TENNESSEE DEPARTMENT
OF
ENVIRONMENT AND CONSERVATION

DIVISION OF REMEDIATION
OAK RIDGE OFFICE

ENVIRONMENTAL MONITORING REPORT
For Work Performed:
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ACRONYMS

A	Ac-228	actinium-228
	Am-241	americium-241 (transuranic isotope)
	ANOVA	analysis of variance in statistics
	ARARs	Agency for Toxic Substances and Disease Registry
	As	arsenic (metal)
	ASER	Annual Site Environmental Report (DOE)
	ATSDR	Agency for Toxic Substances and Disease Registry
	AWQC	Ambient Water Quality Criteria
B	Ba	barium (metal)
	Background site	reference site: background site located outside of a 5-mile radius of potential impact from the Oak Ridge Reservation
	BCK	Bear Creek Station or Bear Creek Kilometer
	BC	blue catfish
	BCAP	Bear Creek Assessment Project
	BC/BCK/BCV	Bear Creek/Bear Creek kilometer or station/Bear Creek Valley
	BCBGs	Bear Creek Burial Grounds
	Be-7	beryllium-7 (metal)
	Benthic Life	Organisms that live on or in the streambed (insects, amphibians, spiders, worms, etc.)
	Bi-214	bismuth-214
	Biocides	Any product or substance used in a cooling tower which is intended to destroy, control or prevent the effects of algae, bacteria, sulfate-reducing bacteria, protozoa, and fungi.
	Bo	boron (metal)
C	CAA	Clean Air Act
	CBSQG	Consensus Based Sediment Quality Guidelines
	CC	channel catfish
	CC/CCK	Clear Creek/Clear Creek kilometer (background stream)
	CCME	Canadian Council of Ministers for the Environment
	Cd	cadmium (metal)
	CEC	Civil and Environmental Consultants
	CERCLA	The Comprehensive Environmental Response, Compensation, and Liability Act (commonly known as Superfund) enacted by Congress on December 11, 1980.
	Cm	curium-242/244
	CMP	Comprehensive Monitoring Plan
	Co-60	cobalt-60
	COC	Chain of Custody
	COCs	Contaminants of Concern
	COND	conductivity
	Cr_6	Hexavalent Chromium (metal)

	CR/CRK	Clinch River/Clinch River kilometer
	Cs-137	cesium-137 (metal)
	CSU	Combined Standard Uncertainty
	Cu	Copper (metal)
D	D&D	Decontamination and Decommissioning
	DO	Dissolved oxygen
	DOE	US Department of Energy
	DoR	Division of Remediation
	DOR-OR	Division of Remediation – Oak Ridge
	DWR	Division of Water Resources
E	EFPC/EFK	East Fork Poplar Creek/East Fork Poplar Creek Kilometer
	EMP	Environmental Monitoring Plan
	EMR	Environmental Monitoring Report
	EMWMF	Environmental Management Waste Management Facility
	EPA	Environmental Protection Agency
	EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
	%EPT – Cheum	Percent EPT - Cheumatopsyche (tolerant Trichoptera)
	ESOA	Environmental Surveillance Oversight Agreement
	ETA	Edgewater Technical Associates (DOE subcontractor)
	ETTP	East Tennessee Technology Park (formerly K-25)
F	FDA	Food and Drug Administration (Federal)
	FFA	Federal Facilities Agreement
	FHC	flathead catfish
	FRMAC	Federal Radiological Monitoring and Assessment Center
G	GCN	greatest conservation need
	GPS	Global Positioning System
H	H_2SO_4	sulfuric acid
	H-3	Tritium
	HAs	Health Advisory Values
	HCl	hydrochloric acid
	HFIR	High Flux Isotope Reactor
	Hg	Mercury (metal)
	HQ	Hazard Quotient (noncarcinogenic risk equations)
	HNO_3	nitric acid
	HRE	Homogeneous Reactor Experiment
I	I-129	Iodine-129
	IC25	Inhibition Concentration 25% reduction in survival, growth and reproduction of test organism
	ISM	Incremental Sampling Methodology
J	ITRC	Interstate Technology Regulatory Council
K	J values	Result less than MQL but greater than or equal to MDL

	K-25	Former site of Gaseous Diffusion Plant closed in 1987, now ETTP
	K-27	Sampling site on ETTP
	K-40	Potassium-40
L	LLW	Low-level radioactive waste
	LMB	largemouth bass
	LSC	Liquid Scintillation Counting
M	MB/MBK	Mill Branch/Mill Branch kilometer (background stream)
	MCL	Maximum Contaminant Limit see NPDWR
	MDC	Minimum Detectable Concentration
	MDL	Minimum Detection Limit
	MeHg	methylmercury
	MH	manhole 1 (MH-1), manhole 2 (MH-2) at Y-12
	MIK	Mitchell Branch/Mitchell Branch kilometer
	MQL	Minimum Quantification Limit
	MQL	Method Quantification Limit
	MSRE	Molten Salt Reactor Experiment
N	NaI	Sodium Iodide (used in gamma scintillator probe)
	Ni	nickle (metal)
	NNSA	National Nuclear Safety Administration
	NAREL	National Air and Radiation Environmental Laboratory (EPA)
	NCBI	North Carolina Biotic Index
	NESHAPS	National Emissions Standards for hazardous Air Pollutants
	NOAA	National Oceanic and Atmospheric Administration
	Np-237	Neptunium-237 (transuranic isotope)
	NPDES	National Pollution Elimination System permit
	NPDWR	National Primary Drinking Water Regulations
	NPL	National Priority List
	NRC	Nuclear Regulatory Commission
	NSDWR	National Secondary Drinking Water Regulations
	NT-5	Bear Creek Northwest Tributary 5
	NTU	nephelometric turbidity units
	NUREG	NRC Regulation
O	OF-200 MTF	Outfall 200 Mercury Treatment Facility at Y-12
	ORAU	Oak Ridge Associated Universities
	OREIS	Oak Ridge Environmental Information System
	ORNL	Oak Ridge National Laboratory, also known as X-10
	ORP	Oxygen Reduction Potential
	ORR	Oak Ridge Reservation
	OSL	Optically Stimulated Luminescence Dosimeter
	%OC	Percent Oligochaeta and Chironomidae
P	Pb	Lead, Pb-212/214
	PC/PCK/PCM	Poplar Creek/Poplar Creek kilometer/Poplar Creek mile

	PCBs	Polychlorinated Biphenyls
	PEC	Probable Effects Concentration
	POP	Persistent Organic Pollutants
	PPE	Personal Protective Equipment
	PRGs	Preliminary Remediation Goals
	Pu	Plutonium-238/239/240 (transuranic isotope)
Q	QA/QC	Quality Assurance/Quality Control
	QAPP	Quality Assurance Project Plan
	QEC	Quality Environmental Containers (Beaver, WI)
R	RA	Remedial Activities
	Ra	radium
	RADCON	Radiation Control Program
	RAIS	Risk Assessment Information System
	RBC	Risk-based Assessment
	RCS	Roving Creel Survey
	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
	SMB	smallmouth bass
	SOP	Standard Operating Procedure
	Sr-90	strontium-90
	SRS	Southern Research Station
	Station	A specific location where environmental sampling or monitoring takes place.
	SU	standard units
	SD	storm drain
	SMCLs	Secondary Maximum Contaminant Levels same as NSDWRs
	SWPPP	Storm Water Pollution Prevention Plan
	SWSA	Solid Waste Storage Area
T	T&E species	State- or Federal-listed threatened and endangered species as protected under the Endangered Species Act of 1973.
	TECs	Threshold Effects Concentrations
	TR	Target Risk
	Tc-99	Technetium - 99
	TDEC	Tennessee Department of Environment and Conservation
	TDEC-DoR	TDEC-Division of Remediation
	TDH	Tennessee Department of Health
	TDH-NEL	TN Dept. of Health-Nashville Environmental Laboratory

	Th	thorium-228/230/232
	THI	Target Hazard Index
	THQ	Target Hazard Quotient
	Tl-208	thallium-208
	TMI	Tennessee Macroinvertebrate Index
	TNUTOL	Total Nutrient Tolerant
	TN AWQC	State of Tennessee Ambient Water Quality Criteria
	TS	tree swallows
	TWQC	Tennessee Water Quality Criteria
	TWRA	TN Wildlife Resources Agency
U	U	Result is less than Method Detection Limit (MDL)
	U-234/235/238	uranium-234/235/238
	UEFPC/UEFK	Upper East Fork Poplar Creek/Upper East Fork Creek Kilometer
	USDI	US Department of the Interior
	UV	ultraviolet
V	VOCs	volatile organic compounds
W	WAC	Waste Acceptance Criteria
	WB	white bass
	WD	wood duck
	WDNR	Wisconsin Department of Natural Resources
	WE	walleye
	WC/WCK	Whiteoak Creek/White Oak Creek/White Oak Creek kilometer
X	X-10	Historical name, renamed Oak Ridge National Lab (ORNL)
Y	Y-12	Y-12 National Security Complex (Building 9213, 9219, 9723-28)

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 2022 (FY2022) Environmental Monitoring Report (EMR) for the period of July 1, 2021, through June 30, 2022. This report is submitted as a comprehensive report of TDEC DoR-OR's monitoring and assessment activities across the Oak Ridge Reservation (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).

TDEC DoR-OR participates in independent monitoring and verification sampling as well as oversight of current DOE activities across the Oak Ridge Reservation, to confirm existing DOE project results, to support environmental restoration decisions, to evaluate performance of existing remedies and to investigate the extent and movement of legacy contamination.

This independent State of Tennessee 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, where necessary, for potential emissions of any materials (i.e. hazardous, toxic, chemical, or radiological) from the ORR to its surrounding environment.

This FY2022 Environmental Monitoring Report (EMR) presents the results of twenty (20) independent projects proposed in the FY2021 Environmental Monitoring Plan (EMP) and completed throughout FY2022 (July 1,2021, through June 30, 2022). Project focus areas include Air Monitoring, Biological Monitoring, Landfill Monitoring, Radiological Monitoring, Sediment Monitoring, Storm Water / Water Discharge Monitoring, Surface Water Monitoring, and Watershed Assessment (Holistic) Monitoring. All work is conducted according to the directives specified in the most recent TDEC DoR-OR Health and Safety Procedures (TDEC, 2020).

Summaries of those FY2022 independent monitoring projects, follow:

Air Monitoring:

- **Fugitive Radiological Air Emissions**

The fugitive radiological air emissions project independently samples air at eight (8) ORR locations, compares the resulting data with DOE's air monitoring program data, and evaluates this data with regards to Federal regulatory standards. This evaluation monitors radiological emissions from ORR's remedial actions and/or waste activities with the purpose of determining whether any air emissions could cause a member of the public to receive an effective dose greater than 10 mrem per year.

All the TDEC DoR-OR collected ORR air sample average concentrations (including (uranium-

234, uranium-235, uranium-238, and technetium-99), were below their respective Federal regulatory limits for this period of performance.

- **RadNet Air**

RadNet is a US Environmental Protection Agency (EPA) nationwide program that monitors the nation's air, precipitation, and drinking water to track radiation in the environment. The project provides radiochemical analysis of air samples taken from four (4) air monitoring stations on the ORR. RadNet samples are collected by TDEC DoR-OR and the analysis is performed at the EPA's National Air and Radiation Environmental Laboratory (EPA NAREL) in Montgomery, Alabama. All of the TDEC DoR-OR RadNet air monitoring gross beta results collected during this period of performance, were well below criteria which would warrant additional analysis. Accordingly, the results indicate ORR activities did not cause any significant radiological impacts to the air that could affect human health and the environment during FY2022, as monitored by these locations.

- **RadNet Precipitation**

This project provides radiochemical analysis of precipitation samples taken from monitoring stations at three (3) ORR locations which are co-located with RadNet Air stations. Two of the sites are located at ORNL, one in Melton Valley and the other in Bethel Valley. The third site is located at the east end of Y-12. RadNet precipitation monitoring sites are located in areas around ORNL and Y-12, where decontamination and decommissioning (D&D) activities have begun or are planned to occur. Samples are collected by TDEC DoR-OR, and analysis of these samples is performed at the EPA NAREL.

All of the TDEC DoR-OR precipitation sample results for cesium-137, cobalt-60, potassium-40, radium-226, and radium-228 collected during this period of performance, were either below their respective detection limits or below drinking water regulatory limits. Accordingly, these results indicate there were no significant ORR radiological impacts through precipitation to human health or the environment during FY2022 at monitored at these locations.

Biological Monitoring:

- **Benthic Ecological Community Health**

This project samples benthic macroinvertebrates to monitor the current and changing conditions of benthic health in the primary ORR exit pathway streams. This is an ongoing project that evaluates populations and presence of aquatic macroinvertebrates as an indicator of stream health. During FY2022, efforts were focused on the Bear Creek watershed.

TDEC DoR-OR benthic community health results showed that most of the macroinvertebrate populations in the upper Bear Creek sites near the west end of Y-12 (BCK 12.3 to BCK 4.5) remained impaired based on metrics and the Tennessee Macroinvertebrate Index (TMI) scores. Site BCK 3.3, the farthest downstream, showed results similar to the reference site.

This indicates that Bear Creek stream health improves with increasing distance downstream from Y-12 legacy contamination.

- **ORR Roving Creel Survey**

This project measures angling efforts at three (3) key areas where impaired ORR watersheds drain into publicly accessible waters. This project was designed to evaluate the extent of fisherman engagement with these areas, and to ascertain if recreational fisherman may have a risk of exposure to ORR contamination.

TDEC DoR-OR staff interviewed 97 fishermen over the course of 12 events, at locations that included the confluence region of White Oak Creek Embayment and the Clinch River, the confluence of Poplar Creek and the Clinch River, and the confluence region of East Fork Poplar Creek and Poplar Creek. Fishermen were asked questions about their current fishing trip. In addition, limited fish tissue sample collection was conducted during one spring and one fall event in these three locations, to provide spot check assessment of fish tissue, with samples sent for laboratory analysis of radiological constituents, metals and PCBs. Of the 3 areas evaluated, the confluence region of White Oak Creek Embayment area and the Clinch River was the most popular among anglers. Sixty-one percent (61%) of all anglers interviewed in this study described themselves as locals, many of whom had fished in these waters previously.

The fish tissue analyses detected low level, constituents including potassium-40, uranium-234, uranium-235, plutonium-238, plutonium-239, cesium-137, metallic strontium, strontium-89, mercury, and PCB Aroclor 1260 at all three (3) sites, at levels above reference site values. Clinch River site CRK 33.8, which is near the White Oak Creek Embayment, had the most detections of the contaminants. These fish tissue samples were limited spot checks and provide preliminary awareness information only. TDEC anticipates working with DOE and continuing CREEL survey projects in the future to supplement this data set during future work scopes.

- **Radiological Uptake in Food Crops**

DOE has historically conducted studies on locally grown and harvested food crops and milk, to analyze the potential impacts of airborne releases of radiation and the possible effects on food crops consumed by residents of local communities. The scope of this TDEC project was intended to build on those similar DOE lead projects, with TDEC DoR-OR independent sampling being used to evaluate additional samples or verify and correlate DOE's similar sample results. This TDEC DoR-OR Food Crops project collected vegetable, hay, and milk samples within five (5) miles of the ORR as well as at background locations outside the sample area to establish background (i.e. reference) levels.

The vegetable, hay, and milk sample analyses showed detections of constituents (low level concentrations of radionuclides, including naturally occurring constituents), which were similar to background location levels. All results were below associated FDA limits.

Groundwater Monitoring:

- **Offsite Groundwater**

Due to COVID-19 restrictions during the period of performance for this report (July 21, 2021, through June 30, 2022) no residential well sampling was conducted. This Offsite Groundwater assessment project was restarted as of FY2023 (July 1, 2022 – June 30, 2023).

Landfill Monitoring:

- **The Environmental Management Disposal Facility (EMDF)**

Surface water quality measurements were collected to delineate the current site conditions in the Bear Creek Valley (BCV) watershed during this period of performance. The BCV watershed includes the proposed Environmental Management Disposal Facility (EMDF) area. The EMDF is proposed to dispose of low-level radioactive waste and hazardous waste generated by ORR CERCLA remedial activities from the ORR. TDEC's monitoring of surface waters in central BCV through this project, support both the surface water evaluation of the Bear Creek Valley assessment project, as well as providing data that may support current or anticipated future data collection efforts at the central Bear Creek Valley site. The TDEC DoR-OR data collected within this project, complements DOE's BCV surface water monitoring program, and will help ensure that water quality parameters collected as background information for this site will be as robust as possible.

- **The Environmental Management Waste Management Facility (EMWMF)**

In FY2022, TDEC DoR-OR measured surface water quality parameters at EMWMF. No analytical lab independent or co-sampling was conducted for during this POP. Surface water parameter results showed that overall conductivity was elevated at the EMWMF-2 sampling location in comparison with the other locations, EMWMF-3 measured slightly higher pH values most of the year, with a markedly higher pH during hotter months than the comparative locations. TDEC also completed quarterly reviews of DOE's FY2022 EMWMF Oak Ridge Environmental Information System (OREIS) analytical as data was provided to the information system.

Radiological Monitoring:

- **Assessment of FFA Projects for Radiological Contaminants**

Much of the low-level radioactive wastes generated from CERCLA clean-up activities are disposed in the EMWMF. During FY2022, soil samples were collected from the EMWMF waste cell drainage ditches and one sediment sample was collected near North Tributary 5 (NT-5). Samples were analyzed to assess if there was the potential for buildup of radiological contamination in those areas that may result from low-level discharges from the landfill or dust disturbance from movement of trucks hauling waste.

No accumulation of uranium-234, uranium-235, uranium-238 or technetium-99 was identified in the ditches, nor were uranium isotopes and technetium present in NT-5 sediments sampled from locations north of the Haul Road.

- **Haul Road Surveys**

During FY2022, seven (7) surveys were conducted along the haul road. None of the roads exhibited any radiological contamination above established limits during those surveys. Five (5) anomalous items were identified. None of those items exceeded free release criteria or exhibited any gamma radiation above background values The five items were flagged, and DOE was notified for disposition.

- **Real Time Measurement of Gamma Radiation**

This project measures concentrations of gamma radiation in real time, at five (5) locations across the ORR, allowing for the assessment of conditions at locations where gamma emissions may fluctuate substantially over relatively short periods of time. Specifically, the areas assessed during this period of performance were, the EMWMF, ORNL Building 3026 the Radioisotope Development Laboratory, the Molten Salt Reactor Experiment, the Spallation Neutron Source, and the background location, Fort Loudoun Dam. FY2022 results indicate none of the monitored locations exceeded exposure limits for members of the public, assessed as 2 mrem in any, one-hour period or 100 mrem/year.

- **Surplus Sales Verification**

At the request of the Y-12 and/or ORNL's Excess Properties staff, TDEC DoR-OR performs pre-disposal radiological verification surveys on items being sold by the Excess Properties Sales Group. During FY2022, using hand-held radiological instruments, TDEC DoR-OR surveyed two DOE surplus sales lots. The TDEC DoR-OR survey results were conveyed to DOE personnel.

Sediment Monitoring:

- **Trapped Sediment (Bear Creek)**

The Bear Creek Trapped Sediment project is focused on monitoring aspects of stream health through sampling and analysis of suspended sediments. 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. During this period of performance, trapped sediment samples were collected twice at North Tributary-5 (NT-5), at Bear Creek km 7.6 (BCK 7.6), and Bear Creek km 3.3 (BCK 3.3) to determine the extent of contamination in this portion of the Bear Creek Valley watershed. Data was evaluated in conjunction with the previous nine (9) years of Bear Creek historical trapped sediment data.

At NT-5 and BCK 3.3, the mercury, uranium, cadmium, and arsenic results were below risk thresholds. At BCK 7.6 the uranium result (16.4 mg/kg) was slightly elevated. At most of these sites, the gross alpha and beta radionuclide activities were above ambient background. At all the sites, the uranium-234 and uranium-238 results were below the risk-based remediation goals for residential use.

- **Trapped Sediment (East Fork Poplar Creek (EFPC))**

As with the Bear Creek trapped sediment project above, the East Fork Poplar Creek (EFPC) Trapped Sediment project is also focused on monitoring aspects of stream health through sampling and analysis of suspended sediments. The trapped sediment collected in EFPC from the western end of Y-12 to the east at Station 17 (East Fork Poplar Creek site 23.4 (EFK 23.4)) was evaluated to determine the extent of potentially mobile contamination in this portion of the EFPC watershed. In addition, a review of EFK 23.4 historical trapped sediment data dating back to nine (9) years was conducted.

For EFPC, during this period of performance barium, boron, cadmium, copper, uranium, and lead results were below their respective risk thresholds, indicating there is a negligible health risk from these metals in the sediments. The mercury result (145 mg/kg) was much higher than its residential soil risk threshold. The FY2022 uranium result was also above its associated residential use soil risk limit.

Storm Water / Water Discharge Monitoring:

- **Accumulated Water Discharge**

This project monitors accumulated water at sites with ongoing CERCLA D&D and/or RA operations. The monitoring in FY2022 included oversight at the Y-12 Outfall-200 Mercury Treatment Facility (OF-200 MTF) headworks construction area. At this site, as well as any other DOE operations site, water can accumulate through either groundwater intrusion or stormwater accumulation, or both, and can disperse contaminants to the environment. TDEC DoR-OR reviewed pertinent DOE sampling data, observed DOE sampling and monitoring activities, and co-sampled as appropriate to confirm that relevant treatment and discharge criteria were met. TDEC DoR-OR oversaw five (5) sampling events conducted by DOE’s subcontractor Edgewater Technical Associates (ETA) at OF-200 MTF, including oversight of sampling of both treated and untreated frac tanks. Mercury, the primary contaminant of concern at OF-200 MTF, was not detected in samples collected from the treated frac tanks during the third quarter of 2021. TDEC DoR-OR completed an assessment of operating procedures at this site, in combination with sampling the frac tanks, and found that ETA’s sample collection protocols properly followed their established SOPs which ensured accurate analytical sample results.

- **Rain Event**

The Rain Event project was comprised of two main components: (1) sampling protocol review and oversight of sampling activities, and (2) co-sampling with DOE and/or collecting independent stormwater samples following qualifying rain events. TDEC DoR-OR also reviewed DOE’s sampling results to ensure compliance with negotiated and agreed upon release criteria. This combination of oversight, review of data, and sampling allowed TDEC DoR-OR to determine if best management practices at remedial action sites are effective in preventing offsite releases of legacy contaminants and ensure criteria for water releases are met.

TDEC DoR-OR storm water sampling followed two (2) rain events in August 2021. Samples were collected at five (5) outfalls across Y-12 and at one (1) manhole at Building 9213. These locations were chosen due to their proximity to future D&D activities with the purpose of establishing a baseline for future reference. Mercury was detected in three Y-12 outfalls, with samples from two of these outfalls at concentrations above 200 ng/L. Uranium metal was also detected in four Y-12 outfalls, with samples from two of these outfalls greater than 2000 ng/L. Gross alpha and beta were detected in three Y-12 outfalls; isotopic uranium was detected in all sampled Y-12 outfalls, and low levels of isotopic plutonium were also detected in two of these outfalls. Gross alpha, gross beta, and isotopic uranium were also detected in all samples collected from Building 9213. Low levels of isotopic plutonium activity were detected in a stormwater sample from Building 9213 in 2021. As DOE RA and D&D activities are conducted throughout the ORR, with focus shifting to Y-12 and ORNL, storm water will continue to have the potential to contact contaminated materials and may disperse contamination into the environment. Storm water monitoring will continue to be important, as a best management practice, to ensure legacy contaminants are not being mobilized off site.

Surface Water Monitoring:

- **Ambient Surface Water Parameters**

To ascertain any impacts to surface water, TDEC DoR-OR conducted monthly sampling to obtain primary water quality parameters (conductivity, pH, temperature, and dissolved oxygen) for three (3) ORR exit pathway streams: East Fork Poplar Creek (EFK), Bear Creek (BCK), and Mitchell Branch (MIK). Mill Branch (MBK) served as an offsite reference stream. Part of an on-going monitoring program which began in 2005, these data are used to assess the impact of site remediation efforts, as well as provide ambient parameter measures for use in the event of a future release. In addition, this data augments DOE's surface water monitoring program.

None of the sampling site results from FY2022 exceeded the State of Tennessee Ambient Water Quality Criteria (TN AWQC) for dissolved oxygen, pH, or temperature. While there is no existing State AWQC for conductivity, the Bear Creek site BCK 12.3 conductivity measurements were significantly higher than all other streams' conductivity results. This higher conductivity may be related to the proximity of this site to the capped Y-12 Complex's S-3 ponds where acidic, nitrate, and uranium-bearing waste was disposed. While overall, Bear Creek shows high conductivity results, historical data indicates conductivity is trending downward over time. Alternately, at East Fork Poplar Creek site EFK 23.4, a steadily increasing trend in conductivity has been observed. The reason(s) for this increase have not yet been determined. By comparison, the reference site, Mill Branch site MBK 1.6, was statistically significantly lower in conductivity than all ORR streams measured.

- **Ambient Surface Water Sampling**

The purpose of this sampling project is to evaluate the impact of DOE ORR contamination on the Clinch River (CR) by focusing sampling efforts at 4 locations including: on the main CR channel, on Poplar Creek (PC), a primary CR tributary, and at two primary exit pathway streams that are PC tributaries, (Bear Creek (BC), and East Fork Poplar Creek (EFPC)). B Main channel CR sampling sites were co-sampled with DOE.

On BC, sites near Y-12 had high uranium concentrations; however, concentrations decreased with distance downstream from Y-12. Additionally, BC mercury concentrations were all below the TN AWQC criteria for organisms and water. Of all the streams sampled, Bear Creek kilometer 0.6 (BCK 0.6) had the highest activities of alpha, beta, and uranium isotopes. No transuranics were detected at BCK 0.6.

On EFPC, radionuclide activities were higher than the reference stream, but were still within risk limits. All transuranic isotopes sampled (e.g. americium, curium, neptunium, and thorium) were not detected at these sites.

PC metal concentrations of uranium and lithium were generally lower than other ORR streams, but concentrations of arsenic and lead were higher than the other streams. Mercury, nickel, and uranium concentrations were also elevated in PC below the Mitchell Branch confluence. Mercury at one of the four (4) sites (PCM 4.6) exceeded the TN state criterion of 0.051 µg/L for organisms and water. Uranium was elevated as compared with Mill Branch (MB), the reference stream, but fell well within the TN AWQC criteria. Overall, PC sampling site radionuclide activities were similar to the background stream (MB).

Overall, CR metal concentrations, particularly mercury, and radiological activities were low or not detected. This indicates the CR is diluting contamination loading from ORR exit pathway streams.

- **White Oak Creek Radionuclides**

This project monitors ambient surface water for strontium-90 (Sr-90) and other radiological contaminant inputs into White Oak Creek (WCK) at four (4) sites and at the creek's confluence with the Clinch River at site CRK 33.5. Samples are collected quarterly. This project was separated from the primary Ambient Surface Water Sampling project to focus specifically on elevated Sr-90 concentrations identified discharging into the Clinch River at CRK 33.5.

For the period of performance at the five (5) sampling stations (WCK 6.8, WCK 3.9, WCK 3.4, WCK 2.3, and CRK 33.5), the majority of the detected gamma emitting isotopes and uranium isotopes were below their respective EPA derived drinking water limits. However, all the samples from WCK 3.9 downstream to the confluence (CRK 33.5) exhibited elevated Sr-90 concentrations which were greater than the EPA derived drinking water limit of 8 pCi/L.

Watershed Assessments (Holistic) Monitoring:

The Watershed Assessments (Holistic) Monitoring program was initiated by TDEC DoR-OR, to support a watershed focused evaluation of current site conditions in watersheds throughout the ORR. For this period of performance there was one (1) project grouped under watershed assessments (holistic) monitoring for the purpose of this EMR. The overall results of this multiyear assessment project will be provided under separate cover. This report is intended to address only the data collected for this period of performance during FY2022.

Bear Creek Valley Assessment

For FY2022, Phase 3 of this project involved sampling of surface water, biota, and sediment in the Bear Creek area.

Sediment: Sediment sampling was conducted by Civil and Environmental Consultants (CEC) in conjunction with TDEC DoR-OR. The Bear Creek (BCK) sediment samples were well below the EPA risk thresholds for mercury (Hg). Both the suspended sediment and CEC sediment core grab samples were below the mercury residential soil threshold indicating there was no human health risk from mercury in Bear Creek sediments. BCK 7.6's uranium result was slightly above its residential soil threshold. No PCBs were detected in any of the sediment site samples.

Soil: Soil sampling was conducted by CEC with assistance from TDEC DoR-OR at three (3) locations in the Bear Creek Valley (BCV). Sample collection and laboratory processing and analyses methods both utilized Incremental Sampling Methodology (ISM), and were analyzed for mercury, PCBs, and uranium. None of the PCB results exceeded the risk thresholds for residential direct contact exposure. Arochlor 1260, was detected in each of the Bear Creek sites at a level below the threshold for residential soil under the direct contact exposure scenario. All the soil sample mercury results were below the mercury residential soil risk threshold. Uranium concentrations were notably high at two sites, BCK 11.97 and BCK 7.87, compared to relevant land use designation risk criteria. At the Bear Creek sites, uranium in soil samples were similar to the findings of the suspended sediment sampling. Uranium results were below risk thresholds, except for BCK 11.97 and BCK 7.87.

Surface Water Toxicity/Biomonitoring: Biomonitoring for toxicity was conducted at four (4) stream locations during March 2022 by CEC with the assistance of TDEC DoR-OR. Two (2) sites were located on Bear Creek, one (1) site on the East Fork Poplar Creek, and the fourth was on Mill Branch. These sampling sites were chosen to validate scores from previous testing done in 2020 and 2021. The test results from all sites sampled for the March 2022 showed, no toxicity or inhibition of reproduction (*Ceriodaphnia dubia*, water flea) or growth (*Pimephales promelas*, fathead minnow). In contrast, toxicity was demonstrated the prior year (FY2021) through water flea reproduction at BCK 12.3 and fathead minnow growth at BCK 3.3 and EFK 2.2. Prior water toxicity sampling in FY2021 was conducted in October and June, which are drier months of the year. During FY2023, in October 2022, the driest month of the year on average, testing will be repeated to determine if toxicity is affected by seasonal differences.

Surface Water Benthic Macroinvertebrate Monitoring:
During this period of performance, TDEC DoR-OR primarily focused the macroinvertebrate monitoring on Bear Creek (BC). Macroinvertebrate samples were taken from the most upstream site (BCK 12.3) and at three (3) points downstream, stopping at BCK 3.3. The results of TDEC DoR-OR's benthic macroinvertebrate sampling along Bear Creek, have continuously shown impairment based on the metrics and TMI scores from this ten-year review. Site improvement can be observed when travelling downstream (BCK 12.3 to BCK 3.3). This suggests that as COCs travel downstream and become diluted the stream becomes less impaired.

Biota: The laboratory results from the analysis of biota (songbird eggs, flying insects, and spiders) samples collected will be reported in the FY2023 EMR.

Surface Water: Surface water parameters (temperature, dissolved oxygen, pH, and specific conductivity) were measured in Bear Creek. Specific conductivity continues to be highest in the headwaters of Bear Creek, at BCK 12.3, compared to all other stream locations measured on the ORR. Specific conductivity decreases downstream in Bear Creek, following patterns seen in recent years. Additionally, during FY2022, surface water was sampled at BCK 0.4, (downstream where Bear Creek is publicly accessible). Mercury concentrations were below AWQC at this downstream location, but uranium metal was detected at concentrations up to 15.1 ug/L. Gross alpha, gross beta, and isotopic uranium activity was also detected at low levels in surface water.

1.0 INTRODUCTION

1.1 PURPOSE OF THE ENVIRONMENTAL MONITORING REPORT (EMR)

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation Oak Ridge Office (DoR-OR), submits its annual (FY2022) Environmental Monitoring Report (EMR) for the period July 1, 2021, through June 30, 2022, 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's) 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 project reviews and if applicable, suggests modifications to current activities.

TDEC DoR-OR personnel, in support of the tri-party (EPA, DOE, TDEC) 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. TDEC 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 report for the FY2022 monitoring and assessment projects conducted by TDEC DoR-OR during this period of performance.

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 (i.e. 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 FY2022 EMR presents the results of twenty (20) independent projects proposed in the

FY2021 Environmental Monitoring Plan (EMP) and completed throughout FY2022. This monitoring report focuses on the following eight (8) general areas: Air Monitoring, Biological Monitoring, Landfill Monitoring, Radiological Monitoring, Sediment Monitoring, Storm Water / Water Discharge Monitoring, Surface Water Monitoring, and Watershed Assessment (Holistic) Monitoring.

1.3 THE OAK RIDGE RESERVATION

The Oak Ridge Reservation (ORR) is comprised of three (3) major facilities:

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

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 (3) 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 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 Complex 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 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.

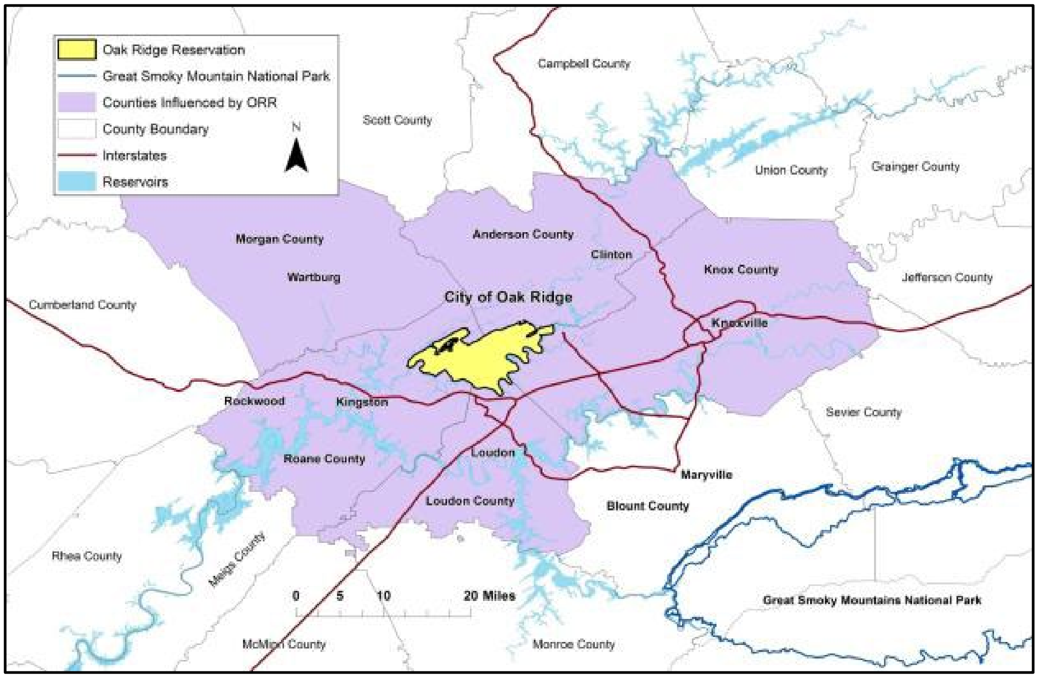

Figure1.3.1: Location of the Oak Ridge Reservation in Relation to Surrounding Counties

1.3.1 Geography of the ORR Area

Located in an East Tennessee valley, 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.

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. According to the DOE 2021 ASER, "Average annual precipitation in the Oak Ridge area for the 30-year period from 1992 to 2021 was 1,417.8 mm (55.82 in.), including about 14.5 cm (5.7 in.) of snowfall. Total precipitation during 2021 as measured at meteorological tower (MT)2 was 1,492.2 mm (58.75 in.), which is 5 percent above the 30-year average".

The Great Valley of East Tennessee (e.g. 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 (e.g. lithologic rock types in the subsurface and wind-directing regional landforms) as well as the regional climate (rainfall, snowfall, 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 1 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 Oak Ridge Reservation (ORR), Oak Ridge, Tennessee, are being managed or performed in a manner protective of human health and the environment.

2.0 AIR MONITORING

2.1 FUGITIVE RADIOLOGICAL AIR EMISSIONS

2.1.1 Background

The K-25 Gaseous Diffusion Plant, now called ETTP, began operations in World War II as part of the Manhattan Project. Its original mission was to produce uranium enriched in the 235-isotope (U-235) for use in the first atomic weapons and later to fuel commercial and government owned reactors. The plant was permanently shut down in 1987. Because of operational practices and accidental releases, many of the facilities scheduled for decontamination and decommissioning (D&D) at ETTP are contaminated to some degree. 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 Complex was also constructed during World War II to enrich uranium in the U-235 isotope, in this case by the electromagnetic separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, to conduct lithium-mercury enrichment operations, to manufacture components for nuclear weapons, to dismantle nuclear weapons, and to store enriched uranium.

Construction of the ORNL began in 1943. While the initial mission of the K-25 and Y-12 plants was the production of enriched uranium, ORNL's mission focused on reactor research and the production of plutonium as well as other activation and fission products, which were 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 and associated radioactive materials were released from operations as gaseous, liquid, and solid effluents, with little or no treatment (ORAU, 2003).

2.1.2 Problem Statements

- Many of the facilities at ETTP, Y-12, and ORNL scheduled for D&D are contaminated. D&D operations at these facilities, as well as the placement of waste from these facilities at the Environmental Management Waste Management Facility (EMWMF), can result in fugitive (i.e. non-point source) dispersal of contaminated constituents. This dispersion is aided by winds that tend to blow up the Tennessee Valley (northeast) in the daytime and then reverse direction by blowing down the Tennessee Valley (southwest) at night.
- At ETTP, 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 from offsite.
- Many of the facilities at ORNL are contaminated with a long list of fission and activation products in addition to uranium and plutonium isotopes. Some of these

facilities are considered the highest risk facilities at ORNL due to their physical deterioration, the presence of loose contamination, and their close proximity to pedestrian, vehicular traffic, privately funded facilities, and active ORNL facilities.

- At Y-12, facilities contaminated with various isotopes of uranium are scheduled for D&D.
- Much of the material from D&D activities on the Oak Ridge Reservation (ORR) is disposed at EMWMF.

2.1.3 Goals

- To protect human health and the environment, TDEC DoR-OR will conduct independent air sampling and compare the results with air sampling data provided by DOE to verify that DOE's ORR activities are not adversely impacting the public.
- TDEC DoR-OR personnel will review the air monitoring sections of the DOE ORR Environmental Monitoring Plan (EMP) and suggest relevant revisions to the DOE EMP.

2.1.4 Scope

TDEC DoR-OR conducted continuous fugitive radiological air emissions monitoring to evaluate DOE's adherence to the Clean Air Act (CAA) regulatory standards to ensure potential DOE ORR radiological emissions will not cause a member of the public to receive an effective dose greater than 10 millirem (mrem) in one year, specifically in the areas of remedial and/or waste management activities. Sampler locations were selected to maximize the likelihood of collecting representative samples from potential sources of airborne contamination.

2.1.5 Methods, Materials, Metrics

Eight (8) high-volume air samplers were used in this project. One was stationed at Fort Loudoun Dam in Loudon County to collect background data for comparison while the remaining samplers were placed at ORR locations where the potential for the release of fugitive airborne emissions is greatest (e. g. locations of the excavation of contaminated soils, demolition of contaminated facilities, and waste disposal operations).

Each of the air samplers used an 8x10-inch, glass fiber filter to collect particulates from air as it was drawn through the unit at a rate of approximately 35 cubic feet per minute. To ensure accuracy, airflow through each sampler was calibrated quarterly, using a Graseby General Metal Works variable resistance calibration kit. Samples were collected from each sampler weekly and composited every four (4) weeks then submitted for laboratory analysis. To assess the concentrations of the contaminants measured for each location, results from each station were compared with the background data and the standards provided in the CAA. Associated findings were supplied to DOE and its contractors when requested and included in TDEC DoR-OR's annual EMR submitted to DOE and the public.

Fugitive Air monitoring was conducted by TDEC DoR-OR to compare to the standards provided by the CAA. Title 40 of the Code of Federal Regulations Part 61 (40CFR61), National Emission Standards for Hazardous Air Pollutants (NESHAPS), Subpart H (National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities) 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.

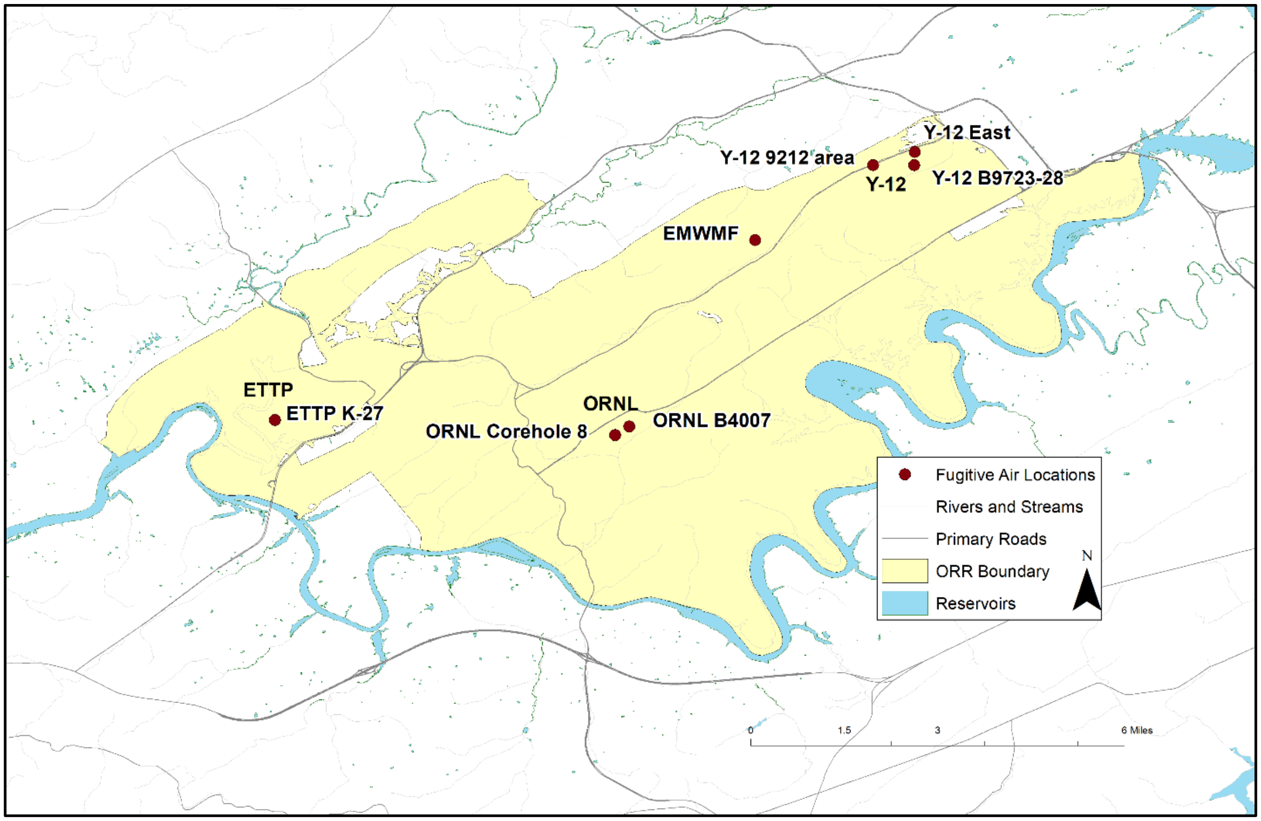

Figure 2.1.1: Fugitive Air Monitoring Locations

2.1.6 Deviations from the Plan

The original project plan was to collect and report on the full year's data, thirteen (13) four-week composite samples, through June 2021. However, available data for this report only consisted of eleven (11) four-week composites for the period 06/02/2021 through 03/09/2022.

2.1.7 Results and Analysis

East Tennessee Technology Park (ETTP)

Historically, the ETTP campus was the site of the original K-25 Gaseous Diffusion Plant; therefore, air monitoring in on-going. For this project, one (1) radiological air monitor, located at the site of K-27, was used for data collection. Analyses of all ETTP air samples include three (3) isotopes of uranium (U-234, U-235, U-238) and technetium-99 (Tc-99) as shown in Table 2.1.2. In this table, a sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.2: ETTP K-27 Air Monitoring Average Results for (pCi/m^3)

K-27 Sampling Location	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average 06/02/2021 to 03/09/2022	5.12E-05	6.32E-06	4.61E-05	2.27E-04	
Average background	5.07E-05	6.12E-06	4.49E-05	3.38E-04	
Net Activity (Avg. minus background)	4.73E-07	2.00E-07	1.18E-06	-1.12E-04	
40CFR Part 61 Limit, Appx. E (Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	6.14E-05	2.82E-05	1.42E-04	-7.97E-04	-5.65E-04

Y-12 National Security Complex

Three (3) samplers were used at Y-12. Analyses for the air samples collected from air monitors at Y-12 include three (3) isotopes of uranium (U-234, U-235, U-238) and Tc-99. Table 2.1.3 shows the results from the samples taken at the Building 9212 area of Y-12. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.3: Y-12 Building 9212 Area Air Monitoring Average Results (pCi/m^3)

Y-12 9212 Sampling Location	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average 06/02/2021 to 03/09/2022	2.15E-04	1.91E-05	6.40E-05	2.13E-04	
Average background	5.07E-05	6.12E-06	4.49E-05	3.38E-04	
Net Activity (Avg. minus background)	1.64E-04	1.30E-05	1.91E-05	-1.26E-04	
40CFR Part 61 Limit, Appendix E (Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	2.13E-02	1.82E-03	2.30E-03	-8.97E-04	2.45E-02

Table 2.1.4 shows the results from the samples taken at the Building 9723-28 area of Y-12. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.4: Y-12 Building 9723-28 Area Air Monitoring Average Results (pCi/m^3)

Y-12 B9723-28 Sampling Location	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average 06/02/2021 to 03/09/2022	6.06E-05	1.03E-05	4.80E-05	2.62E-04	
Average background	5.07E-05	6.12E-06	4.49E-05	3.38E-04	
Net Activity (Avg. minus background)	9.89E-06	4.15E-06	3.12E-06	-7.58E-05	
40CFR Part 61 Limit, Appx. E (Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	1.28E-03	5.84E-04	3.76E-04	-5.42E-04	1.70E-03

Table 2.1.5 shows the results from the samples taken at the East area of Y-12. The sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.5: Y-12 East Area Air Monitoring Average Results (pCi/m^3)

Y-12 East Sampling Location	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average 06/02/2021 to 03/09/2022	6.05E-05	5.89E-06	4.87E-05	4.30E-04	
Average background	5.07E-05	6.12E-06	4.49E-05	3.38E-04	
Net Activity (Avg. minus background)	9.82E-06	-2.27E-07	3.82E-06	9.17E-05	
40CFR Part 61 Limit, Appx. E (Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	1.28E-03	-3.20E-05	4.60E-04	6.55E-04	2.36E-03

Oak Ridge National Laboratory (ORNL)

Two (2) samplers were used at ORNL. Analyses for the air samples collected from air monitors at ORNL include three (3) isotopes of uranium (U-234, U-235, U-238) and gamma spectrometry. The gamma spectrometry analysis results are not shown because only naturally occurring daughter products of radon were detected. No instances of elevated impacts were noted. The sum of fractions of less than one indicates that regulatory limits were not exceeded, as seen in tables 2.1.6 and 2.1.7.

Table 2.1.6: ORNL B4007 Air Monitoring Average Results (pCi/m^3)

ORNL B4007 Sampling Location	U-234	U-235	U-238	Sum of Fractions
Average 06/02/2021 to 03/09/2022	4.38E-05	6.61E-06	4.20E-05	
Average background	5.07E-05	6.12E-06	4.49E-05	
Net Activity (Avg. minus background)	-6.91E-06	4.91E-07	-2.89E-06	
40CFR Part 61 Limit, Appendix E (Table 2)	7.70E-03	7.10E-03	8.30E-03	
Fraction of Limit (Net/Limit)	-8.97E-04	6.91E-05	-3.48E-04	-1.18E-03

Table 2.1.7: ORNL Corehole 8 Air Monitoring Average Results (pCi/m^3)

ORNL Corehole 8 Sampling Location	U-234	U-235	U-238	Sum of Fractions
Average 06/02/2021 to 03/09/2022	4.09E-05	5.13E-06	3.98E-05	
Average background	5.07E-05	6.12E-06	4.49E-05	
Net Activity (Avg. minus background)	-9.79E-06	-9.91E-07	-5.07E-06	
40CFR Part 61 Limit, Appendix E (Table 2)	7.70E-03	7.10E-03	8.30E-03	
Fraction of Limit (Net/Limit)	-1.27E-03	-1.40E-04	-6.11E-04	-2.02E-03

The Environmental Management Waste Management Facility

One (1) sampler is located at EMWMF in Bear Creek Valley (BCV) near Y-12. Analyses for the air samples collected from the air monitor at EMWMF includes three (3) isotopes of uranium (U-234, U-235, U-238) and Tc-99. No identified instances of elevated impacts were noted (Table 2.1.8). The sum of fractions of less than one indicates that regulatory limits were not exceeded.

Table 2.1.8: EMWMF Air Monitoring Average Results (pCi/m³)

EMWMF Sampling Location	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average 06/02/2021 to 03/09/2022	8.12E-05	1.01E-05	7.00E-05	3.24E-04	
Average background	5.07E-05	6.12E-06	4.49E-05	3.38E-04	
Net Activity (Avg. minus background)					
40CFR Part 61 Limit, Appx. E (Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of Limit (Net/Limit)	3.96E-03	5.58E-04	3.02E-03	-1.02E-04	7.43E-03

2.1.8 Conclusions

The average concentrations, minus background, for all sites, were below the federal standards for each isotope measured.
This project's shorter composite intervals can result in the timelier observation of potential problems than other available sampling programs such as the DOE program which analyzes quarterly composite samples.

In past years, this TDEC DoR-OR independent monitoring project's Tc-99 analysis was useful in identifying a calculation error in DOE's ETTP Perimeter Sampling Program (with the error on the part of DOE's contracted laboratory) that reported results that were 10% of the actual calculated values. Results from this program continue to be used by DOE contractors for comparison purposes.

2.1.9 Recommendations

TDEC DoR-OR will review the current monitoring locations and consider sampling modifications according to DOE activities on the ORR.

The air monitoring section of the DOE Environmental Monitoring Plan for the Oak Ridge Reservation was reviewed. At this time, there are no recommendations submitted by TDEC DoR-OR.

2.1.10 References

40 CFR 61, Appx E. 2017. *Title 40 of the Code of Federal Regulations, Chapter 1, Subchapter C, Part 61; National Emission Standards for Hazardous Air Pollutants (NESHAPS)*, Appendix E *Compliance Procedures Methods for Determining Compliance With Subpart I.* https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-61/appendix-Appendix%20E%20to%20Part%2061

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2.2 RadNet Air

2.2.1 Background

In the past, air emissions from DOE activities on ORR were believed to have been a potential cause of illnesses affecting area residents. While these emissions have substantially decreased over the years, concerns have remained that air pollutants from current activities (e.g. production of radioisotopes and demolition of radioactive contaminated facilities) could pose a threat to public health, the surrounding environment, or both. Consequently, TDEC DoR-OR has implemented several air monitoring programs to assess the impact of ORR air emissions on the surrounding environment and the effectiveness of DOE controls and monitoring systems. This project provides additional monitoring along with independent third-party analysis.

The RadNet Air Monitoring project on the ORR began in 1996 and now provides radiochemical analysis of air particulate samples collected twice weekly from four (4) air monitoring stations located near potential sources of radiological air emissions on the ORR. RadNet samples are collected by TDEC DoR-OR and analysis is performed at the EPA NAREL in Montgomery, Alabama.

2.2.2 Problem Statements

The three (3) sites on the ORR, ORNL, the Y-12 Complex, and ETTP, can potentially release radioactive contaminants into the air from current operations, as well as from the deterioration of contaminated buildings at each site, and the D&D of these facilities. As the known contaminated buildings at ETTP have been removed, this project now focuses on sampling at Y-12 and ORNL.

2.2.3 Goals

This project aims to protect 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 four (4) RadNet Air monitoring stations, with up to 400 total samples analyzed yearly. Specific goals include:

- Determine that gross beta radioactivity levels are not above regulatory levels for a beta emitter with stringent criteria, and preferably below screening levels requiring additional analysis.

- Compare gross beta levels from the RadNet Air monitors on the ORR to gross beta levels observed at a RadNet location not on the ORR that can be used as a background location.
- Complement the TDEC DoR-OR Fugitive Radiological Air Emissions project by providing gross beta analysis (and other analyses if screening levels are exceeded) as well as provide additional air monitors for greater area coverage of the ORR and provide more frequent analysis.

2.2.4 Scope

The RadNet Air Monitoring project uses four (4) high-volume air samplers to monitor air for radiological contamination. Two of the air samplers are located at Y-12; one is located near each end of the plant. Two samplers are located at ORNL; one is in Bethel Valley, and one is in Melton Valley. Results from an additional RadNet air sampler operated by TDEC DoR-OR are used for background comparisons.

The four (4) RadNet Air samplers on the ORR were sampled on Mondays and Thursdays except when skipped due to a holiday. Each of the samples were analyzed by EPA NAREL for gross beta, which can mean the analysis of close to 400 samples from the ORR each year. Gamma analysis was performed on any samples with gross beta levels greater than 1 pCi/m^3 and on an annual composite of the year's samples at each station. Once every four years, the EPA laboratory performs uranium and plutonium isotopic analysis on an annual composite of the filters from each station.

2.2.5 Methods, Materials, Metrics

The locations of the four (4) RadNet Air samplers are provided in Figure 2.2.1 and described in the scope of this project. EPA's analytical parameters and frequencies are listed in Table 2.2.1.

The RadNet Air samplers run continuously, collecting suspended particulates 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 from each sampler, twice weekly, following EPA protocol (EPA, 1988; EPA, 2006). After collection, the filters are shipped to EPA NAREL for analysis. Each year nearly 400 samples from the ORR are analyzed by this project. While gross beta analysis is used as a screening tool, with further analysis triggered with levels over 1.0 pCi/ m^3, much lower levels can be seen with average minimum detectable concentrations of about 0.000323 pCi/ m^3 (for the ORR locations from 2011 through 2021).

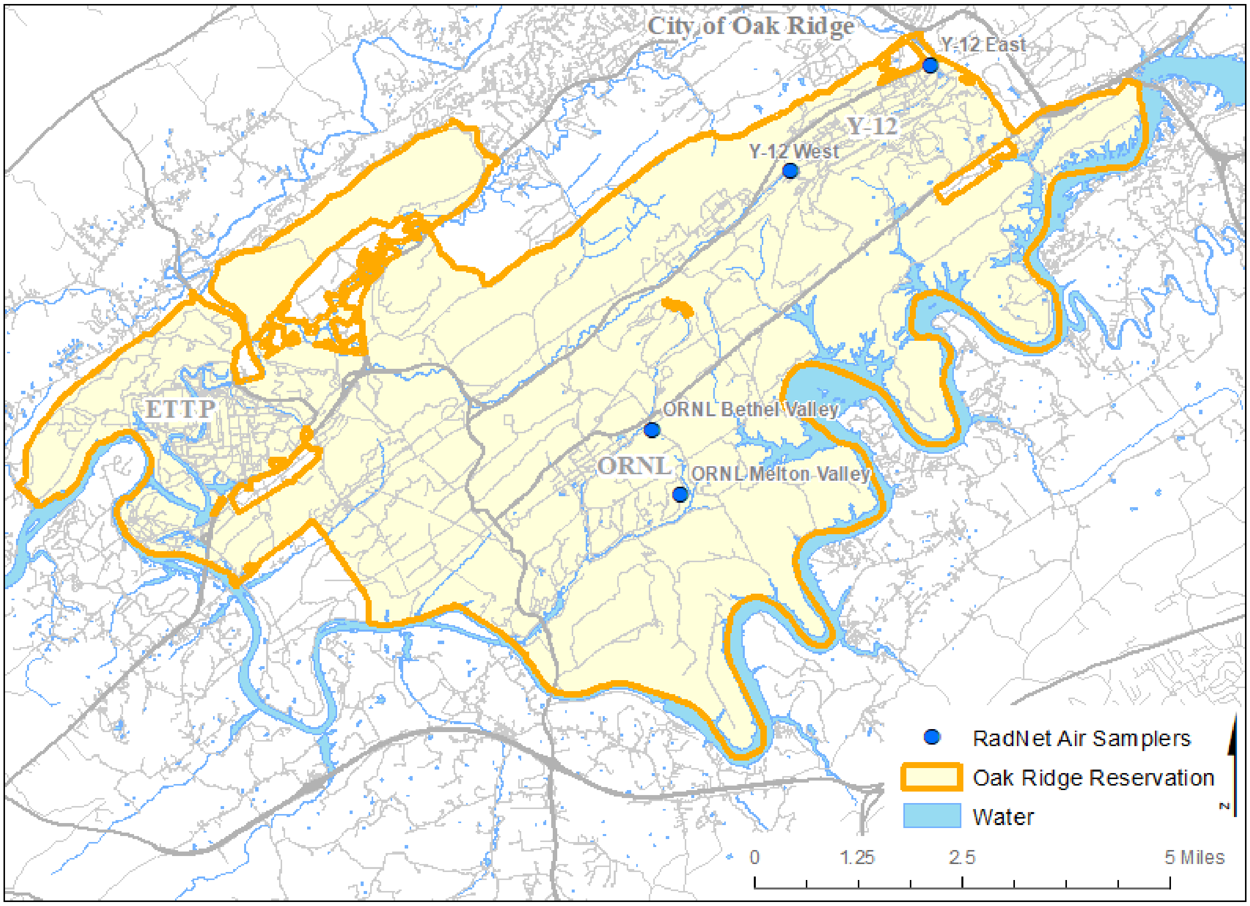

Figure 2.2.1: Locations of RadNet Air Monitoring Stations on the ORR

Table 2.2.1: RadNet Air Monitoring Stations Analyses and Frequencies

	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 composite 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)

Note: The results of EPA NAREL's analyses of the nationwide RadNet Air monitoring data are available at NAREL's website in the Envirofacts RadNet searchable database.

Gross beta results from the RadNet Air Monitoring project are compared to background data from a RadNet Air monitor in Tennessee, as well as to the Clean Air Act (CAA) environmental limit for strontium-90, because it is a pure beta emitter with a conservative limit. The gross beta results provided by this project are useful on their own, as the detection limits are low, and are useful as a screening tool because many gamma emitters also emit beta radiation.

2.2.6 Deviations from the Plan

The ORR RadNet gross beta air sampling results were compared to those from the RadNet Air station located in Nashville instead of the Knoxville location as it was unavailable for comparison during most of this time (with only three samples available, all near the end of June 2022).

Prior to FY2022, there were five (5) RadNet Air stations on the ORR, but there is no longer one at the ETTP site. However, all the known contaminated buildings had been removed by the time this occurred.

The RadNet Air station at the west end of Y-12 was moved southeast to the other end of Old Bear Creek Road on February 17, 2022, but this new location is still at the west end of the Y-12 site and is now less affected by road dust (i. e. compared with the original site which is located near a gravel haul road).

Furthermore, the annual composite analysis for uranium and plutonium that is scheduled every four years was not done for 2017, instead it was completed for the 2018 composite samples and is the most recent available. The most recent annual composite gamma analysis results for RadNet air sampling on the ORR are from 2019.

2.2.7 Results and Analysis

The results of EPA NAREL's analyses of the nationwide RadNet Air sampling are available in the RadNet database on the Envirofacts website, via either a simple or a customized search. The results in this report are from samples collected from July 2021 through June 2022 for the RadNet Air stations on the ORR, and the 2021 results as a whole are also discussed. Gross beta from the RadNet Air Monitoring project on the ORR was compared to background data from the RadNet Air monitor in Nashville and Memphis Tennessee, and to the CAA environmental limit for strontium-90, as it is a pure beta emitter with a conservative limit.
As seen in Figure 2.2.2, the results for the gross beta analysis of samples collected from July 2021 through June 2022 were similar for each of the four (4) ORR RadNet monitoring stations and were similar to the results reported for the Nashville RadNet Air station (i.e. used as a background for comparison). The results for Memphis are also shown for comparison as both Nashville and Memphis are non-ORR locations with much variability, both higher and lower. The fluctuations observed in the results (depicted in Figure 2.2.2) are largely attributable to natural phenomena (e.g. wind, rain, etc.) that influence the amount of particulate suspended in the air and ultimately deposited on the filters. Some of the

differences between the RadNet Air stations on the ORR and the background station in Nashville, as well as the station in Memphis, may be attributed to differences in weather and or collection schedules as well as the distance between the locations. The ORR gross beta results for the RadNet Air Monitoring project from July 2021 through June 2022 were all well below 1.0 pCi/m3, which is the screening level that triggers further analysis.

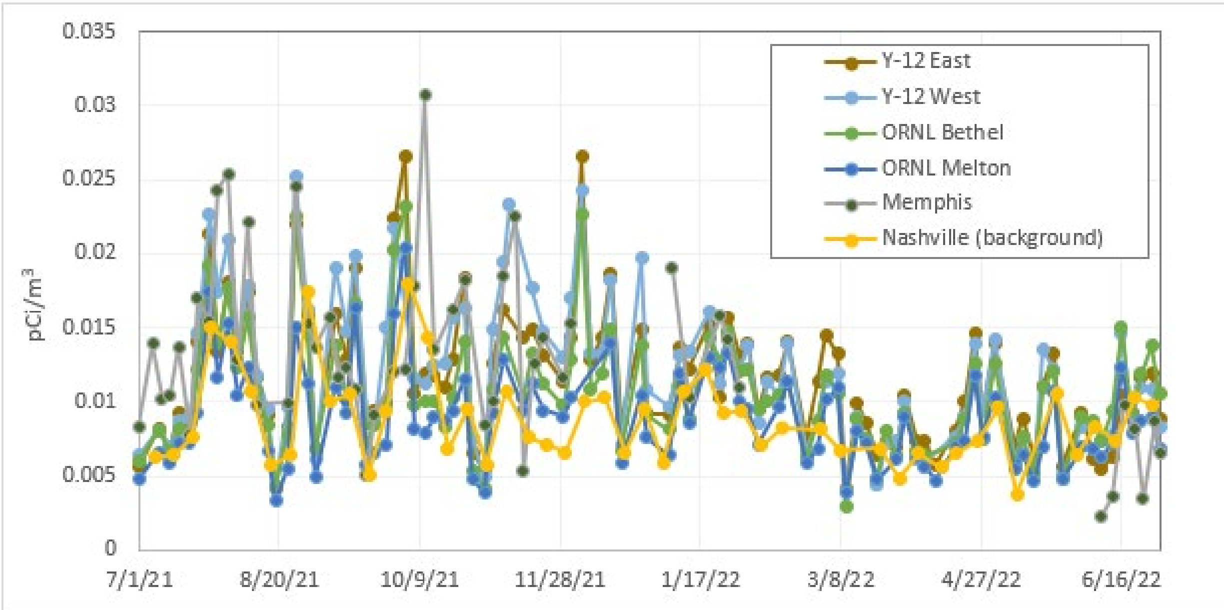

Figure 2.2.2: RadNet Air Monitoring Project Gross Beta Results July 2021 - June 2022

Note: This figure is intended to convey the correlation of the results for the various monitoring stations, not to depict individual results. Individual measurements are available online from EPA.

Figure 2.2.3 depicts the 2021 average gross beta results for each of the four stations in the ORR RadNet Air program, the average background concentrations measured at the Memphis and Nashville RadNet locations, as well as the CAA environmental limit for strontium-90. The 2021 average gross beta activity at each of the four ORR stations fell between the average activities at the Nashville and Memphis locations.

The CAA specifies that exposures to the public from radioactive materials released to the air from DOE facilities shall not cause members of the public to receive an effective dose equivalent greater than 10 mrem above background measurements in a year. For point-source emissions, compliance with this standard is generally determined with air dispersion models that predict the dose at offsite locations. The CAA also provides environmental concentrations for radionuclides equivalent to a dose of 10 mrem in a year (EPA 2010) to determine compliance.

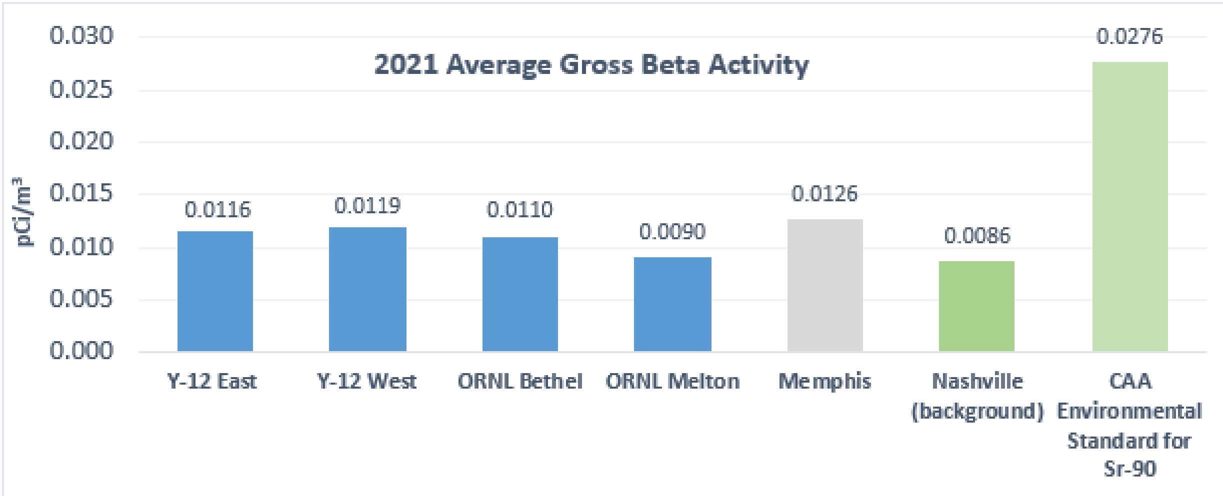

Figure 2.2.3: 2021 RadNet Air Monitoring Program Average Gross Beta Results

Note: Typical background values for gross beta range from 0.005 to 0.1 pCi/m^3 (ORISE, 1993). The standards provided by the Clean Air Act apply to the dose above background; therefore, the standard provided for reference in this figure has been adjusted to include the average of the background measurements taken from the RadNet station in Nashville for 2021 (CAA value for Sr-90 [0.019 pCi/m^3] + annual average gross beta at a background location=CAA environmental standard for Sr-90). The CAA's Environmental Limit for strontium-90 is used as a screening mechanism and is provided here for comparison. It is unlikely that this isotope contributes a major proportion of the gross beta activity reported for the samples.

To evaluate the RadNet data, the RadNet Air Monitoring project compares the average gross beta results reported for the project to the CAA limit for strontium-90, which has one of the most stringent standards of the beta-emitting radionuclides. The CAA standards apply to the dose above background, so the limit represented in Figure 2.2.3 was adjusted to include the average gross beta measurement taken at the RadNet station in Nashville, used as a background. It is important to note that strontium-90 is unlikely to be a large contributor to the total beta measurements reported here and is used only as a reference point to determine if further analysis is warranted.

While the 2021 results at all the RadNet Air stations were mostly comparable (results showed that sites responded in a similar pattern during each sampling period), the average gross beta results for the ORR RadNet Air Monitoring project in 2021 were lower at the ORNL Melton and ORNL Bethel locations. The stations at Y-12 East and Y-12 West showed slightly higher average gross beta levels. The average results from each of the ORR RadNet monitoring stations were well below the strontium-90 limit (Figure 2.2.3).

None of the gross beta results reported for the RadNet Air Monitoring project on the ORR from July 2021 through June 2022 exceeded the screening level (1.0 pCi/m^3) which would have led to additional analysis by gamma spectrometry. The average minimum detectable concentration (MDC) was 0.000323 pCi/ m^3 for the ORR locations from 2011 through 2021. So, while 1 pCi/m^3 is the screening level which triggers further analysis by EPA, concentration levels of about 0.000323 pCi/m^3 and higher can be detected and compared. The actual MDC for each sample is sample specific, but usually isn't far from the average MDC.

The analysis for uranium and plutonium on annual composite samples is set to be performed every four years. The previous most recent composite results available were from 2018, which were presented in last year's report, with all values for each isotope below the limits established by the CAA.

The 2019 composite gamma analysis for ORR RadNet sites were the most recent results available. All Tennessee locations (i.e. Oak Ridge, Knoxville, Nashville, Memphis) had results for the naturally occurring potassium-40 and sodium-22, and most had radium-228 and beryllium-7 results. The only cesium-137 result from Tennessee was from the ORR ORNL Bethel RadNet Air station for the 2019 composite gamma analysis. This value was 4.1 aCi/m^3 but was much lower than the compliance limit of 19,000 aCi/m^3 over background. An attocurie (aCi) represents 10E-18 curies, while a picocurie (pCi) represents 10E-12 curies.

2.2.8 Conclusions

The gross beta results for each of the four RadNet Air monitoring stations exhibited similar trends and concentration levels for the period July 2021 through June 2022. All the data during this time period was well below the values which would warrant further analysis and does not indicate that activities on the ORR pose a significant impact on the environment or public health.

2.2.9 Recommendations

Continued ORR air monitoring for radiological contamination through this and other TDEC DoR-OR programs is recommended in order to ensure that air quality is protective of human health and the environment. This is especially important because of the demolition of contaminated buildings, movement of contaminated soils, operations, and other continued activities on the ORR. These activities all have the potential to impact air quality. In the event of a radiological release either on or off the ORR, the RadNet Air Monitoring project would provide valuable information relating to the extent of radiological contamination in the air before, during, and after the event.

The RadNet Air Monitoring project is a valuable addition to other ORR air monitoring. First, annual sampling via the RadNet Air project collects and analyzes more samples than DOE air monitoring (twice weekly samples with approximately 100 samples analyzed yearly from each of the locations on the ORR). Second, gross beta analysis is not only used as a screening tool with further analysis when levels exceed 1.0 pCi/ m^3, but it also can detect much lower levels with low sample specific Minimum Detectable Concentrations (MDCs), so it can be very effective at detecting elevated gross beta levels as well as variation. Third, gross beta analysis is an effective screening tool since few isotopes of interest are pure gamma or pure beta emitters. If there were a release on the ORR, it is likely there would also be some beta radiation emitted either directly or from daughter products. Consequently, this program would likely detect an increase in radiological levels in air and be able to better pinpoint the time of release due to analysis of twice weekly samples versus the quarterly compositing of weekly air filters done by DOE.

2.2.10 References

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40 CFR 61, Subpart H. 2017. *Title 40 of the Code of Federal Regulations, Chapter 1, Subchapter C, Part 61 National Emission Standards for Hazardous Air Pollutants (NESHAPS), Subpart H National Emission Standards for Emissions of Radionuclides Other than Radon From Department of Energy Facilities.* https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-61/subpart-H

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customized search https://www.epa.gov/enviro/radnet-customized-search

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2.3 RadNet Precipitation

2.3.1 Background

Nationwide, the RadNet Precipitation Monitoring Project measures radioactive contaminants that are carried to the earth's surface by precipitation. On the ORR, the RadNet Precipitation Monitoring Project provides radiochemical analysis of precipitation samples taken from monitoring stations at three (3) locations. Samples are collected by TDEC DoR-OR and gamma analysis is performed on monthly composite samples at EPA NAREL in Montgomery, Alabama. Additional analysis may be conducted by EPA NAREL if a radiological release is known or is indicated by monthly gamma analysis results. While there are no regulatory standards that apply directly to contaminants in precipitation, the data from this project provide an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by the TDEC DoR-OR or DOE air monitors.

The EPA has provided three (3) RadNet precipitation monitors which are co-located with a RadNet air station at each of the three ORR sites. The first precipitation monitor is located at ORNL in Melton Valley, in the vicinity of ORNL's High Flux Isotope Reactor and the Solid Waste Storage Area burial grounds. The second precipitation monitor (previously at ETTP) is now co-located with the RadNet air station at ORNL in Bethel Valley. The third station is located at the east end of the Y-12 Complex. In addition to monitoring Y-12, this station could potentially provide an indication of radioisotopes traveling toward the City of Oak Ridge from ORNL or Y-12. Analysis for gamma radionuclides is performed on the monthly composite samples for each of the three precipitation monitoring locations.

2.3.2 Problem Statements

The sites on the ORR with the greatest potential for releasing radioactive contaminants into the air from previous and current operations as well as from the deterioration of contaminated buildings and the decontamination and decommissioning (D&D) of these facilities are now ORNL and Y-12. The known contaminated buildings at ETTP were demolished prior to the TDEC DoR-OR 2022 fiscal year, and the sampler previously at the ETTP site was moved to Bethel Valley at ORNL.

This project measures any radioactive constituents that are carried to the earth's surface by precipitation. The data provides an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by air monitors.

2.3.3 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.

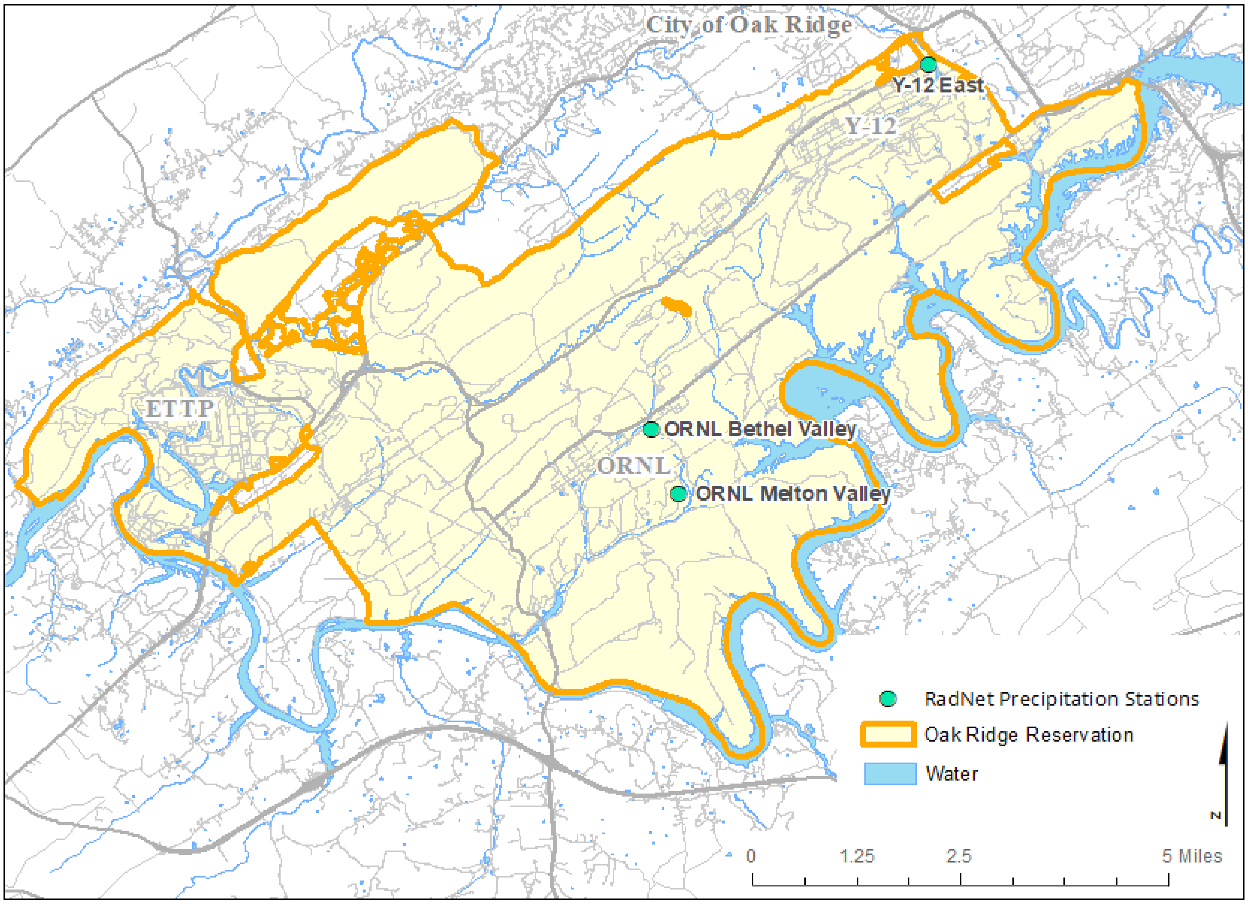

Figure 2.3.1: FY2022 locations of the RadNet Precipitation samplers on the ORR

2.3.4 Scope

Three (3) precipitation samplers are used to monitor the precipitation for radiological contamination. Each sampler is co-located with a RadNet Air station, at three locations on the ORR. One sampler is located at the east end of the Y-12 plant. The second unit is at ORNL in Bethel Valley. The third sampler is located at ORNL in Melton Valley. These locations are shown in Figure 2.3.1. Samples are measured and collected from the three ORR RadNet Precipitation samplers on Mondays and Thursdays, except when skipped due to a holiday. The precipitation samples are composited monthly at the EPA laboratory and analyzed for gamma radionuclides. Additional analysis on individual samples would likely be conducted in the event of elevated findings or for a nuclear release.

2.3.5 Methods, Materials, Metrics

The three (3) precipitation samplers provided by EPA's RadNet Air Monitoring program (locations shown in Figure 2.3.1) are used to collect samples for the RadNet Precipitation Monitoring Project. Each sampler drains precipitation that falls on a 0.5 square meter fiberglass collector into a five-gallon collection bucket. Each sample is measured, then collected from the bucket (into a four-liter container) and sent to EPA when a minimum of two liters of precipitation has accumulated, or less when it is the final sample of the month.

Each sample is processed as specified by EPA (EPA, 1988; EPA, 2017) and then shipped to NAREL in Montgomery, Alabama, for analysis. EPA NAREL composites the samples collected during a month for each station and analyzes each composite for gamma radionuclides. 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, it is likely there would be some gamma radiation emitted either directly or from daughter products. Additional analysis may be conducted if there is a known radiological release or in the event of elevated findings in the monthly gamma analysis results.

No regulatory limits for radiological contaminants in precipitation exist, so the results of the gamma analyses are compared to drinking water limits established by the EPA as conservative reference values. EPA's Radionuclides Rule for drinking water allows gross alpha levels of up to 15 picocuries per liter (pCi/L), while beta and gamma emitters are limited to 4 millirem (mrem) per year and are radionuclide specific. A combined value for radium-226 and radium-228 of up to five pCi/L is also allowed. Table 2.3.1 shows the maximum contaminant levels (MCLs) of beta and gamma emitters that EPA uses as drinking water limits for select isotopes. Not all gamma producing isotopes have EPA drinking water limits. Results from the ORR-located RadNet Precipitation Monitoring stations can also be compared to other sites in the EPA RadNet program. However, 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 2.3.1: 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

2.3.6 Deviations from the Plan

The results in this report would normally cover Fiscal Year 2022 (FY2022), July 2021 through June 2022, but are only available through December 2021 because analysis is still delayed due to COVID. Hence, the 2021 results are discussed (monthly composite results from January through December 2021). In June 2021, the precipitation sampler that was co-located at the ETTP location was moved to the ORNL Bethel Valley location (co-sampling with the RadNet air monitor at that location). For FY2022, the RadNet precipitation monitors were at the locations previously indicated.

2.3.7 Results and Analysis

The results of EPA NAREL's analyses of the nationwide RadNet Precipitation sampling are available in the RadNet database on the Envirofacts website (EPA, 2022), via either a simple or a customized search. The gamma isotopes identified for 2021 sampling results from the ORR precipitation stations include cesium-137, cobalt-60, potassium-40, radium-226, and radium-228. For all except one sample, the potassium-40 result (March 2021 ETTP sample, 12.7 pCi/L), the reported results for each isotope were all less than the minimum detectable concentration (MDC). As stated in the RadNet user guide, the MDCs reflect "*the ability of the analytical process to detect the analyte for a given sample. The MDC is the activity concentration for which the analytical process detects the radioactive material in a given sample that provides a 95% chance that the radioactive material will be detected.*" Potassium-40 is a naturally occurring radionuclide and does not have a drinking water limit.

2.3.8 Conclusions

Overall, the highest values seen in the composited monthly precipitation samples for each of the three (3) ORR stations were all below the MCLs set by the EPA for drinking water, and all but one were below MDCs. While there are no regulatory limits for radionuclides in precipitation, the comparison to EPA's drinking water limits were used as conservative reference values. All results for cesium-137 and cobalt-60 for this time period were less than the MDCs. The other isotopes with results were naturally occurring and all except one were below MDCs as well**.** The 2021 RadNet Precipitation results for the ORR stations were below detection limits or below the regulatory limits used for drinking water and did not indicate a significant impact on the environment or public health from ORR emissions.

2.3.9 Recommendations

Continued monitoring of the ORR precipitation for radiological contamination via the ORR RadNet Precipitation project is recommended in order to ensure that contamination in precipitation seen on the ORR does not present risk to human health and the environment. This is especially important as the demolition of older buildings continues at the ORR sites. Current operations also have the potential to impact precipitation contaminant levels. In the event of an emergency either on or off the ORR, this program would also provide valuable data relating to the extent of radiological contamination in the air and precipitation before, during, and after an event.

2.3.10 References

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customized search https://www.epa.gov/enviro/radnet-customized-search
user guide https://www.epa.gov/enviro/radnet-search-user-guide

3.0 BIOLOGICAL MONITORING

3.1 Benthic Ecological Community Health

3.1.1 Background

The Benthic Macroinvertebrate Monitoring Project monitors the current condition and changing conditions of stream-bottom communities in streams on the ORR. These streams have been negatively impacted by historical Manhattan Project activities, as well as current DOE operational activities. The three (3) facilities on the ORR are as follows: ETTP, ORNL, and Y-12. The purpose of the Benthic Community Health Project is to document the current condition of these stream communities and to note the changes of these conditions as remedial activities continue under CERCLA.

During FY2022, TDEC-DoR-OR began a holistic approach to watershed and stream monitoring. The primary focus of this project for FY2022, was to provide benthic community health data on Bear Creek, to support the overall findings of the holistic Bear Creek Assessment Project (BCAP).

