STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
Division of Remediation - Oak Ridge
761 Emory Valley Road
Oak Ridge, Tennessee 37830

May 28, 2020

Mr. John E. Phelps
Procurement and Contracts Division
U.S. Department of Energy
PO Box 2001
Oak Ridge Tennessee 37831

Mr. Steven Cooke
U.S. Department of Energy
PO Box 2001
Oak Ridge Tennessee 37831

Dear Mr. Phelps and Mr. Cooke

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation – Oak Ridge's (DoR-OR) Environmental Monitoring Report (EMR), July 1, 2018 through June 30, 2019, Grant Number – DE-EM-0001621 (FFA) and Grant Number – DE-SC0019507 (ESOA)

An electronic copy of the TDEC July 1, 2018 – June 30, 2019 EMR is attached. If you have need of a printed or CD copy, please let us know. The EMR is being submitted to the Department of Energy's Oak Ridge Operations in accordance with the Environmental Surveillance Oversight Agreement. The EMR will be made available to the public on TDEC's website: https://www.tn.gov/environment/program-areas/rem-remediation.html.

If you have questions or concerns regarding the report, please contact me by e-mail at Heather.Lutz@tn.gov or by phone at (865) 220-6574.

Sincerely

Heather Lutz

Heather Lutz
TDEC Environmental Manager 4

Enclosure

ec w/enclosure

Alexandra Gilliland, DOE
Andy Binford, TDEC
Bryce Robinson, DOE
Chris Thompson, TDEC
Colby Morgan, TDEC
Dana Ohren, TDEC
David Salyers, TDEC
Emil Gonzalez, DOE
Eric Ward, Director of Communications
Eva Butler, DOE Information Center
Geoffrey Beausoleil, NNSA
Heather Lutz, TDEC
Honorable Ron Woody, ORRCA
James Donnelly, NNSA Y-12 Area Site Office
Jason Darby, DOE
Jay Mullis, DOE
John LeCroy, TDEC
John Shewairy, DOE
Kristof Czartoryski, TDEC
Lucia Spears, ORNL
Michelle Lohmann, OREM SSAB
Mike Higgins, TDEC
Scott McGill, DOE Oak Ridge Operations Offices
Shelly Kimel, OREM SSAB
Steve Goodpasture, CDM Federal Services, INC
Steve Sanders, TDEC
Steven Clemons, DOE
Warren Gooch, Mayor of Oak Ridge
Wayne Carlton, BWXT Y-12

xc w/no enclosure

Rick Tamble, TDEC
Clinton Public Library
Clyde W. Roddy Public Library
Knox County Public Library System
Kingston Public Library
Loudon County Public Library
Meigs County Public Library
Oak Ridge Public Library
University of TN Hodges Library Serials Department
Wartburg Public Library

TENNESSEE DEPARTMENT
OF
ENVIRONMENT AND CONSERVATION

DIVISION OF REMEDIATION
OAK RIDGE OFFICE

ENVIRONMENTAL MONITORING REPORT

For Work Performed:

July 1, 2018 through June 30, 2019

May 2020

Tennessee Department of
Environment and Conservation,
Authorization No. 327023

To reach your local
ENVIRONMENTAL ASSISTANCE CENTER
Call 1-888-891-8332 or 1-888-891-TDEC

This report was published
with 100% federal funds
DE-EM0001620/DE-SC0019507
DE-EM0001621

TABLE OF CONTENTS

Table of Contents i
Acronyms ix
Units of measure and their abbreviations xii
Acknowledgements xiii
Executive Summary xv
1.0 INTRODUCTION 1
1.1 Purpose of the Environmental Monitoring Report (EMR) 1
1.2 Objective 2
1.3 The Oak Ridge Reservation 2
    1.3.1 Geography of the ORR Area 3
    1.3.2 Climate of the ORR Area 4
    1.3.3 Population of the ORR Area 4
1.4 Tennessee's Commitment to the Citizens of Tennessee 5
2.0 RADIOLOGICAL MONITORING 7
2.1 Environmental Dosimeters 7
    2.1.1 Background 7
    2.1.2 Problem Statements 7
    2.1.3 Goals 8
    2.1.4 Scope 8
    2.1.5 Methods, Materials, Metrics 9
    2.1.6 Deviations from the Plan 10
    2.1.7 Results and Analysis 10
    2.1.8 Conclusions 15
    2.1.9 Recommendations 15
    2.1.10 References 17
2.2 Real Time Measurement of Gamma Radiation 17
    2.2.1 Background 17
    2.2.2 Problem Statements 18
    2.2.3 Goals 18
    2.2.4 Scope 18

    2.2.5 Methods, Materials, Metrics 19
    2.2.6 Deviations from the Plan 20
    2.2.7 Results and Analysis 20
    2.2.8 Conclusions 23
    2.2.9 Recommendations 23
    2.2.10 References 24
2.3 Portal Monitoring at EMWMF 24
2.4 Surplus Sales Verification 24
    2.4.1 Background 24
    2.4.2 Problem Statements 25
    2.4.3 Goals 25
    2.4.4 Scope 25
    2.4.5 Methods, Materials, Metrics 25
    2.4.6 Deviation from the Plan 26
    2.4.7 Results and Analysis 26
    2.4.8 Conclusions 26
    2.4.9 Recommendations 26
    2.4.10 References 26
2.5 Haul Road Surveys 27
    2.5.1 Background 27
    2.5.2 Problem Statements 27
    2.5.3 Goals 28
    2.5.4 Scope 28
    2.5.5 Methods, Materials, Metrics 28
    2.5.6 Deviations from the Plan 29
    2.5.7 Results and Analysis 29
    2.5.8 Conclusions 29
    2.5.9 Recommendations 30
    2.5.10 References 30
3.0 BIOLOGICAL MONITORING 31
3.1 Bat Monitoring and Mercury Assessment of Associated Prey on the ORR 31

3.1.1 Background 31
3.1.2 Problem Statements 32
3.1.3 Goals 33
3.1.4 Scope 33
3.1.5 Methods, Materials, Metrics 33
3.1.6 Deviations from the Plan 36
3.1.7 Results and Analysis 37
3.1.8 Conclusions 44
3.1.9 Recommendations 46
3.1.10 References 46
3.2 Mercury Uptake In Biota (Wood Ducks, Tree Swallows and their Prey Items) 50
3.2.1 Background 50
3.2.2 Problem Statements 52
3.2.3 Goals 52
3.2.4 Scope 53
3.2.5 Methods, Materials, Metrics 54
3.2.6 Deviations from the Plan 58
3.2.7 Results and Analysis 58
3.2.8 Conclusions 58
3.2.9 Recommendations 59
3.2.10 References 59
3.3 Radiological Uptake In Vegetation (FY2018 Project) 62
3.3.1 Background 62
3.3.2 Problem Statements 62
3.3.3 Goals 62
3.3.4 Scope 62
3.3.5 Methods, Materials, Metrics 63
3.3.6 Deviations from the Plan 63
3.3.7 Results and Analysis 64
3.3.8 Conclusions 69
3.3.9 Recommendations 69

3.3.10 References 69

3.4 Benthic Macroinvertebrates 70

3.4.1 Background 70

3.4.2 Problem Statements 71

3.4.3 Goals 72

3.4.4 Scope 73

3.4.5 Methods, Materials, Metrics 74

3.4.6 Deviations from the Plan 78

3.4.7 Results and Analysis 79

3.4.8 Conclusions 104

3.4.9 Recommendations 104

3.4.10 References 105

4.0 AIR MONITORING 109

4.1 Fugitive Radiological Air Emissions 109

4.1.1 Background 109

4.1.2 Problem Statements 109

4.1.3 Goals 110

4.1.4 Scope 110

4.1.5 Methods, Materials, Metrics 110

4.1.6 Deviations from the Plan 112

4.1.7 Results and Analysis 112

4.1.8 Conclusions 116

4.1.9 Recommendations 116

4.1.10 References 116

5.0 SURFACE WATER MONITORING 117

5.1 Ambient Surface Water Monitoring 117

5.1.1 Background 117

5.1.2 Problem Statements 117

5.1.3 Goals 118

5.1.4 Scope 118

5.1.5 Methods, Materials, Metrics 118

5.1.6 Deviations from the Plan 120
5.1.7 Results and Analysis 120
5.1.8 Conclusions 129
5.1.9 Recommendations 130
5.1.10 References 130
5.2 Ambient Surface Water Parameters 131
5.2.1 Background 131
5.2.2 Problem Statements 131
5.2.3 Goals 132
5.2.4 Scope 132
5.2.5 Methods, Materials, Metrics 132
5.2.6 Deviations from the Plan 132
5.2.7 Results and Analysis 133
5.2.8 Conclusions 137
5.2.9 Recommendations 138
5.2.10 References 138
5.3 Rain Event Monitoring 139
5.3.1 Background 139
5.3.2 Problem Statements 140
5.3.3 Goals 140
5.3.4 Scope 140
5.3.5 Methods, Materials, Metrics 141
5.3.6 Deviations from the Plan 142
5.3.7 Results and Analysis 142
5.3.8 Conclusions 151
5.3.9 Recommendations 152
5.3.10 References 152
5.4 Surface Water Monitoring at the EMWMF 153
5.4.1 Background 153
5.4.2 Problem Statements 154
5.4.3 Goals 154

5.4.4 Scope 155
5.4.5 Methods, Materials, Metrics 157
5.4.6 Deviations from the Plan 158
5.4.7 Results and Analysis 158
5.4.8 Conclusions 182
5.4.9 Recommendations 183
5.4.10 References 183
6.0 SEDIMENT MONITORING 185
6.1 Ambient Sediment 185
6.1.1. Background 185
6.1.2 Problem Statements 185
6.1.3 Goals 186
6.1.4 Scope 186
6.1.5 Methods, Materials, Metrics 186
6.1.6 Deviations from the Plan 188
6.1.7 Results from Analysis 188
6.1.8 Conclusions 191
6.1.9 Recommendations 192
6.1.10 References 192
6.2 Trapped Sediment 193
6.2.1 Background 193
6.2.2 Problem Statements 194
6.2.3 Goals 195
6.2.4 Scope 195
6.2.5 Methods, Materials, Metrics 195
6.2.6 Deviations from the Plan 197
6.2.7 Results from Analysis 197
6.2.8 Conclusions 206
6.2.9 Recommendations 207
6.2.10 References 207
7.0 GROUNDWATER MONITORING 209

7.1 Offsite Residential Well Monitoring 209

- 7.1.1 Background 209
- 7.1.2 Problem Statements 210
- 7.1.3 Goals 211
- 7.1.4 Scope 211
- 7.1.5 Methods, Materials, Metrics 213
- 7.1.6 Deviations from the Plan 215
- 7.1.7 Results from Analysis 216
- 7.1.8 Conclusions 223
- 7.1.9 Recommendations 223
- 7.1.10 References 223

8.0 RADNET 225

8.1 RadNet Air Monitoring 225

- 8.1.1 Background 225
- 8.1.2 Problem Statements 225
- 8.1.3 Goals 225
- 8.1.4 Scope 226
- 8.1.5 Methods, Materials, Metrics 226
- 8.1.6 Deviations from the Plan 228
- 8.1.7 Results and Analysis 228
- 8.1.8 Conclusions 231
- 8.1.9 Recommendations 231
- 8.1.10 References 231

8.2 RadNet Precipitation Monitoring 232

- 8.2.1 Background 232
- 8.2.2 Problem Statements 232
- 8.2.3 Goals 233
- 8.2.4 Scope 233
- 8.2.5 Methods, Materials, Metrics 234
- 8.2.6 Deviations from the Plan 235
- 8.2.7 Results and Analysis 235

8.2.8 Conclusions 236
8.2.9 Recommendations 237
8.2.10 References 237
8.3 RadNet Drinking Water Sampling 237
8.3.1 Background 237
8.3.2 Problem Statements 238
8.3.3 Goals 238
8.3.4 Scope 238
8.3.5 Methods, Materials, Metrics 239
8.3.6 Deviations from the Plan 240
8.3.7 Results and Analysis 240
8.3.8 Conclusions 243
8.3.9 Recommendations 243
8.3.10 References 243

ACRONYMS

A	ASER	Annual Site Environmental Report
B	BCK	Bear Creek Station or Bear Creek kilometer
	Benthic Life	Organisms that live on or in the streambed (insects, amphibians, spiders, worms, etc.)
	Biocides	Any product or substance intended to destroy, control or prevent the effects of algae, bacteria, sulfate-reducing bacteria, protozoa, and fungi.
C	CCME	Canadian Council of Ministers for the Environment
	CAA	Clean Air Act
	CBSQG	Consensus Based Sediment Quality Guidelines
	CERCLA	The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (commonly known as Superfund) enacted by Congress on December 11, 1980.
	COCs	contaminants of concern
	COND	conductivity
	Cr_6	hexavalent chromium
	CRK	Clinch River kilometer
D	D&D	decontamination and decommissioning
	DO	dissolved oxygen
	DOE	U.S. Department of Energy
	DoR	Division of Remediation
	DOR-OR	Division of Remediation – Oak Ridge
	DWR	Division of Water Resources
E	EFPC	East Fork Poplar Creek
	EMWMF	Environmental Management Waste Management Facility
	EPA	Environmental Protection Agency
	EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)
	%EPT – Cheum	Percent EPT - Cheumatopsyche
	ESOA	Environmental Surveillance Oversight Agreement
	ETTP	East Tennessee Technology Park
F	FFA	Federal Facilities Agreement
	FRMAC	Federal Radiological Monitoring and Assessment Center
G	GCN	greatest conservation need
	GPS	Global Positioning System
H	H_2SO_4	sulfuric acid
	HAs	Health Advisory Values
	HCl	hydrochloric acid
	HFIR	High Flux Isotope Reactor
	Hg	mercury

	HNO_3	nitric acid
	HRE	Homogeneous Reactor Experiment
L	LLW	low-level radioactive waste
	LSC	liquid scintillation counting
M	MCL	Maximum Contaminant Limit see NPDWR
	MDL	minimum detection limit
	MeHg	methylmercury
	MDC	minimum detectable concentration
	MIK	Mitchell Branch kilometer
	MQL	Minimum Quantification Limit
	MSRE	Molten Salt Reactor Experiment
N	NNSA	National Nuclear Safety Administration
	NAREL	National Air and Radiation Environmental Laboratory
	NCBI	North Carolina Biotic Index
	NOAA	National Oceanic and Atmospheric Administration
	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	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	PCBs	polychlorinated biphenyls
	PEC	Probable Effects Concentration
	PRGs	Preliminary Remediation Goals
Q	QA/QC	Quality Assurance/Quality Control
	QAPP	Quality Assurance Project Plan
	QEC	Quality Environmental Containers (Beaver, WI)
R	RA	remedial activities
	RADCON	Radiation Control Program
	RAIS	Risk Assessment Information System
	RER	Remedial Effectiveness Report
	ROD	Record of Decision

	RPM	radiation portal monitor
	RSLs	Regional Screening Levels
S	SAIC	Science Applications International Corporation
	SAP	Sampling and Analysis Plan
	SOP	Standard Operating Procedure
	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
	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.
	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
	TEC	Threshold Effect Concentration
	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	UEFK	Upper East Fork Creek Kilometer
	USDI	U.S. Dept. of the Interior
	USEPA	United States Environmental Protection Agency
	UV	ultraviolet
V	VOCs	volatile organic compounds
W	WAC	Waste Acceptance Criteria
	WD	wood duck
	WCK	White Oak Creek kilometer

UNITS OF MEASURE AND THEIR ABBREVIATIONS

°C	degrees Celsius/Centigrade
µS/cm	micro Siemens per centimeter
mV	millivolts
DO	amount of gaseous oxygen dissolved in water
pH	logarithmic scale of acidity and alkalinitry 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

ACKNOWLEDGEMENTS

The Tennessee Department of Environment and Conservation (TDEC) is responsible for producing this document. TDEC acknowledges with deep appreciation the efforts of all the individuals who provided valuable resources, information, technical data, management, administrative, field and/or other support for the Oak Ridge Reservation Environmental Monitoring Report. Listed below are the project leads/lead authors for each of the respective projects.

- Robert Bishop – Rain Event Monitoring
- Don Gilmore – Surface Water Monitoring at EMWMF
- Rebecca Lenz – Offsite Residential Well Monitoring
- Gerry Middleton – Bat Monitoring and Mercury Uptake in Biota
- John Peryam – Haul Road Surveys, Ambient Sediment, and Trapped Sediment
- Jared Brabazon – Ambient Surface Water Monitoring, Surface Water Physical Parameters
- Natalie Pheasant - Radiological Uptake in Vegetation, RadNet Air Monitoring, RadNet Precipitation Monitoring, and RadNet Drinking Water Sampling
- Gary Riner – Real Time Monitoring of Gamma Radiation on the Oak Ridge Reservation, Portal Monitoring at EMWMF, Fugitive Radiological Air Emissions
- Gareth Davies – Environmental Dosimeters, Surplus Sales Verification
- Dana Higgins – Benthic Macroinvertebrate Monitoring

This Page Intentionally Left Blank

EXECUTIVE SUMMARY

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation, Oak Ridge (DoR-OR), submits the annual Fiscal Year 2019 (FY2019) Environmental Monitoring Report (EMR) for the period of July 1, 2018 through June 30, 2019. This report is submitted 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). TDEC DoR-OR participates in independent monitoring as well as oversight of DOE activities across the Oak Ridge Reservation. The TDEC DoR-OR office also conducts independent environmental monitoring 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.

The objective of the TDEC DoR-OR Environmental Monitoring Program is to provide a comprehensive and integrated monitoring and surveillance program to assess site conditions for all Oak Ridge Reservation (ORR) related environmental media (i.e. air, surface water, soil, sediment, groundwater, drinking water, food crops, fish and wildlife and biological systems). TDEC DoR-OR also uses this monitoring program to provide independent assessment of the emissions of any materials (hazardous, toxic, chemical or radiological) on the ORR, to its surrounding environment. These independent monitoring projects are used to evaluate the effectiveness of the comprehensive Department of Energy (DOE) environmental monitoring program, by collecting data to verify or supplement DOE's data sets.

This FY 2019 EMR presents the results of the 20 independent projects proposed in the FY2018 Environmental Monitoring Plan (EMP) and completed throughout FY2019. This monitoring report focuses on the following seven general areas: Radiological Monitoring, Biological Monitoring, Air Monitoring, Surface Water Monitoring, Sediment Monitoring, Groundwater Monitoring and RadNet.

Radiological Monitoring:

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

Environmental Dosimeters

The Environmental Dosimeters Project is designed to independently assess the potential dose from radiation exposure at various locations across the ORR. Doses are compared to a reference limit of 100 mrem/yr. The Environmental Dosimeters Project focuses on areas at all three ORR facilities, as well as background sites, in and near Oak Ridge. Emphasis is placed on areas where radioactive materials are stored, processed, or disposed. Plots of the quarterly doses from the individual locations show that for the FY 2019 time frame most results did not exceed the reference control level. Exceedances above the reference control levels were identified at ORNL sites, within Melton Valley, at the SNS vent stack and at one location at ETTP.

In FY 2020 the total number of locations monitored will be reduced from 100 to 25 total locations. This revised set of locations shall include primarily the locations associated with results identified consistently above the reference control level and will eliminate the locations that historically have been below the reference control limit.

Real Time Measurement of Gamma Radiation

The Real Time Measurement of Gamma Radiation Project, conducted on the ORR, measures exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods of time. Because facilities on the ORR have been known to release variable amounts of gamma radiation, this project is used to monitor areas on the ORR with the potential for an unplanned release of gamma emitting radionuclides into the environment. During the 2018/2019 monitoring period, gamma monitors were located at the following five (5) locations: Fort Loudoun Dam (Background Site), Environmental Management Waste Management Facility (EMWMF), ORNL Central Campus Remediation/Building 3026 Radioisotope Development Lab, Molten Salt Reactor Experiment (MSRE), and the Spallation Neutron Source (SNS).

No monitored location exceeded the 2 mrem in anyone-hour period limit, and no monitored location exceeded the 100 mrem /year limit for members of the public. In fact, averaged gamma rates on the ORNL campus, though above background, have shown a steady reduction since 2013, from a high of 67.1µrem/hour to the currently observed 15.3 µrem/hour.

Portal Monitoring at EMWMF

The portal monitor at EMWMF was inoperable during this period of performance and funds to repair or replace the equipment were not supported under DOE’s current funding program.

Surplus Sales Verification

At the request of the ORNL's Excess Properties staff, TDEC performs pre-auction verification surveys on items being auctioned by ORNL's Excess Properties Sales. Four independent assessments of surplus sales materials occurred during the period from July 2018 through June 2019. A total of 7 items with activity above background were identified during these surveys and were reported to DOE.

Haul Road Surveys

TDEC staff performs bimonthly surveys of the Haul Road and other waste transportation routes on the ORR that are used by DOE and their contractors to haul wastes for disposal at EMWMF. The periodic surveys of the roads used to haul waste to the EMWMF have historically found that waste items may fall from trucks transporting the waste. The Haul Road walkover surveys conducted during the July 2018 – June 2019 time frame, identified 52 items that potentially originated from the hazardous and/or radioactive waste being transported to the EMWMF. These 52 items were reported to and dispositioned by DOE. While elevated readings were detected, it is important to note that no surface contamination readings exceeded the free release limits during the performance period of this project.

Biological Monitoring:

There were 4 biological monitoring projects conducted during the FY 2019 project year.

Bat Monitoring and Mercury Assessment of Associated Prey Items on the ORR

Monitoring was conducted on the ORR to help evaluate the mercury (Hg) and methyl mercury (MeHg) concentrations in ORR bats and their associated prey items. This project used analytical results of insect prey as possible surrogates for bat internal tissue body burdens.

The data collected during this study show that insects collected along East Fork Poplar Creek contain much higher levels of Hg than insects collected at reference sites.

- Hg and MeHg concentrations in EPT taxa collected from East Fork Poplar Creek were 148 times and 81 times greater respectively compared to Hg and MeHg concentrations in reference site EPT taxa.
- Hg and MeHg concentrations in beetles collected from East Fork Poplar Creek were 8 times and 5.9 times greater respectively compared to Hg and MeHg concentrations in reference site beetles.

- Hg and MeHg concentrations in moths collected from East Fork Poplar Creek were 3.7 times and 5.9 times greater respectively compared to Hg and MeHg concentrations in reference site moths.

The insects collected and analyzed in this study are a major food source for the bat population (including resident threatened and endangered species), as well as other fauna on the ORR. The measured levels of Hg and MeHg in the studied insect population could have impacts to bat populations and other fauna on and across the ORR.

Ecological health, the health of the environment, and impacts to the food web found across the ORR are an important consideration as we collectively evaluate the effectiveness and protectiveness of ongoing remedial decisions and actions, as well as providing further inputs for cleanup decisions in the future.

Radiological Uptake in Vegetation

This project focuses on the detection and characterization of radiological constituents that may bio-accumulate in vegetation. Due to the long turn-around time for laboratory results of this type, data from the prior year's 2018 sampling events are reviewed and discussed in this report. The data gathered from the 2018 Radiological Uptake in Vegetation project suggests that there are still a number of areas associated with the surface water on the ORR that continue to have elevated radionuclide concentrations in their vegetation. Identification of these areas can be useful in evaluating current site conditions and providing input regarding cleanup decisions and actions.

Benthic Macroinvertebrates

While the health of the benthic macroinvertebrate communities in ORR streams has improved since the 1980s, this improvement in creeks such as White Oak Creek at ORNL has leveled off for the past thirteen years (ASER 2017). From August 1996 to May 2014, East Fork Poplar Creek (EFPC) showed steady improvement regarding the benthic macroinvertebrate communities, particularly in its headwaters. Since May 2014, however, the health of the macroinvertebrate communities have remained relatively flat or declined slightly, potentially due to the halting of water augmentation to the creek from the Clinch River. The macroinvertebrate communities found in EFPC remain well below comparable reference stations and score lowest when evaluated across the ORR site. Recent stream mitigation efforts at BCK 12.4 to enhance the habitat limitations caused by channelized sections of the stream from EMWMF, have created a more balanced pool to riffle ratio and have increased the amount of available habitat in Bear Creek. As described in the 2018 DOE RER, remedial actions completed on Bear Creek have narrowed a previously channelized section of stream and restored the creek to its original state (DOE 2018 RER). Our data show that the benthic macroinvertebrate communities in Bear Creek have continued to improve slightly, particularly in its downstream stretches. While Bear Creek has improved since we started monitoring, it is still well below comparable reference stations. Mitchell Branch at ETTP has also improved since the 1980's, particularly in its downstream reaches. The lower stretches of Mitchell Branch are slowly developing a more natural substrate which is replacing the formerly lined channel. The upstream station in Mitchell Branch, however, appears to be slowly deteriorating in quality due to increased sediment input. Concerns are that additional construction in the headwaters may further deteriorate this section of Mitchell Branch.

Air Monitoring:

TDEC conducted 2 projects directly related, and 1 project indirectly related, to air monitoring during this reporting period. The Fugitive Radiological Air Emissions project described below is a state-defined project which collects samples that are analyzed at the State of Tennessee Environmental Laboratory. The RadNet Air Monitoring and RadNet Precipitation Monitoring are addressed together under the separate "RadNet" header, as those samples are managed and analyzed independently through the EPA's National Analytical Radiation Environmental Laboratory.

Fugitive Radiological Air Emissions

TDEC conducts independent air sampling at select sites across the ORR and compares those results with air sampling data provided by DOE. TDEC samplers are placed with in the ORR boundaries, with focus on locations where the potential for the release of fugitive airborne emissions may be higher (e.g., locations of the excavation of contaminated soils, demolition of contaminated facilities, and waste disposal operations, etc.). During this project's period of performance, one elevated uranium reading was observed in the 2/21/2018 composite sample (taken from the monitoring station area located near K27). Further sampling indicated that this reading was reflective of an isolated spike (attributed potentially to demolition activity near the site) and was not reflective of levels recorded throughout the rest of the period of performance. The shorter composite interval sampling times executed in TDEC's sampling program as compared to DOE's quarterly composited analyses can support a more focused observation of potential problems such as this one. Overall, during this project's period of performance, the average results at TDEC's fugitive air monitoring stations were similar to background. The average concentrations, minus background, for all sites, remained below the federal standards at all locations.

Surface Water Monitoring:

The below four projects addressed the surface water on and around ORR specifically during FY2019.

Ambient Surface Water Monitoring

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

Generally, uranium metal concentrations are high in all ORR streams when compared with the sampled reference streams. Both Bear Creek and East Fork Poplar Creek have high uranium metal concentrations that tend to decrease with distance from Y-12. Uranium concentrations in the headwaters are upwards of three (3) to four (4) times greater than the recommended drinking water EPA MCL of 30 μg/L. These high concentrations of uranium metal could potentially have an adverse effect on the natural streams' biota and general environmental health, with effects including bioaccumulation of uranium metal, which has the potential to be transferred through food webs.

Mercury continues to be a major threat to the health of East Fork Poplar Creek with mercury levels much greater than the Tennessee recreation standards for surface water. Nitrite, nitrate, and phosphorus concentrations exceed the ecoregion 67f criteria in East Fork Poplar Creek. Copper and zinc, also tended to have high concentrations in samples collected from East Fork Poplar Creek, especially compared to nearby reference streams.

The Clinch River at the White Oak Creek confluence continues to yield high concentrations of radionuclides including high concentrations of strontium-90, gross beta, and uranium-234. An estimate of flow from the upstream White Oak Dam along with sample concentrations measured during this project indicate the loading of strontium-90 is roughly 2.82×10^{-5} g/yr, which is 459% of the EPA regulatory limit for drinking water (NBS Handbook 69) when considering the median White Oak Dam annual flow rate of 14,325 L/min. This is likely a conservative estimate due to sampling a mixture of Clinch River and White Oak Creek water, which is likely diluted in regard to radionuclides. These high concentrations of radionuclides are not seen at sampling stations directly downstream, likely due to Clinch River dilution.

Ambient Surface Water Parameters

Due to the presence in some areas of anthropogenic point and non-point source contamination on the ORR, there exists the potential for contamination to impact surface water on the ORR. To assess the degree of surface water impacts, stream monitoring data around the ORR was collected monthly, and was input to a TDEC database of physical stream parameters (specific conductivity, pH, temperature and dissolved oxygen) collected since 2005. That parameter database is intended to provide information to assess the impacts of site remediation efforts through long term monitoring of surface water parameters, as well as to provide ambient parameter information for use in the event of a release requiring clean up decisions and guidance.

Of these measurements collected during the FY2019 period of performance, all readings were within the State of Tennessee Water Quality Criteria. While there is no existing State of Tennessee Water Quality Criteria for specific conductivity, Bear Creek site BCK 12.3 was found to be statistically significantly higher than all other streams. Despite this higher conductivity, historical data (2005-2019) indicate that BCK 12.3 has a decreasing trend in conductivity of roughly 36 µS/cm annually. In all, the data shows that this stream is still quite high in conductivity but is decreasing with time.

On East Fork Poplar Creek, site EFK 23.4 has shown a steadily increasing trend of conductivity which is on average roughly 9 µS/cm annually. The reason(s) for this increase have not yet been determined.

As legacy DOE ORR pollution has negatively impacted East Fork Poplar Creek, Bear Creek, and Mitchell Branch, TDEC recommends continued physical parameter monitoring at the seven established monitoring stations in order to identify, categorize, and interpret changing trends such as those identified during this year’s assessments.

Rain Event Monitoring

As remedial actions, contaminated soil excavations and other demolition activities occur throughout the ORR, water can accumulate in excavation pits, trenches, basins, sumps, basements, or during other soil remediation activities. Accumulated water at these sites has the potential to become contaminated and then be dispersed into the environment. To assess and evaluate compliance with discharge requirements related to these water bodies, TDEC monitored DOE’s sampling activities as well as independently collected samples at storm drains at the ORR for independent verification on a quarterly basis. At ETTP, sample location storm drain (SD) 430 was monitored to assess impacts from active D&D activities in that area, and SD 490 was sampled to monitor discharge from the areas impacted by the Tc-

99 release that occurred during the D&D of K-25 in 2013 and continues to impact the environment at ETTP. Review of correlated DOE led sampling results, helped to further ensure compliance with release requirements.

Sample results from this period of performance indicate that legacy contaminants continue to impact the ORR. Data from sampling indicates that Tc-99 continues to be recovered in the storm drain system, though not above regulatory limits. Data from sample location SD-430, shows chromium and uranium being identified in the stormwater samples but neither constituent was found to be above regulatory limits. With ongoing and planned D&D activities at K-25 these data are being used to verify that remedial activities and the management of storm water collected during normal operations associated with those projects, are being conducted in accordance with approved plans and do not contribute to releases from their activities that would impact the environment.

Surface Water Monitoring at the EMWMF

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 Oak Ridge Reservation (ORR) and is operated under the authority of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Much of the contaminated material from CERCLA remediation activities on the ORR are approved for disposal in the EMWMF provided they meet the waste acceptance criteria.

There has been concern that associated contaminants over time could have the potential to migrate from the facility into the environment and be carried by ground and surface waters off site. TDEC conducts this Surface Water Monitoring Project at EMWMF, to provide assurance through independent monitoring and sampling as well as though review and evaluation of DOE’s data, that operation of the EMWMF are protective of public health and the environment, and that they meet the associated remedial actions objectives associated with this facility.

For FY 2019, TDEC sample results corroborate DOE’s sample results on and around EMWMF. Both the TDEC and the DOE data sets appear to detect low level but increasing trends of isotopic uranium constituents in samples from EMWMF-2 (the underdrain location). Increasing technetium-99 is identified in a review of concentrations over time for samples collected from the EMWMF-2 (underdrain) sampling location. The technetium-99 activities are increasing above the detection limit in late 2017 into 2018.

DOE samples EMWMF-2 on a bi-monthly schedule. TDEC DoR-OR also samples EMWMF-2 bi-monthly (months when DOE does not sample). This allows for a full year of monthly sampling of the underdrain location. The basis for TDEC DoR-OR's bi-monthly sampling of the underdrain location is because it is anticipated that the underdrain (EMWMF-2) would likely be the first place that contaminants from the landfill would surface should there be liner impairment or other unusual landfill structural issues. Also, key, is that water from EMWMF 2 is discharged directly to Bear Creek without any treatment.

Sampling data from EMWMF-3 (the sediment basin effluent) also continues to show evidence of discharge of contaminants including elevated technetium-99 (particularly after 2014), elevated gross beta activity, and elevated tritium. Gross beta activity is above 50 pCi/L which is the EPA trigger for water supplies to perform isotope specific analysis, but that result is not at levels that would have violated the EMWMF Record of Decision discharge limits.

Each week, DOE samples the EMWMF-3 effluent on a flow proportional basis. TDEC DoR-OR recommends that as long as the sampling frequency and analyte suite remains consistent, the State should conduct quarterly sampling and spot sampling (based on field observations) at EMWMF-3, to perform continuity checks and help determine if contaminants are discharging into Bear Creek. TDEC DoR-OR also recommends State sampling of contact water ponds/tanks as they are discharged to the unlined ditch. Additional sampling should be conducted during active discharge from that unlined ditch as the water from those contact water ponds / tanks is discharged into the sediment basin.

The sediment basin's sampling results corroborate similar findings with respect to radioactive constituents including elevated gross beta, increasing uranium-238 and increasing potassium-40 constituent levels.

Sediment Monitoring:

There were two sediment investigations conducted during FY2019. The ambient sediment project focused on the naturally accumulated sediments that have been deposited within the environment and how those sediments, and that associated ecosystem, may be affected by discharged contaminants of concern. The trapped sediments project looked at the sediments being carried in the water column as waters transported those sediment materials through the water system. The trapped sediments project addressed what is being carried away from the point of discharge (via entrained sediments in the water column) to potential exit pathway corridors.

Ambient Sediment

Contaminated sediments can directly impact benthic life and indirectly pose a detrimental effect on other organisms. ORR exit pathway streams are subject to contaminant releases from activities at ETTP, ORNL and Y-12. Sampling of sediment is conducted by TDEC DoR-OR staff to help assess current conditions of stream health. Comparisons of radiological data with the preliminary remediation goals (PRGs), obtained from the "ORNL Risk Assessment System" (PRGs correlate to a recreation, target cancer risk 1.0×10^{-5}, total risk scenario) show that none of the sediment samples exceeded the PRGs. Sediment in these streams do not present a radiological risk to human health (RAIS, 2018).

While not presenting a radiological risk to human health, there are constituents in the stream sediments which may affect ecological health. When a metal occurs at a concentration above the threshold effects concentration (TEC), the possibility of impairment to benthic macroinvertebrate populations is present. Above the probable effects concentration (PEC), it is probable that these populations will be impaired.

Mercury and nickel were identified at concentrations above the probable effects concentration (PEC) at Mitchell Branch (MIK 0.1), with chromium, lead, arsenic, copper, and zinc levels identified at that location at concentrations above the TECs. East Fork Poplar Creek kilometer 6.3 (EFK 6.3) also had levels of mercury identified above the PEC and levels of chromium, copper, and lead above their TECs.

Trapped Sediment

The Trapped Sediment Project focused on determining stream health through sampling and analysis of suspended sediment and assessing site remediation efforts through long-term monitoring of suspended sediment. Suspended sediments are important to consider because these are the sediments suspended in the water column that are moving through the watershed system, potentially mobilizing impacts downstream. This project complements the ambient sediment project above which evaluates what constituents of concern may settle out into the sediments along the waterway within the study area.

The analysis of sediment collected from the sediment traps during this period of performance indicates metals contamination at EFK 23.4. Cadmium and copper levels were above the TEC at EFK 23.4 and mercury levels exceeded the PEC. Lead and nickel concentrations were above the TEC in 2015 and 2016 at EFK 23.4. At NT-5, a Bear Creek tributary located southwest of the EMWMF, results from metals analysis in the trapped sediments were less than the TEC. Both EFK 23.4 and NT-5 have levels of gross alpha and beta radioactivity that are above background in the trapped sediment samples collected.

However, these levels are not at a concentration that would be expected to pose a threat to human health or aquatic life.

Groundwater Monitoring:

There was one project relating to groundwater at and around the ORR during FY2019.

Offsite Residential Well Monitoring

Groundwater beneath the ORR was contaminated due to past DOE mission activities (TDEC, 2018; Haase, et al., 1987). The sources of contamination and the extent of the groundwater contamination have not been well defined and require further investigation. While the Clinch River forms one of the boundaries of the ORR, the Tennessee Department of Environment and Conservation (TDEC) does not assume that the Clinch River is a groundwater-flow barrier preventing deeper transport of potential contaminated groundwater beneath the Clinch River, offsite the ORR. That deeper transport pathway could potentially impact residents using the groundwater as a primary drinking water source.

This report for period of performance July 2018 through June 2019, addresses sampling activities from ten (10) offsite residential wells. Sample results documented mostly low concentrations, low activities, and sporadic detections of contaminants that may be a result of human activity. There were no detections above the EPA MCL, EPA SMCL, and EPA HA criteria.

For general comparison reference this project used EPA's Regional Screening Limit PRGs (TR=1E-6) for tapwater from the November 2014 table. Those Preliminary Remediation Goal (PRG) values were exceeded for some radioactive constituents in these residential well samples. Pb-214 was detected above the EPA PRG (2014) at two (2) wells. Ra-226 was detected above that EPA PRG at four (4) wells. Ra-228 was detected above the EPA PRG at three (3) wells. U-233/234 was detected above the EPA PRG at three (3) wells. U-238 was detected above the EPA PRG at two (2) wells.

No determination regarding potential sources of the identified constituents has been made at this time. The results from this limited data set represent a snapshot in time and are not derived from continuous monitoring. Groundwater quality in the fractured rocks and bedrock aquifers can change rapidly due to the speed at which groundwater may move in that environment. Hydrologic characteristics can fluctuate between geographically close locations, and therefore it is difficult to make predictions on potential contaminant pathways and sources of contamination with data from one sampling event.

The contamination of groundwater beneath several areas of the ORR and the potential pathways for contaminant migration to potentially move beyond the ORR boundary make it imperative to continue the monitoring of offsite residential wells that may be a primary or sole source of drinking water for local residents in Anderson, Loudon, and Roane counties.

RadNet:

RadNet is a nationwide monitoring program managed by EPA, which monitors the nation's air, precipitation and drinking water to track radiation in the environment. There were three RadNet sampling projects conducted by TDEC on the ORR during FY2019. In a collaborative, mutually beneficial arrangement, TDEC DoR-OR uses State employees to collect environmental samples from five (5) locations across the DOE reservation (at all three (3) main facility sites) and utilizes EPA's analytical services within this program to complete the sample evaluations. This EPA program allows the State to evaluate independently analyzed data sets at the EPA lab, with no additional analytical costs. Those results are used by TDEC DoR-OR to corroborate data from DOE's own environmental sampling programs, which also assess the potential radiological emission impacts to the environment from DOE operations across the site. This same data is then also used by EPA to provide further regional inputs to the RadNet program data set.

RadNet Air Monitoring

Five RadNet air monitors are stationed on the ORR, with two (2) monitors located at Y-12, two (2) at ORNL, and one (1) at ETTP. Particulate air samples are collected and sent for analysis twice per week. The EPA lab analyzes each sample for gross beta. Gross beta analysis is used as a screening tool (at a level of 1 pCi/m^3) to indicate if more extensive characterization and detailed assessments are warranted. Annually, 100 samples are collected from each sampler station. For FY 2019, the gross beta results for samples collected from each of the five (5) RadNet Air Monitoring stations all exhibited results well below the screening limits of 1 pCi/m^3. This sample data indicates and corroborates that the ORR activities occurring during FY2019 posed no significant impact on the environment or public health from unmonitored ORR air emissions in the areas covered by the air monitors.

RadNet Precipitation Monitoring

There are three (3) RadNet precipitation stations on the ORR, with one (1) at each of the three (3) sites co-located with a RadNet air station. Samples are collected twice a week by TDEC and composited monthly by the EPA lab for analysis. Rainwater can deposit particulate matter from the air onto the ground, and the radionuclides that may be found in that precipitation can eventually be absorbed into vegetation or soil. The highest values seen in the composited monthly precipitation samples for each of the three (3) ORR stations were all below the maximum contaminant levels (MCLs) set by the EPA for drinking water. While there are no regulatory limits for radionuclides in precipitation, the comparison to EPA's drinking water limits were used as a conservative reference. All results for Cs-137, Co-60, Ra-226, and Th-228 for this time period were below the lab's reported minimum detectable concentrations (MDCs).

RadNet Drinking Water Sampling

Radioactive contaminants have the potential to migrate from the ORR to the Clinch River, which serves as a raw water source for area public drinking water. The impact of these contaminants is diminished by the dilution from the Clinch River, and contaminant concentrations are further reduced in finished drinking water by conventional water treatment practices employed by area water treatment plants. Results of samples collected from public water supplies on and in the vicinity of the ORR in association with EPA's RadNet program have all been well below drinking water standards, since the inception of the project in 1996. This project is scheduled to be discontinued in FY2020.

Conclusion:

While DOE past and current operations on the ORR have the potential to release a variety of constituents to the environment via atmospheric, surface water, and groundwater pathways, DOE (as stated in the 2019 Annual Site Environmental Report) "is committed to enhancing environmental stewardship and managing impacts its operations have and may have had on the environment. Each year extensive environmental monitoring is conducted by DOE across the ORR. Thousands of samples and measurements of air, water, direct radiation, vegetation, fish and wildlife are collected from across the reservation and analyzed for both radioactive and nonradioactive contaminants." (2019 ASER)

TDEC DoR-OR continues to be committed to work to assure the citizens of Tennessee that the DOE's activities on and around the Oak Ridge Reservation (ORR) in Oak Ridge, Tennessee, are being performed in a manner protective of human health and the environment. The collaborative efforts of EPA, TDEC and DOE as well as the independent verifications of environmental health and wellness that the state conducts (as described in this environmental monitoring report), allows the State of Tennessee to be an involved active partner in decisions that help ensure that the best possible protections for the State of Tennessee are always at the forefront of every cleanup and environmental management decision.

In accordance with the Environmental Surveillance Oversight Agreement (ESOA), the Federal Facilities Agreement (FFA) and the TDEC mission statement, TDEC DoR-OR will continue to work to assure the citizens of Tennessee that 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.

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 (FY2019) Environmental Monitoring Report (EMR) for the period July 1, 2018 through June 30, 2019, in accordance with the terms of the Environmental Surveillance and Oversight Agreement (ESOA) and in support of activities being conducted under the Federal Facilities Agreement (FFA).

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

In support of the triparty (EPA, TDEC and DOE) Federal Facilities Agreement (the FFA), (and in compliance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), recognizing ORR's presence on the National Priorities List (NPL)), DoR-OR personnel, also conduct independent environmental monitoring to ensure DOE's legacy contamination at these Oak Ridge sites is managed appropriately. Monitoring conducted under the FFA program, is used to support environmental restoration decisions, evaluate performance of existing remedies, and to investigate the extent and movement of legacy CERCLA contamination.

DoR-OR will conduct operations designed to identify, prevent, mitigate and/or abate the release or threatened release of hazardous substances, pollutants, or contaminants from the ORR which may pose 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 FY2019 (period of performance July 2018 through June 2019), monitoring and assessment projects conducted by TDEC.

1.2 OBJECTIVE

This FY2019 EMR presents the results of the 20 independent projects proposed initially in the FY 2018 EMP and completed throughout FY2019 (Period of performance from July 1, 2018 concluding June 30, 2019). This monitoring report focuses on the following general areas: Radiological Monitoring; Biological Monitoring; Air Monitoring; Surface Water Monitoring; Sediment Monitoring; Groundwater Monitoring and RadNet.

1.3 THE OAK RIDGE RESERVATION

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

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

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

The East Tennessee Technology Park (ETTP), a former uranium enrichment complex that historically had been referred to as K-25, 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 ESO 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 Oak Ridge Reservation (ORR), Oak Ridge, Tennessee, are being performed in a manner protective of human health and the environment.

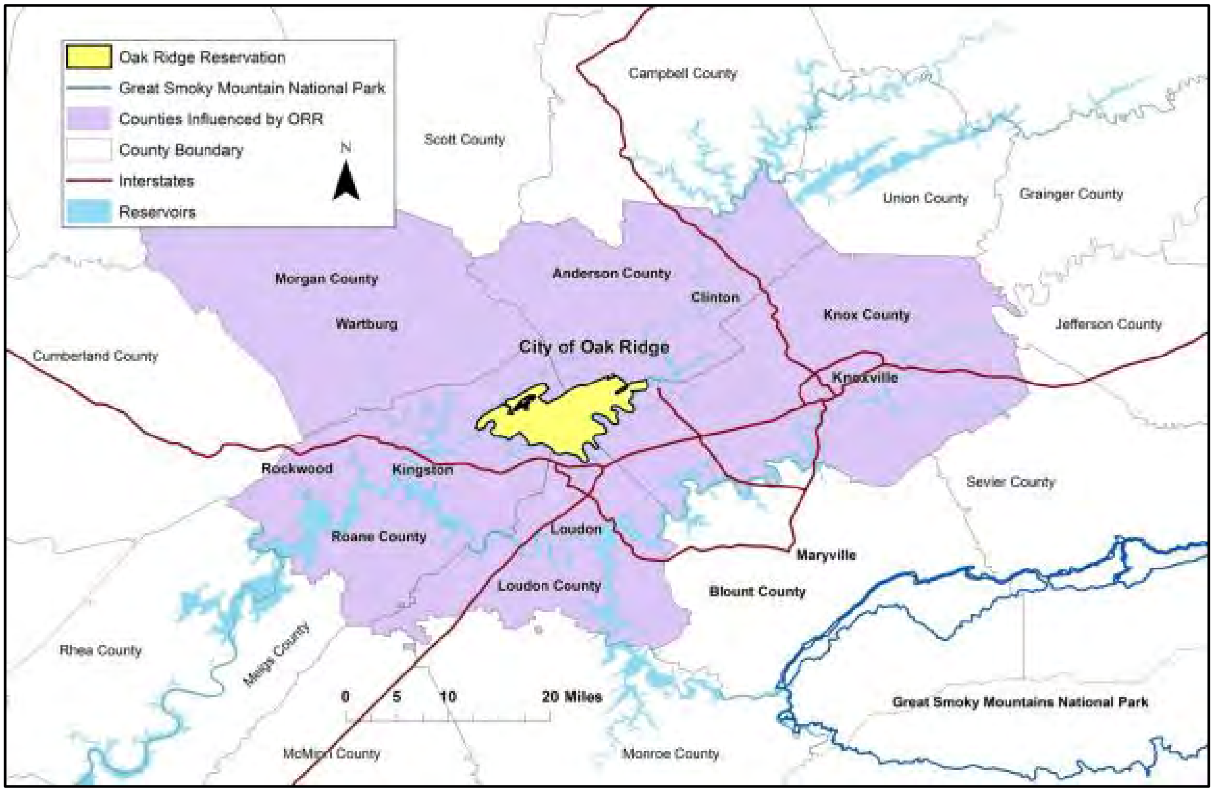


Figure1.3.1: Location of the Oak Ridge Reservation in Relation to Surrounding Counties

1.3.1 Geography of the ORR Area

Located in the valley of East Tennessee, between the Cumberland Mountains and the Great Smoky Mountains, the ORR is bordered partly by the Clinch River. The ORR is located in the counties of Anderson and Roane, and within the corporate boundaries of the city of Oak Ridge, Tennessee. The reservation is bound on the north and east by residential areas of the city of Oak Ridge and on the south and west by the Clinch River. Counties adjacent to the reservation include Knox is to the east, Loudon is to the southeast, with Morgan county located a short distance to the northwest. Portions of Meigs and Rhea counties are immediately downstream from the ORR on the Tennessee River. With the ORR almost entirely located within the city of Oak Ridge, the other 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 (2018 DOE ASER).

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

1.3.2 Climate of the ORR Area

The climate of the ORR region is classified as humid and subtropical; and is characterized by a wide range of seasonal temperature changes between the summer and winter months. Precipitation totals in the most recent calendar year (2018) were about 10 percent above the 30-year mean, with a total of 58.48 in. (DOE 2018 ASER).

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

1.3.3 Population of the ORR Area

More than 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 ESO 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.

This Page Intentionally Left Blank

2.0 RADIOLOGICAL MONITORING

2.1 ENVIRONMENTAL DOSIMETERS

2.1.1 Background

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

2.1.2 Problem Statements

Since its beginning during the Manhattan Project, the ORR has had a long history of working with or on radioactive materials. From its initial work with the Graphite Reactor at the Oak Ridge National Laboratory (ORNL), the Calutrons at Y-12 National Security Complex (Y-12), the Gaseous Diffusion Plant facilities at East Tennessee Technology Park (ETTP), and through a series of reactors that were built on and operated at ORNL, some highly radioactive materials have been generated, used in production, transported, stored, buried, and disposed at this site.

Activities, associated with fuel reprocessing, chemical methods for radioisotope separation, and radioisotope production, have further added to the accumulation of these radioactive materials.

At one time, little of the ORR was accessible to the public. More recently, there has been an intentional movement toward making areas of the ORR more accessible to businesses and to the public. This is particularly true at ORNL and ETTP. While the majority of these locations do not pose any exposure risks to the public, increased access has the potential to create situations where the public (including non-governmental, on-site workers) may be more likely to be exposed to areas such as temporarily stored or buried radioactive materials.

Because of this risk of exposure, it is important that various areas on the ORR, where exposure is more imminent, be monitored. Monitoring activity levels at select locations, provides information on how high levels are in those areas and how they may change as those areas are remediated, materials are moved, or materials are disposed. It is equally important to monitor areas with lower radiation levels, to identify those areas as low-level and determine that those levels remain relatively constant.

Long-term monitoring of the ORR has shown that the majority of areas on the ORR pose no risk to the public. Long-term monitoring of the ORR has also helped to keep a focus on areas where radiation levels may be somewhat elevated or where levels may have the potential to increase due to operations or site usage.

2.1.3 Goals

The goal of the Environmental Dosimeters Project is to maintain independent radiological monitoring to evaluate impacts both on and in the vicinity of the ORR and verify protectiveness of DOE actions. Monitored radiation levels are expected to improve as remediation activities continue, short lived isotopes decay, and stored materials are dispositioned.

2.1.4 Scope

The purpose of this project is to independently assess radiation exposure at discrete areas on and around the ORR, and to determine if the potential public dose from radiation exposure at those locations is kept below the NRC NUREG-1757 reference limit of 100 mrem/yr (Schmidt et al, 2006). The Environmental Dosimeters Project focuses on areas of all three ORR facilities, as well as background sites, in and near Oak Ridge. Emphasis is placed on areas where radioactive materials are stored, processed, or disposed. Areas where radiation levels are particularly of interest to stakeholders, such as the Environmental Management Waste Management Facility (EMWMF) and parts of the ETTP which are recently much more accessible to the public, are also included in this scope. It is important to know where potential problems exist, but it is equally important to inform stakeholders where problems do not exist.

Optically Stimulated Luminescence Dosimeters (OSLs) are used for the project due to their superior sensitivity compared to Thermoluminescent Dosimeters (TLDs) (Boons, Van Iersel, & Genicot, 2012). The majority of the areas will receive only gamma-detecting dosimeters, whereas, areas with the potential for neutron impacts, will also receive neutron-detecting dosimeters.

This project provides:

- Evaluations of potential dose at specific sampling locations.
    - These evaluations relate to the dose, which would be received if the affected entity were present at the stationary sampling location always. From this data, a conservative estimate of the potential dose from exposure to gamma radiation attributable to DOE activities/facilities on the ORR may be estimated.

- Baseline values used to assess the need and/or effectiveness of remedial actions
- Information necessary to establish trends in gamma radiation emissions
- Information relative to the unplanned release of radioactive contaminants on the ORR

2.1.5 Methods, Materials, Metrics

All work on the Environmental Dosimeters Project is conducted under the guidance of TDEC DoR-OR's *2017 Health and Safety Plan* (TDEC, 2017). In this Environmental Dosimeters Project, environmental dosimeters are used to measure the gamma radiation dose attributable to external radiation at selected monitoring stations. Collected data results are compared to background values and the State's primary dose limit for members of the public.

The Environmental Dosimeters Project is conducted on the ORR and at background areas in and around the city of Oak Ridge in order to monitor general radiological conditions. Gamma radiation exposure levels are monitored at all sites and neutron radiation is monitored at select sites. Dosimeters are distributed in select areas of Y-12, EMWMF, the ORNL Main Campus in Bethel Valley, ORNL Melton Valley, ORNL Tower Shielding and Cesium Forest, Spallation Neutron Source at ORNL, ETTP, the City of Oak Ridge and its vicinity, and both Norris and Loudon dams.

The dosimeters used in the Environmental Dosimetry Project are OSLs. Optically Stimulated Luminescence Dosimeters are more sensitive than TLDs; they record levels of exposure as low as 1 mrem versus the TLDs recording levels as low as 10 mrem. The dosimeters are obtained from Landauer, Inc., in Glenwood, Illinois.

Dosimeters at all sites are changed out by TDEC DoR-OR and analyzed (by Landauer, Inc.) on a quarterly schedule, during the months of January, April, July, and October. A total of 145 dosimeters are distributed and retrieved each quarter (new ones placed in the field; those in the field are retrieved from the field and returned to Landauer for processing). Dosimeters are typically received from Landauer, Inc. during the first weeks of January, April, July and October. Upon receipt, the dosimeters are logged in (to ascertain that all units were received) and prepared for distribution to the various sites.

To obtain access to the majority of the ORR sites, TDEC DoR-OR staff coordinates with site personnel to pre-arrange site access to distribute OSLs. At certain sites, the TDEC DOR-OR staff is accompanied by site personnel during OSL distribution. At other sites, gate keys are provided to gain access to the areas.

Every attempt is made to complete the quarterly task within two to three weeks of receiving and logging in the dosimeters. The successful execution of TDEC's schedule depends upon the schedules of site contacts, weather conditions, and other extenuating circumstances (e.g., temporary inability to access certain areas because of ongoing site activities).

After dosimeters are retrieved, they are logged back in (to determine if any are missing), they are then packaged for shipment to Landauer, Inc. for analysis. Packages are shipped via ground delivery to avoid the packages from being x-rayed in transit (packages shipped via air are likely to be x-rayed; x-raying will impact dose readings and will make the data unusable).

After the dosimeters have been analyzed at Landauer, Inc., data files are downloaded, transferred to Excel spreadsheet format, and then placed in tabular format to be used in the annual Environmental Monitoring Report (EMR). Consult the draft TDEC DOR-Oak Ridge Standard Operating Procedure for the Environmental Dosimeters Project (TDEC, 2018) for details.

2.1.6 Deviations from the Plan

The deviation from the plan submitted for 2019 is the total number of dosimeter locations was reduced for the two remaining Quarters for 2019 (see Table 2.1.1 and the discussion below).

2.1.7 Results and Analysis

These most recent results included in this report are for the 1st and 2nd Quarter of 2019. Also included are the results for all four Quarters for 2018.

The Landauer data are reported in Deep Dose Equivalent in mrem (DDE) as a cumulative dose for each Quarter. The Dose Equivalent is H and H = DQ, where D is the absorbed dose and Q is a quality factor. The Quality Factor is an energy value (related to the type of radiation) that is involved with the exposure.

Figure 2.1.1 summarizes the results for all sites, for all four Quarters for 2018, and both Quarters for 2019 for all locations. Figure 2.1.2 summarizes the results for all six Quarters but split into individual areas: A (Offsite), B (EMWMF), C (ETTP), D (ORNL/MV) and D (SNS).

The data are plotted with the abscissa (x-axis) in standard deviations and the logarithm (base 10) of the DDE in millirem (mrem) on the ordinate (y-axis).

This is the simplest way to independently check the statistical distribution of a data set. It is also more convenient because the semi-log axis method can show a greater range of data more conveniently when the numerical range is large (e.g., 1 – 10,000) or there are higher values than low or vice-versa.

Often scientific data are not normally distributed (Reimann and Filzmoser, 1999) but are sometimes log-normally distributed. One way to check this is to make a plot where the y-axis has a logarithm scale. If data are log-normal they will approximate a straight line on such a graph.

The easiest way do this is, using a spreadsheet, enter the data, sort it so it is in ascending order and use the adjacent columns to calculate the percent probability as a fraction. Then one can use the function NORMSINV to calculate the Standard Normal Cumulative Distribution Function for each probability value. The result is the value +/- of standard deviations from a standardized distribution with average 0 and sigma (standard deviations) 1.

If the x-axis shows standard deviations (geometric standard deviation with the logarithmic axis) the geometric mean will be at zero. This type of plot (often called a log-probability plot) (Hazen, 1914) is very useful for checking the actual statistical distribution of a data set. It cannot be assumed that any data set are normally distributed or log-normally distributed (Reimann and Filzmoser, 1999) so this should be independently checked.

Such plots are also very useful in that they tend to split the data up into groups based upon linear distribution trending segments (Groups A and B on Figure 2.1.1) making initial interpretation generally more straightforward.

Note that there are several steps between sub-populations in the data some of which are somewhat artificial in that that data are reported in whole integers so many values look identical and produce straight trends.

The horizontal value labelled “control” is the value that the laboratory designates for the background value for dosimeters that are kept in a lead-container for the entire quarter. A value of 10 mrem is also quoted as Minimal Dose Equivalent Reported – which in this case 10 is used in the plots. As is obvious this value is sometimes reported as well as values less than that. This is because the sometimes-variable quality of the measured radiation, which is sometimes not of good enough quality to report a value greater than 10.

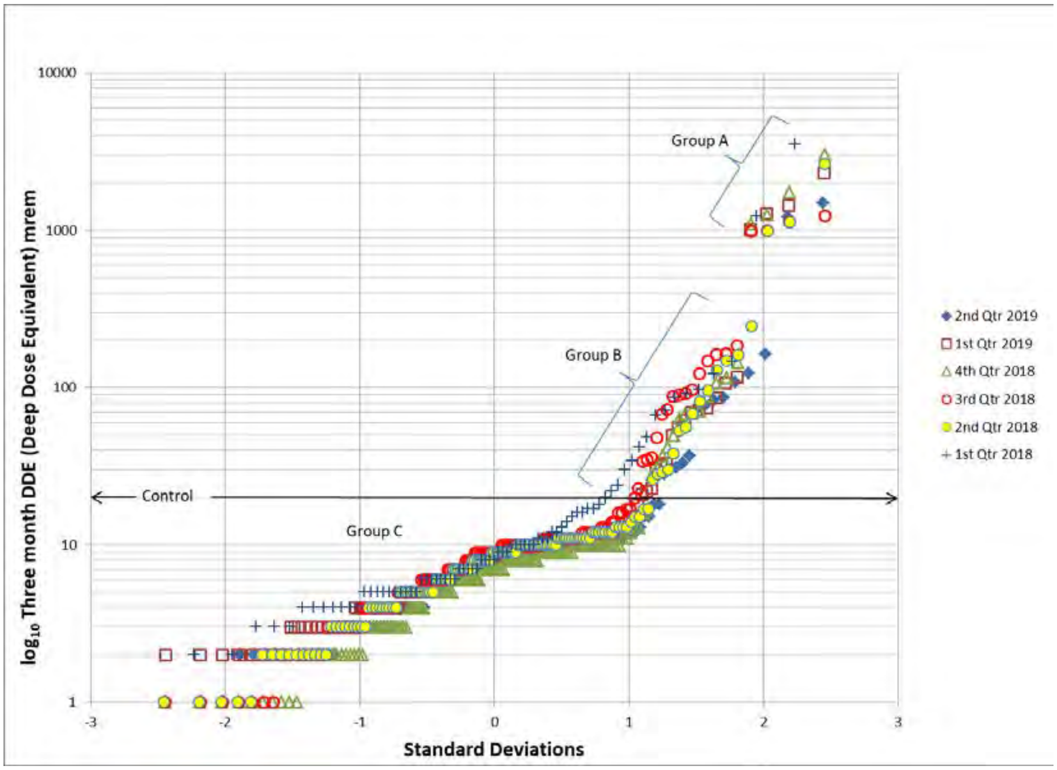


Figure 2.1.1 Dosimeter DDE Comparison All Sites 1st Qtr. 2018 - 2nd Qtr. 2019

It can be said that there are three groups of data described:

Group A. Describes the highest values consistently reported for 3 or 4 locations at ORNL, or Melton Valley (MV).

Group B. Describes a linear trend that extends from 10 mrem or 20 mrem to values near 200 mrem.

Note: These are various locations associated with locations of former or current work using radioactive materials, or storage of radioactive materials and are mostly at ORNL and MV, although two additional locations at SNS and ETTP. Most of these have actual or projected periodic cumulative doses higher than 20 mrem per Quarter, and thus might reach 100 mrem/year or greater, the NRC NUREG-1757 reference limit.

Group C. Describes values that are below 20 mrem (Control Value) or are < 10 mrem (Minimal Dose Equivalent Reported). Since the MDER is 10 mrem that value was used in these plots for all data reported as “M.”

Note that in Figure 2.1.1 the linear trend of Group B starts at an inflection point about 10 DDE even though the Control value used by the laboratory is about 20 or so.

So, generally speaking, above the control value (or above 10 mrem) there is a similar combined trend of values that increase toward about 200 mrem, (labeled Group B) in Figure 2.1.1. These values are to the right of an inflection of another data trend that are all less than 10 mrem and extend to the mean (at zero standard deviations).

So, the linear (distribution) trends (for all sites all Quarters used) of increasing data (Group B) are considered to be significant and describe increased values at locations above-background values. These locations are mostly located on the Oak Ridge Reservation as is shown in Figure 2.1.2. The exception for on-site locations are the data (B) from EMWMF, which are all below the control value.

Group A plots far away from this trend all above 1,000 mrem and is a group of locations that, as can be seen, have consistently high DDE values.

Figure 2.1.1 also shows that the data follow generally the same trends for the last six quarters.

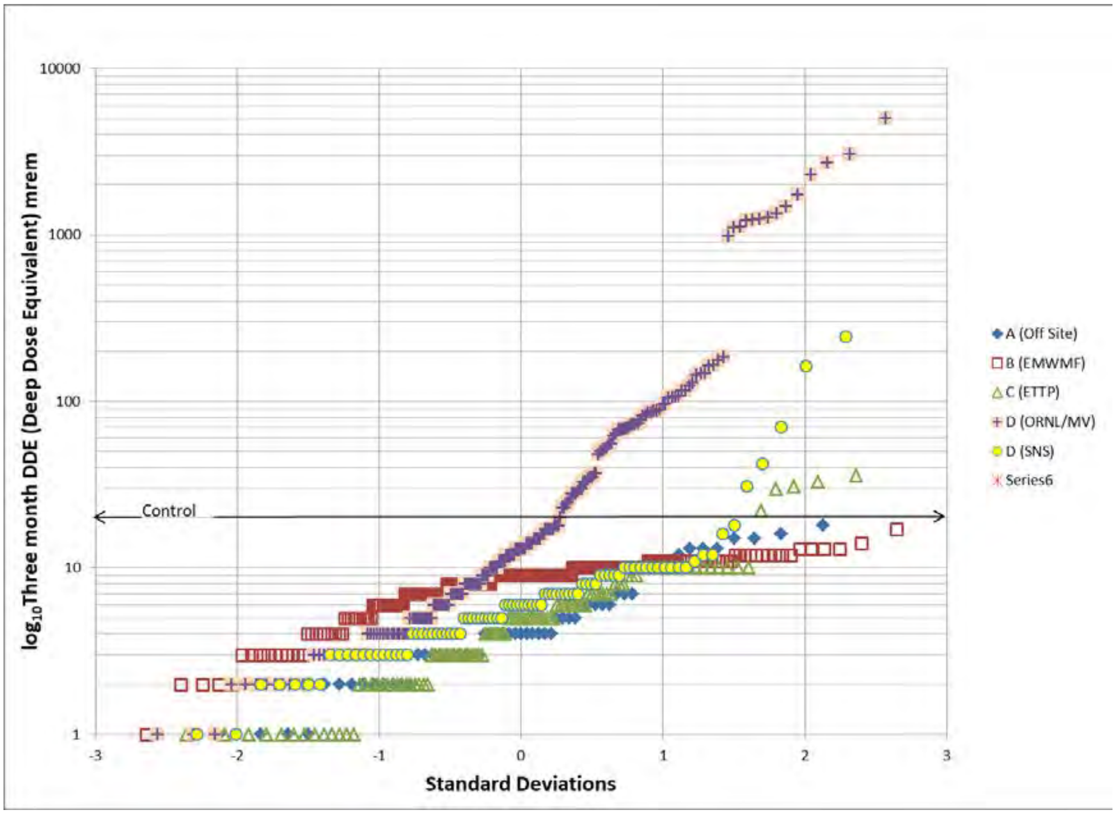


Figure 2.1.2 Dosimeter DDE Comparison, Separate Areas

Figure 2.1.2 plots the data for the individual areas. All six Quarters are plotted together.

First all the data for locations A (Offsite) plot below the Control Level.

This is also the case for all locations at B (EMWMF).

Several data points exceed the Control Level for C (ETTP). These are all DDE values for C-42 (a location across from a waste handler on lower Bear Creek Road).

Several data points also exceed the Control level for D (SNS). These values are all for location D-70 (Central Exhaust Facility).

For ORNL and MV many values exceed the Control Level and form a linear trend up to a maximum of 200 mrem.

Another separate set all plot between about 900 and about 5,000 DDE. This higher DDE set includes:

The Cesium (Cs) Fields (at the Tower Shielding Facility [TSF]), The Cask Storage Area above SWSA 6 in Melton Valley, the Hot Storage Garden at ORNL, and the Irradiated Fuels Building (#3607)

All values on Figure 2.1.2 that are above the Control Level (20 mrem) for one Quarter will be likely to exceed 100 mrem/year (4 x 20 mrem).

In areas where equipment has been moved around (e.g., at ORNL) it was sometimes deemed necessary to perform a dose survey with a Bicron instrument in order to choose the most appropriate location of the dosimeter. In one case such work revealed that the highest dose was from a standard shipping container (Sealand) through gap in the (closed) doors.

The dosimeter results show that many of the DDE values fall below the control level and many also fall below the Minimal Dose Equivalent Reported (M) on the results sheets from Landauer. It has therefore been decided to reduce the number of dosimeters that are used (see below).

Neutron Detecting OSL's

These values are not plotted and make up a small group.

Essentially the results vary from 1,443 DDE – to 4 DDE.

The highest values are from the fence around the Transuranic Processing facility and the dosimeter is located on the fence next to the D-32 (NHF) dosimeter. The values here vary from 1,443 to 108 DDE for the six Quarters.

This is a large range probably because of storage changes during routine work at the facility.

The ORAU South Campus is also monitored for neutrons and those readings are consistently below the Control Level with a maximum of 10 (M) and a minimum of 6 DDE. See Table 2.1.1 below where some changes are recommended for neutron monitoring in the reduced list.

2.1.8 Conclusions

The results show a consistent trend for the quarters that are plotted in Figure 2.1.1 and 2.1.2. Not only does the combined trend of results show little general variation for the period of performance (Figure 2.1.1), but the plot of the individual sites (Figure 2.1.2) shows that only a limited set of DDE values (primarily ORNL and Melton Valley locations) exceed the control level and exceed the Minimal Reportable Level. While these locations are mostly at ORNL/Melton Valley, one location is at SNS and one location is identified at ETTP.

Several locations at those sites (including one each at ETTP and SNS) have cumulative dosimeter DDE values for the 1st and 2nd Quarter of 2019 that could mean that their cumulative DDE total value for the four Quarters would exceed 100 mrem/year. As would be expected, most of these will be monitored in the revised set.

Neutron monitoring shows expected results for the facilities being monitored.

2.1.9 Recommendations

In FY 2020 the total number of dosimeters that are to be exchanged will be reduced to 25 total locations. This set of locations represent the most important locations that were being monitored, but based upon the results as plotted in Figures 2.1.1 and 2.1.2, shows that it is possible to eliminate the majority of the locations that are consistently below the control limit.

Some locations that are to be eliminated are those that may have reported high numbers, but have results that do not change significantly, and represent waste that would be expected to decay in the forthcoming years – particularly when ^{137}Cs and ^{90}Sr are involved, both having relatively short half-lives.

The revised set of monitoring locations does include those that might change, because of materials or equipment that might be moved and where doses might increase or decrease.

Rather than monitor all the locations with dosimeters, surveys with hand-held dose rate meters will be conducted. This procedure was done with one location at ORNL main campus when materials were moved between dosimeter exchanges and dose levels were suspected of changing.

The new reduced set of dosimeter locations that will be exchanged are as follows:

Table 2.1.1 FY2020 Proposed Dosimeter Locations

Station Number	Monitored Location	Type of Radiation
A-12/13	Loudon Dam Air Monitoring Station	Photon Gamma + Neutron
A-22	Scarboro Perimeter Air Monitoring Station	Photon/Gamma
D-14	North Side of central Avenue ORNL	Photon/Gamma
D-17	White Oak Dam@ Hwy 95	Photon/Gamma
D-19	Haw Ridge at Melton Valley Access Road	Photon/Gamma
D-20	MSRE	Photon/Gamma
D-20	White Oak Creek Weir @ Lagoon Rd	Gamma
D-23	Confluence MB,WOK	Photon/Gamma
D-27	HRE	Photon/Gamma
D-28	HFIR	Photon/Gamma
D-30	SWSA 5 TRU Storage Area	Photon/Gamma, Neutron
D-31	SWASA 5 Storage Tank	Photon/Gamma, Neutron
D-32 (D-61N)	New Hydrofracture Facility (former)	Photon/Gamma, Neutron
D-33	MV Haul Road near Creek	Photon/Gamma
D-34	Cask Storage Area above SWSA 6	Photon/Gamma
D-35	Building 3038 N	Photon/Gamma
D-36	Building 3607 materials storage area	Photon/Gamma
D-37	TH-4 Tanks	Photon/Gamma
D-38	Hot Storage Gardens	Photon/Gamma
D-39	Building 3618	Photon/Gamma
D-42	Neutralization Plant	Photon/Gamma
D-62	ORAU Pumphouse	Photon/Gamma, Neutron
D-70	Central Exhaust Facility	Photon/Gamma, Neutron
D-75	LINAC Beam Tunnel Berm No.2	Photon/Gamma, Neutron
D-84	Target Building East	Photon/Gamma, Neutron

2.1.10 References

Hazen, A, 1914, Storage to be provided in impounding reservoirs for municipal water supply, American Society of Civil Engineers, Transactions, v.77, p. 1529-1669.

Reimann, C., and Filzmoser, P., 1999, Normal and lognormal data distribution in geochemistry: death of a myth. Consequences for the statistical treatment of geochemical and environmental data. Environmental Geology, v 39 (9)

2.2 REAL TIME MEASUREMENT OF GAMMA RADIATION

2.2.1 Background

The K-25 Gaseous Diffusion Plant, 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 the X-10 Plant (now known as the Oak Ridge National Laboratory) began in 1943. While the K-25 and Y-12 plants' initial missions were the production of enriched uranium, the ORNL site focused on reactor research and the production of plutonium and other activation and fission products. These 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 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 the Y-12 National Security Complex to dispose of low-level radioactive waste and hazardous waste generated by remedial activities on the reservation.

DoR-OR has deployed gamma-radiation exposure monitors, equipped with microprocessor-controlled data loggers, on the ORR since 1996. The data logger monitors supplement the dosimeter monitors that measure cumulative dose, by providing data which can distinguish a series of smaller releases from a single, large release. 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.

2.2.2 Problem Statements

Monitoring, conducted by the Real Time Monitoring of Gamma Radiation on the Oak Ridge Reservation Project, 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 into the environment.

2.2.3 Goals

The results from monitored sites will be compared to:

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

2.2.4 Scope

Candidate monitoring locations, selected to house gamma radiation monitoring instrumentation, include sites undergoing remedial activities, waste disposal operations, pre- and post-operational site investigations, and areas of environmental response activities. In support of data assessment from other TDEC monitoring programs, anomalous results from DoR-OR’s environmental dosimetry program may warrant conducting additional gamma radiation monitoring at other locations. The current focus area for this project is depicted by Figure 2.2.1, Map of Sampling Site Locations. The instances where anomalous results may occur and additional monitoring may be required, will be evaluated and managed over the course of the year, as necessity arises.

Data recorded by the gamma monitors will be evaluated by comparing the data to background concentrations, the State maximum dose limits (as listed above), and State and DOE primary dose limits.

Gamma monitors were located at the following five (5) locations:

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

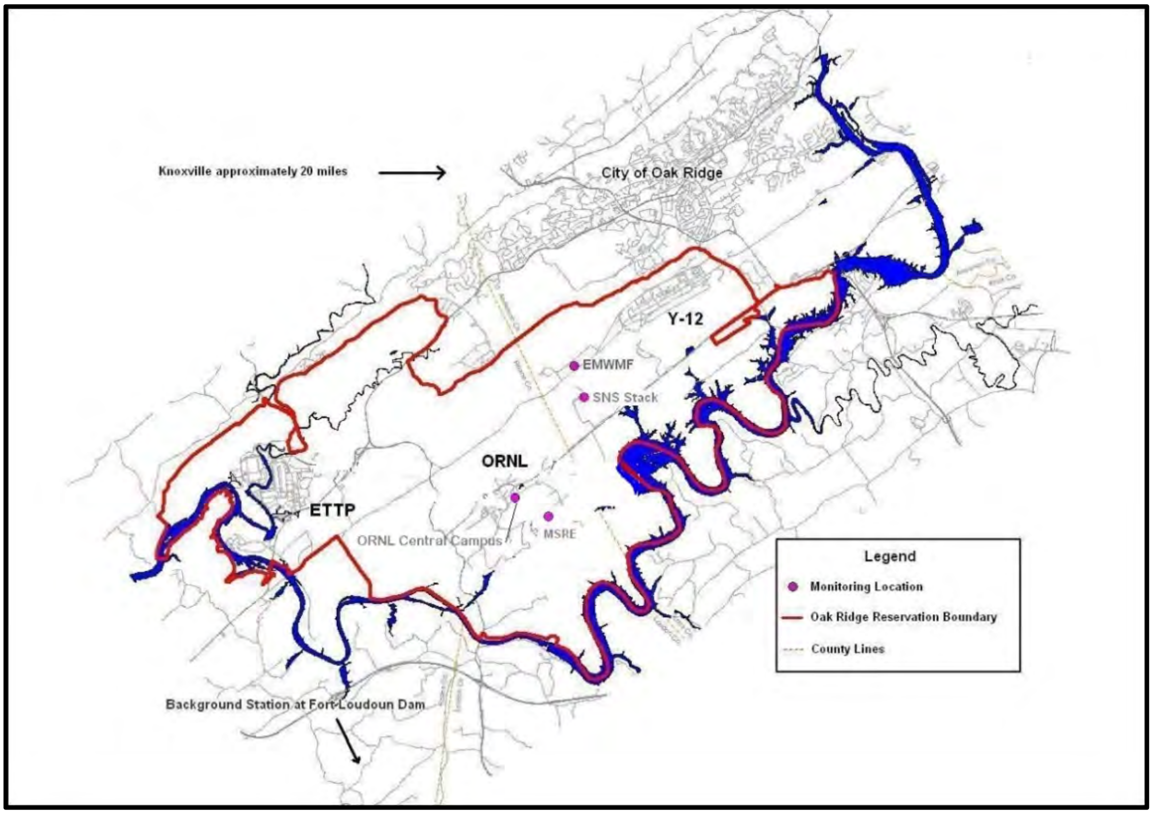


Figure 2.2.1: Map of Sampling Locations

2.2.5 Methods, Materials, Metrics

The gamma exposure rate monitors, deployed Real Time Monitoring of Gamma Radiation on the Oak Ridge Reservation Program, are manufactured by Genitron Instruments and are marketed under the trade name GammaTRACER®. Each unit contains two Geiger Mueller 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 one μrem/hour to one 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 Mueller detectors. The data for any interval from each detector can be accessed. The results recorded by the data loggers are downloaded to a computer by DoR-OR personnel using an infrared transceiver and associated software.

2.2.6 Deviations from the Plan

The instrument located at SNS was inoperable from 04/03/2019 through 06/06/2019. Data for this time period is not available.

2.2.7 Results and Analysis

Fort Loudoun Dam Background

To better assess exposure rates measured on the Reservation and the influence that natural conditions have on these rates, DoR-OR maintains one gamma monitor at Fort Loudoun Dam in Loudon County to collect background information. During the period, 07/01/2018 through 06/30/2019, exposure rates averaged 8.9 μrem/hour and ranged from 7 to 14 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 (near Y-12) to dispose of wastes generated by CERCLA activities on the ORR.

DoR-OR has placed a gamma monitor to be collocated with the Radiation Portal Monitor (RPM), 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 read any gamma radiation-emitting materials that have passed that portal monitor (potentially on the way to disposal at the waste cell). This monitoring system allows for the assessment of gamma impacts to the monitoring detector at that location over a defined time period, and can be used to corroborate DOE's reporting system, allowing for confirmation, if required, that excessive amounts of radiation-emitting materials have not inadvertently passed the monitoring point to be disposed of in the EMWMF facility.

Measurements taken during the period (07/01/2018 through 06/30/2019) averaged 6.9 μrem/hour and ranged from 4 to 12 μrem/hour, similar to the background measurements collected during the period. Refer to Figure 2.2.2, EMWMF Gamma Exposure Rates.

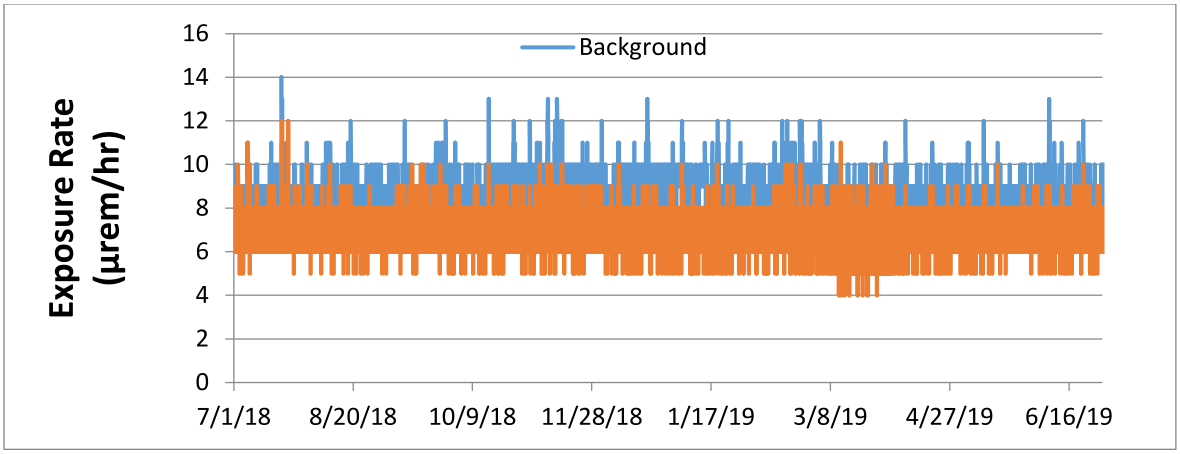


Figure 2.2.2 EMWMF Gamma Exposure Rates

ORNL Central Campus Remediation / Building 3026 Radioisotope Development Lab

- Monitoring on the ORNL Central Campus began in 2012 and has continued through June 2019.
- 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 period, 07/01/2018 through 06/30/2019, gamma radiation measured at the site ranged from 11 to 24 µrem/hour and averaged 15.3 µrem/hour. These values are nearly twice the values of background readings (Table 2.2.1 and Figure 2.2.3).

Table 2.2.1: Gamma Rates from Previous Years Reflect Historical Activity

Previous calendar years	Min	Max	Av
2012	12	88	24.7
2013	12	227	67.1
2014	12	23	17.2
2015	12	24	16.8
2016	12	52	16.5
2017	11	23	15.4

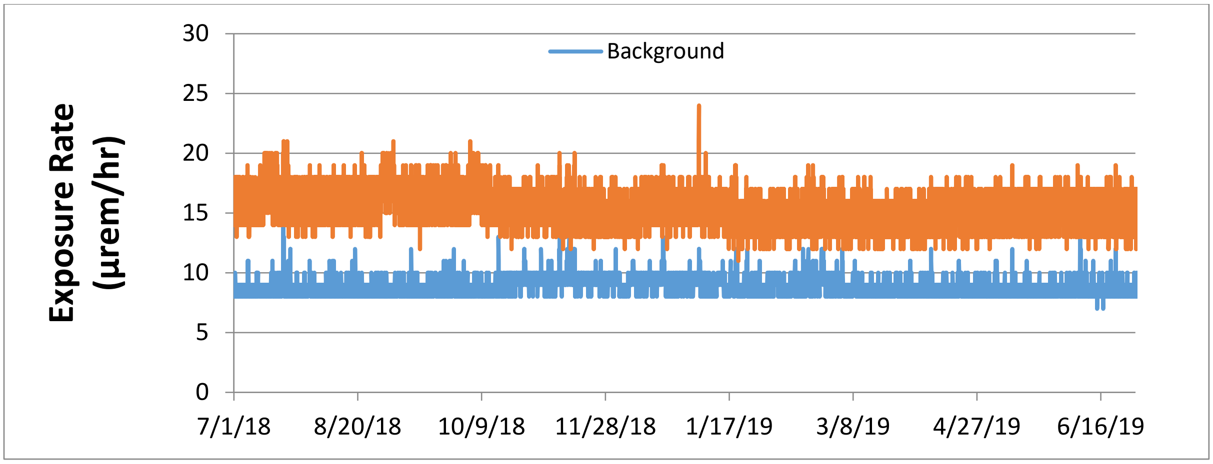


Figure 2.2.3: ORNL Central Campus Gamma Exposure Rates

The Molten Salt Reactor Experiment

Gamma monitoring has been conducted at the Molten Salt Reactor Experiment (MSRE) site from November 1, 2012 through June 30, 2019. DoR-OR records gamma exposure rates with a gamma monitor, placed near the gate where trucks containing radioactive materials (e.g., reactor salts removed from drain tanks) exit MSRE. The monitoring location is near a radiation area, established to store equipment used in remediation activities at this site.

During the 07/01/2018 through 06/30/2019 monitoring period, the average exposure rate ranged from 10 to 188 µrem/hour and averaged 81.1 µrem/hour. The major source of the radiation measured is assumed to result from a salt probe being temporarily stored in the radiation area, adjacent to the monitoring station. Readings dropped dramatically when the probe was removed in early November Figure 2.2.4.

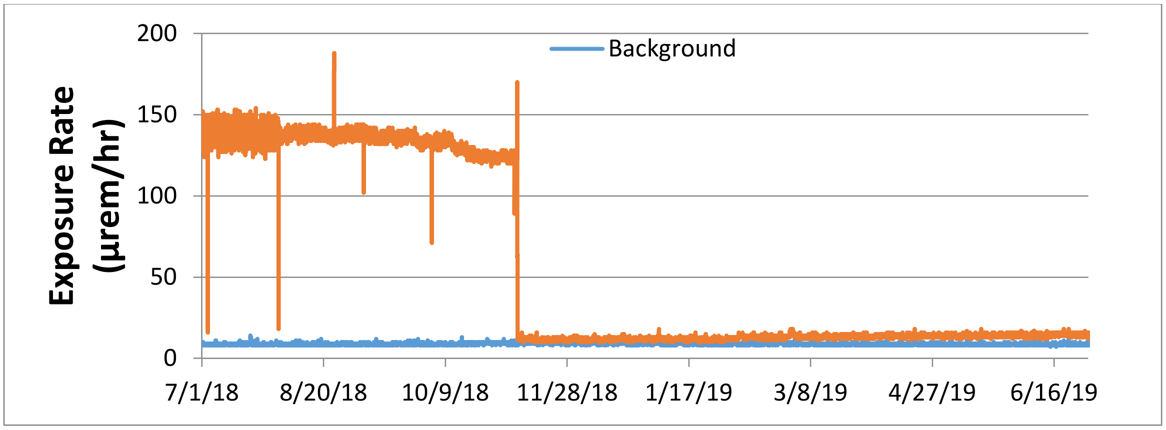


Figure 2.2.4: Gamma Exposure Rate at Molten Salt Reactor Experiment

Spallation Neutron Source

To assess the gamma component of air releases from the Spallation Neutron Source (SNS), DoR-OR's exposure rate monitor is located on the central exhaust stack used to vent air from process areas inside the linac and sample target building. The exposure rates vary, based on the operational status of the accelerator. During periods when the accelerator is not on line, the rates are similar to background measurements. However, much higher levels are recorded during operational periods. The exposure rates measured throughout the sampling period registered between 07/01/2018 through 06/30/2019 was interrupted by an equipment outage form 04/03/2019 through 06/06/2019. Measurements ranged from 6 to 1176 µrem/hour and averaged 85.1 µrem/hour. See Figure 2.2.5. For contextual purposes, the exposure rate of 85.1 µrem/hour would exceed both State and DOE limits of 100 mrem within one year. However, this location is not accessible to the public.

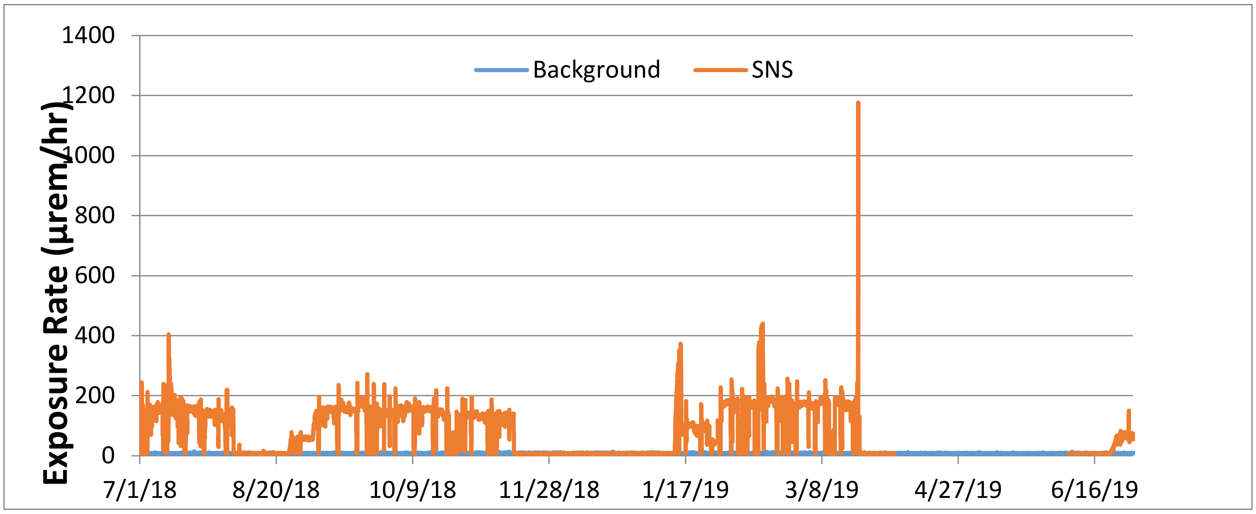


Figure 2.2.5: Spallation Neutron Source

2.2.8 Conclusions

The following conclusions are drawn, based on the data collected 07/01/2018 through 06/30/2019.

- 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.

2.2.9 Recommendations

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

- As DOE does not have a continuous monitoring program, TDEC DoR-OR will continue this program.

2.2.10 References

There are no references for this report.

2.3 PORTAL MONITORING AT EMWMF

The Canberra RadSentry Model S585 portal monitor became unreliable in April 2017 and stopped working completely in September 2017. No EMWMF portal monitoring using the Canberra RadSentry Model S585 portal monitor was conducted during this period of performance due to equipment failure. A gamma monitor was co-located at that position; see section 2.2 for that associated data set.

2.4 SURPLUS SALES VERIFICATION

2.4.1 Background

The Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge Office (DoR-OR), in an oversight capacity of the U.S. Department of Energy (DOE) and its contractors, conducts radiological surveys of surplus materials originating from the Oak Ridge Reservation (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 the Y-12 National Security Complex (Y-12) and at the Oak Ridge National Laboratory (ORNL) regarding surplus sales. With rare exceptions, materials are no longer sold directly to the public by either facility. Materials from ETTP may be released through ORNL Property Excessing. Y-12 now uses an out-of-state contractor to handle the majority 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, 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, DoR-OR immediately reports the finding(s) to the surplus sales program supervisor. A removable contamination assessment may be performed. DoR-OR then follows the response of the sales organizations to see that appropriate steps (i.e., removal of items from sale, resurveys, etc.) are taken to protect the public.

2.4.2 Problem Statements

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

Even when items of concern are found, they may not ultimately prove to be problematic. What first appears as an item with surface contamination may (with a resurvey) proves to be an instance where the suspected contamination can no longer be detected, is non-reportable daughter products, or naturally occurring radioactive material.

2.4.3 Goals

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 where items of concern are found, it prevents the release of potentially contaminated materials to the public.

2.4.4 Scope

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

2.4.5 Methods, Materials, Metrics

Surplus sales verification work is performed under the guidance of *DoR-OR's 2017 Health and Safety Plan* (TDEC 2017). Prior to sales of surplus items being released to the public, 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 DoR-OR's survey results, the Excess Property staff decides whether or not to have the item rechecked by ORNL RADCON. DoR-OR does not attempt to determine if a particular item meets DOE release criteria, but does try to locate items where, depending on which 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.

