TENNESSEE DEPARTMENT
OF
ENVIRONMENT AND CONSERVATION

DIVISION OF REMEDIATION
OAK RIDGE OFFICE

ENVIRONMENTAL MONITORING REPORT

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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 used in a cooling tower which is 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
	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
mg/L	milligrams per liter
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.
mV	millivolts
ng/g	nanograms per gram (parts per billion)
ppm	parts per million

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- Robert Bishop – Rain Event Monitoring
- Don Gilmore – Surface Water Monitoring at EMWMF and Ambient Local Springs Monitoring
- Rebecca Lenz – Offsite Residential Well Monitoring, Background Residential Well Monitoring, and (co-author, Gareth Davies) Stable Isotopes Analyses for Residential Groundwater Projects
- Gerry Middleton – Bat Monitoring and Mercury Uptake in Biota
- John Peryam – Haul Road Surveys, Ambient Surface Water Monitoring, Surface Water Physical Parameters, Ambient Sediment, and Trapped Sediment
- 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
- Andy Robinson – Ambient Surface Water monitoring (Co-Author) and Y-12 FCAP Surface Water Monitoring
- John Wojtowicz – Environmental Dosimeters, Surplus Sales Verification, and Benthic Macroinvertebrate Monitoring

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EXECUTIVE SUMMARY

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation, Oak Ridge (DoR-OR), submits the annual Fiscal Year 2018 (FY2018) Environmental Monitoring Report (EMR) for the period of July 1, 2017 through June 30, 2018. 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). DoR-OR participates in independent monitoring and oversight of FFA related activities, conducting independent environmental monitoring to support environmental restoration decisions, 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 current 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), as well as 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 FY2018 EMR presents the results of the 21 independent projects proposed in the FY2017 Environmental Monitoring Plan (EMP), and completed throughout FY2018. 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, there were five (5) projects grouped under the radiological monitoring header for the purpose of this EMR.

Environmental Dosimeters

The Environmental Dosimeters Project is designed to independently assess if the potential public dose from radiation exposure is kept below the NRC NUREG-1757 reference limit of 100 mrem/yr (Schmidt et al, 2006). 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. At one time, very little of the ORR was accessible to the public. More recently there has been a movement toward making portions of the ORR more accessible to businesses and the public. This is particularly true at the East Tennessee Technology Park (ETTP) and Oak Ridge National Laboratory (ORNL). Increased access has the potential to increase the risk of exposure. Long-term monitoring of the ORR has shown that the majority of the areas pose no risk to the public. During 2017, sixteen monitoring stations at ORNL reported results that exceeded 100 mrem over the span of the year. Three stations showed substantial decreases in exposure during 2017, likely due to changes in what is being stored at the locations or changes in operation of the facility (i.e. facility shutdown). Long-term monitoring of the ORR continues to keep focus on areas of the site where radiation levels may be somewhat elevated or where levels increase.

Real Time Measurement of Gamma Radiation

The Real Time Measurement of Gamma Radiation Project, conducted on the Oak Ridge Reservation (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 2017/2018 monitoring period, no monitored location exceeded the 2 mrem in any one hour period limit, and no monitored location exceeded the 100 mrem /year limit for members of the public.

Portal Monitoring at EMWMF

To help ensure compliance with the waste acceptance criteria (WAC) defined for use at the environmental management waste management facility (EMWMF), TDEC has placed a Radiation Portal Monitor at the check-in station for trucks transporting waste into the EMWMF for disposal. Trucks entering the facility pass between radiation detectors that measure, provide data for review, and allow TDEC to determine if excessive amounts of radiation-emitting materials have passed that portal monitor. This system is intended to corroborate DOE's readings and to confirm that excessive amounts of radiation-emitting materials have not inadvertently been disposed of in the facility. During the period 07/01/2017 through 06/30/2018, no elevated points of concern were identified.

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. Five independent assessments of surplus sales materials occurred during the period July 1, 2017 through June 30, 2018. No items with elevated levels of alpha and beta radiological contamination exceeding the DOE release criteria were found during the surveys.

Haul Road Surveys

TDEC staff performs bimonthly surveys of the Haul Road and other waste transportation routes on the ORR. The periodic surveys of the roads used to haul waste to the EMWMF indicate waste items routinely fall from trucks transporting the waste. The Haul Road walkover surveys identified 18 items in the July 2017 – June 2018 time frame, potentially originating from hazardous and/or radioactive waste being transported to the EMWMF. 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 four (4) biological monitoring projects conducted during the FY2018 project year.

Bat Monitoring on the Oak Ridge Reservation:

Monitoring was conducted on the ORR to help determine the mercury (Hg) and methyl mercury (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. This project also analyzed bat acoustic surveys for the protection of threatened and endangered bat species. Through the course of 35 survey nights, more than 4,500 bat call files were recorded on or around the ORR. Threatened and endangered bat species were detected at 7 of 8 East Fork Poplar Creek (EFPC) sites surveyed. These findings provide useful information for researchers and bat biologists regarding the ecological recovery of EFPC following Hg abatement and remedial activities. This data provides key information to support the evaluation of current and future cleanup decisions, including the assessment of the current ecological conditions on and around the ORR. This project also provides information to be evaluated, when future actions are proposed that may alter or otherwise impact habitat and the environment.

Mercury Uptake in Biota

In 1995, the Lower East Fork Poplar Creek (EFPC) Record of Decision (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 purpose of this project is to investigate Hg and MeHg concentrations in Wood Ducks and Tree Swallows (i.e., in feathers and eggs) and in their associated prey items and to examine additional targeted species including crayfish, salamanders, and small mammals, for Hg and MeHg uptake. Samples were collected from EFPC floodplain and reference sites.

TDEC, during this investigation, demonstrated that Hg and MeHg concentrations are 9 times and 14 times greater, respectively, in EFPC eggs compared to reference eggs. TDEC determined that the largest percentage of Hg in a clutch of eggs is within the first-laid egg. TDEC recorded one spider MeHg result and one salamander MeHg result that fell within this range known to be detrimental to bird reproduction. Birds, consuming prey items such as these spiders and salamanders, could be expected to bioaccumulate similar levels of body burden mercury. This research is valuable in determining the effectiveness of past cleanup decisions, as well as assisting in the evaluation of current site conditions. As TDEC evaluates future clean up actions and decisions that may affect these ecological areas, this data which helps define the impacts of prior actions at the site on the overall ecological health of the environment on and around the ORR will be considered and utilized.

Radiological Uptake in Vegetation

This project focuses on the detection and characterization of radiological constituents that may be bio-accumulated by vegetation. Due to the turnaround time for laboratory results of this type, the 2018 data set is not yet available, but the 2017 data is reviewed and discussed in this report. The data from the samples collected in 2017 for the Radiological 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. Identification of these areas can be useful in evaluating current site conditions and providing input regarding cleanup decisions and actions.

Benthic Macroinvertebrates

The health of the benthic macroinvertebrate communities in ORR 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 years (ASER 2017). East Fork Poplar Creek (EFPC) 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 the halting of the augmented flow, conditions at the Upper East Fork stations have deteriorated. While Bear Creek continues to improve slightly, particularly in its downstream reaches, some portions remain somewhat impaired. While impaired, these impacted portions of Bear Creek do continue 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. Concerns are that additional construction in the headwaters may further deteriorate this section of Mitchell Branch.

Air Monitoring:

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

Fugitive Radiological Air Emissions

With the mission to protect human health and the environment, TDEC conducts independent air sampling and compares those results with air sampling data provided by DOE. During this project's period of performance, an elevated uranium reading was observed with one of the TDEC collected samples. The 2/21/2018 composite sample (taken from the monitoring station area located near K27), identified elevated uranium. While this was only reflective of an isolated spike (attributed potentially to demolition activity near the site), had those elevated rates continued for the entire year, the rates could have exceeded regulatory limits. The shorter composite interval sampling times executed in TDEC's sampling program can result in the more timely observation of potential problems than other available sampling programs such as DOE's program which analyzes their samples quarterly. Overall, during this project's period of performance (with samples collected from 03/22/2017 through 03/21/2018), the average results at TDEC's fugitive air monitoring stations were similar to background. The average concentrations, minus background, for all sites, were below the federal standards.

Surface Water Monitoring:

Five projects addressed the surface water on and around ORR specifically during FY2018.

Ambient Surface Water Monitoring

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

Analytical and benthic data indicate that Bear Creek, from location BCK3.3 and downstream supports a healthy and diverse biological community. East Fork Poplar Creek continues to be impacted by elevated mercury levels above Tennessee Water Quality Criteria (TWQC), elevated nutrient levels, increased gross alpha and beta concentration (as compared to previous years' data), with analytic and biological data that indicates a moderately polluted stream, partially supportive of fish and wildlife. Mitchell Branch also is defined by the analytic and biological data as a moderately polluted stream, partially supportive of fish and wildlife. White Oak Creek continues to be impacted by slight gross alpha and elevated beta radiological activity. The analytical and biological data collected for White Oak Creek defines it as a moderately polluted stream, partially supportive of fish and wildlife. Strontium 90 (Sr-90) impacts from White Oak Creek adversely affect the Clinch River. At the CRK33.5 location along the Clinch River, almost half of the samples collected from Feb 2017 through June 2018 exceeded the derived concentration guidelines (risk-based radiological standards for drinking water, as published by the Nuclear Regulatory Commission) for Sr-90. While the Clinch River dilutes the contamination within a few kilometers downstream of the mouth of White Oak Creek (before the drinking water intake) to levels below the DCG, the contribution from White Oak Creek to the Clinch River, will continue to be monitored and that information will support and guide further cleanup decisions and remedial action discussions.

Ambient Surface Water Parameters

To assess the degree of surface water impact, stream monitoring data around the ORR was collected monthly, to contribute to a database of physical stream parameters (specific conductivity, pH, temperature and dissolved oxygen). That parameter database should provide information to assess the impact of site remediation efforts through long term monitoring of surface water parameters, as well as provide ambient parameter information for use in the event of a release requiring clean up decisions and guidance. Field data was collected monthly from seven exit pathway streams on the ORR. Conductivity trends were found at two locations. Conductivity has been decreasing at Bear Creek historically while increasing at East Fork Poplar Creek as revealed by the 13.5-year data analyses seen in this EMR. While showing an overall decreasing trend at Bear Creek, it is important to note that the conductivity values themselves overall at the Bear Creek sampling location, are still elevated. While there are not Tennessee Water Quality Criteria for conductivity specifically, it is important to note where values are elevated as they may be indicative of elevated contaminants in the surface water at those locations, and additional assessment may be prudent. As legacy DOE ORR pollution has negatively impacted surface water in our area, TDEC continues evaluating these surface water features via many methods to provide a complete and thorough assessment of the surface water both on and around the ORR. TDEC is committed to ensuring appropriate decisions are made surrounding remedial action activities as well as evaluating remedy effectiveness for sites under active management.

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 sampling or independently collected samples at storm drains at the ORR on a quarterly basis, as well as at discharge points for surface impoundments and other locations as applicable. Review of correlated DOE sampling results, also helped to ensure compliance with negotiated and agreed to criteria for release from remedial action activities. Sample results from this period of performance indicate legacy contaminants continue to impact the ORR. These legacy concerns include: radiological contaminants in White Oak Creek, metals in Mitchell Branch, mercury at East Fork Poplar Creek , hexavalent chromium, which was sporadically present in multiple sampling locations, and technetium 99 (Tc-99) which has continued to impact the SD-490 location.

Surface Water Monitoring at the EMWMF

Contaminated materials from CERCLA remediation activities on the ORR are approved for disposal in the EMWMF, provided they meet the waste acceptance criteria. However, there is concern that associated contaminants over time have the potential to migrate from the facility into the environment and be carried by ground and surface waters off site in concentrations above agreed upon limits. TDEC conducts this project to provide assurance through independent monitoring and evaluation of DOE's data, that operations at the EMWMF are protective of public health and the environment and meet the associated remedial actions objectives. In this effort, samples are collected from groundwater, surface waters, and wastewater to help ensure that the EMWMF complies with the established limits and operational requirements. In FY 2018, TDEC sample results were similar to those generated by DOE at the EMWMF-2 sampling point, the discharge for the EMWMF underdrain. As the underdrain passes beneath the EMWMF, this sampling point is the first location where contamination would be expected to be seen if there was a problem with the liner system. Contaminants derived from contact water was evident in discharges from sediment basin (the EMWMF -3 sampling point), but at levels below the current release criteria. These criteria are currently being reevaluated as a part of an FFA dispute on the related *Focused Feasibility Study for Water Management for the Disposal of CECLA Waste, on the Oak Ridge Reservation, Oak Ridge, Tennessee* (DOE/OR/01-2664&D2).

Y12 FCAP Surface Water

In 2016, a Five Year Review completed on the Y-12 Chestnut Ridge Operable Unit 2 Filled Coal Ash pond, indicated that physical changes to the wetland system (approved in the record of decision [ROD] as a natural passive treatment system) may be adversely reducing its capacity to remove arsenic and other metals from the Upper McCoy Branch. TDEC conducted sampling to determine the concentrations of metals in the surface waters of McCoy branch. The data collected by TDEC from the quarterly sampling of metals during this project indicates the remedial capacity of the passive wetland treatment system to efficiently remove metals, especially arsenic, from McCoy Branch has significantly diminished. It may be necessary for DOE to install a new wetland treatment system and/or upgrade the existing wetland treatment system to remedy this issue. In addition, the bi-monthly and quarterly monitoring flow data indicates that the diverted untreated dam spillway surface water (SW-1) flow is intermittent, which may be affecting the contribution of metals constituents to McCoy Branch.

Sediment Monitoring:

There were two sediment investigations conducted during FY2018.

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. These contaminant releases have been detrimental to stream health in the past and present. Sampling of sediment is conducted by TDEC to assess current conditions of stream health. Comparisons of radiological data with the preliminary remediation goals (PRGs), obtained from the "ORNL Risk Assessment System" (PRGs= a 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).

While not presenting a radiological risk to human health, there are constituents in the streams that are worth noting. When a metal occurs at a concentration above the threshold effects concentration (TEC), a possibility of impairment to benthic macroinvertebrate populations is possible. Above the probable effects concentration (PEC), it is probable that these populations will be impaired. East Fork Poplar Creek sediment has mercury concentrations which exceed the PEC of 1.1 mg/kg. Cadmium has also been found downstream in East Fork Poplar Creek that was not identified at background locations. Mitchell Branch sediments are contaminated with mercury and nickel values above the PECs with chromium, lead, arsenic, copper and zinc levels above the TECs. The North Tributary 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, it receives the flow from the sediment retention pond. This tributary contributed approximately 0.7 kg of uranium to Bear Creek in FY2017 (DOE 2018). In Bear Creek, at km3.3, the uranium value (3.99 mg/kg) was almost eight times that of the background stream (0.505 mg/kg). Sediment collected from Clinch River at km32.7 was not contaminated for metals.

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.

Analysis of sediment collected from the sediment traps indicates metals contamination at East Fork Poplar Creek sampling site 23.4. Cadmium and copper levels above the TEC and mercury levels exceeded the PEC. Lead and nickel concentrations were also above the TEC in 2015 and 2016 at that East Fork Poplar Creek sampling location. As discussed in the ambient sediment project, when a metal occurs at a concentration above the TEC, a possibility of impairment to benthic macroinvertebrate populations is possible. When values are identified above the PEC, it is probable that populations will be impaired. The concentrations of metals identified in the trapped sediment samples, from East Fork poplar Creek indicate that there is a probable impairment to the biota of the sediment at that location. At North Tributary 5 of Bear Creek, results from metals analysis were less than the

TEC. Both Poplar Creek and North Tributary 5 of Bear creek showed levels of gross alpha and beta radioactivity that are above background in the trapped sediment samples. While identified above background concentrations, it is important to note that the gross alpha and beta radioactivity levels reported do not pose a threat to human health or the stream life.

The results of these sediment projects will be used to assess and evaluate current effectiveness of former clean up decisions and to guide future decisions that may affect the health of this environment.

Groundwater Monitoring:

There were four projects relating to groundwater at and around the ORR during FY2018.

Offsite Residential Well Monitoring

The contamination of groundwater beneath several areas of the ORR and the potential pathways that allow for contaminant migration beyond the ORR boundary, makes it imperative to monitor groundwater in areas off the reservation. Specific attention is paid to locations where residential wells may be a primary or sole source of water for local residents. The results from residential wells sampled during this period represent a snapshot in time and not continuous monitoring. During FY2018, the constituents of concern identified include mostly low-concentrations, low-activities, and sporadic detections of contaminants that could potentially be a result of human activity. Some of these detections are above EPA secondary drinking water standards or health-based criteria (including elevated aluminum, iron and sodium). Sporadic detections of radiochemical constituents occur in residential well groundwater (including radium-226, radium-228, uranium-233/234 and uranium-238). No determination regarding potential sources of the identified constituents has been made at this time.

Background Residential Well Monitoring

Groundwater data collected from background locations provide important data to aid in understanding the local hydrology and to generate a water quality baseline that could be used for comparison to the groundwater results obtained on-site and off-site the ORR. The five residential wells and two springs sampled during this period represent a snapshot in time. Trend predictions will be made using previous background sample events and as more data is collected.

Stable Isotopes Analyses for Residential Groundwater Projects

Stable Isotope analyses were also completed on offsite and background residential well groundwater samples during the FY 2018 time frame. Two main conclusions from the stable isotope data were made.

- The isotopic oxygen ($\delta^{18}O$) versus isotopic hydrogen ($\delta^{2}H$) plot showed that the majority of the groundwater well samples analyzed were derived from precipitation sources. There was a group of samples that trended toward the heavier hydrogen isotopes. This may be indicative of groundwater mixing with deeper saline groundwater.
- The isotopic nitrogen ($\delta^{15}N$) versus isotopic oxygen ($\delta^{18}O$) plot shows that the majority of the samples fell within natural nitrate ranges. One sample, collected from location OW-422L, identified the potential for man-made impacts in the sample and may require further investigation.

The purpose of stable isotope analyses of groundwater samples is to help identify water origin and transport mechanisms to help provide information with regard to overall groundwater movement and site characterization with respect to clean-up decisions for groundwater at the ORR.

Ambient Local Springs Monitoring

Since 1994, TDEC's sampling of offsite springs has provided data which may be used to evaluate and quantify general background geochemical groundwater parameters. TDEC's spring monitoring project when compared with DOE spring samples, identified that groundwater results from TDEC-sampled and DOE-sampled springs, were similar. These analyses may facilitate the understanding of the general groundwater geochemical composition around ORR that discharges into springs found offsite near the ORR. This data potentially allows for better delineation of "background values" in that groundwater zone.

RADNET

RadNet is a nationwide system that 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 FY2018.

RadNet Air Monitoring

The gross beta results for each of the five RadNet Air Monitoring stations exhibited similar trends and concentration levels for FY 2018 (July 2017 through June 2018). All the data during this time period were well below the value which would warrant further analysis. These samples indicate that ORR activities occurring over this sampling time frame, posed no significant impact on the environment or public health from ORR emissions.

RadNet Precipitation Monitoring

The highest values seen in the composited monthly precipitation samples for each of the three 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 cesium-137, cobalt-60, radium-226, and radium-228 for this time period were less than the 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.

Conclusion:

While DOE operations on the ORR have (and have had) the potential to release a variety of constituents to the environment via atmospheric, surface water, and groundwater pathways, DOE (as stated in the 2017 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." (2017 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), 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. TDEC's Environmental Monitoring Program is a critical component of actions that, when coupled with: the review the DOE active monitoring program, the assessment and comment on proposed planning documents and active participation in review of environmental activities across the ORR, supports DOE and EPA in ensuring complete and protective clean-up of the ORR sites is occurring now and will continue into the future.

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 (FY2018) Environmental Monitoring Report (EMR) for the period July 1, 2017 through June 30, 2018, in accordance with the terms of the Environmental Surveillance and Oversight Agreement (ESOA) and in support of activities being conducted under the Federal Facilities Agreement (FFA).

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

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

DOE and the State, in a spirit of partnership and cooperation, are committed to assure DOE's Oak Ridge activities are performed in a manner that is protective of health, safety, and the environment. This document provides an annual summary report for the FY2018 monitoring and assessment projects conducted by TDEC during this period of performance.

1.2 OBJECTIVE

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

This FY2018 EMR presents the results of the 21 independent projects proposed initially in the FY 2017 EMP, and completed throughout FY2018. 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, is being transitioned into an industrial technology park. Even though the gaseous diffusion activities at ETTP have concluded, residual environmental waste streams and current decommissioning activities have resulted in environmental releases that contain both radionuclides and hazardous chemicals.

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

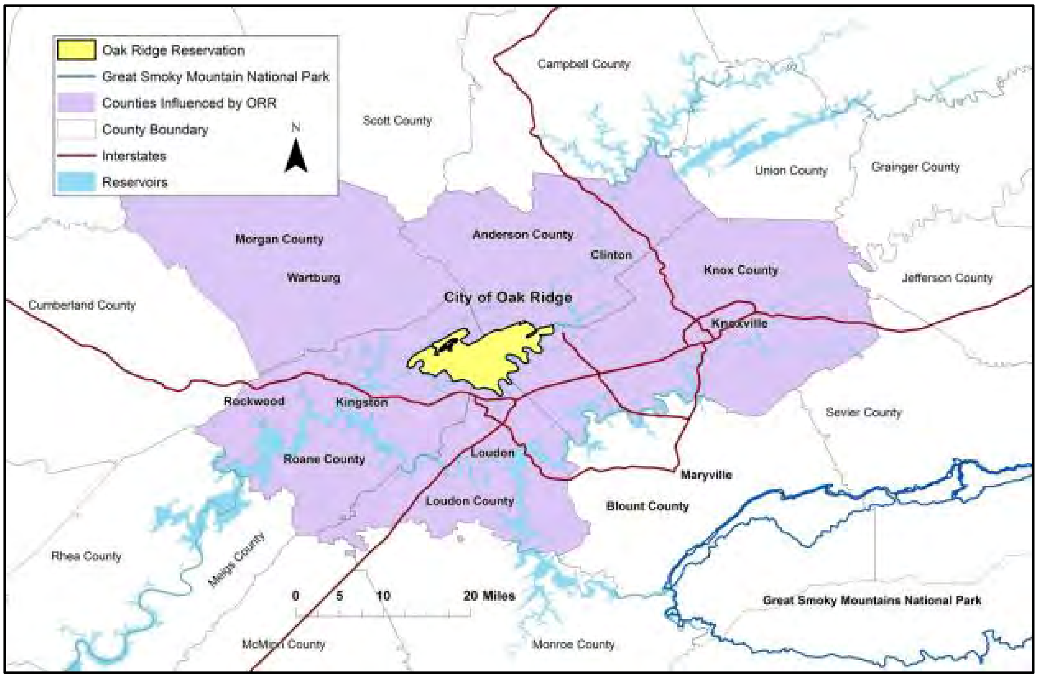


Figure1.1: Location of the Oak Ridge Reservation in Relation to Surrounding Counties

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, and Morgan is to the northwest. Portions of Meigs and Rhea counties are immediately downstream from the ORR on the Tennessee River. The nearest cities are Oak Ridge, Oliver Springs, Clinton, Kingston, Harriman, Farragut, and Lenoir City. The nearest metropolitan area, Knoxville, lies approximately 20 miles to the east (2017 DOE ASER).

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

1.3.2 Climate of the ORR Area

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

The Great Valley of East Tennessee (its shape, size, depth, and orientation), the Ridge-and-Valley physiography contained therein, the Cumberland Plateau, the Cumberland Mountains, and the Great Smoky Mountains all represent major landscape features that affect the wind flow regimes of Eastern Tennessee. Both the local terrain (for example: lithologic rock types in the subsurface and wind-directing regional land forms) 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 ESOA Agreement, the FFA Agreement and the TDEC mission statement , TDEC DoR-OR will work to assure the citizens of Tennessee that the DOE’s historic and current activities on and around the Oak Ridge Reservation (ORR), Oak Ridge, Tennessee, are being managed or performed in a manner protective of human health and the environment.

2.0 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 assess the risks 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, disposed of, etc.

Activities, associated with fuel reprocessing, chemical methods for radioisotope separation, and radioisotope production, have further added to the accumulation of these radioactive materials. Radioactive materials have been and are stored or buried at various locations on the ORR. The majority of these locations do not pose any exposure risks to the public; however, certain areas could.

At one time, little of the ORR was accessible to the public, although, more recently, there has been a movement toward making areas of the ORR more accessible to businesses and to the public. This is particularly true at ORNL and ETTP. Increased access creates situations where the public (including non-governmental, on-site workers) are more likely to be exposed to (temporarily stored or buried) radioactive materials.

Because of this risk of exposure, it is important that various areas, where exposure is more imminent on the ORR, be monitored. Areas where higher levels of radiation are known to exist are important to monitor, but, so are areas where risk levels of exposure are lower. Monitoring elevated activity levels provides information on how high levels are in those areas and how they change as those areas are remediated, materials are moved, or materials are disposed. It is also important to monitor areas with lower radiation levels to identify those areas as low-level and 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 increase.

2.1.3 Goals

The goal of the Environmental Dosimeters Project is to maintain independent monitoring to evaluate DOE's efforts to reduce radiation levels both on and in the vicinity of the ORR. Levels are expected to improve as remediation activities continue and stored materials are dispositioned.

Dosimeters will be distributed and retrieved during a two- to three-week period at the beginning of each quarter (January, April, July, and October). Every attempt will be made to complete the distribution and retrieval (change out) within a two-week period.

2.1.4 Scope

The purpose of this project is to independently assess if the potential public dose from radiation exposure is kept below the NRC NUREG-1757 reference limit of 100 mrem/yr (Schmidt et al, 2006). 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 − 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 neutrons, will also receive neutron-detecting dosimeters.

This project provides:

- Conservative estimates of the potential dose to members of the public from exposure to gamma radiation attributable to DOE activities/facilities on the ORR
- Baseline values used to assess the need and/or effectiveness of remedial actions
- Information necessary to establish trends 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 x-raying 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

There were no deviations from the Plan.

2.1.7 Results and Analysis

The Atomic Energy Act exempts DOE from outside regulation of radiological materials at its facilities, but requires DOE to manage radiological materials in a manner protective of the public health and the environment. Since access to the ORR has been predominately restricted to DOE employees or DOE contractors, locations within the fenced areas of the ORR have been inaccessible to the public. With the reindustrialization and revitalization of portions of the ORR, there has been an influx of workers employed by businesses not directly associated with DOE operations, and, in some cases, property within the reservation boundaries has been deeded to private entities.

Under State regulations, a member of the public is any individual not employed to perform duties that involve exposures to radiation. State regulations limit public exposures to radiation to a dose of 100 mrem/year (above background values and in medical applications), and the release of radiation to unrestricted areas to a dose of two mrem in any one-hour period. In this context, a restricted area is any area with limited access to protect individuals against undue risks from exposure to radiation and radioactive materials.

The dose of radiation an individual receives at any given location is dependent on the intensity and the duration of the exposure. For example, an individual standing at a site where the dose rate is one mrem/hour would receive a dose of two mrem if he or she stayed at the same spot for two hours. If that person were exposed to the same level of radiation for eight hours a day for the approximately 220 working days in one year (1,760 hours), the individual would receive a dose of 1,760 mrem in that year. It is important to note that the doses reported by the Environmental Dosimeters Project are based on an individual's exposure if that individual remained at the monitoring station twenty-four hours per day for one year (8,760 hours). Since this is unlikely, the doses reported are conservative estimates of the maximum dose an individual could receive at each location.

None of the neutron dosimeters recorded a dose during 2017. Results are organized according to location and provide a comparative analysis for 2016 and 2017 data (See Table 2.1. Offsite Dosimeter Stations.).

Since data is based on a one-year-long estimate of exposure, extrapolations were made to estimate one full year's data for any situation where data was incomplete due to missing dosimeters, deployment periods of less than one-year, and instances where certain quarters of data were eliminated because of extreme differences from the expected norm for a station. Monitoring results that varied extremely from the norm were usually found to possess elevated dosage levels for the control (theoretically unexposed) dosimeters. In instances where the result for a given dosimeter was returned as "M" (<1 mrem), the value for that quarter was assumed to be zero (0).

Results for each of the stations off the ORR are presented in TabIe 2.1 and Figure 2.1. Offsite Dosimeter Stations. In 2017, the results for offsite locations ranged from 11 to 67 mrem/year. The highest results reported for offsite locations were for the Emory Valley Pump House station A-23 (68 mrem) and station A-14 the Emory Valley Greenway (55 mrem). Station A-14, adjacent to the Emory Valley Greenway, is approximately one hundred feet from Station A-23, the Emory Valley pump station. The slightly elevated results (compared to other offsite locations) may be an artifact from the use of sediment from the East Fork Poplar Creek flood plain downstream from Y-12 and from fill during the construction of portions of the Oak Ridge sewer system (1982, MMES). For the majority, results were higher in 2017 than they were in 2016. Only one station was lower in 2017 than it was in 2016.

Table 2.1: Offsite Dosimeter Stations

Dosimeter Designation	**Location** *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	**Type of Radiation**	**Dose Reported for 2017 in mrem** *M = Below Minimum Reportable Quantity*				**2017 Total Dose**	**2016 Total Dose**
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
A-11	**Norris Dam Air Monitoring Station (Background)**	**Gamma**	**5**	**3**	**5**	**6**	**19**	**13**
A-12	**Loudoun Dam Air Monitoring Station (Background)**	**Gamma**	**4**	**2**	**5**	**5**	**16**	**10**
A-13	**Loudoun Dam Air Monitoring Station (Background)**	**Gamma**	**5**	**3**	**4**	**5**	**17**	**11**
A-13 (N)	**Loudoun Dam Air Monitoring Station (Background)**	**Neutron**	**M**	**M**	**M**	**M**	**0**	**0**
A-14	**Emory Valley Greenway**	**Gamma**	**13**	**12**	**14**	**16**	**55**	**49**
A-15	**Elza Gate**	**Gamma**	**4**	**2**	**3**	**4**	**13**	**7**
A-16	**California Avenue**	**Gamma**	**3**	**2**	**3**	**4**	**12**	**4**
A-17	**Cedar Hill Greenway**	**Gamma**	**3**	**1**	**4**	**5**	**13**	**6**
A-18	**Key Springs Road**	**Gamma**	**4**	**2**	**2**	**3**	**11**	**4**
A-19	**East Pawley**	**Gamma**	**5**	**5**	**6**	**6**	**22**	**17**
A-21	**West Vanderbilt**	**Gamma**	**8**	**5**	**6**	**Absent**	**25.3**	**27**
A-22	**Scarboro Perimeter Air Monitoring Station**	**Gamma**	**8**	**5**	**6**	**10**	**29**	**25**
A-23	**Emory Valley Pump House**	**Gamma**	**18**	**15**	**15**	**20**	**68**	**67**

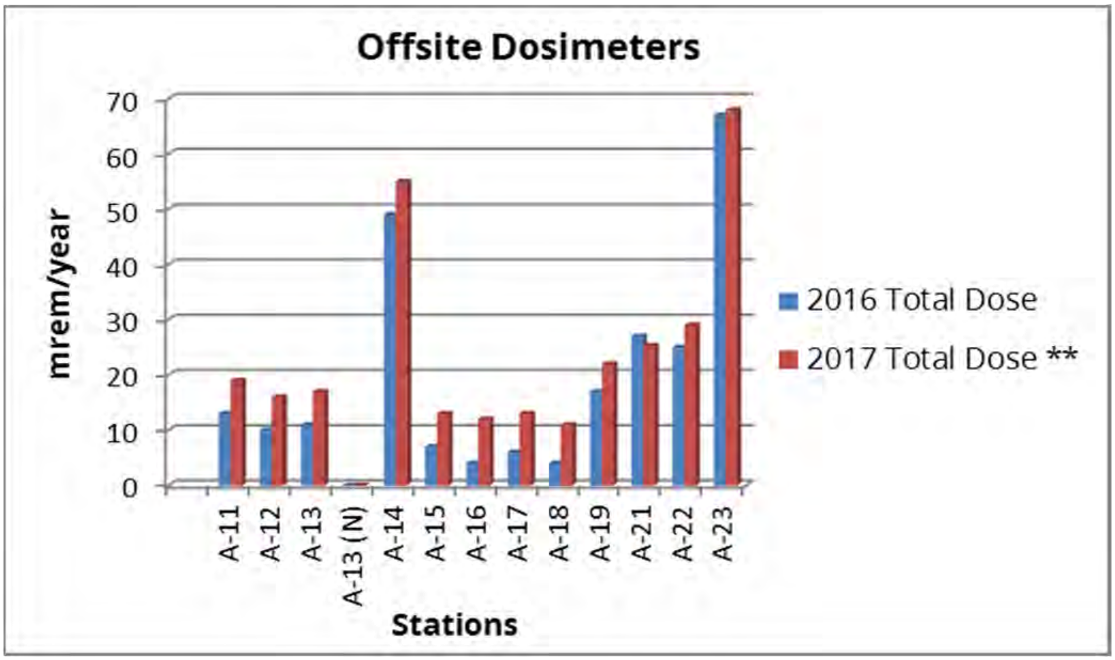


Figure 2.1: Offsite Dosimeters

East Tennessee Technology Park

The K-25 Gaseous Diffusion Plant, now known as ETTP, was constructed during World War II to produce enriched uranium for use in the first atomic weapons and later to fuel commercial- and government-owned reactors. Other site activities included uranium enrichment by liquid thermal diffusion; development and testing of the gas centrifuge method of uranium enrichment; laser isotope separation research and development; and the incineration of 35 million pounds of hazardous and radioactive waste at the Toxic Substance Control Act (TSCA) Incinerator (1991-2012).

The original gaseous diffusion facilities were put in stand-by mode in 1967 and the plant permanently closed in 1987, when the focus turned to site remediation and reindustrialization, with a long-term goal of transitioning ETTP into an industrial park. Under the re-industrialization program, portions of ETTP may be transitioned to private entities for use or development.

During 2017, the results for dosimeters stationed at ETTP ranged from two (2) to 114 mrem/year. The highest results were at stations C-42 (114 mrem/year), C-40 (41.3 mrem/year), C-44 (35 mrem/year), and C-22 (30.7 mrem/year). Station C-42 (with the highest reading) is located just off the ETTP reservation on Bear Creek Road across from an active waste handling business. Station C-42 exceeded 100 mrem/year for 2017, but was below that level in 2016 (90 mrem/year). Other results were similar to background values. The results for the ETTP dosimeters varied; with some being higher in 2017 and some being lower. See Table 2.2, below.

Total dose calculations for 2016 and 2017 are shown on Figure 2.2. Although the annual calculated dose readings may appear high on the graph, it is important to remember that an individual would have to remain at the given station for 24 hours per day for an entire year to receive the calculated dose. Table 2.2 provides the identity of the ETTP dosimeter stations. Figure 2.2 depicts the results for dosimeter data for 2016 and 2017.

Table 2.2: ETTP (Horizon Center) Dosimeter Stations

Dosimeter Designation	Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem				2017 Total Dose **	2016 Total Dose **
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
C-10	K-1401 Building (West side)	Gamma	6	6	7	9	28	23
C-12	K-1420 Building	Gamma	M	M	2	2	4	2
C-17	K-25 Building	Gamma	4	1	3	Absent	10.7	4
C-18	K-27 Building (SW Corner)	Gamma	4	4	6	5	19	22
C-19	K-27 Building (South Side)	Gamma	6	6	7	8	27	27
C-20	K-27 Building (SE Corner)	Gamma	2	2	3	4	11	13
C-21	K-27 Building (NW Corner)	Gamma	5	Absent	5	8	24	30
C-22	K-27 Building (North Side)	Gamma	4	Absent	10	9	30.7	26
C-23	K-27 Building (NE Corner)	Gamma	M	1	M	2	3	4
C-24	K-901 Pond	Gamma	2	1	3	4	10	8
C-25	K-1070-A Burial Ground	Gamma	3	3	2	5	13	9
C-27	ED1 On Pole	Gamma	6	7	7	9	29	24
C-28	K-25 Portal 5	Gamma	5	2	6	6	19	12
C-29	TSCA West Gate	Gamma	M	M	2	M	2	2
C-30	TSCA North Gate	Gamma	M	M	1	2	3	4
C-40	ETTP Visitors Overlook	Gamma	ABSENT	7	11	13	41.3	26
C-41	K-770 Scrap Yard	Gamma	3	M	2	2	7	3
C-42	Bear Creek Road ~ 2800 Feet From Clinch River	Gamma	25	26	29	34	114	90
C-43	Grassy Creek Embayment On The Clinch River	Gamma	4	2	2	5	13	9
C-44	White Wing Scrap Yard	Gamma	9	7	9	10	35	28
C-50	ETTP Uranium Storage Yard (East)	Gamma	ABSENT	2	2	M	5.3	12
C-51	ETTP Uranium Storage Yard (South)	Gamma	4	5	4	6	19	42
C-52	ETTP Uranium Storage Yard (South)	Gamma	3	4	5	7	19	37
C-53	ETTP Uranium Storage Yard (West)	Gamma	M	M	4	2	6	45

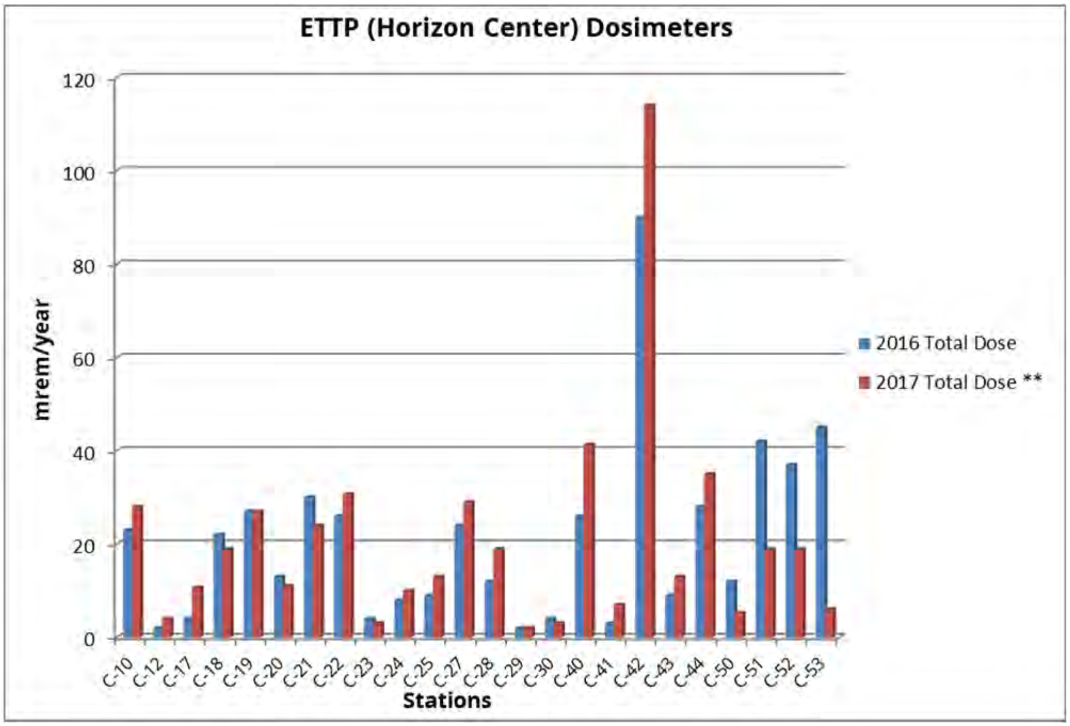


Figure 2.2: Dosimeter data for 2016 and 2017

The Y-12 National Security Complex

Similar to K-25, Y-12 was constructed during World War II to produce enriched uranium by the electromagnetic separation process. In ensuing years, the facility produced fuel for naval reactors, conducted lithium/mercury enrichment operations, manufactured components for nuclear weapons, dismantled nuclear weapons, and stored enriched uranium. A number of Y-12 buildings were used by ORNL for various pursuits: animal studies, Molten Salt Reactor Experiment (MSRE) research, radioactive isotope production, and the Aircraft Nuclear Propulsion Program. Y-12 is the least accessible by the public of the three DOE Oak Ridge facilities.

Three locations within the Y-12 complex are currently being monitored: 1.) the Uranium Oxide Storage Vaults, 2.) the Walk-In Pits, and 3.) the East Perimeter Air Monitoring Station. Table 2.3 provides the locations of the Y-12 dosimeter stations and Figure 2.3 depicts the Y-12 dosimeter station results for the period 2016-2017.

The results for the Y-12 locations ranged from 19 to 21 mrem/year. These low levels are expected because the majority of the material handled at Y-12 emits primarily alpha and beta (not gamma) radiation. Results for 2017 were slightly higher than for 2016.

Table 2.3: Y-12 Dosimeter Stations

Dosimeter Designation	Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem *M = Below Minimum Reportable Quantity*				2017 Total Dose **	2016 Total Dose **
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
B-10	**Y-12 East Perimeter Air Monitoring**	**Gamma**	**4**	**4**	**5**	**6**	**19**	**10**
B-11	**Y-12 at back side of Walk In Pits**	**Gamma**	**6**	**3**	**6**	**6**	**21**	**16**
B-12	**Y-12 Uranium Oxide Storage Vaults**	**Gamma**	**5**	**3**	**6**	**6**	**20**	**13**

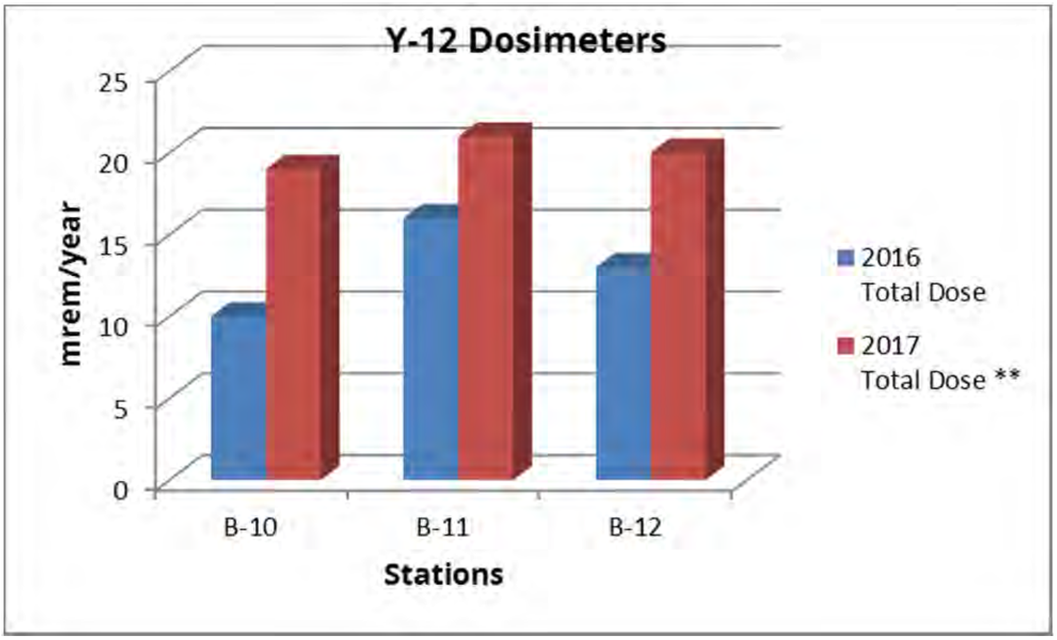


Figure 2.3: Y-12 Dosimeter Stations

Environmental Management Waste Management Facility

The EMWMF was constructed in 2002 to dispose of radioactive and hazardous wastes generated by remedial activities from all three plants on the ORR. The facility operates under the authority of CERCLA, and waste approved for disposal is limited by the waste acceptance criteria agreed upon by DOE, EPA, and the State. EMWMF is located immediately to the west of the Y-12 complex (in Bear Creek Valley). Monitoring stations have been established at the boundary of the waste disposal cells and at secondary waste management systems (contact water ponds). For this report, the dosimeters surrounding the EMWMF waste cell and those surrounding the contact water ponds are discussed, separately. During 2017, the results for the contact water pond dosimeters ranged from 12 to 44 mrem/year. Dosimeters surrounding the EMWMF waste cell ranged from 19 to 45 mrem/year. The results for the contact water ponds were slightly higher in 2017 than they were in 2016. This is also true for the majority of the stations for the EMWMF waste cell.

Figure 2.4 depicts the results for EMWMF dosimeter data for the contact water ponds and Table2.4 provides the identity of the EMWMF Contact Water Pond stations for 2016-2017. Table 2.5 identifies the monitoring stations and Figures 2.5 (A and B) depicts the results for dosimeter data for the EMWMF waste cell for the period 2015-2016.

Table 2.4: EMWMF Contact Water Ponds Dosimeters

Dosimeter Designation (Dosimeter number)	Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem *M = Below Minimum Reportable Quantity*				2017 Total Dose **	2016 Total Dose **
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
B-24	**Leachate Collection Tanks at Gate**	**Gamma**	**3**	**2**	**3**	**4**	**12**	**9**
B-25	**Contact Water Ponds Fence (NW Side)**	**Gamma**	**7**	**9**	**10**	**12**	**38**	**38**
B-26	**Contact Water Ponds Fence (NE Side)**	**Gamma**	**7**	**8**	**8**	**8**	**31**	**35**
B-29	**Contact Water Ponds Fence (SE Side)**	**Gamma**	**9**	**8**	**13**	**14**	**44**	**44**
B-30	**Contact Water Ponds Fence (SW Side)**	**Gamma**	**7**	**7**	**9**	**12**	**35**	**40**
B-32	**Contact Water Tanks Fence (NE Side)**	**Gamma**	**3**	**4**	**5**	**7**	**19**	**20**
B-33	**Contact Water Tanks Fence (NW Side)**	**Gamma**	**2**	**4**	**6**	**7**	**19**	**21**
B-36	**Contact Water Tanks Fence (SW Side)**	**Gamma**	**5**	**7**	**9**	**11**	**32**	**31**
B-37	**Contact Water Tanks Fence (SE Side)**	**Gamma**	**6**	**6**	**8**	**8**	**28**	**30**

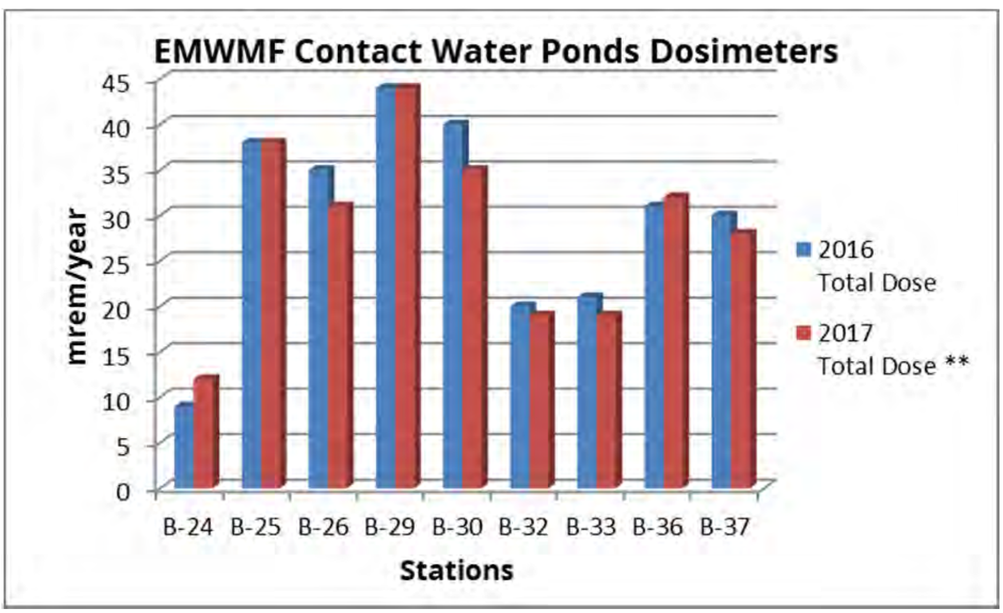
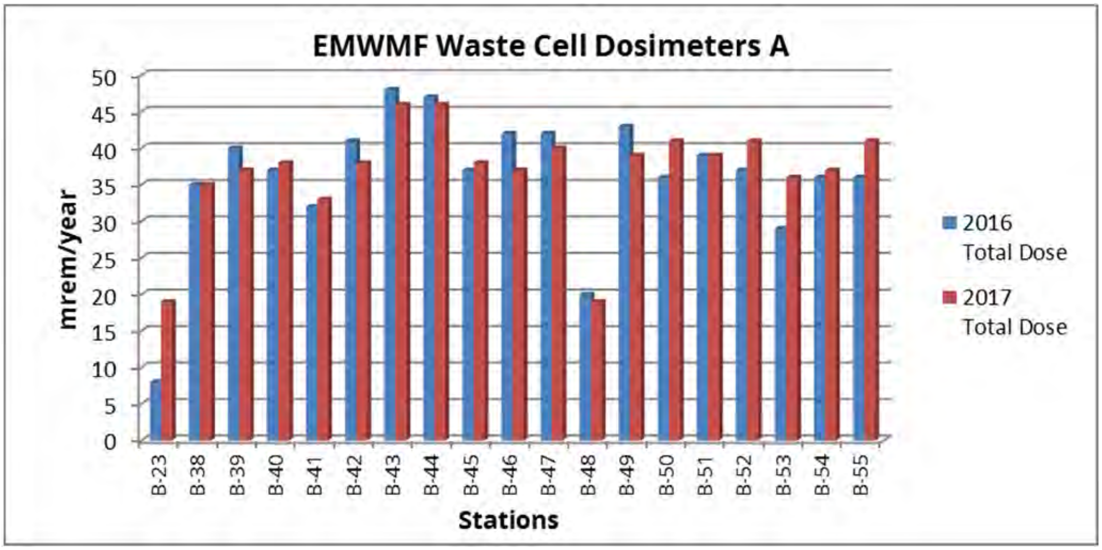


Figure 2.4: EMWMF Contact Water Ponds Dosimeters

Table 2.5: EMWMF Waste Cell Dosimeters

Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem *M = Below Minimum Reportable Quantity*				2017 Total Dose **	2016 Total Dose **
		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
Waste Cell Perimeter Fence @ Gate	**Gamma**	**5**	**4**	**4**	**6**	**19**	**23**
Waste Cell Perimeter Fence (SE Corner)	**Gamma**	**6**	**7**	**10**	**12**	**35**	**35**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**9**	**9**	**8**	**11**	**37**	**40**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**8**	**9**	**11**	**10**	**38**	**37**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**7**	**6**	**9**	**11**	**33**	**32**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**8**	**8**	**10**	**12**	**38**	**41**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**10**	**10**	**13**	**13**	**46**	**48**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**9**	**10**	**12**	**15**	**46**	**47**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**7**	**10**	**9**	**12**	**38**	**37**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**7**	**9**	**10**	**11**	**37**	**42**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**10**	**9**	**9**	**12**	**40**	**42**
Waste Cell Perimeter Fence (South Side)	**Gamma**	**2**	**5**	**7**	**5**	**19**	**20**
Waste Cell Perimeter Fence (SW Corner)	**Gamma**	**8**	**9**	**10**	**12**	**39**	**43**
Waste Cell Perimeter Fence (West Side)	**Gamma**	**8**	**10**	**10**	**13**	**41**	**36**
Waste Cell Perimeter Fence (West Side)	**Gamma**	**7**	**8**	**12**	**12**	**39**	**39**
Waste Cell Perimeter Fence (West Side)	**Gamma**	**8**	**9**	**12**	**12**	**41**	**37**
Waste Cell Perimeter Fence (West Side)	**Gamma**	**6**	**8**	**11**	**11**	**36**	**29**
Waste Cell Perimeter Fence (West Side)	**Gamma**	**8**	**8**	**9**	**12**	**37**	**36**
Waste Cell Perimeter Fence (West Side)	**Gamma**	**9**	**10**	**11**	**11**	**41**	**36**
Waste Cell Perimeter Fence (NW Corner)	**Gamma**	**9**	**10**	**14**	**12**	**45**	**40**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**7**	**7**	**10**	**10**	**34**	**41**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**9**	**8**	**13**	**12**	**42**	**44**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**8**	**9**	**9**	**13**	**39**	**36**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**10**	**10**	**10**	**11**	**41**	**38**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**10**	**10**	**11**	**13**	**44**	**46**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**5**	**5**	**8**	**7**	**25**	**29**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**6**	**8**	**11**	**13**	**38**	**40**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**6**	**9**	**11**	**11**	**37**	**39**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**8**	**9**	**10**	**13**	**40**	**44**
Waste Cell Perimeter Fence (North Side)	**Gamma**	**7**	**7**	**10**	**12**	**36**	**37**
Waste Cell Perimeter Fence (NE Corner)	**Gamma**	**7**	**8**	**10**	**13**	**38**	**38**
Waste Cell Perimeter Fence (East side)	**Gamma**	**3**	**5**	**7**	**6**	**21**	**13**
Waste Cell Perimeter Fence (East side)	**Gamma**	**6**	**6**	**9**	**9**	**30**	**34**
Waste Cell Perimeter Fence (East side)	**Gamma**	**7**	**6**	**9**	**10**	**32**	**34**
Waste Cell Perimeter Fence (East side)	**Gamma**	**6**	**7**	**9**	**10**	**32**	**30**
Waste Cell Perimeter Fence (East side)	**Gamma**	**6**	**7**	**7**	**9**	**29**	**27**
Waste Cell Perimeter Fence (East side)	**Gamma**	**7**	**7**	**9**	**10**	**33**	**31**
Waste Cell Perimeter Fence (East side)	**Gamma**	**4**	**6**	**7**	**9**	**26**	**29**



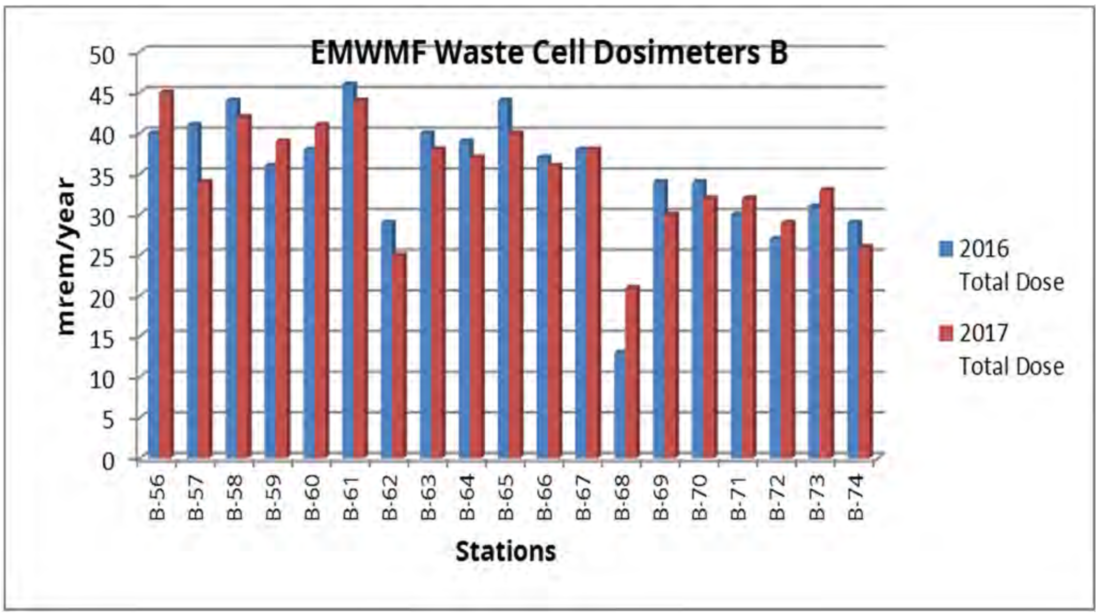


Figure 2.5: EMWMF Waste Cell Dosimeters:

A (Stations: B-23-B-55; B (Stations: B-56-B-74)

Oak Ridge National Laboratory

ORNL was established during the World War II Manhattan Project Era. Its wartime mission focused on reactor research and the production of plutonium and other radionuclides that were chemically extracted from uranium irradiated in ORNL's Graphite Reactor and other ORNL and Hanford reactors. Throughout the years, thirteen reactors were constructed and operated at the ORNL site, including the currently active High Flux Isotope Reactor (HFIR). Since its inception, ORNL has evolved into DOE's largest multi-program national science and energy laboratory hosting thousands of visitors each year. Land adjacent to ORNL's main campus has been deeded to organizations outside of DOE, buildings have been constructed using private funds, and non-DOE contractor facilities now occupy that land adjacent to ORNL (ORAU, 2003).

Many of the remaining facilities at ORNL (constructed during World War II and the cold war era) are contaminated, have fallen into disrepair, and complicate remediation. Access to the site is controlled for security; however, admittance is allowed with an appropriate visitor's pass and the appropriate training. Within the access-controlled areas, certain locations have been designated as radiation areas. Access to these locations, legacy burial grounds, and associated facilities is restricted for safety reasons.

Due to the nature of some radioactive contaminants at ORNL (high-energy gamma emitters), the highest dose rates in the dosimetry project are typically associated with stations at ORNL. The dose rates measured at ORNL in 2017, ranged from zero to 13,667 mrem for the year. The dose rates reported reflect the dose that a person could receive if a person remained at the monitoring station for 365 days a year, 24 hours a day. The actual dose any individual would receive would depend on the time spent at the location, which in all cases would be a fraction of that assumed for the dose estimates. These estimates are conservative, but they identify locations that merit further evaluation. A complete listing of all stations related to ORNL (except SNS) is included in Table 2.6.

Three stations (D-36, D-37, and D-42) showed substantial decreases in exposure during 2017. Station D-36 was 5,965 mrem/year in 2016 and only 3264 mrem/year in 2017; station D-37 was 169 mrem/year in 2016 and only 51 mrem/year in 2017; station D-42 was 691 mrem/year in 2016 and only 307 mrem/year in 2016. The differences at D-36 and D-37 are likely due to changes in what is being stored; the difference at D-42 is likely due to activities leading to facility shutdown.

For this report, discussions of dosimeters at ORNL are grouped, as follows:

- ORNL Main Campus [dosimeters on the main campus of ORNL as well as all other dosimeters not in Melton Valley, at the Spallation Neutron Source (SNS), or South of Melton Valley]. See Table 2.7, Figure 2.6.
- ORNL Melton Valley (dosimeters in the waste areas of Melton Valley). See Table 2.8, Figure 2.7.
- ORNL south of Melton Valley (dosimeters at Tower Shielding and Cesium Forest). See Table 2.9, Figure 2.8.
- ORNL SNS. See Table 2.11, Figure 2.10.

During 2017, sixteen monitoring stations at ORNL reported results that exceeded 100 mrem over the span of the year. Six of the monitoring stations are located on the main campus of ORNL, away from the most heavily traveled areas of the facility except for station D-14. Eight of the sites are located in the considerably less traveled ORNL Melton Valley Area (Table 2.8; Figure 2.7).

Note: Duplicate dosimeter is at New Hydrofracture Facility. Two of the sites are in the Cesium Forest located south of the Melton Valley (Table 2.9; Figure 2.8). One site is at the SNS (Table 2.11; Figure 2.10).

Table 2.6: ORNL-Related Dosimeters (Except SNS)

Dosimeter Designation	Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem				2017 Total Dose **	2016 Total Dose **
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
D-10	Freels Bend Entrance	Gamma	6	3	7	5	21	12
D-12	Graphite Reactor	Gamma	7	6	5	7	25	26
D-13	South Side Of Central Ave.	Gamma	19	19	20	22	80	62
D-14	North Side Of Central Ave.	Gamma	53	54	60	67	234	229
D-16	Old X-3513 Impoundment	Gamma	5	4	5	7	21	17
D-17	White Oak Dam @ Highway 95	Gamma	6	2	3	4	15	2
D-18	SWSA 6 On Fence @ Highway 95	Gamma	6	3	5	7	21	16
D-19	Haw Ridge @ Melton Valley Access Rd.	Gamma	36	41	43	48	168	145
D-20	Molten Salt Reactor Experiment	Gamma	35	14	15	17	81	88
D-21	White Oak Creek Weir @ Lagoon Rd	Gamma	22	25	25	30	102	115
D-22	Building X-7819	Gamma	7	6	7	10	30	23
D-23	Confluence of White Oak Ck & Melton Branch	Gamma	90	76	76	91	333	391
D-24	Old Hydrofracture Pond	Gamma	12	12	14	15	53	52
D-26	SWSA 5 (South 7828)	Gamma	4	4	4	4	16	9
D-27	Homogeneous Reactor Experiment Site	Gamma	4	2	3	5	14	9
D-28	High Flux Isotope Reactor	Gamma	8	6	9	11	34	27
D-30	SWSA 5 TRU Waste Trench	Gamma	34	28	35	42	139	142
D-31	SWSA 5 Near Storage Tank Area	Gamma	21	16	18	24	79	77
D-32	New Hydrofracture Facility	Gamma	108	117	118	148	491	432
D-33	Melton Valley Haul Road Near Creek	Gamma	119	125	156	149	549	606
D-34	Cask Storage Containment Area	Gamma	1175	1189	1229	1424	5017	5136
D-35	Building 3038 N	Gamma	87	90	83	81	341	410
D-36	Building 3607 Material Storage Area	Gamma	656	711	883	1014	3264	5965
D-37	TH4 Tank	Gamma	9	16	12	14	51	169
D-38	Hot Storage Garden (3597)	Gamma	835	1069	1154	1229	4287	4531
D-39	Building 3618	Gamma	60	58	65	71	254	239
D-40	Tower Shielding Facility @ West Gate	Gamma	2	3	5	4	14	17
D-41	Tower Shielding Facility @ North Gate	Gamma	3	2	4	2	11	12
D-42	Neutralization Plant	Gamma	15	17	153	122	307	691
D-50	White Oak Creek @ Coffer Dam	Gamma	M	M	M	M	0	0
D-51	Cesium Fields @ Clinch River	Gamma	6	6	8	8	28	26
D-52	Cesium Forest Boundary	Gamma	19	13	14	18	64	58
D-53	Cesium Forest Boundary (Duplicate)	Gamma	14	13	18	17	62	58
D-54	Cesium Forest @ Base Of Tree	Gamma	4274	2136	3707	3550	13667	11651
D-55	Cesium Forest Satellite Plot	Gamma	50	77	85	97	309	331
D-60	ORNL Melton Valley Trench 7	Gamma	13	11	12	15	51	50
D-61	New Hydrofracture Facility	Gamma	106	115	124	147	492	446
D-61 (N)	New Hydrofracture Facility	Neutron	M	4	30	M	34	0
D-62	ORAU Pumphouse Road	Gamma	6	4	8	12	30	18
D-62 (N)	ORAU Pumphouse Road	Neutron	M	M	M	M	0	0

Table 2.7: ORNL Campus Dosimeters >100 mrem/year

Dosimeter Designation (Dosimeter number)	Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem *M = Below Minimum Reportable Quantity*				2017 Total Dose **	2016 Total Dose **
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
D-14	**North Side Of Central Ave.**	**Gamma**	**53**	**54**	**60**	**67**	**234**	**229**
D-35	**Building 3038 N**	**Gamma**	**87**	**90**	**83**	**81**	**341**	**410**
D-36	**Building 3607 Material Storage Area**	**Gamma**	**656**	**711**	**883**	**1014**	**3264**	**5965**
D-38	**Hot Storage Garden (3597)**	**Gamma**	**835**	**1069**	**1154**	**1229**	**4287**	**4531**
D-39	**Building 3618**	**Gamma**	**60**	**58**	**65**	**71**	**254**	**239**
D-42	**Neutralization Plant**	**Gamma**	**15**	**17**	**153**	**122**	**307**	**691**

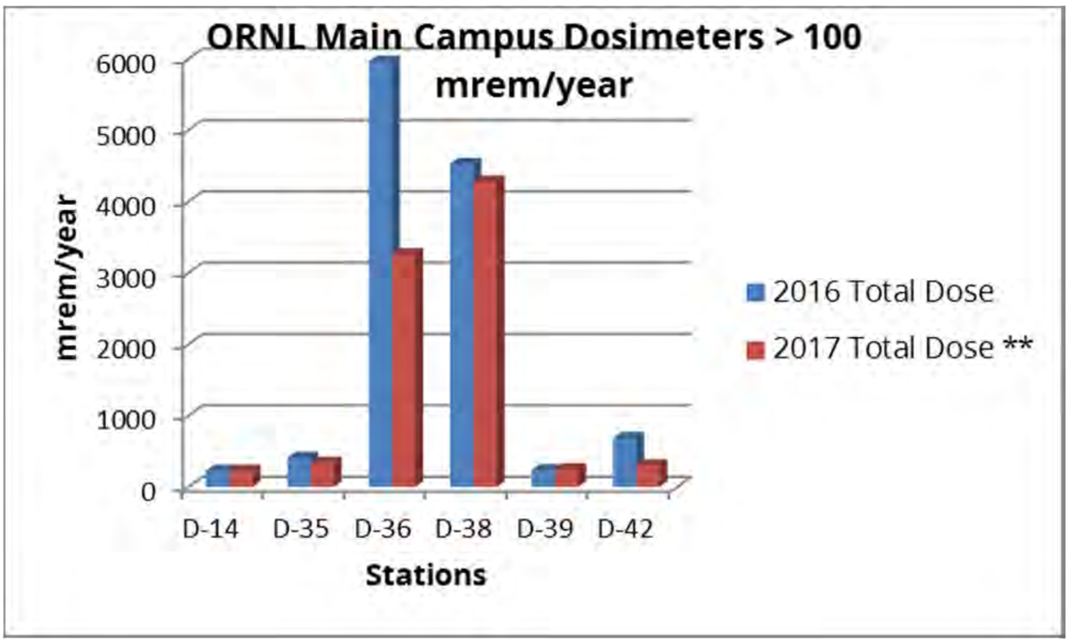


Figure 2.6: ORNL Main Campus Dosimeters >100 mrem/year

Table 2.8: ORNL Melton Valley Dosimeters >100 mrem/year

Dosimeter Designation	Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem *M = Below Minimum Reportable Quantity*				2017 Total Dose	2016 Total Dose
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
D-19 (75)	Haw Ridge @ Melton Valley Access Rd.	Gamma	33	29	42	41	145	148
D-21	White Oak Creek Weir @ Lagoon Rd	Gamma	22	25	25	30	102	115
D-23	Confluence of White Oak Ck & Melton Branch	Gamma	90	76	76	91	333	391
D-30	SWSA 5 TRU Waste Trench	Gamma	34	28	35	42	139	142
D-32	New Hydrofracture Facility	Gamma	108	117	118	148	491	432
D-33	Melton Valley Haul Road Near Creek	Gamma	119	125	156	149	549	606
D-34	Cask Storage Containment Area	Gamma	1175	1189	1229	1424	5017	5136
D-61	New Hydrofracture Facility	Gamma	106	115	124	147	492	446

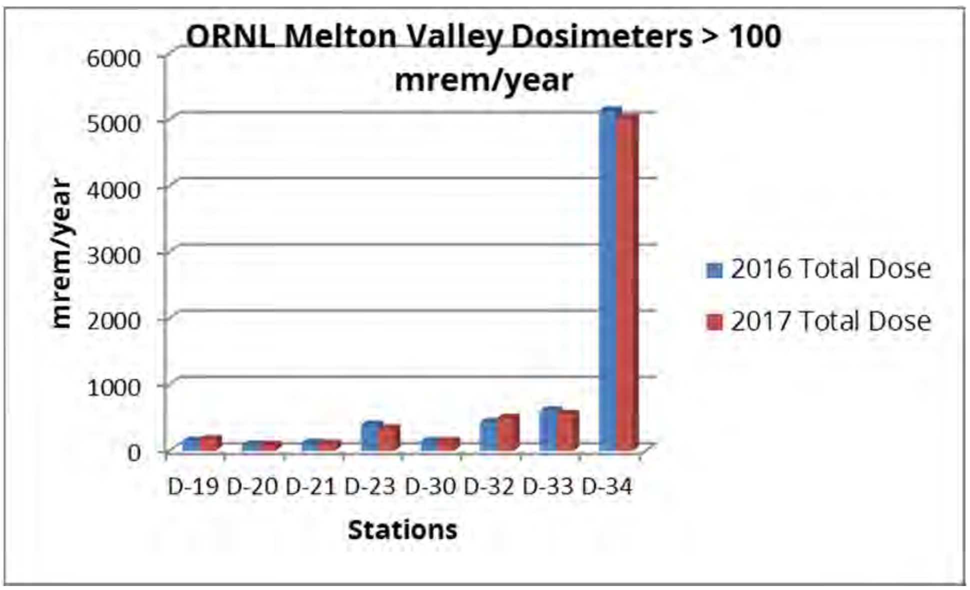


Figure 2.7: ORNL Melton Valley Dosimeters >100 mrem/year

The Cesium Forest is located in a remote, gated area of the reservation posted as a radiation area. Access to the area is obtained with the assistance of ORNL personnel. A dosimeter is secured near the trunk of one tree on the end of a plastic pole. The use of the pole allows for exchange of the dosimeter without entering the roped radiation area. Variability in the year-to-year results, as seen in Table 2.7, is due primarily to the inexact nature of the placement of the dosimeter near the tree. The higher readings (for 2017 compared to 2016) may be due (in part) to a more secure placement of the dosimeter at the base of the sample tree. The highest dose reported in the program for 2017 (13,667 mrem) was at station D-54, which is located at the base of a tree at the Cesium Forest.

In 1962, trees in the Cesium Forest were injected with a total of 360 millicuries of cesium-137 as part of a study on the isotope's behavior in a forest ecosystem (Witkamp, 1964). Overall, the dose rates at the ORNL locations increased slightly in 2017 when compared to 2016 results. Most of these locations are associated with legacy facilities that are either undergoing or are scheduled for remediation. The variability in dose rates, measured from year-to-year, could reflect ongoing activities at ORNL and/or natural variability in the measurement of dose rates. As the cleanup continues, the dose rate measurements are expected to decrease. Exceptions may be found where activities continue. All locations exceeding 100 mrem (tables 2.7, 2.8, and 2.9), warrant continued monitoring.

Table 2.9: ORNL Dosimeters >100 mrem/year South of Melton Valley

Dosimeter Designation	Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem				2017Total Dose **	2016 Total Dose **
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
D-54	**Cesium Forest @ Base Of Tree**	**Gamma**	**4274**	**2136**	**3707**	**3550**	**13667**	**11651**
D-55	**Cesium Forest Satellite Plot**	**Gamma**	**50**	**77**	**85**	**97**	**309**	**331**

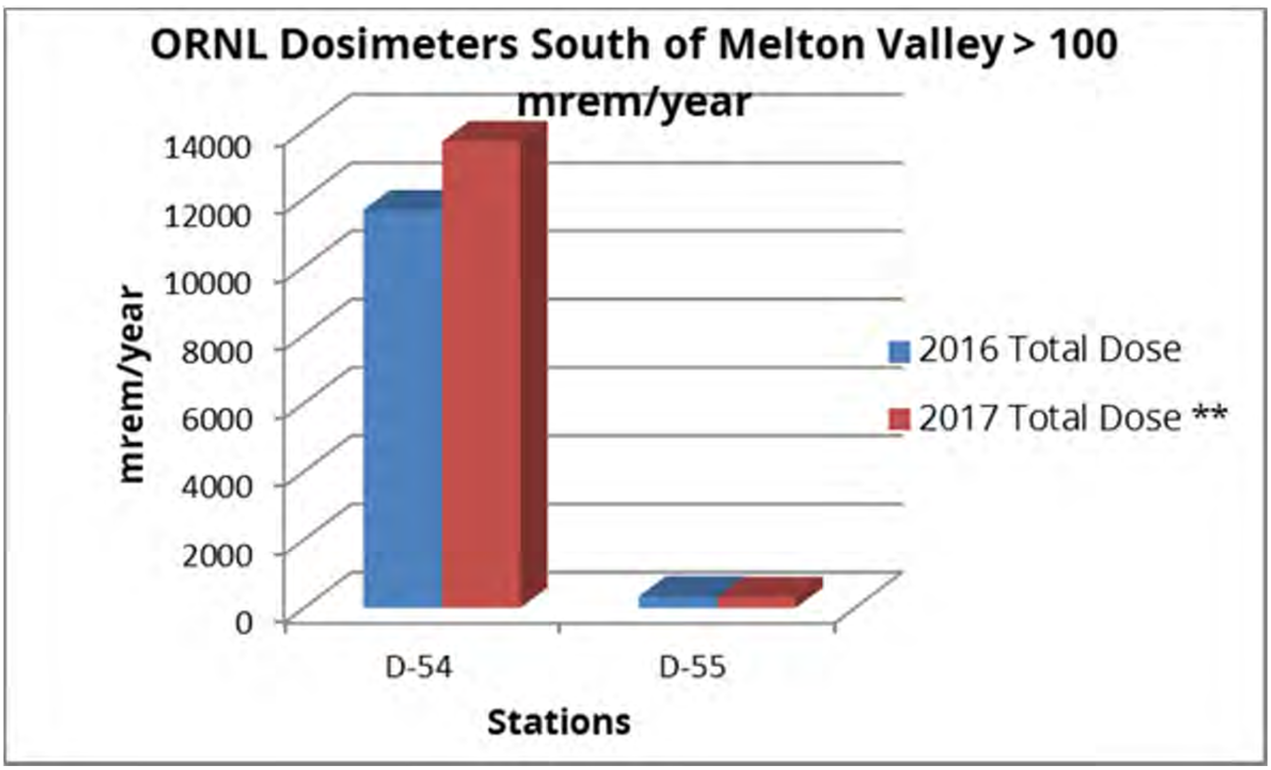


Figure 2.8: ORNL Dosimeters South of Melton Valley

Shown in Table 2.10 and Figure 2.9 are a number of the monitored sites at ORNL that do not exceed an exposure rate of 100 mrem/year. Some of these sites (such as the Cesium Forest Boundary [D-51, D-52]; and, South Side of Central Ave. [D-13]) are located in close proximity to sites that do exceed that level. Other sites on this list (TH4 Tank [D37]; Molten Salt Reactor Experiment [D-20]) have exceeded the 100 mrem/year threshold in the past, but were below it in 2017. Including these sites in the environmental dosimeter project helps to demonstrate that not all areas, even in otherwise contaminated parts of ORNL, are problematic. This should provide some reassurance to the public.

Table 2.10: ORNL Stations (Except SNS) with Annual Readings <100 mrem/year

Dosimeter Designation	Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem *M = Below Minimum Reportable Quantity*				2017 Total Dose **	2016 Total Dose **
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
D-10	Freels Bend Entrance	Gamma	6	3	7	5	21	12
D-12	Graphite Reactor	Gamma	7	6	5	7	25	26
D-13	South Side Of Central Ave.	Gamma	19	19	20	22	80	62
D-16	Old X-3513 Impoundment	Gamma	5	4	5	7	21	17
D-17	White Oak Dam @ Highway 95	Gamma	6	2	3	4	15	2
D-18	SWSA 6 On Fence @ Highway 95	Gamma	6	3	5	7	21	16
D-20	Molten Salt Reactor Experiment	Gamma	35	14	15	17	81	88
D-22	Building X-7819	Gamma	7	6	7	10	30	23
D-24	Old Hydrofracture Pond	Gamma	12	12	14	15	53	52
D-26	SWSA 5 (South 7828)	Gamma	4	4	4	4	16	9
D-27	Homogeneous Reactor Experiment Site	Gamma	4	2	3	5	14	9
D-28	High Flux Isotope Reactor	Gamma	8	6	9	11	34	27
D-31	SWSA 5 Near Storage Tank Area	Gamma	21	16	18	24	79	77
D-37	TH4 Tank	Gamma	9	16	12	14	51	169
D-40	Tower Shielding Facility @ West Gate	Gamma	2	3	5	4	14	17
D-41	Tower Shielding Facility @ North Gate	Gamma	3	2	4	2	11	12
D-50	White Oak Creek @ Coffer Dam	Gamma	M	M	M	M	0	0
D-51	Cesium Fields @ Clinch River	Gamma	6	6	8	8	28	26
D-52	Cesium Forest Boundary	Gamma	19	13	14	18	64	58
D-53	Cesium Forest Boundary (Duplicate)	Gamma	14	13	18	17	62	58
D-60	ORNL Melton Valley Trench 7	Gamma	13	11	12	15	51	50
D-62	ORAU Pumphouse Road	Gamma	6	4	8	12	30	18
D-62 (N)	ORAU Pumphouse Road	Neutron	M	M	M	M	0	0

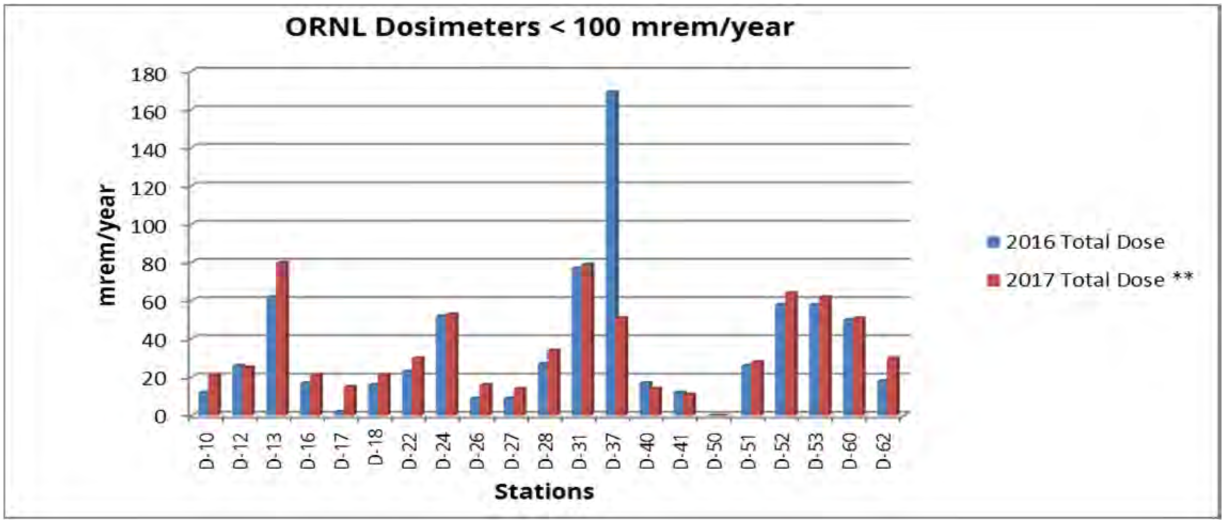


Figure 2.9: ORNL (Except SNS) Dosimeters with Annual Readings <100 mrem/year

Spallation Neutron Source

The SNS is a research facility that produces the most intense pulsed-neutron beams in the world. The SNS was designed and built in partnership with six DOE national laboratories: 1.) Lawrence Berkeley in California, 2.) Los Alamos in New Mexico, 3.) Argonne in Illinois, 4.) Brookhaven in New York, 5.) Thomas Jefferson in Virginia, and 6.) ORNL in Tennessee.

The production process begins with a source that produces negatively-charged hydrogen ions, consisting of one proton and two electrons. The hydrogen ions are injected into a linear-particle accelerator (linac) where they are accelerated to high energies and passed through a magnetic foil that strips off the electrons, converting the ions to protons. The protons pass into an accumulator ring, which releases them in high-energy pulses directed toward a liquid mercury target. When the protons strike the nucleus of the mercury atoms in the target, neutrons are "spalled" or “thrown off” along with other spallation products.

The neutrons released by the spallation process are guided through beam lines to areas containing specialized instruments for conducting experiments. During the process, high-energy protons interact with nuclei of the accelerator components and materials in the air inside the facility, converting the struck nucleus to that of a different isotope, which is often radioactive.

Air evacuated from the facility is:

- held to allow short-lived, radioisotopes to decay
- filtered to remove particulates
- released to the atmosphere through the central exhaust stack

DoR-OR placed dosimeters at the SNS near the linac, accumulator ring, target building, central exhaust stack, and other locations of interest (Table 2.10, Figure 2.9). All DoR-OR dosimeters at SNS are co-located with dosimeters placed by the RADCON staff at SNS. Results for the DoR-OR and SNS RADCON dosimeters have been and will continue to be compared. When evaluated the results of the collocated TDEC and DOE dosimeters are comparable; however, the OSL dosimeters used by DoR-OR record radiation exposure often not detected by the less sensitive blue TLDs used by SNS RADCON.

During 2017, the results ranged from one (1) to 460 mrem/year. Only one reading exceeded 100 mrem in 2017 for one dosimeter located on the central exhaust stack (460 mrem/year). This reading was considerably less than half the reading obtained in 2016 (1250 mrem/year). During 2017, the beam line experienced a number of outages for maintenance and target replacement.

Table 2.11: SNS Dosimeters

Dosimeter Designation	Location *Optically Stimulated Luminescent Dosimeter (OSLs) & neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2017 in mrem *M = Below Minimum Reportable Quantity*				2017 Total Dose **	2016 Total Dose **
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
D-70	Central Exhaust Facility	Gamma	118	54	202	86	460	1250
D-70 (N)	Central Exhaust Facility	Neutron	M	M	M	M	0	0
D-71	Ring Building Perimeter Fence	Gamma	5	4	9	6	24	30
D-71 (N)	Ring Building Perimeter Fence	Neutron	M	M	M	M	0	0
D-72	Beam-dump Bldg # 8520	Gamma	M	3	7	7	17	18
D-72 (N)	Beam-dump Bldg # 8520	Neutron	M	Damaged	M	M	0	0
D-73	SNS Water Tower (overlook) North	Gamma	8	5	15	11	39	51
D-74	LINAC Beam Tunnel Berm West (#1)	Gamma	6	5	9	9	29	30
D-74 (N)	LINAC Beam Tunnel Berm West (#1)	Neutron	M	M	M	M	0	0
D-75	LINAC Beam Tunnel Berm (#2)	Gamma	8	5	12	10	35	43
D-75 (N)	LINAC Beam Tunnel Berm (#2)	Neutron	M	M	M	M	0	0
D-76	LINAC Beam Tunnel Berm (#3)	Gamma	7	6	9	8	30	34
D-76 (N)	LINAC Beam Tunnel Berm (#3)	Neutron	M	Damaged	M	M	0	0
D-77	LINAC Beam Tunnel Berm (#4)	Gamma	9	6	13	11	39	50
D-77 (N)	LINAC Beam Tunnel Berm (#4)	Neutron	M	M	M	M	0	0
D-78	LINAC Beam Tunnel Berm (#5)	Gamma	7	6	12	10	35	32
D-78 (N)	LINAC Beam Tunnel Berm (#5)	Neutron	M	M	M	M	0	0
D-79	LINAC Beam Tunnel Berm (#6)	Gamma	9	7	17	12	45	58
D-79 (N)	LINAC Beam Tunnel Berm (#6)	Neutron	M	M	M	M	0	0
D-80	LINAC Beam Tunnel Berm East (#7)	Gamma	8	4	11	8	31	40
D-80 (N)	LINAC Beam Tunnel Berm East (#7)	Neutron	M	M	M	M	0	0
D-81	SNS Cooling Tower South	Gamma	2	M	5	4	11	21
D-82	Target Bldg West	Gamma	2	1	2	3	8	12
D-82 (N)	Target Bldg West	Neutron	M	M	M	M	0	0
D-83	Target Bldg South	Gamma	2	M	2	3	7	8
D-83 (N)	Target Bldg South	Neutron	M	Damaged	M	M	0	0
D-84	Target Bldg East	Gamma	5	2	7	7	21	23
D-84 (N)	Target Bldg East	Neutron	M	M	M	M	0	0
D-85	SNS Administrative Building	Gamma	2	2	2	5	11	1
D-85 (N)	SNS Administrative Building	Neutron	M	M	M	M	0	0

Table 2.12 provides additional descriptive information to aid in the understanding of tables 2.1 through 2.11 for the Environmental Dosimeters Project.

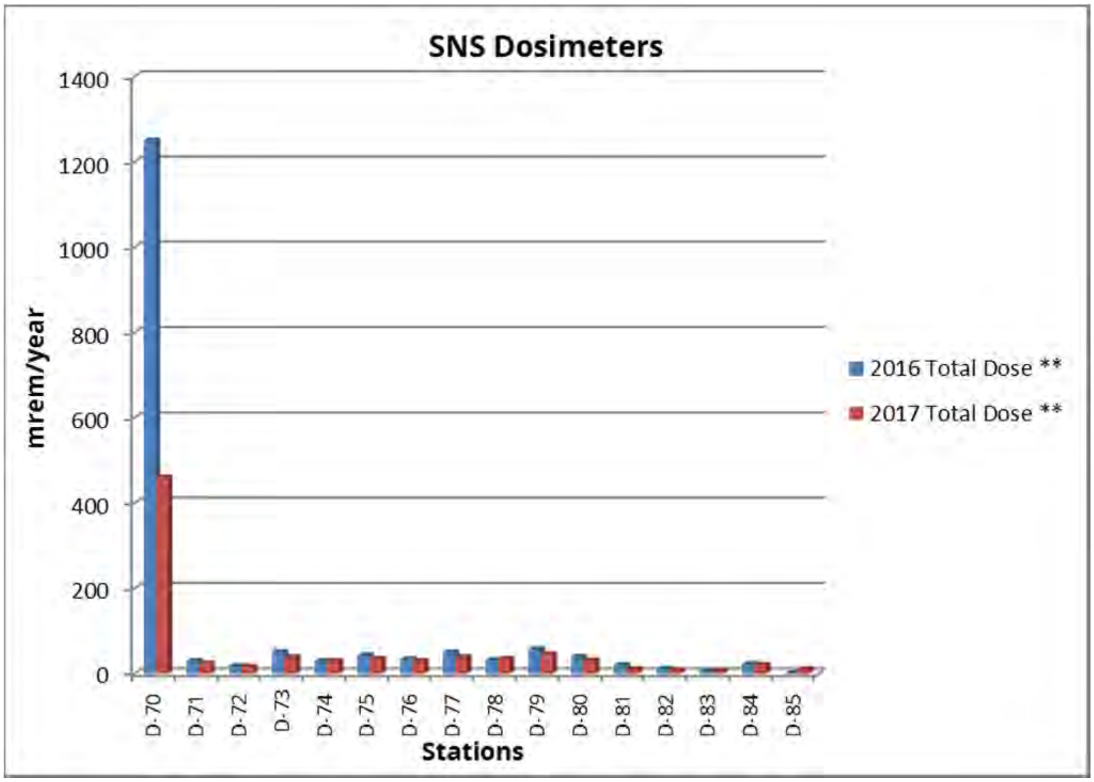


Figure 2.10: SNS Dosimeters

Table 2.12: Descriptive Notes for Tables 2.1 through 2.11

Notes: Two types of dosimeters are used in the program, optically stimulated luminescent dosimeters (OSLs) and neutron dosimeters. The OSLs measure the dose from gamma radiation, which is considered sufficient for most of the monitoring stations. The neutron dosimeters, which have been placed at selected locations, measure the dose from neutrons in addition to the gamma radiation. At the locations where the neutron dosimeters have been deployed, the total dose is the sum of the doses reported for neutrons and the dose reported for gamma radiation
The primary dose limit for members of the public specified in both DOE Orders and 10 CFR Part 20 (Standards for Protection Against Radiation) is 100 mrem total effective dose equivalent in a year, exclusive of the dose contributions from background radiation, any medical administration the individual has received, or voluntary participation in medical research programs. The Nuclear Regulatory Commission limit for a decommissioned facility is 25 mrem/yr.
NEW = Data for the period does not exist for this station because it is new.
M = Below minimum reportable quantity (one mrem for gamma, 10 mrem for thermal neutrons)
NA = Not analyzed or not deployed at location.
Absent = The dosimeter was not found at the time of collection.
Damaged = The dosimeter was physically damaged and the results were not consistent with historical values.
** A control dosimeter is provided with each batch of dosimeters received from the vender. The control dosimeters are used to identify the portion of the dose reported due to radiation exposures received in storage and transit. The dose reported for the control dosimeter is subtracted from the dose reported for each field deployed dosimeter.

2.1.8 Conclusions

The Environmental Dosimeter Project is valuable in monitoring radiation exposure levels (gamma) at a number of sites, both on and off the ORR. In areas where potential exposure above 100 mrem/year exists, the monitoring highlights those areas and tracks changes due to the removal of radioactive materials and remedial activities. In monitored areas where rates are below the 100 mrem/year threshold, the monitoring helps to inform the public of the radioactive exposure conditions on and surrounding the ORR.

Most sites exceeding the 100 mrem/year threshold are on the ORNL property. One of the sites exceeding this level; however, is located along Bear Creek Road, east of the Oak Ridge Water Plant.

2.1.9 Recommendations

The Environmental Dosimeter Project provides valuable information to the public about radiological conditions on and surrounding the Oak Ridge Reservation, and can be used to verify DOE's compliance with exposure regulations. This project provides information that assures the public that DOE's activities are protective.

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 2.11., Map of Sampling Site Locations. Those 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)

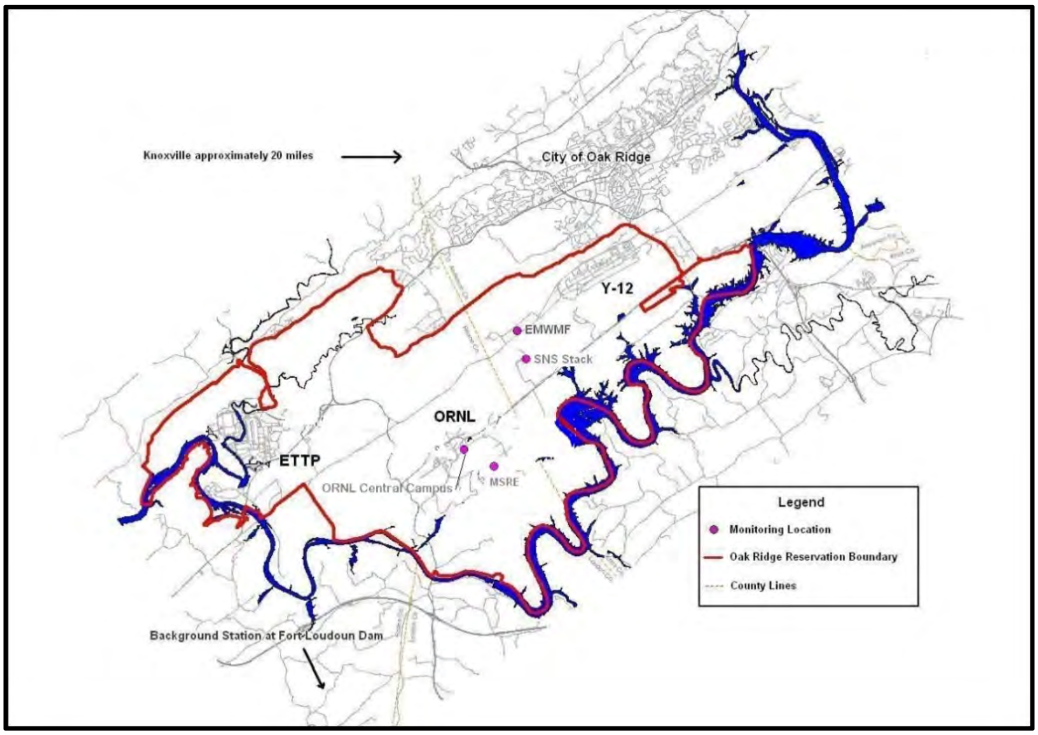


Figure 2.11: Map of Sampling Locations

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

This project had no deviations from its project plan.

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, 07/01/2017 through 06/30/2018, exposure rates averaged 8.85 μrem/hour and ranged from 7 to 14 μrem/hour, which is equivalent to a dose of approximately 77.5 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 (07/01/2017 through 06/30/2018) averaged 7.09 μrem/hour and ranged from 4 to 12 μrem/hour, similar to the background measurements collected during the period. Refer to Figure 2.12. EMWMF Gamma Exposure Rates.

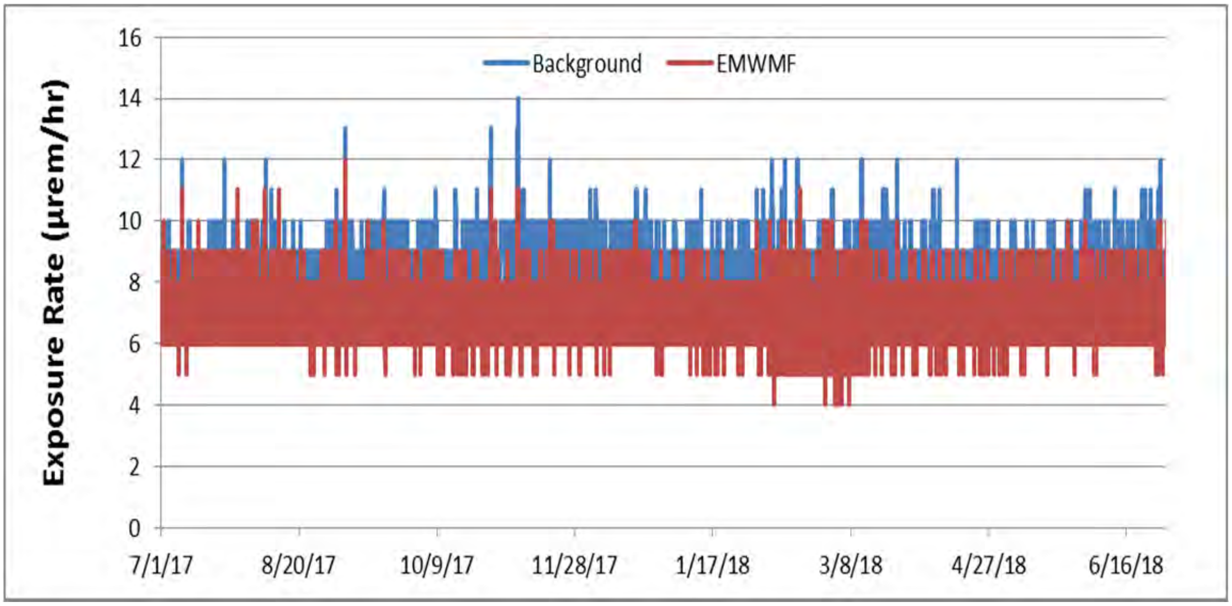


Figure 2.12 EMWMF Gamma Exposure Rates

ORNL Central Campus Remediation / Building 3026 Radioisotope Development Lab

- Monitoring on the ORNL Central Campus began in 2012 and has continued through June 2018.
- 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, 07/01/2017 through 06/30/2018, gamma radiation measured at the site ranged from 11 to 23 µrem/hour and averaged 15.19 µrem/hour. These values are nearly twice the values of background readings (Table 2.13 and Figure 2.13).

Table 2.13: 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

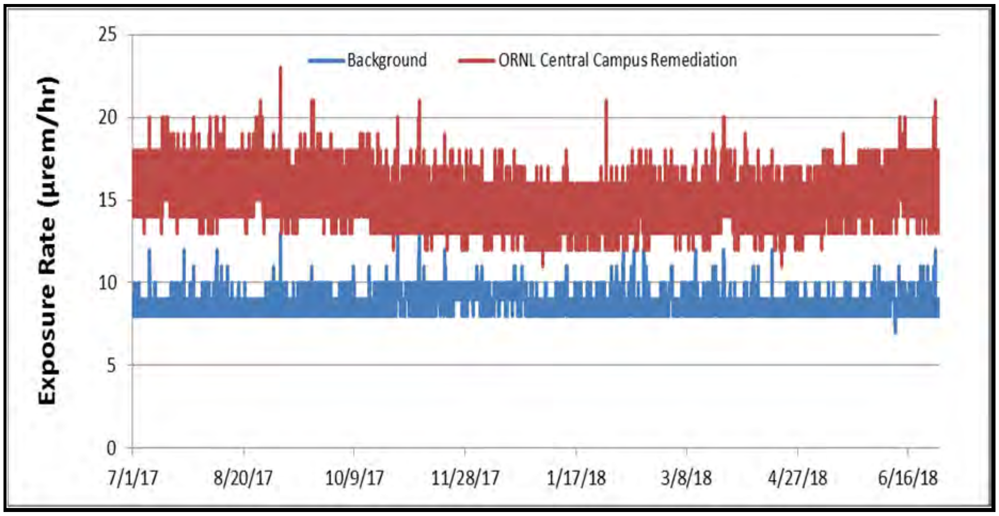


Figure 2.13: ORNL Central Campus Gamma Exposure Rates

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, 2018. 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 07/01/2017 through 06/30/2018 monitoring period, the average exposure rate ranged from 9 to 290 µrem/hour and averaged 72.59 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, as indicated by the spike in Figure 2.14.

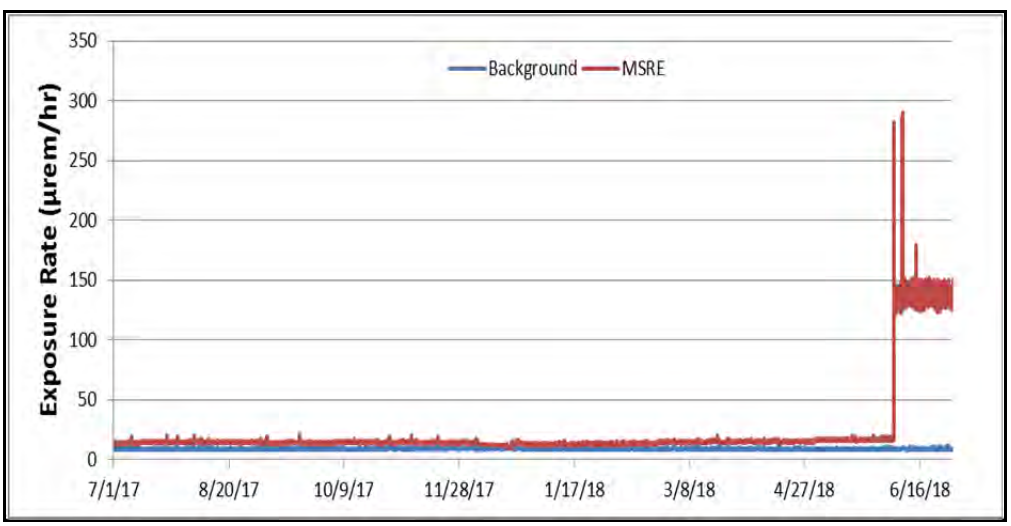


Figure 2.14: Gamma Exposure Rate at Molten Salt Reactor Experiment

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 07/01/2017 through 06/30/2018, ranged from 2 to 1140 μrem/hour, and averaged 87.43 μrem/hour. See Figure 2.15. For contextual purposes, the exposure rate of 87.43 μrem/hour would exceed both State and DOE limits of 100 mrem within one year. However, this location is not accessible to the public.

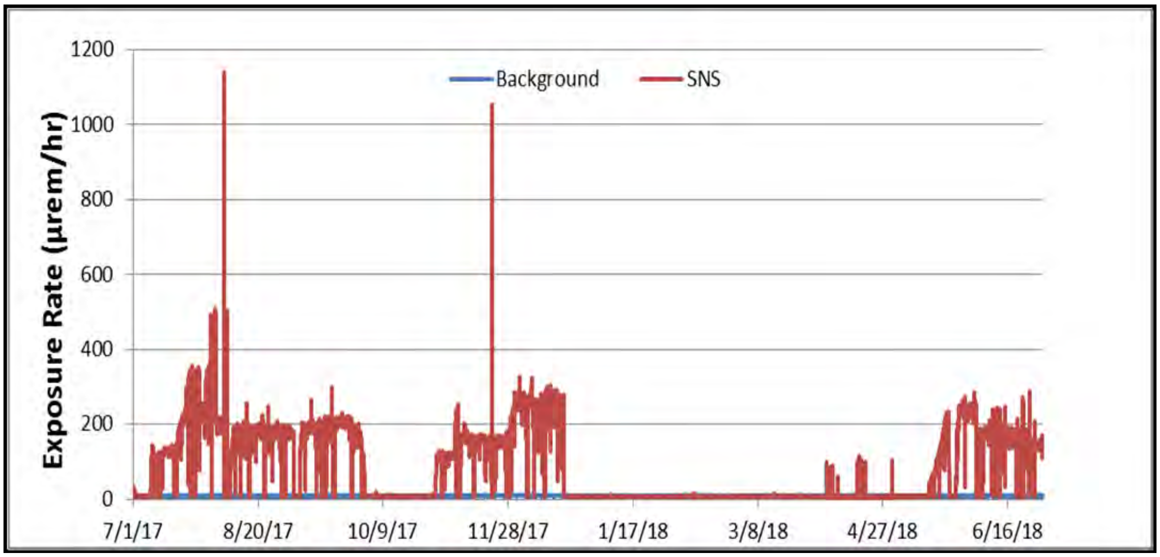


Figure 2.15. Spallation Neutron Source

2.2.8 Conclusions

The following conclusions are drawn, based on the data collected 07/01/2017 through 06/30/2018.

- 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.

2.3 PORTAL MONITORING AT EMWMF

2.3.1 Background

The Environmental Management Waste Management Facility (EMWMF) was constructed for and is dedicated to the disposal of low-level radioactive waste (LLW) and hazardous waste generated by remedial activities on the Department of Energy's (DOE) Oak Ridge Reservation (ORR). Operated under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the facility is required to comply with regulations contained in the Record of Decision authorizing the construction of the facility (DOE, 1999).

2.3.2 Problem Statements

Only low-level radioactive waste, as defined in TDEC 0400-02-11.03(21) with radiological concentrations below limits imposed by Waste Acceptance Criteria (WAC), as agreed to by the FFA tri-parties, (DOE, EPA and TDEC)), is approved for disposal in the EMWMF. DOE is accountable for compliance with the WAC and has delegated responsibility of WAC attainment decisions to its prime contractor, which DOE supervises. The WAC attainment decisions include waste characterization and ultimate approval for disposal in the EMWMF (DOE, 2001). The State and EPA oversee and periodically audit associated activities related to this work, including the review of the decisions authorizing waste lots for disposal.

2.3.3 Goals

To help ensure compliance with the WAC at EMWMF, the DoR-OR has placed a Radiation Portal Monitor (RPM) at the check-in station for trucks transporting waste into the EMWMF for disposal. Trucks entering the facility pass between radiation detectors that measure, provide data for review, and allow TDEC to determine if excessive amounts of radiation-emitting materials have passed that portal monitor. This check system is intended to corroborate DOE's checks and to confirm that excessive amounts of radiation-emitting materials have are not inadvertently disposed of in the facility.

2.3.4 Scope

This project is limited to the assessment of materials at the entry point of the waste cell, as measured by the Portal Monitor located at the EMWMF, located in Bear Creek Valley near Y-12 on the ORR.

