term stability. Uranium sequestered through bioreduction and biomineralization was found to later re-oxidize and become mobile in an environment with near-neutral pH and notable (bi)carbonate concentrations (Wan et al., 2005). When the microbial community was stimulated by the addition of glycerol phosphate, however, the formed U(IV) phosphate biominerals were less likely to oxidize than the U(IV) products formed in the absence of phosphate (Newsome et al., 2015). Based on the lessons learned from previous research on uranium bioremediation, the ISBR treatability studies in this investigation will include testing with the addition of phosphate.

In the case of ISBR treatability tests, batch testing will be a crucial screening step (**Figure 5.3**) to determine if the appropriate microbiological community can be stimulated with the addition of electron-donor substrates. The main criterion used to determine if the appropriate microbiological community can be supported will be an apparent reduction in dissolved uranium and other COC concentrations due to the bioreduction and biomineralization process following addition of an electron-donor substrate. Optional criteria for determining whether the expected bioreduction and biomineralization process has occurred will be observed formation of possible biofilms and mineral precipitates. Any mineral precipitates would be analyzed by the mineralogical data collection methods described in **Appendix D**. In the absence of expected COC concentration reduction during screening ISBR tests, the nonviability of this treatment technology would be confirmed by standard microbiological community analysis methods such as rRNA gene sequencing and quantitative polymerase chain reaction (PCR; Newsome et al., 2015) and/or biological activity reaction tests (BART) that target the typical microorganisms involved in ISBR systems (e.g., iron- and sulfate-reducing microorganisms). If typical microorganisms involved in ISBR systems are not identified, no further ISBR testing will be necessary.

The corrective action technologies for in situ immobilization of uranium and other COCs have documented success for treatment, at least on bench-scale tests, at other sites. However, when considering the implementability at Uranium Mill Tailings Remedial Action (UMTRA) sites, long-term effectiveness, and relative cost, the polyphosphate injection treatments to induce sequestration by hydroxyapatite or autunite have been demonstrated to be the most effective long-term in situ treatment technologies, as documented at the UMTRA site in Rifle, Colorado (Szecsody et al., 2016) and the uranium plume in the vadose zone at the 300 Area of the Hanford Site (CH2M Hill, 2020). An example of methods and approach for treatability tests using polyphosphate amendments, including the rationale and step-wise development process, is provided in **Appendix D**.

6.0 GROUNDWATER PROPOSED FIELD INVESTIGATIONS

This section describes the proposed field data collection needed to address Design CSM data gaps and evaluate corrective action technologies to address COCs in the groundwater system. The mill-impacted groundwater investigation data needs and accompanying PIQs are summarized in **Appendix A, Table A.2** (PIQ2, Near-Field Area), **Table A.3** (PIQ3, Far-Field Area), and **Table A.4** (PIQ4, the North, Northwest, and LVF Areas). The groundwater investigation field data collection activities are focused on evaluation of corrective action elements and consist of the following:

- Conduct geophysical surveys to characterize geologic structure (lithology and faults) as they may influence groundwater flow pathways in potential treatment areas.
- Drill coreholes in target zones and in certain peripheral areas; core samples will be submitted for hydraulic and geochemical laboratory analysis and to support evaluation of corrective action elements.
- Install new monitoring wells to more narrowly define the vertical and horizontal extent of the plume within target zones and identify lithology and extent of fracturing to provide a solid basis for potential pilot tests and potential treatment design.
- Conduct borehole flow logging and EC logging to characterize preferential flow zones adjacent to the borehole that will inform the evaluation of corrective action elements.
- Conduct aquifer tests to determine formation hydraulic properties to help identify preferential groundwater flow paths and local-scale control on groundwater flow in target zones, which will be used in evaluation of potential corrective action elements.

The following subsections describe the hydrogeological field investigations, the hydrogeochemical investigations, and the treatability studies that will provide the field data required to evaluate a wide range of potential corrective action elements for groundwater (**Appendix A, Table A.2, Table A.3**, and **Table A.4**). As described in Section 1.1, an adaptive work plan implementation approach will be employed. For example, some of the findings from the initial treatability tests may apply to other key investigation areas (e.g., Source Area, Near-Field, and Far-Field Areas) and may not necessarily require testing in all areas. The corrective action technologies for COCs in the groundwater are passive hydraulic barriers, passive reactive barriers, in situ groundwater treatment, and ex situ groundwater treatment (**Figure 4.1**).

6.1 Hydrogeological Field Investigations

Stratigraphic and structural features and the hydraulic response of the aquifer to pumping or injection will affect the viability or effectiveness of potential groundwater corrective action technologies. To better understand plume behavior and to evaluate the efficacy of one or more corrective action technologies at controlling the groundwater plume, hydrogeological field investigations will be conducted for the Near-Field and Far-Field plume areas as well as the North, Northwest, and LVF Areas (**Figure 2.1**). Data collected as part of these investigations will not only support evaluation of potential remediation technologies but will also be used to update the flow and transport models of the Site so the model can be used to evaluate potential corrective action elements. Guidance for implementation of the hydrogeological field investigations is provided in **Appendix C**, Field Implementation Guidelines.

6.1.1 Near-Field Areas

Multiple corrective action elements may be required, or a select technology may need to be implemented at multiple target zones, or both, to achieve acceptable constituent concentrations. As a result, five target zones of investigation are identified for the north plume in the Near-Field Area and three target zones for the south plume in the Near-Field Area (**Figure 3.7**). The target zones are identified by the geophysical survey transects GP-9 to GP-13 for the north plume and GP-14 to GP-16 for the south plume (**Figure 6.1**). Each target zone generally consists of one or more existing wells and/or coreholes (**Figure 6.1**). In addition, numerous pre-existing wells at the Site also provide useful information regarding lithology, saturated zone thickness, historical plume extent, and aquifer properties. Existing and proposed coreholes and wells (**Figure 6.1**) will provide higher resolution field data about the heterogenous hydrogeology in the proposed target zones to inform the evaluation of corrective action elements.

The overall investigation approach in each target zone is to implement non-intrusive methods prior to drilling coreholes and wells. Initial non-intrusive methods consist of preliminary field reconnaissance, surface geologic mapping, and assessment of Site access for conducting geophysical surveys and drilling. Geophysical survey transects (**Figure 6.1**) consist of ERT and seismic refraction surveys (**Table 6.1**). ERT will provide information on geologic structures within the Burro Canyon (e.g., faults), while seismic refraction will help delineate stratigraphic boundaries, especially the Burro Canyon-Brushy Basin contact. To the extent practicable, geophysical survey transects will be aligned with existing wells in the target zone and will act as reference points for the geophysical surveys (**Figure 6.1**). Results of the surveys, combined with other surface data and information from existing borings and wells, will provide useful information on stratigraphy and structure when drilling new coreholes and wells. Two new coreholes (or less if there are pre-existing coreholes for a given target zone) will be drilled within each target zone to provide lithologic data and core samples to support evaluation of corrective action elements. Placement of new monitoring wells is based on the following criteria:

- Along the transect of the target zones for purposes of evaluating spatial variability of the plume and the hydrogeology within a target zone to support evaluation of corrective action elements.
- Near-Field plume boundaries at a resolution that supports evaluation of corrective action elements.
- Adjacent to the LTI and UTI to improve delineation of plume egress from these source areas.
- In areas between target zones to facilitate implementation of MMR surveys that have the potential to identify preferential pathways through target zones to enhance evaluation of corrective action elements.

Proposed coreholes and wells are shown in **Figure 6.1** and listed in **Table 6.2** for each target zone. The Near-Field target zones are identified by the geophysical survey transect number (e.g., GP-9) (**Figure 6.1** and **Table 6.2**). Collection of core and installation of wells for each target zone will provide information on geology, hydrogeology, and plume extent. Core and drill cuttings will be logged for lithology and the presence and intensity of fractures. The anticipated depth of coring is 10 to 15 ft below the Burro Canyon-Brushy Basin contact. Core samples will be submitted for laboratory analysis as described in Section 4.2.1. Downhole geophysical tools will consist of caliper, temperature, SP, natural gamma ray, 16-inch and 64-inch normal resistivity, neutron, and single point resistance. These data will be used to identify variability in lithology, fracturing, porosity, and moisture content in profile.

Borehole flow logging and EC profiles will also be used to characterize preferential flow zones vertically along a borehole (**Table 6.3**). Aquifer testing, conducted on one or more of the wells within a target zone, will provide estimates of flow properties including hydraulic conductivity and aquifer storage (for tests conducted with one or more observation wells) (**Table 6.3**). Pneumatic testing methods will be implemented for this phase of evaluation since they do not require extraction and disposal of groundwater. Pneumatic aquifer tests use pneumatic pressure to stress the aquifer and can be implemented as a pneumatic slug test or pneumatic sinusoidal (PneuSine) test. A pneumatic slug test is a short-term test where water is initially evacuated from the well bore and allowed to recover. A PneuSine test relies on sinusoidally varying pressure in the test well to manipulate the water in the well and is designed to test the hydrogeologic system at larger distances from the test well than a slug test. Water levels in combination with well construction details for the new wells will provide aquifer thickness and hydraulic gradients when combined with water level data from other nearby wells. Once wells have been installed, further geophysical surveys will be implemented including MMR and resonance acoustic profiling (RAP) passive seismic surveys. These methods have the potential to provide maps of preferential groundwater pathways in the aquifer. These maps, in conjunction with other data discussed above, can inform a more focused application of any given potential technology within a target zone (**Table 6.3**).

The location and proposed use for each corehole and monitoring well is based on the Characterization CSM and how they will inform the Design CSM. In keeping with adaptive work plan implementation, as new data are collected the predetermined configuration and number of coreholes and monitoring wells may be modified to better achieve the goals of the treatability studies and to better fill gaps in the preliminary Design CSM. The rationale for proposed coreholes and monitoring wells is provided below for each Near-Field target zone.

Target Zone GP-9

The GP-9 target zone is located along the northern edge of the UTI. Proposed coreholes PC-140 and PC-141 and proposed wells PW-140 and PW-141 will provide improved characterization of hydrogeology, constituent concentrations, core samples for analysis, and groundwater and plume pathways in the area where the north plume is migrating from the UTI Source Area. PW-142 is located towards the eastern edge of the UTI and is intended to better define the eastern lateral plume extent. The wells for conducting pneumatic slug tests are PW-141 and PW-142 (**Figure 6.1**; **Table 6.3**). The Source Area well UPW-4 will be paired with well MW-102 for conducting MMR and RAP surveys to estimate preferential flow paths of impacted groundwater migrating from beneath the UTI to the north through the GP-9 target zone (**Figure 6.2**; **Table 6.3**). EC logging and flow logging will be performed on PW-140, PW-141, and OW-UT-9 (**Table 6.3**).

Target Zone GP-10

The GP-10 target zone coincides with well MW-102 (**Figure 6.1**). Proposed well PW-145 is placed towards the estimated outer edge of the uranium plume between the 0.1 mg/L and 1.0 mg/L concentration contours established in the HSSA4 Report (INTERA, 2021b) to enable more accurate identification of the lateral edge of the plume. A pneumatic slug test is proposed for PW-145. Core was previously collected at the location of MW-102 and one additional corehole is proposed at PC-144. Proposed well PW-144 is located along the transect to the northeast of MW-102 and PW-143 is located a short distance upgradient from well MW-102. The test well for conducting a PneuSine test is PW-143 (**Figure 6.1** and **Table 6.3**). OW-UT-9 will be paired with PW-146 for conducting MMR and RAP surveys to estimate preferential flow paths through the GP-10 target zone (**Figure 6.2** and **Table 6.3**). EC and flow logging will be performed on MW-102 and PW-144 (**Table 6.3**). EC and flow logging will be performed on OW-UT-9 and PW-144.

Target Zone GP-11

The GP-11 target zone coincides with well MW-101. Proposed well PW-148 is located further to the northeast to estimate the lateral plume extent, similar in nature to PW-145. Two coreholes are proposed, PC-101 and PC-147. Proposed well PW-147 is located along the transect to the northeast of MW-101 but within the main part of the plume as estimated in the HSSA4 Report (INTERA, 2021b). PW-146 will be paired with RL-3 and RL-1 for conducting MMR and RAP surveys to estimate preferential flow paths through the GP-11 target zone (**Figure 6.2** and **Table 6.3**). EC and flow logging will be performed on wells MW-101 and PW-147.

Target Zone GP-12

Three existing wells lie along the transect for target zone GP-12: MW-109, RL-3, and RL-5. A core was previously collected at the location of MW-109 and one new corehole is proposed at PW-RL3 (to be drilled adjacent to well RL-3). The north plume is conceptualized to migrate westward at this location towards the axis of the Tertiary Anticline. Proposed well PW-149 will be used to estimate the northern extent of the plume. A pneumatic slug test will be performed on PW-149. Two MMR and RAP surveys will be conducted for target zone GP-12. One survey will consist of MW-101 paired with MW-119. The second survey will consist of RL-1 paired with MW-119 (**Figure 6.2** and **Table 6.3**). EC and flow logging will be conducted on MW-109, RL-1, RL-3, and PW-149.

Target Zone GP-13

Target zone GP-13 has one existing well, MW-119. The saturated thickness at MW-119 is approximately 3 ft. This target zone is thought to represent a narrow area where from the La Sal Mountains and the north plume flows across the Tertiary Anticline and into Lisbon Valley and the SBCA, suggesting that larger volumes of water may be flowing through this zone than what the thin saturated zone at MW-119 indicates. This potentially focused flow path may be a viable location for application of a potential groundwater corrective action technology since the cross-sectional flow area of the plume may be more constrained than at other locations upgradient.

Two coreholes are proposed, PC-147 and PC-119, with corehole PC-119 co-located with well MW-119. Proposed wells PW-150 and PW-152 are for estimating plume extent. PW-151 is located in the central part of the target zone along with MW-119 to support evaluation of corrective action elements. Due to the limited saturated thickness observed at MW-119, a pneumatic aquifer test may not be feasible at some or all of the wells at this target zone. However, if a saturated thickness suitable for conducting a pneumatic test is encountered in one of the new wells, then a pneumatic slug test may be conducted. In order to conduct a pneumatic slug test, a minimum water column of approximately 5 ft above the top of the well screen is required. The minimum saturated thickness for conducting a pneumatic slug test would be approximately 10 ft if a minimum 5-foot screen were used. RL-3 will be paired with PW-153 for conducting MMR and RAP surveys to estimate preferential flow paths through the GP-13 target zone (**Figure 6.2** and **Table 6.3**). EC and flow logging will be conducted on MW-119 and PW-151.

Target Zone GP-14

Target zone GP-14 is in the SBCA and has one existing well, MW-136, and one existing corehole, C-136. One additional corehole is proposed at PC-158. The SBCA has a larger saturated thickness than the NBCA, and the plume emanating from the LTI appears to be stratified based on concentrations of constituents at co-located MW-113 and EF-6 to the southeast (**Figure 3.2** and **Figure 6.1**). To provide resolution of the plume vertically at this target zone, PW-136M will be co-located with MW-136 at an intermediate depth. Two additional deep wells will be installed at this target zone. PW-158D will be installed along the transect to the northeast of MW-136 and PW-159D will be installed downgradient from MW-136. PW-158D will provide concentration data to determine lateral plume extent and PW-159D will provide concentration data to determine plume extent in the direction of plume migration downgradient of MW-136. A PneuSine test will be conducted using MW-136 as the test well and MW-136D, PW-158D, and PW-159D acting as observation wells. MW-108 will be paired with EF-6 for conducting MMR and RAP surveys to estimate preferential flow paths through the GP-14 target zone (**Figure 6.2** and **Table 6.3**). EC and flow logging will be conducted on MW-136M, MW-136, PW-158D, and PW-159D.

Target Zone GP-15

Target zone GP-15 is aligned with existing MW-113 (intermediate) and EF-6 (deep) (**Figure 6.1**). Two new cores are proposed, PC-113 (co-located with MW-113 and EF-6) and PC-157. Two new wells are proposed along the transect for delineation of lateral plume extent and to support evaluation of corrective action elements: PW-156D and PW-157D. A PneuSine test will be conducted at EF-6 with MW-113, PW-156D, and PW-157D acting as observation wells. Two MMR and RAP surveys will be conducted for target zone GP-15. One survey will consist of MW-136 paired with PW-155D (**Figure 6.2** and **Table 6.3**). The second survey will consist of MW-136 paired with PW-154D (**Figure 6.2** and **Table 6.3**). The two MMR surveys will help estimate preferential flow paths from the LTI to the northwest into Lisbon Valley in an area that is known to be highly heterogenous, exhibit high hydraulic conductivities, and may be influenced by one or more subsidiary faults to the west of PW-154D. EC and flow logging will be conducted on PW-156D, MW-113, EF-6, and PW-157D.

Target Zone GP-16

Target zone GP-16 is aligned with existing wells MW-117M, MW-117D, and EF-3A. The transect runs northward and to the west of the LTI dam where two coreholes and two wells are proposed, PC-154 and PC-155 and PW-154D and PW-155D, respectively (**Figure 6.1**). The two new coreholes and wells are located in an area where the plume from the LTI is conceptualized to bifurcate with one branch migrating to the northwest and the other branch migrating into the area near EF-3A/MW-117M/MW-117S. Two MMR and RAP surveys will be conducted for target zone GP-16. One survey will consist of EF-6 paired with LPW-8 to evaluate preferential flow paths from the LTI to the northwest. The second survey will consist of EF-6 paired with EF-3A (**Figure 6.2**; **Table 6.3**). The MMR survey between EF-6 and EF-3A will help to delineate whether a transport pathway may exist between EF-6 and the high-concentration part of the plume near EF-3A/MW-117M/MW-117S, or if the area near EF-3A represents a zone of mill-impacted groundwater that is structurally constrained and is limited in its contribution to the portion of the south plume actively migrating to the northwest in Lisbon Valley. EC and flow logging will be conducted on wells PW-154D and PW-155D.

6.1.2 Far-Field Area

The Far-Field Area, target zone GP-17, is a critical area for evaluating potential groundwater corrective action elements due to its location at the northern preliminary LTSM boundary, near wells MW-124 and MW-138S/D (**Figure 6.1**). It is near this location that the north plume migrates into the SBCA and turns to the northwest where it crosses the preliminary LTSM boundary. The evaluation of the effectiveness of corrective action technologies at the Far-Field Area follows the same overall approach to characterization of hydrogeology, plume extent, and transport pathways as described above for the Near-Field Area. A previous electrical resistivity survey was conducted near well MW-124 (INTERA, 2021b; **Figure 6.1**) such that only a seismic refraction survey is proposed for the GP-17 target zone (**Figure 6.1**).

Two pre-existing cores have been collected from the GP-17 target zone, C-124 and C-138 (**Figure 6.1**) and no additional coreholes are planned. Three well clusters are proposed for this area, each with screens at two depths. MW-124 is screened in the intermediate zone, so a deep well is proposed for this location, PW-124D. A two-well cluster is to be located to the west of MW-124 along the GP-17 transect, PW-160M/D. A PneuSine test will be conducted at MW-138D (**Table 6.1**) with other wells in the target zone acting as observation wells. Two MMR and RAP surveys will be conducted for target zone GP-17. One survey will consist of PW-153 paired with MW-

138D. The second survey will consist of PW-153 paired with MW-135 (**Figure 6.2**; **Table 6.3**). The two MMR surveys will help delineate groundwater and plume pathways across the preliminary LTSM boundary. The north plume has been detected at wells MW-124, MW-138S, and MW-138D. The survey between wells PW-153 and MW-138D will help to establish the pathway more clearly near MW-138D that may impact the placement of a corrective action technology. The MMR survey between wells PW-153 and MW-135 will help to delineate whether a groundwater pathway also exists along the northeast side of Lisbon Valley adjacent to the Spring Fault identified near MW-130 and MW-135 (**Figure 6.2**). Delineation of this pathway is important for two reasons. First, if a groundwater pathway is detected along the northeast side of Lisbon Valley near the Spring Fault, the plume may also be migrating along that pathway to north of well MW-124 and east of wells MW-138S and MW-138D. Delineation of this pathway, if it exists, would be needed for evaluation potential groundwater corrective action technologies at the preliminary LTSM boundary. The second reason for evaluating the existence of a groundwater pathway adjacent to the Spring Fault has to do with the potential for the plume to eventually migrate from the deep zone BCA to the shallow zone BCA along the Spring Fault further northwest near WCW, as was determined from flow and transport model in the HSSA4 (INTERA, 2022b). If there is potential for vertical upwelling of deep zone BCA groundwater further northwest (see Section 6.1.3 for proposed evaluation of the upwelling pathway), the potential for the plume to migrate toward the upwelling zone is important for evaluation of groundwater correction action technologies that may need to be implemented along that pathway. EC and flow logging will be conducted on all wells associated with this target zone.

6.1.3 North, Northwest, and LVF Areas

The areas north and northwest of the preliminary LTSM boundary (**Figure 2.1**) are identified in the preliminary Design CSM as potential focus areas for future corrective action because they represent potential exposure pathways for mill-impacted groundwater. In addition, the LVF Area, shown as the area along the footwall of the LVF (**Figure 2.1**), is included in the investigation to evaluate the potential for SBCA groundwater to flow across the LVF in that area, which may represent a flow path to potential receptors for mill-impacted groundwater. The goals of the hydrogeologic evaluation of the North, Northwest, and LVF Areas are to inform the Design CSM and groundwater flow and transport model so these tools can be used to evaluate corrective action elements farther from the plume. The methods employed will be generally the same as those proposed for the Near-Field and Far-Field Areas as described above, except for the need to define the plume extent in these areas.

6.1.3.1 North Area

As noted previously (Section 3.2.3.2) if Site or regional groundwater flow conditions were to change, the north plume could conceivably shift further north of wells RL-4, RL-5, and MW-101 (**Figure 6.3**), before flowing westward across the anticline into Lisbon Valley. Data gaps need to be addressed in the North Area for evaluation of potential corrective action technologies should the north plume begin migrating in that direction. Three wells are proposed for the North Area (**Figure 6.3**) for data collection to fill data gaps: PW-161, PW-162, and PW-163. Data collection will include lithology from drill cuttings, water levels, and hydraulic conductivity estimates from pneumatic aquifer tests. The data collected will be used to update the Site flow and transport model and will improve our understanding of groundwater pathways in the area. In conjunction with data collected to fill geochemistry-related data gaps (Section 6.2.3), the data collected in the North Area will support evaluation of corrective action elements.

6.1.3.2 Northwest and LVF Areas

There are several goals for conducting further investigations in the Northwest Area, including the following:

- Confirm the Characterization CSM assumption that deep zone groundwater migrates upwards into the shallow zone BCA near the Spring Fault.
- Confirm the Characterization CSM assumption that BCA groundwater from the Lisbon Valley discharges to surface water near Rattlesnake Spring.
- Confirm the Characterization CSM assumption that the LVF is a groundwater flow barrier adjacent to the deep zone BCA underlying WCW.
- Confirm the Characterization CSM assumption that shallow zone groundwater crossing the LVF near WCW enters the Navajo and flows westward towards the East and West Wells.

Proposed wells in the Northwest Area are PW-164 through PW-167 (**Figure 6.3**). Proposed well cluster PW-164S/D is located adjacent to the Spring Fault and will be used to determine if groundwater from the deep zone BCA northwest of well MW-130 and east of wells MW-134D/S migrates upward into the shallow zone BCA around or through the Burro Canyon Fines 2, creating a potential exposure pathway that crosses the LVF into the Navajo. The wells will be installed along the GP-18 seismic geophysical survey transect (**Figure 6.3**). The seismic survey will be used to map the depth of the BCA along the transect and is co-located with a previous Electrical Resistivity Mapping (ERM) transect (**Figure 6.3**). Drill cuttings will be logged during drilling and used to evaluate lithology within the BCA. The completed wells will be screened in the deep and shallow BCA zones and water levels will be used to calculate the vertical hydraulic gradient. A PneuSine test will be conducted in PW-164D with well PW-164S acting as an observation well (**Table 6.4**). Results of the aquifer test will be used to determine hydraulic connection between the two well screens and to monitor for a hydraulic response to the Spring Fault which acts as an impermeable barrier to the southeast near wells MW-130 and MW-139. An MMR survey between PW-164D and MW-132S will help to further delineate whether a groundwater pathway exists from the deep zone BCA into the shallow zone BCA and across the LVF (**Table 6.3**).

As discussed in the CSM (Section 3.2.3), groundwater flow in the deep zone BCA is hypothesized to continue migrating to the northwest in the general direction of WCW and Rattlesnake Spring (**Figure 3.1** and **Figure 3.4**). To evaluate deep zone BCA groundwater pathways in this area, 2 geophysical transects (GP-19 and GP-20) extend across the splay fault aligned with Rattlesnake Spring (**Figure 6.3**). The ERT and seismic refraction data will help understand the stratigraphy and structure in this area. Two well clusters are proposed, PW-167S/D and PW-168S/D, placed on each side of the splay fault (**Figure 6.3**). Drill cuttings from the boreholes will be used to identify lithology and, if possible, the degree of fracturing. The wells will be used to conduct a PneuSine test across the fault to evaluate the potential for cross-fault groundwater flow. Four MMR surveys will be conducted in this area and will consist of MMR surveys between proposed wells PW-167D and PW-168D and Rattlesnake Spring (pending landowner permission) and between those two wells and WCW to estimate potential groundwater pathways from the deep zone to the spring and WCW (**Figure 6.2**). The four MMR surveys are designed to help establish preferential pathways for groundwater on each side of the splay fault and whether those pathways lead to Rattlesnake Spring or directly to WCW, or both.

To better understand groundwater flow and chemistry in the Navajo southwest of the LVF, new wells PW-165 and PW-166 will be drilled and installed (**Figure 6.3**). Drill cuttings will be used for lithology interpretation and the wells will provide a measure of the thickness of the Navajo. The wells will provide water levels in the Navajo and pneumatic slug tests will be conducted at each well to provide hydraulic conductivity estimates.

To better understand the hydraulic nature of the LVF and the potential for groundwater to flow through the fault or if the fault acts as a hydraulic barrier, aquifer tests will be conducted in wells adjacent to the fault. Three well locations are targeted for conducting this assessment, PW-133D, PW-169, and PW-174 (**Figure 6.3**). Proposed well PW-133D is in the Northwest Area near wells MW-133ALL/S and MW-132ALL/S. PW-133D will be drilled into the headwall side of the LVF near MW-133S and will be screened at the base of the BCA. A PneuSine test will be conducted in PW-133D with the other wells in this area acting as observation wells. MW-132S is screened in the Navajo and will be monitored for a response across the LVF from the test well. PW-133D will be screened below the Burro Canyon Fines 2 that acts as an aquitard in the BCA in this area. MW-133S, which is screened above the aquitard, will be monitored for a vertical response through the aquitard. PW-133D will also be monitored for a hydraulic response that may indicate the fault is acting as a barrier to flow.

Proposed wells PW-169 and PW-170 are located in the LVF Area (**Figure 2.1, Figure 6.3**) and will be installed adjacent to and in the footwall side of the LVF. Similar to proposed well PW-133D, these two wells will be used to evaluate the potential for cross-fault groundwater flow, should there be sufficient water in the Navajo at PW-169 or in the Wingate Formation at PW-174. If sufficient groundwater is encountered, PneuSine tests will be conducted. The wells will be screened and completed as monitoring wells even if water is not encountered during drilling since water levels in other wells at the Site have been shown to fluctuate due to variable recharge conditions and the observation of any water in wells PW-169 and PW-174 would be useful information and water samples could be collected and analyzed to provide a comparison of geochemistry with the wells in the BCA opposite the fault.

6.2 Hydrogeochemical Investigations

The goals of the hydrogeochemical evaluation of the Near-Field and Far-Field Areas are to enhance the preliminary Design CSM with information that helps predict how corrective action elements might be affected by the geochemistry of aquifer water and solids. Details specific to the Near-Field and Far-Field Areas are described below.

6.2.1 Near-Field Area

The Near-Field Areas of the north and south plume are shown in **Figure 2.1**. Hydrogeochemical samples will consist of groundwater from current and newly installed wells as well as core intervals from proposed coreholes. The new monitoring wells and coreholes will be drilled in the proposed locations indicated in **Figure 6.1**. Representative subsamples of cores will be collected after viewing the entire core and determining intervals within the Burro Canyon that show differing rock type, mineralogy, textures, and physical disturbance such as fracturing. The anticipated depth of coring is 10 to 15 ft below the Burro Canyon-Brushy Basin contact. Groundwater samples will be analyzed for the same water quality and field parameters as other wells at the Site (e.g., INTERA, 2021b). New core samples may be analyzed along with samples of core collected from previous investigations (e.g., Montgomery & Associates, 2014; INTERA, 2021b).

Core samples will be analyzed for the following:

1. solid phases that host uranium and other COCs;
2. sequential extraction tests for uranium and other COCs, major ions, and economic commodities (e.g., rare earth elements);
3. flow-through column leach tests (including stop-flow events) for uranium, other COCs, and major ions using simulated pore water over multiple pore volumes;
4. total and effective porosity;
5. moisture content;
6. bulk density;
7. particle size distribution;
8. specific surface area; and
9. hydraulic conductivity.

The methods used to obtain this information will be the same as or similar to those listed in **Table D.1** (**Appendix D**). More detail about these methods is provided in **Appendix D**.

6.2.2 Far-Field Area

The Far-Field Area is shown in **Figure 2.1**. Hydrogeochemical samples of groundwater and core intervals will be like those collected from the Near-Field Areas, and the sample analysis described for the Far-Field samples with be the same as that for the Near-Field samples (Section 6.2.1).

proposed new monitoring wells and coreholes will be drilled at the locations indicated in **Figure 6.1**.

6.2.3 North, Northwest, and LVF Area

The North and Northwest Areas (**Figure 2.1**) are identified in the preliminary Design CSM as target zones for corrective action because of the possible exposure pathways for mill-impacted groundwater. The overarching goals of the hydrogeochemical evaluation of the North and Northwest Areas are to provide information that can be used to determine major groundwater flow pathways (including the impact of faulting) and potential exposure points. Hydrogeochemical samples will consist of groundwater from current and newly installed wells and core intervals from proposed coreholes. The proposed new monitoring wells and coreholes will be drilled at the proposed locations indicated in **Figure 6.3**. Core samples will be collected from select coreholes and depths to provide comparable information for Burro Canyon solids both outside of and within mill-impacted areas. Groundwater samples from existing and new wells will be analyzed for the same water quality and field parameters as other wells at the Site (e.g., INTERA, 2021b). New core samples may be analyzed along with samples of core collected from previous investigations (e.g., INTERA, 2021b).

Core samples will be analyzed for the following:

1. solid phases that host uranium and other COCs;
2. sequential extraction tests for uranium, other COCs, and major ions;
3. flow-through column leach tests (including stop-flow events) for uranium, other COCs, and major ions using simulated pore water over multiple pore volumes;
4. total and effective porosity;
5. moisture content;
6. bulk density;
7. particle size distribution;
8. specific surface area; and
9. hydraulic conductivity.

The methods used to obtain this information will be the same as or similar to those listed in **Table D.1** (**Appendix D**). More detail about these methods is provided in **Appendix D**.

In addition to the sampling and analysis described above, the North and Northwest Areas will also be surveyed for hydrologic (i.e., environmental) tracers in samples of surface water and groundwater. Hydrologic tracers can provide information on groundwater sources and flow pathways, and possibly residence times. As a result, hydrologic tracers could be important to the Design CSM because they may provide evidence or lack thereof for hydrologic connections between the deep BCA and possible future exposure points in the North and Northwest Areas.

Samples for hydrologic tracers will be collected from existing sample locations in the Northwest Area (**Table 6.4** and **Figure 6.4**) and newly installed wells in the North and Northwest Areas (**Figure 6.3**).

Potential hydrologic tracers to evaluate in the North and Northwest Areas are shown in **Table D.3** (**Appendix D**). **Table D.3** shows examples of regional studies where a given tracer or set of tracers was implemented. The tracers in **Table D.3** are presented in order of preference (from top to bottom) based on the relative ease of implementation. Tracers that are easier to implement are generally those with relatively straightforward sampling procedures and data analysis, are relatively inexpensive, and can be measured by more than a few specialized laboratories.

The hydrologic tracers recommended for evaluation in the North and Northwest Areas consist of the following:

1. constituent ratios and/or PCA of routine water quality results;
2. stable oxygen and hydrogen isotopes of water;
3. sulfur and oxygen isotopes of sulfate;
4. strontium-87 to strontium-86 ratios ($^{87}Sr/^{86}Sr$); and
5. tritium and helium-3.

These tracers can provide information on water sources and processes, and tritium/helium-3 has the added benefit of potentially providing an apparent or relative age for groundwater recharge.

6.3 Near-Field and Far-Field Treatability Tests

Bench-scale investigations of amendment solutions will be performed via batch tests, flow-through column tests, leach solution analysis during testing, and chemical and mineralogical analysis of solid materials during and following testing to determine sequestered forms of uranium and other COCs. As part of the CAAWP data collection, benchtop tests with amendment solutions will be conducted on Near-Field and Far-Field core samples to assess the sorption-desorption rates and reaction kinetics of sequestering uranium and other COCs. Additionally, impacted groundwater from select locations (**Appendix D, Table D.4**) will be tested for the efficacy of ex situ treatment. Treatability tests will assess the viability and efficiency of the corrective action technologies which, based on results from the laboratory testing described in Section 6.2, may be successful at controlling the groundwater plume. The goals for the treatability tests for the Near-Field and Far-Field will be to evaluate the applicability and capacity of corrective action technologies to either reduce or immobilize uranium and other COCs in the Near-Field and Far-Field groundwater plume. Data from treatability studies will be used as an input to the CAA.

6.3.1 In Situ Treatability Studies

Corrective action technologies for the Near-Field and Far-Field Areas that involve in situ treatments include a number of different reagents, slurries, or injectates that can be tested for the treatment of uranium and other COCs for the purpose of immobilization from further migration within the BCA. Selection of the treatability tests will be based on the laboratory analyses described in Section 6.2 that will be conducted on bedrock core samples collected during the CAA field program, described in Section 6.1 (**Figure 6.1**), and will be prepared as described in **Appendix D**. The bedrock core samples will be collected from select coreholes (**Figure 6.1**) and screened based on field and preliminary laboratory results prior to use in treatability tests for sequestration of uranium and the other COCs. A subset of solid samples will undergo treatability tests that represent the observed range in hydrogeologic and hydrogeochemical field conditions, including COC concentrations. The decision-support tool provided in **Figure 5.3** will be used to select the treatability tests for the Near-Field and Far-Field Areas. The in situ treatability tests consist of the potential technology bench-scale tests described in Section 5.3.3, with the exception of ISGR, or technologies that are only implementable within the vadose zone.

6.3.2 Ex Situ Treatability Studies

Treatability tests for other ex situ corrective action technologies in the Near-Field and Far-Field Areas will be performed to evaluate the effectiveness of treatment for the removal of uranium and other COCs for pump-and-treatment scenarios. The objectives for aboveground (ex situ) treatability tests are three-fold:

- Perform bench-scale tests to determine the removal rates of uranium and other COCs for each corrective action technology;
- Estimate the rate and characteristics of waste generation, including 11e.2 material, for a particular corrective action technology and ex situ treatment option; and
- Generate data needed to estimate the life cycle costs for a particular corrective action technology for decision support.

Impacted groundwater from wells in the North Near-Field Area (MW-102 and RL-3), the South Near-Field Area (EF-6 and MW-136), and the Far-Field Area (MW-124) will be tested for ex situ treatment (**Figure 6.1**). These wells were chosen based on a range of chemical compositions that may control the performance of corrective action technologies (**Table D.4**, **Appendix D**). Groundwater from these wells will be collected per the sample volume and preservation criteria established by the contracted treatability testing laboratory(ies). The decision-support tool provided in **Figure 6.5** will be relied on to select the ex situ treatability tests that will be best for the known hydrogeochemical parameters of the Near-Field and Far-Field Areas. The ex situ treatability tests consist of the following potential technology bench-scale tests:

- Evaluation of uranium and other COCs removal via ion exchange resins (Campbell et al., 2018).

- Removal of uranium and other COCs via membrane filtration technologies (de Lurdes Dinis and Fiúza, 2021).
- ZVI fixed-based column reactor (ITRC, 2017).
- Chemical precipitation of uranium and other COCs (Sorg, 1992).

Examples of methods and approaches for ex situ treatability tests are provided in **Appendix D**. The treatability tests and associated laboratory work will focus on the efficacy of sequestration for all COCs. If any treatability test appears to make any one of the COCs more mobile, then that information will be considered in the alternatives analysis.

7.0 DOCUMENTATION AND REPORTING

This section describes how the data collection activities described in the CAAWP will be documented and reported. A Field Investigation Report will be developed to document the field activities and data collection described in this CAAWP, specifically the drilling, coring, geophysical surveys, aquifer testing, sample collection and analysis, and bench-scale treatability study tests. **Figure 7.1** provides a road map for the Site groundwater corrective action process, including the role of the Field Investigation Report. The report is anticipated to be organized as follows:

1) Introduction
2) Geophysical Survey Results
3) Drilling Field Program Preparation Activities
4) Off-Site Borrow Area and Potential Repository Investigation
    4.1. Boreholes
    4.2. Soil Sample Results
5) Soil Moisture Sensor Transects
6) Coring Operations
    6.1. Downhole Geophysical Logging
    6.2. Lithology
    6.3. Sample Collection
7) Monitoring Well Drilling and Installation
    7.1. Downhole Geophysical Logging
    7.2. Monitoring Well Development
8) Testing and Analysis
    8.1. MMR/RAP Groundwater Flow Results
    8.2. Pneumatic Testing Results
9) Sample Collection and Results
    9.1. Hydrogeological Samples

9.2. Geochemical Samples

10) Treatability Test Results (as available)

11) Summary

Findings presented in the Field Investigation Report will be used to update the Design CSM and the groundwater flow and transport model to improve the utility of these tools in the development, evaluation, and selection of a proposed groundwater corrective action (see **Figure 7.1**).

8.0 CORRECTIVE ACTION ASSESSMENT SCHEDULE

The estimated schedule for the components of this CAAWP, and the general CAA process leading to an approved GCAP, is provided in **Appendix E**. The timeframes provided in **Appendix E** are preliminary and will be updated, with appropriate consultation with DWMRC, as RAML progresses through the CAA process presented on **Figure 7.1**. The schedule presents the general sequencing and milestones associated with the CAA process. The CAAWP field program is dependent on BLM approval of the MPO amendment, which could take up to 2 years after submittal. RAML has already engaged the BLM Moab Office and is currently completing many of the required biological and cultural resources surveys to reduce delays to initiation of the field program. Once the MPO is approved by BLM, and this CAAWP is approved by DWMRC, the CAAWP field program may take two field seasons to complete the proposed coring, drilling, and testing activities as described in Section 5.0 and Section 6.0. RAML will sequence the field work, starting on RAML-owned and private property, if necessary.

After DWMRC's approval of this CAAWP, the field preparation activities for the CAAWP field work will then begin. These preparation activities will consist of developing and submitting the appropriate permits and regulatory requirements such as, but not limited to, ground disturbance surveys, monitoring well installation permits, wildlife surveys, and any other permits or requirements necessary. Non-intrusive field work, such as geologic reconnaissance and surface geophysical surveys may also commence. The CAAWP field work, which will involve drilling, coring, well development, aquifer testing, and sampling, will take place once the required permits have been acquired and approvals obtained. A Field Investigation Report (Section 7.0) will be developed after the field program has been completed and will summarize the CAAWP field program and laboratory and bench scale testing (or treatability studies) results, as available.

The data collected during the CAAWP field program, as well as data collected during desktop studies, will be used to update the CSM and the groundwater flow and transport model to better evaluate the corrective action elements and develop a Corrective Action Assessment Plan (CAAP) (**Figure 7.1**). RAML anticipates DWMRC review and approval of the CAAP based on the assessment (or testing) work proposed in the CAAWP. Pilot testing and/or additional treatability testing may be proposed in the CAAP and would be executed to help select a corrective action alternative (**Figure 7.1**). The timeframe required to implement, execute, and evaluate treatability studies and pilot testing is highly uncertain at this time as it is dependent on timeframes needed for data analysis and specifications of the to-be-determined pilot testing scope (**Appendix E**). After the necessary testing has been conducted and an alternative selected, RAML will develop and submit a Corrective Action Assessment Report (CAA Report) for DWMRC review. The CAA Report, with DWMRC's input, will lead to the development of a proposed GCAP for the Lisbon Site (**Figure 7.1**). After the GCAP is reviewed and approved by DWMRC and the public comment period is over, RAML anticipates an approved GCAP for the Site (**Figure 7.1** and **Appendix E**).

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Figures

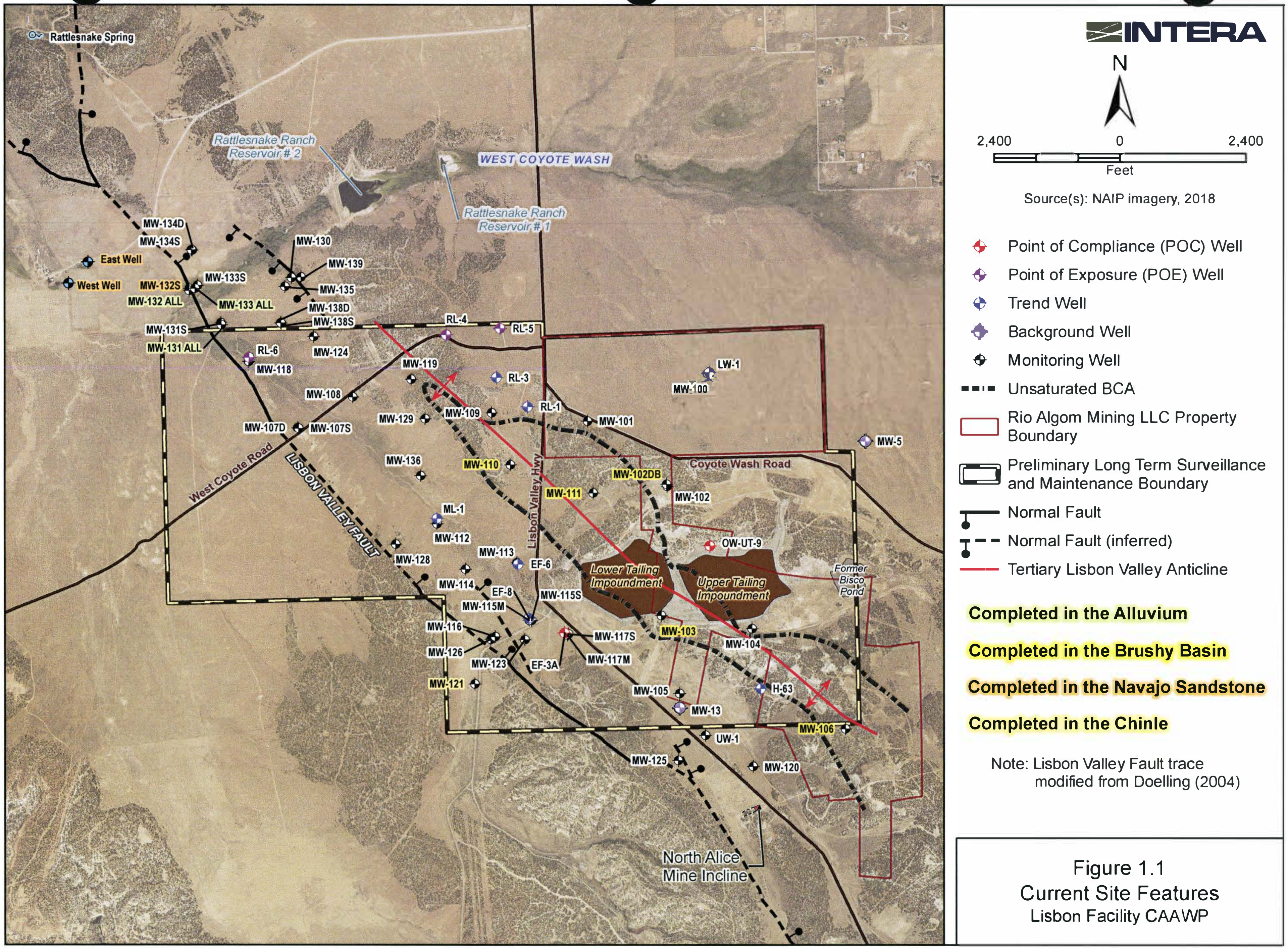

Figure 1.1
Current Site Features
Lisbon Facility CAAWP

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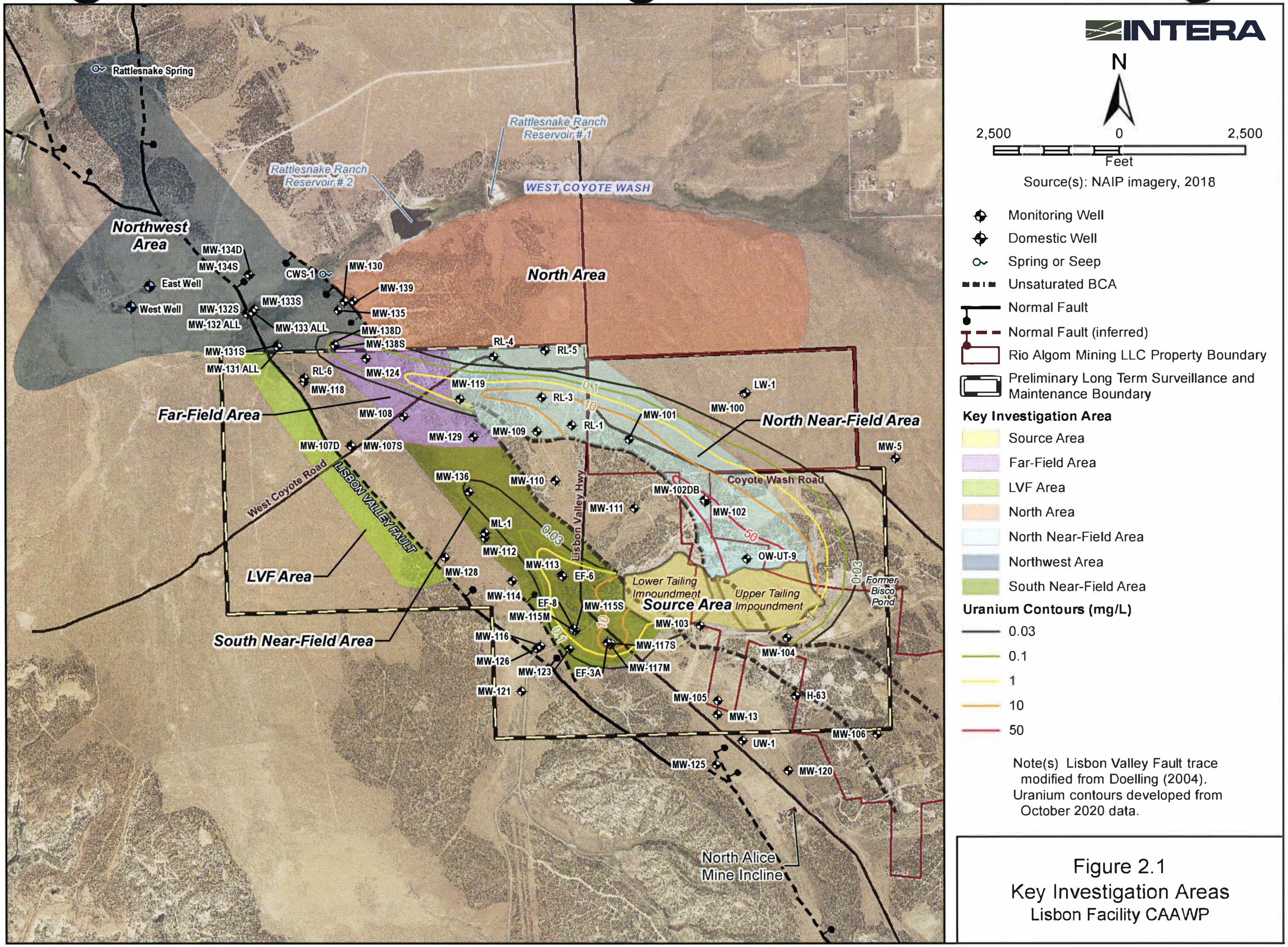

Figure 2.1
Key Investigation Areas
Lisbon Facility CAAWP

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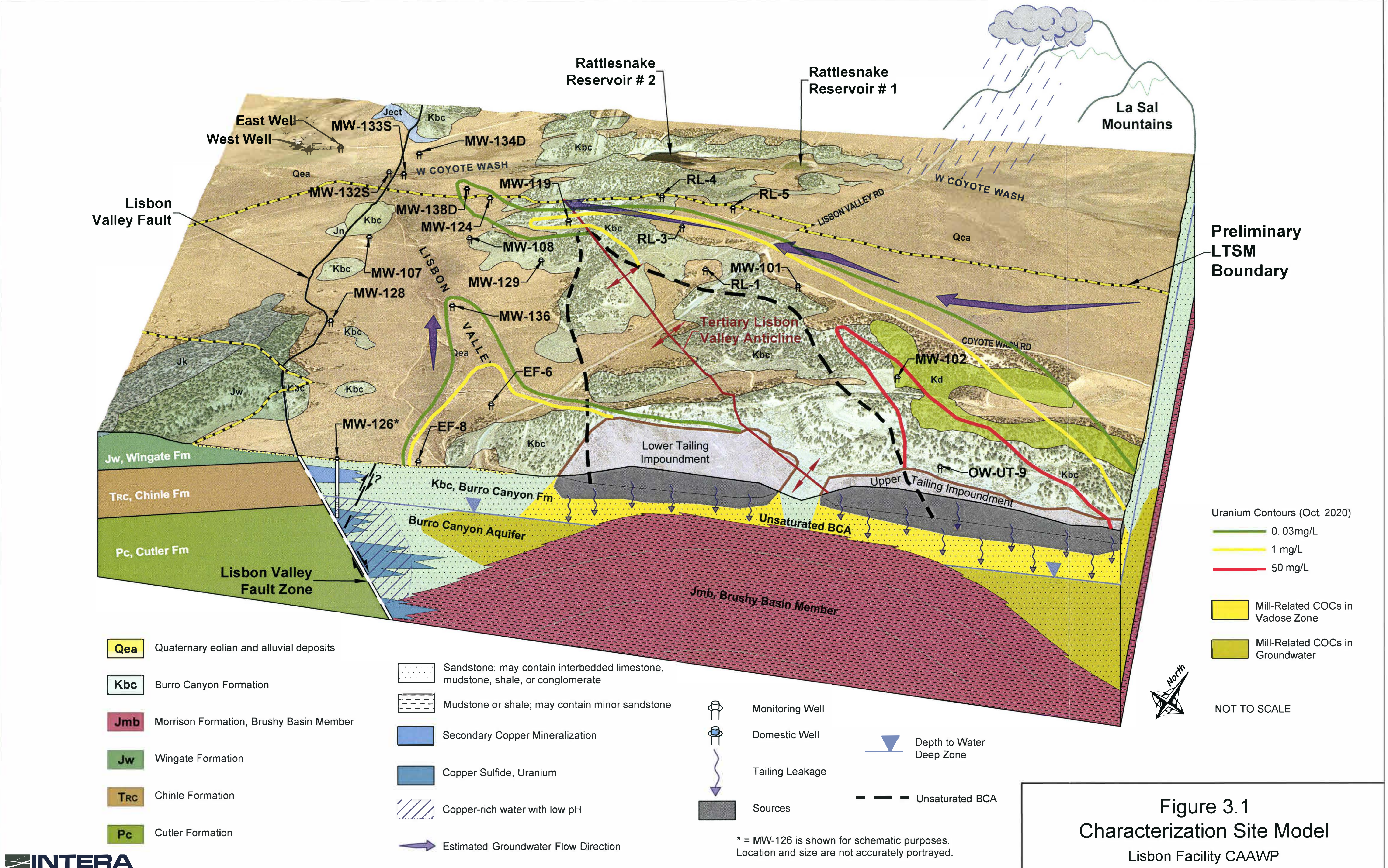
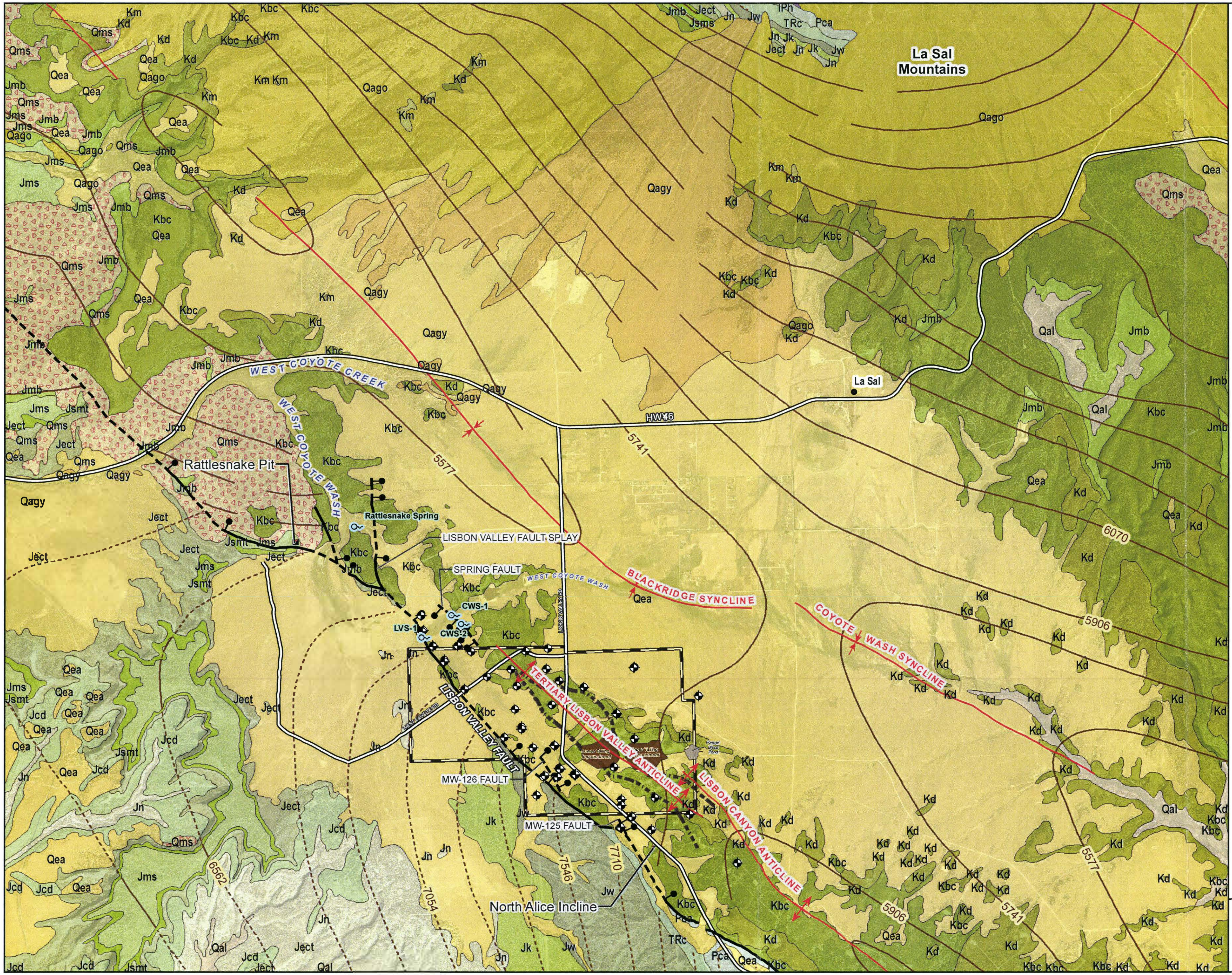


