ENGINEERING EVALUATION/ COST ANALYSIS

FLORIDA STATE UNIVERSITY LOW-LEVEL RADIATION WASTE DISPOSAL SITE

United States Forest Service, Southern Region
Apalachicola National Forest, Florida

FINAL

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LIST OF ACRONYMS

%	Percent
AEC	Atomic Energy Commission
AOPCs	Areas of Potential Concern
ARARs	Applicable, Relevant and Appropriate Requirements
BAT	Best Available Technology
bgs	below ground surface
BMT	BMT Designers & Planners, Inc.
BV	Bed Volume
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Contaminants of Concern
COPC	Contaminant of Potential Concern
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
CWA	Clean Water Act
CY	Cubic Yard
DCGL	Derived Concentration Guideline Level
DOE	Department of Energy
DOL	Department of Labor
DOT	Department of Transportation
DSR	Dose/Source Ratio
EDR	Environmental Data Resources
EE/CA	Engineering Evaluation and Cost Analysis
EPA	Environmental Protection Agency
ERA	Ecological Risk Evaluation
ESI	Expanded Site Inspection
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health
FSS	Final Status Survey
FSU	Florida State University
FSU-LLRW	Florida State University Low Level Radiation Waste Disposal Site
GAC	Granular Activated Carbon
GCTL	Groundwater Cleanup Target Levels

LIST OF ACRONYMS

HASP	Health and Safety Plan
HI	Hazard Index
HHRA	Human Health Risk Evaluation
HSA	Hollow-Stem Auger
HQ	Hazard Quotient
ID	Inside Diameter
ILCR	Incremental Lifetime Cancer Risk
in	inches
IRIS	Integrated Risk Information System
ISCO	In-Situ Chemical Oxidation
K_{ow}	Octanal/Water Partitioning Coefficient
LLRW	Low-Level Radiological Waste
LUCs	Land Use Controls
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCL	Maximum Contaminant Level
MNA	Monitored Natural Attenuation
mrem/yr	millirem per year
mS/cm	milliSiemens per centimeter
mV	Millivolts
MW	Monitoring Well
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
NFr	National Forest Road
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NWI	National Wetlands Inventory
NTCRA	Non-Time Critical Removal Action
O&M	Operating and Maintenance
ORNL	Oak Ridge National Laboratory
P&T	Pump and Treat
PA	Preliminary Assessment
pCi/g	pico Curies/gram
pCi/L	pico Curies/Liter
pH	negative of the $\log_{10}$ of the concentration (moles per liter) of hydrogen ions
POE	Point-of-Entry

LIST OF ACRONYMS

PRB	Permeable Reactive Barrier
PRG	Preliminary Remediation Goals
PRSC	Post Removal Site Control
PW	Piezometer Well
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Program Plan
RAGS	Risk Assessment Guidance for Superfund
RAIS	Risk Assessment Information System
RAO	Removal Action Objectives
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radioactivity
RfD	Reference Dose
RME	Reasonable Maximum Exposure
RSL	Regional Screening Level
SAS	Surficial Aquifer System
SDWA	Safe Drinking Water Act
SSCT	Small System Compliance Technology
SRE	Streamlined Risk Evaluation
SI	Site Inspection
SSI	Supplemental Site Investigation
SUP	Special Use Permit
SVOC	Semi volatile Organic Compound
TBC	To-be-Considered
USDA	United States Department of Agriculture
UFAS	Upper Floridan Aquifer System
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USNRC	United States Nuclear Regulatory Commission
UV	Ultraviolet
μg/L	micrograms per liter
VOC	Volatile Organic Compounds

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EXECUTIVE SUMMARY

An Engineering Evaluation/Cost Analysis (EE/CA) has been developed to address environmental contamination at the Florida State University (FSU) Low-Level Radiation Waste (LLRW) Disposal Site (FSU-LLRW or Site) by identifying the potential problems, focusing on the removal objectives, and evaluating the effectiveness, implementability, and cost of the removal alternatives. This EE/CA satisfies CERCLA and administrative record requirements and selection of the removal alternative will be documented in an Action Memorandum.

The site is located within the Apalachicola National Forest in Leon County, Florida. During the Preliminary Assessment (PA), a groundwater plume with chemical and radiological contaminants was identified in proximity to the former disposal cells and assumed to be the result of previous environmental releases (BAT, 1998, BMT, 2017). A streamlined risk evaluation (SRE) for human health and ecological receptors was conducted to determine the contaminants of concern (COCs) impacting the groundwater associated with the site. The SRE concluded that potential human health risks exist from exposure to 1,4-dioxane and radionuclides in groundwater.

The presence of contaminated groundwater several hundred feet downgradient of the site was observed and necessitated the development of both radiological source treatment and contaminated groundwater treatment options. The following removal alternatives were evaluated in this EE/CA:

- Alternative 1 - No Action
- Alternative 2 - Source Treatment: Contaminated waste removal and off-site disposal
- Alternative 3 - Source Treatment, followed by: Monitored Natural Attenuation (MNA) for Groundwater
- Alternative 4 - Source Treatment, followed by: Targeted In-Situ Treatment for 1,4-dioxane and MNA for Groundwater
- Alternative 5 - Source Treatment, followed by: Interceptor Trench and Ex-situ Pump and Treatment Plan for 1,4-dioxane and radionuclides in Groundwater.

A comparative analysis of removal alternatives is summarized in Tables E-1 and E-2. Table E-1 presents the source treatment options that should occur prior to the execution of treatment options for groundwater listed in Table E-2.

Table E-1: Site Source Removal Options Summary

Alternative	Benefits	Limitations	Cost ($)
No Action	None	1. Will not achieve Applicable or Relevant and Appropriate Requirements (ARARs) or Removal Action Objectives (RAOs). 2. No reduction in toxicity, mobility, or volume.	$0*
Soil Excavation and off-site disposal	1. Disposal at permitted landfills addresses unacceptable human health and ecological risks. 2. Will achieve RAOs.	None	$4,329,500 (Range $3,030,700-$6,494,300)

*For the purposes of this EE/CA, the No Action alternative has a cost of $0.00; however, there are costs associated with a No Action alternative that include maintenance of access roads, permitting and regulatory interface with FSU and FDEP concerning the site, and the need for periodic surveys and site visits to assess the condition of existing site land use controls that include site security fencing.

Table E-2: Site Groundwater Treatment Options Summary

Alternative	Benefits	Limitations	Cost ($)
Monitored Natural Attenuation (MNA)	1. Easily Implemented.	1. Will not achieve ARARs or RAOs. 2. No reduction in toxicity, mobility, or volume.	$968,400 (Range $677,900-$1,452,600)
Targeted Direct Injection of In-situ Chemical Oxidation (ISCO) amendment and MNA	1. Easily Implemented 2. Will reduce potential risks to human health related to 1,4-dioxane	1. Will not achieve all ARARs or RAOs, though will achieve some.	$1,447,900 (Range $1,013,500 - $2,171,800)
Interceptor Trench and Ex-situ Pump and Treatment Plan	1. More completely addresses groundwater contamination issues.	1. Large investment in infrastructure and maintenance required to implement.	$19,466,200 (Range $12,226,400-$26,199,300)

1. INTRODUCTION

This Engineering Evaluation/Cost Analysis (EE/CA) has been developed for the Florida State University (FSU) Low-Level Radiation Waste (LLRW) Disposal Site located within the Apalachicola National Forest in Leon County, Florida. A site location map is shown on Figure 1. This EE/CA is developed in accordance with United States Environmental Protection Agency (EPA) guidance for Non-Time Critical Removal Actions (NTCRA) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (EPA, 1993).

1.1. Site History

On July 20, 1966, the Forest Service granted a Special Use Permit (SUP) to FSU to use the subject property as a waste disposal site for low-level radiological wastes generated from the university's research activities. A Florida Department of Health (FDOH) Bureau of Radiation Control license (#32-10) was also issued to FSU for the disposition of the radiological waste at the site. According to historical records, low-level radiologically contaminated solids containing alpha and beta emitters, containerized liquids, and animal remains were sequentially deposited into 26 disposal cells from March 16, 1967 to June 14, 1979. A total of 40 disposal cells were constructed but only 26 disposal cells were used. Waste was reportedly containerized using 55-gallon steel drums, 5-gallon cans, glass and plastic jars, wooden and cardboard boxes, and plastic bags. Some wastes, specifically whole animal carcasses, may have been disposed without containers. Disposal activities concluded on June 14, 1979, and the site was closed from further disposal activities (BAT, 1998). Figure 2 shows the locations of the waste disposal cells and current monitoring wells.

Radioactivity measured in the disposed waste was from isotopes typically found in biological experiments conducted at FSU. Current monitoring data that identified 1,4-dioxane in the groundwater suggests that other associated hazardous wastes were also disposed of in the disposal area.

Each disposal cell is reportedly eight (8) feet long by seven (7) feet wide by eight (8) feet deep and are arranged in a grid pattern across the site. In Cells 1 through 15, waste was disposed at a depth of four (4) feet to eight (8) feet below grade and then covered with a 4-inch concrete slab directly above, at a depth of four (4) feet below grade. Then, each cell (Cells 1 through 15) was backfilled to grade with approximately 4 feet of local soil. Cells 16 through 26 were reportedly backfilled entirely with soil above the disposed waste but with no concrete slabs (FDEP, 2003). The actual composition and volume of waste is only known from available disposal records (Appendix A).

Since the end of disposal activities at the site in 1979, FSU has conducted groundwater monitoring and maintained the condition of the disposal area within the site fence and performed periodic radiation readings from monitoring wells at the site. Records obtained from FSU suggest that the monitoring wells were sampled at irregular intervals. The FDOH license requires environmental surveillance to be conducted on a regular basis to document the continuing integrity of the disposal area.

The FDOH license did not stipulate a requirement for an engineered barrier (e.g., compacted clay or geomembrane) below or around the waste disposal unit, nor is there any evidence of an engineered hydraulic barrier having been installed that would isolate disposed waste from groundwater. Based on current measured groundwater elevations, a portion of the waste was disposed below the top of the water table. An analysis of monitoring well data was conducted in 2016 and concluded that a release had likely occurred (BMT, 2016b). Subsequent data review and investigations identified groundwater plumes that are the result of prior releases of chemical contaminants and radionuclides from the site.

1.2. Site Location and Physical Setting

The site is located in Leon County within the Wakulla Ranger District of the Apalachicola National Forest and covers approximately 0.36 acres. The waste disposal area, consisting of 26 separate disposal cells, is fenced with a six-foot high chain-link fence topped with three stands of barbed wire with one locked gate and measures approximately 80 feet x 120 feet inside the fencing. Outside the chain-link fence, there is a barbed-wire fence with a locked access gate. Monitoring wells MW009-MW013 that were initially installed to monitor groundwater quality are located between the interior and exterior fences.

1.2.1. Topography

The site is located on a flat plain adjacent to Forest Road 374A and situated at the peak of a shallow ridge. Regionally, elevation ranges from 200 feet above mean sea level (MSL) on nearby hilltops to 50 feet above MSL along the banks of Lake Talquin. Ground surface slopes gently to the southwest and the southeast from the site. A portion of the 7.5-minute United States Geological Survey (USGS) topographic map showing the site location on Forest Road 374A is included as Figure 3.

1.2.2. Geology

The site is located within the Apalachicola Coastal Lowlands physiographic province (Hendry and Sproul, 1966). The Apalachicola Coastal Lowlands are characterized by essentially flat, sandy surfaces with small shallow bays that contain densely wooded swamps. The area is underlain by sand, and clay deposits with an approximate thickness of 80 feet. The site is underlain by the Jackson Bluff Formation, which is a Miocene age sedimentary formation. The Jackson Bluff Formation consists of light gray to greenish gray and brown clayey sands and sandy clays that are macrofossiliferous (Hendry and Sproul, 1966). The dominant soil type at the site is a Class D loamy sand, characterized by very slow infiltration rate, very poor drainage, and high localized water tables (EDR, 2016). A Natural Resource Conservation Service surficial soils map is included as Figure 4. A subsurface geology map is included as Figure 5.

According to the USGS, the Jackson Bluff formation is found at or near the ground surface in Leon, Liberty, and Wakulla counties and described as tan to orange brown to gray green, poorly consolidated, fossiliferous, sandy clay to clayey sand with fossils present (e.g., mollusks, corals, and foraminifers). It is also described as sandy shell marl containing abundant shells of *Cancellaria* and *pectin* (Hendry and Sproul, 1966). Previous field investigations conducted in Wakulla and Leon counties, dating back to the 1960s, describe the Jackson Bluff formation as composed of a very sandy shell marl that is pale orange, light gray, grayish orange, and blue gray covered by 20 feet of younger sands, silts, clay, and peat.

Spodosols underlie the site and its immediate vicinity. Spodosols occur extensively in Florida and are most often developed in coarse textured sandy formations underlying coniferous vegetation such as pine trees (UF, 2016). Spodosols are acidic and defined by an accumulation of aluminum (Al), Iron (Fe) and organic matter in the subsoils (UF, 2016). Some Florida spodosols contain ortstein formations, which are cemented spodic horizons with greater bulk densities than the overlying formation (Lee et al., 1988). Ortstein layers are typically very black and exhibit far greater tensile strength than overlying horizons (Lipiec et al., 2017). Tensile strength measures formation cohesiveness and hardness.

Compared to overlying spodosol horizons, ortstein horizons have a lower volume of large pores and a greater volume of small pores. Greater cementation within the ortstein horizon is caused by the translocation of iron and aluminum from overlying layers and the formation of organo-mineral complexes (Lipiec et al., 2017). The smaller volume of large pores reduces the potential hydraulic conductivity within the ortstein horizon, which can serve as an aquitard between aquifer units.

1.2.3. Hydrogeology

The regional aquifer system is divided into two distinct water bearing units: a Surficial Aquifer System (SAS) and the Upper Floridan Aquifer System (UFAS). Based on information from previous investigations, and site borehole logs, the SAS aquifer measures at least 40 feet in thickness in the vicinity of the site based on borehole logs that were collected in 2018 as part of the Phase II ESI. Miocene sediments of the Jackson Bluff formation act as a confining layer between the SAS and UFAS (Miller, 1986). The upper confining layer is comprised of low permeability clastic rocks. Regionally, groundwater flows from the Apalachicola National Forest east to southeast (Hendry and Sproul, 1966). The water table is situated close to ground surface locally and much of the area can turn swampy during heavy rains (Hendry and Sproul, 1966). Groundwater wells primarily withdraw water from the UFAS. The SAS is not extensively used for public consumption (Ruper and Spencer, 1988).

There are no groundwater withdrawal wells located within a one (1) mile radius of the site (EDR, 2016). One (1) potable water supply well, owned by the Forest Service, is located 2.5 miles south-southwest of the site. There are 98 groundwater withdrawal wells reported to be located within a four (4) mile radius of the site, mostly on the southern shore of Lake Talquin and are associated with residential properties (EDR, 2016).

1.2.4. Ecology

The Apalachicola National Forest is located within the southeastern conifer forests ecoregion. Surrounding vegetation includes conifer trees and saw palmetto plants. Threatened and endangered species have been identified in the Apalachicola National Forest. The pinelands that make up the Apalachicola National Forest, in the vicinity of the site, are home to the red-cockaded woodpecker, which is an endangered species. The red-cockaded woodpecker nests in specific longleaf pines that have nesting cavities and are marked by the Forest Service. These nesting cavity trees are also protected.

1.3. Previous Investigations and Assessments

Several environmental investigations have been conducted at the site. These investigations are summarized in the following subsections. Several environmental investigations have been conducted at the site by the Florida Department of Environmental Protection (FDEP) and the Forest Service. In the final report of each of these investigations, the site name used was similar but varied slightly: Florida State University Burial Site No. 2, Florida State University LLRW-2 Site, Florida State University Low-Level Radioactive Waste Burial Area No. 2 and Florida State University Low-Level Radiation Waste Burial Site No. 2 (FSU-LLRW-2). In order to eliminate any confusion, it should be noted that all of these site names are for the same site as is being evaluated in this EE/CA: ‘FSU-LLRW.’ These investigations are summarized in the following subsections

1.3.1. Preliminary Assessment: 1998

A Preliminary Assessment (PA) was conducted in 1998 by the USFS (BAT, 1998). The PA compiled previous site history information, including the structure and location of the disposal cells and groundwater monitoring activities. A groundwater pathway was identified for the potential release of disposed wastes based on migration through the soil to the groundwater. Exposure pathways to soil, surface water, and air were considered incomplete or not present.

1.3.2. Preliminary Site Investigation: 2003

A Preliminary Site Investigation (PSI) was conducted by the Florida Department of Environmental Protection (FDEP) in 2003 (FDEP, 2003). The PSI involved the following activities:

- A surface gamma (γ) radiation survey was conducted over the actual radiological waste disposal area.
- Eight (8) temporary monitoring wells (MW001 through MW008) were installed around the

perimeter of the site. One (1) additional temporary background monitoring well (MW009) was installed approximately 0.59 miles north of the site. All temporary monitoring wells were removed at the conclusion of the 2003 sampling program.

Chemical contaminants detected in groundwater above relevant Florida groundwater screening criteria included volatile organic chemicals (VOCs) (including total xylenes), semi-volatile organic chemicals (SVOCs) (including bis[2-ethyhexyl]phthalate), and metals (including chromium and mercury). Radionuclides detected in groundwater samples above relevant screening criteria included Carbon-14, Radium-226 and Radium-228, Cesium-137, and Tritium. Additionally, several groundwater samples exhibited elevated overall gross alpha (433 ± 60 pCi/L) and beta activity (173 ± 24 pCi/L/). Lead-210 was detected at a concentration of 220 ± 100 pCi/L in a temporary well point (DPT001) located on the northeast corner of the site perimeter, hydraulically upgradient of the disposal cells, in April 2003.

Groundwater samples with exceedances of relevant Florida chemical and radiological screening criteria were collected primarily from temporary monitoring wells located along the southwest, southern and southeastern corners of the site (hydraulically downgradient from the radiological disposal area). Gross alpha activity, Radium-226, and Radium-228 were detected at elevated concentrations in locations immediately adjacent to the site (FDEP, 2003).

1.3.3. Supplemental Site Investigation Report: 2012

A Supplemental Site Investigation (SSI) was conducted in 2010 and 2011 for the FDEP Dry-Cleaning Solvent/Hazardous Waste Site Cleanup Program (FDEP, 2012). The SSI involved the following desktop and field activities:

- A potable water supply well survey was conducted by searching the FDOH databases for drinking water wells within 2.5 miles from the site. One (1) potable water supply well, owned by the Forest Service, is located 2.5 miles south-southwest of the site. According to an Environmental Data Resources (EDR) report from October 2016, this well is still active (EDR, 2016).

- Six (6) piezometer wells (MW-A through MW-F) were installed after the end of the site waste disposal activities. Groundwater was sampled from them for one round and then the piezometers were abandoned. Five (5) new permanent monitoring wells (MW009 through MW013) were installed around the perimeter of the site (clarification: permanent monitoring well MW009 installed in 2010 is not the same as the temporary background monitoring well MW009 installed in 2003 despite having the same well identification name). The five (5) permanent monitoring wells were installed to a depth of approximately 14 feet below ground surface (bgs) with ten (10) feet of 1” inside diameter (ID) slotted well screen. In addition, these permanent monitoring wells were completed with riser as stickup wells. The monitoring well locations are shown in Figure 2. These wells are called the ‘on-site’ monitoring wells

- Groundwater samples collected from the five (5) monitoring wells were analyzed for VOCs, target analyte list (TAL) metals, gross alpha and beta radioactivity, tritium, gamma-spectral scan and Carbon-14.

- A Geoprobe was used to advance nine (9) temporary well points in the vicinity of the site. Groundwater samples were collected from nine (9) temporary wells located downgradient of the disposal area at up to three (3) depth intervals (i.e., 11-15 ft. bgs, 26-30 ft. bgs, and 36-40 ft. bgs) and analyzed for 1,4-dioxane.

- Temporary groundwater sampling points were advanced to depths of up to 55 feet bgs, but no groundwater was available at this depth or in any groundwater screens advanced beyond 40 feet bgs.

- A surface radiation survey was conducted within the fenced portion of the site. Another radiation survey was conducted around the perimeter of the site, within the barbed-wire fence that surrounds the chain-linked fence. Background radiation measurements were collected from locations approximately 0.25 miles from the site.

Based on well gauging data collected during the SSI, the groundwater gradient was calculated and determined that groundwater flow at the site is to the south and east. Based on the surface radiation survey results, surface radiation at the site was generally less than two (2) times background activity in the vicinity. Background activity was determined by conducting radiation surveys at four (4) off-site locations greater than 0.25 miles from the site. The maximum radiation survey results were measured over Cells 1 to 26 within the southern portion of the site (FDEP, 2012).

Radionuclides in groundwater, sampled from the five (5) permanent monitoring wells, were detected at concentrations below their respective FDEP Groundwater Cleanup Target Levels (GCTLs) (F.A.C.62-777). The new monitoring wells were installed at locations in close proximity to the temporary well points that yielded radionuclide exceedances during the 2003 groundwater sampling event performed by the FDEP. Monitoring well sampling results are summarized below:

- <u>VOCs</u>: Xylenes were detected in two (2) monitoring wells (MW010 and MW011) at concentrations greater than GCTLs.

- SVOCs: 1,4-dioxane was detected in two (2) monitoring wells (MW010 and MW011) at concentrations greater than its GCTL. The SVOC bis(2-ethylhexyl)phthalate was not detected in groundwater during the 2010 and 2011 sampling events.

- Radionuclides: Gross alpha and beta activity and Radium-226 and Radium-228 were detected in all five (5) monitoring wells (MW009 through MW013); however, detected concentrations were below respective Maximum Contaminant Levels (MCLs). Radionuclides were detected at low concentrations in MW009, located upgradient of the disposal area.

1,4-dioxane was detected at a maximum concentration of 910 µg/L in a temporary well located approximately 100 feet south from the southeast corner of the site at a depth of 11-15 feet bgs. 1,4-dioxane also was detected in monitoring wells located directly south of the site, and in other temporary wells no more than 300 feet downgradient of the site at concentrations greater than the GCTL of 3.2 µg/L. Additionally 1,4-dioxane was detected in groundwater at depths of up to 40 feet. The 2012 SSI report recommended additional groundwater sampling downgradient of the site to delineate the 1,4-dioxane plume. The report also recommended additional surface radiation surveys to be performed every five (5) years after November 2010 (FDEP, 2012).

In addition to these findings, the lack of groundwater in temporary groundwater sampling points advanced to depths beyond 40 feet bgs suggested the presence of an aquitard in the vicinity of the site at depths greater than 40 feet bgs. No soil samples were collected for lithology and the potential presence of any groundwater barrier was not evaluated.

1.3.4. Expanded Site Inspection: 2017

An Expanded Site Inspection (ESI) was conducted at the site in January 2017 to verify the presence of contaminants in groundwater and to delineate the 1,4-dioxane plume that was identified in the 2010 and 2011 SSI (BMT, 2017b). The ESI involved the following desktop and field activities:

- Groundwater samples were collected from the five (5) monitoring wells installed in 2010 (FDEP, 2012). Groundwater samples were analyzed for VOCs, SVOCs, TAL total and dissolved metals, and select radionuclides.

- Four temporary piezometer wells were installed downgradient of the site. The piezometer wells were surveyed prior to their abandonment. Groundwater samples collected from the piezometers were analyzed for VOCs, SVOCs, TAL total and dissolved metals, and select radionuclides.

- Ten (10) direct push technology (DPT) points were advanced to a maximum depth of 30 feet bgs at locations sited to delineate the 1,4-dioxane plume identified in previous site investigations. Groundwater samples were collected from two discrete depth intervals: 12-16 feet and 26-30 feet bgs at each DPT location and analyzed for SVOCs (which includes 1,4-dioxane). In addition, select radionuclides were sampled at four (4) of the DPT locations.

- A groundwater contour map was created to show that groundwater flows primarily in a southeastern direction from the site.

- Screening level risks were calculated based on the comparison of the maximum detected analyte concentrations in groundwater to respective EPA Regional Screening Levels (RSLs) (EPA, 2016a).

Originally, the piezometer wells were to be installed using DPT technology. However, site subsurface geology, specifically the cemented soil horizons within the forest spodosol soils caused refusal at multiple depths using the 3.25” diameter DPT tooling specified to install the piezometers. Piezometers were therefore installed using Hollow-Stem Auger (HSA) tooling and as a result, continuous cores could not be collected.

The contaminants, 1,4-dioxane and select radionuclides, including Radium-226 and Radium-228 and gross alpha activity, were detected in groundwater downgradient to the site at concentrations greater than their respective FDEP GCTLs. The 1-4 dioxane plume was found to cover a significantly larger area than was originally estimated in 2011. Radionuclides were detected in temporary groundwater wells downgradient of the site. Both plumes had migrated several hundred feet beyond the fenced boundaries of the site.

Lead-210 was detected in MW009, located upgradient of the disposal cells. Lead-210 had previously been detected in upgradient groundwater in 2003 (FDEP, 2003).

A screening level risk assessment was conducted as part of the 2017 ESI and determined that there are unacceptable risks to human health resulting from concentrations of 1,4-dioxane, bis(2-ethylhexyl) phthalate, and Radium-226 and Radium-228 that exceed their respective RSLs.

1.3.5. Phase II Expanded Site Inspection: 2018

A Phase II ESI was conducted at the site in January 2018 to install permanent monitoring wells located downgradient of the site to further delineate the 1,4-dioxane and radionuclides groundwater plumes. The Phase II ESI involved the following desktop and field activities:

- Groundwater samples were collected from the five (5) monitoring wells installed in 2010 (MW009-MW013) (FDEP, 2012). Groundwater samples were analyzed for SVOCs and select radionuclides.

- Ten (10) permanent monitoring wells were installed upgradient and downgradient of the site using sonic drilling technology. Eight (8) wells were installed as nested pairs. Borehole logs were collected for each monitoring well. These monitoring wells are called the 'off-site' monitoring wells.

- Groundwater samples were collected from the wells and analyzed for SVOCs (including 1,4-dioxane) and select radionuclides.

- An analysis of the waste volumes and activities of each isotope listed in the disposal cell records (Appendix A) was conducted to determine likely sources of elevated gross alpha emitter activity.

The contaminant 1,4-dioxane and select radionuclides, including Radium-226 and Radium-228 and gross alpha activity, were detected in groundwater downgradient to the site at concentrations greater than their respective FDEP GCTLs. Gross alpha activity was detected at elevated concentrations at a site background well (MW014) that is located 100 feet upgradient of the site. Groundwater plume maps were created from the 2018 Phase II ESI data and are included as Figures 6 and 7.

1.4. Regulatory Requirements

The following sections summarize federal and state regulatory requirements for this EE/CA.

1.4.1. CERCLA Requirements

CERCLA provides the federal government with broad authority to respond to disposal sites involving uncontrolled releases of hazardous substances, to develop long-term solutions for sites containing hazardous substances, and to arrange for the restoration of damaged natural resources. The EPA provides guidance on NTCRAs (EPA, 1993) as well as input and criteria on risk management.

1.4.2. State Requirements

The FDOH grants licenses to hospitals, universities, industrial facilities, and entities dealing with radioactivity to manage and handle radiological materials. Licenses specify the quantities of specific isotopes that a licensee may possess during any moment of time.

The FDEP would have input regarding potential removal actions addressing the radiological wastes and groundwater contamination resulting from past contaminant releases.

1.4.3. Response Actions

Two categories of response actions are identified under the National Contingency Plan (NCP) by CERCLA: removal and remedial actions. A removal action involves cleanup or other actions that are taken in response to emergency conditions (e.g., spills) on a short-term or temporary basis. The following factors are considered in determining the appropriateness of a removal action at a particular site [40 CFR 300.415(b)(2)]:

- Actual or potential exposure of nearby populations, animals, or the food chain to hazardous substances or pollutants or contaminants.
- Actual or potential contamination of drinking-water supplies or sensitive ecosystems.
- Hazardous substances or pollutants or contaminants in drums, barrels, tanks, or other bulk storage containers that may pose a threat of release.
- High levels of hazardous substances or pollutants or contaminants in soils, largely at or near the surface, that may migrate.
- Weather conditions that may cause hazardous substances or pollutants or contaminants to migrate or be released.
- Threat of fire or explosion.
- The availability of other appropriate federal or state response mechanisms to respond to the release.
- Other situations or factors that may pose threats to public health or welfare or the environment.

The evaluation of the appropriateness of a removal action is done through a removal site evaluation (40 CFR 300.410). If a removal action is considered appropriate under CERCLA, there are three (3) categories of removal actions; however, it should be noted that CERCLA requires all removal actions to be conducted so as to contribute to the efficient performance of long-term remedial measures that EPA considers practicable. The response action categories are as follows:

- *Emergency,* which generally refers to a release that requires removal activities begin on-site within hours of the lead agency's determination that a removal action is appropriate.

- *Time-critical,* where the lead agency determines that a removal action is appropriate and there is a period of less than 6 months available before removal activities must begin on the site.

- *Non-time-critical,* where the lead agency determines that a removal action is appropriate and there is a planning period of more than 6 months before removal activities must begin.

The removal action deemed appropriate at the site is non-time-critical, and an EE/CA is required under section 300.415(b)(4)(i) of the NCP for all non-time-critical removal actions. Though the site is not listed on the National Priorities List (NPL), evaluation of its environmental issues is presented in this EE/CA in accordance with CERCLA guidelines and regulations.

This EE/CA identifies removal action alternatives, and analyzes the effectiveness, implementability, and cost of each alternative. Removal action objectives (RAOs) for the site include preventing or abating actual or potential contamination of drinking water supplies; and treating or eliminating "significant" levels of hazardous and radiological substances, pollutants, and contaminants in soil where they may migrate.

Effectiveness: Effectiveness is a measure of ability of the removal/remedial option to reduce risk and achieve Applicable or Relevant and Appropriate Requirements (ARARs). For the purposes of evaluating proposed removal options, ARARs include risks to current and future receptor populations (site workers, residents, ecological receptors) resulting from existing contamination at the site.

Measures of effectiveness include:

- Protectiveness of public health, surrounding communities, site workers and the environment

- Compliance with ARARs

- Achievement of RAOs

Implementability: Implementability is a measure of how feasible a potential removal/remedial option is based on known site characteristics, maturity of proposed technology, potential time frame for the implementation and other relevant considerations listed in the ARARs.

Measures of implementability include:

- Technical Feasibility based on construction considerations, useful operational life, adaptability to local environmental conditions and time scale for implementation.

- Availability based on commercial maturity of a technology, and availability of essential personnel.

- Administrative Feasibility based on the ease of permitting, enforcing Land use controls (LUCs), and the likelihood of obtaining statutory exemptions, if necessary.

Cost: Each removal action alternative is evaluated to determine its projected Present Value. The evaluation compares each alternative's direct and indirect capital and post-removal site control (PRSC) costs. Direct capital costs include construction, labor, equipment, material, transport, disposal, and analytical costs. Indirect capital costs include: engineering and design expenses, permit costs, and start-up and shakedown costs. Annual PRSC costs include operating and maintenance (O&M) costs, support, and monitoring costs.

Effectiveness, implementability, and cost for each removal alternative are further discussed in Section 7 of this EE/CA.

2. CONCEPTUAL SITE MODEL

This section presents the conceptual site model for the Site and includes sources of contamination, primary and secondary release mechanisms, and receptor impacts and exposures.

2.1. Introduction

The Conceptual Site Model (CSM) serves to identify the relationship between contaminant sources and known current and potential future receptors through consideration of potential or actual migration and exposure pathways. The CSM was prepared in accordance with EPA Guidance (USEPA, 1998) and presents the current understanding of the site, helps to identify data gaps, and supports the streamlined risk evaluation process that is part of this EE/CA. However, it does not provide quantification of these potential sources, pathways, or exposure levels. A CSM depicting the source area and contaminant migration pathways is included as Figure 2-1.

2.2. Primary Source of Contamination

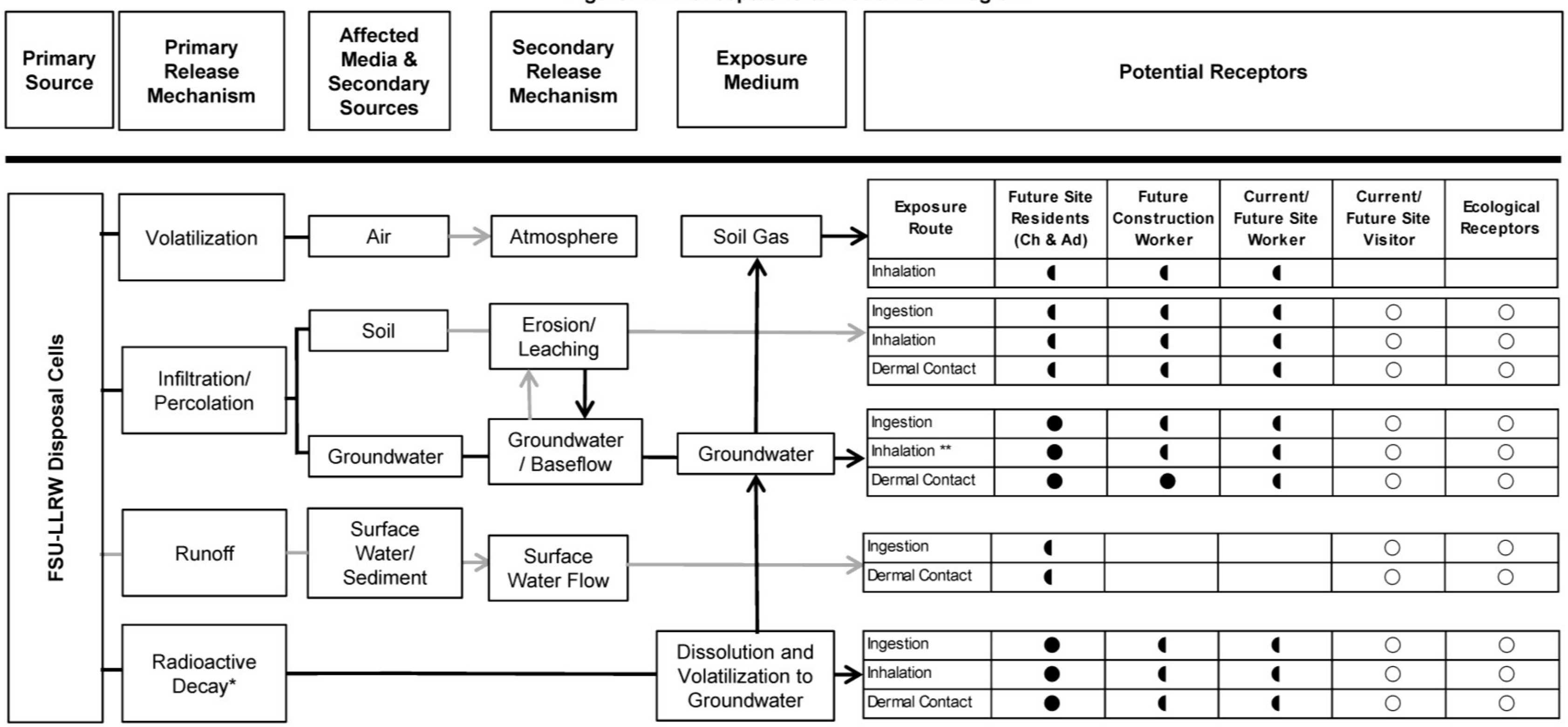
The primary source of contamination at the site is from the waste disposed in the twenty-six (26) cells. Radiological wastes and other research-related wastes were disposed in these cells between 1967 and 1979 (BMT, 2017). In addition to the radiological contamination in the disposal cells, alpha emitting isotopes have been detected in groundwater approximately 100 feet upgradient of the site; although there is no documented source activity or information about this contamination. Upgradient groundwater contamination may also be associated with historical waste disposal practices as no other source of radiological or SVOC contamination (other than FSU laboratory wastes) have been known to take place in the vicinity of the radiological waste disposal cells. No other potential sources of upgradient contamination have been identified.

Records of materials disposed in the waste cells are provided in Appendix A. The majority of the disposed waste includes low-level radiological materials, associated laboratory materials (e.g., scintillation fluid), and containers. The noted waste in the records generally matches detected site contaminants; for example, 1,4 dioxane is associated with the documented scintillation fluid, and the presence of various radionuclides and gross alpha is associated with laboratory waste.

2.3. Primary Release Mechanisms

The following sections describe the primary release mechanisms contributing to the transport and migration of contaminants from the primary waste source (discussed in Section 2.2) at the site.

Figure 2-1: Conceptual Site Model Flow Diagram



Legend

Grey Arrow, unconfirmed or no current pathway. No exposure pathway completed.

Black Arrow, confirmed pathway. Exposure pathway completed.

(blank)	Pathway is not complete. no evaluation required
○	Pathway is or might be complete, but is judged to be minor; not evaluated
◖	Pathway potenitally complete, but is considered negligible or qualitatively evaluated. For Soils, associated with waste mass, no risk assessment required.
●	Pathway is or might be complete and might be significant; sufficient data are available for quantitative evaluation
Radioactive Decay	* Radioactive decay potentially changes chemical properties, toxicity, and next radiological decay process for a given volume of initial contaminant. Exposure pathways impacted include air, soil, and groundwater sources.
**	Region IV accepts the default assumption that inhalation and dermal exposure from showering is equivalent to exposure from daily ingestion of contaminated water

2.3.1. Infiltration and Percolation

The most likely primary release mechanism is from the infiltration and percolation of the contaminants in the disposed radiological and laboratory wastes in the unlined cells. Based on the descriptions in the disposal cell records (Appendix A), liquid wastes were disposed in multiple cells and may have leached into site groundwater. However, the actual release process of the contaminants in the waste is complicated because of where the waste is disposed.

Based on historical information (BMT, 2017a), the soil from the disposal cells was excavated and waste was placed below the current groundwater surface elevation. Groundwater in the vicinity of the site was encountered at depths averaging 3 to 5 feet bgs (BMT, 2018). The waste is most likely in direct contact with groundwater, with potentially infiltrating water from precipitation, and with site soil. Available information relating to disposal cell preparation techniques and waste handling processes is not described in detail, and information regarding pre-disposal staging areas is unknown. There are no records of any liner having been installed prior to waste disposal and disposed wastes were potentially placed in direct contact with previously uncontaminated site soils and/or groundwater. As such, there may be a combination of releases (both primary and secondary) occurring at where the waste is placed.

2.3.2. Radioactive decay

Because the majority of the wastes placed into the cells included radiological materials, radioactive decay is also a potential primary release mechanism. The emission of alpha, beta, and gamma particles is both a source of potential risk and a transformative effect. The resultant degradation products may be the source of additional chemical or radiological risks or they may shift from a radiological source to an inert substance. Because the half-life of each element is different, and sometimes a given element may pass through a number of short or medium length half-lives, radioactive decay may have a large impact on the distribution and potential risk to receptors. The solubility of an element may change substantially as it breaks down creating a complex relationship between observed conditions and historic processes. For example, Radium-226 alpha decays into Radon-222, which can create airborne hazards in confined spaces, such as building basements or through man-made conduits in slab on-grade construction.

2.3.3. Volatilization to Air

There is a potential for the contaminants from the disposed waste to convert into a gaseous state and move up through the soil column and ultimately into the atmosphere. Radiological contaminants may decay into a gas at ambient temperature and conditions and create potential health hazards. The potential presence of radon as a secondary radiological COPC, from radioactive decay of alpha emitting are potential sources of risk for future residential populations in enclosed structures. Though 1,4-dioxane is not a likely source of inhalation hazard, the full inhalation risk was calculated to assure that no future questions regarding this pathway would be made.

2.4. Secondary Release Mechanisms

If there was no liner system installed, the disposal of wastes containing contaminants may have also impacted adjacent and underlying soils. These soils are considered secondary sources. Contaminants that have migrated within surrounding soils have the potential to move to other environmental media through a number of possible secondary release mechanisms. The following describes secondary release mechanisms identified as likely or potentially contributing to the transport and migration of contaminants at the site.

2.4.1. Leaching from Soil to Groundwater

Based on the waste disposal records (Appendix A), the radiological disposal cells were installed below the current water table at the site. Hydraulic barriers are not known to have been placed around or beneath the disposal cells. As noted in Section 2.3.1, contaminants in disposed waste may impact soils and the same contaminants in soil may leach and migrate to groundwater. The single most important property influencing a contaminant's movement with groundwater is its solubility in water. Solubility is a function of the contaminant's chemical properties, soil properties, and groundwater properties.

For example, 1,4-dioxane has a high solubility in water. Radium isotopes and unidentified alpha-emitting isotopes have also been observed in groundwater samples collected from several hundred feet downgradient of the site, implying a high degree of mobility within the aquifer.

When a chemical contaminant enters soil or groundwater, some of it will adhere to soil particles, particularly organic matter, through the processes of absorption and adsorption; and some will dissolve and remain in the aqueous phase but be retained within soil particle interstices. As more water enters the soil through precipitation or groundwater baseflow, the adsorbed contaminant molecules may become detached from soil particles through preferential desorption or the trapped water may be replaced or flushed out into the water column.

The solubility of a chemical contaminant in groundwater and its sorption on soil is typically inversely related to it Octanol/Water Partitioning Coefficient (K_{OW}); increased K_{OW} typically increases sorption to organics in soil, and greater solubility results in less preferential sorption. Once groundwater reaches the low organic zone, the K_{OW} is less important than pH driven mobility. Acidic groundwater or meteoric water conditions can increase a contaminant's solubility; this is especially important when considering mobilization of metallic contaminants, including radioisotopes.

2.4.2. Groundwater Baseflow

Groundwater impacted by contaminated leachate from the radiological disposal cells has been identified as a secondary release mechanism. Base groundwater flow may transport liquid wastes, soluble wastes, leached wastes, and/or infiltrating wastes from the waste cells to a downgradient direction .

The general extent and direction of groundwater baseflow has been assessed through the installation of a groundwater monitoring well network. However, it is unknown how climate seasonality may impact groundwater flow velocity and direction. The site's topography is mostly flat, with a corresponding slight groundwater gradient, and it is possible that localized velocity and directional flow of groundwater might change significantly following large rain events or seasonal increased rains. In addition, the soil cores from the site's soil borings identified a number of high and low conductivity zones and features that may impact the transport of contaminants.

2.4.3. Discharge from Groundwater to Surface Water

There are no known permanent surface water bodies located in the vicinity of the site (BMT, 2017). According to the National Wetlands Inventory (NWI, 2017), freshwater forested/shrub wetlands are located approximately 500 feet downgradient of the site within the current footprint of the comingled groundwater plumes.

