TENNESSEE DEPARTMENT
OF
ENVIRONMENT AND CONSERVATION

DIVISION OF REMEDIATION
OAK RIDGE OFFICE

ENVIRONMENTAL MONITORING PLAN

July 1, 2020 through June 30, 2021

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Environment and Conservation,
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ACRONYMS AND DEFINITIONS

A	ACOs	Artificial cover objects (cover boards)
	ALARA	As Low as Reasonably Achievable
	ANOVA	Statistical test for analysis of variance
	APHA	American Public Health Association
	ARAR	Applicable or Relevant and Appropriate Requirements
	ASER	Annual Site Environmental Report
	ASTM	American Society for Testing and Materials
	AWQC	Ambient Water Quality Criteria
B	3BWMA	Three Bends Wildlife Management Area
	BC	Bear Creek
	BCAP	Bear Creek Assessment Project
	BCBG	Bear Creek Burial Grounds
	BCK	Bear Creek Station or Bear Creek Kilometer
	BCK 3.3	Bear Creek kilometer 3.3 (distance from mouth of stream)
	BCM	Bear Creek Mile
	BCV	Bear Creek Valley
	Benthic	Stream-bottom dwelling organisms.
	Bgs	Below ground surface
	BMP	Best Management Practices
C	°C	Degrees Celsius/Centigrade
	CAA	Clean Air Act
	CBSQGs	Consensus Based Sediment Quality Guidelines
	CBCV	Central Bear Creek Valley
	CCME	Canadian Council of Ministers for the Environment
	CERCLA	Comprehensive Environmental Response, Compensation & Liability

		Act
	CMP	Contaminant Migration Plan
	COC	Contaminants of Concern, Chain of Custody
	COND	Conductivity
	Constraints	Limitation or restrictions to project time, scope, cost, and quality
	Cr_6	Hexavalent Chromium
	CRK	Clinch River kilometer
	Cs-137	cesium 137
	CSM	Conceptual Site Model
	CWA	Clean Water Act
D	D&D	Decontamination and Decommissioning
	DCG	Derived Concentration Guides
	Dichotomous	Dividing into two parts
	DOE	Department of Energy
	DOH	Department of Health
	DoR	Division of Remediation
	DWR	Division of Water Resources
E	EF	East Fork
	%EPT - Cheum	Percentage EPT - Cheumatopsyche
	EFK	East Fork Kilometer
	EFPC	East Fork Poplar Creek
	EMDF	Environmental Management Disposal Facility
	EML	Environmental Measurement Laboratory
	EMP	Environmental Monitoring Plan
	EMR	Environmental Monitoring Report
	EMWMF	Environmental Management Waste Management Facility

	EPA	Environmental Protection Agency
	EPT	Ephemeroptera, Plecoptera, and Trichoptera
	ESOA	Environmental Surveillance Oversight Agreement
	ETTP	East Tennessee Technology Park
F	FFA	Federal Facilities Agreement
	FRMAC	Federal Radiological Monitoring and Assessment Center
	ft	foot, feet
	FWS	US Fish and Wildlife Service
	FY	Fiscal Year
G	G	gram(s)
	GCN	greatest conservation need
	GIS	Geographical Information System (Mapping)
	Goals	A checklist of accomplishments necessary to meet requirements
	GPS	Global Positioning System
	GW	Groundwater
H	H_2SO_4	sulfuric acid
	HA	Health Advisory Values
	HASL	Health and Safety Laboratory
	HCl	hydrochloric acid
	HFIR	High Flux Isotope Reactor
	Hg	mercury
	HNO_3	nitric acid
	HRE	Homogeneous Reactor Experiment
I	In	inch
K	km	kilometer
L	LHAV	Lifetime Health Advisory Values

	LLW	Low-level radioactive waste
	LSC	Liquid Scintillation Counting
M	m	meter
	MB	Mitchell Branch
	MBK	Mill Branch Kilometer
	MBK 1.6	Mill Branch kilometer 1.6 (distance from mouth of stream)
	MCL	Maximum Contaminant Level
	MDC	Minimum Detectable Concentration
	MDL	Minimum Detection Limit
	MeHg	methylmercury
	Mg/kg	Milligrams per kilogram (=ppm; =µg/g)
	MIK	Mitchell Branch kilometer
	millirem	One thousandth of a rem.
	mm	millimeter
	MQL	Minimum Quantification Limit
	MSRE	Molten Salt Reactor Experiment
	mV	millivolts
N	NAREL	National Air and Radiation Environmental Laboratory
	NESHAPS	National Emission Standards for Hazardous Air Pollutants
	NNSA	National Nuclear Safety Administration
	NOAA	National Oceanic and Atmospheric Administration
	NPDES	National Pollutant Discharge Elimination System
	NPDWR	National Primary Drinking Water Regulations
	NPL	National Priorities List
	NSDWR	National Secondary Drinking Water Regulations
	NTU	nephelometric turbidity units

	NT-5	North Tributary 5
	NT	North Tributary
	NUREG	NRC Regulation
	NRC	Nuclear Regulatory Commission
O	OREIS	Oak Ridge Environmental Information System
	ORNL	Oak Ridge National Laboratory
	ORP	Oxygen Reduction Potential
	ORR	Oak Ridge Reservation
	OSL	Optically Stimulated Luminescence Dosimeter
	OU	Operable Unit
P	PCB's	Polychlorinated Biphenyls
	PEC	Probable Effects Concentration
	PRGs	Preliminary Remediation Goals
Q	QA/QC	Quality Assurance/Quality Control
	QAPP	Quality Assurance Project Plan
	QEC	Quality Environmental Containers (Beaver, WI)
R	RA	Remedial Activities
	RADCON	Radiation Control Program
	RAIS	Risk Assessment Information System
	RER	Remedial Effectiveness Report
	ROD	Record of Decision
	RPM	Radiation Portal Monitor
	RSLs	Regional Screening Levels
S	SAIC	Science Applications International Corporation
	SAP	Sampling and Analysis Plan
	SD	storm drain

	SMCL	Secondary Maximum Containment Levels
	SNS	Spallation Neutron Source
	SOP	Standard Operating Procedure
	SRS	Savannah River Site
	ssMDC	sample specific Minimum Detectable Concentration
	Station	A specific location where sampling of surface water takes place
	SU	standard units
	SWPP	Storm Water Pollution Plan
	SWPPP	Storm Water Pollution Prevention Plan
	SWSA	Solid Waste Storage Area
	Tc-99	Technetium - 99
	TDEC	Tennessee Department of Conservation
	TDH	Tennessee Department of Health
	TDH-NEL	TN Department of Health-Nashville Environmental Laboratory
T	TLD	Thermoluminescent Dosimeters
	TN	State of Tennessee
	TRU	transuranic
	TS	tree swallows
	TWQC	Tennessee Water Quality Criteria
	TWRA	TN Wildlife Resources Agency
U	U	Uranium
	U-234	Uranium 234
	U-235	Uranium 235
	U-238	Uranium 238
	UEFPC	Upper East Fork Poplar Creek

	US	United States
	USDI	US Department of the Interior
	UV	ultraviolet
V	VOCs	volatile organic compounds
W	WAC	Waste Acceptance Criteria
	WCK	White Oak Creek kilometer
	WD	wood duck
	WEMA	West End Mercury Area
	WOC	White Oak Creek
Y	Y-12	Y-12 National Security Complex

UNITS OF MEASURE AND THEIR ABBREVIATIONS

°C	degrees Celsius/Centigrade
µS/cm	micro Siemens per centimeter
mV	millivolts
DO	amount of gaseous (O_2) dissolved in water
pH	scale of acidity from 0 to 14
µg/L	micrograms per liter (parts per billion)
mg/L	milligrams per liter (parts per million)
ng/g	nanograms per gram (parts per billion)
µg/g	micrograms per gram (parts per million)
ppb	parts per billion
ppm	parts per million
millirem	A millirem is one thousandth of a rem
rem	A rem is the unit of effective absorbed dose of ionizing radiation in human tissue, equivalent to one roentgen of X-rays
mrem	Abbreviation for millirem which is a unit of absorbed radiation dose

EXECUTIVE SUMMARY

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation, Oak Ridge (DoR-OR), submits the annual Fiscal Year 2021 (FY2021) Environmental Monitoring Plan (EMP) for the period of July 1, 2020 through June 30, 2021. This report is submitted as a comprehensive plan for DoR-OR monitoring and assessment activities in FY2020 across the ORR in accordance with the terms of both the Environmental Surveillance and Oversight Agreement (ESOA), as well as in support of activities being conducted under the Federal Facilities Agreement (FFA).

The objective of the TDEC DOR-OR EMP is to provide an independent, comprehensive and integrated monitoring and surveillance program, designed to evaluate and assess the effectiveness of the existing Department of Energy (DOE) environmental monitoring program. This independent state lead program is designed to assess current conditions for all ORR related environmental media (i.e. air, surface water, soil, sediment, ground water, drinking water, food crops, fish and wildlife and biological systems), by collecting data to verify or supplement DOE's data sets. This program is intended to provide independent assessment as necessary, of potential emissions of any materials (hazardous, toxic, chemical or radiological) on the ORR, to its surrounding environment.

In support of TDEC DoR-OR's independent monitoring and oversight of the ORR for CERCLA legacy waste-related actions (i.e. the FFA grant related projects), these projects provide information and data to support environmental restoration decisions, evaluate performance of existing remedies, and to investigate the extent and movement of existing legacy contamination, by conducting independent environmental monitoring that is used to verify the DOE management of those contaminants are effective.

TDEC DoR-OR also participates in independent monitoring and oversight of ESOA grant related activities (i.e. the current / active ORR process activities not covered under other state permits or regulatory authority) with the intention to evaluate and verify that DOE's current activities and processes do not have an adverse effect on the people and environment of the State of Tennessee.

This FY21 EMP presents summaries of twenty-one (21) proposed independent projects. This monitoring plan focuses on the following nine (9) general areas: Radiological Monitoring, Biological Monitoring, Air Monitoring, Surface Water Monitoring, Landfill Monitoring, Storm Water / Water Discharge Monitoring, Sediment Monitoring, Groundwater Monitoring, and Watershed Assessment (Holistic) Monitoring.

Radiological Monitoring:

While all projects conducted on or around the ORR typically contain components of radiological monitoring or assessment, there are four projects grouped under the radiological monitoring header for the purpose of this EMP.

Environmental Dosimeters

The Environmental Dosimeters Project has been an on-going project supported by TDEC for 25 years. It is designed to place discrete dosimeters at locations around all three ORR facilities, as well as background sites, in and near Oak Ridge. For FY2021 emphasis is placed on 25 total locations. Focus is on areas where radioactive materials are stored, processed, or disposed, or are the project specific background sites. The intent of this project is to allow a snapshot evaluation of radiological dose at these individual locations over time, and to provide independent verification of the established DOE controls at those locations of concern where appropriate.

Due to the nature of some of the temporary storage areas included in this assessment, this data may also be used to help determine if there have been changes to these locations that may have the potential to deliver inadvertent dose due to change in configuration of stored materials.

This data is provided to DOE, who follow guidance associated with maintaining the potential public dose from radiation exposure below the NRC NUREG-1757 reference limit of 100 mrem/yr (Schmidt et al, 2006).

At one time, very little of the ORR was accessible to the public. More recently there has been a movement toward making portions of the ORR more accessible to businesses and the public. This is particularly true at the East Tennessee Technology Park (ETTP) and Oak Ridge National Laboratory (ORNL). Increased access has the potential to increase the risk of exposure.

Real Time Measurement of Gamma Radiation

The Real Time Measurement of Gamma Radiation Project is conducted at 4 locations across the ORR. This project measures concentrations of gamma radiation in real time, thus allowing for the assessment of conditions at locations where gamma emissions may fluctuate substantially over relatively short periods of time. Because some facilities on the ORR have been known to release variable amounts of gamma radiation, this project is used to monitor areas on the ORR that TDEC DoR-OR has determined may have the potential for an unplanned release of gamma emitting radionuclides into the environment.

Surplus Sales Verification

At the request of the ORNL's Excess Properties staff, TDEC performs pre-auction verification surveys on items being auctioned by ORNL's Excess Properties Sales.

Haul Road Surveys

TDEC performs bimonthly surveys of the Haul Road and other waste transportation routes on the ORR. The periodic surveys of the roads used to haul waste to the EMWMF indicate waste items may fall from trucks transporting the waste. TDEC haul road surveys work to independently verify the effectiveness of DOE actions to control impacts from those transportation activities.

Biological Monitoring:

There are three projects grouped under the biological monitoring header for the purpose of this EMP.

Radiological Uptake in Food Crops

The Radiological Uptake in Food Crops Project supports a similar project conducted by DOE, with TDEC DoR-OR independent sampling being used to verify and correlate DOE's sample results. This project is intended to assess the possibility radiological impacts from DOE's activities on and around the ORR, on food crops grown by local farmers and gardeners.

Benthic Community Health

The Benthic Community Health Project consists of macroinvertebrate and diatom community sampling, as well as leaf litter decay rate assessment in order to monitor the current and changing condition of benthic health in streams on the Oak Ridge Reservation (ORR). This Project's purpose is to document the current condition of these stream bottom communities and to identify and document changes to the environment and eco health of these sites as remedial activities conducted under CERCLA continue.

ORR Roving Creel Survey

The ORR Roving Creel Survey Project measures angling efforts at three key locations where impaired Oak Ridge Reservation (ORR) watersheds drain into publicly accessible waters. Fisherman interviews will be conducted at the confluence of Bear Creek and Poplar Creek, the confluence of Poplar Creek and the Clinch River, and at the confluence of White Oak Lake and the Clinch River. Fish tissue samples will be collected from target species on a quarterly basis. Fish bioaccumulate mercury and other contaminants produced on the ORR. Frequently, fish consumption warnings are not visible, missing, or may be disregarded by the public. It is the intent of this project to measure the angling effort at key locations on the ORR where potential human exposure to mercury and other contaminants may exist. Where possible, samples will be

collected to measure the bioaccumulation of mercury and other contaminants in fish tissue at these key locations surrounding the ORR. This work shall link data from the roving creel survey to assess the efficacy of signage and other risk notifications posted in areas on and/or near the reservation which are subject to contamination from ORR activities and are used for recreational purposes by the public.

Air Monitoring:

There are three projects grouped under the air monitoring header for the purpose of this EMP.

Fugitive Radiological Air Emissions

Eight (8) high-volume air samplers are proposed for use in the TDEC DoR-OR Fugitive Air Monitoring Project for FY21. One (1) sampler will be stationed at Fort Loudoun Dam in Loudon County, to collect background data for comparison, while the remaining samplers will be placed at ORR locations where the potential for the release of fugitive airborne emissions is the greatest (for example, locations where contaminated soils are being excavated, contaminated facilities are being demolished, and near waste disposal operations). TDEC sampling locations supplement DOE's fugitive air monitoring program which focuses evaluations and monitoring along the ORR perimeter boundary. As TDEC sampling locations are closer to the active operations, if impacts are identified comparison of results can allow for greater correlation of events and better definition of potential impacts to show how air born constituents may have migrated following release. The TDEC DoR-OR will use CAA regulatory standards to evaluate their data, with the benchmark for comparison being that identified radiological emissions would not cause a member of the public to receive an effective dose greater than (ten (10) mrem/year). This is commensurate with the regulatory standards DOE uses as well.

RadNet Air Monitoring

RadNet is an EPA nationwide program that monitors the nation's air, precipitation, and drinking water to track radiation in the environment. The RadNet Air Monitoring Project provides radiochemical analysis of air samples taken from five (5) air monitoring stations on the ORR. RadNet samples are collected by TDEC and analysis is performed at the EPA NAREL in Montgomery, Alabama.

RadNet Precipitation Monitoring

The RadNet Precipitation Monitoring Project provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations co-located with RadNet Air stations, at the three ORR sites. One site is located in Melton Valley in the vicinity of the ORNL. One site is at ETTP, located off Blair Road. The last site is located East of Y-12. Samples are collected by TDEC DoR-OR, and analysis of these samples is performed at the EPA NAREL.

Surface Water Monitoring:

There are three projects grouped under surface water monitoring for the purpose of this EMP.

Ambient Surface Water Sampling

The primary purpose of the Ambient Surface Water Sampling Project is to evaluate the impact of Department of Energy (DOE) Oak Ridge Operations (ORR) contamination to five primary ORR exit pathway streams (Bear Creek, East Fork Poplar Creek, Melton Branch, Mitchell Branch, and White Oak Creek) and the Clinch River. This project complements the Benthic Macroinvertebrate Monitoring Project as the assessment of a streams' water quality can more accurately determine the stream's total overall biological health. An integral element of this evaluation is the physical and chemical analysis of the streams' surface water.

Ambient Surface Water Parameters

To assess the degree of surface water impact, stream monitoring data around the ORR is collected monthly, to contribute to a database of physical stream parameters (specific conductivity, pH, temperature and dissolved oxygen). The parameter database will provide information to assess the impact of site remediation efforts through long-term monitoring of surface water parameters, as well as provide ambient parameter information for use in the event of a release requiring clean up decisions and guidance.

White Oak Creek Radionuclides

To help monitor potential ORR contamination, an ambient surface water sampling project has been implemented each year since 1993. The project began by investigating the water quality of the Clinch River at five locations near the ORR. The sampling locations for this project have been modified throughout the years, sometimes adding or discontinuing sampling at specific locations.

Elevated Sr-90 concentrations have been found at Clinch River CRK 33.5 which is the White Oak Creek /Clinch River confluence. Specifically, Sr-90 concentrations were found to be nearly seven times the acceptable limit for the drinking water limit of 8 pCi/L.

Accordingly, the purpose of this project is to continue monitoring Sr-90 and other radiological contaminant inputs to the White Oak Creek / Clinch River confluence.

Landfill Monitoring:

There are two projects grouped under landfill monitoring for the purpose of this EMP.

EMWMF

Contaminated materials from CERCLA remediation activities on the ORR are approved for disposal in the EMWMF if they meet the waste acceptance criteria. There is concern that associated contaminants have the potential to migrate from the facility into the environment and be carried by ground and surface waters off site in concentrations above agreed-upon limits. TDEC conducts surface water monitoring at the EMWMF to provide assurance through independent and sampling and comparison of that independent data with DOE's data, that operations at the EMWMF are protective of public health and the environment and meet the agreed to remedial actions objectives with their surface water discharges. In this effort, samples are collected from ground water, surface water, and wastewater to help ensure that the EMWMF complies with regulatory and operational requirements.

EMDF

The Environmental Management Disposal Facility (EMDF) is proposed for the disposal of low-level radioactive waste and hazardous waste generated by remedial activities on the ORR and will be operated under the authority of CERCLA and DOE. While the EMDF facility will hold no permit from the State of Tennessee, the EMDF will be required to comply with DOE orders and substantive portions of ARARs listed in the upcoming CERCLA EMDF Record of Decision (ROD). TDEC's monitoring of groundwater and surface water in central BCV during FY21, will support the surface water evaluation of the Bear Creek Valley assessment project addressed in section 10 of this document, as well as providing data that may support anticipated future data collection efforts at the central Bear Creek Valley site. TDEC DoR-OR will monitor the streams, note discharges and water condition, observe the condition of the banks and note any concerns.

Storm Water / Water Discharge Monitoring:

There are two projects grouped under storm water / water discharge monitoring for the purpose of this EMP.

Rain Event

As contaminated soil excavations, remedial actions and demolition activities occur throughout the ORR, storm water can accumulate in excavation pits, trenches, basins, sumps, basements. This accumulated water (storm water and potentially groundwater intrusion) at these sites has the potential to become contaminated through contact with impacted materials and then be dispersed further into the environment as runoff or storm water discharge. DOE in the 2017 Annual Site Environmental Report states that; "storm water samples have been collected at locations that are affected by RA activities prior to the initiation of these activities in order to determine the conditions present before remediation begins. In addition, storm water samples will be collected at potentially affected outfalls and storm water catch basins after remedial

activities have been undertaken, and after they have been completed, to help gauge the effectiveness of the remediation efforts." DOE also states that "The results of the monitoring effort at the D&D sites, which are a subset of remedial activities, are utilized in determining the effectiveness of BMPs in controlling offsite releases of legacy pollutants." The goal of this project is for TDEC DoR-OR to obtain independent data to determine if DOE ORR best management practices employed during remedial actions is controlling offsite releases of legacy pollution and to provide input for future cleanup decisions. Actions that will be taken to achieve this goal include: Review and comment on documents related to D&D work; Use co-sampling to monitor releases into the environment; Observe D&D and RA sampling activities and review DOE sampling results to ensure compliance with negotiated and agreed to release criteria.

Accumulated Water Discharge

This project will complement the Rain Event project. As previously stated, contaminated soil excavations and demolition activities occur throughout the ORR, water can accumulate through either groundwater intrusion or stormwater accumulation or both, in excavation pits, trenches, basins, sumps, basements, or during other soil remediation activities. For example, based on past DOE D&D activities, estimated volumes of water accumulated at ETTP range from 200 gallons to 1.5 million gallons (UCOR URS / CH2M 2018a). For FY21 accumulated water at sites with ongoing CERCLA D&D and/or RA operations will be monitored, including but not limited to, the Y-12 Outfall-200 Mercury Treatment Facility headworks construction and the ORNL Molten Salt Reactor Experiment basement groundwater sump and its free-released water. Accumulated water at these sites has the potential to become contaminated and then be dispersed into the environment. To evaluate DOE ongoing D&D and RA actions and provide input for future cleanup decisions, TDEC will review pertinent DOE sampling data and observe DOE sampling and monitoring activities and co-sample as appropriate.to confirm that relevant treatment and discharge criteria are met.

Sediment Monitoring:

There is one project grouped under sediment monitoring for the purpose of this EMP.

Trapped Sediment

The Trapped Sediment Project is focused on determining stream health through sampling and analysis of suspended sediments. Suspended sediment analyses support long term monitoring and assessment of completed site remediation efforts, through long-term monitoring of suspended sediment in water columns. Evaluation of contamination within the suspended sediments allows for assessment of contamination which is found within the mobile sediment load migrating through the sampled exit pathway streams. For FY 21, trapped sediment will be evaluated in East Fork Poplar Creek as well as in Bear Creek. The Bear Creek trapped sediment sampling will be reported with the Bear Creek Valley Assessment project.

Groundwater Monitoring:

There are two projects grouped under groundwater monitoring for the purpose of this EMP.

Offsite (Bear Creek Valley and ETTP)

Previously, TDEC DoR-OR has assessed groundwater through multiple projects (background, offsite, and springs). For this project, TDEC will focus some groundwater assessment activities to areas within the BCV watershed. This focus on BCV will tie this project into the holistic assessment of BCV that is described in TDEC DoR-OR's Bear Creek Assessment Project. The intent of this project is to support development of a current baseline for definition of groundwater quality in the BCV. The first part of this project intends to provide greater delineation of potential groundwater impacts within the BCV to evaluate contaminant concentration distributions spatially as well as over time to guide future decisions.

The second part of this project will focus on sample stations located southwest of the ETTP. ETTP was the home of the uranium-235 gaseous diffusion enrichment process for use in atomic weapons during World War II. In addition, the facilities at ETTP historically released uranium isotopes, technetium-99, and other fission and activation products due to the processing of recycled uranium from spent nuclear reactor fuel. Currently, portions of ETTP are being transferred to industrial or public use. This project intends to provide more ETTP data combined with DOE's offsite sampling data from the ETTP area to check for potential exit pathways and potential anthropogenic impacts to groundwater.

Historical Groundwater Trends:

The Historical Groundwater Trend Project will evaluate and summarize previous TDEC DoR-OR groundwater projects, encompassing approximately twenty years of data. This project started in FY20, evaluating the past decade of work, and this project will build on that information, evaluating additional older environmental data as well. This data will be used to assess data gaps in the current monitoring programs, help guide future TDEC DoR-OR groundwater sampling efforts and support FFA groundwater decisions**.**

Watershed Assessments (Holistic) Monitoring:

The Watershed Assessments (Holistic) Monitoring program has been initiated by TDEC, to support a watershed focused evaluation of current site conditions in watersheds throughout the ORR. For FY21, there is one project grouped under watershed assessments (holistic) monitoring for the purpose of this EMP.

Bear Creek Valley Assessment

This project, designed as a holistic assessment of the Bear Creek Valley Watershed, was initiated during FY20, with an extensive historical records review, preliminary sampling and data gap analysis. This FY21 project builds on that prior work and involves field sampling of surface water, sediment, soils, vegetation, toxicity, fish, benthic macroinvertebrates, and other biota (bird eggs, insects, spiders and crayfish) at Bear Creek kilometers (BCK) 3.3, BCK 4.5, BCK 7.6, BCK 9.6, and BCK 12.3. A background stream, Mill Branch, will be sampled at kilometer 1.6 (MBK 1.6). This project is intended to provide a baseline evaluation to be available for future reference about site conditions within this watershed at this point in time. In addition, this project will evaluate current site conditions for the sections of Bear Creek accessible as recreation areas open to the public.

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1.0 INTRODUCTION

1.1 PURPOSE OF THE ENVIRONMENTAL MONITORING PLAN (EMP)

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation Oak Ridge Office (DoR-OR), submits its annual (FY2021) Environmental Monitoring Plan (EMP) for the period July 1, 2020 through June 30, 2021, in accordance with the terms of the Environmental Surveillance and Oversight Agreement (ESOA) and in support of activities being conducted under the Federal Facilities Agreement (FFA).

The Environmental Surveillance Oversight Agreement (ESOA) is designed to assure the citizens of the State of Tennessee that the Department of Energy's (DOE) current activities in Oak Ridge, Tennessee, are being performed in a manner that is protective of their health, safety, and environment. Through a program of independent environmental surveillance oversight and monitoring, the State advises and assesses DOE's environmental surveillance program. Working collaboratively with the Office of Science, National Nuclear Safety Administration (NNSA), and DOE Environmental Management, the State conducts independent monitoring and verification as well as conducting project reviews and suggesting modifications for current activities, if applicable.

DoR-OR personnel, in support of the tri-party (EPA, TDEC, and DOE) Federal Facilities Agreement (FFA), also conduct independent environmental monitoring to ensure legacy contamination is managed appropriately. Monitoring conducted under the FFA supports environmental restoration decisions, evaluates performance of existing remedies, and investigates the extent and movement of legacy contamination. DoR-OR will take appropriate actions to identify, prevent, mitigate and abate the release or threatened release of hazardous substances, pollutants, or contaminants from the ORR which may pose an unacceptable risk to human health or the environment for the State of Tennessee.

DOE and the State, in a spirit of partnership and cooperation, are committed to assure DOE's Oak Ridge activities are performed in a manner that is protective of health, safety, and the environment. This document provides an annual summary plan for the FY2021 monitoring and assessment projects conducted by TDEC during this period of performance.

Each of the proposed TDEC DoR-OR projects for FY2021 were developed and will be executed to protect human health and the environment. Each project has a DOE oversight component and meets the requirements of the ESOA and FFA and in consideration of the stakeholders (Table 1.1.1).

In executing TDEC DoR-OR's EMP, the deliverables as listed in Table 1.1.2 will be provided to the Stakeholders identified in Table 1.1.1. This EMP will be performed in accordance with the TDEC DoR-OR Health and Safety Plan (TDEC, 2020).

Table 1.1.1 Stakeholders

Stakeholders	
Citizens of Tennessee	External
Tennessee Department of Environment and Conservation	External and Internal
Local Governments	External
DOE and Contractors	External

Table 1.1.2 Deliverables

Deliverables	**Due Date**
FY2021 Environmental Monitoring Plan	6/30/2020, (or as soon as possible following approval of annual grant budget requests by DOE)
Quarterly Reports to DOE	Quarterly
FY2020 Environmental Monitoring Report	10/31/2020

1.2 OBJECTIVE

The objective of the TDEC DOR-OR Environmental Monitoring Program is to provide a comprehensive and integrated monitoring and surveillance program for all media (i.e. air, surface water, soil, sediment, groundwater, drinking water, food crops, fish and wildlife and biological systems), as well as the emissions of any materials (hazardous, toxic, chemical or radiological) on the ORR and its surrounding environment. These projects are also used to evaluate the effectiveness of the DOE environmental monitoring program by collecting data to verify DOE data sets.

This FY2021 EMP presents summaries of twenty-one (21) proposed independent projects. This monitoring plan focuses on the following nine (9) general areas: Radiological Monitoring, Biological Monitoring, Air Monitoring, Surface Water Monitoring, Landfill Monitoring, Storm Water / Water Discharge Monitoring, Sediment Monitoring, Groundwater Monitoring, and Watershed Assessment (Holistic) Monitoring.

1.3 THE OAK RIDGE RESERVATION

The ORR is comprised of three major facilities:

- *Oak Ridge National Lab (ORNL), formerly X-10*
- *Y-12 National Security Complex (Y-12)*
- *East Tennessee Technology Park (ETTP), formerly K-25*

Facilities at these sites were constructed initially as part of the Manhattan Project. The ORR was established for the purposes of enriching uranium for nuclear weapons components and pioneering methods for producing and separating plutonium. In the 70 years since the ORR was established, a variety of production and research activities have generated numerous radioactive, hazardous, and mixed wastes. These wastes, along with wastes from other locations, have been, and are being, disposed of on the ORR.

The primary missions of the three ORR facilities have evolved and continue to evolve to meet the changing research, defense, and environmental restoration needs of the United States. Current operations, like historical operations before them, continue to perform missions that have the potential to impact human health and the environment.

The Oak Ridge National Laboratory (ORNL) conducts leading-edge research in advanced materials, alternative fuels, climate change, and supercomputing. ORNL's activities of fuel reprocessing, isotopes production, waste management, radioisotope applications, reactor developments, and multi-program laboratory operations have produced waste streams that have resulted in environmental releases that contain both radionuclides and hazardous chemicals.

The Y-12 National Security Complex (Y-12) continues to be vital to maintaining the safety, security, and effectiveness of the US nuclear weapons stockpile and reducing the global threat posed by nuclear proliferation and terrorism. Residual waste streams from operational processes at this site have resulted in environmental releases that contain both radionuclides as well as hazardous chemicals.

The East Tennessee Technology Park (ETTP), a former uranium enrichment complex, is being transitioned into an industrial technology park. Even though the gaseous diffusion activities at ETTP have concluded, residual environmental waste streams and current decommissioning activities have resulted in environmental releases that contain both radionuclides and hazardous chemicals.

In accordance with the ESOA Agreement, the FFA Agreement and the TDEC mission statement, TDEC DoR-OR shall work to assure the citizens of Tennessee that the DOE's activities on and

around the ORR, Oak Ridge, Tennessee, are being performed in a manner protective of human health and the environment.

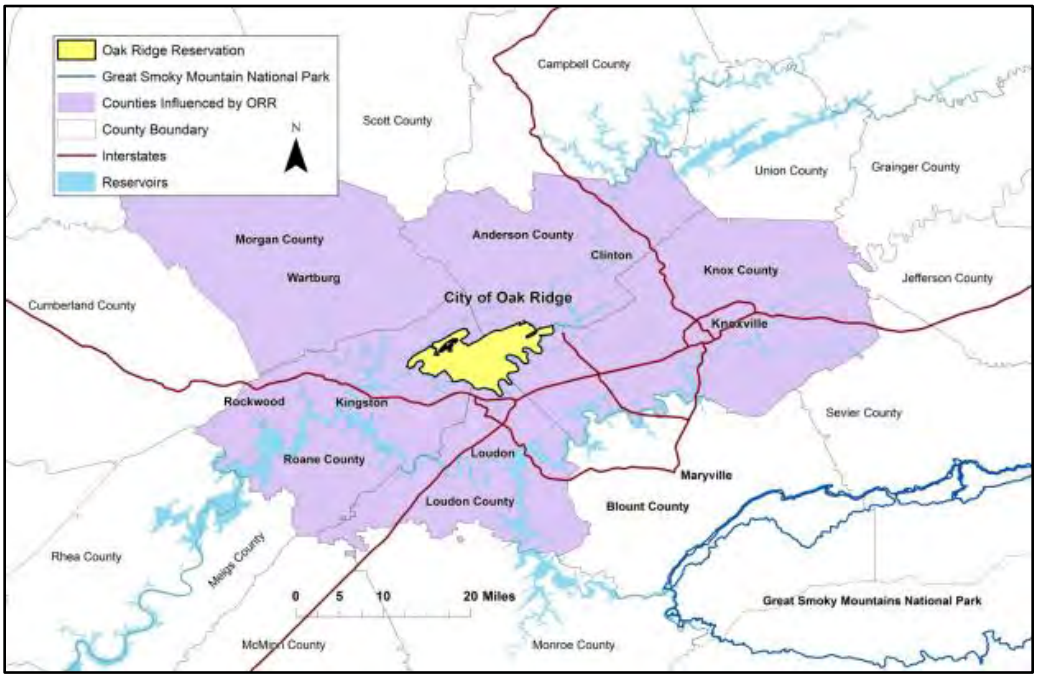

Figure1.3.1: Location of the Oak Ridge Reservation in Relation to Surrounding Counties

1.3.1 Geography of the ORR Area

Located in the valley of East Tennessee, between the Cumberland Mountains and the Great Smoky Mountains, the ORR is bordered partly by the Clinch River. The ORR is located in the counties of Anderson and Roane, and within the corporate boundaries of the city of Oak Ridge, Tennessee. The reservation is bound on the north and east by residential areas of the city of Oak Ridge and on the south and west by the Clinch River. Counties adjacent to the reservation include Knox to the east, Loudon to the southeast, and Morgan to the northwest. Portions of Meigs and Rhea counties are immediately downstream from the ORR on the Tennessee River. The nearest cities are Oak Ridge, Oliver Springs, Clinton, Kingston, Harriman, Farragut, and Lenoir City. The nearest metropolitan area, Knoxville, lies approximately 20 miles to the east (2017 DOE ASER).