Figure 3.1
Characterization Site Model
Lisbon Facility CAAWP



INTERA

N

4,500 0 4,500

Feet

Source(s): Doelling, 2004

- Monitoring Well
- Spring or Seep
- Unsaturated BCA
- Preliminary Long Term Surveillance and Maintenance Boundary
- Normal Fault
- Normal Fault (inferred)
- Fold Axis
- Qal - Stream Alluvium
- Qagy - Younger Alluvial Gravel Deposits
- Qago - Older Alluvial Gravel Deposits
- Qea - Mixed Eolian and Alluvial Deposits
- Qms - Slumps and Landslides
- Km - Mancos Shale
- Kd - Dakota Sandstone
- Kbc - Burro Canyon Formation
- Jmb - Brushy Basin Member of Morrison Formation
- Jms - Salt Wash Member of Morrison Formation
- Jsmt - Tidwell Member of Morrison Formation and Summerville Formation, undivided
- Jsms - Summerville Formation and Tidwell and Salt Wash members of Morrison Formation
- Ject - Slick Rock Member of Entrada Sandstone and Moab Member of Curtis Formation
- Jcd - Dewey Bridge Member of Carmel Formation
- Jn - Navajo Sandstone
- Jk - Kayenta Formation
- Jw - Wingate Sandstone
- TRc - Chinle Formation
- Pca - Arkosic facies of Cutler Formation
- IPh - Honaker Trail Formation

Structural Contours, Contour Interval 164 feet (50 meters)

- structural contour, top of the Jsmt
- structural contour, depression
- structural contour, projected above ground surface

Note: Lisbon Valley Fault trace modified from Doelling (2004)

Figure 3.2
Site Geologic Map
Lisbon Facility CAAWP

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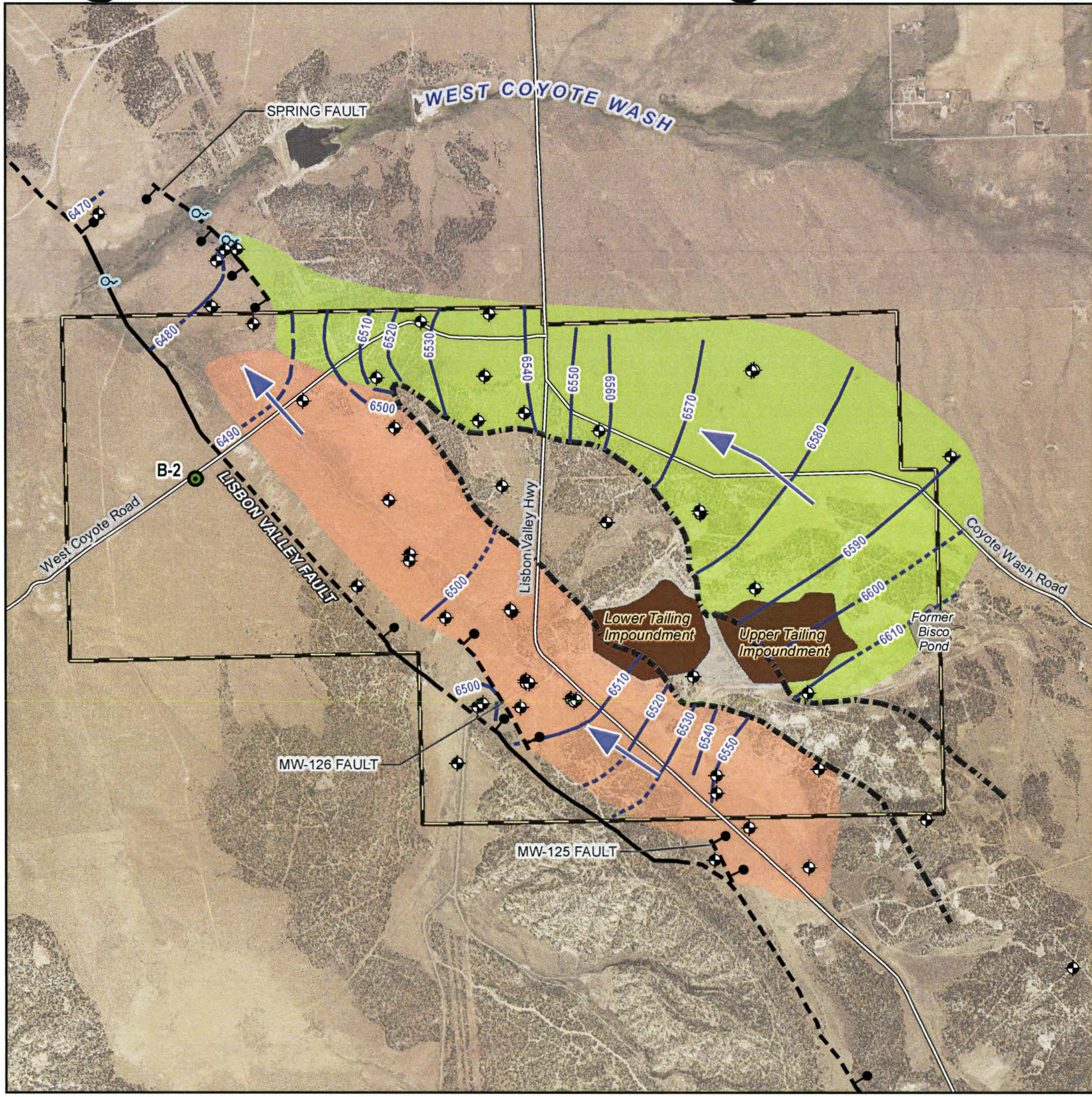

INTERA

N

2,000 0 2,000
Feet

Source(s): NAIP imagery, 2018

- Monitoring Well
- Boring
- Spring or Seep
- Unsaturated BCA
- Preliminary Long Term Surveillance and Maintenance Boundary
- Normal Fault
- Normal Fault (inferred)
- North Burro Canyon
- South Burro Canyon
- Groundwater Elevation 2020 Qrt4 (feet above mean sea level)
- Inferred Where Structures May be Isolating Groundwater Flow
- Inferred Groundwater Elevation Contour
- Estimated Groundwater Flow Direction

Note: Lisbon Valley Fault trace modified from Doelling (2004)

Figure 3.3
Deep Zone Aquifer Site
Water Level Contours
Lisbon Facility CAAWP

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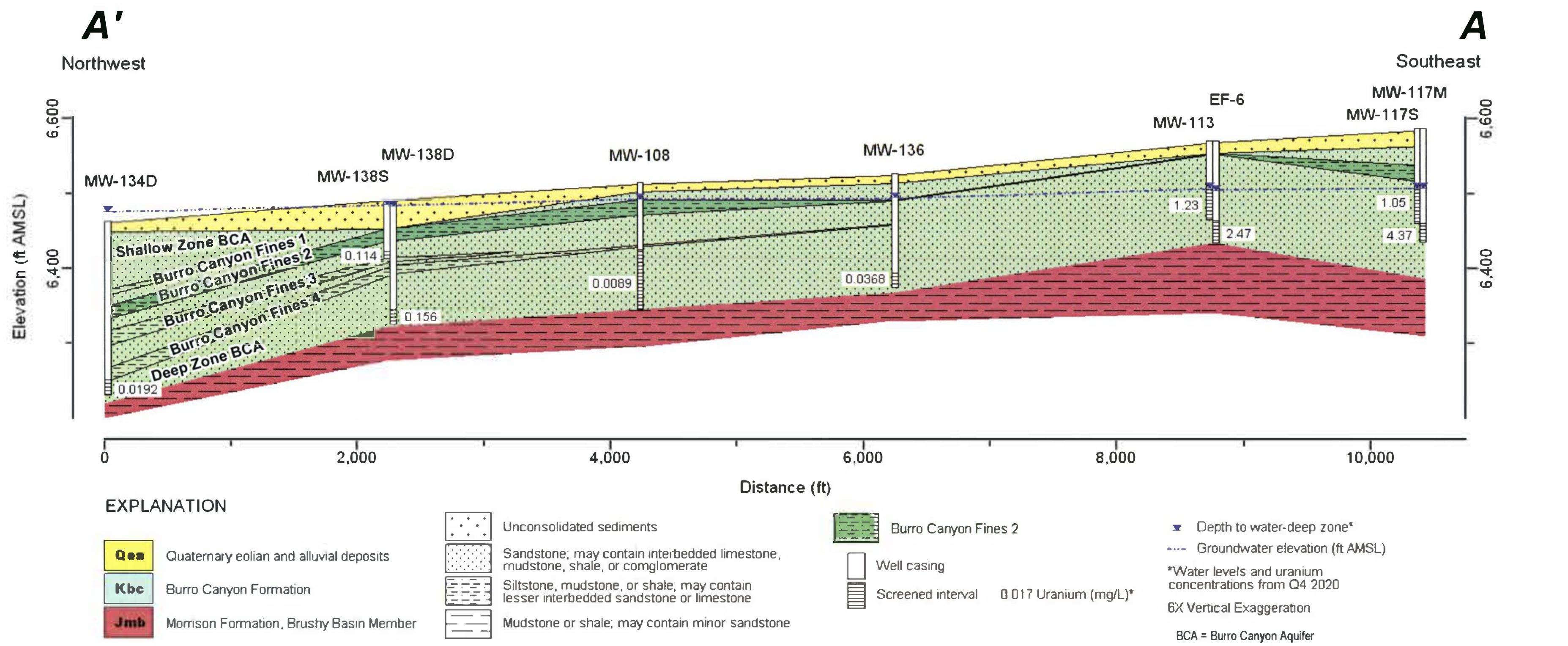

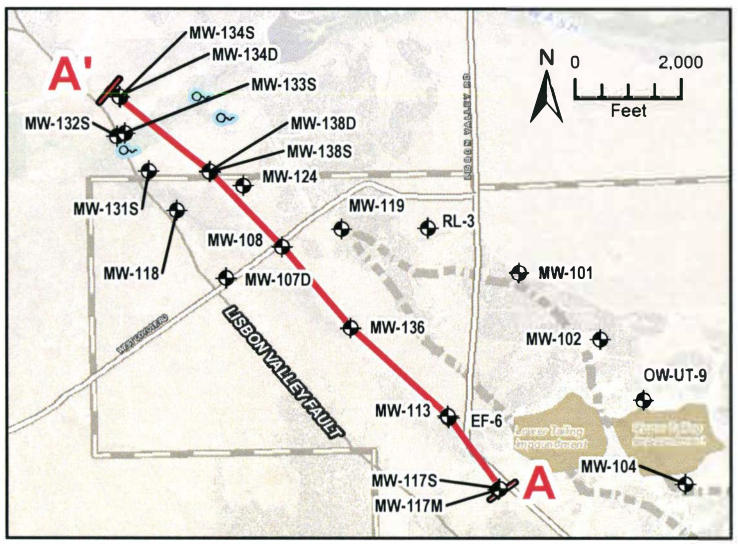

Cross Section Location Map

INTERA

Figure 3.4
Geologic Cross Section A-A'
Lisbon Facility CAAWP

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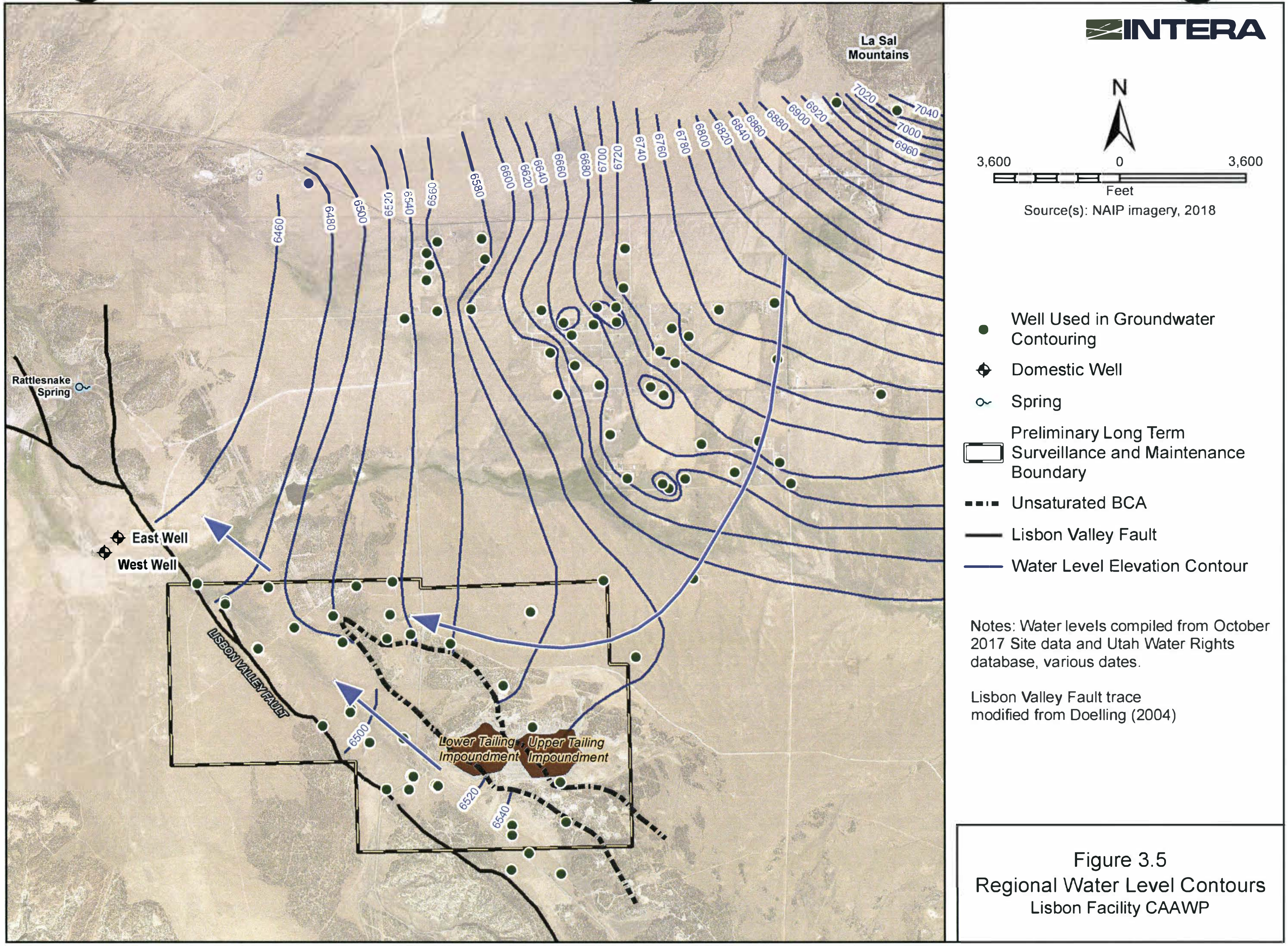
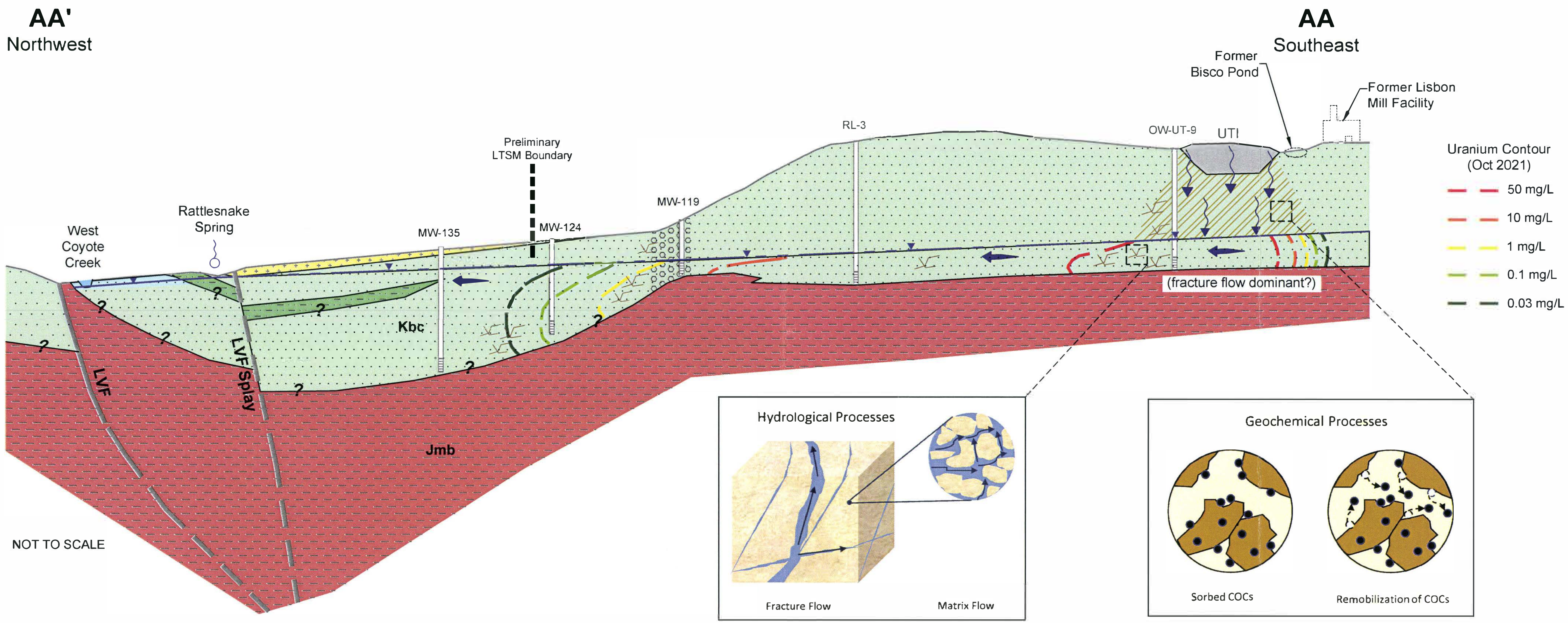


Figure 3.5
Regional Water Level Contours
Lisbon Facility CAAWP



Qea — Quaternary eolian and alluvial deposites

Kbc — Burro Canyon Formation

Jmb — Morrison Formation, Brushy Basin Member

Unconsolidated sediments

Sandstone; may contain interbedded limestone, mudstone, shale or conglomerate

Siltstone, mudstone, or shale; may contain lesser interbedded sandstone or limestone

Mudstone or shale; may contain minor sandstone

Burro Canyon Fines 2

Well casing

Screened interval

Groundwater Flow Direction

Water Table

Groundwater elevation

Spring

Lisbon Valley Fault (LVF)

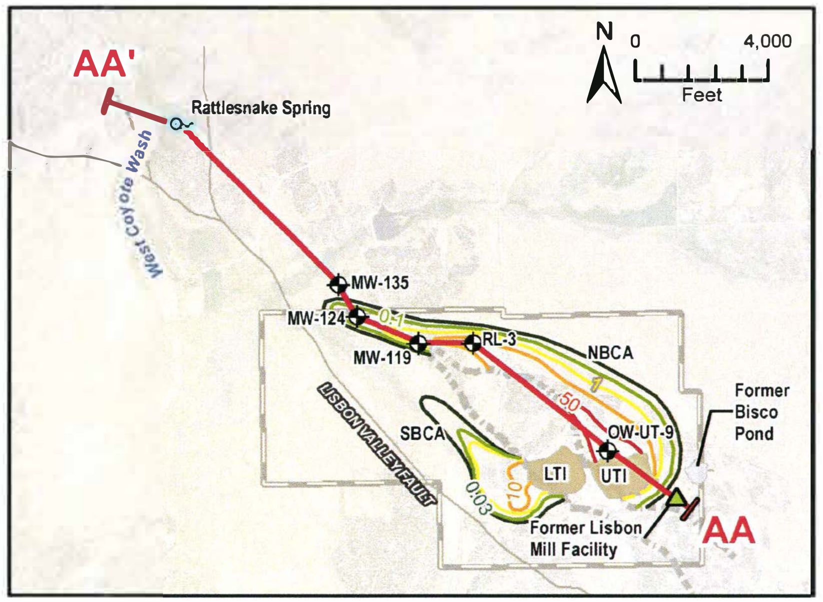
Upper Tailing Impoundment (UTI) - Primary Source

Silicified Sandstone

Possible Secondary Source or COC Sink in Vadose Zone

COC Seepage

Fractures / Small Faults

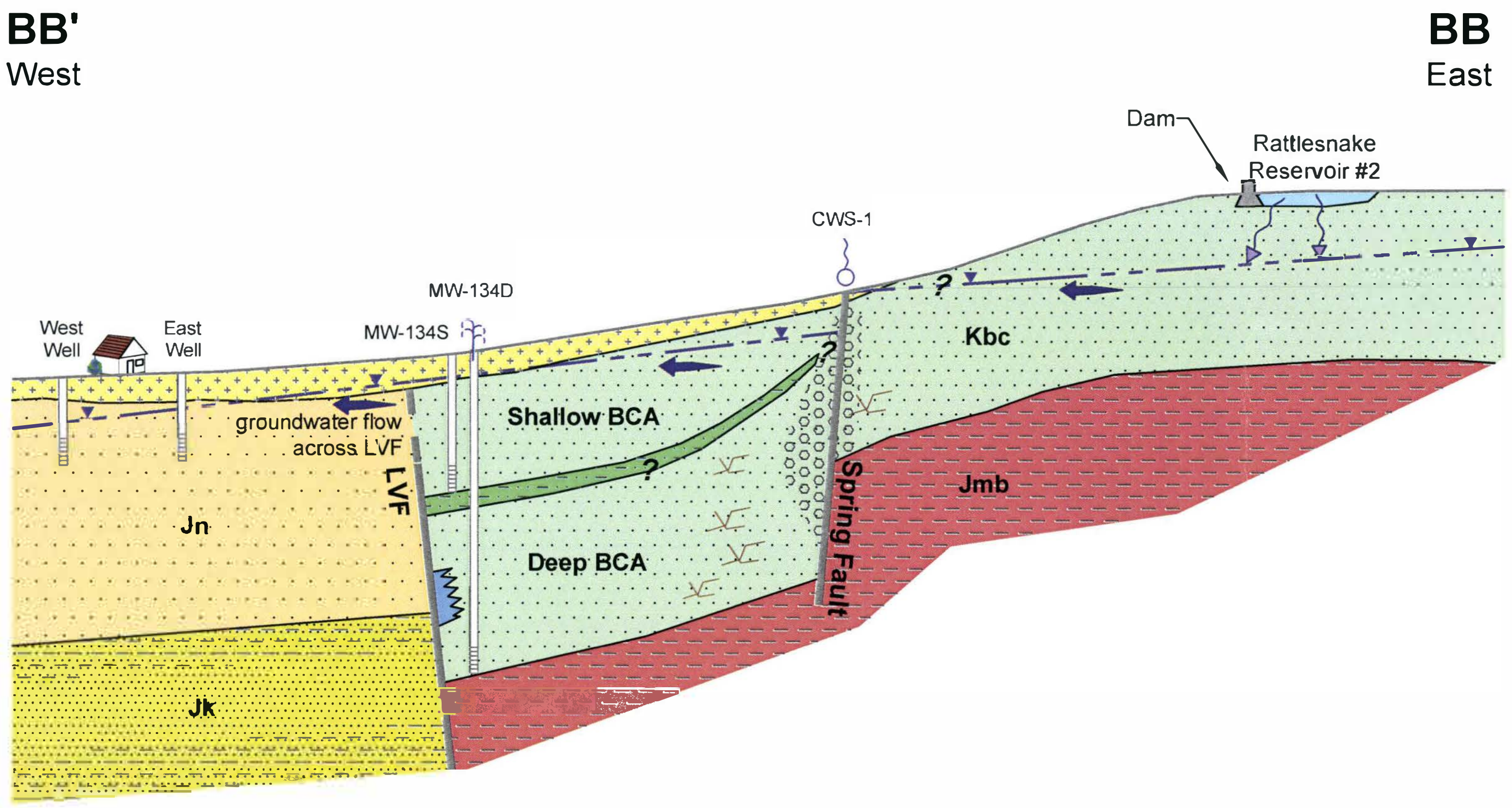


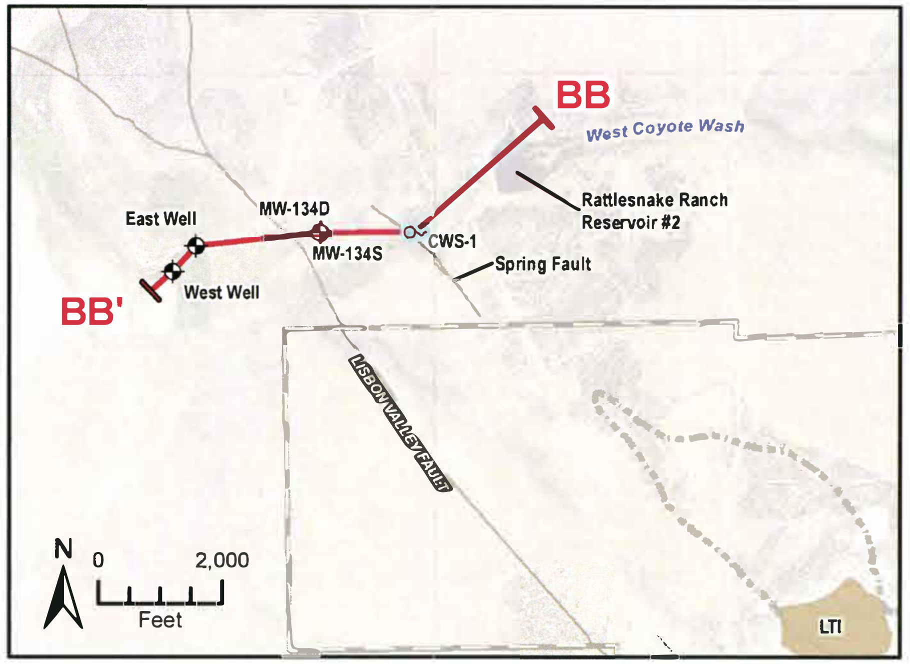
Cross Section Location Map

Figure 3.6a
Preliminary Design CSM, NW-SE Cross Section
Lisbon Facility CAAWP

INTERA

S:\ABQ\RIOAL RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\03_06a_CrossSectionAA.dwg





Cross Section Location Map

Qea	Quaternary eolian and alluvial deposites
Kbc	Burro Canyon Formation
Jmb	Morrison Formation, Brushy Basin Member
Jn	Navajo Sandstone
Jk	Kayenta Formation

Burro Canyon Fines 2
Natural Mineralization along LVF (Lisbon Valley Fault)
Unconsolidated sediments
Sandstone; may contain interbedded limestone, mudstone, shale or conglomerate
Siltstone, mudstone, or shale; may contain lesser interbedded sandstone or limestone
Mudstone or shale; may contain minor sandstone

Silicified Sandstone
Seepage
Fractures / Small Faults

Well casing
Screened interval
Groundwater Flow Direction
Water Table

Groundwater elevation
Spring
Flowing Artesian
Fault

Figure 3.6b
Preliminary Design CSM,
W-E Cross Section
Lisbon Facility CAAWP

INTERA

S:\ABQ\RIOAL RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\03_06b_CrossSectionBB.dwg

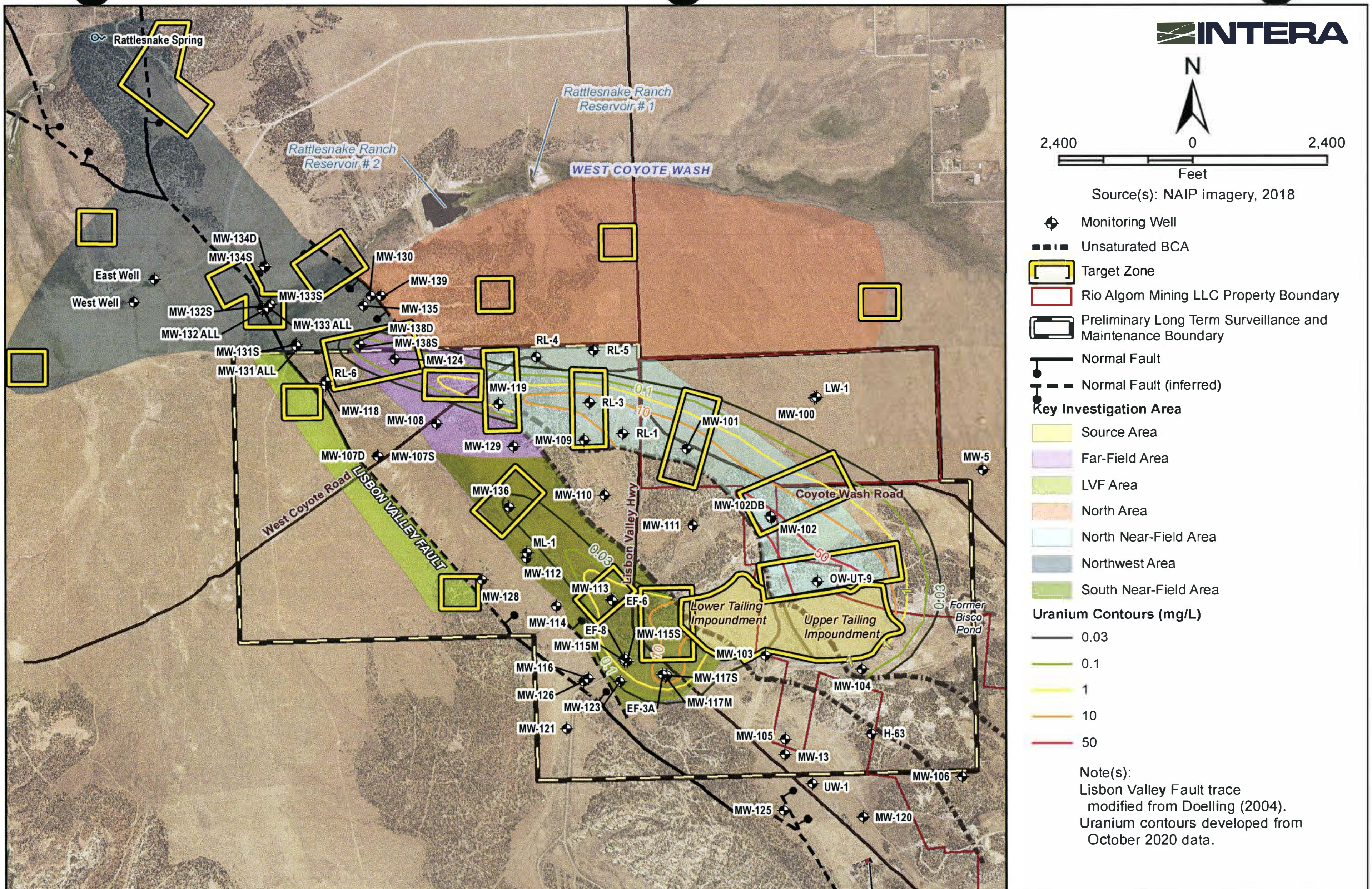


Figure 3.7
Field Program Target Zones
Lisbon Facility CAAWP

FILE: S:\ABQ\RIOAL.RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\03_07_TargetZone.mxd 11/11/2022

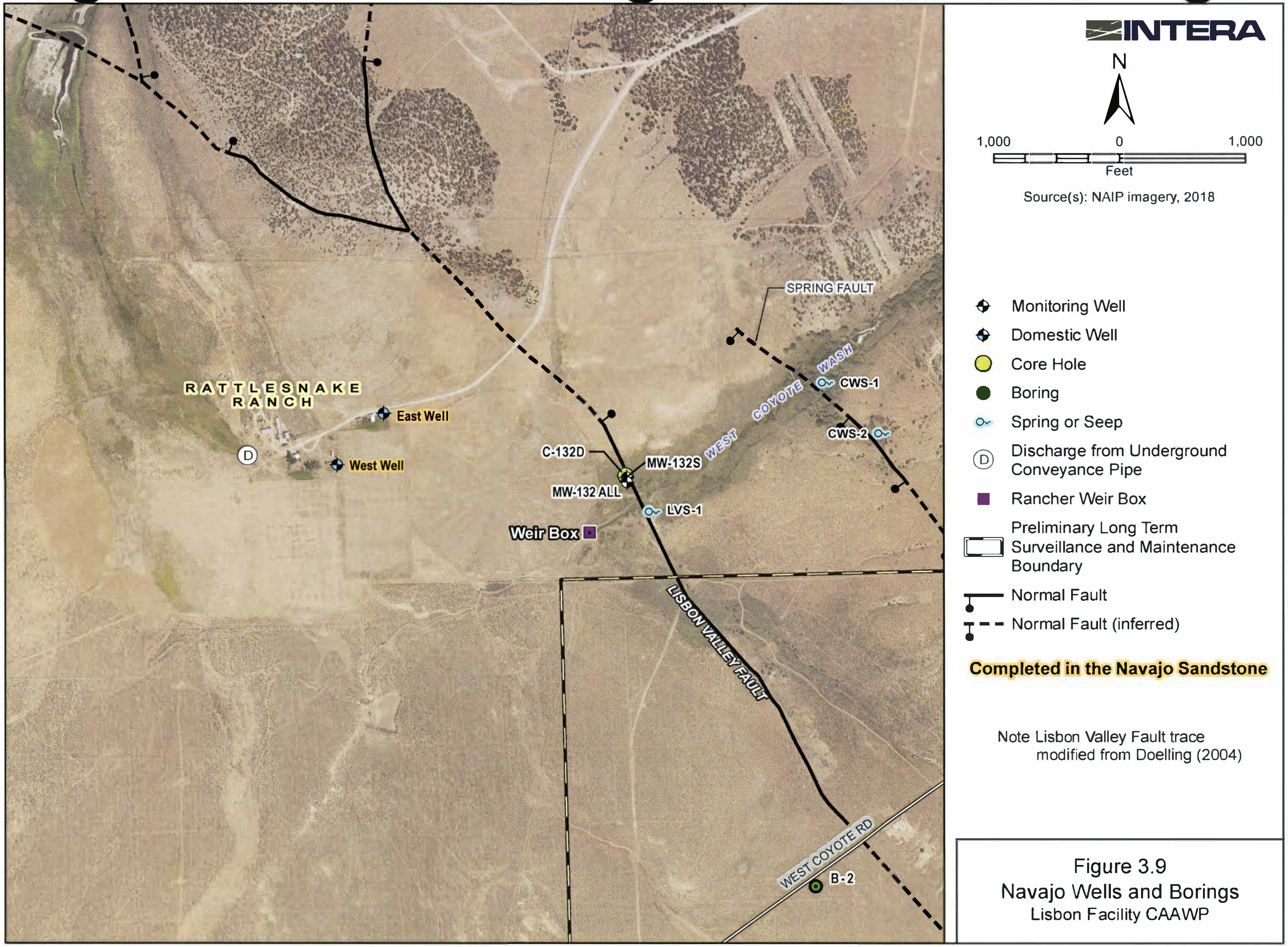
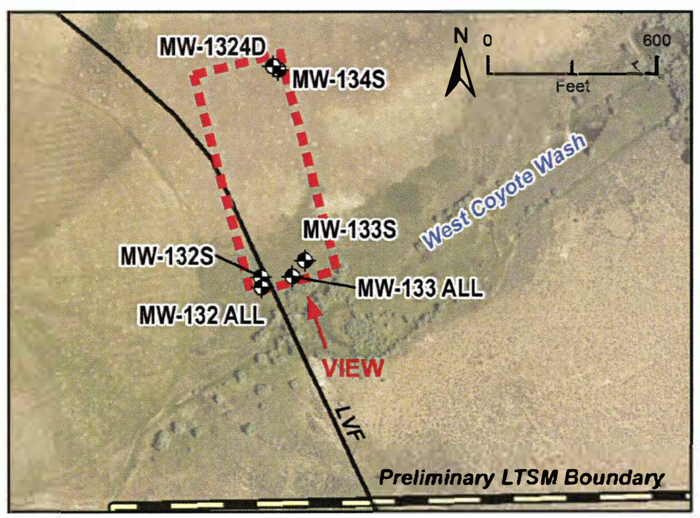


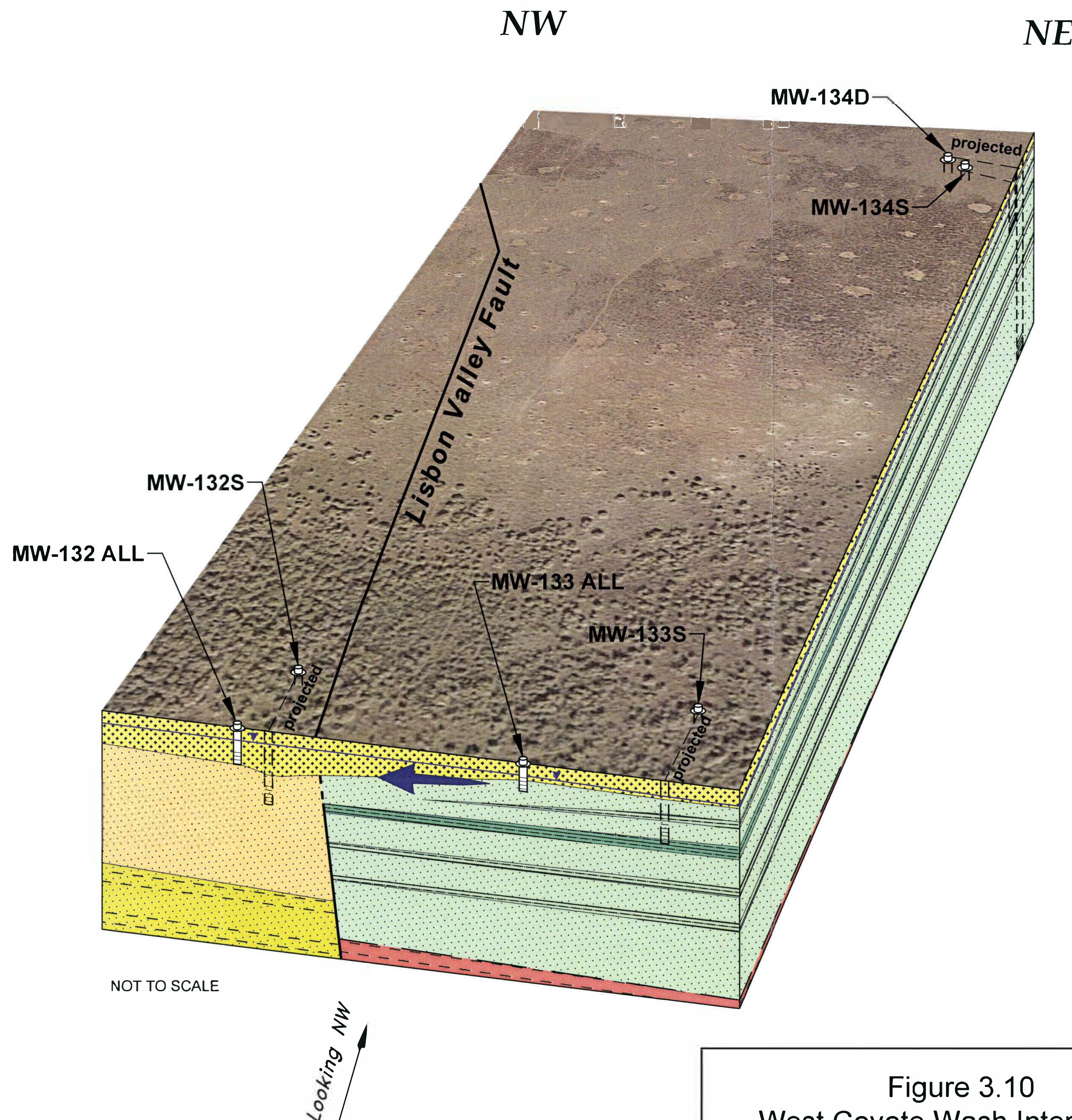
Figure 3.9
Navajo Wells and Borings
Lisbon Facility CAAWP

FILE: S:\ABQ\RIOAL.RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\03_09_NavajoWellBorings.mxd 10/17/2022

- Qea — Quaternary eolian and alluvial deposits
- Kbc — Burro Canyon Formation
- Jmb — Morrison Formation, Brushy Basin Member
- Jn — Navajo Sandstone
- Jk — Kayenta Formation
- Unconsolidated sediments
- Sandstone; may contain interbedded limestone, mudstone, shale, or conglomerate
- Siltstone, mudstone, or shale; may contain lesser interbedded sandstone or limestone
- Mudstone or shale; may contain minor sandstone
- Burro Canyon Fines 2
- Well casing
- Screened interval
- Depth to water-deep zone
- Approximate groundwater flow direction

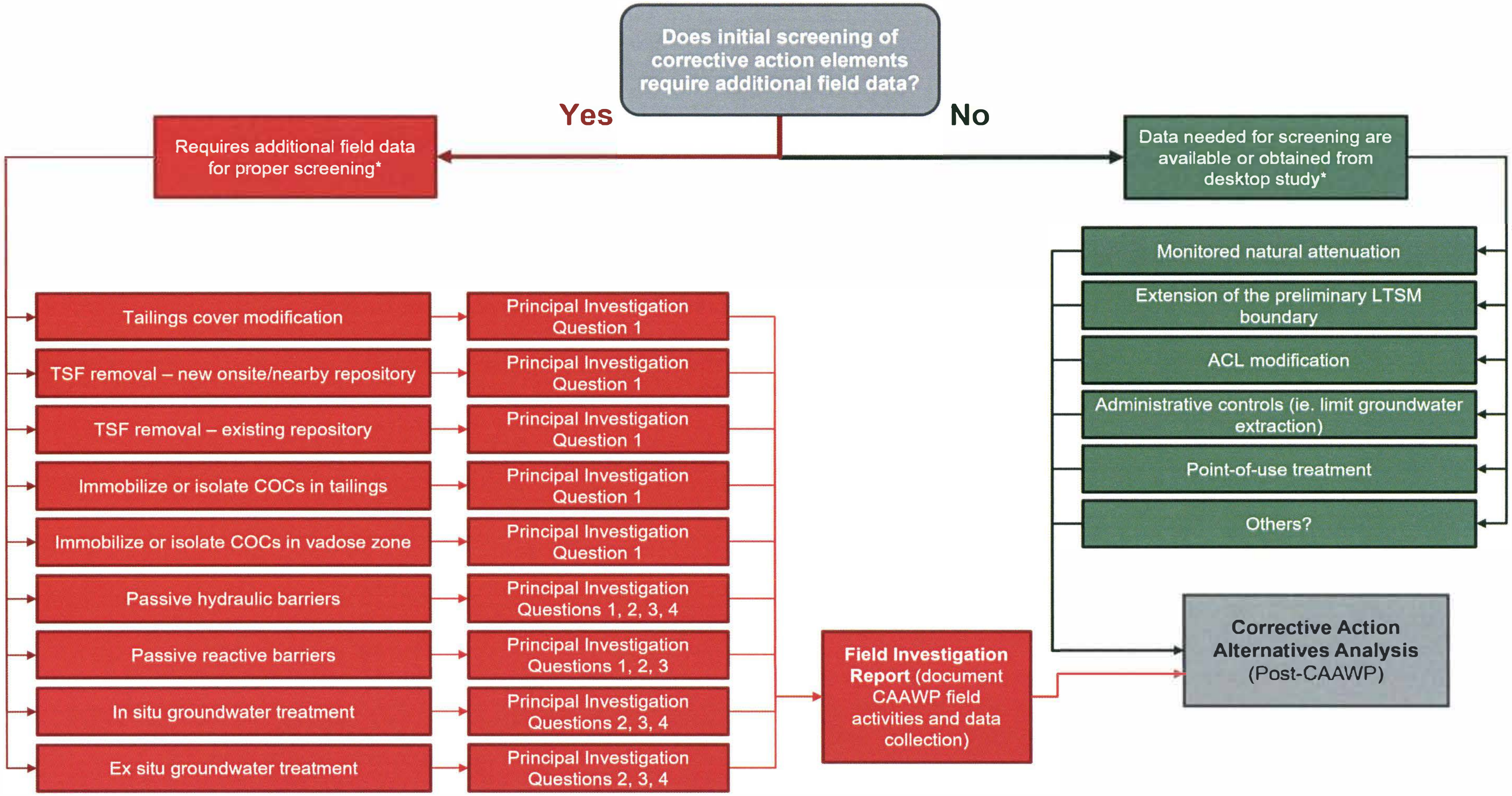


Location Map



INTERA

Figure 3.10
West Coyote Wash Intersection with Lisbon Valley Fault
Lisbon Facility CAAWP



Notes:

*Color does not indicate selection or rejection of a corrective action element or treatment technology

ACL = Alternate Concentration Limits

CAAWP = Corrective Action Assessment Work Plan

COCs = constituents of concern

LTSM = Long Term Surveillance and Maintenance

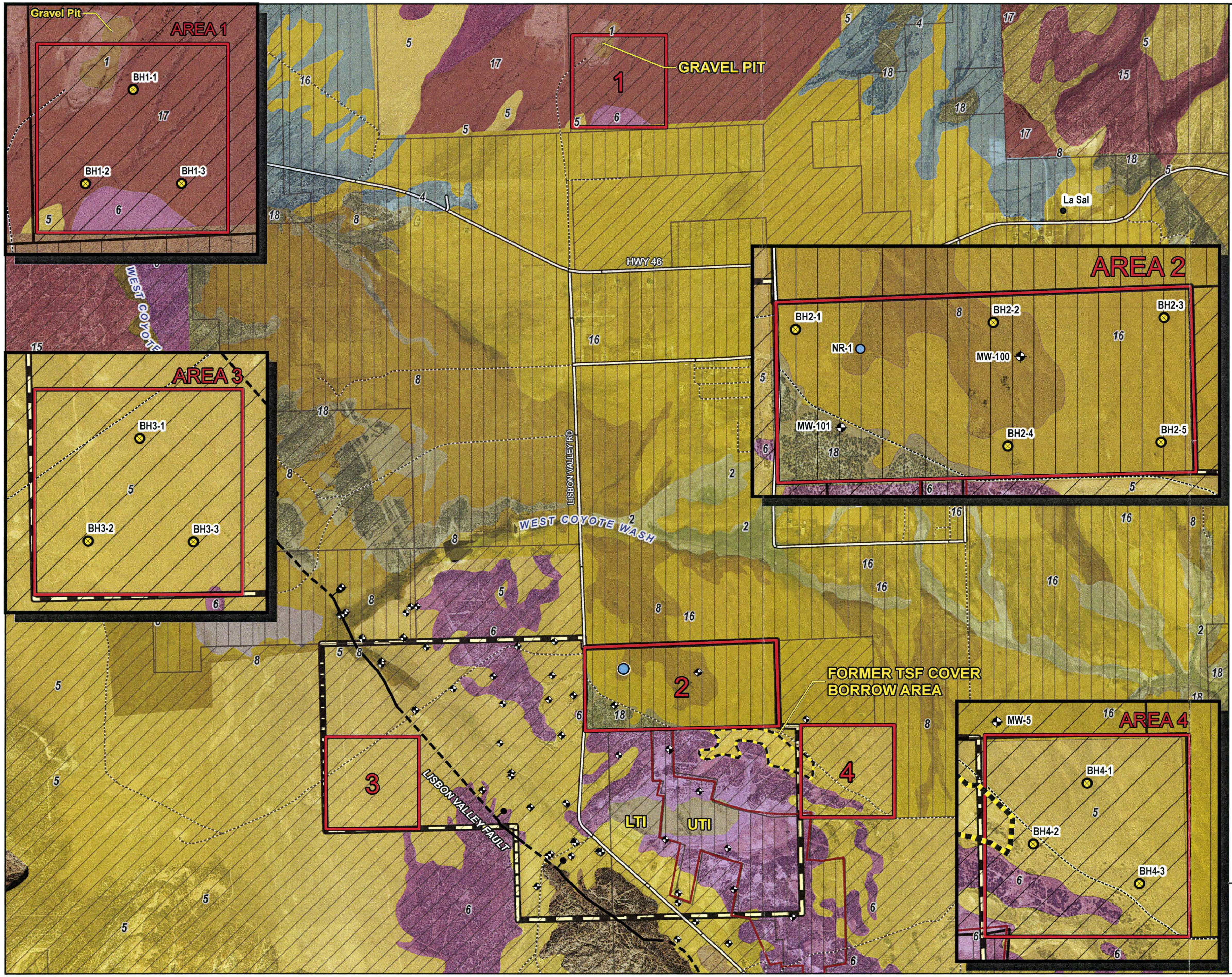
TSF = tailing storage facility

INTERA

Figure 4.1

Flow Diagram for Corrective Action Elements Needing More Data

Lisbon Facility CAAWP



INTERA

N

2,700 0 2,700

Feet

Source(s): Doelling, 2004;
Soils - NRCS, UGRC

- Monitoring Well
- Natural Recharge Boring
- Proposed Hollow Stem Auger Boring
- Proposed Borrow Area and Number
- Rio Algom Mining LLC Property Boundary
- Preliminary Long Term Surveillance and Maintenance Boundary
- Normal Fault
- Normal Fault (inferred)
- Paved Road
- Dirt Road

Land Ownership

- Bureau of Land Management
- Private

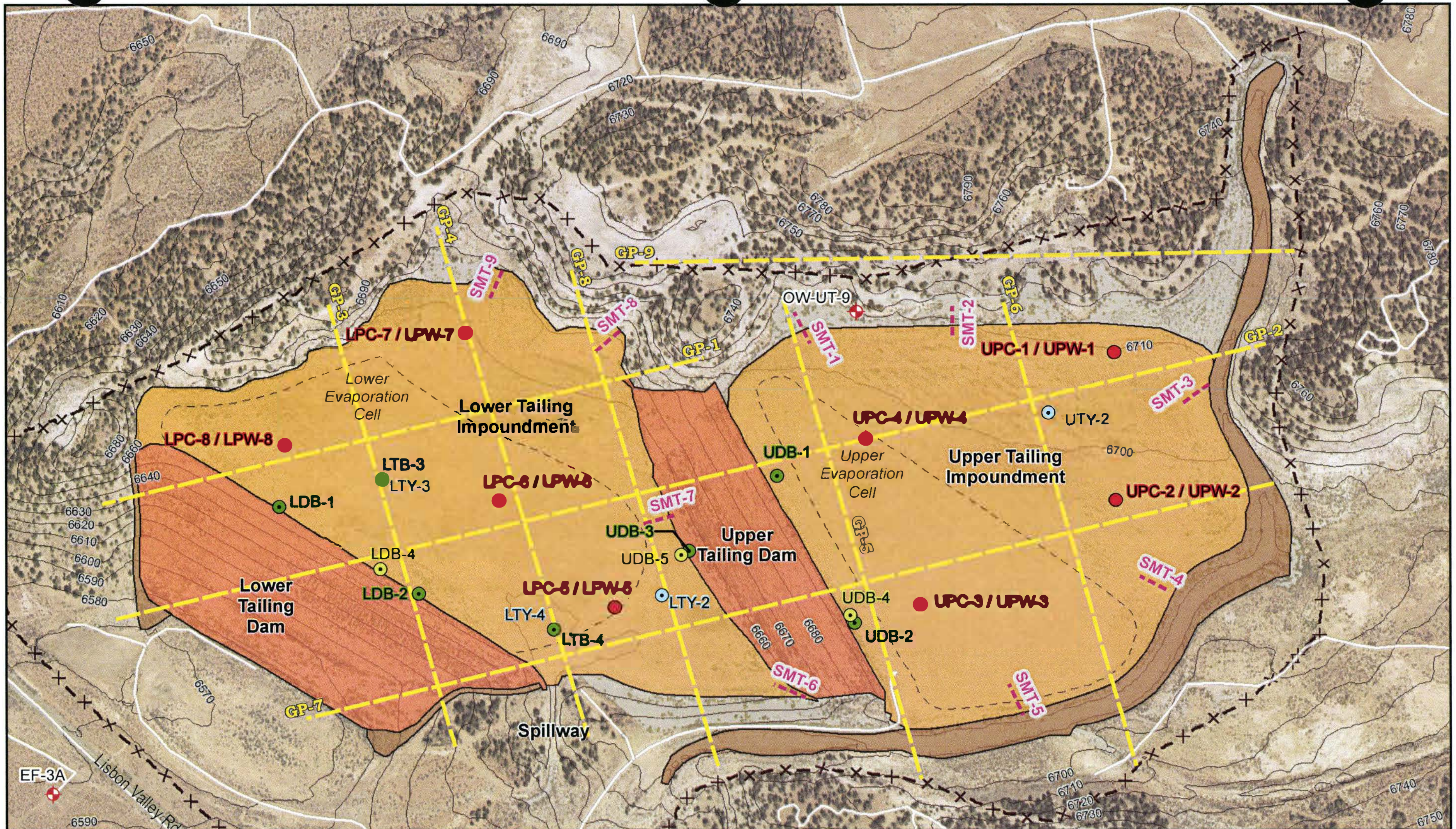
Map Unit Dominant Surface Texture Group

- **1**: pits, gravel
- **2**: clay loam
- **4**: cobbly very fine sandy loam
- **5**: fine sandy loam
- **6**: gravelly fine sandy loam
- **8**: loam
- **10**: silt loam
- **12**: stony loam
- **15**: very cobbly sandy loam
- **16**: very fine sandy loam
- **17**: very stony fine sandy loam
- **18**: very stony very fine sandy loam