Groundwater may discharge to surface water via baseflow or surface seepage. For example, shallow groundwater has the potential to enter the wetlands downgradient of the site following heavy precipitation. The rate of contaminant transport by this mechanism is controlled by solubility, distance traveled, soil properties, and groundwater flow rates. Since ponding and standing water were not observed in the wetlands during the 2017 and 2018 field activities, the potential for groundwater to enter intermittent wetlands is assumed negligible.

2.5. Potential Receptors and Exposure Routes

Receptors identified in the CSM include potential future adult and child residents, current and future trespassers and site visitors, current and future construction/site workers, and ecological receptors. As discussed below, some of these potential receptors are unlikely to be at the site but are considered to evaluate complete site closure and risk scenarios.

Due to the nature of the soil impacts (radiological and laboratory waste) being focused within the disposal site footprint, complete soil pathways are considered negligible beyond the footprint of the actual disposal cells. No other data pertaining to contamination within surficial or subsurface soils is available and will not be calculated in Section 3.

2.5.1. Current and Potential Future Residents

Currently, residential human populations are not living on the site nor are human populations situated downgradient from the site. The nearest human population is a residential development approximately 3.7 miles northwest (hydraulically upgradient) of the site. An artificial basin is located approximately 1.45 miles south-southeast from the site, adjacent to Bloxham-Cutoff road. It is unlikely that the site will be developed for residences in the future; however, the future resident exposure scenario will be considered to provide a conservative estimate of risk and is required by current EPA Risk Assessment Guidance (EPA, 1989 and 2018).

Under this exposure scenario, potential future residents are assumed to have access to, and use, near surface site groundwater for drinking, showering (aerated and inhaled), and doing yard work and gardening. Likewise, vapors and/or gaseous alpha emitting particles may intrude into residential structures. Potential future residents are considered to have access to and contact with surface water, as represented by the nearby intermittent wetlands, and for recreational and/or agricultural activities. This use scenario is purposefully evaluated conservatively to be protective of human health.

The future resident scenario also was considered to evaluate exposure to contaminants in near surface soil. For risk calculations and development of the exposure scenarios, the surface soil interval at the site comprises a depth of 24-inches bgs in accordance with EPA guidance (EPA, 1989 and 2018) representing typical exposures for residential receptors. The exposure pathways, which may potentially be considered complete for hypothetical future residents, are ingestion and dermal absorption tied to direct contact with soil via garden and/or agricultural tracts; along with incidental contacts with soil typically experienced by homeowners (e.g., landscaping and lawn care maintenance).

Future on-site residents may include both child and adult residents. The CSM and risk assessment did not consider the current resident scenario because there are no residents on-site and the nearest residential areas are several miles from the site.

2.5.2. Current and Future Site Workers

With the exception of the site itself, no construction projects have been undertaken in the nearby vicinity. The Apalachicola National Forest, however, is an active timber harvesting area and the site could potentially be used in the future as a temporary worksite, staging area, or other activities performed by USFS personnel and contractors. Therefore, a potential exists to host site workers should temporary or permanent structures or utilities be constructed to support future activities.

Inhalation risks from contaminants in groundwater and soil are considered negligible to site workers. Potential risks from incidental dermal contact with contaminated groundwater are considered.

2.5.3. Construction Worker

Although there are no current plans to develop lands in the vicinity of the site, timber harvesting is possible and may include staging trees and construction of logging roads. Possible future construction projects in the vicinity of the site are unlikely but are considered to provide a conservative risk assessment for all potential site receptors.

A future construction worker may come into contact with contaminants in surface soil, subsurface soil, soil vapor, and shallow groundwater while performing intrusive activities such as site preparation, grading, and soil excavation. The exposure pathways which may potentially be considered complete for a future site worker are:

- Ingestion of chemicals in surface soil, subsurface soil, and shallow groundwater. This pathway is considered negligible.

- Absorption through dermal contact with contaminants in surface soil, subsurface soil, and groundwater. EPA Region 4 Risk Assessment Guidance recommends that dermal contact for radionuclides is not to be evaluated as this pathway is also considered negligible (EPA, 2018a).

- Inhalation of contaminated particulate matter including airborne soil particles or dust.

2.5.4. Current and Future Trespasser and/or Visitor

Potential trespassers and visitors are considered to have similar behaviors and exposure scenarios for the site. Potential trespassers and visitors may include official visitors, people traversing the site, using the site for permitted or non-permitted recreational activities, including hunting, and may include trespassers and visitors of all ages from children to adolescents to adults.

The site is easily accessible via Forest Service roads; however, the actual site is protected by a chain-linked fence (topped with barbed wire), which is surrounded by a 2nd barbed wire fence and is periodically inspected by the USFS and FSU personnel for general site maintenance. The most likely human receptors to enter the site would be persons looking for pedestrian shortcuts, and/or hunters. These trespassers could potentially contact surface soils, which could potentially result in an exposure pathway via ingestion or dermal absorption. Trespassers and recreational users are not considered to have access or exposure to contaminated groundwater. All potential exposure pathways are considered complete but have been judged to be negligible due to the limited time frames for potential exposure.

2.5.5. Ecological Receptors

Plant and animal receptors, whether aquatic or terrestrial in nature, could be susceptible to exposure to soils, sediments, and surface water via dermal contact, inhalation, or ingestion of chemical contaminants at and in the site. This would most likely occur among animal species, which inhabit aquatic or wet soil environs hydraulically downgradient from the source area, or arboreal species with more deeply rooted networks (including native, invasive, and cultivated vegetation). Contaminated groundwater entering downgradient surface water bodies or flowing from related springs and/or seeps in the area could result in extended periods of contact with plants, fish, amphibians, or any number of vertebrate or invertebrate animal species living in wet soils and sediments associated with these physical settings. Ingestion of contaminants is also likely among these "first tier" animals but could also impact predators that rely on these types of animals for food. Potential bio-magnification issues among long-time resident predator species to this immediate area could also result.

Inhalation hazards, although a less likely exposure pathway for ecological creatures, is nevertheless a potential hazard to terrestrial wildlife having prolonged exposure to environmental media. Due to the mobility of most terrestrial animals, including birds, and the small site area, this type of exposure would likely be limited to brief encounters. No significant exposure is expected for ecological species and this pathway is currently incomplete and/or negligible.

3. STREAMLINED RISK EVALUATION

The streamlined risk evaluation (SRE) is intended to be intermediate in scope between the limited risk evaluation performed for emergency removal actions and the conventional baseline risk assessment normally conducted for removal and remedial actions. The streamlined risk evaluation assists in justifying a removal action and identifies what current or potential exposures should be prevented. The streamlined evaluation uses sampling data from the site to identify contaminants of concern (COCs), provides an assessment of the health effects associated with these chemicals, and projects the potential risk of health problems occurring if no cleanup action is taken at a site.

The SRE for the site is intended to focus on the specific risks associated with quantifiable groundwater plumes that have been identified and delineated in previous investigations. The Human Health Risk Assessment (HHRA) evaluated potential risks from groundwater contamination only. Ecological Risk Assessment (ERA) information is discussed in Section 3.2; however, no SRE was performed because groundwater is not an evaluated medium for ecological receptors, the site is small (less than 0.25 acres), ecological receptors are transient, and the disposed waste is situated too deep to come into contact with ecological receptors. The contaminants, 1,4-dioxane and select radionuclides data from January 2018’s groundwater monitoring (i.e., Phase II ESI) were used for the SRE.

3.1. Human Health Risk Assessment

A HHRA is an evaluation of cancer risks and non-cancer risks posed to humans by the release of hazardous substances, pollutants, and contaminants from a site without remediation. The approach for the HHRA at the site is based on EPA Region 4 HHRA guidance (EPA, 2018) and EPA’s *Risk Assessment Guidance for Superfund (RAGS).* RAGS is composed of six parts (EPA, 1989; EPA, 1991a; EPA, 1991b; EPA, 2001; EPA. 2004; EPA, 2009a and EPA, 2009b).

The components of the HHRA as depicted in the following subsections include:

- Data Evaluation
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization

EPA recommends that the HHRA process be documented according to EPA RAGS Part D by completing standard tables that sequentially apply contaminant toxicity and exposure factors using site specific data to calculate estimated risks. These standard tables document the human health risk assessment process and findings, and are summarized and presented at the end of this section and included in Appendix C.

3.1.1. Data Evaluation

The first part of the HHRA process includes the selection of data suitable for use and the second part identifies the constituents of potential concern (COPCs).

3.1.1.1. Selection of Data for Use in the Risk Assessment

For the site HHRA, data evaluation is limited to 1,4-dioxane, Radium-226, and Radium-228 in groundwater. Gross-alpha emitting isotopes were also detected in groundwater at concentrations exceeding the FDEP GTCL, but risks could not be quantified because there is no available speciation for these isotopes. Table 3-1 provides the results of the chemical analyses of contaminants in groundwater from sampling activities as described in the Phase II ESI report (BMT, 2018). Figures 8 and 9 show the analytical results from groundwater sampling conducted in 2018.

3.1.1.2. Selection of Chemicals of Potential Concern (COPCs)

The occurrence, distribution and selection of COPCs in groundwater for site is summarized in RAGS Part D standard Table 2 (Appendix C). As previously described for the purpose of the streamlined risk assessment, the list of COPCs is limited to 1,4-dioxane, Radium-226, and Radium-228 in groundwater. For each of these contaminants detected in groundwater, the maximum detected concentration is compared to their respective EPA Regional Screening Level (RSL) for Chemical Contaminants at Superfund Sites (November 2018) (EPA, 2018a) https://www.epa.gov/risk/regional-screening-levels-rsls. The RSLs used for comparison are based on conservative exposure assumptions that correspond to a non-carcinogenic hazard quotient (HQ) of 0.1 or an incremental lifetime cancer risk (ICLR) of $1x10^{-6}$. For radionuclides, screening values were taken from the Risk Assessment Information System (RAIS) https://rais.ornl.gov/.

3.1.2. Exposure Assessment

The exposure assessment estimates the magnitude, frequency, duration, and route of exposure for all potential human receptors. This process consists of two steps:

- Identification of human health exposure scenarios; and
- Quantifying exposures for each identified COPC for exposure medium for each exposure scenario.

Table 3-1: Contaminant Concentrations in Groundwater from Site Monitoring Wells

Sample ID	1,4-dioxane (µg/L)	Radium-226 (pCi/L)	Radium-228 (pCi/L)	Gross-Alpha (pCi/L)
MW009-GW@9.5’	ND	1.4 ± 0.44	ND	ND
MW014-GW@20’	ND	2.6 ± 0.87	1.6 ± 0.51	18 ± 4.4
MW011-GW@8.9’	25	ND	1.7 ± 0.52	ND
MW012-GW@8.4’	ND	ND	ND	ND
MW015-1-GW@10’	220	8.1 ± 2.1	2 ± 0.71	7.6 ± 2.3
MW015-2-GW@30’	420	5.7 ± 1.6	5.6 ± 1.5	4.6 ± 1.7
MW016-1-GW@10’	ND	5.4 ± 1.5	4.6 ± 1.2	14 ± 3.5
MW016-2-GW@30’	8.3	8.2 ± 2.1	6.6 ± 1.7	31 ± 6.6
MW017-1-GW@10’	5.5	2.2 ± 0.69	6.7 ± 1.7	18 ± 4
MW017-2-GW@30’	20	4.5 ± 2.6	ND	43 ± 9.1
MW018-GW@25’	8.6	2.1 ± 0.83	5 ± 1.4	7.3 ± 2.3
MW019-1-GW@10’	ND	ND	3.4 ± 0.97	ND
MW019-2-GW@30’	ND	7.4 ± 2	6.7 ± 1.7	9.3 ± 2.8
MW010-GW@9’	ND	ND	2.5 ± 0.69	ND
MW013-GW@9.5’	ND	ND	ND	ND

(orange)	Upgradient well
(blue)	Side gradient well
(green)	Downgradient well

3.1.2.1. Selection of Exposure Scenarios

The HHRA is limited to the most conservative exposure scenarios for human receptors. The exposure scenarios identified for human receptors include:

- Current and future site and construction worker exposed to contaminants in groundwater via dermal exposures during excavation and grading activities.
- Potential Future Adult Residents exposed to contaminants in groundwater in soils via ingestion, inhalation, and dermal exposures.
- Potential Future Child Residents exposed to contaminants in groundwater in soils via ingestion, inhalation, and dermal exposures.

EPA HHRA guidance (EPA, 1989) and EPA Region 4 guidance (EPA, 2018) require that a future residential exposure scenario be included with each risk assessment. The selection of HHRA exposure scenarios for the Site is documented in RAGS Part D Standard Table 1 (Appendix C).

3.1.2.2. Exposure Point Concentrations (EPCs)

EPA guidance identifies that the exposure term for HHRA should approximate a Reasonable Maximum Exposure (RME) as the 95% Upper Confidence Limit (UCL) of the arithmetic mean concentration of the COPC in an exposure medium (i.e., soil, groundwater, etc.). To assist in identification of the most appropriate RME UCL, EPA has developed ProUCL software. For each COPC identified in groundwater, an Exposure Point Concentration (EPC) was calculated using EPA's ProUCL v5.1 software (EPA, 2017). The ProUCL results are used to identify the most appropriate RME UCL for each contaminant in soils in RAGS Part D Standard Table 3.1 in Appendix C. The ProUCL input and output files are included in Appendix C.

3.1.2.3. Calculation of Exposures to Contaminants in Groundwater

RAGS Part D Standard Tables 4.1 and 4.2 (Appendix C) provides the parameters and equations used to quantify exposures for contaminants in groundwater associated with dermal and ingestion exposures. Dermal, inhalation, and ingestion exposure doses for groundwater contaminants are reported in RAGs Part D Standard Tables 7.1, 7.2, 7.3, and 7.4 (Appendix C) for current and future site workers and construction workers, future adult residents, and future child residents.

3.1.3. Toxicity Assessment

Toxicity assessment consists of two stages: hazard identification and dose-response assessment. Hazard identification evaluates if a COPC can cause a specific effect and if the adverse health effect occurs in humans. Hazard identification also evaluates the nature and strength of the evidence of causation. Dose-response assessment quantitatively evaluates toxicity information for the chemical to determine the relationship between the administered dose or concentration of the chemical and the incidence of an adverse effect in the exposed population. For non-carcinogens, the toxicity values, or reference doses (RfDs for oral and dermal exposures), are expressed in terms of a threshold value that is below which adverse effects are not expected to be observed. Toxicity values for carcinogens are known as cancer slope factors (CSFs) and are expressed in units of cancer incidence per unit dose of the chemical.

3.1.3.1. Non-Carcinogenic Contaminants

RAGS Part D Standard Table 5 (Appendix C) is used to record the dermal and oral non-cancer toxicity data for 1,4-dioxane. Radionuclides are not evaluated in this table.

3.1.3.2. Carcinogenic Chemical Contaminants

RAGS Part D Standard Table 6.1 (Appendix C) is used to record the dermal and oral cancer toxicity data used in the HHRA for 1,4-dioxane in groundwater. Table 6.1 provides cancer slope factors (CSFs) for oral and dermal exposures, oral adsorption efficiency for dermal exposures, and cancer weight of evidence for 1,4-dioxane. The primary source of CSFs and weight of evidence classification of carcinogenic contaminants are obtained from EPA's IRIS (https://www.epa.gov/iris). Secondary values that have been accepted by EPA are documented as part of the EPA RSLs (https://www.epa.gov/risk/regional-screening-levels-rsls) (EPA, 2018a).

3.1.3.3. Carcinogenic Radionuclides

RAGS Part D Standard Table 6.2 (Appendix C) provides slope factors for radionuclides. Table 6.2 provides slope factors for water ingestion, immersion (dermal exposure) and food ingestion for radionuclides. Slope factors are obtained from the Oak Ridge National Laboratory (ORNL) Risk Assessment Information System (RAIS) (https://rais.ornl.gov/index.html). The RAIS has a calculator to calculate potential risks from radionuclides based on specific isotope, concentration, exposed population and media. RAIS calculator output for Radium-226 and Radium-228, based on EPC concentrations (Appendix C, Table 3), is shown in Appendix C.

Background concentrations of the radium isotopes (Radium-226 and Radium-228) have been measured at less than 2.5 pCi/L within the Florida panhandle, far lower than peak concentrations detected downgradient of the site (USGS, 2018).

3.1.4. Human Health Risk Characterization

The final component of the HHRA is risk characterization. In this step, the exposure and toxicity assessments are combined to produce a quantitative estimate of non-cancer hazards and cancer risks. Risks are calculated for individual COPCs. Risks are also calculated for overall risk assuming simultaneous exposures to all COPCs by a single receptor are additive.

3.1.4.1. Incremental Lifetime Cancer Risks

Carcinogenic risk is calculated as the product of the carcinogenic COPC specific CSF (from RAGS Part D Standard Table 6.1 for oral and dermal exposures of 1,4-dioxane and table 6.2 for radionuclides) and the calculated intake (dose) for oral and dermal exposures or the estimated exposure concentration for inhalation exposures. Carcinogenic effects are expressed in terms of dimension-less numbers that represent the probability of a receptor (adult or child) developing cancer resulting from exposure to each COPC classified as a carcinogen. The estimated dose (or concentration for inhalation exposures) for each carcinogenic COPC is multiplied by the respective CSF to calculate the Incremental Lifetime Cancer Risk (ILCR) value. The expression is as follows:

COPC: ILCR = Intake (mg/kg-day or μg/cm^3) × CSF (1/mg/kg-day or 1/μg/cm^3)

For simultaneous exposure to several carcinogens, the calculated ILCRs are summed within each pathway and then summed for all pathways to yield a total ILCR posed by the site for each receptor. This approach represents the probability of developing a carcinogenic response, which is solely attributable to exposure to chemicals in excess of general background risk.

Inhalation intake rates of 1,4-dioxane in groundwater, resulting from exposures to vapor intrusion from soils, are calculated using EPA's Vapor Intrusion Screening Level (VISL) Calculator (USEPA, 2017). This model is used only for chemicals considered to be volatile, and sufficiently toxic through the soil gas vapor intrusion pathway. The model provides generally recommended risk-based screening-level concentrations for groundwater. The intake rates of groundwater COPCs resulting from vapor intrusion are calculated only for current and future site and adult and child resident exposure scenarios due to their presence in enclosed structures that are assumed under this scenario.

Based on the assumption that any exposure to a carcinogen poses some risk, "zero" risk is not achievable in a practical sense. To be protective of human health, EPA has specified that exposure to site-related carcinogens should be limited to result in an individual upper bound excess lifetime cancer risk not to exceed one in 10,000 or 1E-04. EPA has established the risk range from one in 10,000 (1E-04) to one in a million (1E-06) as being generally acceptable; however, EPA can require further action depending on other exposure factors, toxicity, and possible synergistic effects within this range. Cancer risks of one in a million or less are generally considered insignificant.

RAGS Part D Standard Tables 7.1, 7.2, 7.3, and 7.4 (Appendix C) summarize the calculation of cancer risks for the site. ILCR values are presented as well as a total ILCR across dermal, and ingestion exposure pathways in RAGS Part D Standard Table 9.1 for current and future site and construction workers, Standard Table 9.2 for future adult residents, in Standard Table 9.3 for future child residents, and Standard Table 9.4 for child and adult residents combined (Appendix C).

3.1.4.2. Non-Carcinogenic Risks

RAGS Part D Standard Table 7 (Appendix C) is also used to record risks associated to exposures to non-carcinogens. Non-carcinogenic risks are assessed using the concept of hazard quotient (HQ) and Health Index (HI). The HQ for a COPC is the ratio of the estimated intake or concentration to the reference dose (RfD)

HQ = (Intake) / RfD

And the HI is the sum of the individual HQs for all the COPCs. HQs and HIs are typically evaluated using a value of 1.0. Generally, non-carcinogenic health effects are not anticipated if an HQ or HI, developed on a target organ/effect-specific basis, does not exceed 1.0.

3.1.4.3. Radiological Risks

RAGS Part D Standard Table 8 (Appendix C) is used to record risks associated to exposures to radionuclides in groundwater. Media intakes and slope factors are taken from the RAIS calculator output and RAGS D Table 6.2 (Appendix C), to generate an overall radiation exposure factor that is incorporated into the total cancer risk for the site.

3.1.5. Human Health Risk Summary

Table 3-2 provides an overall summary of the carcinogenic risks calculated for the selected scenarios; including future resident adults, and future resident children exposed to contaminants in groundwater dermal contact and direct ingestion. In accordance with EPA guidance, carcinogenic risks are calculated for a receptor that combines COC intake/exposure concentrations for adult + child residents to calculate total lifetime risks to residential populations. Child resident receptor exposure parameters are described in Table 4.1 of Appendix C . Child risks are summarized in tables 7.3 and 9.3 of Appendix C. Child risks are summarized in tables 7.3 and 9.3 of Appendix C. Adult + Child resident risks are summarized in tables 7.4 and 9.4 of Appendix C..

Risks associated with dermal absorption range from an ILCR of 7.47E-08 for current and future site workers and construction workers to 4.98E-07 for the future resident adults. These risk estimates are below the EPA's acceptable cancer risk range of 1E-04 to 1E-06. Risks associated with inhalation of vapors were calculated, using the VISL model, at 8.60E-08 for all residential populations. These risk estimates are below the EPA's acceptable cancer risk range of 1E-04 to 1E-06. However, cancer risks associated with ingestion are above the EPA's acceptable risks at ILCR values ranging from 1.35E-04 for the future resident child to 2.02E-04 for the future residential adult exposure scenario (Table 3.2). ILCR for radiation exposure was generated using the RAIS information calculator for resident use of untreated tap water. Total ILCR for radiation exposure is 1.42E-04. The calculation for carcinogenic risks from radionuclides does not include unspeciated gross-alpha particle emitting isotopes. ILCR from external radiation is likely higher than the estimate presented in the streamlined risk assessment.

Non-carcinogenic risks are summarized in Table 3-3. No unacceptable non-carcinogenic risks were identified for potential future residents (adult and child) from ingestion and dermal contact with tap water because the total HI value for each of these exposure pathways is less than 1.0.

For both the carcinogenic and non-carcinogenic risk characterization results, the calculated values are based on data reflecting current site conditions. However, risks could increase with further releases and contaminant migration over time.

Table 3-2: Summary of HHRA Cancer Risk Characterization Results

Receptor Population	ILCR Dermal	ILCR Inhalation	ILCR Ingestion	ILCR Radiation	Total ILCR
Site/Construction Worker	7.47E-08	NA	NA	NA	7.47E-08
Future Resident - Adult	4.98E-07	8.60E-08	2.02E-04	1.42E-04	3.45E-04
Future Resident - Child	2.59E-07	8.60E-08	1.35E-04	1.42E-04	2.77E-04
Future Resident - Adult + Child	7.58E-07	8.60E-08	3.37E-04	1.42E-04	4.80E-04

Note: EPA Acceptable Carcinogenic Risk Range: 1E-04 to 1E-06.

Table 3-3: Summary of HHRA Non-Cancer Risk Characterization Results

Receptor Population	Non-Carcinogenic HI Dermal	Non-Carcinogenic HI Inhalation	Non-Carcinogenic HI Ingestion	Total Non-Carcinogenic HI
Site Worker and Construction Worker	6.28E-08	NA	NA	6.28E-08
Future Resident - Adult	0.0006	0.0015	0.2359	0.2380
Future Resident - Child	0.0001	0.0015	0.5242	0.5243

3.2. Ecological Risk Assessment

As mentioned in Section 2.5.5, plant and animal receptors, whether aquatic or terrestrial in nature, could be susceptible to exposure to soils, sediments, and surface water via dermal contact, inhalation, or ingestion of chemical contaminants at, and in the vicinity of, the site. Based on information that known contamination beyond the boundary of the site is limited to groundwater, no significant exposure is expected for ecological species except for a future scenario that includes groundwater discharge to the intermittent wetlands located downgradient of site. The exposure pathway for ecological receptors is currently incomplete and ecological risks are not calculated as part of the streamlined risk assessment.

4. IDENTIFICATION OF REMOVAL ACTION SCOPE, GOALS, AND OBJECTIVES

This section identifies the scope, goals, and objectives of the removal action. These items take into consideration the pertinent applicable or relevant and appropriate requirements (ARARs) to the extent practicable and meeting specified cleanup levels for removal action at the Site.

4.1. Determination of Removal Action Scope

The scope of these removal actions is based on available data from prior environmental investigations and present media-specific estimates of areas and volumes to which a response action may be applied. Assumptions utilized in determining these media-specific estimates are provided. These assumptions, in conjunction with the site-specific characterization data and process knowledge, form the basis of design for implementing the selected alternative.

The HHRA performed, as part of this EE/CA, has been used to generate the risk screening values necessary to evaluate and compare relevant removal and removal technologies, options and comparative costs to implement. However, the final site-specific Remediation Goals (Derived Concentration Guidelines Levels) DCGLs for each of the potential radionuclides of concern (ROCs) have to be calculated and agreed to by the regulatory agency that will have ultimate authority to close the permit post removal. DCGLs are derived using the most current versions of Residual Radioactivity dose modeling software (RESRAD).

4.1.1. Groundwater

Groundwater is the primary medium to be addressed beyond the footprint of the site. Successful treatment of the contaminant source at the disposal area will not address groundwater contamination that has migrated beyond the extents of the disposal cells but will help prevent future contaminant releases. Estimates of affected areas and volumes for groundwater treatment are presented in the following subsections.

4.1.1.1. Estimate of Area for Groundwater Plumes

Figures 6 and 7 show that the 1,4-dioxane and radionuclide groundwater plumes cover an estimated area of approximately 350,000 square feet (approximately 8 acres). Currently, there are no established land use controls beyond the site with respect to groundwater.

4.1.1.2. Estimate of Groundwater Volume for Treatment Technologies

Groundwater contaminants were detected at depths of up to 40 feet bgs in the vicinity of the site. The top of the SAS water table is typically 4-5 feet bgs. Assuming an average saturated media thickness of 35 feet, this is equivalent to a total groundwater volume of approximately 12,250,000 cubic feet. Assuming an average pore fraction in soil of 0.3, this translates to approximately 4,000,000 cubic feet of contaminated groundwater or approximately 30 million gallons requiring treatment. Typical aquifer porosity ranges from 0.2 to 0.4 (Hemond, 2000).

4.1.2. Surface Water

Remediation of potentially contaminated surface water and sediments is not included in the remedy evaluation because there are no identified non-intermittent surface water bodies in proximity to the site.

4.1.3. Air

The atmospheric air is not a medium requiring remediation at the site; however, air pollution preventive measures (e.g., dust suppression) and respiratory protection will be employed as necessary during removal activities.

4.1.4. Disposed Waste and Soil

Disposed waste and nearby surrounding soil are the primary media requiring a removal action at the site. A response action includes excavation. Estimates of areas and volumes for each of these technology types are presented in the following subsections.

4.1.4.1. Estimate of Disposed Waste Contaminant Area

As shown on Figure 1, the site is located within the Apalachicola National Forest in Leon County, Florida. The disposal area consists of a single contiguous field with forty (40) separate disposal cells. Twenty-six (26) of the forty (40) disposal cells were used from 1966 to 1979 and all are located in the southern portion of the site.

The disposal area measures approximately 9,600 square feet (120 feet by 80 feet). Current land use controls include a barbed-wire fence with a locked gate that surrounds the entire site and a six-foot high chain-linked fence topped with three strands of barbed wire with a locking gate around the perimeter of the disposal cells.

4.1.4.2. Estimate of Soil Volume for Excavation Technologies

Excavation of 4 feet of soil cover above each waste cell will generate approximately 40,000 cubic feet of uncontaminated backfill. This soil would potentially be available for use as backfill if clean, and if the contents of the waste cells are excavated. Based on historical records provided by FSU (Section 1.1), there are twenty-six (26) disposal cells, each with an approximate volume of 215 to 250 cubic feet for a total of 5,600 to 6,500 cubic feet or approximately 200 to 240 cubic yards (CY) of waste disposed within the waste cells. When in-situ waste is excavated and left in an unstressed condition, an expansion factor of 25% is appropriate to apply to the final volume produced. Applying a 25% volume increase factor as part of an excavation scenario, approximately 300 CY of waste will be generated from excavation of the former disposal cells. It is assumed that a certain volume of impacted soil would require excavation and off-site disposal due to waste leakage. For the purposes of this EE/CA, it is assumed that 500 CY of disposed radiological waste and impacted soils would require excavation and off-site disposal.

In addition to the data presented in the historical disposal records, additional characterization of the disposal cells utilizing radiological surveying equipment may be utilized to refine or limit the volume of material removed during excavation. The contents of each disposal cell are detailed in the disposal cell records (Appendix A).

4.2. Removal Action Goals and Objectives

Identifying the removal action goals and objectives is a critical step in the EE/CA. These goals and objectives are achieved by meeting cleanup levels while working within the statutory limits and attaining ARARs to the extent practicable.

4.2.1. Removal Action Objectives

RAOs are site-specific goals that define the cleanup requirements for a CERCLA response action. The removal action objectives address the site risks, exposure pathways and media of concern for current and future land use, clean up options, and ARARs.

Achieving the removal action objectives allow for unrestricted use of the site and its surroundings currently impacted by the groundwater plumes. Removal of source wastes from the disposal area and treatment of the groundwater plumes are thus included as removal action objectives. Specific removal action objectives for the site are as follows:

- Remove the radiologically contaminated waste in all 26 disposal cells to eliminate the source of soil and groundwater contamination at and within the vicinity of the site.

- After source removal, reduce the concentration of 1,4-dioxane and radionuclides in groundwater to established clean-up goals.

4.2.2. Compliance with Applicable or Relevant and Appropriate Requirements

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, removal action, location, or other circumstance at a CERCLA site (e.g., 40 CFR 300.415). “Relevant and appropriate” requirements, while not applicable to a hazardous substance, pollutant, contaminant, removal action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the activity conducted.

A third category of ARARs are To-be-Considered (TBC) criteria that are non-promulgated advisories or guidance issued by Federal or State government that are not legally binding and do not have the status of potential ARARs. However, in many circumstances TBCs are considered as part of the site assessment and may be used in determining the necessary level of cleanup for protection of human health or the environment. There are different types of requirements with which removal actions may have to comply. These classifications are presented below:

- *Ambient or chemical-specific requirements* are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

- *Performance, design, or other action-specific requirements* are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous substances.

- *Location-specific requirements* are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they occur in special locations.

ARARs and TBCs must be attained for hazardous substances, pollutants, or contaminants remaining at the completion of the removal action, unless a waiver of an ARAR is justified. In addition, EPA intends that the implementation of removal actions should also comply with ARARs and TBCs to protect human health and the environment. ARARs and TBCs identified for the removal action at the site are presented in Appendix D.

4.2.3. Cleanup Goals

Because the removal action is intended to address primarily the contamination present within the disposal cells at the site and groundwater impacted from the site, waste cleanup goals will be developed for radionuclide contaminants and 1,4-dioxane. Derivation of PRGs and DCGLs will be determined prior to the implementation of established cleanup goals. As mentioned in Section 4.1, generic cleanup goals were used is this EE/CA for preliminary removal action and remedial design and cost estimation only.

5. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section identifies technologies that may be applicable for addressing the source material at the Site and related groundwater plumes. These technologies are screened against site-specific RAOs and conditions to determine which ones are viable to be installed and maintained.

The response actions are divided into four broad categories for technology identification and initial consideration:

- Land Use Controls
- Source Isolation and Containment
- Source removal
- Groundwater treatment

5.1. Land Use Controls

LUCs identified for the site include ongoing access and use restrictions for the site. Access to the site is currently limited to USFS personnel, FSU personnel, and designated site visitors. Intrusive activities within the interior site fencing area are prohibited. Monitoring wells are locked and access to the site monitoring wells is currently controlled by the Forest Service Wakulla Ranger District Office. Site usage and deed restrictions on property within the contaminated areas associated with the site can also be implemented. Additional LUCs include the need to obtain approval from the USFS to perform any field activities within the Apalachicola National Forest.

5.2. Source Isolation and Containment Technologies

Source isolation and containment technologies pertain to segregating the disposed wastes at the site from all surrounding media to prevent future contaminant releases to the environment. The following subsections describe these technologies in greater detail.

5.2.1. Subsurface Barriers

Subsurface barriers refer to a variety of methods whereby low-permeability cutoff walls or diversions are installed below ground surface to contain source areas or groundwater plumes. The most commonly used subsurface barriers are slurry walls, particularly soil-bentonite slurry walls. Less common are cement-bentonite slurry walls, grouted barriers, and sheet piling cutoffs. Directional grouting may also be used to create horizontal barriers for sealing the bottom of source areas.

Slurry walls are typically constructed in a vertical trench that is excavated and filled with a slurry solution. The slurry, usually a mixture of bentonite and water acts essentially like a drilling fluid, may be selected based on surrounding permeability and contaminants in groundwater. The slurry hydraulically shores the trench to prevent collapse, and, at the same time, forms a filter cake on the trench walls to prevent fluid migration to the surrounding subsurface formation. A slurry wall constructed around the perimeter of the disposal cells at the site, in conjunction with a grouted, horizontal barrier below the depth of the cells (acting much like a landfill liner) and a cap with low permeability, have the potential to isolate the wastes in place.

Subsurface barriers may be designed to sorb contaminants from the groundwater, but these amendments impact their ability to act as an aquitard because they typically increase hydraulic conductivity in proportion to increased sorptive capacity.

5.2.2. Capping

For landfills, capping is the preferred remedy due to its ease of installation and well understood features and drawbacks. In general, caps consist of a single confining layer constructed of geomembrane or low-permeability soils, along with other functional and support layers to protect and assure effectiveness of the top layer. Due to an insufficient supply of low permeability soils (i.e., fine clays) around the site, a low permeability geomembrane or impermeable cap (either asphalt or concrete) would likely be the most cost-effective solution.

Non-vegetative caps have the ability to prevent infiltration of precipitation and other surface water into the subsurface, and this removes the vertical migration pathway. However, if waste is determined to be the source of contamination, then caps, in general, contain the source but do not remove it.

5.3. Source Removal Technologies

This section identifies source removal technologies applicable to the disposed contaminated waste and impacted soils within the site footprint. Excavation at waste disposal sites is usually limited to those that are within practical size limitations, have well-defined and accessible waste areas, waste volumes that are less than 100,000 cubic yards (CY), and waste that would continue to pose a threat with the implementation of only containment and land use controls.

5.3.1. Source Removal/Treatment

Source removal includes excavation of animal carcasses, containers, debris, and contaminated soils for disposal in accordance with regulatory guidelines. There are two general approaches to excavation: controlled excavation (e.g., where containers are separated and removed individually) and bulk excavation (i.e., where earth moving equipment removes the soils, containers, and debris, with separation afterwards using sorting equipment).

The disposal cells and their contents have not been disturbed since the end of disposal activities in 1979. Excavation will require removing the overburden, estimated at an average depth of four (4) feet, and stockpiling that soil for subsequent screening for disposal or use as backfill. When the excavation activities reach the disposed waste, the material will be initially segregated for testing and disposal. By keeping the size of the stockpiles relatively small and conducting regular field screening of soils, cross-contamination of clean and contaminated soils can be minimized. Because radiological wastes were placed below the observed water table at the site, the excavated area would require consideration of a dewatering step in the source removal process.

5.3.2. Type of Excavation

This section summarizes different types of excavation that could potentially be used to remove source wastes at the site.

5.3.2.1. Open Pit Excavation

Open cell excavation methods allow for vehicular access into the excavation area and standard excavation practices to be applied. It is simple because it does not require additional materials to support the sidewalls of an excavation (i.e., no side wall sloughing).

Within the site, the delineated waste cells are situated in close proximity to each other. Under these circumstances, soils extending from ground surface to the top of the disposal cells would be considered ‘clean’ for removal action purposes and would be stripped off and set aside for potential re-use. An open pit excavation would include all disposal cells and the lateral soils between the disposal cells as a single excavation area, which would be excavated in order to maintain safe slopes at the sides of the excavation. Due to the sandy soils present at the site it is likely that one-and-one-half horizontal (1:1.5) sides slopes would be used. The cost for open-cell excavation is low relative to shoring/sheet piling and grouting but would require more extensive dewatering efforts to maintain a dry floor within the excavation

5.3.2.2. Shoring/Sheet Piling

Shoring or sheet piling can be used to prevent cave-in of the side walls of an excavation. If an open disposal cell excavation is not used, the side walls of the excavation will need to be shored or stepped in accordance with Department of Labor (DOL) regulations since the excavation will likely be at least eight (8) feet deep. DOL regulations [29 CFR 1926.652(a)(1)(ii)] require shoring for trenches/excavations in excess of 5 feet deep. Interlocking metal sheet piling to support the sidewalls of the excavation will minimize excavation volumes and would protect the disposal area from caving in during removal activities. However, installation of shoring beams or metal sheet piling may require further delineation of the disposal cell boundaries in order to prevent breaking intact bottles and the release of contaminants. Damage or deflection of the sheet piling may occur in rocky soils, resulting in an ineffective installation. Dewatering may still need to be performed under this scenario, but the effort to do so may be less extensive than with an open cell excavation.

5.4. Groundwater Treatment Technologies

Groundwater treatment technologies must address both the chemical (1,4-dioxane) and radionuclide plumes that have been detected downgradient from the site. The estimated volume of contaminated groundwater requiring response is approximately 4,000,000 cubic feet (30 million) gallons (see Section 4.1.1.2).

Chemical and radionuclide contaminants may require different treatment technologies for effective treatment. Based on the selected technologies, the response may be completed in sequence or combined into a single treatment system.

Treatment of Chemical COCs

The SVOC 1,4-dioxane does not readily sorb to soil particles and migrates rapidly in groundwater, often ahead of other contaminants in a groundwater plume (EPA, 2017). The contaminant, 1,4-dioxane does not volatize or readily biodegrade in the natural environment and thus persists in groundwater aquifers after other VOCs and SVOCs have been lost via evaporation or natural attenuation (EPA, 2014). Currently available groundwater treatment options for 1,4-dioxane include:

- In-Situ chemical oxidation (ISCO) to degrade 1,4-dioxane.

- Ex-Situ groundwater treatment via pump (i.e., extraction) and treat systems using
    - Advanced oxidation techniques for the treatment phase; or
    - Bioremediation performed ex-situ within a bioreactor (EPA, 2006).

- In-Situ bioremediation or chemical reduction (EPA, 2006).

Treatment of Radionuclide COCs

Radionuclides (i.e., gross alpha activity, Radium-226, and Radium-228) were detected in groundwater downgradient of the site in 2017 and 2018. Maximum radionuclide concentrations were observed several hundred feet downgradient of the site. The groundwater plumes containing 1,4-dioxane and radionuclides are similar in coverage area; however, their plume shape is different (Figures 7 and 8).

Several ex-situ treatment options exist for treating radium compounds and gross alpha activity in groundwater and they include:

- Ion exchange
- Lime softening
- Electrodialysis/Electrodialysis Reversal
- Activated Alumina
- Coagulation/Filtration

Except for the presence of Radium-226 and Radium-228, the contributors to measured gross alpha activity in groundwater have not been identified. Speciation of groundwater would have to be performed to identify the specific isotopes prior to designing a treatment system.

5.4.1. Groundwater Treatment and Monitoring for 1,4-Dioxane

The contaminant, 1,4-dioxane is highly miscible in groundwater. The high solubility and low affinity for sorbing to soil particles make 1,4-dioxane highly mobile. The contaminant, 1,4-dioxane has a low vapor pressure value and produces negligible volatilization from groundwater to air. The contaminant, 1,4-dioxane is resistant to biodegradation and is relatively stable in the environment (Guiseppi & Whitesides, 2007).

Several removal technologies have been utilized to treat 1,4-dioxane in groundwater. Treatment selection will be influenced by the detected concentrations of contaminants at the site and the groundwater's inherent conditions and properties.

5.4.1.1. Monitored Natural Attenuation

Monitored Natural Attention (MNA) is used to identify contaminant migration, intrinsic abiotic and biotic degradation processes, and the need for future action. A long-term site monitoring program can be established to identify and assess potential adverse environmental or public health impacts associated with changes in site conditions.

The contaminant, 1,4-dioxane has a low affinity to sorb to soil particles and is stable in the environment. Based on historical groundwater data, the 1,4-dioxane plume is expected to expand and migrate south and east of the site. MNA by itself will not achieve RAOs; however, the relatively slow speed of its plume migration and the remoteness of the site from residential populations make MNA a potentially viable option of protecting human health when used in conjunction with another treatment option.

Radionuclides are present at far lower concentrations in comparison to their respective screening levels than 1,4-dioxane. Dilution through plume migration should be expected to reduce radionuclide concentrations below respective screening levels assuming no future contaminant releases from the site.

5.4.1.2. Air Stripping

Air stripping is a mass transfer process in which volatile contaminants in water are transferred to a gas (e.g., the atmosphere). It is commonly used to remove VOCs from aqueous waste streams. Air stripping is frequently accomplished in a packed tower equipped with an air blower. The packed tower operates on the principle of countercurrent flow. The water stream flows down through the packing while the air flows upward and is exhausted through the top. Volatile components have an affinity for the gas phase and tend to transfer from the aqueous stream and into the gas phase. In a cross-flow tower, water flows down through the packing as in the countercurrent packed column; however, the air is pulled across the water flow path by a fan. The coke tray aerator is a simple, low maintenance process requiring no blower. The water is allowed to trickle through several layers of trays. This produces a large surface area for gas transfer. Diffused aeration stripping and induced draft stripping use aeration basins similar to standard wastewater treatment aeration basins. Water flows through the basin from top to bottom or from one side to another while air is dispersed through diffusers at the bottom of the basin. The air-to-water ratio is significantly lower in this setup than in either the packed column or the cross-flow tower.

5.4.1.3. Sorption

Activated carbon adsorption is a technology by which a waste stream flows through one or more activated carbon, packed bed reactors. Selected contaminants are attracted to the internal pores of the activated carbon and adsorbed. Another process involves using powdered carbon that is fed to the waste stream and then separated by sedimentation. Both processes are effective for limited removal of many organic compounds but are most effective for less soluble and more polar compounds.

5.4.1.4. Phytoremediation

Phytoremediation involves the use of trees and other vegetation to facilitate the mass transfer of dissolved phase organic compounds into plant matter through root systems. Hybrid poplars were found to be effective in degrading 1,4-dioxane, even at high groundwater concentrations (100,000 µg/L) (Chiang et al. 2007). However, phytoremediation is only viable at sites with shallow groundwater systems.

Phytoremediation efficacy depends on the depth of root growth for the vegetation species selected for phytoremediation. Based on the ITRC phytoremediation technical and regulatory guidance (ITRC, 2009), the effective depth for normal grasses is typically 1 to 2 feet, and up to 10 to 15 feet for prairie grasses and trees. High concentrations of 1,4-dioxane in groundwater has been detected at 40 feet bgs, and no known vegetative species is known to remediate groundwater to this depth. (BMT, 2018).