Bear Creek is a small to moderate-sized stream whose headwaters begin partly in the west end of the industrialized complex at Y-12. Historically, Bear Creek has received pollution from industrial activities, as well as waste disposal activities at Y-12. Former waste sites, such as the S3 ponds (located at its headwaters) and the EMWMF (located near its upper reaches), continue to negatively influence the water quality of the stream. Bear Creek receives low-level radiological and hazardous wastes from the EMWMF. Additionally, as EMWMF nears capacity, an additional hazardous waste facility (i.e. EMWF) is planned for construction near the middle reaches of Bear Creek to continue clean-up efforts on the ORR. The additional contamination from the new facility may have unintentional impacts on the aquatic system in Bear Creek. Additionally, shallow groundwater and surface water mingle freely in Bear Creek, allowing contamination to be transported greater distances via ground water. Monitoring of the benthic communities in Bear Creek should continue in order to note any changes that may occur due to an influx of environmental stressors.

Stream-bottom communities (e.g. aquatic insects and other macroinvertebrate species) serve as indicators of the health of aquatic systems because these organisms spend most of their lives in water and are continually exposed to contaminants and conditions caused by direct or indirect discharges into Bear Creek. An unimpacted reference stream, Mill Branch (MBK 1.6) or Clear Creek (CCK 1.6), was used to define what a healthy community would look like without the impacts of DOE activities. Benthic communities at impacted and un-impacted stations were compared to help determine the extent of the suspected DOE impacts.

Related DOE Projects:
ORNL conducts benthic macroinvertebrate sampling throughout the ORR (including Bear Creek). They report their findings in both the Remediation Effectiveness Report (RER), published annually, and the Annual Site Environmental Report (ASER). A select number of stream sites are sampled by both TDEC DoR-OR (spring season sampling) and ORNL (both fall and spring season sampling) which allows for an independent verification of monitoring results collected by both parties. Determining impacts to stream bottom communities is a difficult task with many variables that have the potential to introduce error. Consequently, results and interpretations may differ slightly among sampling staff and analysts. Thus, TDEC DoR-OR's benthic project will help build upon ORNL's work to collectively build a better understanding of conditions in ORR streams.

3.1.2 Problem Statements

Benthic macroinvertebrate communities in the four (4) main watersheds (East Fork Poplar Creek, Bear Creek, White Oak Creek, and Mitchel Branch) on the ORR do not compare well with healthy communities from un-impacted reference streams (TDEC DoR-OR EMR 2021). Intolerant species (organisms that do not survive well in polluted areas) are found in significantly fewer instances and smaller quantities at Bear Creek sampling sites (Figure 3.1.9). Tolerant species (organisms that survive and can tolerate polluted areas) are found in significantly more instances and higher quantities in some Bear Creek sites (Figure 3.1.8). These findings likely indicate stream impairment due to anthropogenic activity. These impacts are likely due to the historical Manhattan Project activities and current operational DOE activities. In areas where stream sections have been channelized, problems may be due to a lack of appropriate substrates for the establishment of healthy stream-bottom communities.

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 (e.g. flow rates, heat waves, storm events, etc.). Another part of this variability is due to variation among samplers. Some variation in TDEC-DoR-OR data and ORNL data can be attributed to differences in sampling seasons. TDEC DoR-OR uses a semi-quantitative method in the spring season. ORNL uses a quantitative method in the spring season and a semi-quantitative method in the fall season. DOE fall season data was not available to report on due to the large amount of time it takes to identify macroinvertebrates. Due to these sources of variability, caution should be exercised in drawing conclusions based on the interpretation of this data.

Changing habitat due to severe weather events, such as flooding may influence TDEC DoR-OR sampling site locations. Beaver activity has impacted sampling sites as well. The Bear Creek Kilometer 9.6 sampling site has recently been washed out from flashflood 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 was not moved for this sampling season, but it may need to be adjusted for future sampling events.

3.1.3 Goals

The goals of the Benthic Macroinvertebrate Monitoring Project:

- Monitor the current condition and health of benthic communities at stream sites along Bear Creek.
- Compare the current health of the stream ecosystem to historical data in Bear Creek and its corresponding reference station Mill Branch.
- Provide data for comparison with other ongoing DOE studies of Bear Creek benthic communities. There is normal year-to-year variation in benthic communities, as well as sampling technique. A comparison of data from different sources helps to clarify the current conditions along Bear Creek.
- Benthic macroinvertebrate monitoring was preformed to provide recommendations on potential changes that can be made to help improve the current ecosystem of Bear Creek where primary impacts are due to ORR facilities.

3.1.4 Scope

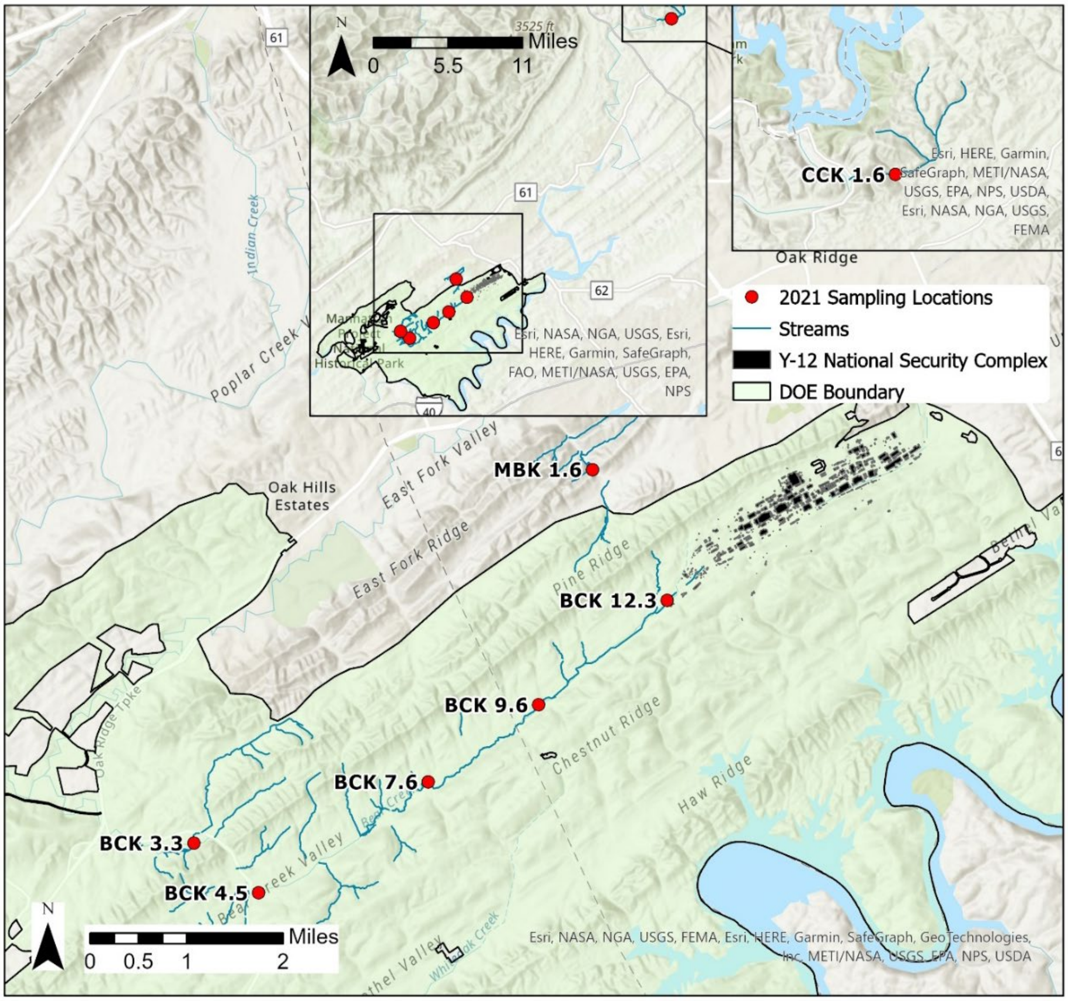
During FY2022, the Bear Creek watershed was the focus of this project, in order to support the BCAP. TDEC-DoR-OR conducted macroinvertebrate sampling in the spring of 2021, at five (5) assessment sites along Bear Creek and one reference station (Table 3.1.1). The sampling stretch of Bear Creek, started near the headwaters (BCK 12.3) and continued at multiple locations in the middle reaches, running downstream to BCK 3.3, near the confluence of Bear Creek with East Fork Poplar Creek (Figure 3.1.3). Sampling included one composited sample per site, two 1 square meter (m^2) kicks.

Specific sampling dates were dependent on availability of staff to perform the sampling, vehicles, and recent weather conditions (i.e., sampling is best completed under normal, not high-water flows). At sites where samples were taken both by TDEC DoR-OR and ORNL, care was taken to plan for a two- to three-week sampling time difference to allow for recovery of the benthic community. Sample processing occurred in the TDEC DoR-OR laboratory and was performed by experienced benthic macroinvertebrate taxonomists. Processing took place between May and September 2021.

Table 3.1.1: Benthic Macroinvertebrate Monitoring Locations

Facility	Watershed	Stations	Reference Stations
Y-12	Bear Creek	BCK 12.3	MBK 1.6 & CCK 1.6*
		BCK 9.9	
		BCK 7.6	
		BCK 4.5	
		BCK 3.3	

**Clear Creek was used as the reference station in 2020 instead of MBK 1.6 (covid-19 related).*
BCK = Bear Creek Kilometer, MBK = Mill Branch Kilometer, CCK = Clear Creek Kilometer



BCK = Bear Creek Kilometer, MBK = Mill Branch Kilometer, CCK = Clear Creek Kilometer

Figure 3.1.1: Bear Creek, Mill Branch, and Clear Creek Sampling Locations

3.1.5 Methods, Materials, Metrics

Sample Collection:

Sampling for this project required two people at a minimum. One person set a one-square-meter kick net with a 500-micron mesh across a predetermined riffle downstream. The other person, using a heavy-duty garden rake, disturbed approximately 1 m^2 area of the stream substrate directly upstream of that net. The organisms, sediment, and detritus flowed into the net. The net was then carefully lifted out of the water and carried horizontally to the streambank. The bottom of the net was positioned in a 500-micron sieve bucket. The net was thoroughly rinsed into the sieve bucket. This process was repeated using a second riffle upstream of the previous kick. The two kicks were then composited, placed in a plastic container, and preserved with 95% ethanol.

Sample Processing:

Processing of benthic samples consisted of two major steps. The first step was sample sorting, where benthic organisms were removed from the detrital material collected. The remainder of the sample was transferred into a numbered tray and evenly distributed. Four random numbers were selected using a random number generator. The corresponding numbers in the tray were then selected as subsamples.

The second step in processing was identification of the organisms collected in the four randomly selected samples. The larger macroinvertebrates were identified by an experienced taxonomist using a binocular dissecting scope and the appropriate organism identification keys, where needed. The smaller macroinvertebrates, which include the *Chironomidae* (non-biting midges) and the smaller *Oligochaeta* (worms), were mounted on slides and identified by an experienced taxonomist using a binocular compound light microscope and the appropriate keys.

The Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC DWQ SOP 2021) requires identification of taxa to only the genus-level. Calculations of all metrics for this study were determined using the genus-level identifications.

Data Analysis:
Once sample identifications were complete, the identifications for each sample were totaled for each genus and recorded via Excel spreadsheet. The data were then sent to the Division of Water Resources (DWR) to calculate the various metrics used in the analysis. A description of each metric and the expected response to environmental stressors is listed in Table 3.1.2. Each metric is calculated and then given a score based on the results of each calculation for each metric. Those scores are then totaled, and the sum is the Tennessee Macroinvertebrate Index (TMI) score. A TMI score of 32 meets all bio-criteria for a healthy benthic macroinvertebrate community with no impairment to the system, while anything below a 32 represents different grades of severity ranging from Severely Impaired to Slightly Impaired. Specifics for calculating each metric can be found in the TDEC DWQ SOP 2021.

Table 3.1.2: Individual Metrics used to calculate TMI scores

Description of Metrics and Expected Responses to Stressors			
Category	**Metric**	**Description**	**Response to Stress**
Richness	Taxa Richness	Measures overall diversity of the macroinvertebrate assemblage	Number Decreases
	EPT Richness	Number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera	Number Decreases
	Intolerant Taxa*	Number of taxa that display a tolerance rating or NCBI score < 3.0	Number Decreases
Composition	% EPT-Cheum	% of EPT abundance excluding Cheumatopsyche taxa	% Decreases
	% OC	% of Oligochaetes and Chironomids present	% Increases
Tolerance	North Carolina Biota Index (NCBI)	Incorporates richness and abundance with a numerical rating of tolerance	Number Increases
	% TNUTOL	% of Nutrient Tolerant organisms, those with NCBI scores > 3.0	% Increases
Habitat	% Clingers	% of organisms with fixed retreats or attach themselves to substrate	% Decreases

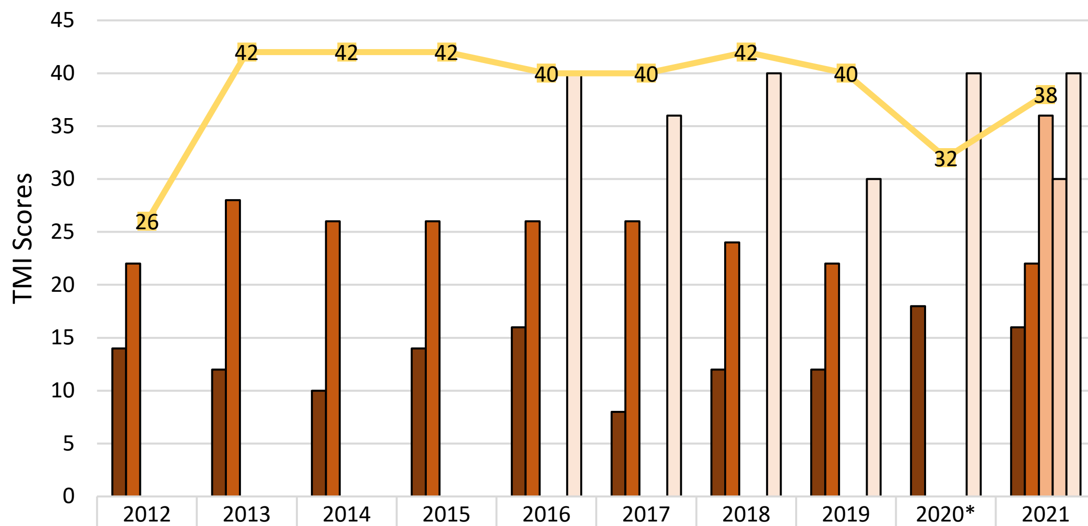
**Intolerant Taxa is no longer included in the TMI score, but provides relevant information to data analysis*

3.1.6 Deviations from the Plan

Due to a change in scope during the project's duration during 2021, diatom sampling did not occur. After a discussion with the TDEC DWR, it was determined by TDEC DoR-OR staff that diatom sampling would not reveal any new information, so it was not performed.

3.1.7 Results and Analysis

TMI Scores for Bear Creek (Figure 3.1.2) were lowest at the upstream station (BCK 12.3) and highest at the most downstream station (BCK 3.3). BCK 12.3 displayed a reduced benthic macroinvertebrate community between 2012 and 2021. It consistently ranks among the poorest performing or least biodiverse sites monitored in this project. On average, BCK 12.3 scores approximately 25 points lower per year than its corresponding reference station (Figure 3.1.2).



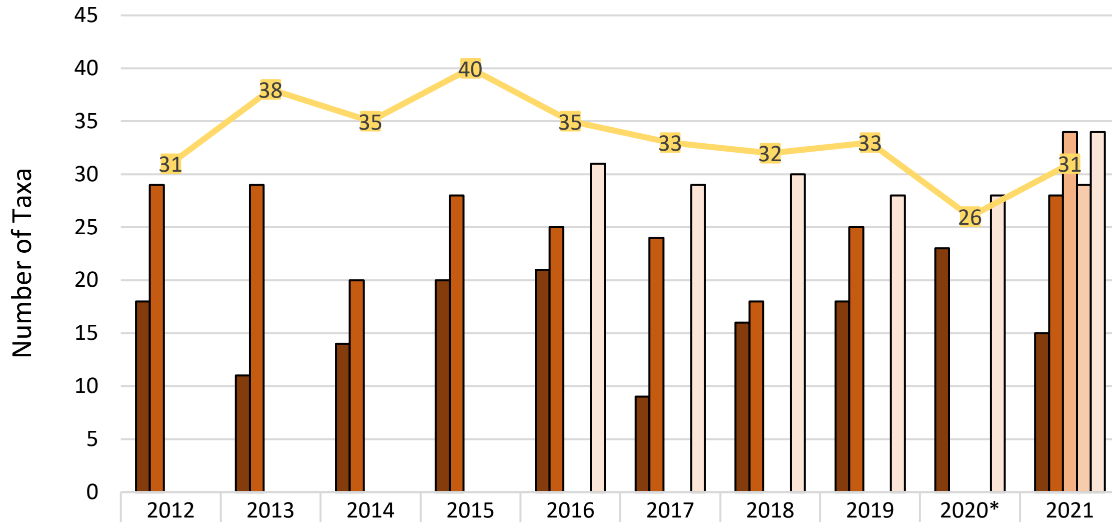
	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021
BCK 12.3	14	12	10	14	16	8	12	12	18	16
BCK 9.6	22	28	26	26	26	26	24	22		22
BCK 7.6										36
BCK 4.5										30
BCK 3.3					40	36	40	30	40	40
MBK 1.6	26	42	42	42	40	40	42	40	32	38

BCK 12.3 BCK 9.6 BCK 7.6 BCK 4.5 BCK 3.3 MBK 1.6

**CCK 1.6 used as reference site rather than MBK 1.6*

Figure 3.1.2: Bear Creek TMI Scores

In 2020 and 2021, BCK 3.3 had a higher TMI score than the corresponding reference sites (Figure 3.1.2). This was likely due to the dilution of contaminants from Y-12 and greater habitat availability. BCK 3.3 is one of the farthest downstream sites that TDEC monitors. It has a greater flow, a more natural substrate, and a pool to riffle ratio that is more conducive for macroinvertebrate habitation than reference stations MBK 1.6 (2021) and CCK 1.6 (2020). In 2021, the TMI scores became increasingly better the further the station was from Y-12. The trend in TMI scores suggests that Contaminants of Concern (COCs) became diluted as they traveled down Bear Creek, therefore allowing the macroinvertebrate species to better survive in a less stressful environment.

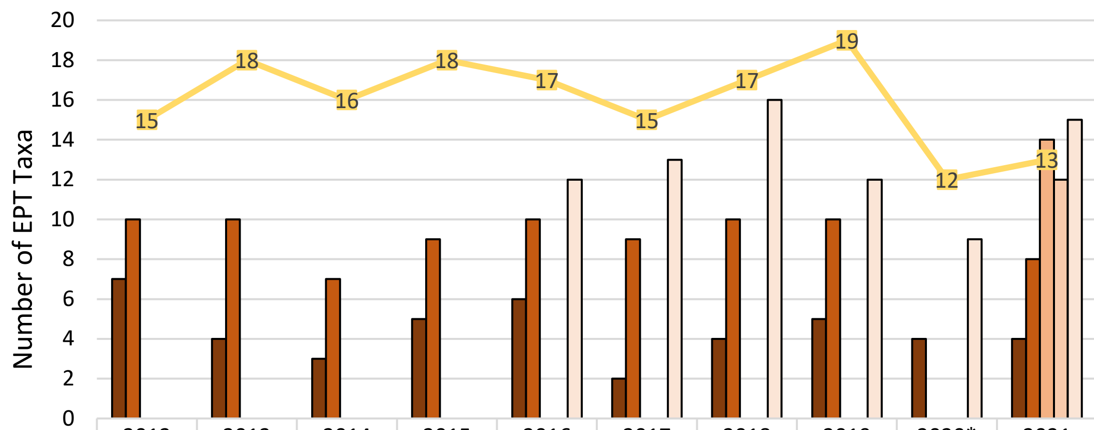


	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021
BCK 12.3	18	11	14	20	21	9	16	18	23	15
BCK 9.6	29	29	20	28	25	24	18	25		28
BCK 7.6										34
BCK 4.5										29
BCK 3.3					31	29	30	28	28	34
MBK 1.6	31	38	35	40	35	33	32	33	26	31

**CCK 1.6 used as reference site rather than MBK 1.6*

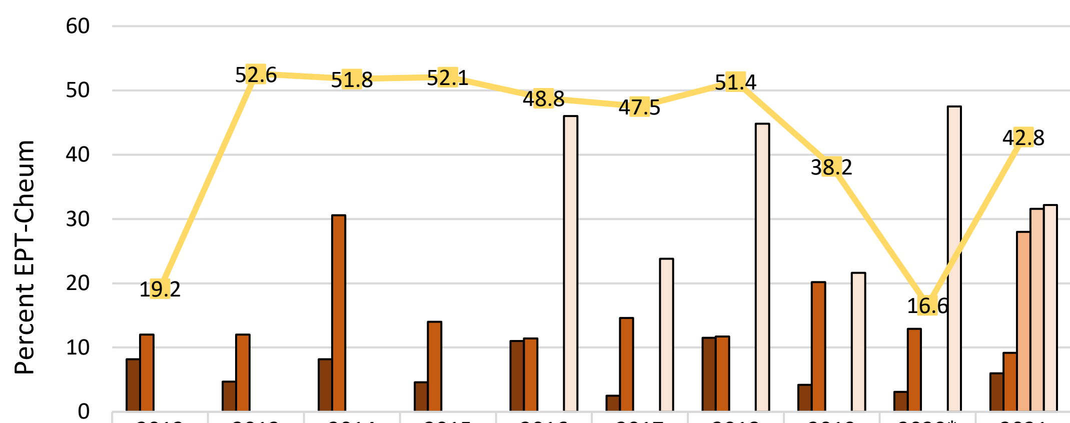
Figure 3.1.3: Bear Creek - Taxa Richness

Following similar trends to the TMI scores, Taxa Richness (Figure 3.1.3) also increased as Bear Creek flowed downstream. Lower taxa richness scores imply there are stressors in the environment causing fewer species of macroinvertebrates to survive. On average, BCK 12.3 had approximately 17 fewer taxa of macroinvertebrates than MBK 1.6 and CCK 1.6 between 2012 – 2021. In contrast, BCK 3.3 performed similar to the reference stations between 2016 – 2021. BCK 3.3 had approximately 3 fewer taxa on average than the reference stations. Since taxa richness followed the same trends as TMI scores, taxa richness represented no new perspective on stream health.



	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021
BCK 12.3	7	4	3	5	6	2	4	5	4	4
BCK 9.6	10	10	7	9	10	9	10	10		8
BCK 7.6										14
BCK 4.5										12
BCK 3.3					12	13	16	12	9	15
MBK 1.6	15	18	16	18	17	15	17	19	12	13

Figure 3.1.4: Bear Creek – EPT Richness



	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021
BCK 12.3	8.2	4.7	8.2	4.6	11	2.5	11.5	4.2	3.1	6
BCK 9.6	12	12	30.6	14	11.4	14.6	11.7	20.2	12.9	9.2
BCK 7.6										28
BCK 4.5										31.6
BCK 3.3					46	23.8	44.8	21.6	47.5	32.2
MBK 1.6	19.2	52.6	51.8	52.1	48.8	47.5	51.4	38.2	16.6	42.8

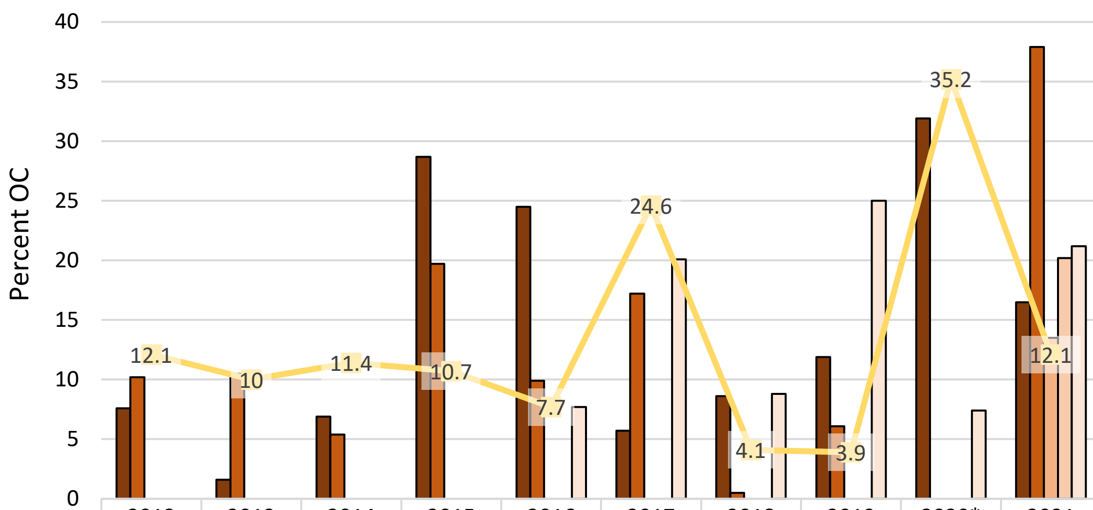
**CCK 1.6 used as reference site rather than MBK 1.6*

Figure 3.1.5: Bear Creek – Percent EPT

EPT richness (Figure 3.1.4) and percent EPT (Figure 3.1.5) represent the number of taxa in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). The organisms in these three (3) orders are typically more sensitive to environmental stressors; therefore, a decreased presence of these taxa represents an impairment in stream health.

On average, BCK 12.3 had 12 fewer EPT taxa than the reference sites (MBK 1.6 and CCK 1.6). In contrast, BCK 3.3 had on average only four fewer EPT taxa than the corresponding reference site. The same trend can be seen in the percent EPT metric, BCK 12.3 had on average 6.4% EPT taxa per sample, whereas BCK 3.3 had 36.0% EPT taxa per sample. The reference stations had an average of 42.1% EPT taxa per sample.

Based on the comparisons of the data presented on EPT taxa, Bear Creek had stressors placed upon it that did not allow EPT taxa to flourish as they did at reference stations. Bear Creek showed impairment based on these metrics and the metrics previously discussed.



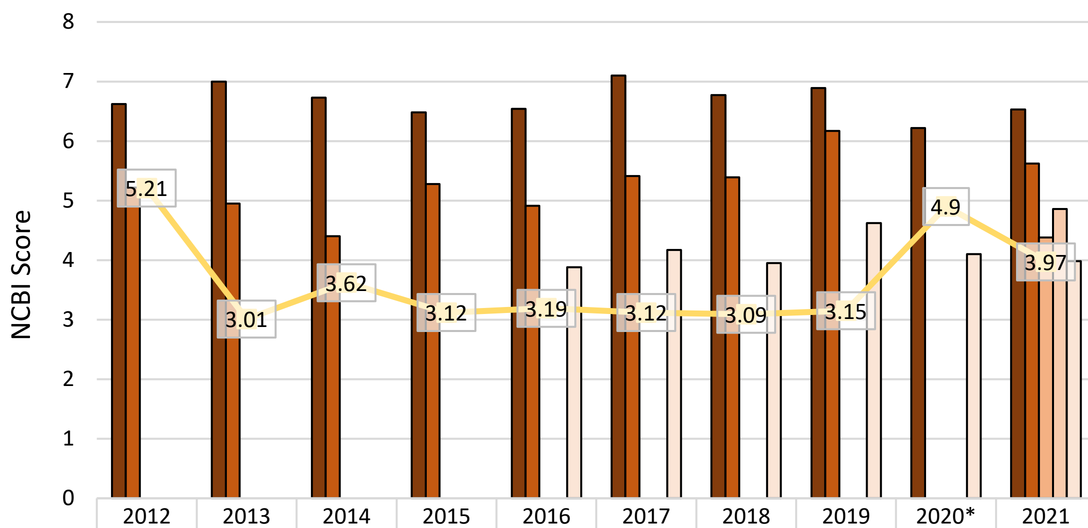
	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021
BCK 12.3	7.6	1.6	6.9	28.7	24.5	5.7	8.6	11.9	31.9	16.5
BCK 9.6	10.2	10.5	5.4	19.7	9.9	17.2	0.5	6.1		37.9
BCK 7.6										13.5
BCK 4.5										20.2
BCK 3.3					7.7	20.1	8.8	25	7.4	21.2
MBK 1.6	12.1	10	11.4	10.7	7.7	24.6	4.1	3.9	35.2	12.1

BCK 12.3 BCK 9.6 BCK 7.6 BCK 4.5 BCK 3.3 MBK 1.6

**CCK 1.6 used as reference site rather than MBK 1.6*

Figure 3.1.6: Bear Creek – Percent Oligochaetes and Chironomids

Percent OC (Figure 3.1.6) represents the percent of the composite of Oligochaeta (aquatic worms) and Chironomidae (midge larvae) in a stream sample. Stress in aquatic environments causes this number to increase, due the high tolerance of the species within these taxa. Overall, Bear Creek sites had relatively low levels of aquatic worms and midge larvae when compared to the reference site. On average, BCK 12.3 had approximately 14.39% of OC in every yearly sample between 2012 – 2021 and BCK 3.3 had approximately 15.03% OC in each sample. Reference stations did not perform much better and had an average of 13.18% OC over the ten-year period. The results from this metric calculation inferred those stressors promoting higher numbers of OC were not present in Bear Creek.



	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021
BCK 12.3	6.62	7	6.73	6.48	6.54	7.1	6.77	6.89	6.22	6.53
BCK 9.6	5.22	4.95	4.4	5.28	4.91	5.41	5.39	6.17		5.62
BCK 7.6										4.38
BCK 4.5										4.86
BCK 3.3					3.88	4.17	3.95	4.62	4.1	3.98
MBK 1.6	5.21	3.01	3.62	3.12	3.19	3.12	3.09	3.15	4.9	3.97

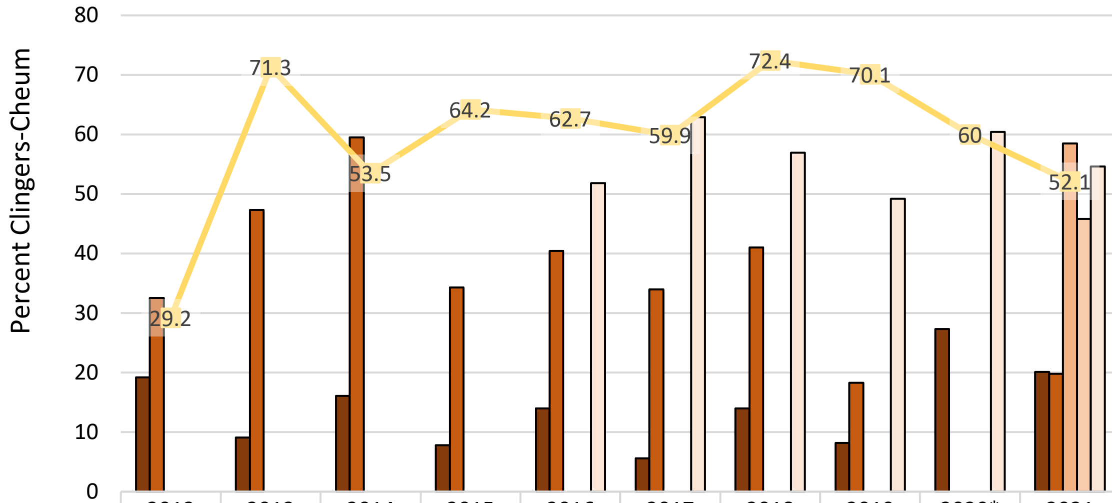
BCK 12.3 BCK 9.6 BCK 7.6 BCK 4.5 BCK 3.3 MBK 1.6

**CCK 1.6 used as reference site rather than MBK 1.6*

Figure 3.1.7: Bear Creek – North Carolina Biota Index Scores

The North Carolina Biota Index (NCBI) (Figure 3.1.7) uses stress tolerance values of macroinvertebrate taxa to weight the abundance in an estimate of overall pollution. The lower the NCBI score a site has, the better the stream's health. Stress will cause this number to increase, due to an increase in more tolerant macroinvertebrate species. Any taxon with an NCBI score less than three is defined as an intolerant taxon, meaning intolerant to environmental stress.

BCK 12.3 had a ten-year NCBI score average of 6.69, and BCK 3.3 had an average of 4.12. Comparatively, reference stations MBK 1.6 and CCK 1.6 had a ten-year average of 3.64 performing better than the Bear Creek sites. This metric indicated there were stressors in Bear Creek that did not allow many intolerant taxa to thrive.



	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021
BCK 12.3	19.2	9.1	16.1	7.8	14	5.6	14	8.2	27.3	20.1
BCK 9.6	32.5	47.3	59.5	34.3	40.4	34	41	18.3		19.8
BCK 7.6										58.5
BCK 4.5										45.8
BCK 3.3					51.8	62.9	56.9	49.2	60.4	54.6
MBK 1.6	29.2	71.3	53.5	64.2	62.7	59.9	72.4	70.1	60	52.1

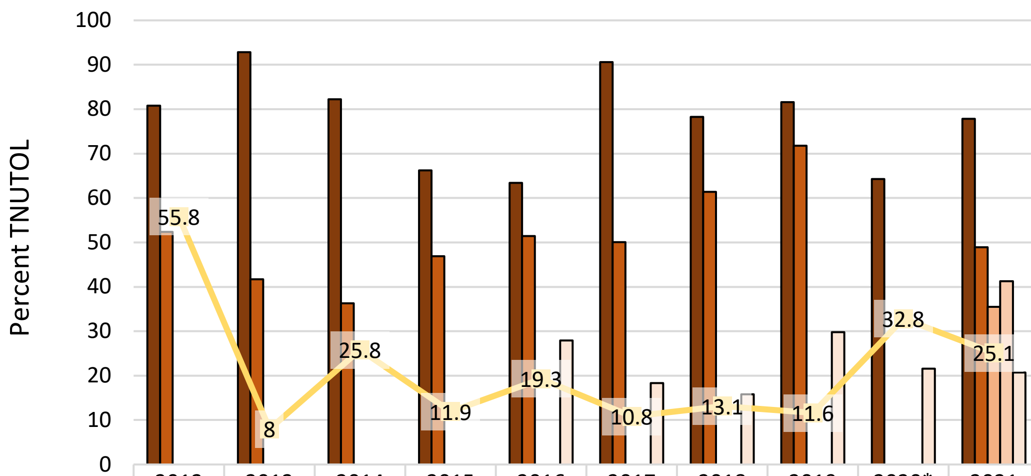
BCK 12.3 BCK 9.6 BCK 7.6 BCK 4.5 BCK 3.3 MBK 1.6

**CCK 1.6 used as reference site rather than MBK 1.6*

Figure 3.1.8: Bear Creek – Percent Clingers

Percent clingers (Figure 3.1.8) pertains to the number of clinging macroinvertebrates there are in a sample. Clinging macroinvertebrates have special adaptations that allow them to cling onto substrate such as pebbles or detritus. The quality of substrate on the stream bottom determines the number of clingers that will be present. Stress causes this number to decrease.

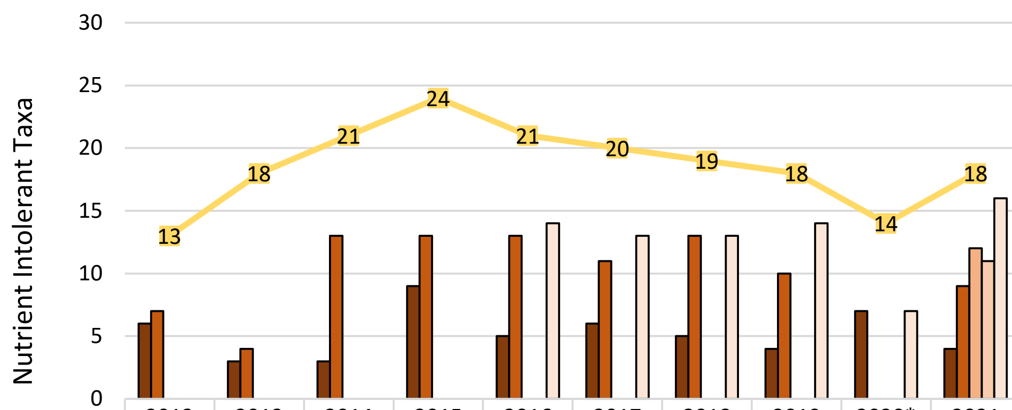
As previously stated, BCK 12.3 does not have a suitable habitat for clinging organisms. Accordingly, the average percent of clingers was only 14.14% for BCK 12.3. In stark contrast, BCK 3.3 performed similarly to the reference stations with an average of 56% clingers. Reference stations (MBK 1.6 and CCK 1.6) had a ten-year average of 59.54%, only 3.54% higher than BCK 3.3. This metric followed the same trends as the TMI scores, Taxa Richness, and EPT taxa richness and percent. BCK 12.3 is impaired, but conditions gradually become better as Bear Creek flows downstream to BCK 3.3.



	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021
BCK 12.3	80.8	92.8	82.2	66.2	63.4	90.6	78.3	81.6	64.3	77.8
BCK 9.6	52.4	41.7	36.3	46.9	51.4	50.1	61.4	71.8		48.9
BCK 7.6										35.5
BCK 4.5										41.3
BCK 3.3					27.9	18.3	15.8	29.8	21.6	20.7
MBK 1.6	55.8	8	25.8	11.9	19.3	10.8	13.1	11.6	32.8	25.1

BCK 12.3 BCK 9.6 BCK 7.6 BCK 4.5 BCK 3.3 MBK 1.6

Figure 3.1.9: Bear Creek – Percent Nutrient Tolerant Taxa



	2012	2013	2014	2015	2016	2017	2018	2019	2020*	2021
BCK 12.3	6	3	3	9	5	6	5	4	7	4
BCK 9.6	7	4	13	13	13	11	13	10		9
BCK 7.6										12
BCK 4.5										11
BCK 3.3					14	13	13	14	7	16
MBK 1.6	13	18	21	24	21	20	19	18	14	18

BCK 12.3 BCK 9.6 BCK 7.6 BCK 4.5 BCK 3.3 MBK 1.6

*CCK 1.6 used as reference site rather than MBK 1.6

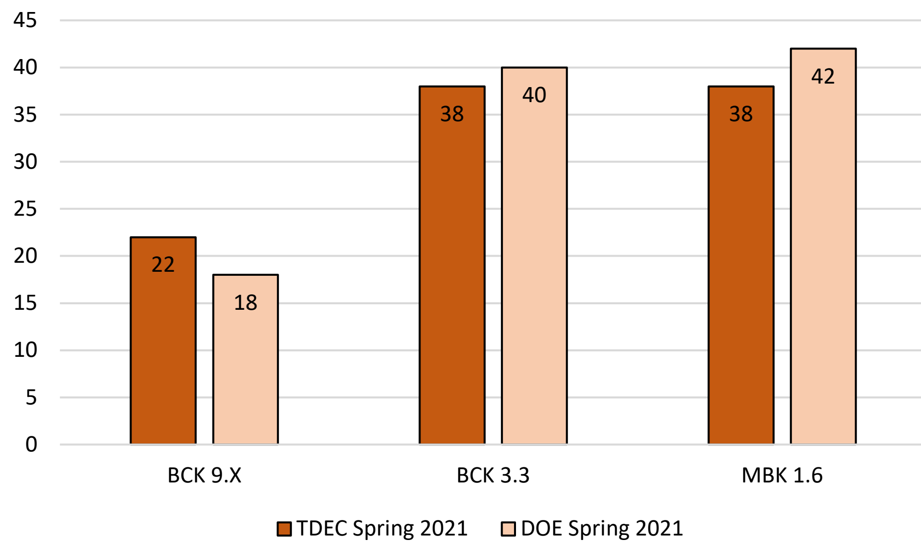
Figure 3.1.10: Bear Creek – Nutrient Intolerant Taxa

Percent Nutrient Tolerant Taxa (Figure 3.1.9) represents the percentage of families considered to be tolerant of various types of environments and nutrient-related stress. This metric is calculated off the NCBI scores for the families of macroinvertebrates. A higher score represents lower stream quality with more tolerant species present. Stress causes this number to increase.

BCK 12.3 had a ten-year average of 77.8% nutrient tolerant taxa and BCK 3.3 had a ten-year average of 22.35%. Similarly, to BCK 3.3, the reference stations averaged 21.42% nutrient tolerant taxa between 2012 – 2021.

The opposite of the percent nutrient tolerant taxa metric is the nutrient intolerant taxa number (Figure 3.1.10). The number of nutrient intolerant taxa metric represents the number of taxa that are intolerant to nutrients and stress. This is also based on a taxon's NCBI score. Anything that has a tolerance level below 3.00 is counted as an intolerant taxon. The number of nutrient intolerant taxa will decrease when there is an increase in stream nitrogen and phosphorous pollution and an increase in stressors within the stream.
BCK 12.3 had an average of five (5) intolerant taxa present among the ten-year sampling period. The down-stream site, BCK 3.3, had an average of 13 intolerant taxa per sample. The reference stations had an average of 19 intolerant taxa per sample.

In summary, the nutrient intolerant and tolerant taxa represented an estimate of pollution and nutrient levels in Bear Creek. BCK 12.3 had fewer intolerant taxa and much greater numbers of tolerant taxa, indicating higher levels of pollution and nutrients at BCK 12.3. Further downstream at BCK 3.3, there were higher numbers of nutrient intolerant taxa and lower numbers of tolerant taxa like the reference stations. As Bear Creek flows downstream the levels of pollution and nutrients were likely diluted, resulting in more successful communities of benthic macroinvertebrates downstream.



"X" represents 9.6 for TDEC DoR-OR data and 9.9 for DOE data

Figure 3.1.11: Comparison of TDEC DoR-OR and DOE TMI Scores

There were variations in the final TMI scores between TDEC DoR-OR and DOE data. Some of this variation can be attributed to the difference in sampling techniques between TDEC DoR-OR and DOE. ORNL samples macroinvertebrates on behalf of DOE and they performed a quantitative sample collection in the spring months. TDEC DoR-OR completed a semi-quantitative sample collection in the spring season. TDEC DoR-OR used a kick net and ORNL used a Hess Stream Bottom sampler. Even though the sampling methods were different, the difference in TMI scores between organizations was minimal. The greatest difference between TMI scores was four points, and the same conclusions can be accurately drawn from each data set.

As previously mentioned in Section 3.1.1 under "Related DOE Projects", DOE samples in the fall season as well. Those fall 2021 samples have not been processed yet, so they are not included here.

3.1.8 Conclusions

The health of the benthic macroinvertebrate communities in ORR streams has improved since the 1980s; however, it has been observed that these improvements have leveled off in recent years. In 2021, TDEC DoR-OR began a holistic approach to some stream and watershed monitoring. TDEC DoR-OR primarily focused on one stream, Bear Creek, to obtain an overview of the entire stream's health. Macroinvertebrate samples were taken from the most upstream site (BCK 12.3) and at three points downstream until finally stopping at BCK 3.3 with a total of five (5) sampling sites. Mill Branch is Bear Creek's corresponding reference site, although in 2020, Clear Creek was used instead of Mill Branch.

The results of TDEC DoR-OR's benthic macroinvertebrate sampling along Bear Creek, have continuously shown impairment based on the metrics and TMI scores from this ten-year review. Site improvement can be observed when travelling downstream (BCK 12.3 to BCK 3.3). This suggests that as COCs travel downstream and become diluted the stream becomes less impaired. Bear Creek performed similar to reference stations at the downstream station (BCK 3.3), but most of the upper stream stations (BCK 12.3 – BCK 4.5) suffered from increased contamination, increased nutrient (i.e. nitrogen/phosphorus) pollution, and other stressors.

3.1.9 Recommendations

Benthic communities in streams on the ORR should continue to be monitored on a regular basis, including an increase in holistic stream studies to monitor entire stream watersheds. Every effort should be made to protect the current quality of streams that meet their designations and to improve those that do not. Enhancing Bear Creek's stream bottom with more natural substrates would help improve this stream by providing more habitat for the benthic communities. Additionally, reducing the input of contaminants into Bear Creek would limit the amounts of new stressors placed on the macroinvertebrate communities.

3.1.10 References

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3.2 ORR ROVING CREEL SURVEY

3.2.1 Background

The Roving Creel Survey project evaluated the level of angler activity and estimated angling pressure at three key locations where impaired ORR watersheds drain into publicly accessible waters. Fisherman interviews were conducted at the confluence region of White Oak Creek Embayment and the Clinch River, the confluence of Poplar Creek and the Clinch River, and the confluence region of East Fork Poplar Creek (EFPC) and Poplar Creek. These streams have been negatively impacted by Manhattan Project activities as well as current operational activities.

Bear Creek and EFPC originate within the confines of 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).

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 physiological damage (Standish, 2016). Fish are especially vulnerable to mercury bioaccumulation due to their habitat and diet.

White Oak Creek originates just north of the ORNL, cuts through the main campus, and discharges into the Clinch River. Radionuclides released from ORNL into this exit water pathway leak from ponds and waste disposal areas and include contaminants such as strontium-90 (Sr-90) and cesium-137 (Cs-137), as well as other byproducts (DOE, 1988). These 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 (Rowan and Rasmussen, 1994). Even in the most mobile aquatic habitats (i.e. flowing rivers), cesium may persist in a biologically available form for several years after release (Sakai et al., 2016).

Little is known about the level of human interaction with these publicly accessibly waters. Some contaminants could be harmful to human health in large quantities and prolonged exposures. Consumption of fish is the most likely human exposure pathway. According to a fish consumption survey conducted in 2008, approximately two thirds of fishermen consumed fish from the waters in the Melton Hill and Blair Creek Road area. Eighty percent of those interviewed were aware of fish consumption advisories. Of those, almost 50% still thought the fish were safe to eat (Campbell, 2002). The fish consumption study overlaps many of the areas in this roving creel survey project. Currently, TDEC DoR-OR's data are not sufficient to determine if enough protective measures are being implemented to limit human exposure on the ORR.

Consumable fish tissue samples were collected from four (4) sampling locations in September of 2021 and April of 2022. Fish were collected from Clinch River Kilometer (CRK) 70.8 (reference site), CRK 33.8, CRK 19.3, and PCK 8.9 (Figure 3.2.1). A total of 12 fish were collected and sent to either ALS Laboratories (ALS) or GEL Environmental (GEL). Fish tissue samples were then analyzed for various COCs (Section 3.2.7 Results and Analysis).

3.2.2 Problem Statements

- Fish bioaccumulate mercury and other contaminants produced on the ORR.
- Fish-consumption warnings are often not visible, missing, or disregarded by the public.
- Although studies have been conducted to evaluate fish consumption habits of fishermen, there is limited data to assess the extent of human interaction with fish taken from exit pathways on the ORR.
- Due to inclement weather surveys can be cancelled.

3.2.3 Goals

- Measure the fishing effort at key locations on the ORR where potential human exposure to mercury and other contaminants may exist.
- Conduct fish collections to analyze the COCs in fish tissue.

3.2.4 Scope

The goal of this project is two-fold: to determine the fishing efforts of anglers and determine if there are any COCs in fish within the TDEC DoR-OR study area. This project was limited to three (3) primary locations. These targeted areas cover approximately 100 square acres each. They are all accessible from a centrally located boat launch. The three areas are as follows: Zone 1 (downstream confluence region of White Oak Creek Embayment and the Clinch River), Zone 2 (confluence of Poplar Creek and the Clinch River), and Zone 3 (confluence region of East Fork Poplar Creek and Poplar Creek) (Figure 3.2.1).

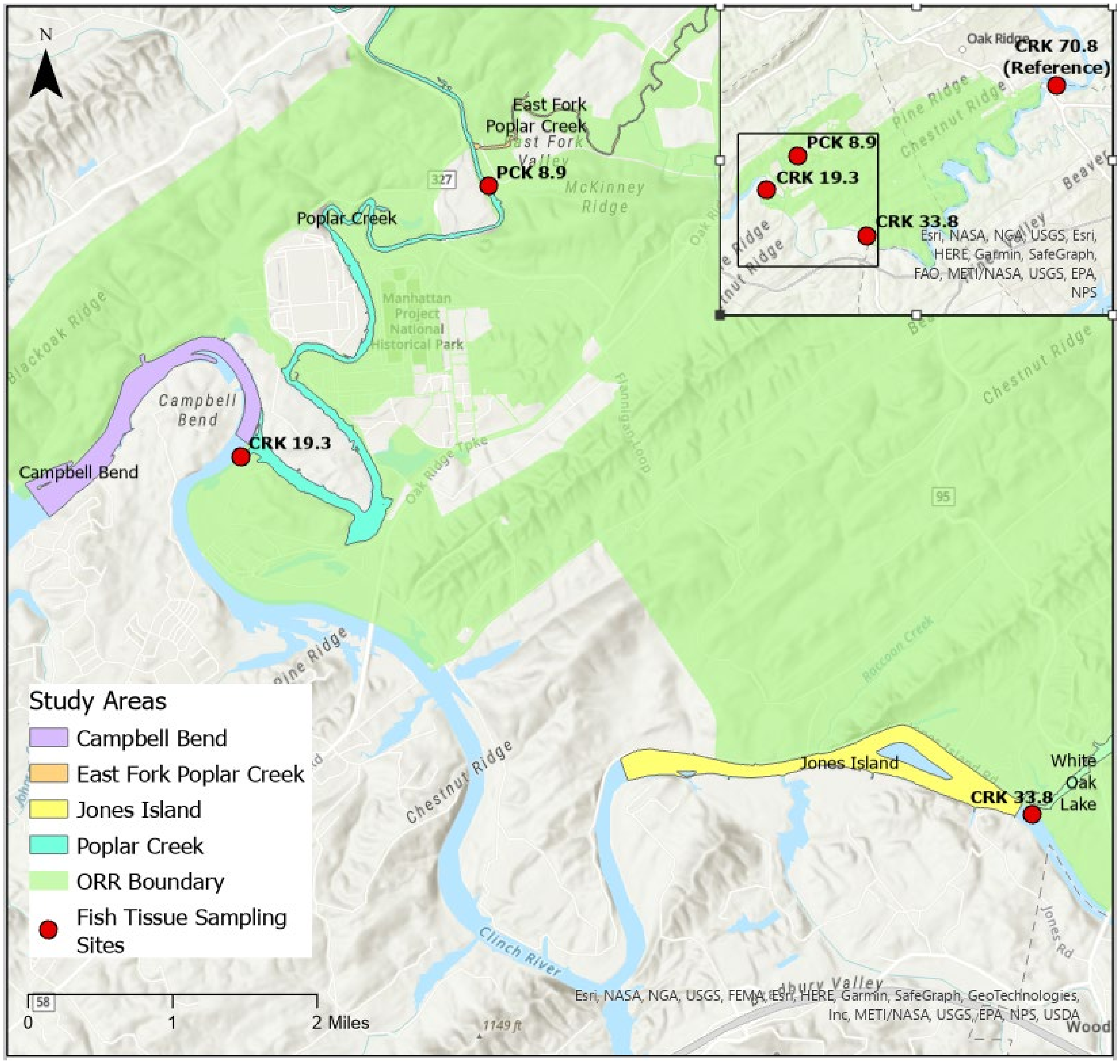


Figure 3.2.1: Angler Interview Zones (Study Areas) and Fish Tissue Sampling Sites

TDEC DoR-OR personnel made every effort to conduct five roving creel survey events per quarter for a goal of twenty sampling events in FY2022, between 7/07/21 and 6/23/22. Due to inclement weather, three (3) sampling events were cancelled. TDEC DoR-OR completed seventeen out of twenty sampling events. Dates selected for sampling events used non-uniform probability, stratified random sampling to maximize sampling efficiency and minimize bias. A randomized sampling schedule was created prior to the beginning of the survey year.

Fish were collected via electroshocking in all three (3) study zones and the reference site (CRK 70.8). TDEC DoR-OR enlisted CEC to conduct the fish sampling events. A total of seven electroshocking events took place in FY2022. Fish were collected in the fall season between

9/7/2021 and 9/10/2021, and during the spring season between 4/19/2022 and 4/21/2022. A total of twelve (12) fish fillets were sent to be analyzed for COCs. The spring season collection of fish fillets was sent to GEL Environmental to be analyzed. The other eight (8) fish fillets from the fall season event were sent to ALS Laboratory to be analyzed for COCs. The fish species collected and analyzed were blue catfish (BC), channel catfish (CC), flathead catfish (FHC), largemouth bass (LMB), small mouth bass (SMB), white bass (WB), and walleye (WE).

3.2.5 Methods, Materials, Metrics

Angler Interview

TDEC DoR-OR personnel conducted angler interviews between 7/7/21 and 6/23/22 at three locations. Anglers were interviewed either before, during, or immediately following fishing trips. All waterbodies were sampled using roving creel survey methods, outlined in the TWRA 2007 Fisheries Report (TWRA, 2007).

Roving creel surveys were conducted by boat for a ½-day sampling period. TDEC DoR-OR interviewed all anglers spotted either on the water or on the shore. There were no efforts to stop vessels underway in order to conduct interviews due to safety concerns.

Upon approaching anglers, TDEC DoR-OR personnel recorded information such as: date and time of interview, location, fishing from the bank or boat, and the number of anglers in the fishing party. When the TDEC DOR-OR personnel reached the angler or angling group, they asked if anglers would mind spending a few moments answering questions related to their fishing trip. If anglers did not wish to be interrupted, then the TDEC DoR-OR personnel moved on to other tasks.

Anglers who agreed to be interviewed were asked the following questions:

- How many hours do you plan to fish today?
- In terms of days per month, how many days do you spend fishing?
- What type of trip are you on? (Commercial or Private)
- What is your primary target species?
- What state and county are you from?
- Are you aware of any posted signage warning against the consumption of fish in this area?
- Have you ever consumed fish from this area?

Fishing Effort

Estimates of fishing efforts were calculated using TWRA's method (John, 1992), the number of anglers interviewed, and the number of hours reported within a sample period. Thus, for any given sampling period, fishing effort measured in angler hours (e) was calculated as the product of the total angler count (c) and the number of hours reported during that sampling period (h), or e=c(h). This value estimates total angler-hours for a single lake section within a single time period. This estimate can be expanded to estimate angler hours for the whole day by dividing (e) by the probability for the secondary sampling unit (time period/lake section) worked that day.

This roving creel survey divided the day into two equal parts, morning and evening. All surveys were performed during the morning section over the same three 100-acre sections. Following TWRA's methodologies, TDEC DoR-OR personnel assumed that morning and evening fishermen counts are roughly equal and provide an adequate approximation of fishermen activity over the course of a whole day. Thus, the time period probability was 0.5 and the lake section was 1.0, therefore the secondary sampling unit probability was 0.5. If (e)=100, then 100/0.5 = 200 angler hours for the whole area for that entire day (E).
To derive estimates of total quarterly fishing effort, whole day angler hours were multiplied by the number of days within that quarter. TDEC's fiscal year runs July 1st – June 30th.

- Quarter 1 = 92 days (July – September)
- Quarter 2 = 92 days (October – December)
- Quarter 3 = 90 days (January – March)
- Quarter 4 = 91 days (April – June)

Fish Tissue Collection
Two separate electroshocking surveying events took place in FY2022 to quantify the COCs in fish tissue. Electroshock sampling was conducted by CEC during the fall season of 2021 and the spring season of 2022. This type of sampling involves sending an electrical current through the water, stunning any fish within a six-to-eight-foot radius. Fish are then collected via net while incapacitated. A total of twelve (12) fish fillets of varying species were sent to either ALS Environmental or GEL Laboratories to be analyzed for COCs.

3.2.6 Deviations from the Plan

Because the sampling events were predetermined, there were instances where inclement weather could not be avoided. TDEC DoR-OR did not operate the boat during unsafe weather conditions. Every effort was made to reschedule sampling events to the following week during a similar timeslot to avoid influencing the random nature of the sample schedule. Three sampling events were canceled after multiple instances of inclement weather.

Fish fillets were analyzed by two different labs due to administrative issues. The fall season 2021 fish fillets were sent to ALS Laboratory to be analyzed, and the spring season fish fillets were sent to GEL Environmental. In addition to administrative issues, some fish fillet samples were processed outside of ALS Laboratory's standard holding time of six months. The analyses that were done after certain samples holding times are denoted in Section 3.2.7: Results and Analysis.

3.2.7 Results and Analysis

Notable Angler Observations:

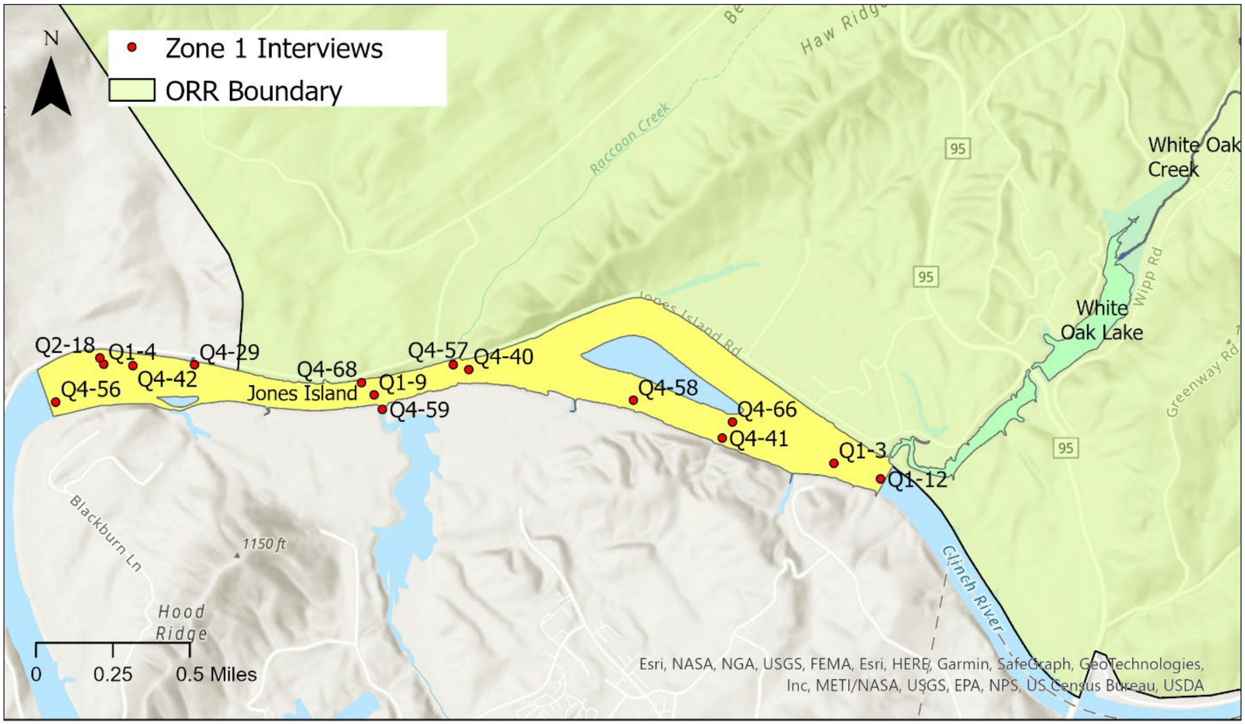
- 76 fishing vessels were encountered in FY2022.
- 147 individuals were observed fishing during that time.
- 143 agreed to participate in the survey.
- 87 individuals, or 61%, of the participants described themselves as "locals".
- 56 individuals, or 39%, of the participants described themselves as "visiting".
- Seven states are represented among anglers that described themselves as "visiting": NC, SC, VA, GA, OH, OK, and TN (visiting anglers from TN traveled greater than 100 miles).
- 120 individuals, or 84%, of the participants were private fishing vessels.
- 23 individuals, or 16%, of the participants were commercial fishing charters.

Notable Angler Comments:

- August 24th, 2021, an angler interviewed stated they fished on the Clinch River, launching from Melton Hill, about once per week. There were two anglers on the boat, and both were locals from Anderson and Knox counties. They reported they would be fishing for five hours that day.
- August 24th, 2021, a commercial angler (fishing charter angler) was interviewed in Zone 1. This angler catches their bait in Poplar Creek for their group fishing trips. On this date, the angler had customers from California who were not familiar with the area. The angler was aware of contamination concerns surrounding the ORR and informed his customers consumption of fish from this area was not recommended. As another notable comment, this angler informed TDEC DoR-OR staff of the poor condition of signage posted at Melton Hill. The angler was concerned that posted signs, warning against the consumption of fish, were in poor condition causing anglers to be unaware of the dangers of consuming the fish.

Zone 1: The confluence region of White Oak Creek and the Clinch River

The Zone 1 region is approximately 100 square acres in size and receives inputs from White Oak Creek. White Oak Creek is dammed to prevent larger quantities of contaminants from entering the Clinch River. This dam is referred to as the White Oak Creek Embayment. The primary contaminants of concern in this area are byproducts from historical nuclear activity as well as current industrial activities. These include cesium-137, strontium-90, and other fission daughter products. Signage is required to dissuade anglers from fishing directly in front of the White Oak Creek Embayment. The signage should read, "Warning, no fishing, no water contact area, contaminated, keep out". TDEC DoR-OR personnel documented the current condition of the signage seen in Figure 3.2.3 – Figure 3.2.5.



**QX-X = Quarter number – interview number*

Figure 3.2.2: Zone 1 Interview Locations

Table 3.2.1: Zone 1 Angler Counts and Reported Hours

Zone 1 Interviews						
Quarter-Interview	Date	Party Size	Reported	Total Hours	Lat (DM)	Long (DM)
Q1-3	8/6/2021	3	4.5	13.5	35.8964020	-84.3355430
Q1-4	8/6/2021	2	3.0	6.0	35.9001560	-84.3698750
Q1-9	8/24/2021	3	7.0	21.0	35.8990000	-84.3571600
Q1-12	9/5/2021	3	3.0	9.0	35.8958000	-84.3333500
Q2-18	12/16/2021	2	4.0	8.0	35.9004100	-84.3700400
Q4-29	4/15/2022	2	8.0	16.0	35.9001432	-84.3655906
Q4-40	4/23/2022	2	12.0	24.0	35.8999693	-84.3527078
Q4-41	4/23/2022	1	4.0	4.0	35.8973525	-84.3407893
Q4-42	4/23/2022	2	10.0	20.0	35.9000999	-84.3685036
Q4-56	5/28/2022	2	12.0	24.0	35.8987297	-84.3721125
Q4-57	5/28/2022	2	7.0	14.0	35.9001423	-84.3534360
Q4-58	5/28/2022	2	6.0	12.0	35.8987909	-84.3449738
Q4-59	5/28/2022	3	6.0	18.0	35.8984410	-84.3567579
Q4-66	6/1/2022	3	4.0	12.0	35.8979714	-84.3403240
Q4-68	6/1/2022	1	5.0	5.0	35.8994677	-84.3577592
Total		33	95.5	206.5		

Table 3.2.2: Zone 1 Fishing Effort

Zone 1		
	Hours/Day	Hours/Quarter
Quarter 1	99	1821.6
Quarter 2	16	294.4
Quarter 3	0	0
Quarter 4	298	5423.6
Yearly	413	7539.6

Fifteen unique vessels were approached in Zone 1 between 8/06/2021 and 6/01/2022, at the locations shown in Figure 3.2.2. Thirty-three (33) anglers that were interviewed reported angling 206.5 total hours on sampling event days (Table 3.2.1). Fishermen in Zone 1 reported fishing between three to twelve hours total on the day that they were interviewed. The average time reported fishing in this area was 6.4 hours. The median reported fishing time was 6 hours. TDEC DoR-OR personnel estimated that angler effort (i.e. amount of time spent fishing) was approximately 7539.6 hours in Zone 1 (Table 3.2.2).

Figure 3.2.3: White Oak Creek Embayment Signage (left side)

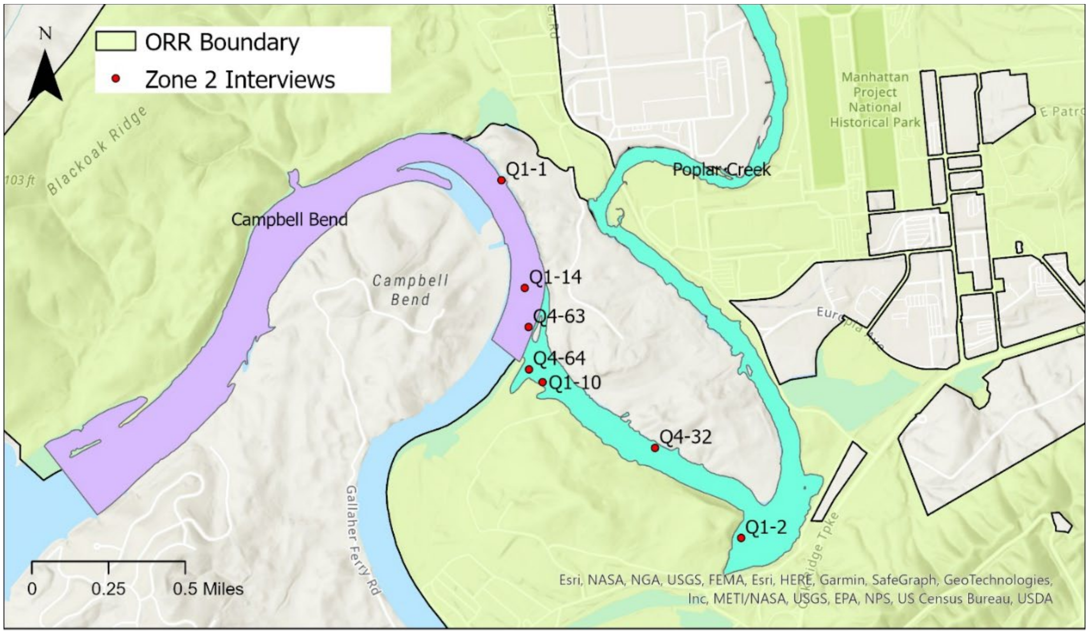
Figure 3.2.4: White Oak Creek Embayment Signage (center)

Figure 3.2.5: White Oak Creek Embayment Signage (right side)

TDEC DoR-OR personnel interviewed two angling parties actively fishing within 50 feet of the signs shown in Figures 3.2.3 – 3.2.5. Interview Q1-12 was a commercial vessel with three anglers fishing for striped bass. They reported fishing for 3 hours that day. Interview Q1-3 reported they were fishing for Stripped bass for 4.5 hours that day.

Zone 2: Confluence region of Poplar Creek and the Clinch River

Zone 2 is located downstream of the former location of K-25 Gaseous Diffusion Processing Building, that has since been demolished and remediated. This area, the ETTP, has been repurposed as an industrial park. Monitoring takes place along this portion of the creek to monitor the historical impacts of DOE activities.



**QX-X = Quarter number – interview number*

Figure 3.2.6: Zone 2 Interview Locations

Table 3.2.3: Zone 2 Angler Counts and Reported Hours

Zone 2 Interviews						
Quarter-Interview	Date	Party Size	Reported	Total Hours	Lat (DM)	Long (DM)
Q1-1	7/7/2021	2	12.0	24.0	35.9323210	-84.4109570
Q1-2	8/6/2021	2	4.5	9.0	35.9186480	-84.3996590
Q1-10	9/5/2021	4	1.0	4.0	35.9246060	-84.4090150
Q1-14	9/5/2021	2	5.5	11.0	35.9282030	-84.4098540
Q4-32	4/15/2022	1	12.0	12.0	35.9220959	-84.4037049
Q4-63	5/28/2022	1	8.0	8.0	35.9267049	-84.4096716
Q4-64	5/28/2022	2	4.0	8.0	35.9250952	-84.4096613
Total		14	47.0	76.0		

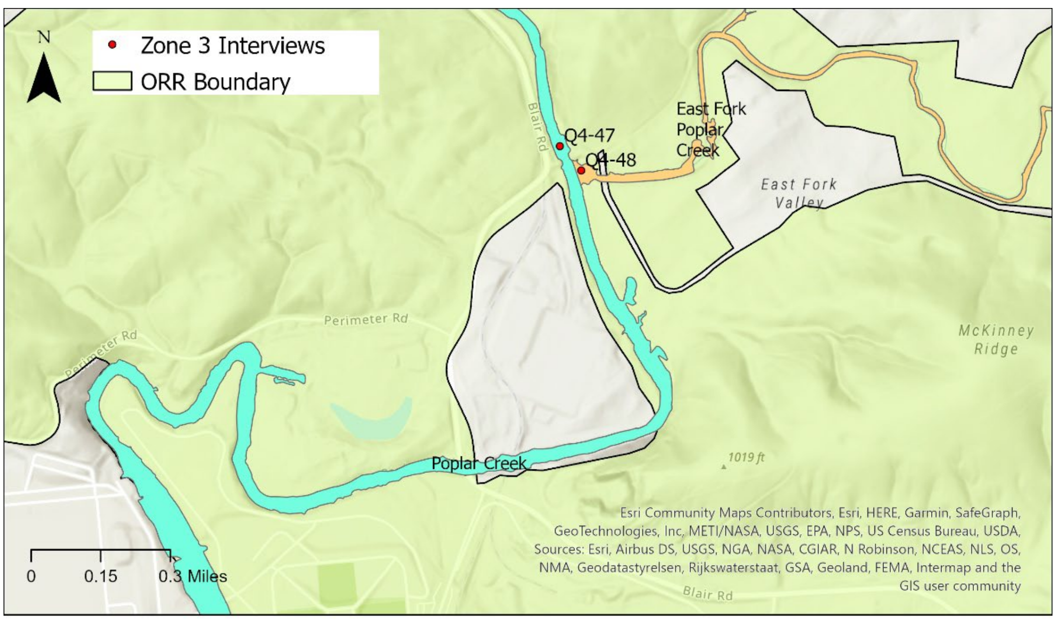
Table 3.2.4: Zone 2 Fishing Effort

Zone 2		
	Hours/Day	Hours/Quarter
Quarter 1	96	1766.4
Quarter 2	0	0
Quarter 3	0	0
Quarter 4	16	291.2
Yearly	112	2057.6

Seven unique vessels were approached in Zone 2 between 7/07/2021 and 5/28/2022 (Figure 3.2.6). Fourteen individual fishermen reported angling 76 total hours on sampling event days (Table 3.2.3). Fishermen in Zone 2 reported fishing between one to twelve hours total on the day that they were interviewed. The average time reported spent on the water in this area was 6.7 hours. TDEC DoR-OR personnel estimated angler effort was approximately 2057.6 hours in Zone 2 (Table 3.2.4).

Zone 3: Confluence region of East Fork Poplar Creek and Poplar Creek

Surveys conducted in FY2021 suggest that the Zone 3 region is typically utilized by locals. These locals regard Poplar Creek as a "prime fishing spot" during the spring and fall fishing seasons, when the Clinch River is crowded. Recent survey efforts show that Zone 3 is typically accessed by foot from East Fork bridge located right at the confluence of EFPC and Poplar Creek, or across Poplar Creek from Blair Road. There is litter scattering the banks of the area across from the bridge and a small trail leading to Poplar creek. This suggests heavy fishing activity. Q4-47 was a fisherman that used the fishing spot often and reported seeing a lot of people using the same spot.



**QX-X = Quarter number – interview number

Figure 3.2.7: Zone 3 Interview Locations

Table 3.2.5: Zone 3 Angler Counts and Reported Hours

Zone 3 Interviews						
Quarter-Interview	Date	Party Size	Reported	Total Hours	Lat (DM)	Long (DM)
Q4-47	4/23/2022	1	4	4	35.9502492	-84.3881436
Q4-48	4/23/2022	1	3	3	35.9496302	-84.3874793
Total		2	7	7		

Table 3.2.6: Zone 3 Fishing Effort

Zone 3		
	Hours/Day	Hours/Quarter
Quarter 1	0	0
Quarter 2	0	0
Quarter 3	0	0
Quarter 4	14	254.8
Yearly	14	254.8

Two unique vessels were approached in Zone 3 on 4/23/2022 at the locations represented on Figure 3.2.7. Two individual fishermen reported angling seven total hours on sampling event days (Table 3.2.5). Fishermen in Zone 3 reported fishing 3 (Q4-48) and 4 (Q4-47) hours total on the day that they were interviewed. The average time reported spent on the water in this area was 3.5 hours (Table 3.2.5). TDEC DoR-OR personnel estimated that fishermen angled for approximately 254.8 hours in Zone 3 (Table 3.2.6). Because TDEC DoR-OR primarily relies on boat surveys and does not adjust methods to measure shore fishing activity, fishing effort estimates may be low for Zone 3. Information from interview Q4-47 also suggests these estimates may be low.

Fish Tissue Analysis

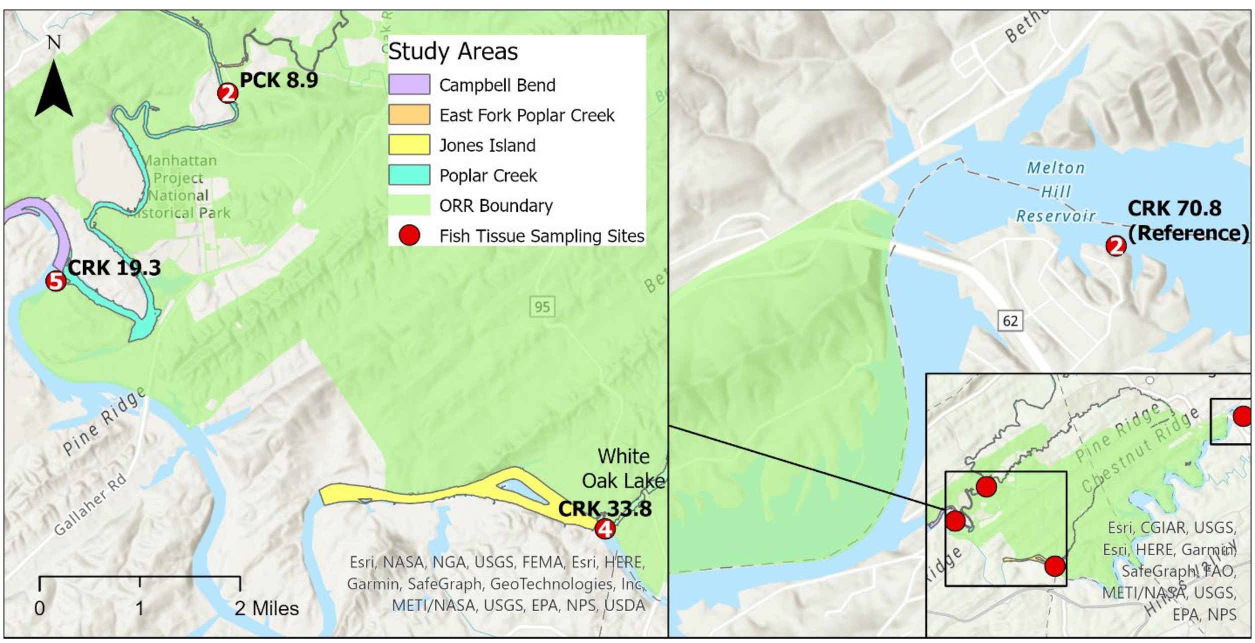
TDEC DoR-OR utilized CEC to collect fish tissue samples for analysis via electroshocking in FY2022. Two sampling events were conducted, one in the fall season of 2021 and the other in the spring season of 2022. Sampling trips were conducted on September 7th, 8th, 9th, and 10th of 2021, and a total of 8 fish were collected and sent to ALS Environmental Labs for COC analysis. During the spring of 2022, sampling trips were conducted on April 19th, 20th, and 21st, and a total of 4 fish were collected and sent to GEL Laboratories for COC analysis.
Fall season samples were analyzed for the following Contaminants of Concern (COCs):

- Gross Alpha/Beta
- Gamma emitting radionuclides
- Strontium-89/90
- Isotopic Uranium
- Isotopic Plutonium
- Plutonium-241
- Technetium-99
- PCBs
- Metals (As, Ba, Be, B, Bd, Cr, Cu, Pb, Ni, Se, Sr, U, Zn)
- Total Mercury

Spring season samples were analyzed for the following COCs:

- Gross Alpha/Beta
- Gamma emitting radionuclides
- Strontium-89/90
- Isotopic Uranium
- Isotopic Plutonium
- Plutonium-241
- Carbon-14
- Plutonium-210
- Technetium-99
- Mercury
- Methylmercury

There are discrepancies in the lists of COCs due to the change in laboratories. ALS Laboratory performed metals, total mercury, technetium-99, and PCBs analyses on all September 2021 fish fillet samples; however, GEL Environmental only performed carbon-14, mercury, and methylmercury analyses on all April 2022 fish fillet samples. All fish fillets sampled tested non-detect for these COCs unless otherwise stated by this report. A list of analyte detections can be found in Table 3.2.7. CRK 70.8 was included as the reference site to establish a baseline comparison between the study site and a reference site of similar ecological make-up.



**CRK = Clinch River Kilometer, PCK = Poplar Creek Kilometer, numbers inside red circles represent the number of fish caught at each site*

Figure 3.2.8: Fish Tissue Sampling Locations along the Clinch River

Table 3.2.7: Fish Tissue Samples and Observed Analytes

Site ID	Latitude	Longitude	Species*	Individuals	Date Collected	Analyte Detections						
CRK 70.8 (Ref)	35.991634	-84.182462	LMB	1	9/7/2021	Gross Beta	Total Mercury	AROCLOR-1260	U-235	Pu-238		
			CC	1	4/21/2022	Gross Beta	K-40					
CRK 33.8	35.895422	-84.331748	LMB	1	9/9/2021	Gross Beta	Total Mercury	AROCLOR-1260	Cs-137			
			WB	1	9/10/2021	Gross Beta	Total Mercury	AROCLOR-1260	U-234	Pu-239	Strontium	Sr-89
			BC	1	9/10/2021	Gross Beta	Total Mercury	AROCLOR-1260				
			WB	1	4/19/2022	Gross Beta	K-40					
CRK 19.3	35.924379	-84.410947	LMB	1	9/8/2021	Gross Beta	Total Mercury	AROCLOR-1260	U-234	Pu-238	Sr-89	
			WE	1	9/10/2021	Gross Beta	Total Mercury	AROCLOR-1260				
			BC,CC	2	4/20/2022	Gross Beta	K-40					
			SMB	1	4/21/2022	Gross Beta	K-40					
PCK 8.9	35.951596	-84.388665	LMB	1	9/8/2021	Gross Beta	Total Mercury	AROCLOR-1260	U-234	Pu-238		
			FHC	1	9/9/2021	Gross Beta	Total Mercury	AROCLOR-1260	Tc-99	Sr-89		

ALS Fall 2021
GEL Spring 2022

Fishes: BC = Blue Catfish; CC = Channel Catfish; FHC = Flathead Catfish; LMB = Large Mouth Bass; SMB = Small Mouth Bass; WB = White Bass; WE = Walleye

Table 3.2.7 shows all fish tissue samples with any detection of listed COCs. All filet samples represented single fish except for sample CRK 19.3 (BC, CC), which was a composite catfish sample. All samples had low level detections of gross beta and potassium-40 (a natural occurrence in the environment). All gamma radiological analysis results were non-detects. All fall season samples had detections of mercury and polychlorinated biphenyl (PCB), AROCLOR-1260. Uranium-234 was detected in CRK 33.8 (WB), CRK 19.3 (LMB), and PCK 8.9 (LMB), but was not detected in any other samples. Uranium-235 (also a naturally occurring isotope) was detected in the reference site sample CRK 70.8 (LMB) but was a non-detect for all other samples. Isotopic plutonium-238 or 239 were found in all four sampling sites. Cesium-137 was found in only one sample at CRK 33.8 (LMB), but there were issues with the sample that could have caused results to be biased high (see Cesium-137 discussion below). Strontium-89 was found at all sites except for the reference site (CRK 70.8). Metallic strontium was found in one sample at CRK 33.8 (WB). Table 3.2.8 shows all the survey interviews conducted at the Clinch River and outside research zones.