Note: Lisbon Valley Fault trace modified from Doelling (2004)

Figure 5.1
Soils Map of Site Vicinity and Proposed Borrow Areas for Investigation
Lisbon Facility CAAWP

FILE: S:\ABQ\RIOAL.RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\05_01_BorrowAreasSoils.mxd 11/14/2022



Proposed Corehole and Well Location

2019 HSA* Boring

2019 Sonic/Core

Lysimeter

Point of Compliance (POC) Well

Site Access Road

Contour (10 ft)

Fence Boundary

Approximate Limits of Former CAP Evaporation Cells

*Abbreviations

HSA: Hollow-stem Auger

Channel

Tailing Dam

Tailing Impoundment

Geophysical Survey Location

Soil Moisture Sensor Transect (SMT)

N

500 250 0 500

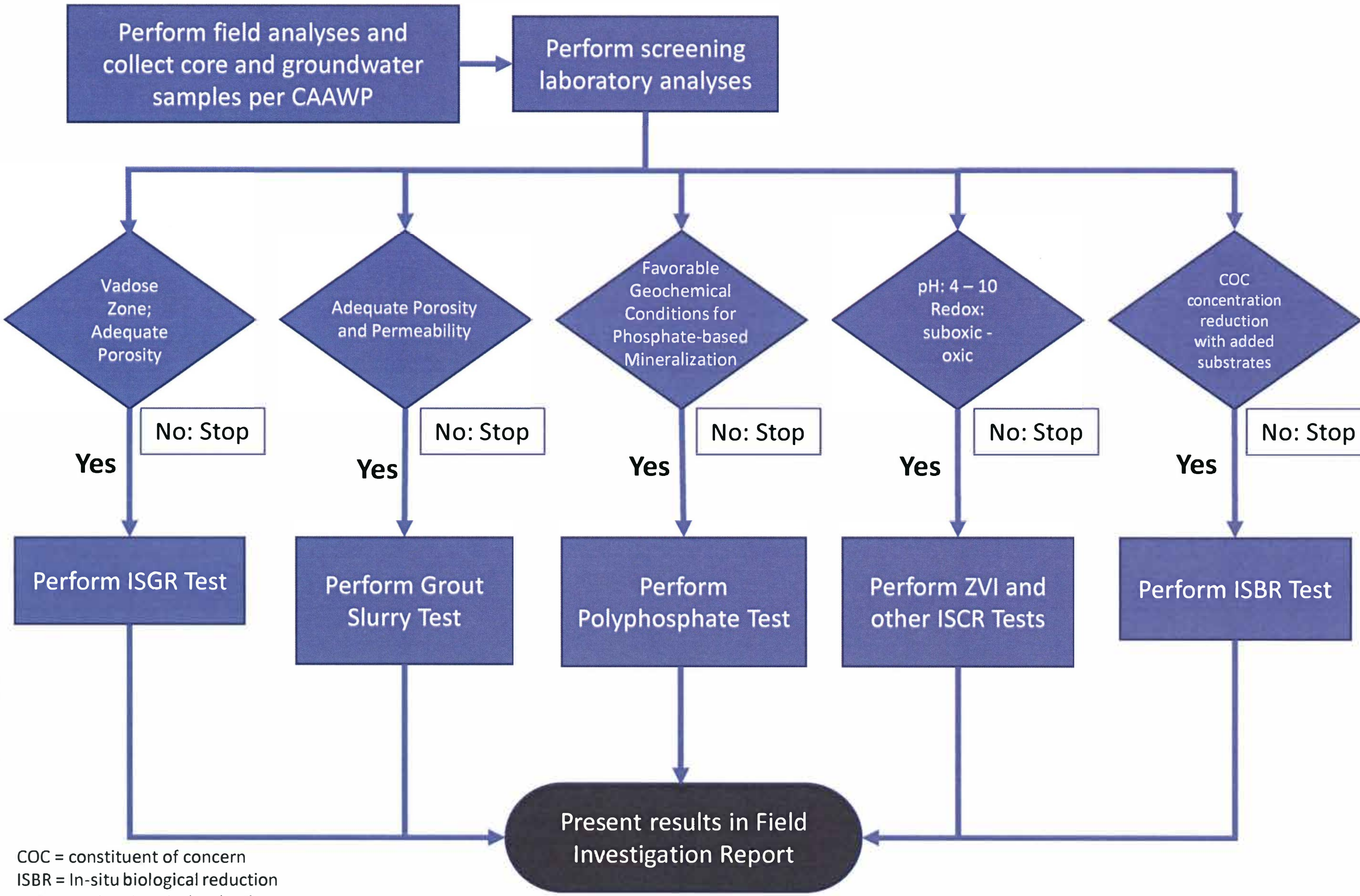
Feet

INTERA

Source(s): Aerial Imgery (NAIP, 2018)

Figure 5.2
Proposed Source Area Installation Locations
Lisbon Facility CAAWP

FILE: S:\ABQ\RIOAL.RioAlgorn\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\05_02_PropSAI_locations.mxd 11/7/2022



COC = constituent of concern
ISBR = In-situ biological reduction
ISCR = In-situ chemical reduction
ISGR = In-situ gaseous reduction
ZVI = Zero-valent iron

INTERA

Figure 5.3
Decision Flowchart: In Situ Treatability
Lisbon Facility CAAWP

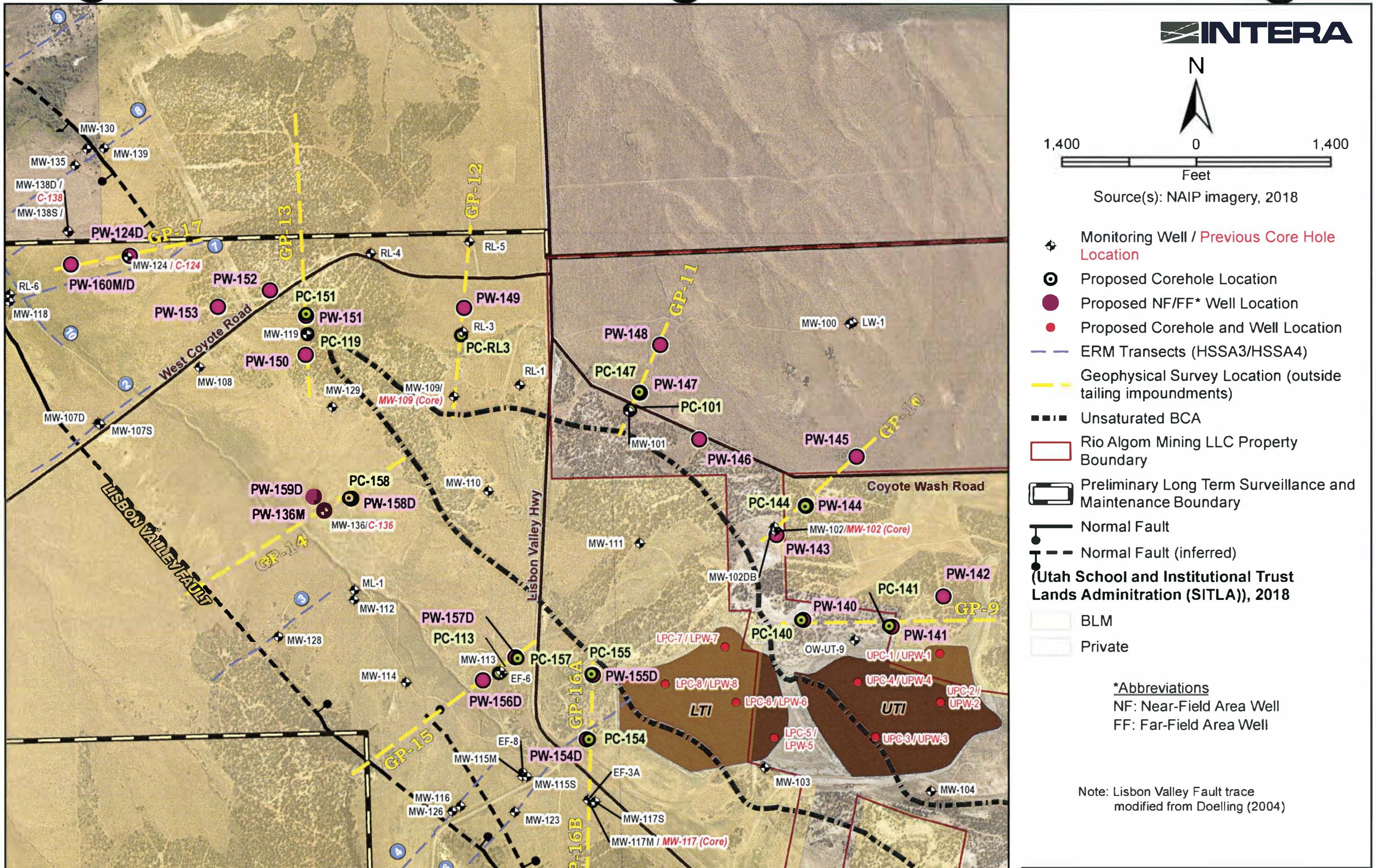


Figure 6.1
Proposed Near-and-Far-Field Installation Locations
Lisbon Facility CAAWP

FILE: S:\ABQ\RIOAL.RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\06_01_PropNAFInstallLocations.mxd 11/11/2022

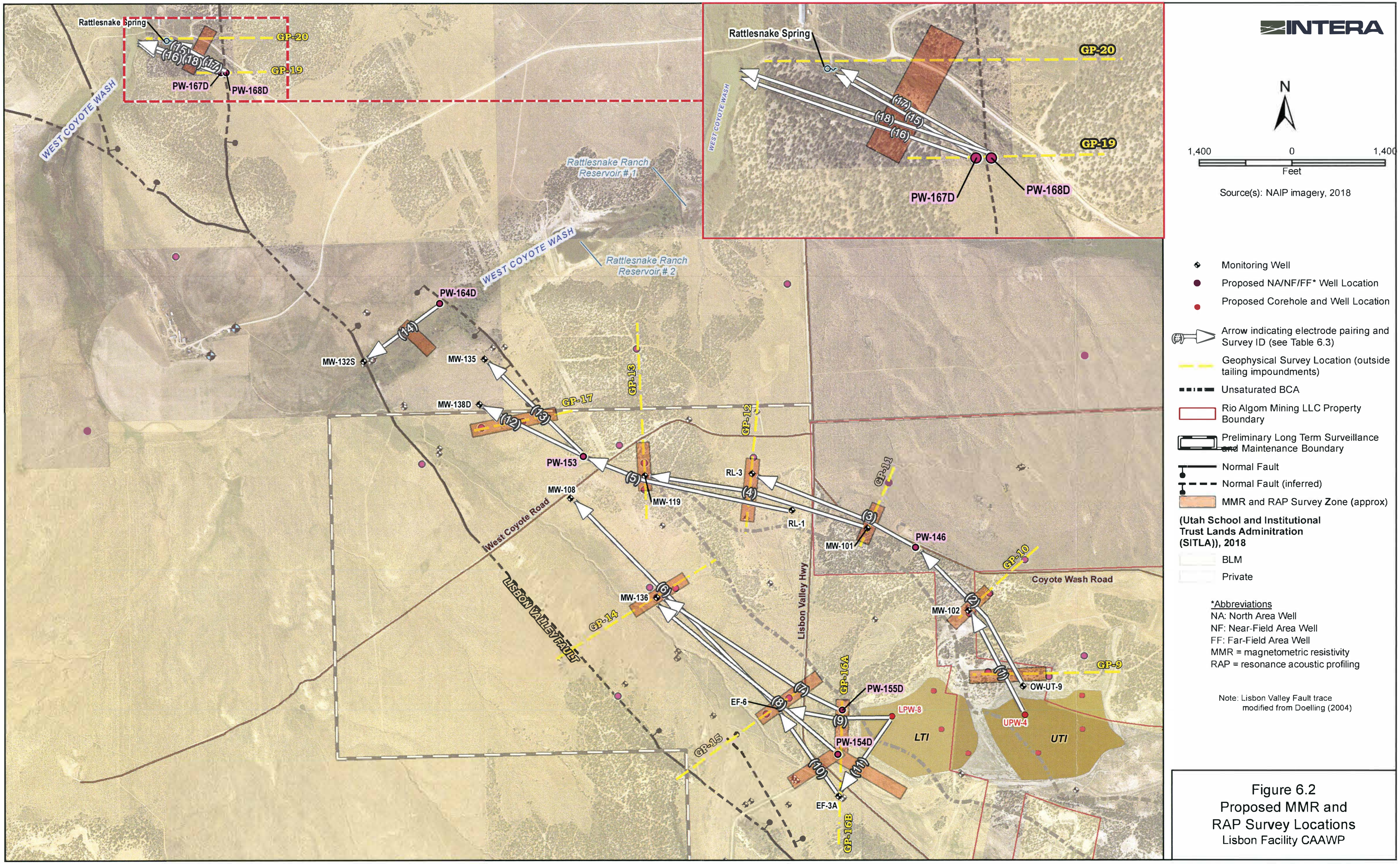


Figure 6.2
Proposed MMR and RAP Survey Locations
Lisbon Facility CAAWP

FILE: S:\ABQ\RIOAL.RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\06_02_MMR_RAP_Survey.mxd 11/15/2022

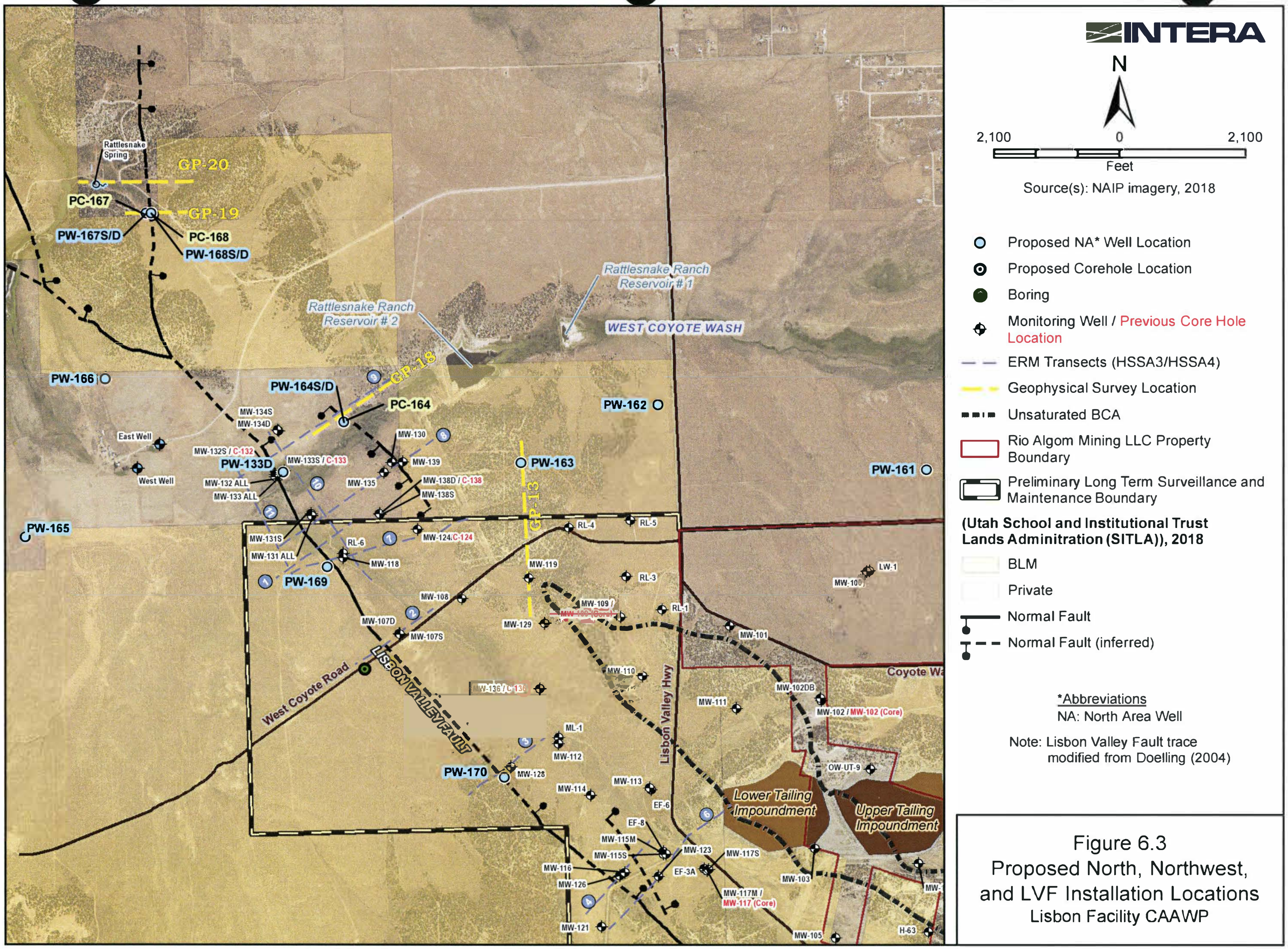


Figure 6.3
Proposed North, Northwest, and LVF Installation Locations
Lisbon Facility CAAWP

FILE: S:\ABQ\RIOAL.RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\06_03_PropN_NW_LVF_InstallLocations.mxd 11/14/2022

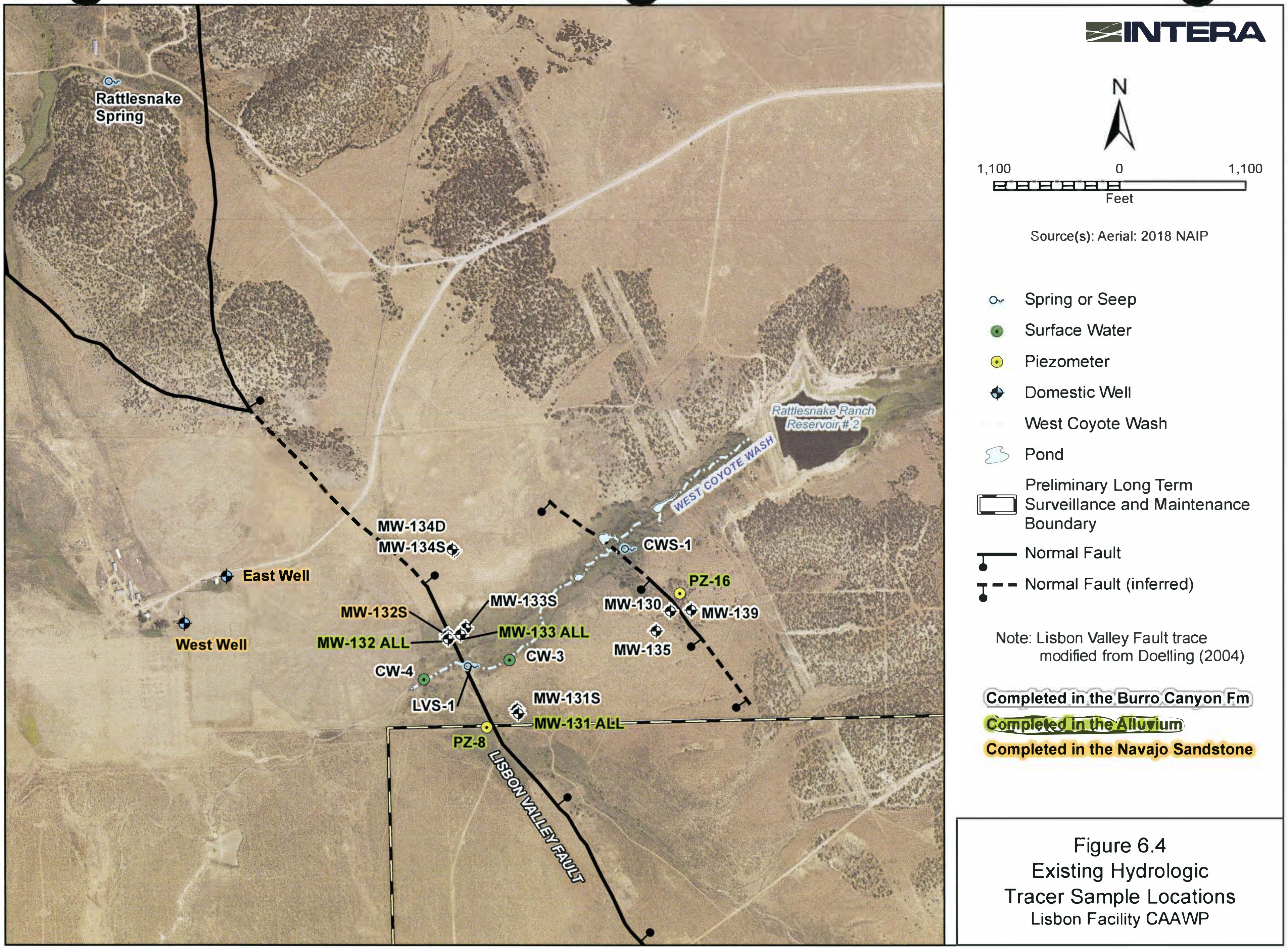
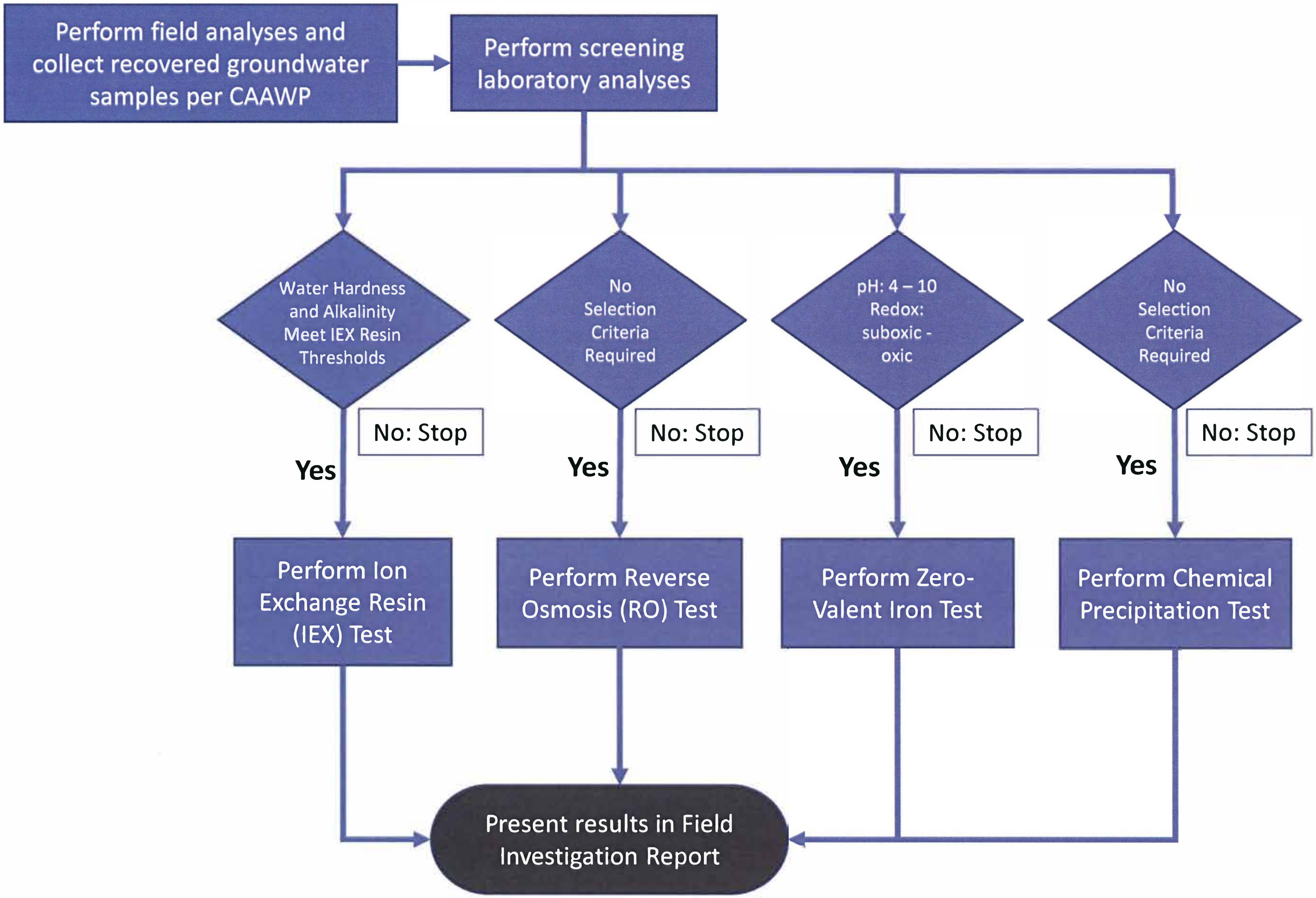


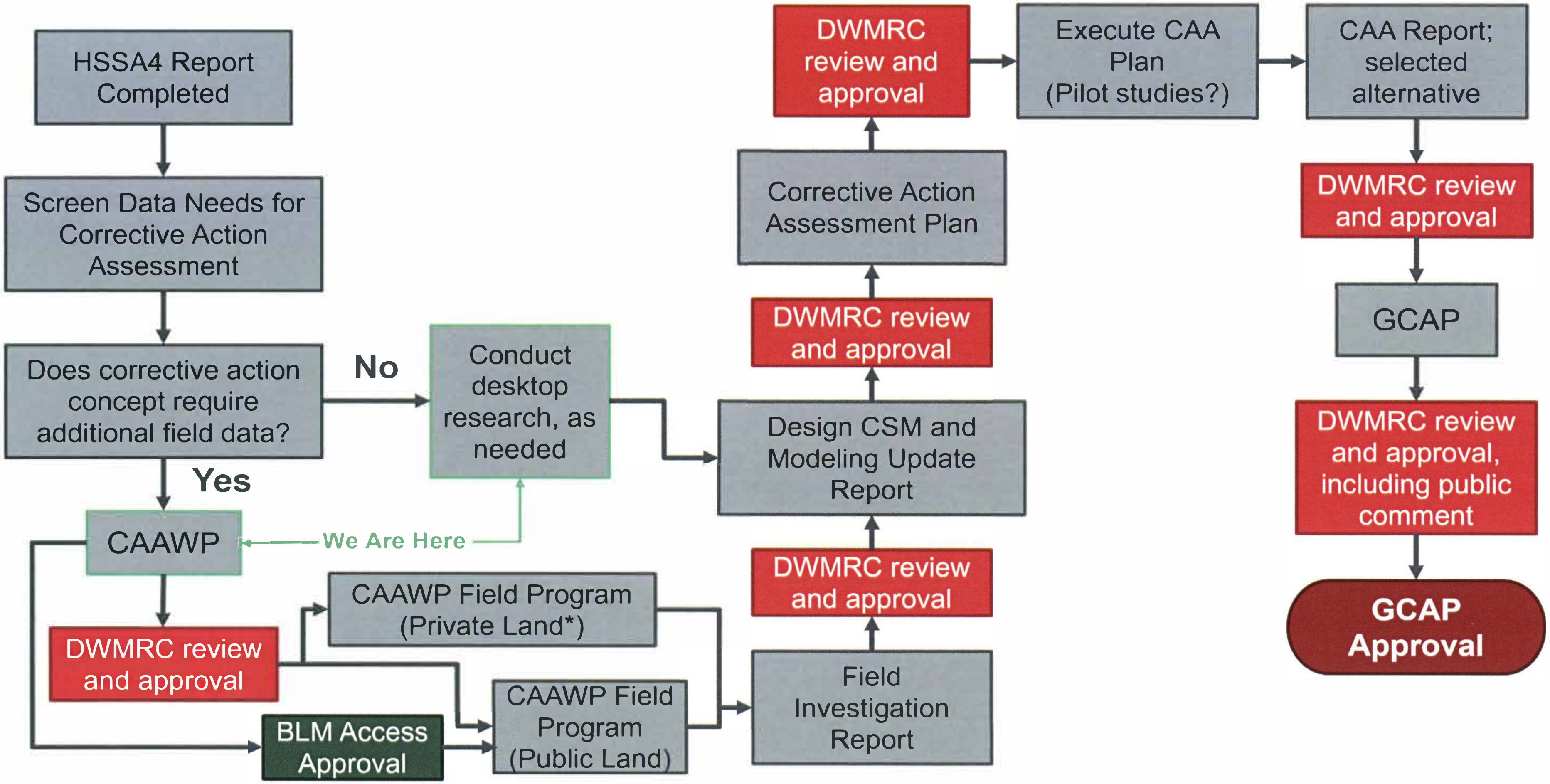
Figure 6.4
Existing Hydrologic Tracer Sample Locations
Lisbon Facility CAAWP

FILE: S:\ABQ\RIOAL.RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\06_04_HydrologicTracerSamples .mxd 11/11/2022



INTERA

Figure 6.5
Decision Flowchart: Ex Situ Treatability
Lisbon Facility CAAWP



Notes:

CAAWP = Corrective Action Assessment Work Plan

CAA = Corrective Action Assessment

DWMRC = Utah Division of Waste Management and Radiation Control

GCAP = Groundwater Corrective Action Plan

HSSA4 = Hydrogeological Supplemental Site Assessment Phase 4

*May include non-intrusive work on public land if consistent with BLM approvals or exemptions

INTERA

Figure 7.1

Flow Diagram of Potential Steps from the CAAWP to the GCAP

Lisbon Facility CAAWP

S:\ABQ\Rio_Lisbon_SupplmentalSiteCharacterization\CAA\CAAWP\WorkPlan\Figures\Working\07_01_FlowDiagramCAASteps_V4.xls

Tables

TABLE 3.1
TSF Pore Water Quality Results from 2016 to June 2022
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Sample Location	Date Sampled	Impoundment	Temperature	pH	ORP (Field)	Dissolved Oxygen	TDS (Lab)	Alkalinity (as $CaCO_3$)	Aluminum	Arsenic	Cadmium	Calcium	Chloride	Cobalt	Copper	Iron	Magnesium	Manganese	Molybdenum	Nickel	Potassium	Selenium	Silicon	Sodium	Strontium	Sulfate	Uranium	Zinc
			°C	s.u.	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LTY-3	6/1/2020	LTI	17	9.31	193.9	66.4	16800	8530	<0.1	<0.1	<0.02	2.1	961	-	0.06	<0.1	1.9	-	30.6	-	23.2	<0.05	-	6310	-	4760	53.7	<0.04
LTY-3	10/25/2020	LTI	17.7	9.61	94.1	3.85	19500	9410	<0.25	0.135	<0.04	1.53	1300	-	<0.1	<0.3	<1	-	32.2	-	22.9	0.0095	-	6810	-	4520	70.1	<0.1
LTY-3	2/19/2021	LTI	-	-	-	-	20500	10100	<1	0.156	<0.16	2.57	982	-	<0.2	<1.2	<4	-	34.7	-	28.5	<0.002	-	7390	-	5490	65.8	<0.4
LTY-3	4/14/2021	LTI	9.8	10.26	241	7.53	20900	10400	<0.25	0.162	<0.04	2.24	753	-	0.408	<0.3	<1	-	36.1	-	22.8	0.00367	-	7140	-	3630	74.5	<0.1
LTY-3	5/18/2021	LTI	15.7	9.64	266	7.82	20700	10400	<0.25	0.17	<0.04	1.67	1130	-	<0.05	<0.3	<1	-	34.3	-	23.2	<0.05	-	7470	-	5650	79.7	<0.1
LTY-3	10/1/2021	LTI	13.8	9.68	225	4.48	21400	10900	<0.1	0.175	<0.016	1.43	975	-	0.092	0.401	<2	-	36.9	-	27.7	<0.0005	-	8050	-	5500	81.6	<0.04
LTY-3	6/7/2022	LTI	-	-	-	-	21400	11000	<1	0.206	<0.016	2.36	1250	-	<0.2	<1.2	<4	-	36.5	-	24.6	0.0021	-	7640	-	5030	93.7	<0.4
LTY-4	6/5/2020	LTI	17.8	8.77	109.7	4.8			<0.05	1.3	<0.008	4.8	2930	-	<0.02	<0.06	1.2	-	16.9	-	33.8	0.18	-	6650	-	5200	73.6	0.02
LTY-4	10/20/2020	LTI	20.5	8.7	86.7	5.87	27300	7940	<0.25	2.81	<0.008	4.71	4030	-	<0.1	<0.3	5.98	-	29.5	-	37.8	0.283	-	9120	-	6870	171	<0.02
LTY-4	2/17/2021	LTI	-	-	-	-	-	-	<0.25	2.9	<0.008	4.98	-	-	<0.05	0.241	7.74	-	36.1	-	52.5	0.494	-	10000	-	-	194	0.026
UTY-2	9/16/2016	UTI	17.4	10.36	211.4	4.23	16700	6720	<0.2	0.273	<0.03	3.1	1200	-	<0.05	<0.1	<1	-	13	-	6	0.009	-	2830	-	5290	65.2	0.18
UTY-2	10/12/2016	UTI	13	10.12	167.3	2.84	21700	8910	<0.6	0.9	<0.1	2	1600	-	<0.2	<0.4	<4	-	43.2	-	15	<0.1	-	8800	-	9630	158	0.4
UTY-2	4/12/2017	UTI	13.19	9.85	-202.3	4.1	38600	15600	<0.6	3.32	<0.1	3	2290	-	<0.2	1.9	<4	-	71.9	-	33	0.073	-	12900	-	11700	200	<0.2
UTY-2	8/18/2017	UTI	20	9.92	-232.2	5.5	40200	17100	<0.8	4.47	<0.1	<3	2520	-	<0.3	3.2	<5	-	89.1	-	31	<0.2	-	15200	-	12200	268	<0.3
UTY-2	10/27/2017	UTI	17.15	9.87	-273.6	0.33	46800	17900	<2	4.8	<0.3	<5	2590	-	<0.5	4	<10	-	85	-	40	0.095	-	15000	-	13900	249	<0.5
UTY-2	1/23/2018	UTI	8.56	10.02	-209.2	3.1	-	-	<0.6	5.04	0.005	<2	-	0.017	0.03	1.7	<4	<0.02	89.1	0.08	36	0.105	82	15500	0.7	-	237	-

Notes

LTI = Lower Tailing Impoundment

UTI = Upper Tailing Impoundment

s.u. = standard pH units

mV = millivolts

mg/L = milligrams per liter

"-" indicate that constituent was not measured for given sample and date

INTERA

TABLE 4.1

Potential Elements of a Groundwater Corrective Action Program

Corrective Action Assessment Work Plan

Rio Algom Mining LLC, Lisbon Valley

	Corrective Action Elements	Key Area(s)	Target Area(s)	Description
Source Control/ Treatment	Cover Mitigation	Source Area	TSF Cover	Cover mitigation or repairs to reduce infiltration and improve performance
	Tailings In Situ Chemical Reduction	Source Area	TSF	In situ chemical injection to sequester COCs in the tailing material
	Engineered Isolation of Tailings	Source Area	TSF	Solidification of tailings through injection of grout, cement, or vitrification of tailing material.
	Tailings Removal	Source Area	TSF	Removal via excavation and transport to an approved new/existing facility.
	Permeable Reactive Barrier (PRB)	Source Area	Vadose Zone	Construction of a permeable reactive zone to sequester COCs in the vadose zone.
	Vadose Zone In Situ Chemical Reduction	Source Area	Vadose Zone	In situ chemical injection to sequester COCs in the vadose zone.
	Passive Hydraulic Barrier	Source Area	Vadose Zone	Injection of grout curtain or slurry wall to prevent seepage of mill-impacted fluid from reaching the groundwater.
Groundwater Control/ Treatment	Monitored Natural Attenuation	Far-Field	Beyond preliminary LTSM boundary	Performance monitoring
	Passive Hydraulic Barrier	Near-Field, Far-Field	BCA	Injection of grout curtain or slurry wall to prevent movement of mill-impacted groundwater.
	Permeable Reactive Barrier	Near-Field, Far-Field	BCA	Construction of a permeable reactive zone to sequester COCs in the Burro Canyon Aquifer (BCA).
	In Situ Chemical Reduction (ISCR)	Near-Field, Far-Field	BCA	In situ chemical injection to sequester COCs in the BCA.
	In Situ Biological Reduction (ISBR)	Near-Field, Far-Field	BCA	In situ biological injection to reduce COCs in the BCA.
	Permeable Reactive Barrier (PRB)	Near-Field, Far-Field	BCA	Installation of permeable treatment zone
	Active Hydraulic Barrier	Far-Field	BCA	Injection of clean or treated water into the BCA to control movement of mill-impacted groundwater.
	Pump and Ex Situ Treatment	Near-Field, Far-Field	BCA	Groundwater extraction and ex situ treatment through physical (i.e. reverse osmosis), chemical, or biological treatment.
	Pump and Deep Well Injection	Near-Field, Far-Field	BCA	Groundwater extraction and deep well injection of treated or untreated water.
	Pump and Evaporate	Near-Field, Far-Field	BCA	Groundwater extraction and evaporation of treated or untreated water.
	Pump and Discharge	Near-Field, Far-Field	BCA	Groundwater extraction, treatment, and surface discharge (NPDES or wetlands treatment).
	Point-of-Use Treatment	Far-Field	At point-of-use	Reverse osmosis, ion exchange, or adsorptive media treatment

	Corrective Action Elements	Key Area(s)	Target Area(s)	Description
Other Controls	Monitored Natural Attenuation	Far-Field	Beyond preliminary LTSM boundary	Performance monitoring
	Extension of Preliminary LTSM Boundary	Far-Field	Beyond preliminary LTSM boundary	Extend the preliminary LTSM boundary farther downgradient.
	ACL Modification	Near-Field, Far-Field	BCA	Update and change ACL requirements for Site COCs.
	Limit Groundwater Extraction	Far-Field	BCA	Limit groundwater extraction in downgradient areas to reduce risk of impacts to health.
	Surface Drainage Controls	Source Area	TSF	Surface water run-on and run-off controls to reduce potential inflow onto source area and lateral flow from drainages or diversion channels
	Institutional Controls	All Areas	All	Various other potential institutional controls could be implemented throughout the Site

Notes:

ACL = Alternative Concentration Limits
BCA = Burro Canyon Aquifer
COCs = constituent of concern
LTSM = Long-term surveillance and maintenance
NPDES = National Pollutant Discharge Elimination System
PRB = Permeable Reactive Barrier
TSF = Tailing Storage Facility

TABLE 6.1
Proposed Surface Geophysical Surveys
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Area	Geophysical Survey ID	Type of Survey	Survey Length (ft, unless noted)	Comments
Site-Wide	GPR	GPR Utility Clearance	13,750	GPR all new roads on private and BLM land
Site-Wide	GPR	GPR Utility Clearance	320,000 sq ft	32 new wells pads 100x100 ft
Source (TSF)	GP-1	Seismic and ERT	2,150	Lithology and structure of tailings and vadose zone
Source (TSF)	GP-2	Seismic and ERT	4,100	Lithology and structure of tailings and vadose zone
Source (TSF)	GP-3	Seismic and ERT	1,650	Lithology and structure of tailings and vadose zone
Source (TSF)	GP-4	Seismic and ERT	1,900	Lithology and structure of tailings and vadose zone
Source (TSF)	GP-5	Seismic and ERT	1,800	Lithology and structure of tailings and vadose zone
Source (TSF)	GP-6	Seismic and ERT	1,700	Lithology and structure of tailings and vadose zone
Source (TSF)	GP-7	Seismic and ERT	3,450	Lithology and structure of tailings and vadose zone
Source (TSF)	GP-8	Seismic and ERT	1,800	Lithology and structure of tailings and vadose zone
Source/ Near-Field	GP-9	Seismic and ERT	2,300	Lithology and structure of vadose zone and BC in near-field
Near-Field	GP-10	Seismic and ERT	1,650	Lithology and structure of BC in North Near-Field target zone
Near-Field	GP-11	Seismic and ERT	1,350	Lithology and structure of BC in North Near-Field target zone
Near-Field	GP-12	Seismic and ERT	2,050	Lithology and structure of BC in North Near-Field target zone
Near-Field	GP-13	Seismic and ERT	3,100	Lithology and structure of BC in North Near-Field target zone
Near-Field	GP-14	Seismic and ERT	2,850	Lithology and structure of BC in South Near-Field target zone
Near-Field	GP-15	Seismic and ERT	2,400	Lithology and structure of BC in South Near-Field target zone
Near-Field	GP-16a	Seismic and ERT	1,250	Lithology and structure of BC in South Near-Field target zone
Near-Field	GP-16b	Seismic and ERT	1,000	Lithology and structure of BC in South Near-Field target zone
Far-Field	GP-17	Seismic and ERT	1,600	Lithology and structure of BC in Far-Field target zone
Northwest	GP-18	Seismic	1,850	Lithology near Spring Fault
Northwest	GP-19	Seismic and ERT	1,100	Lithology and structure near LVF in Northwest Area
Northwest	GP-20	Seismic and ERT	1,950	Lithology and structure near LVF in Northwest Area

Note: the geophysical surveys listed here are for pre-drilling evaluations, MMR and RAP surveys are listed in Table 6.3.
GPR = Ground Penetrating Radar
ERT = Electrical Resistivity Tomography

TABLE 6.2
Proposed Coreholes and Monitoring Wells
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Well / Borehole ID	Type	Area	Geophysical Survey Transect	Target Lithology	Total Depth, (estimated) (ft bgs)	Drilling Method	Purpose in Support of Candidate Technology Evaluation	Other Information
Borrow area/ Repository coring (all 16)	Core hole	Borrow Areas		ALL	Refusal	HSA	Physical, mechanical, and agronomic property analysis for Borrow Areas or new Repository	
Borrow area/ Repository test pits (all 23)	Test pit	Borrow Areas		ALL	15 or refusal	Excavator	Physical, mechanical, and agronomic property analysis for Borrow Areas or new Repository	
UPC-1	Core Hole	Source Area, UTI	GP-8*	Tailing, ALL, BC	180	Sonic	Samples for Lab Analysis, Plume Source Concentration	
UPC-2	Core Hole	Source Area, UTI	GP-7*	Tailing, ALL, BC	120	Sonic	Samples for Lab Analysis, Plume Source Concentration	
UPC-3	Core Hole	Source Area, UTI	GP-5, GP-7	Tailing, ALL, BC	110	Sonic	Samples for Lab Analysis, Plume Source Concentration	
UPC-4	Core Hole	Source Area, UTI	GP-8, GP-5*	Tailing, ALL, BC	120	Sonic	Samples for Lab Analysis, Plume Source Concentration	
LPC-5	Core Hole	Source Area, LTI	GP-4*	Tailing, ALL, BC	80	Sonic	Samples for Lab Analysis, Plume Source Concentration	
LPC-6	Core Hole	Source Area, LTI	GP-4*, GP-2*	Tailing, ALL, BC	80	Sonic	Samples for Lab Analysis, Plume Source Concentration	
LPC-7	Core Hole	Source Area, LTI	GP-1*, GP-4*	Tailing, ALL, BC	90	Sonic	Samples for Lab Analysis, Plume Source Concentration	
LPC-8	Core Hole	Source Area, LTI	GP-1*, GP-3*	Tailing, ALL, BC	100	Sonic	Samples for Lab Analysis, Plume Source Concentration	
PC-140	Core Hole	Near-Field (North)	GP-9	Burro Canyon	160	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-141	Core Hole	Near-Field (North)	GP-9	Burro Canyon	210	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-144	Core Hole	Near-Field (North)	GP-10	Burro Canyon	210	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-147	Core Hole	Near-Field (North)	GP-11	Burro Canyon	170	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-101	Core Hole	Near-Field (North)	GP-11	Burro Canyon	180	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-RL3	Core Hole	Near-Field (North)	GP-12	Burro Canyon	210	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-151	Core Hole	Near-Field (North)	GP13	Burro Canyon	100	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-119	Core Hole	Near-Field (North)	GP13	Burro Canyon	115	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-154	Core Hole	Near-Field (South)	GP-16a	Burro Canyon	120	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-155	Core Hole	Near-Field (South)	GP-16a	Burro Canyon	160	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-113	Core Hole	Near-Field (South)	GP-15	Burro Canyon	145	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-157	Core Hole	Near-Field (South)	GP-15	Burro Canyon	145	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-158	Core Hole	Near-Field (South)	GP-14	Burro Canyon	170	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-164	Core Hole	Northwest Area	GP-18	Burro Canyon	140	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-167	Core Hole	Northwest Area	GP-19, GP-20*	Burro Canyon	140	Sonic	Lithology, Solids Samples for Lab Analysis	
PC-168	Core Hole	Northwest Area	GP-19, GP-20*	Burro Canyon	140	Sonic	Lithology, Solids Samples for Lab Analysis	
UPW-1	Monitoring Well	Source Area, UTI	GP-8*	Tailing, ALL, BC	180	Sonic	Samples for Lab Analysis, Plume Source Concentration	If Burro Canyon saturated zone exists, a well will be installed
UPW-2	Monitoring Well	Source Area, UTI	GP-7*	Tailing, ALL, BC	120	Sonic	Samples for Lab Analysis, Plume Source Concentration, MMR	If Burro Canyon saturated zone exists, a well will be installed
UPW-3	Monitoring Well	Source Area, UTI	GP-5, GP-7	Tailing, ALL, BC	110	Sonic	Samples for Lab Analysis, Plume Source Concentration	If Burro Canyon saturated zone exists, a well will be installed
UPW-4	Monitoring Well	Source Area, UTI	GP-8, GP-5*	Tailing, ALL, BC	120	Sonic	Samples for Lab Analysis, Plume Source Concentration, MMR	If Burro Canyon saturated zone exists, a well will be installed, MMR survey with MW-102
LPW-5	Monitoring Well	Source Area, LTI	GP-4*	Tailing, ALL, BC	80	Sonic	Samples for Lab Analysis, Plume Source Concentration	If Burro Canyon saturated zone exists, a well will be installed
LPW-6	Monitoring Well	Source Area, LTI	GP-4*, GP-2*	Tailing, ALL, BC	80	Sonic	Samples for Lab Analysis, Plume Source Concentration	If Burro Canyon saturated zone exists, a well will be installed
LPW-7	Monitoring Well	Source Area, LTI	GP-1*, GP-4*	Tailing, ALL, BC	90	Sonic	Samples for Lab Analysis, Plume Source Concentration	If Burro Canyon saturated zone exists, a well will be installed

TABLE 6.2
Proposed Coreholes and Monitoring Wells
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Well / Borehole ID	Type	Area	Geophysical Survey Transect	Target Lithology	Total Depth, (estimated) (ft bgs)	Drilling Method	Purpose in Support of Candidate Technology Evaluation	Other Information
LPW-8	Monitoring Well	Source Area, LTI	GP-1*, GP-3*	Tailing, ALL, BC	100	Sonic	Samples for Lab Analysis, Plume Source Concentration, MMR	If Burro Canyon saturated zone exists, a well will be installed, MMR survey with EF-6
PW-140	Monitoring Well	Near-Field (North)	GP-9	Burro Canyon	160	Rotary	Characterize potential treatment zone, EC/flow logging	Possible MMR well with PW-146
PW-141	Monitoring Well	Near-Field (North)	GP-9	Burro Canyon	210	Rotary	Characterize potential treatment zone, EC/flow logging	Possible MMR well with PW-146
PW-142	Monitoring Well	Near-Field (North)	GP-9*	Burro Canyon	230	Rotary	Plume extent to determine treatmetn zone, pneumatic slug test	
PW-143	Monitoring Well	Near-Field (North)	GP-10*	Burro Canyon	210	Rotary	PneuSine test	Pneusine Test with MW-102
PW-144	Monitoring Well	Near-Field (North)	GP-10	Burro Canyon	210	Rotary	Characterize potential treatment zone, EC/flow logging, MMR survey	
PW-145	Monitoring Well	Near-Field (North)	GP-10	Burro Canyon	260	Rotary	Plume extent to determine treatmetn zone, pneumatic slug test	
PW-146	Monitoring Well	Near-Field (North)	Between GP-10 and GP-11	Burro Canyon	180	Rotary	Pneumatic slug test, MMR survey, characterize plume	
PW-147	Monitoring Well	Near-Field (North)	GP-11	Burro Canyon	170	Rotary	Characterize potential treatment zone, pneumatic slug test, EC/flow logging	
PW-148	Monitoring Well	Near-Field (North)	GP-11	Burro Canyon	185	Rotary	Plume extent to determine treatmetn zone, pneumatic slug test	
PW-149	Monitoring Well	Near-Field (North)	GP-12	Burro Canyon	195	Rotary	Plume extent, pneumatic slug test, EC/flowlogging	
PW-150	Monitoring Well	Near-Field (North)	GP-13	Burro Canyon	105	Rotary	Characterize potential treatment zone, plume extent, pneumatic slug test	
PW-151	Monitoring Well	Near-Field (North)	GP-13	Burro Canyon	100	Rotary	Characterize potential treatment zone, pneumatic slug test	
PW-152	Monitoring Well	Near-Field (North) / Far-Field	GP-13*	Burro Canyon	130	Rotary	Plume extent to determine treatmetn zone, pneumatic slug test	
PW-153	Monitoring Well	Near-Field (North) / Far-Field	Between GP-13 and GP-17	Burro Canyon	130	Rotary	Pneumatic slug test, MMR survey, characterize plume for treatment zones	MMR survey with RL-3, MW-138D
PW-154D	Monitoring Well	Near-Field (South)	GP-16a	Burro Canyon	120	Rotary	Plume extent, pneumatic slug test, MMR survey, EC/flow logging	MMR survey with MW-136
PW-155D	Monitoring Well	Near-Field (South)	GP-16a	Burro Canyon	160	Rotary	Plume extent, pneumatic slug test, MMR survey, EC/flow logging	MMR survey with MW-136
PW-156D	Monitoring Well	Near-Field (South)	GP-15	Burro Canyon	145	Rotary	Characterize potential treatment zone, plume extent, PneuSine test, EC/flow logging	
PW-157D	Monitoring Well	Near-Field (South)	GP-15	Burro Canyon	145	Rotary	Characterize potential treatment zone, plume extent, PneuSine test, EC/flow logging	
PW-136M	Monitoring Well	Near-Field (South)	GP-14	Burro Canyon	115	Rotary	Characterize potential treatment zone, plume extent, PneuSine test, EC/flow logging	OW for PneuSine test with MW-136
PW-158D	Monitoring Well	Near-Field (South)	GP-14	Burro Canyon	170	Rotary	Characterize potential treatment zone, plume extent, PneuSine test, EC/flow logging	OW for PneuSine test with MW-136
PW-159D	Monitoring Well	Near-Field (South)	GP-14*	Burro Canyon	170	Rotary	Characterize potential treatment zone, plume extent, PneuSine test, EC/flow logging	OW for PneuSine test with MW-136
PW-160M	Monitoring Well	Far-Field	GP-17	Burro Canyon	130	Rotary	Characterize potential treatment zone, plume extent, PneuSine test, EC/flow logging	OW for PneuSine test with MW-124D
PW-160D	Monitoring Well	Far-Field	GP-17	Burro Canyon	185	Rotary	Characterize potential treatment zone, plume extent, PneuSine test, EC/flow logging	OW for PneuSine test with MW-124D
PW-124D	Monitoring Well	Far-Field	GP-17	Burro Canyon	175	Rotary	Characterize potential treatment zone, PneuSine test, EC/flow logging	PneuSine test well
PW-161	Monitoring Well	North		Burro Canyon	220	Rotary	Pneumatic slug test	
PW-162	Monitoring Well	North		Burro Canyon	200	Rotary	Pneumatic slug test	
PW-163	Monitoring Well	North	GP-13	Burro Canyon	205	Rotary	Pneumatic slug test	
PW-164S	Monitoring Well	Northwest	GP-18	Burro Canyon	70	Rotary	Pneusine test	Test well PW-164D; OW PW-164S
PW-164D	Monitoring Well	Northwest	GP-18	Burro Canyon	140	Rotary	Pneusine test	
PW-133D	Monitoring Well	LVF/Northwest	Near ERM Line 9 and 10	Burro Canyon	230	Rotary	BCA hydraulic properties and cross fault K from Pneusine test	OWs - all MW-132 and MW-133
PW-165	Monitoring Well	Northwest		Navajo	350	Rotary	Pneumatic slug test	
PW-166	Monitoring Well	Northwest		Navajo	335	Rotary	Pneumatic slug test	
PW-167S	Monitoring Well	LVF/Northwest	GP-19, GP-20*	Burro Canyon?	70	Rotary	Cross fault K from PneuSine test	PneuSine test with PW-168S/D
PW-167D	Monitoring Well	LVF/Northwest	GP-19, GP-20*	Burro Canyon?	140	Rotary	Cross fault K from PneuSine test	
PW-168S	Monitoring Well	LVF/Northwest	GP-19, GP-20*	Burro Canyon	70	Rotary	Cross fault K from PneuSine test	PneuSine test with PW-167S/D
PW-168D	Monitoring Well	LVF/Northwest	GP-19, GP-20*	Burro Canyon	140	Rotary	Cross fault K from PneuSine test	

TABLE 6.2
Proposed Coreholes and Monitoring Wells
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Well / Borehole ID	Type	Area	Geophysical Survey Transect	Target Lithology	Total Depth, (estimated) (ft bgs)	Drilling Method	Purpose in Support of Candidate Technology Evaluation	Other Information
PW-169	Monitoring Well	LVF	ERM Line 7	Navajo/Kayenta	140	Rotary	Navajo K and LVF boundary from Pneusine test if saturated zone exists	MW-131S as OW for PneuSine Test
PW-170	Monitoring Well	LVF	ERM Line 3	Wingate/Chinle	185	Rotary	Wingate K and LVF boundary from Pneusine test if saturated zone exists	MW-128 as OW for PneuSine Test

[M]Converted to monitoring well if saturation is present.
*Location not on the geophysical survey transect.
ALL = Alluvium
BC = Burro Canyon
BCA = Burro Canyon Aquifer
D = deep well
EC = electrical conductivity
ERM = electrical resistivity mapping
HSA = hollow stem auger
K = hydraulic conductivity
Lab Analysis - see CAAWP, Appendix D, Table D.1 for proposed analyses
LTI = Lower Tailing Impoundment
LVF = Lisbon Valley Fault
M = medium depth well
MMR = magnetometric resistivity
OW = observation well
PneuSine test = pneumatic sinusoidal aquifer test
S = shallow well
Slug test = pneumatic slug test
SPT = standard penetration test
UTI = Upper Tailing Impoundment
VC = visual classification

TABLE 6.3
Proposed Hydrogeologic Testing and Wells
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Area	Target Zone and Geophysical Survey	Target Zone Wells	New Wells to Identify Plume Extent	Wells for Pneumatic Slug and PneuSine Tests (bold)	MMR/RAP Survey Electrode Well-Pairs (Survey ID shown on Figure 6.3)	Flow Logging & EC Logging
Source (TSF)	Saturated BCA Zone beneath LTI and UTI, GP-1 to GP-8	LPW-1 to LPW-4 UPW-1 to UPW-4	LPW-1 to LPW-4 UPW-1 to UPW-4	LPW-1* to LPW-4* UPW-1* to UPW-4*		LPW-1 to LPW-4 UPW-1 to UPW-4
Near-Field	GP-9	PW-140 OW-UT-9 PW-141 PW-142	PW-142	PW-142	UPW-4 & MW-102 (1)	PW-140 OW-UT-9 PW-141
Near-Field	GP-10	MW-102 PW-143 PW-144 PW-145 PW-146 (between GP10 & GP11)	PW-145	**MW-102** **PW-143 (Test Well)** PW-145	OW-UT-9 & PW-146 (2)	MW-102 PW-144
Near-Field	GP-11	MW-101 PW-147 PW-148	PW-148	**PW-148**	PW-146 & RL-3 (3)	MW-101 PW-147
Near-Field	GP-12	MW-109 RL-3 PW-149 RL-5	PW-149	PW-149	MW-101 & MW-119 (4)	RL-3 PW-149 RL-1 MW-109
Near-Field	GP-13	PW-150 MW-119 PW-151 PW-152 PW-153 (between GP13 & GP17)	PW-150 PW-152	PW-150* PW-152* PW-153*	RL-1 & PW-153 (5)	MW-119 PW-151
Near-Field	GP-14	PW-136M MW-136 PW-158D PW-159D	PW-136M PW-158D PW-159D	**MW-136 (Test Well)** **PW-136M** **PW-158D** **PW-159D**	EF-6 & MW-108 (6)	MW-136 PW-158D PW-159D
Near-Field	GP-15	PW-156D MW-113 EF-6 PW-157	PW-156D PW-157D	**EF-6 (Test Well)** **MW-113** **PW-156D** **PW-157D**	PW-155D & MW-136 (7) PW-154D & MW-136 (8)	EF-6 PW-156D PW-157D
Near-Field	GP-16	PW-154D PW-155D	PW-154D PW-155D	PW-154D PW-155D	LPW-8 & EF-6 (9) EF-3A & EF-6 (10) LPW-8 & EF-3A (18)	PW-154D PW-155D
Far-Field	GP-17	PW-160M PW-160D MW-124 PW-124D MW-136S MW-136D	PW-124D PW-160M PW-160D	**MW-138D** **MW-138S** **MW-124** **PW-124D (Test Well)** **PW-160M** **PW-160D**	PW-153 & MW-138D (11) PW-153 & MW-135 (12)	PW-124D PW-160D MW-138D
North-Northwest-LVF	Geophysical Surveys: GP-18 GP-19 GP-20			PW-161 PW-162 PW-163 **PW-164S/D** PW-165 PW-166 **PW-167S/D** **PW-168S/D (Test Well)** **PW-169 (Test Well)** **MW-118/RL-6** **PW-170 (Test Well)** **MW-128**	PW-164D & MW-132S (13) PW-167D & Rattlesnake Spring (14) PW-167D & WCW (15) PW-168D & Rattlesnake Spring (16) PW-168D & WCW (17)	

* Pneumatic tests conducted only if there is sufficient saturated thickness

BCA = Burro Canyon Aquifer
EC = electrical conductivity
LTI = Lower Tailing Impoundment
LVF = Lisbon Valley Fault
MMR = magnetometric resistivity
RAP = resonance acoustic profiling
TSF = Tailings Storage Facility
UTI = Upper Tailing Impoundment
WCW = West Coyote Wash

TABLE 6.4
Existing Sample Locations for Hydrologic Tracer Analysis
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Location	Water Type
CWS-1	Spring
Rattlesnake Spring	Spring
LVS-1	Seep
CW-3	WCW surface
CW-4	WCW surface
MW-131 ALL	Alluvium
MW-132 ALL	Alluvium
MW-133 ALL	Alluvium
PZ-16	Alluvium
PZ-8	Alluvium
East Well	Navajo Sandstone
West Well	Navajo Sandstone
MW-132S	Navajo Sandstone
MW-130	Burro Canyon Formation
MW-131S	Burro Canyon Formation
MW-133S	Burro Canyon Formation
MW-134S/D	Burro Canyon Formation
MW-135	Burro Canyon Formation
MW-139	Burro Canyon Formation

INTERA

Appendix A

Principal Investigation Questions for the CAAWP

Appendix A
Lisbon CAAWP Principal Investigation Questions

Corrective Action Assessment Work Plan

Rio Algom Mining LLC, Lisbon Facility
San Juan County, Utah

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Principal Investigation Question 1
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Principal Investigation Question 2
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Principal Investigation Question 3
What corrective action technology(s) could effectively mitigate mill-related COCs in groundwater in the Far-Field Area?