5.4.1.5. Bioremediation

Bioremediation utilizes specific microbes to consume organic compounds in media. Bioremediation can be implemented in-situ, with a permeable reactive barrier (PRB) or ex-situ, in a bioreactor or a water treatment plant. The efficacy of bioremediation is determined by a variety of factors including: groundwater temperature, physical parameters (pH, salinity etc.), and existing microbial populations in groundwater.

5.4.1.6. Ex-Situ Chemical Oxidation

Enhanced oxidation processes use a controlled combination of ozone or hydrogen peroxide and ultraviolet (UV) light to induce photochemical oxidation of organic compounds. Ozone alone has the ability to breakdown some organic compounds, but its effectiveness is vastly enhanced with the use of UV light. The combination of UV radiation with ozone treatment results in the oxidation of organic contaminants at a rate many times faster than that obtained from applying UV light or ozone alone.

A typical continuous-flow ozone/UV system consists of an oxygen air source, an ozone generator or hydrogen peroxide feed system, a UV/oxidizer reactor, and an ozone decomposer. If ozone is used, flow patterns and configurations are designed to maximize exposure of the ozone bearing wastewater to the UV radiation, which is supplied by an arrangement of UV lamps. Typical reactor designs range from mechanically agitated reactors to spray, packed, and tray-type towers. Reactor gases are passed through a catalytic decomposer, which converts remaining ozone to oxygen and destroys any VOCs prior to being exhausted or recycled.

5.4.1.7. In-Situ Chemical Oxidation

Chemical oxidants such as sodium persulfate or potassium permanganate have proven to be effective at reducing concentrations of dissolved phase 1,4-dioxane in groundwater (Evans et al. 2018). Chemical oxidants can be applied within a well network as suspended cylinders or dissolved into a slurry and injected within the contaminated media. Commercial products derived from these materials have been developed for use at sites with 1,4-dioxane in groundwater.

5.4.2. Groundwater Monitoring and Treatment for Radionuclides

The radionuclide groundwater plume at the site is comprised of Radium-226, Radium-228, and gross alpha activity. In natural systems, gross alpha activity not caused by the decay of Radium-226 is the result of the radioactive decay sequence for Thorium-232 or Uranium-238 (Zapecza and Szabo, 1986).

Gross alpha activity is presumed be the result of past releases of Americium-241 and Curium-244 but may not be limited to these isotopes.

Several treatment methods are commonly used to remove radium compounds and transuranic compounds from water in treatment plants. A treatment system to remediate radionuclides in groundwater needs to work in concert or in sequence with a treatment system for 1,4-dioxane. This compatibility will be included as part of the selection criteria.

5.4.2.1. Monitored Natural Attenuation

MNA for radionuclides would involve ongoing monitoring to identify contaminant plume migration and radioactive decay, and the need for future action, if necessary. An initial step in any planned groundwater monitoring program for radionuclides would be to identify the specific isotopes contributing to high gross alpha activity readings in groundwater so as to tailor future groundwater sampling.

Monitoring consists of periodic sampling and analysis of sediment and surficial and subsurface soils. A long-term site-monitoring program, linked to applicable screening levels for COCs, could be established to identify and assess potential adverse environmental or public health impacts associated with changes in site conditions and impact of groundwater by soils or erosion leading to increased contamination reaching sediment or surface water bodies. Monitoring establishes a mechanism for identifying changes in site conditions and exposure risks.

Detected concentrations for gross alpha activity and radium compounds are above EPA drinking water standards, which are also the FDEP GTCLs, but not by orders of magnitude. Peak detected concentrations are approximately 2-3 times the relevant screening criteria for respective radionuclides. With no further releases, it is possible that the radionuclide plume will decay and spread until detected concentrations are within appropriate concentration criteria.

5.4.2.2. Ion Exchange

During ion exchange, water is passed through a resin containing exchangeable ions. Stronger binding ions displace weaker binding ions and are removed from the water. There are two types of ion exchange: anion exchange and cation exchange. Anion exchange resins generally exchange chloride for anionic contaminants, like uranium. Cation exchange resins generally exchange sodium or potassium for cationic contaminants, such as radium. Mixed bed resins with cation and anion exchange media in two layers are available for systems that need to remove both radium and uranium. Ion exchange is also effective for the removal of beta particles and photon emitters (EPA, 2018b).

Ion exchange has been identified by EPA as a best available technology (BAT) and Small System Compliance Technology (SSCT) for radium, uranium, gross alpha, and beta particle and photon emitters. It can remove up to 99 percent of these contaminants depending on the resin composition, pH level, and specific types of competing ions. Ion exchange resins are regenerated by backwashing, brining, and rinsing. Ion exchange vessels typically have a service capacity of 200 to 1,500 bed volumes (BV) for radium, as a function of water hardness, and 100,000 to 300,000 BV for uranium.

Ion exchange columns can be automated to require minimal operator attention making them appropriate selections for small systems. They can also be used as point-of-entry (POE) devices. Ion exchange columns can also remove other contaminants. Alkalinity, nitrate, and arsenic are removed by anion exchange. Cation exchange resins remove hardness constituents such as calcium, magnesium, iron, and manganese.

The efficacy of an ion exchange system is dependent on ambient groundwater conditions at the site (e.g., pH and presence of dissolved phase ionic compounds). It is unknown if ion exchange is effective in removing quantities of Americium-241, Curium-244 or other exotic radionuclides from groundwater.

5.4.2.3. Reverse Osmosis

Reverse osmosis is a pressure-driven membrane separation process. Water is forced through a membrane with small pores by pressures ranging from 100 to 150 pounds per square inch (psi). Any molecules larger than the pore openings are excluded from the product stream along with a significant portion of the water passing through. Treated water is collected on the other side of the membrane.

Reverse osmosis also has been identified by EPA as a BAT and SSCT for uranium, radium, gross alpha, and beta particles and photon emitters. It can remove up to 99 percent of these radionuclides, as well as many other contaminants such as arsenic, nitrate, and microbial contaminants. Reverse osmosis units can be process automated and compactly designed (EPA, 2018b).

5.4.2.4. Sorption

Sorption involves the treatment of groundwater by flowing the dissolved phase contaminants through one or more activated beds with specific sorbents. Specific sorptive media have been identified for isotopes of radium and americium in groundwater. A radium selective complexer, Dowex RSC, has been field tested to remove radium isotopes from water (Deng, 2005). Other sorbents that have been tested for Americium isotopes include red clay and volclay bentonite (Plaska et al., 2016).

For radionuclides, ambient water quality criteria, target contaminant concentrations, and potential interferences with chemical treatment systems for groundwater are factors influencing the sorption efficacy.

5.4.3. Groundwater Extraction Methods

Groundwater treatment technologies discussed in Sections 5.4.1 and 5.4.2 (except MNA) would require installation of a water treatment plant near the site. Groundwater would have to be extracted from the aquifer to be treated ex-situ. Two groundwater extraction technologies are described in the following subsections.

5.4.3.1. Groundwater Extraction Wells

Groundwater extraction wells can be installed within the footprint of the groundwater plumes to extract contaminated groundwater from the aquifer and pumped into a treatment system. The placement and construction of the groundwater extraction wells will be dependent upon site lithology, the permeability of the groundwater bearing formation, topography, and how the subsurface confining layers are stratified. To extract groundwater from comingled 1,4-dioxane and radionuclide plumes would require installing a large number of extraction wells and operating them with submersible pumps and controllers.

5.4.3.2. Interceptor Trench

An interceptor trench is a single trench that is designed so that incoming groundwater collects into a series of sumps and is then pumped to the surface for further treatment. An interceptor trench is installed downgradient of the contaminated groundwater to capture the full area of the identified plume. Interceptor trenches have similar design constraints to slurry walls (Section 5.2.1) and require a competent aquitard to prevent contaminated groundwater from flowing beneath the trench or installation to sufficient depth below grade to ensure the trench captures all contaminated groundwater

5.5. Screening of Technologies

Table 5-1 summarizes the screening of technologies for the contaminants at site. Technologies and process options retained will be carried forward for further evaluation in Sections 6 through 8 of this EE/CA.

Table 5-1: Screening of Technologies

General Response Action	Removal/Remedial Technology	Retain Process Option?	Rationale
Land Use Controls	Signage, locks, fencing, deed restriction	Yes	The site contains contaminants that require land use controls to prevent contact with human health receptors
Source Isolation and Containment	Subsurface Barriers such as a slurry wall	No	High cost and technology are uncertain for success at the site
Source Isolation and Containment	Capping	No	Does not meet unrestricted future use for the site
Source Removal	Excavation, sorting and disposal of radiological wastes and contaminated soil.	Yes	Removes primary contaminants from the site
Groundwater Treatment (1,4-dioxane)	Monitored Natural Attenuation	Yes	MNA alone will not meet unrestricted future use for site; however, MNA used in conjunction with source removal and ongoing monitoring has the potential to meet RAOs.
Groundwater Treatment (1,4-dioxane)	Air Stripping	No	Will most likely not reduce 1,4-dioxane concentrations below GCTLs
Groundwater Treatment (1,4-dioxane)	Sorption	No	Will most likely not reduce 1,4-dioxane concentrations below GCTLs
Groundwater Treatment (1,4-dioxane)	Phytoremediation	No	Does not treat 1,4-dioxane at necessary groundwater depth intervals
Groundwater Treatment (1,4-dioxane)	Bioremediation	No	Not a commercially viable technology and may fail at the pilot testing stage
Groundwater Treatment (1,4-dioxane)	In-situ Chemical Oxidation (Direct Injection of Oxidant)	Yes	Can treat high concentrations of 1,4-dioxane in groundwater
Groundwater Treatment (1,4-dioxane)	Ex-situ Chemical Oxidation (Combination of Ozone and Hydrogen Peroxide Treatment)	Yes	Chemical oxidation unit as part of an ex-situ treatment system.
Groundwater treatment (radionuclides)	Monitored Natural Attenuation	Yes	MNA alone will not meet unrestricted future use for site; however, MNA used in conjunction with an active groundwater treatment will
Groundwater treatment (radionuclides)	Ion Exchange (Ion exchange unit as part of an ex-situ treatment system)	Yes	Effective at treatment dissolved phase radionuclides in groundwater
Groundwater treatment (radionuclides)	Reverse Osmosis (Reverse osmosis unit as part of an ex-situ treatment system)	Yes	Effective at treatment dissolved phase radionuclides in groundwater
Groundwater treatment (radionuclides)	Sorption (Sorption unit as part of an ex-situ treatment system)	Yes	Effective at treatment dissolved phase radionuclides in groundwater
Groundwater treatment (radionuclides)	Groundwater Extraction Wells	No	High costs associated with the need to install many extraction wells
Groundwater treatment (radionuclides)	Groundwater Interceptor Trench with Sump Wells (Installed to depth of 40-45’ bgs)	Yes	Has ability to capture all contaminated groundwater within the comingled 1,4-dioxane and radionuclide plumes

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6. DEVELOPMENT OF REMOVAL ACTION ALTERNATIVES

This section presents the development of the removal alternatives at the Site. Each alternative has been developed from the retained technologies and process options described in Section 5. The selected remedy for disposed wastes and groundwater treatment need to be implemented in succession because the groundwater plume will continue to exist if the source is not removed first.

Two (2) removal alternatives were developed for disposed wastes and three (3) removal alternatives were developed for related groundwater contamination. Each alternative is discussed below.

6.1. Preliminary Development of Removal Alternatives – Disposed Radiation Wastes

The following removal alternatives are developed to address the disposal site and impacted soils

- Alternative 1 – No Action

- Alternative 2 – Excavation of all radiological disposal cells and off-site disposal of all such wastes and impacted soils.

6.1.1. Alternative 1 – No Action

This alternative represents a scenario where no removal action, no environmental monitoring, and no LUCs are implemented at the site to address disposed wastes at the site. Disposed wastes would remain at the site as they are currently, and future use scenarios would not be controlled or limited based on the presence of contaminated media. The evaluation of No Action is required under CERCLA to provide a basis for comparison for other alternatives.

6.1.2. Alternative 2 – Excavation and Off-site Disposal of Wastes and Impacted Soils

This removal alternative would include the following activities related to disposed wastes:

<u>Excavation and Treatment</u> – Under this alternative, all disposal cells would be excavated. The contents of all twenty-six disposal cells would be transported to a facility licensed to accept low level radiological materials and disposed. Potentially contaminated soils would be initially segregated for on-site screening. Soils that are determined to be contaminated would be transported to the same facility that will accept the disposal cell wastes.

Under this alternative, it is assumed that multiple waste streams will be produced. Low-level radioactive wastes and impacted soil will require disposal at a facility licensed to accept such materials. Other soils may require off-site disposal at a RCRA Title C facility. for non-radiological hazardous wastes and at a RCRA Title D facility for RCRA non-hazardous soil.

Post Excavation Final Status Survey - Upon the successful removal of all disposed wastes and contaminated soils, a final status survey (FSS) will be completed in accordance with the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (URNRC, 2000). The MARSSIM provides information on planning, conducting, evaluating, and documenting building surface and surface soil final status radiological surveys following scoping, characterization and any necessary removal actions.

Backfilling and Site Restoration – The excavated areas will be backfilled with clean soils of similar composition to local native soils (medium sands with silt) capable of supporting vegetation in order to reduce erosion potential. All existing site infrastructure (fencing) and excavation specific infrastructure, including staging areas, project trailers, security fencing and on-site power generation, will be removed and the site will be restored to its native state.

6.2. Preliminary Development of Removal Alternatives – Groundwater

The following removal alternatives have been developed to address groundwater contamination, at the site.

- Alternative 3 – Monitored Natural Attenuation (MNA)
- Alternative 4 – Targeted Direct Injection Targeting 1,4-dioxane and MNA
- Alternative 5 – Full Scale Pump and Treat (P&T) system to address 1,4-Dioxane and Radionuclides.

6.2.1. Alternative 3 – Monitored Natural Attenuation

This removal alternative would include the following activities related to site monitoring of the groundwater plumes. This alternative will not achieve ARARs in the short term due to existing concentrations of 1,4-dioxane and radionuclides at peak concentrations greater than GTCLs. It is expected that radioactive decay of radionuclides and natural attenuation of 1,4-dioxane will significantly reduce peak contaminant concentrations over the thirty-year time period used as the remedy timeframe in this EE/CA.

Natural attenuation of dissolved phase 1,4-dioxane has been observed in the field (Adamson et al., 2015). Recent field studies in California studies for the Air Force have measured a 1,4-dioxane half-life on the order of 6-7 years (https://www.ncbi.nlm.nih.gov/pubmed/25970261). Peak concentrations of 1,4-dioxane have been observed to decrease between groundwater sampling programs that were conducted between 2011 and 2018.

The rate of radioactive decay is dependent on the half-lives of specific radiological isotopes, and daughter products that are present within the contaminant plume. For this reason, speciation of alpha emitting radionuclides would be conducted at the commencement of a long-term monitoring program.

Though MNA will not address ARARs at the site in the short-term, the slow migration of the plume and relative isolation of the site from any residential any populations does make this option potentially viable.

Speciation of Dissolved Phase Radionuclides – Dissolved phase radionuclides that have been detected in groundwater plumes at the site include Radium-226, Radium-228 and gross alpha emitting isotopes. The specific alpha emitting radioactive isotopes contributing to the elevated alpha activity readings are currently unknown. There is an EPA Drinking water standard for gross alpha activity of 15 pCi/L. Prior to establishing an MNA program, it would be recommended to conduct speciation of alpha emitting radionuclides to determine the specific radiological isotopes contributing to this measurement to identify the potential half-life of these isotopes and to target future monitoring efforts.

Additional Groundwater Monitoring Well Installation – Under an MNA scenario, it is assumed that the currently identified groundwater plumes will disperse and migrate beyond the lateral extent of the current off-site monitoring well network (Figures 6 and 7). It is assumed that up to four (4) additional monitoring wells would be installed further downgradient of the site upon the commencement of a long-term monitoring program and that additional monitoring wells would be installed every five years upon a review of the long-term monitoring data.

Long-Term Monitoring – Long-term monitoring would include collection of groundwater samples from all off-site monitoring wells (MW014 – 019) to monitor the spread and migration of dissolved phase contaminants. Data collected from monitoring will be used to estimate degradation of organic contaminants and radioactive decay of radionuclides.

6.2.2. Alternative 4 – Targeted Direct Injection and MNA of Groundwater Plumes

This alternative includes a targeted in-situ treatment program to address 1,4-dioxane in groundwater combined with MNA for low concentrations of 1,4-dioxane and dissolved phase radionuclides. All assumptions for MNA are included in this option except for the addition of additional monitoring wells at the commencement of the project.

As stated in Section 6.2.1, natural attenuation of dissolved phase 1,4-dioxane has been observed in the field (Adamson et al., 2015). The elimination of the 1,4-dioxane plume ‘hot spot’ would greatly reduce the total toxicity of the plume and reduce concentrations to values low enough that ARARs could be achieved within a 30-year time frame.

In addition to the speciation of dissolved phase radionuclides in groundwater, this removal alternative would include the following activities related to groundwater:
Pre-Injection Characterization of 1,4-Dioxane Plume Center – Direct injection of oxidizing compounds is not viable over a plume with an estimated area of 350,000 square feet (Section 4.1.1). Groundwater monitoring conducted in 2011, 2017, and 2018 suggests that groundwater with high concentrations of 1,4-dioxane (> 50 µg/L) is likely limited to a much smaller area. Prior to conducting a targeted direct injection program at the site, groundwater characterization would be conducted in the vicinity of MW015 (Figure 6) using temporary well points to identify groundwater with high concentrations of 1,4-dioxane.

Bench Scale Testing – Bench scale testing includes a pilot study and laboratory testing of potential in-situ constituents prior to mobilizing a full-scale direct injection program. Bench scale testing is conducted to specify a formulation to be used in the injection mixture and to identify potential site conditions that would impact the efficacy of a specific formulation.

Direct Injection Program – A direct injection program would use an appropriate drilling technology to advance a series of temporary injection points over a pre-defined grid. An injection slurry consisting of oxidizing compounds and water would be injected throughout the water column at each injection point.

Long-Term Monitoring – Targeted direct injection will not address all groundwater contamination. Groundwater with low concentrations of 1,4-dioxane (< 50 µg/L) and dissolved phase radionuclides would remain and require long-term monitoring. Targeted direct injection will greatly reduce the potential risks associated with the 1,4-dioxane plume and it is assumed that fewer monitoring wells would have to be installed during a monitoring program than with Alternative 3.

6.2.3. Alternative 5 – Full Scale Ex-Situ Treatment System

This alternative includes a full-scale ex-situ treatment system to address 1,4-dioxane and radionuclides in groundwater. This alternative represents the most comprehensive option for treating contamination defined within the groundwater plumes (Figures 6 and 7) at the site. This removal alternative would include the following activities related to groundwater:

Bench Scale Testing – Bench scale testing includes a small-scale pilot studies and laboratory testing of potential ex-situ treatment systems that are performed prior to finalizing the design for a full-scale treatment system. Bench scale testing is used to identify potential issues with a proposed treatment system and to optimize a specific treatment sequence.

Installation of Groundwater Interceptor Trenches – As detailed in Sections 5.4.3.1 and 5.4.3.2, groundwater interceptor trenches would generate higher potential groundwater collection rates for an equivalent installation cost and would require a far simplified groundwater pumping set up. Under this alternative, a groundwater interceptor trench, or several groundwater interceptor trenches would be installed within and downgradient of the groundwater plumes using a single pass trencher. Collection sumps would be installed within each interceptor trench to pump groundwater to an ex-situ treatment system.

Installation of Groundwater Injection Wells – A series of groundwater injection wells would have to be installed upgradient of the interceptor trenches. Treated effluent from the pump and treat system would be discharged into the injection wells. Installing injection wells upgradient of the interceptor trenches would facilitate 'flushing' contamination through the system to capture all potential contamination within the groundwater system.

Installation and Operation of an Ex-Situ Treatment System – Extracted groundwater would be disposed of via on-site ex-situ treatment system designed specifically for managing the groundwater and COCs at the site. If an ex-situ treatment is selected, the unit would be placed in an accessible location and groundwater collected in the interceptor trench(s) would be pumped to the ex-situ unit for treatment. Based on observed soil conductivity and groundwater pump tests, the system would require an estimated capacity of 100 to 300 gallons per minute (gpm) to assure capture of the plume. Pending treatability studies, groundwater would likely require five sequential processes:

- **pH treatment:** Recovered groundwater will be treated to raise the pH in order to precipitate alpha emitting radionuclides and other inorganics. Groundwater pH treatment options include lime and calcium carbonate.

- **Flocculation and Settling:** Treatment for high turbidity and metals that have been precipitated out of solution by the pH treatment. Allowing sufficient time for settling increases efficiency and reduces maintenance requirements of the following aeration and granulated activated carbon (GAC) treatment units.

- **Chemical Oxidation:** Chemical oxidation using ultraviolet (UV) light and hydrogen peroxide and/or ozone would be used to consume 1,4-dioxane.

- **Ion Exchange Resin:** Ion exchange resin would serve as a sorptive and ion exchange medium to remove alpha emitting isotopes from treated water.

- **Granulated Activated Carbon:** Treated water will pass through a GAC treatment unit to remove remaining organic contaminants.

An ex-situ treatment system would require continuous operation for several months to several years to treat all identified groundwater contamination. Frequent groundwater monitoring and treated groundwater effluent monitoring will be required to verify the effectiveness of the treatment system.

7. EVALUATION OF REMOVAL ALTERNATIVES

The technologies and process options identified as applicable to the Site are evaluated in this section based on their effectiveness, implementability, and cost, as noted in 40 CFR 300.430(e)(7).

7.1. Evaluation Criteria

All proposed alternatives are evaluated based on their effectiveness, implementability, and cost. A description of these selection criteria is listed in the following subsections.

7.1.1. Effectiveness

This criterion focuses on the degree to which an alternative minimizes residual risks and affords long-term protection; complies with ARARs; achieves long-term effectiveness and permanence; reduces toxicity, mobility, or volume through treatment; and minimizes short-term impacts.

7.1.2. Implementability

This criterion focuses on the technical and administrative feasibility, availability of the technologies each alternative would employ, and the likelihood of state and community acceptance.

<u>Technical Feasibility</u>

The ability of the technology proposed to implement the removal action must be assessed. The reliability of the technology is also a concern, as technical problems associated with implementation may impact the schedule. Potential impacts on the local community during construction operations are also evaluated. Certain technology may be vulnerable to environmental conditions encountered at the site, including local terrain and weather conditions. The technology must also be consistent with future removal actions to be performed (if any) at the site.

<u>Administrative Feasibility</u>

Administrative feasibility evaluates those activities needed to coordinate the removal action with outside offices and agencies. This evaluation would factor in the need for off-site permits, adherence to non-environmental laws during the conduct of the removal action, and concerns of other regulatory agencies (possibly outside of USEPA, FDEP, and USNRC).

<u>Availability of Services and Materials</u>

It is necessary to determine if off-site treatment, storage, and disposal capacity; equipment; personnel; services and materials; and other resources necessary to implement an alternative will be available in time to maintain the removal action schedule.

7.1.3. Cost

The types of costs that are assessed include capital costs, annual O&M costs, and net present value of capital and O&M costs. For this EE/CA, an approximate total cost is presented in Appendix E for each viable excavation alternative. Capital costs include both direct and indirect costs required to implement the alternative. Direct costs consist of construction costs for equipment, materials, labor, transportation, and disposal; indirect costs include those associated with engineering and design, permitting, and construction management. Annual O&M costs include labor and materials associated with the operation and maintenance of the site following the implementation of the alternative; and auxiliary costs such as energy, monitoring, and laboratory costs.

All costs assume a fee for project management. Project management includes general management services that are not specific to the design of an alternative or for on-site construction management during removal action implementation. Project management expenses of 10% are recommended for projects with capital costs less than $100K, and 5% for projects with capital costs greater than $10M, not including construction management (EPA, 2000). Project management expenses of 10% of the total project costs is applied that includes construction management for relevant projects.

Costs for present net worth assume a 5% discount rate in accordance with EPA Guidance (EPA, 1988).

7.2. Alternative 1: No Action

7.2.1. Effectiveness – Alternative 1:

Overall Protection of Human Health and the Environment

This alternative does not satisfy the NCP threshold for overall protectiveness for human health and the environment with regards to soil. Current site workers, trespassers, and visitors and potential future construction workers and theoretical residents would remain exposed to disposed wastes based on the usage patterns. Though unlikely, future construction workers or other receptors could be exposed to unacceptable risk from existing contaminated groundwater produced from continuing releases, which this alternative would not control or minimize.

This alternative would not achieve ARARs or RAOs for the site. This option would lead to no reductions in toxicity, mobility or volume of contaminated media and would not achieve effectiveness in the short term or the long term.

7.2.2. Implementability – Alternative 1:

There is no remedy to implement under the No Action alternative.

7.2.3. Cost – Alternative 1:

Cost estimates and their assumptions are summarized in Table 7-1. The total prevent value cost is $0. The total capital cost is $0 and O&M costs associated with Alternative 1 are also $0. The No Action alternative assumes that no 5-year reviews will be performed to reassess the site's environmental condition.

For the purposes of this EE/CA, the no action alternative has a cost of $0.00. However, there are costs associated with a no-action alternative that include maintenance of access roads, permitting and regulatory interface with FSU concerning the site, and the needs for periodic surveys and site visits to assess the condition of current site land use controls that include site security fencing.

Table 7-1: Costing Summary of Alternative 1 – No Action

Cost Item	Amount	
CAPITAL COST (One Time)		
No Capital Cost	$ 0	
O&M COSTS (Annual Costs)		
No O&M Costs	$ 0	
PERIODIC COSTS (Recurring)		
No Periodic Costs	$ 0	
PROJECT MANAGEMENT		
Project Management	10%	
Total Present Value Assessment		
Discount Rate (@5%)	Present Worth	
Estimated Project Total Cost	**$ 0**	
Estimated Project Total Cost Range	**$ 0**	**$ 0**

7.3. Alternative 2: Excavation and Off-site Disposal of Wastes

This option includes the complete excavation and removal of the disposed waste plus a certain volume of surrounding soil that is assumed to be contaminated. Under this alternative, all disposal cells would be excavated. Excavated wastes will be sorted from surrounding soils using a screening plant. Potentially impacted soils will be screened using radiation monitors and sampled to determine what volume of excavated soil will have to be disposed of off-site.

For the purposes of this EE/CA it is assumed that all excavated low-level radioactive wastes and impacted soils will be disposed of at the EnergySolutions' Clive, Utah disposal facility for low level radiological wastes. The Clive Utah disposal facility is the only facility in the United States currently licensed by the Nuclear Regulatory Commission (NRC) to accept low-level radiological wastes from the site. There are three (3) other facilities that are licensed by the NRC to accept low-level radiological wastes but these facilities can only accept wastes from specific geographical areas (https://www.nrc.gov/waste/llw-disposal/licensing/locations.html)

It is assumed that up to 500 Cy of mixed radiological wastes and impacted soil will require excavation and off-site disposal (Section 4.1.4.2). In addition, water stored in frac tanks will require periodic disposal in accordance with all state and federal statutes. For the purposes of this EE/CA, it is assumed that disposal of 5,000 gallons of water per week using a vacuum truck will be required.

Alternative disposal facilities, including RCRA title D (non-hazardous) and title C (hazardous) landfills or soil treatment areas could potentially accept some portion of the excavated wastes and soils. However, there is insufficient characterization data from within the disposal cells at the site to identify these waste streams and to compare against potential waste acceptance criteria. The identification of alternative disposal locations would be part of the planning process for a removal action.

This alternative is broken up into seven (7) discrete tasks:

1. Planning and Regulatory Approval
2. Site Preparation
3. Sediment and Erosion Controls
4. Excavation Activities
5. Transport and Disposal of low-level radiation wastes and soils
6. Final Status Survey, Sampling and Reporting
7. Site Restoration

7.3.1. Effectiveness – Alternative 2:

This alternative is protective of human health and the environment by removing and treating all disposed wastes and impacted soils to prevent any future contaminant releases. This option would lead to a complete reduction in the toxicity, mobility and volume of wastes within the disposal cells and would be effective at protecting the environment in the long term.

However, this alternative does not address contaminated groundwater that has migrated beyond the footprint of the Site disposal cells.

7.3.2. Implementability – Alternative 2:

Alternative 2 is implementable. the technology and methodology excavating, screening, analyzing and transporting low-level radiation wastes is well understood and commercially available. The volume, activity and content of each disposal cell is known based on detailed disposal cell records (Appendix A).

Commercial facilities exist that can accept low-level radiation wastes. Site access, including access roads, are all on USFS land, and there the terrain presents no issues with implementing this option.

7.3.3. Cost – Alternative 2:

Costs and assumptions made in the estimate are summarized in Table 7-2. The total present value cost for this alternative is approximately $4,329,520. There will be no post-action O&M costs under this alternative. Five-year review costs are not included in this alternative but are included in all three (3) alternatives to address groundwater. A cost summary is provided in Appendix E.

Table 7-2: Costing Summary of Alternative 2 – Excavation and Off-Site Disposal of All Radiation Wastes and Impacted Soils

Cost Item	Amount	
CAPITAL COST (One Time)		
1.0 Planning and Regulatory Interface	$ 30,000	
2.0 Site Preparation	$ 151,700	
3.0 Erosion Controls	$ 92,100	
4.0 Excavation	$ 592,700	
5.0 Transport and Off-Site Disposal	$ 2,658,050	
6.0 Final Status Survey	$ 172,050	
7.0 Site Restoration	$ 237,100	
O&M COSTS (Annual Costs)		
No O&M Costs	$ 0	
PERIODIC COSTS (Recurring)		
No Periodic Costs	$ 0	
PROJECT MANAGEMENT		
Project Management	10%	
Total Present Value Assessment		
Discount Rate (@5%)	Present Worth	
Estimated Project Total Cost	**$ 4,329,520**	
Estimated Project Total Cost Range (-30% to +50%)	**$ 3,030,650**	**$ 6,494,300**

7.4. Alternative 3: Monitored Natural Attenuation

This alternative includes the monitoring of the existing groundwater plumes. Four (4) new monitoring wells will be installed at the beginning of the monitoring program to delineate the extent of the contaminant plumes migrating to the south and southeast from the site. In addition, baseline groundwater sampling will be conducted to speciate the specific isotopes to support future groundwater monitoring efforts.

It is assumed that reviews of the MNA program would be conducted every 5-years with the recommendation to install an additional two (2) monitoring wells to track the migration of the plume. The additional wells will increase the total O&M costs of the monitoring program.

7.4.1. Effectiveness – Alternative 3:

This alternative would satisfy the NCP threshold for overall protectiveness for human health and the environment with regards to groundwater as long as it is combined with LUCs that prevent using shallow aquifer groundwater within the plume area for potable use. MNA and the maintenance of current LUCs can prevent sensitive receptors from coming into contact with dissolved phase groundwater contaminants.

This alternative would be effective in the short term due to the lack of human receptors in close proximity to site. The distance of the site from existing residential communities and groundwater withdrawal wells combined with the slow measured velocity of plume migration would make this option potentially effective in the long term. High concentrations of dissolved phase. 1,4-dioxane may not degrade to concentrations below FDEP GTCLs in 30-year time frame. Radioactive decay has the potential to greatly reduce peak radionuclide concentrations to levels below FDEP GTCLs in a 30-year time frame.

This alternative would not actively reduce toxicity, mobility, or volume of COCs. Some natural degradation of COCs (e.g., 1,4-dioxane, radionuclides. etc.) is expected.

7.4.2. Implementability – Alternative 3:

MNA requires a regular groundwater monitoring program combined with the periodic installation of additional groundwater monitoring wells. The technology and methods for achieving this are commercially available and have been previously implemented at the site.

7.4.3. Cost – Alternative 3:

Costs and assumptions made in the estimate are summarized on Table 7-3. The total present value cost for this alternative is approximately $968,400. The total capital cost is $71,300 and O&M costs associated with Alternative 1 are $44,100 per year primarily associated with regulatory reporting and administration. This alternative assumes that 5-year reviews will be performed to reassess the potential viability of the MNA Program. It is also assumed that additional wells will be installed every 5 years to track the expanding groundwater plumes. The operational costs, not including the initial capital costs amount to $897,100 (30-year present worth with a 5% discount rate). A cost summary is provided in Appendix E.

7.5. Alternative 4: Targeted Direct Injection and MNA of Groundwater Plumes

This alternative includes a targeted in-situ treatment program to address 1,4-dioxane in groundwater combined with MNA for the remaining low concentrations of 1,4-dioxane and dissolved phase radionuclides in groundwater. All assumptions for MNA are included in this option except for the addition of additional monitoring wells at the commencement of the project.

In-situ treatment for 1,4-dioxane would use Persulfox®, an in-situ chemical oxidation (ISCO) product that is specifically formulated to target 1,4-dioxane, or a similar product. That location is currently adjacent to MW015 (Figure 6), but it may have migrated by the time of the implementation of this alternative.

Table 7-3: Costing Summary of Alternative 3 – MNA for Groundwater Plumes

Cost Item	Amount	
CAPITAL COST (One Time)		
1.0 Additional Well Installation and Rad Speciation	$ 71,300	
O&M COSTS (Annual Costs)		
1.0 Administration	$ 7,200	
2.0 Work Plans for MNA Sampling	$ 2,600	
3.0 MNA Sampling	$ 23,900	
4.0 MNA Reporting	$ 6,500	
PERIODIC COSTS (Recurring)		
1.0 CERCLA Review	$ 15,200	
2.0 Additional Monitoring Well Installations	$ 22,400	
3.0 Additional Monitoring Well MNA Sampling	$ 3,800	
PROJECT MANAGEMENT		
Project Management	10%	
Total Present Value Assessment		
Discount Rate (@5%)	Present Worth	
Estimated Project Total Cost	**$ 968,400**	
Estimated Project Total Cost Range (-30% to +50%)	**$ 677,900**	**$ 1,452,600**

In advance of the full direct injection program, a groundwater characterization program would be implemented to locate, delineate and characterize the ‘hot spot’ of the current 1,4-dioxane plume. This will involve the advancement of 40 temporary groundwater wells in the vicinity of MW015 (Figure 6), and sampling groundwater for 1,4-dioxane.

Based on the groundwater results and other data that has been collected, a limited pilot study or bench scale test will be implemented to identify the ideal injection volumes, and groundwater ratio necessary to treat 1,4-dioxane in groundwater. Conducting a pilot study would reduce the chances of an unsuccessful direct injection program.

It is assumed that a total of 72 injection points will be advanced using Sonic drilling technology, or an equivalent methodology, within the previously identified plume ‘hot spot’ over a period of 8 weeks. A total of approximately 90,000 pounds of Persulfox® would be injected. Approximately 165,000 gallons of water would be required to produce an injection slurry. For this EE/CA, it is assumed that potable water can be obtained and transported to the site in a water trailer or water truck. A sample diagram of injection points is presented in Figure 10.

At the conclusion of the direction injection program, MNA will continue for remaining 1,4-dioxane and select radionuclides. It is assumed that one additional monitoring well will be installed every 5-years upon a review of the MNA program.

7.5.1. Effectiveness– Alternative 4:

This alternative would satisfy the NCP threshold for overall protectiveness for human health and the environment with regards to groundwater as long as it is combined with LUCs that prevent using shallow aquifer groundwater within the plume area for potable use. MNA and the maintenance of current LUCs can prevent sensitive receptors from coming into contact with dissolved phase groundwater contaminants.

This alternative would be effective in the short term due to the lack of human receptors in close proximity to the site. The distance of the site from existing residential communities and groundwater withdrawal wells combined with the slow measured velocity of plume migration would make this option potentially effective in the long term. The aggressive, targeted in-situ treatment of 1,4-dioxane greatly increases the probability of achieving ARARs in a 30-year time span for all groundwater contaminants as compared to Alternative 3.

This alternative would not actively reduce toxicity, mobility, or volume of COCs. Some natural degradation of COCs (e.g., 1,4-dioxane, radionuclides. etc.) is expected; however, due to the observed concentrations, natural degradation is unlikely to meet RAOs within a 30-year window.

7.5.2. Implementability – Alternative 4:

While there are no implementation issues associated with the MNA alternative, some regulatory interface would be required prior to commencing a direct injection program due to the fact that an exogenous substance would be injected into the subsurface at the site, which is located within a National Forest. The proposed technology is commercially available.

7.5.3. Cost - Alternative 4:

Costs and assumptions made in the estimate are summarized on Table 7-4. The total present value cost for this alternative is approximately $1,447,300. The total capital cost, including the direction injection program, is $856,200 and O&M costs associated with Alternative 4 are $32,500 per year primarily associated with MNA sampling, regulatory reporting, and administration. This alternative assumes that 5-year reviews will be performed to reassess the potential viability of the MNA Program. It is assumed that one additional well will be installed every 5 years to track the expanding groundwater plumes. It is assumed that the successful in-situ treatment of high concentrations of 1,4-dioxane in groundwater will allow existing monitoring wells to be removed from annual MNA sampling to maintain constant MNA sampling costs over 30 years. Operational costs, not including the initial capital costs amount to $591,700 (30-year present worth with a 5% discount rate). A cost summary is provided in Appendix E.

Table 7-4: Costing Summary of Alternative 4 – Targeted In-Situ Treatment for 1,4-Dioxane and Monitored Natural Attenuation of Groundwater Plumes

Cost Item	Amount	
CAPITAL COST (One Time)		
1.0 Planning	$	7,200
2.0 Radionuclide Speciation in Groundwater	$	34,500
3.0 Pre-Injection Characterization	$	71,500
4.0 Bench Scale Testing	$	45,400
5.0 Direct Injection of Persulfox® to treat 1,4-dioxane	$	619,800
O&M COSTS (Annual Costs)		
1.0 Administration	$	3,600
2.0 Work Plans for MNA Sampling	$	2,880
3.0 MNA Sampling	$	19,500
4.0 MNA Reporting	$	3,600
PERIODIC COSTS (Recurring)		
1.0 CERCLA Review	$	15,200
2.0 Additional Monitoring Well Installations	$	15,000
PROJECT MANAGEMENT		
Project Management		10%
Total Present Value Assessment		
Discount Rate (@5%)	Present Worth	
Estimated Project Total Cost	**$**	**1,447,900**
Estimated Project Total Cost Range (-30% to +50%)	**$ 1,013,500**	**$ 2,171,800**

7.6. Alternative 5: Full Scale Ex-Situ Treatment System

This alternative includes the implementation of a pump and treat (P&T) system to treat 1,4-dioxane and radionuclides in groundwater until all groundwater contamination has been addressed and all ARARs have been achieved.

Two (2) interceptor trenches would be installed, one at the leading edge of the identified plumes, and one through the center line of the area of high 1,4-dioxane concentrations. Sump wells would be installed within the interceptor trenches, that would be connected to submersible pumps to feed a groundwater treatment system with the capacity to treat up to 200 gallons per minute (gpm). A potential interceptor trench alignment is presented as Figure 11.

A treatment train that will include a hydrogen peroxide and ozone chemical oxidation treatment plant as well as high capacity filtration units, resin interchange tanks and pH treatment tanks to remove dissolved phase alpha-emitting radionuclides from groundwater. Treated water would be routed to a series of high capacity injection wells located hydraulically upgradient of the interceptor trenches so that groundwater will not be released until it is clean. A potential interceptor trench alignment, complete with proposed locations for injection wells is presented as Figure 11.

Prior to installing a full-scale system, a bench scale study would be conducted to verify the efficacy of the proposed treatment train and to make necessary adjustments to the final design.

As stated in Section 4.1.1.2, a total volume of the comingled groundwater plumes that were identified and delineated during the 2018 Phase II ESI is estimated at 30 million gallons. Depending on actual retardation factors for 1,4-dioxane and radionuclides in groundwater, it would be necessary to flush two to five plume volumes of groundwater to achieve GTCLs in groundwater. This is would mean that up to 150 million gallons of groundwater would require treatment. It is assumed that pumping rates of 200 GPM may not be sustainable within the aquifer system on a perpetual basis.

It is assumed that a treatment train will be under operation for a period of one year at full capacity or close to full capacity which involves operation 24 hours per day and 7 days per week. Subsequently, the plant would be operated at half capacity for a period of 2 years, consisting of 12-hour operations 7 days per week. Subsequent to that, the plant would be run for a period of 3 years at one-third capacity consisting of a single 8-hour shift per day for 200 days per year. This treatment system assumes that all groundwater contamination can be addressed within 6 years.

Following successful treatment of the groundwater plumes, the treatment plan would be disassembled and removed from the site. The submersible pumps, piping and tubing to the interceptor trenches would be removed. The interceptor trenches would remain at the site and be graded over to return the site to its' original condition.

This alternative assumes that two (2) five-year reviews will be completed during the operation of a pump and treat system and that annual groundwater monitoring would continue at the site for four years after the cessation of pump and treatment plant operations

7.6.1. Effectiveness – Alternative 5:

This alternative would satisfy the NCP threshold for overall protectiveness for human health and the environment with regards to groundwater as it is designed to address all current groundwater contamination that will remain in the vicinity of site after a successful source removal.

The potential to capture all contaminated groundwater and to treat organic constituents and radionuclides would achieve short term effectiveness by preventing further plume migration and long-term effectiveness by either treating or removing all dissolved phase contaminants in groundwater. A complete reduction in the toxicity, mobility and volume of dissolved phase contaminants would potentially be achieved.

7.6.2. Implementability – Alternative 5:

All costs associated with installing and operating a pump and treat system are high due to the remote location of site and the lack of existing facilities at the site. This alternative would require a substantial mobilization of infrastructure in the vicinity of the site that include:

- Installing of an interceptor trench requiring extensive ground disturbance and vegetation clearing
- Installation of a remote power system at the site which does not currently have any facilities for power, water, gas or sewer.
- Installation of a complex treatment train to address multiple contaminants

Furthermore, operational costs will be very high due to the high maintenance requirements of associated with an active pump and treat system.

Implementation and operation of an active P&T system within the Apalachicola National Forest has the potential to disrupt forest activities.

7.6.3. Cost – Alternative 5:

Costs and assumptions made in the estimate are summarized on Table 7-5. The total present value cost for this alternative is approximately $17,466,200. The total capital costs, including the installation of the interreceptor trenches and the construction of a groundwater pump and treat system program are

$2,009,400. O&M costs associated with Alternative 1 are $4,852,700 per year for the first year, primarily associated with operation of the P&T system. These costs would reduce to $3,031,100 per year for the following two-years and $2,290,200 for an additional three-years. At this point, it is assumed the groundwater plume will have been successfully treated and the system can be removed from the site. Annual groundwater monitoring would continue for a period of four (4) years after the cessation of treatment plant operations. Five-year reviews would be conducted during treatment plant operations and groundwater monitoring.