Table 3.2.8: All Interviews Conducted while Surveying the Clinch (Including those outside research zones)

All Interviews							
Quarter-Interview #	Date	Zone	Party Size	Reported	Total Hours	Lat (DM)	Long (DM)
Q1-1	7/7/2021	-	2	12.0	24.0	35.9323210	-84.4109570
Q1-2	8/6/2021	-	2	4.5	9.0	35.9186480	-84.3996590
Q1-3	8/6/2021	1	3	4.5	13.5	35.8964020	-84.3355430
Q1-4	8/6/2021	1	2	3.0	6.0	35.9001560	-84.3698750
Q1-5	8/6/2021	-	2	8.5	17.0	35.8939680	-84.3887580
Q1-6	8/6/2021	-	1	3.0	3.0	35.9053710	-84.3904750
Q1-7	8/6/2021	-	1	3.0	3.0	35.9222620	-84.4168250
Q1-8	8/24/2021	-	2	5.5	11.0	35.8820200	-84.3729200
Q1-9	8/24/2021	1	3	7.0	21.0	35.8990000	-84.3571600
Q1-10	9/5/2021	2	4	1.0	4.0	35.9246060	-84.4090150
Q1-11	9/5/2021	-	2	12.0	24.0	35.8892100	-84.3900400
Q1-12	9/5/2021	1	3	3.0	9.0	35.8958000	-84.3333500
Q1-13	9/5/2021	-	1	5.5	5.5	35.9241730	-84.4134350
Q1-14	9/5/2021	2	2	5.5	11.0	35.9282030	-84.4098540
Q2-15	10/17/2021	-	2	5.0	10.0	35.9238050	-84.4135870
Q2-16	10/17/2021	-	2	3.0	6.0	35.9068440	-84.3947130
Q2-17	10/17/2021	-	1	4.0	4.0	35.9100910	-84.3987170
Q2-18	12/16/2021	1	2	4.0	8.0	35.9004100	-84.3700400
Q3-19	2/2/2022	-	2	4.0	8.0	35.9143700	-84.4126900
Q3-20	2/7/2022	-	1	5.0	5.0	35.9076100	-84.3938200
Q4-21	3/30/2022	-	2	3.0	6.0	35.9046473	-84.3930224
Q4-22	3/30/2022	-	3	9.0	27.0	35.9119583	-84.4038238
Q4-23	4/1/2022	-	2	4.0	8.0	35.8961250	-84.3337138
Q4-24	4/1/2022	-	1	3.0	3.0	35.8812555	-84.3734103
Q4-25	4/1/2022	-	2	5.0	10.0	35.9231245	-84.4278392
Q4-26	4/15/2022	-	3	5.0	15.0	35.9069413	-84.3927768
Q4-27	4/15/2022	-	3	7.0	21.0	35.8944176	-84.3891739
Q4-28	4/15/2022	-	2	6.0	12.0	35.8891423	-84.3901166
Q4-29	4/15/2022	1	2	8.0	16.0	35.9001432	-84.3655906
Q4-30	4/15/2022	-	3	12.0	36.0	35.9108467	-84.3998150
Q4-31	4/15/2022	-	5	8.0	40.0	35.9236261	-84.4129872
Q4-32	4/15/2022	-	1	12.0	12.0	35.9220959	-84.4037049
Q4-33	4/23/2022	-	3	11.0	33.0	35.9042963	-84.3901204
Q4-34	4/23/2022	-	3	8.0	24.0	35.9016612	-84.3889415
Q4-35	4/23/2022	-	2	12.0	24.0	35.8951463	-84.3885666
Q4-36	4/23/2022	-	3	12.0	36.0	35.8858354	-84.3866817
Q4-37	4/23/2022	-	2	4.0	8.0	35.8856894	-84.3862897
Q4-38	4/23/2022	-	2	8.0	16.0	35.8848923	-84.3712072
Q4-39	4/23/2022	-	2	10.0	20.0	35.8887944	-84.3727494
Q4-40	4/23/2022	1	2	12.0	24.0	35.8999693	-84.3527078
Q4-41	4/23/2022	1	1	4.0	4.0	35.8973525	-84.3407893
Q4-42	4/23/2022	1	2	10.0	20.0	35.9000999	-84.3685036
Q4-43	4/23/2022	-	1	3.0	3.0	35.9056040	-84.3903996
Q4-44	4/23/2022	-	3	12.0	36.0	35.9068540	-84.3929304
Q4-45	4/23/2022	-	2	7.0	14.0	35.9213334	-84.4166430

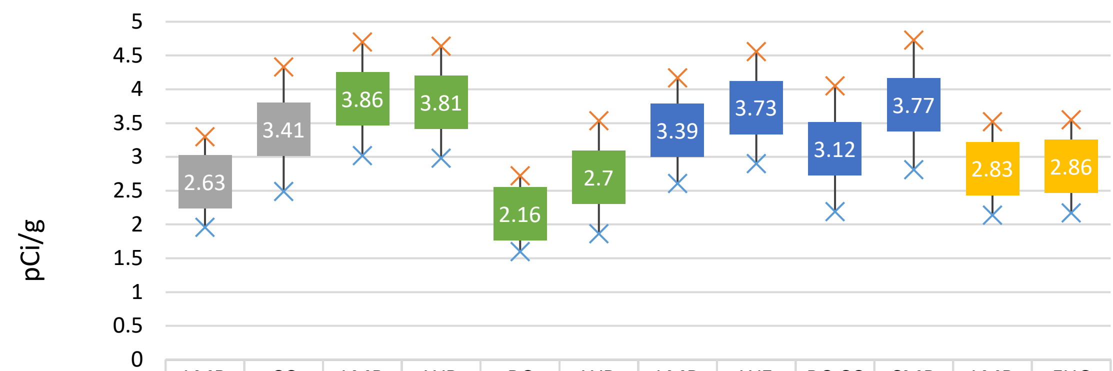
Table 3.2.8 continued

All Interviews							
Quarter-Interview #	Date	Zone	Party Size	Reported	Total Hours	Lat (DM)	Long (DM)
Q4-46	4/23/2022	-	2	5.0	10.0	35.9228554	-84.4153289
Q4-47	4/23/2022	3	1	4.0	4.0	35.9502492	-84.3881436
Q4-48	4/23/2022	3	1	3.0	3.0	35.9496302	-84.3874793
Q4-49	4/23/2022	-	2	16.0	32.0	35.9157375	-84.4147838
Q4-50	4/23/2022	-	2	8.0	16.0	35.9127225	-84.4112125
Q4-51	4/23/2022	-	2	2.5	5.0	35.9119281	-84.4085629
Q4-52	4/23/2022	-	3	4.0	12.0	35.9073017	-84.3942532
Q4-53	5/28/2022	-	1	4.0	4.0	35.8830030	-84.3798263
Q4-54	5/28/2022	-	3	4.0	12.0	35.8912890	-84.3743957
Q4-55	5/28/2022	-	1	10.0	10.0	35.8937922	-84.3744973
Q4-56	5/28/2022	1	2	12.0	24.0	35.8987297	-84.3721125
Q4-57	5/28/2022	1	2	7.0	14.0	35.9001423	-84.3534360
Q4-58	5/28/2022	1	2	6.0	12.0	35.8987909	-84.3449738
Q4-59	5/28/2022	1	3	6.0	18.0	35.8984410	-84.3567579
Q4-60	5/28/2022	-	2	6.0	12.0	35.9061027	-84.3904634
Q4-61	5/28/2022	-	2	7.0	14.0	35.9103149	-84.3964880
Q4-62	5/28/2022	-	2	8.0	16.0	35.9223119	-84.4157252
Q4-63	5/28/2022	2	1	8.0	8.0	35.9267049	-84.4096716
Q4-64	5/28/2022	2	2	4.0	8.0	35.9250952	-84.4096613
Q4-65	6/1/2022	-	2	2.0	4.0	35.9070891	-84.3943224
Q4-66	6/1/2022	1	3	4.0	12.0	35.8979714	-84.3403240
Q4-67	6/1/2022	-	1	2.0	2.0	35.9050822	-84.3919588
Q4-68	6/1/2022	1	1	5.0	5.0	35.8994677	-84.3577592
Q4-69	6/1/2022	-	1	2.0	2.0	35.9142248	-84.4126265
Q4-70	6/20/2022	-	1	3.0	3.0	35.9047158	-84.3931102
Q4-71	6/23/2022	-	1	3.0	3.0	35.8803655	-84.3730715

Gross Beta, Potassium-40, and Cesium-137

Radiological analysis was performed on all samples and all samples came back with low-level detections of beta radiation. Potassium-40 is a naturally occurring isotope that emits low-levels of beta radiation and was also detected in every spring season 2022 site except for PCK 8.9. CEC was unable to obtain a sample from PCK 8.9 during the spring sampling season. All ALS samples were processed outside of the typical sample holding time of six months for radiological activity. Due to radiological decay, samples must be processed within six months to get an accurate representation of radiological activity. The samples were collected between September 7th and 9th, 2021 and were not processed by ALS until March 10th, 2022, one to three days outside of the sample holding time. Due to this issue, detections of radiological alpha and beta activity may be low. However, gamma analysis was performed within the respective holding time of six months and came back as non-detects for all samples.

Cesium-137 (Cs-137) is an isotope that is a by-product of nuclear reactions and was found in one fish tissue sample taken from a largemouth bass (LMB) at site CRK 33.8. The concentration of Cs-137 was observed at 1.46 pCi/g; however, the laboratory qualifier indicated this sample had matrix issues that may have caused results to be biased high. This was the only sample with any detections of Cs-137. CRK 33.8 is located at the confluence of White Oak Lake which is known to receive radiological contaminants from sources upstream such as ORNL. The elevated Cs-137 result may denote an influx of Cs-137 in fish located around CRK 33.8 due to the contaminants found in White Oak Lake. Since this elevated concentration was only found in one fish sample this detection should be interpreted cautiously.

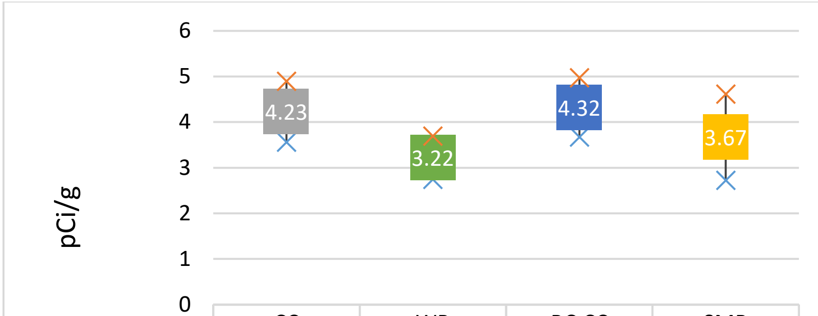


	LMB ALS	CC GEL	LMB ALS	WB ALS	BC ALS	WB GEL	LMB ALS	WE ALS	BC,CC GEL	SMB GEL	LMB ALS	FHC ALS
	CRK 70.8 (Ref)		CRK 33.8				CRK 19.3				PCK 8.9	
Lower Bound	1.96	2.489	3.02	2.98	1.6	1.864	2.61	2.9	2.19	2.813	2.14	2.17
Results	2.63	3.41	3.86	3.81	2.16	2.7	3.39	3.73	3.12	3.77	2.83	2.86
Upper Bound	3.3	4.331	4.7	4.64	2.72	3.536	4.17	4.56	4.05	4.727	3.52	3.55

**Labs: ALS = ALS Laboratory*
GEL = GEL Environmental
***Fishes:*
BC = Blue Catfish *LMB = Large Mouth Bass* *WE = Walleye*
CC = Channel Catfish *SMB = Small Mouth Bass* *FHC = Flathead Catfish* *WB = White Bass*

Figure 3.2.9: Gross Beta Levels in Fish Tissue Samples

All gross beta levels for all sites and tissue samples were relatively low (Figure 3.2.9). The highest levels of gross beta were found at the confluence of White Oak Lake and the Clinch River (Zone 1). The largemouth bass from CCK 33.8 had the highest beta emission at 3.86 pCi/g. This was only 0.45 pCi/g higher than the reference site CCK 70.8 channel catfish sample.



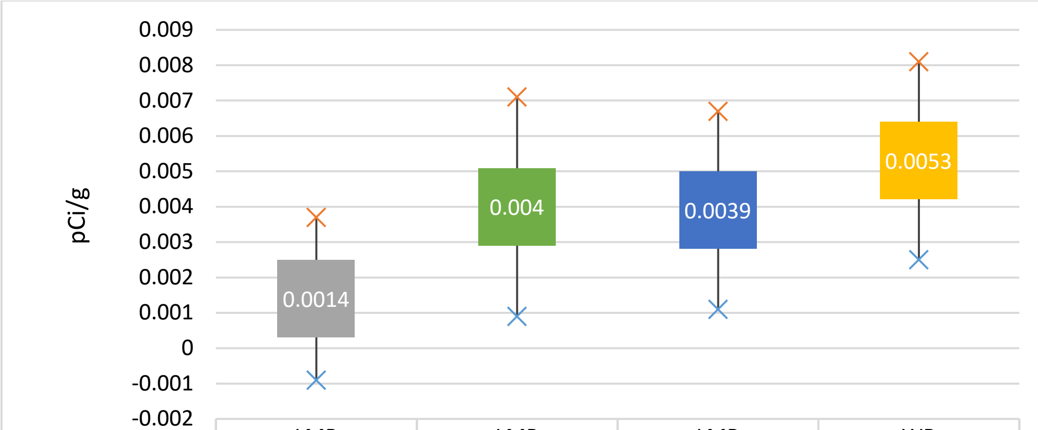
	CC	WB	BC,CC	SMB
	CRK 70.8 (Ref)	CRK 33.8	CRK 19.3	
Lower Bound	3.563	2.748	3.671	2.723
Results	4.23	3.22	4.32	3.67
Upper Bound	4.897	3.692	4.969	4.617

Figure 3.2.10: Potassium-40 Levels in Fish Tissue Samples

All levels of Potassium-40 (K-40) were relatively low (Figure 3.2.10). The site with the highest levels was CRK 19.3 in the blue catfish (BC) and channel catfish (CC) composite sample. This was only 0.09 pCi/g higher than the reference site (CRK 70.8) K-40 levels. Gross beta levels were expected to be slightly elevated due to the presence of the K-40. Since this is a naturally occurring isotope in the environment there are little concerns about these concentrations.

Uranium-234 & U-235

Both fall and spring samples were analyzed for isotopic forms of uranium (U). Results from ALS Laboratory indicated low levels of either U-234 or U-235 at all sampling sites. Uranium-235 was found at the reference site (CRK 70.8) in tissue from a largemouth bass at approximately 0.0014 pCi/g. Uranium-235 is a naturally occurring isotope, so the low-level detection for U-235 at the reference site is not of concern. The other sites, CRK 33.8, PCK 8.9, and CRK 19.3, all had low-levels of U-234 concentrations. In comparison to the reference site, CRK 33.8 had the highest levels of U-234 contamination at 0.0053 pCi/g. CRK 33.8 is located at the mouth of White Oak Lake. The lake is fed by White Oak Creek, which flows downstream from ORNL.

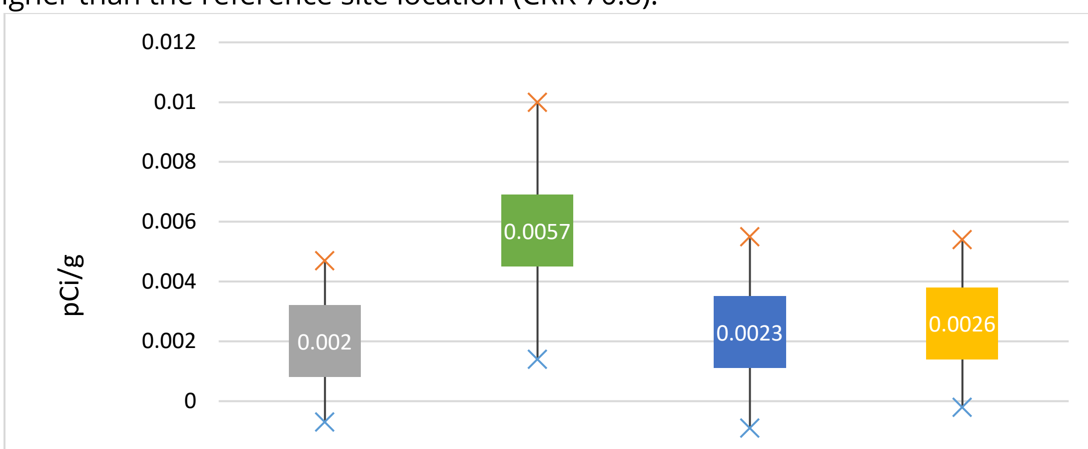


	LMB CRK 70.8 (Ref)	LMB PCK 8.9	LMB CRK 19.3	WB CRK 33.8
Lower Bound	-0.0009	0.0009	0.0011	0.0025
Results	0.0014	0.004	0.0039	0.0053
Upper Bound	0.0037	0.0071	0.0067	0.0081

Figure 3.2.11: Uranium-235 and Uranium-234 Concentrations in Fish Tissue

Plutonium-238 & Pu-239

Plutonium (Pu)-238 and/or Pu-239 were found in low-level concentrations at all sites (Figure 3.2.12). The lowest concentration (0.002 pCi/g) of Pu-238 was in the reference site largemouth bass (LMB) sample. The highest concentration of Pu-238 (0.0057 pCi/g) was found at PCK 8.9 in the largemouth bass sample. Pu-239 was detected in the CRK 33.8 White Bass fish sample at concentrations of 0.0026 pCi/g. These concentrations of Pu are low, but still higher than the reference site location (CRK 70.8).

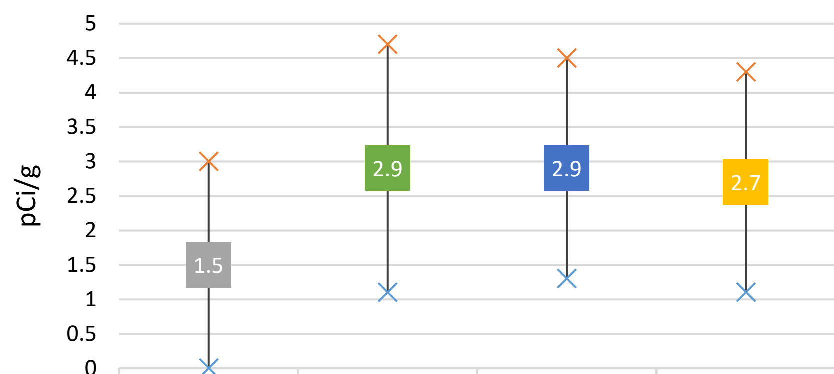


	LMB (Pu-238) CRK 70.8 (Ref)	LMB (Pu-238) PCK 8.9	LMB (Pu-238) CRK 19.3	WB (Pu-239) CRK 33.8
Lower Bound	-0.0007	0.0014	-0.0009	-0.0002
Results	0.002	0.0057	0.0023	0.0026
Upper Bound	0.0047	0.01	0.0055	0.0054

Figure 3.2.12: Fish Tissue Isotopic Plutonium Concentrations

Strontium (Sr)-89 & Metallic Strontium

The laboratory analysis for isotopic strontium was performed either one or two days outside of the sample holding time of six months. This could cause the samples results to indicate lower levels of isotopic strontium than reported. All samples were identified by ALS as having matrix issues that could have caused each sample's results to be biased low. Since the analysis for these contaminants had issues, the Sr-89 results should be interpreted with caution.



	LMB CRK 70.8 (Ref)	FHC PCK 8.9	LMB CRK 19.3	WB CRK 33.8
Lower Bound	0	1.1	1.3	1.1
Results	1.5	2.9	2.9	2.7
Upper Bound	3	4.7	4.5	4.3

Figure 3.2.13: Strontium-89 Fish Tissue concentrations

Strontium-89 is a frequent bi-product of nuclear reactions and was found at every site except CRK 70.8 (ref), the reference site (Figure 3.2.13). The highest levels detected were at PCK 8.9 and CRK 19.3 at concentrations of approximately 2.9 pCi/g. These concentrations were higher than the reference station concentration of 1.5 pCi/g. These results indicate that concentrations of Sr-89 are detectable and elevated in fish tissue samples collected at these sites.

Metallic strontium was found in concentrations of 750 ug/kg in sample CRK 33.8 white bass (WB). All other samples were non-detects for metallic strontium, but since the concentration was elevated in one fish tissue sample, it can be inferred that there are inputs of strontium reaching the Clinch River aquatic life. Further analysis should be done to holistically assess the concentrations of strontium in sites surrounding the ORR.

Total Mercury

Levels of mercury were detected at all sites with the lowest concentration of 0.055 mg/kg at the reference site (Figure 3.2.14). The EPA recommended action limit for mercury concentrations in fish tissue is 0.3 mg/kg, and the Do Not Consume Limit is 1 mg/kg. There were three (3) fish tissue samples that had over the recommended action limit (CRK 19.3

LMB, PCK 8.9 LMB, PCK 8.9 FHC). The rest of the samples were all higher than the reference station and cause some concern for surrounding fish consumption.

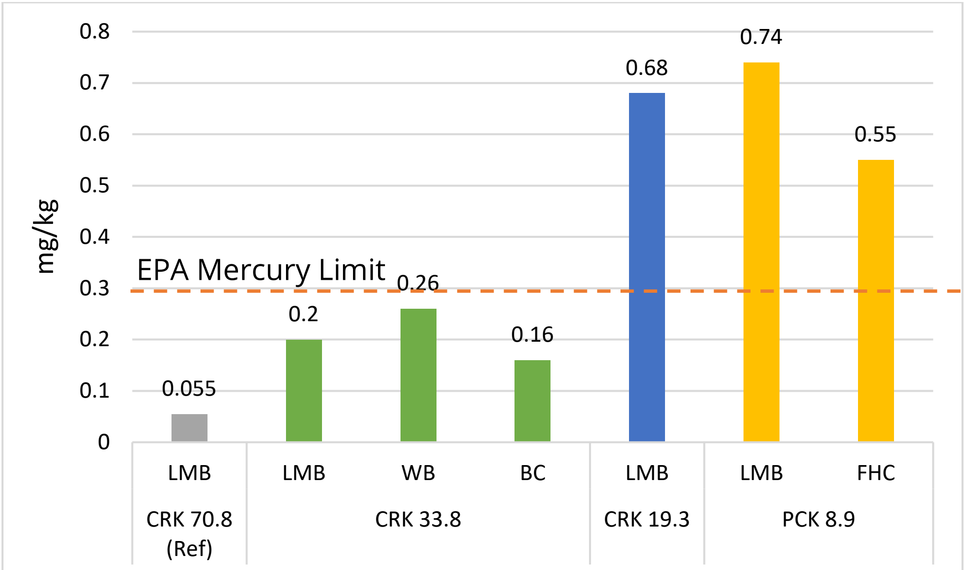


Figure 3.2.14: Total Mercury Concentrations in Fish Tissue

While there were only three (3) samples that exceeded the EPA mercury limit of 0.3 mg/kg, there were two (2) samples that were close to the limit (CRK 33.8 WB and LMB). Mercury has been a constituent of concern in the past and currently is a concern due to historical mercury contamination across the ORR. Elevated levels of mercury in fish tissue can mostly be attributed to the historical or legacy contamination which is continuously monitored due to the risk associated with consuming fish tissue with said contamination.

PCBs (AROCLOR-1260)

All sites except for the reference site showed detectable levels of AROCLOR-1260, a PCB of concern (Figure 3.2.15). The highest level of AROCLOR-1260 was found in the flathead catfish (FHC) sample at PCK 8.9, 0.36 mg/kg. The lowest level (aside from the reference site) was found at CRK 19.3 at 0.017 mg/kg. The EPA recommends fish consumption should not occur at any detection of PCBs above 2 ppm or 2 mg/kg. While levels are below the EPA limit, they are still much higher than the reference site sample concentrations (0.0083 mg/kg). Further analysis should take place to determine the level of human risk when consuming fish from this area.

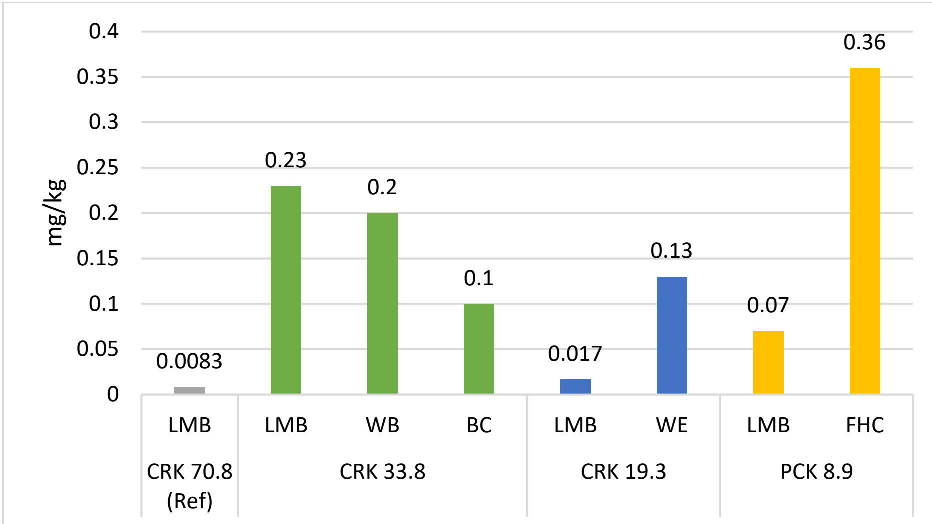


Figure 3.2.15: AROCLOR-1260 Concentrations in Fish Tissue

3.2.8 Conclusions

Roving Creel Surveys (RCS) were conducted on the Clinch River and Poplar Creek in FY 2022. The RCS data suggest that there is more fishing activity near key ORR surface water exit points than previously thought. The confluence region of White Oak Creek Embayment area and the Clinch River (Zone 1) was the most popular among anglers with an estimated 7,539.6 total Angler Hours. The confluence region of Poplar Creek and the Clinch River (Zone 2) had an estimated 2,057.6 total Angler Hours. The confluence region of East Fork Poplar Creek and Poplar Creek (Zone 3) was the second least popular with an estimated 254.8 total Angler Hours, but this estimate may be low.

Sixty-one percent of the individuals who participated in this study described themselves as locals. Many locals reported that they fish frequently and often angle in this area. These results suggest that there is potential for human exposure to contaminants through the consumption of fish, especially amongst locals.

The fish fillet analysis revealed that there were detections of different COCs. There were detections for beta radiation, K-40, U-234, U-235, Pu-238, Pu-239, Cs-137, metallic strontium, Sr-89, mercury, and PCB (AROCLOR-1260). Site CRK 33.8, located near White Oak Lake, had the most detections for the listed COCs. This is concerning because anglers were reported fishing in this area the most during FY2022 and prior years. Most detections were low-level, but signage should be updated in this area to ensure anglers are aware of the risks involved when consuming harvested fish.

3.2.9 Recommendations

Angler activity was found near ORR surface water exit points at a higher level than expected. TDEC DoR-OR is aware that concentrations of contaminants in the water are higher than background levels at these watersheds exit points. TDEC DoR-OR suggests that a more precise study be conducted to evaluate the potential human exposure risk of fishing in these publicly accessible waters.

Fish tissue collection and subsequent analysis should be done periodically to ensure anglers are not exposed to the high levels of contamination. Using the detections of COCs from this year's sampling event can help guide future monitoring efforts. Furthermore, to ensure an accurate angler risk assessment, more fish tissue samples should be collected and analyzed for the constituents detected in fish tissue.

Additionally, signage needs more regular maintenance, with clear warnings about the level of risk anglers are taking by consuming fish they catch around the ORR. This will ensure anglers are aware of the risk and should pursue fishing in these areas with caution.

3.2.10 References

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3.3 Radiological Uptake in Food Crops

3.3.1 Background

DOE has conducted sampling on locally grown vegetables- root crops (turnips), fruiting crops (tomatoes), and leaf crops (turnip greens, lettuce), as well as cow milk and hay to determine if there is evidence of environmental contamination by short or long-term accumulation of radionuclides to foods consumed by local residents. DOE suggested TDEC DoR-OR conduct similar sampling for comparison to DOE's results. This project serves to determine whether radionuclide contamination extends beyond the bounds of the ORR and is taken up into local vegetables, hay, and milk.

DOE initially conducted vegetable sampling at their perimeter monitoring stations on the ORR, from 1992 to 1996. The focus then shifted to sampling from farms and gardens near the ORR. The hay sampling project shifted from multiple locations on and near the ORR to one location at the far eastern edge of the ORR that is harvested for hay by an offsite operation. Initially, cow milk was sampled from a dairy in Claxton, near the ORR, and at a few other local dairies used as reference locations, but this dairy has not been sampled since 2016. Unfortunately, the Claxton Dairy shut down and no other dairy options near the ORR have been found. Despite this closure, possible sources of dairy products are checked each year. DOE's sampling of vegetables, hay, milk (as available), and other media are documented in the annual DOE Environmental Monitoring Plan and the yearly Oak Ridge Reservation Annual Site Environmental Report (ASER) (DOE, 2021).

3.3.2 Problem Statements

- Members of the public have the potential to be exposed to doses of radiological contaminants through the consumption of locally grown food crops.
- Radionuclide deposition from current operations as well as past DOE activities may occur, especially with ongoing D&D and remedial activities, which may transport contaminants beyond the boundaries of the ORR.

3.3.3 Goals

- Obtain data to determine if there is radionuclide contamination in the local food crops due to DOE activities on the ORR.
- Compare TDEC DoR-OR's food crops sampling findings with results from DOE's food crops sampling program.

3.3.4 Scope

The scope of this project was to determine whether radionuclide contamination extends beyond the boundary of the ORR and is impacting local food crops, by sampling and analyzing food crops from gardens, farms, dairies, and other sources within a five-mile radius of the ORR, as well as reference locations beyond this.

3.3.5 Methods, Materials, Metrics

As available, food crops, hay, and milk samples are collected yearly within five miles of the ORR (Figure 3.3.1). Reference samples from locations greater than five miles from the ORR are used to establish background levels. Sample quantities collected depend on laboratory requirements and available amounts of sample material. Samples are shipped to a laboratory for radiological analysis. Samples from on or within 5 miles of the ORR are compared with levels of similar background samples, as well as the results from similar sampling by DOE. The results of the radiological analysis of the DOE samples are published annually in the ASER, with hay and vegetable samples collected annually and cow milk samples collected from a local dairy and a reference dairy, as available.

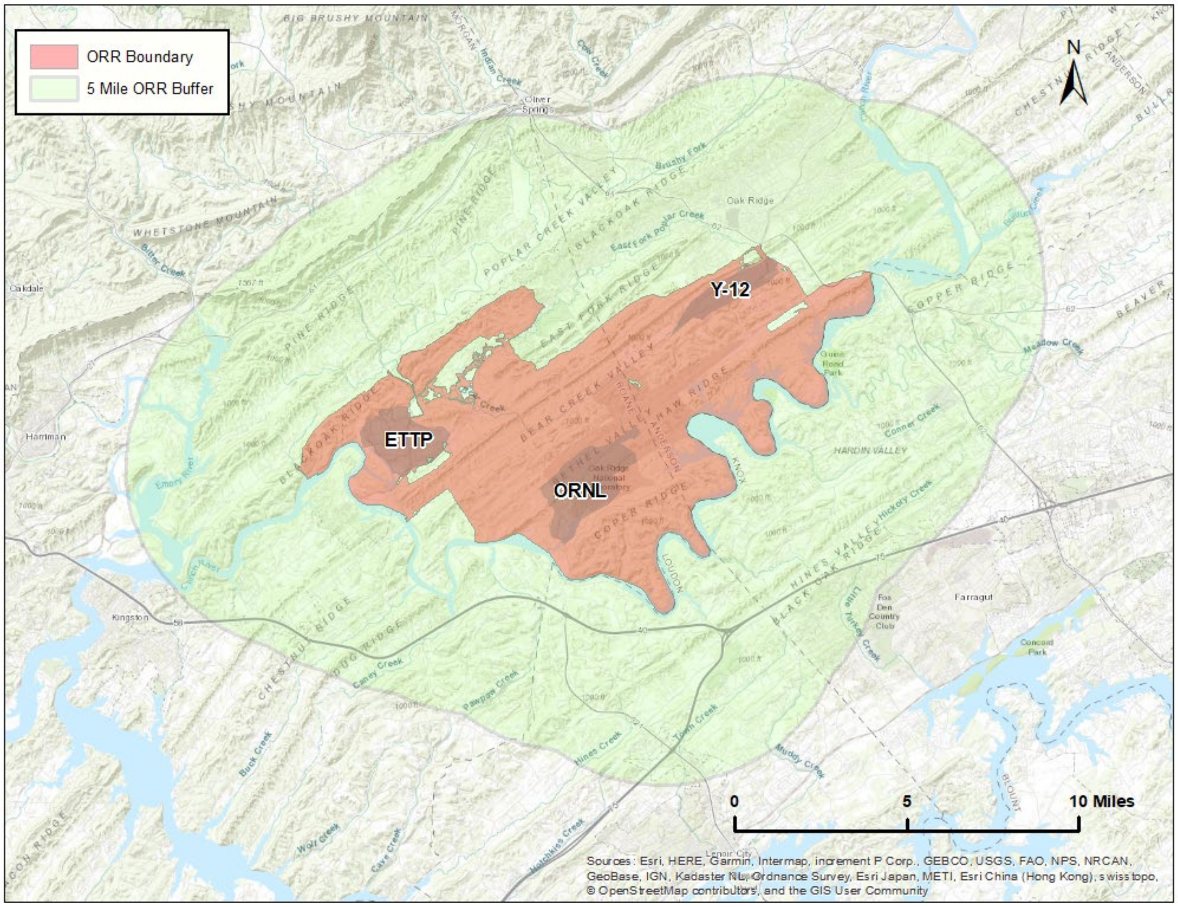

Figure 3.3.1 Map of the five-mile radius around the ORR

Vegetable, hay, and milk samples were collected by TDEC DoR-OR staff in the 2021 growing season in June through October. Samples were shipped to the Tennessee Department of Health-Nashville Environmental Laboratory (TDH-NEL) for radiological analysis. Starting in July 2021 (Fiscal Year 2022), vegetation samples (vegetables and hay) were analyzed for gross alpha, gross beta, and gamma isotopes. Additional analyses (isotopic uranium, strontium-90) were only conducted if alpha or beta levels, or both, were elevated. Prior to this, vegetation samples were also analyzed for isotopic uranium and strontium-90 automatically, even if gross alpha or gross beta levels were low. Milk samples continue to be analyzed for gamma isotopes as well as tritium, isotopic uranium, and strontium-90.

3.1.6 Deviations from the Plan

Eleven (11) samples were collected and analyzed in June 2021. At the time of the last monitoring report, only gross alpha, gross beta, and gamma analysis results were available for the ten vegetable and one hay sample from June 2021, but not the strontium-90 (Sr-90) and isotopic uranium (U) results (U-234, U-235, U-238). So the full results from June 2021 are shown below, in addition to the other summer and fall 2021 samples, especially as they are all from the same 2021 growing season. The 2021 samples from July through October, collected during FY2022, are also shown below. Additional samples were collected in June

2022 but will be discussed in the FY2023 EMR with the other 2022 growing season sample results, as the results are not yet available. The historical DOE vegetable, hay, and milk data through 2019 was provided to our office and is also discussed. The 2020 food crop results from the DOE ASER published in September 2021 are also used for a separate comparison as this comparison with the most recent DOE ASER data will be done each year after the historical DOE Food Crops data is discussed in this year's report.

3.3.7 Results and Analysis

The results of the Food Crops sampling completed by TDEC DoR-OR in 2021 are shown in Table 3.3.1 (vegetables and hay) and Table 3.3.3 (milk). Twenty-eight vegetation samples (seven hay, twenty-one vegetable) and three milk samples were analyzed in 2021. While these samples were collected during different fiscal years, they were collected during the same growing season (2021) and are best compared that way.

Vegetables and Hay

The available vegetation data (from vegetable and hay samples) for 2021 is shown in Table 3.3.1. Results shown in gray text rather than black did not qualify as detects as they had an analytical uncertainty (error) more than a third of the result. Locations with green shaded cells were background or reference locations from greater than five miles from the ORR. The results of the gamma analyses with no values and the entire cell shaded gray, had no reported results for that analyte. Cells that are light gray in the isotopic uranium section and the isotopic beta activity section indicate that no analysis was conducted for those analytes.

Table 3.3.1. Results from TDEC DoR-OR 2021 vegetable and hay food crops sampling (pCi/g)

		gross	gross	isotopic uranium (alpha)			beta		gamma				
Location	Sample	alpha	beta	U-234	U-235	U-238	Sr-90	Tc-99	K-40	Be-7	Pb-212	Pb-214	Bi-214
Clinton farm garden- reference	hay/grasses	-1.2	2.3	0.036	0.016	0.047	0.047		16.3	5.8			
Field east of ORNL	hay/grasses	0.002	5.2	0.078	-0.001	0.07	0.026		13.8	5.6		0.29	
Oak Ridge UT Arboretum field	hay/grasses	0.07	4.2	0.127	0	0.062	0.084		12.9	5.3			
Oak Ridge Scarboro field	hay/grasses	-0.16	2.4	0.077	0.010	0.045	0.015		9.8	6.4		0.27	
ETTP area field	hay/grasses	-0.14	6.1	0.05	-0.011	0.017	0.040		15.3	7.6			
Field at public boat launch near ETTP	hay/grasses	0.66	19.6				0.008	0.17	30.7	29.7		2.34	2.9
Field not far from the ETTP K-1200 area	hay/grasses	0.31	27.6				0.040	1.28	34.3	18.0		0.61	
Clinton home garden- reference	greens- turnip	0.32	6.0	0.0135	0.002	0.0088	0.0171		7.6				
Clinton farm garden- reference	greens- turnip	0.38	4.5						6.32	1.14			0.118
Oak Ridge Scarboro home garden	greens- turnip	0.2	6.8	0.0114	0.0023	0.0185	0.0002		10.0	0.62			
Solway home garden	greens- turnip	0.09	3.5						4.58	0.66			
East Oak Ridge home garden	greens- mustard	-0.06	2.9						4.30				
Clinton home garden- reference	roots- turnip	0.28	2.1	0.0033	-0.0003	0.0038	0.0029		3.69		0.03		
Clinton farm garden- reference	roots- turnip	0.12	2.2						2.03				
Oak Ridge Scarboro home garden	roots- turnip	0.21	3.4						5.08				
Solway home garden	roots- turnip	0.12	3.2						4.68				
East Oak Ridge home garden	roots- mustard	0.11	4.1						5.96				
Clinton farm garden- reference	fruiting- squash	0.04	2.3						2.83				
Oak Ridge Scarboro community garden	fruiting- squash	0.02	1.1						1.52				0.032
Solway home garden	fruiting- squash	0.10	1.7						2.05				
Home garden west of ETTP	fruiting- squash	0.06	1.4						2.03				
East Oak Ridge home garden	fruiting- squash	0.04	1.3	0.004	0.00073	0.0038	0.0022		1.95			0.028	
Home garden east of ORNL	fruiting- squash	0.06	1.0						1.99			0.065	
Home garden north of ETTP	fruiting- squash	0.1	1.6						2.43				
East Oak Ridge home garden	fruiting- cucumber	0.09	1.3	0.0042	0.00022	0.0043	0.0019		2.09				
Home garden southwest of ORNL	fruiting- cucumber	0.02	1.5						2.48				
Clinton home garden- reference	fruiting- tomatoes	0.13	1.4						2.67				
Home garden south of ETTP	fruiting- tomatoes	0.12	1.5						2.14				

blank cells mean that no result was reported for that analysis

Starting in July 2021 (FY2022), vegetation (hay and vegetable) samples were analyzed for gross alpha, gross beta, and gamma isotopes with additional analysis (isotopic uranium or specific beta isotopes) only done if indicated by elevated gross alpha or gross beta results. Consequently, the only 2021 samples shown with isotopic uranium analysis results were from June 2021. The only 2021 samples shown with isotope specific beta analysis were from June 2021 (Sr-90 only), with the exception of the last two hay samples. These samples had elevated gross beta results as well as higher potassium-40 (K-40) and beryllium-7 (Be-7) results. While the higher gross beta levels could have been due to the higher K-40 (which is both a gross beta and a gamma emitter), additional analysis was conducted to see if part of the higher beta values were due to Sr-90 or technetium-99 (Tc-99). Tc-99 was suspected because the samples were collected in the vicinity of the ETTP site which had a recent Tc-99 cleanup. In fact, the sample taken near Highway 58 at ETTP had a detectable amount of Tc-99, 1.28 pCi/g.

All the gross alpha and gross beta results that were less than detection limits (numbers in gray) had a high analytical error. All but three of the gross beta results were less than detection limits and are shown with black text. One gross beta result (4.5 pCi/L) was in the normal range and was from a background location and the other two were the last two hay samples listed, both from the ETTP area, as noted above. Interestingly, the hay samples from 2021 tended to have higher gross beta, K-40, and Be-7 results in comparison with most of the vegetable samples collected in 2021. Grasses are likely better at bioaccumulating these isotopes, though greens and root vegetables did this to some extent too, even at the reference locations (over five miles from the Oak Ridge Reservation). Some amount of isotopic uranium (U-234, U-235, U-238), thorium, gamma emitting daughter products, lead-214 (Pb-214), bismuth-214 (Bi-214), lead-212 (Pb-212), and K-40 are naturally occurring in soils and thus not unexpected. The amount of isotopic uranium in the 2021 samples remains negligible when compared to the IAEA food products standard of 2.7 pCi/g for U-235. There are no known FDA isotopic uranium limits for comparison. Beryllium-7 is a naturally occurring cosmogenic radionuclide and is also not unusual. No Sr-90 results from the 2021 vegetable and hay samples collected by TDEC DoR-OR were above detection limits. None of the 2021 vegetable and hay isotopic uranium results were above detection limits (by MDAs or error).

If higher levels of isotopic uranium are seen at locations with higher levels of gross alpha (seen previously), it may be due to fertilizer use. This correlates with the higher levels of K-40 (a beta and gamma emitter) seen at these locations, as higher levels of K-40 can be seen with increased amounts of potassium in NPK (nitrogen, phosphorus, and potassium) fertilizer. Uranium levels in soils can also be increased with fertilizer use, as uranium and thorium are often concentrated during the manufacture of fertilizers from the levels normally found in the phosphate rocks used to make fertilizer. This can lead to higher gross alpha levels, levels of isotopic uranium, and levels of uranium daughter products emitting gamma radiation (World Nuclear Association, 2020; ORAU 2021). It appears that hay (grasses) and leafy greens may naturally bioaccumulate K-40, as it is seen in higher levels in those samples, even when no fertilizer was likely to have been applied. No additional analysis was needed (as indicated by no elevated gross alpha or gross beta results) at any of the home garden locations for 2021 samples, and the low-level concentrations that were detected were comparable to background locations outside a radius of potential impact from the Oak Ridge Reservation.

2020 DOE ASER Comparisons

The most recent DOE Oak Ridge Reservation Annual Site Environmental Report (ASER) Food Crop data is from 2020 and is located in section 6, in the ORR Environmental Monitoring Program portion. The comparable DOE sampling from the 2020 ASER was limited to tomatoes and hay, with no other vegetables sampled in 2020. The hay and tomato results were converted to the same units (pCi/g) used for the TDEC DoR-OR data in Table 3.3.1 (above) and are shown in Table 3.3.2. Only data with results above detection limits were shown in the 2020 ASER, as opposed to included but shown in gray in Table 3.3.1. Detection limits are likely not the same between sampling projects as different laboratories were used.

Table 3.3.2 2020 DOE vegetable (tomato) and hay data (pCi/g)

	Location	gross alpha	gross beta	gamma		uranium isotopes		
				Be-7	K-40	U-234	U-235	U-238
tomatoes	North of Y-12	0.041	0.993	*n*	*n*	0.002	*n*	*n*
	South of ORNL	*n*	1.24	*n*	1.8	*n*	*n*	*n*
	East of ORNL	0.023	0.899	*n*	*n*	0.005	*n*	*n*
	West of ETTP	0.053	1.16	*n*	1.36	0.006	*n*	0.001
	Reference site	0.061	1.15	*n*	*n*	0.004	*n*	*n*
hay	East ORNL hay*	0.24	12.6	6.35	17.1	0.008	0.002	0.006

* While additional radionuclides analyzed included neptunium, plutonium, strontium, and thorium, these values were listed as less than or equal to the minimum detectable activity.

n not detected, value less than or equal to minimum detectable activity

DOE tomato samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. The 2021 TDEC DoR-OR gross alpha results for tomatoes (Table 3.3.1) were about twice or more the amount seen by the 2020 DOE tomato sampling results, even at the background location. Gross beta and K-40 results were a little higher too, but TDEC DoR-OR only had two tomato samples in 2021, though there were multiple other fruiting vegetable samples (gourds- squashes, cucumbers) collected.

DOE hay analysis included gross alpha, gross beta, gamma emitters, and uranium isotopes. Every five (5) years DOE conducts additional analysis on hay. Additional radiological analyses of their July 2020 hay sample included neptunium, plutonium, strontium, and thorium, but results were below MDAs. As noted in the ASER, “Hay from an area on the eastern edge of

ORR is made available to an off-site farming operation and is sampled annually. Eating beef and drinking milk obtained from cattle that eat hay is a potential radiation exposure pathway to humans, and hay is sampled to characterize any possible doses from this pathway." The July 2020 DOE hay sample was taken at a location close to the TDEC DoR-OR site 'Field East of ORNL' and the results were mostly within the range of the hay results collected by the TDEC DoR-OR project in 2021. However, the DOE results are a little higher for all measurements except isotopic uranium, which were about an order of magnitude smaller than TDEC DoR-OR results. The 2020 DOE sampling results also show the DOE hay sample as having higher concentrations for the analyses shown in Table 3.3.2 than was seen for the tomato samples, also indicating hay as an efficient bioaccumulator.

Milk

As stated in the 2021 DOE ASER, "Milk is a potentially significant exposure pathway to humans for some radionuclides deposited from airborne emissions because of the relatively large surface area on which a cow can graze daily, the rapid transfer of milk from producer to consumer, and the importance of milk in the diet." The available milk data for the TDEC DoR-OR 2021 sampling is shown in Table 3.3.3. Two of the three samples were from reference locations over five miles from the Oak Ridge Reservation. The background goat milk sample was from a private farm. The background cow milk sample was from a commercial dairy. No sampling locations with active dairies were found in 2021 within five miles of the Oak Ridge Reservation, but there was an opportunity to collect a composite goat milk sample from goats feeding on kudzu in an area of the ORR. While this area is not expected to have been contaminated directly, this was the one non-background milk sample collected in 2021.

Results shown in gray text rather than black were below detection limits, meaning below the minimum detectable activity, if available, and or with the uncertainty (error) being more than a third of the result. Locations with green shaded cells were background or reference locations, greater than five miles from the ORR. Interestingly, the 2021 reference milk samples had small amounts of detected cesium-137 (Cs-137) and had varied levels of K-40 with one result similar to the levels seen in 2016 by DOE sampling, one lower, and one higher. Cs-137 was detected in one cow milk and one goat milk sample, both from background locations. Cs-137, a manmade isotope and a common fission product, was released into the environment during nuclear weapon tests and some nuclear accidents. While the radioactive half-life of Cs-137 is about 30 years, it is excreted fairly quickly, with a biological half-life of about 70 days.

Table 3.3.3 Results from TDEC DoR-OR 2021 milk sampling (pCi/L)

		isotopic uranium					gamma			
Location	Sample	U-234	U-235	U-238	Sr-90	Tritium	K-40	Cs-137	Am-241	Bi-214
Reference 6- Knox Co Dairy	cow milk	0.43	0.18	0.178	0.71	133	1320	4.6		
Reference 4- Clinton Farm	goat milk	0.87	0.51	0.52	0.07	110	1730	9.6		
ORR- Gallaher Bend forage	goat milk	0.28	0.16	0.159	0.41	38	679		11.5	16.9

Table 3.3.4. Results of DOE's milk sampling program from 2016 (pCi/L)

	Claxton		Maryville (reference)	
	Mean	Maximum	Mean	Maximum
Potassium-40	1330	1350	1325	1360

Analysis was also done for gamma isotopes, strontium, and tritium for the above samples, but only samples with results above official detection limits were shown in the ASER and are listed here. These results are the equivalent of the black text TDEC results (greyed out TDEC results show results below official detection limits as the results are meaningful but are not official detects).

All TDEC DoR-OR and DOE milk sample Sr-90 results were well below the FDA derived intervention limit of 4400 pCi/L for Sr-90 in milk, and even below detection limits. Analysis from more milk samples and especially goat milk samples would be helpful for more meaningful comparisons. The only results from DOE's 2016 milk sampling program that were above detection limits were for K-40 (Potassium-40) and are shown in Table 3.3.4. The 2020 ASER stated that analysis was done for gamma emitters and strontium, but there were no gamma or strontium detections.

Comparison to Historical DOE Food Data

The DOE food sampling projects have looked at vegetables and hay both on and off the ORR and have used a variety of locations over the years. A variety of sampling locations have been used for the cow dairy milk samples as well. This makes comparisons not quite as directly comparable and due to the large amount of data over time, one of the better ways to look at the data appeared to be to look at the summary maximum and average data between the types of sites: on or near the ORR and reference sites away from the ORR. To get a better idea of the range of the data, all results were included for DOE and TDEC DoR-OR datasets. TDEC DoR-OR sampling of the same media (vegetables, hay, milk) started in 2019 and has had relatively few samples collected. The 2021 sample results shown in Table 3.3.1 (vegetation) and Table 3.3.3 (milk) can also be used for comparison. However, the summary maximum and average data for refence sites and those greater than five miles from the ORR for each of the sample types (hay, greens, roots, and fruiting vegetables divided into gourds and tomatoes as DOE has sampled tomatoes) are also provided below for the TDEC DoR-OR 2019-2021 data.

HAY

The maximum and average summary data for the historical DOE hay sampling (1993-2019) as well as the same for the 2019 to 2021 TDEC hay sampling is shown in Table 3.3.5. For the DOE sampling, from 1993 to 2007, samples were taken on or near the ORR, and at a reference location. Starting in 2015, samples were only taken from one location on the ORR, at the edge of the site and at the far east end from ORNL, listed as the ORISE site in the table below. Maximum or average values should be compared for each isotope or radiation type (row), between site types. Data bars make the visual comparison easier, but are not included for negative numbers, which can be thought of as being approximately zero. They are also not included for isotopes with only one result.

Table 3.3.5. DOE hay sample data (pCi/g)

	DOE hay data						TDEC hay data			
sites	1-2-3, 2-4-5, 6		ORISE site		7,8 reference sites		On or near ORR		Background	
years	1993-2007		2015-2019		1993-2007		2019-2021		2019-2021	
analytes	max	average	max	average	max	average	max	average	max	average
Gross Alpha	1.485	0.164	0.16	0.00103	0.157	0.07295	0.66	0.159	0.84	-0.0167
Gross Beta	16.47	6.91	12.4	8.978	12.4	7.37	27.6	9.93	14.5	7.5
Be-7	17.4	5.25	47	13.16	11.2	4.3	29.7	12.3	5.8	4.46
K-40	27.5	9.17	14.6	10.12	23.4	9.09	34.3	19.47	16.3	11.6
U-234	0.0515	0.0104	0.00467	0.00322	0.00723	0.00322	0.127	0.068	0.0278	0.0273
U-235	0.0062	0.00125	0.00156	0.00064	0.00126	0.00037	0.01	-0.00006	0.016	0.0076
U-238	0.053	0.008965	0.00458	0.00267	0.00421	0.00213	0.07	0.04	0.047	0.0283
Pb-214			0.525				2.34	0.746	0.23	
Tritium	11.07	-0.0195			0.27	0.014				
Co-60	0.0729	0.0100			0.0069	0.00049				
Cs-137	0.0783	0.0135			0.018	0.0075				
I-129	0.054	0.0141			0.027	0.01485				
Ac-228					1.6				0.53	
Os-191*	0.86	0.52								
Pb-212									0.142	
Bi-214							2.9	1.575	0.54	
Sr-90							12	1.74	0.06	0.0497
Tc-99							1.28	0.725		

(grey) no results- no analyis, no detects, or only one sample- max same as average

* only in 2000

The isotopes/radiation types that are the most likely to be of concern and should be carefully examined are alpha, beta, the uranium isotopes (U-234, U-235, and U-238), tritium (H-3), cobalt-60 (Co-60), cesium-137 (Cs-137), and iodine-129 (I-129). Interestingly, for these analyses, the data from 1993-2007 from on and near the ORR seem to be the most elevated, compared to both the ORISE site (at the edge of the ORR) and the refence site, though the timeframes are different. Sr-90 and Tc-99 are also isotopes of potential concern, but analysis for them was only done on some TDEC DoR-OR samples, not all, as noted previously.

These values can be compared to those from the total TDEC DoR-OR hay sampling from 2019 to 2021 (Table 3.3.5) or that done in 2021 (Table 3.3.1). TDEC DoR-OR sampled ten (10) hay samples by the end of 2021, three (3) at background (reference) locations and seven (7) at locations on or near the ORR. Seven (7) of the hay samples were collected in 2021, including one background location. On average, TDEC DoR-OR's results are more or less comparable with DOE's results as shown in Table 3.3.5. Some of the isotopes analyzed for DOE hay samples were not analyzed for by TDEC DoR-OR and vice versa (tritium, I-129, osmium-191 (Os-191) vs. Sr-90, Tc-99). However, gross alpha, gross beta, and gamma analysis was done by TDEC DoR-OR and DOE. Isotopic uranium was analyzed for all except the two samples collected in July 2021, but now will only be requested if gross alpha levels appear elevated. The Sr-90 value in the second part of table 3.3.6 is high, but suspect, because it is from a location with no known contamination that is nearly five (5) miles from the ORR, so a high Sr-90 concentration from a sample there seems unlikely. A sample from the same approximate location was taken in 2022 and will be compared when the results are available. For gross alpha in hay, TDEC DoR-OR values were less or similar to DOE values, especially when comparing average results and taking high maximum values into consideration. For gross beta, TDEC DoR-OR values were higher or similar to DOE values. For the uranium isotopes listed, TDEC DoR-OR results were often double to an order of magnitude higher than DOE results.

The TDEC DoR-OR hay data in comparison with the vegetable data is shown in Table 3.3.7 and Table 3.3.8.

VEGETABLES

DOE vegetable sampling took place starting in 1992 and has continued most years. DOE provided data from 1992 to 2019. The data is also presented each year in the ASER, including more recent data as available. Three (3) tables are shown below, each for a different type of vegetable (i.e. leafy greens, turnip leaves, or lettuce) sampled. For root vegetables the samples were turnips, and for fruiting vegetables, tomatoes were sampled. The data bars are placed to help readers visually compare the maximum values for each type of radiation (gross alpha, gross beta) or isotope between the ORR perimeter sampling sites (1992-1996 only), the sites near the ORR, and the background locations. This can be done for the maximum values and the average values. Colors alternate to allow for visual clarity and ease of comparison. Data values should only be compared for each row individually (each isotope/radiation type). All data provided was included regardless of data qualifiers. Negative values approximate zero and hence don't show data bars. Different locations were often sampled in different years. Table 3.3.7 highlights the results of isotopic analyses that are similar and comparable to TDEC results and for isotopes of potentially greater interest, such as cobalt-60 (Co-60) and cesium-137 (Cs-137). Isotopes or radiation measured in at least some samples from some locations (though fewer than those in Table 3.3.6) included americium-241 (Am-241), curium-242 (Cm-242), curium-244 (Cm-244), neptunium-237 (Np-237), plutonium-238 (Pu-238), plutonium-239 (Pu-239), thorium-228 (Th-228), thorium-230 (Th-230), thorium-232 (Th-232), total strontium, total uranium, and tritium. However, these appear to be additional analyses that were conducted only certain years and that were only present in very low concentrations, allowing for the continuation of only periodic analyses, not annual, and are not included in Table 3.3.6. More information on DOE's past vegetable sampling results can be found in past ASERs.

In Table 3.3.6, the number (#) indicates the number of samples with results for that type (radiation or isotope) for each of the locations: ORR, near ORR, and reference (background). DOE periodically does additional analysis on samples.

Table 3.3.6. DOE vegetable sample select data (pCi/g)

greens	ORR			near ORR			Reference/Background		
	#	Max	Average	#	Max	Average	#	Max	Average
Alpha	47	0.702	0.169	114	0.19	0.0407	20	1.53	0.148
Beta	47	5.13	3.48	114	8.1	3.32	20	5.4	3.2
Be-7	39	1.377	0.539	114	2.09	0.312	19	2.82	0.298
Co-60	47	0.027	0.00181	15	0.012	0.00452	6	0.01647	0.00590
Cs-137	47	0.0432	0.00607	18	0.013	0.00315	6	0.00162	-0.00284
K-40	47	13.77	5.57	114	9.7	4.64	20	14.04	4.61
U-234	39	0.0378	0.0103	114	0.0224	0.00506	19	0.0318	0.00546
U-235	39	0.0054	0.00143	114	0.00591	0.000664	19	0.00864	0.00136
U-238	39	0.01512	0.00545	114	0.0278	0.00429	19	0.0319	0.00372

roots	ORR			near ORR			Reference/Background		
	#	Max	Average	#	Max	Average	#	Max	Average
Alpha	26	0.127	0.0135	98	0.275	0.0280	16	0.101	0.0164
Beta	26	2.97	2.12	98	5.08	2.00	16	3.53	1.72
Be-7	10	0.0918	0.03564	91	0.885	0.0151	14	0.393	0.0153
Co-60	26	0.00972	0.001223	17	0.0079	0.003567	3	0.00432	0.0009
Cs-137	26	0.01296	0.001285	17	0.0072	0.00193	3	0.00324	0.00126
K-40	26	3.78	2.74	98	8.34	2.81	16	4.81	2.61
U-234	18	0.0324	0.0068	98	0.0276	0.002103	15	0.00441	0.002047
U-235	18	0.02052	0.00227	98	0.00405	0.00526	15	0.00288	0.0005107
U-238	18	0.00918	0.002555	98	0.0186	0.00136	15	0.002	0.000362

tomatoes	ORR			near ORR			Reference/Background		
	#	Max	Average	#	Max	Average	#	Max	Average
Alpha	50	0.0594	0.00248	111	0.0402	0.0241	20	0.0134	0.134
Beta	50	2.40	1.51	111	3.33	1.38	20	2.43	1.25
Be-7	19	0.0243	0.00600	93	0.509	-0.00247	15	0.465	-0.0576
Co-60	50	0.0081	0.000707	15	0.00340	0.00153	7	0.00594	0.000934
Cs-137	50	0.00864	0.000243	18	0.00340	0.00112	7	0.00459	0.0013987
K-40	34	3.78	2.62	111	3.48	1.87	18	3.05	1.96
U-234	43	0.00837	0.000995	111	0.0273	0.00290	19	0.0139	0.00240
U-235	43	0.002025	0.000143	111	0.000301	0.000585	19	0.00257	0.000747
U-238	43	0.00486	0.000356	111	0.023	0.00130	19	0.00696	0.00106

The TDEC DoR-OR background data for 2019-2021 for all sample types are shown in Table 3.3.7, and the data for samples collected on or near the ORR are shown in Table 3.3.8. The DOE sampling dataset is more extensive, both in total number of samples and variety of analytes run over time. Both TDEC DoR-OR and DOE analyzed vegetable samples for gross alpha, gross beta, and gamma isotopes, and TDEC DoR-OR automatically requested isotopic uranium and Sr-90 analysis up through June 2021. Starting in July 2021, isotopic uranium and Sr-90 analyses were only conducted if indicated by elevated gross alpha or gross beta activity, respectively. Tc-99 was also run for samples with elevated gross beta in areas where Tc-99 is a contaminant of concern, such as ETTP, starting in 2021.

TDEC 2019-2021 on or near the ORR vs background data

The tables below allow for comparison to DOE vegetation data (vegetables and hay) as well as between each sample type for both background and the activity of samples collected on or near the ORR for each isotope or radiation type (in columns). As mentioned previously, some of the 2019 and 2020 data had suspect elevated activity for some samples, even at background locations, so the maximum values listed below may be higher than they should be. The average values for each may be more indicative, though biased high. The 2021 dataset shown in Figure 3.3.1 can also be used for comparison and does not include the suspect results, which were from 2019 and 2020. Additional sampling will shed more light on these elevated sampling results moving forward.

For gross alpha in greens, TDEC DoR-OR values were mostly lower than DOE values, but the TDEC DoR-OR data was from only seven samples, four from within five miles of the ORR and three from background locations. For gross beta, TDEC DoR-OR values were similar to DOE values for on or near ORR locations, but much higher for background values, largely due to the suspect activity from one sample, with a gross beta of 20.0 pCi/g. Otherwise, the highest background gross beta activity was 6.0, and more similar to the highest near ORR activity of 6.8 pCi/L. Without the outlier, the average would have been 5.3 pCi/g. For the uranium isotopes listed, TDEC DoR-OR results were skewed higher by results from the same sample that had the high gross beta activity.

Table 3.3.7. TDEC DoR-OR background data 2019-2021, all sample types (pCi/g)

			gross	gross	isotopic uranium (alpha)			beta		gamma						
sample type		#	alpha	beta	U-234	U-235	U-238	Sr-90	Tc-99	K-40	Be-7	Pb-212	Pb-214	Bi-214	Tl-208	Ac-228
hay	max		0.84	14.5	0.0278	0.016	0.047	0.06		16.3	5.8	0.142	0.23	0.54		0.53
	average	3	-0.02	7.5	0.0273	0.0076	0.0283	0.0497		11.6	4.46					
greens	max		1.48	20.0	0.057	0.0073	0.049	0.042		23.5	4.1			0.118		
	average	3	0.73	10.2	0.035	0.00465	0.0289	0.0296		12.47	2.62					
roots	max		0.28	2.2	0.0033	-0.0003	0.0038	0.0029		3.69		0.03				
	average	2	0.2	2.15												
fruiting- gourds	max		0.04	2.3						2.83						
	average	1														
fruiting- tomatoes	max		1.65	30.7	0.057	0.016	0.054	0.055		41.5		0.4	0.069	0.078	0.29	
	average	3	0.61	11.2	0.029	0.00817	0.02766	0.0273		15.27						

Table 3.3.8. TDEC DoR-OR on or near ORR data 2019-2021, all sample types (pCi/g)

			gross	gross	isotopic uranium (alpha)			beta		gamma						
sample type		#	alpha	beta	U-234	U-235	U-238	Sr-90	Tc-99	K-40	Be-7	Pb-212	Pb-214	Bi-214	Tl-208	Ac-228
hay	max		0.66	27.6	0.127	0.01	0.07	12	1.28	34.3	29.7		2.34	2.9		
	average	7	0.159	9.93	0.068	-0.00006	0.04	1.74	0.725	19.47	12.3		0.746	1.575		
greens	max		0.09	6.8	0.0114	0.0023	0.0185	2.45		10	0.66			0.118		
	average	4	0.08	4.2	0.0065	0.00145	0.00985	1.225		5.89	0.64					
roots	max		0.21	4.1						5.96						
	average	3	0.147	3.57						5.24						
fruiting- gourds	max		1.1	24.2	0.099	0.018	0.08	0.022		30.8			0.065	0.032		
	average	10	0.266	5.51	0.0488	0.0082	0.042	0.0085		7.54			0.0465			
fruiting- tomatoes	max		0.12	1.9	0.0016	0.0008	0.0002	0.292		2.45		0.022				
	average	5	0.07	1.48	0.00065	0.000425	0.000025	0.0913		2.074						

For gross alpha in roots, TDEC DoR-OR values were generally higher than DOE values, sometimes an order of magnitude higher. For gross beta, TDEC DoR-OR values were higher or similar to DOE values. For the uranium isotopes listed, TDEC DoR-OR results were similar to DOE background results. However, the TDEC DoR-OR data was from only a total of five (5) samples, three (3) from within five miles of the ORR and two (2) from background locations. Isotopic uranium results were only available for one background sample.

For tomatoes, TDEC DoR-OR had a total of eight (8) samples, five (5) from near the ORR and three (3) from background locations. However, one background sample had questionably high results which statistically controlled the maximum activity for alpha, beta, and isotopic uranium, and also skewed the averages for these high values. This background data set is most likely an outlier and should be removed from the analysis. When examining this data set without the outlier, the adjusted background tomato maximum values and average values are shown in Table 3.3.9. These data are more comparable to values seen in DOE sampling of tomatoes from background locations. Gross alpha TDEC DoR-OR tomato values were at least twice DOE values for near ORR sampling. For gross beta, TDEC DoR-OR values were within range of DOE values for near ORR sampling. For the uranium isotopes listed, TDEC DoR-OR results were within range for almost all of these samples but were an order of magnitude less than DOE results for U-238 for near ORR samples.

Table 3.3.9 TDEC DoR-OR background tomato data without high 2020 sample (pCi/g)

	gross	gross	isotopic uranium (alpha)			beta	gamma		
	alpha	beta	U-234	U-235	U-238	Sr-90	K-40	Pb-214	Bi-214
max	0.13	1.5	0.00119	0.00034	0.00132	-0.00046	2.67	0.069	0.078
average	0.09	1.45					2.16		

TDEC DoR-OR also collected other fruiting crops that fit into the overall gourd classification (squashes, cucumbers), not just tomatoes. Unfortunately, two (2) samples from the same garden in Oak Ridge (near the ORR) in 2020 had questionably high results, and there was only one background sample. Results from the 2021 samples seen in Table 3.3.1 were used for comparison instead, although they only represent one growing season. The maximum values and averages for the 2021 gourd samples within five (5) miles of the ORR can be seen in Table 3.3.10 and are more comparable to the TDEC DoR-OR and DOE data as shown in

Table 3.3.9 and Table 3.3.6.

Table 3.3.10 TDEC DoR-OR near ORR gourd data without high 2020 samples (pCi/g)

	gross alpha	gross beta	isotopic uranium (alpha)			beta	gamma		
			U-234	U-235	U-238	Sr-90	K-40	Pb-214	Bi-214
max	0.1	1.7	0.0042	0.00073	0.0043	0.0022	2.48	0.065	0.032
mean	0.06	1.36	0.0041	0.00048	0.00405	0.0021	2.07	0.0465	

MILK

DOE has historically conducted milk sampling, beginning in 2003. The focus of sampling included one potentially affected dairy, areas closer to the ORR (i.e. Claxton), and background locations (i.e. Maryville, Powell, Louisville). The years sampled, as well as the maximum values and average result for each isotope (i.e. H-3, Sr-90, K-40, Be-7) per each site are shown in Table 3.3.11. In addition, the number of samples with analysis (analyses?) for each isotope are also included for each of the sites. In the maximum values table, the concentrations in bold were the highest for each isotope. While two (2) of these were at the Claxton site, the other two (2) were at the background Maryville location, likely indicating that these levels are within the normal range. Also, the two (2) isotopes of greatest interest in Table 3.3.11 below are tritium (H-3) and strontium-90 (Sr-90), both of which had higher average levels at background locations. The number of samples analyzed for each isotope indicates how many samples went into the averages for those same locations.

Table 3.3.11. DOE milk sample data (pCi/L)

max

	2003-2016	2003-2016	2003-2007	2009-2010
	Claxton	Maryville	Powell	Louisville
H-3	1120	**1390**	1120	284
Sr-90	**6.96**	4.44	2.31	3.23
K-40	1480	**1540**	1300	1310
Be-7	**44.4**	38.5	43.5	6.36

average

	2003-2016	2003-2016	2003-2007	2009-2010
	Claxton	Maryville	Powell	Louisville
H-3	177.1	239.5	299.8	-108.3
Sr-90	1.26	1.01	1.34	1.23
K-40	1219.1	1296.9	1216.5	1194.4
Be-7	5.397	3.74	-0.0565	-10.79

number samples analyzed/results

	2003-2016	2003-2016	2003-2007	2009-2010
	Claxton	Maryville	Powell	Louisville
H-3	70	70	26	9
Sr-90	70	70	26	9
K-40	70	70	26	9
Be-7	70	70	26	9

While all results are included above, none of the Be-7 concentrations would be considered as detects as the associated analytical errors were too large. All K-40 concentrations were detected by this metric. Alternatively, the Sr-90 data appears higher than concentrations seen in TDEC DoR-OR milk sampling. There were only three (3) official DOE project Sr-90 detects, including one (1) from a reference site in Maryville and two (2) from the potentially affected area in Claxton. All concentrations were well below the FDA derived intervention limit of 4400 pCi/L for Sr-90 in milk. None of the tritium (H-3) concentrations qualified as detects as the associated analytical error was too large on all samples (over thirty percent of the result). Also, the highest concentration was from a background location, indicating the values seen at the closer location were within the normal range. As noted in the ASER 2020, "Since 2016, no dairies in potential ORR deposition areas have been located, and no milk samples have been collected. Surveys to identify dairies in potential deposition areas are conducted each year, and milk sampling will resume when dairy operations in appropriate areas are located". While there has been no milk sampling since 2016, the 2003-2016 DOE milk data did not indicate elevated H-3 or Sr-90, which could potentially be of concern, at the Claxton location, closest to the ORR.

The TDEC DoR-OR sampling project recognized the difficulty of finding a dairy close to the ORR, therefore, research on other animals, might fill this gap and show elevated levels of any isotopes likely to be from DOE activities. For this reason, sampling of goat milk was added to the project. In future sampling, residential cow milk (i.e. milk from a home or farm) would be acceptable if available. There was an opportunity to get a milk sample from goats foraging on kudzu on a more natural portion of the ORR in 2021. The available TDEC DoR-OR milk sampling data (2019-2021) is shown in Table 3.3.12. Concentrations shown in gray text rather than black did not qualify as detections as the uncertainty (error) was more than thirty percent of the result. Locations with green shaded cells were background or reference locations from greater than five (5) miles from the ORR. Most of the samples for the TDEC DoR-OR project to date have been from reference (background) locations, as seen in Table 3.3.12. The 2019 and 2020 samples were not analyzed for tritium (H-3) and the isotopic uranium analysis failed, so no results are available for those possible contaminants. Interestingly, low levels of Cs-137 were seen at two of the background locations, and americium (Am-241) was seen on the ORR and could be the result of ORR operations. At first glance, these levels appear quite low. This perception is due to the results being analyzed in radiation per liter (pCi/L). After these results are converted from liters to grams, the comparable values are about 1,000 times higher than the levels seen in the vegetation samples. The FDA derived intervention level (DIL) for Am-241 in combination with Pu-238 and Pu-239 in milk is 4,400 pCi/L. While the amount of Pu-238 and Pu-239 is unknown for this sample, the Am-241 is clearly quite low by comparison. However, more TDEC DoR-OR milk sample data would be helpful in the future for better comparisons.

Table 3.3.12. TDEC DoR-OR milk sample data (pCi/L)

			isotopic uranium					gamma			
Location	Sample	date	U-234	U-235	U-238	Sr-90	Tritium	K-40	Cs-137	Am-241	Bi-214
Reference 3- Loudon Co. Dairy	cow milk	10/9/2019	*	*	*	0.73	**	945			
Reference 3- Loudon Co. Dairy	cow milk	7/22/2020	*	*	*	0.67	**	1420			
Reference 4- Clinton Farm	goat milk	6/13/2021	0.87	0.51	0.52	0.07	110	1730	9.6		
ORR- Gallaher Bend forage	goat milk	8/26/2021	0.28	0.16	0.159	0.41	38	679		11.5	16.9
Reference 6- Knox Co Dairy	cow milk	9/15/2021	0.43	0.177	0.178	0.71	133	1320	4.6		

* analysis failed ** sample not analyzed for tritium

3.3.8 Conclusions

The TDEC DoR-OR Food Crops project collected vegetable, hay, and milk samples within five (5) miles of the ORR, as well as at background locations greater than this distance to establish background levels. The samples were analyzed for radiological contaminants and compared to levels seen at background locations. In addition, samples were also compared with the results from similar sampling by DOE in 2016 (milk) and 2020 (vegetables and hay) (DOE, 2017; DOE, 2021). In general for the Radiological Uptake in Food Crops samples (hay, vegetables, milk) collected in 2021, the low-level concentrations that were detected were comparable to background locations outside a radius of potential impact from the Oak Ridge Reservation. Analysis from more hay, vegetable, and milk samples (especially goat milk) would be helpful for more meaningful comparisons. Overall, the TDEC DoR-OR 2021 vegetable, hay, and milk sampling results did not indicate that DOE ORR activities were significantly impacting radionuclide concentrations in food crops in the areas surrounding the ORR. Additionally, DOE data, including both historical and current ASER data, corroborated these results.

3.3.9 Recommendations

The TDEC DoR-OR food crop project has had a limited number of samples analyzed, so interpretation of results should be done with caution. TDEC DoR-OR recommends that additional vegetable, hay, and milk sampling be conducted in order to generate a larger dataset to identify any trends in radionuclide uptake that may be present in the vicinity of the ORR. As an added benefit of additional sampling, the level of corroboration with DOE data and contaminant limits could also be examined with a higher degree of certainty.

3.3.10 References

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4.0 LANDFILL MONITORING

4.1 EMDF

4.1.1 Background

The Environmental Management Disposal Facility (EMDF) is the proposed landfill for the disposal of low-level radioactive waste (LLRW) 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 not hold a permit from the State of Tennessee, the EMDF is required to comply with DOE orders and substantive portions of ARARs listed in the CERCLA Record of Decision (ROD).

4.1.2 Problem Statements

- Contaminants in the proposed 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.
- Only low-level radioactive waste, as defined in TDEC 0400-02-11.03(21) with radiological concentrations below limits imposed by an expected Waste Acceptance Criteria (WAC), and agreed to by the FFA tri-parties, (DOE, EPA and TDEC), will be approved for disposal in the EMDF. DOE will be accountable for compliance with the WAC.

4.1.3 Goals

The goals of the EMDF Monitoring Project were:

- To provide assurance through independent monitoring and evaluation of DOE's data, that collected background or baseline data, discussed below, will be useful in protecting the public health and the environment.
- To verify that DOE adequately determined background water quality parameter levels in the surface water by measuring these water quality parameters (temperature, conductivity, pH, dissolved oxygen, and oxidation reduction potential [ORP]).
- To complement monitoring and analyses for DOE's actions.

4.1.4 Scope

The scope of the EMDF Monitoring Project included the following:

- Measure water quality parameters in streams at six (6) flume discharge locations: SF-1, SF-2, SF-3, SF-4, SF-5 and SF-6 and Spring D10W (Figure 4.1.1). TDEC DoR-OR staff members monitored these locations with the use of a YSI-Professional Plus water quality instrument or equivalent.
- Observe site conditions and measure surface water quality parameters twice per week as conditions and schedules warranted.

4.1.5 Methods, Materials, Metrics

Tasks for this program included monitoring surface water quality parameters at flumes along three (3) Bear Creek tributaries (NT-10, NT-11, and D-10W) located in the vicinity of the EMDF landfill (Figure 4.1.1). The flumes SF-1, SF-2, and SF-3 are installed on North Tributary-11 (NT-11) which is located along the western edge of the EMDF landfill site. The D-10W and NT-10 tributaries are located on the eastern edge of the landfill site, and flumes SF-4 and SF-5 are installed within D-10W, while SF-6 monitors NT-10. Spring D10W is located at the head of D-10W and is located to north of the EMDF landfill site.

TDEC DoR-OR personnel monitored 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 confidence check of this instrument was performed prior to field use. Water sampling for laboratory analysis by TDEC DoR-OR was not conducted. Parameter measurements followed *TDEC DoR Quality Assurance Project Plan* (2015) and the *Sampling and Analysis Plan* (2016).

To ensure DOE utilized best practices to limit possible contaminant migration, on a semi-monthly basis as possible, TDEC DoR-OR visited the EMDF site to perform general monitoring of the site. TDEC DoR-OR monitored the streams, noted discharges and water condition, observed the condition of the streambanks, and noted any concerns. Any concerns observed were brought to the attention of DOE/EMDF personnel. Field notes were recorded in a field book and events were reported in a TDEC DoR-OR project monthly report.

Data collected from these key locations by TDEC DoR-OR were entered into an Excel database for interpretation. Interpretation included construction of tables and graphs illustrating ranges and limits of parameters over the course of the project.

4.1.6 Deviations from the Plan

On certain weeks, some of the monitoring events were not completed due to unavoidable schedule changes, changes in priorities, accessibility, or weather.

4.1.7 Results and Analysis

Tables 4.1.1 and 4.1.2 contain the monthly statistics (maximums, minimums, and averages) for each water quality parameter measured for the seven stations measured during FY 2022. The stations are SF-1, SF-2, SF-3, SF-4, SF-5, SF-6, and Spring D10W. The water quality parameters measured were temperature, in degrees centigrade (T), pH in standard units, conductivity (Cond) in μSiemens/cm, dissolved oxygen (DO) in milligrams/Liter (mg/L), and oxidation reduction potential (ORP) in millivolts (mv). The total number of measurements for each month is listed as ‘n’ on the table. Some stations were not visited due to accessibility concerns.

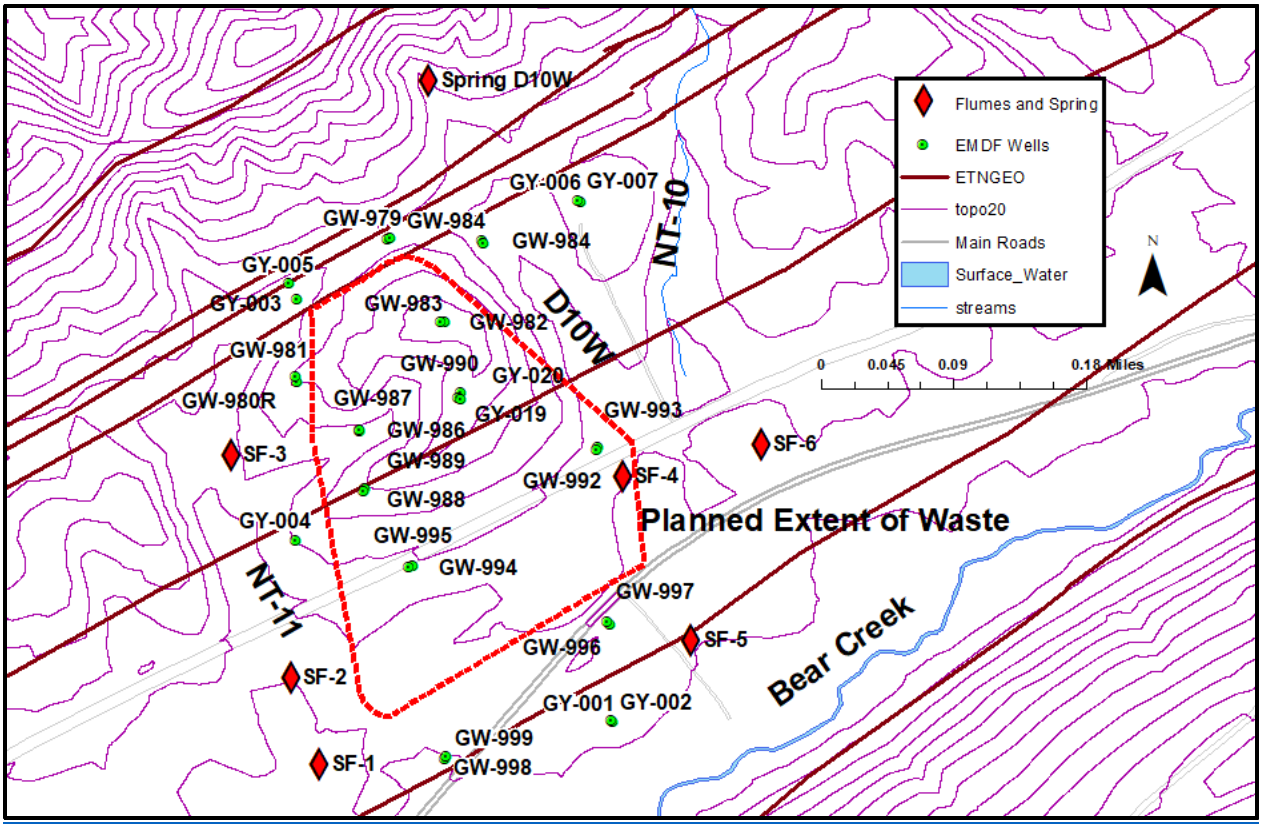

Figure 4.1.1: Sampling Locations EMDF 2021 Monitoring

All the flumes occasionally do not discharge water after extended periods of no precipitation. Additionally, little to no flow was observed at flumes SF-2, SF-4, SF-5, and SF-6 for extended periods until a rainfall event occurred. Water quality parameters were not measured at stations where no flow was observed.

Table 4.1.1 Monthly Statistics for Flume SF-1 through SF-4

Sample Location	Sample Month	Temperature (Degrees C)			pH (Standard Units)			Conductivity (mSeimens/cm)			Dissolved Oxygen (mg/L)			Oxidation-Reduction Potential (mv)		
		Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
SF-1	Jul-21	21.20	20.00	20.50	7.23	6.98	7.10	247.90	163.60	207.25	9.71	7.41	8.92	124.10	97.60	107.13
	Aug-21	22.00	19.00	20.24	7.25	7.05	7.16	286.80	182.20	242.26	9.14	7.41	8.53	122.10	81.80	100.79
	Sep-21	20.10	16.00	18.27	7.21	6.92	7.08	247.50	118.60	213.49	10.85	8.34	9.27	151.30	115.30	129.40
	Oct-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan-22	9.40	3.90	7.08	12.88	9.99	10.89	110.70	79.40	97.80	6.51	6.09	6.36	221.50	165.10	203.83
	Feb-22	11.30	3.40	7.84	12.55	9.99	11.32	152.60	46.80	108.76	6.68	6.34	6.48	262.90	185.80	225.19
	Mar-22	15.10	8.70	12.15	11.21	10.02	9.96	134.90	81.60	109.70	6.98	5.91	6.60	292.60	210.30	250.90
	Apr-22	15.90	10.60	13.25	10.63	9.05	9.84	146.60	87.60	117.10	7.72	7.61	7.67	224.30	185.00	204.65
	May-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jun-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF-2	Jul-21	21.40	19.80	20.50	7.10	6.84	6.91	171.70	114.60	146.25	8.33	6.22	7.34	68.30	8.21	43.53
	Aug-21	21.30	19.20	20.47	6.96	6.59	6.78	213.70	135.20	183.13	8.52	4.38	7.71	112.20	66.40	88.04
	Sep-21	20.10	16.20	18.60	6.90	6.66	6.81	188.70	88.20	161.10	10.68	7.82	9.48	158.60	73.70	114.20
	Oct-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan-22	9.60	4.30	7.40	12.40	9.33	10.52	80.90	61.40	71.15	6.49	6.14	6.33	157.80	135.70	147.27
	Feb-22	11.20	5.40	8.25	11.17	9.33	10.49	105.90	62.60	81.78	6.74	6.41	6.54	225.70	148.50	178.03
	Mar-22	14.60	9.00	11.63	10.13	9.65	9.59	86.90	49.90	72.80	6.95	6.05	6.56	216.30	157.10	178.03
	Apr-22	15.90	10.90	13.40	9.90	8.73	9.32	107.80	67.10	87.45	7.56	7.53	7.55	169.20	102.10	135.65
	May-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jun-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF-3	Jul-21	21.10	19.80	20.40	6.91	6.63	6.76	80.20	50.00	67.23	8.01	7.53	7.76	80.10	51.50	67.68
	Aug-21	22.00	19.10	20.68	7.01	6.53	6.83	92.40	61.60	81.24	9.40	5.33	8.11	66.10	34.40	51.32
	Sep-21	20.20	16.30	18.60	7.21	6.72	6.92	110.00	38.20	75.51	10.75	8.35	9.45	209.40	41.00	84.59
	Oct-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan-22	9.60	6.30	7.95	11.23	8.84	10.04	37.00	37.00	37.00	6.41	6.41	6.41	173.00	153.80	163.40
	Feb-22	9.20	4.70	7.60	12.93	8.84	11.42	46.60	40.10	44.13	6.65	6.55	6.61	183.80	153.60	169.47
	Mar-22	14.10	10.00	11.80	10.12	9.61	9.71	41.70	31.70	36.47	6.67	6.09	6.42	214.30	207.90	169.47
	Apr-22	15.60	11.50	13.55	9.76	9.08	9.42	48.00	33.10	40.55	7.17	6.62	6.90	135.80	98.70	117.25
	May-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jun-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF-4	Jul-21	20.90	20.10	20.35	7.45	6.74	6.97	331.30	127.70	210.80	7.51	5.62	6.99	97.70	63.30	77.70
	Aug-21	21.60	19.00	20.34	6.99	6.77	6.86	350.90	146.10	250.70	9.29	5.40	7.70	118.20	-5.50	73.03
	Sep-21	20.60	16.30	18.82	7.16	6.76	6.91	293.30	103.30	205.16	16.60	8.05	10.32	167.90	64.90	112.03
	Oct-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan-22	8.70	4.70	6.13	12.44	9.89	11.10	114.90	69.40	92.15	6.57	6.09	6.35	231.80	139.50	177.03
	Feb-22	10.00	5.30	7.70	12.10	9.89	11.11	109.10	61.20	88.48	6.69	6.35	6.51	201.60	169.40	181.08
	Mar-22	13.60	8.90	11.22	10.76	9.92	10.22	88.50	59.00	73.23	6.88	5.99	6.50	212.40	174.70	181.08
	Apr-22	15.90	11.40	13.65	9.64	9.23	9.44	130.00	72.10	101.05	7.63	7.29	7.46	166.00	145.90	155.95
	May-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jun-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.1.2 Monthly Statistics for Flume SF-5 through Spring D10W

Sample Location	Sample Month	Temperature (Degrees C)			pH (Standard Units)			Conductivity (mSeimens/cm)			Dissolved Oxygen (mg/L)			Oxidation-Reduction Potential (mv)		
		Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
SF-5	Jul-21	22.90	21.80	22.35	7.27	6.90	7.08	209.80	181.40	201.10	9.44	6.80	7.77	119.40	87.70	102.95
	Aug-21	22.60	19.50	21.72	7.28	7.00	7.17	271.40	204.40	229.70	8.55	7.56	8.04	122.60	81.40	100.48
	Sep-21	21.70	15.60	18.73	7.27	6.75	7.04	251.40	132.80	204.36	90.01	6.63	17.76	150.20	106.00	124.70
	Oct-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan-22	8.20	2.80	5.30	6.57	6.14	6.39	117.00	86.70	98.10	13.36	10.97	11.91	264.90	163.90	206.88
	Feb-22	9.90	2.30	6.37	6.75	6.33	6.51	165.00	63.70	118.37	13.93	10.23	11.91	277.30	138.30	88.08
	Mar-22	14.80	7.80	11.75	7.01	5.92	6.63	151.60	94.40	123.53	11.24	9.01	9.94	307.80	240.60	263.26
	Apr-22	16.40	10.30	13.35	7.84	7.83	7.84	166.80	111.50	139.15	9.94	8.91	9.43	216.00	203.00	209.50
	May-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jun-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SF-6	Jul-21	21.50	20.30	20.80	6.97	6.64	6.84	246.80	99.30	167.00	7.25	6.61	6.97	79.30	18.50	39.25
	Aug-21	22.20	19.70	20.81	6.99	6.60	6.83	305.60	23.40	151.86	9.44	4.55	7.87	95.20	-10.10	38.20
	Sep-21	20.50	16.40	18.87	6.91	6.72	6.83	239.70	77.60	169.47	17.91	8.10	9.89	82.00	6.00	27.43
	Oct-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan-22	9.10	3.20	6.63	6.52	6.09	6.35	64.80	47.20	56.00	12.53	9.47	10.98	154.70	129.20	143.33
	Feb-22	11.60	5.60	8.40	6.76	6.33	6.50	150.20	47.40	78.10	12.16	9.04	10.81	263.00	164.00	57.98
	Mar-22	14.40	10.50	11.66	9.89	9.04	9.26	76.90	40.30	51.26	6.73	6.20	6.47	203.40	169.30	198.20
	Apr-22	16.50	10.70		9.74	7.95	8.85	90.90	53.10	72.00	7.51	7.24	7.38	150.10	60.00	105.05
	May-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jun-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spring D10W	Jul-21	22.20	20.30	21.18	7.01	6.68	6.90	101.70	79.20	93.38	7.30	6.60	7.07	110.80	62.70	86.20
	Aug-21	22.60	19.40	21.19	7.12	6.56	6.91	114.20	98.40	104.59	8.71	4.34	7.08	148.70	56.20	103.79
	Sep-21	20.50	15.40	18.61	7.12	6.81	6.95	128.00	61.30	99.44	11.93	5.10	9.62	181.40	49.30	136.26
	Oct-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan-22	10.70	5.10	7.90	6.58	6.47	6.53	48.80	48.80	48.80	11.43	8.23	9.83	168.70	163.20	165.95
	Feb-22	9.70	4.80	7.90	6.78	6.60	6.70	67.90	60.30	64.37	11.01	9.47	10.19	243.60	178.50	185.35
	Mar-22	16.30	12.10	13.56	6.76	6.20	6.48	53.90	35.60	42.96	9.70	7.91	8.95	217.40	192.20	200.14
	Apr-22	15.40	12.40	13.90	7.43	7.12	7.28	61.30	38.40	49.85	9.15	8.31	8.73	135.10	116.00	125.55
	May-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jun-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figures 4.1.2 through Figure 4.1.10 illustrate the routine water quality parameters measured at the surface water flumes, SF-1 through SF-6, and Spring D10W.