Principal Investigation Question 4
How will the hydrogeology of the groundwater exposure pathways to potential receptors in the North, Northwest, and LVF Areas impact the evaluation and selection of a corrective action(s)?

Introduction

Previous studies at the Rio Algom Mining LLC (RAML) former Lisbon Mill (Site) in southeast Utah (**Figure 1.1**) have provided hydrogeologic and hydrogeochemical data used to develop a Characterization Conceptual Site Model (Characterization CSM) for sources, flow pathways, and potential receptors of mill-impacted groundwater. The Characterization CSM established that a new corrective action is needed to address constituents of concern (COCs) in mill-impacted groundwater at the Site. As a step towards selecting and implementing a new corrective action, a preliminary Design CSM has been developed (**Appendix B**). Drawing from the corrective action data gaps identified in the preliminary Design CSM, this appendix presents the Principal Investigation Questions (PIQs) that drive the proposed work being presented in this Corrective Action Assessment Work Plan (CAAWP). The PIQs are organized by investigation areas (Section 2.1, **Figure 2.1**) where additional field and laboratory data are needed to evaluate a diverse range of potential corrective action elements (**Table 4.1**). Guidance for implementation of the CAAWP field investigations is provided in **Appendix C** and details on the CAAWP data types and methods used to obtain these data are provided in **Appendix D**. The PIQs will be addressed with an adaptive work plan implementation (Section 1.1) to streamline the field and laboratory testing programs.

Table A1a. Principal Investigation Question 1a TSFs

PIQ 1a	What corrective action technology(s) could effectively mitigate mill-related COC migration to groundwater from the Source Area (TSFs)?					
Sub-Questions	**1**	**2**	**3**	**4**	**5**	**6**
1.0 Investigation Sub-Questions	How much of the existing mass of constituents of concern (COCs) in the tailings solids is leachable that can potentially contribute to the vadose zone and groundwater below the Tailings Storage Facilities (TSFs)?	What potential in situ treatment technologies are feasible for reduction or immobilization of COCs within the TSFs?	Are there engineering solutions that can physically isolate tailings in situ and eliminate or reduce COC migration from the TSFs?	What are the chemical, physical, and geotechnical properties of the tailings that might impact tailings removal?	Are there areas on or near the Site that may warrant consideration for a new waste repository?	What are the agronomic and physical properties of soil near the Site for possible use as borrow material, and how much material is available?
2.0 Investigation Goals	Assess the constituent mass flux expected from the TSFs through improved characterization of uranium and other COC sources and mobility.	Perform laboratory analysis to determine efficacy of in situ treatment of the tailings material that would sequester uranium and other COCs in place and minimize contaminant flux from the TSFs.	Determine if isolation or encapsulation of the tailings in place is possible and if doing so would eliminate or reduce additional seepage from the TSFs.	Determine if safe removal of the tailings material is feasible.	Assess candidate location on Rio Algom Mining LLC (RAML) property for building a new waste repository to which to relocate tailing material.	Determine the characteristics and estimated volume of borrow materials within a 5-mile radius of the Site that would be suitable for a variety of construction needs, including but not limited to final cover, embankment fill, or erosion protection.
3.0 Investigation Approach	Data will be obtained for hydrologic, geochemical, and physical characteristics of tailing material. Geochemical characteristics consist of mineral phases that host uranium and other COCs, concentration distributions of uranium and other COCs in the solid phase, and the labile fraction of uranium and other COCs. Solid material collected during 2019 drilling into TSFs may be included in the analysis (INTERA, 2021c). In addition, future coring into TSFs will provide material for various types of geochemical and physical analyses. Geophysical electrical resistivity transects may provide information about the localized areas within the TSFs that may be primary contributors to the constituent mass flux to the vadose zone underneath and will be used to optimize placement of new coreholes. Collection of tailings solid samples will occur during the Corrective Action Assessment (CAA) drilling program. Representative subsamples of tailings will be collected using professional judgement and based on differing material type, minerology, textures, and physical disturbance. Analysis of tailing solids will include (1) evaluation of solid phases that host uranium and other COCs and mineral associations; (2) sequential extraction tests for uranium, other COCs, major ions, and potential economic commodities (e.g., rare earth elements); (3) batch and flow-through column leach tests (including stop-flow events) for uranium, other COCs, and major ions using simulated pore water over several pore volumes. In addition, geochemical analysis will assess the tailings economic value (if any) for potential processing. The tailings solids will be analyzed for the following physical properties: (1) total and effective porosity, (2) moisture content, (3) bulk density, (4) grain-size distribution, and (5) specific surface area. These geochemical and physical analyses will occur before and after laboratory tests where various types of amendment solutions (e.g., polyphosphate, zero valent iron, etc.) have reacted with core samples. Geophysical electrical resistivity surveys will provide a map of the bulk electrical conductivity within the tailings. This data will provide the information needed to estimate how much the tailings solids will continue to contribute to the vadose zone and groundwater as well as to determine what in situ technologies might be feasible for the tailings material. The complete plan for this objective can be found in Section 5.3.				This portion of the investigation will focus on the identification and preliminary evaluation of a candidate disposal location on RAML property. Evaluation will include collection of physical and geotechnical data from a candidate disposal location. Near-surface and subsurface investigation of the candidate Site will use a hollow-stem auger (HSA) mobile drill rig to collect materials for laboratory testing. The laboratory and field testing will be used to determine the engineering and agronomic properties. Ancillary to this investigation will be a cursory (desktop) review of other areas peripheral to the Site that may be suitable for tailings disposal. The complete plan for this objective can be found in Section 5.2.	The proposed investigation includes a level of detail suitable for a preliminary screening of potential borrow areas. This portion of the investigation will consist of the following: (1) identification and evaluation of suitable borrow source(s) for construction material, (2) field investigation to collect representative samples of soil and rock materials, and (3) laboratory analyses to determine engineering and agronomic properties of the soil and rock for use as construction materials. The analytical approach includes (1) collecting samples from target potential borrow areas, (2) conducting laboratory analyses and tests on the borrow materials, and (3) estimating the volume of suitable borrow materials. Near-surface and subsurface investigation of nearby materials will use a HSA mobile drill rig, and excavator/ backhoe to retrieve and identify materials, and for collection of materials for laboratory testing. The laboratory and field test data will be used to develop material volume estimates. The complete plan for this objective can be found in Section 5.1.
4.0 Investigation Area(s)	Investigation areas include the Upper Tailing Impoundment (UTI) and Lower Tailing Impoundment (LTI). Proposed coreholes for this objective include UPC-1, UPC -2, UPC -3, and UPC -4 in the UTI and LPC-5, LPC -6, LPC -7, and LPC -8 in the LTI (**Figure 5.2**). HSA and sonic core drilling locations from 2019 which may provide additional material for sampling include UDB-1, UDB-2, UDB-3, UDB-4, and UDB-5 on the UTI and LDB-1, LDB-2, LDB-4, LTB-3, and LTB-4 on the LTI (**Figure 5.2**).				Suitable areas within a 5-mile radius for construction of a new tailings repository.	The preliminary boundaries of the investigation are suitable borrow material within a 5-mile radius of the Site (**Figure 5.1**). The soils within a 5-mile radius exhibit a wide range of textures that could be viable for construction material. An existing pit within the 5-miles radius of the Site will also be considered for potential construction material sources.
5.0 Specify Performance or Acceptance Criteria	Existing tailings pore water data are geochemically variable among different sample locations, suggesting that the TSF solids are also geochemically variable. Sampling of the tailings solids will be performed in such a way as to collect a representative set that accounts for spatial variability in tailings material characteristics. Drilling and coring of tailings material will be conducted following the accepted practices used during the TSF drilling conducted in 2019 (INTERA, 2021c). Geochemical analysis will follow standard methods, and method-specific quality assurance/quality control (QA/QC) will be performed by an accredited laboratory and audited by RAML consultants. Precision will be determined with replicate analyses. Methods references are provided in **Appendix D.**					Performance and acceptance criteria for the potential borrow areas and their respective materials, as characterized through field investigation and laboratory test, include (1) collecting representative samples from each borrow area to characterize the material, (2) conducting the laboratory tests to determine the physical, engineering, and agronomic properties of the potential borrow material, and (3) estimating the volume of borrow materials in the test areas.

Table A.1b. Principal Investigation Question 1b Vadose Zone

PIQ 1b	What corrective action technology(s) could effectively mitigate mill-related COC migration to groundwater from the Source Area (vadose zone)?			
Sub-Questions	7	8	9	10
1.0 Investigation Sub-Questions	The TSFs are unlined and contributed seepage to the vadose zone and groundwater soon after they were constructed in the 1970s. What is the extent of mill-related impacts in the vadose zone below the TSFs? What are the primary controls on transport to the groundwater?	If the TSFs are to be removed, is it also feasible to remove the impacted vadose zone material underneath the TSFs to reduce COC migration from the vadose zone beneath the TSFs?	What potential in situ treatment technologies are feasible for reduction or immobilization of COCs within the vadose zone?	Are there engineering solutions that can physically isolate the vadose zone and reduce or eliminate COC migration from the vadose zone?
2.0 Investigation Goals	Assess the constituent mass flux expected from the vadose zone located underneath the TSFs through improved characterization of constituent sources and mobility.	Determine if removal of the vadose zone material would minimize the assumed COC loading to the downgradient groundwater and to determine if this corrective action would be feasible.	Perform laboratory analyses to determine efficacy of potential in situ treatments for the vadose zone that can minimize COC flux to the saturated zone and determine if tested technologies might be feasible in the field.	Determine the feasibility of placing physical barriers within the vadose zone to minimize COC loading to the aquifer.
3.0 Investigation Approach	Hydrologic, geochemical, and physical data collection of the vadose zone samples will be undertaken to quantify the leaching rates and labile mass fraction for uranium and other COCs and to assess the long-term drainage rates under variably saturated conditions. Geochemical characteristics consist of mineral phases that host uranium and other COCs, concentration distributions of uranium and other COCs in the solid phase, and the labile fraction of uranium and other COCs. Core collected during the 2019 drilling campaign may be included in future analysis. Future coring into the vadose zone will provide material for various types of analyses. Geophysical electrical resistivity and seismic refraction transects may provide information about optimized placement of new coreholes and wells. Coreholes will be advanced to the base of the Burro Canyon. Collection of vadose zone continuous core will occur during the CAA drilling program. Representative subsamples of core will be collected after viewing the entire core and determining typical intervals within the Burro Canyon that show differing rock type, mineralogy, textures, and physical disturbance such as fracturing. Analysis of vadose zone solids will include (1) evaluation of solid phases that host uranium and other COCs and mineral associations; (2) sequential extraction tests for uranium, other COCs, major ions, and potential economic commodities (e.g., rare earth elements); (3) flow-through column leach tests (including stop-flow events) for uranium, other COCs, and major ions using simulated pore water over several pore volumes. The vadose zone solids will be analyzed for the following physical properties: (1) total and effective porosity, (2) moisture content, (3) matric potential, (4) bulk density, (5) grain-size distribution, and (6) specific surface area. These geochemical and physical analyses will occur before and after laboratory tests where various types of amendment solutions (e.g., polyphosphate, zero valent iron, etc.) have reacted with core samples. Core samples will be analyzed in the laboratory for determination of unsaturated hydraulic conductivity as a function of matric potential to develop constitutive model parameters (e.g., van Genuchten-Mualem model). Downhole geophysical logging such as neutron, spectral gamma, resistivity, etc. will be performed to evaluate moisture content profile, uranium distribution, fracture density, etc. The neutron probe results will need to be converted to volumetric moisture content. If groundwater is detected in the Burro Canyon, groundwater monitoring wells will be installed, and aquifer testing will be conducted. The complete plan for this objective can be found in Section 5.3.			
4.0 Investigation Area(s)	Investigation areas include the vadose zone below the UTI and LTI. Proposed coreholes are UPC-1, UPC-2, UPC-3, and UPC-4 on the UTI. Possible monitoring wells in the UTI are UPW-1, UPW-2, UPW-3, and UPW-4. For the LTI, proposed coreholes are LPC-5, LPC-6, LPC-7, and LPC-8 and possible monitoring wells are LPW-5, LPW-6, LPW-7, and LPW-8 (**Figure 5.2**). Core collected in 2019 from LDB-4, UDB-4, and UDB-5 may provide additional material for sampling.			
5.0 Specify Performance or Acceptance Criteria	Very little geochemical, physical, and hydraulic data are available for the vadose zone below the TSFs; therefore, collecting a representative set of samples will be a priority. Drilling and coring of vadose zone material will be conducted following the accepted practices used during the tailing impoundment drilling conducted in 2019 (INTERA, 2021c). Monitoring wells will be constructed to ensure that no additional seepage pathways from the tailings into the vadose zone are created but will also be constructed similar to monitoring wells installed during the HSSA4 drilling program to ensure comparability (INTERA, 2021b). When collecting new material for analysis, evaluating both horizontal and vertical heterogeneity will be a priority. Continuous core will be collected, and samples will be collected based on geology. Analyses will follow standard methods, and method-specific QA/QC will be performed by an accredited laboratory and audited by RAML consultants. Precision will be determined with replicate analyses. Methods references are provided in **Appendix D.**			

Table A.2. Principal Investigation Question 2

PIQ 2	What corrective action technology(s) could effectively mitigate mill-related COCs in groundwater in the Near-Field?				
Sub-Questions	**1**	**2**	**3**	**4**	**5**
1.0 Investigation Sub-Questions	What are the most promising locations within both the south Near-Field and north Near-Field Areas where groundwater treatment technologies may be feasible?	Are groundwater extraction or injection of treatment solutions feasible for reducing or removing COCs from groundwater with the site-specific hydrologic conditions?	What are the physical and hydrologic properties in target zones of the heterogenous Burro Canyon Aquifer (BCA) that are needed to resolve data gaps and enhance the preliminary Design CSM?	What are the solid-phase distributions of uranium and other COCs within the Near-Field Area of the BCA and how do these phases impact the current groundwater concentration and potential treatment technologies?	Is in situ treatment feasible for reduction or immobilization of COCs within the BCA?
2.0 Investigation Goals	Determine the vertical and lateral aquifer plume extents in promising locations where potential technologies may be implemented.	Evaluate the feasibility of extracting groundwater and injection treatment technologies.	Determine the physical and hydrologic properties of the heterogenous BCA in promising locations where potential technologies may be implemented.	Determine the solid phases that host uranium and other COCs and determine the leaching rates along with sorption-desorption parameters within the BCA in promising locations where potential technologies may be implemented.	Perform laboratory analyses to determine efficacy of potential in situ treatments for the saturated zone that can lead to emplacement of a permeable reactive barrier(s) or a treatment zone.
3.0 Investigation Approach	Geological field mapping will identify surface geology and structure. Additional geophysical surveys (electrical resistivity tomography [ERT], seismic refraction) will identify lithology within the Burro Canyon, delineate the contact between the Burro Canyon and Brushy Basin, and locate faults that may act as flow boundaries. Downhole geophysics measurements (caliper, temperature, SP, natural gamma ray, 16-inch and 64-inch normal resistivity, single point resistance) collected prior to well completion or borehole plugging will supplement borehole lithology interpretations. Continuous core will be collected from the coreholes. Lithologic data and water levels from boreholes will be used to characterize the aquifer extent. Water levels will be measured following well completion. Borehole flow and electrical conductivity logging will be performed to determine preferential flow pathways adjacent to the borehole. Magnetometric resistivity surveys will be conducted between select wells and combined with resonance acoustic profiling to map groundwater flow paths. Aquifer tests will be analyzed for flow boundaries (e.g., faults), hydraulic conductivity, and storage parameters. Chemical analysis of groundwater from completed wells will be used to characterize plume extent. The complete plan for this objective can be found in Section 6.1.		The data collected during field evaluations to address PIQs 1 and 2 will also address PIQs 3 through 5. In addition, hydrologic, geochemical, and physical data collection of Near-Field samples will be undertaken to quantify the leaching rates and labile mass fraction for uranium and other COCs and to assess various treatment technologies. Geochemical characteristics consist of mineral phases that host uranium and other COCs, concentration distributions of uranium and other COCs in the solid phase, and the labile fraction of uranium and other COCs. Core collected during the 2019/2020 drilling campaigns may be included in future analysis (INTERA, 2021b). Future drilling in the Near-Field area will provide material for various types of analyses. Geophysical electrical resistivity transects may provide information about optimized placement of new borings. Representative subsamples of core will be collected after viewing the entire core and determining typical intervals within the Burro Canyon that show differing rock type, mineralogy, textures, and physical disturbance such as fracturing. Information obtained from borehole logging, downhole geophysics, and preliminary geochemical characterization will be used to select core intervals that will be used for benchtop testing. Analysis of core samples will include (1) evaluation of solid phases that host uranium and other COCs and mineral associations; (2) sequential extraction tests for uranium, other COCs, major ions, and potential economic commodities (e.g., rare earth elements); (3) flow-through column leach tests (including stop-flow events) for uranium, other COCs, and major ions using simulated pore water over several pore volumes. The core samples will be analyzed for the following physical properties: (1) total and effective porosity, (2) moisture content, (3) bulk density, (4) grain-size distribution, and (5) specific surface area. The geochemical and physical analyses listed above will be applied to targeted core intervals before and after laboratory tests where various types of amendment solutions (e.g., polyphosphate, zero valent iron, etc.) have reacted with core samples. Results for all tested samples will be compared to assess the degree of variability of sequestration effectiveness. The complete plan for this objective can be found in Sections 6.2 and 6.3.		
4.0 Investigation Area(s)	There are five (5) proposed target zones identified for the north plume (**Figure 6.1**) with 18 proposed new monitoring wells (PW-140, PW-141, PW-142, PW-143, PW-144, PW-145, PW-146, PW-147, PW-148, PW-149, PW-150, PW-151, PW152, and PW-152) and 8 proposed coreholes (PC-140, PC-141, PC-144, PC-101, PC-147, PC-RL3, PC-119, and PC-151). There are three (3) target zones proposed for the south plume (**Figure 6.1**) with seven (7) proposed new monitoring wells (PW-154D, PW-155D, PW-156D, PW-157D, PW-158D, PW-159D, PW-136M) and five (5) proposed coreholes (PC-154, PC-155, PC-157, PC-113, PC-158). Each investigation zone, proposed wells, and proposed corehole will be refined based on Site conditions including access, aquifer properties, and plume extent. Pneumatic aquifer tests may be conducted at wells PW-143, PW-149, MW-136, EF-6, and PW-124D. Additional aquifer testing or tracer injection testing locations may be identified as more data is collected.		Target zones for investigation are located at geophysical transects GP-9 through GP-16 (**Figure 6.1**). Specific zone boundaries will be identified following preliminary data collection and evaluation (e.g., geologic data from logs, geophysical survey data, initial aquifer tests, etc.) and geochemical analytic data from field and laboratory evaluations.		
5.0 Specify Performance or Acceptance Criteria	Preliminary monitoring well and corehole locations have been selected to provide sufficient data points to capture potential heterogeneity of the formation and aquifer in target zones. Drilling, coring, well installation, construction, and aquifer testing will be conducted using accepted practices consistent with the 2019/2020 drilling program (INTERA, 2021b). Water levels will be collected using calibrated sounders and pressure transducers that meet accuracy and precision requirements. Borehole flow logging and fluid EC logging will follow standard methods. Downhole and surface geophysical surveys will be conducted to industry standards. Geochemical analysis of groundwater will follow standard methods. Method-specific analytical QA/QC will be performed by an accredited laboratory and audited by RAML consultants. Precision will be determined with replicate analyses. Methods references are provided in **Appendix D.**		Sampling will be performed in such a way as to collect a representative set. Drilling and coring will be conducted following the accepted practices. Laboratory analysis will follow standard methods, and method-specific QA/QC will be performed by an accredited laboratory and audited by RAML consultants. Precision will be determined with replicate analyses. Methods references are provided in **Appendix D.**		Reduction in leaching rates and cumulative mass released under laboratory conditions will provide information on the efficacy of the treatment and will help optimize the solution composition. Method-specific analytical QA/QC will be performed by the laboratory and audited by RAML consultants.

Table A.3. Principal Investigation Question 3

PIQ 3	What corrective action technology(s) could effectively mitigate mill-related COCs in groundwater in the Far-Field?				
Sub-Questions	1	2	3	4	5
1.0 Investigation Sub-Questions	What are the most promising locations within the Far-Field Area where groundwater treatment technologies may be feasible?	Are groundwater extraction or injection of treatment solutions feasible for reducing or removing COCs from groundwater with the site-specific hydrologic conditions?	What are the physical and hydrologic properties in target zones of the heterogenous BCA that are needed to resolve data gaps and enhance the preliminary Design CSM?	What are the solid phase distributions of uranium and other COCs within the Far-Field Area of the BCA and how do these phases impact the current groundwater concentration and potential treatment technologies?	Is in situ treatment feasible for reduction or immobilizing uranium and other COCs within the BCA?
2.0 Investigation Goals	Determine the vertical and lateral aquifer plume extents in promising locations where potential technologies may be implemented.	Evaluate the feasibility of extracting groundwater and injection treatment technologies.	Determine the physical and hydrologic properties of the heterogenous BCA in promising locations where potential technologies may be implemented.	Determine the solid phases that host uranium and other COCs and determine the leaching rates along with sorption-desorption parameters within the BCA in promising locations where potential technologies may be implemented.	Perform laboratory analyses to determine efficacy of potential in situ treatments for the saturated zone that can lead to emplacement of a permeable reactive barrier(s) or a treatment zone.
3.0 Investigation Approach	Geological field mapping will identify surface geology and structure. Additional geophysical surveys (ERT, seismic refraction) will identify lithology within the Burro Canyon, delineate the contact between the Burro Canyon and Brushy Basin, and locate faults that may act as flow boundaries. Downhole geophysics (caliper, temperature, SP, natural gamma ray, 16-inch and 64-inch normal resistivity, single point resistance) measurements collected prior to well completion or borehole plugging will supplement borehole lithology interpretations. Continuous core will be collected from coreholes. Lithologic data and water levels from boreholes will be used to characterize the aquifer extent. Water levels will be measured following well completion. Borehole flow logging will be performed to determine preferential flow paths. Borehole flow and electrical conductivity logging will be performed to determine preferential flow zones adjacent to the borehole. Magnetometric resistivity surveys will be conducted between select wells and combined with resonance acoustic profiling to map groundwater flow paths. Aquifer tests will be analyzed for flow boundaries (e.g., faults), hydraulic conductivity, and storage parameters. Chemical analysis of groundwater from completed wells will be used to characterize plume extent. The complete plan for this objective can be found in Section 6.1.		The data collected during field evaluations to address PIQs 1 and 2 will also address PIQs 3 through 5. In addition, hydrologic, geochemical, and physical data collection of Far-Field samples will be undertaken to quantify the leaching rates and labile mass fraction for uranium and other COCs and to assess various treatment technologies. Geochemical characteristics consist of mineral phases that host uranium and other COCs, concentration distributions of uranium and other COCs in the solid phase, and the labile fraction of uranium and other COCs. Core collected during the 2019/2020 drilling campaigns may be included in future analysis (INTERA, 2021b). Future drilling in the Far-Field area will provide material for various types of analyses. Geophysical electrical resistivity transects may provide information about optimized placement of new borings. Representative subsamples of core will be collected after viewing the entire core and determining typical intervals within the Burro Canyon that show differing rock type, mineralogy, textures, and physical disturbance such as fracturing. Information obtained from borehole logging, downhole geophysics, and preliminary geochemical characterization will be used to select core intervals that will be used for benchtop testing. Analysis of core samples will include (1) evaluation of solid phases that host uranium and other COCs and mineral associations; (2) sequential extraction tests for uranium, other COCs, and major ions (3) flow-through column leach tests (including stop-flow events) for uranium, other COCs, and major ions using simulated pore water over several pore volumes. The core samples will be analyzed for the following physical properties: (1) total and effective porosity, (2) moisture content, (3) bulk density, (4) grain-size distribution, and (5) specific surface area. The geochemical and physical analyses listed above will be applied to targeted core intervals before and after laboratory tests where various types of amendment solutions (e.g., polyphosphate, zero valent iron, etc.) have reacted with core samples. Results for all tested samples will be compared to assess the degree of variability of sequestration effectiveness across the target treatment areas. The complete plan for this objective can be found in Sections 6.2 and 6.3.		
4.0 Investigation Area(s)	There is one proposed target zone identified for the Far-Field (**Figure 6.1**) and three (3) proposed new monitoring wells (PW-124D, PW-160M, and PW-160D). Each target zone, proposed wells, and proposed coreholes will be refined based on Site conditions including access, aquifer properties, and plume extent. Aquifer testing will be conducted at MW-124 and/or other locations (**Figure 6.1**).				
5.0 Specify Performance or Acceptance Criteria	Preliminary monitoring well and corehole locations have been selected to provide sufficient data points to capture potential heterogeneity of the formation and aquifer in target zones. Drilling, coring, well installation, construction, and aquifer testing will be conducted using accepted practices consistent with the 2019/2020 drilling program (INTERA, 2021b). Water levels will be collected using calibrated sounders and pressure transducers that meet accuracy and precision requirements. Borehole flow logging and fluid EC logging will follow standard methods. Downhole and surface geophysical surveys will be conducted to industry standards. Geochemical analysis of groundwater will follow standard methods. Method-specific analytical QA/QC will be performed by an accredited laboratory and audited by RAML consultants. Precision will be determined with replicate analyses. Methods references are provided in **Appendix D.**		Sampling will be performed in such a way as to collect a representative set. Drilling and coring will be conducted following the accepted practices. Laboratory analysis will follow standard methods, and method-specific QA/QC will be performed by an accredited laboratory and audited by RAML consultants. Precision will be determined with replicate analyses. Methods references are provided in **Appendix D.**		Reduction in leaching rates and cumulative mass released under laboratory conditions will provide information on the efficacy of the treatment and will help optimize the solution composition. Method-specific analytical QA/QC will be performed by the laboratory and audited by RAML consultants.

Table A.4. Principal Investigation Question 4

PIQ 4	How will the hydrogeology of the groundwater exposure pathways to potential receptors in the North, Northwest, and LVF Areas impact the evaluation and selection of a corrective action(s)?				
Sub-Questions	**1**	**2**	**3**	**4**	**5**
1.0 Investigation Sub-Questions	Is deep BCA groundwater upwelling into the shallow BCA and alluvium near the intersection of the Spring Fault and West Coyote Wash (WCW)?	Is deep BCA groundwater flowing across the Lisbon Valley Fault (LVF) into the Navajo Sandstone or other formations?	What is the groundwater flow direction in the Navajo northwest of the preliminary Long-Term Surveillance and Maintenance (LTSM) boundary?	What is the flow pathway of groundwater in the BCA in the Northwest Area, downgradient of existing wells? Does the northern splay of the LVF create a flow boundary or will BCA groundwater discharge at Rattlesnake Spring or WCW?	How might the northern plume groundwater flow pathway change under variable climate conditions (e.g., more, or less recharge)?
2.0 Investigation Goals	Determine whether deep BCA groundwater flows into the shallow BCA and alluvium near the intersection of the Spring Fault and WCW.	Determine whether deep BCA water flows across the LVF and into the Navajo Sandstone or other formations on the footwall side of the LVF, e.g., Wingate Sandstone.	Confirm current assumptions about the flow direction within the Navajo Sandstone.	Confirm current assumptions about exposure pathways of deep and shallow BCA groundwater in Lisbon Valley (e.g., Rattlesnake Spring).	Reduce uncertainty in groundwater flow predictions for the northern plume under variable climate conditions (e.g., more, or less recharge).
3.0 Investigation Approach	The existing ERM data and new ERT data will be evaluated to determine the locations and depths of proposed wells and a corehole near the intersection of the Spring Fault and WCW. ERT surveys will be conducted first to inform the location of proposed borings. New drilling locations will be supported by the existing CSM, existing geological mapping, and new geophysical surveys, if available. Installation of new coreholes and monitoring wells (both deep and shallow) will occur during the CAA drilling program, and solid sample analysis will occur in the following months. Lithologic data will be evaluated to determine the presence or absence of the Burro Canyon Fines 2 unit. Magnetometric resistivity surveys will be conducted between select wells and combined with resonance acoustic profiling to map groundwater flow paths. Water level data and aquifer test data will be evaluated to determine hydraulic connectivity between the deep BCA and shallow BCA. Sampling of new wells will occur as soon as possible after installation and will continue for at least eight sampling events following installation. Water quality and hydrologic tracer data will be evaluated and compared to data from other wells to determine connectivity of the deep BCA and shallow BCA. The complete plan for this objective can be found in Section 6.1.	The existing ERM and seismic refraction data will first be evaluated to determine the location for proposed well PW-133D (**Figure 6.3**). Well PW-133D will be drilled to the base of the BCA and screened at the bottom of the aquifer. Additional proposed wells in the LVF area on the west side of the LVF (PW-169 and PW-170, **Figure 6.3**) will be drilled until groundwater is encountered or to a sufficient depth to determine that the formation is dry, indicating that groundwater in the deep BCA is not flowing across the LVF. Installation of new monitoring wells will occur during the CAA drilling program. Water level data and aquifer test data will be collected and evaluated from pneumatic aquifer tests conducted at well PW-133D, PW-169, and PW-170 (if wells are completed at PW-169 and PW-170) to determine hydraulic conductivity between the deep BCA and the Navajo or Wingate across the LVF. Sampling of the new wells will occur as soon as possible after installation and will continue for at least eight sampling events following installation. Water quality and hydrologic tracer data will be evaluated and compared to data from other wells to determine connectivity to the deep BCA. The complete plan for this objective can be found in Section 6.1 and Section 6.2.	New coreholes and wells are proposed for the Navajo Sandstone west of the LVF (PW-165 and PW-166, **Figure 6.3**). New drilling locations will be informed by the existing CSM, existing geological mapping, and lithology of nearby wells, if available. Installation of new coreholes and monitoring wells will occur during the CAA drilling program, and solid sample analysis will occur in the following months. Lithology data will be evaluated to determine the composition and depth of the Navajo Sandstone. Water level data and aquifer test data will be evaluated to determine hydraulic connectivity between the deep BCA and the Navajo aquifer across the LVF. Sampling of new wells will occur as soon as possible after installation and will continue for at least eight sampling events following installation. Water quality data and hydrologic tracer data will be evaluated and compared to data from other wells to determine connectivity within the Navajo Sandstone. The complete plan for this objective can be found in Section 6.1.	Geological mapping and geophysical surveys (e.g., ERT) are proposed in the Rattlesnake Spring area, to the extent possible, depending on site access. New drilling locations will be informed by the existing CSM, existing and new geological mapping, and new geophysical surveys, if available, to determine the locations and depths of proposed wells in this area (PW-167S/D and PW-168S/D, **Figure 6.3**). The proposed wells will be drilled on either side of the eastern LVF splay to determine if there is hydraulic connectivity across the fault. Installation of new coreholes and monitoring wells will occur during the CAA drilling program, and solid sample analysis will occur in the following months. Lithology data will be evaluated from coreholes (e.g., PC-167 and PC-168) to determine the presence or absence of the Burro Canyon Fines 2 unit. Magnetometric resistivity surveys will be conducted between select wells and combined with resonance acoustic profiling to map groundwater flow paths. Water level data and aquifer test data will be evaluated to determine hydraulic connectivity between potential aquifer zones. Sampling of Rattlesnake Spring for routine water quality analysis has already begun and will continue in the foreseeable future during routine sampling events. Sampling of new wells will occur as soon as possible after installation and will continue for at least eight sampling events following installation. Water quality data and hydrologic tracer data will be evaluated and compared to data from other wells to determine connectivity within the BCA and potentially with Rattlesnake Spring in this area. The complete plan for this objective can be found in Section 6.1.	New monitoring wells are proposed in the area north of RL-4, RL-5, and MW-101 and the preliminary LTSM (PW-161, PW-162, and PW-163, **Figure 6.3**). New drilling locations will be informed by the existing CSM, new geological mapping, and new geophysical surveys, if available. Installation of new coreholes and monitoring wells will occur during the CAA drilling program, and solid sample analysis will occur in the following months. Lithology data will be evaluated to determine the depth of the Burro Canyon/Brushy Basin contact and the depths for proposed new wells. Water level data and aquifer test data will be evaluated to determine groundwater flow directions and hydraulic properties of the BCA in this area. Sampling of new wells will occur as soon as possible after installation and will continue for at least eight sampling events following installation. Water quality data and hydrologic tracer data will be evaluated and compared to data from other wells to determine connectivity and flow pathways within the BCA. The complete plan for this objective can be found in Section 6.1.
4.0 Investigation Area(s)	This investigation will focus on the area near the intersection of the Spring Fault and WCW (**Figure 6.3**). Proposed wells for this area are PW-164S (shallow BCA) and PW-164D (deep BCA) and data collected from these boreholes. A corehole is proposed at PC-164.	The investigation area covers MW-133S, MW-132S, the LVF, and the proposed well PW-133D (**Figure 6.3**), which will be drilled and completed in the deep BCA just below Burro Canyon Fines 2. Proposed well location PW-169 and PW-170 will be drilled southwest of the LVF to determine the presence or absence of groundwater.	The investigation area covers Rattlesnake Ranch west of the LVF, the existing well MW-132S, and the proposed wells PW-165 and PW-166 (**Figure 6.3**).	The investigation area covers Rattlesnake Spring in the north to the proposed new wells PW-167S/D and PW-168S/D near the splay fault of the LVF (**Figure 6.3**).	The investigation area covers proposed wells PW-161, PW-162, and PW-163, all north of the preliminary LTSM boundary and northeast of the Lisbon Valley Anticline (**Figure 6.3**).
5.0 Specify Performance or Acceptance Criteria	Geophysical surveys (ERT) will be conducted to industry standards. Drilling, coring, well installation, and aquifer testing will be conducted using accepted practices consistent with the 2019/2020 drilling program (INTERA, 2021b). Monitoring wells will be of standard construction and will be consistent with well construction methods used in 2019/2020 to ensure comparability (INTERA, 2021b). Collection of new data will follow standard methods and protocols, and method-specific QA/QC will be performed by an accredited laboratory and audited by RAML consultants. Precision will be determined with replicate analyses. Additional information about methods is provided in **Appendix D.**				

Appendix B

Summary of the Lisbon Preliminary Design CSM

Appendix B

Summary of the Lisbon Preliminary Design Conceptual Site Model

Corrective Action Assessment Work Plan

Rio Algom Mining LLC, Lisbon Facility

San Juan County, Utah

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ACRONYMS AND ABBREVIATIONS

COC	constituent of concern
CSM	Conceptual Site Model
RAML	Rio Algom Mining LLC
PCA	Principal Components Analysis (PCA)
Site	Rio Algom Mining LLC Lisbon former uranium mill facility and the surrounding area

B.1 INTRODUCTION

This appendix provides a summary of the preliminary Design Conceptual Site Model (CSM) for the former Lisbon Mill (Site) in southeast Utah (Figure 1.1). Previous studies at the Rio Algom Mining LLC (RAML) Site have provided hydrogeologic and hydrogeochemical data used to develop a Characterization CSM for sources, flow pathways, and potential receptors of mill-impacted groundwater. The Characterization CSM established that a new strategy of corrective action elements is needed to address constituents of concern (COCs) in mill-impacted groundwater at the Site. As a step towards selecting and implementing corrective action elements, this preliminary Design CSM has been developed.

The cross sections depicted in **Plate B.1** of this appendix correspond to **Figure 3.6a** (AA to AA') and **Figure 3.6b** (BB to BB'). These cross sections show current understanding of the hydrogeologic and hydrogeochemical systems at the Site, the potential sources of COCs (in the case of the AA to AA' transect), the groundwater migration pathways, the groundwater hydrological and geochemical processes, and the potential receptors.

The location map in **Plate B.1** of this appendix shows recent uranium concentration contours that are also shown in **Figure 2.1** and discussed in detail by INTERA Incorporated (INTERA, 2021a, 2021b). Mill-impacted groundwater at the Site has a distinct geochemical signature compared to unimpacted groundwater and groundwater impacted by natural mineralization along the Lisbon Valley Fault (LVF) referred to as fault-impacted groundwater (INTERA, 2021a, 2021b). This observation is shown in the Principal Components Analysis (PCA) biplot in this appendix (**Plate B.1**). The PCA results represent analysis of all Burro Canyon Aquifer wells using concentrations from the October 2020 sampling event. Tested variables are alkalinity, molybdenum, arsenic, uranium, selenium, sulfate, and magnesium that appear as light gray vectors. The color coding corresponds to groundwater that is mill impacted, background groundwater and background mixtures, and fault-impacted groundwater.

REFERENCES

INTERA Incorporated (INTERA). 2021a. Hydrogeological Supplemental Site Assessment Phase 4, Lisbon Facility, Rio Algom Mining LLC, Radioactive Material License Number UT 1900481, San Juan County, Utah. October 29, 2021.

______. 2021b. Background Groundwater Quality Report: Lisbon Facility. Radioactive Material License Number UT 1900481, San Juan County, Utah. October 29, 2021.

Plate B.1

Summary of the Lisbon Preliminary CSM

Oversized Drawings/Maps

associated with this document

are located elsewhere in the

DSHW files.

For assistance, please contact

the GRAMA Coordinator.

Appendix C

Field Implementation Guidelines

Appendix C
FIELD IMPLEMENTATION GUIDELINES

Corrective Action Assessment Work Plan

Rio Algom Mining LLC, Lisbon Facility

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ACRONYMS AND ABBREVIATIONS

ACL	Alternate Concentration Limit
ARCH	air rotary casing hammer
bgs	below ground surface
BLM	Bureau of Land Management
Brushy Basin	Brushy Basin Member of the Morrison Formation
Burro Canyon	Burro Canyon Formation
CAAWP	Corrective Action Assessment Work Plan
CAP	Corrective Action Program for controlling migration of groundwater impacted by tailings seepage was approved by the Nuclear Regulatory Commission and was operated from 1990 until 2004
Chinle	Chinle Formation
CME	Central Mine Equipment
CONEX	Container Express
ERM	electrical resistivity method
ERT	Electrical Resistivity Tomography
FIG	Field Implementation Guidelines
FIP	Field Implementation Plan
ft	foot/feet
GL	ground level
GPS	global positioning system
GR	Natural gamma ray log
HSA	hollow-stem auger
HSSA4	Hydrogeological Supplemental Site Assessment Phase 4
HSE	Health, Safety, and Environment
ID	inside diameter
IDW	investigation-derived waste
IDWMP	Investigation-Derived Waste Management Plan
JRA	Job Risk Assessment
Kayenta	Kayenta Sandstone
KB	Kelly Bushing
LVF	Lisbon Valley Fault
LTI	Lower Tailing Impoundment
MMR	magnetometric resistivity
Navajo	Navajo Sandstone Formation
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration
PPE	personal protective equipment
PVC	polyvinyl chloride
RAI	Request for Additional Information
RAML	Rio Algom Mining LLC

RAP	resonance acoustic profiling
RL	reference level on rig
RLN	Long normal resistivity
RQD	Rock Quality Designation
RSN	Short normal resistivity
RSO	Radiation Safety Officer
RWP	Radiation Work Permit
SIMOPS	simultaneous operations
Site	Lisbon Site
SMS	Soil moisture sensors
SP	Spontaneous potential
SPR	Single point resistance
SPT	standard penetration testing
SSHASP	Site-Specific Health and Safety Plan
SWPPP	Storm Water Pollution Prevention Plan
Tertiary Anticline	Tertiary Lisbon Valley Anticline
TSF	tailings storage facility
UAC	Utah Administrative Code
UTI	Upper Tailing Impoundment
Wingate	Wingate Formation

C.1 INTRODUCTION

The Corrective Action Assessment Work Plan (CAAWP) Field Implementation Guidelines (FIG) serves as a guide for development of a CAAWP Field Implementation Plan (FIP) to conduct tasks described in the CAAWP (INTERA, 2022) for the Rio Algom Mining LLC (RAML) Lisbon Site (Site) in Utah. The Site is located near La Sal in San Juan County, southeastern Utah, approximately 30 miles southeast of Moab (**Figure C.1**). A summary of past mine- and mill-related activities can be found in the Hydrogeological Supplemental Site Assessment Phase 4 (HSSA4) Report (INTERA, 2021b). Implementation of previous field programs during the HSSA4 investigation has resulted in the installation of numerous monitoring wells (**Figure C.2**) in addition to other Site characterization activities (INTERA, 2021b). Field procedures will generally follow the guidance presented here but are subject to change depending on field conditions and modifications to the CAAWP. The FIP will be a planning and coordination tool for RAML and its contractors and is not intended as a regulatory submittal. The scope of work includes the following:

- Evaluate potential borrow material at four areas using test pits and hollow-stem auger (HSA) borings.
- Conduct surface geophysical surveys that will help characterize hydrostratigraphic units, geologic structures, and preferential pathways.
- Drill coreholes to provide detailed lithology and to provide material for sampling and testing of corrective action technologies.
- Install monitoring wells for characterizing hydrogeology, constituent concentrations, and testing of corrective action technologies.

RAML will communicate with regulatory agencies, as needed, regarding the status of the CAAWP field program. RAML will communicate with the Rattlesnake Ranch property managers, as needed. All communication with the Rattlesnake Ranch property personnel will be conducted by RAML. A template for identifying contact information for all key personnel, including all RAML contacts and subcontractors is provided in **Attachment C.1**.

The remaining sections of the CAAWP FIG consist of the following:

- Section C.2 Background: background information about the Site, purpose and objectives of the CAAWP field program, and well installation rationale.
- Section C.3 CAAWP Pre-Drilling Activities: details of the pre-drilling activities such as a Health and Safety Plan, surveys, permitting, Site construction, and geologic reconnaissance.

- Section C.4 CAAWP Field Program: details of the field program, including borrow area investigations, surface geophysical surveys, corehole drilling and geophysical logging, monitoring well drilling requirements, core and cuttings logging, well development, corehole plugging and abandoning, and other details.

C.2 BACKGROUND

The Site consisted of a former underground mine, former above-ground mill and mine facilities, two tailings storage facilities (TSFs), and the former Bisco Pond, which is an unlined pond formerly used to treat mine water with barium chloride. Mine and mill construction commenced in 1970 and mining began in 1972. Mining operations ceased in 1988 and milling operations ceased in early 1989. Decommissioning and reclamation of Site facilities occurred from 1995 through 1997. A Corrective Action Program (CAP) for controlling migration of groundwater impacted by tailings seepage was approved by the Nuclear Regulatory Commission (NRC) and was operated from 1990 until 2004, at which point NRC approved an Alternate Concentration Limit (ACL) Application and Long-Term Groundwater Monitoring Program (Lewis, 2001; Komex, 2004). As described in the CAAWP, non-compliance with the Radioactive Materials License UT 1900481 (License) requirements resulted in additional field work to address DWMRC's Requests for Additional Information (RAIs). Additional information about the Site background, License non-compliance, DWMRC's RAIs, and the findings of previous field work is provided in the HSSA Reports (INTERA, 2021a, 2021b).

C.2.1 Program Objectives

The objectives of the CAAWP field program are aimed at evaluating and selecting a comprehensive corrective action program for Site groundwater. The planned field data collection activities include geological mapping, surface geophysical surveys, borrow area investigations, TSF investigations, coring, and monitoring well drilling and installation.

Results of geological mapping and geophysical surveys, combined with other surface data and information from existing borings and wells, will provide data with which to characterize the geology and hydrogeology in the target zones and to inform the Site Geologist and drillers of anticipated local drilling conditions. Surface geophysical surveys are discussed further in Section C.4.5.

Borrow area investigations address specifically the availability of borrow materials near the Site. The location of proposed test pits and boring locations for the TSF borrow area investigation are shown in **Figure C.3**. Implementation of the field investigation into borrow materials is discussed further in Section C.4.6.

Collection of core and installation of monitoring wells for each area of investigation will provide information on geology, hydrogeology, mill-related impacts, and data for evaluation of corrective action technologies. Locations for proposed coreholes in and beneath the TSFs are shown in **Figure C.5**. The location of all existing monitoring wells and the proposed coreholes and monitoring wells are shown in **Figure C.6** for the Near-Field and Far-Field areas, and **Figure C.8** for the north, northwest, and Lisbon Valley Fault (LVF) areas of the Site. The overall objective for the coreholes and monitoring wells in the Near-Field and Far-Field areas is to provide higher resolution information about flow and transport properties of the aquifer material to support evaluation of corrective action technologies for corrective action. Implementation of the core and monitoring well drilling is discussed further in Sections C.4.8 and C.4.9, respectively. Additional information about the objectives of this CAAWP field program is provided in the CAAWP (INTERA, 2022).

C.2.2 Geologic Setting

The Site extends from the slopes of the La Sal Mountains southwestward to Lisbon Valley and from West Coyote Creek in the northwest to where Lisbon Valley Road crosses the LVF to the southeast (**Attachment C.2**). Lisbon Valley is a northwest-to-southeast trending valley and is one of the many northwest-trending stream valleys formed along salt anticlines in the Paradox Basin of the Colorado Plateau. Topography varies throughout the investigation area, ranging from approximately 6,400 ft in the low-lying areas in Lisbon Valley to 8,000 ft in the upper reaches of mountainous terrain to the northeast where the La Sal Mountains are located. Groundwater flow near and downgradient of the mill area is strongly controlled by the Tertiary Lisbon Valley Anticline (Tertiary Anticline) and the LVF (**Attachment C.2**). The LVF is the largest fault in the area and exhibits approximately 2,000 ft of vertical offset. Subsidiary faults in the area run parallel or subparallel to the LVF and exhibit smaller offsets (INTERA, 2021b). Localized faulting and fracturing also occurs along the Tertiary Anticline.

The Burro Canyon Formation (Burro Canyon) forms the main aquifer within which mill-related impacts occur. Geology in the proposed Burro Canyon wells and coreholes (**Table C.1 and Table C.2**, **Figure C.6,** and **Figure C.8**), from top to bottom, consists of unconsolidated materials (e.g., alluvium and colluvium), if present, Burro Canyon (sandstone with some siltstone, mudstone, and limestone), and Brushy Basin Member of the Morrison Formation (Brushy Basin) (mudstone). The Brushy Basin forms the aquitard underlying the Burro Canyon. In the Source Area, cores will be collected in the tailings as well as the underlying Burro Canyon. Three wells will be drilled into the Navajo Sandstone Formation (Navajo) to the west of the LVF (**Figure C.8**). The geology in the proposed Navajo wells, from top to bottom, consists of unconsolidated materials, if present, Navajo Sandstone, and Kayenta Sandstone (Kayenta). The Kayenta forms the aquitard underlying the Navajo and consists of fine-grained sandstone, siltstone, and shale that exhibits low hydraulic conductivity. One well, PW-174, will be drilled into the Wingate Formation (Wingate) adjacent to the LVF (**Figure C.8**). The geology in the proposed Wingate well, from top to bottom, consists of unconsolidated materials, if present; Wingate; and Chinle Formation (Chinle). The Chinle forms the aquitard underlying the Wingate and is composed of sandstone, conglomerate, and mudstone that exhibits low hydraulic conductivity. The geology of the Site is described in Section 3.1 of the CAAWP (INTERA, 2022) and in detail in Section 3.1 of the HSSA4 Report (INTERA, 2021b) and is recommended reading for Site managers, project managers, and field personnel. Additional guidance will be provided from relevant lithologic logs for existing wells, and a binder with the lithologic logs and well completion diagrams for all Site wells will be available in the Container Express (CONEX) unit at the laydown yard. The results of previous geophysical electrical resistivity method (ERM) and seismic refraction surveys will also be provided as guidance for the field crew conducting the proposed geophysical surveys.