The total project costs amount to $19,471,750 (30-year present worth with a 5% discount rate). A cost summary is provided in Appendix E.

Table 7-5: Costing Summary of Alternative 5 – Interceptor Trenches and Pump and Treat System to Address 1,4-Dioxane and Radionuclides

Cost Item	Amount	
CAPITAL COST (One Time)		
1.0 Bench Scale Studies	$	62,600
2.0 Interceptor Trench Installation	$	1,222,400
3.0 Injection Well Installation	$	63,000
4.0 Pump and Treat System Installation	$	393,000
O&M COSTS (Annual Costs)		
1.0 Annual Monitoring Costs	$	103,300
2.0 Pump and Treat System Operational Costs	$	4,288,800
3.0 Annual Groundwater Monitoring	$	19,500
PERIODIC COSTS (Recurring)		
1.0 CERCLA Review	$	15,200
PROJECT MANAGEMENT		
Project Management		10%
Total Present Value Assessment		
Discount Rate (@5%)	Present Worth	
Estimated Project Total Cost	**$**	**19,466,200**
Estimated Project Total Cost Range (-30% to +50%)	**$ 12,266,400**	**$ 26,200,300**

8. COMPARATIVE ANALYSIS OF REMOVAL ALTERNATIVES

Five (5) alternatives have been presented for the Site comprising one (1) No Action alternative, one (1) alternative for removing disposed wastes and three (3) alternatives for capturing and treating groundwater contamination resulting from those disposed wastes. A comparison of the relative implementability, effectiveness and cost of each alternative is presented in Table 8-1.

Alternatives 3, 4 and 5 are targeted at existing, groundwater contamination resulting from past contaminant releases at the site. The completion of these three (3) alternatives assumes the successful source removal and closure of the site (Alternative 2) preventing any future contaminant releases into groundwater.

Table 8-1: Removal Options Summary Comparison

Alternative	Implementability	Effectiveness	Cost ($)
1. No Action	**High:** Requires only administrative controls	**Low:** 1. Will not achieve Applicable, Relevant and Appropriated Requirements (ARARs) or RAOs. 2. No reduction in toxicity, mobility, or volume.	**Low:** $0*
2. Soil Excavation and off-site disposal	**Moderate to High:** Excavation and off-site disposal of low-level radiological wastes requires commercially available technology and methods and follows established regulator guidelines. Would require regulatory interface with appropriate regulatory bodies and approvals prior to commencing sitework.	**High:** 1. Will achieve RAOs.	**High:** $4,329,500 (Range $3,030,700-$6,494,300)
3. Monitored Natural Attenuation	**High:** Requires additional sampling and monitoring well installation. No regulatory requirements preventing implementation of this alternative.	**Moderate:** Will not directly lead to reduction in toxicity, mobility, or volume of groundwater contamination, but site remoteness and slow plume migration velocity may be protective of human health.	**Moderate:** $968,400 (Range $677,900-$1,452,600)
4. Targeted Direct Injection of ISCO amendment and MNA for other contaminants	**Moderate to High:** Targeted direct injection would require approvals and regulatory interface, though these are not assumed to be overly burdensome.	**Moderate to High:** Will to significant reduction in toxicity, mobility, or volume of groundwater contamination, but some contamination will remain to be managed through long term monitoring.	**Moderate:** $1,447,900 (Range $1,013,500 - $2,171,800)
5. Interceptor Trench and Ex-situ Treatment Train to	**Moderate to High:** Scale of system would require extensive site improvements at the Site and require the permitting for injection wells that would involve a potentially high level of regulatory interface. Operations would have the potential to significantly disturb normal forest activities.	**High:** Successful installation and operation of an ex-situ system would lead to complete reduction in toxicity, mobility and volume of groundwater contamination.	**High:** $19,466,200 (Range $12,226,400-$26,199,300)

*For the purposes of this EE/CA, the no action alternative has a cost of $0. However, there are costs associated with a no-action alternative that include maintenance of access roads, permitting and regulatory interface with FSU concerning the site, and the needs for periodic surveys and site visits to assess the condition of current site land use controls that include site security fencing.

9. RECOMMENDED REMOVAL ACTION ALTERNATIVES

The recommended removal action alternatives were selected based on the analysis summarized in Section 8 and in Table 8-1. Alternative 2 and Alternative 4 performed in sequence are the recommended alternatives for the site. The rationale for selecting these recommended alternatives is explained below:

Alternative 2:

Capital Cost: $4,329,500 Annual Cost: $0

> Under Alternative 2, all radioactive materials that were placed in disposal cells and impacted soils within these pits would be removed. This would prevent any potential future releases from occurring and would allow the site to be returned to unrestricted use upon release from the radioactive materials license.

Alternative 4:

Capital Cost: $1,447,900 Annual Cost: $32,483

> Alternative 4 is the selected removal action alternative to address off-site groundwater plumes (Figures 6 and 7). Alternative 4 and Alternative 5 both address dissolved phase 1,4-dioxane groundwater plumes (Figure 6). Unlike Alternative 5, Alternative 4 does not directly address unspeciated alpha emitting isotopes in groundwater (Figure 7). Alpha emitting isotopes were detected at peak concentrations three (3) multiples of the EPA Drinking Water Standards and FDEP GTCLs. 1,4-dioxane was detected at concentrations more than 100 multiples of the FDEP GTCL.
>
> When all radioactive materials have been removed from the FSU-LLRW disposal cells (Alternative 2), alpha emitting isotopes are likely to dilute from peak concentrations to below FDEP GTCLs. 1,4-dioxane in off-site groundwater is likely to remain present at concentrations above FDEP GTCLs for a longer period of time and is considered the issue to be addressed. Alternative 4 will be significantly less expensive to implement than Alternative 5 and will involve less site disturbance and/or permanent alteration of NF lands.

The total estimated costs for the implementation of these proposed alternatives in combination is $5,776,400, and the estimated average annual O&M cost is $32,493, including groundwater monitoring.

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SITE FIGURES

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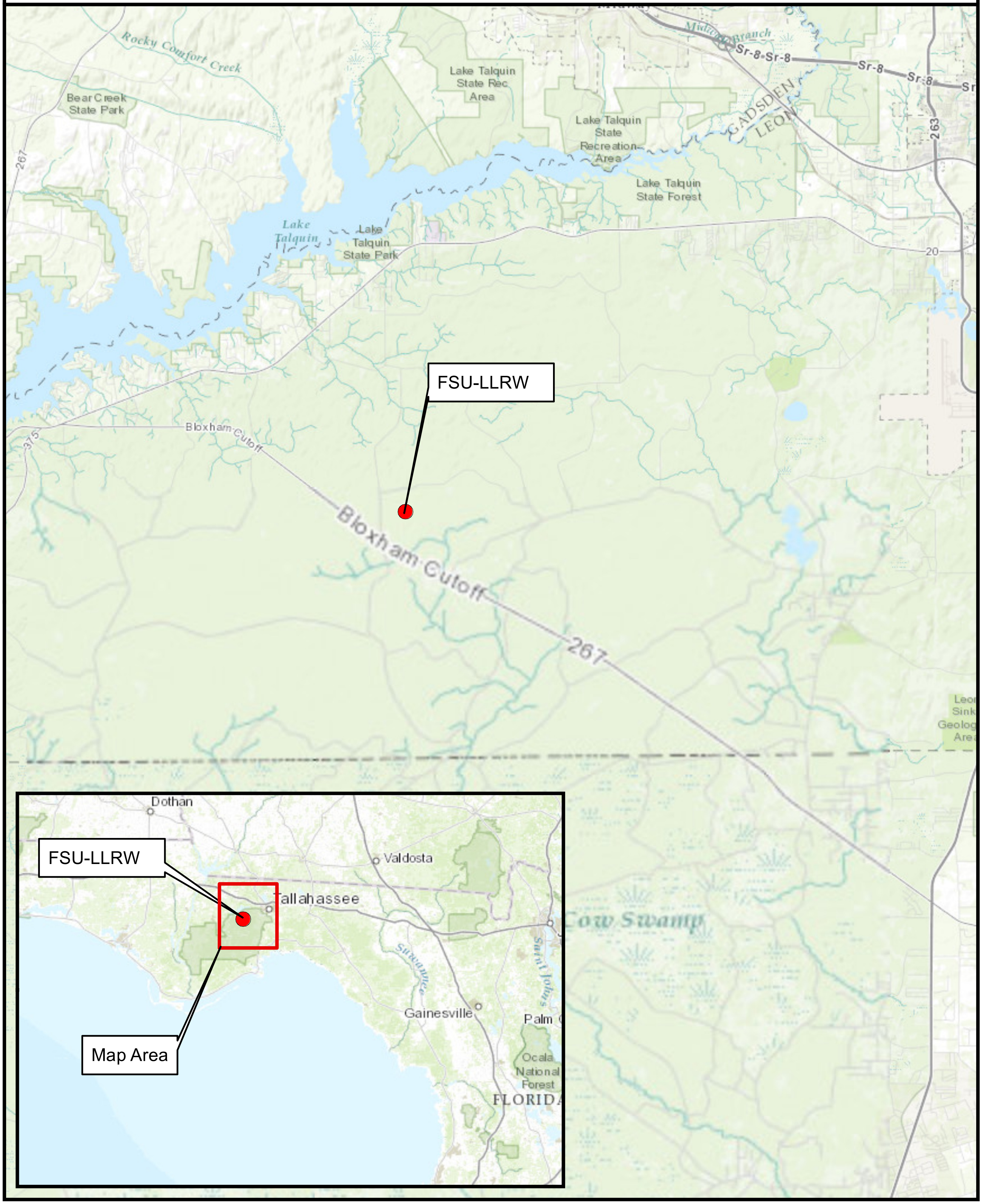
USDA Forest Service - Region 8

Figure 1. FSU-LLRW Site Location Map

0 1.5 3 6 Miles

D. Schanzle
10/09/2016



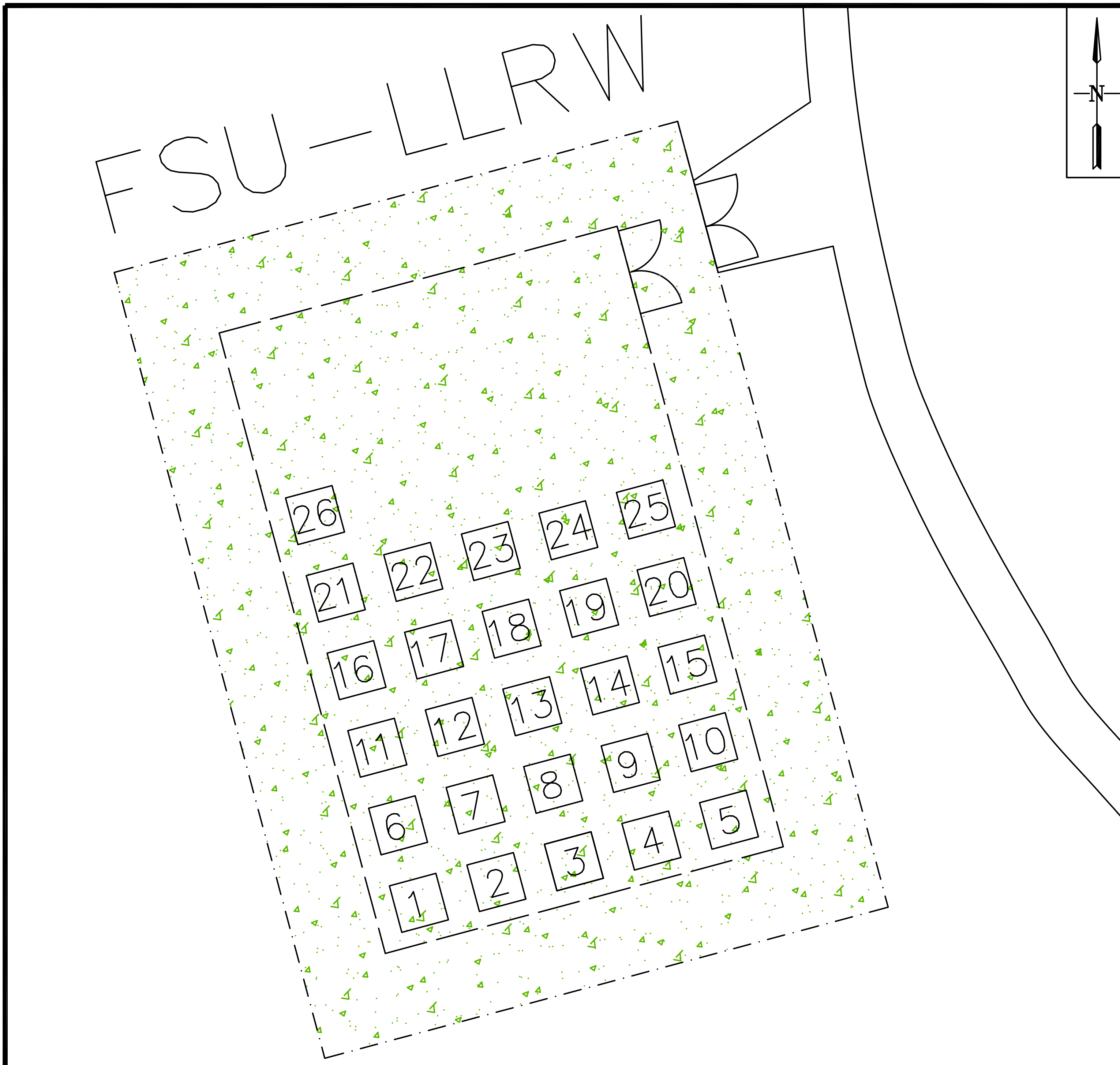


Figure 2.

FSU—LLRW
Site Detail Map

Apalachicola
National Forest
Leon County
Florida

Legend

- Chain Link Fence
- Barbed Wire Fence
- Access Road
- Access Gate
- 16 Radiation Burial Pit

Florida Key Map

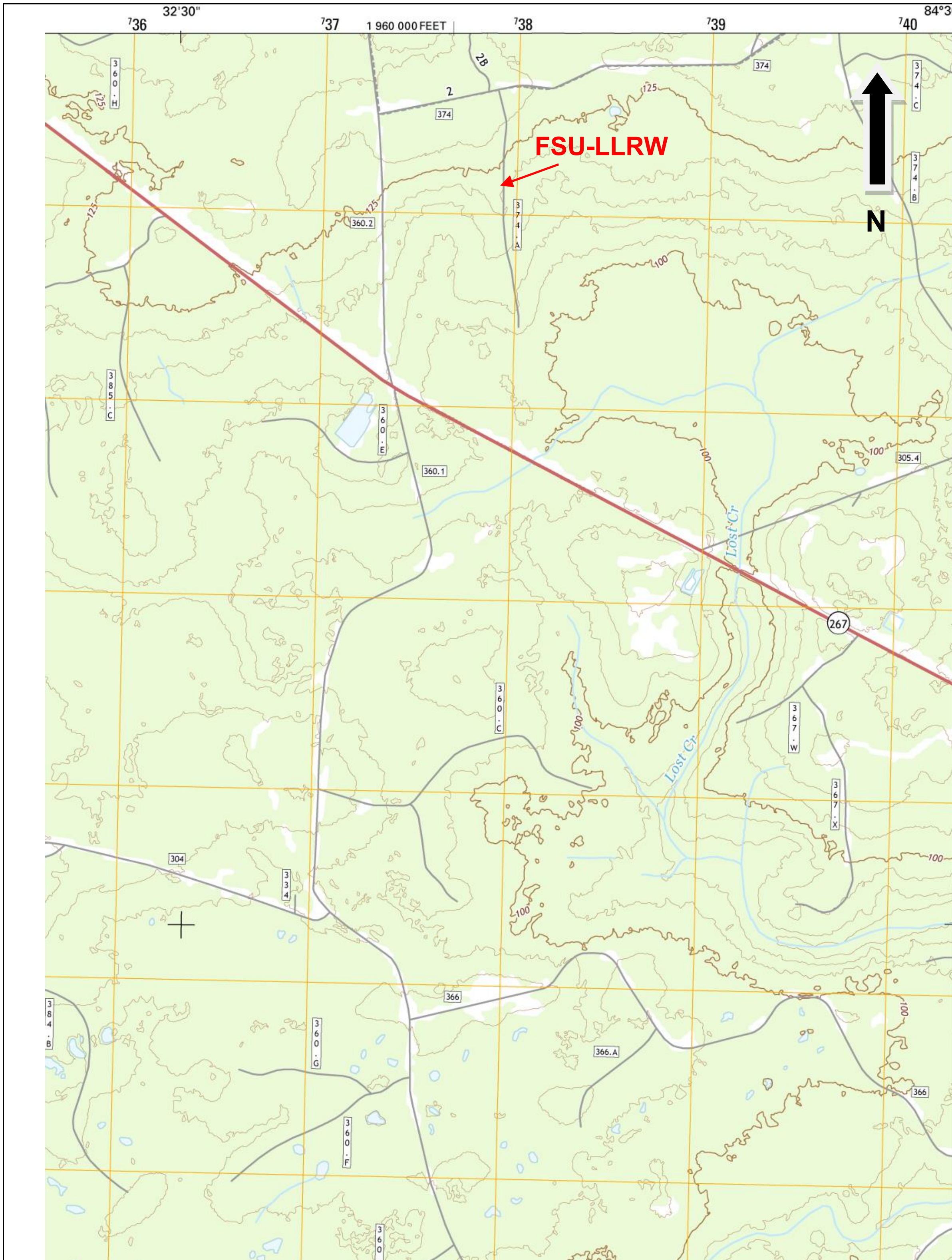


Figure 3: 7.5 Minute Topographic Map
FSU-LLRW
Apalachicola National Forest, Leon County, Florida
N30°22'6.86"N" W84°31'29.93"
7.5 Minute Topographic Map
Lake Talquin SE Quadrangle
Scale: 1” = 2,200 feet
Source: USGS, 2015

Map Unit Symbol	Map Unit Name
23	Leon Sand
47	Talquin Fine Sand
9	Dorovan Mucky Peat

Streams and Canals

Figure 4: National Resource Conservation Soil Map
FSU_LLRW
Apalachicola National Forest
N 30°22'6.86" W84°31'29.93"
Source: USDA Web Soil Survey (NRCS, 2016)
Approximate Scale: 1" = 80 feet

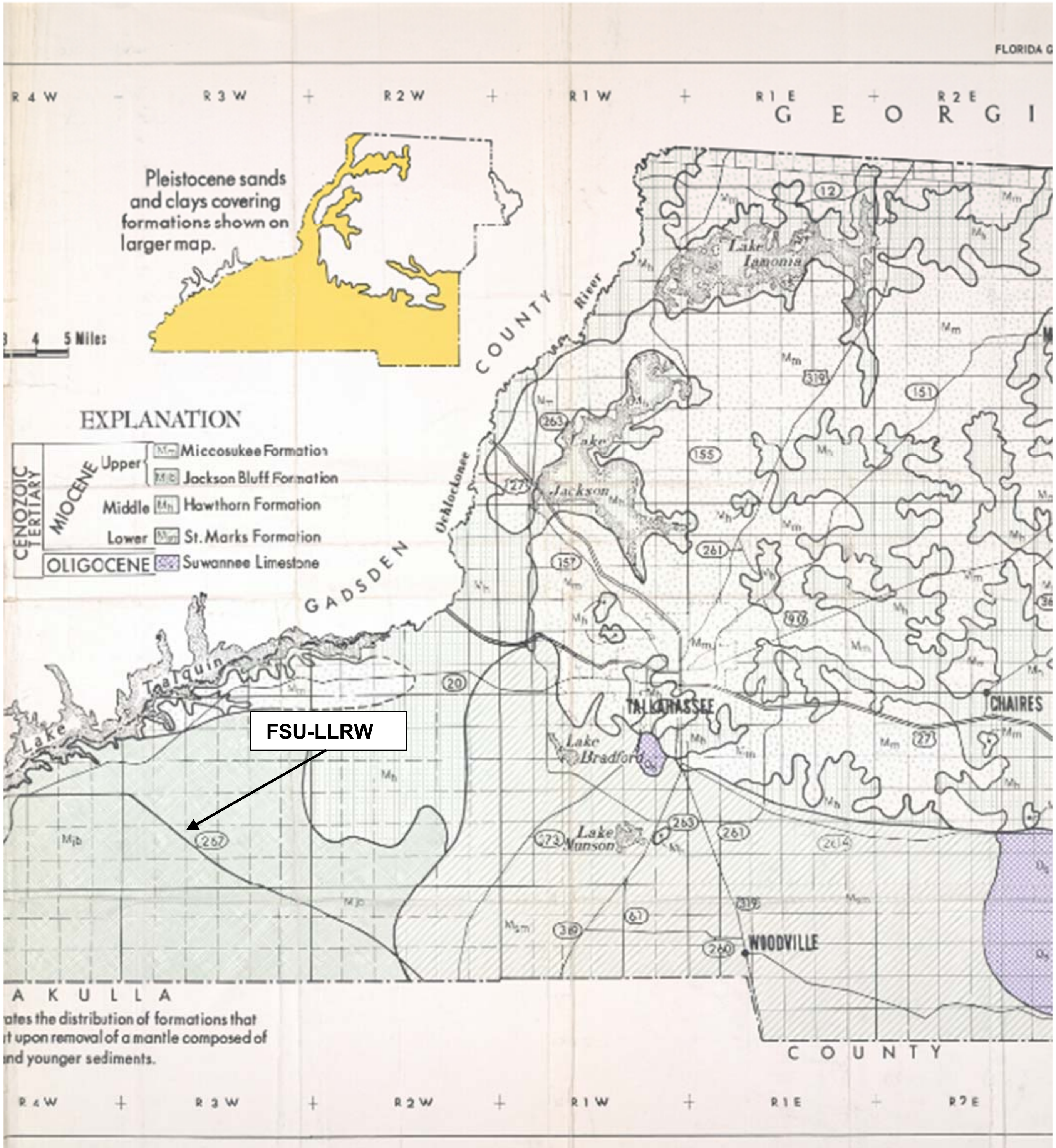


Figure 5: Subsurface Geology Map
FSU-LLRW
Apalachicola National Forest
N30°22'6.86" W 84°31'29.93"
Geologic Map of Leon County Florida
Source: State of Florida State Boar of Conservation Division of Geology, 1966
Approximate Scale: 1" = 5 miles

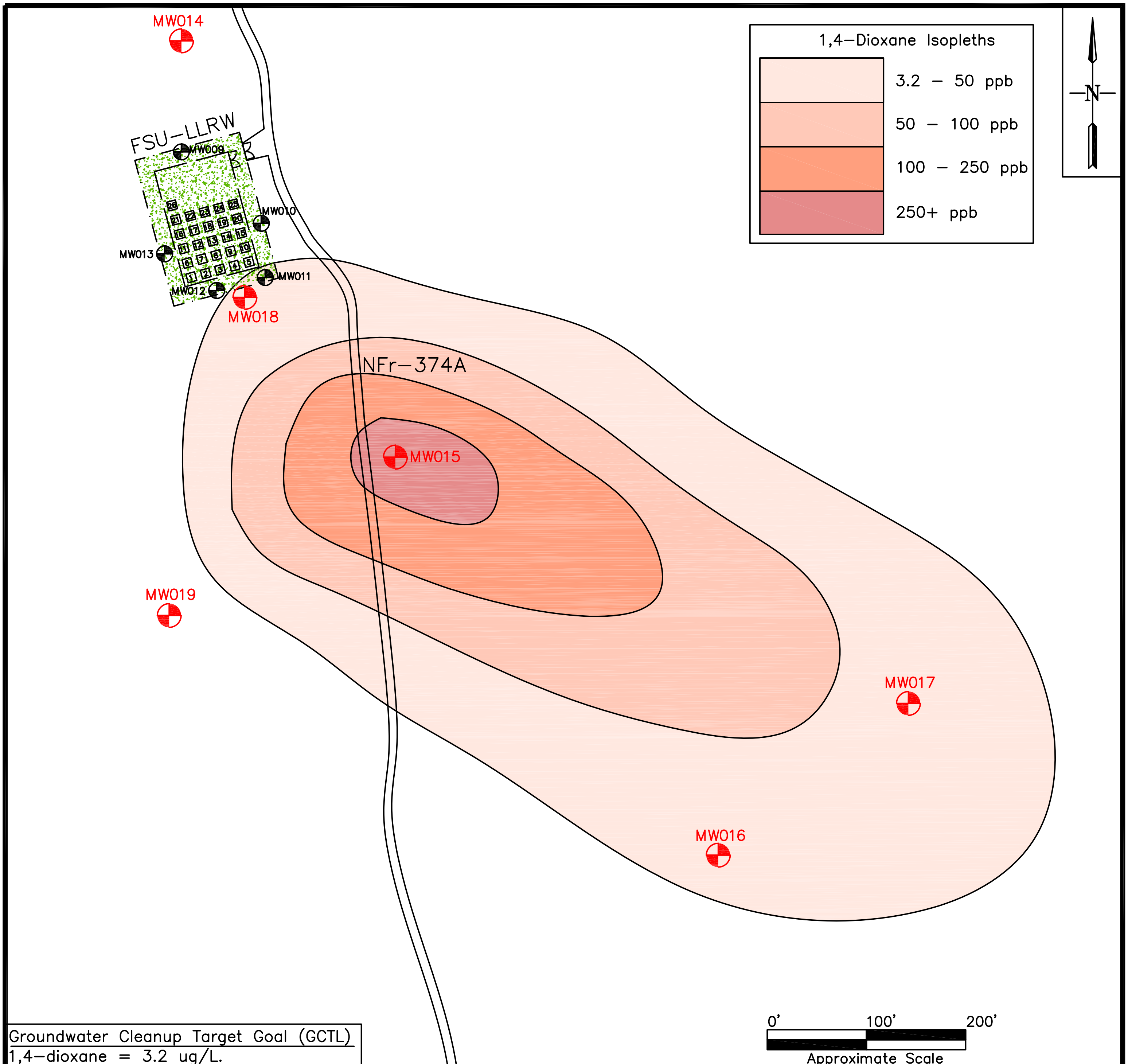


Figure 6.

FSU–LLRW
1,4–dioxane groundwater isopleth plume map
2018 Phase II ESI

Apalachicola National Forest
Leon County
Florida

Legend

- On–site Monitoring Well
- Off–site Monitoring Well Location
- Access Road
- Access Gate
- 16 Radiation Burial Pit

Florida Key Map

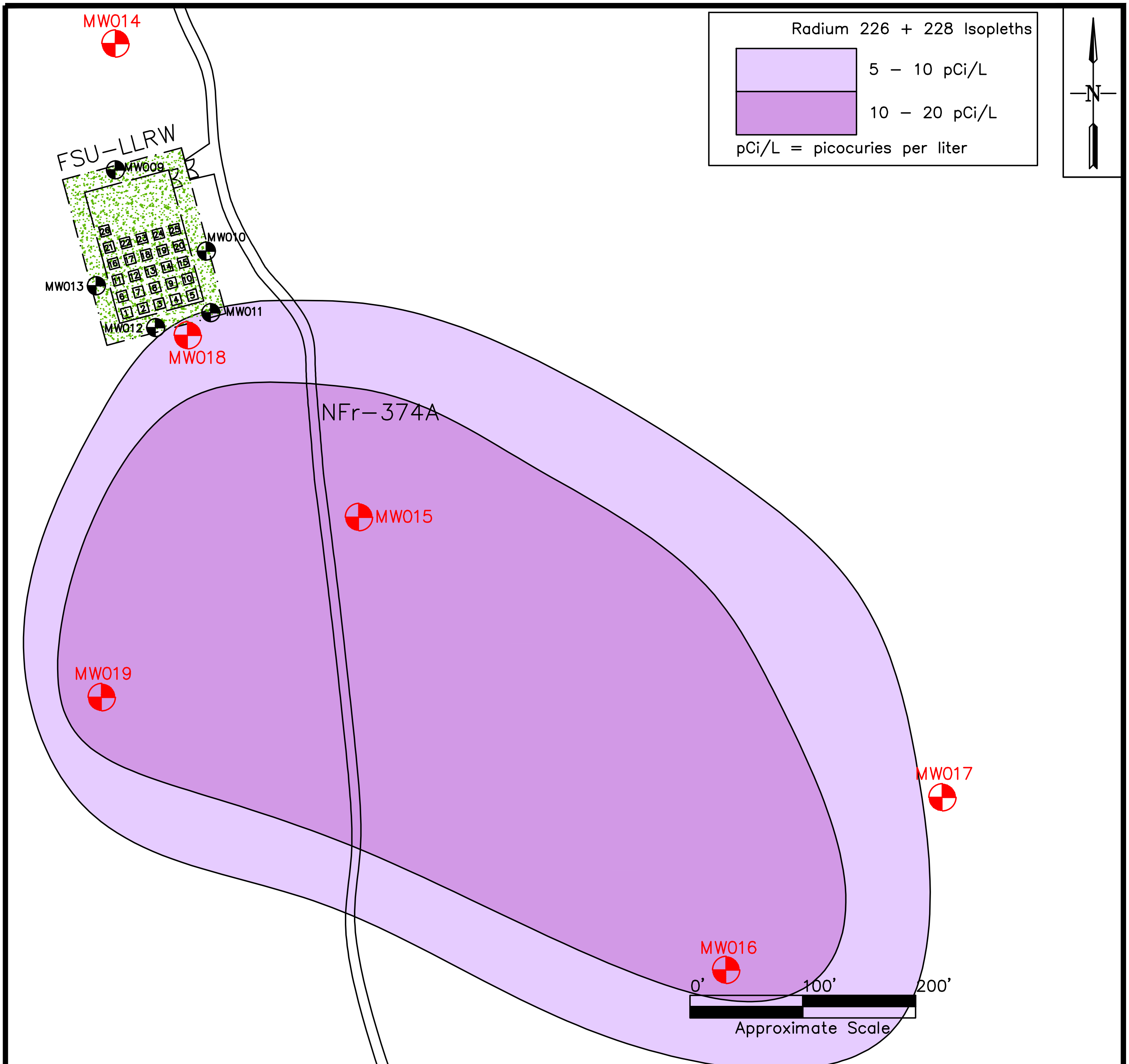


Figure 7.

FSU–LLRW
Radium 226 + 228
isopleth plume map
2018 Phase II ESI

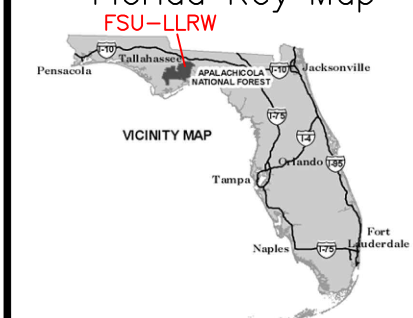
Apalachicola
National Forest
Leon County
Florida

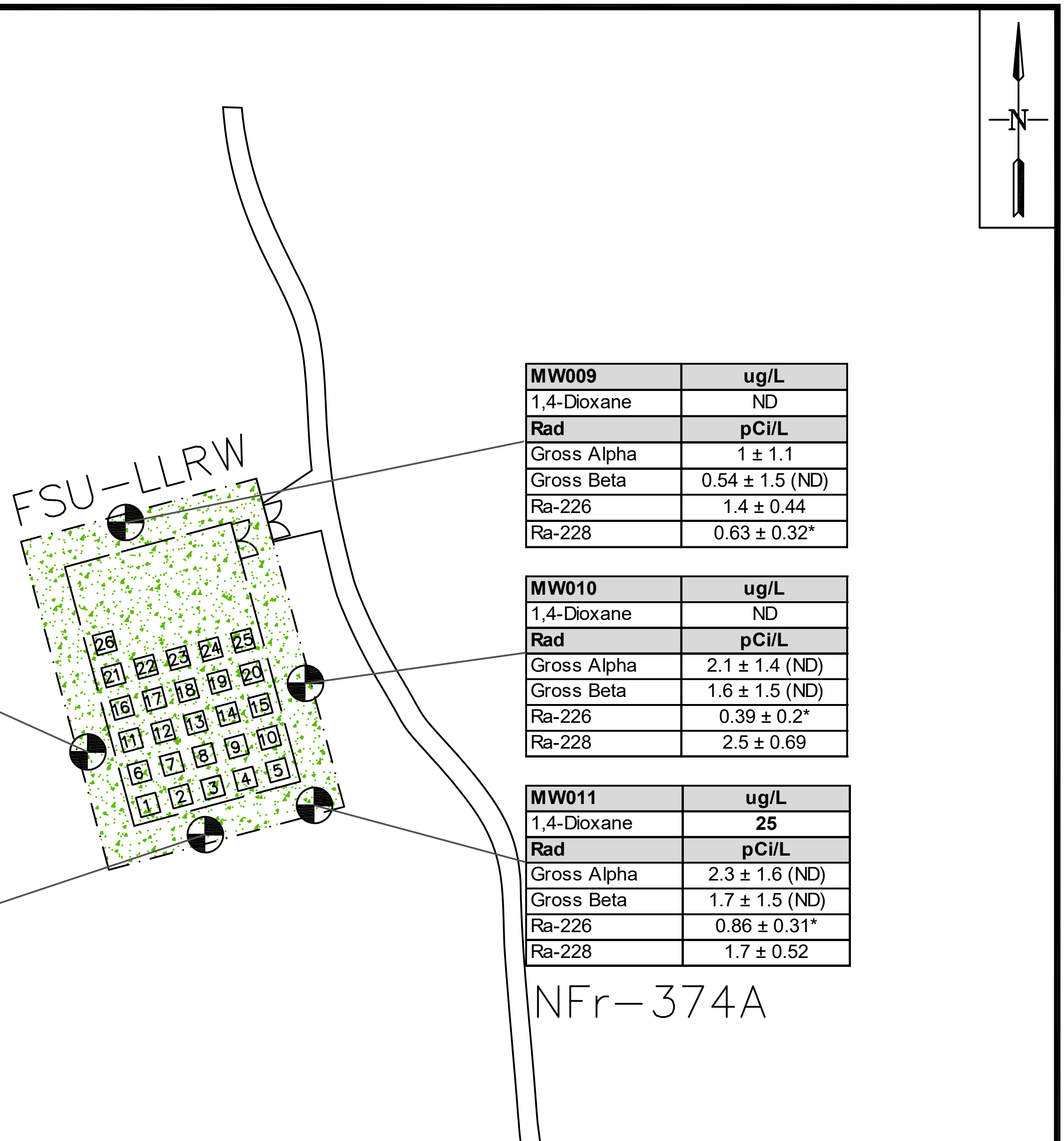
Legend

- Permanent Monitoring Well Location
- Temporary Piezometer Well Location
- Direct Push Georpobe GW Sample Location
- Access Road
- Access Gate
- 16 Radiation Burial Pit

Groundwater Cleanup Target Goal (GCTL)
Radium 226 + 228 = 5 pCi/L

Florida Key Map





MW013	ug/L
1,4-Dioxane	ND
Rad	**pCi/L**
Gross Alpha	2.2 ± 1.7 (ND)
Gross Beta	1 ± 1.5 (ND)
Ra-226	0.75 ± 0.33*
Ra-228	1.6 ± 0.51

MW012	ug/L
1,4-Dioxane	ND
Rad	**pCi/L**
Gross Alpha	1.3 ± 1.4 (ND)
Gross Beta	3.6 ± 1.7 (ND)
Ra-226	0.61 ± 0.27*
Ra-228	0.99 ± 0.41*

MW009	ug/L
1,4-Dioxane	ND
Rad	**pCi/L**
Gross Alpha	1 ± 1.1
Gross Beta	0.54 ± 1.5 (ND)
Ra-226	1.4 ± 0.44
Ra-228	0.63 ± 0.32*

MW010	ug/L
1,4-Dioxane	ND
Rad	**pCi/L**
Gross Alpha	2.1 ± 1.4 (ND)
Gross Beta	1.6 ± 1.5 (ND)
Ra-226	0.39 ± 0.2*
Ra-228	2.5 ± 0.69

MW011	ug/L
1,4-Dioxane	**25**
Rad	**pCi/L**
Gross Alpha	2.3 ± 1.6 (ND)
Gross Beta	1.7 ± 1.5 (ND)
Ra-226	0.86 ± 0.31*
Ra-228	1.7 ± 0.52

0' 100' 200'

Approximate Scale

Note: GCTL Exceedances in Bold

Groundwater Cleanup Target Goal (GCTL)

1,4-dioxane = 3.2 ug/L.
Gross Alpha = 15 pCi/L
Radium 226 +228 = 5 pCi/L
ND = Analyte Not Detected
* = Result less than requested MDC and greater than sample specific MDC
MDC = method detection concentration

Figure 8.

FSU-LLRW
On-Site Monitoring Well Sampling Results

Apalachicola National Forest
Leon County
Florida

Legend

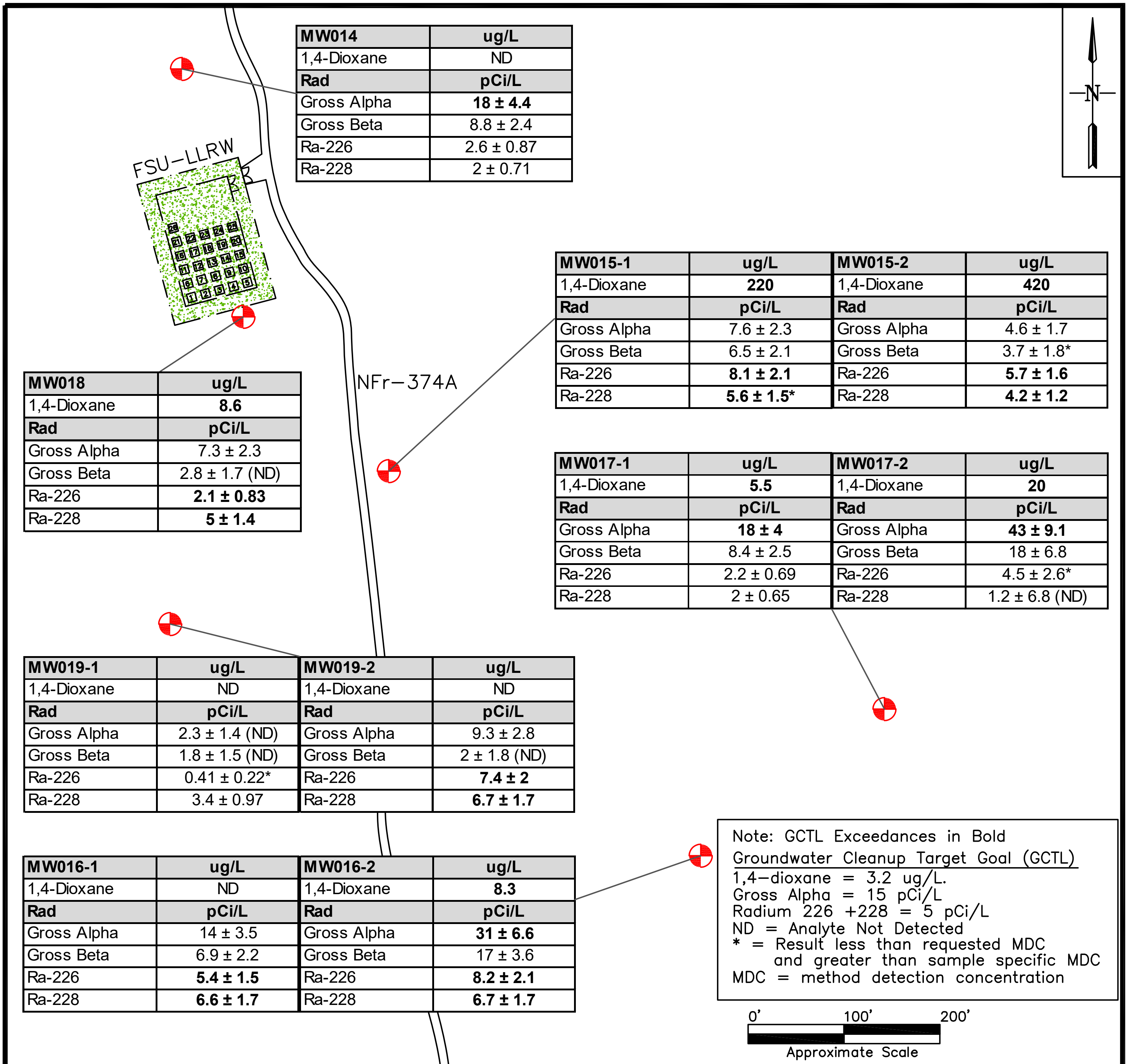
On-site Monitoring Well Location

Access Road

Access Gate

16 Radiation Burial Pit

Florida Key Map



MW014	ug/L
1,4-Dioxane	ND
Rad	**pCi/L**
Gross Alpha	**18 ± 4.4**
Gross Beta	8.8 ± 2.4
Ra-226	2.6 ± 0.87
Ra-228	2 ± 0.71

MW018	ug/L
1,4-Dioxane	**8.6**
Rad	**pCi/L**
Gross Alpha	7.3 ± 2.3
Gross Beta	2.8 ± 1.7 (ND)
Ra-226	**2.1 ± 0.83**
Ra-228	**5 ± 1.4**

MW015-1	ug/L	MW015-2	ug/L
1,4-Dioxane	**220**	1,4-Dioxane	**420**
Rad	**pCi/L**	**Rad**	**pCi/L**
Gross Alpha	7.6 ± 2.3	Gross Alpha	4.6 ± 1.7
Gross Beta	6.5 ± 2.1	Gross Beta	3.7 ± 1.8*
Ra-226	**8.1 ± 2.1**	Ra-226	**5.7 ± 1.6**
Ra-228	**5.6 ± 1.5***	Ra-228	**4.2 ± 1.2**

MW017-1	ug/L	MW017-2	ug/L
1,4-Dioxane	**5.5**	1,4-Dioxane	**20**
Rad	**pCi/L**	**Rad**	**pCi/L**
Gross Alpha	**18 ± 4**	Gross Alpha	**43 ± 9.1**
Gross Beta	8.4 ± 2.5	Gross Beta	18 ± 6.8
Ra-226	2.2 ± 0.69	Ra-226	4.5 ± 2.6*
Ra-228	2 ± 0.65	Ra-228	1.2 ± 6.8 (ND)

MW019-1	ug/L	MW019-2	ug/L
1,4-Dioxane	ND	1,4-Dioxane	ND
Rad	**pCi/L**	**Rad**	**pCi/L**
Gross Alpha	2.3 ± 1.4 (ND)	Gross Alpha	9.3 ± 2.8
Gross Beta	1.8 ± 1.5 (ND)	Gross Beta	2 ± 1.8 (ND)
Ra-226	0.41 ± 0.22*	Ra-226	**7.4 ± 2**
Ra-228	3.4 ± 0.97	Ra-228	**6.7 ± 1.7**

MW016-1	ug/L	MW016-2	ug/L
1,4-Dioxane	ND	1,4-Dioxane	**8.3**
Rad	**pCi/L**	**Rad**	**pCi/L**
Gross Alpha	14 ± 3.5	Gross Alpha	**31 ± 6.6**
Gross Beta	6.9 ± 2.2	Gross Beta	17 ± 3.6
Ra-226	**5.4 ± 1.5**	Ra-226	**8.2 ± 2.1**
Ra-228	**6.6 ± 1.7**	Ra-228	**6.7 ± 1.7**

Note: GCTL Exceedances in Bold
Groundwater Cleanup Target Goal (GCTL)
1,4-dioxane = 3.2 ug/L.
Gross Alpha = 15 pCi/L
Radium 226 +228 = 5 pCi/L
ND = Analyte Not Detected
* = Result less than requested MDC and greater than sample specific MDC
MDC = method detection concentration

Figure 9.