The ORR encompasses approximately 32,500 acres of mostly contiguous land of alternating ridges and valleys of southwest-to-northeast orientation. The Valley and Ridge Province is a zone of complex geologic structures dominated by a series of thrust faults. It is characterized by a succession of elongated southwest-to-northeast trending valleys and ridges. In general, sandstones, limestones, and dolomites underlie the ridges that are relatively resistant to erosion. Weaker shales and more soluble carbonate rock units underlie the valleys. Winds within the valleys can differ substantially in speed and direction from the winds at higher elevation.

1.3.2 Climate of the ORR Area

The climate of the ORR region is classified as humid and subtropical; and is characterized by a wide range of seasonal temperature changes between the summer and winter months. Precipitation totals in the most recent calendar year (2017) are about 10 percent above the 30-year mean, with a total of 58.48 inches. (DOE 2017, ASER).

The Great Valley of East Tennessee (its shape, size, depth, and orientation), the Ridge-and-Valley physiography contained therein, the Cumberland Plateau, the Cumberland Mountains, and the Great Smoky Mountains all represent major landscape features that affect the wind flow regimes of Eastern Tennessee. Both the local terrain (for example: lithologic rock types in the subsurface and wind-directing regional landforms) as well as the regional climate (rainfall, etc.) are factors in determining the potential migration of contamination from the ORR to the surrounding areas.

1.3.3 Population of the ORR Area

More than one million citizens reside in the counties immediately surrounding the ORR. Knoxville is the major metropolitan area near Oak Ridge. Except for Knoxville, the land is semi-rural. The area is used primarily for residences, small farms, and pastures. Fishing, hunting, boating, water skiing, and swimming are popular recreational activities in the area.

1.4 TENNESSEE'S COMMITMENT TO THE CITIZENS OF TENNESSEE

In accordance with the ESOA Agreement, the FFA Agreement and the TDEC mission statement , TDEC DoR-OR will work to assure the citizens of Tennessee that the DOE's historic and current activities on and around the ORR, Oak Ridge, Tennessee, are being managed or performed in a manner protective of human health and the environment.

2.0 RADIOLOGICAL MONITORING

2.1 ENVIRONMENTAL DOSIMETERS

2.1.1 Background

Radiation is emitted by various radionuclides that have been produced, stored, and disposed of on the Department of Energy (DOE) Oak Ridge Reservation (ORR). Associated contaminants are evident in ORR facilities and surrounding soils, sediments, and waters. In order to independently assess the risks posed by these radioactive contaminants, the Oak Ridge Office of the Tennessee Department of Environment and Conservation's (TDEC) Division of Remediation (DoR) began monitoring ambient radiation levels on and near the vicinity of the ORR in 1995. This project provides:

- Conservative estimates of the potential dose to members of the public from exposure to gamma radiation attributable to DOE activities/facilities on the ORR;
- Baseline values used to assess the need and/or effectiveness of remedial actions;
- Information necessary to establish trends or fluctuations in gamma radiation emissions;
- Information relative to the unplanned release of radioactive contaminants on the ORR.

Optically Stimulated Luminescence Dosimeters (OSLs) are used for the project due to their superior sensitivity compared to Thermoluminescent Dosimeters (TLDs) (Boons, Van Iersel, & Genicot, 2012). The majority of the areas will be monitored with only gamma detecting dosimeters, whereas areas with the potential for neutron fluxes will also be monitored with neutron-detecting dosimeters. In addition, hand-held dosimeter instruments will be used to measure the actual dose at a location; if it's deemed necessary and useful, the area will be surveyed. This might happen when an area would be subject to waste being moved, added or removed, thus changing the dose intensity.

2.1.2 Related DOE Projects

At the Spallation Neutron Source (SNS), DOE also deploys and exchanges dosimeters in the same specific locations as does TDEC DoR-OR.

2.1.3 Problem Statements

The purpose of the Environmental Dosimeters Project is to help confirm that the potential dose to members of the public from exposure to gamma radiation, attributable to DOE activities/facilities specifically at ORNL, Melton Valley, SNS, other parts of the ORR and offsite background locations, is at accepted regulatory and safe levels.

2.1.4 Goals

The goal of the Environmental Dosimeters Project is to maintain independent monitoring to evaluate DOE's efforts to reduce radiation levels both on and in the vicinity of the ORR. Specifically, this project will independently assess if the potential public dose from radiation exposure is kept below the NRC NUREG-1757 reference limit of 100 mrem/yr (Schmidt et al, 2006). ORR conditions are expected to improve as remediation activities continue and stored materials are disposed.

2.1.5 Scope

The Environmental Dosimeters Project geographic scope covers the Oak Ridge National Laboratory, Melton Valley, the Spallation Neutron Source, the Oak Ridge South Campus, as well as background sites in and near the City of Oak Ridge. Emphasis is placed on areas where

radioactive materials are stored, processed, used or disposed. It is important to know where potential problems exist, but it is equally important to inform stakeholders where problems do not exist.

2.1.6 Assumptions

- The budget and dosimeter processing costs may change during the fiscal year.
- Levels of radiation are expected to change with remediation of areas.
- Levels of radiation may change from time to time in active work areas based on movement of materials in or out of a given area.

2.1.7 Constraints

- The budget may not allow for an adequate number of dosimeters.
- Missing dosimeters can result in specific site data not being available and an estimated yearly exposure will have to be projected based on available data.
- If dosimeters are late in arriving from Landauer, Inc., distribution and retrieval of dosimeters may be delayed.
- If DOE contacts for distribution of dosimeters are unavailable or an area where dosimeters are placed is temporarily inaccessible, the two to three-week time limit for distribution and retrieval of dosimeters will have to be extended.
- If dosimeters being returned to Landauer, Inc. are x-rayed during shipment, the data for that quarter will be lost and adjustments will need to be made to extrapolate available data to a value for the year.
- If a state vehicle is not available on a particular day, the distribution will need to be delayed.
- If the project lead is not available during the distribution period, arrangements will be made for another individual to complete that part of the task or the entire task if needed.
- There may be circumstances where work is suspended because of natural events or state or national emergencies.

2.1.8 Methods, Materials, Metrics

The Environmental Dosimeters Project work is conducted under the guidance of TDEC DoR-OR's Health and Safety Plan (TDEC, 2020). In this effort, environmental dosimeters are used to measure the gamma radiation dose attributable to external radiation at selected monitoring stations. Collected data results are compared to background values and to the State of Tennessee's primary dose limit for members of the public.

The Environmental Dosimeters Project is conducted on the ORR and at two background locations in the city of Oak Ridge and at Fort Loudoun Dam in order to monitor general radiological conditions. Gamma radiation exposure levels are monitored at all sites and neutron radiation is monitored at selected sites. Dosimeters are distributed in selected areas of the ORNL Main Campus in Bethel Valley, ORNL Melton Valley, the ORNL Spallation Neutron Source, the City of Oak Ridge, and Fort Loudoun Dam.

The dosimeters used in the Environmental Dosimetry Project are OSLs. OSLs are more sensitive than TLDs and they will record levels of exposure as low as 1 mrem vs. the 10 mrem of the TLDs. The dosimeters are obtained from Landauer, Inc. in Glenwood, Illinois.

Dosimeters at all sites are changed out by TDEC DoR-OR and analyzed (by Landauer, Inc.) on a quarterly schedule during the months of January, April, July, and October. A total of 25 dosimeters are distributed and retrieved during each quarter; specifically, new ones are placed in the field, and those in the field are returned for processing.

Dosimeters are typically received from Landauer, Inc. during the first week of January, April, July and October. Upon receipt, the dosimeters are logged in to ascertain that all units were received and then prepared for distribution to the various sites. At the majority of the sites, TDEC DOR-Oak Ridge staff must contact site personnel to arrange for access to certain areas for the distribution. At certain sites, TDEC DOR-Oak Ridge staff are accompanied by site personnel during the distribution; at others, gate keys are borrowed to gain access to the areas.

Every attempt is made to complete the quarterly task within two to three weeks of logging in the dosimeters. Much of this depends on the schedules of site contacts, weather conditions, and other extenuating circumstances (e.g., temporary inability to access certain areas because of ongoing site activities).

After dosimeters are exchanged, those that are destined for analysis are logged back in to determine if any are missing. The dosimeters are then packaged for shipment to Landauer, Inc. for processing. Rather than ship the packages by air, they are shipped via ground delivery to avoid being x-rayed in transit which would impact dose readings and make the resulting data unusable.

After the dosimeters have been analyzed at Landauer, Inc., the analytical data is reviewed and reported in the annual Environmental Monitoring Report (EMR).

2.1.9 References

Boons, R., M. Van Iersel, and J.L. Genicot. (2012) External and Environmental Radiation Dosimetry with Optically Stimulated Luminescent Detection Device - Developed at the

SCK·CEN. World Journal of Nuclear Science and Technology, 2, 6-15 2: 6–15. http://dx.doi.org/10.4236/wjnst.2012.21002.

Schmidt, D.W, K.L. Banovac, J.T. Buckley, D.W. Esh, R.L. Johnson, J.J. Kottan, C.A. McKenney, T.G. McLaughlin, S. Schneider. (2006) Consolidated Decommissioning Guidance, NUREG-1757 2. Retrieved from https://www.nrc.gov/docs/ML0630/ML063000252.pdf

TDEC. (2020). 2020 Health and Safety Plan Including Related Policies. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, Tennessee.

TDEC. (2018). Standard Operating Procedure: Environmental Dosimeters Project (Draft). Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, Tennessee.

2.2 Real Time Measurement of Gamma Radiation

2.2.1 Background

ETTP began operations during World War II as part of the Manhattan Project. Its original mission was producing uranium, enriched in the uranium-235 isotope (U-235), for manufacturing the first atomic weapons and later for fueling commercial- and government-owned reactors. The weapons production facility permanently shut down in 1987.

Consequential to operational practices and accidental releases, many of the facilities at ETTP are contaminated to some degree and scheduled for decontamination and decommissioning (D&D). Uranium isotopes are the primary contaminants, but technetium-99 and other fission and activation products are also present, due to the periodic processing of recycled uranium, obtained from spent nuclear fuel.

The Y-12 site was constructed during World War II for enriching uranium in the U-235 isotope by using the electromagnetic separation process. In ensuing years, Y-12 was expanded and used for producing fuel for naval reactors, conducting lithium and mercury enrichment operations, manufacturing components for nuclear weapons, dismantling nuclear weapons, and storing enriched uranium.

Construction of the ORNL site began in 1943. While the initial missions of K-25 and Y-12 were producing enriched uranium, ORNL focused on researching reactors and producing plutonium and other activation and fission products chemically extracted from uranium irradiated in ORNL's graphite reactor and later at other ORNL and Hanford reactors.

During early operations, leaks and spills were common within the facilities and resulting radioactive materials were released from operations as gaseous, liquid, and solid effluents, with

little or no treatment. The EMWMF near Y-12 in Bear Creek Valley was constructed for the disposal of low-level radioactive and hazardous wastes generated by RA on the ORR.

2.2.2 Related DOE Projects

The DOE conducts ambient gamma sampling at the ORR perimeter sampling locations to ensure DOE's primary dose limit for protecting members of the public (100 mrem/year) is not exceeded. The Real Time Measurement of Gamma Radiation Program is conducted closer to potential sources and would be an indication of potential offsite influences. Sampling closer to the sources would more likely give an indication of the effect to onsite members of the public.

2.2.3 Problem Statements

Facilities on the ORR have the potential to release variable amounts of gamma radiation. The Real Time Monitoring of Gamma Radiation Project focuses on measuring and determining radioactive exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods of time because the potential for an unplanned release of gamma emitting radionuclides into the environment exists.

2.2.4 Goals

Results from monitored sites will be compared to the State of Tennessee (State) and NRC limit of two mrem in one hour to determine the maximum dose exposure to an unrestricted area. The results will also be compared to the State and DOE primary dose limits for protecting members of the public (100 mrem/year).

2.2.5 Scope

This project measures ambient gamma radiation dose/exposure rates at areas on the ORR more likely to have variable dose rates over time. Candidate monitoring locations include sites on the ORR with remedial activities, waste disposal operations, pre and post operational investigations, and environmental response activities. Data recorded by the monitors will be evaluated by comparing it to background concentrations and to the State and NRC maximum dose limit for members of the public.

2.2.6 Assumptions

Sampling locations may not always be accessible due to operational or security concerns.

2.2.7 Constraints

Placement of the gamma radiation monitors can be less than optimal due to facility operational constraints. The gamma radiation monitors cannot interfere with traffic, facility access, or facility operations. Their placement is limited to locations where the security of the instrument can be

assured. At most locations, but not all, the monitors can be chained and locked for security.

Monitoring data must be manually downloaded which requires the technician to visit the site. Consequently, delays may result in a timely response to anomalies.

2.2.8 Methods, Materials, Metrics

The gamma exposure rate monitors deployed for this project are manufactured by Genitron Instruments and are marketed under the trade name, Gamma TRACER®. Each monitor contains two Geiger Mueller tubes, a microprocessor-controlled data logger, and lithium batteries sealed in a weather resistant case to protect internal components. Each monitor can be programmed to measure gamma exposure rates from one μrem/hour to one rem/hour for predetermined intervals from one minute up to two hours.

The results reported by this project are derived from averaging the values of the data recorded by the two Geiger Mueller detectors. The data for any interval from either detector can be independently accessed and used. The results recorded by the data loggers are downloaded monthly, with the exception of the semiannual downloads at the background location, to a DoR-OR computer using an infrared transceiver and associated software. Results from monitored sites will be compared to the State and NRC limit of two mrem in one hour to determine the maximum dose exposure as well as to the results from the exposure rate monitor at the background location at Fort Loudoun Dam. The following locations are planned for monitoring from July 1, 2020 to June 30, 2021 (Figure 2.2.1).

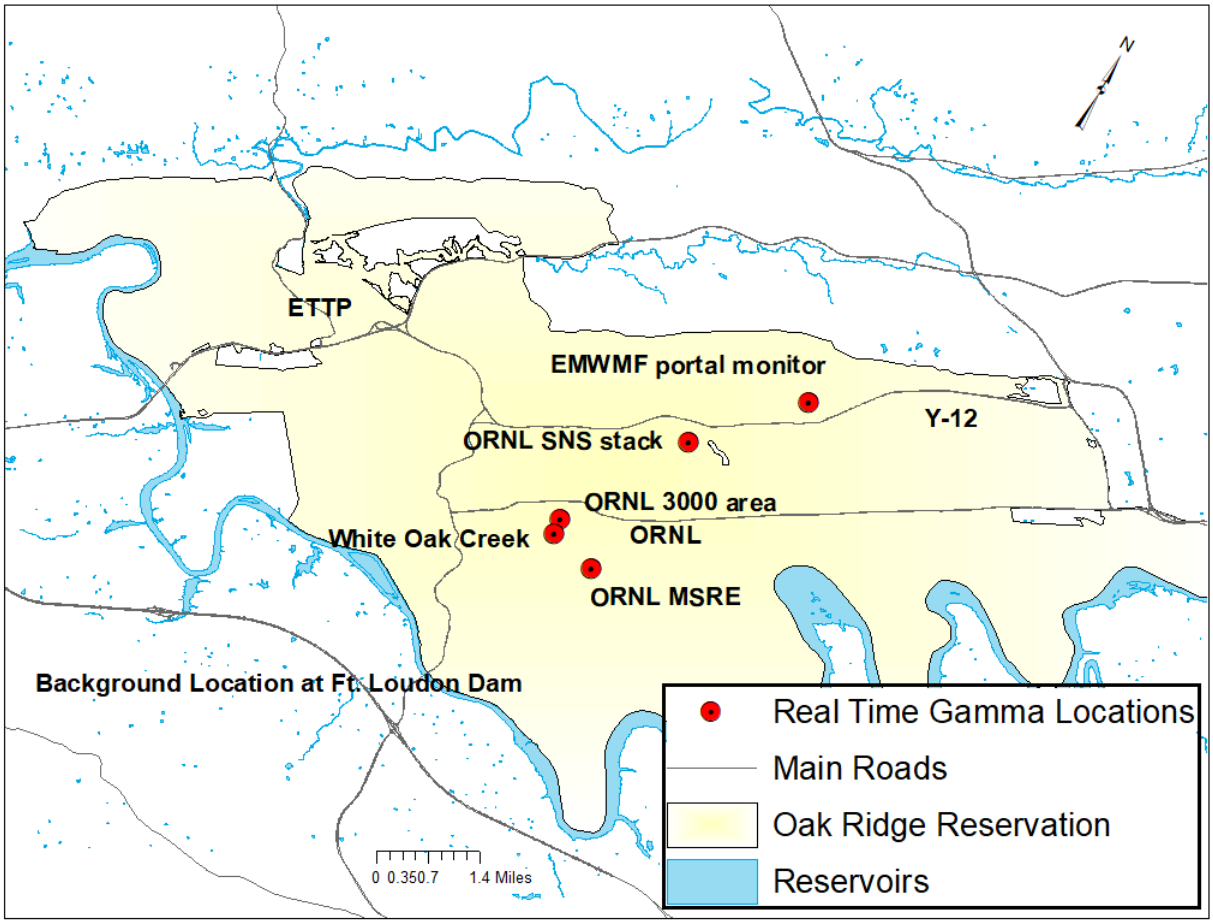

Figure 2.2.1: Monitoring Locations

2.2.9 References

NRC Regulations (10 CFR) > Part Index > § 20.1301 Dose limits for individual members of the public

2.3 Surplus Sales Verification

2.3.1 Background

The Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge Office (DoR-OR), in an oversight capacity of the U.S. Department of Energy (DOE) and its contractors, conducts radiological surveys of surplus materials from the Oak Ridge Reservation (ORR) that are designated for sale to the public. In addition to performing the surveys, the office reviews the procedures used for release of materials under DOE radiological regulations. DOE currently operates their surplus materials release program under DOE O 458.1 Admin Chg 3, Radiation Protection of the Public and the Environment.

Some materials, such as scrap metal, may be sold to the public under annual sales contracts, whereas other materials are staged at various sites around the ORR awaiting auction i.e., sale. Practices have changed at both the Y-12 National Security Complex (Y-12) and at the Oak Ridge National Laboratory (ORNL) regarding surplus sales. With rare exceptions, materials are no longer sold directly to the public by either facility.

Y-12 now uses an out-of-state contractor to handle the majority of their sales. ORNL has a list of organizations approved to bid on sales of materials by the truckload. DoR-OR, at the request of ORNL and Y-12 Property Excessing staff, conducts radiological verification screening surveys to help ensure that no potentially contaminated materials reach the public. In the event that elevated radiological activity is detected above the removable contamination limits set forth in NUREG-1757, Volume 1, Revision 2, Section 15.11.1.1 Release of Solid Materials with Surface Residual Radioactivity (Schmidt et al., 2006) or Reg. Guide 1.86, a quality control check is made with a second meter. If both meters show elevated activity, DoR-OR immediately reports the finding(s) to the surplus sales program supervisor. A removable contamination assessment may be performed. Activity is recorded in dpm/100 cm^2 (dpm = disintegrations per minute) and then reported. DoR-OR then follows the response of the sales organizations to see that appropriate steps (i.e., removal of items from sale, resurveys, etc.) are taken to protect the public.

2.3.2 Related DOE Projects

DOE Radiation Control personnel scan most materials before they are submitted for auction at ORNL or Y-12 surplus sales. Process knowledge may also be used for judging the appropriateness of release of equipment or materials to the public.

2.3.3 Problem Statements

- The source of incidental radioactive contamination on any surface, if present, is most likely related to activities in the building or area from which the material was being used. Material and/or equipment from such locations should be scanned to ensure that no accidental transfer of contaminated equipment occurs during surplus equipment sales. DOE and its contractors follow procedures for unrestricted release of material and equipment and process knowledge. DoR-OR is invited to, and routinely elects to do an additional scan before auction.
- Although the procedure for surplus of materials from the ORR has changed (materials are no longer directly auctioned to the public) the potential for items being released to pre-approved bidders may reach the public. Y-12 now uses an off-site contractor to handle their sales, thus leaving ORNL property sales as the prime focus of this project.
- Even if items of concern are found with surface activity, they may not ultimately prove to be problematic. For example, some activity may be attributed to naturally occurring daughter isotopes (e.g., radioactive daughter isotopes of lead (Pb), polonium (Po),

bismuth (Bi) that can originate from Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) which might be natural (probably thorium (Th) daughters) that can adhere to the surface of various items of varied composition. What first appears as an item with surface contamination may (with proper resurvey techniques) prove to be an instance where daughter isotopes have adhered to the surface of the item and then rapidly decayed away.

2.3.4 Goals

Although DOE made great progress in the reduction of contaminated material for Surplus Sales, in 2019 DoR-OR staff continued to identify contaminated material or material with elevated activity. DoR-OR's goal is to verify materials that have been staged for sale at ORNL's 115 Union Valley Road Property Excessing Facility or other locations are free of radiological surface contamination exceedances. The project attempts to locate any contaminated items that may have evaded detection prior to being staged for sale. In rare instances where items of concern are found, it prevents the release of potentially contaminated materials to the public.

2.3.5 Scope

DoR-OR staff performs pre-auction verification surveys on items being auctioned by ORNL's Excess Properties Sales. These surveys are performed at the request of ORNL's Excess Properties staff. When a request is received, every attempt is made to fulfill that request. Typically, no more than eight events occur during a calendar year. DoR-OR has had no difficulty responding to all requests.

2.3.6 Assumptions

- Funding and budget will be sufficient
- State vehicle will be serviceable and available for the survey
- Adequate staff will be available for the survey
- Sufficient number of alpha/beta scintillation meters will be available for the survey
- DoR-OR will follow up on resolution of the identified potential issues

2.3.7 Constraints

- State vehicle not available for the survey
- Adequate staff not available for the survey
- Adequate number of alpha/beta scintillation meters unavailable on the day of the survey
- The budget and equipment calibration costs may change during the fiscal year
- There may be circumstances where work is suspended because of natural events or state or national emergencies.

2.3.8 Methods, Materials, Metrics

Surplus sales verification work is performed under the guidance of DoR-OR's 2020 Health and Safety Plan (TDEC 2020).

Prior to sales of surplus items from ORNL or Y-12 to the public, DoR-OR conducts a pre-auction survey. The intent of this survey is to spot check items that are for sale with appropriate radiation survey instruments in order to ensure that no radioactively contaminated items are released to the public. Not all items or surfaces of a specific item are surveyed for potential radioactive contamination. Specific (targeted) often referred to as *biased* measurements are often used where specific attention is paid to well-used items where material damage, uncleanliness, or staining is present. However, clean looking items may also be checked. When activity (alpha or beta/gamma) above the removable contamination limits is detected, the item is brought to the attention of Property Excessing staff.

Based on DoR-OR's survey results, it is the Property Excessing's decision whether or not to have the item rechecked by ORNL RADCON. DoR-OR does not attempt to determine if a particular item meets DOE release criteria, but does try to locate items where, depending on the isotopes involved, there is a potential for the item to not meet release criteria.

2.3.9 References

Schmidt, D.W, K.L. Banovac, J.T. Buckley, D.W. Esh, R.L. Johnson, J.J. Kottan, C.A. McKenney, T.G. McLaughlin, S. Schneider. (2006) Consolidated Decommissioning Guidance, NUREG-1757, 2. Retrieved from https://www.nrc.gov/docs/ML0630/ML063000252.pdf

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TDEC. (2018). Standard Operating Procedure: T-532 Operation and Use of a Ludlum Model 2224 and 44-10 Probe (Dual Phosphorus Meter) (Draft). Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office. Oak Ridge, Tennessee.

2.4 HAUL ROAD SURVEYS

2.4.1 Background

The Tennessee Division of Environment and Conservation's (TDEC) Division of Remediation (DoR) Oak Ridge Office (OR) staff perform bimonthly surveys of the Haul Road and other waste transportation routes on the Oak Ridge Reservation (ORR). The Haul Road was constructed and reserved for trucks transporting Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) radioactive and hazardous waste from remedial activities on the ORR to the Environmental Management Waste Management Facility (EMWMF) for disposal.

To account for wastes that may have fallen from the trucks in transit, DoR-OR personnel perform walk over inspections of different segments of the nine-mile long Haul Road and associated access roads on a bimonthly basis. Anomalous items noted along the roads are scanned for radiation, logged, marked with contractor's ribbon, and their descriptions and locations submitted to the Department of Energy (DOE) for disposition.

2.4.2 Related DOE Projects

DOE conducts radiological surveys of the Haul Road utilizing radiological detection instrumentation attached to a tractor. There is some concern that the distance from the radiation detectors on the tractor to the road surface to is too great for effective detection of beta radiation. The tractor does not stop to survey anomalous objects found on or beside the road. Throughout the history of the Haul Road Surveys project, numbers of anomalous items have been identified such as waste debris, personal protection equipment, tarp patches, waste stickers, steel pipe, etc.

2.4.3 Problem Statements

Waste was lost from a DOE contractor dump truck on a Tennessee public highway on Friday, May 14, 2004. This event resulted in a DOE Type B Accident Investigation. As a corrective action and in agreement with the State of Tennessee under CERCLA, a dedicated Haul Road for transporting hazardous waste to onsite disposal facilities was constructed. Since then, the State of Tennessee has performed radiological verification surveys of the Haul Road. This project is a CERCLA verification of an ongoing Remedial Action Work Plan for the transportation of waste from East Tennessee Technology Park to the Environmental Management Waste Management Facility (ETTP-EMWMF).

Only low-level radioactive waste, as defined in TDEC 0400-02-11.03(21) with radiological concentrations below limits imposed by Waste Acceptance Criteria (WAC), as agreed to by the FFA tri-parties, (DOE, EPA and TDEC), is approved to be transported on the Haul Road for disposal in the EMWMF. DOE is accountable for compliance with the WAC and has delegated responsibility

of WAC attainment decisions to its prime contractor. The WAC attainment decisions include waste characterization and ultimate approval for disposal in the EMWMF (DOE, 2001). The State and EPA oversee and periodically audit associated activities related to this work, including the review of the decisions authorizing waste lots for disposal.

2.4.4 Goals

The primary goal is to prevent the spread of contamination, resulting from the transportation of radioactive and hazardous waste, being transported from the originating clean up locations on the ORR to the waste disposal location. In particular, the objectives include the following:

- To locate waste that may have been blown or dropped from waste-hauling trucks in transit.
- To assess the radiological conditions of the Haul Road and objects that may have fallen from trucks.
- To assure that DOE and their contractors continue their waste transportation in a manner that limits potential environmental concerns for the Haul Road and the surrounding areas.

2.4.5 Scope

The scope of this project is limited to locating, surveying, and reporting to DOE any ORR derived waste materials that may have been blown or dropped from waste-hauling trucks on the Environmental Management Waste Management Facility (EMWMF) Haul Road.

2.4.6 Assumptions

- Radioactive spills or materials found along ORR Haul Road can be attributed to the transportation activities on the ORR.
- DOE will continue to use the ORR Haul Road to transport waste.
- DOE waste shipments on the ORR Haul Road have the potential to spread radiological contamination.
- TDEC will have enough manpower to conduct Haul Road surveys.
- Radiological instruments will be available to TDEC staff to conduct surveys.

2.4.7 Constraints

- There may be a shortage of available staff to conduct Haul Road surveys.
- Instrumentation may not be available when others have detectors signed out.
- Reserving a vehicle may not be possible, particularly with impromptu scheduling.
- Weather is a limiting factor; surveys cannot be conducted in the rain or snow.

2.4.8 Methods, Materials, Metrics

The nine-mile long Haul Road is surveyed in segments, typically consisting of one to two miles. For safety and by agreement with DOE and its contractors, DoR-OR (TDEC) staff coordinate with Haul Road site personnel that TDEC personnel intend to perform a survey on the Haul Road. The DOE contractor is responsible for providing briefings on road conditions and any known situation that could present a safety hazard while on the road. When the DOE contractor is not working, staff members call into the designated DOE site safety office for the segment being surveyed. Should excessive traffic present a safety concern, the survey is postponed to a later date. Alternate entrances are sometimes used to access and egress the road with DOE approval, but the basic requirements remain the same.

When TDEC staff members arrive at the segment of the road to be surveyed, the vehicle is parked completely off the road, as far away from vehicular traffic as possible. No fewer than two people perform the surveys, each walking in a serpentine pattern along opposite sides of the road to be surveyed or one person walking in a serpentine pattern across the entire road accompanied by an approved safety buddy. Typically, a Ludlum Model 2221 Scaler Ratemeter with a Model 44-10 2"X2" NaI Gamma Scintillator probe, held approximately six inches above ground surface, is used to scan for radioactive contaminants as the walkover proceeds. A Ludlum 2224 Scaler with a Model 43-93 Alpha/Beta dual detector is used to investigate potential surface contamination on the road surfaces or anomalous items found along the road that may be associated with waste shipments. Any areas or items with contamination levels exceeding 200 dpm/100 cm2 removable beta, 1000 dpm/100 cm2 total beta, 20 dpm/100 cm2 removable alpha, and/or 100 dpm/100 cm2 total alpha that require further investigation are noted.

Anomalous items, found during the survey, are marked with contractor's ribbon at the side of the road and a description of each item and its location are logged and reported to DOE and its contractors for disposition. A survey form is completed for each walkover and is retained at the DoR-OR office. When staff members return to the road for the subsequent inspection, staff members perform a follow-up inspection of items found and reported during previous weeks. If any items remain, they are included in subsequent reports until removed or staff members are advised the item(s) have been determined to be free of radioactive and hazardous constituents.

The planned Haul Road Survey walk down schedule includes 24 surveys, to be completed over a 12-month period (approximately two surveys each month)

2.4.9 References

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3.0 BIOLOGICAL MONITORING

3.1 RADIOLOGICAL UPTAKE IN FOOD CROPS

3.1.1 Background

DOE conducts studies on locally grown and harvested food crops such as root plants, tomatoes, turnips, broadleaf systems (lettuce, collard greens, mustard greens), hay and milk to analyze airborne releases of radiation and its possible effects on food crops and their consumption. The Radiological Uptake in Food Crops Project was recommended to TDEC DoR-OR by DOE to verify DOE's results to determine the possibility of consumers receiving radiation doses resulting from DOE activities on the ORR. This project will serve the better understanding of the effects of radiation uptake in locally grown and harvested food crops.

3.1.2 Related DOE Projects

DOE currently conducts and has previously conducted similar studies as documented in the DOE Environmental Monitoring Plan CY2020. Data pulled from DOE's OREIS database in February 2020 show that DOE sampled milk from cattle as recently as 2016 in Claxton and Maryville, Tennessee. These milk samples were screened for beryllium-7, potassium-40, strontium-90, and tritium. When compared to available FDA derived intervention limits (DILs) for radionuclides in milk and EPA drinking water maximum contaminant limits (MCLs), milk samples collected in 2016 appear to be well below the available FDA DILs for radionuclides, and most samples are below EPA analyte specific MCLs. Potassium-40, with a mean of 1330 pCi/L in Claxton milk and 1325 pCi/L in Maryville milk in 2016, was the only isotope that exceeded an available limit, the EPA drinking water MCL for beta emitters of 8 pCi/L, which is only used for comparison. Vegetables have not been sampled since 1992 (cabbage) or 1996 (lettuce, tomatoes, and turnips). When last sampled and compared to EPA analyte specific MCLs for drinking water as a reference only, cabbage and tomatoes both exceeded antimony, arsenic, cadmium, chromium, selenium, uranium metal, and zinc limits. Cabbage and tomatoes also exceeded the FDA limit for mercury in vegetables. All the

vegetable preliminary results were below EPA drinking water MCLs for radiological contaminants.

3.1.3 Problem Statements

- Members of the public have the potential to be exposed to doses of radiological materials through the consumption of locally grown food crops
- Radiological materials have been released into the atmosphere, groundwater, surface water, soils, and sediment
- Airborne releases from DOE ORR activities can be disturbed and transported beyond the boundaries of the ORR
- Transfer of contamination may take place outside of the sample and monitoring program parameters put in place by DOE

3.1.4 Goals

The goals of this project follow:

- To obtain data to detect radiation contamination in food crops received by consumers because of DOE activities on the ORR
- To verify DOE's findings as they relate to food crops

3.1.5 Scope

To accomplish the Radiological Uptake in Food Crops Project, TDEC will do the following:

- Identify the locations of concern where the food crops are grown and harvested
- Procure the food crops that are grown and harvested within five miles of the ORR
- Ship samples to the Tennessee Department of Health Laboratory (TDH) for sample analyses to test for gross alpha, gross beta, gamma emitting radionuclides (in accordance with EPA 900.0), uranium-234, 235, and 238 isotopes.