Figures 4.1.2 through Figure 4.1.5 represent the water quality parameters for NT-11 which is located at the western edge of the planned waste footprint. The SF-3 flume is the most upstream monitoring location along NT-11 and the SF-1 flume is the most downstream location. Figure 4.1.2 shows the temperature for the Period of Performance (POP) from July 1, 2021, through June 30, 2022. All the flumes recorded similar temperature measurements. Figure 4.1.3 shows the measured pH from the water at the flumes. The pH showed very little variability during the summer with a larger variability during the late winter into spring. Conductivity in NT-11 is seen in Figure 4.1.4. The conductivity increased as the water goes downstream especially in the late summer with similar results in the spring. Dissolved oxygen showed a large variability in summer with muted variability in spring as is graphed in Figure 4.1.5.

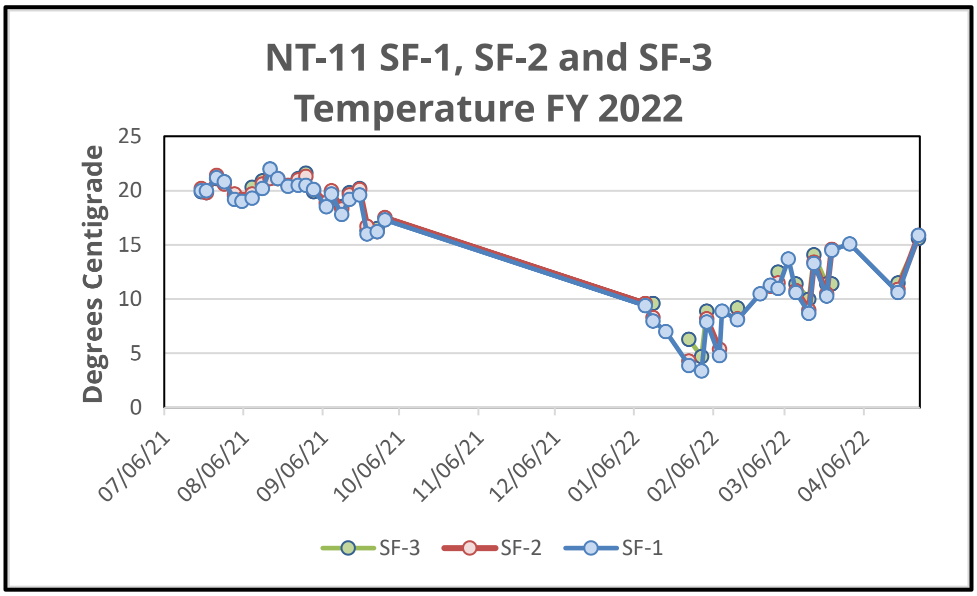

Figure 4.1.2: NT-11: SF-1, SF-2 and SF-3 Temperature

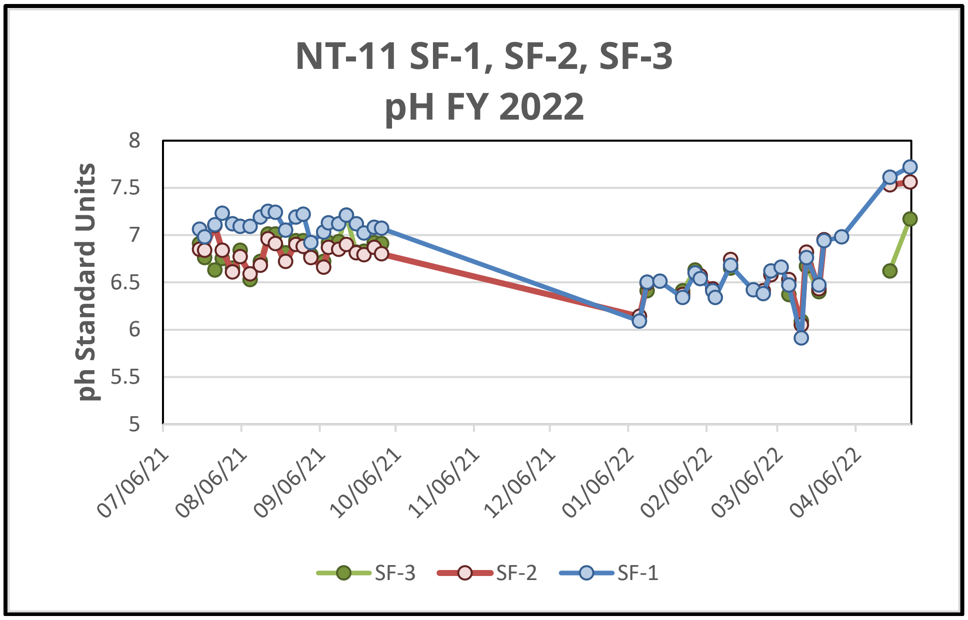

Figure 4.1.3: NT-11: SF-1, SF-2 and SF-3 pH

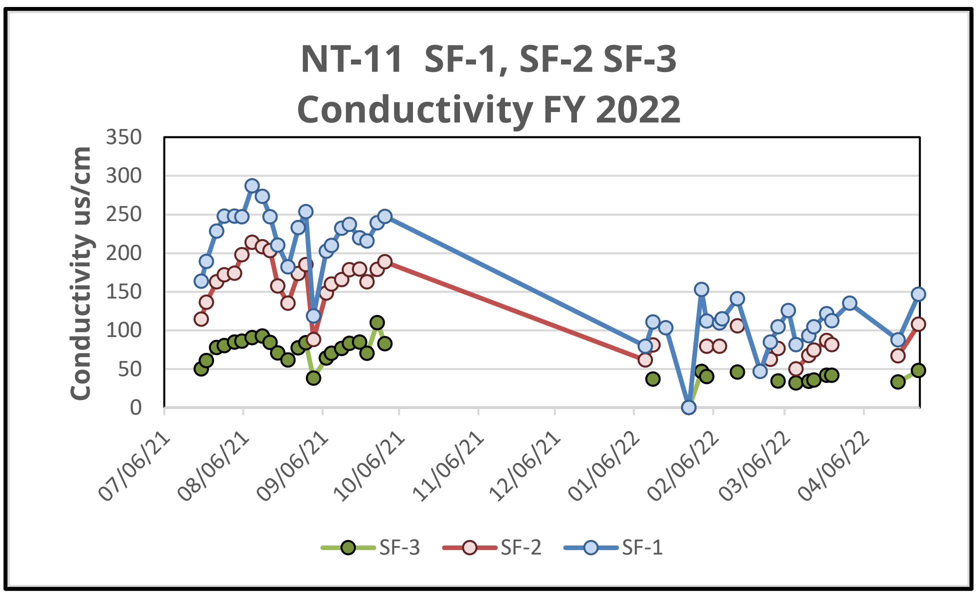

Figure 4.1.4: NT-11: SF-1, SF-2 and SF-3 Conductivity

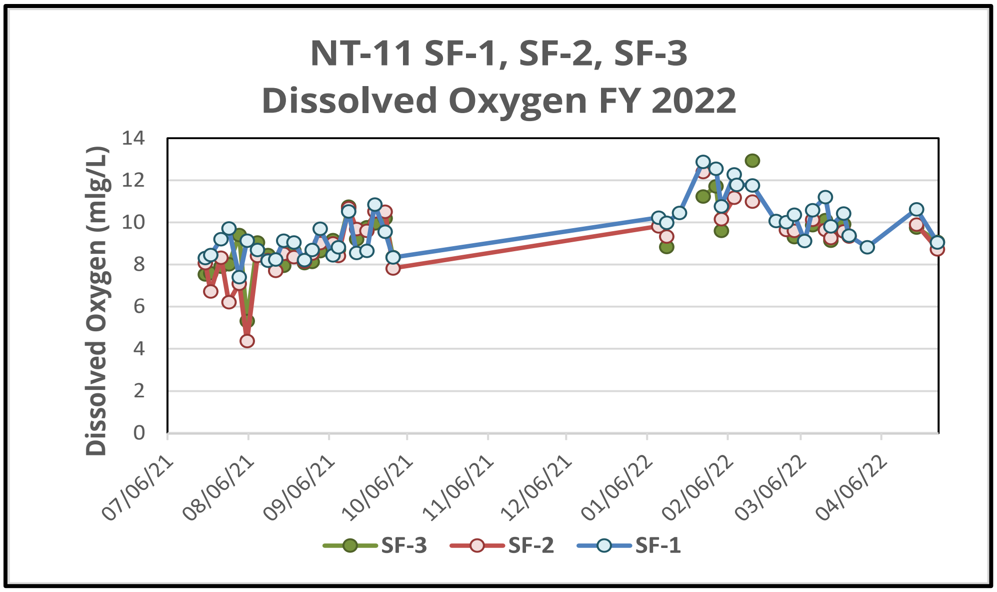

Figure 4.1.5: NT-11: SF-1, SF-2 and SF-3 Dissolved Oxygen (mg/L)

Tributary D-10W (Figures 4.1.6 to Figure 4.1.9) has a spring at its head (Spring D10W) and is monitored by two flumes, SF-4 and SF-5, with SF-5 being the most downstream station. The graphs for this tributary show similar trends as those in NT-11. The dissolved oxygen graph (Figure 4.1.9) has one elevated reading from September with a measurement of 16.6 mg/L measured at SF-4. This may be an artifact of the measuring instrument.

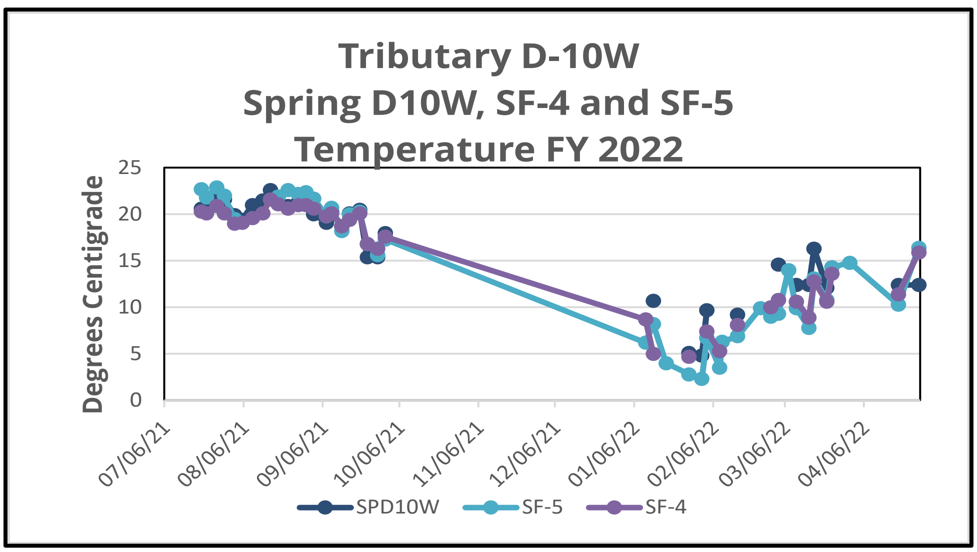

Figure 4.1.6: Tributary D-10W: Spring D10W, SF-4 and SF-5 Temperature

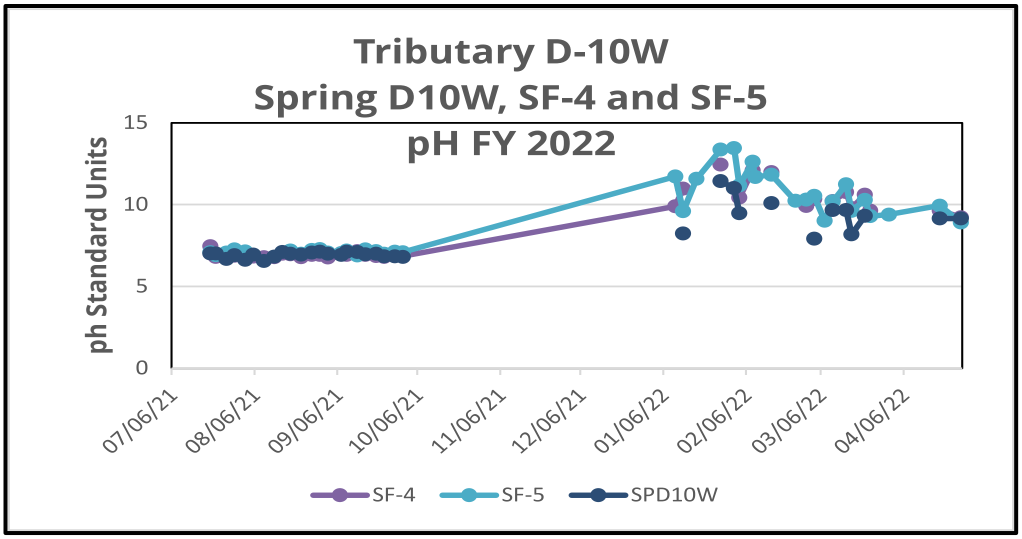

Figure 4.1.7: Tributary D-10W: Spring D10W, SF-4 and SF-5 pH

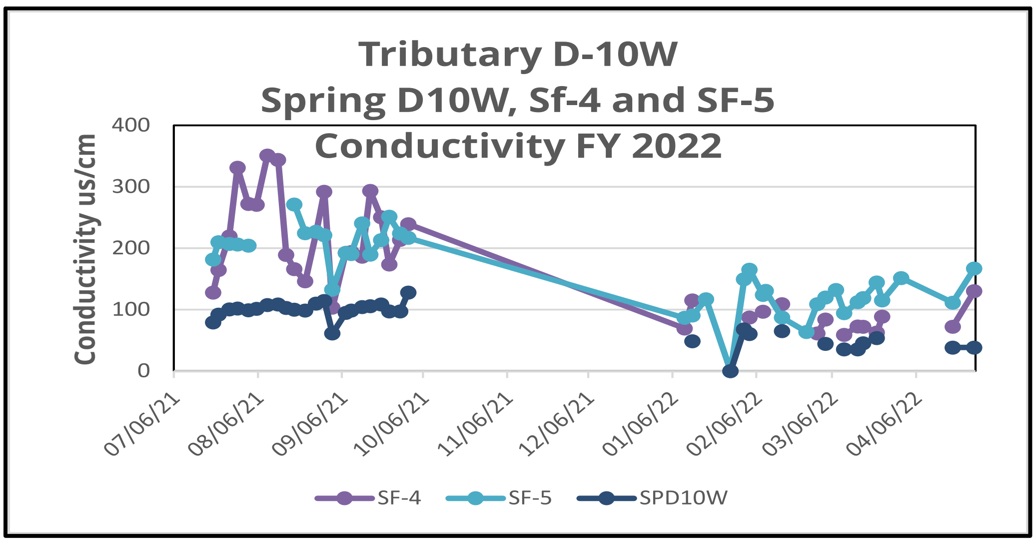

Figure 4.1.8: Tributary D-10W: Spring D10W, SF-4 and SF-5 Conductivity

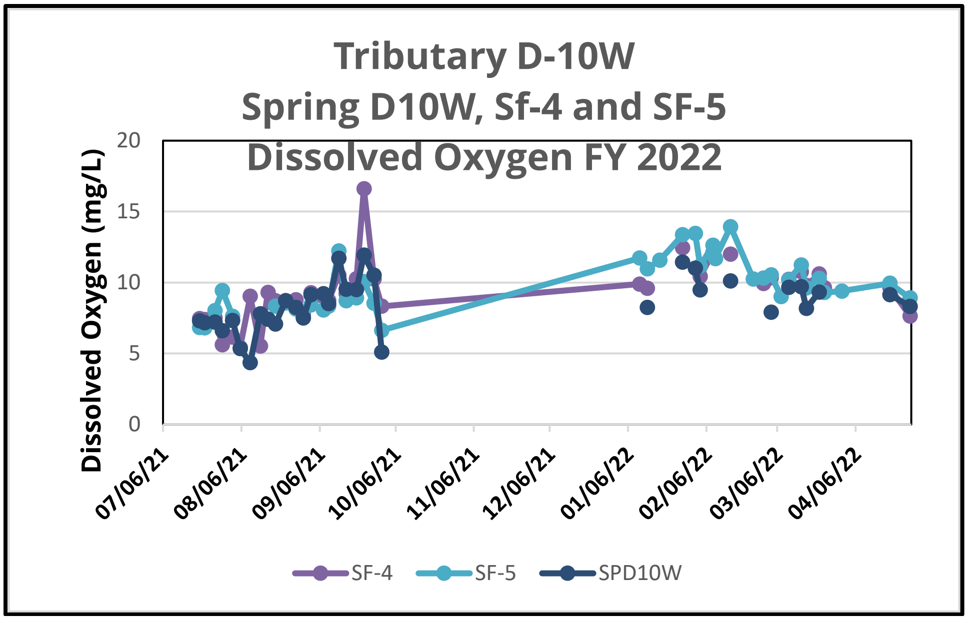

Figure 4.1.9: Tributary D-10W: Spring D10W, SF-4 and SF-5 Dissolved Oxygen

Figure 4.1.10: SF-6 Parameters

4.1.8 Conclusions

After a second year of monitoring surface water flowing from the EMDF site to Bear Creek (Planed for FY23), TDEC DoR-OR anticipates releasing a background set of water quality parameter levels that will be available in the future to DOE and EPA.

4.1.9 Recommendations

TDEC DoR-OR recommends semi-annual sampling and spot sampling based on field observations to perform continuity checks and help determine the health of the tributaries that discharge into Bear Creek. TDEC DoR-OR recommends sampling of surface water at the flumes and the spring into the Bear Creek tributaries. Sampling at these locations should be conducted on a regular basis where the requested analytical suite is radionuclides, metals, and volatile organic compounds.

4.1.10 References

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4.2 EMWMF

4.2.1 Background

The Environmental Management Waste Management Facility (EMWMF) was constructed for the disposal of low-level radioactive waste (LLRW) and hazardous waste (HW) generated by remedial activities on the ORR and is operated under the authority of CERCLA. While the facility holds no permit from any state agency, it is required to comply with applicable or relevant and appropriate requirements contained in the CERCLA ROD (DOE, 1999) and substantive requirements of DOE directives developed to address responsibilities delegated to the agency by the Atomic Energy Act of 1954.

Currently, the only authorized discharge from EMWMF is contaminated storm water and non-contaminated storm water.[1] As designated by the EMWMF SAP/QAP, contact water is derived from precipitation that falls into an active cell, contacts waste, and collects in the disposal cells above the leachate collection system. The contact water is routinely pumped from the disposal cells to holding ponds and tanks where it is then sampled. Based on DOE's analytical results, it is either treated or released to a storm water sedimentation basin which discharges to a tributary of Bear Creek (BCK) known as North Tributary 5 (NT-5).

For radionuclides, the limits on releases from the holding ponds/tanks to the sedimentation basin are currently based on requirements contained in DOE Order 5400.5 which restricts the release of liquid wastes containing radionuclides to an average concentration equivalent to a dose of 100 mrem/year. The limit for discharges from the sedimentation basin to NT-5 and then into Bear Creek are based on TDEC 0400-20-11-.16(2) [10 CFR 61.41] which restricts public dose to radioactive material released from LLRW disposal facilities to 25 millirem (mrem) to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public. EPA provides an approximate Effective Dose Equivalent (EDE) of 10 mrem/year to assist with applying this requirement to radiation risk assessment at CERCLA sites.[2]

For contaminants other than radionuclides, the point of compliance is the discharge point for the contact water ponds, where Tennessee Ambient Water Quality Criteria (TN AWQC) for Fish and Wildlife serves as the limits for the releases of contact water to the sediment basin and via the basin to Bear Creek through NT-5. Bear Creek's designated uses currently include recreational criteria, which have not been incorporated into the EMWMF release criteria contained in the EMWMF Sampling and Analysis Plan/Quality Assurance Project Plan (SAP/QAPP).

4.2.2 Problem Statements

Contaminated materials from CERCLA remediation activities are buried and continue to be buried in the EMWMF. Over time, associated mobile contaminants have the potential to migrate from the facility into the environment and be carried by ground and surface waters to off-site locations in concentrations above agreed upon limits (i.e. Tennessee AWQC and federal/state groundwater MCLs).

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[1] "Contaminated storm water" is designated "contact water" in the EMWMF Sampling and Analysis Plan (SAP)/Quality Assurance Program Plan (QAPP) [DOE/OR/01-2734&D1/R1]. The EMWMF ROD does not include legal definitions for landfill wastewater, such as those in 40 CFR 445.2(b),(f); 40 CFR 260.10; and TDEC 0400-11-01-.01(2). This omission should be corrected when the ROD is revised in accordance with the EPA Administrator's December 31, 2020, dispute resolution decision.

[2] See Footnote 11 in *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination*, OSWER No. 9200.4-18, August 22, 1997. Available at https://semspub.epa.gov/work/HQ/176331.pdf.

4.2.3 Goals

The EMWMF Monitoring Project goals were to accomplish the following:

- Provide assurance through the independent monitoring efforts and evaluation of DOE's data that operations at EMWMF are protective of public health and the environment and meet the remedial actions objectives specified in the EMWMF ROD.
- Verify that DOE contaminated storm water discharges (i.e., storm water that has contacted waste and has not been treated) into Bear Creek comply with the established limits and operational requirements.
- Provide independent data on discharges from the underdrain and evaluate its effectiveness in lowering the groundwater table beneath the landfill.
- Ensure EMWMF is meeting its operational requirements by reviewing weekly discharge data collected by EMWMF.
- Collect confirmation samples to ensure best practices are used to limit contaminant migration.
- Conduct site visits to monitor ongoing activities at EMWMF.

4.2.4 Scope

The scope of the EMWMF Monitoring Project included the following tasks.

- Monitoring of surface water parameters at EMWMF-2 (underdrain discharge), EMWMF-3 (Sediment Basin v-weir discharge), NT5@BCK, and at the flume BCK 11.54A (SW-003) twice weekly using a properly calibrated YSI-Professional Plus water quality instrument or equivalent (Figure 4.2.1).
- Quarterly review of DOE's measured discharge data from EMWMF-2 and EMWMF-3 to ensure EMWMF is meeting its operational requirements.
- Sampling of the contact water ponds/tanks, weirs, EMWMF-2, and EMWMF-3 to confirm that DOE is meeting their discharge limit goals.

Figure 4.2.1 depicts monitoring and sampling locations, and Table 4.2.1 presents the sample rationale at the EMWMF.

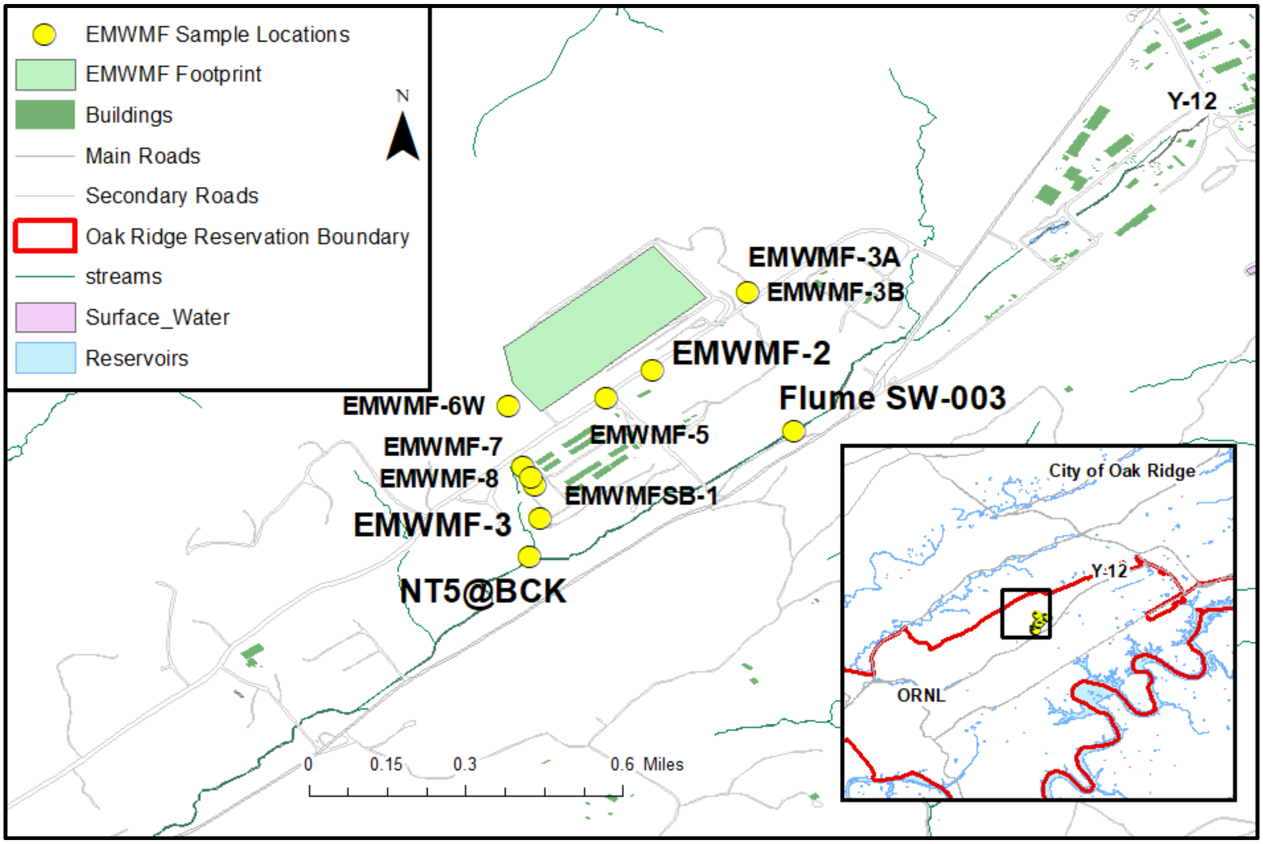

Figure 4.2.1: EMWMF Sampling and Monitoring Locations

Table 4.2.1: EMWMF Sampling and Monitoring Locations

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.
Sediment Basin Effluents (VWEIR)	EMWMF-3, EMWMF-7, EMWMF-8	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	EMWMF-3A	Annually as funds permit	Up-stream surface water location to be used as a baseline.
Cell 6 Drainage	EMWMF-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

4.2.5 Methods, Materials, Metrics

- Twice per week, the project lead performed independent monitoring (check sites and/or measure water quality parameters) at the sites shown on Figure 4.2.1.
- Water samples (from the locations identified in Table 4.2.1 and Figure 4.2.1) were to be collected in accordance with the Project Plan. Due to unexpected deviations described below, no samples were collected, rather, an independent evaluation of DOE-collected data was performed.
- TDEC DoR-OR evaluated the performance of the landfill liner by monitoring parameters collected from the underdrain (EMWMF-2).

The results of water quality parameter monitoring were entered into an Excel database for interpretation. DOE laboratory data was extracted from OREIS, placed into another EXCEL database for interpretation and comparison.

4.2.6 Deviations from the Plan

Two deviations occurred during FY2022.

- For certain weeks during this period of performance, some of the twice weekly surface water quality parameter monitoring events were not completed.
- During this POP none of the TDEC DoR-OR proposed analytical laboratory samples were collected.

EMWMF-2 and EMWMF-3 Water Quality Parameters (*TDEC DoR-OR*)

TDEC DoR-OR staff monitored water quality parameters at EMWMF-2, EMWMF-3, BCK 11.54A (SW-003), and NT5@BCK during FY2022. The parameters measured included pH in standard units, specific conductivity (Cond) in microSiemens per centimeter [mS/cm], water temperature (T) [degrees Centigrade], dissolved oxygen (DO) [milligrams per Liter, mg/L], and oxidation-reduction potential (ORP). Monthly water quality parameter statistics (i.e. maximums, minimums, and averages) for the four (4) stations are presented in Table 4.2.3.

Table 4.2.3 Monthly Parameter Statistics EMWMF-2, EMWMF-3, BCK 11.54A and NT5@BCK Fiscal Year 2022

EMWMF-3 (VWEIR) Fiscal Year 2022

	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Max T	29.2	29.3	25.9				6.4	15.9	17	20.8	24.5	31.5	
Min T	26.7	25.1	20.5				2.5	4.3	8.7	13.8	22.8	25.1	
Ave T	28.0	27.26	23.61				4.90	8.88	13.94	16.40	23.65	28.2	
Max pH	7.56	7.46	7.54				6.47	6.84	7.01	9.41	9.73	10.1	
Min pH	6.55	6.6	6.9				5.64	5.76	5.8	5.8	9.64	8.4	
Ave pH	6.92	7.05	7.23				6.16	6.39	6.38	8.34	9.685	9.4	
Max Cond	278.4	340	361.3				355.9	584.9	311.7	188	210.6	252.9	
Min Cond	184.9	177.6	212.7				239.7	145.8	217.6	217.6	195.2	168.8	
Ave Cond	234.84	262.60	262.81				294.18	346.13	247.97	162.60	202.9	201.1	
Max DO	6.23	8.28	9.98				15.71	15.78	11.82	11.82	7.83	6.9	
Min DO	3.90	6.38	7.16				11.72	5.05	9.1	9.09	6.72	4.4	
Ave DO	5.68	7.11	8.29				13.38	11.64	10.23	9.85	7.275	5.8	
Max ORP	149.80	173.20	232.10				267.5	294.9	293.6	207.60	177.9	218.0	
Min ORP	84.80	133.50	118.60				154.5	187.9	154.3	198.90	157.7	133.9	
Ave ORP	148.79	153.07	197.83				234.53	242.95	233.86	202.83	167.8	184.2	**Total Readings**
n	8	9	9	0	0	0	6	8	9	3	2	9	63

EMWMF-2 (Underdrain) Fiscal Year 2022

	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Max T	18.4	18.7	18.9				18.9	16	16.9	16.9	17.7	18.3	
Min T	17.8	18.2	18.4				18.4	14.5	15.1	15.9	14.1	17.6	
Ave T	18.14	18.47	18.67				18.67	15.64	16.16	16.40	15.90	17.9	
Max pH	6.66	6.75	6.72				6.72	6.4	6.66	6.91	6.7	6.7	
Min pH	6.04	6.03	6.42				6.42	5.76	5.71	5.9	6.42	6.4	
Ave pH	6.39	6.46	6.60				6.60	6.12	6.17	6.46	6.56	6.5	
Max Cond	549.4	550.7	634				634	584.9	584.4	565.3	559.6	543.0	
Min Cond	515.8	513.6	229.9				229.9	544.5	552.3	526.1	538.7	517.7	
Ave Cond	526.98	530.97	525.17				525.17	563.09	566.02	547.73	549.15	528.2	
Max DO	4.1	10.55	9.21				9.21	7.74	5.54	5.31	4.66	2.8	
Min DO	2.2	2.27	2.76				2.76	3.66	3.21	4.73	3.01	1.9	
Ave DO	2.71	4.36	4.80				4.80	5.50	4.31	5.03	3.84	2.5	
Max ORP	146.1	172.6	172.6				172.6	299.1	275.7	211.80	176.40	231.1	
Min ORP	108.9	116.2	116.2				116.2	232.2	193.3	179.10	161.70	115.5	
Ave ORP	127.89	146.69	146.69				146.69	254.28	240.43	198.40	169.05	169.7	**Total Readings**
n	8	9	9	0	0	0	6	8	9	3	2	9	63

BCK 11.54A (SW-003) Fiscal Year 2022

	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Max T	22.7	23	21.8				8.7	11.6	16	15.1	18.1	23.1	
Min T	19.9	19.9	16.9				6.3	3.9	7.5	10.6	17.3	18.5	
Ave T	21.15	21.05	19.52				7.68	8.4125	12.41	12.93	17.70	20.53	
Max pH	7.05	7.1	7.15				6.49	6.73	6.82	7.96	8.58	8.17	
Min pH	6.77	6.87	6.86				6.04	6.23	6.16	6.78	8.01	7.99	
Ave pH	6.91	7.00	7.00				6.29	6.47	6.51	7.42	8.30	8.07	
Max Cond	654	732	727				484.9	559.5	491.5	471.4	562.1	664	
Min Cond	326.9	550.1	550.1				338.7	139	323	164	520.5	461.9	
Ave Cond	576.82	654.89	620.67				413.16	413.45	440.64	321.27	541.30	598.88	
Max DO	8.19	8.62	12.4				13.15	13.47	11.81	10.7	9.5	8.36	
Min DO	6.77	4.51	4.51				10.32	9.98	9.22	9.6	7.81	6.85	
Ave DO	7.51	7.60	9.64				11.32	11.63	10.44	10.03	8.66	7.39	
Max ORP	153.2	127.6	127.6				299.9	300.7	312.4	216.1	211.0	246.2	
Min ORP	103.2	72	87.5				161.3	246.2	216.7	197.4	181.3	169.7	
Ave ORP	128.08	96.96	114.13				255.48	267.40	258.09	209.70	196.2	200.4	**Total Readings**
n	6	8	9	0	0	0	6	8	9	3	2	9	60

NT5@BCK Fiscal Year 2022

	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	
Max T	25.6	25.7	24.4				7.3	12	16	16.2	20.5	25.9	
Min T	22.7	22.4	18.35				2.6	2.8	6.6	10.0	18.6	21.2	
Ave T	23.55	23.38	21.09				5.70	7.17	12.13	13.10	19.55	23.13	
Max pH	7.14	7.19	7.19				6.57	6.81	6.93	8	8.23	8.14	
Min pH	6.94	7.01	6.69				6.21	6.26	6.31	7.79	8.08	7.95	
Ave pH	7.04	7.11	7.11				6.41	6.54	6.63	7.90	8.155	8.03	
Max Cond	399	394.1	715				472.9	463.5	447.5	391.7	376.9	352	
Min Cond	266.3	235	235				403	271.5	294.5	298.8	330	203.3	
Ave Cond	320.7	332.23	373.09				422.68	379.46	380.98	345.25	353.45	289.18	
Max DO	7.48	8.06	8.06				13.53	13.15	12.33	11	7.99	6.52	
Min DO	4.92	5.11	7.30				10.44	10.51	8.58	9.33	6.43	5.47	
Ave DO	6.235	6.97	6.97				11.64	12.10	10.51	10.17	7.21	5.89	
Max ORP	146.6	121.8	145.8				309	262.3	302	215	222.2	218.8	
Min ORP	98.4	70.3	98.1				214.5	170	226.6	214.3	181.3	184.2	
Ave ORP	124.3	95.05	116.211				248.76	231.01	250.92	214.65	201.8	199.9	**Total Readings**
n	6	8	9	0	0	0	5	7	9	3	2	9	58

Max	Maximum	T	Temperature Centigrade	DO	Dissolved Oxygen mg/L
Min	Minimum	pH	Acidity Standard Units	ORP	Oxygen Reduction Potential
Ave	Average	Cond	Conductivity micro seiverts	n	Total number of readings

Figures 4.2.5 through Figure 4.2.8 illustrate the routine water quality parameters measured at EMWMF-2 and EMWMF-3 for FY2022. As shown in Figure 4.2.5, the temperature and conductivity of EMWMF-2 were muted and delayed in relation to EMWMF-3 parameters.

Figure 4.2.6 depicts the temperature and pH at EMWMF-2 and EMWMF-3. During the months with little rain and elevated temperatures the pH measured from the sediment basin effluent (EMWMF-3) began to increase rapidly. The pH increase seemed to be related to filamentous algae building up within the sediment basin during episodes of high temperatures and low water levels. DOE in the Phased Construction Completion Report (PCCR) for 2015 mentioned this as a cause for some exceedances of the AWQC for increased pH and lower dissolved oxygen.

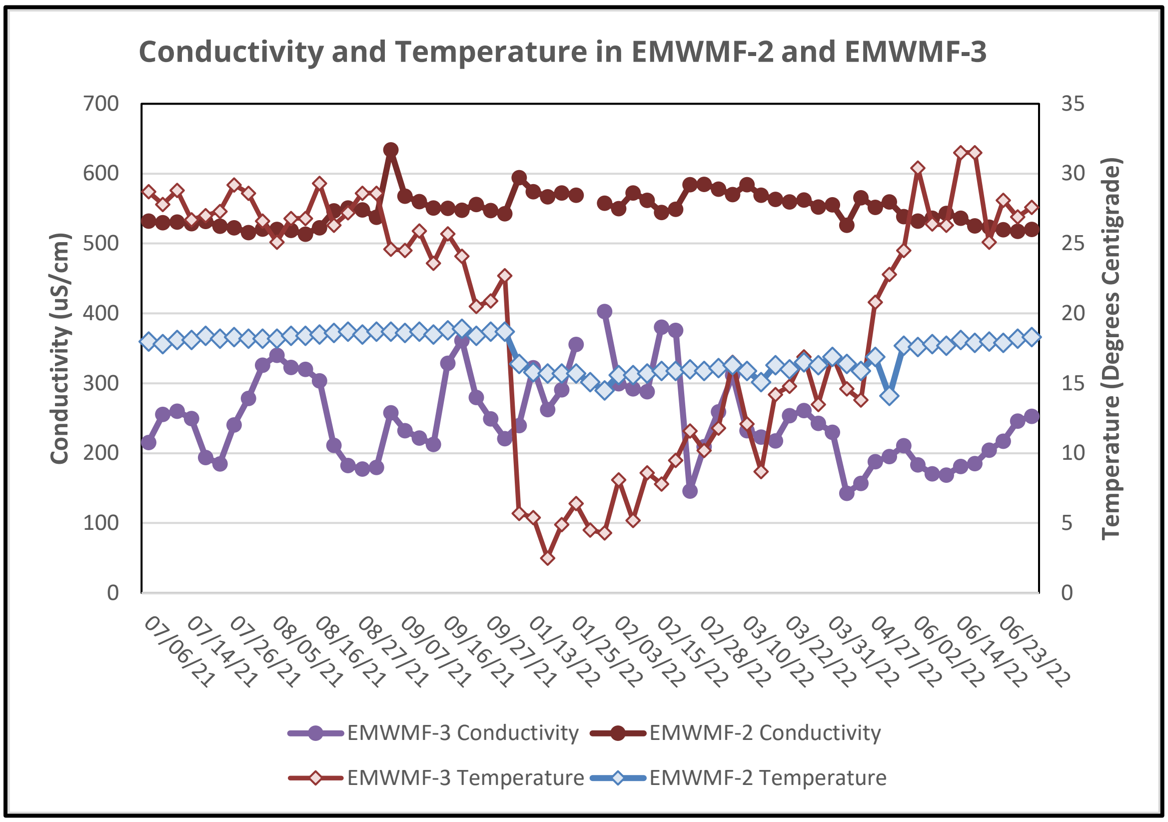

Figure 4.2.5: FY2022 Conductivity and Temperature in EMWMF-2 and EMWMF-3

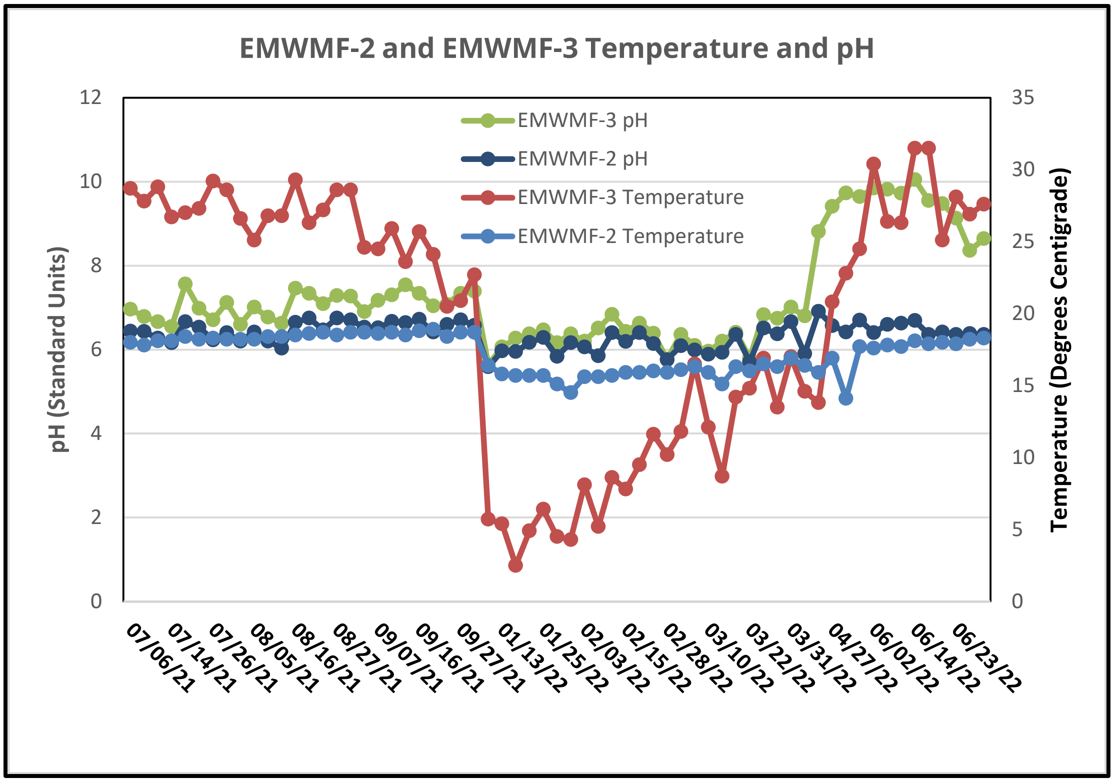

Figure 4.2.6: FY2022 Temperature and pH in EMWMF-2 and EMWMF-3

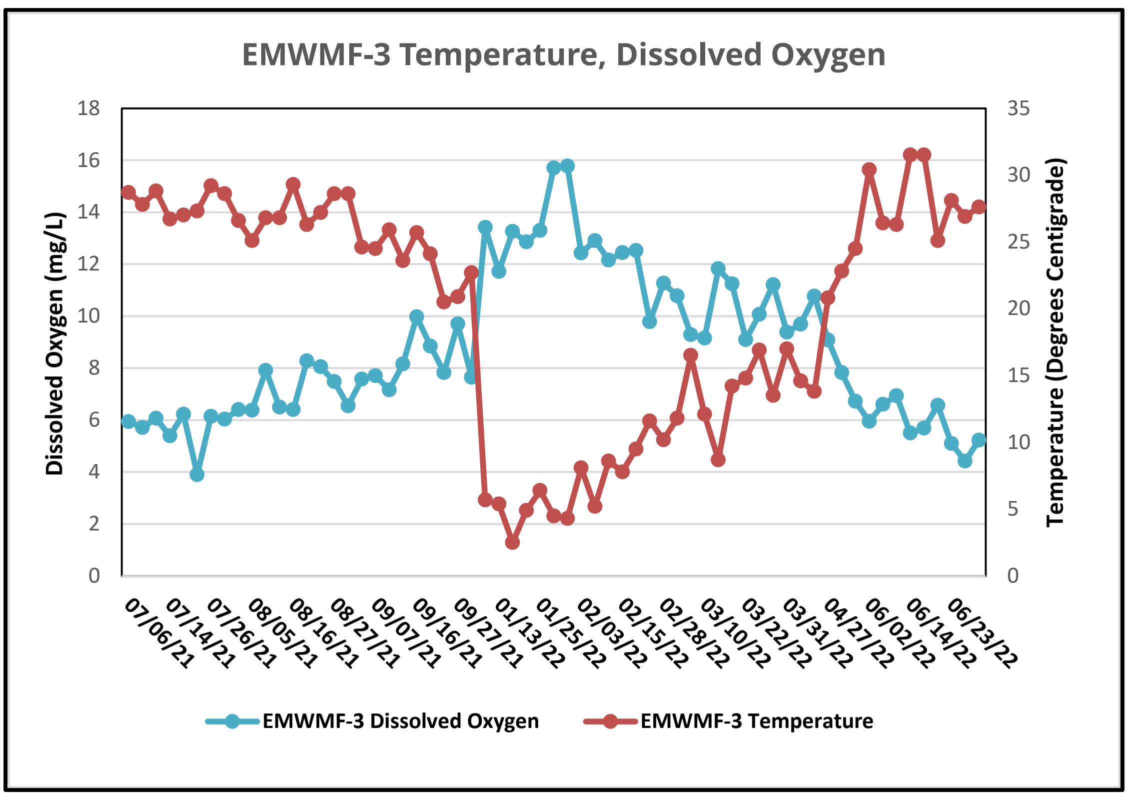

Figure 4.2.7: FY2022 Temperature and Dissolved Oxygen in EMWMF-3

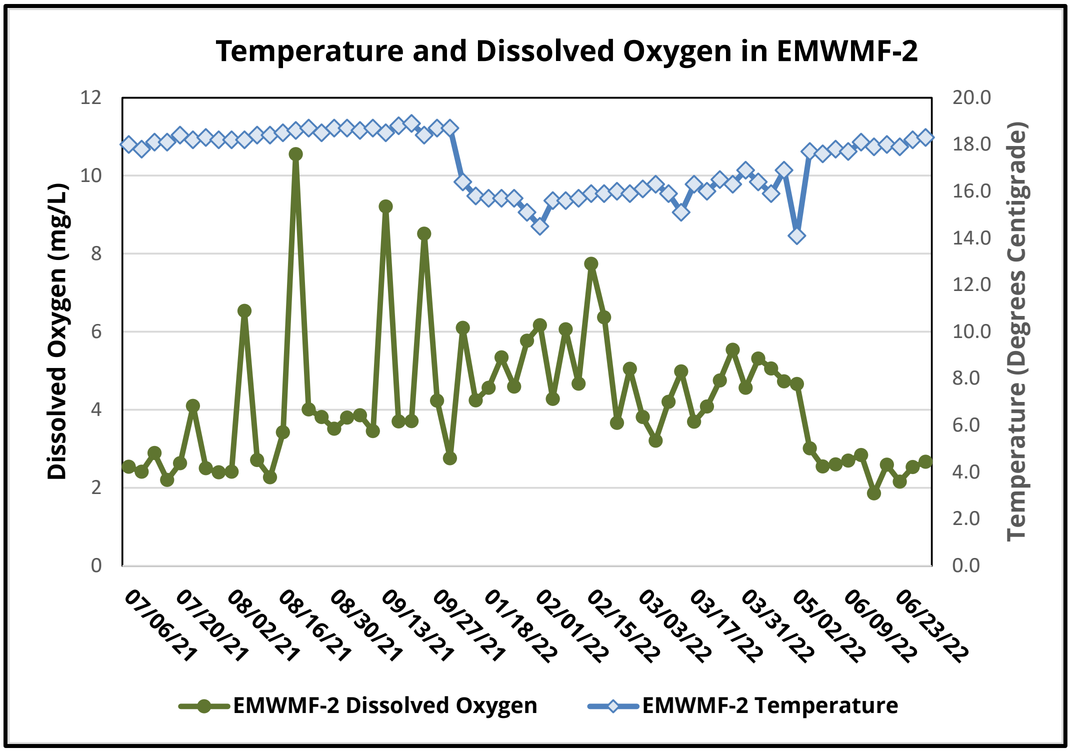

Figure 4.2.8: FY2022 Temperature and Dissolved Oxygen in EMWMF-2

BCK 11.54A (SW-003) and NT5 at Bear Creek Water Quality Parameters (*TDEC DoR-OR*)
Two surface water sites were added during the FY2022; BCK 11.54A (SW-003) which is comprised of a flume in Bear Creek upstream of the EMWMF, and NT5 at Bear Creek, which is downstream of the EMWMF. These two (2) sites were chosen to monitor the water quality of Bear Creek above and below the EMWMF landfill. As with most creek sites the temperature, pH, dissolved oxygen, and conductivity can and will vary during the day as rain cools the water, and the temperature parameters can change with the sunlight or lack thereof. Figures 4.2.9 through 4.2.12 show the water quality parameters that were measured during the POP at BCK 11.54A (SW-003) and NT5 at Bear Creek. These parameters do not indicate any concern for contaminants leaving the site at this time.

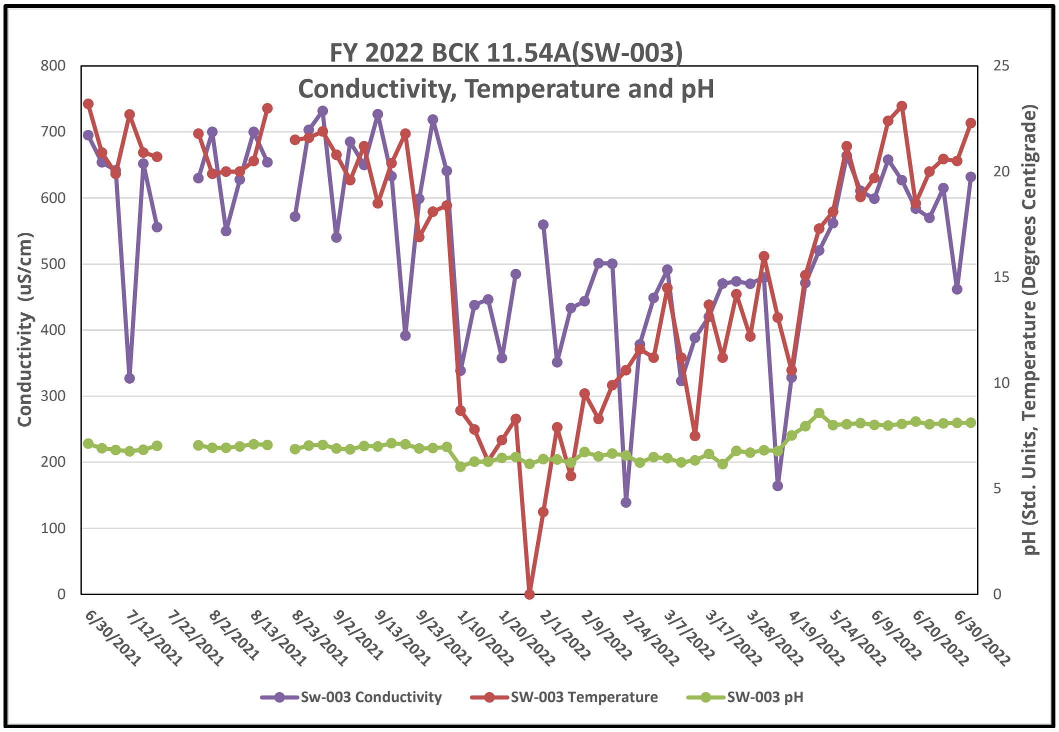

Figure 4.2.9: FY2022 Conductivity, Temperature and pH in BCK 11.54A (SW-003)

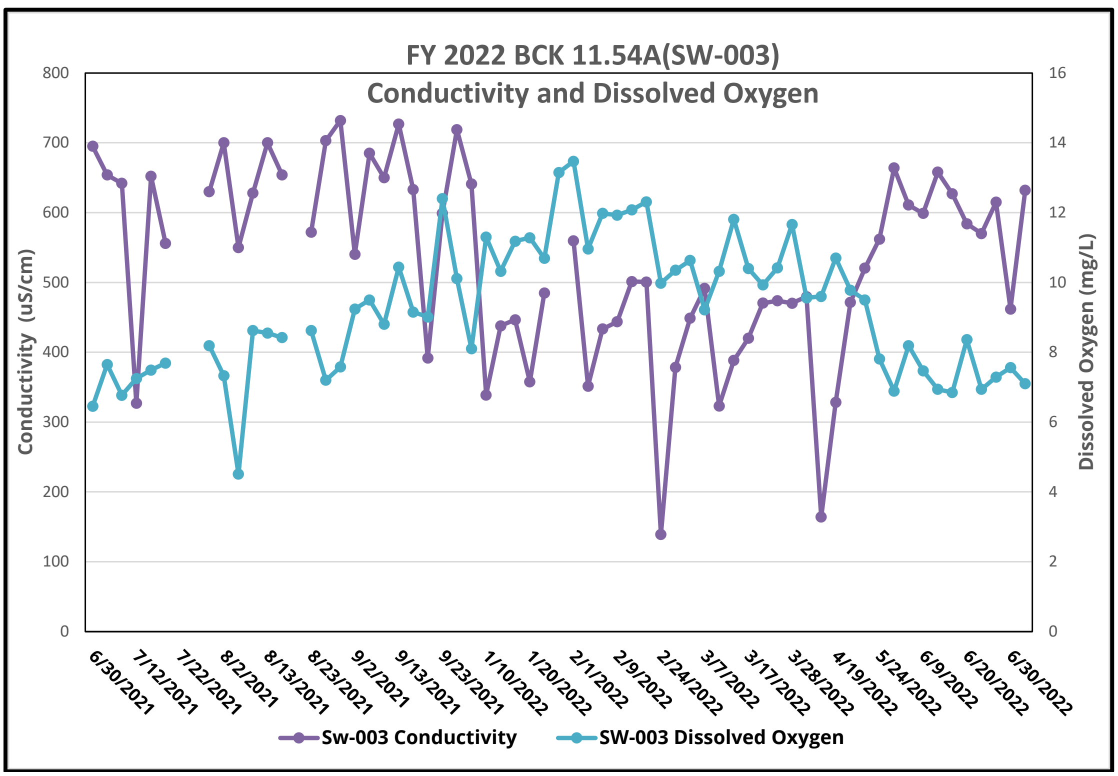

Figure 4.2.10: FY2022 Conductivity and Dissolved Oxygen in BCK 11.54A (SW-003)

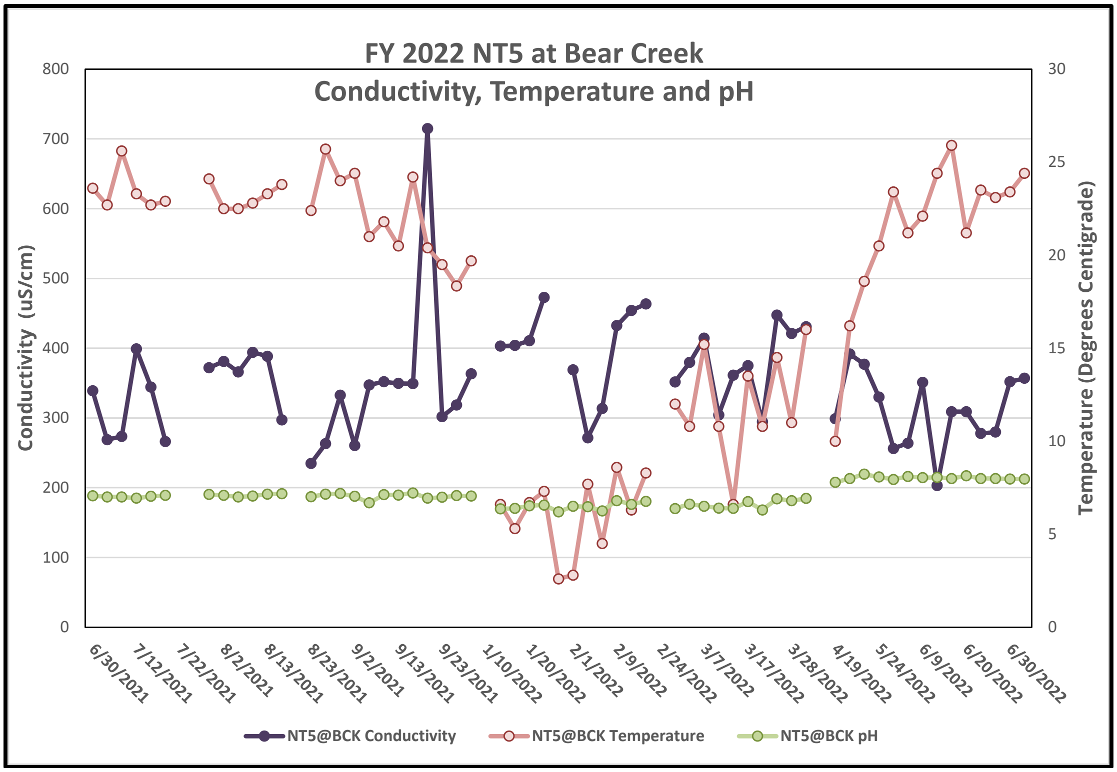

Figure 4.2.11: FY2022 Conductivity, Temperature and pH in NT5 at Bear Creek

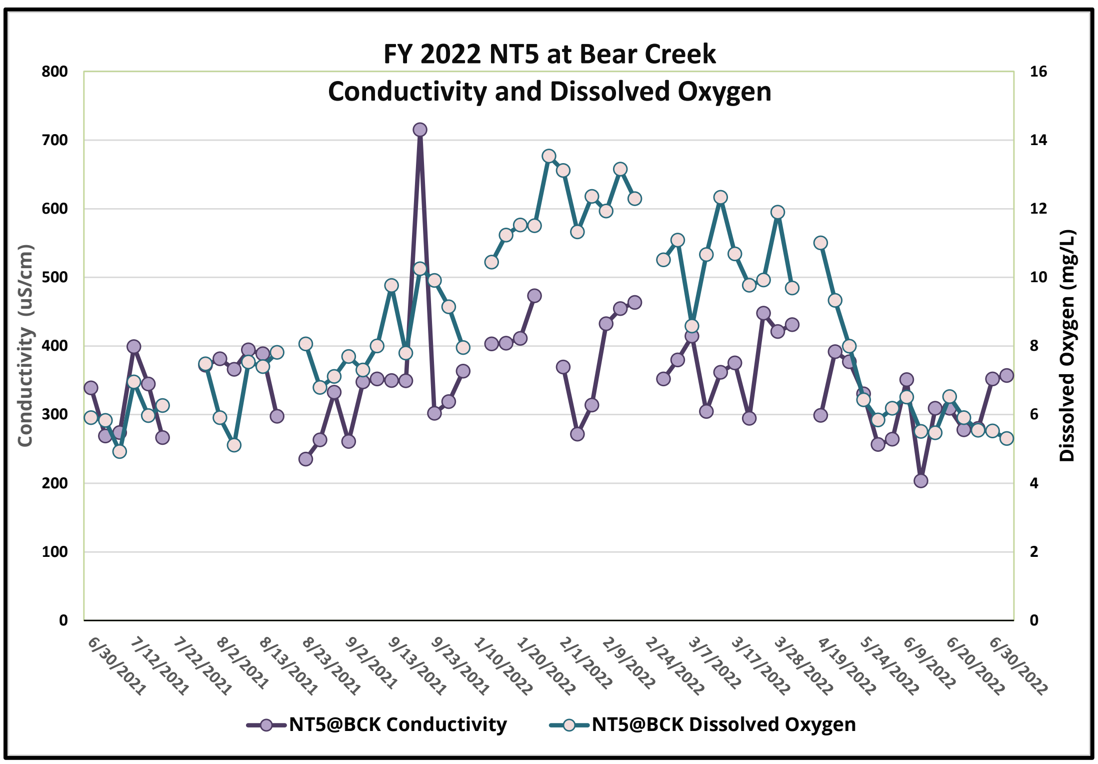

Figure 4.2.12: FY2022 Conductivity and Dissolved Oxygen in NT5 at Bear Creek

4.2.8 Conclusions

Surface water parameters collected during the POP for FY22 will be included in the TDEC water quality database and will be used in conjunction with other parameters collected in these surface water locations moving forward. No identified areas of concern were noted during this POP. 4.2.9

Recommendations

TDEC DoR-OR should continue to sample EMWMF-2 and EMWMF-3.

4.2.10 References

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40 CFR 141, Subpart G. 2004. *Title 40 of the Code of Federal Regulations, Chapter 1, Subchapter D, Part 141 National Primary Drinking Water Regulations, Subpart G Maximum Contaminant Levels and Maximum Residual Disinfectant Levels.* https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-141/subpart-G?toc=1 ; https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations#Radionuclides

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5.0 RADIOLOGICAL MONITORING

5.1 Assessment of FFA Projects for Radiological Contaminants

5.1.1 Background

The Department of Energy's Oak Ridge Reservation began operations in the early 1940s during the Manhattan Project primarily on three sites consisting of ETTP (formally K-25), ORNL (formally X-10), and Y-12. During early operations releases of radioactive and other hazardous substances were common within and from the facilities resulting in these contaminants being released into the environment in the form of gases, liquids, and solids. These releases now fall under CERCLA. Under CERCLA much of the low-level radioactive and other hazardous wastes generated from environmental remediation are being disposed of in the Environmental Management Waste Management Facility (EMWMF) near Y-12 in Bear Creek Valley.

This project collected soil samples from EMWMF waste cell drainage ditches for evaluation of potential contaminant buildup of radiological isotopes. Specifically, eight composite samples were collected for uranium isotopes and technetium-99 (Tc-99) analysis from areas where water tends to puddle or have slow drainage, and one background sample was collected up gradient from the north drainage ditch, see Figure 5.1.1. The north egress road drains into the EMWMF north drainage ditch due to water coming from rainfall and dust suppression trucks. The south EMWMF waste cells drainage ditch was also evaluated for contaminant buildup. An additional sample might be taken from the sedimentation basin under the EMWMF monitoring project.

Figure 5.1.1. Map of EMWMF north and south waste cells drainage ditch locations.

5.1.2 Problem Statements

Legacy releases of CERCLA radioactive wastes and other hazardous wastes are still present on the PRR in standing facilities, soils, and sediments. Demolition of facilities, as well as disturbance of un-remediated soils and sediments, may cause releases on or off the ORR. Trucks exiting from the EMWMF waste cells dumping areas that don't exceed surface contamination levels may be causing a build-up of uranium isotopes and Tc-99 on the road surface that eventually washes into the waste cell ditches by rainfall and dust suppression water. Buildup may occur as trucks leaving the waste cell dumping areas with permissible levels of contamination in a non-radiological area drop contaminated dust or debris, and the contaminants build-up over time due to hundreds or thousands of exiting trucks.

5.1.3 Goals

The EMWMF Waste Cells Drainage Ditch Soil Sampling Project Environmental Monitoring Plan aimed to accomplish the following goals: co-sample with DOE to assess if contaminant buildup of uranium isotopes and Tc-99 in the EMWMF waste cells ditches is occurring, measure contaminants of concern at multiple points in the north and south ditch and collect a background sample upgradient from the ditch near the "Y" adjacent to groundwater monitoring well GW-918.

5.1.4 Scope

The sampling event was completed to determine if contaminants were present or absent in sediments within the EMWMF waste cell ditches. Depending on the results of this project, future sampling may be needed if contaminants are found in elevated activities. The initial sampling event consisted of nine composite samples, eight from the ditch and one background sample. During the sampling event it was determined that a tenth sample should be collected in the overbank deposits of North Tributary-5 (NT-5) just north of the Haul Road.

5.1.5 Methods, Materials, Metrics

DOE contractors collected the samples under the direction of TDEC DoR-OR and EMWMF personnel. The sampling was conducted May 2, 2022. The soil sampling for composite samples was conducted using UCOR/RSI/EPA soil sampling Standard Operating Procedures (SOPS). Soil/sediment aliquots were collected using stainless steel scoops. The aliquots were mixed in cleaned stainless steel bowls. After collection and mixing, the soil was placed by RSI technicians into containers for DOE and TDEC DoR-OR for analysis.

The specific sampling locations are described below and illustrated on Figure 5.1.2 through Figure 5.1.12. The sample locations are identified on the subsequent figures as sample location 1 through 10. In general, the corresponding sample identification for each location is EMW-PROAD## where "##" is number of the sample location (e.g., 1 through 5 and 7 through 9). There are two exceptions, composite sediment samples collected in NT-5. The identifications for sample location number 6 and number 9 are EMW-NT05PRN and EMW-NT05PRS, respectively.

1. EMW-PROAD01 (Sample Location 1): A composite background soil sample located uphill and north of the waste cells drainage ditch near the "Y" by GW-918 (Figure 5.1.3) was collected from an approximate 100-foot section of the ditch. The northern waste cell drainage ditch divide between east and west is at the approximate location of GW-918.
2. EMW-PROAD02 (Sample Location 2): A composite soil sample was collected from the northeast end of the north waste cells ditch and east of the GW-918 drainage ditch divide. About 436 feet of the ditch was sampled. The drainage ditch at this location was reconstructed after EMWMF began operations.
3. EMW-PROAD03 (Sample Location 3): A composite soil sample was collected from the north waste cells ditch at the GW-918 drainage ditch divide. An approximate 200-foot section, 100 feet on either side of the divide, of the ditch was sampled.
4. EMW-PROAD04 (Sample Location 4): A composite soil sample was collected from the north waste cells ditch, west of the GW-918 drainage ditch divide to where the drainage ditch turns toward the sediment basin. About 330 feet of the ditch was sampled.
5. EMW-PROAD05 (Sample Location 5): A composite soil sample was collected from the north waste cells ditch, west of the GW-918 drainage ditch divide to where the drainage ditch turns toward the sediment basin. About 330 feet of the ditch was sampled.

6. EMW-NT05PRN (Sample Location 6): A composite sediment sample was collected from the northwest end of the north waste cells ditch, west to where the drainage ditch turns into NT-5 south toward the sediment basin. About 330 feet of stream sediment was sampled.
7. EMW-PROAD07 (Sample Location 7): A composite soil sample was collected from the southwest end of the south waste cells ditch. About 400 feet of the ditch was sampled.
8. EMW-PROAD08 (Sample Location 8): A composite soil sample was collected from the midpoint of the south waste cells ditch. About 400 feet of the ditch was sampled.
9. EMW-PROAD09 (Sample Location 9): A composite soil sample was collected from the southeast end of the south waste cells ditch. About 400 feet of the ditch was sampled.
10. EMW-NT05PRS (Sample Location 10): A composite sediment sample was collected from just upstream of the Haul Road floodplain on NT-5, about 200 feet of NT-5 over bank was sampled.

Figure 5.1.2: Composite sample locations

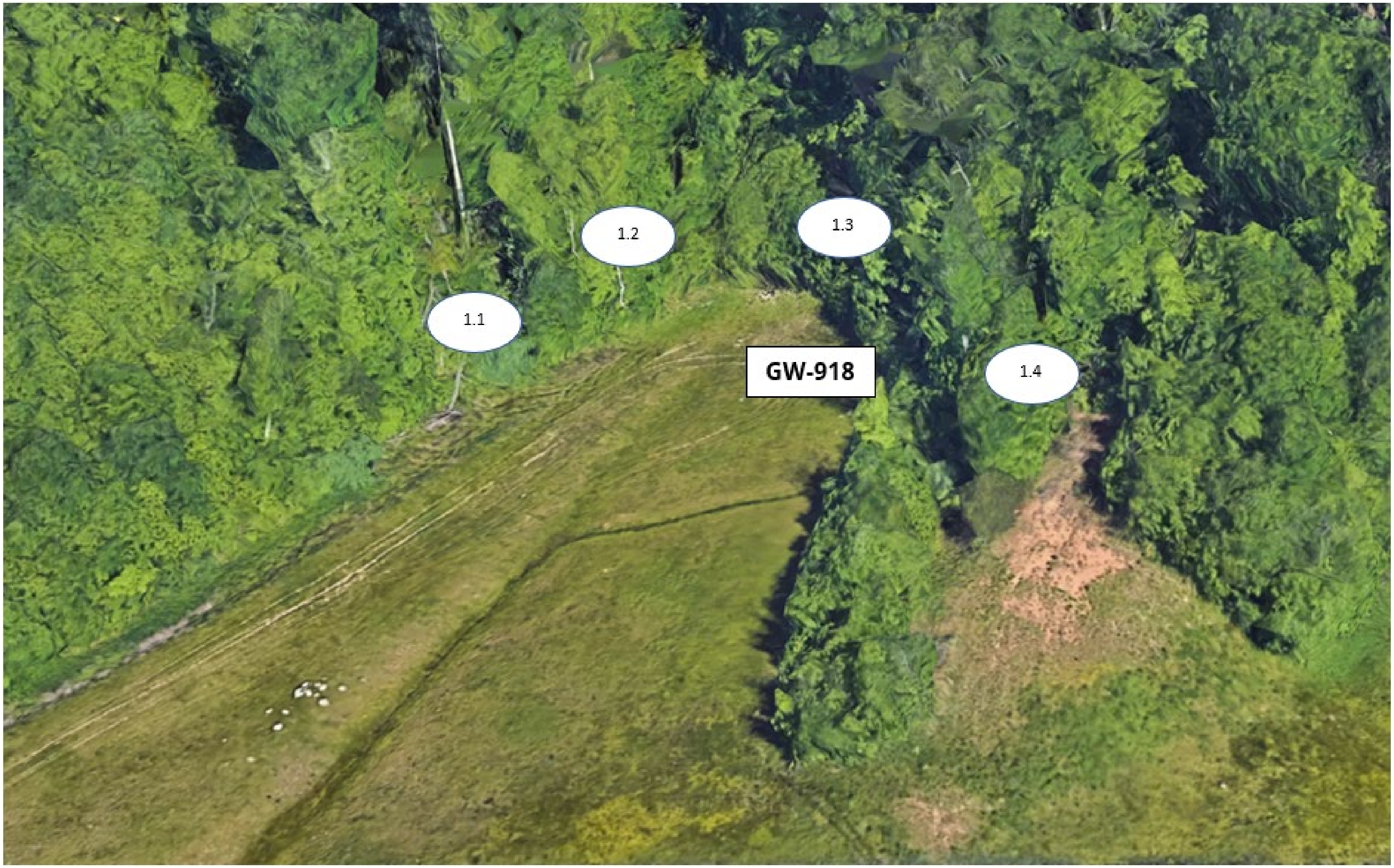

Figure 5.1.3: Sample Location 1. The four locations were composited and identified as sample EMW-PROAD01

Figure 5.1.4 Sample Location 2. The four locations were composited and identified as sample EMW-PROAD04.

Figure 5.1.5: Sample Location 3. The four locations were composited and identified as sample EMW-PROAD03.

Figure 5.1.6: Sample Location 4. The four locations were composited and identified as sample EMW-PROAD04.

Figure 5.1.7: Sample Location 5. The four locations were composited and identified as sample EMW-PROAD05.

Figure 5.1.8: Sample Location 6. The four locations were composited and identified as sample EMW-NT05PRN.

Figure 5.1.9: Sample Location 7. The four locations were composited and identified as sample EMW-PROAD07.

Figure 5.1.10: Sample Location 8. The four locations were composited and identified as sample EMW-PROAD08.

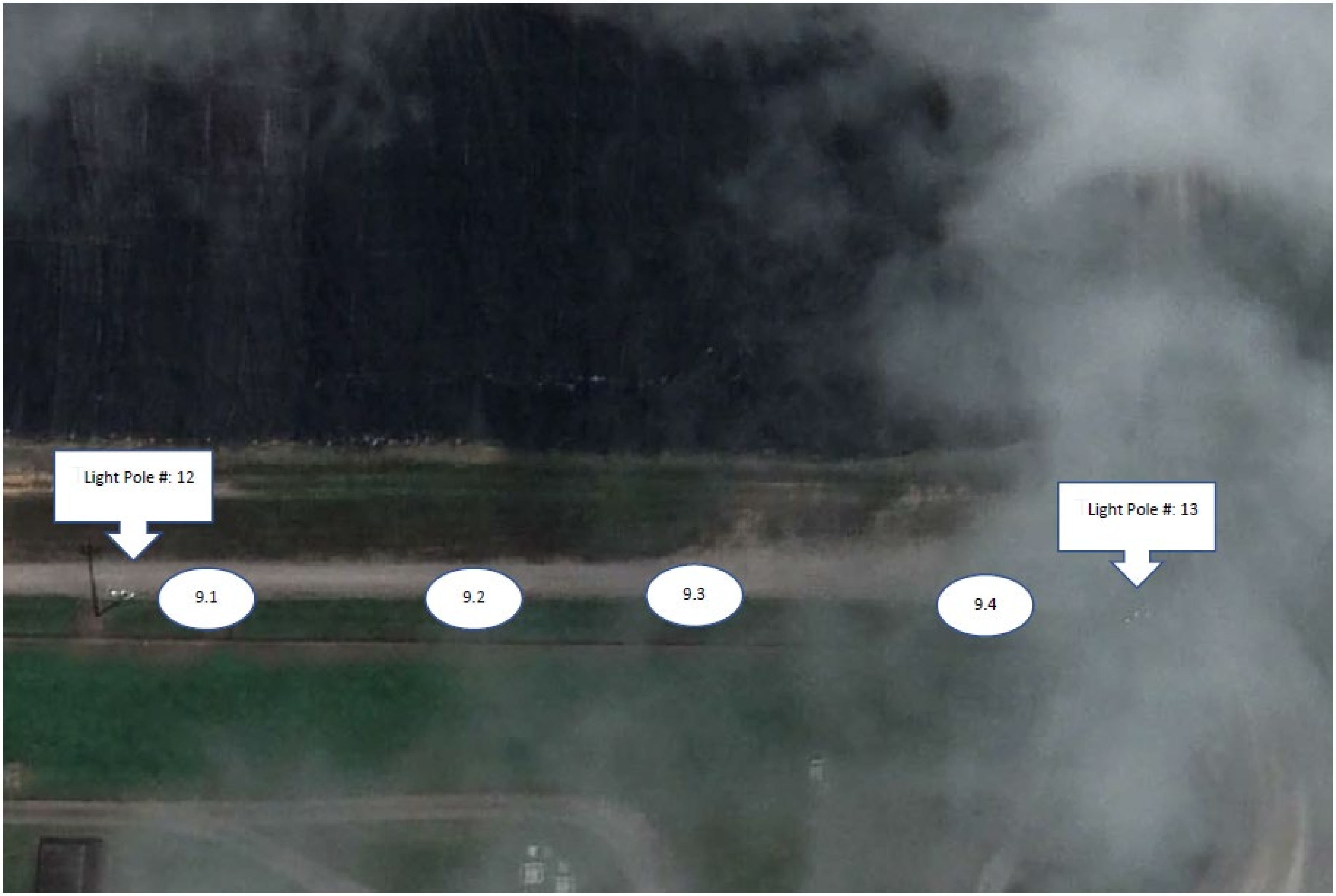

Figure 5.1.11: Sample Location 9. The four locations were composited and identified as sample EMW-PROAD09.

Figure 5.1.12: Sample Location 10. The four locations were composited and identified as sample EMW-NT05PRS.

5.1.6 Deviations from the Plan

Execution of the plan was completed without any changes in procedures. Soil collection locations were moved slightly to ensure enough sample volume was able to be collected for analysis. One additional sample location was added, sample location 10, and consisted of a composite sediment sample from four spots north of the Haul Road in the overbank deposits of NT-5.

5.1.7 Results and Analysis

The samples were collected May 2, 2022, and were received by the TDH lab on May 11, 2022. The samples were sent to Eberline Services, a subcontractor of TDH lab, and analyzed for isotopic uranium using method U-02-RC and Tc-99 using method TCS01.

Figure 5.1.13 captures how the analytes varied in concentration over the length of the ditch, especially EMW-PROAD01 through EMW-PROAD05. In general, uranium (U)-234 (U-234) and U-238 activity were similar between all samples. The activities were generally low and were comparable to background values. The highest U-234 and U-238 activities were at the background sample. Sampling of NT-5 north and south (EMW-NT05PRN and EMW-NT05PRS) showed U-234 was greater at the southern sampling location compared to the northern sampling station. Uranium-235 consistently had lower measured activities than U-234 or U-238. Tc-99 varied throughout the sampling locations as well. It was not unexpected that the activities measured for Tc-99 did not match or follow those of the uranium isotopes.

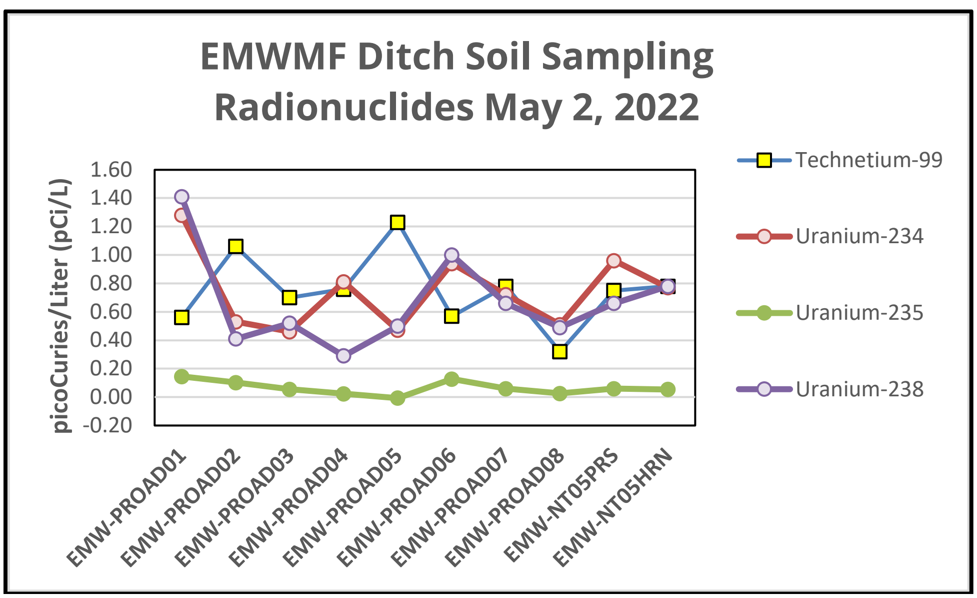

Figure 5.1.13: EMWMF Ditch Soil Sampling Radionuclides May 2, 2022

Table 5.1.1 contains the results from the soil and sediment collection and analysis. The results are all in picoCuries per gram (pCi/g). The measured activity concentrations were not elevated and were comparable to the background levels for radionuclides for the Dismal Gap and Nolichucky formations in Anderson County as seen in Table 5.1.2. The Dismal Gap formation is similar to the Maryville and Pumpkin Valley Shale formations on the EMWMF site. The Nolichucky shale underlies a majority of the EMWMF footprint. The background levels expressed in pCi/g are from Table 7.1a. in the Final report on the Background Soil Characterization Project at the Oak Ridge Reservation, Oak Ridge, Tennessee, DOE/OR/01-1175/V1 (DOE, 1993). According to DOE, "Most of the uranium isotope series occurs naturally in soils but the ORR soils were expected to have additional inputs from local sources, such as Oak Ridge: K-25 Site and Oak Ridge: Y-12 Plant operations. However, the analytical results of background soils do not confirm such speculation" (DOE ,1993).

The Tc-99 results were, with the exception of one value, below the median value (Table 5.1.2). The U-234 and U-238 results from the EMW-PROAD01 were just above the median but below the maximum from either formation, Dismal Gap or Nolichucky. U-235 had three samples above the median for the Nolichucky formation and for the Dismal Gap formation, and at or below the maximum values.