FSU-LLRW
Off-Site Monitoring Well Sampling Results

Apalachicola National Forest
Leon County
Florida

Legend

Off-site Monitoring Well Location
Access Road
Access Gate
16 Radiation Burial Pit

Florida Key Map

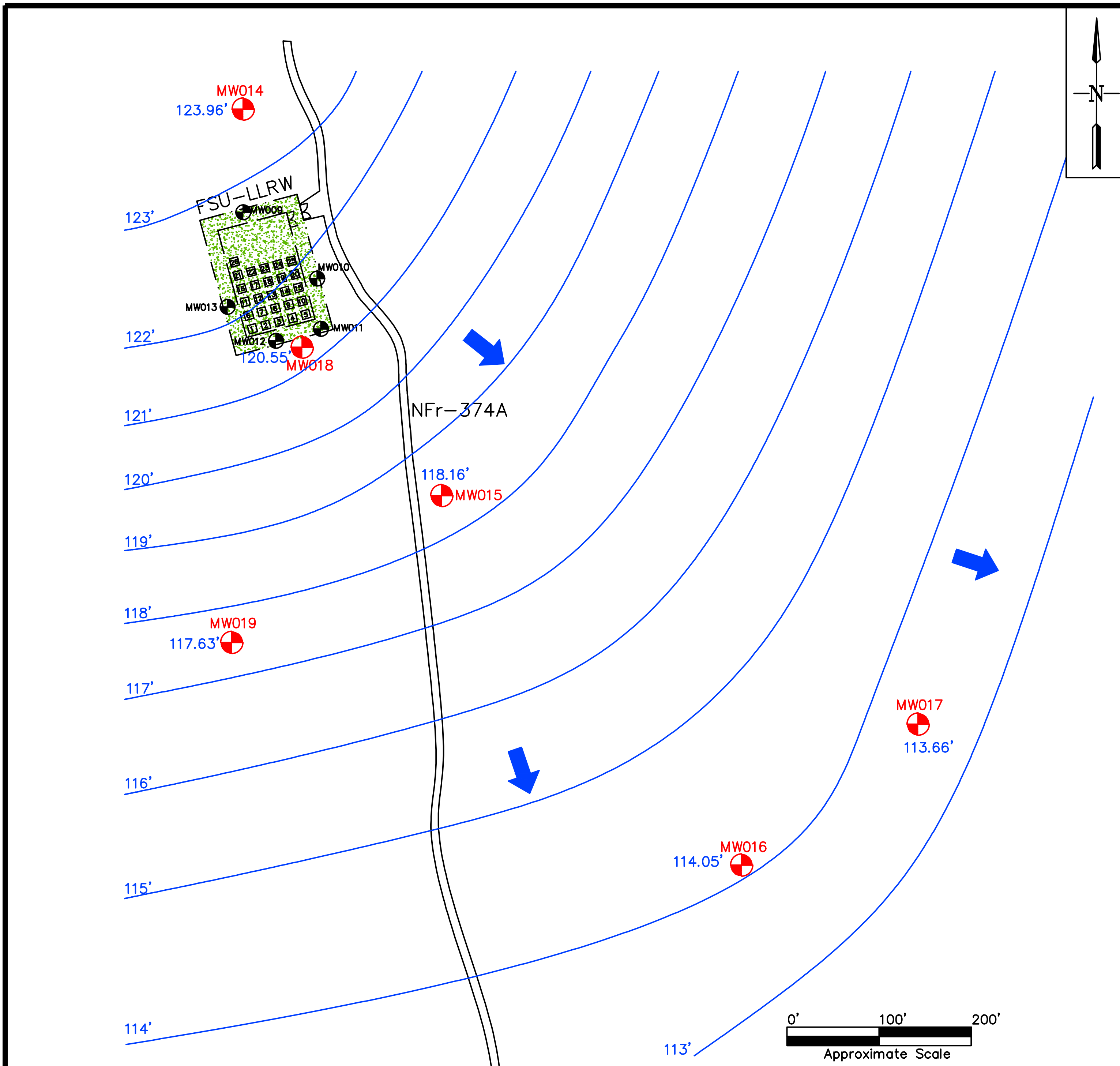


Figure 10.

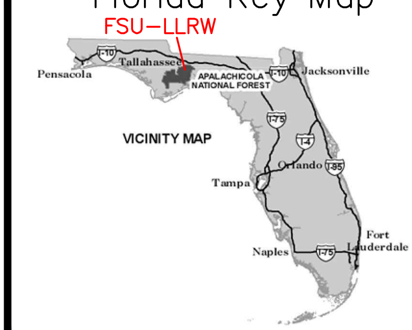
FSU-LLRW
GW Elevation Contours
Well Gauging 01/13/2018

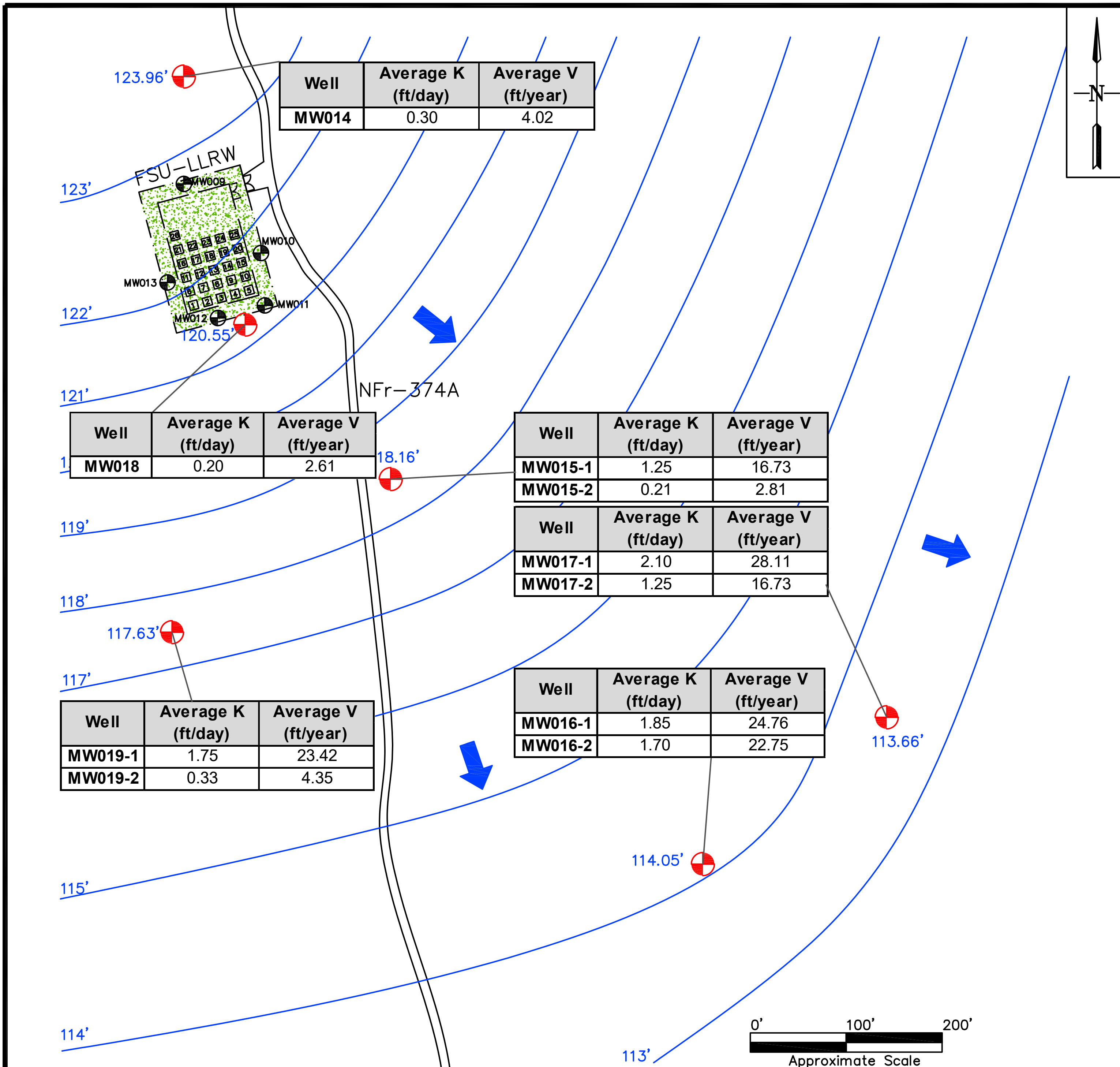
Apalachicola
National Forest
Leon County
Florida

Legend

- On-site Monitoring Well Location
- Off-site Monitoring Well Location
- 121' Extrapolated GW Elevation Contour (2018)
- Extrapolated Primary Groundwater Flow Direction
- Access Road
- Access Gate
- 16 Radiation Burial Pit

Florida Key Map





Well	Average K (ft/day)	Average V (ft/year)
MW014	0.30	4.02

Well	Average K (ft/day)	Average V (ft/year)
MW018	0.20	2.61

Well	Average K (ft/day)	Average V (ft/year)
MW015-1	1.25	16.73
MW015-2	0.21	2.81

Well	Average K (ft/day)	Average V (ft/year)
MW017-1	2.10	28.11
MW017-2	1.25	16.73

Well	Average K (ft/day)	Average V (ft/year)
MW019-1	1.75	23.42
MW019-2	0.33	4.35

Well	Average K (ft/day)	Average V (ft/year)
MW016-1	1.85	24.76
MW016-2	1.70	22.75

Figure 11.

FSU–LLRW
GW Elevation Contours
Aquifer Testing Tag Map
Data Collected 01/2018

Apalachicola
National Forest
Leon County
Florida

Legend

- On–site Monitoring Well Location
- Off–site Monitoring Well Location
- 121’ Extrapolated GW Elevation Contour (2018)
- Extrapolated Primary Groundwater Flow Direction
- Access Road
- Access Gate
- 16 Radiation Burial Pit

Florida Key Map

FSU–LLRW

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APPENDIX A

Site Disposal Pit Burial Records

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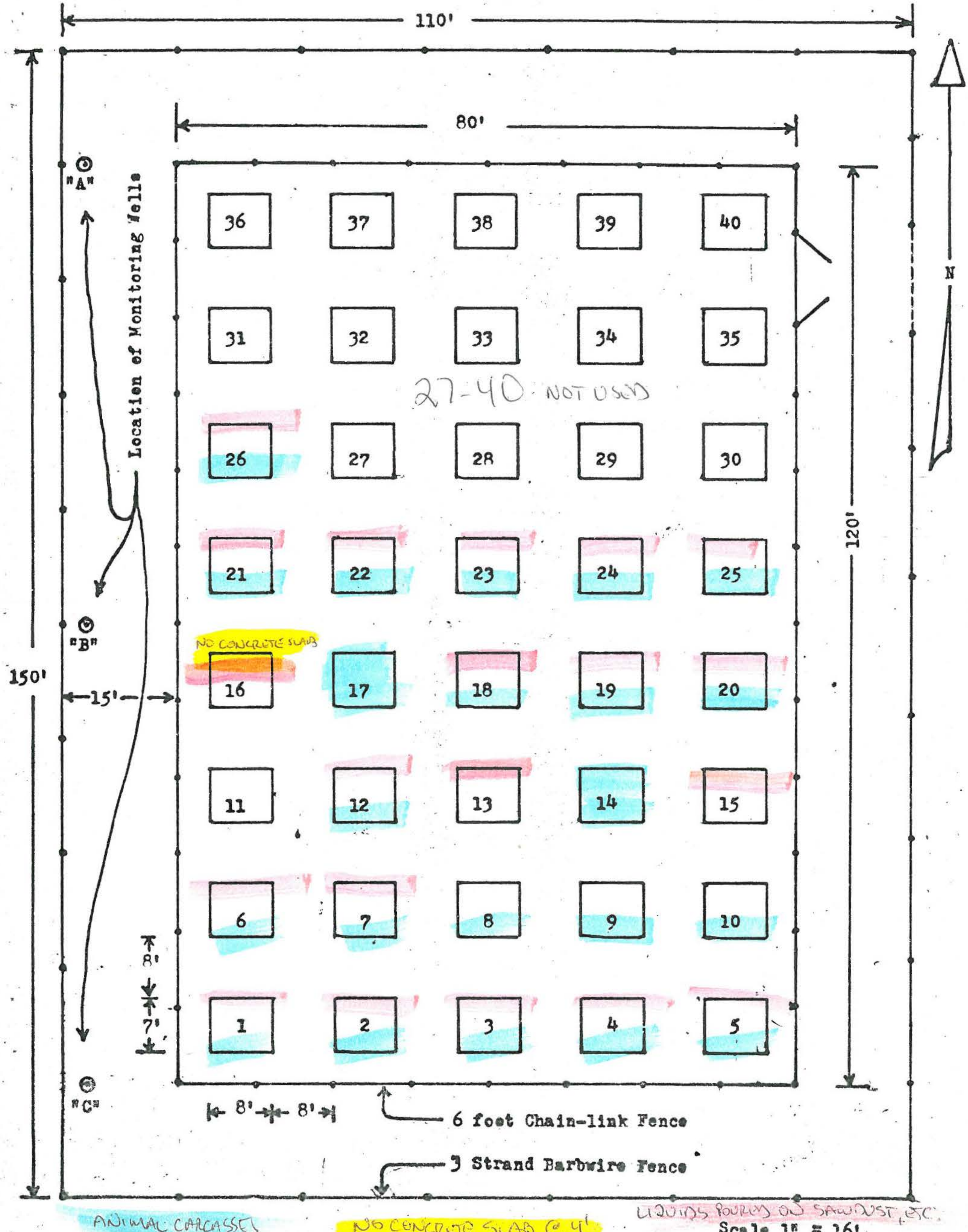
SKETCH - FSU RADIOACTIVE BURIAL SITE #2, APALACHICOLA NATIONAL FOREST, SECTION 27



Scale 1" = 16'

3-16-67

No. 1

Radioactive Burial

Radioactive material was buried in Pit No. 1, Florida State University Site No. 2, Apalachicola National Forest on March 16, 1967.

The following is a list of containers and the radiation levels:

No. Containers	Type Containers	Maximum	Average
48	Cardboard boxes	15 mr/hr	1.5 mr/hr
47	Bottles	22 mr/hr	2.0 mr/hr
5	Cans, 5 gal. (C^{14})	.03 mr/hr	.03 mr/hr
5	Polyethylene Bags (C^{14} - H^3)	.03 mr/hr	.03 mr/hr

The following is a list of the radioisotopes and quantities in μc. The activity calculation date is March 16, 1967.

Radioisotope	Liquid	Solid	Animal	Sub-Total	Ratio of Appendix B x 10^3
H^3	34,211.084	6,587.845	741.776	41,540.705	.166163
C^{14}	3,353.69	7,007.56	49.0	10,410.25	.208205
Na^{22}	.963	1.215		2.178	.000218
Al^{26}		.009		.009	.00009
S^{35}	.006	.041		.047	.000001
Cl^{36}	1.0	.02		1.02	.00102
Mn^{54}	2.2	1.12		3.32	.0332
Co^{57}		.003		.003	.00003
Fe^{59}	.0006	1.347		1.3476	.001348
Co^{60}	1.476	4.989		6.465	.006465
Sr^{90}	13.2139	1.453		14.6669	.146669
Cd^{109}	.45	.396		.846	.000085

Radioisotope	Liquid	Solid	Animal	Sub-Total	Ratio of Appendix B
✓ Cs^{137}	85.956	1.719		87.675	.087675
✓ Ce^{144}		.1101		.1101	.000110
✓ Pm^{147}		.020		.02	.000002
✓ Eu^{152}		.3734		.3734	.003734
Eu 152	23.0187		1.4714	24.4900	
✓ Eu ~~152-~~154	~~25.5763~~ 2.5576	~~1.6349~~ .1635		2.7211 ~~27.2112~~	.272112
✓ Eu^{154}		12.2328		12.2328	.012233
✓ Tm^{171}		.0204		.0204	.000204
✓ Cm^{244}		1.7834		1.7834	.017834
✓ Cf^{252}		.114		.114	.00114
TOTAL	37,695.6158	13,624.006	790.776	52,110.3978	.958538

Total Buried 3-16-67

wet
high water table

7-7-67
no. 2

Radioactive Burial

Radioactive material was buried in Pit No. 2, Florida State University Site No. 2, Apalachicola National Forest on July 7, 1967.

The following is a list of containers and the radiation levels:

No. Containers	Type of Containers	Maximum	Average
17	Cardboard boxes	45 mr/hr	4.8 mr/hr
4	Empty 5 gal. cans	.03 mr/hr	.03 mr/hr
16	Bottles	.2 mr/hr	.05 mr/hr
10	Polyethylene bags	40 mr/hr	4.62 mr/hr

The following is a list of the radioisotopes and quantities in µc. The activity calculation date is July 1, 1967.

Isotope	Solid	Liquid	Animal	Sub-Total	Ratio of Appendix B X 10^3
✓ H^3	4,484.0997	75650.9528	409.498	80,544.5505	.322178
✓ C^{14}	3,188.32	248.5	751.0	4,187.82	.085756
✓ Na^{22}	3.65			3.65	.000365
✓ P^{32}	.0072		79.264	79.2712	.007927
✓ S^{35}	29.2			29.2	.000584
✓ Mn^{54}	8.9088	.228		9.1368	.091368
✓ Fe^{55}		.0007		.0007	.000000
✓ Co^{56}	.0003			.0003	.000003
✓ Co^{57}		.033		.033	.000330
✓ Fe^{59}	.25		.013	.263	.000263

Isotope	Solid	Liquid	Animal	Sub-Total	Ratio of Appendix B X 10^3
Co^{60}	1.28			1.28	.001280
Zr^{95}-Nb^{95}		.0001		.0001	.000001
Sn^{113}		.1792		.1792	.000018
In^{114}		.0001		.0001	.000000
I^{131}	.0016			.0016	.000000
Cs^{137}	97.5			97.5	.097500
Ce^{144}	8.9334			8.9334	.008933
Pm^{147}	36.4512			36.4512	.003451
Eu^{152}-Eu^{154}	4.75		Eu^{152} — 4.275 Eu^{154} — .475	~~4.75~~	.047500
Tm^{170}	.0063			.0063	.000063
Hg^{203}	.95	4.7766		5.7266	.057266
Tl^{204}	8.0081			8.0081	.000160
Pb^{210}	.4815			.4815	.004815
Po^{210}		.3288		.3288	.003288
Am^{241}	10.0			10.0	.100000
U^{238}	.02			.02.	.000000
MFP	5.02			5.02	.050200
Total	7,887.8381	75904.9993	1239.7750	85032.6124	.883249

C

4-24-68
Pit no. 3

Radioactive Burial

Radioactive material was buried in Pit No. 3, Florida State University Site No. 2, Apalachicola National Forest on April 24, 1968.

The following is a list of containers and the radiation levels:

No. Containers	Type of Containers	Maximum	Average
17	Cardboard boxes	15 mr/hr	1.36 mr/hr
7	Bottles	.1 mr/hr	.05 mr/hr
6	Polyethylene bags	.03 mr/hr	.03 mr/hr
1	Empty can	.04 mr/hr	.04 mr/hr
2	Wood drawers	.06 mr/hr	.05 mr/hr

The following is a list of the radioisotopes and quantities in μc. The activity calculation date is March 1, 1968.

Isotope	Solid	Liquid	Animal	Sub-Total	Ratio of Appendix B X 10^3
H 3	18,793.5561	119,203.6914	184.0	138,181.2475	.552725
C 14	2,266.7825	1.1480	803.5	3,071.4305	.061229
Na 22	.8495			.8495	.000085
P 32	.5332		202.5	203.0332	.020303
S 35	.0400			.0400	.000008
Mn 54	5.8850			5.8850	.058850
Co 60	2.6359			2.6359	.002636
Cs 137	17.9696			17.9696	.017970
Ce 144	.9248			.9248	.000925
Pm 147	1.0024			1.0024	.000100
Eu 152-154	.3352 ~~.3724~~ .0372			.3352 ~~.3724~~ .0372	.003724

Pit 3 cont'd

Isotope	Solid	Liquid	Animal	Sub-Total	Ratio of Appendix B X 10^3
✓Tb 160	.0007			.0007	.000007
✓Tm 170	.0035			.0035	.000035
✓Hg 203	.1120	1.0200		1.1320	.011320
✓Tl 204	.0024			.0024	.000000
✓Np 237	.6500			.6500	.006500
✓Am 241	8.6800			8.6800	.086800
✓Cm 244	9.4722			9.4722	.094722
✓Cf 252	.0285			.0285	.000285
✓MFP	1.0100			1.0100	.010100
TOTAL	21,110.5107	119,205.8594	1,190.0	141,506.3701	.928324

O

5-27-69
Pit No. 4

RADIOACTIVE BURIAL

Radioactive material was buried in Pit No. 4, Florida State University Site No. 2, Apalachicola National Forest on ~~April~~ May 27, 1969.

The following is a list of containers and the radiation levels:

NO. CONTAINERS	TYPE OF CONTAINER	MAXIMUM	AVERAGE
5	55 gal. drums	2.0 mr/hr	0.46 mr/hr
5	5 gal. cans	0.08 mr/hr	0.05 mr/hr
1	wooden shelf	0.04 mr/hr	0.04 mr/hr
∿100 lbs.	animal waste	0.04 mr/hr	0.04 mr/hr

The following is a list of the radioisotopes and quantities in microcuries (μc). The activity calculation date is February 15, 1969.

ISOTOPE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
✓ H^{3}	1209.99600	478.75020	17324.87280	19013.61900	0.076294
C^{14}	1083.75000	5.40000	1050.50000	2139.65000	0.044553
✓ P^{32}	.06330			.06330	0.000010
✓ S^{35}	.00310			.00310	0.00000006
✓ Mn^{54}	9.10580			9.10580	0.091090
✓ Ni^{63}	.02300			.02300	0.000020
✓ Sr^{90}	3.44098			3.44098	0.034410
✓ Cd^{109}	.00040			.00040	0.00000001
✓ Sn^{113}	.00200			.00200	0.0000002
✓ I^{125}			6.15000	6.15000	0.061500
✓ Cs^{137}	35.12700			35.12700	0.035127
✓ Ce^{144}	.01888			.01888	0.000019
✓ Pm^{147}	18.31932			18.31932	0.001832
✓ Eu^{152}	40.60140			40.60140	0.406014
✓ Eu^{154}	20.12244			20.12244	0.020122
✓ Hg^{203}	0.00180			0.00180	0.000018
✓ Po^{210}	0.02940			0.02940	0.000294
✓ Am^{241}	5.26000			5.26000	0.052600
✓ Cm^{244}	9.27211			9.27211	0.092721
TOTAL	2435.13693	484.15020	18381.52280	21300.80993	0.916624

0

6-27-69
Pit No. 5

RADIOACTIVE BURIAL

Radioactive material was buried in Pit No. 5, Florida State University Site No. 2, Apalachicola National Forest on June 27, 1969.

The following is a list of containers and the radiation levels:

NO. CONTAINERS	TYPE OF CONTAINER	MAXIMUM	AVERAGE
5	55 gal. drums	10.0 mr/hr	0.26 mr/hr
1	5 gal. can	0.15 mr/hr	0.15 mr/hr
1	2 1/2 l. jug.	0.03 mr/hr	0.03 mr/hr
1	cardboard barrel	0.04 mr/hr	0.04 mr/hr
∿100 lbs	animal waste (frozen)	0.15 mr/hr	0.15 mr/hr

The following is a list of the radioisotopes and quantities in microcuries (μc). The activity calculation date is June 15, 1969.

ISOTOPE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
H^3	665.9190	73400.0000	6351.5360	80427.4550	0.321710
C^{14}	498.1000	30.0000	1099.0000	1627.1000	0.032542
P^{32}	46.0000			46.0000	0.004600
Mn^{54}	1.1640			1.1640	0.011640
Sb^{124}		25.6000		25.6000	0.025600
I^{125}	6.4500		20.9120	27.3620	0.273620
I^{131}	0.0050			0.0050	0.000001
Cs^{137}	9.8900			9.8900	0.009890
Eu^{152}	1.0482			1.0482	0.010482
Eu^{154}	1.0000			1.0000	0.001000
Tl^{204}		117.8000		117.8000	0.002356
U natural	3.0000			3.0000	0.000060
U^{238}	1.0000			1.0000	0.010000
Am^{241}	5.2500			5.2500	0.052500
Cm^{244}	2.2018			2.2018	0.022018
Cf^{252}	0.4830			0.4830	0.004830
MFP		2.0000		2.0000	0.020000
Unknown	1.0000	2.0000		3.0000	0.030000
TOTAL	1241.5110	73577.4000	7481.4480	82300.3590	0.832849

May 8, 1970
Pit # 6

RADIOACTIVE BURIAL

Radioactive material was buried in Pit No. 6, Florida State University Site No. 2, Apalachicola National Forest on May 8, 1970.

The following is a list of containers and radiation levels:

NO. CONTAINERS	TYPE OF CONTAINER	MAXIMUM	AVERAGE
6	55 gallon drums	0.22 mrem/hr	0.08 mrem/hr

The following is a list of the radioisotopes and quantities in microcuries. The activities calculation date is May 8, 1970.

ISOTOPE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
✓H 3	69,798.9058	0.0	24,351.9094	94,150.8152	0.376603
✓C 14	853.3000	450.0000	1,261.9000	2,565.2000	0.051304
✓P 32	12.4010	0.0	0.0001	12.4011	0.012401
✓S 35	1.2480	0.0	0.0	1.2480	0.000024
✓Sc 46	0.0945	0.0	0.0	0.0945	0.000095
✓Mn 54	6.9920	0.0	0.0	6.9920	0.069920
✓Fe 59	0.0	0.0	1.7500	1.7500	0.001750
✓Co 60	0.0	0.9470	0.0	0.9470	0.000947
✓Cd 109	0.0	10.4000	0.0	10.4000	0.001040
✓I 125	0.2806	0.0	61.4320	61.7126	0.006171
✓Cs 137	0.0296	0.0	0.0	0.0296	0.000030
✓Ce 144	2.2380	0.0	0.0	2.2380	0.002238
✓Pm 147	0.2610	0.0	0.0	0.2610	0.000026
✓Eu 152	1.4670	0.0	0.0	2.6748 ~~1.4670~~	0.014670
✓Eu ~~152~~-154	2.9720	0.0	0.0	.2972 ~~2.9720~~	0.029720

May 8, 1970 Burial Pit # 6

ISOTOPE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
✓Eu 155	4.7790	0.0	0.0	4.7790	.047790
✓Hg 203	.7476	0.0	0.0	.7476	.007476
✓Tl 204	.1004	0.0	0.0	.1004	.000002
✓Ra 226	.8600	0.0	0.0	.8600	.008600
✓Th 228	.8933	0.0	0.0	.8933	.008933
✓Th 230	.1000	0.0	0.0	.1000	.001000
✓U 233	1.0000	0.0	0.0	1.0000	.010000
✓Np 237	1.0000	0.0	0.0	1.0000	.010000
✓Pu 239	1.0000	0.0	0.0	1.0000	.010000
✓Am 241	6.5600	0.0	0.0	6.5600	.065600
✓Cm 244	2.9740	0.0	0.0	2.9740	.029740
✓Bk 249	1.5000	0.0	0.0	1.5000	.015000
✓Cf 252	.0836	0.0	0.0	.0836	.000836
✓Ra D&E Pb 210 Bi 210	1.0000	0.0	0.0	1.0000	.010000
✓MFP	1.2000	0.0	0.0	1.2000	.012000
TOTAL	70,703.9874	461.3470	26,230.4915	97,395.8259	.740988

0

Dec 16, 1970
Pit #7

RADIOACTIVE BURIAL

Radioactive material was buried in Pit #7, Florida State University Site #2, Appalachicola National Forest on December 16, 1970. The containers were six 55-gallon drums with an average radiation level of 0.1 mr/hr, maximum was 2.0 mr/hr from one barrel.

The following is a list of the radioisotopes and quantities in microcuries. The activity calculation date is December 15, 1970.

ISOTOPE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
H^3	3129.2990	3947.0000	1390.5710	8466.8700	0.033867
C^{14}	743.3700	224.5000	791.0000	1758.8700	0.035177
Na^{22}	4.0520			4.0520	0.000405
P^{32}	3135.3020			3135.3020	0.313530
S^{35}	739.7220		1710.0000	2449.7220	0.048994
Mn^{54}	3.0000			3.0000	0.030000
Fe^{59}	0.0440			0.0440	0.000044
Co^{60}	0.1177			0.1177	0.000117
Sr^{90}	0.0600			0.0600	0.000600
I^{131}	0.5020			0.5020	0.000005
Cs^{137}	220.2200			220.2200	0.220220
Ce^{144}	0.7300			0.7300	0.000730
Pm^{147}	0.0963			0.0963	0.000009
Eu ~~152~~-154 (152)	3.4556			3.11 .3456 3.4556	0.003455
Hg^{203}	11.5420			11.5420	0.115420
Tl^{204}	2.9999			2.9999	0.000059
Th^{228}	1.0000			1.0000	0.010000
Pu^{239}	0.2000			0.2000	0.000020
Am^{241}	5.0000			5.0000	0.050000
Cm^{244}	4.3830			4.3830	0.043830
Bk^{249}	0.0780			0.0780	0.000780
TOTAL	8005.1735	4171.5000	3891.5710	16,068.2445	0.907262

Pit 8

12-16-71

RADIOACTIVE BURIAL

Radioactive material was buried in Pit No. 8, Florida State University Site No. 2, Apalachicola National Forest on December 16, 1971.

The following is a list of containers and the radiation levels:

NO. CONTAINERS	TYPE OF CONTAINER	MAXIMUM	AVERAGE
6	55 gal. drums	1.3 mr/hr	.04 mr/hr

The following is a list of the radioisotopes and quantities in microcuries (μc). The activity calculation date is December 15, 1971.

ISOTOPE	SOLID	ANIMAL	SUB-TOTAL	RATIO
✓ H^3	20,476.9600	34,111.1550	54,588.1150	.218352
✓ C^{14}	2,512.9513	4,146.7397	6,659.6910	.133190
✓ Na^{22}	.7960		.7960	.000080
✓ P^{32}	4.9023		4.9023	.000490
✓ S^{35}	46.0000		46.0000	.000920
✓ I^{125}	10.8000	64.4000	7.220 6.498 ~~72.2000~~	.007520
✓ $Eu^{152-154}$ (~~152~~ 152)	5.0467		5.0467	.050467
✓ Pu^{239}	.1000		.1000	.000100
✓ Am^{241}	6.5896		6.5896	.065896
✓ Cm^{244}	5.2111		5.2111	.052111
✓ Bk^{249}	.4996		.4996	.004996
✓ Cf^{252}	.7264		.7264	.007264
✓ UNID	1.2450		1.2450	.012450
TOTAL	23,071.8280	38,322.2947	61,394.1227	.553836

0

PIT #9
9/13/72

RADIOACTIVE BURIAL

Radioactive material was buried in Pit No. 9, Florida State University Site No. 2, Apalachicola National Forest on September 13, 1972.

The following is a list of containers and the radiation levels:

APPROX. CUBIC FT.	CONTAINERS	MAXIMUM	AVERAGE
38	5 X 55 gal. drums	5mr/hr	.9mr/hr
20	15 Plastic bags (litter)	.05mr/hr	.03mr/hr
15	Plastic bags (animals)	.1mr/hr	.05mr/hr

The following is a list of the radionuclides and quantities in microcuries. The activity calculation date is September 13, 1972.

NUCLIDE	SOLID	ANIMAL	SUB-TOTAL	RATIO
✓H3	9316.427	24575.593	33892.020	.139568
✓C14	3664.751	1440.000	5104.751	.102097
✓Na22	30.625		30.625	.003063
✓P32	1.203		1.203	.001203
✓S35	.346		.346	.000007
✓Fe59	29.760		29.760	.029760
✓Co60	20.339		20.339	.020339
✓Cd109	33.600		33.600	.003360
✓I125	67.580	199.900	267.480	.026748
✓I131	.087		.087	.000009
✓Cs137	1.688		1.688	.001688
✓Pm147	18.983		18.983	.001898
✓Eu152	.099		2.629 + .099=(2.728)	.000990
✓Eu~~152~~-54	2.921		.2921 ~~2.921~~	.029210
✓Hg203	.187		.187	.001870
✓Ra226	10.000		10.000	.100000
✓U238	5.000		5.000	.050000
✓Pu239	3.700		3.700	.037000
✓Am241	2.697		2.697	.026970
✓Cm244	3.692		3.692	.036920
✓Bk249	.061		.061	.000610
✓Cf252	1.162		1.162	.011620
✓UNID	10.100		10.100	.101000
TOTAL	13225.008	26215.493	39440.501	.725930

PIT #10
10/23/73

RADIOACTIVE BURIAL

Radioactive material was buried in Pit. No. 10, Florida State University Burial Site No. 2, Apalachicola National Forest on October 23, 1973. This burial consisted primarily of radioactive animals. Other solid radioactive waste in this pit was mostly animal litter (sawdust).

The following is a list of the containers and radiation levels:

APPROX. CU. FT.	CONTAINERS	MAXIMUM	AVERAGE
147	Plastic Bags (Animal & Litter)	.1 mr/hr	.05 mr/hr

The following is a list of the radionuclides and the quantities in microcuries. The activity calculation date is October 18, 1973.

NUCLIDE	SOLID	ANIMAL	SUB-TOTAL	RATIO
✓H3	7232.700	76956.996	84189.696	.336759
✓C14		846.000	846.000	.016920
✓S35		289.380	289.380	.005788
✓I125	1219.280	657.480	1876.760	.187676
TOTAL	8451.980	78749.856	87201.836	.547143

0

PIT # 11
11/29/73

RADIOACTIVE BURIAL

Radioactive material was buried in Pit No. 11, Florida State University Burial Site No. 2, Apalachicola National Forest on November 29, 1973.

The following is a list of containers and the radiation levels measured at 1 inch from exterior barrel surface.

VOLUME	CONTAINERS	TYPE OF CONTAINER	MAXIMUM	AVERAGE
59 cu. ft.	8 each	55 gal. drums	11 mr/hr	.4 mr/hr

The following is a list of the radionuclides and quantities in microcuries. The activity calculation date is November 29, 1973.

NUCLIDE	SOLID	RATIO
H3	12735.632	.050907
C14	21179.590	.423592
Na22	8.522	.000852
P32	.104	.000010
S35	1042.607	.020852
Cl36	1.000	.001000
Ca45	.776	.000078
Mn54	.007	.000070
Fe59	.457	.000457
Co60	7.220	.007220
I125	.152	.000015
I131	1.353	.000135
Cs137	1.341	.001341
Eu~~152-~~154 (152)	1.368 .1445 ~~1.445~~	.014450
Pb210	15.009	.150090
Th228	.710	.007100
Am241	5.110	.051100
UNID	3.230	.032300
	35004.265	.761569

PIT # 12
5-16-74

RADIOACTIVE BURIAL

Radioactive material was buried in Pit No. 12, Florida State University Burial Site No. 2, Apalachicola National Forest on May 16, 1974.

The following is a list of containers and the radiation levels measured at 1 inch from exterior barrel surface.

VOLUME	CONTAINERS	TYPE OF CONTAINER	MAXIMUM	AVERAGE
52.5 cu ft.	7 each	55 gal. Drums	.8 mr/hr	.07 mr/hr
7.5 cu ft.	Bulk-animals	Plastic Bags	.05 mr/hr	.04 mr/hr

The following is a list of the radionuclides and quantities in microcuries. The activity calculation date is May 15, 1974.

NUCLIDE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
✓H3	13791.863	2080.427	16943.752	32816.042	.1313
✓C14	5015.010	1181.700	54.000	6250.710	.1250
✓Na22	138.750			138.750	.0139
✓P32	27.298	14.040	.450	41.788	.0042
✓S35	553.453		302.900	856.353	.0171
✓Ca45	1.972			1.972	.0000
✓Fe59	7.800			7.800	.0078
✓Zn65	149.650			149.650	.0150
✓Se75	25.326			25.326	.2533
✓I125	566.690		849.000	1415.690	.1416
✓I131	65.023			65.023	.0065
✓Cs137	1.100			1.100	.0011
✓Pm147 152	1.341			~~1.341~~ 1.341	.0001
✓Eu~~152~~-154	3.076			{2.768 {.308 ~~3.076~~	0308
✓Tl204	.079			.079	.0000
✓Th228	.580			.580	.0058
✓UNID	5.200			5.200	.0520
	20354.211	3276.167	18150.102	41780.480	.8055

0

PIT # 13
2-20-75

RADIOACTIVE BURIAL

Radioactive material was buried in Pit No. 12, Florida State University Burial Site No. 2, Apalachicola National Forest on February 20, 1975.

The following is a list of containers and the radiation levels measured at 1 inch from exterior barrel surface.

VOLUME	CONTAINERS	TYPE OF CONTAINER	MAXIMUM	AVERAGE
52.5	7 each	55 gal. Drums	.6 mr/hr	.05 mr/hr
7.5	Bulk waste	Plastic Cans	.1 mr/hr	.04 mr/hr

The following is a list of the radionuclides and quantities in microcuries. The activity calculation date is February 20, 1975.

NUCLIDE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
H3	73962.435			73962.435	.2958
C14	5864.100			5864.100	.1173
Na22	3.902			3.902	.0004
P32	616.368			616.368	.0616
S35	552.646			552.646	.0011
Ca45	15.908	2.651		18.559	.0019
Fe59	.003			.003	.0000
Co60	3.485			3.485	.0035
Zn65	.463			.463	.0000
I125	621.393			621.393	.0621
I131	53.719			53.719	.0054
Cs137	.347			.347	.0003
Eu~~152~~-154 (152)	10.199			{9.179 / 1.020} ~~10.199~~	.1020
UNID	1.870			1.870	.0187
TOTALS	81706.838	2.651		81709.489	.6701

0

PIT # 14
10-29-75

RADIOACTIVE BURIAL

This Radioactive Burial consisted of Animal Waste only. Buried in Pit No. 14 on October 29, 1975, in Florida State University Burial Site No. 2, Apalachicola National Forest.

The Animals were placed in a 3/4" plywood frame 8' X 7' X 2' high. The frame was placed in the pit and the animals placed in the frame to contain them within the 7' X 8' Burial area. No significant radiation levels above background could be obtained with a GM Survey.

The following is a list of the radionuclides and quantities in microcuries. The calculation Date is October 29, 1975. VOLUME: 8'x7'x2 1/2" = 140 cu. ft.

NUCLIDE	ACTIVITY IN ANIMALS	RATIO
H 3	40921.698	.16369
C 14	2954.000	.05908
S 35	5106.443	.10213
Ca 45	6.701	.00067
I 125	1007.094	.10071
TOTAL	.049995.936	.42628

PIT # 15

12-19-75

RADIOACTIVE BURIAL

Radioactive Material was buried in Pit No. 15, Florida State University Burial Site No. 2, Apalachicola National Forest on December 19, 1975.

The following is a list of solid radioactive waste sealed in barrels and the radiation levels measured at barrel contact.

VOLUME	CONTAINERS	TYPE OF CONTAINERS	MAXIMUN	AVERAGE
60 cu ft	8 each	55 gal Drums	1 mr/hr	0.16 mr/hr

The following is a list of the radionuclides and quantities in microcuries. The activity calculation date is December 18,1975.

NUCLIDE	SOLID	LIQUID	SUB-TOTAL	RATIO
H 3	17744.445	233.280	17977.725	.071911
C 14	7981.060	1001.800	8982.860	.179657
P 32	.440	.540	.980	.000098
S 35	1228.195		1228.195	.024564
Ca 45	2.815		2.815	.000282
Fe 59	5.560		5.560	.005560
Co 60	.058		.058	.000058
Zn 65	.358		.358	.000358
Sr 90	.009		.009	.000090
I 125	392.858		392.858	.039286
I 131	.035		.035	.000004
Cs 137	1.790		1.790	.001790
Pm 147	4.433		4.433	.000443
Eu ~~152~~-154 152	.738		{.664 .074} ~~.738~~	.007380
Tl 204	.011		.011	.000000
U 238	1.000		1.000	.000020
UNID	12.350		12.350	.123500
	.0 27,376.155	1235.620	28611.775	.455001

0

PIT # 16
6-25-76

RADIOACTIVE BURIAL

Radioactive Material was buried in Pit No. 16, Florida State University Burial Site No. 2, Apalachicola National Forest on June 25, 1976. This Pit does not have a Concrete Slab at 4 feet below ground level as the other 15 Pits have. To be in compliance with the current concrete slab requirement, a concrete slab must be placed above ground level prior to removing the chain-link fence.

The following is a list of solid waste in 55 gallon drums. The liquid waste was absorbed in saw-dust, also in 55 gallon drums. The radiation level measurements were made at barrel contact.

VOLUME	CONTAINERS	TYPE OF CONTAINERS	MAXIMUM	AVERAGE
60 cu ft	8 each	55 gal Drums	.8 mr/hr	0.15 mr/hr

The following is a list of the radionuclides and quantities in microcuries. The activity calculation date is June 25, 1976.

NUCLIDE	SOLID	LIQUID	SUB-TOTAL	RATIO
H 3	36374.529		36374.529	.145498
C 14	2458.100	7215.000	9673.100	.193462
P 32	2.037	.829	2.866	.000287
S 35	189.036	4.699	193.735	.003875
Ca 45	7.384		7.384	.000738
CO 60	.954		.954	.000954
I 125	764.985		764.985	.076499
I 131	.637	.500	1.137	.000114
Cs 137	1.962	.002	1.964	.001964
Pm 147	.002		.002	.000000
Eu 152-154	.916		.916	.009160
U 238	15.300		15.300	.153000
UNID (Unidentified)	.050		.050	.000500
TOTAL	36271.434	7221.030	43492.464	.586051

PIT # 17

11-9-76

RADIOACTIVE BURIAL

Radioactive Material was buried in Pit No. 17, Florida State University Burial Site No. 2, Apalachicola National Forest on November 9, 1976.