3.1.6 Assumptions

- Food crops will be available for collection and analyses
- Food crops uptake radiological contamination
- DOE's data will be comparable to TDEC DoR-OR's data
- Radiological contamination originates from DOE ORR activities

3.1.7 Constraints

The Radiological Uptake in Food Crop Project is limited by the following:

- Availability of food crops selected for the study
- Weather can affect the production and availability of food crops

- Adequate funding will be available for this Project
- Laboratory costs can impact the scope of the Project
- Cash outlay to purchase food crops

3.1.8 Methods, Materials, Metrics

- Find sources of food crops by reaching out to local producers and vendors
- Acquire samples weekly, monthly, and quarterly depending on availability
- Vegetation samples should be consistent with respect to readiness for harvest
- Crops may be selected directly from plants or from crates. A note will be made describing the physical condition and state of the sample
- Select a location to collect samples in a minimum of one square yard. In this area, collect at least a 2.2-pound (1 kg) sample for all the different types of food crops.
- A TDH chain of custody form is to be used for all collected samples
- Analytical results will be compared to applicable regulatory limits and to DOE's food crop data
- Figure 3.1.1 and Table 3.1.1 provide information for the proposed sample locations.

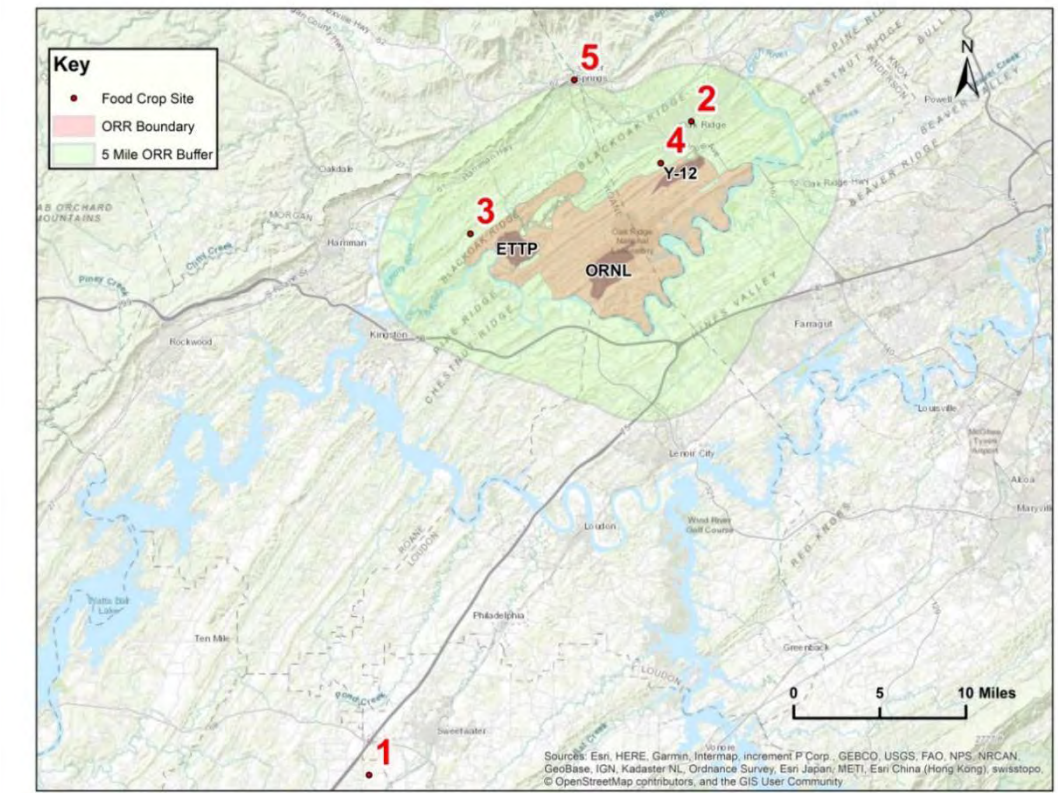

Figure 3.1.1: Proposed Food Crop Sampling Location Map

Table 3.1.1: Proposed Sample Locations

	Proposed Sample Areas
1	Background – Niota, Sweetwater, TN
2	East End – Oak Ridge, TN
3	West End – Oak Ridge, TN
4	Scarboro Area – Oak Ridge, TN
5	Poplar Springs Area – Oak Ridge, TN

3.1.9 References

DOE Environmental Monitoring Plan for Oak Ridge Reservation, CY 2020 TDEC DOR-OR Sampling Plan- Rad Uptake in Food Crops

3.2 BENTHIC COMMUNITY HEALTH

3.2.1 Background

The Benthic Monitoring Project consists of macroinvertebrate and diatom community sampling, as well as leaf litter decay rate assessment in order to monitor the current and changing condition of benthic health in streams on the Oak Ridge Reservation (ORR). Four main watersheds are studied at the three facilities on the ORR. White Oak Creek is the primary watershed on the Oak Ridge National Laboratory (ORNL). Mitchell Branch serves as the main watershed on the East Tennessee Technology Park (ETTP). East Fork Poplar Creek and Bear Creek are watersheds on the Y-12 facility. These streams have been negatively impacted by World War II Manhattan Project activities as well as current operational activities.

The purpose of this monitoring project is to document the current conditions of these stream bottom communities and note any changes in their conditions due to ongoing CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) remedial activities.

Aquatic macroinvertebrate and diatom species serve as indicators of the health of aquatic systems. These bioindicators both quantitatively and qualitatively assess biotic responses to environmental stress (Holt, 2010). As these organism's lives are spent primarily in water, they are continually exposed to any adverse conditions caused by direct or indirect discharges to these waters. Diatoms and detritus, the primary food source for macroinvertebrates, have been found to readily absorb methylmercury and facilitate the upward movement of the toxic substance through higher trophic levels of the food web (Lopez et al., 2013 and Gosnell, 2016). Diatoms

reproduce and respond rapidly to environmental change and provide early warnings of both pollution increases and habitat restoration success (Round, 1991; Kelly et al., 1998).

Measuring leaf litter decomposition rates suggests considerable potential in some circumstances to capture impairment of stream ecosystem functioning (Schiller, 2017). The decomposition of litter is mainly a biological process which is driven by microbial decomposers, fungi and bacteria, and macroinvertebrate detritivores, and it is highly sensitive to changes in environmental conditions (Schiller 2017). The central role of leaf litter decomposition in streams is to provide a pathway for nutrient cycling upward through the food web (Schiller 2017). Additionally, the presence of sulfate-reducing bacteria, which expedite leaf litter decomposition (Bani, 2018), would indicate a higher likelihood of bioavailable methylmercury (Moreau, 2015).

Unimpacted reference streams are used to determine the composition of a healthy community. Their data will then be compared to ORR impacted stream data to help determine the extent of current and changing conditions at these target locations.

All work on this project follows the requirements of TDEC Division of Remediation Oak Ridge Office's (TDEC DoR-OR) Health and Safety Plan (TDEC 2020).

3.2.2 Related DOE Projects

DOE conducts benthic macroinvertebrate sampling throughout the ORR and reports their findings in both the Remediation Effectiveness Report (RER) and the Annual Site Environmental Report (ASER).

ORNL staff also conducts benthic macroinvertebrate monitoring on some of the same streams as TDEC DoR-OR; however, the number of specific stream sites differ between the two organizations. Where specific sites are the same, TDEC's sampling serves as an independent check on ORNL's monitoring results. Determining impacts to stream bottom communities is a difficult task; consequently, results and interpretations may differ among different samplers and analysts. Thus, different perspectives can help delineate actual conditions in ORR streams.

DOE does not currently collect diatom community or leaf litter decay samples.

3.2.3 Problem Statements

- Past studies indicate the majority of benthic community sampling sites located in ORR streams have been negatively impacted when compared to healthy communities in unimpacted reference streams (TDEC EMR 2018, DOE ASER 2018). Many of the impacts affecting these streams result from both historical Manhattan Project activities on the ORR facilities as well as current operational activities. The majority of these impacts are due to typical industrial contaminants (e.g., chlorine releases, toxic chronic and acute

chemical releases, organic loading from point and non-point discharges) and are not related to the radiological contamination of the ORR sampling sites. In areas where stream sections have been channelized, part of the problem may be due to a sparsity or lack of appropriate substrates for the establishment of healthy stream bottom communities.

- Diatom and leaf litter sampling are new additions to this project and need to be evaluated for their effectiveness in assessing stream health, nutrient cycling, and potential for mercury uptake.
- Variability in the data may result from a multitude of factors. Part of this variability is due to the natural year-to-year fluctuations in benthic communities (flow rates, heat waves, storm events… etc.). Another part of this variability is due to variation among samplers. Because of these sources of variability, data recorded from benthic community monitoring benefits from long term sampling and sampling with different experienced personnel.
- Changing habitat due to severe weather events, such as flooding, or beaver activity may influence our sampling behavior. For example, the Bear Creek Kilometer 9.6 sampling site has recently been washed out from flash flood activity and is now backed up with a beaver dam. The once fast-moving shallow section of the stream is now a deep, slow moving pool. The sampling location may need to be shifted.

3.2.4 Goals

- The primary goal of the Benthic Community Monitoring project is to monitor the current condition of benthic communities at stream sites on the Oak Ridge Reservation.
- Ten years of historical data from these streams will be compared to interpret whether these sites have improved, further degraded or remained the same since remedial activities began on the ORR.
- TDEC-DoR-OR intends to provide data for comparison with other ongoing DOE studies of benthic communities. As indicated above, there is a normal year-to-year variation in benthic communities, as well as sampling and analysis induced variation. A comparison of data from different sources may help clarify the current conditions at the ORR stream sites.
- It is imperative that TDEC DoR-OR better understand what is causing impacts in benthic communities on the ORR. At sites where pollution tolerant organisms predominate, the problems could be due to organic loading of the streams by point and/or non-point sources. At sites where mayfly populations are absent or extremely limited, metals toxicity problems of a chronic or acute nature may be responsible. At sites where benthic community densities (i.e., organisms/m^2) are very low, acute and/or episodic toxicity problems (e.g., chlorine or biocides) could be responsible for the low numbers.

- TDEC DoR-OR will provide recommendations for remedial efforts that may help improve the health of streams on and offsite the ORR where primary impacts are due to DOE ORR past and current operations. These recommendations may include upgrading stream areas where banks need stabilization, and where suitable substrate is unavailable, and identifying data that may provide clarity to existing problems.
- Additionally, TDEC DoR-OR will attempt to elucidate impacts from other sources than the ORR facilities which may be having effects on streams that flow both on and off the ORR (e.g., Mitchell Branch, East Fork Poplar Creek, and Bear Creek).

3.2.5 Scope

The physical boundaries of the Benthic Community Monitoring Project include streams located in the primary ORR watersheds. At the Oak Ridge National Laboratory (ORNL) these streams include White Oak Creek from its headwaters to near its confluence with White Oak Lake and Melton Branch. At Y-12, these streams include East Fork Poplar Creek from its headwaters to approximate kilometer 6.3; and Bear Creek from its headwaters to its confluence with East Fork Poplar Creek. At East Tennessee Technology park (ETTP), these streams include Mitchell Branch from its headwaters to near the confluence with Poplar Creek. The offsite reference streams are Mill Branch, Hinds Creek, Clear Creek, and Gum Hollow Creek.

The Benthic Community Monitoring Project will include two one-meter-squared kick netted composite macroinvertebrate samples for twenty-two study sites. Diatoms will be collected from ten study sites. Three leaf litter bags will be deployed at each of ten study sites.

Macroinvertebrates:

Macroinvertebrates will be sampled in May from the sites listed in Table 3.2.1.

Table 3.2.1

Benthic Macroinvertebrate Sampling			
Site Description	**name**	**lat**	**long**
Bear Creek Kilometer 3.3	BCK 3.3	35.94354	-84.34911
Bear Creek Kilometer 9.6	BCK 9.6	35.96032	-84.29741
Bear Creek Kilometer 12.3	BCK 12.3	35.97300	-84.27814
East Fork Poplar Creek Kilometer 6.3	EFK 6.3	35.96293	-84.35905
East Fork Poplar Creek Kilometer 13.8	EFK 13.8	35.99283	-84.31371
East Fork Poplar Creek Kilometer 23.4	EFK 23.4	35.99596	-84.24004
East Fork Poplar Creek Kilometer 24.4	EFK 24.4	35.98922	-84.24282
East Fork Poplar Creek Kilometer 25.1	EFK 25.1	35.98456	-84.25510
Gum Hollow Creek kilometer 2.9	GHK 2.9	35.96419	-84.31573
Hinds Creek Kilometer 20.6	HCK 20.6	36.15797	-83.99944
Mitchel Branch Kilometer 0.45	MIK 0.45	35.93783	-84.38951
Mitchel Branch Kilometer 0.71	MIK 0.71	35.93782	-84.38650
Mitchel Branch Kilometer 1.43	MIK 1.43	35.93784	-84.37747
Melton Branch Kilometer 0.3	MEK 0.3	35.91123	-84.31423
White Oak Creek Kilometer 2.3	WCK 2.3	35.90834	-84.31856
White Oak Creek Kilometer 3.4	WCK 3.4	35.91778	-84.31612
White Oak Creek Kilometer 3.9	WCK 3.9	35.92431	-84.31583
White Oak Creek Kilometer 6.8	WCK 6.8	35.94151	-84.30161
Mill Branch Kilometer 1.6	MBK 1.6	35.98886	-84.28935

Leaf Litter:

Three Leaf litter bags will be deployed at ten sites in conjunction with macroinvertebrate sampling (see Table 3.2.2). The bags will be retrieved after thirty, sixty, and ninety (plus or minus two days) after deployment.

Table 3.2.2

Leaf Litter Sampling			
Site Description	**name**	**lat**	**long**
Bear Creek Kilometer 3.3	BCK 3.3	35.94354	-84.34911
Bear Creek Kilometer 12.3	BCK 12.3	35.97300	-84.27814
East Fork Poplar Creek Kilometer 6.3	EFK 6.3	35.96293	-84.35905
East Fork Poplar Creek Kilometer 23.4	EFK 23.4	35.99596	-84.24004
Mitchel Branch Kilometer 0.45	MIK 0.45	35.93783	-84.38951
Mitchel Branch Kilometer 1.43	MIK 1.43	35.93784	-84.37747
White Oak Creek Kilometer 2.3	WCK 2.3	35.90834	-84.31856
White Oak Creek Kilometer 3.9	WCK 3.9	35.92431	-84.31583
White Oak Creek Kilometer 6.8	WCK 6.8	35.94151	-84.30161
Mill Branch Kilometer 1.6	MBK 1.6	35.98886	-84.28935

Diatoms:

Diatoms will be collected from ten sites in conjunction with macroinvertebrate sampling (see Table 3.2.3).

Table 3.2.3

Diatom Sampling			
Site Description	**name**	**lat**	**long**
Bear Creek Kilometer 3.3	BCK 3.3	35.94354	-84.34911
Bear Creek Kilometer 12.3	BCK 12.3	35.97300	-84.27814
East Fork Poplar Creek Kilometer 6.3	EFK 6.3	35.96293	-84.35905
East Fork Poplar Creek Kilometer 23.4	EFK 23.4	35.99596	-84.24004
Mitchel Branch Kilometer 0.45	MIK 0.45	35.93783	-84.38951
Mitchel Branch Kilometer 1.43	MIK 1.43	35.93784	-84.37747
White Oak Creek Kilometer 2.3	WCK 2.3	35.90834	-84.31856
White Oak Creek Kilometer 3.9	WCK 3.9	35.92431	-84.31583
White Oak Creek Kilometer 6.8	WCK 6.8	35.94151	-84.30161
Mill Branch Kilometer 1.6	MBK 1.6	35.98886	-84.28935

3.2.6 Assumptions

- Adequate funding will be available for laboratory analysis of diatom communities.
- Weather will allow for timely collection of macroinvertebrate, diatom and leaf litter samples.
- Any deployed equipment will not be lost or damaged.
- TDEC DoR-OR personnel will be adequately trained and physically able to conduct the Benthic Community Health Project.
- Chain of custody protocol will be followed.
- Adequate field time will be available to conduct the Benthic Community Health Project.

3.2.7 Constraints

- Inadequate funding may prevent diatom community sampling.
- Inadequate field time due to weather may delay the collection of samples.
- Inadequate laboratory time may delay results collected.

3.2.8 Methods, Materials, Metrics

Macroinvertebrates:

Macroinvertebrates will be collected at nineteen sites on the Oak Ridge Reservation and corresponding reference locations (Table 3.2.1). Duplicate samples will be collected at two of the sites to ensure consistent laboratory analysis.

The standard operating procedure for macroinvertebrate sampling is detailed in document SOP: DoR-OR-T-260 (TDEC 2019).

Leaf Litter:

Leaf litter bags will be deployed in conjunction with macroinvertebrate collection by anchoring three packs to the stream bed with a stake or rebar. The leaf litter bags will be deployed at ten locations (Table 3.2.2). The bags will be collected after thirty, sixty, and ninety days (plus or minus two days).

Samples will be collected using the standard operating procedure outlined in *Methods to Study Leaf Litter Decomposition: A Practical Guide (Graça, 2005).*

Diatoms:

Diatoms will be collected in conjunction with macroinvertebrate collection (May – June) by gently removing the periphyton layer from benthic substrates with a toothbrush. Diatom samples will be collected from ten sites on the Oak Ridge Reservation (Table 3.2.3).

Samples will be collected using the standard operating procedure outlined in the TDEC Division of Water Pollution Control *QSSOP for Periphyton Stream Surveys* (TDEC 2010). Diatom samples will be sent to TDH lab for processing.

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3.3 ORR ROVING CREEL SURVEY

3.3.1 Background

The Roving Creel Survey is a new project that measures angling effort at three key locations where impaired Oak Ridge Reservation (ORR) watersheds drain into publicly accessible waters. Fisherman interviews will be conducted at the confluence of Bear Creek and Poplar Creek, the confluence of Poplar Creek and the Clinch River, and the confluence of White Oak Lake and the Clinch River. These streams have been negatively impacted by Manhattan Project activities as well as current operational activities. Fish consumption is a likely human exposure pathway for contamination uptake.

Bear Creek (BC) and East Fork Poplar Creek (EFPC) originate within the confines of the Y-12 Nuclear Industrial Complex (Y-12) and are fed by springs and numerous outfalls from various plant facilities. During the 1950's and early 1960's, processes and practices of the ORR nuclear weapons program at Y-12 led to the release of large amounts of mercury and other contaminants to the local environment (Brooks et al., 2017). Mercury and other contaminants such as radionuclides were released in a wide range of concentrations to surface waters, sediments, and floodplain soils (Pant et al. 2010).

White Oak Creek (WOC) originates just north of the Oak Ridge National Laboratory (ORNL). Radionuclides released from ORNL to WOC are leaked from ponds and waste disposal areas and include contaminants such as Sr-90 and Cs-137, as well as other byproducts from nuclear and industrial activities (DOE, 1988). These contaminants are significant because of their radiotoxicity, their mobility in the environment, and the quantities released. Other radionuclides of significance include tritium and transuranics (DOE, 1988). The availability of Cs-137 for biological uptake is a major public health concern as it can be transferred to humans through food webs (Ashraf et al., 2014). Even in the most mobile aquatic habitats (i.e., flowing rivers), Cs-137 may persist in a biologically available form for several years after release (Ashraf et al., 2014).

Mercury in streams and wetlands often undergoes methylation and is transformed into toxic methylmercury (MeHg) in conjunction with the activity of microorganisms (Kalisinska et al., 2013). Methylmercury is particularly bioavailable to wildlife and humans and, if ingested, may cause serious neurological, reproductive, and other physical damage (Standish, 2016). Fish are especially vulnerable to mercury bioaccumulation due to their habitat and diet.

Fish tissue samples will be collected from a target species on a quarterly basis. The 2018 annual TWRA Fisheries Report suggests that white bass (*Morone chryops*) and white crappie (*Pomoxis annualris*) are the most commonly harvested fish from the Melton Hill Reservoir (TWRA, 2017). These target species are identified because Melton Hill Reservoir is the closest reservoir to the sites selected for this study.

3.3.2 Related DOE Projects

Currently, there have been no DOE investigations to ascertain the level of human exposure through angling efforts on the ORR.

3.3.3 Problem Statements

- Fish bioaccumulate mercury and other contaminants produced on the ORR.
- Frequently, fish consumption warnings are not visible, missing, or disregarded by the public.
- There are no data to assess the extent of human interface with fish taken from exit water pathways on the ORR.

- There are no data to assess the amount of bioaccumulation in fish at these key confluence locations.

3.3.4 Goals

- To measure the angling effort at key locations on the ORR where potential human exposure to mercury and other contaminants may exist.
- To measure the bioaccumulation of mercury and other contaminants in fish tissue at key locations surrounding the ORR.
- To link data from the roving creel survey to efficacy of signage and other risk notifications in areas on and/or near the reservation subject to contamination from ORR activities and that are used for recreational purposes by the public.

3.3.5 Scope

This project will be limited to three locations, the confluence of Bear Creek and Poplar Creek, the confluence of Poplar Creek and the Clinch River, and the confluence of White Oak Lake and the Clinch River. There will be 20 sampling events, spread out over a year (5 per quarter). Specific sampling event dates will be selected using non-uniform probability based on the guidelines from Pfeiffer (1966). TDEC DoR-OR personnel will be assisted by TWRA personnel.

3.3.6 Assumptions

- Anglers will be present and willing to participate in the survey.
- Some participants will allow TDEC personnel to take a core tissue sample from their catch.
- Adequate funding will exist for laboratory analysis of Hg, MeHg, and radiological samples.
- Adequate field time will be available to carry out the mission.
- Equipment will be available and properly functioning.
- Additional TDEC DoR-OR personnel will have the appropriate training and safety qualifications to conduct the survey.

3.3.7 Constraints

- Time, equipment, and personnel may be limited.
- The weather on pre-selected sampling dates will be safe

3.3.8 Methods, Materials, Metrics

TDEC and TWRA personnel will conduct surveys at three locations with active, on-site methods whereby anglers are interviewed either during, or immediately following fishing trips. Fishery-dependent information collected will include angler effort, trip duration, target preferences, catch, harvest, and release. All waterbodies will be sampled using roving creel survey methods as outlined in the TWRA 2007 Fisheries Report.

The roving survey method uses non-uniform probability and stratified random sampling to maximize sampling efficiency and minimize bias. The fishing day is defined as the period of time from sunrise to sunset. Random sampling schedules will be created prior to the beginning of the survey year.

A roving creel survey sample consists of two parts, angler counts and interviews. The angler counts and interviews will be conducted concurrently by making a single circuit of the lake section within a ½-day sampling period using the count-as-you-go method. All anglers fishing from either boats or from the shore will be counted.

TDEC and TWRA personnel will interview as many anglers as possible during a sample period. If there are more anglers than can be interviewed, then angling parties will be systematically skipped to ensure interviews are conducted throughout the entire section in the allotted time.

Upon approaching anglers, TDEC and TWRA personnel will record information, which does not require interrupting fishing, including date, reservoir, sample area, fishing from the bank or a boat, and the number of anglers in the fishing party. When the team reaches the angler or angling group, they will ask if they would mind spending a few moments answering questions related to their fishing trip. If anglers do not wish to be interrupted, then the creel clerks will move on.

If anglers do not mind being interviewed, then the team will conduct the interview using preprinted forms (Attachment 1). The team will count all fish harvested and record the bulk weight of each harvested species. Anglers will also be asked how many of each species have been released. A fish tissue sample may be collected on a voluntary basis.

Angling Effort:

Estimates of angling effort are calculated using daily angler counts and the number of hours within a sample period. Thus, for any given sampling period, angling effort, measured in angler-hours (*e*), is calculated as the product of the total angler count (*c*) and the number of hours assigned to the sampling period (*h*), or $e = c(h)$. This value estimates total angler-hours for a single lake section within a single time period, which must be expanded to an estimate of angler-hours for the entire lake for the whole day. This expansion is accomplished by dividing *e* by the probability for the secondary sampling unit (time period/lake section) worked that day. For example, if the time period probability was 0.5 and the lake section probability was 0.4, then the secondary sampling unit probability is 0.5 x 0.4, or 0.20, so an estimate of e=100 angler-hours for a given secondary unit would be expanded to 100/0.2 or 100 x 5 = 500 angler-hours for the whole waterbody for that entire day (*E*).

To derive estimates of total quarterly angling effort, means will be taken across the daily values of *E* within each day-type stratum each month. These two daily mean values of angling effort, one for weekends and one for weekdays, will be weighted by the proportional number of those day

types within each month (e.g. weekend weight = no. weekend-days/total days in month), and then summed to provide a mean daily estimate of fishing effort for the quarter. This mean daily value will then be multiplied by the total number of days in the quarter to give total quarterly effort for the entire site (*T*). Intended monthly fishing effort for a given species, or species group, is computed as the proportion of interviewed anglers fishing for that group times total quarterly fishing effort. So, for example, if 25% of the anglers interviewed were fishing for black bass, the monthly-intended fishing effort for black bass would be 0.25(*T*).

Catch Rates (CPE, HPE and RPE):

Catch-per-unit-effort or CPE = the number of fish caught per hour, which includes fish harvested plus fish released back into the water. For roving creel surveys, CPE values are based on the number of fish caught by anglers at the time of interview for uncompleted fishing trips.

For each interview on a given sample day, the total number of fish caught by all anglers in the fishing party (*n*) will be divided by the total time all anglers in the party spend fishing (*f*) up to the point they are interviewed. These individual party CPE values (*n/f*) will then be averaged to provide a daily CPE. A mean will be taken across the daily CPE values within each day-type stratum, and then these weekday and weekend means will be weighted and summed (as described for daily fishing effort above) to give a mean daily CPE for the time block. This mean daily value is representative of the time block as a whole and becomes the monthly or quarterly CPE estimate for all species combined.

3.3.9 References

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4.0 AIR MONITORING

4.1 FUGITIVE RADIOLOGICAL AIR EMISSIONS

4.1.1 Background

ETTP, originally known as the K-25 site, began operations during World War II as part of the Manhattan Project. The site's original mission was producing uranium enriched in the uranium-235 isotope (U-235). This was used for manufacturing the first atomic weapons and later for fueling commercial and government-owned reactors. The enrichment plant was permanently shut down in 1987.

Due to the original operational practices as well as accidental releases, many of the facilities at ETTP are contaminated to some degree and are scheduled for or have already undergone decontamination and decommissioning (D&D). Uranium isotopes are the primary contaminants, but technetium-99 and other fission and activation products are also present due to the periodic processing of recycled uranium obtained from spent nuclear fuel and daughter products due to natural decay of radioactive isotopes.

Y-12 was constructed during World War II for enriching uranium in U-235 by using the electromagnetic-separation process. Later, the Y-12 mission was expanded, and they began producing fuel for naval reactors, conducting lithium and mercury enrichment operations, manufacturing components for nuclear weapons, dismantling nuclear weapons, and storing enriched uranium. The Environmental Management Waste Management Facility (EMWMF) was constructed in Bear Creek Valley near the Y-12 plant for disposing of low-level, radioactive, and hazardous wastes generated by remedial activities on the ORR.

Construction of ORNL began in 1943. While the initial missions of K-25 and Y-12 were producing enriched uranium, ORNL focused on researching reactors and producing plutonium and other activation and fission products chemically extracted from uranium irradiated in ORNL's graphite reactor and later irradiated at other ORNL and Hanford reactors.

During early operations, leaks and spills within the facilities were common, and radioactive materials were released from operations as gaseous, liquid, and solid effluents with little or no treatment.

4.1.2 Related DOE Projects

DOE also conducts high volume air sampling on and around the ORR, though most of the DOE ORR program monitors the perimeter of the site. The results from this sampling are used in calculating the dose exposure for those most at risk off site. The Fugitive Air Monitoring Project sampling data can be compared to DOE results.

4.1.3 Problem Statements

Many ETTP, Y-12, and ORNL facilities scheduled for decontamination and demolition (D&D) are radiologically contaminated. D&D operations at these facilities, as well as the disposal of the waste at EMWMF from these facilities, can result in fugitive (non-point source) dispersal of contaminants. This dispersion is promoted by winds that tend to blow up the valleys (northeast) during the daytime and down the valleys (southwest) during the night. At Y-12, facilities contaminated with various uranium isotopes are scheduled for D&D. Many facilities at ORNL are contaminated with a long list of fission and activation products in addition to uranium and plutonium isotopes. Some facilities at ORNL are considered to be the highest risk facilities on the ORR due to their physical deterioration and because they exhibit the presence of loose contamination. The risk associated with these facilities is heightened by their proximity to pedestrian and vehicular traffic, privately funded facilities, and active ORNL facilities.

4.1.4 Goals

To protect human health and the environment, TDEC DoR-OR will conduct independent air sampling, compare the results with the air sampling data published by DOE, and evaluate DOE's compliance with the Code of Federal Regulations regulatory standards to ensure DOE's radiological emissions would not cause a member of the public to receive an effective dose greater than ten mrem per year, specifically where remedial action or waste management activities are being accomplished.

4.1.5 Scope

The TDEC DoR-OR will conduct the Fugitive Radiological Air Emissions Monitoring Project by continuous air monitoring at each of the ORR sites (K-25, Y-12, ORNL) and a background location

with a total of eight high volume air samplers (see Figure 4.1.1).

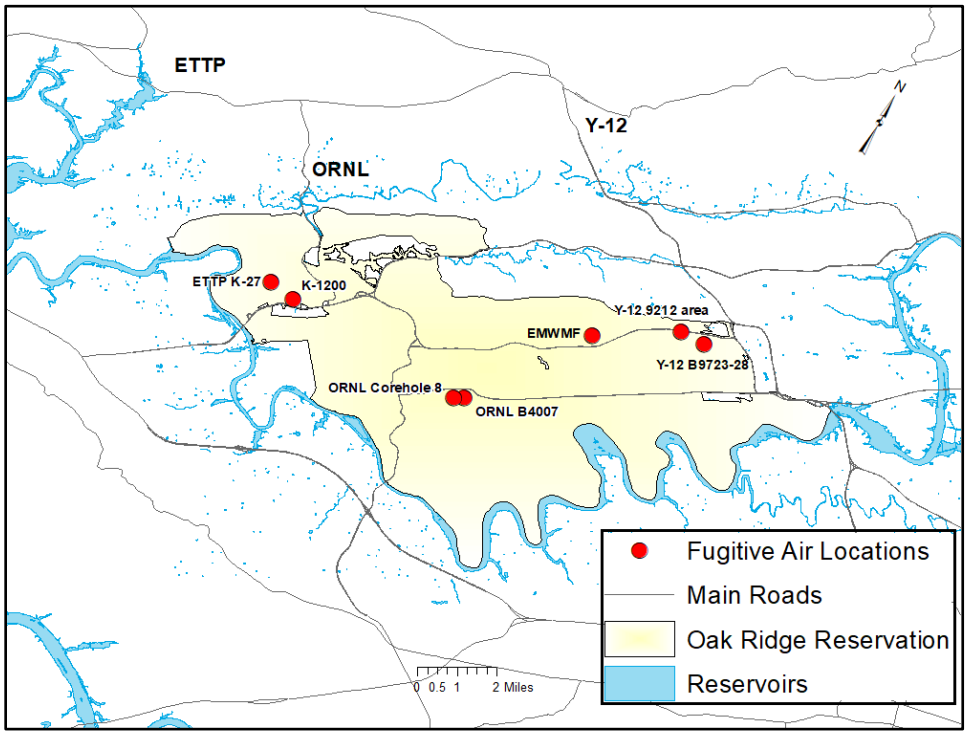

Figure 4.1.1: Fugitive Air Sampling Locations

4.1.6 Assumptions

- Adequate budget will exist to support the methods and materials described for this project.
- Adequate staff will be available to assist with field duties.
- Air sampler locations will have access to electricity.
- Access to desirable air sampler locations will not be restricted due to site operations or security.

4.1.7 Constraints

- It will not be possible to collect and measure all fugitive emissions from any area.
- The 120-volt electrical power, required to operate an air sampler, is not always available at a desired sampling location.
- Sampler locations and their access could be restricted due to site operational or security concerns.

Within these limitations, air sampler locations will be selected to maximize the likelihood of collecting representative samples from potential sources of airborne contamination.

