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DIVISION OF REMEDIATION

DOE OVERSIGHT DIVISION

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EXECUTIVE SUMMARY

The Tennessee Department of Environment and Conservation, Division of Remediation, Department of Energy Oversight Office (the Office) is providing a report of the office's independent environmental monitoring for the 2014 calendar year. Individual reports completed by office personnel make up the report. General areas of interest determine the substance of the reports: Air Quality, Biological, Drinking Water, Groundwater, Radiological, and Surface Water. An abstract is provided in each report. The office's files, containing all supporting information and data used in the completion of these reports, are available for review.

AIR QUALITY MONITORING

Monitoring of Hazardous Air Pollutants on the Oak Ridge Reservation

The Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (DOE-O) Hazardous Air Pollutants (HAPs) monitoring program was initially developed to provide independent monitoring of hazardous metals in air at the East Tennessee Technology Park (ETTP) and to verify the Department of Energy's (DOE) reported monitoring results. Monitoring at Oak Ridge National Laboratory (ORNL or X-10) and at the Y-12 National Security Complex was added as an extension of the HAPs monitoring at ETTP. Due to the continuing reduction in permitted sources on the ORR and the completion of the demolition of the K-25 building at ETTP, this project will be discontinued until other major demolition projects on the ORR are initiated or other potential sources of hazardous air pollutants are identified. No metals analyses were conducted or required during the 2014 calendar year.

RadNet Air Monitoring on the Oak Ridge Reservation

The RadNet Air Monitoring Program on the Oak Ridge Reservation provides radiochemical analysis of air samples taken from five air monitoring stations located near potential sources of radiological air emissions on the Oak Ridge Reservation. RadNet samples are collected by office staff and analysis is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama. In 2014, as in past years, the data for each of the five RadNet air monitors largely exhibited similar trends and concentrations. The results for 2014 do not indicate a significant impact on the environment or public health from Oak Ridge Reservation emissions.

Fugitive Radioactive Air Emissions Monitoring

The TDEC monitors fugitive emissions of radioactive contaminants on the Department of Energy's Oak Ridge Reservation (ORR) as a part of its obligation under the Tennessee Oversight Agreement. The monitoring results are compared to background measurements to determine if releases have occurred and to standards provided by the Clean Air Act to assess compliance with associated emission standards. In 2014, eight high-volume air samplers were deployed in the program. One of the samplers was stationed to collect background information. The remaining units were positioned to monitor remedial and waste management activities on the ORR. Monitored activities included: the decommissioning and demolition of facilities constructed during the World War II Manhattan Era to produce enriched uranium, plutonium, and other radioisotopes used to manufacture the first atomic weapons; remediation of associated waste disposal facilities; and disposal of radioactive waste at the Environmental Management Waste Management Facility (EMWMF). During 2014, the results were very similar to background except for the elevated February to March Tc-99 airborne concentrations observed at the K-25/K-11 sample location. All sites' yearly average concentrations were below the federal standards.

RadNet Precipitation Monitoring on the Oak Ridge Reservation
The RadNet Precipitation Monitoring Program on the ORR provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations on the Department of Energy's Oak Ridge Reservation. Samples are collected by TDEC and analysis is performed at the NAREL. Each composite sample is collected monthly and analyzed for gamma radionuclides. Since there is not a regulatory limit for radioisotopes in precipitation, the results from ORR sampling locations are compared to EPA's drinking water limits and can also be compared to data from other sites nationwide. While the stations located on the Oak Ridge Reservation are in areas near nuclear sources, most of the other stations in the RadNet precipitation program are located near major population centers, with no major sources of radiological contaminants nearby. Regardless, the radiological results seen in the precipitation samples collected during 2014 at the RadNet sites on the ORR were all well below the EPA drinking water limits and thus can be considered protective of human health and the environment. It should be noted that the EPA drinking water limits pertain to drinking water, not precipitation, and are only used here as a conservative reference value.

BIOLOGICAL MONITORING
Benthic Macroinvertebrate Monitoring
The biotic integrity of most impacted streams on the Oak Ridge Reservation is less than optimal compared to reference conditions. Of all sites sampled during 2014, only one location (BCK 12.3) received the lowest Tennessee Macroinvertebrate Index (Alternative Reference Stream Method) scores and ratings, partially supporting/moderately impaired (TMI = 18-20, C rating). The reasons for this stations ranking far below reference stations in score are varied. In part, the poor scores are likely due to continuing pollutional inputs from Y-12. Another consideration is that this site lacks nearby refugia from which recolonization of aquatic invertebrates and insects can occur. A number of the ORR stream sites had biological condition ratings of partially supporting systems with slight to moderate impairment. These include EFK 6.3, EFK 23.4, EFK 25.1, MIK 0.45, MIK 0.71, WCK 2.3, WCK 3.4 and WCK 3.9. Remarkably, four of the impacted stations show scores that favorably compare to those of reference sites. These include BFK 9.6 and EFK 13.8, with scores directly comparable to reference sites, and EFK 24.4 and MEK 0.6 with a score only slightly below that of the reference sites. The high ranking of some of the impaired sites is encouraging and, hopefully, shows the positive results of the remediation work that has been completed at both Y-12 and ORNL. The continued low ranking of some of the impacted sites shows not only that further remediation will be required, but also, that more study will be needed to help determine if the simple answer to increasing recovery is less pollution, or if factors such as a lack of nearby refugia may also play a hand in the slowed recovery of these systems.

White-tailed Deer Monitoring Program on the Oak Ridge Reservation
The DOE-Oversight Office continued White-tailed deer (*Odocoileus virginianus*) tracking activities on the Oak Ridge Reservation (ORR) during 2014. Oak Ridge Reservation deer, grazing and foraging in contaminated areas such as the Melton Valley solid waste storage areas (SWSAs) at Oak Ridge National Laboratory (ORNL), represent a potential vector for

contaminant exposures to the public. The goal is to determine their home range and potential movements outside their home range. The scientific literature provides considerable evidence that wildlife (i.e., carnivores, herbivores, omnivores, piscivores), subsisting in habitats impacted by industrial pollution, are ingesting environmental contaminants from their respective food chains. White-tailed deer mainly consume vegetation, forbs (a type of vegetation known to be contaminated from soils), nuts, fruits and grasses for nourishment, and ingest soils (i.e., licks) to replenish vitamins and minerals. This project is part of a multiyear investigation. Our previous 2011-13 GPS collar investigations show deer taking excursions across the Clinch River into surrounding areas off the ORR. Samples from natural mortality and harvest show uptake of strontium 90. During 2014, office staff captured and successfully collared five deer, all in Melton Valley. Global positioning system (GPS) data were downloaded and home ranges (and excursions from the core area) were determined from three recovered collars presented herein.

Notably, one deer we code named Ophelia was harvested by a hunter. All deer on the managed hunts are tested for strontium-90 and cesium-137 before they are released to the hunter. Ophelia was found to be above the release criteria for strontium-90 and was confiscated from the hunter. This deer was harvested near her original capture point in the woods on the south side of Melton Valley. GPS waypoints indicate Ophelia's home range was confined but extended to suspect areas of Melton Valley. Interestingly she did not persistently occupy the White Oak Creek drainage that is known to be contaminated with strontium 90 but mostly stayed upstream in the Melton Branch area. This is suggestive that burials (radioactive disposal areas) in this area still represent a source to contaminate wildlife.

Fish Tissue Monitoring
Fish samples were collected twice during 2014 in several Oak Ridge Reservation (ORR) and control streams by biologists with the Oak Ridge National Laboratory's Environmental Sciences Division (ORNL ESD). Fish were captured by electroshocking methods to obtain fish tissue and gut content samples for contaminant analysis (i.e., bioaccumulation study). Previous ORR fish monitoring programs have focused on tissue analysis (i.e., fish fillets), but few studies have investigated tissue and gut content contaminants in individual species. Fish fillets were sampled and evaluated for mercury (Hg) and polychlorinated biphenyls (PCBs) content by the ORNL ESD team. In cooperation with ORNL ESD, the TDEC staff obtained the associated gut contents of the filleted fish to conduct taxonomic evaluation and Hg analysis of the gut contents. Laboratory processing of fish samples were not completed in time to meet the 2014 Fish Tissue EMR (Environmental Monitoring Report) publishing deadline. Hence, these results will be presented in the 2015 Fish Tissue EMR.

Pilot Project: Bioaccumulation Study of Metals in Fungi from East Fork Poplar Creek Floodplain
During 2014, TDEC staff collected mushroom sporocarps and other fungi in the upper East Fork Poplar Creek (EFPC) floodplain contaminated by legacy mercury (Hg) releases from the upstream Y-12 National Security Complex (Oak Ridge Reservation, ORR). It has been well documented by researchers that fungi, including wild edible mushrooms, bioaccumulate significant concentrations of mercury and other heavy metals within their fruiting bodies (i.e., sporocarps). Our question: does consumption of wild edible mushrooms (potentially contaminated with Hg) collected from EFPC floodplain pose a potential health concern to a human receptor? Consequently, the goal of the project was to determine if mercury (i.e., toxic

methylmercury) is being taken-up by EFPC fungi at concentrations greater than control samples. Although attempts were made to collect edible mushrooms such as morels, sample availability for all species was sparse during 2014 field sampling excursions. Nevertheless, office staff collected nineteen fungi samples including edible chanterelles in the EFPC floodplain. Based upon the 2014 total mercury results, it is clear that mushrooms in EFPC are in fact bioaccumulating Hg from the contaminated floodplain sediments and soils. The average Hg content for edible fungi collected from East Fork Poplar Creek floodplain (seven samples) of 0.52 mg/kg (dw) is considerably below the reference site sample result of 5.4 mg/kg (dw). However, the sample size (n=19) is too small to generate speculations or to make too many conclusions at this point in time. Office staff will resume and expand fungi sampling in spring 2015 to address the data gaps regarding bioaccumulation of Hg in fungi.

Acoustical Monitoring of Bats on the Oak Ridge Reservation

During the summer of 2014, TDEC continued with an inventory of ORR bat species to provide much needed information to address data gaps where there is little, no, or un-organized bat species data. The investigation was especially designed to identify all bat species but also to determine locations where federally-listed endangered species (i.e., Indiana and Gray bats) and the to-be-listed northern long-eared bat, may be present on the ORR. Bats were monitored using acoustic bat-call recording equipment, thus the study did not involve bat captures. Sites monitored on the ORR in 2014 included: (1) the Haul Road between East Tennessee Technology Park (ETTP) and the Environmental Management Waste Management Facility (EMWMF) located at the west end of the Y-12 National Security Complex, (2) the Tower Shielding area (Oak Ridge National Laboratory) including a cave, (3) Dyllis Orchard area (north of ETTP), (4) building K-1073 (ETTP), and (5) reference sites in Oak Ridge. Over the course of 108 survey nights during 2014, approximately 12,000 files of bat acoustic data were recorded at 81 field stations and were processed with specialized, automated bat identification software (Kaleidoscope PRO) yielding 6,960 bat identifications. An additional 4,006 bats were detected but not identified to species due to poor call quality, inclement weather conditions or field clutter. The 2014 acoustic surveys recorded more than 100 bat calls at 21 study sites including >300 calls at three sites. Twelve (12) species were detected on the ORR including: *Eptesicus fuscus* (big brown bat), *Lasiurus borealis* (eastern red bat), *Lasiurus cinereus* (hoary bat), *Lasionycteris noctivagans* (silver-haired bat), *Myotis grisescens* (gray bat), *Myotis leibii* (eastern small-footed bat), *Myotis lucifugus* (little brown bat), *Myotis septentrionalis* (northern long-eared bat), *Myotis sodalis* (Indiana bat), *Nycticeius humeralis* (evening bat), *Perimyotis subflavus* (tri-colored bat; Eastern Pipistrelle), and *Tadarida brasiliensis* (Brazilian free-tailed bat). Of these species, the eastern red bat (24%), big brown bat (18%), tri-colored bat (18%), and the evening bat (17%) were the dominant combined species detected at all sites. Approximately 5% of all bats detected were federally-listed as endangered species (Indiana bat, Gray bat).

Large portions of the ORR remain un-surveyed such as the mainly forested National Environmental Research Park (NERP), west Bear Creek Valley, White Wing area (Hembree marsh), sections of ETTP, Tower Shielding area, Walker Branch, and Chestnut Ridge (ORNL). Our 2014 study, along with a concurrent ORNL Environmental Science Division bat project, continued to add data for the first long-term, large-scale acoustic bat community investigation on the ORR. Information gained from this bat inventory has addressed missing data gaps but also provided critical occurrence information for the endangered species and for the northern long-eared bat listing, which is being process by the US Fish and Wildlife Service.

Threatened and Endangered Species Monitoring

Protection and stewardship of threatened, endangered and rare species (i.e., the overall biodiversity) in their natural habitat is a major priority to enable their long-term survival as invaluable natural resources on the ORR. In support of this mission, TDEC provided monitoring and mapping of the biodiversity of the natural resources (flora and fauna) on the ORR. Further, office staff members lend field biology assistance and support to the Resource Management Division (Natural Areas Program, Bureau of Parks and Conservation) and the Tennessee Wildlife Resources Agency (TWRA) at ORR natural areas and TWRA-managed sites [i.e., Black Oak Ridge Conservation Easement (BORCE) and the Three Bends Area]. During 2014, office staff monitored flora and fauna (i.e., predominantly bat acoustic surveys) on trails and off-trail areas of the BORCE and other areas of the ORR. Several new populations of TDEC-listed and non-listed flora and fauna were identified. A new aspect of the project, initiated in 2013, is the field mapping and documentation of American Chestnut sprouts (*Castanea dentata*) on the ORR.

Aquatic Vegetation Monitoring on the Oak Ridge Reservation

As a part of its obligations under the Tennessee Oversight Agreement, the DOE Oversight Office conducts monitoring of aquatic vegetation on and near the Department of Energy's Oak Ridge Reservation. In this program, DOE Oversight staff members collect vegetation at locations near or in water with the potential for radiological contamination. If surface water bodies have been impacted by radioactivity, aquatic organisms in the immediate vicinity may uptake radionuclides, bioaccumulating radiological contaminants. The vegetation is analyzed for gross alpha, gross beta and for gamma radionuclides and is compared to the radiological analysis of vegetation taken from background locations. The data collected in 2014 suggest limited areas of elevated radionuclide concentrations in the aquatic vegetation on the Oak Ridge Reservation. The mercury analysis indicated some areas where mercury was detected in floodplain vegetation due to contamination at the three sites on the Oak Ridge Reservation, but these results were well below levels used for mercury advisory levels in fish tissue. Sampling for mercury contamination will be discontinued in 2015, focusing instead on radiological contaminants. In fact, many of the 2014 mercury sampling locations are likely to be used in 2015, but for collection of samples for radiological analysis.

DRINKING WATER MONITORING

Sampling of Oak Ridge Reservation Potable Water Distribution Systems

As the three Department of Energy (DOE) Oak Ridge Reservation (ORR) plants become more accessible to the public, the Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (the office) continues its oversight of DOE facilities' safe drinking water programs. In 2014, TDEC conducted oversight of the potable water distribution systems and the water quality at ORR facilities. The results of the inspections and document reviews revealed that the three potable distribution systems for the ORR provide water that meets state regulatory levels. However, the potential exists for a cross connection between the distribution systems and contamination from the surrounding environmental media when breaks/leaks occur in the system.

RadNet Drinking Water on the Oak Ridge Reservation
The RadNet program was developed by the U.S. Environmental Protection Agency 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 program focuses on nuclear sources and population centers. The RadNet Drinking Water Program in the Oak Ridge area provides for radiochemical analysis of finished water at five public water supplies located near and on the Oak Ridge Reservation. In this effort, quarterly samples are taken by staff from TDEC and analysis for radiological contaminants is performed at NAREL. Analyses include tritium, iodine-131, gross alpha, gross beta, strontium-90, and gamma spectrometry, with further analysis performed when warranted. Gross beta, strontium-90, and tritium, while below drinking water standards, have tended to have higher levels in samples taken from the ETTP Water Treatment Plant than at the other facilities monitored by the program. This is not surprising as the ETTP Water Treatment Plant is the closest facility downstream of White Oak Creek, which is the major pathway for radiological pollutants entering the Clinch River from the ORR. However, this treatment plant was closed at the end of September 2014 and will no longer be included in analyses after the 2014 data are available.

GROUNDWATER MONITORING
Groundwater Monitoring for the Oak Ridge Reservation
The TDEC groundwater program concentrated its efforts on the area located southwest, along strike and downgradient of legacy waste sites in Bethel Valley, on the Oak Ridge Reservation (ORR) in 2014. Due to the geologic/hydrogeologic complexity of the area, construction of the report of the activities performed in 2014 is still being completed. As soon as the report is completed it will be issued as an addendum to this document.

RADIOLOGICAL MONITORING
Facility Survey Program and Infrastructure Reduction Work Plan
The survey program examines each facility's physical condition, process history, inventory of hazardous chemical and radioactive materials, relative level of contamination, past contaminant release history and, present-day potential for release of contaminants to the environment under varying conditions ranging from catastrophic (i.e. earthquake) to normal everyday working situations. This broad-based assessment supports the objectives of Section 1.2.3 of the Tennessee Oversight Agreement, which was designed to inform local citizens and governments of the historic and present-day character of all operations on the reservation. This information is also essential for local emergency planning purposes. Since 1994, the office's survey team has characterized 206 facilities and found that forty-two percent have either historically released contaminants, or pose a relatively high potential for release of contaminants to the environment today. In many cases, this high potential-for-release is related to legacy contamination that escaped facilities through degraded infrastructures over decades of continuous industrial use (e.g. leaking underground waste lines, substandard sumps and tanks, or unfiltered ventilation ductwork). Since the inception of the program, DOE corrective actions, including demolitions, have removed thirty-nine facilities from the office's list of high Potential Environmental Release (PER) facilities. During 2012, ARRA money expired and D&D activities came to a halt. Due to staff reorganization, retirements, and staffing priorities this project had no reportable work completed in 2014. Evaluation and characterization of the facilities intended to be demolished has been reassigned to the Federal Facility Agreement Program within the DOE-O office. This

project reassignment is intended to streamline the work effort in evaluating FFA remedial/removal work documentation and the work prioritization process.

Haul Road Surveys
The Haul Road was constructed for, and is dedicated to, trucks transporting CERCLA radioactive and hazardous waste from remedial activities on the Oak Ridge Reservation to the Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley for disposal. To account for wastes that may have blown or dropped from the trucks in transit, personnel from TDEC perform walk over surveys of the different segments of the nine-mile road and associated access roads weekly. Anomalous items noted are surveyed for radiological contamination, documented, and their description and location submitted to DOE for disposition. During 2014, twenty-two items that had potentially fallen from trucks transporting waste to the EMWMF were documented. None of the items exhibited radioactivity in excess of free release limits and all were removed expeditiously after being reported to the Department of Energy.

Ambient Gamma Radiation Monitoring of the Oak Ridge Reservation Using Environmental Dosimetry
In 1995, the Tennessee Department of Environment and Conservation began monitoring ambient radiation levels on the Oak Ridge Reservation. The program provides conservative estimates of the dose members of the public receive from exposure to gamma and neutron radiation attributable to Department of Energy activities on the reservation and baseline values for measuring the need and effectiveness of remedial activities. In this effort, environmental dosimeters have been placed at selected locations on and near the reservation. Results from the dosimeters are compared to background values and the state dose limit for members of the public.

Overall, the radiation doses measured in the Environmental Dosimetry Program in 2014 decreased or remained statistically the same as in 2013. A total of eighteen locations exceeded the 100 mrem screening level over the year: seventeen at ORNL and one at the Spallation Neutron Source. The majority of these sites were associated with access-restricted areas of the reservation, legacy facilities undergoing or scheduled for remediation, which is expected to significantly lower the future measured doses as the clean-up progresses.

Real Time Monitoring of Gamma Radiation on the Oak Ridge Reservation
Monitoring of gamma radiation exposure rate occurred at six locations in 2014. TDEC staff members placed these monitors on the ORR. These units measure and record gamma radiation levels at predetermined intervals over extended time periods, providing an exposure rate profile that can be correlated with activities and/or changing conditions. Monitoring with the units focuses on the measurement of exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods and/or where there is a potential for an unplanned release of gamma emitting radionuclides to the environment. In 2014, five locations were monitored in the program: the Oak Ridge National Laboratory (ORNL) Central Campus Remediation; the exhaust stack at the Spallation Neutron Source Facility; the Molten Salt Reactor at the ORNL; the Environmental Management Waste Management Facility; and a background station located at Fort Loudoun Dam in Loudon County. The use of gamma radiation exposure rate monitors equipped with microprocessor-controlled data-loggers has

proven to be a flexible and reliable method for monitoring gamma radiation on the reservation. Based on the data collected in 2014, the following conclusions were reached.

- Environmental Management Waste Management Facility gamma levels were consistent with background measurements.
- ORNL Central Campus D&D (3000 Area) gamma levels were within anticipated levels.
- Measurements taken at the MSRE were not indicative of any releases during the period. Exposure levels measured during the year have been attributed to a contaminated salt probe stored near the monitor.
- Gamma levels at SNS were within expected levels and consistent with measurement collected in previous years.

All results were below limits specified by state and Nuclear Regulatory Commission regulations, which require their licensees to conduct operations in such a manner that the external dose in any unrestricted area does not exceed 2.0 millirem (2,000 μrem) in any one-hour period.

Surplus Material Verification

The Department of Energy (DOE) offers a wide range of surplus items for auction/sale to the general public on the Oak Ridge Reservation (ORR). TDEC staff conducted independent radiological monitoring of these surplus materials prior to each auction/sale. During 2014, a total of six inspection visits were conducted at the ORR facilities. Two visits were made for ORNL sales and four visits were made for Y-12 sales. No sales were conducted at the East Tennessee Technology Park (ETTP) facility. Only one item of potential concern was found at the Y-12 auction. During 2014, hundreds of surplus materials items were sold through ORNL and Y-12 surplus sales organizations in separate sales events. DOE does a good job of preventing radiological contamination from reaching the public. One item of potential concern was found at the Y-12 auction.

Monitoring of Waste at the EMWMF Using a Radiation Portal Monitor

The Environmental Management Waste Management Facility (EMWMF) was constructed for the disposal of low level radioactive waste and hazardous waste generated by remedial activities on the ORR. The facility is operated under the authority of CERCLA and required to comply with regulations contained in the Record of Decision authorizing the facility. Only radioactive waste with concentrations below limits imposed by waste acceptance criteria (WAC) agreed to by Federal Facilities Agreement (FFA) parties are authorized for disposal in the facility. To help ensure compliance with the WAC, the DOE Oversight Office has placed a Radiation Portal Monitor (RPM) at the check-in station for trucks transporting waste into the facility. As the waste passes through the portal, radiation levels are measured and monitored by DOE Oversight staff. When anomalies are noted, DOE and EMWMF personnel are notified and basic information on the nature and source of the waste passing through the portal at the time of the anomaly is reviewed. If the preliminary review fails to identify a cause for the anomalous results, associated information is provided to DOE Oversight's Audit Team for review and disposition. In 2014, most of the waste delivered to the EMWMF for disposal was derived from the demolition of uranium enrichment facilities at ETTP, constructed to produce uranium enriched in the U-235 isotope for nuclear weapons and later to fuel commercial and government owned reactors. Associated contaminants were primarily uranium isotopes (predominately alpha emitters) and Tc-99 (a pure beta emitter). In 2014, the only anomalies observed in the results were due to a nuclear density gauge which contains sealed cesium-137 and americium-241 sources. The density gauge is not a waste, but a tool transported into the EMWMF disposal cells as needed and otherwise stored outside the facility.

SURFACE WATER MONITORING

Monitoring of Liquid Effluents, Surface Water, Groundwater and Sediments at the Environmental Management Waste Management Facility

The Tennessee Oversight Agreement requires the State of Tennessee to provide monitoring to verify DOE data and to assess the effectiveness of DOE contaminant control systems on the Oak Ridge Reservation. During 2014, TDEC monitored groundwater elevations, effluents, and surface water runoff at DOE's Environmental Management Waste Management Facility (EMWMF). The monitoring has shown the potential for groundwater levels to be above the geologic buffer along the north and northeast portion of the disposal cells. A groundwater incursion near PP-01 was identified from the 2011 water level data. This incursion has progressed through time. Near PP-01 the water level has risen throughout the year. Further monitoring is needed to see if this incursion is stable or increasing. Additional data loggers have been installed at several wells to get a better idea of how the groundwater system behaves seasonally with regards to precipitation. Additional monitoring is warranted to determine if the incursion near PP-01 is due to issues with the underdrain, the northern trench drain, pore pressure from waste loading of the landfill, or to a function of the additional waste cells. Results from radiological water samples suggest that radionuclides are being discharged from operations conducted at EMWMF. However, those discharges are in compliance under TDEC Rule 0400-20-11-.16.

Ambient Sediment Monitoring Program

Sediment samples from two Clinch River sites and five Poplar Creek sites were analyzed for metals and radiological parameters. Samples were also collected at Bear Creek, East Fork Poplar Creek, and Mitchell Branch. One of the sites, Poplar Creek Mile 7.0 (PCM 7.0/PCK 11.3), serves as a reference site; it is upstream of the mouth of East Fork Poplar Creek on Poplar Creek. Samples were analyzed for aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, and zinc. In addition, samples were analyzed for gross alpha, gross beta and gamma radionuclides.

The East Fork Poplar Creek Mile 3.9 sediment mercury value (14 mg/kg) exceeds the Consensus Based Sediment Quality Guidelines (CBSQG) Probable Effects Concentration (PEC) of 1.06 mg/kg (MacDonald *et al.* 2000). The mercury in East Fork Poplar Creek and Poplar Creek sediments results from historical activities at Y-12 and to a lesser extent, the East Tennessee Technology Park (ETTP). East Fork Poplar Creek empties into Poplar Creek at Poplar Creek Mile 5.5; the mouth of Poplar Creek is approximately at Clinch River Mile (CRM) 12. Of the sites sampled, mercury levels were highest at East Fork Poplar Creek km 6.3 and generally decreased downstream to Poplar Creek and the Clinch River. All of the sites sampled on East Fork Poplar Creek and Poplar Creek had mercury values above the PEC.

Historical data obtained from Oak Ridge Environmental Information System (OREIS), along with 2014 TDEC sediment data, indicate that, sometime between 2004 and 2008, sediment mercury levels increased significantly at Mitchell Branch km 0.1 (K1700). Similarly, nickel, chromium, boron, and barium concentrations increased during the same time period at this location.

The radiological sediment data show no reason for human health concerns; all parameters are well below DOE Preliminary Remediation Goals (PRGs). In 2014, cesium-137 (Cs-137) was detected in both of the Clinch River samples and in the Mitchell Branch sample. The recreational PRG for Cs-137 is 117 pCi/g [total soil/sediment Total Risk (TR) 1.0E-06] (DOE 2013) while the highest Cs-137 value was 1.21 pCi/g at CRM 0.0. Gross beta activity was highest at the Mitchell Branch location (265 pCi/g). A chronological view of sediment gross alpha and beta activity shows strong variability.

Surface Water Physical Parameters Monitoring
There exists the potential for pollution to impair surface waters on the ORR as well as offsite aquatic systems due to the presence of areas of extensive anthropogenic point and non-point source contamination on the Oak Ridge Reservation (ORR),. The local karst topography and related structural geology influences the fate and transport of contaminants that may further degrade the groundwater and surface water quality of aquatic systems adjacent to the ORR. Therefore, during 2014, the TDEC office collected ambient water quality data at six ORR stream locations and one offsite reference stream location.

In addition, continuous water quality data-loggers were installed in Upper East Fork Poplar Creek and Bear Creek to observe water quality parameters for determination of temporal trends. The continuous monitoring of the physical parameters provides a baseline of water quality parameters and how they react to changes in precipitation and other inputs along EFPC and Bear Creek. The continuous monitoring of water quality parameters has shown a potential to document conditions that may need to be addressed in the near future. There are some potential conditions that need to be confirmed along Bear Creek, additional work next year will place a confirmation data logger to determine if the pH exceedances are real and not a malfunctioning pH sensor. The office continues to monitor the streams at Y-12 to determine if fish kills or other discharges can be associated with continuous monitoring.

Ambient Trapped Sediment Monitoring
In order to monitor changes in contaminant flow through sediment transport, passive sediment samplers (traps) were deployed at six locations: Bear Creek km (BCK) 4.5, BCK 12.3, Bear Creek North Tributary 5 (NT5), East Fork Poplar Creek km (EFK) 23.4, EFK 13.8 and EFK 6.3. All of the samples from East Fork Poplar Creek exceeded the consensus-based sediment quality guidelines (CBSQGs) Probable Effects Concentration (PEC) (1.06 mg/kg) for mercury. 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). The CBSQGs are considered to be 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 (Ingersoll *et al.* 2000). East Fork Poplar Creek and Bear Creek

mercury sediment concentrations generally decrease as one travels downstream. Conversely, the proportion of methyl mercury relative to total mercury in each sample increases downstream at both streams. The general trend for other metals (arsenic, uranium, barium, boron, chromium, nickel) at East Fork Poplar Creek is to decrease as one travels downstream from Y-12. The sample collected at BCK 4.5 provided only enough sediment to run total mercury/methyl mercury analyses, so the downstream trend for these metals has not yet been determined for Bear Creek.

Gross alpha and beta values were in normal range and do not indicate contamination. All of the gamma radionuclides detected were naturally-occurring and do not pose a threat to human health. Slight Uranium-235 enrichment at the NT5 sampling location is suggested by the data; other sampling locations did not show U-235 enrichment. All of the gamma radionuclides detected were naturally-occurring and do not pose a threat to human health.

Ambient Surface Water Monitoring
The office conducts semi-annual surface water sampling to detect possible contamination from Department of Energy (DOE) sites. Sampling is conducted at six sites on the Clinch River and four sites on tributaries of the Clinch River (McCoy Branch, Raccoon Creek, Grassy Creek, and Poplar Creek). Samples were analyzed for alpha, beta, and gamma emissions, ammonia, dissolved residue, nitrate and nitrate (NO^3 & NO^2) nitrogen, suspended residue, total hardness, total Kjeldahl nitrogen, total phosphate, arsenic, cadmium, copper, iron, lead, manganese, mercury, chromium, and zinc. In 2014, there was only one case in which TNWQC was not met: dissolved oxygen at Clinch River Mile 78.7. Dissolved oxygen was measured at 4.35 mg/L on 10/23/2014 at Clinch River Mile (CRM) 78.7; this value is below the TNWQC of 6.0 mg/L (fish and aquatic life, trout stream). This sampling location is just a short distance from Norris Dam and the water discharged from the dam comes from a great depth and is low in dissolved oxygen. Factors that affected the low DO value may have been that the sampling location is upstream of the aerating weir dam and, at the time the measurement was taken, the dam was not generating. All other metals, nutrients, and physical parameter measurements were within acceptable limits of the TNWQC.

Strontium-90 specific analysis from the samples collected at Raccoon Creek showed 0.58 pCi/L in the second quarter and 9.2 pCi/L in the fourth quarter; the EPA strontium-90 Maximum Contaminant Level (MCL) for drinking water is 8 pCi/L. Raccoon Creek is believed to be affected by contaminated groundwater from Solid Waste Storage Area (SWSA) 3; the primary radiological contaminant is strontium-90 (Sr-90). Radiological data, other than the Sr-90 detection mentioned previously, show nothing of concern. Gross alpha and gross beta values were typical of background conditions, with the exception of Raccoon Creek which had a gross beta value of 22.5 pCi/L.

Rain Event Surface Water Monitoring
The DOE Office conducted surface water sampling following a rain event of at least one inch in a 24-hour period or two inches in a 72-hour period, at stream sites on the Oak Ridge Reservation in 2014. Samples were collected during the second, third and fourth quarters following a qualifying event. Samples were not collected during the first quarter due to not being able to meet the rain event criteria. Results were consistent with results from a non-contaminated site

following a heavy rain, with the exceptions of mercury at East Fork Popular Creek kilometer 23.4 and radionuclides at Storm Drain 490.

Benthic Macroinvertebrate Surface Water Monitoring Program
(This project was added mid-year.)
The office conducted surface water monitoring at the following Oak Ridge Reservation watersheds in May 2014: Bear Creek, East Fork Poplar Creek, Mitchell Branch, and White Oak Creek/Melton Branch. Surface water samples were collected from eleven impacted stream sites and associated reference sites. Monitoring was also conducted at Clear Creek near Norris Dam which serves as a reference site for all the ORR watersheds. Samples were delivered to the State of Tennessee Department of Health Laboratory for nutrients, metals, and radiological analyses. The surface water data indicate that the surface water quality in the four watersheds was less than optimal when compared to reference streams.

<u>Bear Creek:</u> None of the non-radiological results were greater than the Tennessee General Water Quality Criteria (TWQC). In addition, none of the radiological results were greater than DOE Preliminary Remediation Goals (PRG) goals. Relative to the majority of the above observations, the main trend is that contaminant levels are highest at BCK 12.3 and decrease as Bear Creek flows downstream and to the west. It is likely that as the contaminants travel farther downstream/west, their concentrations are being decreased due to the water dilution effect.
<u>East Fork Poplar Creek:</u> Except for mercury, none of the other non-radiological results were greater than the TWQC. Mercury's TWQC limit in surface water is < 0.051 µg/L. This result was expected due to the Y-12 legacy mercury contamination of EFK. Nonetheless, these elevated EFK mercury values are of great concern as mercury is highly toxic to human beings.
<u>Mitchell Branch:</u> None of the non-radiological results were greater than the TWQC. Relative to the majority of the above observations, the main trend is that contaminant levels are lowest at MIK 1.43 and increase as Mitchell Branch flows downstream and to the west and enters the contaminated footprint of the ETTP/old K-25 complex.
<u>White Oak Creek/Melton Branch:</u> None of the non-radiological results were greater than the TWQC. In addition, none of the radiological results were greater than DOE PRG goals. Phosphorus, zinc, manganese, specific conductivity, total hardness, and dissolved residue values/concentrations were the lower at WCK 6.8 and CCK 1.6 (reference sites) than at WCK 2.3. The radioactive alpha and beta concentrations at WCK 2.3 (14.4 pCi/L) were higher than that of the reference sites. No alpha values were detected at the two reference sites, WCK 6.8 and CCK 1.45.

The comprehensive stream assessment scores calculated from the benthic macroinvertebrate monitoring program indicated the same conclusion.

Overall Considerations
DOE's and the Office's monitoring of groundwater and whitetail deer movements indicate possible ORR contaminant exposure to receptors onsite and offsite. Historical disposal areas are contaminated such that groundwater, soils, vegetation, wildlife and fisheries are affected beyond the containment and controls utilized on the ORR. To date, measures taken to reduce the flux of releases and pathways to receptors are responsible for incremental improvements to the environment, but fall short of eliminating the measurable spread of contamination.

LIST OF COMMON ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
ASER	Annual Site Environmental Report (written by DOE)
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BCID	Bat Call Identification
BCK	Bear Creek Kilometer (station location)
BFK	Brushy Fork Creek Kilometer (station location)
BJC	Bechtel Jacobs Company (past DOE contractor)
BMAP	Biological Monitoring and Abatement Program
BNFL	British Nuclear Fuels Limited
BOD	Biological Oxygen Demand
BWXT	Y-12 Prime Contractor (current)
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAP	Citizens Advisory Panel (of LOC)
CCR	Consumer Confidence Report
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COC	Contaminants of Concern
COD	Chemical Oxygen Demand
CPM (cpm)	counts per minute
CRM	Clinch River Mile
CROET	Community Reuse Organization of East Tennessee
CWA	Clean Water Act
CYRTF	Coal Yard Runoff Treatment Facility (at ORNL)
D&D	Decontamination and Decommissioning
DCG	Derived Concentration Guide
DIL	Derived Intervention Levels
DNA	Division of Natural Areas
DO	dissolved oxygen
DOE	Department of Energy
DOE-O	Department of Energy Oversight Office (TDEC)
DOR	Division of Remediation
DWS	Division of Water Supply (TDEC)
E. coli	*Escherichia coli*
EAC	Environmental Assistance Center (TDEC)
EBOR	East Black Oak Ridge Conservation Easement
ED1, ED2, ED3	Economic Development Parcel 1, Parcel 2, and Parcel 3
EFPC/EFK	East Fork Poplar Creek
EFSA	European Food Safety Authority
EMC	Environmental Monitoring and Compliance (DOE-O Program)
EMWMF	Environmental Management Waste Management Facility
EPA	Environmental Protection Agency

EPT	*Ephemeroptera, Plecoptera, Trichoptera* (may flies, stone flies, caddis flies)
ERS	Economic Research Services
ESA	Endangered Species Act
ET&I	Equipment Test and Inspection
ETTP	East Tennessee Technology Park
FCAP	Filled Coal Ash Pond
FD	frequency dividing
FDA	U. S. Food and Drug Administration
FFA	Federal Facilities Agreement
FRMAC	Federal Radiation Monitoring and Assessment Center
FSP	Facility Survey Program
g	gram
GHK	Gum Hollow Branch Kilometer (station location)
GIS	Geographic Information Systems
GPS	Global Positioning System
GW	Ground Water
GWQC	Ground Water Quality Criteria
ha	hectare
HAP	Hazardous Air Pollutant
HCK	Hinds Creek Kilometer (station location)
HFIR	High Flux Isotope Reactor
HRE	Homogenous Reactor Experiment
IBI	Index of Biotic Integrity
IC	In Compliance
"ISCO" Sampler	Automatic Water Sampler
IWQP	Integrated Water Quality Program
K-####	Facility at K-25 (ETTP)
K-25	Oak Ridge Gaseous Diffusion Plant (now called ETTP)
KBL	Knoxville Branch Laboratory
KFO	Knoxville Field Office
JECFA	(Joint FAO/WAO) Joint Food and Agriculture Organization UN Word Health Organization Expert Committee
l	liter
LEFPK	Lower East Fork Poplar Creek
LC_{50}	Lethal Concentration at which 50 % of Test Organisms Die
LMES	Lockheed Martin Energy Systems (past DOE Contractor)
LWBR	Lower Watts Bar Reservoir
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MACT	Maximum Achievable Control Technologies
MBK	Mill Branch Kilometer (station location)
MCL	Maximum Contaminant Level (for drinking water)
MDC	Minimum Detectable Concentration
MDL	minimum detection limit
MEK	Melton Branch Kilometer (station location)
µg	microgram

mg	milligram
MIK	Mitchell Branch Kilometer (station location)
ml	milliliter
MMES	Martin Marietta Energy Systems (past DOE Contractor)
m	meter
μmho	micro mho (mho=1/ohm)
MOU	Memorandum of Understanding
μR	microroentgen
MQL	method quantitation limit
Mrem	1/1000 of a rem – millirem
N, S, E, W	North, South, East, West
NAAQS	National Ambient Air Quality Standards
NAREL	National Air and Radiation Environmental Laboratory
NAT	No Acute Toxicity
NCBI	North Carolina Biotic Index
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAPs	National Emissions Standards for HAPs
ng	nanogram
NIC	Not In Compliance
NNSS	Nevada National Security Site (formerly the Nevada Test Site, NTS)
NOAEC	No Observable Adverse Effect Concentration (to Tested Organisms)
NOID	No Identification
NOV	Notice of Violation
NPDES	National Pollution Discharge Elimination System
NRDA	Natural Resources Damage Assessment
NRWTF	Non-Radiological Waste Treatment Facility (at ORNL)
NT	Northern Tributary of Bear Creek in Bear Creek Valley
NTS	Nevada Test Site (now the Nevada National Security Site, NNSS)
OMI	Operations Management International (runs utilities at ETTP under CROET)
ORAU	Oak Ridge Associated Universities
OREIS	Oak Ridge Environmental Information System http://w ww-oreis.bechteljacobs.org/oreis/help/oreishome.html
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORRCA	Oak Ridge Reservation Communities Alliance
OSHA	Occupational Safety and Health Association
OSL	Optically Stimulated Luminescent (Dosimeter)
OU	Operable Unit
PACE	Paper, Allied-Industrial, Chemical, and Energy Workers Union
PAH	polycyclic aromatic hydrocarbons
PAM	Perimeter Air Monitor
PEC	Probable Effects Concentration
PER	Potential for Environmental Release

PCB	Polychlorinated Biphenol
pCi	$1x10^{-12}$ Curie (Picocurie)
PCM	Poplar Creek Mile (station location)
pH	Proportion of Hydrogen Ions (acid vs. base)
PWSID	Potable Water Supply Identification "number"
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PPE	Personal Protective Equipment
PRG	Preliminary Remediation Goals
QA	Quality Assurance
QC	Quality Control
R	Roentgen
RBP	Rapid Bioassessment Program
RCRA	Resource Conservation and Recovery Act
REM (rem)	Roentgen Equivalent Man (unit)
RER	Remediation Effectiveness Report
RMD	Resource Management Division
ROD	Record of Decision
ROW	Right of Way
RPM	radiation portal monitor
RSE	Remedial Site Evaluation
RSP	radiation sensor panel
SARA	Superfund Amendments and Reauthorization Act
SLF	Sanitary Landfill
S&M	Surveillance & Maintenance
SNS	Spallation Neutron Source
SOP	Standard Operating Procedure
SPOT	Sample Planning and Oversight Team (TDEC)
SS	surface spring
STP	Sewage Treatment Plant or Site Treatment Plan
SW	surface water
TEC	threshold effects concentrations
TDEC	Tennessee Department of Environment and Conservation
TDS	Total Dissolved Solids
TIE	Toxicity Identification Evaluation
TLD	Thermoluminescent Dosimeter
TMI	Tennessee Macroinvertebrate Index
TNUTOL	Tennessee Nutrient Tolerant Organisms
TOA	Tennessee Oversight Agreement
TRE	Toxicity Reduction Evaluation
TRM	Tennessee River Mile
TRU	Transuranic
TSCA	Toxic Substance Control Act
TSCAI	Toxic Substance Control Act Incinerator
TSS	Total Suspended Solids

TTHM’s	Total Trihalomethanes
TVA	Tennessee Valley Authority
TWI	tolerable weekly intake
TWQC	Tennessee Water Quality Criteria
TWRA	Tennessee Wildlife Resources Agency
UCOR	URS/CH2M Oak Ridge LLC (Current EM Prime Contractor)
UEFPK	Upper East Fork Poplar Creek
U.S.	United States
USDA	United States Department of Agriculture
USFDA	United States Food and Drug Administration
USFWS	United States Fish and Wildlife Services
UT-Battelle	University of Tennessee-Battelle (ORNL Prime Contractor)
VOA	Volatile Organic Analytes
VOC	Volatile Organic Compound
WBOR	West Black Oak Ridge Conservation Easement
WCK	White Oak Creek Kilometer (station location)
WM	Waste Management
WOL	White Oak Lake
X-####	Facility at X-10 (ORNL)
X-10	Oak Ridge National Laboratory
Y-####	Facility at Y-12
Y-12	Y-12 Plant Area Office
ZCA	Zero-Crossings Analysis

INTRODUCTION

In accordance with the Tennessee Oversight Agreement, Attachment A.7.2.2, the Tennessee Department of Environment and Conservation, DOE Oversight Office (the office), is providing this annual environmental monitoring report of the results of its monitoring and analysis activities during the calendar year of 2014 for public distribution. In 1991, the office was established to administer the Tennessee Oversight Agreement (TOA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)-required Federal Facility Agreement. These agreements are designed to assure the citizens of Tennessee that the Department of Energy (DOE) is protecting their health, safety, and environment through existing programs and substantial new commitments.