Table 5.1.1: Analytical Results picoCuries per gram (pCi/g)

Sample Location	Uranium-234	U234 CSU	Uranium-235	U235 CSU	Uranium-238	U238 CSU	Technetium-99	TC99 CSU
EMW-PROAD01	1.28	0.26	0.145	0.095	1.41	0.28	0.56	0.76
EMW-PROAD02	0.53	0.18	0.102	0.088	0.41	0.15	1.06	0.76
EMW-PROAD03	0.46	0.15	0.055	0.060	0.52	0.16	0.7	0.77
EMW-PROAD04	0.81	0.22	0.024	0.047	0.29	0.12	0.76	0.78
EMW-PROAD05	0.47	0.15	-0.007	0.029	0.5	0.16	1.23	0.78
EMW-PROAD06	0.94	0.21	0.127	0.081	1	0.22	0.57	0.71
EMW-PROAD07	0.72	0.20	0.059	0.061	0.66	0.19	0.78	0.76
EMW-PROAD08	0.51	0.18	0.026	0.049	0.49	0.17	0.32	0.76
EMW-NT05PRS	0.96	0.23	0.06	0.066	0.66	0.19	0.75	0.73
EMW-NT05PRN	0.77	0.20	0.054	0.055	0.78	0.20	0.78	0.72

CSU - Combined Sample Uncertainty

Table 5.1.2: Soil Background Activity in pCi/g

	Formation	Minimum	Median	Maximum
Technetium-99	**Nolichucky**	2.79	1.1	2.79
	Dismal Gap	-	-	-
Uranium-234	**Nolichucky**	1.04	1.28	1.51
	Dismal Gap	0.61	0.937	1.40
Uranium-235	**Nolichucky**	0.043	0.0713	0.096
	Dismal Gap	0.0569	0.0792	0.12
Uranium-238	**Nolichucky**	1.04	1.28	1.51
	Dismal Gap	0.75	1.02	1.7

From Table 7.1a DOE/OR/01-1175/V1

Technetium-99 - one detect out of six samples

5.1.8 Conclusions

After evaluating the radiochemical results and reviewing background values, there does not seem to be any build-up of uranium isotopes or Tc-99 that might have deposited in the ditches. There also is no indication of any uranium isotopes or technetium in the sediments of NT-5 located above the Haul Road.

5.1.9 Recommendations

TDEC DoR-OR recommends that a representative number of samples be collected in three years to determine if the low activity of uranium isotopes and Tc-99 remains below or at the background numbers.

5.1.10 References

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

DOE. 1993. Final report on the Background Soil Characterization Project at the Oak Ridge Reservation, Oak Ridge, Tennessee. US Department of Energy, Oak Ridge, TN. DOE/OR/01-1175/V1, DOE/OR/01-1175/V2, DOE/OR/01-1175/V3.
https://public.ornl.gov/orifc/historicalreports.cfm
https://public.ornl.gov/orifc/other/Bgsoil1175v1.pdf
https://public.ornl.gov/orifc/other/Bgsoil1175v2.pdf
https://public.ornl.gov/orifc/other/Bgsoil1175v3.pdf

5.2 Haul Road Surveys

5.2.1 Background

TDEC DoR-OR staff perform surveys of the Haul Road and associated waste transportation routes on the ORR. The Haul Road was constructed and reserved for trucks transporting CERCLA radioactive and hazardous waste resulting from remedial activities on the ORR to the Environmental Management Waste Management Facility (EMWMF) for disposal.

To assess potential impacts from wastes that may have fallen from the trucks in transit, TDEC DoR-OR personnel perform intermittent walk-over inspections of different segments of the Haul Road and associated access roads. Anomalous items noted along the roads are scanned for radiation, logged, and marked with contractor's ribbon. Subsequently, their descriptions and locations are submitted to the DOE for disposition.

5.2.2 Problem Statements

ORNL 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 radioactive and 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 to the 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. The State of Tennessee and EPA oversee and periodically audit associated activities related to this work, including the review of the decisions authorizing waste lots for disposal.

5.2.3 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 EMWMF. In particular, the objectives include:

- Locate waste that may have been dropped from waste-hauling trucks in transit.
- Assess the radiological conditions of the Haul Road and associated access roads.
- 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.
- Verify DOE surveys of the Haul Road and associated access roads.

5.2.4 Scope

The scope of this project is limited to locating, surveying, and reporting to DOE any ORR derived waste materials that may have been lost from waste-hauling trucks on the EMWMF Haul Road and any associated access roads that are currently being used to transport waste.

5.2.5 Methods, Materials, Metrics

The nine-mile-long Haul Road is surveyed in segments, typically consisting of one to two miles per survey event.

Since ETTP is no longer transporting waste to the EMWMF, this main section will only be surveyed if the hauling of waste is resumed. A baseline survey of the approximately 1.1-mile extension of the Haul Road from EMWMF to Y-12 will be performed when the appropriate approvals are obtained from DOE and its contractors. The Reeves Road access to the Haul Road connects ORNL with the main stem of the Haul Road. This road will be surveyed should it be used for hauling waste. For safety and by agreement with DOE and its contractors, TDEC DoR-OR staff coordinate with Haul Road site personnel when TDEC DoR-OR 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 available, 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 survey the road with DOE approval, but the basic requirements remain the same.

When TDEC DoR-OR 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 cm^2 removable beta, 1000 dpm/100 cm^2 total beta, 20 dpm/100 cm^2 removable alpha, and/or 100 dpm/100 cm^2 total alpha are noted for further investigation.

Anomalous items from potential waste lots 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. Anomalous items may have the potential of containing non-radiological hazardous constituents. A survey form is completed for each walkover and is retained at the TDEC 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 on the road, they are included in subsequent reports until removed or staff members are advised by DOE that the item(s) have been determined to be free of radioactive and hazardous constituents.

Six (6) surveys were proposed to be completed over a 12-month period, dependent on waste hauling activity on the Haul Road or any of the access roads.

5.2.6 Deviations from the Plan

No baseline survey of the approximately 1.1-mile extension of the Haul Road from EMWMF to Y-12 was performed this fiscal year.

5.2.7 Results and Analysis

Seven survey events were conducted in FY2022 from November 2021 to May 2022. Five (5) surveys were conducted on the Haul Road after communication with DOE indicated waste transportation had temporarily resumed on the road. The survey event on November 10, 2021, identified five (5) anomalous items located between the transportation hub and the firing range exit. The surveyed items potentially originated from hazardous and/or radioactive waste being transported to the EMWMF. The items identified included a bolt, aluminum metal, slag, and a metal cap. The total alpha and total beta contamination levels were below the threshold for further investigation. Each item was flagged, and the location and description were logged and reported to DOE for disposition. No surface contamination readings exceeded the free release limits. All ambient high energy gamma readings were within the normal background range for the area. No other survey events of the Haul Road had findings.

Two (2) surveys were conducted in April 2022 on Reeves Road, after communication with DOE indicated the road was temporarily used for hauling waste. Together the surveys encompassed the entire length of Reeves Road, from the ORNL truck scale to its intersection with the Haul Road. No anomalous items were identified. No surface contamination readings exceeded the free release limits. All ambient high energy gamma readings were within the normal background range for the area.

5.2.8 Conclusions

The periodic surveys of the roads used to haul waste to the EMWMF indicated waste items are intermittently lost from trucks transporting waste.

5.2.9 Recommendations

More decommissioning, demolition and remedial activities are planned on the ORR in the coming years. The wastes from these projects will be transported on the Haul Road. Based on previous findings, it is recommended that the TDEC DoR-OR Haul Road Surveys project be continued for detection and disposition of anomalous items that may have fallen from waste trucks.

5.2.10 References

DOE. 2005. *Remedial Action Work Plan for the Operation of the East Tennessee Technology Park to Environmental Management Waste Management Facility (ETTP-EMWMF) Haul Road on the Oak Ridge Reservation*. US Department of Energy. Oak Ridge, Tennessee. DOE/OR/01-2220&D1.

TDEC. 2019. *Standard Operating Procedure T-532 Operation and Use of a Ludlum Model 2224 (-1) and 43-93 Probe (Dual Phosphorous Meter)*. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office (TDEC DoR-OR). Oak Ridge, Tennessee.

TDEC. 2019*. Standard Operating Procedure T-540 Operation and Use of a Ludlum Model 2221 and 44-10 Probe (NaI Meter).* Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office (TDEC DoR-OR). Oak Ridge, Tennessee.

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

5.3 Real Time Measurement of Gamma Radiation

5.3.1 Background

The K-25 Gaseous Diffusion Plant, now called the ETTP, began operations in World War II as part of the Manhattan Project. Its original mission was to produce uranium, enriched in the uranium-235 isotope (U-235) for use in the first atomic weapons and later to fuel commercial and government-owned reactors. The K-25 plant was permanently shut down in 1987. As a consequence of operational practices and accidental releases, many of the facilities scheduled for decontamination and decommissioning (D&D) at ETTP are contaminated to some degree. 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 Plant was also constructed during World War II to enrich uranium in the U-235 isotope, in this case, by the electromagnetic-separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, to conduct lithium-mercury enrichment operations, to manufacture components for nuclear weapons, to dismantle nuclear weapons, and to store enriched uranium.

Construction of what is now the ORNL, originally known as the X-10 Plant, began in 1943. ORNL focused on reactor research and the production of plutonium and other activation and fission products. These products were chemically extracted from uranium, irradiated in ORNL's graphite reactor and later used at other ORNL and Hanford reactors. During early operations, leaks and spills were common in the facilities and associated radioactive materials were released from operations as gaseous, liquid, and solid effluents, with little or no treatment (ORAU, 2003).

The EMWMF was constructed in Bear Creek Valley near Y-12 for the disposal of low-level radioactive waste and hazardous waste generated by remedial activities from all three sites (i.e. ETTP, ORNL, Y-12) on the ORR.

TDEC DoR-OR has deployed gamma-radiation exposure monitors, equipped with microprocessor-controlled data loggers, on the ORR since 1996. The Real Time Measurement of Gamma Radiation project tracks gamma exposure rates over time. Exposure rate monitors measure and record gamma radiation levels at predetermined intervals (e.g. minutes) over extended periods of time (months) and provide an exposure rate profile that can be correlated with activities and or changing conditions.

5.3.2 Problem Statements

The Real Time Monitoring of Gamma Radiation project on the Oak Ridge Reservation measures exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods of time. Facilities on the ORR have been known to release variable amounts of gamma radiation, and there is the potential for an unplanned release of gamma emitting radionuclides. The State limit for the maximum dose to an unrestricted area is 2 mrem in any, one-hour period. State and DOE primary dose limits for members of the public are defined in DOE Order 5400.5, which requires that off-site radiation doses do not exceed 100 mrem/year above background for all exposure pathways.

5.3.3 Goals

The results from monitored sites were compared to:

- The State of Tennessee (State) limit for the maximum dose to an unrestricted area (2 mrem in any, one-hour period).
- State and DOE primary dose limits for members of the public (100 mrem/year).

5.3.4 Scope

Candidate monitoring locations for the placement of gamma radiation monitoring instrumentation include sites undergoing remedial activities, waste disposal operations, pre- and post-operational site investigations, and areas of environmental response activities. Figure 5.3.1 shows the FY2022 sampling locations. Data recorded by the gamma monitors was evaluated by comparing the data to background gamma exposure rates. The data was also compared to the State MDLs and to State and DOE primary dose limits (listed above). For FY2022, gamma exposure rate monitors were located at the following locations:

1. Fort Loudoun Dam (Background Site)
2. Environmental Management Waste Management Facility (EMWMF) Portal Monitor
3. ORNL 3000 area/Central Campus Remediation/former building 3026 Radioisotope Development Lab
4. ORNL Molten Salt Reactor Experiment (MSRE)
5. ORNL Spallation Neutron Source (SNS) stack

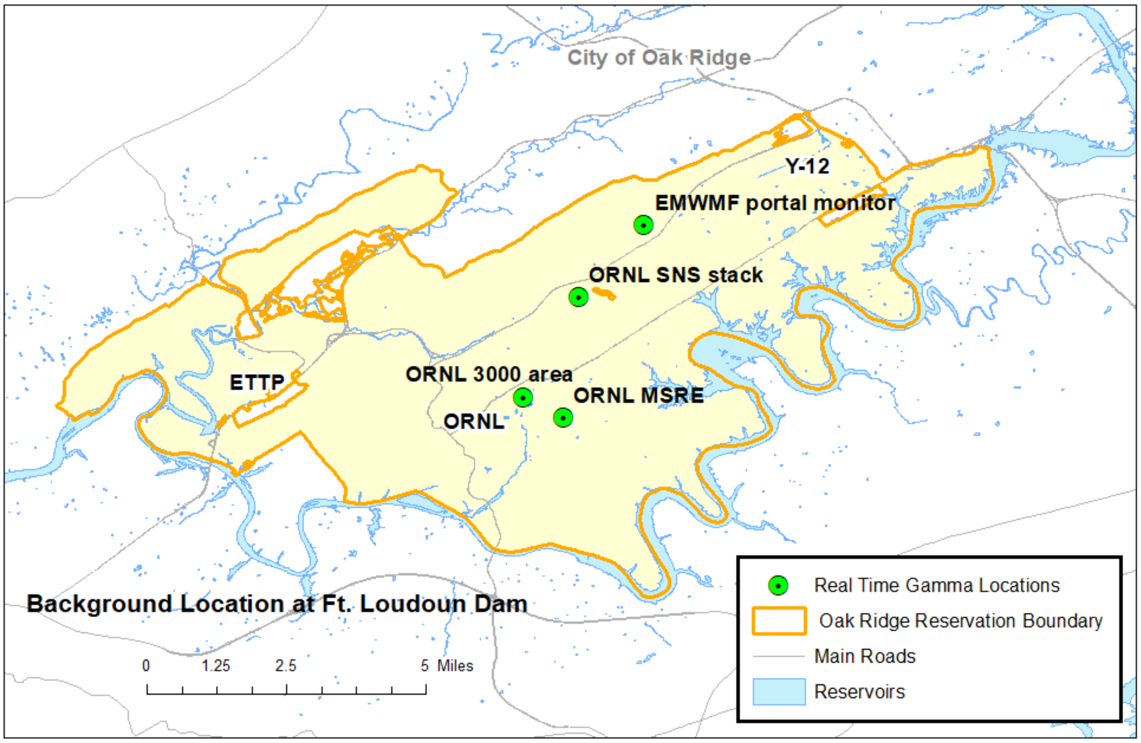

Figure 5.3.1: Gamma Monitor Locations

5.3.5 Methods, Materials, Metrics

The gamma exposure rate monitors deployed for the TDEC DoR-OR Real-Time Measurement of Gamma Radiation project on the ORR, are manufactured by Genitron Instruments and are marketed under the trade name GammaTRACER®. Each unit contains two Geiger-Muller tubes, a microprocessor-controlled data logger, and lithium batteries sealed in a weather-resistant case to protect the internal components. The instruments can be programmed to measure gamma exposure rates from 1 µrem/hour to 1 rem/hour at predetermined intervals from one minute to two hours. The results reported are the average of the measurements recorded by the two Geiger-Muller detectors. The data for any interval from each detector can be accessed. The results recorded by the data loggers were downloaded to a computer by TDEC DoR-OR personnel using an infrared transceiver and associated software.

5.3.6 Deviations from the Plan

The instruments underwent factory maintenance until mid-July 2021 causing a slight delay in the start of sampling. One instrument was found defective and had to be returned to the factory. It was not available to place at MSRE until early December 2021.

5.3.7 Results and Analysis

Fort Loudoun Dam Background

To better assess exposure rates measured on the ORR and the influence that natural conditions have on these rates, TDEC DoR-OR maintains one gamma monitor at Fort Loudoun Dam in Loudon County to collect background information. During the interval 07/21/2021 through 06/30/2021, exposure rates averaged 8.9 μrem/hour and ranged from 7 to 13 μrem/hour, which is equivalent to a dose of approximately 78 mrem/year.

Environmental Management Waste Management Facility

The EMWMF was constructed in Bear Creek Valley (west of Y-12) to dispose of wastes generated by CERCLA activities on the ORR. TDEC DoR-OR has a gamma monitor acting as a portal monitor at the check-in station for trucks transporting waste into the EMWMF for disposal. Trucks, entering the facility, pass the gamma radiation detector allowing the monitor to detect any gamma radiation-emitting materials that have passed on the way to disposal at the waste cells. This monitoring system allows for the assessment of gamma exposure rates at the monitoring detector over a defined time period and can be used to corroborate DOE's reporting system that excessive amounts of radiation-emitting materials have not inadvertently passed the monitoring point to be disposed of in the EMWMF facility. During the interval (07/15/2021 through 07/30/2022), exposure rates averaged 7.33 μrem/hour and ranged from 5 to 14 μrem/hour, similar to the background measurements collected during the same period at Fort Loudoun Dam and seen in Figure 5.3.2.

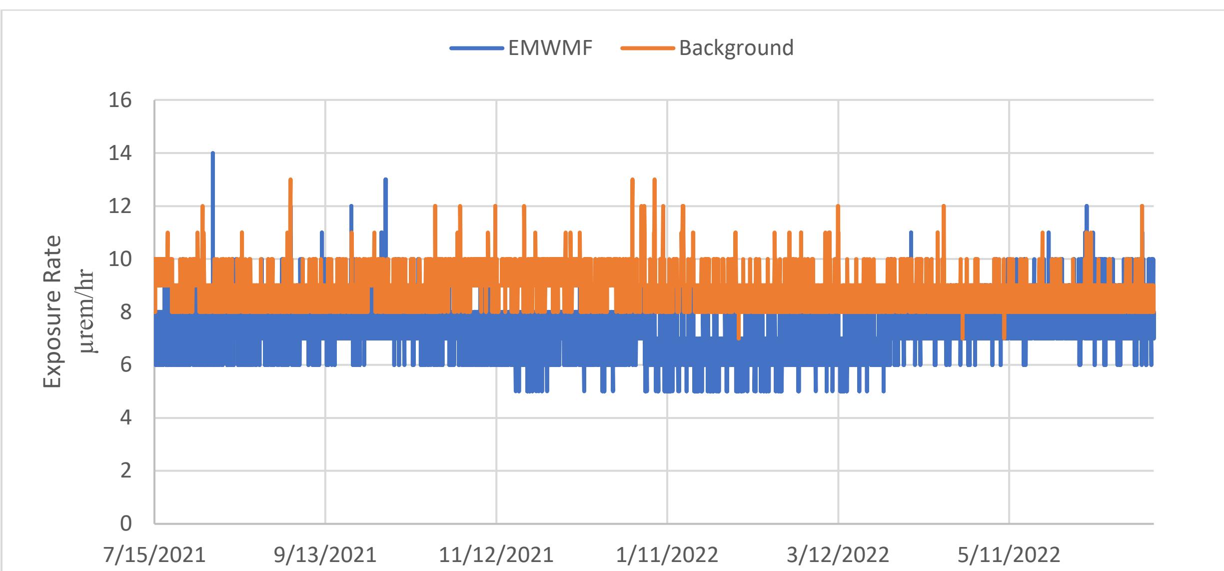

Figure 5.3.2 EMWMF Gamma Exposure Rates

ORNL Central Campus Remediation/Building 3026 Radioisotope Development Lab
Due to the nature of past activities at ORNL, concerns include potential radiological releases during the demolition of high-risk facilities centrally located on ORNL's main campus in close proximity to pedestrian and vehicular traffic.

During the sampling interval (07/15/2021 through 07/30/2022), gamma radiation measured at this ORNL site ranged from 9 to 21 µrem/hour and averaged 12.24 µrem/hour (Figure 5.3.3).

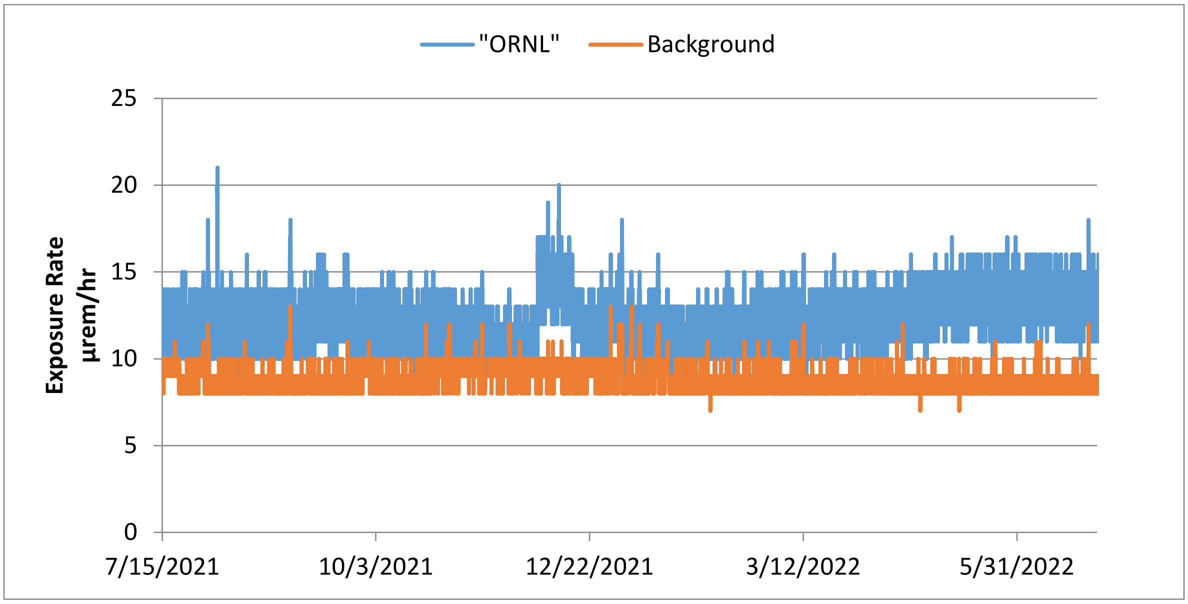

Figure 5.3.3: ORNL Central Campus Gamma Exposure Rates

The Molten Salt Reactor Experiment
During the sampling interval (12/06/2021 through 06/30/2022) monitoring period, exposure rates ranged from 8 to 16 µrem/hour and averaged 11.04 µrem/hour (Figure 5.3.4). The major source of the measured gamma radiation dose above background was assumed to result from a salt probe being temporarily stored in the radiation area, adjacent to the monitoring station.

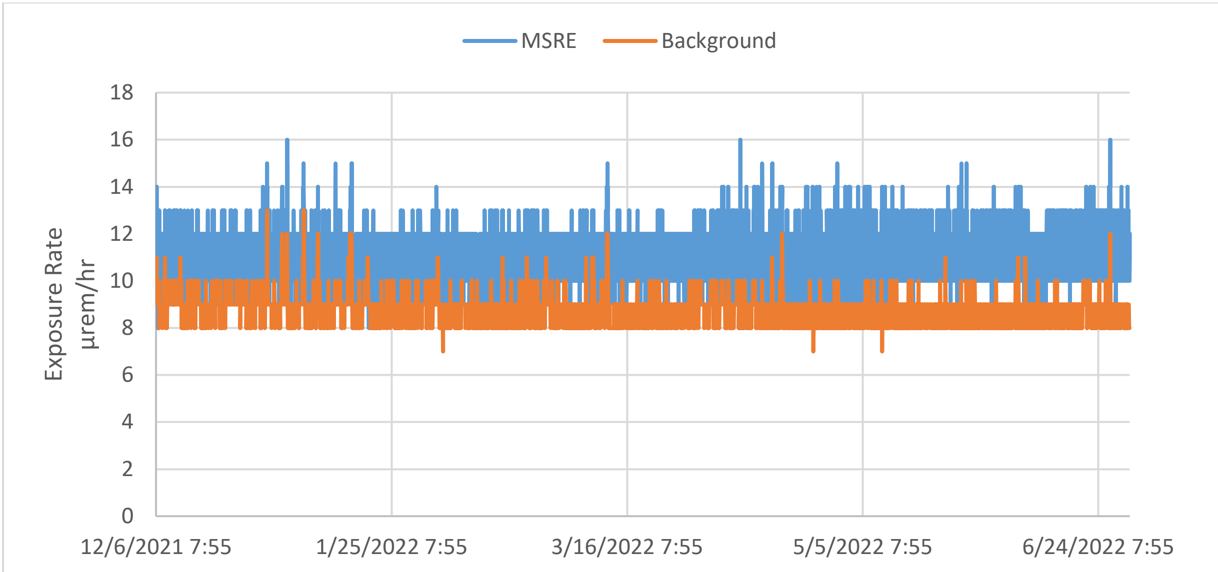

Figure 5.3.4: Gamma Exposure Rate at Molten Salt Reactor Experiment

Spallation Neutron Source

To assess the gamma component of air releases from the Spallation Neutron Source (SNS), TDEC DoR-OR's exposure rate monitor is located on the central exhaust stack used to vent air from process areas inside the linear accelerator (linac) and sample target building. The exposure rates vary based on the operational status of the accelerator. During periods when the accelerator is not online, the rates are similar to background measurements. However, much higher levels are recorded during operational periods.

The exposure rates measured throughout the sampling period (07/19/2021 through 07/30/2022), ranged from 6 to 832 µrem/hour and averaged 244 µrem/hour (Figure 5.3.5). For contextual purposes, the exposure rate of 244 µrem/hour would exceed both State and DOE limits of 100 mrem within one year. However, this location is not accessible to the public.

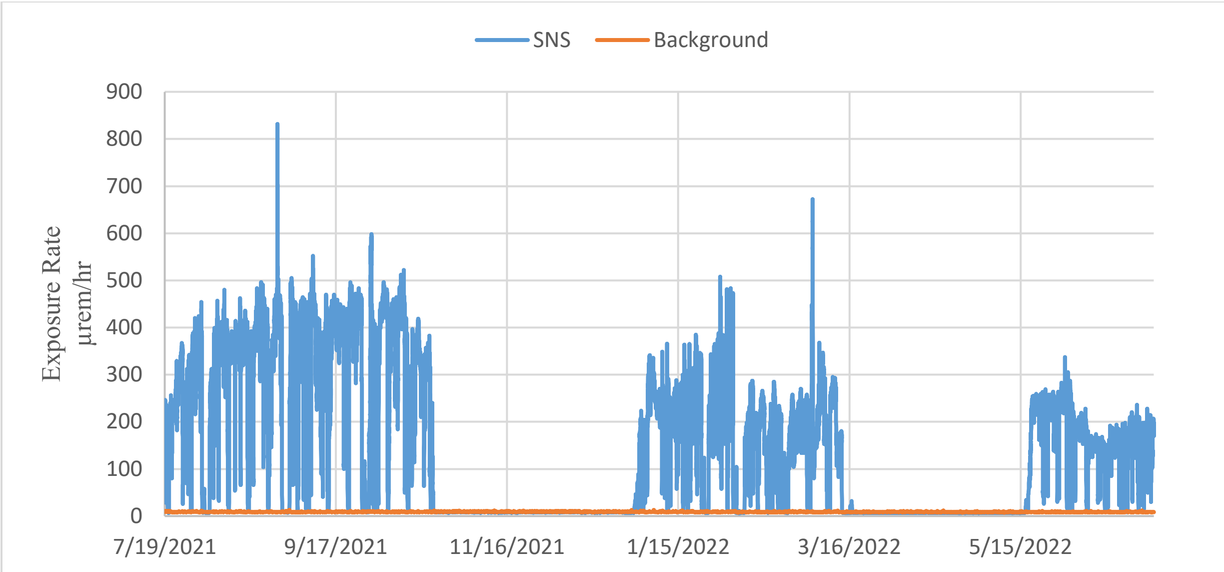

Figure 5.3.5: Spallation Neutron Source

5.3.8 Conclusions

The following conclusions are drawn, based on the data collected from 07/15/2021 through 07/30/2022 at the gamma monitoring locations covered in this report:

- No monitored location exceeded the 2 mrem in any, one-hour period.
- No monitored location exceeded the 100 mrem/year limit for members of the public.

5.3.9 Recommendations

- TDEC DoR-OR proposes to review the current monitoring locations and make modifications according to DOE activities on the ORR.
- As DOE does not have a similar monitoring program, TDEC DoR-OR proposes to continue this program.

5.3.10 References

DOE. 1993. Radiation Protection of the Public and the Environment. DOE Order 5400.5. US Department of Office of Energy, Office of Health, Safety and Security. Washington, DC. https://www.nrc.gov/docs/ML1108/ML110800239.pdf

TDEC. 2017. Rules of the Tennessee Department of Environment and Conservation, Division of Radiological Health. Chap. 0400-20-05, *Standards for Protection Against Radiation.* Tennessee Department of Environment and Conservation, Division of Radiological Health (TDEC-DRH). Nashville, TN. https://publications.tnsosfiles.com/rules/0400/0400-20/0400-20-05.20170912.pdf

5.4 SURPLUS SALES VERIFICATION

5.4.1 Background

The TDEC DoR-OR, in an oversight capacity of DOE and its contractors, conducts radiological surveys of surplus materials originating from the ORR, which 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 Order 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 over time at both Y-12 and at ORNL regarding surplus sales. With rare exceptions, materials are no longer sold directly to the public by either facility. Materials from ETTP may be released through ORNL Property Excessing. Y-12 now uses an out-of-state contractor to handle most of their sales and ORNL focuses their resale operations currently to nine or ten organizations that are approved to bid on sales of materials by the truckload.

At the request of ORNL and/or Y-12 Property Excessing staff, TDEC DoR-OR conducts supplemental radiological verification screening surveys to help ensure that no potentially contaminated materials reach the public. Direct readings are converted to dpm/100 cm^2 (dpm = disintegrations per minute) and reported. 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, TDEC DoR-OR immediately reports the finding(s) to the DOE surplus sales program supervisor. A removable contamination assessment may be performed. TDEC DoR-OR then follows the response of the sales organizations to confirm that appropriate steps (e.g. removal of items from sale, resurveys, etc.) are taken to protect the public.

5.4.2 Problem Statements

Although the procedure for surplus of materials from the ORR has changed (i.e. materials are no longer directly auctioned to the public), the potential still exits for the items being released to pre-approved bidders to reach the public.

Even when items of concern are found, they may not ultimately prove to be problematic. What can first appear to be an item with surface contamination could turn out to be (after resurvey) no longer detectable, a non-reportable daughter product, or a naturally occurring radioactive material.

5.4.3 Goals

TDEC DoR-OR's intent is to verify that materials that have been staged for sale at ORNL's 115 Union Valley Road Property Excessing Facility or other locations are released in compliance with DOE's release policy. The project attempts to locate any contaminated items that may have evaded detection prior to being staged for sale. In rare instances, when items of concern are found, it prevents the release of potentially contaminated materials to the public.

5.4.4 Scope

TDEC DoR-OR staff perform 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 per the ESOA Grant, as an additional check before release to the public. When a request is received, every attempt is made to fulfill that request. Typically, no more than eight events occur during a calendar year.

5.4.5 Methods, Materials, Metrics

Prior to sales of surplus items being released to the public, TDEC DoR-OR (when requested) 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 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 limit is detected, the item is brought to the attention of Excess Property staff. Based on TDEC DoR-OR's survey results, the Excess Property staff decides whether or not to have the item rechecked by ORNL RADCON. TDEC DoR-OR does not attempt to determine if a particular item meets DOE release criteria, but does try to locate items where, depending on which radionuclide isotopes are involved, there is a potential for the item not meeting unrestricted release criteria set forth by the State of Tennessee, Division of Radiological Health (DRH).

5.4.6 Deviations from the Plan

There were no deviations from the plan.

5.4.7 Results and Analysis

The office responded to a total of two Surplus Sales Survey requests from July 2021 to June 2022. During these visits a total of 5 items were identified with activity above the ambient background. These items included grinding wheels and a muffle furnace that probably contained ceramics with potassium-40 (^{40}K) activity. A projection system, and a paper shredder were probably the result of radon. The TDEC DoR-OR survey results were shared with ORNL in an e-mail message and the trip report was written and uploaded to DoRWay.

5.4.8 Conclusions

The independent Surplus Sales Verification Project performed by TDEC DoR-OR is useful as a final check of equipment and material that will be transferred or sold to the general public. All of the Lots were adequately scanned, but there were some pieces with surface areas where either the alpha or beta activity exceeded the ambient background. These surveys assisted DOE in deciding whether equipment met release criteria.

5.4.9 Recommendations

It is recommended that the Surplus Sales Verification Project continue; the project is functional and useful and provides a way for DOE to have an independent survey to confirm their own work. It also allows TDEC DoR-OR staff to become conversant with measuring radioactivity using the proper methods.

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6.0 SEDMENT MONITORING

6.1 TRAPPED SEDIMENT (BEAR CREEK)

6.1.1 Background

This project provides an overview of sediment data from Bear Creek from samples collected not only in Fiscal Year 2022 (FY2022), but also going back nine (9) years.

Sediment is an important part of aquatic ecosystems. Many aquatic organisms depend on sediment for habitat, sustenance, and reproduction. Anthropogenic chemicals and waste materials, such as metals, radionuclides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and agricultural chemicals that are introduced into aquatic systems often accumulate in sediments. Contaminants may accumulate in sediments such that their concentrations are higher than in the water column. Some sediment contaminants may be directly toxic to benthic organisms or may bioaccumulate in the food chain, creating health risks for wildlife and humans. Sediment analysis is an important aspect of environmental quality and impact assessment for rivers, streams, and lakes.

Suspended sediment samples were collected at a tributary of Bear Creek, North Tributary-5 (NT-5), at Bear Creek km 7.6 (BCK 7.6), and Bear Creek km 3.3 (BCK 3.3). The stream chosen for a background stream was Mill Branch, where samples were collected at km 1.6 (MBK 1.6).

6.1.2 Problem Statements

ORR exit pathway streams are subject to contaminant releases from activities at ETTP, ORNL, and Y-12. These contaminant releases have been detrimental to stream health in the past and present. Identified issues include:

- Large quantities (11 million kilograms) of elemental mercury were used at the Y-12 plant from 1950 to 1963 for a lithium isotope separation process. Loss of mercury to the air, soil and to East Fork Poplar Creek (EFPC) are estimated to be 3% of the mercury used at the site. Mercury continues to be released to the creek from contaminated soil and groundwater sources at Y-12 (Brooks and Southworth, 2011).
- The headwaters of EFPC contribute roughly 1000 ng/L chronic base flow concentrations of total mercury to EFPC (Southworth et al., 2013).
- Besides mercury, other metals that have been found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver, uranium, and zirconium (DOE, 1992).

6.1.3 Goals

The goals of this project are:

- Evaluate a component of stream health through sampling and analysis of suspended sediment.

- Assess site remediation efforts through long-term monitoring of suspended sediment.
- Identify trends in data, based on findings, and use those trends to make recommendations in order to improve sediment quality and the health of affected streams.

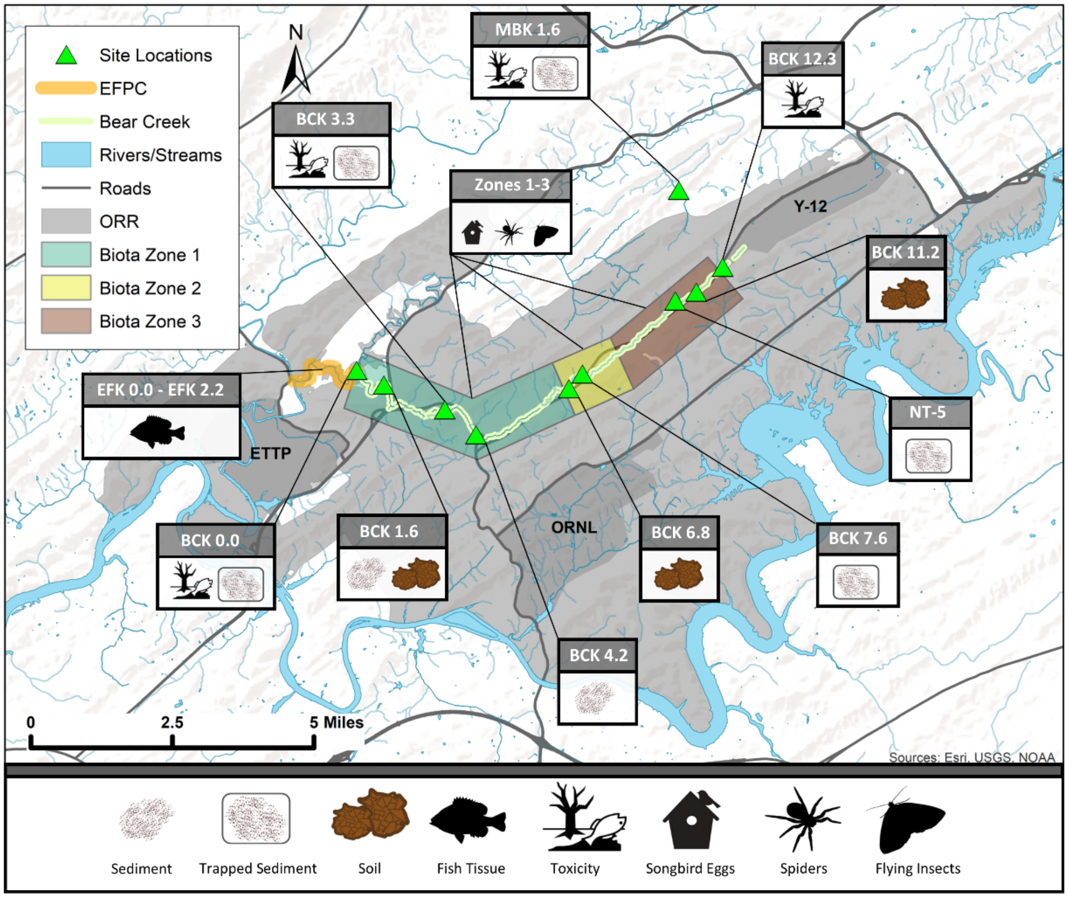

Figure 6.1.1: Map of the BCAP Phase 4 sediment trap sampling locations

6.1.4 Scope

This project evaluates the concentrations of potential contaminants in suspended sediments that are currently being transported in Bear Creek by utilizing passive sediment collectors at three (3) locations in Bear Creek Valley and compares them to levels seen at the Mill Branch background location (Table 6.1.1). The data discussed include FY2022 (July 1, 2021 – June 30, 2022) as well as nine (9) years of prior data. This project does not have a comparable DOE counterpart at the present time, so it provides independent data to assist in the evaluation of the streams that drain the ORR.

Table 6.1.1: BCAP Suspended Sediment Sampling Sites

DWR Name	Site Description	Name	Latitude	Longitude
BEAR002.0RO	Bear Creek kilometer 3.3	BCK 3.3	35.94354	-84.34911
BEAR004.7AN	Bear Creek kilometer 7.6	BCK 7.6	35.95096	-84.31395
BEAR006.5T0.1AN	N. Tributary 5 of Bear Ck.	NT-5	35.96603	-84.29024
FECO67I12	Mill Branch Mile 1.0	MBK 1.6	35.98886	-84.28935

6.1.5 Methods, Materials, Metrics

Sediment sampling was conducted at four locations twice during the year. Sampling locations were NT-5, BCK 7.6, BCK 3.3, and MBK 1.6. Suspended sediment samples were collected using fixed sediment collection devices (traps). Sediment traps were installed in the stream bed in a position where considerable flow through the body of the sediment trap occurs. Suitable sites are often 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 approximately five 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 three days. 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. Sediment samples were analyzed for gross alpha, gross beta, gamma radionuclides, strontium 89, 90 (Sr-89,90), isotopic uranium, and metals (arsenic (As), barium (Ba), beryllium (Be), boron (B), cadmium (Cd), cesium (Cs), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), strontium (Sr), uranium (U), and zinc (Zn)). The sediment samples were sent to the TDH-NEL for analysis.

6.1.6 Deviations from the Plan

Additional sampling was added to the original plan when CEC was contracted to conduct additional sediment grab sampling in the spring of 2022. This additional sediment sampling was part of an effort to characterize mercury, uranium, and PCBs in the Bear Creek Valley.
On April 6, 2022, CEC conducted sediment grab sampling at the two locations listed in Table 6.1.2. These were grab samples collected using a Russian Peat Borer device which obtained core grab samples approximately 8 inches in length. Three grab samples were collected at each site and were analyzed for mercury, PCBs, and uranium only. The results from each of the two grab sampling locations were averaged.

Table 6.1.2: Sediment grab sampling locations (CEC)

Sediment Sampling Locations			
Site Description	Shorthand	Latitude	Longitude
Beaver dam under Haul Road bridge at Hwy 95	BCK 4.2	35.938401	-84.341146
Downstream of entrance to West End Greenway	BCK 1.6	35.94867	-84.364664

6.1.7 Results and Analysis

METALS DATA

Mercury

The CEC sediment mercury results are graphed along with the TDEC DoR-OR sediment trap results in Figure 6.1.2. The sediment core grab samples collected by CEC had lower concentrations than the sediment trap results from the background site, MBK 1.6 (0.0438 mg/kg). The sediment core grab samples were also lower in contaminants than the sediment trap results from the Bear Creek and NT-5 sampling sites, but all were well below the mercury Regional Screening Level (RSL), THI=1, Resident Soil (10.9 mg/kg). RSLs are risk-based chemical concentrations that correspond to fixed levels of risk in soil, air, and water. These concentrations are derived from standardized equations combining exposure information assumptions with EPA toxicity data (EPA 2022). RSLs are protective of human health over a lifetime, but do not address ecological impacts. RSLs are not cleanup standards, but are used to identify areas, contaminants, and conditions that require attention at a site (EPA 2022). In noncarcinogenic risk equations, THQ represents the target hazard quotient and is used for individual substances or exposure routes like ingestion, dermal, and inhalation. The hazard quotient (HQ) relates the dose of noncarcinogen delivered to a pre-determined 'safe' level below which a toxicological response is not likely; the ratio of the two is the HQ. An HQ above 1.0 signifies an increased likelihood of an adverse response (Hertzberg and Teuschler 2002), such as a rash or hair falling out. The THI (Target Hazard Index) is the target across multiple substances or exposure routes (EPA 2022). The Bear Creek Valley Watershed Remedial Action Report Comprehensive Monitoring Plan specifies the use of Risk-Based Concentrations (RBCs) of 1E-5 and HI=1 for residential receptors for Zones 1 and 2 and industrial receptors in Zone 3 (DOE 2019). The boundary between Zones 2 and 3 is approximately at BCK 9.4 or just downstream of the mouth of North Tributary 8 (NT-8). The difference between the core grab samples and the sediment trap (suspended sediment) samples may be due to the larger particle size constituents of the grab samples of sediment collected. Although a particle size analysis was not conducted on the CEC core grab samples, observation of the samples revealed that they were predominantly coarse sediment particles (sand and fine gravel). This is in contrast to the TDEC DoR-OR sediment trap samples that are composed of predominantly silt and clay particles. Fine soil or sediment particles (particularly clay) have more surface area and cation exchange capacity per unit mass than do sands and gravel and can bind more contaminants.

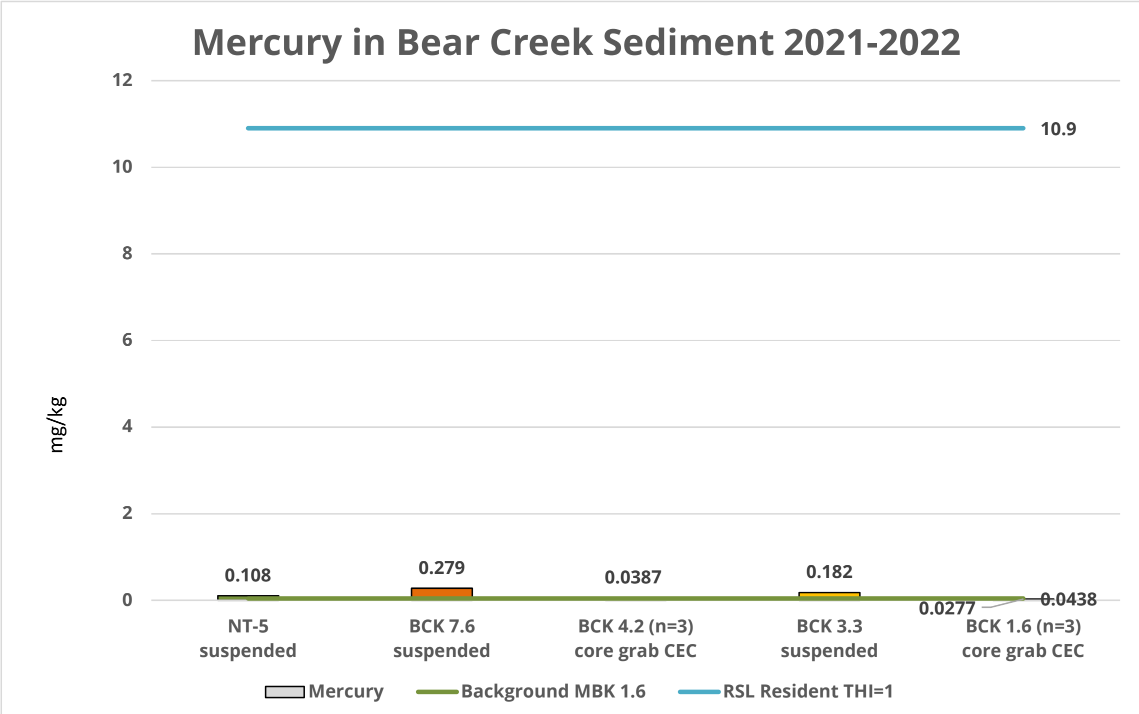

Figure 6.1.2: Mercury in Bear Creek Sediment – Suspended vs. Core Grab Samples (2021-2022)

Figure 6.1.3 shows sediment trap mercury data from 2014 through 2022. Mercury concentrations were less than the resident soil RSL THI=1 (10.9 mg/kg). Although higher levels of mercury were seen at the Bear Creek sites than at the background (MBK 1.6) location (0.0424 mg/kg), the mercury concentrations are less than the RSL, indicating that there is no human health risk from mercury in Bear Creek sediments at this time. If conditions change, a new risk assessment may be warranted.

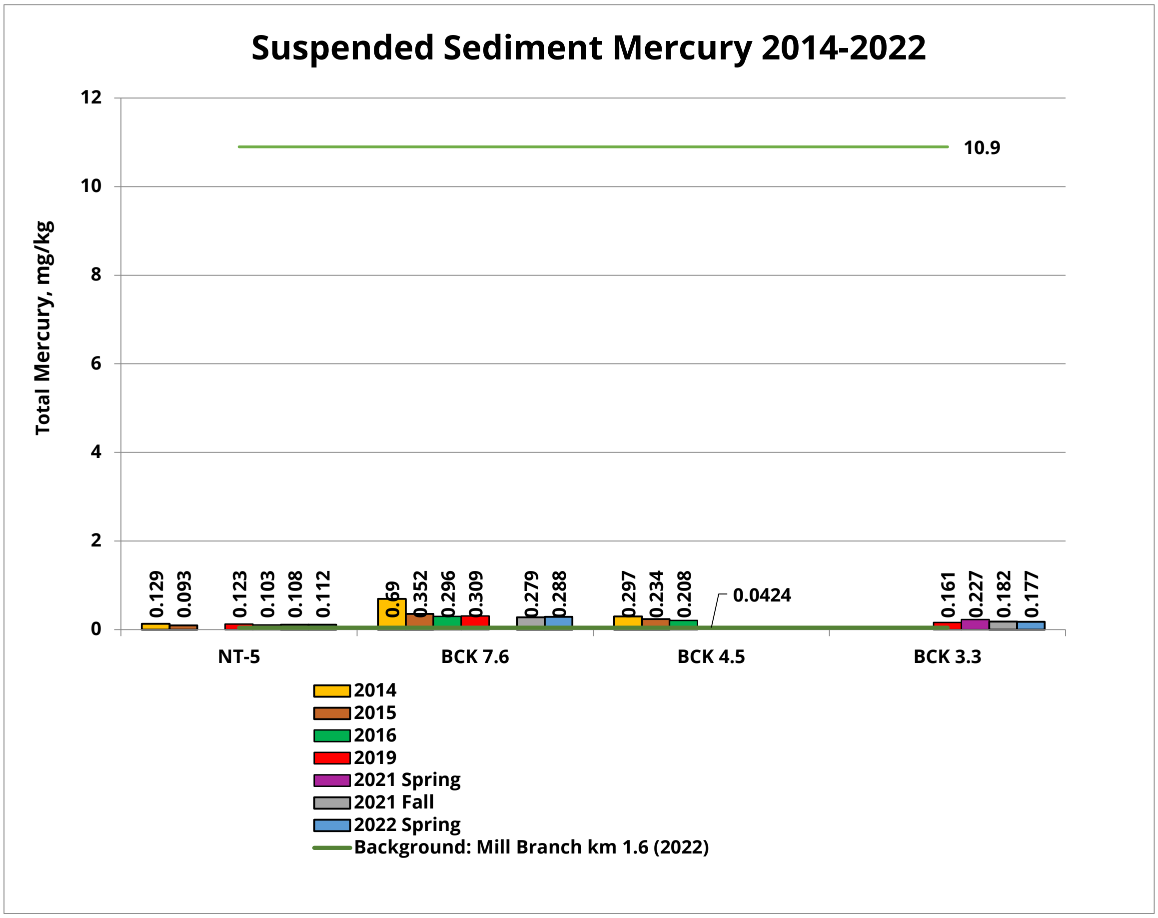

Figure 6.1.3: Mercury in Bear Creek Suspended Sediment (2014-2022)

Uranium

The TDEC DoR-OR and CEC 2021-2022 sediment uranium sampling results (core and suspended) were much lower than the Resident Soil RSL (THI=1) of 15.6 mg/kg with the exception of BCK 7.6 (Figure 6.1.4). The greatest concentration of sediment uranium was collected from the sediment trap at BCK 7.6; this sampling station is downstream of all Bear Creek disposal facilities and NT-8, a tributary that transports considerable amounts of uranium from the Bear Creek Burial Grounds. Core samples were collected at BCK 4.2 and BCK 1.6 by CEC (Figure 6.1.4). In Figure 6.1.5, suspended sediment results from 2014 through 2022 are presented; only the 2022 BCK 7.6 uranium data exceeds the Resident Soil RSL (THI=1).

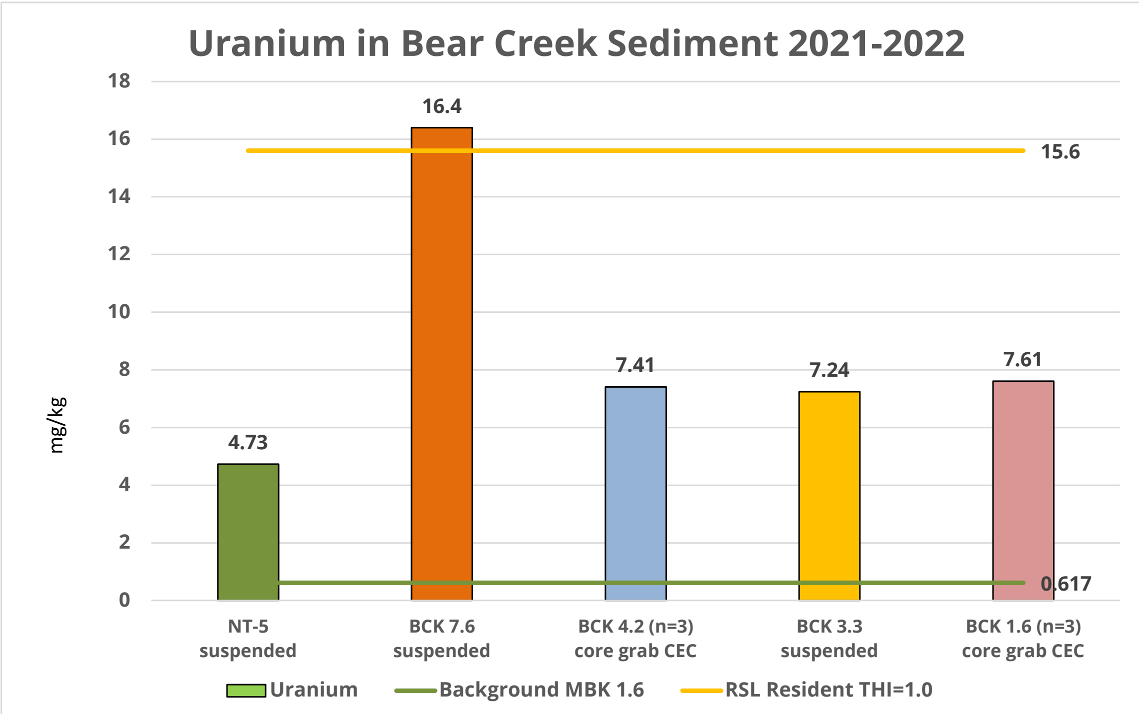

Figure 6.1.4: Uranium in Bear Creek Sediment – Suspended vs. Core Grab Samples (2021-2022)

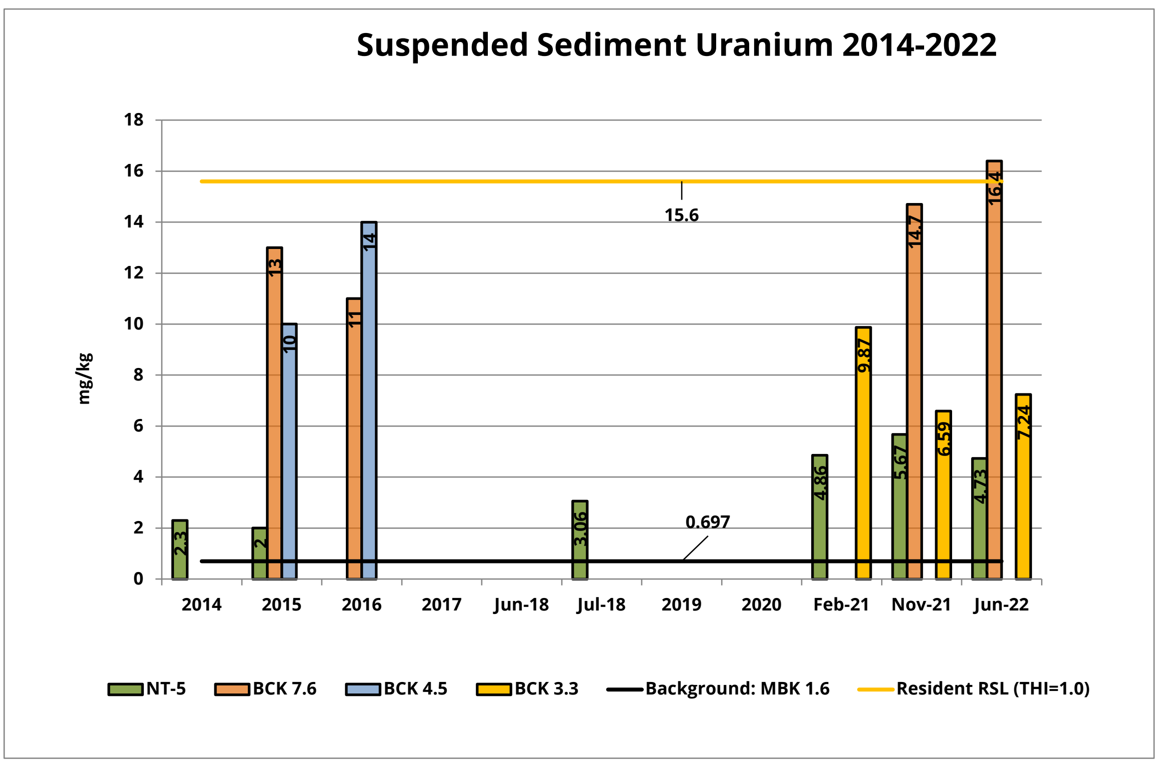

Figure 6.1.5: Uranium in suspended sediment at Bear Creek: 2014-2022

Cadmium concentrations were less than the Resident Soil RSL THI=1 (7.14 mg/kg) at all of the sampling sites (Figure 6.1.6). As with uranium and mercury, BCK 7.6 had the greatest concentrations of cadmium in the suspended sediment samples. The NT-5 cadmium sediment concentration slightly exceeded background in four of five samples and was below background in 2014.

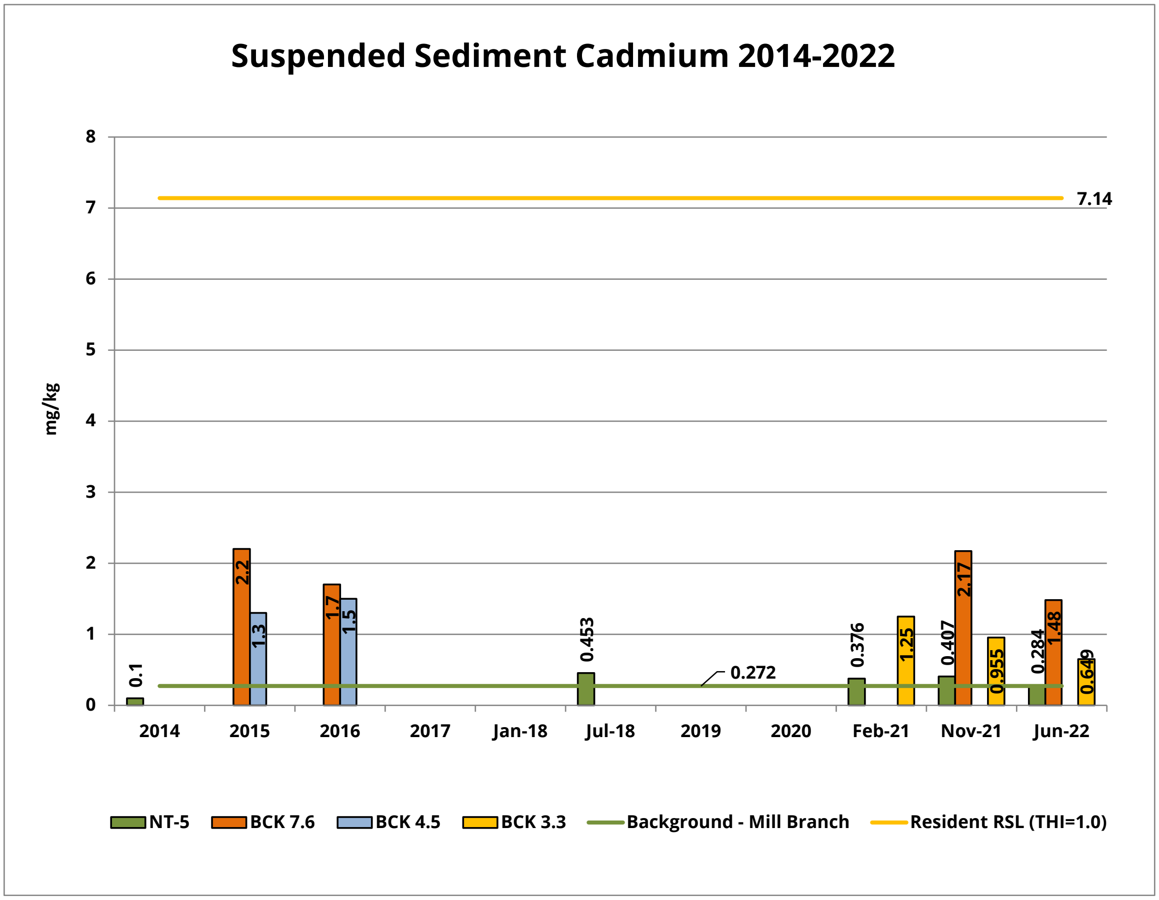

Figure 6.1.6: Cadmium in suspended sediment at Bear Creek: 2014-2022

All of the arsenic data were non-detects or J values (result less than the Method Quantitation Limit (MQL) but greater than or equal to the Method Detection Limit (MDL), and the concentration is an approximate value). All of the barium concentrations were roughly twice that of the MBK 1.6 background site (88.8 mg/kg) but were less than the Resident Soil RSL (THI=1) of 15,000 mg/kg. Beryllium and boron concentrations of the Bear Creek and NT-5 sediment samples were very similar to background. The Consensus Based Sediment Quality Guidelines (CBSQGs) Threshold Effects Concentrations (TECs) were used for comparison for total chromium since an RSL was not available. The Threshold Effects Concentrations (TECs) are concentrations below which adverse effects are not expected to occur (MacDonald et al. 2000). Adverse effects, in this case, refer to the effects to benthic macroinvertebrate species only (WDNR 2003). The CBSQGs are considered protective of human health and wildlife except where bioaccumulative or carcinogenic organic chemicals, such as PCBs or methylmercury, are involved. In these cases, in addition to the CBSQGs, other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue-residue guidelines should be used to assess direct toxicity and food chain effects. The TEC for chromium is 43 mg/kg and the highest sediment value reported was 25 mg/kg in 2015 at the NT-5 site. Values below the TEC indicate that there are no impacts to benthic organisms expected from that metal. Copper, lead, and nickel data were all very close to background and much less than the CBSQGs and the relevant RSLs. Selenium was not detected in any of the sediment samples. Strontium concentrations were roughly twice background (7.06 mg/kg) with the highest concentration at BCK 7.6 (16.6 mg/kg); these concentrations do not present a concern since the strontium (stable) Resident Soil RSL (THI=1) is 47,000 mg/kg. Cesium concentrations were only slightly higher than background at the Bear Creek and NT-5 sites. Zinc concentrations at the Bear Creek Valley sediment sites were approximately twice background (22.8 mg/kg) but are still much lower than the Resident Soil RSL (THI=1) of 23,000 mg/kg.

ORGANIC DATA

Polychlorinated Biphenyl Compounds (PCBs)

PCB analysis was conducted on the sediment samples from BCK 4.2 and BCK 1.6, but the results were less than the detection limit.

RADIOLOGICAL DATA

The gross alpha sediment trap results from 2014 to 2021 are presented in Figure 6.1.7. The NT-5 data had a downward trend through February 2021, dipping below background in 2019 (Figure 6.1.7). However, gross alpha activity in sediment samples collected from BCK 7.6 and BCK 3.3 show no such trend. Most of the gross alpha data from the three Bear Creek Valley sites were higher than the average of the results seen at the background location.

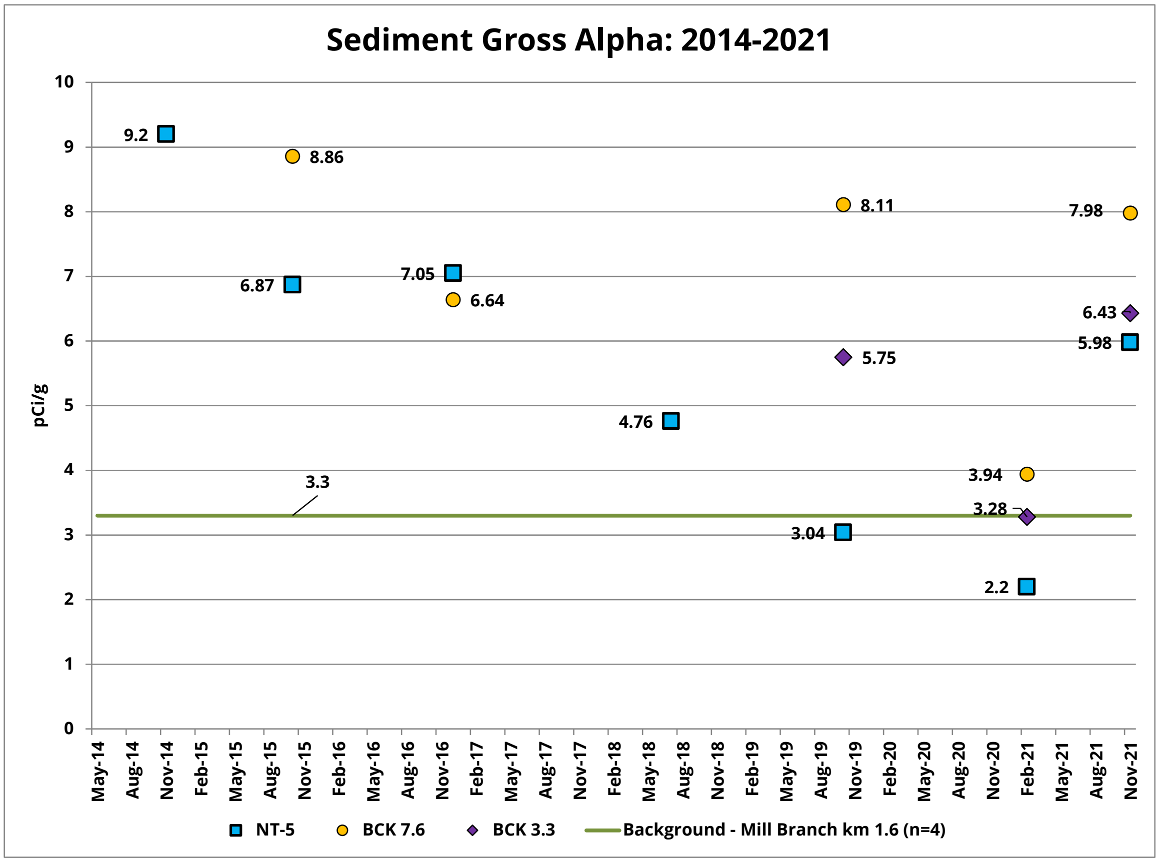

Figure 6.1.7: Suspended Sediment Gross Alpha activity at Bear Creek: 2014-2021

Gross beta activities were greatest at the NT-5 sediment trap site and have risen in recent years (2019 to present) (Figure 6.1.8). The reasons for this increase in gross beta activities may be an artifact of the disposal of Tc-99 containing waste from ETTP in recent years at the EMWMF. Gross beta activities at BCK 7.6 and BCK 3.3 have been fairly consistent over the years that they have been sampled. All of the gross beta results were above those seen at the background location (MBK 1.6).

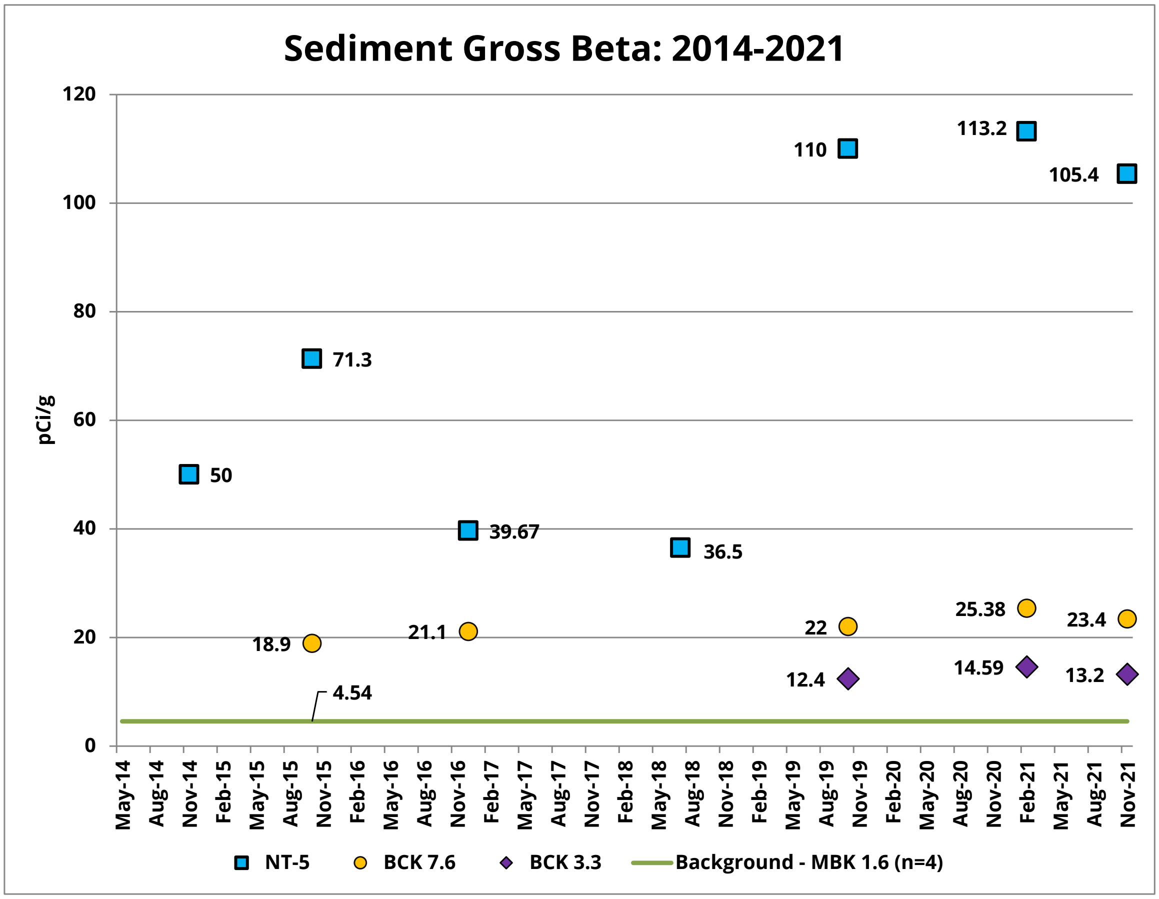

Figure 6.1.8: Suspended Sediment Gross Beta activity at Bear Creek: 2014-2021

Isotopic uranium analysis of sediment trap samples showed that all of the suspended sediment results for U-234 and U-238 were less than the Resident Soil Preliminary Remediation Goal (PRG) TR=1.0E-05 at the three Bear Creek sampling sites (Figure 6.1.9, Figure 6.1.10). The risk-based PRGs for radionuclides are based on the carcinogenicity of the contaminants. Risks are usually expressed as a probability of effects associated with an activity. A Total Risk (TR) of 1.0E-05 means that the probability of an adverse effect is on the order of one in one hundred thousand. The results for U-235 analysis had an unacceptable amount of associated uncertainty; the Combined Standard Uncertainty (CSU) was greater than 30% of the result in all cases with the U-235 data. Similarly, the data for the background site, MBK 1.6, also had unacceptable amounts of associated uncertainty, so the background data were not graphed for U-234 and U-238. U-234 activity was highest at NT-5, whereas U-238 activity was highest at BCK 7.6.

Radiological analysis for Sr-89,90 resulted in invalid data in that the CSU figures were greater than 30% of the results, indicating that there was an unacceptable level of uncertainty in the data.

Gamma spectroscopy of the suspended sediment samples was unremarkable; the analytes detected were naturally occurring and were similar to background.

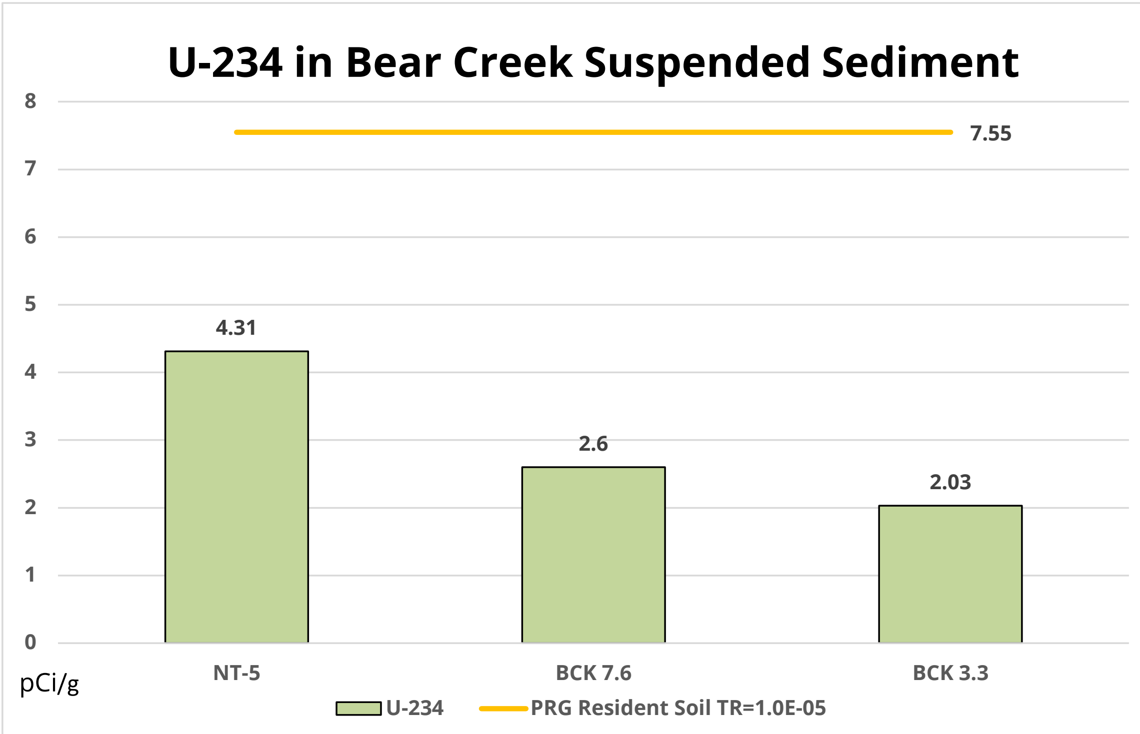

Figure 6.1.9: U-234 Radioactivity in Suspended Sediment at Bear Creek: (2021)

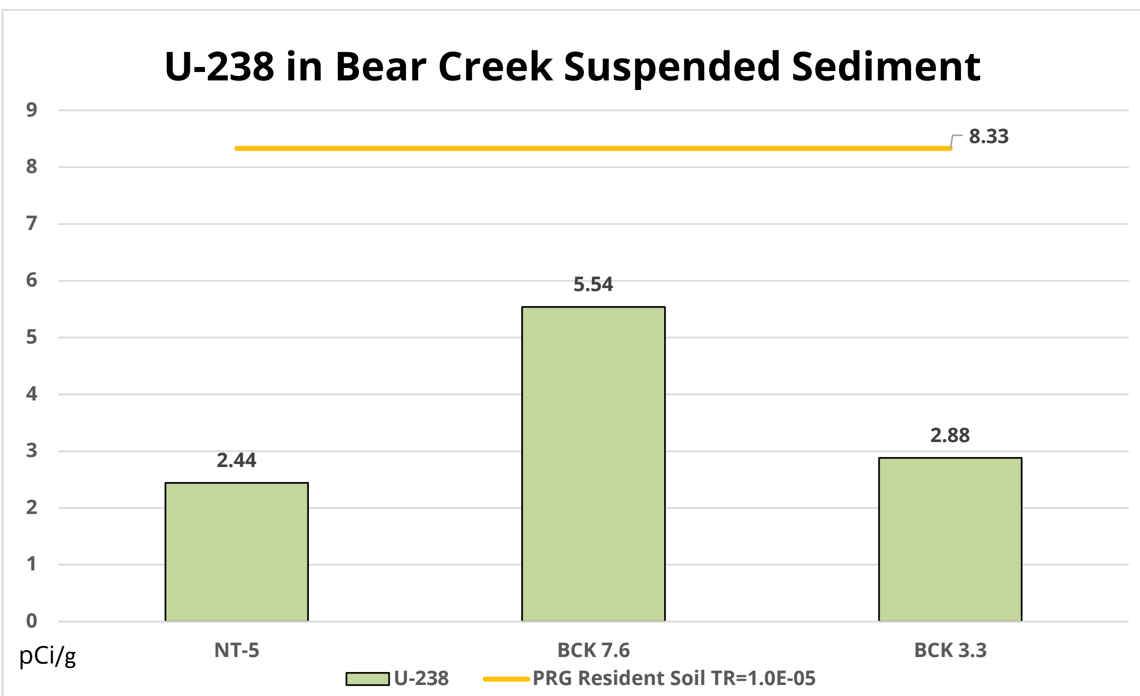

Figure 6.1.10: U-238 Radioactivity in Suspended Sediment at Bear Creek (2021)

6.1.8 Conclusions

Mercury in Bear Creek sediments was detected at levels greater than those seen at the background site but was not at a level considered to be a risk to human health during the sample periods due to all results being less than the resident soil RSL THI=1 (10.9 mg/kg). Both the sediment trap and sediment core grab samples were below the mercury RSL, THI=1, Resident Soil (10.9 mg/kg). Regional Screening Levels (RSLs) are risk-based chemical concentrations that correspond to fixed levels of risk in soil, air, and water. These concentrations are derived from standardized equations combining exposure information assumptions with EPA toxicity data (EPA 2022). RSLs are protective of human health over a lifetime, but do not address ecological impacts. RSLs are not cleanup standards, but are used to identify areas, contaminants, and conditions that require attention at a site (EPA 2022). In noncarcinogenic risk equations, THQ represents the target hazard quotient and is used for individual substances or exposure routes like ingestion, dermal, and inhalation. The THI (Target Hazard Index) is the target across multiple substances or exposure routes (EPA 2022). While the sediment core grab samples were below the background site's mercury sediment trap concentration of 0.0438 mg/kg, the two methods did not appear comparable, likely due to sediment particle size differences between the two types of samples. The sediment trap concentrations at the Bear Creek Valley sites were above mercury levels seen at the background location. Uranium concentrations greatly exceed background. BCK 7.6 was the only site that exceeded the uranium THI=1 RSL, Resident Soil (15.6 mg/kg) with a value of 16.4 mg/kg in June of 2022. Cadmium was less than the Resident Soil RSL (THI=1) at all of the sites. All of the other sediment metal analytes did not present a concern for the sampling time period. PCB analysis was conducted on the sediment samples from BCK 4.2 and BCK 1.6, but the results were less than the detection limit.

Gross alpha activity in the suspended sediment samples was above background in most Bear Creek Valley sediment trap samples from 2014 to 2022. Gross beta activity was greater than twice background in all cases and was particularly elevated (105.4 pCi/g in 2021) at the NT-5 sediment trap location. Isotopic uranium analysis reported U-234 and U-238 activities were less than the resident soil PRG (TR=1.0E-05) at all sites. The Sr-89,Sr-90, U-235, and isotopic uranium background data could not be used because there was too much uncertainty with relation to the CSU.

6.1.9 Recommendations

Suspended sediment sampling is recommended twice a year since trapped suspended sediment shows changes in direct response to environmental contaminant discharges. This monitoring program is needed as it detects changes in concentrations of contaminants of concern in Bear Creek. Suspended sediment sampling is an integral part of stream monitoring on the ORR.

6.1.10 References

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6.2 Trapped Sediment (East Fork Poplar Creek)

6.2.1 Background

Sediment is an important part of aquatic ecosystems. Many aquatic organisms depend on sediment for habitat, sustenance, and reproduction. Anthropogenic chemicals and waste materials, such as metals, radionuclides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and agricultural chemicals that are introduced into aquatic systems often accumulate in sediments. Contaminants may accumulate in sediments such that their concentrations are higher than in the water column. Some sediment contaminants may be directly toxic to benthic organisms or may bioaccumulate in the food chain, creating health risks for wildlife and humans. Sediment analysis is an important aspect of environmental quality and impact assessment for rivers, streams, and lakes.

Sediment samples were collected at East Fork Poplar Creek kilometer 23.4 (EFK 23.4). Mill Branch is a tributary of East Fork Poplar Creek (EFPC) and is used as a background stream (Figure 6.2.1). Figure 6.2.1 shows the locations of all the TDEC DoR-OR sediment traps, but this report only pertains to EFK 23.4 and Mill Branch kilometer 1.6 (MBK 1.6). Samples were analyzed for radiological activity and metals. Past sediment sampling activities by the Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office (DoR-OR) have shown that EFPC has elevated levels of mercury in sediments. This mercury can be attributed to historical discharges from Y-12.

6.2.2 Problem Statements

ORR exit pathway streams are subject to contaminant releases from activities at ETTP, ORNL, and Y-12. These contaminant releases have been detrimental to stream health in the past and present. Identified issues include:

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental

mercury to East Fork Poplar Creek by spills and leakage from subsurface drains, building foundations, contaminated soil, and purposed discharge of wastewater containing mercury (Turner and Southworth,1999).
- The headwaters of EFPC contribute roughly 1000 ng/L chronic base flow concentrations of total mercury to the stream (Southworth et al., 2013).
- Besides 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).

6.2.3 Goals

The goals of this project are to:

- Determine stream health through sampling and analysis of suspended sediment.
- Assess site remediation efforts through long-term monitoring of suspended sediment.
- Identify trends in data, based on findings, and use those trends to make recommendations in order to improve sediment quality and the health of affected streams.

6.2.4 Scope

This project evaluates the concentrations of potential contaminants in suspended sediments that are currently being transported in East Fork Poplar Creek (EFPC) by utilizing a passive sediment collector (sediment trap) at East Fork Poplar Creek km 23.4 (EFK 23.4). This project does not have a comparable DOE counterpart at the present time, so it provides independent data to assist in the evaluation of EFPC.

6.2.5 Methods, Materials, Metrics

In order to monitor for changes in contaminant flow through suspended sediment transport, sediment traps were deployed at EFK 23.4 and at MBK 1.6. The sediment traps were sampled on 11/29/2021 and 6/13/2022.

Sediment samples were analyzed for metals (arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, and uranium) and radiological parameters (gross alpha, gross beta, and gamma-emitting radionuclides). Strontium-89/90, and uranium isotopic analyses were requested but were not conducted due to a laboratory error. The metals data were compared to the EPA Regional Screening Levels (RSLs) and to the Consensus-Based Sediment Quality Guidelines (CBSQGs) (MacDonald et al., 2000) when RSLs were not available. Radiological data were compared to data from the background location, Mill Branch kilometer (MBK) 1.6.

The standard operating protocol (SOP) used for this project is the TDEC DoR-OR Standard Operating Procedure for Sediment Trap Sampling (TDEC DoR-OR 2017). Suspended sediment samples are collected by using fixed sediment collection devices (traps). Sediment traps are installed in a stream bed and positioned to accommodate the most considerable flow through the body of the trap. Suitable sites are limited in a stream; careful consideration must be given to the selection of installation locations for the sediment traps. For optimal functioning of the sediment traps, water flow and depth must be sufficient to provide a strong flow into the trap while keeping the trap submerged at both ends so that the entry and exit ports are underwater.

Following a collection period of approximately five 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 three days. The sediment samples are kept cool during the settling process with an ice bath surrounding the sample containers. After the sediment has settled, the supernatant water is carefully drawn off from the sample with a peristaltic pump. Sediment samples are spooned from the bucket into sample containers of appropriate size and construction for the requested analyses.