2.4.6 Deviation from the Plan

There were no deviations from the plan.

2.4.7 Results and Analysis

The office responded to four Surplus Sales Survey requests made by ORNL since the beginning 2019. In these four requested visits a total of seven items were identified with activity above the ambient background. The survey results were shared with ORNL in an e-mail message and the trip report was written to be uploaded to DoRway.

2.4.8 Conclusions

The independent Surplus Sales Verification Project performed by TDEC DOE-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 are adequately scanned, but there were some pieces with surface areas where either the alpha or beta activity exceeded the ambient background. These surveys assist DOE decide whether equipment can meet release criteria.

2.4.9 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.

2.4.10 References

FRMAC Monitoring and Sampling Manual, Vols. 1 & 2. (2012) DOE/NV/11718-181-Vol. 1 & Vol. 2. Federal Radiological Monitoring and Assessment Center, National Nuclear Security Administration. Nevada Test Site.

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, Oak Ridge, Tennessee. (2005) DOE/OR/01-2220&D1. U.S. Department of Energy.

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation. Operation and Use of a Ludlum Model 2224 (-1) and 43-93 Probe (Dual Phosphorus Meter) (SOP T-532). 2019.

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation. Operation and Use of a Ludlum Model 2221 and 44-10 Probe (NaI Meter) (SOP T-540). 2019.

Tennessee Department of Environment and Conservation (TDEC) ,2017, Division of Remediation, Oak Ridge Office (DoR OR) 2017 Health and Safety Plan Including Related Policies, January 2017. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, TN.

2.5 HAUL ROAD SURVEYS

2.5.1 Background

The Haul Road was constructed for (and is reserved for) trucks transporting Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) radioactive and hazardous waste from remedial activities on the ORR to the Environmental Management Waste Management Facility (EMWMF) for disposal. The Tennessee Division of Environment and Conservation's (TDEC) Division of Remediation (DoR) Oak Ridge (OR) office Haul Road Surveys project team typically performs bi-monthly surveys of the Haul Road and other waste transportation and access routes on the Oak Ridge Reservation (ORR).

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

2.5.2 Problem Statements

- In the history of the Haul Road, a number of incidents resulting in potentially contaminated materials being freed in transport have highlighted the need for regular radiological surveys.

- Throughout the history of the Haul Road Surveys project, many anomalous items have been identified such as waste debris, personal protection equipment, tarp patches, waste stickers, steel pipe, etc.

2.5.3 Goals

This project aims to prevent the spread of contamination resulting from the transportation of radioactive waste from the originating clean-up locations on the ORR to the waste disposal location. In particular, project objectives include the following:

- To locate waste that may have been blown or dropped from waste-hauling trucks in transit
- To support DOE and their contractors through observation of site conditions following waste transportation, verifying that activities conducted by DOE along this corridor are in a manner that limits potential environmental concerns on the Haul Road and for the surrounding areas

2.5.4 Scope

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

2.5.5 Methods, Materials, Metrics

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

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

2.5.6 Deviations from the Plan

No surveys were conducted in December of 2018 or June of 2019, but additional surveys were done in other months to satisfy the project’s goals.

2.5.7 Results and Analysis

The Haul Road surveys identified 52 items in the July 2018 – June 2019 time frame on the Haul Road and access roads. The items potentially originated from hazardous and/or radioactive waste being transported from the ORR to the EMWMF.

- No surface contamination readings exceeded the free release limits
- All ambient high-energy gamma readings were within the range of normal background for the area

2.5.8 Conclusions

The periodic surveys of the roads used to haul waste to the EMWMF indicate waste items routinely fall from trucks transporting waste. The 52 items identified in TDEC surveys were deemed to be non-radiological and dispositioned by DOE.

2.5.9 Recommendations

More decommissioning and demolition as well as additional remedial activities are planned for ETTP and Y-12 in the coming years. The wastes from these projects are expected to be transported on the Haul Road and access roads to the EMWMF. Based on previous findings, it is believed that the continued assessments of the road and associated haul areas, such as are conducted with this project, are necessary to support DOE and their contractors in detecting and dispositioning the anomalous items that may fall or blow from waste-transporting trucks.

2.5.10 References

FRMAC Monitoring and Sampling Manual, Vols. 1 & 2. (2012) DOE/NV/11718-181-Vol. 1 & Vol. 2. Federal Radiological Monitoring and Assessment Center, National Nuclear Security Administration. Nevada Test Site.

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, Oak Ridge, Tennessee. (2005) DOE/OR/01-2220&D1. U.S. Department of Energy.

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation. Operation and Use of a Ludlum Model 2224 (-1) and 43-93 Probe (Dual Phosphorus Meter) (SOP T-532). 2019.

Tennessee Department of Environment and Conservation (TDEC), Division of Remediation. Operation and Use of a Ludlum Model 2221 and 44-10 Probe (NaI Meter) (SOP T-540). 2019.

3.0 BIOLOGICAL MONITORING

3.1 BAT MONITORING AND MERCURY ASSESSMENT OF ASSOCIATED PREY ON THE ORR

3.1.1 Background

On the U.S. Department of Energy's Oak Ridge Reservation (DOE, ORR), East Fork Poplar Creek (EFPC) and Bear Creek (BCK) floodplains have been impacted by large historical releases of mercury (Hg) and by past waste management practices associated with the nuclear weapons program at the Y-12 National Security Complex (Y-12 NSC; Brooks et al., 2017). Mercury, released from industry, often finds its way into aquatic systems where it has long residence times and can bioaccumulate in aquatic food webs (Evers et al., 2005). Stream floodplains and wetlands are prime locations for Hg methylation by microorganisms, generating toxic bioavailable methylmercury (MeHg); (Wiener, Krabbenhoft, Heinz, & Scheuhammer, 2003). Methylmercury biomagnifies as it moves up aquatic food chains from lower trophic level prey to higher level predators such as bats that use their nocturnal hunting skills to locate insects (Bell & Scudder, 2007).

Bats are frequently subjected to multiple anthropogenic stressors (i.e., heavy metals, organic chemicals) while foraging in stream riparian zones and floodplain wetlands, causing a number of species to become endangered or threatened with extinction (Mickleburgh, Hutson, & Racey, 2002). North American bats are also experiencing rapid population loss due to a disease known as white nose syndrome (WNS) (Bernard & McCracken, 2017). Tennessee's sixteen known bat species are long-lived nocturnal insectivores (life expectancy range 5 to >20 years), but the seven cave species are under intense survival pressure due to WNS disease (>50 Tennessee counties have confirmed cases of WNS-infected bats; TBWG, 2018).

The incorporation of MeHg from the leaf litter by detritivores and by predaceous invertebrate species (i.e., centipedes and spiders) that feed on detritivores is a direct pathway to elevated Hg exposure for the next highest trophic level, insectivores (i.e., birds and bats) (Osborne et al., 2011). Insectivorous bats (female bats especially) consume a large volume of food every night (i.e., 75-100% of body weight). This is needed to sustain metabolic requirements of flight, for birthing and nursing their pups, and to build up fat reserves for hibernation (O'Shea, Everette, & Ellison, 2001, Nam et al., 2012). The little brown bat (cave bat) forages on a broad prey base including beetles, wasps, cicadas, leafhoppers, moths, flies, and caddisflies (Whitaker & Hamilton, 1998). Little brown bats weigh about 7-9 grams and feed for approximately 200 nights per year, thus a single little brown bat consumes 3-4 pounds of insects, annually. Bats feeding at these volumes in higher terrestrial trophic levels in the food web, especially consumption of flying insects with benthic larval stages, are at risk of exposure (i.e., sublethal effects) and bioaccumulation of MeHg in their bodies (Osborne et al., 2011). A laboratory study using small mammals found that individuals with fur-Hg levels of 7.8-10.8 ppm (parts per million) showed decreases in motor skills (Burton et al., 1977).

A study conducted at the Hg-impacted South River (Virginia) revealed that the mean value of Hg in bat fur exceeded 28.0 ppm which was eight times greater than bat fur collected at non-impacted reference sites (Yates et al., 2014). Fur–Hg concentrations in wildlife indicate body burden Hg at the time of fur growth when the Hg is remobilized by muscle and organs and sequestered in growing fur (Evers et al., 2005; Yates et al., 2005). Mercury concentrations >10 ppm in bat fur may be associated with adverse effects such as neurobehavioral disorders (Wobeser, Nielsen, & Schiefer, 1976; Burton et al. 1977; S. Alexander, personal communication, February 8, 2018). Mercury levels exceeding 10 ppm in guano (bat excrement) samples could also be associated with adverse effects in bats.

Exposure of bats to persistent food-chain contaminants can be estimated by sampling guano from cave roosts (Clark, LaVal, & Tuttle, 1982; Clark, Moreno-Valdez, & Mora, 1995). O'Shea, Everette, and Ellison (2001) reported that bat guano collected from big brown bat roosts at a contaminated Colorado superfund site had significantly higher concentrations of insecticides, arsenic and Hg, than bat guano collected from a non-impacted reference site. Patterns of contamination in guano and stomach contents of big brown bats at the Colorado superfund site were also seen in bat carcasses and brains (O'Shea, Everette, and Ellison, 2001). However, little is known about Hg concentrations in guano samples as an indicator of internal tissue Hg concentrations. Bat fecal analysis may provide a valuable source of information for feeding habits and metals bioaccumulation in bats without sacrificing or stressing the bats (Belwood & Fenton, 1976).

3.1.2 Problem Statements

Bats may be exposed to levels of Hg high enough to cause sublethal effects through the consumption of large quantities of insects that spend their larval stages in Hg-contaminated stream sediments (Hickey, Fenton, MacDonald, and Soulliere; 2001).

Because there is little or no information regarding Hg concentrations on bat guano in the published literature, the challenge is to understand potentially harmful body burdens of Hg in bat tissue by using guano as a surrogate.

During FY 2018, it was proposed that bat guano samples be collected from eight bat houses (if occupied) for Hg and MeHg analysis plus taxonomic evaluation of masticated insect parts in the sample. In the event that guano samples are not available, then, insect prey will be collected as a proxy for bat guano for Hg and MeHg sample analysis.

The presence of bat species will be determined with acoustic surveys with a special emphasis on threatened and endangered (T&E) species. In particular, the acoustics surveys will focus on bat habitats including caves and trees. Although cave entry is not required for acoustic surveys, certain karst features on the ORR are in restricted areas and access may be problematic.

3.1.3 Goals

The goals of the Bat Monitoring Project on the Oak Ridge Reservation follow:

Determine Hg and MeHg concentrations in ORR bats using the analytical results of bat guano samples or insect prey as possible surrogates for bat internal tissue body burdens.

Provide and analyze bat acoustic surveys for the evaluation of species type, supporting further protection of ORR's T&E bat species.

3.1.4 Scope

During FY 2018, at the ORR, this project will pre-install bat houses at approximately 8 locations. After bat occupancy is confirmed, bat guano samples will be collected to determine Hg and MeHg concentrations in the guano.

Analysis of insect prey items, to be collected, will provide Hg and MeHg analytical support data for this project. Bat acoustic surveys will be used to identify species, including T&E species.

3.1.5 Methods, Materials, Metrics

Bat guano

An early May 2018 inspection revealed there were no bat occupants at any of the 8 ORR bat houses. At that time, it was decided to drop proposed monitoring the bat houses with acoustic bat detectors and conduct additional visual inspections. Follow-up inspections in June and July 2018 also found no occupants.

Due to lack of occupants, it was not possible to collect guano samples from the 8 pre-installed bat houses on the ORR (EFPC) during this period of performance. Plans were also dropped to collect guano from an offsite bat colony at the Norris Dam State Park that was intended to be used a background location.

Insect samples

Emergent flying insects are important prey items for songbirds, ducks, bats and other terrestrial biota. An important aspect of this study (from the food web perspective) is the examination of adult insects such as moths, beetles, and other species for Hg and MeHg content. For example, Murphy (2004) reported extraordinarily high concentrations of total Hg in the adult beetle *Cotinis nitida* (>14.5 ppm) collected from the South River (Virginia) floodplain.

In lieu of guano samples, insects were sampled by DoR-OR staff at 8 EFPC plots (50 m x 50 m) and 1 reference site adult insects (i.e., bat prey items) and an offsite reference as surrogate samples for Hg and MeHg analysis (Figures 3.1.1-3.1.2 and Table 3.1.1). The EFPC insect samples were collected during 4 nights during July 2018 and the Clear Creek reference samples were collected during 1 night in July 2017.

Insects were sampled between dusk and midnight with a black light collector device ("Larry's Lighthouse"-BioQuip Products, Inc., Compton, CA). Nocturnal insects are attracted to the black light which provides maximum insect response from as far away as 500 meters from the light source (Fry and Waring, 1996, Southwood and Henderson, 2000). 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. Approximately 3 sample vials of material were collected at each sampling location. The sample vials were carefully labeled and placed in an ice cooler for transport to the DoR-OR office laboratory. Upon returning to the office, insect samples were stored overnight in the laboratory refrigerator at 4°C (centigrade) until further processing (within 12 hours).

In the TDEC DoR-ORO laboratory, adult insect samples were separated and identified by species or major taxonomic group and weighed to the nearest 0.01 gram on the Ohaus balance and recorded Xin the laboratory sample log. The goal was to collect ≥5.0 grams of material for each species or major taxonomic group. Unfortunately, there was inadequate biomass to sort the taxa by genus/species for the desired Hg and MeHg analyses. Thus, the sample material was sorted and combined into 3 main groups for analysis: (1) beetles, (2) moths, and (3) EPT taxa (Ephemeroptera-Mayflies, Plecoptera-Stoneflies, and Trichoptera-Caddisflies). Sampling and sample preparation followed the standard operating procedures of Southwood and Henderson (2000); Fry and Waring (2001); Ellison et al. (2013); CCME (2016); and Patrick (2016; TDEC (2017).

Sorted adult insect samples were placed into special 2-oz QEC Level 2 pre-cleaned glass jars (Quality Environmental Containers, Beaver, WI) that were labeled and secured with sealed, plastic screw-top lids. These sample jars were stored at -18⁰C in the TDEC DoR-ORO laboratory freezer until their shipment to PACE Analytical Services, LLC for Hg and MeHg analysis.

Analytical laboratory methods

Shipment of adult insect samples was coordinated with the Tennessee Department of Health Nashville Environmental Laboratory (TDH-NEL). However, for the Hg (low level) and MeHg analyses, TDEC DoR staff forwarded these samples directly to PACE Analytical Services, LLC (Green Bay, WI) for analysis.

Mercury (low level) assays follow EPA method 1631E (EPA, 2002) and MeHg (in tissue) analyses follow EPA method 1630 (EPA, 1998).

Sample shipping protocol

Adult insect samples were packed and shipped as specified in the "Procedures for Shipping Samples to the State Lab in Nashville" (TDEC, 2015).

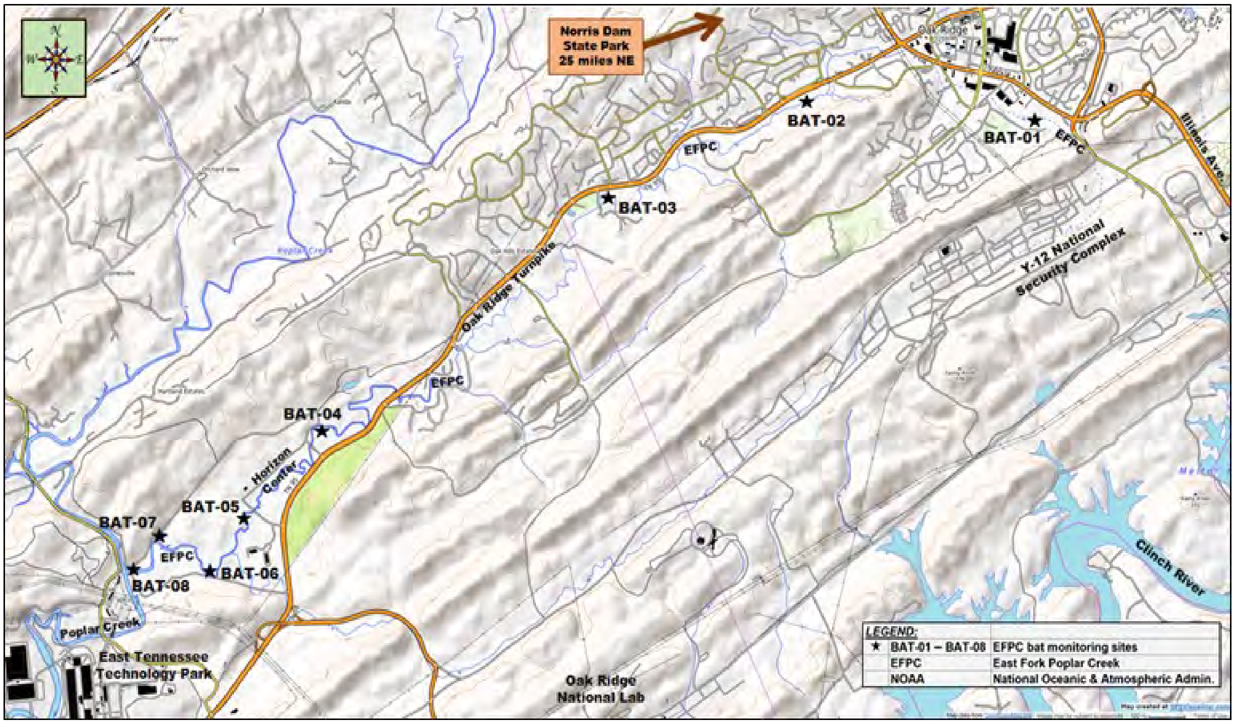


Figure 3.1.1: Proposed Bat House Monitoring Sites (East Fork Poplar Creek)

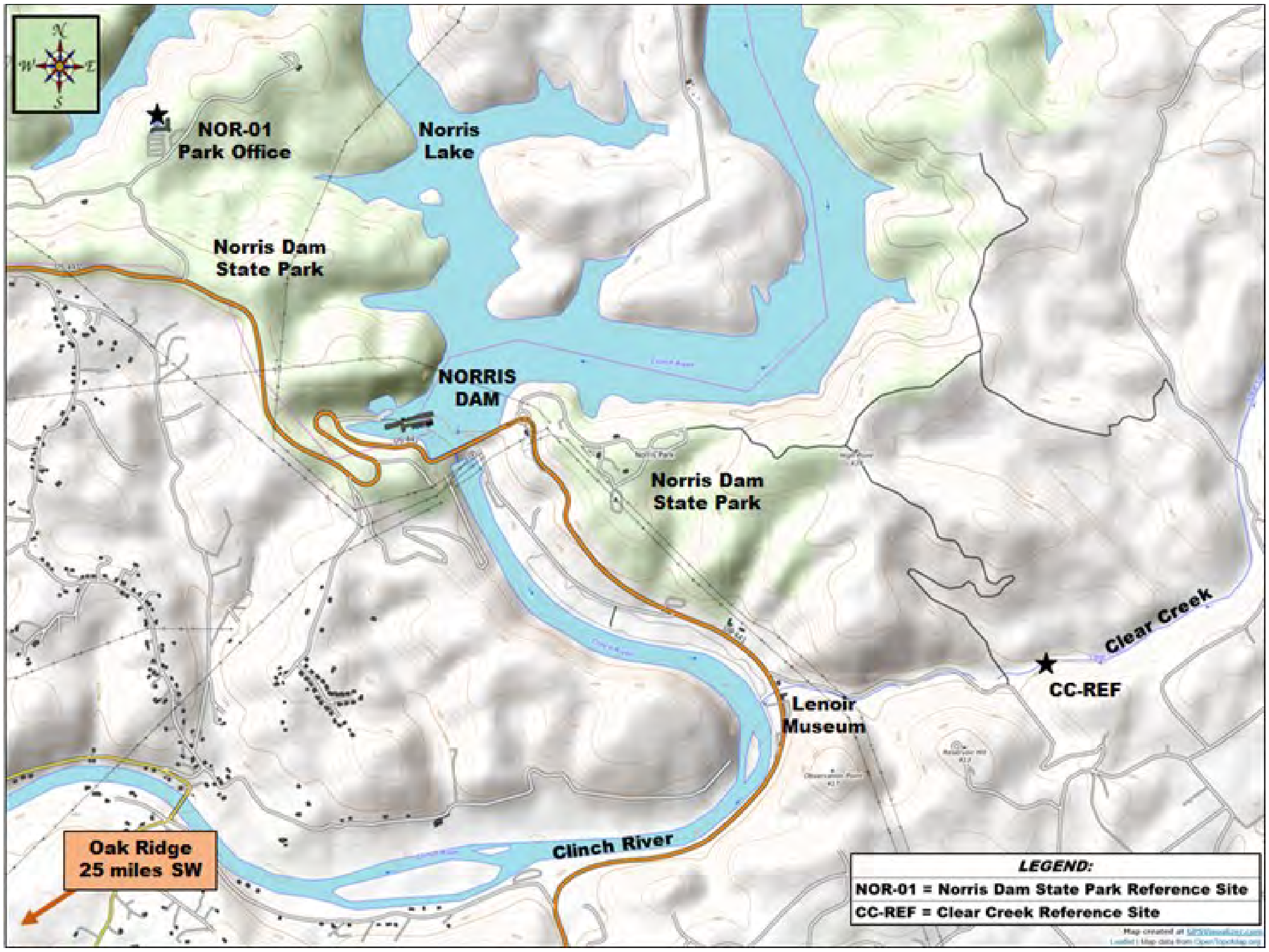


Figure 3.1.2: Norris Dam State Park Reference Sites (Park office/pool area bat colony; Clear Creek reference) NOTE: This location is about 25 miles northeast of the Oak Ridge area.

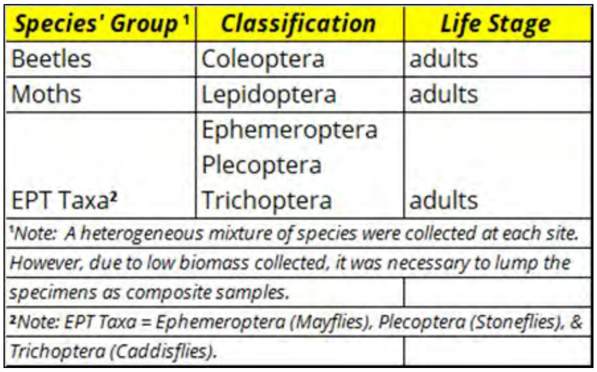
Table 3.1.1: Proposed Monitoring Plot Locations and Descriptions.

Plot I.D.	Latitude	Longitude	Site Description
BAT-01	36.00183	-84.24921	EFPC floodplain, NOAA site, south of Ole Ben Franklin Motors, City of Oak Ridge
BAT-02	36.00372	-84.28522	EFPC floodplain, Bruner site, City of Oak Ridge
BAT-03	35.96232	-84.35936	EFPC floodplain, EFPC 13.8 km site, south of Weigel's, City of Oak Ridge
BAT-04	35.96232	-84.35936	EFPC floodplain, Horizon Center researcher area, east of Imperium Drive
BAT-05	35.95592	-84.36986	EFPC floodplain, Horizon Center large sycamore, west of Novus Drive
BAT-06	35.94902	-84.37485	EFPC floodplain, Poplar Creek Road (north boundary greenway)
BAT-07	35.95335	-84.38336	EFPC floodplain, North Boundary Greenway (East Fork Road), wetlands
BAT-08	35.94945	-84.38683	EFPC floodplain, EFPC bridge (EFPC mouth) at Poplar Creek
NOR-01	36.23959	-84.10978	Norris Dam State Park (reference), bat colony at bath house (swimming pool area, park office)
CC-REF	36.21399	-84.05807	Clear Creek Reference stream (Norris Watershed)

3.1.6 Deviations from the Plan

Although bats did not occupy the bat houses and no guano samples were collected, 26 insect samples were collected and analyzed as surrogate data (i.e., bat prey items) in lieu of bat guano samples. Table 3.1.2 lists the insect taxonomic groups that were actually analyzed for Hg and MeHg content.

Table 3.1.2 Analyzed Taxonomic Groups



Species' Group[1]	*Classification*	*Life Stage*
Beetles	Coleoptera	adults
Moths	Lepidoptera	adults
EPT Taxa[2]	Ephemeroptera Plecoptera Trichoptera	adults

[1] Note: A heterogeneous mixture of species were collected at each site. However, due to low biomass collected, it was necessary to lump the specimens as composite samples.

[2] Note: EPT Taxa = Ephemeroptera (Mayflies), Plecoptera (Stoneflies), & Trichoptera (Caddisflies).

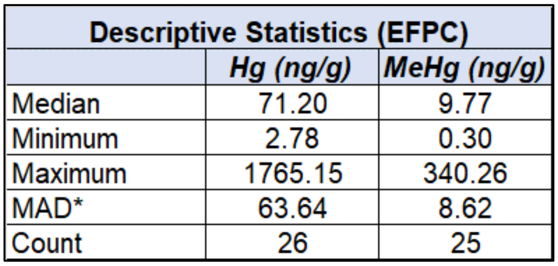
3.1.7 Results and Analysis

Hg and MeHg analyses were conducted on 26 insect samples that were collected with an attended black light trap at 8 EFPC sites and 1 reference site. The median Hg result = 71.20 ng/g and the median MeHg result = 9.77 ng/g for the combined EFPC samples. The median Hg result = 6.80 ng/g and the median MeHg result = 1.90 ng/g for the combined reference samples. Median values were used because arithmetic means sometimes may represent faulty data that did not follow a normal distribution (Reimann and Filzmoser, 1999).

The minimum and maximum EFPC Hg values = 2.78 ng/g and 1765.15 ng/g respectively; the minimum and maximum EFPC MeHg values = 0.30 ng/g and 10.08 ng/g respectively (Table 3.1.3). The minimum and maximum reference Hg values = 1.70 ng/g and 46.80 ng/g respectively; the minimum and maximum reference MeHg values = 0.00 ng/g and 2.20 ng/g respectively (Table 3.1.4).

Mean absolute deviation (MAD) was also calculated to determine a robust absolute measure of dispersion not affected by extreme outliers that can throw off statistical analysis based on means and standard deviations (Hamilton, 1994). Thus, the spread on the median for EFPC Hg = 71.20 +/- 63.64 ng/g and for EFPC MeHg = 9.77 +/- 8.62 ng/g.

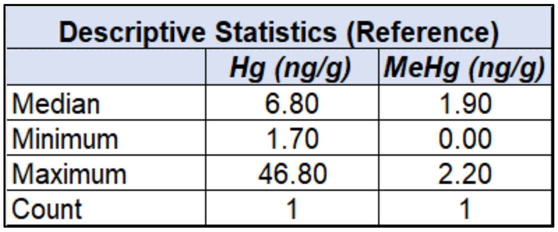
Table 3.1.3 EFPC Numbers



Descriptive Statistics (EFPC)		
	Hg (ng/g)	*MeHg (ng/g)*
Median	71.20	9.77
Minimum	2.78	0.30
Maximum	1765.15	340.26
MAD*	63.64	8.62
Count	26	25

*MAD = mean absolute deviation.

Table 3.1.4 Reference Numbers



Descriptive Statistics (Reference)		
	Hg (ng/g)	*MeHg (ng/g)*
Median	6.80	1.90
Minimum	1.70	0.00
Maximum	46.80	2.20
Count	1	1

Mercury data maps:

Figures 3.1.3 and 3.1.4 are maps of EFPC sampling plot locations and associated snapshots of biota Hg and MeHg analytical data. The maps further illustrate how the monitoring sites are distributed along the course of the EFPC floodplain from upstream to downstream at Oak Ridge, TN.

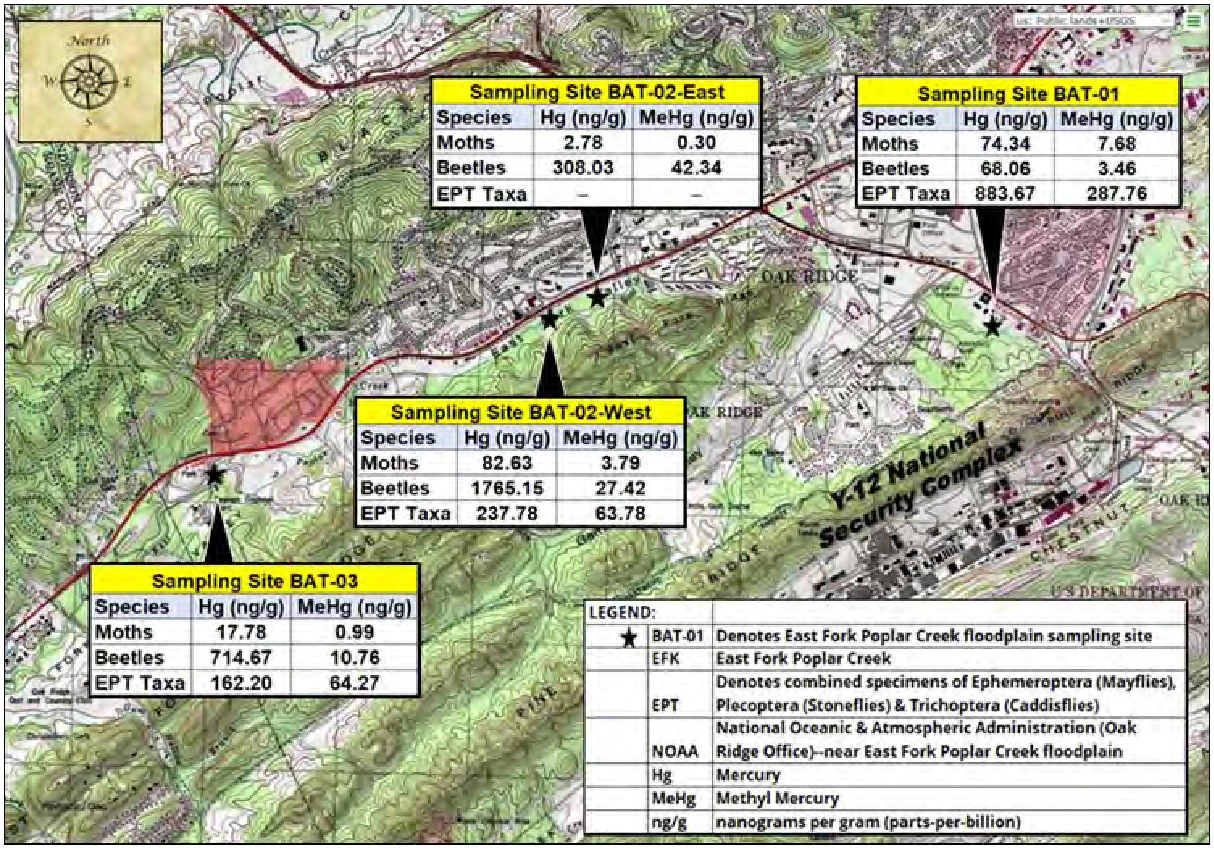
Mercury concentrations in insect taxa (beetles, EPT taxa) collected at the upstream sites (upper EFPC; Figure 3.1.3) were found to be generally higher in concentration than in insect taxa collected at the sites further downstream (lower EFPC; Figure 3.1.4). However, trends for insect MeHg results are less clear.

The MeHg results are relatively high for EPT taxa at station BAT-01 (287.76 ng/g), but then the EPT taxa levels drop to <80 ng/g until downstream stations BAT-05, BAT-06, and BAT-07 where MeHg concentrations range between 156.70-340.26 ng/g. Then the EPT taxa MeHg drops significantly at station BAT-08 (64.27 ng/g).

The highest beetle Hg concentrations were detected at upstream stations BAT-02-West (1765.15 ng/g) and at station BAT-03 (714.67 ng/g). Beetle MeHg was highest at the upstream station BAT-02-West (27.42 ng/g) and at the downstream station BAT-06 (15.51 ng/g).

Moth Hg and MeHg concentrations are all low (<82 ng/g). This is perhaps not too surprising given that moth adults do not feed except for some nectar consumption.

Figure 3.1.5 represents the Clear Creek reference site and its respective biota Hg and MeHg data. Clear Creek is located within the Norris, TN watershed, and is approximately 25 miles northeast of Oak Ridge. The data maps summarize the data spatially and are intended to be self-explanatory. Overall, the median EFPC Hg and MeHg = 71.20 ng/g and 9.77 ng/g respectively compared to the median reference Hg and MeHg = 6.80 ng/g and 1.90 ng/g respectively. Thus, Hg and MeHg is 10.5X greater and 5.1X greater respectively in the EFPC insects compared to the reference insects.



Sampling Site BAT-02-East

Species	Hg (ng/g)	MeHg (ng/g)
Moths	2.78	0.30
Beetles	308.03	42.34
EPT Taxa	–	–

Sampling Site BAT-01

Species	Hg (ng/g)	MeHg (ng/g)
Moths	74.34	7.68
Beetles	68.06	3.46
EPT Taxa	883.67	287.76

Sampling Site BAT-02-West

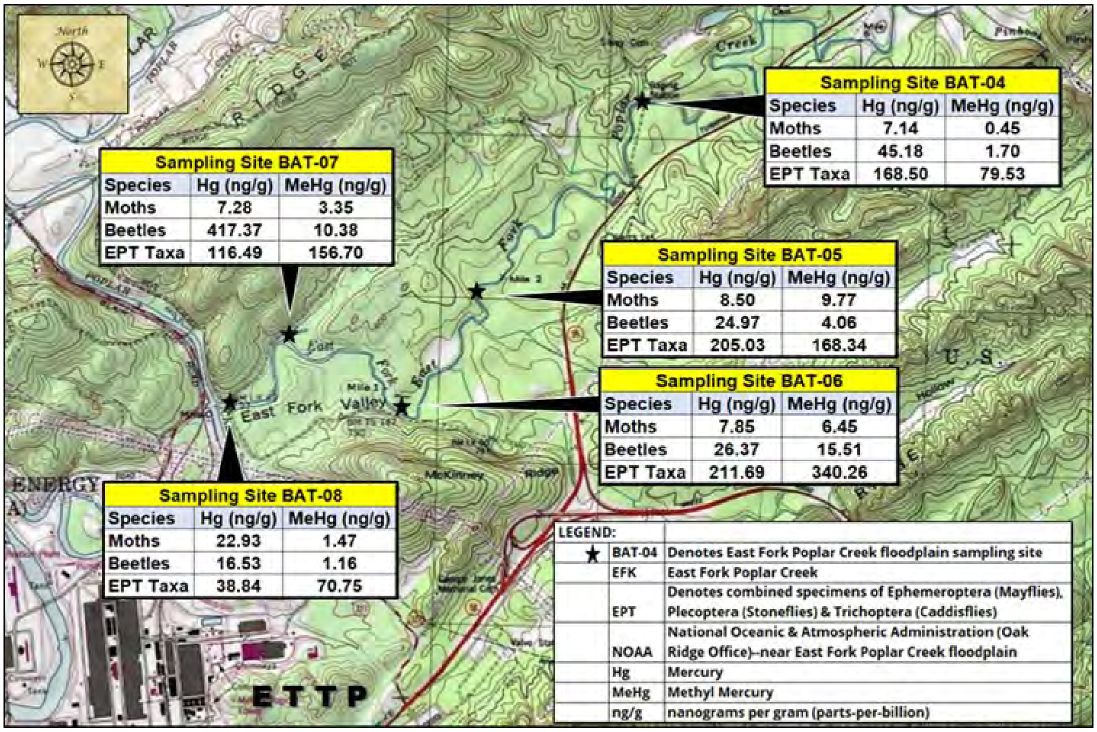
Species	Hg (ng/g)	MeHg (ng/g)
Moths	82.63	3.79
Beetles	1765.15	27.42
EPT Taxa	237.78	63.78

Sampling Site BAT-03

Species	Hg (ng/g)	MeHg (ng/g)
Moths	17.78	0.99
Beetles	714.67	10.76
EPT Taxa	162.20	64.27

LEGEND:		
★	BAT-01	Denotes East Fork Poplar Creek floodplain sampling site
	EFK	East Fork Poplar Creek
	EPT	Denotes combined specimens of Ephemeroptera (Mayflies), Plecoptera (Stoneflies) & Trichoptera (Caddisflies)
	NOAA	National Oceanic & Atmospheric Administration (Oak Ridge Office)--near East Fork Poplar Creek floodplain
	Hg	Mercury
	MeHg	Methyl Mercury
	ng/g	nanograms per gram (parts-per-billion)

Figure 3.1.3: Mercury data map for upper East Fork Poplar Creek biota results.



Sampling Site BAT-04

Species	Hg (ng/g)	MeHg (ng/g)
Moths	7.14	0.45
Beetles	45.18	1.70
EPT Taxa	168.50	79.53

Sampling Site BAT-07

Species	Hg (ng/g)	MeHg (ng/g)
Moths	7.28	3.35
Beetles	417.37	10.38
EPT Taxa	116.49	156.70

Sampling Site BAT-05

Species	Hg (ng/g)	MeHg (ng/g)
Moths	8.50	9.77
Beetles	24.97	4.06
EPT Taxa	205.03	168.34

Sampling Site BAT-06

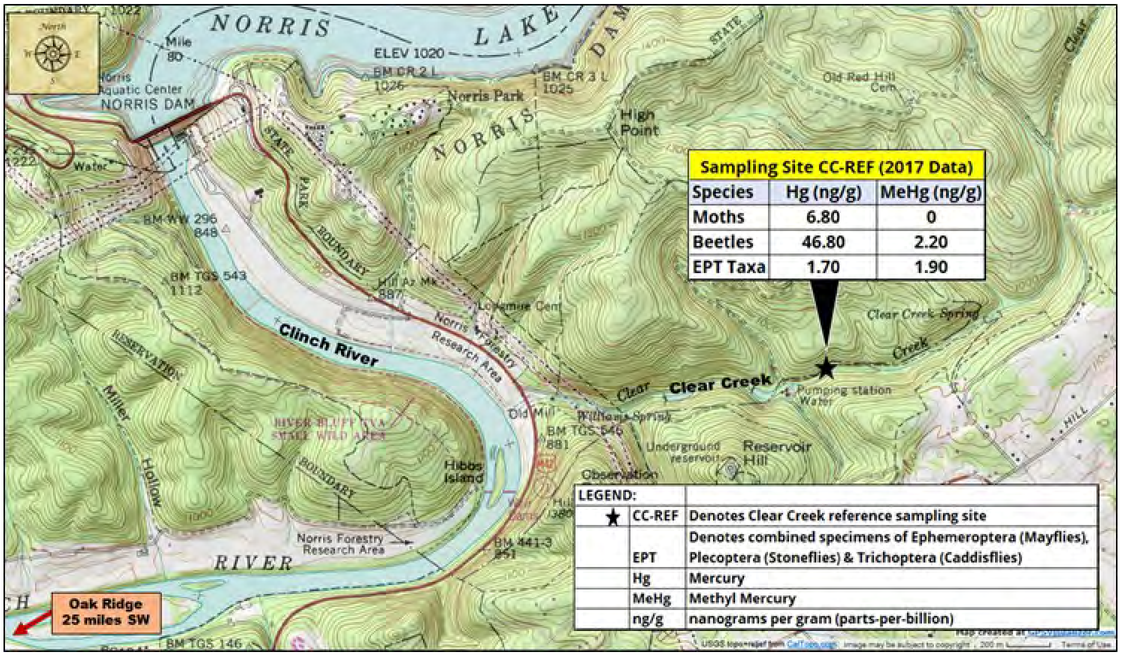
Species	Hg (ng/g)	MeHg (ng/g)
Moths	7.85	6.45
Beetles	26.37	15.51
EPT Taxa	211.69	340.26

Sampling Site BAT-08

Species	Hg (ng/g)	MeHg (ng/g)
Moths	22.93	1.47
Beetles	16.53	1.16
EPT Taxa	38.84	70.75

LEGEND:		
★	BAT-04	Denotes East Fork Poplar Creek floodplain sampling site
	EFK	East Fork Poplar Creek
	EPT	Denotes combined specimens of Ephemeroptera (Mayflies), Plecoptera (Stoneflies) & Trichoptera (Caddisflies)
	NOAA	National Oceanic & Atmospheric Administration (Oak Ridge Office)--near East Fork Poplar Creek floodplain
	Hg	Mercury
	MeHg	Methyl Mercury
	ng/g	nanograms per gram (parts-per-billion)

Figure 3.1.4: Mercury data map for lower East Fork Poplar Creek biota results.



Sampling Site CC-REF (2017 Data)

Species	Hg (ng/g)	MeHg (ng/g)
Moths	6.80	0
Beetles	46.80	2.20
EPT Taxa	1.70	1.90

LEGEND:		
★	CC-REF	Denotes Clear Creek reference sampling site
	EPT	Denotes combined specimens of Ephemeroptera (Mayflies), Plecoptera (Stoneflies) & Trichoptera (Caddisflies)
	Hg	Mercury
	MeHg	Methyl Mercury
	ng/g	nanograms per gram (parts-per-billion)

Figure 3.1.5: Mercury data map for the Clear Creek reference site biota results.

Figure 3.1.6 summarizes the EFPC insect Hg and MeHg data (units = ng/g). Methylmercury (MeHg) is of greatest concern because it is the most toxic and bioavailable form of Hg for uptake into organisms.

The Environmental Protection Agency's current recommended Clean Water Act section 304(a) water quality criterion for methylmercury is expressed as a fish tissue concentration threshold value of 0.3 parts per million methylmercury (= 300 parts per billion, or 300 ng/g; EPA, 2017).

Four EFPC insect Hg results and one MeHg result exceeded the 300 ng/g threshold limit. Note: *Though this is not a direct comparison (with fish tissue), it is the only standard available for comparison with the insect results at this time.*

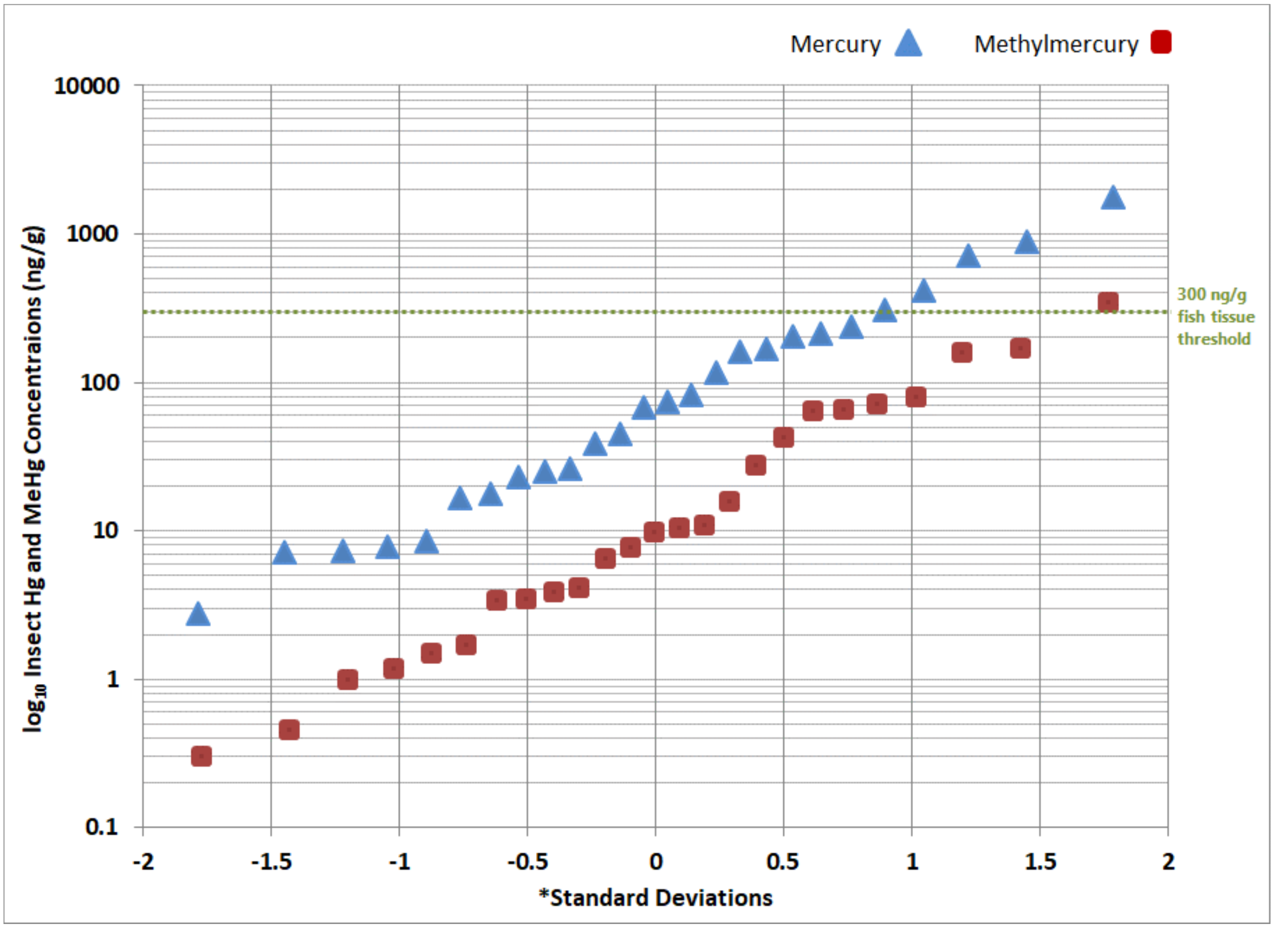


Figure 3.1.6: East Fork Poplar Creek insect Hg and MeHg data distribution.

*Standard deviation is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A small standard deviation means that the values in a statistical data set are close to the mean of the data set, on average, and a large standard deviation means that the values in the data set are farther away from the mean, on average (Smith, 1988).

Upstream East Fork Poplar Creek Insects Compared to Downstream East Fork Poplar Creek Insects:

Beetles (Coleoptera): Figure 3.1.7 shows the beetle Hg/MeHg data for the upstream-to-downstream EFPC sites and also compared to the Clear Creek reference beetle data. Beetles collected from EFPC accumulated the highest Hg concentrations when compared to the other taxonomic groups. In EFPC, beetle Hg ranged from 16.53 ng/g to 1765.15 ng/g (mean beetle Hg= 376.26 ng/g). However, beetle MeHg was several orders of magnitude lower than beetle Hg ranging from only 1.16 ng/g to 42.34 ng/g (mean beetle MeHg= 12.98 ng/g). The Clear Creek reference site yielded beetle Hg concentrations = 46.8 ng/g and beetle MeHg = 2.20 ng/g.

Evaluating the upstream to downstream data, beetle Hg and MeHg concentrations generally decrease downstream with distance from the industrial source of Hg contamination. East Fork Poplar Creek mean beetle Hg concentrations (Hg= 376.26 ng/g) are 8.04X greater compared to the reference site (Hg= 46.8 ng/g). East Fork Poplar Creek mean beetle MeHg concentrations (MeHg= 12.98) are 5.90X greater compared to the reference site (MeHg= 2.20 ng/g).

In summary, between 1.51%-58.80% of the EFPC beetle Hg is present as beetle MeHg (mean = 12.24%), and for the reference site, only 4.70% of the total beetle Hg is present as MeHg.

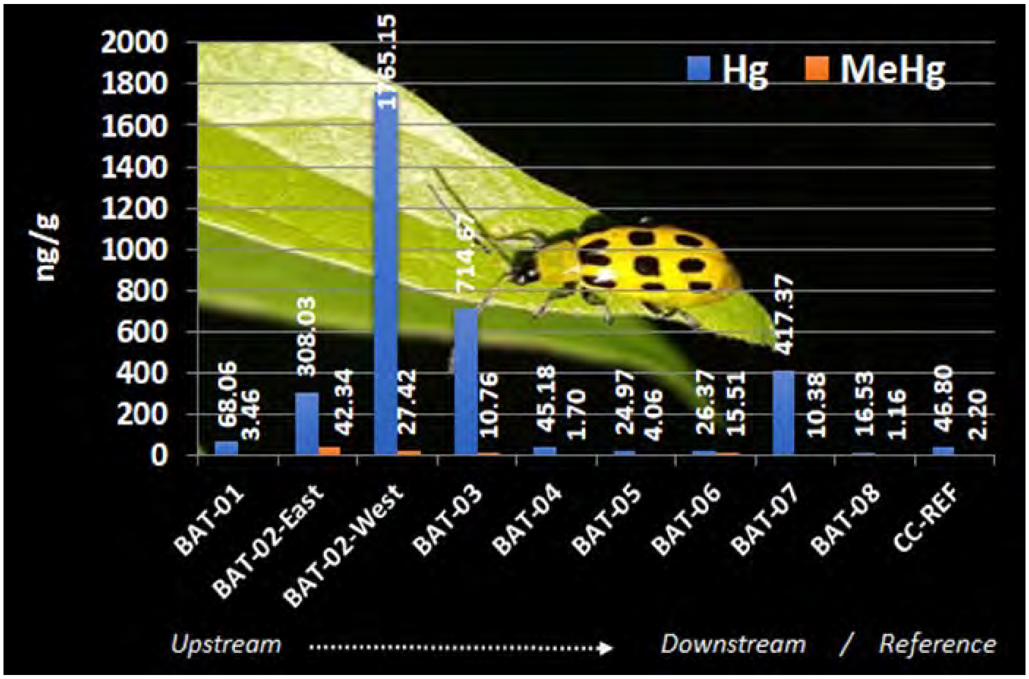


Figure 3.1.7

Moth (Lepidoptera): Figure 3.1.8 shows the moth Hg/MeHg data for the upstream-to-downstream EFPC sites and also compared to the Clear Creek reference moth data. In EFPC, moth Hg ranged from 2.78 ng/g to 82.63 ng/g (mean moth Hg= 25.69 ng/g). However, moth MeHg was several orders of magnitude lower than moth Hg ranging from only 0.30 ng/g to 9.77 ng/g (mean moth MeHg= 3.78 ng/g). The Clear Creek reference site yielded moth Hg concentrations = 6.80 ng/g and moth MeHg = 0.0 ng/g.

Evaluating the upstream to downstream data, moth Hg and MeHg concentrations generally decrease downstream with distance from the industrial source of Hg contamination. East Fork Poplar Creek mean moth Hg concentrations (Hg= 25.69 ng/g) are 3.77X greater compared to the reference site (Hg= 6.80 ng/g). East Fork Poplar Creek mean moth MeHg concentrations (MeHg= 12.98) are 5.90X greater compared to the reference site (MeHg= 2.20 ng/g).

In summation, between 4.58-100% of the EFPC moth Hg is present as moth MeHg (mean = 30.21%), and for the reference site, 0.0% of the total Hg is present as MeHg.

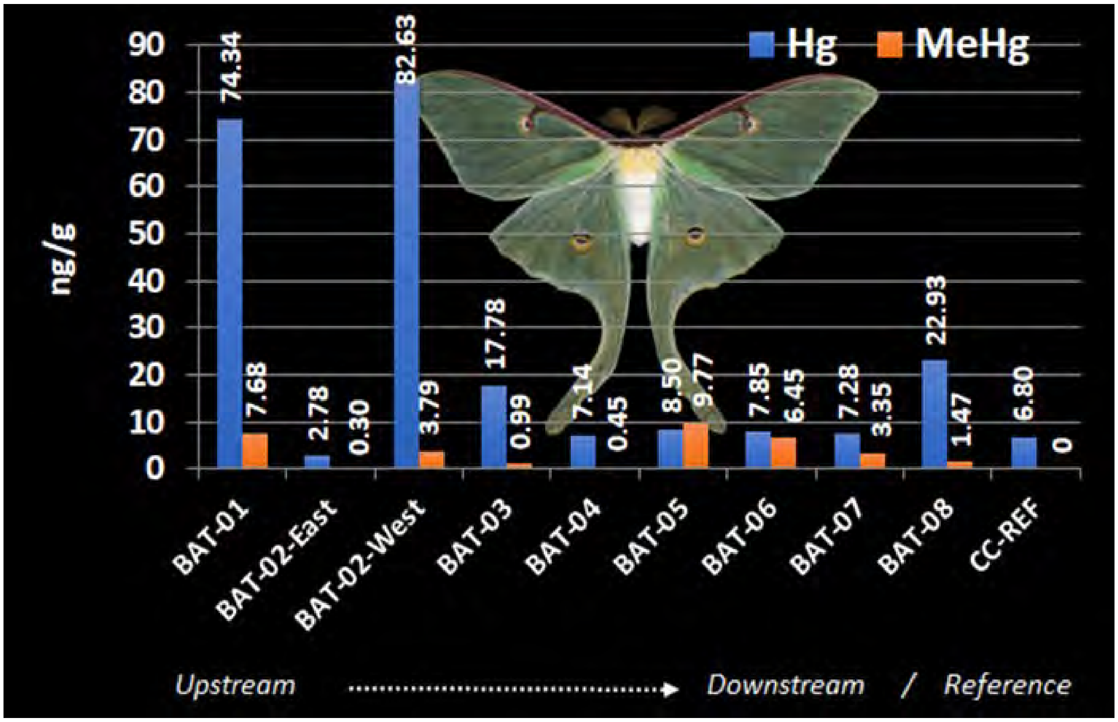


Figure 3.1.8

EPT Taxa (Ephemeroptera/Plecoptera/Trichoptera): Figure 3.1.9 shows the EPT Taxa Hg/MeHg data for the upstream-to-downstream EFPC sites and also compared to the Clear Creek reference EPT Taxa data. In EFPC, EPT Taxa Hg ranged from 38.84 ng/g to 883.67 ng/g (mean EPT Taxa Hg= 253.02 ng/g). However, EPT Taxa MeHg was several orders of magnitude lower than EPT Taxa Hg ranging from only 63.78 ng/g to 340.26 ng/g (mean EPT Taxa MeHg= 153.92 ng/g). The Clear Creek reference site yielded EPT Taxa Hg concentrations = 1.70 ng/g and EPT Taxa MeHg = 1.90 ng/g.

Evaluating the upstream to downstream data, EPT Taxa Hg and MeHg concentrations generally decrease downstream with distance from the industrial source of Hg contamination. East Fork Poplar Creek mean EPT Taxa Hg concentrations (Hg= 253.02 ng/g) are 148.84X greater compared to the reference site (Hg= 1.70 ng/g). East Fork Poplar Creek mean EPT Taxa MeHg concentrations (MeHg= 153.92 ng/g) are 81.01X greater compared to the reference site (MeHg= 1.90 ng/g).

In summary, between 26.82-100% of the EFPC EPT Taxa Hg is present as EPT Taxa MeHg (mean = 35.02%), and for the reference site, 100% of the total Hg is present as MeHg.

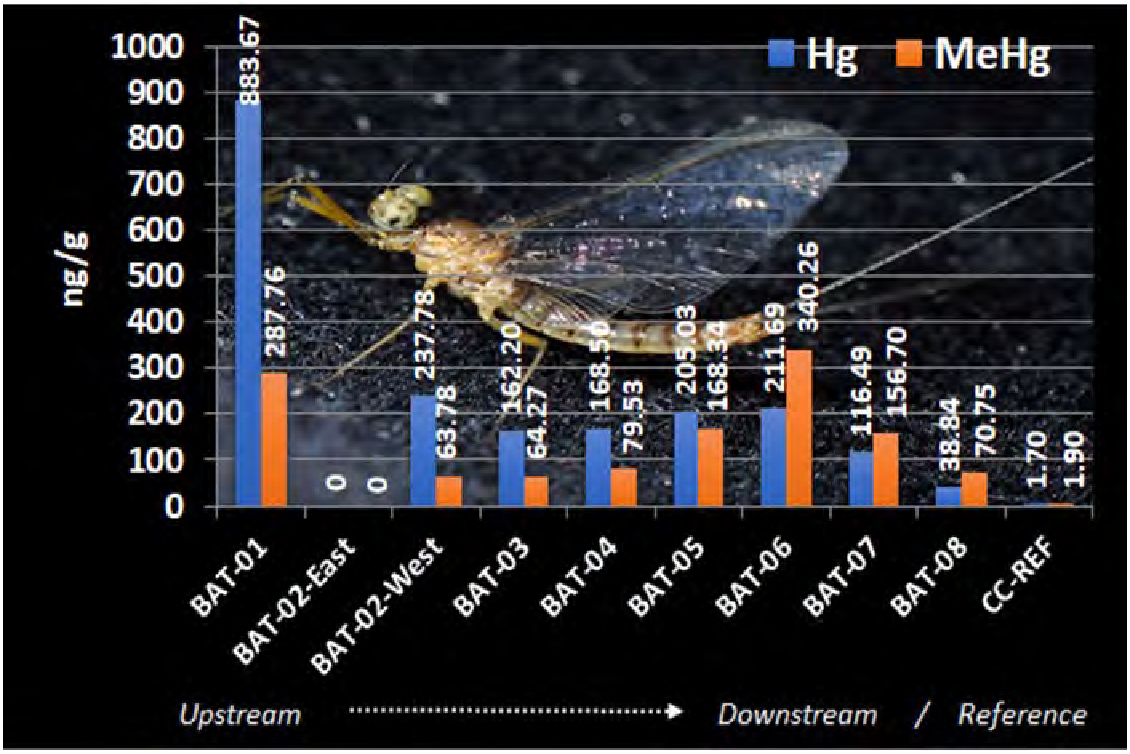


Figure 3.1.9

3.1.8 Conclusions

- For the combined EFPC samples, the mean Hg result = 216.99 ng/g and the mean MeHg result = 53.17 ng/g. For the combined reference samples, the mean Hg result = 18.43 ng/g and the mean MeHg result = 1.33 ng/g.

- Beetles collected from EFPC accumulated the highest Hg concentrations when compared to the other taxonomic groups. In EFPC, beetle Hg ranged from 16.53 ng/g to 1765.15 ng/g (mean beetle Hg= 376.26 ng/g). However, beetle MeHg was several orders of magnitude lower than beetle Hg ranging from only 1.16 ng/g to 42.34 ng/g (mean beetle MeHg= 12.98 ng/g). Some of their major foods for bats include agricultural pests such as cucumber beetles (family Chrysomelidae) and May beetles or June bugs (family Scarabaeida). Whitaker (1972) identified food items in the stomachs of 184 Big brown bats collected over a 9-year period and discovered a predominance of beetles in the diet (43% by volume).

- Moth Hg ranged from 2.78 ng/g to 82.63 ng/g (mean moth Hg= 25.69 ng/g) in EFPC. However, moth MeHg in EFPC was several orders of magnitude lower than moth Hg ranging from only 0.30 ng/g to 9.77 ng/g (mean moth MeHg= 3.78 ng/g). The Clear Creek reference site yielded moth Hg concentrations = 6.80 ng/g and moth MeHg = 0.0 ng/g. Mexican free-tailed bats (which occur in Tennessee) were determined to consume at least 20 species of migratory moths and at least 44 species of agricultural moth pests; approximately 77% of their diet is made up of moths (Krauel et al., 2018).

- The EPT Taxa Hg ranged from 38.84 ng/g to 883.67 ng/g (mean EPT Taxa Hg= 253.02 ng/g) in EFPC. However, EPT Taxa MeHg was several orders of magnitude lower than EPT Taxa Hg ranging from only 63.78 ng/g to 340.26 ng/g (mean EPT Taxa MeHg= 153.92 ng/g). The Clear Creek reference site yielded EPT Taxa Hg concentrations = 1.70 ng/g and EPT Taxa MeHg = 1.90 ng/g. Bats such as the Big brown bat are insectivorous, eating many kinds of insects including beetles, flies, stone flies, mayflies, true bugs, net-winged insects, scorpionflies, and caddisflies (Davis 1994). Clare et al. (2011) reported that the largest proportion of prey consumed by Little brown bats (~32%) were identified as species of the mass emerging Ephemeroptera (mayfly) genus *Caenis*. Both the Big brown and Little brown bats are common in Tennessee.

- Four beetle analytical results exceeded the EPA fish tissue Hg threshold of 0.3 ppm (300 ng/g). Though this is not a direct comparison, it is the only standard available for comparison with the insect results at this time. (See Figures 3.1.3 & 3.1.4 for site locations as mentioned below):

    1) Site Bat-02-East: 0.308 ppm Hg

    2) Site Bat-02-West: 1.765 ppm Hg

    3) Site Bat-03: 0.715 ppm Hg

4) Site Bat-07: 0.417 ppm Hg

- Two EPT Taxa analytical results exceeded the EPA fish tissue Hg threshold of 0.3 ppm (300 ng/g). Though this is not a direct comparison, it is the only standard available for comparison with the insect results at this time. (See Figures 3.1.3 & 3.1.4 for site locations as mentioned below):

  1) Site Bat-01: 0.884 ppm Hg

  2) Site Bat-06: 0.340 ppm MeHg

- Consulting the OREIS database, it does not appear that DOE collects samples of ORR insects for mercury analysis; at least not on any sort of routine basis which we could compare with our TDEC data.

- Hg and MeHg concentrations in EPT taxa collected from EFPC were 148X and 81X greater respectively compared to Hg and MeHg concentrations in reference site EPT taxa.

- Hg and MeHg concentrations in beetles collected from EFPC were 8X and 5.9X greater respectively compared to Hg and MeHg concentrations in reference site beetles.

- Hg and MeHg concentrations in moths collected from EFPC were 3.7X and 5.9X greater respectively compared to Hg and MeHg concentrations in reference site moths.

- Given we could not collect guano samples for Hg/MeHg analysis, we can only speculate that bats consuming EPT taxa, beetles and moths at EFPC floodplain could be expected to bioaccumulate mercury at considerably higher concentrations compared to bats consuming EPT taxa, beetles and moths at the reference site.

3.1.9 Recommendations

- It is suggested that this project be consolidated with the Mercury Uptake in Biota Project. This will be the final Bat Project report as a stand-alone project.

- This measures impacts to local bat population, other fauna, and to endangered bat species it is recommended that this study should continue.

3.1.10 References

Bell, A.H. and B.C. Scudder. (2007). Mercury accumulation in periphyton of eight river ecosystems: Journal of the American Water Resources Association 43:957-968.

Belwood, J. and M. Fenton, M. (1976). Variation in the diet of *Myotis lucifugus* (Chiroptera: Vespertilionidae). Canadian Journal of Zoology 54:1674-1678.

Bernard, R.F. and G.F. McCracken. (2017). Winter behavior of bats and the progression of white nose syndrome in the southeastern United States. Ecology and Evolution 7:1487-1496.

Brooks, S., V. Eller, J. Dickson, J. Earles, K. Lowe, T. Mehlhorn, T. Olsen, C. DeRolph, D. Watson, D. Phillips, & M. Peterson. (2017). Mercury content of sediments in East Fork Poplar Creek: current assessment and past trends. ORNL/TM-2016/578. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN.

Burton, G.V., R.J. Alley, G.L. Rasmussen, P. Orton, V. Cox, P. Jones, and D. Graff. (1977). Mercury and behavior in wild mouse populations. Environmental Research 14:30-34.

CCME. (2016). Guidance manual for environmental characterization in support of environmental and human health risk assessment. SOP No. 14: Terrestrial invertebrate sampling. / SOP No. 15: Benthic invertebrate collection and processing. Volume 3: Suggested operating procedures. PN 1555. Canadian Council of Ministers of the Environment (CCME). Winnipeg, Manitoba.

Clare, E.L., B.R. Barber, B.W. Sweeney, P.D. Hebert, and M.B. Fenton. (2011). Eating local: influences of habitat on the diet of Little brown bat (*Myotis lucifugus*). Molecular Ecology 20:1772-1780.

Clark, D.R. Jr, R.K. LaVal and M.D. Tuttle. (1982). Estimating pesticide burdens of bats from guano analyses. Bulletin of Environmental Contamination and Toxicology 29:214–220.

Clark, D.R. Jr, A.U. Moreno-Valdez and M.A. Mora. (1995). Organochlorine residues in bat guano from nine Mexican caves (in 1991). Ecotoxicology 4:258:265.

Davis, W.B. (1994). The Big Brown Bat: *The Mammals of Texas - Online Edition*. Texas Tech University. Retrieved 10 September 2019.

Ellison, L.E., E.W. Valdez, P.M. Cryan, T.J. O'Shea and M.A. Bogan. (2013). Standard operating procedure for the study of bats in the field. FORT IACUC SOP#: 2013-01 (Revision 2). U.S. Department of the Interior, U.S. Geological Survey. Fort Collins Science Center, Colorado.

Evers, D.C., N. M. Burgess, L. Champoux, B. Hoskins, A. Major, W.M. Goodale, R.J. Taylor, R. Poppenga and T. Daigle. (2005). Patterns and interpretation of mercury exposure in freshwater avian communities in northeastern North America. Ecotoxicology 14:193-221.

Fry, R. and Waring, P. (1996). A guide to moth traps and their use. *The Amateur Entomologist, Volume 24***.**

Fry, R. and P. Waring. (2001). A guide to moth traps and their use. Second edition. The Amateur Entomologists' Society, Orpington, UK. 68 pp.

Hamilton, J. D. (1994). Time Series Analysis. Princeton University Press, Princeton, NJ. 799 pp.

Hickey, M.B.C., M.B. Fenton, K.C. MacDonald and C. Soulliere. (2001). Trace elements in the fur of bats (Chiroptera: Vespertilionidae) from Ontario and Quebec, Canada. Bulletin of the Environmental Contamination and Toxicology 66:669–706.

Krauel, J.J., V.A. Brown, J.K. Westbrook, and G.F. McCracken. (2018). Predator–prey interaction reveals local effects of high-altitude insect migration. Oecologia 186:49-58.

Mickleburgh, S.P., A.M. Hutson and P.A. Racey. (2002). A review of the global conservation status of bats. Oryx 36:18-34.

Murphy, G.W. (2004). Uptake of mercury and relationship to food habits of selected fish species in the Shenandoah River Basin, Virginia. Virginia Polytechnic Institute and State University, Blacksburg, VA.

Nam, D.-H., D. Yates, P. Ardapple, D. C. Evers, J. Schmerfeld, and N. Basu. (2012). Elevated mercury exposure and neurochemical alterations in little brown bats (*Myotis lucifugus*) from a site with historical mercury contamination. Ecotoxicology 21:1094–1101.

Osborne, C. E, D.C. Evers, M. Duron, N. Schoch, D. Yates, D. Buck, O.P. Lane and J. Franklin.

(2011). Mercury contamination within terrestrial ecosystems in New England and Mid-Atlantic States: Profiles of soil, invertebrates, songbirds, and bats. Report BRI 2011-09. Submitted to The Nature Conservancy – Eastern New York Chapter. Biodiversity Research Institute, Gorham, Maine.

O'Shea, T.J., A.L. Everette and L.E. Ellison. (2001). Cyclodiene insecticide, DDE, DDT, arsenic and mercury contamination of big brown bats (*Eptesicus fuscus*) foraging at a Colorado superfund site. Archives of Environmental Contamination and Toxicology 40:112-120.

Patrick, B. (2016). Invertebrates: light trapping version 1.0. DOCCM-286730- Invertebrates. Department of Conservation, Research & Development Group; Christchurch, NZ. 17 pp.

Reimann, C. and P. Filzmoser. (1999). Normal and lognormal data distribution in geochemistry: death of a myth; consequences for the statistical treatment of geochemical and environmental data. Environmental Geology 39:1001-1014.

Smith, G. (1988). Statistical reasoning, 2nd edition. Allyn and Bacon, Inc., Boston, MA. 824 pp.

Southwood, T.R.E., & P.A. Henderson. (2000). Light and other visual traps (p. 283-297). In Ecological methods. Southwood, T.R.E. and P.A. Henderson (eds.). Blackwell Science Ltd., Oxford. 575 pp.

TBWG. (2018). Progress of White Nose Disease in Tennessee (Map). Tennessee Bat Working Group website. (Accessed February 11, 2018).

TDEC. (2015). Procedures for Shipping Samples to the State Lab in Nashville, SOP No. 101, 2015. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, TN.

TDEC. (2017). Tennessee Department Office (DoR OR) 2017 Health and Safety Plan Including Related Policies, January 2017. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, TN. of Environment and Conservation Division of Remediation, Oak Ridge

U.S. EPA. (1998). Method 1630. Methyl mercury in water by distillation, aqueous ethylation, purge and trap, and cold vapor atomic fluorescence spectrometry. U.S.

Environmental Protection Agency. Office of Science & Technology, Engineering & Analytical Division. Washington, DC.

U.S. EPA. (2002). Method 1631, Revision E. Mercury in water by oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry. U.S. Environmental Protection Agency. EPA-821-R-02-019. Office of Water, Washington, DC.

U.S. EPA. (2017) Water quality standards handbook. Chapter 3: Water quality criteria. EPA 823 B17 001. US Environmental Protection Agency, Office of Water.

Whitaker, J. O., Jr. and W. J. Hamilton, Jr. (1998). Mammals of the eastern United States. Cornell University Press, Ithaca, New York. 583 pp.

Wiener, J.G., D.P. Krabbenhoft, G.H. Heinz, & A.M. Scheuhammer. (2003). Ecotoxicology of mercury. In D.J. Hoffman, B.A. Rattner, G.A. Burton, J. Cairns (Eds.), Handbook of Ecotoxicology, Lewis Publishers, Boca Raton, FL. pp. 409-463.

Wobeser, G., N.O. Nielsen NO and B. Schiefer. (1976). Mercury and mink. Part II. Experimental methyl mercury intoxication. Canadian Journal of Comparative Medicine 40:34–45.

Yates, D.E., D.T. Mayack, K. Munney, D.C. Evers, A. Major, T. Kaur and R.J. Taylor. (2005). Mercury levels in mink (*Mustela vison*) and river otter (*Lontra canadensis*) from northeastern North America. Ecotoxicology 14:263–274.

Yates, D.E., E.M. Adams, S.E. Angelo, D.C. Evers, J. Schmerfeld, M.S. Moore, T.H. Kunz, T. Divoll, S.T. Edmunds, C. Perkins. R. Taylor and N.J. O’Driscoll. (2014). Mercury in bats from northeast United States. Ecotoxicology 23:45-55.

3.2 MERCURY UPTAKE IN BIOTA (WOOD DUCKS, TREE SWALLOWS AND THEIR PREY ITEMS)

3.2.1 Background

During the 1950’s and early 1960’s processes and practices of the nuclear weapons’ program at the Y-12 National Security Complex (Y-12 NSC; historically known as Y-12 Plant) led to the release of large amounts of mercury (Hg) into the local environment (Brooks et al., 2017). In the East Fork Poplar Creek (EFPC) 100-year floodplain, mercury is extensively dispersed as black band deposits in a wide range of concentrations in the top three meters of the flood plain soil, and sediment (Pant, Allen, & Tansel, 2010).

Although the 1995 Lower EFPC Record of Decision (EFPC ROD; Jacobs, 1995) required the removal of soils with Hg concentrations >400 ppm at four downstream EFPC floodplain locations (1996-97), contaminated soils remain in the floodplain with Hg concentrations ranging from 100-400 ppm (Han et al., 2012). The EFPC ROD specifies that the removal actions will be protective of human health and the environment as well as plant and animal populations (Jacobs, 1995). Mercury concentrations in EFPC floodplain soils, prior to remediation, were considered a potential threat to biota by Hg exposure through the EFPC food chain (i.e., the transfer from aquatic to terrestrial biota via prey/predator relationships; SAIC, 1995).

Mercury, in streams and wetlands, becomes extensively bound to sediments, undergoes methylation and is transformed into toxic methylmercury (MeHg) in conjunction with the activity of microorganisms (Kalisinska, Kosik-Bogacka, Lisowski, Lanocha, & Jackowski, 2013). Methylmercury is particularly bioavailable to wildlife (and humans) and, if ingested, may cause serious neurological, reproductive, and other physical damage (Standish, 2016). In 1995, there were 17 jurisdictional wetlands in EFPC where wetland animals may continue to accumulate mercury (Jacobs, 1995).

Methylmercury biomagnifies through food chains in higher-level organisms, such as songbirds and ducks, acquiring increasingly larger body burdens of MeHg through consumption of lower trophic-level prey items such as small invertebrates, benthic larval-stage biota, terrestrial and semi-aquatic spiders, and emergent flying insects (Scheuhammer, Meyer, Sandheinrich, & Murray et al., 2007). For example, tree swallows (TS) eat emergent adult insects (with benthic larval stages) such as dragonflies, damselflies, stoneflies, flies, mayflies, and caddisflies. Tree swallows consume wasps, beetles, butterflies, moths, spiders and mollusks (Robertson, Stutchbury, & Cohen, 2011). Wood ducks (WD) forage on the water (dabbling) and on land. They consume spiders, beetles, caterpillars, isopods, crayfish, snails, grains, seeds, and acorns (Hepp & Bellrose, 1995).

The EFPC ROD calls for appropriate monitoring of EFPC floodplain soils, sediments, surface water, and associated biota (Jacobs, 1995). Previous ecological investigations and post-remediation monitoring of EFPC included Hg and MeHg analysis of fish, earthworms, starlings, herons, spiders, benthic macroinvertebrates, small mammals, and other biota (SAIC, 1996; Standish, 2016). For example, mean Hg concentrations were significantly greater in feathers and egg tissue of herons collected on the ORR in comparison with those collected off the ORR (Jacobs, 1995). During a 5-year, post-remediation, ecological assessment of EFPC biota, very high concentrations of bioavailable MeHg were discovered in EFPC floodplain spiders (Mathews, Smith, Peterson, & Roy, 2011). Spiders are preyed upon by some songbirds and waterfowl.

Decreases in reproductive success of 35–50% have been observed in birds with high dietary methylmercury uptake (USDI, 1998). Mercury concentrations, found in eggs and feathers, are good indicators of Hg risk to avian reproduction (Furness, Muirhead, & Woodburn, 1986; Wolfe, Schwarzbach, & Sulaiman, 1998).

3.2.2 Problem Statements

Nearly 100% of the Hg transferred to eggs is in the form of MeHg with the majority (about 85–95%) deposited into the albumen (i.e., egg whites) (Wiener, Krabbenhoft, Heinz, & Scheuhammer, 2003). In some bird species, MeHg levels of ≥1.5 ppm in eggs are associated with decreased egg weight, poor hatchability, and low chick survival (Burger & Gochfeld, 1997). Mercury levels in bird feathers from 5.0≥40 ppm are associated with adverse reproductive effects and decreased nesting success (Burger & Gochfeld, 1997).

Adults of macroinvertebrates that emerge from contaminated aqueous larval stages are eaten by terrestrial insectivores such as songbirds, waterfowl, and spiders: creating a pathway of MeHg transfer and accumulation between biota in aquatic environments to those in terrestrial habitats. It is predicted that MeHg and Hg concentrations in biota samples may likely be greater at Hg-impacted EFPC plots than at non-impacted reference plots.

The ratio of feather-Hg compared to blood-Hg in bald eagles (feather:blood = 6:1) predicts Hg in their blood at time of molting (Weech, Scheuhammer, & Elliott, 2006). The ratio of feather-Hg compared to blood-Hg in tree swallows (feather:blood = 5.8:1) predicts Hg in their blood at time of molting (Brasso & Cristol, 2008). These ratios provide surrogate ratios (wood duck feather samples: predict internal blood-Hg concentrations). In the event that no tree swallows occupy the nest houses, then Carolina wrens will be the preferred songbird species.

3.2.3 Goals

The goals of the Mercury Uptake in Biota Project are stated below:

- Determine the concentrations of Hg and MeHg for the following biota samples collected from impacted EFPC floodplain monitoring plots and non-impacted reference plots: (1) eggs and feathers from Wood Duck (WD), (2) eggs and feathers from Tree Swallows (TS), (3) adult flying insects, (4) benthic larvae, and (5) spiders.
- Investigate the potential MeHg-impact to duck and bird reproduction by closely monitoring the nest houses to determine egg clutch size and determine eventual

hatching success (i.e., chick survival rate).

- Examine additional targeted species for Hg and MeHg uptake collected from EFPC floodplain and reference sites: crayfish, salamanders, and small mammals.

3.2.4 Scope

The purpose of this project is to investigate Hg and MeHg concentrations in WD and TS (i.e., in feathers and eggs) and in their associated prey items. Sampling will be conducted at various locations in the impacted EFPC area as well as at some non-impacted reference monitoring locations.

Confirm nest house occupancy; then collect egg and nest-feathers as environmental samples for Hg and MeHg analyses.

Determine the levels of Hg and MeHg residues in components (albumen or whites, yolk, and shell) of wood duck eggs.

Examine if within-clutch Hg concentrations vary by egg-laying sequence (egg-laying order).

Collect flying insect samples (beetles, other taxa) with Lindgren funnel traps installed at each site.

Collect additional flying insect samples (beetles, moths, caddisflies, mayflies, and stoneflies with BioQuip black light (ultraviolet, UV) traps.

Collect (with dip-nets) benthic larvae samples (caddisflies, mayflies, dragonflies).

Retrieve spider specimens from the riparian shoreline with aquarium nets and 12-inch forceps.

Collect small mammals for mercury analysis with Sherman traps.

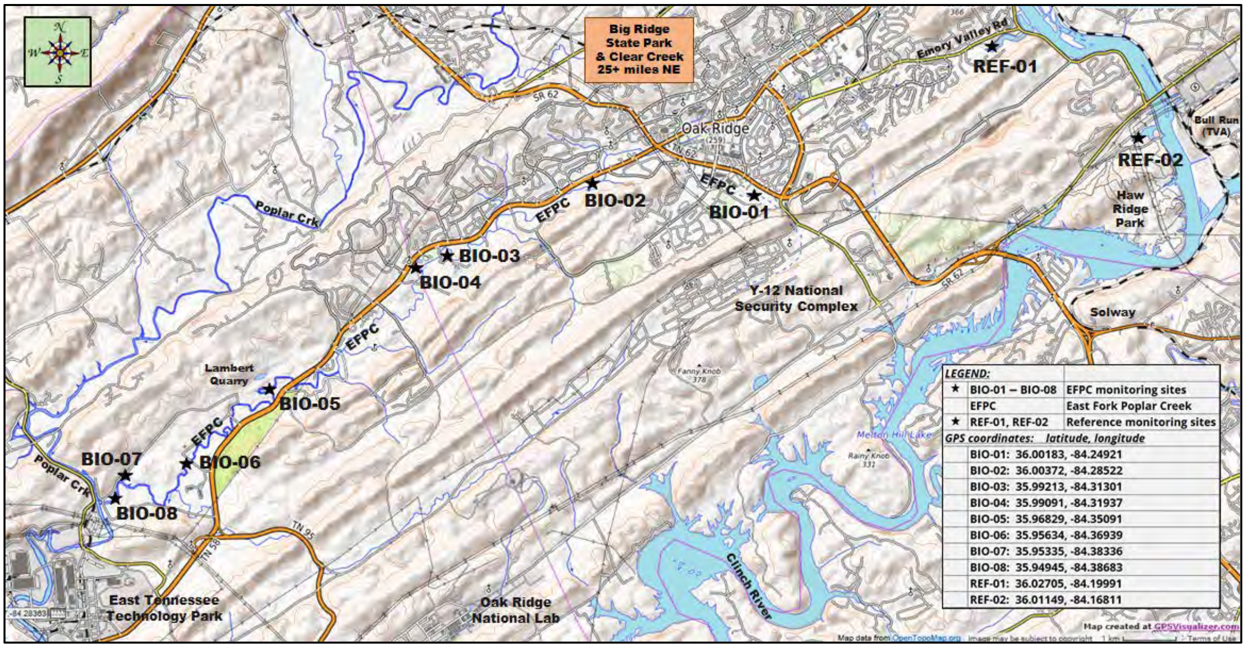
Collect salamanders using drift fence/pit fall traps.

Table 3.2.1: Analytes for Biota Analysis

Monitoring/sampling sites	Analytes	Rationale
All sites (EFPC & references)	mercury (Hg) methylmercury (MeHg) (reported on a wet weight basis)	Investigate Hg & MeHg uptake in EFPC biota compared to reference biota

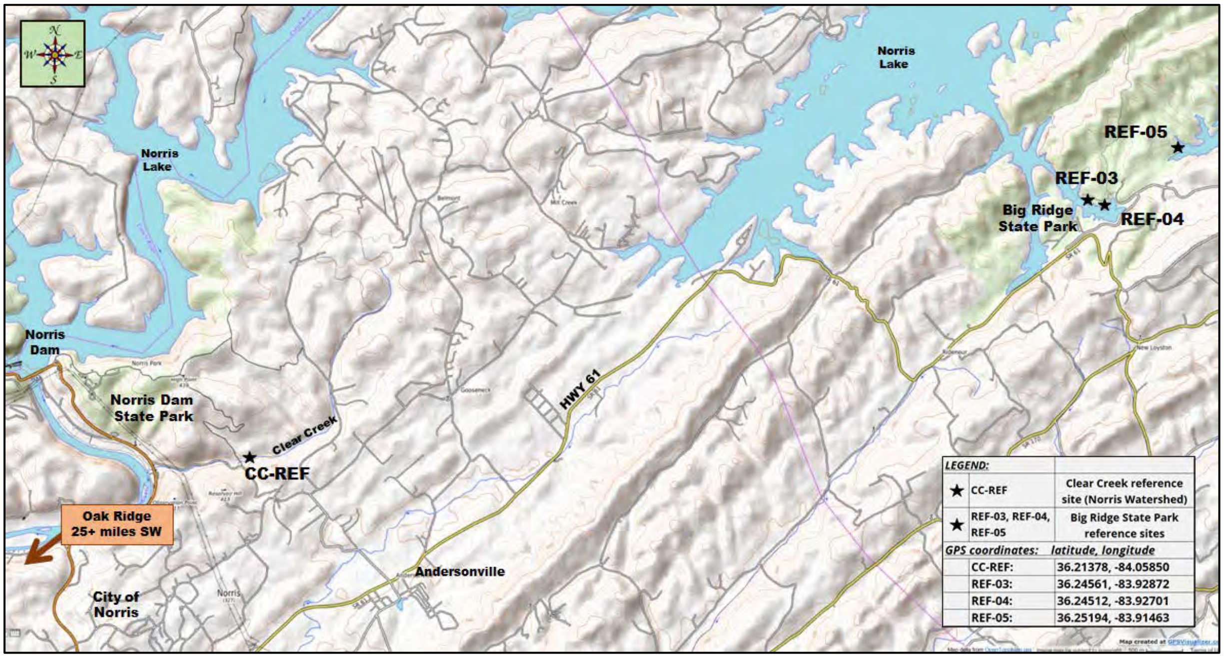
3.2.5 Methods, Materials, Metrics

Biota samples were collected at eight Hg-impacted plots (BIO-01 through BIO-08). Six non-impacted reference sites were also sampled, including local reference sites designated as REF-01 and REF-02; Big Ridge State Park reference sites, designated as REF-03, REF-04, and REF-05; and Clear Creek-Reference site in Norris Watershed (Figures 3.2.1 and 3.2.2, Table 3.2.2). If incidentally collected, species that are state or federal listed as greatest conservation need (GCN), threatened, endangered, or deemed in need of management will not be sampled (unless specified otherwise by conditions of the scientific sampling permit). If listed mammal or avian species were to be trapped, then the specimen(s) will be released unharmed at the point-of-capture. State or federal listed species (if encountered) will be reported to Tennessee Wildlife Resources Agency (TWRA) and US Fish and Wildlife Service (USFWS) within five working days of their being observed. Application requests have been submitted for required state and federal collection permits. All field and laboratory work will follow the safety guidelines per the TDEC DoR-OR 2017 *Health and Safety Plan* (TDEC, 2017).



LEGEND:		
★	BIO-01 – BIO-08	EFPC monitoring sites
	EFPC	East Fork Poplar Creek
★	REF-01, REF-02	Reference monitoring sites
GPS coordinates:	*latitude, longitude*	
	BIO-01: 36.00183, -84.24921	
	BIO-02: 36.00372, -84.28522	
	BIO-03: 35.99213, -84.31301	
	BIO-04: 35.99091, -84.31937	
	BIO-05: 35.96829, -84.35091	
	BIO-06: 35.95634, -84.36939	
	BIO-07: 35.95335, -84.38336	
	BIO-08: 35.94945, -84.38683	
	REF-01: 36.02705, -84.19991	
	REF-02: 36.01149, -84.16811	

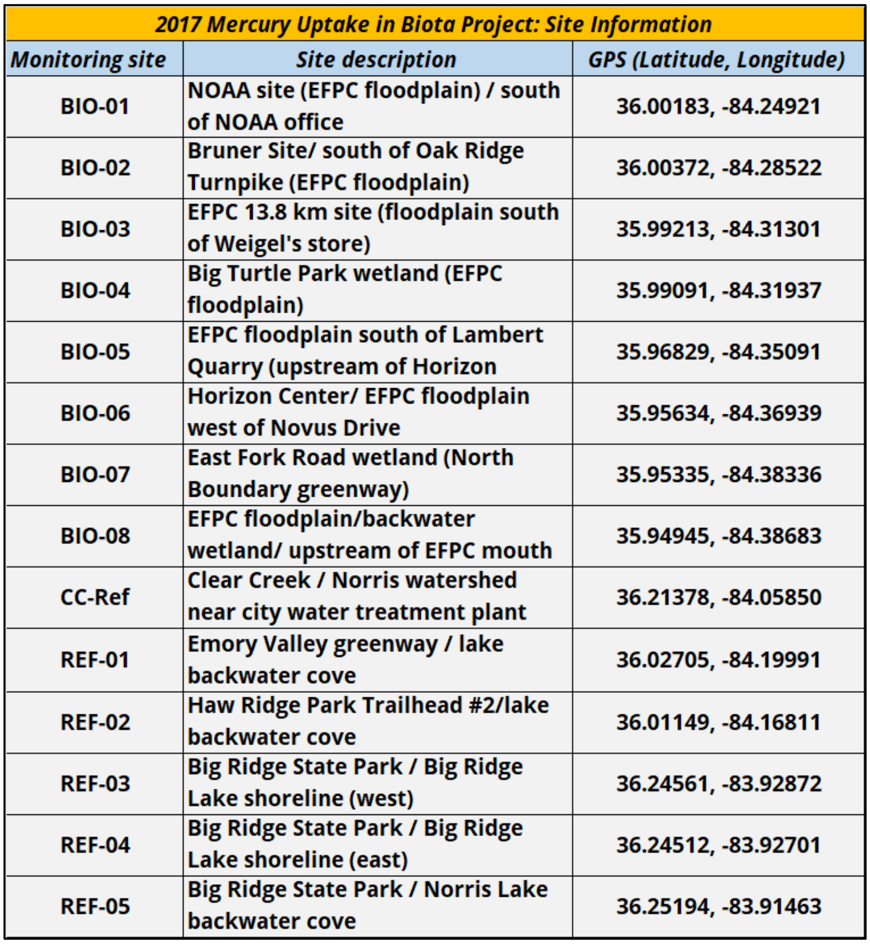
Figure 3.2.1: East Fork Poplar Creek and local reference sampling sites



LEGEND:		
★	CC-REF	Clear Creek reference site (Norris Watershed)
★	REF-03, REF-04, REF-05	Big Ridge State Park reference sites
GPS coordinates:	*latitude, longitude*	
	CC-REF:	36.21378, -84.05850
	REF-03:	36.24561, -83.92872
	REF-04:	36.24512, -83.92701
	REF-05:	36.25194, -83.91463

Figure 3.2.2: Distant reference sampling sites

Table 3.2.2: Sampling Site Descriptions



2017 Mercury Uptake in Biota Project: Site Information		
Monitoring site	***Site description***	***GPS (Latitude, Longitude)***
BIO-01	**NOAA site (EFPC floodplain) / south of NOAA office**	**36.00183, -84.24921**
BIO-02	**Bruner Site/ south of Oak Ridge Turnpike (EFPC floodplain)**	**36.00372, -84.28522**
BIO-03	**EFPC 13.8 km site (floodplain south of Weigel's store)**	**35.99213, -84.31301**
BIO-04	**Big Turtle Park wetland (EFPC floodplain)**	**35.99091, -84.31937**
BIO-05	**EFPC floodplain south of Lambert Quarry (upstream of Horizon**	**35.96829, -84.35091**
BIO-06	**Horizon Center/ EFPC floodplain west of Novus Drive**	**35.95634, -84.36939**
BIO-07	**East Fork Road wetland (North Boundary greenway)**	**35.95335, -84.38336**
BIO-08	**EFPC floodplain/backwater wetland/ upstream of EFPC mouth**	**35.94945, -84.38683**
CC-Ref	**Clear Creek / Norris watershed near city water treatment plant**	**36.21378, -84.05850**
REF-01	**Emory Valley greenway / lake backwater cove**	**36.02705, -84.19991**
REF-02	**Haw Ridge Park Trailhead #2/lake backwater cove**	**36.01149, -84.16811**
REF-03	**Big Ridge State Park / Big Ridge Lake shoreline (west)**	**36.24561, -83.92872**
REF-04	**Big Ridge State Park / Big Ridge Lake shoreline (east)**	**36.24512, -83.92701**
REF-05	**Big Ridge State Park / Norris Lake backwater cove**	**36.25194, -83.91463**

Avian sampling:

WD and TS eggs and feathers were hand-collected from installed nest houses.

One egg and approximately five grams of nesting feathers were collected from each occupied nest house.