4.1.8 Methods, Materials, Metrics

The Fugitive Air monitoring project will use eight high volume air samplers to conduct continuous air monitoring on and near the ORR. One sampler will be stationed at Fort Loudoun Dam in Loudon County to collect background data for comparison while the remaining samplers will be placed at ORR locations where the potential for release of fugitive airborne emissions is the greatest. For example, such locations where contaminated soils are being excavated, contaminated facilities are being demolished, and wastes are being disposed. Each of the high-volume air samplers use 8 x 10-inch glass-fiber filters to collect particulates from air as it drawn through the unit at a rate of approximately 35 ft^3 per minute. To ensure accuracy, airflow through each air sampler will be calibrated quarterly, using a Graseby General Metal Works variable resistance calibration kit, in accordance with the guidelines published for the air samplers.

Samples will be collected from each air sampler weekly, composited every four (4) weeks, and analyzed by Tennessee Department of Health Nashville Environmental Lab. The analysis preformed will be based on contaminants of concern and previous findings for the location being monitored.

To assess contaminant concentrations measured at each location, results will be compared with the background data and the standards provided in Title 40 of the Code of Federal Regulations Part 61 (40CFR61), NESHAPS, Subpart H (National Emission Standards for Emissions of Radionuclides other than Radon from DOE Facilities) which limits DOE radiological emissions to quantities that would not cause a member of the public to receive an effective dose equivalent greater than 10 millirem (mrem) in a year. Associated findings will be reported to DOE, its contractors, and the public in the annual TDEC DoR-OR *Environmental Monitoring Report.*

4.1.9 References

Title 40 of the Code of Federal Regulations Part 61 (40CFR61), NESHAPS, Subpart H

4.2 RADNET AIR

4.2.1 Background

Currently, air pollutants resulting from U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR) activities (e.g., the production of radioisotopes, and the demolition of radioactively contaminated facilities) could pose a risk to public health and/or the surrounding environment. While the average adult ingests less than two liters of water a day, they inhale about 16,000 liters of air a day, so the air we breathe is very important to human health. Consequently, TDEC DoR-OR has implemented air monitoring programs to assess the impact of ORR air emissions to the surrounding environment and the effectiveness of DOE controls and monitoring systems. The TDEC DoR-OR RadNet Air Monitoring Project provides additional monitoring and independent

third-party analytical analysis by the EPA.

The TDEC RadNet Air Monitoring Project on the ORR began in August of 1996. It provides twice weekly radiochemical analysis of air samples taken from five air monitoring stations on the ORR for a total of up to 520 samples each year. RadNet samples are collected by TDEC and analysis is performed at the EPA National Air and Radiation Environmental Laboratory (NAREL).

4.2.2 Related DOE Projects

The sampling for the TDEC RadNet Air Monitoring Project does not correlate directly to DOE's ORR air sampling program.

- The RadNet Air Monitoring Project uses gross beta analysis as a screening tool. Gross beta analysis as a screening tool works because few isotopes of interest are pure gamma or pure beta emitters, so if there were a release on the ORR, most likely there would also be some beta radiation emitted either directly or from daughter products. If the beta concentration is greater than 1 pCi/m^3 EPA RadNet screening level, gamma spectroscopy and possibly other analyses are performed by the EPA. If gross beta levels were elevated but less than the 1 pCi/m^3 screening level, these levels will be detected and seen in the results.
- RadNet Air samples from five locations on the ORR are collected usually twice a week which is more frequent than the quarterly composite analysis run by DOE, though the sampling by DOE varies by ORR site, according to the DOE Annual Site Environmental Report (ASER).

4.2.3 Problem Statements

The three sites on the ORR, ORNL, Y-12, and ETTP can potentially release radioactive contaminants into the air from current operations as well as from the deterioration of contaminated buildings on the sites and the Deactivation and Decommissioning (D&D) of these facilities.

4.2.4 Goals

The goals for this project are as follows:

- Protect the human health and the environment by assuring the public that the State of Tennessee independently evaluates gross beta activity in air on the ORR with the continuous monitoring of five RadNet Air monitoring stations, with about 520 total samples analyzed.
- Determine that levels of gross beta radioactivity are not above EPA regulatory levels for a beta emitter with stringent criteria, and preferably below EPA screening levels requiring additional analysis.

- Compare gross beta levels collected from the five ORR RadNet Air monitoring stations to the levels seen at the RadNet station in Knoxville, which is used as a background location.
- Complement the TDEC Fugitive Radiological Air Emissions Project with the following actions, provide gross beta analysis and additional analysis if EPA screening levels are triggered, provide additional air monitors for greater coverage of the ORR, and provide more frequent analysis; specifically, twice weekly instead of weekly sampling with 4- or 6-week composite analysis. DOE ORR and site-specific air sample analysis is done less frequently with quarterly composites of weekly samples.

4.2.5 Scope

Five high-volume air samplers will be used to monitor the air for radiological contamination in the RadNet Air Monitoring Program. Two of the samplers will be located at Y-12, with one near each end of the plant. One unit will be located at ETTP near Blair Road. Two samplers will be located at ORNL, with one in Bethel Valley and one in Melton Valley. An additional air sampler is located and operated by the TDEC field office in Knoxville, which will be used for background comparison. The five RadNet Air samplers on the ORR will be sampled Mondays and Thursdays except when a sample is skipped due to a holiday.

4.2.6 Assumptions

- Air from various locations on the ORR can be monitored with a particulate air sampler
- Beta analysis of air filters will identify most releases of radiological contaminants; these results may trigger further analysis
- Natural variations in gross beta levels will be similar at all ORR sites
- Small variations due to weather and other factors will be seen at all stations at ambient conditions
- Each sampler will remain operational with consistent power supply and site access

4.2.7 Constraints

- It is not possible to collect and measure all air emissions from each of the ORR sites with the five RadNet air samplers
- The power needed to run the air samplers occasionally goes down
- Sampler motors and sampler electronics can fail
- Sampler locations and access can be restricted due to site operational or security concerns
- The EPA RadNet Air Program provides for specific analysis and no other analyses are available through this program

4.2.8 Methods, Materials, Metrics

The locations of the five RadNet Air samplers are provided in Figure 4.2.1 and EPA's analytical parameters and sampling frequencies are listed in Table 4.2.1. The RadNet Air samplers run continuously where suspended particulates are collected on synthetic fiber filters (10 centimeters in diameter) as air is drawn through the units by a pump at approximately 35 cubic feet per minute. TDEC DoR-OR collects the filters twice weekly from each sampler. Following EPA protocol (EPA 1988, EPA 2006) the filters are then shipped to NAREL in Montgomery, Alabama, for analysis.

NAREL performs gross beta analysis on each sample collected. If the gross beta result for a sample exceeds one picocurie per cubic meter (pCi/ m^3), then gamma spectrometry is performed on the sample. Gamma analysis is performed on the annual composite samples for each station. Every four years, a composite of the air filters collected from each monitoring station during the year is analyzed for uranium and plutonium isotopes. The results of NAREL's analyses of the nationwide RadNet Air data are available at NAREL's website in the Envirofacts RadNet searchable database, via either a simple or a customized search (EPA 2020).

The gross beta data from the RadNet Air Monitoring Project will be compared to background data from the RadNet Air monitor in Knoxville, Tennessee, and to the EPA Clean Air Act environmental limit for strontium-90, which is a pure beta emitter with a conservative limit (EPA 2010a, EPA 2010b).

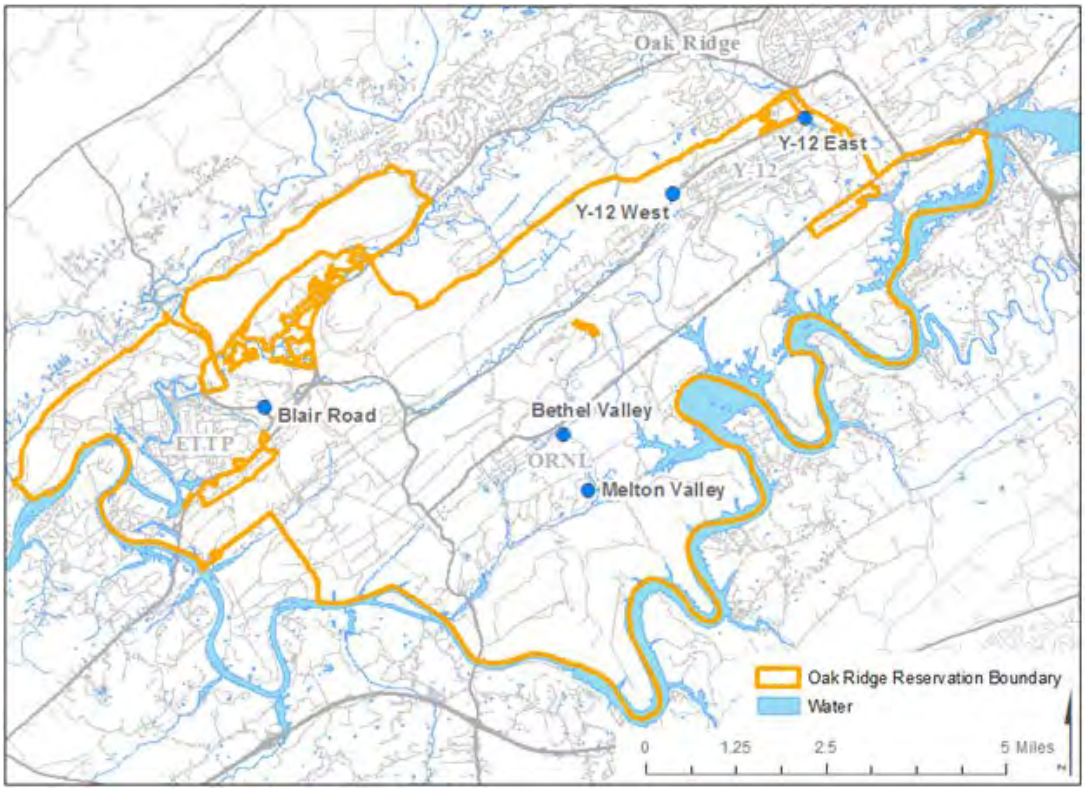

Figure 4.2.1: Locations of RadNet Air monitoring stations on the Oak Ridge Reservation

Table 4.2.1: RadNet Air monitoring analyses and frequencies

ANALYSIS	FREQUENCY
Gross Beta	Each sample, twice weekly
Gamma Scan	As needed on samples showing greater than 1 pCi/m^3 of gross beta and annually on a composite of each site's samples.
•Plutonium-238, Plutonium-239, Plutonium-240 •Uranium-234, Uranium-235, Uranium-238	Every four years on an annual composite from each station (started in 2014, previously done annually)

4.2.9 References

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Envirofacts RadNet Searchable Database:
search https://enviro.epa.gov/enviro/erams_query_v2.simple_query
customized search https://www.epa.gov/enviro/radnet-customized-search

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4.3 RadNet Precipitation

4.3.1 Background

Nationwide, the RadNet Precipitation Monitoring Project measures radioactive contaminants that are removed from the atmosphere and transported to the earth's surface by precipitation. On the Oak Ridge Reservation (ORR), the RadNet Precipitation Monitoring Project provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations, one at each of the ORR sites, ORNL, Y-12, and ETTP. Samples are collected by Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge (TDEC DoR-OR) personnel and gamma analysis is performed on monthly composite samples at EPA's National Air and Radiation Environmental Laboratory (NAREL). The gamma analysis functions as a screening tool because few isotopes of interest are pure beta or pure gamma emitters, so if there were a release on the ORR, most likely there would also be some gamma radiation emitted either directly or from daughter products. Additional analysis may be conducted if a radiological release is known or is indicated by monthly gamma analysis results. For instance, with the Fukushima release in Japan in 2011, additional analyses were completed more frequently as there was a known release of radioactive materials. Interestingly, TDEC DoR-OR sampling was able to detect elevated levels of radioactive iodine (I-131) at levels greater than EPA drinking water limits, despite the distance from the initial release. While there are no regulatory standards that apply directly to contaminants in precipitation, the data from this project provides an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by the TDEC DoR-OR air monitors.

4.3.2 Related DOE Projects

The sampling for this project does not correlate directly to DOE's air sampling program described in the DOE EMP. This project uses precipitation to monitor radioactivity in air and uses gamma analysis as a screening tool where extra analysis may be conducted if elevated gamma levels are observed.

4.3.3 Problem Statements

The three sites on the ORR (ORNL, Y-12, and ETTP) can potentially release radioactive

contaminants into the air from current operations as well as from the deterioration of contaminated buildings and the decontamination and decommissioning (D&D) of these facilities.

This project measures radioactive contaminants that are removed from the atmosphere and are transported to earth's surface by precipitation. The results of the analysis provide an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by air monitors.

4.3.4 Goals

The goal of the RadNet Precipitation Monitoring Project is to measure radioactive contaminants that are washed out of the atmosphere and reach the earth's surface through precipitation. It compares sampling results to drinking water limits used by EPA, as conservative reference values, to assure the public that human health and the environment are being protected. The results from the project can also be used to identify anomalies in radiological contaminant levels, to assess the significance of precipitation in contaminant pathways, to evaluate associated control measures, to appraise conditions on the ORR compared to other locations in the nationwide EPA RadNet Program, and to determine levels of local contamination in the case of a local or distant nuclear disaster.

4.3.5 Scope

Three precipitation samplers will be used to monitor the precipitation for radiological contamination. Each sampler is co-located at RadNet Air stations at each of the three ORR sites. One sampler is located at the east end of the Y-12 plant and could potentially provide an indication of any gamma radioisotopes moving towards the City of Oak Ridge from ORNL or Y-12. One unit is at ETTP, near Blair Road, and monitors contaminants from demolition activities at ETTP. The third sampler is located at ORNL in Melton Valley near ORNL's High Flux Isotope Reactor (HFIR) and the Solid Waste Storage Area (SWSA) 5 burial grounds.

The three RadNet Precipitation samplers on the ORR will be sampled Mondays and Thursdays, except when a sample is skipped due to a holiday. The samples will be composited monthly by the EPA NAREL and analyzed for gamma emitting radionuclides. Additional analysis on individual samples would likely be run in the event of a large radioactive release.

4.3.6 Assumptions

- Gamma analysis of monthly composite precipitation samples will indicate most releases of radiological contaminants; however, further analysis may be warranted.
- Anomalies in radiological contaminant levels can be detected.
- Natural variations in gamma levels will be similar at all ORR sites.
- Sampling equipment will remain in good condition and the sampler will remain

accessible.

4.3.7 Constraints

- This project only detects potential radiological emissions when there is a precipitation event that the plume passes through.
- Monthly composite analysis could potentially miss smaller releases. However, if a radiological release is known to have occurred, EPA will generally analyze each sample rather than a composite and will often expand the analyte list.
- Sampling equipment can fail over time.
- Sampler locations and access can be restricted due to site operational or security concerns.
- The EPA RadNet Precipitation program provides for specific analysis and no other analyses are available through the program.

4.3.8 Methods, Materials, Metrics

The locations of the three RadNet Precipitation samplers are depicted in Figure 4.3.1. The precipitation samplers provided by EPA's RadNet program are used to collect samples for the TDEC DoR-OR ORR RadNet Precipitation Project. Each sampler drains precipitation that falls on a 0.5 square meter fiberglass collector into a five-gallon plastic collection bucket. A sample is measured and then collected from the bucket in a four-liter Cubitainer®. When a minimum of two liters of precipitation has accumulated in the Cubitainer®, or potentially less than that if it is the final sample of the month, the sample is processed as specified by EPA (US EPA 1988, US EPA 2013) and is shipped to the EPA NAREL in Montgomery, Alabama, for analysis. NAREL composites monthly samples for each station and analyzes the samples for gamma emitting radionuclides.

Since there are no regulatory limits for radiological contaminants in precipitation, the results of the gamma analyses are compared to EPA drinking water limits as conservative reference values. EPA's Radionuclides Rule (U.S. EPA 2000) for drinking water allows gross alpha radioactivity levels of up to 15 picocuries per liter (pCi/L), while beta and photon emitters are limited to a dose of four millirem (mrem) per year and are radionuclide specific (U.S. EPA 2015). The results from the TDEC DoR-OR ORR sampling are compared to EPA's drinking water limits and can also be compared to data from other sites nationwide. Not all gamma isotopes have EPA drinking water limits, so only those that do and have been seen in RadNet Precipitation samples are used for comparison. While the stations located on the ORR are in areas near nuclear sources, most of the other stations in the RadNet Precipitation monitoring project are located near major population centers, with no major sources of radiological contaminants nearby. Table 4.3.1 shows the maximum contaminant levels (MCLs) of beta and photon emitters that EPA uses as drinking water limits for select isotopes.

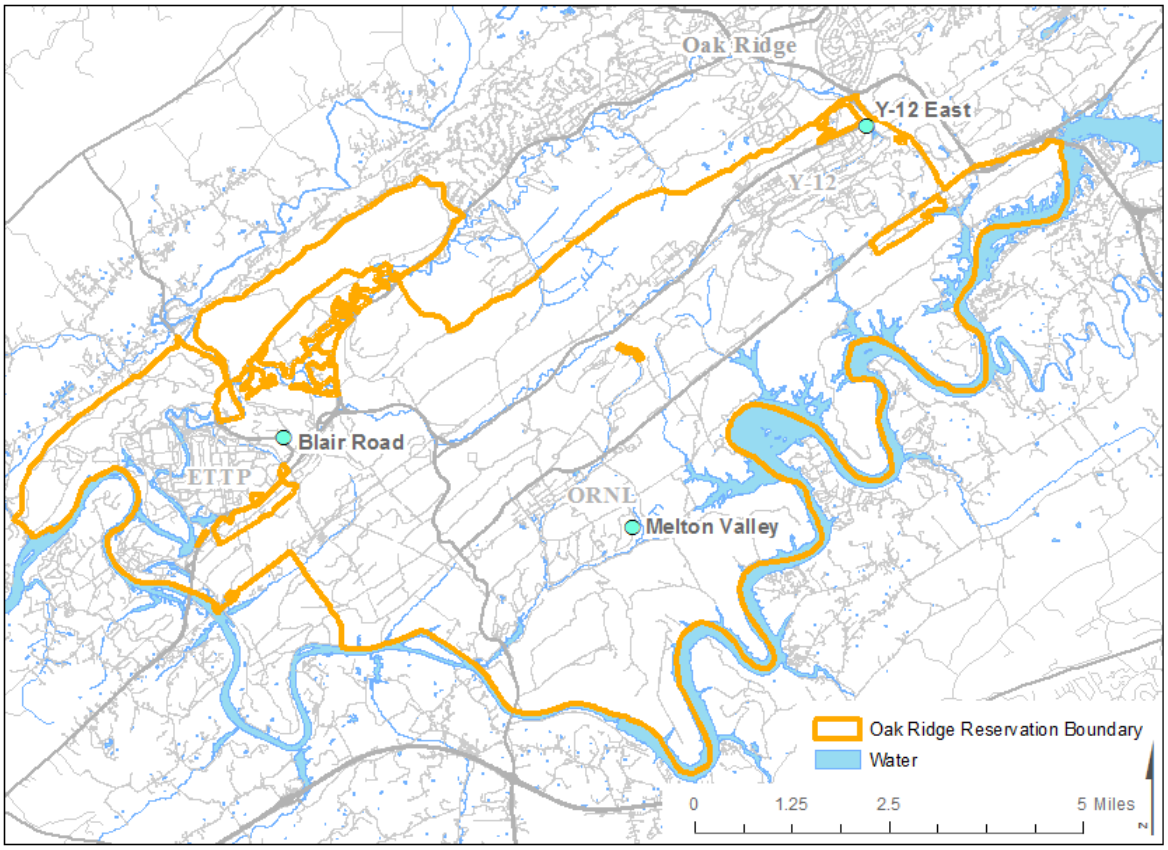

Figure 4.3.1: Locations of RadNet Precipitation monitoring stations on the ORR

The results of NAREL's analyses are available at the EPA Envirofacts RadNet searchable database, by either a simple or a customized search (U.S. EPA 2020). The data are used to identify anomalies in radiological contaminant levels, to assess the significance of precipitation in contaminant pathways, to evaluate associated control measures, to appraise conditions on the ORR compared to other locations in the RadNet project, and to determine levels of local contamination.

Table 4.3.1: EPA Drinking Water Limits (MCLs) for select isotopes

Isotope	EPA limit (pCi/L)
Barium-140 (Ba-140)	90
Beryllium-7 (Be-7)	6,000
Cobalt-60 (Co-60)	100
Cesium-134 (Cs-134)	80
Cesium-137 (Cs-137)	200
Tritium (H-3)	20,000
Iodine-131 (I-131)	3

4.3.9 References

EPA (1988). Environmental Radiation Ambient Monitoring System (ERAMS) Manual. EPA 520/5-84-007, 008, 009.

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Envirofacts RadNet Searchable Database:
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customized search https://www.epa.gov/enviro/radnet-customized-search

5.0 SURFACE WATER MONITORING

5.1 AMBIENT SURFACE WATER SAMPLING

5.1.1 Background

The ORR consists of three (3) site facilities including ORNL, Y-12, and ETTP. Activities at these facilities have resulted in the discharge of hazardous substances (e.g. metals, organics, and radioactive materials) leading to the contamination of waterbodies on the ORR and in the surrounding areas (DOE, 1992; DOE, 2018; Pickering, 1970; Turner & Southworth, 1999).

While legacy waste across the ORR may be responsible for a large portion of contamination to surface water, current projects and processes at these sites also have the potential to significantly contribute to surface water contamination. To help monitor potential contamination, an ambient surface water sampling project has been implemented each year since 1993. This monitoring project began by investigating the water quality of the Clinch River at five (5) locations near the ORR. The sampling locations for this project have been modified throughout the years, sometimes adding or discontinuing sampling at particular locations. Most recently, monitoring focused on five (5) primary ORR exit-pathway streams as well as the Clinch River. This project monitors surface water by sampling for contaminants in waterways that have been impacted by past and present activities on the ORR.

5.1.2 Related DOE Projects

DOE has implemented a surface water monitoring program for several years that consists of sample collection and analysis from a few locations along the Clinch River (DOE, 2017; DOE, 2019). Currently, DOE collects samples quarterly at four (4) sites along the Clinch River, at river kilometers 16, 32, 58, and 66 (Figure 5.1.1) (DOE, 2019). Of these sites, CRK 58 is near the water supply intake for Knox County, and CRK 66 is upstream of the Oak Ridge City water intake. Grab samples are collected at these four (4) sites and are analyzed for water quality parameters such as dissolved oxygen, pH, and water temperature. Samples are also screened for radioactivity by investigating gross alpha, gross beta, and gamma disintegrations. At three (3) of the four (4) sites, analyses are performed to investigate concentrations of mercury. However, mercury samples are not collected by DOE from the Knox County water supply site (CRK 58). Strontium-90 is analyzed at three (3) of the sites: at the confluence of the WOC and Clinch River near ORNL, upstream of the Oak Ridge City water intake, and downstream of the ORR.

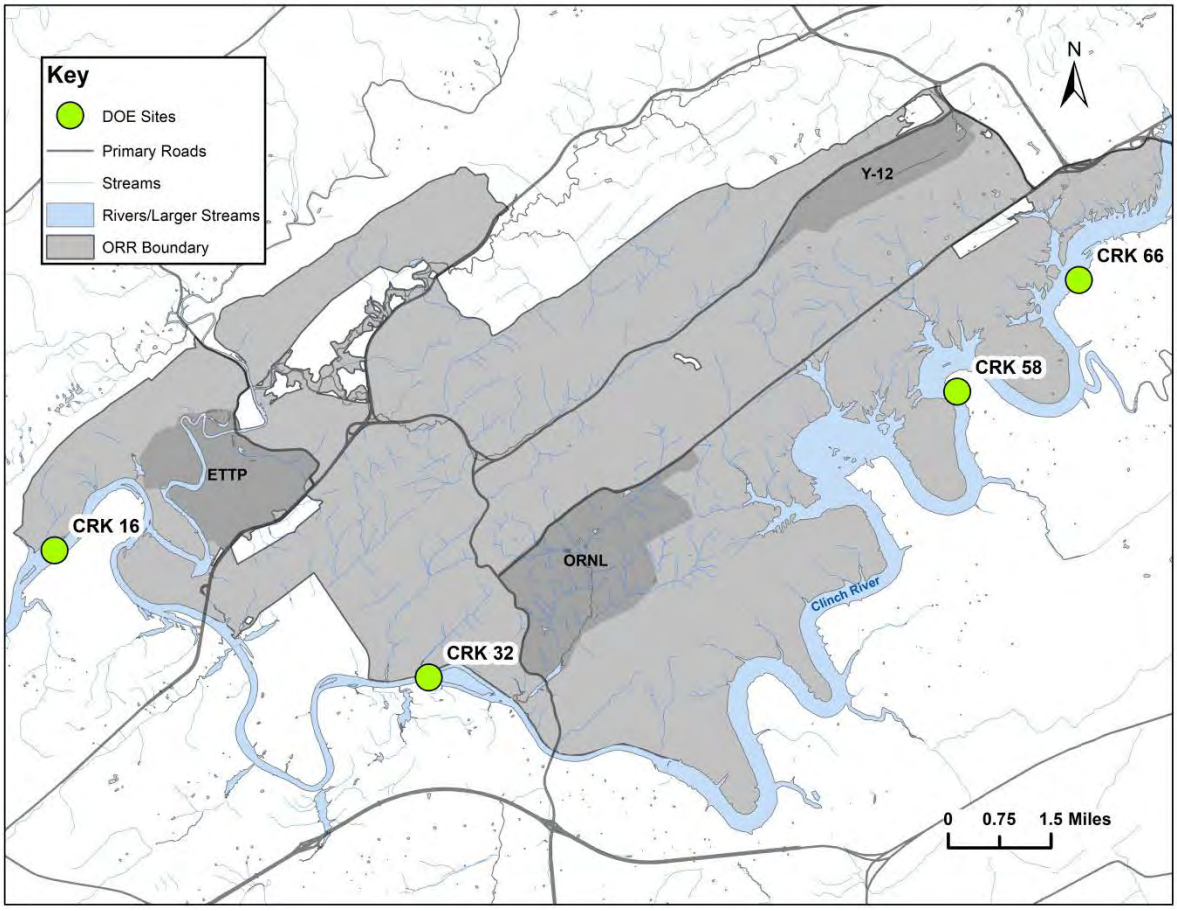

Figure 5.1.1: Map showing DOE sampling sites

The purpose of the current DOE Surface Water Monitoring Project is to assess the impacts from both past and present site operations to surface water bodies as well as to assess the impact of radioactivity to human health. Respective analyte MCLs as defined by the EPA are used to determine potential impacts (EPA, 2009).

While the current DOE project solely samples the Clinch River, the TDEC DoR-OR Surface Water Sampling Project outlined in this report would build upon DOE's sampling by looking at two of the exit-pathway streams. These streams are Bear Creek and East Fork Poplar Creek. Samples and flow measurements will be taken at several locations along these streams with the intent to provide a more representative evaluation of the loading of contaminants from ORR facilities to offsite locations. Additional co-sampling will also be performed at each of the four (4) DOE Clinch River sites (CRK 16, 32, 58, 66) with one site co-sampled quarterly. These co-sampling events will provide data validation and supplementary data for the DOE project. Similar to the DOE project, all sites will be compared to MCLs defined by EPA to determine stream impacts.

5.1.3 Problem Statements

This project will supplement DOE's study of the Clinch River to better understand impacts of exit-pathway streams to human health and the environment. It is estimated, based on 2017 US census data, that nearly 1.2 million people live in the counties surrounding the ORR (DOE, 2017). A large portion of these people have the potential of being influenced by streams that drain from the ORR. All of the exit-pathway streams on the ORR eventually flow into the Clinch River. In turn, the Clinch River ultimately flows into the Tennessee River. Twelve water supplies are located on these rivers within 170 river miles downstream of WOC (DOE, 1992). The Clinch River alone provides drinking water as well as water for industrial use to many municipalities near and downstream of the ORR. These include Anderson County, Knox County, Roane County, the City of Clinton, the City of Kingston, the City of Norris, and the City of Oak Ridge. The Clinch River surface waters are also used for facilities at Y-12, ORNL, and ETTP. It is important to monitor these exit-pathway streams, as well as the Clinch River, to better understand the ORR's impact on the region's widely used water resources.

These ORR exit-pathway streams and the Clinch River have been and are currently subject to contaminant releases from activities at ETTP, ORNL, and Y-12. These releases can be detrimental to the environment and to human health.

Identified concerns include but are not limited to the following:

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury to EFPC by spills and leakage from subsurface drains, building foundations, and contaminated soil, as well as purposed discharge of wastewater containing mercury (Turner and Southworth, 1999).
- EFPC is believed to contribute approximately 0.2 metric tons of mercury to the Clinch River each year (DOE, 1992).
- In addition to mercury, other metals that have been found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver and zirconium (DOE, 1992).
- In regard to Bear Creek, DOE has stated, "The primary contaminants in the surface water are uranium, nitrate, and cadmium. The S-3 site currently contributes approximately 26% of the risk at the [Bear Creek Valley] Watershed Integration Point through releases of uranium" (DOE, 1999).

Monitoring ORR exit-pathway streams will help assess which ORR facilities are contributing to surface water pollution. This monitoring will provide insight to help protect human health and the environment, especially for the important resource of the Clinch River.

5.1.4 Goals

The goal of this Surface Water Monitoring Project is to evaluate the impact of contamination to two ORR exit-pathway streams (East Fork Poplar Creek and Bear Creek). The Clinch River will also be monitored in conjunction with DOE sampling (Figure 5.1.2). More specifically, this project will ultimately seek to understand each respective stream's contribution or loading of uranium and mercury into the Clinch River. An assessment of each stream's impact, including the Clinch River, will be performed by comparing sampling results to EPA defined maximum contaminant levels (EPA, 2009). This project will help to identify areas of concern on the ORR that may significantly impact the surface water resources of Tennessee's citizens.