The following is a list of radioactive animal waste sealed in barrels and the radiation levels measured at barrel contact.

VOLUME	CONTAINERS	TYPE OF CONTAINRS	MAXIUM	AVERAGE
60 cu ft	8 each	55 gal Drums	.07 mr/hr	.04 mr/hr

The following is a list of the radionuclides and quantities in microcuries. The activity calculation date is November 9, 1976.

NUCLIDE	MICROCURIES IN ANIMALS	RATIO
H 3	22210.384	.088842
C 14	2773.200	.055464
S 35	665.204	.013304
Ca 45	813.046	.081305
I 125	541.926	.054194
	27003.760	.293109

0

PIT # 18

11-9-76

RADIOACTIVE BURIAL

Radioactive Material was buried in Pit No. 18, Florida State University Burial Site No. 2, Apalachicola National Forest on November 9, 1976.

The following is a list of radioactive waste sealed in barrels. The radiation levels were measured at barrel contact. Liquid waste was absorbed on saw-dust.

VOLUME	CONTAINERS	TYPE OF CONTAINERS	MAXIUM	AVERAGE
60 cu ft	8 each	55 gal Drums	.07 mr/hr	.04 mr/hr

Following is a list of radionuclides and microcurie quantities buried. The activity calculation date is November 9, 1976.

NUCLIDE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
H 3	19955.562	929.093	2550.199	23434.854	.093739
C 14	2459.600	11500.000	620.000	14579.600	.291592
Na 22	2.257			2.257	.000023
P 32	133.958			133.958	.013396
S 35	379.115	80.882		459.997	.009200
Ca 45	9.740			9.740	.000974
Co 60		1.937		1.937	.001937
Sr 90	.182			.182	.000182
I 125	1884.000	.498	382.189	2266.687	.226667
I 131	28.727			28.727	.002873
Cs 137	1.115			1.115	.001115
Pm 147	3.288			3.288	.000329
Eu ~~152~~-154 152	2.970			2.673 .297 2.970	.029700
Tl 204	.025			.025	.000001
U 238	10.000			10.000	.100000
Am 241		.200		.200	.002000
	24870.539	12512.610	3552.388	40935.537	.773728

0

PIT # 19

RADIOACTIVE BURIAL 6-30-77

Radioactive material was buried in Pit No. 19, Florida State University Burial Site No. 2, Apalachicola National Forest on June 30, 1977.

The following is a list of radioactive waste in tar-lined 55 gallon drums, which were sealed with a hoop closure. Liguid waste was absorbed on saw-dust. Radiation levels were measured at barrel contact.

VOLUME	CONTAINERS	TYPE OF CONTAINERS	MAXIMUM	AVERAGE
60 cu ft	8 each	55 gal drums	.7 mr/hr	.26 mr/hr

The following is a list of radionuclides, the form and microcurie quantities buried. The activity calculation date was 6-30-77.

NUCLIDE	SOLID	LIQUID	ANIMAL	SAWDUST	SUB-TOTAL	RATIO
H 3	15103.979	746.311	368.858	---	16219.148	.064877
C 14	1969.400	2277.800			4247.200	.084944
P 32	108.103	1350.261			1458.364	.145836
S 35	55.863				55.863	.001117
Cl 36	1.000				1.000	.001000
Ca 45	11.514				11.514	.001151
Cr 51	14.993			.318	15.311	.000306
Mn 54	3.572				3.572	.035720
Sr 90	.893				.893	.008930
I 125	3268.451	.532		253.662	3522.645	.352265
Cs 137	1.605				1.605	.001605
Ce 144	.653				.653	.000653
Pm 147	.809				.809	.000081
Eu ~~152~~, 154	3.337				3.337	.033370
Tl 204	1399.056				1399.056	.027981
Po 210	18.504				18.504	.185040
Am 241	.100				.100	.001000
(TOTAL)	21976.825	4374.904	368.858	253.980	26959.574	.945223

RADIOACTIVE BURIAL 6-30-77

Radioactive materials were buried in Pit No. 20, Florida State University Burial Site No. 2, Apalachicola National Forest on June 30, 1977.

The following is a list of radioactive waste in tar-lined 55 gallon drums, which were sealed with a hoop closure. Liquid waste was absorbed on saw-dust. Radiation levels were measured at barrel contact.

VOLUME	CONTAINERS	TYPE OF CONTAINERS	MAXIMUM	AVERAGE
60 cu ft	8 each	55 gal drums	2.2 mr/hr	.41 mr/hr

The following is a list of radionuclides, the form, and microcurie quantities buried. The activity calculation date was 6-30-77.

NUCLIDE	LIQUID	ANIMAL	SAWDUST	SUB-TOTAL	RATIO
H 3		19296.044		19296.044	.077184
C 14	50.000	973.000		1023.000	.020460
S 35		750.184		750.184	.015004
Cr 51			8.318	8.318	.000166
I 125		310.415	470.173	780.588	.078059
Ce 144	2.157			2.157	.002157
Eu 152	46.830			46.830	.468300
Eu 154	5.208			5.208	.005208
Tm 170	1.996			1.996	.049000
Am 241	4.900			4.900	.049000
Cm 244	.080			.080	.000800
(TOTALS)	111.171	21329.643	478.491	21919.305	.736298

RADIOACTIVE BURIAL

PIT # 21

5-18-78
(Burial Date)

Radioactive materials were buried at Florida State University Burial Site No. 2, Apalachicola National Forest, in the Pit # and on the date listed above.

The radioactive waste was compressed into 55 gallon drums and sealed with a hoop closure. Liquid waste was absorbed on saw-dust. Radiation surveys were made of the exterior surface, at contact, of each barrel. The reported maximum mr/hr reading is the highest reading obtained, and the reported average mr/hr reading is the average of the highest readings of all the barrels.

NO. OF BARRELS		TOTAL VOLUME	MAXIMUM	AVERAGE
Solid	3	60 cu. ft.	1.2 mr/hr	.5 mr/hr
Liquid	1			
Animal	4			

The activity decay calculation date is 5-18-78.

The following is a list of radionuclides, the form and microcurie quantities buried.

NUCLIDE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
H 3	9591.752	802.076	15761.090	26154.918	.104620
C 14	1159.210	746.870	1163.000	3069.080	.061382
S 35	103.007		98.395	201.402	.004028
Ca 45	4.004			4.004	.000400
Cr 51			.003	.003	.000000
Zn 65	.042			.042	.000004
I 125	31.190	1.949	45.280	78.419	.007842
Eu 152	.171			.171	.001710
Eu 154	.020			.020	.000020
Th 232	.200			.200	.010000
U 233	1.000			1.000	.010000
U 238	.270			.270	.002700
Am 241	1.729			1.729	.017290
TOTAL	10892.595	1550.895	17067.768	29511.258	.210000

0

RADIOACTIVE BURIAL PIT # 22

5-18-78
(Burial Date)

Radioactive materials were buried at Florida State University Burial Site No. 2, Apalachicola National Forest, in the Pit # and on the date listed above.

The radioactive waste was compressed into 55 gallon drums and sealed with a hoop closure. Liquid waste was absorbed on saw-dust. Radiation surveys were made of the exterior surface, at contact, of each barrel. The reported maximum mr/hr reading is the highest reading obtained, and the reported average mr/hr reading is the average of the highest readings of all the barrels.

NO. OF BARRELS		TOTAL VOLUME	MAXIMUM	AVERAGE
Solid	4	60 cu. ft.	2.4 mr/hr	.6 mr/hr
Liquid	2			
Animal	2			

The activity decay calculation date is 5-18-78.

The following is a list of radionuclides, the form and microcurie quantities buried.

NUCLIDE	SOLID	LIQUID	ANIMAL	SUB-TOTAL	RATIO
H 3	7116.097	2714.585	12786.996	22617.678	.090471
C 14	2535.300	2957.600		5092.900	.101858
P 32	.261			.261	.000026
S 35	.017		165.689	165.706	.003314
Cr 51	29.872			29.872	.000597
Mn 54	3.733			3.733	.037330
Fe 59	.621		.083	.704	.000704
Sr 90	.418			.418	.004180
I 125	560.018	186.062	385.073	1131.153	.113115
Cs 137	.575			.575	.000575
Pm 147	.863			.863	.000086
Eu 152	.445			.445	.004450
Eu 154	.050			.050	.000050
Tl 204	.055			.055	.000001
Th 232	8.000			8.000	.000160
U 238	2.000			2.000	.000040
Am 241	2.329			2.329	.023290
Cm 244	.099			.099	.000990
Bk 249	.087			.087	.000870
TOTAL	9860.840	5858.247	13337.841	29056.928	.382107

FLORIDA STATE UNIVERSITY

PIT # 23 RADIOACTIVE MATERIAL TRANSPORTATION AND BURIAL RECORD Burial Date 12-14-78

Radioactive materials were buried at FSU Radioactive Burial Site # 2, Apalachicola National Forest. The radioactive waste was compressed into 55 gallon drums and sealed with a hoop closure. Liquid waste was absorbed on sawdust, vermiculite or other equivalent absorbent material. The dpm figure indicates the surface contamination of each container. Surface indicates mr/hr, the highest reading taken at the surface of each container, At 3' indicates the highest reading taken at 3 feet from the surface of each container. The figures below each drum number is the amount of activity in microcuries. *Principal Nuclide.

Total number of drums: Solid 4, Liquid 2, Animal 2. Total Volume 60 cu. ft. Activity Date 12-14-78.

DRUM #	101	102	104	105	106	108	114	115	MICROCURIES	PIT
FORM	LIQUID	SOLID	LIQUID	SOLID	ANIMAL	ANIMAL	SAND	SAND	SUB-TOTAL	RATIO
H 3		14661.464	1932.632	9278.040	874.111	5831.616			32577.863	.130311
C 14	657.000	369.180	2030.500	269.000					3325.680	.066514
Na 22				.019					.019	.000002
P 32		.001	.034	.034					.069	.000007
S 35				434.113		102.013			536.126	.010723
Sr 90		.128					.995	.987	2.110	.021100
I 125	58.600	178.447	114.615	1928.971	53.013				2333.646	.233365
Cs 137		.267						.988	1.255	.001255
Ce 144	.386		.124						.510	.000510
Pm 147				1.316					1.316	.000132
Eu 152	10.836	4.284	.527						15.647	.156470
Eu 154	1.166		.391	.059					1.616	.001616
Tm 170	.168								.168	.001680
Tl 204				.270					.270	.000005
U 238	.200								.200	.000004
Am 241	12.786		2.798	.100					15.684	.156840
Cm 244	16.288		.588						16.876	.168760
Bk 249	2.032		.516						2.548	.025480
Cf 252	2.519								2.519	.025190
TOTAL	761.981	15213.771	4082.725	11911.922	927.124	5933.629	.995	1.975	38834.122	.999964
DPM	22	28	30	22	4	32	24	30		
Surface	.03 mr/hr	.04 mr/hr	.04 mr/hr	.04 mr/hr	.02 mr/hr	.06 mr/hr	.03 mr/hr	.02 mr/hr		
At 3'									(For yellow label only)	
Label	I-White	I-White	I-White	I-White	No label	I-White	No label	No label		
*Nuclide	C 14	H 3	H3,C14,I125	I 125	---	H3,S35	---	---		

FLORIDA STATE UNIVERSITY

PIT # 24

RADIOACTIVE MATERIAL TRANSPORTATION AND BURIAL RECORD

Burial Date 12-14-78

Radioactive materials were buried at FSU Radioactive Burial Site # 2, Apalachicola National Forest. The radioactive waste was compressed into 55 gallon drums and sealed with a hoop closure. Liquid waste was absorbed on sawdust, vermiculite or other equivalent absorbent material. The dpm figure indicates the surface contamination of each container. Surface indicates mr/hr, the highest reading taken at the surface of each container, At 3' indicates the highest reading taken at 3 feet from the surface of each container. The figures below each drum number is the amount of activity in microcuries. *Principal Nuclide.

Total number of drums: Solid 4, Liquid 1, Animal 3. Total Volume 60 cu. ft. Activity Date 12-14-78.

DRUM #	103	107	109	110	111	112	113	116	MICROCURIES	PIT
FORM	Solid	Solid	Solid	Animal	Animal	Animal	Solid	Liquid	SUB-TOTAL	RATIO
H 3	161.098	3010.955	437.739	9096.201	8239.032	1967.944	25.563	4930.903	27869.435	.111478
C 14	2185.000	125.300			200.000		86.000	295.150	2891.450	.057829
P 32	.178		36.542				4.542	15.998	57.260	.005726
S 35				648.771		434.108	23.082	70.011	1175.972	.025194
Cr 51			.123					2.132	2.255	.000045
Sr 90	8.711								8.711	.087110
I 125			2.398					990.240	992.638	.013981
Cs 137	12.986		.995						13.981	.013981
Tm 170			.069						.069	.000690
Po 210		11.822							11.822	.118220
Th 230								.500	.500	.005000
U 233		.100							.100	.001000
Np 237								.400	.400	.004000
Pu 239								.500	.500	.005000
Am 241		.100						.100	.200	.002000
TOTAL	2367.973	3148.277	477.866	9744.972	8439.032	2402052	139.187	6305.934	33025.293	.536537
DPM	24	24	16	6	32	30	24	0		
Surface	.05 mr/hr	.05 mr/hr	.02 mr/hr	.02 mr/hr	.02 mr/hr	.06 mr/hr	.03 mr/hr	.02 mr/hr		
At 3'									(For yellow label only)	
Label	I - White	I - White	No label	I - White	I - White	I - White	No label	I - White		
*Nuclide	H3, C 14	H 3	--	H 3	H 3	H 3	--	I 125		

PIT # 25

HAZARD CLASS: Radioactive Material, n.o.s. - Normal form

FLORIDA STATE UNIVERSITY
TALLAHASSEE, FL 32306

ATTENTION: M. C. Riggenbach
SHIPPER

RADIOACTIVE MATERIAL TRANSPORTATION AND BURIAL RECORD

Burial Date 6-14-79

Radioactive materials were buried at FSU Radioactive Burial Site # 2, Apalachicola National Forest. The radioactive waste was compressed into 55 gallon drums and sealed with a hoop closure. Liquid waste was absorbed on sawdust, vermiculite or other equivalent absorbent material. The dpm figure indicates the surface contamination of each container. Survey indicates mr/hr, the highest reading taken at the surface of each container, "T-Index" indicates highest reading taken at 3 feet from the surface of each container. The figures below each drum number is the amount of activity in microcuries.

Total number of drums: Solid 3, Liquid 3, Animal 2. Total Volume 60 cu. ft. Activity Date 6-14-79.

DRUM #	117	118	119	120	121	122	126	132	MICROCURIES SUB-TOTAL	PIT RATIO
FORM	Animal	Solid	Animal	Animal	~~Liquid~~ Solid	Liquid	Solid	Solid		
IV H3	1638.610	1152.317	2617.984	14969.429	36351.843	10409.355	60703.834		127843.372	.511373
IV C 14		229.000			491.750	220.830	1.100		942.680	.018854
~~Na 22~~									--	--
IV P 32							.973		.973	.000079
IV S 35	336.734	28.435	118.479	122.690	[illegible]	.109			606.447	.012129
IV Ca 45		109.822							109.822	.010982
~~Cr 51~~										
III I 125	11.997	76.575		24.402	633.489	25.607	1196.375	171.986	2140.431	.214043
~~Cs 137~~										
III ~~Ce 144~~							3.110		3.110	.003110
~~Pm 147~~										
III Eu 152										
II Eu 154					.010		1.104		1.114	.001114
~~Tl 204~~										
II U 233 *					.010		.010 *		.020	.000020
I Am 241					.010		2.214		2.224	.002224
I Cm 244					.049	.050			.099	.000099
I Bk 249							1.569		1.569	.001569
I Cf 252					.007		1.736		1.743	.001743
Tr Grp	III	III	IV	III	I	I	I	III		
TOTAL	1987.341	1596.149	2736.463	15116.521	37477.168	10655.951	61912.025	171.986	131653.604	.777339
DPM	20	8	2	10	14	6	4	6	(Surface contamination)	
Survey	.04	.9	.04	.03	.03	.03	.03	.03	(mr/hr at Contact)	
T-Index		.1 ~~.87~~					.1		(For Yellow Label Only)	
Label	White I	YELLOW II	White I	White I	White I	White I	YELLOW II	White I	(or no label required)	
Nuclides	H3, S35	H3, C14, Ca45	H3, S35	H3, S35	H3, C14, I125	H3, C14, I125	H3, I125	I125	(Principal Isotope)	

* FISSILE RADIOACTIVE MATERIAL

TRANSPORT GROUP

HAZARD CLASS: Radioactive Material, n.o.s. - Normal form.

FLORIDA STATE UNIVERSITY
TALLAHASSEE, FL 32306

ATTENTION: M. C. Riggenbach - Shipper

PIT # 26

RADIOACTIVE MATERIAL TRANSPORTATION AND BURIAL RECORD

Burial Date 6-14-79

TRANSPORT GROUP

Radioactive materials were buried at FSU Radioactive Burial Site # 2, Apalachicola National Forest. The radioactive waste was compressed into 55 gallon drums and sealed with a hoop closure. Liquid waste was absorbed on sawdust, vermiculite or other equivalent absorbent material. The dpm figure indicates the surface contamination of each container. Survey indicates mr/hr, the highest reading taken at the surface of each container, "T-Index" indicates highest reading taken at 3 feet from the surface of each container. The figures below each drum number is the amount of activity in microcuries.

Total number of drums: Solid 2, Liquid 3, Animal 3. Total Volume 60 cu. ft. Activity Date 6-14-79.

DRUM #	123	124	125	127	128	129	130	131	MICROCURIES SUB-TOTAL	PIT RATIO
FORM	Liq	ani	ani	Liq	Solid	ani	Liq	Solid		
IV H 3	19950.527	2929.748	1705.013		173.427	4788.631	707.595	657.829	30912.770	.123651
IV C 14	466.350				279.010		177.000	285.000	1207.360	.024147
III Na 22					.010				.010	.000001
IV P 32					.020			.511	.531	.000056
IV S 35	198.793	588.174			.132	253.957		178.941	1219.999	.024800
IV Ca 45							(Ca45) 139.556	91.136	230.692	.023069
III I 125	278.800		407.941	41.001	1536.429		1582.833	2110.259	5957.263	.595726
III Cs 137					.319				.319	.000319
III Ce 144				.170					.170	.000170
IV Pm 147					.334				.334	.000033
III Eu 152				.239	.198				.437	.004370
II Eu 154				2.105					2.105	.002105
II Tl 204 *					.004 *				.004	~~.000080~~
II U 233					.010				.010	.000100
III U 238	.500								.500	.005000
I Am 241				13.693	.100				13.793	.137930
I Cm 244				3.687	.149				3.836	.038360
I Bk 249					.088				.088	.000880
I Cf 252				1.640					1.640	.016400
IV Cr 51								91.702	91.702	.001834
Tr Gp	III	IV	III	I	I	IV	IV	III		
TOTAL	20894.970	3517.924	2112.954	62.535	1990.230	5042.588	2606.984	3415.378	39643.563	.998551
DPM	4	24	4	10	12	22	10	4	(Surface contamination)	
Survey	.03	.03	.03	.03	.03	.03	.03	.03	(mr/hr at Contact)	
T-Index	~~.02~~	~~.02~~	~~.02~~	~~.02~~	.1	~~.02~~	~~.02~~	~~.02~~	(For Yellow Label Only)	
Label	I white	I white	I white	I white	YELLOW II	I white	I white	I white	(or no label required)	
Nuclides	H 3	H 3	H3 I125	I125 Am241	I125	H3 S35	I 125	I 125	(Principal Isotope)	

* FISSILE RADIOACTIVE MATERIAL (SNM)

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APPENDIX B

Monitoring Well Boring Logs

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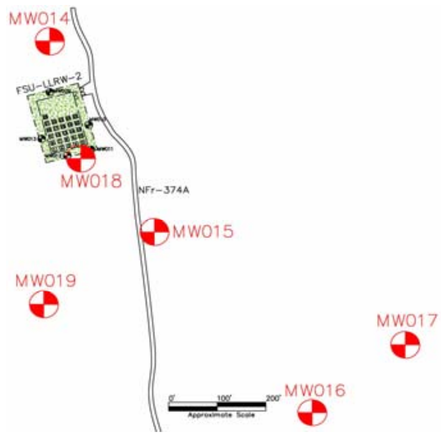
FSU-LLRW-2 ESI - SUBSURFACE SOIL BORING LOG

Site Name: FSU-LLRW-2-ESI
National Forest: Apalachicola National
Date: 01/08/2018
Boring ID: MW014
Coordinates: 497952.5444, 1960585.2902
Total Depth: 30'
Boring Diameter: 4"
Driller: Michael Hanson
Drill Method: Sonic
Drill Rig: TerraSonic Track Mounted
Inspector: Justin Idzenga
Comments: 6" tooling advanced to 30' bgs with continuous cores. Screen interval of 10-30' bgs. 3' stick-up.

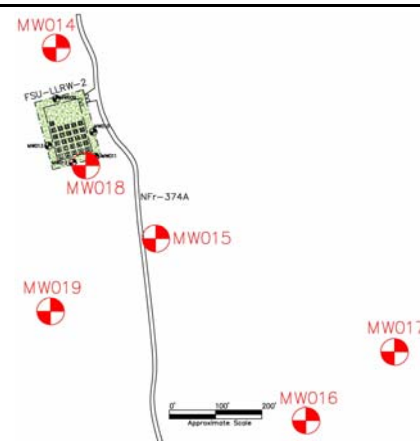


Depth ('bgs)	Recovery (%)	Description	USCS	USCS
5'	95%	0.0 - 1.0 Grey medium to fine SAND. Some organic matter; tree roots, bark, and grass. Moist. No Odor/Staining. 1.0 - 2.5 Dark Grey Silty medium to fine SAND. Some Organics. Moist. No Odor/Staining. 2.5 - 3.5 Tan and Beige medium to fine SAND. Slightly Moist. No Odor/Staining. 3.5 - 5.0 Grey to light grey medium SAND. Slightly moist. No Odor/Staining.		
10'	80%	5.0 - 10.0 Black, grey, and dark grey medium SAND. Some Silt. Moist No Odor/Staining.		
15'	100%	10.0 - 12.0 Dark grey and black silty fine SAND. Moist. No Odor/Staining. 12.0 - 13.0 Dark grey and black heavily cemented silty fine SAND. Moist. No Odor/Staining. 13.0 - 13.5 SAA Saturated.		
20'	80%	15.0 - 20.0 Dark Brown Silty medium to fine SAND. Translucent grains mixed within. Moist No odor/staining.		
25'	100%	20.0 - 23.0 Brown, dark brown, and dark grey medium to fine SAND. Moist. No staining. 23.0 - 23.5 Dark grey Cemented fine SAND. Slight organic odor. Moist. No staining. 23.5 - 27.0 Dark grey and dark brown medium to fine SAND. Slight organic odor. No staining.		
30'	100%	27.0 - 27.5 Dark brown and dark grey cemented fine SAND. Slight organic odor. No staining. 27.5 - 29.5 Dark grey and dark brown medium to fine SAND. Moist. Organic odor. No staining. 29.5 - 30.0 Dark brown and dark grey cemented fine SAND.		

END OF BORING

FSU-LLRW-2 ESI - SUBSURFACE SOIL BORING LOG

Site Name: FSU-LLRW-2-ESI
National Forest: Apalachicola National
Date: 01/09/2018
Boring ID: MW015
Coordinates: 497527.9297, 1960822.3318
Total Depth: 40'
Boring Diameter: 6-8"
Driller: Michael Hanson
Drill Method: Sonic
Drill Rig: TerraSonic Track Mounted
Inspector: Justin Idzenga
Comments: 8" tooling to 20' bgs. 6" tooling to 40' bgs with continuous cores. 2 sets of well screen intervals; 10' to 20' bgs and 25' to 35' bgs. Nested wells. 3' stick-up.

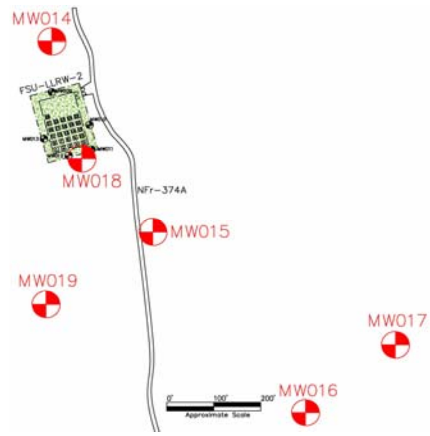


Depth ('bgs)	Recovery (%)	Description	USCS	USCS
5'	100%	0.0 - 1.0 grey and white medium to fine SAND. Slightly moist. Some organics; roots and grass. No odor/staining. 1.0 - 4.0 Grey to dark grey fine SAND. Slightly moist. Moist @ 3'. No odor/staining. 4.0 - 10.0 Dark grey to very dark grey medium to fine SAND. Moist. No odor/staining.		
10'	100%	10.0 - 12.5 Dark grey Silty medium to fine SAND. Moist. No odor/staining.		
15'	100%	12.5 - 13.0 Dark grey cemented fine SAND. Moist. No odor/staining. 13.0 - 14.5 Dark grey Silty medium to fine SAND. Moist. No odor/staining. 14.5 - 15.0 Dark grey cemented fine SAND. Moist. No odor/staining.		
20'	100%	15.0 - 20.0 Dark grey Silty medium to fine SAND. No odor/staining.		
25'	100%	20.0 - 21.5 SAA Saturated 21.5 - 22.5 Dark Grey cemented fine SAND. Saturated. No odor/staining 22.5 - 23.5 SAA 23.5 - 26.0 Dark brown to brown and grey silty fine SAND. Moist to wet. No odor/staining.		
30'	100%	26.0 - 28.0 Brown Silty fine SAND. Moist. No odor/staining. 28.0 - 30.0 Brown Silty medium to fine SAND. Moist. No odor/staining.		
35'	100%	30.0 - 35.5 Brown to brownish grey Silty fine SAND. Moist to wet. No odor/staining.		
40'	100%	35.5 - 40.0 Grey Silty medium to fine SAND. Moist. No odor/staining.		

END OF BORING

FSU-LLRW-2 ESI - SUBSURFACE SOIL BORING LOG

Site Name: FSU-LLRW-2-ESI
National Forest: Apalachicola National
Date: 01/10/2018
Boring ID: MW016
Coordinates: 497152.5368, 1961155.3040
Total Depth: 40'
Boring Diameter: 4"
Driller: Michael Hanson
Drill Method: Sonic
Drill Rig: TerraSonic Track Mounted
Inspector: Justin Idzenga
Comments: 8" tooling to 15' bgs. 6" tooling to 40' bgs with continuous cores. 2 sets of well screen intervals; 5' to 15' bgs and 20' to 35' bgs. Nested wells. 3' stick-up.

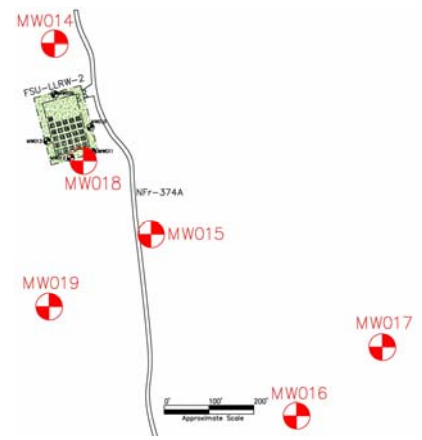


Depth ('bgs)	Recovery (%)	Description	USCS	USCS
5'	100%	0.0 - 1.5 Grey, light grey medium to fine SAND. Some Organics; roots and grass. 1.5 - 2.5 Dark grey to grey medium to fine SAND. Some organics 2.5 - 3.5 Tan and beige medium to fine SAND. Slightly moist. No odor/staining. 3.5 - 4.5 White to light grey medium to fine SAND. Moist. No odor/staining. 4.5 - 10.0 Dark grey Silty medium to fine SAND. Moist to slightly moist. No odor/staining.		
10'	100%	trace translucent medium quartz grains. 10.0 - 15.0 SAA		
15'	100%			
20'	100%	15.0 - 18.0 Cemented Dark grey to very dark grey Silty medium to fine SAND. Moist to very moist. No odor/staining. 18.0 - 20.0 Dark grey and dark brown Silty medium to fine SAND. Trace quartz grains. Moist. No odor/staining.		
25'	100%	20.0 - 23.0 Brown Coarse to fine SAND. Quartz grains. Coarse grains consist of black, grey, translucent, and brown grains. 23.0 - 30.0 Brown Silty fine SAND. Moist. Saturated at 29'. No odor/staining.		
30'	100%			
35'	100%	30.0 - 32.0 SAA. 32.0 - 34.0 White to light grey medium to fine SAND. Moist. No odor/staining.		
40'	100%	34.0 - 39.0 Brown Silty fine SAND. Moist to very moist. No odor/staining. 39.0 - 40.0 Brown Silty medium to fine SAND. Moist. No odor/staining.		

END OF BORING

FSU-LLRW-2 ESI - SUBSURFACE SOIL BORING LOG

Site Name: FSU-LLRW-2-ESI
National Forest: Apalachicola National
Date: 01/10/2018
Boring ID: MW017
Coordinates: 497276.8358, 1961338.0361



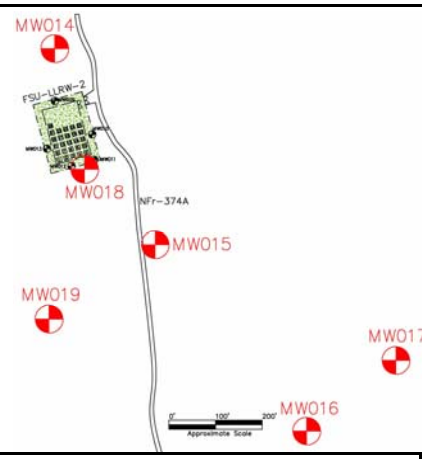
Total Depth: 40'
Boring Diameter: 4"
Driller: Michael Hanson
Drill Method: Sonic
Drill Rig: TerraSonic Track Mounted
Inspector: Justin Idzenga
Comments: 8" tooling to 20' bgs. 6" tooling to 40' bgs with continuous cores. 2 sets of well screen intervals; 8' to 18' bgs and 23' to 33' bgs. Nested wells. 3' stick-up.

Depth ('bgs)	Recovery (%)	Description	USCS	USCS
5'	100%	0.0 - 1.0 Grey medium to fine SAND. Some organics; grass and roots. Moist. No odor/staining. 1.0 - 10.0 Grey to dark grey medium to fine SAND. Some organics; grass and roots. No odor/staining.		
10'	100%			
15'	100%	10.0 - 19.0 Dark grey to brownish grey Silty medium to fine SAND including medium translucent quartz grains. No odor/staining.		
20'	100%	19.0 - 24.0 Dark grey cemented silt and fine SAND. Moist. No odor/staining.		
25'	100%	Dark grey Silty medium to fine SAND including quartz grains. No odor/staining.		
30'	100%	30.0 - 32.0 Brown, greyish brown coarse to fine SAND. Moist. Quartz grained.		
35'	100%	No odor/staining. 32.0 - 36.0 Brown Silty medium to fine SAND. Moist. No odor/staining.		
40'	100%	36.0 - 37.0 Brown, and dark brown cemented Silt and fine SAND. Moist. No odor/staining. 37.0 - 40.0 Brown Silty fine SAND. Moist. No odor/staining.		

END OF BORING

FSU-LLRW-2 ESI - SUBSURFACE SOIL BORING LOG

Site Name: FSU-LLRW-2-ESI
National Forest: Apalachicola National
Date: 01/9/2018
Boring ID: MW018
Coordinates: 497685.8977, 1960668.7068
Total Depth: 40'
Boring Diameter: 4"
Driller: Michael Hanson
Drill Method: Sonic
Drill Rig: TerraSonic Track Mounted
Inspector: Justin Idzenga
Comments: 6" tooling advanced to 30' bgs with continuous cores. Screen interval of 20-30' bgs. 3' stick-up.

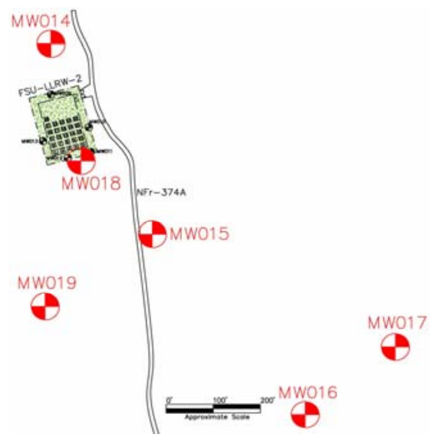


Depth ('bgs)	Recovery (%)	Description	USCS	USCS
5'	100%	0.0 - 1.0 grey medium to fine SAND. Some organics; Grass and roots. Slightly moist. No odor/staining. 1.0 - 1.5 Dark grey to grey Silty medium to fine SAND. Some roots and grass. No odor/staining. 1.5 - 2.5 Beige and tan medium to fine SAND. Slightly moist. No odor/staining.		
10'	100%	2.5 - 3.5 Grey and light grey to white medium SAND. Moist. No odor/staining. 3.5 - 5.0 Grey and dark grey medium SAND. Moist. No odor/staining. 5.0 - 10.0 Dark grey medium to fine SAND. Slightly moist to moist. Slight organic odor. No staining.		
15'	100%	10.0 - 17.0 Dark grey with translucent grains. Silty medium to fine SAND. Moist. No odor/staining.		
20'	100%	17.0 - 17.5 Dark grey cemented fine SAND. Moist. No odor/staining. 17.5 - 19.5 Dark grey Silty medium to fine SAND. Moist. No odor/staining. 19.5 - 20.0 Dark grey cemented fine SAND. Moist. No odor/staining.		
25'	100%	20.0 - 30.0 Dark brown and brown Silty medium to fine SAND. Moist. Some cemented fine Sand near 25'. Slight organic odor. No staining.		
30'	100%			

END OF BORING

FSU-LLRW-2 ESI - SUBSURFACE SOIL BORING LOG

Site Name: FSU-LLRW-2-ESI
National Forest: Apalachicola National
Date: 01/9/2018
Boring ID: MW019
Coordinates: 497364.9358, 1960592.7230
Total Depth: 40'
Boring Diameter: 4"
Driller: Michael Hanson
Drill Method: Sonic
Drill Rig: TerraSonic Track Mounted
Inspector: Justin Idzenga
Comments: 8" tooling to 20' bgs. 6" tooling to 40' bgs with continuous cores. 2 sets of well screen intervals; 8' to 18' bgs and 25' to 35' bgs. Nested wells. 3' stick-up.



Depth ('bgs)	Recovery (%)	Description	USCS	USCS
5'	100%	0.0 - 2.0 White, grey, and dark grey fine SAND. Some organic; roots and grass. 2.0 - 3.0 Brown Silty fine SAND. Little organics. Slightly moist. No odor/staining. 3.0 - 5.0 Beige and tan Silty fine SAND. Moist. No odor/staining		
10'	100%	5.0 - 7.5 Beige to white to grey medium to fine SAND. Moist. No odor/staining. 7.5 - 10.0 Dark grey and dark brown medium to fine SAND. Moist. No odor/staining		
15'	100%	10.0 - 15.0 SAA		
20'	100%	15.0 - 17.0 Dark grey cemented fine SAND. Moist. No odor/staining 17.0 - 18.0 Dark grey and dark brown Silty fine SAND. Moist. Slight organic odor. No staining. 18.0 - 20.0 Brown medium SAND. Little silt. Moist. No odor/staining.		
25'	100%	20.0 - 21.0 Dark grey, brown, dark brown coarse to fine SAND. Moist. No odor/staining. 21.0 - 22.5 Dark brown cemented medium to fine SAND. Moist. No odor/staining. 22.5 - 25.5 Dark brown, brown Silty medium to fine SAND. Moist. No odor/staining.		
30'	100%	25.5 - 26.0 Brown cemented Silty fine SAND. Moist. No odor/staining. 26.0 - 30.0 Brown to light brown Silty medium to fine SAND. Moist. No odor/staining. 30.0 - 35.0 SAA		
35'	100%	Brown to light brown Silty fine SAND. Moist. No odor/staining.		
40'	100%			

END OF BORING

BMT Designers & Planners

Soil Boring and Monitoring Well Construction Log Legend

Soil Boring Litholgy (USCS):

GW	SP	OL
GP	SM	MH
GM	SC	CH
GC	ML	OH
SW	CL	Pt

Monitoring Well Construction:

Casing	Bentonite Chip Grout (Shure-Plug 1/8" Bentonite Chips)
Screen	Pellet Grout (TR-30 1/4" Pel Plug)
Sand Pack	Well Plug

Notes:
(f) = fine, (m) = medium, (c) = coarse.
gr - gravel
w/ - with
& - and

ARS - Agricultural Research Service
BARC - Beltsville Agricultural Research Center
DSI - Drillers Supply International
NM - Not Measured
NA - Not Applicable
NR - Not Recorded in Field Notes
bgs - Below Ground Surface
PID - Photo-ionization Detector
ppm - Parts Per Million
USCS - Unified Soil Classification System
MW - Monitoring Well

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APPENDIX C

Site RAGS D TABLES and Risk Calculations

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RAGS PART D TABLE 1

SELECTION OF EXPOSURE PATHWAYS

FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Scenario Timeframe	Source Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future	Groundwater	Groundwater	Tapwater	Resident	Adult	Dermal Absorption	Quant*	Future Residential Use is a not anticipated but future residents may be exposed to VOCs in groundwater
						Ingestion		
					Child	Dermal Absorption		
						Ingestion		
		Air	Tapwater - Water at Showerhead	Resident	Adult	Inhalation	None	Region 4 guidance (EPA, 2018) accepts the default assumption that inhalation and dermal exposure from showering is equivalent to exposure from the daily ingestion of contaminated water per day.
					Child			
		Air	Volatilization thru soils	Resident	Adult	Inhalation	Quant	Future residents may be exposed to volatilization of VOC vapors from groundwater
					Child		Quant	
Current/Future	Groundwater	Air	Volatilization thru soils	Trespasser/Visitor	Child/Adult	Inhalation	None	Low frequency of site visits and lack of intrusive activities limit potential exposures
				Site/Construction Worker	Adult	Inhalation	None	Considered a neglible source due to the lack of enclosed structures on the site and the nature of potential work to be completed.

VOC = Volatile Organic Chemical

* According to EPA Region 4 guidance the dermal exposure pathway is not used for radionuclides (EPA, 2018)

Exposure pathways for surface and subsurface soils are not considered as data are not available for soils.

Table 2
OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Scenario Timetable: Current/Future
Medium: Groundwater
Exposure Medium: Groundwater

Parameter	CAS RN No.	Frequency of Detection	Maximum Detected Concentration	Maximum Sample ID	Screening Value		Maximum > Screening Value	Comments	COPC
					Conc[1,2]	C,N[3]			
SVOCs (µg/L)									
1,4-Dioxane	123-91-1	7 of 15	4.2E+02	MW015-2-GW@30'	4.6E-01	C	yes		1,4-Dioxane
Radionuclides									
Radium-226	13982-63-3	8 of 15	8.2 ± 2.1	MW016-2-GW@30'	3.97E-04	N	yes		Radium-226
Radium-228	15262-20-1	10 of 15	6.7 ± 1.7	MW016-2-GW@30'	9.66E-04	N	yes		Radium-228
Gross Alpha	NA	9 of 15	43 ± 9.1	MW017-2-GW@30'	NA	NA	NA		
Gross Beta	NA	5 of 15	18 ± 6.8	MW015-2-GW@30'	NA	NA	NA		

Notes

The data summarized in this table represents groundwater data collected in January 2018 from Site monitoring wells

[1] Screening Value for noncarcinogens (N) = U.S. EPA Regional Screening Level (RSL) for Tapwater multiplied by 0.1. Screening Value for carcinogens = RSL for Tapwater.