Egg and feather sampling and sample preparation followed the methods of Kennamer et al. (2005); Longcore, Haines, and Halteman (2007); and Evers (2009).

Adult insects, benthic larvae and spider sampling:

About five grams of material was collected per taxon per site for Hg & MeHg assays.

Adult flying insects were collected with black light traps (ultraviolet) and Lindgren funnel traps.

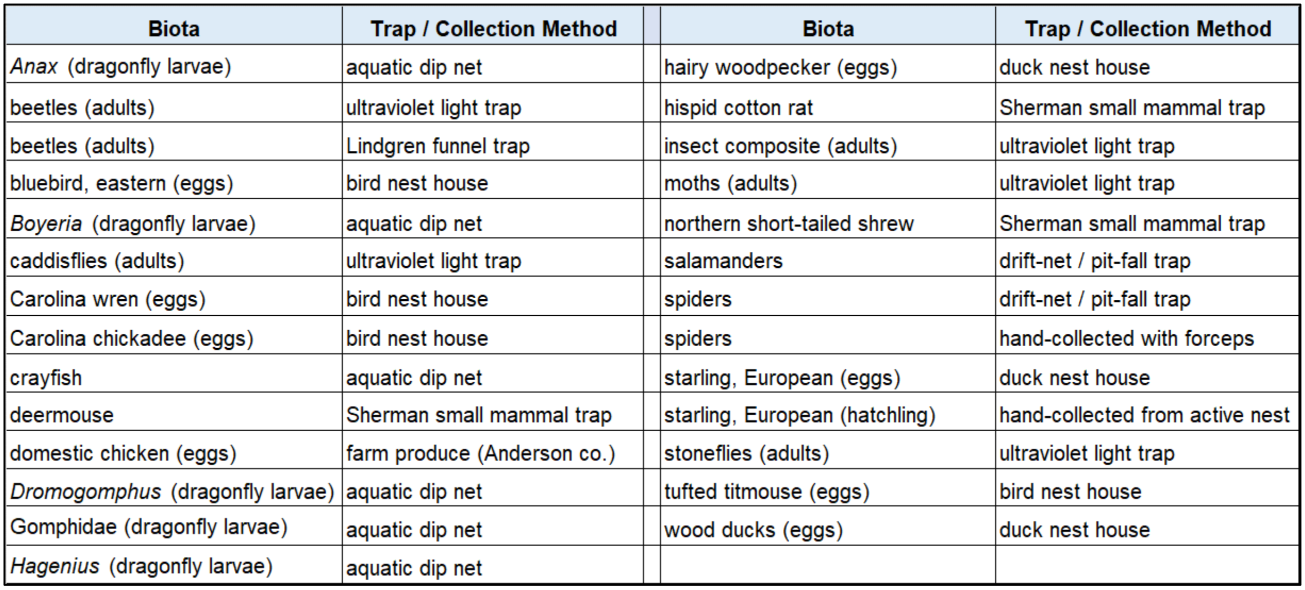
Benthic larvae were collected from aquatic substrates with dip nets.

Spiders were collected near shorelines with aquarium nets or 12-inch forceps.

Sampling and sample preparation followed the standard operating procedures in accordance with the methods of Southwood and Henderson (2000); Vincent and Hadrien (2013); CCME (2016); and TDEC (2011).

Table 3.2.3 provides a summary of the collecting and trapping methods used to sample target biota species.

Table 3.2.3: Biota Sampling Methods



Biota	Trap / Collection Method	Biota	Trap / Collection Method
Anax (dragonfly larvae)	aquatic dip net	hairy woodpecker (eggs)	duck nest house
beetles (adults)	ultraviolet light trap	hispid cotton rat	Sherman small mammal trap
beetles (adults)	Lindgren funnel trap	insect composite (adults)	ultraviolet light trap
bluebird, eastern (eggs)	bird nest house	moths (adults)	ultraviolet light trap
Boyeria (dragonfly larvae)	aquatic dip net	northern short-tailed shrew	Sherman small mammal trap
caddisflies (adults)	ultraviolet light trap	salamanders	drift-net / pit-fall trap
Carolina wren (eggs)	bird nest house	spiders	drift-net / pit-fall trap
Carolina chickadee (eggs)	bird nest house	spiders	hand-collected with forceps
crayfish	aquatic dip net	starling, European (eggs)	duck nest house
deermouse	Sherman small mammal trap	starling, European (hatchling)	hand-collected from active nest
domestic chicken (eggs)	farm produce (Anderson co.)	stoneflies (adults)	ultraviolet light trap
Dromogomphus (dragonfly larvae)	aquatic dip net	tufted titmouse (eggs)	bird nest house
Gomphidae (dragonfly larvae)	aquatic dip net	wood ducks (eggs)	duck nest house
Hagenius (dragonfly larvae)	aquatic dip net		

Sample handling at the TDEC DoR laboratory (all biota samples):

In the TDEC DoR-OR laboratory, all biota samples were weighed (as received at the wet weight) to the nearest 0.01 gram and recorded in the laboratory sample log.

Biota were classified to at least the Family (or genus) level and sorted to create approximately five grams of biomass for each sample.

Egg samples were boiled to facilitate separation of the shell, yoke, and albumen for samples.

All biota samples were placed into two-ounce glass jars provided by the Tennessee Department of Health (TDH) laboratory. These jars were stored at -18⁰C in the TDEC DoR-OR laboratory freezer until their shipment to PACE Analytical Services, LLC.

Methods: Lab Methods

Analytical laboratory methods

Biota sample materials and shipments will be coordinated with the Tennessee Department of Health—Nashville Environmental Laboratory (TDH-NEL). For the Hg and MeHg mercury tests, TDH-NEL forwards these samples to PACE Analytical Services, LLC (Green Bay, WI) for analysis.

Hg (low-level) assays will follow the EPA method 1631E (US EPA 2002) and MeHg assays will follow EPA method 1630 (US EPA 1998).

All Hg and MeHg analytical results will be reported on a “wet weight” basis.

Sample shipping protocol

Frozen biota samples were packed in ice and shipped overnight freight to PACE Analytical Services, LLC, according to the TDH-NEL *Procedures for Shipping Samples* (TDEC, 2015).

The Tennessee Department of Health Laboratory uses EPA methods for sample analysis. The requested analytical methods are listed below:

Table 3.2.4: Lab Methods and Analyses

Method Designation	Test Name	Analytes
Method 1631E	Hg, low level*	Metals (mercury)
Method 1630	MeHg, in tissue*	Metals (methylmercury)
	*Reported on a wet weight basis	

3.2.6 Deviations from the Plan

Although 40+ biota samples were collected during 2019, laboratory budget funds were unavailable for analytical laboratory tests.

3.2.7 Results and Analysis

No results available to discuss due to lack of funding.

3.2.8 Conclusions

- No data is available to determine conclusions at this time.

3.2.9 Recommendations

To determine the level of impacts to the fauna of the ORR through the bioamplification of Hg and MeHg in the food web it is recommended that this project continue to collect data and information so that long term trends can be established and reported to DOE.

3.2.10 References

Brasso, R.L., & D.A. Cristol. (2008). Effects of mercury exposure on the reproductive success of tree swallows (Tachycinea bicolor). Ecotoxicology 17:133–141.

Brooks, S., V. Eller, J. Dickson, J. Earles, K. Lowe, T. Mehlhorn, T. Olsen, C. DeRolph, D. Watson, D. Phillips and M. Peterson. (2017). Mercury content of sediments in East Fork Poplar Creek: current assessment and past trends. ORNL/TM-2016/578. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN.

Burger, J., & M. Gochfeld. (1997). Risk, mercury levels, and birds: relating adverse laboratory effects to field biomonitoring. Environmental Research 75:160-172.

CCME. (2016). Guidance manual for environmental characterization in support of environmental and human health risk assessment. SOP No. 14: Terrestrial invertebrate sampling. / SOP No. 15: Benthic invertebrate collection and processing. Volume 3: Suggested operating procedures. PN 1555. Canadian Council of Ministers of the Environment (CCME). Winnipeg, Manitoba.

Furness, R.W., S.J. Muirhead, & M. Woodburn. (1986). Using bird feathers to measure mercury in the environment: relationships between mercury content and moult. Marine Pollution Bulletin 17:27-30.

Evers, D.C. (2009). BioDiversity Research Institute: Protocol for collecting bird and mammal tissue for contaminant analysis. Report BRI 2009-01, BioDiversity Research Institute, Gorham, Maine.

Han, F. X., Y. Su, Y. Xia, W. Tian, V. Philips, Z. Shi, D. L. Monts, M. Gu, & Y. Liang. (2012). Mercury distribution and speciation in floodplain soils and uptake into native earthworms (Diplocardia spp.). Geoderma 170:261-268.

Hepp, G. R., and F. C. Bellrose. 1995. Wood Duck (*Aix sponsa*). The Birds of North America, No. 169 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

Jacobs. (1995). Record of Decision for Lower East Fork Poplar Creek, Oak Ridge, Tennessee. DOE/OR/02-1370&D2. Jacobs ER Team. Oak Ridge, TN.

Kalisinska, E., D.I. Kosik-Bogacka, P. Lisowski, N. Lanocha, & A. Jackowski. (2013). Mercury in the body of the most commonly occurring European game duck, the mallard (Anas platyrhynchos L. 1758), from northwest Poland. Archives of the Environmental Contamination and Toxicology 64:583-593.

Kennamer, R.A., J.R. Stout, B.R. Jackson, S.V. Colwell, L. Brisbin Jr., & J. Burger. (2005). Mercury patterns in wood duck eggs from a contaminated reservoir in South Carolina, USA. Environmental Toxicology and Chemistry 24:1793-1800.

Longcore, J.R., T.A. Haines, & W.A. Halteman. (2007). Mercury in tree swallow food, eggs, bodies and feathers at Acadia national park, Maine, and an EPA Superfund site, Ayer, Massachusetts. Environmental Monitoring and Assessment 126:129-143.

Mathews, T.J., J.G. Smith, M.J. Peterson, & W.K. Roy. (2011). Assessment of contaminant bioaccumulation in invertebrates and fish in waters in and adjacent to the Oak Ridge Reservation—2010. ORNL/TM-2011/108. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN.

Pant, P., M. Allen, & B. Tansel. (2010). Mercury uptake and translocation in Impatiens walleriana plants grown in the contaminated soil from Oak Ridge. International Journal of Phytoremediation 13:168-176.

Robertson, R. J., B. J. Stutchbury, & R. R. Cohen. (2011). Tree Swallow (Tachycineta bicolor) In The Birds of North America, No. 11 (A. Poole, P. Stettenheim, and F. Gill, eds.) The Birds of North America Online, Ithaca, New York.

SAIC. (1995). Remedial Goal Options for Mercury in Sediment of East Fork Poplar Creek, Oak Ridge, Tennessee. DOE/OR/01-1342&D2. Prepared for U.S. Department of Energy by Science Applications International Corporation (SAIC), Oak Ridge, TN.

SAIC. (1996). Baseline and postremediation monitoring program plan for Lower East Fork Poplar Creek operable unit, Oak Ridge, TN. Y/ER-262. Lockheed-Martin Energy Systems, Inc. Environmental Restoration Program. Science Applications International Corporation, Oak Ridge, TN.

Scheuhammer, A.M., M.W. Meyer, M.B. Sandheinrich, & M.W. Murray. (2007). Effects of environmental methylmercury on the health of wild birds, mammals and fish. Ambio 36:12-18.

Southwood, T.R.E., & P.A. Henderson. 2000. Light and other visual traps (p. 283-297). In Ecological methods. Southwood, T.R.E. and P.A. Henderson (eds.). Blackwell Science

Ltd., Oxford. 575 pp. Standish, C. L. (2016). Evaluation of total mercury and methylmercury concentrations of terrestrial invertebrates along Lower East Fork Poplar Creek in Oak Ridge, Tennessee. Masters Thesis, University of Tennessee, Knoxville, TN.

TDEC. (2011). Quality system standard operating procedures for macroinvertebrate stream surveys. Tennessee Department of Environment & Conservation. Division of Water Pollution Control, Nashville, Tennessee.

TDEC. (2015). Procedures for Shipping Samples to the State Lab in Nashville. SOP No. 101. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, TN.

TDEC. (2017). Tennessee Department of Environment and Conservation Division of Remediation, Oak Ridge Office (DoR OR). Health and Safety Plan Including Related Policies, January 2017. Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office, Oak Ridge, TN.

USDI. (1998). Guidelines for the interpretation of the biological effects of selected constituents in biota, water, and sediment: mercury, Report No. 3. National irrigation water quality program information, United States Department of the Interior.

USEPA. (1998). Method 1630. Methyl mercury in water by distillation, aqueous ethylation, purge and trap, and cold vapor atomic fluorescence spectrometry. U.S. Environmental Protection Agency. Office of Science & Technology, Engineering & Analytical Division. Washington, DC.

USEPA. (2002). Method 1631, Revision E. Mercury in water by oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry. U.S. Environmental Protection Agency. EPA821-R-02-019. Office of Water, Washington, DC.

Vincent, V., & L. Hadrien. (2003). Standardized sampling protocol for spider community assessments in the neotropical rainforest. Journal of Entomology and Zoological Studies 1:18-34.

Weech, S.A., A.M. Scheuhammer, & J.E. Elliott. (2006). Mercury exposure and reproduction in fish-eating birds breeding in the Pinchi Lake region, British Columbia, Canada. Environmental Toxicology and Chemistry 25:1433-1440.

Wiener, J.G., D.P. Krabbenhoft, G.H. Heinz, A.M. Scheuhammer. Ecotoxicology of mercury. (2003). In D.J. Hoffman, B.A. Rattner, G.A. Burton, J. Cairns (Eds.), Handbook of Ecotoxicology, Lewis Publishers, Boca Raton, FL. pp. 409-463.

Wolfe, M.F., S. Schwarzbach, & R.A. Sulaiman. (1998). Effects of mercury on wildlife: A comprehensive review. Environmental Toxicology and Chemistry 17:146-160.

3.3 RADIOLOGICAL UPTAKE IN VEGETATION (FY2018 PROJECT)

3.3.1 Background

This project was executed in the prior fiscal year, but analytical results were not returned in time for incorporation into that EMR. As such this EMR will revisit that project and discuss those findings here.

The three facilities on the Oak Ridge Reservation (ORR) have seen a variety of radiological contaminants. Much of this comes from past operations and burial of waste, but current cleanup and other activities could also contribute to areas with radiological contamination on the ORR. Sampling has mostly focused on areas likely to have radiological contamination, either from past or current Department of Energy (DOE) activities.

3.3.2 Problem Statements

Radiological contamination of the ORR exists in a variety of locations. If surface water bodies have been impacted by radioactivity, vegetation in the immediate vicinity may uptake radionuclides, causing the bioaccumulation of radiological contaminants.

3.3.3 Goals

This project aims to collect vegetation at locations in and near surface waters on the ORR. This project focuses on the detection and characterization of radiological constituents that may be bio-accumulated by vegetation. Results can be used:

- To determine if radiological constituents are migrating into the environment
- To see if remedial efforts are decreasing levels of bioaccumulation seen in vegetation downstream of the remediation
- To determine areas of contamination that may need further characterization by DOE and the Division of Remediation-Oak Ridge office (DoR-OR).

3.3.4 Scope

This project collected and analyzed 6 vegetation samples for radiological contamination in

2018. Samples were collected near surface water bodies potentially impacted by radioactivity, on or near the ORR. Target vegetation for sampling included, but was not limited to, common cattail (*Typha latifolia*) and mixed vegetation. Watersheds such as Bear Creek and its tributaries, White Oak Creek (WOC)/Lake and its tributaries, Mitchell Branch, and East Fork Poplar Creek (EFPC) were all probable target locations for sampling. Samples were analyzed for gross alpha and gross beta activity, and for gamma radionuclides. Additional analysis could be requested if determined necessary.

3.3.5 Methods, Materials, Metrics

Six vegetation samples were collected in areas determined by the Tennessee Department of Environment and Conservation (TDEC) to have high potential for radiological contamination or be in a good potential background and pre-radiological disturbance area. Samples consisted of at least one gallon of vegetation, with a focus to minimize the collection of debris and roots in the samples. Samples were scanned with a radiological instrument for beta and gamma radiation, double-bagged in re-sealable plastic bags, labeled, and transported back to DoR-OR. Samples were refrigerated until shipped to the Tennessee Department of Health (TDH) environmental laboratory in Nashville for radiological analysis.

The samples were analyzed for general radiological contamination. Samples were collected near ORR surface water sites (springs, creeks, wetlands) to determine if radioactive contaminants had accumulated in the vegetation. Sampled species were dependent on what was available at the desired sampling locations. Cattails (*Typha spp*.), watercress (*Nasturtium officinale*), and willow (*Salix spp*.) are good indicator species because of their propensity to uptake radiological contaminants. For planned sampling locations where cattails, watercress, and willow were not available or were not found in sufficient quantities, mixed floodplain vegetation was collected near the edges of water sources, mainly creeks.

A similar method was used by the Federal Radiation Monitoring and Assessment Center (FRMAC) for vegetation sampling, collecting above-ground vegetation (NNSA, 2012). Only areas near surface water, where enough vegetation existed to fill at least a one-gallon bag, were sampled. The vegetation was analyzed for gross alpha activity, gross beta activity, and gamma radionuclides. The laboratory results from vegetation samples are compared to the radiological analytical results of vegetation collected from a background location.

3.3.6 Deviations from the Plan

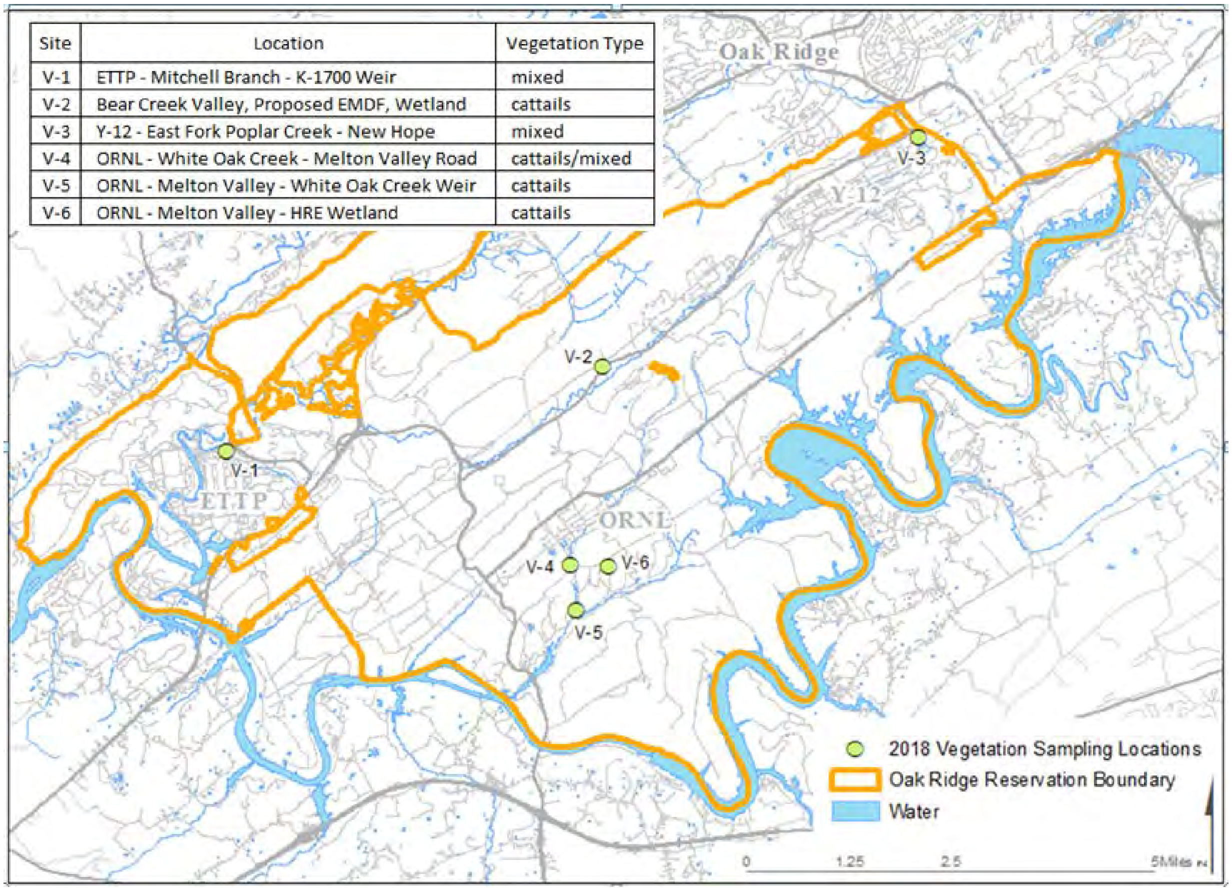
While up to 20 locations were initially planned to be sampled in 2018, funding was only sufficient for sampling at six locations. The results of the six samples collected in 2018 are available for this report but were not yet available at the time of the last report. No funding was provided for vegetation sampling for this project in 2019, so no samples were collected. This project is being discontinued and will instead be done as food vegetation (vegetables) and hay sampling project in future years. The results from the 2018 data are discussed in this report. Also, as the sample collected in an area believed to be clean as a vegetation sample was not clean, the sampling results from the six 2018 vegetation samples were compared to the 2017 background sample results.

3.3.7 Results and Analysis

TDEC gathered six vegetation samples for radiological analysis in May of 2018. Samples were collected at each of the three larger sites on the ORR: ORNL, Y-12, and ETTP. The 2018 vegetation sampling locations are shown in Figure 3.3.1. The EPA does not currently regulate radionuclide levels in vegetation. The Food and Drug Administration (FDA) has established guidelines called Derived Intervention Levels (DILs) to describe radionuclide concentrations at which the introduction of protective measures should be considered (FDA 1998, FDA 2005). These values were derived to be protective in the event of a nuclear incident, where food sources (including vegetation) would be suspected to be radioactively contaminated. The FDA values are specific to certain radionuclides and are not directly comparable to the gross alpha, gross beta, and gamma activity analyzed by this project. Consequently, sample data was compared with gross alpha, gross beta, and gamma activity collected from a background location.

Since the area sampled that was originally designated to be a background site showed elevated levels of radioactivity, the 2018 sampling results are compared to the background sample taken in 2017. Otherwise, samples were taken at locations thought to potentially contain elevated levels of radiological contamination that could be taken up by the nearby vegetation or at sites with previously elevated results. Where sample results are greater than twice background levels, they are considered elevated.

The project was limited to six samples for 2018. Those samples were spread amongst the three ORR sites. Four locations were related to sites of historical elevated concentrations. Three of these samples were taken at ORNL in Melton Valley (V-4, V-5, and V-6) and one in Upper East Fork Poplar Creek just below Y-12 (V-3). A new location was sampled at ETTP at the K-1700 weir (V-1) along Mitchell Branch, as our ambient sediment sampling project had previously indicated elevated gross beta levels at that location. The final site sampled was a location at the site proposed for the new mixed-waste disposal facility, the Environmental Management Disposal Facility (EMDF), in an area expected to be free of radioactive contamination (V-2). Table 3.3.1 provides the results of the gross alpha, gross beta, and gamma analysis of the six vegetation samples collected in 2018 and shows the results for the 2017 background sample for comparison.



Site	Location	Vegetation Type
V-1	ETTP - Mitchell Branch - K-1700 Weir	mixed
V-2	Bear Creek Valley, Proposed EMDF, Wetland	cattails
V-3	Y-12 - East Fork Poplar Creek - New Hope	mixed
V-4	ORNL - White Oak Creek - Melton Valley Road	cattails/mixed
V-5	ORNL - Melton Valley - White Oak Creek Weir	cattails
V-6	ORNL - Melton Valley - HRE Wetland	cattails

Figure 3.3.1: 2018 Vegetation Sampling Locations

The data in Table 3.3.1 have been arranged based on the levels of gross beta, with the most elevated gross beta results at the top of the table. The yellow, blue, green, and light blue bars shown (for gross alpha, gross beta, cesium-137, and potassium 40, respectively) are to visually highlight which values are higher and which are lower; the longer the bar, the higher the result. Data shown in black type depict results with values greater than the sample-specific detection limit for that analysis. Results shown in gray had values less than the sample-specific detection limit for that analysis and can be considered non-detects.

Table 3.3.1: 2018 Vegetation Sampling Results (pCi/g wet weight)

site	location	gross alpha	gross beta	gamma							
				Cs-137	K-40	Be-7	Bi-214	Pb-212	Pb-214	Ac-228	Tl-208
V-6	ORNL - Melton Valley - HRE Wetland	9.00	143		3.66						
V-5	ORNL - Melton Valley - White Oak Creek Weir	1.90	32.2	2.15	2.84						
V-1	ETTP - Mitchell Branch - K-1700 Weir	-0.26	23.7		4.01	0.94					
V-2	Bear Creek Valley, Proposed EMDF, Wetland	1.06	15.4		14.60						
V-4	ORNL - White Oak Creek - Melton Valley Road	0.74	10.1	5.17	3.47		0.276		0.239		
V-3	Y-12 - East Fork Poplar Creek - New Hope	3.03	9.3		4.37	4.79		0.116	0.096	0.156	0.057
V-B	2017 Background- Worthington Cemetery Trail	-0.04	3.0		3.90	0.77					

black# above sample specific detection limit   gray# less than sample specific detection limit

The data suggests the existence of elevated radionuclide concentrations in the vegetation collected near some of the surface water on the ORR. Samples with gross alpha results above the sample-specific detection limits, were collected at the Homogeneous Reactor Experiment (HRE) in Melton Valley at ORNL (9.00 pCi/g), Upper East Fork Poplar Creek behind the New Hope Center at Y-12 (3.03 pCi/g), the White Oak Creek Weir in Melton Valley at ORNL (1.90 pCi/g), and at the site proposed for the new mixed-waste disposal facility, EMDF, in Bear Creek Valley (1.06 pCi/L).

The highest level of gross beta activity for the 2018 samples was from the sample collected at the HRE wetland (143 pCi/g). As seen in Table 3.3.2, all the locations sampled for vegetation in 2018 had elevated gross beta values.

Table 3.3.2: Highest Gross Beta Analyses at HRE Wetland 2012-2018 (pCi/g)

Station	Year	Gross Alpha	Gross Beta	Units
HRE Wetland	2012	2.5	189	pCi/g
HRE Wetland	2013	3.2	213	pCi/g
HRE Wetland	2014	3.0	53.9	pCi/g
HRE Wetland	2015	2.0	69.1	pCi/g
HRE Wetland	2016	5.4	151	pCi/g
HRE Wetland	2017	-2.2	101	pCi/g
HRE Wetland	2018	9.0	143	pCi/g

HRE – Homogeneous Reactor Experiment

Samples have been collected at the HRE area since 2012.The HRE area has yielded the highest gross beta results each year since it has been sampled. The highest gross alpha and gross beta values for HRE are listed for 2012 through 2018 in Table 3.3.2. Again, the yellow and blue bars, shown for gross alpha and gross beta, respectively, are to visually highlight which values are higher and which are lower. Gross alpha levels were similar for most years except for 2016 and 2018, when it was higher, and in 2017, when it was below detection limits. The highest levels of gross beta results seen from sampling vegetation at HRE were from the 2012, 2013, and 2016 samples. Each year HRE samples were collected from slightly different locations and or media compositions, depending upon where vegetation grew, and which vegetation flourished within a small defined portion of the HRE area. These slight variations may account for some of the differences in concentration results.

Two of the six vegetation samples from 2018 showed cesium-137, both were collected from WOC. The other gamma isotopes detected during analysis (K-40, Be-7, Bi-214, Pb-214, Pb-212) can be naturally occurring and are not interpreted to be indicative of contamination due to DOE activities. However, the potassium 40 (K-40) sample from the site proposed for the new mixed-waste disposal facility, EMDF, in Bear Creek Valley was higher than K-40 concentrations historically seen with this project. As discussed above, part of this could be related to the elevated gross beta level at the site. Potential culprits could be clay soils used to create the wetland, fertilizer used on an adjacent soil pile (though the vegetation at the site was smaller rather than larger than most cattails at that time), or potential contamination from nearby waste areas. In prior TDEC DoR-OR radiological vegetation sampling, elevated gross alpha has been seen in vegetation at NT-8. Elevated alpha contamination at NT-8 has also been noted in the DOE RER.

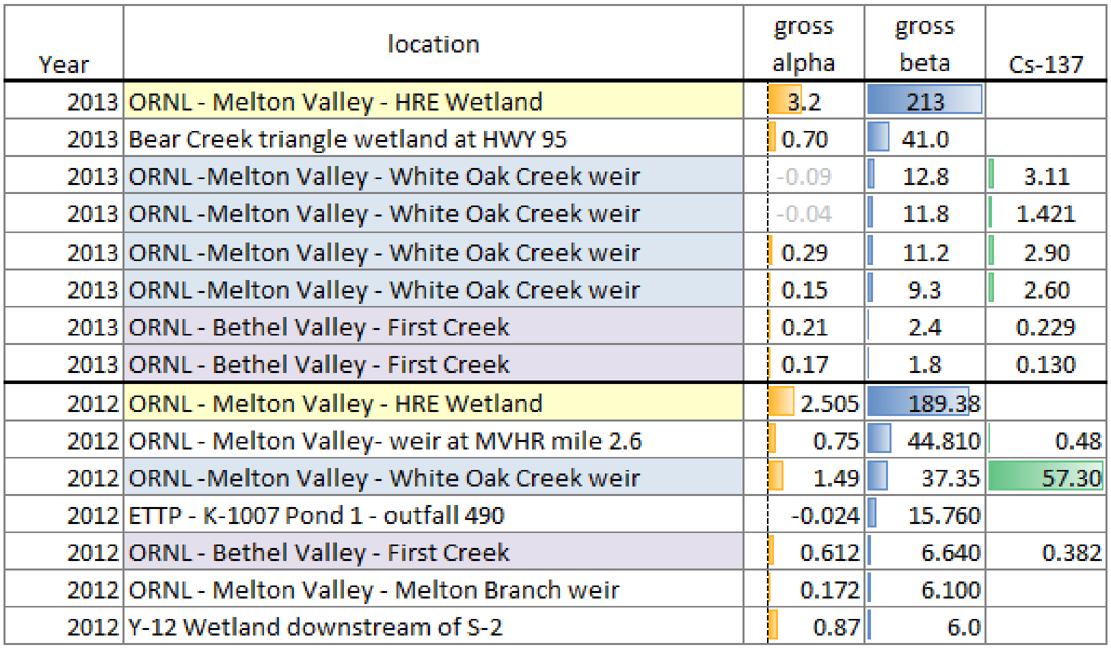
Another unexpected elevated result was the elevated Be-7 value seen at Upper East Fork Poplar Creek, behind the New Hope Center at Y-12 (4.79 pCi/g).

Table 3.3.3 lists the elevated results for gross alpha, gross beta, and cesium 137 in this project from 2012 to 2018. Sample results with levels of gross alpha over 1 pCi/g are shown, as are samples with gross beta results over 6 pCi/g, and those with Cesium 137 (Cs-137) present. Samples are organized by year. Many samples have multiple elevated radiological constituents. Repeated location names are shown in the same color each year in order to make comparisons from year to year easier. For further information on results from each year, please see that year’s vegetation Environmental Monitoring Report.

Table 3.3.3: Most Elevated Radiological Levels Seen in Vegetation Samples 2012 to 2018 (gross alpha over 1 pCi/g, gross beta over 6 pCi/g, Cs-137 present)

year	location	gross alpha	gross beta	Cs-137
2018	ORNL - Melton Valley - HRE Wetland	9.00	143	
2018	ORNL -Melton Valley - White Oak Creek weir	1.90	32.2	2.15
2018	ETTP - Mitchell Branch - K-1700 Weir	-0.26	23.7	
2018	Bear Creek Valley - Proposed EMDF - Wetland	1.06	15.4	
2018	ORNL - White Oak Creek - Melton Valley Road	0.74	10.1	5.17
2018	Y-12 - East Fork Poplar Creek - New Hope	3.03	9.3	
2017	ORNL - Melton Valley - HRE Wetland	-2.21	101	
2017	ORNL -Melton Valley - White Oak Creek weir	-0.65	31.5	0.689
2017	ORNL - White Oak Creek - Melton Valley Road	-0.67	24.8	0.614
2017	ORNL - White Oak Creek - Melton Valley Road	-0.18	15.3	11.10
2017	Y-12 - East Fork Poplar Creek - New Hope	2.67	13.2	
2017	ORNL - Melton Valley - Melton Branch Weir	-0.33	12.7	
2017	ORNL- Melton Valley - HFIR	-0.13	9.8	
2017	ORNL- White Oak Creek - 3rd Street Bridge	-0.19	8.8	3.08
2017	ORNL - Bethel Valley - First Creek	-0.02	6.1	
2016	ORNL - Melton Valley - HRE Wetland	5.40	151	
2016	ORNL- Melton Valley - HFIR	3.33	8.6	
2016	Y-12 - East Fork Poplar Creek - New Hope	1.40	33.8	
2016	ORNL- Melton Valley - HFIR	0.8	20.6	
2016	ORNL - White Oak Creek - Melton Valley Road	0.72	15.4	
2016	ORNL -Melton Valley - White Oak Creek weir	0.54	9.9	
2016	ORNL- White Oak Creek - 3rd Street Bridge	0.45	4.8	4.96
2015	ORNL - Melton Valley - HRE Wetland	2.00	69.1	
2015	ORNL- Melton Valley - HFIR	0.70	29.8	
2015	ORNL - White Oak Creek - Melton Valley Road	0.06	22.2	23.3
2015	ORNL -Melton Valley - White Oak Creek weir	0.37	13.5	1.76
2015	ORNL - Melton Valley - HRE Wetland	0.31	12.4	
2015	ORNL- White Oak Creek - 3rd Street Bridge	0.16	12.3	9.9
2015	ORNL - Melton Valley - Melton Branch Weir	0.43	8.2	
2014	ORNL - Melton Valley - HRE Wetland	3.0	53.9	
2014	Bear Creek Valley- NT-8 - upstream of haul road	3.9	8.9	
2014	ORNL- Melton Valley - HFIR	0.42	6.3	
2014	ORNL -Melton Valley - White Oak Creek weir	0.28	5.6	2.78

Table 3.3.3 (con't): Most Elevated Radiological Levels Seen in Vegetation Samples from 2012 to 2018 (gross alpha over 1 pCi/g, gross beta over 6 pCi/g, Cs-137 present)



Year	location	gross alpha	gross beta	Cs-137
2013	ORNL - Melton Valley - HRE Wetland	3.2	213	
2013	Bear Creek triangle wetland at HWY 95	0.70	41.0	
2013	ORNL -Melton Valley - White Oak Creek weir	-0.09	12.8	3.11
2013	ORNL -Melton Valley - White Oak Creek weir	-0.04	11.8	1.421
2013	ORNL -Melton Valley - White Oak Creek weir	0.29	11.2	2.90
2013	ORNL -Melton Valley - White Oak Creek weir	0.15	9.3	2.60
2013	ORNL - Bethel Valley - First Creek	0.21	2.4	0.229
2013	ORNL - Bethel Valley - First Creek	0.17	1.8	0.130
2012	ORNL - Melton Valley - HRE Wetland	2.505	189.38	
2012	ORNL - Melton Valley- weir at MVHR mile 2.6	0.75	44.810	0.48
2012	ORNL -Melton Valley - White Oak Creek weir	1.49	37.35	57.30
2012	ETTP - K-1007 Pond 1 - outfall 490	-0.024	15.760	
2012	ORNL - Bethel Valley - First Creek	0.612	6.640	0.382
2012	ORNL - Melton Valley - Melton Branch weir	0.172	6.100	
2012	Y-12 Wetland downstream of S-2	0.87	6.0	

3.3.8 Conclusions

The data from the samples collected from 2012 to 2018 for the radiological contaminant uptake in vegetation project suggests that there are still a number of areas with elevated radionuclide concentrations in the vegetation associated with surface water on the ORR that should be addressed by DOE.

3.3.9 Recommendations

DOE should continue to evaluate radiological impacts to vegetation across the ORR. It is apparent that radiological contamination continues to exist at levels that impact environmental media as seen in the vegetation sampling. Areas with elevated results may indicate places where further sampling and potentially remediation efforts may be warranted.

3.3.10 References

National Nuclear Security Administration (2012). Operator Aid FRMAC Early Phase Vegetation Sample 2012-03. Federal Radiological Monitoring and Assessment Center. [https://www.nnss.gov/pages/programs/FRMAC/FRMAC_DocumentsManuals.html Operator Aid FRMAC Early Phase Vegetation Sample](https://www.nnss.gov/pages/programs/FRMAC/FRMAC_DocumentsManuals.html)

Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office (2015). SOP for Shipping Samples to Nashville Lab.

U.S. Food and Drug Administration (1998). Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies. FDA, Center for Devices and Radiological Health. Rockville, Maryland.

https://www.fda.gov/regulatory-information/search-fda-guidance-documents/accidental-radioactive-contamination-human-food-and-animal-feeds
https://www.fda.gov/media/74043/download

U.S. Food and Drug Administration (2005). Guidance Levels for Radionuclides in Domestic and Imported Foods (CPG-7119.14), Sec.560.750.

https://www.fda.gov/food/chemicals/guidance-levels-radionuclides-domestic-and-imported-foods-cpg-711914

https://www.fda.gov/regulatory-information/search-fda-guidance-documents/cpg-sec-560750-radionuclides-imported-foods-levels-concern

https://www.fda.gov/media/72014/download

3.4 BENTHIC MACROINVERTEBRATES

3.4.1 Background

The ongoing Benthic Macroinvertebrate Monitoring Project monitors the current condition and the changing conditions of stream-bottom communities in streams on the Oak Ridge Reservation (ORR). These streams have been negatively impacted by historical Manhattan Project activities, as well as current operational activities at the three facilities on the reservation (i.e., East Tennessee Technology Park (ETTP) formerly known as K-25; Oak Ridge National Laboratory (ORNL); and Y-12 National Security Complex (Y-12). The purpose of the Benthic Macroinvertebrate Project is not only to document the current condition of these stream communities, but also to note the changes of these conditions as remedial activities conducted under CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act; also known as Superfund) continue.

Stream-bottom communities (aquatic insects and other macroinvertebrate species) serve as indicators of the health of aquatic systems. The majority of the lives of these organisms are spent in water, and therefore, they are continually exposed to conditions caused by direct or indirect discharges to these waters. Un-impacted reference streams are used to define what a healthy community would look like, and that determination is then compared to those assessments of impacted sites in streams on the ORR to help determine the extent of impact to the environment.

Four main watersheds are studied at the three facilities on the ORR.

- White Oak Creek is the primary watershed on the Oak Ridge National Laboratory (ORNL) site.
- Mitchell Branch serves as the main watershed on the East Tennessee Technology Park (ETTP) site.
- East Fork Poplar Creek and Bear Creek serve as the watersheds on the Y-12 facility.
- The headwaters of White Oak Creek and Mitchell Branch serve as the reference sites for those watersheds. Because East Fork Poplar Creek and Bear Creek are both impacted in the headwaters, other onsite and offsite streams must serve as reference sites for those watersheds.

ORNL staff also conduct benthic macroinvertebrate monitoring on some of the same streams as TDEC DoR, Oak Ridge., however; a number of the specific sites monitored differ between the two organizations. Even where the specific sites are the same, TDEC's sampling serves as an independent check on ORNL's monitoring results. Determining impacts on stream bottom communities is a difficult task and results and interpretations may vary among different sampling and analysis personnel, which may cause some results to be slightly different. An independent evaluation (TDEC), and comparison with DOE (ORNL) sampling results, collectively helps to produce a clearer picture of actual conditions in ORR streams.

All work on this project follows the requirements of TDEC Division of Remediation Oak Ridge *Office Health and Safety Plan* (TDEC 2017).

3.4.2 Problem Statements

Benthic macroinvertebrate communities at the majority of sites in the four main watersheds in this study do not compare well with healthy communities from un-impacted reference streams. Populations of pollution-intolerant species at a number of the ORR sampling sites are well below the levels of populations of similar or the same species at reference sites. Conversely, populations of pollution-tolerant species at a number of the ORR sampling sites far exceed the populations of similar or the same species at reference sites. Many of the impacts affecting these streams result from both historical Manhattan Project activities as well as current operational activities on the ORR. The majority of these impacts are due to typical industrial contaminants (e.g., residual chlorine and other chemical releases [both chronic and acute], organic loading from point and non-point discharges) and are not related to the radiological contamination of the ORR sampling sites. In areas where stream sections have been channelized, problems can also be due to a sparsity or lack of appropriate substrates for the establishment of healthy stream-bottom communities.

Sampling of benthic macroinvertebrate communities involves inherent variability. Part of this is due to the natural year-to-year fluctuations in benthic communities. Another aspect of this variability is due to variation among samplers and analysts. Because of these sources of variability, sampling of benthic macroinvertebrate communities benefits both from long term (year-after-year) sampling as well as rotation of sampling personnel.

As remedial activities continue on the ORR, ongoing benthic sampling and analysis will help to clarify if this remedial work is improving stream conditions or if other factors, not directly related to remedial activities, are responsible for the impacted conditions of the ORR streams.

3.4.3 Goals

The goals of the Benthic Macroinvertebrate Monitoring Project are varied:

- Primary among these goals is to monitor the current condition and health of benthic communities at stream sites on the Oak Ridge Reservation. The existence of historical data from these streams will help in the interpretation of whether these sites have improved, further degraded, or remained the same since remedial activities began on the ORR. This evaluation may be based on the use of various metrics, as well as the species composition and community density of benthic populations.

- A second goal is to provide data for comparison with other ongoing DOE studies of benthic communities. As indicated above, there is a normal year-to-year variation in benthic communities, as well as sampling- and analysis-induced variation. A comparison of data from different sources could clarify the actual current conditions at the ORR sites.

- A third goal is to better understand the causes of impacts in benthic communities on the ORR. At sites where pollution-tolerant organisms predominate, the problems could be due to organic loading of the streams by point and or non-point sources. At sites where mayfly populations are absent or extremely limited, metals toxicity problems of a chronic or acute nature may be responsible. At sites where benthic community densities (i.e., organisms/m^2) are very low, acute, and/or episodic, toxicity problems (e.g., chlorine or biocides) could be to blame.

- A fourth goal of benthic macroinvertebrate monitoring is to provide recommendations on potential changes that may be made to help improve the current health of streams on the ORR and off the ORR where primary impacts are due to the Oak Ridge facilities. These recommendations could run the gamut from pointing out areas where banks need stabilization, defining areas where suitable substrate is unavailable and identifying data interpretations where a clearer picture of the existing problems may be provided.
- A fifth goal is to attempt to elucidate impacts from sources other than the ORR facilities which may be affecting streams that flow both on and off the ORR (e.g., Mitchell Branch, East Fork Poplar Creek, Bear Creek). Not all impacts in a watershed are due to ORR facilities. Other sources holding back stream recovery must also be identified.

3.4.4 Scope

The physical boundaries of the Benthic Macroinvertebrate Monitoring Project include streams of the major watersheds on the three facilities of the ORR. For the ORNL, these streams include White Oak Creek from its headwaters to near its confluence with White Oak Lake and Melton Branch. At Y-12, these streams include East Fork Poplar Creek from its headwaters to approximate kilometer 6.3 and, Bear Creek from the headwaters to its confluence with East Fork Poplar Creek. At ETTP, Mitchell Branch is surveyed from its headwaters to near its confluence with Poplar Creek. Also included in these physical boundaries are offsite reference sites for the study which include Mill Branch, Hinds Creek and Clear Creek.

The sampling for the project includes two 1 m^2 composited samples for each study site. In addition, duplicate samples are taken at two sites for quality control.

The temporal boundaries for the Benthic Macroinvertebrate Monitoring Project are sampling of all stations in the study between the beginning of May and the middle of June of a given year. 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 and ORNL, care was taken to plan for a two- to three-week sampling time difference to allow for recovery of the benthic community.

No current plans suggest any expansion of the overall physical or temporal scope of the

Benthic Macroinvertebrate Monitoring Project. The last site added to the project was Bear Creek kilometer 3.3 which was added in 2015 at the request of a TDEC DoR staff member to provide benthic information for a sediment sampling site.

3.4.5 Methods, Materials, Metrics

Sample Collection:

On an annual basis the TDEC DoR, Oak Ridge Office conducts benthic macroinvertebrate monitoring surveys of the watersheds, streams, and stations listed in Table 3.4.1. Maps for all current sampling sites are included in Figures 3.4.1-3.4.5. The intent of these surveys is to compare TDEC DoR-OR results to the results obtained by ORNL staff and to provide independent verification of their results.

Sample collection consists of setting a net in place and then using a heavy-duty garden rake to disturb an approximate 1 m^2 area of the stream substrate directly upstream of that net. Two such samples are collected at each site and then composited and preserved with 95% ethanol. At two selected sites, duplicate samples are collected (i.e., two sets of two 1 m^2 composited samples).

Sample Processing:

Processing of benthic samples consist of two major steps. The first of these, called sample sorting, is the removal (separation) of benthic organisms from the detrital material collected along with the organisms.

The majority of the samples are preserved and brought to the DoR-OR laboratory for processing. In the case of White Oak Creek, samples from White Oak Creek Kilometer 3.9 (WCK 3.9), WCK 3.4, and WCK 2.3 and Melton Branch samples from Melton Branch Kilometer 0.3 (MEK 0.3), where elevated levels of radionuclides occur in the samples, processing is performed in the field so that contaminated sediments can be returned to their source and not brought into the laboratory.

The second step in the processing is sample identification of the organisms collected. The larger macroinvertebrates are 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), are often mounted on slides and identified by an experienced taxonomist using a binocular compound light microscope and the appropriate keys.

Table 3.4.1: Sampling Sites for Benthic Macroinvertebrate Monitoring

Facility	Watershed	Stations	Reference Stations
ORNL	White oak Creek	WCK 3.9	WCK 6.8
		WCK 3.4	
		WCK 2.3	
		MEK 0.3	
Y-12	East Fork Poplar Creek	EFK 25.1	HCK 20.6
		EFK 24.4	
		EFK 23.4	
		EFK 13.8	
		EFK 6.3	
	Bear Creek	BCK 12.3	GHK 2.9
		BCK 9.6	MBK 1.6
		BCK 3.3	
ETTP	Mitchell Branch	MIK 0.71	MIK 1.43
		MIK 0.45	

WCK = White Oak Creek Kilometer; MEK = Melton Branch Kilometer; EFK = East Fork Poplar Creek Kilometer; BCK = Bear Creek Kilometer; MIK = Mitchell Branch Kilometer; HCK = Hinds Creek Kilometer; GHK = Gum Hollow Branch Kilometer; MBK = Mill Branch Kilometer.

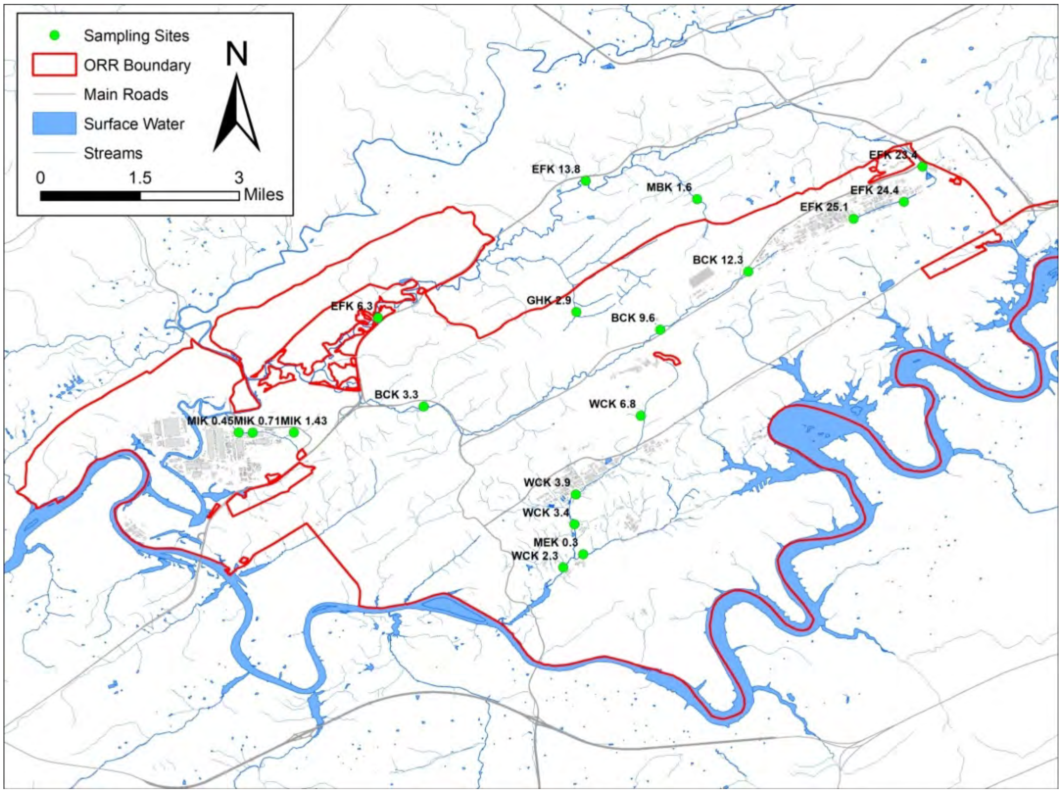


Figure 3.4.1: All Benthic Macroinvertebrate Monitoring Stations (Excluding reference HCK 20.6)

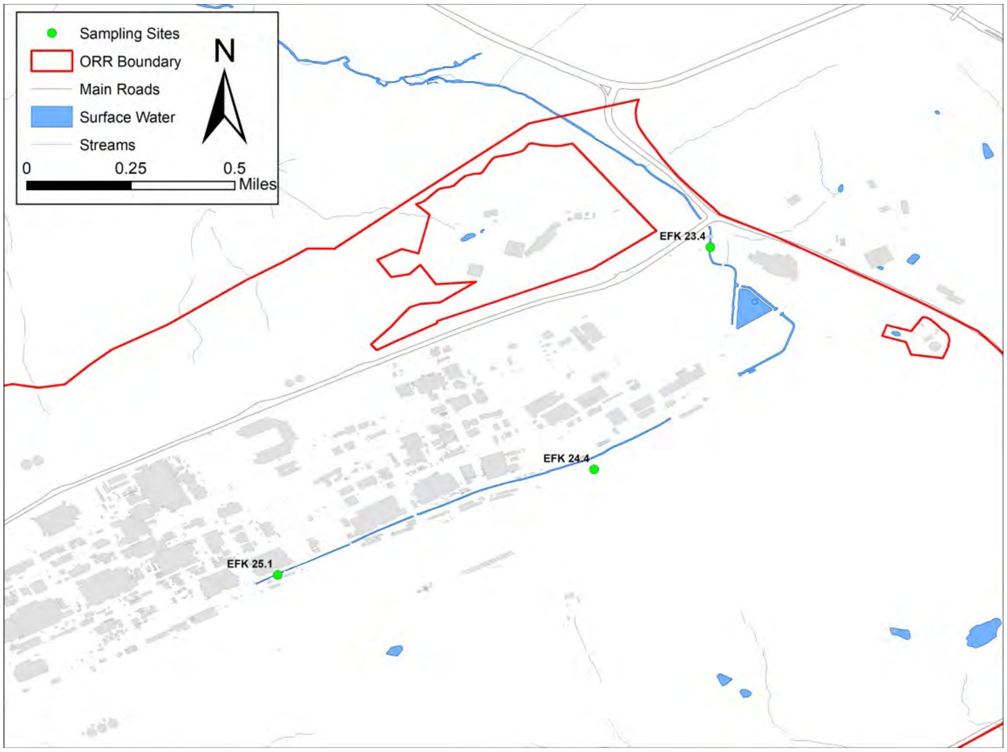


Figure 3.4.2: Benthic Macroinvertebrate Monitoring Stations in Upper East Fork Poplar Creek

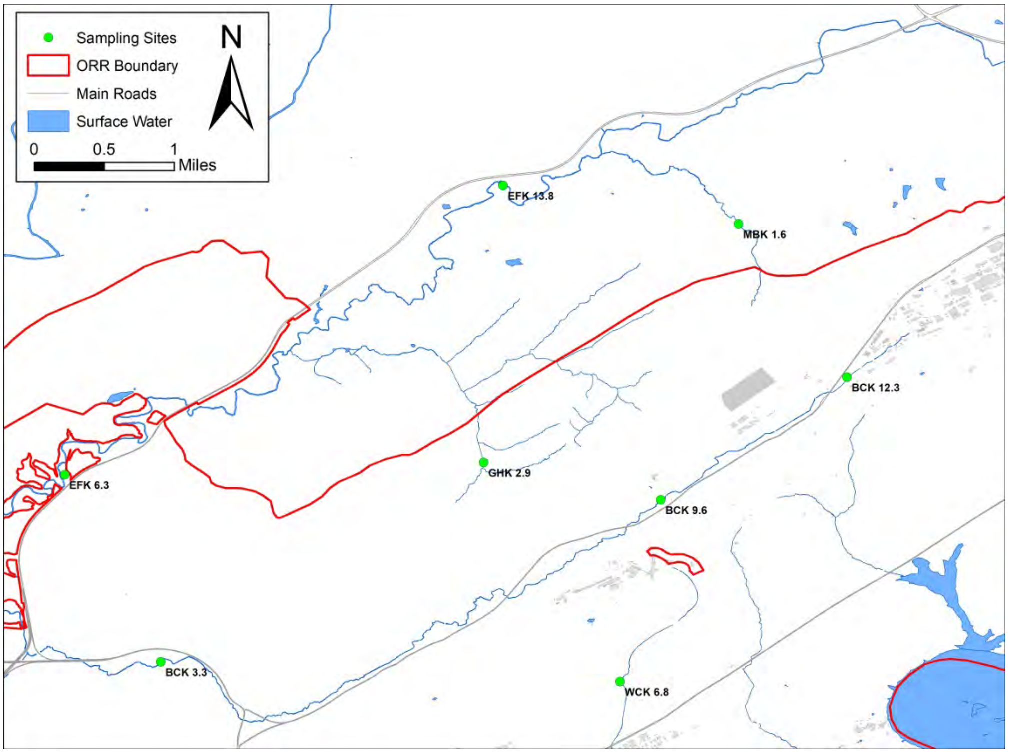


Figure 3.4.3: Benthic Macroinvertebrate Monitoring Stations in Bear Creek, Gum Hollow Branch Mill Branch Creek, and Lower East Fork Poplar Creek

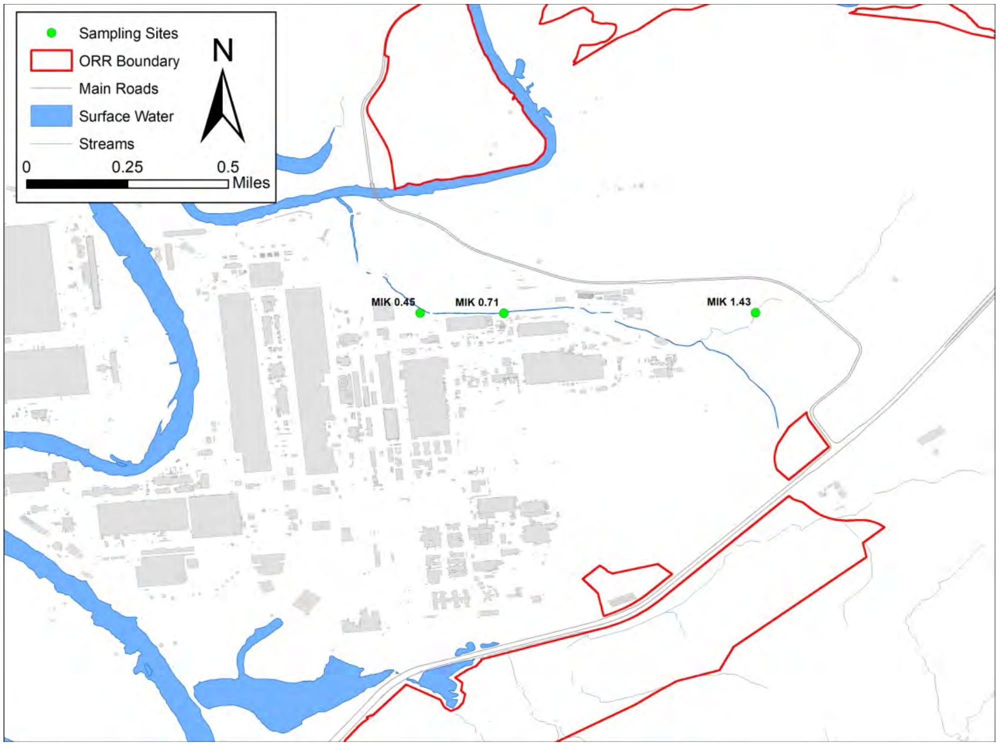


Figure 3.4.4: Benthic Macroinvertebrate Monitoring Sites at Mitchell Branch

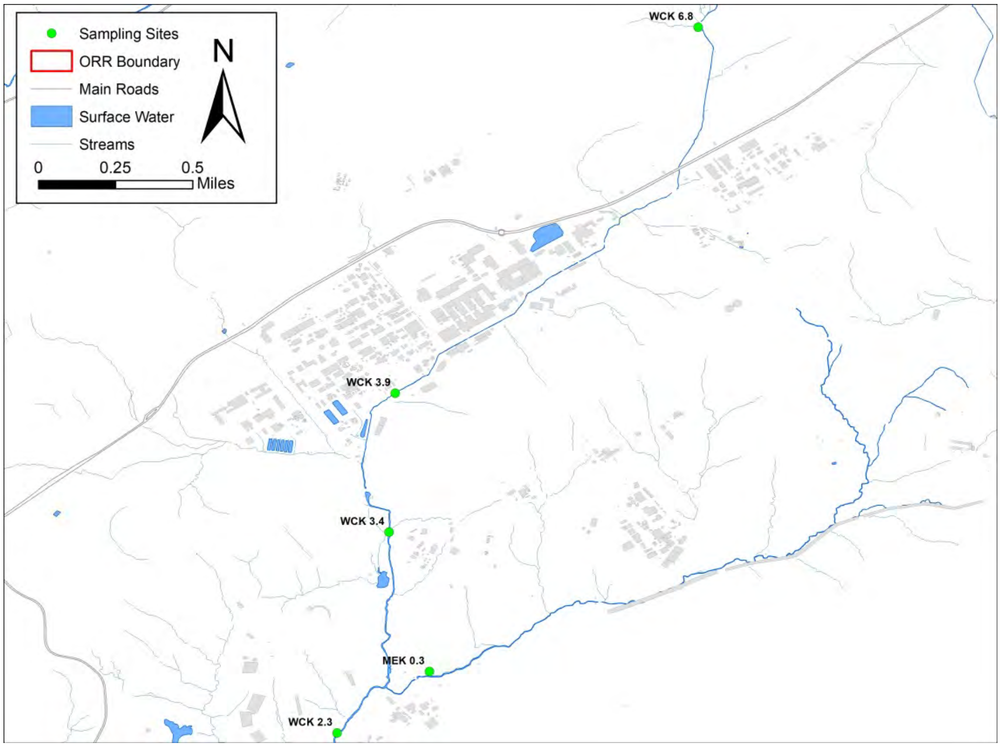


Figure 3.4.5: Benthic Macroinvertebrate Monitoring Sites at ORNL

Data Analysis:

Once sample identifications are complete, the identifications for each sample are totaled for each genus/species and entered into an Excel spreadsheet. The data are then transferred to another Excel spread sheet for calculation of the various metrics used in the analysis. Metrics are then totaled for each sample and comparisons of impacted sites to reference sites are made.

The use of metrics is one way of evaluating the condition of benthic sites. However, use of only these metrics can lead to some erroneous evaluations and/or conclusions. Therefore, further use of the species composition of the sites, as well as the total population size (i.e., number of organisms per m^2) at the sites, is made to help clarify interpretations.

Reference Collection:

Specimens, that are unique to a given site (i.e., have not been found previously at that site; sensitive taxa found at impacted sites), are separately vialed and placed in a reference collection for the project.

Consult the TDEC DOR-Oak Ridge Standard Operating Procedure (Draft) for Benthic Macroinvertebrate Monitoring (TDEC 2018) for details.

3.4.6 Deviations from the Plan

Some of the streams being monitored on the ORR did not meet the conditions necessary for comparison of results to bioregion biocriteria of Tennessee. An alternative reference stream method cited in the *2011 Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2011)* (with some modifications) was used to evaluate the study's results. The primary condition not met was that certain streams in the study were headwater streams (< 2 square miles of drainage area). The description of the alternative reference stream method is provided in Section 1.I, Protocol K: Pages 3 and 4 of the Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2011).

In order to generate a table of values for comparison of reference stations to potentially impacted stream stations, eight metrics were first calculated for all of the reference stations (CCK 1.45, GHK 2.9, HCK 20.6, MBK 1.6, MIK 1.43, and WCK 6.8). Based on the average value of each metric and using the calculations provided in Section 1.I, Protocol K: Pages 3 and 4 of the *Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2011)*, ranges of values for ratings of 6, 4, 2, and 0 for each metric were further determined. The adjusted metric data for the 2017 data is found in Table 3.4.2.

Table 3.4.2: Alternative Reference Stream Metrics

Alternative Reference Stream Metrics				
Metric	**6**	**4**	**2**	**0**
Taxa Richness	>38	25-37	12-24	<12
EPT Richness	>14	9-13	4-8	<4
% EPT - Cheum	>30.61	20.41-30.60	9.80-20.40	<9.80
% OC	<=45.39	45.40-63.59	63.60-81.79	>81.79
NCBI	<=4.99	5.00-6.66	6.70-8.33	>8.33
% Clingers	>26.77	17.85-26.76	8.01-17.84	<8.01
%Tnutol	<=39.43	39.44-59.62	59.63-79.81	>79.82
% Intolerant Taxa	>=15	11-14	8-10	<8

Because some of the streams and stations in the study did not meet the bioregion comparison criteria, modifications were made to procedures in order to differentiate among the benthic communities in the streams. *Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2011)* requires identification of taxa to only the genus-level. Calculations of all metrics for this study were determined using the genus-level identifications.

3.4.7 Results and Analysis

Duplicate Samples and Reference Stations

Table 3.4.3 shows the results from all reference stations in 2018. All reference stations had a Total Metric Index (TMI) score greater then 32, which indicates a supporting, non-impaired stream-bottom community. Benthic macroinvertebrate sampling stations located on the ORR will be compared to these non-impacted streams.

In 2018, duplicate samples were collected from reference stations MBK 1.6 and WCK 6.8. This is done to verify that consistent processing and data analysis are performed across all benthic macroinvertebrate monitoring stations. The 2018 scores (Table 3.4.3) show nearly identical results at both sites with the exception of WCK 6.8, where the number of Intolerant Taxa differs by only one.

Refer to the *Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2011)* for more specifications on Quality Control and Quality Assurance.

Table 3.4.3: Metric Values, Scores, and Biological Condition Ratings for All Reference Stations

2018 RESULTS	**Reference Stations**							
Stream station	**HCK 20.6**		**MIK 1.43**		**GHK 2.9**		**MBK 1.6**	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	41	6	39	6	41	6	57	6
EPT Richness	21	6	9	4	14	6	22	6
% EPT-Cheum	34.83	6	34.44	6	51.81	6	50.23	6
% OC	8.73	6	42.74	6	31.02	6	6.11	6
NCBI	5.34	4	4.79	6	3.55	6	3.20	6
% Clingers	61.46	6	12.45	2	11.75	2	59.45	6
%TNUTOL	47.16	4	9.13	6	9.04	6	11.98	6
Intolerant Taxa	13	4	5	0	12	4	19	6
INDEX SCORE		42		36		42		48
RATING		**A**		**A**		**A**		**A**
Stream station	**MBK 1.6 DUP**		**WCK 6.8**		**WCK 6.8 DUP**			
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE		
Taxa Richness	52	6	46	6	45	6		
EPT Richness	22	6	15	6	17	6		
% EPT-Cheum	54.01	6	46.54	6	51.80	6		
% OC	4.26	6	20.08	6	19.84	6		
NCBI	3.13	6	3.15	6	3.05	6		
% Clingers	57.66	6	40.57	6	41.11	6		
%TNUTOL	11.78	6	6.38	6	5.86	6		
Intolerant Taxa	18	6	14	4	15	6		
INDEX SCORE		48		46		48		
RATING		**A**		**A**		**A**		
Key:	A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20) D = Non Supporting / Severely Impaired (TMI Scores < 10)							

East Fork Poplar Creek

Benthic laboratory results, e.g., metric values, metric scores, overall Tennessee Macroinvertebrate Index (TMI) scores (alternative reference stream method), and biological condition ratings are presented in Table 3.4.4 for the East Fork Poplar Creek (EFK) watershed. Metrics for EFK reference sites are presented in Table 3.4.3. For monitoring purposes, the watershed is herein considered the upper EFK (UEFK) with three sampling stations within Y-12, (EFK 25.1, EFK 24.4, EFK 23.4) (Figure 3.4.1) and lower EFK (LEFK) with two sampling stations (EFK 13.8, EFK 6.3) (Figure 3.4.3). The stream numbers represent distances in kilometers that decrease from headwaters (EFK 25.1) towards the mouth downstream (EFK 0.0). The reference stream for the EFK watershed is Hinds Creek (HCK 20.6). Generally, stream biotic integrity in EFK appeared to be slightly better in the LEFK than in UEFK.

Table 3.4.4: Metric Values, Scores, and Biological Condition Ratings for East Fork Poplar Creek and Reference Station

2018 RESULTS	**East Fork Poplar Creek**											
Stream station	**HCK 20.6**		**EFK 25.1**		**EFK 24.4**		**EFK 23.4**		**EFK 13.8**		**EFK 6.3**	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	41	6	21	2	27	4	40	6	41	6	38	6
EPT Richness	21	6	0	0	3	0	6	2	10	4	7	2
% EPT-Cheum	34.83	6	0.00	0	1.08	0	7.11	0	10.63	2	10.06	2
% OC	8.73	6	87.73	0	86.21	0	58.00	4	38.85	6	37.87	6
NCBI	5.34	4	6.13	4	6.02	4	5.55	4	5.66	4	5.89	4
% Clingers	61.46	6	11.49	2	12.59	2	34.44	6	54.32	6	55.46	6
%TNUTOL	47.16	4	0.00	6	10.31	6	13.56	6	29.18	6	45.85	4
Intolerant Taxa	13	4	1	0	1	0	2	0	5	0	2	0
INDEX SCORE		42		14		16		28		34		30
RATING		**A**		**C**		**C**		**B**		**A**		**B**
Key:	A = Supporting / Non Impaired (TN Macro. Index Scores >= 32)											
	B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31)											
	C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20)											
	D = Non Supporting / Severely Impaired (TMI Scores < 10)											

The East Fork Poplar Creek is one of the streams on the ORR where impacts occur from the headwaters of the stream to a considerable distance downstream in the watershed. The headwaters of the stream originate from tributaries that flow through storm water conduits in the main industrialized portion of Y-12. Downstream, the stream flows through urbanized and suburbanized sections of Oak Ridge before flowing through less developed areas prior to its confluence with Poplar Creek. Near its origin, East Fork Poplar Creek receives inputs of contaminants such as mercury, uranium, volatile organic compounds (VOCs) and other metals and organics. Once leaving the Y-12 boundary, East Fork Poplar Creek receives further contaminant loading from urban and suburban runoff as well as a sewage treatment plant discharge. Only near its mouth does East Fork Poplar Creek flow through relatively undisturbed terrain. Beginning in 2015, no flow augmentation from the Clinch River was provided in East Fork Poplar Creek. Flows in the creek were reduced from years prior to 2014 due to lack of this augmentation. Metrics from 2017 and 2018 benthic sampling are compared to see how the stream has fared since the halting of flow augmentation in May 2014.

In order to determine the condition of the sampling stations in East Fork Poplar Creek, the following series of nine graphs comparing Total Score, Taxa Richness, EPT Richness, %EPT-Cheum, %OC, NCBI , %Clingers, %TNUTOL, and Intolerant Taxa for the years 2017 and 2018 are provided (Figures. 3.4.6-3.4.14). Table 3.4.5 defines these eight metrics. Values for the impacted stations in East Fork Poplar Creek and its corresponding reference station HCK 20.6 are given in Table 3.4.4. Their discussion follows the figures below.

Table 3.4.5: Description of Metrics and Expected Responses to Stressors

Description of Metrics and Expected Responses to stressors			
Category	**Metric**	**Description**	**Response to stress**
Richness Metrics	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 in sample that display a tolerance rating of < 3.0	Number Decreases
Composition Metrics	% EPT - Cheum	% of ETP abundance excluding Cheumatopsyche taxa	% Decreases
	% OC	% of Oligochaetes and Chironomids present in sample	% Increases
Tolerance Metrics	NCBI	North Carolina Biotic Index which incorporates richness and abundance with a numerical rating of tolerance	Number Increases
	% Total Nutrient Tolerance	% of Organism present in sample that are considered tolerant of nutrients	% Increases
Habitat Metric	% Clingers	% of macroinvertebrates present in sample w/ fixed retreats or attach themselves to substrates	% Decreases

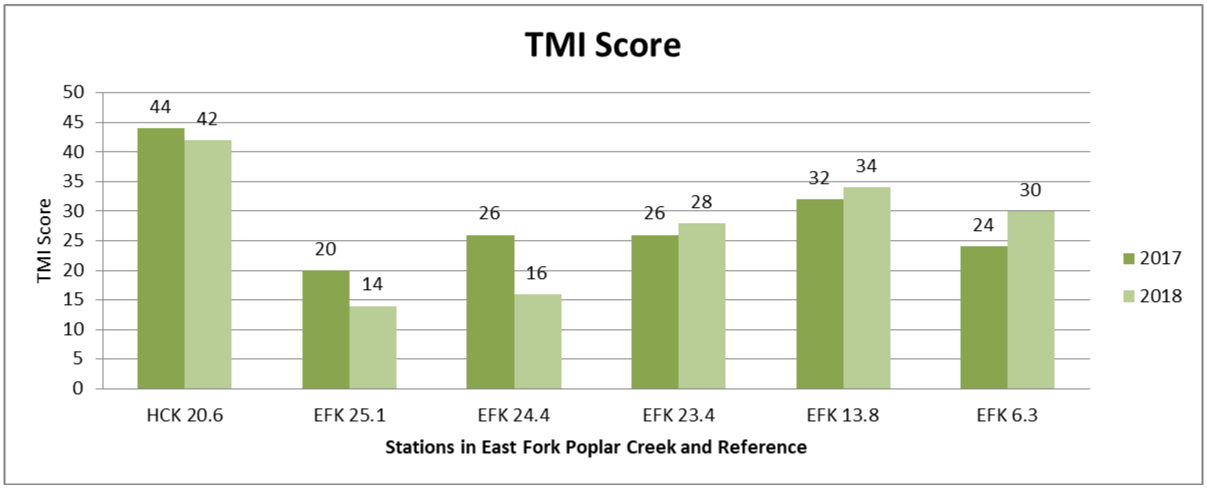


Figure 3.4.6: Total Scores East Fork Poplar Creek 2017 vs. 2018

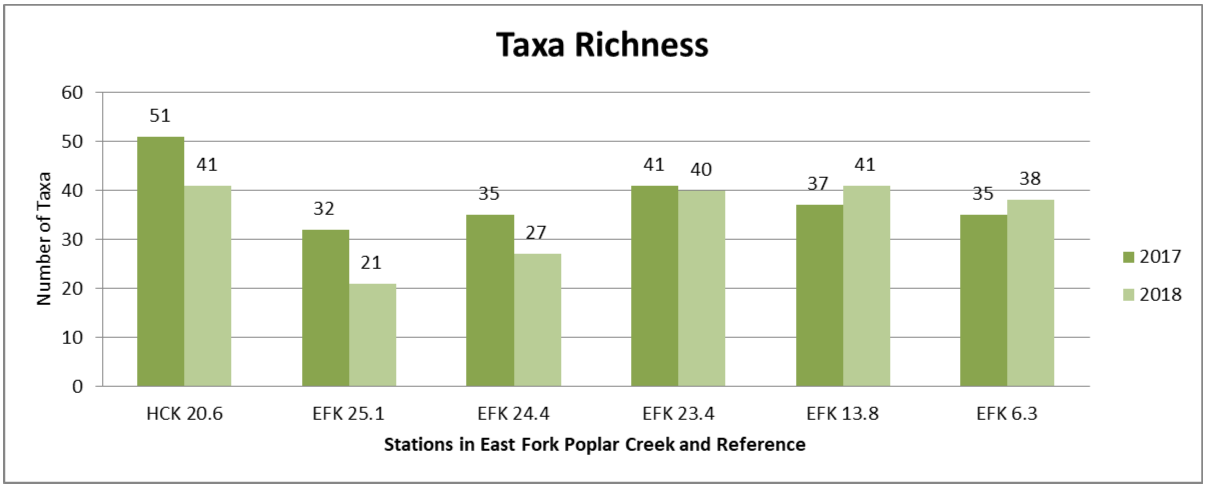


Figure 3.4.7: Taxa Richness East Fork Poplar Creek 2017 vs. 2018

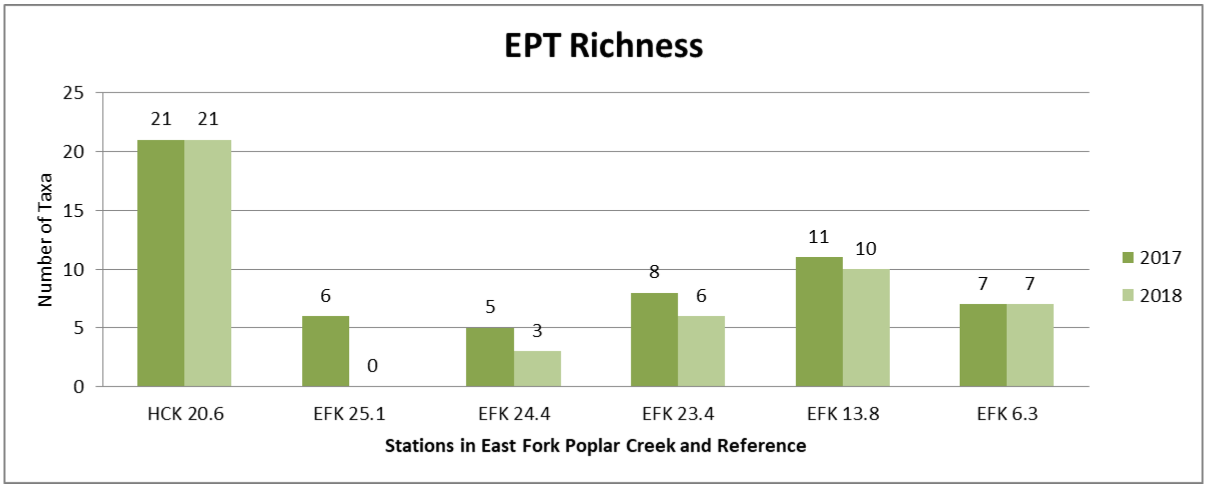


Figure 3.4.8: EPT Richness East Fork Poplar Creek 2017 vs. 2018

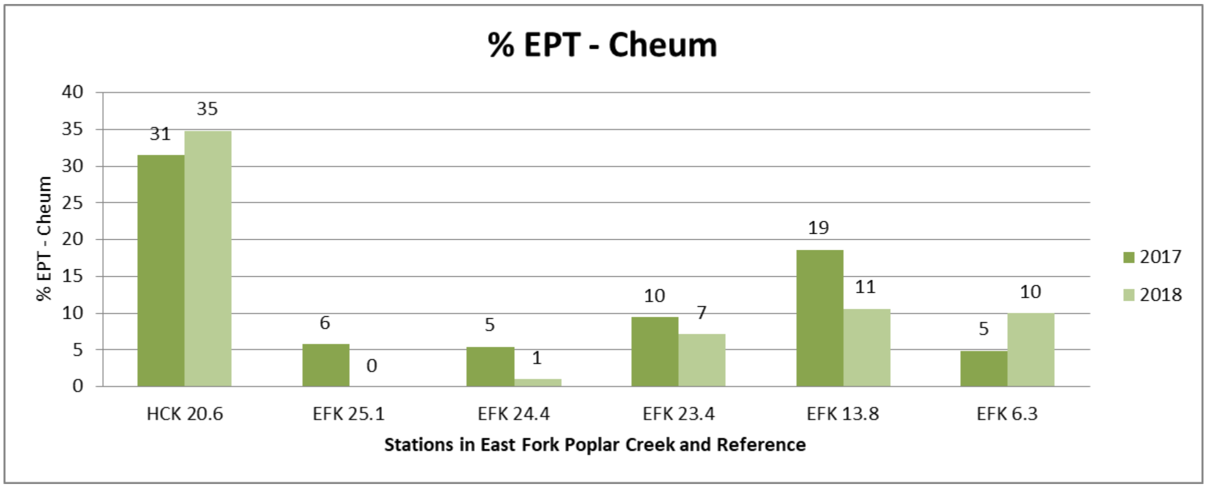


Figure 3.4.9: % EPT-Cheum East Fork Poplar Creek 2017 VS. 2018

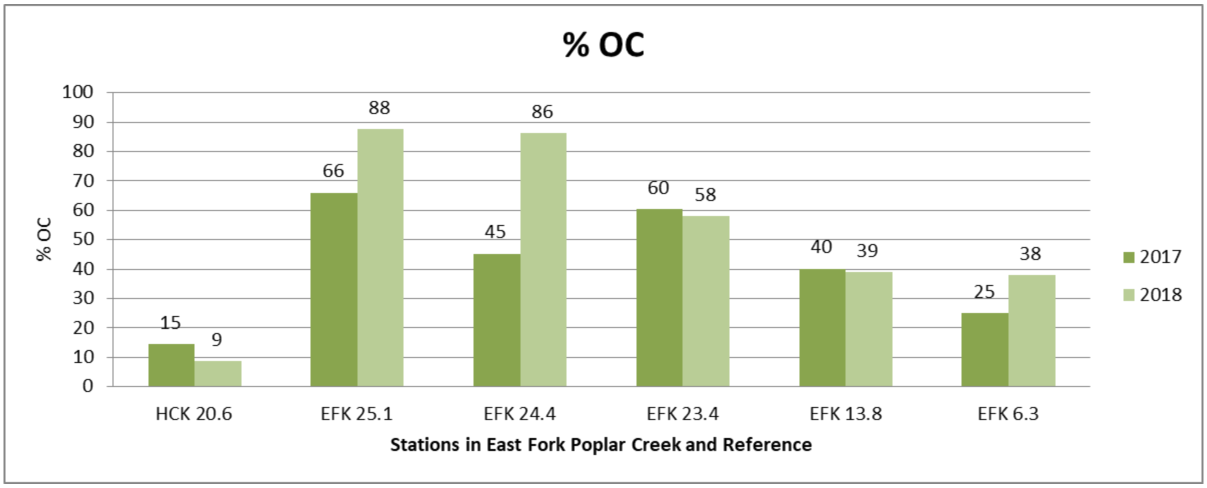


Figure 3.4.10: % OC East Fork Poplar Creek 2017 VS. 2018

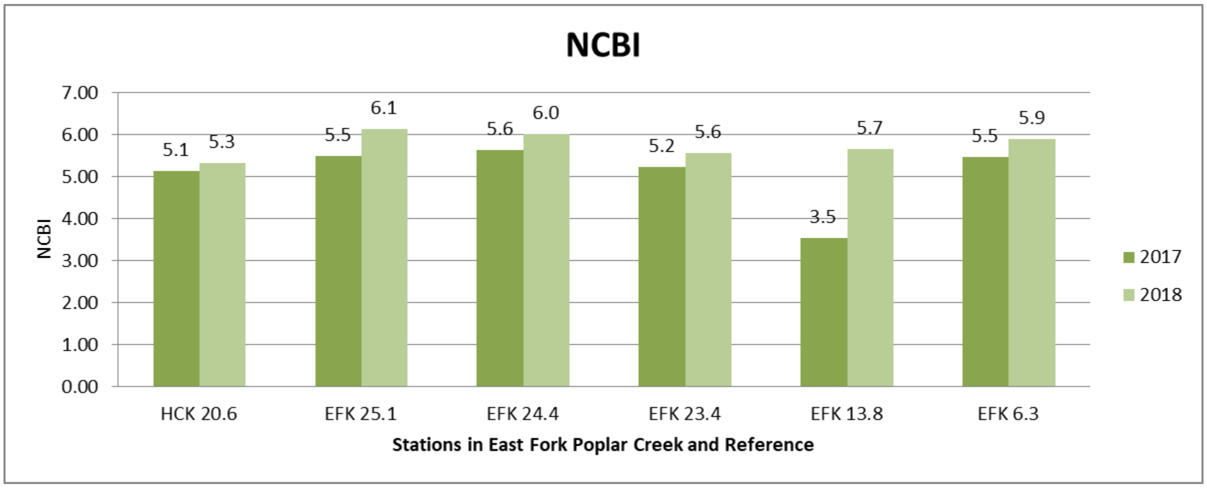


Figure 3.4.11: NCBI East Fork Poplar Creek 2017 VS. 2018

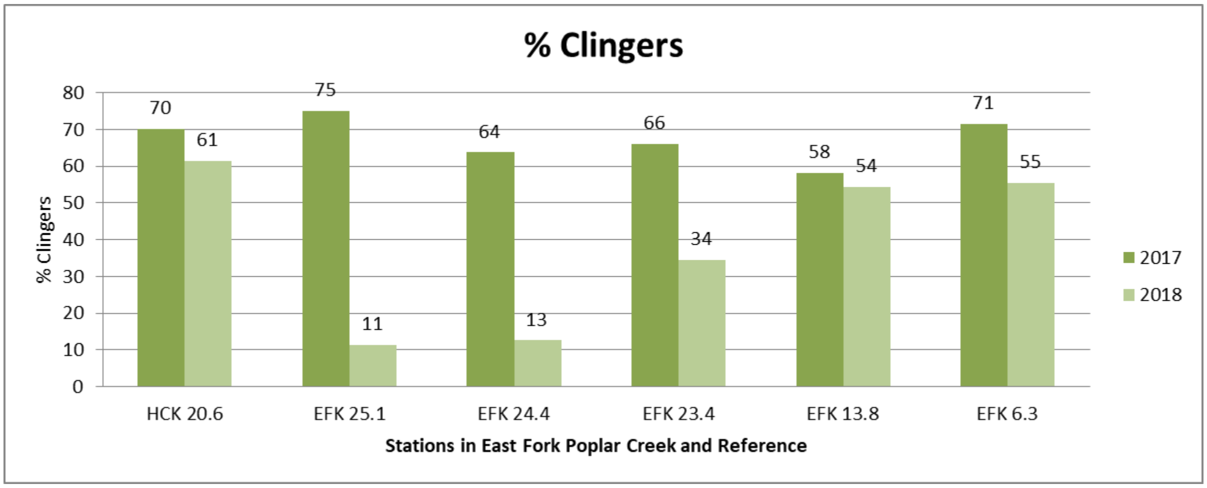


Figure 3.4.12: % Clingers East Fork Poplar Creek 2017 VS. 2018

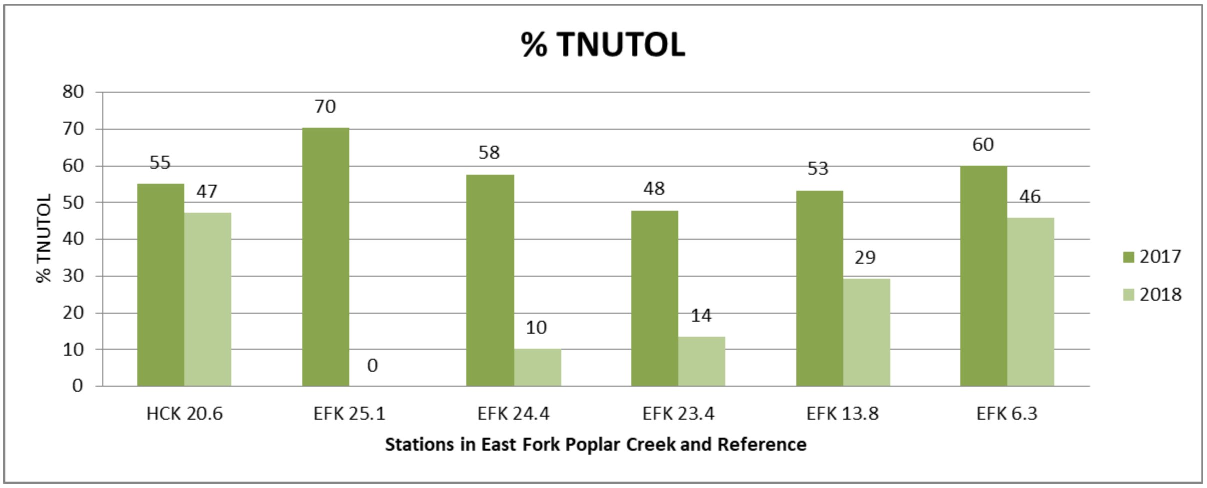


Figure 3.4.13: % TNUTOL East Fork Poplar Creek 2017 VS. 2018

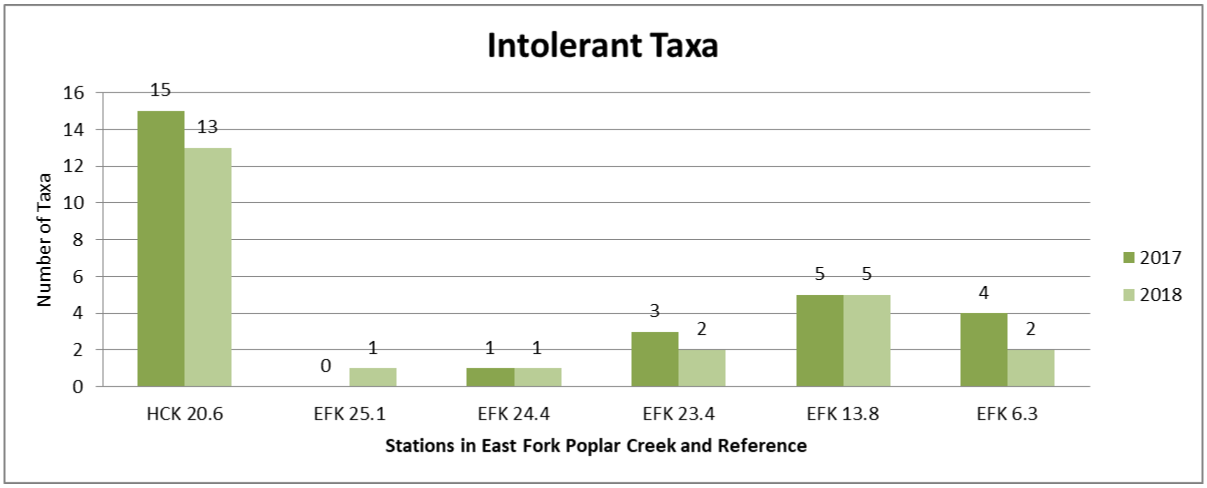


Figure 3.4.14: Intolerant Taxa East Fork Poplar Creek 2017 VS. 2018

Figure 3.4.6 compares the TMI Total Score results for the reference site HCK 20.6 with the five sampling stations in East Fork Poplar Creek for both 2017 and 2018. The score for the reference station HCK 20.6 exceeds those for all stations of East Fork Poplar Creek with only EFK 13.8 approaching the score of the controls in both 2017 and 2018. The metric Taxa Richness (Figure 3.4.7) shows that the reference station displayed a comparable number of Total Taxa to the East Fork Poplar Creek stations. In 2018, EFK 23.4 and EFK 13.8 Taxa Richness measured similarly to the HCK 20.6 reference station. The 2018 data shows a downward trend in taxa richness in the upper reaches of East Fork Poplar Creek and an upward trend in taxa richness in the lower reaches of the creek compared to 2017. EPT Richness (Figure 3.4.8) shows a distinct difference between the reference stations and the East Fork Poplar Creek stations with the best East Fork Poplar Creek station (EFK 13.8) possessing approximately half as many EPT as HCK 20.6 in both 2017 and 2018. No EPT were collected at EFK 25.1 in 2018. The data shows the number of EPT taxa increasing in a downstream direction. EPT richness for all stations on East Fork Poplar Creek decreased between 2017 and 2018 with the exception of EFK 6.3 which remained the same.