2.3.5 Methods, Materials, Metrics

A Canberra RadSentry Model S585 portal monitor is used in this project. The system is comprised of two large area gamma-ray scintillators, an occupancy sensor, a control box, a computer, and associated software. The gamma-ray scintillators and instrumentation are contained in radiation sensor panels (RSPs) mounted on stands on each side of the road at the check-in station for trucks hauling waste into the disposal area. Measurements (one per 200 milliseconds) are initiated by the occupancy sensor when a truck enters the portal. Results are transmitted from the RSPs to the control box where it is stored. Data is routinely downloaded by DoR-OR staff. If radiation levels exceed a predetermined amount, DOE and EMWMF personnel are contacted and the source of the waste passing through the portal monitor at the time of the measurements is determined.

2.3.6 Deviations from the Plan

The Canberra RadSentry Model S585 portal monitor became unreliable in April 2017 and stopped working completely in September 2017. The Canberra RadSentry Model S585 manufacturer declined to provide repair service or replacement parts. Quotes have been obtained for a replacement portal monitor and they will be included in a supplemental grant request. A gamma detector, from another sampling program, was co-located with the portal monitor and operated during the entire sampling period 07/01/2017 through 06/30/2018.

2.3.7 Results and Analysis

Most of the waste delivered to the EMWMF for disposal in FY 2018, was derived from the demolition of uranium enrichment facilities at ETTP. The associated contaminants of concern were primarily uranium isotopes (predominately alpha emitters) and Tc-99 (a pure beta emitter). When measured by the portal monitor, as well as the separate collocated gamma detector, the identified radiation levels were no different from background values as referenced in Figure 2.16, below.

The only observed elevated results were determined to be due to the portal monitor's interaction with the monitor of a nuclear-density gauge (that contained sealed and shielded cesium-137 and americium-241 sources) used to measure the compaction of the waste. The density gauge is not a waste, but is a tool transported to the EMWMF disposal cells, as needed, by the waste cell operators and is otherwise stored outside the facility.

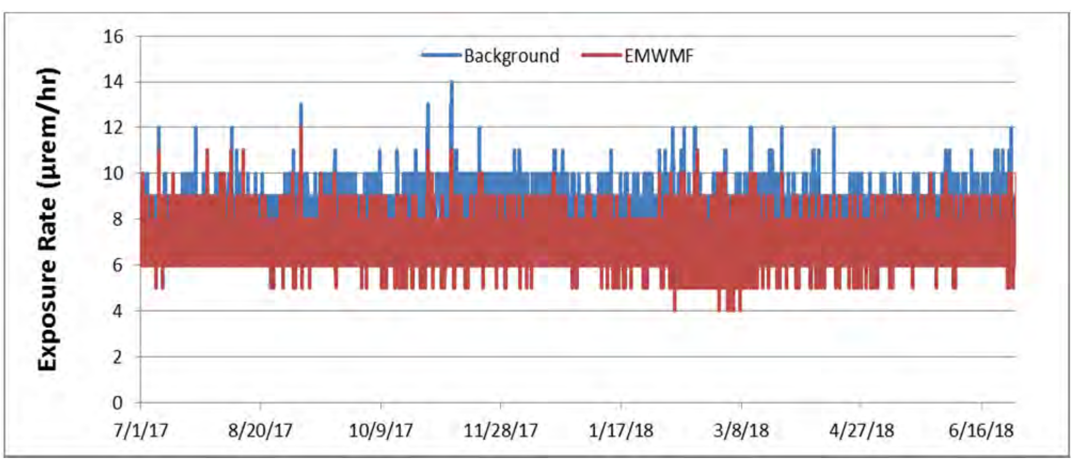


Figure 2.16 EMWMF Gamma Exposure Rate.

2.3.8 Conclusions

Measurements, taken during the period 07/01/2017 through 06/30/2018, averaged 7.09 μrem/hour and ranged from 4 to 12 μrem/hour, which was similar to the background measurements collected during the period. Examination of Annual Site Environmental Reports (ASER) has not revealed any information relevant to this sampling initiative.

2.3.9 Recommendations

While the majority of the readings recorded during FY 2018 were consistent with background values, it is important to note that deviations are identifiable, as evidenced through the identification of the gamma spikes, whenever the nuclear-density gauge interaction was identified by the monitor. This level of compliance verification is useful to provide assurances to the State and the citizens of Tennessee that the WAC is being followed and no excessive gamma contaminated materials are transported into the waste cell for disposal. TDEC recommends the continued use of the gamma instrument from the Real Timer Monitoring of Gamma Radiation on the Oak Ridge Reservation Project) until a replacement portal monitor can be obtained.

The 2017 ASER and other data useful to this project will be reviewed as they become available.

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 that are designated for sale to the public from the Oak Ridge Reservation (ORR). In addition to performing the surveys, the office reviews the procedures used for release of materials under DOE radiological regulations. DOE currently operates their surplus materials release program under DOE O 458.1 Admin Chg 3, Radiation Protection of the Public and the Environment.

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

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

2.4.2 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. Y-12 now uses an off-site contractor to handle their sales leaving ORNL property sales as the prime focus of this project.

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) prove to be an instance where the suspected contamination can no longer be detected.

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), and the draft *DoR-OR Standard Operating Procedure for Surplus Sales Verification* (TDEC 2018). Prior to sales of surplus items from ORNL or Y-12 to the public, DoR-OR conducts a pre-auction survey. The intent of this survey is to spot check items that are for sale with appropriate radiation survey instruments in order to ensure that no radioactively contaminated items are released to the public. Not all items or surfaces of a specific item are surveyed for potential radioactive contamination. Specific 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 to meet release criteria.

2.4.6 Deviation from the Plan

There were no deviations from the Plan.

2.4.7 Results and Analysis

Five inspections were conducted from July 1, 2017 through June 30, 2018 at ORNL (8-04-2017, 9-15-2017, 11-20-2017, 1-30-2018, and 4-11-2018). No sales were held at Y-12 or at ETTP. Occasionally, items with elevated levels of alpha and beta radiological contamination requiring further evaluation were discovered during the surveys; however, no items exceeding DOE release criteria were discovered during this period. Some items containing NORM (naturally occurring radioactive material) may be included among the auction items. These include old cathode ray tube televisions, electronic insulators, ceramic sinks, and other items made from ceramics (ceramics contain naturally occurring radioisotopes). When found, these items are noted and that information is provided to auction personnel.

An important find was made during the 08-04-2017 pre-auction survey. On that date, a DoR-OR staff member examining items not currently for auction, noted considerable loose material accumulated in an open duct on the bottom of a Empire Baghouse Dust Collector. Out of curiosity, the staff member took a one-minute gamma count of the loose material using a handheld radiation meter. Initial indications were of somewhat elevated activity levels. This finding was relayed to ORNL's Excess Sales staff.

A re-examination of the item by ORNL RADCON did not show elevated activity of any consequence; however, further examination did show evidence of the presence of beryllium. Although the item did not come from a radiological area, the residue from sandblasting did contain levels of beryllium. Further research by DoR-OR staff found that materials used in sandblasting may contain certain levels of beryllium. When items of concern are found, they are re-evaluated by ORNL to ensure they meet the appropriate DOE criteria for release of items to the public.

2.4.8 Conclusions

During the period July 1, 2017 through June 30, 2018, no items with elevated levels of alpha and beta radiological contamination exceeded the DOE release criteria during the surveys.

However, occasional items requiring further evaluation were found. Items with problems other than excess radioactivity are sometimes found during the performance of pre-auction survey (see beryllium incident in Results and Analysis, above.

2.4.9 Recommendations

The Surplus Materials Verification project has proven its value as a secondary check on materials being released for sale from the Oak Ridge Reservation. Since its initiation, it has detected radiologically contaminated items that would have otherwise been released for public sale. In addition, it has resulted in the discovery of items with nonradiological contaminants that could have been released.

The project requires minimal staff time and materials costs. Its benefits far exceed the time and monies required to conduct it. Continuation of this project will help assure the public that release of materials from ORR facilities for public sale are within acceptable policy guidelines.

2.5 HAUL ROAD SURVEYS

2.5.1 Background

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

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

2.5.2 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, numbers of anomalous items have been identified such as waste debris, personal protection equipment, tarp patches, waste stickers, steel pipe, etc.

2.5.3 Goals

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

To locate waste that may have been blown or dropped from waste-hauling trucks in transit.

To allow DOE and their contractors to continue their waste transportation in a manner that limits potential environmental concerns on the Haul Road and the surrounding areas.

2.5.4 Scope

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

2.5.5 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 coordinate 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 surface contamination on the road surfaces or anomalous items found along the road that may be associated with waste shipments. Any areas or items with contamination levels exceeding 200 dpm/100 cm2 removable beta, 1000 dpm/100 cm2 total beta, 20 dpm/100 cm2 removable alpha, and/or 100 dpm/100 cm2 total alpha that require further investigation are noted.

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

2.5.6 Deviations from the Plan

No surveys were conducted in January or May of 2018, but additional surveys were done in other months to satisfy the project's requirements.

2.5.7 Results and Analysis

The Haul Road walkover surveys identified 18 items in the July 2017 – June 2018 time frame, potentially originating from hazardous and/or radioactive waste being transported to the EMWMF. No surface contamination readings exceeded the free release limits. With the exception of gamma anomalies detected on 11/29/17 and 12/04/17, all other ambient high energy gamma readings were within the range of normal background for the area. The anomalous elevated gamma readings, discovered on 11/29/17 and 12/04/17, were determined to be airborne releases from the Spallation Neutron Source. Although the readings were above background readings, they did not exceed any regulatory limits nor present a threat to the environment or human health.

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 the waste.

2.5.9 Recommendations

More decommissioning and demolition and remedial activities are planned for ETTP and Y-12 in the coming years. The wastes from these projects will be transported on the Haul Road. Based on previous findings, it is believed that the continuation of this project is necessary for detecting and dispositioning anomalous items that may have fallen or been blown from trucks.

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3.0 BIOLOGICAL MONITORING

3.1 BAT MONITORING ON THE OAK RIDGE RESERVATION

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, leaf-hoppers, 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 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).

During FY 2018, it is proposed that bat guano samples will 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.

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.

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 protection of 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 T&E species.

3.1.5 Methods, Materials, Metrics

North American bats (Order Chiroptera) use ultrasonic echolocation (i.e., biosonar) as a navigation tool in obstacle avoidance and the location of prey (Simmons & Conway, 2003). These ultrasonic echolocation signals can be recorded with acoustic bat detectors, which collect data over multiple nights. The recorded data is downloaded and then analyzed with software programs designed to compare the calls of unidentified species' with the calls of known species' in an effort to identify the bat species present at a study site (McCracken, Giffen, Haines, Guge, & Evans; 2015).

All field and laboratory work will follow the safety guidelines per the TDEC Division of Remediation, Oak Ridge Office, 2017 Health and Safety Plan (TDEC, 2017). Through the detection, recording, and analysis of bat vocalizations, researchers can learn much about bat ecology and behavior (Parsons & Szewczak, 2009), and they can quickly and efficiently characterize and inventory bat communities in multiple areas (O'Farrell & Gannon, 1999).

The FY 2018 ORR Bat Monitoring project had two components which are discussed at length in the following:

1. Bat Guano Sampling and Analysis
2. Bat Acoustic Surveys and Analysis

BAT GUANO SAMPLING AND ANALYSIS

Bat guano was planned to be collected, sampled, and analyzed from 8 pre-installed bat houses on the ORR (EFPC) and from an offsite bat colony at the Norris Dam State Park (Figures 3.1-3.2, Table 3.1).

Anabat bat detectors were deployed at each bat house to screen for bat species that may be present.

Occupied bat houses were inspected weekly for any bat guano deposited into the sample buckets. After the required biomass of material
(5 grams) was collected from each bat house, sampling would have been completed.

Collections of reference site guano (from the Norris Dam State Park bat colony) involved leaving five 1-gallon buckets below their entry point (building near the swimming pool) to collect bat droppings for 1-2 nights.

Latex gloves would have been worn to collect and prepare each guano sample. Each sample would have been mixed thoroughly with a clean spatula. Two samples (5 grams each) would have been taken from the mixed material and sealed in labeled bags; samples would have been placed into an ice cooler and transported to the DoR-OR (Division of Remediation, Oak Ridge) laboratory and prepared for shipment to the Nashville Environmental Laboratory.

All guano samples would have been stored in the DoR-OR laboratory refrigerator at 4°C (centigrade) until further processing (within 12 hours).

Guano sampling standard operating procedures were planned in accordance with the methods of O'Shea, Everette, and Ellison, (2001) and Ellison, Valdez, Cryan, O'Shea, and Bogan, (2013).

Sample handling at the DoR-OR laboratory (bat guano samples)

In the TDEC DoR-ORO laboratory, guano samples would have been weighed to the nearest 0.01 gram and recorded on the laboratory sample log.

The two representative guano samples, collected from each occupied bat house (or reference bat colony), would have been handled as follows:

A taxonomic sample of approximately 5 grams would have been used to identify masticated insect parts in the guano to at least Order (or Family).

Approximately 5 grams of guano biomass would have been used for Hg (low level) and MeHg analyses.

Biota samples for Hg assays would have been placed into special 2-oz QEC (Quality Environmental Containers, Beaver, WI) Level 2 pre-cleaned glass jars (with labels and plastic screw-top lids). These sample jars would have been stored at -18ºC in the TDEC DoR-ORO laboratory freezer until their shipment to PACE Analytical Services, LLC for analysis.

Analytical laboratory methods

Guano samples would have been coordinated with the Tennessee Department of Health

Nashville Environmental Laboratory (TDH-NEL). For the Hg (low level) and MeHg analyses, TDH-NEL would have forwarded these samples 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

Guano samples would have been packed and shipped as specified in the "Procedures for Shipping Samples to the State Lab in Nashville" (TDEC, 2015).

Bat Acoustic Surveys and Sampling

Bat acoustic surveys were conducted near the pre-installed bat houses and near the non-impacted reference site (Figures 3.1-3.2, Table 3.1) to characterize each site for bat species. Note: The reference site is about twenty miles northeast of the Oak Ridge area.

Bat acoustic surveys could have also been conducted at ORR caves and karst areas suspected of providing bat habitat where T&E species may occur.

TDEC DoR-ORO acoustic bat surveys used Anabat bat detectors (Titley Scientific, Columbia, MO) to record bat echolocation calls. Acoustic bat surveying standard operating procedures follow the methods of Loeb et al., (2015) and USFWS, (2017).

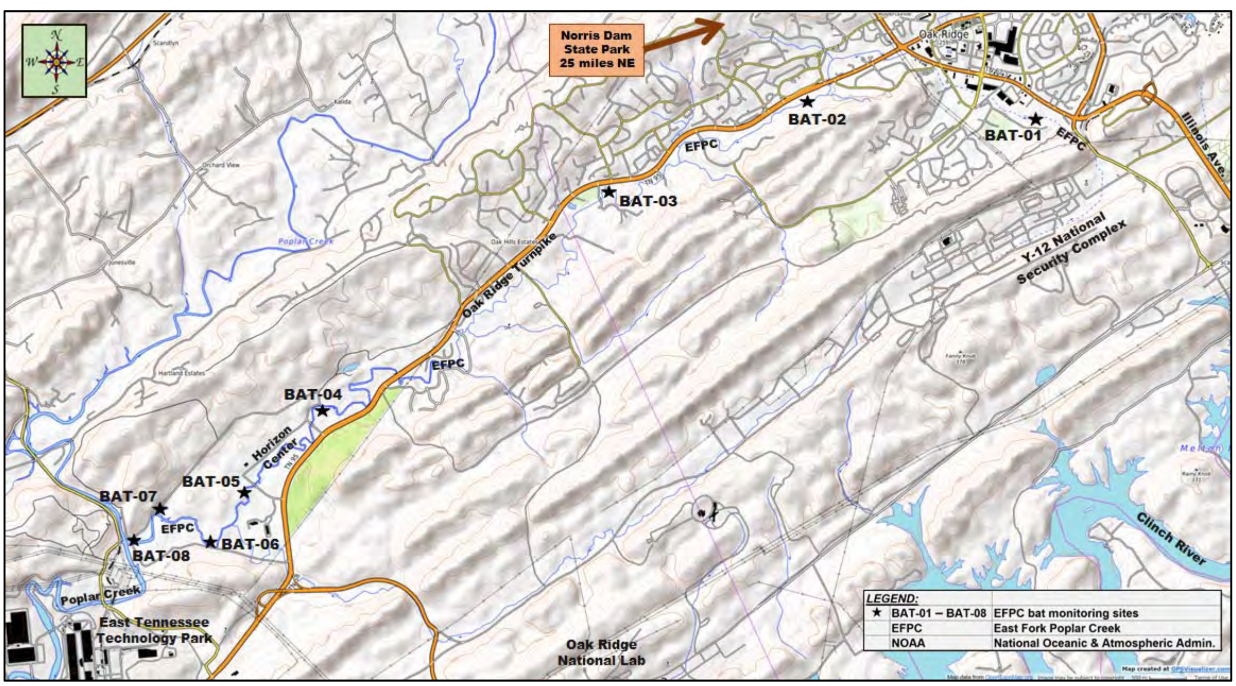


Figure 3.1: Proposed Bat House Monitoring Sites (EFPC and BCK)

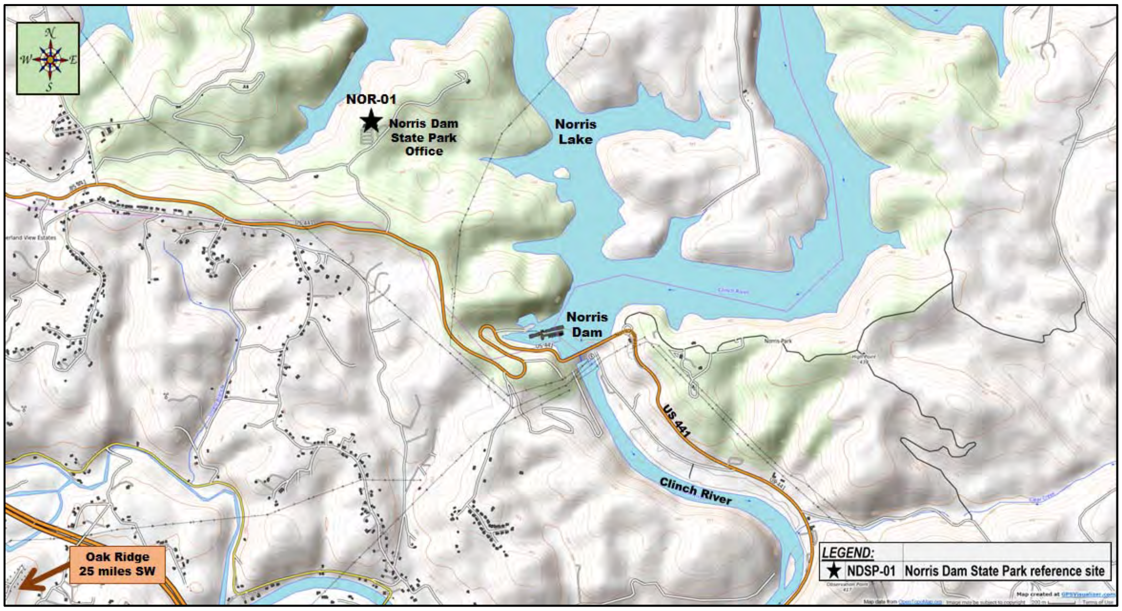


Figure 3.2: Norris Dam State Park Reference Site (Park office/pool area bat colony; NOTE: This location is about 20 miles northeast of the Oak Ridge area.

Anabats were pre-programmed to record nightly for up to two weeks, beginning thirty minutes prior to sunset and ending 30 minutes after sunrise. Other sounds, within the specified frequency range, were recorded: these included insect prey ultrasonic sounds, some of which jammed bat foraging calls, and other non-bat-call noise (McCracken, Giffen, Haines, Guge, and Evans, 2015).

Bat call files were recorded, downloaded from the detectors, and analyzed with specialized bat identification software [i.e., Kaleidoscope PRO, Wildlife Acoustics, Inc., Concord, MA; and Bat Call Identification, Inc., Kansas City, MO (BCID-East)] to enable acoustic identification of species.

TABLE 3.1: 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)

3.1.6 Deviations from the Plan

Bat boxes were inspected five times during the summer of 2018 and no bats occupied the bat houses. As a result, bat guano samples were not collected. Instead, 27 insect proxy samples (bat prey samples) were collected (using ultraviolet light traps) from the 8 EFPC bat sampling plots for mercury and methylmercury analysis as discussed in Section 7, Bat Guano Sampling.

3.1.7 Results and Analysis

BAT GUANO SAMPLING

Given that no guano samples were available to be collected, 27 insect proxy samples were collected instead (using ultraviolet light traps) from the 8 EFPC bat sampling plots for Hg and MeHg analysis. The specimens collected were primarily adult flying insects (i.e., moths, beetles, flies, midges, mosquitoes, caddisflies, mayflies, etc.) that are frequently preyed upon by bats. Due to project budget reductions, the insect samples were not shipped to the lab for analysis and remain in frozen storage at the TDEC laboratory. The holding time for frozen samples is 6 months.

ACOUSTIC BAT SURVEYS

The purpose of the acoustic study was to identify the species of bats that might have been roosting in the bat houses deployed at the 8 EFPC locations. The bat houses were designed and located to attract bats into occupancy from the EFPC floodplain bat population such that guano pellet samples could be collected for Hg and MeHg analysis of the pellets.

TDEC monitored 8 EFPC floodplain sites and 1 reference site (Norris Dam State Park) with acoustic detectors. Through the course of 35 combined survey nights more than 4,500 bat call files were recorded. Approximately 4,036 bat calls were identified to species; an additional 449 calls were detected, but were not identified. Threatened and endangered bat species were detected at 7 of 8 EFPC sites surveyed. More than 81,000 additional noise files were recorded during Anabat deployments due to wildlife, insects, weather, streams, and anthropogenic noise.

The acoustic monitoring results are summarized in Table 3.2 including the Anabat data from each monitoring site and additional software output from the Kaleidoscope PRO bat identification software program. The values listed below each bat species column in the Table 3.2 represent the number of bat calls recorded at each monitoring station, ***not*** the number of bats present: The Kaleidoscope software program cannot distinguish the number of bats at a site. Dashed boxes in the table means no bat calls were recorded for that particular species.

Figures 3.3 through 3.11 provide hourly, site-specific bat call density information as it was recorded from dusk until dawn at each site. On each graph, it is clear that the buildup of bat call activity intensifies about 1 hour past dusk (or near dusk) and then the activity diminishes considerably about 1 hour before dawn or near dawn. There are also fluctuations of bat activity between midnight and the pre-dawn hours because females leave their respective roosts several times per night to feed and then return to the roost to feed their young.

Summarizing findings, the species with the highest mean number of bat calls during the surveys included the Big Brown bat, Eastern Red bat, Silver-haired bat, Big-eared bat, and Little-brown bat. It is important to collect *Myotis* group information from the bat call analysis output because these bats are mainly cave or mine bats, include three threatened and endangered species (T&E species), and are at risk to white nose syndrome (WNS) disease. Threatened and endangered species were detected during our survey at the two EFPC monitoring sites located at the east and west boundaries of the Horizon Center (industrial park). The federally-listed Gray bat (endangered species) only comprised 3% of the overall population density, but was detected at 7 sites, and was a prominent species at EFPC monitoring site BIO-05 (Figure 3.3). Federally-listed Indiana bat (endangered species) activity was at 6 sites and was prominent among species detected at the location of EFPC monitoring site BIO-04. The federally-listed Northern Long-eared bat (threatened species) was detected at 4 locations but at very small densities. There are known caves within 1-2 miles of monitoring sites BIO-04 and BIO-05 that may harbor small bat communities.

Table 3.2: Raw data from Anabat overnight acoustic surveys

	Anabat detector results														***Additional Kaleidoscope PRO software output***		
Bat species →	**CORY**	**EPFU**	**LABO**	**LACI**	**LANO**	**MYAU**	**MYGR**	**MYLE**	**MYLU**	**MYSE**	**MYSO**	**NYHU**	**PESU**	**TABR**	**NOID** (recorded but not identified)	**Total calls recorded**	**Noise recorded**
Survey sites ↓	**Number of bat calls recorded and identified per species**																
BAT-01	12	531	126	41	63	—	2	—	92	1	2	38	11	6	151	1076	22459
BAT-02	1	402	19	2	386	—	—	—	4	—	—	15	1	26	44	900	1721
BAT-03	—	68	18	10	5	—	3	—	25	—	4	6	14	—	53	206	20551
BAT-04	205	263	43	2	7	—	11	—	31	2	17	2	16	—	82	681	10299
BAT-05	—	15	139	5	11	—	73	—	46	—	1	19	55	3	64	431	4910
BAT-06	—	11	32	—	4	6	3	2	3	1	4	1	6	—	19	92	9537
BAT-07	1	13	23	10	—	2	5	—	13	2	1	3	24	1	12	110	10983
BAT-08	—	37	38	—	3	—	3	—	14	—	—	13	43	2	21	174	1088
NOR-01 (reference)	—	799	—	2	1	—	1	—	4	5	—	—	—	—	3	851	36
species subtotals	***219***	***2139***	***438***	***72***	***480***	***8***	***101***	***2***	***232***	***11***	***29***	***97***	***170***	***38***	**449**	**4521**	**81584**

•Notes: The numbers shown in each bat species box represents the number of bat calls recorded per species, ***not*** the number of bats present. A call is the series of frequency sweeps which a bat emits (i.e., biosonar) for navigation or location of a prey item (McCracken et al. 2013). NOISE files include insect noise, wind, rain, and anthropogenic noise. NOID: Bat calls were recorded but not identified to species. Dashed boxes = no bat calls recorded at a specific survey site for that species.

•Bat species codes: **CORY** = *Corynorhinus* species (Big-eared bat), **EPFU** = *Eptesicus fuscus* (Big Brown Bat), **LABO** = *Lasiurus borealis* (Eastern Red Bat), **LACI** = *Lasiurus cinereus* (Hoary Bat), **LANO** = *Lasionycteris noctivagans* (Silver-haired Bat), **MYAU** = *Myotis austroriparius* (Southeastern Myotis), **MYGR** = *Myotis grisescens* (Gray Bat, endangered species), **MYLE** = *Myotis leibii* (Eastern Small-footed Bat), **MYLU** = *Myotis lucifugus* (Little Brown Bat), **MYSE** = *Myotis septentrionalis* (Northern Long-eared Bat, threatened species), **MYSO** = *Myotis sodalis* (Indiana Bat, endangered species), **NYHU** = *Nycticeius humeralis* (Evening Bat), **PESU** = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), **TABR** = *Tadarida brasiliensis* (Brazilian Free-tailed bat). Federally listed-species are highlighted in green.

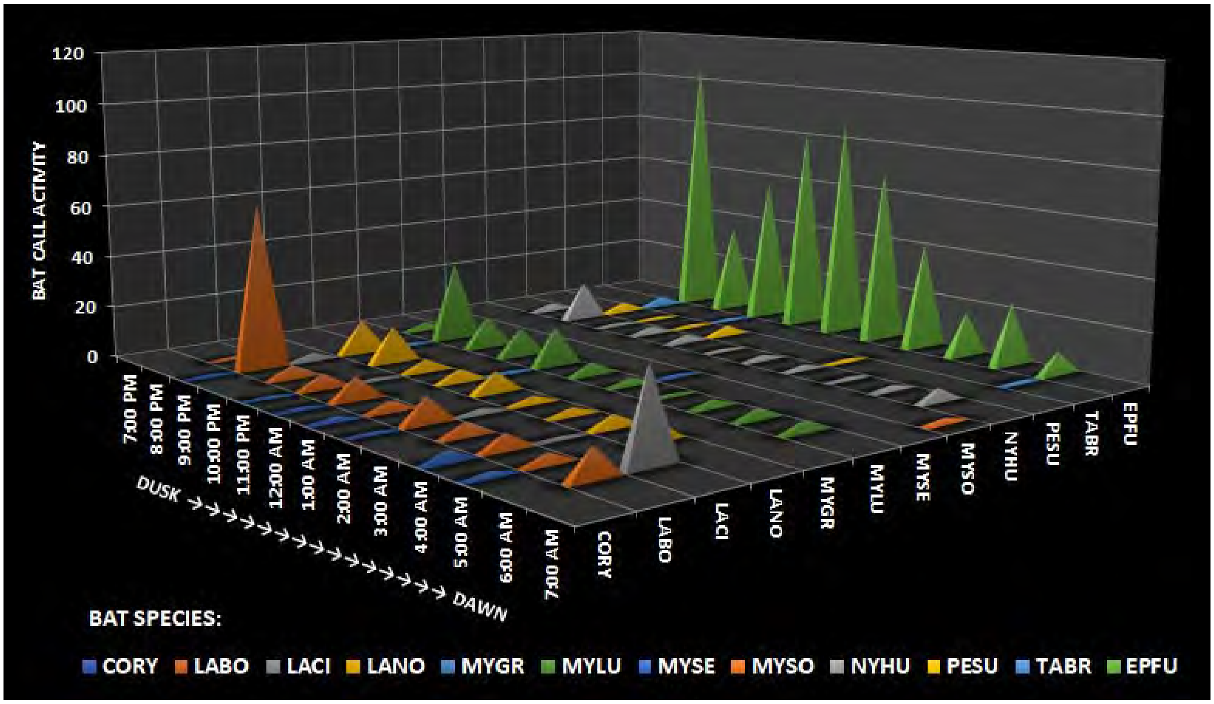


Figure 3.3: (EFPC Site BAT-01): Bat species activity per hour — from dusk to dawn

(See Table 3.2 for bat species code descriptions.)

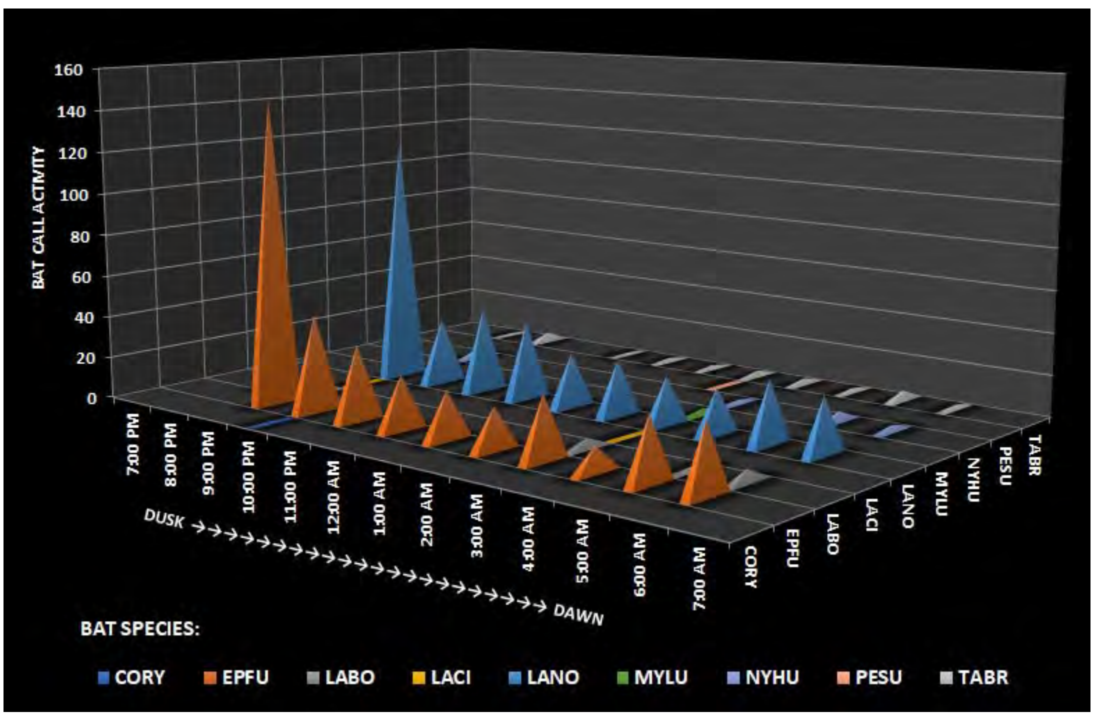


Figure 3.4: (EFPC Site BAT-02): Bat species activity per hour — from dusk to dawn

(See Table 3.2 for bat species code descriptions.)

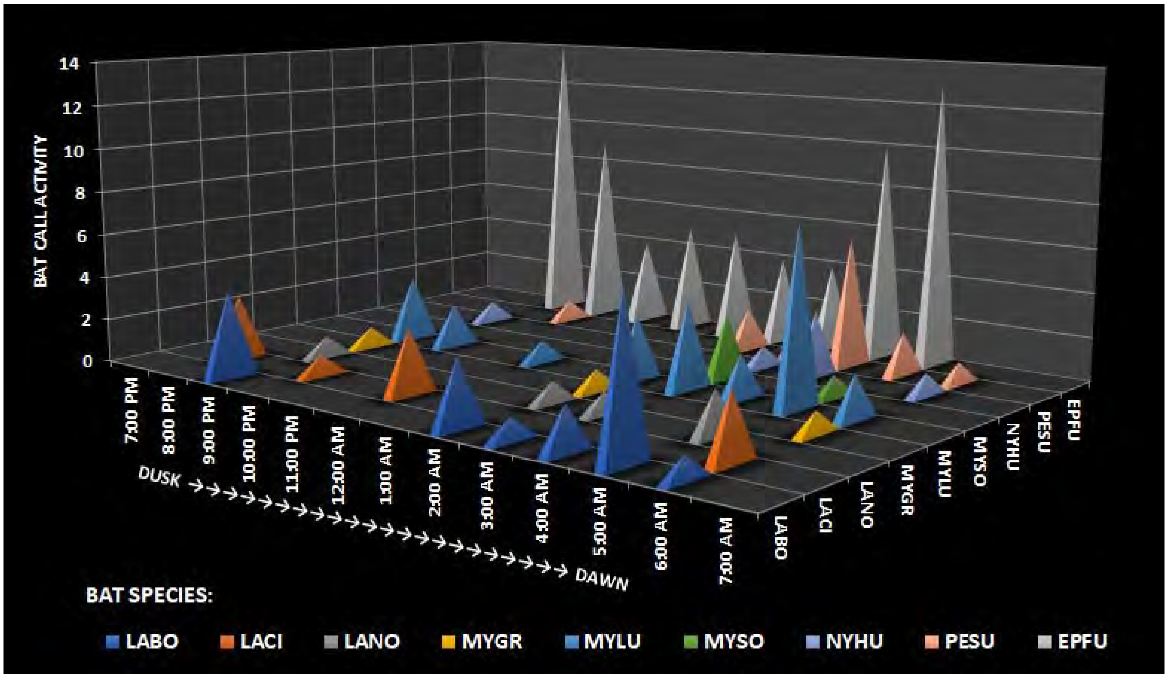


Figure 3.5: (EFPC Site BAT-03): Bat species activity per hour — from dusk to dawn

(See Table 3.2 for bat species code descriptions.)

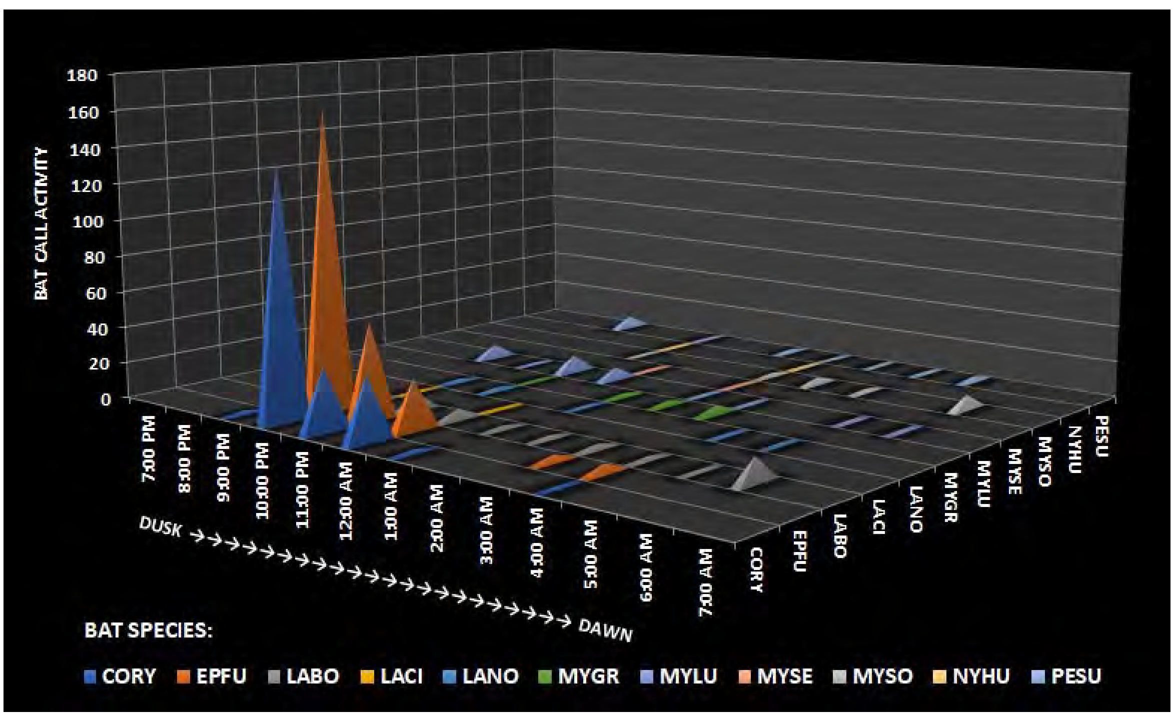


Figure 3.6: (EFPC Site BAT-04): Bat species activity per hour — from dusk to dawn

(See Table 3.2 for bat species code descriptions.)

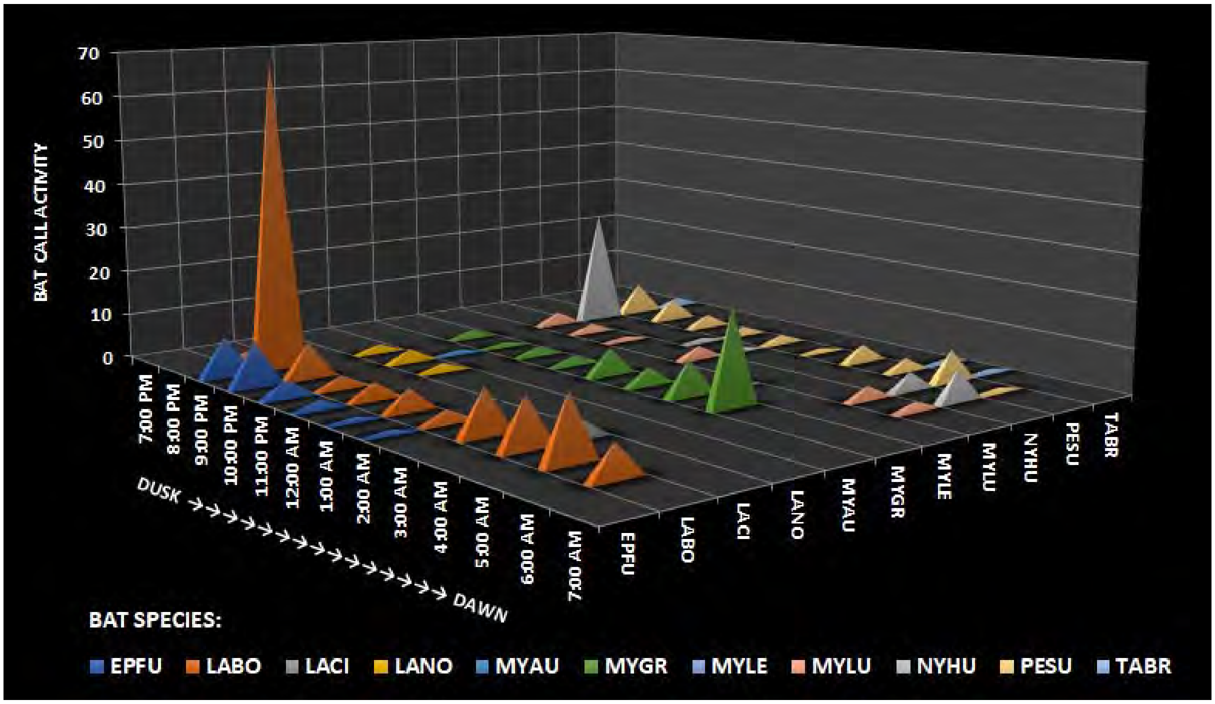


Figure 3.7 (EFPC Site BAT-05): Bat species activity per hour — from dusk to dawn
(See Table 3.2 for bat species code descriptions.)

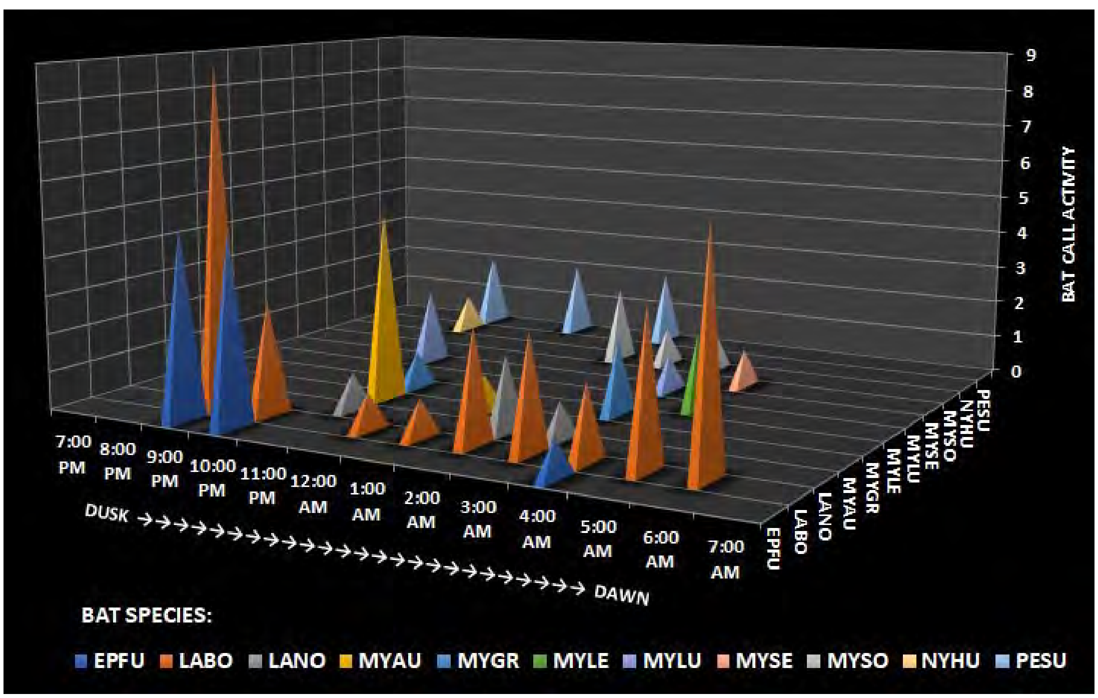


Figure 3.8 (EFPC Site BAT-06): Bat species activity per hour — from dusk to dawn
(See Table 3.2 for bat species code descriptions.)

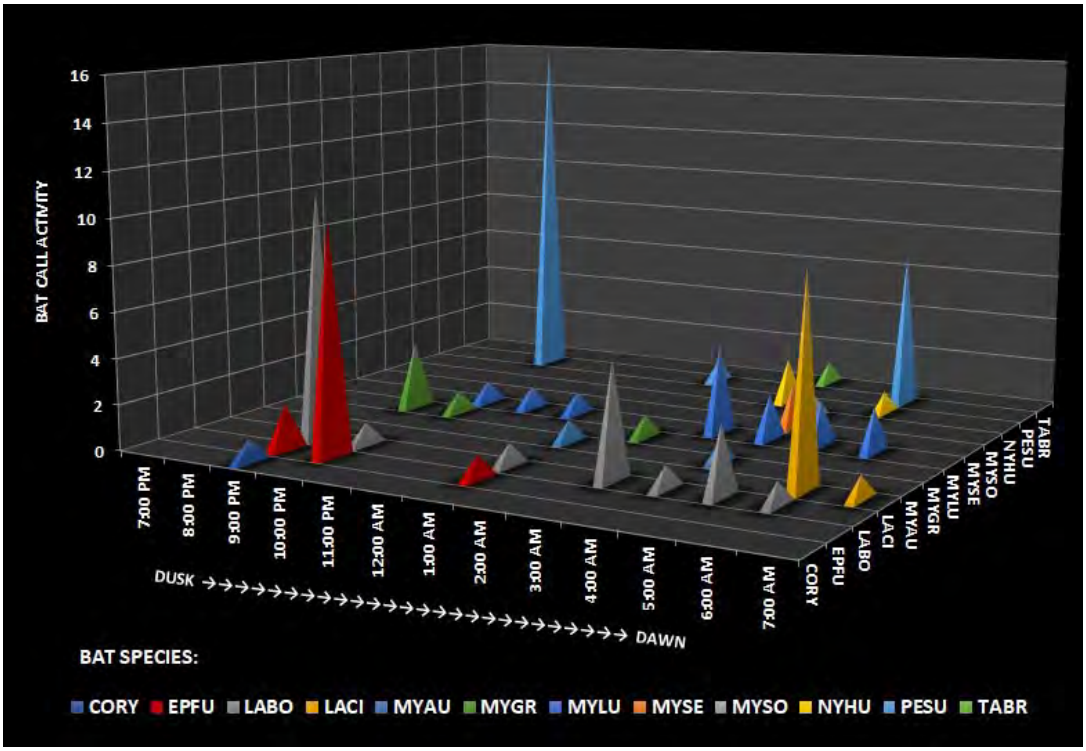


Figure 3.9: (EFPC Site BAT-07): Bat species activity per hour — from dusk to dawn
(See Table 3.2 for bat species code descriptions.)

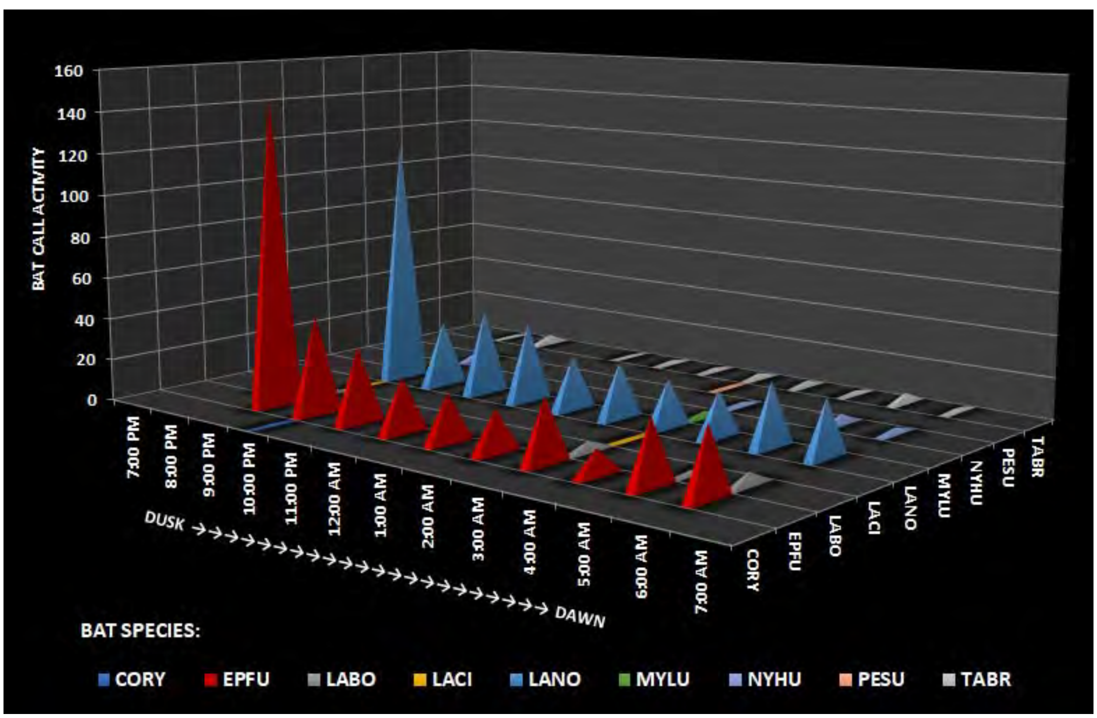


Figure 3.10: (EFPC Site BAT-08): Bat species activity per hour — from dusk to dawn
(See Table 3.2 for bat species code descriptions.)

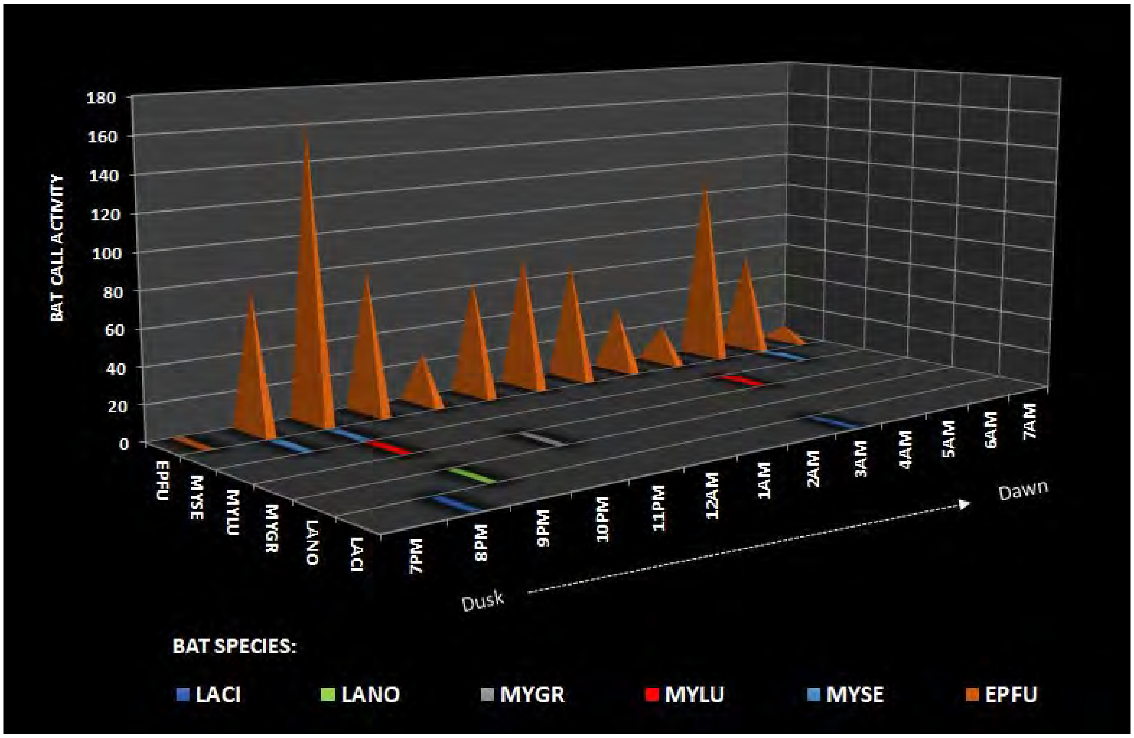


Figure 3.11. (Norris Dam reference: NOR-01): Bat species activity per hour from dusk to dawn
(See Table 3.2 for bat species code descriptions.)

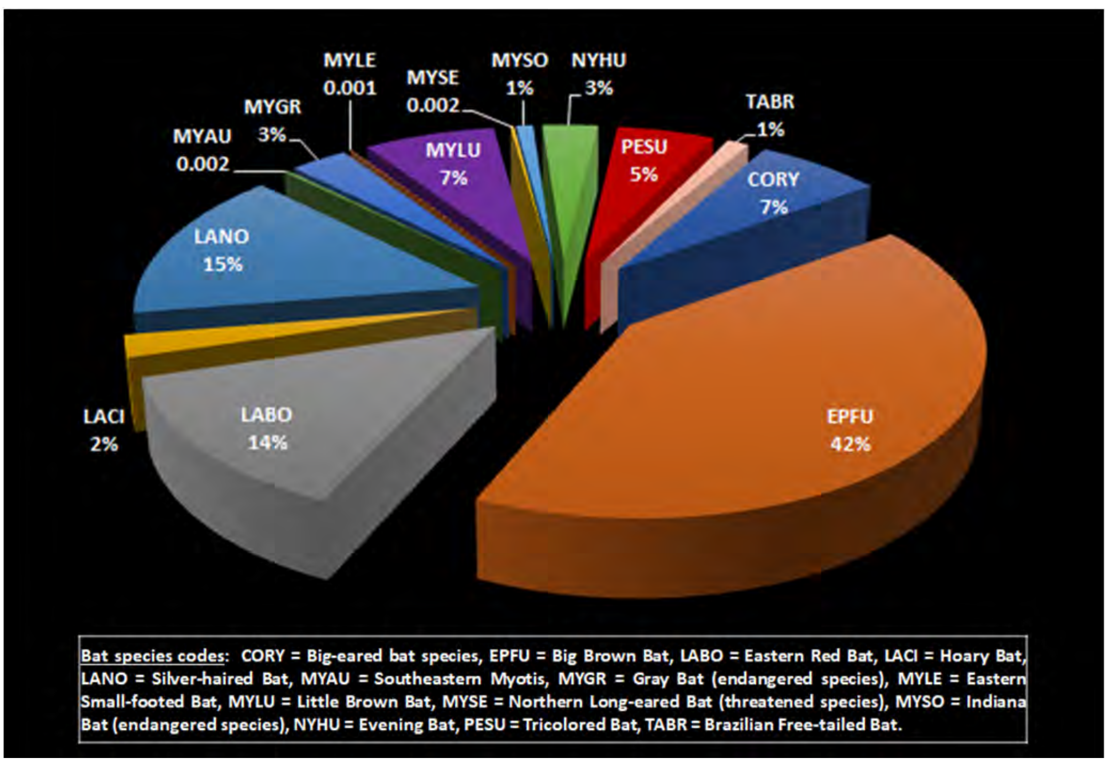


Figure 3.12: Bat species composition pie chart (combined for all 8 EFPC sites)

3.1.8 Conclusions

Although the guano was not collected, this project was beneficial. TDEC personnel achieved a level of success from the acoustic surveys by detecting and identifying the presence of T&E species along the course of upper and lower EFPC. The findings provide useful information for researchers and bat biologists regarding the ecological recovery of EFPC following Hg abatement and remedial activities.

3.1.9 Recommendations

Although guano was unable to be collected during the time frame of this project, it is recommended that the guano sampling project be redirected for future studies under the Mercury Uptake in Biota Project. However, bat acoustic surveys were successful and will continue to produce meaningful data for ecological and remedial action decision making.

3.2 Mercury Uptake In Biota

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 floodplain 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 WD, (2) eggs and feathers from 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: 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 3.13 and 3.14, Table 3.3). 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).

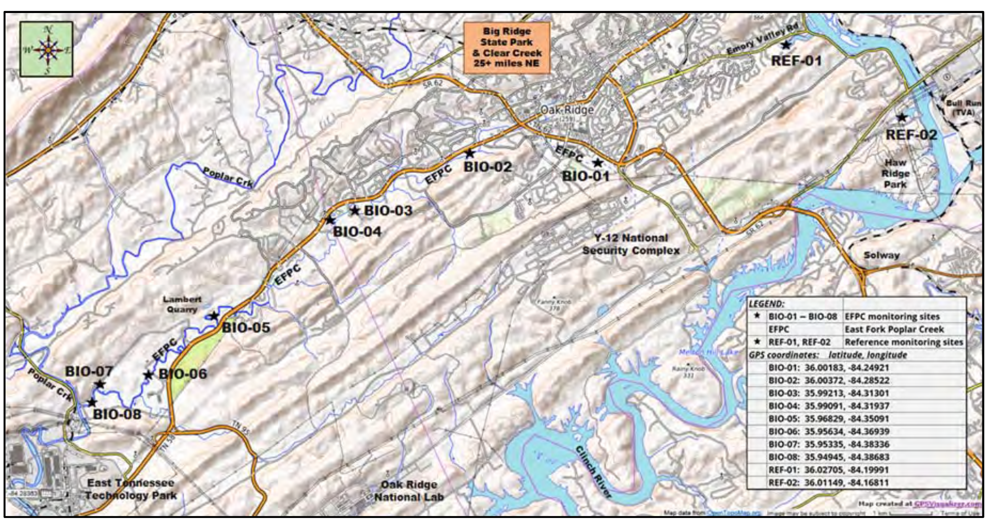


Figure 3.13: East Fork Poplar Creek and local reference sampling sites

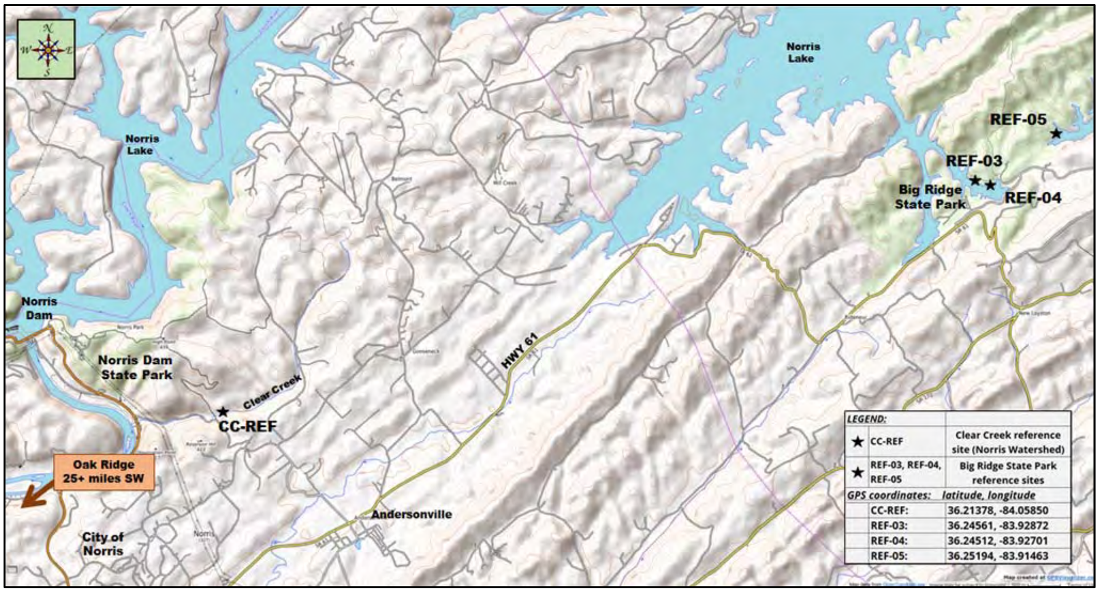


Figure 3.14: Distant reference sampling sites

Table 3.3: 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 3.4 provides a summary of the collecting and trapping methods used to sample target biota species.

Table 3.4: 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 on 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 laboratory. These jars were stored at -18ºC in the TDEC DoR-ORO 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 3.5: 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

TDEC's small mammal traps were compromised by raccoons, coyotes, and vandals which resulted in lost sample material. During sampling, both targeted and non-targeted species were captured and the non-targeted species were used as surrogate samples. An unfortunate incident during sample shipment to the PACE Analytical Laboratory (Green Bay, WI) by the shipment carrier caused approximately 35 frozen biota samples to be lost. Although expedited field efforts were conducted to replace the lost material, this incident caused data gaps in our biota results. Collection of feather samples from the nest houses proved problematic because: (1) insufficient amount of biomass was collected for Hg and MeHg analysis; (2) often it was not possible to determine if the feathers found in a nest house were from the resident bird or if the resident bird collected feathers from other species to line the nest; (3) although tree swallows (TS) were the target species, TS did not occupy any of the nest houses and no TS eggs were collected.

3.2.7 Results from Analysis

The results for this EMR are subdivided into two parts: (Part I) 2017 Terrestrial and Aquatic Species Sampling Results, and (Part II) 2018 Avian Species Sampling Results. Each part corresponds to the planned approach of sampling biota in annual phases. The results section of this report is self-explanatory (like a virtual tour), where the reader may explore the data, and draw their own conclusions.

Part I: 2017 Terrestrial and Aquatic Species Sampling Results

The following organisms were collected with drift net/pit fall traps, funnel traps, UV-light traps, Sherman traps, and aquatic dip nets: (1) adult stage insects (beetles, caddisflies, stoneflies, moths), (2) crayfish, (3) benthic dragonfly larvae (Odonata), (4) salamanders, (5) small mammals, and (6) spiders (See Table 3.6.).

Table 3.6: Biota Species Sampled

Aquatic / Terrestrial species	*classification*	*life stage (as collected)*
Anax	Odonata	benthic larvae
beetles	Coleoptera	adults
Boyeria	Odonata	benthic larvae
caddisflies	Trichoptera	adults
crayfish	Crustaceae	adults + juveniles
deermouse	Mammalia	adults + juveniles
Dromogomphus	Odonata	benthic larvae
Gomphidae	Odonata	benthic larvae
Hagenius	Odonata	benthic larvae
hispid cotton rat	Mammalia	adults
insect composite[a]	Insecta	adults
moths	Lepidoptera	adults
northern short-tailed shrew	Mammalia	adults
salamanders	Amphibia	juveniles
spiders[b]	Arachnida	adults + juveniles
stoneflies	Plecoptera	adults
[a]*insect composite* sample includes: midges, mosquitoes, thrips, dipterans (flies), winged ants, lacewings, gnats, true bugs, etc.		
[b]*spider* sample includes: mixture of wolf spiders (Lycosidae) & fishing spiders (Pisauridae)		

Figure 3.15 illustrates the big picture of the combined mean Hg/MeHg data for all species from EFPC and the Clear Creek reference site (Norris Watershed, about 25 miles northeast of the ORR). From the figure we deduce that EFPC biota have mean Hg and MeHg concentrations that are 17 times and 8 times greater respectively compared to their counterpart biota at the Clear Creek reference site.

All analytical data as received from the laboratory is based on a wet weight basis. We normalized all Hg and MeHg data by using mean biota body weights (i.e., estimated, actual and literature-derived weights) for calculations. Literature weight information came from the following sources:

(1) Salamanders: Bank, Loftin, and Jung (2005), Pfingsten et al. (2013), Walker (2017),

(2) Moths: García-Barros (2015),

(3) Odonata: Bried, Bennett, and Ervin (2005), Pandion, Mathavan, and Jeyagopal (1979),

(4) Spiders: Standish (2016), Uetz, Bischoff, and Raver (1992),

(5) Beetles: Davis, Attarha, and Piefke (2013),

(6) Caddisflies: Alexander and Smock (2005), Sanchez and Hendricks (1997),

(7) Crayfish: Anderson and Simon (2015),

(8) Mammals: Schwartz and Schwartz (2001).

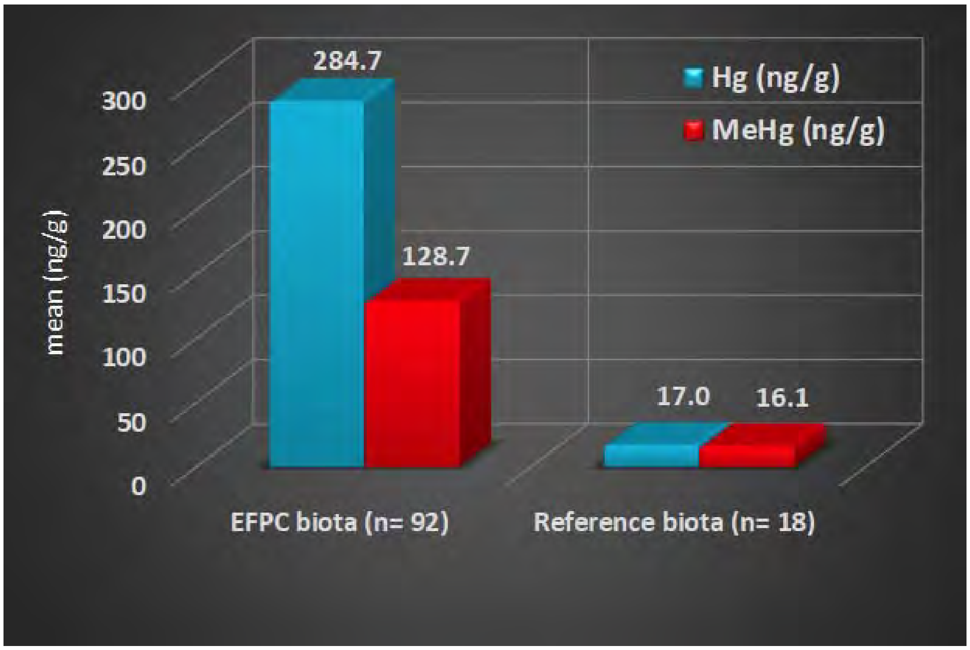


Figure 3.15: Combined biota Hg & MeHg results
East Fork Poplar Creek vs. Reference site

Figures 3.16 and 3.17 are maps of Upper and Lower EFPC with sampling plot locations and illustrated snapshots of respective Hg and MeHg biota data. The maps illustrate how the monitoring sites are distributed along the course of EFPC (upstream EFPC to downstream EFPC). Figure 3.18 represents the Clear Creek reference site location and respective biota data. Clear Creek is located at Norris, TN, about 25 miles northeast of the ORR. Due to sampling difficulties (including a lost shipment of samples), TDEC was not able to replicate Hg and MeHg results at all 9 biota groups among all sites.

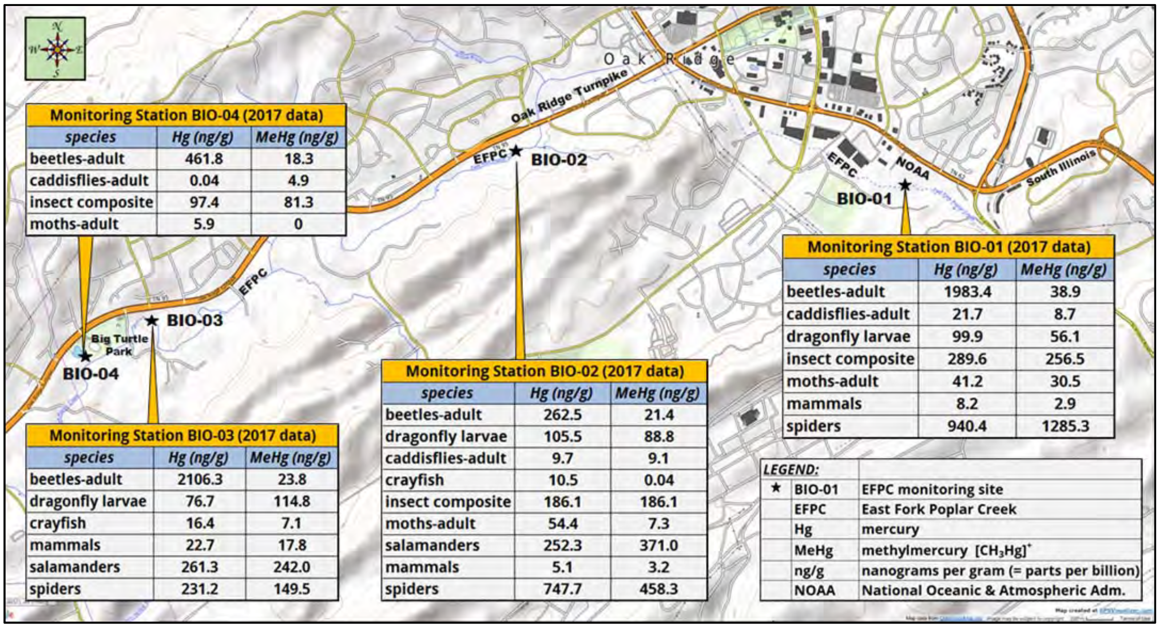


Figure 3.16: Upper East Fork Poplar Creek monitoring stations and Hg & MeHg results (2017)

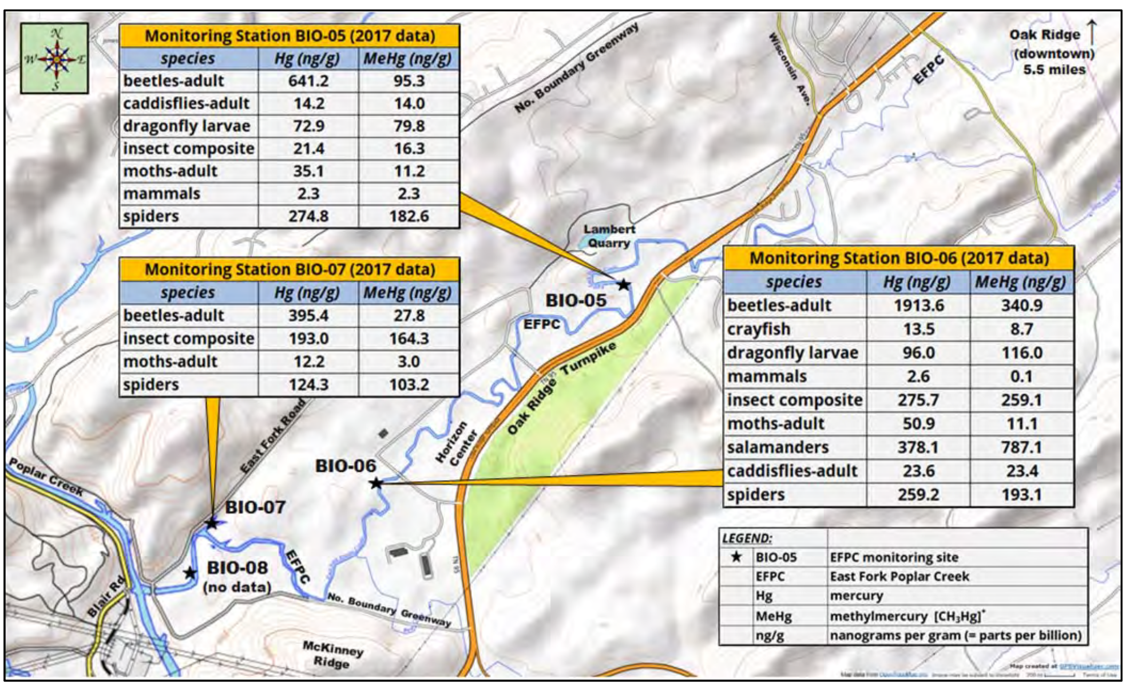


Figure 3.17: Lower East Fork Poplar Creek monitoring stations and Hg & MeHg results (2017)

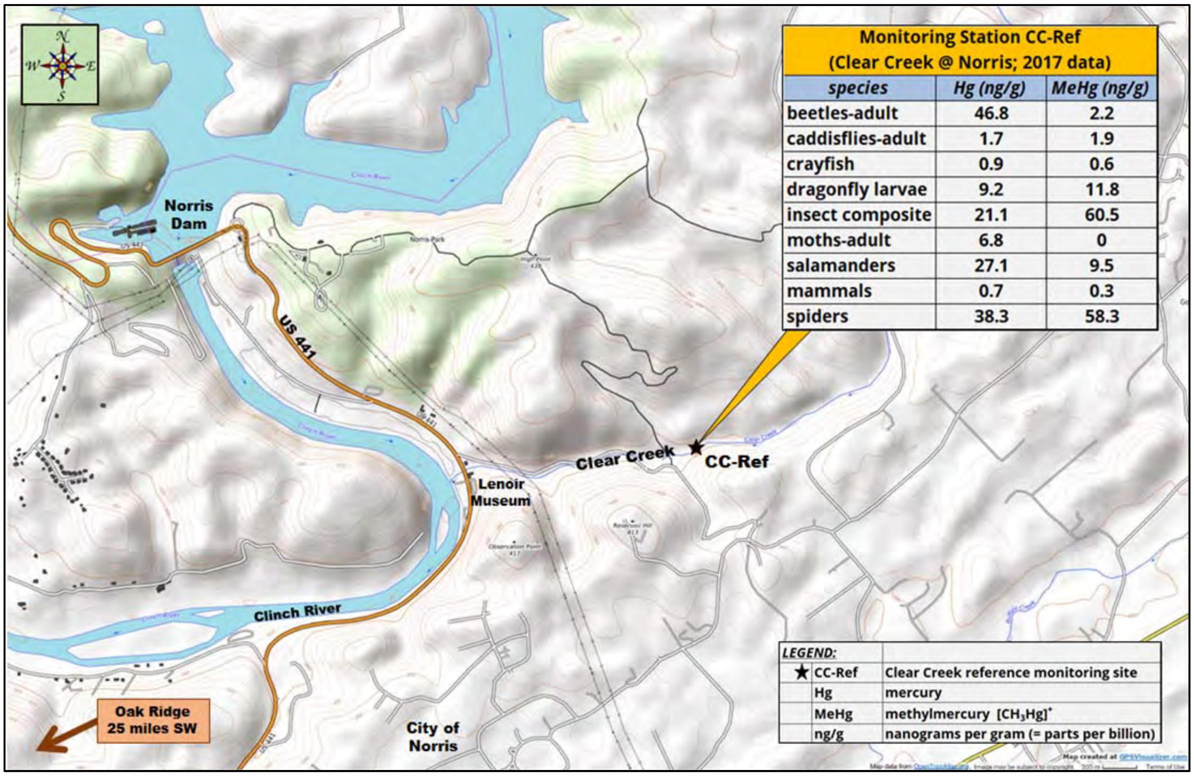


Figure 3.18: Clear Creek (reference) monitoring location and Hg & MeHg results (2017)

Beetles (*Coleoptera*) adult Figure 3.19 shows the beetle Hg/MeHg data for the upstream-to-downstream EFPC sites compared to the Clear Creek reference beetle data. Beetles were collected from 7 EFPC sites plus 1 reference site with ultraviolet light traps and funnel traps. Beetles collected from EFPC accumulated the highest Hg concentrations when compared to any other organism. In EFPC, beetle Hg ranged from 262.5 ng/g to 2106 ng/g (mean beetle Hg= 1109.2 ng/g). However, beetle MeHg was several orders of magnitude lower than beetle Hg ranging from only 18 ng/g to 341 ng/g (mean beetle MeHg= 80.8 ng/g). The Clear Creek reference site yielded beetle Hg concentrations = 46.8 ng/g and beetle MeHg = 2.2 ng/g.

Evaluating the upstream to downstream data, beetle Hg and MeHg concentrations exhibit decreased, increased, decreased, and increased pattern. This outcome may be an artifact of the significant variation in beetle species and specimen sizes collected from each site. Nevertheless, it is unclear why the EFPC beetles have such a large concentration of Hg compared to the other 8 EFPC biota groups. It is also unclear why MeHg only represents such a small fraction of the beetle Hg present as MeHg.

In summation, only 7.28% of the total EFPC beetle Hg is present as beetle MeHg and for the reference site, 4.25% of the total Hg is present as MeHg. The EFPC beetle mean Hg and MeHg results are 23 times and 40 times greater, respectively, than the reference beetle mean Hg and MeHg results.

Crayfish (*Crustaceae*) Figure 3.20 shows the crayfish Hg/MeHg data for the upstream-to-downstream EFPC sites, compared to the Clear Creek reference crayfish data. Crayfish were collected with aquatic dip nets from 3 EFPC sites and 1 reference site. Crayfish collected from EFPC exhibited relatively low concentrations of Hg and MeHg. In EFPC, crayfish Hg ranged from 10.5 ng/g to 16.4 ng/g (mean crayfish Hg = 13.46 ng/g). Crayfish MeHg ranged from 0.04 ng/g to 8.7 ng/g (mean crayfish MeHg = 5.28 ng/g). The Clear Creek reference site yielded crayfish Hg concentrations= 0.9 ng/g and crayfish MeHg = 0.6 ng/g.

Evaluating the upstream to downstream data, crayfish Hg and MeHg concentrations generally increased downstream. Similar trends have been noted for MeHg increasing downstream in EFPC fish. It was assumed that mercury in fish would respond to decreased inputs of dissolved mercury to EFPC headwaters. However, during the past two decades, when mercury inputs were decreasing, mercury concentrations in fish in Lower EFPC, downstream of Y-12, increased while those in Upper EFPC decreased (Southworth, Greeley, Peterson, and Lowe, 2010).

In summation, 39.33% of the total crayfish Hg is present as MeHg and for the reference site, 77.77% of the total Hg is present as MeHg. The EFPC crayfish mean Hg and MeHg are 15 times and 8 times greater, respectively, compared to their reference crayfish mean Hg and MeHg results.

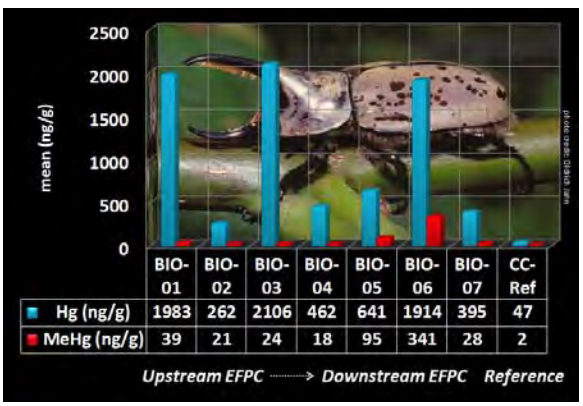


Figure 3.19: Beetles Hg/MeHg results

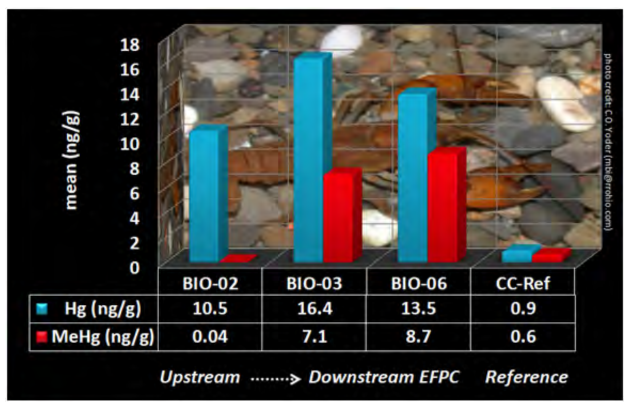


Figure 3.20: Crayfish Hg/MeHg results

Caddisflies (*Trichoptera*)-adult Figure 3.21 shows the adult caddisfly Hg/MeHg data for the upstream-to-downstream EFPC sites compared to the Clear Creek reference caddisfly data. Adult caddisflies were collected from 5 EFPC sites plus 1 reference site with ultraviolet light traps. Caddisflies collected from EFPC exhibited relatively low concentrations of Hg and MeHg. In EFPC, caddisfly Hg ranged from 0.04 ng/g to 23.6 ng/g (mean caddisfly Hg= 13.83 ng/g). Caddisfly MeHg ranged from 4.9 ng/g to 23.4 ng/g (mean caddisfly MeHg= 12.01 ng/g). The Clear Creek reference site yielded mean caddisfly Hg concentrations= 1.7 ng/g and caddisfly MeHg= 1.9 ng/g.

Evaluating the upstream to downstream data, caddisfly Hg and MeHg concentrations decreased and then increased again downstream.

In summation, 86.84% of the total caddisfly Hg is present as MeHg and for the reference site, 100+% of the total Hg is present as MeHg. The EFPC caddisfly mean Hg and MeHg are 8 times and 6 times greater respectively compared to their reference caddisfly mean Hg and MeHg results.

Insect composite (*Insecta*) Figure 3.22 shows the insect Hg/MeHg data for the upstream-to-downstream EFPC sites compared to the Clear Creek reference insect data. Insect composite samples (adults) were collected from 6 EFPC sites plus 1 reference site with ultraviolet light traps. The insect composite samples were evaluated by compositing the following taxa into one sample: midges, mosquitoes, thrips, dipterans, winged ants, lacewings, gnats, true bugs, etc. Insects collected from EFPC exhibited relatively low concentrations of Hg and MeHg. In EFPC, insect Hg ranged from 21 ng/g to 290 ng/g (mean insect Hg = 177.2 ng/g). Insect MeHg ranged from 16 ng/g to 259 ng/g (mean insect MeHg = 160.6 ng/g). The Clear Creek reference site yielded insect mean Hg concentrations = 21 ng/g and insect MeHg = 61 ng/g.

Evaluating the upstream to downstream data, insect Hg, and MeHg concentrations decreased and then increased again downstream.

In summation, 90.63% of the total insect composite Hg is present as MeHg and for the reference site, 100+% of the total Hg is present as MeHg. The EFPC insect mean Hg and MeHg are 8 times and 6 times greater, respectively, compared to their reference insect mean Hg and MeHg results.

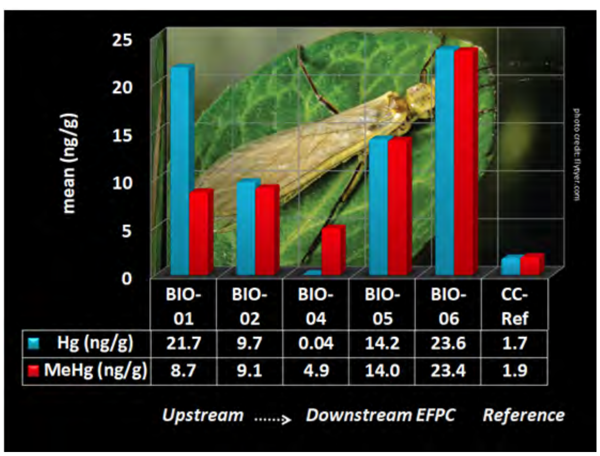


Figure 3.21: Caddisfly adults Hg/MeHg results

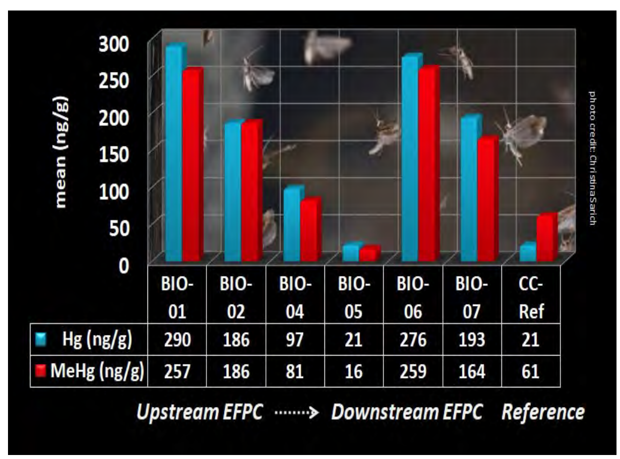


Figure 2.22: Insect composite Hg/MeHg results

Small mammals (*Mammalia*)

Figure 3.23 shows the mammal Hg/MeHg data for the upstream-to-downstream EFPC sites compared to the Clear Creek reference mammal data. Small mammals were collected from 6 EFPC sites and 1 reference site with Sherman traps. Mammals collected from EFPC exhibited relatively low concentrations of Hg and MeHg. In EFPC, mammal Hg ranged from 2.3 ng/g to 22.7 ng/g (mean mammal Hg = 8.19 ng/g). Mammal MeHg ranged from 0.1 ng/g to 17.8 ng/g (mammal mean MeHg = 4.39 ng/g). The Clear Creek reference site yielded mean mammal mean Hg concentrations = 0.7 ng/g and mammal mean MeHg = 0.3 ng/g.

Evaluating the upstream to downstream data, mammal Hg, and MeHg concentrations decreased, increased, and then deceased again downstream. One explanation for these variations downstream is due to one small mammal being a terrestrial invertebrate predator (shrew) compared to the other species collected, that were herbivores (deer mice, hispid cotton rat). The diet of the short tailed shrew is primarily made up of small vertebrates, detritivores insects, and earthworms, potentially causing a higher exposure to mercury (Cristol et al., 2008; Newman, Xu, Condon, and Liang, 2011; Standish, 2016). The EFPC shrew accumulated 5 times greater Hg and 10 times greater MeHg body burden concentrations compared to the herbivores.

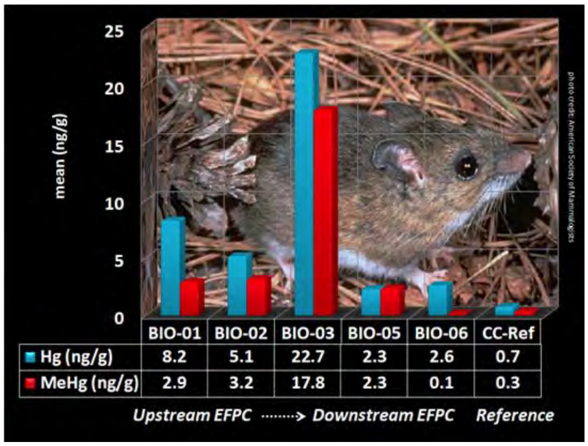
In summation, 64.63% of the total mammal Hg is present as MeHg and for the reference site, 42.85% of the total Hg is present as MeHg. The EFPC mammal mean Hg and MeHg are 10 times and 14.6 times greater, respectively, compared to their reference mammal mean Hg and MeHg results. A 1993 study reported that 4-16% of EFPC soil Hg was absorbed when fed to adult mice in laboratory experiments (Talmage and Walton, 1993).

On the ORR, terrestrial biota sampling in the White Oak Creek/Melton Branch floodplain was conducted in 2009 (DOE, 2017). White-footed mice (*Peromyscus leucopus*), deer mice (*Peromyscus maniculatus*), and hispid cotton rats (*Sigmodon hispidus*) were selected for sampling because they live and forage in these areas, are food for other mammals, and have relatively small home ranges. Small mammal Hg and MeHg analyses were not reported so a comparison of White Oak Creek/Melton Branch biota results cannot be made to EFPC biota Hg and MeHg results.

Moth (*Lepidoptera*)-adults Figure 3.24 shows the moth Hg/MeHg data for the upstream-to-downstream EFPC sites compared to the Clear Creek reference moth data. Moth samples (adults) were collected from 6 EFPC sites plus 1 reference site with ultraviolet light traps. Moths collected from EFPC exhibited relatively low concentrations of Hg and MeHg. In EFPC, moth Hg ranged from 5.9 ng/g to 54.4 ng/g (mean moth Hg = 33.2 ng/g). Moth MeHg ranged from 0 ng/g to 30.5 ng/g (mean moth MeHg = 6.89 ng/g). The Clear Creek reference site yielded moth mean Hg concentrations= 6.8 ng/g and moth MeHg = 0 ng/g.

Evaluating the upstream to downstream data, moth Hg and MeHg concentrations decreased and then increased again downstream.

In summation, 31.53% of the total moth composite Hg is present as MeHg and for the reference site, 0% of the total Hg is present as MeHg. The mean of the EFPC moth Hg data is 5 times greater when compared to its reference moth Hg results (the mean).



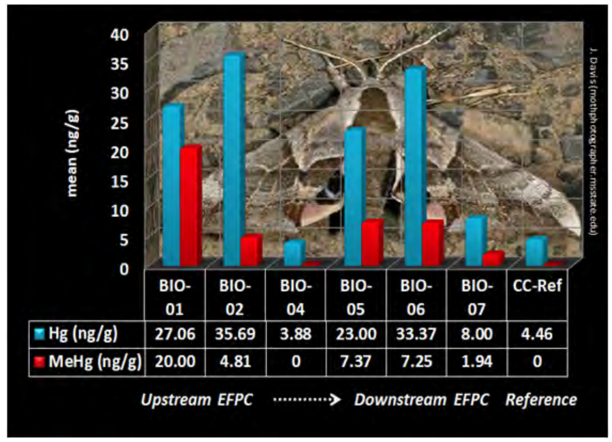


Figure 3.23: Mammals Hg/MeHg results

Figure 3.24: Moths Hg/MeHg results

Dragonfly larvae (*Odonata*) Figure 3.25 shows the dragonfly larvae Hg/MeHg data for the upstream-to-downstream EFPC sites compared to the Clear Creek reference dragonfly larvae data. Dragonfly larvae were collected from 5 EFPC sites plus 1 reference site with aquatic dip nets. Dragonfly larvae collected included *Anax* sp., *Boyeria* sp., *Dromogomphus* sp., *Hagenius brevistylus* and a few others. In EFPC, dragonfly Hg ranged from 72.9 ng/g to 105.5 ng/g (mean dragonfly larvae Hg = 90.18 ng/g). Dragonfly larvae MeHg ranged from 56.1 ng/g to 116.0 ng/g (mean dragonfly larvae MeHg = 91.09 ng/g). The Clear Creek reference site yielded mean dragonfly larvae Hg concentrations= 9.2 ng/g and dragonfly larvae MeHg = 11.8 ng/g.

Evaluating the upstream to downstream data, dragonfly larvae Hg and MeHg concentrations decreased and then increased again downstream. Similar trends have been noted for MeHg increasing downstream in EFPC fish (Southworth et al., 2010).

In summation, 100+% of the total dragonfly larvae Hg is present as MeHg and for the reference site, 100+% of the total Hg is present as MeHg. The EFPC dragonfly larvae mean (Hg and MeHg) is 10 times and 8 times greater, respectively, compared to their reference dragonfly larvae mean Hg and MeHg results.

Salamanders (*Amphibia*) Figure 3.26 shows the salamander Hg/MeHg data for the upstream-to-downstream EFPC sites compared to the Clear Creek reference salamander data. Salamanders were collected from 3 EFPC sites plus 1 reference site with aquatic dip nets. Species collected were predominantly 2-lined salamander nymphs. In EFPC, salamander Hg ranged from 252.3 ng/g to 378.1 ng/g (mean salamander Hg = 297.20 ng/g). Salamander MeHg ranged from 242.0 ng/g to 787.1 ng/g (mean salamander MeHg = 466.67 ng/g). The Clear Creek reference site yielded mean salamander larvae Hg concentrations = 27.1 ng/g and salamander MeHg = 9.5 ng/g.

Evaluating the upstream to downstream data, salamander Hg and MeHg concentrations increased downstream. Similar trends have been noted for MeHg increasing downstream in EFPC fish. It was assumed that mercury in fish would respond to decreased inputs of dissolved mercury to EFPC headwaters. However, during the past two decades when mercury inputs were decreasing, mercury concentrations in fish in Lower EFPC downstream of Y-12 increased while those in Upper EFPC decreased (Southworth et al., 2010).

In summation, 100+% of the total salamander Hg is present as MeHg and for the reference site, 35.05% of the total Hg is present as MeHg. The EFPC salamander mean Hg and MeHg are 11 times and 49 times greater respectively compared to their reference salamander mean Hg and MeHg results. Overall, EFPC salamanders had the 3rd highest body burden concentrations of Hg and MeHg compared to the rest of the biota results. Only spiders and beetles recorded higher body burden concentrations.

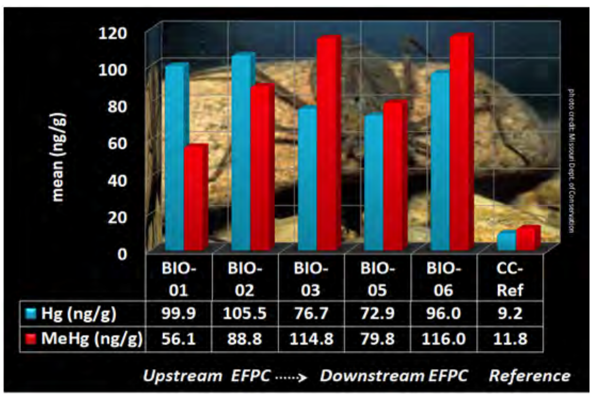


Figure 3.25: Dragonfly larvae Hg/MeHg results

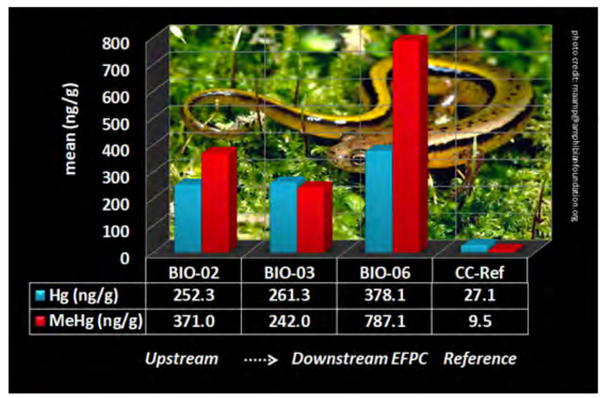


Figure 3.26: Salamander Hg/MeHg results

Spiders (*Arachnida*) Figure 3.27 shows the spider Hg/MeHg data for the upstream-to-downstream EFPC sites compared to the Clear Creek reference spider data. Spiders were collected from 3 EFPC sites plus 1 reference site with aquatic dip nets and pit-fall/drift net traps. Species collected were predominantly wolf spiders (Lycosidae) and fishing spiders (Pisauridae). In EFPC, spider Hg ranged from 124.3 ng/g to 940.4 ng/g (mean spider Hg = 429.58 ng/g). Spider MeHg ranged from 103.2 ng/g to 1285.3 ng/g (mean spider MeHg = 395.34 ng/g). The Clear Creek reference site yielded mean spider larvae Hg concentrations= 38.3 ng/g and spider MeHg = 58.3 ng/g.

Evaluating the upstream to downstream data, spider Hg and MeHg concentrations decreased progressively downstream.

In summation, 92% of the total spider Hg is present as MeHg and for the reference site, 100+% of the total Hg is present as MeHg. The EFPC spider mean Hg and MeHg are 11 times and 7 times greater respectively compared to their reference spider mean Hg and MeHg results. Interestingly, EFPC spider Hg and MeHg body burden concentrations were higher than any other organisms sampled except for the beetle which also had high Hg results. A recent ecological assessment of LEFPC revealed new data indicating high concentrations of mercury in spiders in the LEFPC floodplain which included a high concentration of the bioavailable methylmercury in spiders (Mathews et al., 2011). Two other EFPC studies recorded high Hg and MeHg body burdens in wolf spiders and fishing spiders (Smith et al., 2016, Standish, 2016). Carolina wrens may opportunistically forage on spiders and insects connected to contaminated aquatic food webs.

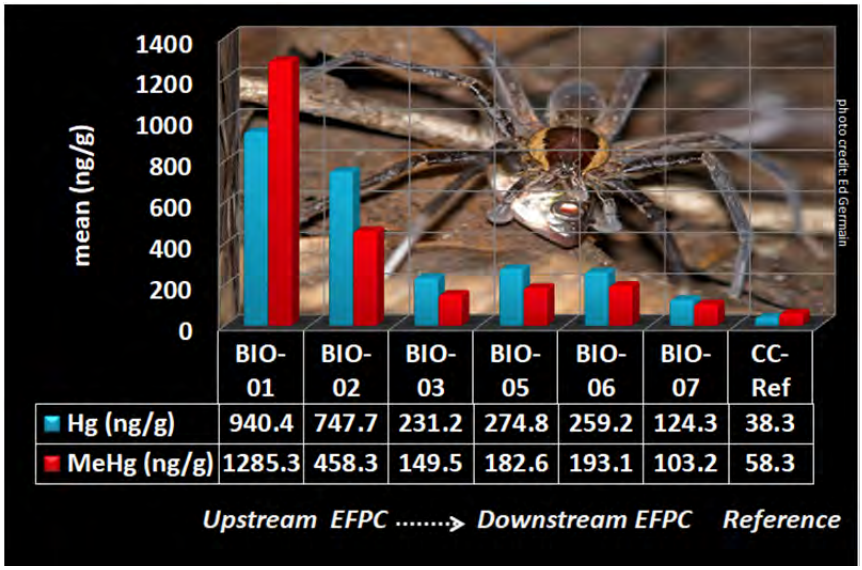


Figure 3.27: Spiders Hg/MeHg results

Figure 3.28 brings all the terrestrial/aquatic biota together for comparison of their respective Hg and MeHg results compared to mean reference results. At a glance, it is obvious which biota groups have the largest body burdens of Hg and MeHg, beetles, salamanders and spiders. The beetles by far recorded the largest body burden of Hg (1109.2 ng/g) compared to all other organisms, but overall beetle Hg is 14 times greater than beetle MeHg (80.9 ng/g).

The combined biota mean Hg and MeHg concentrations are 17 times and 8 times greater respectively compared to their counterpart biota at the Clear Creek reference site. Our results for beetles, salamanders and spiders provide evidence that elevated concentrations of Hg and MeHg may move up the EFPC food chain by consumption of these organisms to higher level terrestrial predators such as birds and ducks. 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).

In summary, Part I results, TDEC had 2 spider samples, 2 salamander samples, and 6 beetle samples that exceeded the EPA fish tissue threshold of 0.3 ppm (300 ng/g). Because avian species such as Carolina wrens consume macroinvertebrate adults that emerge from aquatic larval stages such as those evaluated in Part I, we expanded our biota study during

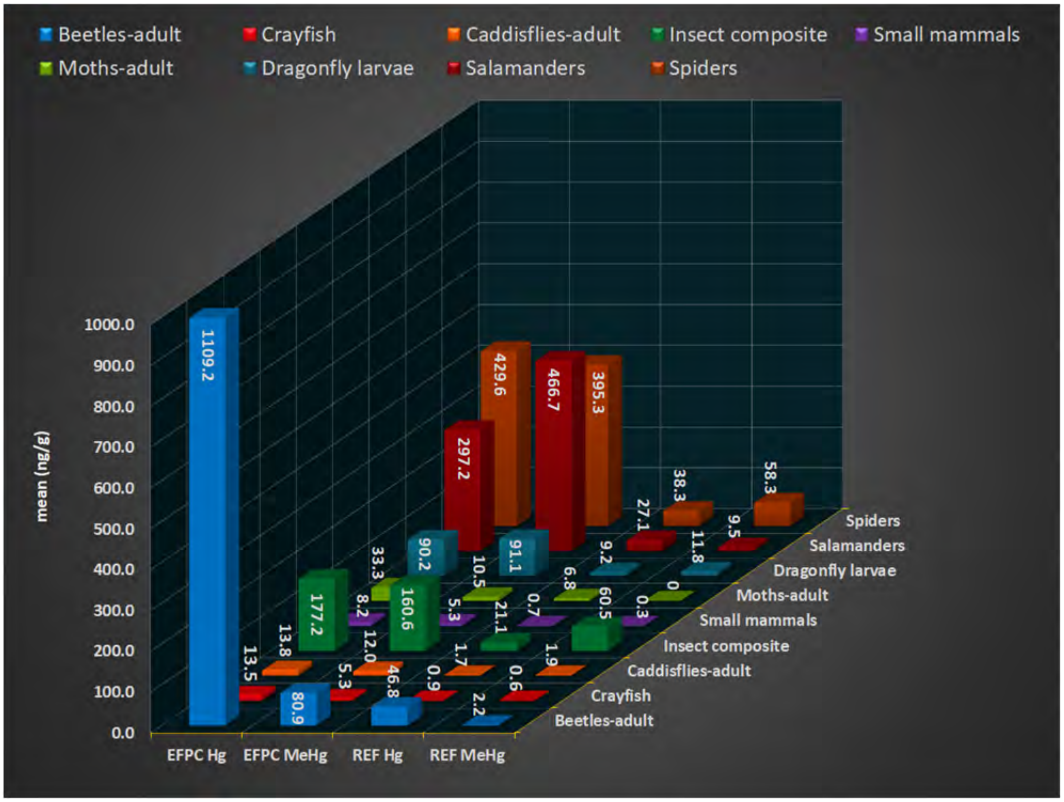


Figure 3.28: EFPC and reference combined biota—mean Hg & mean MeHg (Means were derived from sample sizes ranging from 2 to 7 results.)

2018 with an investigation of Hg and MeHg bioaccumulation in ORR birds and ducks. These findings are presented below in Part II of this report.

PART II: 2018 Avian Species Sampling Results

Birds are ubiquitous, top predators in many aquatic and terrestrial habitats, and often are subjected to elevated methylmercury concentrations (Cristol et al., 2008; Eagles-Smith, Ackerman, De La Cruz, and Takekawa, 2009; Ackerman et al., 2016). Birds are vulnerable to neurological and reproductive impacts from elevated mercury levels (Burger, 1993; Evers et al., 2005; Schulwitz, Chumchal, and Johnson, 2015).

Predicting a species' susceptibility to mercury toxicity based on its foraging guild (e.g., frugivore, insectivore) is a simple first step to identifying species at greatest risk of mercury contamination in the terrestrial environment (Rimmer et al., 2005; Osborne et al., 2011). Methylmercury levels of ≥1.5 ppm (1,500 ng/g) in eggs are associated with decreased bird egg weight, poor hatchability and low chick survival (Burger & Gochfeld, 1997).

Birds primarily reduce body burdens of mercury during feather molt as mercury has a high affinity for keratin, although adult females can also depurate mercury during egg production (Crewther et al. 1965) which is why TDEC chose to investigate mercury uptake in bird and duck eggs for this project phase. And to answer the question, can TDEC use eggs as an indicator of the effectiveness of DOE's remedial correction activities to clean up mercury in EFPC and on the ORR?

At each monitoring site, we installed one duck nest house and one songbird nest house for a combined total of 26 nest houses. Houses were monitored weekly for occupancy. TDEC collected bird and duck egg samples from 8 EFPC and 5 reference locations. Overall, approximately 65% of all nest houses were occupied but not always by the intended species. For example, we had several duck nest houses where starlings, a Carolina wren, and a hairy woodpecker built nests and laid eggs. We also monitored the wood duck nest houses for egg clutch size. Wood duck females occupied 3 nest houses at sites BIO-07, BIO-08, and REF-01 where eventually the female ducks laid 13, 15, and 14 eggs respectively (average of 14 eggs per nest). TDEC was unable to determine the duckling survival rate.

The feather sampling segment of this project did not materialize as planned for the following reasons: (1) insufficient biomass for analytical tests (too few feathers), (2) uncertain identity of feathers present in the nest houses; some birds often use molted feathers of other bird species to line their nests, and (3) undue stress to birds present in nest houses at time of sampling.

Table 3.7 lists all avian species that were sampled during 2018. We also collected local farm produce (domestic chicken eggs) for two purposes: (1) as a laboratory blind sample for our quality control protocol and as additional reference egg information. TDEC should note that sites REF-01 and REF-02 served two functions: (1) local reference egg information, and (2) the close proximity of the local reference sites to the TVA Bull Run steam plant. TDEC wanted to examine if mercury-outfall from the plant generating operations (stack gas pathway) might be manifested as elevated Hg and MeHg cocentrations in birds and ducks residing near Bull Run.

Table 3.7: Avian Species Monitored

Avian species	Classification (Family)	Life stage (as collected)
Eastern bluebird	Turdidae	eggs
Carolina chickadee	Paridae	eggs
Carolina wren	Troglodytidae	eggs
Domestic chicken	Phasianidae	eggs (quality control)
Hairy woodpecker	Picidae	eggs
European Starling	Sturnidae	eggs; hatchling
Tufted titmouse	Paridae	eggs
Wood duck	Anatidae	eggs

The avian sample data in Figures 3.28, 3.29 and 3.30 represent Hg and MeHg analytical data for whole egg samples, unless otherwise specified. Egg samples were either analyzed individually or in groups of 2 or more (from the same clutch) and composited into one sample. Other egg clutches were sampled whereby the first-, second- and third-laid eggs were collected and analyzed separately for Hg and MeHg. One wood duck egg sample was divided into shell, yolk, and albumen (white) for analysis. Where different species of bird or duck egg data are compared, all the Hg and MeHg analytical results were normalized by their respective species' egg weights.