This report consists of a compilation of individual reports that involve independent environmental monitoring projects conducted by the office. The individual reports are organized by general areas of interest: Air Quality, Biological, Drinking Water, Groundwater, Radiological and Surface Water. Abstracts and conclusions are available in each report to provide a quick overview of the content and outcome of each monitoring effort. All supporting information and data used in the completion of these reports are available for review in the office's program files. Due to the geologic/hydrogeologic complexity of the area, construction of the groundwater monitoring report activities performed in 2014 is still being completed. As soon as that report is completed, it will be issued as an addendum to this document. Overall, this report characterizes and evaluates the chemical and radiological emissions in the air, water, and sediments both on and off the Oak Ridge Reservation (ORR).

The office considers location, environmental setting, history, and on-going DOE operations in each of its environmental monitoring programs. The information gathered provides information for a better understanding of the fate and transport of contaminants released from the ORR into the environment. This understanding has led to the development of an ambient monitoring system and increased the probability of detecting releases in the event that institutional controls on the Oak Ridge Reservation fail.

Currently, the office's monitoring activities have not detected imminent threats to public health or the environment outside of the Oak Ridge Reservation. Unacceptable releases of contaminants from past DOE operational and disposal activities continue to pose risk to the environment and it is imperative to note that, if current institutional controls fail or if the present contaminant source controls can no longer be maintained, the public would be at risk from environmental contamination.

Site Description

The ORR, as shown in Figure 1, encompasses approximately 35,000 acres and three major operational DOE facilities: the Oak Ridge National Laboratory (ORNL), the Oak Ridge Y-12 Plant (Y-12), and the East Tennessee Technology Park (ETTP, formerly the K-25 Gaseous Diffusion Plant). The initial objectives of the ORR operations were the production of plutonium and the enrichment of uranium for nuclear weapons components. 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, were disposed on the ORR. Early waste disposal methods on the ORR were rudimentary compared to today's standards.

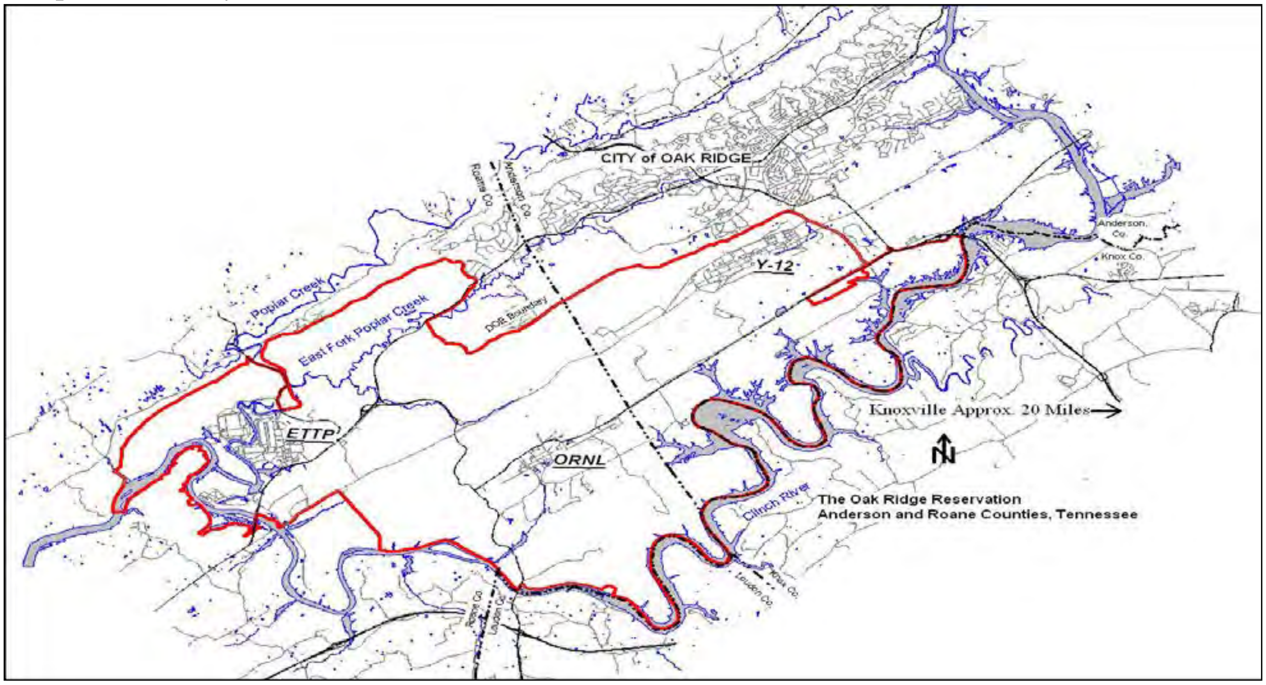

Figure 1: The Oak Ridge Reservation

The ORR is located in the counties of Anderson and Roane within the corporate boundaries of the City of Oak Ridge, Tennessee. The reservation is bound on the north and east by residential areas of the City of Oak Ridge and on the south and west by the Clinch River. Counties adjacent to the reservation include Knox to the east, Loudon to the southeast and Morgan to the northwest. Meigs and Rhea counties are immediately downstream on the Tennessee River from the ORR. The nearest cities are Oak Ridge, Oliver Springs, Kingston, Lenoir City, Harriman, Farragut, and Clinton. The nearest metropolitan area, Knoxville, lies approximately 20 miles to the east. Figure 2 depicts the general location of the Oak Ridge Reservation in relation to nearby cities and surrounding counties.

The ORR lies in the Valley and Ridge Physiographic Province of East Tennessee. The Valley and Ridge Province is a zone of complex geologic structures dominated by a series of thrust faults and characterized by a succession of elongated southwest-northeast trending valleys and ridges. In general, sandstones, limestones, and/or dolomites underlie the ridges that are relatively resistant to erosion. Weaker shales and more soluble carbonate rock units underlie the valleys.

The hydrogeology of the ORR is very complex with a number of variables influencing the direction, quantity, and velocity of groundwater flow that may or may not be evident from surface topography. In many areas of the ORR, groundwater appears to travel primarily along short flow paths in the storm flow zone to nearby streams. In other areas, evidence indicates substantial groundwater flow paths, possibly causing preferential contaminant transport in fractures and solution cavities in the bedrock for relatively long distances and at considerable depths increasing the probability for off-site migration of those contaminants to the public.

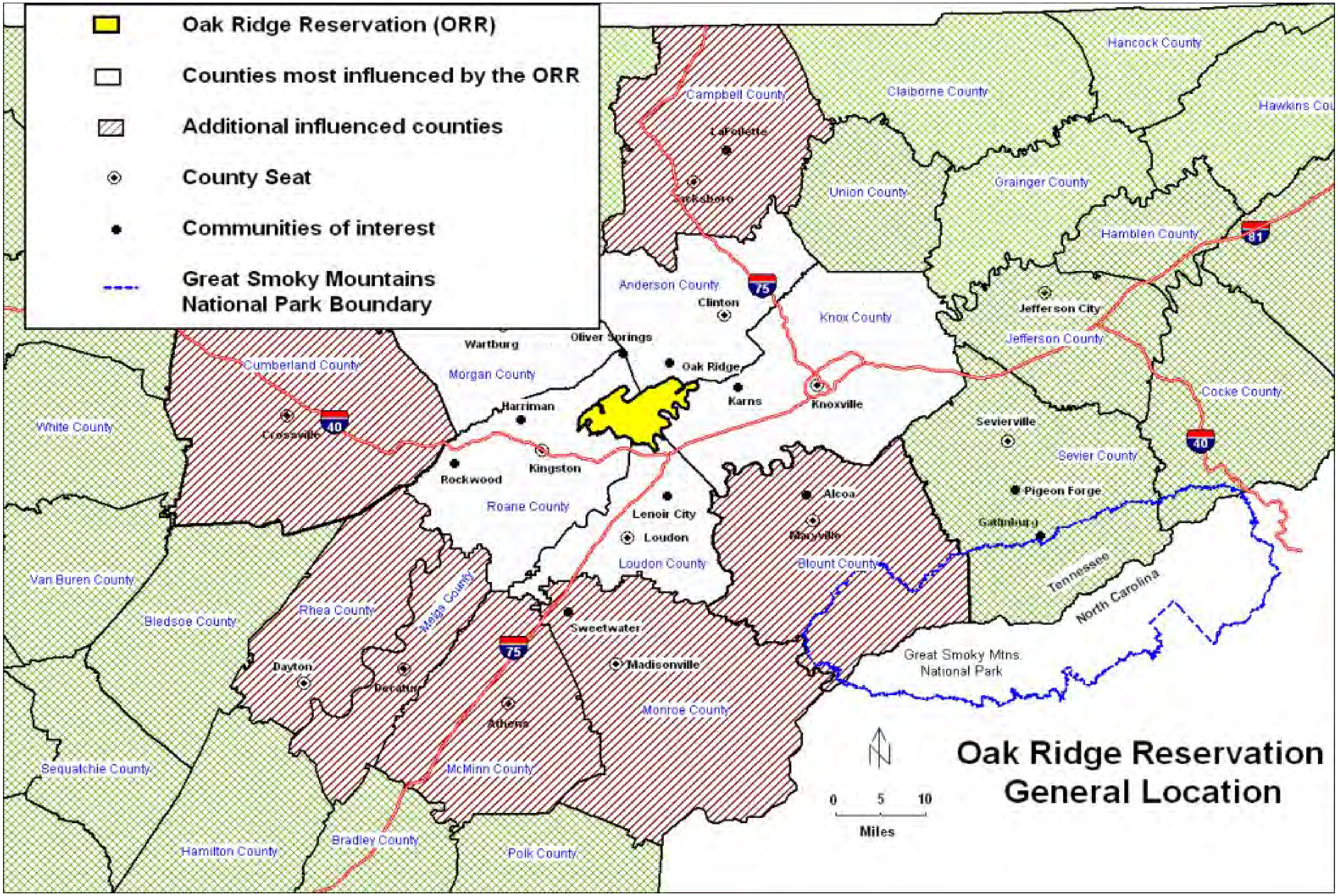

Figure 2: Location of the Oak Ridge Reservation in relation to surrounding counties

As seen in Figure 3, streams on the ORR drain to the Clinch River and then to the Tennessee River. Melton Hill Dam impounded the Clinch River in 1963. Contaminants released on the Oak Ridge Reservation, and that do not remain permanently in the groundwater, enter area streams (e.g., White Oak Creek, Bear Creek, East Fork Poplar Creek, and Poplar Creek) and are transported into the Clinch River and Watts Bar Reservoir on the Tennessee River. Groundwater travels through fractures and solution channels to offsite locations, including underneath the Clinch River.

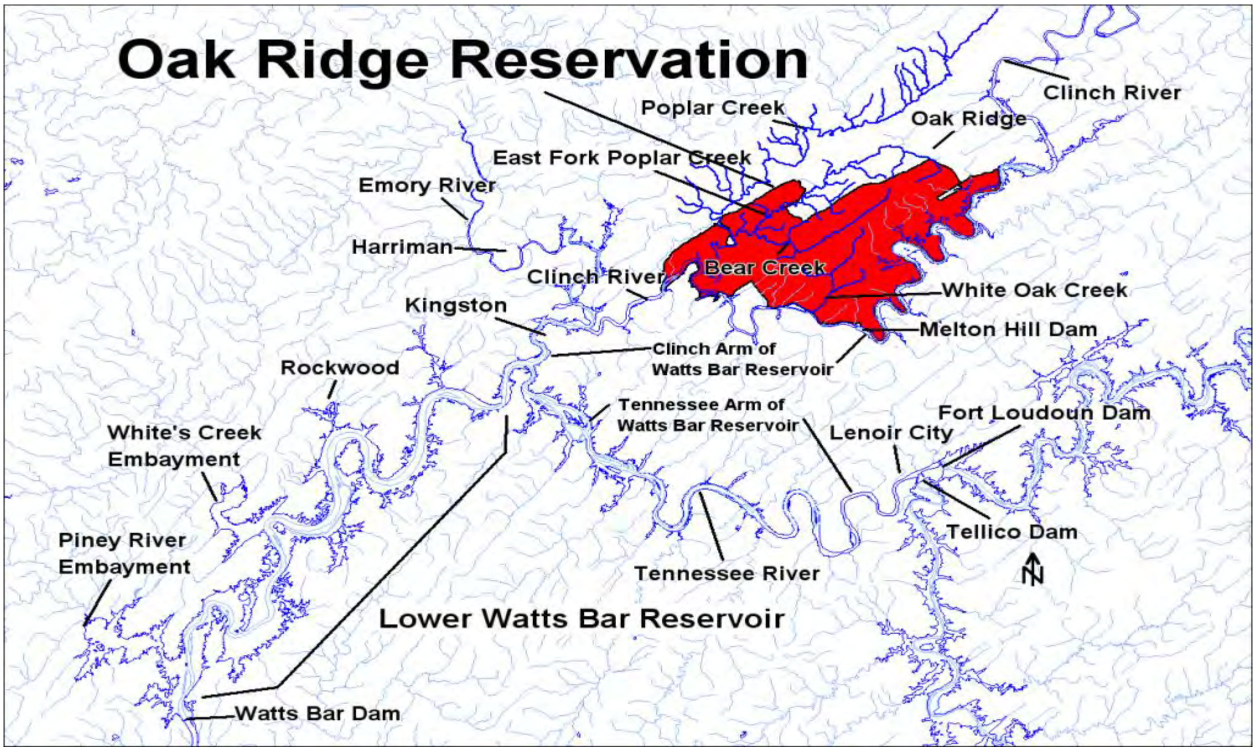

Figure 3: Watts Bar Reservoir

The climate of the region is moderately humid and the annual average precipitation is around 55 inches. Winds on the reservation are controlled, in large part, by the valley and ridge topography with prevailing winds moving up the valleys (northeasterly) during the daytime and down the valleys (southwesterly) at night.

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AIR QUALITY MONITORING

Monitoring of Hazardous Air Pollutants on the Oak Ridge Reservation

Principal Authors: Sid Jones, Don Gilmore

Abstract

The Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (DOE-O) Hazardous Air Pollutants (HAPs) monitoring program was initially developed to provide independent monitoring of hazardous metals in air at the East Tennessee Technology Park (ETTP) and to verify the Department of Energy's (DOE) reported monitoring results. Monitoring at Oak Ridge National Laboratory (ORNL or X-10) and at the Y-12 National Security Complex was added as an extension of the HAPs monitoring at East Tennessee Technology Park (ETTP). Although permitted emissions have declined at DOE facilities, a number of DOE operations on the Oak Ridge Reservation (ORR), primarily the demolition of contaminated buildings, continue to have the potential to emit hazardous metals. The HAPs monitoring program continued through 2014 as an on-demand independent monitoring effort performed by TDEC's Division of Remediation (DOR), DOE-O Office to provide data on hazardous metals in ambient air on the ORR and as independent verification of DOE's monitoring at ETTP. The possibility of doing metals analysis due to an unforeseen release in an emergency, such as a fire or building collapse in a tornado is retained, as the filters will be archived automatically for at least six months.

Due to the continuing reduction in permitted sources on the ORR and the completion of the demolition of the K-25 building at ETTP, this project will be discontinued until other major demolition projects on the ORR are initiated or other potential sources of hazardous air pollutants are identified. No metals analyses were conducted or required during the 2014 calendar year.

Introduction

This independent monitoring project is conducted under authority of the Tennessee Oversight Agreement. The project was initiated in 1997 at the East Tennessee Technology Park (ETTP or K-25 site) in response to the heightened level of public concern regarding potential impacts to public health from the TSCA Incinerator emissions. Monitoring of hazardous metals in air expanded to include the National Security Complex (Y-12) and the Oak Ridge National Laboratory (ORNL or X-10) in the following year. Following the closure of the TSCA Incinerator at ETTP, the project continues to monitor hazardous metals in fugitive emissions associated with demolition activities or other non-point sources at the three Oak Ridge Reservation (ORR) sites. Levels of arsenic, beryllium, cadmium, chromium, lead; nickel and uranium (as a metal only) in the ambient air are monitored if necessary.

During 2014, projected demolition activities on the Oak Ridge Reservation were primarily limited to the remaining K-25 units. These units should produce similar fugitive emissions of metal to those resulting from past demolition activities at the K-25 building. Completion of K-25 demolition was accomplished in 2014. At the time of completion, known potential sources of fugitive emissions on the ORR were significantly reduced. At this time, sampling will continue and filters will be collected for radionuclide analysis, but metals analysis will be discontinued unless a new potential source of hazardous metals is identified. The possibility of doing metals analysis due to an unforeseen release in an emergency, such as a fire or building collapse in a tornado, is retained, as the filters will be archived automatically for at least six months.

In the future, including 2015, metals analysis may be resumed if new potential sources of hazardous air pollutant emissions are identified. One scenario that might trigger future metals monitoring is demolition of buildings with significant lead or beryllium contamination, as both metals were used extensively in some ORR buildings. In addition, mercury monitoring in air may be considered when buildings with elevated levels of mercury contamination are demolished in the future. Mercury monitoring would require additional equipment and a change in sampling protocol. No buildings with high levels of mercury contamination are scheduled for demolition in the next few years, so, for the 2014 year, there were no changes in sampling locations, sampling protocols, or analytical methods.

A high-volume total suspended particulate (TSP) ambient air sampler is deployed at each site at one of several potential sampling locations. These locations were selected based on wind rose data, availability of electrical power, and co-location with DOE and TDEC radiological air monitors. The proposed sampling sites for next year differ slightly from those used over the previous eight years. The sites are as follows:

- ORNL: X-10E, RadNet station east of the main entrance to the site

  X-10C, station at the Corehole 8 remediation site
  X-10W, station No. 3 west of the site (See Figure 1)

- Y-12: Y-12E, RadNet station east of the plant entrance

  Y-12W, RadNet station west of the plant site (See Figure 2)

- ETTP: K-11, near the north end of the K-25 building

  K-42/TSCA-1, on Blair Road
  K-35/TSCA-2, on Gallaher Road (See Figure 3)

Samplers are located at the X-10C, Y-12E and K-11 sites, and, if necessary, staff splits samples with the radiological monitoring group throughout the year at all three sites. Due to closure of the TSCA incinerator, the K-2 site was abandoned in favor of the K-11 site, which is closer to the ongoing demolition activities at the K-25 and K-27 gaseous diffusion buildings. As was the case with the K-2 site, DOE maintains an air monitor for metals and radiological emissions at the K-11 site. Monitoring results from this site may still be compared to data collected by DOE. The X-10C site is located adjacent to the Tank W1A (Corehole 8) soil removal project, which is nearing completion but is located near potential sources of fugitive emissions from ORNL demolition activities. This sampler is mounted on a trailer and may be moved to either the X-10E or X-10W site if conditions at ORNL warrant a change in sample location. Power supply at the X-10E site is provided via a temperature-sensitive source, making deployment at this site potentially problematic during the coldest months. The Y-12E air monitor was relocated a few hundred meters to the north of the old site to accommodate construction activities on the east end of the Y-12 plant.

Methods and Materials

Wind rose data indicating that the selected sites were in the prevailing wind flow patterns downwind of potential sources on the ORR were considered when establishing the monitoring stations. The wind flow during the day is generally a southwest to northeast pattern. During the night the flow pattern is reversed. The placement of TDEC's monitoring sites allowed for sampling that would be representative of a 24-hour wind flow pattern at the ORR. Until 2006, monitors were moved quarterly in an attempt to sample downwind of sources during both night and day. In 2007, the Y-12 and ETTP monitors were permanently located at the K-2 and Y-12 East sites where 2005 and 2006 data indicated the highest concentrations of HAPs metals in ambient air. As stated above, the ORNL monitor was later moved to the interior of the plant in 2006 to facilitate monitoring of radionuclides and hazardous metals near the site of the Tank W1A removal action and the ETTP monitor was moved to the K-11 site in 2012 because of proximity to active demolition projects. An additional factor in selecting monitoring locations was the availability of a power source.

When the program was initiated, sampling for arsenic, beryllium, cadmium, chromium, and lead was performed. In 1999, nickel and uranium were added to the list of analytes. Samples were collected on glass fiber filters on a weekly basis and mailed to the Tennessee Department of Health (TDH) laboratory in Nashville for analysis through 2006. Since 2007, laboratory analysis has primarily been performed quarterly on composited samples. In addition, the analytical method was changed in 2007 from inductively coupled plasma (ICP) analysis of metals to analysis by ICP – mass spectroscopy (ICP-MS), lowering detection and quantification limits for all metals. Since 2012, the HAPs program has split filters taken for radiological analysis by the Radiological Monitoring program at the X-10 site. Beginning at the start of the third quarter of 2012, the HAPs program and Radiological Monitoring program have split samples at the ETTP and Y-12 sites.

Results and Discussion

Composited filters collected for radiological analysis were not required to be analyzed for metals in 2014. Therefore there was no information gathered in 2014 for this project.

Conclusion

Due to the continuing reduction in permitted sources on the ORR and the completion of the demolition of the K-25 building at ETTP, this project will be discontinued until other major demolition projects on the ORR are initiated or other potential sources of hazardous air pollutants are identified.

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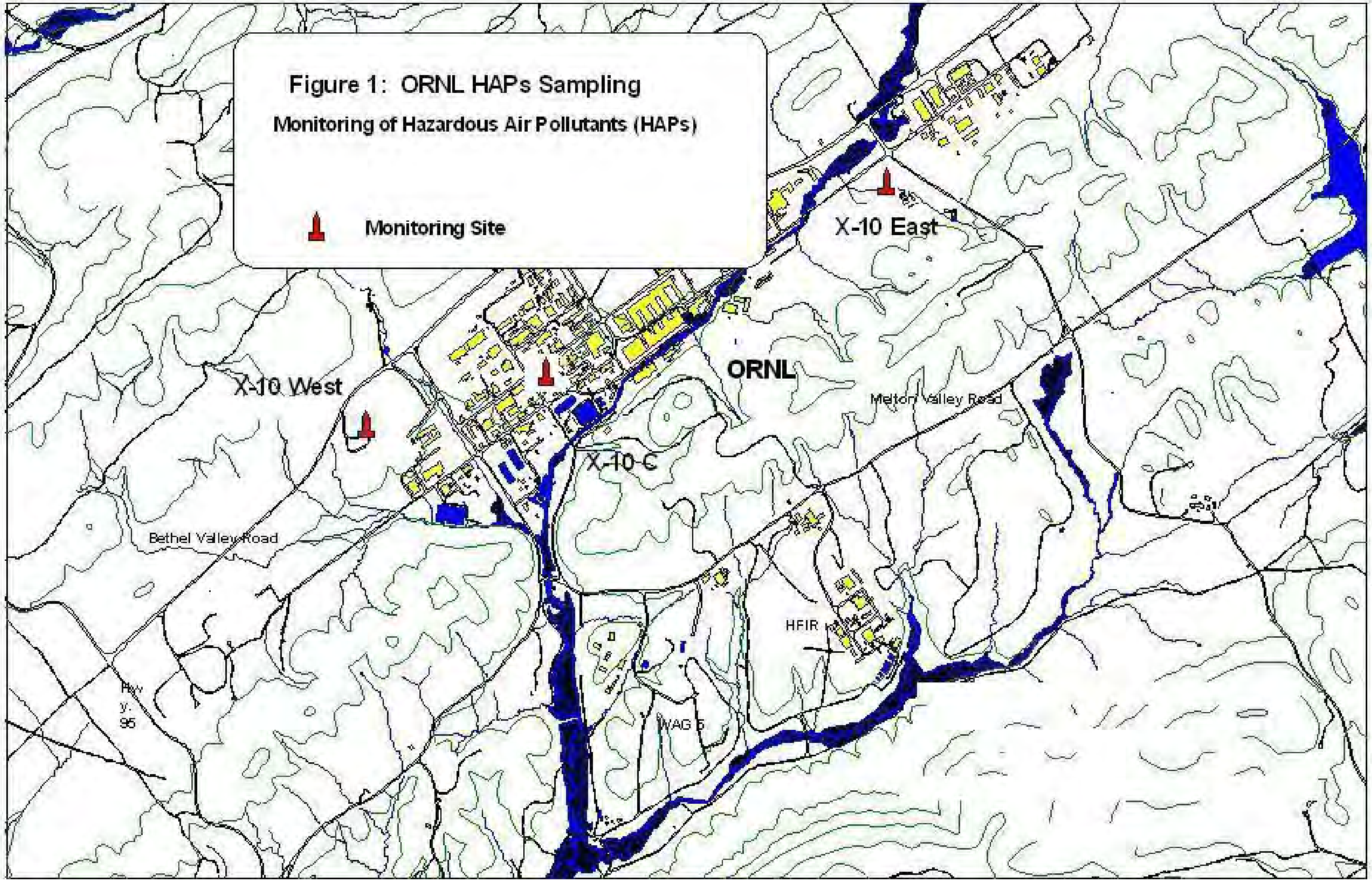

Figure 1: ORNL HAPs Sampling Locations

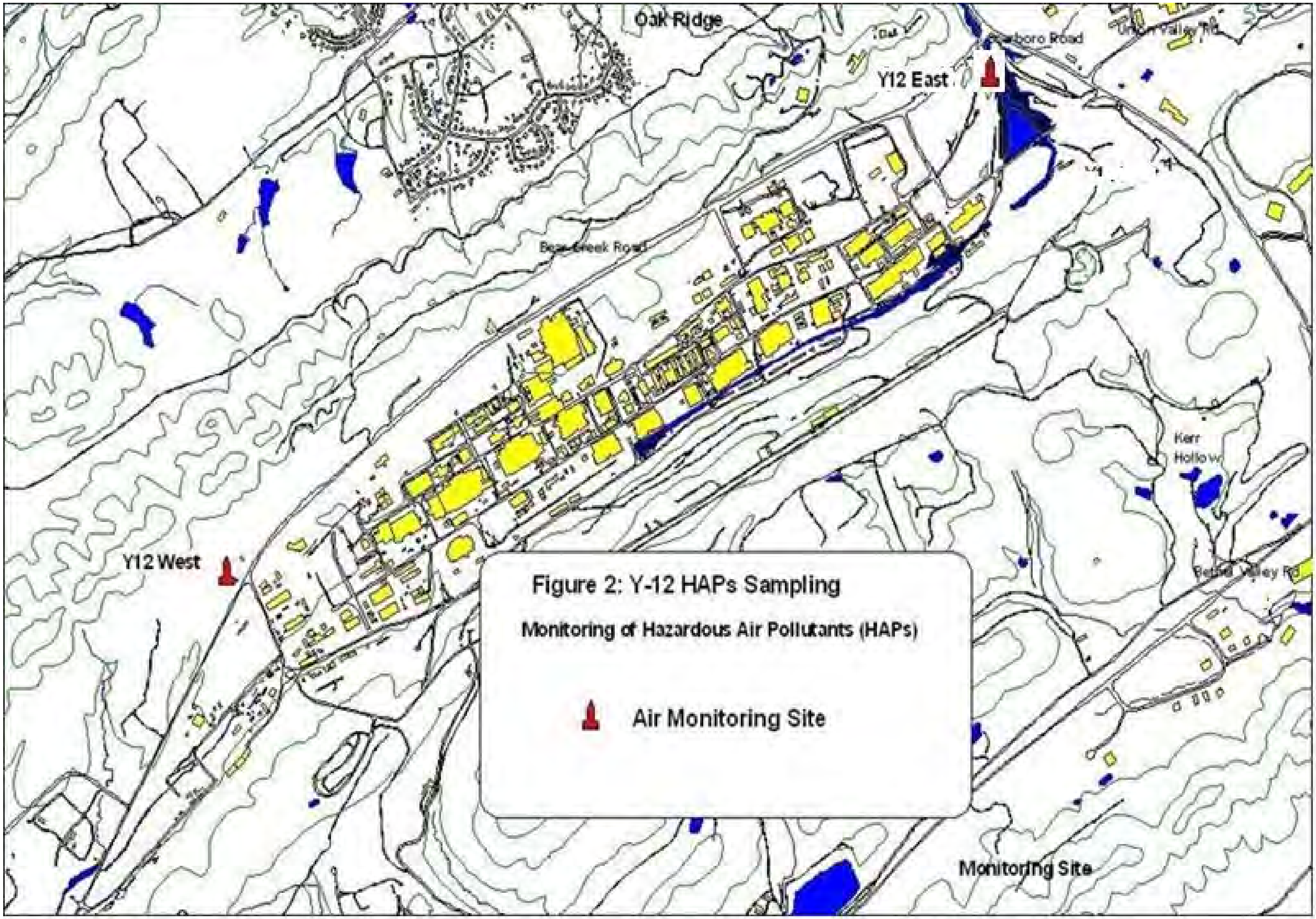

Figure 2: Y-12 HAPs Sampling Locations

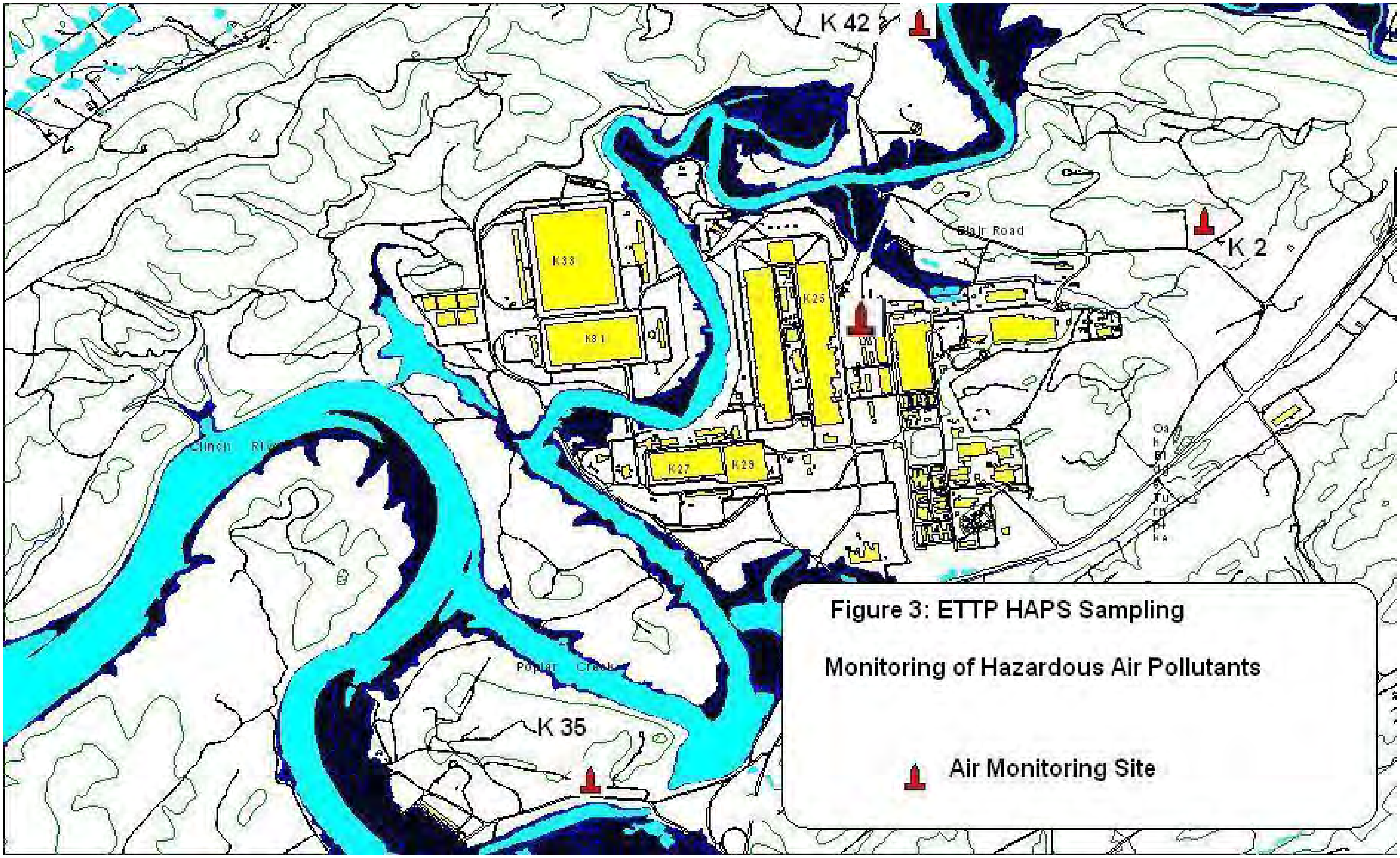

Figure 3: ETTP HAPs Sampling Locations

RadNet Air Monitoring on the Oak Ridge Reservation

Principal Author: Natalie Pheasant

Abstract

The RadNet Air Monitoring Program on the Oak Ridge Reservation 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 Oak Ridge Reservation. RadNet samples are collected by staff of the Tennessee Department of Environment and Conservation and analysis is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory in Montgomery, Alabama. In 2014, as in past years, the data for each of the five RadNet air monitors largely exhibited similar trends and concentrations. The results for 2014 do not indicate a significant impact on the environment or public health from Oak Ridge Reservation emissions.

Introduction

In the past, air emissions from Department of Energy (DOE) activities on the Oak Ridge Reservation (ORR) were believed to have been a potential cause of illnesses affecting area residents. While these emissions have substantially decreased over the years, concerns have remained that air pollutants from current activities (e.g., production of radioisotopes and demolition of radioactively contaminated facilities) could pose a threat to public health, the surrounding environment, or both. As a consequence, the Tennessee Department of Environment and Conservation (TDEC) has implemented a number of air monitoring programs to assess the impact of ORR air emissions on the surrounding environment and the effectiveness of DOE controls and monitoring systems. TDEC's fugitive air monitoring program (described in an associated report) focuses on monitoring non-point sources of emissions. TDEC's participation in the Environmental Protection Agency's (EPA) RadNet air and precipitation monitoring programs supplements information generated by TDEC's fugitive air monitoring program, targets specific operations such as the High Flux Isotope Reactor (HFIR) and supplements state and DOE monitoring data, providing independent third party analysis.

Methods and Materials

The locations of the five RadNet air samplers are provided in Figure 1 and EPA's analytical parameters and frequencies are listed in Table 1. The RadNet air samplers run continuously, collecting suspended particulates on synthetic fiber filters (10 centimeters in diameter) as air is drawn through the units by a pump at approximately 35 cubic feet per minute. TDEC staff collect the filters from each sampler twice weekly and estimate the radioactivity on each filter using the supplied alpha-beta scintillation detector. Following EPA protocol (U.S. EPA 1988, U.S. EPA 2006), the filters are then shipped to EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama, for analysis.

NAREL performs gross beta analysis on each sample collected. If the gross beta result for a sample exceeds one picocurie per cubic meter (pCi/m^3), gamma spectrometry is performed on the sample. A composite of the air filters collected from each monitoring station during the year is analyzed for uranium and plutonium isotopes annually.

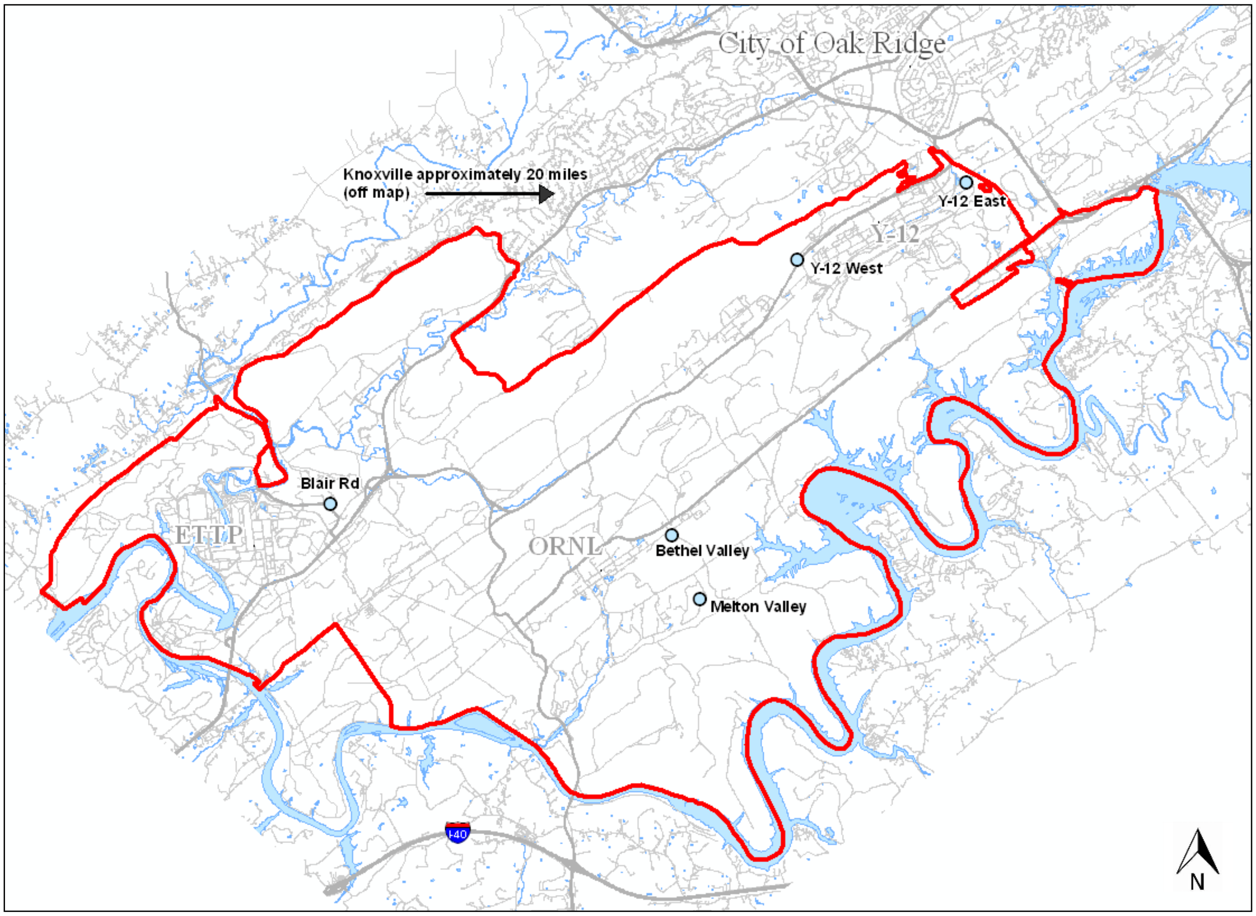

Figure 1: Locations of air stations monitored by TDEC on the Oak Ridge Reservation in association with EPA's RadNet air monitoring program

The results of NAREL's analyses of the nationwide RadNet air data is available at NAREL's website in the Envirofacts RadNet Searchable Database, via either a simple or customized search (websites listed in references).

Table 1: EPA Analysis of Air Samples Taken in Association with EPA's RadNet Program

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	Annually on a composite of the filters from each station

Gross beta from the RadNet air monitoring program is now compared to background data from the RadNet air monitor in Knoxville, TN, and to the Clean Air Act (CAA) environmental limit for strontium-90, as it is a pure beta emitter with a conservative limit. Previously, the RadNet

ORR data was compared to the TDEC Fugitive Air monitoring program background location, but the program no longer runs analysis for gross beta at the background location.

Results and Discussion

As seen in Figure 2, the results for the gross beta analysis in 2014 were generally similar for each of the five ORR RadNet monitoring stations and most were similar to the results reported for the Knoxville RadNet air station used as background for comparison. There was one main exception to this in 2014, which can easily be seen in Figure 2. The slightly elevated result of 0.0361 pCi/m^3, seen at the ETTP location for the sample collected March 13, 2014, is well below the 1.0 pCi/m^3 screening level requiring further analysis. The likely cause of the elevated result was the cleaning of the concrete slab where the K-25 building had recently been demolished. The Fugitive Radiological Air Emissions Monitoring Program saw elevated levels of technetium-99 at one of the samplers also located at ETTP during a similar time period. The general fluctuations that can be seen in the results in Figure 2 are largely attributable to natural phenomena (e.g., wind and rain) that influence the amount of particulates suspended in the air and, thus, what is ultimately deposited on the filters. Again, the 2014 gross beta results are all well below 1.0 pCi/m^3, which is the screening level requiring further analysis.

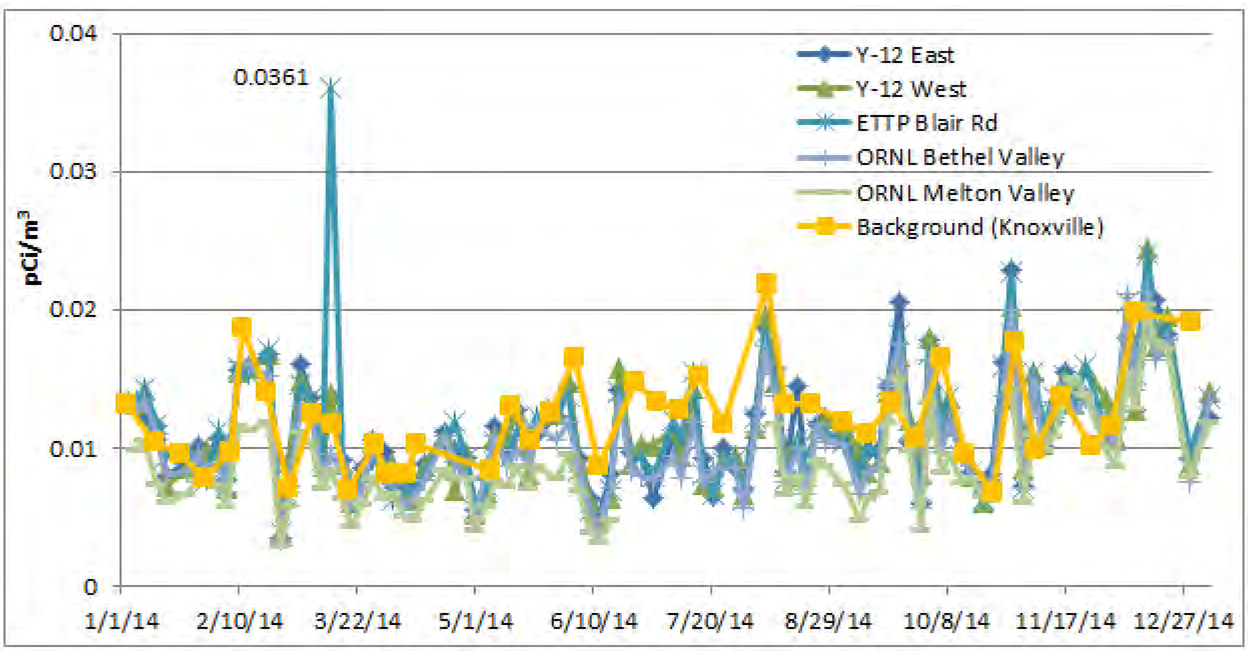

Figure 2: 2014 Gross beta results from air samples taken on the ORR in association with EPA's RadNet air monitoring program and background measurements from the DOE-Oversight Office's fugitive air monitoring program

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 at the DOE-O office.