C.3 CAAWP DRILLING PREPARATION

C.3.1 Field Logistics

Prior to mobilization to the Site, personnel should become acquainted with the following aspects of the CAAWP field program:

- Read and become familiar with CAAWP (INTERA, 2022).
- Read and become familiar with the Site-Specific Health and Safety Plan (SSHASP).
- Attend and participate in the RAML-led Site training, which will include Site induction training, RAML safety procedures, Site radiation-safety requirements, and other information. The Site radiation-safety requirements will be provided by the Site Radiation Safety Officer (RSO). Roles and contact information will be provided in a table similar to that shown in **Attachment C.1.**
- Become familiar with the laydown yard and storage yard including ingress and egress procedures, specific uses, and locations of the CONEX storage units.
- Review ERM and seismic refraction survey results to confirm identified structures and depth to the alluvium-bedrock contact, (pre-CAAWP surveys will be provided to the appropriate field crew).
- Review and obtain the required equipment included in the equipment checklist (example included in **Attachment C.3**).
- Confirm the required drilling permits have been obtained from Utah Division of Water Rights.
- Review, and become familiar with the areas covered by the underground utility clearance using ground penetrating radar prior to mobilization. Underground utilities identified during the HSSA4 field program are provided in **Attachment C.4**.
- Review, and become familiar with, the height of overhead power lines to determine clearance for equipment access to each well pad location. Overhead electrical and utility clearances identified during the HSSA4 field program are provided in **Attachment C.4**. New overhead electrical and utility clearances will be conducted, and the information provided to the appropriate field crew.
- The drilling sites will be located on drill pads that are approximately 100 ft by 100 ft in area encompassing each corehole and well drilling location (**Figure C.4**) for the Near-Field, Far-Field, north, northwest, and LVF areas (**Figure C.6** and **Figure C.8**). Drill pads

will be finalized once final corehole and monitoring well locations are finalized following preliminary site reconnaissance and surface geophysical surveys. Minor earthwork may be needed for access to, and work conducted at the borrow area test pits and boring locations. Plastic sheeting will be placed on the ground beneath the coring, drilling, development, and testing equipment during operations.

- Supporting equipment, including roll-off bins, frac tanks, and well materials will be stored at the laydown yard or storage yard.
- Portable toilets, a waste bin, and clean-water frac tank will be located at the laydown yard or storage yard (**Figure C.2**).

C.3.2 Site-Specific Health and Safety Plan

A SSHASP will be prepared to comply with applicable requirements of BHP's Safe Work Plan during all Site activities. The SSHASP should be reviewed by all personnel involved in performing field activities described in the final FIP. RAML required training will include site induction training, site-specific Safe Work Plan, Work Permits, Job Risk Assessments (JRAs), radiation safety training, Storm Water Pollution Prevention Plan (SWPPP) training, and any other training necessary to complete the drilling program.

RAML representatives are responsible for the overall Health, Safety, and Environment (HSE) implementation and verification activities; however, all personnel will be held accountable for executing work according to these requirements and the commitments outlined in the applicable permits and JRAs. In general, compliance with the permits and JRAs will be delegated to the work stream leads, who have the authority to make amendments and sign-off on the JRAs. RAML-specific permits, such as Ground Disturbance, Hot Work, Confined Space, Working at Heights, etc. may only be issued by RAML.

All field activities will be conducted under direct supervision of RAML. Coordination for each step of the CAAWP field program will be reviewed and approved by the RSO. During field activities, modified Level D personal protective equipment (PPE) will be used, including hard hats, safety glasses, and safety-toed boots. Nitrile gloves will be used to handle geologic samples, when appropriate. A safety meeting will be conducted prior to the initiation of work each day, and chemical and physical hazards of the day's work will be reviewed and discussed. Safety tailgate meetings are mandatory and will be held each field day with RAML and all other contractors scheduled to work that day. At the conclusion of the CAAWP field program, copies of all RAML Work Permits, RAML JRAs, daily tailgate meeting, and the Radiation contractor's scan out forms will be requested, compiled, and sent to Site health and safety officer.

Cellular coverage is poor in the area, so radios and line-of-sight signals will be the primary means of communication. Adequate cell phone coverage can be found by parking on the dirt shoulder of Lisbon Valley Road, on the east side of the road immediately north of the intersection with East Coyote Wash Road in the area referred to as the "cell phone booth" (**Figure C.2**). A global positioning system (GPS) device (SPOT satellite GPS messenger or similar) will be available for emergency situations in the event that cellular coverage is not available.

C.3.3 Permitting

The CAAWP field program will be conducted under a DWMRC-approved CAAWP (INTERA, 2022), which will be recommended reading for Site hydrologists and geologists. Permission to conduct the CAAWP field program on public land managed by the Bureau of Land Management (BLM) will be provided under the Amended Modified Plan of Operations and Letter to Proceed. The permits to construct non-production wells on both private and BLM property are provided by Utah Division of Water Rights and will be provided prior to commencement of drilling.

C.3.4 Utility Clearance

Underground utility surveys will be conducted prior to commencement of the CAAWP field program, and the information will be provided to the appropriate field crew. Known underground utility clearance areas identified during the HSSA4 field program (INTERA, 2021b) are indicated in **Attachment C.4** (shown as Subsurface Features). Overhead utility clearance is also required for overhead electrical power lines. Known heights of the overhead electrical power lines identified during the HSSA4 field program (INTERA, 2021b) are indicated in **Attachment C.4.**

C.3.5 Road and Well Pad Construction

Access to the well pads is via unimproved and improved dirt roads (**Figure C.4**). The new roads will be constructed to be approximately 10 feet (ft) wide. Newly constructed roads and maintenance of existing roads on public land administered by the BLM are limited to a total disturbance width of 10 ft. Greater widths are allowable for both construction and maintenance of roads on private lands within the project. The well pads will be approximately 100 ft by 100 ft unless the topography does not permit a square pad to be constructed or due to SWPPP considerations (**Figure C.4**). The earthwork will be conducted by an earthwork's contractor under the direction of RAML. All construction activities will comply with the SWPPP. SWPPP training will be included in the RAML-led site training prior to the start of the CAAWP field program.

C.3.6 Investigation-Derived Waste

The investigation-derived waste (IDW) for this CAAWP field program will be managed according to the Investigation-Derived Waste Management Plan (IDWMP) provided by the IDW contractor. The IDWMP will be managed by IDW contractor and will be covered during the RAML-led site training prior to the start of the CAAWP field program. Equipment decontamination will be completed by individual contractors as needed. The Radiation Work Permit (RWP) will be implemented and managed by the radiation contractor.

C.3.7 Other Activities

Water for drilling and road dust suppression will be supplied by a local water contractor, from a clean water source, and will be transported to the Site by a water hauling service. The water will be stored in a 'clean' frac tank or similar, to be located at the laydown yard or storage yard. Clean water use will be monitored, and the Site manager will be responsible for maintaining an adequate supply.

Sanitation services will be set up at the laydown yard. Sanitation facilities will be serviced 1 to 2 times per week depending on the number of workers at the Site. Portable toilets will also be stationed at the laydown yard, within the fenced area at the Lower Tailing Impoundment (LTI), and at active drilling sites on Rattlesnake Ranch property. If additional servicing or facilities are needed, contact the Site manager (see **Attachment C.1** for contact information).

Garbage and waste that is not IDW will be disposed in a designated roll-off bin at the laydown yard or storage yard.

C.4 CAAWP FIELD PROGRAM IMPLEMENTATION

This CAAWP field program will include up to 14 HSA coreholes in the borrow areas, 24 sonic coreholes (**Table C.1**), and up to 46 monitoring wells (**Table C.2**). Approximate locations of the borings, coreholes, and monitoring wells are shown in **Figure C.5**, **Figure C.6**, and **Figure C.8**. Estimated coring intervals, drilling depths, and formation thicknesses are detailed in **Table C.1** and **Table C.2**.

The tasks required for the drilling activities for the CAAWP drilling program are as follows:

- Road and drill-pad preparation.
- Core drilling, logging, and storage.
- Geophysical logging of coreholes.
- Plugging and abandoning coreholes.
- Monitoring well drilling, completion, and development.
- IDW management under IDW contractor direction and according to IDWMP.

Each of these tasks is described in more detail below.

C.4.1 Sequence and Timing

Earthwork for roads, pads, and storage yard construction will be completed prior to digging test pits, coring, or monitoring well drilling activities at the Site. Results from ERM and seismic refraction surveys will be used to help identify final drilling locations and will be conducted prior to all drilling activities at the Site, except for HSA drilling in the Borrow Areas.

Start dates will be contingent on completion of equipment safety certification, field conditions, and rig availability. RAML may decide to suspend field investigation activities during the winter because conditions can make fieldwork unsafe or difficult. Unfinished field scopes will resume when field conditions are conducive and necessary clearances have been established.

The anticipated drilling sequence for the coreholes and monitoring wells will be provided by RAML. The drilling schedule will be provided by RAML and will be included in the FIP once received and the FIP finalized.

C.4.2 Daily On-Site Operating Protocol

The following describes, in general, how the CAAWP field program will be executed on a day-to-day basis. The work schedule may be up to 20 days of work on-site (a "tour") with 10 days off, or as otherwise arranged by RAML. Weather conditions at the Site (e.g., precipitation and lightening) may interrupt work until field conditions improve.

At the start of every shift, all personnel will sign in at the laydown yard (**Figure C.2**) and participate in a safety moment in which any learning, concerns, or issues will be discussed. The intent of this meeting is to focus on what went well, what can be improved, and if the days' activities represent any substantial changes from the previous day. This will also be the time in which any simultaneous operations (SIMOPS) will be identified.

Following the safety moment, personnel will break out into their individual work groups to prepare for execution of their respective tasks for the day, including SIMOPS considerations. In general, this includes reviewing and signing their respective JRAs, equipment inspection, and coordination. Once the JRA for a specific task has been reviewed and signed off, that work stream may begin.

The various work streams will be managed by their respective leads (e.g., **Attachment C.1**). RAML personnel will provide general oversight; HSE verification; coordination; and conflict resolution.

Cellular coverage is poor in the area, so radios and line-of-sight signals will be the primary means of communication. Adequate cell phone coverage can be found by parking on the dirt shoulder of Lisbon Valley Road, on the east side of the road immediately north of the intersection with East Coyote Wash Road in the area referred to as the "cell phone booth" (**Figure C.2**). A GPS device (SPOT satellite GPS messenger or similar) will be available for emergency situations in the event that cellular coverage is not available.

Personnel may reconvene after work shifts to discuss the day's activities. A Daily Activity Form, similar to that shown in **Attachment C.5**, will be completed by personnel working at the Site. Site sign-out procedures will follow established Site protocols and License requirements.

C.4.3 Laydown and Storage Yards

A laydown yard is located on RAML-owned property and will be used as the base of operations for this CAAWP field program (**Figure C.2**). A second yard, the storage yard, is located on the north side of East Coyote Wash Road. The purposes of both areas will be discussed in the RAML-led Site training. Roll-off bins and frac tanks may be stored in the storage yard. In the event of an emergency, First Responders will be directed to the laydown yard, south of East Coyote Wash Road indicated on **Figure C.2**, and then escorted by Site personnel to specific locations. Contractors or visitors to the Site will also be directed to the existing laydown yard for induction, orientation, and sign-in.

The SWPPP project signage, rainfall gauge, and visitor sign-in sheet will be located at the laydown yard. This location will also be used for inspecting and staging equipment and supplies. CONEX storage units are available at the laydown yard. The CONEX storage units are for the storage of supplies but are not intended to be used as a work area. A clean-water tank will be located at the laydown yard or storage yard to provide a source of clean water for earthwork and drilling activities. The layout of the laydown yard and storage yard will be provided by RAML prior to commencement of field activities.

C.4.4 Traffic Management Plan

The Site work will involve significant vehicular traffic on narrow roads. Traffic management and call-in procedures will be implemented on a location-by-location basis. Traffic management plans, which will document one-way haulage patterns, radio call-in procedures, and work-zone restrictions, will be outlined in the JRA. Signage will be placed along the public roads as appropriate to advise commuters that operations are underway. Spotters with high-visibility clothing, radios, and pilot vehicles may be used during equipment moves.

C.4.5 Surface Geophysical Surveys

Geophysical surveys will consist of Electrical Resistivity Tomography (ERT), seismic refraction, magnetometric resistivity (MMR), and resonance acoustic profiling (RAP) passive seismic surveys. Seismic refraction surveys will provide data that will help delineate the base of the TSFs and the Burro Canyon-Brushy Basin contact. Results of the seismic and ERT surveys will be used to refine anticipated drilling depths of coreholes and borings. Proposed ERT and seismic refraction surveys are shown in **Figure C.5, Figure C.6,** and **Figure C.8.** MMR and RAP surveys will be used to evaluate groundwater flow paths in the target zones being investigated (**Figure C.7**). All surface geophysics are non-intrusive and will be overseen by RAML personnel and their contractors.

C.4.6 Borrow Area and Disposal Area Evaluation

C.4.6.1 Borrow Area Evaluation

The field activities at each of the four candidate borrow areas (**Figure C.3**) consists of advancing a maximum of 14 total borings **(Table C.3; Figure C.3)**. Borings will be completed through unconsolidated alluvium until refusal in underlying bedrock. The objective of the auger drilling is to visually identify the materials to depth of refusal and conduct standard penetration testing (SPT) as described further below. The auger drilling will help in initially determining the thickness of alluvium within each area and inform the planning for potential future data collection.

A mobile Central Mine Equipment ([CME]-75) HSA drill rig (or equal) will be used to advance the boreholes. The auger will have a 3.25-inch inside diameter (ID) and create a 6.5-inch borehole. Drilling will be in accordance with ASTM D6151-15 (ASTM, 2015) standards for using HSA for geotechnical exploration and soil sampling. A qualified professional will be responsible for logging and overseeing the auger drilling and sampling. The materials encountered in the borings will be visually classified in accordance with ASTM D2488-17 (ASTM, 2017b). Information gathered from the auger drilling will be recorded in a field book and boring logs will be created. Final boring logs will consist of the information collected in the field during drilling and laboratory analysis of material samples (gravimetric moisture content).

SPT will be conducted in each boring in accordance with ASTM D1586/D1586M-18 (ASTM, 2022) at intervals of 2 ft below grade, 5 ft below grade, and 5-ft intervals thereafter until auger refusal. At these same intervals, a grab sample of the materials from the auger cuttings will be bagged and marked for determination of gravimetric moisture content. Blow counts from the SPT will be recorded per each 6 inches of penetration in the field book and on the boring log. The SPT information will be used to assess the relative density of the in-place materials, and collectively with the gravimetric moisture content, is helpful in assessing the in-place conditions of the materials for possible future excavation for borrow. Each boring will be backfilled using the materials augered to the surface from the boring. Photographs will be taken to document the field investigation and nature of the materials encountered.

Samples of materials encountered will be collected from each boring as follows:

- Clean, new 5-gallon buckets with lids will be used.
- The first sample will be collected representing the materials from the surface to 2 ft below ground surface (bgs).
- One sample will be collected thereafter that represents a visual distinct and noticeable change in material to the base of the excavation.
- One composite sample of the materials will be collected representing the materials excavated from the boring in bulk.

For materials encountered having rocks larger than 1 inch in diameter, two (2) 5-gallon buckets of the materials will be collected. It is very important to collect an adequate volume of sample for laboratory analysis, particularly when a significant volume of the material contains gravel (and larger) size material. Each bucket of sample will be labeled with the following:

- "Lisbon" Borrow Area number and Test Pit number
- Date of collection
- Depth interval of collection
- Bucket no. __ of __ (as appropriate)

The laboratory tests proposed for the samples collected from the borings are summarized in **Table C.3** and **Appendix D, Table D.1**; including test method references. Samples collected from the borings have a dual purpose. The composite samples (an estimated total of 14) representing the materials in bulk from each of the borings will be analyzed to determine their index engineering properties – those properties used to classify the materials including particle size distribution, Atterberg limits, gravimetric moisture content, and Unified Soil Classification System (USCS) classification. One selected sample from each of the borrow areas will be remolded and tests conducted to determine their hydraulic properties (**Appendix D, Table D.1**). Additionally, laboratory testing will be done on one selected sample from each borrow area to assess the agronomic properties of the materials for supporting vegetation (**Appendix D, Table D.1**).

From this information, it will be possible to estimate the fraction of sand, silt, clay, and rock in each sample. In combination with the distribution of materials as recorded in field notes and test pit logs, the laboratory analyses will be used to calculate an estimate of the volume of those materials available for borrow. This information is adequate to use for the evaluation of future construction materials.

C.4.6.2 Disposal Area Evaluation

The proposed data collection for a possible new disposal area is the same as that for Borrow Area 2. The data for Area 2, together with the existing data from the two wells and one boring for that area, will be sufficient for an initial screening of the area for use as a disposal cell. The data will be used to including the following:

- Evaluation of unconsolidated alluvium on top of underlying bedrock
  - Thickness, extent, and volume
  - General engineering and agronomic properties
  - Preliminary suitability as borrow for cover, embankment, and erosion protection
- Nature of bedrock underlying the alluvium
  - Stratigraphy
  - Potential for excavation (degree of induration)
  - Depth to the water table
  - Potential for limiting infiltration
  - Potential for sidewall stability applications

C.4.7 TSF Soil Moisture Sensors

Soil moisture sensors (SMSs) will be installed at several locations near the edge of the LTI and Upper Tailings Impoundment (UTI) to measure changes in moisture content that may occur from recharge of surface flows along the lateral margins of the impoundments (**Figure C.5**). At each SMS transect, sensors will be placed at depths ranging from near the surface to the base of the tailings. Depending on sensor depth and location, sensors will be installed within a trench dug with a backhoe or in hand-augered holes. The specific number and location of sensors to be installed at each transect will be determined during preliminary Site reconnaissance and desktop evaluation. The sensors will be connected to one or more above-ground data loggers at each transect. The loggers will be connected to a metal T-post or similar structure. To protect the cables from the elements and animal tampering, the cables running from the sensors to the loggers will be buried until they reach the logger post, where they will enter polyvinyl chloride (PVC) pipe that extends from underground to the base of the logger. All HSE protocols associated with 11e.2 material will need to be adhered to.

C.4.8 Core Drilling

The Field Geologist will be responsible for logging the coreholes and overseeing the geophysical logging of all coreholes. Twenty-four (24) coreholes are proposed (**Table C.1**, **Figure C.5**, **Figure C.6**, and **Figure C.8**). The contact between the base of the alluvium and the top of the bedrock formation may be difficult to interpret, but the field team will strive to determine that contact accurately. In addition, the contact between the Burro Canyon and the underlying Brushy Basin may be difficult to interpret. Coring should continue into the Brushy Basin a minimum of 10 ft; however, drilling 15 ft to 20 ft into the Brushy Basin may be necessary to provide confidence in identification of the Brushy Basin since shales with similar geological characteristics exist in the Burro Canyon and have been at times misidentified as Brushy Basin shales. ERM surveys, seismic refraction surveys, and lithologic logs from previous corehole and well drilling will provide valuable information on the anticipated depth of the Brushy Basin and will be provided to the field crew. Information about what geology to expect is provided above in Section C.2.2, in the CAAWP (INTERA, 2022), and in relevant well logs. The methods for collection, description, and handling of rock core are described in subsequent sections and are based on the geologic literature and guidance documents by ASTM D2113-14 (ASTM, 2014). The proposed coreholes are listed in **Table C.1**.

C.4.8.1 Coring Method

Coring in the tailings will utilize sonic drilling methods. Continuous core will be collected from the proposed coreholes from ground surface to bedrock. Intact core will be collected in 5 ft Lexan core tubes or equivalent. Samples will be collected in accordance with sampling described in the Lisbon Valley Principal Investigation Questions (Appendix A, CAAWP). Should collection of core using sonic methods prove infeasible, HSA coring methods will be used for collection of core as described in Section C.4.6.1 and as was done during the HSSA4 tailings geotechnical investigation (INTERA, 2021c).

Rock core will be obtained using a sonic drilling rig. Core will be collected starting in rock just below the alluvial/bedrock or tailings/bedrock contact to obtain core from the entire bedrock interval to total depth. It is essential that the drilling contractor work diligently to obtain the most complete core recovery in every run and to advise the Field Geologist and/or document any physical changes in drilling, including penetration rate, vibration, or lost circulation during coring.

Artesian aquifer conditions were encountered in the northwest area during drilling at the Site (INTERA, 2021b, main text and Appendix 2A). Artesian conditions were observed during drilling at the following locations (for both coreholes and monitoring wells at these locations; from southeast to northwest): MW-136, MW-108, MW-124, MW-135, MW-138S, MW-138D, MW-134S, and MW-134D (**Attachment C.2, Figure C.2**). The artesian conditions are due to the fine-grained layer, Burro Canyon Fines 2, within the Burro Canyon (INTERA, 2022; INTERA, 2021b). Flowing artesian conditions were encountered during drilling of wells MW-138S and MW-134D. Flowing artesian conditions have been subsequently observed to be seasonal in nature. To prevent leakage from the artesian zone in the Burro Canyon into the overlying alluvium during coring, conductor casing will be permanently grouted into the borehole, extending from ground surface to a depth below the alluvium-Burro Canyon contact and above any Burro Canyon confining layers, as was done during HSSA4 drilling program (INTERA, 2021b, Appendix 2A). To ensure groundwater does not flow on the surface during coring, a diverter will be welded on top of the casing to control groundwater flow as needed. Any discharged groundwater will be containerized and treated as IDW in accordance with the IDWMP.

Clean water will be used for drilling fluid for rock coring. **Should a mud mix be needed to complete coring, the decision to use a mud-mix drilling fluid during coring will be done in consultation with the Field Geologist and RAML.** Samples should be collected to represent each type or batch of water or mud used for coring. Coring fluid will be collected from each corehole in case laboratory analysis is required at a later time. Sample bottles will be provided and will be used to collect core-drilling fluids, one sample to be collected from the top portion of the hole and one sample from the bottom of the hole. The sample bottles should be labeled with the drilling location, depth of sample, date and time, and name of field geologist collecting the sample. Samples will be stored in a cooler and kept cool with ice. The Program Manager will be notified of sample collection and will make the decision if the samples should be submitted to the laboratory for analysis.

C.4.8.2 Core Handling and Storage

The procedure for core collection is as follows:

1) Core should be extracted from the core barrel carefully, with minimal hammering or shaking of the barrel to dislodge the core. The return from each core run should be transferred to the box so that the top (higher elevation) is always to the logger's left. Using the industry standard method of placing the core in the box so that the top of the core is placed in the upper left and the bottom of the core is placed in the lower right, when viewing the box from the side (**Attachment C.6**).
2) The boring identification number and core interval will be clearly labeled on the inner and outer end of the box. In addition, the core run number depths at the top and bottom of the run, date, and time should be noted.

3) Wood blocks or another labeled separator should be placed in the box to identify core depth intervals or identify the interval of unrecovered core. In areas of no recovery place two blocks side by side with the upper and lower edge of the no recovery zone labeled. In places where the core has broken apart, two parallel marks should be made along the length of the core over the fractured area in its original orientation.

4) Core should be photographed and logged according to details provided in Section C.4.8.2.

5) Core in boxes will be stored in a location which protects the boxes from the elements. Boxes should be stored in sequential order with the label facing out for ease of retrieval and documentation.

6) Cores should be retained in marked core boxes until released for discard by the project manager.

The core samples will be placed in standard, waxed cardboard core storage boxes. The core storage boxes will be suitable for storing 10-ft intervals of core, and around sufficient wooden blocks (1-inch by 1-inch by ½ -inch) to identify missing core intervals and other critical depths in the core boxes. The driller will be collecting core and placing it in the boxes following instruction by the Field Geologist. The Field Geologist must be certain that the driller or RAML representative understands exactly how the core should be collected and boxed in case the Field Geologist is not available when core is being stored. After the core has been photographed and logged, the full core boxes will be transported to and stored in the CONEX storage unit at the laydown yard or storage yard.

C.4.8.3 Core Description

The rock units are expected to consist of sedimentary units such as sandstone, siltstone, mudstone, and shale. The lithologic descriptions, provided in the following paragraphs (Logging Core and Core Descriptions below), will be based on visual inspection with a 10-power hand lens and will be recorded on a field core logging form (**Attachment C.7**). Core features will be measured using a tape measure and recorded with dimensions of feet, tenths, and hundredths of a foot. The rock core will be described by the Field Geologist and/or Senior Geologist. The lithologic logs and monitoring well completion details from previous Site work can be helpful resources when describing the rock cores.

C.4.8.3.1 Logging Core

1) Core extraction and photography: Core should be extracted from the core barrel carefully, with minimal hammering or shaking of the barrel to dislodge the core. The return from each core run should be transferred to the V trough so that the top (higher elevation) is always to the logger's and photographer's left. The core should then be photographed. Each photo should include clear and visible markers (e.g., index cards) with the boring number, core run number depths at the top and bottom of the run,

date, and time. A consistent project-designated bar scale should also be included in each photo. For uniformity, the core should be photographed in lengths not exceeding four feet.

2) Marking core: After photographing, the core may be marked with two vertical marker stripes down its entire length to establish an orientation benchmark or scribe line and to allow for the reassembly of the core if the core pieces are mixed up and/or removed and replaced. Sections chosen for laboratory analyses should not be marked but extracted prior to marking and replaced with a wooden/Styrofoam block of equivalent length, marked appropriately as 'sample extracted for lab'. Depths should then be marked on the core in black marker. Intervals of core loss, when identifiable, can be replaced with a core loss block with the depths marked on the block. If the core run is incomplete, yet the location of the missing length is unknown, place a 'partial recovery' block representing the missing length at the end of the expected core length.

3) The total core recovery for that core run should be measured and recorded. The total recovery, as a percentage, is defined as:

Total recovery (%) = (length of core pieces recovered / total length drilled) x 100.

4) The Rock Quality Designation (RQD) of the core should then be determined.

The RQD is defined as:

RQD = (length of intact core pieces 4 inches or greater in length) / total length drilled.

Pieces shorter than 4 inches (10 cm) in length resulting from close fractures or weathering should not be summed. Pieces broken during the drilling process or during handling ("mechanical breaks") should be fitted together and considered as one piece. These features are usually identifiable as fresh breaks with a different character than natural discontinuities. The RQD values of individual beds, structural domains, weakness zones, etc. should be logged separately.

5) Core logging: The core should be logged in sufficient detail to meet the project objectives, as defined by the project manager and site-specific work plan. In general, logging information should be recorded for all lithologic, sedimentary and structural observations, including rock type (lithology), mineralogy and percentages (e.g. % mafic minerals), color according to the Munsell color classification (includes hue, value, and chroma), weathering – include degree (fresh, slightly, moderately, highly, completely), hardness, fossils – occurrence (type) and abundance, grain size, grain shape, sorting from the geologic perspective (where a sample with similar grain sizes is well sorted), rounding, sphericity, cementation or induration, visible sedimentary structures such as thick/thin bedding/cross bedding, and visible porosity (i.e., are vugs or other holes visible between grains in rock chips).

6) Fracture logging: The generic term for discontinuities without reference to genesis or mode of origin is 'fracture'. A 'joint' is defined as a fracture that has experienced

opening movement normal to the fracture plane. A 'fault' is defined as a fracture for which movement parallel to the fracture plane can be demonstrated. The term 'fracture' should be used in the log description unless sufficient evidence exists for a term describing its origin. Mechanical breaks should be labeled 'MB' on the photographed core. Fracture description should include wall roughness – smooth or rough, clean – no fracture filling material, staining – including coloration and stain penetration into matrix, filling – including mineralogy if identified (e.g. carbonate, silica), fracture orientation – the orientation measured with a protractor relative to the core scribe line, slickensides – the occurrence of slickensides and their relative orientation to vertical and the scribe line, and separation distance between fracture walls – if apparent.

7) Cores will be retained in marked core boxes and stored in the Conex located at the laydown yard.

C.4.8.3.2 Core Descriptions

Lithology with Lithologic Descriptors

The core descriptions will include the following information:

1. General Rock Name (i.e. sandstone, mudstone, shale, etc., granite, diorite, gabbro, schist, phyllite, gneiss, etc., based on American Geologic Institute [Walker and Cohen, 2009] standard rock classification)
2. Color (Munsell color chart)
3. Grain/particle size (i.e. fine-grained, medium-grained, coarse-grained, pebble, cobble, etc., using grain-size chart)
4. Composition (mineralogy, i.e. quartz 75%, feldspar 20%, lithic fragments 5%, etc., using hand lens and percentage chart and standard geologic texture terms)
5. Sorting (well sorted, poorly sorted, etc., using sorting chart)
6. Rounding (well rounded, angular, etc., using rounding chart)
7. Cementation, silicification, and mineralization, including reaction to hydrochloric acid
8. Bedding/lamination/foliation/flow texture (bedding, cross bedding, lamination, fissile, shaley parting, etc.)
9. Contacts (bedding or geologic unit contacts)
10. Rock unit (member or formation) name (if known)
11. Other (i.e. fossils, carbonized wood, petrified wood, etc.)

Example Lithologic Descriptions

SANDSTONE. Fine- to very fine grained, well sorted, quartz 85%, feldspar 8%, dark rock fragments 2%, clay matrix 5%, trace iron staining as discrete spots, rounded to well rounded, light brown, 7.5 YR 7/4. Well cemented, thinly laminated with dark grain layers, dry, moderate HCL reaction. Formation name, if known.

MUDSTONE. Clay 60%, quartz grains 30%, feldspar grains 5%, carbonate grains 3%, organic matter 1%, trace iron oxide, light reddish brown 2.5 YR 5/4. Quartz and feldspar medium grained to silt, subrounded to rounded, poorly sorted. Well cemented to slightly friable, dry, no reaction to HCL. Formation Name, if known.

SHALE. Clay 90%, silt 5%, organic matter 5%, dark grayish-brown 5YR 2/2. Thinly laminated, fissile, parting on bedding planes. Dry, no reaction to HCL. Formation name, if known.

LIMESTONE. Fine-grained, calc-arenite (sand:fine detrital = 9:1) to fine-grained limestone (sand:fine detrital = 1:9), grayish-blue 2.5B 5/2. Describe fossils, unabraded fossils, fecal pellets, ooids, pisoliths, shells, etc. Formation name, if known.

FAULT BRECCIA. Angular clasts of sandstone and limestone in sand and clay matrix. (describe clast lithology, size, shape, texture, cementation, color), (describe matrix lithology, cementation, color, texture), (describe structure, i.e. slickenlines, cataclasis, cementation, etc.), HCL reaction, etc.

FAULT GOUGE. Describe lithology, (clay, sand, rock fragments), cementation (loose, poorly cemented, well cemented, etc.), color, structure (streaked, layered, etc.), wet, dry, HCL reaction, etc.

Unconsolidated alluvial material will be described according to the Unified Soil Classification System (USCS), ASTM D2487-17, Standard Practice for Classification of Soils for Engineering Purposes (ASTM, 2017).

Structural Discontinuity Description

Structural discontinuities consist of all structural breaks in the rock core, such as joints, shears/faults, and fault zones. Observing and documenting these features is important to the core drilling and sampling program.

The following features, if present, will be identified and documented:

- Joints: a type of natural fracture, relatively planar, with no obvious displacement; document joint characteristic such as open, healed, filled. Joints occur in sets and typically have uniform orientation.

- Shear: a structural break where differential movement has occurred, characterized by polished surfaces, striations, slickensides, gouge, breccia, mylonite, or any combination of these.
- Fault: a shear with significant continuity which can be correlated between observation locations.
- Shear/fault zone: a band of parallel or subparallel fault or shear planes.
- Shear/fault gouge: pulverized material derived from crushing or grinding of rock by shearing.
- Shear/fault breccia: cemented or uncemented, predominantly angular and commonly slickensided rock fragments resulting from crushing or shattering of rock.

Rock Quality Designation

RQD may be evaluated on the core if such data is expected to be useful for evaluating groundwater flow and transport. RQD is a fracture index, which consists of the total length of solid core that is greater than or equal to 4 inches long, divided by the length of the core interval (core run) in inches. **Attachment C.8** provides a diagram for how to calculate and document RQD.

C.4.8.4 Core Sampling

Sections of core will be sampled for geochemical analysis after the core has been collected, logged, and photographed. The sampling will be conducted by project geochemists and hydrogeologists. Intervals of drill cuttings produced during monitoring well installation will also be preserved for possible future geochemical analysis. In both cases, samples will be chosen to represent the following lithologies: (1) alluvium just above the Burro Canyon; (2) Burro Canyon sandstone near the top (unsaturated) and bottom (saturated) of the formation; (3) the top and bottom of the Burro Canyon fine-grained beds that occur throughout the Site, generally at about 60-70 ft bgs; (4) the top of the Brushy Basin; and (5) any distinct zones within the Burro Canyon that show different mineralogy and/or textures, or physical disturbance such as fracturing.

C.4.8.5 Geophysical Logging

Upon completion, coreholes will be geophysically logged to measure different physical properties of the formation along the corehole. The geophysical logging contractor will be directed by the Field Geologist and RAML Site representative.

The geophysical logging suite will consist of the following:

- Electric Logs:
- Spontaneous potential (SP)

- Short normal resistivity (16 inch) (RSN)
- Long normal resistivity (64 inch), (RLN)
- Single point resistance (SPR, Point)
- Natural gamma ray log (GR)
- Neutron
- Caliper log and borehole volume
- Temperature

Geophysical logging should occur as soon as practicably possible following completion of coring to minimize the possibility of corehole collapse. The logging process is expected to take approximately 6 hours, and the field copies of the geophysical logs will be made available by the geophysical contractor immediately after logging. The core log and geophysical log will be reviewed to determine the drilling specifications for the twinned monitoring well screen interval. Guidance on documentation during the geophysical logging is provided below.

Documentation of Geophysical Logging

Prior to commencing geophysical logging, the following information should be recorded in the field log book:

1) Date and borehole number, personnel on-site, visitors, weather, anticipated logging depth(s), borehole size(s) and condition (e.g., post mud circulation, expected collapse zones, etc.).
2) Geophysical logging contractor and logging appurtenances (e.g., self-contained logging vehicle/truck, winch truck with logging tools, other).
3) Requested geophysical logging suite.
4) All information provided to geophysical logging contractor for inclusion on log header. Determine how the logging contractor determined the elevation on the log and make sure that they have given the GPS unit plenty of time to locate correctly and that the satellite accuracy is as good as possible. If the elevation is from GPS, it must be clearly identified on the header as "GPS approximate". When filling out the Datum make sure that it is filled in correctly; datums are typically Kelly Bushing (KB), reference level on rig (RL), or ground level (GL).
5) Confirmation from logging contractor of date of logging tool(s) calibration.
6) A written list of email addresses for the people who will receive, at a minimum, .pdf, .tif, and .LAS files of the logs. This includes checking in with said persons to confirm that they have received the logs and the all the necessary information has been included. If it is not, it is the responsibility of the field geologist to remedy the situation. It is ideal if the logging

company can email the log through satellite internet connection. If they cannot, discuss the situation with the logging contractor and determine exactly when they will be able to get the log to the appropriate persons. If this time frame is more than one hour and there is cell phone service, take a photo of the geophysical logs, make sure that it is straight, and send it to the necessary parties.

7) Description/photo of logging setup over borehole.
8) Date/time of commencement and completion of geophysical logging, including reruns.
9) Note drilling and logging total depths and reconcile differences by reference to KB/rotary table or other common points.
10) Note of geophysical log file name(s), including date and time.

C.4.8.6 Plugging and Abandoning

After the coreholes have been geophysically logged, the coreholes will be plugged and abandoned. Coreholes will be pressure grouted with tremie pipe from bottom to top using neat cement grout, sand cement grout, unhydrated bentonite, or bentonite grout in accordance with Section R655-4 of the Utah Administrative Code (UAC) (UDWR, 2018). The coreholes with permanent conductor casing installed to control artesian conditions will be plugged and abandoned with the conductor casing left in place.

C.4.9 Monitoring Well Drilling

Forty six (46) monitoring wells are proposed to be drilled, completed, and developed during the CAAWP field program (**Table C.2**, **Figures C.5**, **C.6**, and **C.8**). Well construction permits (Start Cards) will be provided prior to drilling startup.

The field geologist will be responsible for logging cuttings as they come out of the drill hole and provide input to RAML and the driller on estimated drilling depth. The borings without a twinned corehole will be geophysically logged (**Table C.2**).

All of the wells will be 4-inch ID, schedule 80 PVC and screen. The wells will be completed with a minimum of 20 ft of screen or as directed by the field geologist in the target aquifer. A different screen interval may be determined based on field parameters, including the aquifer interval identified from the lithologic log, the core, depth to water, saturated thickness, and the geophysical log. Each well will be completed with an above-ground surface completion consisting of a concrete pad, a protective steel casing, and a locking lid and protective bollards. Whether or not evidence of saturation is found in the boring, monitoring wells will be constructed.

The following sections include specific steps for completing the monitoring wells.

C.4.9.1 Drilling Process Details

The groundwater monitoring wells will be constructed according to the specifications in ASTM D5092 / D5092M-16 (ASTM, 2016) and in Utah Water Well Handbook (UDWR, 2018). The RAML Site Representative will manage and direct the drilling operations and oversee all boring specifications. Preliminary boring specifications are provided in **Table C.2**. The preferred method for drilling monitoring wells will be air rotary; drilling muds will be used if other methods are unsuccessful. If drilling fluid is required, this must be discussed with the Program Manager and Lead Hydrogeologist before implementation. Clean water will be used for drilling fluid for rock coring. **Should a mud mix be needed to complete coring, the decision to use a mud-mix drilling fluid during coring will be done in consultation with the Field Geologist and RAML.** Fresh water will be available in a tank at the laydown yard or storage yard.

As mentioned above for core drilling (Section C.4.8.1), artesian aquifer conditions were encountered in the northwest area during drilling at the Site (INTERA, 2021b, main text and Appendix 2D) and similar considerations need to be made for well drilling as those for coring.

C.4.9.2 Drill Cuttings Logging

The Field Geologist will log cuttings from all monitoring wells as they come out of the drill hole. Lithologic and discontinuity observations will be recorded on a drill cuttings logging form (**Attachment C.9**). Lithologic samples (drill cuttings) will be collected at a minimum of every 10 ft by the Field Geologist, or at textural or stratigraphic changes, and placed in the labeled cuttings boxes (chip trays). The driller will provide a means of collecting the samples from the cuttings container and advise the geologist of the 10-foot drilling intervals. Larger samples may be collected depending on geology and depth and will be determined in the field by the Field Geologist. Details for logging drill cuttings is included below:

1) Drill cuttings should be obtained and logged at 10-ft intervals, or at textural or stratigraphic changes, if these occur at less than 10-ft intervals.
2) Logging of drill cuttings includes:
   a. Classification in accordance with the USCS equivalent to ASTM D2488-17 (ASTM 2017b), and
   b. Geologic descriptions of cuttings, including mineralogic composition and percentages (e.g. % mafic minerals), color according to the Munsell color classification (includes hue, value, and chroma), grain size, grain shape, sorting from the geologic perspective (where a sample with similar grain sizes is well sorted), rounding, sphericity, fossils – occurrence (type) and abundance: in the case of rock chips, cementation or induration, visible sedimentary structures such as thick/thin bedding/cross bedding, and visible porosity (i.e., are vugs or other holes visible between grains in rock chips).

c. Each interval should be logged in detail; the term "same as above" or equivalent is not acceptable.

3) Any relevant observations regarding the drilling process (e.g., changes in drilling rate, excessive rig chattering, etc.) should be recorded.
4) All log entries should be written such that reproductions will be clear and legible.
5) Borehole depth information should be recorded to the nearest 0.1 ft and a consistent cross-check with the driller documented. The driller should clearly explain the specific heights on the rig that correspond to 5, 10, 15 and 20 feet above the KB.
6) Samples of cuttings should be placed in sealed plastic bags (1-gallon bags filled approximately half full are sufficient), clearly marked with borehole number, date, and sample depth interval.
7) Bagged cuttings samples should be retained in the order taken in labelled 5-gallon buckets with lids. Retained samples will not be discarded without project manager permission and documentation.

Estimates of anticipated formation thicknesses are provided in **Table C.2.** The contact between the base of the alluvium and the top of the bedrock formation may be difficult to interpret, but every effort will be made to determine that contact accurately. The driller will drill a minimum of 10 ft into the Brushy Basin mudstone or the Kayenta sandstone, as directed by the Field Geologist and/or RAML Site Representative. In some instances, drilling 15 ft to 20 ft into the Brushy Basin may be necessary to provide confidence in identification of the Brushy Basin since shales with similar geological characteristics exist in the Burro Canyon and have been at times misidentified as Brushy Basin shales. Geophysical surveys and lithologic logs from nearby previously drilled borings or coreholes will help reduce the uncertainty associated with the depth of the Burro Canyon-Brushy Basin contact. Similarly, the contact between the Navajo and the underlying Kayenta may also be difficult to identify. Information about what geology to expect is provided in Section 2.2 in Appendix 2A of the HSSA4 Report (INTERA, 2021b), and well and core and boring logs which will be available on-site.

C.4.9.3 Geophysical Logging

Borings drilled for monitoring wells may be geophysically logged depending on the proximity of the boring to nearby borings or coreholes that have been previously logged. **Table C.2** indicates which borings will be geophysically logged. The suite of geophysical logging tools will be the same as that indicated for coreholes (Section C.4.8.5).

C.4.9.4 Monitoring Well Specifications

The RAML Site representative will manage and direct the drilling operations and oversee all monitoring well specifications. Preliminary monitoring well specifications are provided in **Table**

C.2. The Field Geologist will be responsible for ensuring proper construction of the monitoring wells. For additional well installation information, refer to the following:

- The State of Utah Water Well Handbook (UDWR, 2018),
- ASTM D5092 / D5092M-16 (ASTM, 2016).
- Monitoring well installation details provided in the HSSA3 Report (INTERA, 2021a) and the HSSA4 Report (INTERA, 2021b).

Monitoring well construction will be documented in a monitoring well construction diagram, similar to that shown in **Attachment C.10**. Key monitoring well specifications are provided below:

- Monitoring well rotary borings may vary but will be of sufficient diameter for placement of 4-inch PVC pipe and sand pack; if artesian conditions exist, larger diameter boreholes will be needed (e.g., 14-inch, INTERA, 2022b) for installation of 10-inch conductor casing to a depth to be determined based on the thickness of alluvium (Section C.4.9.1).
- Monitoring wells will be constructed with 4-inch, Schedule 80 PVC pipe.
- Screens will be a 20-ft, 0.020-inch slot, Schedule 80 PVC pipe in the target aquifer.
- A minimum 4-inch difference between the well outer diameter and the borehole diameter is required (R655-4-11.4.3.1 UAC) (UDWR, 2018).
- Stainless steel centralizers will be placed every 60 ft on the blank casing, if this will not interfere with material installation with tremie pipe.
- The sand pack will be composed of 10/20 silica sand placed around the screen and 2 ft above the screen.
- A bentonite seal composed of ⅜-inch time-release bentonite pellets will be placed in the borehole a minimum of 5 ft above top of sand pack and hydrated with potable water in 1-ft lifts (unless in saturated zone).
- The neat cement grout will be composed of 1 x 94-pound sack of Portland cement and 5% (4.7 pounds) powdered bentonite with approximately 6 gallons of clean water and will be used to grout to the surface (ASTM, 2016).
- For wells where artesian flowing conditions are not expected, surface completion will be a 2.5-ft PVC casing stick-up with PVC well cap with a standard 8-inch steel protective casing with locking lid, casing painted yellow.
- For wells where flowing artesian conditions are possible, surface completions will include a pressure gauge and sample port threaded fitting at the top of the casing which will be enclosed in a Tuscan vault (**Figure C.9**) (INTERA, 2021b, Appendix D).

- A concrete pad will be constructed around the surface completion with a 2-ft minimum radius and 4-inch minimum thickness, sloping away from the protective casing, with well identification imprinted in concrete prior to concrete solidification.
- All Tuscan vaults and steel monuments will be fitted to accept locks.

C.4.9.5 Monitoring Well Development

A groundwater monitor well requires development prior to obtaining water level measurements or water quality samples. After installation, the wells will be developed in accordance with ASTM Standard D5521/D5521M-13 (ASTM, 2013).

The Field Geologist will be responsible for confirming that the wells have been adequately developed. If drilling muds are used during the monitoring well drilling, additional well development may be required. The well will be developed using a development rig, and development will consist of one or a combination of pumping, swabbing, airlifting, surging, and bailing techniques. All produced water will need to be disposed of properly under the IDW plan. Well development will be documented on a field well development form (**Attachment C.11**).

The intent of well development is to:

- Reduce compaction and intermixing of grain sizes produced during drilling;
- Increase porosity and permeability of the artificial filter pack via removal of fines introduced near the screen during drilling/well installation; and
- Remove residual drilling fluids/foreign material from the borehole or the adjacent natural formation.

Common development methods of a groundwater monitor well that may be implemented by field personnel during the CAAWP field program are as follows:

- Mechanical Surging;
- Air Surging or Jetting;
- Pumping; and
- Bailing.

Common well development methods used solely or in conjunction facilitate the movement of water through a well screen, thereby moving any residual fines (silt and clay particles) trapped in the filter pack around the well screen into aqueous suspension within the well casing. The sediment-laden water is then removed from the well casing using a pump, bailer, or air compressor.

A groundwater monitor well is determined to be effectively developed upon achievement of one or both of the following criteria, as applicable:

- At least three (3) well casing volumes have been removed and water quality parameters for pH, temperature, and conductivity, as appropriate, have stabilized; or
- Five (5) well casing volumes have been removed.

Development of a groundwater monitoring well should occur no earlier than 24 hours after initial installation to allow enough time for (1) the well's annular seal and grout to properly set and (2) to maximize the hydraulic connection between the well and surrounding aquifer material. Settling periods longer than 24 hours may be required for wells where a more vigorous well development method (e.g., surging) is planned to minimize the potential for well development procedures to compromise the annular seal.

C.4.10 Wellhead Survey

The wellhead survey will consist of a professional survey of X and Y coordinates of the well locations, as well as the latitude and longitude of the well. Elevation of the ground surface (top of concrete pad), Z, and the measuring point on the wellhead, i.e. top of PVC casing inside the protective casing, will be surveyed with respect to mean sea level. Field Staff will be responsible for coordinating and overseeing the wellhead survey.

C.5 REFERENCES

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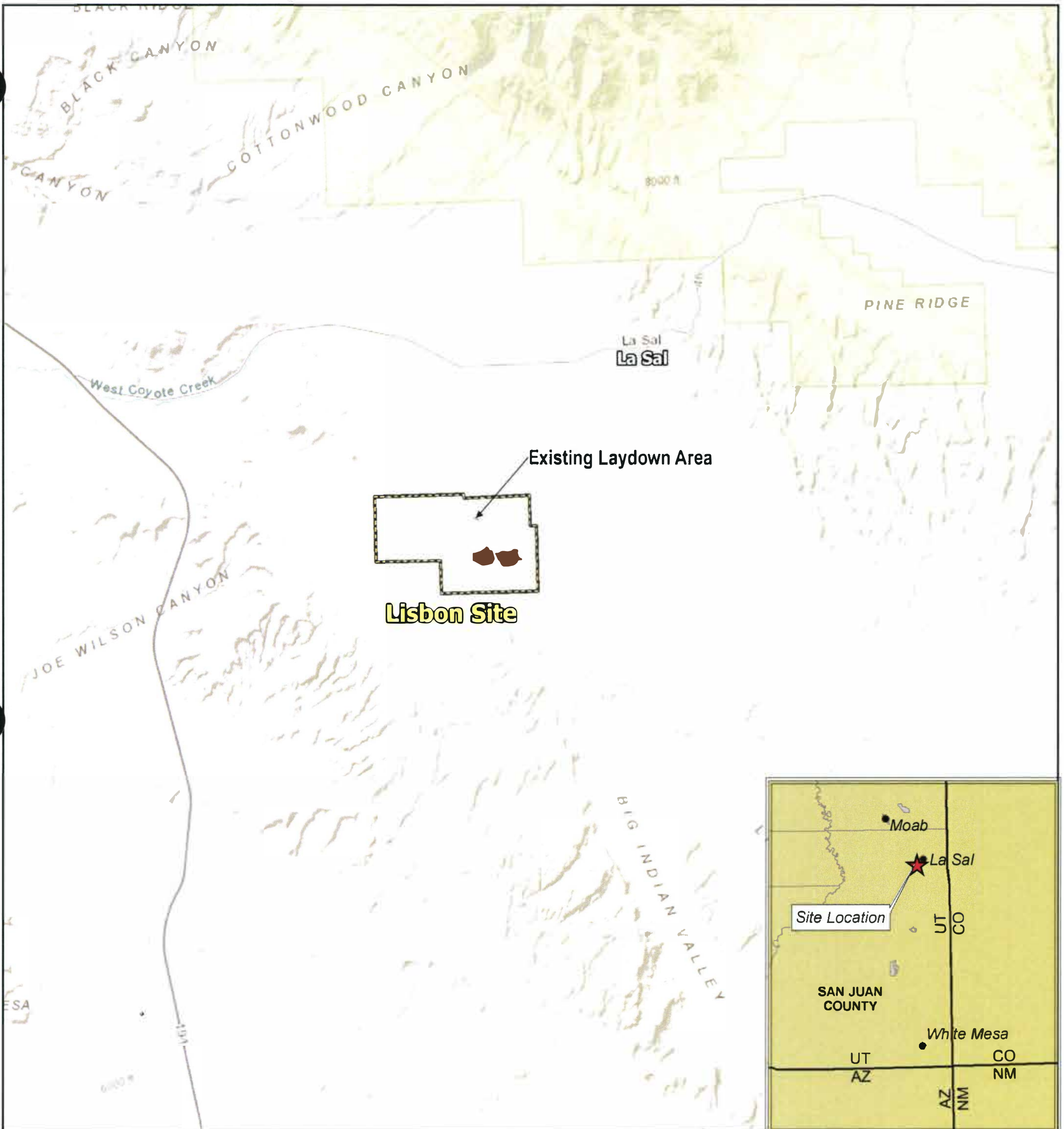
Figures



Preliminary Long Term Surveillance and Maintenance Boundary

Tailing Impoundment

Paved Road

Gravel Road

N

2 1 0 2

Miles

Source(s): USA Topo Map; ArcGIS Online.