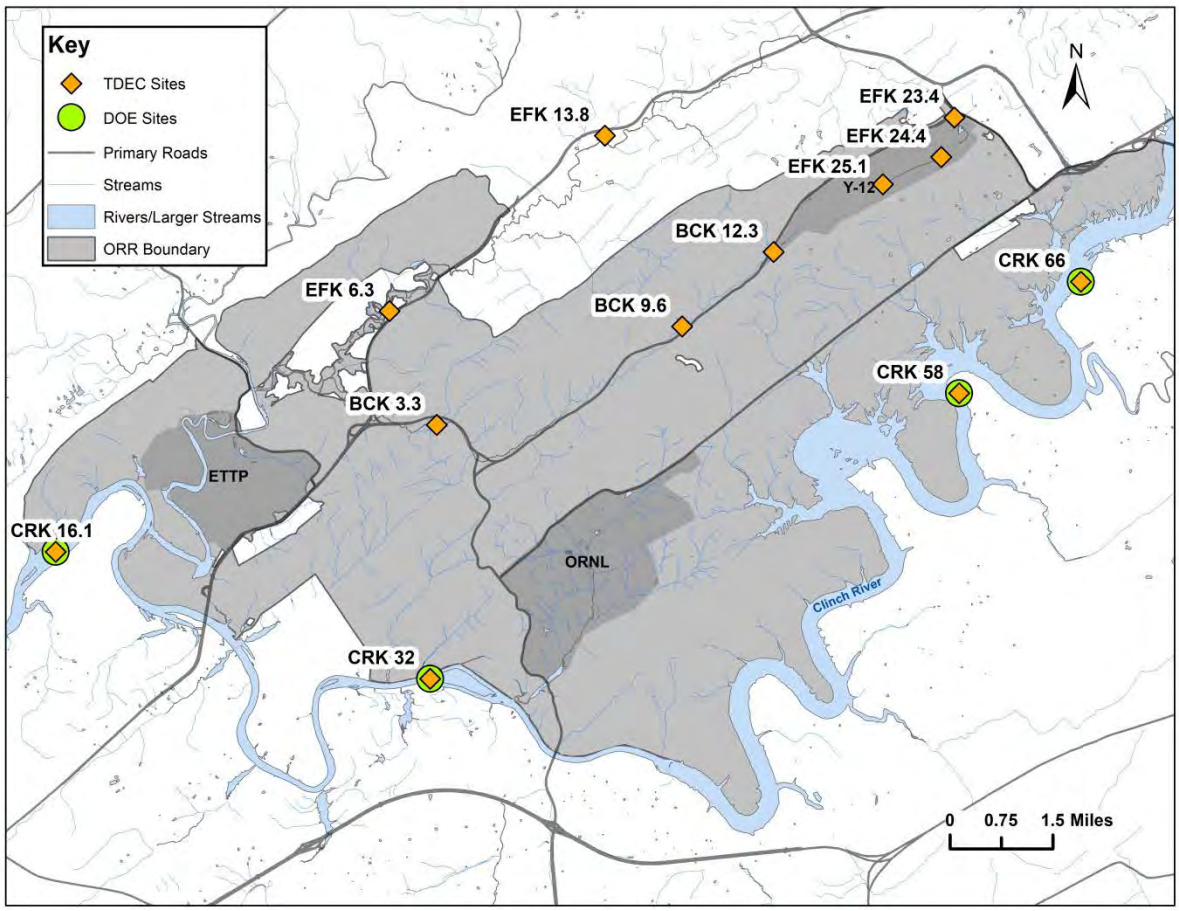

Figure 5.1.2: Map showing proposed TDEC sites and DOE sampling sites

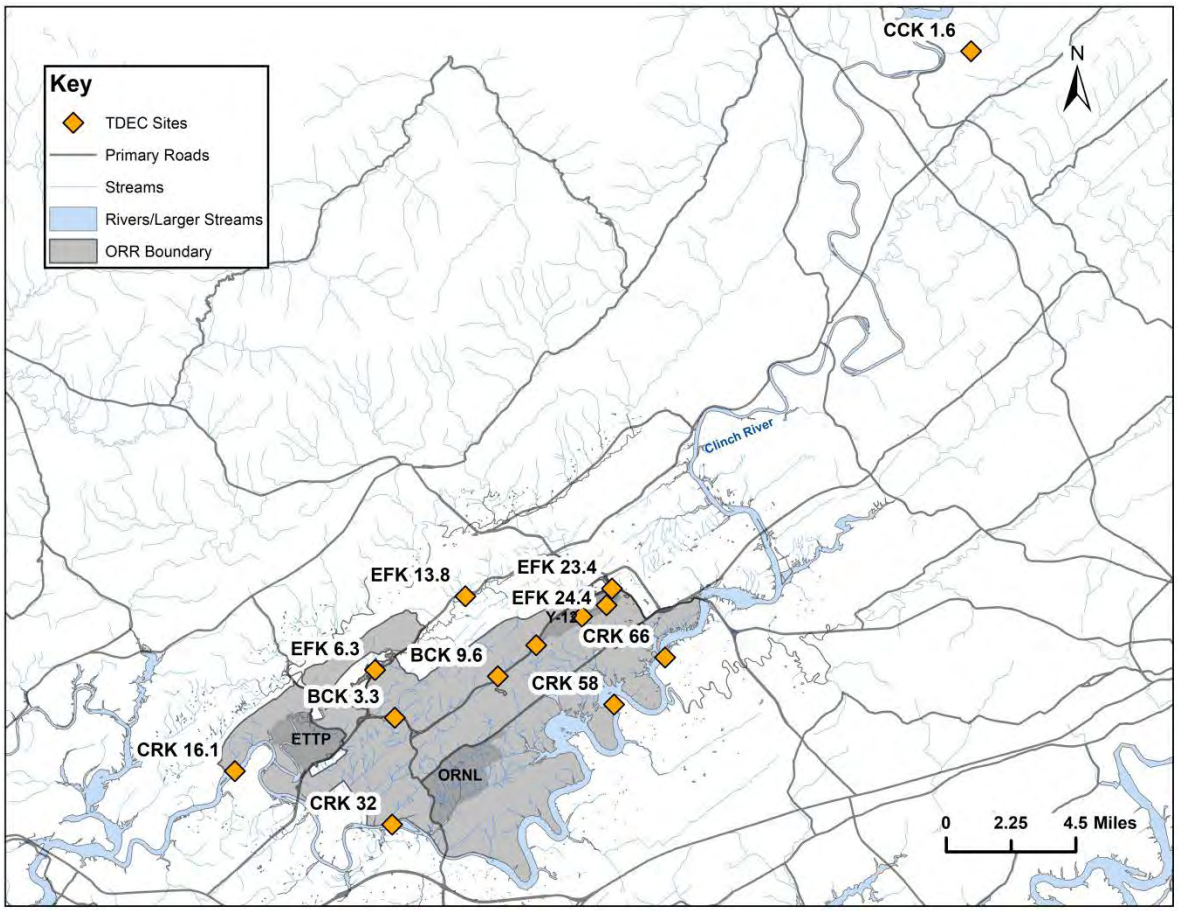

Figure 5.1.3: Zoomed out map showing proposed TDEC sampling sites. The number associated with each site represents the distance in kilometers from the mouth of the stream or river to that location.

To accomplish this goal, several objectives need to be completed. These objectives include:

- Collect surface water samples quarterly at two ORR exit-pathway streams, one ORR background stream, and the Clinch River (Figure 5.1.3).
    - Bear Creek (BCK): sample three (3) locations at BCK 12.3, BCK 9.6, and BCK 3.3 for uranium, mercury, and major cations/anions
    - East Fork Poplar Creek (EFK): sample five (5) locations EFK 25.1, EFK 24.4, EFK 23.4, EFK13.8, and EFK 6.3 for uranium, mercury, and major cations/anions
    - Clear Creek (CCK): sample one (1) location at CCK 1.3 for uranium, mercury, and major cations/anions. This information is to be used as a background comparison stream to the onsite streams
    - Clinch River (CRK): co-sample with UT-Battelle quarterly at one (1) of the four (4) sites CRK 66, CRK 58, CRK 32, and CRK 16.1 with each site sampled at least once throughout the project. These sites will be sampled for gross alpha/beta, mercury, and strontium-89,90

- Measure physical water parameters (e.g. conductivity, dissolved oxygen, pH, and temperature) at each site at time of sampling
- Take a cross-sectional transect of each stream and measure for stream flow rates at the time of sampling, excluding the CRK samples
- Evaluate resulting data
    - The contaminant flux will be calculated for each stream excluding the CRK
    - Results from CRK sites will be compared with data obtained from co-sampling with DOE (statistical methods such as analysis of variance may be used to show any significant differences)
    - Results will be compared to historical TDEC data (e.g. historical uranium and mercury data). Statistical methods such as an analysis of variance may be used to show significant differences from historical data
    - Statistical programming software and mapping technology will be used to identify increasing or decreasing trends in data

5.1.5 Scope

The scope of this project is to characterize stream conditions and assess contaminant flux through sampling, stream flow measurements, and analysis of surface water from two (2) ORR exit-pathway streams that flow into the CR. A segment of the CR will also be assessed spanning from the Oak Ridge City water intake at CRK 66 downstream to CRK 16.1 which is downstream of all ORR exit stream inputs.

5.1.6 Assumptions

This scope of this project is based on the following assumptions:

- Mercury contamination of East Fork Poplar Creek (EFPC) is attributable to activities at Y-12
- Potential contamination is attributable to activities on the ORR
- Scheduling will allow for co-sampling with DOE
- Flow meter and physical parameter probe remain operational

5.1.7 Constraints

Constraints that may impact this project include:

- Availability of funding, manpower, and access to controlled areas on the ORR
- Laboratory costs remain the same throughout the project
- Streams have measurable flow
- Excessive rain or drought which may prevent the ability to adequately sample or take stream measurements

5.1.8 Methods, Materials, Metrics

Sample Collection

Surface water samples will be collected quarterly at three (3) sites on BC, one (1) site on CC, the background stream, and five (5) sites on EFPC. Each quarter, one (1) of four (4) CR sites will be co-sampled, with each CR site being sampled once throughout the project. Samples from BC, CC, and EFPC will be sampled and analyzed for metals such as mercury and uranium, inorganic cations such as sodium, potassium, calcium, and magnesium, and inorganic anions including fluoride, chloride, sulfate, phosphorus, and nitrate. Samples collected from the CR sites will be analyzed for gross alpha, gross beta, mercury, and strontium-90 (Table 5.1.1). Quality assurance/quality control (QA/QC) samples will be collected for every 10th sample of any given analyte. If fewer than ten (10) samples of a given analyte are collected, at least one (1) QA/QC sample will still be taken (Table 5.1.1). Sampling protocols will follow the Tennessee Department of Environment and Conservation Division of Water Resources *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2018).

Field Parameter Measurements

At each site, physical water parameters will be collected during the time of sampling. Physical parameters will be measured using a multiple parameter water quality meter. Parameters of conductivity (µS/cm), dissolved oxygen (mg/L), pH, and temperature (°C) will be recorded along with the time of measurement.

Stream Flow Measurements

Stream flow measurements will be taken at each stream at the time of sampling. This will be accomplished by measuring the cross-sectional transect perpendicular to the flow of the stream as well as measuring the flow rate using a FlowTracker2® instrument. The FlowTracker2® instrument allows for an accurate measurement of a stream's cross section as well as flow. Results from the flow measurements will be analyzed using Sontek Flowtracker software to best characterize the stream flow. It is to be noted that the CR sites will be excluded from stream flow measurements.

Table 5.1.1: Planned samples and site information

			Planned Sampling				
Latitude	Longitude	DoR-OR Site	Rads	Uranium	Mercury	Major Cation	Major Anion
35.92186	-84.42942	CRK 16.1	1		1		
35.9002	-84.35049	CRK 32	1		1		
35.94891535	-84.23902273	CRK 58	1		1		
35.967958	-84.213382	CRK 66	1		1		
35.973	-84.27814	BCK 12.3		4	4	4	4
35.96032	-84.29741	BCK 9.6		4	4	4	4
35.94354	-84.34911	BCK 3.3		4	4	4	4
35.98456	-84.2551	EFK 25.1		4	4	4	4
35.98922	-84.24282	EFK 24.4		4	4	4	4
35.99596	-84.24004	EFK 23.4		4	4	4	4
35.99283	-84.31371	EFK 13.8		4	4	4	4
35.96293	-84.35905	EFK 6.3		4	4	4	4
36.21346	-84.05983	CCK 1.3		4	4	4	4
DOE Co-Sample		FB		3	3	3	3
Ambient		FD	1	4	4	4	4
QA/QC		Total for FY	**5**	**43**	**47**	**43**	**43**

Note:

Rads: gross a/b, Sr-90

Major Cation: sodium, potassium, calcium, magnesium

Major Anion: fluoride, chloride, sulfate, total phosphorus, nitrate/nitrite, total alkalinity

Data Evaluation

Using R programming language, several analyses will be performed to better understand the results. First, results will be compared with any available co-sampled DOE data. Applicable methods such as analysis of variance or the Kruskal-Wallis test may be used to see if samples from TDEC DoR-OR and DOE are statistically significantly different. Second, results will be compared with TDEC DoR-OR's historical data for selected streams excluding CR sites. Again, an analysis of variance or the Kruskal-Wallis test may be used to compare these two (2) data sets. Along with basic descriptive statistics: mean, median, minimum, maximum, etc., increasing or decreasing trends in data will be analyzed. Data will be assessed using TDEC and EPA defined MCLs to determine if there is a potential impact to human health and the environment (EPA, 2009, TDEC, 2013). Any exceedances may invoke further investigation.

5.1.9 References

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5.2 AMBIENT SURFACE WATER PARAMETERS

5.2.1 Background

The ORR consists of three (3) major sites: ORNL, Y-12, and ETTP. Activities at these sites, both historically and now, have resulted in the discharge of hazardous substances (e.g. metals, organics, and radioactive materials) leading to the contamination of waterbodies on the ORR and in the surrounding areas (DOE, 1992; DOE, 2018; Pickering, 1970; Turner & Southworth, 1999). While legacy waste across the ORR may be responsible for a large portion of the contamination to surface water, current projects and processes at these sites also have the potential to significantly contribute to surface water contamination.

In an effort to both complement and verify the DOE environmental program and to ensure the citizens and environmental resources of Tennessee are not severely impacted by surface water contamination, this Ambient Surface Water Parameter Project has been implemented each year since 2005. This project aims to assess the degree of surface water impact relative to potential contamination displacement. To accomplish this, stream monitoring data are proposed to be collected monthly to establish and build upon a database of physical stream parameters (specific conductivity, pH, temperature, and dissolved oxygen).

5.2.2 Related DOE Projects

DOE has conducted a surface water monitoring program for several years that consists of sample collection and analysis from various locations on the Clinch River. As part of this program, stream water quality parameters are measured at the time of sampling (DOE, 2019). However, as this DOE program is focused on the Clinch River, many ORR surface water exit-pathway streams that flow into the Clinch River are not frequently monitored. Thus, this complementary TDEC-DoR-OR project allows for further monitoring of water quality parameters on various exit-pathway streams from the ORR.

5.2.3 Problem Statements

ORR exit-pathway streams and the Clinch River have been and are currently subject to contaminant releases from activities at ETTP, ORNL, and Y-12. These releases can be detrimental to the environment and to human health.

Identified concerns include but are not limited to the following:

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury into East Fork Poplar Creek (EFPC). Mercury has been released into the environment by

spills, leakage from subsurface drains, and purposed discharge of wastewater. Contaminated building foundations and soils also contributed to these mercury releases (Turner and Southworth, 1999).

- EFPC is believed to contribute approximately 0.2 metric tons of mercury into the Clinch River each year (DOE, 1992).
- Besides mercury, other metals that have been found in ORR exit pathway streams at levels greater than background include cadmium, chromium, lead, nickel, silver and zirconium (DOE, 1992).

As DOE's current surface water monitoring program focuses solely on the Clinch River (DOE, 2019), TDEC DoR-OR's Ambient Surface Water Parameters project will complement DOE's project by helping to identify any shifts or changes in water quality parameters in three (3) ORR streams. An additional background stream will also be measured for comparison to the selected ORR streams.

5.2.4 Goals

The goal of TDEC DoR-OR's Ambient Surface Water Parameters project is to measure surface water parameters in EFPC, Bear Creek (BC), and Mitchell Branch within the ORR to complement DOE's surface water monitoring program, generate and provide data that can assist in the evaluation of site activities, and record ambient conditions that can be used for comparisons in the event of unexpected releases that may have impacted surface water bodies. Mill Branch will also be measured to serve as an offsite background stream. See Figure 5.2.1 and Table 5.2.1 below for sample locations.

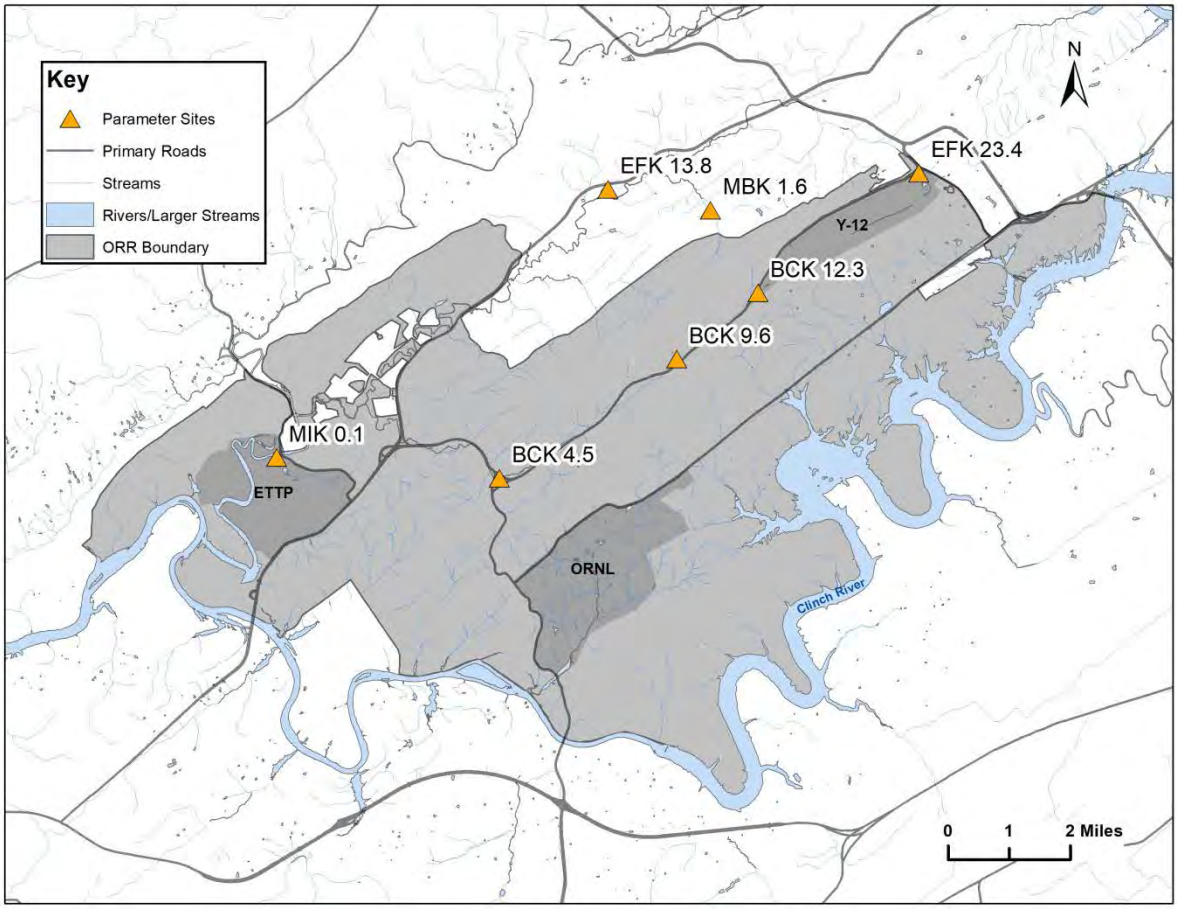

Figure 5.2.1: Map showing TDEC DoR-OR proposed surface water parameter sites

Table 5.2.1: Proposed site locations

Site DWR Name	DOE-O Site Description	DOE-O Site	Site Latitude	Site Longitude
EFPOP014.5AN	East Fork Poplar Creek Mile 14.5	EFK 23.4	35.99596	-84.24004
EFPOP008.6AN	East Fork Poplar Creek Mile 8.6	EFK 13.8	35.99283	-84.31371
BEAR007.6AN	Bear Creek Mile 7.6	BCK 12.3	35.973	-84.27814
BEAR006.0AN	Bear Creek Mile 6.0	BCK 9.6	35.96032	-84.29741
BEAR002.8RO	Bear Creek Mile 2.8	BCK 4.5	35.9375	-84.33938
MITCH000.1RO	Mitchell Branch Mile 0.1	MIK 0.1	35.94146	-84.3922
FECO67I12	Mill Branch Mile 1.0	MBK 1.6	35.98886	-84.28935

The goals of this project will be accomplished by measuring and recording physical water parameters (e.g. conductivity, dissolved oxygen, pH, and temperature) at each site monthly. Results will be analyzed using statistical programming software to identify trends as well as any anomalous data.

5.2.5 Scope

This project is limited to the characterization of physical stream parameters of three ORR streams (EFPC, BC, and Mitchell Branch) and one (1) background stream (Mill Branch).

5.2.6 Assumptions

The assumptions for this project include:

- Ambient physical parameters at the Mill Branch background station are indicative of a normal healthy stream
- Baselines or trends are already established for the physical parameters at the sampling stations
- Sampling of the background stream will be sufficient in providing a baseline for comparison against the selected ORR streams

5.2.7 Constraints

This project is contingent on funding, manpower, and access to controlled areas on the ORR.

5.2.8 Methods, Materials, Metrics

Field Parameter Measurements

At each site, physical water parameters will be measured and recorded. Physical parameters will be measured using a multiple parameter water quality meter. Parameters of conductivity (µS/cm), dissolved oxygen (mg/L), pH, and temperature (°C) will be recorded along with the time of measurement. Measurements will be taken in accordance with the Tennessee Department of Environment and Conservation Division of Water Resources *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC, 2018).

Data Evaluation

Recorded measurements will be stored in a database. Using R programming language, several statistical analyses will be performed to better understand the results. Trend analysis will be performed using linear regression to identify any increasing or decreasing trends in data. Anomalous data will also be identified. Basic descriptive statistics (mean, median, minimum, maximum, etc.) will also be assessed.

The selected ORR streams will be compared to the Mill Branch background stream using statistical approaches such as an analysis of variance to see if they are significantly similar in water parameters.

5.2.9 References

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5.3 WHITE OAK CREEK RADIONUCLIDES

5.3.1 Background

To help monitor potential ORR contamination, an ambient surface water sampling project has been implemented each year since 1993. This monitoring project began by investigating the water quality of the Clinch River at five locations near the ORR. The sampling locations for this project have been modified throughout the years, sometimes adding or discontinuing sampling at particular locations. At Clinch River kilometer (CRK) 32, TDEC DoR-OR staff co-sampled surface water with ORNL environmental staff on a quarterly basis during 2018-2019. For the first two quarters, TDEC DoR-OR samples were analyzed for strontium-90 (Sr-90) which is the primary radiological contaminant of concern (COC) for White Oak Creek (WOC). In addition to Sr-90, isotopic uranium and gross alpha/beta were included in the analytical COC suite for the last two quarters.

High Sr-90 concentrations were found at site CRK 33.5 which is the WOC and Clinch River confluence. Sr-90 concentrations were found to be nearly seven times the acceptable limit for the drinking water limit of 8 pCi/L. Site CRK 32 just downstream of CRK 33.5, had a significantly lower concentration of Sr-90. This is likely due to dilution from the Clinch River.

The average flow rate at the WOC dam, calculated from records provided by DOE, is 24,460 L/min with a median value of 14,325 L/min. As recent flow data was not available at this site, these values were calculated from 3,571 measurements conducted from 1993 to 2017.

Sr-90 was sampled at site CRK 33.5 on the Clinch River. The average concentration of Sr-90 over three sampling events was 36.7 pCi/L which is well above the EPA recommended 8 pCi/L limit for drinking water. Assuming the median flow value from sampling is representative of WOC near the Clinch River confluence and assuming that the average concentration of Sr-90 is representative of WOC, it is estimated that over 2.82E-05 grams per year (g/yr) of Sr-90 is added to the Clinch River from WOC.

The purpose of this project is to continue monitoring Sr-90 and other radiological contaminant inputs to WOC while loading of these contaminants to the Clinch River remains high.

5.3.2 Related DOE Projects

DOE has implemented a surface water monitoring program for several years that consists of sample collection and analysis from a few locations along the Clinch River (DOE, 2017; DOE, 2019). Currently, DOE collects quarterly samples at four sites along the Clinch River including CRK16, 32, 58, and 66 where CRK 58 is near the water supply intake for Knox County, and CRK 66 is upstream of the City of Oak Ridge water intake (DOE 2019), (Figure 5.3.1). Grab samples are collected at these four sites and are analyzed for water quality parameters such as dissolved oxygen, conductivity, pH, and water temperature. Samples are also screened for radioactivity by measuring gross alpha, gross beta, and gamma disintegrations. Strontium-90 is analyzed at three of the sites, specifically at the confluence of WOC and Clinch River near ORNL, upstream of the City of Oak Ridge water intake, and downstream of the ORR.

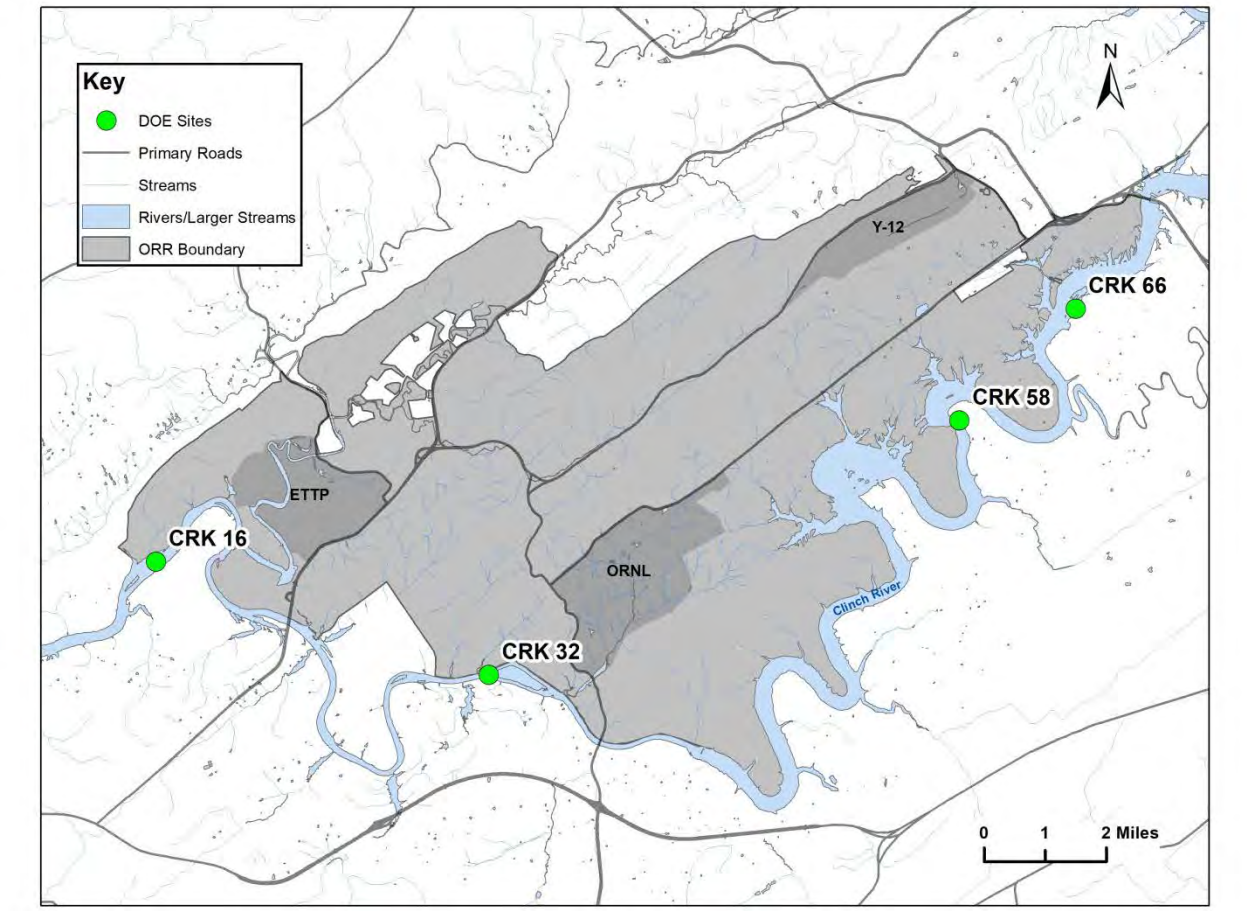

Figure 5.3.1: Map showing DOE sampling sites

The purpose of the current DOE surface water monitoring program is to assess radiological impacts of site operations, both past and present, to surface water bodies as well as human health. Respective analyte maximum contaminant levels (MCLs) as defined by the Environmental Protection Agency (EPA) are used to determine potential impacts (EPA, 2009).

While the current DOE project solely samples the Clinch River, the TDEC DoR-OR WOC radionuclide monitoring project will augment DOE sampling by looking at specific points along WOC and the Clinch River. Samples will be taken at points along WOC with the intent to provide a more representative evaluation of the contaminants entering the Clinch River. Similar to the DOE project, TDEC DoR-OR site data will be compared to EPA MCLs to determine stream impacts.

5.3.3 Problem Statements

This project will supplement DOE's study of the Clinch River to better understand the possibility of human beings being affected by migrating ORR radioactivity. Based on 2017 US census data, it is estimated that nearly 1.2 million people live in the counties surrounding the ORR (DOE, 2017). A large portion of these people have the potential of being influenced by streams that drain the

ORR. All of the exit-pathway streams on the ORR eventually flow into the Clinch River. In turn, the Clinch River ultimately flows into the Tennessee River. Twelve water supplies are located on these rivers within 170 river miles downstream of WOC (DOE, 1992). The Clinch River alone provides drinking water as well as water for industrial use to many municipalities near and downstream of the ORR. These include Anderson County, Knox County, Roane County, the City of Clinton, the City of Kingston, the City of Norris, and the City of Oak Ridge. The Clinch River surface waters are also used for facilities at the Y-12 National Security Complex (Y-12), the Oak Ridge National Laboratory (ORNL), and the East Tennessee Technology Park (ETTP). Thus, it is important to monitor this exit pathway stream, as well as the Clinch River, to better understand the ORR's impact on the region's widely used water resources.

These ORR exit-pathway streams and the Clinch River are subject to legacy and current contaminant releases from activities at ETTP, ORNL, and Y-12. These releases can be detrimental to the environment and to human health. Identified concerns include but are not limited to the following:

- The Clinch River received approximately 665 curies of cesium-137 (Cs-137) from White Oak Creek between 1954 and 1959. (DOE, 1992)
- Elevated levels of radioactive strontium-90 have been seen in WOC after a 2015 ruptured pipe mobilized the contaminant at the Process Waste Treatment Complex (DOE, 2018)

By monitoring WOC, TDEC DoR-OR can better assess what locations on the ORR are contributing to surface water pollution and provide insight to help protect human health and the environment, especially for the important resource of the Clinch River.

5.3.4 Goals

The goal of this WOC radionuclide monitoring project is to evaluate the impacts of DOE ORR contamination to WOC and the Clinch River (see Fig. 5.3.2). This project will ultimately seek to understand WOCs contribution of contaminants to the Clinch River. An assessment of WOCs impacts to the Clinch River will be performed by comparing results to EPA maximum contaminant levels (EPA, 2009). Overall, this project will help to define areas of concern on the ORR that may be significantly impacting the surface water resources of Tennessee.

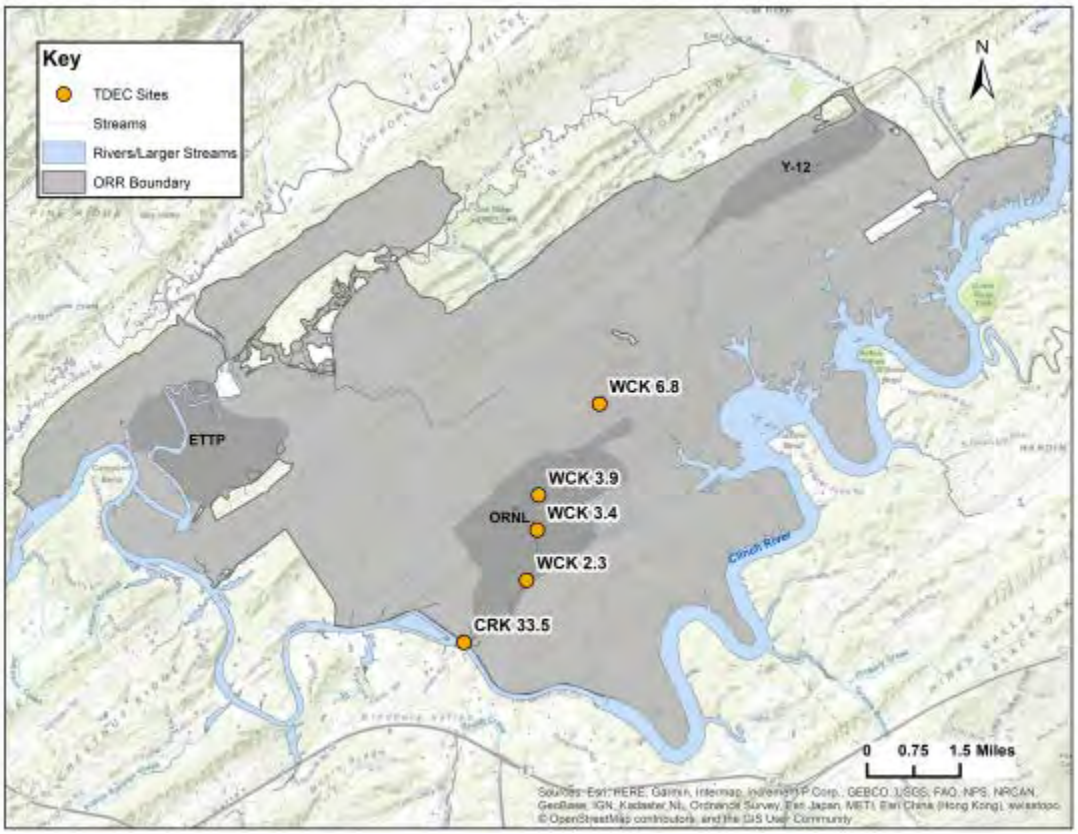

Figure 5.3.2: Map showing TDEC proposed sampling sites

To accomplish this goal, several objectives need to be completed. These objectives include:

- Collect quarterly surface water samples at the selected WOC and Clinch River sites (see Figure 5.3.2)
    - Samples will be collected and analyzed for Sr-90
- During sampling, physical waters parameters (e.g. conductivity, dissolved oxygen, pH and temperature) will be measured
- Evaluate resulting data
    - Statistical programming software and mapping technology will be used to identify increasing or decreasing trends in data

5.3.5 Scope

The scope of this project is to characterize stream conditions and assess contaminant flux through sampling of WOC and the Clinch River.

5.3.6 Assumptions

This project has a few assumptions, including:

- Strontium-90 contamination of WOC is due to activities at ORNL.
- Contamination is attributable to activities on ORR
- The water quality meter will remain operational

5.3.7 Constraints

Constraints that may impact this project include:

- Availability of funding, manpower, and access to controlled areas on the ORR
- Laboratory costs remain the same throughout the project

5.3.8 Methods, Materials, Metrics

Surface water samples will be collected quarterly at four sites on WOC and one on the Clinch River. Samples will be collected and analyzed for strontium-89,90 at each site (see Table 5.3.1). Quality assurance/quality control (QA/QC) samples will be taken every 10^{th} sample of a given analyte. If less than ten samples are collected for a given analyte, at least one QA/QC sample will still be collected (see Table 5.3.1). To ensure reproducible results, sample collection will utilize the *TDEC, DWR, Quality System SOPs for Chemical and Bacteriological Sampling of Surface Water,* DWR-WQP-P-01- QSSOP-Chem-Bact-082918.