Figure 3 depicts the 2014 average gross beta results for each of the five stations in the ORR RadNet Program, the average background concentration measured at the Knoxville RadNet location, and the Clean Air Act (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. Staff use these concentrations to assess the compliance of the emissions measured with the CAA dose limit.

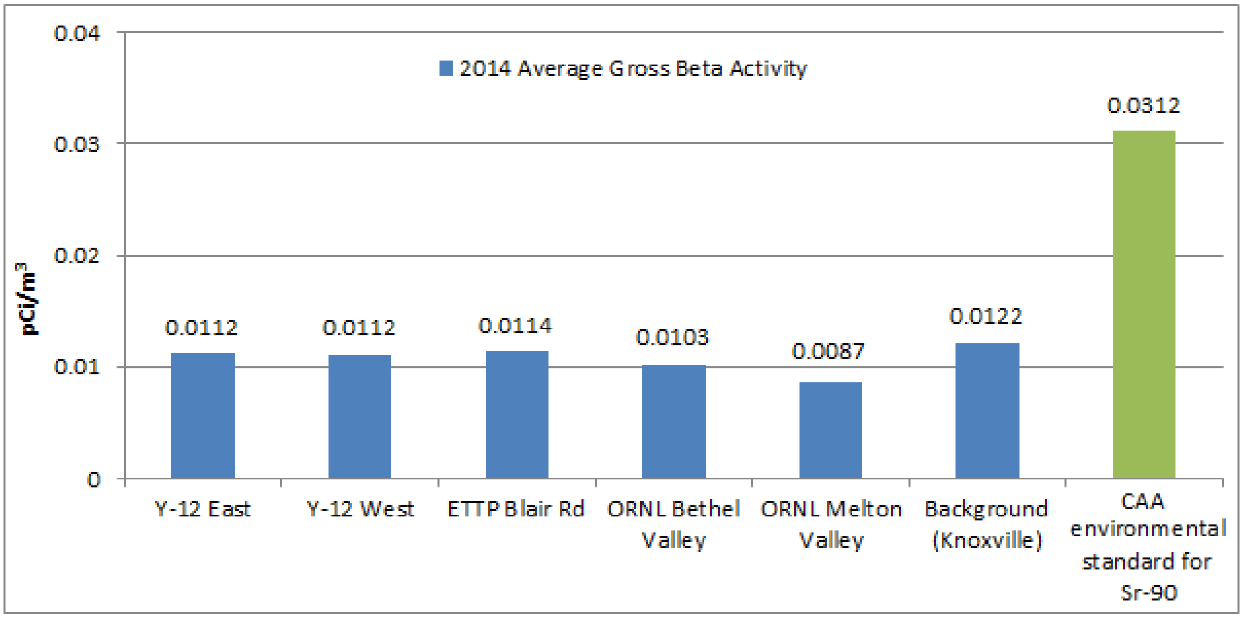

Figure 3: 2014 Average gross beta results for air samples taken on the ORR in association with EPA's RadNet air monitoring program

Note: Typical background values for gross beta range from 0.005- 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 2014 (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, staff compare the average gross beta results reported for the program to the CAA limit for strontium-90, which has one of the most stringent standards of the beta-emitting radionuclides. The standards apply to the dose above background, so the limit represented in Figure 3 has been adjusted to include the average gross beta measurement taken at the RadNet station in Knoxville, TN, 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 2014 results at all the RadNet air stations are largely comparable (results showed that all sites responded in a similar pattern during each sampling period), the average gross beta results for the RadNet program in 2014 were lower, overall, at the ORNL Melton Valley and ORNL Bethel Valley locations. The station with the highest gross beta average for 2014 on the ORR, the ETTP Blair Road location, was just slightly over that seen at the two Y-12 stations. The average results from each of the ORR RadNet monitoring stations fall well below the strontium-90 limit (Figure 3).

In 2014, none of the gross beta results reported for the program exceeded the screening level (1.0 pCi/m^3) leading to analysis by gamma spectrometry. The 2014 results for the uranium and plutonium analysis performed on annual composites of the air filters were not available at the time of this report. The 2013 results would normally be available by this time but the lab is performing method validation work on their procedures to analyze the composites and those are also not available yet. The 2012 results are repeated in Table 2, but using the RadNet station in Knoxville as the background, rather than the background from the fugitive air monitoring program.

Table 2: 2012 Composite Results for Uranium and Plutonium in RadNet Air (pCi/m^3)

	Y-12 East	Y-12 West	ETTP Blair Road	ORNL Bethel Valley	ORNL Melton Valley	Background (Knoxville RadNet)	CAA standard (amount includes background)
Pu-238	1.70E-07	4.20E-07	3.50E-07	-2.10E-07	1.50E-07	-2.90E-07	2.10E-03
Pu-239/240	0.00E+00	1.10E-07	1.30E-07	-1.60E-07	3.10E-07	1.00E-07	2.00E-03
U-234	2.55E-05	4.81E-05	2.25E-05	1.22E-05	6.80E-06	1.13E-05	7.71E-03
U-235	5.00E-07	4.30E-06	2.04E-06	-1.10E-07	6.20E-07	8.80E-07	7.10E-03
U-238	5.90E-06	9.80E-06	5.10E-06	6.80E-06	4.81E-06	8.00E-06	8.31E-03

Note: The colored bars can be used as a quick comparison of results of the same isotope (same color). Negative values are not compared for simplicity's sake.

The annual composite uranium and plutonium values for the five Oak Ridge Reservation RadNet air stations are compared to the values from the RadNet air station in Knoxville as the background location. This data was previously shown in comparison to the background location used by the previous Monitoring and Oversight's fugitive air monitoring program. The 2013 and future composite analyses will be compared to Knoxville, using it as the background location, and is hence shown this way in comparison to the available 2012 isotopic composite data. The background levels of each isotope seen at the Knoxville location were generally comparable to the composite results seen at the five stations on the Oak Ridge reservation. The Clean Air Act (CAA) standard is an amount over background. All values in Table 2 are well below the Clean Air Act standards for each isotope.

Conclusion

As in the past, the 2014 gross beta results for each of the five RadNet air monitoring stations generally exhibited similar trends and concentrations. The available RadNet data for 2014 do not indicate a significant impact on the environment or public health from ORR emissions.

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Fugitive Radiological Air Emissions Monitoring

Principal Author: Gary Riner

Abstract

As a part of its obligation under the Tennessee Oversight Agreement, the Tennessee Department of Environment and Conservation's Division of Remediation monitors fugitive emissions of radioactive contaminants on the Department of Energy's Oak Ridge Reservation (ORR). The results are compared to 1) background measurements to determine if releases have occurred and 2), to standards provided by the Clean Air Act to assess compliance with associated emission standards. In 2014, eight high-volume air samplers were deployed in the program. One of the samplers was stationed to collect background information. The remaining units were positioned to monitor remedial and waste management activities on the ORR. Monitored activities included: the decommissioning and demolition of facilities constructed during the World War II Manhattan Era which produced enriched uranium, plutonium, and other radioisotopes used in the manufacture of the first atomic weapons; remediation of associated waste disposal facilities; and disposal of radioactive waste at the Environmental Management Waste Management Facility. Findings indicate that fugitive releases occurred during 2014, but the concentrations measured were below federal standards.

Introduction

As part of the State's obligation under the Tennessee Oversight Agreement, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation performs routine monitoring of fugitive air emissions on the Department of Energy's (DOE) Oak Ridge Reservation (ORR). Monitoring in the program focuses on locations where there is a potential for airborne releases of radioactive contaminants from diffuse (non-point) sources. In 2014, monitored activities included: the decommissioning and demolition of uranium enrichment facilities at the East Tennessee Technology Park (ETTP); the Central Campus Removal Action at the Oak Ridge National Laboratory (ORNL); footprint reduction activities at the Y-12 Nation Security Complex (Y-12); and the disposal of radioactive waste at the Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley. Data from the program are used to:

- identify and characterize unplanned releases;
- evaluate DOE controls to prevent releases to the environment;
- verify data reported by DOE and its contractors; and
- assess the potential impact of DOE activities on the public health and environment.

Eight high-volume air samplers are used in the program. Seven of the units are mounted on trailers or elevated platforms positioned near activities of interest. The eighth sampler has been stationed at Fort Loudoun Dam in Loudon County to collect background information.

Methods and Materials

The eight high-volume air samplers used in the program run continuously, except during sample collection, maintenance, or power outages. Seven of the samplers are used to monitor activities on the ORR: the eighth to collect background information. Each sampler uses an 8x10 inch, glass-fiber filter to collect particulates from air as it is drawn through the unit at a rate of approximately 35 cubic feet per minute. Airflow through each sampler is calibrated quarterly and routine maintenance is performed as described in DOE Oversight Standard Operational Procedure 203, *High Volume Total Suspended Particulate System Maintenance.* Samples are collected weekly. Samples are composited every four weeks and shipped to the State of Tennessee's Environmental Laboratory in Nashville, Tennessee, for analysis.[1] Analyses are based on the radionuclides of concern for the location being monitored, and vary for different locations.

When the results are received from the laboratory, the data from the reservation samplers are compared to the background results to assess if releases have occurred and to ensure that limits provided in 40CFR61, Appendix E, Table 2 (*Concentration Levels for Environmental Compliance)* are in compliance. The locations of the 2014 monitoring stations are depicted in Figure 1. The analysis for stations ETTP K-25 K-11, ETTP Portal 4, EMWMF, Y-12 Building B9723, Y-12 Building 9212, and the background station at Ft. Loudoun Dam were isotopic uranium and technetium-99 (Tc-99). ORNL stations B4007 and Corehole 8 were analyzed for isotopic uranium.

[1] Analysis maybe performed by the state radiochemistry laboratory or a contract laboratory of their choosing.

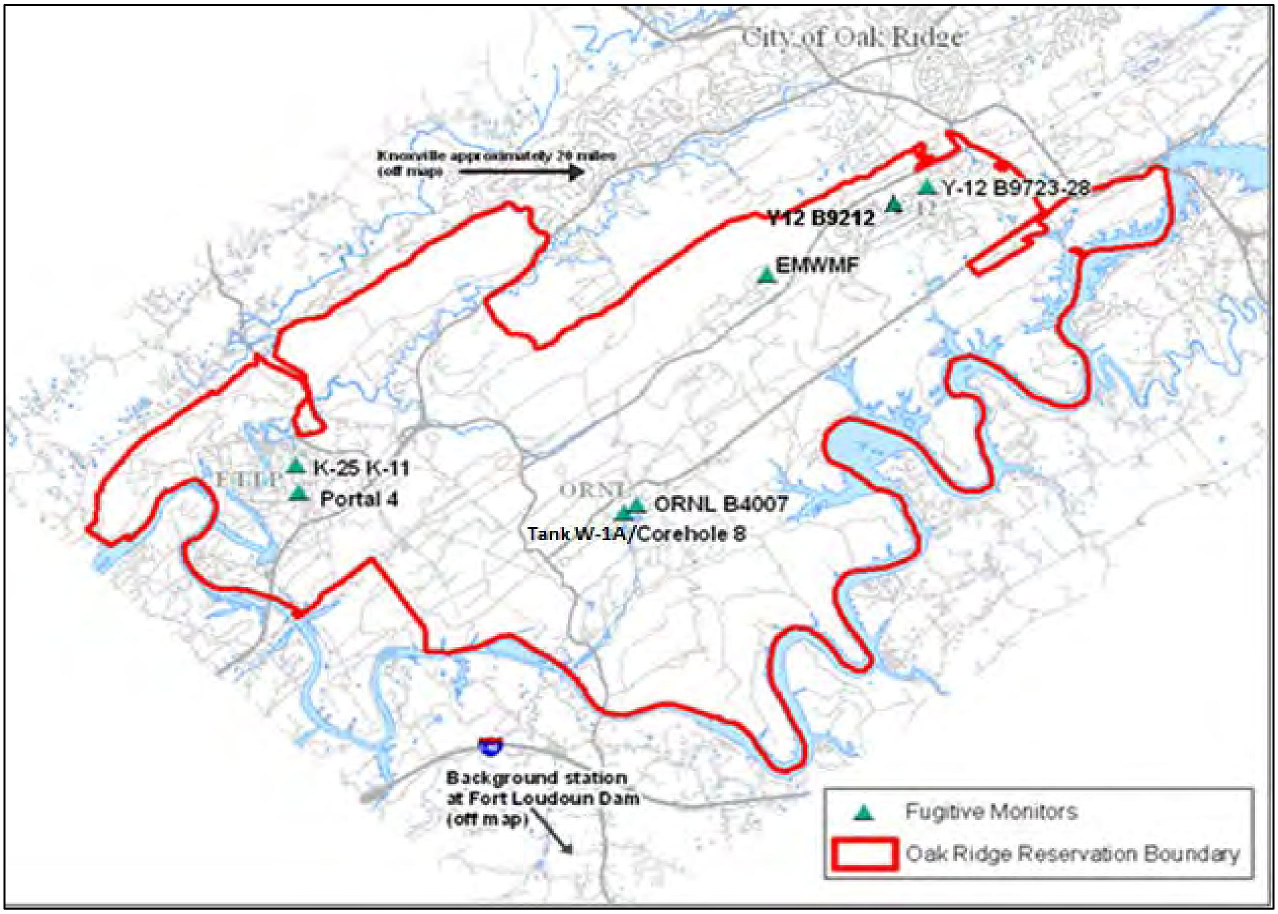

Figure 1: Approximate locations of sites monitored for fugitive air emissions in 2014

Results from the ORR samplers are compared 1) to the results from the background location in order to determine if releases have occurred and, 2) to standards provided in the Clean Air Act (CAA) to assess compliance with federal regulations. 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[2] greater than 10 millirem (mrem) in a year. Appendix E, Table 2 of the rule provides environmental concentration for individual radionuclides that would be equivalent to the 10 mrem/year dose limit, if inhaled continuously over the course of a year. To account for the synergistic effect of multiple radionuclides, the rule calls for a sum of fractions[3] to determine compliance when more than one radionuclide is present. DOE is also required to meet provisions of the law that require all radioactive emissions to be as low as reasonably achievable (ALARA).

[2] Effective dose equivalent means the sum of the products of absorbed dose and appropriate factors to account for differences in biological effectiveness due to the quality of radiation and its distribution in the body of reference, man. The unit of the effective dose equivalent is the rem. [40CFR61.91(a)]

[3] To calculate a sum of fractions, the annual average concentration for each radionuclide is divided by its limit and the results summed. If the sum of the fractions is equal to, or greater than, one, the facility would be considered out of compliance. The compliance point is the nearest off-site residence, school, business or office.

It should be noted, that the Fugitive Air Monitoring Program was designed to identify air releases from non-point sources (e.g., remedial activities) to the environment and to evaluate DOE control measures and ALARA considerations. Consequently, the monitors are located as near to the activity of interest as feasible. The actual compliance point for the 40CFR61 Subpart H standard is the nearest off-site residence, school, business, or office occupied by members of the public.

Results and Discussion

East Tennessee Technology Park (ETTP/K-25)

The K-25 Gaseous Diffusion Plant, now known as the East Tennessee Technology Park, 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 ETTP are contaminated to some degree. Uranium isotopes are the primary contaminants, but Tc-99 and other fission and activation products are also present, due to the processing of recycled uranium obtained from spent nuclear fuel that originated from reactors. Two samplers (K-25/K-11 & Portal 4) are stationed at ETTP to monitor D&D of the contaminated buildings and associated remedial activities. Samples are collected weekly from the two units and composited every four weeks for radiochemical analysis. Current analysis includes uranium (U) -234, U-235, U-238, and Tc-99. Tables 1 and 2 provide a summary of the results for K-25/K-11 and Portal 4, respectively. Samples collected for the four weeks ending 03/26/2014 had noticeably elevated Tc-99 readings. The net result was approximately twenty-three times the background rate. A contractor reported that workers were cleaning the K-25 building pad during the time period, possibly causing the elevated numbers. Tc-99 results for the year did not exceed regulatory limits.

Table 1. ETTP K-25/K11 Air Monitoring Average Result for 2014 (pCi/M3)

	U-234	U-235	U-238	Tc-99	Sum Of Fractions
12 Month Average for 2014	5.89E-05	4.31E-06	4.33E-05	1.12E-02	
Average Background (Ft Loudoun Dam)	3.95E-05	4.20E-06	3.89E-05	3.69E-03	
Net Activity (Avg. minus Background)	1.94E-05	1.12E-07	4.44E-06	7.55E-03	
40CFR Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of limit Net/ Limit	2.51E-03	1.58E-05	5.35E-04	5.39E-02	0.06

Table 2. ETTP Portal 4 Air Monitoring Average Result for 2014 (pCi/M3)

	U-234	U-235	U-238	Tc-99	Sum Of Fractions
12 Month Average for 2014	6.77E-05	5.26E-06	4.82E-05	5.39E-03	
Average Background (Ft Loudoun Dam)	3.95E-05	4.20E-06	3.89E-05	3.69E-03	
Net Activity (Avg. minus Background)	2.82E-05	1.06E-06	9.31E-06	1.70E-03	
40CFR Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of limit Net/ Limit	3.67E-03	1.49E-04	1.12E-03	1.22E-02	0.02

Y-12 National Security Complex (Y-12)

The Y-12 Plant, now known as the Y-12 National Security Complex, was also constructed during World War II to enrich uranium, 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 highly enriched uranium. The Y-12 B9723 air monitor was located centrally at Y-12, near building 9723, in July 2010 to monitor the D&D of contaminated facilities associated with the Y-12 Integrated Facilities Disposition Project. A second air monitor was stationed east of Building 9212 in September 2012 to monitor footprint reduction activities. Building 9212 was constructed in 1945 and is currently used to process highly enriched uranium. The aging facility is expected to be replaced by the proposed Uranium Processing Facility in the future. In 2014, samples were collected weekly from the two Y-12 samplers and composited every four weeks for radiochemical analysis. Current analysis includes U-234, U-235, U-238 and Tc-99. Tables 3 and 4 provide a summary of the results for Building 9212 and 9723-28 area fugitive air monitors, respectively.

Table 3. Y-12 Building 9212 Air Monitoring Average Result for 2014 (pCi/M3)

	U-234	U-235	U-238	Tc-99	Sum Of Fractions
12 Month Average for 2014	3.31E-04	2.00E-05	4.42E-05	2.05E-04	
Average Background (Ft Loudoun Dam)	3.95E-05	4.20E-06	3.89E-05	3.69E-03	
Net Activity (Avg. minus Background)	2.91E-04	1.58E-05	5.25E-06	-3.48E-03	
40CFR Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of limit Net/ Limit	3.78E-02	2.23E-03	6.33E-04	-2.49E-02	0.02

Table 4. Y12 Building 9723-28 Air Monitoring Average Result for 2014 (pCi/M3)

	U-234	U-235	U-238	Tc-99	Sum Of Fractions
12 Month Average for 2014	6.81E-05	6.23E-06	4.64E-05	1.28E-04	
Average Background (Ft Loudoun Dam)	3.95E-05	4.20E-06	3.89E-05	3.69E-03	
Net Activity (Avg. minus Background)	2.86E-05	2.03E-06	7.47E-06	-3.56E-03	
40CFR Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of limit Net/ Limit	3.71E-03	2.86E-04	9.00E-04	-2.54E-02	-0.02

Oak Ridge National Laboratory (ORNL/X-10)

Construction of the Oak Ridge National Laboratory began in 1943. While the K-25 and Y-12 Plant's initial missions were the production of enriched uranium, the ORNL site focused on reactor research, the production of plutonium, and other activation and fission products which were chemically extracted from uranium irradiated in ORNL's Graphite Reactor and, later, in 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). As a consequence, many of the facilities are contaminated with a long list of fission and activation products. Many of these facilities are considered the highest risk facilities at ORNL, due to their physical deterioration, to the presence of loose contamination, and to their proximity to privately funded facilities, active ORNL facilities, and pedestrian & vehicular traffic. Over recent years, a concerted effort has been made to D&D these facilities, and to remediate associated sites. Two of the fugitive air monitors are currently positioned to monitor the remedial efforts: one to the southwest of the W1A/Core Hole 8 removal action which was completed in 2012, and the other at Building B4007, which is northeast of the D&D of the 3026 Radioisotope Development Laboratory, and in the vicinity of other facilities undergoing, or scheduled for, remediation.

The 3026 Radioisotope Development Laboratory consisted of two facilities (3026-C & 3026-D) sharing a common wall, which were constructed in the early 1940s to house operations for the separation of barium-140 from uranium fuel slugs irradiated in the Graphite Reactor and Hanford reactors. Over the years, the facilities were modified for various uses, including the separation of radioisotopes from liquid wastes generated by processing of irradiated uranium fuel elements for plutonium. 3026-D was modified in the 1960s to support processing of fuel from the Molten Salt Reactor Experiment, and examine irradiated metallurgical reactor components. Both facilities were shut down in the late 1980s. In the interim, the wood frame structures physically deteriorated to the point of failure.

As a consequence of the hazards presented by radioactive contamination present in the 3026 C & D faculties, a time-critical removal action was initiated in 2009 to include demolition of the 3026 wooden frame structures and stabilization of the hot cells contained in each of the two 3026 facilities. The 3026 wooden superstructure was demolished in 2010 and demolition of the 3026-C hot cells was completed in 2012. Although hindered by high radiation levels, the 3026-D hot cell demolition was completed in 2013. Due to the nature of historic operations in the facilities, potential contaminants make up a long list of radionuclides including cesium-137, strontium-90, carbon-14, nickel-59 & 63, iron-55 & 59, krypton-85, promethium-147, silver-110m, tritium, Tc-99, zinc-65, americium-241, and neptunium-239, along with isotopes of europium (153, 154, & 155), plutonium (239, 240, & 241), and uranium (233, 234, 235, 236, & 238). In 2014, samples were collected weekly from the two ORNL samplers and composited every four weeks for radiochemical analysis. Current analysis includes uranium (U) -234, U-235, U-238, and gamma spectrometry. The gamma spectrometry analysis is not shown, as only naturally occurring daughter products of radon were detected. Tables 5 and 6 provide a summary of the isotopic uranium results for B4007 and Corehole 8 area fugitive air monitors, respectively.

Table 5. ORNL B4007 Air Monitoring Average Result for 2014 (pCi/M3)				
	U-234	U-235	U-238	Sum Of Fractions
12 Month Average for 2014	4.06E-05	3.66E-06	3.72E-05	
Average Background (Ft Loudoun Dam)	3.95E-05	4.20E-06	3.89E-05	
Net Activity (Avg. minus Background)	1.07E-06	-5.40E-07	-1.65E-06	
40CFR Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	
Fraction of limit Net/ Limit	1.39E-04	-7.61E-05	-1.99E-04	-0.0001

Table 6. ORNL Corehole 8 Air Monitoring Average Result for 2014 (pCi/M3)				
	U-234	U-235	U-238	Sum Of Fractions
12 Month Average for 2014	3.39E-05	2.95E-06	3.37E-05	
Average Background (Ft Loudoun Dam)	3.95E-05	4.20E-06	3.89E-05	
Net Activity (Avg. minus Background)	-5.63E-06	-1.25E-06	-5.19E-06	
40CFR Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	
Fraction of limit Net/ Limit	-7.31E-04	-1.76E-04	-6.26E-04	-0.002

The Environmental Management Waste Management Facility (EMWMF)

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. During disposal, and prior to being covered, wastes disposed in the facility are subject to dispersion by winds that tend to blow up the valley (northeast) in the daytime and down the valley (southwest) at night. To monitor the air emissions at the EMWMF, one of the fugitive air samplers was placed at the southeast corner of the facility in December 2004. Since many different radionuclides are contained in waste disposed in the EMWMF, gross alpha, gross beta, and gamma spectrometry are used to screen samples and isotopic analysis was performed as warranted. Samples were collected weekly and composited every four weeks for radiochemical analysis. Current analysis includes U-234, U-235, U-238 and Tc-99. Table 7 provides a summary of the results for the EMWMF area fugitive air monitor.

Tabke 7. EMWMF Air Monitoring Average Result for 2014 (pCi/M3)					
	U-234	U-235	U-238	Tc-99	Sum Of Fractions
12 Month Average for 2014	5.76E-05	5.12E-06	4.62E-05	1.81E-04	
Average Background (Ft Loudoun Dam)	3.95E-05	4.20E-06	3.89E-05	3.69E-03	
Net Activity (Avg. minus Background)	1.81E-05	9.17E-07	7.29E-06	-3.51E-03	
40CFR Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of limit Net/ Limit	2.35E-03	1.29E-04	8.79E-04	-2.51E-02	-0.02

Conclusion

During 2014, the sampling results were very similar to background except for the elevated February to March Tc-99 airborne concentrations observed at the K-25/K-11 sample location. All sites' yearly average concentrations were below the federal standards.

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RadNet Precipitation Monitoring on the Oak Ridge Reservation

Principal Author: Natalie Pheasant

Abstract

The RadNet Precipitation Monitoring Program on the Oak Ridge Reservation (ORR) provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations on the Department of Energy's Oak Ridge Reservation. Samples are collected by the Tennessee Department of Environment and Conservation and analysis is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory. Analysis for gamma radionuclides is performed on each composite monthly. Since there is not a regulatory limit for radioisotopes in precipitation, the results from ORR sampling locations are compared to EPA's drinking water limits and can also be compared to data from other sites nationwide. While the stations located on the Oak Ridge Reservation stations are in areas near nuclear sources, most of the other stations in the RadNet precipitation program are located near major population centers, with no major sources of radiological contaminants nearby. Regardless, the radiological results seen in the precipitation samples collected at the RadNet sites on the ORR were all well below the EPA drinking water limits. It should be noted that the EPA drinking water limits pertain to drinking water, not precipitation, and are only used here as a conservative reference value.

Introduction

In association with the Environmental Protection Agency's (EPA) RadNet Monitoring Program, staff from the DOE Oversight Office (DOE-O) of the Tennessee Department of Conservation's Division of Remediation monitor precipitation on the Department of Energy's Oak Ridge Reservation (ORR). The RadNet Precipitation Monitoring Program measures radioactive contaminants that are washed out of the atmosphere and carried to the earth's surface by precipitation. There are no standards that apply directly to contaminants in precipitation. However, the data provide an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by DOE-O's air monitors. EPA has provided three monitors to date, which have been co-located at RadNet air stations at each of the ORR sites. One is located in Melton Valley, in the vicinity of the Oak Ridge National Laboratory (ORNL). Another is located east of the East Tennessee Technological Park (ETTP), off of Blair Road. The third is co-located with the RadNet air station east of the Y-12 National Security Complex (Y-12). Figure 1 depicts the locations of the precipitation samplers.

The first precipitation monitor provided by EPA is located at an existing RadNet air station near ORNL's High Flux Isotope Reactor (HFIR) and the Solid Waste Storage Area 5 (SWSA5) Burial Grounds in Melton Valley. The station is used to monitor that area of ORNL for gamma radionuclides. The second precipitation monitor is located off of Blair Road to monitor contaminants from demolition activities at ETTP. The third station is used to monitor the Y-12 facility and is adjacent to the RadNet air monitor at the east end of Y-12. In addition to monitoring Y-12, the station could potentially provide an indication of any other gamma radioisotopes traveling towards the city of Oak Ridge from Oak Ridge National Lab. Analysis for gamma radionuclides is performed on each composite monthly sample for each of the three precipitation monitoring locations.

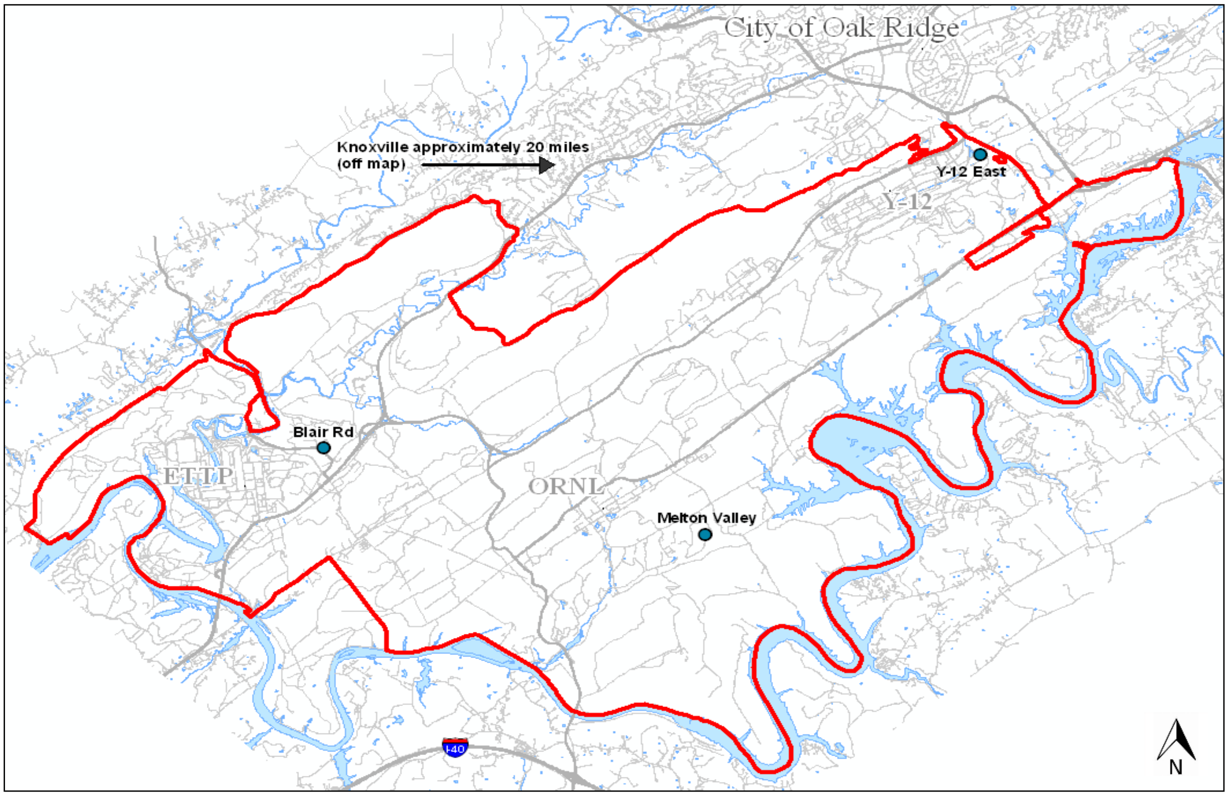

Figure 1: Locations of the RadNet Precipitation Samplers on the Oak Ridge Reservation

Since there are no regulatory limits for radiological contaminants in precipitation, the results of the gamma analyses are compared to drinking water limits used by EPA as a conservative limit. EPA's Radionuclides Rule for drinking water allows gross alpha levels of up to 15 pCi/L, while beta and photon emitters are limited to 4 mrem per year and are radionuclide specific. The monthly composite samples are now solely analyzed for gamma radionuclides, but not all isotopes have EPA drinking water limits. A large portion of the results are non-detects, with the result less than the minimum detectable concentration. Barring nuclear accidents, the results for gamma radionuclides with drinking water limits would be expected to be below these regulatory limits. Table 1 shows, for select isotopes, the maximum contaminant levels (MCLs) of beta and photon emitters that EPA uses as drinking water limits.

Table 1: EPA Drinking Water Limits for Select Isotopes (MCLs)

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

Methods and Materials

The precipitation samplers provided by EPA's RadNet program are used to collect samples for the RadNet precipitation program. Each sampler drains precipitation that falls on a 0.5 square meter fiberglass collector into a five-gallon plastic collection bucket. A sample is collected from the bucket (in a four-liter Cubitainer®) and sent in to EPA when a minimum of two liters of precipitation has accumulated in the Cubitainer®, or potentially less than that if it is the final sample of the month. The sample is processed as specified by EPA (U.S. EPA, 1988) and is shipped to EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama, for analysis. NAREL composites samples collected during the month for each station and analyzes each composite by gamma spectrometry.

The results of NAREL's analyses are available at NAREL's website in the Envirofacts RadNet Searchable Database, via either a simple or customized search (websites listed in references). The data is used to identify anomalies in radiological contaminant levels, to assess the significance of precipitation in contaminant pathways, to evaluate associated control measures, to appraise conditions on the Oak Ridge Reservation compared to other locations in the RadNet program, and to determine levels of local contamination in the case of a nuclear disaster anywhere in the world.

Results and Discussion

For 2014, gamma spectrometry analysis was available through December. The gamma isotopes for which there were data for 2014 were beryllium-7, cobalt-60, cesium-137, potassium-40, and radium-228. For all isotopes except beryllium-7, the reported results were less than the minimum detectable concentration (MDC) and are considered non-detects. The average result for beryllium-7 for the three ORR samplers in 2014 was 50.2 pCi/L, compared to an average minimum detectable concentration of 24.7 pCi/L. The national average for the same time period was 41.9 pCi/L. The highest beryllium-7 result for the ORR stations in 2014, was 85 pCi/L. Beryllium-7, however, is a cosmogenic isotope, formed by the action of cosmic rays on the atmosphere. Also, 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 quite small.

Overall, the highest values seen for 2014 in the composited monthly precipitation samples for each of the three ORR stations, were all well below the MCLs set by the EPA for drinking water. In fact, all the results for barium-140, cobalt-60, cesium-137, potassium-40, and radium-228 for this time period were non-detects, with the results less than the minimum detectable concentrations (MDCs). While there are not regulatory limits for radionuclides in precipitation, the comparison to EPA's drinking water limits can be used as a conservative reference value.

Conclusion

The 2014 gamma data also show results well below EPA drinking water limits and often below detection limits. These data indicate that levels of gamma radiation in precipitation at the three monitored locations are much lower than EPA drinking water limits and thus can be considered protective of human health and the environment.

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BIOLOGICAL MONITORING

Benthic Macroinvertebrate Monitoring

Principal Authors: John Wojtowicz and Gerry Middleton

Abstract

The biotic integrity of streams originating on the Oak Ridge Reservation (ORR) was determined during 2014 by collecting semi-quantitative benthic macroinvertebrate kick samples (i.e., "SQKICK") from thirteen stream stations in four watersheds impacted by Department of Energy (DOE) operations. In addition, six reference stream stations were sampled. Benthic samples were collected and processed following the State of Tennessee standard operating procedures for macroinvertebrate surveys (with some modification). Generated data was analyzed using applicable metrics. An assessment score was calculated from the metrics and a site rating was assigned for all stream stations. Results indicate the biotic integrity at a number of the impacted sites in all four stream systems is less than optimal compared to reference conditions. Continued benthic macroinvertebrate monitoring is necessary to provide a more thorough and accurate assessment of stream conditions. The effectiveness of DOE remedial activities can be assessed with long term monitoring efforts.

Introduction

Benthic macroinvertebrates include insects, crustaceans, annelids, mollusks, and other organisms with long aquatic life cycles (i.e., multiple stages of larval instars) that inhabit the bottom substrates of aquatic systems, and can be easily collected using aquatic sampling nets of ≤500 µm (Hauer and Resh 1996). Occupying the primary consumer trophic level in aquatic ecosystems, macroinvertebrates serve as a link between producers (e.g. algae) and decomposers (e.g. microorganisms) in a food chain, provide a major food source for fisheries, and maintain a diverse spectrum in species composition (Song 2007). Because they are ubiquitous, sedentary, and sensitive, in varying degrees, to anthropogenic pollutants and other stressors, macroinvertebrate communities can provide considerable information regarding the biological condition of water bodies (Davis and Simons 1995, Karr and Chu 1998). Further, aquatic macroinvertebrate assemblages provide a surrogate measure of water chemistry and physical stream conditions (Cummins 1974, Vannote et al. 1980, Rosenberg and Resh 1993, Weigel et al. 2002) to indicate the overall health of the aquatic system (Meyer 1997, Karr 1999).

Introduction of nutrients (organic pollution) and heavy metals into a stream, dilution by tributaries, uptake of contaminants by aquatic organisms, and changes in stream structure/function create a pollution gradient from upstream to downstream, which is superimposed on the natural longitudinal gradient of the stream (Vannote et al. 1980, Clements 1994, Clements and Kiffney 1995, Medley and Clements 1998). Anthropogenic impacts inducing eutrophication (i.e., organic pollution) in aquatic systems are known to have dramatic effects on stream invertebrates (Hynes 1978, Wiederholm 1984, Rosenberg and Resh 1993, Suren 2000). Thus, nutrient enrichment can decrease species richness (Paul and Meyer 2001) by elimination of sensitive taxa, most often represented by the insect orders *Ephemeroptera, Plecoptera* and *Trichoptera* (EPT; mayflies, stoneflies, caddisflies, Lenat 1983). Simultaneously, taxa considered resistant to pollution and adapted to unstable habitats, such as midges (chironomids) and worms (oligochaetes), are enhanced (Hynes 1978).

In streams where metals concentrations are sufficiently high, benthic macroinvertebrates may be entirely absent or their abundance greatly reduced (Clements 1991). Where metals and organic pollutants do not entirely eliminate the community, however, measures of taxa richness (e.g., total number of species present) or abundance of metals-sensitive taxa provide the most sensitive and reliable measure of community level effects (Barbour et al. 1992, Clements and Kiffney 1995, Kiffney 1996, Carlisle and Clements 1999). Many mayfly species are sensitive to metals contamination (Warnick and Bell 1969), and a reduction in the number of mayfly species present is an effective and reliable measure of metals impacts on benthic macroinvertebrate communities (Ramusino et al. 1981, Specht et al. 1984, Van Hassel and Gaulke 1986, Clements 1991, Clements et al. 1992, Kiffney and Clements 1994). For example, heptageniids (i.e., mayflies) are highly sensitive to heavy metals and are usually absent in metal-polluted streams (Clements 1994, Clements and Kiffney 1995). Hence, macroinvertebrate biomonitoring is a proven method of assessing and documenting stressors and any community and population changes that may occur within the impacted ecosystem.

Semi-quantitative kick net samples (i.e., SQKICK) provide a snapshot of the benthic community population at a particular stream location and the respective taxonomic identifications and taxa counts present at this site are used to calculate the Tennessee Macroinvertebrate Index (TMI, TDEC 2011). Several quantifiable attributes of the biotic assemblage (i.e., "metrics") that assess macroinvertebrate assemblage structure, composition, and function comprise these indices (Hilsenhoff 1982, 1987, 1988, Fore et al. 1996, Karr and Chu 1998), and metrics are used to measure and calculate an overall score to represent the ecological condition and integrity of stream health. This multimetric index approach is effective for evaluating anthropogenic disturbance and pollution, for standardizing assessment and for communicating the biotic condition of streams (Barbour et al. 1999), because susceptibility to toxic agents varies with the response of individual genera and species (Resh et al. 1988, 1996).

Historically, four aquatic systems originating on the Oak Ridge Reservation (East Fork Poplar Creek, Bear Creek, Mitchell Branch, and the White Oak Creek/Melton Branch watershed) have been impacted by DOE-related activities. East Fork Poplar Creek and Bear Creek have received inputs from the Y-12 Plant, Mitchell Branch from the East Tennessee Technology Park (ETTP), and the White Oak Creek/Melton Branch watershed from the Oak Ridge National Laboratory (ORNL). Contaminant releases to surface water and groundwater vary among these industrial sites, but generally include organic pollutants, heavy metals and radionuclides. Benthic macroinvertebrate samples were collected from various locations on these streams for semi-quantitative analysis. Surface water samples were collected at the sites and analyzed for various constituents in support of the biomonitoring. Parameters analyzed included nutrients, mercury, metals, hardness, residue, and radiological constituents. The objectives of this study were to quantify benthic macroinvertebrate communities and to assess the degree of impact compared to reference conditions.

Methods and Materials

Site Description

The Oak Ridge Reservation (ORR) is a 33,515-acre site owned and operated by the US Department of Energy (DOE) and is nestled in the ridge and valley physiographic province of east Tennessee (Anderson and Roane counties). Geologically, the ORR bedrock consists of thrust faulted and folded lithostratigraphic units of limestone, siliceous dolomite, siltstone, shale, and sandy shale. The ORR contains three major facilities: the Oak Ridge National Laboratory (ORNL) for energy research and development; the Oak Ridge Y-12 Plant (Y-12) for weapons production; and the East Tennessee Technology Park (formerly the Oak Ridge Gaseous Diffusion Plant), which was utilized for enriching uranium. Major streams impacted by DOE industrial activities include East Fork Poplar Creek (EFK), Bear Creek (BCK), Mitchell Branch (MIK), and White Oak Creek (WOC).

Field Sampling

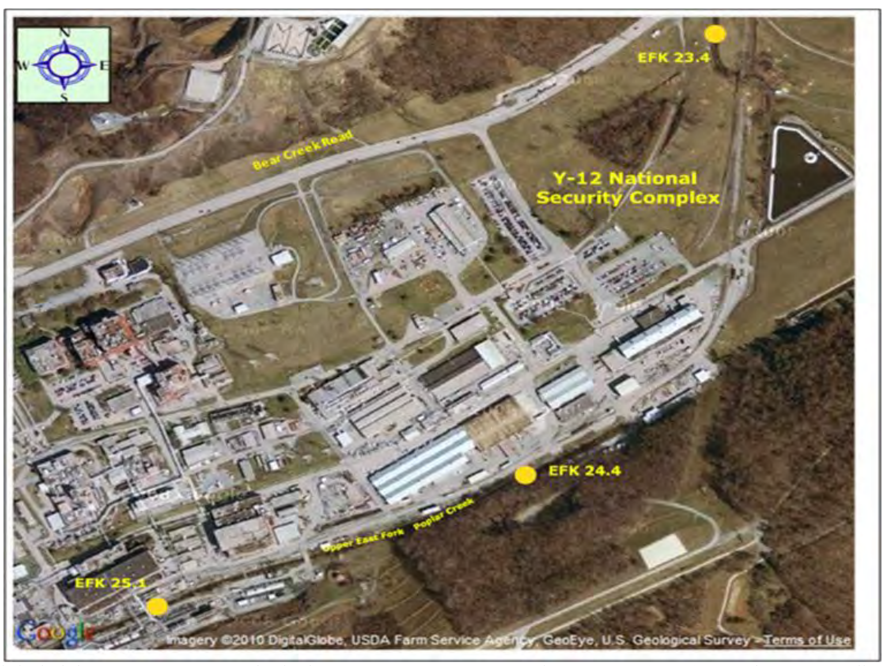
Benthic macroinvertebrate communities were semi-quantitatively sampled (i.e., kick sampling, "SQKICK") between May 6, 2014 and May 22, 2014, using the current US Environmental Protection Agency, US Geological Survey, and Tennessee Department of Environment and Conservation, Division of Water Pollution Control, now Division of Water Resources (DWR), standard operating procedures for macroinvertebrates (Barbour et al. 1999, Moulton et al. 2000, TDEC 2006: revision 4, 2011: revision 5). Thirteen stream stations were sampled during 2014 on the ORR from the four main watersheds (i.e., EFK, BCK, MIK, & WOC). Melton Branch (MEK) is a tributary to WOC. Six other reference streams were also sampled (Table 1, Figures 1-5).