Figure C.1
Site Location
Lisbon Facility CAAWP
Field Implementation Guidelines

INTERA

N

2,400 0 2,400

Feet

Source(s): NAIP imagery, 2018

- Point of Compliance (POC) Well
- Point of Exposure (POE) Well
- Trend Well
- Background Well
- Monitoring Well
- Cell Phone Booth
- Unsaturated BCA
- Rio Algom Mining LLC Property Boundary
- Preliminary Long Term Surveillance and Maintenance Boundary
- Normal Fault
- Normal Fault (inferred)
- Storage Area
- Laydown Area
- Decon Area (approximate locations)

Completed in the Alluvium

Completed in the Brushy Basin

Completed in the Navajo Sandstone

Completed in the Chinle

Note: Lisbon Valley Fault trace modified from Doelling (2004)

Figure C.2
Site Features
Lisbon Facility CAAWP
Field Implementation Guidelines

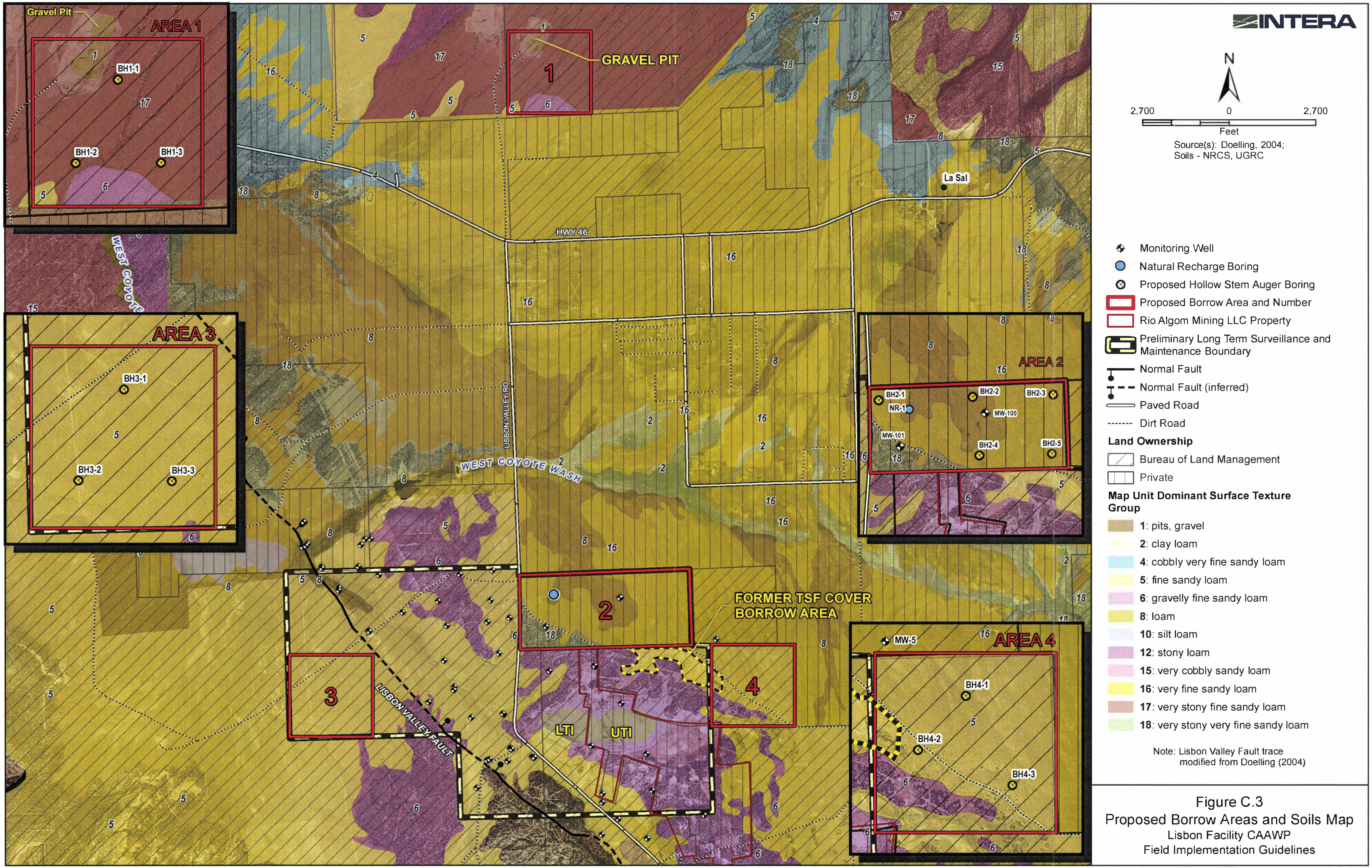


Figure C.3
Proposed Borrow Areas and Soils Map
Lisbon Facility CAAWP
Field Implementation Guidelines

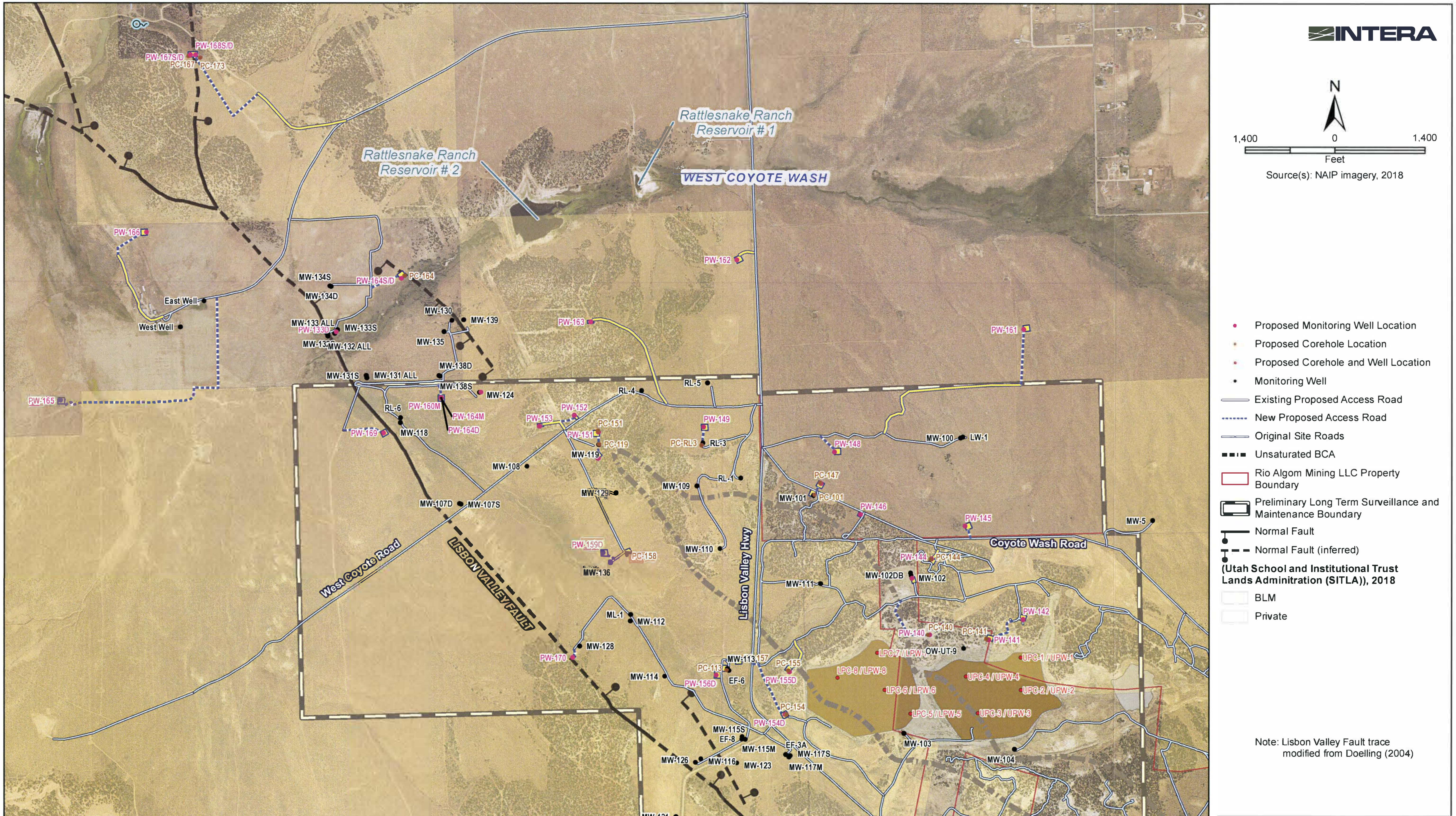
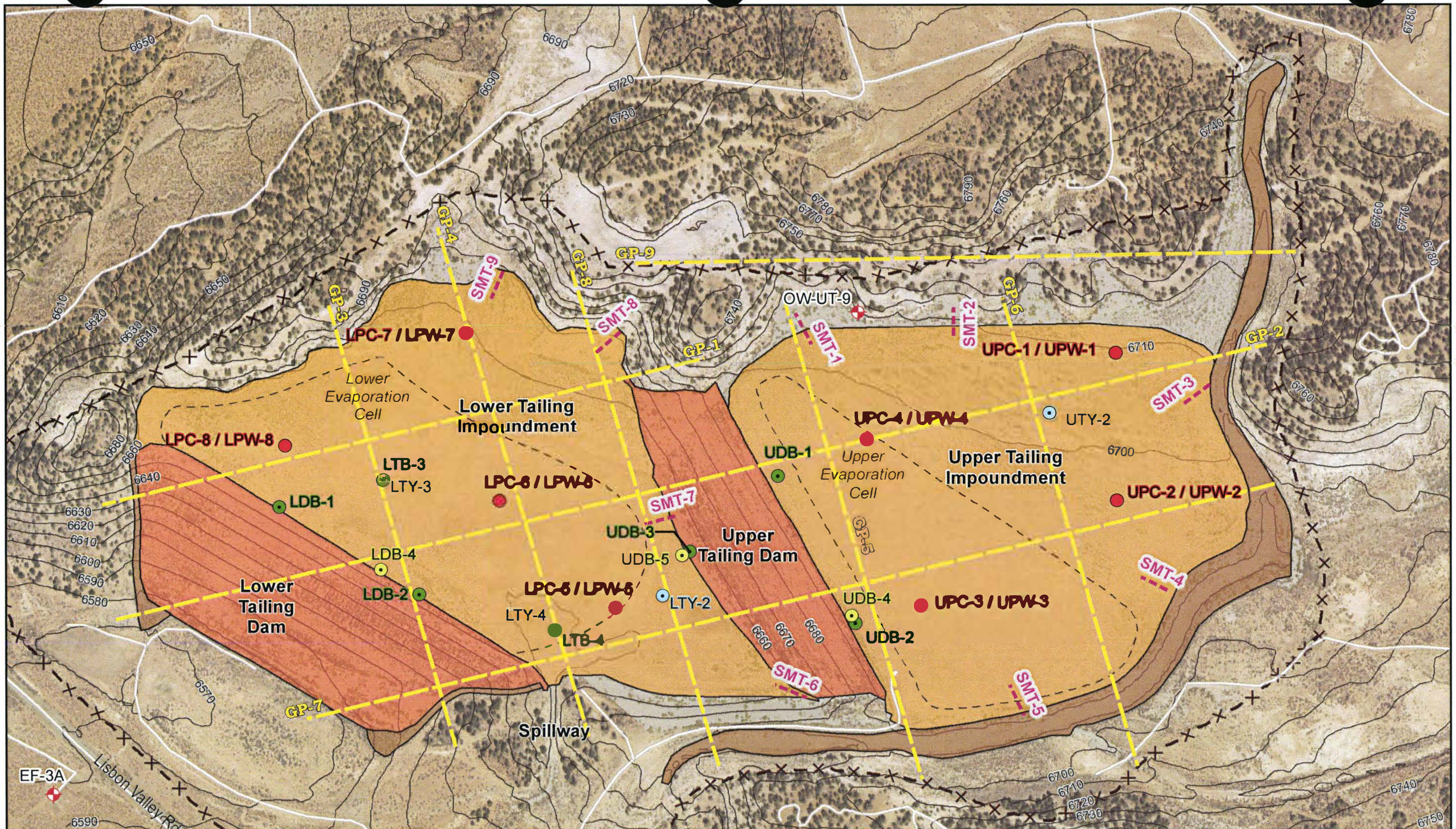


Figure C.4.
Proposed Pads and Roads
Lisbon Facility CAAWP
Field Implementation Guidelines



- Proposed Corehole and Well Location
- 2019 HSA* Boring
- 2019 Sonic/Core
- Lysimeter
- Point of Compliance (POC) Well
- Site Access Road
- Contour (10 ft)
- Fence Boundary
- Approximate Limits of Former CAP Evaporation Cells
- Channel
- Tailing Dam
- Tailing Impoundment
- Geophysical Survey Location
- Soil Moisture Sensor Transect (SMT)

N

500 250 0 500

Feet

*Abbreviations

HSA: Hollow-stem Auger

INTERA

Source(s): Aerial Imgery (NAIP, 2018)

Figure C.5
Proposed Source Area Installation Locations
Lisbon Facility CAAWP
Field Implementation Guidelines

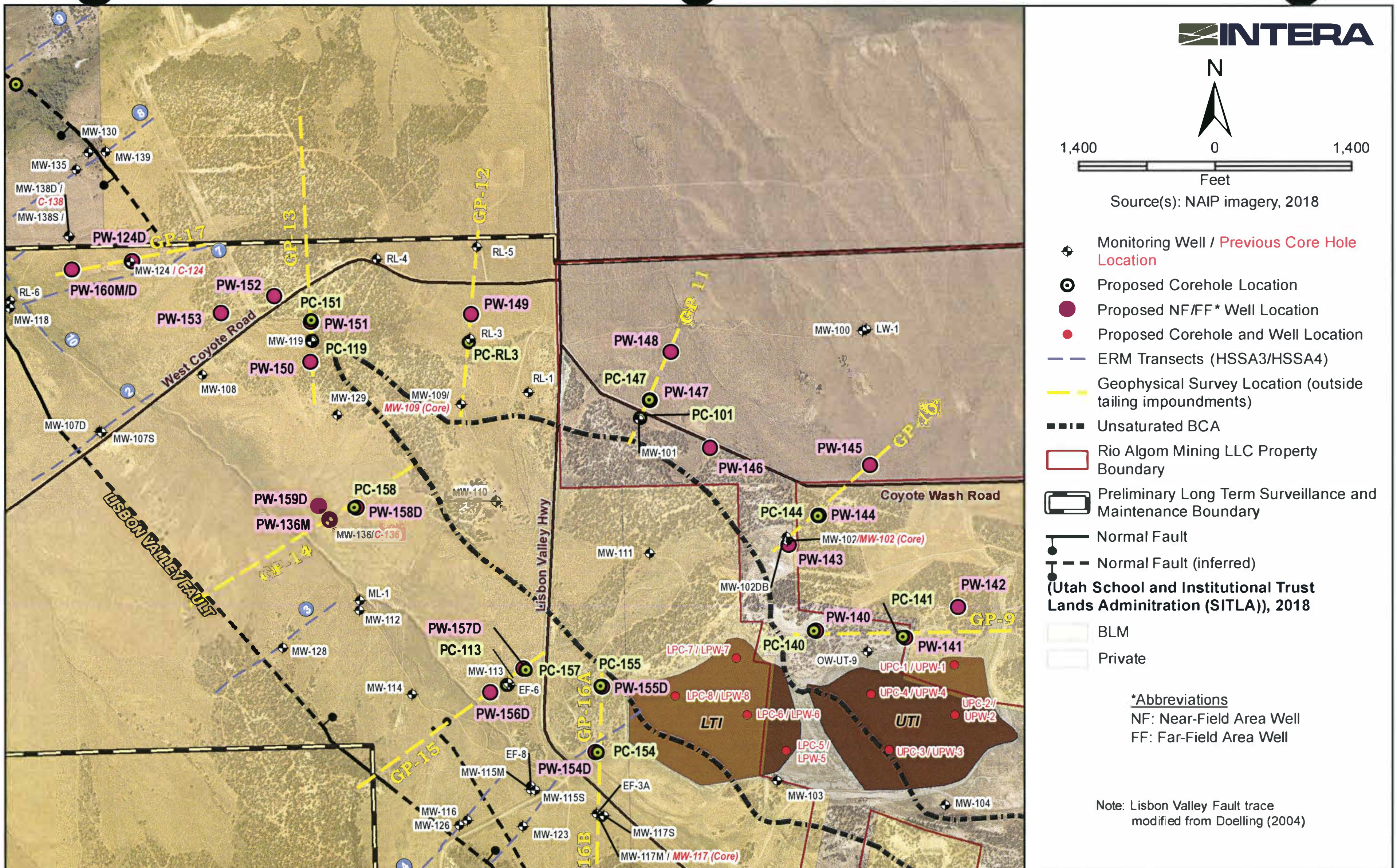
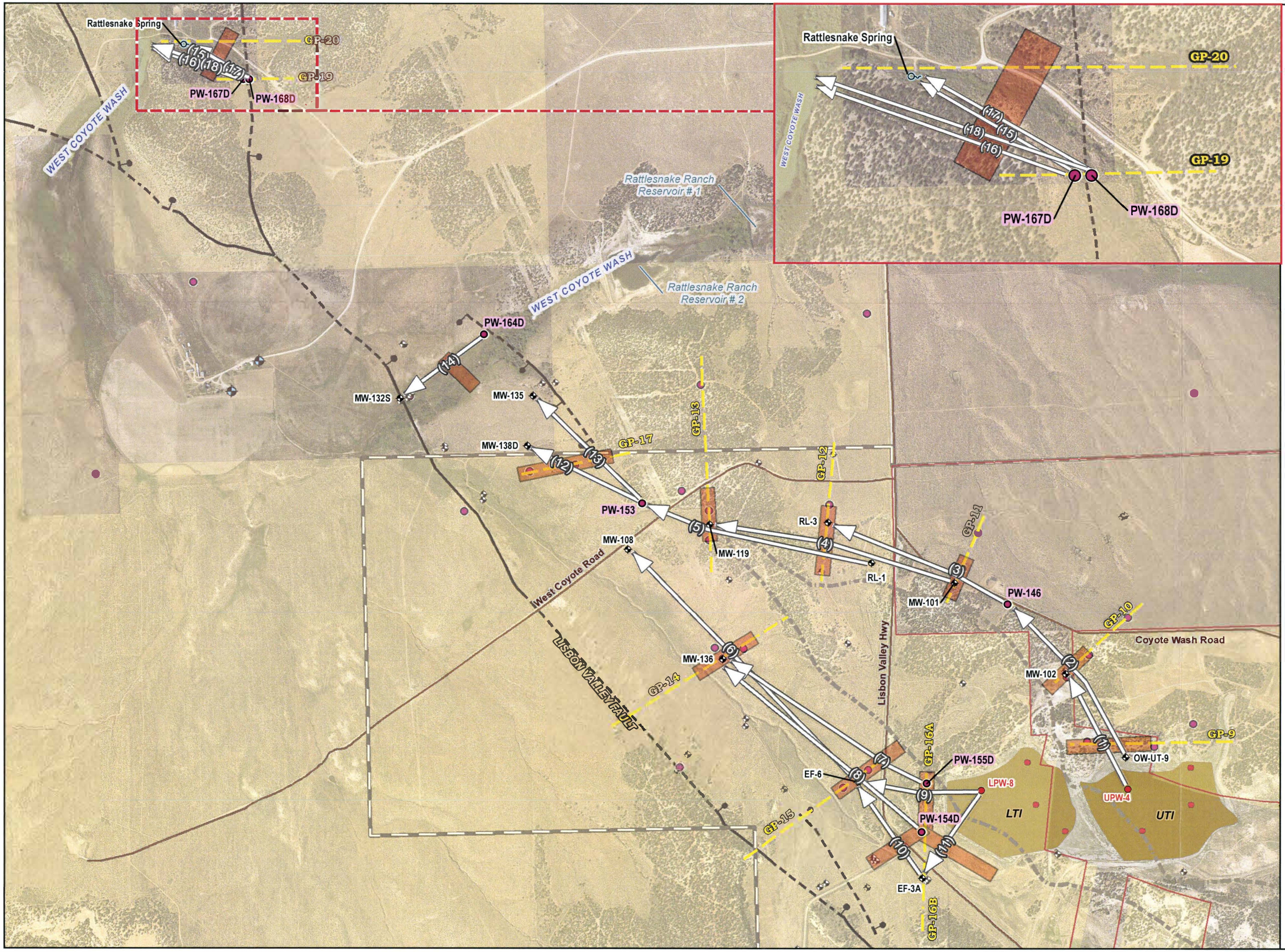


Figure C.6
Proposed Near-and-Far-Field Installation Locations
Lisbon Facility CAAWP
Field Implementation Guidelines



INTERA

N

1,400 0 1,400

Feet

Source(s): NAIP imagery, 2018

- Monitoring Well
- Proposed NA/NF/FF* Well Location
- Proposed Corehole and Well Location
- (#) Arrow indicating electrode pairing and Survey ID (see Table 6.3)
- Geophysical Survey Location (outside tailing impoundments)
- Unsaturated BCA
- Rio Algom Mining LLC Property Boundary
- Preliminary Long Term Surveillance and Maintenance Boundary
- Normal Fault
- Normal Fault (inferred)
- MMR and RAP Survey Zone (approx)

(Utah School and Institutional Trust Lands Adminitration (SITLA)), 2018

- BLM
- Private

*Abbreviations
NA: North Area Well
NF: Near-Field Area Well
FF: Far-Field Area Well

Note: Lisbon Valley Fault trace modified from Doelling (2004)

Figure C.7
Proposed MMR and RAP Survey Locations
Lisbon Facility CAAWP

FILE: S:\ABQ\RIOAL.RioAlgom\Graphics\Lisbon\MapDocs\CAAWP\Work_Plan\06_02_MMR_RAP_Survey.mxd 11/14/2022

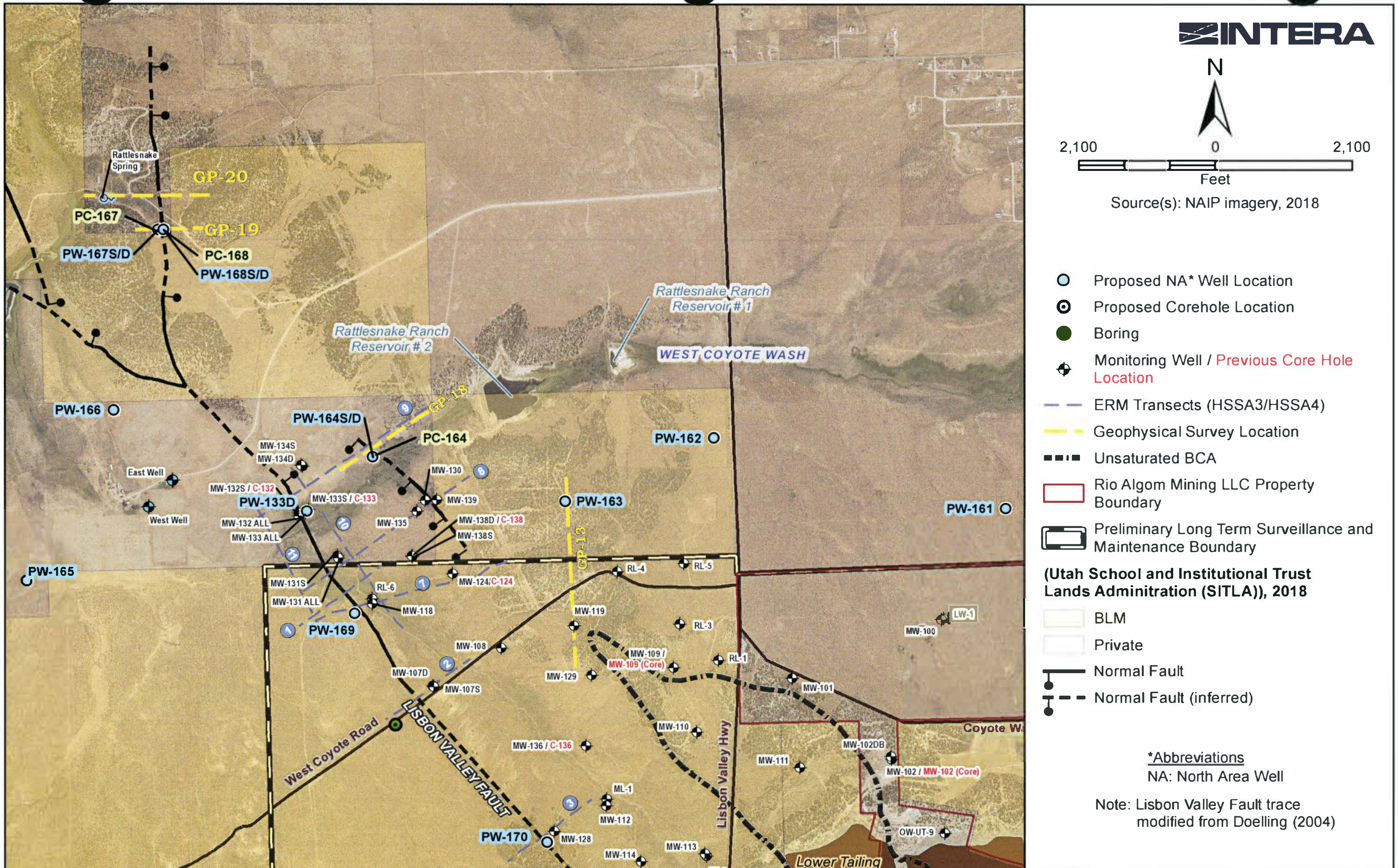


Figure C.8
Proposed North, Northwest, and LVF Installation Locations
Lisbon Facility CAAWP
Field Implementation Guidelines

Figure C.9
Surface Completion with a Pressure Gauge
and Sampling Port Enclosed within a Tuscan Vault
Lisbon Facility CAAWP
Field Implementation Guidelines

Tables

Table C.1 Proposed core holes for CAAWP field program.

Index	Core Hole ID	Final Completion	Lithology	Artesian Conditions	11e.2 Material	Geophysical Log	Total Depth (ft bgs)	Alluvial Thickness (ft)	Conductor/ Casing Size (in)	Core Size (in)	Tailing Core Length (ft)	Rock Core Length (ft)	Comment
1	UPC-1	P&A	0-5' Impoundment Cover 5-35' Tailing Material 35-45' Alluvium 45-170' Burro Canyon 170-180' Brushy Basin		Yes	Yes	180		6	Tailing: 4.0 OD Bedrock: HQ/2.5 ID	30	150	Complete as monitoring well if saturation zone exists in the Burro Canyon.
2	UPC-2	P&A	0-5' Impoundment Cover 5-35' Tailing Material 35-45' Alluvium 45-110' Burro Canyon 1110-120' Brushy Basin		Yes	Yes	120		6	Tailing: 4.0 OD Bedrock: HQ/2.5 ID	30	90	Complete as monitoring well if saturation zone exists in the Burro Canyon.
3	UPC-3	P&A	0-5' Impoundment Cover 5-45' Tailing Material 45-50' Alluvium 50-100' Burro Canyon 100-110' Brushy Basin		Yes	Yes	110		6	Tailing: 4.0 OD Bedrock: HQ/2.5 ID	40	70	Complete as monitoring well if saturation zone exists in the Burro Canyon.
4	UPC-4	P&A	0-5' Impoundment Cover 5-60' Tailing Material 60-65' Alluvium 65-110' Burro Canyon 110-120' Brushy Basin		Yes	Yes	120		6	Tailing: 4.0 OD Bedrock: HQ/2.5 ID	55	65	Complete as monitoring well if saturation zone exists in the Burro Canyon.
5	LPC-5	P&A	0-10' Impoundment Cover 10-20' Tailing Material 20-25' Alluvium 25-85' Burro Canyon 85-95' Brushy Basin		Yes	Yes	95		6	Tailing: 4.0 OD Bedrock: HQ/2.5 ID	10	85	Complete as monitoring well if saturation zone exists in the Burro Canyon.
6	LPC-6	P&A	0-10' Impoundment Cover 10-50' Tailing Material 50-60' Alluvium 60-85' Burro Canyon 85-95' Brushy Basin		Yes	Yes	95		6	Tailing: 4.0 OD Bedrock: HQ/2.5 ID	40	55	Complete as monitoring well if saturation zone exists in the Burro Canyon.
7	LPC-7	P&A	0-5' Impoundment Cover 5-25' Tailing Material 25-70' Burro Canyon 70-80' Brushy Basin		Yes	Yes	80		6	Tailing: 4.0 OD Bedrock: HQ/2.5 ID	20	60	Complete as monitoring well if saturation zone exists in the Burro Canyon.
8	LPC-8	P&A	0-5' Impoundment Cover 5-60' Tailing Material 60-90' Burro Canyon 90-100' Brushy Basin		Yes	Yes	100		6	Tailing: 4.0 OD Bedrock: HQ/2.5 ID	55	45	Complete as monitoring well if saturation zone exists in the Burro Canyon.
9	PC-140	P&A	0-10' Alluvium 10-150' Burro Canyon 150-160' Brushy Basin		Yes	Yes	160	10	6	HQ/2.5 ID		150	
10	PC-141	P&A	0-10' Alluvium 10-200' Burro Canyon 200-210' Brushy Basin		Yes	Yes	210	10	6	HQ/2.5 ID		200	
11	PC-144	P&A	0-10' Alluvium 10-200' Burro Canyon 200-210' Brushy Basin		Yes	Yes	210	5	6	HQ/2.5 ID		205	
12	PC-147	P&A	0-5' Alluvium 5-160' Burro Canyon 160-170' Brushy Basin		Yes	Yes	170	5	6	HQ/2.5 ID		165	

Index	Core Hole ID	Final Completion	Lithology	Artesian Conditions	11e.2 Material	Geophysical Log	Total Depth (ft bgs)	Alluvial Thickness (ft)	Conductor/ Casing Size (in)	Core Size (in)	Tailing Core Length (ft)	Rock Core Length (ft)	Comment
13	PC-101	P&A	0-5' Alluvium 5-170' Burro Canyon 170-180' Brushy Basin		Yes	Yes	180	5	6	HQ/2.5 ID		175	
14	PC-RL3	P&A	0-10' Alluvium 10-200' Burro Canyon 200-210' Brushy Basin		Yes	Yes	210	10	6	HQ/2.5 ID		200	
15	PC-151	P&A	0-5' Alluvium 5-90' Burro Canyon 90-100' Brushy Basin		Yes	Yes	100	5	6	HQ/2.5 ID		95	
16	PC-119	P&A	0-5' Alluvium 5-105' Burro Canyon 105-115' Brushy Basin		Yes	Yes	115	5	6	HQ/2.5 ID		110	
17	PC-113	P&A	0-10' Alluvium 10-135' Burro Canyon 135-145' Brushy Basin		Yes	Yes	145	10	6	HQ/2.5 ID		135	
18	PC-154	P&A	0-10' Alluvium 10-110' Burro Canyon 110-120' Brushy Basin		Yes	Yes	120	20	6	HQ/2.5 ID		100	
19	PC-155	P&A	0-10' Alluvium 10-180' Burro Canyon 180-190' Brushy Basin		Yes	Yes	160	10	6	HQ/2.5 ID		150	
20	PC-157	P&A	0-10' Alluvium 10-135' Burro Canyon 135-145' Brushy Basin		Yes	Yes	145	10	6	HQ/2.5 ID		135	
21	PC-158	P&A	0-10' Alluvium 10-160' Burro Canyon 160-170' Brushy Basin	No*	No	Yes	170	10	6	HQ/2.5 ID		160	
22	PC-164	P&A	0-10' Alluvium 10-130' Burro Canyon 130-140' Brushy Basin	Possibly flowing artesian	No	Yes	140	10	6	HQ/2.5 ID		130	
23	PC-167	P&A	0-10' Alluvium 10-130' Burro Canyon 130-140' Brushy Basin	Possibly flowing artesian	No	Yes	140	10	6	HQ/2.5 ID		130	
24	PC-168	P&A	0-10' Alluvium 10-130' Burro Canyon 130-140' Brushy Basin	Possibly flowing artesian	No	Yes	140	10	6	HQ/2.5 ID		130	
	Totals						**3415**	**115**				**2600**	

Core Specifications

Sonic Casing	Sonic drill 6in casing into bedrock
Stablizer	HWT or similar to stablize drill rod in casing
Drilling Fluid	Lean mud mix such as EZ mud or fresh water that is contained and recirculated in a mud / shaker system
Plug and Abandon	1 x 94 lb Portland cement + 4.7 lbs powdered bentonite with no more than 6 gallons of clean water

Notes:

1. Actual depths and screen intervals will be determined in the field at the time of drilling.
2. Corehole and MW depths are estimates based on limited subsurface data. Total depths are intended to be conservative (i.e. deeper than may be necessary).
3. Core diameter for tailing should be minimum 3.75 in OD or larger polycarbonate tubes.

* Artesian conditions may be encountered within certain intervals of the Burro Canyon during drilling but water levels are not expected to rise above the top of the Burro Canyon

Table C.2 Proposed monitoring wells for CAAWP field program.

Index	Well ID	Drill Depth (ft bgs)	Completion Depth (ft bgs)	Expected Lithology	Artesian Conditions	11e.2 Material	Geophysical Log	Alluvial (or Tailing for SA wells) Thickness (ft)	Min. Borehole Diameter (in)	Surface Artesian Borehole Diameter (in)	Screen Target	Casing Size (ID inches)	Steel Surface Casing***	Blank Interval (ft)			Screen Interval (ft)			Screen Size (in)	Sand Pack (screen length +2 ft)			Neat Cement Grout****			Bentonite Seal (3.8-inch time release pellets)			Comment	Well Pad & Road Work
														From	To	Length	From	To	Length		From	To	Length	From	To	Length	From	To	Length		
1	UPW-1**	180	170	0-30' Tailing 30-170' Burro Canyon 170-180' Brushy Basin	No	Yes	No (will log core hole)	30	9.25	NA	Burro Canyon	4	10	0	160	160	160	170	10	0.020 "20-slot"	158	170	12	0	155	155	155	160	5	Complete as monitoring well if saturation zone exists in the Burro Canyon.	Needs road upgrade and pad improvement
2	UPW-2**	120	110	0-30' Tailing 30-110' Burro Canyon 110-120' Brushy Basin	No	Yes	No (will log core hole)	30	9.25	NA	Burro Canyon	4	10	0	100	100	100	110	10	0.020 "20-slot"	98	110	12	0	95	95	95	100	5	Complete as monitoring well if saturation zone exists in the Burro Canyon.	Needs road upgrade and pad improvement
3	UPW-3**	110	100	0-40' Tailing 40-100' Burro Canyon 100-110' Brushy Basin	No	Yes	No (will log core hole)	40	9.25	NA	Burro Canyon	4	10	0	90	90	90	100	10	0.020 "20-slot"	88	100	12	0	85	85	85	90	5	Complete as monitoring well if saturation zone exists in the Burro Canyon.	Needs road upgrade and pad improvement
4	UPW-4**	120	110	0-55' Tailing 55-110' Burro Canyon 110-120' Brushy Basin	No	Yes	No (will log core hole)	55	9.25	NA	Burro Canyon	4	10	0	100	100	100	110	10	0.020 "20-slot"	98	110	12	0	95	95	95	100	5	Complete as monitoring well if saturation zone exists in the Burro Canyon.	Needs road upgrade and pad improvement
5	LPW-5**	95	85	0-10' Tailing 10-85' Burro Canyon 85-95' Brushy Basin	No	Yes	No (will log core hole)	10	9.25	NA	Burro Canyon	4	10	0	75	75	75	85	10	0.020 "20-slot"	73	85	12	0	70	70	70	75	5	Complete as monitoring well if saturation zone exists in the Burro Canyon.	Needs road upgrade and pad improvement
6	LPW6**	95	85	0-40' Tailing 40-85' Burro Canyon 85-95' Brushy Basin	No	Yes	No (will log core hole)	40	9.25	NA	Burro Canyon	4	10	0	75	75	75	85	10	0.020 "20-slot"	73	85	12	0	70	70	70	75	5	Complete as monitoring well if saturation zone exists in the Burro Canyon.	Needs road upgrade and pad improvement
7	LPW7**	80	70	0-20' Tailing 20-70' Burro Canyon 70-80' Brushy Basin	No	Yes	No (will log core hole)	20	9.25	NA	Burro Canyon	4	10	0	60	60	60	70	10	0.020 "20-slot"	58	70	12	0	55	55	55	60	5	Complete as monitoring well if saturation zone exists in the Burro Canyon.	Needs road upgrade and pad improvement
8	LPW-8**	100	90	0-55' Tailing 55-90' Burro Canyon 90-100' Brushy Basin	No	Yes	No (will log core hole)	55	9.25	NA	Burro Canyon	4	10	0	80	80	80	90	10	0.020 "20-slot"	78	90	12	0	75	75	75	80	5	Complete as monitoring well if saturation zone exists in the Burro Canyon.	Needs road upgrade and pad improvement
9	PW-140	160	150	0-10' Alluvium 10-150' Burro Canyon 150-160' Brushy Basin	No	Yes	No (will log core hole)	10	9.875	NA	Burro Canyon	4	10	0	130	130	130	150	20	0.020 "20-slot"	128	150	22	0	125	125	125	130	5		Needs road upgrade and pad improvement
10	PW-141	210	200	0-10' Alluvium 10-200' Burro Canyon 200-210' Brushy Basin	No	Yes	No (will log core hole)	10	9.875	NA	Burro Canyon	4	10	0	180	180	180	200	20	0.020 "20-slot"	178	200	22	0	175	175	175	180	5		Needs road and pad
11	PW-142**	230	220	0-10' Alluvium 10-220' Burro Canyon 220-230' Brushy Basin	No	Yes	Yes	10	9.875	NA	Burro Canyon	4	10	0	210	210	210	220	10	0.020 "20-slot"	208	220	12	0	205	205	205	210	5		Needs road upgrade; needs pad
12	PW-143	210	200	0-5' Alluvium 5-200' Burro Canyon 200-210' Brushy Basin	No	Yes	Yes	5	9.875	NA	Burro Canyon	4	10	0	195	195	195	200	5	0.020 "20-slot"	193	200	7	0	190	190	190	195	5		Needs road upgrade; needs pad
13	PW-144	210	200	0-5' Alluvium 5-200' Burro Canyon 200-210' Brushy Basin	No	Yes	No (will log core hole)	5	9.875	NA	Burro Canyon	4	10	0	180	180	180	200	20	0.020 "20-slot"	178	200	22	0	175	175	175	180	5		Needs road upgrade; needs pad
14	PW-145**	260	250	0-5' Alluvium 5-250' Burro Canyon 250-260' Brushy Basin	No	Yes	Yes	5	9.875	NA	Burro Canyon	4	10	0	240	240	240	250	10	0.020 "20-slot"	238	250	12	0	235	235	235	240	5		Needs road and pad
15	PW-146	180	170	0-5' Alluvium 5-170' Burro Canyon 170-180' Brushy Basin	No	Yes	Yes	5	9.875	NA	Burro Canyon	4	10	0	150	150	150	170	20	0.020 "20-slot"	148	170	22	0	145	145	145	150	5		Needs pad
16	PW-147	170	160	0-5' Alluvium 5-160' Burro Canyon 160-170' Brushy Basin	No	Yes	No (will log core hole)	5	9.875	NA	Burro Canyon	4	10	0	140	140	140	160	20	0.020 "20-slot"	138	160	22	0	135	135	135	140	5		Needs road and pad
17	PW-148**	185	175	0-5' Alluvium 5-175' Burro Canyon 175-185' Brushy Basin	No	Yes	Yes	5	9.875	NA	Burro Canyon	4	10	0	165	165	165	175	10	0.020 "20-slot"	163	175	12	0	160	160	160	165	5		Needs road and pad
18	PW-149	195	185	0-10' Alluvium 10-185' Burro Canyon 185-195' Brushy Basin	No	Yes	Yes	10	9.875	NA	Burro Canyon	4	10	0	175	175	175	185	10	0.020 "20-slot"	173	185	12	0	170	170	170	175	5		Needs road and pad
19	PW-150**	105	95	0-5' Alluvium 5-95' Burro Canyon 95-105' Brushy Basin	No	Yes	Yes	5	9.875	NA	Burro Canyon	4	10	0	85	85	85	95	10	0.020 "20-slot"	83	95	12	0	80	80	80	85	5		Needs road and pad
20	PW-151	100	90	0-5' Alluvium 5-90' Burro Canyon 90-100' Brushy Basin	No	Yes	No (will log core hole)	5	9.875	NA	Burro Canyon	4	10	0	80	80	80	90	10	0.020 "20-slot"	78	90	12	0	75	75	75	80	5		Needs road and pad
21	PW-152**	130	120	0-5' Alluvium 5-120' Burro Canyon 120-130' Brushy Basin	No	Yes	Yes	5	9.875	NA	Burro Canyon	4	10	0	110	110	110	120	10	0.020 "20-slot"	108	120	12	0	105	105	105	110	5		Needs road upgrade and pad improvement
22	PW-153**	130	120	0-5' Alluvium 5-120' Burro Canyon 120-130' Brushy Basin	No	Yes	Yes	5	9.875	NA	Burro Canyon	4	10	0	110	110	110	120	10	0.020 "20-slot"	108	120	12	0	105	105	105	110	5		Needs road improvement and pad
23	PW-154D	120	110	0-20' Alluvium 20-120' Burro Canyon 110-120' Brushy Basin	No	Yes	No (will log core hole)	20	9.875	NA	Burro Canyon	4	10	0	90	90	90	110	20	0.020 "20-slot"	88	110	22	0	85	85	85	90	5		Needs road and pad
24	PW-155D	160	150	0-10' Alluvium 10-150' Burro Canyon 150-160' Brushy Basin	No	Yes	No (will log core hole)	10	9.875	NA	Burro Canyon	4	10	0	130	130	130	150	20	0.020 "20-slot"	128	150	22	0	125	125	125	130	5		Needs road upgrade; needs pad
25	PW-156D	145	135	0-10' Alluvium 10-135' Burro Canyon 135-145' Brushy Basin	No	Yes	Yes	10	9.875	NA	Burro Canyon	4	10	0	115	115	115	135	20	0.020 "20-slot"	113	135	22	0	110	110	110	115	5		Needs road and pad
26	PW-157D	145	135	0-10' Alluvium 10-135' Burro Canyon 135-145' Brushy Basin	No	Yes	No (will log core hole)	10	9.875	NA	Burro Canyon	4	10	0	115	115	115	135	20	0.020 "20-slot"	113	135	22	0	110	110	110	115	5		Needs road and pad
27	PW-136M	115	115	0-10' Alluvium 10-115' Burro Canyon	No*	Yes	No - C-136 at same location	10	9.875	NA	Burro Canyon	4	10	0	95	95	95	115	20	0.020 "20-slot"	93	115	22	0	90	90	90	95	5		Use existing MW-136 pad
28	PW-158D	170	160	0-10' Alluvium 10-160' Burro Canyon 160-170' Brushy Basin	No*	Yes	No (will log core hole)	10	9.875	NA	Burro Canyon	4	10	0	140	140	140	160	20	0.020 "20-slot"	138	160	22	0	135	135	135	140	5		Needs minor road work; needs pad
29	PW-159D	170	160	0-10' Alluvium 10-160' Burro Canyon 160-170' Brushy Basin	No*	Yes	Yes	10	9.875	NA	Burro Canyon	4	10	0	140	140	140	160	20	0.020 "20-slot"	138	160	22	0	135	135	135	140	5		Needs road and pad

Index	Well ID	Drill Depth (ft bgs)	Completion Depth (ft bgs)	Expected Lithology	Artesian Conditions	11e.2 Material	Geophysical Log	Alluvial (or Tailing for SA wells) Thickness (ft)	Min. Borehole Diameter (in)	Surface Artesian Borehole Diameter (in)	Screen Target	Casing Size (ID inches)	Steel Surface Casing***	Blank Interval (ft)			Screen Interval (ft)			Screen Size (in)	Sand Pack (screen length +2 ft)			Neat Cement Grout****			Bentonite Seal (3.8-inch time release pellets)			Comment	Well Pad & Road Work
														From	To	Length	From	To	Length		From	To	Length	From	To	Length	From	To	Length		
30	PW-160M	130	130	0-10' Alluvium 10-130' Burro Canyon	Possibly flowing artesian	Yes	No	10	9.875	14	Burro Canyon	4	10	0	110	110	110	130	20	0.020 "20-slot"	108	130	22	0	105	105	105	110	5	Possible flowing artesian conditions	Needs road and pad
31	PW-160D	185	175	0-10' Alluvium 10-175' Burro Canyon 175-185' Brushy Basin	Possibly flowing artesian	Yes	Yes	10	9.875	14	Burro Canyon	4	10	0	155	155	155	175	20	0.020 "20-slot"	153	175	22	0	150	150	150	155	5	Possible flowing artesian conditions	Needs road and pad (same as PW-160M)
32	PW-124D	175	165	0-20' Alluvium 20-165' Burro Canyon 165-175' Brushy Basin	No*	Yes	No - C-124 at same location	20	9.875	NA	Burro Canyon	4	10	0	145	145	145	165	20	0.020 "20-slot"	143	165	22	0	140	140	140	145	5		Use existing MW-124 pad
33	PW-161	220	210	0-10' Alluvium 10-210' Burro Canyon 210-220' Brushy Basin	No	No	Yes	10	9.875	NA	Burro Canyon	4	10	0	190	190	190	210	20	0.020 "20-slot"	188	210	22	0	185	185	185	190	5		Needs road upgrade; needs pad
34	PW-162	200	190	0-10' Alluvium 10-190' Burro Canyon 190-200' Brushy Basin	No	No	Yes	10	9.875	NA	Burro Canyon	4	10	0	170	170	170	190	20	0.020 "20-slot"	168	190	22	0	165	165	165	170	5		Needs road upgrade; needs pad
35	PW-163	205	195	0-10' Alluvium 10-195' Burro Canyon 195-205' Brushy Basin	No	No	Yes	10	9.875	NA	Burro Canyon	4	10	0	175	175	175	195	20	0.020 "20-slot"	173	195	22	0	170	170	170	175	5		Needs road upgrade; needs new pad?
36	PW-164S	70	70	0-25' Alluvium 25-70' Burro Canyon	Possibly flowing artesian	No	No (will log core hole)	25	9.875	14	Burro Canyon	4	10	0	50	50	50	70	20	0.020 "20-slot"	48	70	22	0	45	45	45	50	5	Possible flowing artesian conditions	Needs road and pad
37	PW-164D	140	130	0-25' Alluvium 25-130' Burro Canyon 130-140' Brushy Basin	Possibly flowing artesian	No	No (will log core hole)	25	9.875	14	Burro Canyon	4	10	0	110	110	110	130	20	0.020 "20-slot"	108	130	22	0	105	105	105	110	5	Possible flowing artesian conditions	Needs road and pad (same as PW-164S)
38	PW-133D	230	220	0-25' Alluvium 25-220' Burro Canyon 220-230' Brushy Basin	Likely flowing artesian	No	Yes (C-133 does not go to bottom of BCA)	25	9.875	14	Burro Canyon	4	10	0	200	200	200	220	20	0.020 "20-slot"	198	220	22	0	195	195	195	200	5	Possible flowing artesian conditions	Existing MW-133ALL/S well pad
39	PW-165	350	240	0-30' Alluvium 30-340' Navajo 340-350' Kayenta	No	No	Yes	30	9.875	NA	Navajo Sandstone	4	10	0	220	220	220	240	20	0.020 "20-slot"	218	240	22	0	215	215	215	220	5		Needs road and pad
40	PW-166	335	325	0-30' Alluvium 30-335' Navajo 325-335' Kayenta	No	No	Yes	30	9.875	NA	Navajo Sandstone	4	10	0	305	305	305	325	20	0.020 "20-slot"	303	325	22	0	300	300	300	305	5		Needs road and pad
41	PW-167S	70	70	0-10' Alluvium 10-70' Burro Canyon	Possibly flowing artesian	No	No (will log core hole)	10	9.875	14	Burro Canyon	4	10	0	50	50	50	70	20	0.020 "20-slot"	48	70	22	0	45	45	45	50	5	Possible flowing artesian conditions	Needs road and pad
42	PW-167D	140	130	0-10' Alluvium 10-130' Burro Canyon 130-140' Brushy Basin	Possibly flowing artesian	No	No (will log core hole)	10	9.875	14	Burro Canyon	4	10	0	110	110	110	130	20	0.020 "20-slot"	108	130	22	0	105	105	105	110	5	Possible flowing artesian conditions	Needs road and pad (same as PW-167S)
43	PW-168S	70	70	0-10' Alluvium 10-70' Burro Canyon	Possibly flowing artesian	No	No (will log core hole)	10	9.875	14	Burro Canyon	4	10	0	50	50	50	70	20	0.020 "20-slot"	48	70	22	0	45	45	45	50	5	Possible flowing artesian conditions	Needs road and pad
44	PW-168D	140	130	0-10' Alluvium 10-130' Burro Canyon 130-140' Brushy Basin	Possibly flowing artesian	No	No (will log core hole)	10	9.875	14	Burro Canyon	4	10	0	110	110	110	130	20	0.020 "20-slot"	108	130	22	0	105	105	105	110	5	Possible flowing artesian conditions	Needs road and pad (same as PW-168S)
45	PW-169	140	120	0-10' Alluvium 10-120' Kayenta 120-140' Wingate	No	No	Yes	10	9.875	NA	Navajo Sandstone	4	10	0	100	100	100	120	20	0.020 "20-slot"	98	120	22	0	95	95	95	100	5	Complete well even if dry.	Needs road and pad
46	PW-170	185	165	0-10' Alluvium 10-165' Wingate 165-185' Chinle	No	No	Yes	10	9.875	NA	Wingate Sandstone	4	10	0	145	145	145	165	20	0.020 "20-slot"	143	165	22	0	140	140	140	145	5	Complete well even if dry.	May need road improvement; needs pad
46	**Totals**		**1390**					**50**							**1285**				**105**				119			1250			35		

Non-flowing Artesian Well Specifications:

Casing Blank	4in ID Flush Threaded Schedule 80 PVC with kwik-Zip centralizer per 50ft of casing
Screen	4in ID Flush Threaded Schedule 80 PVC, 0.020 in slot w/ PVC threaded bottom cap
Sand Pack	10/20, minimum 2ft above top of well screen
Seal	3/8 bentonite chips or pellets, minimum of 5ft above top of sand pack, hydrate with fresh water in 1ft lifts
Grout to Surface	Neat cement grout (1 x 94-pound sack of Portland cement and 4.7 pounds of powdered bentonite with no more than 6 gallons of clean water), Pressure grout with tremie pipe from bottom to top.
Surface Completion	2.5ft PVC stick-up with PVC well cap. Standard 8in steel protective casing w/ locking lid. Key same as existing well locks 2 ft radius concrete pad, 4in thick, sloped away from protective casing, well ID scribed in concrete Four, 6ft metal bollards / traffic posts set 2ft bgs in concrete, painted yellow
Drilling Fluid	Air w/ fresh water as needed for dust suppression

Flowing Artesian Well Specifications:

Casing Blank	3in ID or 4 in ID Flush Threaded Schedule 80 PVC with kwik-Zip centralizers per 50ft of casing 8 in ID steel casing from surface to confining layer to seal off alluvium from flowing artesian conditions
Screen	3in ID Flush Threaded Schedule 80 PVC, 0.020 in slot w/ stainless steel threaded bottom cap
Screen	10/20, 12/20, or 6/9 (depending on conditions), minimum 2 ft above top of well screen
Screen	1/4 TR 30 bentonite chips or pellets, minimum of 5ft above top of sand pack, hydrate with fresh water in 1ft lifts
Screen	Neat cement grout (1 x 94-pound sack of Portland cement and 4.7 pounds of powdered bentonite with no more than 6 gallons of clean water), Pressure grout with tremie pipe from bottom to top.
Surface Completion	2.5ft PVC stick-up with stainless steel, sealing well cap. Protective vault (such as Tucson vault) with insulation. Pressure gauge and release valve. Key same as existing well locks 2 ft radius concrete pad, 4in thick, sloped away from protective casing, well ID scribed in concrete Four, 6ft metal bollards / traffic posts set 2ft bgs in concrete, painted yellow
Drilling Fluid	Air w/ fresh water as needed for dust suppression

Notes:

1. For drilling into the Brushy Basin, it is assumed that 10' will be sufficient to confirm Brushy Basin shale, however 15' or 20' may be necessary to reduce uncertainty at some locations.
2. Actual depths and screen intervals will be determined in the field at the time of drilling.
3. The 11e.2 Material designation is for waste management purposes and is not a determination of whether a specific area or media is affected by by-product material.
4. Utah regulations specify that there must be a 4-inch difference between the casing OD and the borehole. R655-4-11.4.3.1UAC (Utah Division of Water Rights, 2018)
5. Non-flowing artesian monitoring wells are Schedule 80 PVC, 4-inch ID, 4.5-inch OD.
6. Flowing artesian monitoring wells may be Schedule 80 PVC, 3-inch ID, 3.5-inch OD.
7. Flowing artesian monitoring wells: Screen 0.020-inch ("20-slot"), Sand Pack appropriate for conditions (10/20, 12/20, 6/9, etc).
8. Non-flowing artesian monitoring wells: Screen 0.020-inch ("20-slot), Sand Pack 10/20.
9. All monitoring wells will be developed during a single development mobilization after all wells have been fully completed.

* Artesian conditions may be encountered within certain intervals of the Burro Canyon during drilling but water levels are not expected to rise above the top of the Burro Canyon

** Wells screens for specific wells may be adjusted following determination of the saturated thickness in the field.

*** Does not include surface casing for artesian wells

**** May change based on drilling method for artesian wells.

Table C.3 Proposed Borrow Areas and Potential Tailings Disposal Site

Borrow Area	Size (acres)	Surface Geology[2]	Soils[3]	Auger Borings[4]	Number of Samples[5]
1	155	Qea, Qagy	17, 6, 5	3	Index Engineering (3 composite) Hydraulic (1 selected) Agronomic (1 selected)
2[1]	310	Qea, Kbc	8, 16	5	Index Engineering (5 composite) Hydraulic (2 selected) Agronomic (1 selected)
3	155	Qea	5	3	Index Engineering (3 composite) Hydraulic (1 selected) Agronomic (1 selected)
4	155	Qea, Kd	5, 6	3	Index Engineering (3 composite) Hydraulic (1 selected) Agronomic (1 selected)

Notes

[1]Borrow Area 2 coincides with a preliminary investigation of a tailings disposal site.

[2]See **Figure 2.1** for surface geology information. Qea = mixed eolian and alluvial deposits; Qagy = younger alluvial gravel deposits; Kbc = Burro Canyon Fm; Kd = Dakota Ss

[3]See **Figure C.3** for candidate borrow area locations overlayed on soils map. 17 = very stony fine sandy loam; 16 = very fine sandy loam; 15 = very cobbly sandy loam; 8 = loam; 6 = gravelly fine sandy loam; 5 = fine sandy loam

[4]Number of proposed auger borings. See **Figure C.3** for proposed locations.

[5]Proposed laboratory testing of samples as described in **Appendix D, Table D.2**.