The % EPT-Cheumatopsyche (Cheum) (Figure 3.4.9) shows a decrease throughout the stations of East Fork Poplar Creek (EFK 25.1, EFK 24.4, EFK 23.4, and EFK 13.8) during 2018 compared to 2017; however, this metric shows an increase at its lowest station (EFK 6.3). The value for this metric is considerably lower at all East Fork Poplar Creek stations compared to reference stream. HCK 20.6 measures nearly three times higher than any other station on East Fork Poplar Creek. The % OC (percent Oligochaeta and Chironomidae) metric (Figure 3.4.10) shows a distinction between the reference stations and all stations in East Fork Poplar Creek. All East Fork Poplar Creek sites display a higher proportion of oligochaetes and midges in 2018 compared to 2017 and especially compared to its reference site HCK 20.6. This is often a sign of degrading conditions. The metric for NCBI (Figure 3.4.11) does not distinguish clearly between the reference station and East Fork Poplar Creek. Hinds Creek flows through an agricultural area which may influence why the reference station HCK 20.6 does not obviously differ from those of the East Fork Poplar Creek stations. The same may be said of the % TNUTOL data (Figure 3.4.13) with Hinds Creek more closely comparing with East Fork Poplar Creek Stations. The East Fork Poplar Creek stations show a clear trend in the 2018 data with the % TNUTOL increasing in a downstream direction (the upper stations showing a lesser impact). This trend is not as clear in the 2017 data. The % Clingers (Figure 3.4.12) metric also fails to distinguish between the reference streams and impacted sites with Hinds Creek being more similar to the results for East Fork Poplar Creek Stations.

A comparison of the number of Intolerant Taxa between reference and impacted streams (Figure 3.4.14) shows a dramatic difference with impacted stations displaying appreciably fewer sensitive taxa. Both the 2017 and 2018 data shows a gradual increase in the number of sensitive taxa in a downstream direction in East Fork Poplar Creek.

Although East Fork Poplar Creek has shown improvement over the time since the 1980s when sampling initially began, improvements have leveled off somewhat in the past few years with estimated conditions fluctuating from year to year (sometimes slightly better, sometimes slightly worse). Current conditions in upper East Fork Poplar Creek may well reflect the increased remedial activities at Y-12 National Security Complex.

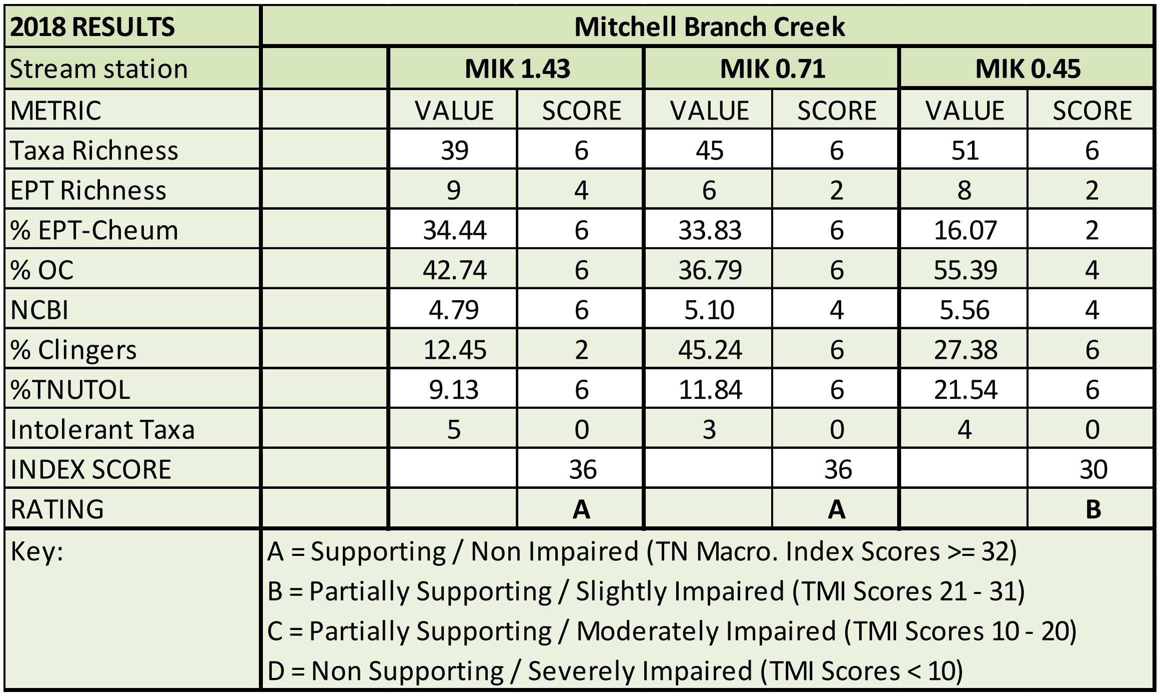
Mitchell Branch

Mitchell Branch is a small headwater tributary to Poplar Creek at the ETTP. The highest upstream station, which serves as the reference station (MIK 1.43), does not meet the criteria for rating, according to the bioregion concept, due to the size of the watershed above it (<two square miles). Because of the small upstream watershed and variable flow conditions depending on annual rainfall, MIK 1.43 does not always provide a clear picture of the

impacted condition of the downstream stations (MIK 0.71 and MIK 0.45). Historically, MIK 1.43 has been relatively unimpacted by the presence of ETTP. The lower stations (MIK 0.71 and MIK 0.45) have been impacted not only from former industrial activities at ETTP and waste areas but have also been channelized with much of the channel being replaced with unnatural substrate.

In order to determine the condition of the sampling stations in Mitchell Branch, the following series of nine graphs comparing Total Score, Taxa Richness, EPT Richness, % EPT-Cheum, % OC, NCBI , % Clingers, % TNUTOL, and Intolerant Taxa have been provided (Figures 3.4.15–3.4.23). Metric data for all stations, including the reference station (MIK 1.43), are found in Table 3.4.6. The discussion of the data follows the table and figures below.

Table 3.4.6: Metric Values, Scores, and Biological Condition Ratings for Mitchell Branch



2018 RESULTS	**Mitchell Branch Creek**						
Stream station		**MIK 1.43**		**MIK 0.71**		**MIK 0.45**	
METRIC		VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness		39	6	45	6	51	6
EPT Richness		9	4	6	2	8	2
% EPT-Cheum		34.44	6	33.83	6	16.07	2
% OC		42.74	6	36.79	6	55.39	4
NCBI		4.79	6	5.10	4	5.56	4
% Clingers		12.45	2	45.24	6	27.38	6
%TNUTOL		9.13	6	11.84	6	21.54	6
Intolerant Taxa		5	0	3	0	4	0
INDEX SCORE			36		36		30
RATING			**A**		**A**		**B**
Key:	A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20) D = Non Supporting / Severely Impaired (TMI Scores < 10)						

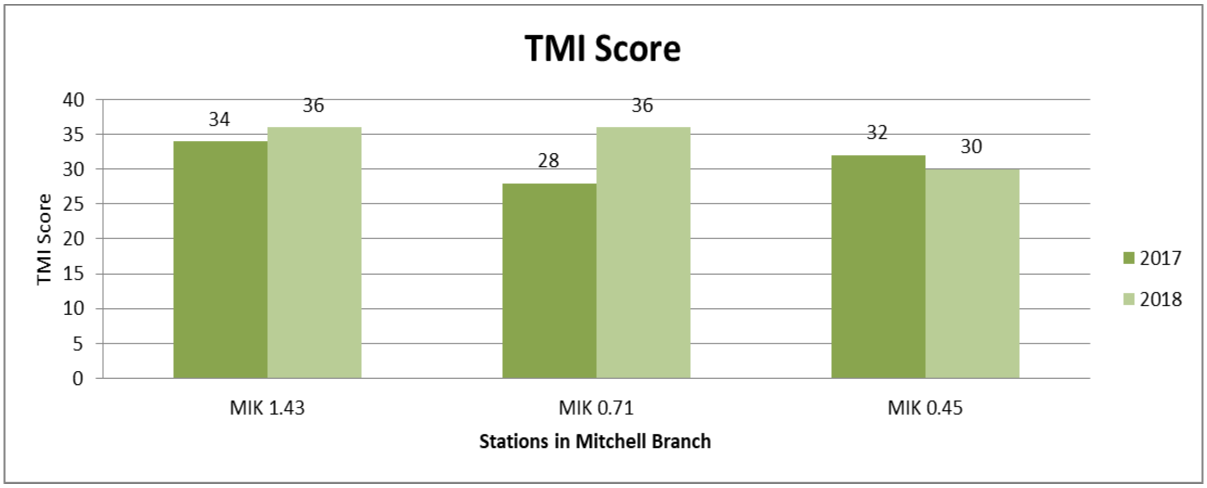


Figure 3.4.15: Total Score Mitchell Branch

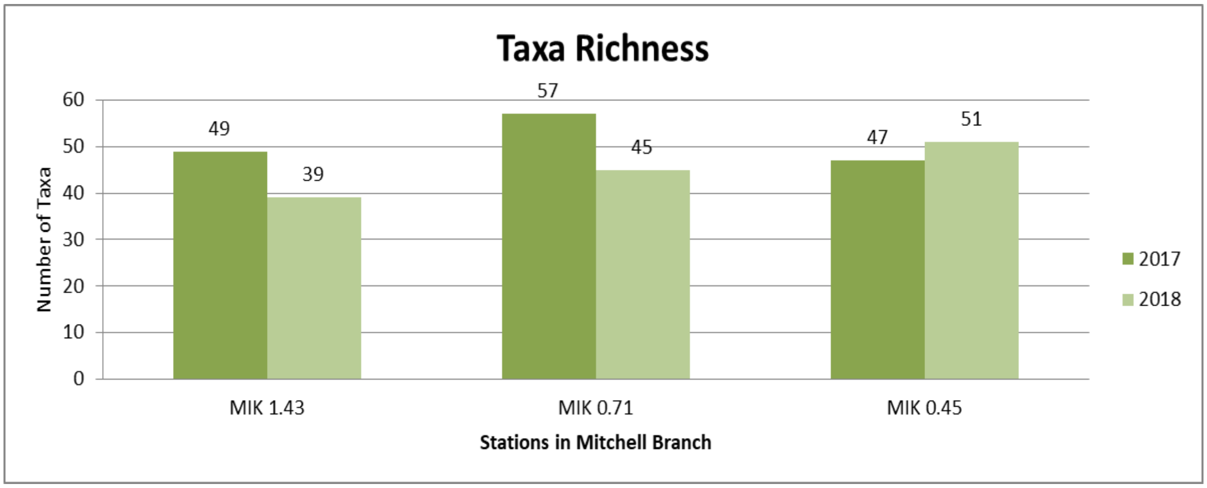


Figure 3.4.16: Taxa Richness Mitchell Branch

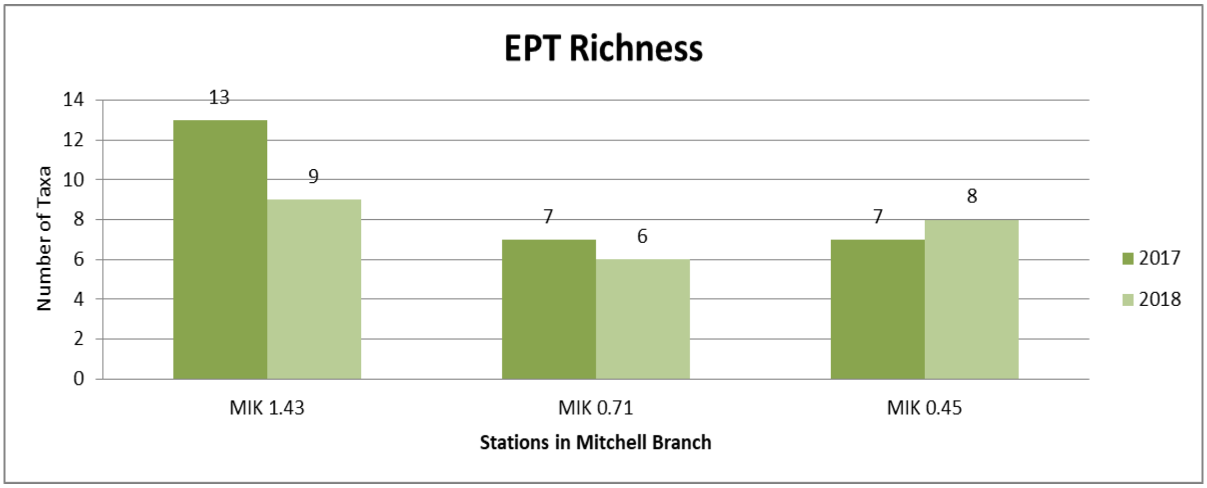


Figure 3.4.17: EPT Richness Mitchell Branch

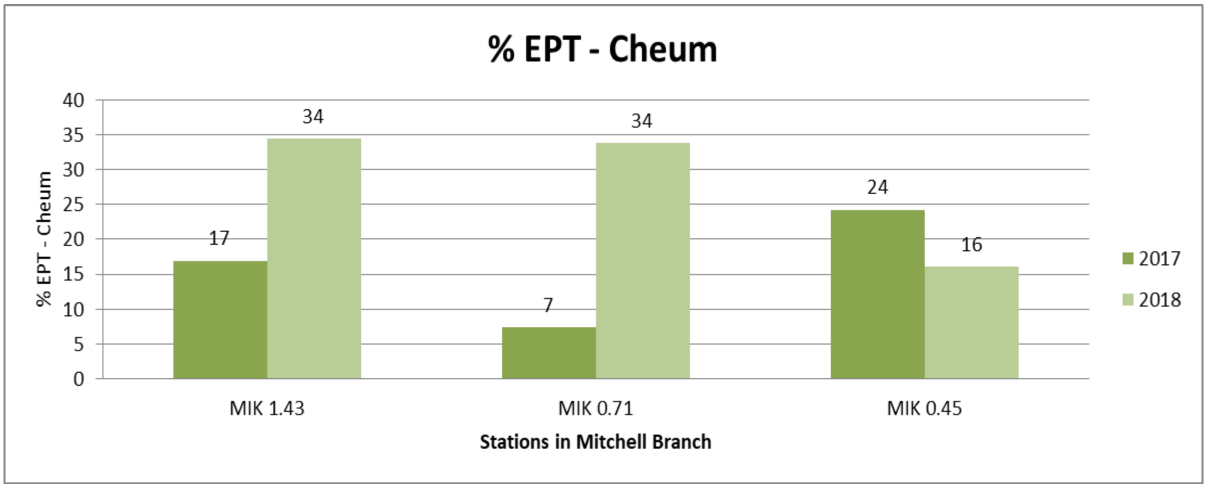


Figure 3.4.18: % EPT - Cheum Mitchell Branch

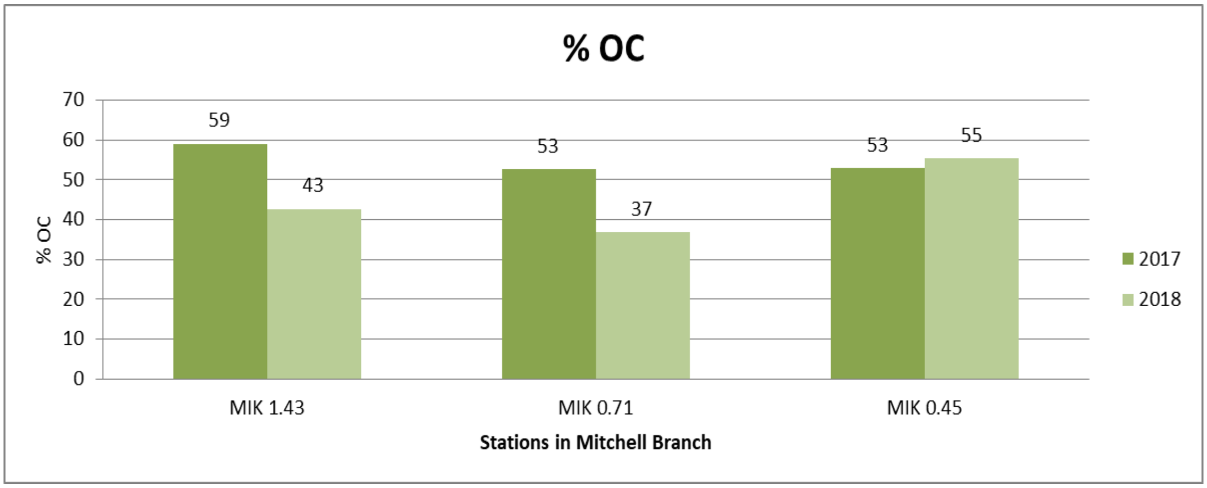


Figure 3.4.19: % OC Mitchell Branch

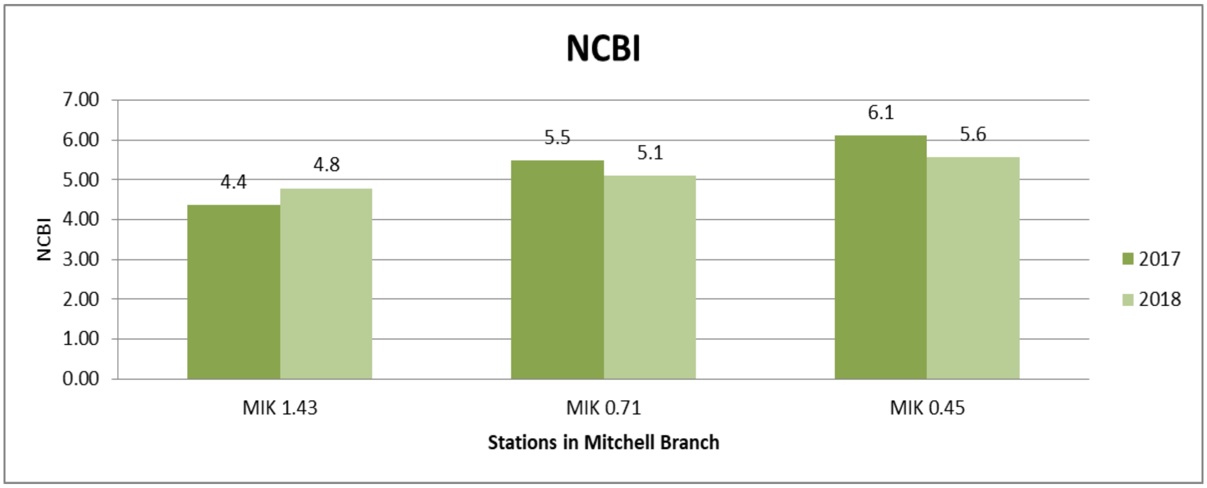


Figure 3.4.20: NCBI Mitchell Branch

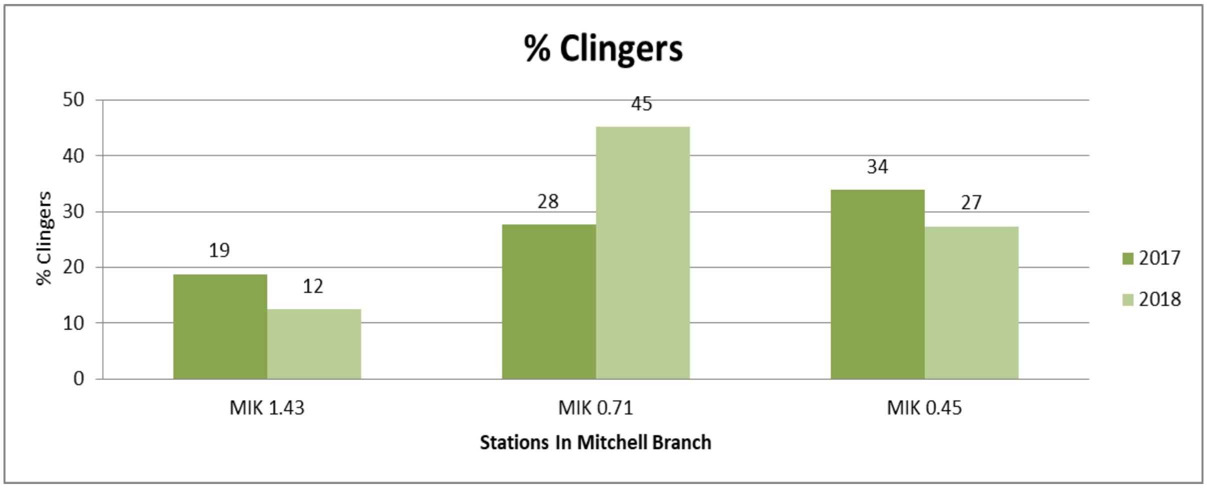


Figure 3.4.21: % Clingers Mitchell Branch

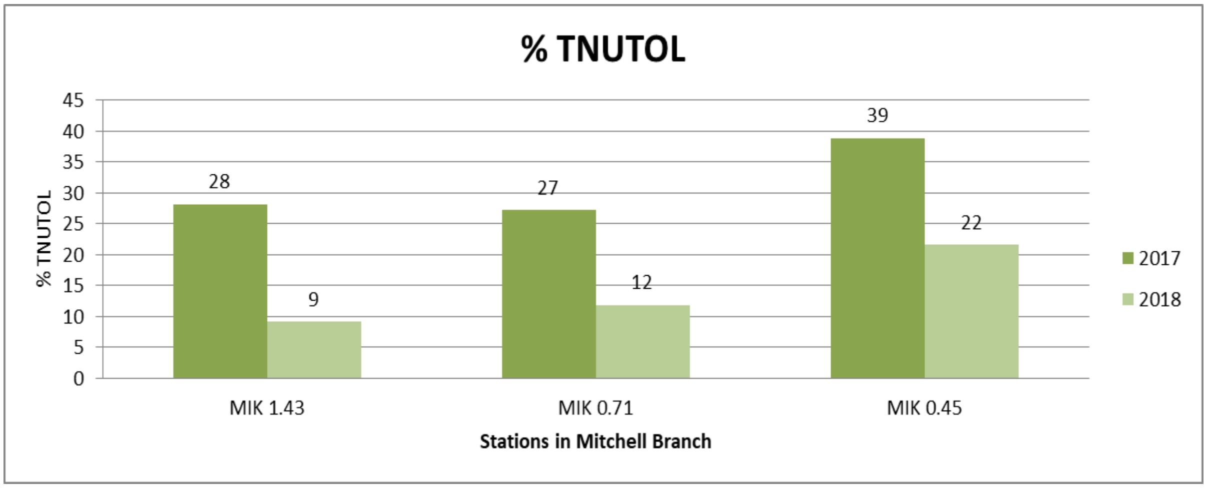


Figure 3.4.22: % TNUTOL Mitchell Branch

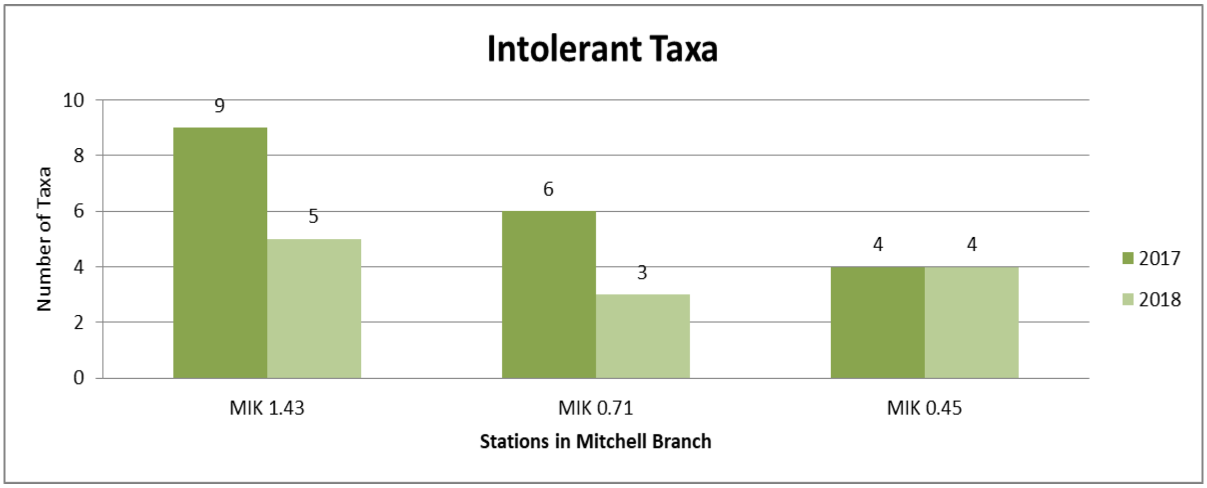


Figure 3.4.23: Intolerant Taxa Mitchell Branch

Neither the 2017 nor 2018 Total Score metric data (Figure 3.4.15) show appreciable differences between MIK 1.43 (reference station) and the lower two impacted Mitchell Branch stations (MIK 0.71 and MIK 0.45). The total scores for 2018 are higher for stations MIK 1.43 and 0.71 and slightly lower for station MIK 0.45 compared to 2017. The Taxa Richness data for both 2017 and 2018 (Figure 3.4.16) also does not provide a clear difference between unimpacted and impacted stations. However, the 2018 data show a slight increase in Taxa Richness in a downstream direction. This trend is not apparent in the 2017 data. EPT Richness (Figure 3.4.17) does not show an apparent trend in 2018, with all sites performing similarly. The EPT Richness at MIK 1.43 decreases from 2017 to 2018.

The 2018 % EPT-Cheum (Figure 3.4.18) shows more stressed conditions at the farthest downstream station in Mitchell Branch (MIK 0.45). Both MIK 1.43 and MIK 0.71 had a significant positive increase in the % EPT-Cheum from 2017 to 2018, increasing by 17% and 27%, respectively. Similarly, the % OC 2018 data (Figure 3.4.19) are indicative of somewhat more stressful conditions at MIK 0.45. Both MIK 1.43 and MIK 0.71 show a decrease in the % OC. Stress is shown by the more tolerant EPT community at these stations as well as the higher proportion of chironomid midges and oligochaetes (worms).

The NCBI Scores for both 2017 and 2018 (biotic integrity) are better (i.e., lower) at MIK 1.43 than at MIK 0.71 and MIK 0.45 (Figure 3.4.20), indicating a somewhat healthier community at the reference station. The % Clingers metric (Figure 3.4.21) is higher at the impacted stations than at MIK 1.43 for both the 2017 and 2018 data. This does not agree with expected conditions as, generally, a greater proportion of Clingers is indicative of better health of the community. The 2017 and 2018 % TNUTOL metric (Figure 3.4.22) increases in a downstream direction and shows a decrease in the % TNUTOL at all sites in Mitchell Branch. Typically, a higher proportion of nutrient tolerant organisms at a site are indicative of a less healthy community.

Based on the majority of metrics, the lower stations of Mitchell Branch appear to be moderately improving in condition. Over time, the substrate (stream bottom) is becoming more natural at the lower stations (MIK 0.71 and MIK 0.45) of Mitchell Branch allowing a more diverse community to inhabit those stations. Further improvements in substrate as well as water quality improvements due to remedial activities should allow Mitchell Branch to continue to slowly improve. Perhaps more significant than these improvements is the apparent slow degradation of the upstream portions of Mitchell Branch. Siltation, in particular, appears to be having a negative impact on the health of MIK 1.43. The proposed construction of an airport at the site may cause further degradation of that station.

Bear Creek

Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Scores increase considerably from BCK 12.3 (with a score of 24) downstream to BCK 9.6 (with a score of 34). 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 (at its headwaters), continue to negatively influence the water quality of the stream. Heading downstream from its source, Bear Creek continues to be impacted by inputs from various former and current waste sites. Bear Creek is also a stream where shallow groundwater and surface waters mingle freely throughout its length to its confluence with East Fork Poplar Creek. Because Bear Creek is impacted from its headwaters, two small tributaries to East Fork Poplar Creek are utilized as its references (Mill Branch, MBK 1.6; and Gum Hollow Branch, GHK 2.9).

In order to determine the condition of the sampling stations in Bear Creek, the following series of nine graphs comparing Total Score, Taxa Richness, EPT Richness, % EPT-Cheum, % OC, NCBI , % Clingers, % TNUTOL, and Intolerant Taxa have been provided (Figures 3.4.24 – 3.4.32). Metric data for all Bear Creek stations may be found in Table 3.4.7. Table 3.4.7 also contains metric data for the two reference stations (GHK 2.9 and MBK 1.6). The discussion of the data follows the table and figures below.

Table 3.4.7: Metric Values, Scores, and Biological Condition Ratings for Bear Creek

2018 RESULTS	**BEAR CREEK**									
Stream station	**GHK 2.9**		**MBK 1.6**		**BCK 12.3**		**BCK 9.6**		**BCK 3.3**	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	41	6	57	6	33	4	46	6	47	6
EPT Richness	14	6	22	6	7	2	19	6	22	6
% EPT-Cheum	51.81	6	50.23	6	11.46	2	20.11	2	44.60	6
% OC	31.02	6	6.11	6	9.03	6	0.62	6	9.25	6
NCBI	3.55	6	3.20	6	7.21	2	5.66	4	3.80	6
% Clingers	11.75	2	59.45	6	10.07	2	45.28	6	59.49	6
%TNUTOL	9.04	6	11.98	6	77.78	2	4.63	6	14.51	6
Intolerant Taxa	12	4	19	6	3	0	9	2	9	2
INDEX SCORE		42		48		20		38		44
RATING		**A**		**A**		**C**		**A**		**A**
Key:	A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20) D = Non Supporting / Severely Impaired (TMI Scores < 10)									

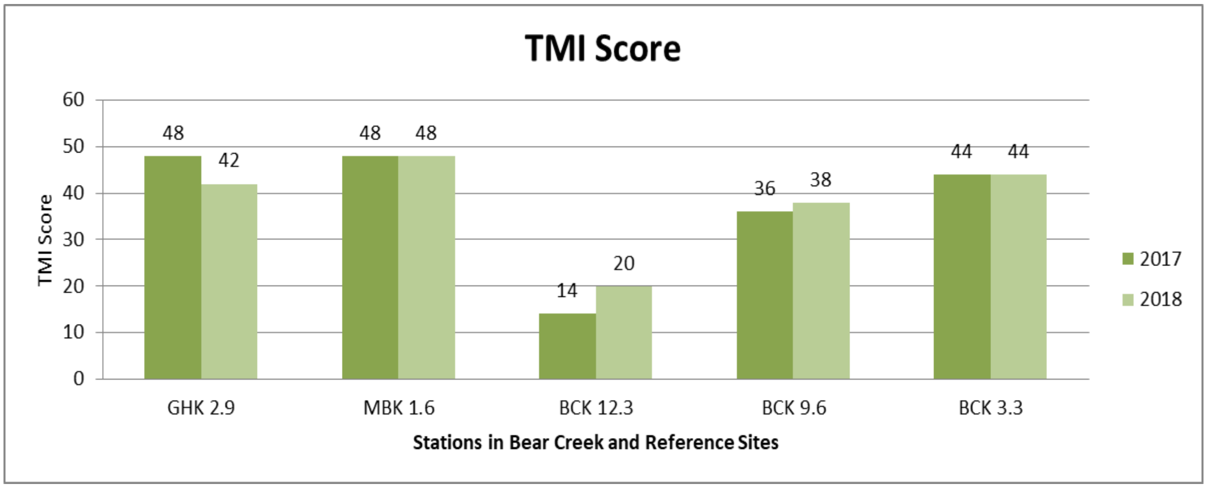


Figure 3.4.24: Total Score Bear Creek

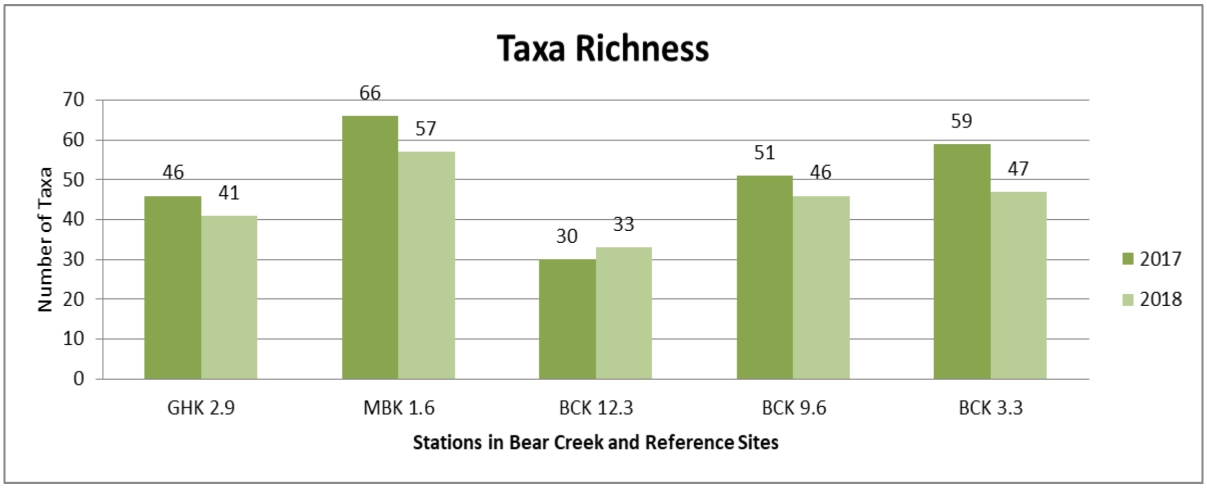


Figure 3.4.25: Taxa Richness Bear Creek

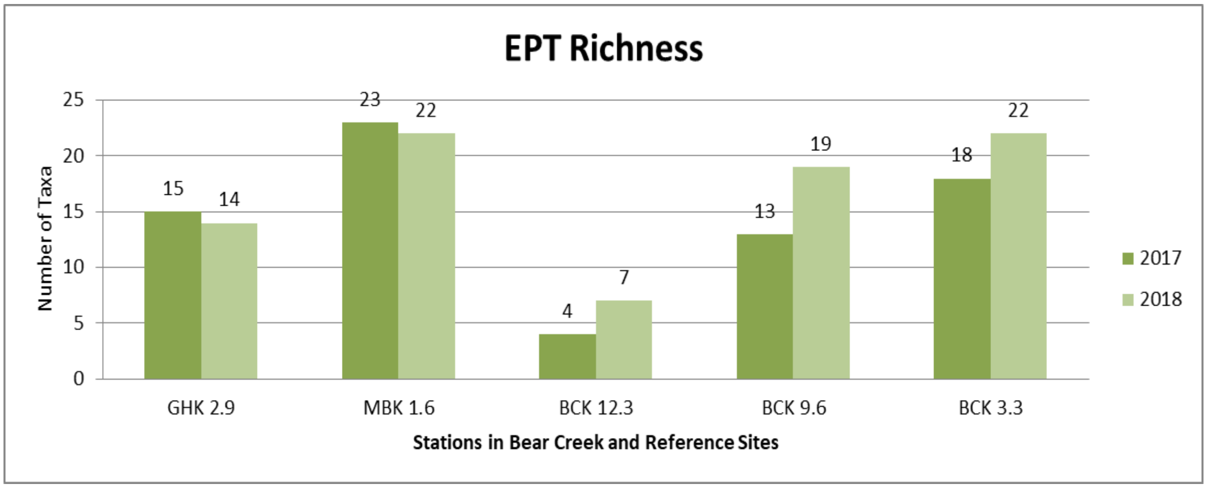


Figure 3.4.26: EPT Richness Bear Creek

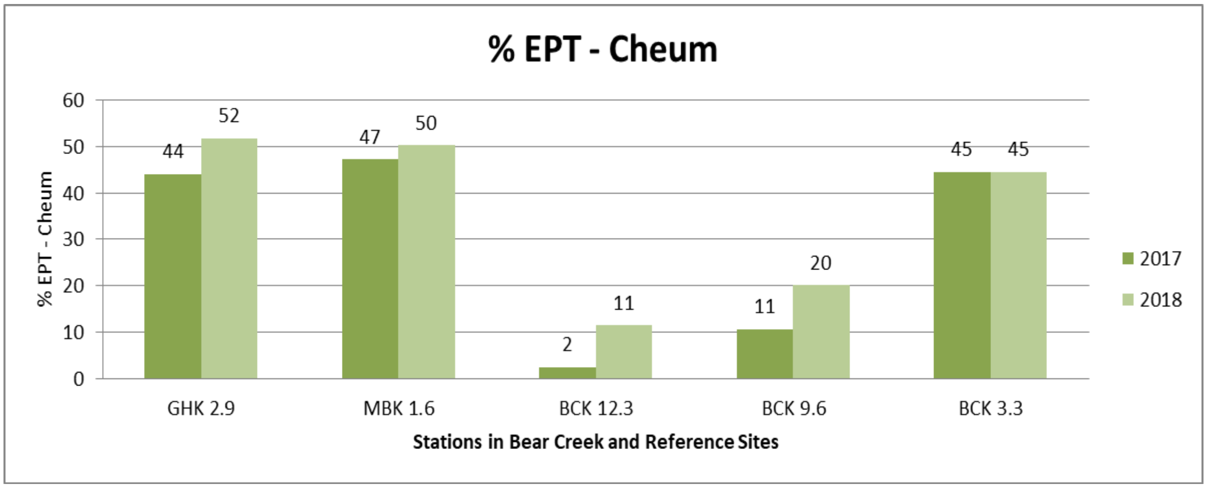


Figure 3.4.27: % EPT-Cheum Bear Creek

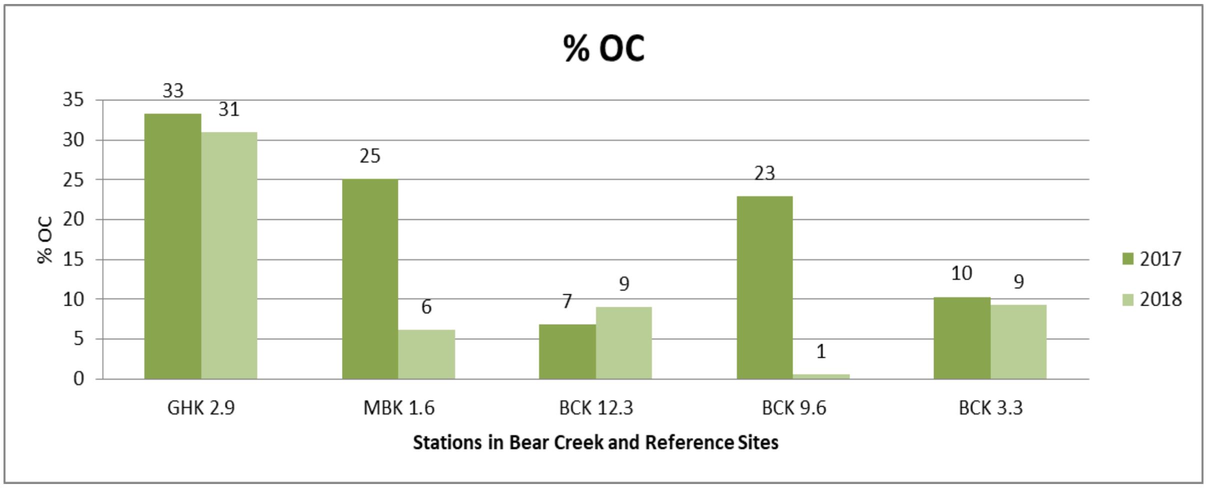


Figure 3.4.28: % OC Bear Creek

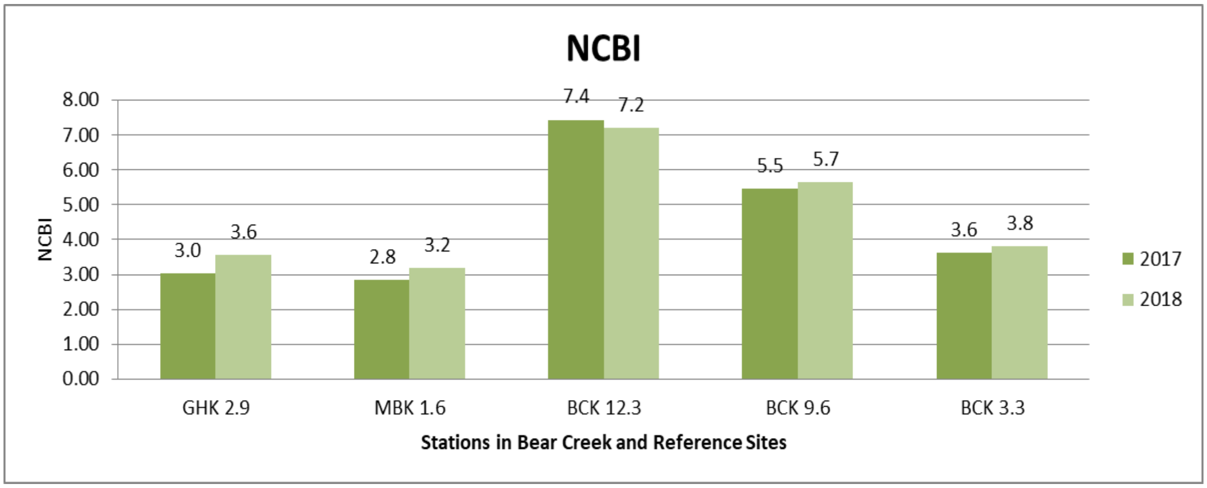


Figure 3.4.29: NCBI Bear Creek

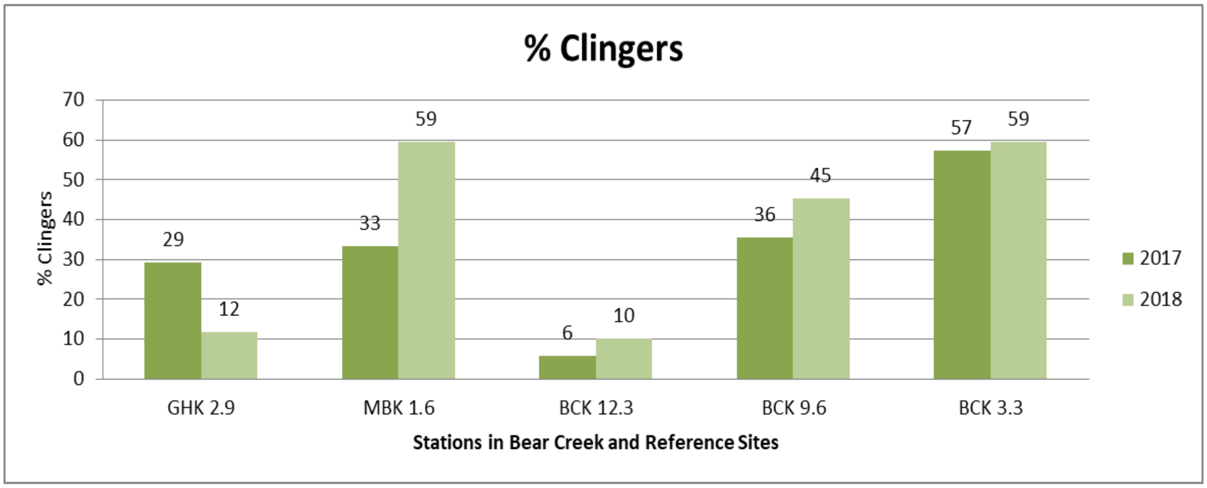


Figure 3.4.30: % Clingers Bear Creek

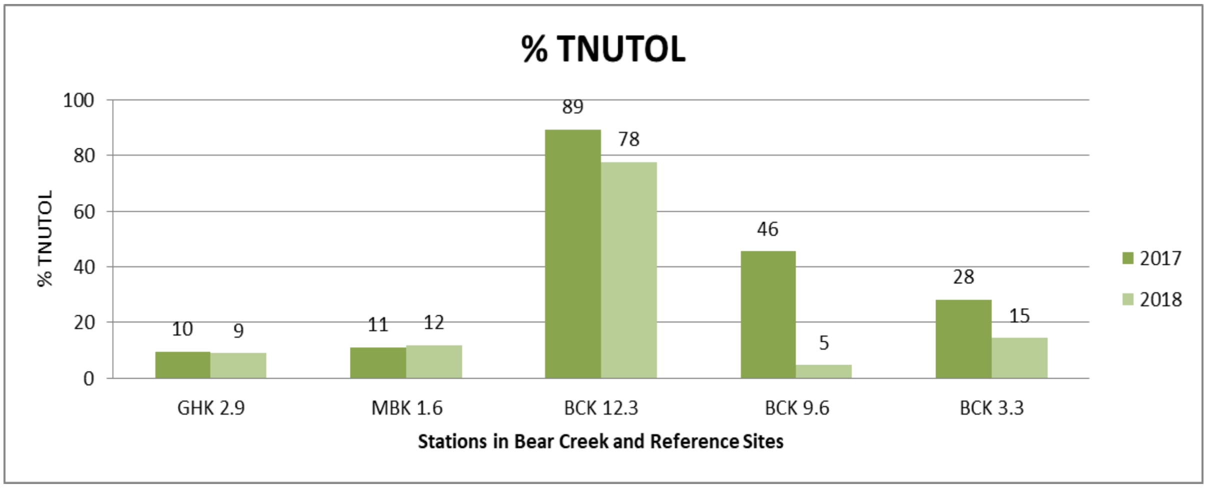


Figure 3.4.31: % TNUTOL Bear Creek

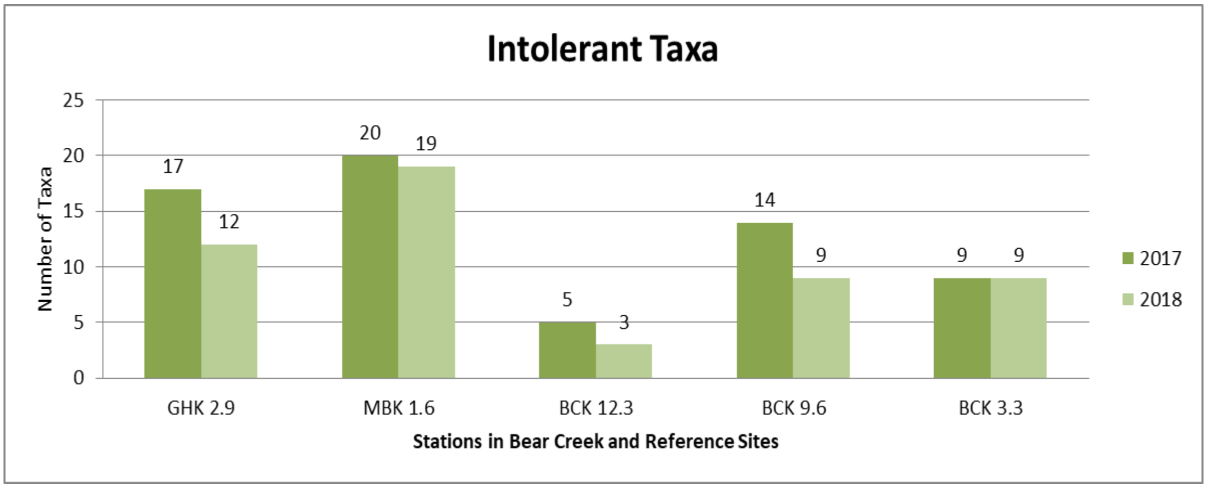


Figure 3.4.32: Intolerant Taxa Bear Creek

Bear Creek 12.3 displays a reduced benthic macroinvertebrate community, although BCK 12.3 was at one time the station in this study with the lowest TMI score. Its score has been steadily increasing and now ranks above two stations in upper East Fork Poplar Creek (EFK 25.1 and EFK 23.4).

TMI Scores for the reference stations (MBK 1.6 and GHK 2.9) are similar for both 2017 and 2018 (Figure 3.4.24). TMI Scores for Bear Creek stations BCK 12.3, BCK 9.6, and BCK 3.3 are lowest at the upstream station (BCK 12.3) and highest at the most downstream station (BCK 3.3) for both 2017 and 2018. The TMI Scores for 2018 at both BCK 12.3 and BCK 9.6 are higher than the 2017 values. Scores for BCK 9.6 and BCK 3.3 approach or equal values expected for reference sites for both 2017 and 2018 data. In 2018 Taxa Richness values for reference stream MBK 1.6 exceeded those of all Bear Creek stations (Figure 3.4.25). In 2018 the Taxa Richness for GHK 2.9 was comparable to both BCK 9.6 and BCK 3.3 but exceeded that for BCK 12.3.

EPT Richness (Figure 3.4.26) shows a similar pattern to Taxa Richness with MBK 1.6 having higher values than Bear Creek stations BCK 12.3 and BCK 9.6. In 2018, BCK 3.3 had an increase in EPT Richness comparable to reference station MBK 1.6. In 2016 all reference station values exceeded those of Bear Creek stations. The % EPT-Cheum values for reference stations far exceeded those for BCK 12.3 and BCK 9.6 in both 2017 and 2018 (Figure 3.4.27) but were similar to the results for BCK 3.3 in both years. The % OC metric data (Figure 3.4.28) does not show a distinct trend for the 2018 data. Impacted sites are expected to have higher proportions of oligochaetes worms and chironomidae (midges). The data does not support that assumption. NCBI values (Figure 3.4.29) align with expectations in both 2017 and 2018 with reference sites having lower values than both BCK 12.3 and BCK 9.6. BCK 3.3 had NCBI values similar to the reference values in both years. The % Clingers metric (Figure 3.4.30) shows a consistent trend, with the percent of clingers increasing father downstream. There was an increase in the percent of clingers at all sites with the exception of reference station GHK 2.9 from 2017 to 2018. One would expect the reference stations to have higher % Clingers values than the impacted stations.

The % TNUTOL metric shows a distinct difference between reference and impacted stations (Figure 3.4.31). Impacted stations are typically expected to be more nutrient enriched than the reference stations. The Intolerant Taxa metric (Figure 3.4.32) also meets expectations with reference sites far exceeding impacted sites in numbers of Intolerant Taxa.

Bear Creek 12.3 continues to receive inputs from industry and former and current waste sites. In addition, remedial work and its resulting disturbance have occurred in the vicinity of BCK 12.3. Historically, BCK 12.3 has lacked adequate substrate for colonization by many aquatic organisms. The watershed upstream of BCK 12.3 is limited in size, thus affecting the amount of flow at the station, particularly in the summer. Also, BCK 12.3 suffers from a paucity of aquatic macroinvertebrate refuges in its vicinity from which recolonization of the station can occur. Despite all these negatives, a few sensitive taxa are still hanging on, though not flourishing.

BCK 9.6 continues to be at least maintaining itself if not improving. This station compares well with the two reference stations (GHK 2.9 and MBK 1.6) in a number of the metrics. With a TMI score of 38 (36 in 2017) (Figure 3.4.24; Table 3.4.7), BCK 9.6 lags only slightly behind GHK 2.9 and MBK 1.6 (Figure 3.4.24; Table 3.4.7). BCK 3.3 compares most closely to the reference stations in a number of metrics. The TMI Score for both 2017 and 2018 matched those of the reference stations (Figure. 3.4.24).

MBK 1.6 is one of the higher scoring reference stations being used in this study. With a TMI score of 48 (Table 3.4.7; Figure 3.4.24), MBK 1.6 scored a maximum ranking on all of the metrics calculated for 2017 and 2018. This stream appears to have high diversity and little organic loading. Historically, GHK 2.9 has scored similarly to MBK 1.6 and was also regarded as one of the healthiest stations used in this study. However, in recent years some road work in the vicinity of GHK 2.9 has caused an increase in sediment loading. This may be one factor affecting its decreased TMI score. If not corrected, this could be deleterious to the health of this station. Consideration is being made to remove this reference site if it continues to decline.

White Oak Creek and Melton Branch

The TMI Total Scores (Figure 3.4.33) for the White Oak Creek watershed are highest for the upstream reference site (WCK 6.8) and for the site on Melton Branch, a tributary to White Oak Creek in Melton Valley (MEK 0.3). Scores for stations in lower White Oak Creek (WCK 3.9, WCK 3.4, and WCK 2.3) are lower, indicating some degree of impairment.

White Oak Creek is the main drainage for the majority of ORNL’s disturbed areas. As such, it flows from its headwaters near the Spallation Neutron Source and through the main plant area in Bethel Valley, then passing into Melton Valley, flowing through the Solid Waste Storage Areas and entering White Oak Lake before exiting the reservation through White

Oak Embayment and flowing into the Clinch River. The reference station (WCK 6.8) is in the headwaters fed by several springs just below SNS. Station WCK 3.9 is located in the main plant area in Bethel Valley, with both WCK 3.4 and WCK 2.3 located in the SWSAs in Melton Valley. Melton Branch drains the eastern portion of Melton Valley with the sampling station MEK 0.3 being located near the High Flux Isotope Reactor facility. Before the development of SNS, WCK 6.8 was relatively unimpacted. The construction of SNS resulted in some sediment inputs into White Oak Creek, but the negative impacts caused by that sedimentation have since dissipated. WCK 3.9 is located on the south side of the ORNL complex and downstream of Fifth Creek, which receives inputs from a large part of the main campus of ORNL. This station at one time was impacted heavily by discharges, spills, and former waste sites. WCK 3.4 is located on the north side of the SWSAs soon after White Oak Creek passes over into Melton Valley. WCK 3.4 receives inputs from the main portion of White Oak Creek as well as inputs from First Creek. WCK 2.3 is on the south side of the SWSAs and receives added impact from the SWSAs. MEK 0.3, located near HFIR, historically received impacts from HFIR as well as other facilities in the area. Parts of Melton Branch have also been channelized.

Traditionally, all samples were collected in the field, preserved in ethanol, and returned to the TDEC laboratory for processing; however, processing samples in the TDEC lab left TDEC with radioactive sediments to be properly disposed. In 2015, the decision was made to process White Oak Creek contaminated sites (WCK 3.9, WCK 3.4, WCK 2.3, and MEK 0.3) in the field to avoid having to return sediments to the laboratory. During 2017, all contaminated sites were processed in the field removing all organisms and returning the sediments to the site of their origin. The complete sorts done in the field were later identified in the TDEC laboratory.

In order to determine the condition of the sampling stations in White Oak Creek and Melton Branch, the following series of nine graphs comparing Total Score, Taxa Richness, EPT Richness, % EPT-Cheum, % OC, NCBI , % Clingers, % TNUTOL, and Intolerant Taxa have been provided (Figure 3.4.33-3.4.41). Metric data for all White Oak Creek stations and Melton Branch may be found in Table 3.4.8. The discussion of the data follows the table and figures below.

Table 3.4.8: Metric Values, Scores, and Biological Condition Ratings for White Oak Creek and Melton Branch

2018 RESULTS	**White Oak Creek and Melton Branch**									
Stream station	**WCK 6.8**		**WCK 3.9**		**WCK 3.4**		**WCK 2.3**		**MEK 0.3**	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	46	6	26	4	28	4	32	4	53	6
EPT Richness	15	6	2	0	4	2	8	2	17	6
% EPT-Cheum	46.54	6	2.33	0	1.10	0	22.71	4	12.64	2
% OC	20.08	6	25.58	4	11.71	6	12.61	6	5.08	6
NCBI	3.15	6	5.27	4	5.21	4	4.86	6	4.88	6
% Clingers	40.57	6	63.37	6	85.67	6	64.45	6	75.73	6
%TNUTOL	6.38	6	29.07	6	59.37	4	37.61	6	49.21	4
Intolerant Taxa	14	4	3	0	3	0	2	0	9	2
INDEX SCORE		46		24		26		34		38
RATING		**A**		**B**		**B**		**A**		**A**
Key:	A = Supporting / Non Impaired (TN Macro. Index Scores >= 32) B = Partially Supporting / Slightly Impaired (TMI Scores 21 - 31) C = Partially Supporting / Moderately Impaired (TMI Scores 10 - 20) D = Non Supporting / Severely Impaired (TMI Scores < 10)									

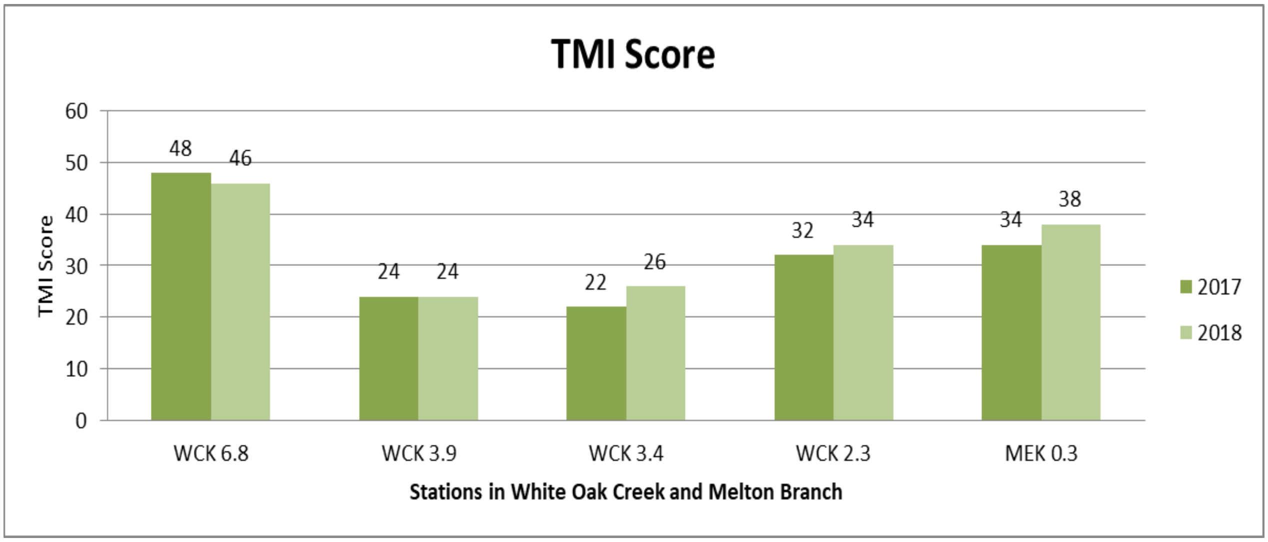


Figure 3.4.33: Metric Values, Scores, and Biological Condition Ratings for White Oak Creek and Melton Branch

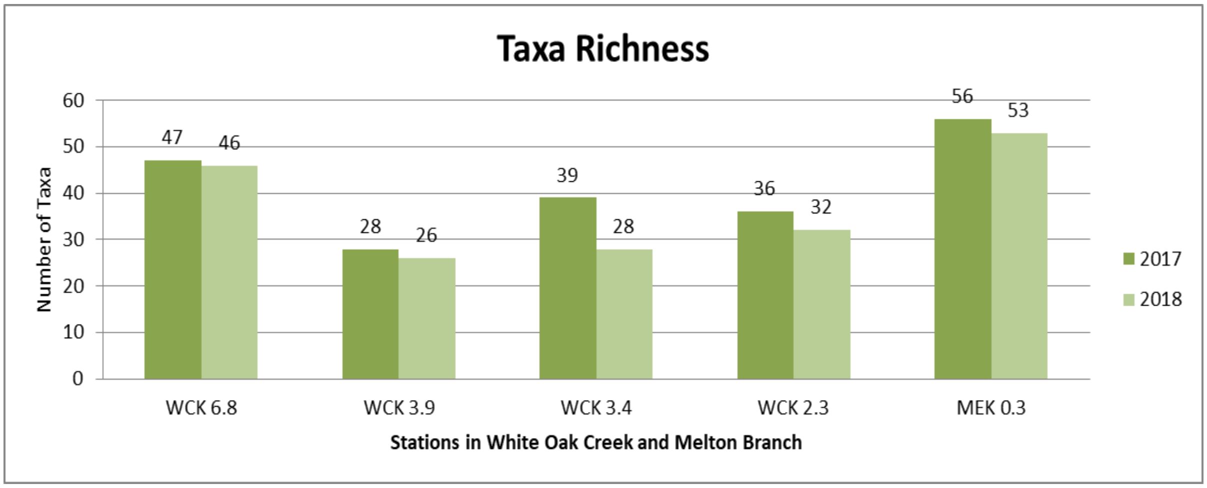


Figure 3.4.34: Taxa Richness for White Oak Creek and Melton Branch

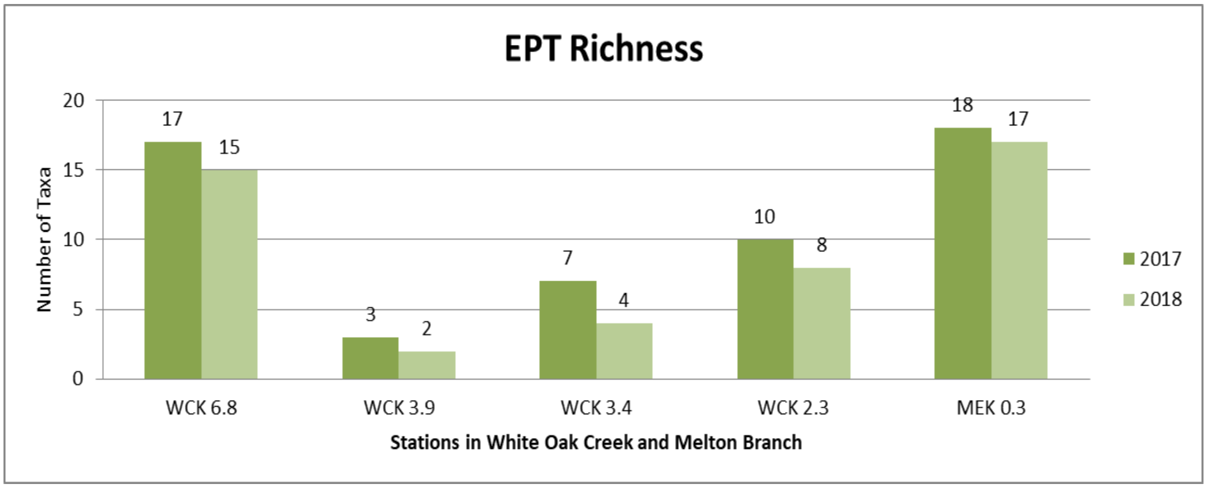


Figure 3.4.35: EPT Richness for White Oak Creek and Melton Branch

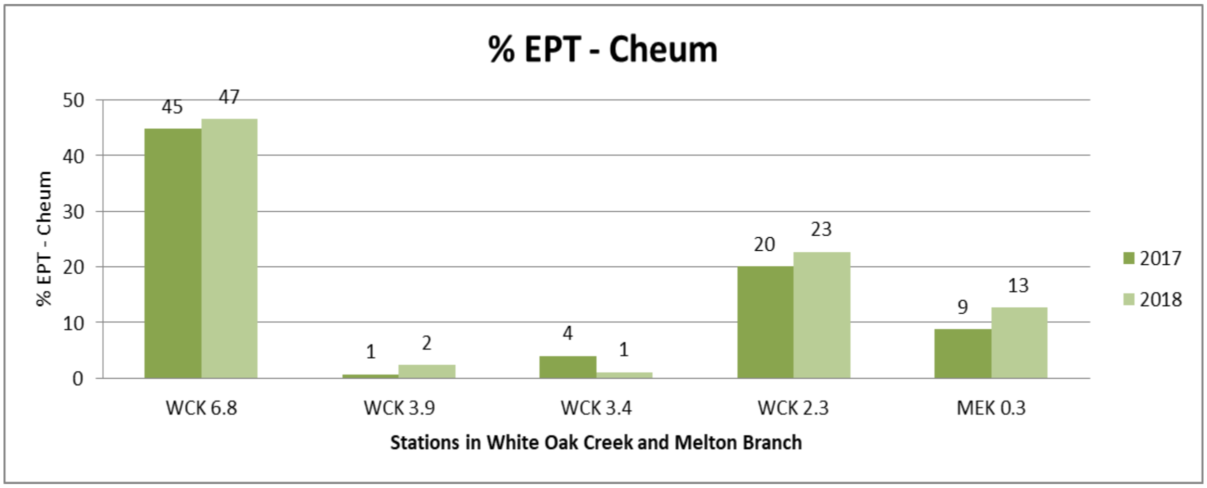


Figure 3.4.36: % EPT-Cheum for White Oak Creek and Melton Branch

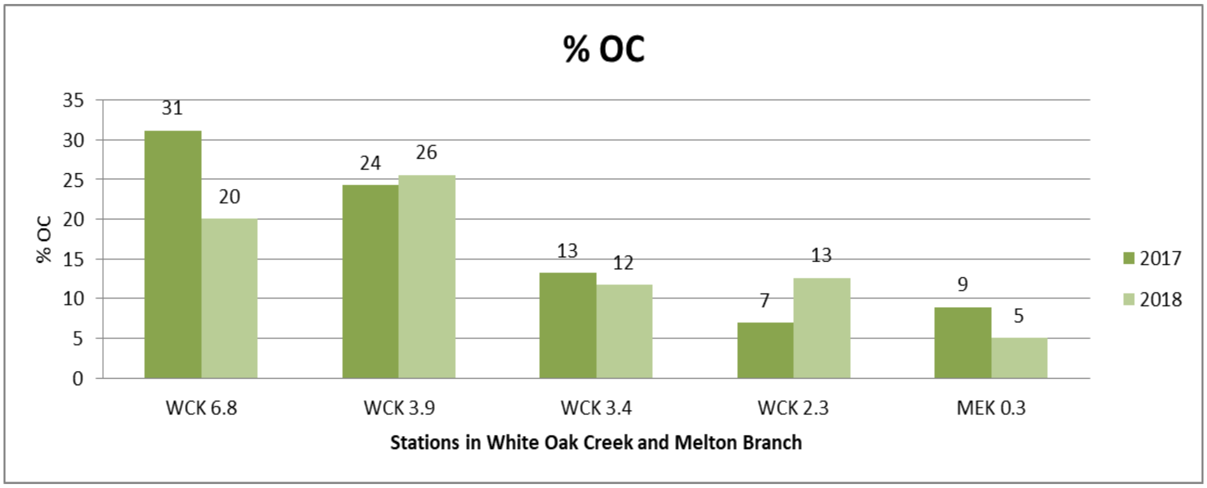


Figure 3.4.37: % OC White Oak Creek and Melton Branch

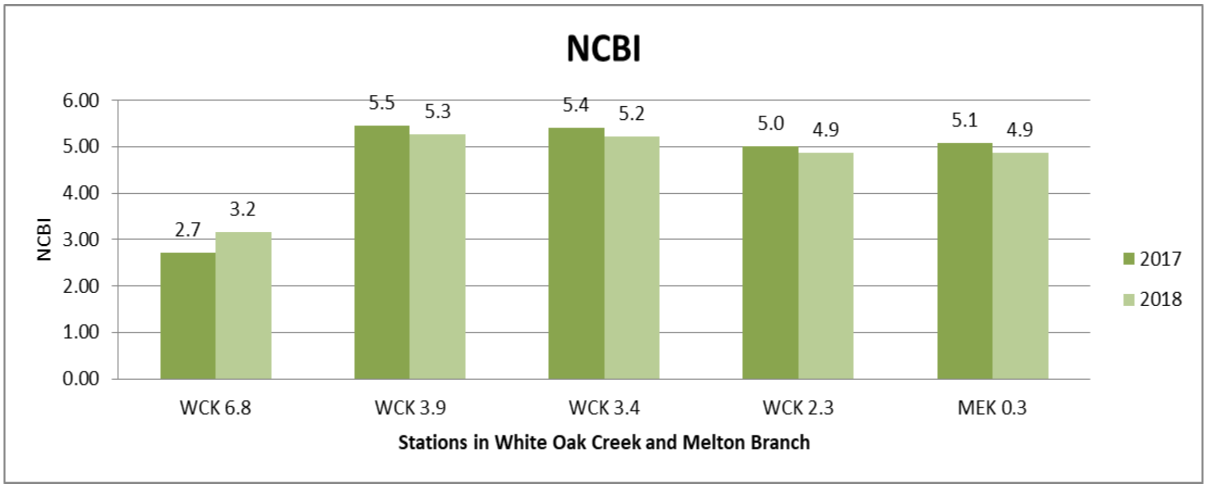


Figure 3.4.38: NCBI Score for White Oak Creek and Melton Branch

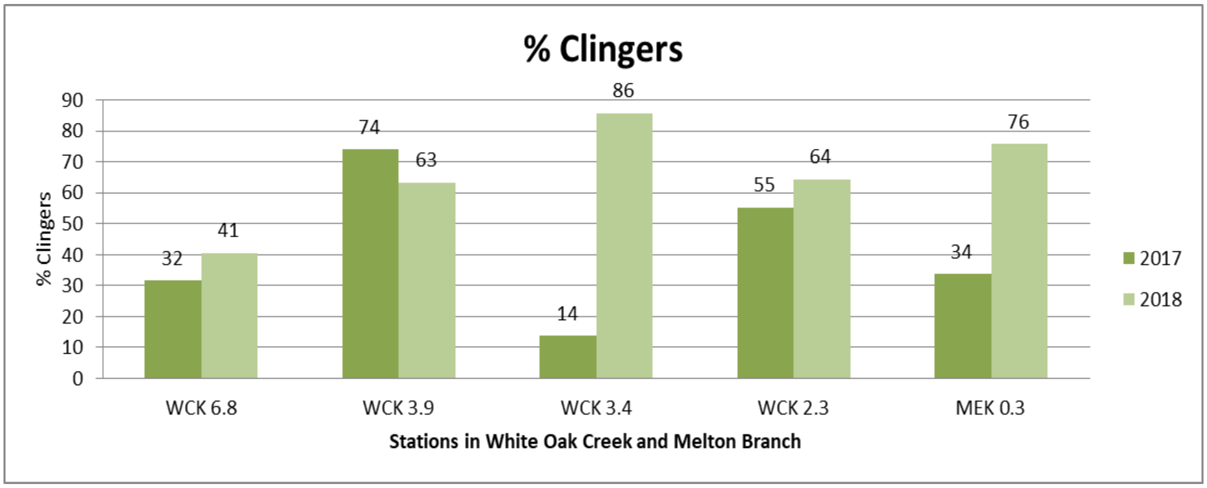


Figure 3.4.39: % Clingers for White Oak Creek and Melton Branch

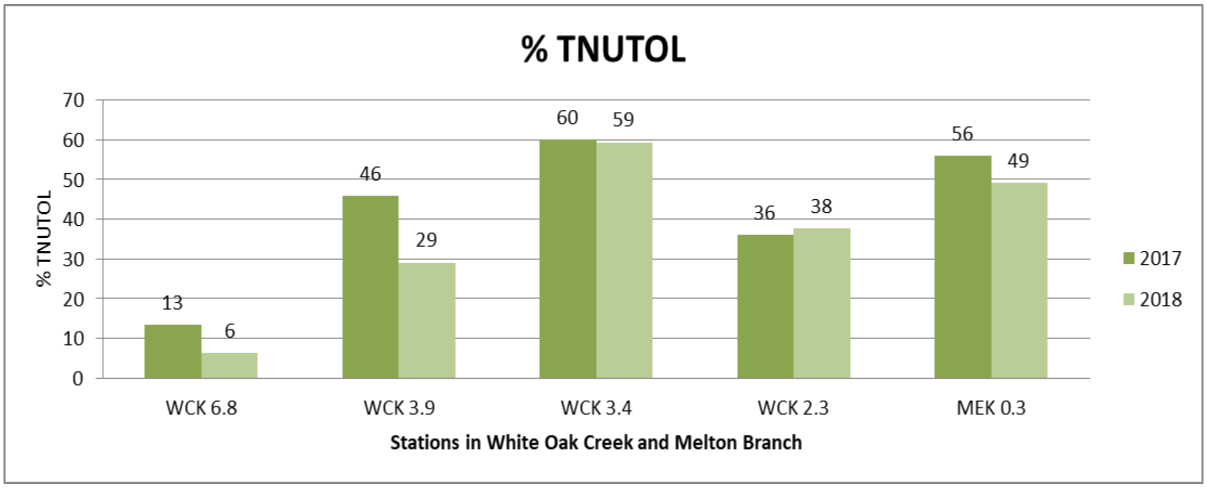


Figure 3.4.40: % TNUTOL for White Oak Creek and Melton Branch

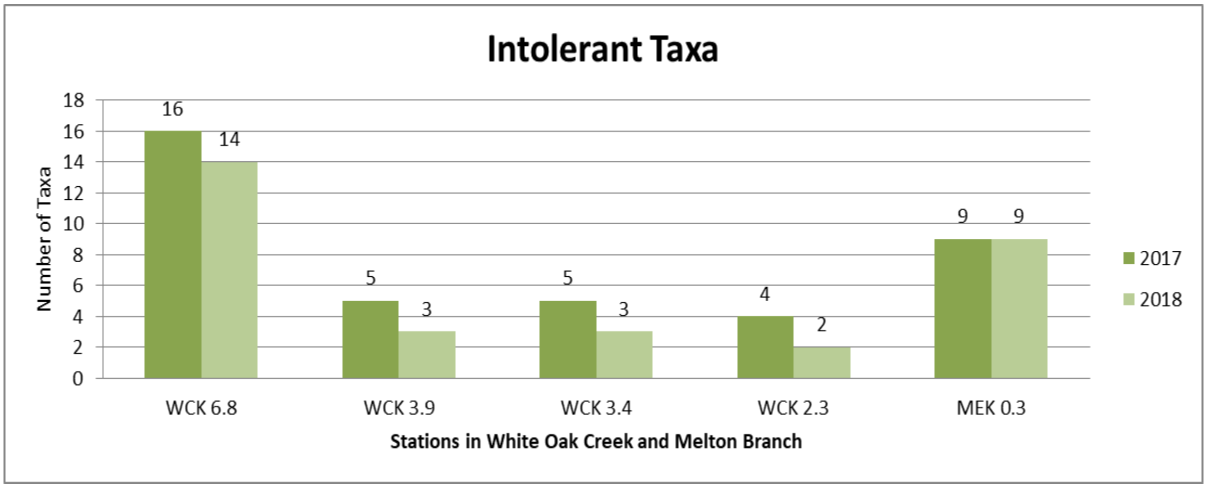


Figure 3.4.41: Intolerant Taxa for White Oak Creek and Melton Branch

As indicated above, the reference stations WCK 6.8, MEK 0.3, and WCK 2.3 score high on the TMI (Figure 3.4.33) in both 2017 and 2018. The remaining White Oak Creek stations also score fairly well in both years; however, their scores are indicative of some degree of impairment. As in 2017, the 2018 data show Taxa Richness (Figure 3.4.34) is highest for the reference station (WCK 6.8) and MEK 0.3, for both years with the remaining White Oak Creek stations (WCK 3.9, WCK 3.4, WCK 2.3) possessing considerably fewer total taxa. WCK 6.8 and MEK 0.3 also compare well in terms of EPT Richness (Figure 3.4.35) for both 2017 and 2018. In terms of EPT-Cheum (Figure 3.4.36), % OC (Figure 3.4.37), NCBI Score (Figure 3.4.38), and % TNUTOL (Figure 3.4.40), MEK 0.3 is more similar to the other White Oak Creek stations (WCK 3.9, WCK 3.4 and WCK 2.3) than to the reference station WCK 6.8.

Parameters % TNUTOL, NCBI and % EPT-Cheum may be indicative of greater organic loading present at MEK 0.3 than at the WCK 6.8 reference station in both 2017 and 2018. The major differences between the impacted White Oak Stream Stations (WCK 3.9, WCK 3.4, and WCK 2.3) and the reference station (WCK 6.8) are apparent in both 2017 and 2018 in the reduced number of EPT taxa at impacted stations (Figure 3.4.35), and the decrease in the % EPT-Cheum (Figure 3.4.36) at the impacted stations. The % OC metric for both 2017 and 2018, as in other watersheds on the reservation, shows the reverse of what might be expected with values higher at the reference station than at the impacted stations (Figure 3.4.37). The % Clingers metric (Figure 3.4.39) for both years (with the exception of WCK 3.4 in 2017) also show the opposite of what is expected with values higher at the impacted stations than at the reference station. There was an unusually low % Clingers at WCK 3.4 in 2017. Intolerant Taxa at the impacted stations in both 2017 and 2018 (Figure 3.4.41) are lower than at the reference station as would be expected. All these differences indicate that the White Oak Creek stations (WCK 3.9, WCK 3.4, and WCK 2.3) continue to be biologically impaired but show slight improvement from 2017 to 2018.

All sites were subsampled with approximately one seventh of the sample picked clean of organisms. The values for the subsampled sites were extrapolated and adjusted to organisms/m^2. The resulting numbers are presented in Figure 3.4.42, below.

As seen from Figure 3.4.42, WCK 2.3, WCK 3.4, and WCK 3.9 fall far below any other sites in density of populations of benthic macroinvertebrates. Clearly, something adverse is affecting these stations. Stations with good, clean water can be expected to have diverse communities (many different species, especially intolerant EPTs) and healthy population sizes. Stations with organic loading will typically have less diverse communities with fewer and more tolerant species, but still high population densities. There is some indication that biocides used in cooling towers could be a significant part of the problem. The White Oak Creek stations (with lower diversity, fewer intolerant species, and extremely reduced population numbers) may indicate these stations are being impacted by intermittent slugs of toxic pollutants. Further study is needed to clearly define what is happening at these stations in order to attempt to remediate impacts and allow for eventual recovery of the stream.

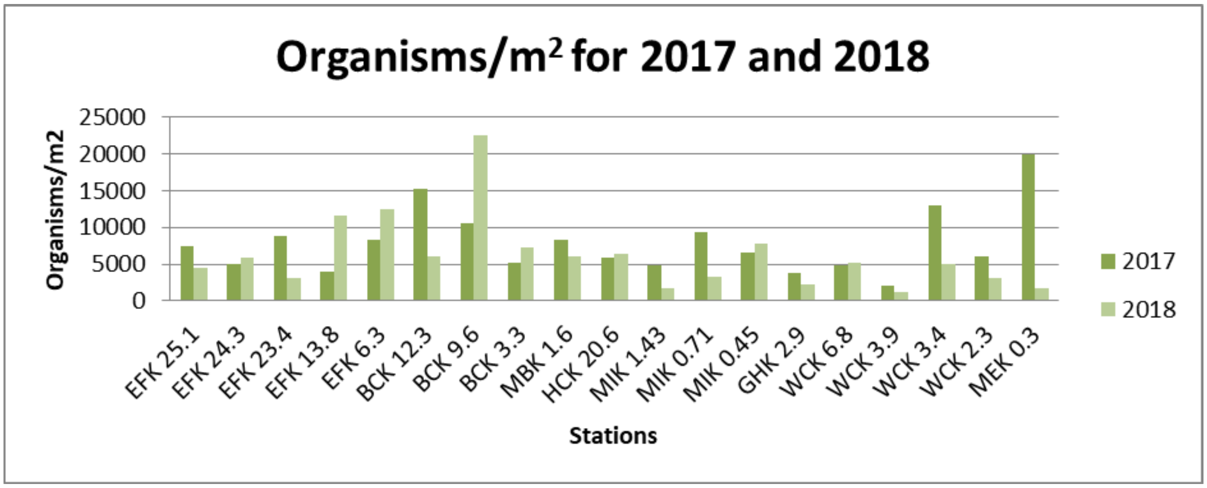


Figure 3.4.42: Organisms/m2 for 2015 and 2016

3.4.8 Conclusions

The health of the benthic macroinvertebrate communities in Oak Ridge Reservation streams has improved since the 1980's, but this improvement in creeks such as White Oak Creek at ORNL has leveled off for the past thirteen or so years. East Fork Poplar Creek improved over the years, particularly in its headwater reaches. A great part of this improvement was due to the augmented flow that was provided during the period August 1996 through May, 2014. Since augmented flow conditions were halted, conditions at the upper East Fork Poplar Creek stations have deteriorated. Bear Creek continues to improve slightly, particularly in its downstream reaches. BCK 12.3 remains somewhat impaired but continues to support some pollution intolerant taxa.

Mitchell Branch has improved since the 1980's, particularly in its downstream reaches. The lower stations of Mitchell Branch are slowly developing a more natural substrate which is replacing the formerly lined channel. The upstream station in Mitchell Branch appears to be slowly deteriorating in quality due to sediment input. The construction of the proposed airport in its headwaters may further deteriorate this section of Mitchell Branch.

3.4.9 Recommendations

Benthic communities in streams on the Oak Ridge Reservation should continue to be monitored on a regular basis. Changes in the condition of these communities (improvement or otherwise) serves as an indicator of positive remediation effects or negative effects of pollution. Every effort should be made to protect the current quality of streams that meet their designations and to improve those that do not.

3.4.10 References

Barbour, M. T., Gerritsen, J., Snyder, B. D., and Stribling, J. B. Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition. EPA 841-B-99-002. Office of Water, U.S. Environmental Protection Agency, Washington, D.C. 1999.

Brigham, A. R., W.U. Brigham, and A. Gnika, eds. Aquatic Insects and Oligochaetes of North and South Carolina. Midwest Aquatic Enterprises, Mahomet, Illinois. 837 pp. 1982.

Carlisle, D. M. and W. H. Clements. Sensitivity and Variability of Metrics Used in Biological Assessments of Running Waters. Environmental Toxicology and Chemistry 18:285-291. 1999.

Clements, W. H. Community Responses of Stream Organisms to Heavy Metals: A review of Observational and Experimental Approaches. In Metal Ecotoxicology: Concepts & Applications. M.C. Newman and A.W. McIntosh (eds.). Chelsea, MI: Lewis Publishers. 1991.

Clements, W. H., D. S. Cherry, and J. H. van Hassel. Assessment of the Impact of Heavy Metals on Benthic Communities at the Clinch River (Virginia): Evaluation of an Index of Community Sensitivity. Canadian Journal of Fisheries and Aquatic Sciences 49:1686-1694. 1992.

Cummins, K. W. Structure and Function of Stream Ecosystems. BioScience 24:631-641. 1974.

Edmunds, G., S. L. Jensen and L. Berner. Mayflies of North and Central America. University of Minnesota Press. Minneapolis, Minnesota. 330 pp. 1976.

Epler, J. H. Identification Manual for the Aquatic and Semi-aquatic Heteroptera of Florida: Belostomatidae, Corixidae, Gelastocoridae, Gerridae, Hebridae, Hydrometridae, Mesoveliidae, Naucoridae, Nepodae, Notonectidae, Ochiteridae, Pleidae, Saldidae, Veliidae. State of Florida. State of Florida Department of Environmental Protection, Division of Environmental Assessment and Restoration. Tallahassee, Florida. 2006.

Epler, J. H. Identification Manual for the Larval Chironomidae (Diptera) of North and South Carolina: A Guide to the Taxonomy of the Midges of the Southeastern United States, Including Florida. Special Publication SJ2001-SP13. North Carolina

Department of Environment and Natural Resources, Raleigh, NC, and St. Johns River Water Management District, Palatka, Florida. 526 pp. 2001.

Epler, J. H. The Water Beetles of Florida: An Identification Manual for the Families: Chrysomelidae, Curiculionidae, Dryopidae, Dytiscidae, Elmidae, Gyrinidae, Halipidae, Helophoridae, Hydraenidae, Hydrochidae, Hydrophildae, Noteridae, Psephenidae, Ptilodactylidae and Sciritidae. State of Florida Department of Environmental Protection. Division of Environmental Assessment and Restoration. Tallahassee, Florida. 2010.

Fore, L. S., J. R. Karr and R. W. Wisseman. Assessing Invertebrate Responses to Human Activities: Evaluating Alternative Approaches. Journal of the North American Benthological Society 15:212-231. 1996.

Gelhaus, J. K. Manual for the Identification of Aquatic Crane Fly Larvae for Southeastern United States. Academy of Natural Sciences, Philadelphia, Pennsylvania. 2002.

Hilsenhoff, W. L. Using a Biotic Index to Evaluate Water Quality in Streams. Technical Bulletin No. 132. Wisconsin Department of Natural Resources. Madison, Wisconsin. 1982.

Karr, J. R. Defining and Measuring River Health. Freshwater Biology 41:221-234. 1999.

Kiffney, P. M. and W. H. Clements. Effects of Heavy Metals on a Macroinvertebrate Assemblage from a Rocky Mountain Stream in Experimental Microcosms. Journal of the North American Benthic Society 13(4):511-523. 1994.

Lenat D. R. Chironomid Taxa Richness: Natural Variation and Use in Pollution Assessment. Freshwater Invertebrate Biology 2: 192–198. 1983.

McAlpine, J. F., Peterson, B. V., Shewell, G. E., Teskey, H. J., Vockeroth, J. R., and Wood, D. M. (Coordinators) Manual of Nearctic Diptera. Vol. 1. Research Branch, Agriculture Canada Monograph, 27: 674 pp. 1981.

McAlpine, J. F., Peterson, B. V., Shewell, G. E., Teskey, H. J., Vockeroth, J. R., and Wood, D. M. (Coordinators) Manual of Nearctic Diptera. Vol. 2. Research Branch, Agriculture Canada Monograph, 28: 658 pp. 1987.

Merritt, R. W., M. B. Berg, and K. W. Cummins. An Introduction to the Aquatic Insects of North America (4th ed.). Kendall/Hunt Publishing Co., Dubuque, Iowa. 1158 pp. 2008.

Meyer, J. L. Stream Health: Incorporating the Human Dimension to Advance Stream Ecology. Journal of the North American Benthological Society 16:439-447. 1997.

Needham, J. G., M. J. Westfall, Jr. and M. L. May. Dragonflies of North America (Revised Edition). Scientific Publishers. Gainesville, Florida, 939 pp. 2000.

Oliver, D. R. and M. E. Roussel. The Insects and Arachnids of Canada, Part II: The Genera of Larval Midges of Canada; Diptera: Chironomidae. Agriculture Canada Publication 1746, 263 pp. 1983.

Paul, M. J. and J. L. Meyer. Streams in the Urban Landscape. Annual Reviews of Ecology and Systematics 32: 333–365. 2001.

Pennak, R. W. Fresh-Water Invertebrates of the United States-Protozoa to Mollusca. 3rd Ed. John Wiley & Sons, Inc. New York. 628 pp. 1989.

This Page Intentionally Left Blank

4.0 AIR MONITORING

4.1 FUGITIVE RADIOLOGICAL AIR EMISSIONS

4.1.1 Background

The K-25 Gaseous Diffusion Plant, 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 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 East Tennessee Technology Park (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 National Security Complex Plant (Y-12) 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 Oak Ridge National Laboratory (ORNL) began in 1943. While the K-25 and Y-12 plants' initial mission was the production of enriched uranium, ORNL's mission focused on reactor research and the production of plutonium and 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).

The Environmental Management Waste Management Facility (EMWMF) was constructed in in Bear Creek Valley near the Y-12 plant for the disposal of low-level, radioactive waste, and hazardous waste generated by remedial activities on the Oak Ridge Reservation (ORR).

4.1.2 Problem Statements

- Many of the facilities at ETTP, Y12, and ORNL scheduled for decommissioning and demolition (D&D) are contaminated. D&D operations at these facilities, as well as the placement of waste from these facilities at EMWMF, can result in fugitive (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. DOE Oak Ridge provides annual dose assessments, including a dose air emissions report, to the public from the ongoing operations. At Y12, the facilities contaminated with various isotopes of uranium are scheduled for D&D.

4.1.3 Goals

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

4.1.4 Scope

The TDEC will conduct continuous Fugitive Air Monitoring to evaluate DOE's compliance with 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 will be selected to maximize the likelihood of collecting representative samples from potential sources of airborne contamination.

4.1.5 Methods, Materials, Metrics

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

Each of the air samplers will use an 8x10-inch, glass fiber filter to collect particulates from air as it drawn through the unit at a rate of approximately 35 cubic feet per minute. To ensure accuracy, airflow through each sampler will be calibrated quarterly, using a Graseby General Metal Works Variable Resistance Calibration Kit.

Samples will be collected from each sampler weekly which are composited every four weeks and analyzed at the State of Tennessee's Environmental Laboratory based on the contaminants of concern for the location being monitored and from previous findings. Where gross analyses are used, radionuclide-specific analysis will be performed if the results exhibit significant spikes, upward trends, consistently elevated results, and/or exceeded screening levels (gross alpha and gross beta measurements will be the CAA limits for uranium-235 and strontium-90, respectively).

To assess the concentrations of the contaminants measured for each location, results from the station will be compared with the background data and the standards provided in the CAA. Associated findings will be reported to DOE and its contractors and included in TDEC DoR-OR's annual Environmental Monitoring Report submitted to DOE and the public.

Fugitive air monitoring will be conducted by the DoR 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.