Table 1: Oak Ridge Reservation Benthic Monitoring Sites

Station	Description	Cover	TDEC DWR Designation
EFK 25.1	East Fork Poplar Creek km 25.1	thin canopy	EFPOP015.6AN
EFK 24.4	East Fork Poplar Creek km 24.4	canopy	EFPOP015.2AN
EFK 23.4	East Fork Poplar Creek km 23.4	open	EFPOP014.5AN
EFK 13.8	East Fork Poplar Creek km 13.8	open	EFPOP008.6AN
EFK 6.3	East Fork Poplar Creek km 6.3	canopy	EFPOP003.9RO
HCK 20.6	Hinds Creek km 20.6 Reference	canopy	HINDS012.8AN
CCK 1.45	Clear Creek km 1.45 Reference	thin canopy	ECO67F06
GHK 2.9	Gum Hollow Branch km 2.9 Reference	canopy	GHOLL001.8RO
MIK 1.43	Mitchell Branch km 1.43 Reference	canopy	MITCH000.9RO
MIK 0.71	Mitchell Branch km 0.71	open	MITCH000.4RO
MIK 0.45	Mitchell Branch km 0.45	thin canopy	MITCH000.3RO
BCK 12.3	Bear Creek km 12.3	canopy	BEAR007.6AN
BCK 9.6	Bear Creek km 9.6	canopy	BEAR006.0AN
MBK 1.6	Mill Branch km 1.6 Reference	canopy	FECO67I12
WCK 6.8	White Oak Creek km 6.8 Reference	thin canopy	WHITE004.2RO
WCK 3.9	White Oak Creek km 3.9	thin canopy	WHITE002.4RO
WCK 3.4	White Oak Creek km 3.4	canopy	WHITE002.1RO
WCK 2.3	White Oak Creek km 2.3	canopy	WHITE001.4RO
MEK 0.3	Melton Branch km 0.3	thin canopy	MELTO000.2RO

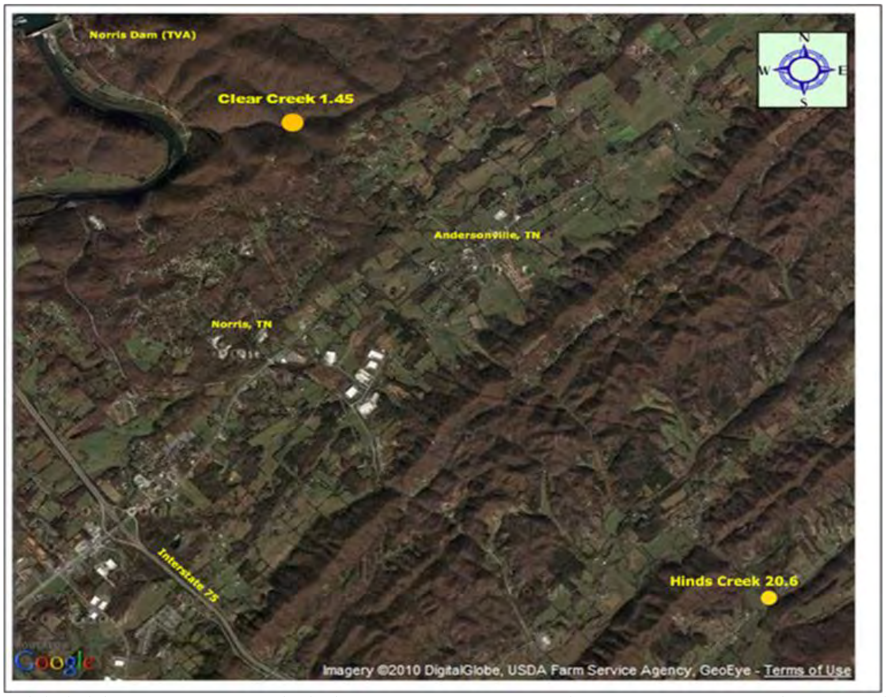
DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 1: 2014 Benthic Sites at ORNL (White Oak Creek / Melton Branch)



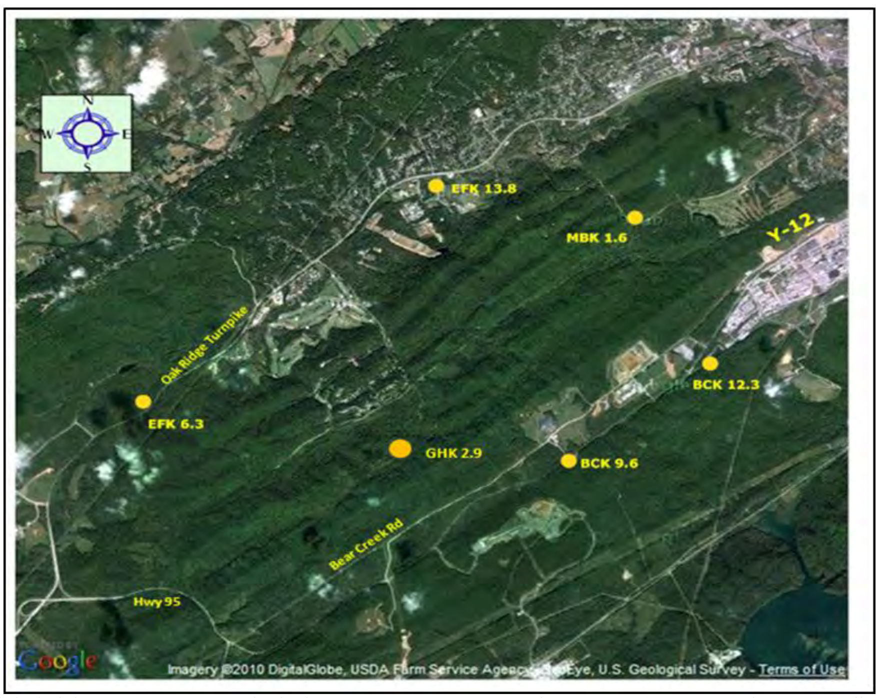
DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 2: 2014 Benthic Sites at Upper East Fork Poplar Creek



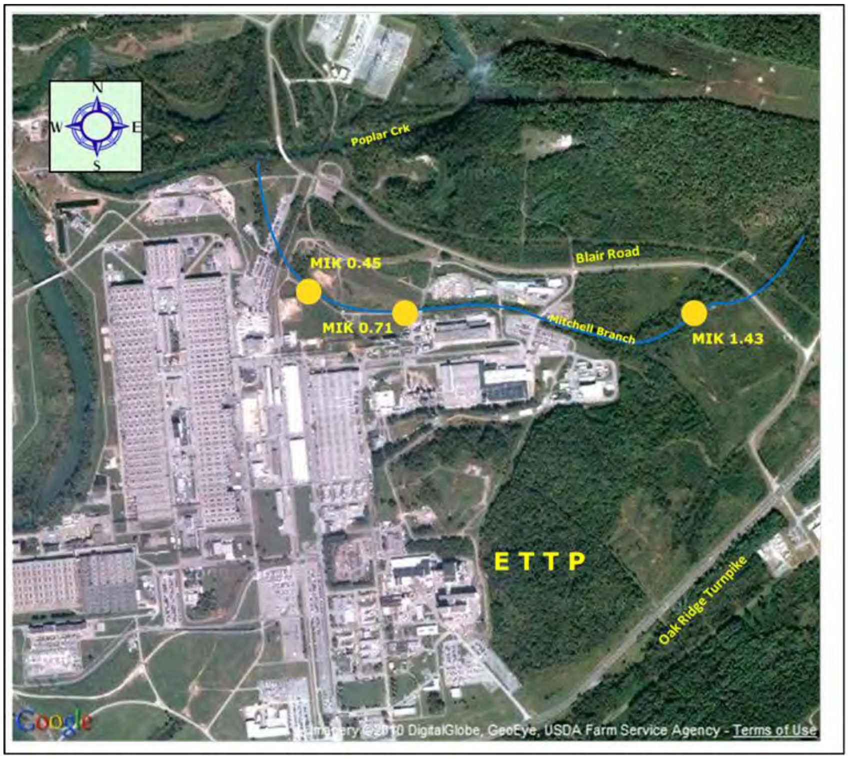
DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 3: 2014 Benthic Sites at the Hinds Creek & Clear Creek Reference Streams



DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 4: 2014 Benthic Sites at Bear Creek, Mill Branch, Gum Hollow Branch, and Lower East Fork Poplar Creek



DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 5: 2014 Benthic Sampling Sites at Mitchell Branch

Benthic organisms (typically larvae) were collected at each site by combining samples from two similar riffles using a one-square meter kick net (Figures 6-8). Typically the sampling crew consisted of 2-3 staff. One individual held the double-handle kick net perpendicular to the current with the net's weighted bottom resting firmly on the streambed. Another person disrupted the substrate with heavy duty garden rake in a one-square-meter stretch just upstream of the net. The third person recorded field data and provided additional field support. Benthic organisms were dislodged and drifted into the waiting net. After allowing suitable time for all the debris to flow into the net, the person performing the kick lifted the bottom of the net in a smooth, continuous motion while the person holding the net at the top was careful not to let the top edge dip below the water's surface (to prevent losing sample). One end of the kick net was then carefully placed into a 3-gallon sieve bucket (541 µm mesh) and macroinvertebrates and detritus were rinsed from the net and retained in the bucket. After a second riffle kick was completed, organisms and associated detritus were collected in the sieve bucket, picked from the net and transferred into labeled sample jars as a composite sample. Benthic macroinvertebrate samples were preserved in 95% ethanol with internal and external site-specific labels. Labeling information included site name, sampling date, and samplers' initials. If more than one sample container was needed at a site, the debris was split evenly with internal and external labels completed for each container (modified from TDEC 2011).

Lastly, surface water samples were collected from each 2014 benthic sampling location. The laboratory results are presented in the Benthic Macroinvertebrate Surface Water Monitoring Program section of this report. Personnel safety while conducting field and laboratory work followed the guidelines of the TDEC DOE-Oversight Office Health and Safety Plan (Yard 2013).


Figure 6: Kick sampling


Figure 7: Rinsing organisms


Figure 8: Picking organisms

Laboratory Processing

Due to the potential for radioactive contamination associated with the lower White Oak Creek / Melton Branch sediments (WCK 3.9, WCK 3.4, WCK 2.3, MEK 0.6), those benthic samples were picked and sorted at the Environmental Protection and Waste Services' laboratory facility, Building 4500S, Oak Ridge National Laboratory. Benthic material was separated from the detritus of each sample until at least 200 organisms had been counted. The picked organisms were then transferred to sealable plastic vials, labeled and preserved in 85% ethanol**.** The remaining benthic samples (i.e., BCK, EFK, MIK, and reference stations) were stored and later processed following sub-sampling procedures (i.e., picking and sorting; TDEC 2011) at the TDEC DOE Oversight laboratory.

In the laboratory, samples were picked and benthic macroinvertebrates were enumerated and microscopically identified (by in-house staff) to the genus and species (where possible) level, thus producing raw taxonomic data for each stream station. TDEC Division of Water Pollution Control revision 5 of the macroinvertebrate SOP (TDEC 2011) was used to calculate the metrics and revision 4 (TDEC 2006) was used to aid in interpretation of results. Macroinvertebrate larvae were identified using various taxonomic keys (Edmunds et al. 1976, Simpson and Bode 1980, Brigham et al. 1982, Oliver and Roussel 1983, Stewart and Stark 1988, McAlpine et al. 1981, 1987, Pennak 1989, Wiggins 1996, Needham et al. 2000, Epler 2001, 2006, 2010, Gelhaus 2002, Westfall and May 2006, Merritt et al. 2008, Pfeiffer et al. 2008).

Biological Metrics

Metrics were calculated from the raw data in order to develop an overall site assessment rating. Eight calculated metrics included Taxa Richness, EPT Richness [*Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), *Trichoptera* (caddisflies)], % EPT-*Cheumatopsyche* (% EPT-*Cheum*), % OC (oligochaetes and chironomids), NCBI (North Carolina Biotic Index), % Clingers, % Nutrient Tolerant organisms and Intolerant Taxa (, Hilsenhoff 1982, 1987, 1988, KDOW 2009, TDEC 2006, 2011). The EPTs are pollution-sensitive to environmental contamination and the OCs are pollution-tolerant. The biometrics used to generate stream ratings and the expected response of each metric to stress introduced to the system are presented in Table 2.

Table 2: Description of Metrics and Expected Responses to Stressors.

Category	Metric	Description	Response to Stress
Richness Metrics	Taxa Richness	Measures the overall variety of the macroinvertebrate assemblage	Number decreases
	EPT Richness	Number of taxa in the orders *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies)	Number decreases
	Intolerant Taxa	Number of taxa in sample that display a tolerance rating of <3.0	Number decreases
Composition Metrics	% EPT-*Cheum*	% of EPT abundance excluding *Cheumatopsyche* taxa	% decreases
	% OC	% of oligochaetes (worms) and chironomids (midges) present in sample	% increases
Tolerance Metrics	NCBI	North Carolina Biotic Index which incorporates richness and abundance with a numerical rating of tolerance	Number increases
	% Nutrient Tolerant (%TNUTOL)	% of organisms present in sample that are considered tolerant of nutrients	% increases
Habit Metric	% Clingers	% of macroinvertebrates present in sample w/ fixed retreats or attach themselves to substrates	% decreases

Because some of the streams being monitored on the Oak Ridge Reservation do 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 SOP for macroinvertebrates, TDEC 2011) (with some modifications) was used to evaluate the study's results. The primary condition not met is that certain of the streams in the study were headwater streams (i.e., < 2 sq. mi. of drainage area). The description of the Alternative Reference Stream Method is provided in Section 1.I, Protocol K: Pages 3 & 4 of the TDEC SOP for macroinvertebrates (TDEC 2011).

In order to generate a table of values for use of comparison of Reference Stations to potentially impacted stream stations, the 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 these average values and using the calculations provided in Section 1.I, Protocol K: Pages 3 & 4 of the TDEC SOP for macroinvertebrates (TDEC 2011), ranges of values for ratings of 6, 4, 2, and 0 for each metric were further determined. The results of these calculations may be found in Table 3.

Table 3: Alternative Reference Stream Metrics.

Alternative Reference Steam Metrics				
Metric	**6**	**4**	**2**	**0**
Taxa Richness	> 37	24-36	11-23	< 11
EPT Richness	>14	9-13	4-8	<4
% EPT- Cheum	>39.81	25.54-39.80	12.27-25.53	<12.27
% OC	<36.22	36.21-57.48	57.47-78.74	>78.74
NCBI	<4.76	4.75-6.51	6.50-8.26	>8.26
% Clingers	>28.71	19.14-28.70	9.57-19.13	<9.57
% TNUTOL	<37.14	37.13-58.09	58.08-79.04	>79.04

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 more clearly differentiate among the benthic communities in the streams. The TDEC SOP for macroinvertebrates (TDEC 2011) requires identification of taxa to only the genus level. Taking certain of the 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*) may have more than one species occurring at a sample site. This is particularly true of the genera *Baetis* and *Maccaffertium*. Reference sites may contain as many as five species in these combined genera, whereas impacted sites 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 (i.e., 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 done using the species-level identifications.

Results and Discussion

Semi-quantitative Assessments (SQKICK Sample Results)

Table 4: Metric Values, Scores and Biological Condition Ratings for Reference Stations

2014 RESULTS	Benthic Macroinvertebrate Reference Stations															
Stream station	CCK 1.45		CCK 1.45 DUP		HCK 20.6		MIK 1.43		GHK 2.9		MBK 1.6		WCK6.8		WCK6.8 DUP	
METRIC	VAL	SCR	VAL	SCR	VAL	SCR	VAL	SCR	VAL	SCR	VAL	SCR	VAL	SCR	VAL	SCR
Taxa Richness	52	6	56	6	45	6	42	6	45	6	56	6	50	6	58	6
EPT Richness	19	6	24	6	21	6	14	4	18	6	21	6	18	6	21	6
% EPT-Cheum	57.14	6	42.12	6	28.9	6	45.81	6	58.85	6	51.05	6	69.7	6	71.05	6
% OC	14.02	6	7.18	6	12.72	6	29.61	6	22.86	6	12.59	6	7.06	6	13.66	6
NCBI	2.15	6	2.64	6	4.83	6	3.6	6	2.49	6	3.24	6	2.52	6	2.64	6
% Clingers	33.69	6	43.07	6	75.34	4	26.82	4	18.88	2	45.31	6	34.92	6	28.24	4
%TNUTOL	4.22	6	11.67	6	44.7	6	25.7	6	7.52	6	25.31	6	4.24	6	6.12	6
Intolerant Taxa	16	0	22	0	16	0	12	0	19	0	16	0	10	0	13	0
INDEX SCORE (Tenn. Macro. Index)		42		42		40		38		38		42		42		40
RATING		A		A		A		A		A		A		A		A

East Fork Poplar Creek

Benthic laboratory results [i.e., metric values, metric scores, overall TMI scores (Alternative Reference Stream Method)] and biological condition ratings) are presented in Table 5 for the EFK watershed. For monitoring purposes, the watershed is herein considered as the upper EFK (UEFK) with three sampling stations (i.e., within Y-12 Plant, EFK 25.1, EFK 24.4, EFK 23.4) and lower EFK (LEFK) with two sampling stations (EFK 13.8, EFK 6.3). The stream numbers represent distances in kilometers that decrease from headwaters (EFK 25.1) towards the mouth downstream (EFK 0.0). The reference streams 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.

The East Fork Poplar Creek is one of the streams on the Oak Ridge Reservation 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 the Y-12 Plant. 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 (VOAs) 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 sewage treatment plant discharge. Only near its mouth does East Fork flow through relatively undisturbed terrain. A couple of weeks prior to the 2014 benthic sampling on East Fork Poplar Creek, flow augmentation of approximately 4.5 million gallons per day from the Clinch River (DOE 2013) was halted due to a request from TDEC in Nashville. This flow augmentation which began in 1996 (DOE 2013) has helped improve the biological condition of particularly the Upper East Fork Poplar Creek sample sites. It is expected that the reduced flows, particularly in the upper section of East Fork Poplar Creek will have a negative impact on aquatic communities. It will be interesting to compare this year's results with those of 2015, after a year of reduced flows.

Table 5: Metric Values, Scores and Biological Condition Ratings for East Fork Poplar Creek

2014 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	27	4	38	6	43	6	41	6	39	6
EPT Richness	4	2	5	2	6	2	11	4	7	2
% EPT-Cheum	8.76	0	29.85	4	17.55	2	33.4	4	7.64	0
% OC	76.89	2	45.15	4	76.89	2	28.76	6	45.78	4
NCBI	5.17	4	4.67	6	5.05	4	5.02	4	5.24	4
% Clingers	67.86	6	48.73	6	35.94	6	57.94	6	67.31	6
%TNUTOL	54.98	4	23.84	6	40.02	4	36.7	6	55.01	4
INDEX SCORE (Tenn. Macro. Index)		22		34		26		36		26
RATING		C		C		C		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)

To gain a clearer understanding of 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 have been provided (Figures 9-17). Values for the impacted stations in East Fork are given in Table 5; values for reference stations are provided in Table 4. Their discussion follows the figures below.

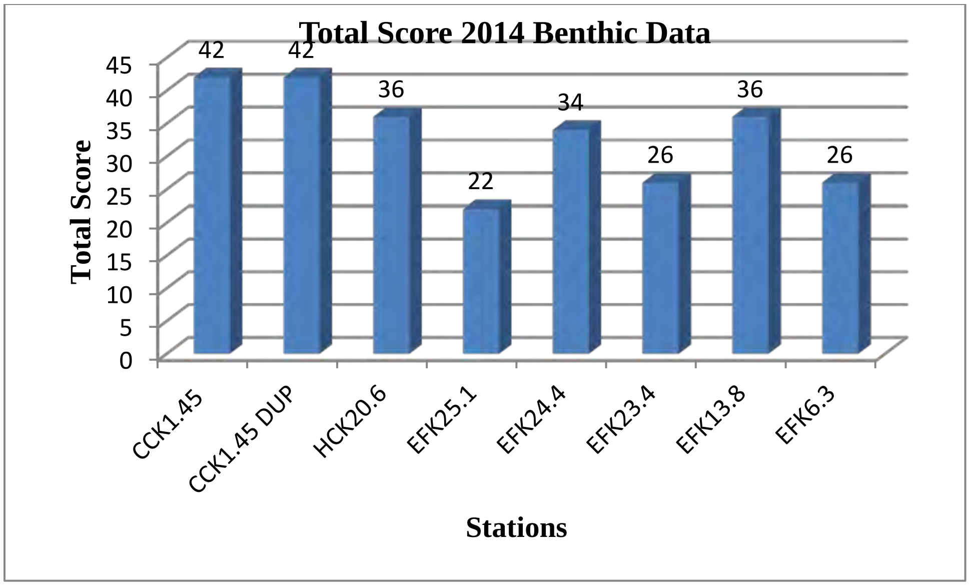


Figure 9: Total Score East Fork.

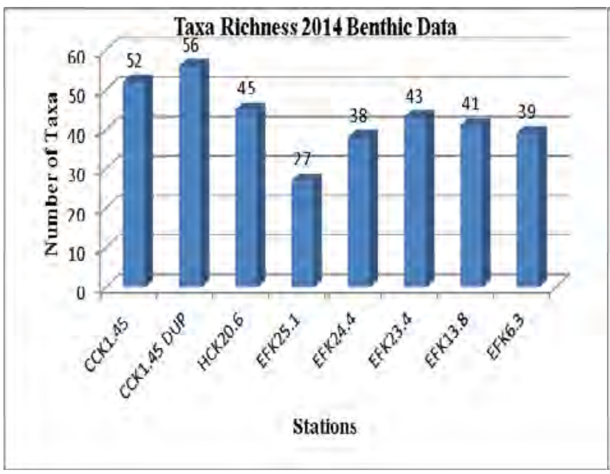


Figure 10: Taxa Richness East Fork.

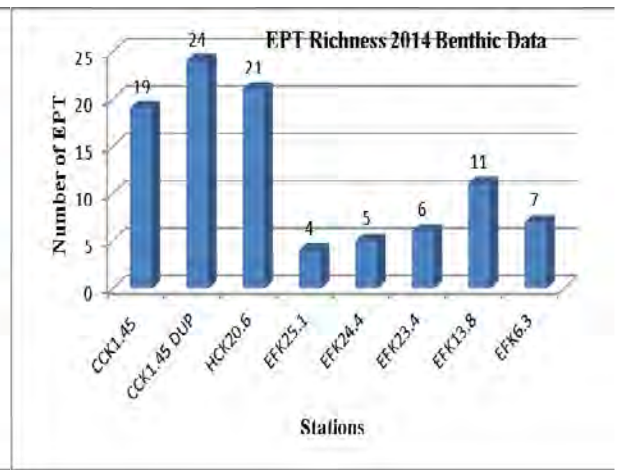


Figure 11: EPT Richness East Fork.

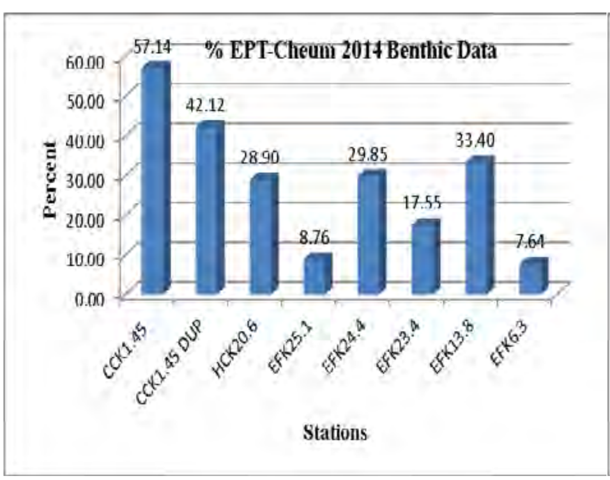


Figure 12: % EPT-Cheum East Fork.

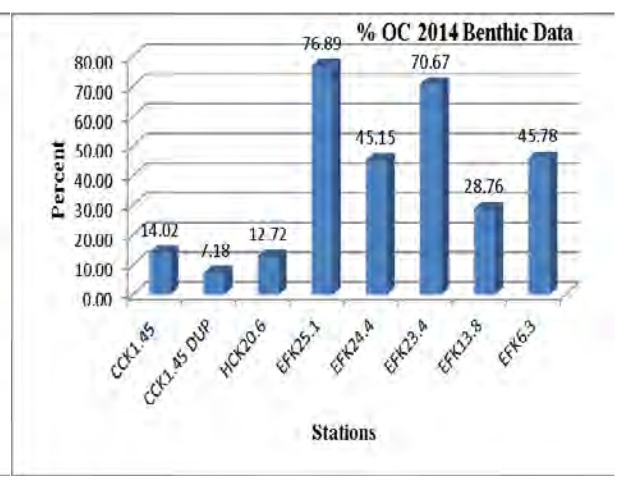


Figure 13: % OC East Fork.

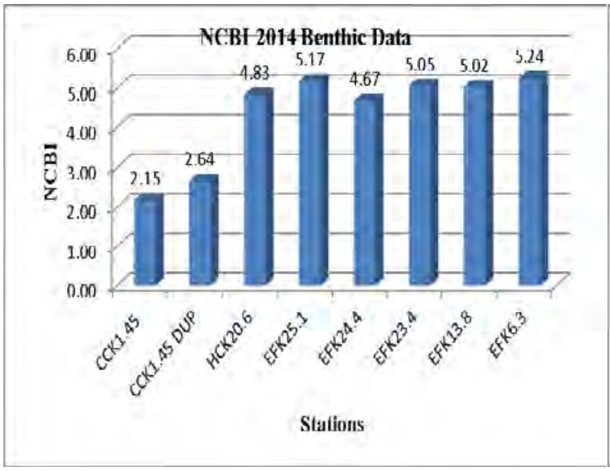


Figure 14: NCBI East Fork.

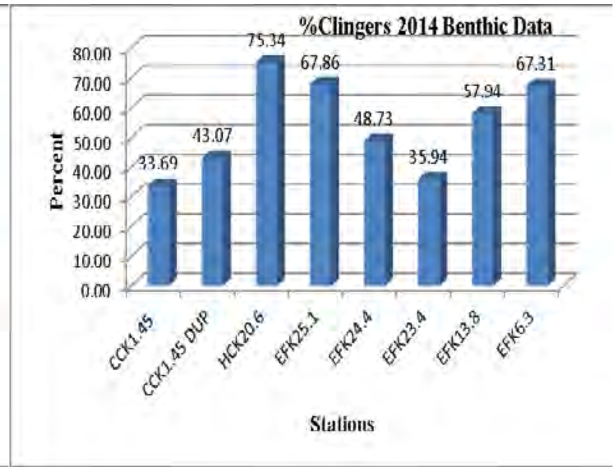


Figure 15: % Clingers East Fork.

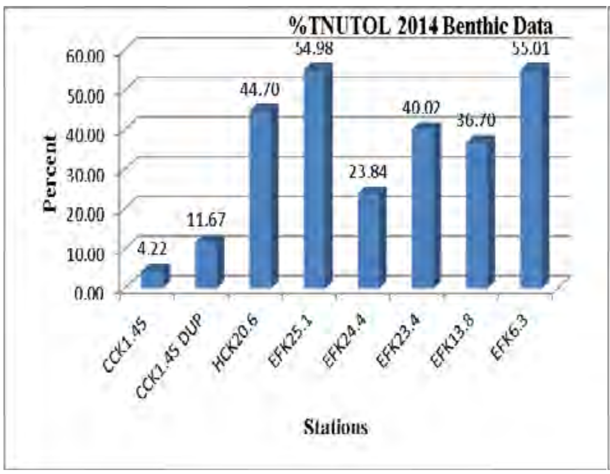


Figure 16: %TNUTOL East Fork.

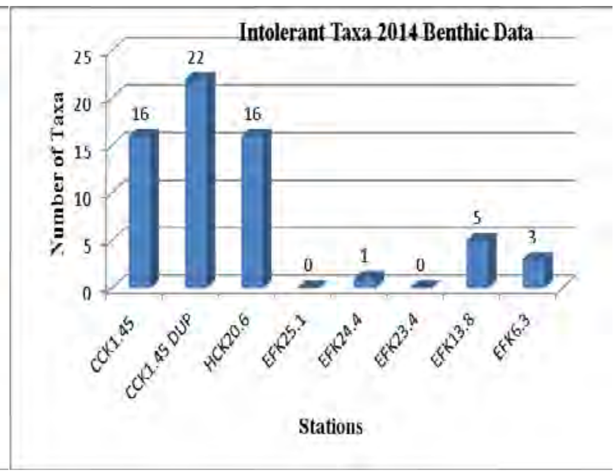


Figure 17: Intolerant Taxa East Fork.

Figure 9 compares the Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Score results for the two reference sites (CCK 1.45 & HCK 20.6) with the five sampling stations in East Fork Poplar Creek. The scores for the two reference stations (including a duplicate sample taken on Clear Creek) clearly exceed those for all stations of East Fork with the exception of EFK 13.8 and EFK 24.4. The metric Taxa Richness (Figure 10) shows that the reference stations (CCK & HCK) displayed a higher number of Total Taxa than any of the East Fork stations, although four of the five East Fork stations were not far behind the reference stations in numbers of taxa. EPT Richness (Figure 11) shows a distinct difference between the reference stations and the East Fork stations with the best East Fork station (EFK 13.8) possessing roughly one-half as many EPT taxa as the lowest number for the reference stations (CCK). The % OC (Percent Oligochaeta and Chironomidae) metric shows a clear distinction between the reference stations and all stations in East Fork. All East Fork sites display a much higher proportion of oligochaetes and midges, often a sign of degraded conditions. The metrics for NCBI (Figure 14), % Clingers (Figure 15) and % TNUTOL (Figure 16) also fail to clearly distinguish between the reference streams and impacted sites. The reference station HCK 20.6

displays NCBI (Figure 14) value that is virtually indistinguishable from those of the East Fork stations. The rankings of both reference stations and East Fork stations for % Clingers (Figure 15) are all the maximum of 6 (Table 4, Table 5). The metric % TNUTOL (Figure 16) also fails to distinguish clearly between reference and impacted stations with the values for the majority of the East Fork stations aligning more closely with HCK 20.6 than with CCK 1.45. This discrepancy is likely due to HCK 20.6 being a "cow creek" (i.e., coursing primarily through agricultural land), while Clear Creek is a more pristine, protected watershed serving as the drinking water source for the city of Norris. The comparison of the number of Intolerant Taxa between reference and impacted streams (Figure 17) shows a dramatic difference between reference and impacted stations with impacted stations displaying very few sensitive taxa.

More is needed than use of the Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Score in interpreting and understanding the condition of the various impacted stream stations in East Fork Poplar Creek. Based on only that metric, stations EFK 13.8 and EFK 24.4 would appear to be approaching the condition of the reference streams. Other metrics, particularly EPT Richness (Figure 11) and Intolerant Taxa (Figure 17), show this to clearly not be the case. Differences are especially dramatic in terms of the number of Intolerant Taxa present (Figure 17). The lack of or low numbers of Intolerant Taxa in the impacted stations of East Fork are indicative of a stressed environment.

The results of the 2014 sampling of CCK 1.45 showed that the low number of Total Taxa (27 taxa) in the 2013 sampling was an anomaly. In 2014, results for a sample and a duplicate sample from Clear Creek far exceeded the 2013 result with CCK 1.45 yielding 52 taxa and CCK 1.45 DUP yielding 56 taxa. It appears that there may have been inadequacies with the 2013 sampling. As indicated in last year's report, this may have in some part been due to weather conditions immediately prior to the date of sampling. If water levels had been high enough to scour the stream bed it would have taken some time for full population recovery to have occurred. Sampling may have occurred prior to recovery from such an event.

Although East Fork Poplar Creek has shown considerable improvement over the time since the 1980's when sampling initially began, improvements have leveled off somewhat in the past few years. Part of this stagnation in improvement may be due to continuing impacts emanating from Y-12, as well as urban inputs and the discharge of the Oak Ridge Sewage Treatment Plant into East Fork downstream of EFK 13.8. However, a large part of this stagnation may also be due, especially in the upper East Fork stations, to a lack of a source for recolonization of aquatic insects. Recolonizaton of aquatic insects into impacted sections of streams may occur by a number of mechanisms (Wallace 1990). Included among these mechanisms are (1) migration from the deeper hyporheic zone to surface substrates; (2) upstream movements; (3) downstream drift from upstream or tributary areas; and (4) aerial recolonization by adults of many insects (Wallace 1990). The hyporheic zone is the area beneath and adjacent to the stream bed where there is a mixing of shallow ground water and surface water. As indicated by Wallace (1990) "In some riverine systems with well-developed hyporheic zones, macrobenthic fauna may be abundant deep (>20 cm) into the substratum as well as many meters laterally from the stream margin (e.g., Coleman and Hynes 1970, Stanford and Gaufin 1974, Bretschko 1981, Pennak and Ward 1986)." In some streams aquatic insects and other invertebrates can move upstream on the stream bed to recolonize impacted areas. Downstream drift from either unimpacted headwater areas or tributaries could potentially be very significant in the recolonization of impacted reaches of streams. Finally, adult aquatic insects migrating from either downstream and tributaries or nearby healthy streams and laying their eggs in the impacted stream could serve as a source for recolonization. Unfortunately, the upper reaches of East Fork lack any of these potential sources for recolonization. Long term impacts from Y-12 have most likely eliminated the hyporheic zone as a source of recolonization. There are no unimpacted headwaters in East Fork with former tributaries now flowing through storm drains. The entirety of East Fork proper has been historically impacted long term and, below the upper reaches of East Fork, urbanization has impacted many of the tributary sources of potential recolonization (both from upstream movements of fauna and sources for adult insects for aerial recolonization). A couple of known healthy tributaries do exist along East Fork (i.e., Mill Branch (MBK) and Gum Hollow Creek (GHK). Further study will be necessary to determine if other healthy tributaries exist and also to elucidate any positive effects that known sources of recolonization may be having on the East Fork system.

Interestingly, during the 2014 sampling and analysis, a taxon of perlid stonefly (*Perlesta* sp.) was discovered at EFK 6.3. ORNL has number of records of occasional stoneflies in East Fork at various stations (personal communication, J.G. Smith, 2014). Although *Perlesta* sp. is known to occur in tributaries to East Fork (Gum Hollow Branch and Mill Branch) it is a different species than that found at EFK 6.3. Stonefly specimens of *Leuctra* sp. were collected at EFK 13.8. ORNL has a number of records for this taxon at EFK 13.8 (personal communication, J.G. Smith, 2014). Scattered records of stonefly collection may be an indication of slowly improving conditions in East Fork. Unfortunately, now that flow augmentation has been halted conditions in East Fork may begin to deteriorate. Determination of the current condition of East Fork awaits the 2015 benthic sampling and analysis.

Mitchell Branch
Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Scores (Figure 18) decrease downstream in Mitchell Branch, suggesting deteriorating water quality conditions at MIK 0.71 and MIK 0.45 compared to the upstream reference (MIK 1.43). Mitchell Branch is a small headwater tributary of 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 (i.e., < 2 square miles). Because of the small upstream watershed and variable flow conditions which depend on annual rainfall, MIK 1.43 does not always provide a clear picture of the impacted condition of the downstream stations (MIK 0.71 & MIK 0.45). Historically, MIK 1.43 has been relatively unimpacted by the presence of ETTP. The lower stations (MIK 0.71 and MIK 0.45) have, however, been impacted, not only from former industrial activities at the ETTP and waste areas, they have also been channelized with much of the channel being replaced with unnatural substrate.

In order to gain a clearer understanding of 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 18-26). Metric data for all stations including the reference station (MIK 1.43) may be found in Table 6. The discussion of the data follows the table and figures below.

Table 6: Metric Values, Scores and Biological Condition Ratings for Mitchell Branch

2014 RESULTS		MITCHELL BRANCH						
Stream station		MIK 1.43		MIK 0.71		MIK 0.45		
METRIC		VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	
Taxa Richness		42	6	40	6	38	6	
EPT Richness		14	6	8	2	7	2	
% EPT-Cheum		45.81	6	25.26	2	30.94	4	
% OC		29.61	6	37.37	4	39.41	4	
NCBI		3.6	6	5.17	4	6.00	4	
% Clingers		26.8	4	53.59	6	39.41	6	
%TNUTOL		25.7	6	42.71	4	40.39	4	
Intolerant Taxa		12	0	7	0	5	0	
INDEX SCORE (Tenn. Macro. Index)			40		28		30	
RATING			A		B		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)							

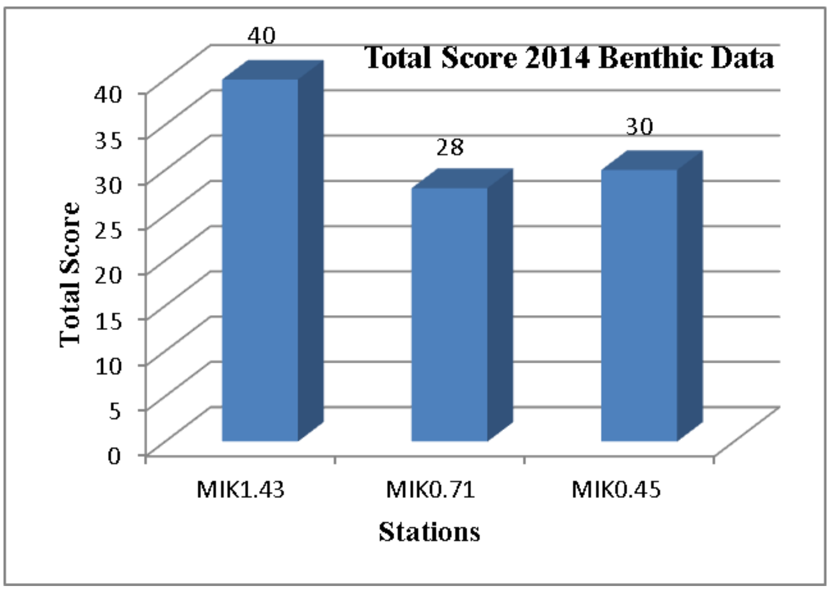


Figure 18: Total Score Mitchell Branch

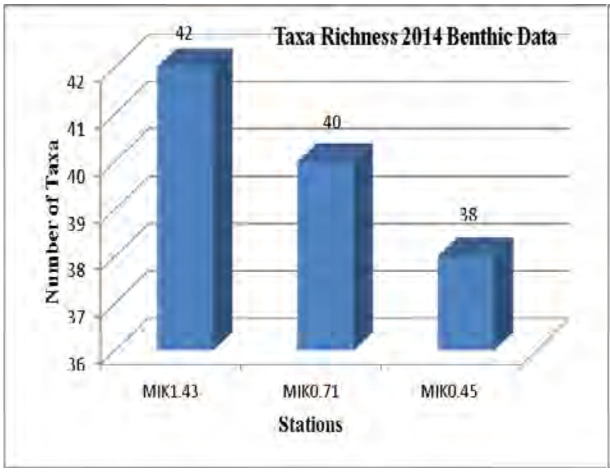


Figure 19: Taxa Richness Mitchell Br.

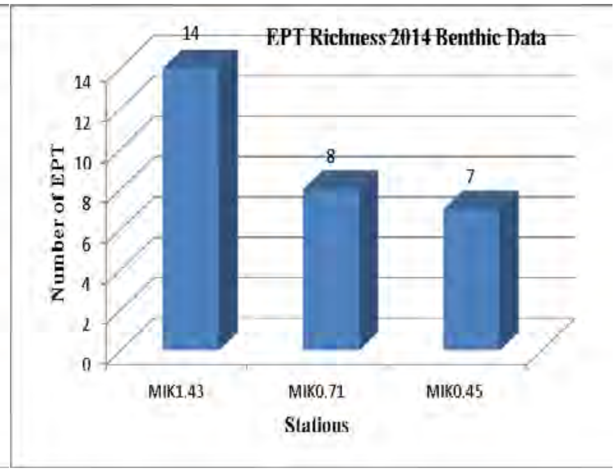


Figure 20: EPT Richness Mitchell Br.

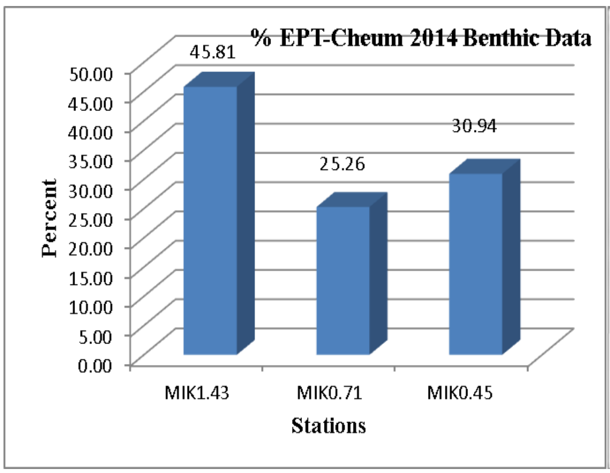


Figure 21: % EPT-Cheum Mitchell Br.

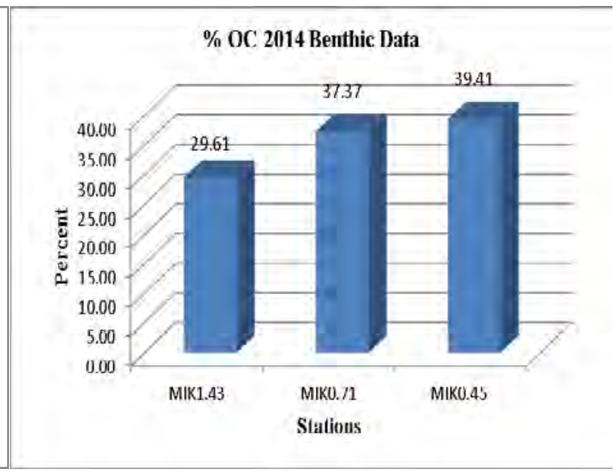


Figure 22: % OC Mitchell Br.