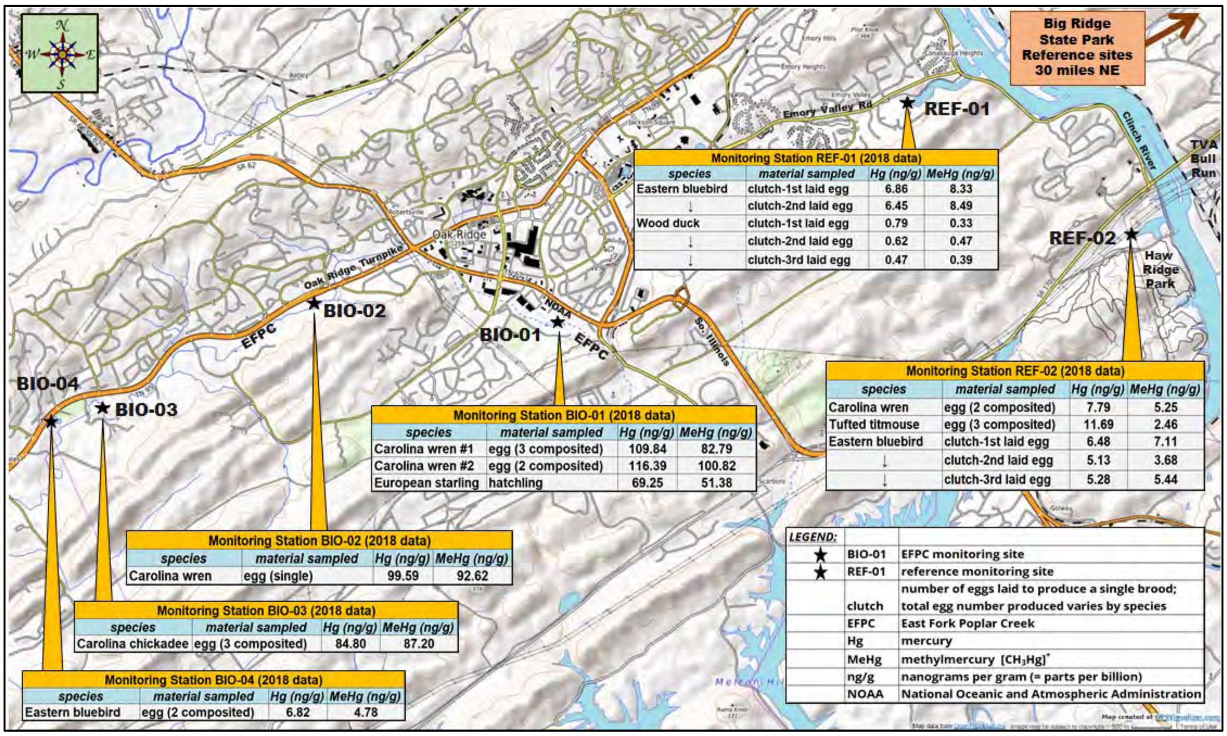


Figure 3.28: Upper East Fork Poplar Creek monitoring sites and egg Hg/MeHg data (2018)

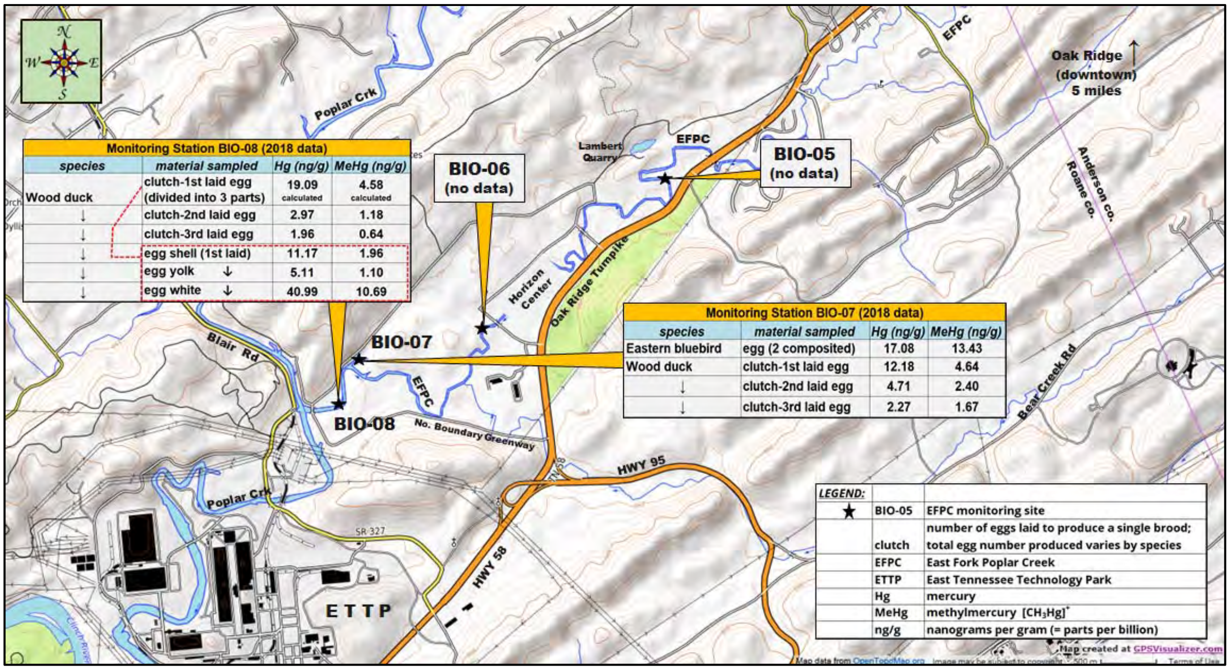


Figure 3.29: Lower East Fork Poplar Creek monitoring sites and egg Hg/MeHg data (2018)

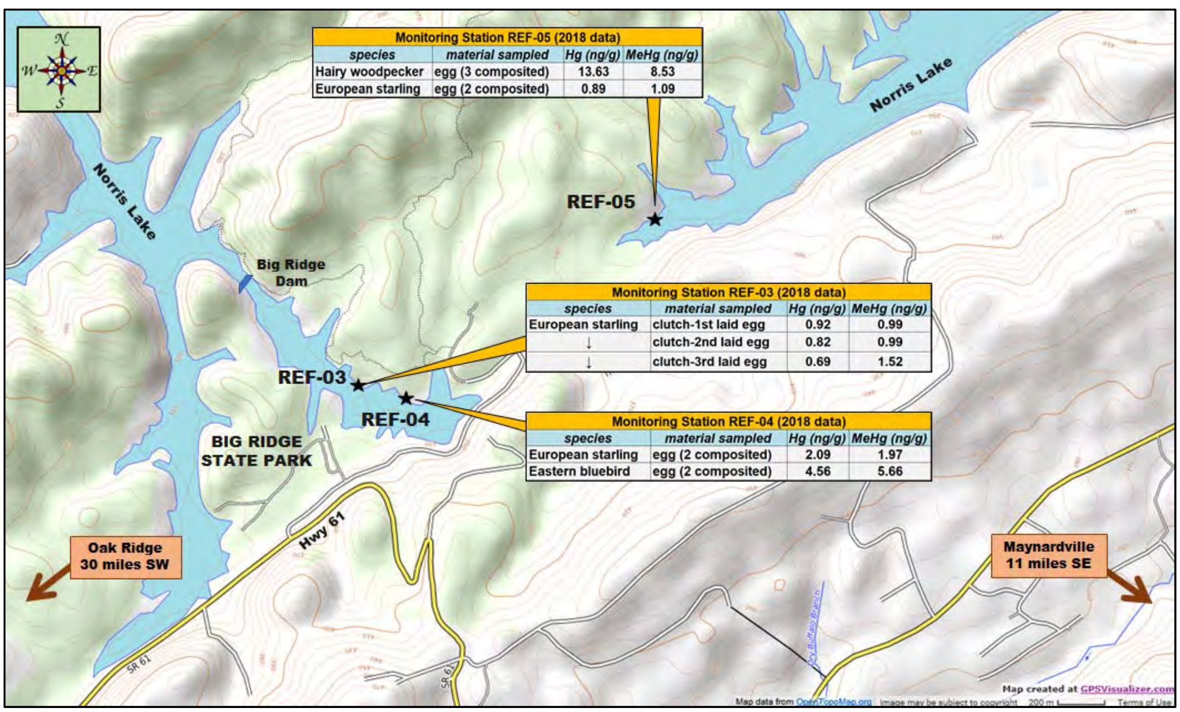


Figure 3.30: Big Ridge State Park (reference) monitoring sites and egg Hg/MeHg data (2018)

Normalization of avian egg data

Following each egg sampling event, TDEC returned to the TDEC DoR-OR laboratory to pre-process egg samples (including weights and dimensions). Accordingly, TDEC had good measurement data for each egg sent to the PACE Analytical laboratory for Hg and MeHg analysis. All analytical laboratory data reported are on a "wet weight" basis. This information was invaluable in normalizing the egg weight data.

The Hg and MeHg analytical data information as presented in figures 3.31-3.33 have been normalized to account for differences in body mass between various species of birds and ducks. For example, TDEC measured wood duck eggs and found a mean weight of 42.45 grams where in contrast, eastern bluebird eggs had a mean weight of 3.18 grams; showing that wood duck eggs are 13 times greater in biomass than eastern bluebird eggs. Normalizing the Hg and MeHg analytical results by their respective bird species' egg weights supports a much more accurate analysis and data interpretation from eggs collected from large vs. small birds.

Figure 3.31 illustrates the combined Hg/MeHg data (means) for all species from EFPC and the Big Ridge State Park reference sites (about 30 miles northeast of the ORR). TDEC deduced that EFPC biota have mean Hg and MeHg concentrations that are 9 times and 13.5 times greater, respectively, compared to their counterpart biota at the Big Ridge State Park reference sites.

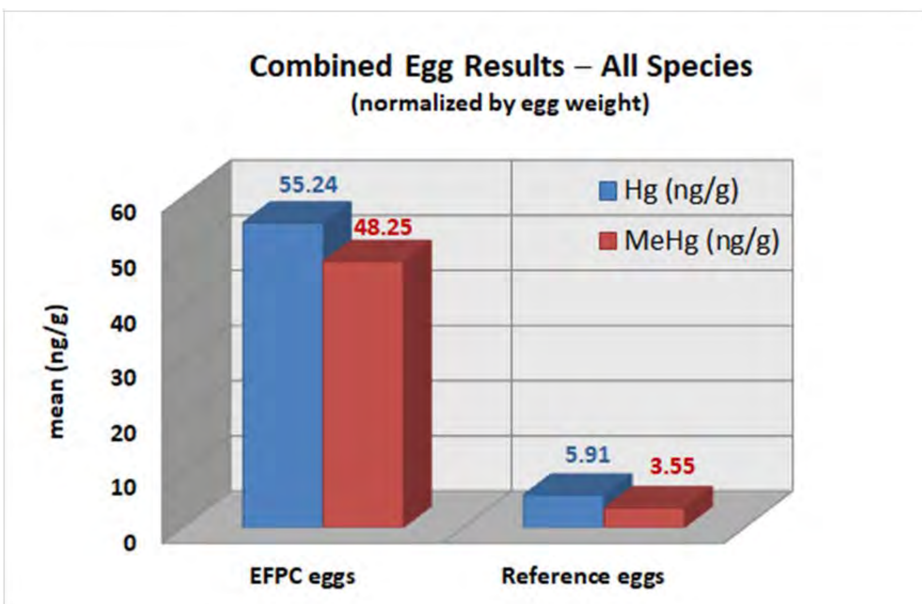


Figure 3.31: Combined 2018 egg results — mean Hg & MeHg (normalized)

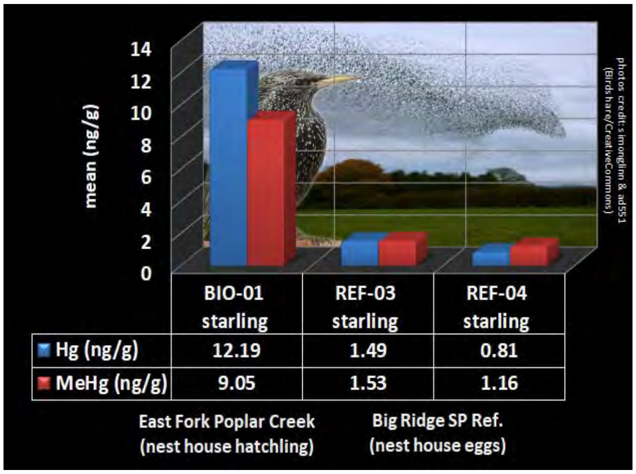


Figure 3.32: European starling Hg/MeHg data

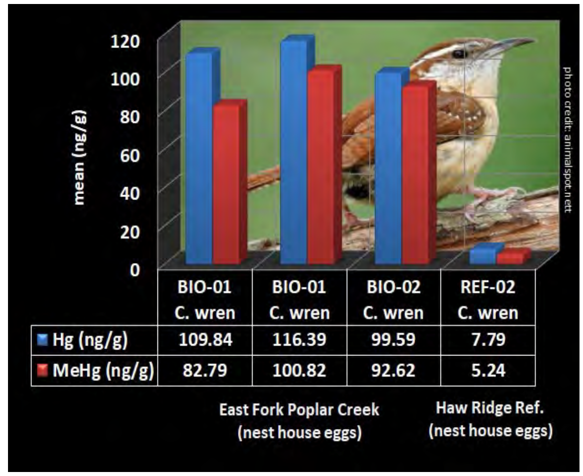


Figure 3.33: Carolina wren Hg/MeHg data

European starling (*Sturnus vulgaris*)

Figure 3.32 shows the starling Hg/MeHg data for 1 EFPC site compared to 2 Big Ridge State Park reference starling data sets. Starling eggs and 1 nest hatchling (nestling) were collected for analysis. The hatchling was collected from the NOAA site (BIO-01) near where DOE conducted remedial activities in the mid-1990s to remove Hg-contaminated soils from the EFPC floodplain. Concentrations of Hg in the starling hatchling = 12.9 ng/g and MeHg = 9.05 ng/g. The distant Big Ridge State Park reference sites yielded starling egg Hg concentrations ranging from 0.81 ng/g to 1.49 ng/g (mean starling egg Hg = 1.15 ng/g). The reference site MeHg for starling egg ranged from 1.16 ng/g to 1.53 ng/g (mean starling egg MeHg = 1.35 ng/g).

In summation, 74% of the total EFPC starling Hg is present as MeHg and for the BRSP reference sites, 100+% of the total Hg is present as MeHg. The EFPC starling hatchling Hg and MeHg was 11 times and 6.7 times greater, respectively, than the Big Ridge State Park starling eggs Hg and MeHg results.

According to the 1995 ROD for Lower East Fork Poplar Creek, the endpoint organisms for the EFPC soil monitoring program are earthworms and the European starling (*Sturnus vulgaris*).

Carolina wren (*Thryothorus ludovicianus*)

Figure 3.33 shows the Carolina wren Hg/MeHg egg data for EFPC compared to the reference site. Carolina wren eggs were collected at 3 EFPC sites and 1 reference site (the local Haw Ridge Park site). In EFPC, Carolina wren egg Hg ranged from 99.59 ng/g to 116.39 ng/g (mean Carolina wren egg Hg = 108.61 ng/g). The EFPC Carolina wren egg MeHg ranged from 82.79 ng/g to 100.82 ng/g (mean Carolina wren egg MeHg = 92.08 ng/g). The Haw Ridge Park reference site Hg and MeHg for Carolina wren eggs = 7.79 ng/g and 5.24 ng/g respectively. The Haw Ridge Park site (Melton Lake backwater cove) served a secondary role as a monitor of potential Hg outfall from the TVA Bull Run steam plant stack gas. The Haw Ridge Park reference egg Hg and MeHg results are just slightly higher compared to the Big Ridge State Park starling egg Hg and MeHg results.

In summation, 84.78% of the total EFPC Carolina wren Hg is present as MeHg and for the Haw Ridge Park reference site, 67.26% of the total Hg is present as MeHg. The EFPC Carolina wren Hg and MeHg was 14 times and 17.5 times greater than the Haw Ridge Park reference Carolina wren egg Hg and MeHg results.

DOE biologists state that there is no empirical data to support that Carolina wrens are negatively affected in EFPC floodplain (Peterson, 2018). Based upon models, DOE proposes to change the soil PRGs (preliminary remedial goals) for Carolina wren from 3.6 ppm Hg to 77-215 ppm Hg for EFPC ecological risk assessments (Peterson, 2018). None of TDEC's 2018 Carolina wren Hg/MeHg results fall within the proposed range of 77-215 ppm.

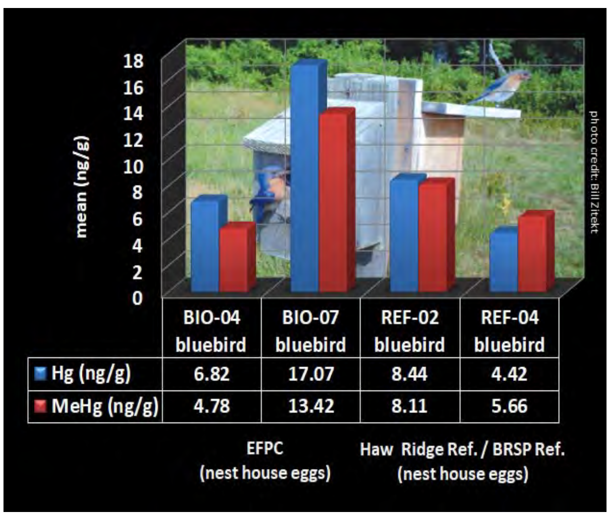


Figure 3.34: Eastern bluebird Hg/MeHg data

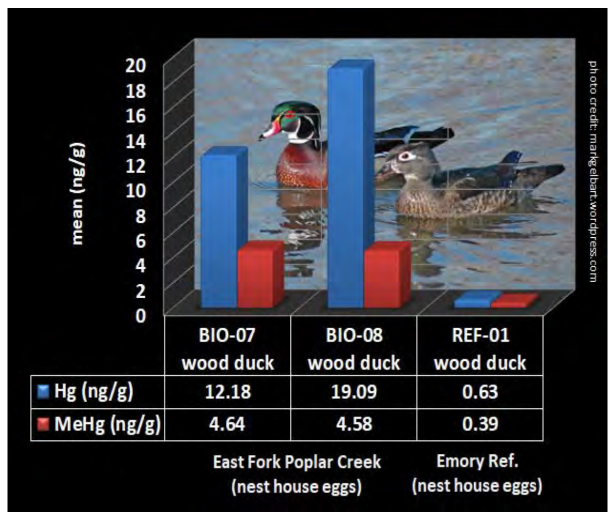


Figure 3.35: Wood duck Hg/MeHg data

Eastern bluebird (*Sialia sialis*)

Figure 3.34 shows the Eastern Bluebird Hg/MeHg egg data for EFPC compared to the reference site. Eastern Bluebird eggs were collected at 2 EFPC sites and 2 reference sites (the local Haw Ridge Park site and the distant Big Ridge State Park site). In EFPC, eastern bluebird egg Hg ranged from 6.82 ng/g to 17.07 ng/g (mean eastern bluebird egg Hg = 11.94 ng/g). The EFPC Eastern Bluebird egg MeHg ranged from 4.78 ng/g to 13.42 ng/g (mean eastern bluebird egg MeHg = 9.1 ng/g). The Haw Ridge Park reference site Hg and MeHg for eastern bluebird eggs = 8.44 ng/g and 8.11 ng/g respectively. The Big Ridge State Park reference egg Hg and MeHg results = 4.42 ng/g and 5.66 ng/g respectively.

In summation, 76.21% of the total EFPC eastern bluebird Hg is present as MeHg. For the reference sites, 53.85% and 75.60% of the total EFPC eastern bluebird Hg is present as

MeHg at the Haw Ridge and Big Ridge sites, respectively. The combined EFPC Eastern Bluebird egg mean Hg and mean MeHg was 1.7 times and 1.3 times greater respectively than the combined reference eastern bluebird egg Hg and MeHg results. The Haw Ridge Park site served a secondary role as a monitor of potential Hg outfall from the TVA Bull Run steam plant stack gas. We noted very little difference between Hg and MeHg concentrations present in Bluebird eggs collected at the Haw Ridge Park reference site and the Big Ridge State Park reference site.

Wood duck (*Aix sponsa*)

Figure 3.35 shows the wood duck Hg/MeHg egg data for EFPC compared to the reference site. Wood duck eggs were collected at 2 EFPC sites and 1 reference sites (the local Emory Valley greenway site). In EFPC, wood duck egg Hg ranged from 12.18 ng/g to 19.09 ng/g (mean wood duck egg Hg = 15.63 ng/g). The EFPC wood duck egg MeHg ranged from 4.58 ng/g to 4.64 ng/g (mean wood duck egg MeHg = 4.61 ng/g). The Emory Valley greenway reference site Hg and MeHg for wood duck eggs = 0.63 ng/g and 0.39 ng/g respectively.

In summation, 29.49% of the total EFPC wood duck Hg is present as MeHg. For the Emory Valley greenway reference site, 57.14% of the total EFPC wood duck Hg is present as MeHg. The combined EFPC wood duck egg mean Hg and mean MeHg was 25 times and 12 times greater, respectively, than the reference wood duck egg Hg and MeHg results. The Emory Valley greenway site (adjacent to a Melton Lake backwater cove) served a secondary role as a monitor of potential Hg outfall from the TVA Bull Run steam plant stack gas. TDEC noted very little difference between Hg and MeHg concentrations present in wood duck eggs collected at the Emory Valley greenway reference site and the Big Ridge State Park reference site.

During the hunting season (Sep–Jan) at a mercury-contaminated river in Virginia, another duck species, mallards harvested at contaminated sites had approximately twice (2.2 times) the mercury concentrations in feathers as wood ducks and 4.8 times that of Canada geese. Mercury concentrations in mallard pectoral muscles were 7.0 times higher in mallards than wood ducks and 11.7 times higher in mallards, than found in Canada geese (Cristol et al., 2012).

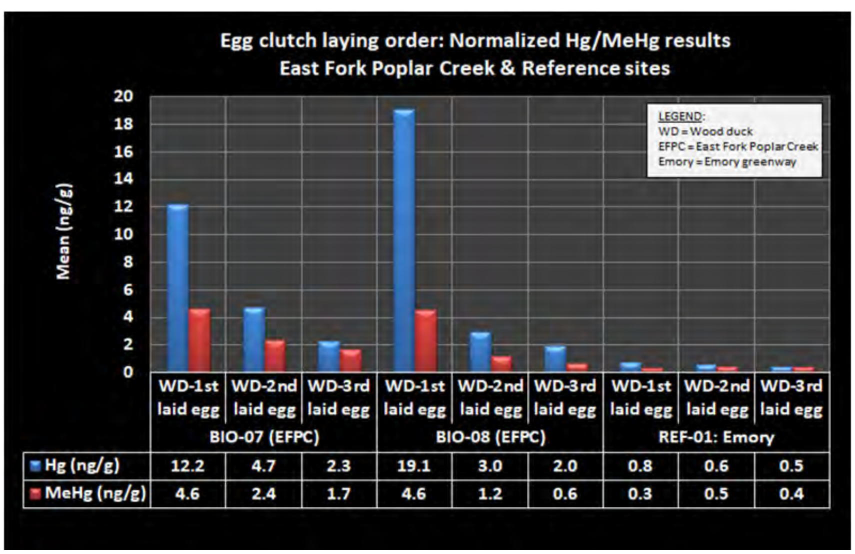
Egg laying order

Another phase of this study was to investigate if there were differences in Hg/MeHg uptake concentrations relating to egg clutch laying order. TDEC also examined Hg/MeHg residues in egg components (shell, yolk, albumen, or whites). Wood ducks were selected for this purpose because they are a waterfowl species that readily takes to nest houses, frequently nests on the ORR, and produce a large clutch of eggs (10-15 eggs/clutch). The sampling plan was to track laying order at each occupied nest house and collect the initial 3 eggs for Hg and MeHg analysis.

Kennamer et al., (2005) found that Hg concentrations in the albumen (egg whites) of wood ducks (sample size = 138) collected from a contaminated pond in South Carolina steadily declined through the first 5 eggs [i.e., 0.33 ppm (330 ppb) in 1st-laid to <0.20 ppm (200 ppb) in eggs 6-8]. The females offload their Hg burdens into their eggs such that the first few eggs get a pulse of the hens' excess Hg.

Augspurger, et al., (2008) investigated a coastal North Carolina river associated with contamination from a now-closed chlor-alkali plant; eggs were collected from wood duck nest boxes and evaluated for Hg and PCBs. The reported egg Hg concentration of 0.14 ug/g (140 ng/g) was higher in Hg than reference site concentrations. Heinz (1979) reported abnormal egg-laying and lower productivity in female mallard eggs that contained 0.79–0.86 ug/g (790-860 ng/g) mercury (Augspurger et al., 2008). In a review of the mallard data and other avian toxicological data, Thompson (1996), indicated that mercury concentrations in eggs between 0.5 and 2.0 ug/g (500-2000 ng/g) correlated with reproductive impairment. Burger and Gochfeld (1997) reported that MeHg levels ≥1.5 ppm (1,500 ng/g) are associated with decreased egg weight, poor hatchability, and low chick survival.

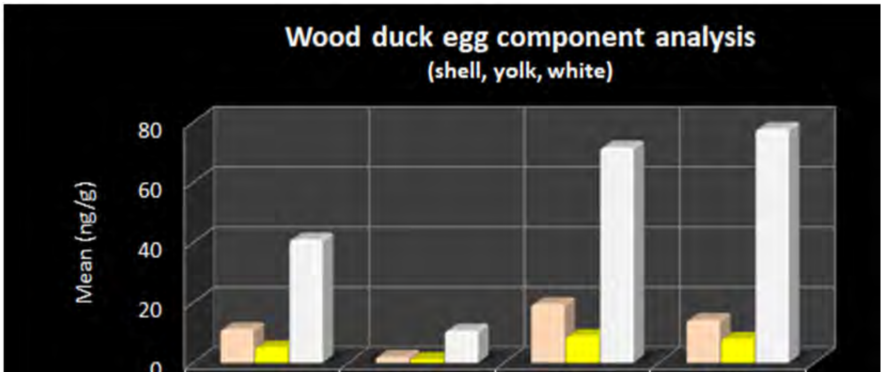
TDEC's wood duck data results, although based on a small sample size (n = 9), suggest that Hg and MeHg concentrations steadily decrease from the 1st-laid to 3rd-laid eggs collected from TDEC's EFPC and reference wood duck nest houses (Figure 3.36). That is, the 2nd-laid egg has less Hg than the 1st-laid egg, etc. All TDEC's wood duck egg Hg and egg MeHg results were below 1,500 ng/g, a level beyond which is believed to be associated with egg reproductive impairment and low chick survival. However, Jackson et al., (2011) argued that songbirds can suffer negative reproductive effects at mercury concentrations as low as 0.7 ppm (700 ppb).TDEC also examined the Hg/MeHg uptake in a few clutches of Eastern Bluebird and European starling eggs which generally followed a similar trend as the wood ducks of decreasing egg Hg/MeHg burdens with egg-laying order, but less robust.



	BIO-07 (EFPC) WD-1st laid egg	BIO-07 (EFPC) WD-2nd laid egg	BIO-07 (EFPC) WD-3rd laid egg	BIO-08 (EFPC) WD-1st laid egg	BIO-08 (EFPC) WD-2nd laid egg	BIO-08 (EFPC) WD-3rd laid egg	REF-01: Emory WD-1st laid egg	REF-01: Emory WD-2nd laid egg	REF-01: Emory WD-3rd laid egg
Hg (ng/g)	12.2	4.7	2.3	19.1	3.0	2.0	0.8	0.6	0.5
MeHg (ng/g)	4.6	2.4	1.7	4.6	1.2	0.6	0.3	0.5	0.4

Figure 3.36: Egg-laying sequence — mean Hg & MeHg (normalized)

The single-egg component analysis revealed that the egg shell Hg / MeHg = 11.17 ng/g / 1.96 ng/g; egg yolk Hg / MeHg = 5.11 ng/g / 1.10 ng/g; and the egg white Hg = 40.98 ng/g / 10.69 ng/g. TDEC calculated the % Hg and % MeHg portions for the egg white (albumen) component which is about 71% and 77%, respectively, of the total egg biomass. TDEC results for the egg component analysis is consistent with the South Carolina wood duck egg study that found ≥86% of the egg Hg was concentrated in the albumen (Kennamer et al., 2005; Figure 3.37).



	Hg (ng/g)	MeHg (ng/g)	Hg (% of egg biomass)	MeHg (% of egg biomass)
egg shell	11.17	1.96	19.50	14.25
egg yolk	5.11	1.10	8.92	8.00
egg white	40.98	10.69	71.57	77.75

Figure 3.37: Egg Hg/MeHg data and % component biomass

What is the ecological significance of the egg laying order and the egg component analysis?

The information presented suggests that collection of 1st laid eggs for contaminant analysis may provide evidence of ecosystem recovery and an assessment of maximal Hg exposure to developing embryos of avian species in an ecosystem.

Avian egg trends- East Fork Poplar Creek vs. Reference sites

Caveat: Due to bird nesting preferences, eggs from some species were not consistently collected from site-to-site. For example, European starlings and a woodpecker were found nesting in duck nest boxes instead of wood ducks.

Figures 3.40 and 3.41 compare mercury uptake in birds by species. Within EFPC, Carolina wren and Carolina chickadee eggs accumulated significantly greater concentrations of Hg and MeHg compared to the eastern bluebird and wood duck. Mean EFPC egg Hg (all species) = 55.24 ng/g and mean EFPC egg MeHg (all species) = 48.25 ng/g. Mean reference egg Hg (all species) = 5.91 ng/g and mean reference egg MeHg (all species) = 3.55 ng/g. As far as the percent Hg that is MeHg, 87.34% of the total EFPC species Hg is present as MeHg and 60.06% of the total reference species, Hg is present as MeHg.

These results would suggest that the Carolina wren and Carolina chickadee have similar diet preferences. According to the Cornell Ornithology Laboratory, Common foods of the Carolina wren include spiders, insects, and occasionally lizards, frogs, or snakes. They consume a small amount of plant matter, such as fruit pulp and seeds from bayberry, sweetgum, or poison ivy (Haggerty and Morton, 2014). In winter, the Carolina Chickadee's diet is about half plant, half animal. The rest of the year about 80–90 percent of their diet is mostly insects and spiders (Mostrum, Curry, and Lohr, 2002).

To compare between EFPC and the reference, there are only three species that were present and laid eggs at both the EFPC and the reference nest houses; those species are Carolina wren, Eastern Bluebird and the wood duck. As a result, TDEC will only explore some trends between these species. The EFPC Carolina wren egg Hg and MeHg was 14 times and 18 times greater, respectively, compared to the reference egg Hg and MeHg concentrations. The EFPC eastern bluebird egg Hg and MeHg was 1.8 times and 1.3 times greater, respectively, when compared to the reference egg Hg and MeHg concentrations. And lastly, the EFPC wood duck egg Hg and MeHg was 26 times and 11.5 times greater, respectively, when compared to the reference egg Hg and MeHg concentrations.

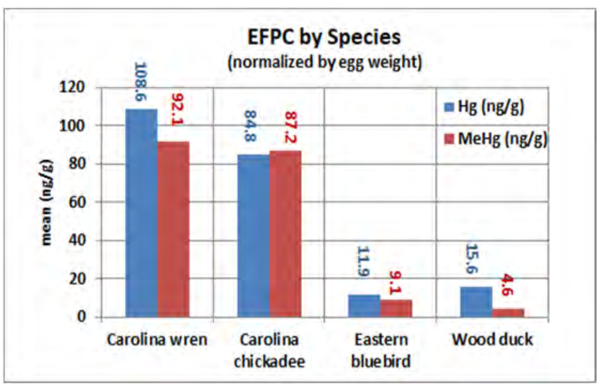


Figure 3.38: EFPC egg results by species

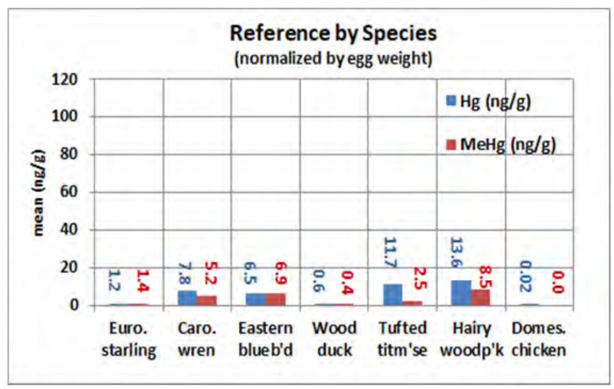


Figure 3.39: Reference egg results by species

Figures 3.38 and 3.39 compare mercury uptake in birds, by type. Only two have common types between EFPC and the reference, songbirds and waterfowl. Within EFPC, songbird eggs accumulated significantly greater concentrations of Hg and MeHg compared to waterfowl. EFPC songbird egg Hg and egg MeHg are 4 times and 13.6 times greater than EFPC water fowl Hg and waterfowl MeHg, respectively. Within the reference, the woodpecker egg Hg and egg MeHg was at least 2 times greater when compared to the other types. However, TDEC did not collect woodpecker eggs at EFPC. The game fowl (i.e., farm produce, domestic chicken egg) was included in the study as a laboratory quality control sample.

As far as the percent of Hg that is MeHg in songbirds, 91.73% of the total EFPC species Hg is present as MeHg and 58.70% of the total reference species Hg is present as MeHg. In waterfowl, 29.51% of the total EFPC species Hg is present as MeHg and 62.90% of the total reference species Hg is present as MeHg. The reason for the songbird mercury uptake being several orders of magnitude greater than the waterfowl may be explained by differences in diet.

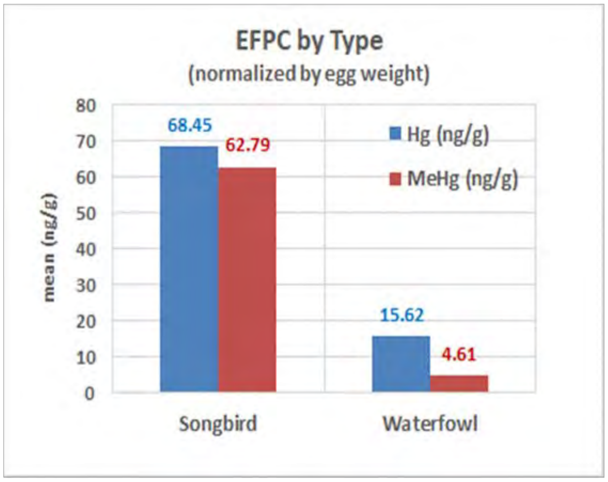


Figure 3.40: EFPC egg results by type

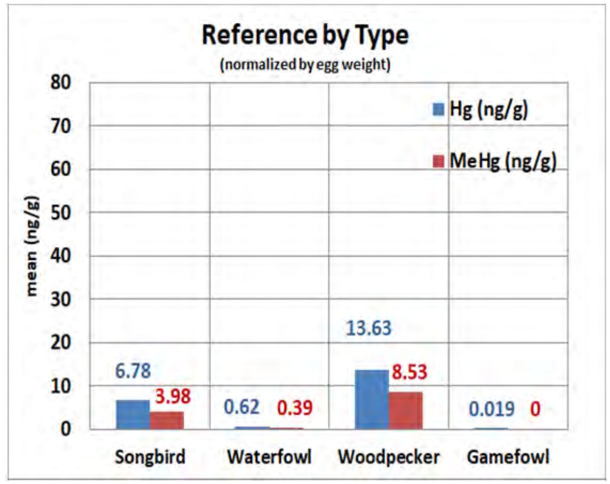


Figure 3.41: Reference egg results by type

Figures 3.42 and 3.43 break down the species/types into their respective feeding groups (by diet). As TDEC has seen in the comparisons between types, the EFPC Hg and MeHg by diet are several orders of magnitude greater when compared to the reference Hg and MeHg. TDEC gives a comparison of two main dietary groups, insectivores and omnivores. The diet of omnivores, such as wood ducks, includes mostly plant materials (i.e., waste grains, seeds, etc.) plus a small amount of invertebrates. Songbirds are known to forage near their nest on a diet of insectivorous birds such as Carolina wrens connected to the aquatic food web that may have high concentrations of Hg (Cristol et al., 2008; Keller, Xie, Buchwalter, Franzreb, and Simons, 2014; Gann et al., 2015). The diet of the Carolina wren includes spiders, caterpillars, moths, stick bugs, leafhoppers, beetles, grasshoppers, crickets, cockroaches, and occasionally lizards, frogs, or snakes. Given the evidence presented previously in this report about high concentrations of Hg in spiders (Smith, Mathews, Peterson, Jones, and Jones, 2016; Standish, 2016), it is not surprising that the insectivorous group accumulated greater egg Hg and egg MeHg concentrations than omnivores.

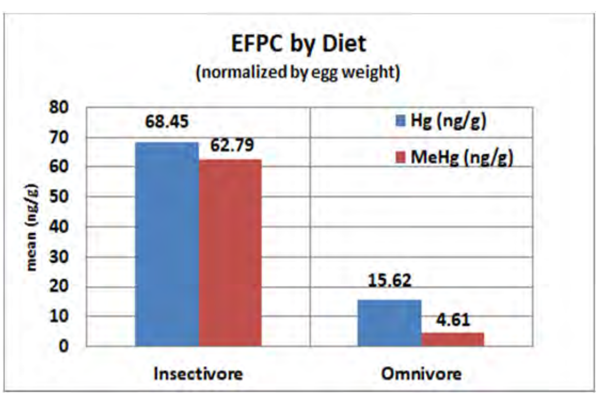


Figure 3.42: Mean EFPC egg results by diet

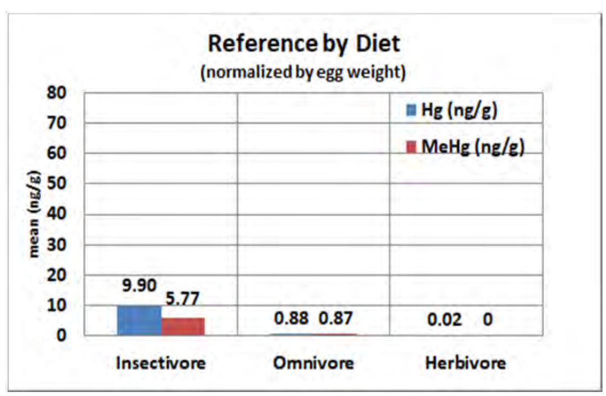


Figure 3.43: Mean Reference egg results by diet

Finally, it is important to consider Figure 3.44, the percent egg Hg difference between egg samples collected between EFPC and the reference sites. We calculated that Carolina wren eggs in EFPC had a 1,295% increase in egg Hg and a 1,657% increase in egg MeHg compared to the reference site eggs. Eastern bluebird egg Hg and egg MeHg exhibited increases of 83% and 32%, respectively, compared to the reference eggs. Wood duck egg Hg and egg MeHg exhibited increases of 2,419% and 1,082%, respectively, when compared to the reference eggs.

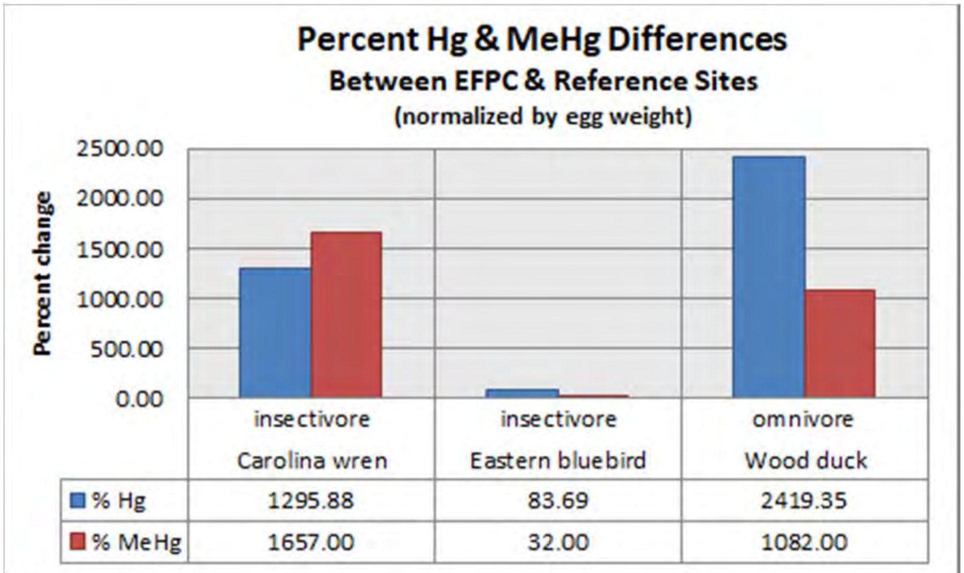


Figure 3.44: Percent Hg & MeHg increase at EFPC compared to Reference

3.2.8 Conclusions

TDEC'S study is unique because few if any recent avian egg mercury uptake studies have been conducted on the ORR with the exception of European starling reproduction studies at EFPC. And no ORR studies have investigated mercury uptake based on egg-laying sequence nor investigation of the Hg/MeHg composition of the 3 egg components (shell, yolk, albumen). However, extensive avian studies including wood ducks and other aquatic birds have been conducted at DOE's Savannah River Site including radiological and mercury uptake studies (Colwell, Kennamer, and Brisbin, 1996; Kennamer et al., 2005; Kennamer et al., 2017).

TDEC demonstrated that Hg and MeHg concentrations are 9 times and 14 times greater, respectively, in EFPC eggs compared to reference eggs. TDEC also found that the egg albumen component of the 3 egg parts constitutes the major portion of mercury in the whole egg (our result suggest >70% of the Hg is in the egg white). TDEC determined that the largest percentage of Hg in a clutch of eggs is within the first-laid egg.

Avian research has reported detrimental effects to bird reproduction at Hg concentrations ranging from 0.7 ppm (700 ng/g) to 2.0 ppm (2,000 ng/g) (Thompson, 1996; Burger and Gochfeld, 1997; Augspurger et al., 2008, Jackson et al., 2011).

Note that TDEC has 1 spider MeHg result and 1 salamander MeHg result that fall within this range known to be detrimental to bird reproduction (see below). Birds consuming prey items such as these spiders and salamanders could be expected to bioaccumulate similar levels of body burden mercury.

Spiders are one of the few organisms for which TDEC has comparable DOE mercury data to evaluate. At upper EFPC site BIO-01 (NOAA site), TDEC determined spider MeHg concentration of 1285.3 ng/g (1.285 ppm). Our result is above the EPA fish tissue threshold of 0.3 ppm (300 ppb) and also exceeds levels of MeHg that are reported to be detrimental to reproduction in birds. In our literature review, TDEC found at least two recent DOE-related reports with spider MeHg information:

A 2016 upper EFPC biota study reported spider MeHg = 1.29 ppm (mean of 837 samples; Standish, 2016). This result is very close to TDEC spider MeHg result of 1.285 ppm from upper EFPC.

A 2015 ORR biota study reported a spider MeHg concentration of 0.431 ppm (431 ng/g) collected from upper EFPC at EFPC 23.4 km (station 17) (Smith, Mathews, Peterson, Jones, and Jones, 2016). The MeHg result is lower than that reported in this study and the Standish study.

Two salamander samples exceeded the EPA fish tissue threshold of 0.3 ppm (300 ng/g) MeHg:

- BIO-02 site: 371.0 ng/g = 0.371 ppm (MeHg)
- BIO-06 site: 787.1 ng/g = 0.7871 ppm (MeHg)

Six beetle Hg results exceeded the EPA fish tissue threshold of 0.3 ppm (300 ng/g). Though this is not a direct comparison, this is the only standard available for comparison for this project during this time MeHg:

- BIO-01 site: 1983.4 ng/g = 1.983 ppm (Hg)
- BIO-03 site: 2106.3 ng/g = 2.106 ppm (Hg)
- BIO-04 site: 461.8 ng/g = 0.4618 ppm (Hg)
- BIO-05 site: 641.2 ng/g = 0.6412 ppm (Hg)
- BIO-06 site: 1913.6 ng/g = 1.9136 ppm (Hg)
- BIO-07 site: 395.4 ng/g = 0.3954 ppm (Hg)

Future avian studies on the ORR should include monitoring radionuclides and mercury in waterfowl where duck hunts are allowed on the ORR (Three Bends Wildlife Management Area). Currently, DOE does not radiologically monitor the game birds that are harvested by hunters on the ORR.

3.2.9 Recommendations

Based on the current measured concentrations in soil and tissue concentrations collected, the absorbed doses to the terrestrial organisms collected along the confluence of Melton Branch and WOC and in the floodplain upstream of White Oak Lake were less than 0.1 rad/day (DOE, 2017).

The following work is planned to commence during FY2019. Starling eggs will be collected from nest boxes during the spring (early April-May). Sampling of broods will occur prior to fledging, which occurs over a 12 to 21-d period following the onset of egg laying. From one brood, three eggs and three nestlings (from different nestboxes) are planned to be sampled at each site. If the starlings produce two broods in a season, reproductive success for each brood will be assessed, but only the first brood will be sampled. During sampling of starlings for body burden analyses, reproductive success of starlings will be monitored by counting the number of eggs and offspring in starling nest boxes (SAIC, 1996). Although earthworm sampling data has been available in a recent EFPC study (Standish, 2016), TDEC has not seen the starling monitoring data that is required under the ROD.

3.3 Radiological Uptake In Vegetation

3.3.1 Background

The three facilities on the Oak Ridge Reservation (ORR) have seen a variety of radiological contamination. 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 focused on areas likely to have radiological contamination, either from past or current 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 Oak Ridge Reservation. 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).

An additional goal of this project is to review and provide constructive comments to DOE on the applicable sections of the DOE Environmental Monitoring Plan (EMP) and the DOE Annual Site Environmental Report (ASER).

3.3.4 Scope

This project collected and analyzed 20 vegetation samples for radiological contamination in 2017. Samples were collected near surface water bodies (potentially impacted by radioactivity) on or near the ORR and one from a background location. Target vegetation for sampling included, but was not limited to, common cattail (Typha latifolia) and mixed vegetation. Potential monitoring locations included: springs, seeps, streams, creeks, wetlands, ponds, floodplains, and adjacent areas. Watersheds such as Bear Creek and its tributaries, White Oak Creek/Lake and its tributaries, Mitchell Branch, and East Fork Poplar Creek were all probable target locations for sampling. Samples were analyzed for gross alpha and gross beta activity, and for gamma radionuclides. The results can then be compared to the radiological analysis of vegetation taken from a background or other location with low levels of radiological contamination. Additional analysis can be requested if determined necessary.

3.3.5 Methods, Materials, Metrics

Twenty vegetation samples were collected in areas determined by TDEC to have high potential for radiological contamination. Samples consisted of at least one gallon of vegetation (with focus to minimize 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 lab. Samples were processed and sent to the Tennessee Department of Health (TDH) environmental laboratory in Nashville for radiological analysis.

The samples, which included a background sample, were collected and analyzed for general radiological contamination. Samples were collected near ORR surface water sites, including springs, creeks, and 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. In planned sampling locations where cattails, watercress, and willow were not available or 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 (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

The results of the 20 samples collected in 2017 are available for this report. The results from the 2018 sampling are not yet available for this report. Consequently, only the 2017 data are discussed in this report.

3.3.7 Results from Analysis

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. As such, sample data was compared with gross alpha, gross beta, and gamma activity collected from a background location. Where sample results are greater than twice background levels, they are considered elevated.

TDEC gathered 20 vegetation samples for radiological analysis in May and early June of 2017. The 2017 vegetation sampling locations are shown in Figure 3.45. One sample was taken as a background (V-1). Other 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. Samples were collected at each of the three larger sites on the ORR: ORNL, Y-12, and ETTP.

Four samples were taken at ETTP at locations near surface water (V-2, V-3, V-4, and V-5). Ten samples were taken at ORNL (V-6 through V-15). Many of these samples were taken in Melton Valley. A series of samples was taken along White Oak Creek (V-8, V-9, V-10, V-13, V-14, and V-15), in Melton Valley and Bethel Valley. Five samples were collected in Bear Creek Valley; two near Y-12; and three farther west in Bear Creek Valley. Table 3.8 provides the results of the gross alpha, gross beta, and gamma analysis of the twenty vegetation samples collected in 2017.

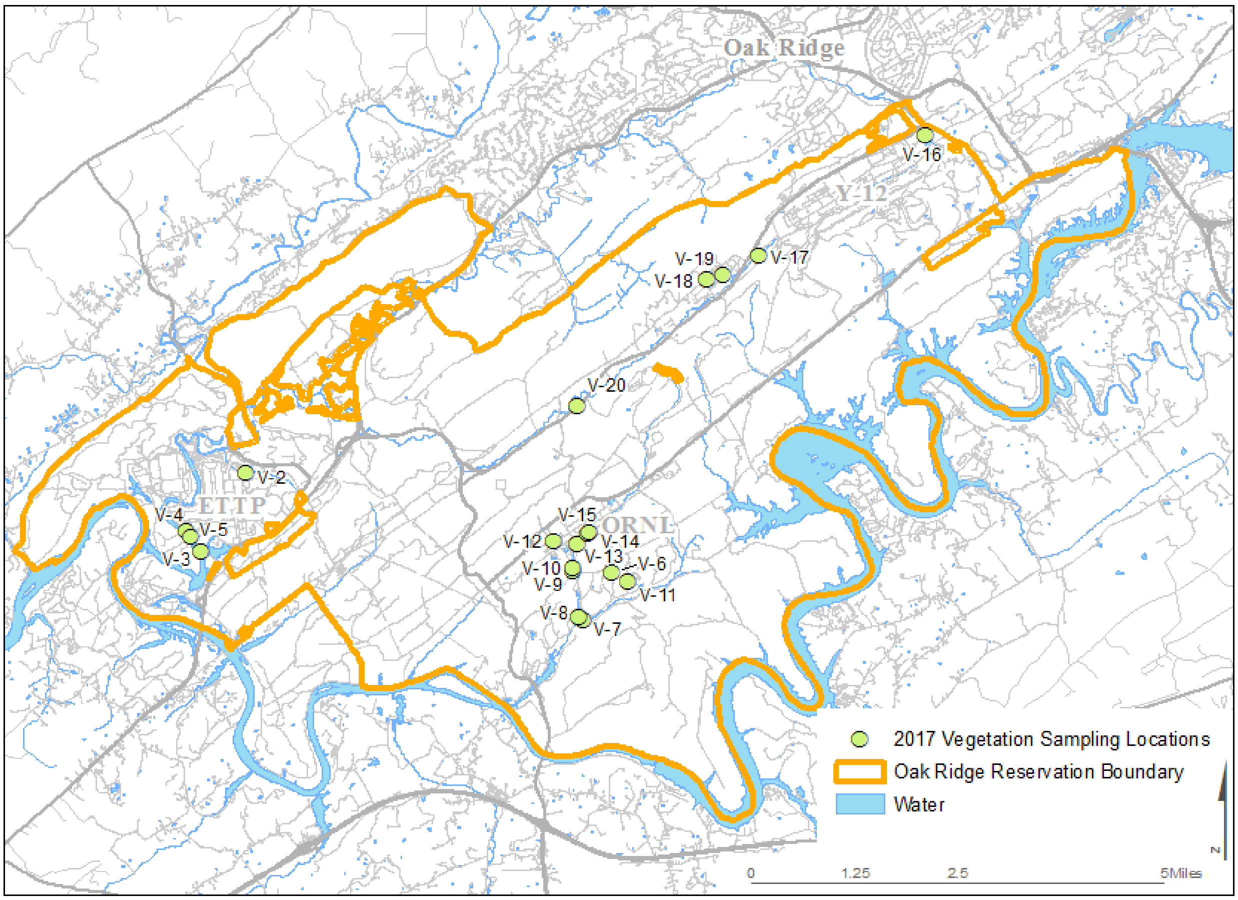


Figure 3.45: 2017 Vegetation Sampling Locations

Table 3.8: 2017 Vegetation Sampling Locations

Site	Location	Vegetation Type
V-1	Offsite Background- Worthington Cemetery Trail	mixed/cattails
V-2	ETTP Mitchell Branch	mixed
V-3	K-1007 P-1 Pond west	cattails
V-4	ETTP West End D&D	cattails
V-5	Poplar Creek, below SD-440	mixed/cattails
V-6	HRE Wetland	cattails
V-7	Melton Branch Weir	mixed
V-8	White Oak Creek Weir	cattails
V-9	White Oak Creek, Melton Valley Road, downstream	cattails
V-10	White Oak Creek, Melton Valley Road, upstream	mixed
V-11	HFIR Drainage	cattails
V-12	ORNL 1st Creek Upstream of Central Ave	mixed
V-13	White Oak Creek, 3rd Street Bridge, upstream	mixed
V-14	White Oak Creek, below fifth creek	mixed
V-15	White Oak Creek, above fifth creek	mixed
V-16	East Fork Poplar Creek, behind New Hope Center	mixed
V-17	Y-12 Bear Creek below S-2	mixed/cattails
V-18	EMWMF Underdrain	cattails
V-19	NT-3 near Bone Yard Burn Yard	cattails
V-20	Bear Creek Valley, SS-6 Spring	mixed

Table 3.9: 2017 Vegetation Sampling Results (pCi/g wet weight)

vegetation type	site	location	gross alpha	gross beta	gamma					
					Cs-137	K-40	Be-7	Bi-214	Pb-214	Pb-212
cattails	V-6	HRE Wetland	-2.21	101		4.12		0.233	0.208	
cattails	V-8	White Oak Creek Weir	-0.65	31.5	0.689	2.93				
cattails	V-9	White Oak Creek, Melton Valley Road, downstream	-0.67	24.8	0.614	3.34				
mixed	V-10	White Oak Creek, Melton Valley Road, upstream	-0.18	15.3	11.10	3.90	2.14			
mixed	V-16	East Fork Poplar Creek, behind New Hope Center	2.67	13.2		4.01		0.077	0.097	0.048
mixed	V-7	Melton Branch Weir	-0.33	12.7		4.88	1.24	0.065	0.066	
cattails	V-11	HFIR Drainage	-0.13	9.8		5.18				
mixed	V-13	White Oak Creek, 3rd Street Bridge, upstream	-0.19	8.8	3.08	5.68			0.125	
mixed	V-12	ORNL 1st Creek Upstream of Central Ave	-0.02	6.1		4.25	2.41			
mixed	V-20	Bear Creek Valley, SS-6 Spring	-0.06	4.9		4.59	2.21			
mixed/cattails	V-17	Y-12 Bear Creek below S-2	-0.01	4.3		3.66	1.23			
cattails	V-19	NT-3 near Bone Yard Burn Yard	-0.09	4.1		4.43			0.070	
mixed	V-2	ETTP Mitchell Branch	0.00	3.7		4.57	1.02			
mixed	V-14	White Oak Creek, below fifth creek	0.03	3.7		2.73	1.47	0.107		
mixed	V-15	White Oak Creek, above fifth creek	-0.06	3.7		3.35		0.081	0.060	
mixed/cattails	V-5	Poplar Creek, below SD-440	-0.06	3.3		3.15			0.126	
cattails	V-18	EMWMF Underdrain	-0.09	3.3		3.52				
cattails	V-3	K-1007 P-1 Pond west	-0.02	3.2		4.37	0.58			
cattails	V-4	ETTP West End D&D	-0.08	3.1		3.57		0.078		
mixed/cattails	V-1	Offsite Background- Worthington Cemetery Trail	-0.04	3.0		3.90	0.77			

gray# less than sample specific detection limit black# above sample specific detection limit ## more than 2x background

The data 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, and green bars shown in Table 3.9 (for gross alpha, gross beta, and cesium-137, respectively,) are to visually highlight which values are higher and which are lower; the longer the bar, the higher the result. Cells with values greater than twice background have a light yellow background to make them easier to identify (Table 3.9).

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 3.9)

The data suggests the existence of elevated radionuclide concentrations in the vegetation collected near some of the surface water / wetlands on the ORR. The only gross alpha result above the sample-specific detection limits for the 2017 samples, was from the sample collected at V-16 on East Fork Poplar Creek, behind the New Hope Center at Y-12. The highest level of gross beta activity for the 2017 samples was from the sample collected at V-6 (the HRE wetland). That sample was collected at the edge of the wetland area behind the old Homogeneous Reactor Experiment site (HRE) in ORNL's Melton Valley. That sample had an elevated gross beta level of 101 pCi/g. 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 (beginning in 2012). As Table 3.10 shows, the highest gross alpha and gross beta values for HRE are listed for 2012 through 2017. 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 all years except for 2016, 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 samples were collected from slightly different locations and/or media composition, depending upon where vegetation grew and which vegetation flourished within a small defined portion of the HRE area. These slight variations may account for the differences in concentration results.

As seen in Table 3.9, the next three highest gross beta values all came from samples collected along White Oak Creek in Melton Valley (V-8, V-9, and V-10). A value of 31.5 pCi/g was seen at White Oak Weir (V-8), the farthest downstream site on White Oak Creek sampled by this project. Also along the White Oak Creek, the next site upstream that was sampled (V-9) yielded the next highest gross beta result at: 24.8 pCi/g. This site was just downstream of the bridge along Melton Valley Road on the west side of the creek. The site just upstream of the bridge on the east side of the creek (V-10), had a gross beta result of 15.3 pCi/g. One more sample along White Oak Creek (V-13) yielded an elevated level of gross beta, with a sample collected upstream of the Third Street bridge (8.8 pCi/g).

Table 3.10: Highest Gross Beta Analyses at HRE Wetland 2012-2017 (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	53.9	pCi/g
HRE Wetland	2015	2	69.1	pCi/g
HRE Wetland	2016	5.4	151	pCi/g
HRE Wetland	2017	-2.2	101	pCi/g

HRE – Homogeneous Reactor Experiment

Two samples were collected farther upstream along White Oak Creek (both below and above Fifth Creek). Each showed gross beta values more similar to background levels.

Other vegetation samples from ORNL showed gross beta values greater than twice those of background, including:

- Melton Branch Weir (V-7) at 12.7 pCi/g
- A drainage area at HFIR(V-11) at 9.8 pCi/g
- First Creek upstream of Central Ave (V-12) at 6.1 pCi/g

Melton Valley, much of it burial grounds, is known to have areas of radiological contamination. Portions of White Oak Creek and Melton Branch are also known to have radiological contamination. The sample with the highest level of gross alpha activity (V-16) from East Fork Poplar Creek behind the New Hope Center also had an elevated gross beta result of 13.2 pCi/g.

Locations with detectable gross beta results but less than twice the results of background included the following:

- The SS-6 spring in Bear Creek Valley (V-20) 4.9 pCi/g
- Bear Creek at Y-12 below S-2 (V-17) 4.3 pCi/g

- North Tributary 3 in Bear Creek Valley near the Bone Yard Burn Yard (V-19) 4.1 pCi/g
- Mitchell Branch at ETTP (V-2) 3.7 pCi/g
- The White Oak Creek below Fifth Creek (V-14) 3.7 pCi/g
- White Oak Creek above Fifth Creek (V-15) 3.7 pCi/g

Four of the twenty vegetation samples showed cesium-137, all from White Oak Creek. There were lower levels of cesium-137 seen in White Oak Creek at the weir (V-8) and downstream of the bridge at Melton Valley Road (V-9). Higher cesium-137 levels were detected in the samples upstream of the Third Street Bridge (V-13) 3.08 pCi/g and upstream the bridge at Melton Valley Road (V-10) 11.10 pCi/g.

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.

3.3.8 Conclusions

The data from the samples collected in 2017 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.

3.3.9 Recommendations

Areas with elevated sampling results will likely continue to be monitored by TDEC or DOE. Areas with elevated results may indicate places where further sampling and potentially remediation efforts may be warranted.

3.4 Benthic Macroinvertebrates

3.4.1 Background

The Benthic Macroinvertebrate Monitoring Project is an ongoing project to monitor the current condition and changing conditions of stream-bottom communities in streams on the Oak Ridge Reservation (ORR). These streams have been negatively impacted by Manhattan Project activities as well as current operational activities at the three facilities on the reservation (i.e., ETTP= East Tennessee Technology Park formerly known as K-25; ORNL = Oak Ridge National Laboratory; and Y-12 = Y-12 National Security Complex). 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 the suspected impacts.

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 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 conducts 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 differ among different samplers and analyzers. An independent evaluation 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 on 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 sampling by different samplers and analysts.

As remedial activities continue on the ORR, continued 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 the pointing out of 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, the stream involved is Mitchell Branch 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 is to include two 1m^2 composited samples for each study site. In addition, duplicate samples will be 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 depend 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 are taken both by TDEC DoR and

ORNL, care is 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 3.11. Maps for all current sampling sites are included in Figures 3.46-3.50. 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.

Table 3.11. 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	CCK 1.43
		EFK 24.4	HCK 20.6
		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; CCK = Clear Creek Kilometer; HCK = Hinds Creek Kilometer; GHK = Gum Hollow Branch Kilometer; MBK = Mill Branch Kilometer.

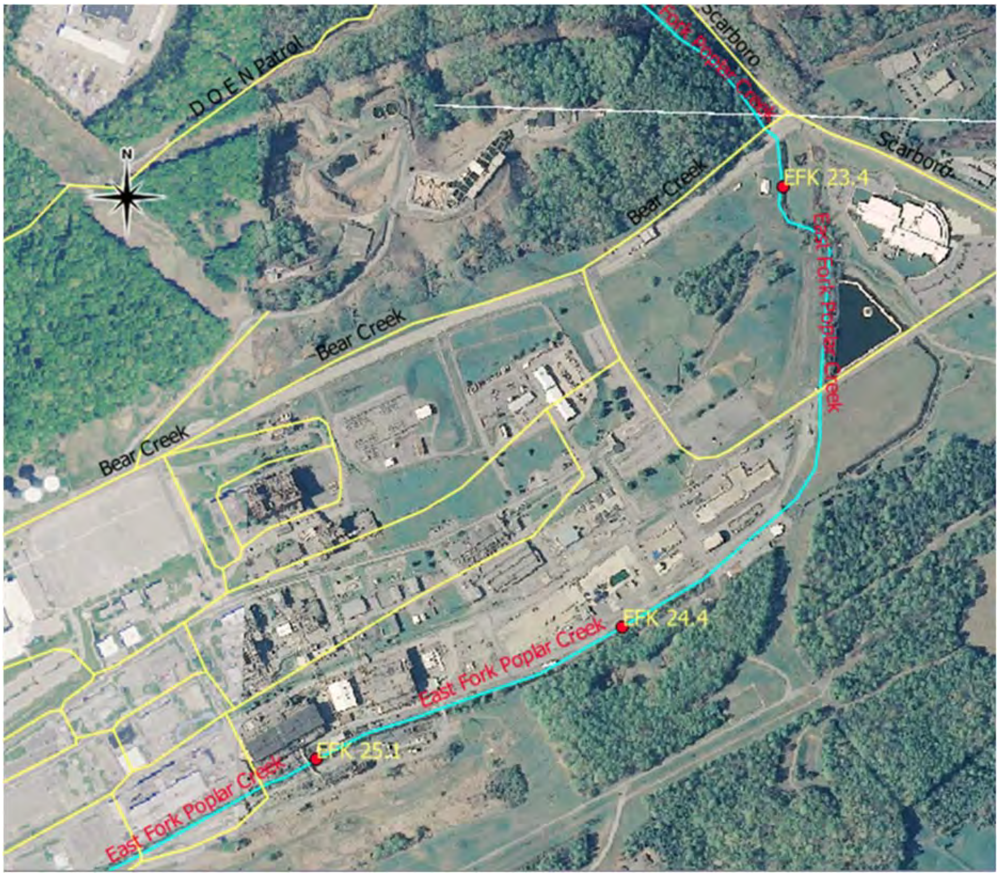


Figure 3.46: Benthic Sites at Upper East Fork Poplar Creek

Figure 3.47: Benthic Sites at the Hinds Creek and Clear Creek Reference Streams

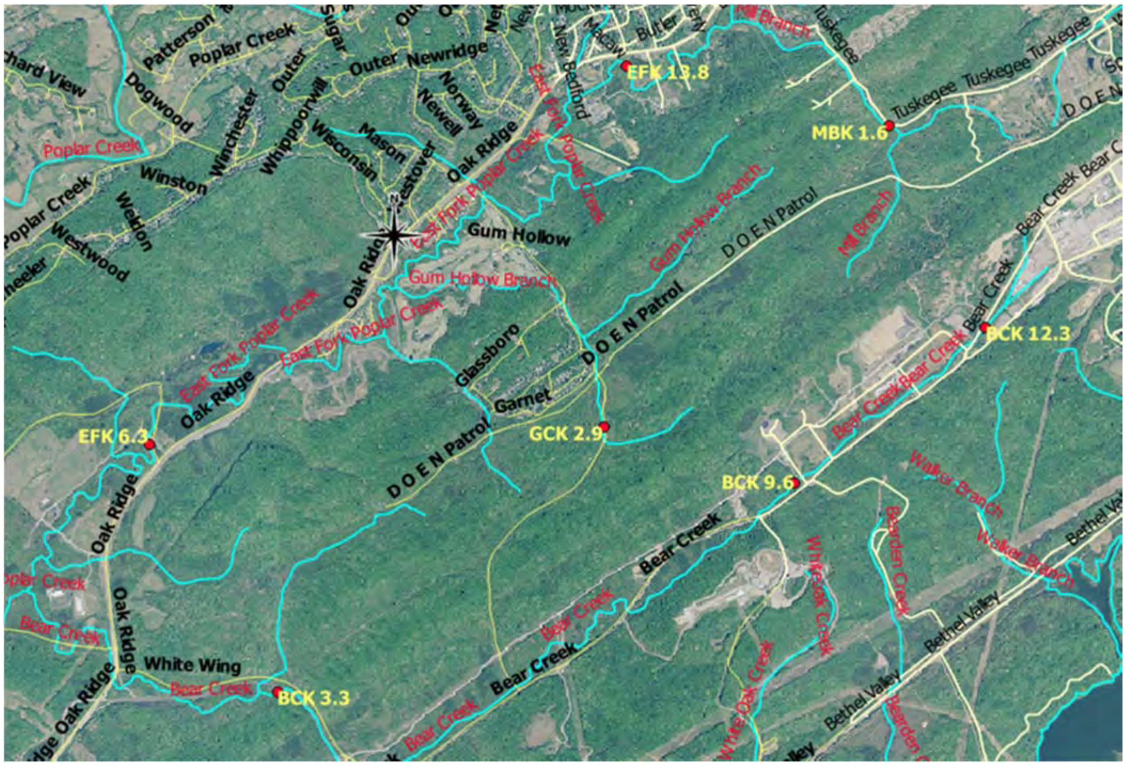


Figure 3.48: Benthic Sites at Bear Creek, Mill Branch, Gum Hollow Branch, and Lower East Fork Poplar Creek

Figure 3.49: Benthic Sites at Mitchell Branch

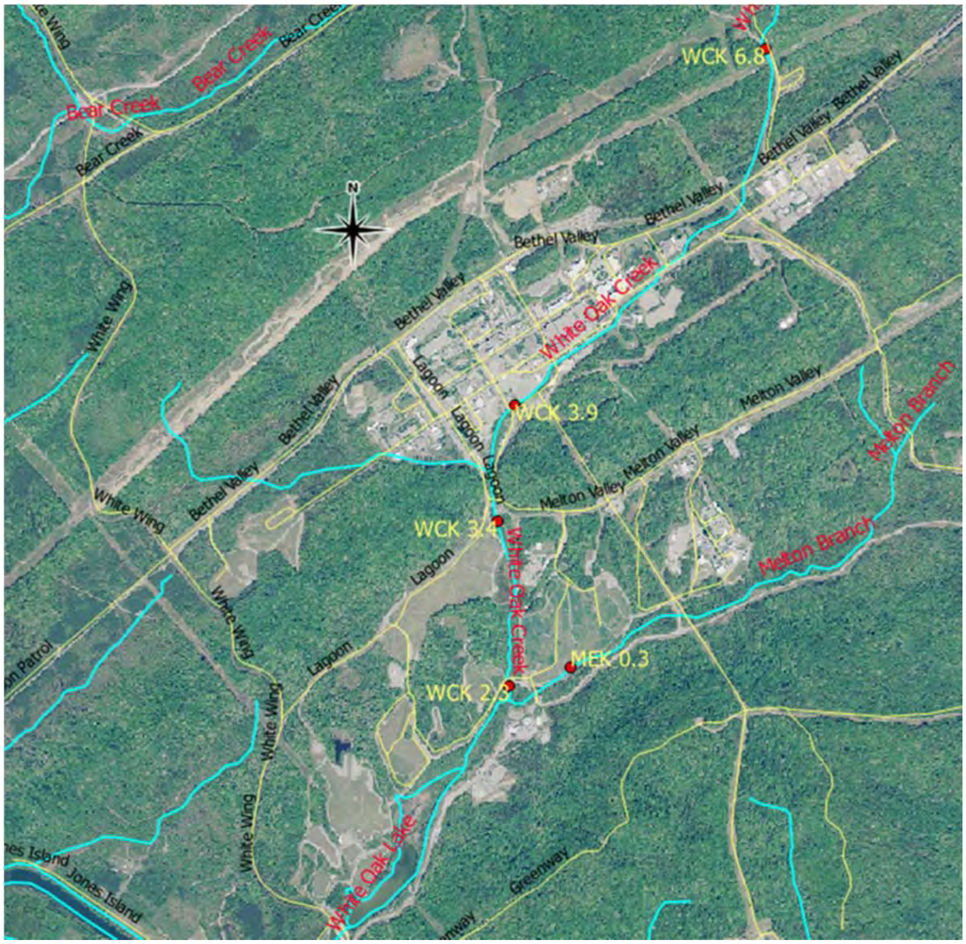


Figure 3.50: Benthic Sites at ORNL

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:

Sample 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 returned to the laboratory before 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. 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 microscope and the appropriate keys. Most identifications are to genus level; however, where possible, identifications are taken to the species level.

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

There were no deviations from the Plan.

3.4.7 Results and Analysis

Because some of the streams being monitored on the ORR did not meet the conditions necessary for comparison of results to bioregion biocriteria, 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 3.12.

Table 3.12: Alternative Reference Stream Metrics

Alternative Reference Steam 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, some 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. Taking certain taxa to the species level, where possible, allows for a clearer picture of the health of a site to be developed. Certain genera of mayflies

(Ephemeroptera) and caddisflies (Trichoptera) may have more than one species occurring at a sample site. This is particularly true of the genera *Baetis*, *Maccaffertium*, and *Rhyacophila*. Reference sites may contain as many as five species in these combined genera, whereas, an impacted site may only have two of these species, if any. Because of this difference, the numbers generated for EPT taxa richness and total taxa richness could vary (increase) when using species-level identification versus genus-level identification. Species-level identification could also be important in other genera including the caddisflies *Pycnopsyche* and *Neophylax*. Calculations of all metrics for this study were determined using the species-level identifications.

East Fork Poplar Creek

Benthic laboratory results, i.e., metric values, metric scores, overall Tennessee Macroinvertebrate Index (TMI) scores (alternative reference stream method), and biological condition ratings are presented in Table 3.13 for the East Fork Poplar Creek (EFK) watershed. Metrics for EFK reference sites are presented in Table 3.14. 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 3.46) and lower EFK (LEFK) with two sampling stations (EFK 13.8, EFK 6.3) (Figure 3.48). The stream numbers represent distances in kilometers that decrease from headwaters (EFK 25.1) towards the mouth downstream (EFK 0.0). The reference streams (Figure 3.47) for the EFK watershed include Hinds Creek (HCK 20.6) and Clear Creek (CCK 1.45). Generally, stream biotic integrity in EFK appeared to be slightly better in the LEFK than in UEFK.

Table 3.13: Metric Values, Scores, and Biological Condition Ratings for East Fork Poplar Creek

2017 RESULTS	EAST FORK POPLAR CREEK									
Stream station	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
Taxa Richness	32	4	35	4	41	6	37	4	35	4
EPT Richness	6	2	5	2	8	2	11	4	7	2
% EPT-Cheum	5.82	0	5.47	0	9.50	0	18.66	2	4.92	0
% OC	66.04	2	45.28	6	60.33	4	40.14	6	25.04	6
NCBI	5.49	4	5.64	4	5.23	4	3.53	6	5.46	4
% Clingers	75.05	6	63.75	6	66.08	6	58.27	6	71.45	6
%TNUTOL	70.36	2	57.73	4	47.89	4	53.35	4	60.02	2
Intolerant Taxa	0	0	1	0	3	0	5	0	4	0
INDEX SCORE (Tenn. Macro. Index)		20		26		26		32		24
RATING	C			B		B		A		B

Key:
A = Supporting / Non Impaired (Tenn. 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)

Table 3.14: Metric Values, Scores, and Biological Condition Ratings for East Fork Reference Sites

2017 RESULTS	2017 EAST FORK REFERENCE SITES					
Stream station	CCK 1.45		CCK 1.45 DUP		HCK 20.6	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	40	6	42	6	51	6
EPT Richness	18	6	19	6	21	6
% EPT-Cheum	64.61	6	43.96	6	31.49	6
% OC	11.4	6	11.47	6	14.54	6
NCBI	2.56	6	2.42	6	5.13	4
% Clingers	13.5	2	49.52	6	70.19	6
%TNUTOL	14.02	6	3.86	6	55.17	4
Intolerant Taxa	16	6	14	4	15	6
INDEX SCORE (Tenn. Macro. Index)		38		42		38
RATING	C	A		A		A

Key:
A = Supporting / Non Impaired (Tenn. 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 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 receives further contaminant loading from urban and suburban runoff as well as a sewage treatment plant discharge. Only near its mouth does East Fork flow through relatively undisturbed terrain. Beginning in 2015, no flow augmentation from the Clinch River was provided in East Fork. Flows in the creek were reduced from years prior to 2014, due to lack of this augmentation. Metrics from 2016 and 2017 benthic sampling are compared to see how the stream has fared since the halting of flow augmentation.

In order to determine the condition of the sampling stations in East Fork, 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 2015 and 2016 are provided (Figures 3.53-3.59). Table 3.16 defines these nine metrics. Values for the impacted stations in East Fork are given in Table 3.13 and values for reference stations are provided in Table 3.14. Their discussion follows the figures below.

Figure 3.51: Total Scores East Fork Poplar Creek 2016 vs. 2017

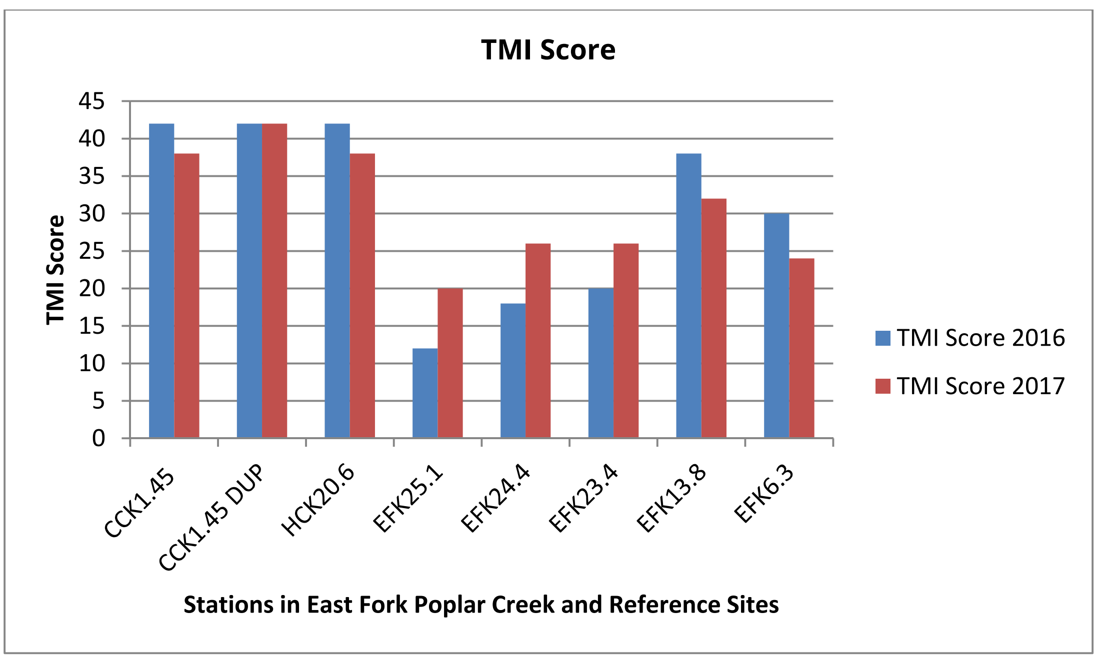


Table 3.15: Description of Metrics and Expected Responses to Stressors

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	CCK 1.43
		EFK 24.4	HCK 20.6
		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	

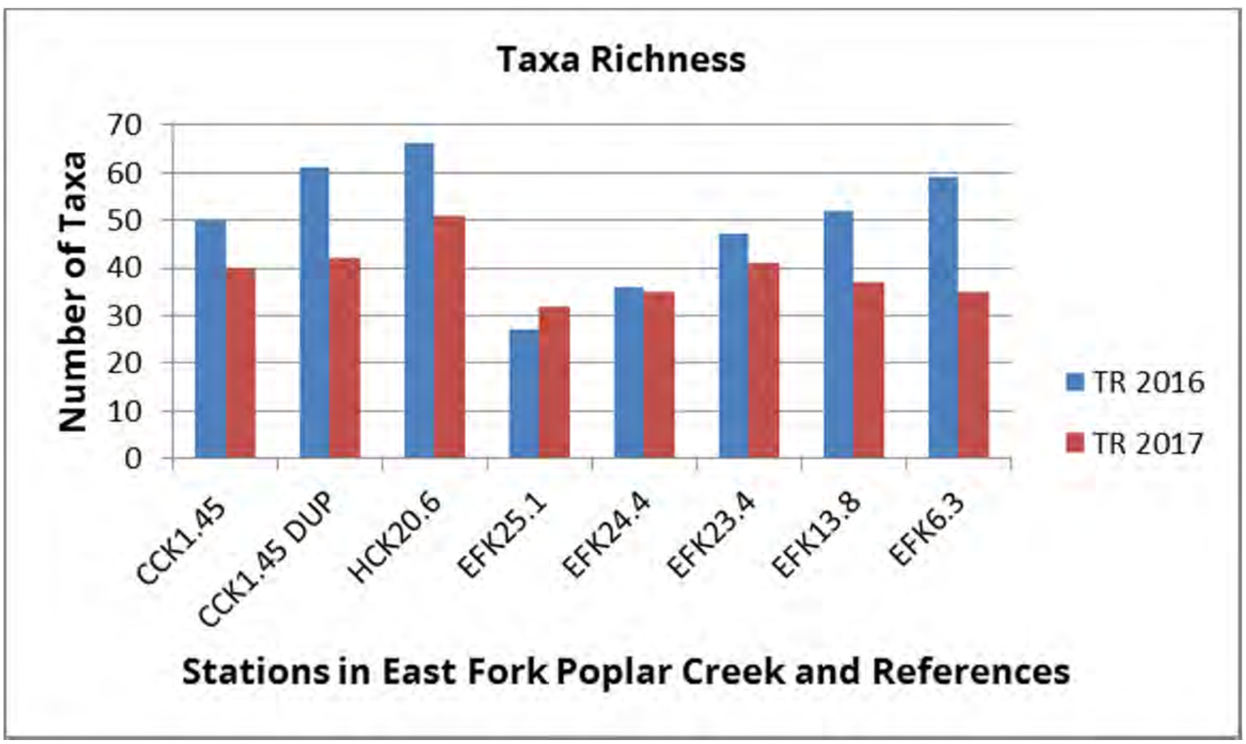


Figure 3.52: Taxa Richness East Fork Poplar Creek

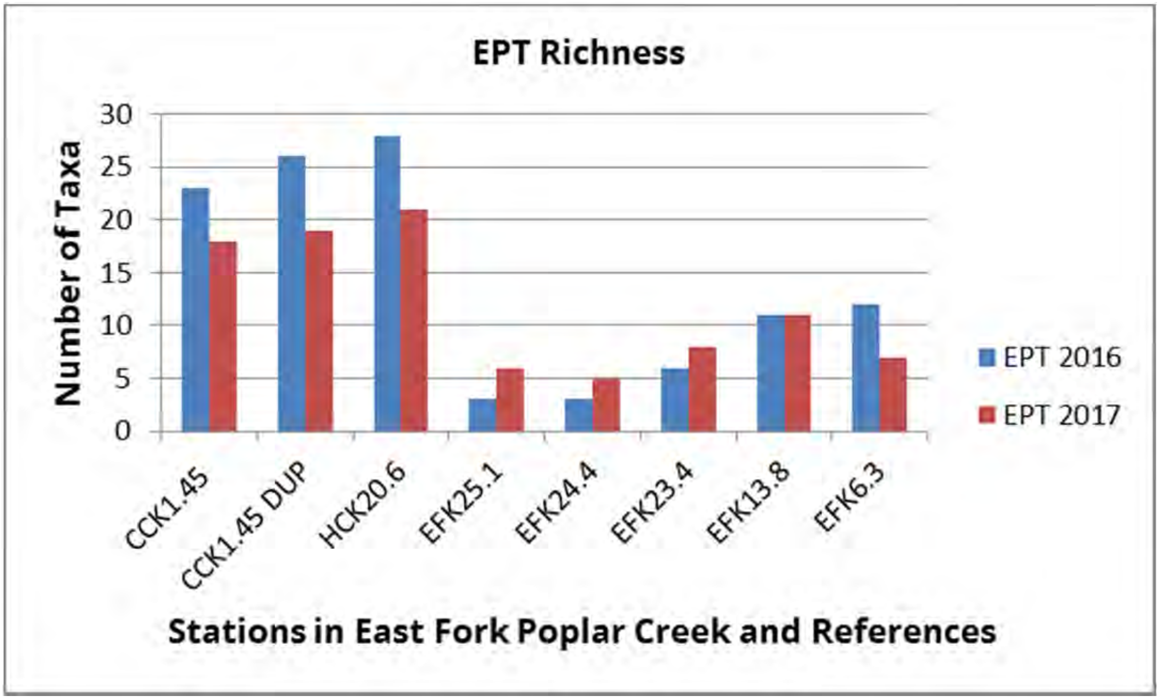


Figure 3.53: EPT Richness East Fork Poplar Creek

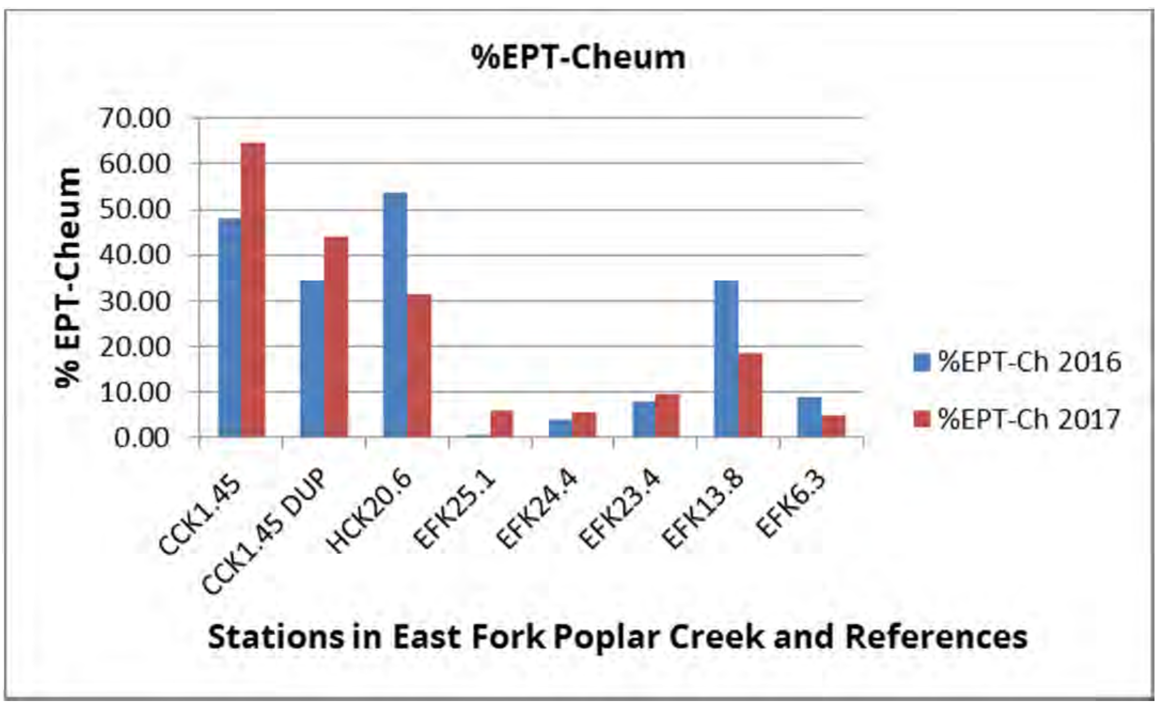


Figure 3.54: Percent (%) EPT-Cheum East Fork Poplar Creek

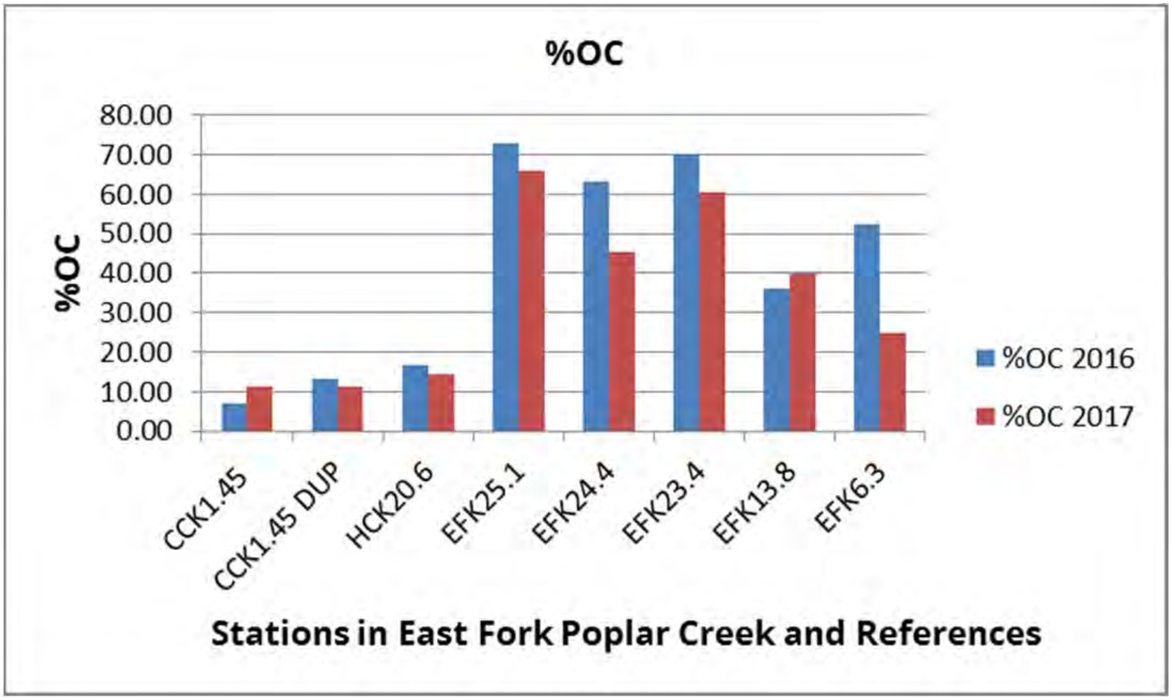


Figure 3.55: Percent (%) OC East Fork Poplar Creek

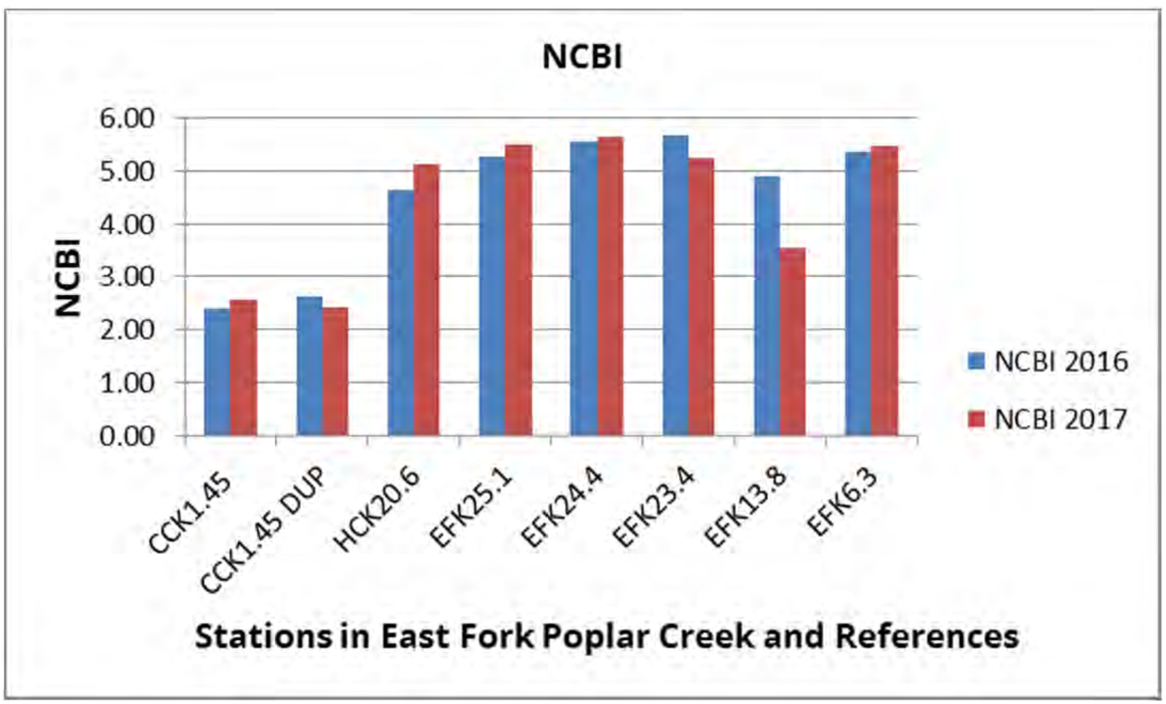


Figure 3.56: NCBI East Fork Poplar Creek

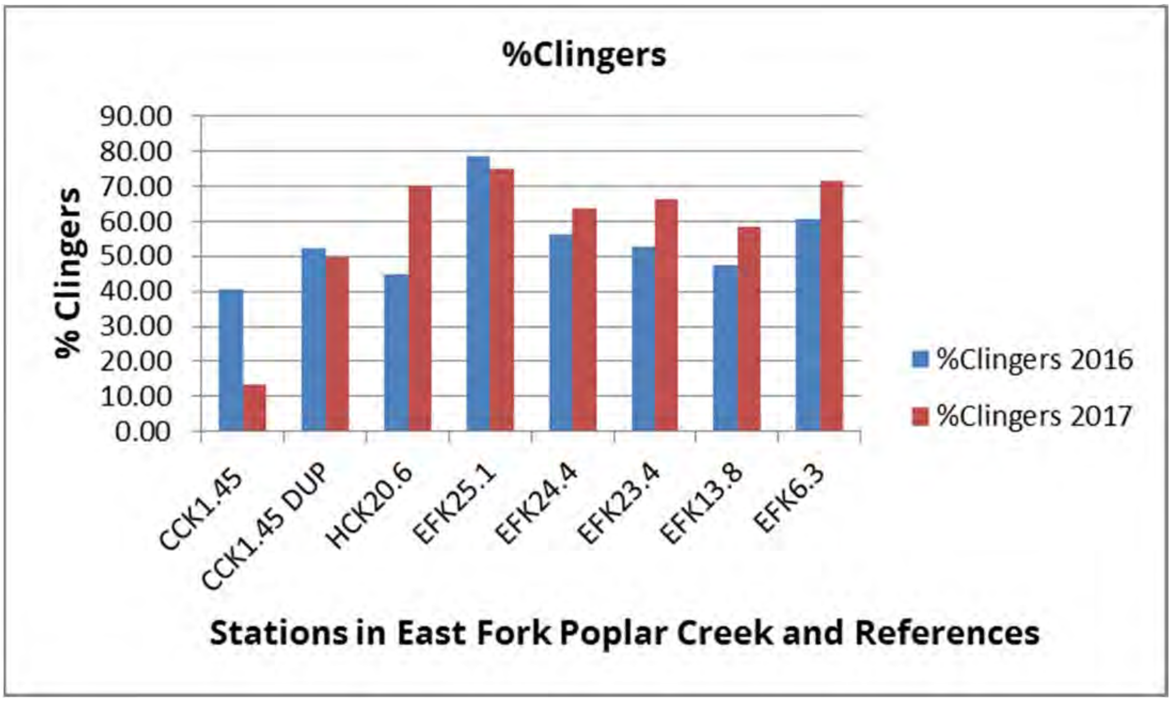


Figure 3.57: Percent (%) Clingers East Fork Poplar Creek

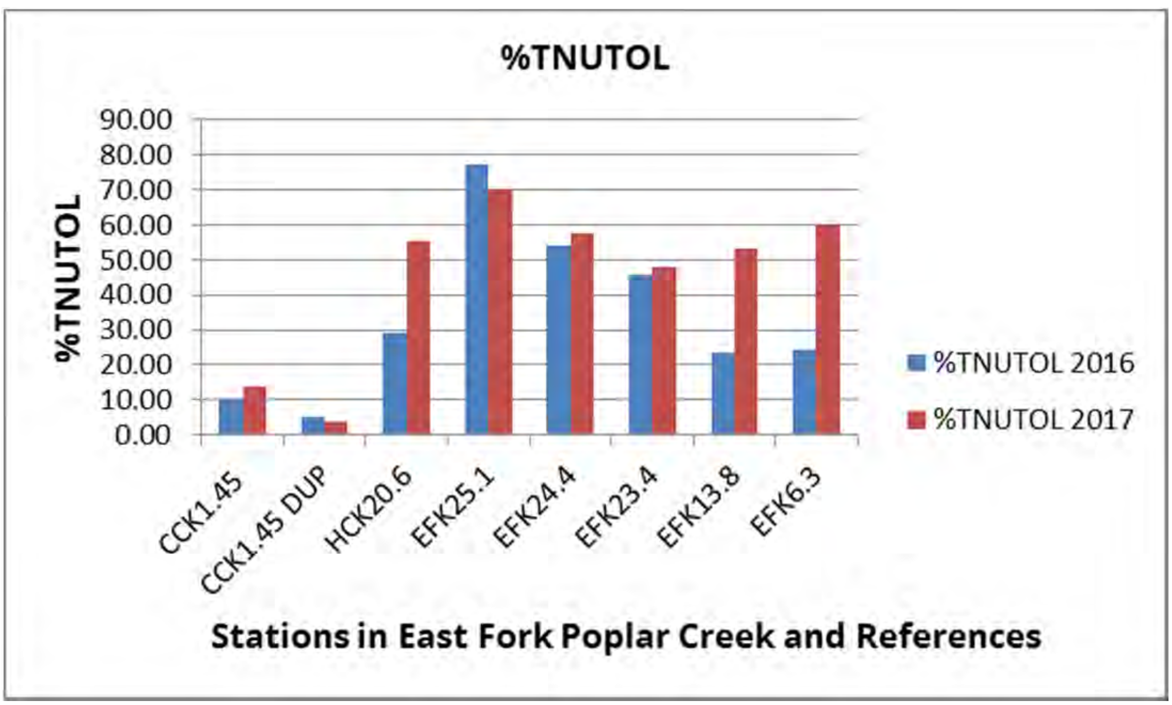


Figure 3.58: Percent (%) TNUTOL East Fork Poplar Creek

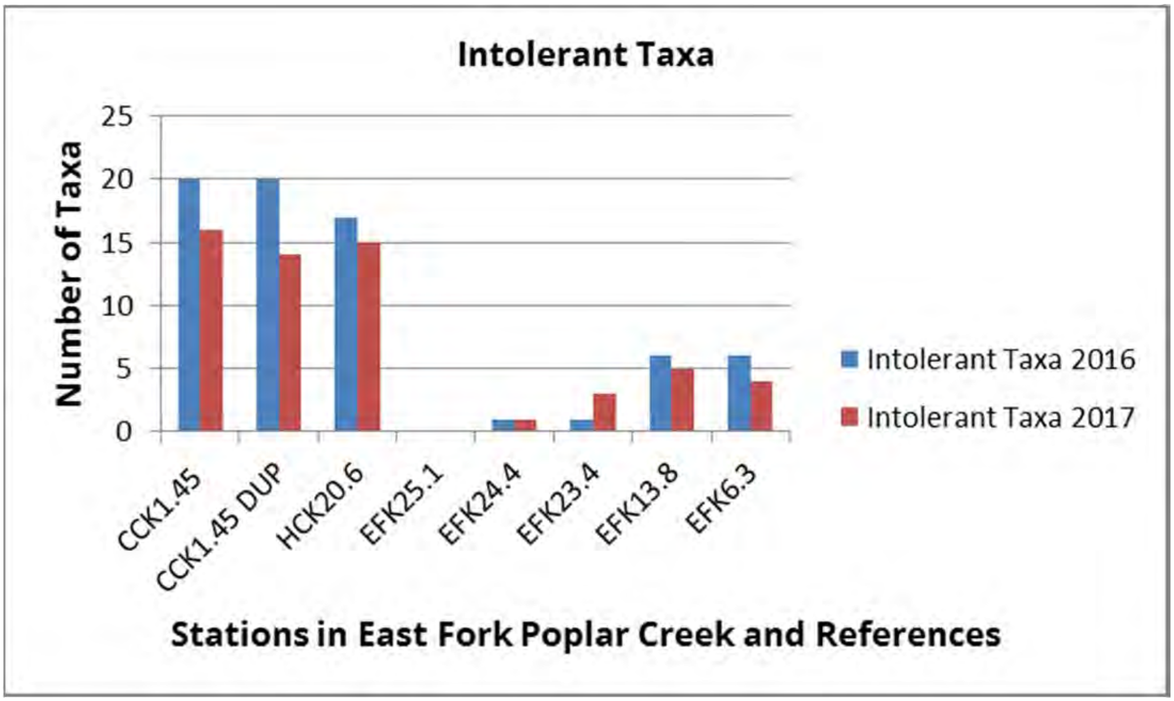


Figure 3.59: Intolerant Taxa East Fork Poplar Creek

Figure 3.51 compares the TMI Total Score results for the two reference sites (CCK 1.45 and HCK 20.6) with the five sampling stations in East Fork Poplar Creek for both 2016 and 2017. The scores for the two reference stations (including a duplicate sample taken on Clear Creek) exceed those for all stations of East Fork with only EFK 13.8 approaching the score of the controls in both 2016 and 2017. The metric Taxa Richness (Figure 3.52) shows that the reference stations (CCK and HCK) displayed a higher number of Total Taxa than any of the East Fork stations with the exception of EFK 13.8 and EFK 6.3 in 2016 and EFK 23.4 in 2017. Although the 2016 data shows a trend with the number of taxa increasing incrementally in a downstream direction, the 2017 data does not. EPT Richness shows a distinct difference between the reference stations and the East Fork stations with the best East Fork station (EFK 6.3) possessing approximately half as many EPT as the lowest number for the reference stations (CCK 1.45) in 2016 and a lower value in 2017. The same trend as with Total Taxa Richness may be seen here with the number of EPT taxa for the 2016 data increasing in a downstream direction. This trend is not clear in the 2017 data.

The % EPT- Cheumatopsyche (Cheum) (Figure 3.54) shows a slight increase in the upper stations of East Fork (EFK 25.1, EFK 24.4, and EFK 23.4) during 2017 compared to 2016; however, this metric shows a decrease in 2017 2016 at the lower stations (EFK 13.8 and EFK 6.3). The value for this metric is considerably lower at all East Fork stations compared to reference streams. The % OC (percent Oligochaeta and Chironomidae) metric (Figure 3.55) shows a distinction between the reference stations and all stations in East Fork; however, all the values in East Fork are reduced when compared to the values found in 2016. All East Fork sites display a higher proportion of oligochaetes and midges, often a sign of degraded conditions. The metric for NCBI (Figure 3.56) does not distinguish clearly between the reference stations and East Fork. Although the values for CCK 1.45 are clearly superior to those of the East Fork stations, the value for HCK 20.6 (another reference station) does not obviously differ from those of the East Fork stations. Hinds Creek flows thorough an agricultural area, while Clear Creek is a protected watershed and the source of Norris' drinking water. The same may be said of the % TNUTOL data (Figure 3.58) with Hinds Creek more closely comparing with East Fork Stations. The East Fork stations show a clear trend in the 2016 data with the % TNUTOL decreasing in a downstream direction (the upper stations showing the greater impact). This trend is not as clear in the 2017 data. The % Clingers (Figure 3.57) metric also fails to distinguish between the reference streams and impacted sites with Hinds Creek and the duplicate from Clear Creek both being more similar to the results for East Fork Stations.

A comparison of the number of Intolerant Taxa between reference and impacted streams (Figure 3.59) shows a dramatic difference with impacted stations displaying appreciably fewer sensitive taxa. Both the 2016 and 2017 data shows a gradual increase in the number of sensitive taxa in a downstream direction in East Fork. Although East Fork Poplar Creek has shown improvement 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 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 un-impacted by the presence of ETTP. The lower stations (MIK 0.71 and MIK 0.45) have, however, been impacted not only from former industrial activities at ETTP and waste areas; they 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 15–23). Metric data for all stations, including the reference station (MIK 1.43), are found in Table 3.16. The discussion of the data follows the table and figures below.