Table 5.3.1: Site locations, descriptions, and list of proposed analytes

DoR-OR Site	Site Latitude	Site Longitude	Analyte
WCK 6.8	35.94151	-84.30161	Sr-89/90
WCK 3.9	35.92435	-84.31579	Sr-89/90
WCK 3.4	35.91778	-84.31612	Sr-89/90
WCK 2.3	35.90834	-84.31856	Sr-89/90
CRK 33.5	35.896653	-84.333161	Sr-89/90
Field Blank	35.94151	-84.30161	Sr-89/90
Field Duplicate	35.91778	-84.31612	Sr-89/90

At each site, physical water parameters will be collected during the time of sampling. Physical parameters will be measured using a multiple parameter water quality meter. Parameters of conductivity (µS/cm), dissolved oxygen (mg/L), pH, and temperature (°C) will be recorded along with time of measurement. The water quality meter will be used according to manufacture specifications.

Upon receiving sampling results, data will be stored in a database maintained in the DOR-OR office. Using R programming language, several analyses will be performed to better understand the results. First, results will be compared with any available co-sampled DOE data. Applicable methods such as analysis of variance or the Kruskal-Wallis test may be used to see if samples from TDEC DoR-OR and DOE are statistically significantly similar. Increasing or decreasing trends in data will be analyzed. Data will be compared to an EPA defined MCL to determine if there are any exceedances (EPA, 2009). Any exceedances may invoke further investigation. See the table below for criteria to be tested (see Table 5.3.2).

Table 5.3.2: Criteria for screening samples

Contaminant	Criterion	Reference
Sr-89/90	8 pCi/L*	EPA 2009

*EPA has established a Maximum Contaminant Level (MCL) of 4 millirems per year for beta particle and photon radioactivity from manmade radionuclides in drinking water. The value shown is the average concentration assumed to yield 4 millirems per year. If other radionuclides that emit beta particles and photon radioactivity are present in addition to this contaminant, the sum of the annual dose from all the radionuclides cannot exceed 4 millirems per year.

5.3.9 References

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6.0 LANDFILL MONITORING

6.1 EMWMF

6.1.1 Background

The EMWMF was constructed for the disposal of low-level radioactive waste and hazardous waste generated by remedial activities on the ORR and is operated under the authority of CERCLA and DOE. While the EMWMF facility holds no permit from the State of Tennessee, the EMWMF is required to comply with DOE orders and substantive portions of ARARs listed in the CERCLA EMWMF Record of Decision (ROD) (DOE, 1999).

Currently, the only authorized discharge from EMWMF is contaminated storm water (contact water), which ponds in the disposal cells above the leachate collection system. The contact water is routinely pumped from the disposal cells to holding ponds and tanks, and then it is sampled (Figure 6.1.1). Depending on contaminant levels, it is either treated onsite or released to a storm water sedimentation basin which discharges into the NT-5 Bear Creek tributary.

The EMWMF was designed with a 5% slope along the centerline of each disposal cell to direct storm water and leachate to the southern (lower) end of the cells (Williams, 2004). The low-porosity native soils form a protective layer over the leachate collection system. This low-porosity protective layer resulted in excessive pooling of the contact water at the lower end of the cells (Williams, 2004).

Heavy rainfall during the first year of operations resulted in the storm water and associated leachate overflowing the cell berms; and releasing contaminants to adjacent land and into surface water. To avoid similar incidents, the DOE moved the compliance point from the holding ponds to the discharge point from the storm water sedimentation basin.

The limits on waste discharge releases from the holding ponds to the sedimentation basin are published in DOE Order 5400.5 (now DOE Order 435.1) which restricts the release of liquid wastes containing radionuclides to an average concentration equivalent of 100 mrem/year. The limit for discharges from the sedimentation basin to NT-5 are based on State of Tennessee regulations (TDEC 0400-20-11-.16{2}) (TDEC 2012) which restrict concentrations of radioactive material released to the general environment in groundwater, surface water, air, soil, plants, or animals to an annual dose equivalent of 25 mrem (TDEC 0400-20-11-.16{2}). In addition, DOE Order 458.1 limits gross alpha and gross beta activity of settleable solids in liquid effluents to 5.0 pCi/g and 50 pCi/g, respectively.

The TDEC Surface Water Monitoring at the EMWMF Project began in 2006 and has continued until the present. TDEC's monitoring of groundwater and surface water assist DOE in their efforts to comply with the requirements stated in the EMWMF ROD (DOE 1999) and Tennessee General Water Quality Criteria (TDEC 2019). Each year since 2006, samples of surface water, groundwater, and sediment have been collected, analyzed, and the results published in the annual TDEC DoR-OR EMR.

6.1.2 Related DOE Projects

DOR currently monitors surface water quarterly at NT-5, and NT-3 for potential releases from the landfill. Figure 6.1.1 shows the locations of the sampling locations described in this plan. Monthly samples from the Underdrain and the V-weir are also collected. The water released from the Sediment Basin at the V-weir (EMWMF-3) is collected by an automatic sampler using a weekly flow-rated composite sample as it is discharged (named VCOMP). This is used to calculate the volume weighted sum of fractions. Additional DOE sampling of surface water takes place at EMWNT-03B, EMWNT-05, NT-4 and the V-weir semi-annually after a qualifying precipitation event (> 0.1 inches). And, DOE collects a suspended solids sample is at the V-weir after a qualifying precipitation event (> 0.5 inches).

Annually, DOE's results from this sampling are published in the Phased Construction Completion Report (PCCR) (DOE 2020) which are entered into the Oak Ridge Environmental Information System (OREIS).

TDEC DoR-OR sampling and analysis results are intended to complement DOE's monitoring of the water discharges to the environment.

6.1.3 Problem Statements

- Contaminants in the waste materials from CERCLA remediation activities are buried in the EMWMF and may leach out and enter the environment.
- Surface water or groundwater may carry these contaminants off site in concentrations or activities above agreed-to limits.
- Only low-level radioactive waste, as defined in TDEC 0400-02-11.03(21) with radiological concentrations below limits imposed by Waste Acceptance Criteria (WAC), and agreed to by the FFA tri-parties, (DOE, EPA and TDEC), is approved for disposal in the EMWMF. DOE is accountable for compliance with the WAC and has delegated responsibility of WAC attainment decisions to its prime contractor.

6.1.4 Goals

The goals of the Surface Water Monitoring at the EMWMF Project follow:

- This project will provide assurance through independent monitoring and evaluation that DOE operations at the EMWMF are protective of public health and the environment.
- Verify DOE's remedial effectiveness objectives for the EMWMF.
- Provide independent data on discharges from the Underdrain and evaluate its effectiveness in lowering the groundwater table under the landfill.
- Surface water monitoring will verify that DOE is adhering to published (DOE/OR/01-2734&D1/R1) agreed-to-limits. These limits are currently under review by DOE and the EPA (Table 6.1.2).
- Surface water monitoring will act as complementary sampling and analysis for DOE's actions.
- Determine an estimate of discharged water volume from the Contact Water ponds/tanks. Keep a record of discharged volumes for later analysis.

6.1.5 Scope

The scope of the Surface Water Monitoring at the EMWMF Project includes the following:

- Measure water quality parameters in EMWMF discharges at four locations, EMWMF-2 (Underdrain) and EMWMF-3 (Sediment Basin v-weir discharge), weir SW-003 (upstream of EMWMF at BCK 11.54), and NT5@BCK (confluence of NT-5 and Bear Creek) (Figure 6.1.1). The measured water quality parameters are temperature, pH, specific conductivity, dissolved oxygen, and oxidation reduction potential. TDEC DoR-OR personnel will monitor these locations at least twice each week with the use of a YSI-Professional Plus water quality instrument or equivalent.
- To ensure best practices are used by DOE to limit possible contaminant migration, monitoring will occur at least twice weekly at the EMWMF and be documented.

- TDEC DoR-OR will collect confirmation samples identified in Table 6.1.1 and shown in Figure 6.1.1 on a routine basis from the selected locations to ensure contaminants from the landfill are not adversely affecting the downstream environment.
- Sediment samples will be collected annually from sediment basin areas that are sufficiently dry to facilitate collection by hand. These samples will be composited into one sample for analysis.
- To ensure EMWMF is meeting its operational requirements, discharge data collected by EMWMF personnel will be collected and reviewed weekly.
- Samples will be collected from EMWMF-2 once every two months.
- Prior to being discharged into the sediment basin, water collected in the contact ponds or the contact water tanks will be collected bi-monthly.
- EMWNT-03A/EMWNT-03B or EMWMF-6W (Cell 6 discharge) will be sampled and analyzed annually if conditions warrant and funds are available.
- Samples will be collected using criteria specified in the TDEC Quality Systems *Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water Revision 5* (TDEC 2018), and the EPA *SESD Operating Procedure for Surface Water Sampling,* SESDPROC-201-R4.
- Samples will be shipped for analysis using the TDEC DoR-OR Procedures for Shipping Samples to the State Lab in Nashville. SOP No. 101.

6.1.6 Assumptions

- Sampling and monitoring are contingent upon availability of DOE Radiological Protection Technicians to measure for possible radioactive contamination deposited on TDEC DoR-OR sampling equipment, collected samples, or personnel personal protective equipment (PPE).
- Availability of equipment for conducting water parameter measurements.
- Mercury, radionuclides and volatile organics are constituents of concern (COC).

6.1.7 Constraints

- Inclement weather may preclude conducting water parameter measurements.
- Samples will be shipped to the State of Tennessee Laboratory (TDH) for analysis.
- Availability of equipment for water parameter measurement.
- Availability of vehicles and trained personnel.
- Availability of TDEC DoR-OR funds for analysis of collected samples.

6.1.8 Methods, Materials, Metrics

Surface water grab samples will be collected on a routine basis for lab analysis, and the site will be monitored at least twice a week to measure water quality parameters and observe landfill conditions (Table 6.1.1).

Table 6.1.3 contains the list of analytes for this project. Collected samples will be analyzed for radionuclides (gamma radionuclides, strontium-89/90, technetium-99, tritium, transuranics and isotopic uranium, volatile organics, perfluorooctanesulfonic acid (PFOS), metals (arsenic, chromium, cobalt, copper, lead, nickel, uranium, vanadium, zinc, mercury), and inorganics. Table 6.1.6 presents the requested analytical methods for the COCs.

- Locations of sampling and monitoring are shown on Figure 6.1.1 and described with the rationale for sampling in Table 6.1.1.
- Sampling at EMWMF-2 (Underdrain) will be conducted bi-monthly to complement DOE sampling.
- Sampling at either, EMWMF-3 (VWEIR), EMWMF-5, EMWMF-7 or EMWMF-8 will be conducted bi-monthly to confirm DOE analyses and to coincide with a weekly "VCOMP" collection by DOE at EMWMF-3.
- Samples collected at EMWMF-5, EMWMF-7 and EMWMF-8 will be comprised of discharged water from a Contact Water pond or tank.
- Sampling of sediments at the Sediment Basin (EMWMFSB-1) will be conducted annually as conditions allow. If the bed of the sediment basin is dry enough to safely walk on, sample aliquots will be collected and composited into one sample for analysis.
- To capture contaminants that could be migrating from the cells laterally in shallow groundwater, the NT-3 tributary will be sampled down gradient of the waste cells at the locations currently monitored under the EMWMF surface water program (EMWNT-03A/EMWNT-03B).
- If conditions allow, additional water samples will be collected at EMWMF-1 [GW-918], and EMWMF-Cell6W.
- Observations of operations and surface water parameter measurements will be made twice a week as operations warrant. Additional locations for parameter measurements are NT5@BCK and BCK11.54A at the flume (SW-003) (Figure 6.1.1)
- On a quarterly basis, DOE PEMS sediment basin discharged water data will be downloaded and analyzed.

TDH Laboratory analyses will be entered into an Excel database for interpretation. Interpretation may include construction of tables and graphs illustrating ranges and limits of constituents over the course of the project. Included on the graphs will be pertinent water quality criteria from the EPA and TDEC (Tables 6.1.2, 6.1.4 and 6.1.5). In certain circumstances, DOE criteria may be used for additional illustration.

The EPA human and aquatic life criteria and the State of Tennessee aquatic life criteria will be used to compare the possible effects that discharged surface water could have on the environment.

The criteria for sediment include EPA's Regional Screening Levels for the Soil to Groundwater pathway using the Soil Screening Level (SSL) tool. Migration of contaminants from soil to groundwater can be envisioned as a two-stage process where contaminants in soil are first released to soil leachate and then the contaminants are transported through the underlying soil and aquifer to a receptor well. Another criterion is the Consensus Based Sediment Quality Criteria from the Wisconsin Department of Natural Resources which gives a Threshold Effects Concentration (TEC) and a Probable Effects Concentration (PEC).

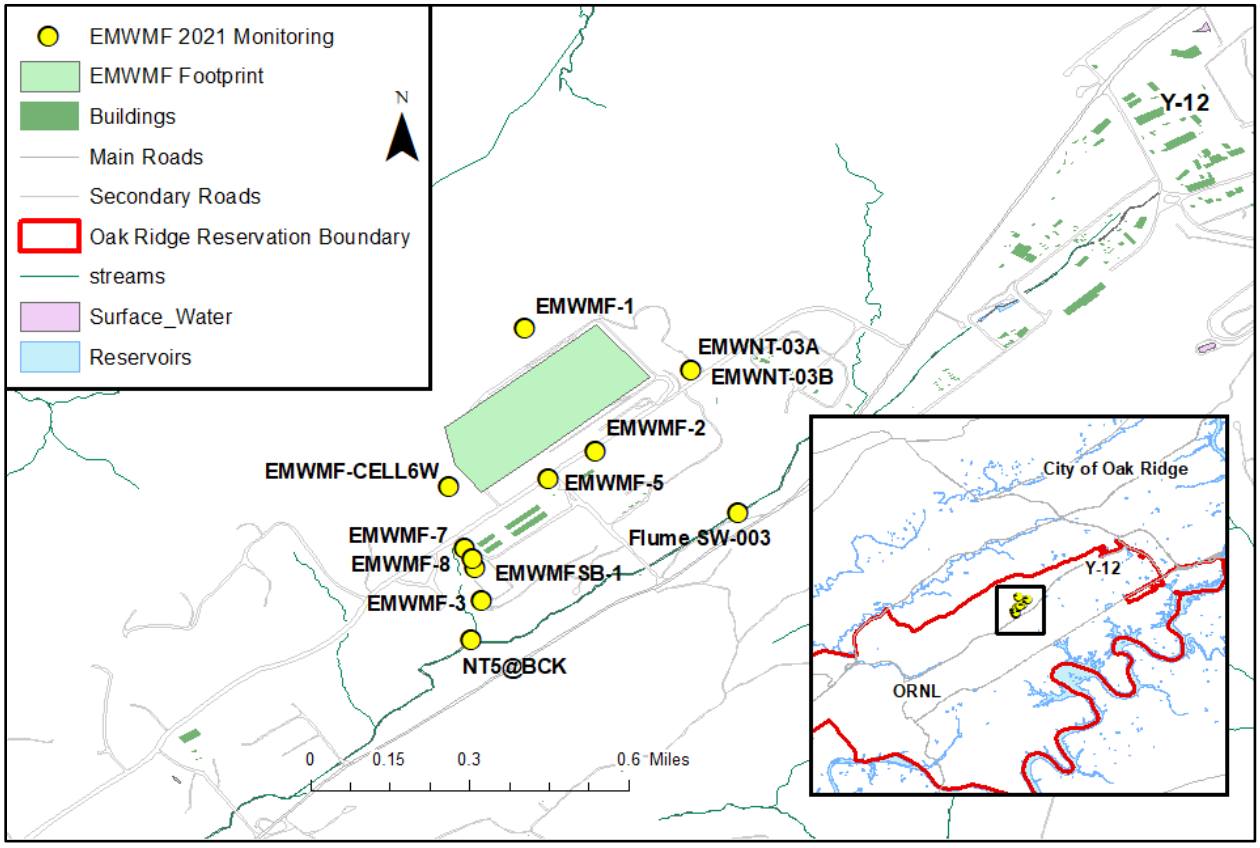

Figure 6.1.1: TDEC DoR-OR EMWMF Sampling Locations for 2021 Monitoring

Table 6.1.1: Sampling Locations and Frequency of TDEC DoR-OR Sample Collection

Station	Sample ID	Frequency	Sampling Rationale
EMWMF Underdrain	EMWMF-2	Bi-Monthly	NT-4 discharge below the landfill. The underdrain was installed below Cell 3 and it is theorized that if cells 1,2 2, and 3 were to leak contaminants, they would first be observed at the underdrain.
Contact Water Ponds/Tanks	EMWMF-5, EMWMF-7, EMWMF-8	1 Location Bi-Monthly	Provides confirmation of contaminant levels being discharged to the sediment basin.
Sediment Basin Effluents (VWEIR)	EMWMF-3	Bi-Monthly	Provides confirmation of contaminant levels being discharged from the sediment basin.
Sedimentation Basin Sediment	EMWMFSB-1, EMWMFSB-2	One Composite	This location is only sampled when the sediment basin is dry. The results are used to observe the loading of radionuclides in the sediment of the basin.
NT-3 Tributary	EMWNT-03A or EMWNT-03B	Annually as funds permit	Up-stream surface water location to be used as a baseline.
Cell 6 Drainage	EMWMF Cell-6W	Annually as funds permit	This location is used as a verification that water collected in Cell 6 (prior to waste placement_ is storm water.

GW - groundwater

EMWMF - Environmental Management Waste Management Facility

NT - North Tributary

Table 6.1.2: ARARs for Contact Water/Surface Water from EMWMF SAP/QAPP DOE/OR/01-2734&D1/R1

Monitored medium	Required action	Performance objectives	Performance measures
Contact Water	Monitor the quality of contact water discharges	TDEC 1200-04-03-.3(3) * 10 *CFR* 20.1301(a) TDEC 1200-2-11-.16(2) *	EMW-VWEIR, contact water ponds, and contact water tanks: Compare analytical results to AWQC under TDEC-40-03-.03(3) Surface water samples from EMW-VWEIR are analyzed for radiological COCs to perform the sum of fractions required for dose calculations

*Now TDEC 0400-40-03-.03(3) and TDEC 0400-20-11-.16

Table 6.1.3: TDEC DoR-OR EMWMF Monitoring Analyte List

EMWMF ANALYTE LIST		
Water	**Sediment**	
Gamma Activity	Gamma, Sediments	Iron
Sr-89, 90 in water	Sr-89, 90 in solids	Lead
Technetium 99	Technetium 99	Magnesium
Tritium in water	Tritium in solids	Manganese
Transuranics/Isotopic Uranium	Istopic Uranium in solids	Mercury
Arsenic	Aluminum	Nickel
Chromium	Arsenic	Potassium
Cobalt	Antimony	Selenium
Copper	Barium	Silver
Lead	Beryllium	Sodium
Mercury	Cadmium	Thallium
Nickel	Calcium	Uranium
Uranium	Chromium	Vanadium
Vanadium	Cobalt	Zinc
Zinc	Copper	
perfluorooctanesulfonic acid (PFOS)		

Table 6.1.4: EMWMF Monitoring Surface Water Criteria Comparison

Surface Water Criteria Comparison						
	Human Life Criteria		TN Aquatic Life Criteria		EPA Aquatic Life Criteria	
EMWMF ANALYTE LIST Water	Human Health for the consumption of Water + Organism (µg/L)	Human Health for the consumption of Organism Only (µg/L)	Freshwater CMC1 (acute) (µg/L)	Freshwater CCC2 (chronic) (µg/L)	Freshwater CMC1 (acute) (µg/L)	Freshwater CCC2 (chronic) (µg/L)
Gamma Activity	—	—	—	—	—	—
Sr-89, 90 in water	—	—	—	—	—	—
Technetium 99	—	—	—	—	—	—
Tritium in water	—	—	—	—	—	—
Transuranics/Isotopic Uranium	—	—	—	—	—	—
Arsenic	0.018	0.14	340	150	340	150
Chromium III	MCL	—	570	74	570	74
Cobalt	—	—	—	—	—	—
Copper	1,300	—	13	9	—	—
Lead	—	—	65	2.5	82	3.2
Mercury	—	—	1.4	0.77	1.4	0.77
Nickel	610	4,600	470	52	470	52
Uranium	—	—	—	—	—	—
Vanadium	—	—	—	—	—	—
Zinc	7,400	26,000	120	120	120	120

1/ CMC: Criterion Maximum Concentration

2/ CCC: Criterion Continuous Concentration

Table 6.1.5: EMWMF Monitoring Sediment Criteria Comparison

Sediment Levels for Risk Comparisons			
	EPA RSL Soil to Goundwater SSL mg/kg	TEC* mg/kg	PEC** mg/kg
Aluminum	30000	n.a	n.a
Arsenic	0.0015	9.8	33
Antimony	0.35	2	33
Barium	160	n.a	n.a
Beryllium	20	n.a	n.a
Cadmium	0.69	0.99	5
Calcium	n.a	n.a	n.a
Chromium	4.00E+07	43	110
Cobalt	0.27	n.a	n.a
Copper	28	32	150
Iron	350	20000	40000
Lead	14 MCL based	36	130
Magnesium	n.a	n.a	n.a
Manganese	28	460	1100
Mercury	14	0.18	1.1
Nickel	26	23	49
Potassium	n.a	n.a	n.a
Selenium	0.52	n.a	n.a
Silver	0.8	1.6	2.2
Sodium	n.a	n.a	n.a
Thallium	0.014	n.a	n.a
Uranium	1.8	n.a	n.a
Vanadium	86	n.a	n.a
Zinc	370	120	460
Gamma, Sediments	Use EPA PRGs for comparison	n.a	n.a
Sr-89, 90 in solids	Use EPA PRGs for comparison	n.a	n.a
Technetium 99	Use EPA PRGs for comparison	n.a	n.a
Tritium in solids	Use EPA PRGs for comparison	n.a	n.a
Istopic Uranium in solids	Use EPA PRGs for comparison	n.a	n.a

*Consensus Based Sediment Quality Criteria, Threshold Effects Concentration (McDonald et al. 2000)

**Consensus Based Sediment Quality Criteria, Probable Effects Concentration (McDonald et al. 2000)

n.a. - criteria not established for that characteristic

Table 6.1.6: Lab Methods and Analyses

Method Designation	Test Name	Analytes
Method 200.7	ICP-OES	Metals
Method 200.8	ICP-MS	Metals
Method 245.1	Mercury	Mercury
Method 8260B	GC/MS	Volatile Organic Compounds
Method 901.1	Gamma water	Gamma radiation
Method ENV-Rad-SOP-401-R.1.3	Gross Alpha-Beta water by LSC	Gross alpha-beta activity
Method 905.0	Sr-89-90 water	Strontium 89-90
Eichrom Method TCW02	Technetium-99 water	Technetium-99
Method 906.0	Tritium water	Tritium

6.1.9 References

DOE 1999, Department of Energy. 1999. Record of Decision for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste (DOE/OR/01-1791&D3)

DOE 2020, Department of Energy. 2020. Fiscal Year 2020 Phased Construction Completion Report for the Oak Ridge Reservation Environmental Management Waste Management Facility, Department of Energy, DOE/OR/01-2846&D1, March 2020

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United States Environmental Protection Agency. Regional Screening Levels for Chemical Contaminants at Superfund Sites. (March 2020).

6.2 EMDF

Although TDEC planned the work in this section as a component of the watershed-wide Bear Creek Assessment Project addressed in section 10.0 Watershed Assessments (Holistic) Monitoring, this section 6.2 has been designated under the EMDF header in anticipation of TDEC support for the project as DOE initiates additional site characterization and design data collection following execution of the ROD.

6.2.1 Background

The Environmental Management Disposal Facility (EMDF) is proposed for the disposal of low-level radioactive waste and hazardous waste generated by remedial activities on the ORR and will be operated under the authority of CERCLA and DOE. While the EMDF facility will hold no permit from the State of Tennessee, the EMDF will be required to comply with DOE orders and substantive portions of ARARs listed in the upcoming CERCLA EMDF Record of Decision (ROD).

The TDEC surface water monitoring along the portion of the creek in BCV where the potential future EMDF Project may be sighted, will begin in Fiscal Year 2021. TDEC's monitoring of

groundwater and surface water will support the Bear Creek Valley assessment project addressed in section 10 of this document, as well as supporting anticipated future data collection efforts at the Central Bear Creek Valley site.

6.2.2 Related DOE Projects

DOE currently monitors Bear Creek, and some Bear Creek tributaries (NT-5, NT-4, and NT-3) for potential releases from the Environmental Management Waste Management Facility (EMWMF) landfill. The water released from the EMWMF sediment basin is collected by an automatic sampler using a weekly flow-rated composite sample and then it is discharged. Annually, the results from these sampling efforts are published in the Phased Construction Completion Report (PCCR) or the *Oak Ridge Reservation Remedial Effectiveness Report*.

The analysis of the results from TDEC's EMDF monitoring project is intended to complement and supplement DOE's monitoring of the surface water in the environment.

6.2.3 Problem Statements

- Contaminants in the waste materials from CERCLA remediation activities will be buried in the EMDF and may leach out and enter the environment.
- Surface water or groundwater may carry these contaminants off site in concentrations or radiological activities above agreed-to limits.

6.2.4 Goals

The goals of the Surface Water Monitoring at the EMDF Project follow:

- This project will provide data to identify current site conditions along Bear Creek Valley in the Central Bear Creek valley watershed area. Sampling will provide assurance through independent monitoring and coincident evaluation of DOE's data, that collected background or baseline data is appropriate for use in future stream health comparisons.
- Surface water monitoring by TDEC will verify that DOE has determined background water quality parameter levels in the surface water by measuring the same water quality parameters.
- Surface water monitoring will act as complementary monitoring and analysis for DOE's actions.

6.2.5 Scope

The scope of the Surface Water Monitoring at the EMDF Project includes the following:

- Staff members will measure water quality parameters in streams at six flume discharge locations: SF-1, SF-2, SF-3, SF-4, SF-5 and SF-6 and spring D10W (Figure 6.2.1). Staff

members will monitor these locations with the use of a YSI-Professional Plus water quality instrument or equivalent.
- Observations of site conditions and surface water parameter measurements will be made twice a week as conditions warrant.

6.2.6 Assumptions

- Monitoring is contingent upon availability of a DOE escort.
- Mercury, radionuclides and volatile organics are constituents of concern.

6.2.7 Constraints

- Monitoring is contingent upon availability of a DOE escort.
- Inclement weather may preclude conducting parameter measurements.
- Availability of equipment for conducting water parameter measurements.

6.2.8 Methods, Materials, Metrics

Tasks for this program include monitoring parameters at seven locations, SF-1, SF-2, SF-3, SF-4, SF-5 and SF-6 and spring D10W (Figure 6.2.1). TDEC DoR-OR personnel will perform basic monitoring of these locations for temperature, pH, conductivity, dissolved oxygen, and oxidation reduction potential at least twice weekly utilizing a YSI-Professional Plus water quality meter or its equivalent. Calibration and/or a confidence check of this instrument is performed prior to field use.

On a bi-weekly basis TDEC DoR-OR will visit SF-1, SF-2, SF-3, SF-4, SF-5 and SF-6 and spring D10W to perform general monitoring of the site. TDEC DoR-OR will monitor the streams, note discharges and water condition, observe the condition of the banks and note any concerns. Concerns will be brought to the attention of DOE. Field notes will be recorded in a field book and events will be reported in a TDEC project monthly report.

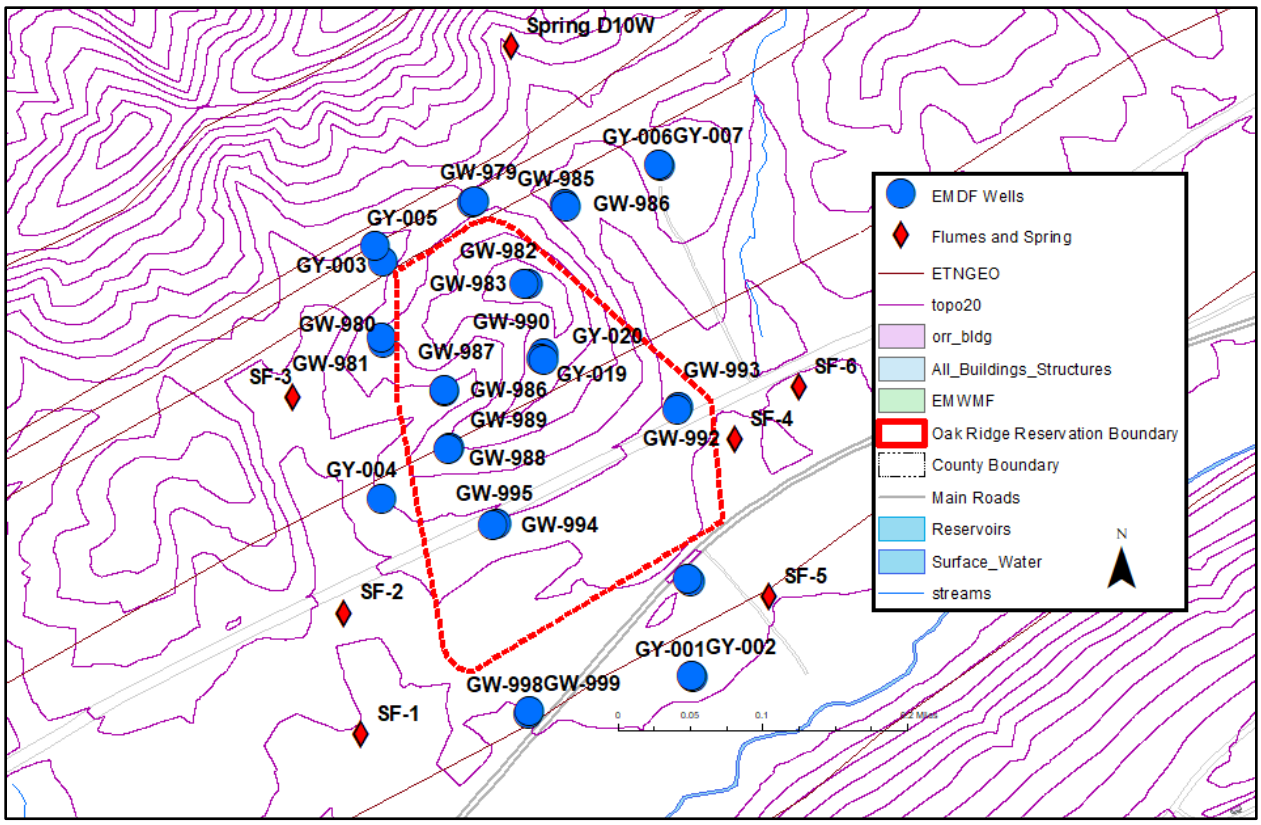

Figure 6.2.1: Sampling Locations CBCV Site 2021 Monitoring

Data collected from these key locations by DoR-OR and DOE will be entered into an Excel database for interpretation. Interpretation will include construction of tables and graphs illustrating ranges and limits of constituents and parameters over the course of the project. Water quality parameters include temperature, pH, specific conductivity, oxygen reduction potential and dissolved oxygen. Water sampling for analysis by DoR-OR may be conducted if funds become available. Analytes will be determined at that time. Pertinent water quality regulatory criteria from the EPA and TDEC will be included on the graphs.

6.2.9 References

TDEC 2019, Rules of the Tennessee Department of Environment and Conservation. Chap. 0400-40-03, General Water Quality Criteria, Tennessee Department of Environment and Conservation. (2019)

Tennessee Department of Environment and Conservation, Environmental Sampling of the ORR and Environs Quality Assurance Project Plan. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, TN, 2015.

Tennessee Department of Environment and Conservation, Sampling and Analysis Plan for General Environmental Monitoring of the Oak Ridge Reservation and its Environs, Division of Remediation Oak Ridge (2016)

Tennessee Department of Environment and Conservation Division of Remediation, Oak Ridge Office (DoR OR) 2019 Health and Safety Plan Including Related Policies. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, TN. January 2020.

Tennessee Department of Environment and Conservation, Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water, Tennessee Department of Environment and Conservation, Division of Water Pollution Control (2018).

United States Environmental Protection Agency. Regional Screening Levels for Chemical Contaminants at Superfund Sites. (March 2020).

7.0 STORM WATER / WATER DISCHARGE MONITORING

7.1 RAIN EVENT

7.1.1 Background

In general, rainwater and groundwater do not exhibit static flow behavior. Water from ORR excavations, D&D and RA operations can accumulate in pools and then flow into basements, sediment and/or stormwater basins, and subsequently permeate into soils. For example, based on past DOE D&D activities, estimated volumes of water accumulated at ETTP range from 200 gallons to 1.5 million gallons (UCOR URS / CH2M 2018a). It is possible accumulated water may contain at least one contaminant that needs to be treated before it is discharged into the environment.