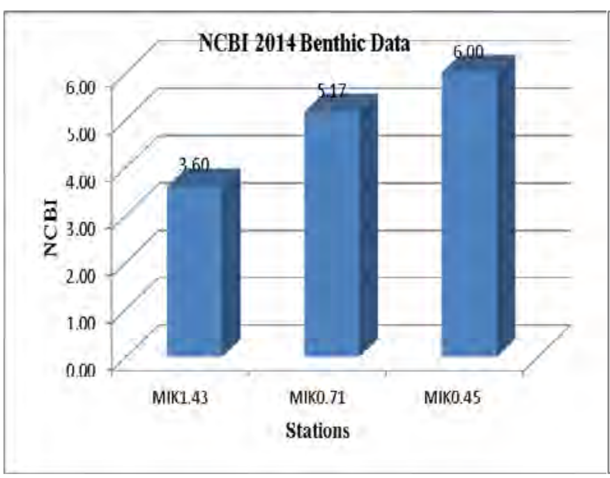


Figure 23: NCBI Mitchell Br.

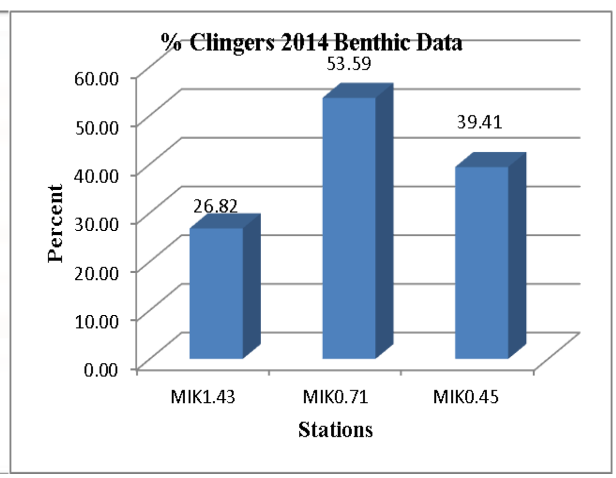
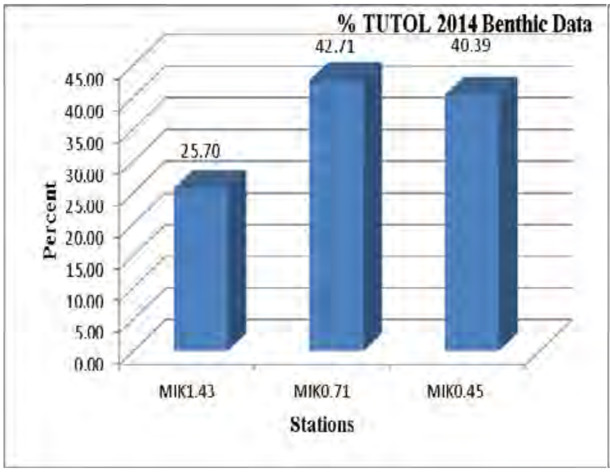


Figure 24: % Clingers Mitchell Br.



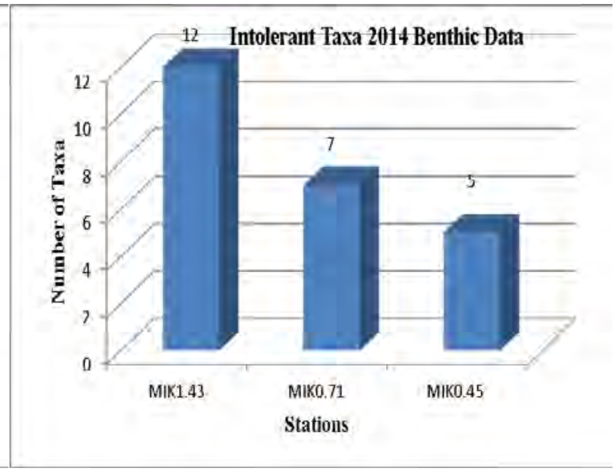


Figure 25: %TNUTOL Mitchell Br. **Figure 26: Intolerant Taxa Mitchell Br.**

With the exception of Taxa Richness (Figure 19) and % Clingers (Figure 24) all other metrics appear to fairly clearly show the superior condition of MIK 1.43 as opposed to MIK 0.71 and MIK 0.45. Like East Fork Poplar Creek, Mitchell Branch has improved considerably in quality since the 1980's. A part of these improvements are due to reduced industrial and buried waste inputs from the ETTP as remediation has occurred over the years. Another part of the improvement in stations MIK 0.71 and MIK 0.45 is due to a more natural substrate having replaced much of the artificial substrate in Mitchell Branch at those stations. Unlike East Fork, Mitchell Branch has a source for recolonization of aquatic macroinvertebrates in that the headwaters reference station (MIK 1.43) has been relatively unimpacted over the years. Although station MIK 0.71 is overall less healthy than MIK 1.43 based on the majority of the metrics, a closer similarity of MIK 0.71 to the reference station can be seen in such metrics as Taxa Richness (Figure 19), EPT Richness (Figure 20), and Intolerant Taxa (Figure 26) showing, perhaps, the effects of recolonization from upstream. Pollutional inputs from ETTP and current and former waste areas likely still continue to impact MIK 0.71 and MIK 0.45.

Bear Creek

Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Scores (Figure 27) increase dramatically from BCK 12.3 (with a score of 18) downstream to BCK 9.6 (with a score of 38). 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 a number of pollutional insults from industrial activities, as well as from waste disposal activities at the Y-12 complex. Former waste sites such as the S3 ponds (at its very 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 very 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 gain a clearer understanding of 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 27-35). Metric data for both Bear Creek stations may be found in Table 7. Metric Data for the two reference stations (GHK 2.9 & MBK 1.6) may also be found in Table 7. The discussion of the data follows the table and figures below.

Table 7: Metric Values, Scores and Biological Condition Ratings for Bear Creek.

2014 RESULTS								
Stream station	GHK 2.9		MBK 1.6		BCK 12.3		BCK 9.6	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	45	6	56	6	26	4	50	6
EPT Richness	18	6	21	6	4	2	14	6
% EPT-Cheum	58.85	6	51.05	6	7.8	0	13.79	2
% OC	22.86	6	12.59	6	9.22	6	6.94	6
NCBI	2.49	6	3.24	6	6.99	2	4.34	6
% Clingers	18.88	2	45.31	6	16.08	2	77.16	6
%TNUTOL	7.52	6	25.31	6	70.72	2	35.45	6
Intolerant Taxa	19	0	16	0	2	0	10	0
INDEX SCORE (Tenn. Macro. Index)		38		42		18		38
RATING		A		A		C		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)							

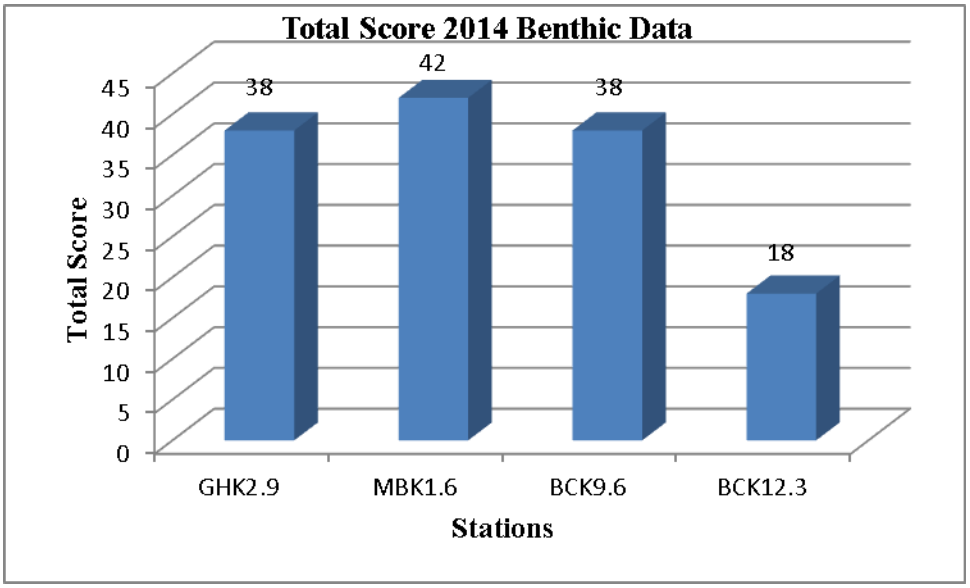


Figure 27: Total Score Bear Creek

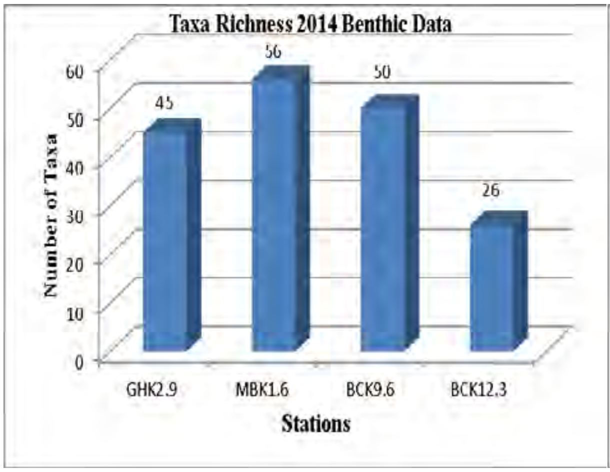


Figure 28: Taxa Richness Bear Creek.

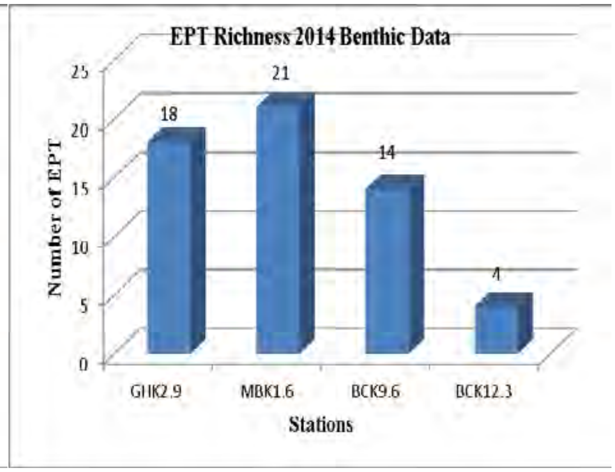


Figure 29: EPT Richness Bear Creek.

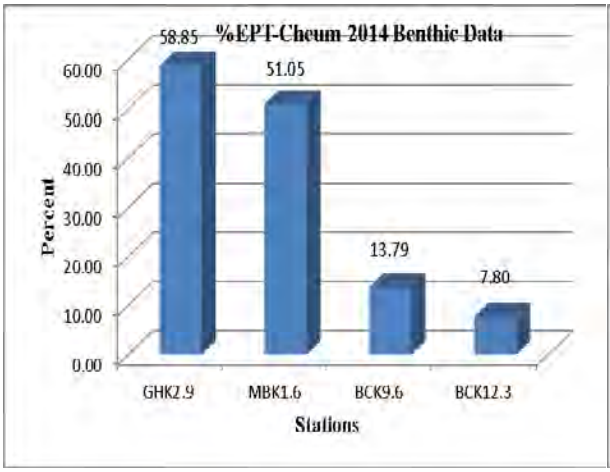


Figure 30: % EPT-Cheum Bear Creek.

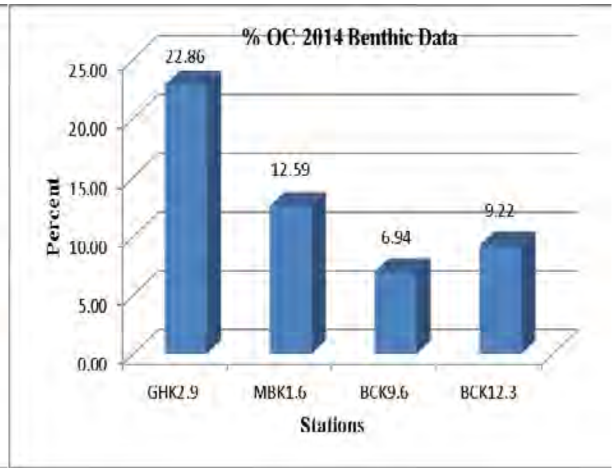


Figure 31: % OC Bear Creek.

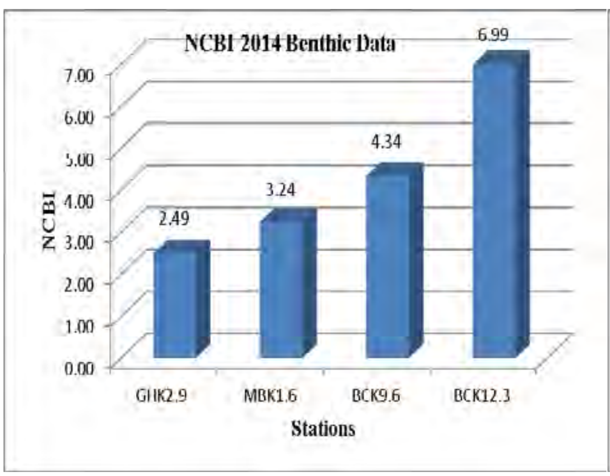


Figure 32: NCBI Bear Creek.

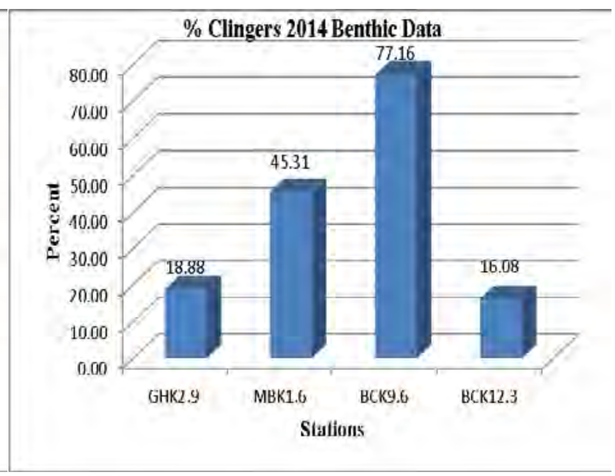


Figure 33: % Clingers Bear Creek.

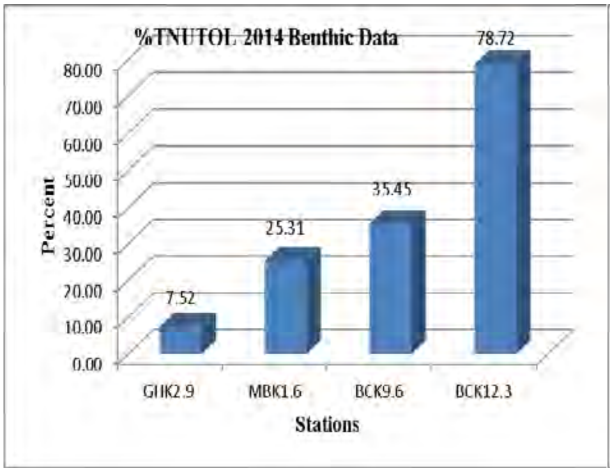


Figure 34: %TNUTOL Bear Creek.

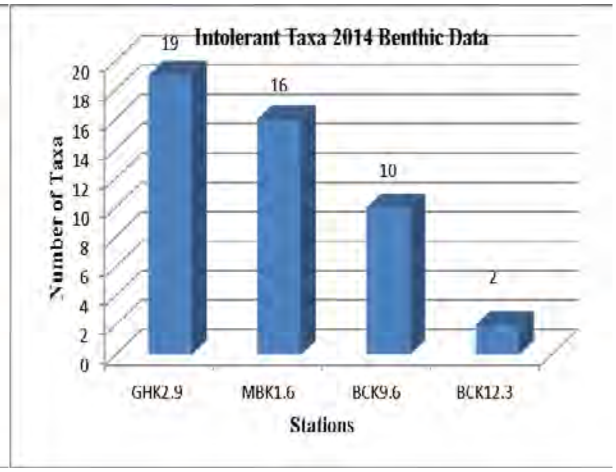


Figure 35: Intolerant Taxa Bear Creek.

Bear Creek 12.3 continues to display a reduced benthic macroinvertebrate community. With a TMI Score (Alternative Reference Stream Method) of only 18 (Figure 27), it is our lowest scoring station. BCK 12.3 also continues to score low on the majority of the metrics in comparison to other healthier stream stations (Figures 28-30; 32-35). Regardless, a couple of Intolerant Taxa (Figure 35) continue to hold on at this station. At least one additional Intolerant Taxon (*Pycnopsyche luculenta*) was noted during field work, but was not picked up in the lab analysis. Bear Creek 12.3 likely continues to receive pollutional inputs from industry and from former and current waste sites. However, this is only a part of the problem holding back continued recovery of the station. The watershed upstream of BCK 12.3 is very limited in size, thus affecting the amount of flow at the station, particularly in the summer. Also, as noted previously for East Fork Poplar Creek, BCK 12.3 suffers from a paucity of aquatic macroinvertebrate refuges in its vicinity from which recolonization of the station can occur. Little is currently known of the condition of Bear Creek proper between BCK 12.3 and BCK 9.6; however, a number of the tributaries in that reach of stream have likely been impacted from former and current waste activities. Further study will be necessary to determine if any refugia of aquatic macroinvertebrates exist in the vicinity of BCK 12.3.

BCK 9.6 continues to show improvement as noted in 2012 and again in 2013. This station compares well with the two reference stations (GHK 2.9; MBK 1.6) in a number of the metrics. With a TMI (Alternative Reference Stream Method) score of 38 (Figure 27; Table 6), BCK 9.6 matches that of GHK 2.9 and lags only slightly behind that of MBK 1.6. (Figure 27; Table 7). BCK 9.6 also compares favorably with the reference stations in Taxa Richness (Figure 28), EPT Richness (Figure 29), and Intolerant Taxa (Figure 35). Although not a bad score, BCK 9.6 has a higher North Carolina Biotic Index (NCBI) score than either GHK 2.9 or MBK 1.6 (Figure 32). BCK 9.6 also shows a considerably higher value for the percent of nutrient tolerant organisms (% TNUTOL: Figure 34), as well as a considerably higher value for % Clingers (Figure 33) than either of the reference stations.

GHK2.9 and MBK 1.6 continue to be some of the higher scoring reference stations being used in this study. With a TMI (Alternative Reference Stream Method) scores of 42 (Table 7; Figure 27) MBK 1.6 scores a maximum ranking on all of the metrics calculated. GHK 2.9 lags only slightly behind with a score of 38. Particularly notable are the scores for Taxa Richness (Figure 28), EPT Richness (Figure 29), NCBI (Figure 32), % TNUTOL (Figure 34) and numbers of Intolerant Taxa (Figure 35). In all, these streams appear to have high diversity and little organic loading.

White Oak Creek and Melton Branch
Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Scores (Figure 36) for the White Oak Creek watershed are highest for the upstream reference site (WCK 6.8; WCK 6.8 DUP) and for the site on Melton Branch, a tributary to White Oak Creek in Melton Valley (MEK 0.6). Scores for stations in lower White Oak Creek (WCK 3.9, WCK 3.4, WCK 2.3) are somewhat 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 (SNS) and through the main plant area in Bethel Valley. It then passes into Melton Valley, flowing through the Solid Waste Storage Areas (SWSAs) 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 which is 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 0.6 being located near the High Flux Isotope Reactor (HFIR) facility. Before the development of the SNS, WCK 6.8 was relatively unimpacted. The construction of the SNS resulted in some sediment inputs into White Oak Creek, but the negative impacts caused by that sedimentation has 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 into First Creek. WCK 2.3 is on the south side of the SWSAs and receives added impact from the SWSAs. MEK 0.6, located near the HFIR, historically received impacts from the HFIR and other facilities in the area. Parts of Melton Branch have also been channelized.

In order to gain a clearer understanding of 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 36-44). Metric data for both all White Oak Creek stations and Melton Branch may be found in Table 8. The discussion of the data follows the table and figures below.

Table 8: Metric Values, Scores and Biological Condition Ratings for White Oak Creek and Melton Branch.

2014 RESULTS	White Oak Creek and Melton Branch											
Stream station	WCK 6.8		WCK 6.8 DUP		WCK 3.9		WCK 3.4		WCK 2.3		MEK 0.6	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	50	6	58	6	29	4	24	4	28	4	48	6
EPT Richness	18	6	21	6	3	0	4	2	7	2	17	6
% EPT-Cheum	69.7	6	71.05	6	13.5	2	7.41	0	9.47	0	18.62	2
% OC	7.06	6	13.66	6	41.1	4	34.26	6	40.83	4	20.54	6
NCBI	2.52	6	2.64	6	5.26	4	4.92	4	5.30	4	5.05	4
% Clingers	34.92	6	28.24	4	57.06	6	72.22	6	50.89	6	57.97	6
%TNUTOL	4.24	6	6.12	6	45.4	4	37.04	6	47.93	4	40.5	4
Intolerant Taxa	10	0	13	0	2	0	2	0	4	0	10	0
INDEX SCORE (Tenn. Macro. Index)		42		40		24		28		24		34
RATING		A				B		B		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)											

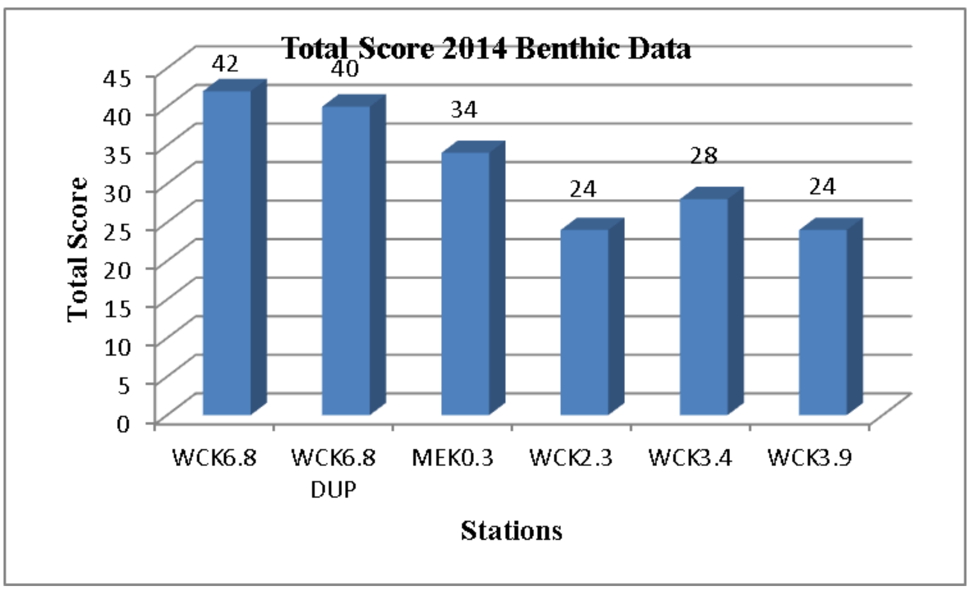


Figure 36: Total Score White Oak Creek and Melton Branch

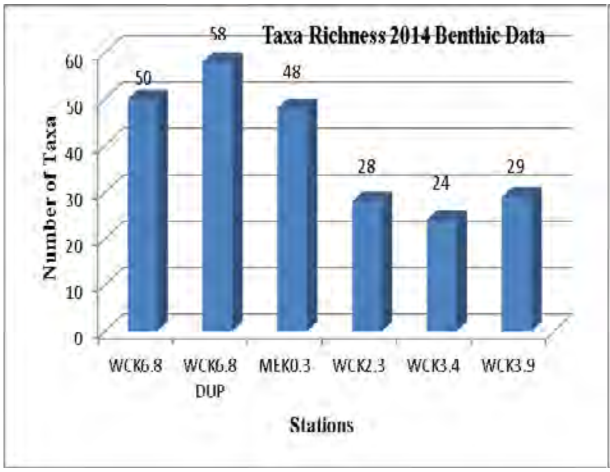


Figure 37: Taxonomic Richness White Oak Creek and Melton Br.

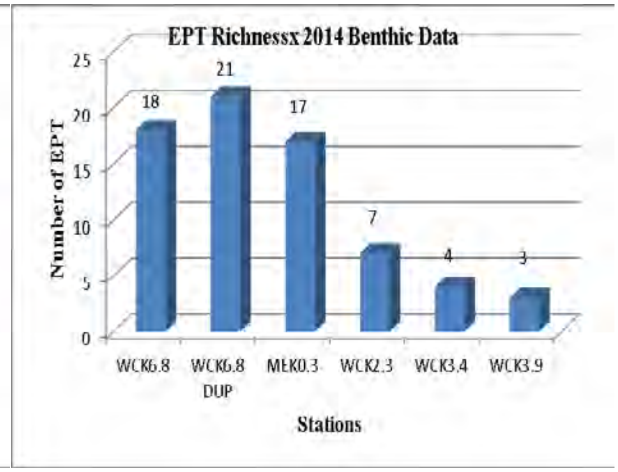


Figure 38: EPT Richness White Oak Creek and Melton Br.

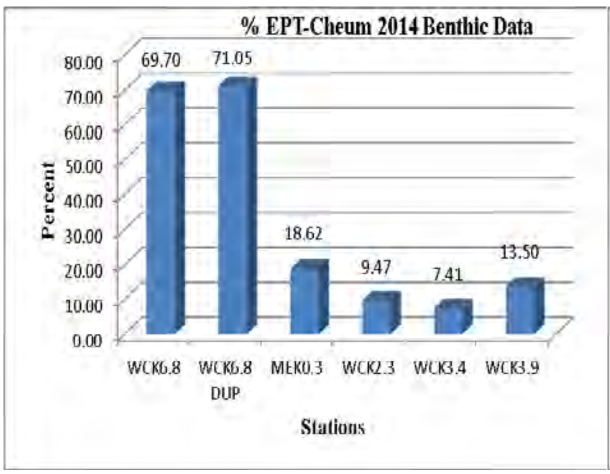


Figure 39: % EPT-Cheum White Oak Creek and Melton Br.

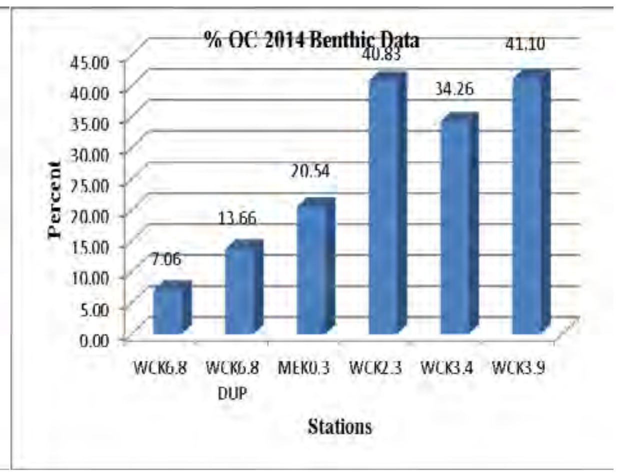


Figure 40: % OC White Oak Creek and Melton Br.

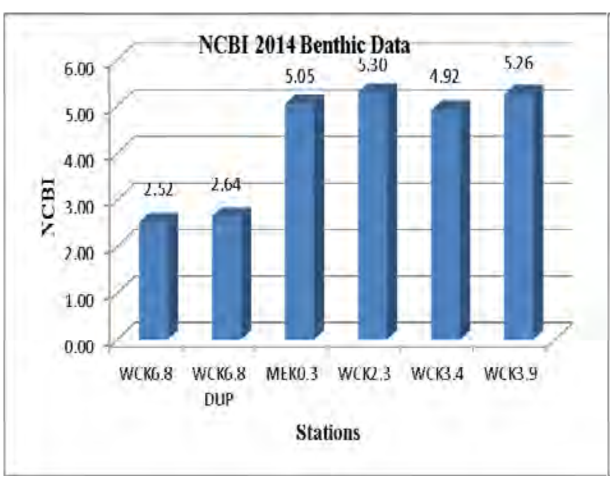


Figure 41: NCBI White Oak Creek and Melton Br.

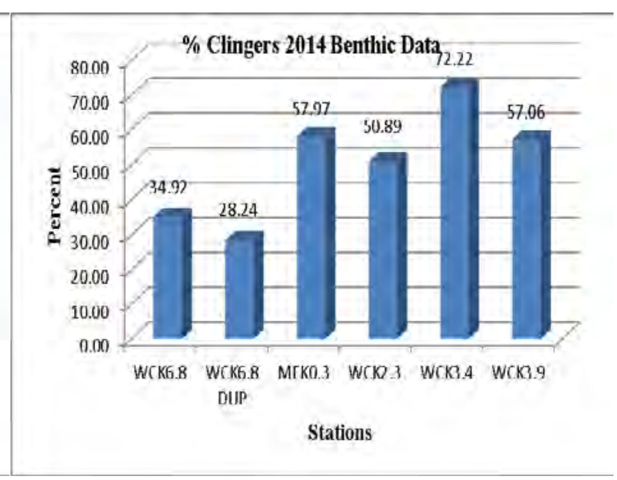
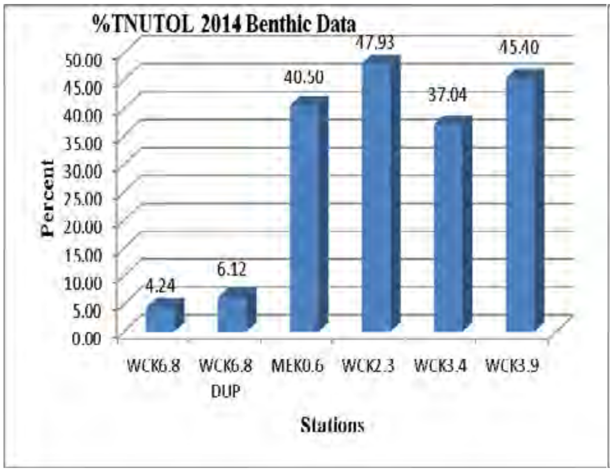


Figure 42: % Clingers White Oak Creek and Melton Br.



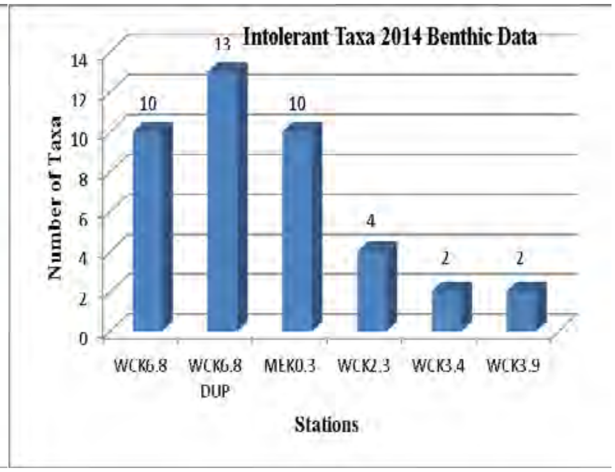


Figure 43: %TNUTOL White Oak Creek and Melton Br.

Figure 44: Intolerant Taxa White Oak Creek and Melton Br.

As indicated, both the reference station WCK 6.8 (and WCK 6.8 DUP) and MEK 0.6 score high on the Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) (Figure 36). The remaining White Oak Creek stations also score fairly well; however, their scores are indicative of some degree of impairment. The 2014 data show Taxa Richness (Figure 37) to be considerably higher for the reference station (WCK 6.8; WCK 6.8 DUP) and MEK 0.6 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 compare well in terms of EPT Richness (Figure 38), %OC (Figure 40), and Intolerant Taxa (Figure 44). In terms of % NUTOL (Figure 43), NCBI (Figure 41), % Clingers (Figure 42), and % EPT-Cheum (Figure 39), MEK 0.6 is more similar to the other White Oak Creek stations (WCK 3.9, WCK 3.4 & WCK 2.3) than to the reference station WCK 6.8. Percent NUTOL, NCBI and % EPT-Cheum may be indicative of somewhat greater organic loading being present at MEK 0.6. The major differences between the impacted White Oak Stream Stations (WCK 3.9, WCK 3.4, & WCK 2.3) and the reference station (WCK 6.8) are apparent in the reduced number of EPT taxa at impacted stations (Figure 38), the decrease in the % EPT-Cheum (Figure 39) at the impacted stations, in the increased % OC at the impacted stations (Figure 40), in the significantly higher NCBI score at the impacted stations (Figure 41) and in the decreased number of Intolerant Taxa at the impacted stations (Figure 44). All these differences indicate that the White Oak Creek stations (WCK 3.9, WCK 3.4, & WCK 2.3) continue to be biologically impaired.

Quality Control Results

Duplicate samples were collected at two sites and there was a quality control check for field sampling and laboratory sample processing during 2014. Per Table 9, the Clear Creek 1.45 station and its duplicate sample returned remarkably similar results both attaining the same TMI score (Alternative Reference Stream Method). The sample from the White Oak Creek 6.8 and its duplicate also shows extremely similar results. Although the White Oak Creek 6.8 Duplicate scored slightly less than its other sample based on % Clingers, the % Clingers score for the duplicate was very close to rating a 6 rather than a 4. These results indicate that both field sampling and lab processing were done with a high rate of consistency.

Table 9: Metric Values, Scores & Biological Condition Ratings for Quality Control Duplicates

2014 Results	Quality Control Duplicates							
Stream station	CCK 1.45		CCK 1.45 DUP		WCK 6.8		WCK 6.8 DUP	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	52	6	56	6	50	6	58	6
EPT Richness	19	6	24	6	18	6	21	6
% EPT-Cheum	57.14	6	42.12	6	69.7	6	71.05	6
% OC	14.02	6	7.18	6	7.06	6	13.66	6
NCBI	2.15	6	2.64	6	2.52	6	2.64	6
% Clingers	33.69	6	43.07	6	34.92	6	28.24	4
%TNUTOL	4.22	6	11.67	6	4.24	6	6.12	6
Intolerant Taxa	16	0	22	0	10	0	13	0
INDEX SCORE (Tenn. Macro. Index)		42		42		42		40
RATING		A		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)							

Conclusions

The biotic integrity of most impacted streams on the Oak Ridge Reservation is less than optimal compared to reference conditions (Figure 45). Of all sites sampled during 2014, only one location (BCK 12.3) received the lowest Tennessee Macroinvertebrate Index (Alternative Reference Stream Method) scores and ratings, partially supporting/moderately impaired (TMI = 18-20, C rating). The reasons for this station's ranking being far below reference stations in score are varied. In part, the poor scores are likely due to continuing pollutional inputs from Y-12. Another consideration is that this site lacks nearby refugia from which recolonization of aquatic invertebrates and insects can occur. A number of the ORR stream sites had biological condition ratings of partially supporting systems with slight to moderate impairment. These include EFK 6.3, EFK 23.4, EFK 25.1, MIK 0.45, MIK 0.71, WCK 2.3, WCK 3.4 and WCK 3.9. Remarkably, four of the impacted stations show scores that favorably compare to those of reference sites. These include BFK 9.6 and EFK 13.8, with scores directly comparable to reference sites, and EFK 24.4 and MEK 0.6 with a score only slightly below that of the reference sites. The high ranking of some of the impacted sites is encouraging and, hopefully, shows the positive results of the remediation work that has been completed at both Y-12 and ORNL. The continued low ranking of some of the impacted sites shows not only that further remediation will be required, but also, that more study will be needed to help determine if the simple answer to increasing recovery is less pollution, or if factors such as a lack of nearby refugia may also play a hand in the slowed recovery of these systems.

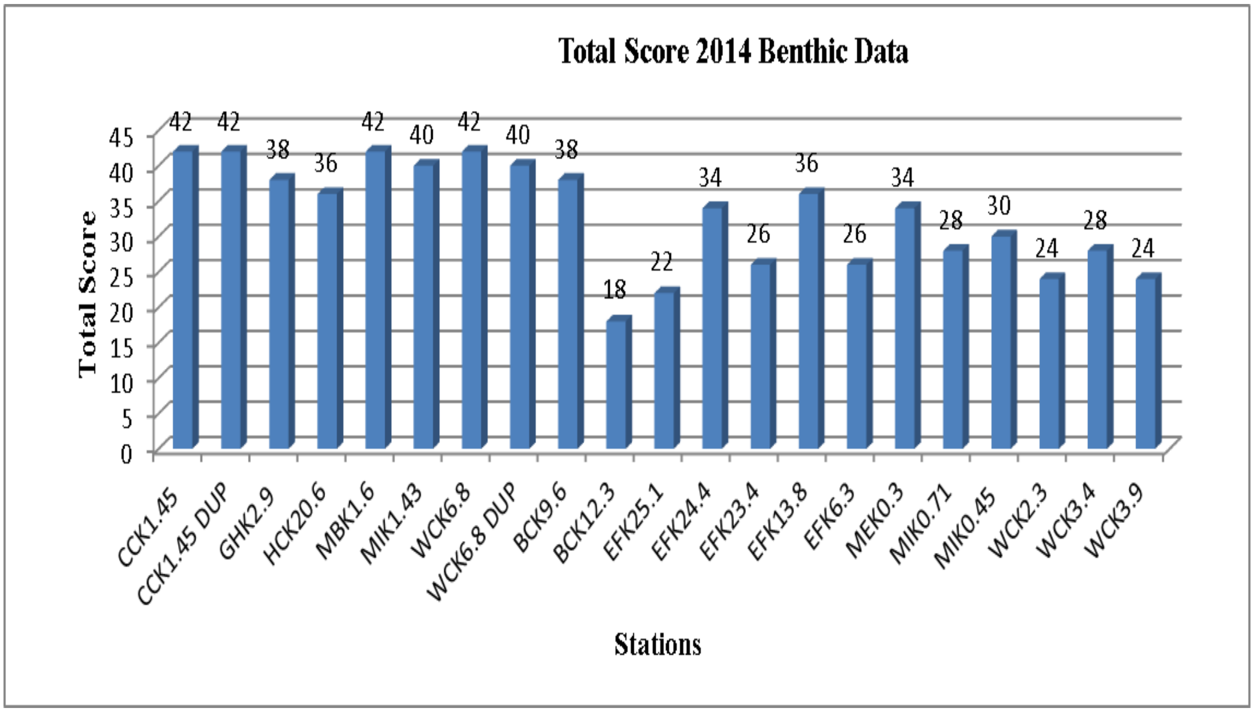


Figure 45: Total Scores for All Reference and Impacted Stations in 2014

Future benthic monitoring will include a closer look at what healthy tributaries exist in the impacted watersheds as refugia for recolonizers of impacted streams. Ongoing CERCLA remedial activities on the ORR continue to have an impact on the aquatic biological communities in East Fork Poplar Creek, Mitchell Branch, the White Oak Creek watershed and Bear Creek. Future benthic monitoring should capture temporal and spatial changes by documenting changes in the macroinvertebrate communities on the ORR.

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White-tailed Deer Monitoring Program on the Oak Ridge Reservation

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Abstract

The DOE-Oversight Office of the TDEC Division of Remediation (TDEC DOEO) continued white-tailed deer tracking activities on the Oak Ridge Reservation (ORR) during 2014. The goal is to determine their home range and potential movements outside their home range. The scientific literature provides considerable evidence that wildlife (i.e., carnivores, herbivores, omnivores, piscivores), subsisting in habitats impacted by industrial pollution, are ingesting environmental contaminants from their respective food chains. White-tailed deer (*Odocoileus virginianus*) mainly consume vegetation, forbs, nuts, fruits and grasses for nourishment, and ingest soils (i.e., licks) to replenish vitamins and minerals. Oak Ridge Reservation deer, grazing and foraging in contaminated areas such as the Melton Valley solid waste storage areas (SWSAs) at Oak Ridge National Laboratory (ORNL), represent a potential vector for contaminant exposures to the public. This project is part of a multiyear investigation. Our previous 2011-13 GPS collar investigations show deer taking excursions across the Clinch River into surrounding areas off the ORR. Samples from natural mortality and harvest show uptake of strontium 90. During 2014, division staff captured and successfully collared five deer, all in Melton Valley. Global positioning system (GPS) data were downloaded and home ranges (and excursions from the core area) were determined from three recovered collars and are presented herein.

Introduction

The Oak Ridge Reservation (ORR) contains a large biodiversity of plants, wildlife, and game animals, providing wildlife habitat imbedded in large areas of relatively undisturbed mature eastern deciduous forest, wetlands, old fields, river bluffs, cedar barrens, and grasslands. The United States Department of Energy (DOE) ORR wildlife management plan has historically provided for the management and radiological monitoring of white-tailed deer (*Odocoileus virginianus*) and other game animals during annual hunts on the ORR Wildlife Management Area (WMA, Salk and Parr 2006, Giffen et al. 2007). The ORR WMA annual hunts, managed by the Tennessee Wildlife Resources Agency (TWRA), began in 1985 as a method of population control and to reduce increasing deer/vehicle collisions (Parr and Evans 1992, Pierce 2010). Although harvested deer are scanned radiologically prior to public release during ORR WMA hunts, there has been little or no monitoring of heavy metals in ORR game meat (i.e., venison and organ meat).

Ashwood et al. (1994) reported that contaminated animals (e.g., Canada geese, white-tailed deer, kingfishers, wild turkeys) with large home ranges have been collected at locations outside the boundaries of the ORR. It has been well documented that deer are strong swimmers and have the capability to swim long distances in rivers and lakes (McCulloch 1967, Nelson and Mech 1984, Lopez 2006, Jordan et al. 2010). Thus, ORR deer that may swim or otherwise migrate offsite (i.e., Knox County, City of Oak Ridge), and if ultimately harvested, represent an exit pathway (i.e., vector) for exposures to the public through the consumption of un-monitored and potentially contaminated venison and liver. Wildlife researchers have reported that ORR contaminated animals (e.g., Canada geese, white-tailed deer, kingfishers, wild turkeys) with large home ranges were collected at locations outside the boundaries of the reservation (Ashwood 1992, Ashwood et al. 1994).

Research specific to red deer (Lazarus et al. 2004) and white-tailed deer (Kocan et al. 1980, Woolf et al. 1982, Sileo and Beyer 1985, Crête et al. 1987, Schultz et al. 1994) have documented uptake of elevated concentrations of metals (i.e., industrial & mining sources) in organs, hair, antler, teeth, bone, tissue and feces. Garten (1995) suggested that elevated levels of strontium 90 (^{90}Sr) in some deer killed during the ORR WMA deer hunts indicate that deer could forage in contaminated areas and then leave the ORR. Grazing wildlife (ruminants) can also ingest metals such as mercury (Hg) either by consuming herbage (browse) that is contaminated (Schwesig and Krebs 2003), or by consuming contaminated soils (mineral licks, Wilkinson et al. 2003). Thus, contaminants may be bioaccumulated by deer during ingestion of contaminated browse and soil (i.e., mineral licks, Grodzińska 1983, Harrison and Dyer 1984, Peles and Barrett 1997, Han et al. 2006, Beyer et al. 2007).