Table 3.16: Metric Values, Scores, and Biological Condition Ratings for Mitchell Branch

2017 RESULTS	MITCHELL BRANCH							
Stream station		MIK 1.43		MIK 0.71		MIK 0.45		
METRIC		VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	
Taxa Richness		49	6	57	6	47	6	
EPT Richness		13	4	7	2	7	2	
% EPT-Cheum		16.93	2	7.31	0	24.20	4	
% OC		59.12	4	52.75	4	53.08	4	
NCBI		4.36	6	5.48	4	6.12	4	
% Clingers		18.83	4	27.73	6	33.97	6	
%TNUTOL		28.18	6	27.20	6	38.85	6	
Intolerant Taxa		9	2	6	0	4	0	
INDEX SCORE (Tenn. Macro. Index)			32		28		32	
RATING			A		B		A	
Key:	A = Supporting / Non Impaired (Tenn. 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)							

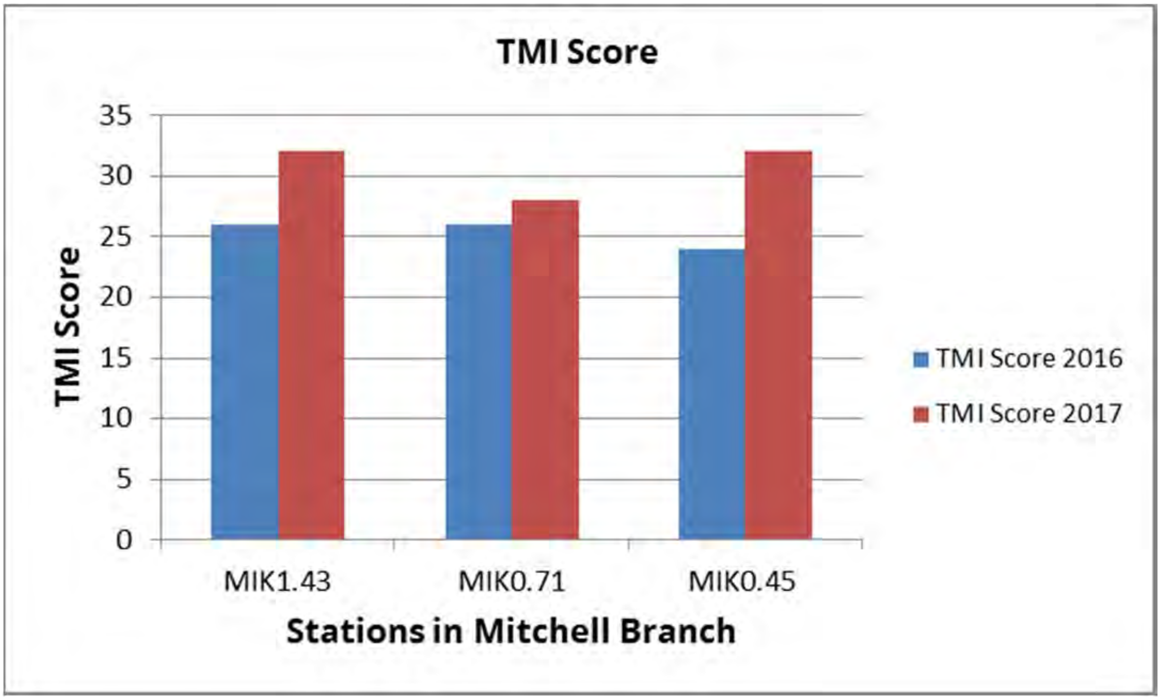


Figure 3.60: Total Score Mitchell Branch

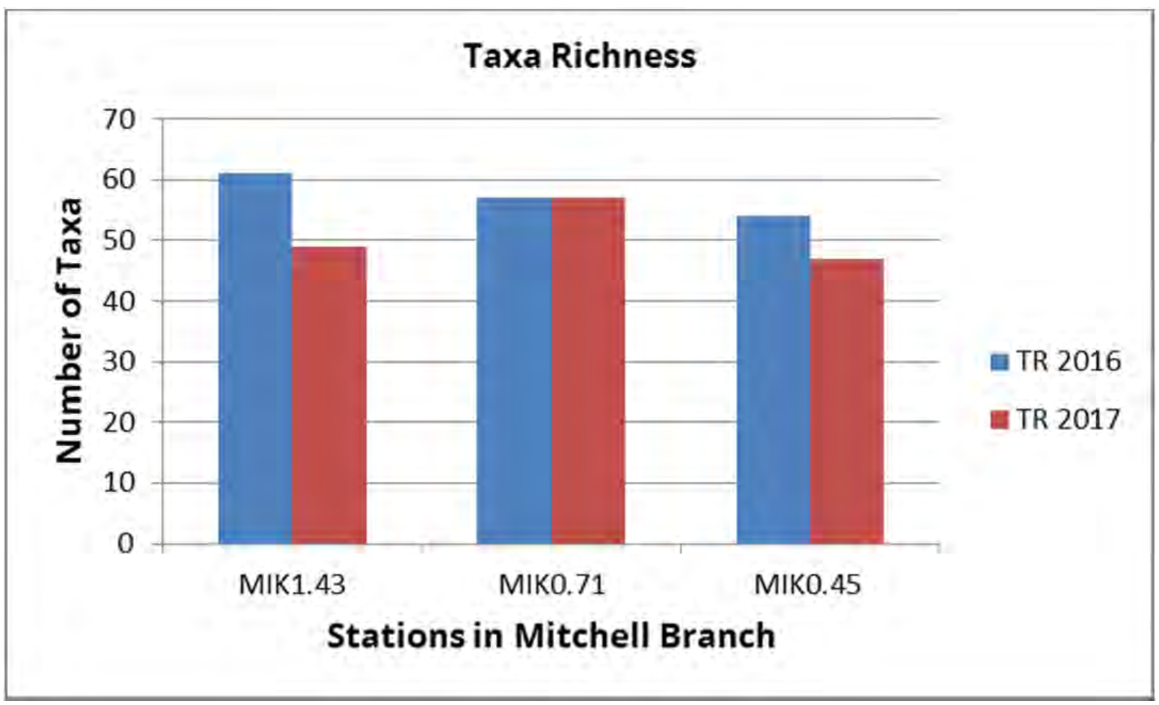


Figure 3.61: Taxa Richness Mitchell Branch

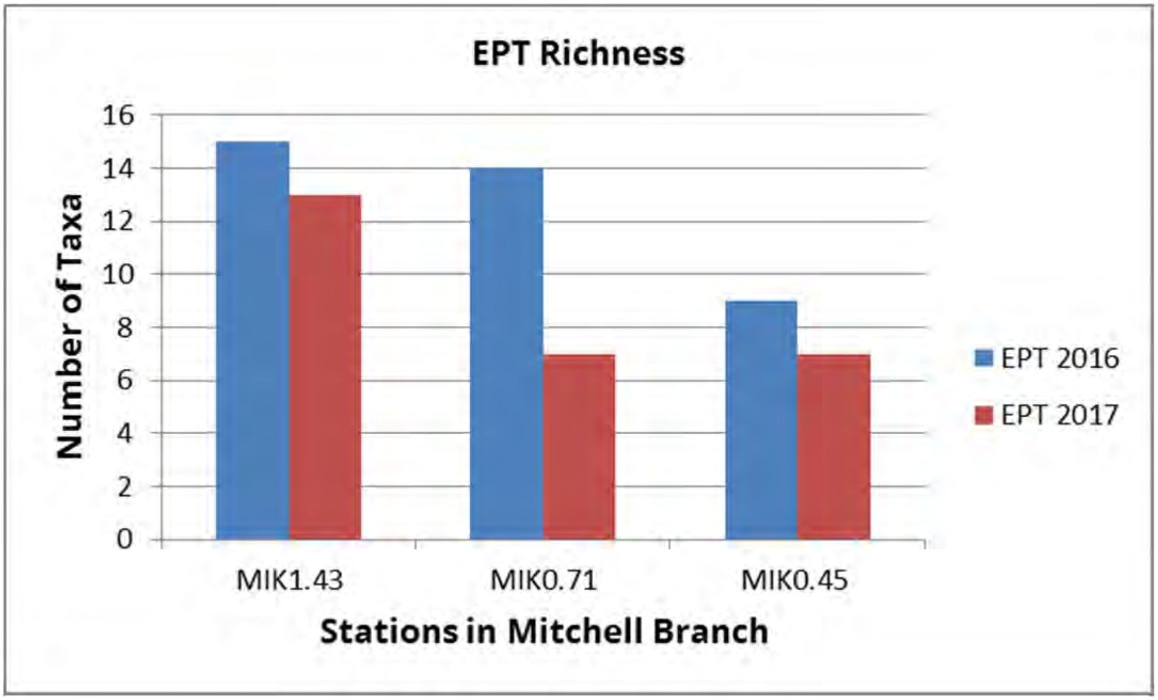


Figure 3.62: EPT Richness Mitchell Branch

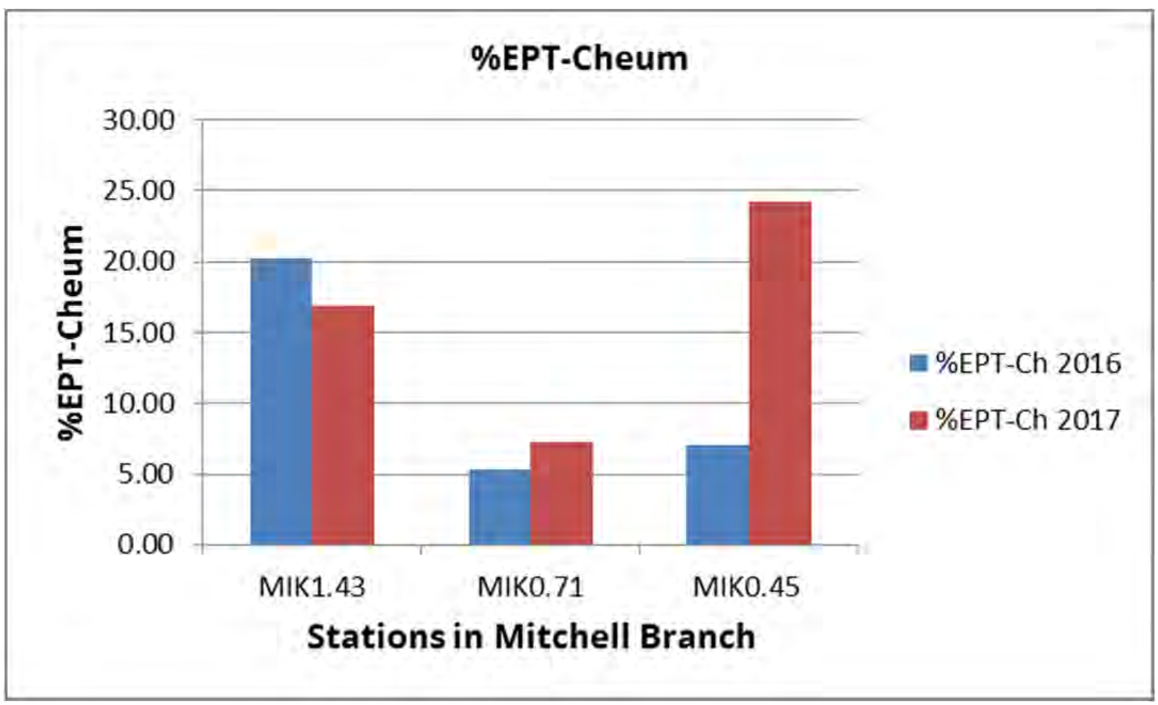


Figure 3.63: Percent (%) EPT-Cheum Mitchell Branch

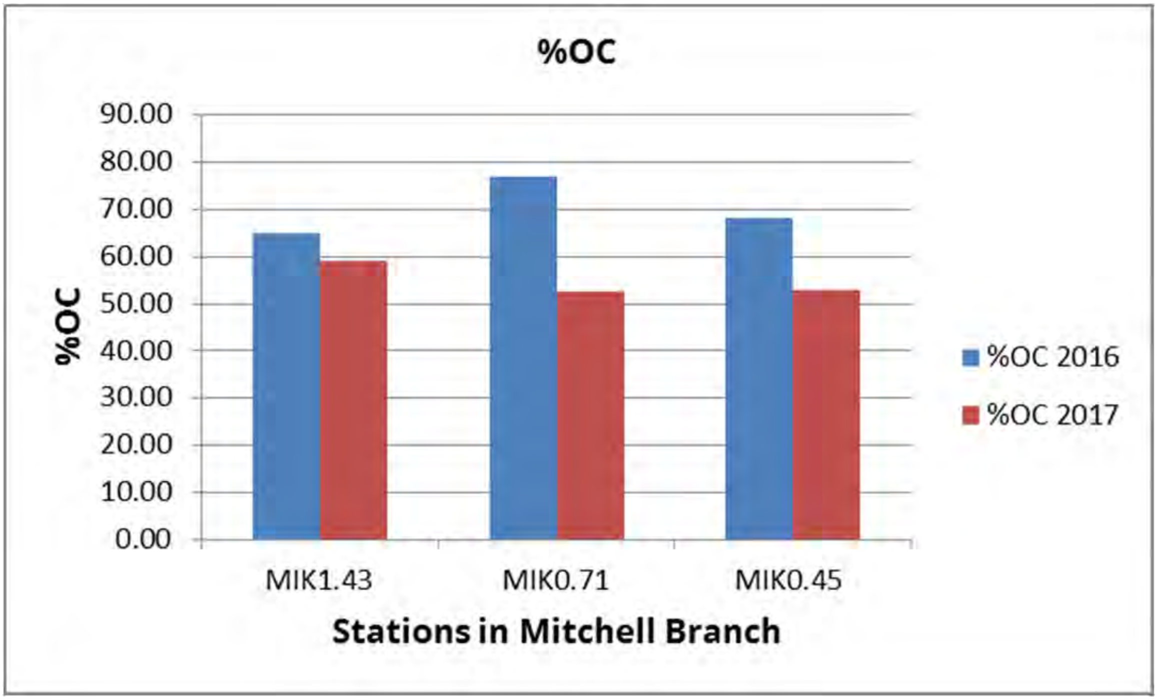


Figure 3.64: Percent (%) OC Mitchell Branch

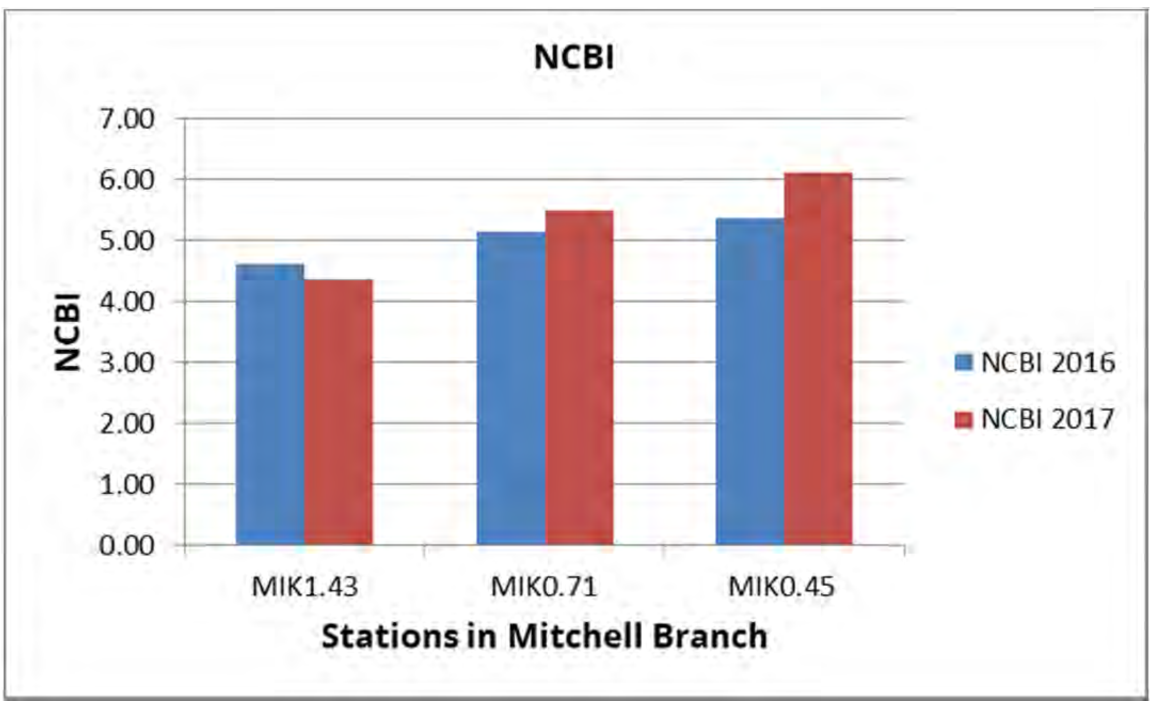


Figure 3.65: NCBI Mitchell Branch

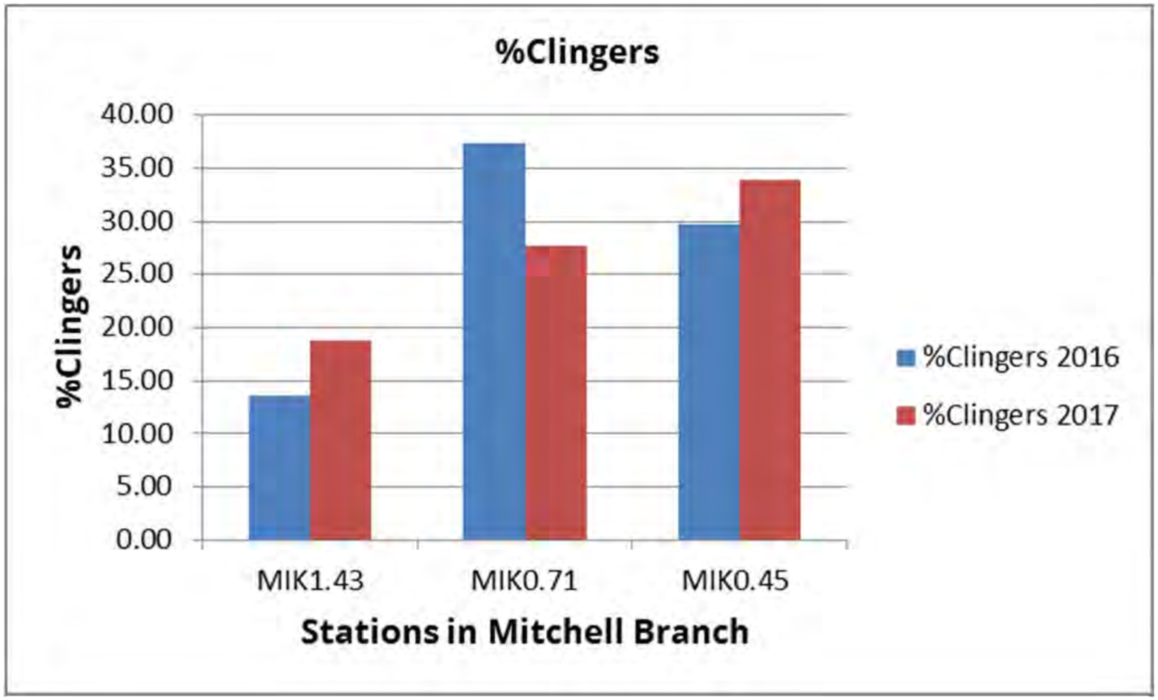


Figure 3.66: Percent (%) Clingers Mitchell Branch

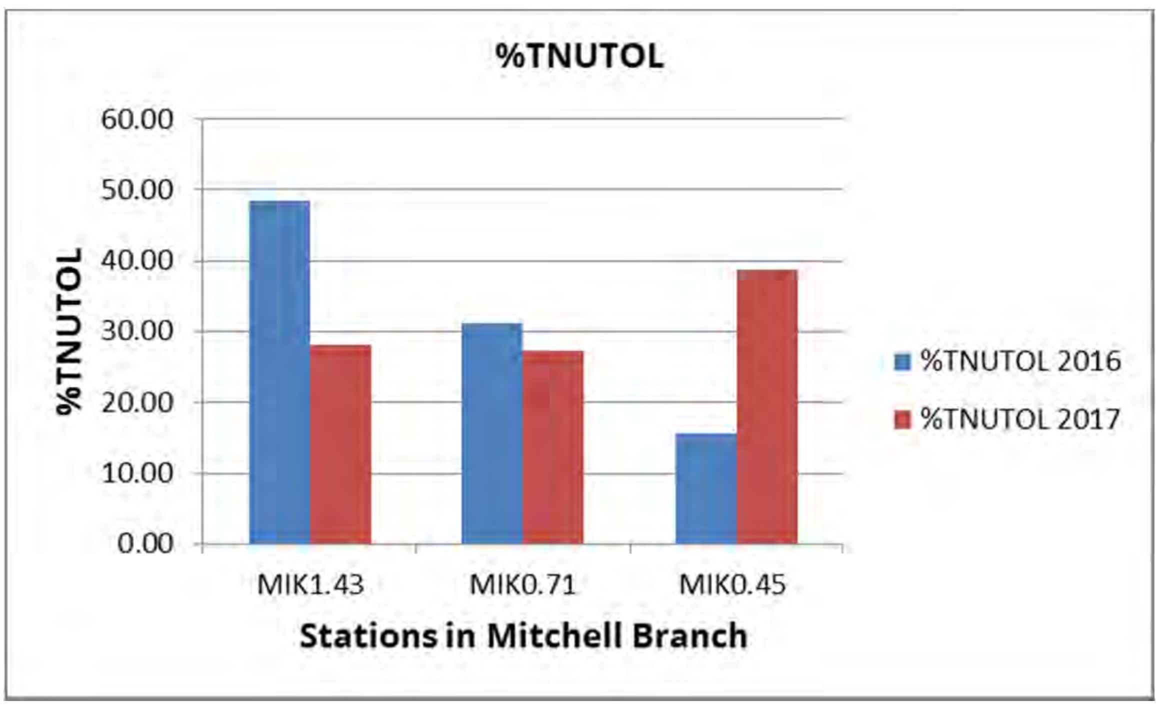


Figure 3.67: Percent (%) TNUTOL Mitchell Branch

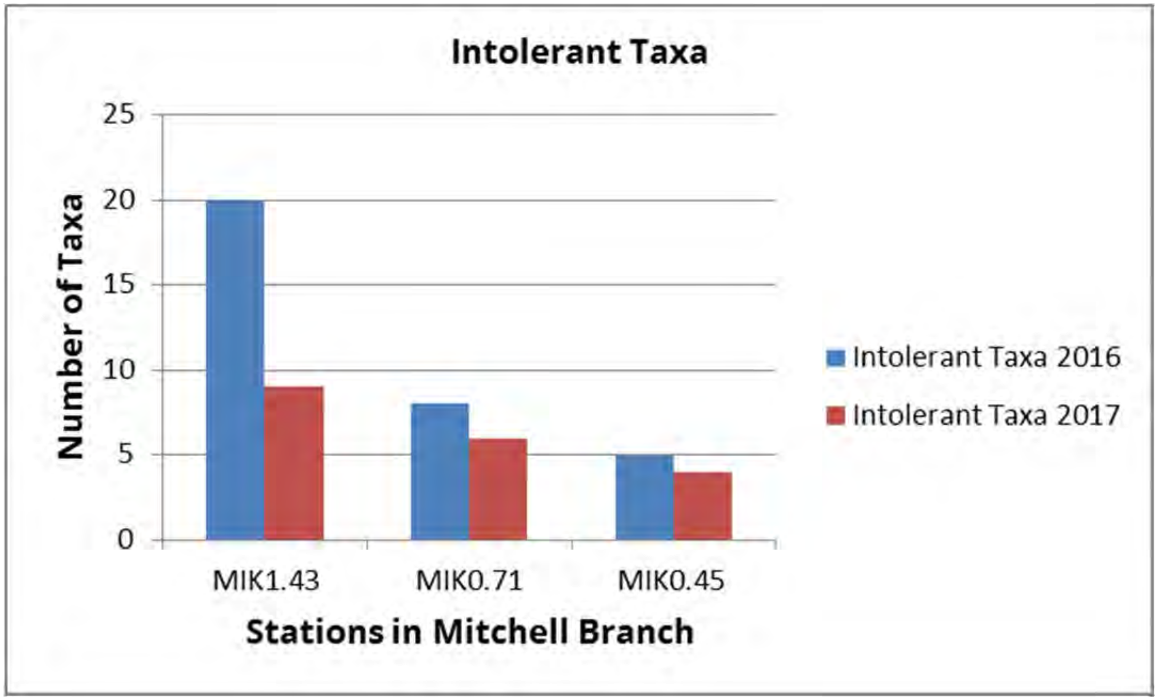


Figure 3.68: Intolerant Taxa Mitchell Branch

Neither the 2016 or 2017 Total Score metric data (Figure 3.60) show appreciable differences between MIK 1.43 (reference stations) and the lower two impacted Mitchell Branch stations (MIK 0.71 and MIK 0.45; however, the total scores for 2017 are slightly higher for all stations. The Taxa Richness data for both 2016 and 2017 (Figure 3.61) does not provide a clear difference between unimpacted and impacted stations. The 2016 data shows a slight decrease in Taxa Richness in a downstream direction. This trend is not apparent in the 2017 data. EPT Richness (Figure 3.62) shows a decrease in a downstream direction for both 2016 and 2017. The difference is more distinct for the 2017 data. The 2016 % EPT-Cheum (Figure 3.63) shows more stressed conditions at the downstream stations in Mitchell Branch. In the 2017 EPT-Cheum data, however, MIK 0.45 appears less stressed than MIK 1.43 (reference station). The % OC 2016 data (Figure 3.64) are indicative of somewhat more stressful conditions at MIK 0.71 and MIK 0.45; however, the 2017 % OC data show slightly less stressed conditions at the lower Mitchell Branch stations. 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 2016 and 2017 (biotic integrity) are better (i.e., lower) at MIK 1.43 than at MIK 0.71 and MIK 0.45 (Figure 3.65), indicating a somewhat healthier community at the reference station. The % Clingers metric (Figure 3.66) is higher at the impacted stations than at MIK 1.43 for both the 2016 and 2017 data. This does not agree with expected conditions as, generally, a greater proportion of Clingers is indicative of better health of the community. The 2016 % TNUTOL metric (Figure 3.67), decreases in a downstream direction. Typically, a higher proportion, of nutrient-tolerant organisms at a site, is indicative of a less healthy community. Again, this does not agree with expected conditions. The 2017 % TNUTOL data shows a more typical trend with the reference station (MIK 1.43) slightly less enriched than the downstream stations. The number of Intolerant Taxa (Figure 3.68) for both the 2016 and 2017 data show a decrease in downstream direction. The 2017 data for MIK 1.43 is considerably lower than for the 2016 data, perhaps indicating a degrading condition for the upstream reference station.

Based on the majority of metrics, the lower stations of Mitchell Branch appear to be somewhat 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 Polar 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 3.69 – 3.77). Metric data for both Bear Creek stations may be found in Table 3.17. Table 3.17 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.

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 increased (Figure 3.69) in 2016 ranking it above two stations in upper East Fork (EFK 25.1 and EFK 23.4). BCK 12.3 also continues to score low on the majority of the metrics compared to other healthier stream stations (Figures 3.69 through 3.77). Conditions have improved as shown in the 2016 sampling.

Table 3.17: Metric Values, Scores, and Biological Condition Ratings for Bear Creek

2017 RESULTS	BEAR CREEK											
Stream station	GHK 2.9		MBK 1.6		MBK 1.6 DUP		BCK 12.3		BCK 9.6		BCK 3.3	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	46	6	66	6	68	6	30	4	51	6	59	6
EPT Richness	15	6	23	6	21	6	4	2	13	4	18	6
% EPT-Cheum	44.07	6	47.22	6	33.40	6	2.49	0	10.64	2	44.56	6
% OC	33.33	6	25.17	6	31.34	6	6.83	6	22.98	6	10.33	6
NCBI	3.03	6	2.83	6	3.49	6	7.44	2	5.47	4	3.61	6
% Clingers	29.19	6	33.24	6	39.45	6	5.68	0	35.59	6	57.40	6
%TNUTOL	9.60	6	11.02	6	18.76	6	89.39	0	45.63	4	28.19	6
Intolerant Taxa	17	6	20	6	22	6	5	0	14	4	9	2
INDEX SCORE (Tenn. Macro. Index)		42		42		42		14		32		42
RATING		A		A		A		C		A		A
Key:	A = Supporting / Non Impaired (Tenn. 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)											

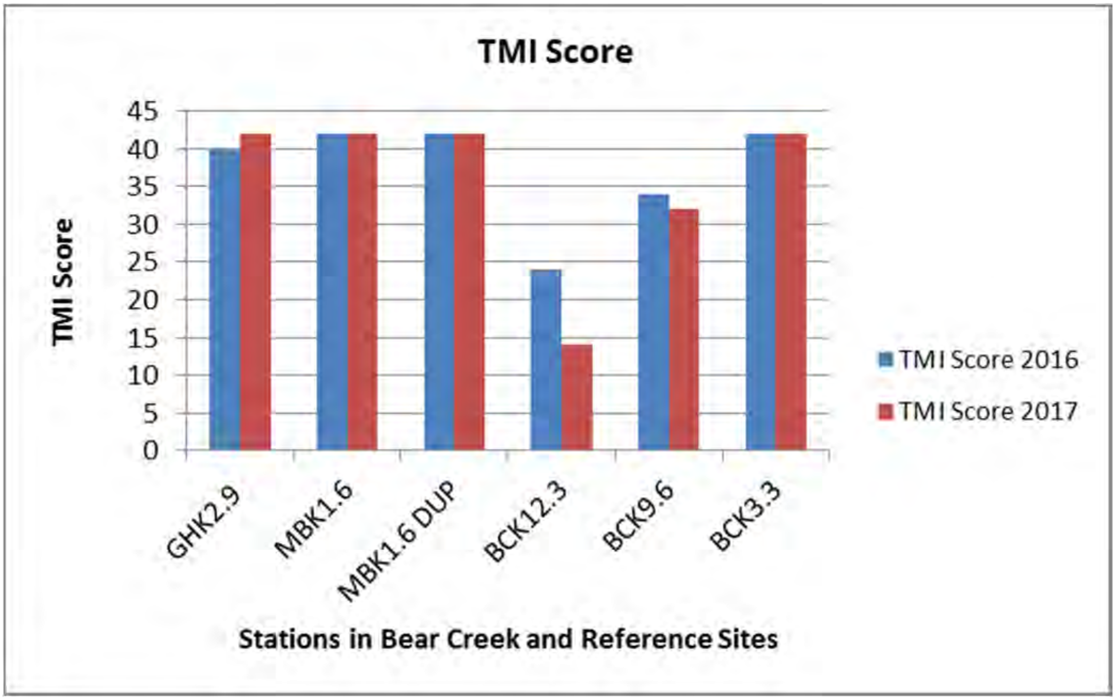


Figure 3.69: Total Score Bear Creek

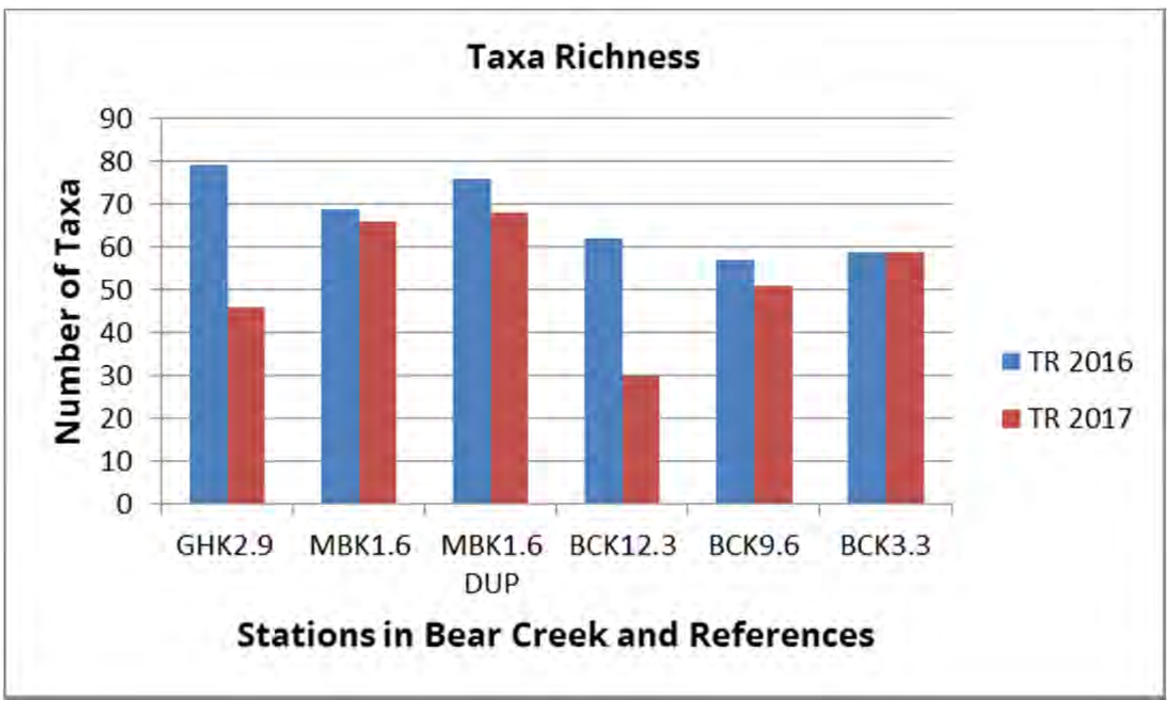


Figure 3.70: Taxa Richness Bear Creek

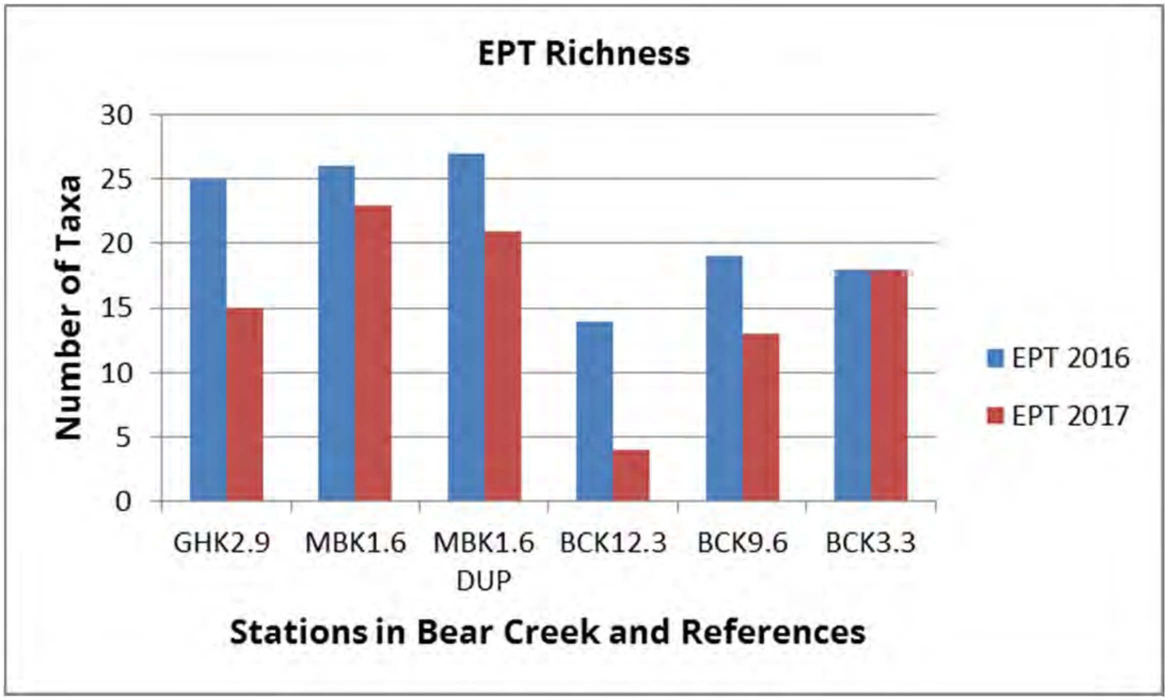


Figure 3.71: EPT Richness Bear Creek

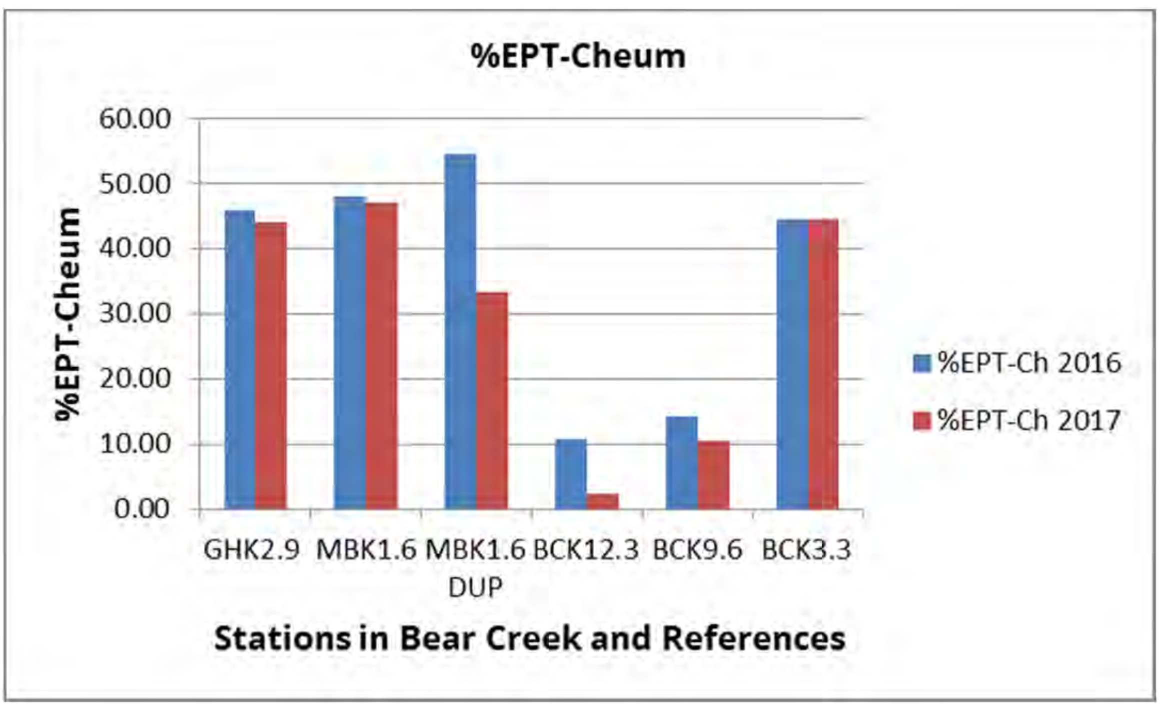


Figure 3.72: Percent (%) EPT-Cheum Bear Creek

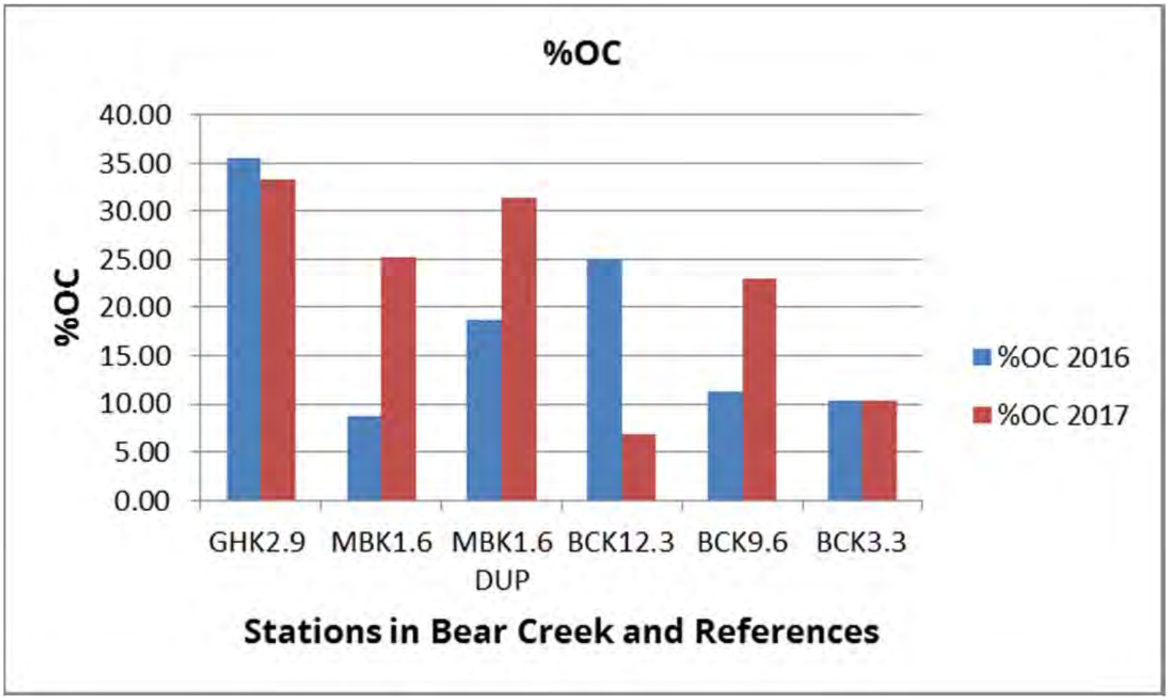


Figure 3.73: Percent (%) OC Bear Creek

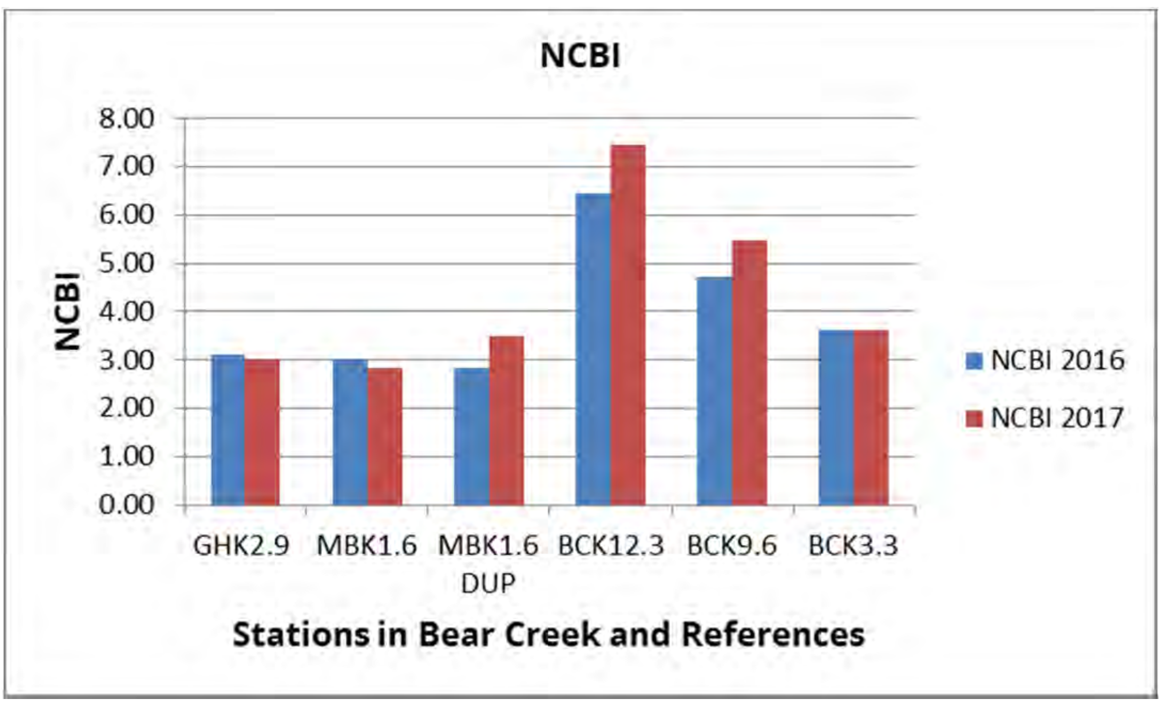


Figure 3.74: NCBI Bear Creek

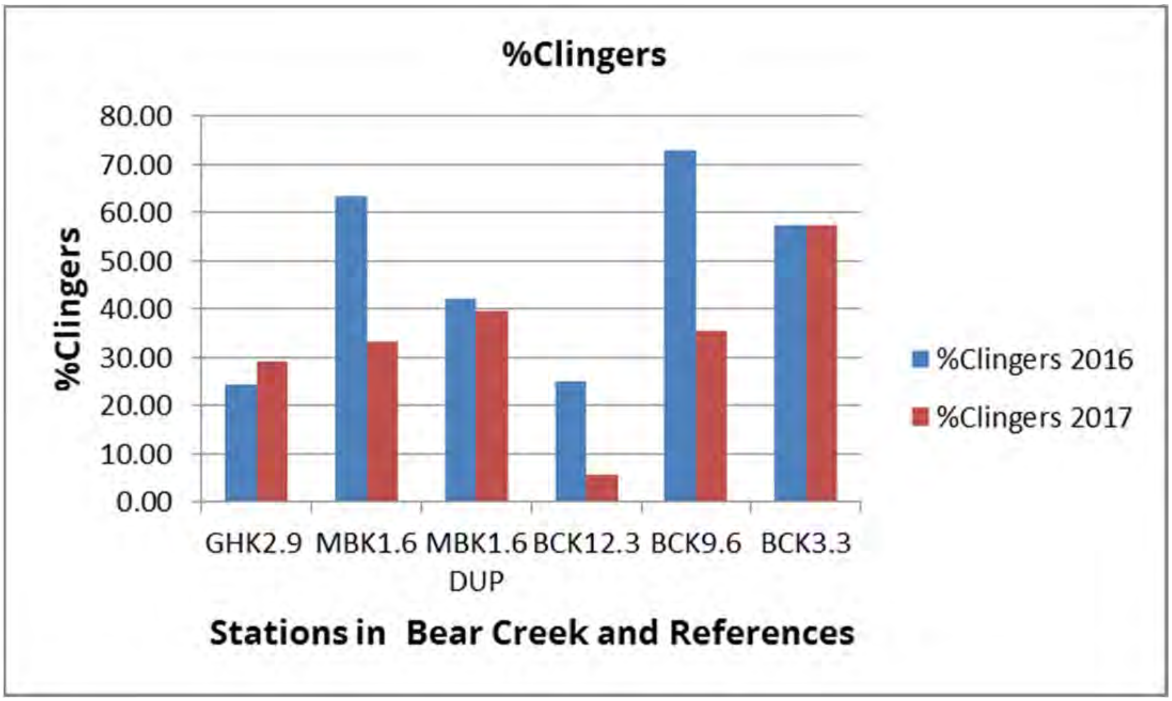


Figure 3.75: Percent (%) Clingers Bear Creek

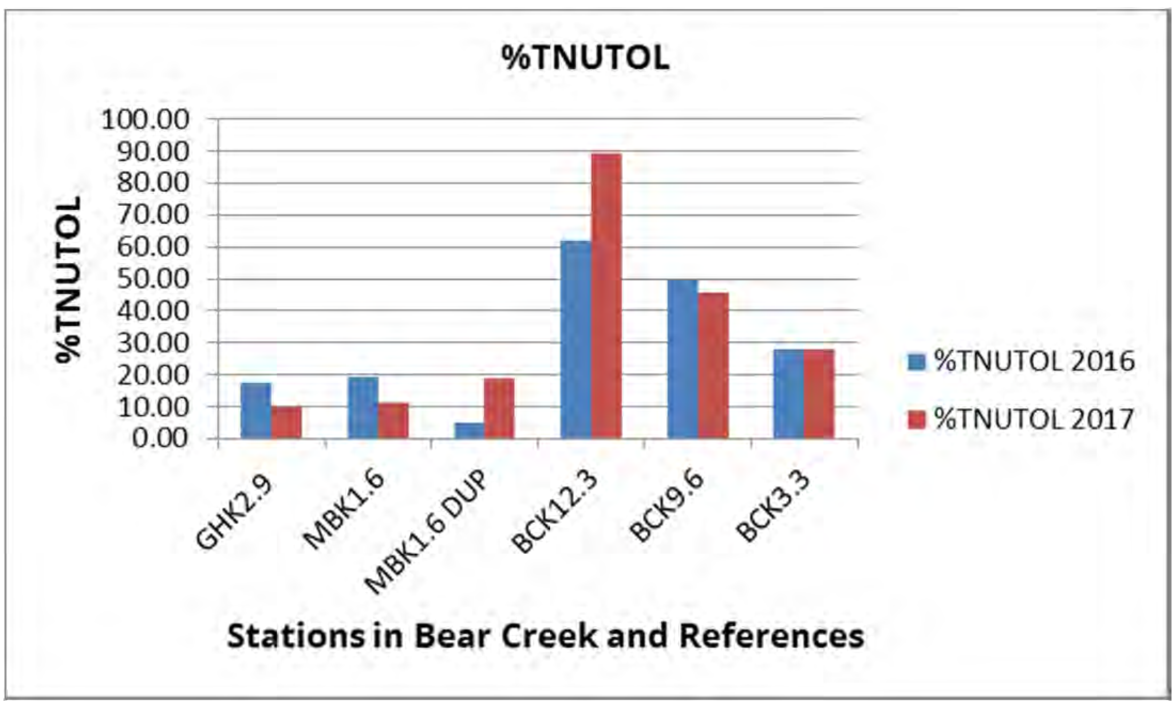


Figure 3.76: Percent (%) TNUTOL Bear Creek

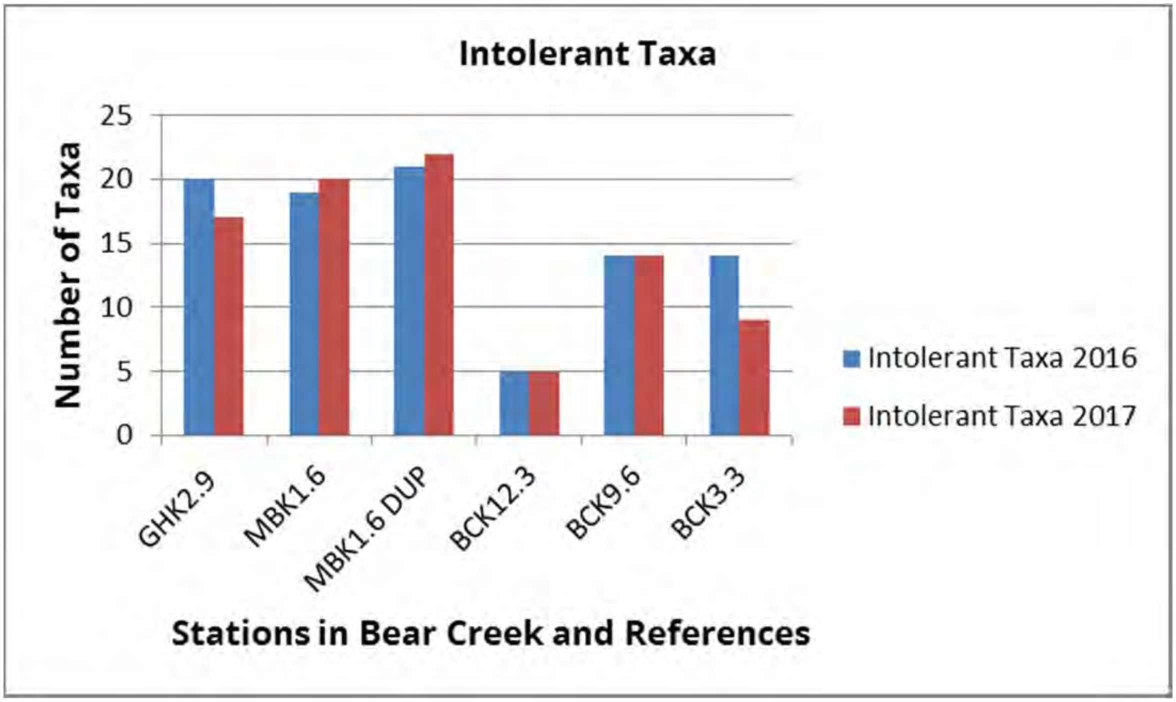


Figure 3.77: Intolerant Taxa Bear Creek

TMI Scores for the reference stations (MBK 1.6 and GHK 2.9) are similar for both 2016 and 2017 (Figure 3.69). 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 2016 and 2017. The TMI Scores for 2017 at both BCK 12.3 and BCK 9.6 are lower than the 2017 values. Scores for BCK 9.6 and BCK 3.3 approach or equal values expected for reference sites for both 2016 and 2017 data. In 2016, Taxa Richness values for reference streams exceeded those of all Bear Creek stations (Figure 3.70). In 2017, the Taxa Richness for GHK 2.9 was somewhat lower than BCK 9.6 and BCK 3.3, but exceeded that for BCK 12.3.

EPT Richness (Figure 3.71) shows a similar pattern to Taxa Richness with MBK 1.6 having higher values than all Bear Creek stations and GHK 2.9 having similar values to BCK 9.6 and lower values than BCK 3.3 in 2017. 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 2016 and 2017 (Figure 3.72), but were similar to the results for BCK 3.3 in both years. The %OC metric data (Figure 3.73) does not show a distinct trend for the 2016 data; however, like Mitchell Branch it shows the opposite from what would be expected, with the reference stations having a higher proportion of oligochaetes worms and chironomidae (midges). Again, impacted sites are expected to have higher proportions of these taxa. NCBI values (Figure 3.74) align with expectations in both 2016 and 2017 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 3.75) shows no consistent trends between the reference and impacted stations, although one would expect the reference stations to have higher values than the impacted stations.

The %TNUTOL metric shows a distinct difference between reference and impacted stations (Figure 3.76). Impacted stations are typically expected to be more nutrient enriched than the reference stations. The Intolerant Taxa metric also meets expectations with reference sites far exceeding impacted sites in numbers of Intolerant Taxa.

Interestingly, at station BCK 12.3, a number of the Intolerant Taxa continue to successfully reproduce at the site, although actual numbers of these sensitive organisms are down from previous years. 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 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; MBK 1.6) in a number of the metrics. With a TMI score of 32 (34 in 2016) (Figure 3.69; Table 3.17), BCK 9.6 lags only slightly behind GHK 2.9 and MBK 1.6).

BCK 3.3 compares most closely to the reference stations in a number of metrics. The TMI Score for both 2016 and 2017 matched those of the reference stations (Figure 3.69).

GHK2.9 and MBK 1.6 are two of the higher scoring reference stations being used in this study. With TMI scores of 42 (Table 3.17; Figure 3.69), Both GHK 2.9 and MBK 1.6 scored a maximum ranking on all of the metrics calculated for 2017. In all, these streams appear to have high diversity and little organic loading. In recent years, some road work in the vicinity of GHK 2.9 has caused an increase in sediment loading. If not corrected, this could be deleterious to the health of the community at the station.

White Oak Creek and Melton Branch

The TMI Total Scores (Figure 3.78) 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 and 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 site samples (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 samples were processed in the field removing all organisms and returning the sediments to the site of their origin. The complete organism 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 (Figures 3.78-3.86).

Metric data for all White Oak Creek stations and Melton Branch may be found in Table 3.8. The discussion of the data follows the table and figures below.

Table 3.18: Metric Values, Scores, and Biological Condition Ratings for White Oak Creek and Melton Branch

2017 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	47	6	28	4	39	6	36	4	56	6
EPT Richness	17	6	3	0	7	2	10	4	18	6
% EPT-Cheum	44.78	6	0.68	0	3.99	0	20.05	2	8.78	0
% OC	31.16	6	24.32	6	13.21	6	6.99	6	8.94	6
NCBI	2.71	6	5.46	4	5.41	4	5.00	4	5.09	4
% Clingers	31.59	6	73.97	6	13.67	2	55.33	6	33.67	6
%TNUTOL	13.33	6	45.89	4	60.07	2	36.08	6	55.93	4
Intolerant Taxa	16	6	5	0	5	0	4	0	9	2
INDEX SCORE (Tenn. Macro. Index)		42		24		22		32		32
RATING		A		B		B		A		A

Key: A = Supporting / Non Impaired (Tenn. 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)

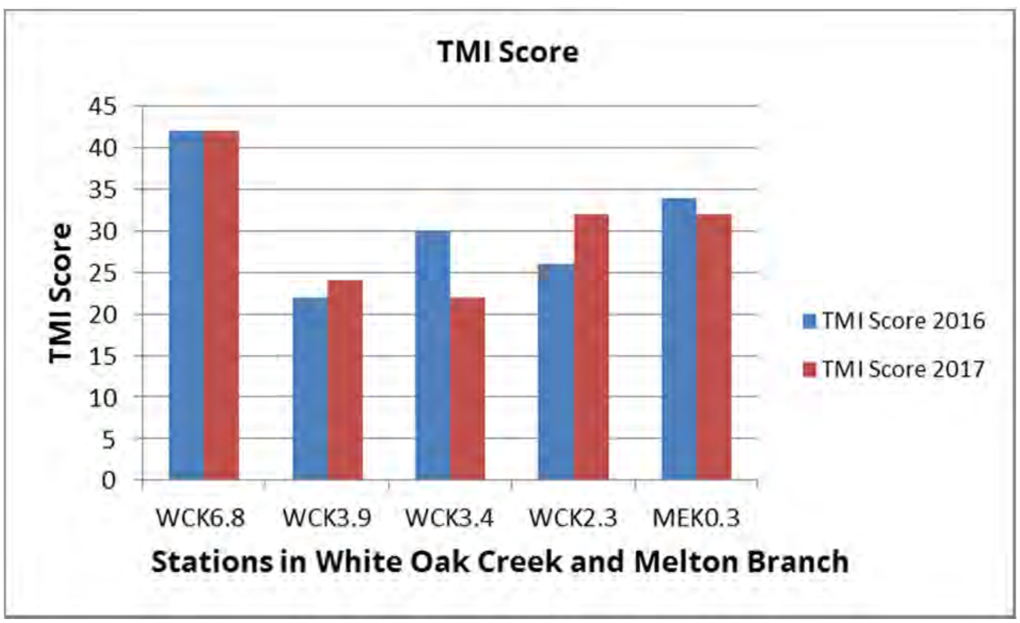


Figure 3.78: Metric Values, Scores, and Biological Condition Ratings for White Oak Creek and Melton Branch

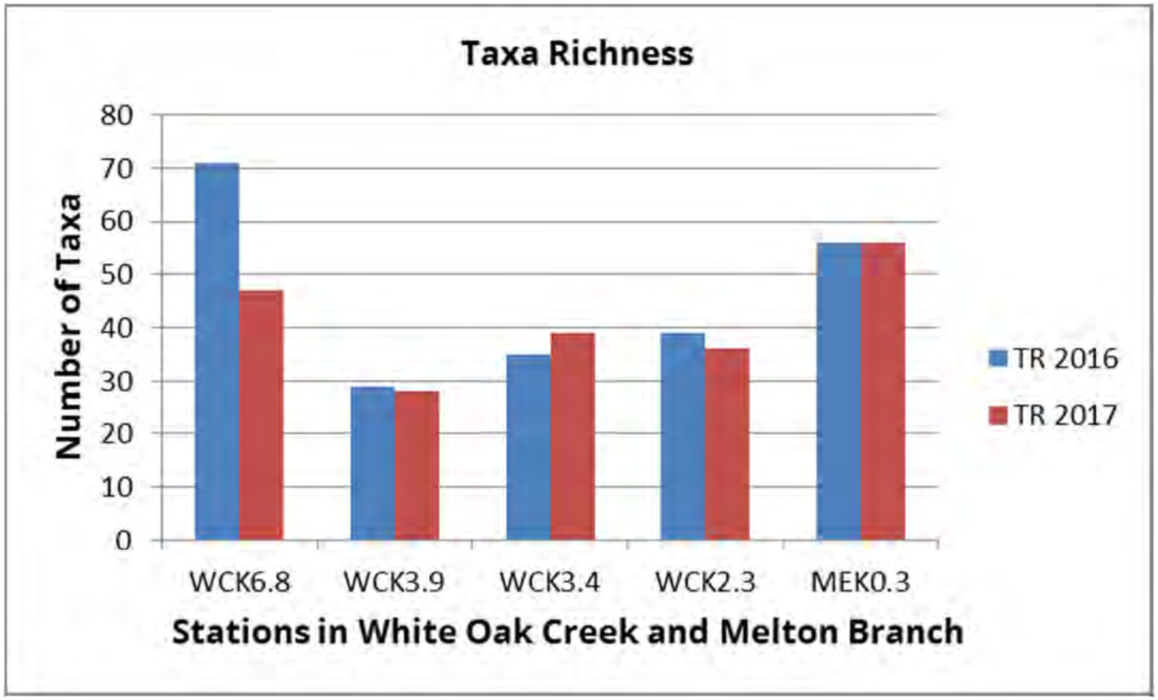


Figure 3.79: Taxa Richness for White Oak Creek and Melton Branch

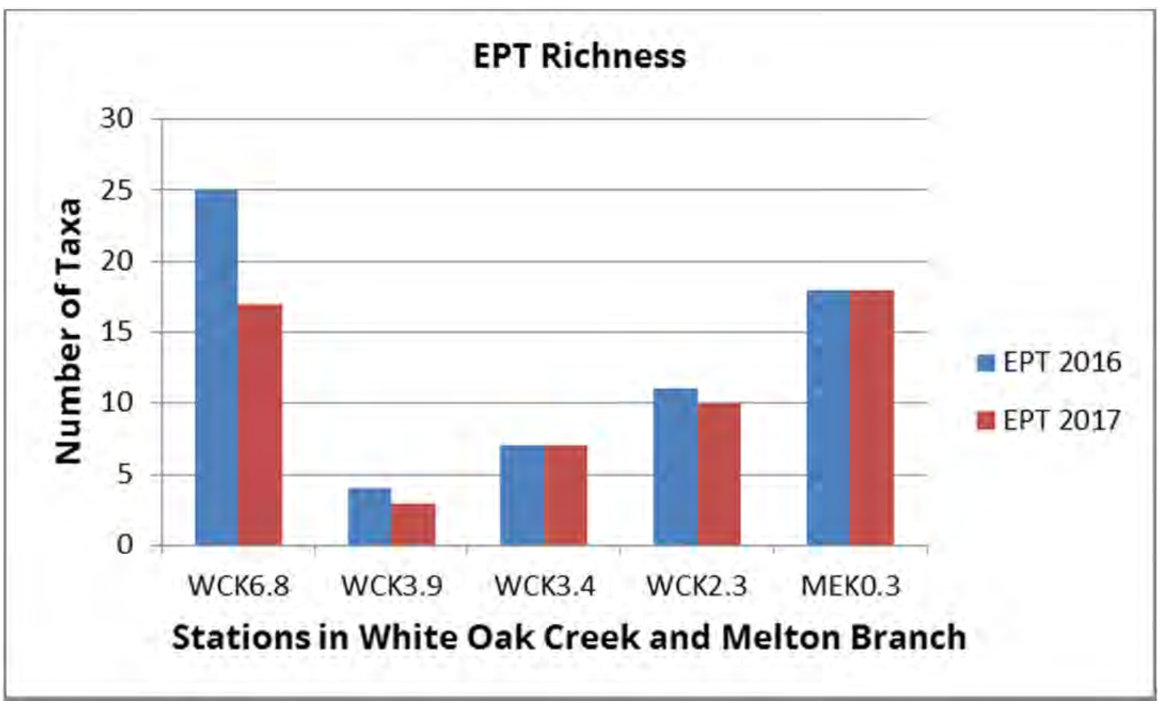


Figure 3.80: EPT Richness for White Oak Creek and Melton Branch

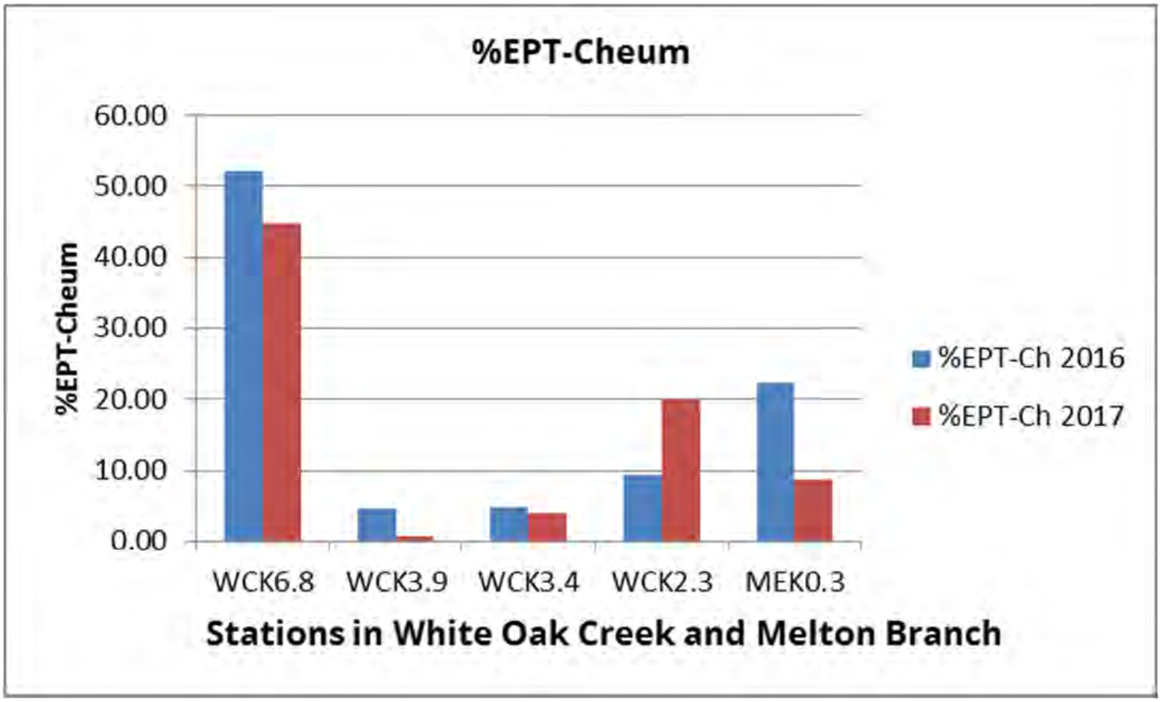


Figure 3.81: Percent (%) EPT-Cheum for White Oak Creek and Melton Branch

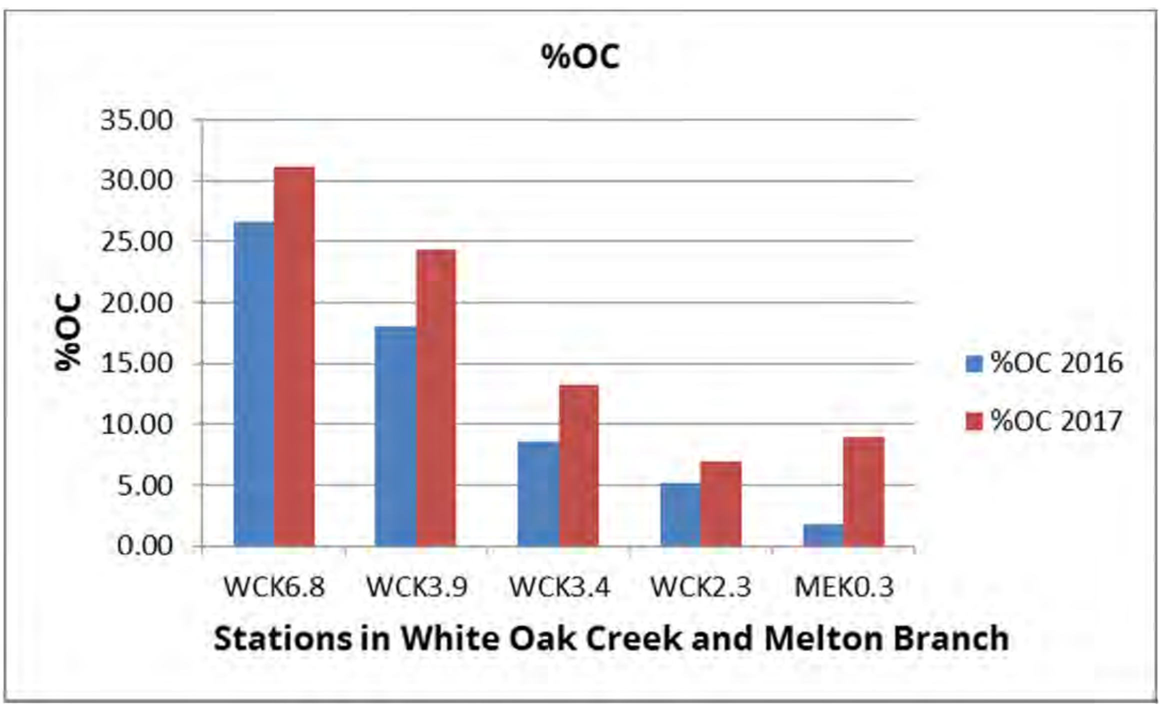


Figure 3.82: Percent (%) OC White Oak Creek and Melton Branch

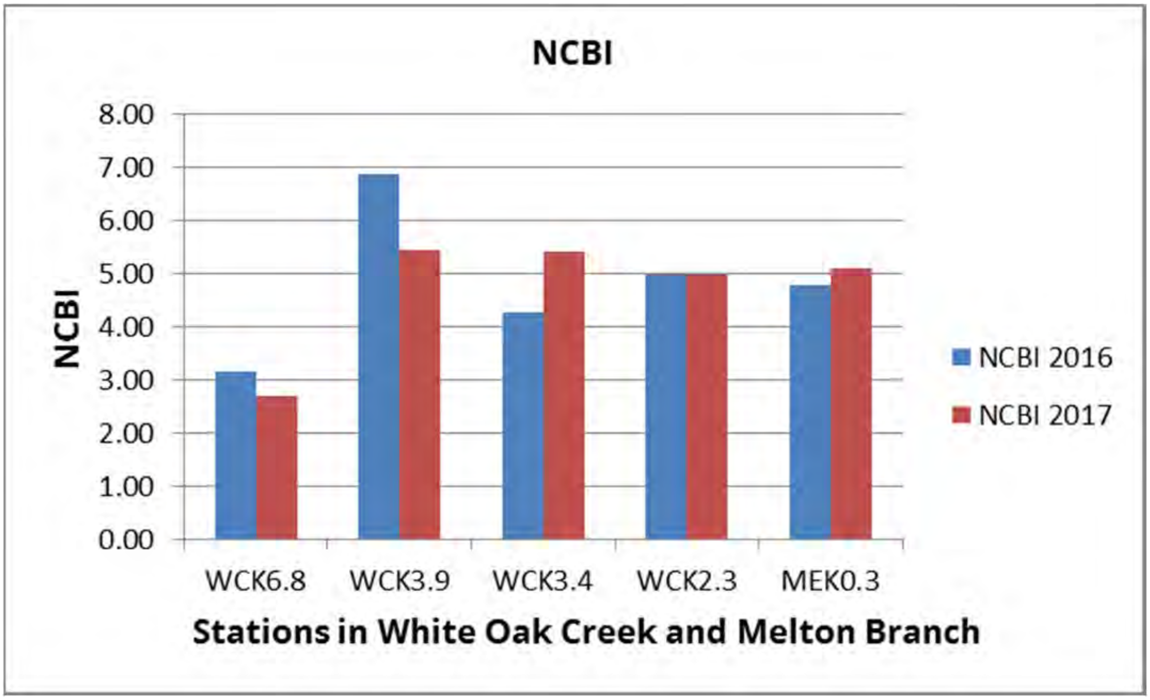


Figure 3.83: NCBI Score for White Oak Creek and Melton Branch

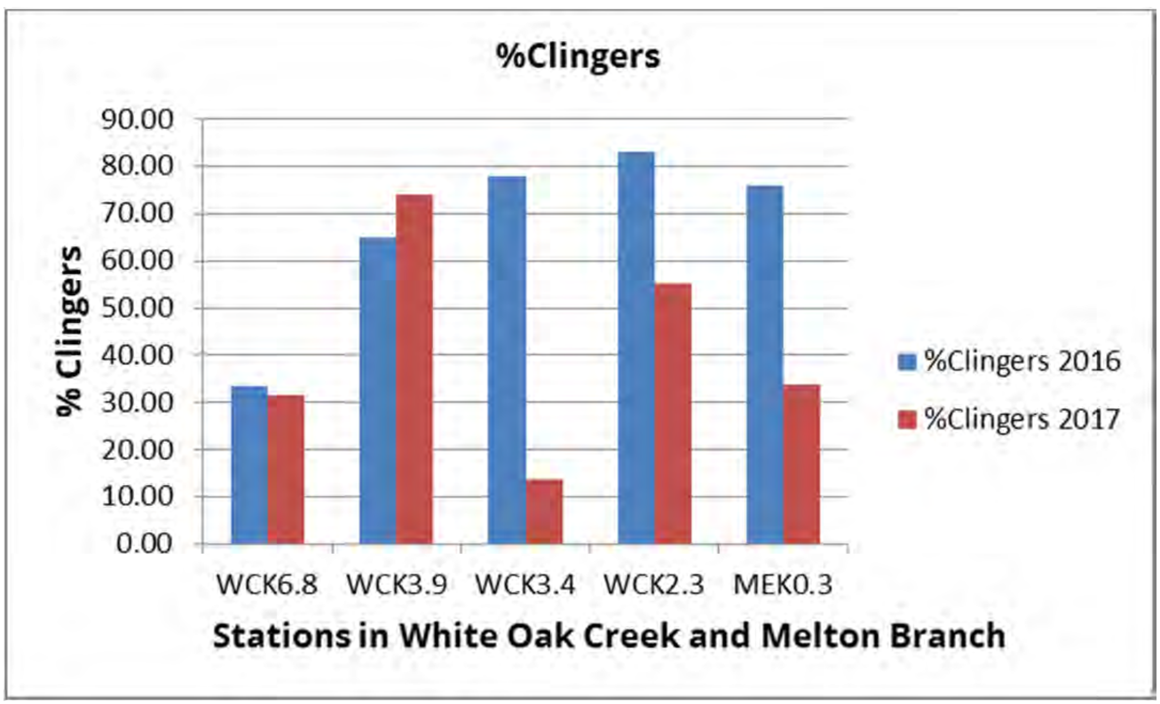


Figure 3.84: Percent (%) Clingers for White Oak Creek and Melton Branch

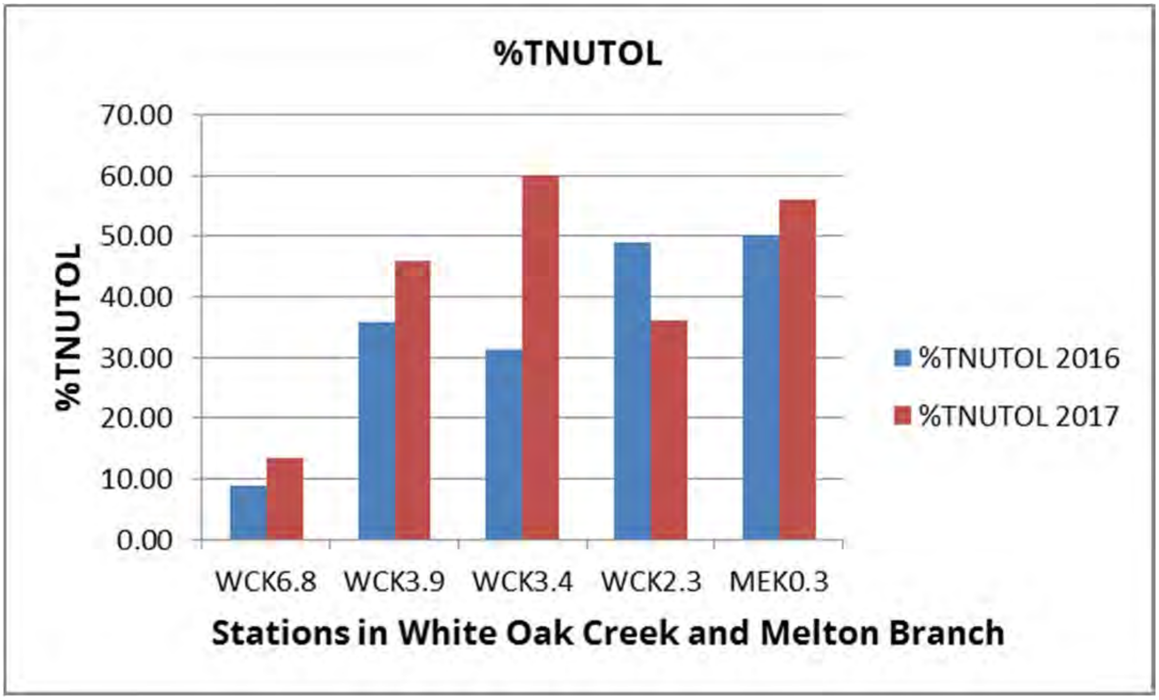


Figure 3.85: Percent (%) TNUTOL for White Oak Creek and Melton Branch

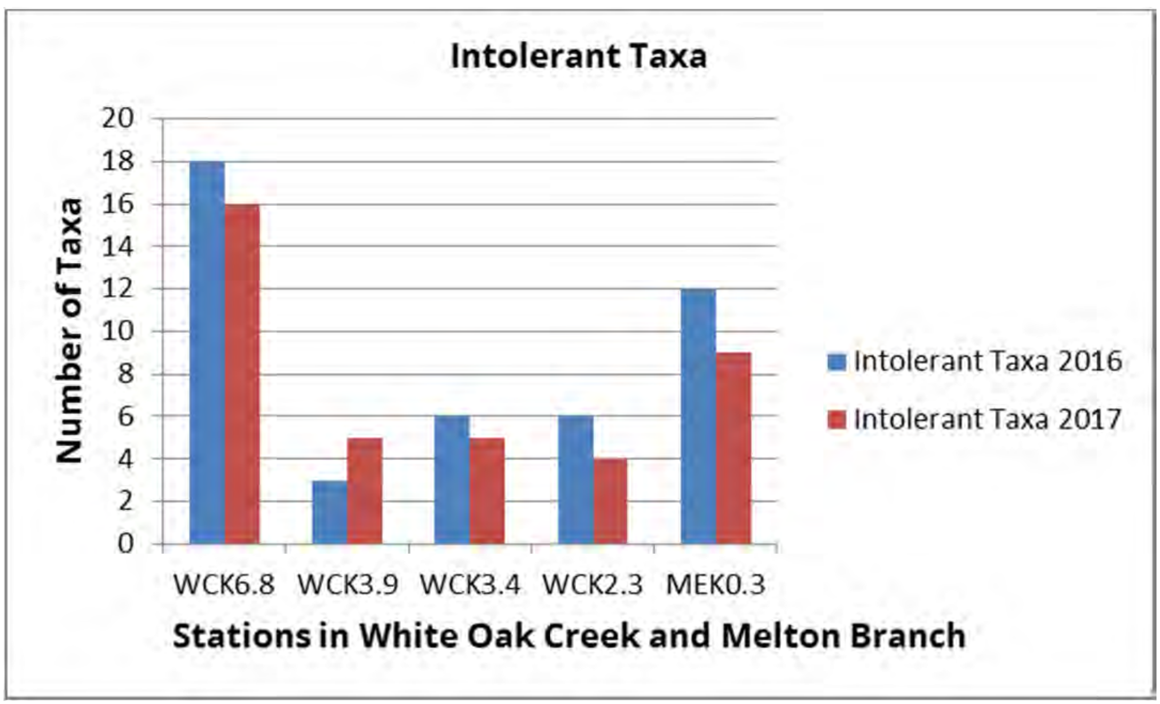


Figure 3.86: Intolerant Taxa for White Oak Creek and Melton Branch

As indicated above, both the reference station WCK 6.8 and MEK 0.3 score high on the TMI (Figure 3.78) in both 2016 and 2017. WCK 2.3 scored high on the TMI in 2017, but not in 2016. The remaining White Oak Creek stations also scored fairly well in both years; however, their scores are indicative of some degree of impairment. As in 2016, the 2017 data show Taxa Richness (Figure 3.79) 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 0.6 also compare well in terms of EPT Richness (Figure 3.80) for both 2016 and 2017. In terms of EPT-Cheum (Figure 3.81), % OC (Figure 3.82), NCBI Score (Figure 3.83), and % TNUTOL (Figure 3.85), 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 2016 and 2017. 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 2016 and 2017 in the reduced number of EPT taxa at impacted stations (Figure 3.79), and the decrease in the % EPT-Cheum (Figure 3.81) at the impacted stations. The % OC metric for both 2016 and 2017, 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 3.83). The %Clingers metric (Figure 3.84) for both years (with the exception of WCK3.4 in 2017) also show the opposite of what is expected with values higher at the impacted stations than at the reference station. Intolerant Taxa at the impacted stations in both 2016 and 2017 (Figure 3.86) 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.

All sites exclusive of MEK 0.3, WCK 3.9, WCK 3.4, and WCK 2.3 (all contaminated White Oak Creek watershed sites) were subsampled with approximately 1/7th of the sample picked clean of organisms. In the case of the contaminated White Oak Creek watershed sites, the entire sample was picked. The values for the subsampled sites were extrapolated and adjusted to organisms/m2. The resulting numbers are presented in Figure 3.87.

As seen from the Figure, 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 tolerant 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 (personal communication, Mark Peterson, 2018) that biocides used in cooling towers could be a significant part of the problem. The White Oak Creek stations (with lower diversity, few tolerant species, and extremely reduced population numbers) lead one to believe that 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.

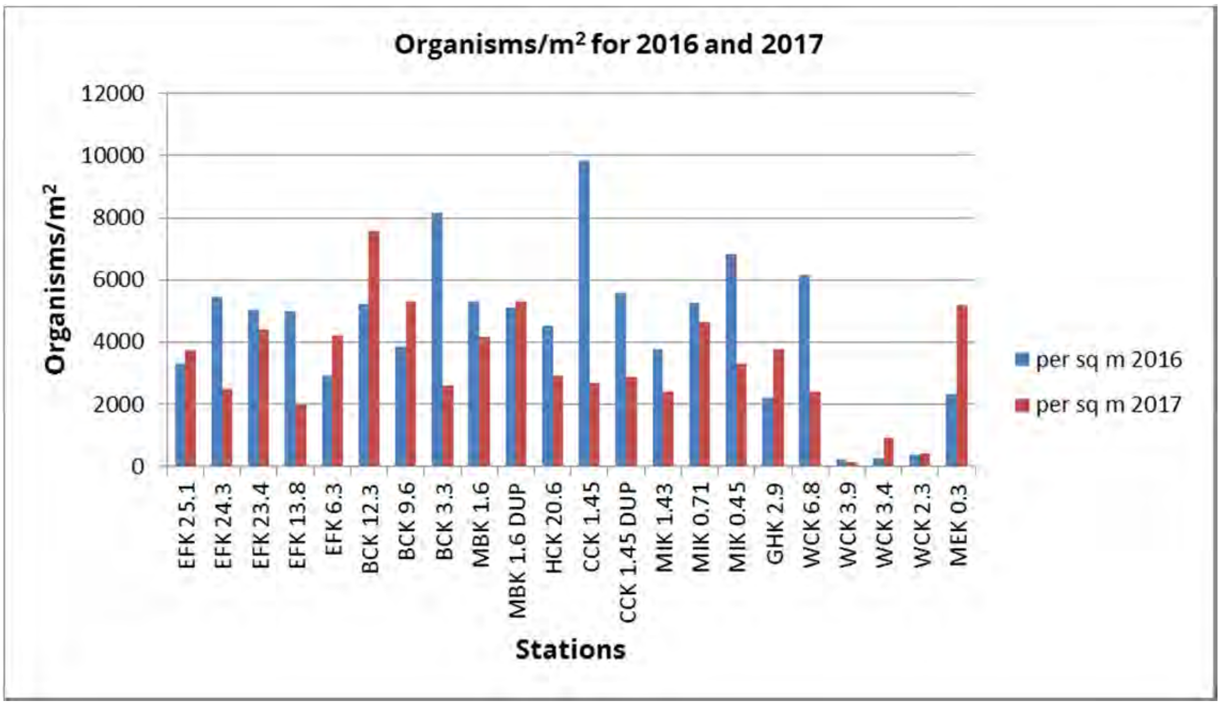


Figure 3.87: Organisms/m2 for 2015 and 2016

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 years (ASER 2017). 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 the halting of the augmented flow, conditions at the upper East Fork 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. Concerns are that 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 pollution effects. Every effort should be made to protect the current quality of streams that meet their designations and to improve those that do not.

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 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 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 reservation.

4.1.2 Problem Statements

- Many of the facilities at ETTP, Y12, and ORNL scheduled for decontamination and decommissioning are contaminated. Decontamination and Demolition (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 contaminate constituents. This dispersion is aided by winds that tend to blow up the valley (northeast) in the daytime and down the 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, in the past, obtained from spent nuclear fuel.

- 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 from the air emissions, 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 health and the environment, TDEC will conduct independent air sampling and compare the results with air sampling data provided by DOE.
- DoR-OR and TDEC personnel will review the air monitoring section of DOE (ORR's) Environmental Monitoring Plan 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 DOE radiological emissions would 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, in accordance with *DoR-OR Standard Operating Procedure (SOP) 202, Calibrating High Volume Total Suspended Particulate Sampler*. Maintenance on the samplers will be performed as described in *DOR-OR SOP 203, High Volume Total Suspended Particulate System Maintenance*.

Samples will be collected from each sampler weekly, 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.

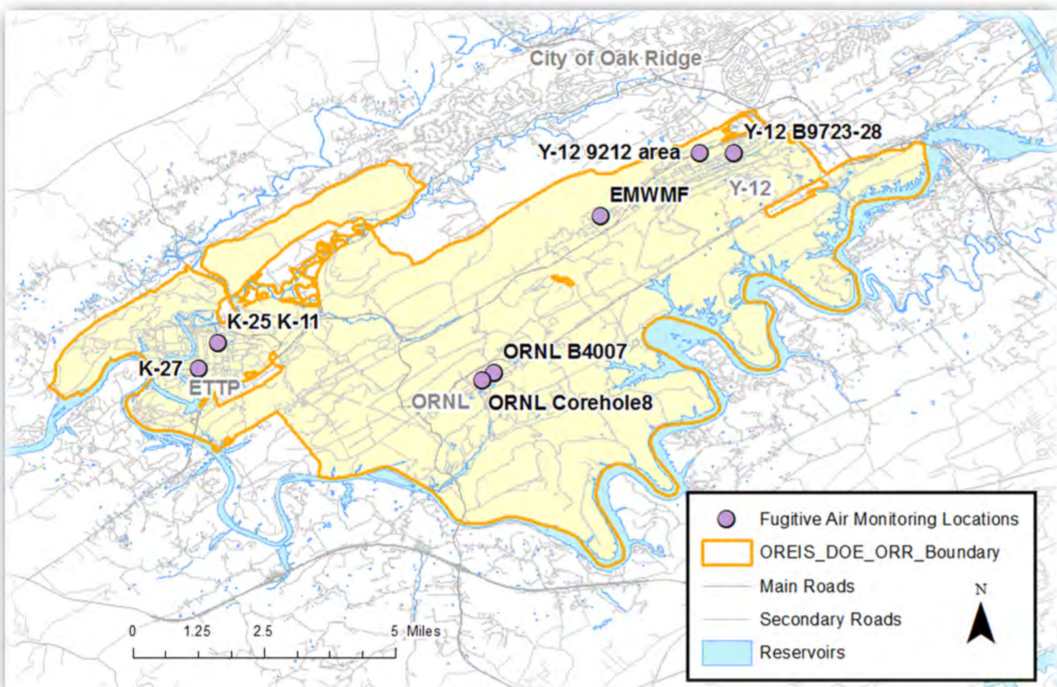


Figure 4.1. Fugitive Air Monitoring Locations

4.1.6 Deviations from the Plan

The original Project Plan was to collect and report on data through June 2018. However, the most recent sampling results are for the sampling period that ended 03/21/2018. Data examined in this report is for the 13 consecutive, previous, four-week composited samples, beginning 03/22/2017. Sampling and analysis was conducted in accordance with the Plan.

4.1.7 Results from 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 and 4.2. Table 4.1 shows the results from the samples taken at ETTP K-25/K11 Sampling Location and the results indicate no exceedances of regulatory limits.

Table 4.1: 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 for 3/22/2017 through 3/21/2018	4.76E-05	5.68E-06	4.68E-05	1.04E-04	
Average Background (Ft. Loudoun Dam)	4.28E-05	5.53E-06	4.16E-05	1.16E-04	
Net Activity (Avg. Minus Background)	4.76E-06	1.45E-07	5.24E-06	-1.17E-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	6.18E-04	2.04E-05	6.31E-04	-8.36E-05	1.19E-03

ETTP K-27 Area

At the ETTP K27 area, the Uranium isotopic rate increased substantially on the 4-week composite, ending on 02/21/2018. The amount of increase on 2/21/2018 compared to the remaining 12 composited periods for U234 was 49 times higher, U235 was 32 times higher, and U238 was 19 times higher. Tc-99 for the period was only 35% as much as the average.

Reportedly, work during that sample collection period included U-contaminated soil excavation on the southwest area of the K-25 footprint and D&D of the contaminated K-631 and K-633 buildings to the west of the K-27 area pad. The DOE ETTP Perimeter Sampling Program composites weekly samples, quarterly. DOE's sampling program also observed elevated readings for that time period (Reference Table 4.2.).

Table 4.2: 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 for 3/22/2017 through 3/21/2018	2.37E-04	2.42E-05	1.22E-04	1.08E-04	
Average Background (Ft. Loudoun Dam)	4.28E-05	5.53E-06	4.16E-05	1.16E-04	
Net Activity (Avg. Minus Background)	1.94E-04	1.86E-05	8.06E-05	-8.12E-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	2.52E-02	2.62E-03	9.71E-03	-5.80E-05	3.75E-02

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 4.3 shows the results from the samples taken at Building 9212 area and the results indicate no exceedances of regulatory limits.

Table 4.3: 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 for 3/22/2017 through 3/21/2018	1.74E-04	1.36E-05	5.04E-05	9.66E-05	
Average Background (Ft. Loudoun Dam)	4.28E-05	5.53E-06	4.16E-05	1.16E-04	
Net Activity (Avg. Minus Background)	1.31E-04	8.07E-06	8.77E-06	-1.96E-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	1.70E-02	1.14E-03	1.06E-03	-1.40E-04	1.91E-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 4.4 shows the results from the samples taken at Building 9723-28 area and the results indicate no exceedances of regulatory limits.

Table 4.4: 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 for 3/22/2017 through 3/21/2018	9.69E-05	1.15E-05	5.21E-05	8.63E-05	
Average Background (Ft. Loudoun Dam)	4.28E-05	5.53E-06	4.16E-05	1.16E-04	
Net Activity (Avg. Minus Background)	5.41E-05	5.96E-06	1.05E-05	-2.98E-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	7.03E-03	8.39E-04	1.27E-03	-2.13E-04	8.92E-03

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. Reference tables 4.5 and 4.6.

Table 4.5: ORNL B4007 Air Monitoring Average Result (pCi/m3)

ORNL B4007 Area	U-234	U-235	U-238	Sum of Fractions
Average for 3/22/2017 through 3/21/2018	3.89E-05	5.64E-06	3.70E-05	
Average Background (Ft. Loudoun Dam)	4.28E-05	5.53E-06	4.16E-05	
Net Activity (Avg. Minus Background)	-3.93E-06	1.11E-07	-4.57E-06	
40CFR Part 61 Limit Appendix E (Table 2)	7.70E-03	7.10E-03	8.30E-03	
Fraction of Limit Net/Limit	-5.10E-04	1.56E-05	-5.51E-04	-1.05E-03

Table 4.6: ORNL Corehole 8 Air Monitoring Average Result (pCi/m3)

ORNL Corehole 8 Area	U-234	U-235	U-238	Sum of Fractions
Average for 3/22/2017 through 3/21/2018	3.84E-05	5.12E-06	3.78E-05	
Average Background (Ft. Loudoun Dam)	4.28E-05	5.53E-06	4.16E-05	
Net Activity (Avg. Minus Background)	-4.44E-06	-4.08E-07	-3.82E-06	
40CFR Part 61 Limit Appendix E (Table 2)	7.70E-03	7.10E-03	8.30E-03	
Fraction of Limit Net/Limit	-5.76E-04	-5.74E-05	-4.60E-04	-1.09E-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 4.7).

Table 4.7. EMWMF Air Monitoring Average Result (pCi/m3)

EMWMF	U-234	U-235	U-238	Tc-99	Sum of Fractions
Average for 3/22/2017 through 3/21/2018	7.21E-05	8.05E-06	6.22E-05	1.16E-04	
Average Background (Ft. Loudoun Dam)	4.28E-05	5.53E-06	4.16E-05	1.16E-04	
Net Activity (Avg. Minus Background)	2.93E-05	2.52E-06	2.05E-05	-3.77E-07	
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	3.80E-03	3.54E-04	2.48E-03	-2.69E-06	6.63E-03

4.1.8 Conclusions

Elevated uranium readings were observed on the 2/21/2018 composited sample taken from the monitoring station area near K27. Had those rates continued for the entire year, the rates would likely have exceeded regulatory limits. Work conducted, at that time, was not likely to have included Tc-99 areas of the K25 area because Tc-99 rates were reduced during the period.

This project's shorter composite interval can result in the more timely observation of potential problems than other available sampling programs such as the DOE program which analyzes their samples quarterly.

In past years, this 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.

During 03/22/2017 through 03/21/2018, the average results were similar to background. The average concentrations, minus background, for all sites, were below the federal standards.

4.1.9 Recommendations

During the 4-week period ending 2/21/2018, the suppression of airborne contamination at the referenced D&D site (ETTP) was inadequate. Future actions at ETTP and other ORR sites should be more strictly controlled.

5.0 SURFACE WATER MONITORING

5.1 AMBIENT SURFACE WATER MONITORING

5.1.1 Background

The primary purpose of the Ambient Surface Water Monitoring Project is to evaluate the impact of Department of Energy (DOE) Oak Ridge Operations (ORR) contamination to five primary ORR exit pathway streams (Bear Creek, East Fork Poplar Creek, Melton Branch, Mitchell Branch, and White Oak Creek) and the Clinch River. Due to the presence of areas of extensive anthropogenic point and non-point source contamination on the ORR, the potential for pollution to contaminate surface waters exists on the ORR as well as downstream offsite aquatic systems.

Bear Creek, East Fork Poplar Creek, Melton Branch, Mitchell Branch, and White Oak Creek each flow into the Clinch River. The public municipalities and ORR nuclear processing complex/laboratories located in this area of the Clinch River are Anderson County, Knox County, Roane County, the City of Clinton, the City of Kingston, the City of Norris, the City of Oak Ridge, the Y-12 National Security Complex (Y-12), the Oak Ridge National Laboratory (ORNL), and the East Tennessee Technology Park (ETTP). To obtain public drinking water and/or industrial plant processing water, all of these areas use the surface waters of the Clinch River. From the city of Norris (north of ORR) to the city of Kingston (south of ORR), this span of the Clinch River is approximately thirty miles in length. The Clinch River stretch is often used by swimmers and boaters engaged in recreational activities. Therefore, because of its recreational popularity and accessibility, it is imperative to know ORR's impact to the Clinch River.

This project complements the Benthic Macroinvertebrate Monitoring Project as the assessment of a stream's water quality can more accurately determine the stream's total overall biological health. The evaluation of benthic macroinvertebrate communities is used to determine if a stream is supportive of fish and aquatic life. An integral element of this evaluation is the physical and chemical analysis of the stream's surface water.

5.1.2 Problem Statements

ORR exit pathway streams and the Clinch River 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 concerns include, but are not limited to, the following:

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury into East Fork Poplar Creek by spills and leakages from subsurface drains, building foundations, and contaminated soils, as well as purposed discharges of waste water containing mercury. (Turner and Southworth, 1999)

- East Fork Poplar Creek is believed to contribute approximately 0.2 metric tons (440.9 lbs.) 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, have the potential of being influenced by streams that drain the ORR. (DOE, 1992)
- ORNL has been releasing low-level, radioactive liquid wastes to the Clinch River via White Oak Creek since 1943. (Pickering, 1970)
- The Clinch River received approximately 665 curies of cesium-137 (Cs-137) from White Oak Creek between 1954 and 1959. (DOE, 1992)

5.1.3 Goals

Characterize stream conditions through the sampling and analysis of surface water.

Serve as an integral component of watershed monitoring and sampling (physical, chemical, and biological conditions of the waterbody).

Assess site remediation efforts through long-term monitoring and sampling of surface water.

Identify trends in data, based on findings, and use those trends to make recommendations 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 the monitoring, sampling, and analysis of surface water attained from the tributaries that drain the ORR and the surface water of the Clinch River spanning from the mouth of White Oak Creek at Clinch River kilometer (CRK) CRK 33.5 downstream to CRK 0.0, where it meets the Tennessee River. Figure 5.1 provides a regional site map of this project's areas of interest.

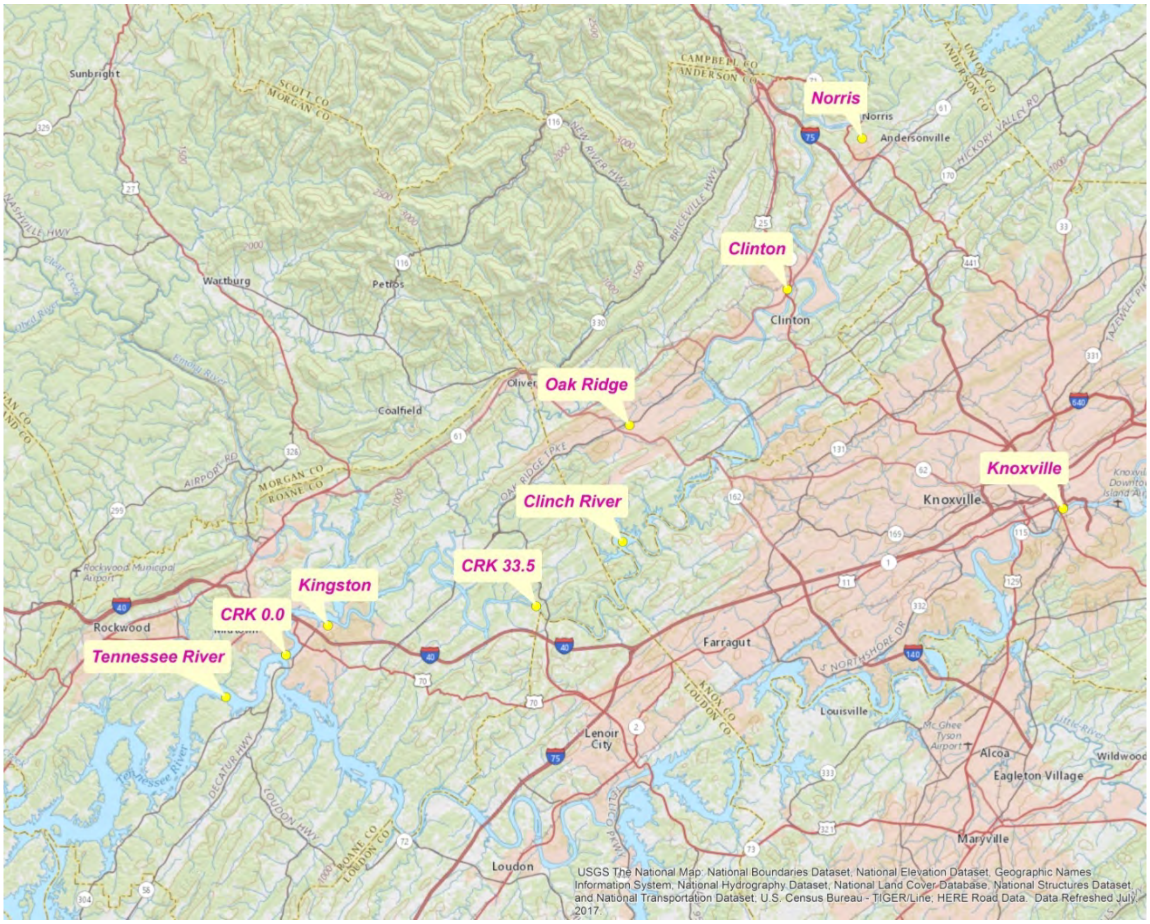


Figure 5.1: Regional Site Map

5.1.5 Methods, Materials, Metrics

The Tennessee Department of Environment and Conservation, Division of Water Resources, *Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC DWR. 2018), was used for this project.

This project has two aspects:

1. Ambient: Annual sampling is conducted at 13 sampling stations on the major exit pathway streams of the ORR. These sampling stations are on Bear Creek, East Fork Poplar Creek, Mitchell Branch, and White Oak Creek. (The sampling station at the White Oak Creek headwaters (WCK 6.8) is included in the Ambient Surface Water Project and also serves as the background location for TDEC's Benthic Macroinvertebrate Project.) Three ambient background sampling stations for the Ambient Surface Water Project are on Clear Creek, Mill Branch, and Hinds Creek. Sampling is conducted in April.
2. Sr-90: Monthly sampling will be conducted at four sampling stations, chosen to

assess the presence of Sr-90 in the Clinch River in the area near the mouth of White Oak Creek. Three of these stations are on the Clinch River and one is at the headwaters of White Oak Creek.

The Tennessee Department of Environment and Conservation (TDEC), Division of Remediation (DoR), Oak Ridge Office (OR) (TDEC-DoR-OR) collected ambient surface water samples during April 2018.

Stream trending, over the length of exit pathway streams, was not possible this year due to budget cuts that affected the Ambient Surface Water Project. Sampling was reduced and limited to one sampling station on each of the five exit pathway streams (Bear Creek, East Fork Poplar Creek, Melton Branch, Mitchell Branch, and White Oak Creek). Four background sampling stations were sampled.

Figure 5.2 provides a map and identifies the sampling stations' locations for this project. Table 5.1 lists the sampling locations and sampling rationale. Table 5.2 lists the test analyses, units, method detection limits (MDLs), method quantification limits (MQLs), and analytical methods. The data from this project will be used to establish a baseline for the detection of changes to the health of the streams.