EPA Regional Screening Levels (RSLs) for Chemical Contaminants at Superfund Sites. (November 2018). https://www.epa.gov/risk/regional-screening-levels-rsls

[2] Screening values for radionuclides are the PRG (in pCi/L) for residential tapwater (https://rais.ornl.gov/cgi-bin/prg/PRG_search?select=rad)

[3] N = not a carcinogen; C = carcinogen; NA = not available; N/A = not applicable

UCL Statistics for Data Sets with Non-Detects	
User Selected Options	
Date/Time of Computation	ProUCL 5.111/19/2018 6:02:37 PM
From File	ProUCL_1,4-D.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

1,4-Dioxane

General Statistics			
Total Number of Observations	15	Number of Distinct Observations	11
Number of Detects	7	Number of Non-Detects	8
Number of Distinct Detects	7	Number of Distinct Non-Detects	4
Minimum Detect	5.5	Minimum Non-Detect	9.4
Maximum Detect	420	Maximum Non-Detect	9.8
Variance Detects	25752	Percent Non-Detects	53.33%
Mean Detects	101.1	SD Detects	160.5
Median Detects	20	CV Detects	1.588
Skewness Detects	1.733	Kurtosis Detects	2.239
Mean of Logged Detects	3.374	SD of Logged Detects	1.694
Normal GOF Test on Detects Only			
Shapiro Wilk Test Statistic	0.683	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.803	Detected Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.397	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.304	Detected Data Not Normal at 5% Significance Level	
Detected Data Not Normal at 5% Significance Level			
Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs			
KM Mean	51.14	KM Standard Error of Mean	31.16
KM SD	111.7	95% KM (BCA) UCL	106.3
95% KM (t) UCL	106	95% KM (Percentile Bootstrap) UCL	105
95% KM (z) UCL	102.4	95% KM Bootstrap t UCL	873.9
90% KM Chebyshev UCL	144.6	95% KM Chebyshev UCL	187
97.5% KM Chebyshev UCL	245.8	99% KM Chebyshev UCL	361.2
Gamma GOF Tests on Detected Observations Only			
A-D Test Statistic	0.751	**Anderson-Darling GOF Test**	
5% A-D Critical Value	0.751	Detected Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.338	**Kolmogorov-Smirnov GOF**	
5% K-S Critical Value	0.327	Detected Data Not Gamma Distributed at 5% Significance Level	
Detected Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics on Detected Data Only			
k hat (MLE)	0.51	k star (bias corrected MLE)	0.387
Theta hat (MLE)	198.1	Theta star (bias corrected MLE)	261.3
nu hat (MLE)	7.142	nu star (bias corrected)	5.415
Mean (detects)	101.1		

	A–E	F	G–K	L
52	**Gamma ROS Statistics using Imputed Non-Detects**			
53	GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs			
54	GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)			
55	For such situations, GROS method may yield incorrect values of UCLs and BTVs			
56	This is especially true when the sample size is small.			
57	For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates			
58	Minimum	0.01	Mean	47.96
59	Maximum	420	Median	5.5
60	SD	117	CV	2.44
61	k hat (MLE)	0.175	k star (bias corrected MLE)	0.185
62	Theta hat (MLE)	273.3	Theta star (bias corrected MLE)	259.5
63	nu hat (MLE)	5.264	nu star (bias corrected)	5.544
64	Adjusted Level of Significance (β)	0.0324		
65	Approximate Chi Square Value (5.54, α)	1.412	Adjusted Chi Square Value (5.54, β)	1.173
66	95% Gamma Approximate UCL (use when n>=50)	188.4	95% Gamma Adjusted UCL (use when n<50)	226.7
67				
68	**Estimates of Gamma Parameters using KM Estimates**			
69	Mean (KM)	51.14	SD (KM)	111.7
70	Variance (KM)	12482	SE of Mean (KM)	31.16
71	k hat (KM)	0.21	k star (KM)	0.212
72	nu hat (KM)	6.286	nu star (KM)	6.362
73	theta hat (KM)	244.1	theta star (KM)	241.1
74	80% gamma percentile (KM)	69.4	90% gamma percentile (KM)	154.6
75	95% gamma percentile (KM)	259.4	99% gamma percentile (KM)	545.3
76				
77	**Gamma Kaplan-Meier (KM) Statistics**			
78	Approximate Chi Square Value (6.36, α)	1.828	Adjusted Chi Square Value (6.36, β)	1.545
79	95% Gamma Approximate KM-UCL (use when n>=50)	178	95% Gamma Adjusted KM-UCL (use when n<50)	210.6
80				
81	**Lognormal GOF Test on Detected Observations Only**			
82	Shapiro Wilk Test Statistic	0.859	**Shapiro Wilk GOF Test**	
83	5% Shapiro Wilk Critical Value	0.803	Detected Data appear Lognormal at 5% Significance Level	
84	Lilliefors Test Statistic	0.251	**Lilliefors GOF Test**	
85	5% Lilliefors Critical Value	0.304	Detected Data appear Lognormal at 5% Significance Level	
86	**Detected Data appear Lognormal at 5% Significance Level**			
87				
88	**Lognormal ROS Statistics Using Imputed Non-Detects**			
89	Mean in Original Scale	51.58	Mean in Log Scale	2.61
90	SD in Original Scale	115.5	SD in Log Scale	1.412
91	95% t UCL (assumes normality of ROS data)	104.1	95% Percentile Bootstrap UCL	106.3
92	95% BCA Bootstrap UCL	133.1	95% Bootstrap t UCL	808.6
93	95% H-UCL (Log ROS)	135.4		
94				
95	**Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution**			
96	KM Mean (logged)	2.637	KM Geo Mean	13.97
97	KM SD (logged)	1.283	95% Critical H Value (KM-Log)	3.221
98	KM Standard Error of Mean (logged)	0.366	95% H-UCL (KM -Log)	95.97
99	KM SD (logged)	1.283	95% Critical H Value (KM-Log)	3.221
100	KM Standard Error of Mean (logged)	0.366		
101				
102	**DL/2 Statistics**			

	A	B	C	D	E	F	G	H	I	J	K	L
103	**DL/2 Normal**						**DL/2 Log-Transformed**					
104					Mean in Original Scale	49.71					Mean in Log Scale	2.409
105					SD in Original Scale	116.2					SD in Log Scale	1.451
106					95% t UCL (Assumes normality)	102.6					95% H-Stat UCL	124.7
107	**DL/2 is not a recommended method, provided for comparisons and historical reasons**											
108												
109	**Nonparametric Distribution Free UCL Statistics**											
110	**Detected Data appear Lognormal Distributed at 5% Significance Level**											
111												
112	**Suggested UCL to Use**											
113					97.5% KM (Chebyshev) UCL	245.8					99% KM (Chebyshev) UCL	361.2
114												
115	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
116	Recommendations are based upon data size, data distribution, and skewness.											
117	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
118	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
119												

	A	B	C	D	E	F	G	H	I	J	K	L
1	UCL Statistics for Data Sets with Non-Detects											
2												
3	User Selected Options											
4	Date/Time of Computation			ProUCL 5.111/19/2018 6:08:43 PM								
5	From File			ProUCL_Radium-226.xls								
6	Full Precision			OFF								
7	Confidence Coefficient			95%								
8	Number of Bootstrap Operations			2000								
9												
10	Radium-226											
11												
12	General Statistics											
13	Total Number of Observations					15	Number of Distinct Observations					15
14	Number of Detects					9	Number of Non-Detects					6
15	Number of Distinct Detects					9	Number of Distinct Non-Detects					6
16	Minimum Detect					1.4	Minimum Non-Detect					0.39
17	Maximum Detect					8.2	Maximum Non-Detect					5.4
18	Variance Detects					7.556	Percent Non-Detects					40%
19	Mean Detects					4.689	SD Detects					2.749
20	Median Detects					4.5	CV Detects					0.586
21	Skewness Detects					0.205	Kurtosis Detects					-1.936
22	Mean of Logged Detects					1.363	SD of Logged Detects					0.67
23												
24	Normal GOF Test on Detects Only											
25	Shapiro Wilk Test Statistic					0.875	Shapiro Wilk GOF Test					
26	5% Shapiro Wilk Critical Value					0.829	Detected Data appear Normal at 5% Significance Level					
27	Lilliefors Test Statistic					0.221	Lilliefors GOF Test					
28	5% Lilliefors Critical Value					0.274	Detected Data appear Normal at 5% Significance Level					
29	Detected Data appear Normal at 5% Significance Level											
30												
31	Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs											
32	KM Mean					3.042	KM Standard Error of Mean					0.794
33	KM SD					2.878	95% KM (BCA) UCL					4.338
34	95% KM (t) UCL					4.44	95% KM (Percentile Bootstrap) UCL					4.337
35	95% KM (z) UCL					4.348	95% KM Bootstrap t UCL					4.623
36	90% KM Chebyshev UCL					5.424	95% KM Chebyshev UCL					6.503
37	97.5% KM Chebyshev UCL					8	99% KM Chebyshev UCL					10.94
38												
39	Gamma GOF Tests on Detected Observations Only											
40	A-D Test Statistic					0.475	Anderson-Darling GOF Test					
41	5% A-D Critical Value					0.727	Detected data appear Gamma Distributed at 5% Significance Level					
42	K-S Test Statistic					0.205	Kolmogorov-Smirnov GOF					
43	5% K-S Critical Value					0.281	Detected data appear Gamma Distributed at 5% Significance Level					
44	Detected data appear Gamma Distributed at 5% Significance Level											
45												
46	Gamma Statistics on Detected Data Only											
47	k hat (MLE)					2.896	k star (bias corrected MLE)					2.005
48	Theta hat (MLE)					1.619	Theta star (bias corrected MLE)					2.339
49	nu hat (MLE)					52.13	nu star (bias corrected)					36.08
50	Mean (detects)					4.689						
51												

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	2.898
Maximum	8.2	Median	2.1
SD	3.092	CV	1.067
k hat (MLE)	0.376	k star (bias corrected MLE)	0.345
Theta hat (MLE)	7.709	Theta star (bias corrected MLE)	8.396
nu hat (MLE)	11.28	nu star (bias corrected)	10.35
Adjusted Level of Significance (β)	0.0324		
Approximate Chi Square Value (10.35, α)	4.165	Adjusted Chi Square Value (10.35, β)	3.693
95% Gamma Approximate UCL (use when n>=50)	7.205	95% Gamma Adjusted UCL (use when n<50)	8.124

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	3.042	SD (KM)	2.878
Variance (KM)	8.28	SE of Mean (KM)	0.794
k hat (KM)	1.117	k star (KM)	0.938
nu hat (KM)	33.52	nu star (KM)	28.15
theta hat (KM)	2.722	theta star (KM)	3.242
80% gamma percentile (KM)	4.92	90% gamma percentile (KM)	7.114
95% gamma percentile (KM)	9.32	99% gamma percentile (KM)	14.47

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (28.15, α)	17.04	Adjusted Chi Square Value (28.15, β)	15.99
95% Gamma Approximate KM-UCL (use when n>=50)	5.023	95% Gamma Adjusted KM-UCL (use when n<50)	5.356

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.896	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.829	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.173	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.274	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	3.187	Mean in Log Scale	0.78
SD in Original Scale	2.823	SD in Log Scale	0.907
95% t UCL (assumes normality of ROS data)	4.471	95% Percentile Bootstrap UCL	4.408
95% BCA Bootstrap UCL	4.612	95% Bootstrap t UCL	4.777
95% H-UCL (Log ROS)	6.18		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	0.501	KM Geo Mean	1.651
KM SD (logged)	1.207	95% Critical H Value (KM-Log)	3.088
KM Standard Error of Mean (logged)	0.338	95% H-UCL (KM -Log)	9.26
KM SD (logged)	1.207	95% Critical H Value (KM-Log)	3.088
KM Standard Error of Mean (logged)	0.338		

DL/2 Statistics

	A	B	C	D	E	F	G	H	I	J	K	L
103			**DL/2 Normal**						**DL/2 Log-Transformed**			
104					Mean in Original Scale	3.094					Mean in Log Scale	0.468
105					SD in Original Scale	2.958					SD in Log Scale	1.37
106					95% t UCL (Assumes normality)	4.439					95% H-Stat UCL	14.03
107	**DL/2 is not a recommended method, provided for comparisons and historical reasons**											
108												
109	**Nonparametric Distribution Free UCL Statistics**											
110	**Detected Data appear Normal Distributed at 5% Significance Level**											
111												
112	**Suggested UCL to Use**											
113					95% KM (t) UCL	4.44						
114												
115	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
116	Recommendations are based upon data size, data distribution, and skewness.											
117	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
118	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
119												

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.111/8/2019 12:43:21 PM
From File	ProUCL_Radium-228.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Radium-228

General Statistics			
Total Number of Observations	15	Number of Distinct Observations	13
		Number of Missing Observations	0
Minimum	0.63	Mean	3.388
Maximum	6.7	Median	2.5
SD	2.224	Std. Error of Mean	0.574
Coefficient of Variation	0.656	Skewness	0.446
Normal GOF Test			
Shapiro Wilk Test Statistic	0.882	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.881	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.2	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.22	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	4.399	95% Adjusted-CLT UCL (Chen-1995)	4.403
		95% Modified-t UCL (Johnson-1978)	4.41
Gamma GOF Test			
A-D Test Statistic	0.421	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.746	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.155	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.224	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	2.231	k star (bias corrected MLE)	1.829
Theta hat (MLE)	1.518	Theta star (bias corrected MLE)	1.852
nu hat (MLE)	66.94	nu star (bias corrected)	54.88
MLE Mean (bias corrected)	3.388	MLE Sd (bias corrected)	2.505
		Approximate Chi Square Value (0.05)	38.86
Adjusted Level of Significance	0.0324	Adjusted Chi Square Value	37.2
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	4.785	95% Adjusted Gamma UCL (use when n<50)	4.998
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.934	**Shapiro Wilk Lognormal GOF Test**	

	A	B	C	D	E	F	G	H	I	J	K	L
53					5% Shapiro Wilk Critical Value	0.881	Data appear Lognormal at 5% Significance Level					
54					Lilliefors Test Statistic	0.13	**Lilliefors Lognormal GOF Test**					
55					5% Lilliefors Critical Value	0.22	Data appear Lognormal at 5% Significance Level					
56	**Data appear Lognormal at 5% Significance Level**											
57												
58	**Lognormal Statistics**											
59					Minimum of Logged Data	-0.462					Mean of logged Data	0.98
60					Maximum of Logged Data	1.902					SD of logged Data	0.759
61												
62	**Assuming Lognormal Distribution**											
63					95% H-UCL	5.764					90% Chebyshev (MVUE) UCL	5.636
64					95% Chebyshev (MVUE) UCL	6.617					97.5% Chebyshev (MVUE) UCL	7.978
65					99% Chebyshev (MVUE) UCL	10.65						
66												
67	**Nonparametric Distribution Free UCL Statistics**											
68	**Data appear to follow a Discernible Distribution at 5% Significance Level**											
69												
70	**Nonparametric Distribution Free UCLs**											
71					95% CLT UCL	4.332					95% Jackknife UCL	4.399
72					95% Standard Bootstrap UCL	4.315					95% Bootstrap-t UCL	4.517
73					95% Hall's Bootstrap UCL	4.263					95% Percentile Bootstrap UCL	4.329
74					95% BCA Bootstrap UCL	4.388						
75					90% Chebyshev(Mean, Sd) UCL	5.111					95% Chebyshev(Mean, Sd) UCL	5.891
76					97.5% Chebyshev(Mean, Sd) UCL	6.974					99% Chebyshev(Mean, Sd) UCL	9.101
77												
78	**Suggested UCL to Use**											
79					95% Student's-t UCL	4.399						
80												
81	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
82	Recommendations are based upon data size, data distribution, and skewness.											
83	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
84	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
85												

TABLE 3

EXPOSURE POINT CONCENTRATION (EPC) SUMMARY

REASONABLE MAXIMUM EXPOSURE (RME)

FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical of Potential Concern	Units	Frequency of Detection	Arithmetic Mean of Detected Values	Maximum Detected Concentration	Exposure Point Concentration (EPC) (ProUCL)		
						Recommended UCL[a]	Distribution	Statistic
FSU-LLRW Groundwater	**Semi-Volatile Organic Compounds (SVOCs)**							
	1,4-Dioxane	µg/L	7 of 15	1.01E+02	4.20E+02	2.46E+02	Non-parametric	97.5% Chebyshev
	Radionuclides							
	Radium-226	pCi/L	8 of 15	4.69E+00	8.20E+00	4.44E+00	Normal	95% KM (t) UCL
	Radium-228	pCi/L	11 of 15	4.06E+00	6.70E+00	4.40E+00	Normal	95% KM (t) UCL

[a] UCL = Upper Confidence Limit of the arithmatic mean equals the EPC. EPCs are identified using ProUCL 5.1.00 Statistical Software.(https://www.epa.gov/land-research/proucl-software

TABLE 4.1 RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal Absorption	Resident	Adult	Water Table Aquifer	CW	Chemical Concentration in Water	See Table 3	mg/L	See Table 3	Dermally Absorbed Dose (DAD) (mg/kg-day) =
			Tap Water	FA	Fraction Absorbed by Water	Chemical Specific	- -	Table 4.2	DA-event x EV x ED x EF x SA x 1/BW x 1/AT
				K_p	Permeability Constant	Chemical Specific	cm/hr	Table 4.2	where for organic compounds,
				SA	Skin Surface Area	19,652	cm^2	EPA, 2014	DA-Event =
				tau-event	Lag t ime per event	Chemical Specific	hours	Table 4.3	2FA x Kp x CW x CF x SQRT{(6 x tau-evemt x t-event)/pi}
				t-event	Event Duration	0.33	hours	EPA, 2003	or, if tevent > time to reach steady state (t*), then:
				B	Ratio of permeability coefficient of a	Chemical Specific	- -	EPA, 2001	DA-event = FA x Kp x CW x {(t-event/(1+B)) +
					compound through the stratum corneum relative				2 x tau-event x ((1+(3 x B) + (3 x B x B))/(1 + B)2)}
					to its permeability coefficient across the viable				and where for inorganic compounds,
					epidermis				DA-event = KP x CW x CF x t-event
				EV	Event Frequency	1	Events/day	EPA, 2001	
				EF	Exposure Frequency	350	days/year	EPA, 2014	
				ED	Exposure Duration	20	years	EPA, 2014	
				CF	Volumetric Conversion Factor for Water	0.001	l/cm^3	- -	
				BW	Body Weight	80	kg	EPA, 2014	
				AT-C	Averaging Time - Cancer	25,550	days	EPA, 2014	
				AT-N	Averaging Time - Non-Cancer	7,300	days	EPA, 2014	
		Child	Water Table Aquifer	CW	Chemical Concentration in Water	See Table 3	mg/L	See Table 3	Dermally Absorbed Dose (DAD) (mg/kg-day) =
			Tap Water	FA	Fraction Absorbed by Water	Chemical Specific	- -	Table 4.2	DA-event x EV x ED x EF x SA x 1/BW x 1/AT
				K_p	Permeability Constant	Chemical Specific	cm/hr	Table 4.2	where for organic compounds,
				SA	Skin Surface Area	6,365	cm^2	EPA, 2014	DA-Event =
				tau-event	Lag t ime per event	Chemical Specific	hours	Table 4.10	2FA x Kp x CW x CF x SQRT{(6 x tau-evemt x t-event)/pi}
				t-event	Event Duration	0.33	hours	EPA, 2003	or, if tevent > time to reach steady state (t*), then:
				B	Ratio of permeability coefficient of a	Chemical Specific	- -	EPA, 2001	DA-event = FA x Kp x CW x {(t-event/(1+B)) +
					compound through the stratum corneum relative				2 x tau-event x ((1+(3 x B) + (3 x B x B))/(1 + B)2)}
					to its permeability coefficient across the viable				and where for inorganic compounds,
					epidermis				DA-event = KP x CW x CF x t-event
				EV	Event Frequency	1	Events/day	EPA, 2001	
				EF	Exposure Frequency	350	days/year	EPA, 2014	
				ED	Exposure Duration	6	years	EPA, 2014	
				CF	Volumetric Conversion Factor for Water	0.001	l/cm^3	- -	
				BW	Body Weight	15	kg	EPA, 2001	
				AT-C	Averaging Time - Cancer	25,550	days	EPA, 2014	
				AT-N	Averaging Time - Non-Cancer	2,190	days	EPA, 2014	`

Sources:

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

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

EPA 2001: Risk Assessment Guidance for Superfund. Volume1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim.

EPA 2003: Region III Techniclal Guidance Manual, Risk Assessment. Updated Dermal Exposure Assessment Guidance. June.

EPA 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. OSWER Directive 9200.1-120.

TABLE 4.1 RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Scenario Timeframe: Current/Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal Absorption	Construction Worker	Adult	Water Table Aquifer Tap Water	CW	Chemical Concentration in Water	See Table 3	mg/L	See Table 3	Dermally Absorbed Dose (DAD) (mg/kg-day) =
				FA	Fraction Absorbed by Water	Chemical Specific	- -	Table 4.2	DA-event x EV x ED x EF x SA x 1/BW x 1/AT
				K_p	Permeability Constant	Chemical Specific	cm/hr	Table 4.2	where for organic compounds,
				SA	Skin Surface Area	3,300	cm^2	EPA, 2014	DA-Event =
				tau-event	Lag t ime per event	Chemical Specific	hours	Table 4.10	2FA x Kp x CW x CF x SQRT{(6 x tau-evemt x t-event)/pi}
				t-event	Event Duration	0.33	hours	EPA, 2003	or, if tevent > time to reach steady state (t*), then:
				B	Ratio of permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis	Chemical Specific	- -	EPA, 2001	DA-event = FA x Kp x CW x {(t-event/(1+B)) + 2 x tau-event x ((1+(3 x B) + (3 x B x B))/(1 + B)2)} and where for inorganic compounds, DA-event = KP x CW x CF x t-event
				EV	Event Frequency	1	Events/day	EPA, 2001	
				EF	Exposure Frequency	250	days/year	EPA, 2014	
				ED	Exposure Duration	25	years	EPA, 2014	
				CF	Volumetric Conversion Factor for Water	0.001	l/cm^3	- -	
				BW	Body Weight	80	kg	EPA, 2001	
				AT-C	Averaging Time - Cancer	25,550	days	EPA, 2014	
				AT-N	Averaging Time - Non-Cancer	9,125	days	EPA, 2014	`
Ingestion	Resident	Adult	Water Table Aquifer Tap Water	CW	Chemical Concentration in Water	See Table 3.1	mg/L	See Table 3.1	Chronic Daily Intake (CDI) (mg/kg-day)=
				IR-W	Ingestion Rate of Water	2.5	L/day	EPA, 2014	CW x IR-W x EF x ED x 1/BW x 1/AT
				EF	Exposure Frequency	350	days/year	EPA, 2014	
				ED	Exposure Duration	20	years	EPA, 2014	
				BW	Body Weight	80	kg	EPA, 2014	
				AT-C	Averaging Time - Cancer	25,550	days	EPA, 2014	
				AT-N	Averaging Time - Non-Cancer	7,300	days	EPA, 2014	
		Child	Water Table Aquifer Tap Water	CW	Chemical Concentration in Water	See Table 3.1	mg/L	See Table 3.1	Chronic Daily Intake (CDI) mg/kg-day)=
				IR-W	Ingestion Rate of Water	1	L/day	EPA, 1989	CW x CF1 x IR x EF x ED x 1/BW x 1/AT
				EF	Exposure Frequency	350	days/year	EPA, 2014	
				ED	Exposure Duration	6	years	EPA, 2014	
				BW	Body Weight	15	kg	EPA, 2014	
				AT-C	Averaging Time - Cancer	25,550	days	EPA, 2014	
				AT-N	Averaging Time - Non-Cancer	2,190	days	EPA, 2014	

Sources:

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

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

EPA 2001: Risk Assessment Guidance for Superfund. Volume1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim.

EPA 2003: Region III Technicial Guidance Manual, Risk Assessment. Updated Dermal Exposure Assessment Guidance. June.

EPA 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. OSWER Directive 9200.1-120.

TABLE 4.2.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Vapor

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Inhalation (1)	Resident	Adult	Water Vapors from Showerhead	(1)	(1)	(1)	(1)	(1)	Foster & Chrostowski Shower Inhalation Model (ICF - Clement Associates, Inc., 1987)

(1) Refer to Risk Assessment text for details of the model intake methodology and paramaters used to calculate modeled intake values for the VISL model cacluator too..

Table 4.3
Chemical Specific Data

COPC Parameters	Event Duration t-event (hours)	Time to reach steady state (t*) (hours)	$t_{event} \leq t^*$	Lag Time per Event Tau-event (hours)	Fraction Absorbed by Water (FA) (unitless)	Permeability Constant (Kp) (cm/hour)	Source
SVOCs							
1,4-Dioxane	0.33	0.8	Y	0.33	1	3.3E-04	EPA 2001
Radionuclides							
Radium-226	0.33	NA	NA	NA	NA	NA	
Radium-228	0.33	NA	NA	NA	NA	NA	

Source
EPA 2001: Risk Assessment Guidance for Superfund. Volume1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Interim, Exhibit B-3

NA. Not Applicable

TABLE 5

NON-CANCER TOXICITY DATA -- ORAL/DERMAL

FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD		Oral Absorption Efficiency for Dermal (1)	Absorbed RfD for Dermal (2)		Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	RfD:Target Organ(s)	
		Value	Units		Value	Units			Source(s)	Date(s)
SVOCs										
1,4-Dioxane	Chronic	3E-02	mg/kg-day	1	3E-02	mg/kg-day	Liver/kidney	300	IRIS	Nov-18
Radionuclides										
Radium-226	NA	NA	NA	NA	NA	NA	Lung	NA	IRIS	Nov-18
Radium-228	NA	NA	NA	NA	NA	NA	Lung	NA	IRIS	Nov-18

Notes:

1. Source: Risk Assessment Guidance For Superfund. Volume1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. Section 4.2 and Exhibit 4-1.

2. Absorbed RfD = Oral RfD * Oral Absorption Efficiency

Definitions:

NA = Not available

IRIS = Integrated Risk Information System, EPA

TABLE 6.1

CANCER TOXICITY DATA -- ORAL/DERMAL

FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Chemical of Potential Concern	Oral Cancer Slope Factor		Oral Absorption Efficiency for Dermal (1)	Absorbed Cancer Slope Factor for Dermal		Weight of Evidence/ Cancer Guideline Description	Oral CSF	
	Value	Units		Value	Units		Source(s)	Date(s)
SVOCs								
1,4-Dioxane	1.0E-01	1/mg/kg-day	1	1.0E-01	1/mg/kg-day	B1	IRIS	Nov-18

1. Source: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. Section 4.2 and Exhibit 4-1.
2. Absorbed Cancer Slope Factor = Oral CsF * Oral Absorption Efficiency

IRIS = Integrated Risk Information Sysytem

Definitions:
A = Human carcinogen
B1 = Probable Human Carcinogen - Agents for which there is limited human data available from epidemiologic studies and/or is classified as a likely human carcinogen.
B2 = Probable Human Carcinogen - Indicates sufficient evidence in animals and inadequate or no evidence in humans
C = Possible human carcinogen
D = Not classifiable as to human carcinogenicity/ inadequate information
E = Evidence of noncarcinogenicity for humans

TABLE 6.2
CANCER TOXICITY DATA -- EXTERNAL (RADIATION)
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Chemical of Potential Concern	Water Ingestion Slope Factor		Immersion Slope Factor		Food Ingestion Slope Factor		Oral CSF	
	Value	Units	Value	Units	Value	Units	Source(s)	Date(s)
Radionuclides								
Radium-226	3.85E-10	Risk/pCi	1.68E-11	Risk/year/pCi/L	5.14E-10	Risk/pCi	RAIS	Nov-18
Radium-228	1.04E-09	Risk/pCi	8.15E-12	Risk/year/pCi/L	1.42E-09	Risk/pCi	RAIS	Nov-18

1. Source: Risk Assessment Information System
https://rais.ornl.gov

TABLE 7.1.RME
CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Scenario Timeframe: Current/Future
Receptor Population: Site/Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
			Dermal Absorption	1,4-Dioxane	2.46E-01	mg/L	7.5E-07	mg/kg-day	1.0E-01	1/mg/kg-day	7.47E-08	2.1E-06	mg/kg-day	3.0E-02	mg/kg-day	6.3E-08
			Exp. Route Total								7.47E-08					6.28E-08
		Exposure Point Total									7.47E-08					6.28E-08
	Exposure Medium Total										7.47E-08					6.28E-08

TABLE 7.2.RME
CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Aquifer Tap Water	Dermal Absorption	1,4-Dioxane	2.46E-01	mg/L	5.0E-06	mg/kg-day	1.0E-01	1/mg/kg-day	4.98E-07	1.7E-05	mg/kg-day	3.0E-02	mg/kg-day	0.0006
			Exp. Route Total								4.98E-07					0.0006
			Ingestion	1,4-Dioxane	2.46E-01	mg/L	2.0E-03	mg/kg-day	1.0E-01	1/mg/kg-day	2.02E-04	7.1E-03	mg/kg-day	3.0E-02	mg/kg-day	0.2359
			Exp. Route Total								2.02E-04					0.2359
			Inhalation	1,4-Dioxane	2.46E-01	mg/L	VISL Model				8.60E-08	VISL Model				0.0015
			Exp. Route Total								8.60E-08					0.0015
		Exposure Point Total									2.03E-04					0.2380
	Exposure Medium Total										2.03E-04					0.2380

TABLE 7.3.RME
CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Aquifer Tap Water	Dermal Absorption	1,4-Dioxane	2.46E-01	mg/L	2.6E-06	mg/kg-day	1.0E-01	1/mg/kg-day	2.59E-07	2.6E-06	mg/kg-day	3.0E-02	mg/kg-day	0.0001
			Exp. Route Total								2.59E-07					0.0001
			Ingestion	1,4-Dioxane	2.46E-01	mg/L	1.3E-03	mg/kg-day	1.0E-01	1/mg/kg-day	1.35E-04	1.6E-02	mg/kg-day	3.0E-02	mg/kg-day	0.5242
			Exp. Route Total								1.35E-04					0.5242
			Inhalation	1,4-Dioxane	2.46E-01	mg/L	VISL Model				8.60E-08	VISL Model				0.0015
			Exp. Route Total								8.60E-08					0.0015
		Exposure Point Total									1.35E-04					0.5258
	Exposure Medium Total										1.35E-04					0.5258

TABLE 7.4.RME
CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Aquifer Tap Water	Dermal Absorption	1,4-Dioxane	2.46E-01	mg/L	7.6E-06	mg/kg-day	1.0E-01	1/mg/kg-day	7.58E-07	2.0E-05	mg/kg-day	3.0E-02	mg/kg-day	0.0007
			Exp. Route Total								7.58E-07					0.0007
			Ingestion	1,4-Dioxane	2.46E-01	mg/L	3.4E-03	mg/kg-day	1.0E-01	1/mg/kg-day	3.37E-04	2.3E-02	mg/kg-day	3.0E-02	mg/kg-day	0.7601
			Exp. Route Total								3.37E-04					0.7601
			Inhalation	1,4-Dioxane	2.46E-01	mg/L	VISL Model				8.60E-08	VISL Model				0.0015
			Exp. Route Total								8.60E-08					0.0015
		Exposure Point Total									3.38E-04					0.7623
	Exposure Medium Total										3.38E-04					0.7623

TABLE 8 RME

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations				
					Value	Units	Intake/Activity		CSF		Cancer Risk
							Value	Units	Value	Units	
Groundwater	Groundwater	Groundwater Plume	Dermal Absorption	Radium-226	4.44	pCi/L	3.09E+00	pCi/year/L	6.27E-14	Risk/pCi/L	1.94E-13
				Radium-228	4.40	pCi/L	3.07E+00	pCi/year/L	5.02E-16	Risk/pCi/L	1.54E-15
			Exp. Route Total								1.95E-13
			Ingestion	Radium-226	4.44	pCi/L	8.42E+04	pCi	3.85E-10	Risk/pCi	3.24E-05
				Radium-228	4.40	pCi/L	8.42E+04	pCi	1.04E-09	Risk/pCi	8.76E-05
			Exp. Route Total								1.20E-04
			Produce Ingestion	Radium-226	4.44	pCi/L	1.29E+04	pCi	5.14E-10	Risk/pCi	6.63E-06
				Radium-228	4.40	pCi/L	1.06E+04	pCi	1.42E-09	Risk/pCi	1.51E-05
			Exp. Route Total								2.17E-05
			Inhalation	Radium-226	4.44	pCi/L	NA	NA	2.820E-08	Risk/pCi	NA
				Radium-228	4.40	pCi/L	NA	NA	4.370E-08	Risk/pCi	NA
			Exp. Route Total								
		Exposure Point Total									1.42E-04
	Exposure Medium Total										1.42E-04
Groundwater Total											1.42E-04

TABLE 9.1.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

Scenario Timeframe: Current/Future
Receptor Population: Site/Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Aquifer Tap Water	1,4-Dioxane	--	--	7.47E-08	--	7.47E-08	Liver/Kidney	--	--	6.28E-08	6.28E-08
			Chemical Total	--	--	7.47E-08	--	7.47E-08		--	--	6.28E-08	6.28E-08
		Exposure Point Total						7.47E-08					6.28E-08
	Exposure Medium Total							7.47E-08					6.28E-08

Total Risk Across All Media	7.47E-08	6.28E-08
Total Liver HI Across all media		6.28E-08
Total Kidney HI Across all media		6.28E-08

TABLE 9.2.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

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

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Aquifer Tap Water	1,4-Dioxane	2.02E-04	8.60E-08	4.98E-07	1.42E-04	3.45E-04	Liver/Kidney	0.2359	0.0015	0.0006	0.2380
			Chemical Total	2.02E-04	8.60E-08	4.98E-07	1.42E-04	3.45E-04		0.2359	0.0015	0.0006	0.2380
		Exposure Point Total						3.45E-04					0.2380
	Exposure Medium Total							3.45E-04					0.2380

Total Risk Across All Media	3.45E-04	0.2380
Total Liver HI Across all media		0.2380
Total Kidney HI Across all media		0.2380

TABLE 9.3.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

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

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Aquifer Tap Water	1,4-Dioxane	1.35E-04	8.60E-08	2.59E-07	1.42E-04	2.77E-04	Liver/Kidney	0.5242	0.0015	0.0001	0.5258
			Chemical Total	1.35E-04	8.60E-08	2.59E-07	1.42E-04	2.77E-04		0.5242	0.0015	0.0001	0.5258
		Exposure Point Total						2.77E-04					0.5258
	Exposure Medium Total							2.77E-04					0.5258
							Total Risk Across All Media	2.77E-04					0.5258
												Total Liver HI Across all media	0.5258
												Total Kidney HI Across all media	0.5258

TABLE 9.4.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
FSU-LLRW SITE, APALACHICOLA NATIONAL FOREST, FLORIDA

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

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Aquifer Tap Water	1,4-Dioxane	3.37E-04	8.60E-08	7.58E-07	1.42E-04	4.80E-04	Liver/Kidney	0.7601	0.0015	0.0007	0.7623
			Chemical Total	3.37E-04	8.60E-08	7.58E-07	1.42E-04	4.80E-04		0.7601	0.0015	0.0007	0.7623
		Exposure Point Total						4.80E-04					0.7623
	Exposure Medium Total							4.80E-04					0.7623
							Total Risk Across All Media	4.80E-04					0.7623
												Total Liver HI Across all media	0.7623
												Total Kidney HI Across all media	0.7623

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APPENDIX D

Applicable or Relevant and Appropriate Requirements (ARARs)

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Appendix D: List of Potential ARARS for the FSU-LLRW

REGULATIONS	CFR/FDEP REFERENCES	POTENTIAL ARARs
RCRA	40 CFR 268; FAC 62-730.183 (Hazardous Waste Disposal)	Land Disposal Restrictions: Applicable for RCRA designated wastes. Contaminated soils, sediments, leachates, etc. must be managed as RCRA wastes. FDEP requirements are likely to take precedence over most RCRA requirements.
	40 CFR 264; FAC 62-730.180-181 (Hazardous Waste Disposal)	Disposal and Closure Requirements RCRA requirements for disposal and site closure (removal area) may become relevant and appropriate if contaminated materials are excavated from the site during the removal action. FDEP requirements are likely to take precedence over most RCRA requirements.
	40 CFR 264.251 (c) (d); 40 CFR 264.273 (c) (d); 40 CFR 264.301 (c) (d); 40 CFR 264.258 (b); 40 CFR 264.310; FAC 62-40.432	Surface Water Control Control and prevent run-on and run-off from a 24-hour, 25-year storm (waste piles, land treatment facilities, and landfills). FDEP requirements may also be applicable and may take precedence.
	40 CFR 262.30 through 31	Transport Requirements Materials removed from the burial site, which are classified as hazardous waste, will be required to follow packaging and labeling regulations, prior to transport.
	40 CFR 261.10 (261.24 Toxicity Characteristic; FAC 62-730.030	Criteria for Identifying the Characteristics of Hazardous Waste Hazardous wastes (including soils, debris, etc.) may potentially be excavated from the burial site. The characteristics of these wastes will determine if RCRA disposal requirements apply. FDEP requirements may also be applicable and may take precedence.
SDWA	40 CFR 141.11 through 12, 40 CFR 15 through 16; FAC 62-777	National Primary Drinking Water Regulations Maximum contaminant levels (MCLs) for radionuclides, organic chemicals, and inorganic chemicals in community drinking systems may be considered during remedial activities. MCLs and non-zero maximum contaminant level goals (MCLGs) may be relevant to groundwater at the site, although the surficial aquifer is not believed to be a current source of drinking water. Criteria may be used as threshold levels for selection of contaminants of concern (COCs) to assess potential impact to the environment. Florida has Groundwater Target Cleanup Levels (GTCLs) for some contaminants for which there is no established MCL or MCLG
	40 CFR 143.3;	Secondary Maximum Contaminant Levels Secondary Maximum Contaminant levels may be applicable to groundwater quality at the site. Groundwater quality must be suitable for its intended use.

Appendix D: List of Potential ARARS for the FSU-LLRW

REGULATIONS	CFR/FDEP REFERENCES	POTENTIAL ARARs
DOT	49 CFR 173.24; FAC 62-550	General Requirements for Hazardous Material Packaging and Packages Specifications for the packaging of materials and the packages prior to transport. DOT regulations may be applicable or relevant to hazardous materials removed from the site.
	49 CFR 177.848	Segregation of Hazardous Materials Provides instructions for using the segregation table for hazardous materials, which outlines specifications for the transport of different types or classes of hazardous materials. These requirements would be applicable or relevant to materials and/or debris excavated from the burial site.
DOT	49 CFR 173.3	Shipping Requirements for Hazardous Materials - Specifications for the transport of hazardous materials. These requirements may be applicable for contaminated soils, debris, etc. during the remedial action.
	49 CFR 177.842	Carriage by Public Highway - Class 7 (radioactive) material Provides specifications for the transport of radioactive materials. Requirements may be applicable or relevant to waste materials excavated from the site.
CAA	NAAQS 40 CFR 50, 40 CFR 61; FAC 62-204	Chemical Discharges from Remedial Activities or Treatment Discharges to ambient air from remedial activities must not cause nuisance odors or pose excess risk to human health or the environment. Includes National Ambient Air Quality Standards (NAAQS), and New Source Performance Standards (NSPS); Florida Administers provisions of the CAA.
	CAA Section 101 and 40 CFR 52	Fugitive and Odor Emission Control Plan Action Odor regulations are intended to limit nuisance conditions from air pollution emissions. Fugitive emission controls are one feature of the state implementation plan used to achieve/maintain the ambient air quality standards for particulate matter. Florida Administers provisions of the CAA.
Endangered Species Act of 1973	50 CFR 200, 50 CFR 402; FAC 68A-27	Endangered Species Act - The determination/protection of endanger species or threatened species at the site.
Radiation (DOE)	10 CFR 20.101, 10 CFR 20.104	Radiation Protection Programs For the protection of workers during remediation activities, DOE programs may be applicable or relevant. Programs consist of a variety of radiation exposure limits including dose limits of 1.25 rem/quarter to whole body.
	10 CFR 20.1701-20.1702. 10 CFR 20.1703	Respiratory Protection and Controls to Restrict Internal Exposure in Restricted Areas - The best available measures, to the extent practicable, should be considered to control the concentration of radioactive materials in the air. The use of individual respiratory equipment should be required to limit the intake of radioactive materials in the air. In addition, a respiratory protection program should be implemented through the entire duration of the remediation.

Appendix D: List of Potential ARARS for the FSU-LLRW

REGULATIONS	CFR/FDEP REFERENCES	POTENTIAL ARARs
Radiation (DOE)	10 CFR 61.41	Protection of the General Population from Releases of Radioactivity - Limits the concentration of radioactive material that may be released into the air, water, soil, plants, and animals.
	10 CFR 61.50; FAC 64E-5.907	Technical Requirements for Land Disposal Facilities Following the excavation, the elimination of radioactively contaminated materials or wastes will be required to comply with appropriate disposal site suitability criteria.
	10 CFR 71.43-71.47	General Standards and External Radiation Standards for Packages - The transport of radioactive wastes must meet specific packaging and external radiation standards. Requirements may be applicable to potential debris and soils removed from the burial site.
OSHA	29 CFR 1910.96; 29 CFR 1926.53	Ionizing Radiation Provides specifications and requirements for the protection of human health from exposure to radiation in restricted areas. This may be applicable to personnel during the site remediation.
	29 CFR 1910.120; 29 CFR 1926.65	Hazardous Waste Operations and Emergency Response Provides employee exposure specifications for dealing with clean-up of NPL sites, corrective actions of RCRA sites, voluntary clean-up of federal property, and emergency response operations for releases, or potential releases of hazardous substances.
	29 CFR 1910.120; 29 CFR 1926.103	Respiratory Protection Outline of respiratory protection requirements for employees that may be exposed to harmful dusts, fogs, fumes, mists, gases, smokes, etc., while working on site. The use of respirators or and respiratory protection program may be applicable during remedial activities.
	29 CFR 1926.55	Gases, Vapors, Fumes, Dusts, and Mists Provides exposure limits and compliance specifications for inhalation, ingestion, skin absorption, or contact with any substance at a concentration above those specified in the “Threshold Limit Values of Airborne Contaminates for 1970". Provisions for the protection of employees during remedial activities.

Appendix D: List of Potential ARARS for the FSU-LLRW

REGULATIONS	CFR/FDEP REFERENCES	POTENTIAL ARARs
OSHA	29 CFR 1926.651; 29 CFR 1926.652	<u>Specific Excavation Requirements and Requirements for Protective Systems</u> Safety requirements and protective systems for excavations will be relevant and applicable to excavation activities during the site remediation. Specifications include: underground installations (utilities), access and egress (structural ramps), oxygen monitoring, exposure to vehicular traffic, protection from cave in, etc.

APPENDIX E

Presumptive Remedy Costing Sheets

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Alternative 1
No Action
FSU-LLRW Burial Site

Alternative Description: This alternative will include no further action at the FSU-LLRW in regards to the actual buried wastes and contaminated groundwater. No monitoring or land use controls will be implemented to address soils contamination.

Item	Quantity	Units	Unit Cost	Total Cost	Subtotals	Notes
Capital Costs						
No Capital Costs						
CAPITAL COSTS TOTAL					**$ -**	
Project Management	10%				$ -	
Operations and Maintenance - Annual						
1.0 Administration						
Task 1 Subtotal					**$ -**	
2.0 Regulatory Interaction						
Task 2 Subtotal					**$ -**	
O&M Costs Subtotal					**$ -**	
Project Management	10%				$ -	
O&M ANNUAL COSTS TOTAL					**$ -**	
5-Year Site Review Costs						
1.0 CERCLA Review						
Task 1 Subtotal					**$ -**	
Site Review Costs Subtotal					**$ -**	
Project Management	10%				$ -	
SITE REVIEW COSTS TOTAL					**$ -**	

Note:

Alternative 1
No Action
FSU-LLRW Burial Site

Alternative Description: This alternative will include no further action at the FSU-LLRW in regards to the actual buried wastes and contaminated groundwater. No monitoring or land use controls will be implemented to address soils contamination.