For managed populations of white-tailed deer, understanding dispersal and movements within home ranges is important for effective management (McCoy et al. 2005). Yearling male white-tailed deer are more likely to disperse from their natal (area of birth) home range than other sex and age classes, and dispersal often is the greatest movement of any individual in the population (Hawkins et al. 1971, Nelson and Mech 1984, Tierson et al. 1985). Capturing deer allows biologists to equip individuals with identification tags and global positioning system (GPS) collars in order to study herd demographics, determine home range information and collect biological data (e.g., physical measurements, tissue samples; Vercauteren et al. 1999).

Home ranges in white-tailed deer typically vary from 50-500 hectares (ha) (123-1235 acres [ac], Marchinton and Hirth 1984). Previous investigations on the ORR found that the average home range for radio-collared deer examined (number of [*n*] = 15) was found to be 345 ha (852 ac), and dispersal distances of up to 33 kilometers (km) (20.5 miles [mi]) were recorded (Kitchings and Story 1979, Story and Kitchings 1982, 1985).

White-tailed Deer Behavior and Breeding

White-tailed deer are gregarious with two basic social groups: family groups centered on a matriarch with females (fawns of previous generations) and their fawns, and fraternal groups made up of adults and occasionally yearling males (Hawkins and Klimstra 1970). Marking and rubbing behaviors are an integral part of social interactions, especially during the mating season (Moore and Marchinton 1974). Buck rubs and scraping are visual and olfactory signposts displayed by older males to establish dominance and facilitate intersexual communication (Kile and Marchinton 1977). The forehead of males contains sudoriferous glands that are most active in dominant males during the rut (Atkeson and Marchinton 1982). Together with secretions from the preorbital gland and saliva, males mark overhanging branches, twigs, and the bark of small saplings and stems with their head and antlers (Smith 1991). Rutting activity is during the fall and early winter.

Temporary movements outside of home ranges have been documented for both yearling and adult male white-tailed deer (Hawkins and Klimstra 1970, Nelson and Mech 1981, Nixon et al. 1991, Skuldt et al. 2008, Clements et al. 2011). White-tailed deer often expand their home ranges and undertake frequent long-distance movements during the hunting season (Downing et al. 1969, Pilcher and Wampler 1982, Root et al. 1988). Sparrowe and Springer (1970) determined that hunting activities influenced deer movements more than any other factor, although adult males apparently do not move to refuge areas to avoid hunters (Hawkins et al. 1971, Kammermeyer and Marchinton 1977, Pilcher and Wampler 1982, Root et al. 1988). Dispersal in white-tailed deer occurs predominantly among yearling males and usually is exhibited by 50 percent (%) of these individuals (Nixon et al. 1994, Rosenberry et al. 1999, Long et al. 2005, Shaw et al. 2006). Yearling males typically disperse 8–12 km, but movements of >150 km have been reported (Nelson 1993, Kernohan et al. 1994, Nixon et al. 1994). However, the hunting season in many areas coincides with rut, and movements associated with breeding activities may confound interpretation of hunting-related deer movements (Sargent and Labisky 1995). Knowledge relating to home-ranges may provide insight into various facets of the species' social organization and foraging ecology (Gallina et al. 1997).

Just before breeding season, male activities intensify (i.e., rubbing, scraping, sparring, and searching for estrous females) and movement and home ranges increase (Guyse 1978, Hawkins and Klimstra 1970, Hosey 1980, Tomberlin 2007). Additionally, white-tailed deer may temporarily leave their home range to avoid hunting pressure and other disturbances (Hood and Inglis 1974, Naugle et al. 1997, Vercauteren and Hygnstrom 1998). Dispersal movements are predominantly made by juvenile (1.5-year-old) male white-tailed deer and often result in permanent emigration (Brinkman et al. 2005, McCoy et al. 2005, Rosenberry et al. 1999, Shaw 2005), whereas excursions are temporary movements outside an established home range. As estrus approaches, females concentrate movement and scent markings within their core areas (Fraser 1968, Holzenbein and Schwede 1989, Ivey and Causey 1981, Marchinton 1968, Nelson and Mech 1981), which may increase the chance of males detecting females by focusing activities within a small area (Holzenbein and Schwede 1989, Ozoga and Verme 1975). By luring courting males into a chase and venturing outside her core area, females might attract attention from other potential mates (Karns et al. 2011). Once engaged in the chase, males might easily be led outside their home range and into unfamiliar territory, possibly bringing multiple males together and stimulating intrasexual competition (Cox and Le Boeuf 1977, Emlen and Oring 1977). After being tended and bred, females will decrease activity, return to core areas, and resume normal levels of movement and activity (Cox and Le Boeuf 1977, Holzenbein and Schwede 1989, Ozoga and Verme 1975). In rare instances, females may make excursions outside their home range during the breeding season even with abundant mature males in the population (Kolodzinski 2008).

Methods and Materials

For 2014, the focus of this investigation was to equip Melton Valley deer with GPS radio-collars to track and document their movements and determine home-ranges. The investigation is attempting to answer the question: Are potentially contaminated Melton Valley deer leaving the ORR and wandering into adjacent urban areas surrounding the ORR (i.e., City of Oak Ridge, Knox Co., and Roane Co.)? If ORR deer migrate offsite and are harvested, they would not be scanned for radiological contamination (i.e., as per the ORR WMA deer hunt radiological scanning of deer bone and tissue). Results from this study may also indicate that more remedial actions are necessary in Melton Valley and other areas to prevent uptake by wildlife.

Study Area
The ORR consists of three main sites, Y-12 National Security Complex (Y-12), Oak Ridge National Lab (ORNL, or X-10), and the East Tennessee Technology Park, (ETTP, or the K-25 gaseous diffusion plant), and is located in Anderson and Roane Counties, Tennessee. The ORR encompasses 13,855 ha, and lies in an area of thrust-faulted sedimentary rocks of Cambro-Ordovician age creating rolling hills and valleys in eastern Tennessee between the Cumberland Mountains to the northwest and the Blue Ridge Mountains to the southeast (DOE 2002). The Clinch River forms a border to the south, west, and east of the ORR. For 2014, the study area was the ORR solid waste storage areas (SWSAs) of Melton Valley (ORNL). Melton Valley includes legacy waste disposal areas and adjacent drainages contaminated with radionuclides since the 1940s and 1950s. The watershed has received considerable environmental contamination from previous ORNL operations especially the seepage pits and waste trenches comprising the SWSAs. Browse and forage in the study area are abundant and there are also several mineral licks in both Melton Valley and offsite areas frequented by deer.

Global Positioning System Collars
Each deer was fitted with a releasable Telonics TGW-4500 GPS collar (Telonics, Inc., Mesa, Arizona) which stored location data internally (i.e., store-on-board). Each collar was also equipped with a CR-2A release mechanism and a very high frequency (VHF) transmitter. The GPS collars are located in the field using a VHF receiver following drop-off from the animal. Releasable GPS wildlife collars have been used frequently in the field by other researchers to eliminate the need for re-capture of the animal for collar retrieval (Merrill et al. 1998, Nelson et al. 2004, Demma and Mech 2009). The Telonics deer collars were pre-programmed to record deer locations (i.e., GPS fixes) every 90 minutes and to drop-off (release) either at 1-year or 2-year intervals (Kjær et al. 2007). The collars transmitted VHF telemetry signals at preprogrammed intervals to allow tracking and ultimate recovery, and all GPS fix data were stored for downloading upon collar recovery. Accordingly, VHF radio frequencies programmed in the collar transmitters are as follows: 151.205 megahertz (MHz), 151.250 MHz, 151.295 MHz, and 151.415 MHz. Radio-tracking allows the study of deer spatial dynamics without having to observe deer directly (Nelson and Sargeant 2008). To ensure collars were properly functioning and study animals were alive; deer were monitored weekly from established telemetry stations using the Telonics TR-4 VHF receiver (Brinkman et al. 2002, Cox et al. 2002).

Initial waypoints (sets of GPS coordinates that identify a point in physical space) from the collars were checked for consistency with capture waypoints and landmarks. Excursion waypoints were “clicked” through one by one to be sure they were in chronological sequence and not individual outliers. Outliers are usually evident in that they are misplaced and out of sequence. All waypoints in the study area were considered valid. One outlier was identified at an improbable distance from the study area. Error was variable depending on canopy cover and satellite constellation, but was categorically acceptable for the purposes of this study.

Capture Methods
White-tailed deer were captured during the winter/spring of 2014 in Melton Valley (n=5) using the mobile approach (i.e., drive-by) and by darting deer (chemical immobilization) accustomed to the presence of humans in the solid waste storage areas (SWSAs) of Melton Valley at ORNL (controlled access areas). Deer are crepuscular (animals that are primarily active at twilight

[dawn and dusk]), thus captures were attempted during morning daylight hours between 0700 and 1100. The deer field team members (i.e., ideally 4: equipment manager, two handlers, data collector) captured deer by means of immobilization drugs administered by a dart projector. Following capture, deer were fitted with a GPS/VHF collar and ear tags. Field procedures also followed the office's Health and Safety Plan (Yard 2013).

Chemical Immobilization (Anesthesia) and Handling

Melton Valley deer were darted by Tennessee Department of Environment and Conservation (TDEC) staff at a range of 30-60 yards with 1.5 cc Pneudart Type C disposable darts propelled from a Pneu-Dart Model 389 dart projector (cartridge-powered; Pneu-Dart, Inc., Williamsport, PA). Every attempt was made to deliver the dart to an area of muscle mass at the junction of the neck and shoulder of the deer. The darts were loaded with a 2:1 mixture of 5.0 mg/kg Telazol® (i.e., Cyclohexamine immobilization agent, Fort Dodge Animal Health, Fort Dodge, IA, USA; Safe-Capture 2012) and 2.5 mg/kg Xylazine (i.e., neuroleptic tranquilizer drug, Fort Dodge Animal Health, Fort Dodge, IA, USA; Safe-Capture 2012). This solution is administered at one milliliter (ml) per 85 pounds (lbs) per Safe-Capture International high dose method two recommended for free ranging wild deer. A dose for a 120-130 lb. deer is 1.5 ml of this mixture. This mixture has a wide safety margin for lighter weight animals and can still immobilize ones that are somewhat heavier. This also enables biologists to use a small dart size that minimizes impact trauma.

When combined with schedule III cyclohexamines (i.e., ketamine or Telazol®), Xylazine works synergistically, improving efficacy and reducing drug volume (Wenkler 1998; Kilpatrick and Spohr 1999; Walsh and Wilson 2002, Miller et al. 2009). Xylazine is partially reversed by available antagonists such as Tolazoline (Greene and Thurmon 1988; Webb et al. 2004).

Following dart delivery, deer were quietly observed from a distance during induction time until effects of the drugs became evident (i.e., 6-10 minutes) and it was determined that the animal was down. The induction time is the interval between initial injection of drugs via dart delivery and immobilization of the animal (Kreeger et al. 1986, Kreeger and Armeno 2007). The field team quietly approached the area in an evenly spread search pattern where the deer was known to be down or last seen. If the animal was aware of field team's approach (as evidenced by lifting its head or moving its ears or eyes), but was unable to rise off the ground, a dose of Ketamine was administered at 2.5 milligrams per kilogram (mg/kg) (2.5 mg/kg: 1.4 ml of 100 milligram per milliliter [mg/ml] for a 120 lb. deer) intramuscular (IM) syringe into the neck muscle to enhance immobilization of the deer (Safe-Capture 2012).

Deer were generally found recumbent within 50-250 yards from the location where the animal was originally darted. Once immobilization was complete, and it was safe to approach the deer, the handler positions the deer in a sternal recumbent position, ensures the respiratory pathway (airway) is clear and unobstructed, and holds the deer's head above the level of the gut rumen. The equipment manager applies a sterile ophthalmic lubricant to the deer's eyes (Kjær et al. 2007, Karns et al. 2011), blindfolds the deer, and determines age and sex which is recorded. Next, the equipment manager quickly installed the GPS collar on the deer. Once the collar has been applied, the equipment manager and the handler monitored the deer vital signs. Once the heart rate, temperature and respiration have been measured and recorded, then the equipment manager applies the numbered ear tags, and removes the dart from the deer. Space blankets were sometimes used to help keep the animal warm during recovery from the immobilizing drugs. The data collector takes photographs and records important details pertinent to the capture (TDEC 2013).

During recovery time, measurements of the deer were taken (i.e., length, girth). Approximately 2-5 grams of hair sample was collected with a curry-comb from the caudal or mid-dorsal region for later laboratory analyses (i.e., heavy metals; Stevens et al. 1997, Duffy et al. 2005, Brookens et al. 2007). Analysis of hair samples has been commonly used to assess accumulation of methylmercury in wildlife (Cumbie 1975, Born et al. 1991, Halbrook et al. 1994, Ben-David et al. 2001, Beckman et al. 2002, Harkins and Susten 2003). The deer's vital signs were monitored every 5 to10 minutes while the deer was immobilized. After the effects of Telazol® wear off (80 minutes), the deer was administered Tolazoline by a syringe to reverse the effects of Xylazine. Drugged deer are usually aroused and able to walk away in 30-60 minutes after the dose of Tolazoline has been administered. Deer immobilization (captures) and handling followed the standard operating procedures per the TDEC White-tailed Deer Capture Plan (TDEC 2013), the Health and Safety Plan (Yard 2014), the Safe-Capture Training Manual (Safe-Capture 2012), and additional guidance found in Kreeger et al. (1986), Wisdom et al. (1993), Caulkett and Haigh (2004), Nelson et al. (2004), Gannon et al. (2007), Kreeger and Arnemo (2007), Muller et al. (2007), James and Stickles (2010), Karns et al. (2011), and Sikes et al. (2011). Lastly, the TWRA provided invaluable field support and guidance for this project.

All tissue metals analyses (except methylmercury, MeHg) were conducted by Laboratory Services, Nashville, Tennessee. The MeHg tissue samples, when analysed, were farmed-out and analyzed by Brooks-Rand Laboratory, Seattle, Washington. No hair samples were analysed for report this year. Sample collecting practices and methods followed recommendations of TWRA staff, and Travis et al. (1989), Sample et al. (1997), O'Hara et al. (2001, 2003), Kierdorf and Kierdorf (2005), Duffy et al. (2005), Gannon et al. (2007), Giffen et al. (2007), and Sikes et al. (2011).

Results and Discussion

White-tailed deer that were captured and collared during 2013-2014 are shown in Tables 1 and 2; deer captured and collared during 2015 are shown in Table 3. During January and February 2014, five Melton Valley deer were chemically immobilized and fitted with GPS collars in the legacy burial areas of the ORNL SWSAs (Table 1). Three of these collars were retrieved for data analysis for this report while two are scheduled for retrieval in 2016. The data downloads from each collar are represented in Figures 1-3 to show their respective core areas and excursions from the core area.

Using MapInfo, ArcGIS or Google Maps programs to plot our deer GPS data points, we found that the three deer for this year's report all stayed in Melton Valley and did not leave the Oak Ridge Reservation while collared. Short excursions extended up and down the valley (Figures 1, 2 and 3).

Notably, one deer we code named Ophelia (Figure 1) was harvested by a hunter. All deer on the managed hunts are tested for strontium-90 and cesium-137 before they are released to the hunter. Ophelia was found to be above the release criteria for strontium-90 and was confiscated from the hunter. This deer was harvested near her original capture point in the woods on the south side of Melton Valley. GPS waypoints indicate Ophelia's home range was confined but extended to suspect areas of Melton Valley. Interestingly she did not persistently occupy the White Oak Creek drainage that is known to be contaminated with strontium-90 but mostly stayed upstream in the Melton Branch area. This is suggestive that burials in this area still represent a source to contaminate wildlife.

During January-March 2015, six additional deer were immobilized and collared in Melton Valley (Table 3). One deer collared in 2012(Elizabeth) remains at large with the collar still attached because the release mechanism failed on the preprogrammed release date of January 15, 2013. There is a risk that the data from this collar may be lost because the VHF transmitter batteries will expire. Then there will be no VHF signal to enable relocating the collar. Collar recovery efforts will continue until March of 2016 because two collars deployed in 2014 will continue to collect GPS coordinates for two years. All collars deployed in 2015 are set to release after one year. In total, nine collars should be available for GIS analysis in 2016. This project is a multiyear effort that will result in GIS data from 19 deer. The project may be summarized in 2016 or continued if objectives are not met. Public and professional interests will be considered in revised data quality objectives.

Tables and Figures

Table 1: 2013 Deer Capture Data

Deer	Date captured	Est. Age	Est. Weight (lbs.)	GPS collar	VHF frequency	Successful Pulse	Collar Release
Elizabeth*	2/14/2012	3.5 yrs	n/a	2-yr	151.415	60 bpm	1/15/2014
Henrietta**	4/18/2012	1.5 yrs	90	2-yr	151.295	60 bpm	1/15/2014
Kathy	1/31/2013	4.0 yrs	105 lbs	1-yr	151.295	50 bpm	12/15/2013
Lawrence	2/6/2013	10 mos.	65 lbs.	1-yr	151.250	60 bpm	12/15/2013
Michelle**	2/8/2013	2.5 yrs	100 lbs	2-yr	151.205	50 bpm	12/15/2014

bpm - beats per minute; Est. - estimated; GPS - global positioning system; lbs - pounds; VHF - very high frequency; yr - year

* Elizabeth's collar failed to release on 1/15/2014; deer and collar remain at large.

**Died of natural causes.

Table 2: 2014 Deer Capture data

Deer	Date captured	Est. Age	Est. Weight (lbs.)	GPS collar	VHF frequency	Successful Pulse	Collar Release
Nicole	1/13/2014	2.5 yrs	130 lbs	1-yr	151.415	50 bpm	1/15/2015
Ophelia	1/14/2014	1.5 yrs	110 lbs	2-yr	151.205	60 bpm	1/15/2016
Penelope	1/15/2014	2.5 yrs	118 lbs	1-yr	151.295	50 bpm	1/15/2015
Quey	3/5/2014	1.5 yrs	120 lbs	2-yr	151.295	60 bpm	3/1/2016
Renee	3/19/2014	3.5 yrs	130 lbs	2-yr	151.205	50 bpm	3/1/2016

bpm - beats per minute; Est. - estimated; GPS - global positioning system; lbs - pounds; VHF - very high frequency; yr - year

Table 3: 2015 Deer Capture Data

Deer	Date captured	Est. Age	Est. Weight (lbs.)	GPS collar	VHF frequency	Successful Pulse	Collar Release
Samuel	1/26/2015	.8	80	1-yr	151.415	60 bpm	1/20/2016
Teresa	1/27/2015	2.5	120	1-yr	151.250	50 bpm	1/20/2016
Ursula	1/28/2015	1	80	1-yr	151.205	50 bpm	1/20/2016
Veronica	2/3/2015	2.5?	120	1-yr	151.295	50 bpm	1/20/2016
Wilson	2/5/2015	1	110	1-yr	151.205	60 bpm	1/20/2016
Xandra	3/24/2015	1	100	1-yr	151.415	50 bpm	1/20/2016

bpm - beats per minute; Est. - estimated; GPS - global positioning system; lbs - pounds; VHF - very high frequency; yr - year

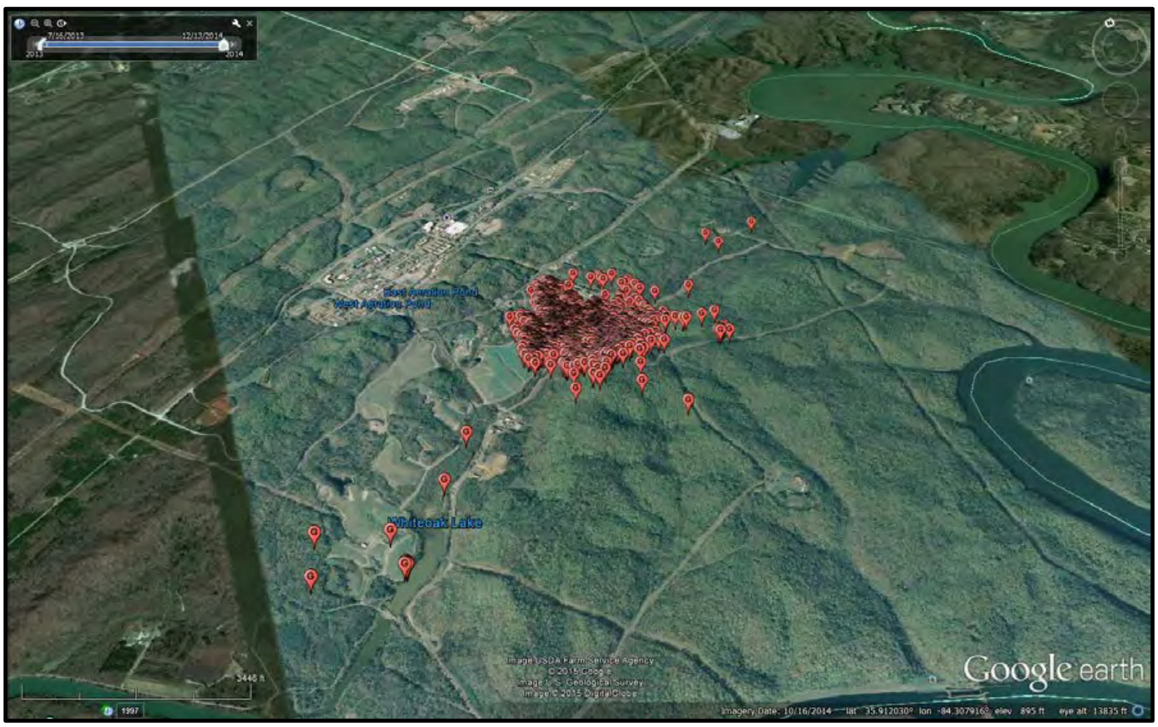

Figure 1: Ophelia's Home Range and Excursions

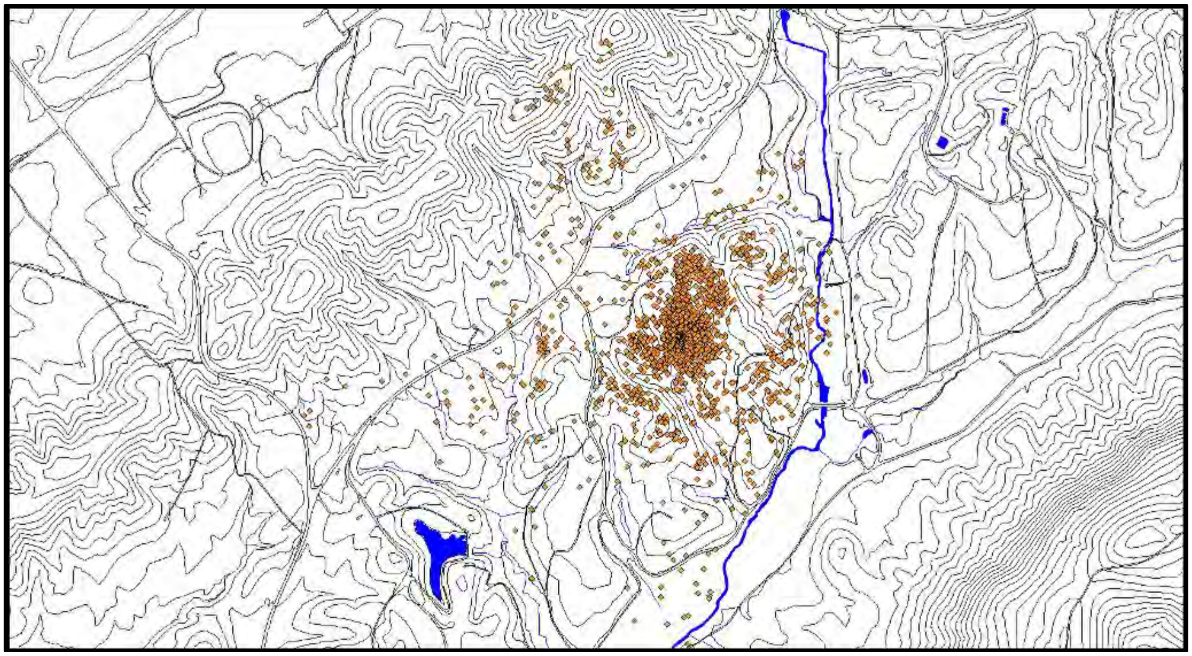

Figure 2: Penelope’s Home Range, on MapInfo Plot

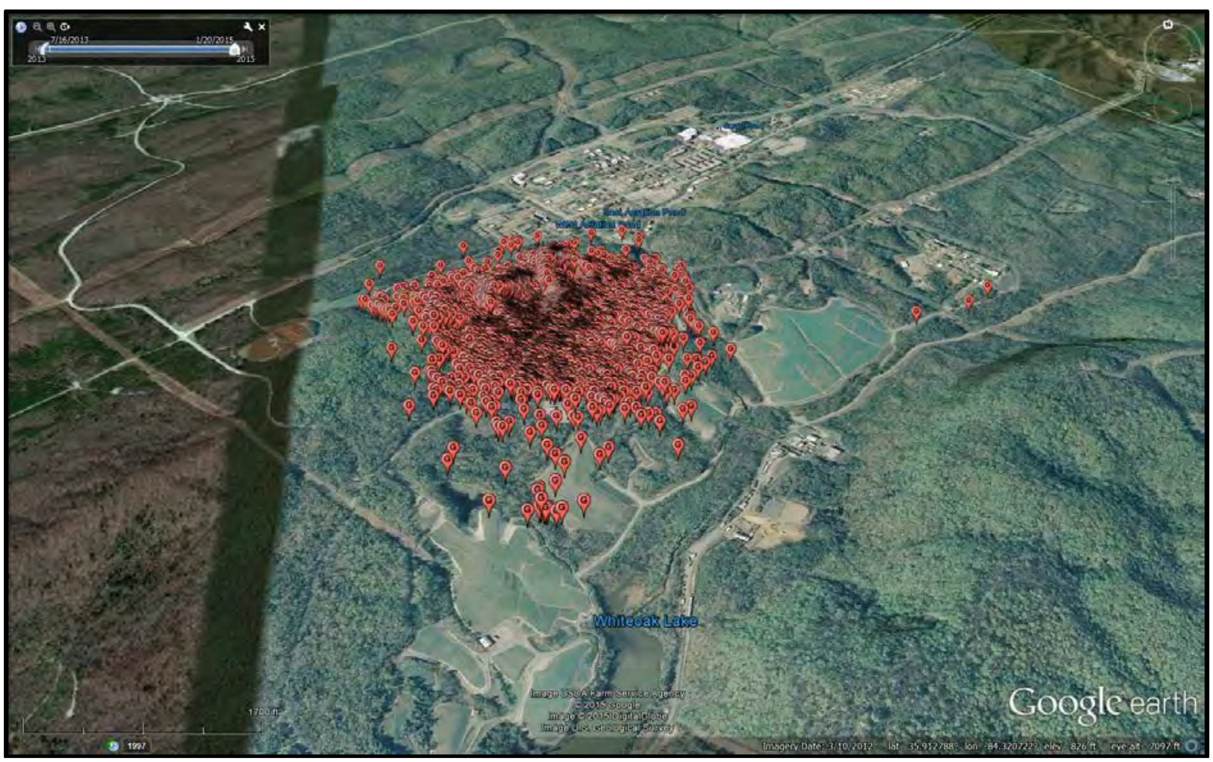

Figure 3: Nicole’s Home Range and Excursion

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Fish Tissue Environmental Monitoring Report

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Abstract

Fish samples were collected twice during 2014 in several Oak Ridge Reservation (ORR) and control streams by biologists with the Oak Ridge National Laboratory's Environmental Sciences Division (ORNL ESD). Fish were captured by electroshocking methods to obtain fish tissue and gut content samples for contaminant analysis (i.e., bioaccumulation study). Previous ORR fish monitoring programs have focused on tissue analysis (i.e., fish fillets), but few studies have investigated tissue and gut content contaminants in individual species. Fish fillets were sampled and evaluated for mercury (Hg) and polychlorinated biphenyls (PCBs) content by the ORNL ESD team. In cooperation with ORNL ESD, the TDEC Division of Remediation (TDEC DOR) staff obtained the associated gut contents of the filleted fish to conduct taxonomic evaluation and Hg analysis of the gut contents. Laboratory processing of fish samples were not completed in time to meet the 2014 Fish Tissue EMR (Environmental Monitoring Report) publishing deadline. Hence, these results will be presented in the 2015 Fish Tissue EMR.

Introduction

Historically, contaminant releases (i.e., stressors) from the Y-12 Plant to EFPC have been chlorine, mercury (Hg), PCBs (polychlorinated biphenyls), nutrient loading, hydrological regime alteration, miscellaneous spills, and habitat-related factors (Peterson et al. 2011). Previous investigations in EFPC identified mercury and PCBs as the primary substances that have accumulated to elevated levels in fish, and posing health concerns to human consumers and to terrestrial wildlife (Loar et al. 1992, Hinzman et al. 1993, Sample et al. 1996, Southworth et al. 2011). Redbreast sunfish may provide a good sentinel species for toxicity assessments of EFPC because they are ubiquitously distributed throughout the creek, bioaccumulate Hg and PCBs, are relatively short-lived, and found to have restricted home ranges such that contaminant burdens reflect exposure at the site of collection (Southworth 2011). However, since the mid-2000s, the ORNL ESD biologists have found that redbreast sunfish have been increasingly difficult to collect throughout EFPC and rock bass, which typically have higher mercury concentrations in their tissues, have been collected instead. Thus, non-destructive sampling for mercury (i.e., biopsy plug samples) and reducing PCB sampling (which requires sacrificing fish) may alleviate some of the pressure on the redbreast population in EFPC (Peterson et al. 2013). Accordingly, TDEC DOR agreed that it would not be appropriate to initiate another fish shocking project which would add additional pressure on the ORR stream fish community due to over-sampling. Following negotiations, TDEC DOR further agreed to accept the fish guts associated with the fish specimens collected by ORNL ESD for their bioaccumulation study (i.e, fillet analysis). TDEC DOR will execute a taxonomic evaluation of the fish gut contents plus administer mercury analysis.

Mercury and Methylmercury

Although mercury bioaccumulation was found to decrease in EFPC fish in the headwater reach, it has paradoxically increased in the lower reaches of EFPC (Southworth et al. 2000). Both fish and aquatic macroinvertebrate communities in Upper East Fork Poplar Creek (UEFPC) lack key species indicative of unimpaired aquatic systems and are numerically dominated by pollution-tolerant organisms (Peterson et al. 2013). Mercury concentrations in fish in lower EFPC, in contrast to uppermost EFPC, have increased nearly 40% since the mid-1980s (Southworth et al.

2011). Indeed, the fish community at the downstream kilometer 13.8 EFPC site has species richness and abundance that approximately equals background, but average Hg concentrations in redbreast sunfish (i.e., body burdens) at this site have been in the range of 0.6 to 1 mg/kg (ppm) since 1984 (Suter II et al. 1999). In contrast, PCB concentrations in fish generally decreased downstream (Southworth et al. 2011).

Although most mercury occurs in the inorganic form, MeHg, an organic form, is the most toxic and readily bioaccumulated form of mercury. Methylmercury normally occurs in the environment at extremely low concentrations; however, it is taken up easily by aquatic organisms and bioaccumulated. Mercury bioaccumulates in aquatic plants, invertebrates, fish, and mammals, and the concentration tends to increase with increasing trophic level (Hg biomagnifies). Mercury accumulation in fish results from the complex interactions of a series of environmental components, including supply, methylation rates, trophic interactions, and fish bioenergetics (Rodgers 1996). Methylmercury has been reported to constitute from 70 to 99% of the total-Hg in skeletal muscle in fish (Huckabee et al. 1979; EPA 1985; Riisgård and Famme 1986; Greib et al. 1990; Saroff 1990, Spry and Wiener 1991, Bloom 1987, 1992, Southworth et al. 1995, Environment Canada 2002).

In fish, the accumulation of mercury from water occurs via the gill membranes. Gills take up aqueous MeHg more readily than inorganic mercury (Huckabee et al. 1979; Boudou et al. 1991). Methylmercury is eventually transferred from the gills to muscle and other tissues where it is retained for long periods of time (Julshamn et al. 1982; Riisgård and Hansen 1990). However, biomagnifications of MeHg through dietary pathways, rather than gill uptake from water alone, is considered the dominant mechanism for elevated MeHg concentrations in fish (Jernelöv and Lann 1971, Phillips and Buhler 1978, Rodgers and Beamish 1981, Harris and Snodgrass 1993, Rodgers 1994, 1996, Hall et al. 1997).

Elemental Hg, bivalent inorganic Hg, and MeHg are the three most important forms of Hg occurring in natural aquatic environments (Battelle 1987). The process of methylation of inorganic Hg to MeHg, which is highly bioavailable, is thus an important key to the fate of mercury in the environment (Beckvar et al. 1996). Research has demonstrated that MeHg generation may be exclusive to the in-situ Hg methylation by anaerobic, sulfate-reducing bacteria (microbial organisms) such as *Verrocumicrobia*, ε-*Proteobacteria*, and the δ-*Proteobacteria* within the EFPC community (Vishnivetskaya et al. 2011). However, Sellers et al. (1996) suggest that photodegradation of Hg to MeHg may be another important process where light penetration of the water column is significant in aquatic systems. Further detailed information and reviews are available in the scientific literature regarding Hg methylation in aquatic systems (Robinson and Tuovinen 1984, Compeau and Bartha 1985, Craig and Moreton 1983, Berman and Bartha 1986, Callister and Winfrey 1986, Jackson 1986, Weis et al. 1986, Korthals and Winfrey 1987, Foster 1987, Parks et al. 1989, D'ltri 1991, Gilmour and Henry 1991, Kelly et al. 1995, Leermakers et al. 1995, Southworth et al. 1995, 2000, 2011), although chemical methylation also occurs (Weber 1993). Lastly, dissolved organic carbon (DOC) in aquatic systems significantly increases Hg solubility (St. Louis et al. 1994), thus abundant Hg methylation occurs in wetlands where microbial activity and DOC are high (Environment Canada 2002). Indeed, Hurley et al. (1995) demonstrated a positive correlation between % wetland in a watershed (i.e., high DOC) and increased MeHg yield to rivers.

The Food and Drug Administration and EPA now agree that 0.3 ppm is the appropriately protective level for mercury in locally-consumed freshwater fish. Thus, TDEC considers the evidence compelling that fish tissue MeHg levels >0.3 parts per million have a potentially detrimental effect on the health of Tennesseans, particularly children (Denton 2007). Table 1 shows current criteria used for issuing fish consumption advisories in Tennessee.

Table 1. State of Tennessee fish tissue advisory criteria

Contaminant	Level (ppm)
PCBs	1.00
Hg	0.30

Objectives:

1. Identify the principal diet items of the selected ORR stream fish species
2. Identify collected fish to species
3. Assess Hg and methylmercury content of fish gut contents collected from ORR and control streams
4. Determine the magnitude of the contamination in edible portions of EFPC fish species where pollutants could be incidentally consumed by humans

Methods

Study area

The focus of the monitoring effort is the EFPC watershed and comparable reference streams, including Clear Creek, Whites Creek and Hinds Creek. The study area is located in the Valley and Ridge physiographic province of the Southern Appalachians with EFPC headwaters originating within the confines of the Y-12 National Security Complex and extends generally southwest for approximately 25 km to its mouth at Poplar Creek. Parallel northeast-trending ridges constitute the northern (Black Oak Ridge) and southern (Chestnut Ridge) boundaries of the watershed (Peterson et al. 2013). The ridges are composed primarily of sandstones and dolostones and the valleys are underlain by shales, limy shales, and limestones (Geraghty and Miller, Inc. 1985).

Fish sampling

Fish samples were collected in ORR and control streams (Table 2) by the ORNL Environmental Sciences Division by electro-shocking. All fish collected were counted and identified to species, weighed, measured, and age estimated (i.e., young-of-the-year, juvenile, adult). Fish sampling protocols recommend at least six fish per sample for laboratory analysis of metals and PCBs. Fish captured that are large enough for human consumption will be evaluated for risk to human health and smaller fish will be evaluated for risk to the ecosystem. A fish community analysis may also be conducted if sampling efforts are deemed to provide a representative sample of species present at each sampling station. All work associated with this project were conducted in compliance with the Office's 2014 Health and Safety Plan.

Methods include:

1. Electro-shocking in spring and fall (ORNL ESD)
2. Collect fish gut contents (save for TDEC DOR)

Laboratory analyses
The Tennessee Department of Health Laboratory Services has expertise in a broad scope of services and analyses. This expertise is available to the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office and other TDEC divisions statewide. General sampling and analysis methods will follow Environmental Protection Agency (EPA) guidelines as listed in appropriate parts of Title 40 Code of Federal Regulations (CFR). Laboratory Services may subcontract certain analyses and QC samples out to independent laboratories. Bench level quality assurance/quality control (QA/QC) records and chain-of-custody records are maintained at Laboratory Services, as are QA records on subcontracted samples.

DOE-O will primarily use the Tennessee Department of Health's Nashville Laboratory Services. Wet chemistry, metals samples and organics samples will be sent on to the Central Laboratory in Nashville. Methylmercury (MeHg) samples are farmed out and analyzed at Brooks-Rand Laboratory in Seattle, Washington. All Laboratory Services analyses will follow appropriate methods as documented in the Laboratory Services Inorganic Chemistry SOP and Organic Chemistry SOP. Specific analytical methods are covered in the standard operating procedure (SOP) manuals for Laboratory Services. The SOPs direct analysts to the proper EPA or other methodology.

Because MeHg is known to constitute essentially 99% of the total mercury in fish tissue (Environment Canada 2002), for QA/QC purposes, only 10% of fish samples will be analyzed for both total-Hg and MeHg. That is, 90% of fish samples collected for the project will only be analyzed for total-Hg (plus PCBs). Accordingly, the assumption is made that all analytical results (concentration) of total-Hg determined for fish muscle samples will equal the same concentration of MeHg.

Table 2: Potential fish monitoring sites and respective laboratory analyses

	Stream km	Analytes	Expected Species
EFPC	21.5, 18, 14, 6, 1.5	Hg/ MeHg	Redbreast sunfish, rockbass, bluegill, stonerollers, carp, largemouth bass, other species
BCK	12.3, 9.6	Hg/ MeHg	Available species, as above
MIK	1.43, 0.71, 0.45	Hg/ MeHg	Available species, as above
Hinds Creek	20.6 (reference)	Hg/ MeHg	Redbreast sunfish, rockbass, bluegill, stonerollers, carp, largemouth bass, other species
Whites Creek	2.3 (reference)	Hg/ MeHg	Redbreast sunfish, rockbass, bluegill, stonerollers, carp, largemouth bass, other species
Clear Creek	1.45 (reference)	Hg/ MeHg	Redbreast sunfish, rockbass, bluegill, stonerollers, carp, largemouth bass, other species

Fish electro-shocking

ORNL ESD fisheries biologists collected fish from ORR and reference streams (Figures 1-3) twice during 2014 (i.e., spring and fall) using a backpack electro-shocker to obtain fish specimens for a bioaccumulation study (i.e., Hg, PCBs). Whenever possible, the fisheries biologists collected biopsy plugs from the shocked fish for Hg analysis because taking fillet samples requires sacrificing the fish, thus, the less invasive and preferred sampling method is collection of biopsy plug samples (for Hg analysis). Field sampling procedures followed the guidance and standard operating procedures of the ORNL ESD, Adams et al. (1999), Barbour et al. (1999), EPA (2000), and Peterson et al. (2013) for sampling in wadeable streams to assess fish assemblages.

Fish gut contents sampling

Several nonlethal methods have been developed to sample the stomach contents of fish, including gastroscopes, tubes, stomach suction, stomach flushing, emetics, forceps, and chronic fistulas (Strange and Kennedy 1981, Kamler and Pope 2001, Waters et al. 2004). Techniques have been devised which enable removal of stomach contents without harming the fish and among the simplest of these is removing stomach contents with forceps (Wales 1962). Fish gut contents will be analyzed for Hg and MeHg. Samples were received frozen from the ORNL ESD and will be kept frozen until processing (taxonomic evaluation of gut contents) and Hg analysis.

Fish tissue (fillets)

Redbreast sunfish (*Lepomis auritus*) are a primary species for contaminant analysis (i.e., body burden of Hg and PCBs), but rock bass (*Ambloplites rupestris*), bluegill (*Lepomis macrochirus*) or other species may also be sampled if redbreast sunfish are unavailable. Sunfish species are ideal fish to monitor changes in bioaccumulation over time or space; they are short-lived and sedentary and thus represent recent exposure to contaminants at the site of collection (Peterson et al. 2013). Muscle tissue from six individual fish from each site will be analyzed for mercury and/or PCBs. At sites where PCB analyses are conducted, muscle fillets of fish will be taken as a sample size of at least 3 grams is needed for PCB analysis. However, for fish that only need mercury analysis, a nondestructive technique known as a biopsy sample is taken from the live fish (i.e., only 100 mg of tissue required for Hg analysis), and then the fish are tagged using a Passive Integrated Transponder (PIT) and re-released at the site of capture (Figures 4 and 5, Peterson et al. 2013). This method provides the additional advantage where the same individual fish may be re-captured in the future and re-analyzed for mercury again allowing for an assessment of bioaccumulation and growth rates. This is particularly important for redbreast sunfish (*Lepomis auritus*) because this species has been increasingly difficult to collect throughout EFPC and rock bass, which typically have higher mercury concentrations in their tissues, have been collected by other researchers as a surrogate species for contaminant analysis (Peterson et al. 2013). In short, non-destructive sampling for mercury and reducing PCB sampling (which requires sacrificing fish) may alleviate some of the pressure on the redbreast population in EFPC (Peterson et al. 2013). Fish sampling and sample preparation techniques will follow the guidance of the Environmental Protection Agency's standardized practices for sampling and analyzing fish (EPA 2000), fish sample preparation techniques from Southworth et al. (2011), but also see techniques in Peterson et al (2013) for biopsy plug sampling.