Attachment C.1

Contact Information Table (Template)

Attachment C.1
Contact Information for Key Personnel

Name/Company	Role	Phone Number	Email
Sandra Ross/BHP	RAML Lisbon Site Manager	916-947-7637	sandra.ross@bhp.com
Joel Bauman/BHP	RAML Principal Hydrogeologist	530-574-4797	Joel.bauman@bhp.com
Ryan Schietinger/BHP	RAML Project Engineer	713-584-4943 415-466-5931	ryan.j.schietinger@bhp.com
Kent Applegate/BHP	RAML Lisbon Site Supervisor	505-287-8851 505-801-1761	kent.kc.applegate@bhp.com
	Program Manager		
	Project/Site Manager/Principal Engineer Engineer-of-Record		
	Health and Safety Officer/Engineer		
	Project Manager		
	Lead Field Geologist		
	Field Geologist		
	Field Geologist		
	Lead Hydrogeologist		
	Radiation Safety Officer (RSO)/IDW Management		
	Radiation Safety Officer (RSO)		

Name/Company	Role	Phone Number	Email
	SWPPP development and training		
	Drilling contact	Contact BHP Site Lead	
	IDW management		
	Geophysical logging		
	Earthworks and non-IDW management		
	Frac tanks and water transport		
	Water		
	Portable Toilets		
	Buried utility clearance		
	Survey boundary markers and wellhead survey		

INTERA

Attachment C.2

Geologic Maps and Cross Sections

INTERA

N

1,600 0 1,600

Feet

Source(s): Doelling, 2004

- Monitoring Well
- Boring
- Historical Well (Plugged and Abandoned)
- Domestic Well
- Spring or Seep
- Unsaturated BCA
- Preliminary Long Term Surveillance and Maintenance Boundary
- Normal Fault
- Normal Fault (inferred)
- Fold Axis
- Qea - Mixed Eolian and Alluvial Deposits
- Kd - Dakota Sandstone
- Kbc - Burro Canyon Formation
- Jmb - Brushy Basin Member of Morrison Formation
- Ject - Slick Rock Member of Entrada Sandstone and Moab Member of Curtis Formation
- Jcd - Dewey Bridge Member of Carmel Formation
- Jn - Navajo Sandstone
- Jk - Kayenta Formation
- Jw - Wingate Sandstone
- TRc - Chinle Formation

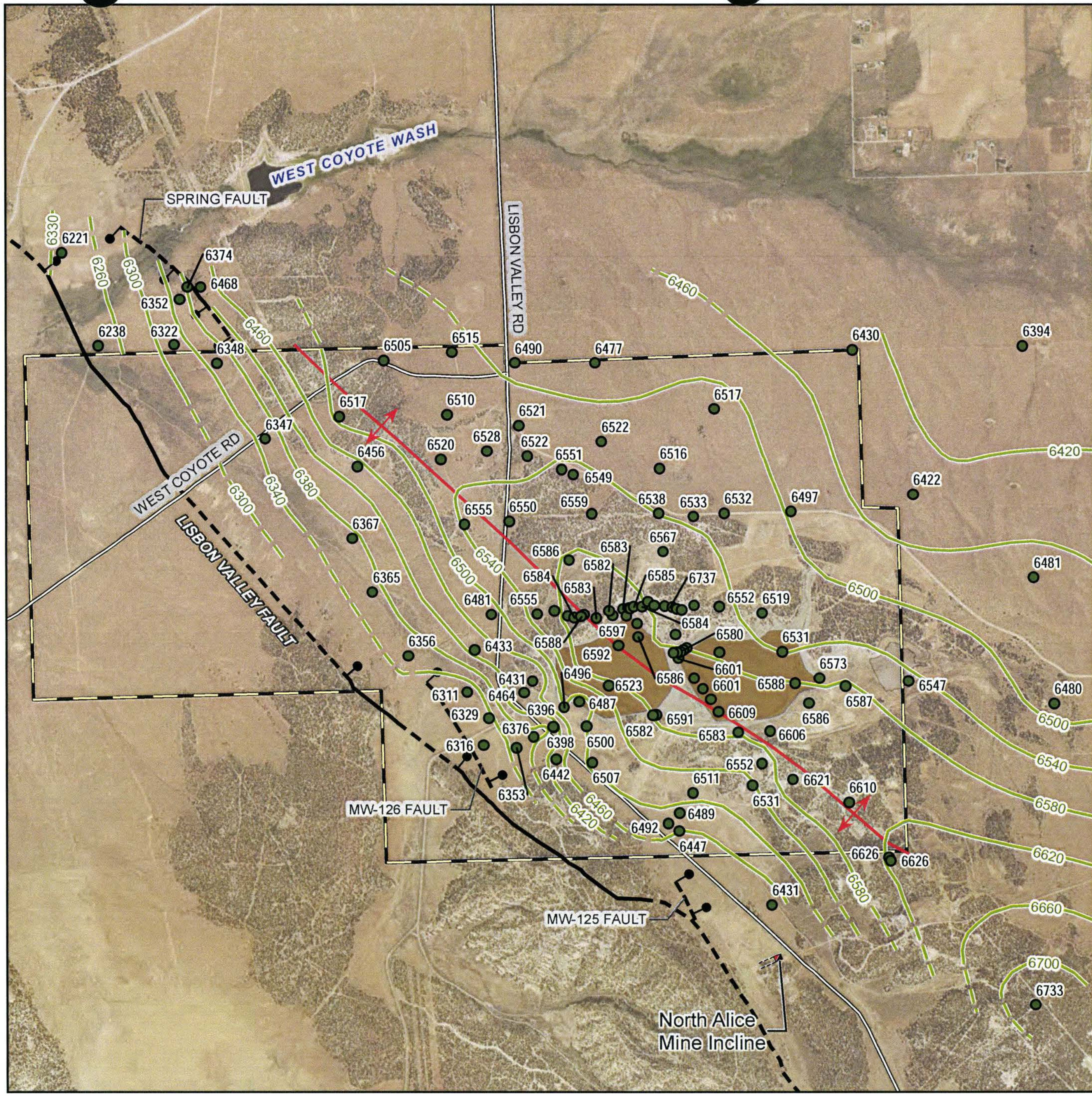
Structural Contours, Contour Interval 164 feet (50 meters)

- structural contour, top of the Jsmt
- structural contour, projected above ground surface

Misidentified Burro Canyon-Brushy Basin Contact

Note: Lisbon Valley Fault trace modified from Doelling (2004)

Attachment C.2
Local Geologic Map
Lisbon Facility CAAWP Appendix C
Field Implementation Guidelines



INTERA

N

2,000 0 2,000

Feet

Source(s): NAIP imagery, 2018

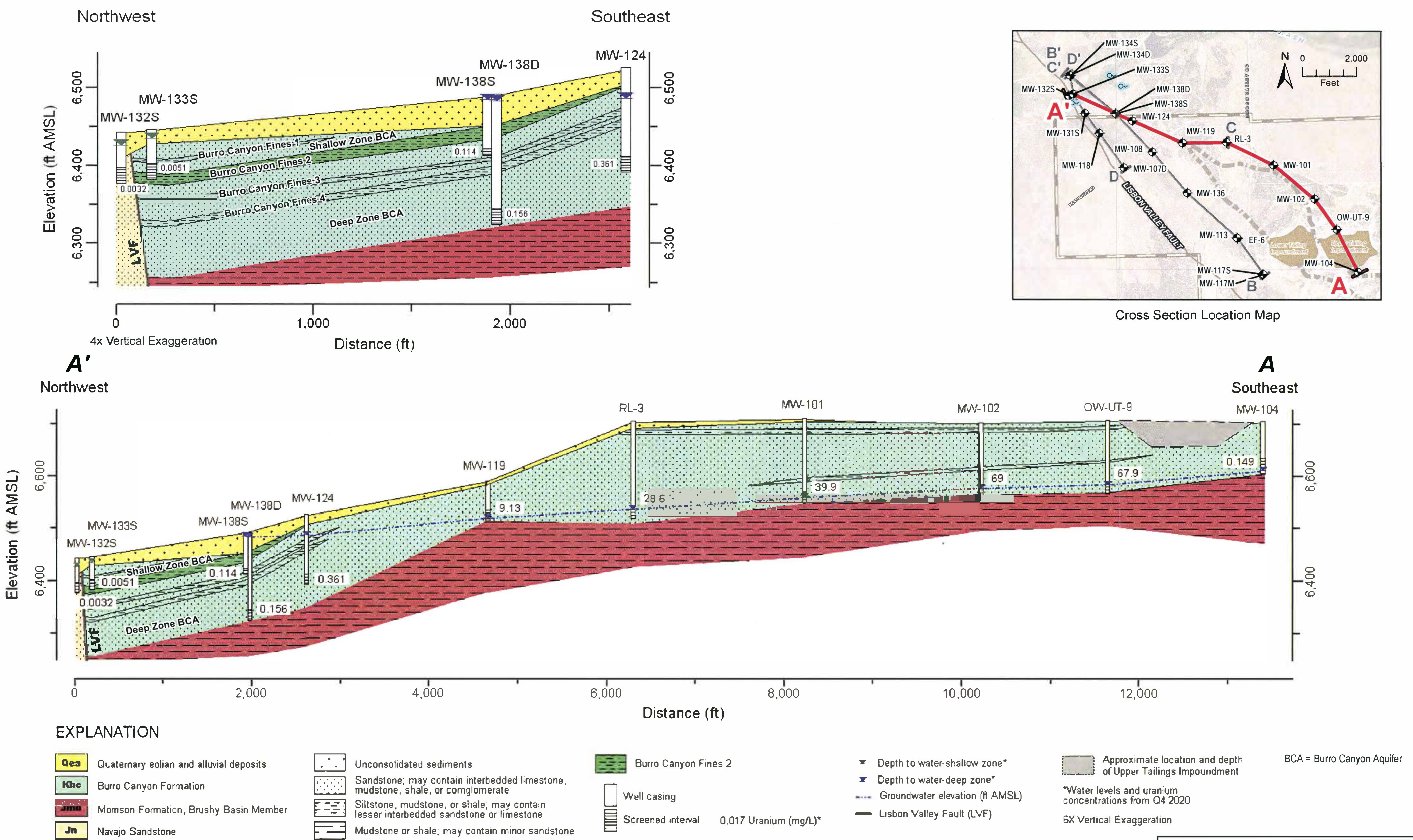
- Elevation, top Jmb*, ft, amsl (not all elevations labeled due to congestion)
- Preliminary Long Term Surveillance and Maintenance Boundary
- Normal Fault
- Normal Fault (inferred)
- Tertiary Lisbon Valley Anticline
- Elevation, top Jmb*, ft, amsl, dashed where approximate. Contour interval: 50 ft

*Jmb = Brushy Basin Member of the Morrison Formation

Notes:

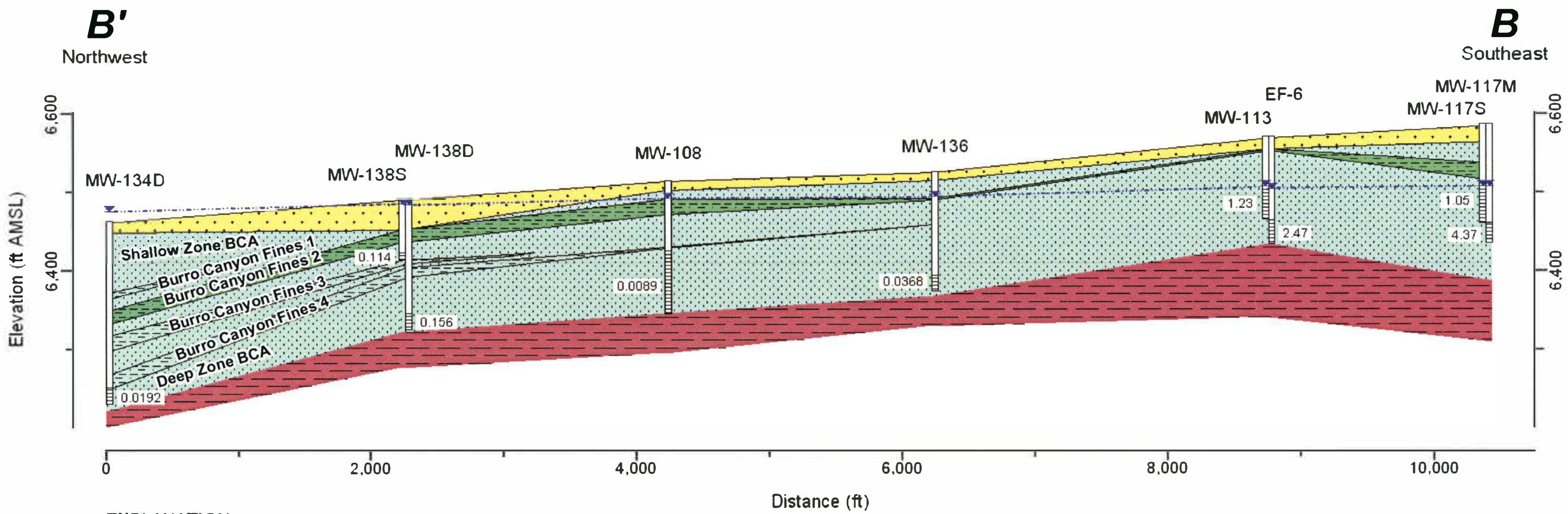
1. Lisbon Valley Fault trace modified from Doelling (2004).
2. Elevation picks based on interpreted lithologic and geophysical logs, data from historical reports, Montgomery and Associates (2014), and INTERA Field Program Report.

Figure C2.2
Structural Contour Map, Top of Brushy Basin Formation
Lisbon Facility CAAWP
Field Implementation Guidelines



INTERA

Figure C2.3
Geologic Cross Section A-A'
Lisbon Facility CAAWP
Field Implementation Guidelines



EXPLANATION

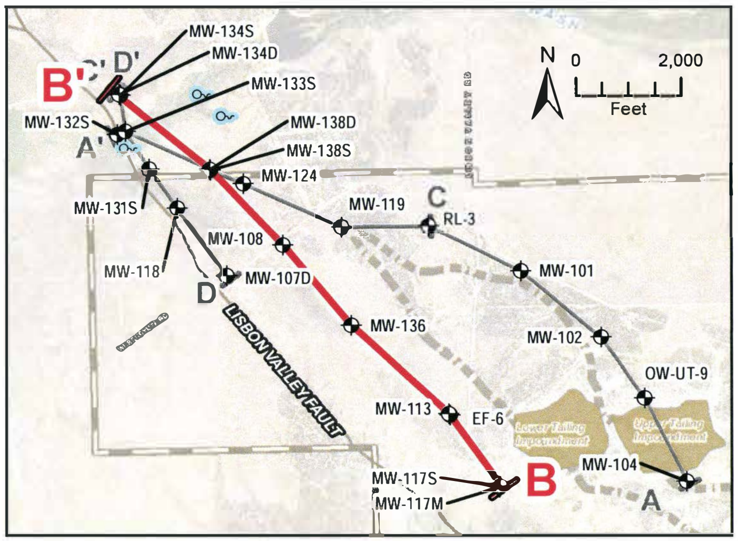
Qea	Quaternary eolian and alluvial deposits
Kbc	Burro Canyon Formation
Jmb	Morrison Formation, Brushy Basin Member

- Unconsolidated sediments
- Sandstone; may contain interbedded limestone, mudstone, shale, or comglomerate
- Siltstone, mudstone, or shale; may contain lesser interbedded sandstone or limestone
- Mudstone or shale; may contain minor sandstone
- Burro Canyon Fines 2
- Well casing
- Screened interval 0.017 Uranium (mg/L)*
- Depth to water-deep zone*
- Groundwater elevation (ft AMSL)

*Water levels and uranium concentrations from Q4 2020

6X Vertical Exaggeration

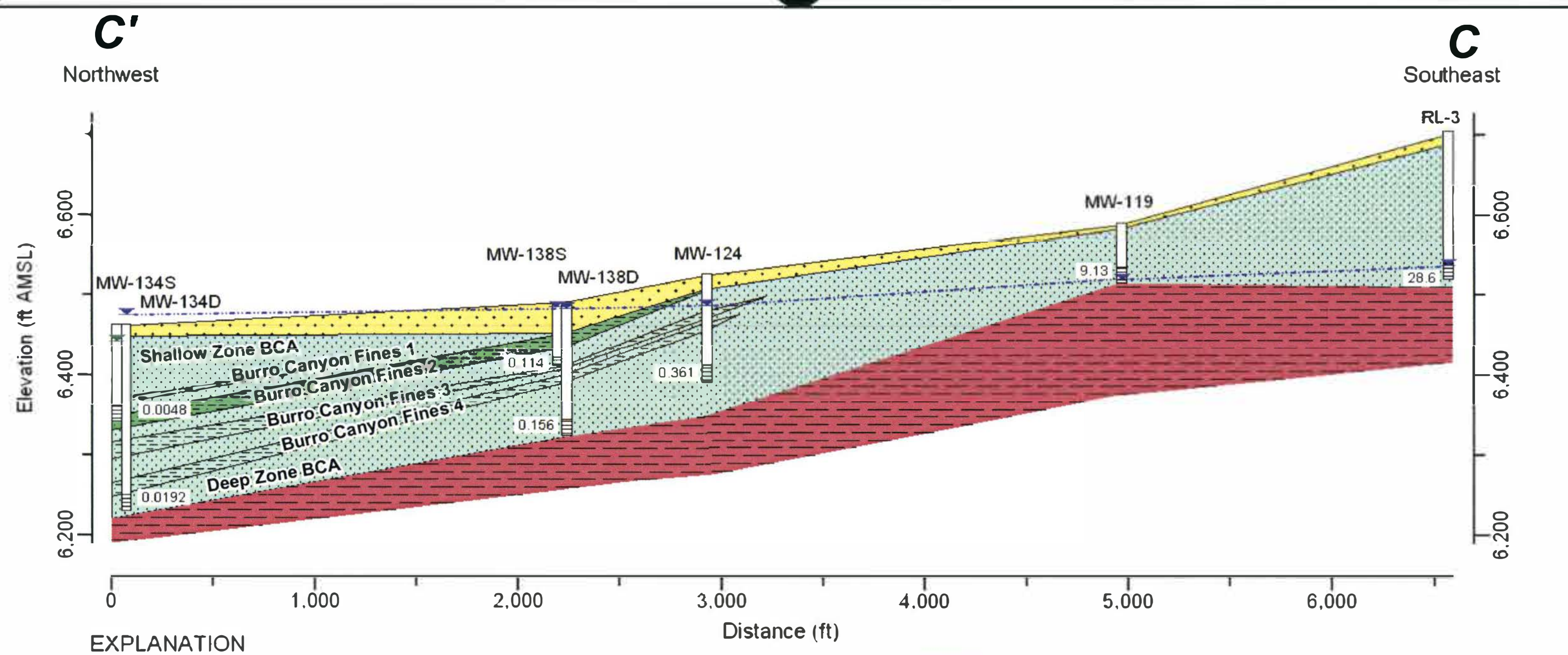
BCA = Burro Canyon Aquifer



Cross Section Location Map

INTERA

Figure C2.4
Geologic Cross Section B-B'
Lisbon Facility CAAWP
Field Implementation Guidelines



EXPLANATION

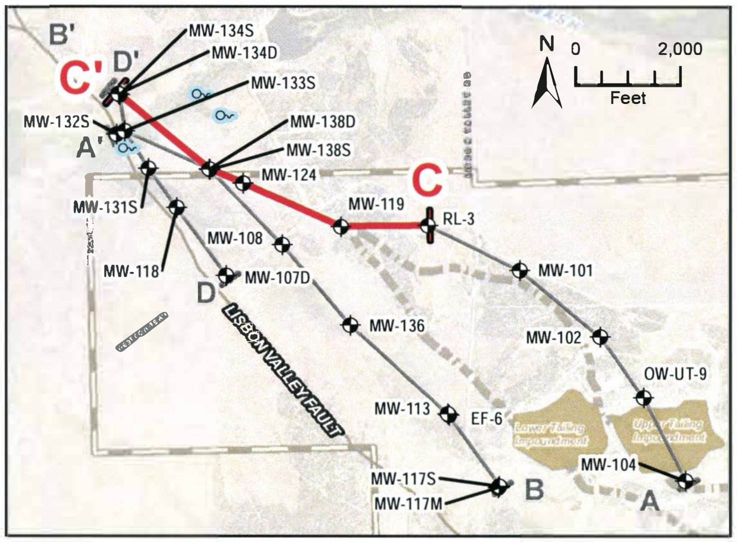
Qea	Quaternary eolian and alluvial deposits
Kbc	Burro Canyon Formation
Jmb	Morrison Formation, Brushy Basin Member

- Unconsolidated sediments
- Sandstone; may contain interbedded limestone, mudstone, shale, or comglomerate
- Siltstone, mudstone, or shale; may contain lesser interbedded sandstone or limestone
- Mudstone or shale; may contain minor sandstone
- Burro Canyon Fines 2
- Well casing
- Screened interval 0.017 Uranium (mg/L)*
- Depth to water-shallow zone*
- Depth to water-deep zone*
- Groundwater elevation (ft AMSL)

*Water levels and uranium concentrations from Q4 2020

4X Vertical Exaggeration

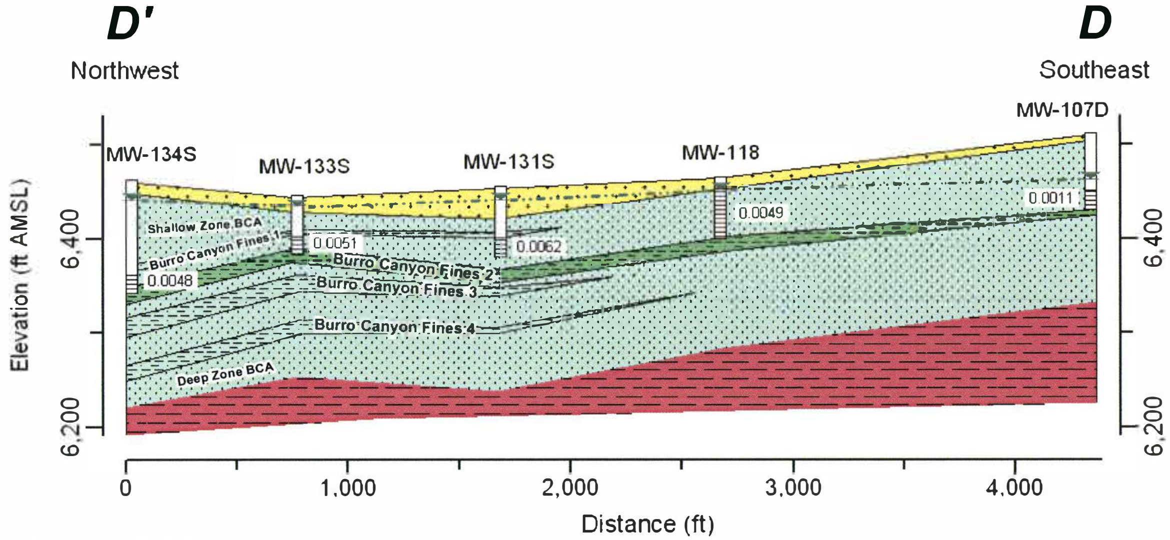
BCA = Burro Canyon Aquifer



Cross Section Location Map

INTERA

Figure C2.5
Geologic Cross Section C-C'
Lisbon Facility CAAWP
Field Implementation Guidelines



EXPLANATION

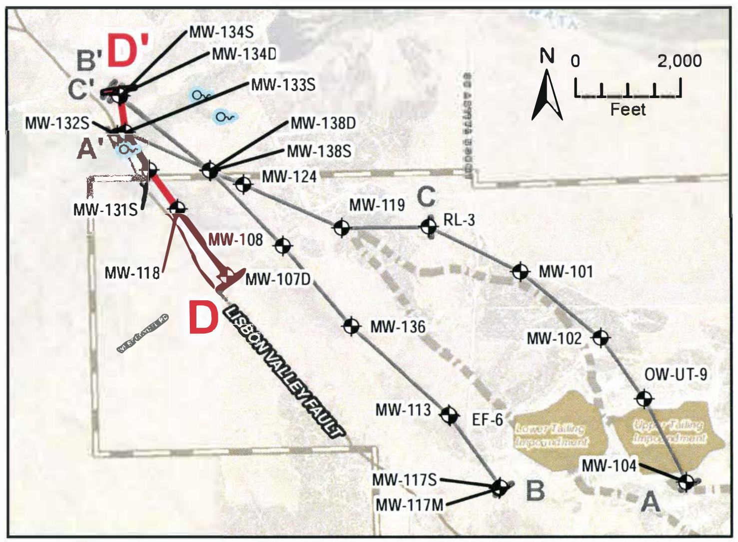
Qea	Quaternary eolian and alluvial deposits
Kbc	Burro Canyon Formation
Jmb	Morrison Formation, Brushy Basin Member

- Unconsolidated sediments
- Sandstone; may contain interbedded limestone, mudstone, shale, or comglomerate
- Siltstone, mudstone, or shale; may contain lesser interbedded sandstone or limestone
- Mudstone or shale; may contain minor sandstone
- Burro Canyon Fines 2
- Well casing
- Screened interval 0.017 Uranium (mg/L)*
- Depth to water shallow zone*
- Groundwater elevation (ft AMSL)

*Water levels and uranium concentrations from Q4 2020

4X Vertical Exaggeration

BCA = Burro Canyon Aquifer

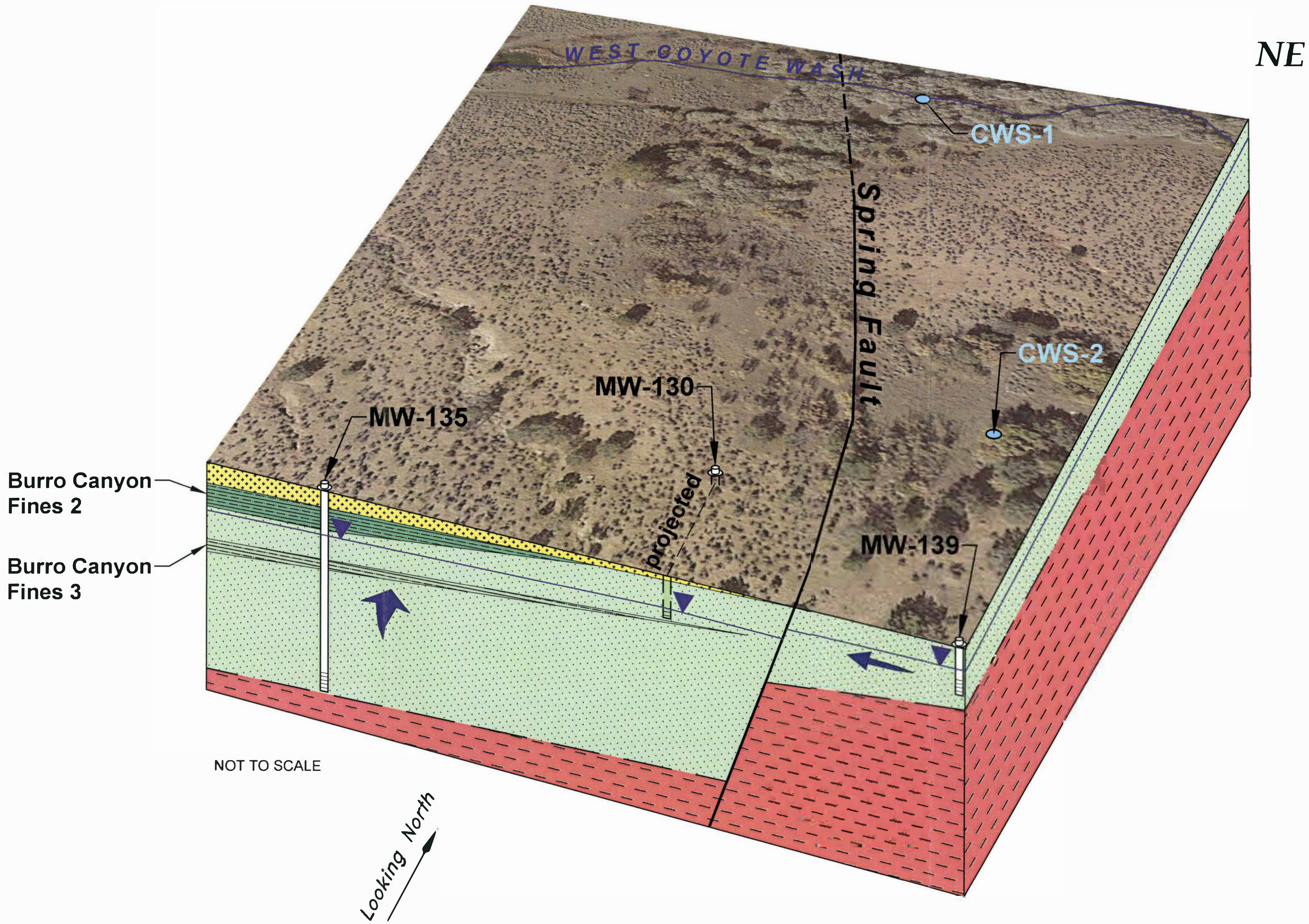


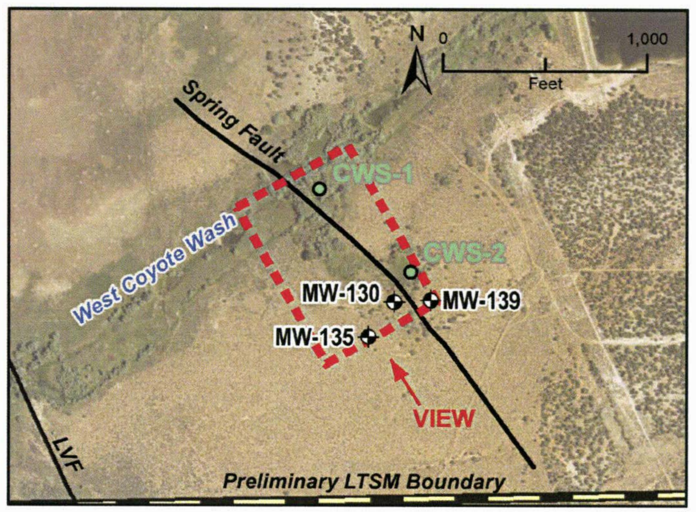
Cross Section Location Map

INTERA

Figure C2.6
Geologic Cross Section D-D'
Lisbon Facility CAAWP
Field Implementation Guidelines

Qea	Quaternary eolian and alluvial deposits
Kbc	Burro Canyon Formation
Jmb	Morrison Formation, Brushy Basin Member
	Unconsolidated sediments
	Sandstone; may contain interbedded limestone, mudstone, shale, or conglomerate
	Siltstone, mudstone, or shale; may contain lesser interbedded sandstone or limestone
	Mudstone or shale; may contain minor sandstone
	Burro Canyon Fines 2
	Spring or seep
	Well casing
	Screened interval
	Depth to water-deep zone
	Approximate groundwater flow direction





Location Map

INTERA

Figure C2.7
Spring Fault
Lisbon Facility CAAWP
Field Implementation Guidelines

Attachment C.3

Equipment List

Attachment C.3

Equipment List for Fieldwork			
Activity	**Quantity**	**Equipment**	**Loaded**
		Notify Dig Test at least 48 hours prior to drilling	
		Rent truck, 4x4	
		Proof of auto insurance	
		Rent equipment as needed	
		Sign out equipment w/Equipment Officer	
		Make hotel arrangements and leave info with office personnel	
		Have list of cell numbers for people you are meeting at site	
Water Sampling		**Items to Bring:**	
		Submersible Pump (Bladder, Geotech, etc)	
		Generator	
		Nitrogen tanks	
		Peristalic sampling pump (rental) w/internal battery	
		pump heads (07015-20) w/manual*	
		Field filters (i.e 0.45 micron)	
		Silicone tubing for peristaltic pump	
		feet of polyethylene tubing (1/4" ID x 3/8" OD) ??	
		feet of polyethylene tubing (1/2" ID x 5/8" OD)*	
		small hose clamps	
		car battery/ charger	
		Water level meter	
		Interface Probe	
		YSI 556 (Water Quality Meter) (Temp/pH/Cond/DO/ORP)	
		extra pH standard (10.0, 7.0 & 4.0)	
		Oakton Meter (Temp/pH/Cond)	
		electrical conductivity standard (1000 - 2000 us/cm) or higher	
		Disposable bailers (2" or 3")	
		Bailer Tips for VOC sampling	
		string for disposable bailers	
		builder's level	
		survey tripod	
		stadia rod	
		Sharpies and pens	
		FED-EX shipping slips	
		plastic beakers or cups	
		distilled water (gallons)	
		boxes of 1-gal or 2-gal ziplock freezer bags	
		clear packing tape	
		extra sample labels	
		extra Chain of Custody forms	
		extra Chain of Custody seals	
		packing material (optional, only bring a little if any)	
		H2S meter/ PID	

Equipment List for Fieldwork

Activity	Quantity	Equipment	Loaded
Slug Testing		slug (copper for 2" wells)* - as backup	
(optional)		Hermit datalogger*	
(optional)		Pressure transducers*	
(optional)		50' of string/rope* - as backup for slug	
(optional)			
Soil Sampling		PID w/isobutylene cal. gas	
		LEL/O2 meter	
		Heated headspace equipment (jars, aluminum foil)	
		Hand Auger Kit (stainless steel)	
		crescent wrenches (needed for hand auger kit)	
		Soil Sampling Field Kit	
		Stainless-steel hand trowels	
		disposable hand trowels (if any are still around)	
		stainless-steel bowls (for mixing/compositing)	
		putty knife or equivalent	
		Photo scale w/dry erase markers	
		hand lens	
		Chip trays (12 x 24 compartment)	
		Plastic sample bags (ziplock freezer bags, 1 quart)	
		Sample catcher (strainer w ith long handle)	
(optional)		drum dolly	
(optional)		Shovel	
Aquifer Testing		stop watch	
(optional)		slug (copper for 2" wells)* - as backup	
(optional)		50' of string/rope* - as backup for slug	
(optional)		In-Situ pressure transducers	
		lap top computer and diskettes	
Misc.		**SITE KEYS: Gates and wells**	
		Project Work Plan	
		Field Implementation Plan	
		Site-Specific Health and Safety Plan	
		Waste Management Plan	
		USGS Topographic Map of the Site	
		Geologic Map of the Site	
		shade structure	
		folding table	
		folding chairs x2	
		digital camera	
		nylon measuring tape (200' or more)	
		surveying wheel	
		Brunton/compass	
		GPS (w/manual)	
		Walkie Talkies (3 sets of 2)	

Equipment List for Fieldwork

Activity	Quantity	Equipment	Loaded
Misc (cont)		duct tape	
		roll of plastic sheeting	
		Tool Kit	
		Socket wrenches (9/16" and 3/4" is most commonly used size)	
		bolt cutters	
		pliers (& Leatherman tool)	
		drums (55-gal)	
		drum ratchets and sockets (15/16" & 11/16")	
		hammer for drums & etc.	
		sledge hammer for stakes	
		utility knife/pocket knife/ scis ors	
		File info/maps & latest reports in file box	
		Travel map(s)	
		Field box w/field forms and guides (ASTM, Munsel etc.)	
		Field log book (also take extra spiral notebook)	
		Metal clipboard	
		Black and red permanent markers	
		Engineers scale w ith protractor	
		Pens, mechanical pencils	
		calculator	
		Mobile phone	
		Mobile phone booster	
		Paint Pen for Drum/Well Labeling	
		spray paint	
		traffic cones	
		pin flags, flagging, or stakes	
		funnel	
		tape measure in tenths of a foot (25')	
		proof of auto insurance (in mailbox)	
Decon		Decon brushes	
		pressurized sprayer	
		squeeze/spray bottles	
		5-gal plastic buckets	
		jug/box of alconox	
		roll of paper towels (buy more when needed)	
		box of large trash bags	
Health & Safety		first aid kit	
PPE		fire extinguisher	
		Delorme	
		Charging Station	
		pair steel toed work boots	
		pair of rubber boots	
		steel-toed rubber boots	
		high visibility vest or clothing	
		hard hat	
		Nitrile gloves	

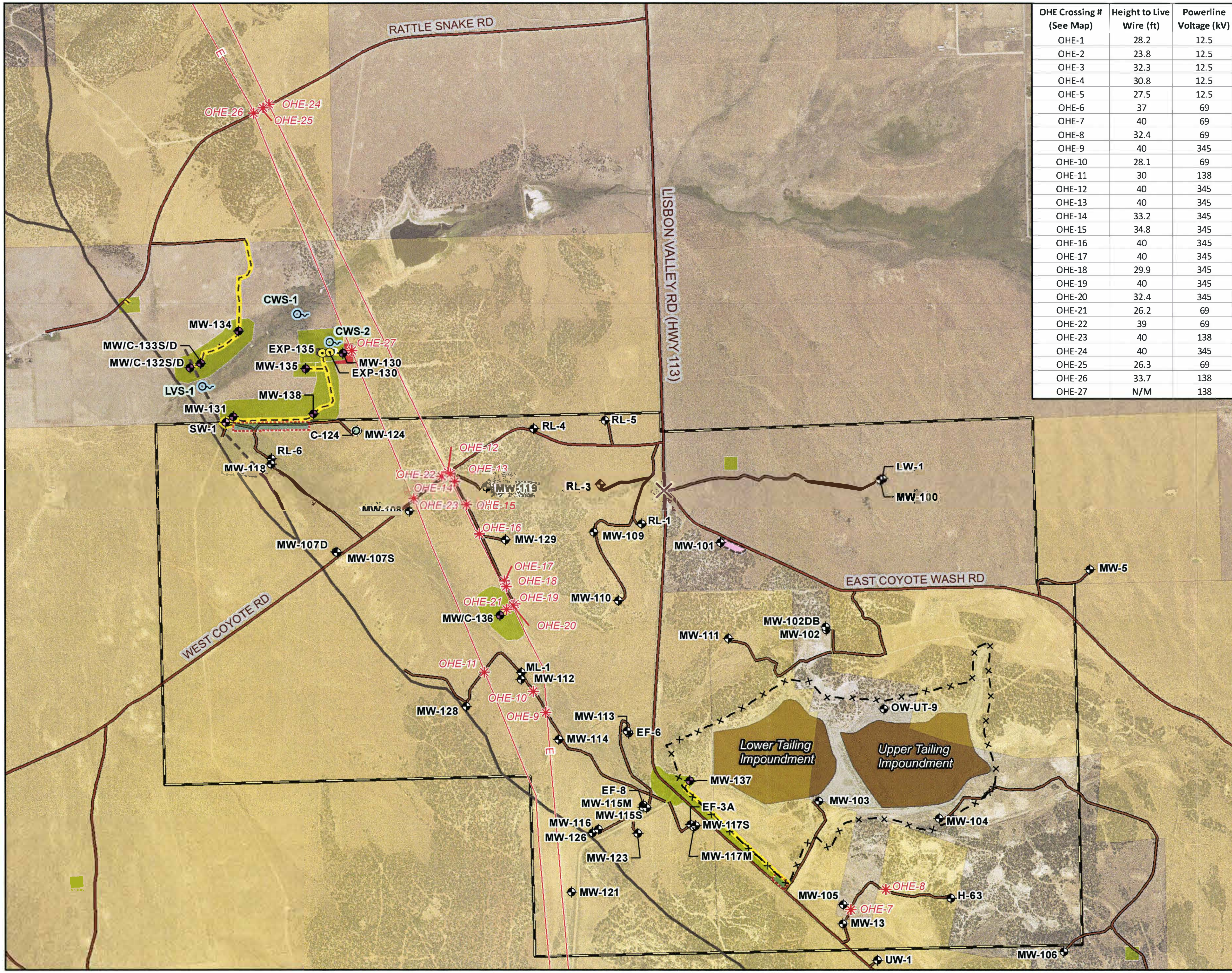
Equipment List for Fieldwork

Activity	Quantity	Equipment	Loaded
PPE (cont)		Leather work gloves	
(optional)		tyvek suit (XL/XXL)	
		rain gear	
		pair of safety glasses	
		ear plugs	
		sun screen	
		can of insect repellent	
		hat/cap	
		drink cooler	
		safety triangles	
		Long sleeve work shirt (mandatory)	
Items to Arrive from		coolers (with containers & trip blanks for analyses specified)	
Lab			

INTERA

Attachment C.4

Utility Clearance and Overhead Power Lines



OHE Crossing # (See Map)	Height to Live Wire (ft)	Powerline Voltage (kV)
OHE-1	28.2	12.5
OHE-2	23.8	12.5
OHE-3	32.3	12.5
OHE-4	30.8	12.5
OHE-5	27.5	12.5
OHE-6	37	69
OHE-7	40	69
OHE-8	32.4	69
OHE-9	40	345
OHE-10	28.1	69
OHE-11	30	138
OHE-12	40	345
OHE-13	40	345
OHE-14	33.2	345
OHE-15	34.8	345
OHE-16	40	345
OHE-17	40	345
OHE-18	29.9	345
OHE-19	40	345
OHE-20	32.4	345
OHE-21	26.2	69
OHE-22	39	69
OHE-23	40	138
OHE-24	40	345
OHE-25	26.3	69
OHE-26	33.7	138
OHE-27	N/M	138

INTERA

N

1,400 700 0 1,400

Feet

ACL Program

- Existing Monitoring Well
- Proposed Monitoring Well
- Proposed Exploration Borehole
- Proposed Core
- Stock Well
- Spring or Seep Sample
- Fault Trench
- Fence Boundary
- Site Roads: Existing
- Site Roads: Proposed
- Overhead Electrical (OHE)
- OHE Crossing
- Roads
- Doelling LVF
- ERM LVF
- Cell Phone Booth
- Subsurface Features (see Sunbelt Geophysics September 2019 report)
- Approximate Completed Arch/Bio Survey (EcoSphere and Woods Canyon)
- Existing Laydown Area
- Preliminary Long Term Surveillance & Maintenance Boundary
- Tailing Impoundment

Land Owner Agency

(Utah School and Institutional Trust Lands Administration (SITLA)), 2018

- BLM
- Private

Attachment C.4
HSSA4 OHE and Utility Clearance
Lisbon Facility CAAWP Appendix C
Field Implementation Guidelines

Attachment C.5

Daily Activity Report

Attachment C.5

DAILY ACTIVITY REPORT

Well Name:				Date:		Depth:	
Field Name:				Day:		Footage:	
				Operation at Report Time:			

Rig Time Distribution			
Drilling		Logs	
Rig Serv.		Other	
Survey		WOO	
Tripping		Fishing	
Circ.		Coring	
Casing			
Cement			
WOC		Total	0
Mix Mud			
Rig U/D			
Welding			
Rig Repair			

Bottom Hole Assembly		
No.	Desc.	Length
1	Bit	
2	Sub	
3		
4		
5		
6		
7		
8		
9		
10		
11		
	Total	0

Bit Record				
Bit #				
Size				
MFG.				
Type				
Jets				
S/N				
Out				
In				
Total Ft.				
Hrs				
Cond.				

Mud Properties.			
Time			
Depth			
Wt.			
Vis. Fun			
pH			
WL			
Cake			
Chlor.			
Oil			
Solids			
Sand			
Daily Cost			

Finish			
Depth	Deviation	Depth	Deviation

PUMP INFO

COMPRESSOR INFO

Field Sketch

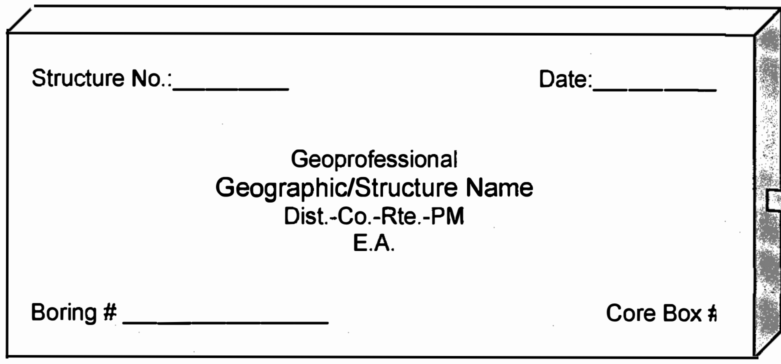
Comments

Attachment C.6

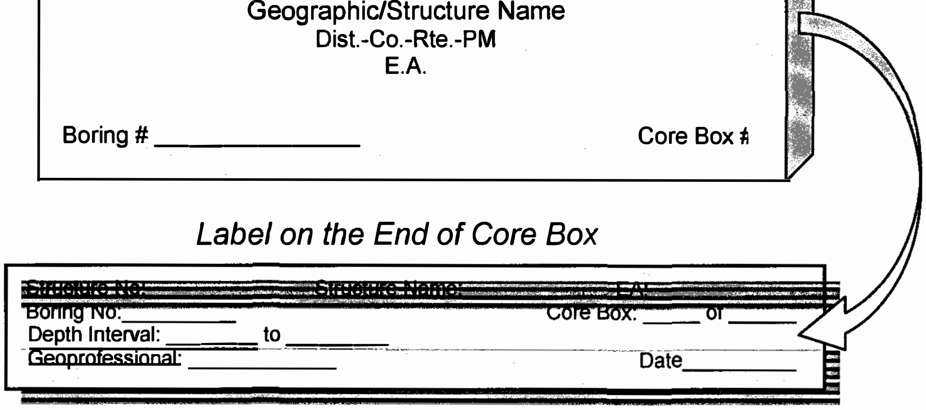
Core Box Layout Diagram

Attachment C.6

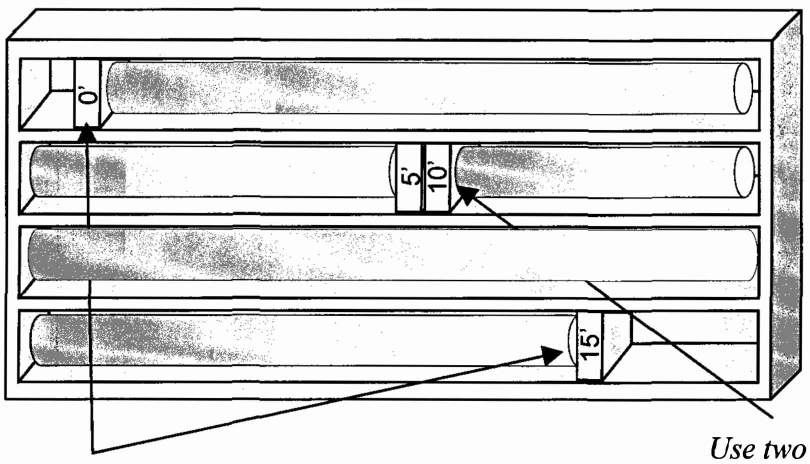
Core Box Layout and Label



Label on the End of Core Box



Inside Core Box



Note depth on core blocks at beginning and end of each run

Use two blocks in segments of no recovery

Attachment C.7

Core Logging Form

Attachment C.7

PROJECT: ROCK CORE LOG

BORING NO.	PROJECT NO.	LOCATION		SHEET OF
TIME START	DRILLING CONTRACTOR	DRILLING EQUIPMENT		DATE
TIME STOP	DRILLER	DRILLING METHOD	SAMPLING METHOD	
TOTAL DEPTH	BACKFILL MATERIAL	WATER FIRST ENCOUNTERD	FINAL DEPTH TO WATER	

DEPTH (FT)	CORE RUN (IN)	RECOV. CORE LENGTH (IN)	TOTAL CORE RECOVERY (%)	SOLID CORE RECOVERY (%)	RQD (%)	FRCT. DENSITY (# PER FT)	PENETRATION RATE (FT/HR)	SMPL. FOR TEST	GRAPHIC LOG	DESCRIPTION/LITHOLOGY/COMMENTS
1										
2										
3										
4										
5										
6										
7										
8										
9										
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										

LOGGED BY: ______________________ OFFICE: ______________ DATE: ______________

INTERA

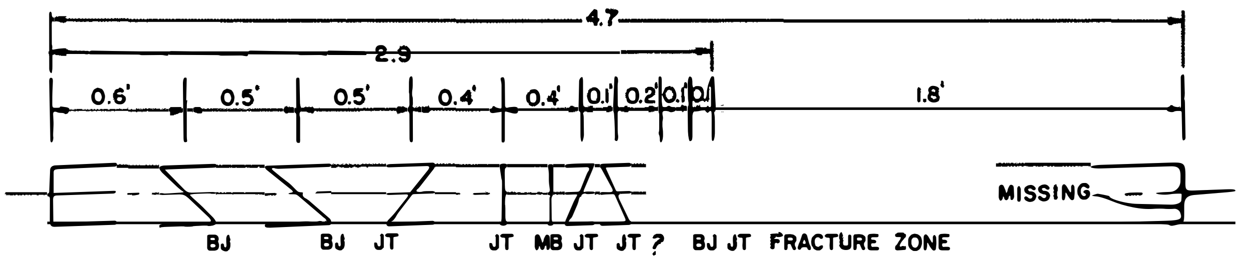
Attachment C.8

RQD Computation and Diagram

Attachment C.8

Rock Quality Designation (RQD) Computation

1. PERCENTAGE OF SOLID CORE SEGMENTS LONGER THAN 0.33 ft (100mm) RELATIVE TO CORE RUN LENGTH, EXCLUDING MECHANICAL BREAKS.
2. RECORDED AS CALCULATED PERCENTAGE FOR EACH RUN.
3. BEST FOR N-SIZE OR LARGER SIZE CORE.
4. MAY NOT BE APPLICABLE FOR VERY LOW STRENGTH, FISSILE OR FOLIATED ROCKS WHICH BREAK OR PART EASILY.



$$RQD = \frac{\text{Sum of length of pieces} \geq 0.33\text{ ft (4in)}}{\text{(total length of core run)}} \times 100 = \frac{2.4}{4.7} \times 100 = 51\%$$

Attachment C.9

Drill Cuttings Logging Form

Attachment C.9

LOG OF BORING

(Page of)

Project Name:	Date Started : Date Completed : Drilling Method : Sampling Method : Drilling Company :	Driller : Depth to Water : Logged By :
Project #:		

Depth in Feet	Sample Interval	Sample #	Pen./Rec.	PID (ppm)	**Group** (soil) name (clay, sand, silty sand, etc), percentage of non-predominant soil type, **grading** (coarse-grained soils only), **particle-size** (coarse-grained soils only), **angularity, shape, maximum particle size** (gravel only), **plasticity** (fine-grained soils only; non, low, medium, high), **density** (coarse-grained soils only; very loose, loose, medium dense, dense, very dense), **consistency** (fine-grained soils only; very soft, soft, firm, hard, very hard), **color**, **odor**, **moisture** (dry, moist, wet), **reaction with HCl** (none, weak, strong), **structure**, **cementation**, other (roots, mica, gypsum, caliche nodules, drilling conditions), geologic name (if known). DESCRIPTION	Group Symbol

Notes:

INTERA

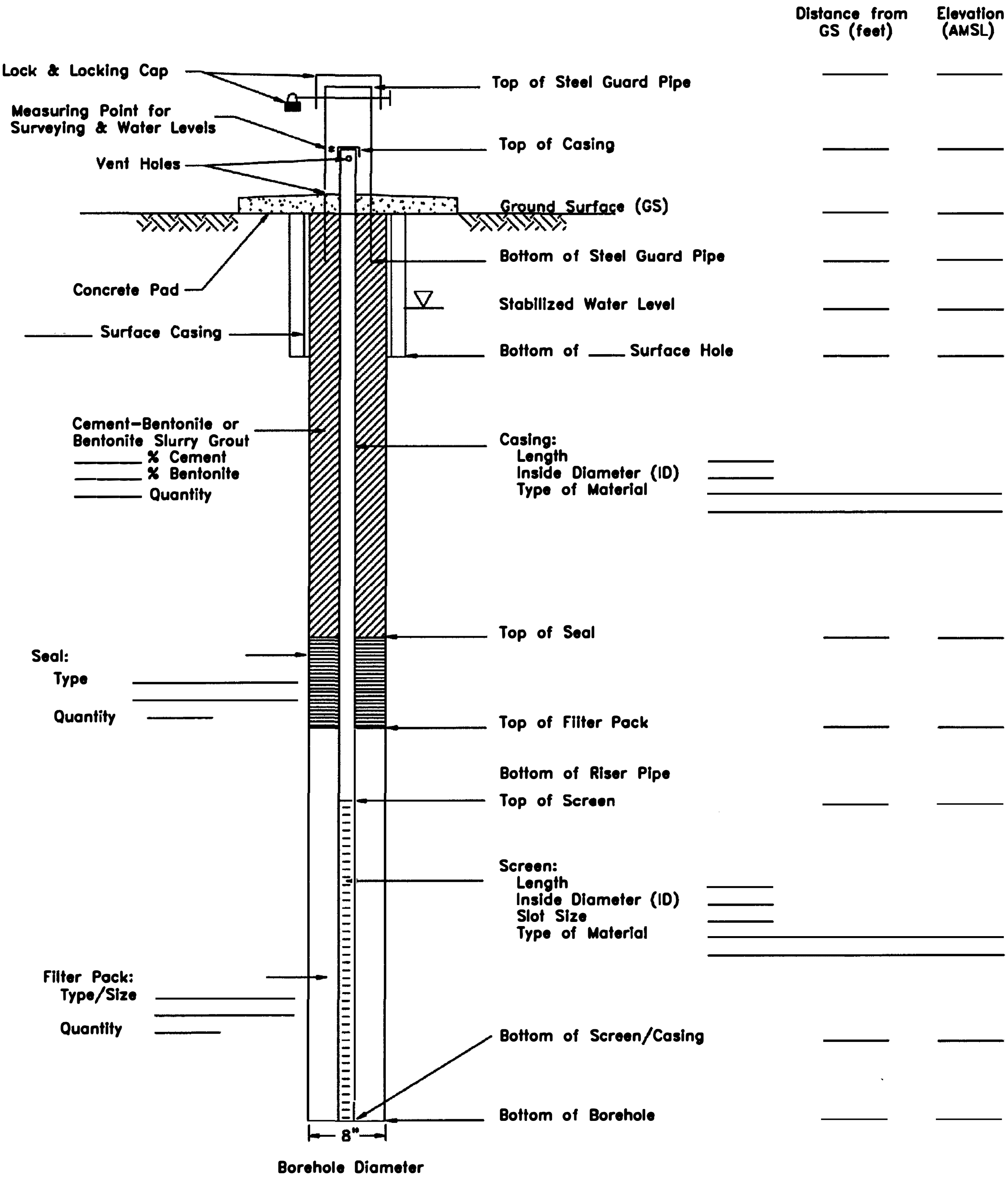
Attachment C.10

Monitoring Well Construction Diagram

Attachment C.10

Project No. ________ Client: ________ Site: ________	Well No. ________
Well Location: ________	Date Installed: ________
Contractor: ________ Method: ________	

MONITORING WELL CONSTRUCTION DETAIL



* Describe Measuring Point: ________

Attachment C.11

Well Development Form

PROJECT NAME: ______________________________ WELL NO.: ____________

PROJECT NO.: ____________ DATE: ____________ FORM COMPLETED BY: ____________

WELL CONSTRUCTION

TOTAL DEPTH BELOW MEASURING POINT (BMP) (FT): ________ BOREHOLE DIAMETER (IN): ____________

TOTAL DEPTH BELOW LAND SURFACE (FT BLS): ____________ WELL DIAMETER INSIDE (IN): __________

WELL PROTECTOR: ☐ YES ☐ NO PADLOCK NO.: ____________ WELL DIAMETER OUTSIDE (IN): _________

SAND PACK INTERVAL (BLS) (FT): ____________________ SCREEN INTERVAL (BLS) (FT): _________

WATER VOLUME CALCULATION

DATE/TIME OF MEASUREMENT:__________________

MEASURING POINT:__________ ELEV.:__________

WATER LEVEL INSTRUMENT USED:______________

INITIAL WATER LEVEL (BMP) (FT):______________

LINEAR FEET OF WATER:____________________

LINEAR FEET SATURATED GRAVEL PACK:__________

ITEM	WATER VOLUME	
	FT^3	GAL
Well Casing		
Sand Pack		
Drilling Fluids		
TOTAL		

NOTE: *Quantities are to be calculated prior to development.*

DEVELOPMENT CRITERIA

METHOD OF DEVELOPMENT: ______________________________

WATER VOLUME TO BE REMOVED (GAL): ________ WATER VOLUME ACTUALLY REMOVED (GAL): ______

TIME DEVELOPMENT STARTED: ______________ TIME DEVELOPMENT COMPLETED: ______________

NOTE: *Development is to be performed in accordance with Standard Operating Procedure No. 8.*

WATER QUALITY INSTRUMENTS

INSTRUMENT	SERIAL NO.	TIME CALIBRATION PERFORMED	TECH	COMMENTS

WATER QUALITY READINGS DURING DEVELOPMENT

DATE/TIME	TOTAL WATER PURGED (gal)	TEMP (°C)	CONDUCTIVITY (µS/cm)	TURB (NTU)*	pH	TECH	COMMENTS

*If measured.