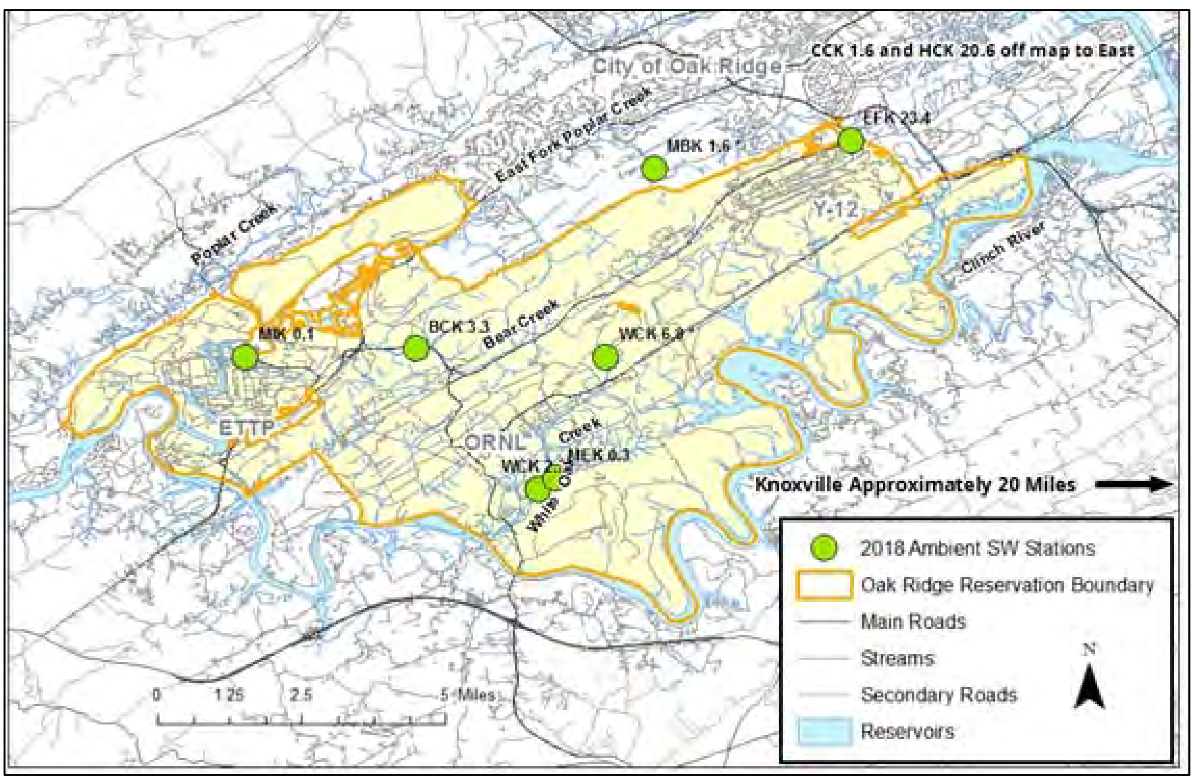


Figure 5.2: Map of Sampling Locations

Table 5.1: Sampling Locations

Sampling Locations					
Monitoring Location	**DWR ID**	**Alt. ID**	**Monitoring Rationale**	**Latitude**	**Longitude**
Bear Creek Mile 2.0	BEAR002.0RO	BCK 3.3	Surveillance of Bear Creek water quality downstream of Y-12 footprint.	35.94354	-84.34911
Clinch River Mile 32	CLINC019.9RO	CRK 32	Surveillance of Clinch River water quality 1.5 miles downstream of the mouth of White Oak Creek.	35.9026	-84.34406
Clinch River Mile 33.5	CLINC020.8RO	CRK 33.5	Surveillance of Clinch River water quality at the mouth of White Oak Creek.	35.896653	-84.333161
East Fork Poplar Creek Mile 14.5	EFPOP014.5AN	EFK 23.4	Surveillance of water quality at point where EFPC leaves leaves DOE property and enters Oak Ridge.	35.99596	-84.24004
Melton Branch Mile 0.2	MELTO000.2RO	MEK 0.3	Surveillance of Melton Branch (MEK) at a point influenced by Melton Valley Burial Grounds.	35.91123	-84.31423
Mitchell Branch Mile 0.1	MITCH000.1RO	MIK 0.1	Surveillance of MIK water quality at a point influenced by ETTP activities.	35.94146	-84.3922
White Oak Creek Mile 1.4	WHITE001.4RO	WCK 2.3	Surveillance of White Oak Creek (WCK) at a point downstream of Melton Valley Burial Grounds.	35.94151	-84.30161
White Oak Creek Mile 4.2	WHITE004.2RO	WCK 6.8 *	Reference site	35.90834	-84.31856
Hinds Creek Mile 12.8	HINDS012.8AN	HCK 20.6 *	Reference site	36.15797	-83.99944
Clear Creek Mile 1.0	ECO67F06	CCK 1.6*	Reference site	36.21346	-84.05983
Mill Branch Mile 1.0	FECO67I12	MBK 1.6 *	Reference site	35.98886	-84.28935

DWR ID = Division of Water Resources site designation

Alt. ID is an abbreviation of the stream name with the distance from mouth in km; * = Reference Stream

Table 5.2: Test Analyses, Units, MDLs, MQLs, and Methods

Test Analyses, Units, MDLs, MQLs, and Methods					
Parameter	**Unit**	**MDL**	**MQL**	**Analytical Method Context**	**Analytical Method ID**
Ammonia-nitrogen	mg/l	0.0205	0.100	USEPA	350.1
Arsenic	µg/l	0.770	5.00	USEPA	200.8
Cadmium	µg/l	0.260	1.00	USEPA	200.8
Chromium	µg/l	0.810	5.00	USEPA	200.8
Copper	µg/l	0.500	1.00	USEPA	200.8
Dissolved oxygen (DO)	mg/l	0.01	0.01	USEPA	360.1
Hardness, Ca, Mg	mg/l	0.115	0.25	USEPA	200.7
Inorganic nitrogen (nitrate and nitrite)	mg/l	0.0190	0.100	USEPA	353.2
Kjeldahl nitrogen	mg/l	0.175	0.500	USEPA	351.2
Lead	µg/l	0.290	1.00	USEPA	200.8
Magnesium	mg/L	0.0280	0.100	USEPA	200.7
Mercury	ng/L	1.80	5.00	USEPA	245.7
Nickel	µg/l	0.460	1.00	USEPA	200.8
pH	None	7.80	0.01	USEPA	150.1
Phosphorus	mg/l	0.00756	0.0500	USEPA	365.1
Specific conductance	µS/cm	0.1	0.1	USEPA	120.1
Temperature, water	deg C	0.01	0.01	USEPA	170.1
Zinc	µg/l	1.70	5.00	USEPA	200.8
Parameter	**Unit**	**Rad Error**	**MDL**	**Analytical Method Context**	**Analytical Method ID**
Gross alpha radioactivity, (Thorium-230 ref std)	pC/L	0.43 - 2.9	1.8 - 2.4	USEPA	900
Gross beta radioactivity, (Cesium-137 ref std)	pC/L	1.9 - 4.4	3.5 - 4.0	USEPA	900
Strontium-89	pC/L	1.4	0.44	USEPA	901.1
Technetium-99	pC/L	0.24	0.69	USEPA	901.1
Strontium-90	pC/L	2.9	0.22	USEPA	901.1

5.1.6 Deviations from the Plan

Stream trending over the physical length of exit pathway streams was not possible this year due to budget cuts which affected this project. Sampling was limited to one sampling station on each of the five exit pathway streams (Bear Creek, East Fork Poplar Creek, Melton Branch, Mitchell Branch, and White Oak Creek). Table 5.1 identifies the locations of the stations that were actually sampled. The Project Plan called for monthly sampling at all of the Clinch River sampling stations; however, sampling was reduced to quarterly sampling, only at CRK 32 and CRK 33.5.

5.1.7 Results and Analysis

Data summaries (of the 2018 physical parameters, metals, and nutrients) are presented in Table 5.3 for all streams sampled where exceedances are highlighted (in light red). Because CRK 32, CRK 33.5, and MEK 0.3 were only sampled for Sr-90, they are not listed in Table 5.3; however, their results are reported in Table 5.4 and figures 5.12 and 5.13.

Table 5.3: Physical Parameters, Metals, and Nutrients Results

Physical Parameters, Metals, and Nutrients Results										
Parameter	**BCK 3.3**	**EFK 23.4**	**MIK 0.1**	**WCK 2.3**	**Units**	**TWQC***	**CCK 1.6†**	**MBK 1.6†**	**WCK 6.8†**	**HCK 20.6†**
pH	7.95	7.74	7.64	7.50	None	5.5-9[a]	7.97	7.93	7.70	7.80
Specific conductance	213	464	320	312	µS/cm	n.a.	224	160	221	282
Temperature, water	11.3	14.5	12.3	14.0	°C	<=30.5	10.6	12.1	12.7	8.3
Dissolved oxygen (DO)	9.76	8.48	8.77	8.20	mg/L	5.0[a]	10.8	9.59	10.2	11.1
Flow	17.2	5.2	1.44	8.35	cfs	n.a.	3.86	2.46	1.71	33.0
Ammonia	U	U	U	U	mg/L	n.a.	U	U	U	U
Phosphorus	0.0204	0.252	0.0210	0.0859	mg/L	n.a.	U	0.0231	U	0.00783
Total Kjeldahl Nitrogen	U	U	U	U	mg/L	n.a.	U	U	U	U
Nitrate and Nitrite	0.427	3.05	0.195	0.561	mg/L	n.a.	0.359	0.0787	0.170	0.466
Calcium	26.5	56.6	49.3	41.7	mg/L	n.a.	26.4	21.6	23.5	36.7
Magnesium	8.0	15.9	12.0	8.59	mg/L	n.a.	12.0	4.57	11.3	12.5
Hardness, Ca, Mg	99.1	207	172	140	mg/L	n.a.	116	72.7	105	143
Arsenic	U	1.32	1.15	U	µg/L	10[c]	U	U	U	U
Cadmium	U	0.311	U	U	µg/L	2.0[d]	U	U	U	U
Chromium	U	0.938	2.66	1.15	µg/L	16[e]	0.828	U	0.993	U
Copper	U	3.52	7.70	51.8	µg/L	13[d]	U	U	U	U
Lead	U	U	4.82	1.41	µg/L	5[f]/65[a]	U	U	U	U
Nickel	1.14	2.16	16.8	2.15	µg/L	470	0.843	0.530	0.471	1.14
Zinc	U	21.4	27.4	10.9	µg/L	120[d]	2.10	U	U	U
Mercury	U	153	U	U	ng/L	51[c]	U	U	U	U

*Tennessee Water Quality Criteria:

[a] Fish and Aquatic Life (FAL), applies to all sites

[b] Industrial Water Supply, applies only to Clinch River Sites

[c] Recreation (organisms only), applies to all sites

[d] Fish and Aquatic Life (FAL), applies to all sites. This value is for total hardness of 100mg/L

[e] FAL (Chromium VI)

[f] Domestic Water Supply

** Equipment Error - failure of DO sensor or calibration error

J - signifies a figure that is between the Method Detection Limit and the Method Quantification Limit; it is an estimate.

U - Undetected

n.a. - not applicable

† - Reference Station

Table 5.4 presents a summary of the 2018 radiological results for all streams sampled, annually. The Clinch River results are found in figures 5.12 and 5.13.

Table 5.4: Radiological Results

Surface Water Radiological Results in pCi/L									
Parameter	**BCK 3.3**	**EFK 23.4**	**MEK 0.3**	**MIK 0.1**	**WCK 2.3**	**CCK 1.6**	**HCK 20.6**	**MBK 1.6**	**WCK 6.8**
Gross alpha radioactivity, (Thorium-230 ref std)	3.44	15.9	n.a.	5.38	6.9	0.54	0.12	0.26	0.32
Gross alpha combined standard uncertainty at 1-sigma	0.61	1.5	n.a.	0.74	0.9	0.44	0.44	0.46	0.45
Gross beta radioactivity, (Cesium-137 ref std)	3.1	22	n.a.	11.1	100.7	-2.1	-0.2	-0.1	-0.2
Gross beta combined standard uncertainty at 1-sigma	1.8	2.1	n.a.	1.9	3.7	1.8	1.8	1.8	1.8
Strontium-89 (Th-230 ref std)	0.0929	-0.0997	0.077	-0.63	4.12	0.0906	-1.41	0.105	-0.471
Sr-89 combined standard uncertainty at 1-sigma	0.722	0.616	0.701	0.768	3.5	0.941	0.805	0.758	2.21
Strontium-90 (Th-230 ref std)	-0.176	-0.25	-0.113	0.46	47.4	-0.37	0.338	-0.195	pending
Sr-90 combined standard uncertainty at 1-sigma	0.493	0.419	0.429	0.559	9.04	0.58	0.521	0.496	3.56

Footnote for Table 5.4: Strontium-90 at WCK 6.8 is pending the receipt of laboratory results.

Specific, analytical results and discussions for Bear Creek, Clinch River, East Fork Poplar Creek, Mitchell Branch, and White Oak Creek are provided in the following five sections of this Project Report. The TDEC-DoR-OR 2018-2017 Tennessee Macrobiotic Index (TMI) scores have yet to be published. It is anticipated that their total scores will be similar to previous TDEC-DoR-OR 2017-2016 TMI total scores. Accordingly, the 2017-2016 TMI scores will be used in conjunction with the 2018 analytical results to formulate conclusions and make recommendations.

Bear Creek–(Figures 5.3 & 5.4)

The 2018 metals and nutrient data from BCK 3.3 indicates healthy conditions; most metals results were non-detects and nutrients were within a statistical normal range.

- The BCK 3.3 2017-2016 TMI score was 42 (supporting / non impaired).
- Radiological data from BCK 3.3 show values for gross alpha and beta activity that are above background; Sr-90 was not detected.
- Since 2016, sampling has not been conducted at BCK 12.3 due to budget cuts. A nine-year review (2008 through 2016) of data was recently conducted. The gross alpha activity found at BCK 12.3 is much higher than background (See Figure 5.3.).
- Gross beta values are much higher than background values at BCK 12.3 and the values have increased for the last two years that the station was sampled (2015 and 2016) (See Figure 5.4.).

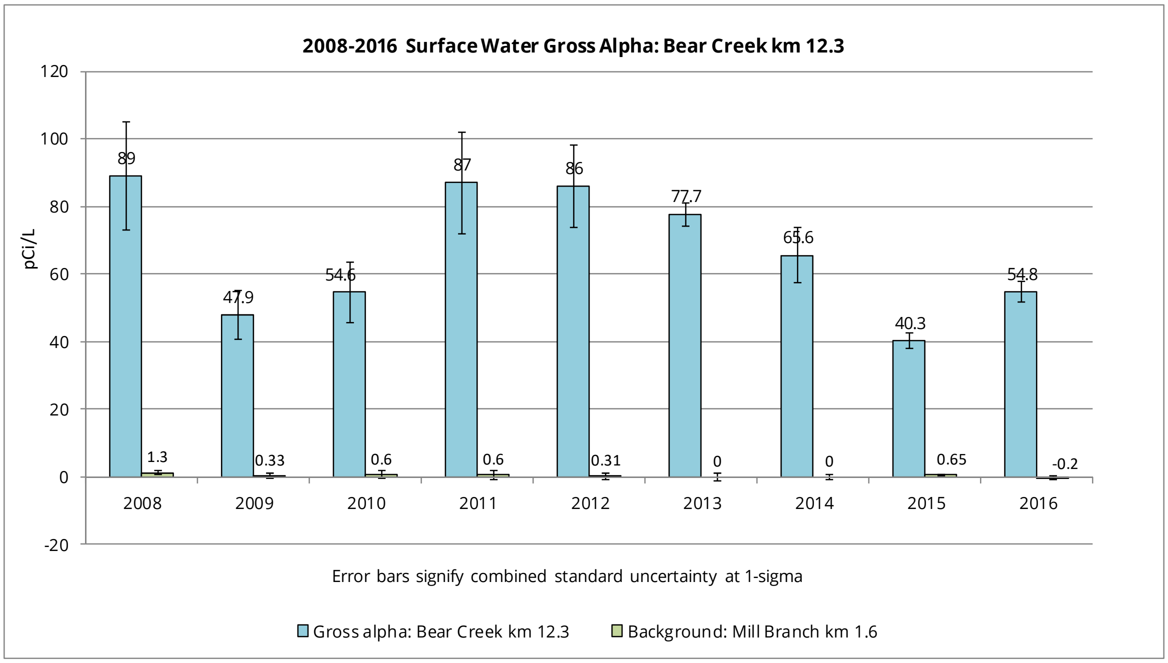


Figure 5.3: Gross Alpha Activity in Surface Water at Bear Creek km 12.3

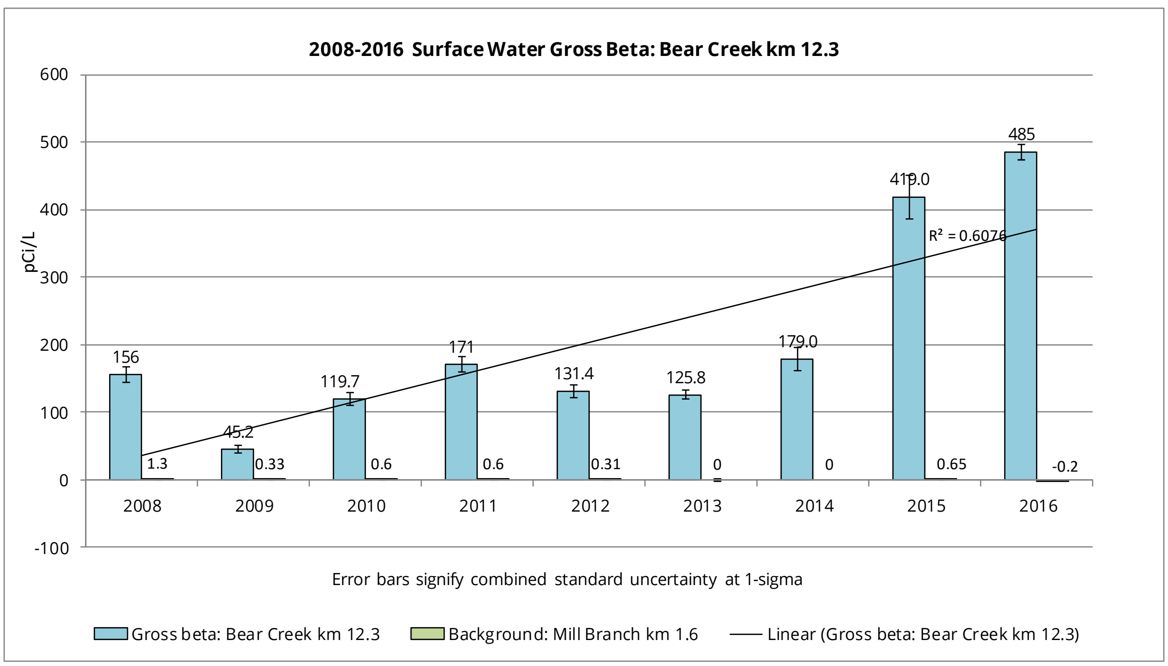


Figure 5.4: Gross Beta Activity in Surface Water at Bear Creek km 12.3

East Fork Poplar Creek– (Figures 5.5, 5.6, & 5.7)

At EFK 23.4, the total mercury concentration was 0.153 µg/L in 2018, which is three times greater than the mercury limit established by the Tennessee Water Quality Criteria for Recreation (0.051 µg/L). The mercury data collected by TDEC DoR-OR at EFK 23.4 since 2008 are shown in Figure 5.5. Sampling was not conducted at EFK 23.4 in 2013 or 2014. However, in 2016 and 2017, sample analysis results did not detect mercury at EFK 23.4.

Nitrate and nitrite testing for EFK 23.4 resulted in a value of 3.05 mg/L. Natural levels of nitrate in streams are usually less than 1 mg/L. TDEC's recommended interpretation of the existing narrative criteria for nitrate + 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.

The EFK 23.4 2017-2016 TMI score was 20 (partially supporting / moderately impaired).

The total phosphorus concentration at EFK 23.4 was 0.252 mg/L. TDEC's recommended interpretation of the existing narrative criteria for total phosphorus is 0.04 mg/L for ecoregion 67f.

Radiological testing of the surface water at EFK 23.4 was not conducted in 2013, 2014, and 2017. Gross alpha activity has been well above background for every year that it was tested since 2008 (Figure 5.6). The value for 2018 was greater than it has been in 10 years (15.9 pCi/L).

Gross beta in 2018 was much greater than background at EFK 23.4 and appears to have increased significantly in 2018 to almost 2.5 times the 2016 value (Figure 5.7). The reason for these recent radiological activity increases has not been determined.

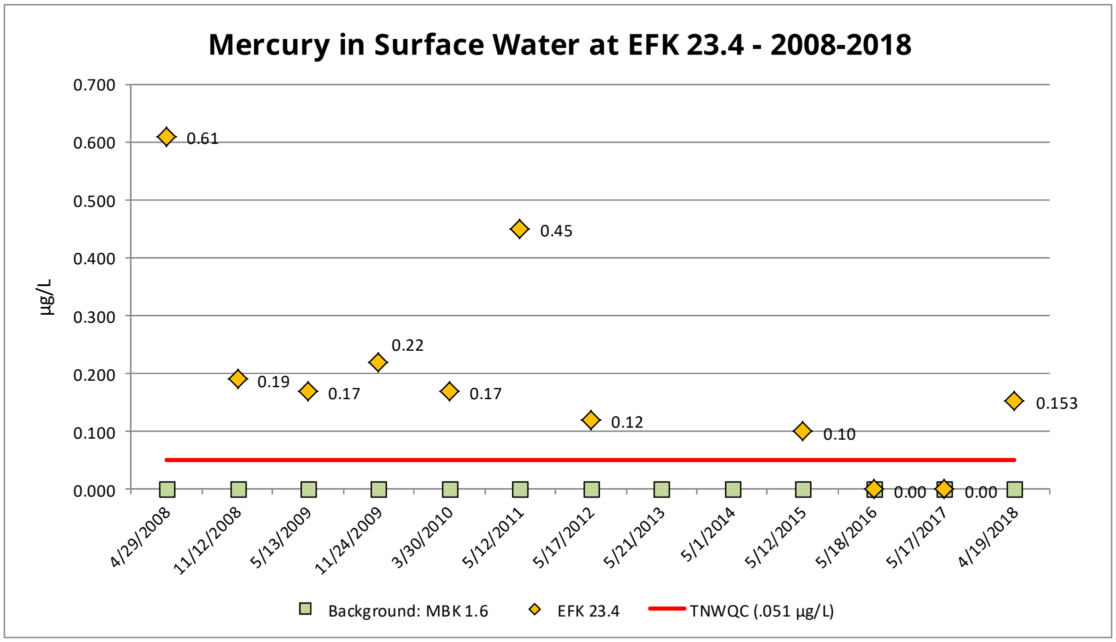


Figure 5.5: Total Mercury in Surface Water at East Fork Poplar Creek km 23.4, (2008-2018)

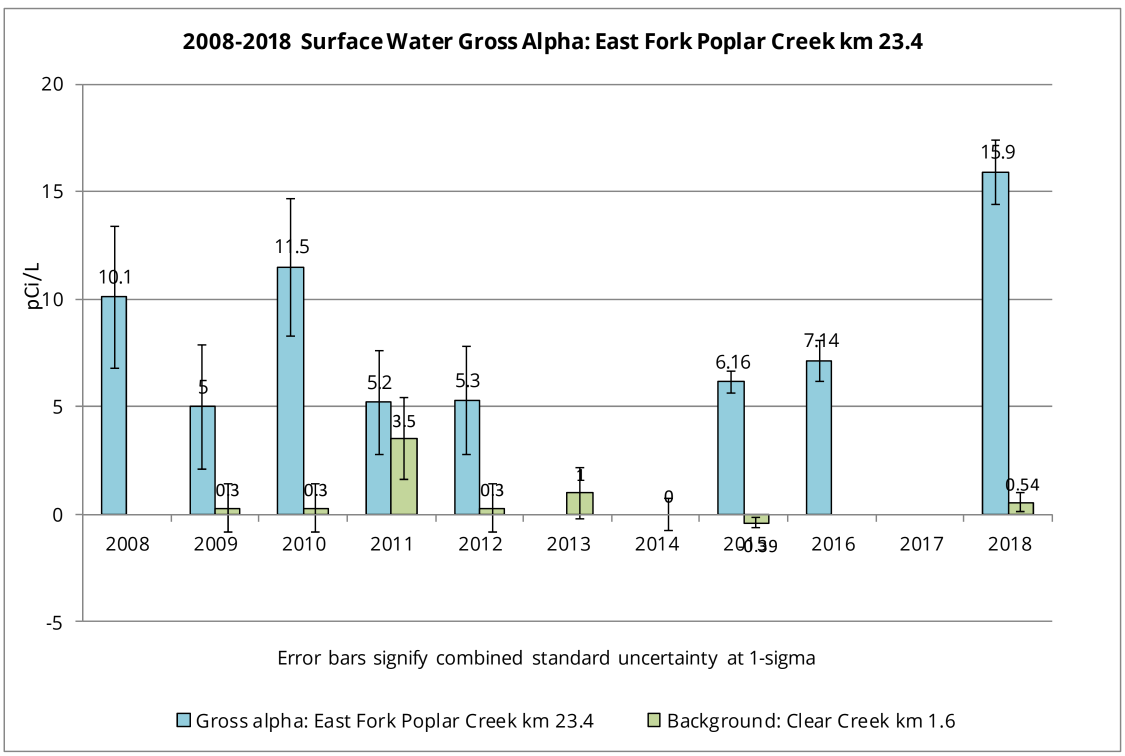


Figure 5.6: Gross Alpha Activity in Surface Water at East Fork Poplar Creek km 23.4, (2008-2018)

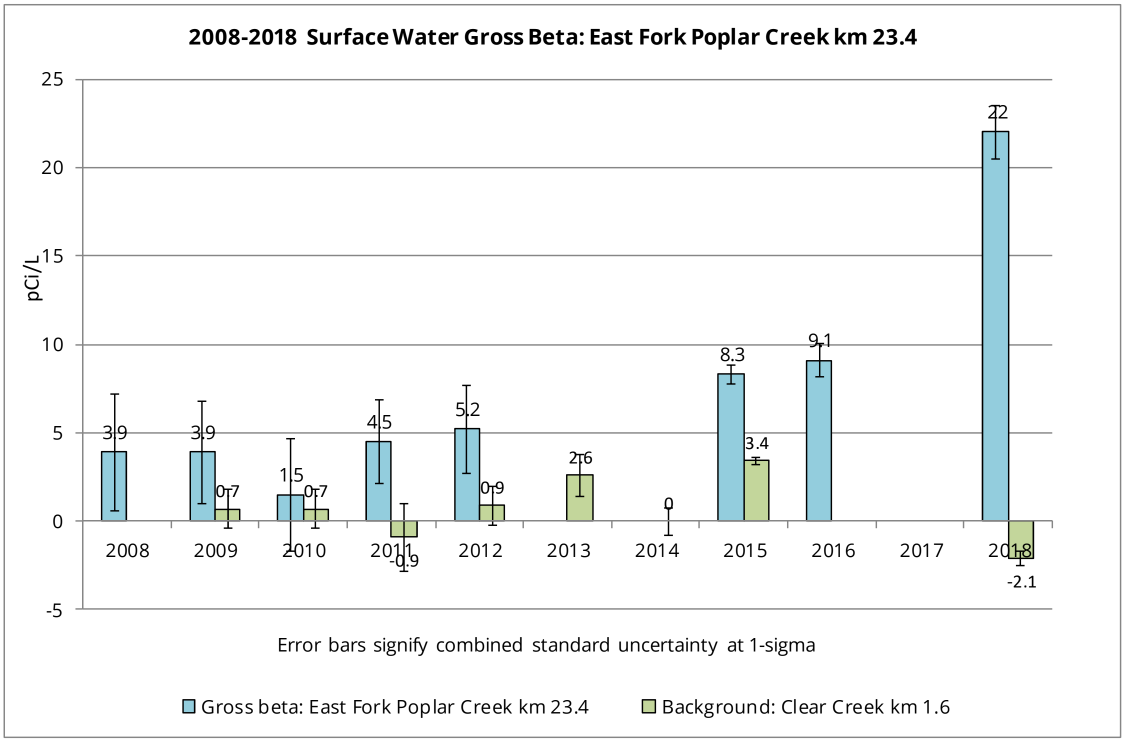


Figure 5.7: Gross Beta Activity in Surface Water at East Fork Poplar Creek km 23.4, (2008-2018)

Mitchell Branch– Figure 5.8, Figure 5.9

With the exception of cadmium and mercury, metals concentrations were much higher at Mitchell Branch than at any of the four background streams, but they were less than Tennessee Water Quality Criteria (TWQC). (Cadmium and mercury were not detected.)

Nutrients were within the statistical normal range for a natural stream.

The closest Mitchell Branch benthic sampling site to MIK 0.1 is MIK 0.45. The MIK 0.45 2017-2016 TMI score was 24 (partially supporting / slightly impaired).

Gross alpha and beta activity at MIK 0.1 have been well above background for each year that MIK 0.1 has been tested since 2008 (figures 5.8, 5.9).

Gross alpha activity has been on a declining trend for the last 11 years.

The MIK 0.1 gross beta value for 2018 (10.6 pCi/L) was lower than it has been in 5 years.

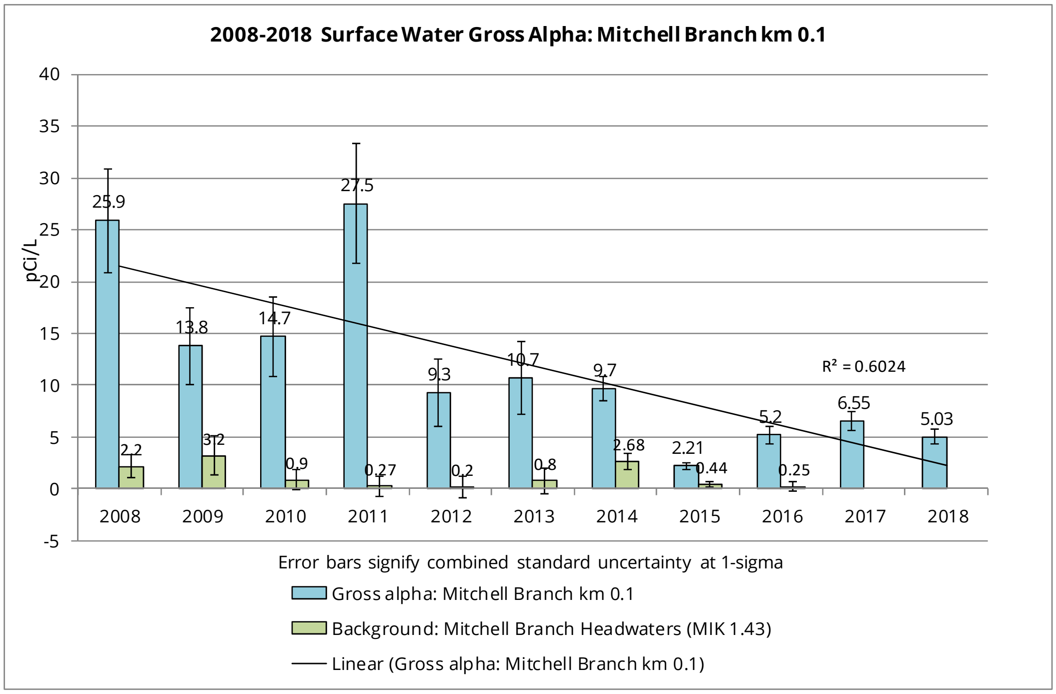


Figure 5.8: Gross Alpha Activity in Surface Water at Mitchell Branch km 0.1, (2008-2018)

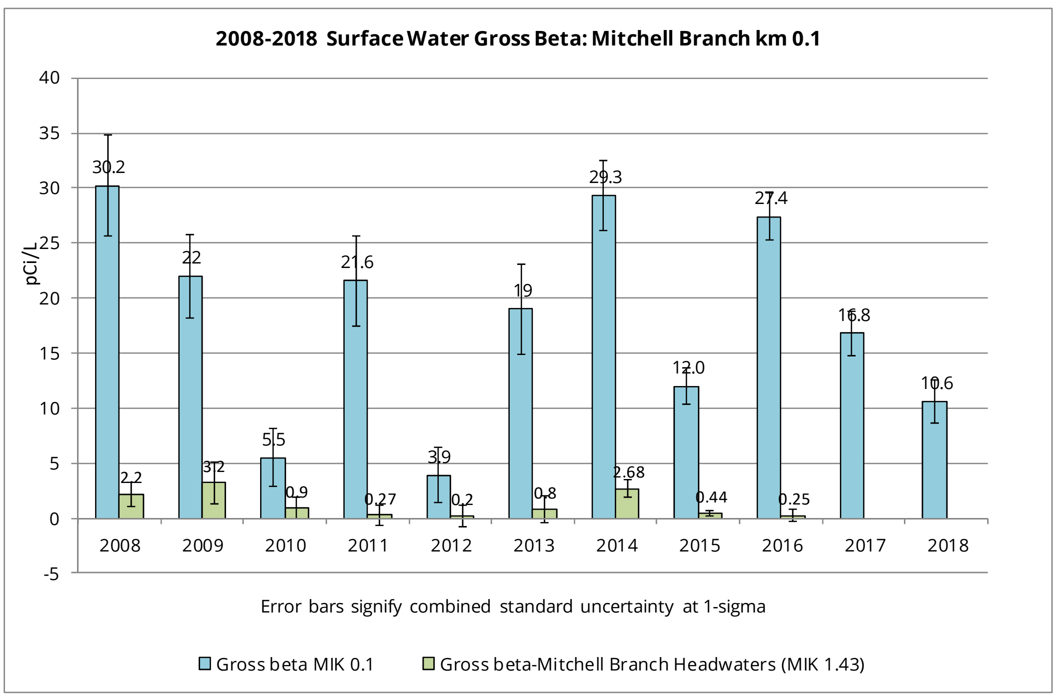


Figure 5.9: Gross Beta Activity in Surface Water at Mitchell Branch km 0.1, (2008-2018)

White Oak Creek– Figures 5.10, & 5.11

At WCK 2.3, copper (51.8 µg/L) exceeded TWQC for Fish and Aquatic Life (18.5 µg/L for hardness of 140 mg/L).

Gross alpha and beta activity at WCK 2.3 were above background levels for each year that WCK 2.3 was tested since 2008. The WCK 2.3 gross beta value for 2018 was the lowest it has been throughout the 2008-2018 review of data. The background sampling station used for comparison was White Oak Creek km 6.8, which is located upstream of ORNL.

The WCK 2.3 2017-2016 TMI score was 26 (partially supporting / slightly impaired).

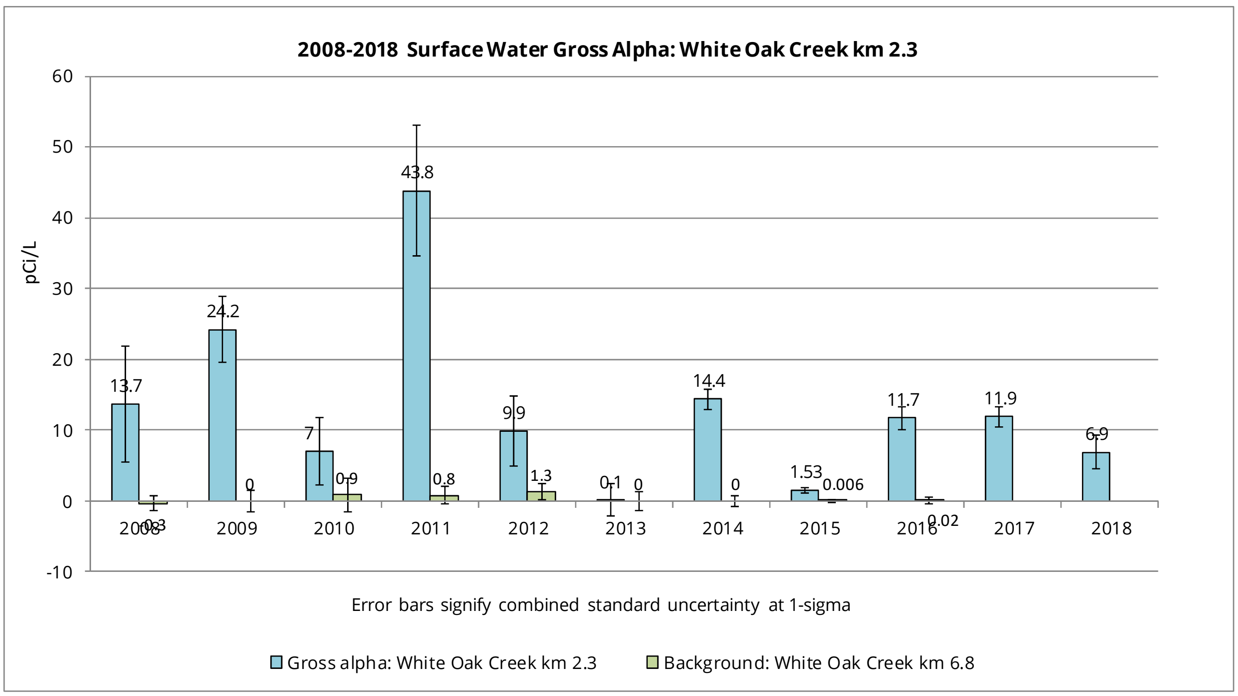


Figure 5.10: Gross Alpha Activity in Surface Water at White Oak Creek km 2.3 2008-2018

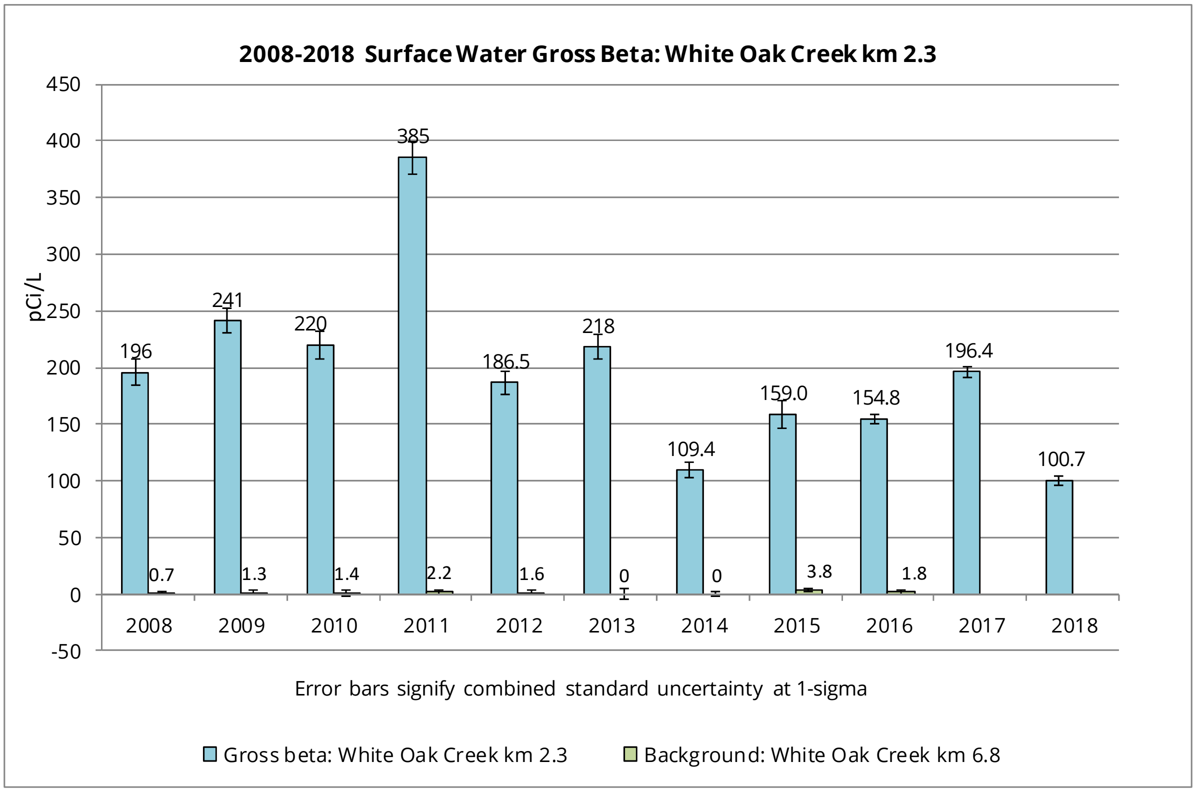
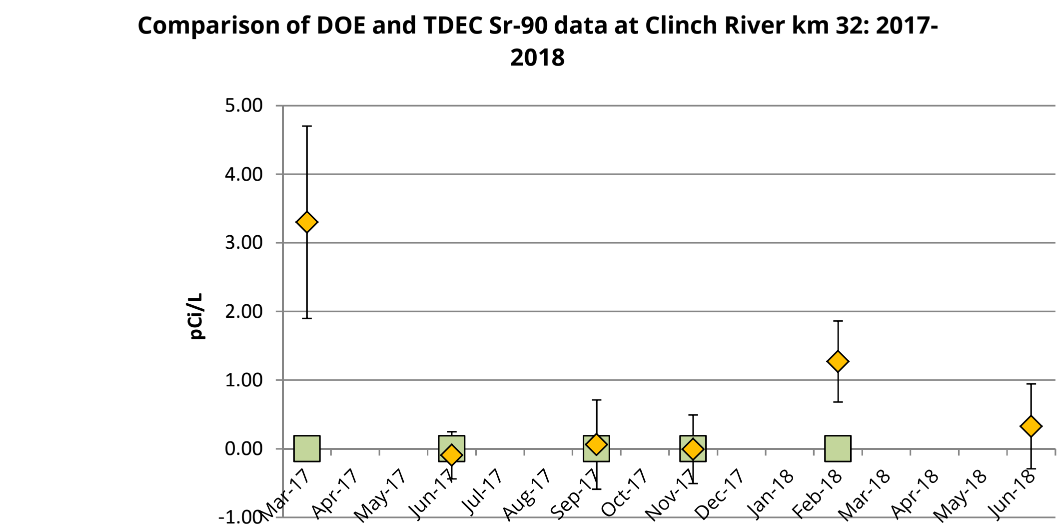


Figure 5.11: Gross Beta Activity in Surface Water at White Oak Creek km 2.3, (2008-2018)

Clinch River– Figures 5.12, & 5.13

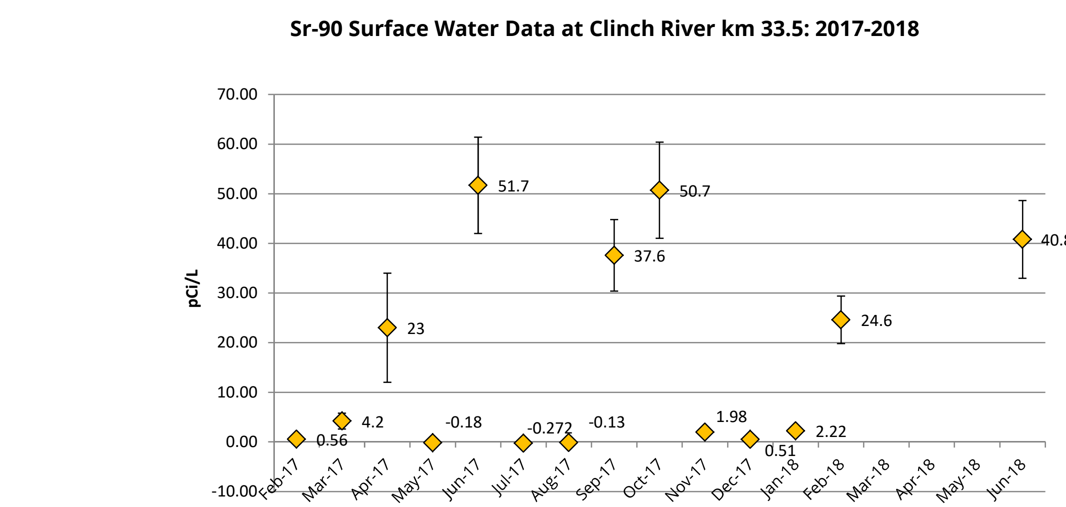
At CRK 32, TDEC staff co-sampled surface water with ORNL environmental staff quarterly during 2017-2018. The TDEC samples were only analyzed for Sr-90, the primary radiological contaminant of concern from White Oak Creek. The ORNL data was compared with the TDEC data and that comparison of data is shown in Figure 5.12. All of the ORNL data results were non-detects. TDEC data confirms detections in March of 2017 (3.3 pCi/L) and February of 2018 (1.27 pCi/L). The ORNL data from June of 2018 have not yet been received.

Surface water Sr-90 data from CRK 33.5 is shown in Figure 5.13. Samples were collected and analyzed monthly from February 2017 through February 2018, then quarterly until present. The Derived Concentration Guideline (DCG) for Sr-90 is 8 pCi/L for drinking water; the DCG is the level that yields a dose of 4 mrem/year to the total body or to any critical organ. Six samples exceeded the DCG for the period of time that sampling was conducted.



	Mar-17	Jun-17	Sep-17	Nov-17	Feb-18	Jun-18
ORNL data - (all non-detects)	0.00	0.00	0.00	0.00	0.00	
TDEC data	3.30	-0.0953	0.06	-0.009	1.27	0.325

Figure 5.12: Sr-90 Activity in Surface Water at Clinch River km 32, (2017-2018)



	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18
Sr-90	0.56	4.2	23	-0.1	51.7	-0.2	-0.1	37.6	50.7	1.98	0.51	2.22	24.6				40.8

Figure 5.13: Sr-90 Activity in Surface Water at Clinch River km 33.5, (2017-2018)

5.1.8 Conclusions

Bear Creek (BCK)

The analytical and benthic TMI data indicate Bear Creek at location BCK 3.3 and downstream supports a healthy and diverse biological community.

East Fork Poplar Creek (EFK)

The stream at location EFK 23.4 continues to be impacted by elevated mercury levels which are greater than their associated TWQC. Elevated nutrient levels may be impacting the biological community at EFK 23.4. In addition, gross alpha and beta levels at EFK 23.4 are greater than results from the past ten years. The analytical and benthic TMI data indicate East Fork Poplar Creek at location EFK 23.4 is a moderately polluted stream and partially supportive of fish and aquatic life.

Mitchell Branch (MIK)

The MIK 0.1 radiological data indicates slight gross alpha and beta activity which has been trending downward over the past ten years. The analytical and benthic TMI data indicate Mitchell Branch at location MIK 0.1 is a moderately polluted stream and partially supportive of fish and aquatic life.

White Oak Creek (WCK)

The stream at location WCK 2.3 continues to be impacted by slight gross alpha and elevated beta radiological activity. However; radiological data have been trending downward over the past ten years. One of the causes of the elevated radiological activity in White Oak Creek is the influx of groundwater containing radioactive contamination from legacy wastes buried at ORNL. In addition, it is believed that contamination of the creek is also due to beta-emitting radionuclides, such as Sr-90, disposed of in the Melton Valley Burial Grounds that have migrated through groundwater pathways into White Oak Creek. The analytical and benthic TMI data indicate White Oak Creek at location WCK 2.3 is a moderately polluted stream and partially supportive of fish and aquatic life.

Clinch River (CRK)

White Oak Creek adversely affects the Clinch River with Sr-90. Almost half of the samples taken, during the February 2017 to June 2018 sampling period, exceeded the Derived Concentration Guideline (DCG) for Sr-90 at CRK 33.5. (The DCGs are risk-based radiological standards for drinking water as published by Nuclear Regulatory Commission. However, the Clinch River dilutes the contamination within a few kilometers downstream of the mouth of White Oak Creek (before drinking water intake) to levels below the DCG, as evidenced by the Sr-90 data from CRK 32.

5.1.9 Recommendations

All the streams in this study are impacted by ORR contaminants. Until all the 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 program to continue assessing ORR/CRK surface water conditions. It is also recommended to increase the number of sample locations for Bear Creek, East Fork Poplar Creek, Melton Branch, White Oak Creek, and the Clinch River to obtain a better assessment of possible impacts to ORR/CRK surface waters.

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 include the Oak Ridge National Laboratory (ORNL), The Oak Ridge Y-12 Plant (Y-12), and East Tennessee Technology Park (ETTP; former 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 site and in the surrounding areas.

An ambient surface water parameter 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 by spills and leakage from subsurface drains, building foundations, contaminated soil, and purposed discharge of wastewater containing mercury (Turner and Southworth, 1999).

- East Fork Poplar Creek 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).
- ORNL has been releasing low-level radioactive liquid wastes to the Clinch River via White Oak Creek since 1943 (Pickering, 1970).
- The Clinch River received approximately 665 curies of cesium-137 (Cs-137) from White Oak Creek from 1954 to 1959 (DOE, 1992).

5.2.3 Goals

- Populate a database/baseline of surface water conditions on and around the ORR.
- Assess the impact of site remediation efforts through long-term monitoring of surface water parameters.
- Record ambient parameters that can be used for comparisons in the event of accidental releases of contaminants that may impact surface water.

5.2.4 Scope

Due to the presence of anthropogenic point- and non-point source contamination on the ORR 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. Ambient physical parameters (specific conductivity, dissolved oxygen, pH, and temperature) measured at the Mill Branch background station are indicative of a normal healthy stream. Dissolved oxygen readings, greater than the saturation point for the given water temperature, are indicative of an instrument or calibration error. See Figure 5.14 for the proposed monitoring locations.

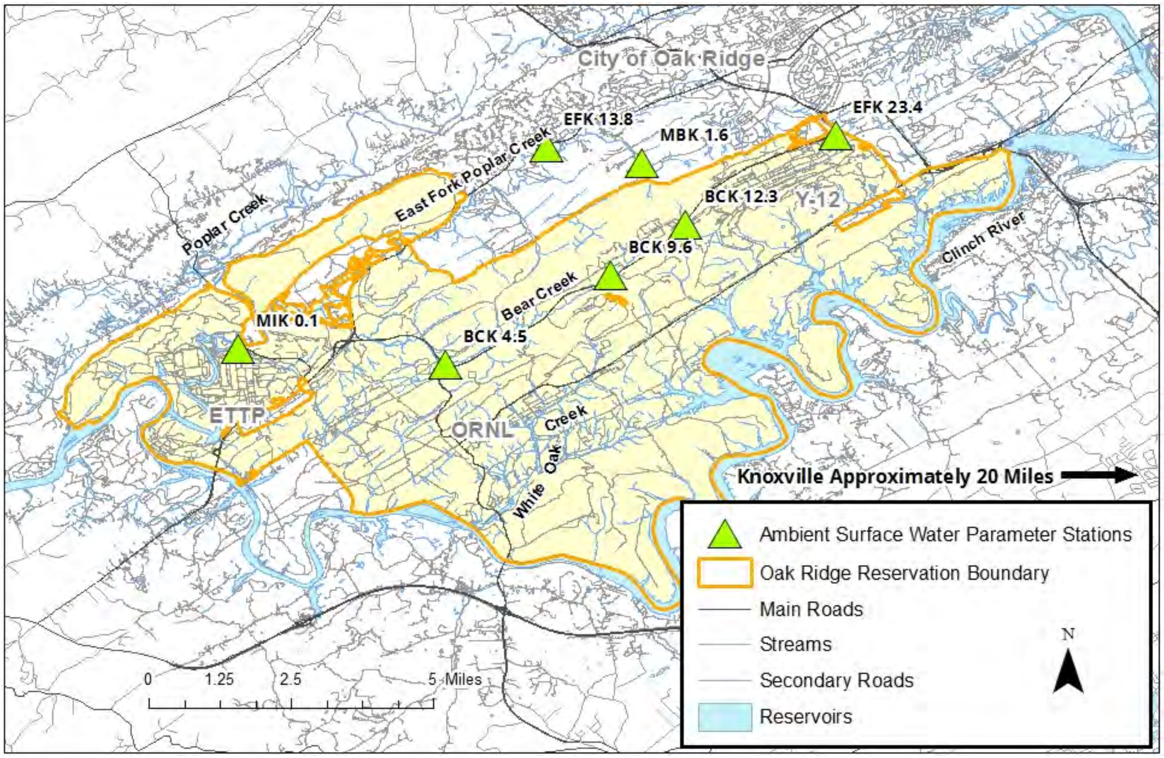


Figure 5.14: Proposed Monitoring Locations

Table 5.5: Proposed Monitoring Locations

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

5.2.5 Methods, Materials, Metrics

The surface water physical parameters of temperature, pH, conductivity, and dissolved oxygen will be measured monthly with a YSI Professional Plus multi-parameter water quality instrument. Field monitoring will follow 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.

When field readings such as pH and conductivity were beyond benchmark ranges, then one or more of the following actions were taken: 1) wait 24 hours, re-calibrate the instrument, and collect new physical parameter readings; 2) if readings are still deviant, investigate possible causes (e.g., defective equipment, storm surge/rain events, releases that may have affected pH, etc.); 3) following the investigation, report findings to appropriate program(s) within the TDEC office to determine if further action is warranted. Field and monitoring methods followed the *Tennessee Division of Water Resources Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water* (TDEC DWR 2011), and health and safety procedures were followed per the *TDEC DoR-OR Health, Safety, and Security Plan* (TDEC 2018).

5.2.6 Deviations from the Plan

There were no deviations from the project plan.

5.2.7 Results from Analysis

Field data (parameters including: specific conductivity, dissolved oxygen, pH, and temperature) were collected on a monthly basis from the seven monitoring sites. Data from 2005 to present were evaluated for trends. Trends in conductivity were found at two of the sampling stations, Bear Creek km 12.3 (BCK 12.3) and East Fork Poplar Creek km 23.4 (EFK 23.4). The following graphs display 13.5 years (2005-2018) of conductivity data for the BCK 12.3 and EFK 23.4 sampling stations. Points on the graphs represent the mean of each year's data. Conductivity has been decreasing at BCK 12.3 (Figure 5.15) and increasing at EFK 23.4 (Figure 3) as revealed by the 13.5 year data analysis.

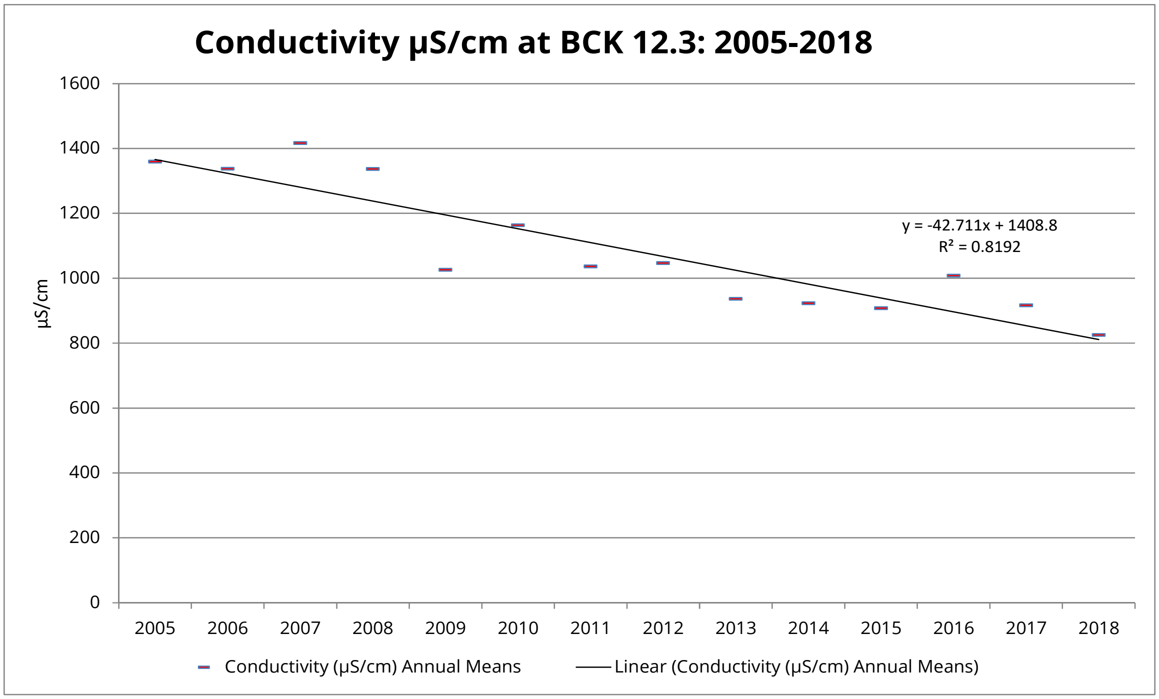


Figure 5.15: 2005-2018 Conductivity at BCK 12.3

Bear Creek km 12.3 consistently showed elevated conductivity values. There were no Tennessee Water Quality Criteria for conductivity to give perspective to the elevated values. Elevated conductivity values indicate the presence of contaminants which suggest degraded surface water quality in Bear Creek. All three Bear Creek sites are located downstream of the legacy capped S-3 ponds and the Y-12 West End water treatment facility. A contaminated groundwater plume has migrated into the surface water, and is reported to have caused the elevated conductivity values in Bear Creek (DOE, 2016). The decrease in conductivity at BCK 12.3 over the last 13.5 years may be the result of attenuation of the contaminant sources in the area of the S-3 ponds and the Y-12 West End Water Treatment Facility.

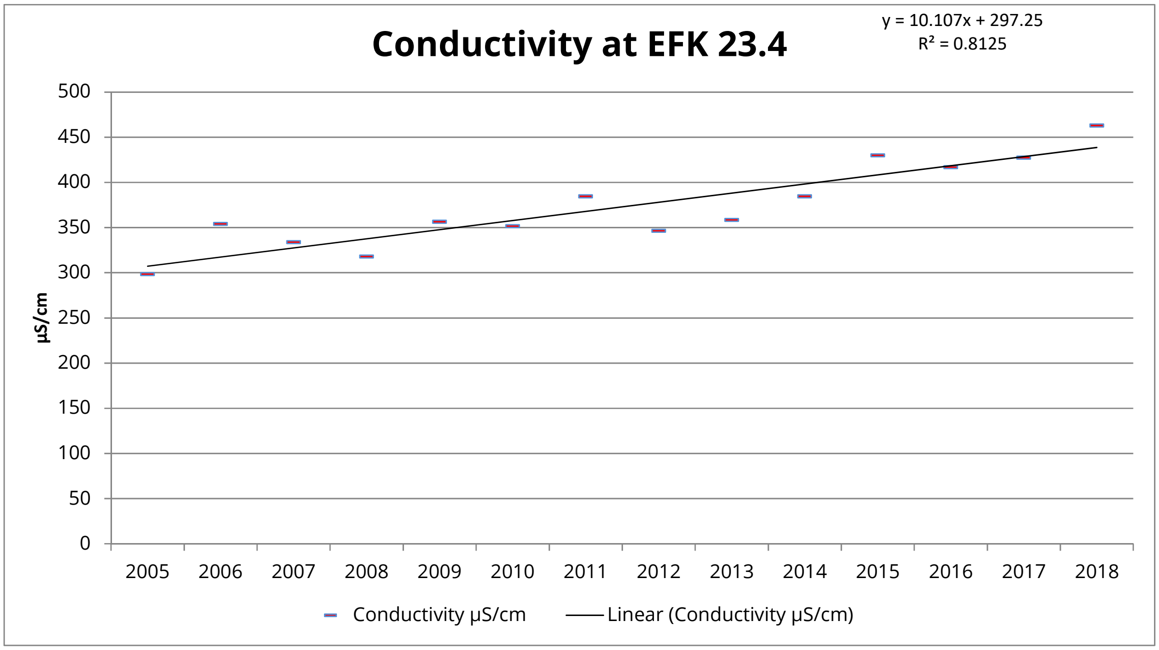


Figure 5.16: 2005-2018 Conductivity at EFK 23.4

Conductivity at East Fork Poplar Creek km 23.4 has increased over the years from 2005 to 2018. The reason(s) for this change have not yet been determined.

5.2.8 Conclusions

For the surface water physical parameters data, all readings were within Tennessee water quality criteria at the seven monitoring stations on the ORR. The elevated conductivity values observed in Bear Creek are of concern because they likely indicate the presence of contaminants such as dissolved metals. Conductivity data at BCK 12.3 show a decreasing trend over the last 13.5 years. This change may be a result of attenuation of the contaminant sources in that area. Data also indicate that conductivity has been increasing at EFK 23.4 over the last 13.5 years.

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 km 23.4 and the downward trend of conductivity at Bear Creek km 12.3.

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: the 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 of 1980 (CERCLA) in November 1991.

As of November 2017, DOE lists 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 are 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 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) and remedial action (RA) activity sites). Most of this water accumulation contains at least one contaminant required to be treated before discharging it to the environment. (Estimated volumes of this 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 the 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 near remediation activities to gather data for evaluations of D&D activities.
- Review and comment on documents related to D&D work.
- Use split and or independent sampling to monitor releases into the environment.
- Observe D&D and RA activities to ensure compliance with TDEC, EPA, and DOE negotiated and agreed to discharge criteria.
- Review DOE sampling results, to ensure compliance with negotiated and agreed to criteria for release.

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 (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 in 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 ensure release criteria are being met.
- All samples will be collected, preserved, and shipped following approved TN Department of Health and TDEC DOR-OR office standard operating procedures.
- Independent sampling will occur 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, (which 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 Tennessee Department of Environment and Conservation's, *Division of Water Quality QS-SOP for Chemical & Bacteriological Sampling of Surface Water* Revision 3 (TDEC, 2011). A brief treatment of the sampling procedure is described in the paragraphs that follow.

If the surface water body can be waded, the easiest way to collect a sample is by the dip method. The sampler should face upstream so that the sample can be taken without collecting disturbed sediment. The sampler loosens the lid of the sample container, submerges the container, and finishes removing the lid. If possible, after the sample is collected, the lid is replaced under water.

For samples, containing a preservative, bottles must be closely observed, and 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.

If the sampler has any concern using the direct method on a preserved sample, then the sampler may employ the dip method. The sample is taken by dipping a clean non-preserved bottle and transferring the sample collected into the prepared sample container. This can be accomplished from either sampling by hand or from 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.

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. Samples will be taken randomly to attempt to get a representative sample.

Sampling Plan

Samples will be collected at storm drains (for oversight of D&D work) on a quarterly basis, and at discharge points for surface impoundments and other locations samples will be collected as needed. Refer to Table 5.6 for laboratory analysis methods.

Table 5.6: Laboratory Analysis

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
PCB's	8082
Mercury	245.1
Gamma Analysis	901.1
Gross Alpha/Beta	D7283-13
Strontium 90	D5811
Technetium 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 second quarter of 2018 and deviated from the submitted *Tennessee Environment and Conservation, Division of Remediation, Oak Ridge Office, Environmental Monitoring Plan*, *July 2017 – June 2018 (EMP).*

5.3.7 Results from Analysis

Beginning in January 2017 and ending July 2018, seven locations (originating on the ORR) were sampled, quarterly. Mill Branch serves as a reference location and is located off the ORR. Table 5.7 and Figure 5.17 show locations that were selected for sampling. Figure 5.18 shows Tennessee Department of Environment and Conservation (TDEC) staff collecting water samples following a storm event.

Table 5.7. Sampling Locations in Kilometers

Sample locations in Kilometers (mile Equivalents)	
Site	**Location**
EFK 23.4 (14.5)	East Fork Poplar Creek (Station 17)
WCK 0.0 (0.0)	White Oak Creek (Weir at Clinch River)
BCK 4.5 (2.8)	Bear Creek (Weir at Hwy. 95
MIK 0.1 (0.6)	Mitchell Branch (weir at ETTP)
SD430	Storm Drain located at ETTP
SD490	Storm Drain located at ETTP
P1 Pond Weir	Weir located at ETTP
MBK 1.6 (1.0)	Mill Branch (reference)

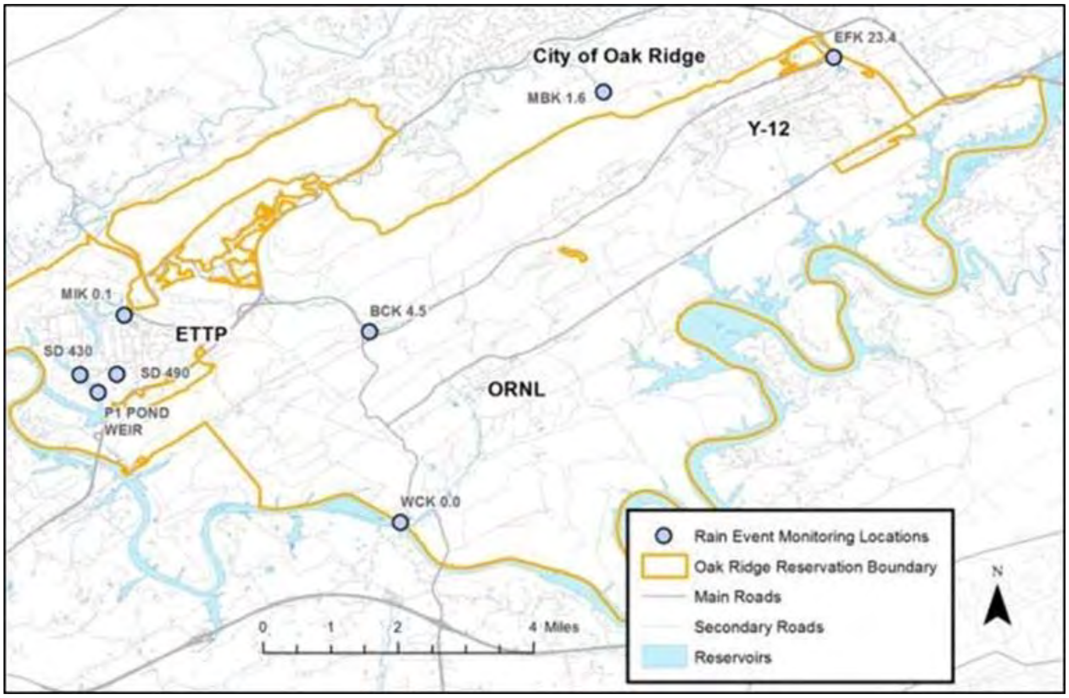


Figure 5.17: Map of Sampling Locations

Figure 5.18: 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 2017 and continuing through June 2018. Samples were collected on July 7, 2017, August 8, 2017, October 9, 2017, October 24, 2017, February 7, 2018, February 8, 2018, April 16, 2018, and April 24, 2018. Figure 5.19 illustrates data for the seven 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 a 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:

Third Quarter 2017:

Metals: Arsenic, chromium, copper, lead, manganese, zinc, mercury, and iron were analyzed for all locations. Collected samples were tested for uranium at the P1 Pond Weir, SD-490, SD-430, and MBK-1.6. Samples were collected for hexavalent chromium analysis at MIK-0.1, SD-490, SD-430, and the P-1 Pond Weir.

Radionuclides: Analysis for gross alpha and gross beta was conducted at all sites. Gamma radionuclide was sampled for at WCK 0.0. Tc-99 was collected at SD-430 and SD-490. Tritium was sampled for at SD-490.

PCB's: Polychlorinated Biphenyls (PCB's) were sample at SD-430.

Fourth Quarter 2017:

Metals: Arsenic, chromium, copper, lead, manganese, zinc, mercury, and iron were analyzed at all locations. Uranium was sampled at SD-430. Samples were collected for hexavalent chromium analysis at MIK-0.1, SD-490, SD-430, and the P1 Pond Weir.

Radionuclides: Analysis for gross alpha and gross beta was conducted at all sites. Gamma radionuclide was sampled at WCK-0.0. Tc-99 was collected at SD-430 and SD-490. Tritium was sampled at SD-490.

PCB's: Polychlorinated Biphenyls (PCB's) were sample at SD-430.

First Quarter 2018:

Metals: Arsenic, chromium, copper, lead, manganese, zinc, mercury, and iron were analyzed at all locations. Collected samples were tested for uranium at the P1 Pond Weir, SD-490, SD-430, and MBK-1.6. Samples were collected for hexavalent chromium analysis at MIK-0.1, SD-490, SD-430, and the P1 Pond Weir.

Radionuclides: Analysis for gross alpha and gross beta was conducted at all sites. Gamma radionuclide was sampled at WCK-0.0. Tc-99 was collected at SD-430 and SD-490. Tritium was sampled at SD-490.

PCB's: Polychlorinated Biphenyls (PCB's) were sample at SD-430.

Second Quarter 2018:

Metals: Samples were collected for hexavalent chromium analysis at SD-490 and SD-430.

Radionuclides: Analysis for gross alpha and gross beta was conducted at SD-490 and SD-430. Tc-99 was collected at SD-430 and SD-490. Tritium was sampled at SD-490.

PCB's: Polychlorinated Biphenyls (PCB's) were sample at SD-430.

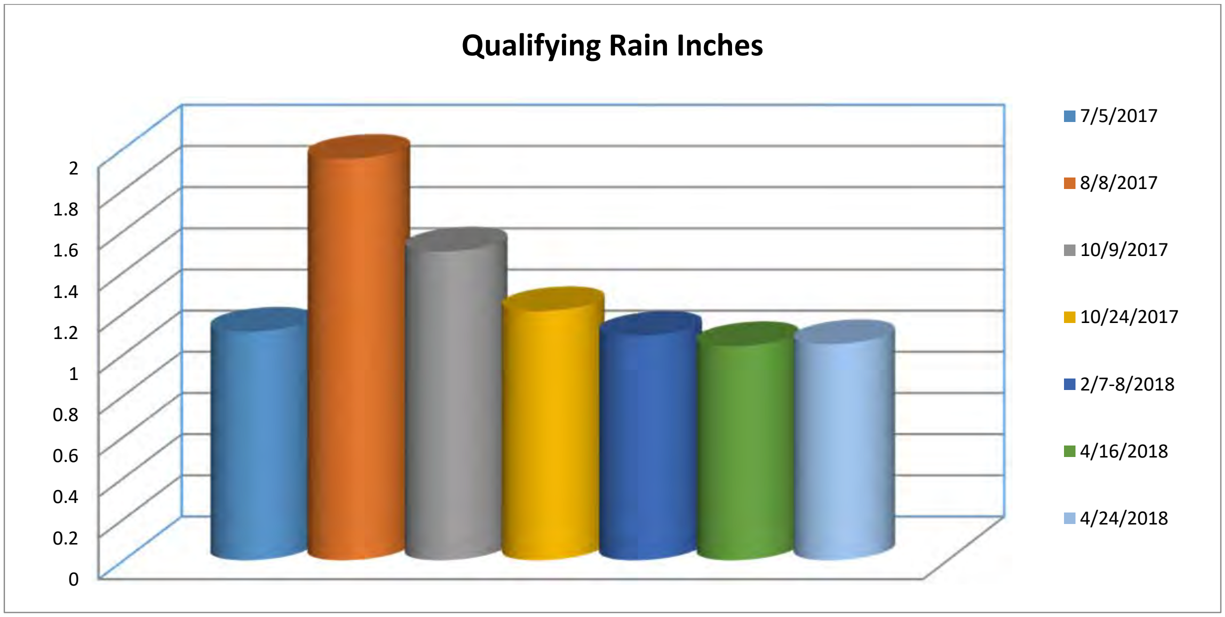


Figure 5.19: Qualifying Rain Events for Each Sampling Event

Relative to the six rain events, summarized field parameters are presented in figures 5.20 through 5.23.

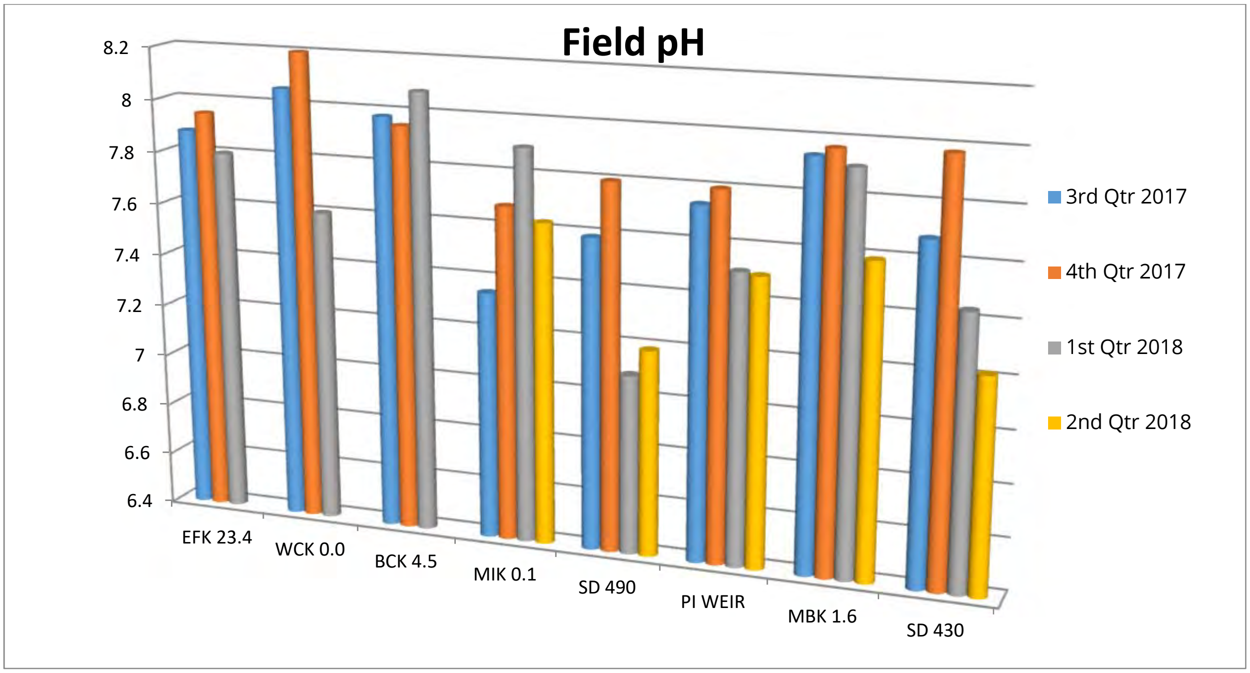


Figure 5.20: Field pH Measurements

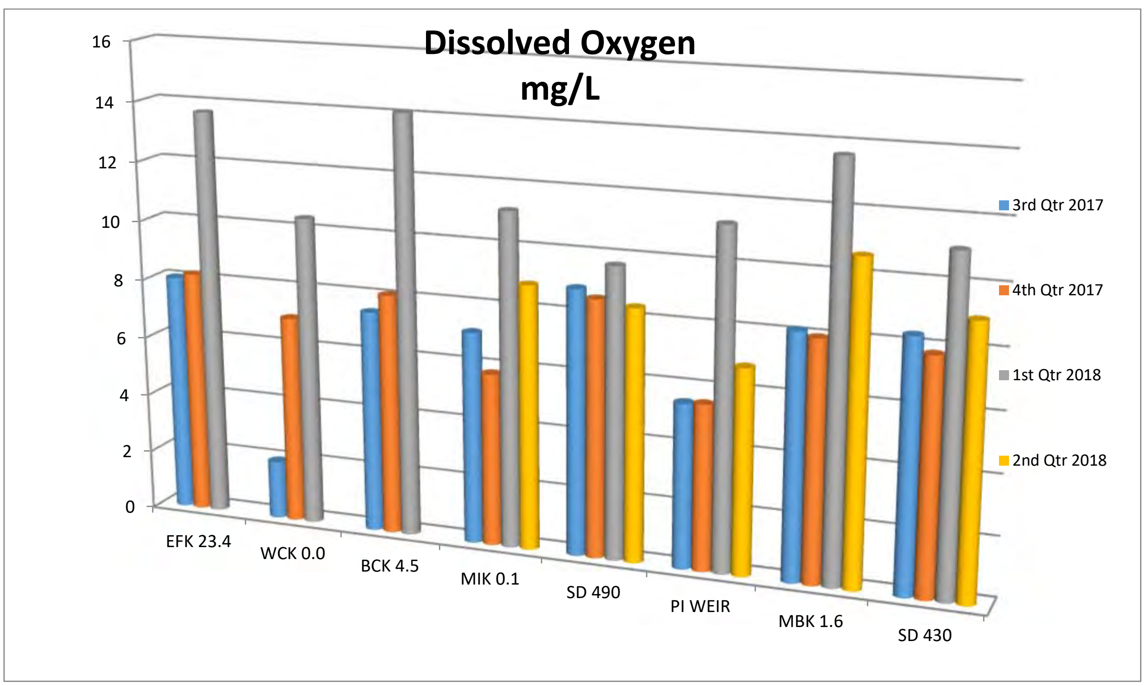


Figure 5.21: Dissolved Oxygen in mg/L

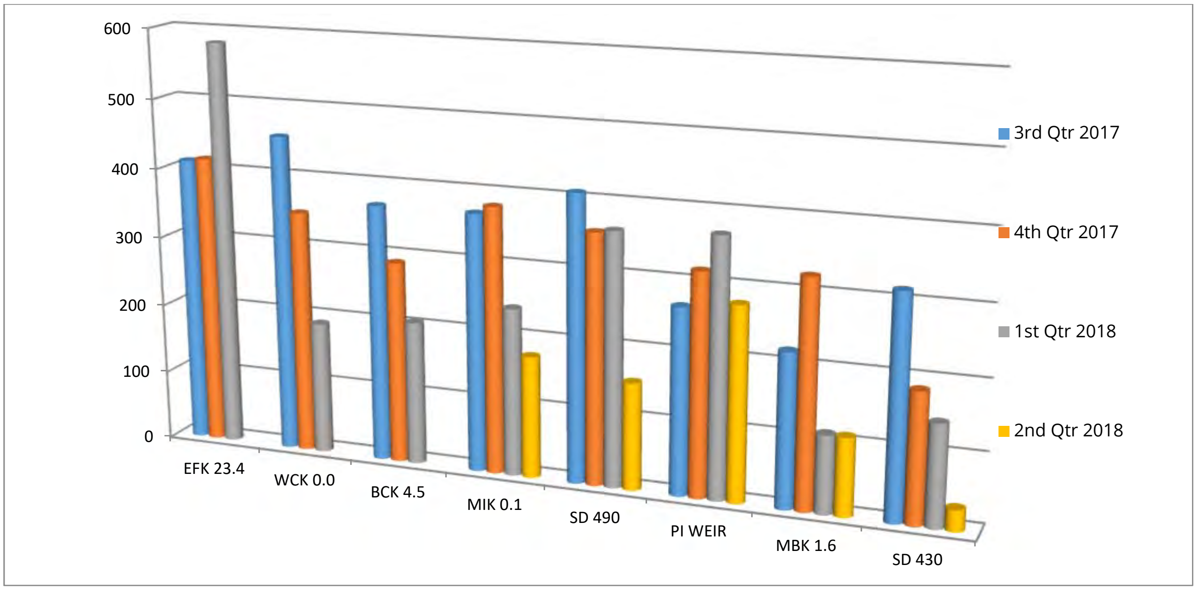


Figure 5.22: Conductivity in µS/cm (Micro Siemens Per Centimeter)

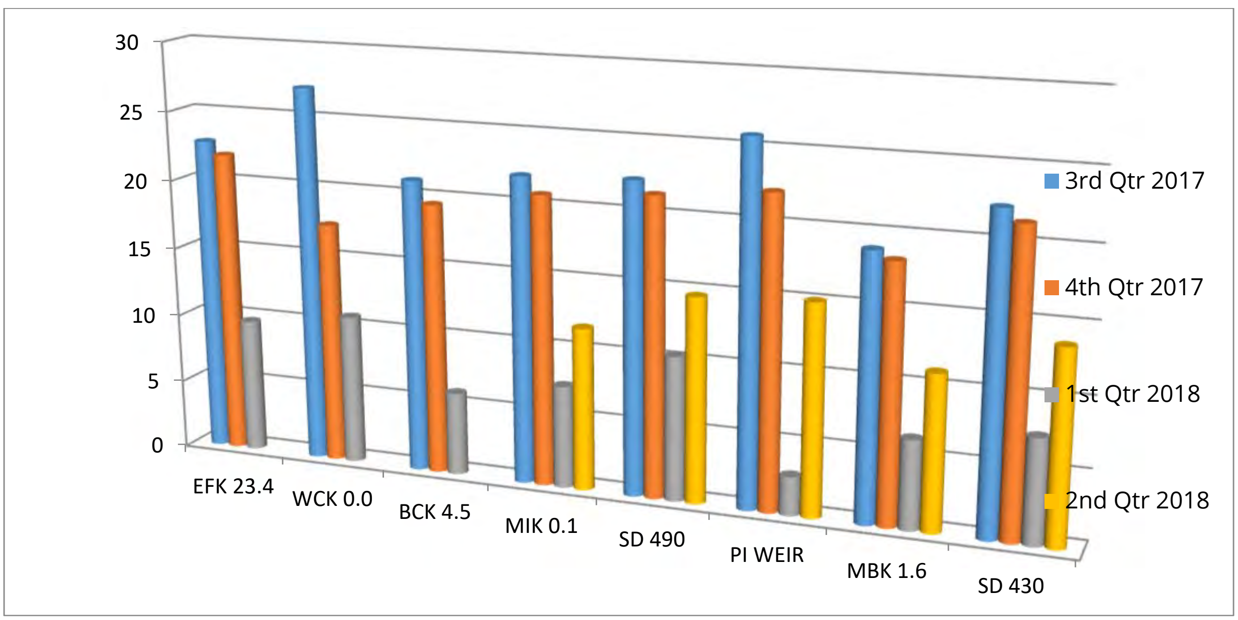


Figure 5.23: Temperature in Degrees Celsius

The results of metals analysis are shown in the following table, Table 5.8.

The levels of chromium at site MIK-0.1 continues to be elevated, likely due to the history of CERCLA clean-up activities in the vicinity of the stream. Figure 5.24 illustrates MIK-0.1 chromium concentrations sampled during qualifying rain events which encompasses years 2014 through 2018.

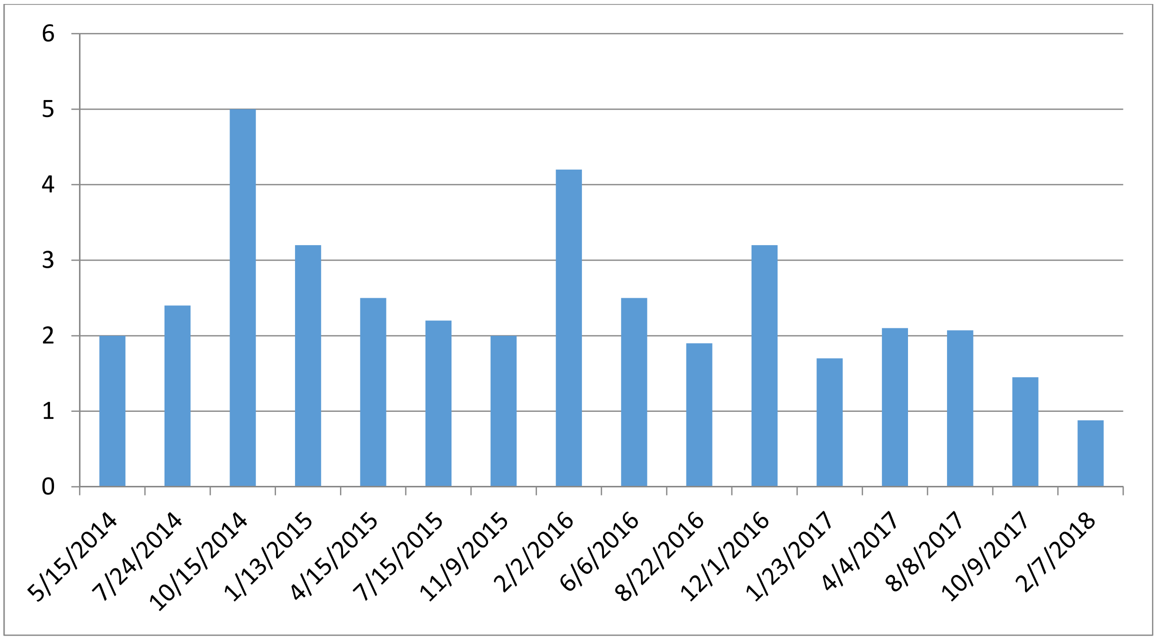


Figure 5.24: Chromium results in ug/L

Table 5.8: Metal Analysis

Metal Analysis									
SITE	As 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 2017							
EFK 23.4	U	2.1 J	4	120	U	29	0.16 J	13	X
WCK 0.0	0.89 J	1.8 J	1.3	280	0.5 J	180	U	2.7 J	X
BCK 4.5	U	1.5 J	U	220	U	57	U	U	X
MIK 0.1	U	2.07 J	4.2	430	0.487 J	53	U	9	X
SD490	U	1.41 J	3.3	160	0.609 J	790	U	20	3.1
P1 WEIR	0.808 J	U	U	390	U	290	U	2.48 J	0.325 J
MBK 1.6	U	1.7 J	U	590	0.36 J	64	U	4.2 J	U
SD430	U	3.82 J	1.9	540	1.4	12	U	12	0.882 J
		4th Qtr 2017							
EFK 23.4	U	0.865	3.01	96.8	U	25	U	14.4	X
WCK 0.0	U	1.81	3.46	467	1.27	120	U	8.59	X
BCK 4.5	U	1.84	1.14	340	0.384	49.1	U	3.57	X
MIK 0.1	U	1.45	3.33	153	U	51.4	U	6.27	X
SD490	U	1.51	1.17	51.3	U	42.1	U	9.32	X
P1 WEIR	U	U	U	499	0.417	108	U	3.27	X
MBK 1.6	U	U	U	318	U	33.9	U	1.7	X
SD430	U	2.68	3.88	845	5.55	179	U	14.2	0.808
		1st Qtr 2018							
EFK 23.4	U	1.14	2.87	93	U	27.3	U	19.9	X
WCK 0.0	U	1.22 J	1.35	332	1.2	75.9	U	8.93	X
BCK 4.5	U	0.914 J	U	129	0.296 J	27.7	U	U	X
MIK 0.1	U	1.56 J	2.91	263	117	58.3	U	10	5.37
SD490	U	2.14 J	0.754J	121	1.63	43.8	U	16.8	2.05
P1 WEIR	U	1.27J	U	293	0.374 J	87.8	U	U	0.874 J
MBK 1.6	U	0.880 J	U	116	U	28.3	U	U	X
SD430	U	3.73 J	4.37	2210	7.93	325	U	1.7	0.854
		2nd Qtr 2018							
EFK 23.4	X	X	X	X	X	X	X	X	X
WCK 0.0	X	X	X	X	X	X	X	X	X
BCK 4.5	X	X	X	X	X	X	X	X	X
MIK 0.1	X	X	X	X	X	X	X	X	X
SD490	X	X	X	X	X	X	X	X	X
P1 WEIR	X	X	X	X	X	X	X	X	X
MBK 1.6	X	X	X	X	X	X	X	X	X
SD430	X	X	X	X	X	X	X	X	X

U= undetected
J = Estimated Value between MDL and MQL
X=No sample taken

Site EFK-23.4 exhibited a mercury concentration which was higher than the Tennessee Water Quality Criteria (TWQC) for Recreation (Organisms only) Criterion Maximum Concentration of 0.051 ug/L. The EFK-23.4 value which exceeded the TWQC was 0.16 ug/L on 7/5/2017. The elevated mercury level at EFK-23.4 was expected, given the levels of mercury contamination present in East Fork Poplar Creek. Figure 5.25 illustrates EFK-23.4 mercury in qualifying rain events in ug/L results from years 2014 until 2018.

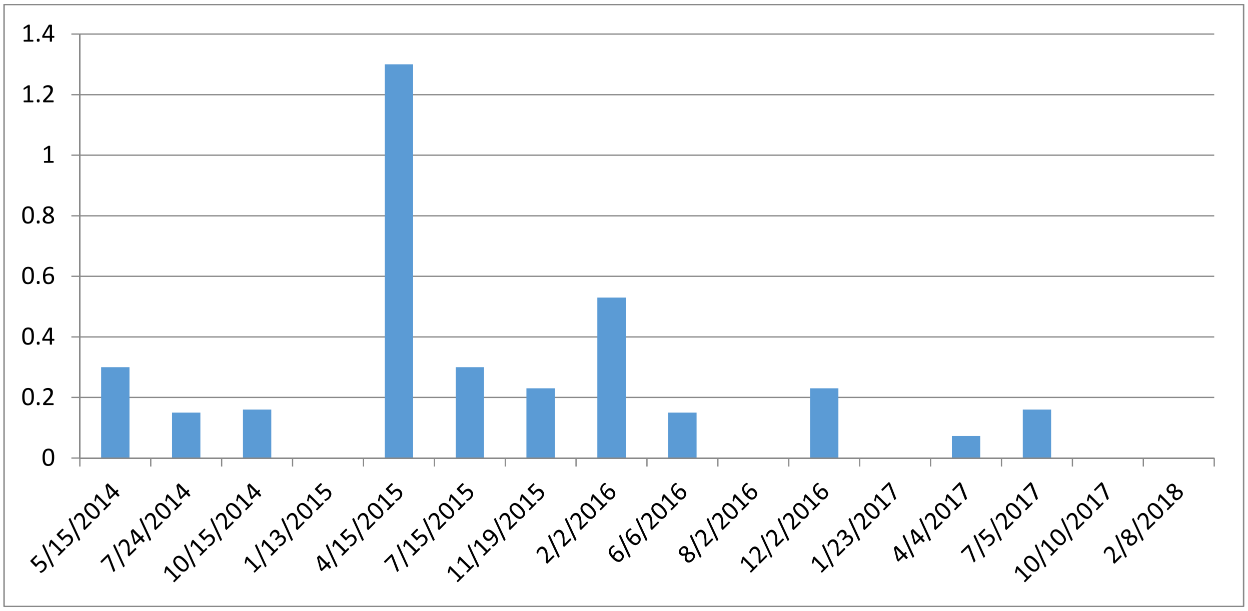


Figure 5.25: Mercury results in ug/L

The results of the gross alpha, gross beta, and gamma radionuclide scans are shown in Table 5.9 and Table 5.10.

Table 5.9. 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
		3RD Qtr 2017		
EFK 23.4	8.08	0.78	15.8	2
WCK 0.0	11.5	1	188.2	4
BCK 4.5	12.8	1	20.9	4
MIK 0.1	13.73	0.98	25.5	2.2
SD 490	0.11	0.48	64.9	4
P1 WEIR	0.16	0.45	25.8	4
SD 430	0.17	0.48	64	2.8
MBK 1.6	0.68	0.48	12.6	2
		4TH Qtr 2017		
EFK 23.4	15.7	1.1	28.2	4
WCK 0.0	13	2.4	131	4
BCK 4.5	4.77	0.64	47	4
MIK 0.1	14.1	1	38.5	2.4
SD 490	-2.9	0.6	280.5	6.8
P1 WEIR	-0.61	0.45	48	2.4
SD430	1.02	0.49	40.2	2.3
MBK 1.6	-0.9	0.42	27.4	2.2
		1st Qtr 2018		
EFK 23.4	21.5	3.3	21.6	2.1
WCK 0.0	4.6	1.5	44.7	4
BCK 4.5	3.54	0.9	6	1.8
MIK 0.1	5.1	1	9.1	1.9
SD 490	-6.5	1.2	234.6	7.9
P1 WEIR	-0.19	1.78	22.2	2.1
SD 430	0.14	0.7	9.7	1.9
MBK 1.6	-0.29	0.67	-0.01	3.6
		2nd Qtr 2018		
EFK 23.4	NS			
WCK 0.0	NS			
BCK 4.5	NS			
MIK 0.1	NS			
SD 490	-5.34	0.75	300.7	8.5
P1 WEIR	0.86	0.49	19.1	2
SD 430	0.59	0.47	16.4	2
MBK 1.6	NS			
*CSU represents combined standard uncertainity at 1 - sigma				
NS - No Sample				

Table 5.10: Gamma Radionuclides

Site	Gamma Pb-212 pCi/L	Gamma *CSU ± pCi/L	Gamma Pb-214 pCi/L	Gamma *CSU ± pCi/L	Gamma Bi-214 pCi/L	Gamma *CSU ± pCi/L	Cs-137 pCi/L	*CSU pCi/L
			3rd Qtr 2017					
WCK 0.0			15.8	9.2	29	8.4		
			4th Qtr 2017					
WCK 0.0	NDA							
			1st Qtr 2018					
WCK 0.0					15.5	6.9		
			2nd Qtr 2018					
WCK 0.0	NS							
NDA- Indicates that the analyte was analyzed but not detected								
*CSU Represents combined standard uncertainty at 1 - sigma								
NS- No sample taken								

Stronium-90 was analyzed for at WCK-0.0 due to historical evidence of contamination at this site. Tritium and Tc-99 were sampled at SD-490, P1 Pond Weir, and SD-430. Analysis was conducted to monitor for contamination from CERCLA work in these areas. Results from these analyses are shown in tables 5.11 and 5.12.

Table 5.11: Strontium Radionuclide Analysis

Strontium Radionuclide Analysis		
Site	**Strontium-90 pCi/L**	**Strontium-90 *CSU ± pCi/L**
	3rd Qtr 2017	
WCK 0.0	83.3	15.6
	4th Qtr 2017	
WCK 0.0	51.8	9.8
	1st Qtr 2018	
WCK 0.0	18.3	3.6
	2nd Qtr 2018	
WCK 0.0	NS	
*CSU Represents combined standard uncertainty at 1 - sigma		
NS- No sample taken		

Table 5.12: Results of Tritium (H-3), Tc-99, & Isotopic Uranium

Results of Tritium (H-3) , Tc-99, & Isotopic Uranium				
Site	**Tritium pCi/L**	**Tritium *CSU**	**Tc-99 pCi/L**	**Tc- 99 *CSU**
	3rd Qtr 2017			
SD 490	11	30	64.8	2.3
P1 Weir	64	31	21.32	0.74
SD 430	NS		63.4	2.2
	4th Qtr 2017			
SD 490	76	29	273	12
P1 Weir	167	37	24.88	0.88
SD 430	NS		18.75	0.66
	1st Qtr 2018			
SD 490	54	27	205.6	8.3
P1 Weir	131	27	21.54	0.76
SD 430	NS		4.54	0.31
	2nd Qtr 2018			
SD 490	120	25	271	12
P1 Weir	155	31	18.5	0.68
SD 430	NS		15.7	0.71
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 East Tennessee Technology Park (ETTP). Subsequently, Tc-99 and gross beta were recorded at SD-490. The slower-than-expected reduction of Tc-99 in sample point SD-490 has led to the continued monitoring and sampling of the storm drain. Figure 5.26 illustrates the fluctuations of Tc-99 at SD-490 from the 2nd quarter of 2014 until 2nd quarter of 2018.

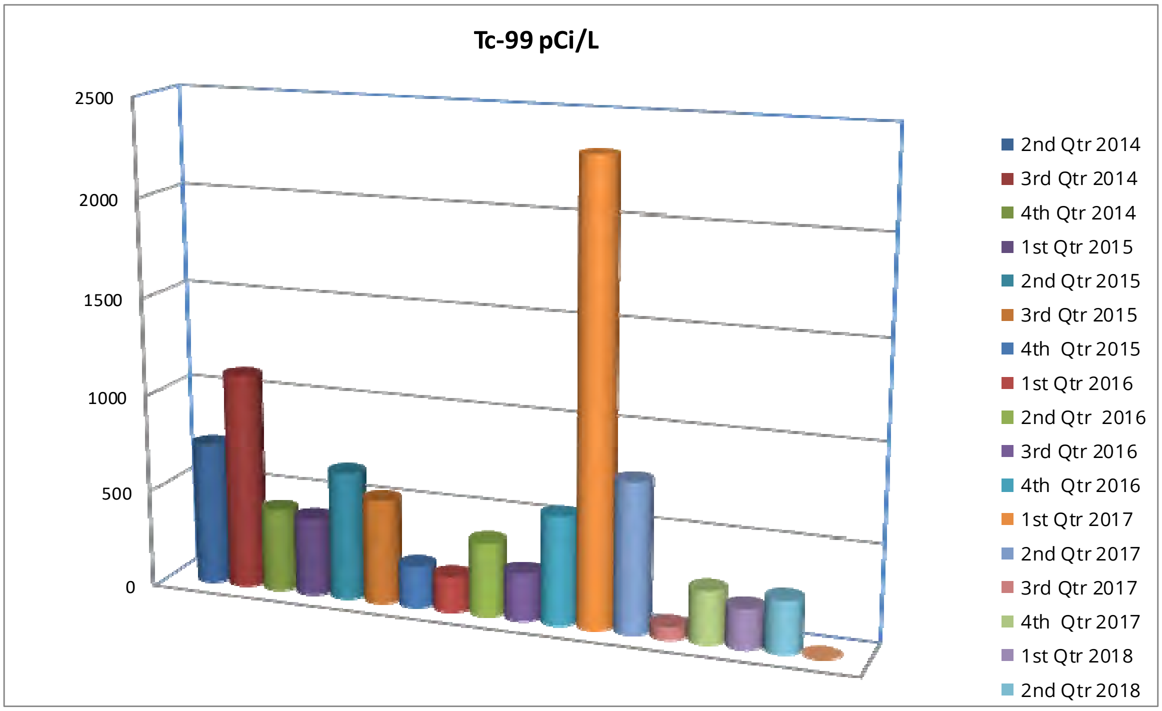


Figure 5.26: Tc-99 Results in pCi/L

Results are presented in Table 5.13 for isotopic uranium analyzed at SD-430.

Table 5.13: Isotopic Uranium Radiological Analysis

Isotopic Uranium Radiological Analysis						
Site	**Uranium-233/234 pCi/L**	**Uranium-233/234 *CSU**	**Uranium-235 pCi/L**	**Uranium-235 *CSU**	**Uranium -238 pCi/L**	**Uranium -238 *CSU**
	3rd Qtr 2017					
SD 430	3.53	0.48	0.235	0.07	1.19	0.02
	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 P1 Pond Weir, SD-490, SD-430, and MIK-0.1. The basis for these sites to be monitored is the CERCLA D&D work being conducted on the East Tennessee Technology Park. PCB's were analyzed at SD-430 to monitor for possible contamination from past CERCLA work performed in the area. PCB's were undetected in all samples submitted for analysis. Table 5.14 shows results for Cr6 and PCB's sampling.

Table 5.14: Hexavalent Chromium & PCB's

Hexavalent Chromium & PCB's						
SITE		DATE	PCB'S		Cr 6	
		3rd Qtr 2017			mg/L	
P1 Pond Weir			NS		0.0000317 J	mg/L
SD490			NS		0.000725	mg/L
SD430			U		0.00316	mg/L
Mik 0.1			NS		0.00116	mg/L
		4th Qtr 2017				
P1 Pond Weir			NS		U	mg/L
SD490			NS		U	mg/L
SD430			U		U	mg/L
Mik 0.1			NS		U	mg/L
		1st Qtr 2018				
P1 Pond Weir			NS		U	mg/L
SD490			NS		0.00108	mg/L
SD430			U		0.00203	mg/L
Mik 0.1			NS		0.000436J	mg/L
		2nd Qtr 2018				
P1 Pond Weir			NS		0.000387	mg/L
SD490			NS		0.00042	mg/L
SD430			U		0.0006	mg/L
Mik 0.1			NS		0.000674	mg/L
U= undetected						
J= Estimated value between MDL and MQL						
NS= No sample taken						

5.3.8 Conclusions

Results indicate legacy contaminants continue to impact the ORR. These legacy concerns include radiological contaminants in White Oak Creek, metals in Mitchell Branch, while mercury continues to be a concern at East Fork Poplar Creek. Hexavalent chromium is sporadically present in SD-490, SD-430, and MIK-0.1. A radiological contaminant (Tc-99) from the 2013 release at K-25 continues to impact SD-490.

5.3.9 Recommendations

With the increase in CERCLA activity on the ORR, the DoR-OR's recommendation is to discontinue the monitoring of surface water sampling points for legacy releases. The focus of the program should instead be directed on the monitoring and oversight of areas impacted by recent or ongoing CERCLA activities.

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 discharge from EMWMF is 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.

The EMWMF was designed with a 5% slope along the centerline of each disposal cell to direct storm water and leachate to the southern (lower) end of the cells (Williams, 2004). This design feature, along with the abundant rainfall of the region, and low porosity native soils used as a protective layer over the leachate collections system, have resulted in excessive pooling of the contact water at the lower end of the cells (Williams, 2004). Heavy rainfall the first year of operations resulted in the storm water and associated leachate overflowing the cell berms, releasing contaminants to adjacent land, and into the NT-5 tributary. To avoid similar incidents, the allowable release limits at the contact water ponds were relaxed and the compliance point for radionuclides subsequently moved from the ponds/tanks to the discharge from the storm water sedimentation basin.

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 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 uses currently 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 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 and 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, quarterly.
- 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. However, deviations from the Project Plan are identified in Section 5.4.6, Deviations from the Plan.

- 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.
- 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 5.15).
- 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
- To ensure EMWMF is meeting its operational requirements, discharge data from EMWMF-2 and EMWMF-3 will be collected by DOE. TDEC-DoR-OR will review the discharge data received from DOE, quarterly.
- TDEC will collect confirmation samples as referenced by Table 5.15 and Figure 5.27.
- Samples will be collected from the weirs (EMWMF-2 monthly and EMWMF-3 quarterly) as referenced by Figure 5.27.
- DOE collects samples quarterly from EMWMF-1 (GW-918) and DoR-OR will analyze the samples, received from DOE, semiannually.
- EMWMF-4B will be sampled and analyzed semi-annually.

Table 5.15 and Figure 5.27 depict monitoring and sampling locations and sample rationale at the EMWMF.

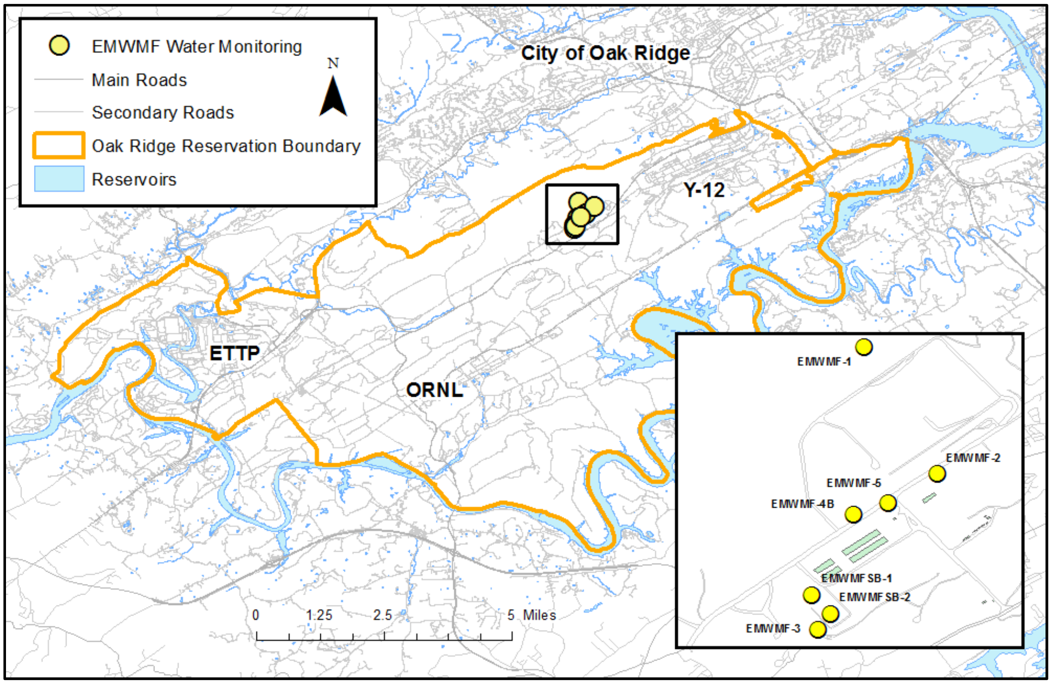


Figure 5.27: Proposed EMWMF Sampling and Monitoring Locations

Table 5.15: Proposed EMWMF Sampling and Monitoring Locations

Station	Sample ID	Frequency	Sampling Rationale
GW-918	EMWMF-1	SemiAnnually	Upgradient well linked to a spring. The spring is the headwaters for NT-4. This sample is co-sampled with the EMWMF personnel for quality control.
EMWMF Underdrain	EMWMF-2	Monthly	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.
Sediment Basin Effluents	EMWMF-3	Quarterly	Provides confirmation of contaminant levels being discharged froom the sediment basin.
Sedimentation Basin Sediment	EMWMFSB-1, EMWMFSB-2	Annually	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-4B	SemiAnnually	This location is used as a verification that water collected in Cell 6 (prior to waste placement) is storm water.

GW - groundwater

EMWMF - Environmental Management Waste Management Facility

NT - North Tributary

5.4.5 Methods, Materials, Metrics

Twice per week, the Project Lead will perform independent monitoring (check and record water quality parameters and sites) shown on Figure 5.27.