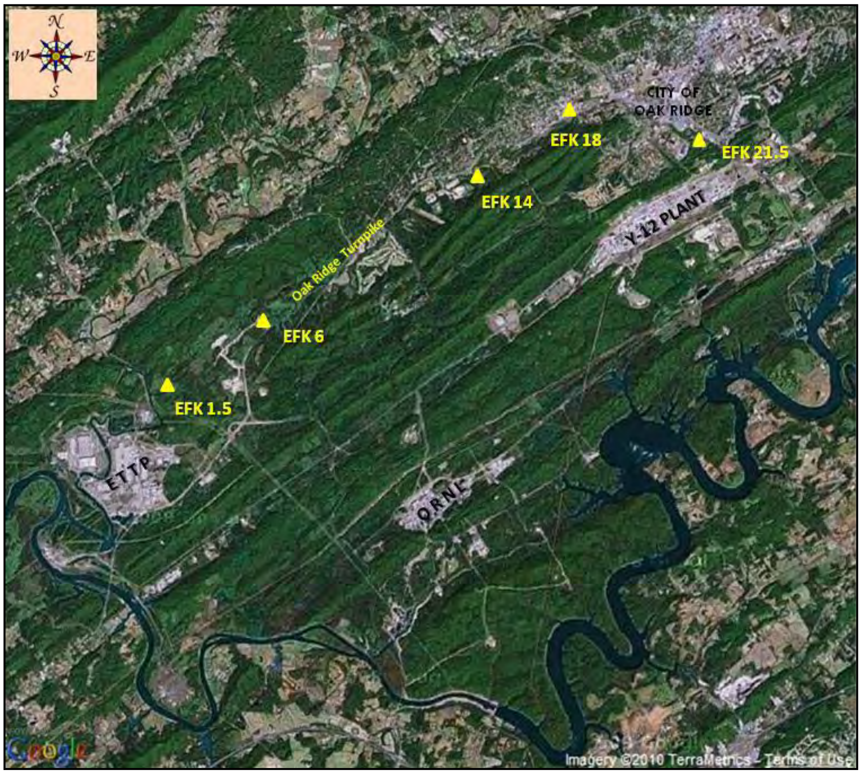

Figure 1: Fish monitoring sites in East Fork Poplar Creek

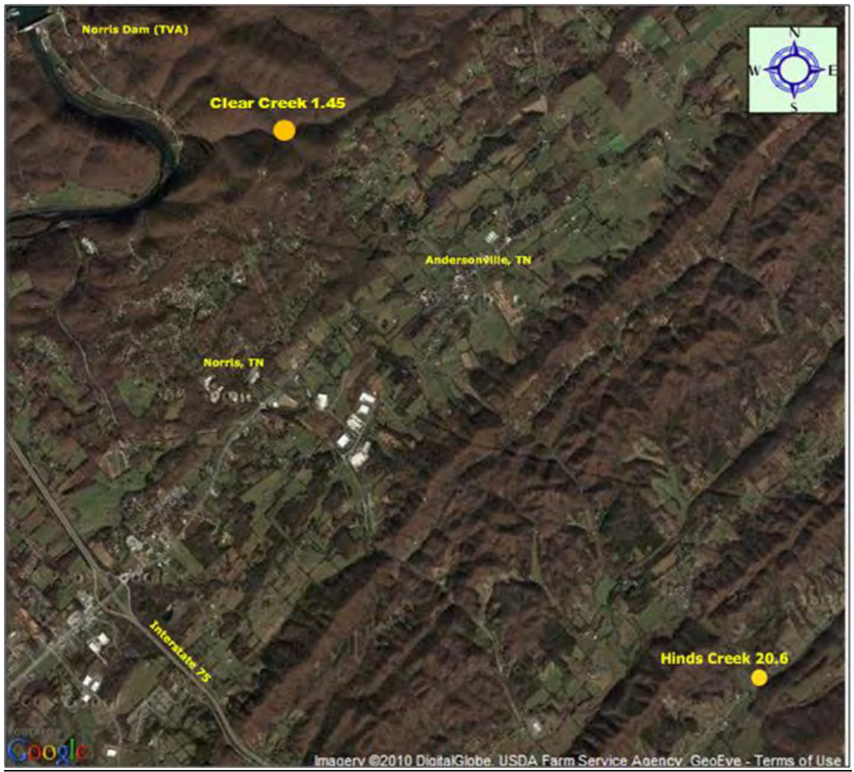

Figure 2: Fish monitoring sites at Clear Creek and Hinds Creek reference streams

Figure 3: Fish monitoring site at Whites Creek reference stream

Figure 4: Fish biopsy plug sample.
(Photo credit: Peterson et al. 2013)

Figure 5: Passive Integrated Transponder (PIT) tag equipment for identification of fish recaptures.
(Photo credit: Peterson et al. 2013)

Results

Approximately twenty-five fish gut samples, collected during 2014 from ORR and control streams, were obtained from the ORNL ESD biology staff. However, laboratory processing of fish samples were not completed in time to meet the 2014 Fish Tissue EMR (Environmental Monitoring Report) publishing deadline. Hence, these results will be presented in the 2015 Fish Tissue EMR.

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Pilot Project: Bioaccumulation Study of Metals in Fungi from East Fork Poplar Creek Floodplain

Principal Author: Gerry Middleton

Abstract

During 2014, the Tennessee Department of Environment and Conservation (Division of Remediation, [DOR]) staff collected mushroom sporocarps and other fungi in the upper East Fork Poplar Creek (EFPC) floodplain contaminated by legacy mercury (Hg) releases from the upstream Y-12 National Security Complex (Oak Ridge Reservation, ORR). It has been well documented by researchers that fungi, including wild edible mushrooms, bioaccumulate significant concentrations of mercury and other heavy metals within their fruiting bodies (i.e., sporocarps). Our question: does consumption of wild edible mushrooms (potentially contaminated with Hg) collected from EFPC floodplain pose a potential health concern to a human receptor? Consequently, the goal of the project was to determine if mercury (i.e., toxic methylmercury) is being taken-up by EFPC fungi at concentrations greater than control samples. Although attempts were made to collect edible mushrooms such as morels, sample availability for all species was sparse during 2014 field sampling excursions. Nevertheless, office staff collected nineteen fungi samples including edible chanterelles in the EFPC floodplain. Field sampling was conducted in EFPC floodplain locations south of the Staybridge Suites/former Kroger site and the Holiday Inn Express in Oak Ridge, Tennessee. Laboratory analyses revealed total Hg concentrations in collected fungi samples ranged from 0-29.0 mg/kg (dry weight); the control fungi sample (i.e., background) yielded a total Hg result = 5.4 mg/kg (dry weight). Staff collected 7 samples of known edible fungi with a mean Hg content = 0.52 mg/kg (dry weight). Thus, the Hg uptake in the edible mushrooms collected during 2014 was well below the background sample result of 5.4 mg/kg (dry weight).

Introduction (Fungi and Mushrooms)

There are more than10,000 described species of mushrooms in North America (>75,000 species worldwide), but little is known regarding species present on the ORR. A mushroom is the fruiting body of a larger underground fungus that typically appears aboveground and contains the reproductive units, or spores of the organism (Lincoff 1981, Figure 1). Although fungi and mushrooms are usually considered members of the plant kingdom, they differ from most plants in that they lack chlorophyll and are not photosynthetic, hence they must obtain their nutrition from other living or dead organisms (i.e., decomposers; Lincoff 1981). Fungi meet their nutritional requirements in three ways: as saprophytes, as parasites, and as mycorrhizae. Saprophytes decompose and recycle dead organic matter such as dead wood, dead tissue of trees, dung, leaf litter, or conifer trees. Many mushroom species live symbiotically with host trees, colonizing the fine roots of trees and forming underground structures called mycorrhizae (literally “fungus-roots”; Pilz et al. 2003) or mycelium which are often manifested by fairy rings of mushroom fruiting bodies at the ground surface. Parasitic fungi attack living plants (or animals) to meet their nutritional requirements (Lincoff 1981). High soil humidity during the fruiting season also allows mushrooms to continue growing without drying out (Kasparavičius 2000). A few fungi species, such as Chanterelles, grow slowly (2 to 5 cm per month) and persist for an average of 44 days and occasionally more than 90 days (Largent and Sime 1995, Norvell 1995, Weber 2001). However, the average lifetime of mushroom fruiting bodies is 10-14 days (Das 2005).

Green vascular plants accumulate large concentrations of heavy metals including inorganic mercury and methylmercury from sediment and water in root, stem, and leaf sections (Alberts et al. 1990; Boudou et al. 1991, Kalač and Svoboda 2000, 2005). In contrast, heavy metal concentrations in cryptogams (i.e., lower plants such as fungi that reproduce by spores) are considerably greater than those in agricultural crop plants, vegetables, and fruit (Manzi et al. 2001, Zhu et al. 2011).

Wild edible mushrooms such as the King Bolete (*B. edulis*) and the common chanterelle (*C. cibarius*; Kasparavičius 2000) have been documented as effective bioaccumulators of methyl-Hg from impacted substrates which is a human health concern (Ferlandysz and Bielawski 2001, Stihi et al. 2011, Falandysz 2012a).

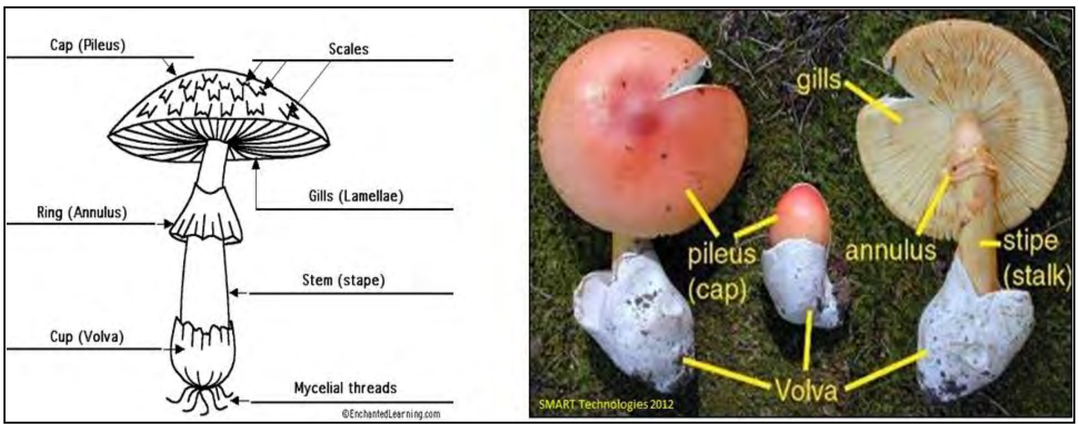

Figure 1: Mushroom morphology

Guidance and Advisories: Human Exposure to Hg-Contaminated Food

Contamination of food resources associated with the industrial releases of mercury (Hg) to the environment continues to be a threat to food safety (Olivero et al. 2002). To protect human health and the environment, TDEC and the Environmental Protection Agency mandated Hg and methyl-Hg advisories for public consumption of fish and shellfish: "TDEC uses 0.3 ppm as a trigger point for consideration of fishing advisories for Tennessee waters. The type of advisory considered appropriate when methylmercury (methyl-Hg) levels are over 0.3 ppm, but not above 1.0 ppm, will be the precautionary advisory which advises pregnant or nursing mothers, plus children, to avoid any consumption of fish. All other persons will be advised to limit fish consumption to one or two meals per month. If 1.0 ppm is exceeded, all persons will be advised to avoid consumption in any amount" (Denton 2007). However, based upon a literature review, it appears there is little or no existing state or federal guidelines/regulations providing advisory limits for Hg and methyl-Hg that may be consumed in foods such as wild edible mushrooms. The U.S. Food and Drug Administration does provide guidance and precautions regarding consumption of poisonous wild mushrooms (USFDA 2013), but little or no guidance or advisories relating to heavy metals in mushrooms was found in the scientific literature.

According to data compiled by the U.S. Department of Agriculture's (USDA) Economic Research Service (ERS), per capita use of all mushrooms (on a fresh-weight basis) totaled about 4.0 pounds in 2011 (USDA 2011), compared with about 0.69 pounds in 1965 (Lucier et al.

2003). Surveys have determined that 22 percent of Americans collect wild mushrooms, and 15 percent consume the mushrooms they collect (Fine 1998). In contrast, more than 50% of Scandinavians pick and consume approximately 1 kg per capita annually of wild edible mushrooms (Hultman 1983, Zhang et al. 2010). In the Czech Republic, 72 % of families take part in wild-mushroom picking, with an average yield of 7-10 kg fresh weight per household annually. In the Sichuan Province in China, the annual wild mushroom consumption rate exceeded 20-24 kg per capita (Zhang et al. 2010). So, it is clear that worldwide consumption of wild edible mushrooms is significant.

In order to protect human exposure from Hg found in the food supply, the international Joint Food and Agriculture Organization (United Nations/World Health Organization Expert Committee (Joint FAO/WHO, or "JECFA") on Food Additives established an inorganic Hg provisional tolerable weekly intake (PTWI) = 4.0 μg/kg (0.004 mg/kg) body weight (bw) and a PWTI for methyl-Hg = 1.6 μg/kg (0.0016 mg/kg) body weight in 2010 (JECFA 2010, 2011). Subsequent meetings of the European Food Safety Authority (EFSA, United Nations) in December 2012, considered new developments regarding inorganic Hg and methyl-Hg toxicity and evaluated whether the JECFA provisional tolerable weekly intakes for methyl-Hg of 1.6 μg/kg bw and of 4 μg/kg bw for inorganic Hg were still appropriate. The 72nd JECFA noted that there was a lack of quantitative data on methylmercury in non-fish products and on inorganic mercury in foods in general. In line with JECFA, the EFSA Contamination Panel established a tolerable weekly intake (TWI) for inorganic Hg of 4 μg/kg (0.004 mg/kg) bw, expressed as mercury. For new developments in epidemiological studies on methyl-Hg, , the EFSA panel established a TWI for methyl-Hg = 1.3 μg/kg (0.0013 mg/kg) bw, expressed as mercury (EFSA 2012).

Some species of higher mushrooms, however, accumulate, in their fruiting bodies, levels of mercury that are higher than these limits (Stijve and Roschnik 1974, Falandysz et al. 2002, Tüzen and Soylak 2005, Falandysz et al. 2007). The USFDA has issued a 1 ppm action level for Hg in wheat (pink kernels; USFDA 2000). This is the closest Hg action level currently available that could be used for comparison with mushroom Hg results.

Heavy Metals and Mercury

Mercury is an environmental contaminant that is present in fish and seafood products largely as methyl-Hg. Food sources other than fish and seafood products may also contain mercury (i.e., plants, vegetables, etc.), but mostly in the form of inorganic mercury (JECFA 2010, 2013). Although current interest in the ecotoxicity of mercury is mainly focused on the bioaccumulative form methylmercury, inorganic mercury [Hg(II)] is also a significant environmental pollutant. The inorganic form of the metal exerts direct toxic effects towards a variety of organisms including microbes, invertebrates and plants (Tipping et al. 2010). Mercury, and especially the organic form methyl-Hg, are highly toxic for microorganisms, animals and humans (Boening 2000, Mason and Benoit 2003). Interestingly, different groups of organisms like bacteria and mushrooms have demonstrated the capacity to methylate Hg (Vonk and Sijpesteijn 1973). A positive association was found between soil methyl-Hg concentrations and the concentrations in fruiting bodies of fungi (Fischer et al. 1995). A similar relationship was also observed for total Hg in the fruiting bodies of *Macrolepiota procera* and *Mycena* spp. (Falandysz and Chwir 1997).

Metal contents in fruiting bodies are affected by the age and sheer size of the subterranean mycelium and the interval between fructifications (i.e., formation of fruiting bodies; Das 2005). Mushrooms are well known to take up and bioconcentrate Hg (e.g. Stegnar et al. 1973, Byrne et al. 1976, Seeger and Nutzel 1976, Minagava et al. 1980, Kalač et al. 1991, 1996, Sesli and Tüzen 1999, Alonso et al. 2000, Svododa et al. 2000, Falandysz et al. 2002, 2003, Cocchi et al. 2006; Ita et al. 2006, Svoboda et al. 2006, Melgar et al. 2009) due to their filamentous mode of growth, branching and extra cellular release of enzymes and metabolites. In contrast, studies on the accumulation of methyl-Hg in mushrooms are few (Stegnar et al. 1973; Minagava et al. 1980; Bargagli and Bald 1984; Fischer et al. 1995).

Mercury released to the atmosphere can be distributed over long distances and deposited in areas far away from its source. For example, long-lived lichens in the subpolar latitudes take up significant quantities of atmospheric mercury in their thallus (body) and are consumed by caribou and reindeer which bioaccumulate body burdens of Hg.

Anthropogenic activity such as mining, ore processing (Kalač et al. 1996; Svoboda et al. 2000, Kocman et al. 2004; Swain et al. 2007) or heavy industry (Zagury et al. 2006; Gibičar et al. 2009) may often foster higher concentrations of heavy metals such as Hg in soils and water. Numerous fungi heavy metal studies have been completed globally and subsequent reported Hg concentrations in mushroom fruiting bodies range from <1.0 ng/g in fairly undisturbed pristine environments to >200,000 ng/g near mines, industrial facilities, and smelter sites (Stijve and Roschnik 1974, Seeger and Nutzel 1976, Bargagli and Baldi 1984, Zurera et al. 1986, Kalac et al. 1991, 1996, Alonzo et al. 2000, Demirbaş 2000, 2001, Falandysz and Bielawski 2001, Falandysz et al. 2002, Cocchi et al. 2006. Dursun et al. 2006, Svoboda et al. 2000, 2006, Yamaça et al. 2007, Chen et al. 2009, Falandysz et al. 2011, Rieder et al. 2011, Zhu et al. 2011, Quarcoo and Adotey 2013). To our knowledge, metals content of wild edible mushrooms, specifically mercury concentrations, has seldom been investigated on the Oak Ridge Reservation (ORR).

Methylmercury

Methyl-Hg, the most toxic form of mercury, is found mainly in aquatic environments at the base of the food web, and is biomagnified at each successive trophic level of the food chain as predatory organisms bioaccumulate increasing concentrations of methyl-Hg (JECFA 2011, 2013). Generally, methyl-Hg, and also total mercury levels in terrestrial animals and plants, are usually very low (JECFA 2011, 2013). Further, a positive association is known to exist between soil methyl-Hg concentrations and the concentrations in fruiting bodies of fungi, although the number of evidences is very limited (Fischer et al. 1995). A similar relationship was also observed for total Hg in Parasol Mushroom, *Macrolepiota procera* (Falandysz and Chwir 1997). It can be argued that some of the mercury uptake by green plants and mushrooms is due to atmospheric deposition from fossil fuel power plant emissions and natural sources. However, National Priority List sites (i.e., the U. S. Department of Energy's Y-12 National Security Complex) that release industrial wastewater into the environment often pollute floodplain soils with stream deposited anthropogenic mercury and other heavy metals which may be taken-up (bioabsorbed) by plants and fungi.

Methylmercury concentrations in water, soil, and sediments are usually very low especially when compared to the less toxic inorganic form (Zhang et al. 2010). However, methyl-Hg can accumulate (bioaccumulation) and be magnified (biomagnification) in aquatic food webs and even some terrestrial plants, for instance rice, eventually posing a serious threat to humans through the consumption of fish and/or rice (Zhang et al. 2010). Methylmercury enters the base of the food web and is bio-magnified at each successive level of the food chain. The highest methyl-Hg levels are found in predators at the top of the aquatic food web (USGS 2013).

Methods

The study site included reaches of the upper East Fork Poplar Creek (EFPC) floodplain in Oak Ridge, Tennessee. Sampling sites were selected based upon high concentrations of Hg present in EFPC floodplain soil samples (OREIS Database; Figure 2). Specifically, we sampled two main areas during 2014: (1) the EFPC floodplain behind and south of the K-Mart and Staybridge Suites hotel, and (2) the EFPC floodplain behind and south of the Holiday Inn Express hotel (Figures 3-4). Our control sampling location was in the EFPC floodplain in west Oak Ridge (Figure 5).

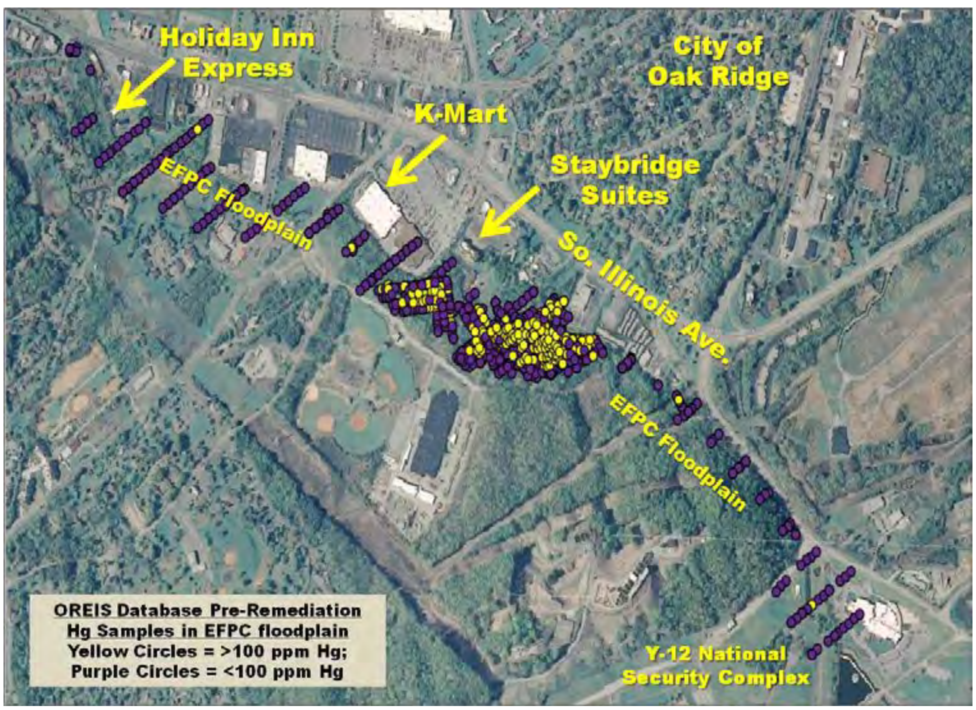

Figure 2: Former mercury soil sampling locations (OREIS Database)

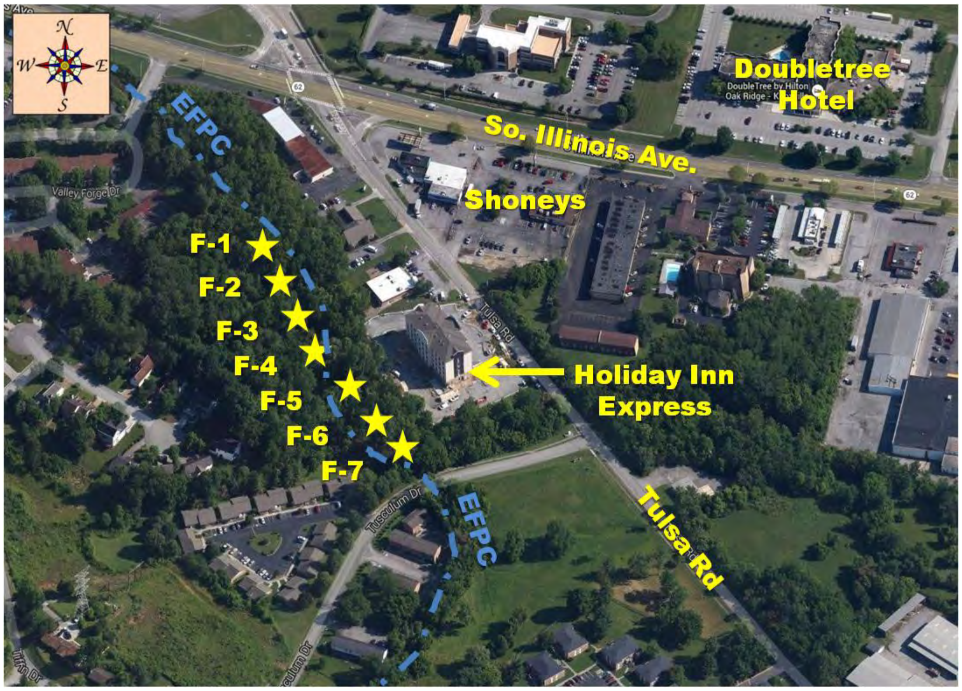

Figure 3: East Fork Poplar Creek (EFPC) / Holiday Inn Express sampling sites

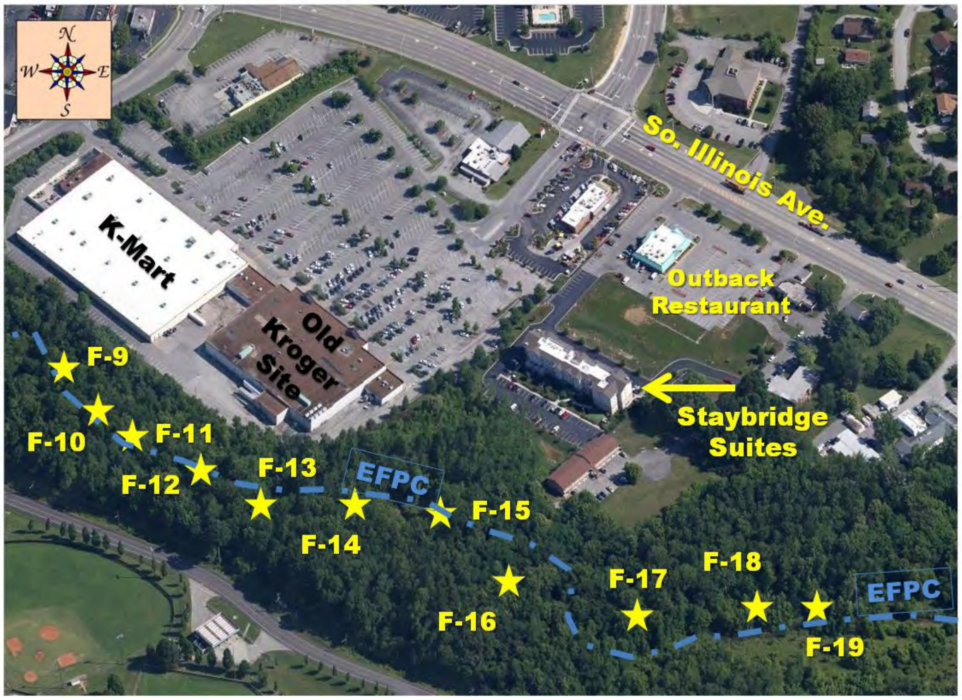

Figure 4: East Fork Poplar Creek (EFPC) / K-Mart/Staybridge Suites sampling sites

Figure 5: Control (background) sampling site: EFPC floodplain (west Oak Ridge)

This project will require multi-year surveys taking advantage of precipitation events as a sampling trigger to increase the probability of collecting most if not all the resident fungi in East Fork Poplar Creek floodplain (North et al. 1997, Brown 2002, Castellano et al. 2004, Molina 2008). The greater the number of survey visits, the less chance of a false negative survey result and the greater chance of sampling maximum species richness (Smith et al. 2002, Lodge et al. 2004). Our survey protocol is written to target more than one fungal species, which maximizes field visits and efficiency. Specifically we were interested in collecting wild edible mushroom species wherever possible in the floodplain. These methods can also be used for site revisits that are occasionally needed to monitor continued species presence. This standard operating procedure is developed by and modified from macrofungi survey protocols and guidelines found in the scientific literature (Eckl et al. 1986, Halling 1996, Fine 1998, Rossman et al. 1998, Castellano et al. 1999, 2004, O'Dell 1999, Derr et al. 2003, Falandysz et al. 2004, Lodge et al. 2004, Halling and Mueller 2005, Van Norman et al. 2008, Elekes et al. 2010, Radulescu et al. 2010, Van Norman and Huff 2012, and Vinichuk 2012).

During the 2014 field season, we conducted sampling trips in May, June, October, and November following significant precipitation events. The plan was to sample mushrooms using two methods: (1) random sampling, and (2) sampling of fixed-size plots. During initial field sampling excursions, it became rapidly apparent that the fixed-size plots sampling method would be rather futile because the overall abundance of mushrooms and fungi was very sparse. In fact, the initial two surveys yielded few or no fungi samples. Eventually, it became necessary to walk down a large portion of the two separate study areas (K-Mart/Staybridge site and the Holiday Inn Express site) several times in order to collect a minimal amount of sample material.

In the field, entire fungal sporocarps (i.e., fruiting body) were collected from each of the 18 East Fork Poplar Creek floodplain study sites plus one control (background) sample site. Fresh latex gloves were worn while sampling to prevent cross-contamination. Established fungi sampling protocols suggests that sampling plots be approximately ten square meters and additional subplots may be added if mushrooms are sparse and additional sampling is necessary to bolster fungal biomass for laboratory analyses (Halling 1996, Rossman et al. 1998, O'Dell 1999, Derr et al. 2003, Falandysz 2002, Falandysz et al. 2003, Van Norman and Huff 2012). However, during 2014 field excursions, sampling was limited to mushrooms and fungi that were actually available at a given location on that particular sampling day, and the sampling plot/subplot protocol unraveled.

The goal was to collect enough fruiting bodies of each species to provide a 5-10 gram dry weight sample for laboratory analysis (Eckl et al. 1986). Mushrooms were photographed before extraction as an aid to taxonomic identification of each sporocarp. Mushrooms were carefully extracted from substrates with plastic, glass or pottery instruments to avoid any metal contacts that can influence the results (Elekes et al. 2010). Samples were stored either in plastic tackle boxes, wax paper or aluminum foil for transport to the laboratory. Samples were stored in at 4°C until analysis at the analytical laboratory (Halling 1996, Rossman et al. 1998, O'Dell 1999, Derr et al. 2003, Castellano et al. 2004, Van Norman et al. 2008, Van Norman and Huff 2012).

A brief habitat description was recorded for each sampling location including the substrates sampled (dead or living wood, soil or leaf litter). Tree species growing in the area were also noted, because many fleshy fungi will associate with particular types of tree roots.

Once collected, the mushroom specimens were wrapped in aluminum foil or waxed paper, and placed in a plastic box or fishing tackle box for protection and moisture retention while in the field. The wrapped mushrooms were then placed in a sturdy basket, box, or bag, and carried to the laboratory. Care was taken to prevent delicate mushrooms from being broken. Small tin boxes, rigid plastic boxes, or fishing tackle boxes are useful for collecting and transporting small or fragile specimens (Halling 1996, Rossman et al. 1998, O'Dell 1999, Derr et al. 2003, Castellano et al. 2004, Van Norman et al. 2008, Van Norman and Huff 2012).

Equipment List

- Aluminum foil, wax paper bags (full sandwich size) or brown paper bags and a roll of aluminum or wax paper for larger specimens (fungi can be placed inside and the ends twisted to contain the specimen like a tootsie-roll)
- Plastic trowel or large knife to dig up base of sporocarps
- Specimen field tags
- Survey data forms and fungal description forms
- GPS unit
- Camera, preferably digital
- Permanent marking pens
- Flagging and permanent tags to mark collection sites
- Basket, fishing tackle box, field pack or bucket to carry collected specimens

Laboratory Procedures

The Tennessee Department of Health, Environmental Laboratory and Microbiological Laboratory Organization (the state lab) has expertise in a broad scope of services and analyses available to the Tennessee Department of Environment and Conservation (TDEC) Department of Energy Oversight (DOE-O) and to other TDEC divisions statewide. General sampling and analysis methods are to follow Environmental Protection Agency (EPA) guidelines as listed in appropriate parts of 40 Code of Federal Regulations (CFR) as well as TDEC sampling procedures and health and safety guidelines (TDH 1999, Yard 2013). Laboratory Services may subcontract certain analyses and QC samples out to independent laboratories. For example, methylmercury samples are typically farmed out to Brooks-Rand Laboratory, Seattle, Washington for analysis. Bench level Quality Assurance/Quality Control (QA/QC) records and chain-of-custody records are maintained at the Tennessee Environmental Laboratory, as are QA records on subcontracted samples. However, only total mercury analyses were conducted on 2014 samples. We assume that the greater part (>90%) of the bioaccumulated Hg in the fungi samples to be methyl-Hg.

Fungi samples were identified (prior to cleaning and drying) to as low a taxonomic level as possible using the following literature: Peterson 1977, Miller 1978, Lincoff 1981, Barron 1999, Courtecuisse 1999, Foster and Duke 2000, Phillips 2005, Bessette et al. 2007, Ostry et al. 2011. Specimens were re-photographed in the lab prior to sample preparation activities for archival purposes.

Freshly collected fruiting bodies of mushrooms were washed with deionized water to remove extraneous material (i.e., plant and substrate debris) and cut with a clean plastic knife in small pieces (Falandysz et al. 2004). Samples were dried at 60°C between 12 and 15 h in an oven (Radulescu et al. 2010, Rieder et al. 2010, Falandysz et al. 2012b) and finally weighed (Halling 1996, Rossman et al. 1998, Falandysz 2002, Derr et al. 2003, Falandysz et al. 2003, Radulescu et al. 2010, Van Norman and Huff 2012). Species determined to be edible were examined to consider how mercury may impact human health and those deemed inedible will be examined to determine if there are risks to wildlife and the ecosystem. For example, box turtles and white-tailed deer are known to consume mushrooms.

Dried mushrooms were sealed in polyethylene bags and labeled with chain of custody labels for delivery to the laboratory for mercury analysis (Halling 1996, Rossman et al. 1998, Falandysz 2002, Derr et al. 2003, Falandysz et al. 2003, Van Norman and Huff 2012).

Results

Overall, we collected 19 mushroom/fungi samples during 2014; 18 samples from impacted sites plus one control sample. Table 1 and Figure 6 present the laboratory analytical results for those samples (stations F-1 through F-19) for total mercury (mg/kg (dry weight, dw). The control sample (station F-8, west Oak Ridge) yielded a total Hg result = 5.4 mg/kg (dw); *Chlorophyllum* sp. mushroom. Reported total Hg values ranged from 0-29 mg/kg (dw) and the statistical mean, 2.29 mg/kg (dw). The results for three samples reported 0 mg/kg (non-detect; we assumed ND = 0). *Marasmius rotula* (Pinwheel mushroom), collected at station F-13 in the EFPC floodplain south of and behind the former Kroger store, contained the highest total Hg concentration, 29 mg/kg (dw). It is important to note that the station F-13 sample was the only sample to exceed the total Hg of the control sample. However, at station F-16, a second sample of *M. rotula* yielded a considerably lower Hg concentration, 0.66 mg/kg (dw). Kalač et al. (2004) found that *Marasmius* sp. bioconcetrated Hg at levels between 0.73-0.93 mg/kg (dw). Yilmaz et al. (2003) reported that *Marasmius* sp. also bioconcentrates large quantities of lead (Pb).

Additional samples collected from the EFPC floodplain reporting total mercury values >0.50 mg/kg (dw) included station F-5 (unknown black fungi, 1.7 mg/kg, dw), station F-6 (Coral fungi, 0.70mg/kg, dw), station F-10 (roof mushroom, 1.8 mg/kg, dw), station F-16 (*Marasmius* sp., 0.66 mg/kg, dw), and station F-18 (puffball, 2.3 mg/kg, dw). Figures 7-23 are photographs of species encountered and sampled during 2014 in the EFPC floodplain. Although we did not find specimens of the highly prized morel mushrooms, we did collect specimens from ten different wild edible mushroom or fungi groups in EFPC floodplain. Most of these groups likely contain genera with species that are edible and other species of the same genus that are poisonous. Hence, it is important to be 100% positive of wild mushroom identifications before consumption. For example, mushroom species within the *Amanita* genus such as the Destroying Angel and Death Cap are deadly poisonous while other species of *Amanita* are not toxic.

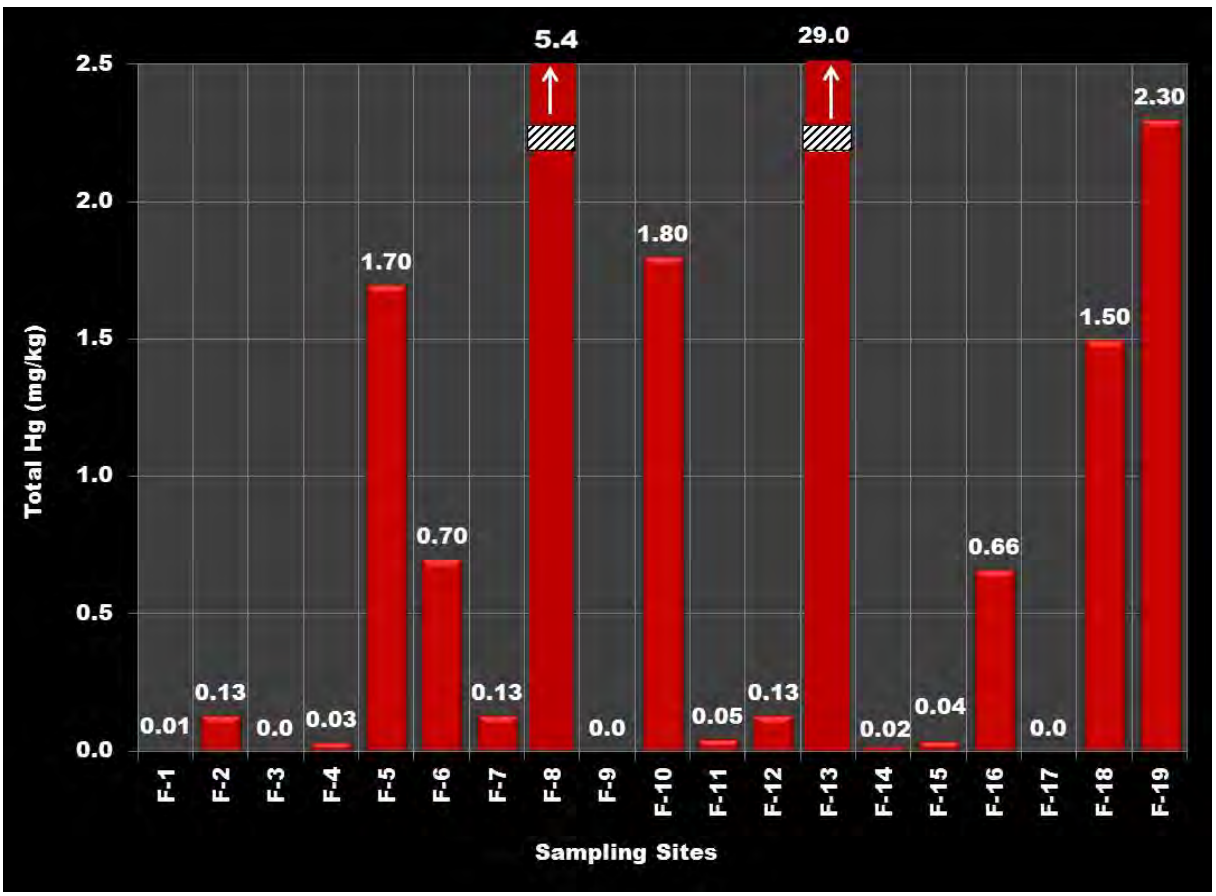

Figure 6: Bar-graph of total mercury results (mg/kg, dw) in fungi samples, East Fork Poplar Creek

Table 1: Mushroom and fungi sample results (mg/kg, dw, total mercury)

Site #	Site Description	Sampling Date	Fungi Taxa (Common & Scientific Name)	Edibility[1]	Total Hg[2] (mg/kg)	*Descriptive Statistics*	
F-1	UEFPC floodplain/south of Holiday Inn Express, Oak Ridge		*Russula* sp. (red) Russulaceae Family	Some edible, some poisonous	0.010		
F-2	UEFPC floodplain/south of Holiday Inn Express, Oak Ridge	10/8/2014	*Amanita* sp. (white) Amanitaceae Family	Many *Amanita* species are **deadly** poisonous	0.13	Mean	2.2943
F-3	UEFPC floodplain/south of Holiday Inn Express, Oak Ridge	10/8/2014	Chanterelle (Cantharellaceae) *Cantharellus cibarius*	Edible, with caution	0	Standard Error	1.5148
F-4	UEFPC floodplain/south of Holiday Inn Express, Oak Ridge	10/8/2014	Dead man's fingers (Flask Fungi) *Xylaria polymorpha*	Not edible but some species of this group used medicinally	0.032	Median	0.13
F-5	UEFPC floodplain/south of Holiday Inn Express, Oak Ridge	10/8/2014	*Golden-gilled gerronema* ** *Gerronema* aff. *strombodes*	Edibility uncertain, avoid!	1.7	Mode	0.13
F-6	UEFPC floodplain/south of Holiday Inn Express, Oak Ridge	10/8/2014	Coral fungi Clavariaceae Family	Some edible, some toxic	0.70	Standard Deviation	6.603
F-7	UEFPC floodplain/south of Holiday Inn Express, Oak Ridge	10/8/2014	Jelly fungi Agaricomycotina (Tremellales)	Most species edible; few species posionous	0.13	Sample Variance	43.6
F-8	North Boundary Greenway (Oak Ridge)/ Near Lambert Quarry	10/8/2014 Control	*Chlorophyllum* sp. (white) Agaricaceae Family	Poisonous	5.4	Kurtosis	17.21
F-9	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	Chanterelle (Cantharellaceae) *Cantharellus cibarius*	Edible, with caution	0	Skewness	4.0854
F-10	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	Honey fungus ***Armillaria* sp.	Edible, with caution	1.8	Range	29
F-11	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	Weeping milk-cap ***Lactarius* aff. *volemus*	Edible, with caution	0.046	Minimum	0
F-12	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	Turkey-tail fungi (Polyporaceae) (*Trametes versicolor*)	Not a delicacy, but edible; cancer medicinal properties	0.13	Maximum	29
F-13	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	*Pinwheel mushroom* ** *Marasmius* sp. (*M. rotula*)	Inedible	29	Sum	43.592
F-14	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	White shelf/bracket fungi (Polyporaceae Family)	Some edible, some inedible; few species used medicinally	0.018	Count	19
F-15	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	Bolete (*Boletus* sp.) Boletaceae Family	Some edible, some poisonous	0.036		
F-16	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	*Pinwheel mushroom* ** *Marasmius* sp. (*M. rotula*)	Inedible	0.66		
F-17	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	Rooted agaric **Hymenopellis furfuracea (syn: Oudemansiella furfuracea, Xerula furfuracea)	Edibility uncertain, avoid!	0		
F-18	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	Puffballs Bassidiomycota (Agaricales)	Most species edible when puffballs are young	1.5		
F-19	UEFPC floodplain/south of Staybridge Suites, Oak Ridge	11/5/2014	Unknown fungi	unknown	2.3		

[1]**WARNING**: Although we provide information about edibility, **DO NOT eat** any mushroom unless you are absolutely certain of its identity and that it is safe to consume; many mushroom species look alike and some species are **deadly poisonous**.

[2]Laboratory: minimum detection limit (mdl) = 0.0039 mg/kg

**Taxonomic identifications courtesy of Dr. Brandon Matheny & Dr. Ron Petersen, University of Tennessee Ecology & Evolutionary Biology Department. Note that in some cases, all diagnostic features were not available during diagnosis because the specimens were identified from photographs.

Conclusions

Based upon the 2014 total mercury results, it is clear that mushrooms in EFPC are in fact bioaccumulating Hg from the contaminated floodplain sediments and soils. However, the sample size (n=19) is too small to generate speculations or make too many conclusions at this point in time.