Table 6.2.1: Sampling Locations

Sampling Location	DWR ID	Alt. ID	Sampling Rationale	Latitude	Longitude
East Fork Poplar Creek km 23.4	EFPOP014.5AN	EFK 23.4	Surveillance of suspended sediment at point where EFPC leaves DOE property.	35.99596	-84.24004
Mill Branch Mile km 1.6	FECO67I12	MBK 1.6	Surveillance of suspended sediment at a background location.	35.98886	-84.28935

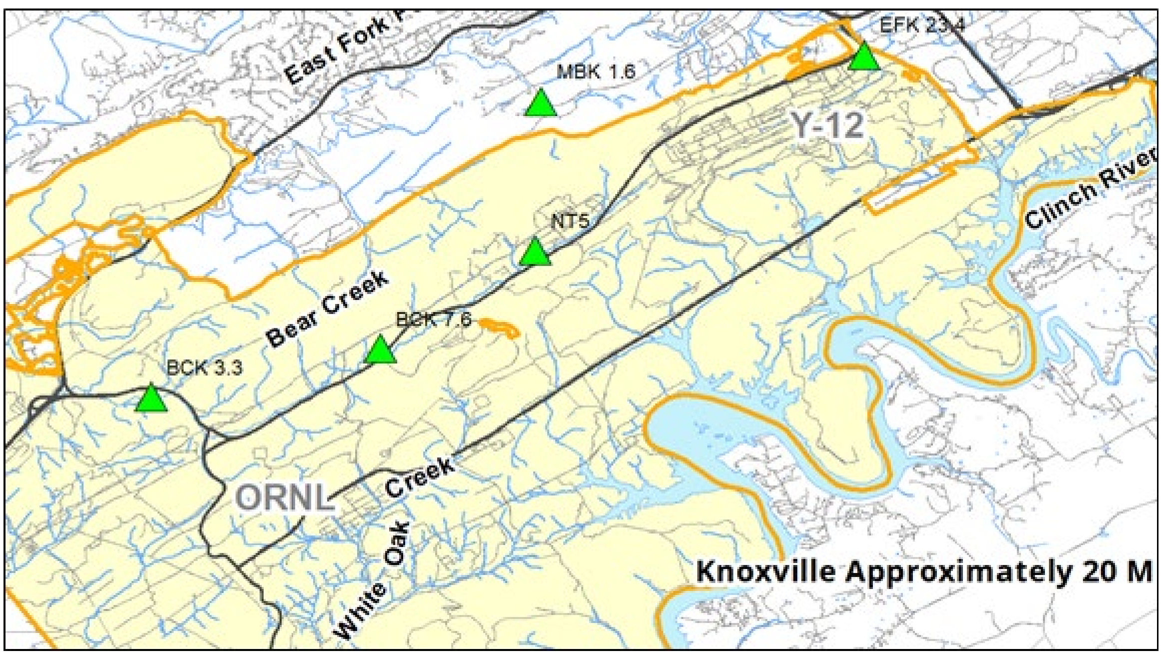


Figure 6.2.1: Sediment Sampling Locations

6.2.6 Deviations from the Plan

Strontium-89/90, and uranium isotopic analyses were requested but were not conducted due to a laboratory error.

6.2.7 Results and Analysis

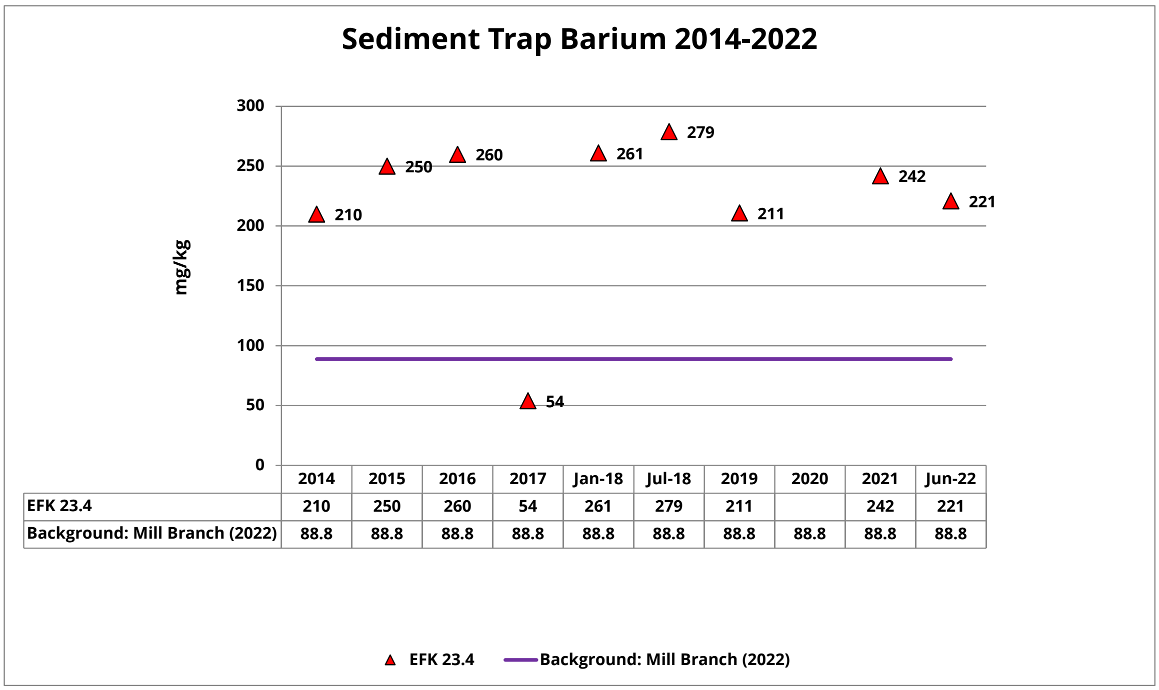
Trapped sediment metals' results were compared with the EPA Regional Screening Levels (RSLs). RSLs are risk-based chemical concentrations that correspond to fixed levels of risk in soil, air, and water. These concentrations are derived from standardized equations combining exposure information assumptions with EPA toxicity data (EPA 2022). RSLs are protective of human health over a lifetime, but do not address ecological impacts. RSLs are not cleanup standards, but are used to identify areas, contaminants, and conditions that require attention at a site (EPA 2022). In noncarcinogenic risk equations, THQ represents the target hazard quotient and is used for individual substances or exposure routes like ingestion, dermal, and inhalation. The hazard quotient (HQ) relates the dose of noncarcinogen delivered to a pre-determined 'safe' level below which a toxicological response is not likely; the ratio of the two is the HQ. An HQ above 1.0 signifies an increased likelihood of an adverse response (Hertzberg and Teuschler 2002), such as a rash or hair falling out. The THI (Target Hazard Index) is the target across multiple substances or exposure routes (EPA 2022).

The Consensus Based Sediment Quality Guidelines (CBSQGs) Threshold Effects Concentrations (TECs) were used for comparison for total chromium since an RSL was not available. The TECs are concentrations below which adverse effects are not expected to occur (MacDonald et al. 2000). Adverse effects, in this case, refer to the effects to benthic macroinvertebrate species only (WDNR 2003). The CBSQGs are considered protective of human health and wildlife except where bioaccumulative or carcinogenic organic chemicals, such as PCBs or methylmercury, are involved. In these cases, in addition to the CBSQGs, other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue-residue guidelines should be used to assess direct toxicity and food chain effects (WDNR 2003). In addition, sample results were compared to data from MBK 1.6, the background site. The following graphs and associated charts follow the sediment data through recent years. There are some omissions in the charts to be noted:

- MBK 1.6 data is shown in the graphs as a bar; this bar symbolizes only the data from June 2022.
- Blanks in the following charts (figures 6.2.2-6.2.8), signify the parameter was not analyzed in that year.
- Analysis of the 10/7/2020 samples was delayed due to budget issues; as a result, the metals samples were held beyond the analytical holding time and the results were not used.
- Strontium-89/90, and uranium isotopic analyses were requested for the November 2021 samples but were not conducted due to a laboratory error.
- The radiological results for the June 2022 samples have not yet been received from the laboratory.

Barium

Barium concentrations in sediment at EFK 23.4 were found to be greater than the concentration of the Mill Branch background station but much less than the Resident RSL THI=1 (15,000 mg/kg). The highest barium concentration at EFK 23.4 was 279 mg/kg. Barium forms insoluble salts with carbonate and sulfate in the environment. As such, it is not mobile and poses little risk. It is found in low levels in most terrestrial soils, but hazardous waste (HW) sites may have higher levels. Barium and barium compounds can be found at 798 of the 1,684 current or former NPL sites. Most naturally occurring barium compounds are not a health risk due to their low solubility in water (ATSDR 2007).

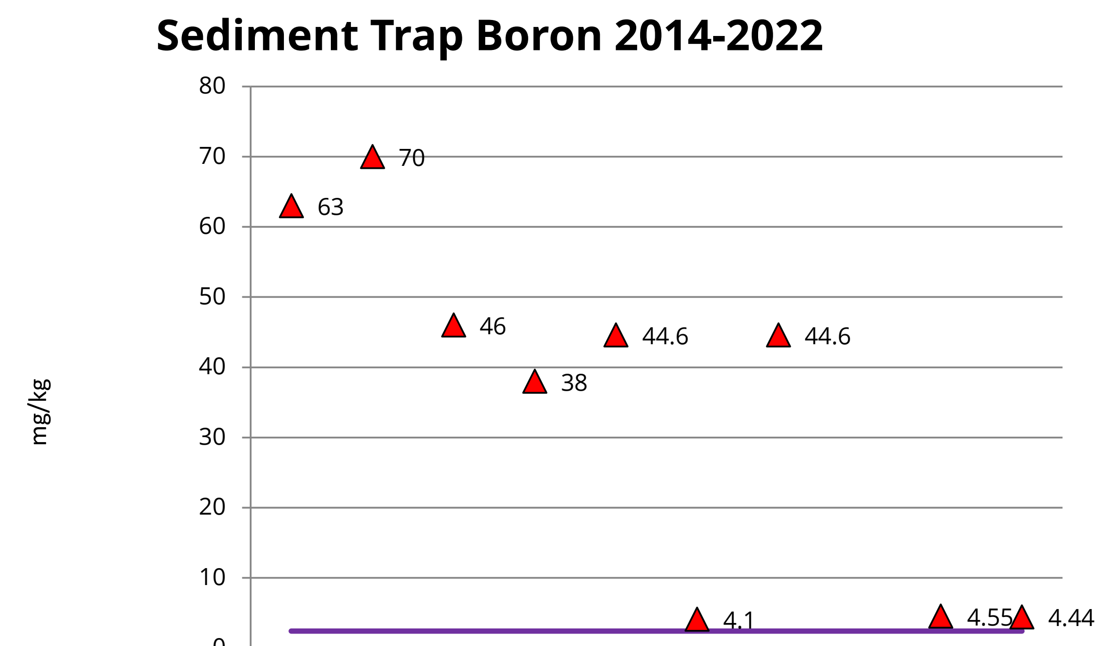


	2014	2015	2016	2017	Jan-18	Jul-18	2019	2020	2021	Jun-22
EFK 23.4	210	250	260	54	261	279	211		242	221
Background: Mill Branch (2022)	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8	88.8

Figure 6.2.2: Sediment Trap Barium: 2014-2022

Boron

Boron values were higher than background, but much lower than the Resident RSL THI=1 value of 16,000 mg/kg (Figure 6.2.3). The highest sediment boron figure of 70 mg/kg was obtained in 2015; the June 2022 figure is 4.44 mg/kg. Boron is the 51st most common element in the earth's crust. The average boron concentration of the entire earth's crust is 8 mg/kg; average soil concentrations are 26-33 mg/kg. Boron combines with oxygen in the environment to form borates. Borate minerals are mined, processed, and used for such purposes as: glass and ceramics, soaps, bleaches, fire retardants, and pesticides (ATSDR 2010). The isotope boron-10 is used as radiation shielding and for radioactivity control. Exposure to humans is primarily through ingestion of food and water or through pesticides or cosmetics containing boron. Adults consume on average about 1.0 to 1.28 mg of boron each day mainly from fruits and vegetables. Boron concentrations in natural soils can be as high as 300 mg/kg; the amounts found in East Fork Poplar Creek, although higher than background, are not out of the ordinary and do not pose a health risk to humans or wildlife.



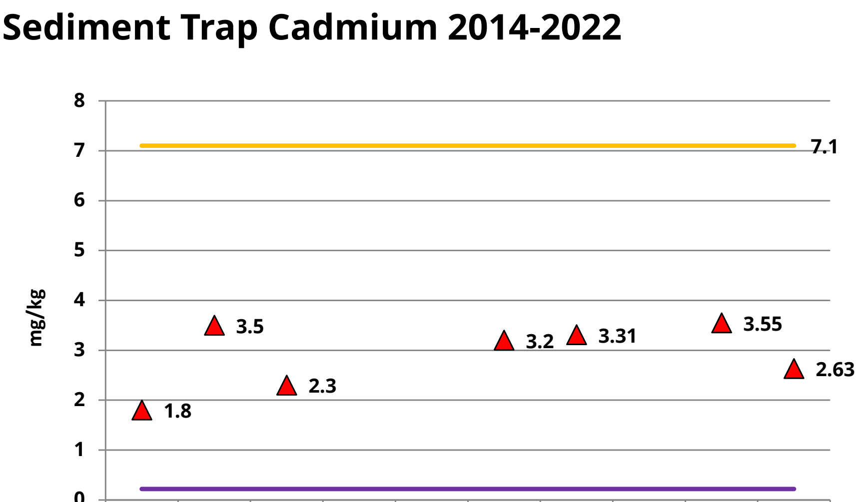
	2014	2015	2016	2017	Jan-18	Jul-18	2019	2020	2021	Jun-22
EFK 23.4	63	70	46	38	44.6	4.1	44.6		4.55	4.44
Background: Mill Branch (2022)	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42

▲ EFK 23.4 — Background: Mill Branch (2022)

Figure 6.2.3: Sediment Trap Boron: 2014-2022

Cadmium

Cadmium levels at EFK 23.4 were above background; but were less than the Resident RSL THI=1 (Figure 6.2.4). Cadmium is found in the earth's crust, usually associated with zinc, lead, and copper ores and is extracted during the processing of these other metals. Cadmium is predominantly used for batteries (83%), with other uses including pigments, coatings and platings, stabilizers for plastics, nonferrous alloys, and photovoltaic devices. Cadmium chloride and cadmium sulfate are soluble in water. Cadmium binds strongly to organic matter and can bioaccumulate in aquatic organisms and vegetation (ATSDR 2012).

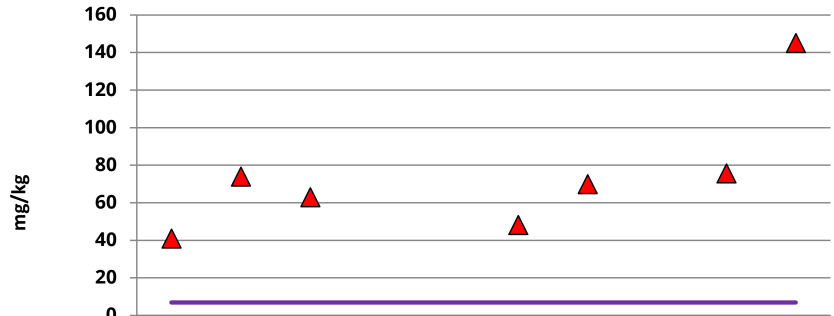


	2014	2015	2016	2017	Jan-18	Jul-18	2019	2020	2021	Jun-22
EFK 23.4	1.8	3.5	2.3			3.2	3.31		3.55	2.63
Background - Mill Branch (2022)	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217	0.217
RSL Resident THI=1.0	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1

Figure 6.2.4: Sediment Trap Cadmium: 2014-2021

Copper

Copper values for EFK 23.4 were consistently higher than background (Fig 6.2.5) but lower than the Resident RSL THI=1 (3130 mg/kg). In June 2022, copper increased to roughly twice the concentration of previous years; continued monitoring of copper is warranted. Copper binds strongly to organic matter and minerals and does not travel very far after release in the environment. However, in streams, it can travel far when bound to sediment particles that are capable of being suspended in the current. Copper is stable and does not break down in the environment; it can accumulate in biota where it is found in soils and sediments.

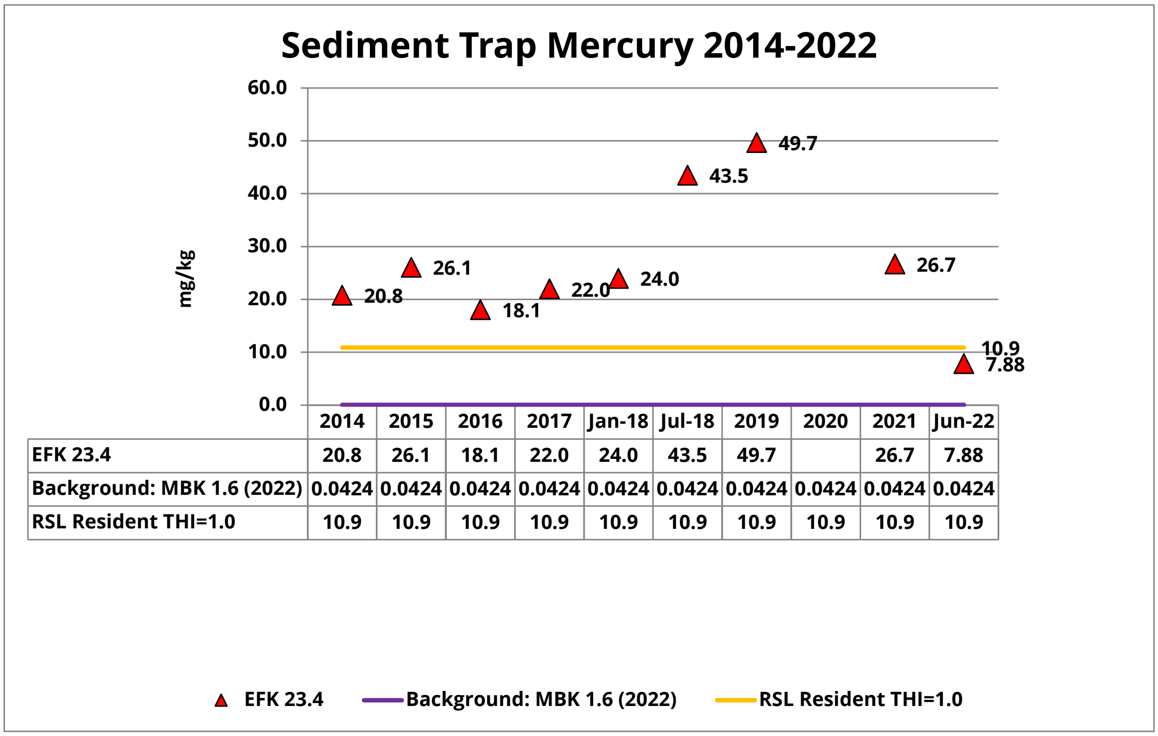


	2014	2015	2016	2017	Jan-18	Jul-18	2019	2020	2021	Jun-22
EFK 23.4	41	74	63			48.2	69.9		75.7	145
Background: MBK 1.6 (2022)	6.92	6.92	6.92	6.92	6.92	6.92	6.92	6.92	6.92	6.92

Figure 6.2.5: Sediment Trap Copper: 2014-2022

Mercury

Mercury values for EFK 23.4 were much higher than the Resident RSL THI=1 (10.9 mg/kg) with the exception of the June 2022 sample (Figure 6.2.6). Mercury occurs naturally in the environment as metallic mercury (elemental mercury), inorganic mercury (mercuric sulfide and mercuric chloride), and organic mercury (methylmercury). Large quantities (11 million kilograms) of elemental mercury were used at the Y-12 plant from 1950 to 1963 for a lithium isotope separation process. Loss of mercury to the air, soil and to EFPC are estimated to be 3% of the mercury used at the site. Mercury continues to be released to the creek from contaminated soil and groundwater sources at Y-12 (Brooks and Southworth 2011). Anthropogenic releases of mercury are predominantly emissions to the air from fossil fuel combustion, mining, and smelting. Solid waste incinerators also contribute releases of mercury. A smaller fraction of the anthropogenic contribution is agricultural mercury-containing fungicides used up until the 1970's and municipal solid waste containing old batteries, electrical switches, and thermometers. Methylmercury is a major health concern because it accumulates in fish and aquatic mammals to a great extent. If elemental mercury is present, bacteria and fungi produce most of the methylmercury in the environment by the process of methylation (ATSDR, 1999).

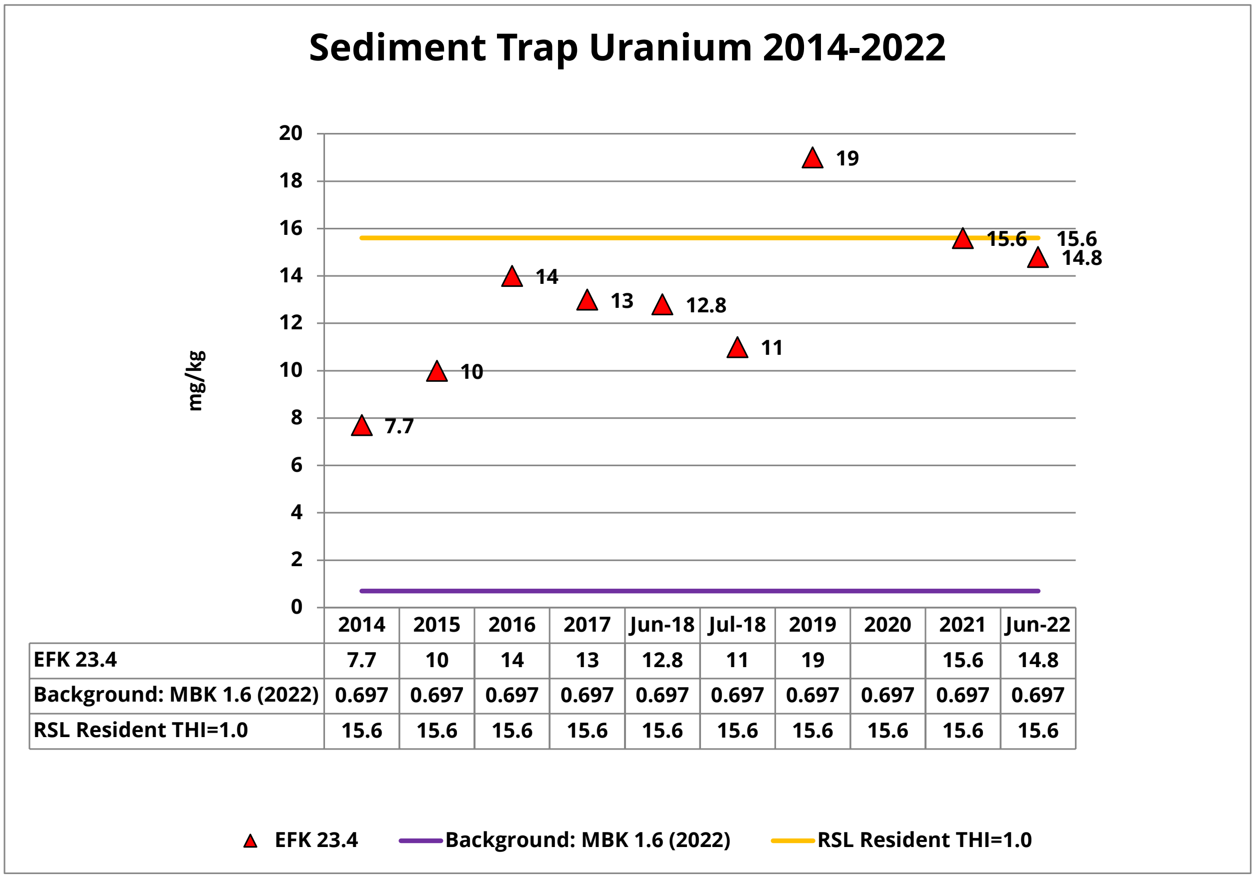


	2014	2015	2016	2017	Jan-18	Jul-18	2019	2020	2021	Jun-22
EFK 23.4	20.8	26.1	18.1	22.0	24.0	43.5	49.7		26.7	7.88
Background: MBK 1.6 (2022)	0.0424	0.0424	0.0424	0.0424	0.0424	0.0424	0.0424	0.0424	0.0424	0.0424
RSL Resident THI=1.0	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9

Figure 6.2.6: Sediment Trap Mercury: 2014-2022

Uranium

Uranium values were greater than background at EFK 23.4 from 2014-2022 (Figure 6.2.7). The uranium concentration in 2019 (19 mg/kg) exceeded the Resident RSL THI=1 (15.6 mg/kg). Uranium is a dense, silver-white, radioactive metal in its pure state. It is found in the environment in rocks, soil, water, and air in very small amounts. Phosphate fertilizers usually contain considerable amounts of uranium due to the materials from which they are made. Mining and erosion from mine tailings can result in increased amounts of uranium in the environment. Uranium became more prevalent in the environment with the development of nuclear energy applications, such as nuclear power plants and weaponry. Exposure to small amounts of natural uranium is not particularly dangerous. People who are exposed to high amounts of uranium, particularly enriched uranium, have a chance of developing cancer. Nuclear power plant accidents can result in the release of enriched uranium to the environment.

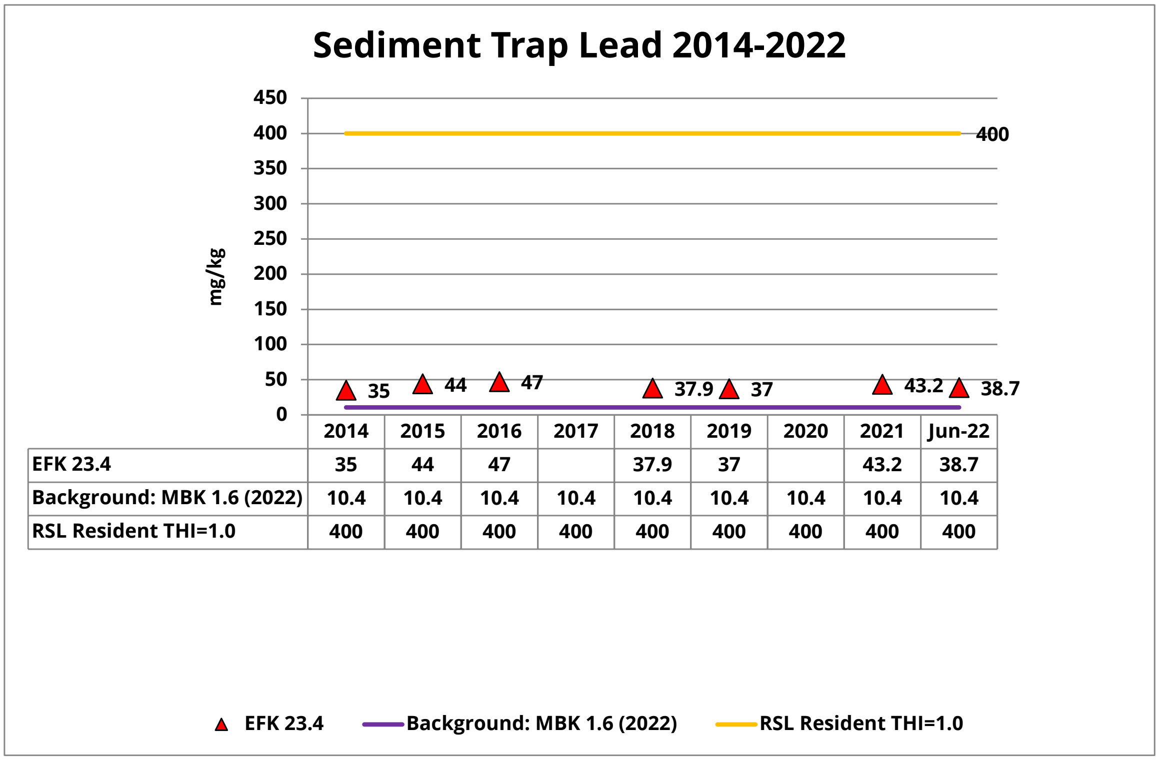


	2014	2015	2016	2017	Jun-18	Jul-18	2019	2020	2021	Jun-22
EFK 23.4	7.7	10	14	13	12.8	11	19		15.6	14.8
Background: MBK 1.6 (2022)	0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697	0.697
RSL Resident THI=1.0	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6

Figure 6.2.7: Sediment Trap Uranium: 2014-2022

Lead

Lead concentrations in the sediment samples from EFK 23.4 were higher than background but less than the Resident RSL THI=1 (Figure 6.2.8). Lead does not degrade in the environment and can take several chemical forms. Lead is constantly cycling between air, water, and soil/sediment by natural physical and chemical processes. The largest source of lead found in soils not impacted by other means is by atmospheric deposition. Soils and sediments serve as environmental sinks for lead, which is adsorbed strongly to most soils and sediments (ATSDR 2020).



	2014	2015	2016	2017	2018	2019	2020	2021	Jun-22
EFK 23.4	35	44	47		37.9	37		43.2	38.7
Background: MBK 1.6 (2022)	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
RSL Resident THI=1.0	400	400	400	400	400	400	400	400	400

Figure 6.2.8: Sediment Trap Lead: 2014-2022

Other Metals

The arsenic data from June 2022 were J values for both EFK 23.4 and background; a J value indicates that the result is less than the method quantitation limit (MQL) but greater than or equal to the minimum detection limit (MDL), and the concentration is an approximate value. The beryllium concentration at EFK 23.4 (0.610 mg/kg) was similar to that of the background site, MBK 1.6 (0.620 mg/kg). These beryllium figures are much less than the Resident RSL THI=1 (160 mg/kg). There is not an RSL specific for total chromium, so the CBSQGs were used for comparison to the sediment chromium data. All of the total chromium data from 2014-2022 (range 6 to 36 mg/kg) were less than the TEC (43 mg/kg). When a metal is at a concentration below the TEC, it is unlikely that it is adversely affecting stream organisms that inhabit sediments. Nickel concentrations in the sediment samples collected at EFK 23.4 were about twice background in most cases, but these sediment nickel concentrations (6.3 to 32 mg/kg) were much less than the Resident RSL THI=1 for Nickel, soluble salts (1500 mg/kg). Selenium data were all less than the minimum detection limit. Although the zinc concentration at EFK 23.4 (539 mg/kg) was much higher than background (22.8 mg/kg), it was much lower than the Resident RSL THI=1 (23,000 mg/kg).

Gross Alpha

Gross alpha activity was greater than background in the sediment trap samples in most years but was less than background in February 2021 and in July 2018 (Figure 6.2.9). The background figure from MBK 1.6 (4.12 pCi/g) is from November 2021. The June 2022 results have not yet been received from the laboratory.

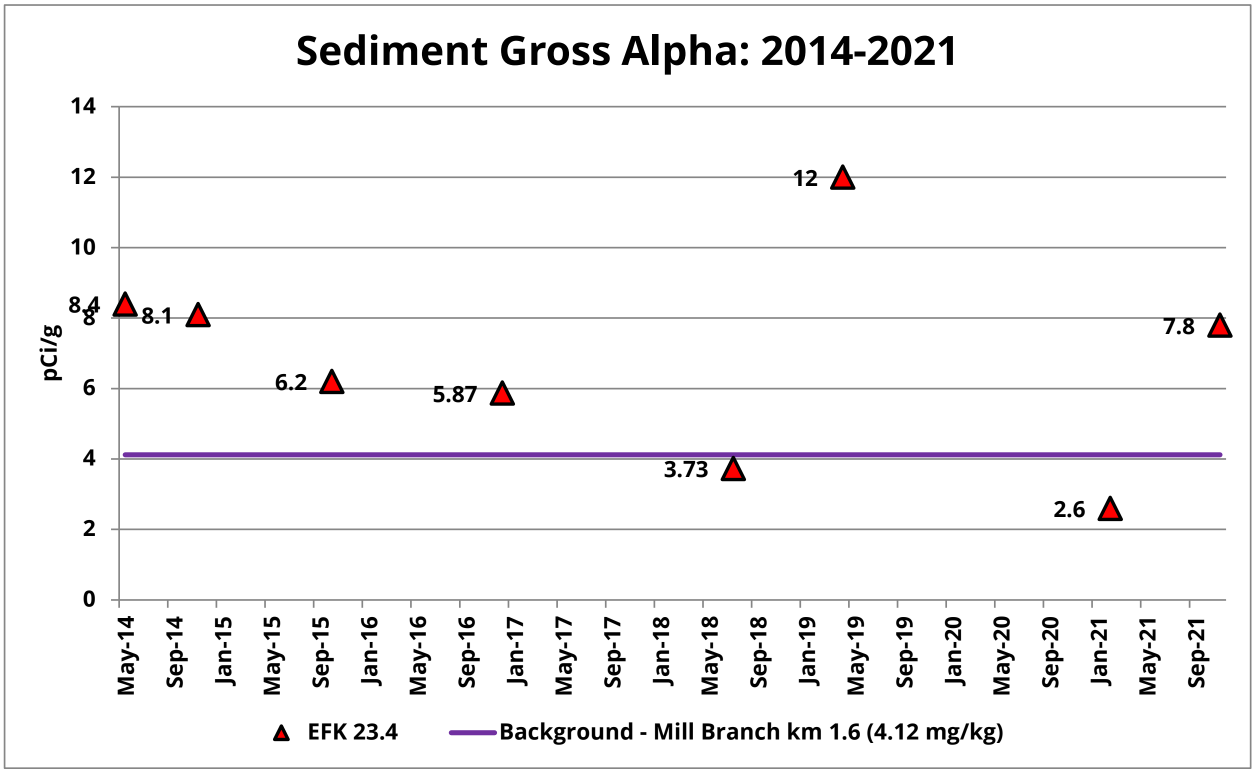


Figure 6.2.9: Sediment Trap Gross Alpha

Gross Beta

Gross beta activity was greater than background in the sediment trap samples (Figure 6.2.10). Both the U-238 and U-235 decay series produce several beta-emitting daughter nuclides with very short half-lives, (e.g., bismuth-214 and lead-214) and may be causing the elevated beta radioactivity in suspended sediment at EFK 23.4. The background level from MBK 1.6 (4.59 pCi/g) is from November 2021. The June 2022 results have not yet been received from the laboratory.

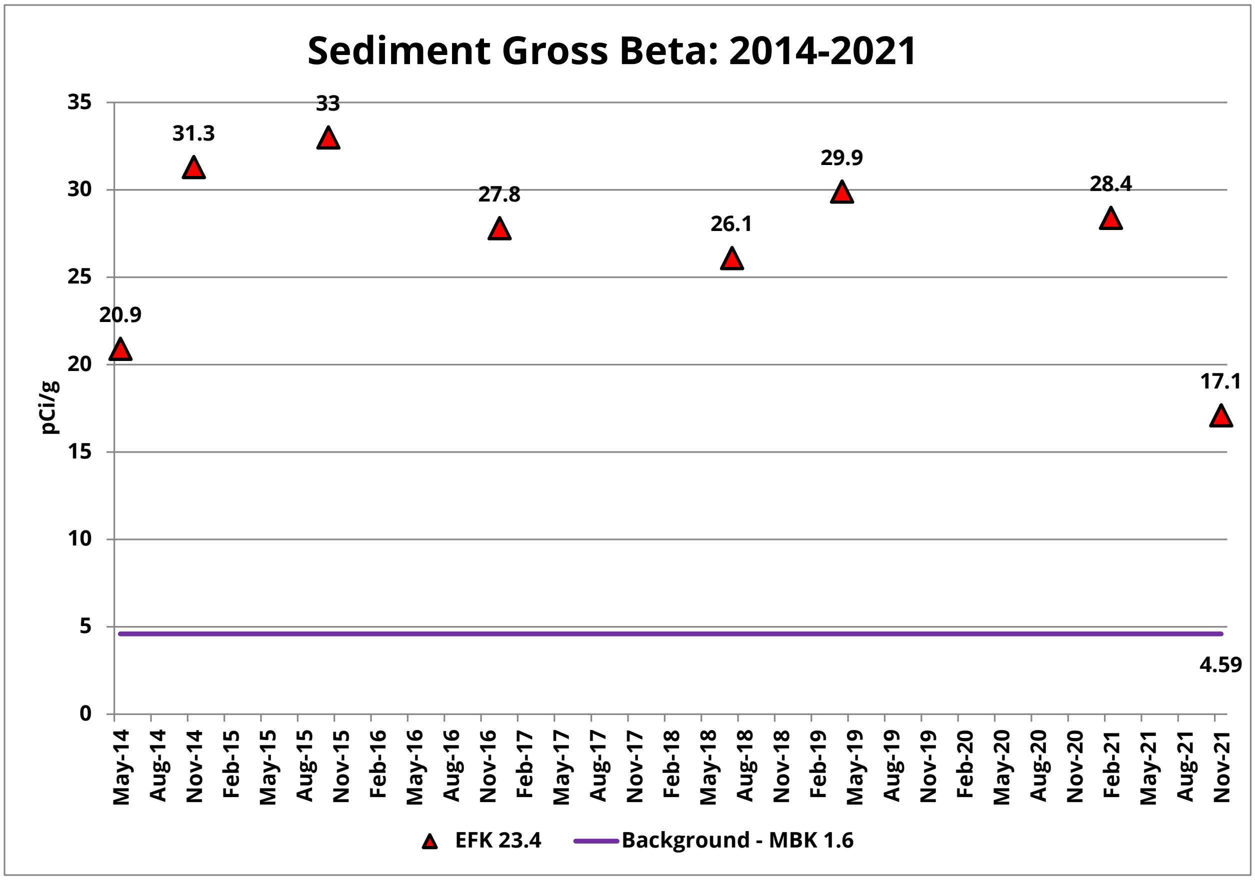


Figure 6.2.10: Sediment Trap Gross Beta

Uranium Isotopic and Strontium 89,90

Strontium-89/90 (Sr-89/90), and uranium (U) isotopic analyses were requested for the November 2021 samples but were not conducted due to a laboratory error. Unfortunately, due to this laboratory error, there are no data to discuss in terms of uranium and strontium isotopes.

Gamma Radionuclides

Some naturally occurring gamma-emitting radionuclides were detected. These radioisotopes, such as bismuth-214 (Bi-214), potassium-40 (K-40), lead-212 (PB-212) and others had similar levels of gamma radioactivity as did the background station, MBK 1.6.

6.2.8 Conclusions

The analysis of sediment collected from the EFK 23.4 indicates metals contamination at EFK 23.4 where mercury concentrations were higher than the Resident RSL THI=1. The uranium concentration was higher than the Resident RSL THI=1 in 2019. Other metals concentrations were above background but below the resident RSL THI=1 concentrations. EFK 23.4 had levels of gross alpha and beta radioactivity that were above background in the trapped sediment samples collected. Gamma radioactivity is not a concern; some naturally occurring gamma radionuclides were detected and their activity was similar to the background site.

6.2.9 Recommendations

Sediment traps capture suspended sediments that are being carried by the stream. Analysis of the sediments collected in this manner gives an idea of what has been travelling down the stream in the period that the trap was deployed. Sediment traps provide an intermediary form of information between sediment grab sampling and surface water sampling. It is the purpose of this project to stay abreast of the quality of sediment being transported in the ORR exit pathway streams. The TDEC DoR-OR trapped sediment project is needed to provide this information. In the coming years, it is anticipated there will be many D&D projects as well as construction projects in the upper EFPC watershed. To provide ample information about the EFPC in the years ahead, the trapped sediment project should be continued and funded as necessary.

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7.0 STORM WATER / WATER DISCHARGE MONITORING

7.1 ACCUMULATED WATER DISCHARGES

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. 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, the number of CERCLA regulated sites as listed by DOE include more than 400 sites at ETTP, more than 300 sites at ORNL, more than 100 sites at Y-12, and at least eight (8) sites off the ORR. Since June 2017, the following RA projects have been ongoing at the three major operating sites on the ORR:

1. An estimated 12,500 yd^3 of contaminated soil removal at ETTP.
2. A soils excavation projected estimated to be greater than 80,000 yd^3 at Y-12.
3. A soil excavation project estimated to be greater than 100,000 yd^3 at ORNL.

These RA 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 more than 54 inches of precipitation, on average, per year. 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.

Beginning in 2018, DOE created and operated treatment systems for the remediation of accumulated water. TDEC DoR-OR, in cooperation with DOE and its contractors, conduct random oversight of sampling activities at the treatment systems. In addition, TDEC DoR-OR reviews the analytical results provided by DOE and does periodic sampling at the treatment systems. The overall goal of the program is to monitor DOE efforts in preventing contamination from leaving the reservation (ORR).

7.1.2 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 then disperse contaminants into the environment.

- D&D projects can release diverse contaminants that can be transported beyond the boundaries of the ORR through water pathways.

7.1.3 Goals

The goals of this project are:

- Obtain and review pertinent sampling data to evaluate DOE's treatment system to ensure compliance with negotiated criteria and to use the sampling data to provide input for future cleanup decisions.
- Review and comment on DOE documents related to D&D work.
- Collect co-samples at treatment systems to monitor sampling results.
- Observe D&D and RAs to ensure compliance with TDEC, EPA, and DOE negotiated and agreed-to-discharge criteria.
- Observe sampling events to ensure compliance with SOPs.

7.1.4 Scope

The scope of the accumulated water discharge project includes monitoring of sites with D&D and/or RA operations. Sites that are commonly monitored include (but are not limited to) the Y-12 Outfall-200 Mercury Treatment Facility (OF-200 MTF) headworks construction area. Sampling events by DOE or their subcontractors are observed to ensure that proper sampling methods are used. If a contractor's standard operating procedures (SOPs) are released to TDEC DoR-OR, the sampling processes are compared to those SOPs. Otherwise, observations are compared to industry or EPA standards. At the Y-12 OF-200 MTF, TDEC DoR-OR collects co-samples with DOE contractors to confirm that relevant treatment and discharge criteria are met.

7.1.5 Methods, Materials, Metrics

Sampling events were scheduled when a treatment system had accumulated enough treated water for release. DOE contractors notified TDEC DoR-OR staff when sampling events were scheduled. If available, TDEC DoR-OR staff members completed biased oversight of the sampling events using the Edgewater Technical Associates, *Outfall 200 Mercury Treatment Facility Liquid Waste Sampling* guidance document as reference.

Upon notification of a sampling event, staff members gathered necessary Personal Protective Equipment (PPE) and proceeded to the sampling area. Each sampling event was observed as close to the sampling point as possible, while avoiding any interference with the sampling process.

For treatment systems with tanks as water containers, observation was made from the catwalk if possible. Following the guidelines of the *Outfall 200 Mercury Treatment Facility Liquid Waste Sampling* document, observers noted the order in which samples were taken, the sampling procedures, the sampling tools and equipment used, and disposal of excess liquids.

If two TDEC DoR-OR staff members were present for the oversight, one staff member observed the sampling, while the other staff member observed the transport, labeling, bagging, and storage of the samples. If any action was observed to be in violation of the reference document, it was noted in the field book and a discussion was held with the field samplers before further action was taken.

If co-samples were to be collected, sampling followed the guidelines set forth in the TDEC, DWR, Quality System SOPs for *Chemical and Bacteriological Sampling of Surface Water, DWR-WQPP-01-QSSOP-Chem-Bact-082918*. Samples were collected at the same location and time and followed the same procedure as the DOE contractor's samples.

Analytes chosen for each treatment system were based on COCs listed in the applicable ROD, Comprehensive Monitoring Plan (CMP), or the Storm Water Pollution Prevention Plan (SWPPP). Analytical results were compared to the National Pollution Elimination System (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 was a long-term project, trends in concentrations were reviewed over time for evaluation.

7.1.6 Deviations from the Plan

There were no deviations from the plan; however, significant focus on the Outfall (OF) 200 MTF during FY2022 was triggered as a result of increasing and sustained high mercury concentrations documented by DOE's contractor in water samples at the construction site beginning April through June of 2021. Mercury concentrations ranged from around 1000 parts per trillion (ppt) to over 140,000 ppt (1000 ng/L to > 140,000 ng/L) during this time. The average mercury concentration in this time period was 7010.3 ppt, and the median concentration was 1060 ppt. Prior to discharge from the OF 200 MTF headworks construction site, water was collected and treated. Between April and June 2021, mercury concentrations of the treated water ranged from 38 ppt to over 9000 ppt. Average mercury concentrations of treated and discharged water during this period were 1650.6 ppt, and the median mercury concentration was 998 ppt. For reference, the UEFPC Phase I ROD goal for discharges to EFPC passing through Station 17, just downstream from OF 200, is 200 ng/L or 200 ppt.

7.1.7 Results and Analysis

Activities as part of the Accumulated Water project in FY2022 consisted of generating the Environmental Assessment Report of the Mercury Treatment Facility sampling program and collecting co-samples to confirm the quality of DOE results.

TDEC DoR-OR conducted this study in order to ensure the DOE activities employed sound environmental management practices to assure compliance with environmental program requirements. The assessment report reviewed facility sampling from February 27, 2020, through March 8, 2022, and conducted oversight of five sample collection events. The assessment included:

- Attended the opening meeting with the DOE subcontractor performing the sampling procedure, Edgewater Technical Associates (Edgewater), to define expectations and roles in the oversight program.

- Detailed review of the *Edgewater Technical Associates Outfall 200 Mercury Treatment Facility Liquid Waste Sampling.*
- TDEC DoR-OR conducted random oversight of DOE sampling events at the OF-200 MTF. Oversight of sampling events included several tasks: ensuring the sampler was prepared with certified clean sample containers, labels, and all necessary equipment and supplies; monitoring if actions were taken to prevent cross-contamination and that samples were collected using the appropriate method as determined by the SOP; observing field quality control and blank sampling; and, observing completion of the chain of custody (COC) and relinquishing of samples to the transporter.
- TDEC DoR-OR oversaw five (5) sampling events conducted by Edgewater at the treatment system from August 9 through December 27, 2021. TDEC DoR-OR personnel observed the standard metal sampling methods and collection at each location. Sampling locations included an untreated water tank and two treated water tanks (one of which was empty during all oversight observations).
- Inspection of the COC and field logbook. The entries in the logbook were reviewed against the requirements of the SOP documentation.
- Attended the closing meeting with Edgewater to discuss observations made by TDEC DoR-OR.

In addition to the Assessment Report and to ensure the quality of DOE's results, TDEC DoR-OR personnel collected co-samples from two frac tanks during the sampling event on August 31, 2021. TDEC DoR-OR followed the same procedure utilized by Edgewater. Samples were shipped to the TDH-NEL for analysis. The results are summarized in Table 7.1.1, below. In August 2021, mercury (Hg) concentrations in untreated water samples were much lower, and mercury in treated water prior to discharge was not detected. Mercury concentrations in both treated and untreated water remained low and within typical ranges, hovering around the 200 ng/L (200 ppt) goal defined in the UEFPC Phase I ROD, through the remainder of the 2021 calendar year.

Table 7.1.1

Location	Date	Analysis	Result (ng/L or ppt)	Sampler
Tank 4-A325605 (untreated)	8/30/2021	Hg	317	TDEC DoR-OR
Tank 5-A3911(treated)	8/30/2021	Hg	Non-Detect	TDEC DoR-OR

Unfortunately, in early September 2021 and again in December 2021, water discharges into East Fork Poplar Creek associated with the OF 200 MTF construction were paused as a result of ongoing issues with sediment build-up in the settling tanks used for water treatment prior to discharge. In response to these issues, TDEC DoR-OR observed that DOE built a retaining wall and added pumps to better manage the water accumulating in the OF 200 MTF dig site, and filter socks were added into the treatment chain to remove sediment prior to collecting water in the settling tanks. Vacuum trucks were utilized on a more frequent schedule moving forward, removing sediment every couple of months, to better manage sediment accumulation in the tanks and improve water management and treatment efficiency.

7.1.8 Conclusions

The oversight of sampling activities associated with the Mercury Treatment Facility confirm the samples were collected following the procedure established by DOE subcontractor. The Environmental Assessment Report concluded that the operations of DOE, in relation to the sampling of the Mercury Treatment Facility, were conducted following the requirements in the *Edgewater Technical Associates Outfall 200 Mercury Treatment Facility Liquid Waste Sampling* as it was presented to TDEC DoR-OR. The assessment found that the DOE subcontractor had a concise and in-depth SOP which encompassed the measures required for accurate results.

7.1.9 Recommendations

As remedial activities continue across the ORR, the need for water treatment systems will increase. TDEC DoR-OR recommends continued oversight of treatment systems and water management protocols, and monitoring of trends in effluent concentrations on the ORR.

7.1.10 References

ETA. *Outfall 200 Mercury Treatment Facility Liquid Waste Sampling*. Edgewater Technical Associates. Oak Ridge, TN. ETA-OF200MTF-001.

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

TDEC. 2018. *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water*. DWR-WQP-P-01-QSSOP-Chem-Bact-082918. Tennessee Department of Environment and Conservation, Division of Water Resources (TDEC-DWR). Knoxville, TN. https://www.tn.gov/content/dam/tn/environment/water/policy-and-guidance/DWR-WQP-P-01-QSSOP-Chem-Bact-082918.pdf

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. Nashville, TN. https://www.epa.gov/sites/default/files/2014-12/documents/tn-chapter1200-4-3.pdf

TDEC. 2022. *Environmental Assessment Report of the Sampling Program at the Outfall 200*

Mercury Treatment Facility at Y-12. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office (TDEC DoR-OR). Oak Ridge, Tennessee.

UCOR. 2018. *Surface Water Sampling, Manual and Automated*. SOW-MS-PROCES2203-1278. United Clean up Oak Ridge LLC. Oak Ridge, TN.

7.2 RAIN EVENT

7.2.1 Background

In general, rainwater does not exhibit static flow behavior. It accumulates, pools, and makes its way into basements, basins, and soil excavations (from decontamination and decommissioning (D&D)) and remedial action (RA) activity sites. Water that enters an abandoned building has the potential to transport contaminants beyond the confines of the building.

As of November 2017, the number of CERCLA regulated sites as listed by DOE include 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.

DOE collects storm water samples for compliance with the NPDES permit at the selected discharge points across the ORR. The role of TDEC DoR-OR in this program is to provide oversight of sampling events related to discharges and to establish an existing baseline before remedial actions begin.

7.2.2 Problem Statements

The TDEC DoR-OR Rain Event oversight focuses on the following problems:

- During and following a rain event, contamination from legacy and ongoing D&D and RAs can be disturbed and transported beyond the physical boundaries of the ORR.
- Each D&D project can develop new pathways for contamination to be released into the environment.

7.2.3 Goals

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

- 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.
- Sample to create a baseline before D&D and RAs are conducted.

7.2.4 Scope

The scope of the Rain Event Monitoring is to observe DOE sampling procedures at selected discharge locations and to create a baseline before D&D and RAs have begun. If possible, samples will be collected over the course of a year. Sample analysis will be aligned with the constituents of concern for buildings undergoing D&D or RA.

7.2.5 Methods, Materials, Metrics

Analytical results will be compared to NPDES permit discharge limits, DOE, EPA and TDEC agreed-upon-limits or water quality standards of the receiving body of water where applicable. If a sampled area is comprised of long-term outfall sample points, trends in concentrations over time will be reviewed for future sampling or observations. The outfalls selected as sampling locations are based on current DOE D&D activities. If sampling is being conducted to create a baseline, a sample should be taken monthly for a year. If a year timeframe is not available, an attempt will be made to sample twelve (12) times in the timeframe available.

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-Q1-QSSOPCHEM-BACT-082918. If possible, TDEC DoR-OR samples will be collected as co-samples with DOE activities. Analytes will be determined for each sampling site based on COCs as listed in the Comprehensive Monitoring Plan or DOE's SWPPP.

7.2.6 Deviations from the Plan

There was no opportunity to collect co-samples in conjunction with DOE or to observe DOE sampling procedures. In addition, DOE analytical results were not available for analysis and comparison at the time of this report.

7.2.7 Results and Analysis

Following heavy rain events, samples were collected at five (5) outfalls across Y-12 and at one manhole at Building 9213 (9213 F5403). These locations were chosen due to associated future D&D work of buildings near these outfalls. Samples were collected over two sampling events on August 16 and 31, 2021. Samples were sent to the TDH-NEL for metals and radiological analysis. August 2021 results are presented in Tables 7.2.1 Outfall Metals Results, 7.2.2 Outfall Radiological Results, 7.2.3 Building 9213 Manhole F5403 Metals Results, and 7.2.4 Building 9213 Manhole Radiological Results.

Table 7.2.1 Metals Results (results in µg/L)

Date	Outfall	Mercury	Low-Level Mercury	Beryllium	Uranium
8/16/2021	Y-12 055	0.0860 J	--	< 0.165 U	2.44
8/16/2021	Y-12 125	0.262	--	< 0.165 U	0.181 J
8/31/2021	Y-12 063	6.94 D	--	0.267 J	8.3
8/31/2021	Y-12 064	< 0.0405 U	0.0089	< 0.165 U	0.501 J

Note: U = Result is less than Method Detection Limit
J = Result is less than the Method Quantification Limit but greater than or equal to Method Detection Limit and the concentration is an approximate value
D = Result is obtained from the analysis of a dilution.

Table 7.2.2 Radiological Results (results in pCi/L)

Date	Outfall	Gross Alpha	Gross Beta	U-234	U-235	U-238	Pu-238	Pu-239/240	Tc-99	Th-228	Th-232	Th-230
8/16/2021	Y-12 055	2.9	-0.5	2.89	0.4	1.15	--	--	--	--	--	--
8/16/2021	Y-12 125	--	--	1.78	0.44	0.57	0.05	0.05	-0.28	0.2	0.05	0.36
8/31/2021	Y-12 063	2.1	4	2.57	0.2	1.22	--	--	--	--	--	--
8/31/2021	Y-12 064	0.54	0.6	0.4	0.088	0.36	--	--	--	--	--	--
8/31/2021	Y-12 134	--	--	0.43	0.055	0.153	0.05	0.06	-0.12	-0.02	0.05	0.16

Table 7.2.3 Building 9213 Manhole F5403 Metals Results (results in µg/L)

Date	Outfall	Mercury	Uranium	Arsenic	Cadmium	Chromium	Copper	Lead	Manganese
8/31/2021	9213 F5403	< 0.0405 U	0.762 J	< 0.607 U	< 0.101 U	< 3.49 U	3.79	1.14	48.4

Note: U = Result is less than Method Detection Limit
J = Result is less than the Method Quantification Limit but greater than or equal to Method Detection Limit and the concentration is an approximate value

Table 7.2.4 Building 9213 Radiological Results

Date	Outfall	Bi-214	Pb-214	Gross Alpha	Gross Beta	U-234	U-235	U-238	Pu-238	Pu-239/240
8/31/2021	9213 F5403	--	--	1.99	0.6	3.04	0.082	0.4	0.15	0.19
*3/23/2021	9213 MH1	536	516	10.19	2	7.3	0.03	0.62	-0.04	0.026
*3/23/2021	9213 MH2	64	55	48.1	6.9	48.4	1.43	5.51	0.062	0.007

*Note: These samples were collected during FY2021 but are included here for comparison to the sample collected near Building 9213 in FY2022.

On March 23, 2021, TDEC DoR-OR collected samples from manholes at Building 9213 in an effort to establish a baseline rain event at this location within Y-12. TDEC DoR-OR personnel developed nomenclature for the sample locations to be MH1 (Manhole 1) and MH2 (Manhole 2). From previous walkdowns of Building 9213, TDEC DoR-OR personnel observed these manholes to be holding water. UCOR radiological technicians were present, performing radiological surveys throughout the sampling event. The samples were sent to the TDH-NEL for gross alpha/beta, isotopic uranium, isotopic plutonium, and gamma spec analysis.

Results are presented in Table 7.2.4 for comparison along with the results for the sample collected from manhole F5403 near Building 9213 (9213 F5403) in FY2022.

Outfall 55 (Y-12055), Outfall 63 (Y-12063), and Outfall 64 (Y-12064) have been sampled by TDEC DoR-OR up to four (4) times since 2020 (from October 2020 to August 2021). These outfalls were consistently sampled for uranium and mercury metals, along with a radiological analysis which included gross alpha, gross beta, and uranium isotopes. The trends in concentration at each outfall are depicted in the Figure 7.2.1, below.

The mercury results below can be compared to the goals established by ROD for Phase I in the Upper East Fork Poplar Creek (UEFPC) (DOE, 2002). The ROD was prepared in accordance with requirements of CERCLA and agreed by DOE, TDEC, and EPA. The ROD established a goal of 200 ppt (or 0.2 ppb) of mercury in surface water for samples collected at Station 17. Station 17 is located downstream of the samples collected by TDEC DoR-OR at Outfalls 55, 63, and 54, and is the compliance point for surface water leaving the ORR. Only the sample collected at Outfall 63 on January 26, 2021, exceeded the goals established in the ROD, see Figure 7.2.1.

Metal Concentration (µg/L)	Radiological Contamination (pCi/L)

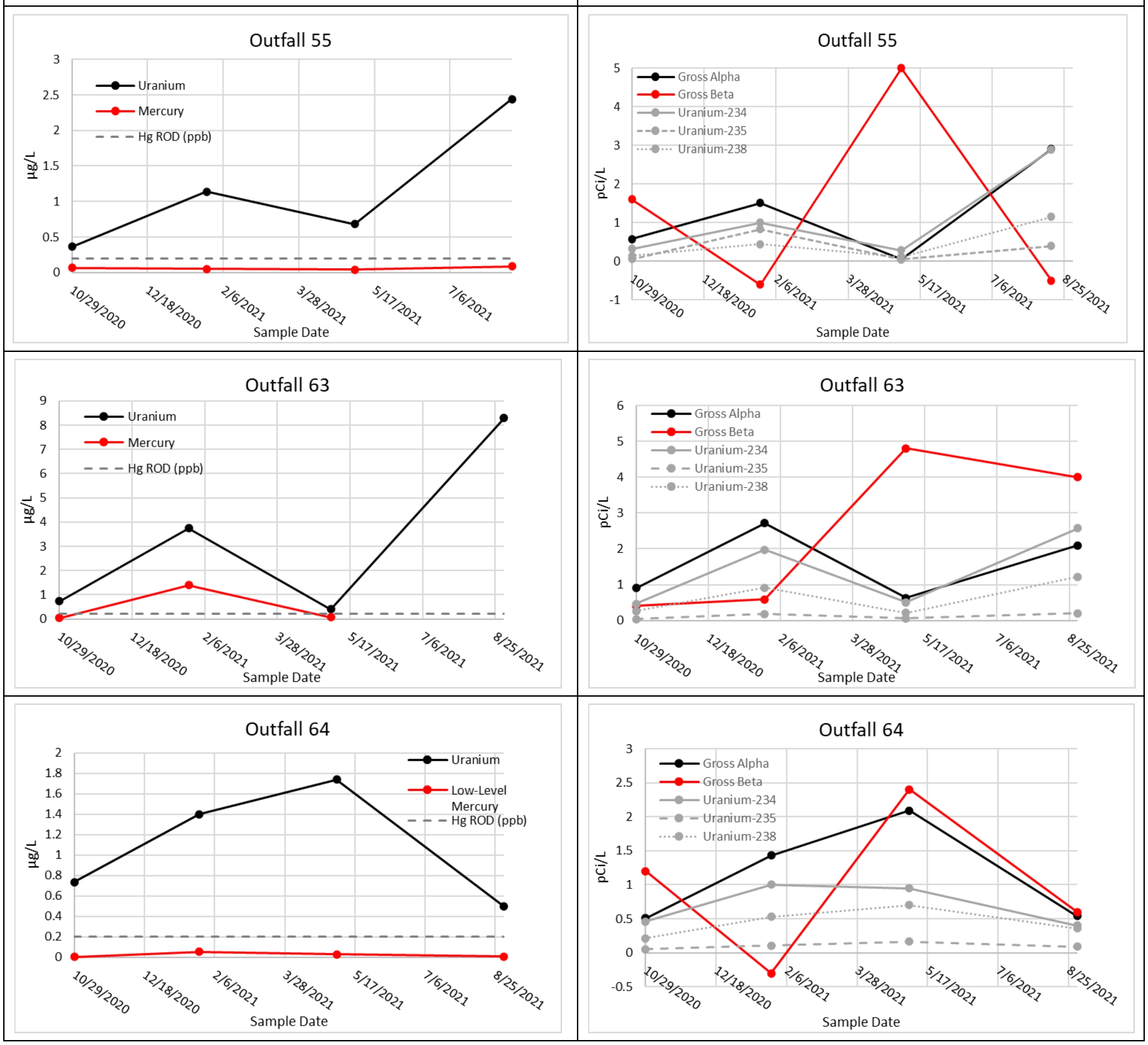

Figure 7.2.1 Trend Analysis of Metal Concentration and Radiological Contamination from DoR-OR Rain Event Sampling (2020 – 2021)

One additional TDEC DoR-OR sample can be compared to the mercury ROD goal, which is the sample collected at Outfall 125 on August 16, 2021. There is no historical data at this site, therefore a trend analysis could not be completed. The mercury concentration at Outfall 125 was measured at 0.262 µg/L, which is greater than the 0.2 ppb criteria established in the ROD.

7.2.8 Conclusions

TDEC DoR-OR collected storm water samples following rain events at several locations throughout Y-12. This effort will establish a baseline of the existing conditions prior to D&D activities at these locations. In addition, TDEC DoR-OR results are available to compare to DOE analytical results to confirm sound procedures are followed. The Rain Event monitoring program provides oversight to existing and future operations across the ORR.

7.2.9 Recommendations

As remedial activities continue and move to new locations on the ORR, there is the potential of a negative impact on the environment from rain events. TDEC DoR-OR recommends continued oversight of DOE CERCLA activities at Y-12 and ORNL where contaminants and contaminant mobility issues may be encountered.

7.2.10 References

DOE. 2002. *Record of Decision for Phase I Interim Source Control Actions in the Upper East Fork Poplar Creek Characterization Area, Oak Ridge, Tennessee*. US Department of Energy, Office of Environmental Management. Oak Ridge, Tennessee.

TDEC. 2018. *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water*. DWR-WQP-P-01-QSSOP-Chem-Bact-082918. Tennessee Department of Environment and Conservation, Division of Water Resources (TDEC-DWR). Knoxville, TN. https://www.tn.gov/content/dam/tn/environment/water/policy-and-guidance/DWR-WQP-P-01-QSSOP-Chem-Bact-082918.pdf

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8.0 SURFACE WATER MONITORING

8.1 AMBIENT SURFACE WATER PARAMETERS

8.1.1 Background

The ORR consists of three (3) major sites: ORNL, Y-12, and ETTP. Activities at these sites, both historically and at present, 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, 2021; 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 (i.e. specific conductivity, pH, temperature, and dissolved oxygen).

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 (CR). 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 CR, many ORR surface water exit-pathway streams that flow into the CR 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.

8.1.2 Problem Statements

ORR exit-pathway streams and the Clinch River (CR) 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, 2021), TDEC DoR-OR's Ambient Surface Water Parameters project complements DOE's project by helping to identify any shifts or changes in water quality parameters in three (3) ORR streams. An additional background stream was also measured for comparison to the selected ORR streams.

8.1.3 Goals

The goal of TDEC DoR-OR's Ambient Surface Water Parameters project was to measure surface water parameters in EFPC, Bear Creek (BC), and Mitchell Branch (MIK) 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. These releases can potentially impact surface water bodies. Mill Branch (MB) was also measured to serve as an offsite background stream. See Figure 8.1.1 and Table 8.1.1 below for sample locations.

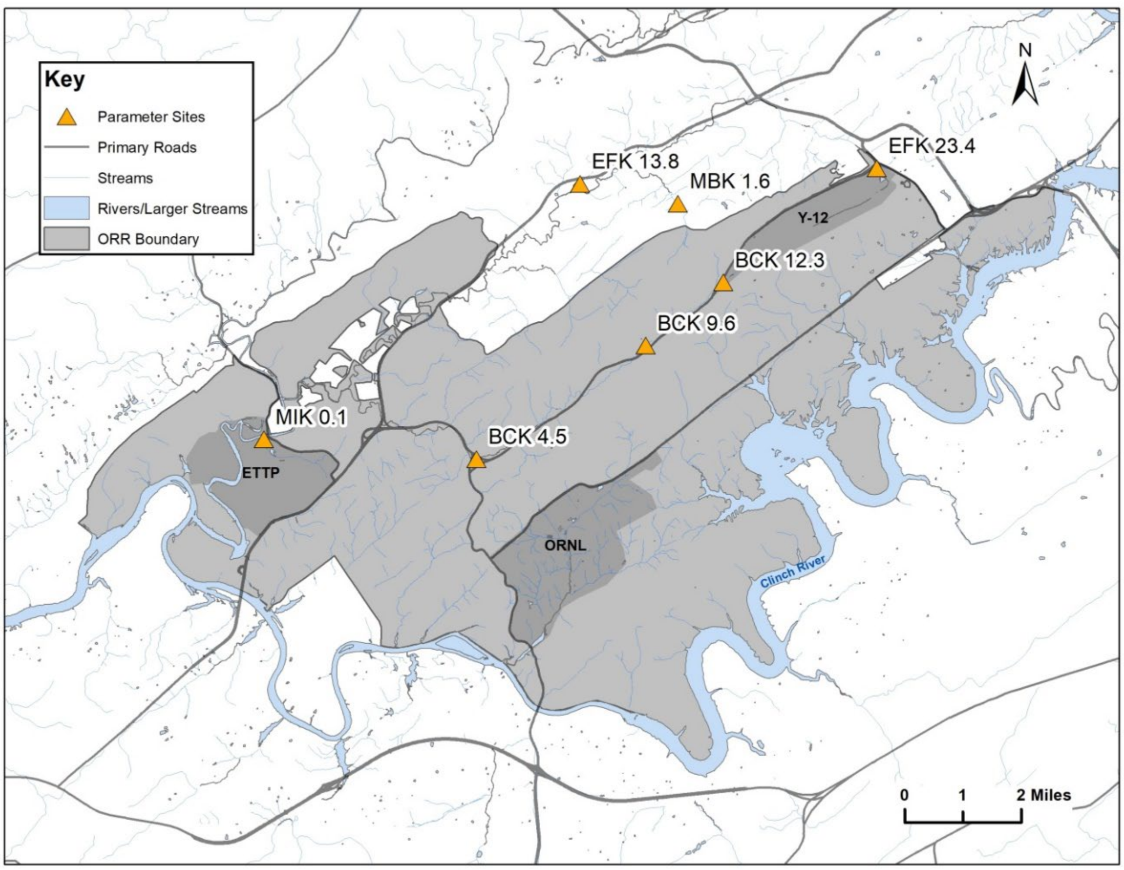

Figure 8.1.1: Map showing TDEC DoR-OR proposed surface water parameter sites

Table 8.1.1: Proposed site locations

DWR Name	Site Description	TDEC Site	Latitude	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 were accomplished by measuring and recording physical water parameters (e.g. conductivity, dissolved oxygen, pH, and temperature) at each site monthly.

8.1.4 Scope

This project was limited to the characterization of physical stream parameters of three (3) ORR streams (EFPC, BC, and MIK) and one (1) background stream (Mill Branch (MB)).

8.1.5 Methods, Materials, Metrics

Field Parameter Measurements

At each site, physical water parameters were measured and recorded. Physical parameters were measured using a multiple parameter water quality meter. Parameters of conductivity (µS/cm), dissolved oxygen (mg/L), pH, and temperature (°C) were recorded along with the time of each measurement. Measurements were taken in accordance with the Tennessee Department of Environment and Conservation Division of Water Resources (TDEC-DWR) Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water (TDEC, 2022).

Data Evaluation

Recorded measurements were stored in a database. Using R programming language, several statistical analyses were performed to better understand the results. Trend analyses were performed using linear regression to identify any increasing or decreasing trends in data. Basic descriptive statistics (mean, median, minimum, maximum, etc.) were also assessed.
The selected ORR streams were compared to MB using statistical approaches such as an analysis of variance (ANOVA) to see if they were significantly different in water parameters.

8.1.6 Deviations from the Plan

No deviations from the plan occurred.

8.1.7 Results and Analysis

Field parameters including conductivity, dissolved oxygen, pH, and temperature were collected monthly from the seven (7) monitoring locations (Figure 8.1.1). These data generally seemed to follow similar patterns over time for each respective parameter. However, a few monitoring locations had slight deviations for certain parameters. Significant differences among streams were analyzed and discussed below.

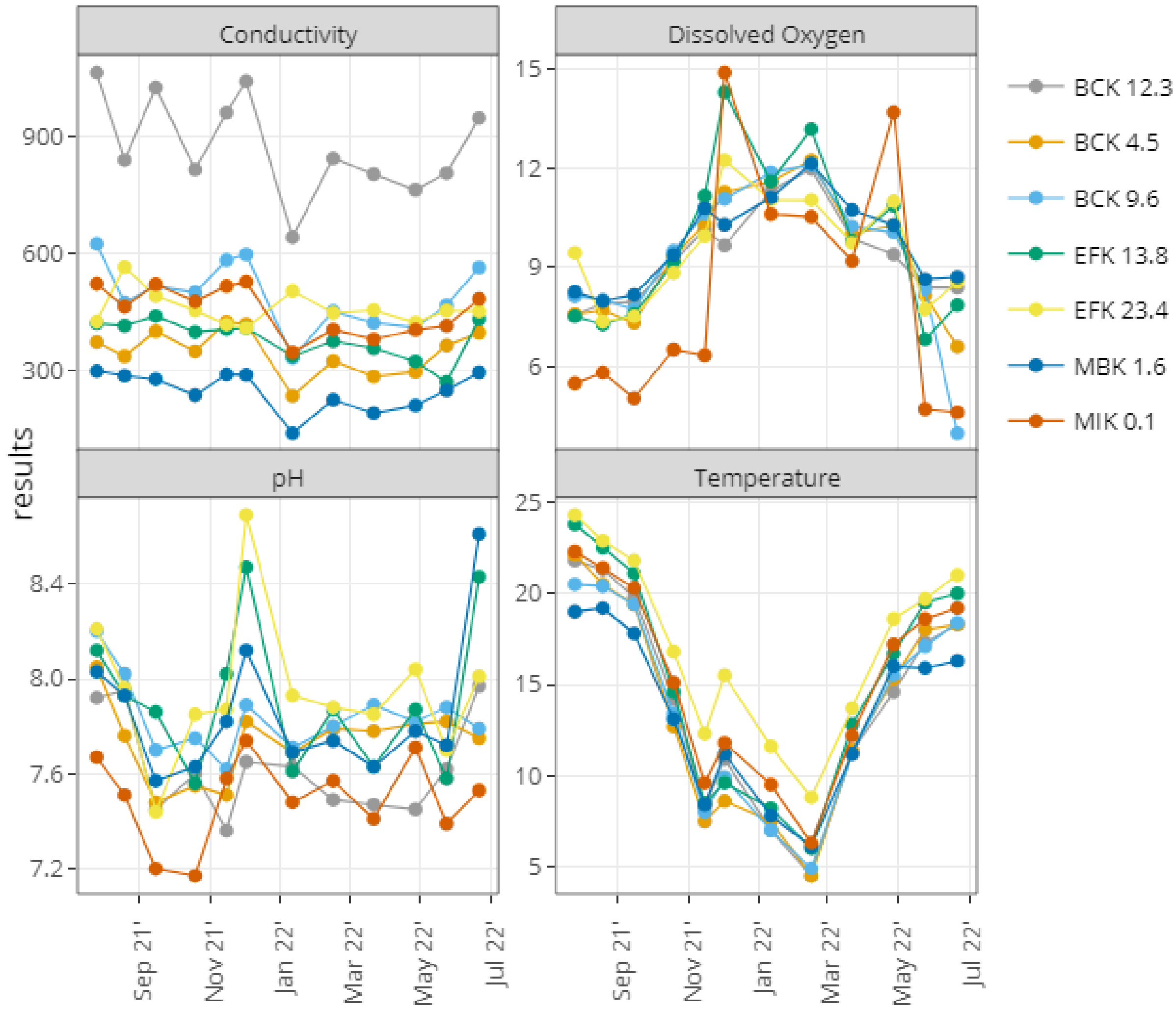

Figure 8.1.2: Field parameter results from July 2021 through June 2022. Units for conductivity, dissolved oxygen, pH, and temperature are µS/cm, mg/L, std. unit, and °C, respectively.

One of the field parameters with significant differences among streams was conductivity. Mean conductivity values from measurements collected July 2021 to June 2022 ranged from 882 to 249 µS/cm, among all of the monitoring sites. Bear Creek sites BCK 12.3 and BCK 9.6 had the highest mean conductivity values of 882 and 496 µS/cm, respectively. Further downstream, BCK 4.5 had a lower mean value of 351 µS/cm. On EFPC, site EFK 23.4, near the eastern border of Y-12, had a mean conductivity of 459 µS/cm. Downstream of EFK 23.4, site EFK 13.8 had a lower mean value of 382 µS/cm. The Mitchell Branch site MIK 0.1 at ETTP had a mean conductivity value of 456 µS/cm. As expected, Mill Branch (MBK 1.6) had the lowest conductivity among all streams measured with a mean value of 249 µS/cm.

An ANOVA was performed to determine if mean conductivity differed significantly among streams. Results from the ANOVA indicated statistically significant differences with $p < 0.05$. A post hoc Tukey test was performed to distinguish which monitoring sites were significantly different in conductivity. Results of the Tukey test indicated Bear Creek site BCK 12.3 was statistically significantly higher in conductivity than all other monitored sites with $p < 0.05$ (see Table 8.1.2). Similarly, Mill Branch (MBK 1.6) was found to be statistically significantly lower in conductivity than all other monitored sites with $p < 0.05$. These findings were consistent with historical comparisons of these streams.

Table 8.1.2: Results of Tukey comparison of means test for conductivity

Site	Mean Conductivity (µS/cm)
BCK 12.3*	881.6
BCK 9.6†	496.1
EFK 23.4†‡	458.8
MIK 0.1†‡	455.6
EFK 13.8‡§	382.3
BCK 4.5§	350.5
MBK 1.6¶	248.8

**, †, ‡, §, and ¶ represent statistically similar groupings defined by Tukey test with p < 0.05. If a site does not share a grouping with another site, then they are considered statistically different.*

Dissolved oxygen values were also evaluated from measurements collected July 2021 to June 2022. Mean values of dissolved oxygen ranged from 9.8 to 8.1 mg/L. East Fork Poplar Creek, site EFK 13.8, had the highest oxygen concentration among all sites. The ETTP Mitchell Branch site, MIK 0.1, had the lowest mean concentration of dissolved oxygen. In general, streams were quite similar in dissolved oxygen concentrations.

An ANOVA was performed to see if any significant differences existed among streams for dissolved oxygen concentrations. Results from the ANOVA indicated that no streams were statistically significantly different ($p < 0.05$) in dissolved oxygen concentrations. Mean dissolved oxygen concentrations for each site are shown below (Table 8.1.3).

Table 8.1.3: Results of Tukey comparison of means test for dissolved oxygen

Site	Mean Dissolved Oxygen (mg/L)
EFK 13.8	9.8
MBK 1.6	9.7
EFK 23.4	9.5
BCK 4.5	9.4
BCK 12.3	9.3
BCK 9.6	9.3
MIK 0.1	8.1

Mitchell Branch (MIK 0.1) tends to have lower dissolved oxygen levels during the summer months, when the weather is hotter. For a typical stream, an increase in water temperature results in a decrease in dissolved oxygen concentrations. These higher water temperatures, which would be typical for this time of year, could perhaps explain this decrease in oxygen concentrations. However, sites on EFPC, specifically EFK 23.4 and EFK 13.8, maintain higher water temperatures than Mitchell Branch for much of the year, yet these sites still maintain higher dissolved oxygen concentrations. Perhaps, in addition to water temperature, an oxygen demanding contaminant is loaded to Mitchell Branch from increased runoff during these hotter and wetter months. Another explanation may be the growth of oxygen demanding plants that may be more likely to thrive in warmer weather. More research is needed to fully understand why Mitchell Branch tends to have these lower dissolved oxygen concentrations.

The field parameter of pH was analyzed for measurements collected July 2021 to June 2022 (Table 8.1.4). Mean pH values ranged from 7.95 to 7.50 among all sites. EFPC site EFK 23.4 had the highest pH readings. Mitchell Branch site MIK 0.1, while similar to other streams, was lower with an average pH of 7.5.

Table 8.1.4: Average pH

Site	Mean pH (Std. Unit)
EFK 23.4	7.95
EFK 13.8	7.91
MBK 1.6	7.86
BCK 9.6	7.84
BCK 4.5	7.73
BCK 12.3	7.63
MIK 0.1	7.50

Lastly, temperature data were evaluated for all sites measured July 2021 to June 2022. Mean water temperatures ranged from 17.3 to 13.5 degrees Celsius with EFPC being the warmest and Mill Branch being the coolest among all sites. An ANOVA indicated no statistically significant differences in water temperature among sites (see Table 8.1.5).

Table 8.1.5: Average water temperatures

Site	Mean Temperature (°C)
EFK 23.4	17.3
MIK 0.1	15.3
EFK 13.8	15.3
BCK 12.3	14.1
BCK 4.5	13.8
BCK 9.6	13.8
MBK 1.6	13.5

The above-mentioned field parameter data collected July 2021 to June 2022 were also analyzed in conjunction with data collected 2005 to 2022 (Figure 8.1.3).

Figure 8.1.3: Mean annual values for Conductivity, Dissolved Oxygen, pH, and Temperature from 2005 to the present for all sites. Units for conductivity, dissolved oxygen, pH, and temperature are μS/cm, mg/L, std. unit, and °C, respectively

Data were evaluated for significant increasing or decreasing trends for each parameter averaged by year. Significant linear trends with $p < 0.05$ were found for two field parameters at two different stations.

A statistically significant negative correlation was found between mean annual conductivity and time for BCK 12.3 with $p < 0.05$. This correlation was found through linear regression, with mean annual conductivity as the dependent variable and time as the independent variable. The coefficient of determination (R^2) was 0.784, indicating a good fit. This indicates that there is a trend of decreasing conductivity with time for site BCK 12.3. The slope of the regression line illustrates that this decrease is occurring at roughly 29 μS/cm annually. Similarly, a statistically significant positive correlation was found with mean annual conductivity and time for EFK 23.4 with $p < 0.05$. The coefficient of determination (R^2) was 0.826, which indicates the regression fits the data well. This trend illustrates that conductivity has increased with time since 2005 for EFK 23.4. The slope of the regression line shows that this increase is occurring at roughly 8 µS/cm annually (Figure 8.1.4).

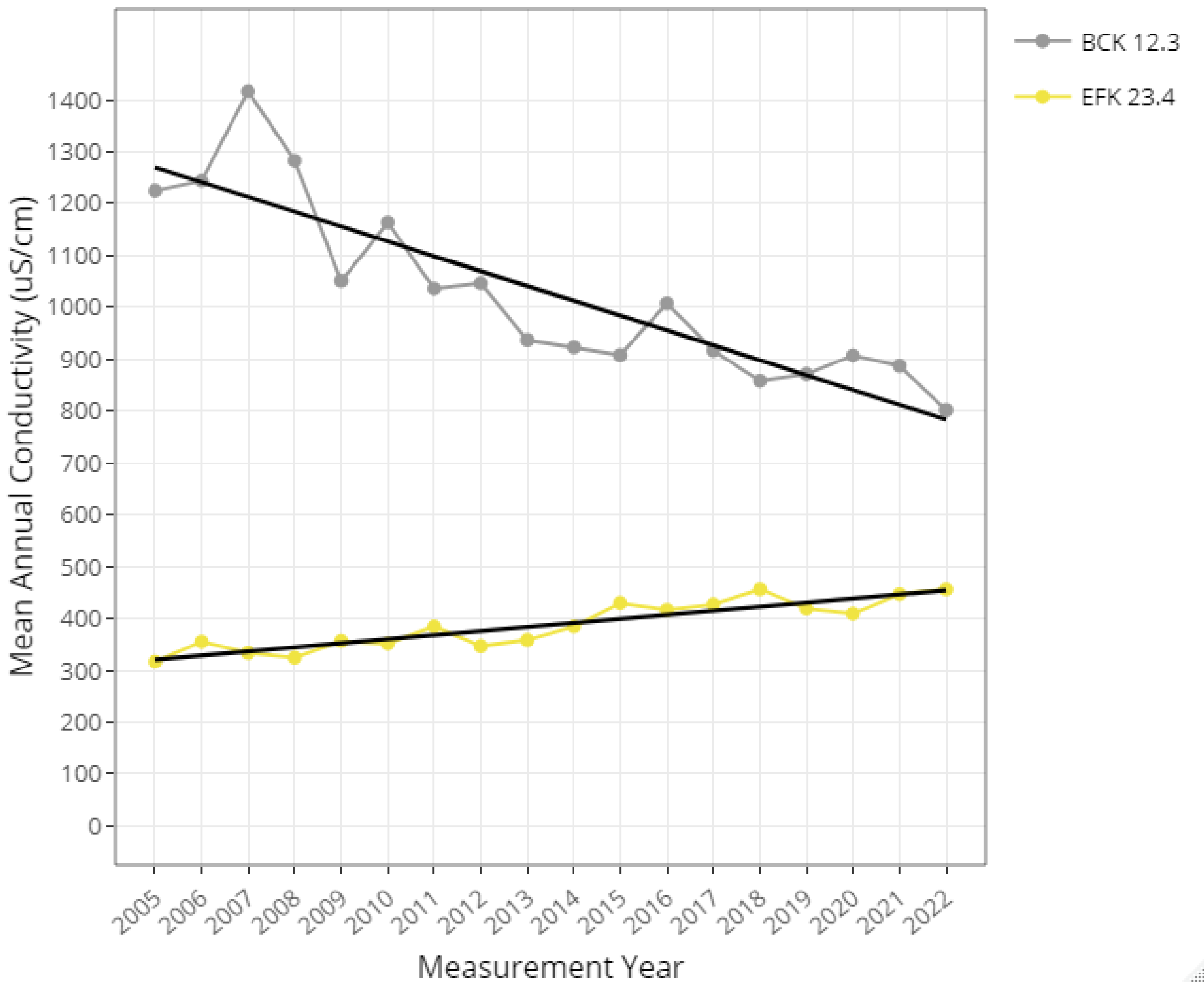

Figure 8.1.4: Linear regression of mean annual conductivity with respect to time for sites on Bear Creek (BCK 12.3) and East Fork Poplar Creek (EFK 23.4)

8.1.8 Conclusions

Field parameters including conductivity, dissolved oxygen, pH, and temperature were collected monthly from the seven (7) monitoring locations. These data serve to populate a database and baseline for surface water conditions for many streams in the ORR as well as help to assess impact of remediation efforts and identify accidental releases.