Stabilization = Temp ±1°C; pH ±0.2 units; Sp. Cond. ±10%; Turb. ±10%

WATER QUALITY READINGS DURING DEVELOPMENT (continued)

DATE/TIME	TOTAL WATER PURGED (gal)	TEMP (°C)	CONDUCTIVITY (μS/cm)	TURB (NTU)*	pH	TECH	COMMENTS

*If measured.

Stabilization = **Temp** ±1°C; **pH** ±0.2 units; **Sp. Cond.** ±10%; **Turb.** ±10%

Appendix D

Details on Data Types and Methods Used in the CAAWP

Appendix D

Details on Data Types and Methods Used in the CAAWP

Corrective Action Assessment Work Plan

Rio Algom Mining LLC, Lisbon Facility

San Juan County, Utah

Table of Contents

List of Tables

Acronyms and Abbreviations

$^{87}Sr/^{86}Sr$	strontium-87 to strontium-86 ratio
μ	fluid viscosity
µm	micrometer
ρ_w	fluid density
ASTM	ASTM International
BET	Brunauer-Emmett-Teller
BCA	Burro Canyon Aquifer
BSE	backscattered electron
CAAWP	Corrective Action Assessment Work Plan
cm	centimeter/centimeters
COC	constituent of concern
CSM	Conceptual Site Model
EDS	energy dispersive spectroscopy
EPMA	electron probe microanalysis
g	gravitational acceleration or gram/grams
h	soil water pressure head or groundwater hydraulic head
INTERA	INTERA Incorporated
ISBR	in situ biological reduction
k	permeability
Ks	saturated hydraulic conductivity
LTI	Lower Tailing Impoundment
M	molarity
mg	milligram/milligrams
mL	milliliter/milliliters
MLA	Mineral Liberation Analysis
mm	millimeter/millimeters
MMR	magnetometric resistivity
MPa	megapascals
PCA	principal components analysis
PCR	polymerase chain reaction
PIQ	Principal Investigation Question
QEMSCAN	Quantitative Evaluation of Minerals by SCANning electron microscopy
RAP	resonance acoustic profiling
SEM	scanning electron microscopy
SEM-EDS	SEM combined with energy dispersive spectroscopy
Site	RAML Lisbon facility
SPLP	Synthetic Precipitation Leaching Procedure
SSA	specific surface area
T	transmissivity
TSF	Tailings Storage Facility
UTI	Upper Tailing Impoundment

WSL	water-soluble leach
wt %	weight percent
XRD	x-ray diffraction
XRF	x-ray fluorescence spectroscopy
ZVI	zero-valent iron

D.1 Introduction

This appendix provides detailed information for some of the less commonly encountered data types and methods proposed for the Lisbon Facility (Site) Corrective Action Assessment Work Plan (CAAWP). A list of these data types and methods is provided in **Table D.1**. This table includes references to specific principal investigation questions (PIQs; **Appendix A**) that a given data type and method are meant to address. The method descriptions below focus on those that have not been presented previously (INTERA, 2020, 2021a, 2021b, 2021c) and are not listed as ASTM International (ASTM) procedures. Methods already used in previous studies at the Site are included by reference. The data types and methods described below that involve laboratory testing are some hydraulic properties, solid mineralogy and chemistry analysis, leach tests, and physical properties. These laboratory tests will be applied both before and after treatability tests to evaluate the effectiveness of treatment options and inform the Design Conceptual Site Model (CSM).

D.2 Hydrologic Properties

Additional data for the hydrologic properties in the key investigation areas (**Figure 2.1**) are necessary for determining the most appropriate corrective action elements for each area. The hydrologic properties of vadose zone core samples will be determined using the HYPROP, WP4C, and multi-step method (Lipovetsky et al., 2020) performed on intact core in the laboratory and neutron moisture logging within boreholes (Alberty et al., 1992). Borehole flow and electrical conductivity logging will be performed in newly installed boreholes in the Near-Field and Far-Field Areas of the Site. After new wells have been installed, existing and new wells will be used for magnetometric resistivity (MMR; Jessop et al., 2018) and resonance acoustic profiling (RAP; Nakamura, 1989; Okada, 2003) surveys. Both MMR and RAP provide maps of potential preferential groundwater pathways in the aquifer, which can inform the selection of treatment areas and systems. The above hydrologic data collection methods are described in more detail below.

D.2.1 HYPROP, WP4C, and Multi-Step Method

A full soil-moisture curve can be derived using the HYROP and WP4C methods (METER Group, Munich, Germany) applied to intact core. Data from these methods can be fitted to and evaluated against various water retention models (e.g., van Genuchten) using HYROP FIT Software. These methods have been successfully applied to soils and porous carbonate rock (Lipovetsky et al., 2020).

The HYROP measurement system uses an evaporation method to determine water retention and hydraulic conductivity of porous media. It involves pressure head measurements over time at two depths within a saturated cylindrical sample as water evaporates from its surface. The evaporation rate is determined by continuous weighing of the column setup. Water retention and hydraulic conductivity are estimated from the average water content, the pressure heads provided by the two tensiometers, and the mean total head gradient between the two tensiometers.

The WP4C method involves a chilled-mirror dew point method carried out on a dry sample (~7 milliliter [mL] volume) inserted into a psychrometer, the WP4C Dewpoint PotentiaMeter (metergroup.com). The WP4C determines the relative humidity of the air above the sample in a sealed chamber. Once the sample is equilibrated with the air, relative humidity is determined by chilling a tiny mirror until dew starts to form. At the dew point, the instrument measures the mirror and sample temperatures and calculates a water potential value (accurate between -0.1 and -300 megapascals [MPa]) and a pF value (where pF = -log|h|, h = soil water pressure head).

Absolute porosity and permeability of a sample can be measured using a DV-4000 Poropermeameter, an automatic steady-state gas permeameter-porosimeter system (Weatherford Laboratories, Houston, USA). Porosity is measured using helium gas and permeability is measured using nitrogen gas. Saturated hydraulic conductivity (Ks) is found by:

$$Ks = \rho_w g k/\mu$$

where k is the permeability, ρ_w is the fluid density, g is gravitational acceleration, and μ is fluid viscosity.

D.2.2 Neutron Moisture Logging

Borehole neutron moisture logging is described by Alberty et al. (1992) and summarized here. Neutron probes are based on the concept of neutron moderation where fast neutrons emitted from a radioactive source are slowed by collisions with surrounding atoms. Slowed (thermalized) neutrons are detected and measured by the probe as 'counts.' Fast neutron collisions with heavier atoms result in little loss of neutron velocity, whereas collisions with equivalent-mass atoms (particularly hydrogen) result in appreciable neutron slowing. As a soil is wetted, the thermalized neutron density near a neutron source increases, increasing probe counts. A relationship between probe counts and volumetric soil moisture can be established using factory calibration; previously established soil moisture-count curves for similar soils; or most preferably, calibration in the field or laboratory using native soil samples of known gravimetric moisture content and bulk densities. Neutron moisture logging will be included with the suite of proposed downhole geophysical logging as identified in Section 6.1.

D.2.3 Borehole Flow and Electrical Conductivity Logging

Borehole flow logging can be used to construct vertical profiles of transmissivity and allows for the identification of transmissive and confining intervals along a borehole. Measured inflow, using a flowmeter (e.g., impeller, heat-pulse types) under various well conditions is used to determine zone transmissivity (T) and head (h) using radial-flow relationships. Flowmeter data can be fitted to a steady borehole flow model for more accurate estimations of T and h if the following criteria are met: (1) hydraulic head values are independently measured for each zone; (2) a single steady-state flow profile is combined with a measurement of the open-hole water level with respect to one of the known hydraulic heads; and (3) flow profiles and water levels are measured under two different steady-state flow conditions (e.g., ambient, constant pumping rate, constant injection rate) (Paillet, 2000). Borehole flow logging can be combined with geophysical techniques like electrical conductivity logging to (1) confirm the identity of aquifer zones and confining units based on contrasts in pore water salinity and (2) verify flow log interpretations of injection tests (Paillet and Reese, 2000).

D.2.4 Magnetometric Resistivity

The MMR technology is a quick and nonintrusive imaging methodology specifically designed to identify, map and model preferential seepage flow paths and patterns through, beneath and around reservoir embankments (Jessop et. al., 2018; www.willowstick.com). The technology uses a signature electric current as a contrast agent to image and visualize the flow of seepage and can quickly and accurately render two-dimensional maps and/or three-dimensional models of seepage flow paths and patterns within an aquifer. The application of the technology is based on the principle that seepage generally increases the conductivity of earthen materials through which it flows. As a signature electric current flows between strategically placed electrodes, it concentrates in the more conductive zones (i.e., in hydrated areas of highest permeability) where seepage preferentially flows. Magnetic fields generated by the flow of the signature electric current are measured and modeled to identify preferential electric current flow paths and patterns. The electric current flow paths and patterns are then modeled and interpreted to characterize seepage flow paths and patterns.

D.2.5 Resonance Acoustic Profiling

The RAP method detects structural weaknesses in soil and rock and is apt at locating zones of higher permeability (Nakamura, 1989; Okada, 2003; www.willowstick.com). The constant cycle of tidal motion that affects the oceans, resulting in high and low tides twice a day, imposes tidal movements in the earth's crust as a result of these gravitational forces. Earth tides fluctuate between 15 centimeters (cm) and 45 cm a day depending on the location on the earth's surface and the position of the sun, moon, and earth in relation to one another. Over time, stresses build in the earth's crust from the repeated rising and falling of the earth's crust until stress release points or zones are established. As the earth moves, frictional grinding takes place along faults and fractures in rock formations and along zones of secondary permeability in soil and rock formations. This grinding creates a resonance signal. The movement and grinding of the earth's crust, in conjunction with water naturally collecting in these areas, produces resonance signals that can be measured and modeled to identify zones of higher permeability in the rock and soil matrix. High-frequency RAP measurements (within the resonance frequency domain) indicate that the stress relief point is near the surface. Lower resonance frequencies (within the resonance frequency domain) indicate a deeper anomalous zone. As a result, the zones of highest structural weaknesses within the soil and rock matrix can be identified and aligned with the results of a MMR investigation to provide a more accurate model of seepage flow paths within the aquifer.

D.3 Solid Mineralogy and Chemistry

Solid mineralogy and chemistry data collection is planned for samples of tailings, the vadose zone below the tailings storage facility (TSF), the Burro Canyon and Brushy Basin in the Near-Field, Far-Field, North, and Northwest Areas, and the Navajo Sandstone in the Northwest Area (**Figure 2.1**). The purpose of solid mineralogy and chemistry data collection is to provide information on the distribution and stability of solid phases that host COCs before and after flow-through leach tests (described in Section D.4.2) and treatability tests (described in Section D.7.1) to evaluate the effectiveness of in situ treatment. Results from mineralogical and chemical characterization will be used to screen which samples will undergo flow-through leach tests and treatability tests. A subset of solid samples will undergo flow-through leach and treatability tests that represent the range in observed mineralogical and chemical characteristics, including COC concentrations. This set of data collection methods applied to samples of tailings, the vadose zone, and the Near-Field Areas will also be used to determine if commodities of interest (e.g., rare-earth elements) are present at economic concentrations, and whether they could be used to offset some of the cost of corrective actions.

Cores collected over the past decade at the Site are available for additional analysis. Cores collected by Montgomery & Associates in 2012 and 2013 are C-102DB, C-103, C-109, C-116, C-117M, C-118, MW-117, MW-107D, and MW-116 (Montgomery & Associates, 2014). Cores collected by INTERA Incorporated (INTERA) in 2017 are C-125, C-126, C-127ALT, and C-128 (INTERA, 2021a). Cores collected by INTERA in 2019 and 2020 are C-124, EXP-130, C-131D, C-132D, C-133D, EXP-135, C-136, C-138D, C-139, LDB-4, UDB-4, and UDB-5 (INTERA, 2021b). New drilling installations are proposed for the CAAWP in all key investigation areas (**Figure 2.1** and **Figures 5.7**, **6.1**, and **6.3**). New core samples may be analyzed along with previously collected core samples for the CAAWP.

Core samples collected during the 2019 and 2020 drilling campaigns were analyzed by x-ray diffraction (XRD) with Rietveld refinement (Rietveld, 1969) for bulk semi-quantitative mineralogy, x-ray fluorescence spectroscopy (XRF) for whole rock chemistry, and select samples were also made into thin sections for petrographic analysis and qualitative mineralogy (INTERA, 2021b). Additional core samples will also be analyzed using XRD with Rietveld refinement, XRF, and petrographic analysis. Detection and practical quantitation limits for XRD with Rietveld refinement are typically 1 to 3 weight percent (wt %) at best (Burleson et al., 2004), which is relatively high. As a result, additional data collection methods are recommended and will consist of those described below.

D.3.1 Thin Section Analysis

The solid phases that tend to host contaminants such as arsenic, molybdenum, selenium, and uranium can be challenging to identify at the bulk scale, and often require analysis at the grain-scale in thin sections. Scanning electron microscopy (SEM) and electron probe microanalysis (EPMA) are common grain-scale analytical tools for imaging solids and providing qualitative chemical information. When SEM is combined with energy dispersive spectroscopy (SEM-EDS) qualitative chemical information for individual points on the thin section can be obtained. EPMA can provide chemical information for entire regions of a thin section, but the detection limits tend to be relatively high and increase for lighter elements (Cousins et al., 1997). Both SEM-EDS and EPMA are useful for obtaining qualitative mineralogy and solid chemistry relatively quickly and are therefore useful screening techniques that can help to prioritize samples for additional analysis.

Automated mineralogy is a technique that is based on SEM analysis. This technique can provide a backscattered electron (BSE) image and thousands of EDS points for an entire thin section. Minerals are classified based on their BSE intensities and an associated EDS spectrum found in a reference mineral database. If a location in the thin section contains a unique EDS spectrum, new reference minerals can be added to the database. The most common automated mineralogy techniques are known as MLA (Mineral Liberation Analysis) and QEMSCAN (Quantitative Evaluation of Minerals by SCANning electron microscopy). When an entire thin section is analyzed, thousands of particles can be characterized for chemical composition, modal mineralogy, grain size, element liberation potential, and mineral textural relationships. Automated mineralogy is increasingly being used to characterize mine waste (e.g., Brough et al., 2017; Hudson-Edwards et al., 2019). Automated mineralogy can detect minerals at a lower detection limit compared to XRD with Rietveld refinement and it can also identify and quantify solids that are not crystalline (e.g., Kimball et al., 2019), making automated mineralogy a particularly useful tool for characterizing contaminant-bearing solids that are difficult to characterize using more standard techniques.

D.3.2 Sequential Extractions

Sequential extraction procedures are a type of mineralogical data collection method that aims to quantify the distribution of trace elements associated with different solid phases in a sample, and they are used to understand the source of mobile trace elements. Sequential extractions can provide clarity on the less abundant solid phase hosts of COCs, particularly when results from techniques such as XRD are uncertain due to higher detection limits. There are multiple variations of sequential extraction procedures, but most share similar characteristics. Typically, a solid sample is subjected to a sequence of batch reactions with extraction solutions of increasingly aggressive chemicals to attack and dissolve the targeted solid fractions. The procedure first targets more mobile trace element species (e.g., loosely bound to cation-exchange sites of clay minerals, or coprecipitated with semi-crystalline minerals), followed by less mobile species (e.g., substituted into sulfide and silicate minerals). Sequential extractions can characterize trace elements associated with specific minerals, mineral groups, and non-crystalline solids, which may be preferred over solids tested as a whole using bulk methods.

A sequential extraction procedure optimized for uranium-bearing solids is recommended for the CAAWP following Szecsody et al. (2020). Other COCs and constituents of interest can be characterized with this procedure as well. The proposed sequential extraction procedure is similar to that performed on the cores collected during the 2019 and 2020 campaigns (INTERA, 2021b), but is more comprehensive in the number and types of targeted solid fractions. Furthermore, the previous sequential extractions were only applied to core samples in the

Northwest, Far-Field, and South Near-Field Areas (**Figure 2.1**), and not to samples in the other areas that are key to this investigation. Six sequential extraction steps are conducted in series on solid samples at a sediment to solution ratio of 1:2 at room temperature, except for step six, which is carried out at 95 °C. Each extraction step uses a different reagent to target different solid fractions. At the end of each step, the slurry is centrifuged, and the supernatant is drawn from the solids and filtered before analysis of the leachate. The leachate will be analyzed for uranium and other COCs, major ions, and in the case of tailings solids and Near-Field core samples, economic commodities (e.g., rare earth elements). The methods and reagents used for each extraction step, the targeted fraction, and the mobility behavior in the environment for the targeted fraction are given in **Table D.2**. The sequential extraction procedure is planned for tailings solid samples and crushed bedrock core samples (up to 2 millimeters [mm] in size and up to 4 mm in size) before and after solids undergo flow-through leach tests (described in Section D.4.2) and in situ treatability tests (described in Section D.7.1).

D.4 Leach Tests

The purpose of the leach tests described below is to provide information about the mass of COCs released from solids before and after treatability tests. Leach tests prior to treatability tests will be used to estimate the mass flux of COCs in the current system, whereas leach tests after treatability tests will be used to quantify the effectiveness of different in situ treatment options. Pre-treatability leach tests applied to samples of tailings, the vadose zone, and the Near-Field Areas will also be used to determine if commodities of interest (e.g., rare-earth elements) are present at economic concentrations, and whether they could be used to offset some of the costs of corrective action.

Leach tests are typically designed to simulate natural weathering processes. Most leach tests are conducted as either batch or flow-through tests. In batch tests, solids and solutions are combined in a flask, open or closed to the atmosphere, and are stirred or agitated for some amount of time before the solution is separated from the solids and analyzed for dissolved constituents. In flow-through tests, solids are placed in a reaction vessel that allows solutions to flow through the reactor at a known rate, either continuously or intermittently, before being collected at the outflow for analysis of dissolved constituents. The solids used in both batch and flow-through tests are usually characterized for mineralogy and chemistry before and after the leach test. Batch tests were performed previously on core samples from the Site (INTERA, 2021b) and both batch and flow-through tests are proposed for the CAAWP. Details on these tests are provided below.

D.4.1 Batch Tests

The Synthetic Precipitation Leaching Procedure (known as SPLP or Method 1312; USEPA, 1994) is a type of batch test. The SPLP was performed on the core samples collected during the 2019 and 2020 campaigns with the following modifications: (1) instead of synthetic precipitation, the leaching solution was uncontaminated Site groundwater; (2) instead of the recommended solid-to-solution ratio of 1 to 20, a ratio of 1 to 4 was used; and (3) instead of the 0.6- to 0.8-micrometer (µm) pore size filter recommended in the method, filtration after leaching was performed with a 0.45-µm filter. This modified SPLP is similar to the first step of the sequential extraction procedure described above (Section D.3.2), so this procedure is not recommended again for the CAAWP, provided sequential extractions are used.

Another type of batch test, referred to as a water-soluble leach (WSL), will be performed on tailings solid samples to estimate tailings porewater concentrations of COCs and other constituents. Constituents dissolved in tailings porewater are part of the primary source of constituents at the Site. Concentrations of COCs and other constituents in tailings porewater are already available from lysimeters in one location in the Upper Tailing Impoundment (UTI) and two locations in the Lower Tailing Impoundment (LTI) but maintaining a hydraulic connection between the lysimeters and tailings porewater has not been possible for all lysimeters, and only three sample locations is not ideal for representing the full range of tailings porewater concentrations. Applying a WSL to tailings solid samples from multiple locations and depths within the impoundment will provide a better estimate of the heterogeneity and range of tailings porewater concentrations. As discussed in Section 5.3, eight locations for coring are proposed for the tailings impoundments (**Figure 5.2**), and solid samples will be collected at least every 5 feet, including at noteworthy changes in the material.

The WSL procedure combines equal masses of dried and sieved solids (60 to 80 grams) and deionized water. The slurry is combined in screw-cap jars and is briefly shaken by hand and then placed on a mechanical orbital shaker for one hour. The samples are allowed to settle overnight until the supernatant liquid is clear. The supernatant is carefully decanted, filtered (0.45 µm), and analyzed for conductivity, pH, alkalinity, anions, and cations, including all COCs.

Batch tests will also be performed as an initial step during in situ treatability testing as described in Section D.7.1. The purpose of initial batch tests will be to determine essential parameters (e.g., number of pore volumes) to be used during in situ treatability flow-through column testing. In the case of in situ biological reduction (ISBR) treatability testing, batch testing will be a crucial screening step (**Figure 5.3**) to determine if the appropriate microbiological community can be stimulated with the addition of electron-donor substrates (see Section 5.3.3 for additional discussion). The criteria used to determine if the appropriate microbiological community can be supported will be (1) an apparent reduction in dissolved uranium and other COC concentrations due to the bioreduction and biomineralization process and (2) identification of typical microorganisms (e.g., iron- and sulfate-reducing microorganisms) found in ISBR systems as determined by standard microbiological community analysis methods (e.g., rRNA gene sequencing and quantitative polymerase chain reaction [PCR]; Newsome et al., 2015).

D.4.2 Flow-Through Tests

Flow-through reactors will test the one-dimensional flow and reactive behavior of groundwater with tailings solids or bedrock core samples following Szecsody et al. (2020). Columns (e.g., 25 mm in diameter) will be oriented vertically and packed with solid material that has already been analyzed for total mass, gravimetric moisture content, and dry bulk density so that pore volume and porosity can be calculated. The length of the columns and the total mass used in each column will depend on the contracted laboratory and their ability to perform the flow-through tests with acceptable quality controls. Unimpacted groundwater from the Site or artificial groundwater will be injected at the base of the column and flow at a rate approximately the same as that expected for groundwater at the Site. Effluent samples will be collected at the top of the column periodically and analyzed for pH, electrical conductivity, uranium and other COCs, major ions, and in the case of tailings solids and Near-Field core samples, economic commodities (e.g., rare earth elements). Samples will be collected more frequently in the beginning of the test (e.g., every two pore volumes) and less frequently as constituent concentrations begin to stabilize. Stop-flow events lasting 12 hours, 24 hours, and 48 hours will periodically be applied to the tests to provide time for COCs in mobile phases to partition into pore water. COC release rates can be determined by the change in effluent concentrations before and after a stop-flow event. The flow-through procedure is planned for tailings solid samples and crushed bedrock core samples before and after solids undergo treatability tests. Two size fractions of crushed bedrock should be tested (up to 2 mm [sand] and up to 4 mm [gravel]) to ensure that scaling effects do not generate drastically different mass release of COCs.

D.5 Physical Properties

The physical property data collection methods listed in **Table D.1** are necessary for scaling laboratory leaching rates to field leaching rates and improving estimates of field hydraulic properties. These data collection methods will be applied to samples before and after treatability tests to determine the efficacy of different in situ treatment options.

Most of the data types listed in **Table D.1** as physical properties have an associated ASTM method or have been described before (INTERA, 2021b). The exception is measurement of specific surface area (SSA), which is the total surface area of solid material per unit mass of material. This measurement is critical for scaling laboratory leach rates to field leach rates (Maest et al., 2005). The most common method for measuring SSA is the Brunauer-Emmett-Teller (BET) method, where nitrogen gas is allowed to adsorb to the solid material and the SSA is calculated from the adsorption isotherm (Brunauer et al., 1938). The SSA will depend on the size of the particles and the structure and porosity of the material. An aliquot of all samples that undergo leach tests needs to be characterized for SSA. The SSA for certain minerals can be estimated by weighting the SSA results by modal mineralogy results obtained by XRD and/or automated mineralogy.

D.6 Hydrologic Tracers

Hydrologic tracers (e.g., environmental tracers) can provide information on groundwater sources and flow pathways, and possibly residence times. As a result, hydrologic tracers could be critical to the Design CSM because they may provide evidence or lack thereof for hydrologic connections between the deep BCA and possible future exposure points in the North and Northwest Areas. The North and Northwest areas of the Site (**Figure 2.1**) will be surveyed for hydrologic tracers in samples of surface water and groundwater. Samples for hydrologic tracers will be collected from existing sample locations in the Northwest Area (**Table 6.4** and **Figure 6.4**) and newly installed wells in the North and Northwest Areas (**Figure 6.3**).

Potential hydrologic tracers to evaluate in the North and Northwest Areas of the Site are shown in **Table D.3**. **Table D.3** shows examples of regional studies where a given tracer or set of tracers was implemented. **Table D.3** also shows the general benefits and limitations of each tracer. It is not feasible to evaluate all the tracers shown in **Table D.3** within a reasonable timeframe for the CAAWP. As a result, the tracers in **Table D.3** are presented in order of preference (from top to bottom) based on the relative ease of implementation. Tracers that are easier to implement are generally those with relatively straightforward sampling procedures and data analysis, are relatively inexpensive, and can be measured by more than a few specialized laboratories. The hydrologic tracers recommended for evaluation in the North and Northwest areas include the following: (1) constituent ratios and/or principal components analysis (PCA) of routine water quality results; (2) stable oxygen and hydrogen isotopes of water; (3) sulfur and oxygen isotopes of sulfate; (4) strontium-87 to strontium-86 ratios ($^{87}Sr/^{86}Sr$); and (5) tritium and helium-3. These tracers can provide information on water sources and processes, and tritium/helium-3 has the added benefit of potentially providing an apparent or relative age for groundwater recharge.

D.7 Treatability Tests

D.7.1 General Approach for In Situ Treatability Tests

Due to the existing large area of groundwater impacts for which corrective action may be needed, the choice of in situ treatment through injection of treatment solutions (e.g., polyphosphate solution) may be a strong candidate technology given that the solution amendments can be delivered in large quantities and injected in a controlled manner under field conditions at strategically placed boreholes and delivered to the depths of interest. Furthermore, concentrations of treatment solutions can be readily customized prior to injection to optimize sequestration of uranium and other COCs over time. Several different solution amendments will be evaluated in the laboratory to assess the reaction kinetics that sequester uranium and other COCs under expected field conditions where water saturation may vary as a function of time. To test the efficacy of such treatments, the following individual steps, some of which will be conducted in parallel, are proposed:

1. Based on the hydrogeological and hydrogeochemical evaluations (discussed in Sections 5.3.1 and 5.3.2 for the vadose zone; and Sections 6.1 and 6.2 for the BCA) representative core samples will be identified from deeper zones with relatively high concentrations of COCs.

2. Preliminary numerical modeling, based on the current CSM information and realistic input parameters from the literature, will be undertaken to determine the most sensitive parameters for laboratory and field testing design (e.g., the radius of influence from injection wells in areas of treatment). Areas of treatment are likely to be deeper portions of the vadose zone with higher uranium concentrations or the saturated zones within the BCA with higher uranium concentrations. Using site data and geochemical information from the initial steps, a reactive transport model will be developed to test the efficacy of

COC sequestration under site-specific geochemical conditions. The reactive transport modeling would guide understanding of the controls on processes that lead to sequestration of COCs.

3. The insights gained from numerical modeling will be used to design and perform bench-scale laboratory tests to evaluate the efficacy of treatment. Following the bench-scale tests, flow-through column tests will be designed and performed. Both batch tests and flow-through column tests will need to be performed using core samples collected during the CAAWP field program (identified in Step 1). Initially, the focus will be on batch tests due to quick turnaround times. The test design will include contacting the impacted sediment (<2 mm size and <4 mm size range) with the treatment solution over different contact periods and solid-to-solution ratios. Afterwards, solids will undergo mineralogical and chemical characterization (Section D.3) to assess the changes in labile uranium and other COCs. The results of batch testing will be used in the determination of the number of pore volumes that will be targeted in field and flow-through column tests.

4. Testing under flow-through conditions will be designed after the evaluation of batch tests (from Step 3). Ideally, undisturbed core samples should be used for flow-through columns with flow rates consistent with the field conditions, but this may not be feasible given the limitations of the test apparatus and testing period and the currently unknown characteristics of cored materials from target intervals. An alternate approach would be to crush the contaminated core sample into two sizes (sand size [< 2 mm] and gravel size [< 4 mm]) and then pack the columns in such a manner as to be consistent with the bulk density of the core samples. The test design should include performing the experiment for each size range for up to 10 pore volumes (based on practical consideration) in such a manner that it is contacted with (1) ambient pore water for all 10 pore volumes; (2) treatment solution for 1 pore volume and then by ambient pore water for next 9 pore volumes; (3) treatment solution for 2 pore volumes and then by ambient pore water for next 8 pore volumes; and (4) treatment solution for 4 pore volumes and then by ambient pore water for next 6 pore volumes. Constant monitoring of the effluent will be performed to evaluate changes in pH, ionic strength, redox conditions, concentrations of selected dissolved ions, uranium, and other COCs as a function of pore volumes. Following the cessation of flow-through testing, the samples from the column test will be analyzed as described in Section D.3.

5. The results from laboratory testing will be used to update the reactive transport numerical model to predict the impact of the treatment. The results will then be used to design the field-scale treatability test plan with appropriate spacing of the injection wells and monitoring wells.

6. In Far-Field Areas, where circumneutral pH conditions exist and where more than one treatment solution may be effective, a combination of treatment solutions will be tested (for example, mixture of polyphosphate solutions with zero-valent iron (ZVI) nanoparticles) to evaluate any synergistic effects (non-linear cumulative effects). The above listed steps for laboratory testing will be performed to assess the efficacy of the treatment under site-specific conditions (e.g., formation of calcium-uranyl-carbonate complexes can suppress reduction and sorption effects of ZVI).

D.7.2 General Approach for Ex Situ Treatability Tests

The major alternative to in situ treatment technologies is pump-and-treatment combined with ex situ treatment. Treatability tests for other candidate technologies in the Near-Field and Far-Field Areas will be performed to evaluate the effectiveness of groundwater treatment for the removal of uranium and other COCs for pump-and-treatment scenarios. Impacted groundwater from wells in the North Near-Field (MW-102 and RL-3), the South Near-Field (EF-6 and MW-136), and the Far-Field (MW-124) will be tested for ex situ treatment (**Figure 6.1**). These wells were chosen based on a range of chemical compositions that may control the performance of potential ex situ treatment technologies (**Table D.4**).

Based on the documented success of treating uranium and other groundwater constituents at the Hanford 200 West Area Pump-and-Treat Facility (Campbell et al., 2018), ion exchange resins can be considered a technically demonstrated treatment to effectively remove uranium and other constituents from extracted groundwater. Additional proven ex situ technologies for the removal of uranium and the other COCs from extracted groundwater include chemical precipitation (Dinis and Fiúza , 2021) and ZVI (similar reactions as tested with in situ treatability tests) mixed with gravel beneath a sawdust layer as a column reactor, such as the implementation performed at the Rocky Flats Mining Remediation Site (ITRC, 2017).

The purpose for the ex situ technology treatability studies is to:

- Determine the optimal removal efficiencies for uranium and the other COCs from the TSF leachate and groundwater.
- Perform testing for the parameters that affect the viability and success for ex situ treatment, which include, but are not limited to, the following: pH; redox potential; total dissolved solids (TDS); total suspended solids; concentrations of alkalinity, sulfate, iron, calcium, and magnesium, which are common mineral-forming constituents; silt density index; chemical oxygen demand; and the spectral absorption coefficient.
- Determine the viable and most effective reactive media or sequence of reactors and/or filtration media for the optimal removal efficiencies for COCs.

Chemical Precipitation

Chemical precipitation methods are the most widely used treatment for uranium mill tailings water effluents. Chemical precipitation transforms soluble uranium and other COCs into an insoluble form. The components for the chemical precipitation batch tests will include the following:

- The chemical reagent added to cause precipitation, known as the precipitant, will be calcium hydroxide, sodium hydroxide, magnesium hydroxide, carbonates, sulfates, sulfides, phosphates, or a polymer.
- The chemical precipitant is added to the aqueous sample in a stirred reaction vessel.
- The sedimentation stage involves the use of flocculants for separation.

Among the parameters most relevant for consideration in treatability studies for chemical precipitation are the sludge generation rates, temperature, pH, and flow rate through the media (Dinis and Fiúza , 2021).

Ion Exchange Resins

Ex situ treatability tests aim to determine the most efficient resin or series of resins to remove uranium and other COCs. The tests will also determine the duration period for resin expenditure cycle between backwash, regeneration and pressure increases due to potential fouling. The aim will be to assess the specific feedwater geochemistry and its effects on the tested resins. Ex situ treatability tests will assess the potential for organic and inorganic fouling with the aim to determine the conditions that will prevent fouling and the irreversible fixation of materials to the resins. Ex situ treatability tests will identify which single or series of prefiltration or pretreatment methods may be required to remove organic and inorganic materials in the recovered groundwater, such as filtration with activated carbon, biofiltration, or oxidation/reduction processes.

The components for the ion exchange resin and/or membrane filtration tests will consist of the following:

- Determine the effective loading of uranium and other COCs on the spent resin or filter using mass balance calculations on concentrations measured in the contacting solutions prior to and after passage through the resin or filter. Concentrations will be analyzed by the appropriate inductively coupled plasma (ICP) method for metals and ion chromatography (IC) for anions.
- The impact of feedwater composition on the retention of uranium and other COCs by the resins or filter will be evaluated by testing impacted groundwater from the Site that covers a range of pH values and concentrations of total dissolved solids, alkalinity, calcium, and COCs (**Table D.4**).
- Resin or filter elution studies will evaluate the effectiveness of the stripping solutions to remove/desorb uranium and other COCs. For example, approximately 100 milligrams (mg) of pristine resin, COC-loaded resin, and three bench-scale spent resins using the Site

groundwater will each be treated with 6 mL of 1 molarity (M) HCl, 1 M $NaHCO_3$, or 1.5 M NaOH, to be contacted for a 24-hour period at ambient temperature. The resultant supernatant will then be analyzed by the appropriate ICP method for metals and IC for anions.

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Tables

Table D.1. List of data types and methods proposed for the Lisbon Facility CAAWP.

PIQ 1	PIQ 2	PIQ 3	PIQ 4	Medium	Data Types	Method/Protocol Reference	Purpose
Existing Information							
1, 2, 3, 4	1, 2	1, 2	1, 2, 3, 4, 5	extracted water, extracted solids, in situ groundwater, in situ bedrock	historical documentation	previous reports	comparison with new data
Borrow Area and Repository Evaluations							
5, 6				soil	particle size distribution with hydrometer	ASTM D7928	Index engineering properties (composite samples)
5, 6				soil	Atterberg limits	ASTM D4318	Index engineering properties (composite samples)
5, 6				soil	moisture conent (gravimetric)	ASTM D2216	Index engineering properties (composite samples)
5, 6				soil	USCS classification	ASTM D2487	Index engineering properties (composite samples)
5, 6				soil	saturated hydraulic conductvity (flex/rigid)	ASTM D5856/ ASTM D6836	hydraulic properties (2 selected samples per Area)
5, 6				soil	unsaturated conductivity/CMCCs	ASTM D7263	hydraulic properties (2 selected samples per Area)
5, 6				soil	Porosity, void ratio, specific gravity (<4.75mm/>4.75mm)	ASTM D854/C127	hydraulic properties (2 selected samples per Area)
5, 6				soil	Extractable nutrients (phosphorus, potassium, calcium, magnesium, sulfur, micronutrients [aluminum and lead]), cation exchange capacity/soil acidity, pH/exchangeable acidity, organic matter, nitrate nitrogen, soluble cations (calcium, magnesium, sodium, potassium), calcium carbonate	Robertson et al. (1999); Karlin et al. (2021)	agronomic properties (2 selected samples per Area)
Geophysical Evaluations							
6, 7, 8, 9, 10	1, 2, 3	1, 2, 3	1, 2, 3, 4, 5	in situ bedrock	borehole geophysical logs (caliper, temperature, SP, natural gamma ray, spectral gamma, 16 inch and 64-inch normal resistivity, single point resistance)	INTERA (2021b) Appendix 2D	vertical profiles to determine lithologic changes
1, 2, 3, 4, 7, 8, 9, 10	1, 2, 3	1, 2, 3	1, 2, 3, 4, 5	in situ bedrock	geophysical survey transect results	INTERA (2021b) Appendix 2A	bedrock transects to characterize faulting and lithology changes
	1	1	1, 2, 4	in situ groundwater	Magnetometric resistivity survey (MMR)	Jessop et al., (2018); www.willowstick.com	identify groundwater pathways
	1	1	1, 2, 4	in situ groundwater	Resonance acoustic profiling (RAP)	Nakamura (1989); Okada (2003); www.willowstick.com	identify groundwater pathways (in conjunction with MMR)
Hydrologic Properties							
4, 7, 8, 9, 10				in situ vadose zone	HYPROP, WP4C, and multi-step method	Lipovetsky et al. (2020)	estimation of unsaturated hydraulic properties for core-scale samples
4, 7, 8, 9, 10				in situ vadose zone	neutron moisture logging	Alberty et al. (1992)	measurement of volumetric moisture content along a vertical profile
4, 7, 8, 9, 10	1, 2	1, 2	1, 2, 3, 4, 5	in situ groundwater	water levels	INTERA (2020)	determine potentiometric surface and potential flow paths
	1, 2	1, 2	1, 2, 3, 4, 5	in situ groundwater	aquifer test: pneumatic	INTERA (2021b) Section 2.4; Appendix 2E	determine hydraulic conductivity and storage; detect flow boundaries
	1, 2	1, 2		in situ groundwater	borehole flow logging	Paillet (2000)	estimate transmissivity of flow zones along a borehole
	1, 2	1, 2		in situ groundwater	fluid electrical conductivity logging	Paillet & Reese (2000)	identify preferential flow zones along a borehole
Geochemical Properties: Solid Mineralogy and Chemistry							
1, 2, 3, 4, 7, 8, 9, 10	3, 4, 5	3, 4, 5	4, 5	extracted solids	mineralogy (XRD, petrography, SEM-EDS)	INTERA (2021b) Section 4.3.2	determine possible sources and sinks of COCs
1, 2, 3, 4, 7, 8, 9, 10	3, 4, 5	3, 4, 5	4, 5	extracted solids	major element chemistry (XRF, SEM-EDS)	INTERA (2021b) Section 4.3.2	mineral phases, determine possible sources and sinks of COCs
1, 2, 3, 4, 7, 8, 9, 10	3, 4, 5	3, 4, 5	4, 5	extracted solids	automated mineralogy (e.g., QEMSCAN)	Kimball et al. (2019)	determine possible sources and sinks of COCs, particle size distribution
1, 2, 3, 4, 7, 8, 9, 10	3, 4, 5	3, 4, 5	4, 5	extracted solids	sequential extraction	See CAAWP Section C.3.2 and Table C.2	determine concentration of COCs in various reactive solids
Geochemical Properties: Leach Tests							
1, 2, 3, 4, 7, 8, 9, 10	3, 4, 5	3, 4, 5	4, 5	extracted solids	batch tests	INTERA (2021b) Section 4.3.2; CAAWP Section C.4.1	determine relative mobility of COCs from solids under given leaching conditions
1, 2, 3, 4, 7, 8, 9, 10	3, 4, 5	3, 4, 5	4, 5	extracted solids	flow-through tests	See CAAWP Section C.4.2	determine more realistic partition coefficients (Kd values) and reaction rates
		2	5	extracted solids	vertical profile of leachable chloride	INTERA (2021c) Section 5.4.1	estimate recharge

Table D.1. List of data types and methods proposed for the Lisbon Facility CAAWP.

PIQ 1	PIQ 2	PIQ 3	PIQ 4	Medium	Data Types	Method/Protocol Reference	Purpose
Physical Properties							
1, 2, 3, 4, 7, 8, 9,10	3, 4, 5	2, 3, 5	4, 5	extracted solids	specific surface area (BET)	Brunauer et al. (1938)	information used to scale up laboratory leaching rates to field leaching rates
1, 2, 3, 4, 7, 8, 9,10	3, 4, 5	2, 3, 5	4, 5	extracted solids	particle (grain) size distribution	ASTM D6913	information used to scale up laboratory leaching rates to field leaching rates
1, 2, 3, 4, 7, 8, 9, 10	3, 4, 5	2, 3, 5	4, 5	extracted solids	total primary porosity	ASTM D854/ASTM D7263	combined with effective porosity, provides measure of mobile/immobile domains for primary porosity
1, 2, 3, 4, 7, 8, 9, 10	3, 4, 5	2, 3, 5	4, 5	extracted solids	effective primary porosity	Stephens et. al. (1998)	provides parameters for determining water/rock ratio and seepage velocity
1, 2, 3, 4, 7, 8, 9, 10	3, 4, 5		4, 5	extracted solids	moisture content	ASTM D854/ASTM D7263	parameter needed to calculate effective porosity
7, 8, 9,10				extracted solids	matric potential	ASTM D3404	critical hydraulic property for unsaturated bedrock
1, 2, 3, 4, 7, 8, 9,10	1, 2, 3	1, 2, 3	1, 2, 3, 4, 5	extracted solids	borehole lithology	INTERA (2021b) Appendix 2D	vertical profiles to determine changes in mineralogy, lithology, fracture zones
Hydrologic Tracers							
7, 8, 9	1	1	1, 2, 3, 4, 5	extracted water	field parameters and water quality	INTERA (2020)	comparison with historical data; determine water sources and flow paths
			1, 2, 3, 4, 5	extracted water	stable oxygen and hydrogen isotopes	INTERA (2021b) Section 3.3.1; Appendix 3A	comparison with previous data (INTERA, 2021b); determine water sources and flow paths
			1, 2, 3, 4, 5	extracted water	sulfur and oxygen isotopes in sulfate	Carmody et al. (1998); Révész et al. (2012)	determine water sources and flow paths
			1, 2, 3, 4, 5	extracted water	strontium-87 to strontium-86 ratios	Christensen et al. (2018)	determine water sources and flow paths
			1, 2, 3, 4, 5	extracted water	tritium and helium-3	Solomon & Cook (2000)	determine water sources and flow paths; determine apparent/relative recharge age

Notes

PIQ = Principal Investigation Question (Appendix A)

For other acronym definitions, see text in Appendix D

TABLE D.2
Sequential Extraction Procedure
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Step	Reagents	Conditions	Target Fraction	Mobility Behavior
1	uncontaminated Site groundwater or artificial groundwater	solution and solid interaction for 1 hr at room temperature	aqueous and some sorbed phases	most mobile phases
2	0.5 M magnesium nitrate at pH 8	solution and solid interaction for 1 hr at room temperature	readily desorbed phases	readily mobile through equilibrium partitioning
3	acetate solution at pH 5	solution and solid interaction for 1 hr at room temperature	readily dissolved carbonates and other readily dissolved precipitates	moderately mobile
4	acetic acid at pH 2.3	solution and solid interaction for 5 days at room temperature	most carbonates and hydrous uranium silicates (e.g., uranophane)	slow dissolution; low mobility with respect to impacting groundwater
5	0.1 M ammonium oxalate and 0.1 M oxalic acid	solution and solid interaction for 1 hr at room temperature	some aluminosilicates and iron oxides	slow dissolution; very low mobility with respect to impacting groundwater
6	8 M nitric acid	solution and solid interaction for 2 hr at 95 °C	low-solubility uranium precipitates (e.g., autunite) and some remaining minerals	very slow dissolution; functionally immobile

Notes

Procedure developed by Szecsody et al. (2020)

M = molarity

hr = hours

°C = degrees Celsius

TABLE D.3
Potential Hydrologic Tracers to Evaluate in the North-Northwest Area
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Tracer	Regional Application	Benefits	Limitations
Constituent ratios and/or PCA results	INTERA (2021b, 2021d)	• can provide information on water sources and processes • data come from routine analysis (no added cost)	• results can be ambiguous when variance is low
Stable oxygen and hydrogen isotopes of water	Hurst & Solomon (2008); McHaley (2016); Naftz et al. (2011)	• can provide information on water sources and processes • relatively inexpensive; straightforward sample collection • relatively straightforward data analysis	• results can be ambiguous when variance is low
Sulfur and oxygen isotopes in sulfate	Blake et al. (2019); Hurst & Solomon (2008); Kamp & Morrison (2014); Naftz et al. (2011); Otton et al. (2010); Ries (1982)	• can provide information on water sources and processes • relatively inexpensive • straightforward sample collection • relatively straightforward data analysis	• results can be ambiguous when variance is low
Strontium-87 to strontium-86 ratio	Christensen et al. (2018)	• can provide information on water sources and processes • relatively inexpensive • straightforward sample collection • relatively straightforward data analysis	• results can be ambiguous when variance is low
Tritium and helium-3	Hurst & Solomon (2008); Kamp & Morrison (2014); McHaley (2016); Naftz et al. (2011); Robertson et al. (2016)	• can provide apparent or relative age of recharge • straightforward sample collection	• moderately expensive • tritium levels may be below detection

TABLE D.3
Potential Hydrologic Tracers to Evaluate in the North-Northwest Area

Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Tracer	Regional Application	Benefits	Limitations
		• relatively straightforward data analysis	
Chlorine-36	Davis et al. (2003)	• can provide apparent or relative age of recharge • can provide information on water sources • straightforward sample collection	• moderately expensive • complicated data analysis
Chlorofluorocarbons (CFCs)	Hurst & Solomon (2008); Robertson et al. (2016)	• can provide apparent or relative age of recharge • relatively inexpensive	• complicated sample collection • complicated data analysis
Dissolved gases (e.g., N2, Ar, Xe)	Hurst & Solomon (2008); Naftz et al. (2011); Robertson et al. (2016)	• can be a temperature proxy for recharge (needed to interpret CFC data)	• relatively expensive • complicated sample collection • complicated data analysis
Stable carbon isotopes in dissolved inorganic carbon (DIC)	Robertson et al. (2016)	• can identify source(s) of DIC (needed for carbon-14 dating) • relatively inexpensive; straightforward sample collection • relatively straightforward data analysis	• results can be ambiguous when variance is low
Carbon-14	Robertson et al. (2016)	• can provide apparent or relative age of recharge	• relatively expensive • complicated data analysis

TABLE D.4
Impacted Groundwater for Ex Situ Treatment Tests
Corrective Action Assessment Work Plan
Rio Algom Mining LLC, Lisbon Facility

Sample Location	Area	pH		Total Dissolved Solids		Alkalinity (as $CaCO_3$)		Calcium		Nitrate/Nitrite (as N)		Arsenic		Molybdenum		Selenium		Uranium	
Unit		s.u.	s.u.	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
		[1]mean	[2]median	mean	median	mean	median	mean	median	mean	median	mean	median	mean	median	mean	median	mean	median
OW-UT-9	NNF	9.87	9.81	38156	38600	17594	17700	8.85	5.00	26.3	27.0	3.00	2.94	47.9	48.4	0.0225	0.0210	80.7	80.3
MW-102	**NNF**	**8.99**	**8.95**	**10473**	**10030**	**2823**	**2750**	**21.0**	**20.0**	**15.3**	**15.2**	**0.2538**	**0.2535**	**15.3**	**15.2**	**0.1200**	**0.1185**	**80.3**	**74.8**
MW-101	NNF	7.35	7.39	11750	11550	1926	1895	140	141	29.2	29.2	0.0041	0.0040	21.0	20.7	0.0486	0.0490	47.8	47.0
RL-1	NNF	7.13	7.08	9458	9465	1054	1060	515	509	22.9	23.1	0.0030	0.0030	12.6	12.9	0.0775	0.0750	43.2	43.3
RL-3	**NNF**	**7.11**	**7.05**	**8431**	**8440**	**1161**	**1180**	**364**	**335**	**25.2**	**25.2**	**0.0022**	**0.0020**	**10.4**	**10.7**	**0.0547**	**0.0530**	**33.1**	**32.8**
MW-119	NNF	7.33	7.30	5067	5150	378	378	603	602	21.0	20.6	0.0016	0.0020	0.0013	0.0010	0.0510	0.0510	9.49	9.58
MW-124	**FF**	**7.15**	**7.07**	**1875**	**1750**	**270**	**269**	**255**	**245**	**6.91**	**6.50**	**0.0079**	**0.0080**	**0.0015**	**0.0010**	**0.0179**	**0.0200**	**0.442**	**0.361**
MW-138D	FF	7.36	7.18	1440	1390	244	244	202	197	4.59	4.60	0.0050	0.0050	0.0013	0.0010	0.0116	0.0110	0.183	0.151
EF-3A	SNF	7.50	7.52	5585	5570	1076	1115	207	210	3.77	3.80	0.1690	0.1705	2.62	2.59	0.0398	0.0390	20.6	20.6
EF-8	SNF	7.42	7.39	2465	2510	472	482	308	311	9.72	10.4	0.0397	0.0400	0.0072	0.0070	0.0179	0.0180	2.48	2.59
EF-6	**SNF**	**7.19**	**7.19**	**1922**	**1980**	**394**	**394**	**150**	**154**	**7.76**	**7.80**	**0.0189**	**0.0170**	**0.0021**	**0.0020**	**0.0150**	**0.0140**	**2.37**	**2.40**
MW-136	**SNF**	**7.21**	**7.18**	**1385**	**1385**	**247**	**247**	**183**	**184**	**6.63**	**6.55**	**0.0068**	**0.0070**	**0.0031**	**0.0030**	**0.0093**	**0.0090**	**0.042**	**0.041**

Notes

s.u. = standard pH units

mg/L = milligrams per liter

1 = mean calculated based on available values from October 2017 to October 2022

2 = median calculated based on available values from October 2017 to October 2022

NNF = North Near-Field

FF = Far-Field

SNF = South Near-Field

Only values above the method detection limit were used for calculations.

Values in bold represent wells chosen for ex situ treatment tests.

INTERA

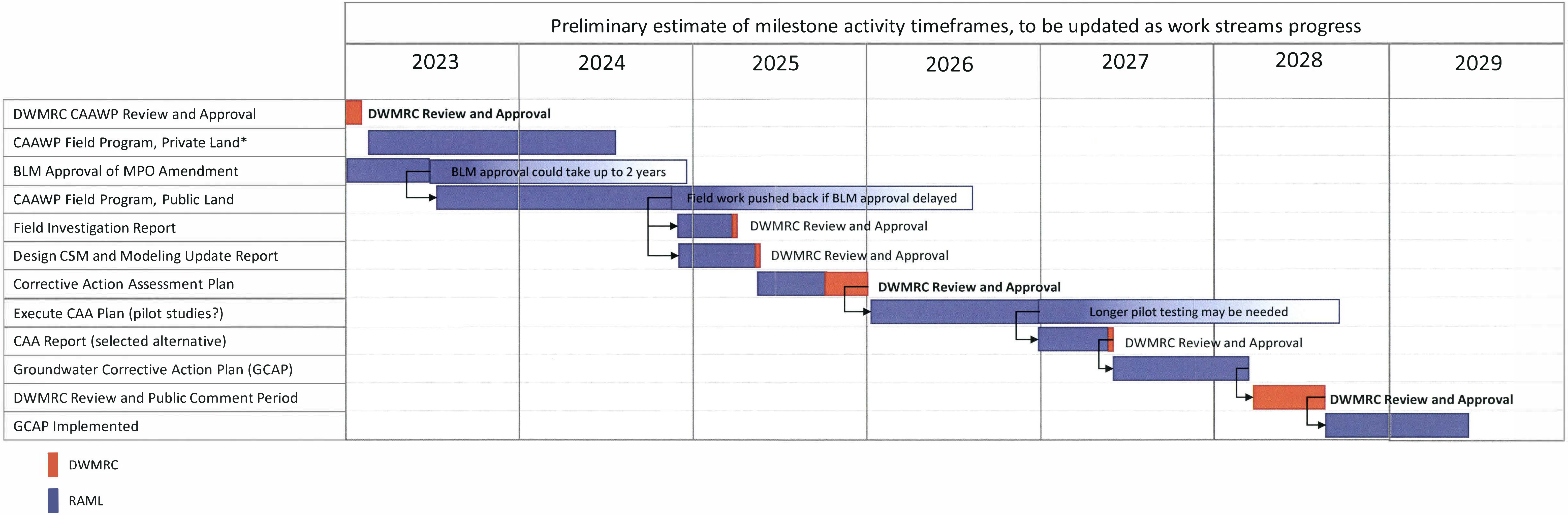
Appendix E

Preliminary Corrective Action Assessment Schedule

Appendix E

Preliminary Corrective Action Assessment Timeline

Corrective Action Assessment Work Plan, Rio Algom Mining LLC, Lisbon Facility



Notes:
BLM = Bureau of Land Management
CAAWP = Corrective Action Assessment Work Plan
CAA = Corrective Action Assessment
CSM = Conceptual Site Model
DWMRC = Utah Division of Waste Management and Radiation Control
MPO = Mine Plan of Operations
GCAP = Groundwater Corrective Action Plan
*May include non-intrusive work on public land if consistent with BLM approvals and exemptions