Water samples (from the locations identified in Table 5.15 and Figure 5.27) 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 5.16:

Table 5.16: 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

Samples from GW-918, were collected by DOE semiannually. Three different samples were provided to and analyzed by TDEC

EMWMF-2 was planned to be sampled and analyzed monthly, but was only samples and analyzed six times because of budget constraints.

EMWMF-3 was scheduled to be sampled quarterly but was sampled only three times because of budget constraints.

The Sediment Basin was not sampled for sediments because the basin did not dry enough to safely sample.

Two spot samples were collected from the ditch valve (EMWMF-5) to mitigate the inability to sample the Sediment Basin. This had not been scheduled in the Project Plan.

Discharge data was not reviewed quarterly because it was not received from DOE.

5.4.7 Results from Analysis

From the monitoring of the effluents from EMWMF-2 (Underdrain) and the sediment basin (EMWMF-3) data reflected the chemical constituents and the water quality parameters of the water released.

General Water Quality Parameters

The water quality parameters measured, included water temperature in degrees centigrade, pH (scale of acidity), specific conductivity (COND), dissolved oxygen (DO), and oxidation reduction potential (ORP). Water quality parameters were collected as a cost-effective screening tool to evaluate overall water quality. If a change of conditions is identified, deviations of monitored parameters would be expected and could be used to determine if additional sampling or assessment may be required.

Tables 5.17 and 5.18 provide the monthly maximum, minimum and average of the parameters measured. The charts (Figures 5.28 and 5.29) show the relationship of the maximums, the minimums, and the averages for each of the parameters for the fiscal year for location EMWMF-2. Figure 5.29 uses the x axis in logarithmic scale. This compresses the scale so the relationships between measurements of diverse numbers can be located on the same chart.

EMWWMF-2 (The Underdrain)

The source of water coming from EMWMF-2 is from uphill and beneath the landfill. The conductivity continues to remain steady and correlates with temperature. Significant changes over time in any one of these five parameters might signify an impact from EMWMF liner system.

As reflected in Figure 5.28 the water quality parameters recorded during this sampling interval reflect relatively stable conditions. The temperature, pH and conductivity reflect minimal month-to-month variation.

Table 5.17: FY 2018 Water Quality Parameters Measured at EMWMF-2 (Underdrain)

Water Quality Parameters Measured - EMWMF-2 UNDERDRAIN													
		Jul 2017	Aug 2017	Sep 2017	Oct 2017	Nov 2017	Dec 2017	Jan 2018	Feb 2018	Mar 2018	Apr 2018	May 2018	Jun 2018
pH	MAX	7.12	7.02	7.21	7.06	7.06	6.67	6.82	6.93	7	7.53	7.42	7.38
	MIN	6.85	6.52	6.53	6.63	6.41	6.4	6.35	6.34	6.58	6.65	6.56	6.56
	AVE	7.01	6.71	6.88	6.83	6.70	6.57	6.62	6.71	6.79	6.94	7.01	6.90
DO	MAX	3.10	3.01	3.21	6.07	4.87	6.63	7.33	5.56	5.52	4.80	4.75	4.01
	MIN	2.19	1.79	2.01	2.91	3.86	3.19	4.12	3.27	2.94	3.13	2.06	2.06
	AVE	2.63	2.38	2.65	4.32	4.48	5.21	5.23	4.86	4.23	4.15	3.39	2.61
Cond	MAX	571.7	579	532.8	559.7	588	564.4	537.3	600.2	561.1	566.9	566	543.4
	MIN	505.7	533.6	514.3	513.1	523.3	513.1	508.7	512.6	533.2	535.5	519.6	513
	AVE	553.36	556.77	527.04	537.84	542.90	530.76	524.60	574.34	550.33	550.64	535.81	526.86
Temp	MAX	18.5	18.7	18.4	18.5	17.9	16.2	16	16.2	16.2	16.6	17.4	18
	MIN	17.8	18.2	17.9	16.8	15.8	14.5	14.1	14.8	14.7	15.1	16	17.2
	AVE	18.10	18.39	18.21	17.54	16.91	15.63	15.21	15.64	15.69	15.90	16.81	17.54
ORP	MAX	302.80	291.70	283.20	268.50	316.70	279.30	447.90	482.70	486.00	448.00	448.00	431.40
	MIN	177.60	210.40	177.80	134.50	151.90	200.17	283.90	220.90	272.70	348.70	53.30	53.30
	AVE	221.46	246.04	239.03	222.87	254.56	241.37	338.10	318.53	347.31	380.57	292.53	257.87
visits		7	9	7	9	5	7	7	7	8	7	5	4

MAX - High Measurement
MIN - Low Measurement
AVE - Average Measurement
pH - Alkalinity in Std. Units
Cond - Specific Conductivity in micro Siemens per centimeter
DO-Dissolved Oxygen in milligrams per Liter
TEMP- Temperature in degrees centigrade
ORP - Oxidation Reduction Potential in milliVolts

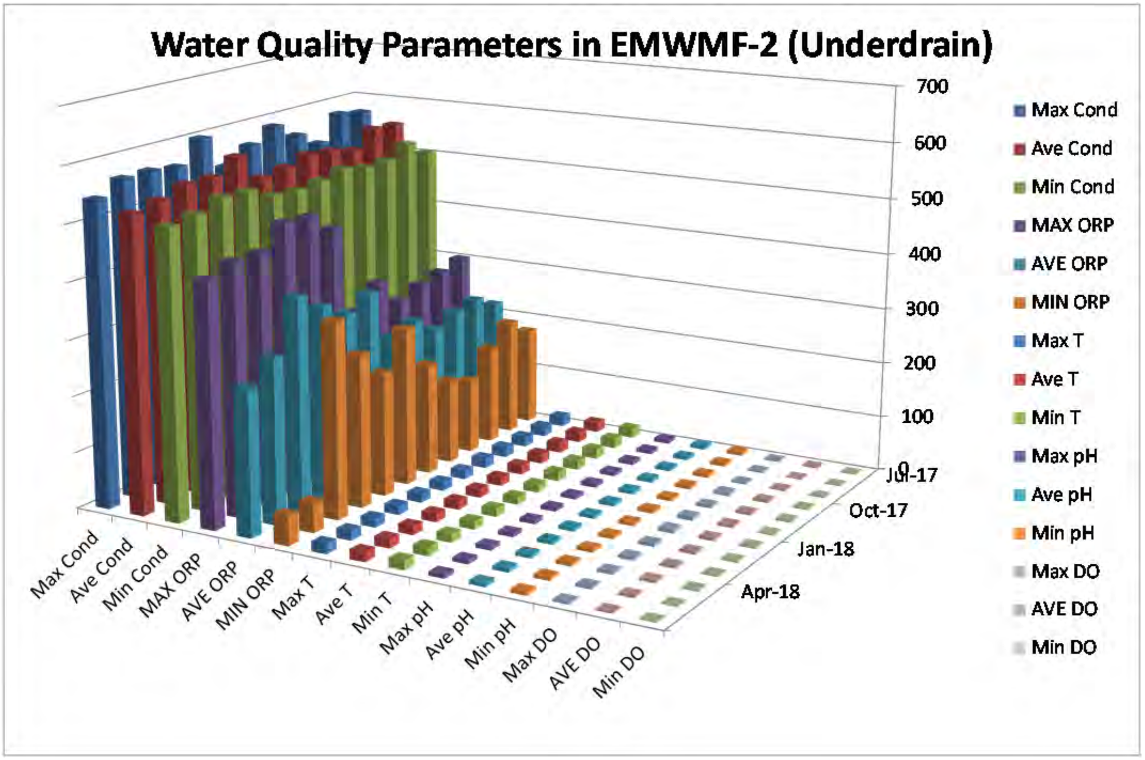


Figure 5.28: EMWMF-2 (Underdrain) in Various Units

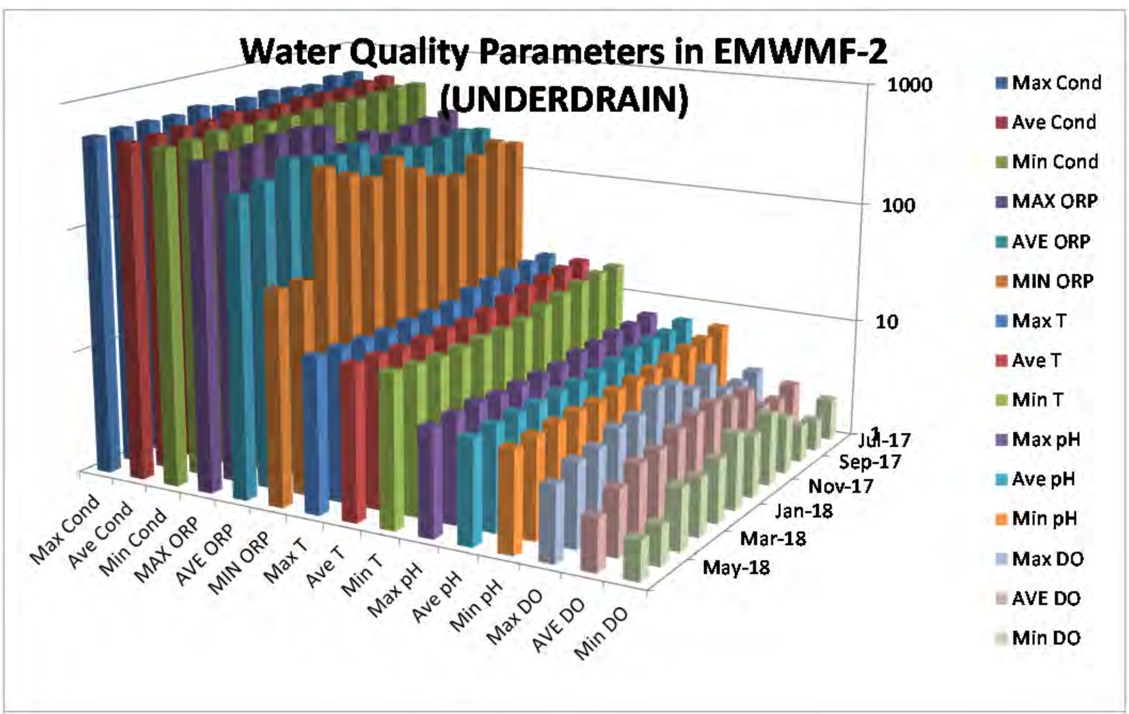


Figure 5.29: EMWMF-2 (Underdrain) in Logarithmic Scale

EMWWMF-3 (Sediment Basin V-Weir)

Table 5.18 contains the water quality parameter measurements for the Sediment Basin outfall EMWMF-3 or the V-WEIR. The table lists the maximum, minimum, and averages for each month in the fiscal year.

Figures 5.30 and 5.31 graphically illustrate the relationships of the different parameters. Figure 5.30 shows all of the parameters for FY2018 on one axis. Conductivity and ORP have the highest readings and are orders of magnitude greater than pH, temperature, or dissolved oxygen.

The varying nature of ORP, maximums, minimums, and averages, is seen in Figure 5.30. The conductivity measured is also quite variable as seen in the figure. One month (March 2018) has a conductivity measurement of 796 micro Siemens per centimeter. March had several rainfall events and there was a significant amount of muddy water discharging the day the maximum was measured. The average is also elevated in respect to the other COND measurements for the rest of the year.

Dissolved oxygen and temperature have the most variability. This variability is normal as the basin is open to the elements and the water heats and cools with the environment.

Table 5.18: FY2018 Water Quality Parameters Measured at EMWMF-3 (V-Weir)

Water Quality Parameters Measured - EMWMF-3 V-WEIR													
		Jul 2017	Aug 2017	Sep 2017	Oct 2017	Nov 2017	Dec 2017	Jan 2018	Feb 2018	Mar 2018	Apr 2018	May 2018	Jun 2018
pH	MAX	8.2	8.55	8.75	8.78	8.54	8.31	7.89	7.43	7.47	8.11	8.24	8.24
	MIN	7.7	7.16	7.28	7.31	7.18	7.25	6.95	6.92	7.01	7.17	6.87	6.87
	AVE	7.89	7.66	8.03	7.78	7.73	7.47	7.37	7.16	7.24	7.48	7.68	7.58
DO	MAX	7.62	7.97	9.65	13.11	15.03	14.75	18.01	15.00	14.00	11.13	9.25	8.45
	MIN	6.01	6.09	7.40	7.02	9.91	11.36	14.56	10.45	10.12	8.84	5.67	5.54
	AVE	6.67	7.18	8.35	9.65	12.67	12.97	15.97	12.61	11.74	9.67	7.81	7.00
Cond	MAX	379	396.5	340.6	358.3	503.1	503.1	534.2	554.9	796	545.4	542	542
	MIN	163.3	247.6	165.3	160.3	160.3	170.7	170.7	151.7	362.2	200	200	134.1
	AVE	249.51	320.32	226.51	227.88	279.01	343.82	334.78	369.97	580.63	362.31	385.14	381.27
Temp	MAX	29.3	28.8	25.5	23.3	16.7	11.7	10.1	14.8	16.6	16.7	27.1	27.1
	MIN	26.2	24.7	17.3	10.5	7.0	2.0	2.0	1.64	7.9	10.6	10.6	18.1
	AVE	28.10	26.69	21.96	17.28	11.22	7.03	4.59	7.76	11.24	14.44	24.02	24.33
ORP	MAX	229.20	216.60	216.50	315.30	271.10	245.00	327.80	435.00	316.00	402.40	321.70	402.50
	MIN	165.70	169.00	150.10	185.10	206.30	194.10	229.50	189.30	233.00	250.10	165.40	70.00
	AVE	189.29	189.50	183.33	221.17	224.77	223.50	271.26	298.59	279.57	311.66	270.36	209.51
visits		7	9	7	9	5	7	7	7	8	7	5	4

MAX - High Measurement

MIN - Low Measurement

AVE - Average Measurement

pH - Alkalinity in Std. Units

Cond - Specific Conductivity in micro Siemens per centimeter

DO-Dissolved Oxygen in milligrams per Liter

TEMP- Temperature in degrees centigrade

ORP - Oxidation Reduction Potential in milliVolts

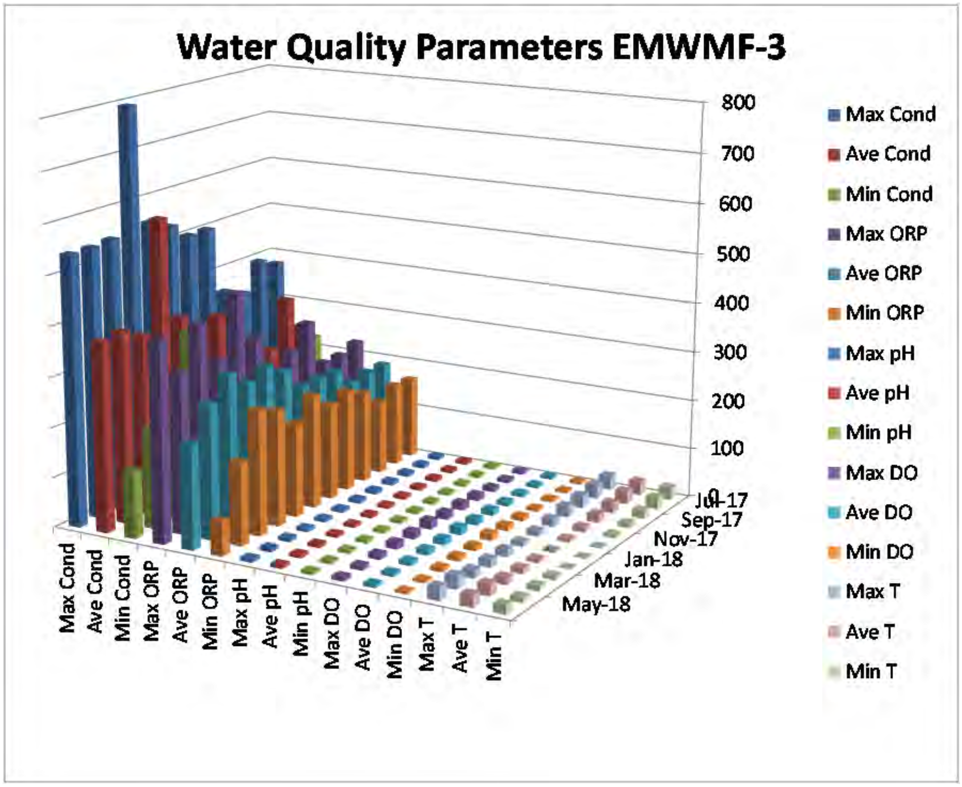


Figure 5.30: EMWMF-3 in Various Scales

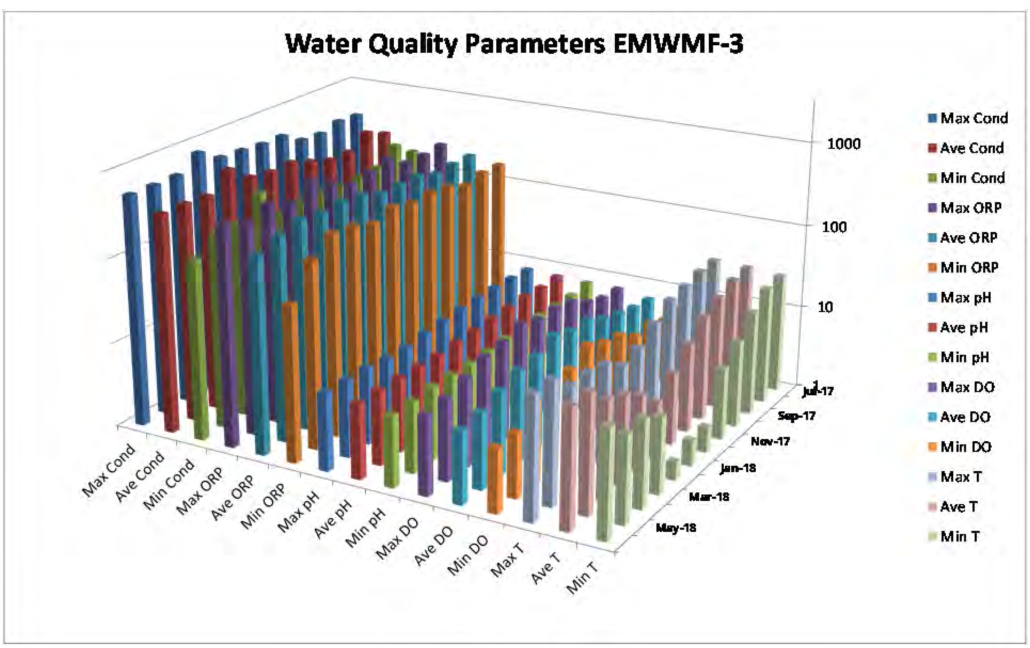


Figure 5.31: EMWMF-3 in Logarithmic Scale

Laboratory Analysis Results

EMWMF-2 Underdrain

Six samples were collected during this study. Five were analyzed for radioactive constituents. One sample collected in August 8, 2017 at EMWMF-2 was analyzed for only metals. The results for these analyses can be seen in Tables 5.19 and 5.20.

The maximum radioactivity results for EMWMF-2 are as follows:

- gross alpha activity 1.33 picoCuries per Liter(pCi/L), was detected on June 6, 2017
- gross beta activity 14.8 pCi/L, was detected on September 21, 2017
- strontium-90 activity 0.82 pCi/L, was detected on September 21, 2017
- technetium-99 activity 0.44 pCi/L, was detected on July 11, 2017
- tritium activity 55 pCi/L, was detected on June 6, 2017
- uranium-234 activity 0.548 pCi/L, was detected on June 6, 2017
- uranium-235 activity 0.077 pCi/L, was detected on September 21, 2017
- uranium-238 activity 0.292 pCi/L. was detected on June 6, 2017

None of these results exceeded regulatory criteria. In an effort to determine the total uranium in the effluents of the EMWMF the activities of the three uranium isotopes are summed. This is seen in the bottom row of Table 5.19.

Figures 5.32 and 5.33, show radiological results for selected constituents and isotopic constituents from the samples collected at the EMWMF-2 Underdrain location.

A typical suite of metals was run on a sample collected August 8, 2017. The list of analytes and the results are seen in Table 5.20. There were 8 (eight) detections out of 23 analytes. The eight are naturally occurring constituents in water in and around Oak Ridge. Calcium, iron, magnesium, potassium, sodium, barium, manganese and nickel were all detected. Two of the constituents of note are barium at 110 micrograms per liter (µg/L) and nickel at 2.1 µg/L. DoR-OR spring and residential well sampling results since 1995, show barium above the average of 53.06 µg/L and nickel slightly above the average of 1.59 µg/L. They are, however, not above regulatory guidance.

Table 5.19: EMWMF-2 Laboratory Radiochemical Analysis Results

EMWMF-2 (Underdrain) Radiochemical Results					
Analyte	6/6/2017	07/11/17	09/21/17	12/21/17	4/26/2018
Gross Alpha (pCi/L)	1.33	1.03	0.06	0.75	0.5
Gross Beta (pCi/L)	4	2.2	14.8	5.6	2.2
Strontium-89 (pCi/L)	0.20	0.79	-2	-1.7	0.11
Strontium-90 (pCi/L)	-0.23	-0.25	0.82	0.69	-0.172
Technetium-99 (pCi/L)	-0.25	0.44	-0.25	0.26	-0.22
Tritium (pCi/L)	55	22	20	51	36
U-234 (pCi/L)	0.548	0.308	0.318	0.244	0.45
U-235 (pCi/L)	0.0513	0.045	0.077	0.01	0.072
U-238 (pCi/L)	0.292	0.194	0.193	0.154	0.201
Calculated Total Uranium (pCi/L)	0.891	0.547	0.588	0.408	0.723

pCi/L - picoCuries per Liter

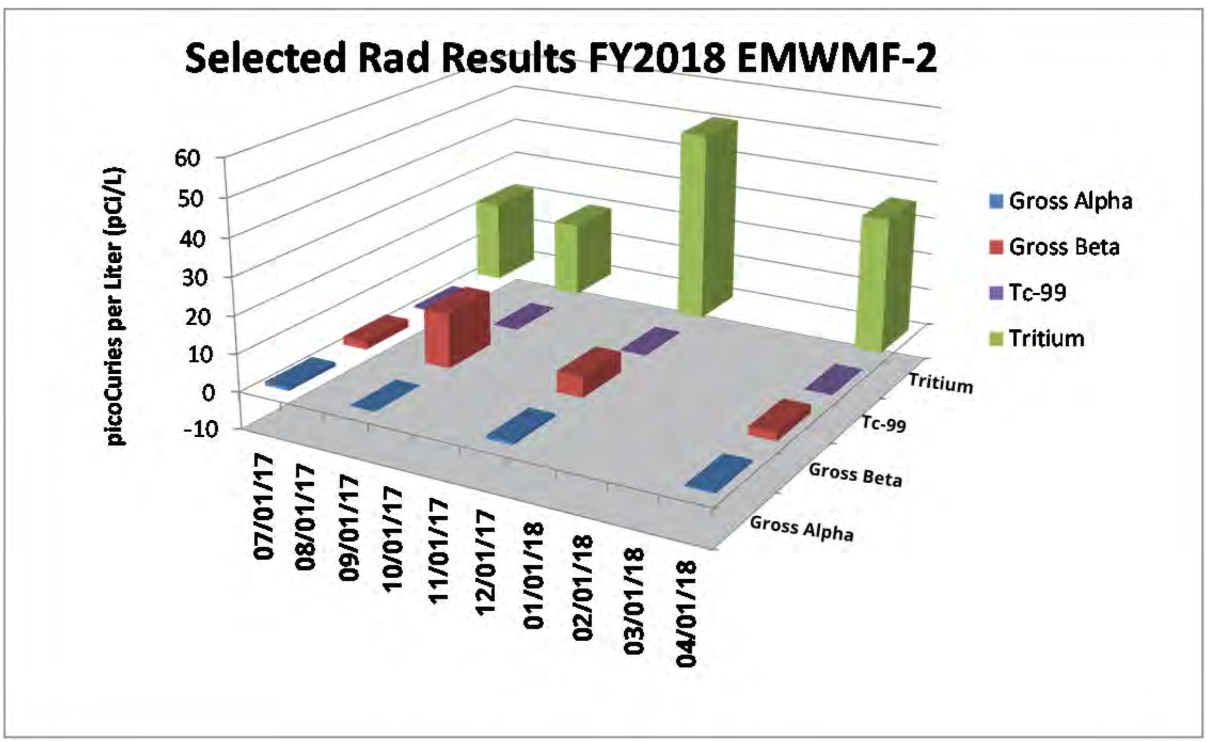


Figure 5.32: EMWMF-2 Selected Rad Results FY2018

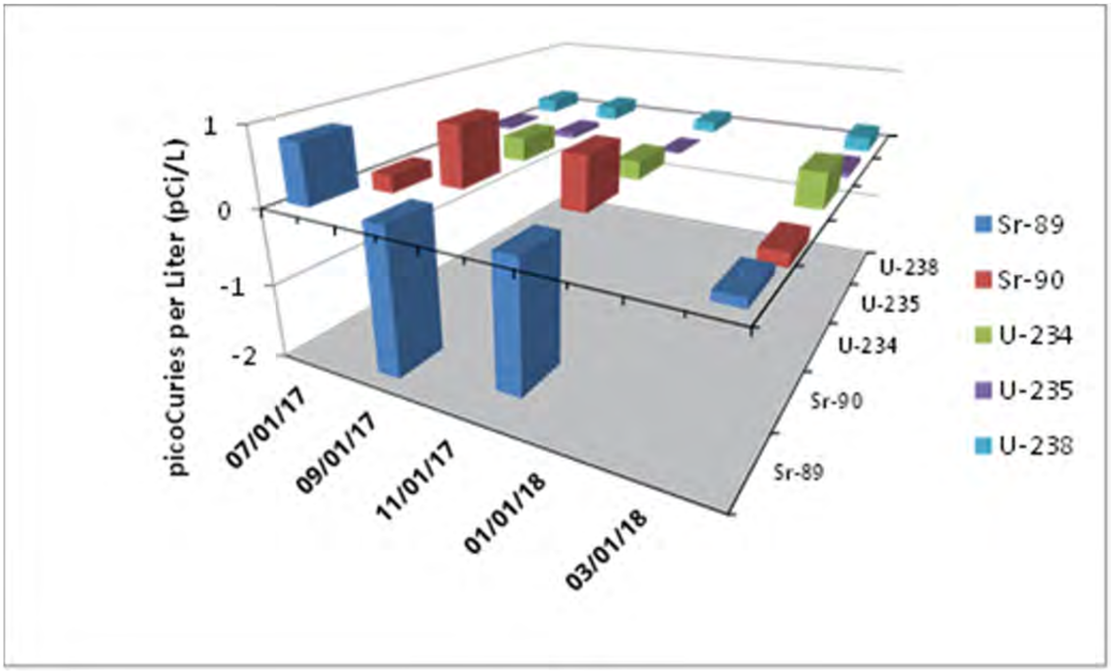


Figure 5.33: EMWMF-2 Strontium and Uranium Results FY2018

Table 5.20: EMWMF-2 Metals Analysis Results

EMWMF-2 (Underdrain) Metals Results Sampled 8/8/2017			
Analyte	**Result**	**Result Qualifier**	**Units**
Calcium	88		mg/L
Iron	6.2	J	ug/L
Magnesium	13		mg/L
Potassium	2.3		mg/L
Sodium	10		mg/L
Aluminum	U	U	ug/L
Antimony	U	U	ug/L
Arsenic	U	U	ug/L
Barium	110		ug/L
Beryllium	U	U	ug/L
Cadmium	U	U	ug/L
Chromium	U	U	ug/L
Cobalt	U	U	ug/L
Copper	U	U	ug/L
Lead	U	U	ug/L
Manganese	1.6		ug/L
Nickel	2.1		ug/L
Selenium	U	U	ug/L
Silver	U	U	ug/L
Thallium	U	U	ug/L
Vanadium	U	U	ug/L
Zinc	U	U	ug/L
Mercury	U	U	ug/L

mg/L - milligrams per Liter

ug/L - micrograms per Liter

Quantification Limit; it is an estimate.

U = Undetected

Comparison of TDEC and DOE Radioactivity Data

Figures 5.34 and 5.35 illustrate the comparison between DoR-OR gross alpha activity, gross beta activity, and DOE's alpha and beta activity. The OREIS database only contained alpha and beta activity measured since May 24, 2017. No records of alpha or beta activity existed prior to that date. All of the isotopic results are, with a very few instances, equal to or below the detection levels or within their radiological error calculations.

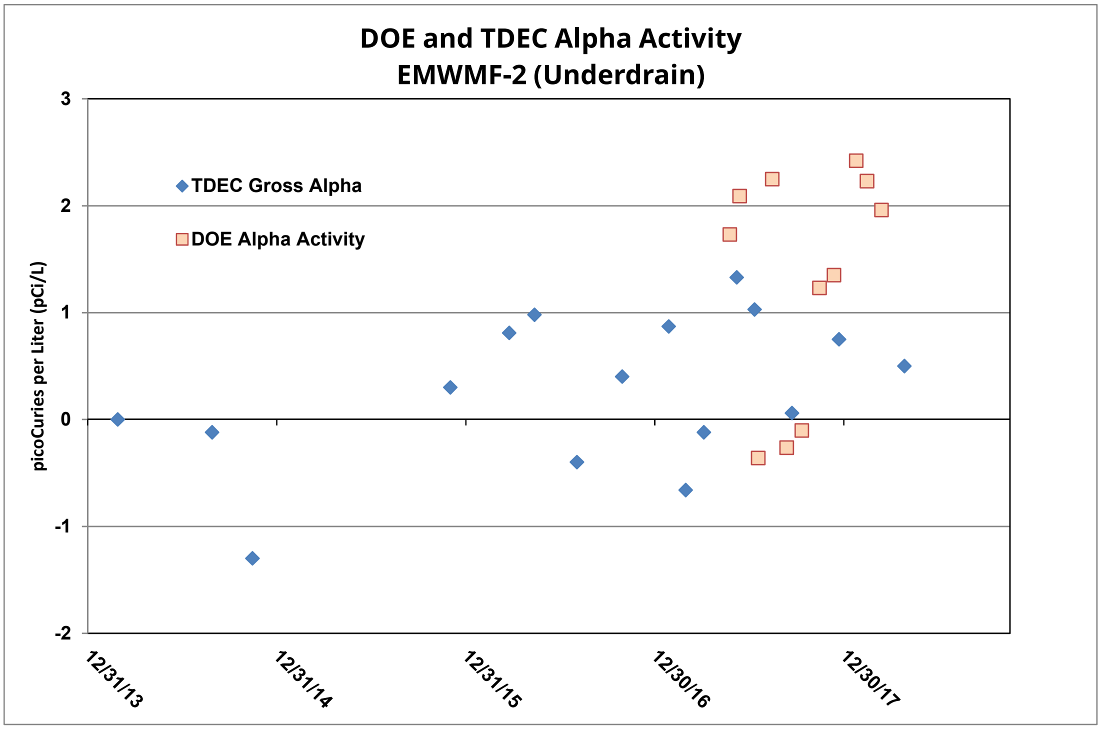


Figure 5.34: EMWMF-2 DOE and TDEC Alpha Activity

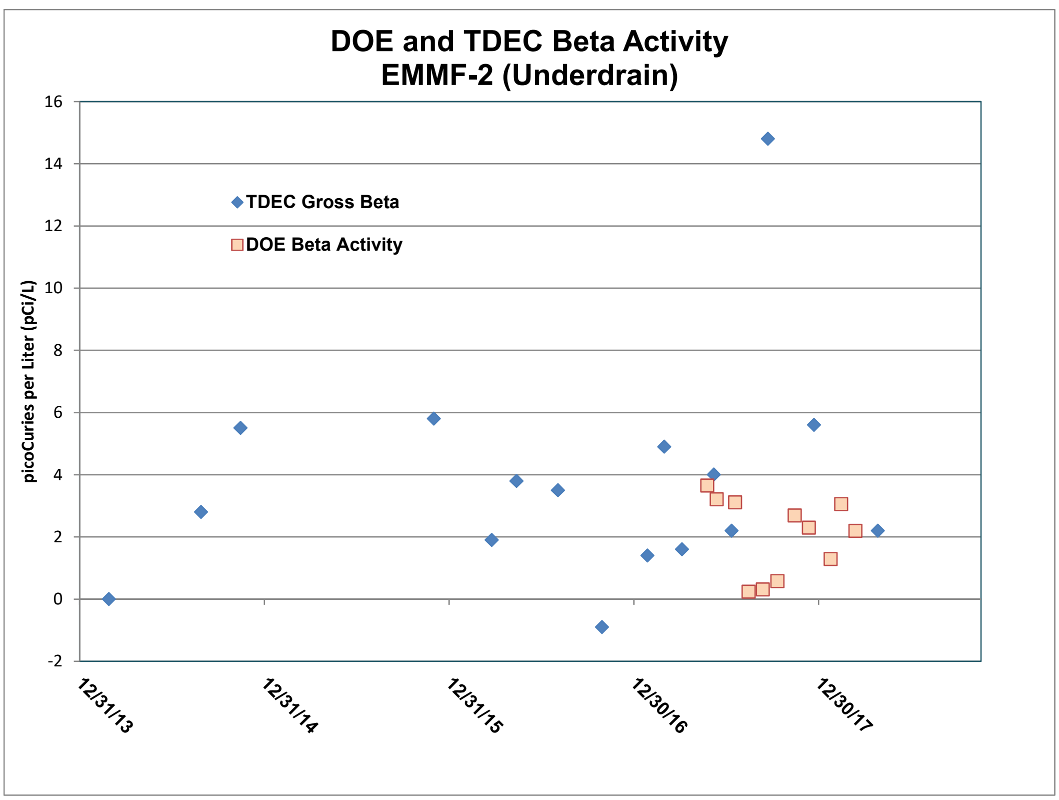


Figure 5.35: EMWMF-2 DOE and TDEC Beta Activity

EMWMF-3 VWEIR

Three samples were collected and analyzed for radioactivity from EMWMF-3 during this study. One additional sample collected on June 6, 2017 is also included in this data set. The results for these analyses can be seen in Table 5.21. The June 6 sampling result was discussed in the previous year's EMR but the laboratory results were not available to be included in the report and are included here.

The maximum radioactivity results are as follows:

- gross alpha activity 12.7 (pCi/L), was detected on December 19, 2017
- gross beta activity 85.2 pCi/L, was detected on August 15, 2017
- strontium-89 activity 1.6 pCi/L, was detected on August 15, 2017
- strontium-90 activity 0.65 pCi/L, was detected on December 19, 2017
- technetium-99 activity 26.88 pCi/L, was detected on December 19, 2017
- tritium activity 900 pCi/L, was detected on December 19, 2017
- uranium-234 activity 11.5 pCi/L, was detected on June 6,2017
- uranium-235 activity 0.936 pCi/L, , was detected on June 6, 2017
- uranium-238 activity 1.4 pCi/L, was detected on June 6, 2017

In an effort to determine the total uranium in the effluents of the EMWMF the activities of the three uranium isotopes are summed. This is also seen at the last row of the bottom row of Table 5.21. None of these results exceeded regulatory criteria.

Figures 5.36 and 5.37, show radiological results for selected constituents and isotopic constituents from the samples collected at the EMWMF-3 VWEIR location.

Table 5.21: EMWMF-3 Laboratory Radiochemical Analysis Results

EMWMF-3 Laboratory Radiochemical Analysis Results				
Analyte	06/06/17	08/15/17	09/21/17	12/19/17
Gross Alpha (pCi/L)	11.16	3.14	4.53	12.7
Gross Beta (pCi/L)	25.5	85.2	17.2	32.5
Strontium-89 (pCi/L)	-0.31	1.6	0.55	-1.84
Strontium-90 (pCi/L)	-0.31	-0.09	0.23	0.65
Technetium-99 (pCi/L)	17.33	21.69	10	26.88
Tritium (pCi/L)	386	570	313	900
U-234 (pCi/L)	11.5	6.92	3.93	8.12
U-235 (pCi/L)	0.936	0.67	0.339	0.62
U-238 (pCi/L)	1.4	0.76	0.486	1.28
Calculated Total Uranium (pCi/L)	13.84	8.35	4.755	10.02

pCi/L - picoCuries per Liter

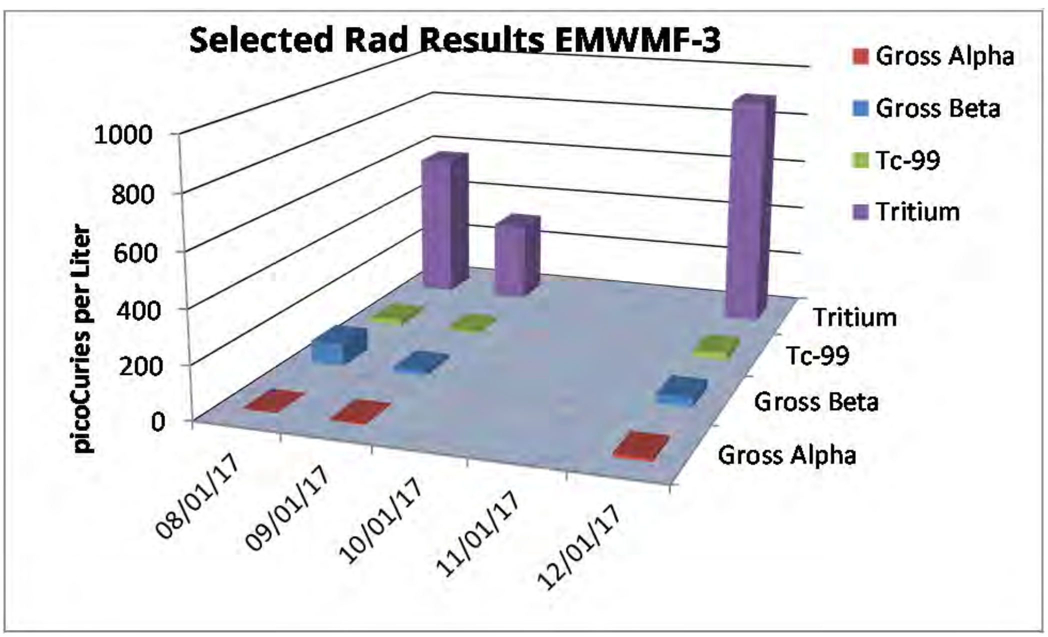


Figure 5.36: Selected Radiological Results for EMWMF-3

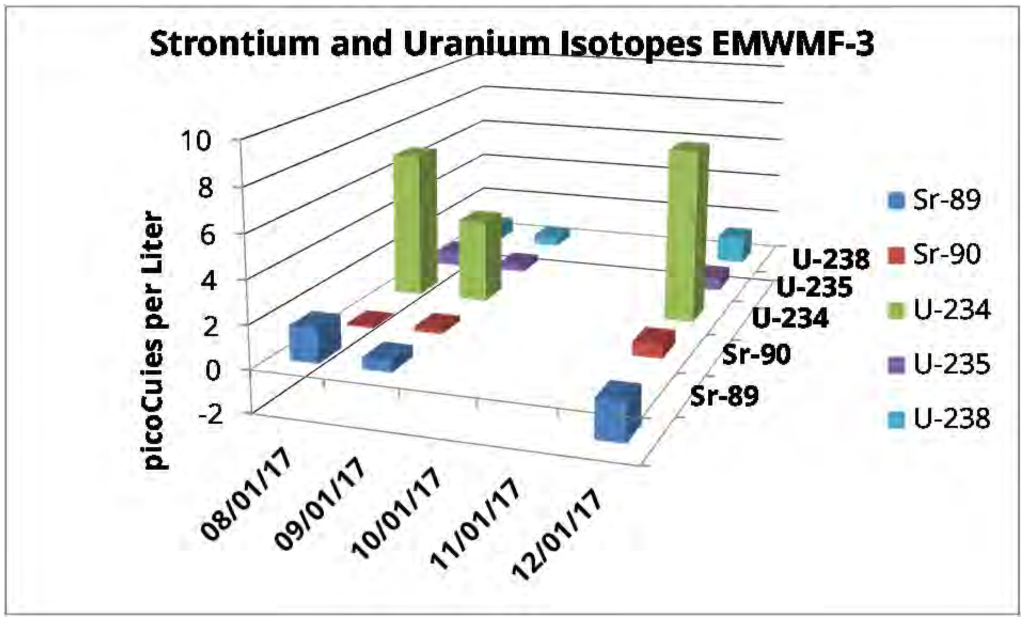


Figure 5.37: Strontium and Uranium Isotope Results for EMWMF-3

Comparison of TDEC and DOE Gross Alpha and Gross Beta Activities

It should be noted that gross analysis is typically used to screen samples to determine if additional analysis is warranted. While it can be helpful, gross analysis has notable limitations and is not used to assess compliance with EMWMF release criteria, which requires isotope specific analysis.

Figure 5.38 is a comparison of DOE and TDEC DoR-OR gross alpha results for samples of effluents collected at the sedimentation basin v-weir (EMWMF-3). As the sediment basin receives storm water runoff from the EMWMF grounds in addition to contact water, the results can be expected vary based on a number factors, with the highest concentrations associated with releases of contact water to the basin. The timing of the sampling relative to a release, the concentration of contaminants in the contact water, and the amount of clean storm water available to dilute contaminants all add to the variability in sample results taken during different time periods and environmental conditions. DoR-OR has been sampling EMWMF-3 continuously, since 2008. Since sampling events are not coordinated with DOE the results vary in agreement, but follow similar trends and correlate reasonably well depending on the circumstances. Figure 5.39 is similar except for beta activity. Again, most of the results are similar, but due to the different sampling times and other variables , some differ considerably For instance, in Figure 5.39 the point labelled 1009.8 was collected February 4, 2015 while DOE's sample point labeled 523, was taken February 2, 2015.

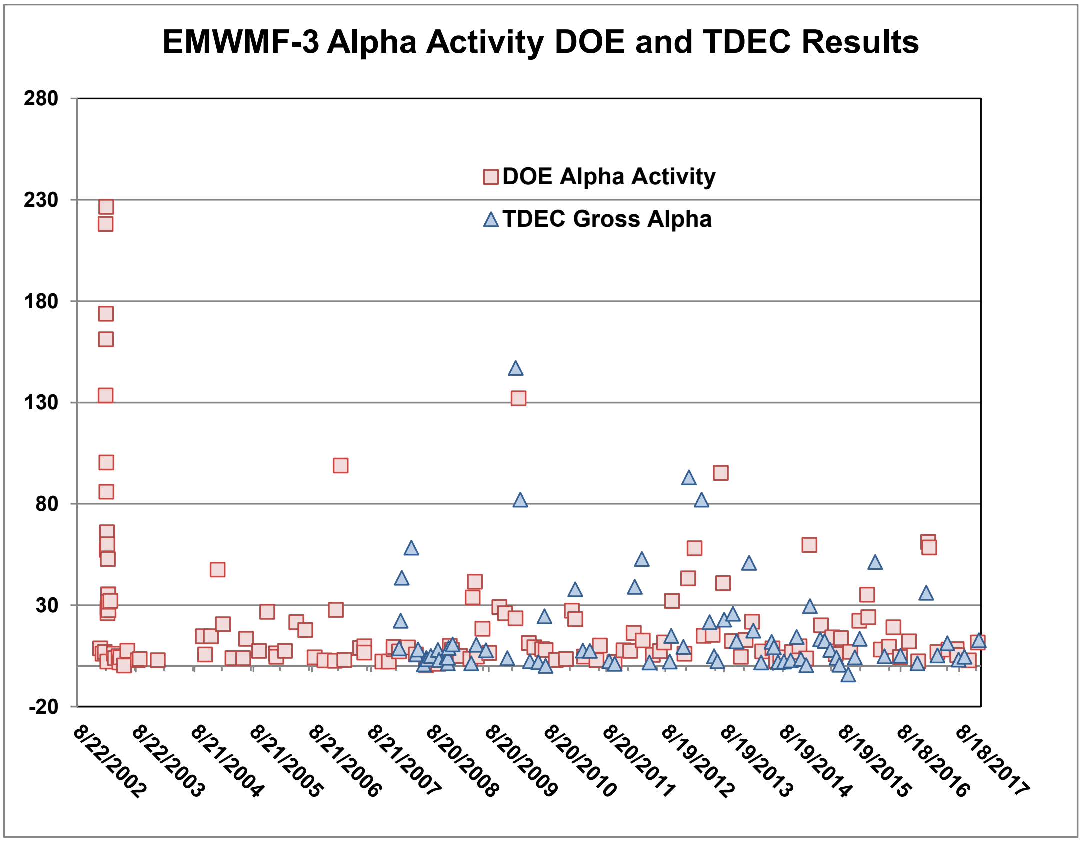


Figure 5.38: EMWMF-3 Alpha Activity DOE and TDEC Results

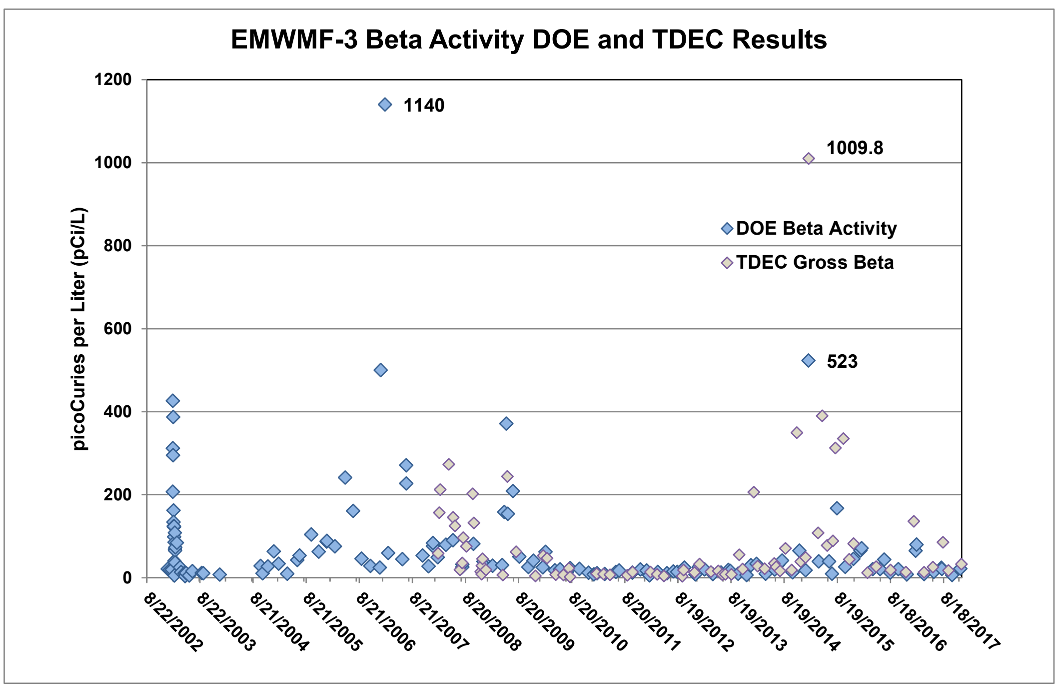


Figure 5.39: EMWMF-3 Beta Activity DOE and TDEC Results

Figure 5.40 shows EMWMF-3 sampling results for technetium-99 (Tc-99) and Figure 5.41 tritium results from samples collected independently by DOE and TDEC DoR-OR. While two of the most mobile radionuclides in surface and ground waters, they are not considered the most hazardous. The release limits for the sediment basin outfall for Tc-99 and tritium are 25,000 and 500,000 pCi/L respectively. However, their abundance in EMWMF wastewaters and their mobility in the environment make them important indicators of unauthorized release at the EMWMF should they occur.

As can be seen in Figure 5.40, DOE and TDEC results for Tc-99 have been relatively consistent, given the variability associated with monitoring the sediment basin outfall. The elevated results beginning in 2014 in both data sets correlate with the disposal of the K-25 purge cascades that were known to contain high levels of Tc-99. DOE subsequently took steps to lower the concentrations of Tc-99 in contact water and the results overall decreased in both data sets.

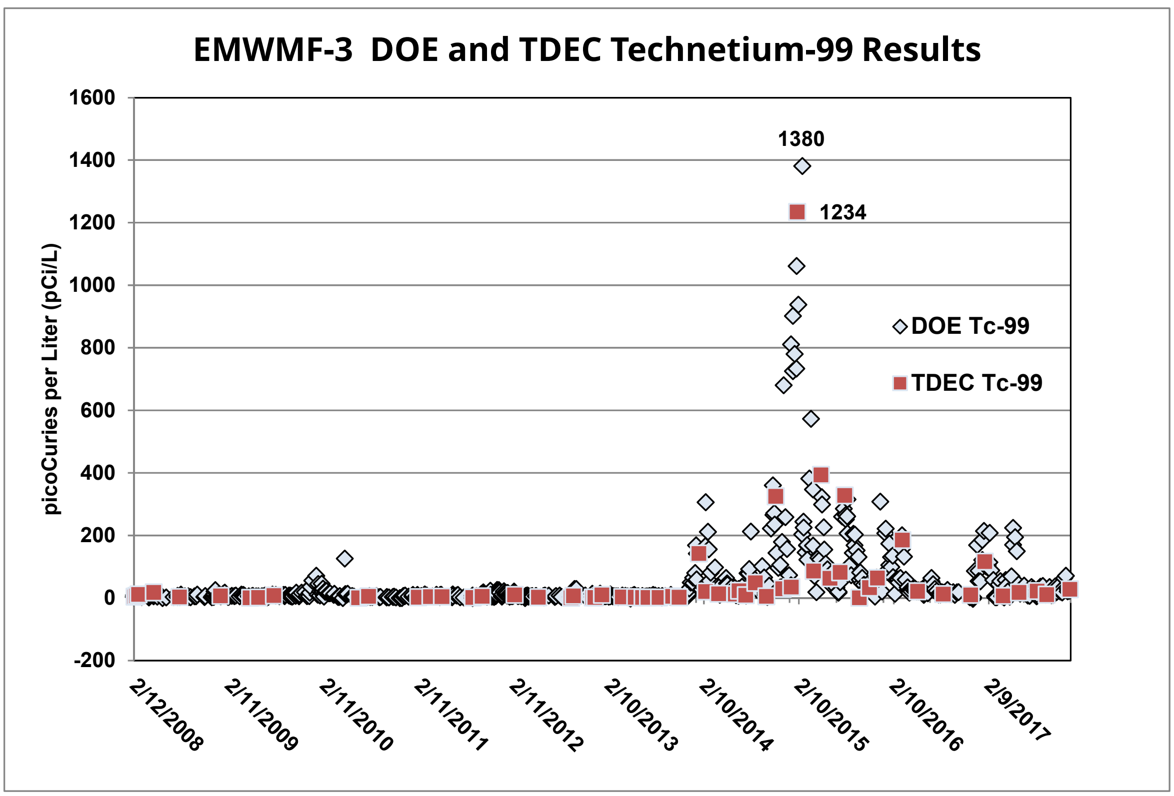


Figure 5.40: EMWMF-3 DOE and TDEC Technetium-99 Results

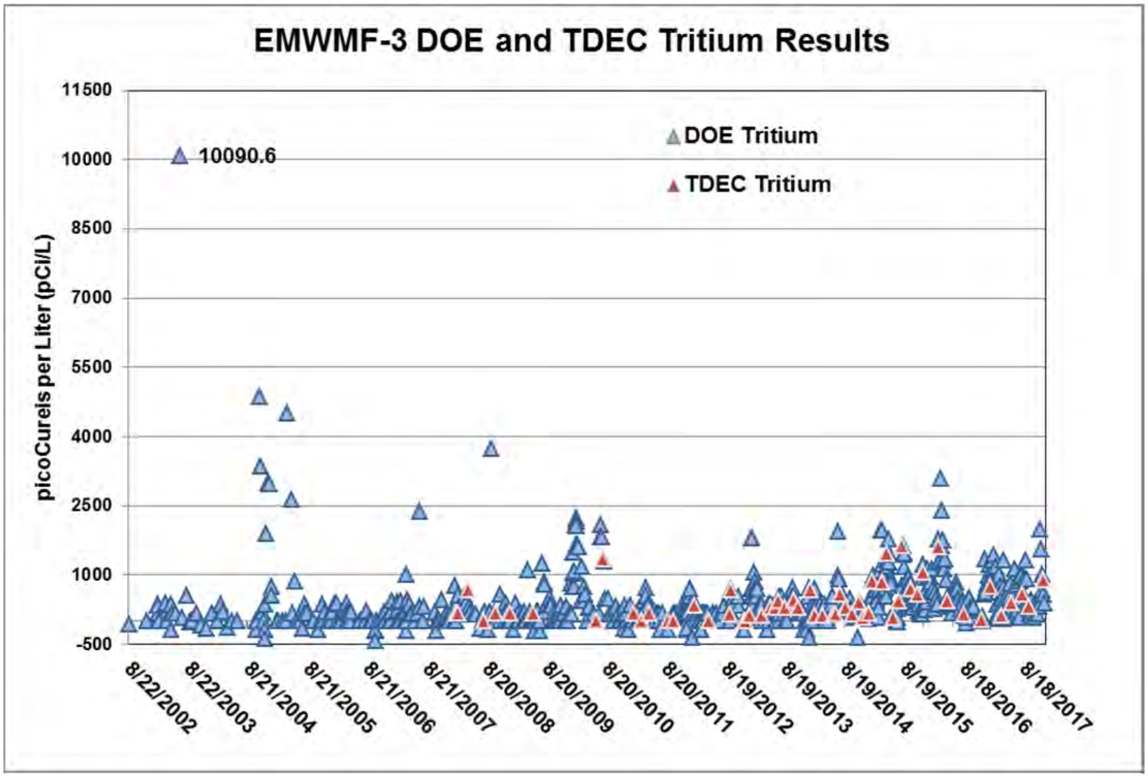


Figure 5.41: EMWMF-3 DOE and TDEC Tritium Results

Tritium is considerably more difficult to analyze than most radionuclides, resulting in relatively high detection limits and associated uncertainty. Nevertheless, TDEC and DOE data appear relatively consistent. Tritium is generally associated with ORNL wastes and the highest concentrations in Figure 5.41 were during a period beginning in 2004 when remedial activities focused on ORNL waste streams.

EMWMF-4B/Cell 6

This location is a storm drain that directs water collected from Cell 6 and channels the water to the sediment basin. As a spot check, the culvert was sampled twice; in October 2017 and December 2017. Each sample was analyzed for radionuclides. Table 5.22 contains the analytical results from the sampling accomplished during 2017. The latter two samples satisfied the Project Plan for semiannual samples. The results overall indicate that the water collected was from a non-contaminated area. The lone elevated tritium result is believed to be an artifact of the analysis.

Table 5.22: EMWMF-4B Laboratory Radiochemical Analysis Results

EMWMF-4B Laboratory Radiochemical Analysis Results						
Date	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Total Uranium (pCi/L)	Tritium (pCi/L)
1/26/2016	1.73	5.2	0.13	0.99	0.616	304
4/4/2016	1.48	5.5	-0.12	-0.22	0.476	1034
7/12/2016	0.22	1.6	0.48	0.04	0.271	-6
1/24/2017	1.33	5.4	0.07	-0.12	0.949	324
2/14/2017	0.55	2.3	-0.01	0.08	0.413	202
4/11/2017	0.12	1.8	0.05	0.37	0.46	53
10/24/2017	0.26	2.2	0.66	-0.35	0.395	69
12/12/2017	0.17	-2.1	0.61	0.49	0.557	126

pCi/L - picoCuries per Liter

EMWMF-5 Contact Water Pond Discharge/Ditch Valve

This location is a drainage ditch where water from the contact water ponds transfers to the sediment basin prior to discharge to NT-5 of Bear Creek. Pumping the ponds is not a scheduled activity but when it is observed during a site visit, it may be sampled based on the discretion of the project manager. The discharge from contact water pond 4 (CWP-4) was sampled twice; 9/26/2017 and 3/6/2018. Table 5.23 provides the results from the two sampling events.

The levels of radiological contaminants in Table 5.23 were greater than baseline because the samples were taken from water that contacted waste inside the active landfill but did not percolate through the waste into the leachate collection system. The contact water is sampled by DOE before its discharge, and based on the results is either released into a sediment basin, or sent for treatment at the Oak Ridge National Laboratory (ORNL) Process Waste Treatment Facility.

Table 5.23: EMWMF-5 Laboratory Radiochemical Analysis Results

EMWMF-5 (Ditch Valve) Laboratory Radiochemical Analysis Results				
Analytes	**Contact Water Pond 4 Discharge**	**Rad Error**	**Contact Water Pond 1 Discharge**	**Rad Error**
Date	9/26/2017		3/6/2018	
Bismuth-214 (pCi/L)	16.8	7.8	29.30	8.8
Lead-214 (pCi/L)	ND	ND	25.20	8.2
Gross Alpha (pCi/L)	17.9	1.2	65.90	4.6
Gross Beta (pCi/L)	166.6	4.9	203.30	8.4
Strontium-89 (pCi/L)	-0.30	1	-2.07	0.78
Strontium-90 (pCi/L)	0.93	0.7	0.77	0.55
Technetium-99 (pCi/L)	190.70	8.7	166.10	6.7
Tritium (pCi/L)	1230.00	180	1974.00	28
U-234 (pCi/L)	17.20	2.1	62.90	7.6
U-235 (pCi/L)	1.37	0.21	4.23	0.70
U-238 (pCi/L)	2.33	0.32	9.80	1.3
Calculated Total Uranium (pCi/L)	20.90	-	76.93	-

pCi/L - picoCuries per Liter   ND - Not Detected

EMWMF-1 GW-918

EMWMF-1 is an Upgradient background monitoring point for groundwater. GW -918 is sampled by DOE, and a replicate sample is collected and provided to TDEC for analysis. The well was sampled quarterly and was analyzed by DoR-OR three times which is one additional sample from what was planned, as mentioned in the Variance from the Plan for this project.

Table 5.24 contains the DoR-OR laboratory results from the samples collected in FY2018 along with other samples analyzed beginning in 2015. The results are all well within ranges for water that has not been contaminated.

According to OREIS, 63 DOE sampling events resulted in the following:

- two detects for tritium
- three detects for strontium-90

- two detects for carbon-14
- three detects for uranium-238
- three detects for uranium-235/236
- twenty detects for uranium-233/234

The detections of uranium-233/234 were all below 2.0 pCi/L (which is the maximum that was measured).

Table 5.24: EMWMF-1 (GW-918) Laboratory Radiochemical Analysis Results

EMWMF-1 (GW918) Laboratory Radiochemical Analysis Results						
Date	Gross Alpha (pCi/L)	Gross Beta (pCi/L)	Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Total Uranium (pCi/L)	Tritium (pCi/L)
2/25/2015	-0.02	6.8	0.58	0.17	0.71	-13
8/11/2015	0.61	1.5	-0.34	0.02	0.045	58
2/10/2016	0.95	2.9	0.16	-0.23	0.461	144
8/10/2016	0.18	2.6	0.08	-0.18	0.407	12
2/13/2017	0.47	3	0.02	-0.06	0.071	16
5/24/2017	-0.35	3.5	-0.15	0.19	0.413	11
8/16/2017	-0.23	5.5	-0.41	0.1	0.11	-57
2/14/2018	0.66	1.4	0.06	0.26	0.205	75
5/16/2018	0.34	1.9	-0.187	0.49	0.197	26

pCi/L - picoCuries per Liter

5.4.8 Conclusions

TDEC sample results are similar to DOE's sample results and detected insignificant contamination from EMWMF underdrain. This sampling point is the location where contamination from the landfill's waste would most likely be seen if there was problem with the EMWMF liner system. EMWMF-3 continues to discharge contaminants, but the levels are well below the current release criteria.

5.4.9 Recommendations

Weekly, DOE samples the effluents at EMWMF-3 on a flow proportional basis. DoR-OR recommends continuing TDEC quarterly sampling and spot sampling based on field observations, to perform continuity checks and determine if significant levels of contaminants are discharged into Bear Creek.

Bi-monthly, DOE samples EMWMF-2 (the underdrain), while DoR-OR samples the location monthly. The basis for monthly sampling is because the underdrain (EMWMF-2) appears to present the most likely pathway for contaminants released from the liner of the EMWMF to migrate to Bear Creek and therefore is the best location to identify releases as quickly as possible and prevent their spread to off-site locations.

5.5 Y-12 FCAP Surface Water

5.5.1 Background

The Y-12 Chestnut Ridge Operable Unit (OU) 2 Filled Coal Ash Pond (FCAP) surface water sampling program was established to evaluate the impact of heavy metals to the surface waters of McCoy Branch. The 1996 FCAP Record of Decision (ROD) identified the primary contaminants of concern (COCs) to be aluminum, arsenic, iron, manganese, mercury, selenium and zinc.

The FCAP is located near the crest of Chestnut Ridge, approximately 0.5 mile south of the Y-12 Plant. In 1955, a 62-foot high earthen dam facing southwest was constructed across Upper McCoy Branch to create a retention pond which was used as a settling basin for coal ash generated from the Y-12 steam plant (Department of Energy, 1996). A slurry, comprised of steam plant coal ash and untreated Clinch River water, was pumped to the crest of Chestnut Ridge (north side of ridge) and over into the sluice channel area (south side of ridge). Influenced by gravity, the slurry flowed from the sluice channel area and down the south slope of the ridge into the pond. By 1967, the pond was filled with the coal ash slurry. Until 1989, the slurry was allowed to overtop the dam and flow down its spillway into Upper McCoy Branch and into Rogers Quarry (Department of Energy, 1996).

By the end of 1989, all coal ash slurry discharges from the steam plant and into the ash pond had ceased. Since then, the deposited coal ash behind the dam (in the pond, Upper McCoy floodplain, and the sluice channel area) has been left in place. Until the remedial action (RA) was undertaken, the dam and its spillway were unsafe due to deterioration caused by vegetation being allowed to grow on the dam.

In the early 1990s, remedial investigative studies were conducted and the results indicated that FCAP vicinity surface water, sediment, and soil were contaminated from the deposited coal ash and its leachate. Typical coal ash COCs are primarily comprised of naturally occurring metals: aluminum, arsenic, copper, iron, lead, manganese, mercury, selenium, zinc, and thorium. In 1995, in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a proposed RA plan was completed to address the contamination and the unsafe dam issues (Jacobs ER Team, 1995). In 1996, the finalized ROD was approved for remediating the FCAP site (Department of Energy, 1996). In 1997, the RA was completed (Department of Energy, 1997).

The ROD scope and basis for response actions states, “The response action for FCAP will address contaminant abatement for surface waters, sediments, and soils of Upper McCoy

Branch and will upgrade the dam to reduce risk of an uncontrolled release of the ash into the Upper McCoy Branch watershed. The principal threat to human health is limited risks from exposure to the radionuclide 228Th and its daughters through direct exposure to the ash under hypothetical trespasser and residential scenarios. Current risks to the environment are primarily to terrestrial biota through exposure and potential accumulation of selenium and arsenic from uptake or ingestion of the ash, its leachate, or organisms affected by it. The purposes and components of this response action are to (1) reduce or eliminate the risk of an uncontrolled release by strengthening the dam and spillway, (2) restrict human access to the site to control the potential for direct exposure, and (3) reduce or eliminate contaminant entry into the Upper McCoy Branch surface waters through enhancement of an existing wetland which currently acts as a natural passive treatment system, which will remove metals by oxidation, sedimentation/precipitation, settling, filtration, and biological processes similar to those occurring in the existing wetland. Implementation of these measures will constitute the final response action for this OU."

The 2013 Remedial Effectiveness Report (RER) specifies that the State of Tennessee Ambient Water Quality Criteria (TN AWQC) will be used solely for comparative purposes to track reduction in "contaminant migration to surface water" and "risk to ecological receptors." The ROD does not mandate that contaminant concentrations must be in compliance with TN AWQC.

The headwaters of the Upper McCoy Branch are comprised of two Chestnut Ridge tributaries which are located above the dam. The tributaries converge at the ash pond and surface water flows over and through the ash in the pond and then down the dam's spillway. The discharge point for pond subsurface flow/leachate is located at the base of the dam; this leachate flows into the passive wetland system for treatment. However, the dam's spillway is constructed so that its surface water flow completely bypasses the wetland treatment system. The wetland-treated leachate effluent and the untreated dam spillway surface water flow converge just south of the wetland. Upper McCoy Branch then flows into Rogers Quarry. Using the S19 National Pollutant Discharge Elimination System (NPDES) outfall site, surface water flows out of the quarry, underneath Bethel Valley Road, and becomes Lower McCoy Branch. About one mile downstream of Bethel Valley Road, the Lower McCoy Branch drains into the Clinch River/Melton Valley Lake.

If a CERCLA ROD's remedy leaves contamination in place above unrestricted land use cleanup criteria, then a five-year review (FYR) is conducted for the site. As the FCAP ROD remedy did not require any of the coal ash to be removed, FYRs are mandatory for the site. Since the RA was completed, four FYRs have been conducted.

Until recently, no significant deficiencies were reported in the FYRs. However, the 2016 FYR indicates physical changes to the wetland system may be adversely reducing its capacity to remove arsenic and other metals from the Upper McCoy Branch. This development is of concern as the ROD states, "the system will intercept and treat contaminated water seeping under the dam, reducing contaminant levels in the surface water of Upper McCoy Branch."

An additional concern is that the dam spillway surface water flow which bypasses the wetland system may be contaminating Upper McCoy Branch. Accordingly, the question arises; does the ROD allow dam spillway surface water flow to bypass the wetlands treatment system? A recent 2017 Tennessee Department of Environment and Conservation (TDEC) review of the administrative record indicates it is currently permissible for dam spillway surface water flow to bypass the wetland for metals removal treatment. The ROD indicates the Upper McCoy Branch tributaries are intermittent streams. However, recent 2017 TDEC FCAP site observations of algal growth on spillway substrates indicate the untreated spillway surface water flow component of Upper McCoy Branch may be flowing down the spillway at a near constant rate regardless of seasonal weather patterns.

Although the United States Department of Energy (DOE) is in the process of addressing the aforementioned two concerns, it is prudent for TDEC to independently investigate these concerns.

5.5.2 Problem Statements

The capacity of the passive wetland treatment system to efficiently remove toxic metals from McCoy Branch may be diminishing. Also, diverted untreated dam spillway surface water flow may be contaminating McCoy Branch with metals.

5.5.3 Goals

Determine the concentrations of metals, primarily arsenic, in the surface waters of McCoy Branch and in the dam spillway surface water flow.

Understand if the remedial capacity of the wetland treatment system has decreased, compared to past performance.

Determine if untreated dam spillway surface water flow is contaminating McCoy Branch, and evaluate if untreated dam spillway surface water flow down the spillway is constant regardless of seasonal weather patterns. Any surface water that bypasses the wetland treatment system could be a possible source of contamination to McCoy Branch.

Monitor DOE's activities to determine if physical changes to the wetland system are reducing its capacity to lower metals concentrations in McCoy Branch. The three primary physical changes include: The water flowing through the wetlands is not evenly dispersed; rather it is flowing around the edges via channelization.

The central portion of the wetlands is slightly elevated compared to the outer edges of the wetland, possibly due to sediment buildup, vegetation growth, and seasonal die-back over the years.

The cattail community has been somewhat displaced by an invasive grass species.

It is important to understand if implementing improvements to the wetland system are needed.

5.5.4 Scope

This project will be conducted entirely within the confines of the Y-12 Chestnut Ridge FCAP Site.

- On a bi-monthly and quarterly basis, field physical parameters will be measured.
- On a bi-monthly and quarterly basis, the flow rates of the dam leachate entering (influent) and exiting the wetlands system (effluent) and the surface water flowing down the dam spillway will be monitored.
- On a quarterly basis, surface water site samples and associated quality control samples will be collected.
- On a quarterly basis, the collected water samples will be submitted to the State of Tennessee Department of Health Nashville Environmental Laboratory (TDH-NEL) for metals analysis. Each monitoring and/or sampling event will be completed in one working day or less.
- On a quarterly basis, TDH-NEL analytical final results reports will be reviewed. On an annual basis, an environmental monitoring report (EMR) encompassing a review of field observations, field measurements, and TDH-NEL analytical data will be published and submitted to the public.
- On a continual basis, DOE investigations and/or action plans to address site issues will be reviewed and monitored.

Some site conditions not included in the scope of this project include:

- Field radiological scanning of personnel, monitoring, and/or sampling equipment will not be conducted as the risk for human exposure to the radionuclide ^{228}Th and its daughters is negligible.
- Coal ash, sediment, and/or soil samples will not be collected and submitted to TDH-NEL for radiological and/or metals analyses.
- Benthic macroinvertebrates will not be collected for TDEC quantification and identification.

- Fish will not be collected for TDEC quantification and identification and submitted to TDH-NEL for radiological and/or metals analyses.

Assumptions made to define this scope are as follows:

- The 2013 RER specifies that TN AWQC will be used solely for comparative purposes to track the reduction in “contamination migration to surface water”. The ROD does not mandate that contaminant concentrations must be in compliance with TN AWQC. Therefore, the latest 2015 TN AWQC (April revision) is being used for comparative purposes.
- Between the time of the 1997 RA and 2016, the comparison of toxicity risks for human exposure to alpha decay emissions from 228Th and its daughters indicates a slight increase in risk to human health. As RA institutional controls continue to restrict access to the site, human exposure to harmful alpha radiation remains negligible (DOE 2016).

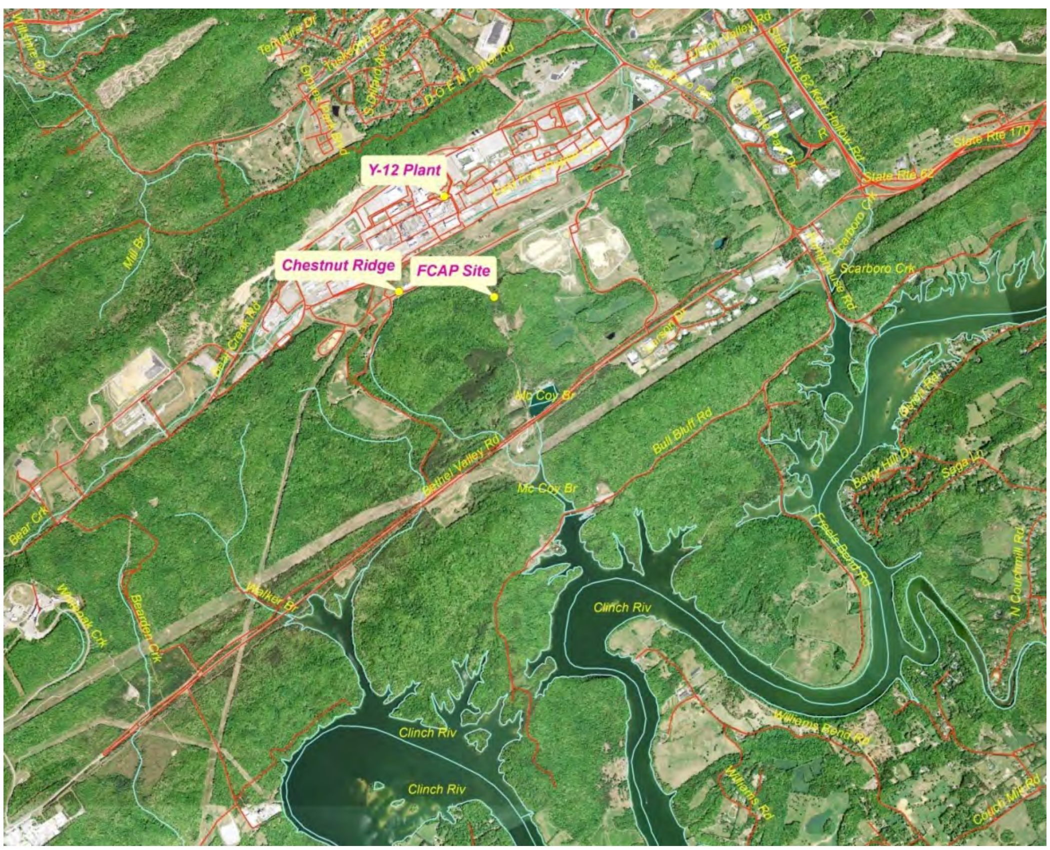


Figure 5.42: Y-12 Chestnut Ridge FCAP Satellite Site Map

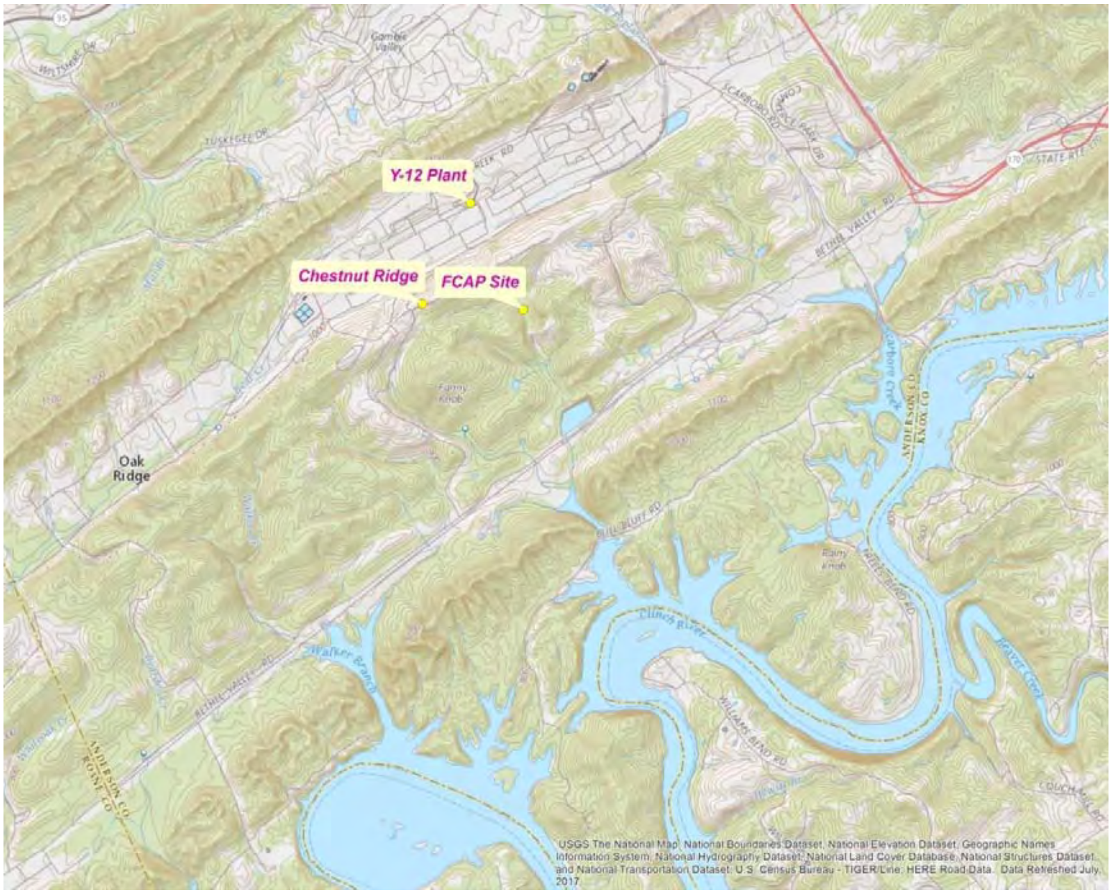


Figure 5.43: Y-12 Chestnut Ridge FCAP Topographical Site Map

5.5.5 Methods, Materials, Metrics

Flow rates of the wetland treatment system influent, the wetland treatment system effluent, and surface water flowing down the dam spillway were measured by recording how long it took to fill an 8.85 liter (2.34 gallon) bucket with water.

The field physical parameters of temperature, pH, conductivity, and dissolved oxygen were measured with a YSI Professional Plus water quality instrument. The instrument was calibrated according to the manufacturer's procedures. All field measurements were recorded in the FCAP bound field logbook.

Five surface water site samples were collected. At a minimum, field quality control (QC) samples were collected at a frequency of one for every ten samples; accordingly, one trip blank, one field blank, and one sample duplicate was collected. Therefore, a total of eight water samples were collected per quarterly sampling event.

TABLE 5.25: BI-MONTHLY AND QUARTERLY MONITORING LOCATIONS/TASKS

Sample ID	Location	Frequency	Tasks
SW-1	Dam spillway flow	Bi-Monthly	PP, FR
		Quarterly	PP, FR, SC
SW-2	Influent point of the wetland	Bi-Monthly	PP, FR
		Quarterly	PP, FR, SC
SW-3	Effluent point of the wetland	Bi-Monthly	PP, FR
		Quarterly	PP, FR, SC
SW-4	Confluence of the dam spillway flow and wetland effluent	Bi-Monthly	PP
		Quarterly	PP, SC
SW-5	South exit of the McCoy Branch Bethel Valley Road culvert	Bi-Monthly	PP
		Quarterly	PP, SC

PP = Physical parameters are measured FR = Flow rates are measured
SC = Surface water samples are collected

The water samples were collected using the grab methodology specified in the TDEC Division of Water Pollution Control Quality System Standard Operating Procedure (SOP) for Chemical & Bacteriological Sampling of Surface Water, Revision 4, Effective Date: August 1, 2011 (TDEC 2011).

Collected surface water and field quality control samples were packed and shipped to Tennessee Department of Health (TDH) in accordance with the TDEC Procedures for Shipping Samples to the State Lab in Nashville, SOP No.: 101, Revision 3/2/15 (TDEC-DOE- O 2015).

The surface water sampling kit included Nano pure water, one liter metals plastic sample bottles preserved with nitric acid, and sample tags obtained from TDH-NEL prior to sample collection.

The QC and surface water site samples were only analyzed for metals. (Table 5.26)

TDH-NEL analytical final results data were compared to 2015 TN AWQC (April revision) to track the reduction in “contaminant migration to surface water”. Arsenic was the primary contaminant of concern.

Figure 5.44: FCAP Monitoring/Sampling Locations Satellite Map

TABLE 5.26: METALS ANALYTICAL SUITE

Analyte	Test	Method	Performing Lab
Aluminum	ICP-MS	200.8	TDH
Arsenic	ICP-MS	200.8	TDH
Iron	ICP-OES	200.7	TDH
Manganese	ICP-MS	200.8	TDH
Mercury	Total Mercury	245.1	TDH
Selenium	ICP-MS	200.8	TDH
Zinc	ICP-MS	200.8	TDH

Figure 5.45: FCAP Monitoring/Sampling Locations Topographical Map

5.5.6 Deviations from the Plan

There were no deviations from the FCAP 2018 FY EMP to report.

5.5.7 Results from Analysis

The bi-monthly monitoring and quarterly sampling event dates are presented in Table 5.27: the quarterly sampling dates are highlighted in yellow.

Data summaries of the bi-monthly monitoring and quarterly sampling physical parameters (temperature, pH, dissolved oxygen, and specific conductivity) are presented in Tables 5.28 – 5.31 and in the following.

TABLE 5.27: BI-MONTHLY AND QUARTERLY MONITORING EVENT DATES

1st Quarter	7/5/17	7/19/17	8/9/17	8/24/17	9/13/17	9/28/17
2nd Quarter	10/11/17	10/25/17	11/8/17	11/22/17	12/6/17	12/19/17
3rd Quarter	1/10/18	1/24/18	2/6/18	2/21/18	3/14/18	3/28/18
4th Quarter	4/11/18	4/25/18	5/9/18	5/23/18	6/6/18	6/20/18

- All of the temperature data fell within 2015 TN AWQC acceptance criteria. It is expected that the wetland influent (SW-2) would exhibit minimal change through the year as it is groundwater/leachate exiting from the dam base/outfall and entering the wetland treatment system. As the wetland effluent (SW-3) location is near SW-2, approximately forty yards downstream of SW-2, it is also expected to show minimal change. The dam spillway (SW-1), the confluence (SW-4), and the culvert (SW-5) all reflect the wide range of yearly seasonal temperature fluctuations.
- All of the pH data fell within 2015 TN AWQC acceptance criteria.
- All of the dissolved oxygen data fell within 2015 TN AWQC acceptance criteria, except SW-2 mean and minimum values. However; this was not an issue as ground water typically exhibits low dissolved oxygen values.
- All of the surface water locations (SW-1, SW-3, SW-4, and SW-5) specific conductivity values were less than those of the ground water outfall location (SW-2) values.

TABLE 5.28: Bi-Monthly and Quarterly Monitoring Temperature Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	TN AWQC*
Spillway (SW-1)	°C	10.9	2.2	23.6	7.2	<= 30.5a
Influent (SW-2)	°C	14.3	13.5	14.9	0.4	<= 30.5a
Effluent (SW-3)	°C	13.9	11.7	16.9	1.4	<= 30.5a
Confluence (SW-4)	°C	13.5	5.3	17.9	2.5	<= 30.5a
Culvert (SW-5)	°C	15.1	6.9	20.0	4.5	<= 30.5a

* 2015 State of Tennessee Ambient Water Quality Criteria (April Revision)

[a] Fish and Aquatic Life / Recreational Water and Organisms

TABLE 5.29: Bi-Monthly and Quarterly Monitoring PH Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	TN AWQC*
Spillway (SW-1)	none	7.54	7.04	8.32	0.43	between 6-9[a]
Influent (SW-2)	none	7.09	6.60	7.46	0.20	between 6-9[a]
Effluent (SW-3)	none	7.38	6.86	7.67	0.23	between 6-9[a]
Confluence (SW-4)	none	7.39	6.97	7.77	0.19	between 6-9[a]
Culvert (SW-5)	none	7.43	7.04	8.01	0.24	between 6-9[a]

* 2015 St ate of Tennessee Ambient Water Quality Criteria (April Revision)

[a] Fish and Aquatic Life / Recreational Water and Organisms

TABLE 5.30: Dissolved Oxygen

MONTHLY AND QUARTERLY	Units	Mean	Minimum	Maximum	Standard Deviation	TN AWQC*
Spillway (SW-1)	mg/L	9.72	7.94	12.30	1.65	> 5.0[a]
Influent (SW-2)	mg/L	**3.30**[b]	**1.36**[b]	6.15	1.17	> 5.0[a]
Effluent (SW-3)	mg/L	8.67	6.67	10.50	0.88	> 5.0[a]
Confluence (SW-4)	mg/L	9.05	6.74	12.37	1.11	> 5.0[a]
Culvert (SW-5)	mg/L	7.09	5.50	8.76	0.82	> 5.0[a]

* 2015 St ate of Tennessee Ambient Water Quality Criteria (April Revision)

a Fish and Aquatic Life

b Value is less than TN AWQC

TABLE 5.31: Bi-Monthly and Quarterly Monitoring Specific Conductivity Data

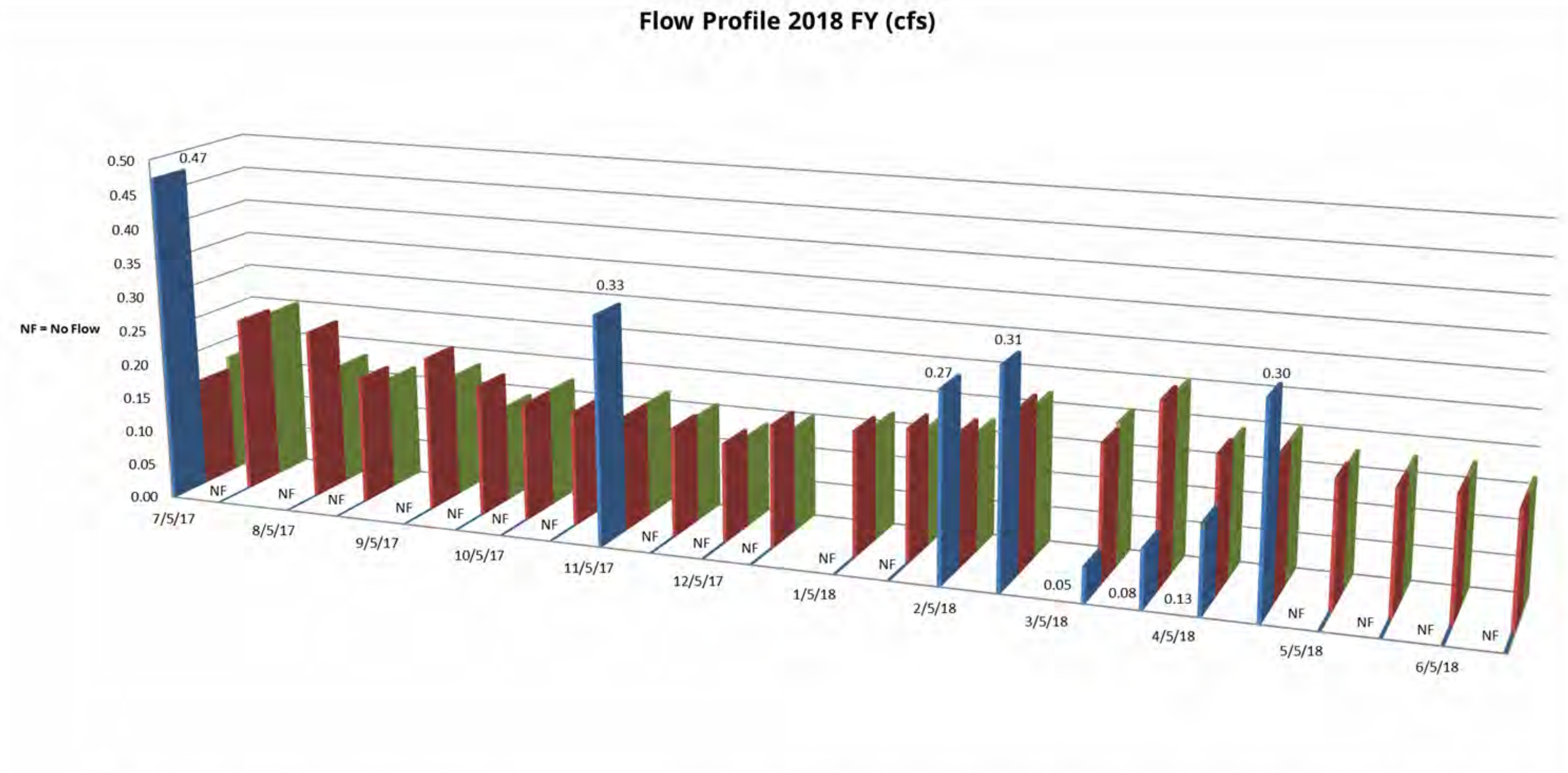
Site	Units	Mean	Minimum	Maximum	Standard Deviation	TN AWQC*
Spillway (SW-1)	µS/cm	140.2	119.2	174.7	19.9	n.a.
Influent (SW-2)	µS/cm	321.7	273.3	344.6	20.9	n.a.
Effluent (SW-3)	µS/cm	316.7	272.9	336.2	19.7	n.a.
Confluence (SW-4)	µS/cm	293.7	166.9	337.6	53.8	n.a.
Culvert (SW-5)	µS/cm	257.9	234.9	287.1	17.9	n.a.

* 2015 State of Tennessee Ambient Water Quality Criteria (April Revision)

n.a. = Not applicable

The bi-monthly monitoring and quarterly sampling water flow data is presented in Figure 5.29.

The SW-1 measurements indicate intermittent dam spillway flow activity with variable flow volumes. In contrast, both SW-2 and SW-3 measurements indicate a constant wetland influent/effluent flow pattern with similar flow volumes.



	7/5/17	7/19/17	8/9/17	8/24/17	9/13/17	9/28/17	10/11/17	10/25/17	11/8/17	11/22/17	12/6/17	12/19/17	1/10/18	1/24/18	2/6/18	2/21/18	3/14/18	3/28/18	4/11/18	4/25/18	5/9/18	5/23/18	6/6/18	6/20/18
Spillway (SW-1)	0.47	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0.27	0.31	0.05	0.08	0.13	0.30	0	0	0	0
Influent (SW-2)	0.16	0.25	0.25	0.18	0.22	0.19	0.17	0.16	0.16	0.16	0.14	0.18	0.18	0.19	0.19	0.23	0.20	0.26	0.20	0.20	0.18	0.17	0.17	0.16
Effluent (SW-3)	0.17	0.25	0.18	0.16	0.18	0.14	0.17	0.19	0.16	0.15	0.13	0.15	0.16	0.17	0.17	0.22	0.20	0.25	0.19	0.20	0.17	0.17	0.17	0.16

Figure 5.46: Bi-Monthly and Quarterly Monitoring Flow Data

The quarterly sampling water metals data (aluminum, arsenic, iron, manganese, mercury, selenium, and zinc) is presented in figures 5.47 – 5.53.

- Arsenic, iron, manganese, and zinc depict similar concentration profiles for all four sampling events.
- SW-3 (wetland effluent) metal concentrations were consistently less than their associated SW-2 (wetland influent) metal concentrations.
- SW-1 (dam spillway) metal concentrations were minimal for the first sampling event.
- There was no dam spillway flow at the three subsequent sampling events; additional SW- 1 metals data is unavailable.

During all four sampling events, SW-4 (confluence) metal concentrations were unexpectedly greater than the associated effluent SW-3 metal concentrations. SW-4's location is very near to SW-3's (with SW-4 located approximately fifteen yards downstream of SW-3). (Figure 5.45) SW-1's intermittent surface water flow added negligible amounts of metals to SW-4). It was anticipated that SW-4 metal concentrations would be consistently less than or equal to (≤) SW-3 metal concentrations due to the combination of SW-1 and SW-3 contributing surface water inputs to the sampling location at SW4. The source of elevated metals results seen at SW4 is undetermined.

A review of the TDEC protocols used to collect the quarterly samples and the TDH-NEL quarterly analytical data indicated the SW-4 metals data was valid. It is not understood what chemical and/or physical mechanism(s) is causing this unusual situation.

- For all four sampling events, the SW-5 (Bethel Valley road culvert) metal concentrations were either low, low-estimated (J coded), or non-detect (U coded).
- Aluminum had the same profile as the arsenic/iron/manganese/zinc group with one exception; SW-3 metal concentrations were greater than the associated SW-2 metal concentrations.
- For all four sampling events, SW-3 arsenic concentrations were greater than their associated 2015 TN Recreational Water & Organisms AWQC of 10.0 µg/L. However as the 2013 RER specifies, the TN AWQC standards will be used solely for comparative purposes to track the reduction in "contamination migration to surface water". The ROD (DOE, 1996) does not mandate that contaminant concentrations must be in compliance with TN AWQC.
- For all four sampling events mercury concentrations were non-detect (U).
- For all four sampling events, selenium concentrations were either low-estimated (J) or non- detect (U).

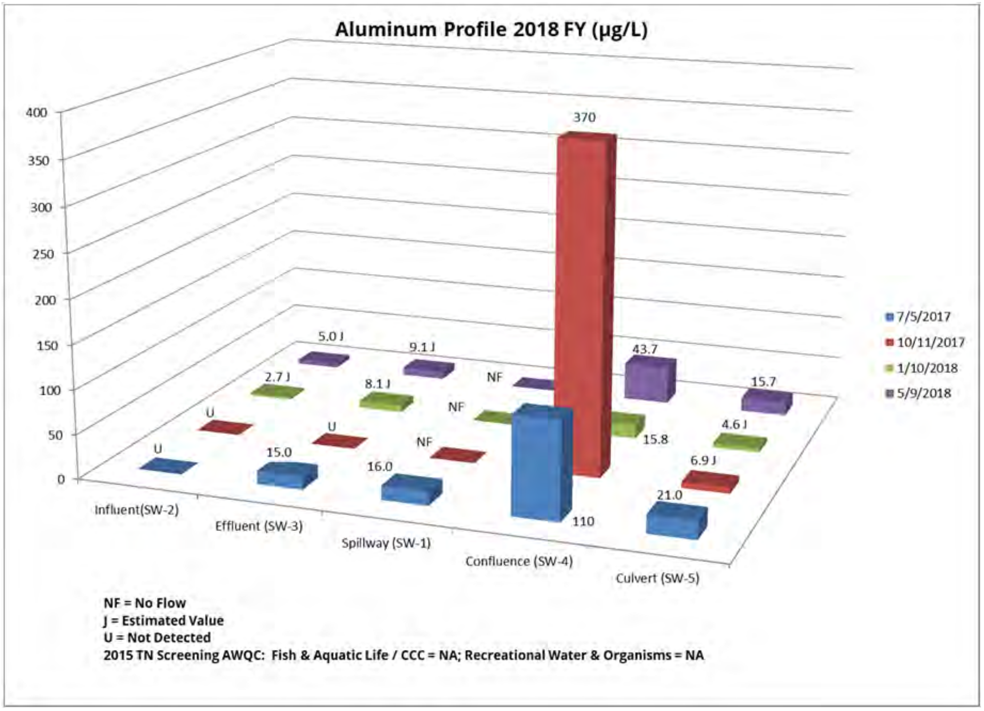


Figure 5.47: Quarterly Sampling Aluminum Data

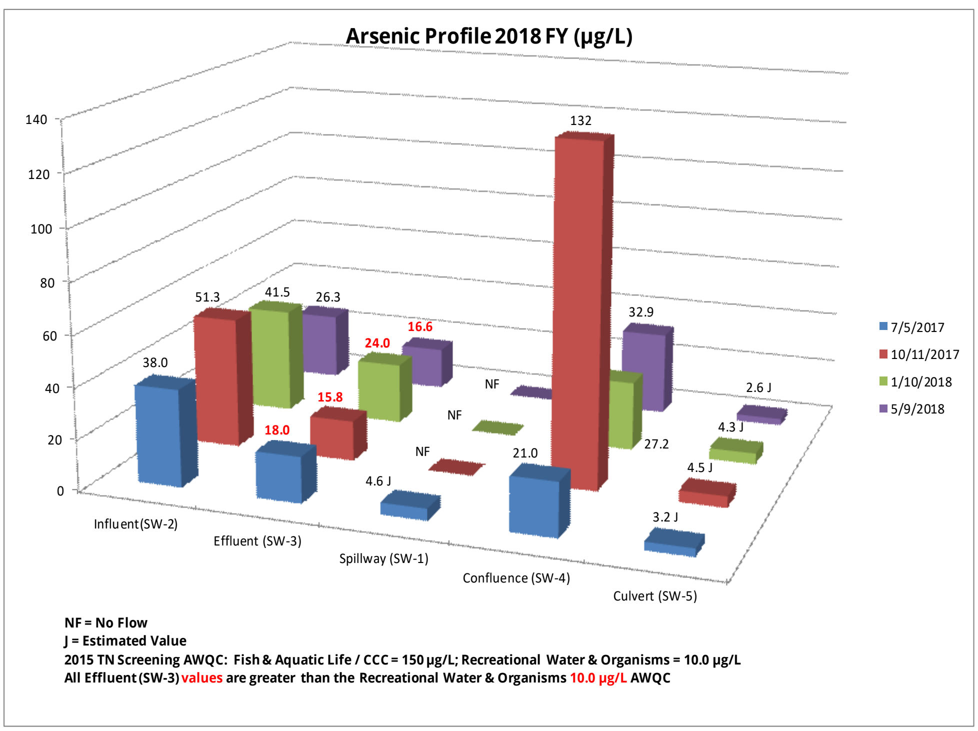


Figure 5.48: Quarterly Sampling Arsenic Data

Note for Figure 5.48: While data for all analytes were collected, the ROD focuses on Arsenic specifically, stating "reduce or eliminate contaminant entry into the McCoy Branch surface waters through enhancement of an existing wetland." That existing wetland currently acts as a natural passive treatment system. As a result of this focus, arsenic data is highlighted in figure 5.48.

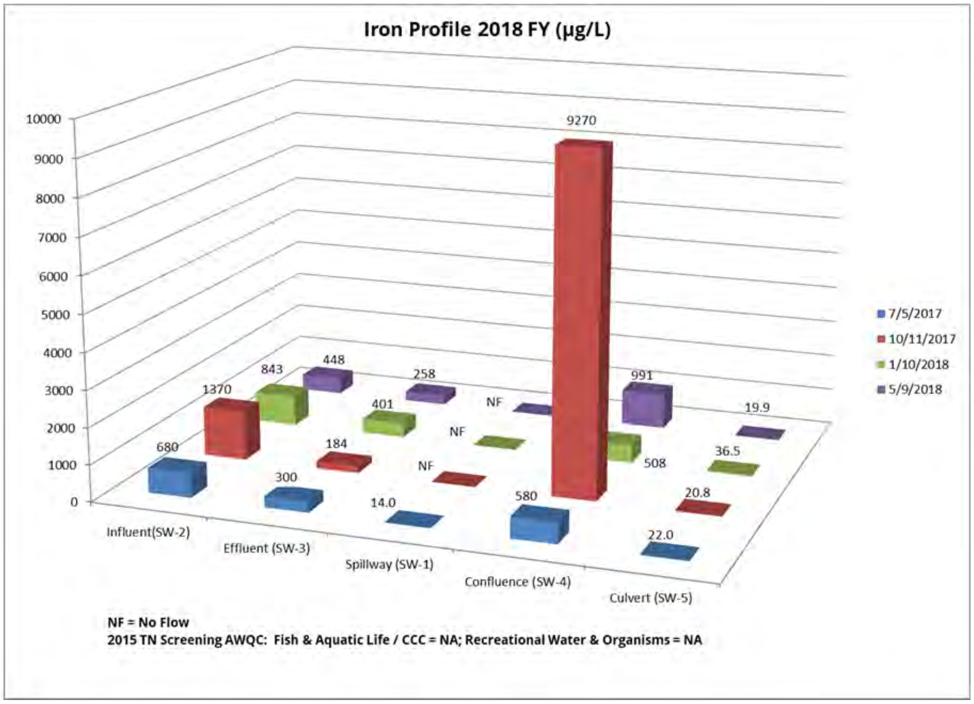


Figure 5.49: Quarterly Sampling Iron Data

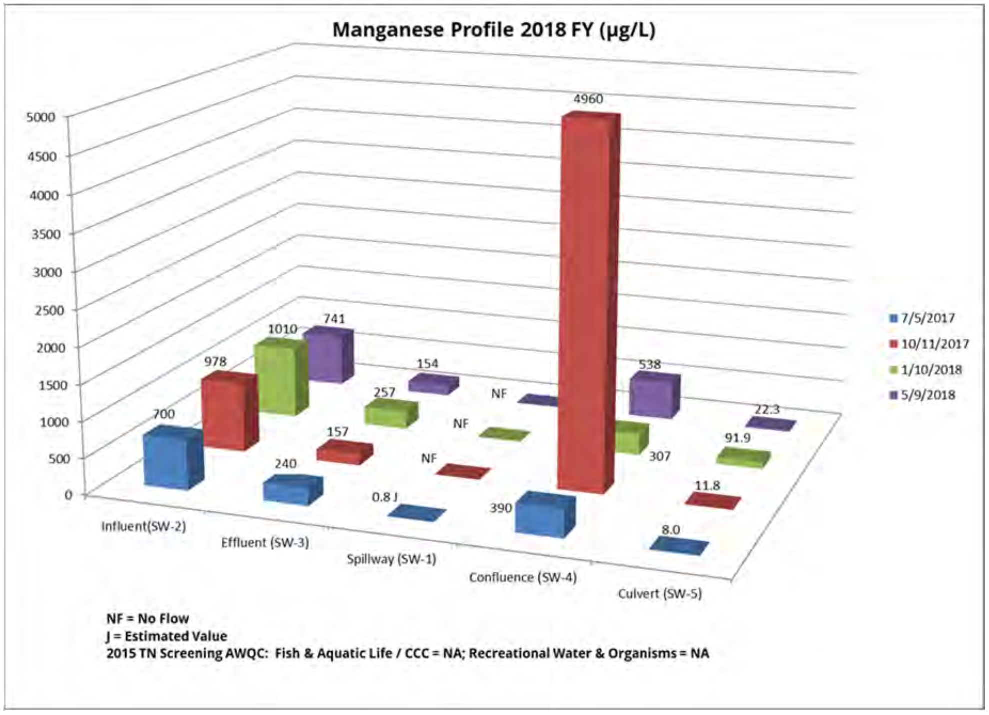


Figure 5.50: Quarterly Sampling Manganese Data

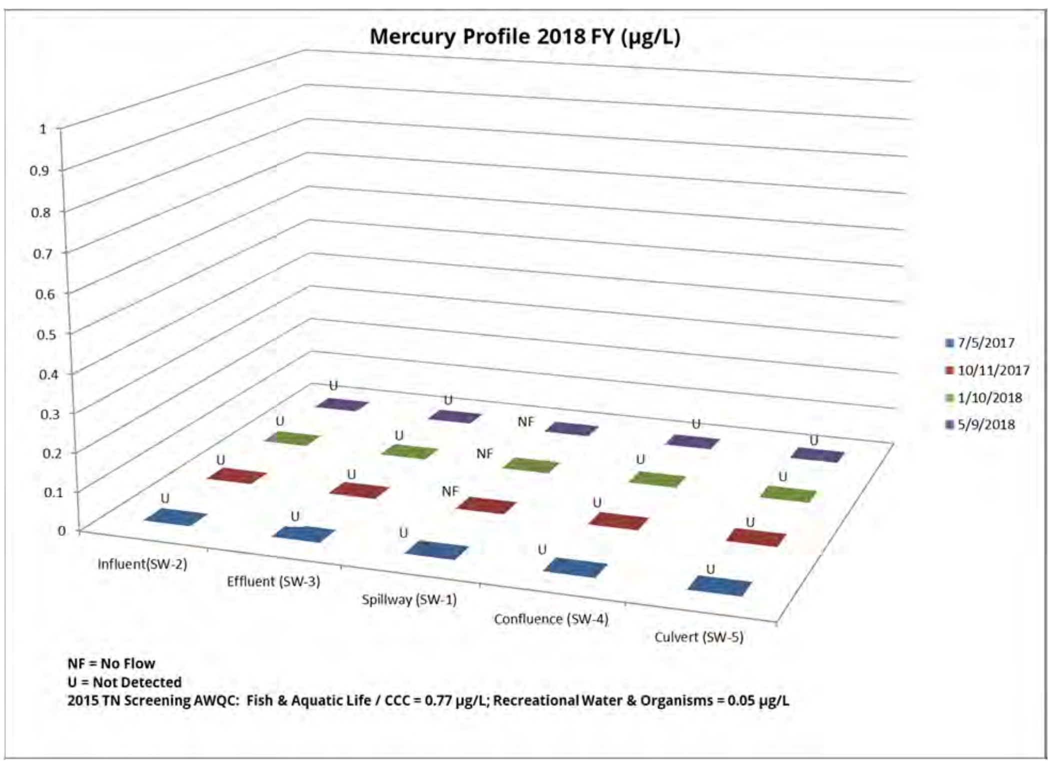


Figure 5.51: Quarterly Sampling Mercury Data

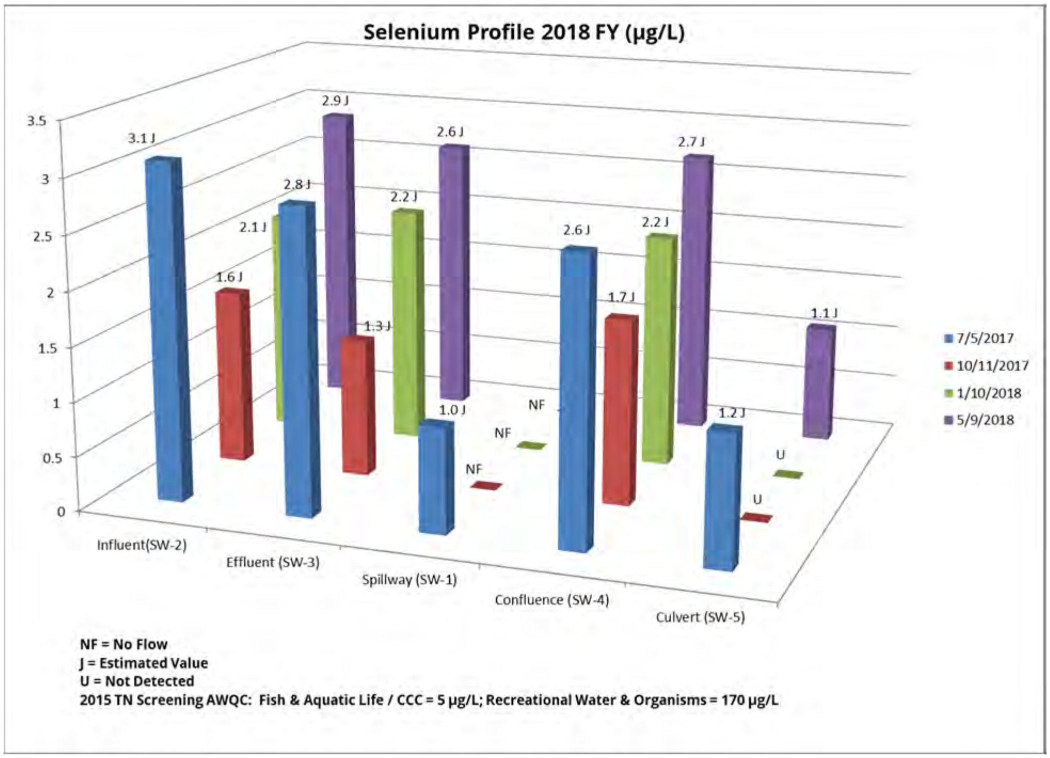


Figure 5.52: Quarterly Sampling Selenium Data

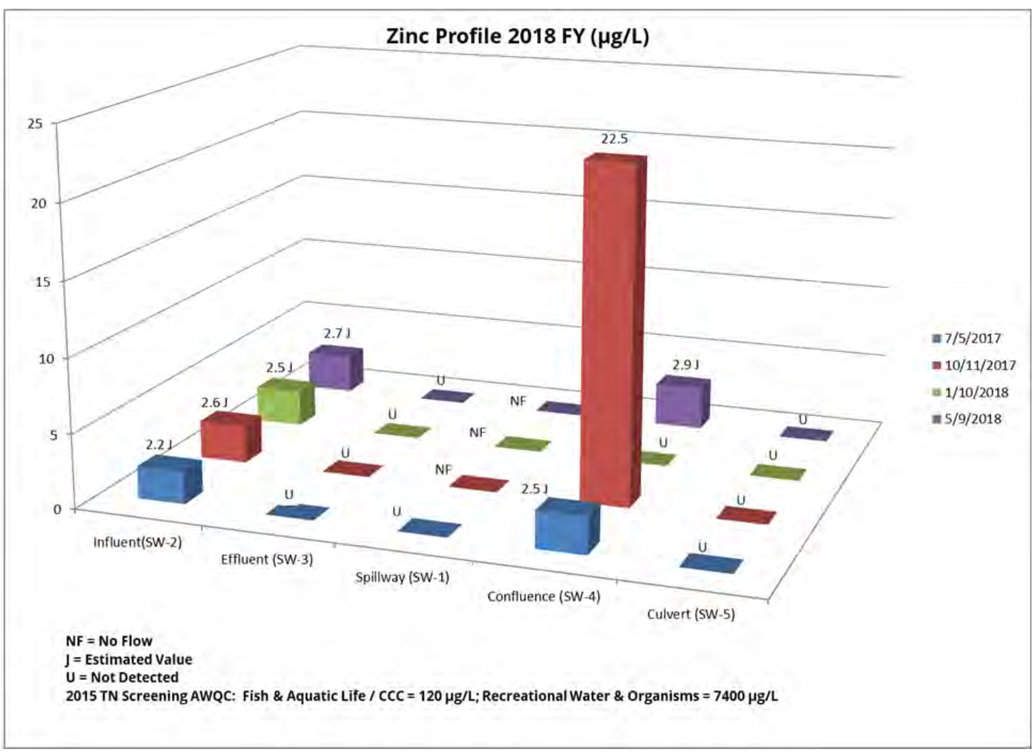


Figure 5.53: Quarterly Sampling Zinc Data

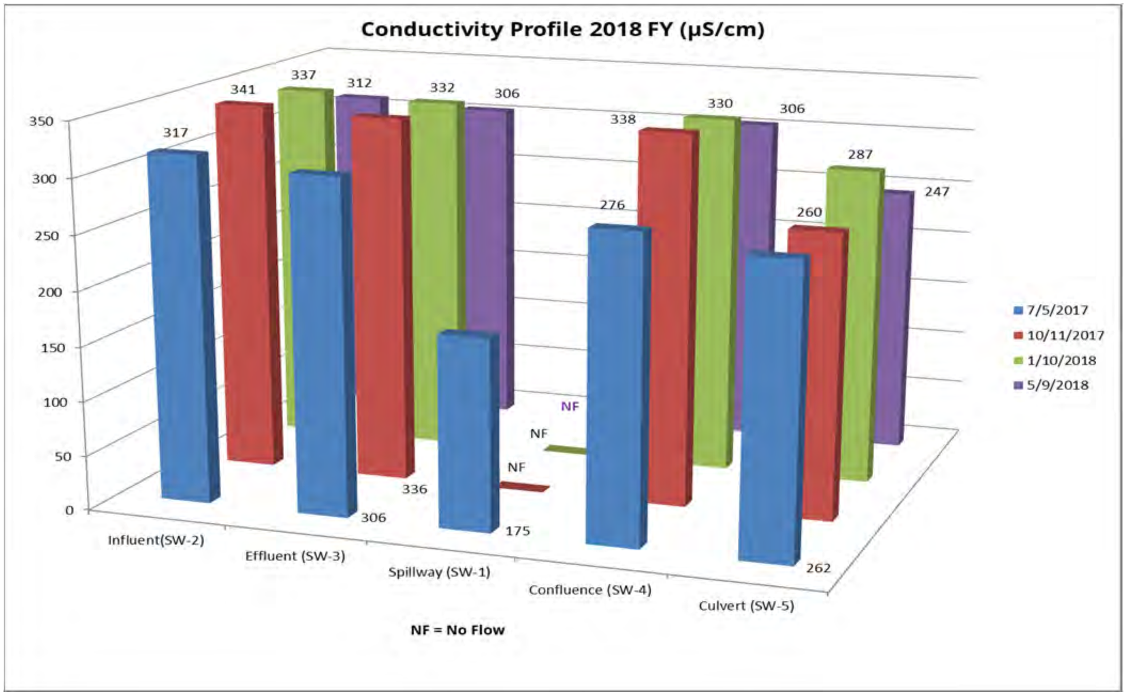


Figure 5.54: Quarterly Sampling Specific Conductivity Data

The data from quarterly sampling for specific conductivity is presented in Figure 5.54.