Base Year	2020
Location:	Leon County, Florida
Discount Rate:	5%
Project Length:	30 years

Year	Capital Costs	Annual O&M Costs	Periodic Costs	Total Annual Expenditure	Discount Factor	Present Value
0	$ -	$ -	$ -	$ -	1.0000	$ -
1	$ -	$ -	$ -	$ -	0.9524	$ -
2	$ -	$ -	$ -	$ -	0.9070	$ -
3	$ -	$ -	$ -	$ -	0.8638	$ -
4	$ -	$ -	$ -	$ -	0.8227	$ -
5	$ -	$ -	$ -	$ -	0.7835	$ -
6	$ -	$ -	$ -	$ -	0.7462	$ -
7	$ -	$ -	$ -	$ -	0.7107	$ -
8	$ -	$ -	$ -	$ -	0.6768	$ -
9	$ -	$ -	$ -	$ -	0.6446	$ -
10	$ -	$ -	$ -	$ -	0.6139	$ -
11	$ -	$ -	$ -	$ -	0.5847	$ -
12	$ -	$ -	$ -	$ -	0.5568	$ -
13	$ -	$ -	$ -	$ -	0.5303	$ -
14	$ -	$ -	$ -	$ -	0.5051	$ -
15	$ -	$ -	$ -	$ -	0.4810	$ -
16	$ -	$ -	$ -	$ -	0.4581	$ -
17	$ -	$ -	$ -	$ -	0.4363	$ -
18	$ -	$ -	$ -	$ -	0.4155	$ -
19	$ -	$ -	$ -	$ -	0.3957	$ -
20	$ -	$ -	$ -	$ -	0.3769	$ -
21	$ -	$ -	$ -	$ -	0.3589	$ -
22	$ -	$ -	$ -	$ -	0.3418	$ -
23	$ -	$ -	$ -	$ -	0.3256	$ -
24	$ -	$ -	$ -	$ -	0.3101	$ -
25	$ -	$ -	$ -	$ -	0.2953	$ -
26	$ -	$ -	$ -	$ -	0.2812	$ -
27	$ -	$ -	$ -	$ -	0.2678	$ -
28	$ -	$ -	$ -	$ -	0.2551	$ -
29	$ -	$ -	$ -	$ -	0.2429	$ -
30	$ -	$ -	$ -	$ -	0.2314	$ -
Estimated Project Total Cost					**$ -**	
Estimated Project Total Cost Range (-30%/+50%)					**$ -**	**$ -**

Alternative 1 - No Action

No Action

FSU-LLRW Burial Site

Initial, Annual, and Periodic Costs

CAPITAL COSTS (One Time)			
	No Capital Costs	$ -	
CAPITAL COSTS CONTINGENCY, PROJECT MANAGEMENT, TECHNICAL SUPPORT			
	Project Management	10%	
O&M COSTS (Annual Costs)			
	1.0 Administration	$ -	
	2.0 Regulatory Interaction	$ -	
PERIODIC COSTS (Recurrent)			
	1.0 CERCLA Review	$ -	
O&M COSTS CONTINGENCY, PROJECT MANAGEMENT, TECHNICAL SUPPORT			
	Project Management	10%	

Total Present Value Assessment		
Discount Rate 5%	**COST (Present Worth)**	
Estimated Project Total Cost	**$ -**	
Estimated Project Total Cost Range (-30%/+50%)	**$ -**	**$ -**

*For the purposes of this EE/CA, the no action alternative has a cost of $0.00. However, there are costs associated with a no-action alternative that include maintenance of access roads, permitting and regulatory interface with FSU concerning the site, and the needs for periodic surveys and site visits to assess the condition of current site land use controls that include site security fencing.

Alternative 2
Excavation and off-site disposal of Low-Level Radiological Wastes and Contaminated Soils
FSU-LLRW Burial Pits

Alternative Description: Excavation and off-site disposal of Low-Level Radiological Wastes and Contaminated Soil. Post Excavation Survey and Site Restoration to Occur at Conclusion of Removal Action

Item	Quantity	Units	Unit Cost	Total Cost	Subtotals	Note
Capital Costs						
1.0 Planning and Regulatory Interface						
1.1 Work Plan Development and Approval	1	LS	$ 30,000	$ 30,000		1
Task 1 Subtotal					**$ 30,000**	
2.0 Site Preparation						
2.1 Mobilization and Site Preparation	1	LS	$ 40,000	$ 40,000		1
2.2 Concrete Laydown Area	7,500	SF	$ 6	$ 45,000		2
2.3 Concrete Laydown Area Sump and Pits	4	EACH	$ 2,000	$ 8,000		1, 2
2.4 Construction of Access Roads (1/4 mile road to site)	21,120	SF	$ 3	$ 52,800		1,3,4
2.5 Construction Equipment Trailer	6	MON	$ 150	$ 900		2
2.6 Removal and Disposal of Existing Site Fencing	1	LS	$ 5,000	$ 5,000		1
Task 2 Subtotal					**$ 151,700**	
3.0 Erosion Controls						
3.1 Erosion Prevention Control Plan	1	LS	$ 9,200	$ 9,200		1
3.2 Super Silt Fencing	2,500	LF	$ 1	$ 2,900		2
3.3 Security Fencing (8 foot high)	4,000	LF	$ 20	$ 80,000		5
Task 3 Subtotal					**$ 92,100**	
4.0 Excavation						
4.1 Front End Loader	60	DAY	$ 1,800	$ 108,000		4
4.2 Excavator - Excavation	60	DAY	$ 2,000	$ 120,000		4
4.3 RSO and Radiation Monitoring	12	WK	$ 5,000	$ 60,000		1
4.4 Site Labor	1,440	HR	$ 90	$ 129,600		6
4.5 On Site - Sorting Plant for Loose Wastes	3	MO	$ 4,000	$ 12,000		5
4.6 Frac Tanks for Dewatering	3	MO	$ 2,000	$ 6,000		5
4.7 Health and Safety and Air Monitoring	12	WK	$ 1,000	$ 12,000		1,9
4.8 Water Testing & Analysis	12	WK	$ 1,000	$ 12,000		1
4.9 Delivery and Rental of Rad Waste Containers	30	EA	$ 4,511	$ 135,330		5,7
Task 4 Subtotal					**$ 594,930**	
5.0 Transport and Off-site Disposal						
5.1 Public Meeting and Notification	120	HR	$ 90	$ 10,800		1,9
5.2 Planning and Development of Non-Rad Manifests	100	HR	$ 100	$ 10,000		1
5.3 Planning and Development of Rad Manifests	1	LS	$ 40,000	$ 40,000		1,5
5.4 Transport and Disposal of RCRA Non-Haz Soil	500	Ton	$ 100	$ 50,000		1
5.5 Transport and Disposal of RCRA Title C Soil	200	Ton	$ 500	$ 100,000		1
5.6 Tranport Rad Wastes	30	IM	$ 8,975	$ 269,250		5,7
5.7 Disposal of Radionuclide wastes	30	IM	$ 68,000	$ 2,040,000		5,7
5.8 Disposal of Water in Frac Tanks	12	EA	$ 19,000	$ 228,000		1,5,11
5.9 Decontamination and Screening Out of Site Equipment	1	LS	$ 20,000	$ 20,000		1,9
5.10 Sampling of Excavated Wastes	100	EA	$ 500	$ 50,000		1
Task 5 Subtotal					**$ 2,818,050**	
6.0 Final Status Survey						
6.1 Planning	120	HR	$ 100	$ 12,000		5,7
6.2 RSO	2	WK	$ 5,000	$ 10,000		1
6.3 Frac Tank for Dewatering	1	MO	$ 1,250	$ 1,250		5
6.4 Disposal of Water in Frac Tanks	2	EA	$ 19,000	$ 38,000		1,5,11
6.4 Post excavation Confirmation Samples	50	EA	$ 500	$ 25,000		1
6.5 Post excavation Sampling Labor	320	HR	$ 90	$ 28,800		1,8
6.6 Post Excavation Radiation Survey	1	LS	$ 25,000	$ 25,000		1,9
6.7 Final Status Survey Report	200	HR	$ 100	$ 20,000		1,9
6.8 Final Closure Approval	120	HR	$ 100	$ 12,000		1
Task 6 Subtotal					**$ 172,050**	

Alternative 2
Excavation and off-site disposal of Low-Level Radiological Wastes and Contaminated Soils
FSU-LLRW Burial Pits

Alternative Description: Excavation and off-site disposal of Low-Level Radiological Wastes and Contaminated Soil. Post Excavation Survey and Site Restoration to Occur at Conclusion of Removal Action

Item	Quantity	Units	Unit Cost	Total Cost	Subtotals	Note
Capital Costs						
7.0 Site Restoration						
7.1 Clean Fill (Delivered to Site)	3,000	CY	$ 40	$ 120,000		2
7.2 Front End Loader	10	DAY	$ 1,800	$ 18,000		4
7.3 Excavator	10	DAY	$ 2,000	$ 20,000		4
7.4 Site Labor	320	HR	$ 90	$ 28,800		1,8
7.5 Breakup concrete pad and dispose of off-site	7,599	SF	$ 3	$ 22,797		1,2
7.7 Remove Sed and Erosion Controls	1	LS	$ 2,500	$ 2,500		1
7.8 Final grading and site restoration	1	LS	$ 25,000	$ 25,000		1
Task 7 Subtotal					**$ 237,097**	
Capital Costs Subtotal					**$ 4,095,927**	
Project Management	10%				$ 409,593	
CAPITAL COSTS TOTAL					**$ 4,505,520**	

Notes:

1. Based on BMT experience with CERCLA and non-CERCLA Remediation Projects, including review cycles
2. Get-a-quote.net
3. Assume a road 16 feet across has to be constructed to allow heavy vehicles to access site.
4. Day rate for equipment and operator
5. Vendor quote
6. Assume three (3) full time equivalents (FTEs) for a three-months
7. Assume 30 IM containers for 555 tons of total rad debris and impacted soil
8. Four FTE equivalents for 80 hours each
9. Performed In accordance with MARSSIM and/or NRC Guidance
10. Assume a total of 16,000 gallons of water produced from dewatering
11. Assumed that Frac Tank will require emptying for off-site disposal every two-weeks

MARSSIM - Multi-Agency Radiation Survey and Site Investigation Manual

Alternative 2
Excavation and off-site disposal of Low-Level Radiological Wastes and Contaminated Soils
FSU-LLRW Burial Pits

Alternative Description: Excavation and off-site disposal of Low-Level Radiological Wastes and Contaminated Soil. Post Excavation Survey and Site Restoration to Occur at Conclusion of Removal Action

Base Year	2020
Location:	Leon County, Florida
Discount Rate:	5%
Project Length:	30 years

Year	Capital Costs	Annual O&M Costs	Periodic Costs	Total Annual Expenditure	Discount Factor	Present Value
0	$ 4,505,520	$ -		$ 4,505,520	1.0000	$ 4,505,520
1	$ -	$ -	$ -	$ -	0.9524	$ -
2	$ -	$ -	$ -	$ -	0.9070	$ -
3	$ -	$ -	$ -	$ -	0.8638	$ -
4	$ -	$ -	$ -	$ -	0.8227	$ -
5	$ -	$ -	$ -	$ -	0.7835	$ -
6	$ -	$ -	$ -	$ -	0.7462	$ -
7	$ -	$ -	$ -	$ -	0.7107	$ -
8	$ -	$ -	$ -	$ -	0.6768	$ -
9	$ -	$ -	$ -	$ -	0.6446	$ -
10	$ -	$ -	$ -	$ -	0.6139	$ -
11	$ -	$ -	$ -	$ -	0.5847	$ -
12	$ -	$ -	$ -	$ -	0.5568	$ -
13	$ -	$ -	$ -	$ -	0.5303	$ -
14	$ -	$ -	$ -	$ -	0.5051	$ -
15	$ -	$ -	$ -	$ -	0.4810	$ -
16	$ -	$ -	$ -	$ -	0.4581	$ -
17	$ -	$ -	$ -	$ -	0.4363	$ -
18	$ -	$ -	$ -	$ -	0.4155	$ -
19	$ -	$ -	$ -	$ -	0.3957	$ -
20	$ -	$ -	$ -	$ -	0.3769	$ -
21	$ -	$ -	$ -	$ -	0.3589	$ -
22	$ -	$ -	$ -	$ -	0.3418	$ -
23	$ -	$ -	$ -	$ -	0.3256	$ -
24	$ -	$ -	$ -	$ -	0.3101	$ -
25	$ -	$ -	$ -	$ -	0.2953	$ -
26	$ -	$ -	$ -	$ -	0.2812	$ -
27	$ -	$ -	$ -	$ -	0.2678	$ -
28	$ -	$ -	$ -	$ -	0.2551	$ -
29	$ -	$ -	$ -	$ -	0.2429	$ -
30	$ -	$ -	$ -	$ -	0.2314	$ -
Estimated Project Total Cost					**$ 4,505,520**	
Estimated Project Total Cost Range (-30%/+50%)					**$ 3,153,864**	**$ 6,758,280**

Alternative 2

:xcavation and off-site disposal of Low-Level Radiological Wastes and Contaminated Soil:

FSU-LLRW Burial Pits

Initial, Annual, and Periodic Costs

CAPITAL COSTS (One Time)			
	1.0 Planning and Regulatory Interface	$	30,000
	2.0 Site Preparation	$	151,700
	3.0 Erosion Controls	$	92,100
	4.0 Excavation	$	594,930
	5.0 Transport and Off-site Disposal	$	2,818,050
	6.0 Final Status Survey	$	172,050
	7.0 Site Restoration	$	237,097
O&M COSTS (Annual Costs)			
	No O&M Costs	$	-
PERIODIC COSTS (Recurrent)			
	No Periodic Costs	$	-
CONTINGENCY, PROJECT MANAGEMENT, TECHNICAL SUPPORT			
	Project Management		10%

Total Present Value Assessment			
Discount Rate 5%			**COST (Present Worth)**
Estimated Project Total Cost	**$**		**4,505,520**
Estimated Project Total Cost Range (-30%/+50%)	**$ 3,153,864**	**$**	**6,758,280**

Alternative 3
Groundwater: Monitored Natural Attenuation
FSU-LLRW Burial Pits

Alternative Description: Natural reduction of radionuclides through radioactive decay and continued degradation of 1,4-dioxane. This alternative will include the installation of additional monitoring wells and conducting annual groundwater monitoring at the FSU-LLRW.

Item	Quantity	Units	Unit Cost	Total Cost	Subtotals	Notes
Capital Costs						
1.0 Additional Monitoring Well Installation and Radionuclide Speciation						
1.1 Workplans	40	HR	$ 90	$ 3,600		2
1.2 Mobilization	1	LS	$ 5,000	$ 5,000		1
1.3 Monitoring Well Installation Costs	4	EA	$ 4,500	$ 18,000		2
1.4 Radionuclide Speciation Sampling and Analysis	14	EA	$ 2,000	$ 28,000		3
1.5 IDW Disposal	12	DRUM	$ 250	$ 3,000		2
1.6 Reporting	80	HR	$ 90	$ 7,200		2
Task 1 Subtotal					**$ 64,800**	
O&M Costs Subtotal					**$ 64,800**	
Project Management	10%				$ 6,480	
O&M ANNUAL COSTS TOTAL					**$ 71,280**	
Operations and Maintenance - Annual						
1.0 Administration						
1.1 Planning and Regulatory Interface	80	HR	$ 90	$ 7,200		1
Task 1 Subtotal					**$ 7,200**	
2.0 Workplans for MNA Sampling						
2.1 Workplans (Annual sampling requirement)	32	HR	$ 80	$ 2,560		1,2
Task 2 Subtotal					**$ 2,560**	
3.0 MNA Sampling						
3.1 Labor	80	HR	$ 90	$ 7,200		1,2
3.2 Mobilization	1	LS	$ 1,500	$ 1,500		1,2
3.3 Equipment	2	WK	$ 500	$ 1,000		1,2
3.4 Samples	14	EA	$ 1,000	$ 14,000		2
3.5 Expendables	3	DAY	$ 50	$ 150		1,2
Task 3 Subtotal					**$ 23,850**	
4.0 MNA Sample Reporting						
4.1 MNA Reporting	40	HR	$ 90	$ 3,600		1,2
4.2 Regulatory Support	32	HR	$ 90	$ 2,880		1
Task 4 Subtotal					**$ 6,480**	
O&M Costs Subtotal					**$ 40,090**	
Project Management	10%				$ 4,009	
O&M ANNUAL COSTS TOTAL					**$ 44,099**	

Alternative 3
Groundwater: Monitored Natural Attenuation
FSU-LLRW Burial Pits

Alternative Description: Natural reduction of radionuclides through radioactive decay and continued degradation of 1,4-dioxane. This alternative will include the installation of additional monitoring wells and conducting annual groundwater monitoring at the FSU-LLRW.

Item	Quantity	Units	Unit Cost	Total Cost	Subtotals	Notes
5-Year Costs						
1.0 CERCLA Review						
1.1 Reporting	150	HR	$ 90	$ 13,500		1
1.2 Meetings and Regulatory Support	16	HR	$ 95	$ 1,520		1
1.3 Announcements	2	EA	$ 100	$ 200		1
Task 1 Subtotal					**$ 15,220**	
2.0 Additional Monitoring Well Installation						
2.1 Workplans and Approvals	40	HR	$ 90	$ 3,600		2
2.2 Mobilization	1	LS	$ 5,000	$ 5,000		1,2
2.3 Installation Costs	2	EA	$ 4,500	$ 9,000		1,2
2.5 IDW Disposal	6	DRUM	$ 200	$ 1,200		2
2.6 Reporting	40	HR	$ 90	$ 3,600		1,2
Task 2 Subtotal					**$ 22,400**	
3.0 Additional Monitoring Well MNA Sampling						
3.1 Labor	10	HR	$ 80	$ 800		2
3.2 Equipment	0.1	WK	$ 500	$ 50		2
3.3 Samples	2	EA	$ 1,000	$ 2,000		2
3.4 Expendables	1	DAY	$ 50	$ 50		2
3.5 Reporting	10	HR	$ 90	$ 900		
Task 3 Subtotal					**$ 3,800**	
Site Review Costs Subtotal					**$ 41,420**	
Project Management	10%				$ 4,142	
SITE REVIEW COSTS TOTAL					**$ 45,562**	

1. Engineering Experience on competed projects by BMT within the last 5 years.

2. Experience at previous investigations conducted at the FSU-LLRW by BMT

3. Vendor quote

Alternative 3
Groundwater: Monitored Natural Attenuation
FSU-LLRW Burial Pits

Alternative Description: Natural reduction of radionuclides through radioactive decay and continued degradation of 1,4-dioxane. This alternative will include the installation of additional monitoring wells and conducting annual groundwater monitoring at the FSU-LLRW.

Assume two new wells installed every five years with 20% increase in MNA monitoring costs.

Base Year	2020
Location:	Leon County, Florida
Discount Rate:	5%
Project Length:	30 years

Year	Capital Costs	Annual O&M Costs	Periodic Costs	Total Annual Expenditure	Discount Factor	Present Value
0	$ 71,280	$ -		$ 71,280	1.0000	$ 71,280
1	$ -	$ 44,099	$ -	$ 44,099	0.9524	$ 41,999
2	$ -	$ 44,099	$ -	$ 44,099	0.9070	$ 39,999
3	$ -	$ 44,099	$ -	$ 44,099	0.8638	$ 38,094
4	$ -	$ 44,099	$ -	$ 44,099	0.8227	$ 36,280
5	$ -	$ 48,279	$ 37,620	$ 85,899	0.7835	$ 67,304
6	$ -	$ 48,279	$ -	$ 48,279	0.7462	$ 36,027
7	$ -	$ 48,279	$ -	$ 48,279	0.7107	$ 34,311
8	$ -	$ 48,279	$ -	$ 48,279	0.6768	$ 32,677
9	$ -	$ 48,279	$ -	$ 48,279	0.6446	$ 31,121
10	$ -	$ 52,459	$ 37,620	$ 90,079	0.6139	$ 55,301
11	$ -	$ 52,459	$ -	$ 52,459	0.5847	$ 30,672
12	$ -	$ 52,459	$ -	$ 52,459	0.5568	$ 29,211
13	$ -	$ 52,459	$ -	$ 52,459	0.5303	$ 27,820
14	$ -	$ 52,459	$ -	$ 52,459	0.5051	$ 26,495
15	$ -	$ 56,639	$ 37,620	$ 94,259	0.4810	$ 45,340
16	$ -	$ 56,639	$ -	$ 56,639	0.4581	$ 25,947
17	$ -	$ 56,639	$ -	$ 56,639	0.4363	$ 24,711
18	$ -	$ 56,639	$ -	$ 56,639	0.4155	$ 23,535
19	$ -	$ 56,639	$ -	$ 56,639	0.3957	$ 22,414
20	$ -	$ 56,686	$ 37,620	$ 94,306	0.3769	$ 35,543
21	$ -	$ 56,686	$ -	$ 56,686	0.3589	$ 20,347
22	$ -	$ 56,686	$ -	$ 56,686	0.3418	$ 19,378
23	$ -	$ 56,686	$ -	$ 56,686	0.3256	$ 18,455
24	$ -	$ 56,686	$ -	$ 56,686	0.3101	$ 17,576
25	$ -	$ 60,866	$ 37,620	$ 98,486	0.2953	$ 29,083
26	$ -	$ 60,866	$ -	$ 60,866	0.2812	$ 17,118
27	$ -	$ 60,866	$ -	$ 60,866	0.2678	$ 16,303
28	$ -	$ 60,866	$ -	$ 60,866	0.2551	$ 15,526
29	$ -	$ 60,866	$ -	$ 60,866	0.2429	$ 14,787
30	$ -	$ 65,046	$ 37,620	$ 102,666	0.2314	$ 23,755
Estimated Project Total Cost					**$**	**968,411**
Estimated Project Total Cost Range (-30%/+50%)					**$ 677,887**	**$ 1,452,616**

Alternative 3
Groundwater: Monitored Natural Attenuation
FSU-LLRW Burial Pits

Initial, Annual, and Periodic Costs

CAPITAL COSTS (One Time)		
	Additional MW Installation and Radionuclide Speciation	$ 71,280
CAPITAL COSTS CONTINGENCY, PROJECT MANAGEMENT, TECHNICAL SUPPORT		
	Project Management	$ 0
O&M COSTS (Annual Costs)		
	1.0 Administration	$ 7,200
	2.0 Workplans for MNA Sampling	$ 2,560
	3.0 MNA Sampling	$ 23,850
	4.0 MNA Sample Reporting	$ 6,480
PERIODIC COSTS (Recurrent)		
	1.0 CERCLA Review	$ 15,220
	2.0 Additional Monitoring Well Installation	$ 22,400
	3.0 Additional Monitoring Well MNA Sampling	$ 3,800
O&M COSTS CONTINGENCY, PROJECT MANAGEMENT, TECHNICAL SUPPORT		
	Project Management	10%

Total Present Value Assessment		
Discount Rate 5%		**COST (Present Worth)**
Estimated Project Total Cost	**$ 968,411**	
Estimated Project Total Cost Range (-30%/+50%)	**$ 677,887**	**$ 1,452,616**

Alternative 4

Groundwater: Targeted Direct Injection and Monitored Natural Attenuation

FSU-LLRW Burial Pits

Alternative Description: Targeted direct injection program within plume center to treat 1,4-dioxane high concentration area. This alternative includes the installation of additional monitoring wells and conducting annual groundwater monitoring at the FSU-LLRW. Radionuclides to be treated by MNA.

Item	Quantity	Units	Unit Cost	Total Cost	Subtotals	Notes
Capital Costs						
1.0 Planning						
1.1 Workplan	40	HR	$ 90	$ 3,600		1,2
1.2 Regulatory Interface	40	HR	$ 90	$ 3,600		1,2
Task 1 Subtotal					**$ 7,200**	
2.0 Radionuclide Speciation in Groundwater						
2.1 Workplans	40	HR	$ 90	$ 3,600		2
2.2 Mobilization and Sampling	1	LS	$ 5,000	$ 5,000		2
2.4 Radionuclide Speciation	10	EA	$ 2,000	$ 20,000		3
2.5 IDW Disposal	2	DRUM	$ 250	$ 500		2
2.6 Reporting	60	HR	$ 90	$ 5,400		2
Task 2 Subtotal					**$ 34,500**	
3.0 Pre-Injection Characterization						
3.1 Groundwater characterization Planning	40	HR	$ 90	$ 3,600		1,2
3.2 Mobilization	1	LS	$ 2,500	$ 2,500		1,2
3.3 Drill rig for groundwater screenpoint characterization	1,600	Ft	$ 25	$ 40,000		2
3.4 Groundwater characterization sampling	40	EA	$ 500	$ 20,000		1,2
3.5 Reporting	60	HR	$ 90	$ 5,400		1,2
Task 3 Subtotal					**$ 71,500**	
4.0 Bench Scale Testing - Persulfox						
4.1 Bench scale testing for treatment of 1,4-dioxane	1	LS	$ 40,000	$ 40,000		1
4.1 Bench Scale Reporting	60	HR	$ 90	$ 5,400		1
Task 4 Subtotal					**$ 45,400**	
5.0 Direct Injection of Persulfox to treat 1,4-Dioxane						
5.1 Planning	100	HR	$ 90	$ 9,000		2,4
5.2 Mobilization	1	LS	$ 20,000	$ 20,000		1,2,4
5.3 Drill Rig Injection Point Advancement (sonic drill rig)	2,880	FT	$ 75	$ 216,000		1,2
5.4 Pursulfox Injection Material	90,000	LB	$ 2	$ 202,500		2,4
5.5 On-site water truck	8	WK	$ 2,500	$ 20,000		4
5.6 Potable water	1,600	100-GAL	$ 0.35	$ 560		5
5.7 IDW	50	DRUM	$ 250	$ 12,500		2
5.8 Site Labor	1,280	HR	$ 90	$ 115,200		1,2
5.9 Post injection groundwater sampling	15	EA	$ 1,000	$ 15,000		1,2
5.10 After Action Reporting	100	HR	$ 90	$ 9,000		1,2
Task 5 Subtotal					**$ 619,760**	
Capital Costs Subtotal					**$ 778,360**	
Project Management	10%				$ 77,836	
O&M ANNUAL COSTS TOTAL					**$ 856,196**	

Alternative 4
Groundwater: Targeted Direct Injection and Monitored Natural Attenuation
FSU-LLRW Burial Pits

Alternative Description: Targeted direct injection program within plume center to treat 1,4-dioxane high concentration area. This alternative includes the installation of additional monitoring wells and conducting annual groundwater monitoring at the FSU-LLRW. Radionuclides to be treated by MNA.

Item	Quantity	Units	Unit Cost	Total Cost	Subtotals	Notes
Operations and Maintenance - Annual						
1.0 Administration						
1.1 Regulatory Interface	40	HR	$ 90	$ 3,600		1,2
Task 1 Subtotal					**$ 3,600**	
2.0 Workplans for MNA Sampling						
2.1 Workplans (Annual sampling requirement)	32	HR	$ 90	$ 2,880		1,2
Task 2 Subtotal					**$ 2,880**	
3.0 MNA Sampling						
3.1 Labor	80	HR	$ 90	$ 7,200		1,2
3.2 Mobilization	1	LS	$ 1,500	$ 1,500		1,2
3.3 Equipment	1	WK	$ 500	$ 500		1,2
3.4 Samples	10	EA	$ 1,000	$ 10,000		1,2
3.5 Expendables	5	DAY	$ 50	$ 250		1,2
Task 3 Subtotal					**$ 19,450**	
4.0 MNA Sample Reporting						
4.1 MNA Reporting	40	HR	$ 90	$ 3,600		1,2
Task 4 Subtotal					**$ 3,600**	
O&M Costs Subtotal					**$ 29,530**	
Project Management	10%				$ 2,953	
O&M ANNUAL COSTS TOTAL					**$ 32,483**	
5-Year Costs						
1.0 CERCLA Review						
1.1 Reporting	150	HR	$ 90	$ 13,500		1
1.2 Meetings and Regulatory Support	16	HR	$ 95	$ 1,520		1
1.3 Announcements	2	EA	$ 100	$ 200		1
Task 1 Subtotal					**$ 15,220**	
1.0 Additional Monitoring Well Installation						
1.1 Workplans and Approvals	40	HR	$ 90	$ 3,600		1,2
1.2 Mobilization	1	LS	$ 2,500	$ 2,500		1,2
1.3 Installation Costs	1	EA	$ 4,500	$ 4,500		1,2
1.5 IDW Disposal	3	DRUM	$ 250	$ 750		1,2
1.6 Reporting	40	HR	$ 90	$ 3,600		1,2
Task 1 Subtotal					**$ 14,950**	
Site Review Costs Subtotal					**$ 30,170**	
Project Management	10%				$ 3,017	
SITE REVIEW COSTS TOTAL					**$ 33,187**	

1. Engineering Experience on competed projects by BMT within the last 5 years.
2. Experience at previous investigations conducted at the FSU-LLRW by BMT
3. Get-a-quote.net
4. Vendor quote
5. Rates from city of Tallahassee https://www.talgov.com/you/you-water.aspx

Alternative 4
Groundwater: Targeted Direct Injection and Monitored Natural Attenuation
FSU-LLRW Burial Pits

Alternative Description: Natural reduction of radionuclides through radioactive decay and continued degradation of 1,4-dioxane. This alternative will include the installation of additional monitoring wells and conducting annual groundwater monitoring at the FSU-LLRW.

Base Year	2020
Location:	Leon County, Florida
Discount Rate:	5%
Project Length:	30 years

Year	Capital Costs	Annual O&M Costs	Periodic Costs	Total Annual Expenditure	Discount Factor	Present Value
0	$ 856,196	$ -		$ 856,196	1.0000	$ 856,196
1	$ -	$ 32,483	$ -	$ 32,483	0.9524	$ 30,936
2	$ -	$ 32,483	$ -	$ 32,483	0.9070	$ 29,463
3	$ -	$ 32,483	$ -	$ 32,483	0.8638	$ 28,060
4	$ -	$ 32,483	$ -	$ 32,483	0.8227	$ 26,724
5	$ -	$ 32,483	$ 33,187	$ 65,670	0.7835	$ 51,454
6	$ -	$ 32,483	$ -	$ 32,483	0.7462	$ 24,239
7	$ -	$ 32,483	$ -	$ 32,483	0.7107	$ 23,085
8	$ -	$ 32,483	$ -	$ 32,483	0.6768	$ 21,986
9	$ -	$ 32,483	$ -	$ 32,483	0.6446	$ 20,939
10	$ -	$ 32,483	$ 33,187	$ 65,670	0.6139	$ 40,316
11	$ -	$ 32,483	$ -	$ 32,483	0.5847	$ 18,992
12	$ -	$ 32,483	$ -	$ 32,483	0.5568	$ 18,088
13	$ -	$ 32,483	$ -	$ 32,483	0.5303	$ 17,226
14	$ -	$ 32,483	$ -	$ 32,483	0.5051	$ 16,406
15	$ -	$ 32,483	$ 33,187	$ 65,670	0.4810	$ 31,588
16	$ -	$ 32,483	$ -	$ 32,483	0.4581	$ 14,881
17	$ -	$ 32,483	$ -	$ 32,483	0.4363	$ 14,172
18	$ -	$ 32,483	$ -	$ 32,483	0.4155	$ 13,497
19	$ -	$ 32,483	$ -	$ 32,483	0.3957	$ 12,855
20	$ -	$ 32,483	$ 33,187	$ 65,670	0.3769	$ 24,750
21	$ -	$ 32,483	$ -	$ 32,483	0.3589	$ 11,660
22	$ -	$ 32,483	$ -	$ 32,483	0.3418	$ 11,104
23	$ -	$ 32,483	$ -	$ 32,483	0.3256	$ 10,576
24	$ -	$ 32,483	$ -	$ 32,483	0.3101	$ 10,072
25	$ -	$ 32,483	$ 33,187	$ 65,670	0.2953	$ 19,393
26	$ -	$ 32,483	$ -	$ 32,483	0.2812	$ 9,136
27	$ -	$ 32,483	$ -	$ 32,483	0.2678	$ 8,701
28	$ -	$ 32,483	$ -	$ 32,483	0.2551	$ 8,286
29	$ -	$ 32,483	$ -	$ 32,483	0.2429	$ 7,892
30	$ -	$ 32,483	$ 33,187	$ 65,670	0.2314	$ 15,195
Estimated Project Total Cost					**$ 1,447,866**	
Estimated Project Total Cost Range (-30%/+50%)					**$ 1,013,507**	**$ 2,171,800**

Alternative 4
Groundwater: Targeted Direct Injection and Monitored Natural Attenuation
FSU-LLRW Burial Pits

Initial, Annual, and Periodic Costs

CAPITAL COSTS (One Time)			
	1.0 Planning	$	7,200
	2.0 Radionuclide Speciation in Groundwater	$	34,500
	3.0 Pre-Injection Characterization	$	71,500
	4.0 Bench Scale Testing - Persulfox	$	45,400
	5.0 Direct Injection of Persulfox to treat 1,4-Dioxane	$	619,760
CAPITAL COSTS CONTINGENCY, PROJECT MANAGEMENT, TECHNICAL SUPPORT			
	Project Management	$	0
O&M COSTS (Annual Costs)			
	1.0 Administration	$	3,600
	2.0 Workplans for MNA Sampling	$	2,880
	3.0 MNA Sampling	$	19,450
	4.0 MNA Sample Reporting	$	3,600
5-Year Costs			
	1.0 CERCLA Review	$	15,220
	2.0 Additional Monitoring Well Installation	$	14,950
O&M COSTS CONTINGENCY, PROJECT MANAGEMENT, TECHNICAL SUPPORT			
	Project Management		10%

Total Present Value Assessment		
Discount Rate 7%	**COST (Present Worth)**	
Estimated Project Total Cost	**$ 1,447,866**	
Estimated Project Total Cost Range (-30%/+50%)	**$ 1,013,507**	**$ 2,171,800**

Alternative 5
Pump and Treat System with Chemox (1,4-dioxane) and Resin Sorption (for Alpha Emitting Radionuclides)
FSU-LLRW Burial Pits

Alternative Description: Construction of a complete impermeable slurry wall cutoff wall around the extents of comingled groundwater plumes and operation of an ex-situ pump and treat system to treat groundwater using chemical oxidation, resin sorption, ion exchange and sediment precipitation

Item	Quantity	Units	Unit Cost	Total Cost	Subtotals	Note
Capital Costs						
1.0 Bench Scale Studies						
1.1 Workplans	120	HR	$ 90	$ 10,800		1
1.2 Bench Scale Testing of Treatment Train	1	LS	$ 80,000	$ 80,000		1,4
1.3 Reporting	80	HR	$ 90	$ 7,200		
Task 1 Subtotal					**$ 98,000**	
2.0 Trench Installation						
2.1 Erosion Control Plans	80	HR	$ 90	$ 7,200		1
2.2 Silt Fencing	4,000	LF	$ 1	$ 4,640		3
2.3 Mobilization	1	LS	$ 80,000	$ 80,000		1,4
2.4 Installation	1	LS	$ 400,000	$ 400,000		4
2.5 Installation Support Labor	320	HR	$ 80	$ 25,600		1,4
2.6 Installation Support Equipment	1	LS	$ 25,000	$ 25,000		1,4
2.7 Sump extraction pumps	6	EA	$ 25,000	$ 150,000		4
2.8 Pump controllers	1	LS	$ 150,000	$ 150,000		1,4
2.9 Site Restoration	1	LS	$ 20,000	$ 20,000		1
2.10 Manage Manifests for Waste and Spent Materials	1	LS	$ 10,000	$ 10,000		1
2.11 Testing and analysis	150	EA	$ 500	$ 75,000		1
2.12 Offsite Soil Disposal	1,000	TON	$ 250	$ 250,000		1,2
2.13 Offsite Water disposal	100	DRUM	$ 250	$ 25,000		1,2
Task 2 Subtotal					**$ 1,222,440**	
3.0 Injection Wells						
3.3 Permitting	40	HR	$ 90	$ 3,600		9
3.3 Injection Well Installation	10	EA	$ 4,500	$ 45,000		9
3.3 Injection Well Reporting	80	HR	$ 90	$ 7,200		9
3.4 IDW Disposal (Non-haz)	30	DRUM	$ 250	$ 7,500		
Task 3 Subtotal					**$ 63,300**	
4.0 Pump and Treat System Capital Costs						
4.1 Workplans	200	HR	$ 90	$ 18,000		1,4
4.2 Mobilization/Setup Costs	1	LS	$ 250,000	$ 250,000		1,4
4.3 Demobilization	1	LS	$ 75,000	$ 75,000		1,4
4.4 Power Connection	1	LS	$ 90,000	$ 100,000		4
Task 4 Subtotal					**$ 443,000**	
Capital Costs Subtotal					**$ 1,826,740**	
Project Management	10%				$ 182,674	
CAPITAL COSTS TOTAL					**$ 2,009,414**	

Alternative 5
Pump and Treat System with Chemox (1,4-dioxane) and Resin Sorption (for Alpha Emitting Radionuclides)
FSU-LLRW Burial Pits

Alternative Description: Construction of a complete impermeable slurry wall cutoff wall around the extents of comingled groundwater plumes and operation of an ex-situ pump and treat system to treat groundwater using chemical oxidation, resin sorption, ion exchange and sediment precipitation

Item	Quantity	Units	Unit Cost	Total Cost	Subtotals	Note
Operations and Maintenance - Annual						
1.0 Treatment System Monitoring						
1.1 Analytical Laboratory Costs	50	EA	$ 1,000	$ 50,000		1,4
1.1 Expendable Equipment and Mobilization	4	LS	$ 1,000	$ 4,000		1
1.3 Data Validation	1	LS	$ 12,500	$ 12,500		1
1.4 Field Labor	320	HR	$ 70	$ 22,400		1,2
1.5 Annual Reporting	160	HR	$ 90	$ 14,400		1,2
Task 1 Subtotal					**$ 103,300**	
2.0 Pump and Treat Operational Costs						
2.2 Equipment Maintenance/Operation	12	MO	$ 90,000	$ 1,080,000		4
2.2 Equipment Maintenance/Consumables	12	MO	$ 100,000	$ 1,200,000		4
2.4 Operational Labor	12	MO	$ 160,000	$ 1,920,000		4
2.3 Power Requirements	876,600	KWH	$ 0	$ 88,800		5,6
Task 2 Subtotal					**$ 4,288,800**	7
3.0 Annual Groundwater Monitoring						
3.1 Labor	80	HR	$ 90	$ 7,200		1,2
3.2 Mobilization	1	LS	$ 1,500	$ 1,500		1,2
3.3 Equipment	1	WK	$ 500	$ 500		1,2
3.4 Samples	10	EA	$ 1,000	$ 10,000		1,2
3.5 Expendables	5	DAY	$ 50	$ 250		1,2
Task 3 Subtotal					**$ 19,450**	
O&M Costs Subtotal					**$ 4,411,550**	
Project Management	10%				$ 441,155	
O&M ANNUAL COSTS TOTAL					**$ 4,852,705**	
5-Year Costs						
1.0 CERCLA Review						
1.1 Reporting	150	HR	$ 90	$ 13,500		1
1.2 Meetings and Regulatory Support	16	HR	$ 95	$ 1,520		1
1.3 Announcements	2	EA	$ 100	$ 200		1
Task 1 Subtotal					**$ 15,220**	
O&M Costs Subtotal					**$ 15,220**	
Project Management	10%				$ 1,522	
O&M ANNUAL COSTS TOTAL					**$ 16,742**	

Notes:

1. Engineering Experience on competed projects by BMT within the last 5 years.
2. Experience at previous investigations conducted at the FSU-LLRW by BMT
3. Get-a-quote.net
4. Vendor quote
5. Utility rates for City of Tallahassee
6. 100 kw of power required during operation.
7. Assume 24/7 operation for first year, two years at 12 hour/day shift and four years at 8 hour/day shift.

Alternative 5

Pump and Treat System with Chemox (1,4-dioxane) and Resin Sorption (for Alpha Emitting Radionuclides)
FSU-LLRW Burial Pits

Alternative Description: Construction of a complete impermeable slurry wall cutoff wall around the extents of comingled groundwater plumes and operation of an ex-situ pump and treat system to treat groundwater using chemical oxidation, resin sorption, ion exchange and sediment precipitation

Base Year	2020
Location:	Leon County, Florida
Discount Rate:	5%
Project Length:	30 years

Year	Capital Costs	Annual O&M Costs	Periodic Costs	Total Annual Expenditure	Discount Factor	Present Value
0	$ 2,009,414			$ 2,009,414	1.0000	$ 2,009,414
1	$ -	$ 4,852,705	$ -	$ 4,852,705	0.9524	$ 4,621,623
2	$ -	$ 3,031,050	$ -	$ 3,031,050	0.9070	$ 2,749,251
3	$ -	$ 3,031,050	$ -	$ 3,031,050	0.8638	$ 2,618,335
4	$ -	$ 2,290,200	$ -	$ 2,290,200	0.8227	$ 1,884,153
5	$ -	$ 2,290,200	$ 16,742	$ 2,306,942	0.7835	$ 1,807,549
6	$ -	$ 2,290,200	$ -	$ 2,290,200	0.7462	$ 1,708,982
7	$ -	$ 21,395	$ -	$ 21,395	0.7107	$ 15,205
8	$ -	$ 21,395	$ -	$ 21,395	0.6768	$ 14,481
9	$ -	$ 21,395	$ -	$ 21,395	0.6446	$ 13,791
10	$ -	$ 21,395	$ 16,742	$ 38,137	0.6139	$ 23,413
11	$ -		$ -	$ -	0.5847	$ -
12	$ -		$ -	$ -	0.5568	$ -
13	$ -		$ -	$ -	0.5303	$ -
14	$ -		$ -	$ -	0.5051	$ -
15	$ -		$ -	$ -	0.4810	$ -
16	$ -		$ -	$ -	0.4581	$ -
17	$ -		$ -	$ -	0.4363	$ -
18	$ -		$ -	$ -	0.4155	$ -
19	$ -		$ -	$ -	0.3957	$ -
20	$ -		$ -	$ -	0.3769	$ -
21	$ -		$ -	$ -	0.3589	$ -
22	$ -		$ -	$ -	0.3418	$ -
23	$ -		$ -	$ -	0.3256	$ -
24	$ -		$ -	$ -	0.3101	$ -
25	$ -		$ -	$ -	0.2953	$ -
26	$ -		$ -	$ -	0.2812	$ -
27	$ -		$ -	$ -	0.2678	$ -
28	$ -		$ -	$ -	0.2551	$ -
29	$ -		$ -	$ -	0.2429	$ -
30	$ -		$ -	$ -	0.2314	$ -
Estimated Project Total Cost					**$**	**17,466,198**
Estimated Project Total Cost Range (-30%/+50%)					**$ 12,226,339**	**$ 26,199,297**

Alternative 5

Pump and Treat System with Chemox (1,4-dioxane) and Resin Sorption (for Alpha Emitting Radionuclides)
FSU-LLRW Burial Pits

Initial, Annual, and Periodic Costs

CAPITAL COSTS (One Time)			
	1.0 Bench Scale Studies		$ 98,000
	2.0 Trench Installation		$ 1,222,440
	3.0 Injection Wells		$ 63,300
	4.0 Pump and Treat System Capital Costs		$ 443,000
CAPITAL COSTS CONTINGENCY, PROJECT MANAGEMENT, TECHNICAL SUPPORT			
	Project Management		10%
O&M COSTS (Annual Costs)			
	1.0 Treatment System Monitoring		103,300
	2.0 Pump and Treat Operational Costs		4,288,800
	3.0 Annual Groundwater Monitoring		19,450
O&M ANNUAL COSTS TOTAL			
	1.0 CERCLA Review		15,220
O&M COSTS CONTINGENCY, PROJECT MANAGEMENT, TECHNICAL SUPPORT			
	Project Management		10%
Total Present Value Assessment			
Discount Rate 5%			**COST (Present Worth)**
Estimated Project Total Cost		**$**	**17,466,198**
Estimated Project Total Cost Range (-30%/+50%)		**$ 12,226,339**	**$ 26,199,297**

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