Of these measurements, all readings were within the State of Tennessee Water Quality

Criteria (TDEC, 2019). While there is no existing TN AWQC for conductivity, Bear Creek site BCK 12.3 was found to be statistically significantly higher than all other streams. Despite this higher conductivity, historical data (2005-2022) suggests that BCK 12.3 has a predicted decreasing trend in conductivity of roughly 29 µS/cm annually. In all, this stream is still quite high in conductivity, but is decreasing with time. This higher conductivity may be related to the proximity of this site to the capped S-3 ponds and the Y-12 West End Water Treatment Facility which contained high concentrations of metals (e.g. calcium, magnesium, sodium, potassium, and aluminum) as well as high concentrations of trace metals (Brooks, 2001). The decrease in conductivity at BCK 12.3 since 2005 may be the result of attenuation of contaminant sources in the immediate area around the S-3 ponds and water treatment plant. On East Fork Poplar Creek, site EFK 23.4 has shown a steadily increasing trend of conductivity which is on average roughly 8 µS/cm annually. The reason(s) for this increase have not yet been determined. Mill Branch (MBK 1.6) was statistically significantly lower in conductivity than all ORR streams measured. This may be due to operations on the ORR that have the potential to load these streams with more solutes.

8.1.9 Recommendations

As legacy DOE ORR pollution has negatively impacted East Fork Poplar Creek, Bear Creek, and Mitchell Branch, TDEC DoR-OR recommends continued physical parameter monitoring at the seven (7) monitoring stations in order to identify, categorize, and interpret changing trends such as the upward trend of conductivity in East Fork Poplar Creek at site EFK 23.4 and the downward trend of conductivity at Bear Creek site BCK 12.3.

8.1.10 References

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8.2 Ambient Surface Water Sampling

8.2.1 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 (CR) 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 two (2) 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.

DOE has similarly 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; DOE, 2020a; DOE, 2021). Currently, DOE collects samples quarterly at four (4) sites along the Clinch River at river kilometers 16, 32, 58, and 66 (Figure 8.2.1) (DOE, 2021). Of these sites, Clinch River kilometer (CRK) 58 is near the water supply intake for Knox County, and CRK 66 is upstream of the Oak Ridge City water supply 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 White Oak Creek (WOC) and Clinch River near ORNL (CRK 32), upstream of the Oak Ridge City water supply intake (CRK 66), and downstream of the ORR (CRK 16).

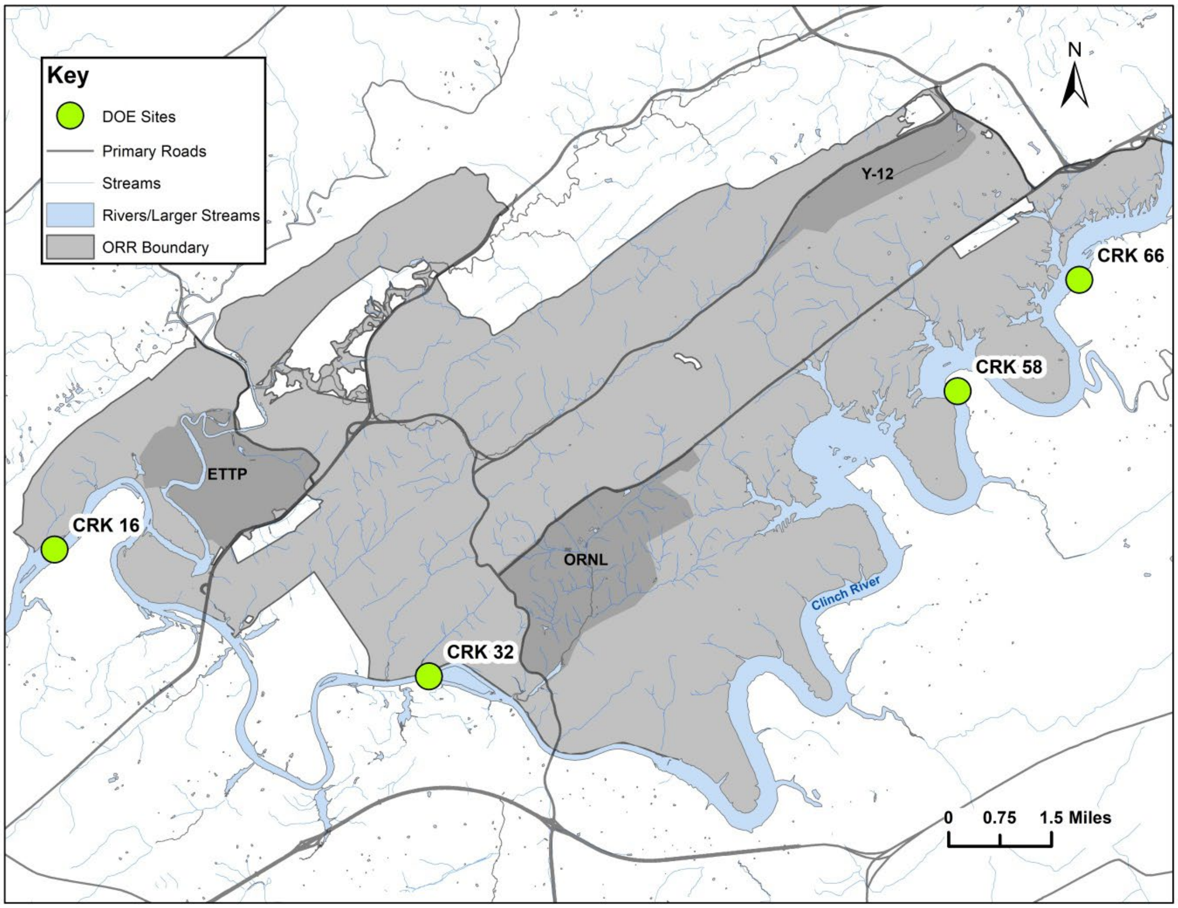

Figure 8.2.1: Map showing DOE sampling sites

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 maximum contaminant levels (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 builds upon DOE's sampling by looking at three ORR exit-pathway streams. These streams include Bear Creek (BC), East Fork Poplar Creek (EFPC), and Poplar Creek (PC) (Figure 8.2.2). BC flows into EFPC downstream of the EFK 6.3 sample location. In turn, EFPC flows into PC at PC mile (PCM) 5.5. Poplar Creek eventually flows to the CR directly downstream of PCM 0.15 (see Figure 8.2.2 above). Thus, any contamination from BC and EFPC could potentially enter PC and in turn move into the CR.

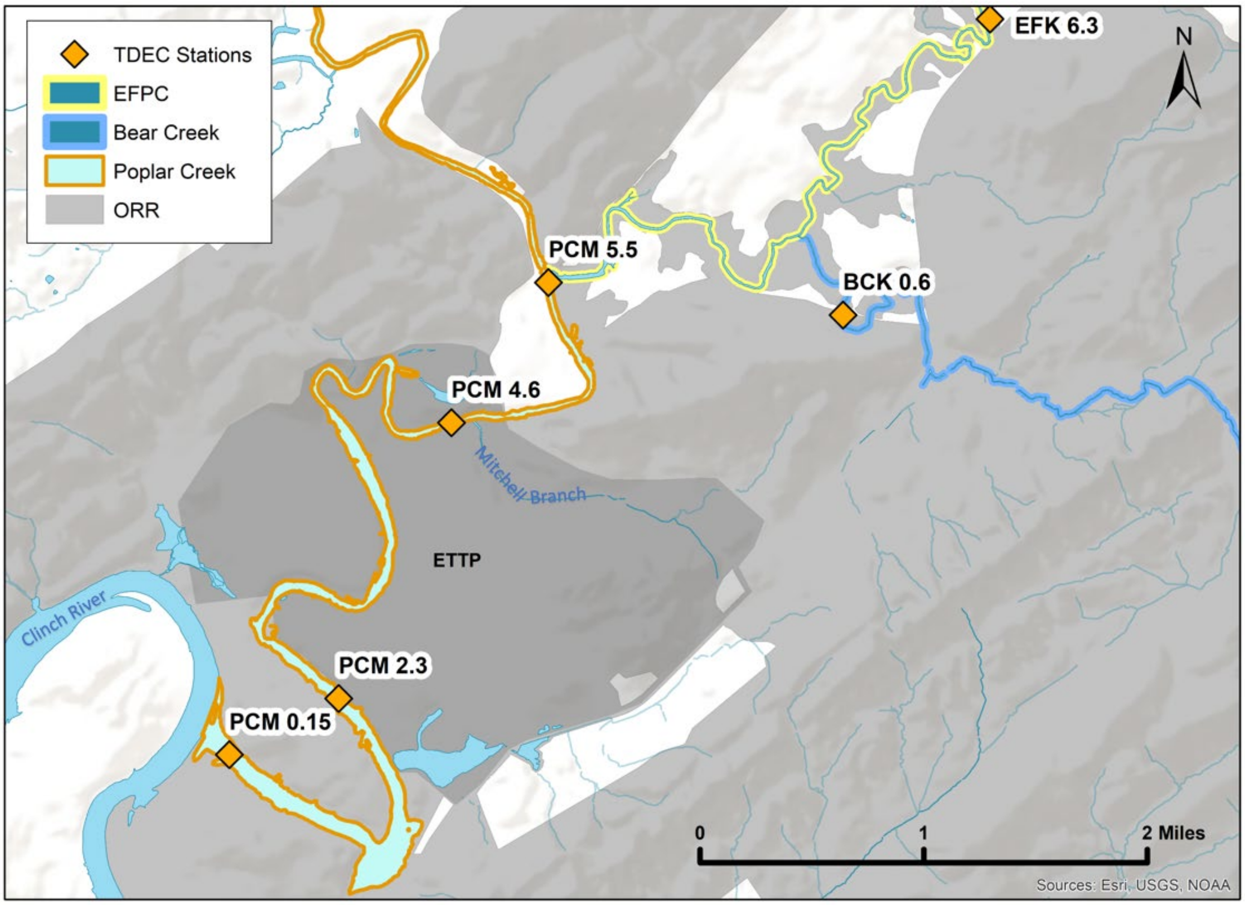

Figure 8.2.2: Map showing locations of Bear Creek (blue), East Fork Poplar Creek (yellow), and Poplar Creek (orange)

Samples were collected at several locations in the Poplar Creek ETTP area with the intent to provide a more representative evaluation of the loading of contaminants from ORR facilities to offsite locations. Additional co-sampling was also performed at each of the four (4) DOE Clinch River sites (CRK 16, 32, 58, 66) with one site co-sampled quarterly.

8.2.2 Problem Statements

This Project supplements DOE's study of the Clinch River (CR) to better understand impacts of exit-pathway streams to human health and the environment. It is estimated, based on 2020 US census data, that nearly 1.1 million people live in the counties surrounding the ORR (DOE, 2021). 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 (CR) ultimately flows into the Tennessee River. Twelve water supplies are located on these rivers within 170 river miles downstream of White Oak Creek (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).
- Regarding 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 from potential ORR surface water pollution.

8.2.3 Goals

The goal of this Surface Water Monitoring Project was to evaluate the magnitude of contamination within Poplar Creek near ETTP. East Fork Poplar Creek and Bear Creek were also characterized near their respective mouths to help understand contaminant contributions to Poplar Creek. The Clinch River (CR) was also monitored in conjunction with DOE sampling (Figure 8.2.3). Mill Branch (MB) was again used as a background comparison site to those sampled in the ETTP area. Surface water chemistry data was also used to assess Poplar Creek's general chemistry at different locations to better understand any contributing groundwater and surface water to the creek.

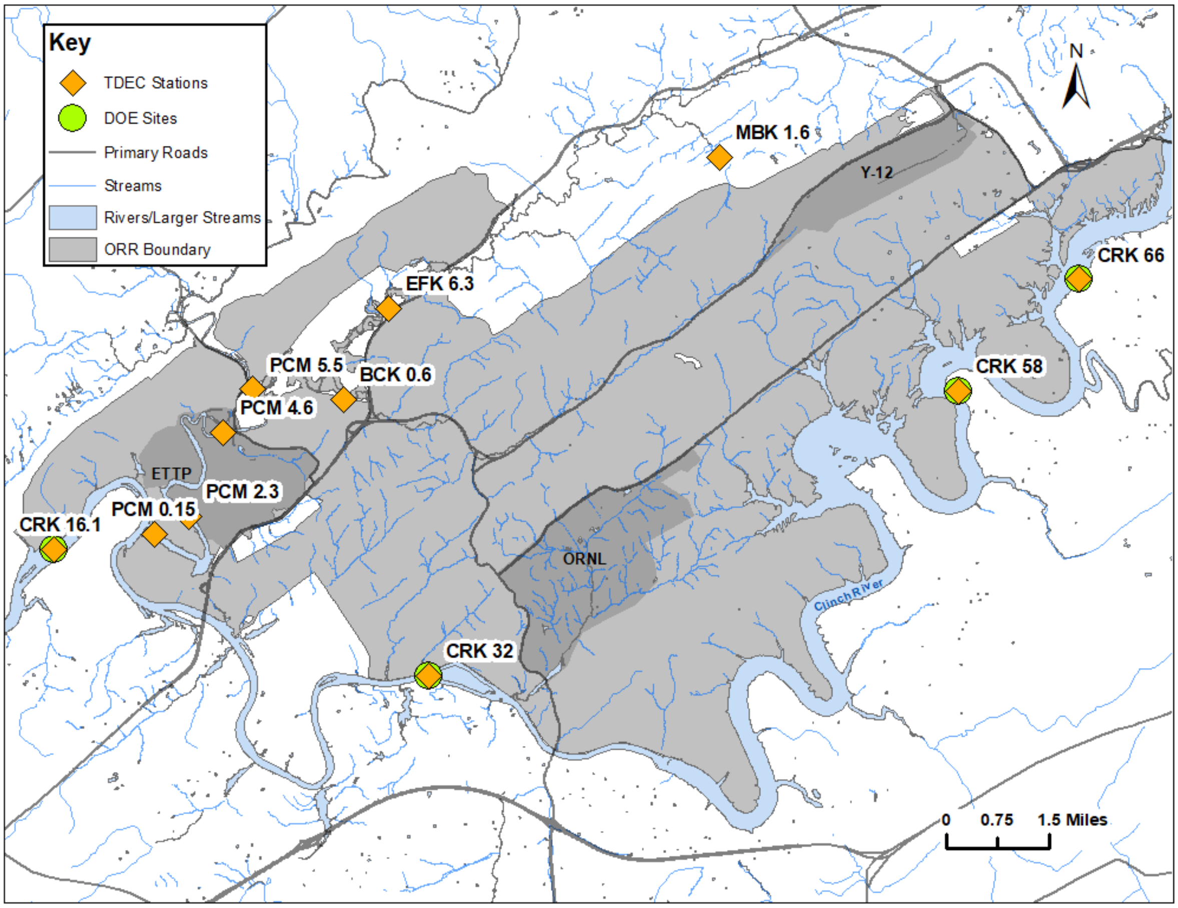

Figure 8.2.3 Map showing TDEC sites and DOE sampling sites. The number associated with each site represents the distance in kilometers from the mouth of the stream or river to that location

8.2.4 Scope

The scope of this project was to characterize stream conditions and assess the presence or absence of contaminants through sampling and analysis of surface water from Poplar Creek, which flows into the CR. East Fork Poplar Creek and Bear Creek were also characterized near their respective mouths to help understand contaminant contributions to Poplar Creek. A segment of the CR was also 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.

8.2.5 Methods, Materials, Metrics

Sample Collection

Surface water samples were collected quarterly at one (1) site on BC, one (1) site on EFPC, one (1) site on MB, and four (4) sites on PC. Each quarter, one (1) of four (4) CR sites were co-sampled, with each CR site being sampled once throughout the project. Samples from BC, EFPC, and PC were sampled and analyzed for metals and radionuclides. Additionally, the PC sites were analyzed for major cations and anions. Samples collected from the CR sites were analyzed for gross alpha/beta, isotopic uranium, mercury (Table 8.2.1). Strontium-90 was sampled at CRK 32. Sampling protocols followed the TDEC-DWR Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water (TDEC, 2022).

Table 8.2.1: Performed Sampling

			Performed Sampling						
Latitude	Longitude	DoR-OR Site	Sr-90	TRU*	Rads*	Mercury	Metals*	Major Cat*	Major An*
35.92186	-84.42942	CRK 16.1			1	1			
35.9002	-84.35049	CRK 32	1		1	1			
35.94891535	-84.23902273	CRK 58			1	1			
35.967958	-84.213382	CRK 66			1	1			
35.949173	-84.38759	PCM 5.5		3	3	3	3	3	3
35.941844	-84.393869	PCM 4.6		3	3	3	3	3	3
35.927427	-84.401154	PCM 2.3		4	4	4	4	4	4
35.924484	-84.408234	PCM 0.15		4	4	4	4	4	4
35.94747	-84.36855	BCK 0.6		4	4	4	4		
35.96293	-84.35905	EFK 6.3		4	4	4	4		
35.98886	-84.28935	MBK 1.6		4	4	4	4		
DOE Co-Sample		FD	1	2	4	3	3	2	2
Ambient									
QA/QC		Total for FY	2	28	34	33	29	16	16

Note:

Major Cat: sodium, potassium, calcium, magnesium

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

Metals: Antimony, Arsenic, Beryllium, Cadmium, Chromium, Lithium, Lead, Nickel, Thallium, Uranium

Rads: Isotopic Uranium, Gross alpha, Gross Beta

TRU: Am-241, Cm-243/244, Np-237, Iso-Pu

Field Parameter Measurements

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

8.2.6 Deviations from the Plan

A few deviations from the plan occurred. For specific deviations, see Table 8.2.2 below.

Table 8.2.2: Description of deviations from plan by quarter (e.g., Q1 = 1st quarter)

DOE-O Site Description	DoR-OR Site	Variance
Clinch River Mile 10.0	CRK 16.1	Q4: Did not co-sample w\ UT-Battelle
Poplar Creek Mile 3.4	PCM 5.5	Q3: Did not sample; water too low
Poplar Creek Mile 2.8	PCM 4.6	Q3: Did not sample; water too low

8.2.7 Results and Analysis

Data summaries of sampled constituents are shown below. See tables 8.2.3 – 8.2.8 for quarterly sampling results. The marking of "*" indicates that a sample was not taken. The "U" indicates that a constituent was not detected at or above the method detection limit. This section includes a detailed discussion of the metals, radionuclides, and general chemistry results based on these results.

Table 8.2.3: Quarterly sampling results for metals in ORR streams

Site Description	DoR-OR Site	Antimony (ug/L)	Arsenic (ug/L)	Beryllium (ug/L)	Cadmium (ug/L)	Chromium (ug/L)	Lead (ug/L)	Lithium (ug/L)	Mercury (ug/L)	Nickel (ug/L)	Thallium (ug/L)	Uranium (ug/L)	Date	Quarter
Bear Creek Mile 0.4	BCK 0.6	U	U	U	U	U	U	5.59	0.00168	0.423	0.103	14.9	9/15/2021	1
Bear Creek Mile 0.4	BCK 0.6 (DUP)	U	0.608	U	U	U	U	5.4	0.00171	0.423	0.103	15.1	9/15/2021	1
Bear Creek Mile 0.4	BCK 0.6	U	U	U	U	U	U	0.583	0.000297	U	U	0.162	11/15/2021	2
Bear Creek Mile 0.4	BCK 0.6	U	U	U	U	U	U	4.64	0.000631	U	U	8.79	2/15/2022	3
Bear Creek Mile 0.4	BCK 0.6	U	U	U	U	4	U	5.5	0.0028	0.539	U	4.39	6/6/2022	4
East Fork Poplar Creek Mile 3.9	EFK 6.3	U	U	U	U	U	U	7.69	0.043	1.04	U	7.31	9/15/2021	1
East Fork Poplar Creek Mile 3.9	EFK 6.3	U	U	U	U	U	U	11	U	0.423	U	14.3	11/15/2021	2
East Fork Poplar Creek Mile 3.9	EFK 6.3	U	U	U	U	U	U	4.14	0.0187	0.773	U	4.53	2/15/2022	3
East Fork Poplar Creek Mile 3.9	EFK 6.3	U	U	U	U	U	0.228	5.6	0.0422	1.95	U	11.8	6/6/2022	4
Mill Branch Mile 1.0	MBK 1.6	U	U	U	U	U	U	5.24	0.00123	U	U	0.363	9/15/2021	1
Mill Branch Mile 1.0	MBK 1.6	U	U	U	U	U	U	4.2	0.000972	U	U	0.284	11/15/2021	2
Mill Branch Mile 1.0	MBK 1.6	U	U	U	U	U	U	2.98	0.000469	0.514	U	0.204	2/15/2022	3
Mill Branch Mile 1.0	MBK 1.6	U	U	U	U	U	U	5	U	U	U	0.292	6/6/2022	4
Poplar Creek Mile 0.1	PCM 0.15	U	0.734	U	U	U	0.604	2.45	0.0382	U	U	1.11	8/24/2021	1
Poplar Creek Mile 0.1	PCM 0.15	U	0.666	U	U	U	0.161	2.14	0.00239	0.498	U	0.201	11/17/2021	2
Poplar Creek Mile 0.1	PCM 0.15	U	U	U	U	U	0.344	1.64	0.00373	0.867	U	1.02	2/7/2022	3
Poplar Creek Mile 0.1	PCM 0.15	U	U	U	U	U	U	1.77	0.0161	0.964	U	0.688	6/1/2022	4
Poplar Creek Mile 1.4	PCM 2.3	U	0.671	U	U	U	0.855	1.9	0.0751	0.649	U	0.665	8/24/2021	1
Poplar Creek Mile 1.4	PCM 2.3	U	U	U	U	U	0.379	2.4	0.0196	0.955	U	1.16	11/17/2021	2
Poplar Creek Mile 1.4	PCM 2.3	U	U	U	U	U	0.366	1.65	0.00705	0.901	U	1.06	2/7/2022	3
Poplar Creek Mile 1.4	PCM 2.3	U	U	U	U	U	0.501	1.67	0.0124	1.08	U	0.957	6/1/2022	4
Poplar Creek Mile 1.4	PCM 2.3 (DUP)	U	U	U	U	U	0.509	1.74	0.0153	1.31	U	0.973	6/1/2022	4
Poplar Creek Mile 2.8	PCM 4.6	U	0.813	U	U	U	0.953	1.9	0.0466	0.968	U	0.741	8/24/2021	1
Poplar Creek Mile 2.8	PCM 4.6	U	U	U	U	U	0.232	2.61	0.0168	1.19	U	1.68	11/17/2021	2
Poplar Creek Mile 2.8	PCM 4.6 (DUP)	U	U	U	U	U	0.239	2.62	0.026	1.26	U	1.73	11/17/2021	2
Poplar Creek Mile 2.8	PCM 4.6	•	•	•	•	•	•	•	•	•	•	•	•	3
Poplar Creek Mile 2.8	PCM 4.6	U	U	U	U	1.99	0.427	2.1	0.011	1.31	U	2.13	6/1/2022	4
Poplar Creek Mile 3.4	PCM 5.5	U	0.657	U	U	U	0.785	1.01	0.0105	0.705	U	U	8/24/2021	1
Poplar Creek Mile 3.4	PCM 5.5	U	U	U	U	U	0.199	3.72	0.0262	1.44	U	3.28	11/17/2021	2
Poplar Creek Mile 3.4	PCM 5.5	•	•	•	•	•	•	•	•	•	•	•	•	3
Poplar Creek Mile 3.4	PCM 5.5	U	U	U	U	U	0.341	1.06	0.00201	0.886	U	0.161	6/1/2022	4

Note: Highlighted results indicate an exceedance of the State of Tennessee (TN) water quality mercury criterion of 0.051 µg/L for organisms in water.

Table 8.2.4: Quarterly sampling results for inorganics and nutrients in Poplar Creek

Site Description	DoR-OR Site	Alkalinity (mg/L)	Calcium (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Magnesium (mg/L)	Nitrate/Nitrite (mg/L)	Phophorus (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Sulfate (mg/L)	Date	Quarter
Poplar Creek Mile 0.1	PCM 0.15	88.4	29	5.11	0.115	7.83	0.721	0.15	2.19	5.02	19.2	8/24/2021	1
Poplar Creek Mile 0.1	PCM 0.15	115	38.4	3.65	0.0597	10.1	0.354	0.0275	1.67	3.95	13.5	11/17/2021	2
Poplar Creek Mile 0.1	PCM 0.15	62.4	21.4	3.36	0.0695	5.46	0.478	0.0461	1.25	2.69	12.7	2/7/2022	3
Poplar Creek Mile 0.1	PCM 0.15	105	32.3	5.09	0.0955	8.91	0.275	0.0879	2.21	4.66	13.2	6/1/2022	4
Poplar Creek Mile 1.4	PCM 2.3	71.9	22.1	3.79	0.11	6.16	0.505	0.143	2.24	3.78	16.4	8/24/2021	1
Poplar Creek Mile 1.4	PCM 2.3	97.5	34.6	5.08	0.105	8.78	0.529	0.125	2.5	5.07	19	11/17/2021	2
Poplar Creek Mile 1.4	PCM 2.3	61.9	22.2	3.37	0.0711	5.8	0.475	0.0507	1.27	2.77	12.9	2/7/2022	3
Poplar Creek Mile 1.4	PCM 2.3	77.3	26.3	4.47	0.101	6.69	0.337	0.107	2.3	4.07	13.1	6/1/2022	4
Poplar Creek Mile 1.4	PCM 2.3 (DUP)	78	26.4	4.5	0.102	6.77	0.338	0.111	2.35	4.1	13.1	6/1/2022	4
Poplar Creek Mile 2.8	PCM 4.6	66.2	23.6	3.8	0.102	5.67	0.569	0.171	2.71	3.16	11.4	8/24/2021	1
Poplar Creek Mile 2.8	PCM 4.6	111	38.5	6.36	0.106	9.32	1.21	0.248	2.47	6.25	18.9	11/17/2021	2
Poplar Creek Mile 2.8	PCM 4.6 (DUP)	111	38.5	6.37	0.107	9.32	1.22	0.265	2.47	6.26	18.9	11/17/2021	2
Poplar Creek Mile 2.8	PCM 4.6	*	*	*	*	*	*	*	*	*	*	*	3
Poplar Creek Mile 2.8	PCM 4.6	94.1	32.2	5.76	0.0872	7.84	0.74	0.169	2.29	5.1	14.1	6/1/2022	4
Poplar Creek Mile 3.4	PCM 5.5	55	18.7	2.33	0.0941	5.55	0.245	0.086	2.66	2.3	13.4	8/24/2021	1
Poplar Creek Mile 3.4	PCM 5.5	137	48.2	11.8	0.158	11.4	2.41	0.526	3.17	9.9	20.2	11/17/2021	2
Poplar Creek Mile 3.4	PCM 5.5	*	*	*	*	*	*	*	*	*	*	*	3
Poplar Creek Mile 3.4	PCM 5.5	81	26.4	3.11	0.0788	7.45	0.367	0.0585	1.97	3.26	12.6	6/1/2022	4

Note: Highlighted results indicate nutrients are greater than the State of TN 90th percentile of all streams within eco region 67f (i.e., > 0.04 mg/L for total phosphorus or >1.22 mg/L for Nitrate/Nitrite, respectively) (TDEC, 2004).

Table 8.2.5: Quarterly sampling results for radionuclides (excluding transuranics) in ORR streams (in pCi/L)

DoR-OR Site	Alpha Activity	Beta activity	Uranium-234	Uranium-235	Uranium-238	Date	Quarter
BCK 0.6	**4.18 ± 0.7**	**7.5 ± 1.6**	**3.74 ± 0.69**	0.33 ± 0.2 (U)	**4.83 ± 0.82**	9/15/2021	1
BCK 0.6 (DUP)	**5.35 ± 0.7**	**7.8 ± 1.6**	**4.03 ± 0.69**	0.54 ± 0.2 (U)	**4.84 ± 0.82**	9/15/2021	1
BCK 0.6	**5.78 ± 0.79**	**8.4 ± 1.6**	**2.57 ± 0.67**	0.38 ± 0.26 (U)	**3.95 ± 0.86**	11/15/2021	2
BCK 0.6	**3.62 ± 0.65**	**7.1 ± 1.6**	**1.81 ± 0.38**	0.53 ± 0.21 (U)	**4.21 ± 0.65**	2/15/2022	3
BCK 0.6	**3.49 ± 0.57**	**6.6 ± 1.5**	1.83 ± 0.76 (U)	0.49 ± 0.43 (U)	**4.1 ± 1.2**	6/6/2022	4
EFK 6.3	**2.37 ± 0.57**	4.2 ± 1.6 (U)	**3.67 ± 0.78**	0.33 ± 0.24 (U)	**3.04 ± 0.69**	9/15/2021	1
EFK 6.3	**2.39 ± 0.55**	2.9 ± 1.6 (U)	**2.29 ± 0.45**	**1.19 ± 0.33**	**2.32 ± 0.45**	11/15/2021	2
EFK 6.3	**2.52 ± 0.56**	4 ± 1.5 (U)	**1.32 ± 0.31**	0.22 ± 0.13 (U)	**2.39 ± 0.44**	2/15/2022	3
EFK 6.3	**2.21 ± 0.52**	4.1 ± 1.5 (U)	1.08 ± 0.34 (U)	0.12 ± 0.12 (U)	**1.5 ± 0.42**	6/6/2022	4
MBK 1.6	-0.07 ± 0.46 (U)	1.8 ± 1.6 (U)	**2.05 ± 0.5**	0.3 ± 0.2 (U)	1.04 ± 0.34 (U)	9/15/2021	1
MBK 1.6	0.42 ± 0.44 (U)	1.1 ± 1.6 (U)	0.33 ± 0.14 (U)	0.073 ± 0.084 (U)	0.18 ± 0.11 (U)	11/15/2021	2
MBK 1.6	0.14 ± 0.43 (U)	3.6 ± 1.5 (U)	**0.51 ± 0.14**	0.28 ± 0.11 (U)	0.216 ± 0.09 (U)	2/15/2022	3
MBK 1.6	-0.05 ± 0.43 (U)	2.7 ± 1.5 (U)	0.47 ± 0.23 (U)	0.035 ± 0.096 (U)	0.34 ± 0.2 (U)	6/6/2022	4
PCM 0.15	**2.43 ± 0.52**	0.5 ± 1.5 (U)	**0.42 ± 0.12**	0.076 ± 0.061 (U)	**0.5 ± 0.14**	8/24/2021	1
PCM 0.15	0.15 ± 0.45 (U)	0.7 ± 1.5 (U)	0.137 ± 0.072 (U)	-0.004 ± 0.025 (U)	0.106 ± 0.062 (U)	11/17/2021	2
PCM 0.15	0.53 ± 0.45 (U)	3 ± 1.5 (U)	0.42 ± 0.13 (U)	0.193 ± 0.095 (U)	**0.5 ± 0.14**	2/7/2022	3
PCM 0.15	0.42 ± 0.45 (U)	2.1 ± 1.5 (U)	0.38 ± 0.22 (U)	0.14 ± 0.15 (U)	0.18 ± 0.15 (U)	6/1/2022	4
PCM 2.3	0.8 ± 0.46 (U)	0.1 ± 1.5 (U)	**0.4 ± 0.12**	0.114 ± 0.067 (U)	0.39 ± 0.12 (U)	8/24/2021	1
PCM 2.3	0.31 ± 0.46 (U)	**6.2 ± 1.6**	0.45 ± 0.17 (U)	0.051 ± 0.066 (U)	0.54 ± 0.19 (U)	11/17/2021	2
PCM 2.3	1.57 ± 0.5 (U)	3.2 ± 1.5 (U)	**0.56 ± 0.15**	0.25 ± 0.11 (U)	**0.54 ± 0.15**	2/7/2022	3
PCM 2.3	0.2 ± 0.44 (U)	4.5 ± 1.5 (U)	0.15 ± 0.13 (U)	0.13 ± 0.14 (U)	0.55 ± 0.25 (U)	6/1/2022	4
PCM 2.3 (DUP)	0.76 ± 0.46 (U)	**6.1 ± 1.5**	0.56 ± 0.25 (U)	0.032 ± 0.087 (U)	0.55 ± 0.24 (U)	6/1/2022	4
PCM 4.6	0.54 ± 0.45 (U)	-1.6 ± 1.5 (U)	0.38 ± 0.12 (U)	0.159 ± 0.082 (U)	0.43 ± 0.13 (U)	8/24/2021	1
PCM 4.6	0.9 ± 0.48 (U)	2.2 ± 1.5 (U)	**0.98 ± 0.26**	0.39 ± 0.18 (U)	**1.08 ± 0.27**	11/17/2021	2
PCM 4.6 (DUP)	1.29 ± 0.5 (U)	3.4 ± 1.6 (U)	**0.86 ± 0.22**	0.085 ± 0.073 (U)	**1.39 ± 0.29**	11/17/2021	2
PCM 4.6	*	*	*	*	*	*	3
PCM 4.6	1.29 ± 0.48 (U)	1.3 ± 1.5 (U)	0.91 ± 0.32 (U)	0.09 ± 0.11 (U)	0.78 ± 0.29 (U)	6/1/2022	4
PCM 5.5	-0.04 ± 0.43 (U)	-0.9 ± 1.5 (U)	0.193 ± 0.084 (U)	0.073 ± 0.057 (U)	0.102 ± 0.06 (U)	8/24/2021	1
PCM 5.5	**1.92 ± 0.54**	3.8 ± 1.6 (U)	**0.78 ± 0.22**	0.18 ± 0.12 (U)	**0.83 ± 0.23**	11/17/2021	2
PCM 5.5	*	*	*	*	*	*	3
PCM 5.5	**3.13 ± 0.55**	-0.3 ± 1.4 (U)	0.27 ± 0.19(U)	0.11 ± 0.13 (U)	0.17 ± 0.15 (U)	6/1/2022	4

Note: Results are shown ± the combined standard uncertainty (CSU). Samples that yielded CSUs greater than 30% of the result activity were identified as “U”, indicating that they were not detected.

Table 8.2.6: Quarterly sampling results for transuranics in ORR streams (in pCi/L)

DoR-OR Site	Americium-241	Curium-243/244	Neptunium-237	Plutonium-238	Plutonium-239/240	Thorium-228	Thorium-230	Thorium-232	Date	Quarter
BCK 0.6	0.13 ± 0.15 (U)	0.13 ± 0.13 (U)	0 ± 0.064 (U)	-0.014 ± 0.044 (U)	-0.007 ± 0.042 (U)	pending	pending	pending	9/15/2021	1
BCK 0.6 (DUP)	*	*	*	*	*	*	*	*	9/15/2021	1
BCK 0.6	0.14 ± 0.11 (U)	0.071 ± 0.078 (U)	0 ± 0.17 (U)	0.045 ± 0.098 (U)	0.07 ± 0.11 (U)	pending	pending	pending	11/15/2021	2
BCK 0.6	0 ± 0.81 (U)	0.14 ± 0.13 (U)	0 ± 0.13 (U)	0.1 ± 0.17 (U)	0.1 ± 0.17 (U)	0.062 ± 0.087 (U)	0.13 ± 0.1 (U)	0.19 ± 0.12 (U)	2/15/2022	3
BCK 0.6	0.25 ± 0.21 (U)	-0.0009 ± 0.092 (U)	0 ± 0.25 (U)	-0.028 ± 0.09 (U)	0.14 ± 0.16 (U)	0.024 ± 0.075(U)	0.066 ± 0.081 (U)	0.016 ± 0.047 (U)	6/6/2022	4
EFK 6.3	0.15 ± 0.13 (U)	0.024 ± 0.073 (U)	0 ± 0.066 (U)	0.06 ± 0.16 (U)	0.029 ± 0.089 (U)	pending	pending	pending	9/15/2021	1
EFK 6.3	0.28 ± 0.21 (U)	0.024 ± 0.076 (U)	0 ± 0.068 (U)	0.03 ± 0.11 (U)	0.01 ± 0.093 (U)	pending	pending	pending	11/15/2021	2
EFK 6.3	0.38 ± 0.19 (U)	0.038 ± 0.066 (U)	0 ± 0.033 (U)	0.1 ± 0.16 (U)	0.013 ± 0.085 (U)	0.087 ± 0.091 (U)	0.056 ± 0.071 (U)	0.065 ± 0.084 (U)	2/15/2022	3
EFK 6.3	0.07 ± 0.11 (U)	0.04 ± 0.11 (U)	0 ± 0.1 (U)	0.05 ± 0.11 (U)	0 ± 0.11 (U)	0.22 ± 0.19 (U)	0.12 ± 0.15 (U)	0.048 ± 0.092 (U)	6/6/2022	4
MBK 1.6	0.017 ± 0.099 (U)	0.044 ± 0.075 (U)	0 ± 0.069 (U)	0.007 ± 0.068 (U)	0.065 ± 0.086 (U)	pending	pending	pending	9/15/2021	1
MBK 1.6	0.024 ± 0.074 (U)	0.09 ± 0.11 (U)	0 ± 0.061 (U)	0 ± 0.089 (U)	0.011 ± 0.067 (U)	pending	pending	pending	11/15/2021	2
MBK 1.6	-0.032 ± 0.056 (U)	0.087 ± 0.095 (U)	0 ± 0.07 (U)	0.1 ± 0.23 (U)	-0.03 ± 0.16 (U)	0.016 ± 0.044 (U)	0.041 ± 0.053 (U)	0.04 ± 0.063 (U)	2/15/2022	3
MBK 1.6	0.019 ± 0.078 (U)	0.019 ± 0.078 (U)	0 ± 0.073 (U)	0.032 ± 0.077 (U)	0.04 ± 0.11 (U)	0.45 ± 0.25 (U)	0.09 ± 0.1 (U)	0 ± 0.084 (U)	6/6/2022	4
PCM 0.15	0.12 ± 0.15 (U)	0.1 ± 0.13 (U)	0 ± 0.14 (U)	0.01 ± 0.13 (U)	0.028 ± 0.088 (U)	0.05 ± 0.15 (U)	0.35 ± 0.26 (U)	0.15 ± 0.19 (U)	8/24/2021	1
PCM 0.15	0.21 ± 0.17 (U)	-0.032 ± 0.071 (U)	0 ± 0.11 (U)	-0.01 ± 0.066 (U)	0.009 ± 0.061 (U)	pending	pending	pending	11/17/2021	2
PCM 0.15	0.004 ± 0.029 (U)	0.09 ± 0.072 (U)	0 ± 0.045 (U)	0.062 ± 0.094 (U)	0.027 ± 0.074 (U)	0.011 ± 0.065 (U)	0.011 ± 0.034 (U)	0.14 ± 0.11 (U)	2/7/2022	3
PCM 0.15	0.2 ± 0.17 (U)	0.017 ± 0.072 (U)	0 ± 0.086 (U)	-0.013 ± 0.076 (U)	0.025 ± 0.076 (U)	0.045 ± 0.076 (U)	0.08 ± 0.1 (U)	-0.004 ± 0.052 (U)	6/1/2022	4
PCM 2.3	0.03 ± 0.42 (U)	0.39 ± 0.5 (U)	0 ± 0.16 (U)	0.06 ± 0.16 (U)	0.06 ± 0.14 (U)	0.087 ± 0.094 (U)	0.063 ± 0.072 (U)	-0.005 ± 0.033 (U)	8/24/2021	1
PCM 2.3	0.1 ± 0.14 (U)	0.17 ± 0.17 (U)	0 ± 0.093 (U)	-0.0001 ± 0.057 (U)	0.05 ± 0.086 (U)	pending	pending	pending	11/17/2021	2
PCM 2.3	0.041 ± 0.09 (U)	0.07 ± 0.11 (U)	0 ± 0.085 (U)	-0.0001 ± 0.05 (U)	0.051 ± 0.077 (U)	0.077 ± 0.083 (U)	0.037 ± 0.056 (U)	0.115 ± 0.098 (U)	2/7/2022	3
PCM 2.3	0.23 ± 0.19 (U)	0.012 ± 0.075 (U)	0 ± 0.2 (U)	0.022 ± 0.092 (U)	0.04 ± 0.1 (U)	0.1 ± 0.12 (U)	0.08 ± 0.1 (U)	-0.017 ± 0.055 (U)	6/1/2022	4
PCM 2.3 (DUP)	0.14 ± 0.14 (U)	-0.015 ± 0.06 (U)	0 ± 0.13 (U)	0.04 ± 0.1 (U)	0.04 ± 0.12 (U)	0.057 ± 0.085 (U)	0.14 ± 0.13 (U)	0.035 ± 0.067 (U)	6/1/2022	4
PCM 4.6	0.11 ± 0.18 (U)	0.41 ± 0.35 (U)	0 ± 0.18 (U)	0.04 ± 0.15 (U)	0 ± 0.11 (U)	0.05 ± 0.065 (U)	0.132 ± 0.098 (U)	0.016 ± 0.06 (U)	8/24/2021	1
PCM 4.6	0.02 ± 0.13 (U)	-0.0003 ± 0.14 (U)	0 ± 0.07 (U)	-0.17 ± 0.13 (U)	-0.029 ± 0.047 (U)	pending	pending	pending	11/17/2021	2
PCM 4.6 (DUP)	0.03 ± 0.065 (U)	0.037 ± 0.064 (U)	0 ± 0.048 (U)	-0.02 ± 0.041 (U)	0.03 ± 0.19 (U)	pending	pending	pending	11/17/2021	2
PCM 4.6	*	*	*	*	*	*	*	*	*	3
PCM 4.6	0.31 ± 0.21 (U)	-0.011 ± 0.067 (U)	0 ± 0.096 (U)	-0.041 ± 0.075 (U)	0.035 ± 0.096 (U)	-0.005 ± 0.06 (U)	-0.005 ± 0.059 (U)	0.013 ± 0.056 (U)	6/1/2022	4
PCM 5.5	0.05 ± 0.14 (U)	0.31 ± 0.21 (U)	0 ± 0.15 (U)	-0.11 ± 0.16 (U)	0.17 ± 0.22 (U)	0.03 ± 0.065 (U)	0.24 ± 0.15 (U)	0.19 ± 0.13 (U)	8/24/2021	1
PCM 5.5	0.1 ± 0.11 (U)	0.008 ± 0.053 (U)	0 ± 0.11 (U)	-0.03 ± 0.059 (U)	0.037 ± 0.064 (U)	pending	pending	pending	11/17/2021	2
PCM 5.5	*	*	*	*	*	*	*	*	*	3
PCM 5.5	0.052 ± 0.079 (U)	0 ± 0.078 (U)	**1 ± 0.29**	0.045 ± 0.085 (U)	-0.005 ± 0.06 (U)	0.17 ± 0.15 (U)	0.06 ± 0.1 (U)	0.014 ± 0.06 (U)	6/1/2022	4

Note: Results are shown ± the combined standard uncertainty (CSU). Samples that yielded CSUs greater than 30% of the result activity were identified as "U", indicating that they were not detected.

Table 8.2.7: Quarterly sampling results for radionuclides and metals in the Clinch River (radionuclides in pCi/L)

DOE-O Site Description	DoR-OR Site	Alpha Activity	Beta activity	Strontium-89	Strontium-90	Uranium-234	Uranium-235	Uranium-238	Mercury (ug/L)	Date	Quarter
Clinch River Mile 41.0	CRK 66	U	U	*	*	0.57 ± 0.14	U	U	0.003	9/20/2021	1
Clinch River Mile 36.0	CRK 58	U	U	*	*	U	U	U	0.00375	12/20/2021	2
Clinch River Mile 19.7	CRK 32	U	U	U	U	U	U	U	0.0019	3/31/2022	3
Clinch River Mile 19.7	CRK 32 (DUP)	U	U	U	U	U	U	U	*	3/31/2022	3
Clinch River Mile 10.0	CRK 16.1	pending	pending	*	*	pending	pending	pending	0.00903	6/21/2022	4

Note: Radionuclide results are shown ± the combined standard uncertainty (CSU). Samples that yielded CSUs greater than 30% of the result activity were identified as “U”, indicating that they were not detected.

Table 8.2.8: Quarterly field parameter measurements in ORR streams and the Clinch River

DOE-O Site Description	DoR-OR Site	Temperature (C)	pH	Dissolved Oxygen (mg/L)	Conductivity (uS/cm)	Date	Quarter
Bear Creek Mile 0.4	BCK 0.6	20.4	7.7	7.69	376.5	9/15/2021	1
Bear Creek Mile 0.4	BCK 0.6	7.8	7.95	10.7	374.5	11/15/2021	2
Bear Creek Mile 0.4	BCK 0.6	5	7.85	12.23	290.5	2/15/2022	3
Bear Creek Mile 0.4	BCK 0.6	19.8	7.94	7.98	369.9	6/6/2022	4
East Fork Poplar Creek Mile 3.9	EFK 6.3	21.3	7.63	7.14	440.9	9/15/2021	1
East Fork Poplar Creek Mile 3.9	EFK 6.3	9.5	7.69	9.95	407.3	11/15/2021	2
East Fork Poplar Creek Mile 3.9	EFK 6.3	6.6	7.63	11.57	376.6	2/15/2022	3
East Fork Poplar Creek Mile 3.9	EFK 6.3	20.7	7.83	7.36	412.7	6/6/2022	4
Mill Branch Mile 1.0	MBK 1.6	17.8	7.57	8.17	277.4	9/15/2021	1
Mill Branch Mile 1.0	MBK 1.6	8.4	7.82	10.79	290	11/15/2021	2
Mill Branch Mile 1.0	MBK 1.6	6.1	7.74	12.14	224.7	2/15/2022	3
Mill Branch Mile 1.0	MBK 1.6	16.9	8.04	8.95	275.8	6/6/2022	4
Poplar Creek Mile 0.1	PCM 0.15	22.8	7.62	6.04	241.1	8/24/2021	1
Poplar Creek Mile 0.1	PCM 0.15	13.7	7.62	8.64	267.4	11/17/2021	2
Poplar Creek Mile 0.1	PCM 0.15	6.1	7.78	11.47	165.3	2/7/2022	3
Poplar Creek Mile 0.1	PCM 0.15	22.8	7.49	3.82	285.1	6/1/2022	4
Poplar Creek Mile 1.4	PCM 2.3	23.7	7.49	5.55	192.6	8/24/2021	1
Poplar Creek Mile 1.4	PCM 2.3	12.4	7.35	7.87	253.8	11/17/2021	2
Poplar Creek Mile 1.4	PCM 2.3	6	7.19	11.45	168.2	2/7/2022	3
Poplar Creek Mile 1.4	PCM 2.3	22.5	7.49	6.11	196.5	6/1/2022	4
Poplar Creek Mile 2.8	PCM 4.6	23.5	7.53	5.61	183	8/24/2021	1
Poplar Creek Mile 2.8	PCM 4.6	9.9	7.63	9.28	285.9	11/17/2021	2
Poplar Creek Mile 2.8	PCM 4.6	*	*	*	*	*	3
Poplar Creek Mile 2.8	PCM 4.6	21.5	8.25	5.89	255.2	6/1/2022	4
Poplar Creek Mile 3.4	PCM 5.5	23.7	7.43	5.78	156.9	8/24/2021	1
Poplar Creek Mile 3.4	PCM 5.5	11	7.78	9.56	401	11/17/2021	2
Poplar Creek Mile 3.4	PCM 5.5	*	*	*	*	*	3
Poplar Creek Mile 3.4	PCM 5.5	21.5	8.02	5.75	231	6/1/2022	4
Clinch River Mile 41.0	CRK 66	24.4	8.2	8.7	*	9/20/2021	1
Clinch River Mile 36.0	CRK 58	10.6	7.7	10.3	*	12/20/2021	2
Clinch River Mile 19.7	CRK 32	12.3	8.1	10.5	289	3/31/2022	3
Clinch River Mile 10.0	CRK 16.1	23.5	8.1	7.79	290.8	6/21/2022	4

Metals

Metals were sampled at each of the stream locations investigated in this project. Many metals sampled between July 2021 – June 2022 such as antimony, cadmium, and beryllium were not detected at any of the streams. Arsenic, chromium, and thallium were rarely detected across all locations and often were only detected in one or two quarters, if at all (see Table 8.2.3). The CR was only sampled for mercury and was not sampled for other metals mentioned above. This section focuses on those metals that had more frequent detections in the streams investigated.

East Fork Poplar Creek (EFPC)

EFPC has been shown to receive high concentrations of both mercury and uranium, both of which are likely sourced from Y-12. Concentrations of these metals tend to be higher near Y-12 and decrease downstream (TDEC, 2021). EFK 6.3 was investigated as part of this project as it is within the downstream reach of EFPC yet is upstream of the BC and EFPC confluence. Thus, this location provides a last look at what contaminants are present in this lowest reach of EFPC before being influenced by BC. Lead, lithium, mercury, nickel, and uranium were detected at this location between July 2021 – June 2022. Of these detected metals, the concentrations of lithium, mercury, nickel, and uranium were all higher in EFPC than the concentrations of these metals measured in the background stream MB (see Figure 8.2.4 below). No TN state water criteria were exceeded for these detected metals at this location. However, the highest mercury concentration measured at this location was 0.043 µg/L, which is relatively close to the TN state criterion of 0.051 µg/L for organisms in water. Uranium was also relatively high, with a maximum concentration of 14.3 µg/L, which is nearly half of the EPA drinking water MCL for reference (EPA, 2009). It should be noted that EFPC is not used for drinking water, but the EPA MCL provides a useful comparison.

Bear Creek (BC)

In previous studies, Bear Creek (BC) has been shown to have high concentrations of contaminants near its headwaters that eventually become diluted downstream. One example is uranium metal, which yields concentrations at nearly 220 µg/L near the head waters of BCK 12.3 and has concentrations near 20 µg/L downstream at BCK 3.3. This decreasing concentration trend is typical for many metals and nutrient contaminants in Bear Creek (TDEC, 2021). BCK 0.6, which was investigated for this project, is downstream of the DOE controlled areas and is in a publicly accessible location. Many metals sampled between July 2021 – June 2022 at this location were not detected by laboratory method detection limits. These metals include antimony, beryllium, cadmium, and lead. Metals such as arsenic, chromium, nickel, and thallium were detected at least in one quarter, but were not detected in the other sampling events. These metals were all below TN state criteria. Lithium, mercury, and uranium were consistently detected, but were also below TN state criteria (see Table 8.2.3). Concentrations of both lithium and mercury were comparable to the Mill Branch (MBK 1.6). Uranium metal concentrations were much higher than levels found in MBK 1.6, reaching upwards of 15.1 µg/L (see Figure 8.2.4 below). For reference purposes, BCK 0.6 uranium concentrations are roughly half of the EPA drinking water MCL, which is 30 µg/L (EPA, 2009).

It should be noted that BC is not used for drinking water, but the EPA MCL provides a useful comparison.

Poplar Creek (PC)

Compared to the upstream EFK 6.3 and BCK 0.6 inputs, PC generally yielded lower metal concentrations for uranium and lithium. However, PC sampling locations tended to have higher concentrations of arsenic and lead relative to MB and to the upstream inputs. In fact, PC was the only stream of all the streams investigated to yield detections of lead. These lead concentrations likely come from upstream reaches of PC as lead is not detected in BC or EFPC. Mercury and nickel concentrations remained elevated in PC, yielding results similar to the upstream input of EFPC (see Figure 8.2.4). Mercury, nickel, and uranium slightly increased at PCM 4.6, which is directly downstream of the Mitchell Branch confluence. This suggests that Mitchell Branch (MIB) may be loading these constituents to PC. Mercury exceeded the TN state criterion of 0.051 μg/L for organisms in water on 8/24/21 at PCM 2.3. All other metals were below TN state criteria. Uranium concentrations were much lower within PC than in upstream inputs, averaging around 1.17 μg/L. However, uranium concentrations were elevated relative to MB.

Mill Branch (MB)

Mill Branch is used as a reference stream for this project. MB did not yield any TN state criteria exceedances for any of the metals sampled, with most metals never being detected (see Table 8.2.3). MB yielded lower metal concentrations than all other streams sampled (see Figure 8.2.4).

Clinch River (CR)

The Clinch River (CR) was co-sampled quarterly with UT-Battelle. Mercury samples were taken at each sampling location. Mercury results were all below TN state criteria and were relatively low in concentrations. The most downstream location CRK 16.1 yielded the highest concentration among CR sites of 0.00903 μg/L and CRK 32 near the confluence of White Oak Creek (WOC) had the lowest concentration of mercury at 0.0019 μg/L. (see Table 8.2.7).

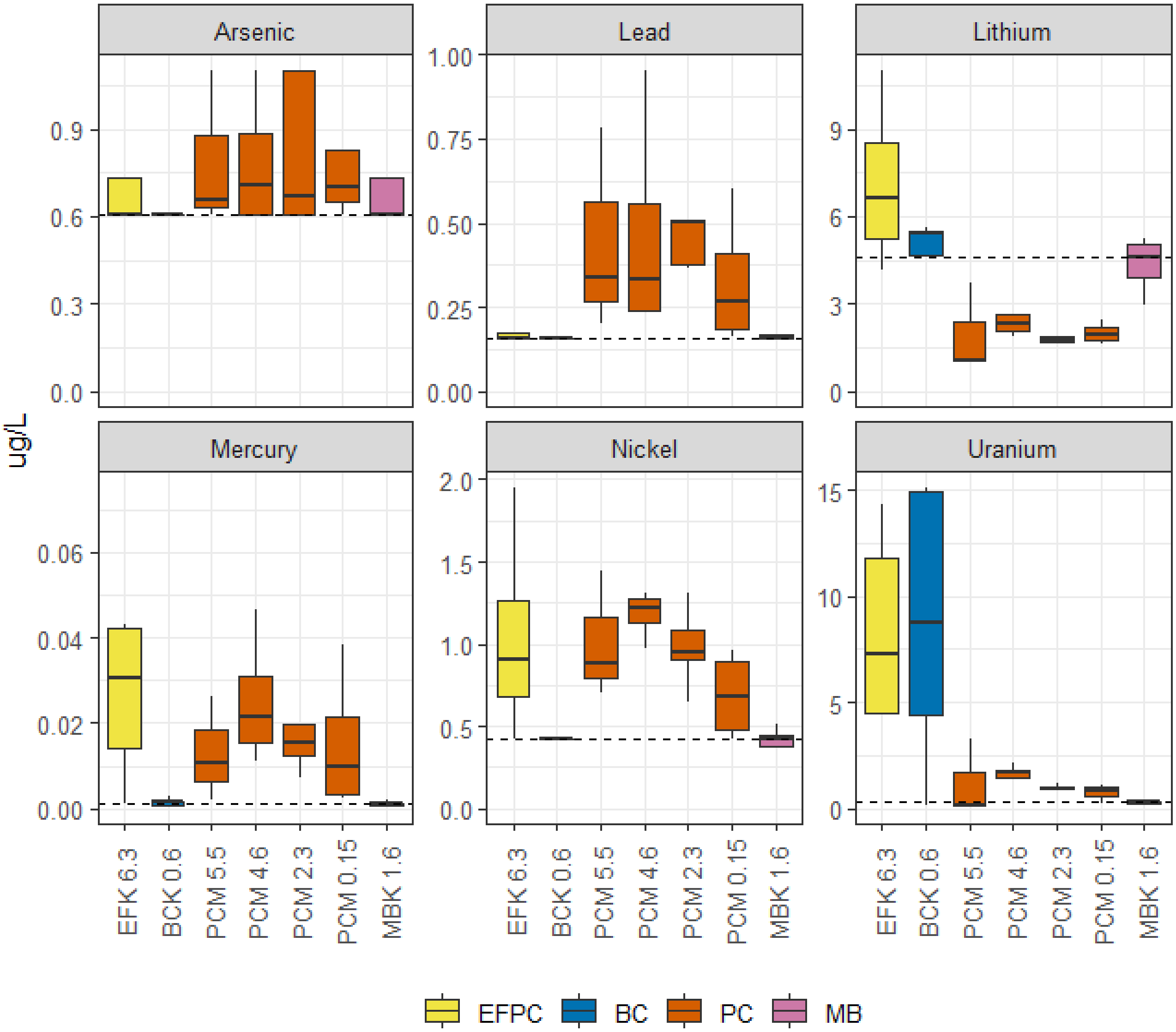

Figure 8.2.4: Metal results of all four sampling dates shown collectively as boxplots for EFPC (yellow), BC (blue), PC (orange), and background stream MB (pink). The black dashed line represents the median result at the background MB location for comparison. Other metals that were not frequently detected can be found in Table 8.2.3.

Radionuclides
Laboratory radionuclide reports present radioactivity with some measure of uncertainty. While radioactivity may be presented by the laboratory results, the uncertainty should also be considered. All radionuclides sampled for this project were qualified using a method based on the combined standard uncertainty (CSU) of the laboratory result. Samples that yielded CSUs greater than 30% of the result activity were identified as "U", indicating that, within this report, they were not detected (see Tables 8.2.5 and 8.2.6).

East Fork Poplar Creek (EFPC)
East Fork Poplar Creek station EFK 6.3 yielded radionuclide activities higher than MB for alpha activity and all of the uranium (U) isotopes (i.e. 243, 235, and 238). U-235 was only detected in one sampling event, which was the only U-235 detection among all sampled streams. All of the transuranic isotopes sampled (e.g. americium, curium, neptunium, plutonium, and thorium) were not detected at this location (see Tables 8.2.5 and 8.2.6). Alpha activities, while being above the background location at MB, were still rather low (see Figure 8.2.5).

Bear Creek (BC)
Of all the streams sampled, BCK 0.6 tended to have the highest activities of radionuclides. More specifically, alpha activity, beta activity, and uranium isotopes (i.e., 243 and 238) were all higher at BCK 0.6 than other streams. These radionuclides were often much higher than the background MB location (see Figure 8.2.5). All of the transuranic isotopes sampled (e.g., americium, curium, neptunium, plutonium, and thorium) were not detected at this location (see Tables 8.2.5 and 8.2.6). Similarly, uranium-235 was not detected. Uranium-238, while being detected at a low activity in surface water, was also identified in fish tissue as part of a 2021 spring fish tissue sampling event by DOE according to data available in the Oak Ridge Environmental Information System (OREIS). Activities of uranium-238 in fish tissue were found to be an average of 0.013 pCi/g at this BCK 0.6 location. Due to a limited sample size of both fish and surface water samples, any significant correlations between these results cannot be determined at this time.

Poplar Creek (PC)
Radionuclides sampled at the PC locations were generally similar with results of MB. However, occasional detections of both alpha and beta activity were higher in activity in PC than the background location. Beta activity was only identified at sample location PCM 2.3. This may be related to surface and groundwater interactions at ETTP within the geological syncline that trends northeast and southwest near the K-27 area. Again, as with other locations, the activities identified were quite low (see Figure 8.2.5). Uranium-234 and uranium-238 were identified, but at low activities. Of all of the transuranic isotopes sampled (e.g. americium, curium, neptunium, plutonium, and thorium), only neptunium-237 was identified in one sample at PCM 5.5.

Uranium-238 was also identified in fish tissue at the PCM 5.5 location as part of a 2021 spring fish tissue sampling event by DOE according to OREIS. The average activity for uranium-238 activity was 0.0165 pCi/g in fish tissue at PCM 5.5. From sample results received back from the laboratory, the average detected uranium-238 activity within PC locations was 0.8 pCi/L in surface water. In addition to uranium-238, other radionuclides were detected at low concentrations in both water samples and in recent TDEC DoR-OR fish studies. These include alpha activity, beta activity, and neptunium-237. Due to a limited sample size of both fish and surface water samples, any significant correlations between these results cannot be determined at this time.

Mill Branch (MB)

MB was again used as the background stream for radionuclide sampling. This location typically yielded the lowest activities for all radionuclides sampled with most never being detected (see Figure 8.2.5). Uranium-234 activities were detected, but at very low activities.

Clinch River (CR)

The CR was sampled for gross alpha and beta activity along with uranium isotopes each quarter. These samples were taken as part of a co-sampling event with UT-Battelle and were taken from shores and docks. These single samples likely are not representative of the CR as a whole due to the large size of the river. However, these samples do provide some information of the nature of the CR surface water. Alpha and beta activities were not detected in the CR. Uranium-234 was detected at CRK 66, but at very low activities at background levels (see Table 8.2.7).

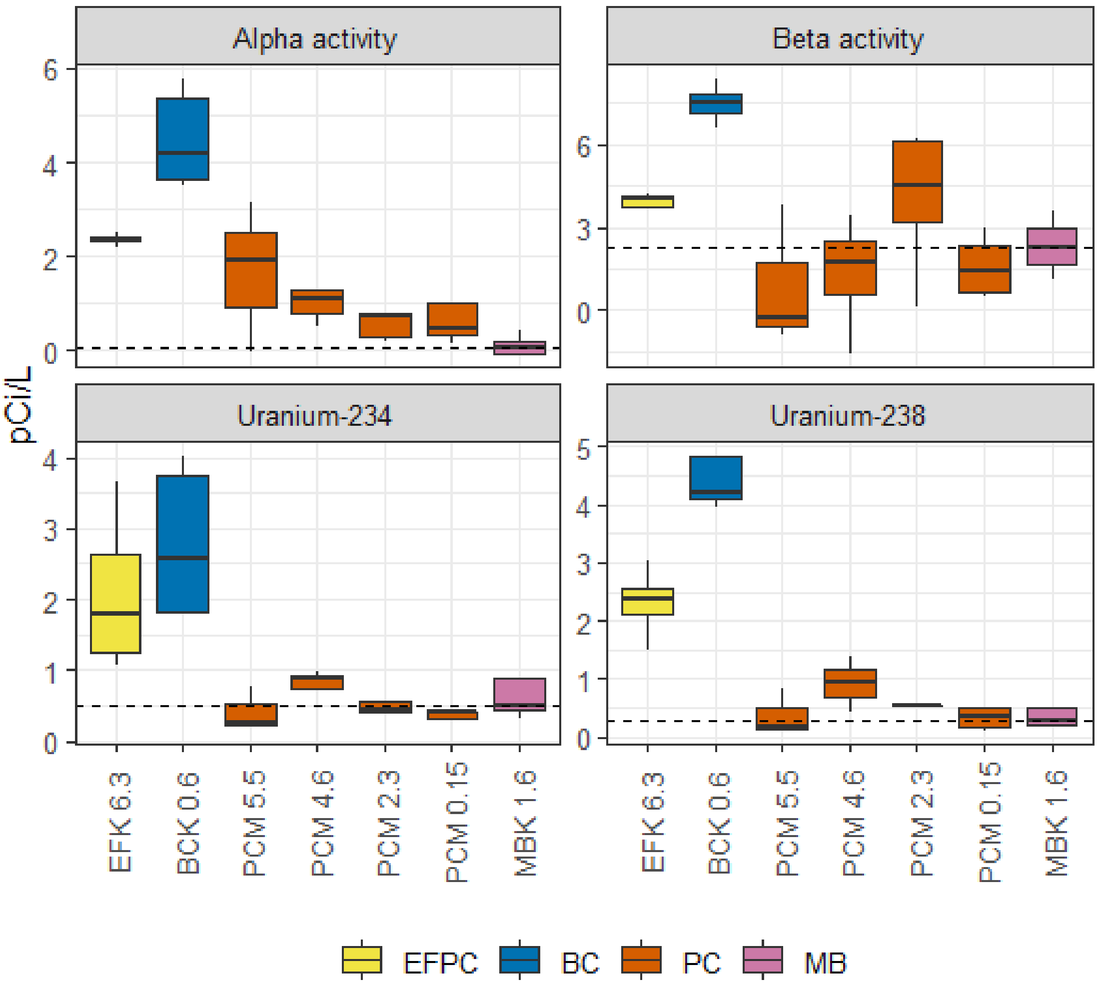

Figure 8.2.5: Radionuclide results for commonly detected radionuclides. All four sampling dates are shown collectively as boxplots for EFPC (yellow), BC (blue), PC (orange), and background stream MB (pink). The black dashed line represents the median result at the background MB location for comparison. For comparison purposes, any non-detected values are illustrated here as the published result from the analytical laboratory.

Water Quality Parameters

East Fork Poplar Creek (EFPC)

Water quality parameters were measured at each of the sampling events for all streams. EFPC had the highest conductivity of all streams with results above the background MB stream. Conductivity was an average of 409 uS/cm throughout the year. Temperatures were higher than MB and ranged from 6.6 degrees Celsius to 21.3 degrees Celsius throughout the year. Dissolved oxygen had an average of 9 mg/L over the year which is slightly lower than MB. Values for pH were similar to all other streams measured (Figure 8.2.6).

Bear Creek (BCK)

Bear Creek had higher conductivity than PC and the background stream MB. Conductivity was an average of 353 uS/cm throughout the year, which is quite similar to EFPC (Figure 8.2.6). Temperatures were higher than MB and ranged from 5 degrees Celsius to 20.4 degrees Celsius throughout the year. Dissolved oxygen had an average of 9.65 mg/L over the year which is also slightly lower than MB. Values for pH were similar to all other streams measured (Figure 8.2.6).

Poplar Creek (PC)

The surface water parameters at the PC sample locations were all rather similar among stations. Conductivity ranged from 156.9 uS/cm to 401 uS/cm and yielded a yearly average of 234.5 uS/cm (see Table 8.2.8). Dissolved oxygen had an average of 7.34 mg/L over the year among all PC locations. Temperatures in PC were highest among all streams and ranged from 6 degrees Celsius to 23.7 degrees Celsius yet were very similar to EFPC and BC. Values for pH were similar to all other streams measured (Figure 8.2.6).

Mill Branch (MB)

MB had the lowest conductivity at 267 uS/cm. It also had the highest dissolved oxygen among streams at an average of 10 mg/L over the year. Temperatures in the summer months were much lower at MB compared to other streams with temperatures throughout the year ranging from 6.1 degrees Celsius to 17.8 degrees Celsius. Values for pH were similar to all other streams measured (Figure 8.2.6).

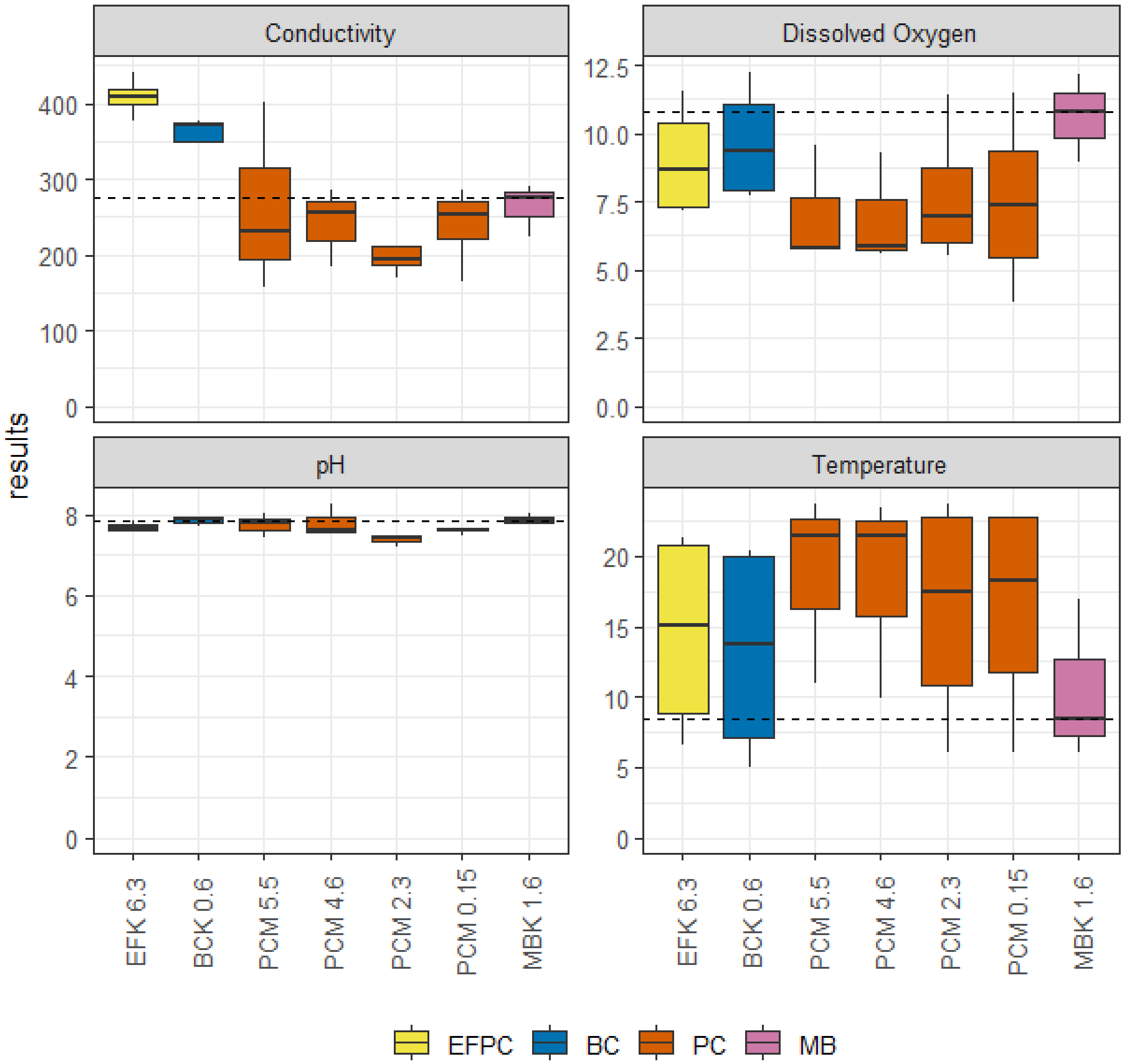

Figure 8.2.6: Water quality parameter results of all four sampling dates shown collectively as boxplots for EFPC (yellow), BC (blue), PC (orange), and background stream MB (pink). The black dashed line represents the median result at the background MB location for comparison

General Surface Water Chemistry

Poplar Creek (PC)

Nutrients and inorganic constituents were sampled quarterly at all PC sampling locations (see Table 8.2.4). In general, PC yielded an ionic composition of calcium and carbonate/bicarbonate. Magnesium and sulfate were also present with a smaller amount of sodium chloride (see Figure 8.2.7). This ionic composition was essentially identical at all locations with no noticeable difference and is typical due to the local limestone and dolomite geology. Higher concentrations of these same constituents were present in the November sampling events compared to the rest of the year. However, the overall ionic composition remained the same (see Figure 8.2.8). This change in concentrations may be due to scheduled TVA dam releases which result in lower PC water levels in the winter months creating the potential to yield more concentrated constituents.

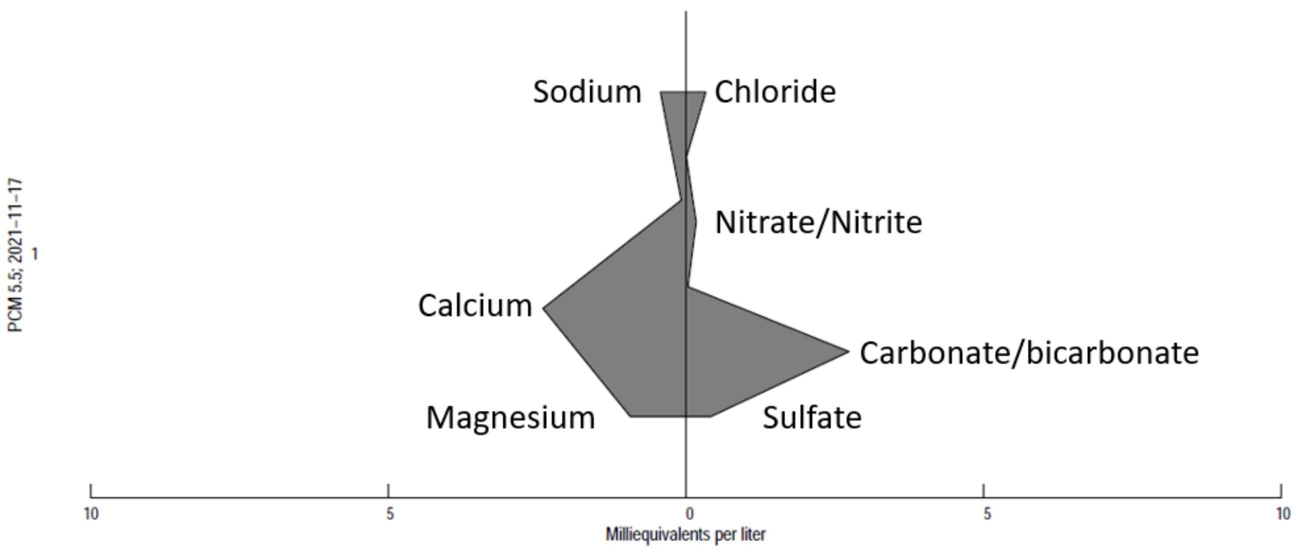

Figure 8.2.7: Typical Poplar Creek stiff plot. This plot shows PCM 5.5 on 11/17/2021 in milliequivalents per liter. Note the predominately calcium carbonate water signature.

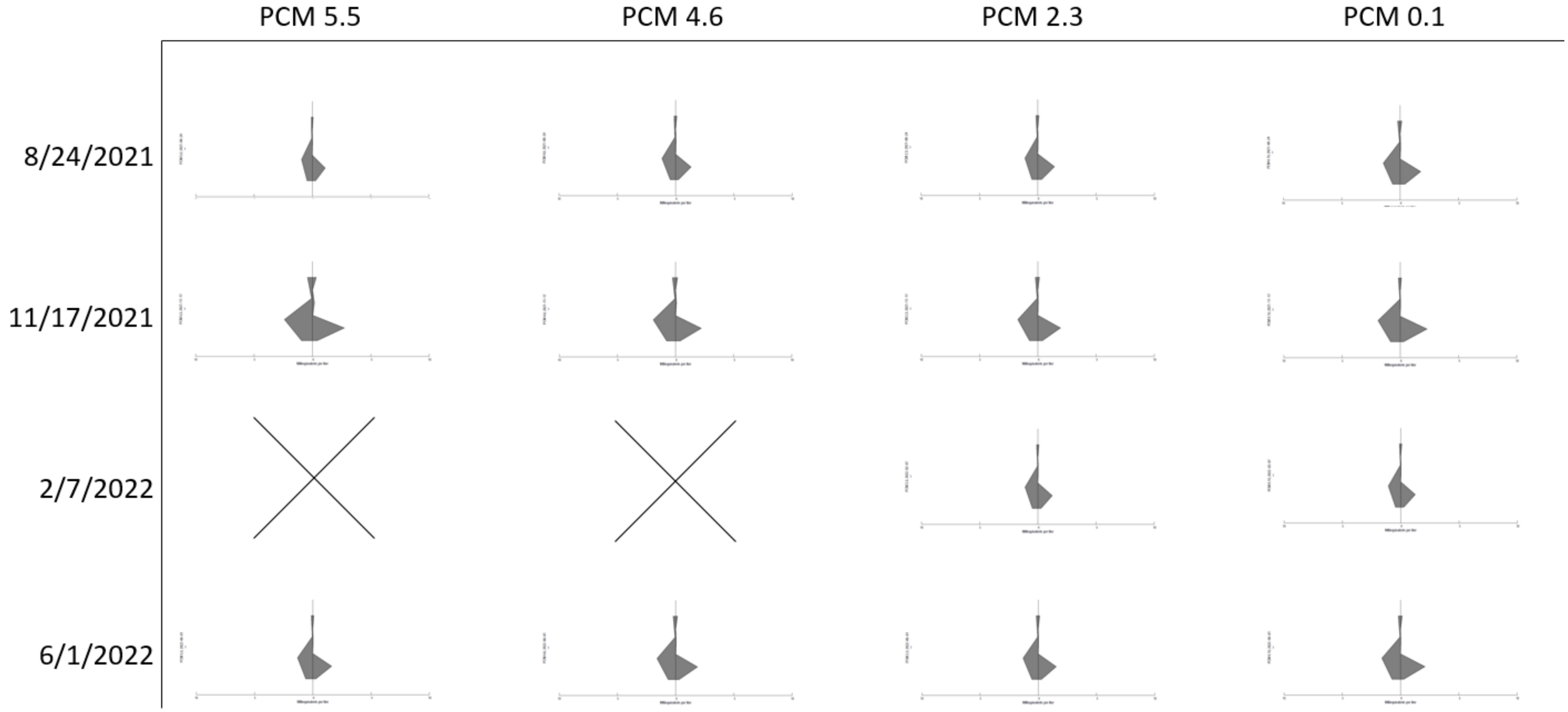

Figure 8.2.8: Poplar Creek stiff plots in milliequivalents per liter for four sampling events. Nodes on left side of stiff plot axis from top to bottom include sodium, potassium, calcium, and magnesium. Nodes on the right side of axis from top to bottom include chloride, fluoride, nitrates, phosphate, carbonate/bicarbonate, and sulfate. A predominant calcium bicarbonate water is shown at all sampling events with a fair amount of magnesium. A small amount of sodium, chloride, nitrate, and sulfate are also present. No sampling occurred for the "X" dates and stations.

Nutrients such as nitrate/nitrite and phosphorus were above the TN 90th percentile (i.e. > 0.04 mg/L for total phosphorus or >1.22 mg/L for Nitrate/Nitrite, respectively) of all streams within eco region 67f, which is the Southern Limestone/Dolomite Valleys and Low Rolling Hills from Bristol, TN to Chattanooga, TN (TDEC, 2004). Phosphorus was above the 0.04 mg/L guidance level at all PC sampling locations. Occasional exceedances were identified above the 1.22 mg/L level for nitrate/nitrite at PCM 4.6 and PCM 5.5.

8.2.8 Conclusions

Lower EFPC, Lower BC, and PC

Lower EFPC was identified to have elevated lithium, mercury, nickel, and uranium metal concentrations relative to other streams investigated. However, only mercury and nickel seem to carry into PC. The lithium and uranium metal concentrations tend to be much lower in PC relative to EFPC. The uranium metal is also elevated at BC, which would likely increase the likelihood of elevated uranium metal in PC. However, the uranium concentrations are much lower in PC, perhaps due to dilution or loss of uranium to sediment due to the decreased capacity of PC to carry sediment because of the often slow or absent flow caused by the TVA dam. Mercury and nickel concentrations did however persist into PC. Both of these constituents increased slightly at PCM 4.6, which is directly downstream of the PC and Mitchell Branch (MIB) confluence. These metals tended to decrease downstream towards the CR, likely due to dilution. For radionuclides, alpha and beta activities as well as uranium isotopes were relatively higher in EFPC and BC but did not seem to be carried through to PC (see Figure 8.2.9). Again, this result may be due to dilution of PC or due to settling of sediment from slower or intermittent flow in PC. Detectable beta activity was identified frequently at PCM 2.3, which may be related to groundwater and surface water connections with the ETTP syncline near K-27. However, these detections were rather low in activity. Contaminants such as arsenic and lead were identified in PC yet were not identified in EFPC or BC. These constituents may originate from a location upstream of the EFPC and PC confluence.

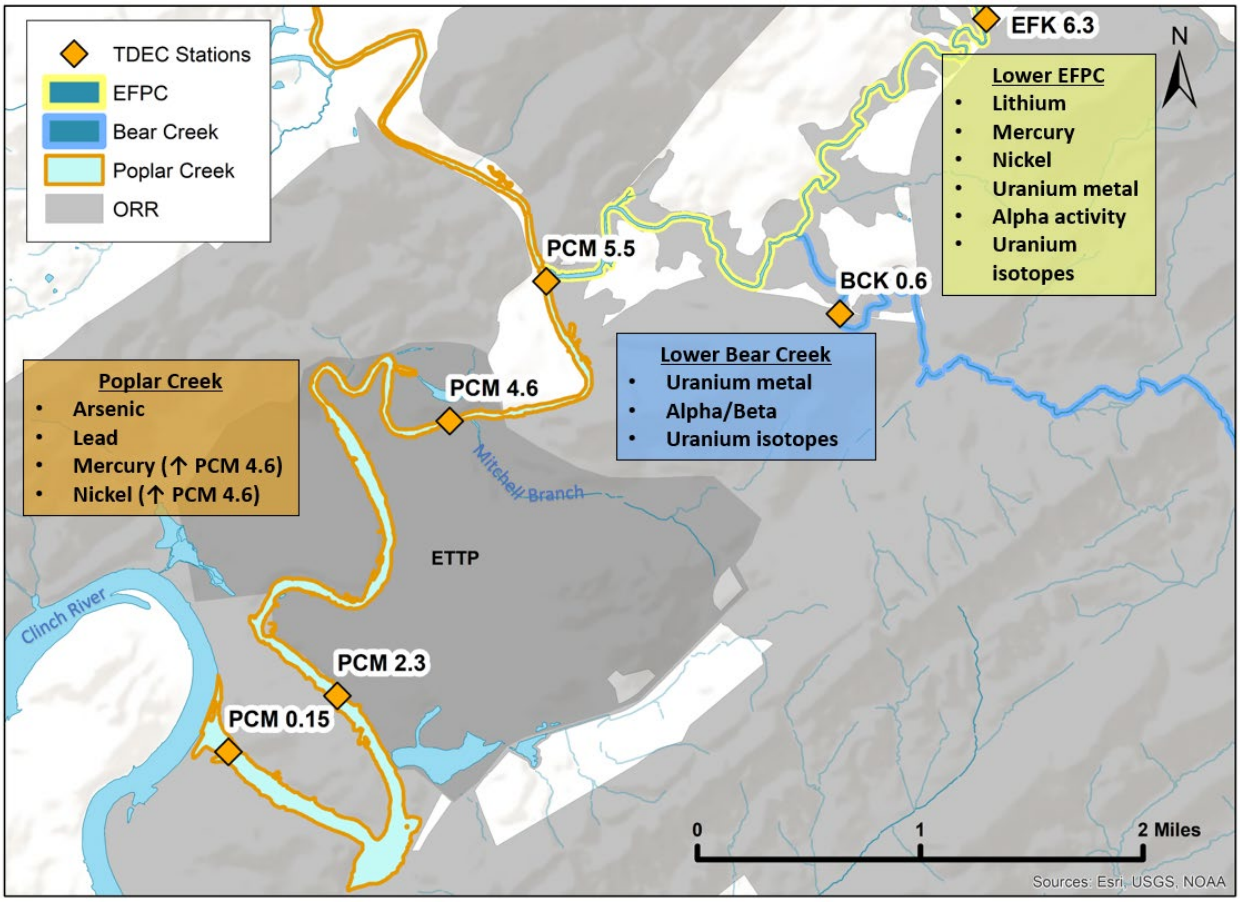

Figure 8.2.9: Map illustrating the three ORR streams investigated. Constituents are listed that were elevated or relatively higher in concentration/activities than the other streams or the Mill Branch background stream

All concentrations for metals were below TN state criteria in all streams with the one exception of a mercury exceedance of the TN state criterion of 0.051 µg/L for organisms in water at PCM 2.3. PC also had elevated phosphorus and nitrate/nitrite levels higher than the TN 90th percentile (i.e. > 0.04 mg/L for total phosphorus or >1.22 mg/L for Nitrate/Nitrite, respectively) of all streams within eco region 67f (TDEC, 2004). Uranium metal concentrations in both lower EFPC and lower BC were elevated, when compared to the EPA drinking water MCL as a reference (EPA, 2009). However, no exceedances occurred. Radionuclides were present in EFPC and BC but did not seem to readily carry into PC at elevated activities.