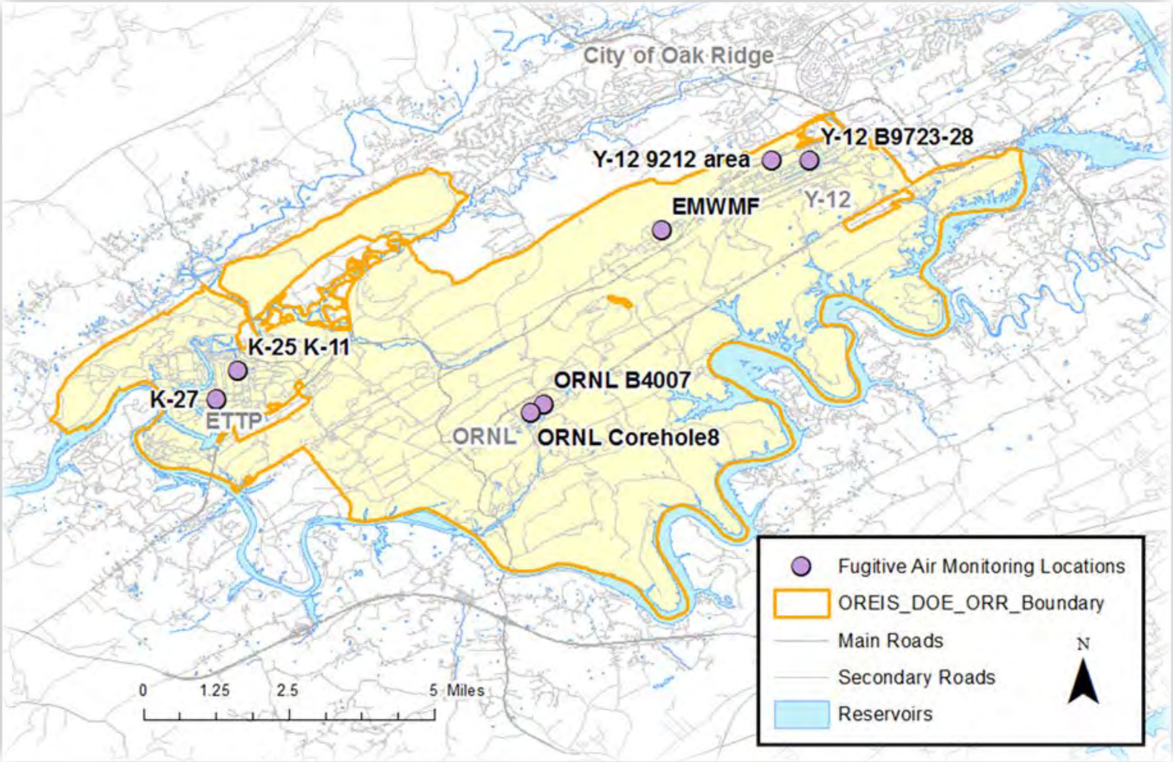


Figure 4.1.1: Fugitive Air Monitoring Locations

4.1.6 Deviations from the Plan

The original Project Plan was to collect and report on data through June 2019. However, the most recent sampling results are for the sampling period that ended 04/03/2019. The original plan was to composite four-weekly samples for each analysis. Budget restraints required the composite number to be increased to six-week samples. Data examined in this report is for 9 four-week composited samples, and 3 six-week composite samples representing continuous sampling through 04/03/2019. Other than composite interval, and the end date, the sampling and analysis was conducted in accordance with the Plan.

4.1.7 Results and Analysis

East Tennessee Technology Park

Two samplers were used at ETTP, K-25 Gaseous Diffusion Plant. Analyses include uranium, U-234, U-235, U-238, and Tc-99 as shown in Tables 4.1.1 and 4.1.2. Table 4.1.1 shows the results from the samples taken at ETTP K-25/K11. The sum of fractions of less than 1 indicates that regulatory limits were not exceeded.

Table 4.1.1: ETTP K-25/K-11 Air Monitoring Average Result (pCi/m3)

ETTP K-25/K11 Sampling Location	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average through 04/03/2019	6.48E-05	7.73E-06	4.42E-05	1.14E-04	
Average Background (Ft. Loudoun Dam)	4.44E-05	6.69E-06	3.88E-05	1.12E-04	
Net Activity (Avg. Minus Background)	2.04E-05	1.04E-06	5.42E-06	2.22E-06	
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	2.65E-03	1.46E-04	6.53E-04	1.59E-05	3.47E-03

Table 4.1.2 shows the results from the K-27 area sampling location. The sum of fractions of less than 1 indicates that regulatory limits were not exceeded.

Table 4.1.2: ETTP K-27 Air Monitoring Average Result for (pCi/m3)

ETTP K-27 Area	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average through 04/03/2019	6.76E-05	8.94E-06	7.45E-05	8.31E-05	
Average Background (Ft. Loudoun Dam)	4.44E-05	6.69E-06	3.88E-05	1.12E-04	
Net Activity (Avg. Minus Background)	2.32E-05	2.25E-06	3.58E-05	-2.91E-05	
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	3.01E-03	3.17E-04	4.31E-03	-2.08E-04	7.43E-03

Y-12 National Security Complex - Building 9212 Area

Two samplers were used at the Y-12 National Security Complex. Current analyses include U-234, U-235, U-238, and Tc-99. Table 4.1.3 shows the results from the samples taken at Building 9212 area. The sum of fractions of less than 1 indicates that regulatory limits were not exceeded.

Table 4.1.3: Y-12 Building 9212 Area Air Monitoring Average RESULT (pCi/m3)

Building 9212 Area	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average through 04/03/2019	2.23E-04	1.91E-05	6.05E-05	8.67E-05	
Average Background (Ft. Loudoun Dam)	4.44E-05	6.69E-06	3.88E-05	1.12E-04	
Net Activity (Avg. Minus Background)	1.78E-04	1.24E-05	2.17E-05	-2.55E-05	
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	2.32E-02	1.75E-03	2.61E-03	-1.82E-04	2.73E-02

Y-12 - Building 9723-28 Area

Two samplers were used at the Y-12 National Security Complex. Current analyses include U-234, U-235, U-238, and Tc-99. Table 4.1.4 shows the results from the samples taken at Building 9723-28 area. The sum of fractions of less than 1 indicates that regulatory limits were not exceeded.

Table 4.1.4: Y-12 Building 9723-28 Area Air Monitoring Average Result (pCi/m3)

Building 9723-28 Area	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average through 04/03/2019	1.01E-04	1.37E-05	5.82E-05	1.27E-04	
Average Background (Ft. Loudoun Dam)	4.44E-05	6.69E-06	3.88E-05	1.12E-04	
Net Activity (Avg. Minus Background)	5.67E-05	7.06E-06	1.94E-05	1.50E-05	
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	7.36E-03	9.94E-04	2.34E-03	1.07E-04	1.08E-02

Oak Ridge National Laboratory - ORNL B4007 Area

Two samplers were used at ORNL. Analyses include U-234, U-235, U-238, and gamma spectrometry. The gamma spectrometry analysis is not shown because only naturally occurring daughter products of radon were detected. No identified peaks or instances of elevated impacts were noted. The sum of fractions of less than 1 indicates that regulatory limits were not exceeded. Reference tables 4.1.5 and 4.1.6.

Table 4.1.5: ORNL B4007 Air Monitoring Average Result (pCi/m3)

ORNL B4007 Area	U-234	U-235	U-238	Sum of Fractions
Average through 04/03/2019	4.05E-05	6.26E-06	3.76E-05	
Average Background (Ft. Loudoun Dam)	4.44E-05	6.69E-06	3.88E-05	
Net Activity (Avg. Minus Background)	-3.90E-06	-4.30E-07	-1.21E-06	
40CFR Part 61 Limit Appendix E (Table 2)	7.70E-03	7.10E-03	8.30E-03	
Fraction of Limit Net/Limit	-5.06E-04	-6.05E-05	-1.46E-04	-7.13E-04

Table 4.1.6: ORNL Corehole 8 Air Monitoring Average Result (pCi/m3)

ORNL Corehole 8 Area	U-234	U-235	U-238	Sum of Fractions
Average through 04/03/2019	3.79E-05	4.22E-06	3.69E-05	
Average Background (Ft. Loudoun Dam)	4.44E-05	6.69E-06	3.88E-05	
Net Activity (Avg. Minus Background)	-6.49E-06	-2.47E-06	-1.83E-06	
40CFR Part 61 Limit Appendix E (Table 2)	7.70E-03	7.10E-03	8.30E-03	
Fraction of Limit Net/Limit	-8.42E-04	-3.48E-04	-2.20E-04	-1.41E-03

The Environmental Management Waste Management Facility

One sampler is located at EMWMF in Bear Creek Valley near the Y-12 National Security Complex. Analyses include U-234, U-235, U-238, and Tc-99. No identified peaks or instances of elevated impacts were noted (Table 4.1.7). The sum of fractions of less than 1 indicates that regulatory limits were not exceeded.

Table 4.1.7. EMWMF Air Monitoring Average Result (pCi/m3)

EMWMF	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average through 04/03/2019	6.23E-05	8.73E-06	5.56E-05	1.06E-04	
Average Background (Ft. Loudoun Dam)	4.44E-05	6.69E-06	3.88E-05	1.12E-04	
Net Activity (Avg. Minus Background)	1.79E-05	2.04E-06	1.68E-05	-6.37E-06	
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	2.32E-03	2.87E-04	2.03E-03	-4.55E-05	4.59E-03

4.1.8 Conclusions

The average concentrations, minus background, for all sites, were below the federal standards.

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 their samples quarterly.

In past years, this TDEC independent monitoring project's Tc-99 analysis was useful in identifying a (DOE's contracted laboratory) calculation error in DOE's ETTP Perimeter Sampling Program 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.

4.1.9 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 DOE (ORR's) Environmental Monitoring Plan in the DOE EMP was reviewed. There are no recommendations at this time.

4.1.10 References

There were no references used for this report.

5.0 SURFACE WATER MONITORING

5.1 AMBIENT SURFACE WATER MONITORING

5.1.1 Background

Due to the complex nature of the Oak Ridge Reservation (ORR) National Priorities List (NPL) site, continued Ambient Surface Water Monitoring is an essential project. Surface water across the ORR represents a primary way in which contamination has moved and exited the site historically. An ambient surface water project has been implemented by TDEC each year since 1993. The project began with the monitoring of Clinch River water quality at five locations near the ORR. The sampling locations for this project have been modified throughout the years, sometimes adding or discontinuing sampling at particular locations, depending upon active site conditions, concerns and data needs. This project monitors water quality through active sampling for contaminants in waterways that have been impacted by past and present activities on the ORR.

5.1.2 Problem Statements

ORR exit pathway streams and the Clinch River are subject to contaminant releases from activities at the East Tennessee Technology Park (ETTP), Oak Ridge National Laboratory (ORNL), and Y-12 National Security Complex (Y-12). These contaminant releases have been detrimental to stream health in the past and present. 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 East Fork Poplar Creek (EFPC) by spills and leakage from subsurface drains, building foundations, and contaminated soil, as well as purposed discharge of waste water 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)

- Besides mercury, other metals found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver, and zirconium (DOE, 1992)

- Water supply facilities, serving an estimated population of 200,000 persons on the Tennessee River downstream of White Oak Creek (WOC) have the potential of being influenced by streams that drain the ORR (DOE, 1992)

- The Clinch River received approximately 665 curies of cesium-137 (Cs-137) from WOC between 1954 and 1959 (DOE, 1992)

5.1.3 Goals

- Characterize stream conditions through sampling and analysis of surface water
- Serve as an integral component of watershed monitoring (physical, chemical, and biological conditions of the waterbody)
- Assess site remediation efforts through long-term monitoring of surface water
- Identify trends in data, based on findings, and use those trends to make recommendations in an effort to improve water quality and the health of affected streams

5.1.4 Scope

The scope of this project is to characterize stream conditions through sampling and analysis of surface water from the tributaries that drain the ORR and the surface water of the Clinch River spanning from the mouth of WOC at Clinch River km (CRK) 33.5 downstream to CRK 0.0 where it meets the Tennessee River.

5.1.5 Methods, Materials, Metrics

The Tennessee Department of Environment and Conservation's (TDEC) Division of Water Resources (DWR) *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water (Nashville, Tennessee. 2011)* will be the guidance document for this project. This project has two aspects:

- Ambient: Annual sampling is conducted at 13 sampling stations located at points on the major exit pathway streams of the ORR. These are located on Bear Creek, EFPC, Mitchell Branch (MB), and WOC. In addition, three ambient background sampling stations are located on Clear Creek, Mill Branch, and Hinds Creek. Sampling is conducted in April. The sampling station at the White Oak Creek km headwaters (WCK 6.8) is included in this effort because it is a background location for the benthic macroinvertebrate stream evaluations
- Sr-90/WOC: Monthly sampling will be conducted at four sampling stations which were chosen to assess the presence of Sr-90 in the Clinch River in the area near the mouth of WOC. Three of these stations are located on the Clinch River and one is located at the headwaters of WOC

Table 5.1.1: Proposed Sampling Plan

					Number of Samples				
DWR Name	Station Description	DoR-OR Name	Latitude	Longitude	Sr-90	Gross a/b	U Isotopic	Nutrients	Metals
CLINC019.9RO	Clinch River Mile 19.7	CRK 32	35.9002	-84.35049	12				
CLINC020.8RO	Clinch River Mile 20.8	CRK 33.5	35.89665	-84.33316	12				
CLINC021.7RO	Clinch River Mile 21.7	CRK 34.9	35.97071	-84.2145	12				
WHITE004.2RO	White Oak Creek Mile 4.2	WCK 6.8	35.94151	-84.30161	12	1	1	1	1
BEAR002.0RO	Bear Creek Mile 2.0	BCK 3.3	35.94354	-84.34911				1	1
BEAR006.0AN	Bear Creek Mile 6.0	BCK 9.6	35.96032	-84.29741				1	1
BEAR007.6AN	Bear Creek Mile 7.6	BCK 12.3	35.973	-84.27814		1	1	1	1
EFPOP015.6AN	East Fork Poplar Creek Mile 15.6	EFK 25.1	35.98456	-84.2551				1	1
EFPOP015.2AN	East Fork Poplar Creek Mile 15.2	EFK 24.4	35.98922	-84.24282				1	1
EFPOP014.5AN	East Fork Poplar Creek Mile 14.5	EFK 23.4	35.99596	-84.24004				1	1
EFPOP008.6AN	East Fork Poplar Creek Mile 8.6	EFK 13.8	35.99283	-84.31371				1	1
EFPOP003.9RO	East Fork Poplar Creek Mile 3.9	EFK 6.3	35.96293	-84.35905				1	1
MITCH000.1RO	Mitchell Branch Mile 0.1	MIK 0.1	35.94146	-84.3922				1	1
WHITE001.4RO	White Oak Creek 1.4	WCK 2.3	35.90834	-84.31856	1	1	1	1	1
WHITE002.1RO	White Oak Creek Mile 2.1	WCK 3.4	35.91778	-84.31612	1	1	1	1	1
WHITE002.4RO	White Oak Creek Mile 2.4	WCK 3.9	35.92435	-84.31579	1	1	1	1	1
ECO67F06	Clear Creek Mile 1.0	CCK 1.6	36.21346	-84.05983				1	1
FECO67I12	Mill Branch Mile 1.0	MBK 1.6	35.98886	-84.28935				1	1
HINDS012.8AN	Hinds Creek Mile 12.8	HCK 20.6	36.15797	-83.99944				1	1
TRIPBLANKDoROR	Trip Blank	TB	36.01752	-84.23844	5	1	1	2	2
FIELDBLANKDoROR	Field Blank	FB	36.01752	-84.23844	5	1	1	2	2
********.***-FD	Field Duplicate	FD	36.01752	-84.23844	5	1	1	2	2
				Totals:	66	8	8	22	22

🟦	Sr-90 White Oak Creek
🟩	Background
🟧	Ambient
⬜	QA/QC

Nutrients suite includes: Ammonia, Nitrate and Nitrite, Total Kjeldahl Nitrogen, Total Phosphorus.

Metals suite includes: arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

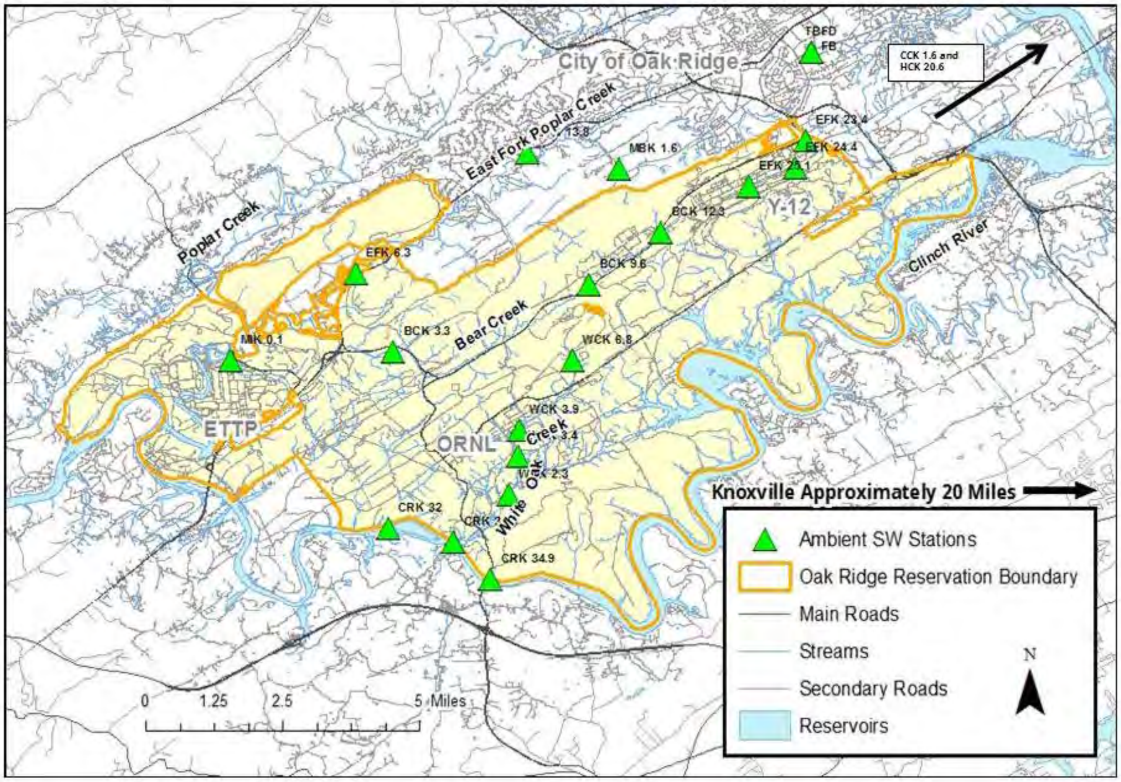


Figure 5.1.1: Proposed Sampling Locations

Table 5.1.2: Proposed Sampling Rationale

DoR-OR Name	Monitoring Rationale
CRK 32	Surveillance of water quality possibly influenced by radiological contaminants from the Oak Ridge National Laboratory and/or the Melton Valley burial grounds.
CRK 33.5	Surveillance of water quality possibly influenced by radiological contaminants from the Oak Ridge National Laboratory and/or the Melton Valley burial grounds.
CRK 34.9	Surveillance of water quality possibly influenced by radiological contaminants from the Oak Ridge National Laboratory and/or the Melton Valley burial grounds.
WCK 6.8	Background sampling station
EFK 25.1	Surveillance of water quality at East Fork Poplar Creek (EFPC) headwaters.
EFK 24,4	Surveillance of water quality at EFPC intermediate to EFK 25.1 and EFK 23.4.
EFK 23.4	Surveillance of water quality at point where EFPC leaves leaves DOE property and enters Oak Ridge.
EFK 13.8	Surveillance of EFPC water quality just upstream of Oak Ridge sewage treatment outfall.
EFK 6.3	Surveillance of EFPC water quality downstream of Oak Ridge.
BCK 12.3	Surveillance of Bear Creek water quality near headwaters.
BCK 9.6	Surveillance of Bear Creek water quality downstream of Environmental Management Waste Management Facility (EMWMF).
BCK 3.3	Surveillance of Bear Creek water quality downstream of Y-12.
MIK 0.1	Surveillance of Mitchell Branch (MIK) water quality downstream of ETTP.
WCK 3.9	Surveillance of White Oak Creek (WCK) at a point influenced by ORNL.
WCK 3.4	Surveillance of White Oak Creek (WCK) at a point downstream of ORNL.
WCK 2.3	Surveillance of White Oak Creek (WCK) at a point downstream of Melton Valley Burial Grounds.
CCK 1.6	Reference site upstream of DOE facilities.
HCK 20.6	Reference site north of Oak Ridge.
MBK 1.6	Reference site in Oak Ridge.

5.1.6 Deviations from the Plan

Due to changes in budget, many of the sites were not sampled with the same frequency as described in the project plan. More specifically, Clinch River sites, CRK 32, CRK 33.5, and CRK 34.9, were not sampled monthly as planned. Sites CRK 32 and CRK 33.5 were sampled quarterly while site CRK 34.9 was not sampled at all. Site WCK 6.8 was sampled as a spot check sample to confirm high values from a spring of 2018 sampling event. This site was also sampled in the spring of 2019. At a few sites, additional analytes such as radioactive strontium, gross alpha and beta, and isotopic uranium were also analyzed. At the Bear Creek sites, additional analytes including technetium-99, tritium, gamma, and total hardness were also analyzed. Due to a decreased frequency of sampling, fewer trip blanks, field blanks, and field duplicates were taken than planned for radioactive strontium, nutrients, and metals. Site BCK 12.3 had one additional spot check sample to confirm high data values collected in the spring of 2018. Similarly, site EFK 23.4 also had one additional spot check sample to confirm high beta values from a spring 2018 sampling event.

5.1.7 Results and Analysis

Data summaries for sampled parameters are shown below. See Table 5.1.3 for metals and general inorganic results and Table 5.1.4 for radionuclide results. It is to be noted that the majority of data has not yet been received from the TDH laboratory. Therefore, these anticipated data values are indicated as “pending” in the tables.

Table 5.1.3: Metals and general inorganics results

Parameter	BCK 12.3	BCK 9.6	BCK 3.3	EFK 25.1	EFK 24.4	EFK 23.4	EFK 13.8	EFK 6.3	MIK 0.1	WCK 6.8*	WCK 3.9	WCK 3.4	WCK 2.3	CCK 1.6*	HCK 20.6*	MBK 1.6*	Units	Criteria$^+$
Ammonia	U	U	U	0.795	0.0822	0.0264	U	U	U	pending	pending	pending	pending	U	U	U	mg/l	na
Arsenic	U	U	U	U	U	U	U	U	U	pending	pending	pending	pending	U	U	U	ug/l	10
Cadmium	U	U	U	0.46	0.194	U	U	U	U	pending	pending	pending	pending	U	U	U	ug/l	2
Calcium	92.6	93.6	50.2	52.2	53.8	52.7	50.6	46	65.9	pending	pending	pending	pending	30.6	48.9	31.3	mg/l	na
Chloride	28.8	9.65	4.67	16	21.2	18.6	8.05	8.91	8.54	pending	pending	pending	pending	2.33	3.76	2.31	mg/l	na
Chromium	U	U	U	U	U	U	U	U	U	pending	pending	pending	pending	U	U	U	ug/l	570
Copper	0.61	U	U	9.17	6.09	4.11	1.18	1.08	1.94	pending	pending	pending	pending	U	0.594	U	ug/l	13
Hardness, Ca, Mg	290	169	111	na	na	na	na	na	na	na	na	na	na	na	na	na	mg/l	na
Inorganic nitrogen (nitrate and nitrite)	27.1	6.58	0.786	3.79	3.54	2.9	1.09	2.65	0.311	pending	pending	pending	pending	0.483	0.681	0.12	mg/l	1.22
Lead	0.158	0.19	0.153	0.545	U	U	0.171	0.276	0.239	pending	pending	pending	pending	U	0.466	U	ug/l	65
Magnesium	13.5	10.6	8.35	12.4	13.9	13.6	9.06	7.77	13.1	pending	pending	pending	pending	14.5	19.9	6.56	mg/l	na
Mercury	0.00455	0.00192	U	0.411	0.286	0.171	0.0484	0.0518	0.00806	pending	pending	pending	pending	U	0.00073	0.00129	ug/l	0.051
Nickel	3.82	1.9	1.08	1.53	1.4	1.37	1.31	1.39	5.22	pending	pending	pending	pending	0.623	1.16	0.751	ug/l	470
Phosphorus	U	U	U	0.333	0.271	0.184	0.0516	0.173	0.0231	pending	pending	pending	pending	0.0137	0.0293	0.0285	mg/l	0.04
Selenium	U	U	U	U	U	U	U	U	U	pending	pending	pending	pending	U	U	U	ug/l	20
Settleable Solids	U	U	U	U	U	U	U	U	U	pending	pending	pending	pending	U	U	U	ml/l	na
Sodium	23.7	7.4	3.53	12.5	17.8	13.6	5.95	6.7	6.85	pending	pending	pending	pending	0.767	2.09	2.21	mg/l	na
Sulfate	pending	pending	pending	43.5	38.5	31.4	16.3	12.2	36.6	pending	pending	pending	pending	2.93	7.69	10.6	mg/l	na
Total Dissolved Solids	394	215	130	271	283	261	205	192	269	pending	pending	pending	pending	pending	pending	140	mg/l	na
Total Kjeldahl Nitrogen	0.294	U	U	1.14	0.342	0.193	0.133	0.279	0.115	pending	pending	pending	pending	U	U	U	mg/l	na
Total Suspended Solids	2.37	4.75	2.71	3.96	0.62	1.22	2.09	3.23	2.2	pending	pending	pending	pending	0.7	13	1.93	mg/l	na
Uranium	146	30.2	11.4	92.1	52.9	52.9	39.5	11.4	4.92	pending	pending	pending	pending	U	0.263	U	ug/l	na
Zinc	U	U	U	36.7	16.6	9.56	1.48	2.9	U	pending	pending	pending	pending	U	U	U	ug/l	120

na – not applicable

J – signifies a figure that is between the method detection limit and the method quantification limit; it is an estimate

U- Undetected

Pending – sample results not yet received from laboratory

Red highlight – indicates an exceedance (specific exceedance discussed in later section)

+ Criteria are derived from TN Fish and Aquatic and TN Recreation limits (whichever is more stringent); Ecoregion values are used for nitrate and phosphorus

Table 5.1.4: Radionuclide results

Parameter	BCK 12.3	BCK 9.6	BCK 3.3	CRK 32	CRK 33.5	EFK 25.1	EFK 24.4	EFK 23.4	EFK 13.8	EFK 6.3	MIK 0.1	WCK 6.8*	WCK 3.9	WCK 3.4	WCK 2.3	CCK 1.6*	HCK 20.6*	MBK 1.6*	Units	Criteria^{+}
Strontium-89	pending	pending	pending	0.0932	7.4	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pCi/l	20
Strontium-90	pending	pending	pending	0.5	53	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pCi/l	8
Gross alpha	pending	pending	pending	-0.33	6.47	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pCi/l	15
Gross Beta	pending	pending	pending	0.9	100.4	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pCi/l	50
U-234	pending	pending	pending	0.15	2.54	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pCi/l	0.74
U-235	pending	pending	pending	0.016	0.115	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pCi/l	0.75
U-238	pending	pending	pending	0.08	0.24	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pending	pCi/l	0.82
Technetium-99	pending	pending	pending	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	pCi/l	900
Tritium	pending	pending	pending	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	pCi/l	20000
Gamma	pending	pending	pending	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	pCi/l	na

na – not applicable

J – signifies a figure that is between the method detection limit and the method quantification limit; it is an estimate

U- Undetected

Pending – sample results not yet received from laboratory

Red highlight – indicates an exceedance (specific exceedance discussed in later section)

+ Criteria are derived from EPA primary drinking standards and EPA PRG for tap water (only applicable to Clinch River Sites)

Note: Sites CRK 32 and CRK 33.5 show the highest value analyzed over multiple sample events from July 1, 2018 – June 30, 2019

Specific discussion on analytical results for Bear Creek, Clinch River, EFPC, MB, and WOC are provided in the following sections of this project report. These discussions are to be considered preliminary due to pending laboratory results.

Bear Creek

Metals and nutrient concentrations for Bear Creek are generally below Tennessee water quality criteria (WQC). However, nitrite and nitrate levels exceed the ecoregion 67f criteria. Natural levels of nitrate in streams are usually less than 1 mg/L. TDEC's recommended interpretation of the existing narrative criteria for nitrate and nitrite is 1.22 mg/L for ecoregion 67f. Above this level, a stream is no longer representative of the reference stream conditions and will be considered in violation of the criteria, unless it has been conclusively demonstrated that no loss of biological integrity or adverse downstream effects have occurred. This stream yielded a result of 27.1 mg/L and 6.58 mg/L at sites Bear Creek km (BCK) BCK 12.3 and BCK 9.6, respectively. These sites both exceed the 1.22 mg/L criterion.

Uranium metal is also very high for Bear Creek. Uranium metal has an EPA drinking water standard of 30 µg/L. While this drinking water criterion may not be directly applied to this stream, it provides reference to the level of uranium metal present within the stream. As shown in Figure 5.1.2, concentrations of uranium metal are 146 µg/L and 30.2 µg/L at sites BCK 12.3 and BCK 9.6, respectively. These values are consistent with DOE historical data which indicates nearly all sites, excluding those downstream of BCK 4.55, have had concentrations above the drinking water standard of 30 µg/L since 2010. Radionuclide results will be analyzed upon completion of laboratory analysis.

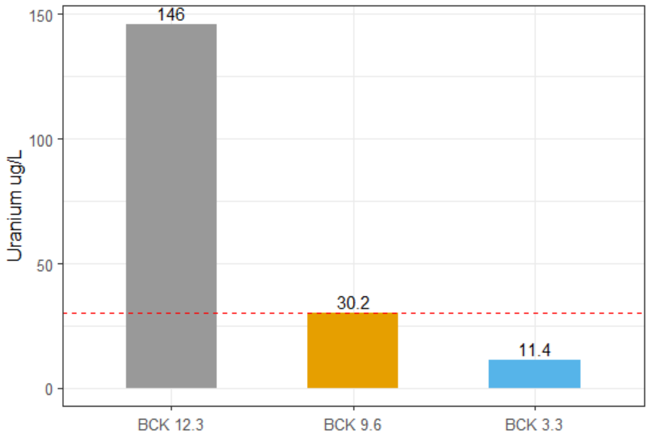


Figure 5.1.2: Uranium concentrations on Bear Creek with red dashed line representing EPA drinking water criterion of 30 µg/L; Sites listed upstream (left) to downstream (right)

Clinch River

At CRK 32, TDEC staff co-sampled surface water with ORNL environmental staff quarterly during 2018-2019. For the first two quarters, TDEC samples were analyzed for Sr-90, which is the primary radiological contaminant of concern from WOC. Additional analytes including isotopic uranium and gross alpha/beta were taken along with Sr-90 for the last two quarters.

High Sr-90 concentrations were found at site CRK 33.5, which is the WOC and Clinch River confluence. Sr-90 concentrations were found to be nearly seven times the acceptable limit for drinking water of 8 pCi/L. As shown in Figure 5.1.3, site CRK 32 just downstream of CRK 33.5, had a significantly lower concentration of Sr-90. This is likely due to dilution from the Clinch River.

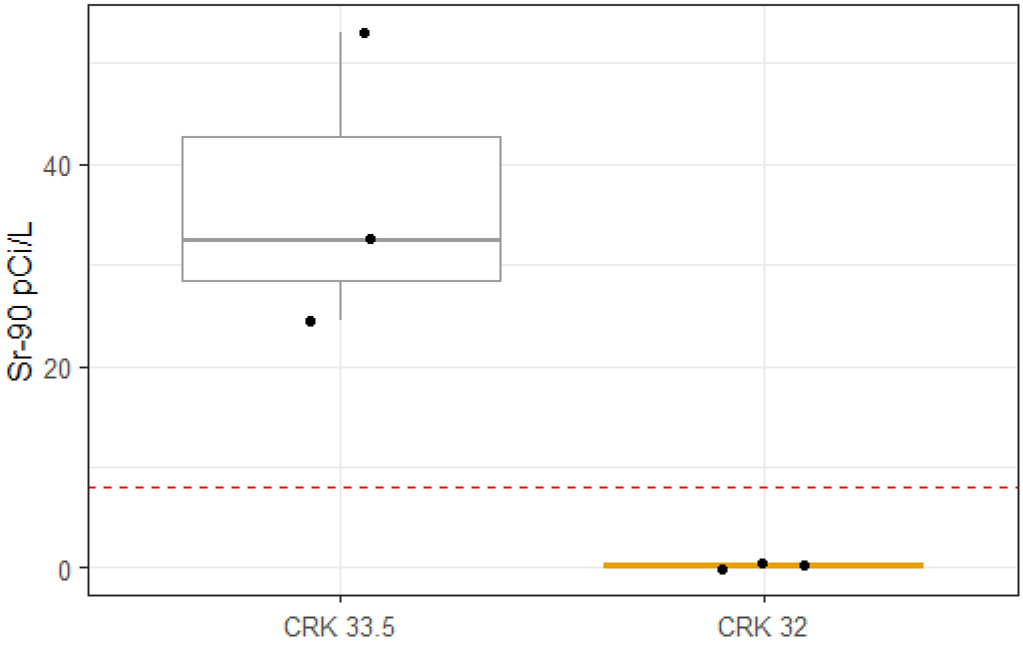
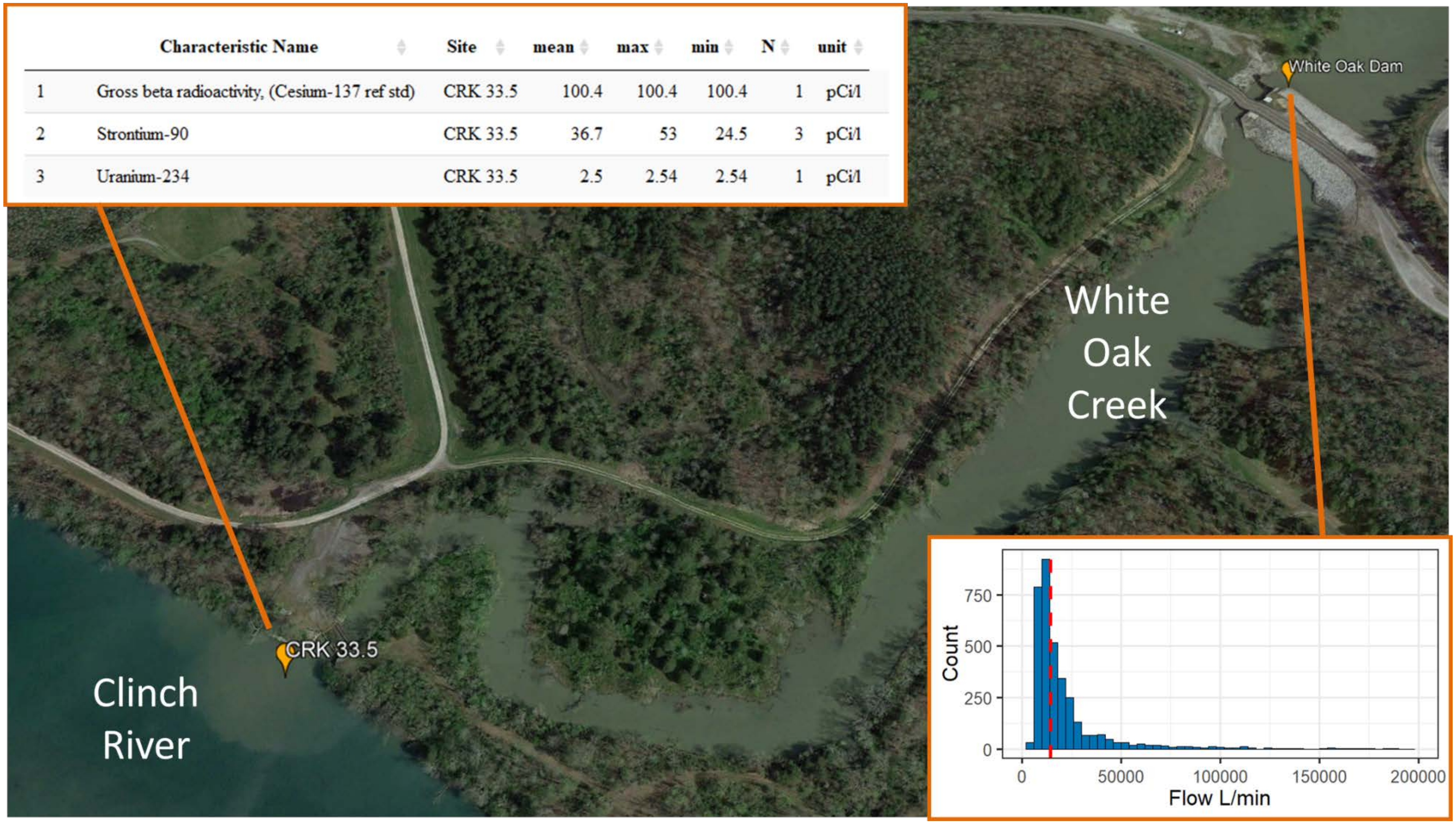


Figure 5.1.3: Box and whisker plots of Strontium-90 concentrations on Clinch River sites with red-dashed line representing EPA 8 pCi/L drinking water standard as a reference; note the large difference between upstream CRK 33.5 and downstream CRK 32

Gross beta concentrations were also quite high at CRK 33.5. The EPA recommends that further isotopic analysis occur when gross beta concentrations exceed 50pCi/L. At site CRK 33.5, gross beta concentrations were over 100 pCi/L. A TDEC isotopic uranium analysis indicates elevated levels of U-234 above the EPA PRG for tap water, which may be a major contributor to the high gross beta emissions.

Loading is an important process to consider for WOC. This is due to the creek discharging directly into the Clinch River. Loading is calculated by multiplying the concentration by a flow rate, which yields a quantity of mass discharged over a specified time interval. For WOC, the average flow rate at the White Oak Dam, calculated from records provided by DOE, is 24,460 L/min with a median value of 14,325 L/min. As recent flow data was not available at this site, these values were calculated from 3,571 measurements from 1993 to 2017. For this project, Sr-90 and gross beta were sampled at site CRK 33.5 on the Clinch River. The average concentration of Sr-90 over three sampling events was 36.7 pCi/L, which is well over the EPA recommended 8 pCi/L for drinking water. A single sampling event of gross beta yielded a result of 100.4 pCi/L. Assuming the median flow value from sampling is representative of WOC near the Clinch River confluence and assuming that the average concentration of Sr-90 is representative of WOC, it is estimated that over 2.82E-05 grams per year (g/yr) of Sr-90 is loaded to the Clinch River from WOC. This is likely a conservative estimate as sample concentrations at site CRK 33.5 consist of a mixture of Clinch River water and WOC water. While this number may seem small, it is 459% of the EPA MCL (6.15E-06 g/yr) for this given flow rate (median White Oak Dam flow rate 14,325 L/min). The Clinch River water likely dilutes the concentrations of these radionuclides from WOC significantly (See Figure 5.1.4). A better estimate could be obtained with more recent flow measurements taken closer to the confluence of the Clinch River and WOC with samples taken directly from WOC. Regardless, it is evident that WOC loads a large quantity of Sr-90 to the Clinch River, a major source of drinking water for Tennessee citizens.



	Characteristic Name	Site	mean	max	min	N	unit
1	Gross beta radioactivity, (Cesium-137 ref std)	CRK 33.5	100.4	100.4	100.4	1	pCi/l
2	Strontium-90	CRK 33.5	36.7	53	24.5	3	pCi/l
3	Uranium-234	CRK 33.5	2.5	2.54	2.54	1	pCi/l

Figure 5.1.4: DOE White Oak Dam flow measurement location with histogram showing distribution of flow in L/min. Note the red-dashed line on histogram illustrating the median flow value of 14,325 L/min. For illustration purposes the histogram has been truncated. It is to be noted that the flow data actually ranges from 4,164 to 651,093 L/min. A table is also shown illustrating average values for samples taken at CRK 33.5 in the 2018-2019 sampling season. Distance between the White Oak Dam and CRK 33.5 is approximately 1 stream kilometer.

East Fork Poplar Creek

Metals and nutrient concentrations for EFPC are generally below Tennessee WQC. However, mercury levels were much higher than the 0.051 µg/L the Tennessee recreation criterion. EFPC sites EFK 25.1, 24.4, 23.4, and 6.3 all exceeded this criterion. As shown in Figure 5.1.5, mercury values were 0.411, 0.286, 0.171, and 0.052 µg/L at sites EFK 25.1, 24.4, 23.4, and 6.3, respectively. These sites decreased in mercury concentrations downstream, ranging from eight times greater than the Tennessee criterion to nearly matching it.

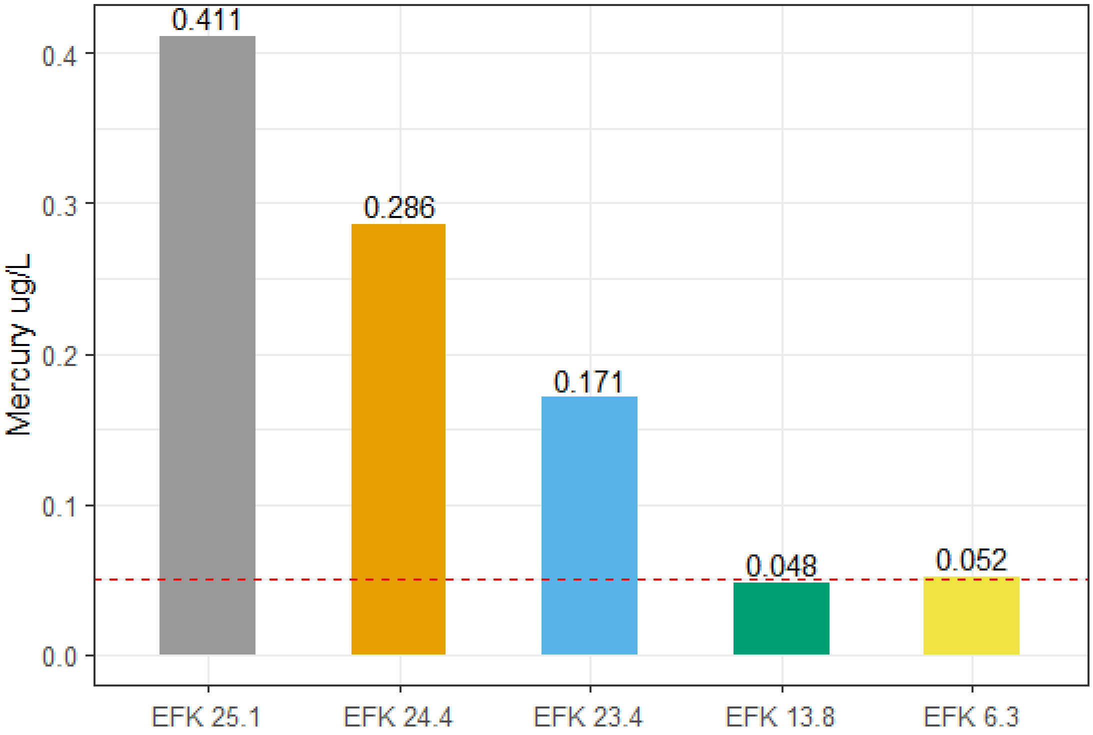


Figure 5.1.5: Mercury concentrations on East Fork Poplar Creek with red dashed line representing TN recreation criterion of 0.051 µg/L; Sites listed upstream (left) to downstream (right)

Other metals were also high in concentrations for EFPC. Specifically, uranium concentrations were three times the EPA uranium metal maximum contaminant level (MCL) for drinking water at site EFK 25.1, as shown in Figure 5.1.6. Other sites were also very high in uranium concentration but decreased downstream. While this contaminant level may not be directly applied for this stream, it offers a reference for uranium concentrations. Copper and Zinc, although below Tennessee WQC levels, were also much higher than all other streams sampled.

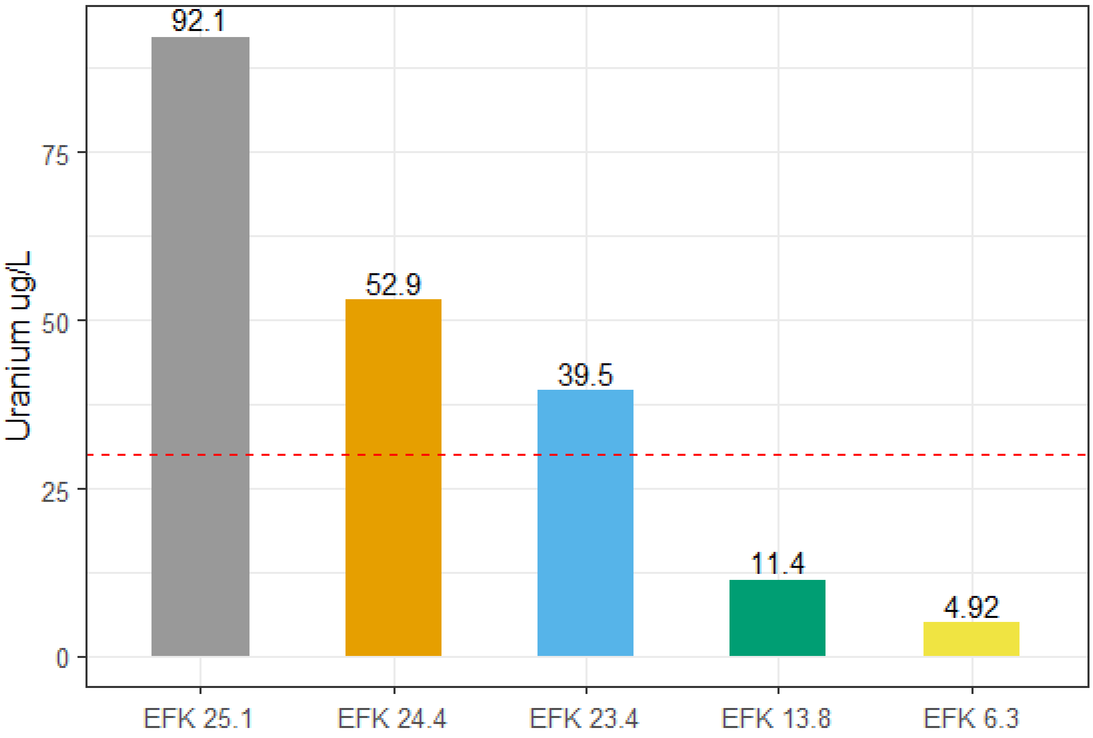


Figure 5.1.6: Uranium concentrations on East Fork Poplar Creek with red-dashed line representing EPA drinking water maximum contaminant criterion of 30 µg/L; Sites listed upstream (left) to downstream (right)

Nitrite and nitrate levels are also of concern on EFPC. These parameters exceed the ecoregion 67f criterion of 1.22 mg/L. At sites EFK 25.1, 24.4, 23.4, and 6.3, the nitrite and nitrate concentrations were 3.79, 3.54, 2.9, and 2.65 mg/L, respectively. All of these sites exceed the 1.22 mg/L criterion for ecoregion 67f.

Similarly, phosphorus concentrations at several of the EFPC sites also exceed the ecoregion 67f criterion of 0.04 mg/L. Concentrations were 0.3, 0.27, 0.18, 0.05, and 0.17 mg/L at sites EFK 25.1, 24.4, 23.4,13.8, and 6.3, respectively.

Results from radionuclides will be analyzed upon completion of laboratory analysis.

Mitchell Branch

Metals and nutrient concentrations for MB were all under Tennessee WQC. The level for nickel was much higher in this stream than in all other streams measured, however, it did not exceed any criteria.

Results from radionuclides will be analyzed upon completion of laboratory analysis.

White Oak Creek

Results from metals, inorganic parameters, and radionuclides will be analyzed upon completion of laboratory analysis.

5.1.8 Conclusions

Full stream characterization cannot be done at this time due to pending laboratory analysis for several of the sampled analytes. However, preliminary results indicate that certain parameters may be of concern for a few of the sampled streams.

In general, uranium metal concentrations are quite high in all ORR streams especially when compared to the sampled reference streams. Both Bear Creek and EFPC have high uranium concentrations that tend to decrease with distance from Y-12. Uranium concentrations in the headwaters are upwards of three to four times greater than the recommended drinking water EPA MCL of 30 µg/L. While these streams may not be used directly for drinking water, both streams eventually empty into the Clinch River which is a main source of drinking water for many Tennessee citizens. High uranium concentrations in drinking water can result in damage to kidneys and lead to an increased risk of cancer. Also, these persistently high uranium metal concentrations could potentially have an adverse effect on the natural stream's biota and overall stream's environmental health. Such effects could include bioaccumulation of uranium metal, which has the potential to be transferred through food webs and can cause physical impairment or toxic effects on biota from ingestion.

In addition to uranium metal, several contaminants are of concern for EFPC. Specifically, mercury appears to be a major threat to the stream health. Mercury levels are much greater than the Tennessee recreation standards for surface water. Additionally, nitrite, nitrate, and phosphorus concentrations exceed the ecoregion 67f criteria. Other metals, including copper and zinc, also tend to have high concentrations in EFPC, especially compared to nearby reference streams. High concentrations of these contaminants may pose a threat to stream's biota and to the stream's environmental health. Some examples of threats include the increased demands of stream oxygen concentrations, potential bioaccumulation in biota, and transfer of pollutants through the food web. Additionally, fish-kills or physical impairment to biota through ingestion could occur.

Lastly, the Clinch River at the WOC confluence consistently yields high concentrations of radionuclides. More specifically, high concentrations of strontium-90, gross beta, and uranium-234 were found. An estimate of flow from the upstream White Oak Dam along with sample concentrations measured during this project indicate the loading of strontium-90 is roughly 2.82E-05 g/yr, which is 459% of the EPA MCL when considering the median White Oak Dam annual flow rate of 14,325 L/min. This is likely a conservative estimate due to sampling a mixture of Clinch River and WOC water, which is likely diluted in regard to radionuclides. These high concentrations of radionuclides are not seen at sampling stations directly downstream, likely due to Clinch River dilution.

5.1.9 Recommendations

All streams in this study are impacted by ORR contaminants. Until all areas of extensive anthropogenic-point and non-point source contamination on the ORR are fully remediated, the potential exists for pollution to contaminate surface waters on the ORR as well as downstream offsite aquatic systems. Accordingly, it is prudent for this project to continue assessing ORR/CRK surface water conditions. In addition, it is recommended that flow measurements be taken in conjunction with surface water sampling to assess the loading of contaminants from the ORR into the Clinch River, a major resource for many Tennessee citizens.

5.1.10 References

DOE (1992). Federal Facility Agreement (FFA). Appendices for the Oak Ridge Reservation. Oak Ridge Site Description – UCOR, Appendix B (2017 revision). DOE/OR-1014. U. S. Department of Energy. Retrieved from http://www.ucor.com/docs/ffa/appendices/AppendixB.pdf

Pickering, R. (1970). Composition of Water in Clinch River, Tennessee River, and Whiteoak Creek as Related to Disposal of Low-Level Radioactive Liquid Wastes. (Geological Survey Professional Paper No. 433–J). Retrieved from https://pubs.usgs.gov/pp/0433j/report.pdf

Turner, R. R., & Southworth, G.R. (1999). Mercury-Contaminated Industrial and Mining Sites in North America: an Overview with Selected Case Studies. In R. Ebinhaus, R. R. Turner, L. D. de Lacerda, O. Vasilev, & W. Salomons (Eds.), Environmental Science: Mercury Contaminated Sites. Springer-Verlag.

5.2 AMBIENT SURFACE WATER PARAMETERS

5.2.1 Background

The Oak Ridge Reservation (ORR) is a complex National Priority List (NPL) site. Built in the 1940's, the federally-owned 37,000-acre reservation includes three Department of Energy (DOE) facilities created as integral parts of the Manhattan Project. The three site facilities are the Oak Ridge National Laboratory (ORNL), the Y-12 National Security Complex (Y-12), and the East Tennessee Technology Park (ETTP), formerly the K-25 Plant. Activities at site facilities have resulted in the discharge of hazardous substances (metals, organics, and radioactive materials) leading to the contamination of waterbodies at the ORR NPL site and in the surrounding areas.

An ambient surface water parameters project has been implemented each year since 2005. Due to the presence in some areas of anthropogenic point- and non-point source contamination on the ORR, there exists the potential for contamination to impact surface water on the ORR. To assess the degree of surface water impact relative to this potential contamination displacement, stream monitoring data will be collected monthly to establish a database of physical stream parameters (specific conductivity, pH, temperature, and dissolved oxygen).

5.2.2 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 (EFPC) by spills and leakage from subsurface drains, building foundations, contaminated soil, and 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)
- 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)
- Water supply facilities, serving an estimated population of 200,000 persons, on the

Tennessee River downstream of White Oak Creek have the potential of being influenced by streams that drain the ORR (DOE, 1992)

- The Clinch River received approximately 665 curies of cesium-137 (Cs-137) from White Oak Creek from 1954 to 1959 (DOE, 1992)

5.2.3 Goals

- Create a database/baseline of surface water conditions on and around the ORR
- Assess site remediation efforts through long-term monitoring of surface water
- Record ambient conditions that can be used for comparisons in the event of accidents that may have impacted surface water bodies

5.2.4 Scope

Due to the presence in some areas of anthropogenic point- and non-point source contamination on the ORR and the potential for contamination to impact surface water parameters, this project is limited to collecting and recording physical stream parameter measurements of ambient surface water of the exit pathway streams that drain the ORR to establish a baseline of conditions on and around the ORR.

5.2.5 Methods, Materials, Metrics

The surface water physical parameters of temperature, pH, conductivity, and dissolved oxygen were measured monthly with an YSI Professional Plus multi-parameter water quality instrument. Field monitoring followed the 2011 Tennessee Department of Environment and Conservation (TDEC), Division of Water Resources (DWR), *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water*.

Table 5.2.1: Proposed Monitoring Locations

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

5.2.6 Deviations from the Plan

There were no deviations from the project plan.

5.2.7 Results and Analysis

Field parameters including specific conductivity, dissolved oxygen, pH, and temperature were collected monthly from the seven monitoring locations (Figure 5.2.1). 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 will be analyzed and discussed below.

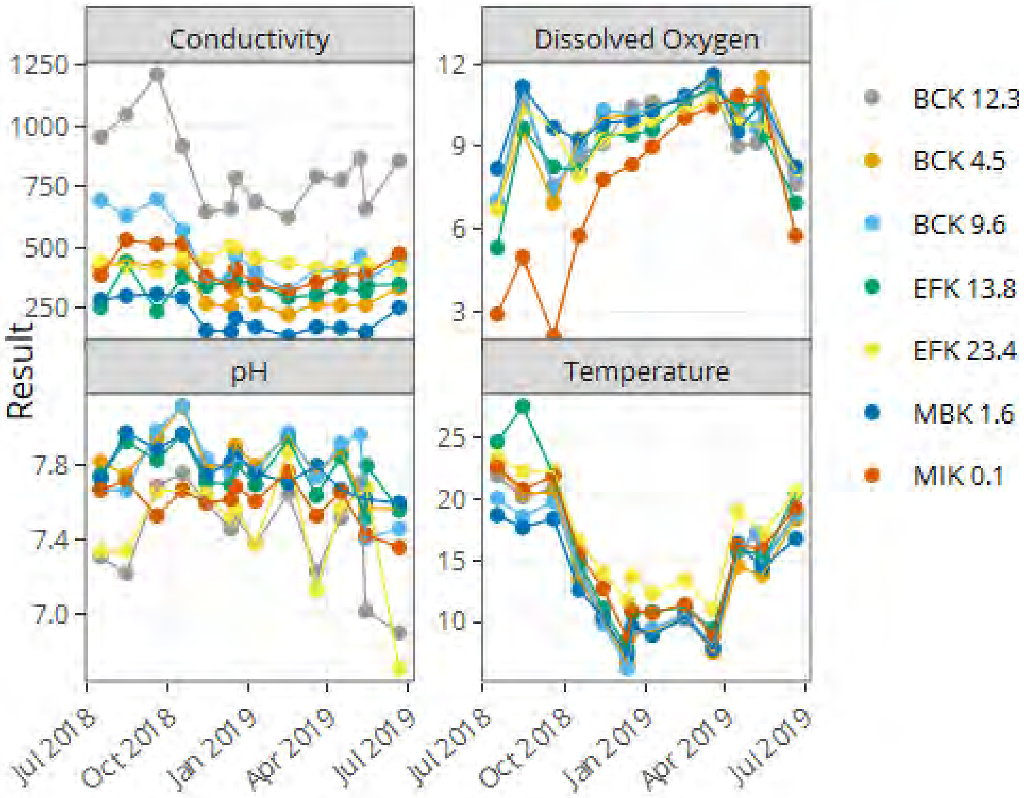


Figure 5.2.1: Field parameter results from July 2018 through June 2019. Units for conductivity, dissolved oxygen, pH, and temperature are μS/cm, mg/L, std. unit, and °C, respectively.

One of the field parameters with significant differences among streams was specific conductivity. Mean specific conductivity values from measurements collected July 2018 to June 2019 ranged from 819 to 210 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 819 and 470 μS/cm, respectively. Further downstream, BCK 4.5 had a lower mean value of 320 μS/cm. On EFPC, site EFK 23.4 near the eastern border of the Y-12 Security Complex had a mean specific conductivity of 440 μS/cm. Downstream site EFK 13.8 had a lower mean value of 330 μS/cm. The Mitchell Branch site MIK 0.1 at ETTP had a mean conductivity value of 410 μS/cm. Mill Branch (MBK 1.6), an ecological reference site, had the lowest conductivity among all streams measured with a mean value of 210 μS/cm.

An analysis of variance (ANOVA) was performed to determine if mean specific conductivity differed significantly among streams, and statistically significant differences were detected with $p < 0.05$. A post hoc Tukey test was performed to distinguish which monitoring sites are significantly different in specific conductivity. Results of the Tukey test indicate that Bear Creek site BCK 12.3 is statistically significantly higher in conductivity than all other monitored sites with $p < 0.05$ (see Table 5.2.2).

Table 5.2.2: Results of Tukey comparison of means test for conductivity

Site	Mean Conductivity (uS/cm)
BCK 12.3*	818.7929
BCK 9.6†	469.7857
EFK 23.4†‡	439.9154
MIK 0.1†‡§	409.7615
EFK 13.8‡§	330.4714
BCK 4.5§¶	319.5308
MBK 1.6¶	209.9923

**, †, ‡, §, ¶ 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 2018 to June 2019. Mean values of dissolved oxygen ranged from 9.9 to 7.4 mg/L. The ecological reference site, Mill Branch (MBK 1.6), had the highest oxygen concentration among all streams. 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 exist among streams for dissolved oxygen concentrations. Results from the ANOVA indicated that at least one stream was statistically significantly different ($p < 0.05$) in dissolved oxygen concentrations. A post hoc Tukey test was performed to distinguish which streams are statistically different. Results of the Tukey test revealed two groupings. Mitchell Branch (MIK 0.1) is statistically significantly different, having lower concentrations of dissolved oxygen, than MBK 1.6, BCK 9.6, and BCK 4.5. However, Mitchell Branch is similar to sites BCK 12.3, EFK 23.4, and EFK 13.8. No site was significantly different than all other monitoring sites in dissolved oxygen concentrations (Table 5.2.3).

Mitchell Branch (MIK 0.1) tends to have lower dissolved oxygen levels during the months of June through October, when the weather is hotter and wetter. 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 year-round, 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. More research is needed to fully understand why Mitchell Branch tends to have these lower dissolved oxygen concentrations.

Table 5.2.3: Results of Tukey comparison of means test for dissolved oxygen

Site	Mean Dissolved Oxygen (mg/L)
MBK 1.6*	9.9
BCK 9.6*	9.7
BCK 4.5*	9.6
BCK 12.3*†	9.4
EFK 23.4*†	9.4
EFK 13.8*†	9.1
MIK 0.1†	7.4

**, † 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.*

The field parameter of pH was analyzed as well for measurements collected July 2018 to June 2019. Measurements of pH ranged from 7.82 to 7.42. In Bear Creek, pH increased downstream with sites BCK 12.3, BCK 9.6, and BCK 4.5 having mean values of 7.43, 7.80, and 7.82, respectively. East Fork Poplar Creek similarly increased in pH downstream with upstream site EFK 23.4 having an average pH of 7.47 and EFK 13.8 yield an average pH of 7.77. Mill Branch MBK 1.6 had a mean pH of 7.78 and Mitchell Branch MIK 0.1 had a mean pH of 7.60. An ANOVA and post hoc Tukey test indicated two distinct groupings. However, no site was significantly different than all other sites in pH levels (see Table 5.2.4).

Table 5.2.4: Results of Tukey comparison of means test for pH

Site	Mean pH (Std. Unit)
BCK 4.5*	7.82
BCK 9.6*	7.80
MBK 1.6*	7.78
EFK 13.8*	7.77
MIK 0.1*†	7.60
EFK 23.4†	7.47
BCK 12.3†	7.43

**, † 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.*

Lastly, temperature data were evaluated for all sites measured collected July 2018 to June 2019. Mean water temperatures ranged from 16.7 to 13.0 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 5.2.5).

Table 5.2.5: Average water temperatures

Site	Mean Temperature (°C)
EFK 23.4	16.7
EFK 13.8	15.5
MIK 0.1	15.0
BCK 12.3	14.1
BCK 9.6	13.8
BCK 4.5	13.6
MBK 1.6	13.0

The above-mentioned field parameter data collected July 2018 to June 2019 were also analyzed in conjunction with data collected 2005 to 2018. Data were evaluated for significant increasing or decreasing trends. Significant trends were found in conductivity for two monitoring stations, BCK 12.3 and EFK 23.4.

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 0.806, indicating a good fit. This indicates that there is a trend of decreasing specific conductivity with time for site BCK 12.3. The slope of the regression line illustrates that this decrease is occurring at roughly 36 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 0.812, which indicates the regression fits the data well. This trend illustrates that specific 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 9 µS/cm annually (Figure 5.2.2).

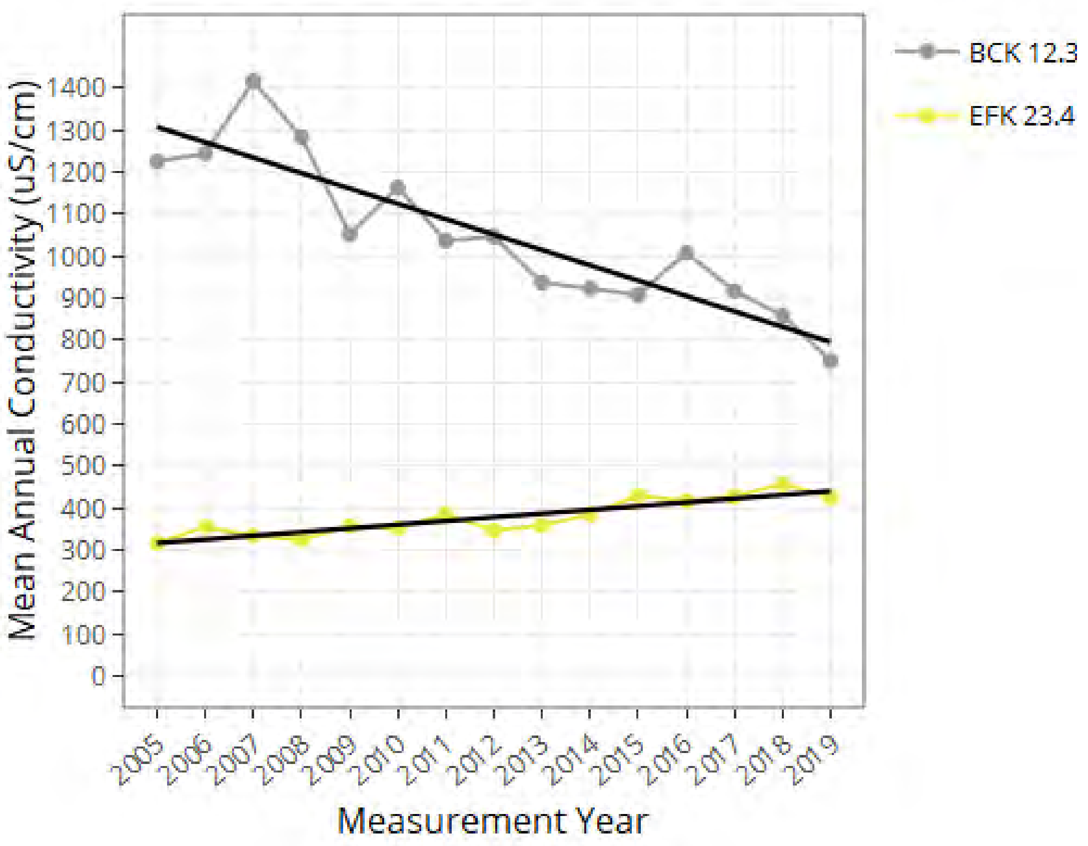


Figure 5.2.2: Linear regression of mean annual conductivity with respect to time for sites Bear Creek (BCK 12.3) and East Fork Poplar Creek (EFK 23.4)

5.2.8 Conclusions

Field parameters including specific conductivity, dissolved oxygen, pH, and temperature were collected monthly from the seven 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. While there is no existing State of Tennessee Water Quality Criteria for specific conductivity, Bear Creek site BCK 12.3 was found to be statistically significantly higher than all other streams. Despite this higher conductivity, historical data (2005-2019) indicate that BCK 12.3 has a decreasing trend in conductivity of roughly 36 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 on the Y-12 Security Complex 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 area of the S-3 ponds and the Y-12 West End Water Treatment Facility. Further evaluation is necessary here. On East Fork Poplar Creek, site EFK 23.4 has shown a steadily increasing trend of conductivity which is on average roughly 9 µS/cm annually. The reason(s) for this increase have not yet been determined.

5.2.9 Recommendations

As legacy DOE ORR pollution has negatively impacted East Fork Poplar Creek, Bear Creek, and Mitchell Branch, TDEC recommends continued physical parameter monitoring at the seven 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.

5.2.10 References

DOE (1992). Federal Facility Agreement (FFA). Appendices for the Oak Ridge Reservation. Oak Ridge Site Description – UCOR, Appendix B (2017 revision). DOE/OR-1014. U. S. Department of Energy. Retrieved from http://www.ucor.com/docs/ffa/appendices/AppendixB.pdf

Brooks, S. (2001) - Waste Characteristics of the Former S-3 Ponds and Outline of Uranium Chemistry Relevant to NABIR Field Research Center Studies. March 2001. ORNL/TM-2001/27 Prepared by Scott C. Brooks, Environmental Sciences Division. Retrieved from https://public.ornl.gov/orifc/other/brooks_rpt.pdf

Pickering, R. (1970). Composition of Water in Clinch River, Tennessee River, and Whiteoak Creek as Related to Disposal of Low-Level Radioactive Liquid Wastes. (Geological Survey Professional Paper No. 433–J). Retrieved from https://pubs.usgs.gov/pp/0433j/report.pdf

Turner, R. R., & Southworth, G.R. (1999). Mercury-Contaminated Industrial and Mining Sites in North America: an Overview with Selected Case Studies. In R. Ebinhaus, R. R. Turner, L. D. de Lacerda, O. Vasilev, & W. Salomons (Eds.), Environmental Science: Mercury Contaminated Sites. Springer-Verlag.

5.3 RAIN EVENT MONITORING

5.3.1 Background

The Oak Ridge Reservation (ORR), a government-owned, contractor-operated facility, contains three major operating sites: Y-12 National Security Complex (Y-12), Oak Ridge National Laboratory (ORNL), and East Tennessee Technology Park (ETTP). The ORR was established in the early 1940s as part of the Manhattan Project that produced the materials for the first atomic bombs. That work and subsequent research, development, and production activities have involved and continue to involve radiological and hazardous materials.

On November 21, 1989, the Environmental Protection Agency (EPA) added the ORR to the National Priorities List. The State of Tennessee, the EPA, and the Department of Energy (DOE) entered into a Federal Facility Agreement (FFA) under Section 1200 of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 in November 1991.

In November 2017, DOE listed more than 400 sites at ETTP, more than 300 sites at ORNL, more than 100 sites at Y-12, and at least eight sites off the ORR – each of which fall under the guidelines of CERCLA. In June 2017, there was the removal of an estimated 12,500 cubic yards of contaminated soils in progress at ETTP; an estimated soil excavation at Y-12 of more than 80,000 yards; and greater than 100,000 cubic yards' excavation estimated for projects at ORNL.

Rain water and groundwater are not static. Water accumulates, pools, and makes its way into basements, basins, and soil excavations from decontamination and decommissioning (D&D) activity and remedial action (RA) sites. Most of this water accumulation contains at least one contaminant required to be treated before discharging it to the environment.

Estimated volumes of accumulated water at ETTP range from 200 gallons to 1.5 million gallons.

5.3.2 Problem Statements

- Contamination from legacy and ongoing activities can be disturbed and transported beyond the physical boundaries of the ORR by D&D or RA activities during a rain event
- Water can accumulate in D&D or RA areas through entry into basins, sumps, basements, or during soil remediation activities. Accumulated water may become contaminated and dispersed into the environment

5.3.3 Goals

The goal of this project is to obtain data to evaluate DOE's remedial actions and to provide input into the future of cleanup decisions. Actions to achieve this goal follow:

- Monitor storm drains (SD) near remediation activities to gather data for the evaluation of D&D activities
- Use split and or independent sampling to monitor releases into the environment
- Observe sampling activities associated with D&D and RA activities
- Review DOE sampling results

5.3.4 Scope

The scope of this project is to assess, monitor, sample, observe, and analyze data pertaining to rain events associated with DOE's remedial actions. A rain event is defined by the *Division of Water Quality QS-SOP for Chemical & Bacteriological Sampling of Surface Water Revision 3 (TDEC, 2011)* as ≥ 0.25 inches of rain in the last 24 hours prior to sample collection during the wet season (January to March) or ≥ 0.5 inches of rain in the last 24 hours prior to sample collection during the dry season (August to October). Samples taken during months outside of this definition will be taken after a measurable rain of 0.5 inches or greater.

- Samples taken during D&D and RA activities will evaluate if agreed to release criteria are being met
- All samples will be collected, preserved, and shipped following approved Tennessee (TN) Department of Health and Tennessee Department of Environment and Conservation (TDEC) Division of Remediation (DoR) Oak Ridge office (OR) standard operating procedures

- Independent sampling will be performed to confirm DOE sampling results
- Operations will be observed to ensure compliance with site-specific performance documents
- Possible new or ongoing releases to the environment (that are not being monitored by DOE) may warrant the sampling of seeps, drains, burial grounds, etc.

5.3.5 Methods, Materials, Metrics

Sample collection will be conducted following the guidelines set forth in the *Division of Water Quality QS-SOP for Chemical and Bacteriological Sampling of Surface Water, Revision 3 (TDEC, 2011).* A brief treatment of the sampling procedure is described in the paragraphs that follow.

For samples containing a preservative, bottles must be closely observed. When the sample volume reaches the neck of the bottle, the bottle must be removed from the flow. This ensures that the sample preservative is not diluted or allowed to enter the stream.

Samples will be taken as close to the point of generation as possible. In most cases, this will require sampling from storm drains. Samples will be taken from manholes or at the discharge points of the storm drain. If the sample is taken from the discharge end of the pipe, the sample is to be taken using the dip method. This is accomplished by collecting the sample in a clean unpreserved sample bottle and transferring the sample collected into a prepared sample container. This can be accomplished by either sampling by hand or attaching the dip bottle to a device that will allow the sampler to extend their reach, safely. Care must be taken not to touch the dip container to the prepared sample bottle.

Due to depth to water, samples taken from manholes will need to be taken by peristaltic pump to eliminate contamination from disturbing sediment in the pipe. At each site, new tubing will be used. Samples of water that have to be pumped from a location will be done after enough water transfer has occurred to allow for purging of the transfer line. Best efforts will be made to take samples from the mid-point for the flow depth. Samples will be taken randomly to attempt to get a representative sample.

Sampling Plan

Samples will be collected at storm drains for the oversight of D&D work on a quarterly basis; at discharge points for surface impoundments; and at other locations, samples will be collected as needed. Refer to Table 5.3.1 for the laboratory analysis methods used.

Table 5.3.1: Laboratory Analysis Methods

Analysis	State Laboratory Analysis Method
ICP Digestion	200.2
Metals IP-OES	200.7
Metals IP-MS	200.8
Total Suspended Solids	2540-D
Hexavalent Chrome	218.6
Polychlorinated Biphenyls (PCB's)	8082
Mercury	245.1
Gross Alpha/Beta	D7283-13
Strontium 90	D5811
Technetium 99 (Tc-99)	TWC02
Isotopic Uranium	U-02-RC
Tritium	906

5.3.6 Deviations from the Plan

Due to project budget cuts, samples and analysis were reduced in the 4th quarter of 2018 and in the 1st quarter of 2019. Of the scheduled samples, a total of eighteen (18) metals and seven radiological samples were uncollected in the 4th quarter of 2018. In the 1st quarter of 2019, sixteen metals, six radiological, and one Polychlorinated Biphenyls (PCB) sample was cut from the sampling program. Sampling was curtailed in the 2nd quarter of 2019 resulting in (20) twenty metals, seven radiological, and one PCB sample not being collected.

A reduced sampling budget did not allow for split sampling of treated water before release as proposed in goals.

5.3.7 Results and Analysis

Beginning in July 2018 and ending in June 2019, two locations originating on the ORR were sampled, quarterly. SD430 was sampled to monitor D&D activity occurring on the ETTP. SD490 was sampled to monitor the ongoing TC-99 release that began with the D&D of K-25 in 2013. Table 5.3.2 identifies, and Figure 5.3.1 shows the locations selected for sampling. Figure 5.3.2 shows TDEC staff collecting water samples at (Storm Drain Outfall) SD430 following a storm event.

Table 5.3.2 Sampling Locations

Sample locations				
Site		**Location**		
SD430		Storm Drain located at ETTP		
SD490		Storm Drain located at ETTP		

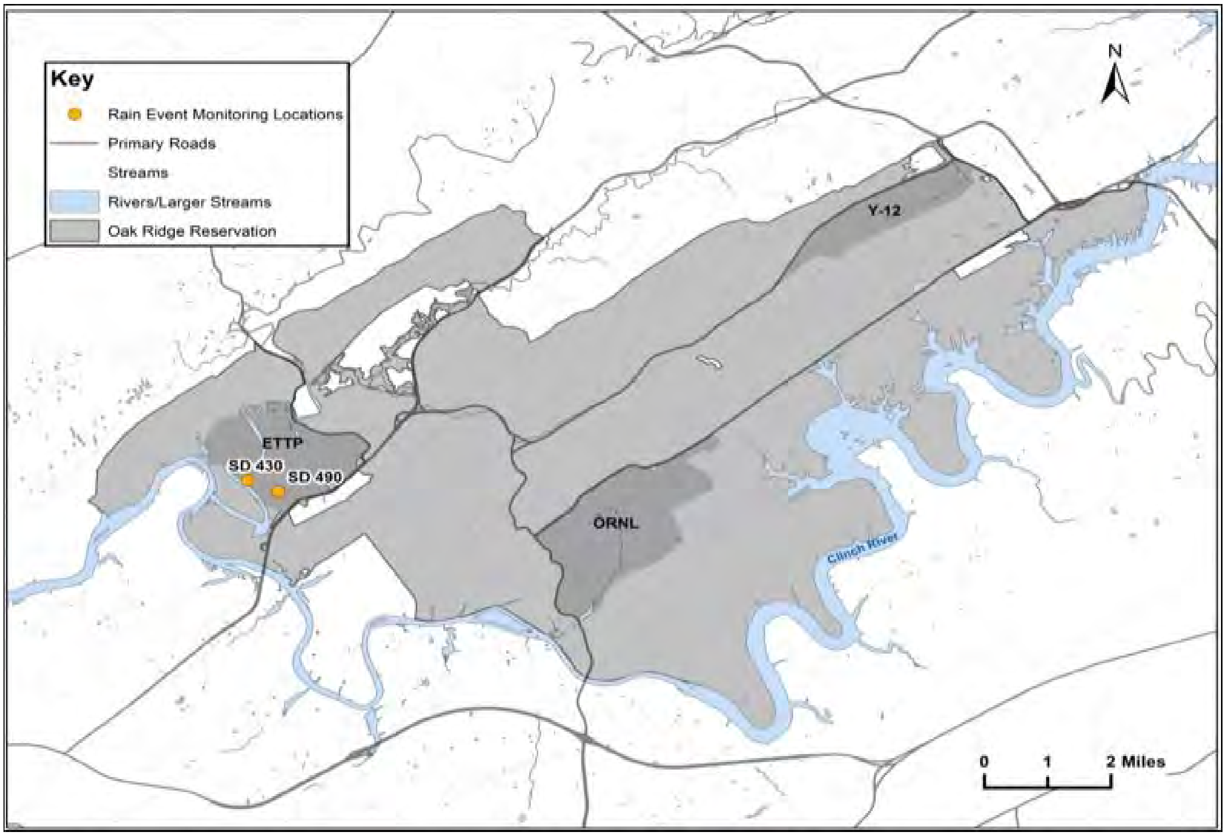


Figure 5.3.1 Map of Sampling Locations

Figure 5.3.2: TDEC Staff Collecting Samples Following a Rain Event (Photo was taken by Mike Coffey, CDMSmith.)

Qualifying rain event samples were collected following rain events during each calendar quarter starting in July 2018 and continuing through June 2019. Samples were collected on August 2, 2018; November 9, 2018; and January 24, 2019. Figure 5.3.3 illustrates data for the three sampling events which exceeded the definition of a rain event as recorded at the *Oak Ridge Office of the National Oceanic and Atmospheric Administration* data site. The following field parameters were taken using an YSI meter at each site when a field sample was taken pH, temperature, dissolved oxygen, and conductivity. Water samples collected during this reporting period were analyzed for the following parameters:

<u>Third Quarter 2018</u>:

Metals: Arsenic, cadmium, chromium, iron, lead, manganese, mercury, zinc, uranium, hexavalent chromium were sampled at SD430.

SD490: Arsenic, chromium, copper, iron, lead, manganese, mercury, zinc, uranium hexavalent chromium.

Radionuclides: Analysis for gross alpha and gross beta was conducted at SD430 and SD490. Tc-99 was collected at SD430 and SD490. Tritium was sampled for at SD490.

Fourth Quarter 2018:

Metals: Hexavalent chromium was sampled at SD430 and SD490.

Radionuclides: Tc-99 was collected at SD430.

PCB's: PCB's were sample at SD430.

First Quarter 2019:

Metals: Samples were collected for hexavalent chromium analysis at SD490 and SD430. Mercury was sampled for at SD430 and SD490.

Radionuclides: Analysis for gross alpha and gross beta was conducted at SD430 and SD490. Tc-99 was collected at SD430 and SD490. Tritium was sampled at SD490.

Second Quarter 2019:

Metals: No samples were collected.

Radionuclides: No samples were collected.

PCB's: No samples were collected.

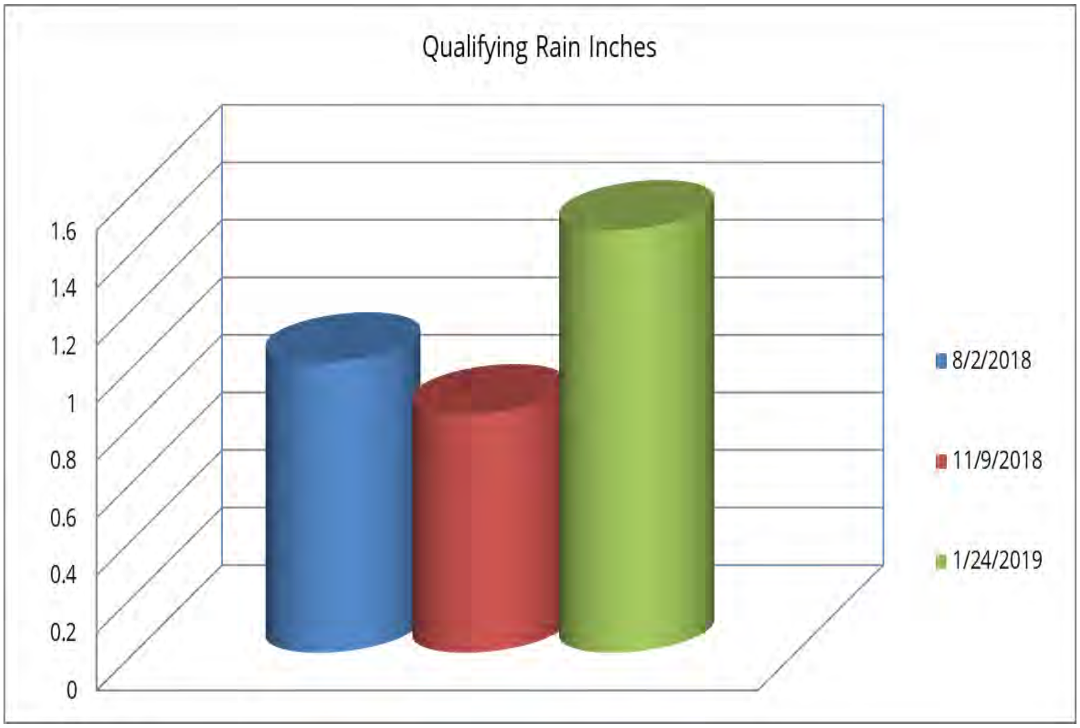


Figure 5.3.3: Qualifying Rain Events for Each Sampling Event

Relative to the three rain events, summarized field parameters are presented in figures 5.3.4 through 5.3.7.

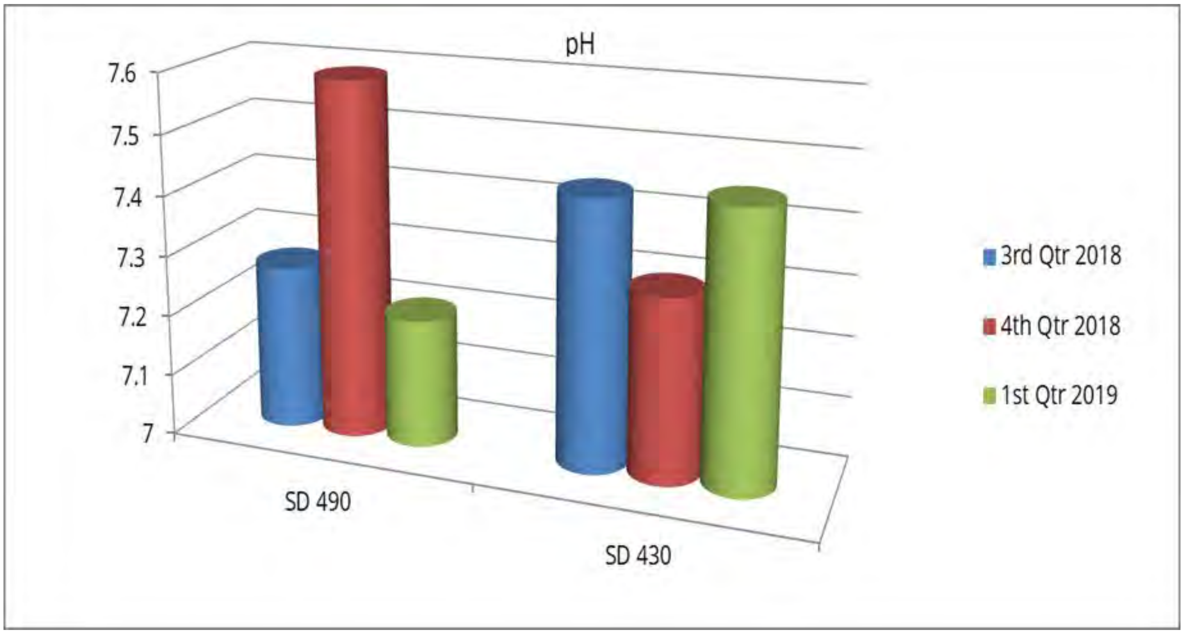


Figure 5.3.4: Field pH Measurements

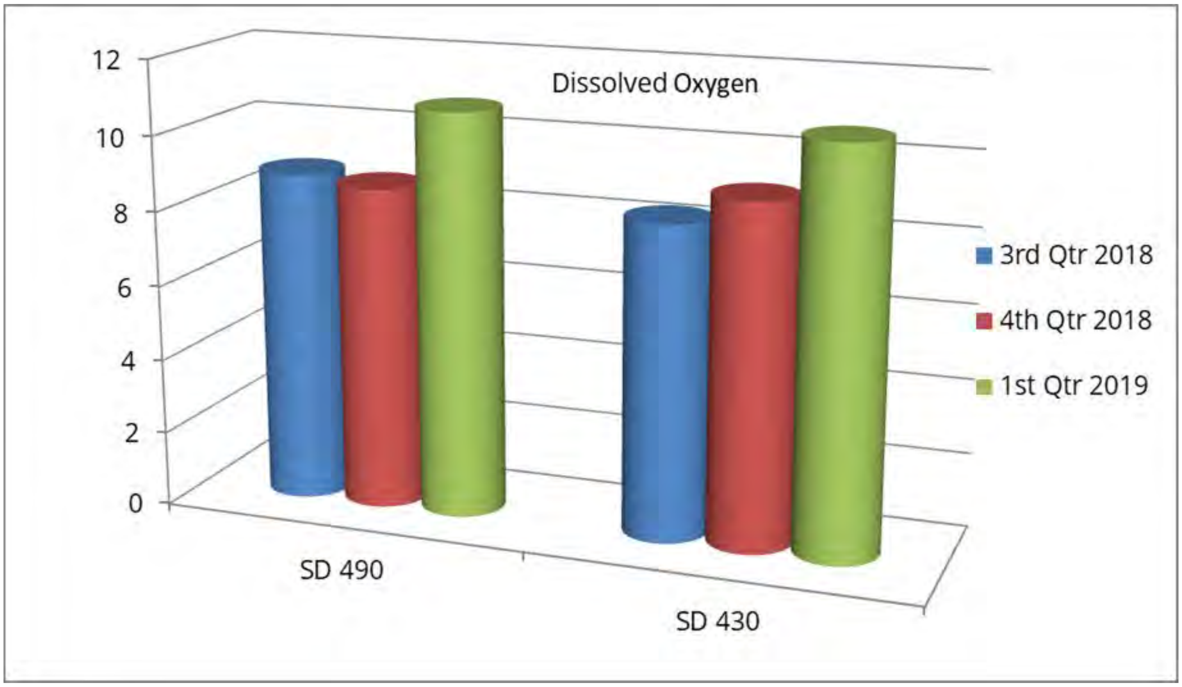


Figure 5.3.5: Dissolved Oxygen in mg/L

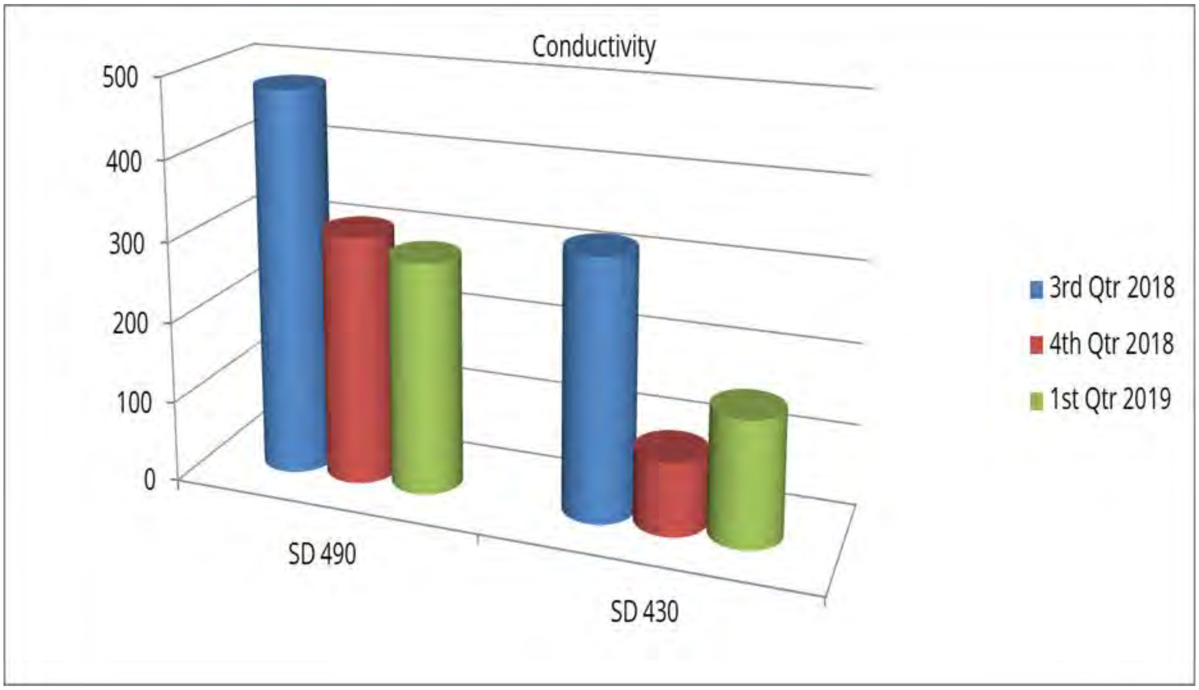


Figure 5.3.6: Conductivity in µS/cm (Micro Siemens per Centimeter)

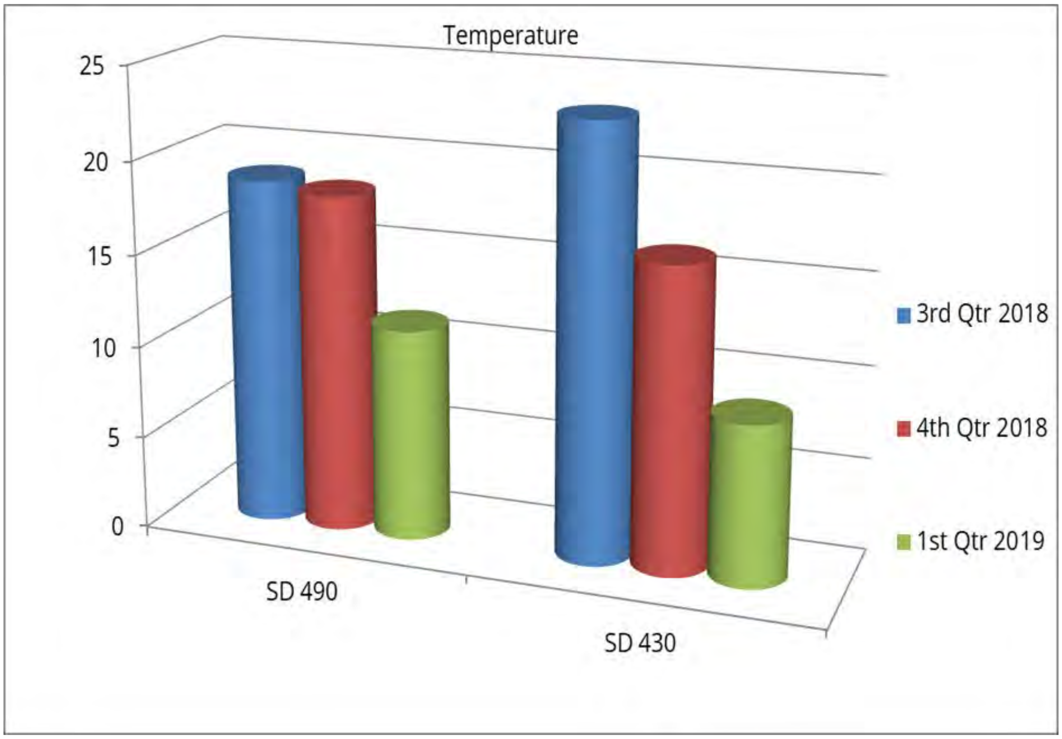
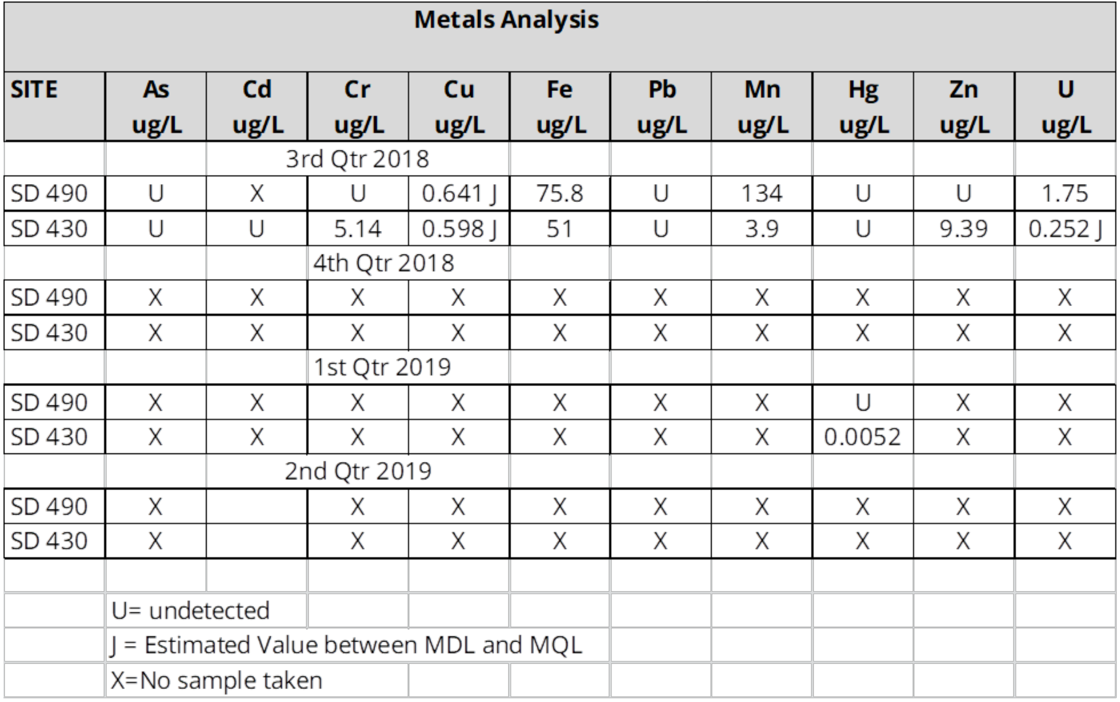


Figure 5.3.7: Temperature (Degrees Celsius)

The results of metals analysis are shown in the following table, Table 5.3.3.