For the four sampling events at the five sampling locations, the specific conductivity values are similarly low.

A summary of quarterly arsenic percent reductions in treated wetland influent (SW-2) is presented in Figure 5.55.

Between the completion of the RA in 1997, and late 2015, as published by the DOE, the wetland treatment system consistently removed approximately 95% of arsenic from SW-2 (DOE, 2016). However; the TDEC 2018 FY quarterly sampling of arsenic indicated that the wetland treatment system only removed approximately 50% of arsenic from SW-2. Consequently; the TDEC 2018 FY data indicated the remedial capacity of the wetland treatment system to efficiently remove arsenic from SW-2 significantly decreased when compared to past performance.

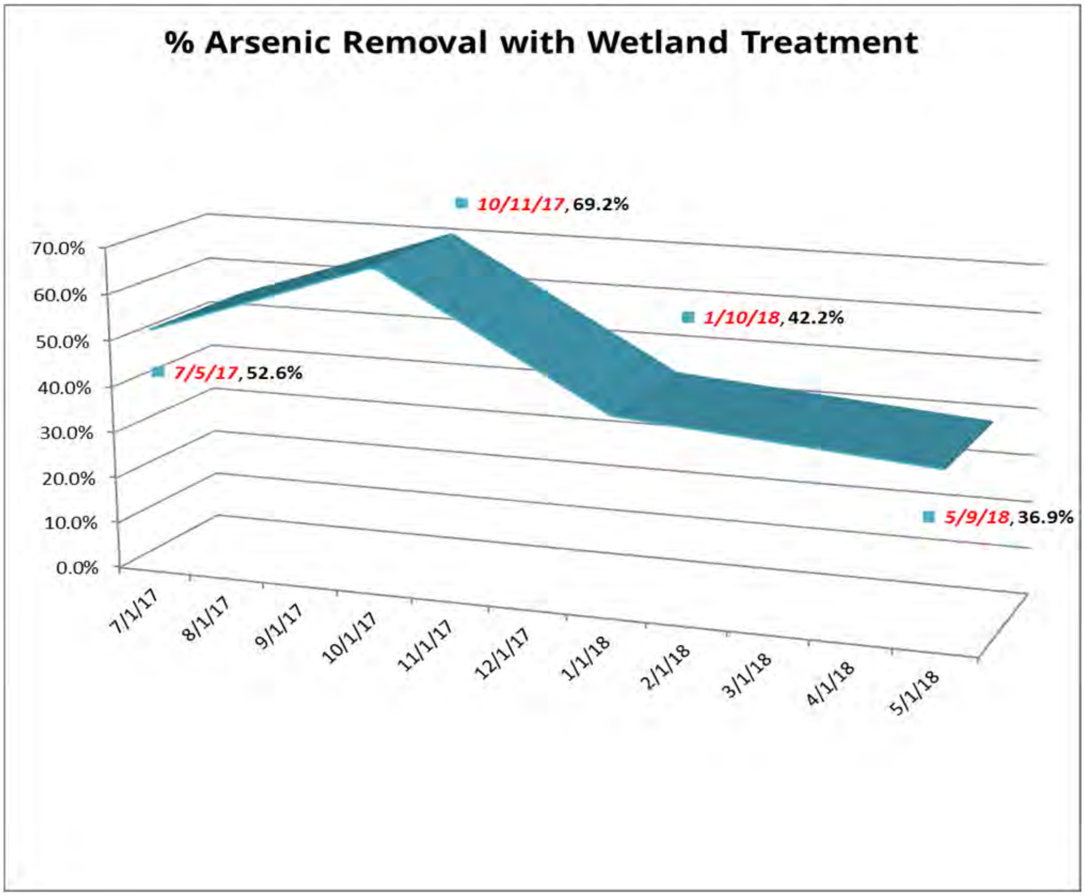


Figure 5.55: Quarterly Percent Arsenic Reductions in Treated Wetland Influent (SW-2)

5.5.8 Conclusions

The data from the quarterly sampling of metals indicates the remedial capacity of the passive wetland treatment system to efficiently remove metals, especially arsenic, from McCoy Branch has significantly diminished. It may be necessary for DOE to install a new wetland treatment system and/or upgrade the existing wetland treatment system to remedy this issue.

In addition, the bi-monthly and quarterly monitoring flow data indicates diverted untreated dam spillway surface water (SW-1) flow is intermittent. When SW-1 surface water flow is present, the amount of metals added to McCoy Branch is insignificant.

As previously discussed, it is not understood what chemical and/or physical mechanism(s) is causing the unusual confluence (SW-4) metals situation.

5.5.9 Recommendations

DOE intends to present their FCAP final investigation plan in the DOE 2019 Remedial Effectiveness Report (RER); the investigation monitoring results will be presented in future RERs. It is recommended that DOE FCAP investigation monitoring results be reviewed by TDEC personnel on an annual basis and continue oversight and surveillance of DOE activities by TDEC DoR-OR.

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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 accepted as 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, DoR-OR 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 ORR exit pathway streams.

Due to the complex nature of the ORR National Priority List (NPL) site sediment monitoring is necessary for the long term. An ambient sediment project has been implemented by the Tennessee Department of Environment and Conservation (TDEC) Division of Remediation (DoR), Oak Ridge (OR), each year since 1994. The project began with the monitoring of Clinch River water quality at five locations near the Oak Ridge Reservation (ORR). This project has evolved over the years and locations and frequency of sampling have changed.

6.1.2 Problem Statements

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

- From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury to East Fork Poplar Creek by spills and leakage from subsurface drains, building foundations, contaminated soils, and purposed discharge of wastewater containing mercury. (Turner and Southworth, 1999)
- East Fork Poplar Creek 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)
- ORNL has been releasing low-level radioactive liquid wastes to the Clinch River via White Oak Creek since 1943. (Pickering, 1970)

- The Clinch River received approximately 665 curies of cesium-13 (Cs-137) from White Oak Creek 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

This program monitors and samples for sediment contaminants in waterways that have been impacted by past and current activities on the ORR. This project is limited to only the tributaries that drain the ORR and the Clinch River from the mouth of White Oak Creek 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 (Tables 6.1 and 6.2) at points on the major exit pathway streams of the ORR:

- Bear Creek
- Northwest Tributary 5 of Bear Creek (NT5)
- East Fork Poplar Creek
- Mitchell Branch
- Clinch River
- Mill Branch (the designated background location)

Sampling is conducted in October. Sampling is not conducted at White Oak Creek due to the Sr-90 levels in the sediment. Sampling is conducted according to the Standard Operating Procedure for 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 the pre-determined or 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

The schedule for sediment sampling at each of six stations occurs annually in October. The six stations are listed in Tables 6.1 & 6.2 and shown on Figure 6.1, Map of Sampling Stations (Figure 6.1).

Table 6.1: Proposed Ambient Sediment Sampling Stations and Sample Frequency

				Analyses				
Site DWR Name	**DOE-O Site Description**	**DoR-OR Station**	**# samples**	**Gross a/b**	**Gamma**	**Sr-89, 90**	**U Isotopic**	**Metals**
BEAR002.0RO	Bear Creek Mile 2.0	BCK 3.3	1	1	1	1	1	1
BEAR006.5T0.1AN	N. Tributary 5 of Bear Creek	NT5	1	1	1	1	1	1
EFPOP003.9RO	East Fork Poplar Creek Mile 3.9	EFK 6.3	1					1
MITCH000.1RO	Mitchell Branch Mile 0.1	MIK 0.1	1	1	1	1	1	1
CLINC020.3RO	Clinch River Mile 20.3	CRK 32.7	1	1	1	1	1	
FECO67I12	Mill Branch Mile 1.0	MBK 1.6	1	1	1	1	1	1
********.***-FD	Field Duplicate	FD	1	1	1	1	1	1
		Totals:	7	6	6	6	6	6
Metals suite includes: arsenic, barium, beryllium, boron, cadmium, chromium, copper, lead, mercury, nickel, uranium, and zinc.								

Table 6.2: Ambient Sediment Sampling Rationale

Ambient Sediment Sampling Locations 2017-2018					
Sampling Location	ID	Alternate ID	Sampling Rationale	Latitude	Longitude
Clinch River km 32.7	CLINC020.3RO	CRK 32.7	Evaluate the effect of contaminant sources in the White Oak Creek watershed on sediment quality in the Clinch River.	35.90034	-84.33959
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 Bear Creek.	35.96603	-84.29024

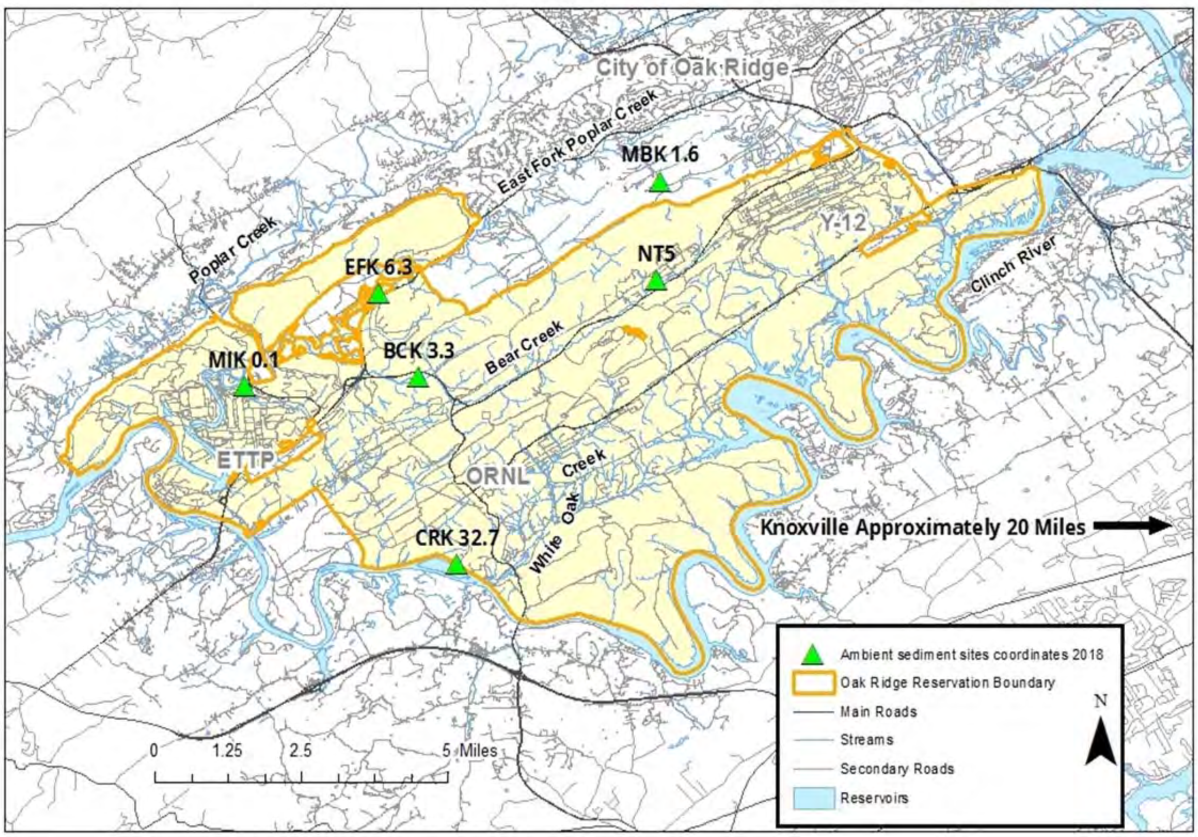


Figure 6.1. Map of Ambient Sediment Sampling Stations

6.1.6 Deviations from the Plan

This Project reports no deviations from its Project Plan.

6.1.7 Results from Analysis

Sediment samples were collected at all stream locations on 10/18/2017 and at CRK 32.7 on 11/21/2017 after river levels decreased enough to allow wading at the sampling point. Samples were collected using the methods described in the DOR-OR *Sediment Monitoring Standard Operating Procedure (TDEC 2017)*. Grab samples were collected by hand with a stainless steel spoon.

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 State Laboratories 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, and uranium. Samples from all stations, except EFK 6.3, were analyzed for gross alpha, gross beta, gamma radionuclides, strontium-89/90, and isotopic uranium.

Metals Analyses

The metals results were compared to the Consensus Based Sediment Quality Guidelines (CBSQGs) as well as to the data results from the background sampling location, Mill Branch km 1.6 (MBK 1.6). Mill Branch is a tributary of East Fork Poplar Creek 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 that were 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 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 (EFK 6.3, MIK 0.1) and nickel (MIK 0.1). The mercury concentration in sediment at EFK 6.3 (5.82 mg/kg) exceeds the PEC of 1.1 mg/kg (MacDonald et al. 2000). The mercury in East Fork Poplar Creek 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. The TECs were exceeded for several metals (arsenic, chromium, copper, lead, nickel, mercury, and zinc) at MIK 0.1.

Table 6.3: Summary of Metals Data

Ambient Sediment Metals Results 2017-2018									
Parameter	**Units**	**BCK 3.3**	**NT5**	**EFK 6.3**	**MIK 0.1**	**CRK 32.7**	**MBK 1.6†**	**TEC***	**PEC****
Arsenic	mg/kg	3.74	4.97	2.04	14.6	2.48	1.56	9.8	33
Barium	mg/kg	74.7	142		130	35.2	49	n.a.	n.a.
Beryllium	mg/kg	0.565	0.57	0.327	0.663	0.22	0.426	n.a.	n.a.
Boron	mg/kg	27.8	34.2	17.4	55.3	0.84	23.8	n.a.	n.a.
Cadmium	mg/kg	0.345	0.07	0.256	0.934	0.0911	U; (0.05)	0.99	5
Chromium	mg/kg	17.9	19.2	12.2	73.8	5.01	12.5	43	110
Copper	mg/kg	7.31	9.22	7.77	116	3.6	5.34	32	150
Lead	mg/kg	9.74	8.7	9.57	63.5	6.37	6.92	36	130
Mercury	mg/kg	0.12	0.09	5.82	2.82	0.017	0.0325	0.18	1.1
Nickel	mg/kg	12.7	15.3	6.54	267	4.64	7.97	23	49
Uranium	mg/kg	3.99	2.59	1.27	21.8	0.165	0.505	n.a.	n.a.
Zinc	mg/kg	29.4	53.6	35.1	271	21.8	18.4	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 Oak Ridge National Laboratory (ORNL) Risk Assessment Information System (RAIS). PRGs are isotope concentrations that correspond to estimated risk levels in various media. The PRGs in Table 6.4 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. White Oak Creek sediments were not sampled due to their known radiological contamination; sediments collected from White Oak Creek would not be cleared for release by UT-Battelle radiological technicians.

Table 6.4: Summary of Radiological Data

Ambient Sediment Radiological Results							
Parameter	**Units**	**BCK 3.3**	**CRK 32.7**	**MIK 0.1**	**NT5**	**MBK 1.6†**	**PRG**
Radioactivity, alpha	pCi/g	2.47	0.64	9.3	8.00	1.32	n.a.
combined standard uncertainty	pCi/g	0.38	0.26	1.1	0.37	0.30	
Radioactivity, beta	pCi/g	8.8	3.7	200.0	33.8	5.0	n.a.
combined standard uncertainty	pCi/g	1.2	1.1	10.0	2.1	1.2	
Actinium-228	pCi/g	0.89	0.47	1.75	1.39	0.93	2.95E+06
combined standard uncertainty	pCi/g	0.19	0.12	0.44	0.42	0.23	
Bismuth-214	pCi/g	0.5	U	3.12	0.85	0.84	3.11E+07
combined standard uncertainty	pCi/g	0.15	U	0.51	0.25	0.20	
Cesium-137	pCi/g	U	0.528	0.96	U	U	1.30E+03
combined standard uncertainty	pCi/g	n.a.	0.05	0.42	U	U	
Lead-212	pCi/g	0.53	U	1.8	0.92	0.72	6.37E+06
combined standard uncertainty	pCi/g	0.12	U	1	0.18	0.12	
Lead-214	pCi/g	0.63	0.39	2.8	0.74	0.66	1.95E+08
combined standard uncertainty	pCi/g	0.14	0.10	1.2	0.22	0.17	
Strontium-89	pCi/g	0.05	0.1	-1	1.0	-0.50	1.60E+05
combined standard uncertainty	pCi/g	1.7	1.1	1.4	1.8	1.80	
Strontium-90	pCi/g	0.07	0.12	0.51	0.57	0.36	6.47E+02
combined standard uncertainty	pCi/g	0.29	0.29	0.25	0.26	0.31	
Thallium-208	pCi/g	0.324	U	0.68	0.26	0.329	8.94E+07
combined standard uncertainty	pCi/g	0.084	U	0.17	0.11	0.083	
Uranium-234	pCi/g	1.23	0.36	28.5	8.33	0.68	2.81E+02
combined standard uncertainty	pCi/g	0.2	0.11	2.8	0.8	0.14	
Uranium-235	pCi/g	0.118	0.009	2.25	0.70	0.095	2.21E+02
combined standard uncertainty	pCi/g	0.07	0.026	0.35	0.15	0.055	
Uranium-238	pCi/g	2.24	0.171	8.37	1.5	0.49	3.10E+02
combined standard uncertainty	pCi/g	0.33	0.073	0.91	0.22	0.11	

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 East Fork Poplar Creek km 6.3 sediment mercury concentrations (5.82 mg/kg) exceed the PEC of 1.1 mg/kg (MacDonald *et al.* 2000). The mercury in East Fork Poplar Creek sediments results from historical activities at Y-12. Cadmium, which was not detected at the background site, was found at EFK 6.3 at 0.256 mg/kg.

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 North Tributary 5 (NT5) 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, it receives the flow from the sediment retention pond. NT5 contributed approximately 0.7 kg of uranium to Bear Creek in FY 2017 (DOE 2018).

Bear Creek km 3.3 sediment did not exceed any of the CBSQGs. However, CBSQGs have not been developed for uranium. The uranium value (3.99 mg/kg) was almost eight times that of the background stream (0.505 mg/kg).

The sediment sample collected from the Clinch River at km 32.7 was not contaminated in terms of metals. Most of the metals concentrations were less than the background values of the Mill Branch sediment.

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 East Fork Poplar Creek km 23.4, it is also recommended that radiological testing of sediment be resumed at EFK 6.3 to monitor for changes in sediment quality there.

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 that are introduced into aquatic systems often accumulate in sediments. Contaminants may accumulate in sediments such that their concentrations are higher than in the water column. Some sediment contaminants may be directly toxic to benthic organisms or may bioaccumulate in the food chain, creating health risks for wildlife and humans. Sediment analysis is an important aspect of environmental quality and impact assessment for rivers, streams, and lakes.

Mill Branch is a tributary of East Fork Poplar Creek and is used as a background stream. NT5 is the main outfall for the Environmental Management Waste Management Facility (EMWMF); EMWMF is a mixed-waste landfill that has received waste resulting primarily from ETTP decommissioning and demolition activities since 2002. Samples were analyzed for radiological activity and metals. Past sediment sampling activities by the Tennessee Department of Environment and Conservation, Division of Remediation, Oak Ridge Office (DoR-ORO) have shown that Poplar Creek and East Fork Poplar Creek have elevated levels of mercury in sediments. This mercury can be attributed to historical discharges from Y-12 and, to a lesser extent, East Tennessee Technology Park (ETTP).

6.2.2 Problem Statements

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

From 1950 to 1963, Y-12 released approximately 100 metric tons of elemental mercury to East Fork Poplar Creek by spills and leakage from subsurface drains, building foundations, contaminated soil, and purposed discharge of wastewater containing mercury. (Turner and Southworth, 1999)

East Fork Poplar Creek 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)

ORNL has been releasing low-level radioactive liquid wastes to the Clinch River via White Oak Creek since 1943. (Pickering, 1970)

The Clinch River received approximately 665 curies of cesium-13 (Cs-137) from White Oak Creek 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 East Fork Poplar Creek (EFPC), Mill Branch, and North Tributary 5 (NT5) by utilizing 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 Northwest Tributary 5 of Bear Creek (NT5), East Fork Poplar Creek, and Mill Branch (Table 6.5, Figure 6.2). Mill Branch is a background location. Samples are retrieved from the sediment traps at scheduled intervals throughout the year. Table 6.6 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 White Oak Creek due to the elevated Sr-90 levels in the sediment.

The standard operating protocol used for this project is the TDEC DoR-OR Standard Operating Procedure for Sediment Trap Sampling (TDEC DoR-OR 2017). Suspended sediment samples are collected by using fixed sediment collection devices (traps). Sediment traps are installed in a stream bed and positioned to accommodate the most considerable flow through the body of the trap. Suitable sites are limited in a stream; careful consideration must be given to the selection of installation locations for the sediment traps. To completely immerse the sediment traps, water flow and depth must be sufficient.

Following a collection period (a minimum of six 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 6.5: Sampling Locations

Sampling Location	DWR ID	Alt. ID	Sampling Rationale	Site Latitude	Site Longitude
East Fork Poplar Creek Mile 14.5	EFPOP014.5AN	EFK 23.4	Surveillance of suspended sediment at point where EFPC leaves DOE property.	35.99596	-84.24004
Mill Branch Mile 1.0	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	NT5	Surveillance of suspended sediment downstream of EMWMF	35.96603	-84.29024

Table 6.6: Deployment Dates of Sediment Traps

Sampling Station	Deployed	Sampled
EFK 23.4	9/21/2017	1/29/2018
EFK 23.4	4/12/18	7/16/2018
NT5	9/21/2017	7/16/2018
MBK 1.6	6/12/2017	7/16/2018

Sediment traps were deployed at the following stream locations: East Fork Poplar Creek km 23.4 (EFK 23.4), NT5, and at Mill Branch km 1.6 (MBK 1.6) (as shown in Figure 6.2).

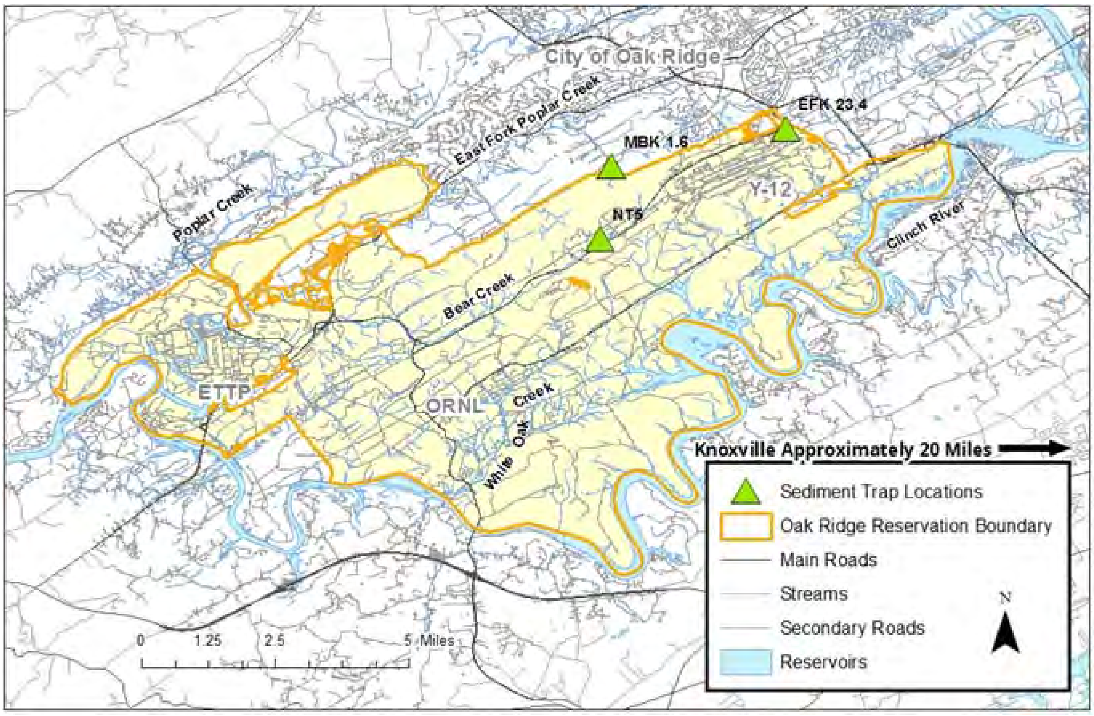


Figure 6.2: Sampling Locations

6.2.6 Deviations from the Plan

The only deviation from the EMP was a mid-year interruption of the sampling period at EFK 23.4 (Table 6.5). The first deployment of the tandem sediment traps at EFK 23.4 was from 9/21/17 to 1/29/18. The sediment trap was sampled on 1/29/18 in response to a water main break at Y-12. Due to a laboratory error, the mercury sample data was not valid. Other metals data and radiological data from the 1/29/18 samples were valid. The tandem sediment traps at EFK 23.4 were redeployed on 4/12/18 and sampled on 7/16/18.

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).

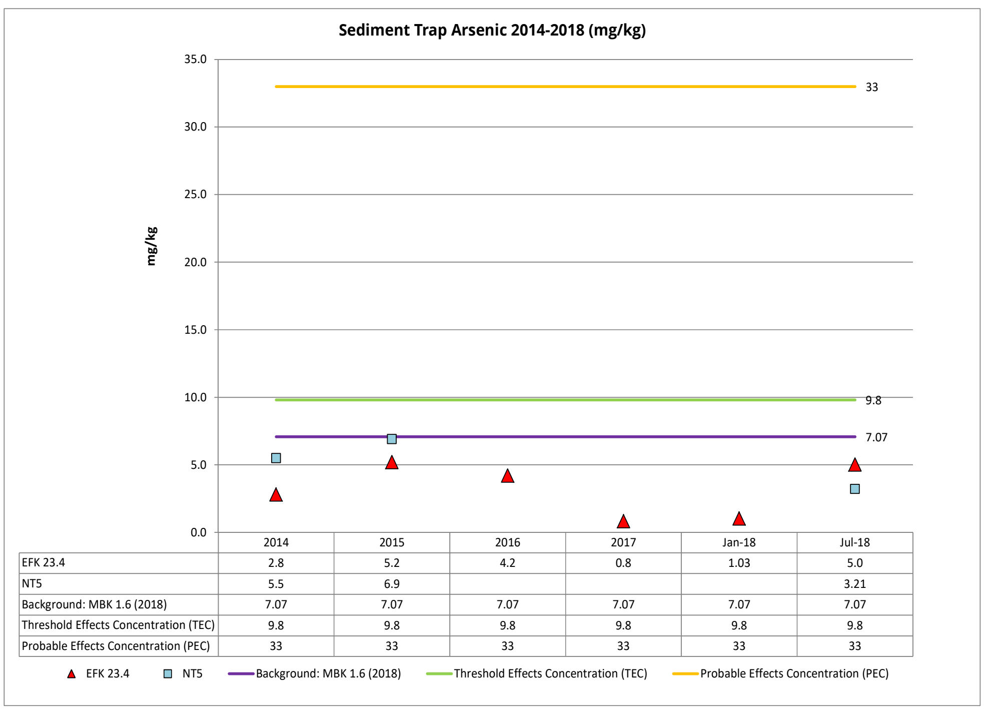
In addition, sample results were compared with data from a background sediment trap sampling station, Mill Branch km 1.6 (MBK 1.6).

The following graphs and associated charts follow the sediment data through five years of sampling. There are some omissions in the charts to be noted:

- Only EFK 23.4 was sampled in January of 2018.
- In 2016 and 2017, the sediment trap at NT5 had an insufficient yield for metals analysis.
- The background stream's (Mill Branch) data is shown in the graphs as a bar; this bar symbolizes only the data from 2018.
- Blanks in the following charts (figures 6.3-6.12), mean that the parameter was not analyzed for in that year.

Arsenic

Arsenic at both EFK 23.4 and NT5 is lower than the background sampling station, Mill Branch km 1.6, and also lower than the Threshold Effects Concentration (Figure 6.3).

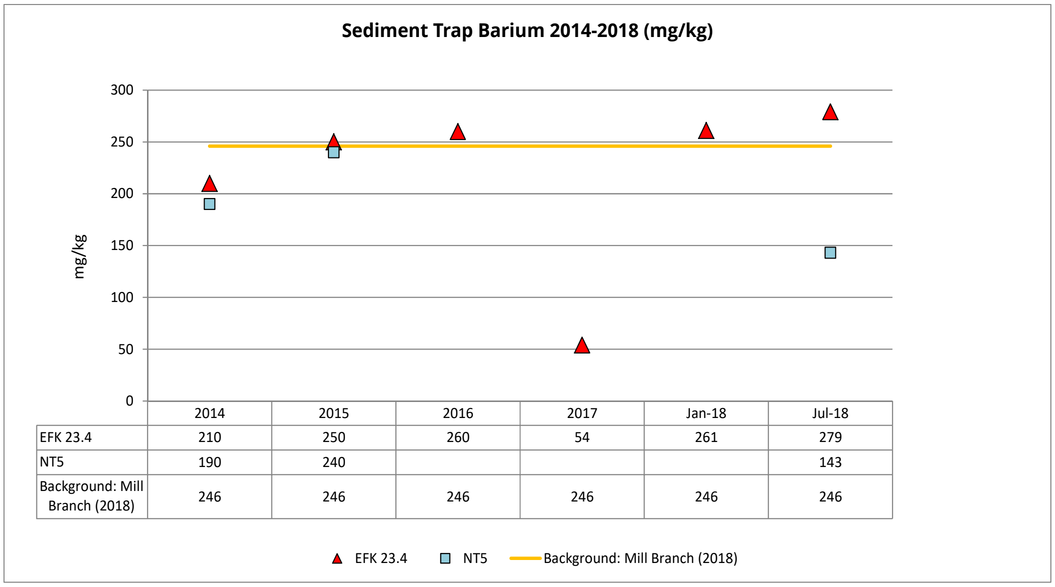


	2014	2015	2016	2017	Jan-18	Jul-18
EFK 23.4	2.8	5.2	4.2	0.8	1.03	5.0
NT5	5.5	6.9				3.21
Background: MBK 1.6 (2018)	7.07	7.07	7.07	7.07	7.07	7.07
Threshold Effects Concentration (TEC)	9.8	9.8	9.8	9.8	9.8	9.8
Probable Effects Concentration (PEC)	33	33	33	33	33	33

Figure 6.3: Sediment Trap Arsenic: 2014-2018

Barium

Barium at both EFK 23.4 and NT5 was found to be at a similar concentration as the Mill Branch background station (Figure 3). There are no CBSQGs for barium.

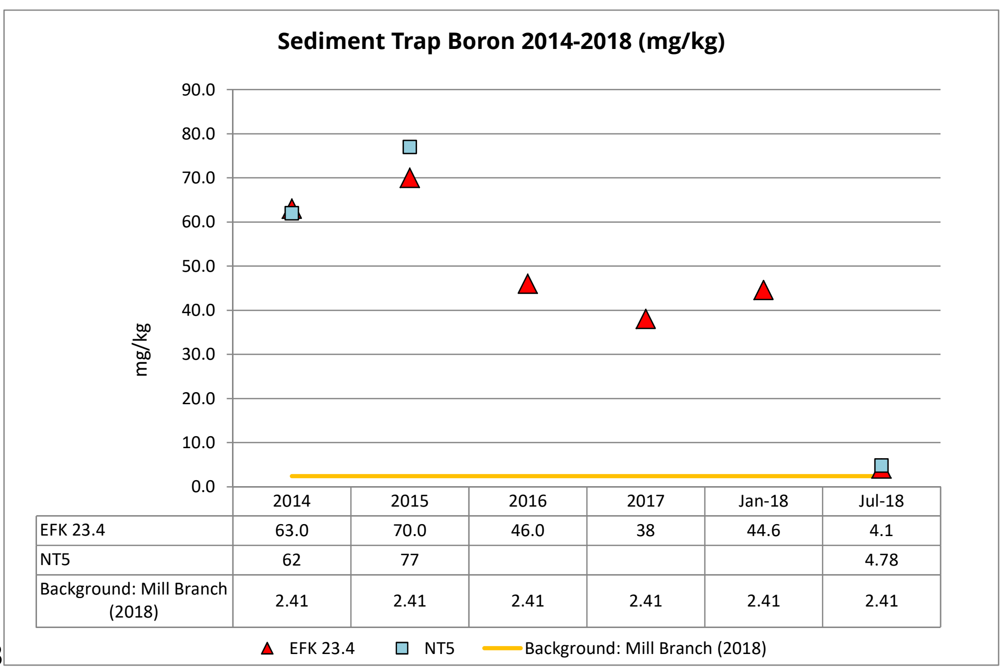


	2014	2015	2016	2017	Jan-18	Jul-18
EFK 23.4	210	250	260	54	261	279
NT5	190	240				143
Background: Mill Branch (2018)	246	246	246	246	246	246

Figure 6.4: Sediment Trap Barium: 2014-2018

Boron

Boron values were much higher than background (Figure 4). Boron-10 is used as radiation shielding and for radioactivity control. The 2018 data were unusually low for both EFK 23.4 and NT5; the data is under review by the laboratory.



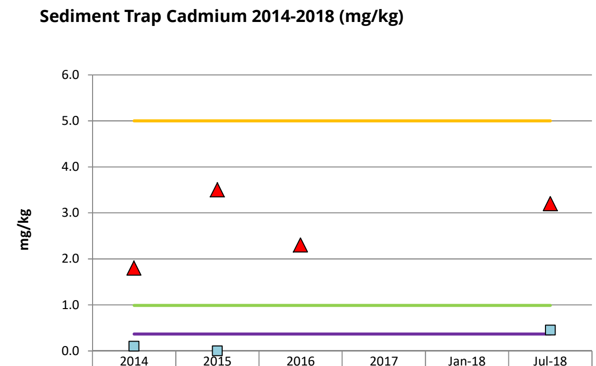
	2014	2015	2016	2017	Jan-18	Jul-18
EFK 23.4	63.0	70.0	46.0	38	44.6	4.1
NT5	62	77				4.78
Background: Mill Branch (2018)	2.41	2.41	2.41	2.41	2.41	2.41

3

Figure 6.5: Sediment Trap Boron: 2014-2018

Cadmium

Cadmium levels at EFK 23.4 are elevated; data were higher than both the TEC and background, but lower than the PEC (Figure 5). NT5 cadmium data were near background or undetected.

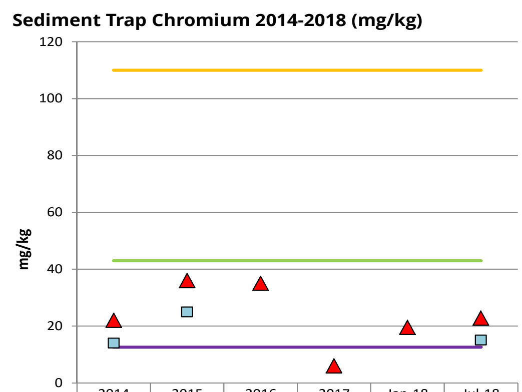


	2014	2015	2016	2017	Jan-18	Jul-18
EFK 23.4	1.8	3.5	2.3			3.20
NT5	0.1	0				0.453
Background - Mill Branch (2018)	0.365	0.365	0.365	0.365	0.365	0.365
Threshold Effects Concentration	0.99	0.99	0.99	0.99	0.99	0.99
CBSQG Probable Effects Concentration	5	5	5	5	5	5

Figure 6.6: Sediment Trap Cadmium: 2014-2018

Chromium

Chromium values, for all stations, are below the TEC and are not a concern for wildlife (Figure 6.7).

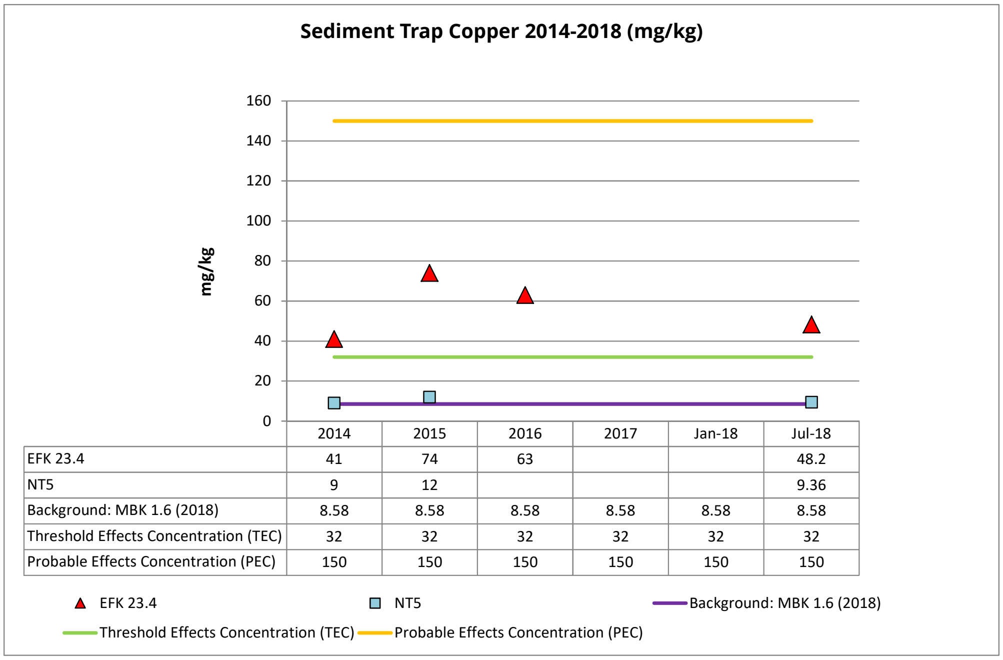


	2014	2015	2016	2017	Jan-18	Jul-18
EFK 23.4	22	36	35	6.0	19.5	22.8
NT5	14	25				15.1
Background: MBK 1.6 (2018)	12.6	12.6	12.6	12.6	12.6	12.6
Threshold Effects Concentration (TEC)	43	43	43	43	43	43
Probable Effects Concentration (PEC)	110	110	110	110	110	110

Figure 6.7: Sediment Trap Chromium: 2014-2018

Copper

Copper data for EFK 23.4 are greater than the TEC and less than the PEC (Figure 6.8). Analysis for copper was not conducted in 2017 and in 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 NT5 were similar to background.

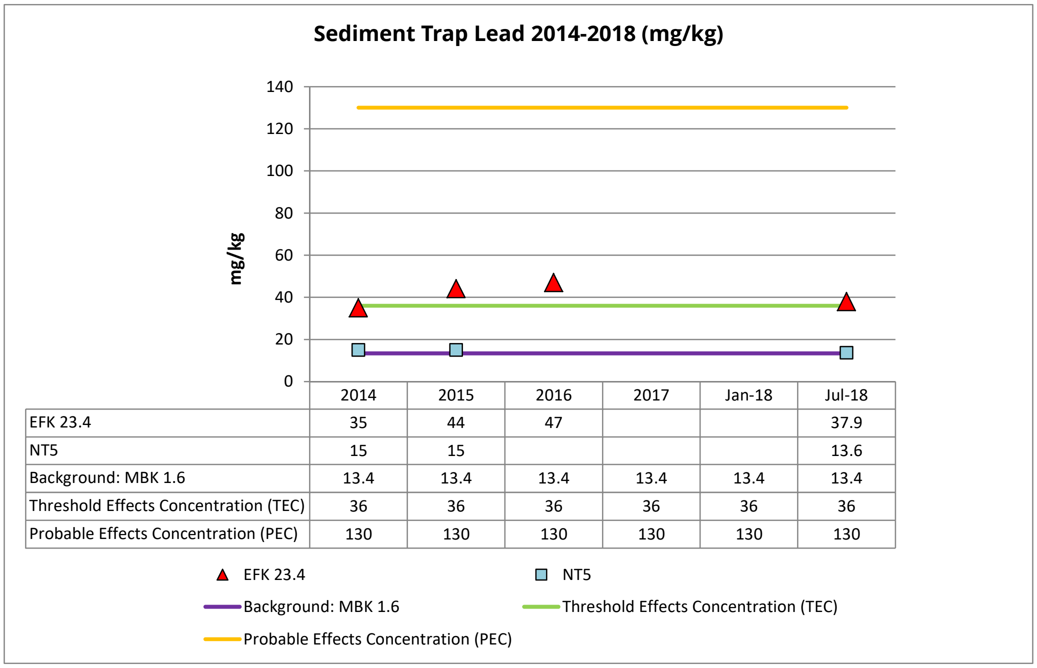


	2014	2015	2016	2017	Jan-18	Jul-18
EFK 23.4	41	74	63			48.2
NT5	9	12				9.36
Background: MBK 1.6 (2018)	8.58	8.58	8.58	8.58	8.58	8.58
Threshold Effects Concentration (TEC)	32	32	32	32	32	32
Probable Effects Concentration (PEC)	150	150	150	150	150	150

Figure 6.8: Sediment Trap Copper: 2014-2018

Lead

Lead values for EFK 23.4 are slightly above the TEC for the most part. As such, there is a slight chance that lead could be harming the benthic macroinvertebrate community, particularly in concert with other metals that exceed the TEC.

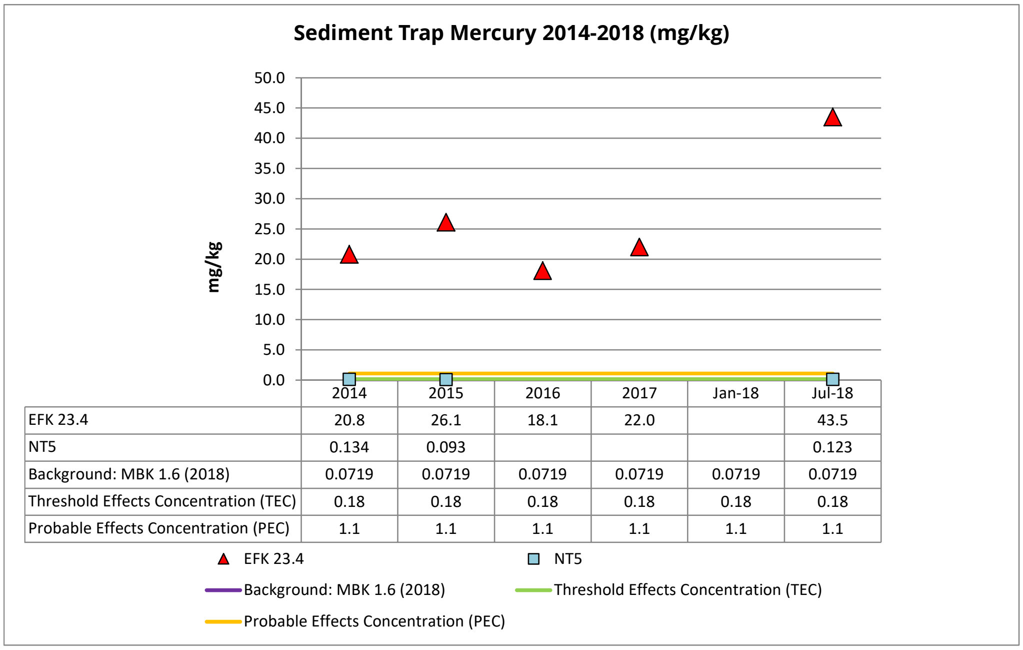


	2014	2015	2016	2017	Jan-18	Jul-18
EFK 23.4	35	44	47			37.9
NT5	15	15				13.6
Background: MBK 1.6	13.4	13.4	13.4	13.4	13.4	13.4
Threshold Effects Concentration (TEC)	36	36	36	36	36	36
Probable Effects Concentration (PEC)	130	130	130	130	130	130

Figure 6.9: Sediment Trap Lead: 2014-2018

Mercury

Mercury values for EFK 23.4 were much higher than the PEC (Figure 6.9); metals found at levels above the PECs indicate that the metal(s) in question are probably having an adverse effect on benthic macroinvertebrate populations. The latest sample, collected on 7/16/2018, shows a mercury value around two times greater than the previous samples. The sample taken in January of 2018 is not entered into the graph because it was not processed by the laboratory within the recommended holding time; the value reported is 24.0 mg/kg. Mercury values at NT5 were slightly higher than background but below the TEC.

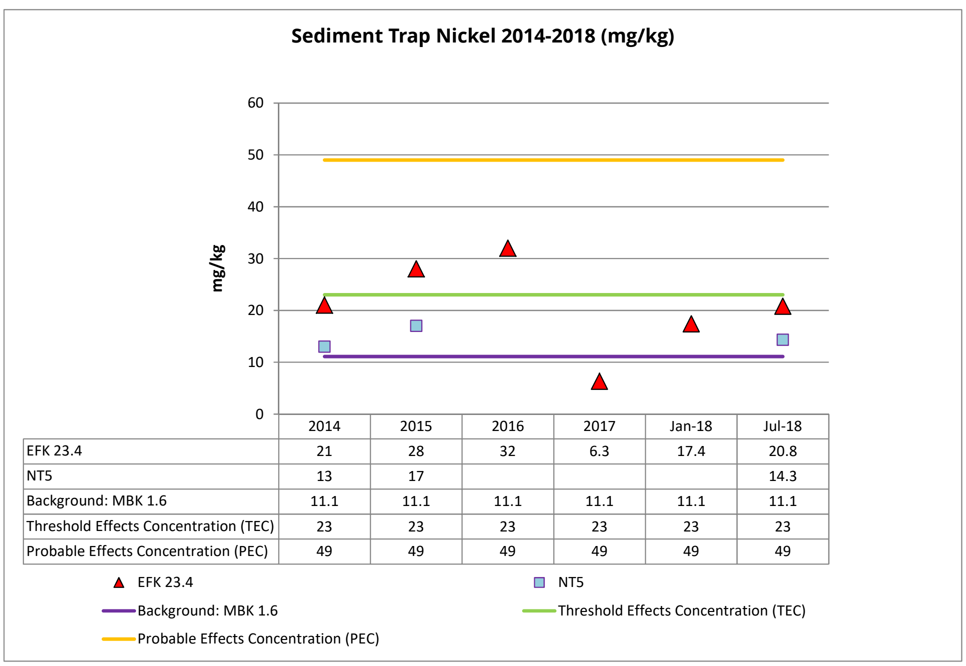


	2014	2015	2016	2017	Jan-18	Jul-18
EFK 23.4	20.8	26.1	18.1	22.0		43.5
NT5	0.134	0.093				0.123
Background: MBK 1.6 (2018)	0.0719	0.0719	0.0719	0.0719	0.0719	0.0719
Threshold Effects Concentration (TEC)	0.18	0.18	0.18	0.18	0.18	0.18
Probable Effects Concentration (PEC)	1.1	1.1	1.1	1.1	1.1	1.1

Figure 6.10: Sediment Trap Mercury: 2014-2018

Nickel

Nickel is greater than background at EFK 23.4 and NT5 in 2014-2018 (11.1 mg/kg) with the exception of the 2017 datum (Figure 6.10). The data are clustered around the TEC (23 mg/kg).

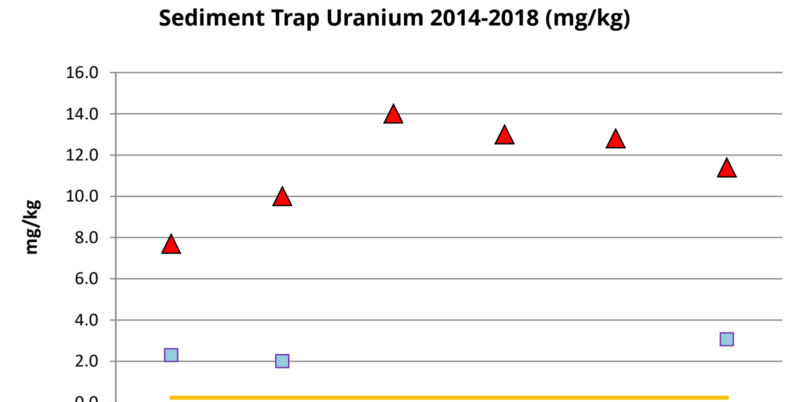


	2014	2015	2016	2017	Jan-18	Jul-18
EFK 23.4	21	28	32	6.3	17.4	20.8
NT5	13	17				14.3
Background: MBK 1.6	11.1	11.1	11.1	11.1	11.1	11.1
Threshold Effects Concentration (TEC)	23	23	23	23	23	23
Probable Effects Concentration (PEC)	49	49	49	49	49	49

Figure 6.11: Sediment Trap Nickel

Uranium

Uranium is greater than background at EFK 23.4 and NT5 from 2014-2018 in the sediment trap samples. There are no CBSQGs established for uranium metal .



	2014	2015	2016	2017	Jun-18	Jul-18
EFK 23.4	7.7	10	14	13	12.8	11
NT5	2.3	2				3.06
Background: MBK 1.6 (2018)	0.24	0.24	0.24	0.24	0.24	0.24

Figure 6.12: Sediment Trap Uranium

Gross Alpha

Gross alpha activity is greater than background in the sediment trap samples (Figure 6.13). There are no CBSQGs established for gross alpha radioactivity.

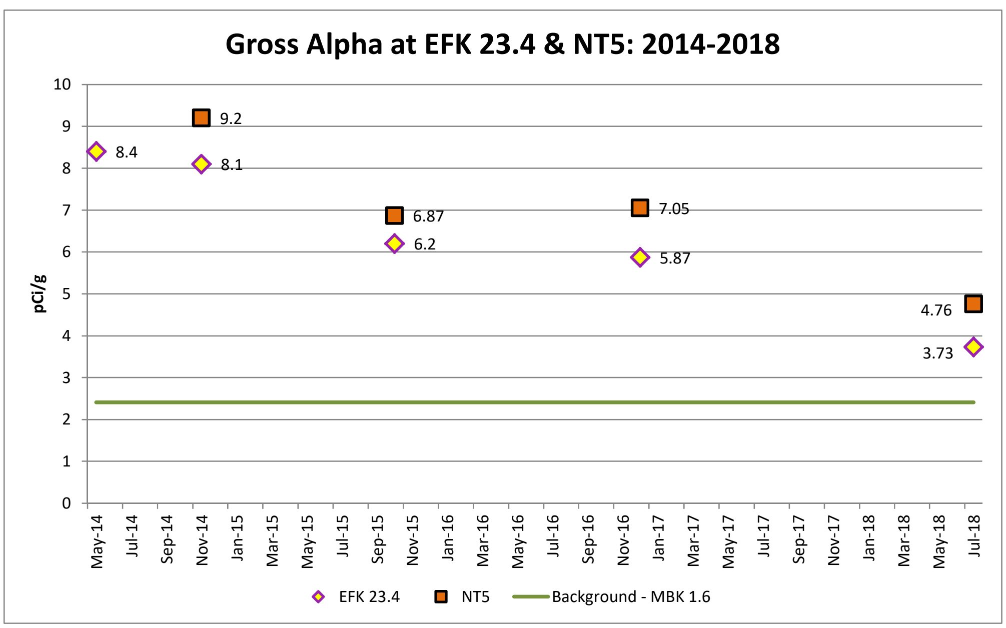


Figure 6.13: Sediment Trap Gross Alpha

Gross Beta

Gross beta activity is greater than background in the sediment trap samples (Figure 6.14). There are no CBSQGs established for gross beta radioactivity.

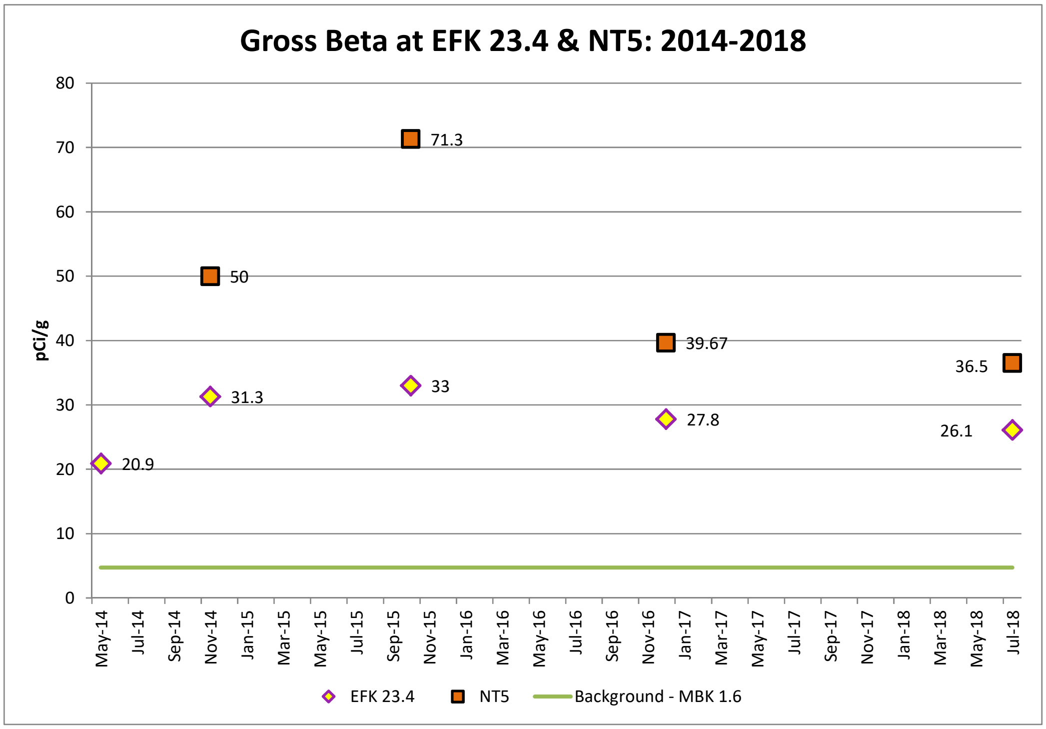


Figure 6.14: Sediment Trap Gross Beta

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 NT5, results from metals analysis were less than the TEC. Both EFK 23.4 and NT5 have levels of gross alpha and beta radioactivity that are above background in the trapped sediment samples collected. However, the levels do not 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 this manner gives an idea of what has been travelling down the stream in 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 DoR-OR trapped sediment project is needed to provide this information. In the coming years, there will be many decommissioning and demolition (D&D) projects as well as construction projects in the upper East Fork Poplar Creek watershed. The trapped sediment project should be continued and funded as necessary to provide ample information about East Fork Poplar Creek during these years ahead. In addition, the trapped sediment project should continue to provide information about what is in the suspended sediments being released from the EMWMF outfall on NT5.

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7.0 GROUNDWATER MONITORING

7.1 OFFSITE RESIDENTIAL WELL MONITORING

7.1.1 Background

As a consequence of past Department of Energy (DOE) missions, groundwater beneath several areas of the ORR has become contaminated. Through the Comprehensive Environmental Resource Compensation and Liabilities Act (CERRCLA cleanup process, measures have been implemented to attempt to isolate the remaining contaminant sources from groundwater. Additional efforts are needed, however, to characterize and respond, where applicable, to ongoing legacy groundwater contamination challenges. Portions of the Oak Ridge Reservation (ORR) have been used for decades as regional burial grounds for hazardous and radioactive waste produced by DOE facilities. DOE radioactive waste was disposed of in landfills, shallow burial sites, unlined trenches, drain fields, waste pits, auger holes, grout sheets, concrete casks, and above-grade vaults. Waste was disposed of in a variety of containers, some unpackaged, with varying degrees of documentation. Disposal included waste 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. In many cases chemical waste had significant associated radioactivity (TDEC, 2018).

Additionally, subsurface disposal on the ORR was also done at hydrofracture facilities with waste materials injected into shale units 200-300 meters (~650-980 feet) below ground surface. The hydrofracture facilities originated as three test facilities. Two facilities were experimental (hydrofracture sites 1 and 2). Hydrofracture test site 3, became developmental and is now referred to in historic documentation as “the Old Hydrofracture Facility.” A fourth facility is referred to as “the New Hydrofracture Facility.” The third and fourth facilities (combined) have also been referred to, in some documentation, simply as “the ORNL Hydrofracture Facility” (Haase et al., 1987; TDEC, 2018).

Groundwater flow in fractured rocks is rapid for carbonate, karst, and fractured clastic rocks (Worthington et al., 2000; Worthington, et. al, 2016). The implication of this is that the groundwater quality can change rapidly, and any geochemical parameter or contaminant concentration detected in groundwater may or may not be the highest or lowest concentrations at that location, if sampled occasionally. Additionally, hydrologic characteristics in these settings mean that groundwater quality can fluctuate between geographically close locations.

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 shows the reservation boundary and the three primary DOE facilities: ETTP, Y-12, and ORNL. Each of these facilities has had some releases and sources of contamination. The extent of the groundwater contamination is not well defined and requires ongoing investigation. Since the Clinch River forms one of the boundaries of the ORR, ongoing sampling and analysis in the offsite areas is necessary. 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, Oak Ridge Office (TDEC DoR-OR) no longer assumes that the Clinch River is a groundwater-flow barrier. Contaminated groundwater is capable of moving beneath the Clinch River and may pose threats to residents using the groundwater as a water source.

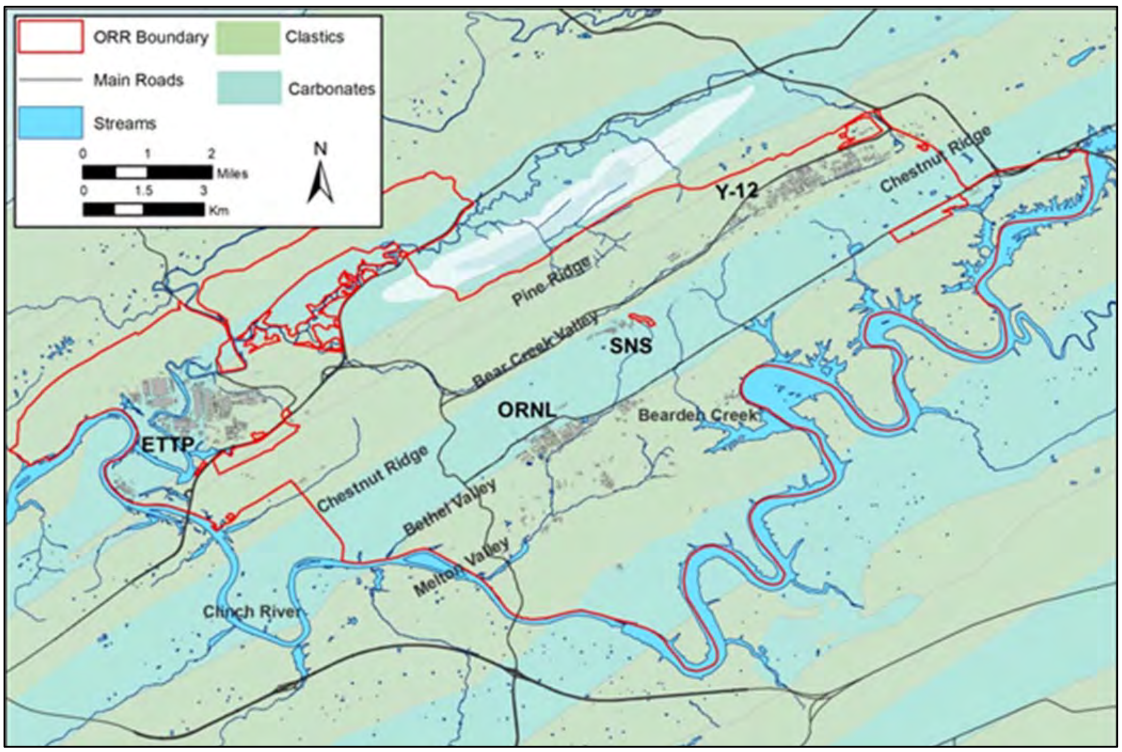

Figure 7.1: Primary DOE facilities, ORR boundary, and basic lithology (with the valley and ridge locations identified.)

7.1.3 Goals

As part of the Federal Facilities Agreement (FFA), the Offsite Residential Well Monitoring Project looks for potential CERCLA legacy waste contaminants in residential wells and furthers the Tennessee Department of Environment and Conservation (TDEC) mission of protecting human health and the environment. The project expectations were to fulfill the DoR-OR Environmental Monitoring Plan (EMP) by co-sampling privately-owned groundwater wells with DOE to better understand the distribution of potential contaminant pathways from the ORR.

The overarching goal of this project was to better understand the nature and extent of ORR-related contamination and associated contaminant transport pathways.

The main objectives were:

- Collect groundwater samples from thirty-four residential wells downgradient and southwest of the ORR
- Evaluate received data for potential constituents of concern (COCs) and groundwater chemistry
- Compare laboratory results to background groundwater sample data

The data were 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 are downgradient from the ORR, along geologic strike. Groundwater, and 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 are limited to the areas offsite of 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 maps in Figure 7.2 show the sample locations.

Thirty-four samples were planned (twenty-one samples were collected), and QA/QC samples were collected from 10% of the sample locations. Some previously sampled locations were resampled, including wells north and northwest as well as east of the ORR. Some current fiscal year samples and historical samples archived in the laboratory refrigerator were analyzed for stable isotopes to determine possible nitrate and recharge source areas.

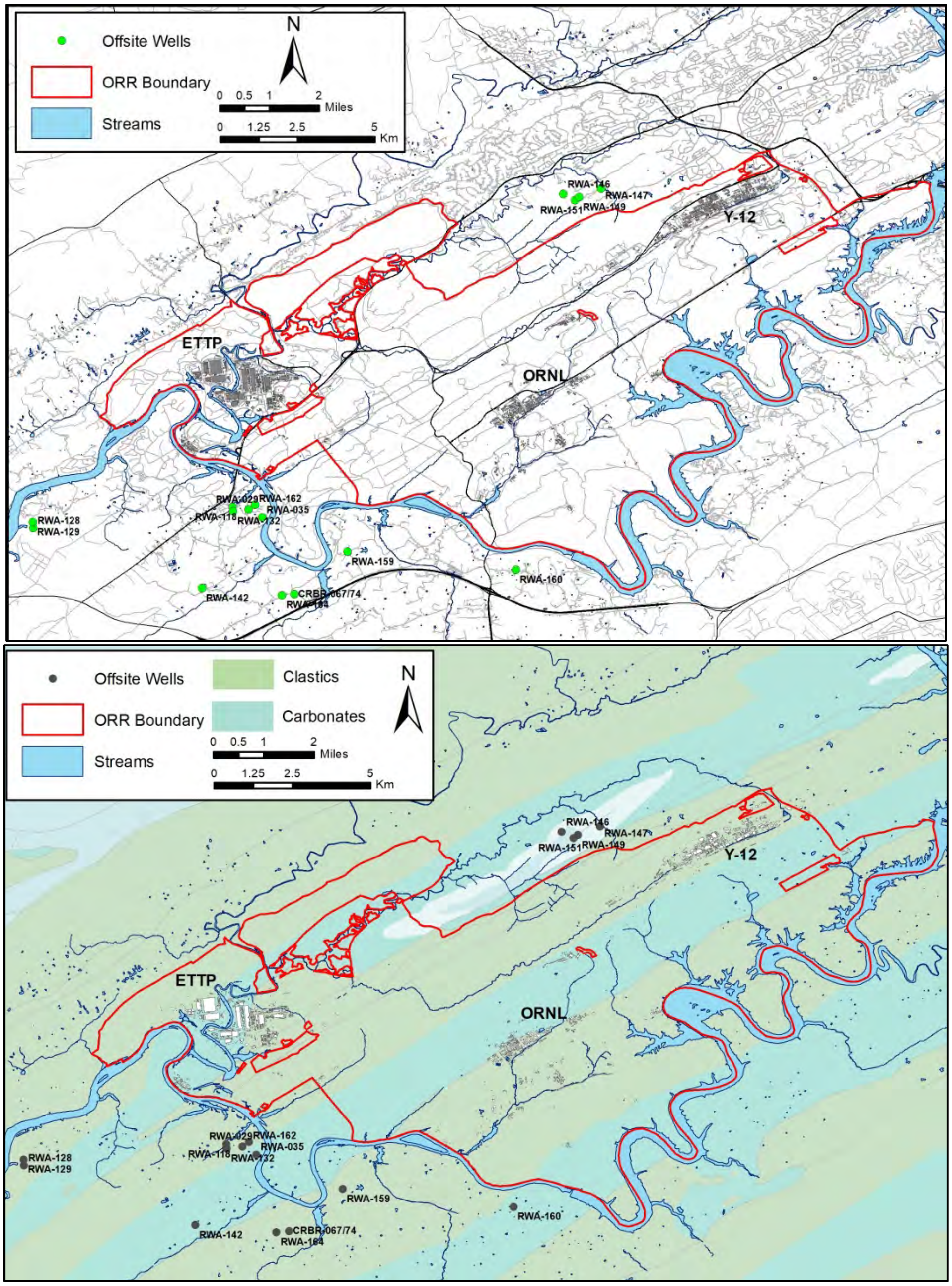

Figure 7.2: Downgradient well sample locations shown on a location map (above) and sample locations shown on a basic geologic map (below).

7.1.5 Methods, Materials, Metrics

Groundwater samples were collected from sixteen locations between July 2017 and March 2018. A total of twenty-one sample suites were collected, including one location that was sampled twice. Two associated quality assurance and quality control (QA/QC) samples were also collected. QA/QC sampling includes a duplicate sample and a field blank (deionized water) filled at the sampling site.

The area of investigation includes locations that are downgradient (generally south and southwest) of the ORR which are along inferred regional groundwater pathways away from the ORR. Samples were also collected from wells, located to the north and northwest, as well as to the east of the ORR in areas just beyond the ORR boundaries. Groundwater samples were collected from residential wells and were sent to the Tennessee Department of Health Laboratory (TDH) for analysis.

Sampling Techniques

A consistently-implemented groundwater sampling procedure helped ensure data comparability between sampling events and between sites. The samples for QA/QC were used to ensure the security and quality of the samples during collection and shipping to the laboratory for analysis.

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. Offsite sampling, conducted during this project time frame, except the resample of RWA-029, was co-sampled with DOE. The samples were analyzed for the analyte suite in Table 7.1.

Table 7.1: 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	sulfate	fluoride
chloride	nitrate and nitrite	ammonia
total dissolved solids		
RADIONUCLIDES		
gross alpha	tritium	radium-228
gross beta	gamma radionuclides[2]	isotopic uranium
strontium-89	technetium-99	transuranic radionuclides
strontium-90	radium-226	
STABLE ISOTOPES		
oxygen-18 (in nitrate)[3]	deuterium (in water)[3]	oxygen-18 (in water)[3]
nitrogen-15 (in nitrate)[3]		

[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

[3] stable isotope data includes some historical samples

Water quality indicator parameters were collected using a 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 7.2.

Table 7.2: 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 that may have been connected to the well sampling port at the residential well locations were removed prior to sampling.

Samples were collected directly into the appropriate sample containers. The preferred order of sampling is: volatile organic compounds (VOCs), metals, inorganics, stable isotopes, and then radiochemical analytes.

With the exception of the four 1-gallon containers collected in each sample suite for radionuclide analysis, all samples were stored on ice and out of direct sunlight prior to Fed-Ex delivery at the state laboratory.

The groundwater samples were sent to TDH Laboratory in Nashville for analyses of the analytes in Table 7.1. The twenty-one groundwater samples also included sample aliquots that were shipped to the University of Arkansas, Department of Geosciences Stable Isotope Laboratory for analysis of stable nitrogen, oxygen, and deuterium (hydrogen) isotopes to determine the sources of nitrate in groundwater (i.e. industrial, soil, human/animal waste, and/or fertilizer), and the types or sources of recharge to groundwater.

The constituent suite analyzed in this offsite project is consistent with the constituent suite that was analyzed for the Background Residential Well Monitoring Project, and this correlation of analyses will support comparisons of groundwater composition between these two projects.

7.1.6 Deviations from the Plan

Thirty-four samples (10% QA/QC) were planned to be collected and analyzed during the 2018 FY. These samples were planned to come from locations downgradient and southwest of the ORR. However, due to budget constraints affecting this Project, only twenty-one samples were collected. The majority of these samples were collected from downgradient and southwest of the ORR; however, some wells in the Tuskegee area to the northeast of the ORR were also sampled. The wells were all sampled one time except RWA-029. This well was sampled twice due to the identification of atypical groundwater cations and anions and high sodium in the first set of results from impacts from the water softener system at the residence. The follow-up sampling was collected from a sample port that bypassed the water softener.

7.1.7 Results from Analysis

The analytical results for this report were assessed with regards to potential for impact, by asking the following three questions:

- Are ORR-related contaminants detected?
- Are concentrations or activities above U.S. EPA identified criteria listed in the tables?
- Can identified contaminants be attributed to DOE waste disposal activities?

Some radionuclides are present naturally in groundwater due to interactions with the atmosphere, soil, or bedrock. Therefore, one of the many challenges of the Offsite Residential Well Monitoring Project is to be able to definitively state that the radionuclides present in the reported results are man-made, natural, or a mix of both.

Regulatory Comparison Values

In order to understand the hydrochemical composition of groundwater in private wells, the results of the analyses were compared to EPA standards. The U.S. EPA has established the National Primary Drinking Water Regulations (NPDWR) to maintain water quality in public water supplies. These criteria include Maximum Contaminant Levels (MCL)s and Secondary Maximum Contaminant Levels (SMCL)s.

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 items 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 were not available, other EPA criteria for comparison values were used. These guidelines included: EPA Lifetime Health Advisory Values (HAs), EPA Regional Screening Levels (RSLs), and EPA Preliminary Remediation Goals (PRGs). These levels are not enforceable for public water utilities, but they can help put the results in context for comparison.

Has 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. HAs 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 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/dwstandardsregulationsor 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 a YSI Professional Plus Multi-parameter Instrument. Table 7.3 shows the final stable readings taken immediately before collecting samples at each sampling event.

EPA SMCL criteria for recommended pH concentrations in public drinking water fall within 6.5 and 8.5 standard units (SUs). One well during the study period had a pH level above this range; refer to Table 7.3. Naturally high pH values are uncommon in this geological setting (White et al., 1963). This well is southwest of the ORR and downgradient of ORNL.

Table 7.3: Field Parameters for Offsite Wells

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	
CRBR-067/74	7/6/2017	18.2	707	9.38	114.0	9.14	0.23
RWA-160 & DUP	7/18/2017	16.5	452.0	7.55	32.2	4.02	6
RWA-146	11/6/2017	15.5	808	7.13	-69.1	0.58	1.64
RWA-151	11/7/2017	15.9	510.2	7.16	18.3	6.28	0.26
RWA-029	11/8/2017	14.3	438.3	7.04	61.7	7.34	0.02
RWA-029	3/12/2018	13.3	391.6	7.16	285.1	7.94	0.16
RWA-128	11/9/2017	15.5	367.5	7.45	58.1	4.28	0.00
RWA-162	11/16/2017	14.8	394.3	7.30	259.1	6.76	0.74
RWA-159	11/20/2017	15.3	521.2	7.51	31.7	1.00	0.65
RWA-118	11/30/2017	14.6	425.7	7.21	284.1	1.37	9.78
RWA-035	2/20/2018	13.7	215.4	7.09	171.9	7.89	0.70
RWA-132 & DUP	2/22/2018	14.4	424.0	6.91	156.9	4.61	30.26
RWA-147	3/1/2018	14.6	396.1	6.25	26.6	0.74	2.16
RWA-142	3/6/2018	15.4	304.3	7.27	133	4.67	3.57
RWA-129	3/7/2018	15.6	375.1	7.44	70.0	0.53	0.52
RWA-164	3/14/2018	16.4	386.4	8.30	15.0	0.74	0.86
RWA-149	3/15/2018	13.7	531.0	7.06	435.2	1.11	2.64

-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). Only the wells with detections are listed in Table 7.4, because many VOCs were undetected in the laboratory results.

VOC were detected in two wells during this fiscal year, RWA-160 and RWA-132. Their associated QA/QC samples also had detections. No VOC constituent was detected to be above EPA MCL or RSL comparison criteria. Acetone is a common laboratory contaminant. Possible sources of the other constituents are still being investigated.

Table 7.4: VOC Results

Offsite Volatile Organic Compound Results (µg/L)								
Analyte	EPA MCL	EPA RSL	RWA-160	RWA-160 DUP	RWA-160 FB	RWA-132	RWA-132 DUP	RWA-132 FB
Date			7/18/2017	7/18/2017	7/18/2017	2/22/2018	2/22/2018	2/22/2018
acetone		14,000	1.99 BJ	U	U	U	U	1.52 J
bromodichloromethane	80		0.849	0.944	U	U	U	U
chlorodibromomethane	80		0.464J	0.46	U	U	U	U
chloroform	80		2.42	2.42	0.309J	U	U	U
cis-1,2-Dichloroethene	70		U	U	U	0.249 BJ	0.289 BJ	0.259 BJ

µg/L- micrograms per liter
J- Estimated Value
U-Undetected
B-The sample analyte is in the accociated blank
DUP- Duplicate
FB- Field Blank

Metals

Concentrations above comparison ranges for aluminum, iron, lithium, manganese, and sodium were detected in offsite wells during this sampling event. There were no detections above EPA MCL criteria. Refer to Table 7.5. Aluminum, iron, and manganese were detected above EPA SMCL criteria. Aluminum was above this criteria in one well and its corresponding duplicate. This same well pairing also had manganese detected above the EPA SMCL criteria. Iron was detected in three wells above the EPA SMCL criteria. One of the wells that were above the iron EPA SMCL was also above the manganese EPA SMCL criteria. Lithium was identified at levels above the EPA RSLs for tap water at one location. Sodium was detected above the EPA HA in 5 locations. One of these locations, RWA-029, was sampled twice and only exceeded this criteria in the first sampling event. This may be due to possibly sampling the water softener during the first sampling event.

Inorganics

The inorganics results for this sampling period are in Table 7.6. There is one result well above the EPA SMCL criteria for total dissolved solids. The rest of the wells were below regulatory comparison values for all of the inorganic analytes. There were six samples that did not have ammonia reported on the laboratory result sheets, and two samples that did not have total alkalinity reported on their laboratory result sheets.

Radiochemical Analytes

There are some radionuclides that are naturally present in groundwater due to 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 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 7.7.

Radium-226 was detected above the EPA PRG at six wells. Radium-228 was detected above the EPA PRG at five wells. Curium-245/246 exceeded the EPA PRG at one well. Uranium-233/234 and uranium-238 was detected above the EPA PRG at the same three wells. These uranium constituents could be from naturally occurring or man-made sources. No determination regarding potential sources of the identified constituents has been made at this time, and further investigation will continue.

7.1.8 Conclusions

The contamination of groundwater beneath several areas of the ORR and the potential pathways for contaminant migration beyond the ORR boundary makes it imperative to continue this project and the monitoring offsite residential wells. This project is currently the primary system for monitoring groundwater in areas off the reservation that may be a primary or sole source of water for local residents in Roane, Anderson, and Loudon counties.

Groundwater flow in fractured rocks can be rapid in bedrock aquifers (Worthington et al., 2000; Worthington, et al., 2016). The results from residential wells sampled during this period represent a snapshot in time and not continuous monitoring. Groundwater quality in these settings 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 data from one sampling event. This TDEC DoR-OR EMR documents mostly low-concentrations, low-activities, and sporadic detections of contaminants that could potentially be a result of human activity. Some of these detections are above EPA 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.

Table 7.5: Metal Results

Offsite Metals Results

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"	CRBR-067/74	RWA-160	RWA-160 DUP	RWA-160 FB	RWA-146	RWA-151	RWA-029	RWA-029	RWA-128	RWA-162	RWA-159	RWA-118	RWA-035	RWA-132	RWA-132 DUP	RWA-132 FB	RWA-147	RWA-142	RWA-129	RWA-164	RWA-149
Date						7/6/2017	7/18/2017	7/18/2017	7/18/2017	11/6/2017	11/7/2017	11/8/2017	3/12/2018	11/9/2017	11/16/2017	11/20/2017	11/30/2017	2/20/2018	2/22/2018	2/22/2018	2/22/2018	3/1/2018	3/6/2018	3/7/2018	3/14/2018	3/15/2018
aluminum	µg/L		50-200			U	U	2.6J	U	U	4.73J	4.12J	5.18J	U	U	U	126	U	380	383	U	25.0	68.3	U	U	11.0
antimony	µg/L	6			6	U	1.1	1.2	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
arsenic	µg/L	10		0.052		U	U	U	U	U	U	U	U	U	0.787J	U	U	U	U	U	U	U	U	U	U	U
barium	µg/L	2,000		3,800		38	17	17	U	50.3	22.8	U	9.48	91.9	15.7	166	101	80.7	80.8	81.2	U	27.8	118	130	143	31.4
beryllium	µg/L	4		4		U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
boron	µg/L			4,000	6000	870	U	U	U	285	71.7	U	3.56J	8.30J	U	226	11.9	13.7	3.94J	4.74J	U	98.8	58.1	48.3	371	55.5
cadmium	µg/L	5		9.2	5	U	1.7	1.7	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
calcium	mg/L					0.82	47	46	U	105	63.8	U	39.2	48.1	40.3	36.0	51.7	48.9	53.2	51.6	U	46.1	51.1	41.1	10.8	69.9
chromium	µg/L	100				U	0.84J	0.98J	U	U	U	1.12J	U	0.812J	U	U	U	U	0.838J	0.810J	U	U	0.844J	U	U	U
copper	µg/L	1,300	1000			1.5	0.99J	0.93J	U	0.612J	64.6	2.58	3.21	3.24	1.23	2.01	1.72	3.13	9.68	9.34	U	2.00	7.63	0.608J	1.72	3.82
iron	µg/L		300	14000		810	47	49	U	768	47.4	U	5.50J	5.60J	14.6	49.3	155	U	202	207	U	8090	95.4	9.50J	9.30J	57.7
lead	µg/L	15		15		U	4.0	4.1	U	U	2.32	U	U	0.459J	1.07	U	0.692J	U	4.45	4.48	U	U	0.344J	U	U	0.956J
lithium	µg/L			40		72	0.56J	0.62J	U	39.6	17.4	U	0.524J	11.0	U	42.2	3.50	0.522J	1.39	1.56	U	31.0	5.16	NR	45.2	13.4
magnesium	mg/L					0.18	29	29	U	94.8	35.1	U	26.3	21.2	25.5	27.6	22.1	26.8	30.5	29.6	U	17.1	19.4	22.7	9.60	32.1
manganese	µg/L		50	non diet 430	300	8.2	7.9	8.4	U	16.7	18.5	U	U	U	U	7.13	20.2	U	161	165	U	307	4.40	U	3.63	5.53
mercury	µg/L	2		0.63	2	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
nickel	µg/L				100	U	4.2	4.6	U	2.65	3.37	U	1.08	2.24	0.576J	U	2.12	1.38	3.21	3.14	U	25.2	0.988J	1.35	0.501J	2.48
potassium	mg/L					0.94	1.3	1.3	U	5.53	1.75	0.179	0.667	1.86	0.741	2.89	1.10	1.03	1.25	1.22	U	3.71	2.11	2.27	1.78	1.44
selenium	µg/L	50		100	50	U	U	U	U	U	3.07J	U	U	U	U	U	U	U	U	U	U	U	U	U	U	3.82J
silver	µg/L		100	94	100	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
sodium	mg/L				20	160	5.8	5.7	U	29.6	8.15	106	1.57	0.731	0.718	35.2	4.13	1.25	1.68	1.64	U	10.5	6.67	3.98	67.7	5.61
strontium	µg/L			stable 12,000	4,000	23	23	24	U	1800	576	U	14.5	291	16.2	4,130	185	29.8	137	141	U	357	293	308	222	264
thallium	µg/L	2				U	U	U	U	U	U	U	U	U	U	0.676J	U	U	U	U	U	U	U	U	U	U
uranium	µg/L	30				U	6.3	6.4	U	U	0.374J	U	U	3.19	0.612J	U	0.420J	0.570J	0.513J	0.517J	U	U	0.409J	2.61	U	0.413J
vanadium	µg/L			86		U	U	U	U	U	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	U	1000	860	U	3.04	42.8	2.59	7.56	10.0	5.90	3.91J	16.0	1.97J	40.1	38.2	U	30.6	4.91J	4.20J	2.57J	10.6
total hardness	mg/L					2.8	240	230	U	653	304	U	206	207	206	204	220	233	259	251	U	186	207	196	66.5	307

- EPA MCL Exceedance
- EPA SMCL Exceedance
- EPA RSL Exceedance
- EPA HA Exceedance
- Comparison Values used

µg/L - micrograms per liter
mg/L -milligrams per liter

DUP -Duplicate
FB -Field Blank
J - Estimated Value
U - Undetected
NR -Not Reported

Table 7.6: Inorganic Results

Offsite Inorganic Results (mg/L)																									
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"	CRBR-067/74	RWA-160	RWA-160 DUP	RWA-160 FB	RWA-146	RWA-151	RWA-029	RWA-029	RWA-128	RWA-162	RWA-159	RWA-118	RWA-035	RWA-132	RWA-132 DUP	RWA-132 FB	RWA-147	RWA-142	RWA-129	RWA-164	RWA-149
Date					7/6/2017	7/18/2017	7/18/2017	7/18/2017	11/6/2017	11/7/2017	11/8/2017	3/12/2018	11/9/2017	11/16/2017	11/20/2017	11/30/2017	2/20/2018	2/22/2018	2/22/2018	2/22/2018	3/1/2018	3/6/2018	3/7/2018	3/14/2018	3/15/2018
ammonia					U	0.023J	U	U	0.245	1.16	U	NR	U	U	U	0.0461J	U	U	U	U	NR	NR	NR	NR	NR
chloride		250			1.6J	17	17	0.91J	2.99	1.88J	3.48	3.41	1.96J	2.72	1.99J	6.68	3.63	3.55	3.56	U	1.82J	2.21J	4.40	1.93J	2.30J
fluoride	4	2			1.1	0.035J	0.035J	U	0.135	0.160	0.0259J	U	0.490	0.0326J	0.274	0.186	0.117	0.327	0.330	U	0.446	0.294	0.514	0.358	0.201
nitrate and nitrite	10			10	U	0.74	0.74	U	U	0.0763J	0.724	0.187	0.203	0.450	U	0.238	1.83	1.05	1.06	U	U	0.353	U	U	0.719
sulfate		250			30	13	13	U	281	47.5	2.05J	1.85J	6.66	9.41	36.8	13.5	4.72	5.23	5.23	U	82.5	3.49	23.3	13.0	46.6
total dissolved solids		500			390	240	250	4J	501	318	280	218	209	206	304	235	244	243	259	U	274	216	201	237	312
total alkalinity					360	210	210	4.92J	399	279	232	216	193	205	250	208	214	225	224	6.34J	128	NR	NR	195	244

	- EPA MCL Exceedance	DUP -Duplicate
	- EPA SMCL Exceedance	FB -Field Blank
	- EPA RSL Exceedance	J - Estimated Value
	- EPA HA Exceedance	U - Undetected
	- Comparison Values used	NR -Not Reported
		mg/L -milligrams per liter

Table 7.7: Radiochemical Results

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										
CRBR-067/74	7/6/2017	NDA	NDA	0.12 BDL	0.6 BDL	0.21 BDL	0.27	0.593 BDL	-0.316 BDL	0.06 BDL	-43 BDL	0.017 ± 0.033 BDL	0.008 ± 0.025 BDL	0.033 ± 0.037 BDL	0.027 ± 0.044 BDL	0.004 ± 0.030 BDL	0.05 ± 0.055 BDL	0.042 ± 0.031	0.302 ± 0.074	0.012 ± 0.018 BDL	0.051 ± 0.027
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 ± 0.031 BDL	0.007 ± 0.032 BDL	-0.002 ± 0.023 BDL	0.048 ± 0.057 BDL	0.048 ± 0.035	0.021 ± 0.054 BDL	0.048 ± 0.032	1.4 ± 0.23	0.07 ± 0.037 BDL	1.61 ± 0.26
RWA-160 DUP	7/18/2017	NDA	NDA	5.72	6.8	1.27	0.23 BDL	1.02 BDL	-0.242 BDL	0.88	16 BDL	0.001 ± 0.039 BDL	-0.005 ± 0.028 BDL	0 ± 0.042 BDL	-0.015 ± 0.053 BDL	0.014 ± 0.033 BDL	0.109 ± 0.056	0.021 ± BDL	1.43 ± 0.24	0.088 ± 0.041	1.7 ± 0.28
RWA-160 FB	7/18/2017	NDA	NDA	-0.32 BDL	0.1 BDL	0.17 BDL	-0.05 BDL	0.724 BDL	-0.464 BDL	0.35 BDL	-10 BDL	-0.011 ± 0.027 BDL	0.012 ± 0.034 BDL	0.03 ± 0.031 BDL	0.001 ± 0.052 BDL	0.014 ± 0.025 BDL	0.091 ± 0.061	0.056 ± 0.033	0.041 ± 0.031 BDL	0.02 ± 0.019 BDL	0.019 ± 0.021 BDL
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 ± 0.045 BDL	0.016 ± 0.032 BDL	0.013 ± 0.038 BDL	-0.01 ± 0.065 BDL	0.019 ± 0.036 BDL	0.062 ± 0.061 BDL	0.025 ± 0.028 BDL	0.292 ± 0.072	0.063 ± 0.034	0.178 ± 0.052
RWA-151	11/7/2017		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 ± 0.039 BDL	-0.009 ± 0.029 BDL	0.035 ± 0.046 BDL	0.033 ± 0.053 BDL	0.015 ± 0.048 BDL	0.09 ± 0.056 BDL	0.054 ± 0.037 BDL	0.418 ± 0.091	0.027 ± 0.023 BDL	0.184 ± 0.053
RWA-029	11/8/2017	51	47.6	0.04 BDL	-0.3 BDL	-0.34 BDL	-0.39 BDL	0.16 BDL	-0.44 BDL	-0.16 BDL	137	0.036 ± 0.049 BDL	0.014 ± 0.032 BDL	0.035 ± 0.045 BDL	0.049 ± 0.083 BDL	0.035 ± 0.034 BDL	0.046 ± 0.053 BDL	0.022 ± 0.029 BDL	0.135 ± 0.051	0.026 ± 0.027 BDL	0.092 ± 0.043
RWA-029	3/12/2018	167	136	0.21 BDL	-0.3 BDL	0.17 BDL	0.35 BDL	-0.82 BDL	-0.8 BDL	0.29 BDL	66 BDL	-0.002 ± 0.029 BDL	0.004 ± 0.017 BDL	-0.023 ± 0.035 BDL	0.062 ± 0.049 BDL	0.025 ± 0.025 BDL	0.046 ± 0.044 BDL	0.035 ± 0.026	0.15 ± 0.053	0.036 ± 0.025	0.097 ± 0.042
RWA-128	11/9/2017	49		6.91	3.8 BDL	9.3	5.8	0.79 BDL	-0.6 BDL	-0.06 BDL	27 BDL	0.006 ± 0.034 BDL		-0.027 ± 0.032 BDL	0.059 ± 0.062 BDL	0.012 ± 0.036 BDL	0.053 ± 0.062 BDL	0.026 ± 0.029 BDL	2.17 ± 0.37	0.122 ± 0.058	1.17 ± 0.22
RWA-162	11/16/2017	70	60	1.09 BDL	0.9 BDL	-0.25 BDL	0.28 BDL	-1.06 BDL	0.44 BDL	-0.33 BDL	127	0.021 ± 0.040 BDL		-0.009 ± 0.039 BDL	0.038 ± 0.047 BDL	0.016 ± 0.040 BDL	0.063 ± 0.044	0.045 ± 0.030	0.51 ± 0.11	0.089 ± 0.041	0.282 ± 0.073
RWA-159	11/20/2017	146	81	0.44 BDL	4.8	0.12 BDL	0.19 BDL	-0.4 BDL	0.13 BDL	-0.28 BDL	247	0.021 ± 0.036 BDL		0 ± 0.036 BDL	0.059 ± 0.058 BDL	0.022 ± 0.034 BDL	0.08 ± 0.064 BDL	0.047 ± 0.038 BDL	0.166 ± 0.058	0.05 ± 0.030	0.042 ± 0.031
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 ± 0.051 BDL	-0.01 ± 0.025 BDL	0.003 ± 0.032 BDL	0.017 ± 0.059 BDL	0 ± 0.029 BDL	0.018 ± 0.044 BDL	0.044 ± 0.027	0.475 ± 0.102	0.073 ± 0.038	0.22 ± 0.063
RWA-035	2/20/2018	32.2	20.3	1.28 BDL	1 BDL	-0.41 BDL	0.05 BDL	0.39 BDL	0.05 BDL	0.04 BDL	38 BDL	0.023 ± 0.037 BDL	0.005 ± 0.021 BDL	-0.012 ± 0.028 BDL	0.003 ± 0.040 BDL	-0.011 ± 0.023 BDL	0.054 ± 0.046 BDL	0.027 ± 0.020	0.318 ± 0.079	0.045 ± 0.028	0.195 ± 0.056
RWA-132	2/22/2018	NDA	NDA	1.98 BDL	1.7 BDL	0.1 BDL	0.43 BDL	-1.6 BDL	1.33	0.16 BDL	126	0 ± 0.038 BDL	0.017 ± 0.030 BDL	-0.046 ± 0.031 BDL	0.007 ± 0.054 BDL	0.006 ± 0.028 BDL	0.04 ± 0.043 BDL	0.027 ± 0.023	0.481 ± 0.103 BDL	0.055 ± 0.031	0.267 ± 0.071
RWA-132 DUP	2/22/2018	44	27.4	3.2	2.6 BDL	0.73 BDL	1.18	-0.96 BDL	0.72 BDL	0.2 BDL	134	-0.026 ± 0.055 BDL	-0.008 ± 0.019 BDL	0.057 ± 0.073 BDL	0.032 ± 0.043 BDL	-0.006 ± 0.029 BDL	0 ± 0.040 BDL	0.053 ± 0.029	0.387 ± 0.091	0.067 ± 0.035	0.17 ± 0.055
RWA-132 FB	2/22/2018	70	29.1	0.3 BDL	-3.4 BDL	-0.28 BDL	0 BDL	0.15 BDL	-0.03 BDL	1.34	16 BDL	-0.004 ± 0.036 BDL	0.009 ± 0.025 BDL	0.024 ± 0.033 BDL	-0.008 ± 0.044 BDL	0 ± 0.018 BDL	0.039 ± 0.043 BDL	0.047 ± 0.027	0.046 ± 0.029	0.029 ± 0.022	0.038 ± 0.022
RWA-147	3/1/2018	122	107	1.61 BDL	1.1 BDL	-0.14 BDL	-0.07 BDL	-3.21 BDL	0.85 BDL	-0.01 BDL	20 BDL	-0.006 ± 0.027 BDL	0.008 ± 0.021 BDL	-0.038 ± 0.027 BDL	0.008 ± 0.036 BDL	0 ± 0.029 BDL	0.019 ± 0.047 BDL	0.044 ± 0.028	0.072 ± 0.036	0.018 ± 0.021 BDL	0.047 ± 0.027
RWA-142	3/6/2018	178	124	0.78 BDL	1.1 BDL	-0.25 BDL	0.18 BDL	0.76 BDL	-0.006 BDL	0.31 BDL	45 BDL	0.02 ± 0.040 BDL	-0.011 ± 0.017 BDL	-0.01 ± 0.028 BDL	0.001 ± 0.037 BDL	0.009 ± 0.018 BDL	0.105 ± 0.053	0.032 ± 0.024	0.239 ± 0.072	0.041 ± 0.033	0.134 ± 0.054
RWA-129	3/7/2018	88	67	11.9	10.5	1.96	0.55	0.79 BDL	-0.08 BDL	0.17 BDL	-47 BDL	-0.002 ± 0.029 BDL	0.004 ± 0.017 BDL	-0.023 ± 0.035 BDL	0.062 ± 0.049 BDL	0.025 ± 0.025 BDL	0.046 ± 0.044 BDL	0.035 ± 0.026	0.150 ± 0.053	0.036 ± 0.025	0.097 ± 0.042
RWA-164	3/14/2018	96	94	1.95 BDL	3.9 BDL	-0.06 BDL	0.39	-0.63 BDL	-0.3 BDL	0.8	24 BDL	0 ± 0.033 BDL	-0.008 ± 0.018 BDL	0.000 ± 0.033 BDL	0.004 ± 0.039 BDL	0.004 ± 0.028 BDL	0.039 ± 0.049 BDL	0.041 ± 0.029 BDL	0.246 ± 0.070	0.015 ± 0.023	0.081 ± 0.038
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 ± 0.039 BDL	-0.001 ± 0.019 BDL	0.022 ± 0.036 BDL	0.633 ± 0.177	0.008 ± 0.025 BDL	0.046 ± 0.050 BDL	0.046 ± 0.033	0.589 ± 0.122	0.030 ± 0.026 BDL	0.176 ± 0.055

- EPA MCL Exceedance
- EPA SMCL Exceedance
- EPA PRG Exceedance
- EPA HA Exceedance

FB -Field Blank
DUP -Duplicate
TR -Target Risk
pCi/L - picoCuries per liter
BDL -Below Detection Limit
NDA - Not Detected Analyte

Blank Page

7.1.9 Recommendations

Recommendations for future work on this project include:

A continuation of the Offsite Residential Well Monitoring Project to obtain a larger statistical distribution of data between wells and over time is recommended.

Borehole logging with the United States Geological Survey (USGS) to geophysically, visually, and geochemically profile wells in strategic offsite locations should be evaluated. This effort may support the correlation between the results from the evaluation of residential groundwater that could be dependent on well construction and water-producing rock types identified in the open boreholes.

Work at Oak Ridge by DOE and its contractors currently use the “basin approach” to evaluate groundwater. In the terrain around the ORR, it is documented that the boundaries of groundwater basins are not coincident with surface water or topographic boundaries. TDEC DOR-OR recommends further delineation of groundwater basin boundaries. Basin delineation may require an understanding of the subtle differences of local flow paths and regional flow paths. Several different tracers may be used, including water quality parameters, chemistry and natural isotopes, and injected substances, such as fluorescent dyes.

TDEC DoR-OR will compare future offsite groundwater data with the data collected by DOE under the Remedial Site Evaluation Phase 2 Offsite Detection Monitoring Work Plan Oak Ridge, Tennessee (DOE/OR/01-2788&D1).

7.2 Background Residential Well Monitoring

7.2.1 Background

Portions of the Oak Ridge Reservation (ORR) were used for decades as regional burial grounds for hazardous and radioactive wastes, mostly those from the Department of Energy (DOE). The disposed waste was contaminated with inorganic and organic chemicals including volatile and semi-volatile organic compounds, beryllium, mercury, and other heavy metals, polychlorinated biphenyls (PCBs), laboratory and cleaning chemicals, biological waste, and inorganic salts. In many cases, the chemical waste had significant associated radioactivity. Transuranic (TRU) wastes, typically alkaline and nitrate-rich, were a part of the disposed waste. The radioactive waste was disposed in landfills, shallow burial sites, unlined trenches, waste pits, auger holes, and in deep wells located at the ORR hydrofracture facilities. Each of these waste disposal sites and methods pose a potential environmental concern (DOE, 1999).

The ORR is located within the Valley and Ridge province of eastern Tennessee which is composed of bedded carbonates and silicate rocks. The carbonates are in the valleys and silicates on the ridges, but the Knox Group dolomite, on the ridges, is the exception (Hatcher et al., 1992). These rock formations extend long distances across the eastern United States. The regional groundwater flow is parallel to geologic strike—generally moving from the northeast to the southwest—and has been documented as flowing over long distances (Davies, Worthington, and Sebastian, 2012). For this reason, the fundamental chemical characteristics of groundwater in these similar lithologies, and within similar rock formations, should have comparable chemical compositions across the region. (Figure 7.3.)

7.2.3 Problem Statements

Background (baseline) groundwater studies have been focused on individual remedial action sites and not on the ORR as a whole. The sites located on the ORR are often not regionally up-gradient and therefore not true background locations.

National studies of groundwater chemistry in similar rock types to those on and downgradient of the ORR were used to compare the results (DeSimone, 2009). However, the national studies are not specific to Oak Ridge and do not include all the contaminants of concern. The background samples help support a specific understanding of the upper and lower ranges of concentrations of chemicals in the regional groundwater.