Poplar Creek was found to have an ionic composition of calcium and carbonate/bicarbonate. Magnesium and sulfate were also present with a smaller amount of sodium chloride. This composition was consistent along the section of PC investigated and did not vary dramatically with season. No dramatic changes of ionic composition were identified, making it difficult to draw any conclusions of the influence of groundwater or other tributaries. The PC surface water chemistry was typical of limestone and dolomite geology, which underlies the PC stream channel.

Clinch River

The CR yielded low mercury concentrations at all locations sampled. Radionuclides were similarly low or not detected at these locations. Generally, it seemed that the overall volume of the CR helped in diluting any contaminants that may be entering from the ORR at the locations sampled. Previous and ongoing TDEC-DoR-OR sampling directly at the confluence of White Oak Creek (WOC) have identified elevated levels of contaminants within the Clinch River (see WOC Radionuclides section within this EMR). However, these contaminants tend to be diluted downstream. Even though concentrations and activities may be lower due to Clinch River dilution, loading can still be quite high from these ORR inputs (TDEC, 2020 & 2021).

8.2.9 Recommendations

It is recommended that further investigations be conducted for the influence of EFPC and BC to PC. Understanding how contaminants transport from one stream to the next offers insight into the overall loading of contaminants to the CR. As uranium metal and radionuclides typically were much lower in concentrations/activities relative to the upstream EFPC and BC inputs, it is recommended that PC sediment be investigated to better understand the fate and transport of these contaminants. Finally, it is recommended that future studies help to identify any significant relationships between fish tissue contaminant concentrations and those contaminants found in surface water.

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8.3 WHITE OAK CREEK RADIONUCLIDES

8.3.1 Background

To help monitor potential ORR contamination, an ambient surface water sampling project has been implemented each year since 1993. This monitoring project originally began by investigating the water quality of the Clinch River (CR) at locations near the ORR. The sampling locations for the ambient surface water sampling project have been modified throughout the years, sometimes adding and sometimes discontinuing sampling at particular locations. Elevated levels of Sr-90 were observed at the sampling station (CRK 33.5) located at the confluence of White Oak Creek (WC) and the CR immediately downstream of the WC Embayment sediment retention structure (Figure 8.3.1). As a result, the WC radionuclide surface water sampling project was developed to focus on monitoring surface water quality along WC and at the confluence with the CR. The purpose of this project is to continue monitoring Sr-90, the main COC, plus other radiological contaminant inputs.

8.3.2 Problem Statements

This project will supplement the DOE's ongoing investigation of Sr-90 contributors to WOC and DOE's study of the CR to better understand impacts to human health. It is estimated, based on 2020 US census data, that nearly 1.1 million people live in the counties surrounding the ORR (DOE, 2021). A large portion of these people have the potential of being negatively affected by streams that drain the ORR. All the exit-pathway streams on the ORR eventually flow into the CR which ultimately flows into the Tennessee River. Twelve (12) water supply intakes are located in these rivers within 170 miles downstream of the WC-CR confluence (DOE, 1992). In addition to providing drinking water, the CR also supplies water for industrial use to many municipalities near and downstream of the ORR including Anderson County, Knox County, Roane County, the City of Clinton, the City of Kingston, and the City of Oak Ridge. CR surface waters are also used for facilities at Y-12, ORNL, and the ETTP. As such, it is important to monitor WOC, in addition to the DOE's monitoring of the CR, to better understand the ORR's impact on this widely used resource.

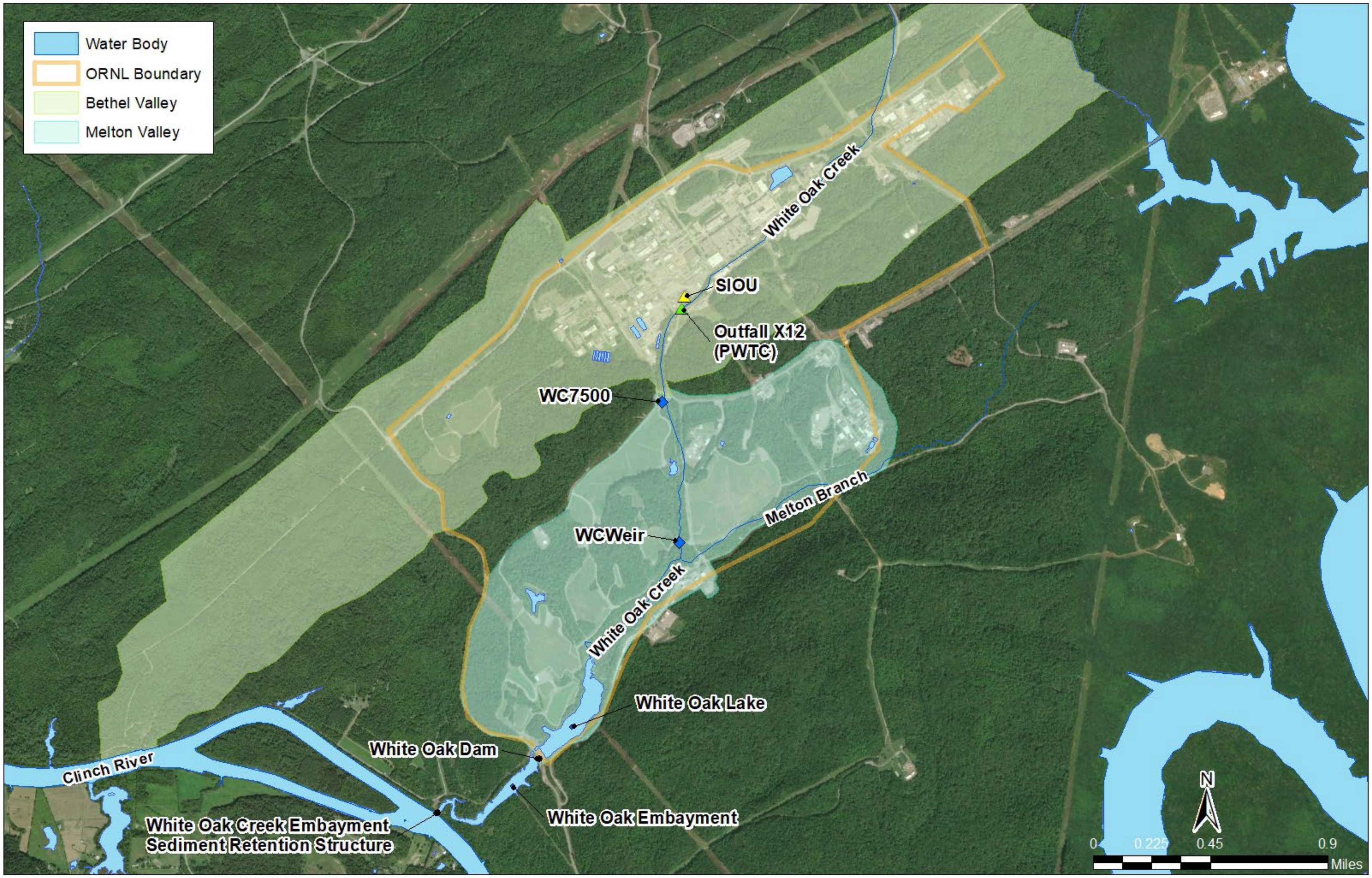


Figure 8.3.1: Map illustrating location of White Oak Creek and pertinent features

The ORR exit-pathway streams and the Clinch River have historically and are currently being subject to contaminant releases from activities at Y-12, ORNL, and ETTP. These releases can be detrimental to the environment and to human health. Identified concerns for White Oak Creek include but are not limited to the following:

- ORNL has been releasing low-level radioactive liquid wastes to the Clinch River via White Oak Creek since 1943. (Pickering, 1970).
- The Clinch River received approximately 665 curies of cesium-137 from White Oak Creek between 1954 and 1959. (DOE, 1992).
- Groundwater collected from the solid waste storge areas (SWSAs) in Melton Valley is transferred to the Process Waste Treatment Complex (PWTC) in Bethel Valley for treatment. The PWTC does not entirely remove strontium-90 from the waste stream and ultimately discharges treated wastewater containing elevated levels of strontium-90 into White Oak Creek at Outfall X12 (Figure 8.3.1).
- Historic and ongoing discharges of strontium-90 and cesium-137 into White Oak Creek is impacting surface water quality. Known sources include, but are not limited to, impacted floodplain soils from the former Surface Impoundment Operable Unit (SIOU) area (Figure 8.3.1) and baseflow groundwater seepage into White Oak Creek (DOE, 2022).

By monitoring White Oak Creek, we can better assess how it contributes to surface water contamination and provide insight to help protect human health and the environment, especially for the important resource of the Clinch River.

8.3.3 Goals

The goal of the White Oak Creek radionuclides monitoring project is to evaluate the impacts of DOE ORR contamination to White Oak Creek and the Clinch River at the White Oak Creek confluence (see Figure 8.3.2). This project ultimately seeks to understand White Oak Creeks contribution of contaminants to the Clinch River. Although White Oak Creek is not currently used as a drinking water source, an assessment of White Oak Creeks impacts to the Clinch River was performed by comparing analytical results to the U.S. Environmental Protection Agency (EPA) derived drinking water concentrations for radionuclides (EPA, 2009). Overall, this project helped define areas of concern on the ORR that may be significantly impacting the surface water resources of Tennessee.

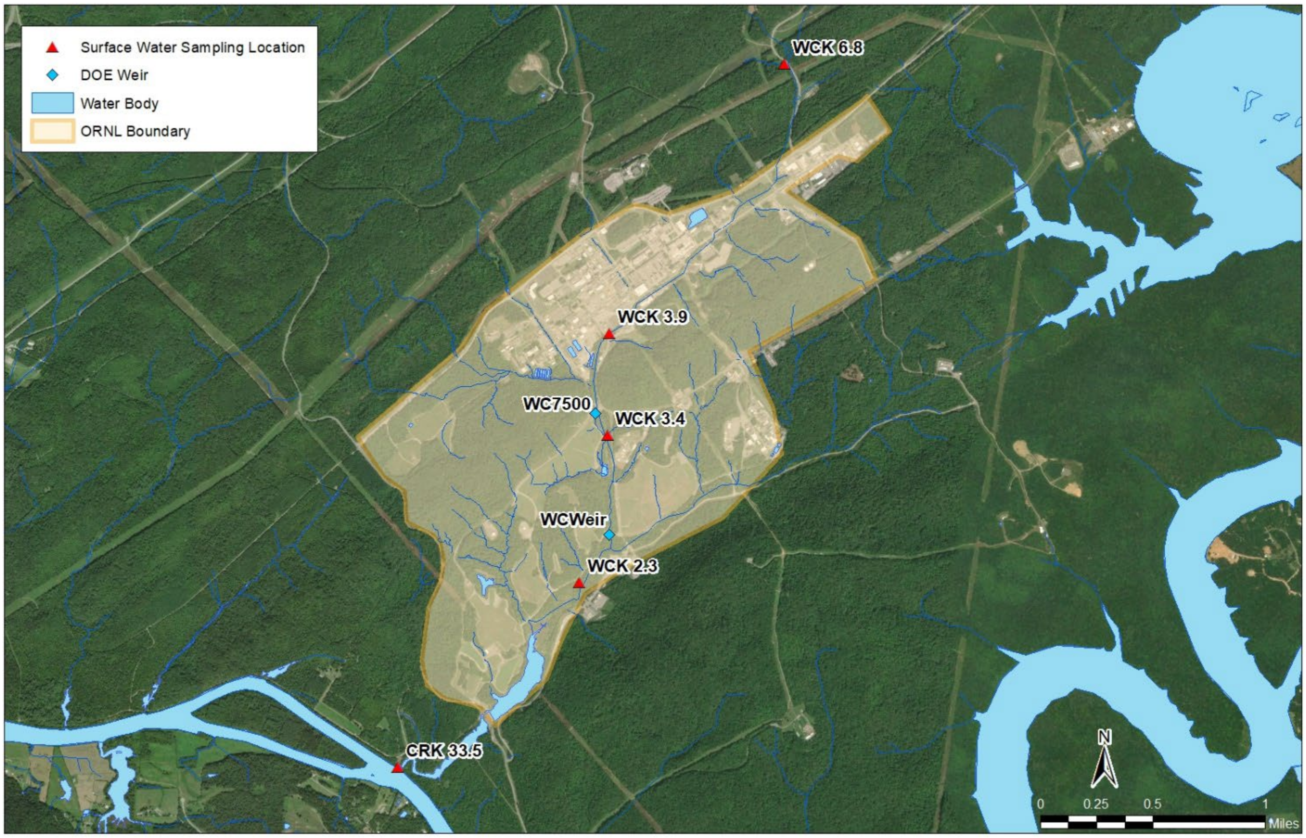


Figure 8.3.2: Map showing TDEC DoR-OR White Oak Creek Surface Water Sampling Locations and DOE Weir Locations

To accomplish this goal, the following activities were completed:

1. Collected surface water samples quarterly at four sample locations along White Oak Creek and one sample location at the confluence of White Oak Creek and the Clinch River (Figure 8.3.2) and submitted laboratory analysis for strontium-90, isotopic uranium, and gamma isotopes.
2. Measured physical water quality parameters (e.g., specific conductivity, pH, and temperature) at each sample location at time of sampling.
3. Evaluated resulting data and identified increasing or decreasing trends.

8.3.4 Scope

The scope of this project was to collect quarterly surface water samples for analysis of select radionuclides at four locations along White Oak Creek (WOC) and at the confluence of White Oak Creek at the Clinch River (CR).

8.3.5 Methods, Materials, Metrics

Sample Collection

Surface water samples were collected quarterly at five locations, four samples were collected along White Oak Creek (WCK 2.3, WCK, 3.4, WCK 3.9, and WCK 6.8) and the fifth sample was collected at the confluence of White Oak Creek and the Clinch River (CRK 33.5). Samples were submitted for laboratory analysis of strontium-90, isotopic uranium, and gamma isotopes. Sampling protocols followed 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, 2022).

Field Water Quality Parameter Measurements
At each site, water quality parameters were measured in the field at the time of sampling using a properly calibrated multi-parameter water quality meter. The following water quality parameters were measured: pH, temperature, and specific conductivity.

8.3.6 Deviations from the Plan

Field water quality parameters were not measured during the Q3 2021 sampling event at all five sampling stations and during the Q4 2021 sampling event at CRK 33.5.

8.3.7 Results and Analysis

Streamflow
Although streamflow was not directly measured in the field, TDEC DoR-OR downloaded available streamflow records for White Oak Creek from the Oak Ridge Environmental Information System (OREIS) to evaluate the hydrologic regime of White Oak Creek. TDEC DoR-OR identified two DOE maintained weirs, WC7500 and WCWeir, that had daily streamflow measurements. For the period of record between 2009 and 2020, the average annual flow was 8.7 cubic feet per second (cfs) at WC7500 and 17.3 cfs at WCWeir. Figure 8.3.3 presents daily streamflow data for the time period from June 1, 2019, to September 30, 2021, which coincides with TDEC DoR-OR's White Oak Creek surface water sampling efforts. As evident in this figure, streamflow was highly variable likely as a result from precipitation events. Additionally, the streamflow data presented in Figure 8.3.3 suggests that White Oak Creek is a gaining stream evident by the increase in measured streamflow as you move downstream from the weir at the 7500 bridge (WC7500) to the WCWeir.

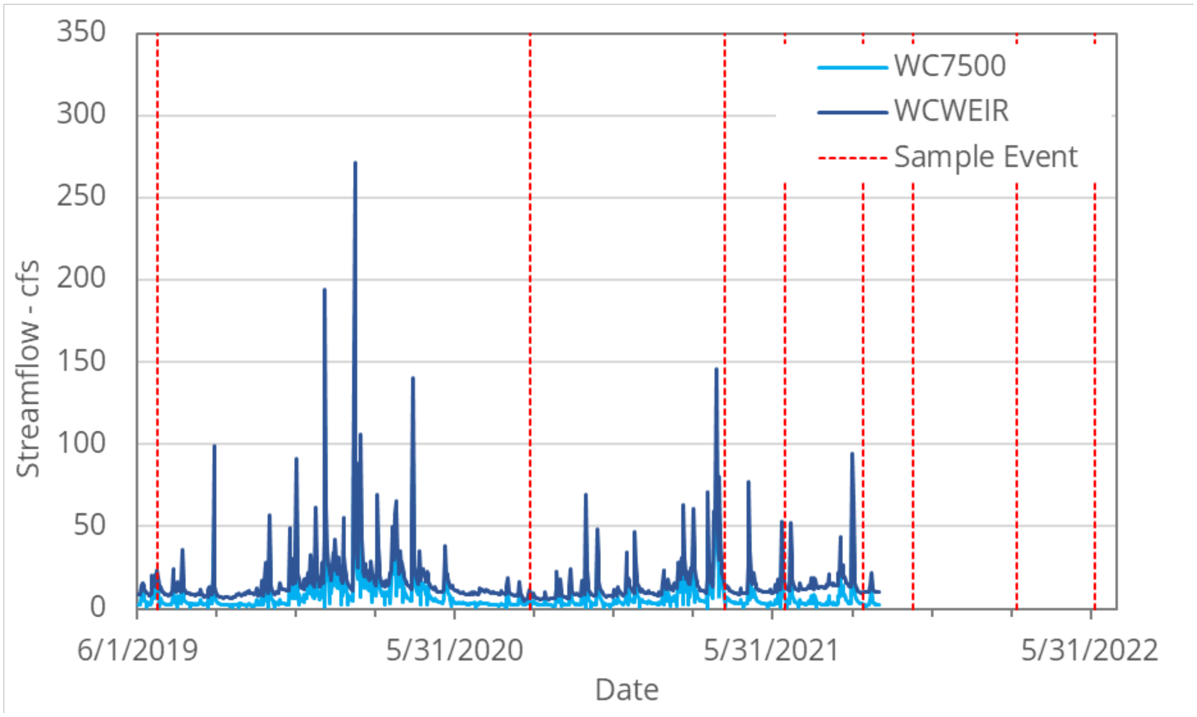
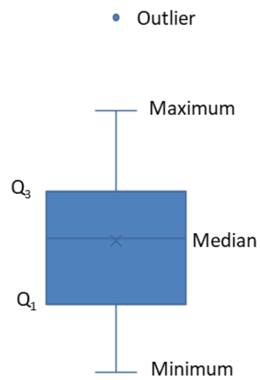


Figure 8.3.3. Streamflow measured at the WC7500 weir and the WCWeir. Vertical red lines represent TDEC DoR-OR surface water sampling events

Increases in streamflow could be a result of various contributions such as smaller tributaries/drainages, outfalls, and baseflow groundwater seepage. The TDEC DoR-OR surface water sampling locations did not coincide with these two weirs; therefore, contaminant fluxes were not calculated.

Field Water Quality Parameter

Water quality parameters, pH, temperature, and specific conductivity were measured in the field during sample collection. A summary of the measured water quality parameters is provided below and the variability of these field parameters across the (5) five surface water sampling locations are visually displayed using box plots. A box plot is generated using five numbers which include the minimum, 25th percentile (Q_1), median, 75th percentile quartile (Q_3), and maximum. During generation of these plots, outliers are visually illustrated, but are not included when calculating the five numbers.



As shown above in the generic box plot, the top and bottom horizontal lines are the maximum and minimum values, the top and bottom of the box are the lower (Q_1) and upper quartiles (Q_3), the horizontal line in the box is the median, the “X” marker displays the mean value, and the dots represent outlier values. The sampling station labels on the box plots includes the sample size (n) at each sampling location.

pH

The pH is a measure of the hydrogen ion concentration and has a measurement unit of standard units (su). Values measured over the three quarters ranged from 7.63 (CRK 33.5) to 8.15 (WCK 3.9). As illustrated in Figure 8.3.3, the mean pH values for the four (4) WOC sample locations are very similar with an approximate pH value of 8.0, while the mean pH value at CRK 33.5 is slightly lower with a value of 7.7.

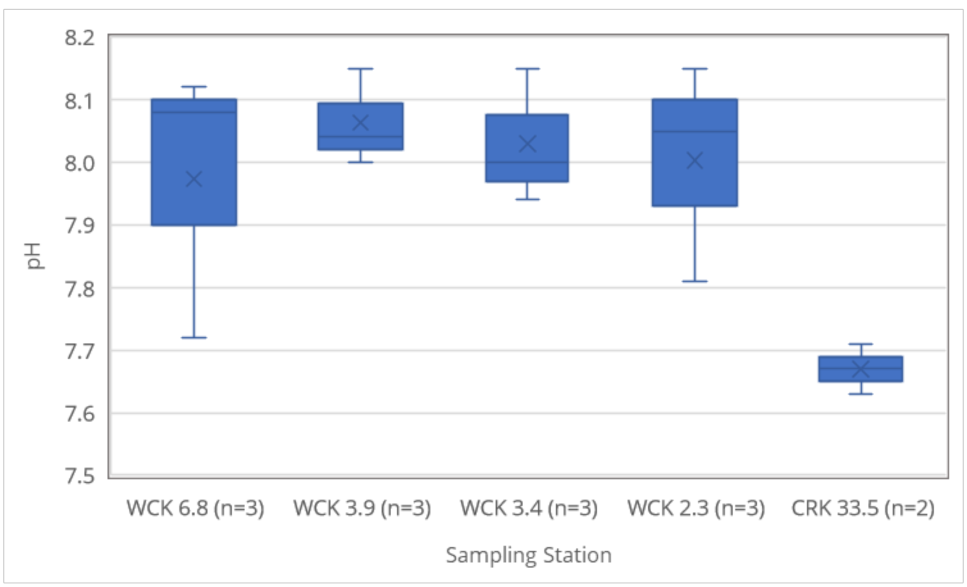


Figure 8.3.3. Box plot of pH values for each sample station. Sample stations are ordered from upstream (WCK 6.8) to downstream (CRK 33.5)

Temperature

Surface water temperatures ranged from 12.4 degrees Celsius (ºC) at WCK 2.3 to 21.4 ºC CRK 33.5. In general, as shown on Figure 8.3.4, the mean temperature between the five (5) sample stations are similar with CRK 33.5 having slightly higher temperatures on average.

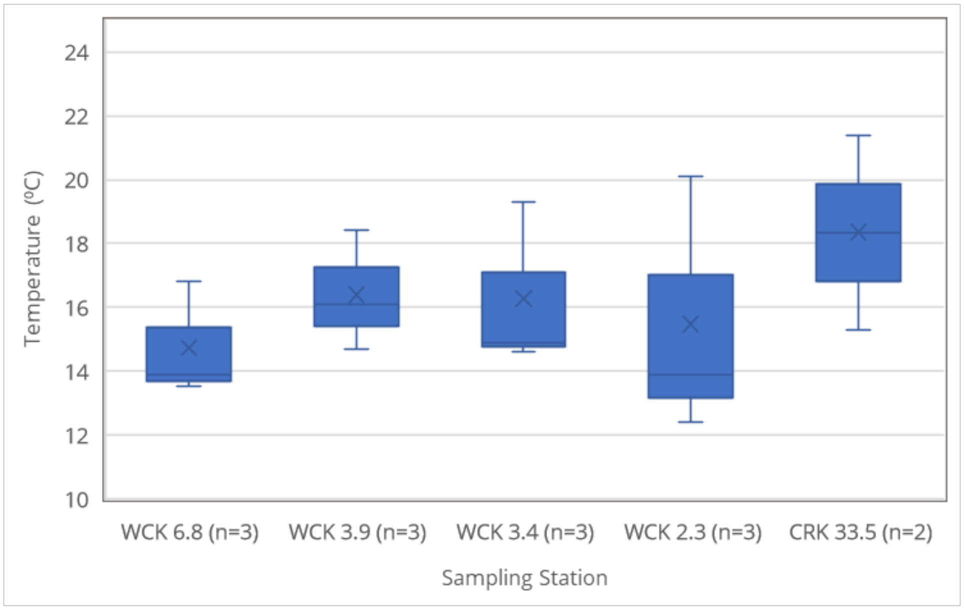


Figure 8.3.5. Box plot of temperature values for each sample station. Sample stations are ordered from upstream (WCK 6.8) to downstream (CRK 33.5)

Specific Conductivity

Specific conductivity is an indirect measurement of the concentration of dissolved ions in solution. Higher specific conductivity values can indicate more dissolved minerals or salts in the water. Specific conductivity values ranged from 231.2 microsiemens per centimeter (μS/cm) at WCK 6.8 to 485.5 μS/cm at WCK 3.9. As illustrated in Figure 8.3.5, the mean specific conductivity values at WCK 3.9, WCK 3.4, and WCK 2.3 were similar and on average were approximately 430 μS/cm. Comparably, the mean specific conductivity values at WCK 6.8 (290 μS/cm) and CRK 33.5 (301 μS/cm) were much lower. The highest specific conductivity values were noted within the known impacted stream section of WOC and could also be indicative that water samples from these three sample locations contained more dissolved ions compared to the other two sample locations.

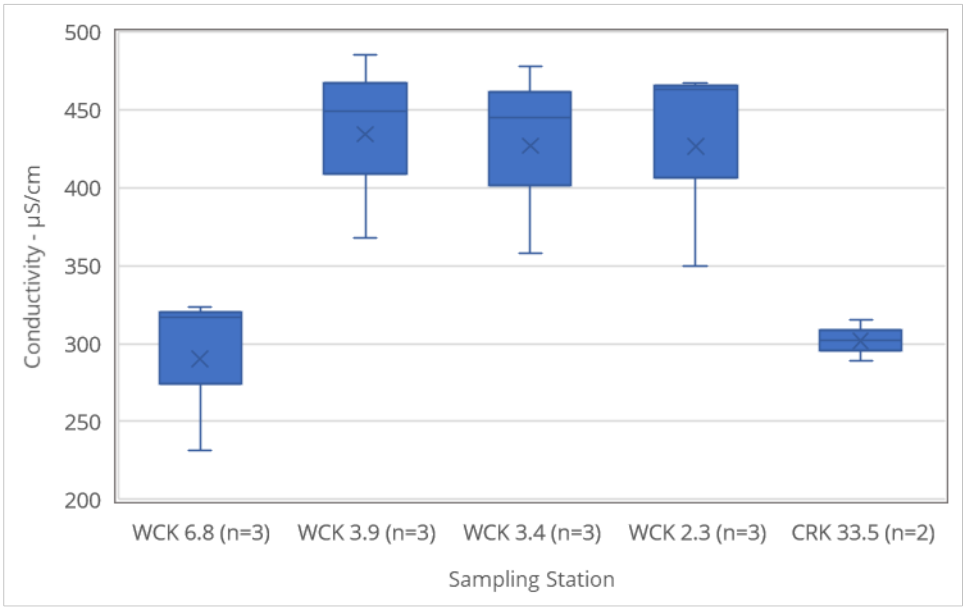


Figure 8.3.5. Box plot of specific conductivity values for each sample station. Sample stations are ordered from upstream (WCK 6.8) to downstream (CRK 33.5)

Surface Water Analytical Results

This section presents the analytical results of the quarterly surface water sampling events. Analytical testing of surface water revealed that select gamma isotopes (bismuth-214, cesium-137, lead-214, and potassium-40) were infrequently detected, isotopic uranium was detected at low concentrations at all sampling stations, and elevated strontium-90 concentrations were observed at WCK 3.9, WCK 3.4, WCK 2.3, and CRK 33.5. The analytical data is presented in Table 8.3.1 and select data is illustrated in various figures throughout this section. Additionally, a trend analysis was conducted on the entire strontium-90 data set which includes data collected in previous fiscal years. Although White Oak Creek is not used for drinking water, the EPA derived drinking water concentrations for uranium at mill tailings sites and for beta and photon emitters are referenced here solely for comparison purposes.

Table 8.3.1. Summary table of the quarterly surface water analytical results.

Sample Location	Sample Date	Bismuth-214	Cesium-137	Lead-214	Potassium-40	Strontium-89	Strontium-90	Uranium-234	Uranium-235	Uranium-238
Derived Concentrations[1,2]		NE	200	NE	NE	20	8	30	NE	30
Concentration		pCi/L								
WCK 6.8	9/14/2021	48 ±14	-	19 ±13	-	-0.5 ±1.2	1.23 ±0.96	0.6 ±0.14	0.071 ±0.053	0.296 ±0.098
	11/9/2021	-	-	-	-	1.2 ±1.1	-0.43 ±0.57	0.34 ±0.10	0.078 ±0.054	0.21 ±0.081
	3/8/2022	22.4 ±9.9	19.0 J	-	-	-0.6 ±1	0.39 ±0.75	0.29 ±0.093	0.173 ±0.077	0.264 ±0.088
	6/6/2022	-	-	-	-	0.04 ±1.1	0.38 ±0.81	0.33 ±0.10	0.02 ±0.030	0.132 ±0.061
WCK 3.9	9/14/2021	-	-	-	-	-1.4 ±1.6	**20 ±10**	1.14 ±0.20	0.134 ±0.66	0.49 ±0.12
	11/9/2021	12.7 ±8.2	-	-	-	-1 ±1.5	**39 ±15**	1.37 ±0.26	0.062 ±0.056	0.232 ±0.090
	3/8/2022	-	18.6 J	-	-	-1.2 ±1.5	**56 ±21**	2.4 ±0.36	0.194 ±0.087	0.5 ±0.13
	6/6/2022	-	-	-	-	0.8 ±1.6	**26 ±18**	0.4 ±0.11	0.086 ±0.058	0.156 ±0.070
WCK 3.4	9/14/2021	-	38.3 ±7.4	-	-	-2.2 ±1.8	**48 ±22**	5.69 ±0.67	0.31 ±0.10	0.64 ±0.14
	11/9/2021	15.9 ±9.4	-	-	-	-0.3 ±1.5	**40 ±18**	1.42 ±0.25	0.058 ±0.051	0.38 ±0.12
	3/8/2022	-	19.7 J	-	-	-1.5 ±1.5	**43 ±17**	1.9 ±0.29	0.182 ±0.080	0.38 ±0.11
	6/6/2022	-	-	-	47 ±28	-1.4 ±1.1	**19.4 ±7.1**	0.82 ±0.20	0.031 ±0.041	0.228 ±0.097
WCK 2.3	9/14/2021	-	-	-	-	-2.9 ±2	**82 ±34**	8.07 ±0.95	0.14 ±0.76	0.44 ±0.12
	11/9/2021	-	-	-	-	5.4 ±4.6	**83 ±87**	1.53 ±0.26	0.063 ±0.049	0.35 ±0.10
	3/8/2022	-	16.4 J	-	-	0.6 ±1.6	**69 ±26**	1.34 ±0.23	0.271 ±0.099	0.56 ±0.14
	6/6/2022	52 ±13	-	30 ±10	-	-1.5 ±1.2	**35 ±14**	0.94 ±0.22	0.106 ±0.079	0.39 ±0.14
CRK 33.5	9/13/2021	-	-	-	-	-0.8 ±1.5	**48 ±20**	3.57 ±0.49	0.128 ±0.072	0.41 ±0.12
	11/2/2021	-	32.7 ±7.1	-	82.1 ±46.6	-3.6 ±2.1	**63 ±27**	2.09 ±0.32	0.061 ±0.048	0.46 ±0.12
	3/8/2022	21.6 ±9.7	37.8 ±7.7	-	-	-0.9 ±1.6	**51 ±19**	1.39 ±0.25	0.194 ±0.089	0.36 ±0.11
	6/6/2022	67 ±14	-	43 ±11	-	0.05 ±1.5	**41 ±19**	1.06 ±0.22	0.09 ±0.065	0.198 ±0.085

Notes:
Bolded values exceed the derived drinking water concentration.
- not detected
CSU = Combined standard uncertainty reported as ± with analytical result.
J = estimated value. CSU not reported for estimated values.
NE = No drinking water derived concentration established.
pCi/L = picocurie per liter
1 = Derived concentrations of beta and photon emitters in drinking water taken from NBS Handbook 69.
2 = EPA derived isotopic uranium concentrations taken for uranium mill tailing sites.

The uranium isotopes, uranium-234, uranium-235, and uranium-238, were detected in all surface water samples. Uranium-234 concentrations ranged from 0.29 picocurie per liter (pCi/L) (WCK 6.8) to 8.07 pCi/L (WCK 2.3), uranium-235 concentrations ranged from 0.058 pCi/L (WCK 3.4) to 0.31 pCi/L (WCK 3.4), and uranium-238 concentrations ranged from 0.21 pCi/L (WCK 6.8) to 0.64 pCi/L (WCK 3.4). The concentrations of uranium-234 and uranium-238 were below the EPA derived drinking water concentration of 30 pCi/L, a derived drinking water concentration has not been established for uranium-235.

As illustrated in Figure 8.3.6, elevated concentrations of strontium-90 were observed in surface water samples collected at WCK 3.9, WCK 3.4, WCK 2.3, and CRK 33.5 with detected concentrations all exceeding the derived drinking water concentration of 8 pCi/L.

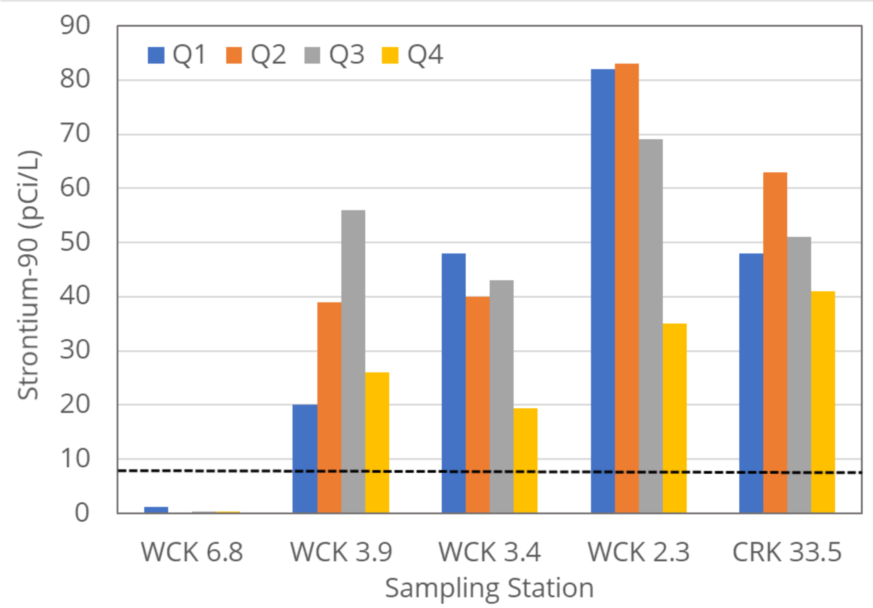


Figure 8.3.6. Quarterly strontium-90 concentrations for each sample station, EPA derived drinking water concentration is illustrated by the black dashed line. Sample stations are ordered from upstream (WCK 6.8) to downstream (CRK 33.5)

The strontium-90 concentrations ranged from non-detect (-0.43 pCi/L) at WCK 6.8 to 83 pCi/L measured at WCK 2.3, the furthest downstream sample station along White Oak Creek. The mean strontium-90 concentrations were much higher at WCK 3.9 (38.3 pCi/L), WCK 3.4 (37.6 pCi/L), WCK 2.3 (67.3 pCi/L), and CRK 33.5 (54 pCi/L), compared to WCK 6.8 (0.5 pCi/L). A box plot illustrating strontium-90 data collected between June 2019 and June 2022 is provided as Figure 8.3.7. The concentration trend between sampling stations over this three-year period was consistent with respect to the quarterly data collected during FY2022.

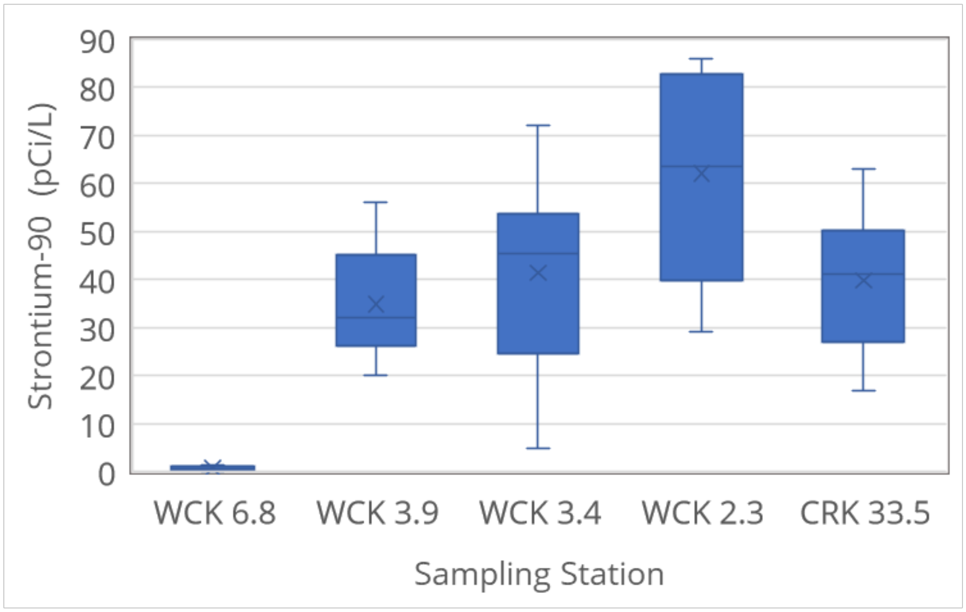


Figure 8.3.7. Box Plot of strontium-90 for each sample station (June 2019 to June 2022). Sample stations are ordered upstream (WCK 6.8) to downstream (CRK 33.5)

Trend Analysis

A time series illustrating strontium-90 concentrations measured between June 2019 and June 2022 at the five sampling stations is provided as Figure 8.3.8. A trend analysis was performed on this three-year data set to determine if strontium-90 concentrations are increasing or decreasing over time.

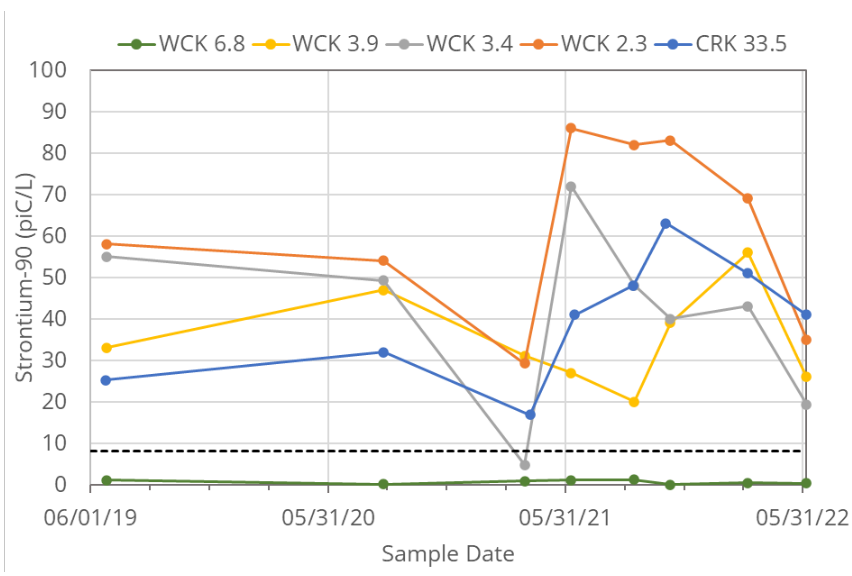


Figure 8.3.8. Strontium-90 concentration time series (June 2019 to June 2022)

A Mann-Kendall trend test was completed using EPA's ProUCL software (version 5.2.0). For analysis purposes, the negative strontium-90 result for the November 2021 sample at WCK

6.8 was set to zero. Results from the Mann-Kendall trend test indicate that there was insufficient evidence to identify a significant trend at all five sampling stations at the specified level of significance (0.05).

8.3.8 Conclusions

In conclusion, analytical testing of surface water at WCK 6.8, WCK 3.9, WCK 3.4, WCK 2.3, and CRK 33.5 revealed the following:

- Select gamma isotopes (bismuth-214, cesium-137, lead-214, and potassium-40) were sporadically detected across all sampling stations. Only cesium-137 has an EPA derived drinking water concentration of 200 pCi/L, and all cesium-137 concentrations were well below this value.
- The uranium isotopes, uranium-234, uranium-235, and uranium-238, were detected in all surface water samples. The concentrations of uranium-234 and uranium-238, which have an established EPA derived drinking water concentration of 30 pCi/L, were detected below this value.
- Elevated strontium-90 (Sr-90) concentrations were observed at WCK 3.9, WCK 3.4, WCK 2.3, and CRK 33.5. All surface water samples collected at these four (4) locations had strontium-90 detected at concentrations greater than the EPA derived drinking water concentration of 8 pCi/L.
- Strontium-90 concentrations increased from upstream (WCK 6.8) to downstream (WCK 2.3) locations along White Oak Creek (WOC). The Clinch River sample station exhibited a slight decrease in strontium-90 concentration compared to WCK 2.3, likely due to dilution since this sample was collected within the Clinch River immediately downgradient of the White Oak Creek Embayment sediment retention structure.
- The absence of elevated levels of radiological contaminants in surface water at WCK 6.8 was most likely due to this sample location being located upstream from major ORNL strontium-90 sources or discharges.

8.3.9 Recommendations

TDEC DoR-OR recommends continuing monitoring White Oak Creek for radiological contaminants of concern. Due to the ongoing hydrogeologic characterization at the Molten Salt Reactor Experiment (MRSE) site, TDEC DoR-OR recommends adding additional surface water sampling along Melton Branch and its tributaries.

8.3.10 References

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9.0 WATERSHED ASSESSMENTS (HOLISTIC) MONITORING

9.1 BEAR CREEK VALLEY ASSESSMENT

9.1.1 Background

This project was a follow-up evaluation of the health of the Bear Creek Watershed, with a focus on providing new sampling data to fill in data gaps left from the Phase 2 investigation of Bear Creek. This follow-up project provides new data for toxicity/biomonitoring of surface water, biota (bird eggs, spiders, and flying insects), and sediment.

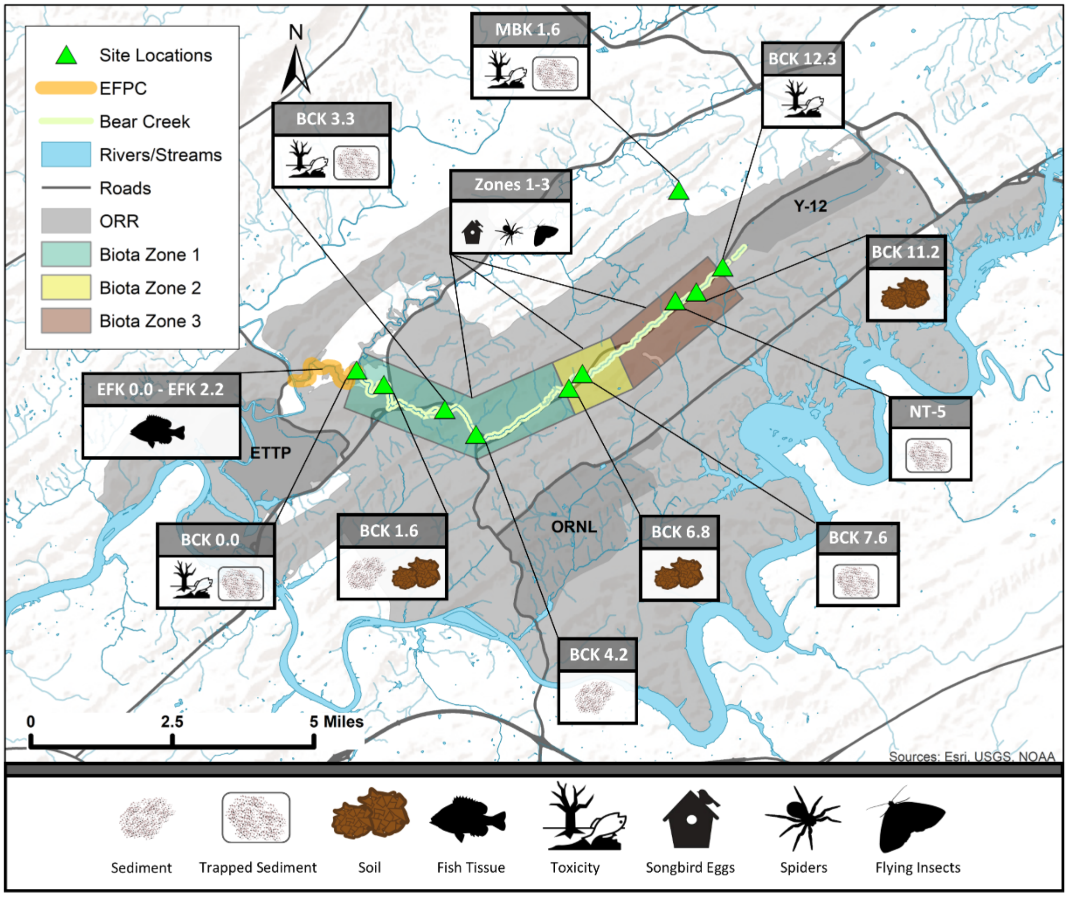

Figure 9.1.1: Map of the BCAP Phase 3 sampling locations

9.1.2 Problem Statements

DOE has not conducted a comprehensive assessment of BCK 3.3 or areas downstream on Bear Creek. This project was 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.

9.1.3 Goals

The goal of this project was to provide a comprehensive evaluation of Bear Creek in order to provide a baseline for future reference after the construction of the proposed EMDF landfill. In addition, this project sought 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.

9.1.4 Scope

The scope of this phase of the Bear Creek Assessment Project includes the environmental assessment of Bear Creek through the testing of surface water toxicity, sediment, soil, fish tissue, and other biota tissue (bird eggs, crayfish, adult insects, and spiders). The stream reach being assessed is from the mouth of Bear Creek (BCK 0.0) at East Fork Poplar Creek km 2.2 (EFK 2.2) to BCK 12.3. The sampling locations are listed in Table 9.1.1 and on Figure 9.1.1.

Table 9.1.1: BCAP Sampling Sites

Site Description	Name	Latitude	Longitude
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 7.87	BCK 7.87	35.950622	-84.313795
Bear Creek kilometer 9.6	BCK 9.6	35.96032	-84.29741
North Tributary 5 of Bear Creek	NT-5	35.96603	-84.29024
Bear Creek kilometer 11.97	BCK 11.97	35.971489	-84.279735
Bear Creek kilometer 12.3	BCK 12.3	35.973	-84.27814
East Fork Poplar Creek kilometer 2.2	EFK 2.2	35.95169	-84.3716
Emory Background Site	EMORY	36.02698	-84.19983
Hinds Creek kilometer 20.6	HCK 20.6	36.15797	-83.99944
Mill Branch kilometer 1.6	MBK 1.6	35.98886	-84.28935
Pinhook Branch kilometer 1.6	PBK 1.6	35.963495	-84.326492

9.1.5 Methods, Materials, Metrics

Sediment

Sediment sampling was conducted at four (4) locations bi-annually; sampling locations are: NT-5, BCK 7.6, BCK 3.3, and MBK 1.6. Suspended sediment samples were collected by using fixed sediment collection devices (traps). Sediment traps were installed in the stream bed in a position where considerable flow through the body of the trap occurs. Suitable sites are often 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 present to completely immerse the sediment traps.

Following a collection period of approximately five (5) 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 three days. 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. Sediment samples were analyzed for gross alpha, gross beta, gamma radionuclides, strontium 89, 90 (Sr-89,90), isotopic uranium, and metals (arsenic (As), barium (Ba), beryllium (Be), boron (B), cadmium (Cd), cesium (Cs), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), strontium (Sr), uranium (U), and zinc (Zn)). The sediment samples were sent to the TDH-NEL for analysis.

On April 6, 2022, the CEC conducted sediment sampling at the two locations listed in Table 9.1.2. These were grab samples collected using a Russian Peat Borer device which obtained core grabs approximately 8 inches in length. Three (3) grab samples were collected at each site and were analyzed for mercury, PCBs, and uranium only.

Table 9.1.2: Sediment grab sampling locations (CEC)

Sediment Sampling Locations			
Site Description	**Shorthand**	**Latitude**	**Longitude**
Beaver dam under Haul Road bridge at Hwy 95	BCK 4.2	35.938401	-84.341146
Downstream of entrance to West End Greenway	BCK 1.6	35.94867	-84.364664

Surface Water Toxicity/Biomonitoring

Toxicity and biomonitoring sampling was conducted in the spring of 2022 at BCK 12.3, BCK 3.3, EFK 2.2 (BCK 0.0), and at the background site, MBK 1.6. Two to three gallons of stream water were collected at each of the sampling sites on Monday, Wednesday, and Friday for one week and then shipped immediately to Waypoint Analytical Laboratory for testing. Testing included survival and reproduction for water fleas (*Ceriodaphnia dubia)* and survival and growth for fathead minnows (*Pimephales promelas*). This sampling project was conducted by CEC with assistance from TDEC DoR-OR.

Soil

Soil sampling was conducted on April 6, 2022, by CEC with assistance from TDEC DoR-OR at three (3) locations in the Bear Creek Valley (Table 2.1.3). Samples were collected with Incremental Sampling Methodology (ISM) using a grid of 30 1-meter^2 cells at each of the sites. The laboratory, Waypoint Analytical, used ISM protocols in the processing and handling of the soil samples. These soil samples were analyzed for mercury, PCBs, and uranium. Sampling was conducted in accordance with the Interstate Technology Regulatory Council (ITRC) document Incremental Sampling Methodology (ISM) dated February 2012 (ITRC 2012) and the Incremental Sampling Methodology (ISM) Update document dated October 2020 (ITRC 2020). Incremental sampling uses a normalized composite sampling and processing approach to reduce variability. ISM provides a relatively unbiased representation of the average constituent concentration in the sample material and over the assessed area. This approach leads to more consistent and reproducible results that are representative of the assessed area. A sample grid was staked out at each of the three (3) sample locations and a 30-point bulk sample was collected for laboratory processing and subsampling.

Table 9.1.3: Soil Sampling Locations

Soil Sampling Locations			
Site Description	**Shorthand**	**Latitude**	**Longitude**
Bear Creek adjacent to entrance to EMWMF	BCK 11.2	35.967848	-84.284913
Approx. 100 yards west of SS-6 on Bear Creek	BCK 6.8	35.947910	-84.317419
Downstream of entrance to West End Greenway	BCK 1.6	35.94867	-84.364664

Songbird eggs

Eggs were collected from biota Zones 1 and 3 (Figure 9.1.1) in the spring of 2022. Zone 2 is an approximately 1-mile long buffer area between the upstream Zone 3 and the downstream Zone 1; due to the small size of Zone 2, there was not sufficient area with which to collect enough songbird eggs for analysis. Songbird nest boxes were checked periodically to determine occupancy. Once a nest box was confirmed to have a bird occupant, the box was checked twice per week to collect the 1st-laid and 2nd-laid eggs for analysis. Songbird breeding season runs from March to August and may have multiple broods per season. The samples were sent to the TDH-NEL for arsenic, cadmium, mercury, and uranium analysis.

Adult insects

Insects were collected from biota Zones 1, 2, and 3 (Figure 9.1.1) in the spring of 2022. The sample mass obtained from Zone 2 was less than required for analysis, so no data were obtained for Zone 2. ORR insects were collected 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. The analysis of the samples included arsenic, cadmium, mercury, and uranium.

Spiders

Spiders, mainly Wolf and Fishing spiders, were collected from biota Zones 1, 2, and 3 (Figure 9.1.1) in the spring of 2022. The sample mass obtained from Zone 2 was less than required for analysis, so no data were obtained for Zone 2. During night hours, flashlights held at eye level will locate the reflective spider eyes near the stream shoreline or adjacent floodplain area. Then, the spider will be retrieved using 12-inch tongs. During collection, spider specimens will be placed into plastic cups with lids, to prevent escape, until sufficient biomass is achieved per sample. The analysis of the samples included arsenic, cadmium, mercury, and uranium.

9.1.6 Deviations from the Plan

Additional sampling projects were added to the original plan when CEC was contracted to conduct additional soil, sediment, and toxicity/biomonitoring sampling in the spring of 2022. These activities were needed to validate results obtained from Phase 2 sampling.

9.1.7 Results and Analysis

TDEC DoR-OR and CEC staff visited soil and sediment sampling locations on Bear Creek (Tables 9.1.2, 9.1.3) to conduct sampling at each location on April 5 and 6, 2022. The soil sampling grids were marked on the 5th and the sampling was conducted on the 6th. Both sediment and soil sampling took place at BCK 1.6; soil was sampled on the floodplain and sediment was sampled in the creek near the soil sampling grid.

The CEC sediment mercury results are graphed along with the TDEC DoR-OR sediment trap results in Figure 9.1.2. The sediment grab samples collected by CEC had results lower than the sediment trap results from the background site, MBK 1.6 (0.0438 mg/kg). The data are compared to EPA RSLs. These RSLs are risk-based chemical concentrations that correspond to fixed levels of risk in soil, air, and water. The concentrations are derived from standardized equations combining exposure information assumptions with EPA toxicity data. RSLs are protective of human health over a lifetime, but do not address ecological impacts (EPA 2022). RSLs are not cleanup standards, but are used to identify areas, contaminants, and conditions that require attention at a site (EPA 2022).

The sediment trap results from the Bear Creek and NT-5 sampling sites were higher than the sediment grab samples but well below the mercury RSL, Total Hazard Index (THI)=1, Resident Soil (10.9 mg/kg). In noncarcinogenic risk equations, THQ represents the target hazard quotient and is used for individual substances or exposure routes like ingestion, dermal, and inhalation. The hazard quotient (HQ) relates the dose of noncarcinogen delivered to a pre-determined 'safe' level below which a toxicological response is not likely; the ratio of the two is the HQ. An HQ above 1.0 signifies an increased likelihood of an adverse response (Hertzberg and Teuschler, 2002), such as a rash or hair falling out. The THI (Target Hazard Index) is the target across multiple substances or exposure routes (EPA 2022). The Bear Creek Valley (BCV) Watershed Remedial Action Report Comprehensive Monitoring Plan (CMP) specifies the use of Risk-Based Concentrations (RBCs) of 1E-5 and HI=1 for residential receptors for Zones 1 and 2 and industrial receptors in Zone 3 (DOE 2019). The boundary between Zones 2 and 3 is approximately at BCK 9.4 or just downstream of the mouth of North Tributary 8 (NT-8). The difference between the grab samples and the sediment trap samples may be due to the larger particle size constituents of the grab samples of sediment collected. Although a particle size analysis was not conducted on the CEC grab samples, observation of the samples revealed that they were predominantly coarse sediment particles (sand and fine gravel). This is in contrast to the TDEC DoR-OR sediment trap samples that are composed of predominantly silt and clay particles. Fine soil or sediment particles (particularly clay) have more surface area and cation exchange capacity per unit mass than do sands and gravel and can bind more contaminants.

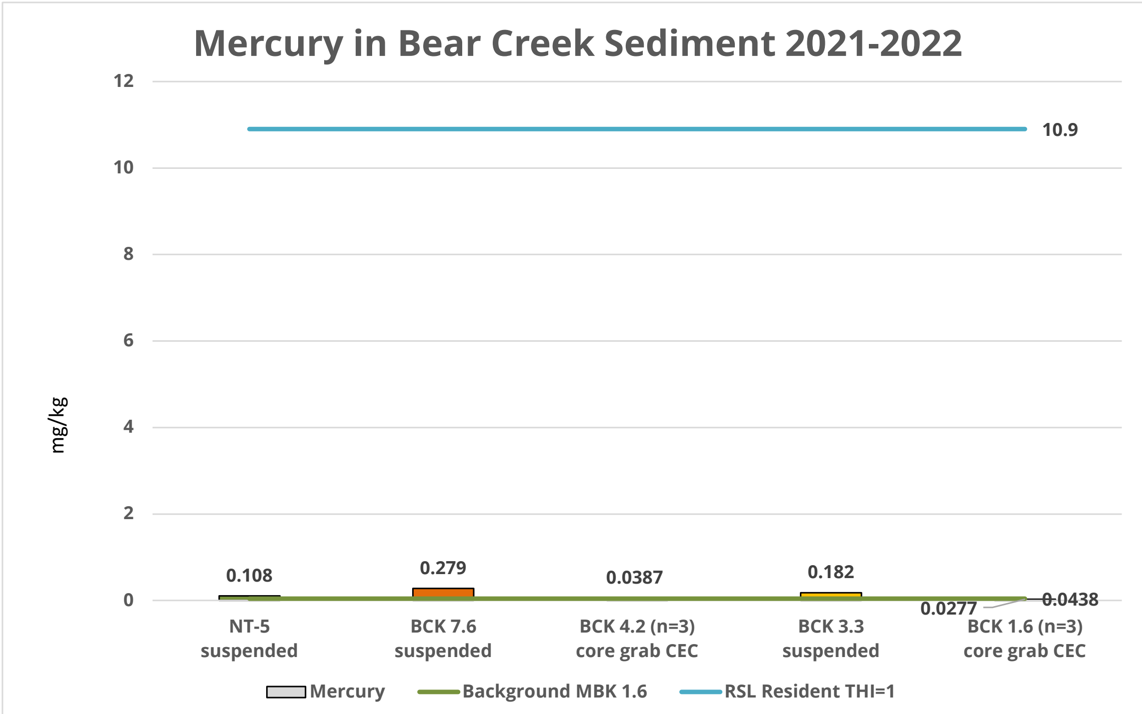

Figure 9.1.2: Mercury in Bear Creek Sediment - Suspended vs. Core Grab Samples (2021-2022)

Sediment uranium results were lower than the Resident Soil RSL (THI=1) of 15.6 mg/kg, with the exception of BCK 7.6 (Figure 9.1.3). The greatest concentration of sediment uranium was collected from the sediment trap at BCK 7.6; this sampling station is downstream of all Bear Creek disposal facilities and is just downstream of NT-8, a tributary that transports considerable amounts of uranium from the Bear Creek Burial Grounds (BCBGs). Core samples were collected at BCK 4.2 and BCK 1.6 by CEC.

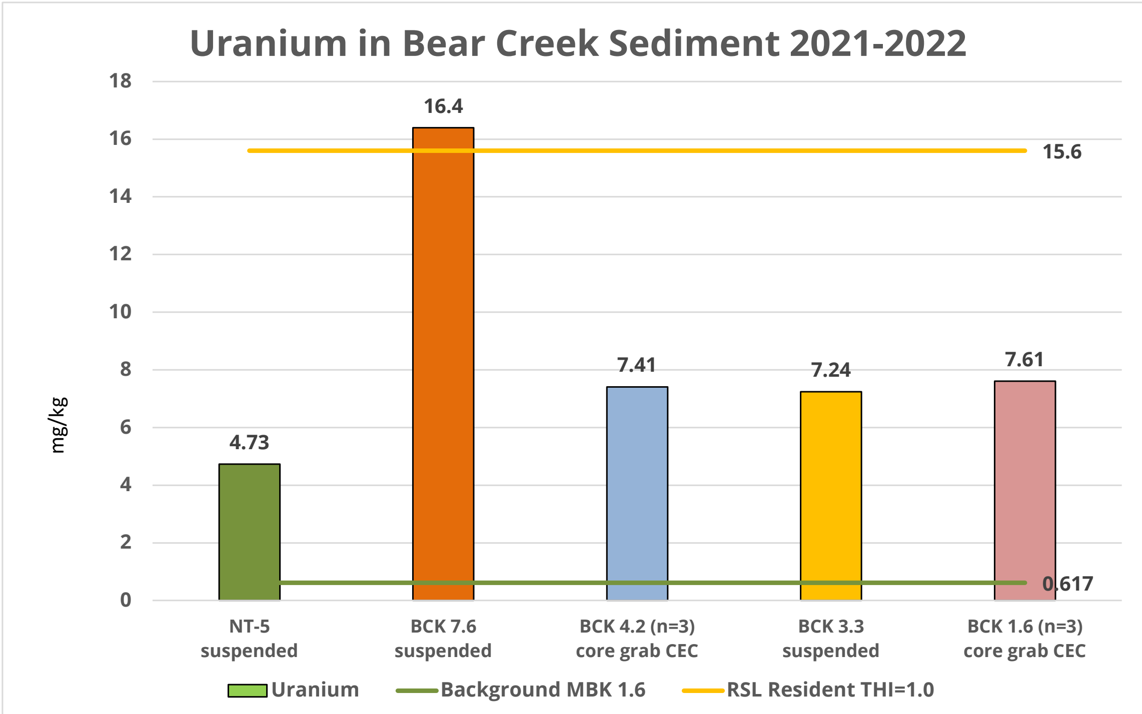

Figure 9.1.3: Uranium in Bear Creek Sediment – Suspended vs. Core Grab Samples (2021-2022)

Analysis for PCBs was conducted on the sediment samples and there were no detections above minimum detection limits (MDLs). The soil samples, however, showed some PCB contamination at several of the sampling stations (Figure 9.1.4). The 2022 soil sampling results were compared to soil results from 2021 in the Bear Creek Valley. Both soil studies were conducted by CEC with TDEC DoR-OR assistance. The 2022 soil sample collected at BCK 6.8 had the highest concentration of Aroclor 1260 of all the samples. However, all of the soil samples were less than the Resident RSL TR=1E-5 of 2.4 mg/kg. The Composite Worker RSL TR=1E-5 (9.91 mg/kg), which pertains to the sampling sites in Zone 3 (BCK 11.97, BCK 11.2, and BCK 9.6), is higher than the Resident RSL and is not shown in Figure 9.1.4. The screening level TR=1E-5 indicates the chemical concentration that corresponds to a one-in-one hundred thousand risk of cancer (EPA 2022). Aroclor 1260 was the only PCB compound detected above the MDL of 0.0592 mg/kg in the soil samples.

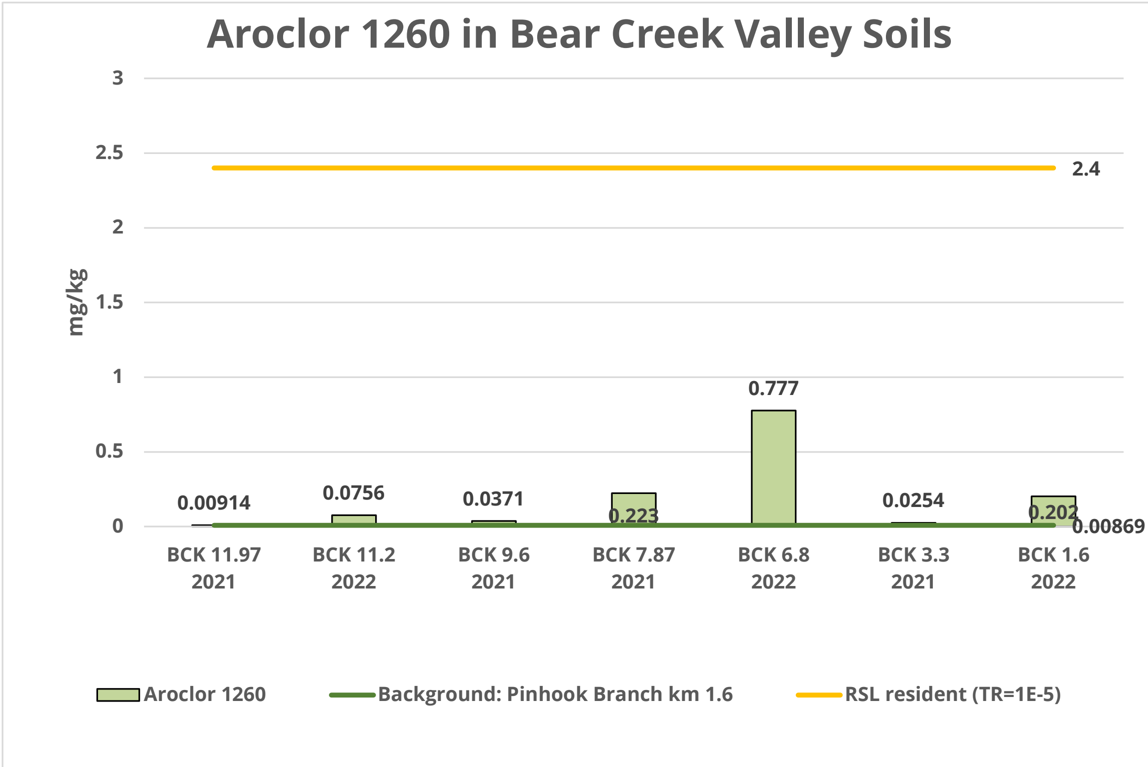

Figure 9.1.4: Aroclor 1260 in Bear Creek Valley Soils (2021-2022)

Mercury concentrations in the soil samples were greatest in the headwaters of Bear Creek (BCK 11.97, 11.2). None of the sampling stations exceeded the Resident RSL (THI=1) for mercury (10.9 mg/kg). The Composite Worker RSL THI=1, which is relevant to the sampling sites BCK 11.97, 11.2, and BCK 9.6, is much higher (45.6 mg/kg) and is not shown in Figure 9.1.5. Mercury at the sampling stations decreased gradually as one travels downstream in the valley (Figure 9.1.5).

Figure 9.1.5: Mercury in Bear Creek Valley Soil (2021-2022)

The uranium concentration in soil compared to the Resident RSL for U in the Bear Creek Valley (BCV) had two notable high points; one was upstream in the headwaters at BCK 11.97, and the other was at BCK 7.87 (Figure 9.1.6). The former S-3 Ponds site may be the source of the uranium contamination at the upstream sites, BCK 11.97 and BCK 11.2; these sites and BCK 9.6 are in Zone 3 where the data are compared to the Composite Worker RSL THI=1 (233 mg/kg) rather than the resident screening level. BCK 7.87 receives flow from the area of all the BCV disposal facilities and is just downstream of NT-8, a major source of uranium from the BCBGs. Two of the soil sampling locations (BCK 7.87 and BCK 6.8) exceeded the Resident RSL THI=1 screening level of 16 mg/kg, indicating that further evaluation of the potential risks by uranium is appropriate.

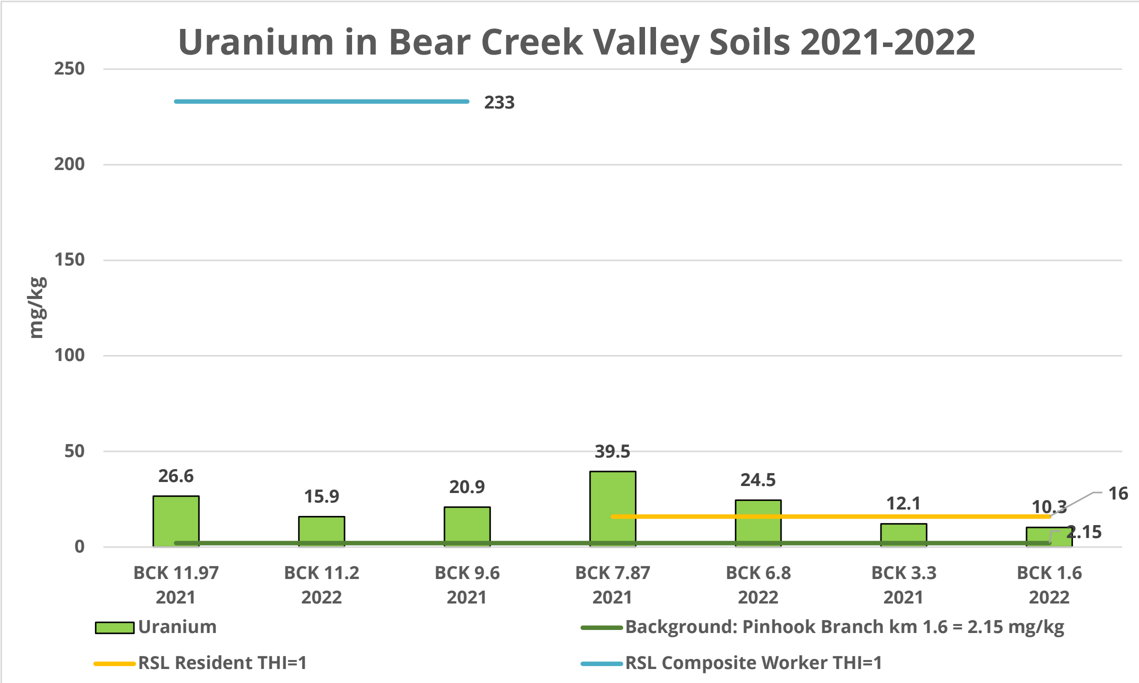

Figure 9.1.6: Uranium in Bear Creek Valley Soil (2021-2022)

Toxicity/biomonitoring was conducted at four (4) locations during the week of March 13, 2022, by CEC with assistance from TDEC DoR-OR staff. The locations were BCK 12.3, BCK 3.3, EFK 2.2/BCK 0.0, and MBK 1.6 (Table 9.1.1). These sampling sites were chosen to validate scores from previous testing done in 2020 and 2021. To determine if water or effluent is causing acute or chronic toxicity, the IC25 value is used. The IC25 value is a statistical calculation of the effluent concentration which causes a 25% reduction in survival, growth, or reproduction of test organisms. *Ceriodaphnia dubia* (water flea) inhibition was demonstrated at BCK 12.3 during testing conducted on the weeks of 10/18/2020 and 6/6/2021. Using the Linear Interpolation Method, the IC25 was reported as being greater than (>) 100% effluent for survival and equal to 26.8% effluent for reproduction. The overall IC25 is reported as the lesser of the two values (26.8% effluent). Since the IC25 result (26.8% effluent) was less than 100% effluent, the effluent was considered to be toxic to the daphnia (reproduction) at BCK 12.3 in 2020. On a second testing event in June of 2021, BCK 12.3 had an IC25 score of 77.3%, still exhibiting inhibition of reproduction.

In 2020 and 2021, inhibition of *Pimephales promelas* (fathead minnow) was demonstrated at two sites: BCK 3.3 and EFK 2.2 (BCK 0.0) (Figure 9.1.7). At BCK 3.3, the October 2020 IC25 (growth) was 87%; the June 2021 IC25 (growth) was 39.3%. The worst performing site was EFK 2.2 in November 2020, with an IC25 of 21.8% (growth); the IC25 for survival here was 56.3%. EFK 2.2 samples were collected in the mixing zone in East Fork Poplar Creek at the mouth of Bear Creek (BCK 0.0).

Collection of surface water samples for toxicity/biomonitoring testing was conducted during the course of a work week; samples were collected on Monday, Wednesday, and Friday. Water samples were collected for analysis of toxicity and biomonitoring for *Ceriodaphnia dubia* (water flea) and *Pimephales promelas* (fathead minnow). The test results from all of the sampling sites for the March 2022 sampling had perfect scores; no toxicity or inhibition was observed (Figures 9.1.7, 9.1.8). The results from the March 2022 testing are shown in Figures 9.1.7 and 9.1.8 together with the testing results from 2020 and 2021. The testing and analysis of the 2020 and 2021 samples was conducted by Pace Analytical Laboratories, whereas the 2022 samples were processed by Waypoint Laboratories. Another round of Bear Creek toxicity/biomonitoring sampling will be conducted in October of 2022; this test is being conducted during the driest month of the year, on average, to try to determine if low flow and the possible influence of groundwater has an effect on the toxicity testing results.

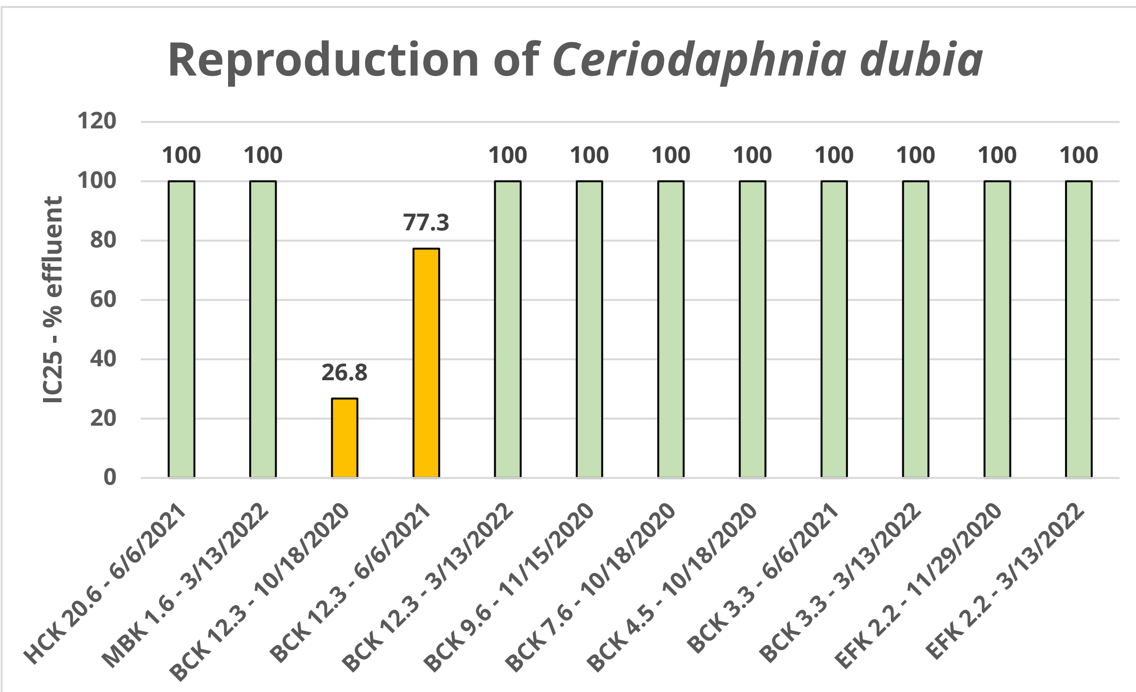

Figure 9.1.7: Reproduction of *Ceriodaphnia dubia* (water flea) in Bear Creek (2020-2022)

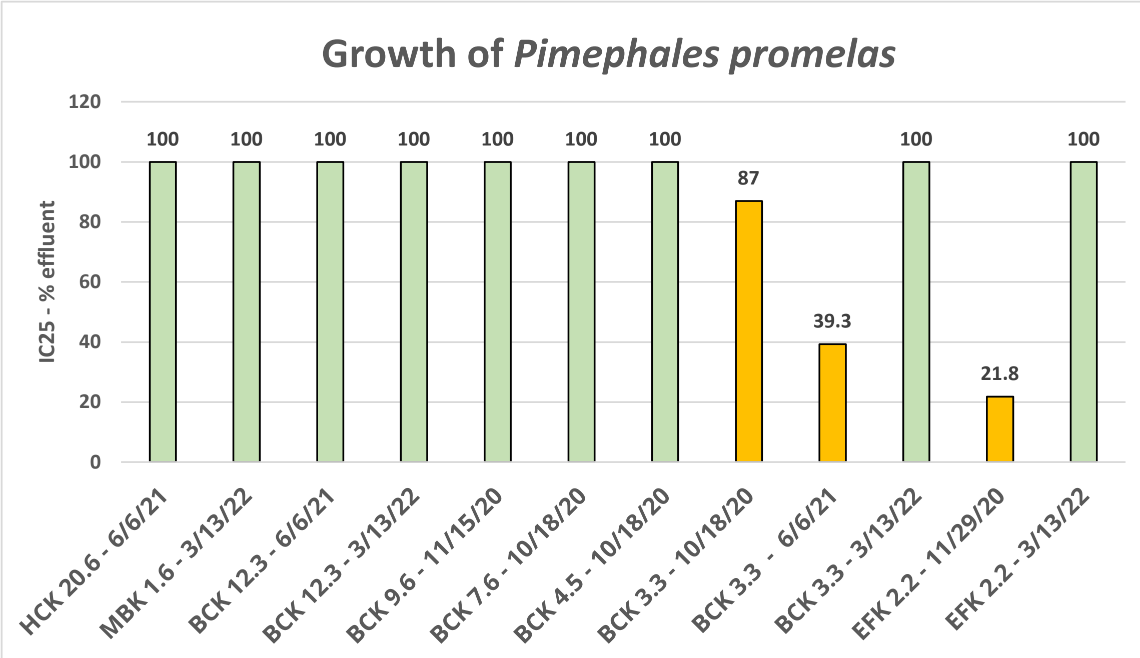

Figure 9.1.8: Growth of *Pimephales promelas* (fathead minnow) in Bear Creek (2020-2022)

The laboratory results from the analysis of biota (songbird eggs, flying insects, and spiders) samples collected have not yet been received. These biota laboratory results will be reported in the FY2023 EMR.

9.1.8 Conclusions

Mercury in Bear Creek (BC) sediments was detected but is not at a level of concern at the present time. The sediment core grab samples were below the background site's mercury concentration of 0.0438 mg/kg, but the sediment trap concentrations were above background. RSLs are risk-based chemical concentrations that correspond to fixed levels of risk in soil, air, and water. These concentrations are derived from standardized equations combining exposure information assumptions with EPA toxicity data (EPA, 2022). RSLs are protective of human health over a lifetime, but do not address ecological impacts (EPA, 2022). Both the sediment trap and sediment core grab samples were below the Resident Risk-Based mercury RSL, THI=1, Soil (10.9 mg/kg) indicating that there is no human health risk from mercury in Bear Creek sediments at this time. If conditions change, a new risk assessment may be warranted. In noncarcinogenic risk equations, THQ represents the target hazard quotient and is used for individual substances or exposure routes like ingestion, dermal, and inhalation. The hazard quotient (HQ) relates the dose of noncarcinogen delivered to a pre-determined 'safe' level below which a toxicological response is not likely; the ratio of the two is the HQ. An HQ above 1.0 signifies an increased likelihood of an adverse response (Hertzberg and Teuschler, 2002), such as a rash or hair falling out. The THI (Target Hazard Index) is the target across multiple substances or exposure routes (EPA 2022). Uranium sediment concentrations exceeded the Resident Soil RSL THI=1 (15.6 mg/kg) at BCK 7.6 only. Since the uranium concentration at BCK 7.6 (16.4 mg/kg) exceeds the THI=1 RSL, this indicates that further evaluation of the potential risks by uranium in sediment is appropriate. PCB concentrations were below detection limits in the sediment samples.

All of the Bear Creek Valley soil mercury concentrations were less than the THI=1 RSL, Resident Soil (10.9 mg/kg). Two of (2) the soil sampling results exceeded the Resident THI=1 RSL for uranium (16 mg/kg). The former S-3 Ponds site may be the source of the uranium contamination at the upstream sites, BCK 11.97 and BCK 11.2; these sites and BCK 9.6 are in Zone 3 where the data are compared to the Composite Worker RSL THI=1 (233 mg/kg) rather than the resident screening level. These Zone 3 sampling sites had results much less than the Composite Worker screening level. The most upstream soil sampling site, BCK 11.97, had a uranium concentration of 26.6 mg/kg and BCK 9.6 had a uranium concentration of 20.9 mg/kg. The highest soil uranium concentration was found at BCK 7.87 (39.5 mg/kg) in 2021; a soil sample collected nearby at BCK 6.8 had a uranium concentration of 24.5 mg/kg in 2022. PCB Aroclor 1260 was found above background (0.00869 mg/kg) at all of the soil sampling sites, but none of the concentrations exceeded the Resident TR=1E-5 RSL (2.4 mg/kg). The Composite Worker RSL TR=1E-5 (9.91 mg/kg) is used as the screening level for the Zone 3 sampling sites (BCK 11.97, BCK 11.2, and BCK 9.6). The screening level TR=1E-5 indicates the chemical concentration that corresponds to a one-in-one hundred thousand risk of cancer (EPA 2022).

Surface water toxicity/biomonitoring testing results from March of 2022 showed no toxicity or inhibition of reproduction (*C. dubia*) or growth (*P. promelas*) at any of the sampling locations. This contrasts with the results obtained in FY2021. Previous toxicity/biomonitoring testing conducted by in FY2021 reported inhibition at BCK 12.3, BCK 3.3, and EFK 2.2. Testing will be repeated in October of 2022, during the driest month of the year on average, to determine if seasonal differences in toxicity are present. Results details for the Surface Water Benthic Macroinvertebrate Monitoring summary are presented in the EMR section 3.1, Benthic Ecological Community Health, main report. Generally, the headwaters of Bear Creek (BCK 12.3) had the lowest Tennessee Macroinvertebrate Index (TMI) scores, indicating impairment that was characterized by lower benthic macroinvertebrate species diversity, fewer pollution intolerant species, and more pollution tolerant species. In contrast, benthic macroinvertebrate communities farther downstream reverted to compositions more like the reference site, with communities at BCK 3.3 more or less indistinguishable from reference site communities.

9.1.9 Recommendations

Considering the concentrations of uranium and the presence of mercury and PCBs in the soils and sediments of the Bear Creek Valley, it is recommended to repeat the soil sampling on a regular basis to monitor mercury, PCB, and uranium concentrations. Future remedial actions in the BCV may result in the release of contaminants into the watershed. Flooding events in the future will continue to deposit new layers of sediment on soils in the watershed, possibly increasing the contaminant content of the soils. The increase in contamination of the floodplain soils could result in elevated human risk and ecological impacts. The recommended frequency for soil sampling is every three to five years since changes in soils occur slowly unless there is a major release or spill upstream in the watershed. Suspended sediment sampling is recommended twice a year since trapped suspended sediment shows changes in direct response to environmental contaminant discharges. Toxicity/biomonitoring testing should be repeated until a clear picture of the in-stream habitat is obtained. The results obtained so far have been inconsistent; the results from FY2021 showed inhibition of reproduction at BCK 12.3 and inhibition of growth at BCK 3.3 and EFK 2.2, but results from FY2022 showed no inhibition. The current plan is to conduct toxicity/biomonitoring testing in October of 2022 in order to obtain dry-season results. The rationale for dry-season sampling is that, during the dry season, groundwater may have a greater influence on the surface water in Bear Creek and may influence the results of the toxicity/biomonitoring testing.

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