Table 5.3.3: Metals Analysis



Metals Analysis										
SITE	As ug/L	Cd ug/L	Cr ug/L	Cu ug/L	Fe ug/L	Pb ug/L	Mn ug/L	Hg ug/L	Zn ug/L	U ug/L
		3rd Qtr 2018								
SD 490	U	X	U	0.641 J	75.8	U	134	U	U	1.75
SD 430	U	U	5.14	0.598 J	51	U	3.9	U	9.39	0.252 J
			4th Qtr 2018							
SD 490	X	X	X	X	X	X	X	X	X	X
SD 430	X	X	X	X	X	X	X	X	X	X
			1st Qtr 2019							
SD 490	X	X	X	X	X	X	X	U	X	X
SD 430	X	X	X	X	X	X	X	0.0052	X	X
		2nd Qtr 2019								
SD 490	X		X	X	X	X	X	X	X	X
SD 430	X		X	X	X	X	X	X	X	X
	U= undetected									
	J = Estimated Value between MDL and MQL									
	X=No sample taken									

The results of the gross alpha, gross beta scans are shown in Table 5.3.4.

Table 5.3.4: Results of Gross Alpha/Beta Radionuclide Analysis

Results of Gross Alpha/Beta Radionuclide Analysis				
Site	**Gross Alpha**	***CSU**	**Gross Beta**	***CSU**
	pCi/L	**± pCi/L**	**pCi/L**	**± pCi/L**
	3RD Qtr 2018			
SD 490	-6.65	0.077	298.5	8.4
SD 430	-2.94	0.37	13.6	4
	4TH Qtr 2018			
SD 490	NS			
SD 430	NS			
	1st Qtr 2019			
SD 490	-6.65	0.077	298.5	8.4
SD 430	-0.27	0.72	7	4
	2nd Qtr 2019			
SD 490	NS			
SD 430	NS			

NS – No sample taken

*CSU – Represents combined standard uncertainty at 1-Sigma

Tritium and Tc-99 were sampled at SD490 and SD430. Analysis was conducted to monitor for contamination from CERCLA work in these areas. Results from these analyses are shown in Table 5.3.5.

Table 5.3.5: Results of Tritium (H-3) and Tc-99,

Results of Tritium (H-3) & Tc-99				
Site	**Tritium pCi/L**	**Tritium *CSU**	**Tc-99 pCi/L**	**Tc- 99 *CSU**
	3rd Qtr 2018			
SD 490	47	28	201.8	8.1
SD 430	N/S		9.16	0.48
	4th Qtr 2018			
SD 490	N/S		244	10
SD 430	N/S			
	1st Qtr 2019			
SD 490	253	32	275	12
SD 430	N/S		4.86	0.8
	2nd Qtr 2019			
SD 490	N/S			
SD 430	N/S			
NS - No sample taken				
*CSU Represents combined standard uncertainty at 1-sigma				

In mid-2013, a Tc-99 release occurred while building K-25 was undergoing demolition at the ETTP. Subsequently, Tc-99 and gross beta were recorded at SD490. The slower-than-expected reduction of Tc-99 in sample point SD490 has led to the continued monitoring and sampling of the storm drain. Figure 5.3.8 illustrates the fluctuations of Tc-99 at SD490 from the 2nd quarter of 2014 until the 1st quarter of 2019; the cause of the 2017 1st quarter elevated Tc-99 concentration is unknown.

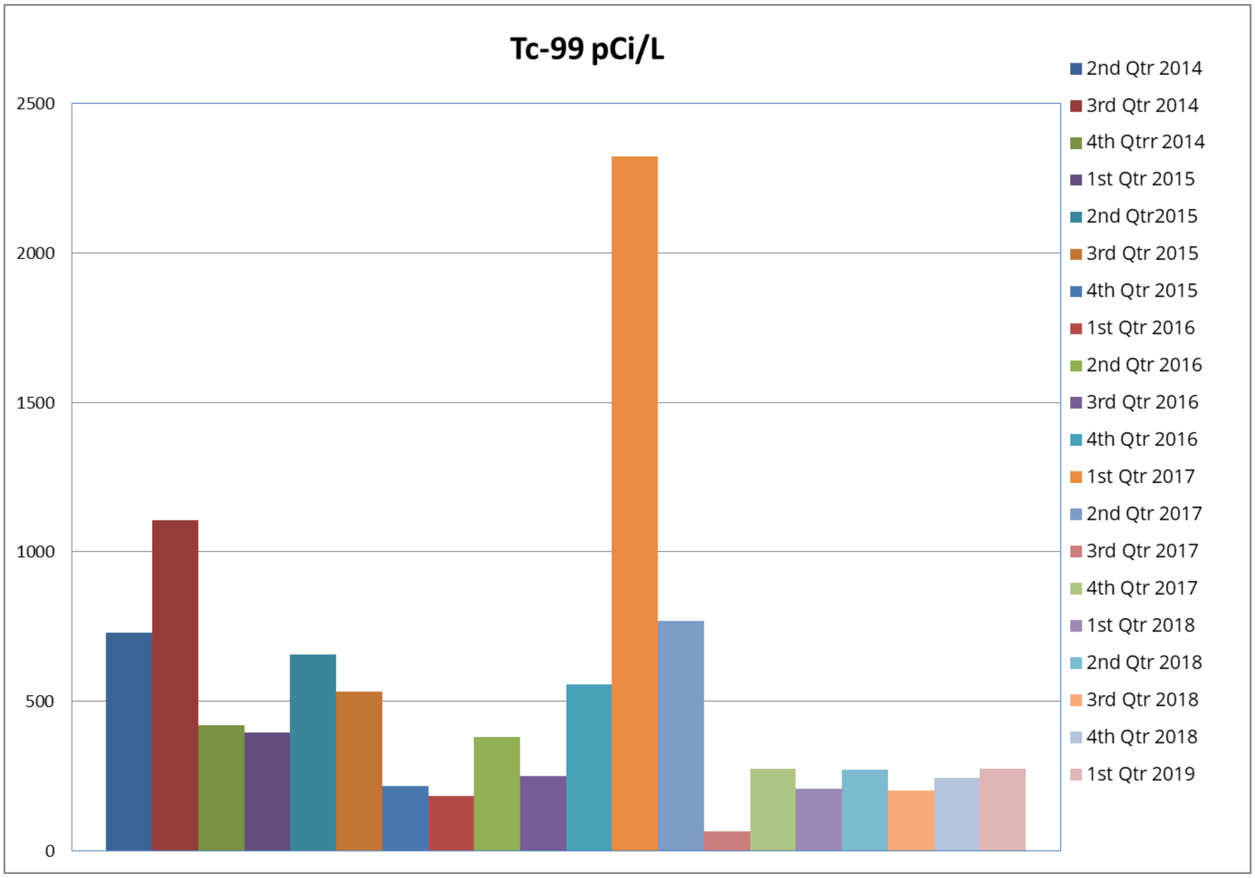


Figure 5.3.8: Tc-99 Results in pCi/L

Table 5.3.6 shows results for Isotopic Uranium sampling.

Table 5.3.6 Isotopic Uranium

Isotopic Uranium Radiological Analysis						
Site	**Uranium-233/234**	**Uranium-233/234**	**Uranium-235**	**Uranium-235**	**Uranium -238**	**Uranium -238**
	pCi/L	***CSU**	**pCi/L**	***CSU**	**pCi/L**	***CSU**
	3rd Qtr 2018					
SD 430	0.42	0.13	0.085	0.072	0.31	0.1
	4th Qtr 2017					
SD 430	0.355	0.072	0.06	0.022	0.25	0.058
	1st Qtr 2018					
SD 430	0.4	0.072	0.22	0.016	0.203	0.046
	2nd Qtr 2018					
SD 430	NS					
*CSU Represents combined standard uncertainty at 1-sigma						
NS - No sample taken						

Hexavalent Chromium is being monitored at the SD490 and SD430. The basis for monitoring Hexavalent Chromium is the CERCLA D&D work being conducted on the ETTP. PCB's were analyzed at SD430 to monitor for possible contamination from past CERCLA work performed in the area. PCB’s were undetected in all samples submitted for analysis. Table 5.3.7 shows results for Hexavalent Chromium and PCB’s sampling results.

Table 5.3.7: Hexavalent Chromium & PCB’s

Hexavalent Chromium & PCB's						
SITE	DATE		PCB'S		Cr 6	
	3rd Qtr 2018				mg/L	
SD 490			NS	mg/L	0.0013	mg/L
SD 430			NS	mg/L	0.0046	mg/L
	4th Qtr 2018					
SD 490			NS	mg/L	0.001	mg/L
SD 430			U	mg/L	0.0018	mg/L
	1st Qtr 2019					
SD 490			NS	mg/L	0.0011	mg/L
SD 430			NS	mg/L	0.0028	mg/L
	2nd Qtr 2019					
SD 490			NS	mg/L		mg/L
SD 430			NS	mg/L		mg/L

NS- No Sample

U- Undetected

5.3.8 Conclusions

During the D&D of the K-25 building in 2013 Technietium-99 (Tc-99) was released into the environment. This isotope continues to be recovered in the storm drain system. EPA has set a Maximum Contaminant Level (MCL) of 4 millirem per year for beta particle and photon radioactivity from man-made radionuclides in drinking water. Tc-99 would be covered under this MCL. The average concentration of Tc-99 which is assumed to yield 4 millirem per year is 900 picocuries per liter (pCi/L). The data for Tc-99 from this sampling project was found to be below the regulatory limits for drinking water and thus would not create a significant impact to human health or the environment.

The current federal drinking water standard for total chromium is 0.1 mg/L or 100 ppb. To ensure that the greatest potential risk is addressed, EPA assumes that measurement of total chromium is 100 percent hexavalent chromium. The sample results from the timeframe covered by this report are below the regulatory limits used for drinking water.

During observation of the DOE sampling of water to be released from the treatment systems and the collection of storm event samples, there were no concerns raised due to sample methodology or handling of samples. DOE provided sampling results from both treatment systems in operation at ETTP as well as results from storm event sampling. TDEC reviewed these results. Hexavalent chromium is sporadically present in SD490 and SD430. A radiological contaminant (Tc-99) from the 2013 release at K-25 continues to impact SD490.

5.3.9 Recommendations

With the continuing D&D and RA projects on the ORR, the oversight of the storm drain sampling programs will ensure that DOE is monitoring the discharges created by the re-industrialization of the reservation.

Rain water and ground water accumulate in areas of D&D and RA projects. These areas include soil excavations, basements, sumps, etc. Most of this accumulated water contains at least one contaminant that requires treatment before discharge. These contaminants include arsenic, chromium, mercury, Technetium-99, PCBs, TCE, and uranium. Treatment systems are being designed and implemented for specific areas of concern on the reservation.

Oversight of these areas would result in greater protection of human health and the environment.

5.3.10 References

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

State of Tennessee (State of Tennessee, 2018a) Department of Environment and Conservation Division of Water Resources Quality System Standard Operating Procedure for CHEMICAL AND BACTERIOLOGICAL SAMPLING OF SURFACE WATER, August 29, 2018

UCOR URS / CH2M (UCOR 2018a): ETTP Water Treatment Update presented April 12, 2018

U.S. Department of Energy (DOE, 2017a) Remediation of Effectiveness Report for the U.S Department of Energy, Oak Ridge Reservation, Oak Ridge Tennessee DOE/OR/01-2731&D2

5.4 SURFACE WATER MONITORING AT THE EMWMF

5.4.1 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 Oak Ridge Reservation (ORR) and is operated under the authority of Comprehensive Environmental Response, Compensation and Liability Act (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 1946.

Currently, the only authorized discharges from EMWMF are uncontaminated storm water and contact water. 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 the results, it is either treated or released to a storm water sedimentation basin which discharges to the NT-5 tributary of Bear Creek.

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 are based on State regulations (TDEC 0400-20-11-.16{2}) restricting concentrations of radioactive material released from LLRW disposal facilities to the general environment in groundwater, surface water, air, soil, plants, or animals to an annual dose equivalent of 25 mrem/year.

Neither dose limit is currently considered protective under CERCLA, based on EPA guidance in OSWER Directive 9285.6-20 (June 13, 2014). The issue is currently being addressed as a part of a FFA dispute on the related Focused Feasibility Study for *Water Management for the Disposal of CERCLA Waste on the Oak Ridge Reservation, Oak Ridge, Tennessee* (DOE/OR/01-2664&D2).

For contaminants other than radionuclides, the point of compliance is the contact water ponds, where Tennessee Ambient Water Quality Criteria (AWQC's) for fish and wildlife has served as the limits for the releases of contact water to the sediment basin and via the basin to NT-5 and Bear Creek. Bear Creek’s designated use includes recreational which has not been incorporated into the EMWMF release criteria. This issue is also being addressed as part of the FFA dispute on the FFS for Water Management for the Disposal of CERCLA Waste document cited above.

5.4.2 Problem Statements

Contaminated materials from CERCLA remediation activities are buried and continue to be buried in the EMWMF. Over time, associated 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.

5.4.3 Goals

The Surface Water Monitoring of the EMWMF Project aims to accomplish the following goals:

- To 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.
- To provide assurance through the independent monitoring efforts and evaluation of DOE’s data that operations at EMWMF meet the remedial actions objectives specified in the EMWMF ROD.
- To verify that DOE discharges into Bear Creek of contaminated storm water (e.g. storm water that has contacted waste and has not been treated) comply with the established limits and operational requirements.
- To provide independent data on discharges from the underdrain and to evaluate its effectiveness in lowering the groundwater table under the landfill.
- To ensure EMWMF is meeting its operational requirements, discharge data collected by EMWMF will be reviewed by TDEC DoR-OR quarterly.
- TDEC DoR-OR will collect confirmation samples to ensure best practices are used to limit contaminant migration; site visits will be performed to monitor ongoing activities at EMWMF.

5.4.4 Scope

The Surface Water Monitoring of the EMWMF Project proposed each of the following tasks:

1. Staff will monitor parameters at the EMWMF-2 (underdrain discharge) and EMWMF-3 (Sediment Basin v-weir discharge) sites at least twice weekly with the use of a YSI-Professional Plus water quality instrument or equivalent.

2. To ensure contaminants from the cell are not adversely affecting the surrounding environment, water samples will be collected on a routine basis from select sites (Table 5.4.1).

3. Sediment samples will be collected from the sediment basin when it is dry (there is no or little water in the sediment basin). These samples will be composited into one sample for analysis.

4. To ensure EMWMF is meeting its operational requirements, discharge data from EMWMF-2 and EMWMF-3 will be collected by DOE. On a quarterly basis, TDEC DoR OR will review the discharge data received from DOE.

5. TDEC DoR OR will collect confirmation samples as referenced by Table 5.4.1 and Figure 5.4.1.

6. Samples will be collected from the weirs (EMWMF-2 monthly and EMWMF-3 quarterly) as referenced by Figure 5.4.1.

7. DOE collects quarterly samples from EMWMF-1 (GW-918).TDEC DoR-OR will analyze these samples on a semiannual basis.

8. EMWMF-4B will be sampled and analyzed semi-annually.

Deviations from the Project Plan Scope listed above that occurred during the execution of the project are identified in Section 5.4.6.

Table 5.4.1 and Figure 5.4.1 depict monitoring and sampling locations and sample rationale at the EMWMF.

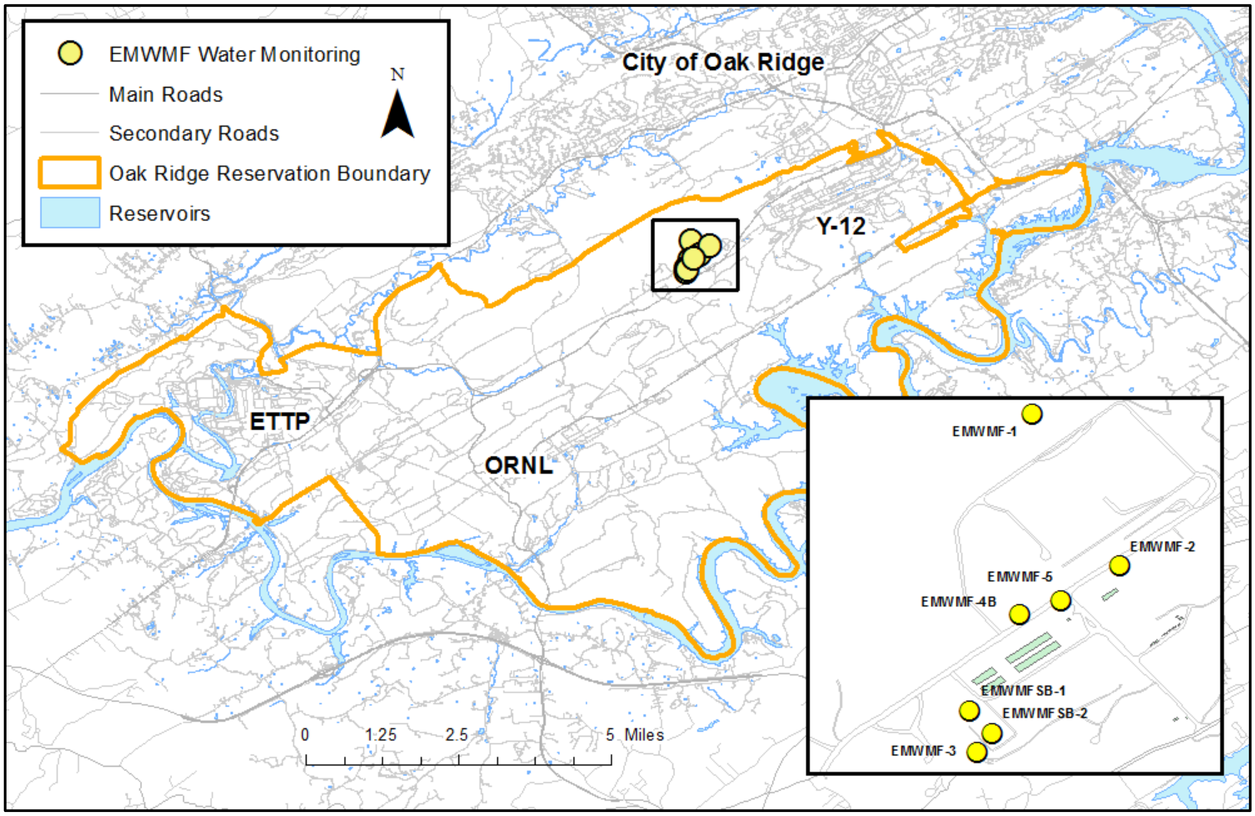


Figure 5.4.1: Proposed EMWMF Sampling and Monitoring Locations

Table 5.4.1: Proposed EMWMF Sampling and Monitoring Locations

Station	Sample ID	Frequency	Sampling Rationale
EMWMF Underdrain	EMWMF-2	Every other month	NT-4 discharge below the landfill. The underdrain was installed below Cell 3 and it is theorized that if cells 1, 2, and 3 were to leak contaminants, they would first be observed at the underdrain.
Contact Water Pond/Tank Effluents	EMWMF-3, EMWMF-5, EMWMF-7, EMWMF-8	Quarterly, from one location	Sampling at these locations provides confirmation of contaminant levels being discharged from the sediment basin.
NT-3 Tributary	EMWMF-3A	Semi-annually as funds permit	Up-stream surface water location to be used as a baseline.
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.
Cell 6 Drainage	EMWMF-6W, EMWMF-4B	Semi-annually as funds permit	This location is used as a verification that water collected in Cell 6 is only storm water.

GW - groundwater

EMWMF - Environmental Management Waste Management Facility

NT - North Tributary of Bear Creek

5.4.5 Methods, Materials, Metrics

Twice per week, the Project Lead will perform independent monitoring (check and record water quality parameters at the various sites) shown on Figure 5.4.1.

Water samples (from the locations identified in Table 5.4.1 and Figure 5.4.1) will be collected in accordance with the Project Plan.

To assess compliance with the radiological limits placed on the outfall of the sedimentation basin, samples will be taken from the discharge from the v-weir at the basin (EMWMF-3), quarterly.

Analysis will focus on radionuclides that have historically contributed the most to the annual dose limits for each discharge location.

Evaluate the performance of the landfill liner by monitoring parameters and analysis of samples collected from the underdrain (EMWMF-2).

EMWMF-1 (GW-918) will be co-sampled with DOE as a background well.

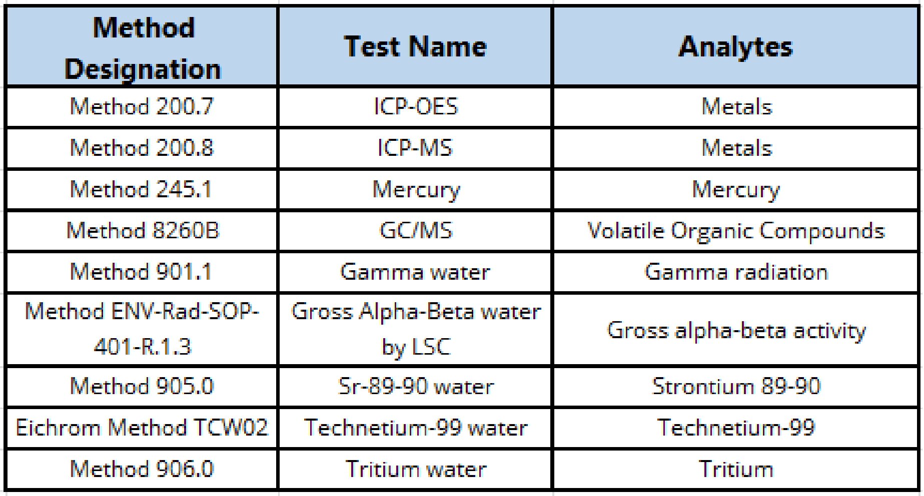
Sediment samples are typically collected from the sediment basin during the fall when there is less precipitation and the bottom of the basin is dry and safe to sample.

Groundwater and sediment sampling will follow *TDEC DoR Quality Assurance Project Plan* (2015) and the *Sampling and Analysis Plan* (2016).

Methods: Lab Methods

The Tennessee Department of Health Laboratory uses EPA methods for sample analysis. The requested analytical methods for this project are listed below in Table 5.4.2:

Table 5.4.2: Lab Methods and Analyses



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

The results of laboratory analyses were entered into an Excel database for interpretation. Interpretation included construction of tables and graphs illustrating ranges and limits of constituents over the course of the project. Included on the graphs are pertinent water quality criteria from the EPA and TDEC.

5.4.6 Deviations from the Plan

Task 1 was not able to be completed due to equipment not being suitable for deployment. No secondary option was available for this task and funding was not available for new equipment.

Certain weeks there were only one or no monitoring opportunities completed. This was due to unavoidable schedule changes, changes in priorities, weather, and an addition of a Radiological Work Plan (RWP) at the end of May that required a UCOR RadCon technician be there to watch and to measure radiological activity from instruments and scan workers that might come into contact with groundwater at the EMWMF. This is to gather information about radiation exposure from the groundwater and may last only a few months as per UCOR RadCon technicians.

Changes in grant amounts for laboratory analyses forced a reevaluation of locations to sample for analysis. From Table 1 in the Charter:

- Water from GW-918 was not analyzed,
- EMWMF-2 was not sampled monthly but bi-monthly,
- EMWMF-3 was analyzed quarterly not monthly,
- NT-3A was not sampled and,
- Cell 6 Drainage was not sampled

In order to measure the effluent from a contact water pond discharging to the Sediment Basin one of the sampling points was changed from the sediment basin to EMWMF-5 (the discharge ditch).

5.4.7 Results and Analysis

5.4.7.1 EMWMF-2 and EMWMF-3 Charts Utilizing DOE Data

DOE, as part of its monitoring requirements for this site, samples and analyzes wells, pipes, streams, ponds, tanks and air. Most sampling is conducted on monthly, quarterly, annually and biennially time frames. Of main interest in this report are samples collected for analysis from two discharge point locations.

- EMW-VWEIR is a surface water sampling location. TDEC refers to this location as EMWMF-3 (VWeir) in their reporting.
- EMW-VWUNDRDRAIN is a groundwater sampling location, referred to as EMWMF-2, (Underdrain) in TDEC reporting.

DOE's contaminants of concern (COCs) for each sampling event vary depending on the data usage requirements. Fourteen wells are sampled quarterly for "Key COCs," which include: metals, mercury, cyanide, selected anions, pesticides, and isotopic radionuclides consisting of Iodine-129, Strontium-90, Technetiun-99, Tritium, Uranium-233/234, Uranium-235/236, and Uranium-238. Annually, those wells are also sampled and analyzed for "Extended COCs" which additionally include volatile organic compounds, along with benzoic acid, five more metals, PCBs, dioxin, and additional radionuclides (Carbon-14, Cesium-137, Chlorine-36, Radium-226, andThorium-230). Biennially, the well samples are analyzed for even more analytes "All COCs"; which includes the EPA 8260 list of 36 compounds, EPA's 8270 list of 45 semi-volatile analytes, 32 metals, PCBs, mercury, 21 pesticides, 2 herbicides, cyanide, propylene glycol, methanol, dioxin, and 45 radioisotopes.

DOE sampling points EMWMF-3, EMWNT-03A, EMWNT-05, the Contact Water Ponds 1 through 4, and the Contact Water Tanks A through D follow the same sampling and analysis regiment as above for annual and biennial sampling events. EMWMF-2 is collected bi-monthly; EMWNT-03B and EMWNT-05 are collected quarterly for Key COCs. The Contact Water ponds, and Contact Water Tanks are analyzed for Key COCs prior to each release. The details of the analytes and the schedule are delineated in the *Sampling and Analysis Plan/Quality Assurance Project Plan for Environmental Monitoring at the Environmental Management Waste Management Facility, Oak Ridge, Tennessee,* DOE/OR/01-2734&D1/R1.

5.4.7.1.1 DOE Analysis Metals Results Discussion

EMWMF-2 (also known as EM-VWUNDRDRAIN) is the point of emergence of a drain designed to mitigate groundwater impingement in the geologic buffer underneath cells 2 and 3. EMWMF-2 was installed from late 2003 to early 2004. A look at some selected metals results collected from that location over time is shown in Figures 5.4.2 and 5.4.3.

In figure 5.4.2, magnesium, sodium, and barium all show increasing concentration trends since inception of sampling in 2005. Aluminum, boron and iron after early fluctuations appear to stabilize. Strontium continues to fluctuate with a slight increasing trend over time.

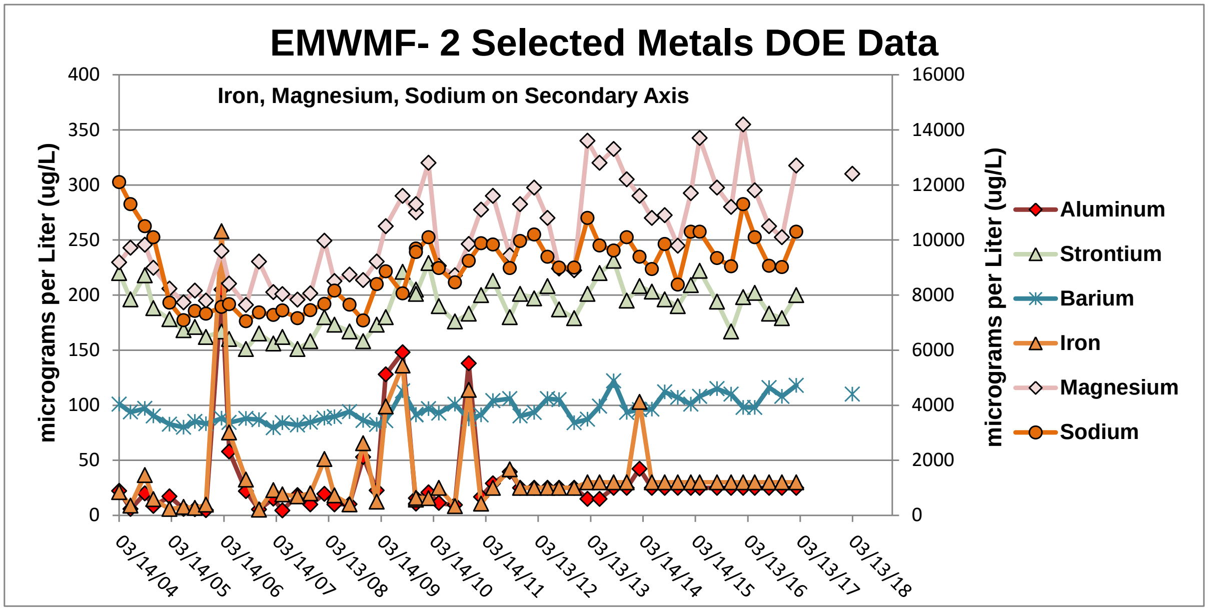


Figure 5.4.2: EMWMF-2 Selected Metals DOE Data

Figure 5.4.3 graphs antimony, arsenic, boron, cadmium, vanadium, and zinc that were detected in lower concentrations than addressed in figure 5.4.2 above. Metals not detected in these analyses include beryllium, chromium, cobalt, lead, lithium, mercury, nickel, and uranium.

Metals detected but not graphed are calcium, potassium, and manganese because they all have large concentrations and are commonly found in soils.

Cadmium and vanadium concentrations appear to become steady after 2012. Boron continues to fluctuate in concentration, but the overall trend is going down. Zinc's concentration fluctuated after 2012 but settled down and is now steady. Antimony and arsenic concentrations have increased for one sampling event each in 2018; this will need to be watched further in the future.

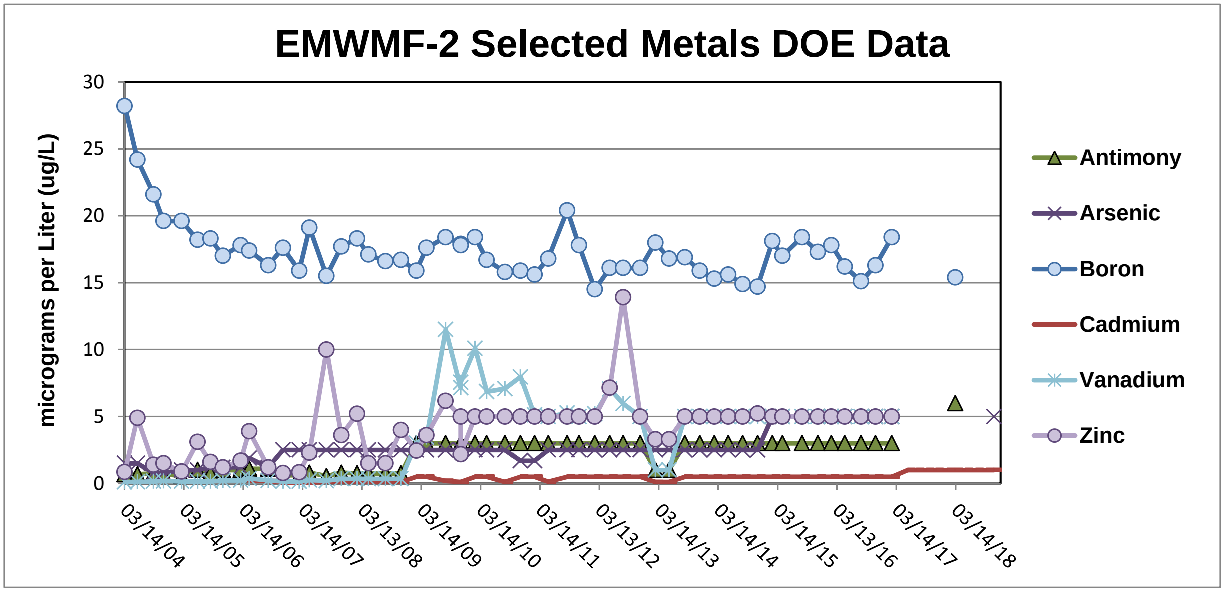


Figure 5.4.3: EMWMF-2 Selected Metals DOE Data

The water that reaches the sediment basin consists of water discharged from the contact water ponds, water discharged from the contact water tanks and what is known as clean storm water. During storm events, rain water that falls on the enhanced cover over Cells 1, 2, and 3 is directed straight to the sediment basin by unlined ditches. Water that collects in the clean area of Cell 6 is also discharged to the sediment basin after analysis. All of the storm water mixes with the discharged water from the tanks and ponds before flowing into NT-5 and then into Bear Creek. The location that is sampled is named by DOE as EM-VWEIR; TDEC uses the name EMWMF-3.

Four charts below show the relationships between EMWMF-3 selected metals (Figures 5.4.4 through 5.4.7). Metals analysis results with no detectable concentrations are not presented. The metals that had no detectable concentrations include cadmium, cobalt, hafnium, lithium, selenium, silver, thallium and tin. The figures are split into ranges of concentration to better illustrate the make-up of the water being discharged from the sediment basin.

Figure 5.4.4 shows metals with large concentrations of aluminum, calcium, sodium and iron. All four of these analytes routinely come from breakdown of soil and rock by percolating water. Calcium is a component of concrete and the demolition and decommissioning of ETTP has increased the amount of concrete and therefore the amount of calcium disposed in the waste cells.

Figure 5.4.5 illustrates those metals with concentrations between 200 and 20,000 micrograms per Liter (µg/L). Potassium and magnesium concentrations have increased in the samples collected after the start of calendar year 2012 and continue to the present.

Figure 5.4.6 shows metals with concentrations less than 200 µg/L. All of the metals (in this chart) are somewhat attenuated with the exception of titanium after 2012. Titanium concentrations fluctuated and then settled down after May of 2014.

Figure 5.4.7 depicts those metals with concentrations less than 65 µg/L. Nickel, uranium and vanadium concentrations decreased from 2012 until 2017 and then their concentrations increased in 2018 along with chromium concentrations.

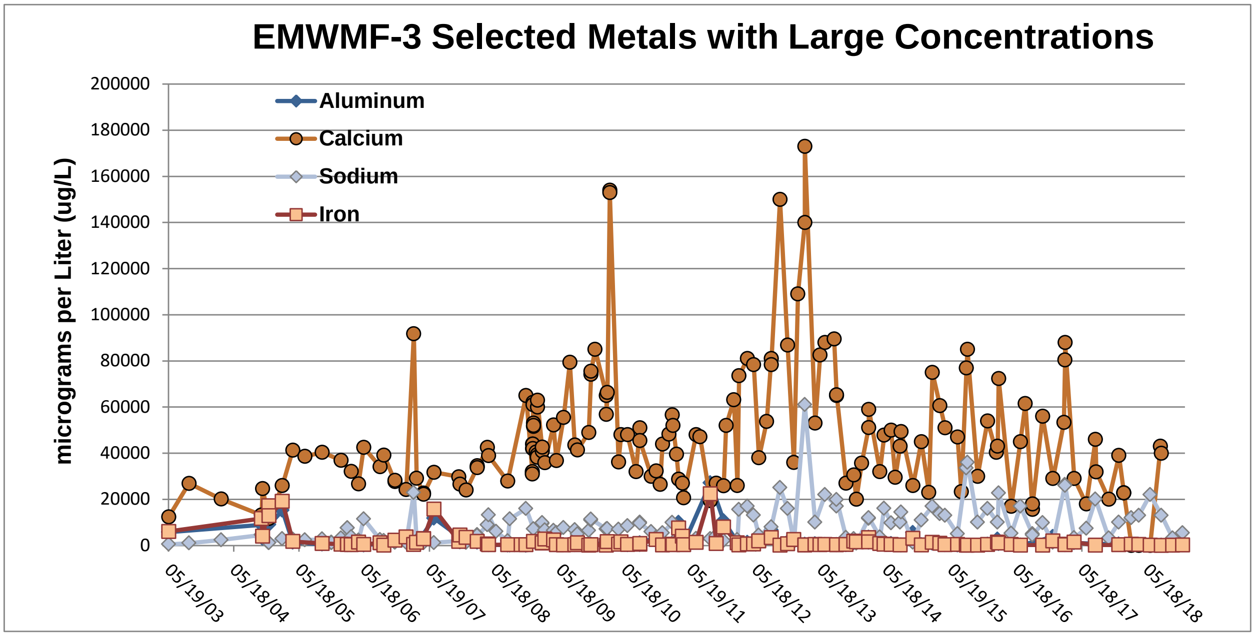


Figure 5.4.4: EMWMF-3 Selected Metals with Large Concentrations

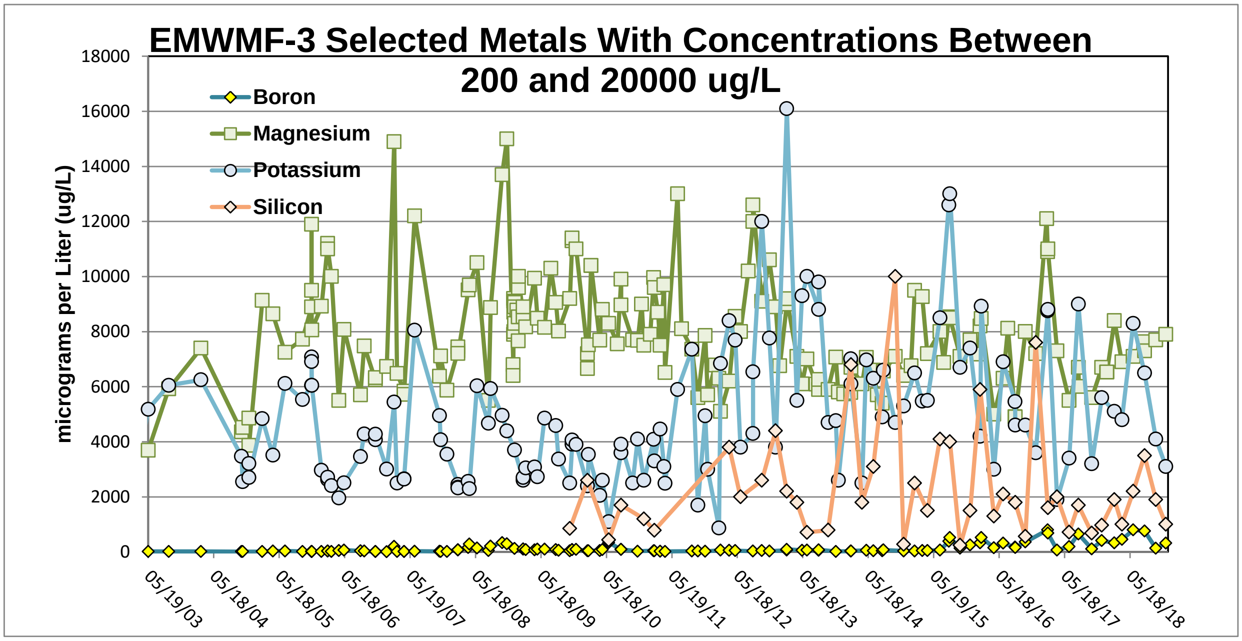


Figure 5.4.5: EMWMF-3 Selected Metals (Concentrations between 200 and 20000 µg/L)

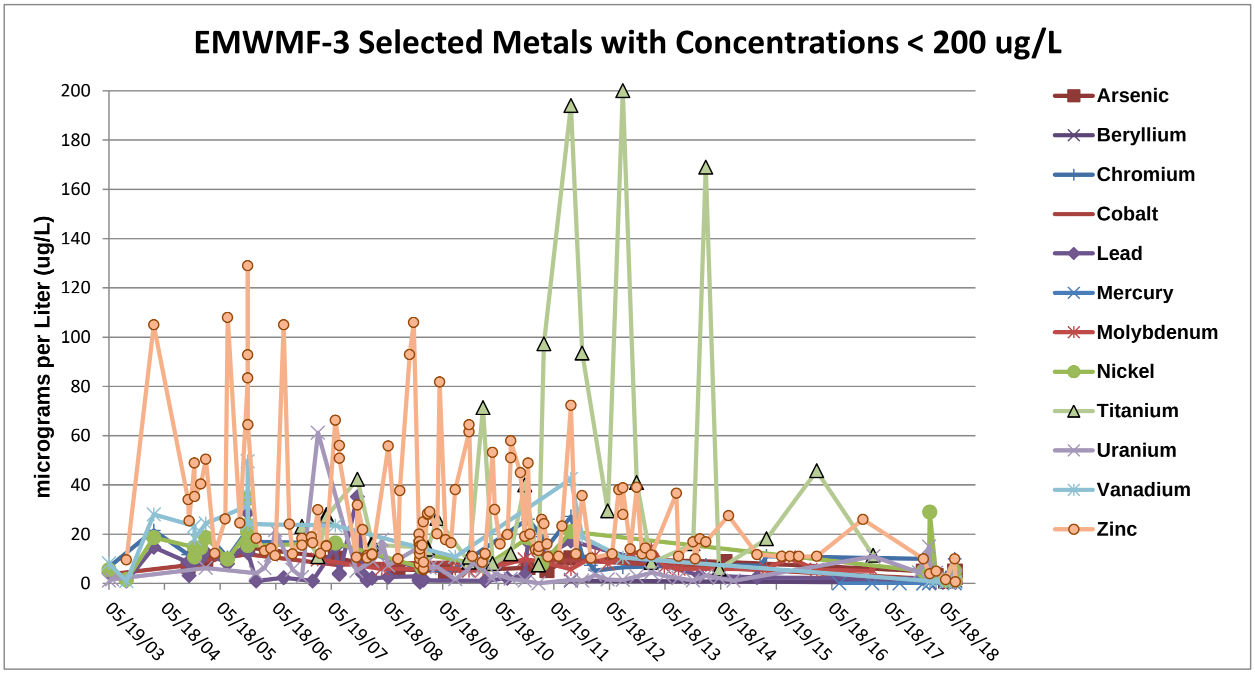


Figure 5.4.6: EMWMF-3 Selected Metals (Concentrations Less Than 200 µg/L)

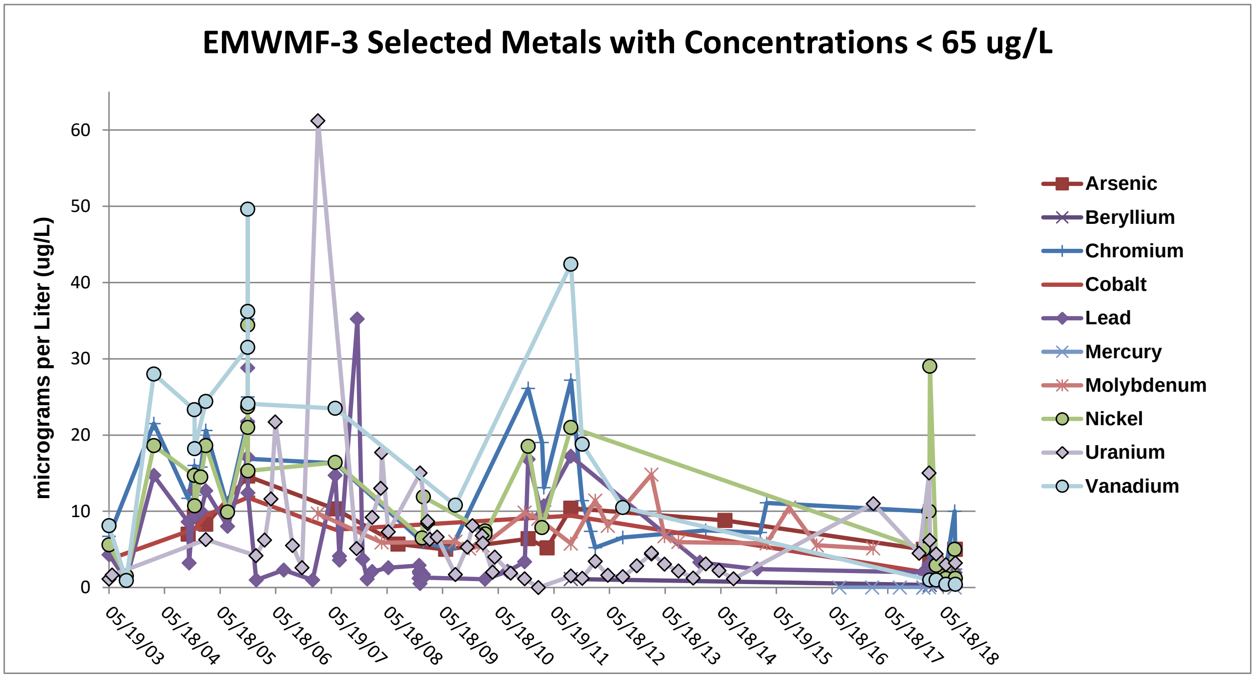


Figure 5.4.7: EMWMF-3 Selected Metals (Concentrations Less Than 65 µg/L)

5.4.7.1.2 DOE Analysis Radionuclide Results Discussion

Radionuclide Activities from EMWMF-2 (March 2004 – Dec 2018)

Figures 5.4.8 through 5.4.11 depict radionuclide activities in water from EMWMF-2 from March 2004 to December 2018. The four graphs are for:

- Isotopic uranium activity (Figure 5.4.8),
- Iodine-129, technetium-99, lead-210 (Figure 5.4.9),
- Strontium-90, and yttrium-90 (Figure 5.4.10) and
- Alpha and beta activity (Figure 5.4.11)

The first graph (Figure 5.4.8) shows the activities of isotopic uranium (uranium-233/234, uranium-235/236, and uranium-238). All three uranium isotope pairs are slowly increasing in activity. The activity levels are small and the project quantification level (PQL) as identified in the EMWMF SAP/QAPP {2016&2017) is 0.5 picocuries per Liter (pCi/L). Uranium-233/234 is already above the PQL and the last several uranium-238 results are also. It is unclear what is causing this; therefore, further monitoring is warranted.

The identified trends were calculated by the Excel spreadsheet and graphing program. One must be careful when trying to identify trends in radionuclide analyses, when analytical data is close to or below the detection limit the data are subject to large variability and uncertainty.

Figure 5.4.9 shows activities of selected radionuclides, iodine-129 and technetium-99. The iodine numbers are steady, but the technetium-99 activities are increasing above the detection limit in late 2017 into 2018. The PQL for technetium-99 is 5 pCi/L and the detections have not reached that number, but the Excel calculated trend indicates that it might within 2 years. Figure 5.4.10 strontium and yttrium shows an increasing Excel calculated trend as well. The PQL for strontium-90 is 2 pCi/L and the Excel calculated trend is increasing but could flatten out below the PQL.

Figure 5.4.11 shows the measurements of alpha and beta activities beginning in May 2017. Measuring alpha and beta activities are new additions to the analytes at EMWMF. The beta activity appears to be increasing as there is more technetium-99 being placed in the landfill. The alpha activity is somewhat steady, but there is some fluctuation**.** Gross alpha and gross beta activity results can be variable as natural elements with alpha and beta activity may be released into the groundwater due to fluctuations with even slight water chemistry changes. Therefore, spikes or outliers of increased activity may not be an indication of release.

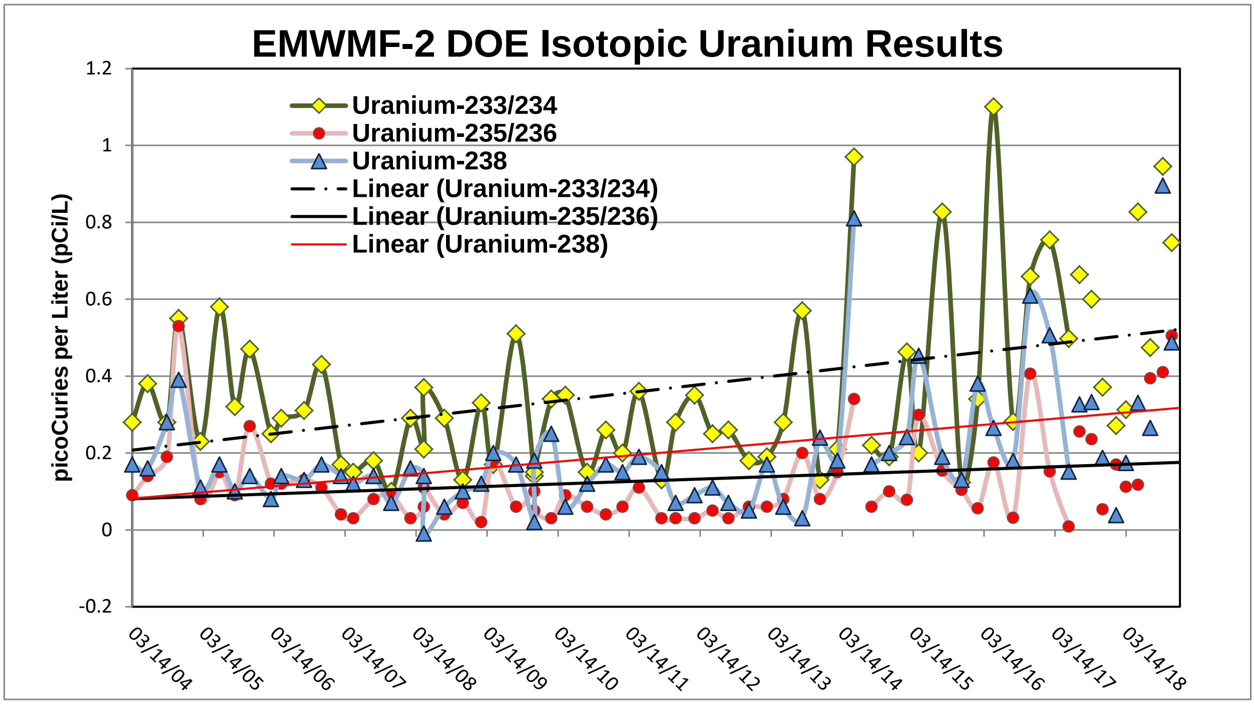


Figure 5.4.8: EMWMF-2 DOE Uranium Isotope Results

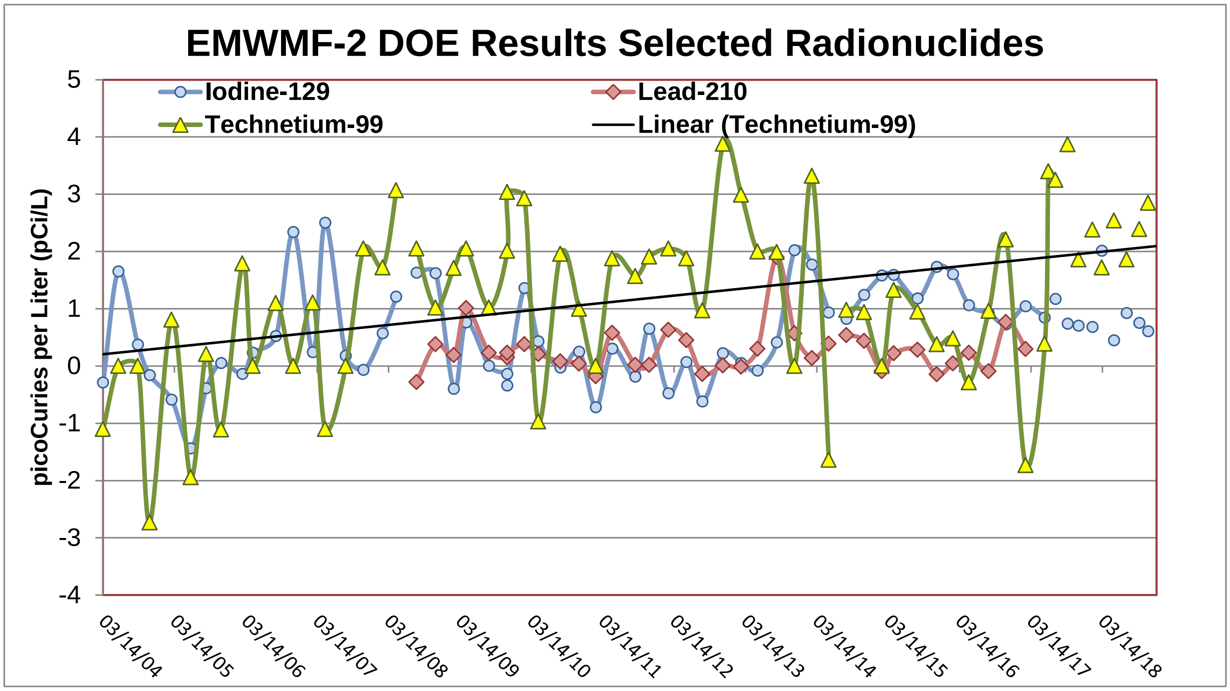


Figure 5.4.9: EMWMF-2 DOE Results Selected Radionuclides

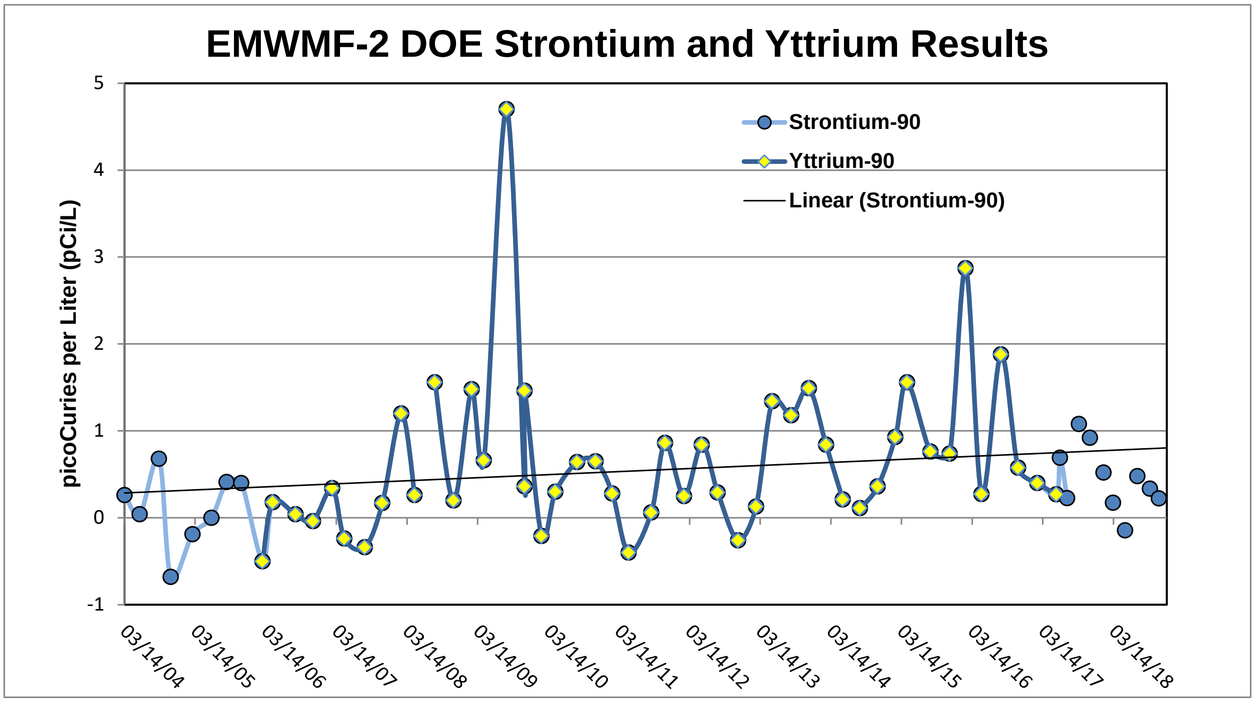


Figure 5.4.10: EMWMF-2 DOE Strontium-90 and Yttrium-90 Results

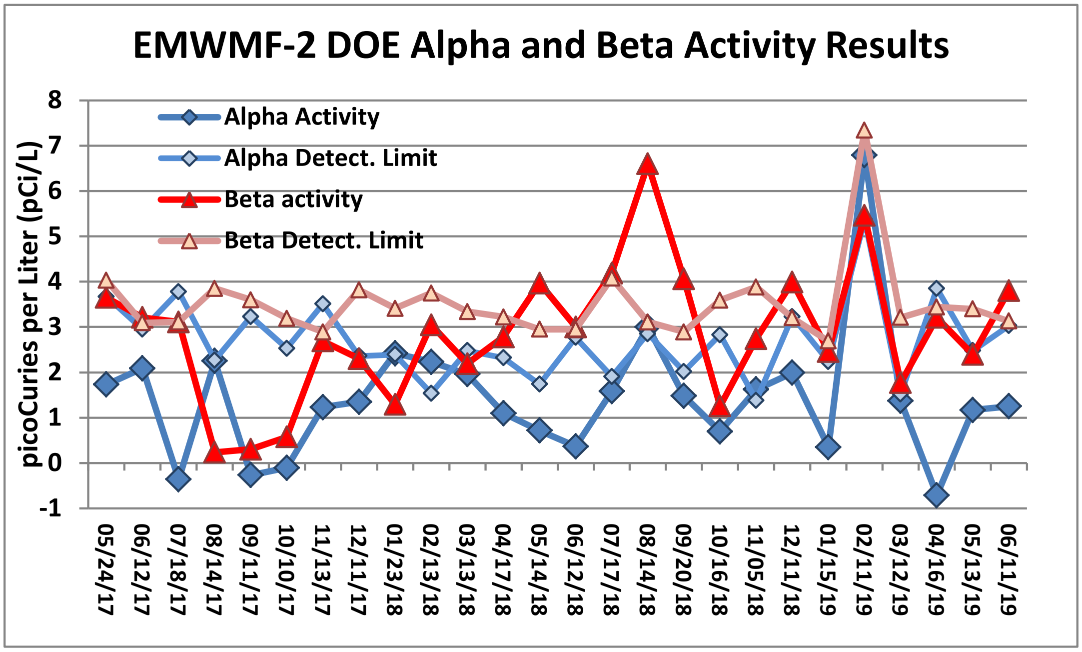


Figure 5.4.11: EMWMF-2 DOE Alpha and Beta Activity Results

5.4.7.1.3 Radionuclide Activities from EMWMF-3 (August 2002 – present)

Figures 5.4.12 to Figure 5.4.14 illustrate the radionuclides analyzed by DOE of the effluent from the Sediment Basin. The monitoring station is named EMW-VUNDRDRAIN by DOE and EMWMF-3 (VWEIR) by TDEC. Continuous sampling at EMWMF-3 began in August of 2002 until the present.

Figure 5.4.12 is a graph of carbon-14, and alpha and beta activity. Beta activity is mostly steady (10 to 100 pCi/L); however, there are several spikes indicating greatly increased activity. The maximum beta activity reported is 1140 pCi/L on Feb. 14, 2007. Alpha activity varies as well, with the maximum alpha activity of 226 pCi/L measured on Feb. 21, 2003. Stacking of alpha and beta results in 2003 is a factor of scale. Samples were collected daily for almost two weeks starting February 16, 2003 through March 7, 2003. The range of results is relatively constant over the course of sampling. Carbon-14 has a relatively consistent activity until August 2014, when there was more of a range with more activities in the positive side than the negative. This could be due to placing waste from ETTP in the landfill.

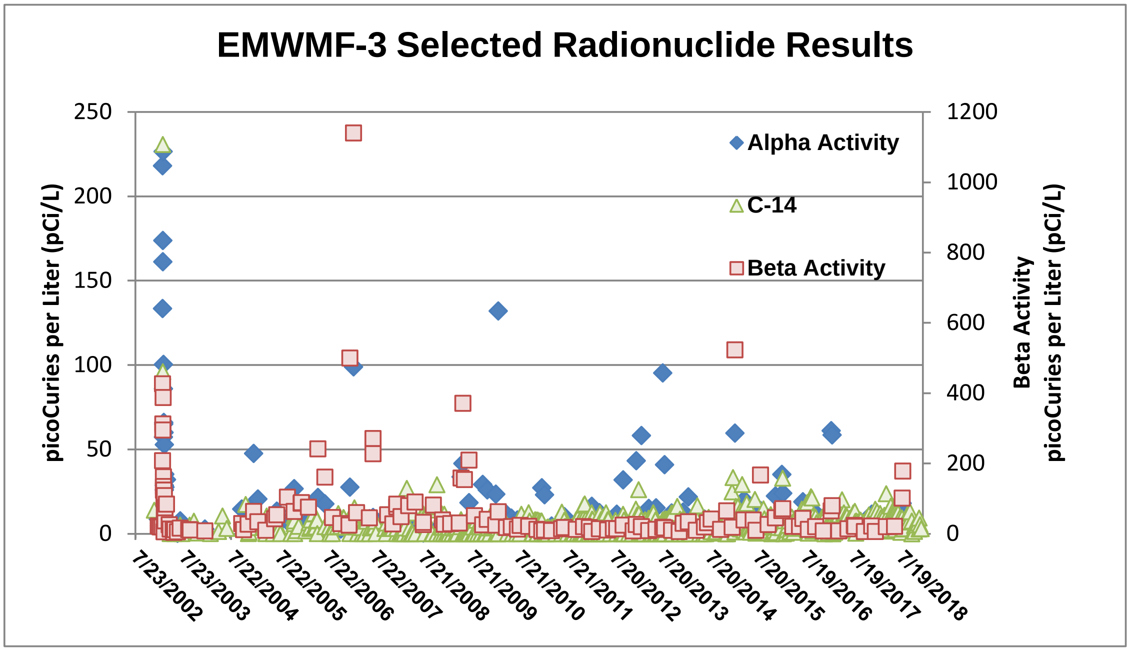


Figure 5.4.12: EMWMF-3 DOE Selected Radionuclides Results

Figure 5.4.13 depicts the graphed activities of strontium-90 and technetium-99 from 2002 to December 2018. There was an increase of strontium-90 measured from mid-2004 through mid-2007 with another increase from 2008 through 2009. Since 2009, strontium-90 activity has fallen to almost not detected. There are a few instances where the strontium-90 activity increased but then decreased. Technetium-99 activity is almost undetectable from mid-2003 to the beginning of 2014 where it then begins to be detected in almost every sample. In 2016 many of the measurements were lower, but in 2018 increased from approximately 20 pCi/L to a maximum of 1150 pCi/L.

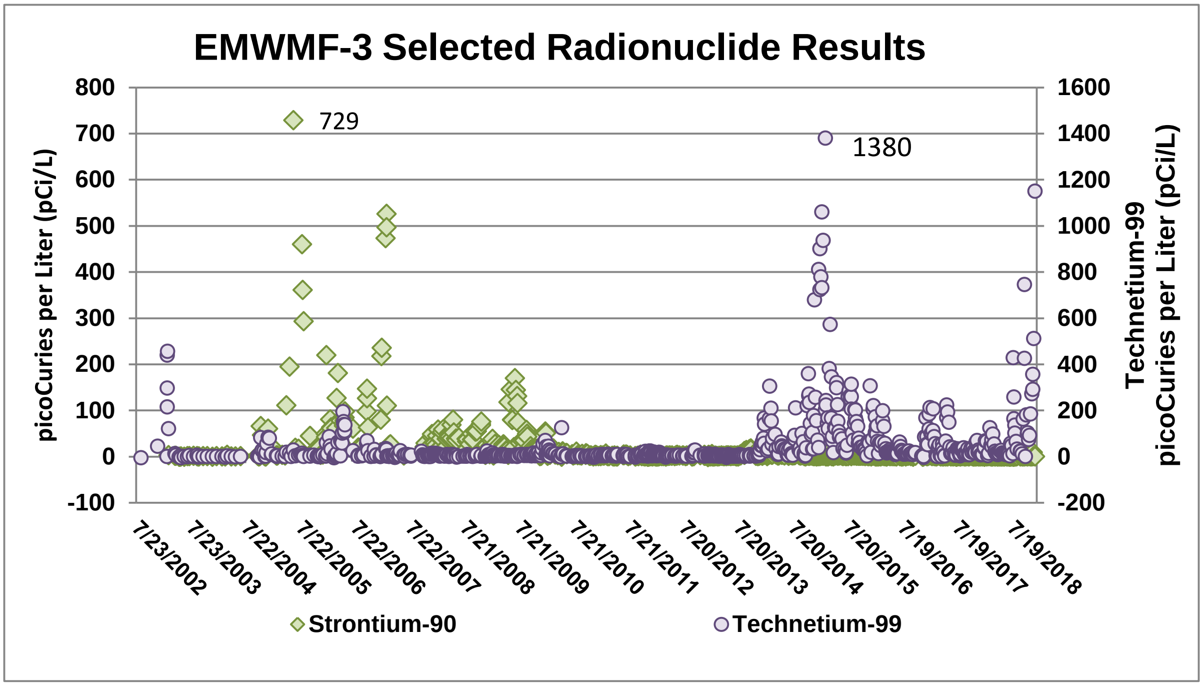


Figure 5.4.13: EMWMF-3 DOE Selected Radionuclides Results

Figure 5.4.14 illustrates uranium isotope results from 2002 until the December 2018.

Uranium-235/236 activity spikes at the end of July into August 2013 with a maximum activity of 15.6 pCi/L. Another smaller spike in activities is seen from the end of January to April where the maximum activity is 7.67pCi/L. Another spike is seen from the end of December 2016 to the end of March 2017 where the maximum activity for U-235/236 was 12.7 pCi/L; the rest of the measurements range between 1 and 2 pCi/L. Another uranium isotope graphed is uranium-234/235; it is an energetic isotope as can be seen in the graph with spikes in activity mirroring those of uranium-235/236. Uranium-238 activities from 2003 until 2006 had two large spikes near 100 pCi/L. After 2006 to the present, the uranium-238 activity rarely exceeded 10 pCi/L.

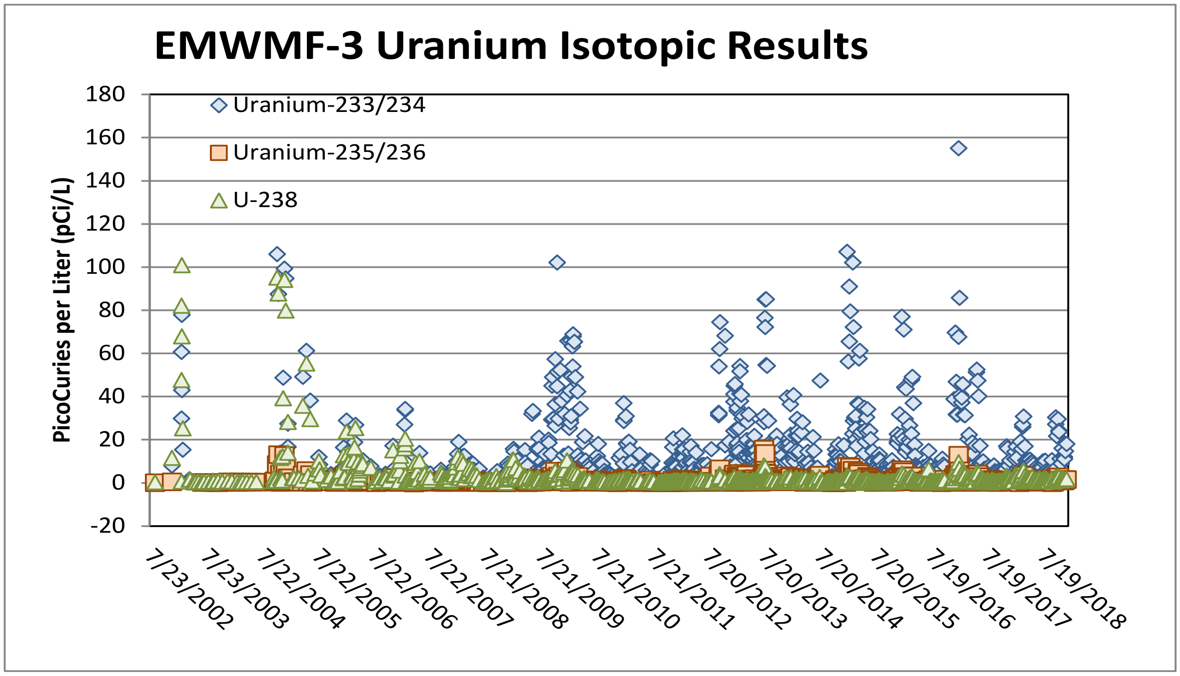


Figure 5.4.14: EMWMF-3 DOE Uranium Isotopic Results

Currently, DOE uses the rolling sum of fractions statistical method to determine the dose to the public from the water released. The release limits for the EMWMF allot the whole 25 mrem/yr to the water pathway, instead of all pathways.

5.4.7.2 EMWMF-2, EMWMF-3, EMWMF-5 Charts Utilizing TDEC Data

5.4.7.2.1 TDEC Metals Discussion

During this period of performance, TDEC sampled EMWMF-2 (the underdrain location) twice, (February 21 and April 30, 2019) and once (also on February 21, 2019) from the ditch that moves contact water from the landfill to the ponds (location EMWMF-5), see Figure 5.4.15. The metals make-up of EMWMF-2 is typical for water from this area as calcium, magnesium, sodium and potassium are common constituents of the soils and rocks of Bear Creek valley. The metals make-up of EMWMF-5 (from the contact water ditch); however, is quite different, see Figure 5.4.16. Manganese, along with iron and aluminum are the highest concentration metals. Calcium and manganese are much lower, but still greater than most of the other constituents.

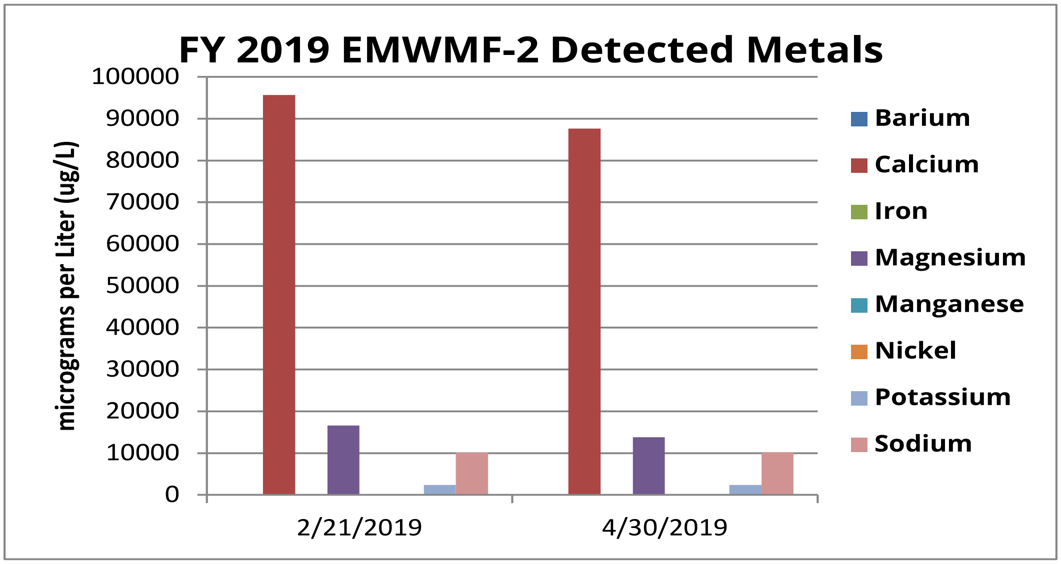


Figure 5.4.15: EMWMF-2 TDEC FY 2019 Detected Metals Results

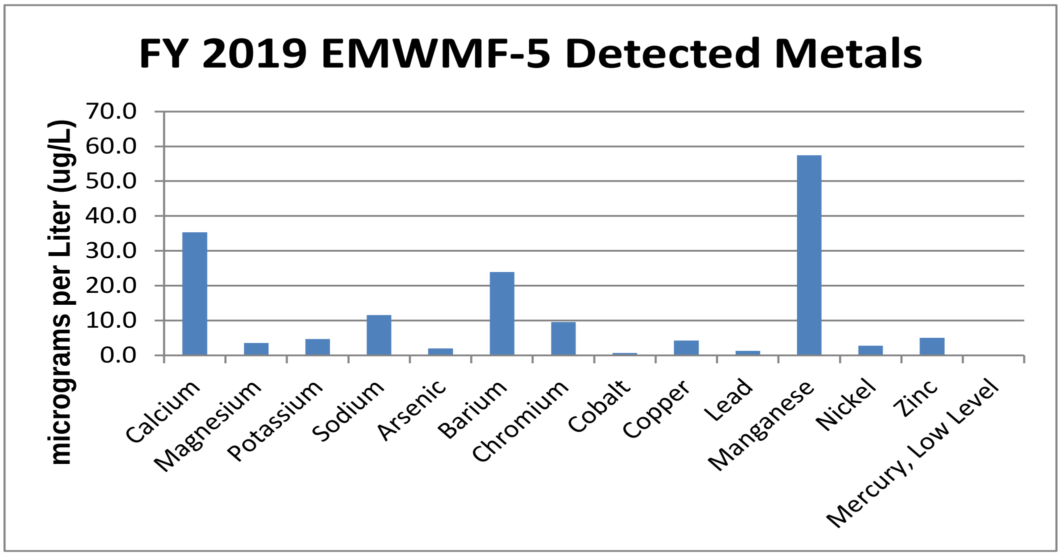


Figure 5.4.16: EMWMF-5 TDEC FY 2019 Detected Metals Results

5.4.7.2.2 Parameters Discussion

Figures 5.4.17 through Figure 5.4.22 illustrate graphically the routine water quality parameters measured at EMWMF-2 and EMWMF-3 on a routine basis. These water quality parameters can indicate situations, possibly problems, with the liner or in the case of EMWMF-3 contaminated storm water that was previously not identified. The parameters measured are pH, specific conductivity, water temperature, oxidation-reduction potential and the depth of water leaving the weirs.

Figure 5.4.17 depicts the seasonal changes in temperature and conductivity measured since 2012 to the present. This graph shows seven seasonal cycles and the corresponding highs and lows of temperature and conductivity. EMWMF-3 occasionally did not discharge water after extended periods of no precipitation which caused the zero measurements. The temperature and conductivity of EMWMF-2, UT and UCond on the graph are muted and delayed in relation to EMWMF-3 parameters (VWT and VWCond).

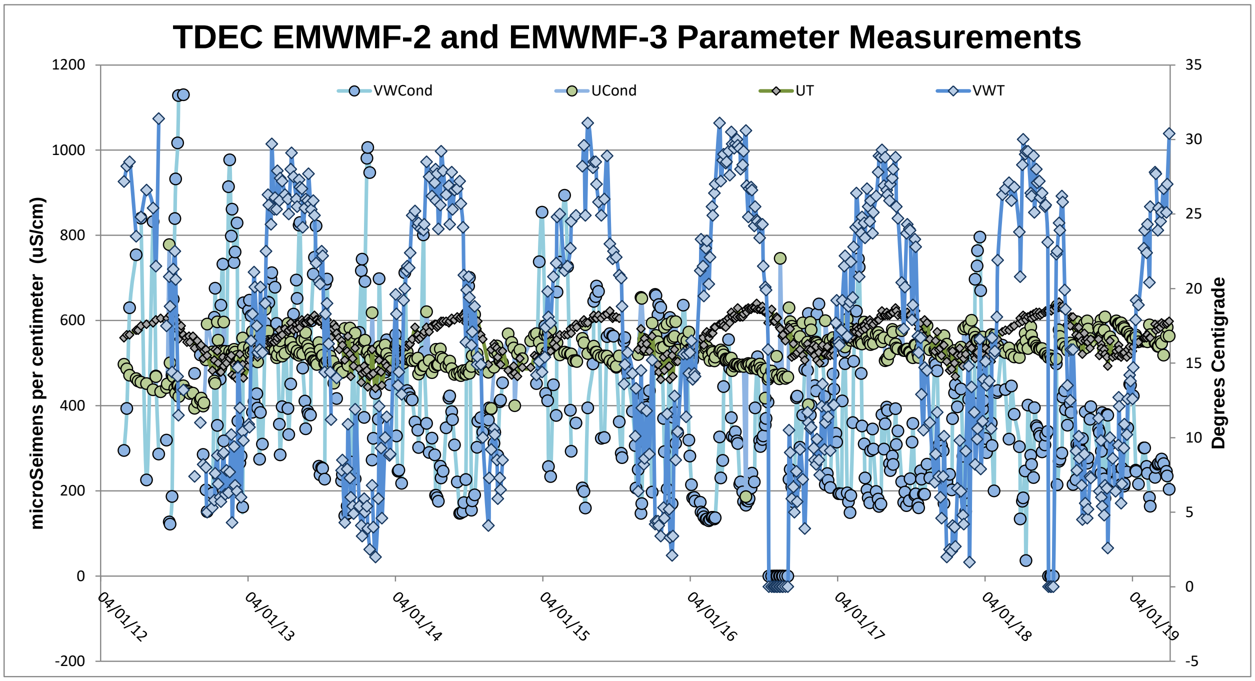


Figure 5.4.17: TDEC EMWMF-2 and EMWMF-3 Parameter Measurements

(2012 – June 2019)

Figure 5.4.18 is a depiction of the reporting year's measurements of conductivity and temperature. In September 2018 there was no flow over the weir in EMWMF-3 so there are no measurements from that time.

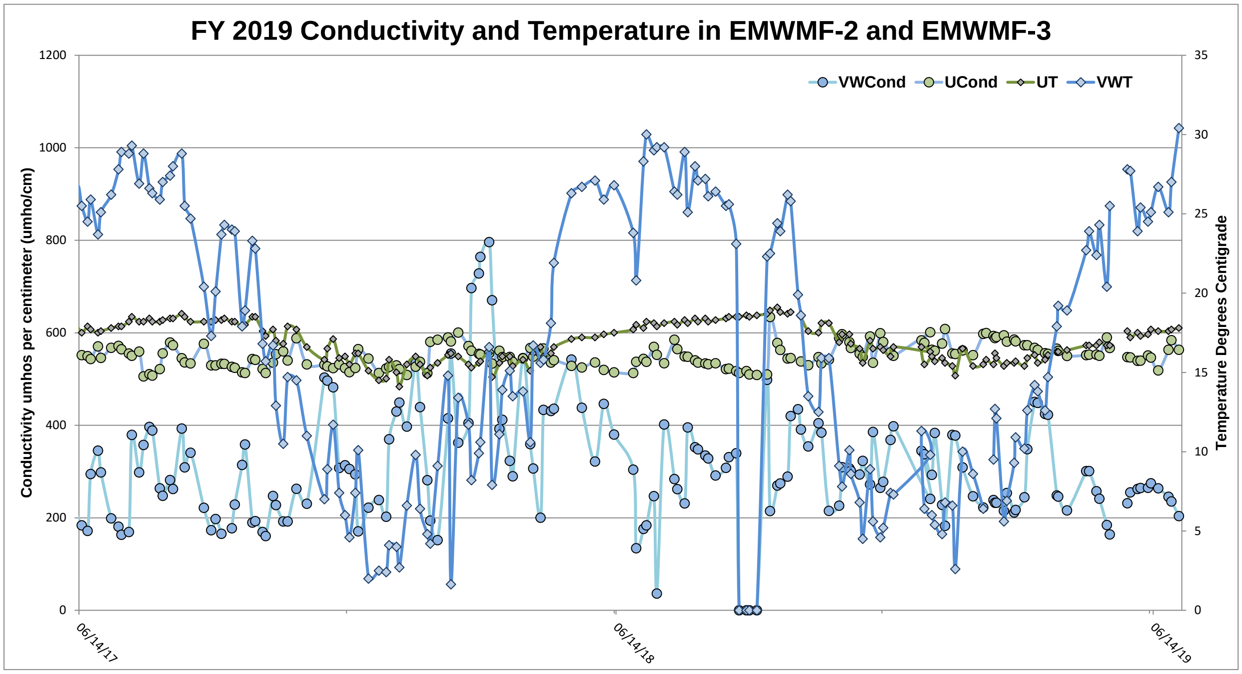


Figure 5.4.18: FY 2019 Conductivity and Temperature in EMWMF-2 and EMWMF-3

Figures 5.4.19 through Figure 5.4.22 illustrate graphically the routine water quality parameters measured at EMWMF-2 and EMWMF-3 on a routine basis for the 2019 fiscal year beginning July 1, 2018 and ending June 30, 2019.

Figure 5.4.19 graphs the water temperatures in EMWMF-2 and EMWMF-3 for the 2019 reporting year. In September 2018 after a period of no rain EMWMF-3 ceased to flow. The temperatures from EMWMF-2 do not have the amplitude as EMWMF-3 due mainly to the water in EMWMF-2 is groundwater.

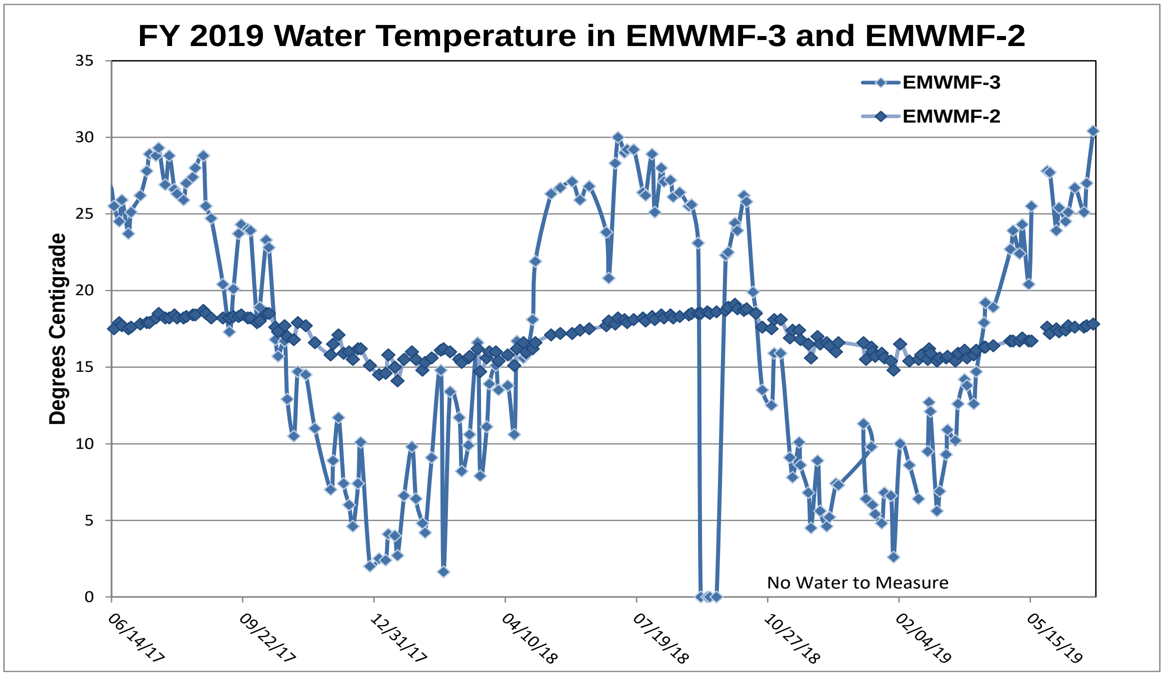


Figure 5.4.19: Water Temperature in EMWMF-3 and EMWMF-2

Figure 5.4.20 presents the conductivity measured in both stations. EMWMF-3 is open to the environment, collects water from different sources, and has a variability that the EMWMF-2 water does not. The seasonal variation in the conductivity of the EMWMF-2 water is seen here.

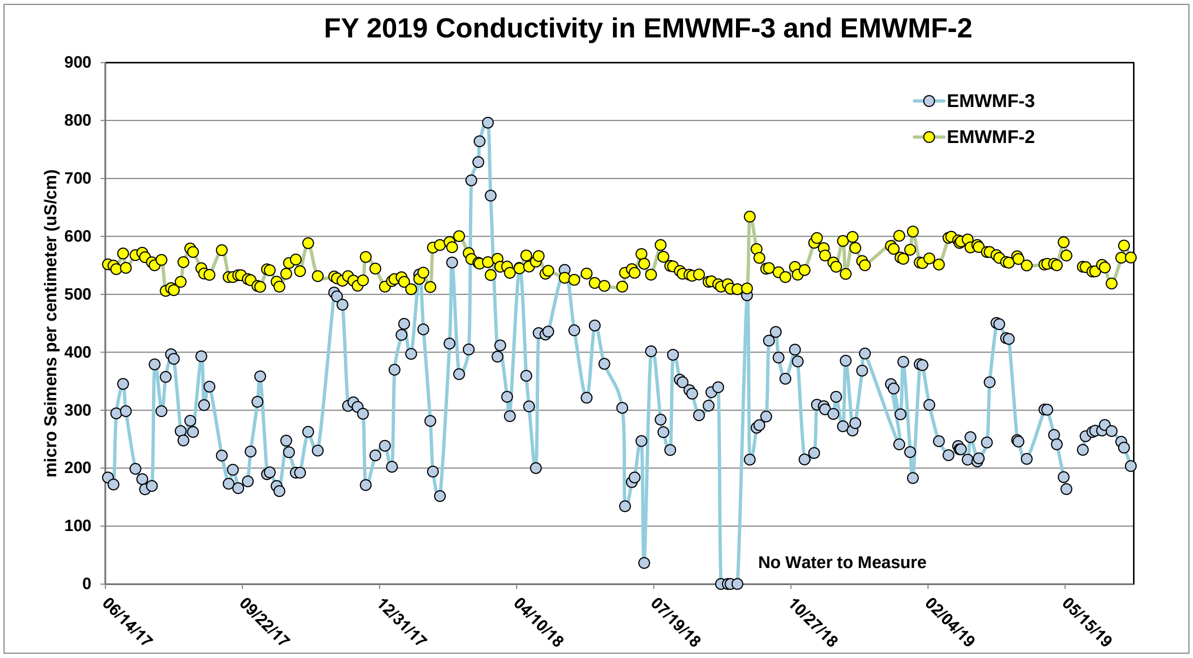


Figure 5.4.20: FY 2019 Conductivity in EMWMF-3 and EMWMF-2

Figure 5.4.21 graphs pH measurements for the reporting year of 2019. Seasonal variability is present for both stations with the range of measurements greater in EMWMF-3. This is to be expected due to the water open to the environment. The pH fluctuations in March of 2019 correlated to a replacement of the pH probe in the measuring instrument. While probe replacement occurred in March 2019 and a drop in pH is identified at that same time, it is important to note that the elevated pH's identified in April and May 2019 that followed that probe replacement are also reflected in increases in conductivity, temperature and other measurement parameters (which are measured with different probes). All calibration parameters were met for these instruments prior to all sampling events as well. As such, it is interpreted here that those elevated readings are reflective of site conditions at that time.