7.1.2 Related DOE Projects

The *2017 Annual Site Environmental Report* states,

"Remedial Activities, CERCLA, and Legacy Pollutant Monitoring"

"Storm water samples have been collected at locations that are affected by RA activities prior to the initiation of these activities in order to determine the conditions present before remediation begins. In addition, storm water samples will be collected at potentially affected outfalls and storm water catch basins after remedial activities have been undertaken, and after they have been completed, to help gauge the effectiveness of the remediation efforts."

"The results of the monitoring effort at the D&D sites, which are a subset of remedial activities, are utilized in determining the effectiveness of BMPs in controlling offsite releases of legacy pollutants."

7.1.3 Problem Statements

- Contamination from legacy and ongoing activities can be disturbed and transported beyond the physical boundaries of the ORR by D&D or RA activities during and following a rain event.
- Each D&D project can develop new COC exit pathways.

7.1.4 Goals

The goal of this project is to obtain data to determine if DOE ORR best management practices employed during remedial actions is controlling offsite releases of legacy pollution and to provide input for future cleanup decisions. Actions to achieve this goal are:

- Review and comment on documents related to D&D work.
- Use co-sampling to monitor releases into the environment.
- Observe D&D and RA sampling activities and review DOE sampling results to ensure compliance with negotiated and agreed-to-release criteria.

7.1.5 Scope

To assess the degree of ORR surface water impacts caused by rainfall events and accumulated water, in conjunction with DOE, sampling of streams may be conducted following heavy rainfall events to determine the presence or absence of contaminants of concern. In addition, observation of such sampling events will be undertaken to ensure that good sampling methods are used. Comparison to standard operating procedures (SOP) will be done if a sampling contractor's SOP's are released to this office. If SOPs are released, then observations will be made against industry or EPA standards. Specific tasks include the following:

- Samples taken during D&D and RA activities will ensure release criteria are being met.
- Possible new or ongoing releases to the environment which are not being monitored by DOE may warrant the sampling of seeps, drains, burial grounds, etc.
- Independent sampling will occur to confirm DOE sampling results.
- Operations will be observed to ensure compliance with site-specific performance documents.

7.1.6 Assumptions

- Legacy contaminants are transported offsite or into receiving bodies of water during or following a rain event.
- Staff will be available for field work on short notice to perform observation when notification is given by DOE.
- During D&D and RA, not all contaminants of concern (COC) are kept within the facility

boundaries or transported offsite for final disposal.

- During D&D and RA, COC's that have entered containment areas, sumps, and storm drains may not be detected by the sampling performed under parameters set forth by the National Pollutant Discharge Elimination System (NPDES) Permit.

7.1.7 Constraints

- Availability of DOE staff or contractors to accompany and facilitate entry into work areas.
- Availability of DoR-OR personnel to assist with sampling.
- Availability of a suitable vehicle to transport equipment and personnel to sampling sites.
- Lack of or late notification by DOE concerning water discharges or sampling events.

7.1.8 Methods, Materials, Metrics

Submitted results will be compared to NPDES permit discharge limits, DOE, EPA and TDEC agreed-upon-limits or water quality standards for the receiving body of water.

If a sampled area is comprised of long-term outfall sample points, trends in concentrations will be reviewed for future sampling or observations. The outfall selected sampling locations are based on current DOE D&D activities.

Sample collection will be conducted following the guidelines set forth in the *TDEC, DWR, Q*uality System SOPs *for Chemical and Bacteriological Sampling of Surface Water*, DWR-WQP-P-Q1-QSSOP-CHEM-BACT-082918. Samples will be collected at the same point and time as the DOE contractor's samples are being taken.

Analytes will be determined for each sampling site based on COCs as listed in the Contamination Migration Plan or DOE's SWPPP (Storm Water Pollution Prevention Plan).

7.1.9 References

TDEC, DWR, Quality System SOPs for Chemical and Bacteriological Sampling of Surface Water, DWR-WQP-P-01- QSSOP-Chem-Bact-082918.

DOE. (2017) Oak Ridge Reservation, Annual Site Environmental Report. DOE/ORO-2511

7.2 ACCUMULATED WATER DISCHARGES

7.2.1 Background

In general, rainwater and groundwater do not exhibit static flow behavior. Water from ORR excavations, D&D and RA operations can accumulate in pools and then flow into basements, sediment and/or stormwater basins, and subsequently permeate into soils. For example, based on past DOE D&D activities, DOE's contractors estimate volumes of water accumulated at ETTP remedial action sites range from 200 gallons to 1.5 million gallons (UCOR URS / CH2M 2018a). It

is possible accumulated water may contain at least one contaminant that needs to be treated before it is discharged into the environment.

As of November 2017, DOE listed more than 400 sites at ETTP, more than 300 sites at ORNL, more than 100 sites at Y-12, and at least eight sites off the ORR where each site is regulated by CERCLA.

Since June 2017, the following projects have been ongoing at the three major operating sites on the ORR:

1. an estimated 12,500 cubic yards of contaminated soil removal at ETTP
2. a soils excavation project estimated to be greater than 80,000 cubic yards at Y-12
3. a soil excavation project estimated to be greater than 100,000 cubic yards at ORNL

These remedial action soil excavation activities present many opportunities for rainwater and/or groundwater to accumulate and mix with hazardous and/or radioactive legacy waste. Additionally, the ORR receives on average 54 inches of precipitation per year; an extended period of rain in February 2020 resulted in greater than ten inches of precipitation on the ORR in less than two weeks. Together, the numerous ongoing ORR CERCLA remedial actions and considerable regional precipitation warrants independent oversight of DOE sampling and treatment operations at ORR excavation sites where additional wastes have possibly been generated by the accumulation and infiltration of water.

7.2.2 Related DOE Projects

Remedial activities, CERCLA, and legacy pollutant monitoring are addressed in the DOE *Oak Ridge Reservation 2017 Annual Site Environmental Report (DOE, 2018)* with the following two statements,

- *"In addition, storm water samples will be collected at potentially affected outfalls and storm water catch basins after remedial activities have been undertaken, and after they have been completed, to help gauge the effectiveness of the remediation efforts."*
- *"The results of the monitoring effort at the D&D sites, which are a subset of remedial activities, are utilized in determining the effectiveness of BMPs in controlling offsite releases of legacy pollutants."*

7.2.3 Problem Statements

The TDEC DoR-OR Accumulated Water Project focuses on the following problems:

- Water can accumulate in D&D or RA areas by entry into basins, sumps, and basements or during soil remediation activities
- Accumulated water may become contaminated and dispersed into the environment
- Each D&D project can generate diverse COCs and create different water exit pathways

7.2.4 Goals

The goals of this project are to obtain and review pertinent sampling data to evaluate DOE's D&D and RA actions and use that data to provide input for future cleanup decisions. Actions to achieve these goals are:

- Review and comment on DOE documents related to D&D work
- At various sampling sites, DOE and TDEC DoR-OR will collect co-samples at D&D and RA sites
- to monitor releases into the environment
- Observe D&D and RA activities to ensure compliance with TDEC, EPA, and DOE negotiated and agreed-to-discharge criteria
- Review DOE sampling results to ensure compliance with negotiated and agreed to release criteria.

7.2.5 Scope

- Sites with D&D and/or RA operations will be monitored, including but not limited to, the Y-12 Outfall-200 Mercury Treatment Facility headworks construction and the ORNL Molten Salt Reactor Experiment basement groundwater sump and its free-released water.
- Sampling events will be observed to ensure that proper sampling methods are used. If a contractor's standard operating procedures (SOPs) are released to this office, sampling processes will be compared to those SOPs. Otherwise, observations will be compared to industry or EPA standards.
- At various sampling sites, a maximum of three accumulated water sites, TDEC DoR-OR and DOE co-samples will be collected and analyzed to confirm that relevant treatment and discharge criteria are met.

7.2.6 Assumptions

The execution of this project is based on the following assumptions:

- Samples taken during D&D and RA activities will ensure release criteria are being met
- Co-sampling will be accomplished to confirm DOE sampling results
- Operations will be observed to ensure compliance with site-specific performance documents (Storm Water Pollution Prevention Plan (SWPPP), Comprehensive Monitoring Plan (CMP), etc.)
- Possible new or ongoing releases to the environment, which are not currently monitored by DOE, may warrant TDEC DoR-OR sampling and monitoring of these release areas

7.2.7 Constraints

- Availability of TDEC DoR-OR personnel to assist with sampling

- Availability of a suitable vehicle to transport equipment and personnel to sampling sites
- Lack of or late notification by DOE concerning water discharges or sampling events

7.2.8 Methods, Materials, Metrics

- Sample collection will be conducted following the guidelines set forth in the TDEC, DWR, *Quality System SOPs for Chemical and Bacteriological Sampling of Surface Water,* DWR-WQP-P-01- QSSOP-Chem-Bact-082918.
- Samples will be collected at the same location and time as the DOE contractor's samples are being taken.
- Submitted results will be compared to NPDES permit discharge limits, DOE, EPA and TDEC agreed-upon-limits, or water quality standards for the receiving body of water.
- If the sampled area is a long-term project, trends in concentrations will be reviewed for future sampling or observations.
- Analytes chosen for each sampling site will be based on COCs listed in the applicable ROD, CMP, or the SWPP. The available data will be compared to NPDES discharge limits and EPA CWA standards.

7.2.9 References

UCOR URS / CH2M 2018 presentation

TDEC, DWR, Quality System SOPs for Chemical and Bacteriological Sampling of Surface Water, DWR-WQP-P-01- QSSOP-Chem-Bact-082918.

8.0 SEDIMENT MONITORING

8.1 TRAPPED SEDIMENT

8.1.1 Background

A sediment trap project has been implemented each year the Tennessee Department of Environment and Conservation (TDEC), Department of Remediation (DoR) Oak Ridge Office (OR) since 2015. The project began with the monitoring of sediment quality at six locations on or near the Oak Ridge Reservation (ORR). This project has evolved over the years, resulting in changes in locations and frequencies of sampling. This program monitors for suspended sediment transported contaminants in waterways that have been impacted by past and present activities on the ORR. This method of sampling sediment can provide samples from streams that lack sediment deposition areas suitable for traditional sampling, such as the upper reaches of East Fork Poplar Creek located within the Y-12 Plant.

Contaminated sediments can directly impact benthic life and pose detrimental indirect effects on other organisms, including humans, through bioaccumulation and subsequent transfer through

the food web. Sediment-associated contaminants are recognized as an important ongoing environmental problem that impacts the uses of many water bodies. In order to assess the degree of contamination at the benthic level, attributable to the activities of the DOE, TDEC DoR-OR is collecting sediment samples for chemical analysis from tributaries that drain the ORR and enter into the Clinch River.

8.1.2 Related DOE Projects

DOE does not currently sample suspended sediments with a sediment trap device.

8.1.3 Problem Statements

Sediment is an integral component of stream ecosystems, serving as a sink for many contaminants. The sediment traps that are used for this project collect suspended sediment particles from the stream. The information gathered from the chemical analysis of these sediments reveals what is being transported downstream in the water column. The sediment traps are a means of detecting changes in sediment associated contaminants.

Work done with the sediment traps is crucial in that this type of sampling is not conducted by DOE. Contaminant releases from Y-12 can possibly be detected by the sediment traps. With the ongoing remediation work at Y-12, it is important to have the sediment traps located at East Fork Poplar Creek kilometer 23.4 (EFK 23.4) to detect releases that are out of the norm.

8.1.4 Goals

The goal of the project is to detect releases of contaminants in suspended sediments from the DOE facilities at Y-12. The data obtained from the sediment trap will be used to assess the extent of sediment transported contamination in East Fork Poplar Creek and to provide a baseline of data for comparison to future data.

8.1.5 Scope

This project will provide independent data to assist in the evaluation of East Fork Poplar Creek. The trapped sediment project will sample suspended sediment and analyze for various metals and radiological parameters.

8.1.6 Assumptions

- Sediment traps continue to function as designed.
- Maintenance is performed weekly.
- Flooding does not damage the traps or installations.
- Funding is available for chemical analysis of samples.

8.1.7 Constraints

- Exceptionally high flows during flooding events may damage the sediment trap installations and result in loss of sediment traps.
- Sustained low flows may result in insufficient yield of sediment for analysis.

8.1.8 Methods, Materials, Metrics

In order to monitor for changes in contaminant flow through sediment transport, passive sediment samplers (traps) are deployed. Biannual sampling is proposed for East Fork Poplar Creek (EFPC). Samples will be retrieved from the sediment trap at scheduled intervals throughout the year. Sediment samples will be analyzed for metals (arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, uranium, and zinc) and radiological parameters (gross α/β, gamma, Sr-89,90, isotopic U). The metals data will be compared to the Consensus Based Sediment Quality Guidelines (CBSQGs) (MacDonald et al. 2000). Radiological data will be compared to data from background locations. Since DOE does not conduct this type of sampling, there is not another relevant dataset for data comparison.

Method Summary

The standard operating procedure used for this project is the TDEC DoR-OR Standard Operating Procedure for Sediment Sampling (TDEC DoR-OR 2019). Suspended sediment samples may be collected by using fixed sediment collection devices (traps). Sediment traps are installed in a stream bed in a position where considerable water flows through the body of the trap. Suitable sites are limited in a stream and careful consideration must be given to selecting installation locations for the sediment traps. Sufficient flow and adequate depth must be sufficient to completely immerse the sediment traps.

Following a collection period of a minimum of four months at EFK 23.4 (Figure 8.1.1), the collected sediment is emptied from a sediment trap and is transferred to a clean bucket where the sediment is allowed to settle on ice for 24 to 48 hours. After the sediment is allowed to settle, the supernatant water is carefully drawn off the sample with a peristaltic pump. Sediment samples are spooned from the bucket into sample containers.

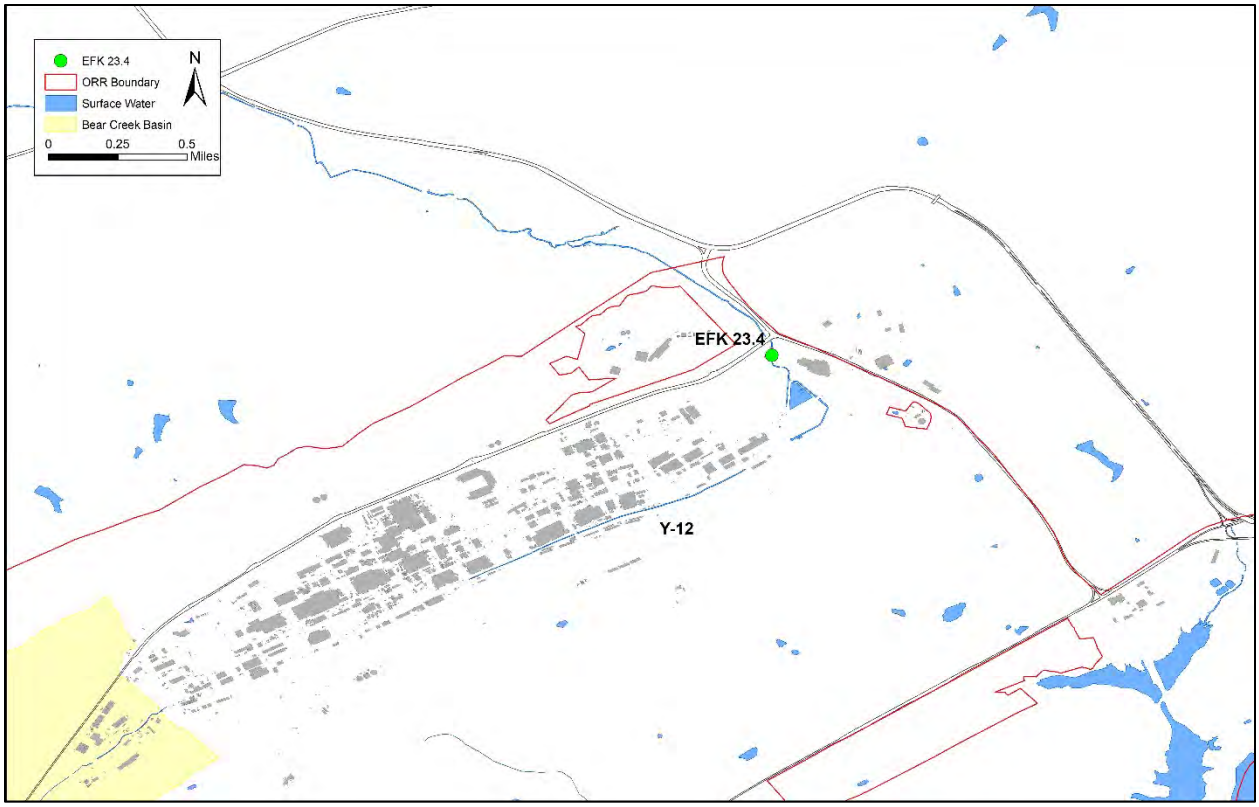

Figure 8.1.1: Sediment Sampling Station EFK 23.4

8.1.9 References

MacDonald, D. D., Ingersoll, C. G., & Berger, T. A. (2000). Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology, 39, 20–31.

TDEC DoR-OR. (2019). Quality System Standard Operating Procedure for Sediment Sampling (T-600). Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, Tennessee.

9.0 GROUNDWATER MONITORING

9.1 OFFSITE (BEAR CREEK VALLEY AND ETTP)

9.1.1 Background

Historically, offsite groundwater which is down gradient of the Department of Energy (DOE) Oak Ridge Reservation (ORR) has been monitored by both the Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office (TDEC DoR-OR) and the DOE. This project will continue this monitoring with a focus on ORR offsite areas located within the Bear Creek Valley (BCV) and southwest of the East Tennessee Technology Park (ETTP).

BCV encompasses many different DOE ORR sites. See Figure 9.1.1 for location of BCV within the ORR. The main BCV sites include (TDEC, 2015; DOE, 2017):

- Y-12 National Security Complex,
- Environmental Management Waste Management Facility (EMWMF),
- the proposed Environmental Management Disposal Facility (EMDF),
- Bear Creek Burial Grounds (BCBG), and
- Y-12 West End Mercury Area (WEMA).

Bear Creek (BC) originates within the Y-12 complex and is impacted by storm water runoff, groundwater infiltration, and BC tributaries that drain historical waste sites (BCBG) as well as the current EMWMF (DOE, 2018a). S-3 Ponds in BCV "were located on a shallow groundwater and surface water divide," and "contaminated groundwater plumes emanate from this site and extend to the east and west" (DOE,1999). The main contaminants in this area are uranium, nitrate, and cadmium (DOE, 1999). Historically, certain enrichment processes discharged large amounts of mercury into the environment, primarily from the process buildings located in the Y-12 West End Mercury Area (WEMA) (TDEC, 2015; DOE, 2017). The BCBG and oil waste management areas in BCV are also known sources of volatile organic compounds (VOCs), uranium, and other trace metals (DOE, 2018a).

Previously, TDEC DoR-OR has assessed groundwater through multiple projects (background, offsite, and springs). For FY 2020, TDEC DoR-OR will focus some groundwater assessment activities to areas within the BCV watershed. This focus on BCV will tie this project into the holistic assessment of BCV that is described in TDEC DoR-OR's Bear Creek Assessment Project. The intent of this project is to support development of a current baseline for definition of groundwater quality in the BCV. The first part of this project intends to provide greater delineation of potential groundwater impacts within the BCV to evaluate contaminant concentration distributions spatially as well as over time to guide future decisions.

The second part of this project will focus on sample stations located southwest of the ETTP. ETTP was the home of the uranium-235 gaseous diffusion enrichment process for use in atomic weapons during World War II. In addition, the facilities at ETTP historically released uranium isotopes, technetium-99, and other fission and activation products due to the processing of recycled uranium from spent nuclear reactor fuel. Currently, portions of ETTP are being transferred to industrial or public use. This project intends to provide more ETTP data combined with DOE's offsite sampling data from the ETTP area to check for potential exit pathways and potential anthropogenic impacts to groundwater.

The BCV and the ETTP study areas are connected by being in the same surface watershed, Figure 9.1.2.

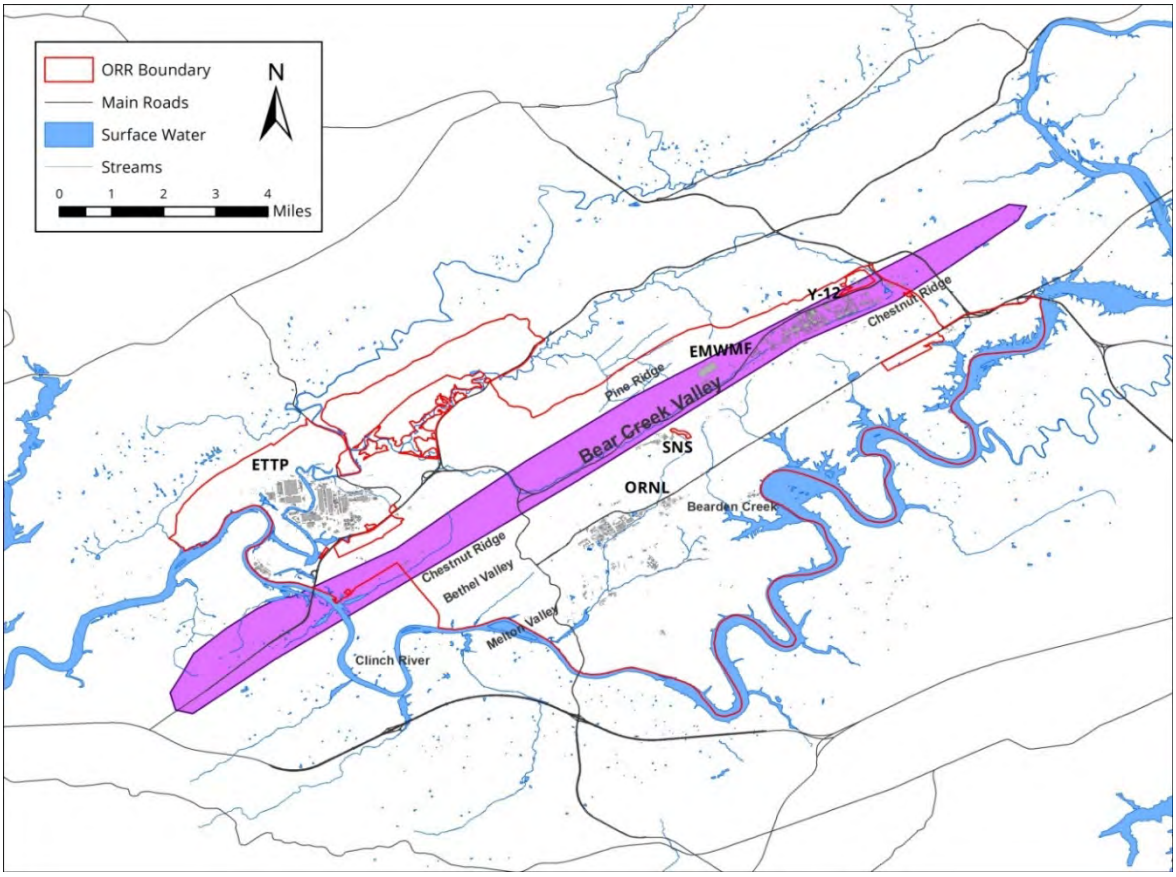

Figure 9.1.1: Map showing DOE sites and valleys within the study area. The approximate location of BCV is shown in purple.

9.1.2 Related DOE Projects

This TDEC DoR-OR Offsite Groundwater Monitoring Project correlates to current DOE projects in the following ways:

Exit pathway monitoring is currently conducted by DOE within the BCV and offsite ETTP areas. This project will provide additional data to support continued assessment of ORR legacy contamination which may be migrating offsite, past the boudaries of the ORR.

Currently, the EMWMF discharges to watersheds located in the BCV and ETTP offsite areas. It is anticipated that the proposed EMDF will also dicharge to these same watersheds. This groundwater project intends to provide additional relevant data to support delineation of potential impacts to water quality that may be attributed to those facilities in the future and for comparison to current site conditions.

DOE sampling areas are based on surface watersheds (Figure 9.1.2), primarily because remedial decisions on the ORR have been made at the watershed scale due to surface water being a major

exit pathway for contaminants (DOE, 2018c). DOE bases the current groundwater conceptual site model (CSM), which guides assessment modeling and clean up decisions, on surface water watersheds as well. Focused sampling in surface watersheds will provide data sets collected at a similar time frame for standardized constituents to support future decisions.

Delineating offsite impacts and potential additional offsite impacts to groundwater located down gradient in BCV and offsite ETTP, will provide guidance for TDEC DoR-OR groundwater decisions for future ORR Federal Facility Agreements (FFA).

The 2018 RER (DOE, 2018c) states that to *"reduce further migration of contaminants offsite"* and to *"address sources of offsite surface water and groundwater contamination"* are priorities for remediation work.

During FY 2021, DOE plans to sample ten groundwater wells located within BCV and southwest of ETTP as part of the Remedial Site Evaluation (RSE) Phase 2 project (DOE, 2018b).

"Groundwater quality data obtained during CY 2017 from the exit pathway monitoring wells indicate that groundwater is contaminated above drinking water standards in the Maynardville Limestone" (DOE, 2018a). The exceedances include gross-alpha activity, nitrate, barium, cadmium, nickel, and uranium (DOE, 2018a). With these exceedances, ORR offsite monitoring needs to continue.

There is a surface water divide within BCV where surface water flows both southwest and northeast. The northeastern portions of this area have been sampled rarely by TDEC DoR-OR. As stated in the 2017 DOE Annual Site Environmental Report (ASER*), "the surface water in Bear Creek, the springs, and the groundwater in the Maynardville Limestone are hydraulically connected"* (DOE, 2018a). The interconnected nature of surface water and groundwater is a key component of evaluating groundwater flow in BCV. Assumptions in the DOE groundwater strategy CSM imply that the region's shallow groundwater may also follow the BCV surface water divide structure. Groundwater and contaminant transport throughout BCV are shown in the conceptual site model in Figure 9.1.3 (https://public.ornl.gov/orifc/orfrc3_site.cfm).

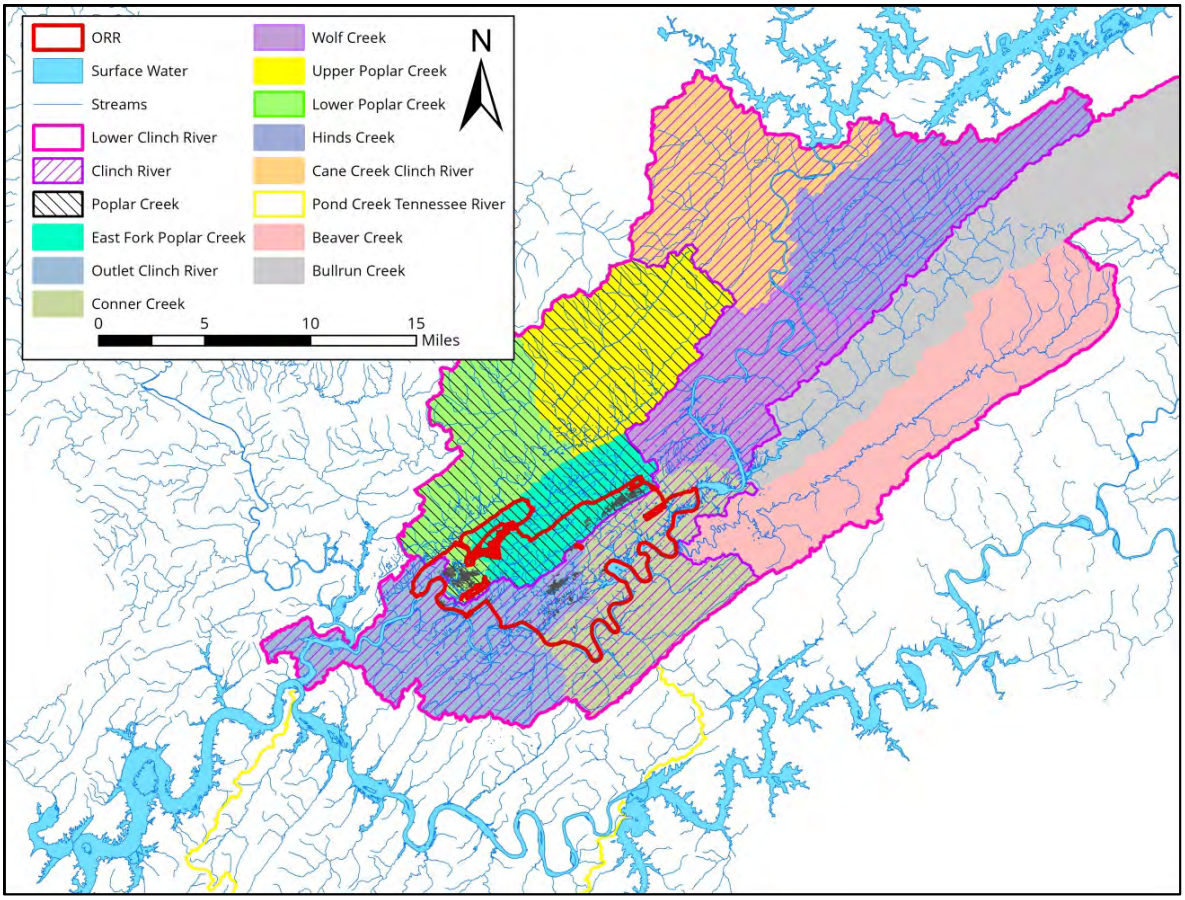

Figure 9.1.2: Map showing surface watersheds (TNGIS, no date)

The 2018 DOE ASER states *"Contaminant conditions in the groundwater exit pathway areas are generally stable and similar to conditions in the recent years (DOE, 2019a)."* The East Tennessee Technology Park Main Plant Groundwater Feasibility Study states there are no offsite receptors and that there is no risk offsite. The study focuses on volatile organic carbons (VOCs) and technetium-99 (DOE, 2019b). This TDEC project intends to ascertain if there are any offsite anthropogenic impacts in groundwater by sampling for VOCs, inorganics, metals, and radiochemical analytes.

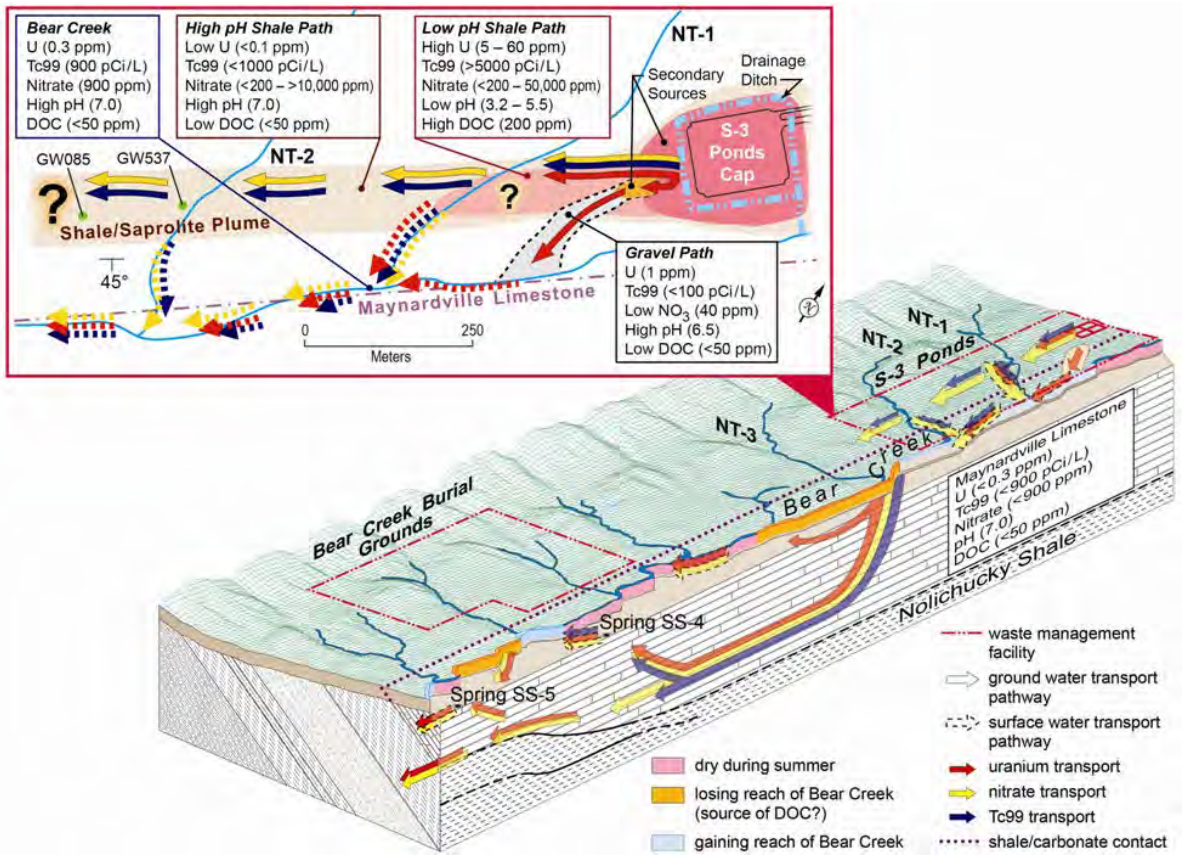

Figure 9.1.3: Source zones and flow paths in BCV watershed (https://public.ornl.gov/orifc/orfrc3_site.cfm).