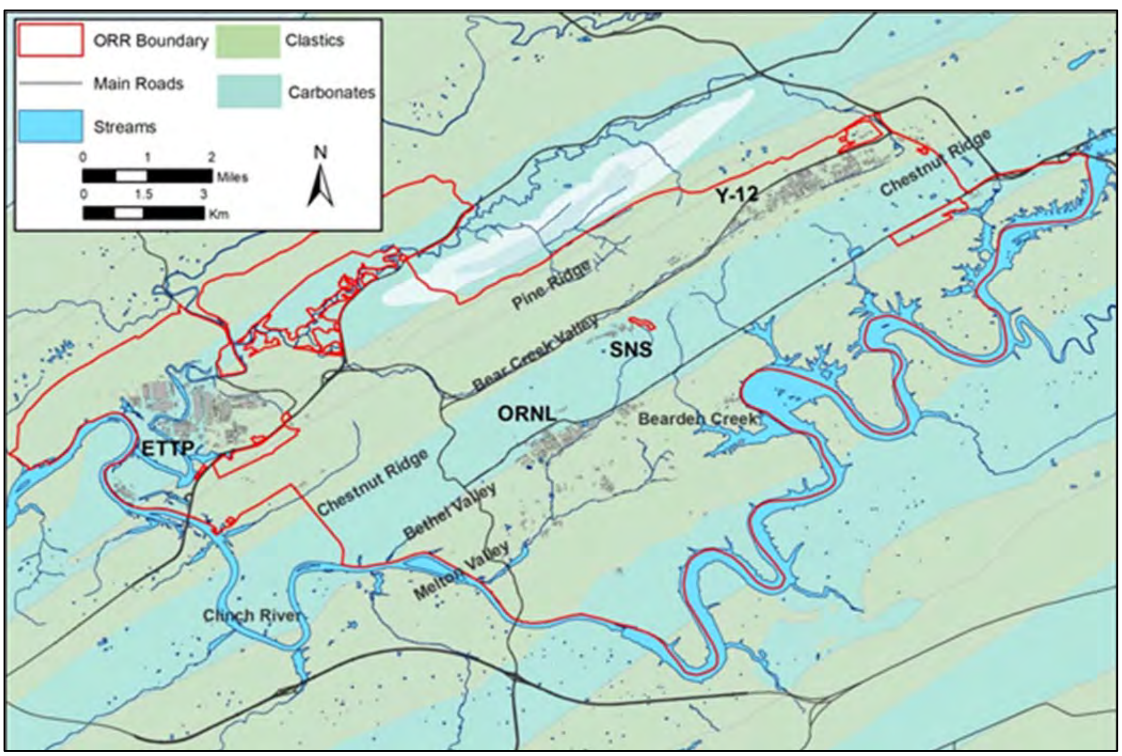

Figure 7.3: Primary DOE facilities, ORR boundary, and basic lithology with the Valley and Ridge locations.

7.2.4 Goals

The goal of the Background Residential Well Monitoring project was to sample and analyze the chemical composition of the regionally up-gradient (background) groundwater, northeast of the ORR, which is assumed to be comparable to the chemical composition of the downgradient groundwater and unaffected by ORR operations.

The data was evaluated by comparing it against other background and offsite 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 people by the release of contaminants.

7.2.5 Scope

The wells and springs, sampled as part of this project, are up-gradient along the geologic strike, and in the same lithology as the samples from the Offsite Residential Well Monitoring Project. Some of the wells and springs sampled previously were resampled. The sample locations for FY 2018 are shown in Figure 7.4. Some of the current fiscal year samples and historical samples which were archived in the laboratory refrigerator were analyzed for stable isotopes to determine possible nitrate and recharge source areas.

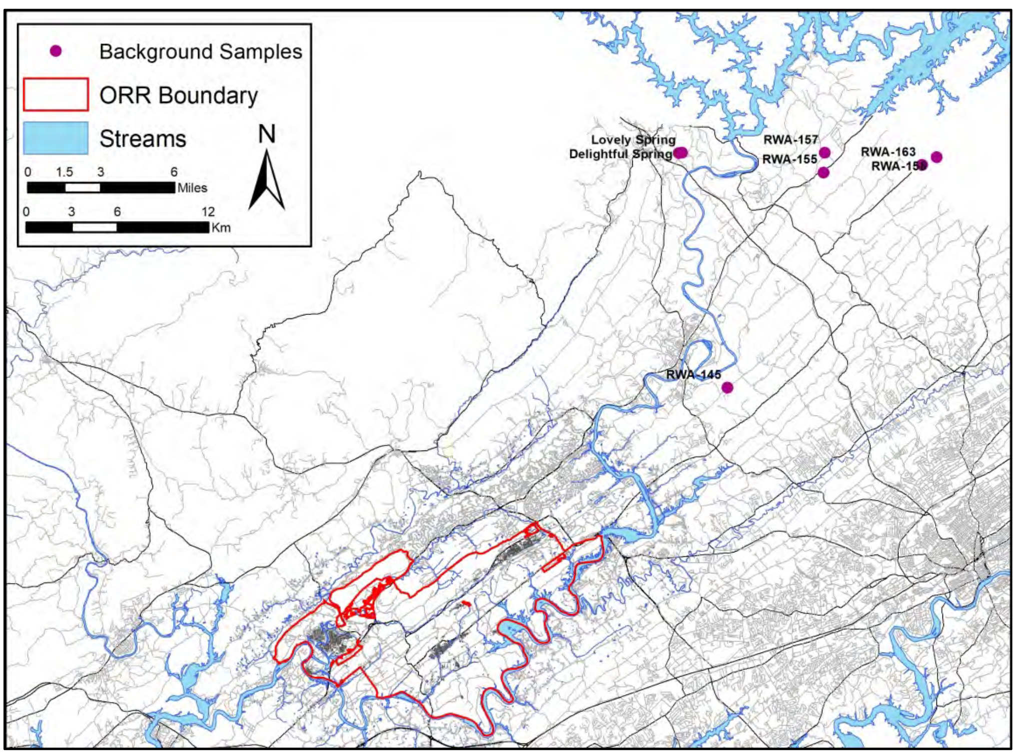

Figure 7.4: Background Sample Locations.

7.2.6 Methods, Materials, Metrics

Groundwater samples were collected from seven locations between December 2017 and April 2018. A total of nine sample suites were collected, including one associated quality assurance and quality control (QA/QC) sample. QA/QC samples include a duplicate sample and a field blank (deionized water) filled at the same location. The duplicate and field blank are typically associated with the same sample location.

The sampling locations are up-gradient and, when possible, in the same lithologies as ORR contamination sources and offsite samples. The groundwater samples collected from residential wells and springs were sent to the Tennessee Department of Health (TDH) Laboratory for analysis.

Sampling Techniques

A consistently-implemented groundwater sampling procedure helped ensure data comparability between sampling events and between sites. A sample for QA/QC was used to ensure the security and quality of the samples during collection and shipping to the laboratory for analysis.

Most of the locations selected for background sampling were residential wells, i.e., wells with plumbing in-place. In addition to the wells that were sampled, two groundwater springs were also sampled. The background sample locations are shown in Figure 7.4. The samples were analyzed for the analytes listed in Table 7.8, Analyte List.

Table 7.8: Analyte List

Groundwater Analyte List for Background 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	sulfate	fluoride
chloride	nitrate and nitrite	ammonia
total dissolved solids		
RADIONUCLIDES		
gross alpha	tritium	radium-228
gross beta	gamma radionuclides[2]	isotopic uranium
strontium-89	technetium-99	transuranic radionuclides
strontium-90	radium-226	
STABLE ISOTOPES		
oxygen-18 (in nitrate)[3]	deuterium (in water)[3]	oxygen-18 (in water)[3]
nitrogen-15 (in nitrate)[3]		

[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

[3] stable isotope data includes some historical samples

Prior to sampling the selected locations, groundwater was purged (i.e., let run from the sample port for a certain duration of time until water quality parameters stabilized). The intent of the purging process was to remove water that may have been standing in a holding tank or in another location to allow samplers to obtain a groundwater sample that was pulled directly from the surrounding groundwater aquifer (i.e., sampling “formation water”).

Water quality indicator parameters were collected using a YSI Professional Plus Multi-parameter Instrument during purging. Field parameters are indicators used to determine when the formation water was being removed. Stabilization of parameters is required before samples may be collected for laboratory analysis. Field parameter stabilization is defined as four consecutive readings within the criteria presented in Table 7.9. Field water quality parameter measurements were made at five-minute intervals.

Table 7.9: 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 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 that may have been connected to the well sampling port, at the residential well locations, were removed prior to sampling.

Samples were collected directly into the appropriate sample containers. The preferred order of sampling is: volatile organic compounds (VOCs), metals, inorganics, stable isotopes, and then radiochemical.

With the exception of the four 1-gallon containers, collected in each sample suite for radionuclide analysis, all samples were stored on ice and out of direct sunlight prior to Fed-Ex delivery to the state laboratory.

The groundwater samples were sent to the TDH Laboratory in Nashville for analyses. The nine groundwater samples also included sample aliquots that were shipped to the University of Arkansas, Department of Geosciences Stable Isotope Laboratory for analysis of stable nitrogen, oxygen, and deuterium (hydrogen) isotopes to determine the sources of nitrate in groundwater (i.e., industrial, soil, human and or animal waste, and or fertilizer), and the types or sources of recharge to groundwater.

The constituent suite analyzed in this background project is consistent with the constituent suite being analyzed in the Offsite Residential Well Monitoring Project, and this correlation of analyses will support comparisons of groundwater composition between these two projects.

7.2.6 Deviations from the Plan

Sixteen samples (10% QA/QC) were planned to be collected and analyzed during the 2018 FY. Due to budget changes which impacted this project, only nine samples were collected from seven locations. Samples were intended to represent unaltered groundwater; however, one well (RWA-145) is downgradient from a landfill and may be influenced by it. The project plan indicated duplicate and field blank QA/QC would be collected from the same sample location; however, they were collected from different locations.

7.2.7 Results from Analysis

This project has collected groundwater data, including fundamental geochemical parameters that are known to occur in natural groundwater, as well as chemical groundwater parameters that include contaminants of concern in ORR legacy waste. Some of those constituents of concern from ORR legacy waste may also be present in the environment from worldwide nuclear and industrial activities. Analyzing the background sample dataset will help DoR-OR better distinguish between what can be attributed to background levels or to additional man-made influences derived from ORR or other non-ORR activities.

Regulatory Comparison Values

The hydrochemical compositions of groundwater in private wells were compared to EPA standards for this project. The EPA has established the National Primary Drinking Water Regulations (NPDWR) to maintain the quality of water in public water supplies. These criteria include Maximum Contaminant Levels (MCL)s and Secondary Maximum Contaminant Levels (SMCL)s.

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 the public acceptance of water. These constituents include items 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 guidelines include: EPA Lifetime Health Advisory Values (HAs), EPA Regional Screening Levels (RSLs), and EPA Preliminary Remediation Goals (PRGs). These levels are not enforceable for public water utilities, but they can provide context for comparison of the results.

HAs 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 constituents 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 a YSI Professional Plus Multiparameter Instrument. Table 7.10 shows the final stable readings, taken immediately before collecting samples at each sampling event.

Table 7.10: Field Parameters for Background Wells

Field Parameters for Background 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-158 & DUP	12/4/2017	15.4	396.7	7.40	176.4	2.04	0.85
Delightful Spring	12/6/2017	13.5	412.8	7.62	254.6	8.24	0.39
Lovely Spring	12/6/2017	11.1	353.6	7.80	254.6	9.85	0.68
RWA-163	2/28/2018	15.3	235.2	6.92	142.6	7.32	1.64
RWA-155	3/19/2018	13.9	553.9	6.87	199.3	2.07	4.41
RWA-157	3/21/2018	15.6	309.2	8.06	172.0	2.53	0.90
RWA-145	4/2/2018	15.9	387.3	7.13	-50.9	0.23	17.95

-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 background samples 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) Because many VOCs were undetected in the results, only the wells with detections are listed in Table 7.11.

Three samples detected J coded concentrations of VOCs during this fiscal year at very low estimated values. Acetone can be a common laboratory contaminant. No VOC constituent was detected to be above EPA MCL or RSL comparison criteria.

Table 7.11: VOC Results

Background Volatile Organic Compound Results (µg/L)					
Analyte	EPA MCL	EPA RSL	Delightful Spring	Lovely Spring FB	RWA-145
Date			12/6/2017	12/6/2017	4/2/2018
acetone		14,000	1.06J	3.00J	U
chloroform	80		U	U	0.000170J

µg/L- micrograms per liter
J- Estimated Value
U-Undetected
FB- Field Blank

Metals

Table 7.12 lists the background metal results. Two wells detected comparison-value exceedances. Iron detected in RWA-145 was above the EPA SMCL, and sodium detected in RWA-157 was above the EPA HA. There were no metals detected above the EPA MCL for the sampling period. The levels of metals detected are low, natural concentrations. There were samples with elevated strontium that require further investigation. This investigation shows that very low detections to undetected results may be considered background or baseline levels.

Inorganics

The inorganics results for this sampling period are in Table 7.13. There are no EPA comparison criteria exceedances for the sampling event. There are no anomalous inorganics results associated with this sampling period. very low to undetected inorganics results may be indicative of background or baseline levels for the area.

Radiochemical Analyses

There were no detections above the EPA comparison criteria for radiochemical analytes. However, six samples did have detections of plutonium-239/240, nine samples did have detections of uranium-233/234, uranium-235/236, and uranium-238. These detections show influence of man-made radionuclides.

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Table 7.12: Metal Results

Background Metal Results														
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-158	RWA-158 DUP	Delightful Spring	Lovely Spring	Lovely Spring FB	RWA-163	RWA-155	RWA-157	RWA-145
Date						12/4/2017	12/4/2017	12/6/2017	12/6/2017	12/6/2017	2/28/2018	3/19/2018	3/21/2018	4/2/2018
aluminum	µg/L		50-200			U	U	U	8.83J	U	NR	13.1	U	13.1
antimony	µg/L	6			6	U	U	U	U	U	U	U	U	U
arsenic	µg/L	10		0.052		U	U	U	U	U	U	U	U	U
barium	µg/L	2,000		3,800		108	112	191	73.2	U	65.8	23.6	12.0	317
beryllium	µg/L	4		4		U	U	U	U	U	U	U	U	U
boron	µg/L			4,000	6,000	5.57J	6.83J	U	U	U	4.63J	31.4	63.0	15.3
cadmium	µg/L	5		9.2	5	U	U	U	U	U	U	U	U	U
calcium	mg/L					41.4	41.7	45.0	35.6	U	25.7	113	35.8	66.6
chromium	µg/L	100				U	U	U	U	U	1.36	U	U	U
copper	µg/L	1,300	1000			1.55	1.09	U	U	U	4.40	5.61	1.17	2.83
iron	µg/L		300	14000		51.2	38.9	U	9.30J	U	50.5	39.2	11.1	1530
lead	µg/L	15		15		U	U	U	U	U	0.381J	0.765J	U	U
lithium	µg/L			40		13.1	14.4	0.955J	U	U	NR	2.12	11.3	11.5
magnesium	mg/L					22.6	22.4	26.8	23.0	U	15.6	11.6	8.02	8.85
manganese	µg/L		50	non diet 430	300	0.922J	0.883J	U	2.04	U	1.51	4.45	U	12.8
mercury	µg/L	2		0.63	2	U	U	U	U	U	U	U	U	U
nickel	µg/L				100	1.30	1.24	1.44	1.40	U	1.04	2.48	0.881J	1.45
potassium	mg/L					2.66	2.63	0.584	0.660	U	1.88	1.28	1.58	1.17
selenium	µg/L	50		100	50	U	U	U	U	U	U	U	U	U
silver	µg/L		100	94	100	U	U	U	U	U	U	U	U	U
sodium	mg/L				20	2.81	2.75	0.712	1.47	U	1	2.6	21.80	5.46
strontium	µg/L			stable 12,000	4,000	3680	3220	73.1	19.9	U	18.5	153	128	249
thallium	µg/L	2				U	U	U	U	U	U	U	U	U
uranium	µg/L	30				U	U	1.05	U	U	U	U	0.383J	U
vanadium	µg/L			86		U	U	U	U	U	U	U	U	U
zinc	µg/L		5,000	6,000	2,000	U	2.95J	U	U	U	3.82J	10.2	227	31.9
total hardness	mg/L					196	196	223	184	U	129	329	122	203

- EPA MCL Exceedance
- EPA SMCL Exceedance
- EPA RSL Exceedance
- EPA HA Exceedance
- Comparison Values used

µg/L - micrograms per liter
mg/L - milligrams per liter

DUP - Duplicate
FB - Field Blank
J - Estimated Value
U - Undetected
NR - Not Reported

Table 7.13: Inorganic Results

Background Inorganic Results (mg/L)													
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-158	RWA-158 DUP	Delightful Spring	Lovely Spring	Lovely Spring FB	RWA-163	RWA-155	RWA-157	RWA-145
Date					12/4/2017	12/4/2017	12/6/2017	12/6/2017	12/6/2017	2/28/2018	3/19/2018	3/21/2018	4/2/2018
ammonia					U	U	U	U	U	NR	NR	0.0206J	U
chloride		250			4.15	6.84	2.18J	2.90	0.827J	2.49J	10.0	2.15J	3.27
fluoride	4	2			1.12	1.86	0.118	U	U	0.0520J	0.110	0.309	0.0733J
nitrate and nitrite	10			10	0.0297J	0.0309J	0.299	0.673	U	1.39	3.75	0.698	0.138
sulfate		250			34.3	29.0	8.48	3.80	U	2.15J	7.59	7.02	6.98
total dissolved solids		500			224	216	189	232	U	133	325	179	208
total alkalinity					172	174	186	220	6.48J	116	265	155	198

- EPA MCL Exceedance
- EPA SMCL Exceedance
- EPA RSL Exceedance
- EPA HA Exceedance
- Comparison Values used

DUP -Duplicate
FB -Field Blank
J - Estimated Value
U - Undetected
NR -Not Reported
mg/L -milligrams per liter

Table 7.14: Radiochemical Results

Background 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
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				
NBS Handbook 69 (correlation of pCi/L to 4mrem/year (TR=1E-4))	NA							20	8	900	20,000
RWA-158	12/4/2017	100	85	2.3	3.3 BDL	-0.02 BDL	0.51 BDL	-0.11 BDL	0.72 BDL	0.14 BDL	56 BDL
RWA-158 DUP	12/4/2017	91	87	2.1 BDL	4.6	0.2 BDL	0.56 BDL	-0.45 BDL	0.07 BDL	0.51 BDL	52 BDL
Delightful Spring	12/6/2017	44.8	34.1	2.11	2.2 BDL	-0.2 BDL	0.03 BDL	-0.52 BDL	0.06 BDL	0.3 BDL	-69 BDL
Lovely Spring	12/6/2017	50.2	36	-0.04 BDL	1.4 BDL	-0.25 BDL	-0.2 BDL	1.1 BDL	-0.35 BDL	0.42 BDL	62 BDL
Lovely Spring FB	12/6/2017	NDA	NDA	0.52 BDL	-0.3 BDL	-0.67 BDL	-0.2 BDL	0.4 BDL	-0.19 BDL	0.5 BDL	-11 BDL
RWA-163	2/28/2018	113	99	0.13 BDL	0.3 BDL	-0.16 BDL	0.03 BDL	0.68 BDL	-0.32 BDL	-0.17 BDL	0 BDL
RWA-155	3/19/2018	98	82	0.93 BDL	1.6 BDL	-0.2 BDL	-0.14 BDL	-0.43 BDL	0.3 BDL	-0.19 BDL	75 BDL
RWA-157	3/21/2018	58	49	0.85 BDL	1.2 BDL	-0.06 BDL	-0.01 BDL	0.57 BDL	-0.45 BDL	-0.04 BDL	48 BDL
RWA-145	4/2/2018	82	78	0.42 BDL	1 BDL	-0.31 BDL	-0.14 BDL	-0.365 BDL	-0.109 BDL	0.02 BDL	54 BDL

Well Name	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										
EPA PRG tapwater TR=1E-6 Nov 2014	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))										
RWA-158	0.009 ± 0.028 BDL	-0.011 ± 0.020 BDL	0.009 ± 0.019 BDL	0.019 ± 0.035 BDL	0.002 ± 0.018 BDL	0.03 ± 0.044 BDL	0.026 ± 0.022 BDL	0.36 ± 0.084	0.077 ± 0.037	0.133 ± 0.047
RWA-158 DUP	0.044 ± 0.032	0.005 ± 0.022 BDL	0.083 ± 0.046	0.028 ± 0.024 BDL	0.016 ± 0.019 BDL	0.05 ± 0.054 BDL	0.034 ± 0.027	0.298 ± 0.077	0.042 ± 0.027	0.107 ± 0.041
Delightful Spring	0.014 ± 0.029 BDL	0.014 ± 0.025 BDL	0.026 ± 0.031 BDL	-0.007 ± 0.044 BDL	-0.007 ± 0.023 BDL	0.019 ± 0.048 BDL	0.019 ± 0.027 BDL	0.649 ± 0.128	0.083 ± 0.038	0.357 ± 0.083
Lovely Spring	0 ± 0.038 BDL	0.007 ± 0.022 BDL	0 ± 0.023 BDL	0.027 ± 0.040 BDL	0.007 ± 0.017 BDL	0.007 ± 0.040 BDL	0.036 ± 0.027	0.252 ± 0.069	0.058 ± 0.034	0.141 ± 0.043
Lovely Spring FB	0.016 ± 0.028 BDL	0 ± 0.019 BDL	0.011 ± 0.027 BDL	0.015 ± 0.041 BDL	-0.004 ± 0.026 BDL	0.046 ± 0.045 BDL	0.05 ± 0.034	0.107 ± 0.044	0.058 ± 0.031	0.037 ± 0.028 BDL
RWA-163	0.011 ± 0.030 BDL	0.011 ± 0.017	-0.003 ± 0.033 BDL	0 ± 0.038 BDL	0.012 ± 0.018 BDL	0.057 ± 0.055 BDL	0.059 ± 0.032	0.098 ± 0.043	0.022 ± 0.020	0.066 ± 0.032
RWA-155	0.031 ± 0.028 BDL	0 ± 0.025 BDL	0.007 ± 0.022 BDL	0.011 ± 0.044 BDL	-0.004 ± 0.025 BDL	0.02 ± 0.047 BDL	0.029 ± 0.027 BDL	0.176 ± 0.055	0.03 ± 0.026	0.087 ± 0.036
RWA-157	0.009 ± 0.030 BDL	-0.004 ± 0.022 BDL	-0.007 ± 0.022 BDL	-0.003 ± 0.029 BDL	0.025 ± 0.039 BDL	0.038 ± 0.047 BDL	0.045 ± 0.031	0.342 ± 0.083	0.052 ± 0.032	0.16 ± 0.051
RWA-145	0.041 ± 0.032 BDL	0.005 ± 0.022 BDL	-0.007 ± 0.017 BDL	0.036 ± 0.036 BDL	0.015 ± 0.025 BDL	0.046 ± 0.048 BDL	0.044 ± 0.032	0.182 ± 0.057	0.051 ± 0.030	0.09 ± 0.038

- EPA MCL Exceedance
- EPA SMCL Exceedance
- EPA PRG Exceedance
- EPA HA Exceedance

FB -Field Blank
DUP -Duplicate
TR -Target Risk
pCi/L - picoCuries per liter
BDL -Below Detection Limit
NDA - Not Detected Analyte

7.2.8 Conclusions

Groundwater data collected from background locations provide important data to aid in understanding the local hydrology and to generate a water quality baseline that could be used for comparison to the groundwater results obtained on-site and offsite the ORR. The DOE collected offsite background data prior to beginning operations on the ORR. The five residential wells and two springs sampled during this period represent a snapshot in time, and therefore, it is difficult to make predictions about spatial- and temporal-trend behavior of groundwater, as well as potential contaminant pathways. Trend predictions will be made using previous background sample events and as more data is collected.

7.2.9 Recommendations

Recommendations for future work on this project include:

Due to the rapid groundwater flow rates which can be observed in fractured carbonate, karst, and fractured clastic rock types (Worthington et al., 2000; Worthington et. al, 2016), the groundwater quality at specific sampling locations in this study (and within these regional rock units) has the potential to change rapidly. This project should be continued in the future in order to obtain a more representative sampling of water quality data within those rocks. Additional monitoring will support incorporation of a larger statistical range of spatial and temporal data into the background dataset, allowing for a more complete assessment of background with future studies.

Borehole logging with the USGS to geophysically, visually, and geochemically profile wells in strategic background locations may be appropriate. This effort would help in understanding residential well construction and would support the identification of the water-producing rock types within the open borehole structure where residential water wells are typically constructed. This additional physical well information would assist with the interpretation of results from these wells.

7.3 Stable Isotopes Analyses for Residential Groundwater Projects

7.3.1 Background

Project Background:

This stable isotope section incorporates data from both the offsite (Section 7.1) and background (Section 7.2) residential well monitoring projects. The problem statements, goals, scope, assumptions, constraints, stakeholders, and methods, and recommendations are the same for this portion of the groundwater investigation as was identified previously in the offsite and background residential well monitoring sections above. There are no variances due to the stable isotopes being listed in the analyte list. The data incorporated in this study includes historical and 2017-2018 fiscal year (FY) samples.

Stable Isotope Background:

Several isotopes are naturally occurring and radioactively stable, i.e. stable isotopes. The notation for stable isotopes is the change from the standard (delta, δ) in permil (‰). Stable isotopes fractionate (separate), with respect to their slight difference in mass, exchange reactions, and kinetic processes. Original processes set the ratios, and in generally closed systems, remain the same through the flow system. Isotopes that are less abundant act as tracers; for example, oxygen isotope ratio ($^{18}O/^{16}O$) compared to a standard may be used to trace certain changes in hydrological processes. These changes may help to distinguish different water types from each other.

In water, isotopic relationships were first determined in precipitation using plots of $\delta^{18}O$ versus $\delta^{2}H$ (Craig, 1961). These plots helped to establish a global relationship for precipitation, the Global Meteoric Water Line (GMWL). This line is described by: $\delta^{2}H = 8\ \delta^{18}O + 10$ (Kendall and Caldwell, 1998). The slope, 8, represents the equilibrium Raleigh condensation of rain at about 100% humidity, or is close to the ratio of equilibrium fractionation factors of hydrogen and oxygen isotopes. As a result of fractionation, waters and substances dissolved in them developed unique ratios that can be indicative of the processes where they originated (Kendall and Caldwell, 1998).

Nitrogen is the main component of the atmosphere (78%) and is in precipitation, soil, surface water, groundwater, human waste, and animal waste. Nitrates are used to produce fertilizers, so elevated nitrates are typically found in fertilized soil. Ammonia is another common form of nitrate found in surface and groundwater. Lastly, another form—nitric acid— is commonly used at facilities that separate uranium and other heavy metals. There has been an abundant use of nitric acid on the ORR and most of the ORR waste has been described as "nitrate rich." There are two stable nitrogen isotopes, ^{14}N and ^{15}N.

Historical and 2017-2018 fiscal year sample aliquots were analyzed at the University of Arkansas, Department of Geosciences Stable Isotope Laboratory for oxygen-18 (^{18}O; ratio $^{18}O/^{16}O$) and hydrogen (deuterium ^{2}H; ratio $^{2}H/H$) in water, and ^{18}O and nitrogen-15 (^{15}N) in nitrate. Samples were sent in two batches: 2016-2017 fiscal year and 2017-2018 fiscal year. The results from both batches are presented in this report. The historical samples were held in the laboratory refrigerator until ready for shipment.

7.3.2 Results from Analysis

Oxygen and Hydrogen Isotopes

^{18}O and ^{2}H in groundwater were used to determine the possible sources or recharge area (Figure 7.5). A graph of $\delta^{18}O$ versus $\delta^{2}H$ helped in source determination and to determine if groundwater closely related to meteoric water (precipitation) by a sample's relationship to the GMWL. If the meteoric water signature in groundwater at depth was present, there must be rapid recharge and rapid circulation through the bedrock system. If groundwater flow was slow, then it would not be meteoric anymore, and it would plot further away from the GMWL. This groundwater would also become more saline as minerals in the bedrock are dissolved. Most of the samples plot near the GMWL (are meteoric water), are “young” waters, and thus contamination may be transported long distances in the subsurface (Figure 7.5). Some of the waters plot to the left and far away from the GMWL. These waters appear to trend towards the heavier (less negative) hydrogen isotope, seen in the gray area in Figure 7.5. Heavy hydrogen isotopes are considered unusual isotopic compositions, and may be associated with deep saline waters often associated with Precambrian crystalline rocks (Hoefs, 1997).

Analysis and interpretation of the oxygen and hydrogen isotopes is ongoing.

Nitrogen and Oxygen Isotopes

The nitrogen and oxygen isotopic data were plotted on a graph of $\delta^{15}N$ versus $\delta^{18}O$ with the various data ranges for known types of nitrate and an arrow showing the denitrification trend, Figure 7.6.

A large group of samples plot within the soil nitrogen range and the manure and septic waste grouping, while some plot just in the manure and septic waste grouping. This is typical of rural groundwater wells. Some other samples also have overlapping signatures of ammonium (NH_4); in fertilizer, rain, and soil Nitrogen changed by bacterial action. These results appear to be natural and what would be expected in rural settings.

There were other samples that may not be natural. These wells fall within the manure and septic waste grouping and the Hanford-identified Nitrate Purex Process Grouping. There were no samples that fell only within the Hanford-identified Nitrate Purex Process Grouping.

One well, in this grouping, OMW-422L, fell more in the Hanford-Identified Nitrate Purex Process Grouping than the other group. This well had thorium-238 (825 ± 316 pCi/L) and lead-212 (1050 ± 444 pCi/L) detections in 2013. It was determined that this well also had free product that was identified by the TDH Laboratory as diesel fuel. Hanford-identified Nitrate Purex Process Grouping is the same field that nitrate used in the plutonium-uranium separation process at Hanford, Washington, plots (Christensen et al., 2006). These processes may have been similar to what was used on the ORR. Since this well is in both groupings, it has the potential to have been influenced from either manure or septic waste; and/or the Hanford-identified Nitrate Purex Process Grouping.

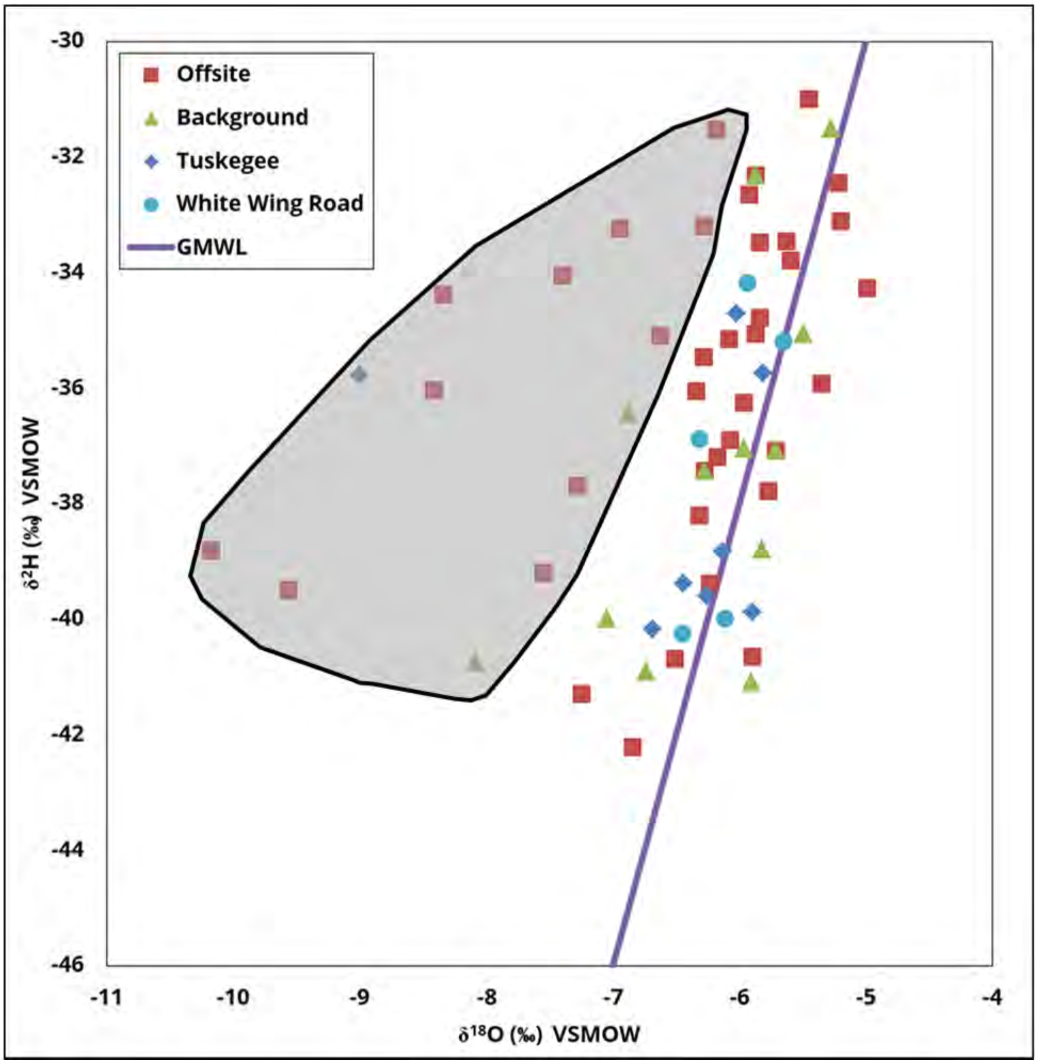

Figure 7.5: $\delta^{18}O$ versus $\delta^{2}H$ with a legend showing the sample areas.

The gray area plots farther away from the GMWL and trends towards the heavier hydrogen isotope. This gray area mainly contains offsite samples.

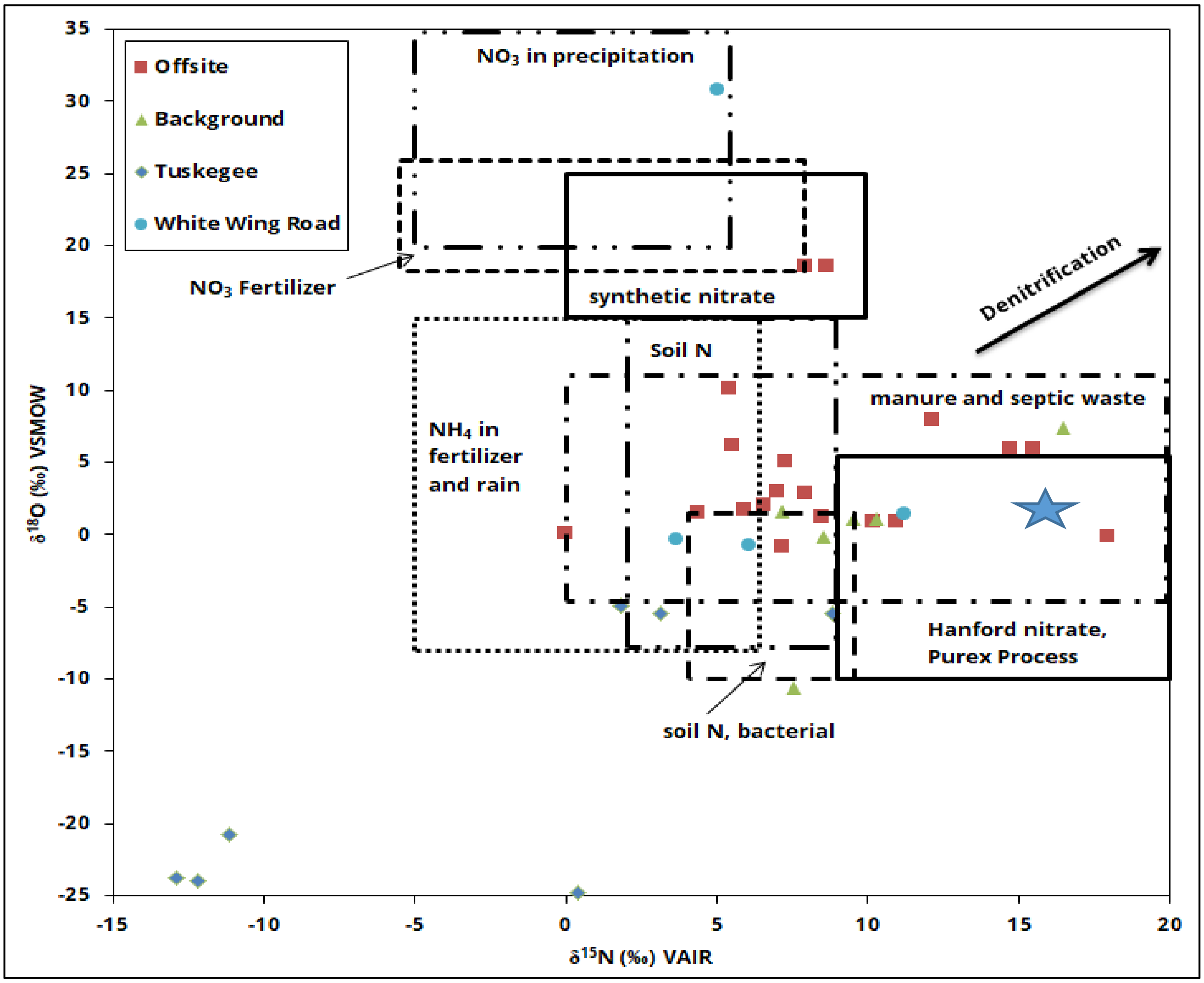

FIGURE 7.6: δ15N versus δ18O with a legend showing the sample areas.

The established nitrate data range groupings are also shown and labeled. The arrow shows denitrification trend. The star is used to mark the OW-422L well.

7.3.3 Conclusions

Two main conclusions from the stable isotope data were made.

- The $\delta^{18}O$ versus $\delta^{2}H$ plot showed that the majority of the samples were meteoric water. There was a group of samples that were to the left of the GMWL that trends toward heavier hydrogen isotopes. This may be indicative of groundwater mixing with deeper saline groundwater.
- The $\delta^{15}N$ versus $\delta^{18}O$ plot shows that the majority of the samples fell within natural nitrate ranges. One sample, collected from OW-422L, identified the potential for man-made impacts and may require further investigation.

7.4 Ambient Local Springs Monitoring

7.4.1 Background

Since the beginning of the Manhattan Project, spills, leaks, and releases of varying constituents have made their way into the groundwater on the Oak Ridge Reservation (ORR) and have traveled off of the ORR. With no sampling of groundwater on the ORR before the Manhattan Project, no baseline or background (sampling results) data is available from before the establishment of the Manhattan Project. Therefore, a study of springs on and around the Oak Ridge Reservation's (ORR) was warranted to help determine baseline chemical constituent conditions of groundwater.

The Ambient Local Springs Monitoring Project initiated in 2014, originally planned to monitor 69 springs and sample fifteen named springs. The rationale for sampling the 15 named springs was based on their physical parameter measurements. Springs selected for monitoring were selected from named springs located on USGS topographic quadrangles.

Samples collected were analyzed for metals, inorganics, volatile organics, and radionuclides. Water quality parameters (temperature, pH, and specific conductivity, oxidation-reduction potential, and dissolved oxygen) provide indications of different flow regimes (deep/shallow flow or base flow/overflow springs) that may be encountered in groundwater. The information gathered from this project may be of use to DOE and other TDEC activities as they pertain to background concentrations identified in native groundwater.

7.4.2 Problem Statements

Since the beginning of the Manhattan Project, spills, leaks, and releases of varying contaminants have made their way into the groundwater on the ORR and some may have traveled off of the ORR.

The background chemical make-up of groundwater in and around the ORR has not been determined definitively. This information is used when regulating the design and operation of groundwater remediation.

The drilling of wells by TDEC to sample groundwater off and on the ORR is extremely difficult due to logistics and cost. Therefore, springs represent opportunities to sample groundwater.

Sometimes a water constituent is naturally elevated and cannot be attributed to DOE activities.

7.4.3 Goals

The goals of the Ambient Local Springs Monitoring Project follow:

- Collect meaningful analytical data to assist with the determination of background water makeup.
- Compare data from DOE sampling to data from TDEC sampling in this Project Report
- Identify areas requiring further investigation.
- Make recommendations, based on findings, to focus remediation efforts in areas that are most impacted by contaminants.

7.4.4 Scope

Springs have been historically sampled on the ORR and the samples analyzed to evaluate the quality of groundwater at groundwater discharge locations (springs). Sixty-nine springs, 40 of which are historic springs, documented on topographic maps, were scheduled to be visited by TDEC to document their water quality parameters. Water quality parameters (temperature, pH, specific conductivity, oxidation-reduction potential and dissolved oxygen) can provide indications of the different flow regimes (deep/shallow flow or baseflow/overflow springs) that may be encountered.

The 69 springs, their associated sampling rationale, and a suggested list of analytical parameters are provided in Table 7.15 and shown on Figure 7.7.

Table 7.15: Spring Sampling Locations

Spring Sampling Locations			
Spring	**Station Number**	**Analysis Requested**	**Sampling Rationale**
Knight	SPG-041	See Notes: M IV R1	No previous infromation from this spring hydraulically upgradient from ORNL
Carter Big	SPG-048		No previous infromation from these springs that are south of ORNL
Malone	SPG-049		
McNeely	SPG-050		
Concord	SPG-051		No previous infromation from these springs that are southeast of ORNL
Herron	SPG-052		
Duncan	SPG-053		
Dentist	SPG-054		
Blue (SE)	SPG-055		
Eldridge	SPG-056		No previous information for these springs that are east of ORNL
Pitts	SPG-057		
Roberts	SPG-076		
Horizon	2015SPGEMP15-11		Regional Spring and spring with no previous information with potential for Y-12 contaminants
Haynes	SPG-042		
Gamble (Quarry)	SPG-043		No previous information for these springs that are hydraulically upgradient from Y-12
Holbert	SPG-044		
Miller	SPG-045		
Yarnell	SPG-046		No previous information for these springs that are hydraulically upgradient from Y-12
Turpin	SPG-047		
Love	2015SPGEMP15-20		No previous information for these springs that are hydraulically downgradient from Y-12
Dead Horse	2015SPGEMP15-19		
Green Barn Sp.	2015SPGEMP15-08		Spring below the Chestnut Ridge/Landfills
RCB Spring	2015SPGEMP15-23		Regional spring Northeast from Y-12
SS-5 Sp.	2015SPGEMP15-28		Spring drains most of western Y-12/SNS/EMWMF
SS-7 Sp.	2015SPGEMP15-29		Spring drains most of western Y-12/EMWMF
Gallaher Sp.	2015SPGEMP15-30		Regional offsite spring in Bear Creek Valley near the Clinch River
SS-4 Sp.	2015SPGEMP15-31		Spring drains most of western Y-12. Historic analytical data suggest discharge is from S-3 ponds
Gum Branch 1 Sp.	2015SPGEMP15-33		Spring north of the burial grounds, EMWMF and EMDF
Gum Branch 2 Sp.	2015SPGEMP15-34		
Pinhook Sp.	2015SPGEMP15-35		
Bootlegger Sp.	2015SPGEMP15-38		Baseflow spring that drains Chestnut Ridge/Security Pits
Cattail Sp./Cattail Sp. East	2015SPGEMP15-39		Spring drains east end of Y-12 volatile plume
Blue(CEC)	2015SPGEMP15-10		Characterization of basic water quality parameters and south of ORNL

MIVR1 - Metals, Inorganics, Volatiles, and Radionuclides (Gross Alpha\Beta, Gamma Radionuclides, Tritium)

MIVR2 - Metals, Inorganics, Volatiles, and Radionuclides (Gross Alpha\Beta, Gamma Radionuclides, Technetium-99, Tritium)

MIVR3 - Metals, Inorganics, Volatiles, and Radionuclides (Gross Alpha\Beta, Gamma Radionuclides, Strontium-90, Technetium-99, Tritium)

Sp. - Spring

Table 7.15 (continued): Spring Sampling Locations

Spring Sampling Locations			
Spring	Station Number	Analysis Requested	Sampling Rationale
Key Sp.	SPG-058	See Notes: M I V R2	No previous information from these springs hydraulically upgradient from ETTP
Bacon Sp.	SPG-059		
Deep	SPG-060		
Shetterly	SPG-061		
Burress	SPG-062		
Shinlever	SPG-063		
Pop Hollow	SPG-064		
Martin	SPG-065		
Mill	SPG-066		Located in Sugar Grove Valley, west of ETTP
Dickey	SPG-067		Located in Sugar Grove Valley, west of ETTP
Turnpike Sp.	2015SPGEMP15-02		Regional offsite spring, western Oak Ridge
Edwards Sp.	2015SPGEMP15-09		Located in Sugar Grove Valley
Regina Loves Bobby Sp	2015SPGEMP15-27		Located in Sugar Grove Valley
21002 Sp.	2015SPGEMP15-32		Spring has been dye traced from K-1070A.
Rarity Sp.	2015SPGEMP15-36		Regional spring located in Clinch River
USGS 10-895 Sp.	2015SPGEMP15-37		Suspect to discharge from the Contractor Spoils Area and or K-1070A
Sugar Grove Sp.	2015SPGEMP15-15		Offsite spring in Sugar Grove Valley
PCO Spring	SPG-079		Determine if any new inputs from remedial activities at ETTP are discharging to this spring
Sands	SPG-068	M I V R3	Characterization of basic water quality parameters and hydraulically upgradient from ORNL
Black Ferry	SPG-069		Characterization of basic water quality parameters and hydraulically upgradient from ORNL
Moore	SPG-070		
Fowler	SPG-071		
Bowman	SPG-072		
Conner	SPG-073		
Lewis	SPG-074		
Big	SPG-075		
CCC-Sp.	2015SPGEMP15-03		Springs in the Copper Ridge Formation, hydraulically downgradient from ORNL
Poplar Sp.	2015SPGEMP15-04		
Concrete Box or County Line Sp.	SPG-077		Drains Chestnut Ridge
N.W. Trib Sp.	2015SPGEMP15-06		Spring drains parts of WAG 3
Rifle Range Sp./0956 Sp.	2015SPGEMP15-17		Spring drains Chestnut Ridge towards ORNL
Crooked Tree Sp.	2015SPGEMP15-18		Spring drains WAG 6
Mt. Vernon Sp.	SPG-080		Baseflow spring that drains Chestnut Ridge/Landfills
Sycamore Sp./Raccoon Creek Trib.	2015SPGEMP15-26		Spring drains parts of WAG 3
Mtn. Dew/Overhang Sp.	2015SPGEMP15-40		Provide confirmation sampling
Ish Weir Sp.	SPG-078		Spring that drains a portion of Bear Creek Valley, near the Firing Range

MIVR1 - Metals, Inorganics, Volatiles, and Radionuclides (Gross Alpha\Beta, Gamma Radionuclides, Tritium)

MIVR2 - Metals, Inorganics, Volatiles, and Radionuclides (Gross Alpha\Beta, Gamma Radionuclides, Technetium-99, Tritium)

MIVR3 - Metals, Inorganics, Volatiles, and Radionuclides (Gross Alpha\Beta, Gamma Radionuclides, Strontium-90, Technetium-99, Tritium)

Sp. - Spring

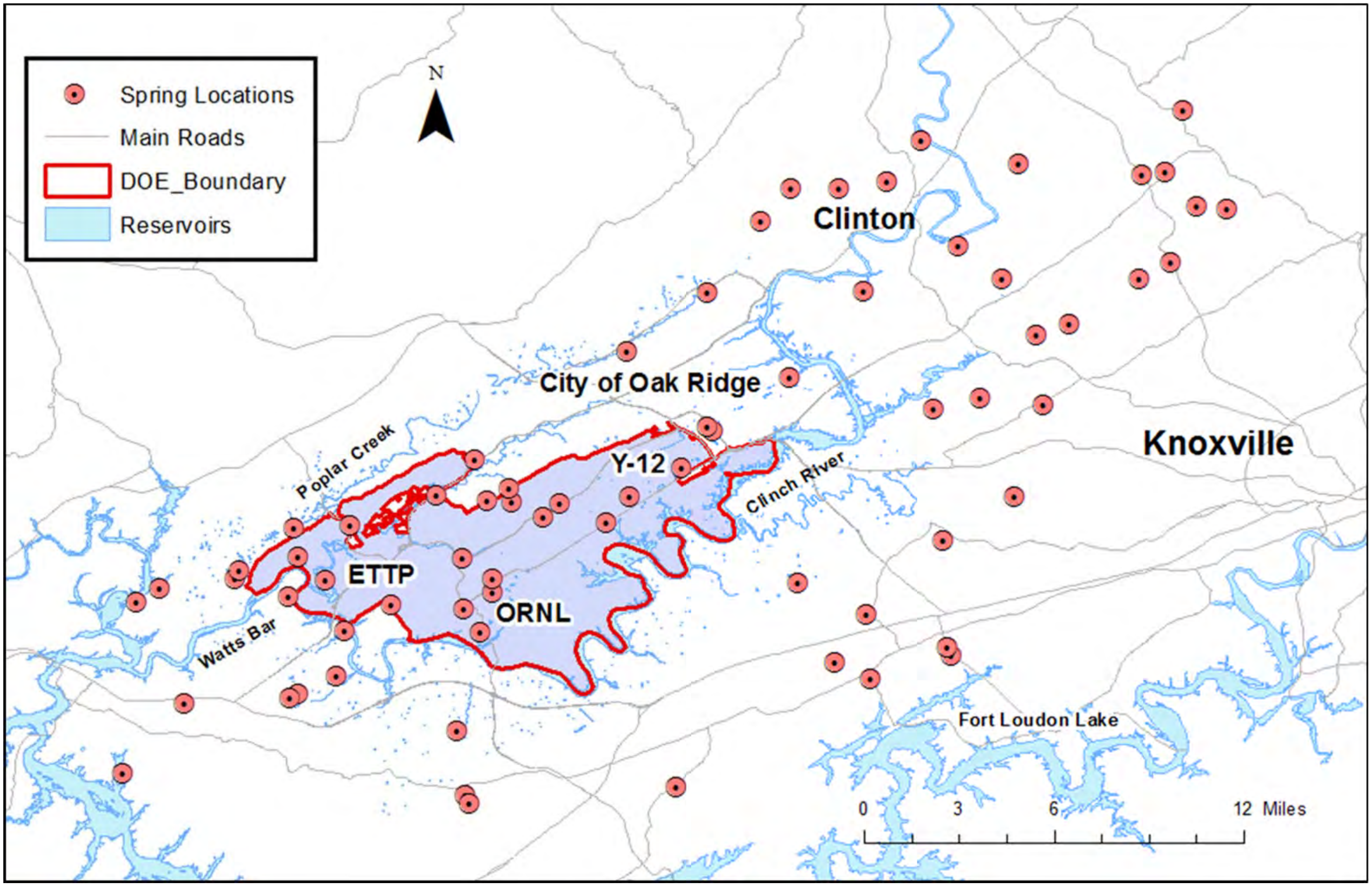

Figure 7.7. Springs Monitoring/Sampling Locations

Fifteen springs of the 69 were also sampled for analytical parameters. The sample locations and analytical parameters selected were determined based on representative measured water quality data and the spring location. Analytical samples were tested for metals, inorganics, volatile organics, and radionuclides.

For the current fiscal year, no samples were collected nor sent for laboratory analysis instead, a historical review of TDEC samples was conducted. TDEC results are compared with DOE groundwater (springs) data to assess for trends.

7.4.5 Methods, Materials, Metrics

Springs and seeps were sampled according to the TDEC Environmental Monitoring Plan and in compliance with EPA and TDEC standard operating procedures. Parameters such as pH, temperature, turbidity, oxidation reduction potential, and conductivity were measured before sampling and recorded in the field notes to determine which springs were sampled. Springs were sampled based on field observation of flow and safety considerations.

Waters influenced by ETTP were analyzed for Tc-99. Waters influenced by ORNL were analyzed for Sr-89/90. If a sample showed a gross alpha activity greater than 5 picocuries/liter then a radionuclide isotope-specific analysis for alpha emitters was evaluated for additional analysis (e.g., radium 226/228).

Analysis at all sampling locations included calcium, magnesium, sodium, potassium, chloride, sulfate, nitrate, bicarbonate (alkalinity as $CaCO_3$), and carbonate (hardness as $CaCO_3$) in order to calculate ionic charge balances and to perform groundwater geochemical "fingerprints". Volatile organic compounds (VOCs) were analyzed from samples collected at all springs.

The Tennessee Department of Health analytical laboratory in Nashville, Tennessee furnished sample containers. Samples were collected using approved procedures. Nitrile or vinyl examination gloves, decontamination of equipment, and other sample management and handling procedures were utilized to avoid cross contamination. TDEC DoR-OR sample coolers were used for transport to the state laboratory.

Data collected over the course of the spring monitoring project, compared current results with previous analyses of groundwater in order to determine and verify trends.

Standard Operating Procedures (SOPs)

- Water Pollution Control QSSOP: Tennessee Department of Environment and Conservation. Quality System Standard Operating Procedure for *Chemical and Bacteriological Sampling of Surface Water*, Tennessee Department of Environment and Conservation, Division of Water Pollution Control (2011).
- Division of Remediation Oak Ridge: *Sampling and Analysis Plan for General Environmental Monitoring of the Oak Ridge Reservation and its Environs* (2016).

- Division of Remediation Oak Ridge: *Environmental Sampling of the Oak Ridge Reservation and Its Environs, Quality Assurance Project Plan* (2015).
- Surface Water sampling EPA's SESDPROC 201-R4 (2016).

Methods: Lab Methods

The Tennessee Department of Health Laboratory uses EPA methods for sample analysis. The requested analytical methods are listed in Table 7.16.

For the five samples sent for laboratory analysis in 2017, gross alpha ranged from -0.22 to 1.82 picoCuries per Liter (pCi/L). (The EPA drinking water standard (NPDWR) for gross alpha activity is 15 pCi/L.) Gross beta ranged from 1.1 to 4.3 pCi/L with the NPDWR 4 millirem per year (mrem/yr.), which is approximately 50 pCi/L. Strontium-90 ranged from 1.11 to .324 pCi/L and the NPDWR is also 4 mrem/yr, which is approximately 8 pCi/L. Tritium ranged from -31 to 18 pCi/L and the NPDWR is also 4 mrem/yr which works out to 20,000 pCi/L. Refer to Table 7.16.

Table 7.17, 7.18 and 7.19, provides summary of the analyses for all offsite springs sampled by TDEC over the course of the project (2015 and 2017). The numbers of samples analyzed varied by constituents depending upon sample sets evaluated on any given year. The maximum concentration/activity for three metals constituents (aluminum, iron, manganese) showed levels above NSDWR regulatory values. The maximum concentration of uranium metal was identified at 0.42 ug/L. NPDWR regulatory level is 30 ug/L.

There were no NPDWR exceedances in the maximum concentration column for organic analyte evaluation for the offsite spring samples.

Table 7.16: 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

7.4.6 Deviations from the Plan

Samples were not collected and there were no trips made to collect parameters for this project during this fiscal year. Instead, historical spring data was assessed. Groundwater evaluation through spring sampling will be incorporated into the overall groundwater projects in the future.

7.4.7 Results and Analysis

Radiochemical sampling analyses results for samples collected in June 2017 were not reported in the 2017 EMR. The results were not received in time for inclusion in the report. They are included and discussed here. Table 7.17 contains a summary of those results for inorganic, organic, and radiochemical analyses.

None of the measured constituents from the FY2017 offsite spring sampling events reported gross alpha and beta; gamma radionuclides, strontium-89, and strontium-90, technetium-99, and tritium that were elevated above NPDWR standards.

Table 7.17, Summary of Analyses for Springs Sampled in 2017

Analytes	Number of Samples Analyzed	Number of Analytes Detected	Min. Conc./ Activity	Max. Conc./ Activity	NPDWR (P) NSDWR (S)	Units
INORGANIC ANALYTES						
Aluminum	5	5	4.6	320	50 - 200 S	ug/L
Arsenic	5	0	0	0	10 P	ug/L
Barium	5	5	3.4	91	2000 P	ug/L
Boron	5	5	4.8	11	No Criteria	ug/L
Cadmium	5	0	0	0	5 P	ug/L
Calcium	5	5	18	59	No Criteria	mg/L
Chromium	5	0	0	0	100 P	ug/L
Iron	5	5	0	380	300 S	ug/L
Lead	5	3	0	2.1	15 P	ug/L
Lithium	5	2	0	2.3	No Criteria	ug/L
Magnesium	5	5	7.6	20	No Criteria	mg/L
Manganese	5	5	0.9	290	50 S	ug/L
Mercury	5	0	0	0	2 P	ug/L
Nickel	5	5	0.8	2.3	100 TDEC	ug/L
Potassium	5	5	1.1	2.3	No Criteria	mg/L
Selenium	5	0	0	0	50 P	ug/L
Sodium	5	5	1.3	3	No Criteria	mg/L
Strontium	5	5	26	73	No Criteria	ug/L
Uranium	5	0	0	0	30 P	ug/L
Calcium Hardness BC	5	5	44	150	No Criteria	mg/L
Chloride by IC	5	5	1.7	4.85	250 S	mg/L
Nitrate and Nitrite	2	2	0.5	1	10 P	mg/L
Nitrate by IC	5	5	0.37	1.3	10 P	mg/L
Sulfate	5	5	4.8	9.3	250 S	mg/L
Total Alkalinity	5	5	79.3	214	No Criteria	mg/L
Total Dissolved Solids	5	5	96	218	500 S	mg/L
Total Hardness	1	1	91	91	No Criteria	mg/L
RADIOCHEMICAL ANALYTES						
Gross Alpha	5	5	-0.22	1.82	15 P	pCi/L
Gross Beta	5	5	1.1	4.3	4 mrem/yr ~50 pCi/L P	pCi/L
Gamma Radionuclides	5	5	NDA	NDA	4	mrem/yr
Bi-214	5	5	14.9	87	4	mrem/yr
Pb-214	5	5	15.3	85	4	mrem/yr
Sr-89	5	5	-1.85	2.58	4	mrem/yr
Sr-90	5	5	-1.11	0.324	4	mrem/yr
Tc-99	5	5	-0.49	0.43	4	mrem/yr
Tritium	5	5	-31	18	4	mrem/yr
ORGANIC ANALYTES						
Bromodichloromethane	5	1	0.333	0.333	No Criteria	ug/L
Chloroform	5	1	1.88	1.88	No Criteria	ug/L
Trichloroethene	5	3	0.199	0.209	5 P	ug/L

Max. - maximum
Conc. - concentration
ug/L = micrograms per liter
umhos/cm = micromhos per centimeter
QA/QC = Quality Assurance/Quality Control
NPDWR (P) = National Primary Drinking Water Regulations
pCi/L = pCi/L is one trillionth (10E-12) of a Curie
TDEC = Determined by the State of Tennessee Rule 0400-40-03-.03j

Min. - minimum
mg/L - milligram per liter
BC = By Calculation
IC = Ion Chromatography
J = Estimated Concentration
NSDWR (S) = National Secondary Drinking Water Regulations
NDA - No Detectable Activity
mrem/yr = A millirem is 1/1000 of the calculated

Table 7.18: Summary of Analyses for all Off-site Springs Sampled by TDEC

ANALYTES	Number of Samples Analyzed	Number of Analytes Detected	Min. Conc. ug/L, mg/L	Max. Conc. ug/L, mg/L	NPDWR (P) NSDWR (S)	Units
INORGANIC ANALYTES						
Metals						
Aluminum	15	15	4.6	320	50 - 200 S	ug/L
Arsenic	15	0	0	0	10 P	ug/L
Barium	15	15	23	91	2000 P	ug/L
Boron	15	5	4.8	34	No Criteria	ug/L
Cadmium	15	0	0	0	5 P	ug/L
Calcium	15	15	18	88	No Criteria	mg/L
Chromium	14	0	0	0	100 P	ug/L
Iron	15	14	12	400	300 S	ug/L
Lead	15	4	0.42	2.1	15 P	ug/L
Lithium	7	6	0.46	2.3	No Criteria	ug/L
Magnesium	15	15	3.4	25	No Criteria	mg/L
Manganese	15	15	0.63	290	50 S	ug/L
Mercury	15	0	0	0	2 P	ug/L
Nickel	15	15	0.63	5.5	100 TDEC	ug/L
Potassium	15	15	0.6	2.3	No Criteria	mg/L
Selenium	15	0	0	0	50 P	ug/L
Sodium	15	15	0.7	12	No Criteria	mg/L
Strontium	15	15	25	140	No Criteria	ug/L
Uranium	15	1	0.42	0.42	30 P	ug/L
Inorganics						
Chloride by IC	15	15	1.6	23	250 S	mg/L
Conductivity	13	13	120	400		umhos/cm
Nitrate and Nitrite	10	10	0.11	1.1	10 P	mg/L
Acidity (pH)	7	7	6.57	7.23		Std. Units
Sulfate by IC	15	15	1.88	13	250 S	mg/L
Total Alkalinity	15	15	79.3	230	No Criteria	mg/L
Total Dissolved Solids	15	15	96	290	500 S	mg/L
Total Hardness	7	7	91	210	No Criteria	mg/L

Max. - maximum

Conc. - concentration

ug/L = micrograms per liter

umhos/cm = micromhos per centimeter

QA/QC = Quality Assurance/Quality Control

NPDWR (P) = National Primary Drinking Water Regulations

pCi/L = pCi/L is one trillionth (10E-12) of a Curie

TDEC = Determined by the State of Tennessee Rule 0400-40-03-.03j

Min. - minimum

mg/L - milligram per liter

BC = By Calculation BL = By Laboratory

IC = Ion Chromatography

J = Estimated Concentration

NSDWR (S) = National Secondary Drinking Water Regulations

mrem/yr = A millirem is 1/1000 of the calculated radioactive dose equivalent to the Total Body or any Critical Organ

Table 7.19: Summary of Organic and Radiochemical Analyses for all Off-site Springs Sampled by TDEC

ANALYTES	Number of Samples Analyzed	Number of Analytes Detected	Min. Conc. ug/L /Activity pCi/L	Max. Conc. ug/L /Activity pCi/L	NPDWR (P) NSDWR (S)	Units
ORGANIC ANALYTES						
1,1,1-Trichloroethane	15	1	0.37	0.37	200 P	ug/L
1,1-Dichloroethane	15	1	2.54	2.54	No Criteria	ug/L
1,1-Dichloroethene	15	1	0.75	0.75	7 P	ug/L
1,2,4-Trichlorobenzene	15	1	0.675	0.675	No Criteria	ug/L
Bromodichloromethane	15	1	0.333	0.333	No Criteria	ug/L
Carbon disulfide	11	1	0.104	0.104	No Criteria	ug/L
Chloroform	15	5	0.107	1.88	No Criteria	ug/L
Chloromethane	15	1	0.35	0.35	No Criteria	ug/L
cis-1,2-Dichloroethene	15	1	1.48	1.48	70 P	ug/L
Tetrachloroethene	15	1	1.14	1.14	5 P	ug/L
Trichloroethene	15	4	0.196	0.42	5 P	ug/L
RADIOCHEMICAL ANALYTES						
Gross Alpha	15	15	-0.35	1.82	15 P	pCi/L
Gross Beta	15	15	-0.2	4.4	4 mrem/yr ~50 pCi/L P	pCi/L
Bi-214	15	14	11.4	161	4	mrem/yr
Pb-214	15	14	15.2	163	4	mrem/yr
Sr-89	14	14	-1.85	3.14	4	mrem/yr
Sr-90	14	14	-1.11	0.38	4	mrem/yr
Tc-99	7	7	-0.49	0.58	4	mrem/yr
Tritium	15	15	-31	366	4	mrem/yr

Max. - maximum

Conc. - concentration

ug/L = micrograms per liter

umhos/cm = micromhos per centimeter

QA/QC = Quality Assurance/Quality Control

NPDWR (P) = National Primary Drinking Water Regulations

pCi/L = pCi/L is one trillionth (10E-12) of a Curie

TDEC = Determined by the State of Tennessee Rule 0400-40-03-.03j

Min. - minimum

mg/L - milligram per liter

BC = By Calculation BL = By Laboratory

IC = Ion Chromatography

J = Estimated Concentration

NSDWR (S) = National Secondary Drinking Water Regulations

mrem/yr = A millirem is 1/1000 of the calculated radioactive dose equivalent to the Total Body or any Critical Organ

Comparison of DoR-OR Results with DOE Results

Tables 7.17, 7.18 and 7.19 present summaries of the number of samples, the number of analyte detections; and minimum, maximum and averages of individual analytes for offsite spring data collected by both TDEC and DOE. DOE results are from the 2016 and 2017 Offsite Groundwater Assessment reports. TDEC results listed in the above tables include TDEC sampling data from offsite springs performed since 1994.

Differences exist within the two data sets (DOE and TDEC), including types of analytes, analysis methods, and analyte names. Some of the DOE data only provides record for detections above EPA screening levels which may skew the averages. However, relative comparisons between the two data sets can be made.

Inorganics

Of the 65 samples analyzed by TDEC for the analyte, chloride, there were 59 detects with the maximum being 23 milligrams per Liter (mg/L). DOE analysis revealed a maximum of 5 mg/L for chloride. The averages, however, are similar with TDEC overall average for chloride at 4.33 mg/L and DOE's average 2.763 mg/L.

Sulfate results showed a disparity between the TDEC maximum of 140 mg/L and the DOE maximum sulfate detection of 0.0778 mg/L.

For the remainder of the inorganic suite, comparisons of DOE and TDEC results are similar. Laboratory detection limit differences occurred occasionally where either TDEC or DOE had a low result when the other's results were non-detects likely due to differences in laboratory reporting methods. This is presented in Table 7.18.

The list of metals contains 30 analytes ranging from aluminum to zinc. Comparisons of metals results are similar to each other. One exception is vanadium. Vanadium was detected by TDEC in spring samples 9 of 47 times with a concentration range of 0.17 to 11 mg/L. DOE did not detect vanadium in any of their thirty samples, analyzed. See Table 7.19.

Radionuclides

Radionuclides were analyzed by both TDEC and DOE. TDEC analyzes samples using methods such as, gross alpha and gross beta activity and gamma radionuclides. Gross alpha and beta are analyses that lump individual isotope activities together to give a collective measure of activity for alpha and beta particles. Gamma radionuclides scan for isotope activities at differing energies and using a list of energies will determine which isotopes are present and their respective activities. When samples are analyzed for gamma radionuclides, TDEC does not analyze for individual isotopes.

The DOE analyzes water samples for the individual isotopes along with alpha activity and beta activity. These are also found in Table 7.20. There is some variation between the data sets. For example, TDEC did not measure any actinium-227, cesium-137, cobalt 60, plutonium-238, potassium-40, protactinium-234 metastable or radium-226 and 228. DOE did not measure beryllium-7, lead-210, and strontium-89.

TDEC measured actinium-228 in 2 of 149 samples and the average was 14.20 pCi/L. DOE's average for actinium-228 over 30 samples was -0.44767 pCi/L. Alpha activity for one spring that TDEC sampled in 2009 was high at 102 pCi/L. Following the identification of the elevated concentration, the spring was resampled by TDEC. After resampling twice, attempts to identify the alpha emitters for that one sample were unsuccessful. Subsequent sampling and analysis of that spring resulted in an average of 1.70 pCi/L.

The comparisons of tritium averages between TDEC and DOE data sets varied significantly. DOE's average, with 10 detections out of 30 samples was 327.46 pCi/L, while TDEC's concentration of tritium average for 62 detections out of 116 samples resulted in an average concentration of 75.29 pCi/L.

With the exception of those analyses above, DOE and TDEC analyses are comparable.

Volatile Organics

Both TDEC and DOE have sampled for volatile organics (VOCs) in almost all of their samples. DOE's sampling results for VOCs appear to be all not detected in their offsite sampling.

TDEC sampled for VOCs 159 times in offsite springs since 1994. Trichloroethylene was detected 34 times with a maximum concentration of 9.6 micrograms per liter (ug/L), The average concentration of trichloroethylene was 4.97 ug/L. NPDWR regulatory limits for trichloroethylene is 5 ug/L. Several other compounds were detected but at small concentrations not above regulatory levels.

Table 7.20: Comparison of DOE and TDEC Spring Analytical Data (page 1 of 3)

	TDEC OFFSITE SPRING DATA					DOE OGWA SPRING DATA					
Chemical Name	Number of detected results	Number of results	Minimum	Maximum	Average	Number of detected results	Number of results	Minimum	Maximum	Average	Units
Chloride	59	65	1	23	4.33	3	30	1.54	5	2.763	mg/L
Fluoride	15	33	0.34	10	3.16	3	30	0.00035	0.00117	0.000659	mg/L
Nitrate/Nitrite as Nitrogen	68	72	0.05	2.08	0.47	3	30	0.0015	0.0015	0.0015	mg/L
Sulfate	36	39	2.2	140	14.28	3	30	0.0552	0.0778	0.0666	mg/L
Aluminum	36	43	0.0023	5	0.58	17	30	0.118	1.65	0.618625	mg/L
Antimony	1	33	0.43	0.43	0.43	3	30	0.001	0.001	0.001	mg/L
Arsenic	3	99	0.002	0.0087	0.01	7	30	0.0017	0.00214	0.001798571	mg/L
Barium	35	48	0.016	0.28	0.06	3	30	0.0364	0.0657	0.052866667	mg/L
Beryllium	2	50	0.00051	0.0016	0.0011	3	30	0.0002	0.0002	0.0002	mg/L
Boron	6	28	0.000092	0.088	0.04	3	30	0.00916	0.0177	0.013086667	mg/L
Cadmium	0	96	0	0	0.00	3	30	0.00011	0.00011	0.00011	mg/L
Calcium	53	54	18.8	96	48.90	3	30	41.6	43	42.1	mg/L
Chromium	22	102	0.00077	0.0055	0.002	3	30	0.001	0.00125	0.001083	mg/L
Chromium, Hex	1	3	0.0165	0.0165	0.02	N/A	N/A	N/A	N/A	N/A	mg/L
Cobalt	16	40	0.000071	0.016	0.0016	3	30	0.0001	0.000497	0.000252667	mg/L
Copper	15	33	0.00034	0.01	0.0032	3	30	0.00035	0.00117	0.000659	mg/L
Iron	49	52	0.012	15	0.93	18	30	0.145	2.02	0.664666667	mg/L
Lead	27	103	0.00019	0.034	0.0036	3	30	0.0005	0.000966	0.000655333	mg/L
Lithium	22	22	0.00046	0.0056	0.0016	3	30	0.002	0.002	0.002	mg/L
Magnesium	52	53	2.3	125.5	13.73	3	30	6.34	11.1	9.38	mg/L
Manganese	47	51	0.00063	2.6	0.12	8	30	0.00601	2.06	0.50095125	mg/L
Mercury	3	84	0.000032	0.00024	0.00014	6	30	0.000000579	0.000286	9.22465E-05	mg/L
Nickel	35	79	0.00057	0.014	0.00315	3	30	0.0015	0.0015	0.0015	mg/L
Phosphorus	1	2	0.87	0.87	0.87	3	30	0.015	0.0233	0.017766667	mg/L
Potassium	50	51	0.46	4.1	1.57	3	30	0.903	1.49	1.237666667	mg/L
Selenium	0	96	0	0	0.00	3	30	0.0015	0.0015	0.0015	mg/L
Silicon	6	6	6	9.65	8.63	3	30	3.63	4.72	4.13	mg/L
Silver	3	32	0.018	0.1	0.06	3	30	0.0002	0.0002	0.0002	mg/L
Sodium	54	56	0.49	27.4	2.52	3	30	1.67	3.58	2.42	mg/L
Strontium	28	28	0.025	0.14	0.07	3	30	0.0552	0.0778	0.0666	mg/L
Thallium	14	87	0.00003	0.0015	0.0004	3	30	0.00045	0.000641	0.000534143	mg/L
Uranium	15	37	0.00007	0.0005	0.00025	3	30	0.0001	0.000147	0.000117	mg/L
Vanadium	9	47	0.17	11	2.99	3	30	0.001	0.001	0.001	mg/L
Zinc	69	75	0.001	0.05	0.00665	3	30	0.0033	0.00636	0.00432	mg/L

Table 7.20 (continued): Comparison of DOE and TDEC Spring Analytical Data (page 2 of 3)

	TDEC OFFSITE SPRING DATA					DOE OGWA SPRING DATA					
Chemical Name	Number of detected results	Number of results	Minimum	Maximum	Average	Number of detected results	Number of results	Minimum	Maximum	Average	Units
Actinium-227	N/A	N/A	N/A	N/A	N/A	3	30	-6.51	2.36	-1.264	pCi/L
Actinium-228	2	149	12.1	16.3	14.20	3	30	-5.38	4.91	-0.4476667	pCi/L
Alpha activity	106	150	-8	102	1.70	3	30	-1.6	1.3	0.253	pCi/L
Americium-241	2	2	0.026	0.032	0.03	3	30	-0.0024	0.0128	0.00456	pCi/L
Beta activity	134	150	-2	79.6	2.66	3	30	0.845	3.52	1.7656667	pCi/L
Beryllium-7	1	149	23.6	23.6	23.60	N/A	N/A	N/A	N/A	N/A	pCi/L
Bismuth-212	0	149	0	0	0.00	3	30	-8.35	10.9	1.16	pCi/L
Bismuth-214	119	149	6.5	315	63.06	10	30	14.6	378	245.66	pCi/L
Cesium-137	N/A	N/A	N/A	N/A	N/A	3	30	-1.18	-0.312	-0.7153	pCi/L
Cobalt-60	N/A	N/A	N/A	N/A	N/A	3	30	-0.692	2.55	1.156	pCi/L
Curium-243/244	1	1.0000	0.033	0.033	0.03	3	30	-0.00162	0.00689	0.0017567	pCi/L
Lead-210	1	1	154.8	154.8	154.80	N/A	N/A	N/A	N/A	N/A	pCi/L
Lead-212	1	1	9.3	9.3	9.30	7	30	-3.65	8.14	3.3640143	pCi/L
Lead-214	98	149	10.6	175.5	61.61	17	30	18.5	423	230.91176	pCi/L
Neptunium-237	1	2	0	0.027	0.01	3	30	-0.00683	0	-0.0029333	pCi/L
Plutonium-238	N/A	N/A	N/A	N/A	N/A	3	30	-0.00717	0.00633	-0.00028	pCi/L
Plutonium-239/240	2	2	0.025	0.1	0.06	3	30	-0.00676	0.00475	0.0002867	pCi/L
Potassium-40	N/A	N/A	N/A	N/A	N/A	6	30	-28	71.8	22.416667	pCi/L
Protactinium-234m	N/A	N/A	N/A	N/A	N/A	3	30	0.0396	0.0479	0.0430667	pCi/L
Radium-226	N/A	N/A	N/A	N/A	N/A	18	30	0.123	1.56	0.5285	pCi/L
Radium-228	N/A	N/A	N/A	N/A	N/A	5	30	-0.271	0.857	0.3154	pCi/L
Radium-226/228	N/A	N/A	N/A	N/A	N/A	2	30	0.174	0.229	0.2015	pCi/L
Strontium-89	40	41	-1.85	3.14	0.17	N/A	N/A	N/A	N/A	N/A	pCi/L
Strontium-90	40	41	-1.11	0.806	-0.01	3	30	-0.364	-0.16	-0.2363	pCi/L
Technetium-99	86	86	-38	11.4	0.05	3	30	0.0432	0.61	0.2670667	pCi/L
Tritium	62	116	-290	1610	75.29	10	30	6.48	1820	327.458	pCi/L
Uranium-233 /234	20	20	0.08	1.35	0.33	3	30	0.0634	0.0848	0.07713	pCi/L
Uranium-235 /236	19	20	-0.005	0.41	0.09	3	30	0.0099	0.0183	0.0154667	pCi/L
Uranium-238	20	20	0.007	0.49	0.17	3	30	0.0396	0.0479	0.0430667	pCi/L

Table 7.20 (continued): Comparison of DOE and TDEC Spring Analytical Data (page 3 of 3)

TDEC OFFSITE SPRING DATA						DOE OGWA SPRING DATA					
Chemical Name	Number of detected results	Number of results	Minimum	Maximum	Average	Number of detected results	Number of results	Minimum	Maximum	Average	Units
2-Butanone	1	159	20	20	20.00						ug/L
Acetone	2	159	32	41.1	36.55						ug/L
Chloroform	4	159	0.2	1.7	0.73						ug/L
Chloromethane	6	159	0.12	1.27	0.49						ug/L
cis-1,2-Dichloroethene	4	159	1.48	3	2.12						ug/L
Methylene Chloride	2	159	0.1	2.9	1.50						ug/L
Toluene	4	159	0.26	0.5	0.36						ug/L
Trichloroethylene	34	159	0.42	9.6	4.97						ug/L
Bicarbonate											mg/L
Carbonate											mg/L
Dissolved Solids	64	64	66	290	161.47	7	30	0.00045	0.000641	0.0005341	mg/L
Suspended Solids	15	45	2	6440	460.73	3	30	2.81	9.25	5.303	mg/L

7.4.8 Conclusions

Since 1994, TDEC's sampling of offsite springs has provided data which may be used to evaluate and quantify general background geochemical groundwater parameters. This project collected information about the groundwater offsite of the Oak Ridge Reservation. TDEC's spring monitoring project and recent efforts by DOE, in their offsite groundwater assessment (of springs), when compared, identified with few exceptions, that groundwater results from spring samples were similar. These analyses may facilitate the understanding of the general groundwater geochemical composition of groundwater around ORR that discharges into springs found offsite of the Oak Ridge Reservation. This data potentially allows for better delineation of "background values" in that groundwater zone.

7.4.9 Recommendations

The continuation of the collection of general groundwater parameters as well as selected spring sampling will be continued within TDEC's overall groundwater monitoring program.

8. RADNET

8.1 RADNET AIR MONITORING

8.1.1 Background

In the past, air emissions from DOE activities on the 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 radioactively contaminated facilities) could pose a threat to public health, the surrounding environment, or both. As a consequence, 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 program provides additional monitoring along with independent third party analysis.

The RadNet Air Monitoring Program on the Oak Ridge Reservation (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 in Montgomery, Alabama (NAREL).

8.1.2 Problem Statements

The three sites on the Oak Ridge Reservation Oak Ridge National Laboratory (ORNL), 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, (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 used for background comparison.

The five RadNet air samplers on the ORR are sampled on Mondays and Thursdays except when one of those days falls on a holiday. Samples are analyzed for gross beta and gamma analysis is performed on those samples with elevated gross beta levels (greater than 1 pCi/m^3). Once every four years, the EPA lab 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 and described in the scope of this project. EPA's analytical parameters and frequencies are listed in Table 8.1.

The RadNet air samplers run continuously, collecting suspended particulates on synthetic fiber filters (10 centimeters in diameter) as air was drawn through the units by a pump at approximately 35 cubic feet per minute. TDEC collected the filters from each sampler, twice weekly. Following EPA protocol (U.S. EPA, 1988, U.S. EPA, 2006), after collection, the filters were shipped to the EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama, for analysis.

NAREL performed gross beta analysis on each sample collected. If the gross beta result for a sample exceeded one picocurie per cubic meter (pCi/m^3), gamma spectrometry was 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.

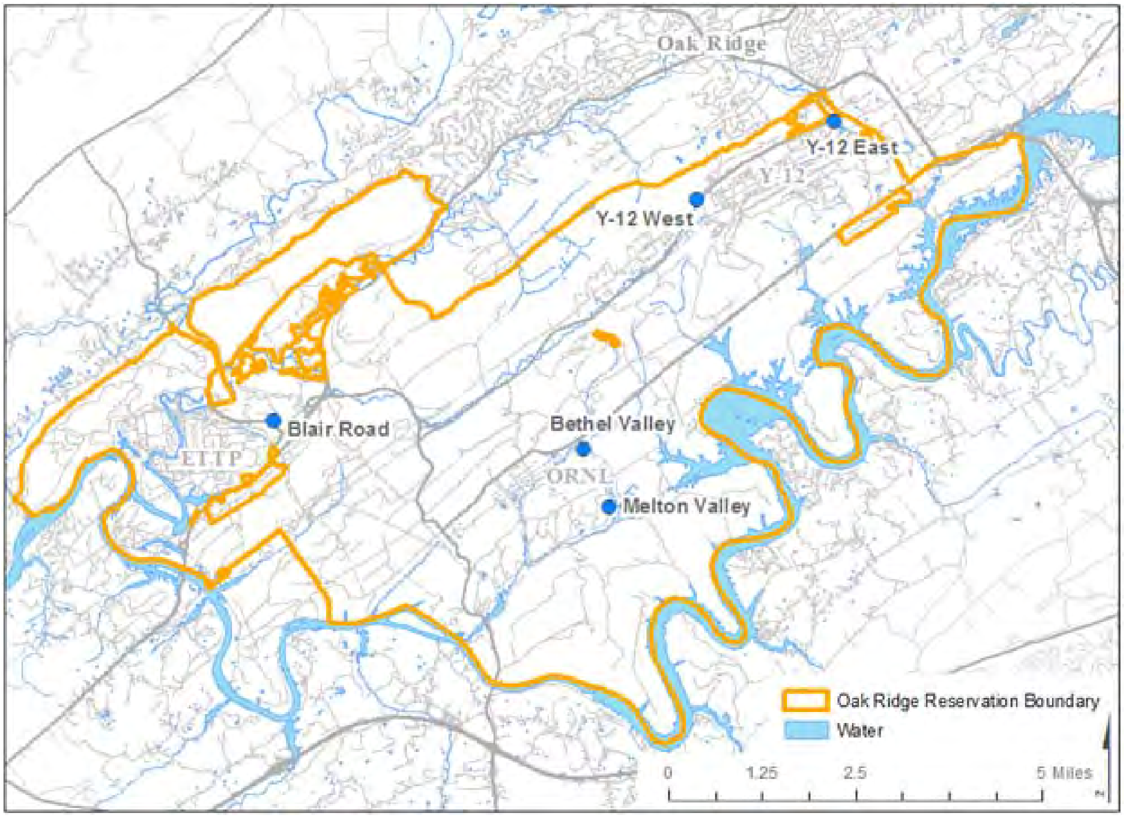

FIGURE 8.1: Locations of RadNet Air Monitoring stations on the ORR

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.

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 just now being created, so no results will be available for several months nor published in this EMR. When the results are available, they can be viewed on line and will be published in next year's report.

TABLE 8.1: RadNet Air Monitoring Analyses and Frequencies

ANALYSIS	FREQUENCY
Gross Beta	Each sample, twice weekly
Gamma Scan	As needed on samples showing greater than 1 pCi/m^3 of gross beta
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)

8.1.7 Results and Analysis

The results of NAREL's analyses of the nationwide RadNet air data are available at NAREL's website in the Envirofacts RadNet searchable database, via either a simple or a customized search. The results shared in this report are from samples collected from July 2017 through June 2018, for the RadNet air stations on the Oak Ridge Reservation. 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 8.2, the results for the gross beta analysis of samples collected July 2017 through June 2018 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 8.2) 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 stations on the ORR and the background station in Knoxville may be attributed to differences in collection schedules. The ORR gross beta results for the RadNet Air project from July 2017 through June 2018 are all well below 1.0 pCi/m^3, which is the screening level requiring further analysis.

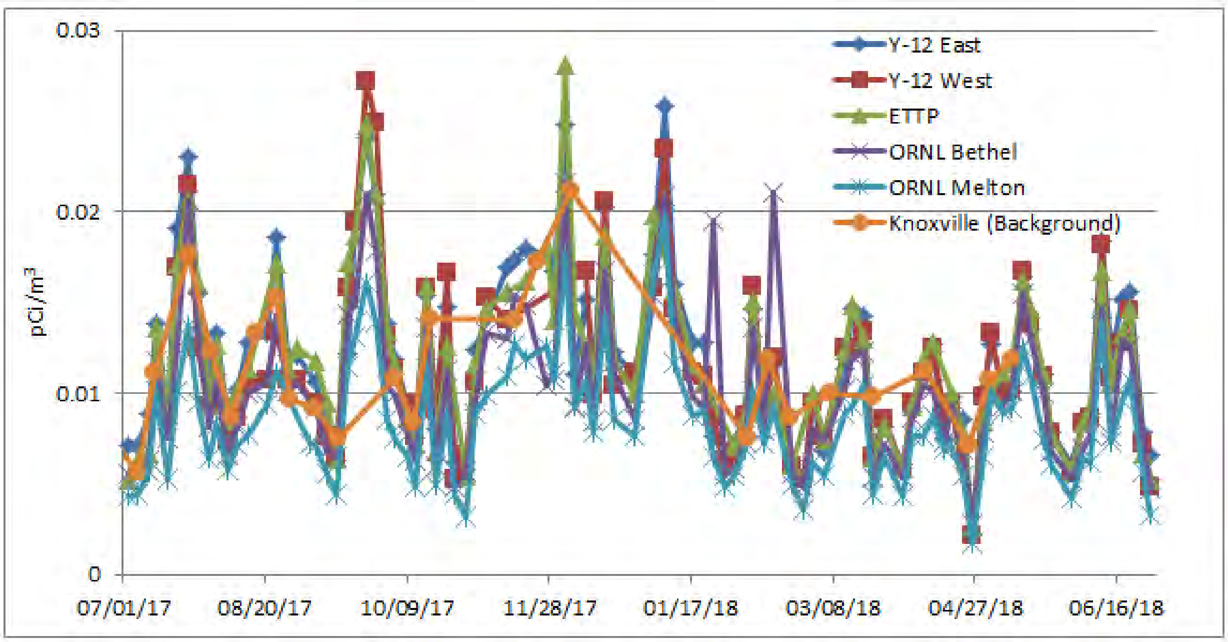

FIGURE 8.2: RadNet Air Monitoring Project Gross Beta Results July 2017 - June 2018

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.

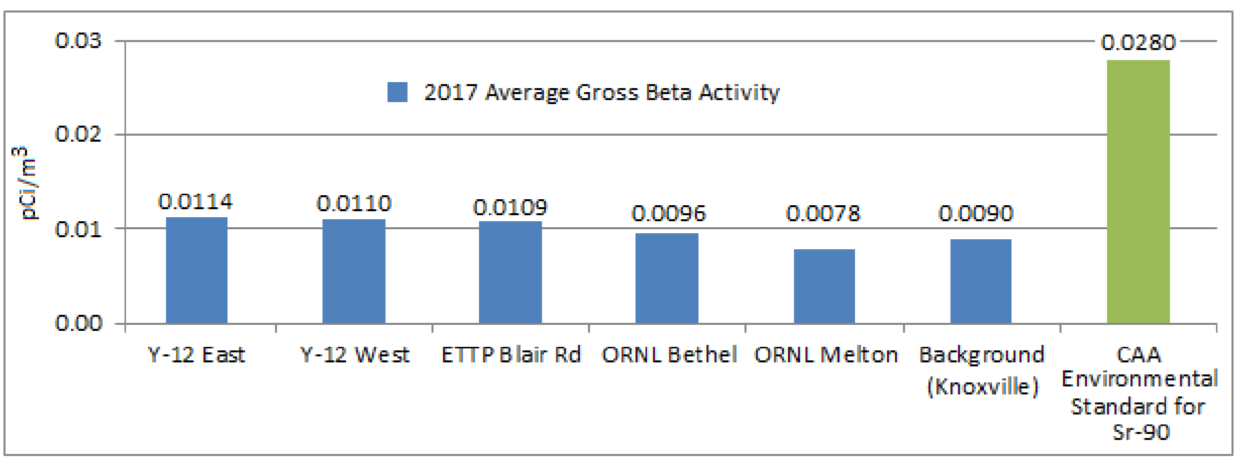

FIGURE 8.3: 2017 RadNet Air Monitoring Program Average Gross Beta Results

Figure 8.3 depicts the 2017 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.

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 2017 (CAA value for Sr-90 [0.019 pCi/m^3] + annual average gross beta at a background location=CAA environmental standard for Sr-90).The CAA's Environmental Limit for strontium-90 is used as a screening mechanism and is provided here for comparison. It is unlikely that this isotope contributes a major proportion of the gross beta activity reported for the samples**.**

To evaluate the RadNet data, DoR-OR 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 8.3 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 2017 results at all the RadNet air stations are comparable (results showed that all sites responded in a similar pattern during each sampling period), the average gross beta results for the RadNet Air project in 2017 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 8.3).

None of the gross beta results reported for the RadNet Air project on the ORR from July 2017 through June 2018 exceeded the screening level (1.0 pCi/m^3) which would have led to additional analysis by gamma spectrometry.

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 last year's report, with all values for each isotope below the limits established by the Clean Air Act. The composites for 2017 are just now being created, No results will be available for several months nor published in this report.

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 2017 through June 2018. 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.

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.

8.2 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 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 air monitors.

EPA has provided three precipitation monitors which are co-located with RadNet air stations at each of the ORR sites.

The first precipitation monitor provided by EPA is located at ORNL in Melton Valley in the vicinity of ORNL's HFIR (High Flux Isotope Reactor) and the Solid Waste Storage Area 5 (SWSA5) burial grounds. The second precipitation monitor is located off Blair Road to monitor contaminants from demolition activities at ETTP. The third station is located at the east end of Y-12. In addition to monitoring Y-12, this station could potentially provide an indication of any gamma radioisotopes traveling toward the city of Oak Ridge from ORNL. Analysis for gamma radionuclides is performed on the monthly composite samples for each of the three precipitation monitoring locations. Figure 8.4 depicts the locations of the RadNet Precipitation samplers.

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 (D&D) 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 as compared to 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 8.4. The three RadNet air samplers on the ORR are sampled Mondays and Thursdays, except when that Monday or Thursdays falls on 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 critical findings or for a large release.

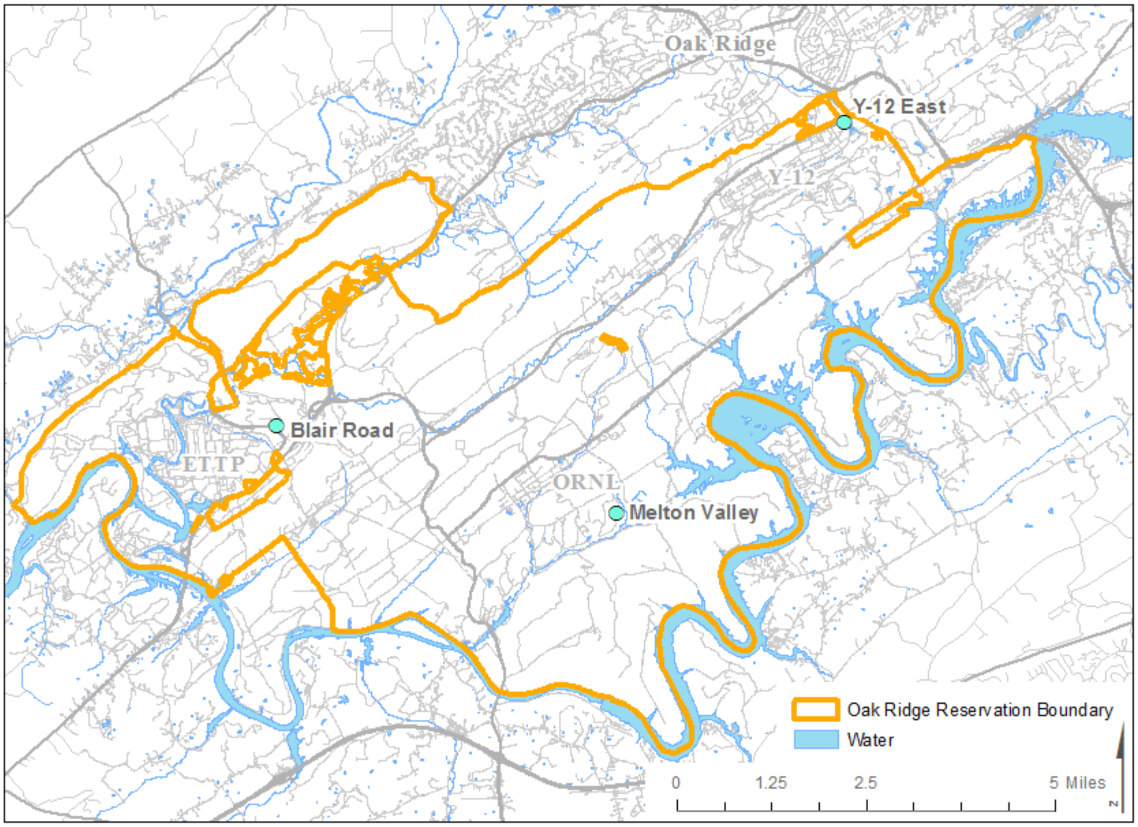

Figure 8.4: Locations of the RadNet Precipitation samplers on the ORR

8.2.5 Methods, Materials, Metrics

The precipitation samplers provided by EPA's RadNet project were used to collect samples for the RadNet Precipitation Project. Each sampler drained precipitation that fell on a 0.5 square meter fiberglass collector into a five-gallon, plastic collection bucket. Each sample was measured, then collected from the bucket (in a four-liter Cubitainer®), and sent to EPA when a minimum of two liters of precipitation accumulated in the Cubitainer®, or less than that when a sample was the final sample of the month. The sample was processed as specified by EPA (US EPA, 1988; US EPA, 2013) and then shipped to NAREL in Montgomery, Alabama, for analysis. The NAREL laboratory composites the samples collected during a month for each station and analyze each composite by gamma spectrometry/gamma radionuclides. Not all gamma isotopes have EPA drinking water limits

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.

The results from ORR sampling locations were compared to EPA's drinking water limits and can also be compared to data from other sites nationwide. 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 shows the maximum contaminant levels (MCLs) of beta and photon emitters that EPA uses as drinking water limits for select isotopes.

TABLE 8.2: 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

The results of NAREL's analyses are available at NAREL's website in the Envirofacts RadNet searchable database, via either a simple or a customized search. Conditions and approvals

This project charter was prepared to assist with the State of Tennessee's (State) commitments under both the Environmental Surveillance Oversight Agreement (ESOA) and the Federal Facilities Agreement for the Oak Ridge Reservation (FFA). In accordance with those agreements, a portion of the time spent on this project will be in reviewing the Department of Energy (DOE) Environmental Monitoring Plan (EMP) and Annual Site Environmental Report (ASER) for the Oak Ridge Reservation (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 February 2018, so instead the data from January 2017 through February 2018 will be discussed.

8.2.7 Results and Analysis

The results of NAREL's analyses of the nationwide RadNet air data are available at NAREL's website in the Envirofacts RadNet searchable database, via either a simple or a customized search. The gamma isotopes identified from January 207 through February 2018 include: beryllium-7, cesium-137, cobalt-60, potassium-40, radium-226, and radium-228. For all isotopes except beryllium-7 and potassium-40, 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 2017 through February 2018) was 62.3 pCi/L, compared to an average minimum detectable concentration of 37.5 pCi/L. The national average for the same time period was 55 pCi/L. The highest beryllium-7 result for the ORR stations during this time period was 96 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 2017 through February 2018, three of the forty-two samples did show detectable levels. The three potassium-40 results with detectable levels were 22.1, 20.3, and 21 pCi/L, with an average MDC of 17.7 pCi/L. Potassium-40 is a naturally occurring radionuclide and does not have a drinking water limit.

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, radium-226, and radium-228 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 do not indicate a significant impact on the environment or public health from ORR emissions.

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 the event.

8.3 RadNet Drinking Water Sampling

8.3.1 Background

The RadNet program was developed by EPA to ensure public health and environmental quality as well as to monitor potential pathways for significant population exposures from routine and accidental releases of radioactivity (U.S. EPA, 1988). The 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 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 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, it is still a concern that area water supplies could be impacted by ORR contaminants. The RadNet program also provides a mechanism to evaluate the impact of DOE activities on the area drinking water supplies. Samples were collected at:

- Anderson County Water Authority Water Treatment Plant (background location)
- Y-12 Water Treatment Plant (run by the City of Oak Ridge)
- West Knox Utility District Water Treatment Facility
- Kingston Water Treatment Plant

This sampling also supplements DOE monitoring, providing independent, third-party analyses of finished drinking water. Figure 8.5 depicts the locations of the raw water intakes associated with these facilities.

8.3.2 Problem Statements

Past and present radiological contamination on the three sites of the ORR (Y-12, ETTP, and ORNL), can potentially enter local streams and be transported to the Clinch River and into the local drinking water.

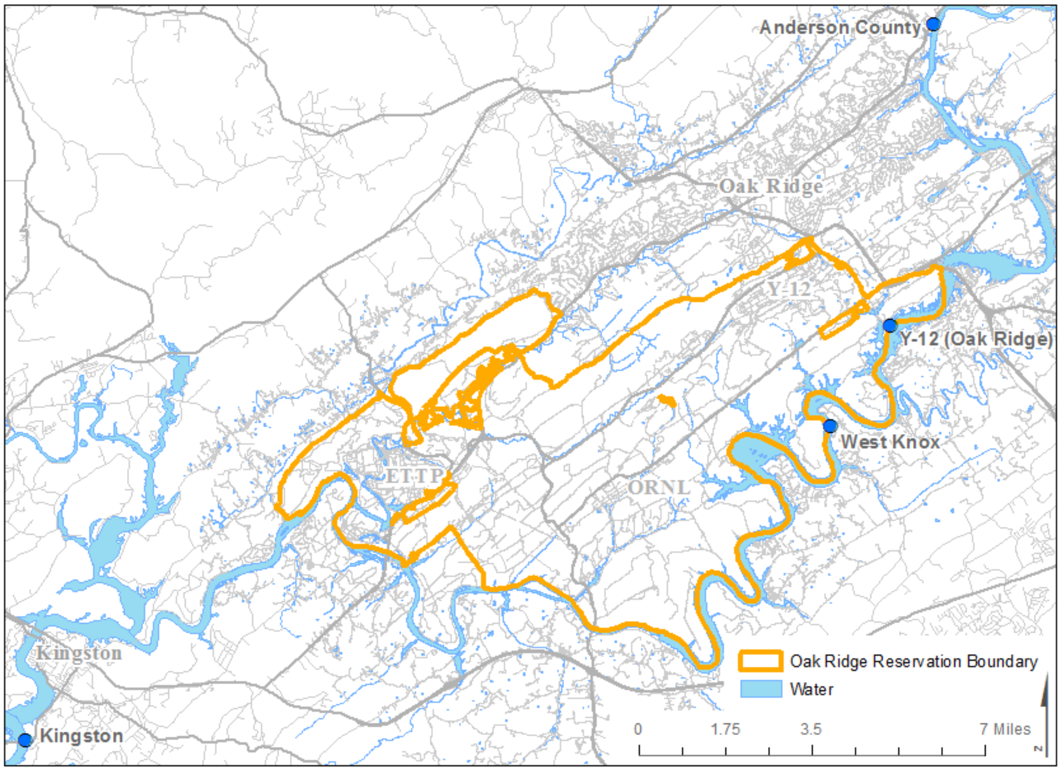

FIGURE 8.5: RadNet Drinking Water Facility Intakes

8.3.3 Goals

- Protect the 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 releases of radioactivity from the ORR.
- Review data and identify and report long-term trends of radionuclides present in finished drinking water.
- Provide reference data to facilitate evaluation of water quality as it relates to radioactive constituents of concern.

8.3.4 Scope

The RadNet Drinking Water project collected 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). Tritium analysis was performed on each quarterly sample. Other radiological analyses were performed annually.

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:. The four locations are the Anderson County Water Authority Water Treatment Plant (background location), the Y-12 Water Treatment Plant (run by the City of Oak Ridge), the West Knox Utility District Water Treatment Facility, and the 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 spectrometry, with further analysis performed, when warranted. The analytical frequencies and parameters are provided in Table 8.3.

The results of NAREL's analyses are available, along with nationwide data, at NAREL's website in the Envirofacts RadNet searchable database, via either a simple or a customized search (websites listed in references).

Table 8.3: RadNet Drinking Water Analyses

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

8.2.6 Deviations from the Plan

There were no deviations from the planned sampling for this project for FY2017. The composite samples for the 2017 gamma radionuclide analyses are not complete and are not available for this report. Composite sample results, from the FY2016 sampling event, are included in this report.

8.2.7 Results and Analysis

Many radioactive contaminants, transported off the ORR in surface water, enter the Clinch River by way of White Oak Creek, which drains the ORNL complex and associated waste disposal areas in Bethel and Melton valleys. When contaminants, carried by White Oak Creek and other ORR streams, enter the Clinch River their concentrations are significantly lowered by dilution, by 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 White Oak Creek 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 White Oak Creek 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 8.4).

Table 8.4: EPA Drinking Water Standards (pCi/L)

Isotope	EPA MCL (pCi/L)
Iodine-131 (I-131)	3
Strontium-90	8
Tritium (H-3)	20,000
Cobalt -60	100
Cesium-137 (Cs-137)	200

EPA - Environmental Protection Agency
MCL - Maximum Contaminant Levels (national primary drinking water regulation limits)
pCi/L - picoCuries per Liter

The results of NAREL's analyses of the nationwide RadNet Drinking Water data are available at NAREL's website in the Envirofacts RadNet searchable database, via either a simple or a customized search. The results shared in this report cover January 2017 through June 2018.

Tritium results from 2017 and the first two quarters of 2018 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 White Oak Creek into the Clinch River. Of the quarterly samples taken during this time period from each of the four area water treatment plants, all were well below the minimum detectable concentration (MDC) for each sample.

The average result for the 2017 quarterly tritium samples and the first two quarters of 2018 was 11 pCi/L with an average MDC of 124 pCi/L. Historically, the results of the tritium analyses have been below the MDCs. The results, for tritium at the drinking water plants monitored since the program's inception, ranged from undetected to1,000 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 was analyzed for iodine-131 (I-131). I-131 analysis for 2018 was performed for the second quarter sample at each of the four stations. The results were below the MDC 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. The 2017 analyses for I-131 had results below MDCs.

Gross alpha, gross beta, gamma, and strontium-90 analyses were performed annually on a composite of the quarterly samples taken from each of the monitored facilities. The results of the 2017 annual composite results are noted below.

In 2016 and 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 2016 and 2017 were all below this amount.

There were no gross beta results from the 2016 or the 2017 annual composite analyses that were greater than the sample-specific MDCs. 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 2017 were not yet available. The gamma spectrometry on the annual composites for 2016 showed no values above MDCs for cobalt-60 (Co-60) or cesium-137 (Cs-137). Potassium-40 (K-40) had one result greater than the sample-specific MDC (with results of 12.1 pCi/L) at the Kingston Water Treatment Plant. However, Potassium-40 is a naturally occurring radioactive isotope of potassium and it is widely distributed in nature. The 2016 gamma results were below the EPA drinking water standards and below or near the sample-specific MDCs.

Analysis for Strontium 90 (Sr-90) is performed on an annual 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 from this project for the Oak Ridge area have been below the associated drinking water standards and often below the minimum detectable concentrations.

8.2.8 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.

8.2.9 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 site.

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