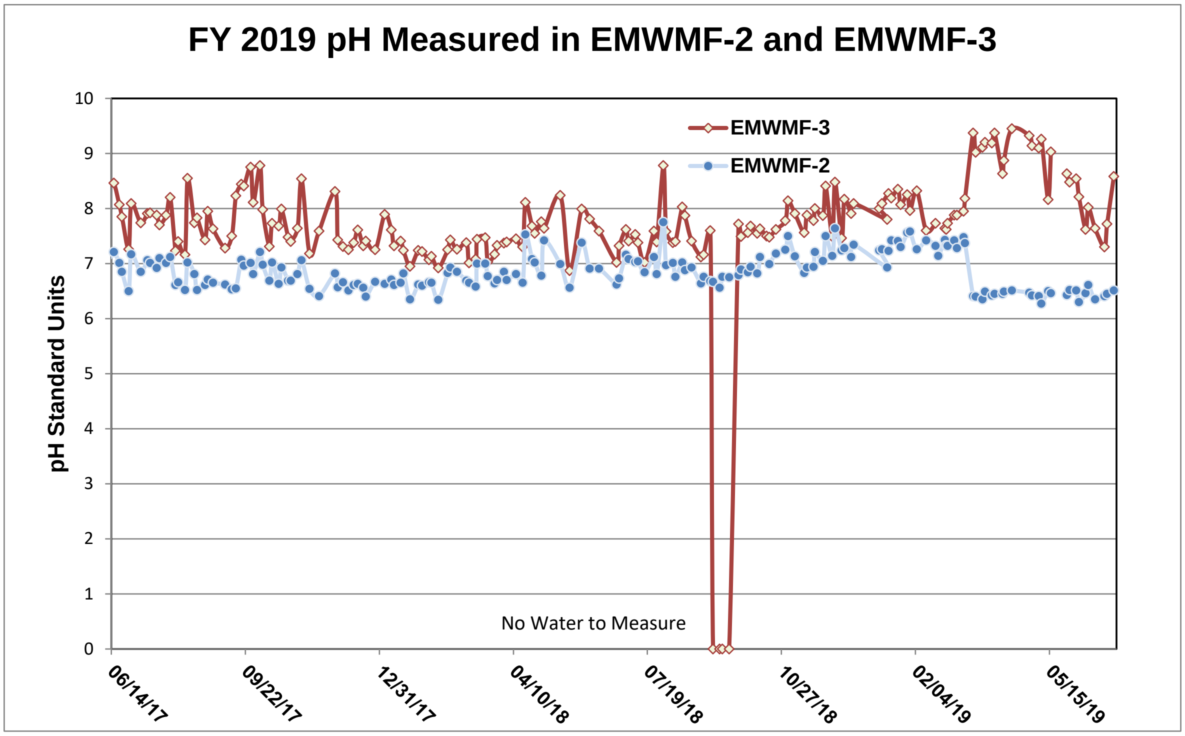


Figure 5.4.21: FY 2019 pH Measured in EMWMF-2 and EMWMF-3

Figure 5.4.22 shows the measured depth at the weirs from both EMWMF-2 and EMWMF3. This can be used to determine flow and calculate constituent flux over time. Water in EMWMF-2 is quite stable at 2 inches at the "vee". However, during an extremely wet period in February 2019, the water from the weir was unable to drain due to the amount of runoff. Therefore; the measurement of 4.25 inches instead of 2 inches was expected. The depth of water flowing from EMWMF-3 is dependent on storm water (precipitation collected from the uncontaminated areas of the landfill site) and the discharge of contact water from the ponds and tanks on site. Before discharge, the water in the ponds and tanks are analyzed to make sure they meet the agreed upon discharge limits. Those agreed to discharge limits include but are not limited to, the 0400-04-03-.03(3) Tennessee General Water Quality Criteria for Fish and Aquatic Life (referred to generally as the TN AWQC's).

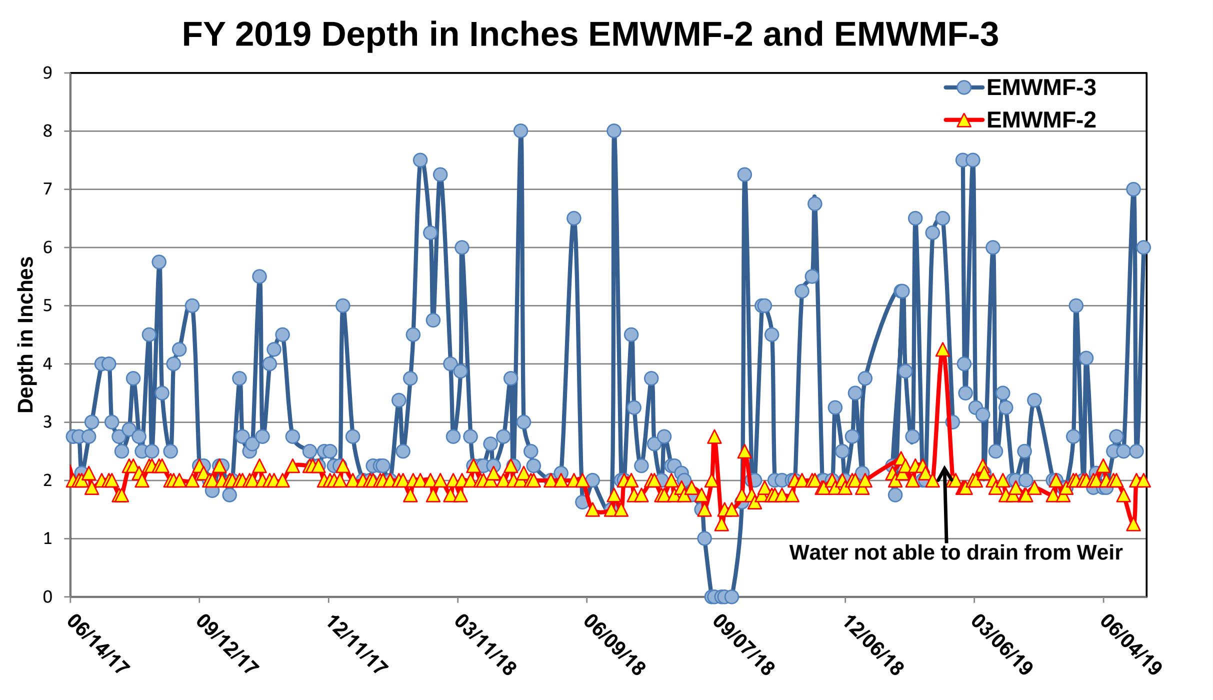


Figure 5.4.22: FY 2019 Water Depth in Inches EMWMF-2 and EMWMF-3

5.4.7.2.3 TDEC Analysis Radionuclide Results Discussion

Figure 5.4.23 graphs the radionuclide analyses from the five sampling events during this reporting year. All of the gamma radionuclide results with the exception of that collected in April 30, 2019 are above their detection level. The sample collected February 21, 2019 had no detectable activity. The rest of the radionuclides are at or near their respective laboratory method detection levels.

Tritium activities decreased in water from EMWMF-2 during this period of performance while uranium isotopes stayed relatively constant with low activities. Gross alpha and gross beta activities also remained relatively consistent. Uranium-234 activity increased from barely detected to 14.7 pCi/L in February but was measured at lower levels near the method detection levels in April and June.

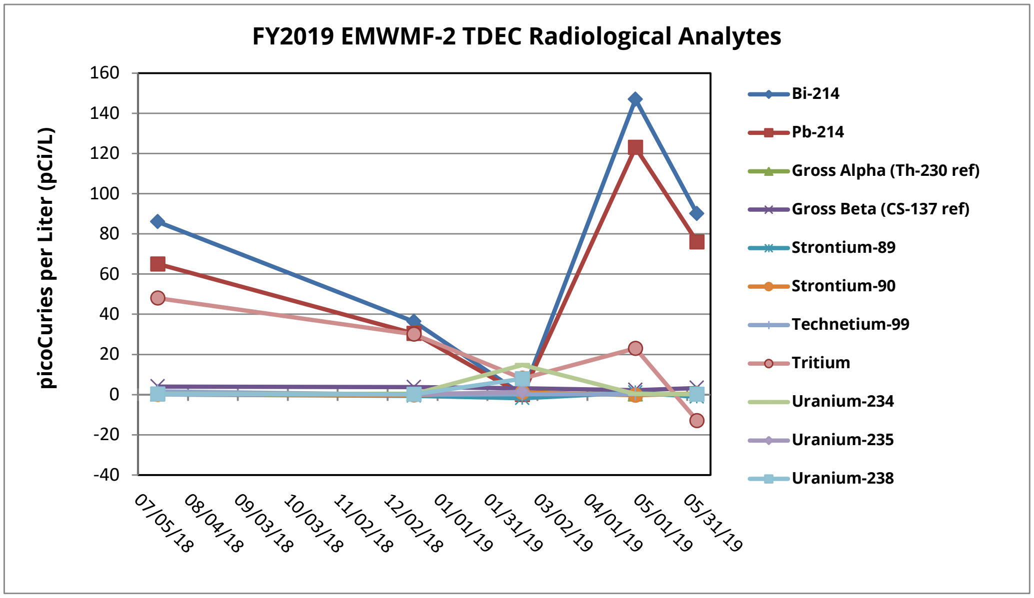


Figure 5.4.23 FY 2019 EMWMF-2 Radiological Analyte Results

Figure 5.4.24 illustrates the radiological results collected from location EMWMF-5 during the active pumping of a contact water pond to the sediment basin. That water is eventually discharged into Bear Creek from NT-5. Gross beta activity, technetium-99 and tritium are elevated with respect to the rest of the analytes.

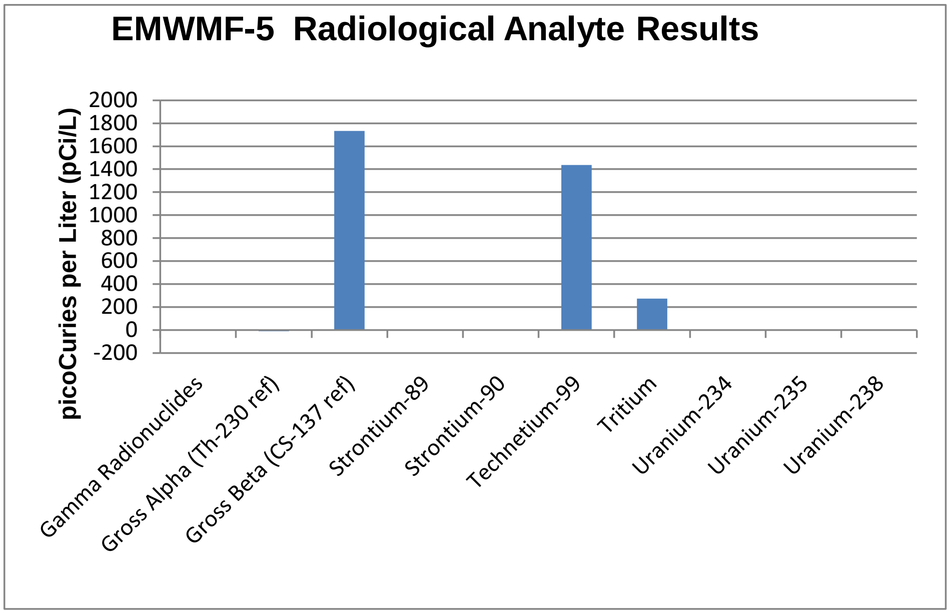


Figure 5.4.24 FY 2019 EMWMF-5 Radiological Analyte Results

Additional radiological analytes were evaluated for sampling location EMWMF-5. Those analytes not seen on Figure 5.4.24 are provided below in Table 5.4.3.

Table 5.4.3 EMWMF-5 Additional Radiological Analyte Results

Station	Date Collected	Chemical Name	Results	Units	Rad Error as CSU
EMWMF-5	2/21/2019	Gamma Radionuclides	NDA	pCi/L	NR
EMWMF-5	2/21/2019	Gross Alpha (Th-230 ref)	-8.9	pCi/L	1.5
EMWMF-5	2/21/2019	Gross Beta (CS-137 ref)	1734	pCi/L	51
EMWMF-5	2/21/2019	Strontium-89	-0.1	pCi/L	0.93
EMWMF-5	2/21/2019	Strontium-90	-0.2	pCi/L	0.57
EMWMF-5	2/21/2019	Technetium-99	1437	pCi/L	46
EMWMF-5	2/21/2019	Tritium	274	pCi/L	27
EMWMF-5	2/21/2019	Uranium-234	0.362	pCi/L	0.065
EMWMF-5	2/21/2019	Uranium-235	0.038	pCi/L	0.022
EMWMF-5	2/21/2019	Uranium-238	0.215	pCi/L	0.014

CSU - combined sample uncertainty
NDA - no detectable activity
pCi/L - picoCuries per Liter of water
Th-230 ref -Thorium-230 reference
Cs-137 ref -Cesium-137 reference

Figure 5.4.25 charts the radionuclide results from just one sampling event for EMWMF-3, collected on December 18, 2018. EMWMF-3 was scheduled for quarterly sampling, but budgetary issues pared the number to only one event. Gross beta activity, technetium-99 and tritium are all elevated. Gross beta activity is above 50 pCi/L which is the EPA trigger for water supplies to perform isotope specific analysis.

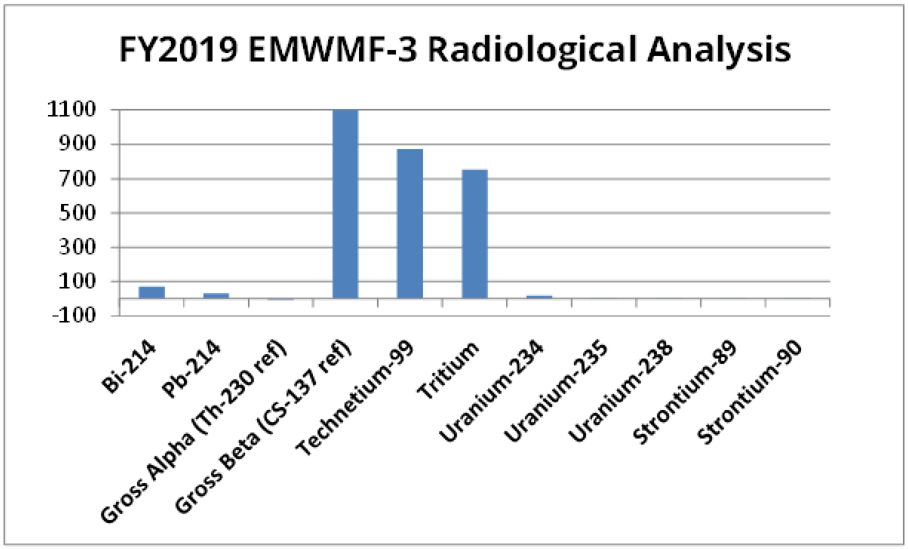


Figure 5.4.25 FY 2019 EMWMF-3 Radiological Analyte Results

5.4.7.2.4 Sediment Basin Sampling

Sediment is sampled from the sediment basin to help determine the constituent load. The sediment basin is the primary surface water discharge point for the EMWMF.

On September 6, 2018 a composite sample of sediment was collected from the bottom of the sediment basin. There was almost no water in the basin at the time and the bottom was deemed safe to walk on. The bottom clay was dry and cracked in most areas. Two locations were collected with cleaned stainless-steel spoons and were placed into a clean stainless-steel bowl for mixing. Two jars were filled with the composited sediment. One sample was sent to the lab for metals analysis and the other was sent for radionuclide analysis (Table 5.4.3).

Figures 5.4.26 through Figure 5.4.29 depict the analyses from the sediment basin sampling events from 2006 to 2018. The station names and corresponding sampling dates for each of the sampling events are EMWMF Sed Basin C-1 (August 2006), SB-1 and SB-2 (October 2016) and EMWMFSB-1 (September 2018).

Figure 5.4.26 is a graph that shows the gamma activity for analyses from the August 4, 2006 (EMWMF Sed Basin C-1), and the September 6, 2018 (EMWMFSB-1) samples. The results are similar with slightly more potassium-40 in 2006 than in 2018.

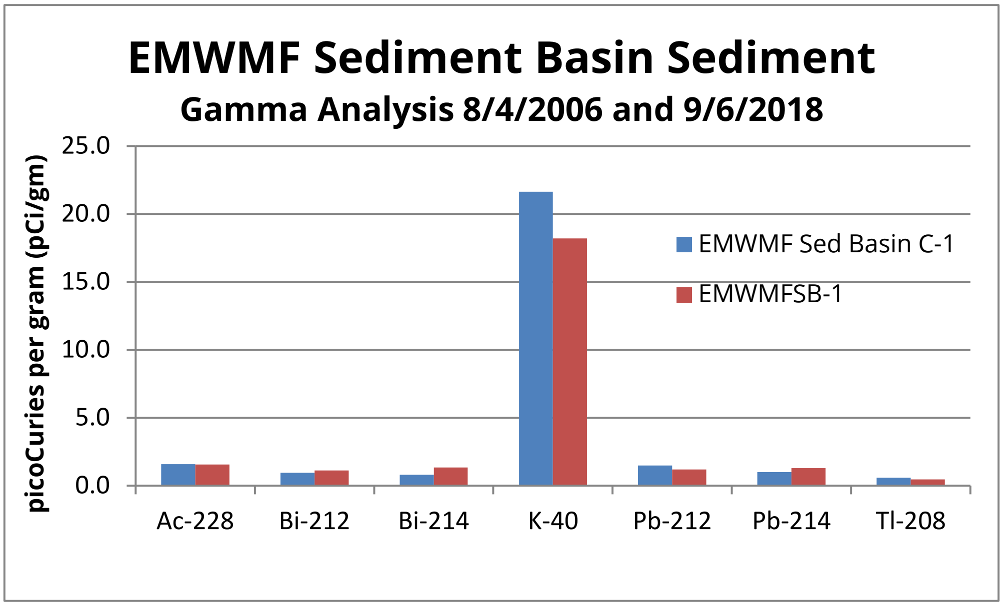


Figure 5.4.26 EMWMF Sediment Basin Gamma Analysis Results 2006 and 2018

Figure 5.4.27 illustrates the alpha and beta activity from all three TDEC sampling events, August 4, 2006, October 19, 2016 and September 6, 2018. The sediment basin was not sampled in 2017 due to water remaining in the basin all year.

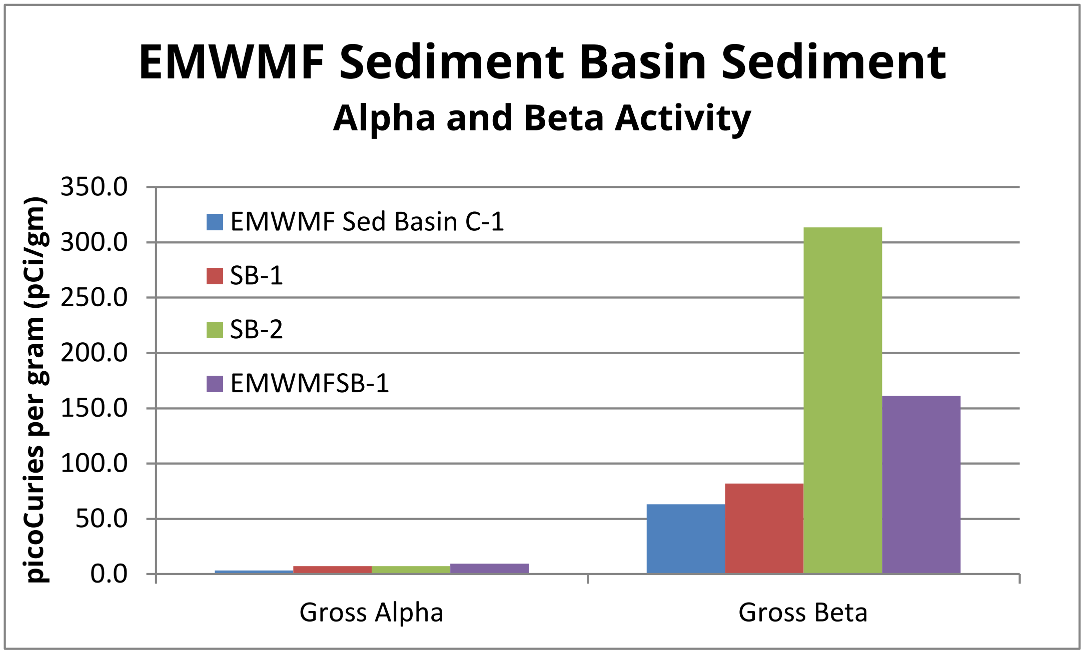


Figure 5.4.27 EMWMF Sediment Basin Sediment Alpha and Beta Activity

Gross alpha activity is steady throughout the samplings. Gross beta activity in the sediment has increased with sample SB-2's elevated measurement. SB-2 (Figure 5.4.28) is also elevated for technetium-99 activity with a measurement of 206 pCi/g while strontium-90 is steady with almost no detectable activity.

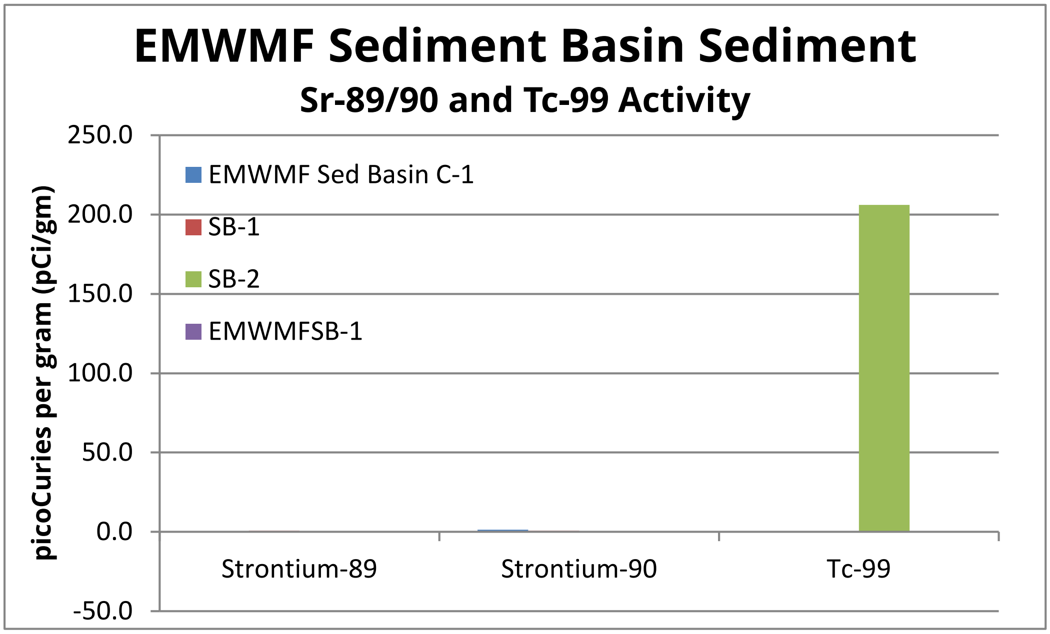


Figure 5.4.28 EMWMF Sediment Basin Sediment Sr-90 and Tc-99 Activity

Figure 5.4.29 depicts isotopic uranium analyses for the October 2016 and September 2018 sampling events. Uranium-234 activity has increased in all of the samples when compared to the other uranium isotopes (uranium-235, and uranium-238). Uranium-235 and uranium-238 have slightly increased from 2016 to 2019.

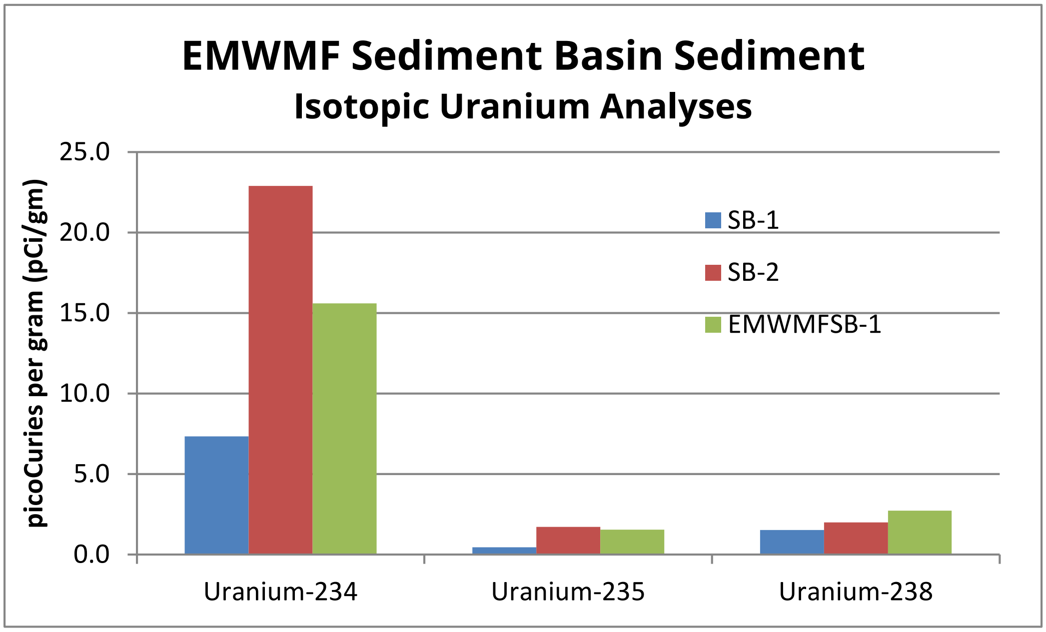


Figure 5.4.29 EMWMF Sediment Basin Sediment Isotopic Uranium Analyses

Table 5.4.3 EMWMF Sept 2018 Sediment Basin Analysis Results

EMWMF Sediment Basin
Sediment Metals Analysis Results September 6, 2018

Analyte	Result	Result Qualifier	Units	Detection Limit	Quantitation Limit	Analysis Date	Analysis Method
% Solids	61.0		%	0.1	0.1	10/19/2018	2540-G
% Moisture	39.0		%	0.1	0.1	10/19/2018	2540-G
Calcium	49200		mg/kg	8.16	19.6	10/19/2018	200.7
Iron	21000		mg/kg	1.09	1.96	10/19/2018	200.7
Magnesium	14900		mg/kg	6.19	9.80	10/19/2018	200.7
Potassium	2160		mg/kg	9.34	19.6	10/19/2018	200.7
Sodium	123		mg/kg	4.80	9.80	10/19/2018	200.7
Antimony	<0.0267	U	mg/kg	0.0267	0.0980	11/20/2018	200.8
Arsenic	2.40		mg/kg	0.710	0.980	11/20/2018	200.8
Beryllium	0.522		mg/kg	0.0272	0.0980	11/20/2018	200.8
Cadmium	0.602		mg/kg	0.0455	0.0980	11/20/2018	200.8
Chromium	18.4		mg/kg	1.76	4.90	11/20/2018	200.8
Cobalt	7.56		mg/kg	0.0361	0.0980	11/20/2018	200.8
Copper	11.0		mg/kg	0.0462	0.0980	11/20/2018	200.8
Lead	17.8		mg/kg	0.0321	0.0980	11/20/2018	200.8
Nickel	15.0		mg/kg	0.151	0.490	11/20/2018	200.8
Selenium	<0.308	U	mg/kg	0.308	0.490	11/20/2018	200.8
Silver	0.107		mg/kg	0.00342	0.0245	11/20/2018	200.8
Thallium	0.155		mg/kg	0.0146	0.0980	11/20/2018	200.8
Uranium	4.13		mg/kg	0.0651	0.0980	11/20/2018	200.8
Vanadium	16.1		mg/kg	2.57	4.90	11/20/2018	200.8
Zinc	29.4		mg/kg	5.03	9.80	11/20/2018	200.8
Barium	144		mg/kg	0.0858	2.45	11/20/2018	200.8
Manganese	474		mg/kg	0.423	0.490	11/20/2018	200.8
Aluminum	7140		mg/kg	92.0	196	11/20/2018	200.8

mg/kg milligrams per kilogram same as parts per million (ppm)
< less than
Analyses conducted by Tennessee Dept. of Health Environmental Laboratory

U undetected during analysis
% percent

5.4.8 Conclusions

For FY 2019, TDEC sample results corroborate DOE's sample results on and around EMWMF.

Both the TDEC and the DOE data sets appear to detect low level but increasing trends of isotopic uranium constituents in samples from EMWMF-2 (the underdrain location). Increasing technetium-99 is identified in a review of concentrations over time for samples collected from the EMWMF-2 (underdrain) sampling location. The technetium-99 activities are increasing above the detection limit in late 2017 into 2018. (See DOE's data in figures

5.4.8 through 5.4.11 and TDEC data in Figure 5.4.23).

Sampling data from EMWMF-3 (the sediment basin effluent) also continues to show evidence of discharge of contaminants including elevated technetium-99 (particularly after 2014), elevated gross beta activity, and elevated tritium Gross beta activity is above 50 pCi/L which is the EPA trigger for water supplies to perform isotope specific analysis., but not at levels that violated the EMWMF Record of Decision discharge limits.

The sediment basin's sampling results also corroborate similar findings with respect to radioactive constituents including elevated gross beta, increasing uranium-238 and increasing potassium-40 levels.

5.4.9 Recommendations

Each week, DOE samples the EMWMF-3 effluent on a flow proportional basis. TDEC DoR-OR recommends that as long as the sampling frequency and analyte suite remains consistent, the State should conduct quarterly sampling and spot sampling (based on field observations) at EMWMF-3, to perform continuity checks and help determine if contaminants are discharging into Bear Creek. TDEC DoR-OR also recommends State sampling of contact water ponds/tanks as they are discharged to the unlined ditch. Additional sampling should be conducted during active discharge from that unlined ditch as the water from those contact water ponds / tanks is discharged into the sediment basin.

DOE samples EMWMF-2 on a bi-monthly schedule. TDEC DoR-OR also samples EMWMF-2 bi-monthly (months when DOE does not sample). This allows for a full year of monthly sampling of the underdrain location. The basis for TDEC DoR-OR's bi-monthly sampling of the underdrain location is because it is anticipated that the underdrain (EMWMF-2) would likely be the first place that contaminants from the landfill would surface should there be liner impairment or other unusual landfill structural issues. Also, key, is that water from EMWMF 2 is discharged directly to Bear Creek without any treatment. Sampling at EMWMF-2 should continue to be conducted on a regular basis and include at a minimum analyses for radionuclides and metals to provide comparison points with DOEs similar sampling program.

5.4.10 References

Environmental Sampling of the Oak Ridge Reservation and its Environs Quality Assurance Project Plan, Division of Remediation Oak Ridge: (2015)

Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water, Tennessee Department of Environment and Conservation, Division of Water Pollution Control (2011).

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

6.0 SEDIMENT MONITORING

6.1 AMBIENT SEDIMENT

6.1.1. Background

Contaminated sediments can directly impact benthic life and indirectly pose detrimental effects on other organisms, including humans, through bioaccumulation and subsequent transfer through the food web. Sediment-associated contaminants are an important ongoing environmental problem that impacts the use of many water bodies. In order to assess the degree of contamination attributable to the activities of the DOE, the Tennessee Department of Environment and Conservation (TDEC), Division of Remediation (DoR) Oak Ridge (OR) Sediment Monitoring Project collects sediment samples at the benthic level for chemical analysis from the Clinch River and some of its tributaries. Sediment samples have been and are proposed to be collected at six locations on the Oak Ridge Reservation (ORR) at exit pathway streams.

An Ambient Sediment Project has been executed by TDEC-DoR-OR each year since 1994. The project first monitored the Clinch River for water quality at five locations near the ORR. This project has evolved over the years, and locations and frequency of sampling have changed. Due to the complex nature of the ORR National Priority List (NPL) site, sediment monitoring is necessary for the long term.

6.1.2 Problem Statements

ORR exit pathway streams are subject to contaminant releases from activities on the ORR at East Tennessee Technology Park (ETTP), Oak Ridge National Laboratory (ORNL), and the Y-12 National Security Complex (Y-12). These contaminant releases have been detrimental to stream health in the past and present. Identified issues include the following:

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury to East Fork Poplar Creek (EFPC) by spills and leakage from subsurface drains, building foundations, contaminated soils, and purposed discharges 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)
- Metals, other than mercury, that have been found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver, and

zirconium (DOE, 1992)

- Water supply facilities, serving an estimated population of 200,000 persons on the Tennessee River downstream the White Oak Creek (WOC), have the potential of being influenced by streams that drain the ORR (DOE, 1992)
- The Clinch River received approximately 665 curies of cesium-13 (Cs-137) from WOC from 1954 to 1959 (DOE, 1992)

6.1.3 Goals

This project will focus on the following:

- Characterize stream conditions through the sampling and analysis of sediment
- Serve as an integral component of watershed monitoring (physical, chemical, and biological conditions of the waterbody)
- Assess site remediation efforts through long-term monitoring, sampling, and analysis of sediment
- Based on findings, identify trends in data, interpret the findings, and use those interpretations to make recommendations to improve sediment quality and the health of affected streams

6.1.4 Scope

The Ambient Sediment Project will sample for sediment contaminants in waterways that have been impacted by past and current activities on the ORR. This project is limited to sampling only the tributaries that drain the ORR and the Clinch River from the mouth of WOC at Clinch River km (CRK) 33.5, downstream to CRK 0.0, where the Clinch River meets the Tennessee River.

6.1.5 Methods, Materials, Metrics

Annual sampling was conducted at six sampling stations (Table 6.1.1) at points on the major exit pathway streams of the ORR:

1. Bear Creek
2. Northwest Tributary 5 (NT 5) of Bear Creek
3. East Fork Poplar Creek (EFPC)
4. Mitchell Branch (MB)

5. Clinch River
6. Mill Branch (background location)

Sampling is conducted in October. Sampling is not conducted at White Oak Creek due to the high Sr-90 levels in the sediment. Sampling is conducted according to the TDEC-DoR *Standard Operating Procedure, Sediment Sampling* (TDEC, 2017):

- Sediment samples at each location are collected with stainless steel spoons.
- Sediment sampling is accomplished by wading into the surface water body and while facing upstream (into the current), scooping the sample from sediment depositional areas of the stream. This process is repeated until a sufficient amount of sediment sample for the desired analyses has been collected.
- The sediment is then placed into a stainless-steel bowl and stirred until the sample is homogenized.
- Samples are stored on ice; chemical preservatives are not used for sediment samples.
- Sediment samples that will be analyzed for metals and/or radiological analyses will be placed in 16-ounce plastic containers with plastic lids. After the containers are capped, they are then taped with electrical tape to prevent leakage.
- Accurate, representative samples are collected and secured with this procedure.

Sampling Plan

Sediment sampling at each of six stations occurs annually in October. The six stations sampled during this reporting period are listed in Table 6.1.1 and shown on Figure 6.1.1.

Table 6.1.1: Ambient Sediment Sampling Rationale

Ambient Sediment Sampling Locations 2018-2019					
Sampling Location	**ID**	**Alternate ID**	**Sampling Rationale**	**Latitude**	**Longitude**
Clinch River km 23.3	CLINC014.5RO	CRK 23.3	Evaluate the effect of contaminant sources in the White Oak Creek watershed on sediment quality in the Clinch River.	35.90659	-84.39054
Mill Branch km 1.6	POPLA003.5RO	MBK 1.6	Provide a background sediment sampling station to compare to other streams.	35.98886	-84.28935
East Fork Poplar Creek km 6.3	EFPOP003.9RO	EFK 6.3	Evaluate the effect of Y-12 contaminant sources on sediment quality in East Fork Poplar Creek.	35.96293	-84.35905
Bear Creek km 3.3	BEAR002.8RO	BCK 3.3	Evaluate the effect of Y-12 contaminant sources on sediment quality in Bear Creek.	35.94354	-84.34911
Mitchell Branch km 0.1	MITCH000.1RO	MIK 0.1	Evaluate the effect of ETTP contaminant sources on sediment quality in Mitchell Branch.	35.94146	-84.39220
North Tributary 5 of Bear Creek	BEAR006.5T0.1AN	NT5	Evaluate the effect of EMWMF contaminant sources on sediment quality in a tributary of Bear Creek.	35.96603	-84.29024

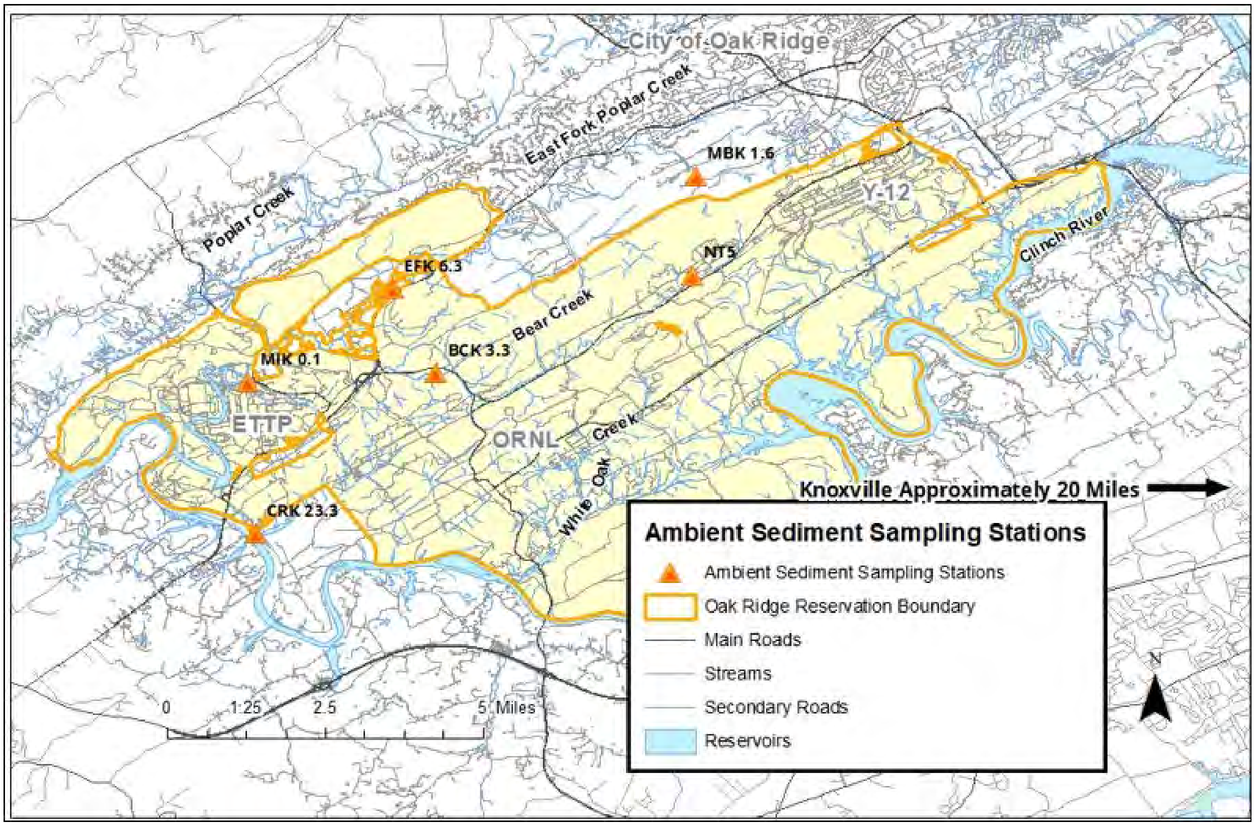


Figure 6.1.1: Map of Ambient Sediment Sampling Stations

6.1.6 Deviations from the Plan

Clinch River km 23.3 was sampled instead of CRK 32.7 because the sediment depositional area at CRK 32.7 washed away during an extended period of heavy rains; CRK 32.7 was no longer a suitable site for sediment collection after the heavy rains. CRK 23.3 has an extensive sediment depositional area suitable for sediment sampling.

6.1.7 Results from Analysis

Sediment samples were collected at most stream locations on10/23/2018. MBK 1.6 was sampled on 10/30/2018 and the CRK 23.3 site was sampled on10/31/18. Grab samples in wade-able streams were collected by hand with a stainless-steel spoon. CRK 23.3 was sampled with a petite PONAR grab device.

At least three grab samples were collected from each sampling location. The grab samples were combined and containerized for transport to the analytical laboratory. The Tennessee Department of Health Laboratory Services (TDH) processed the samples, according to Environmental Protection Agency (EPA) approved methods. Samples were analyzed for arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium, and uranium. Samples from all stations were analyzed for gross alpha, gross beta, gamma radionuclides, Sr-89/90, and isotopic uranium.

Metals Analyses

Table 6.1.2 *Summary of Metals Data* provides the results from metals analysis when compared to:

- the Consensus Based Sediment Quality Guidelines (CBSQGs) and
- the data results from the background sampling location, Mill Branch kilometer 1.6 (MBK 1.6)

Mill Branch is a tributary of EFPC that is unaffected by the influences of the DOE facilities in Oak Ridge. It is a stream with exceptional water quality and is designated as an ecoregion reference stream.

The Probable Effects Concentrations (PECs) are CBSQGs established as concentrations of individual chemicals above which adverse effects in sediments are expected to occur frequently (MacDonald, et al. 2000). Adverse effects, in this case, refer to the adverse effects to the 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, other tools, such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue-residue guidelines should be used (in addition to the CBSQGs) to assess direct toxicity and food chain effects (WDNR, 2003). The Threshold Effects Concentrations (TECs) are concentrations below which adverse effects are not expected to occur (MacDonald, et al., 2000).

The only metals found at concentrations above the CBSQG PEC were mercury found at Mitchell Branch kilometer 0.1 (MIK 0.1) and East Fork Kilometer 6.3 (EFK 6.3) and nickel at MIK 0.1.

- The mercury in EFPC sediment results from historical activities at Y-12.
- Mitchell Branch is contaminated as a result of being adjacent to a complex nuclear processing facility. It has been affected adversely by contaminated groundwater and surface water runoff. TECs were exceeded for several metals: arsenic, chromium, copper, lead, nickel, mercury, and zinc at MIK 0.1.

Table 6.1.2: Summary of Metals Data

Ambient Sediment Metals Results 2018-2019									
Parameter	**Units**	**BCK 3.3**	**NT5**	**EFK 6.3**	**MIK 0.1**	**CRK 23.3**	**MBK 1.6†**	**TEC***	**PEC****
Arsenic	mg/kg	U; 3.60	U; 3.61	U; 0.356	N.A.	5.69	U; 3.61	9.8	33
Barium	mg/kg	66.1	124	57.4	122	86.1	63.4	n.a.	n.a.
Beryllium	mg/kg	0.507	0.563	0.415	0.676	0.595	0.571	n.a.	n.a.
Boron	mg/kg	23.6	31.5	21.1	49.8	32.6	26	n.a.	n.a.
Cadmium	mg/kg	0.551	0.241	0.744	1.32	0.627	0.258	0.99	5
Chromium	mg/kg	10.8	13.5	10.2	58	13.5	11.1	43	110
Copper	mg/kg	5.85	5.63	11.4	88.5	9.94	5.24	32	150
Lead	mg/kg	9.43	7.57	13.9	67.7	21.1	8.27	36	130
Mercury	mg/kg	0.0179	0.051	6.56	2.47	0.648	0.609	0.18	1.1
Nickel	mg/kg	9.77	9.52	7.67	255	10.9	8.69	23	49
Selenium	mg/kg	U; 1.56	U; 1.56	U; 0.313	U; 0.313	U; 1.57	U; 1.56	n.a.	n.a.
Uranium	mg/kg	3.44	0.937	2.31	25	1.11	0.439	n.a.	n.a.
Zinc	mg/kg	U; 25.5	28.2	48.8	213	48.2	U; 25.5	120	460

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

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

Values above the TEC are shaded orange; values above the PEC are shaded red.

U - undetected; (detection limit)

n.a. - criteria not established for that characteristic

mg/kg - milligrams per kilograms

† background sampling station

Radiological Analyses

Radiological results were compared to Preliminary Remediation Goals (PRGs) obtained from the ORNL Risk Assessment Information System (RAIS). PRGs are isotope concentrations that correspond to estimated risk levels in various media. The PRGs in Table 6.1.3 were calculated using the recreation scenario with a target cancer risk of 1.0E-5. The total PRG risk scenario calculation includes external exposure, ingestion, and inhalation factors. Data results from the sampled streams did not exceed the PRGs; these streams do not present a radiological risk to human health. WOC sediments were not sampled due to their known radiological contamination. Sediments collected from WOC would not be cleared for release by UT-Battelle radiological technicians.

Table 6.1.3: Summary of Radiological Data

Ambient Sediment Radiological Results								
Parameter	**Units**	**BCK 3.3**	**CRK 23.3**	**EFK 6.3**	**MIK 0.1**	**NT5**	**MBK 1.6†**	**PRG**
Radioactivity, alpha	pCi/g	3.76	4.18	4.35	15.1	3.10	1.91	n.a.
combined standard uncertainty	pCi/g	0.48	0.53	0.54	1.6	0.44	0.35	
Radioactivity, beta	pCi/g	6	25.1	5.4	204.0	12.1	2.3	n.a.
combined standard uncertainty	pCi/g	1.1	0.2	1.1	14.0	1.4	1	
Actinium-228	pCi/g	0.96	1.1	0.74	1.45	1.29	1.01	2.95E+06
combined standard uncertainty	pCi/g	0.25	0.32	0.19	0.37	0.23	0.28	
Bismuth-214	pCi/g	0.82	1.01	0.72	1.47	0.75	0.83	3.11E+07
combined standard uncertainty	pCi/g	0.19	0.24	0.15	0.27	0.18	0.22	
Cesium-137	pCi/g	U	27	U	1.11	U	U	1.30E+03
combined standard uncertainty	pCi/g	n.a.	0.99	n.a.	0.17	n.a.	n.a.	
Lead-212	pCi/g	0.82	0.97	0.668	1.53	1.03	0.78	6.37E+06
combined standard uncertainty	pCi/g	0.12	0.2	0.096	0.2	0.15	0.15	
Lead-214	pCi/g	0.73	1.12	0.71	1.38	0.71	0.72	1.95E+08
combined standard uncertainty	pCi/g	0.17	0.30	0.13	0.28	0.15	0.2	
Strontium-89	pCi/g	2.5	1.4	0.4	1.4	1.3	2.80	1.60E+05
combined standard uncertainty	pCi/g	1.9	1.7	1.8	2	1.8	1.70	
Strontium-90	pCi/g	0.27	0.38	0.6	0.67	0.25	0.33	6.47E+02
combined standard uncertainty	pCi/g	0.24	0.25	0.25	0.28	0.25	0.24	
Thallium-208	pCi/g	0.336	0.51	0.273	0.56	0.354	0.372	8.94E+07
combined standard uncertainty	pCi/g	0.099	0.21	0.066	0.13	0.079	0.099	
Uranium-234	pCi/g	1.64	1.26	1.15	14.7	2.7	0.93	2.81E+02
combined standard uncertainty	pCi/g	0.3	0.29	0.26	1.6	0.44	0.27	
Uranium-235	pCi/g	0.182	0.14	0.18	1.83	0.20	0.058	2.21E+02
combined standard uncertainty	pCi/g	0.098	0.1	0.11	0.37	0.12	0.074	
Uranium-238	pCi/g	1.67	0.99	1.33	8.9	0.9	0.45	3.10E+02
combined standard uncertainty	pCi/g	0.3	0.25	0.28	1	0.23	0.18	

U - undetected

n.a. - not applicable

† - background station

PRG - Preliminary Remediation Goal from the ORNL Risk Assessment Information System

6.1.8 Conclusions

Comparisons of radiological data with PRGs (recreation, target cancer risk 1.0E-5, total risk scenario) show that none of the sediment samples exceeded the PRGs. These streams do not present a radiological risk to human health (RAIS, 2018).

The EFPC km 6.3 sediment mercury concentrations (6.56 mg/kg) exceed the PEC of 1.1 mg/kg (MacDonald et al., 2000). The mercury in EFPC sediments results from historical activities at Y-12.

Mitchell Branch sediments are contaminated with chromium, lead, nickel, mercury, arsenic, copper, and zinc. Mercury and nickel values are above the PECs, meaning that stream life is probably being affected adversely. Chromium, lead, arsenic, copper, and zinc levels were above the TECs; there is a possibility that stream life could be affected at these levels. This host of contaminants present in Mitchell Branch can be attributed to the legacy activities at the old K-25 site (ETTP).

The NT-5 of Bear Creek is also contaminated with uranium, but to a lesser extent than Mitchell Branch. This stream is influenced by the EMWMF facility. In addition to groundwater inputs, NT-5 receives the flow from the sediment retention pond. NT-5 contributed approximately 0.7 kg of uranium to Bear Creek in FY 2017 (DOE 2018).

The sediment sample collected from the Clinch River at km 23.3 had mercury (0.648 mg/kg) above the TEC (0.18 mg/kg) Most of the other CRK 23.3 metals concentrations were less than the background values of the Mill Branch sediment. TDH Lab reported that MBK 1.6 had a mercury level (0.609mg/kg) above the TEC (0.18 mg/kg). This is a most unusual circumstance since MBK 1.6 is an ecoregions reference site and is not expected to have that level of mercury in the sediments. The TDH lab was contacted and it was confirmed that the mercury value was correct.

6.1.9 Recommendations

Changes in sediment contamination occur gradually, which is the reason that this project only samples sediment once per year. In order to keep track of possible trends and sediment health, it is recommended that this project continue sampling on an annual basis. With the decommissioning and demolition projects planned for Y-12 and the recent discovery of increased beta activity found in water samples at EFPC km 23.4, it is also recommended that radiological testing of sediment be resumed at EFPC km 6.3 to monitor for changes in sediment quality there.

6.1.10 References

DOE 2013. Risk Assessment Information System. Office of Environmental Management, Oak Ridge Operations (ORO) Office, U.S. Department of Energy, Oak Ridge, Tennessee. (http://rais.ornl.gov/).

DOE 2018. 2018 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Site, Oak Ridge, Tennessee. DOE/OR/01-2757&D1. 2018.

Federal Facility Agreement (FFA). (1992) Appendices for the Oak Ridge Reservation. Oak Ridge Site Description – UCOR, Appendix B (2017 revision). DOE/OR-1014. United States Department of Energy. Retrieved from http://www.ucor.com/_docs/ffa/appendices/appendb.pdf

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

Pickering, R. (1970) Composition of Water in Clinch River, Tennessee River, and Whiteoak Creek as Related to Disposal of Low-Level Radioactive Liquid Wastes. (Geological Survey Professional Paper No. 433–J). Retrieved from https://pubs.usgs.gov/pp/0433j/report.pdf

Quality System Standard Operating Procedure for Sediment Sampling. (2017) Tennessee Department of Environment and Conservation, Division of Remediation Oak Ridge Office, Tennessee.

Turner, R. R., & Southworth, G.R. 1999. Mercury-Contaminated Industrial and Mining Sites in North America: an Overview with Selected Case Studies. In R. Ebinhaus, R. R. Turner, L. D. de Lacerda, O. Vasilev, & W. Salomons (Eds.), Environmental Science: Mercury Contaminated Sites. Springer-Verlag.

WDNR 2003. Consensus-based Sediment Quality Guidelines: Recommendations for Use & Application, Interim Guidance. PUBL-WT-732 2003. Wisconsin Department of Natural Resources.

6.2 TRAPPED SEDIMENT

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 introduced into aquatic systems often accumulate in sediment. Contaminants may accumulate in sediments such that 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 and create health risks for wildlife and humans. Sediment analysis is an important aspect of environmental quality and impact assessments for rivers, streams, and lakes.

Mill Branch is a tributary of East Fork Poplar Creek (EFPC) and is used as the background stream for the Trapped Sediment project. North Tributary 5 (NT-5) of Bear Creek is the main outfall for the Environmental Management Waste Management Facility (EMWMF). EMWMF is a mixed-waste landfill that since 2002 has received waste primarily from East Tennessee Technology Park (ETTP) decommissioning and demolition activities. Samples are analyzed for radiological activity and metals. Sediment sampling activities accomplished by the Tennessee Department of Environment and Conservation (TDEC), Division of Remediation (DoR), Oak Ridge (OR) have shown that Poplar Creek and EFPC have elevated mercury levels in sediments that can be attributed to historical discharges from Y-12 National Security Complex (Y-12) and to a lesser extent ETTP.

6.2.2 Problem Statements

Oak Ridge Reservation (ORR) exit pathway streams are subject to contaminant releases from activities at ETTP, Oak Ridge National Laboratory (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 EFPC by spills and leakage from subsurface drains, building foundations, contaminated soil, and 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).
- Besides mercury, other metals found in ORR exit pathway streams at levels greater than background are cadmium, chromium, lead, nickel, silver, and zirconium (DOE, 1992).
- Water supply facilities, serving an estimated population of 200,000 persons on the Tennessee River downstream of White Oak Creek (WOC), have the potential of being influenced by streams that drain the ORR (DOE, 1992).
- The Clinch River received approximately 665 curies of cesium-13 (Cs-137) from WOC from 1954 to 1959 (DOE, 1992).

6.2.3 Goals

The goals of this project are:

- 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 EFPC, Mill Branch, and NT-5 by using passive sediment collectors. 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.

6.2.5 Methods, Materials, Metrics

In order to monitor for changes in contaminant flow through sediment transport, passive sediment samplers (traps) were deployed. Annual sampling is needed for two major exit pathway streams of the ORR, including but not limited to, NT-5 of Bear Creek, EFPC, and Mill Branch (See Table 6.2.1 and Figure 6.2.1.). Mill Branch is the background location. Samples are retrieved from the sediment traps at scheduled intervals throughout the year. Table 6.2.2 provides the deployment dates of the sediment traps.

Sediment samples are analyzed for metals (arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, uranium, and zinc) and radiological parameters (Sr-90 and Cs-137). The metals data is compared to the Consensus-Based Sediment Quality Guidelines (CBSQGs) (MacDonald et al., 2000). Radiological data is compared to data from background locations.

Note: Sampling was not conducted at WOC due to the elevated Sr-90 levels in the sediment.

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. To completely immerse the sediment traps, water flow and depth must be sufficient.

Following a collection period (a minimum of four months), the collected sediment is emptied from a sediment trap and is transferred to a clean bucket where the sediment is allowed to settle on ice from 24 to 48 hours. 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
North Tributary 5 of Bear Creek	BEAR006.5T0.1AN	NT-5	Surveillance of suspended sediment downstream of EMWMF	35.96603	-84.29024
Bear Creek km 7.6	BEAR004.7RO	BCK 7.6	Surveillance of suspended sediment downstream of proposed EMDF	35.95096	-84.31395
Bear Creek km 3.3	BEAR002.0RO	BCK 3.3	Surveillance of suspended sediment downstream of Y-12	35.943538	-84.349114

Table 6.2.2: Deployment Dates of Sediment Traps

Sampling Station	Deployed	Sampled
EFK 23.4	4/12/18	7/16/2018
EFK 23.4	10/3/18	4/15/19
NT-5	9/21/2017	7/16/2018
NT-5	10/3/18	Still deployed
MBK 1.6	6/12/2017	7/16/2018
MBK 1.6	10/3/18	Still deployed
BCK 3.3	2/5/19	Still deployed
BCK 7.6	2/5/19	Still deployed

Sediment traps were deployed at the following stream locations: EFPC km EFK 23.4, North Tributary 5 of Bear Creek (NT-5), Bear Creek km 7.6 (BCK 7.6), BCK 3.3, and at Mill Branch km 1.6 (MBK 1.6) (Figure 6.2.1).

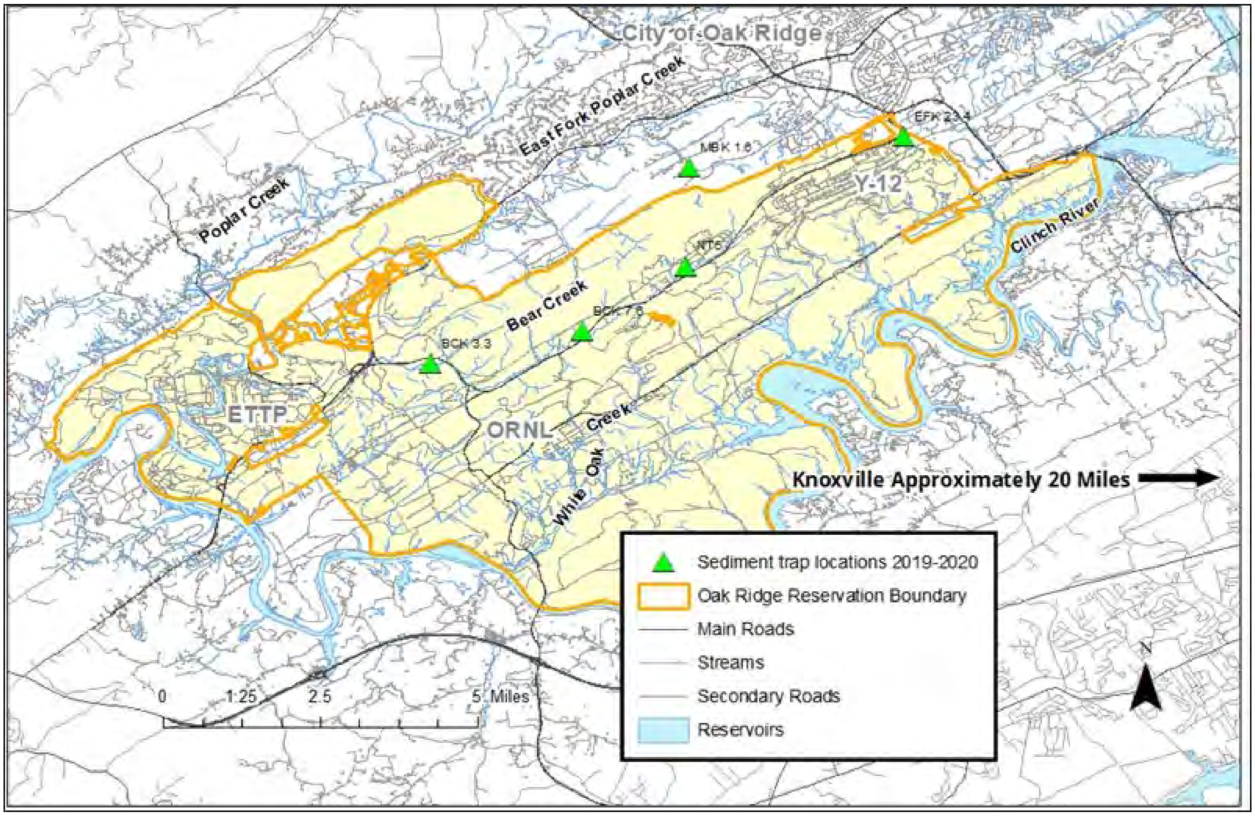


Figure 6.2.1: Sampling Locations

6.2.6 Deviations from the Plan

Two new sediment traps were installed at BCK 3.3 and BCK 7.6 on 2/5/19; these installations were not included in the original EMP. These sampling locations were added to provide data for the Bear Creek Assessment Project. None of the sediment traps were sampled in June of 2019 due to a budgetary shortfall.

6.2.7 Results from Analysis

Trapped sediment results were compared with the Consensus Based Sediment Quality Guidelines (CBSQGs) Probable Effects Concentrations (PECs) for each metal. The PECs are CBSQGs that were established as concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur (Ingersoll 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, other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue-residue guidelines should be used in addition to the CBSQGs, to assess direct toxicity and food chain effects (WDNR 2003). The threshold effects concentrations (TECs) are concentrations below which adverse effects are not expected to occur (MacDonald et al. 2000).

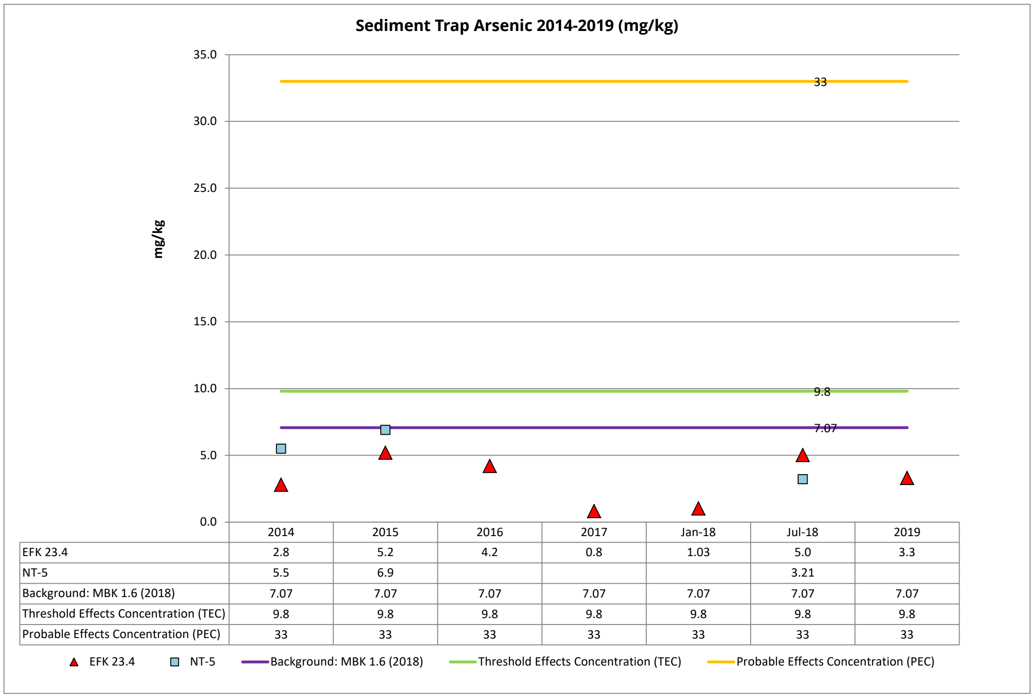
In addition, sample results were compared with data from a background sediment trap sampling station, Mill Branch km 1.6 (MBK 1.6).

The following graphs and associated tables follow the sediment data through five years of sampling. There are some omissions in the tables to be noted:

- Only EFK 23.4 was sampled in January of 2018
- NT-5's sediment trap had an insufficient yield for metals analysis in 2016 and 2017
- The data for Mill Branch the background stream is shown in the graphs as a bar to symbolize that the data is only from 2018
- Blanks in the following charts (figures 6.2.2-6.2.11), indicate the parameter was not analyzed that year

Arsenic

Arsenic at both EFK 23.4 and NT-5 is lower than the background sampling station (Mill Branch km 1.6) and the Threshold Effects Concentration (Figure 6.2.2).

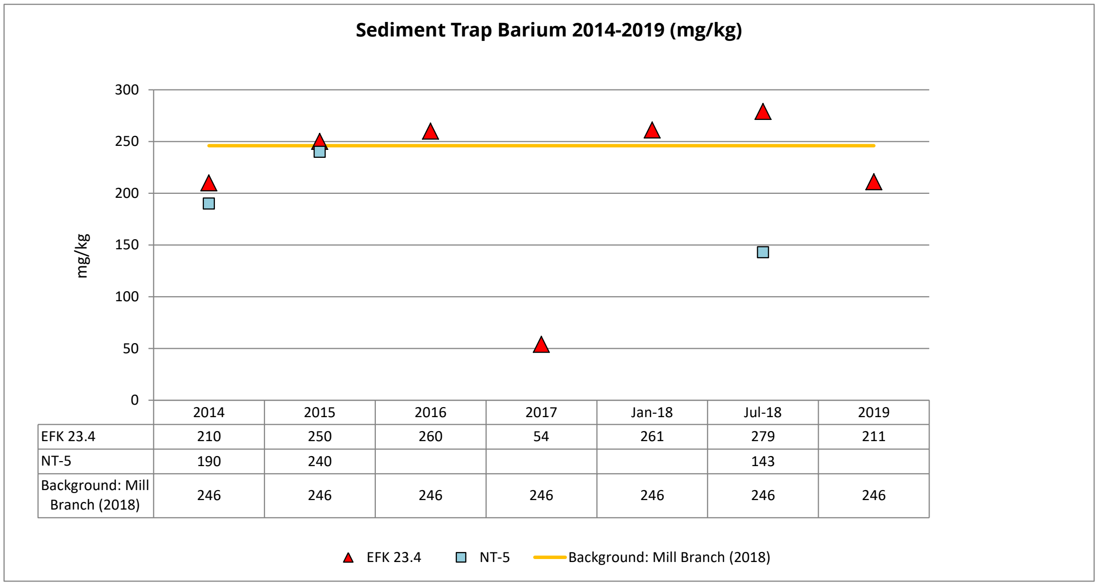


	2014	2015	2016	2017	Jan-18	Jul-18	2019
EFK 23.4	2.8	5.2	4.2	0.8	1.03	5.0	3.3
NT-5	5.5	6.9				3.21	
Background: MBK 1.6 (2018)	7.07	7.07	7.07	7.07	7.07	7.07	7.07
Threshold Effects Concentration (TEC)	9.8	9.8	9.8	9.8	9.8	9.8	9.8
Probable Effects Concentration (PEC)	33	33	33	33	33	33	33

Figure 6.2.2: Sediment Trap Arsenic: 2014-2019

Barium

Barium at both EFK 23.4 and NT-5 was found to be at a similar concentration as the Mill Branch background station (Figure 6.2.3). There are no CBSQGs for barium.

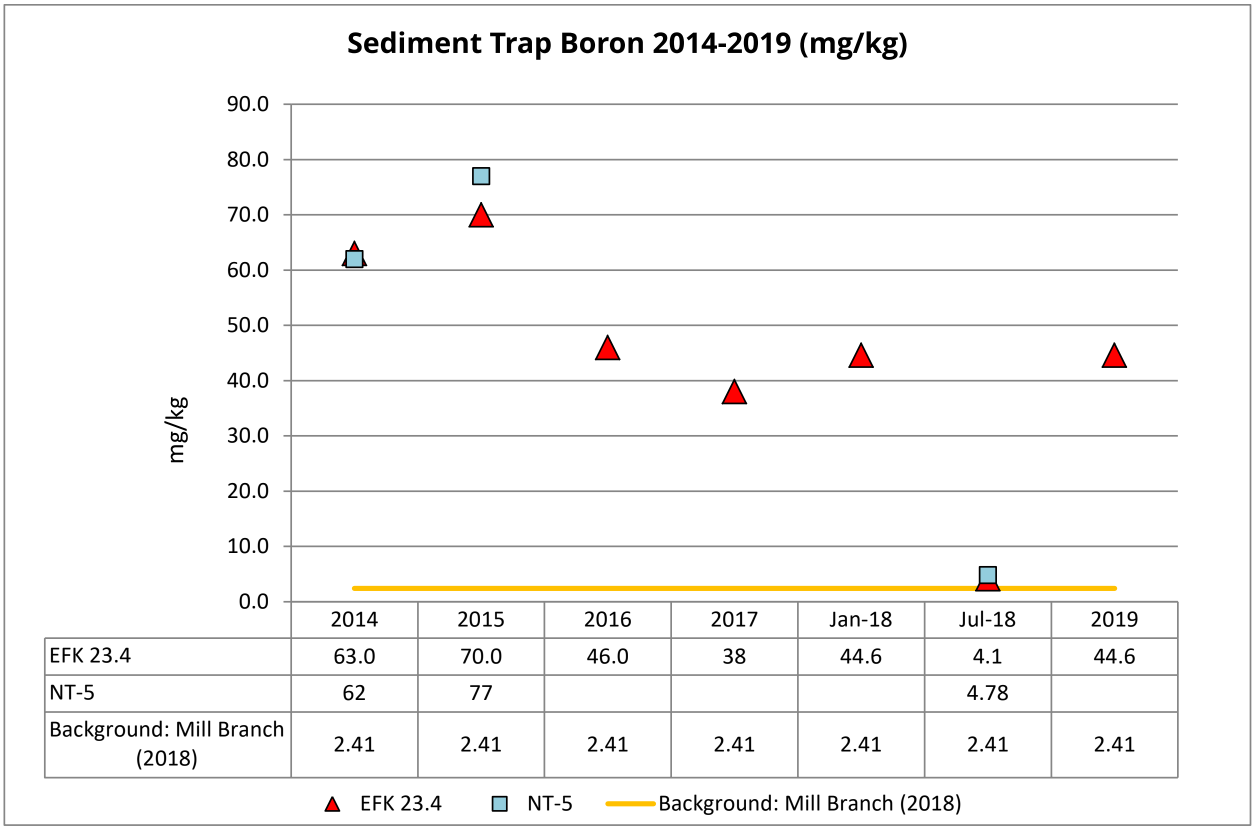


	2014	2015	2016	2017	Jan-18	Jul-18	2019
EFK 23.4	210	250	260	54	261	279	211
NT-5	190	240				143	
Background: Mill Branch (2018)	246	246	246	246	246	246	246

Figure 6.2.3: Sediment Trap Barium: 2014-2019

Boron

Boron values were much higher than background values (Figure 6.2.4). Boron-10 is used for radiation shielding and for radiation control. The 2018 data were unusually low for both EFK 23.4 and NT-5; the data are under review by the TDH laboratory.

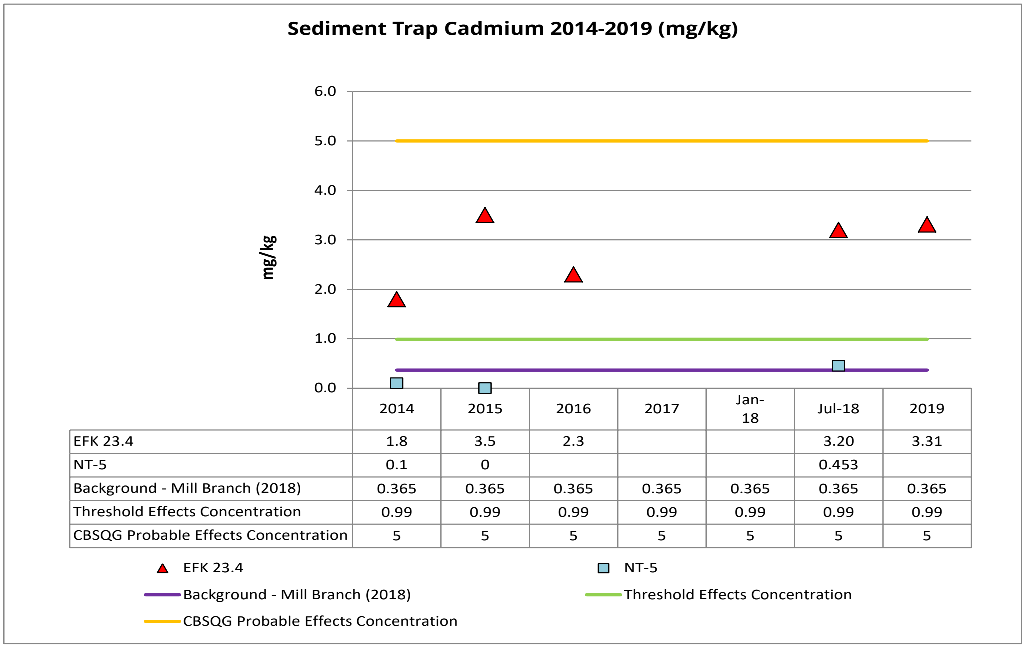


	2014	2015	2016	2017	Jan-18	Jul-18	2019
EFK 23.4	63.0	70.0	46.0	38	44.6	4.1	44.6
NT-5	62	77				4.78	
Background: Mill Branch (2018)	2.41	2.41	2.41	2.41	2.41	2.41	2.41

Figure 6.2.4: Sediment Trap Boron: 2014-2019

Cadmium

Cadmium levels at EFK 23.4 are elevated; data were higher than both the TEC and background, but lower than the PEC (Figure 6.2.5). NT-5 cadmium data were near background or undetected.

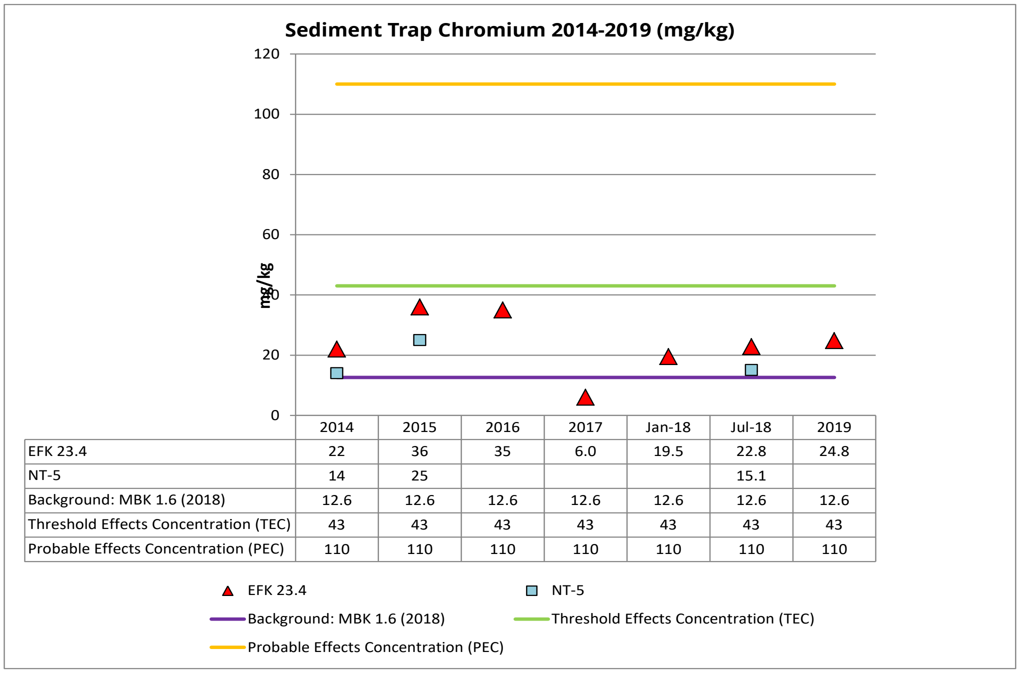


	2014	2015	2016	2017	Jan-18	Jul-18	2019
EFK 23.4	1.8	3.5	2.3			3.20	3.31
NT-5	0.1	0				0.453	
Background - Mill Branch (2018)	0.365	0.365	0.365	0.365	0.365	0.365	0.365
Threshold Effects Concentration	0.99	0.99	0.99	0.99	0.99	0.99	0.99
CBSQG Probable Effects Concentration	5	5	5	5	5	5	5

Figure 6.2.5: Sediment Trap Cadmium: 2014-2019

Chromium

For all stations, Chromium values are below the TEC and are not a concern for wildlife (Figure 6.2.6).

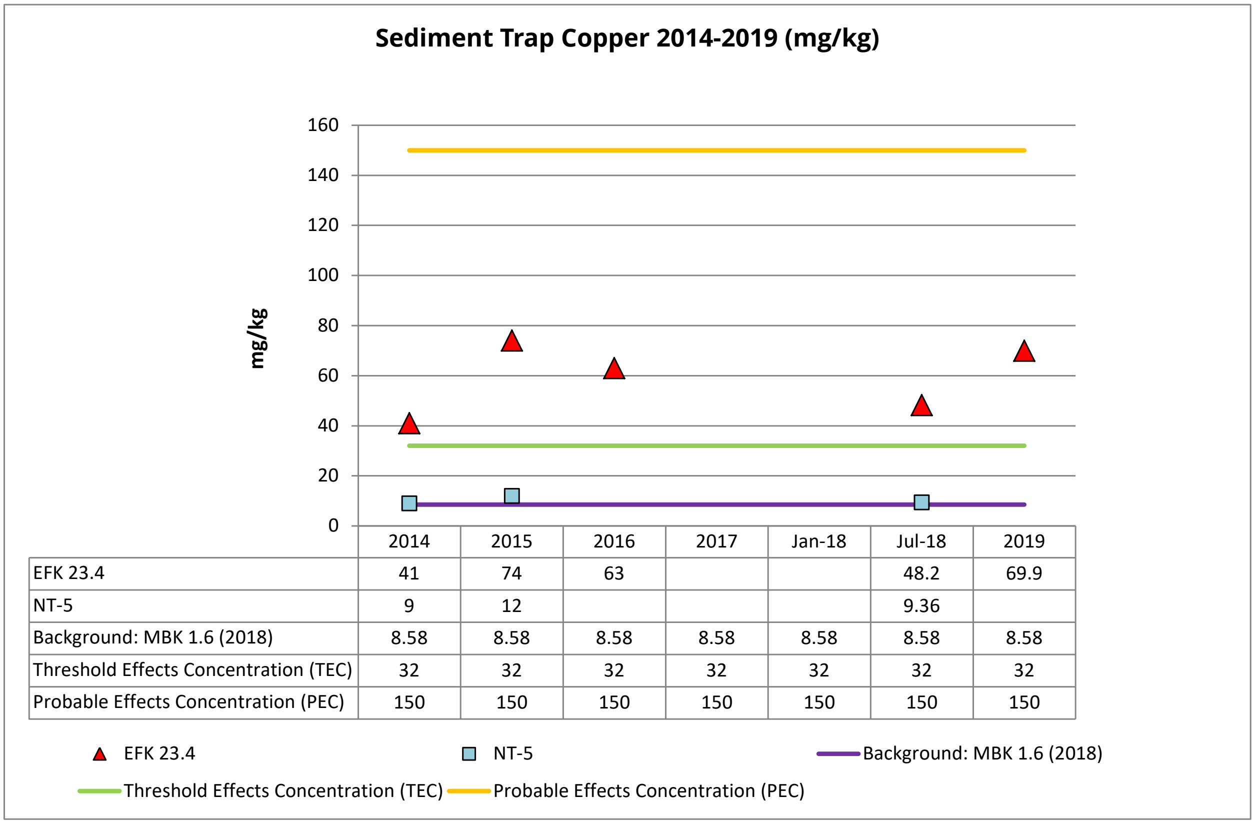


	2014	2015	2016	2017	Jan-18	Jul-18	2019
EFK 23.4	22	36	35	6.0	19.5	22.8	24.8
NT-5	14	25				15.1	
Background: MBK 1.6 (2018)	12.6	12.6	12.6	12.6	12.6	12.6	12.6
Threshold Effects Concentration (TEC)	43	43	43	43	43	43	43
Probable Effects Concentration (PEC)	110	110	110	110	110	110	110

Figure 6.2.6: Sediment Trap Chromium: 2014-2019

Copper

Copper data for EFK 23.4 are greater than the TEC and less than the PEC (Figure 6.2.7). An analysis for copper was not conducted in 2017 or January 2018. Values above the TEC indicate that the metal may be adversely affecting stream organisms that inhabit sediments, such as benthic macroinvertebrates. The copper values for NT-5 were similar to background.

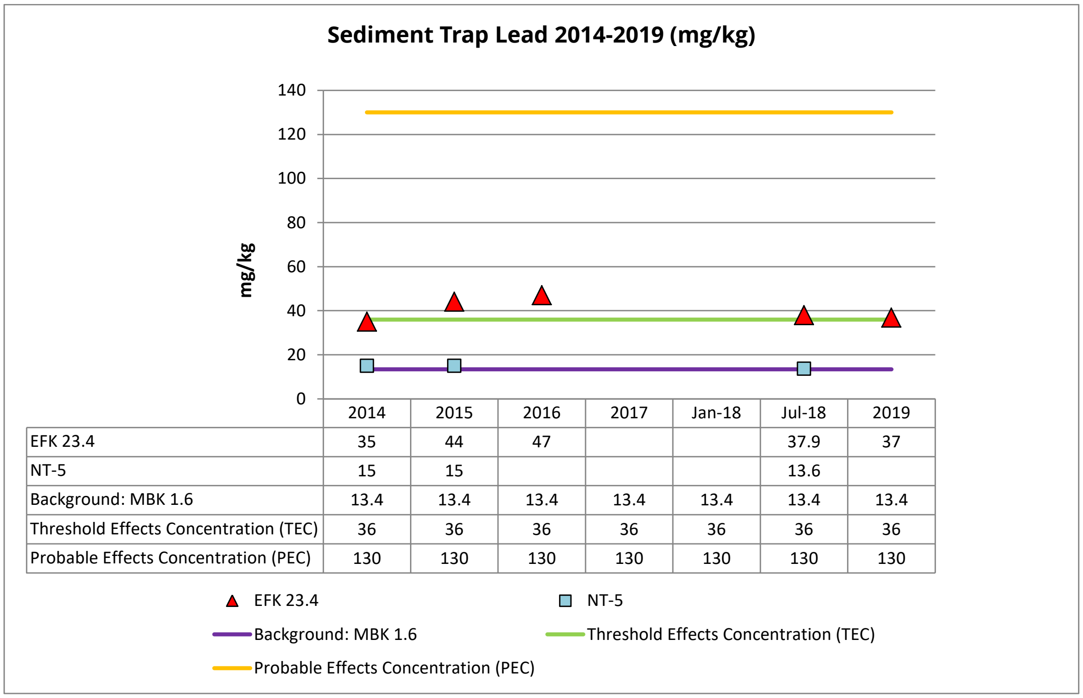


	2014	2015	2016	2017	Jan-18	Jul-18	2019
EFK 23.4	41	74	63			48.2	69.9
NT-5	9	12				9.36	
Background: MBK 1.6 (2018)	8.58	8.58	8.58	8.58	8.58	8.58	8.58
Threshold Effects Concentration (TEC)	32	32	32	32	32	32	32
Probable Effects Concentration (PEC)	150	150	150	150	150	150	150

Figure 6.2.7: Sediment Trap Copper: 2014-2018

Lead

Most lead values for EFK 23.4 were slightly above the TEC (Figure 6.2.8). It's possible that lead could be harming the benthic macroinvertebrate community, particularly considering synergistic effects of other metals that exceed the TEC.

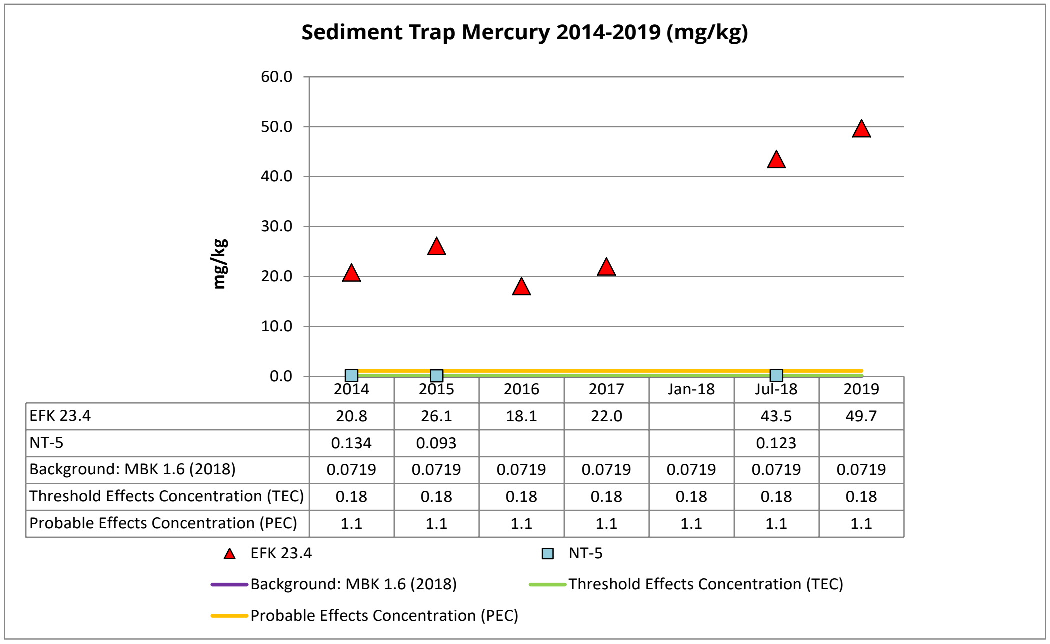


	2014	2015	2016	2017	Jan-18	Jul-18	2019
EFK 23.4	35	44	47			37.9	37
NT-5	15	15				13.6	
Background: MBK 1.6	13.4	13.4	13.4	13.4	13.4	13.4	13.4
Threshold Effects Concentration (TEC)	36	36	36	36	36	36	36
Probable Effects Concentration (PEC)	130	130	130	130	130	130	130

Figure 6.2.8: Sediment Trap Lead: 2014-2019

Mercury

Mercury values for EFK 23.4 were much higher than the PEC (Figure 6.2.9); metals found at levels above the PECs indicate that the metal(s) in question are probably having an adverse effect on benthic macroinvertebrate populations. On 7/16/18, the latest sample was collected. It shows a mercury value that is nearly two times greater than the previous samples. Mercury values at NT-5 were slightly higher than background but below the TEC.

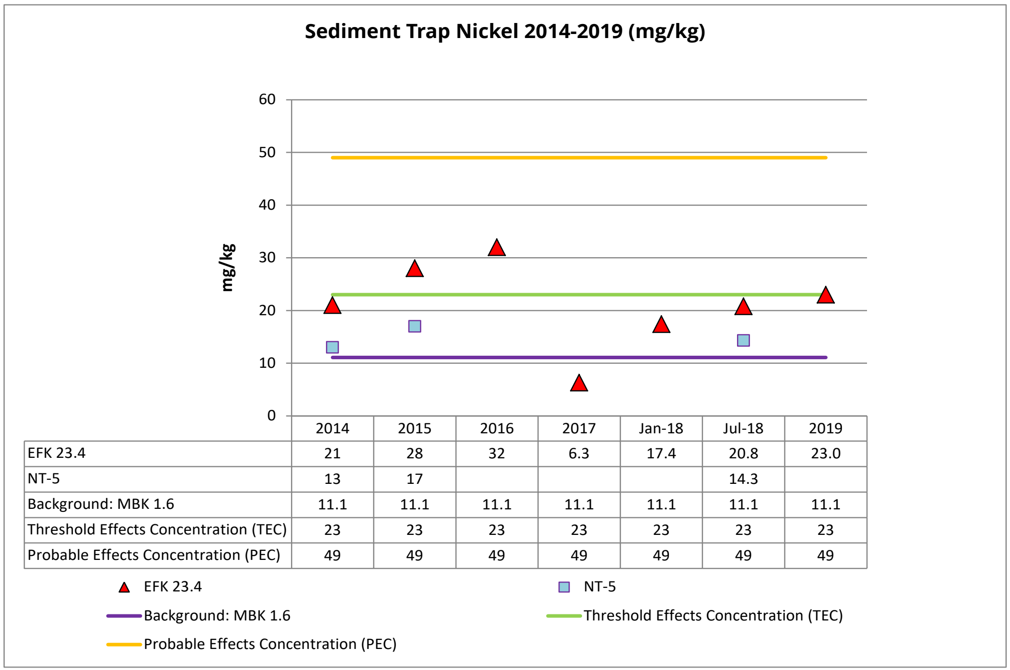


	2014	2015	2016	2017	Jan-18	Jul-18	2019
EFK 23.4	20.8	26.1	18.1	22.0		43.5	49.7
NT-5	0.134	0.093				0.123	
Background: MBK 1.6 (2018)	0.0719	0.0719	0.0719	0.0719	0.0719	0.0719	0.0719
Threshold Effects Concentration (TEC)	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Probable Effects Concentration (PEC)	1.1	1.1	1.1	1.1	1.1	1.1	1.1

Figure 6.2.9: Sediment Trap Mercury: 2014-2019

Nickel

The level for nickel has been greater than background at EFK 23.4 and NT-5 from 2014 through 2018 (11.1 mg/kg) with the exception of the 2017 datum (Figure 6.2.10). The data are clustered around the TEC (23 mg/kg).