9.1.3 Problem Statements

- Delineation of the nature and extent of groundwater contamination is incomplete in many areas of the ORR (DOE, 2018c). Groundwater in BCV was contaminated mainly due to Y-12 waste disposal and uranium separation operations. The disposal of Y-12 acidic liquid wastes at the S-3 site caused a reduction in groundwater pH (DOE, 2018a). This reduction in pH decreases metal precipitation, so metals stay in solution longer and migrate away from the source areas (DOE, 2018c). The most prevalent trace metal in BCV is uranium where a major source is the Boneyard Burnyard site (DOE, 2018a). VOCs are widespread in BCV and may occur at depths up to 300ft (92m) bgs (DOE, 2018a).

- Contaminant plumes in BCV are defined by DOE as elongated due to groundwater preferentially migrating parallel to strike (to the south and southwest) (DOE, 2018a). Groundwater, surface water, and springs are hydraulically related. Exit pathway monitoring wells have indicated that groundwater in the Maynardville Limestone is contaminated (DOE, 2018a). Monitoring to evaluate the extent of plume migration along strike should continue to support protection of human health and the environment.

- The East Tennessee Technology Park Main Plant Groundwater Feasibility Study states there are no offsite receptors and that there is no risk offsite. The study focuses on VOCs and technetium-99 (DOE2019b). DOE's Remedial Site Evaluation Phase 2 Offsite Detection Monitoring Work Plan collects samples from five stations southwest of ETTP, and the samples are analyzed for VOCs, gross alpha, gross beta, uranium-233/234, uranium-235/236, uranium-238, and select fission products (DOE, 2018b). TDEC DoR-OR monitoring in the same area for a full suite of analytes (VOCs, metals, inorganics, and radionuclides) will assess if there are health risks to receptors located offsite the ORR.

9.1.4 Goals

TDEC DoR-OR's Offsite Groundwater Monitoring Project intends to collect groundwater samples from sites located to the southwest and northeast of Y-12 within BCV and southwest of ETTP to detect and evaluate potential legacy contaminant migration and to establish a baseline to facilitate assessment of groundwater quality in these areas. The project will assist the FFA cleanup decision-making process by providing additional data and information to support an understanding of current site conditions that will be used in future decision-making processes. In addition, the project will assist with FFA ORR groundwater decisions for the BCV and offsite ETTP areas by evaluating additional potential exit pathways.

The project will provide information to support the holistic assessment of BCV being conducted by the TDEC DoR-OR. The offsite groundwater work will evaluate onsite BCV groundwater data collected by DOE to allow for comparisons between onsite and offsite groundwater.

The overarching goal of this project is to identify contaminants detected in offsite groundwater samples and delineate their possible sources to better understand the nature and extent of BCV and ETTP related contamination and associated contaminant transport pathways.

9.1.5 Scope

The main project objectives are:

- Collect groundwater samples from residential groundwater wells or springs (18 total locations; 20 samples total with QA/QC)
    - Northeast in BCV: approximately 3 locations
    - Southwest in BCV: approximately 8 locations
    - Southwest of ETTP: approximately 7 locations
    - 2 QA/QC samples, duplicates will be taken with samples 9 and 18.
- Evaluate and analyze sampling data for potential constituents of concern (COCs) and water chemistry

- Use graphing and mapping technology to determine possible trends between sampling areas in BCV (northeast and southwest of ORR).

Some of the analytes are naturally occurring, while some are contamination signatures. Some chemicals (e.g., metals and some radionuclides) exist in nature, but their concentrations may be impacted by or increased to levels that pose risks to human health and the environment through the release of legacy contaminants.

Parameters including alkalinity, pH, and total hardness will be measured to help characterize geochemical conditions or groundwater types within the aquifer.

Approximately 18 locations will be sampled and quality assurance/ quality control (QA/QC) samples will be collected from approximately 10% of the sample locations for a total analytical set of 20 samples including two duplicates. Groundwater samples will be collected from residential wells and springs, some may have been previously sampled by TDEC DoR-OR. The potential sampling stations in addition to DOE's Remedial Site Evaluation Phase 2 Offsite Detection Monitoring Work Plan sampling stations are shown in Figures 9.1.4 and 9.1.5.

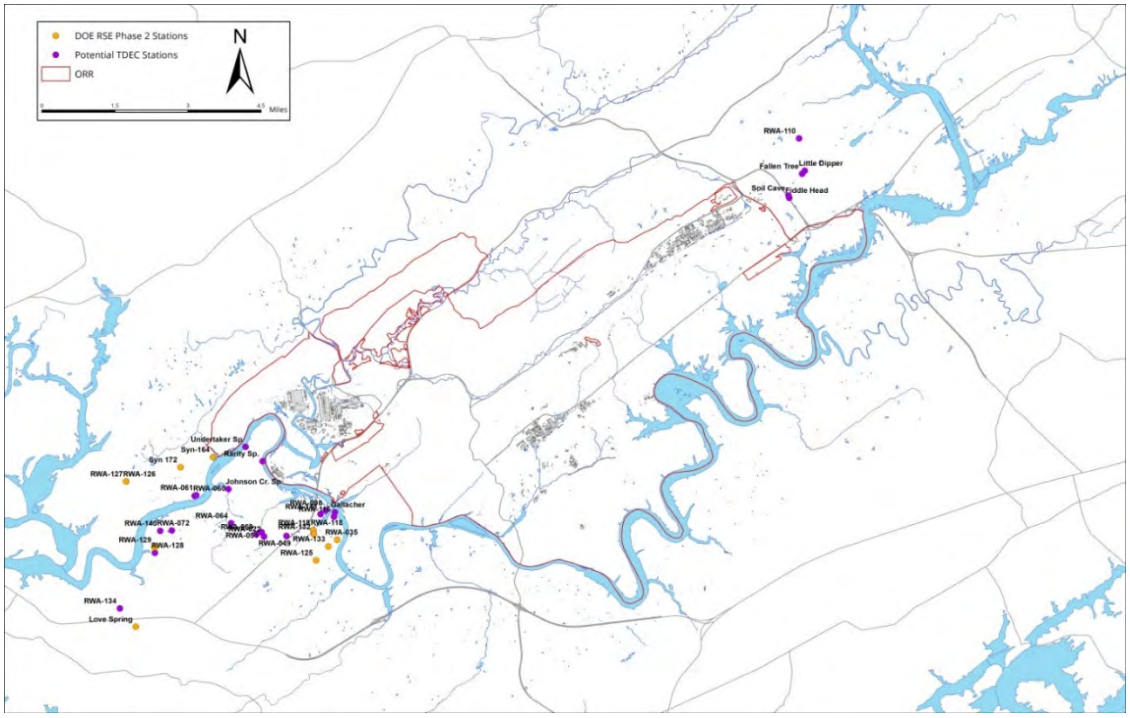

Figure 9.1.4: Map showing the potential TDEC FY2021 sample locations and DOE RSE Phase 2 sample locations.

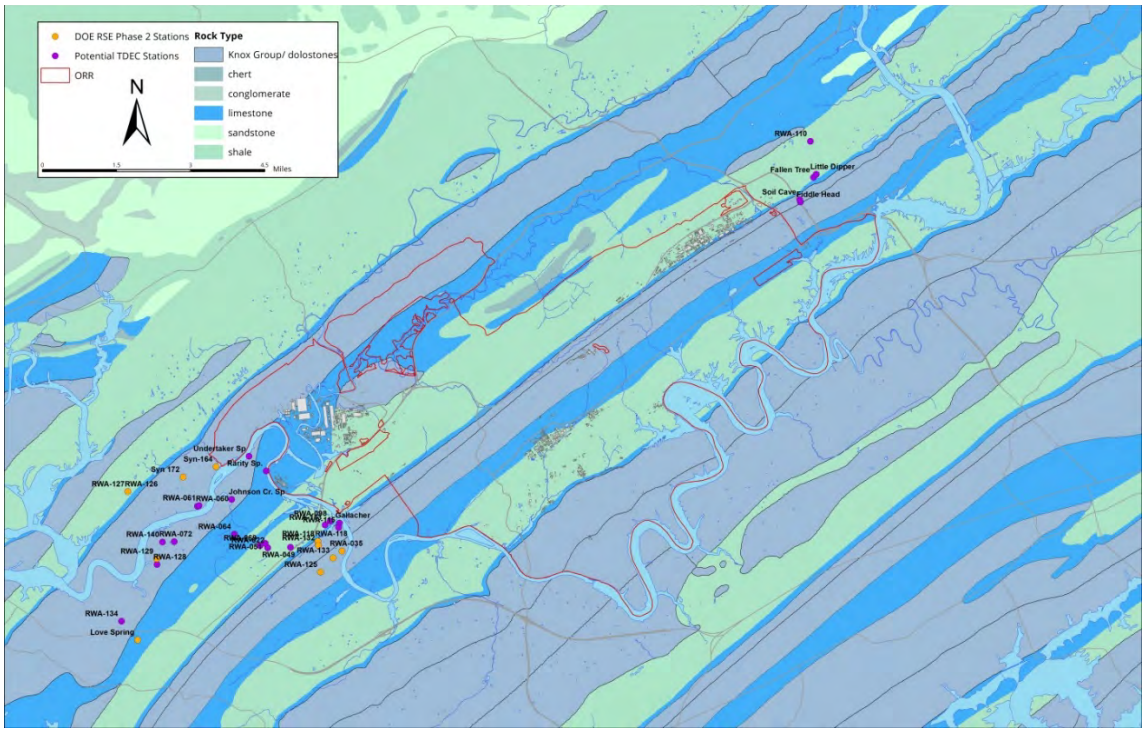

Figure 9.1.5: Geologic map showing the potential TDEC FY2021 sample locations and DOE RSE Phase 2 sample locations.

9.1.6 Assumptions

The assumptions for the project are:

- Funding for this project will be sufficient for the entire analyte suite for the proposed number of samples.
- Residents will be willing to have their wells sampled.
- Residents have accessible groundwater wells.
- State and contracted laboratories will report sample results in an efficient and timely manner.
- Unforeseen budget shortages will not inhibit sampling.

9.1.7 Constraints

A few constraints may impact this project:

- Residents interviewed may not want to participate in the groundwater well study.
- The budget and laboratory costs may change during the fiscal year.
- It may be difficult or impossible to bypass filtration systems, water softeners, etc. which would affect the quality or usefulness of the data.

- Lack of information on well construction such as depth may make data interpretation and analysis difficult.
- Planned spring sampling locations may be difficult to navigate to and some may be overflow (dependent on rain amounts).

9.1.8 Methods, Materials, Metrics

Groundwater samples will be collected from approximately 18 locations with QA/QC samples from at least 10% of the locations. The residential well groundwater samples will be collected from an outside tap located as close to the well as possible and before water passes through filtration and water softener systems. Wells that are not in use and have no viable dedicated pump system may be sampled by a peristaltic or bladder pump depending on well conditions as appropriate. Springs shall be sampled utilizing a dipper or a peristaltic pump.

Any wells or spring locations being sampled by TDEC DoR-OR may be co-sampled with DOE contractors.

The field parameters that will be measured include temperature (°C), electrical conductivity (µS/cm), pH (SU), oxidation reduction potential (mV), dissolved oxygen (mg/L), and turbidity (NTU). Wells will be purged until the volume of water stored in the pressure tank or other water storage container has been removed and field parameters become stable. Field parameter stabilization is defined as four consecutive readings presented in Table 9.1.1.

Table 9.1.1: Water Quality Indicator Parameters

Measurement (units)	Normal Range	Acceptable Variability[1]
Temperature (°C)	10 to 18	± 10%
pH (SU)	4.6 to 8.5	± 0.1
Specific Conductivity	10 to 8,000	± 5%
Turbidity (NTU)	variable	± 10%
ORP[Eh](mV)	variable	± 10 mv

[1] Acceptable variability over four consecutive readings.

°C -Degrees Celsius
µS/cm -MicroSiemens per centimeter
mV -Millivolt
NTU -Nephelometric turbidity unit
SU -Standard Units
ORP -Oxidation Reduction Potential
Eh -Reduction Potential

Samples will be sent to the TDH (Tennessee Department of Health) Division of Laboratory Services within specified holding times for VOCs, inorganics, and radiochemical analyses. Table 9.1.2 lists the proposed analyte list which is comprehensive. Although "the primary groundwater contaminants in the Bear Creek regime are nitrate, trace metals, VOCs, and radionuclides", the list is extensive due to EMWMF and other waste burial sites within the valley (DOE, 2017).

The data will be compared to the National Primary Drinking Water Regulations (NPDWR) (U.S. Environmental Protection Agency (EPA), 2009) and National Secondary Drinking Water Regulations (NSDWR) (EPA, no date). When neither of these criteria are available for a particular contaminant, the data will be compared to other EPA standards including: Regional Screening Levels (RSLs) (EPA, 2017), Lifetime Health Advisory Values (LHAV) (EPA, 2012), or Preliminary Remediation Goals (PRG) (EPA, no date). These EPA standards align with Tennessee public water utility standards.

A summary package of the sample results will be prepared and provided to the well owners. Residents whose groundwater well contaminants exceed EPA drinking water criteria or who would like health information will be referred to TDH for a health consultation.

Table 9.1.2: Proposed Analyte List

VOCs		
EPA 8260 B list for low level detection[1]		
METALS		
aluminum	copper	selenium
antimony	iron	silver
arsenic	lithium	sodium
barium	lead	strontium
beryllium	magnesium	thallium
boron	manganese	uranium
cadmium	mercury	vanadium
calcium	nickel	zinc
chromium	potassium	total hardness, as calcium
INORGANICS		
calcium carbonate	total dissolved solids	nitrate and nitrite
chloride	sulfate	ammonia
fluoride		
RADIONUCLIDES		
gross alpha	tritium	radium-228
gross beta	gamma	isotopic uranium
strontium-89	technetium-99	transuranic radionuclides
strontium-90	radium-226	

[1] EPA-8260 B- volatile organic compound analyses list: https://www.epa.gov/sites/production/files/2015-12/documents/8260b.pdf

[2] gamma list includes: Ra-226, Pb-210, Pb-212, Pb-214, Tl-206, Tl-208, Bi-212, Bi-214, K-40

The TDEC DoR-OR offsite data will be compared to onsite groundwater data collected by DOE. The data will also be compared to historical TDEC DoR-OR groundwater data. Results will be plotted in formats that will include Piper Diagrams, basic geochemistry plots, various radiochemical plots, and contaminants of concern (COC) plots to evaluate BCV concentrations spatially and temporally.

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9.2 HISTORICAL GROUNDWATER TRENDS

9.2.1 Background

The primary intent of Tennessee Department of Environment and Conservation Division of Remediation Oak Ridge (TDEC DoR-OR) groundwater projects has been to protect human health and the environment by monitoring for possible U.S. Department of Energy (DOE) legacy contamination that may migrate from the Oak Ridge Reservation (ORR) into the surrounding areas.

Groundwater samples have been collected and analyzed by TDEC DoR-OR since the late 1990s. In the beginning, only springs and offsite groundwater wells located south and southwest of ORR were sampled. Background groundwater samples collected from residential wells and springs located north and northeast of the ORR were added to the groundwater program in 2016. This background sampling was added to establish a baseline for groundwater on the ORR and its surrounding areas. In 2009, the analyte list was increased to include cations, anions, metals, as well as individual radionuclides and transuranics (not just gross alpha and gross beta). At that time, the radiochemical counting times for radiological analytical tests were increased as well. Due to these actions, the analytical data was significantly enhanced.

While data has been collected by TDEC DoR-OR and DOE for many years, a comprehensive TDEC DoR-OR data evaluation of trends over time has not been completed. Phase 1 of the Historical Groundwater Trends Project (analyzing the dataset from 2016-2019) was completed in FY 2020.

9.2.2 Related DOE Projects

The different phases of the Historical Groundwater Trend Project will evaluate and summarize previous TDEC DoR-OR groundwater projects, encompassing approximately twenty years of data. This data may be used to assess data gaps in the current monitoring programs and should help guide future TDEC DoR-OR groundwater sampling efforts and offsite groundwater decisions.

Although this project will focus on TDEC DoR-OR data, it correlates to the DOE groundwater related projects across the ORR, including:

- Melton Valley/Bethel Valley Exit Pathway Remedial Investigation Work Plan (DOE, 2018a)
- East Tennessee Technology Park Main Plant Groundwater Feasibility Study (DOE, 2019)
- Offsite Groundwater Assessment Remedial Site Evaluation projects (DOW, 2018b)
- Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation (DOE, 2014)

9.2.3 Problem Statements

TDEC DoR-OR offsite groundwater samples have been collected and analyzed since the late 1990s. There have been little to no trend analyses performed on the historical analytical data. This makes it challenging to look at the spatial data temporally and draw conclusions for future work both on and off the ORR. TDEC DoR-OR's offsite groundwater data includes residential wells, background residential wells, and springs adjacent to the ORR. The analytical and trend analysis datasets are currently housed separately but should be combined and evaluated holistically. A lack of a trend analysis for the historical analytical dataset impairs TDEC DoR-OR's information review and project planning. A solid understanding of current site conditions and historical impacts are needed to support complete and informed Federal Facilities Agreement (FFA) decision making relating to groundwater. This project will also enhance TDEC DoR-OR's monitoring and oversight of the DOE ORR cleanup process.

9.2.4 Goals

The Historical Groundwater Project is intended to organize and analyze historical TDEC DoR-OR data from offsite and background wells and springs. The project will illustrate possible trends through time and relate them spatially.

The main objectives are:

- Compare TDEC DoR-OR historical laboratory data from offsite wells, background wells, and spring locations.
- Make a table with wells, analytes sampled, year sampled, etc.
- Use graphing and mapping technology to determine possible trends.
- Make recommendations on future sampling including locations and sample analytes.

9.2.5 Scope

The project for Phase 2 will encompass the second dataset, 2010-2015 TDEC DoR-OR laboratory and available field data. This project encompasses a large amount of data and will be broken up into five-year increments, to follow DOE's five-year review model as seen in the Remediation Effectiveness Report (RER) requirements.

- Phase 1: 2016-2021; FY-2020
- Phase 2: 2010-2015; FY-2021 (this project)
- Phase 3: 2004-2009; FY-2022
- Phase 4: 2003-1998/1996; FY-2023
- Phase 5: Combine all the datasets into one analysis

9.2.6 Assumptions

- The historical data is organized and easily accessible.
- The historical datasets are complete and accurate.

9.2.7 Constraints

- Lack of complete datasets or datasets evaluated for different analyses may impede interpretation and analysis for some constituents.
- Lack of information on physical parameters, original sampling location information including well construction details such as depth, water level and/or age may make data interpretation and analysis challenging.

9.2.8 Methods, Materials, Metrics

Existing analytical data will be gathered and where required (such as where data is only available as a hard copy) will be digitized. Statistics, tables, graphs, and maps may be generated using various statistical methods, graphing, and mapping technology. This technology includes but is not limited to software such as Excel, R programming, and GIS. The analyses conducted will include basic geochemical assessment tools including diagrams such as ternary diagrams, trend graphs, and piper plots. Contaminants of concern (COCs) will also be graphed and mapped to show any possible temporal and spatial trends as well as potential fingerprint patterns for constituent combinations from various wells.

Care will be taken to manage original and secondary data sets to preserve laboratory data information as well as standardize the reporting formats.

The analyses, maps, and graphs will correlate with and/or match the Phase 1 dataset report.

9.2.9 References

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10.0 WATERSHED ASSESSMENTS (HOLISTIC) MONITORING

10.1 BEAR CREEK VALLEY ASSESSMENT

10.1.1 Background

This project involves an intensive evaluation of the environmental health of the Bear Creek Watershed. It involves field sampling of surface water, sediment, soils, vegetation, toxicity, fish, benthic macroinvertebrates, and other biota (bird eggs, insects, spiders and crayfish) at Bear Creek kilometer (BCK) 3.3, BCK 4.5, BCK 7.6, BCK 9.6, and BCK 12.3. A background stream, Mill Branch, will be sampled at kilometer 1.6 (MBK 1.6). The surface water sampling component of the Bear Creek Assessment Project (BCAP) was conducted in 2019. Sampling of the other environmental media is planned for the 2020-2021 fiscal year.

The BCK 12.3 site is representative of the headwater's region of the stream. BCK 9.6 is located at the downstream end of Bear Creek Remediation Zone 3. Similarly, BCK 7.6 is located at the downstream end of Bear Creek Valley Zone 2. BCK 4.5 is located at the point where Bear Creek leaves the Y-12 restricted area at the downstream extent of Zone 1. The offsite region of Bear Creek is represented by BCK 3.3; this section of the stream from BCK 4.5 downstream to Poplar Creek is not restricted from public access by the Department of Energy (DOE).

10.1.2 Related DOE Projects

Although DOE conducts environmental sampling of surface water, toxicity, fish and benthic macroinvertebrates, it has not been determined if they sample sediment, soils, vegetation, or biota (bird eggs, adult insects, spiders, and crayfish) in the Bear Creek Watershed. G.R. Southworth and others conducted an ecological study of Bear Creek that included surface water,

sediments, fishes, benthic macroinvertebrates, and toxicity monitoring. The report, *Biological Effects of Contaminants and Remedial Actions in Bear Creek*, was published in January of 1992.

10.1.3 Problem Statements

DOE has not conducted a comprehensive assessment of BCK 3.3 or areas downstream on Bear Creek; this project is being conducted to assure the public that the areas of Bear Creek outside of the Y-12 restricted area are safe for recreation. Another purpose for this project is to provide a baseline of environmental data prior to the construction of the proposed EMDF landfill.

10.1.4 Goals

- To provide an intensive evaluation of Bear Creek in order to provide a baseline for future reference after the construction of the proposed EMDF landfill.
- To assure that the sections of Bear Creek accessible to the public do not pose a health threat to those using the area for recreation.

10.1.5 Scope

- The scope of this project is limited to the environmental assessment of Bear Creek through sampling and analysis of surface water, surface water toxicity, sediment, soil, benthic macroinvertebrate communities, fish tissue, vegetation, and other biota tissue (bird eggs, crayfish, adult insects, and spiders). The stream reach being assessed is from the mouth of Bear Creek at East Fork Poplar Creek km 2.2 (EFK 2.2) to BCK 12.3. The only sampling that will take place at EFK 2.2 will be for fish; namely Rock bass (Ambloplites rupestris), since this is one of the fish species most likely to be consumed by anglers at Bear Creek.
- The sampling locations are listed in Table 10.1.1.

Table 10.1.1 Sampling Locations

Site Description	name	lat	long
Bear Creek Kilometer 3.3	BCK 3.3	35.94354	-84.34911
Bear Creek Kilometer 4.5	BCK 4.5	35.93731	-84.34013
Bear Creek Kilometer 7.6	BCK 7.6	35.95096	-84.31395
Bear Creek Kilometer 9.6	BCK 9.6	35.96032	-84.29741
Bear Creek Kilometer 12.3	BCK 12.3	35.97300	-84.27814

- For the biota background/reference samples, one or more of the locations in Table 10.1.2 will be used. The sites named REF in Table 10.1.2 are sites located in narrow coves of the Clinch River.

Table 10.1.2 Biota Background / Reference Locations

Site Description	name	lat	long
Mill Branch Kilometer 1.6	MBK 1.6	35.98886	-84.28940
Emory	REF	36.02698	-84.19983
Union	REF	36.02209	-84.18517
Haw	REF	36.01142	-84.16819

10.1.6 Assumptions

- Sampling devices continue to function as designed.
- Weather will allow for sampling to take place.
- Funding is available for chemical analysis of all samples.
- Biota sampling has sufficient yield for all analyses.
- Staff is available to conduct data collection, field work, and report writing.

10.1.7 Constraints

- Funding may not be sufficient to conduct all sampling as planned.
- Exceptionally high flows during flooding events may damage sediment trap installations and result in loss of sediment traps.
- Sustained low flows may result in insufficient yield of sediment for analysis.
- Low yield of biota sampling may not be sufficient for analysis.
- Staff may be unavailable for data collection, field work, and report writing.

10.1.8 Methods, Materials, Metrics

- **Vegetation** sampling will be conducted one time in March-April of 2021 at all sampling locations in Table 10.1.1, except for BCK 7.6 as vegetation there is unsuitable. Also, MBK 1.6 will be sampled as a background site. Herbaceous terrestrial plant parts (soft leaves and shoots) living in the flood plain are harvested by hand with scissors in order to obtain the samples. Samples will be analyzed for gross alpha, gross beta, Sr-89,90, isotopic uranium, and metals (As, Ba, Be, B, Cd, Cs, Cr, Cu, Pb, Hg, Ni, Se, Sr, U, and Zn). The vegetation samples will be shipped to the Tennessee Department of Health (TDH) Laboratory Services in Nashville for analysis.
- **Toxicity** sampling will be conducted in the fall of 2020 for each location in Table 10.1.1. Mill Branch (MBK 1.6) will also be sampled as a background site. Two gallons of stream water will be collected at each of the sampling sites listed in Table 10.1.1 and MBK 1.6 listed in Table 10.1.2 each day for one week and then shipped to Pace Analytical Lab for testing. Testing will include survival and reproduction for *Ceriodaphnia dubia* and fathead minnows (*Pimephales promelas*).

- **Soil** sampling will occur once in the fall of 2020 at each location in Table 10.1.1 and at Mill Branch km 1.6 (background location). Samples will be collected by hand auger to a depth of six inches. Several samples will be collected at each location and composited for the sample submitted for analysis. Samples will be analyzed for gross alpha, gross beta, Sr-89,90, isotopic uranium, semivolatiles, PCBs, pesticides, and metals (As, Ba, Be, B, Cd, Cs, Cr, Cu, Pb, Hg, Ni, Se, Sr, U, and Zn).
- **Fish** sampling will take place once in the fall of 2020 at three locations: BCK 3.3, EFK 2.2, and at the background stream, Hinds Creek (HCK 20.6). Fish will be collected by electroshocking. Rock bass fish tissue will be analyzed for gross alpha, gross beta, gamma radionuclides, Sr-89,90, isotopic uranium, isotopic Pu, Pu-241, C-14, Po-210, Tc-99, semivolatiles, PCBs, dioxins/furans, pesticides, and metals (As, Ba, Be, B, Cd, Cs, Cr, Cu, Pb, Hg, MeHg, Ni, Se, Sr, U, and Zn). The fish sampling will be a cooperative activity with the Oak Ridge National Laboratory's (ORNL) Environmental Sciences Division (ESD). Analysis of the fish tissue will be conducted by ALS Laboratory.
- **Biota** sampling will occur over the period from April – August 2020 at five locations in the Bear Creek floodplain (see Table 10.1.1) and from one or more of the reference sites listed in Table 10.1.2. The sampling plan for these sites includes collecting duck and bird eggs, spiders, adult insects, and crayfish. Biota samples will be analyzed for gross alpha, gross beta, gamma radionuclides, Sr-89/90, Tc-99, and metals (As, Ba, Be, B, Cd, Cs, Cr, Cu, Pb, Hg, MeHg, Ni, Se, Sr, U, and Zn).

  Waterfowl:

  Wood duck nest boxes have been installed at five Bear Creek locations and four reference locations. Duck boxes will be checked periodically to determine occupancy. Once a nest box is confirmed to have a duck or bird occupant, the box is checked twice per week to collect the initial eggs for analysis. Wood ducks, mallards, teal, (either green or blue-winged), and hooded mergansers are the target species. The breeding season for wood ducks runs from March through August, and there may be a second brood. If other species occupy a nest box, then its eggs may be sampled as surrogates for the duck eggs.

  Songbirds:

  Songbird nest boxes have been installed at five Bear Creek locations and four reference locations on the ORR. Songbird nest boxes will be checked periodically to determine occupancy. Once a nest box is confirmed to have a bird occupant, the box is checked twice per week to collect the 1st-laid and 2nd-laid eggs for analysis. Based upon the TDEC DoR-OR 2018 egg sample results, Hg concentrations were greater in 1st-laid eggs than in the 2nd-laid eggs (TDEC, 2018). Songbird breeding season runs from March-August and may have two broods per season.

Spiders:
Spiders, mainly Wolf and Fishing spiders, will be sampled by TDEC DoR-OR staff at five Bear Creek sites and at Mill Branch (MBK 1.6). Sampling activities will occur between May and August 2020. During night hours, flashlights held at eye level will locate the reflective spider eyes near the stream shoreline or adjacent floodplain area (Northam et al., 2011). Then, the spider will be retrieved using either the aquarium net or 12-inch forceps. During collection, spider specimens will be placed into plastic cups with lids, to prevent escape, until ≥ 5 grams of biomass is achieved per sample.

Adult Insects:
Insects will be sampled by DoR-OR staff at five Bear Creek sites and at Mill Branch (MBK 1.6). ORR insects will be collected between May and August 2020 with a black light collector device ("Larry's Lighthouse"-BioQuip Products, Inc.). Nocturnal insects are attracted to the black light which provides maximum insect response from as far away as 500 meters from the light source. The Larry's Lighthouse device has a white mesh globe, no-see-um material, with the black light inside that attracts the insects after dark. After numerous insects have landed on the globe, they are hand collected using an aspirator vacuum tool which sucks the bugs off the white no-see-um mesh globe and secures them in replaceable sample vials.

Crayfish:
Crayfish will be sampled by DoR-OR staff at five Bear Creek sites and at Mill Branch (MBK 1.6). Crayfish will be collected between May and August 2020. Crayfish will be collected from the stream banks and benthic substrates using aquatic dip nets or 1-meter 2 kick sampling nets (Hauer and Resh, 1996).

Sampling and Handling at the TDEC DoR-OR Laboratory (all biota samples):
In the TDEC DoR-OR laboratory, all biota samples will be weighed to the nearest 0.01 gram and recorded in the laboratory sample log. Biota will be classified at least to Family or genus and sorted to create approximately 5 grams of biomass for each sample. Egg samples will be weighed to the nearest 0.01 gram. Measurements of egg width, breadth, and eggshell thickness will be recorded with a digital micrometer in millimeters. Some egg samples will be boiled to facilitate separation of shell, yolk and albumen. All biota samples will be placed into special 2-oz QEC (Quality Environmental Containers, Beaver, WI) Level 2 pre-cleaned glass jars with labels and screw-top plastic lids. These sample jars will be stored at -18ºC in the TDEC DoR-OR laboratory freezer until shipment to PACE Analytical Services, LLC for analysis.

Analytical Laboratory Methods:
Biota samples chain of custody forms will be forwarded to the Tennessee Department of Health Nashville Environmental Laboratory (TDH-NEL). TDH-NEL will ship all samples directly to the Green Bay, WI PACE Analytical Services, LLC Laboratory for assays of Hg, MeHg, radiochemistry and metals.

Analytical Shipping Protocol:
Biota samples will be packed and shipped to the Green Bay, WI PACE Analytical Services, LLC Laboratory as specified in "Procedures for Shipping Samples to the State Lab in Nashville" (TDEC, 2015).

Data Analysis:
TDEC DoR-OR biota data results will be compared to available DOE biota datasets in OREIS. The Hg, MeHg, and radiological analytical data information will be normalized to account for differences in body mass, and where applicable, among and between species. Total Hg versus MeHg graphs and figures will be generated to compare among sites on the ORR and reference sites. Total Hg and MeHg concentrations and radiological contaminants will be compared among feeding guilds, by diet which includes insectivores, omnivores, and herbivores.

- **Sediment** sampling will take place at four locations twice during the year; sampling locations are: NT-5, BCK 7.6, BCK 3.3, and MBK 1.6. Suspended sediment samples will be collected by using fixed sediment collection devices (traps). Sediment traps are installed in a stream bed in a position where considerable surface water flows through the body of the trap. Suitable sites are limited in a stream and careful consideration must be given to selecting installation locations for the sediment traps. Sufficient flow and adequate depth must be sufficient to completely immerse the sediment traps.

  Following a collection period of a minimum of four months, the collected sediment is emptied from a sediment trap and is transferred to a clean bucket where the sediment is allowed to settle for 24 to 48 hours. After the sediment is allowed to settle, the supernate is carefully drawn off the sample with a peristaltic pump. Sediment samples are spooned from the bucket into sample containers. Sediment samples will be analyzed for gross alpha, gross beta, gamma radionuclides, Sr-89,90, isotopic uranium, semivolatiles, PCBs, pesticides, and metals (As, Ba, Be, B, Cd, Cs, Cr, Cu, Pb, Hg, Ni, Se, Sr, U, and Zn). The sediment samples will be sent to TDH Lab Services for analysis.
- **Benthic macroinvertebrates** will be sampled in the spring of 2021 at BCK 12.3, BCK 9.6, and BCK 3.3. Various population metrics will be determined from the sample compositions. Information about the methods and materials used can be found in the benthic community health monitoring plan.

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