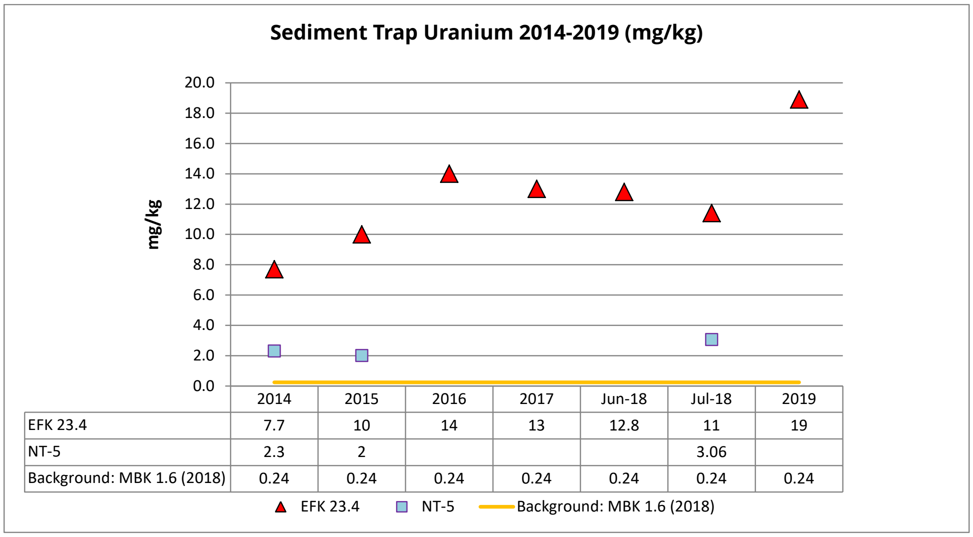


	2014	2015	2016	2017	Jan-18	Jul-18	2019
EFK 23.4	21	28	32	6.3	17.4	20.8	23.0
NT-5	13	17				14.3	
Background: MBK 1.6	11.1	11.1	11.1	11.1	11.1	11.1	11.1
Threshold Effects Concentration (TEC)	23	23	23	23	23	23	23
Probable Effects Concentration (PEC)	49	49	49	49	49	49	49

Figure 6.2.10: Sediment Trap Nickel

Uranium

The uranium level has been greater than the background level at EFK 23.4 and NT-5 from 2014 through 2018 in the sediment trap samples (Figure 6.2.11). There are no CBSQGs established for uranium metal.



	2014	2015	2016	2017	Jun-18	Jul-18	2019
EFK 23.4	7.7	10	14	13	12.8	11	19
NT-5	2.3	2				3.06	
Background: MBK 1.6 (2018)	0.24	0.24	0.24	0.24	0.24	0.24	0.24

Figure 6.2.11: Sediment Trap Uranium

Gross Alpha

Gross alpha activity is greater than background in the sediment trap samples (Figure 6.2.12). There are no CBSQGs established for gross alpha radioactivity.

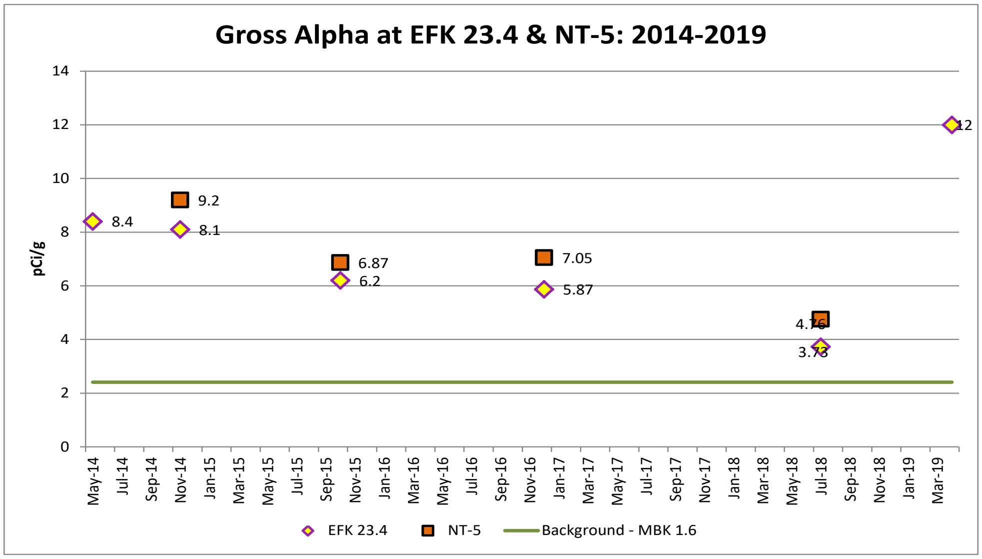


Figure 6.2.12: Sediment Trap Gross Alpha

Gross Beta

Gross beta activity is greater than background in the sediment trap samples (Figure 6.2.13). There are no CBSQGs established for gross beta radioactivity.

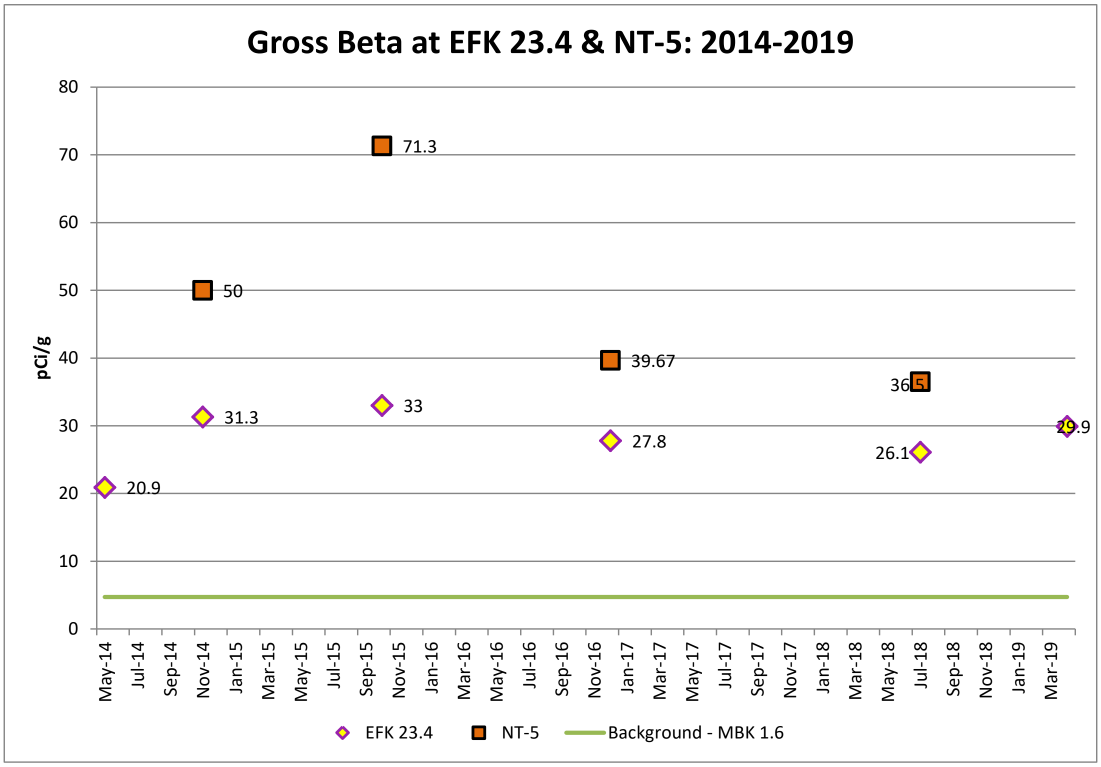


Figure 6.2.13: Sediment Trap Gross Beta

Gamma Radionuclides

Only naturally occurring gamma radionuclides were detected. These radioisotopes, such as Bi-214, K-40, 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 sediment traps indicates metals contamination at EFK 23.4.

Cadmium and copper levels were above the TEC at EFK 23.4 and mercury levels exceeded the PEC. Lead and nickel concentrations were above the TEC in 2015 and 2016 at EFK 23.4. When a metal occurs at a concentration above the TEC, a possibility of impairment to benthic macroinvertebrate populations is possible. Above the PEC, it is probable that these populations will be impaired. The concentrations of these metals indicate that there is a probable impairment to the biota of the sediment.

At NT-5, results from metals analysis were less than the TEC.

Both EFK 23.4 and NT-5 have levels of gross alpha and beta radioactivity that are above background in the trapped sediment samples collected. However, these levels are not at a concentration that would be expected to pose a threat to human health or the stream life.

6.2.9 Recommendations

These sediment traps capture suspended sediments that are being carried by the current of the stream. Analysis of the sediments collected in the sediment traps gives an idea of what metal contaminants have been travelling down the stream during the period of time 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, there will be many decommissioning and demolition projects as well as construction projects in the upper EFPC watershed. The Trapped Sediment Project is recommended to be continued and funded as necessary to provide ample information about EFPC during these years ahead. In addition, the Trapped Sediment Project should continue to provide information about what other possible contaminants are in the suspended sediments being released from the EMWMF outfall on NT-5.

6.2.10 References

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

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

This Page Intentionally Left Blank

7.0 GROUNDWATER MONITORING

7.1 OFFSITE RESIDENTIAL WELL MONITORING

7.1.1 Background

The Oak Ridge Reservation (ORR) is located in Roane and Anderson counties, Tennessee. The ORR played a major role in the atomic bomb development during World War II. Oak Ridge went from being a rural remote farming area to a “secret city” that developed weapons-grade materials for the Manhattan Project (Facts sheet: Oak Ridge Reservation) The three main sites of the ORR are the Oak Ridge National Laboratory (ORNL), formerly X-10, Y-12 National Security Plant, and East Tennessee Technology Park (ETTP), formerly the K-25 Gaseous Diffusion Plant. ORNL (X-10) was the site that developed the processes used to separate plutonium from irradiated fuel for use in the atomic bomb (Facts: Oak Ridge Reservation, 2018). Currently, ORNL is a national laboratory conducting research on applied energy technologies and global security. Fuel reprocessing, isotope production, waste management, radioisotopes, reactor developments, and other laboratory operations produced waste streams that led to releases of radionuclides and hazardous chemicals from ORNL. The Y-12 National Security Complex’s historical mission was to separate uranium-235 from other uranium forms by the electromagnetic process. Y-12 served as a weapons component manufacturing facility until the early 1990s, and now serves as part of the U.S. Department of Energy (DOE) weapons dismantlement complex (Oak Ridge Site, no date). ETTP (K-25) was the home of the uranium-235 enrichment for atomic weapons during both World War II and the Cold War. The facilities at ETTP historically released uranium isotopes, technetium-99, and other fission and activation products due to the processing of recycled uranium from spent nuclear fuel. The ORR is responsible for discharging large amounts of mercury into the environment, primarily from the Y-12 West End Mercury Area (WEMA) (TDEC, 2015; DOE, 2017).

Portions of the ORR were used for decades as a regional burial ground for hazardous and radioactive wastes from other DOE facilities (TDEC, 2018). The disposed waste was contaminated with inorganic and organic chemicals including volatile and semi-volatile organic compounds, beryllium, mercury and other heavy metals, PCBs, laboratory and cleaning chemicals, biological waste, and inorganic salts. Transuranic (TRU) wastes were a part of this disposal. The waste was typically alkaline and nitrate rich (TDEC, 2018). DOE disposed of radioactive waste in landfills, shallow burial sites, unlined trenches, waste pits, auger holes, and hydrofracture facilities. All of these waste disposal sites and methods were best practices at time of implementation; however, now pose potential environmental concerns.

7.1.2 Problem Statements

Groundwater beneath the ORR was contaminated due to past DOE mission activities (TDEC, 2018; Haase, et al., 1987). Figure 7.1.1 shows the reservation boundary and the three primary DOE facilities: ETTP, Y-12, and ORNL. These facilities have released some contamination. The sources of contamination and the extent of the groundwater contamination have not been well defined and require further investigation.

Continued sampling and analysis offsite is recommended due to the Clinch River forming one of the boundaries of the ORR and the hydrogeological nature of the area. Historical waste injections and burial grounds extend into the bedrock below the river level (Haase, et al., 1987). The DOE and the Tennessee Department of Environment and Conservation (TDEC) no longer assume that the Clinch River is a groundwater-flow barrier. Contaminated groundwater is capable of moving beneath the Clinch River, offsite the ORR, and may pose threats to residents using the groundwater as a drinking water source.

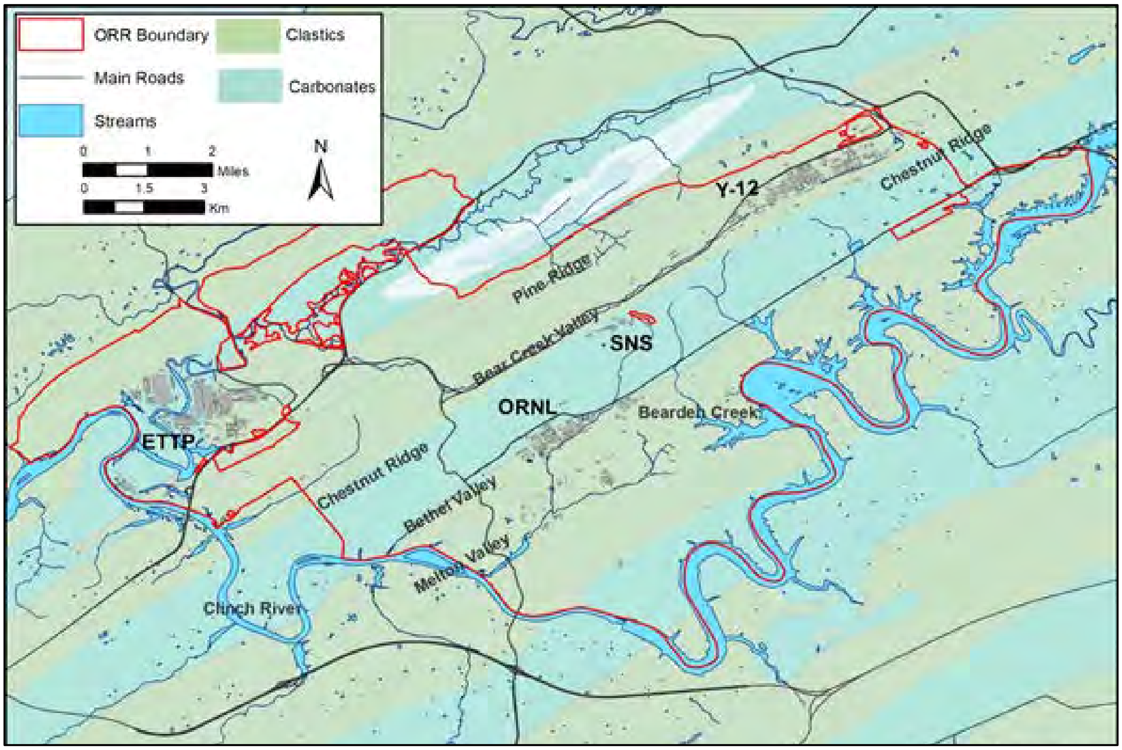


Figure 7.1.1: Primary DOE facilities, ORR boundary, and basic lithologies with the Valley and Ridge locations.

7.1.3 Goals

The Offsite Residential Well Monitoring Project planned to collect groundwater samples downgradient of the ORR (south and southwest) to detect and evaluate potential contaminant migration and to assist in the clean-up decision-making process under the Federal Facility Agreement (FFA) by providing data and information and to fulfill TDEC's mission of protecting human health and the environment.

The overarching goals of this project were to identify the possible sources of any contaminants detected in groundwater samples south and southwest of the ORR, and to better understand the nature and extent of ORR-related contamination and associated contaminant transport pathways.

The main objectives were:

- Collect groundwater samples from approximately 25 residential wells downgradient of the ORR
- Evaluate received data for potential constituents of concern (COCs) and water chemistry
- Compare laboratory results to historical data from offsite, onsite, and background locations
- Use graphing and mapping technology to determine possible trends

The data were to be evaluated by its comparison to other offsite and background samples, regulatory comparison values, ORR known contaminants, and naturally occurring sources. Some of the analytes are naturally occurring, while some are contamination signatures. Some chemicals (e.g., metals and some radionuclides) exist in nature, but their concentrations may be increased to levels that pose risks to human health by release of contaminants.

7.1.4 Scope

The offsite wells identified for sampling were downgradient from the ORR, along geologic strike. Groundwater and its associated contamination flow preferentially along strike—i.e., parallel to the ridges and valleys—throughout the ORR and the surrounding Valley and Ridge province (Hatcher et al. 1992; DOE, 2014).

The groundwater samples selected for this project were limited to the areas offsite the ORR and in the same lithology as the main DOE facilities on the ORR. The main lithologies or rock types are carbonates and clastics (Hatcher et al. 1992). Both of these lithologies transmit groundwater, primarily through natural fractures and conduits. The two maps in Figure 7.1.2 show the study area and the sampled wells.

Twenty-five samples were planned; with quality assurance and quality control (QA/QC) samples to be collected from at least 10% of the sample locations.

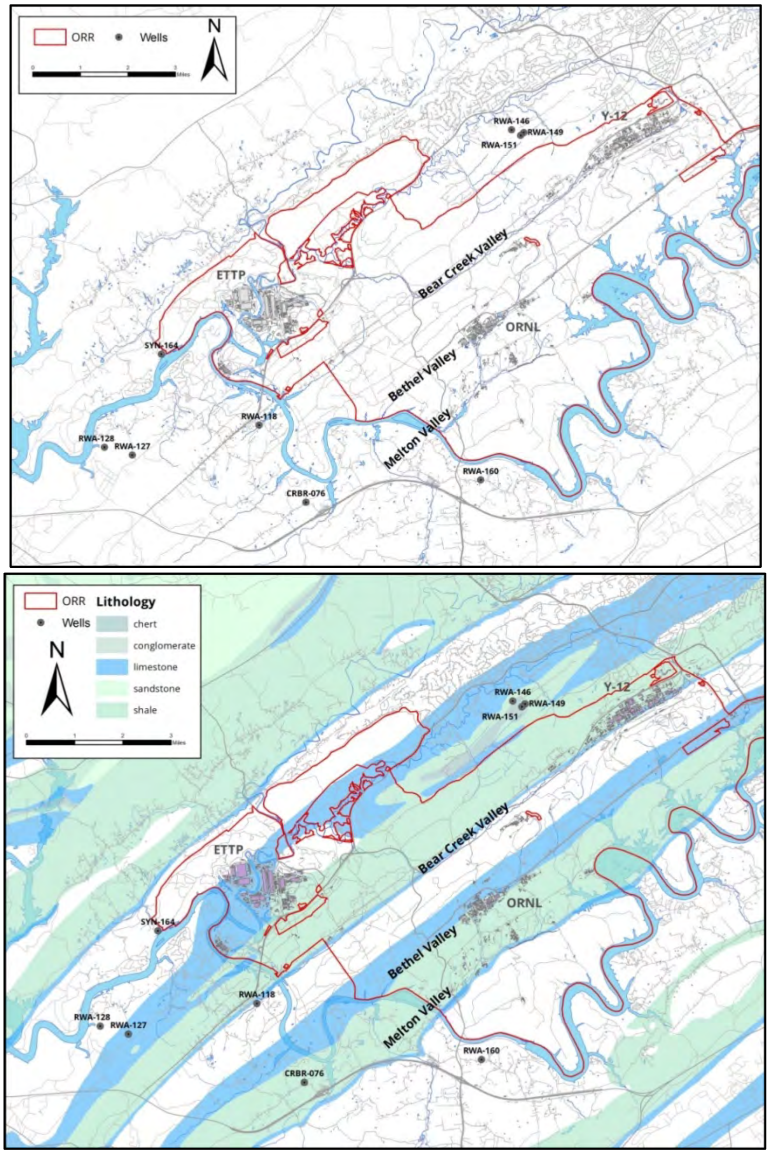


Figure 7.1.2: Downgradient well sample locations shown on a location map (above) and sample locations shown on a basic geologic map (below).

7.1.5 Methods, Materials, Metrics

Groundwater samples were collected from nine locations between July 2018 and June 2019. One QA/QC sample was also collected. QA/QC sampling includes a duplicate sample taken at the same time as the sample. A total of ten sample suites were collected.

Sampling Techniques

A consistently implemented groundwater sampling procedure helped ensure data comparability between sampling events and between sites. The sample for QA/QC was used to ensure the security and quality of the samples during collection and shipping to the laboratory for analysis.

Table 7.1.1: Analyte List

Groundwater Analyte List for Offsite Samples		
VOCs		
EPA 8260 B list for low level detection[1]		
METALS		
aluminum	copper	selenium
antimony	iron	silver
arsenic	lithium	sodium
barium	lead	strontium
beryllium	magnesium	thallium
boron	manganese	uranium
cadmium	mercury	vanadium
calcium	nickel	zinc
chromium	potassium	total hardness, as calcium carbonate
INORGANICS		
calcium carbonate alkalinity	total dissolved solids	nitrate and nitrite
chloride	sulfate	ammonia
fluoride		
RADIONUCLIDES		
gross alpha	tritium	radium-228
gross beta	gamma radionuclides[2]	isotopic uranium
strontium-89	technetium-99	transuranic radionuclides
strontium-90	radium-226	

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

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

All of the well locations selected for offsite sampling were residential wells, i.e., wells with in-place plumbing. The offsite sample locations are shown in Figure 7.1.2. Offsite sampling conducted during this project time frame was co-sampled with DOE except for RWA-128. The samples were analyzed for the analyte suite in Table 7.1.1.

Water quality indicator parameters that were measured are: temperature (°C), electrical conductivity (µS/cm), pH (SU), oxidation reduction potential (mV), dissolved oxygen (mg/L), and turbidity (NTU). The parameters were collected using an YSI Professional Plus Multiparameter Instrument during purging. Field parameters are indicators used to determine when the formation water is being removed. Stabilization of parameters was required before samples could be collected for laboratory analysis. Field water quality parameter measurements were made at five-minute intervals. Field parameter stabilization is defined as four consecutive readings within the criteria presented in Table 7.1.2.

Table 7.1.2: Water Quality Indicator Parameters

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

[1] Acceptable variability over four consecutive readings.

°C- Degrees Celsius

µS/cm- MicroSiemens per centimeter

mV- Millivolt

NTU- Nephelometric Turbidity Unit

SU- Standard Units

ORP- Oxidation Reduction Potential

Eh- Reduction Potential

Sample Collection

Samples were collected following the stabilization of parameters, from a valve or cold-water tap located as close to the well as possible. Where possible, samples were collected from ports located prior to any storage, pressure tanks, or physical and chemical treatment system that might have been present in the residential water system. This prevents impacts from system components such as water softener salts that may change the formation water chemistry. All hoses or other attachments, if connected to the well sampling port at the residential well locations, were removed prior to sampling.

Samples were collected and placed directly into the appropriate sample containers. The preferred sampling order is volatile organic compounds (VOCs), metals, inorganics, stable isotopes, and then radiochemical analytes. All samples were stored on ice and out of direct sunlight prior to Fed-Ex delivery at the TDH Laboratory. The groundwater samples were sent to the TDH Laboratory in Nashville within the specified holding times for analyses of the analytes given in Table 7.1.1.

The data was compared to standards in National Primary Drinking Water Regulations (NPDWR) (EPA, 2009) and National Secondary Drinking Water Regulations (NSDWR) (EPA, no date). When neither of these are available for a particular contaminant, the data will be compared to other EPA standards including: Regional Screening Levels (RSLs) (EPA, 2017), Lifetime Health Advisory Values (HA) (EPA, 2012), or Preliminary Remediation Goals (PRG) (EPA, no date). These standards align with Tennessee public water utility standards. A summary package of these results was prepared and provided to the well owners to help explain the sampling results. Residents, whose groundwater contaminants exceeded drinking water criteria or who would want health information, were referred to the TDH for a health consultation.

7.1.6 Deviations from the Plan

There were many deviations from the project plan for FY 2019:

- Instead of collecting samples from twenty-five wells, only nine wells were sampled with one duplicate (ten sample suites).
- The data for the FY could not be compared to background data for the FY19 due to the discontinuation of the Background Groundwater Project.
- Sampling for stable isotopes was cut due to budget constraints.
- Mercury sampling was changed to low level mercury in February due to potential mercury concerns which slightly increased the sample cost.
- The data were not compared to onsite samples due to time constraints, and resource reallocation.

Due to the limited budget, wells chosen for sampling were focused to a couple of wells offsite each of the three main ORR sites. Two wells were chosen due to their inclusion in DOE's *Remedial Site Evaluation Phase 2 Offsite Detection Monitoring Work Plan (DOE/OR/01-2788&D2)*. The three Tuskegee wells were included to jump start the Bear Creek Valley groundwater investigations as part of a Bear Creek Valley Exit Pathway Assessment Project. The remaining wells in the Tuskegee neighborhood are planned to be sampled in FY 2020.

The trends analysis with maps and graphs will be accomplished next FY. This has become a separate groundwater project, which will look at all historical TDEC DoR-OR groundwater data. For this report, the 2019 FY data were still compared to the most recent historical TDEC DoR-OR data for each well.

7.1.7 Results from Analysis

Radionuclides are naturally present in groundwater due to interactions with the atmosphere, soil, or bedrock. One of the many challenges of the Offsite Residential Well Monitoring Project is definitively stating that the radionuclides present in the reported results are man-made, natural, or a mix of both.

The FY19 samples were compared to the most recent historical TDEC DoR-OR offsite data. However, not all of the data was received from the TDH Laboratory in time for its inclusion in this report. That data will be provided to the well owners as soon as it is received from the laboratory and will be reported in the FY20 EMR.

Regulatory Comparison Values

The results of the analyses from the private wells sampled were compared to EPA standards, but are not enforceable on private wells. The EPA has established the NPDWR to maintain good quality of water in public water supplies. These criteria include Maximum Contaminant Levels (MCLs) and Secondary Maximum Contaminant Levels (SMCLs).

- MCLs are standards used to protect people by limiting levels of harmful contaminants in public drinking water supplies. MCLs are legally enforceable rules for public water utilities.

- SMCLs are associated with public acceptance of water. These constituents include characteristics such as taste, odor, and color, as well as the staining of teeth, clothing, or fixtures. SMCLs are only guidelines for public water utilities.

When EPA MCLs and SMCLs are not available, other EPA criteria for comparison values are used. These EPA guidelines include HAs, RSLs, and PRGs. These levels are not enforceable for public water utilities, but they can be useful when putting results in context for comparison.

- HA’s identify the concentration levels of a constituent of concern in drinking water at which or below which adverse health effects are not anticipated to occur over a lifetime of exposure. HA’s are non-regulatory and reflect EPAs assessment of the best available peer-reviewed science.

- RSLs are a screening tool that the EPA sets for CERCLA sites. They are calculated by combining exposure assumptions with chemical-specific toxicity in humans. If an RSL is met or exceeded, then further investigation or cleanup may be necessary because of a concern about adverse health effects.
- PRGs are calculated during the risk-assessment stage of a CERCLA regulated project to identify levels of a constituent which a cleanup project aims to reach. PRGs are concentration levels that correspond to a specific cancer risk level, (i.e. 10-4 or 10-6). PRGs may be modified throughout a cleanup project as more site-specific information becomes available. PRGs are concentration levels that correspond to a specific cancer risk level of 10-6. If a radionuclide exceeds a target risk (TR) of 10-6, then the risk of a drinker contracting cancer is one in one million (1 in 1,000,000). For more information on EPA's drinking water standards, visit https://www.epa.gov/dwstandardsregulations or https://www.epa.gov/risk.

Field Parameters

Temperature, electrical conductivity, pH, oxidation-reduction potential (ORP), dissolved oxygen, and turbidity were measured during the initial purging of the wells using an YSI Professional Plus Multiparameter Instrument. Table 7.1.3 shows the final stable readings taken immediately before collecting samples at each sampling event. The only field parameter with a comparison criteria is pH. All of the wells are within the EPA SMCL criteria for pH concentrations.

Table 7.1.3: Field Parameters

Field Parameters for Offsite Wells							
Well Name	**Sampling Date**	**Temperature (°C)**	**Electrical Conductivity (µS/cm)**	**pH (SU)**	**Oxidation Reduction Potential (mV)**	**Dissolved Oxygen (mg/L)**	**Turbidity (NTU)**
EPA SMCL		**NA**	**NA**	**6.5-8.5**	**NA**	**NA**	
RWA-118	10/3/2018	15.1	419.9	7.26	90.6	1.57	1.29
RWA-128	10/10/2018	16.2	369.5	7.43	86.5	3.11	0.19
RWA-160	10/18/2018	16.9	542.4	7.24	91.9	4.38	1.16
CRBR-076	11/5/2018	15.8	366.6	7.77	79.5	2.01	1.26
RWA-127	2/27/2019	15.4	331.6	7.38	134.3	5.61	0.65
SYN-164	3/11/2019	14.6	186.2	7.50	150.9	8.8	0.22
RWA-149	5/14/2019	15.8	457.2	6.80	132.5	4.65	1.88
RWA-146& DUP	6/4/2019	18.1	1110	6.76	-29.9	2.04	0.24
RWA-151	6/6/2019	16.6	529.4	7.11	112.7	6.06	0.18

🟪 **-Outside EPA SMCL guidance**
°C - Degrees Celsius
µS/cm - MicroSiemens per centimeter
mV - Millivolt
NTU - Nephelometric Turbidity Unit
SU - Standard Units
DUP - Duplicate

Volatile Organic Compounds

All offsite residential wells were analyzed for the EPA 8260 B list of Volatile Organic Compounds (VOCs) (https://www.epa.gov/sites/production/files/2015-12/documents/8260b.pdf). No wells had VOCs detected in them.

Metals

Mercury analysis was switched to low level mercury analysis in February. RWA-146 and RWA-146DUP had the most exceedances. They both exceeded the iron SMCL, lithium RSL, and sodium HA. Their numbers have gone up from the previous sample. There were two wells (RWA-118 and RWA-149) with concentrations above the EPA SMCL criteria for aluminum. There were no other criteria exceedances for FY19. RWA-118 was also above the EPA SMCL for aluminum in the previous sample (11/30/2017), but its value has gone down in the most recent sample. No laboratory data has been received yet for RWA-151. Refer to Table 7.1.4.

The current FY data results were close to the historical data results for all of the wells. RWA-146 was above the iron EPA SMCL criteria and the EPA HA criteria for sodium in the historical data. In the current FY data, RWA-146 and RWA-146DUP exceeded the comparison criteria for iron and sodium as well as lithium.

Inorganics

There were two comparison criteria exceedances for the current FY data: RWA-146 and RWA-146DUP exceeded the EPA SMCL for sulfate and total dissolved solids (Refer to Table 7.1.5). RWA-146 had detections above the EPA SMCL for sulfate and total dissolved solids in the most recent historical data as well. However, the current FY data detected higher total dissolved solids than the previous sampling event.

Radiochemical Analytes

Some radionuclides are naturally present in groundwater due to its interactions with the atmosphere, hydrosphere, soil, or bedrock. Therefore, one of the many challenges of the Offsite Residential Well Monitoring Project is an objective evaluation of the data and the differentiation between man-made and naturally occurring radionuclides and naturally occurring nuclides that were and are used in the DOE-ORR processes.

There were no detections above the EPA MCL, EPA SMCL, and EPA HA criteria, Table 7.1.6.

Lead-214 was detected above the EPA PRG at two wells, RWA-127 and SYN-164. Radium-226 was detected above the EPA PRG at RWA-128, CRBR-076, RWA-149, and RWA-160. Radium-228 was detected above the EPA PRG at three wells, RWA-118, RWA-128, and SYN-164. Uranium-233/234 was detected above the EPA PRG at three wells, RWA-128, RWA-160, and RWA-127. Uranium-238 was detected above the EPA PRG at two wells, RWA-128 and RWA-160.

No data was received for RWA-151, RWA-146, and RWA-146DUP for inclusion in this report.

Lead-214 increased from the most recent historical data to the current sample for well RWA-127. Radium-228 increased in RWA-118 and decreased in RWA-160. Uranium-233/234 increased in RWA-160, RWA-128, and RWA-127. Uranium-238 increased in RWA-128 and RWA-160.

Table 7.1.4: Metals

Offsite Metals Results																								
						Current Fiscal Year										Most Recent Historical Data								
Analyte	Units	EPA national primary drinking water standards MCL	EPA drinking water standards SMCL (March 2018)	EPA RSLs PRG (tapwater) (Nov 2017)	EPA Health Advisory (lifetime) from the "2018 edition of drinking water standards and health advisory tables"	RWA-118	RWA-128	RWA-160	CRBR-076	RWA-127	SYN-164	RWA-149	RWA-146	RWA-146 DUP	RWA-151	RWA-118	RWA-128	RWA-160	CRBR-076	RWA-127	SYN-164	RWA-149	RWA-151	RWA-146
Date						10/3/2018	10/10/2018	10/18/2018	11/5/2018	2/27/2019	3/11/2019	5/14/2019	6/4/2019	6/4/2019	6/6/2019	11/30/2017	11/9/2017	7/18/2017		3/11/2015		3/15/2018	11/7/2017	11/6/2017
aluminum	µg/L		50-200			55.0	U	U	U	U	U	58.4	U	U		126	U	U		U		11.0	4.73J	U
antimony	µg/L	6			6	U	U	U	U	U	U	U	U			U	U	1.1		U		U	U	U
arsenic	µg/L	10		0.052		U	U	U	U	U	U	U	U	U		U	U	U		U		U	U	U
barium	µg/L	2,000		3,800		102	102	16.2	154	36.2	35.3	28.5	49.1	49.2		101	91.9	17		37		31.4	22.8	50.3
beryllium	µg/L	4		4		U	U	U	U	U	U	U	U	U		U	U	U		U		U	U	U
boron	µg/L			4,000	6000	21.3	17.2	3.31J	276	8.32J	U	108	313	310		11.9	8.30J	U		U		55.5	71.7	285
cadmium	µg/L	5		9.2	5	U	U	1.90	U	U	U	U	U	U		U	U	1.7		U		U	U	U
calcium	mg/L					54.2	46.5	54.3	19.2	41.5	21.1	54.7	102.0	103		51.7	48.1	47		39		69.9	63.8	105
chromium	µg/L	100				U	U	U	U	U	U	U	U	U		U	0.812J	0.84J		U		U	U	U
copper	µg/L	1,300	1000			2.43	4.13	8.40	0.940J	4.81	1.38	2.98	144	4.52		1.72	3.24	0.99J		2.7		3.82	64.6	0.612J
iron	µg/L		300	14000		58.5	U	14.8	16.3	U	8.90J	138	1030	1110		155	5.60J	47		U		57.7	47.4	768
lead	µg/L	15		15		0.268J	0.474J	2.48	U	0.308J	0.363J	0.467J	0.598J	U		0.692J	0.459J	4.0		U		0.956J	2.32	U
lithium	µg/L			40		3.54	18.7	0.353J	34.9	4.43	U	3.65	43.8	42.4		3.50	11.0	0.56J		5.6		13.4	17.4	39.6
magnesium	mg/L					23.8	21.6	32.2	14.1	21.3	12.7	29.9	92.2	90.4		22.1	21.2	29		20		32.1	35.1	94.8
manganese	µg/L		50	non diet 430	300	2.92	U	1.48	3.43	U	U	10.3	26.6	25.2		20.2	U	7.9		U		5.53	18.5	16.7
mercury	µg/L	2		0.63	2	U	U	U	U	U	U	U	U	U		U	U	U		U		U	U	U
nickel	µg/L				100	0.595J	1.33	5.54	U	0.565J	U	1.72	1.91	2.1		2.12	2.24	4.2		1.3		2.48	3.37	2.65
potassium	mg/L					1.12	2.13	1.24	2.33	1.27	1.12	1.11	5.89	5.91		1.10	1.86	1.3		1.3		1.44	1.75	5.53
selenium	µg/L	50		100	50	U	U	U	U	U	U	3.25J	U	U		U	U	U		U		3.82	3.07J	U
silver	µg/L		100	94	100	U	U	U	U	U	U	U	U	U		U	U	U		U		U	U	U
sodium	mg/L				20	4.09	0.81	5.80	45.1	0.663	0.554	3	33.5	33.7		4.13	0.731	5.8		0.73		5.61	8.15	29.6
strontium	µg/L			stable 12,000	4,000	194	413	26.0	583	341	11.8	127	2050	1830		185	291	23		360		264	576	1,800
thallium	µg/L	2				U	U	U	U	U	0.403J	U	U	u		U	U	U		U		U	U	U
uranium	µg/L	30				0.416J	4.11	10.6	U	1.66	0.271J	0.391J	0.431J	0.399j		0.420J	3.19	6.3		1.8		0.413J	0.374J	U
vanadium	µg/L			86		U	U	U	U	U	U	U	U	u		U	U	U		U		U	U	U
zinc	µg/L		5,000	6,000	2,000	31.8	10.7	644	7.23	8.47	U	8.80	3.02J	u		16.0	10.0	1,000		9.8		10.6	42.8	3.04J
total hardness	mg/L					233.0	205	268	106	191	105	260	636	629		220	207	240		180		307	304	653

🟧	- EPA MCL Exceedance	DUP	-Duplicate
🟨	- EPA SMCL Exceedance	J	- Estimated Value
🟫	- EPA RSL Exceedance	U	- Undetected
🟪	- EPA HA Exceedance	NR	-Not Reported
🟦	- Comparison Values used	µg/L	- micrograms per liter
⬜	-Data not yet Received	mg/L	-milligrams per liter
🟥	-No Previous DoR OR Data		

Table 7.1.5: Inorganics

Offsite Inorganic Results (mg/L)																							
					Current Fiscal Year										Most Recent Historical Data								
Analyte	EPA national primary drinking water standards MCL	EPA drinking water standards SMCL (March 2018)	EPA RSLs PRG (tapwater) (Nov 2017)	EPA Health Advisory (lifetime) from the "2018 edition of drinking water standards and health advisory tables"	RWA-118	RWA-128	RWA-160	CRBR-076	RWA-127	SYN-164	RWA-149	RWA-146	RWA-146 DUP	RWA-151	RWA-118	RWA-128	RWA-160	CRBR-076	RWA-127	SYN-164	RWA-149	RWA-151	RWA-146
Date					10/3/2018	10/10/2018	10/18/2018	11/5/2018	2/27/2019	3/11/2019	5/14/2019	6/4/2019	6/4/2019	6/6/2019	11/30/2017	11/9/2017	7/18/2017		3/11/2015		3/15/2018	11/7/2017	11/6/2017
ammonia					U	U	U	0.024J	0.0238J	U	U	0.224	0.244	0.419	0.0461J	U	0.023J		U		NR	1.16	0.245
chloride		250			6.27	2.04J	20	1.85J	2.09J	1.64J	2.20J	3.16	3.34	2.23J	6.68	1.96J	17		2.1J		2.30J	1.88J	2.99
fluoride	4	2			0.180	0.720	U	0.178	0.209	0.134	0.141	0.120	0.120	NR	0.186	0.490	0.035J		0.22		0.201	0.160	0.135
nitrate and nitrite	10			10	0.242	0.125	0.289	0.0202J	0.514	0.720	0.331	U	U	0.0956J	0.238	0.203	0.74		0.50		0.719	0.0763J	U
sulfate		250			12.5	9.29	21.2	13.3	4.95	2.42J	18.6	252	273	36.2	13.5	6.66	13		5.2		46.6	47.5	281
total dissolved solids		500			235	204	291	215	181	111	259	741	731	266	235	209	240		180		312	318	501
total alkalinity					212	126	250	193	186	104	228	357	366	246	208	193	210		170		244	279	399

🟧	- EPA MCL Exceedance	DUP	-Duplicate
🟨	- EPA SMCL Exceedance	J	- Estimated Value
🟫	- EPA RSL Exceedance	U	- Undetected
🟪	- EPA HA Exceedance	mg/L	-milligrams per liter
🟦	- Comparison Values used	NR	-Not Reported
⬜	-Data not yet Received		
🟥	-No Previous DoR OR Data		

Table 7.1.6: Radiochemical Analytes

			Offsite Radiochemical Results (pCi/L)																			
	Well Name	Date	bismuth-214	lead-214	Gross Alpha	Gross Beta	radium-226	radium-228	strontium-89	strontium-90	technetium-99	tritium	americium-241	curium-242	curium-243/244	curium-245/246	neptunium-237	plutonium-238	plutonium-239/240	uranium-233/234	uranium-235/236	uranium-238
	EPA National Primary Drinking Water Standards 2018 MCLs	NA			15	50																
	EPA PRG tapwater TR=1E-6 Nov 2014	NA	270	150			0.14	0.05					0.5	1.4	Cm-243=0.55; Cm-244=0.62	Cm-245=0.50; Cm-244=0.51	0.84	0.4	Pu-239=0.39; Pu-240=0.39	U-233=0.73; U-234=0.74	U-235=0.75; U-236=0.78	0.82
	NBS Handbook 69 (correlation of pCi/L to 4mrem/year (TR=1E-4))	NA							20	8	900	20,000										
Current Fiscal Year	RWA-118	10/3/2018	68	62	0.49 BDL	0.6 BDL	0.19 BDL	0.05 BDL	-0.618 BDL	0.198 BDL	0.05 BDL	159	0.01 BDL	-0.011 BDL	-0.048 BDL	0.057 BDL	0.028 BDL	0.061 BDL	0.033 BDL	0.525	0.074	0.241
	RWA-128	10/10/2018	56	44.4	5.13	4.7	2.08	0.2 BDL	-1.04 BDL	0.22 BDL	0.48 BDL	75 BDL	0.023 BDL	0.02 BDL	0.024 BDL	0.016 BDL	0.008 BDL	0.126	0.091	2.66	0.096	1.21
	RWA-160	10/18/2018	10.9	NDA	8.82	6.2	1.44	-0.22 BDL	0.52 BDL	-0.23 BDL	0.29 BDL	-44 BDL	0.004 BDL	0.009 BDL	0.007 BDL	0.007 BDL	0.019 BDL	0.124	0.068	2.57	0.198	3.2
	CRBR-076	11/5/2018	99	64	1.04 BDL	2.3 BDL	0.29 BDL	-0.13 BDL	-0.95 BDL	0.41 BDL	0.38 BDL	-2 BDL	-0.012 BDL	0.003 BDL	-0.002 BDL	-0.018 BDL	0.003 BDL	0.163	0.065	0.123	0.009 BDL	0.02 BDL
	RWA-127	2/27/2019	210	167	1.64 BDL	2.8 BDL	-0.09 BDL	-0.03 BDL	0.02 BDL	0.08 BDL	0.15 BDL	68 BDL	0.011 BDL	0.006 BDL	-0.006 BDL	0.014 BDL	0.015 BDL	0.133	0.031	0.83	0.05	0.54
	SYN-164	3/11/2019	224.0	212	0.16 BDL	2.2 BDL	-0.31 BDL	0.43 BDL	-0.52 BDL	0.15 BDL	0.78	24 BDL	0.044 BDL	0.028 BDL	0.031 BDL	0.062 BDL	0.01 BDL	0.026 BDL	0.055	0.238	0.031	0.1
	RWA-149	5/14/2019	74	72	0.59 BDL	2.36 BDL	0.24 BDL	-0.55 BDL	-1.27 BDL	0.218 BDL	0.31 BDL	39 BDL	-0.001 BDL	0 BDL	0.025 BDL	-0.001 BDL	0.024 BDL	0.058 BDL	0.062	0.433	0.07 BDL	0.136
	RWA-151	6/6/2019																				
	RWA-146	6/4/2019																				
	RWA-146 DUP	6/4/2019																				
Most Recent Historical Data	RWA-118	11/30/2017	64	38.4	1.09 BDL	1.6 BDL	0.11 BDL	0.01 BDL	-0.16 BDL	-0.07 BDL	0.33 BDL	75 BDL	0.049 BDL	-0.01 BDL	0.003 BDL	0.017 BDL	0 BDL	0.018 BDL	0.044	0.475	0.073	0.22
	RWA-128	11/9/2017	49	NDA	6.91	3.8 BDL	9.3	5.80	0.79 BDL	-0.6 BDL	-0.06 BDL	27 BDL	0.006 BDL	NDA	-0.027 BDL	0.059 BDL	0.012 BDL	0.053 BDL	0.026 BDL	2.17	0.122	1.17
	RWA-160	7/18/2017	NDA	NDA	5.18	4.8	0.91	0.44	0.428 BDL	0.0958 BDL	0.21 BDL	-30 BDL	0.003 BDL	0.007 BDL	-0.002 BDL	0.048 BDL	0.048	0.021 BDL	0.048	1.4	0.07	1.61
	CRBR-076																					
	RWA-127	3/11/2015	NDA	25.8	1.83	6.8	NR	NR	0.08 BDL	0.13 BDL	-0.29 BDL	-9 BDL	0.0399 BDL	NDA	0.0165 BDL	NDA	0.0158 BDL	0.0145 BDL	0.0202	0.966	0.0642	0.785
	SYN-164																					
	RWA-149	3/15/2018	67	56.1	2.41	1.4 BDL	0.2 BDL	0.78	-0.5 BDL	0.48 BDL	0.22 BDL	3 BDL	0.003 BDL	-0.001 BDL	0.022 BDL	0.633	0.008 BDL	0.046 BDL	0.046 BDL	0.589	0.03 BDL	0.176
	RWA-151	11/7/2017	NR	13	0.8 BDL	0.6 BDL	0.95	-0.08 BDL	-0.18 BDL	-0.19 BDL	-0.2 BDL	54 BDL	0.023 BDL	-0.009 BDL	0.035 BDL	0.033 BDL	0.015 BDL	0.09	0.054	0.418	0.027 BDL	0.184
	RWA-146	11/6/2017	47	44.9	3.78	7.2	1.06	0.35 BDL	-0.75 BDL	0.21 BDL	-0.26 BDL	-46 BDL	-0.013 BDL	0.016 BDL	0.013 BDL	-0.01 BDL	0.019 BDL	0.062 BDL	0.025 BDL	0.292	0.063	0.178

🟧	- EPA MCL Exceedance	DUP	-Duplicate
🟨	- EPA SMCL Exceedance	TR	-Target Risk
🟫	- EPA PRG Exceedance	pCi/L	- picoCuries per liter
🟪	- EPA HA Exceedance	BDL	-Below Detection Limit
⬜	-Data not yet Received	NDA	- Not Detected Analyte
🟥	-No Previous DoR OR Data	NR	-Not Reported

7.1.8 Conclusions

The results from this limited data set represent a snapshot in time and not from continuous monitoring. Groundwater quality in the fractured rocks and bedrock aquifers can change rapidly. Hydrologic characteristics can fluctuate between geographically close locations, and therefore it is difficult to make predictions on potential contaminant pathways and sources of contamination with one sampling event of data. This report documents mostly low concentrations, low activities, and sporadic detections of contaminants that may be a result of human activity. This limited data set has a small number of detections above health-based criteria. Sporadic detections of transuranic isotopes occur in residential well groundwater. No determination regarding potential sources of the identified constituents has been made at this time.

The contamination of groundwater beneath several areas of the ORR and the potential pathways for contaminant migration beyond the ORR boundary make it imperative to continue the monitoring of offsite residential wells that may be a primary or sole source of drinking water for local residents in Anderson, Loudon, and Roane counties.

7.1.9 Recommendations

Recommendation for future TDEC DoR-OR groundwater projects include:

- Focus limited resources to sampling offsite the ORR one valley at a time; compare the results to onsite data results. The first focus is intended to be Bear Creek Valley.
- Take an in-depth look at the TDEC DoR-OR offsite historical groundwater data in conjunction with DOE offsite data to help guide future groundwater decisions.
- Conduct a data search for each valley and analyze onsite data focusing on the main COCs from each main area (Y-12, ORNL, ETTP, etc.), to evaluate impacts to offsite receptors.

7.1.10 References

Facts: Oak Ridge Reservation. Retrieved February 26 2018, from https://www.tn.gov/environment/program-areas/rem-remediation/rem-oak-ridge-reservation-clean-up/rem-oak-ridge-facts.html

Haase, C.S., Von Damm, K.L., and Stow, S. H., (1987) Closure of the Oak Ridge National Laboratory, Hydrofracture Facility: An Opportunity to Study the Fate of Radioactive Waste Disposal by Subsurface Injection, Proceedings International Symposium on Class V Well Technology, September 22-24, 1987. Washington, D.C., p. 512.

Hatcher Jr., R. D., Lemiszki, P. J., Dreier, R. B., Ketelle, R. H., Lee, R. R., Leitzke, D. A., McMasterm W. M., Foreman, J. L., Lee, S. Y. (1992). Status Report on the Geology of the Oak Ridge Reservation (Rep. No. 3860). Oak Ridge, TN: U.S. Department of Energy (DOE). ORNL/TM-12074

Tennessee Department of Environment and Conservation (TDEC). Groundwater Monitoring Report (2018). Division of Remediation (DoR) – Oak Ridge (OR), TN.

Tennessee Department of Environment and Conservation (TDEC). (2015). Environmental Monitoring Report (2015). Division of Remediation (DoR) - Oak Ridge (OR), TN.

U.S. Department of Energy (DOE). (2017). Removal Action Report for the Mercury Reduction Project at the Y-12 National Security Complex. Oak Ridge, Tennessee. DOE/OR/01-2595&D1/R1

U.S. Department of Energy (DOE). (2014). Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee. DOE/OR/01-2628/V1&D2

U.S. Environmental Protection Agency (EPA). (2017, November). Regional Screening Levels (RSLs)-Generic Tables (November 2017). Retrieved 2018 from https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2017

U.S. Environmental Protection Agency (EPA). (2012). 2012 Edition of the Drinking Water Standards and Health Advisories. EPA 822-S-12-001 Retrieved 2018 from https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf

U.S. Environmental Protection Agency (EPA). (2009, May). National Primary Drinking Water Regulations. Retrieved 2018 from https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulation-table

U.S. Environmental Protection Agency (EPA). Secondary Drinking Water Standards: Guidance for Nuisance Chemicals. Retrieved 2018 from https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals#table

U.S. Environmental Protection Agency (EPA). Waste and Cleanup Risk Assessment. Retrieved 2018 from Preliminary Remediation Goals for Radionuclides (PRG): https://epa-prgs.ornl.gov/radionuclides/prg_guide.html

8.0 RADNET

8.1 RADNET AIR MONITORING

8.1.1 Background

In the past, air emissions from Department of Energy (DOE) activities on the Oak Ridge Reservation (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. As a consequence, the Tennessee Department of Conservation (TDEC) has implemented a number of 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 August of 1996 and provides radiochemical analysis of air samples taken from five air monitoring stations located near potential sources of radiological air emissions on the ORR. RadNet samples are collected by TDEC and analysis is performed at the EPA National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama.

8.1.2 Problem Statements

The three sites on the ORR − ORNL, Y-12 National Security Complex (Y-12), and East Tennessee Technology Park (ETTP) − can potentially release radioactive contaminants into the air from current operations, as well as from the deterioration of contaminated buildings on the sites, and the decontamination and decommissioning (D&D) of these facilities.

8.1.3 Goals

The goals for this project follow:

- Protect the human health and the environment by assuring the public that the State of Tennessee independently evaluates gross beta activity in air on the ORR with the five RadNet air monitoring stations
- Determine that levels of gross beta radioactivity 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 the RadNet station in Knoxville, the project background location
- Complement the Fugitive Air Project by providing gross beta analysis (and other analysis if screening levels are exceeded) as well as provide additional air monitors for greater area coverage of the ORR

8.1.4 Scope

The RadNet Air Monitoring Project uses five high-volume air samplers to monitor air for radiological contamination. Two of the five air samplers are located at Y-12; one is located near each end of the plant. One sampler is located at ETTP, off of Blair Road. Two samplers are located at ORNL; one is located in Bethel Valley and one is located in Melton Valley. An additional air sampler is located and run by the TDEC field office in Knoxville and is only used for background comparison.

The five RadNet air samplers on the ORR are sampled on Mondays and Thursdays except when skipped due to a holiday. Samples are analyzed for gross beta. Gamma analysis is performed on those 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.

8.1.5 Methods, Materials, Metrics

The locations of the five RadNet air samplers are provided in Figure 8.1.1 and described in the scope of this project. EPA's analytical parameters and frequencies are listed in Table 8.1.1.

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 collects the filters from each sampler, twice weekly, following EPA protocol (U.S. EPA, 1988; U.S. EPA, 2006). After collection, the filters are shipped to the EPA's NAREL in Montgomery, Alabama, for analysis. Each year about 500 samples are analyzed through this project.

NAREL performs gross beta analysis on each sample collected. If the gross beta result for a sample exceeds one picocurie per cubic meter (pCi/m^3), gamma spectrometry is performed on the sample. Every four years, a composite of the air filters collected from each monitoring station during the year is analyzed for uranium and plutonium isotopes.

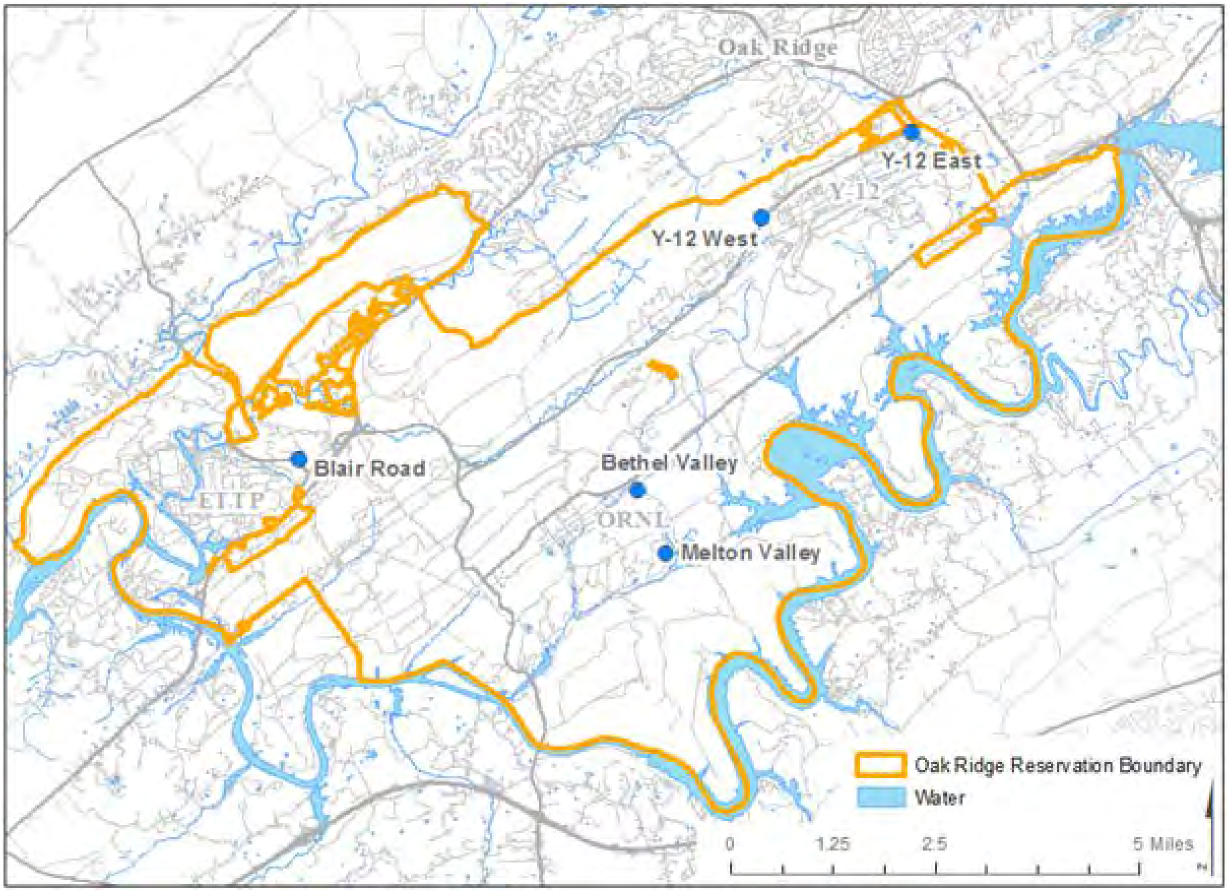


Figure 8.1.1: Locations of RadNet Air Monitoring Stations on the ORR

Table 8.1.1: RadNet Air Monitoring 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)

The results of NAREL's analyses of the nationwide RadNet Air Monitoring are available at NAREL's website in the Envirofacts RadNet searchable database, via either a simple or a customized search.

Gross beta from the RadNet Air Monitoring project was compared to background data from the RadNet air monitor in Knoxville, Tennessee, and to the Clean Air Act (CAA) environmental limit for strontium-90, because it is a pure beta emitter with a conservative limit. Gross beta is a useful screening tool because many gamma emitters also emit beta radiation.

8.1.6 Deviations from the Plan

No deviations from the planned sampling for this project resulted. However, the composites for 2017 for Uranium and Plutonium are still not available, so no results will be published in this EMR. When the results are available, they can be viewed on line and will be published in next year's Environmental Monitoring Report. Also, the data from the last week of June 2019 is not yet available, so no data from that week is in this report.

8.1.7 Results and Analysis

The results of 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 shared in this report are from samples collected from July 2018 through the third week of June 2019, for the RadNet air stations on the ORR. Samples collected from a RadNet station in Knoxville, Tennessee, were used for comparison.

Gross beta from the RadNet Air Monitoring Project on the ORR was compared to background data from the RadNet air monitor in Knoxville, 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 8.1.2, the results for the gross beta analysis of samples collected July 2018 through the third week of June 2019 were similar for each of the five ORR RadNet monitoring stations and were similar to the results reported for the Knoxville RadNet air station (used as background for comparison). However, some exceptions were observed during this time period. The fluctuations observed in the results (depicted in Figure 8.1.2) are largely attributable to natural phenomena (wind and rain) that influence the amount of particulates 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 Knoxville may be attributed to differences in collection schedules. Two results from the ORNL Bethel location are noticeably higher than the other stations for the same time period and the actual results of these are noted on Figure 8.1.2. The February 28, 2019 sample result was 0.0216 pCi/m^3 and the April 25, 2019 result was 0.0826 pCi/m^3. The TDEC ORNL FFA team lead was notified of these elevated readings for follow up and for dissemination of this information through the project team to the DOE and EPA, following the FFA process. The ORR gross beta results for the RadNet Air Monitoring Project from July 2018 through the third week of June 2019 are all well below 1.0 pCi/m^3, which is the screening level requiring further analysis.

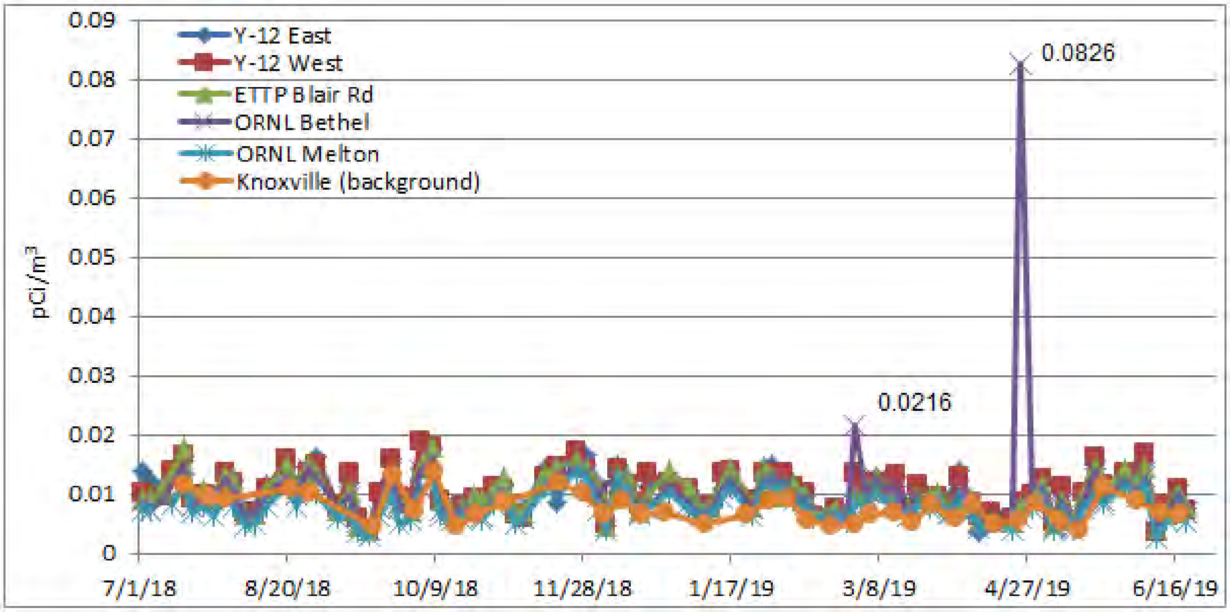


Figure 8.1.2: RadNet Air Monitoring Project Gross Beta Results July 2017 - June 2018

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.

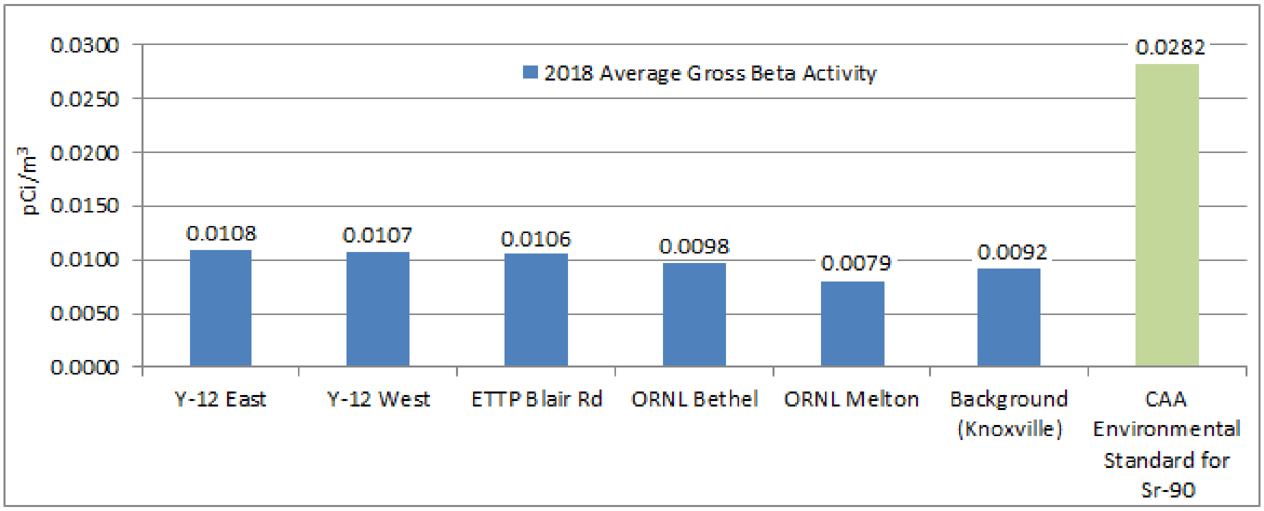


Figure 8.1.3: 2018 RadNet Air Monitoring Program Average Gross Beta Results

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 Knoxville for 2018 (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**.**

Figure 8.1.3 depicts the 2018 average gross beta results for each of the five stations in the ORR RadNet Air program, the average background concentration measured at the Knoxville RadNet location, and the CAA environmental limit for strontium-90.

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.

To evaluate the RadNet data, the RadNet Air Monitoring Project compared 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 8.1.3 was adjusted to include the average gross beta measurement taken at the RadNet station in Knoxville, 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 2018 results at all the RadNet air stations are mostly comparable (results showed that sites responded in a similar pattern during each sampling period), the average gross beta results for the RadNet Air Monitoring Project in 2018 were lower, overall, at the ORNL Bethel Valley and ORNL Melton Valley locations. The station with the highest gross beta average for 2017 on the ORR (the Y-12 East location) was just slightly greater than the gross beta average seen at the Y-12 West and ETTP Blair Road locations. The average results from each of the ORR RadNet monitoring stations fall below the strontium-90 limit (Figure 8.1.3).

None of the gross beta results reported for the RadNet Air Monitoring Project on the ORR from July 2018 through the third week in June 2019 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 0.000366 pCi/ m^3 for the ORR locations from 2010 through 2018. So, while 1 pCi/m^3 is the screening level which triggers further analysis by EPA, concentration levels of about 0.000366 pCi/m^3 can be detected and compared. The actual MDC for each sample is sample specific, but usually isn't far from the mean MDC listed.

The analysis for uranium and plutonium on annual composite samples is performed every four years. The most recent composite results available were from 2013, which were presented in a prior report, with all values for each isotope below the limits established by the CAA. However, the composites for 2017 are not yet available.

8.1.8 Conclusions

The gross beta results for each of the five RadNet air monitoring stations exhibited similar trends and concentration levels for the period July 2018 through the third week of June 2019 with the two noted exceptions at the ORNL Bethel sampling location. All the data during this time period was well below the value which would warrant further analysis and does not indicate that ORR activities pose a significant impact on the environment or public health from ORR emissions for this timeframe.

8.1.9 Recommendations

Continued ORR air monitoring for radiological contamination 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 at all three ORR sites. These activities all have the potential to impact air quality. In the event of a release either on or off of 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.

8.1.10 References

ORISE (1993). Environmental Air Sampling Handout from Applied Health Physics Course. Oak Ridge Institute for Science and Education (ORISE).

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

U.S. Environmental Protection Agency (2006). Andersen™ Flow Manager High Volume (FMHV) Air Particulate Sampler Operation Procedure. RadNet/SOP-3. Monitoring and Analytical Services Branch, National Air and Radiation Environmental Laboratory. Montgomery, Alabama.

U.S. Environmental Protection Agency (2010). Clean Air Act. Code of Federal Regulations. Title 40: Protection of Environment. Part 61: National Emission Standards for Hazardous Air Pollutants. Appendix E, Table 2: Concentration Levels For Environmental Compliance.

U.S. Environmental Protection Agency (2010). Clean Air Act. Code of Federal Regulations. Title 40: Protection of Environment. Part 61: National Emission Standards for Hazardous Air Pollutants. Subpart H: National Emissions Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities.

U.S. Environmental Protection Agency (2019). NAREL RadNet Data links.
Envirofacts RadNet Searchable Database:
search http://iaspub.epa.gov/enviro/erams_query_v2.simple_query
customized search https://www.epa.gov/enviro/radnet-customized-search

8.2 RADNET PRECIPITATION MONITORING

8.2.1 Background

Nationwide, the RadNet Precipitation Monitoring Project measures radioactive contaminants that are carried to the earth's surface by precipitation. On the Oak Ridge Reservation (ORR), the RadNet Precipitation Monitoring Project provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations. Samples are collected by the Tennessee Department of Environment and Conservation (TDEC) and analysis is performed at EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama. While there are no standards that apply directly to contaminants in precipitation, the data provides an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by the TDEC or Department of Energy (DOE) air monitors.

The Environmental Protection Agency (EPA) has provided three precipitation monitors which are co-located with RadNet air stations at each of the three ORR sites. The first precipitation monitor is located at Oak Ridge National Laboratory (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 is located off Blair Road to monitor contaminants from demolition activities at East Tennessee Technology Park (ETTP). The third station is located at the east end of the Y-12 National Security Complex (Y-12). 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.

8.2.2 Problem Statements

The three sites on the ORR: ORNL, Y-12, and ETTP, have the potential to release radioactive contaminants into the air from previous and current operations as well as from the deterioration of contaminated buildings and the decontamination and decommissioning of these facilities.

This project measures radioactive contaminants 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.

8.2.3 Goals

This project compares the RadNet precipitation monitoring samples to the 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 be used to:

- Identify anomalies in gamma concentrations in precipitation on the ORR
- Assess the significance of precipitation in contaminant pathways
- Evaluate contamination control measures during D&D or remediation activities on the ORR
- Compare precipitation concentrations from the ORR with other locations in the nationwide EPA RadNet Program
- Determine levels of local contamination in the event of a nuclear incident

8.2.4 Scope

Three precipitation samplers are used to monitor the precipitation for radiological contamination. Each sampler is co-located at RadNet air stations at each of the three ORR sites. One sampler is located at the east end of the Y-12 plant. One unit is located at ETTP, off of Blair Road. The third sampler is located at ORNL in Melton Valley. These locations are shown in Figure 8.2.1. The three RadNet Air samplers on the ORR are sampled Mondays and Thursdays, except when skipped due to a holiday. The samples are composited monthly at the EPA laboratory and analyzed for gamma radionuclides. Additional analysis on individual samples would likely be run in the event of elevated findings or for a nuclear release.

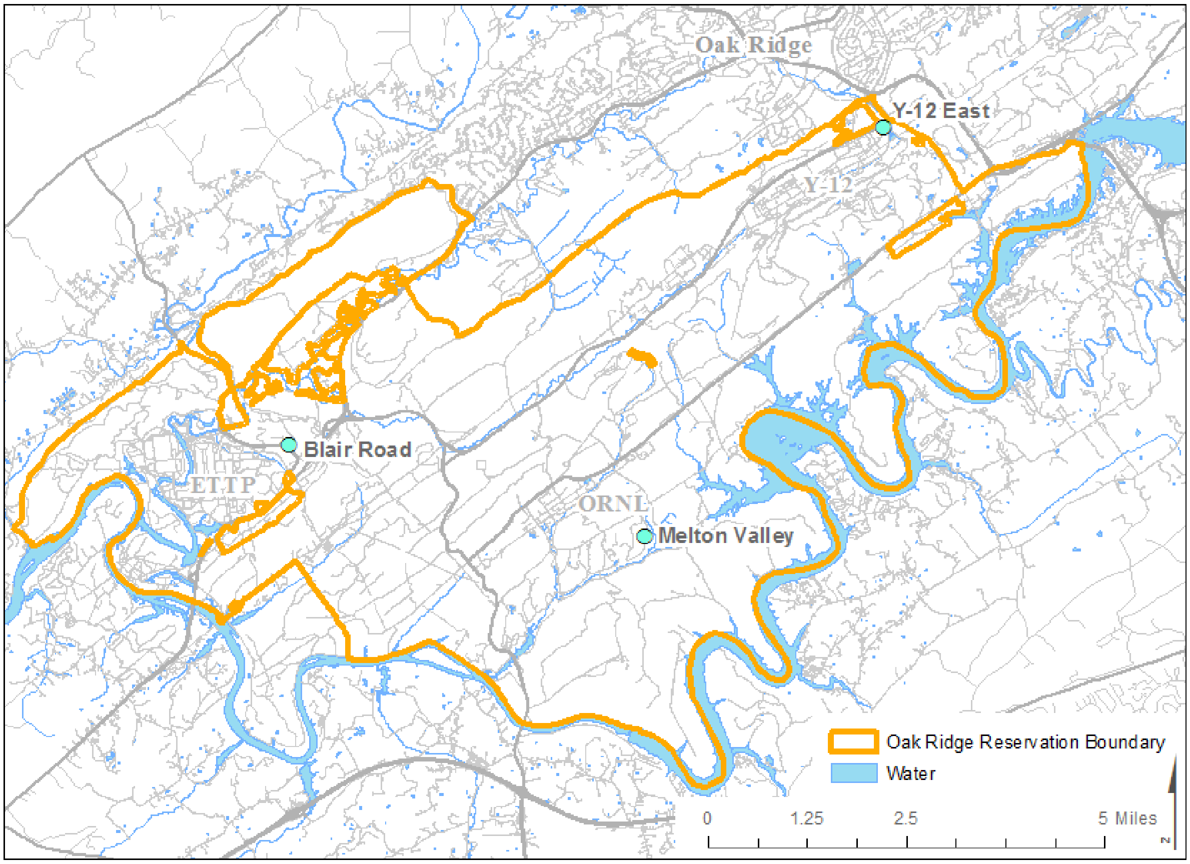


Figure 8.2.1: Locations of the RadNet Precipitation samplers on the ORR

8.2.5 Methods, Materials, Metrics

The three precipitation samplers provided by EPA's RadNet Air Monitoring program (locations shown in Figure 8.2.1) were 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 (in a four-liter container) and sent to EPA when a minimum of two liters of precipitation is accumulated, or less when it is the final sample of the month. Each sample is processed as specified by EPA (EPA, 1988; EPA, 2013) and then shipped to NAREL in Montgomery, Alabama, for analysis. NAREL composites the samples collected during a month for each station and analyzes each composite for gamma radionuclides.

No regulatory limits for radiological contaminants in precipitation exist, so the results of the gamma analyses were 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 fifteen picocuries per liter (pCi/L), while beta and photon emitters are limited to four millirem (mrem) per year and are radionuclide specific. Table 8.2.1 shows the maximum contaminant levels (MCLs) of beta and photon emitters that EPA uses as drinking water limits for select isotopes. Not all gamma 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 8.2.1: 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

This project report was prepared to assist with the State of Tennessee's commitments under both the Environmental Surveillance Oversight Agreement (ESOA) for the ORR. In accordance with those agreements, a portion of the time spent on this project will be in reviewing the DOE Environmental Monitoring Plan (EMP) and Annual Site Environmental Report (ASER) for the ORR and/or applicable FFA remedy documents. This project may evaluate data from various sources to include, but not limited to: data uploaded to the Oak Ridge Environmental Information System (OREIS), data provided to or collected by other State regulatory agencies, split sampling with DOE parties, or independent sampling in accordance with accepted standard procedures. Information analyzed by the TDEC Division of Remediation, Oak Ridge Office (DoR-OR) will be used to make recommendations to existing DOE environmental surveillance programs.

8.2.6 Deviations from the Plan

The results in this report would normally cover July 2017 through June 2018, but are only available through March 2019, so instead the data from January 2018 through March 2019 will be discussed.

8.2.7 Results and Analysis

The results of NAREL's analyses of the nationwide RadNet Precipitation sampling are available in the RadNet database on the Envirofacts website, via either a simple or a customized search. The gamma isotopes identified from January 2018 through March 2019 include beryllium-7, cesium-137, cobalt-60, potassium-40, radium-226, radium-228, and thorium-228. For all isotopes except beryllium-7 and potassium-40, and radium 228, the reported results were 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.

The average result for beryllium-7 for the three ORR samplers from January 2018 through March 2019 was 63.3 pCi/L, compared to an average MDC of 42.8 pCi/L. The national average for the same time period was 54.2 pCi/L. The highest beryllium-7 result for the ORR stations during this time period was 127 pCi/L. When compared to the relatively conservative EPA drinking water limit for beryllium-7 of 6,000 pCi/L, the values seen in the monthly composite precipitation samples on the ORR are relatively small.

While most of the potassium-40 results were below detection limits from January 2018 through March 2019, three of the forty-five samples did show detectable levels. The three potassium-40 results with detectable levels were 22.4, 30.5, and 21 pCi/L, with an average MDC of 16.7 pCi/L. Potassium-40 is a naturally occurring radionuclide and does not have a drinking water limit.

Three of the ORR RadNet Precipitation results from January 2018 through March 2019, all at the ORNL Melton location, showed radium-228 levels greater than, but just over, sample specific detection limits. One precipitation sample collected by others at a RadNet station in Nashville also did during this timeframe.

8.2.8 Conclusions

Overall, the highest values seen in the composited monthly precipitation samples for each of the three ORR stations were all below the MCLs set by the EPA for drinking water. 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, cobalt-60, and radium-226 for this time period were less than the MDCs. The data during this time period were below detection limits or below the relatively conservative regulatory limits used for drinking water and did not indicate a significant impact on the environment or public health from ORR emissions from January 2018 through March 2019.

8.2.9 Recommendations

Continued monitoring of the ORR precipitation for radiological contamination 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 building continues at all three ORR sites. Current operations also have the potential to impact precipitation contaminant levels. In the event of an emergency either on or off of 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.

8.2.10 References

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

Environmental Protection Agency (2000). Radionuclides in Drinking Water. Radionuclide Rule. http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/

Environmental Protection Agency (2013). NAREL Standard Operating Procedure for Collecting RadNet Precipitation Samples. SC/SOP-2. National Analytical Radiation Environmental Laboratory, Office of Radiation and Indoor Air. Montgomery, Alabama.

Environmental Protection Agency (2015). Derived Concentrations of Beta and Photon Emitters in Drinking Water. https://www.epa.gov/sites/production/files/2015-09/documents/guide_radionuclides_table-betaphotonemitters.pdf

Environmental Protection Agency (2019). NAREL RadNet Data links.
Envirofacts RadNet Searchable Database:
search http://iaspub.epa.gov/enviro/erams_query_v2.simple_query
customized search https://www.epa.gov/enviro/radnet-customized-search

8.3 RADNET DRINKING WATER SAMPLING

8.3.1 Background

The RadNet program was developed by the Environmental Protection agency (EPA) to track radiation in the environment and ensure public health and environmental quality as well as to monitor potential pathways for significant population exposures from routine and accidental releases of radioactivity (EPA, 1988). The EPA RadNet Drinking Water program provides quarterly radiological sampling of finished water at public water supplies near major population centers throughout the United States. The RadNet Drinking Water Sampling project in the Oak Ridge area provides radiochemical analysis of finished water at four public water supplies located near and on the Oak Ridge Reservation (ORR). Quarterly, samples are collected by the Tennessee Department of Environment and Conservation (TDEC) and the analysis for radiological contaminants is performed at the EPA National Analytical Radiation Environmental Laboratory (NAREL).

Radioactive contaminants released on the ORR can potentially enter local streams and be transported to the Clinch River. While monitoring of the river and local water treatment facilities has indicated that concentrations of radioactive pollutants are below regulatory standards, a concern still exists that area water supplies could be impacted by ORR contaminants. The RadNet project provides a mechanism to evaluate the impact of DOE activities on the area drinking water supplies. This sampling also provides independent third-party analyses of finished drinking water.

8.3.2 Problem Statements

Past and present radiological contamination on the three sites of the ORR − ORNL, Y-12, and ETTP − can potentially enter local streams and be transported to the Clinch River and into the local drinking water.

8.3.3 Goals

- Protect human health and the environment by assuring that the public drinking water is safe.
- Sample drinking water to detect radiological contaminants that might be related to the release of radioactivity from the ORR.
- Review data as well as identify and report long-term trends of radionuclides present in finished drinking water.
- Provide reference data to facilitate the evaluation of water quality as it relates to radioactive constituents of concern.

8.3.4 Scope

The RadNet Drinking Water project collects finished water samples quarterly from each of four local water treatment plants, ranging from upstream of the city of Oak Ridge along the Clinch River to downstream of the ORR in Kingston, Tennessee. Figure 8.3.1 depicts the locations of the raw water intakes associated with the facilities where RadNet drinking water samples are collected for this project. Tritium analysis is performed on each quarterly sample. Other radiological analyses are performed annually.

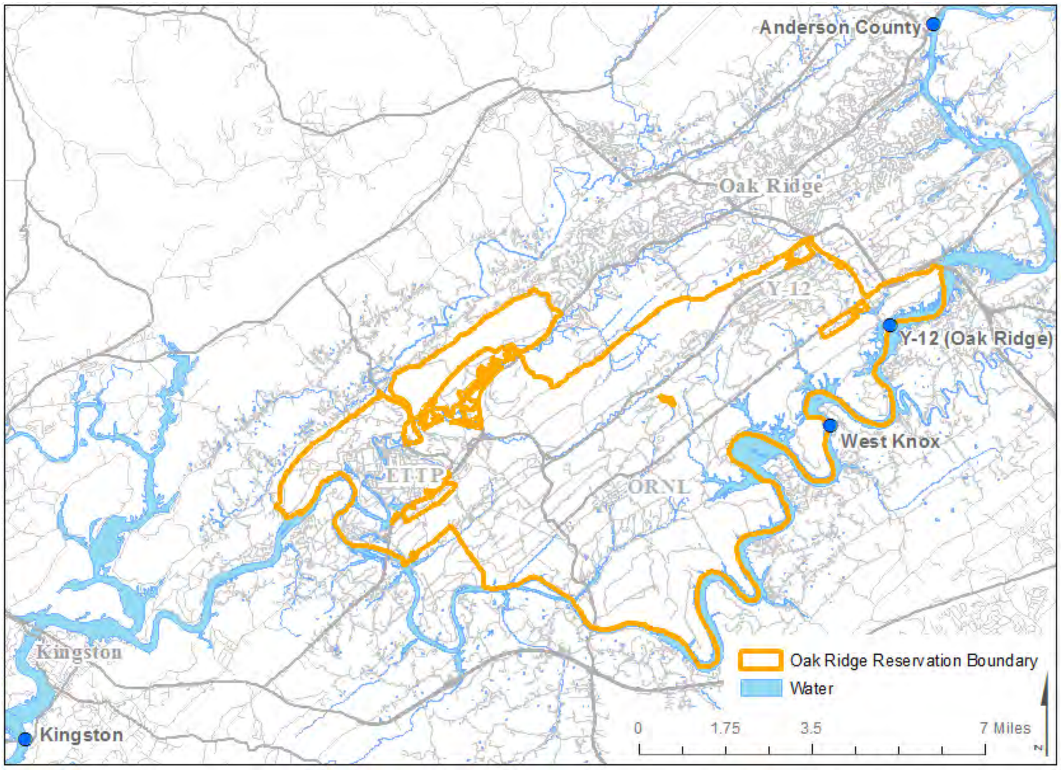


Figure 8.3.1: RadNet Drinking Water Facility Intakes

8.3.5 Methods, Materials, Metrics

For the Oak Ridge RadNet Drinking Water project, EPA provides radiochemical analysis of finished drinking water samples collected quarterly by TDEC at four public water supplies.

Samples are collected at:

- Anderson County Water Authority Water Treatment Plant (upstream background location)
- Oak Ridge Water Treatment Plant (at Y-12)
- West Knox Utility District Water Treatment Facility
- Kingston Water Treatment Plant

The 3.5-liter samples are collected from each of four area water treatment plants, using procedures and supplies prescribed by EPA protocol (U.S. EPA, 1988; U.S. EPA, 2013). The samples are analyzed by NAREL for tritium, iodine-131, gross alpha, gross beta, strontium-90, and gamma radionuclides with further analysis performed when warranted. The analytical frequencies and parameters are provided in Table 8.3.1.

The results of NAREL's analyses of the nationwide RadNet Drinking Water data are available in the RadNet database on the Envirofacts website, via either a simple or a customized search.

Table 8.3.1: RadNet Drinking Water Analyses and Frequencies

ANALYSIS	FREQUENCY
Tritium	Quarterly
Iodine-131	Annually on one individual sample/sampling site
Gross Alpha, Gross Beta, Gamma Scan	Annually on composite samples
Strontium-90	Performed on composite samples from one-fourth of the stations on a four-year rotating schedule (last 2014)
•Radium-226 •Uranium-234, Uranium-235, Uranium-238 •Plutonium-238, Plutonium-239, Plutonium-240	Annually on samples with gross alpha >2 pCi/L
Radium-228	Annually on samples with Radium-226 between 3-5 pCi/L

8.3.6 Deviations from the Plan

There were no deviations from the planned sampling for this project for the July 2018 through June 2019 sampling period. The 2018 composite analyses are not yet complete and are therefore not available for this report. Composite sample results from 2017 sampling are included in this report.

8.3.7 Results and Analysis

Many radioactive contaminants are transported off the ORR in surface water and enter the Clinch River by way of White Oak Creek (WOC), which drains the ORNL complex and associated waste disposal areas in Bethel and Melton valleys. When contaminants carried by WOC and other ORR streams enter the Clinch River, their concentrations are significantly lowered by dilution from the river. Contaminant levels are typically further reduced in finished drinking water by conventional water treatment practices used by area water treatment plants. Consequently, the levels of radioactive contaminants measured in the Clinch River and at area water supplies, are far below the concentrations measured in WOC and many of the other streams on the ORR.

The data collected since the Oak Ridge RadNet Project began in July of 1996, indicates that water treatment plants closest to WOC exhibit the highest concentrations of radioactive constituents. However, all results for these water treatment facilities have remained below applicable MCL drinking water standards set by EPA (Table 8.3.2).

Table 8.3.2: EPA Drinking Water Standards (pCi/L)

Isotope		EPA MCL
Iodine-131	(I-131)	3
Strontium-90	(Sr-90)	8
Tritium	(H-3)	20,000
Cobalt-60	(Co-60)	100
Cesium-137	(Cs-137)	200

EPA - Environmental Protection Agency
MCL - Maximum Contaminant Level (National Primary Drinking Water Regulation limits)
pCi/L - picoCuries per Liter

The results of NAREL's analyses of the nationwide RadNet Drinking Water sampling are available in the RadNet database on the Envirofacts website, via either a simple or a customized search. The results shared in this report cover January 2018 through June 2019 as available, with some historical results and trends noted.

Tritium results from 2018 and the first two quarters of 2019 are available at the Envirofacts website. These tritium results are similar to the results from past years. NAREL typically performs tritium analysis on each of the quarterly samples taken at the ORR facilities. Tritium is not readily removed by conventional treatment processes and is one of the most prevalent contaminants discharged by WOC into the Clinch River. Of the quarterly samples taken during this time period from each of the four area water treatment plants, all were below the minimum detectable concentration (MDC) for each sample.

The average result for the 2018 quarterly tritium samples and the first two quarters of 2019 was 14.5 pCi/L with an average MDC of 120 pCi/L. Historically, most of the results of the tritium analyses have been below the MDCs: The results for tritium from samples at the drinking water plants monitored since the program's inception, range from undetected to1,001 pCi/L. The drinking water standard for tritium is 20,000 pCi/L, so even the highest levels of tritium that have been detected for the Oak Ridge area by this project are below this limit.

One quarterly sample per location per year is analyzed for iodine-131 (I-131). I-131 analysis for 2019 was performed for the second quarter sample at each of the four stations; the results were below the MDC for the four sampling locations. The 2018 analyses for I-131 had results below MDCs for three of the four sampling locations. The sample from the station at the Kingston Water Plant showed a detectable amount of I-131 at 0.51 pCi/L, but this was not much greater than the MDC of 0.47 pCi/L for that sample. Also, it was well below the MCL of 3.0 pCi/L, which is the EPA's drinking water standard for I-131. Historically, the project on the ORR has only seen four samples over the MDCs for the Oak Ridge area RadNet Drinking Water project. Two samples were from after the Fukushima nuclear event in March 2011 (0.632 pCi/L and 0.279 pCi/L), one was the 2018 sample mentioned above, and one was from a sample collected mid-June in 1997 (0.295 pCi/L).

Gross alpha, gross beta, and gamma analyses are performed annually on a composite of the quarterly samples taken from each of the monitored facilities. The results of the 2017 annual composite samples are noted below as no new data is currently available.

In 2017, no gross alpha results were greater than the sample-specific MDC. EPA's drinking water standard for gross alpha in drinking water is 15 pCi/L (MCL). The composite samples from 2017 were all below this amount. Historically, for the RadNet Drinking Water locations monitored by the Oak Ridge portion of the program, six of the one hundred and seven samples have shown gross alpha levels over the MDC. A 2015 composite gross alpha sample showed 3.4 pCi/L, with an MDC of 2.9 pCi/L. Three samples showed gross alpha levels over the MDC in the 1997 composites (1.37 pCi/L, 1.73 pCi/L, 1.05 pCi/L), one did in 1998 (0.7 pCi/L), and one did in 1999 (0.7 pCi/L).

There were no gross beta results from the 2017 annual composite analyses were greater than the sample-specific MDCs. Historically, about 66% of the annual gross beta composites for the RadNet Drinking Water sites had levels greater than the sample-specific MDCs, though the majority of these were from annual composites from before 2011. Only five of the thirty-two (15.6%) composite samples after 2011 had gross beta levels greater than the sample-specific MDCs. The average gross beta result for these locations since the inception of the program in March of 1996 was 2.18 pCi/L, with the highest value being 4.9 pCi/L. The drinking water standard for beta emitters depends on the specific radionuclides present, but radionuclide-specific analysis is generally not required at gross beta measurements below 50 pCi/L.

The gamma spectrometry results for 2018 were not yet available. The gamma spectrometry on the annual composites for 2017 showed no values above MDCs for cobalt-60 (Co-60), cesium-137 (Cs-137), Ra-228, or Potassium-40 (K-40). The 2017 gamma results were below the EPA drinking water standards and below the sample-specific MDCs.

Analysis for Strontium 90 (Sr-90) is performed on an annual composite sample from each station every four years. The 2017 analyses for Sr-90, had no results greater than the sample-specific MDCs.

Since the project's inception, all samples collected by and analyzed for this project from the Oak Ridge area have been below the associated drinking water standards and often below the minimum detectable concentrations.

8.3.8 Conclusions

Radioactive contaminants migrate from the ORR to the Clinch River, which serves as a raw water source for area public drinking water. The impact of these contaminants is diminished by dilution from the waters of the Clinch River. Contaminant concentrations are further reduced in finished drinking water by conventional water treatment practices employed by area water treatment plants. Results of samples collected from public water supplies on and in the vicinity of the ORR in association with EPA's RadNet program have all been well below drinking water standards, since the inception of the project in 1996.

8.3.9 Recommendations

Continued radiological analysis is recommended to ensure drinking water from area water treatment plants near or downstream the ORR are protective of human health and the environment. This is especially important as current operations, remediation, and the demolition of older buildings continue at all three ORR sites.

8.3.10 References

Argonne National Laboratory (2007). Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas. Human Health Fact Sheet: Potassium-40. https://www.remm.nlm.gov/ANL_ContaminantFactSheets_All_070418.pdf

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

Environmental Protection Agency (2013). NAREL Standard Operating Procedure for Collecting RadNet Drinking Water Samples. SC/SOP-3. National Analytical Radiation Environmental Laboratory, Office of Radiation and Indoor Air. Montgomery, Alabama.

Environmental Protection Agency (2015). Derived Concentration of Beta and Photon Emitters in Drinking Water. https://www.epa.gov/sites/production/files/2015-09/documents/guide_radionuclides_table-betaphotonemitters.pdf

Environmental Protection Agency (2019). NAREL RadNet Data links.
Envirofacts RadNet Searchable Database:
search http://iaspub.epa.gov/enviro/erams_query_v2.simple_query
customized search https://www.epa.gov/enviro/radnet-customized-search