Of special note, 16 of 19 mushroom/fungi samples exceed the Joint FAO/WHO (JECFA 2010, 2011) and European Food Safety Authority (EFSA 2012) limits of 0.004 mg/kg body weight (bw; average North American bw = 70 kg/person; 70 kg x 0.004 mg/kg = 0.28 mg/kg) inorganic Hg for fish and food additives. The reader is referred to the ATSDR website for further information regarding dosage (http://www.atsdr.cdc.gov/HAC/phamanual/appg.html). Eight mushroom/fungi samples exceed the Tennessee action level of 0.3 ppm methyl-Hg (fish consumption advisory) and six exceed the USFDA limit of 1.0 ppm Hg (for wheat, USFDA 2000). The average Hg content for edible fungi collected from East Fork Poplar Creek floodplain (seven samples) = 0.52 mg/kg (dw). This outcome is considerably below the reference site sample result = 5.4 mg/kg (dw). Office staff will resume and expand fungi sampling in spring 2015 to address the data gaps regarding bioaccumulation of Hg in fungi.

Figure 7: (site F-1): *Russula* sp.

Figure 8: (site F-2): *Amanita* sp.

Figure 9: (site F-3): Chanterelle (photo similar to fungi actually sampled)

Figure 10: (site F-4): Dead man's fingers (photo similar to fungi actually sampled)

Figure 11: (site F-5): Golden-gilled gerronema

Figure 12: (site F-6): Coral fungi

Figure 13: (site F-7): Jelly Fungi

Figure 14: (F-8): *Chlorophyllum* sp.

Figure 15: (F-9): Chanterelle
(photo similar to fungi actually sampled)

Figure 16: (F-10): Honey fungus

Figure 17: (site F-11): Weeping milk-cap

Figure 18 (site F-12): Turkey-tail fungi

Figure 19: (site F-13): Pinwheel mushroom

Figure 20: (site F-14): Shelf (Bracket) fungi

Figure 21: (site F-15): Bolete (photo similar to fungi actually sampled)

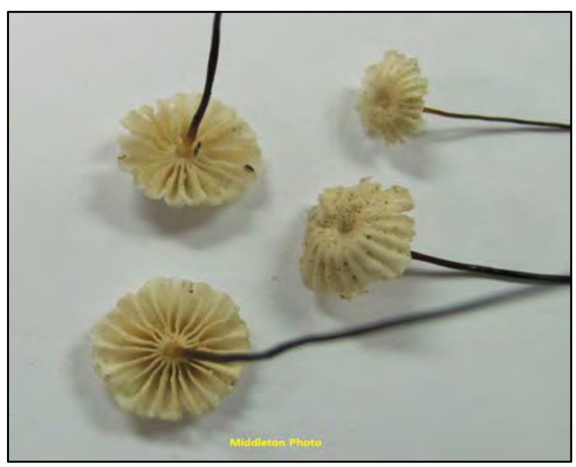

Figure 22: (site F-16): Pinwheel mushroom

Figure 23: (site F-17): Rooted agaric

Figure 24: (site F-18): Puffballs

Figure 25: (site F-19): Unknown fungi (photo similar to fungi actually sampled)

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Acoustical Monitoring of Bats on the Oak Ridge Reservation

Principal Author: Gerry Middleton

Abstract

Information is sparse regarding the distribution and occurrence of bats in the southeastern United States, including knowledge of bat species on the Oak Ridge Reservation (ORR). Although the presence of the federally endangered gray bat has been documented on the ORR, the status of the federally endangered Indiana bat and knowledge of the overall bat community is not well known. Previous ORR bat investigations have been limited to short term surveys of mist-netting and acoustic surveys, and thus no long term, intensive bat monitoring data is available. During the summer of 2014 the Tennessee Department of Environment and Conservation, Division of Remediation (TDEC DOR) continued with an inventory of ORR bat species to provide much needed information to address data gaps where there is little, no, or un-organized bat species data. The investigation was especially designed to identify all bat species but also determine locations where federally-listed endangered species (i.e., Indiana and Gray bats) and the to-be-listed Northern Long-eared bat may be present on the ORR. Bats were monitored using acoustic bat call recording equipment, thus the study did not involve bat captures. Sites monitored on the ORR in 2014 included: (1) Haul Road between East Tennessee Technology Park (ETTP) and the Environmental Management Waste Management Facility (EMWMF) located at the west end of the Y-12 National Security Complex, (2) Tower Shielding area (Oak Ridge National Laboratory) including a cave, (3) Dyllis Orchard area (north of ETTP), (4) building K-1073 (ETTP), and (5) reference sites in Oak Ridge. Over the course of 108 survey nights during 2014, approximately 12,000 files of bat acoustic data were recorded at 81 field stations and were processed with specialized, automated bat identification software (Kaleidoscope PRO) yielding 6,960 bat identifications. An additional 4,006 bats were detected but not identified to species due to poor call quality, inclement weather conditions or field clutter. The 2014 acoustic surveys recorded >100 bat calls at 21 study sites including >300 calls at three sites. Twelve (12) species were detected on the ORR including: *Eptesicus fuscus* (Big Brown bat), *Lasiurus borealis* (Eastern Red bat), *Lasiurus cinereus* (Hoary bat), *Lasionycteris noctivagans* (Silver-haired bat), *Myotis grisescens* (Gray bat), *Myotis leibii* (Eastern Small-footed bat), *Myotis lucifugus* (Little Brown bat), *Myotis septentrionalis* (Northern Long-eared bat), *Myotis sodalis* (Indiana bat), *Nycticeius humeralis* (Evening bat), *Perimyotis subflavus* (Tricolored bat; Eastern Pipistrelle), and *Tadarida brasiliensis* (Brazilian Free-tailed bat). Of these species, the Eastern Red bat (24%), Big Brown bat (18%), Tricolored bat (18%), and the Evening bat (17%) were the dominant combined species detected at all sites. Approximately 5% of all bats detected were federally-listed endangered species (Indiana bat, Gray bat). This research should provide valuable baseline information for the management of natural resources on federal-owned lands and additionally to render useful information for the fight against white nose syndrome (WNS) disease.

Introduction

Bats (Order *Chiroptera*) are the only mammals capable of true, sustained flight and are fundamental ecosystem components for insect suppression, pollination and seed dispersal (Tuttle 1988, Britzke et al. 2011, Ammerman et al. 2012). The earliest confirmed (and surprisingly well preserved) bat fossils (Figures 1-2), dates from the early Eocene (approx. 51 Mya) in North America (Gunnell & Simmons 2005, Teeling et al. 2005) from the Green River Formation, in southwestern Wyoming, but other early taxa are also present in European, African and

Australian fossil deposits. Surprisingly, fossil bats show nearly all the key innovative morphological adaptative elements of extant bat taxa (i.e., fully developed flight and echolocation; Simmons & Geisler 1998). Bats evolved a specialized, modified hand for wings by elongation of the fingers; early bats were believed to be gliders.

Icaronycteris index

Figure 1

Palaeochiropteryx tupaiodon

Figure 2

North American bats have the ability to use ultrasonic echolocation as a navigation tool in obstacle avoidance and location of prey items (Simmons and Conway 2003, Britzke 2003). Echolocating bats typically emit an ultrasonic (>20 kilohertz) pulse, and analyze the returning echo to determine the distance to the object as well as what type of object it is (Fenton 1992). Some researchers hold that echolocation calls of most bats are species specific (Fenton and Bell 1981, O'Farrell et al. 1999), whereas others suggest caution using these calls to identify bats (Barclay 1999). Temperate bat species are nocturnal and exhibit nightly and seasonal activity patterns that vary among species and individuals (Hirshfield et al. 1977, Anthony et al. 1981). During summer nights, bat roost-emergence activity commonly peaks immediately after sunset and can continue for several hours (Kunz 1973, Barclay 1982). Typically, a lesser activity peak occurs before sunrise as bats return to their diurnal roosts after foraging (Kunz 1973). During the night, bats roost at intervals, either at their diurnal roosts or at night-roosts nearer their foraging areas (Adam and Hayes 2000, Johnson et al. 2002, Daniel et al. 2008).

Preparation for hibernation in most mammals involves deposition of fat reserves which provides the sole source of energy during a prolonged winter fast (Young 1976, Mrosovsky 1985). Bats in the eastern United States typically enter hibernation in mid-September and emerge in mid-April (Figures 3-4; Britzske et al. 2006). Hibernation is a physiological state of inactivity characterized by low body temperature, slow breathing and heart rate (10-20 bpm compared to 600 bpm when aroused), and low metabolic rate. The function is to conserve energy and fat reserves during a period when sufficient food is unavailable (Kunz et al. 1998). Hibernation may last several days, weeks, or months (~80-85 days) depending on the species. Caves, mines, or rock crevices are the most common hibernacula (Kunz et al. 1998, Ammerman et al. 2012).

Indiana bats (*Myotis sodalis*) may forage in forests with intact canopies, floodplains, wetlands, near headwater streams (Menzel et al. 2005, Schirmacher et al. 2007), and within riparian zones and upland forests (Webb 2000, Ford et al. 2005). The Indiana bat is highly migratory and may form maternity roosts in sunlit shaggy-barked trees and snags with exfoliating bark during summer and then hibernate in caves during winter (Figures 5-6; Gardner and Hofmann 1986, Caceres and Barclay 2000, Menzel et al. 2001, Timpone et al. 2010). The sunlight is thought to speed the development of the young pups (French 2009). However, Salyers et al. (1996) discovered two male Indiana bats roosting in a bat box in Indiana, and elsewhere, immature males were captured beneath a concrete bridge (Mumford and Cope 1958). Locally, a male Indiana bat was mist-netted by a University of Tennessee/Oak Ridge National Laboratory (UT/ORNL) team at Freels Bend in June 2013 providing solid proof that Indiana bats are present on the ORR during the non-hibernating season (McCracken et al. 2013). This was the first confirmation of an Indiana bat on the ORR since 1950.

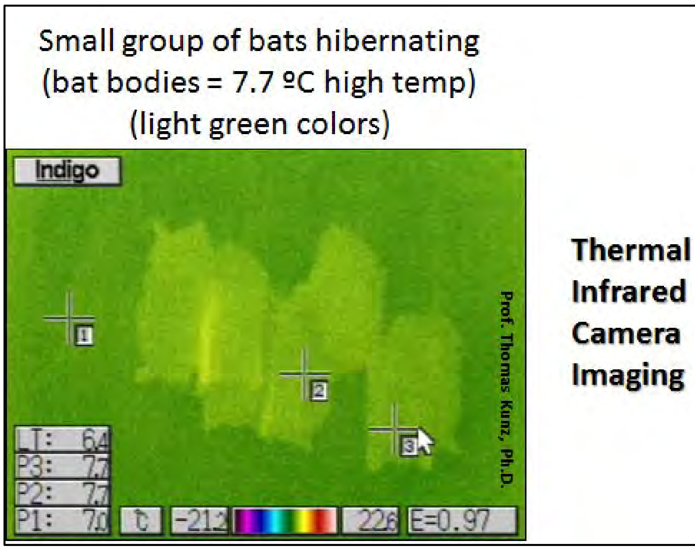


Figure 3

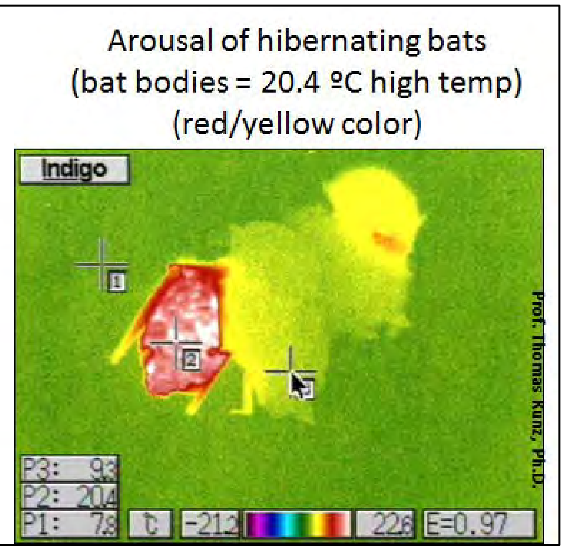


Figure 4

Figure 5

Figure 6

Bats of the genus *Myotis* (i.e., mouse-eared bats) are primarily insectivorous (Best et al. 1997). The federally-endangered gray bat is also highly migratory, establishes nursery colonies in warm caves during summer, hibernates in different cold caves during the winter (Gardner and Hofmann 1986, Gore 1992, Decher and Choate 1995), and typically forages almost exclusively over rivers, streams and lakes where insects are abundant, usually within 2 km of their cave or abandoned mine (Tuttle 1976, La Val et al. 1977, La Val and La Val 1980, Mitchell and Martin 2002). They migrate between summer and winter caves and will use transient or stopover caves along the way. One-way migrating distance between winter and summer caves may vary from 10 miles to ≥ 200 miles. An important hibernaculum for gray bats in Tennessee is Hubbards Cave which has been gated since the early 1970s to prevent disturbances of the bat colony (Tuttle 1985, 1986). Gray bats may roost at man-made sites that simulate summer caves, such as old barns (Gunier and Elder 1971) and storm drains (Hayes and Bingham 1964, Timmerman and McDaniel 1992). Factors contributing to the global decline of bat species include stream channelization, farming, habitat losses, insecticides, urban expansion, wind mill plants, and white nose syndrome disease (Gardner and Hofmann 1986, Gargas et al. 2009, Meteyer et al. 2009).

Worldwide there are more than 1,230 known bat species (Figure 7). In the United States there are at least 45 species with 10 being listed as endangered or threatened (Figure 8, Table 1). According to the Tennessee Bat Working Group, there are 16 known bat species in Tennessee including the federally-endangered Indiana bat and the Gray bat (Table 2). However, there is a paucity of information regarding the distribution and occurrence of bats in the southeastern United States, including a lack of bat species knowledge in east Tennessee.

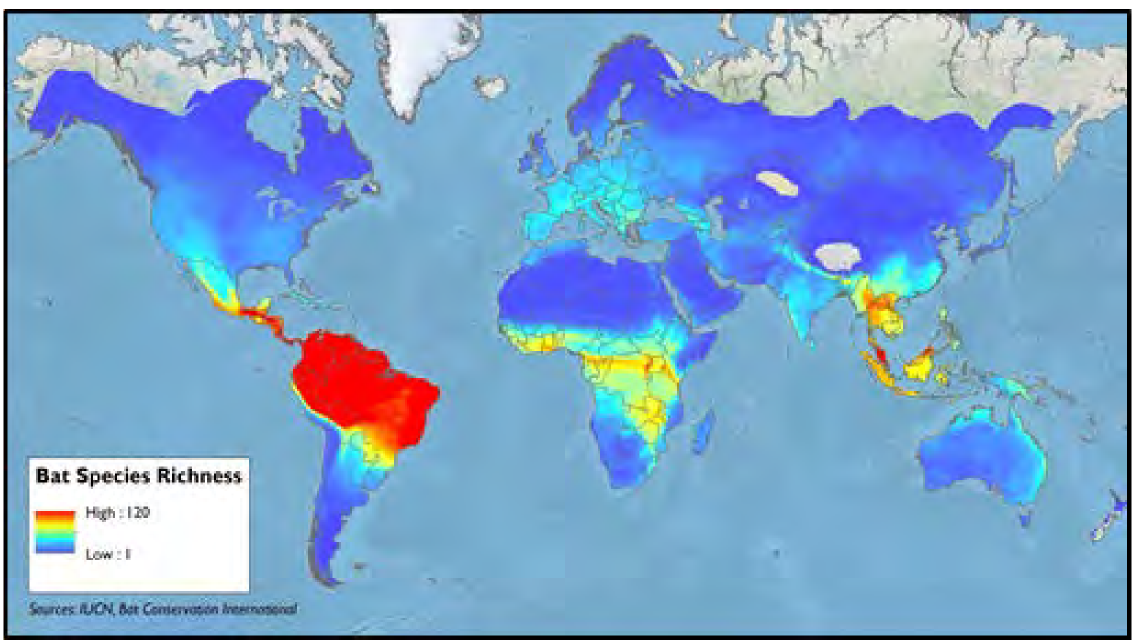


Figure 7

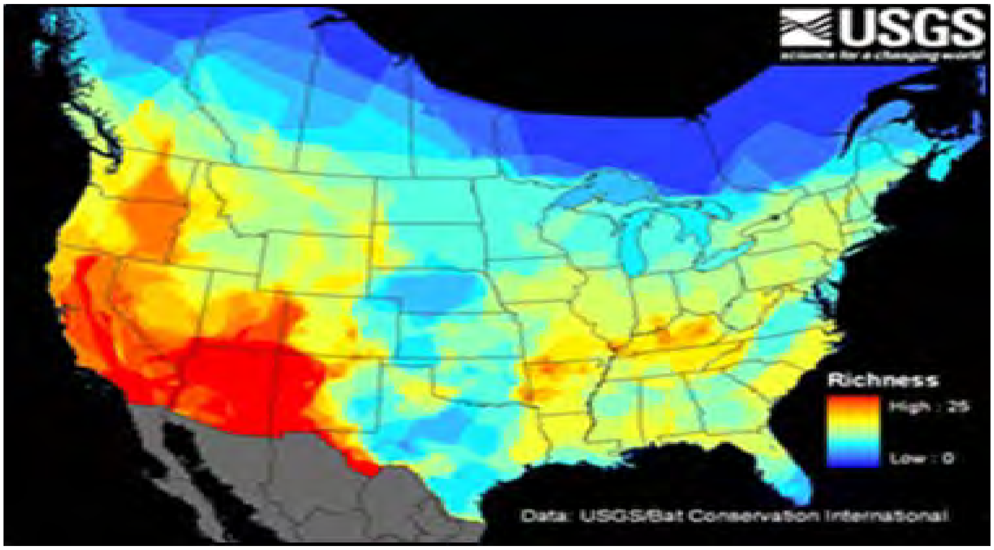


Figure 8

Table 1

Bat Name	Scientific Name	Distribution	Status
Bat, Florida bonneted	Eumops floridanus	U.S.A. (FL)	E
Bat, gray	Myotis grisescens	Central and SE U.S.A.	E
Bat, Hawaiian hoary	Lasiurus cinereus semotus	U.S.A. (HI)	E
Bat, Indiana	Myotis sodalis	Central and SE US	E
Bat, lesser long-nosed	Leptonycteris curasoae yerbabuenae	U.S.A. (AZ, NM), Mexico, Central America	E
Bat, little Mariana fruit	Pteropus tokudae	Western Pacific Ocean_U.S.A. (Guam)	E
Bat, Mariana fruit (=Mariana flying fox)	Pteropus mariannus mariannus	Western Pacific Ocean,U.S.A. (GU, MP)	T
Bat, Mexican long-nosed	Leptonycteris nivalis	U.S.A. (NM, TX), Mexico, Central America	E
Bat, Ozark big-eared	Corynorhinus (=Plecotus) townsendii ingens	U.S.A. (MO, OK, AR)	E
Bat, Virginia big-eared	Corynorhinus (=Plecotus) townsendii virginianus	U.S.A. (KY, NC, WV, VA)	E
		Source: USFWS April 2014	

E = Endangered T = Threatened

Table 2

taxa code	scientific name	common name	Est. Lifespan	Characteristic Frequency**
CORA	*Corynorhinus rafinesquii*	Rafinesque's Long-eared Bat	8-10 yrs	23 kHz (LOW)
COTO	*Corynorhinus townsendii*	Townsend's Big-eared Bat	16 yrs	23.5 kHz (LOW)
EPFU	*Eptesicus fuscus*	Big Brown Bat	19 yrs	28 kHz (LOW)
LABO	*Lasiurus borealis*	Eastern Red bat	12-14 yrs	35 kHz (MID)
LACI	*Lasiurus cinereus*	Hoary Bat	7-14 yrs	20 kHz (LOW)
LANO	*Lasionycteris noctivagans*	Silver-haired Bat	12 yrs	26.5 kHz (LOW)
LASE	*Lasiurus seminolus*	Seminole Bat	No data	35 kHz (MID)
MYAU	*Myotis austroriparius*	Southeastern Bat	8 yrs	43.5 kHz (MYO)
MYGR	*Myotis grisescens*	Gray Bat	15 yrs	45.5 kHz (MYO)
MYLE	*Myotis leibii*	Eastern Small-footed Bat	9 yrs	44.5 kHz (MYO)
MYLU	*Myotis lucifugus*	Little Brown Bat	20 yrs	40 kHz (MYO)
MYSE	*Myotis septentrionalis*	Northern Long-eared Bat	18 yrs	43 kHz (MYO)
MYSO	*Myotis sodalis*	Indiana Bat	14 yrs	41 kHz (MYO)
NYHU	*Nycticeius humeralis*	Evening Bat	5 yrs	38 kHz (MID)
PESU	*Perimyotis subflavus*	Tri-colored Bat (Pipistrelle)	15 yrs	35 kHz (MID)
TABR	*Tadarida brasiliensis*	Brazilian Free-tailed Bat	12-18 yrs	25.5 kHz (LOW)

**J. M. Szewczak, Humboldt State University Bat Lab

Project Scope and Justification

Ultrasonic detectors are widely used for bat censuses (i.e., inventory) and have improved conservation efforts by: (1) providing increased knowledge of bat ecology, and (2) characterizing bat communities (Vaughan et al. 1997, Barataud 1998, Pauza and Pauziene 1998, Avila-Flores and Fenton 2005, Britzke et al. 2011). Numerous researchers have used detectors to conduct bat species surveys and assess habitat use. This method is especially valuable for species that are difficult to capture (Ahlén and Baagøe 1999, Murray et al. 1999, O'Farrell and Gannon 1999, Duffy et al. 2000, Parsons et al. 2000, Russo and Jones 2003, Owen et al. 2004, Britzke et al. 2011). A considerable benefit of acoustic surveys is that bats do not have to be captured and stressed, but identify areas where mist net surveys are needed to obtain positive identifications of endangered species.

Acoustic surveys of bat echolocation calls are often used to model a species' occurrence at a site (i.e., occupancy model, French 2009). Variation in the acoustic structure of bat echolocation calls can often provide sufficient information for reliable and efficient species identification. Acoustic surveying of sites and analysis of corresponding bat files using acoustic libraries built into automated identification software programs provide a consistent and standardized method for surveying areas rapidly (Hughes et al. 2011).

The TDEC DOR investigated and inventoried the bat community present on the ORR during 2014 using ultrasonic acoustic bat call recording equipment. Accordingly, the principal goal of this monitoring project was to assess seasonal use of DOE federal lands by bat species. Particularly the status of federally endangered bats (Indiana bat, Gray bat) in Tennessee is not well known. Acoustic information should be helpful in identifying areas where netting surveys could further build upon bat distribution data, especially where calls of the genus *Myotis* are recorded most frequently. Further, dispersal information is sparse regarding the Northern Long-eared bat which is currently under consideration for listing as an endangered species by the U.S. Fish and Wildlife Service (USFWS). Many bat investigations on federal land have been limited to short term 2-4 night surveys of mist-netting and acoustic surveys to meet the Indiana bat monitoring requirements of Section 7 of the Endangered Species Act. As a result, few bat acoustic surveys have been conducted over the years. Bat data is spotty, inconsistent, or often non-existent in critical habitat areas such as the huge forested NERP (National Environmental Research Park) area of the ORR.

Data from this project will determine ORR bat species present and their distribution. It will also provide valuable information for management of natural resources on federal-owned lands. Lastly, this research will support the protection and conservation of endangered bat species, a major component of the TDEC mission, and it will also support efforts to combat white-nose syndrome (WNS). This study is unique because a serious lack of bat community information was addressed by providing comprehensive, multi-night acoustic surveys at 81 survey stations. This allowed partial characterization of the +30,000 acres of federal lands comprising the ORR. Furthermore, this project, along with a concurrent ORNL Environmental Science Division bat project, represents the first long term, large-scale acoustic bat community investigation on the ORR.

Objectives

1. Conduct field habitat assessments on the ORR and identify likely endangered species roosting habitat for acoustic monitoring. Specifically, Indiana bats may form maternity roosts in sunlit trees and standing snags with exfoliating or loose bark during summer and then hibernate in caves during winter (Menzel et al. 2001, Timpone et al. 2010). Bat habitats for other species will also be identified for acoustic monitoring such as:
    a) Caves & abandoned mine works
    b) Rock bluffs and outcroppings
    c) Bridges & tunnels
    d) Field/forest edge
    e) Culverts/storm sewers
    f) Forest corridors (linear features: fence lines, access roads, trails)
    g) Waterways (wetlands, ponds, streams, rivers)

h) Abandoned buildings
(LaVal et al. 1977, Racey 1998, Grindal and Brigham 1999, Menzel et al. 2005)

2. Monitor field stations identified in #1 above utilizing acoustic bat detector equipment and determine all species present on the ORR.

3. Collect bat echolocation calls 24/7 at pre-selected ORR caves (with known bat populations) in an attempt to detect potential erratic behavior which could be an indication of WNS-infected bats.

Bat Echolocation

Most United States bats have the ability to use echolocation as a navigation tool in obstacle avoidance and hunting (Simmons and Conway 2003, Ammerman et al. 2012). Echolocating bats typically emit a series of ultrasonic pulses that vary in properties, and analyze the returning *echoes,* redirect its sonar beam at the target, then determine the distance to the object and identify the object (Fenton 1984, Fenton 1992, Grinnell 1995, Ulanovsky and Moss 2008). Bats use a wide range of ultra-sonic tonal frequencies in echolocation, from ~20,000 Hz (20 kHz, kilohertz) to >200,000 Hz (200 kHz; Figure 9). As the bat flies, it emits frequency sweeps (e.g., 100 kHz down to 30 kHz) into a wide cone of space ahead of it (cone = 120º- 150° wide; Figure 10). Bat calls are produced by a single mode of vibration and consist of a series of harmonics which are multiples of the sound frequencies used by the bat, thus pinpointing the location of insect prey (Figures 11-12: Fenton 1992, Grinnell 1995). The maximum target detection range of the bat echolocation apparatus is about 20 meters (Ammerman et al. 2012).

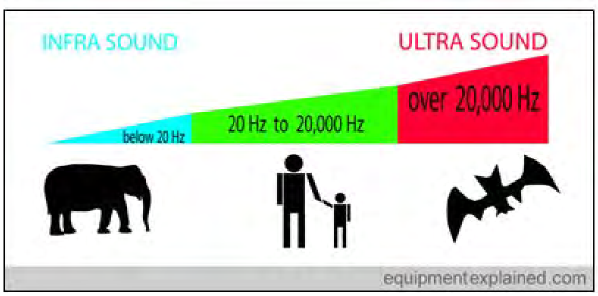


Figure 9

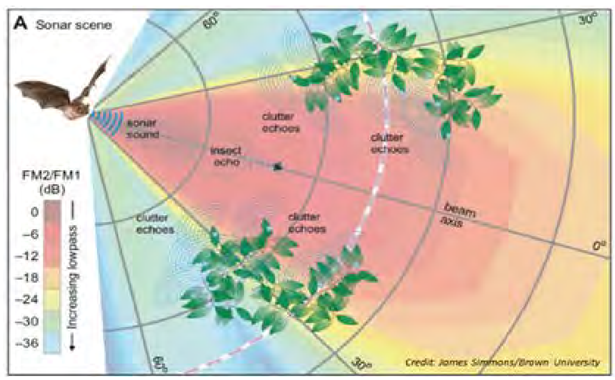


Figure 10

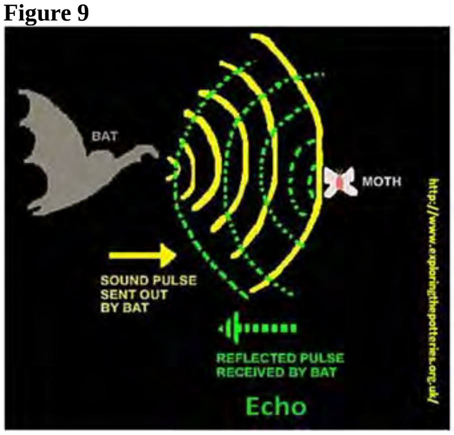


Figure 11

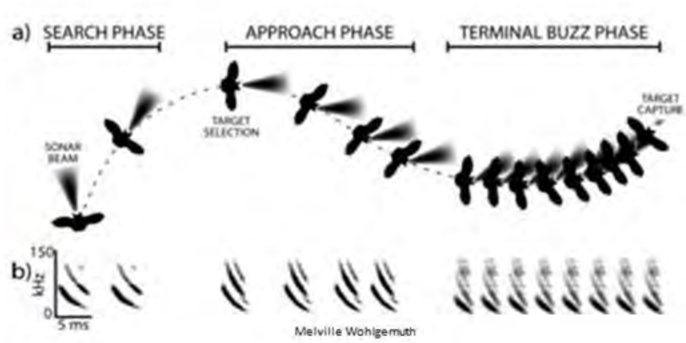


Figure 12

Bats synchronize their echolocation calls with their wing beats (Figure 13).

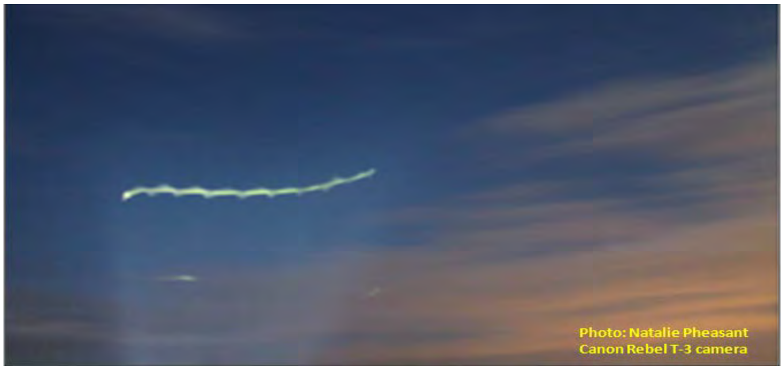


Figure 13: Bat illuminated and photographed in flight (note wing beats)

So, what is a bat call? A bat call is a series of frequency sweeps which the bat emits to aid in navigation and location of prey items (McCracken et al. 2013). Most bat families use short, downward frequency-modulated (FM) sounds that sweep through about an octave; FM calls determine range and distance. An example of an FM bat is the Big Brown Bat. Another common echolocation signal pattern is constant-frequency (CF) signals which determine if prey move towards or away from the bat (Fenton and Bell 1981, Betts 1998, O'Farrell et al. 1999). These signals have a long (10–100 ms) CF component preceding an FM sweep (Grinnell 1995).

Bat calls (echolocation) can be considered as *bio-sonar*. Most of our bats echolocate using their larynx and associated super-fast throat muscles to produce ultrasonic clicks (i.e., >190 signals/sec); in contrast, some species use tongue clicks (Holland and Waters 2005). In bats that use laryngeal echolocation, the stylohyal bone (Figure 14, shown in blue) directly connects the tympanic bone (yellow) with the larynx which allows the bat to generate the outgoing ultrasonic clicks (Veselka et al. 2010). The returning echoes are detected with highly specialized ear structures (Figure 15) which are in turn transmitted to specialized regions of the bat brain for processing and calculation of prey location (Figure 16; Suga and O'Neill 1979). The inner ears of laryngeal echolocating bats show several structural adaptations for detecting ultrasonic echoes; in particular, their cochleae are often enlarged (Suga et al. 1975, Simmons et al. 1975, Suga 1990). The bat broadens the area from which it collects information by moving its head, ears, and tragus while echolocating thus amplifying the returning echo (Ammerman et al. 2012).

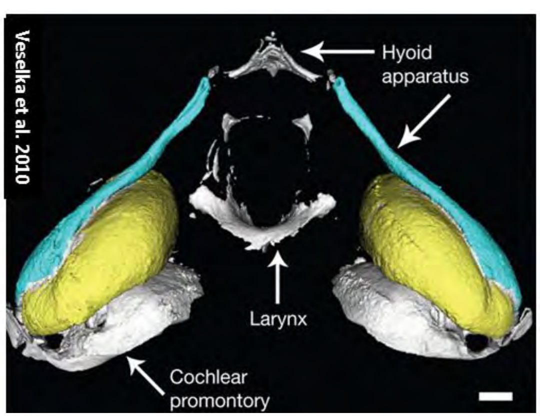
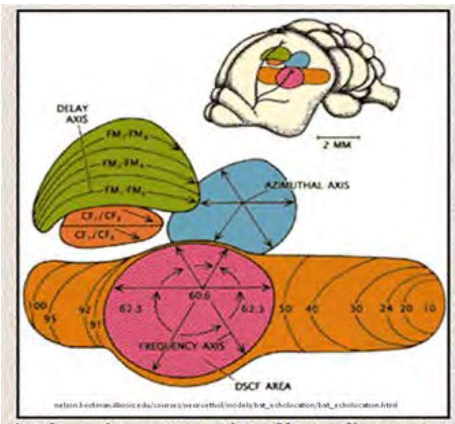


Figure 14

Figure 15

During flight, the dominant constant-frequency (CF) component of the distinctive calls of some bats (e.g., Horseshoe bat, Mustache bat, and other species) is shifted as a result of Doppler effects (Figure 17, Metzner et al. 2002, Hiryu et al. 2005). These bats compensate for even subtle frequency shifts in the echo caused by flight induced Doppler effects by lowering the frequency of their echolocation calls below the resting frequency (the call frequency emitted when not flying and not experiencing Doppler shifts; Schnitzler 1968, Metzner et al. 2002).



A schematic representation of bat auditory cortex

Figure 16

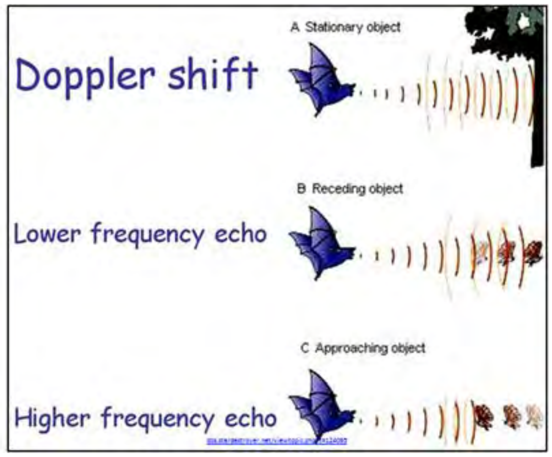


Figure 17

Bat Habitat

Bat *homes* (i.e., roosts, maternity colonies, hibernacula) are illustrated in Figures 18-37. When not foraging for food, bats rest, groom, and interact socially with other bats at sites known as roosts or hibernacula (Ammerman et al. 2012). Bats roost in a variety of naturally occurring and anthropogenic structures such as abandoned buildings, caves, rock bluffs, rock crevices, dead tree snags, trees with exfoliating bark, tree leaves/branches, tree cavities, bridges, abandoned mines, railroad tunnels, forest/field edge, wetlands, utility right-of-ways, ponds, stream riparian zones, lakes, and spring houses (Ammerman et al. 2012).

To capture insect prey items, bats swoop low over the surface of water bodies, snap prey out of the air, and even land on the ground to pursue prey (Ammerman et al. 2012). Insect-eating bats (insectivorous) may use their tail to capture the insect or use their long canines to seize and pierce their prey, which is then reduced to minute fragments by the sharp-edged premolars and blade-like crests of the molar teeth. The sharp cusps and ridges of the opposing teeth act as scissors to cut up the insect food into tiny pieces (Ammerman et al. 2012).

Figure 18

Figure 19

Figure 20

Figure 21

Figure 22

Figure 23

Figure 24

Figure 25

Figure 26

Figure 27

Figure 28

Figure 29

Figure 30

Figure 31

Figure 32

Figure 33

Figure 34

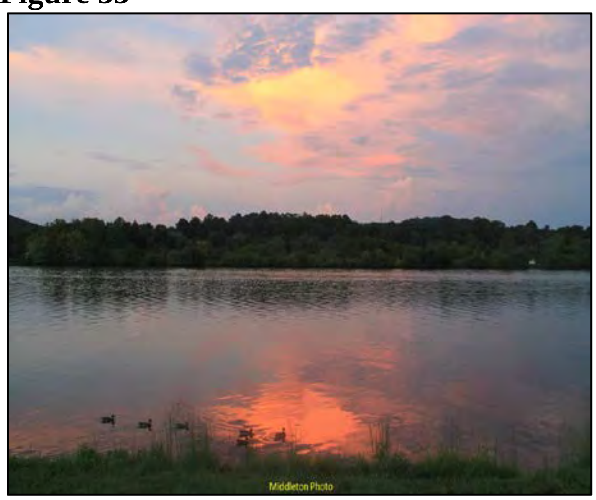


Figure 35

Figure 36

Figure 37

Methods

The Tennessee Oversight Agreement mandates a comprehensive and integrated monitoring and surveillance program for all media (i.e., air, surface water, soil sediments, groundwater, drinking water, food crops, **fish and wildlife, and biological systems**) and the emissions of any materials (hazardous, toxic, chemical, radiological) on the ORR and environs. Accordingly, monitoring the ecological recovery progress of wildlife and the environmental restoration of habitat are important aspects of remedial activities on the ORR.

Following emergence from winter hibernation, bats were surveyed to record echolocation calls using ultrasonic frequency bat detectors. Bat habitat surveyed included trees with loose or peeling bark (e.g., shagbark hickory), dead snags, ponds, wetlands, riparian stream zones, caves, rock bluffs, hiking trails/greenways, gravel access roads, powerline ROWs (right-of-way), anthropogenic structures (i.e., abandoned buildings, bridges, culverts), and field/forest edge (forest corridors). Bat call files obtained from the detectors were analyzed with specialized bat identification software (i.e., Kaleidoscope PRO) to determine species likely present at ORR survey sites. We used a combination of active and passive ultrasonic field surveys that began in mid-April 2014, and continued through late October 2014.

Our project methods followed the bat monitoring guidance and protocols of Kuenzi and Morrison (1998), Murray et al. (1999), Jones et al. (2004), Szewczak 2004, Manley et al. (2006), Britzke et al. (2011), and the U.S. Fish and Wildlife Service (USFWS 2011, 2013). This research was in cooperation with the Division of Natural Areas (TDEC Bureau of Parks and Conservation), Tennessee Wildlife Resources Agency, the Forestry, Wildlife and Fisheries Department of the University of Tennessee, the US Fish and Wildlife Service, and the Oak Ridge National Laboratory Environmental Sciences Division.

Per the Health & Safety Plan, all field work was conducted in teams of two or more biologists (Yard 2013). Appropriate training and pre-exposure rabies vaccinations are required for those individuals that may handle bats while assisting with mist-netting surveys under another researcher's federal collection permit (USFWS 2011).

Field Equipment

Recording and analyzing ultrasonic bat calls present a challenging code-breaking problem, thus modern bat detector technology allows us to tap the bat phone and decipher their bat-speak code. The application of bat ultrasonic monitoring devices such as the zero-crossing Anabat™ SD-2 bat detector and Titley Roost Logger (Titley Scientific USA, Columbia, MO) has allowed ecologists to quickly and efficiently characterize and inventory bat communities at multiple areas (O'Farrell and Gannon 1999, Owen et al. 2004), and transform those calls into frequencies which are audible to humans (Parsons et al. 2000). Newer full spectrum technology such as the Wildlife Acoustics SongMeter SM-2BAT+ and SM-3BAT+ detectors allow a more complete recording of the bat call providing some advantages over the Anabat technology.

We used six types of bat detectors over the course of the project to passively and actively monitor for bat echolocation passes (i.e., a series of echolocation pulses), at carefully selected ORR sites before, during, and after the pregnancy and lactation periods (April through October; Sasse and Perkins 1996). Table 3 lists the bat detectors, associated features for each unit, and the bat identification software programs that are compatible for each detector.

WAC files (*.wac*) = Wildlife Acoustics Audio Compression format is a proprietary audio format produced by Song Meter and Echo Meter recorders. A *.wac* file may contain one or more channels (mono or stereo recordings), and these recordings may be either continuous or triggered. Triggered recordings are used for ultrasonic work (e.g. recording bats) where only periods of detected activity (a triggered event or "bat pass") are recorded.

WAV files (*.wav* format) = Waveform Audio File format is a defacto standard developed by IBM and Microsoft for representing multi-channel audio recordings. There are several flavors of *.wav* file formats that may utilize different forms of audio compression and meta data.

The Zero-crossing (ZC) *.dat* ? (also, *??#*) format is a proprietary format used in Anabat and legacy zero-crossing bat detectors developed in the early 1990s by Chris Corben for Titley Electronics. These are not "recordings" in the conventional sense but, rather, the time between a number (division ratio) of sequential zero crossings stored in the file. With sufficient signal-to-noise ratio, the dominant frequency sweep through time produced by the echolocation calls of bats can be represented.

(http://media.nhbs.com/equipment/Kaleidoscope%20Pro.pdf accessed 3/15/2015)

Additional field equipment:

- Bat detectors
- Waterproof lockable boxes for Anabat equipment
- Tripods & painter poles for microphone extension
- Bungee cords, rope
- Machete, saw
- Toolbox, tools
- Headlamps, high candlepower flashlights, extra batteries
- Security locks & cables to protect detectors from theft or damage
- GPS, field maps, field notebook, etc.
- First aid kit, insect repellent

Table 3

Bat Detectors						
Features ↓	Anabat SD-2	Roost Logger	Bat Box	SongMeter SM2BAT+	SongMeter SM3BAT	EchoMeter SM3
Manufacturer	Titley Scientific	Titley Scientific	Batbox Ltd. (UK)	Wildlife Acoustics	Wildlife Acoustics	Wildlife Acoustics
Programmable	Yes	Yes	No	Yes	Yes	Yes
Technology	Zero-crossing (ZC) / frequency division	Zero-crossing (ZC) / frequency division	Heterodyne / frequency division	Full spectrum / ZC	Full spectrum / ZC	Full spectrum / ZC / Heterodyne
Deployment	Active/Passive	Active/Passive	Active	Passive	Passive	Active
Battery life	30 hrs	>1000 hrs	30 hrs	230 hrs	180-700 hrs	12 hrs
Memory card	CF card	SD card	requires recorder	SD card	SD card	SD card
Directionality	Directional	Directional	Directional	Omni directional	Omni directional	Directional
File output	dat ? Anabat files	dat ? Anabat files	WAV	WAV / WAC / ZC	WAV / WAC / ZC	WAV / WAC / ZC
Frequency (kHz)	5-200 kHz	40-42 kHz	17-125 kHz	8-220 kHz (recommended)	8-220 kHz (recommended)	1-192 kHz
Weatherproof	No	Yes	No	Yes	Yes	No
Microphones	Attached / External on tripod mount	Built-in	Built-in	Attached / External on pole mount	Attached / External on pole mount	Built-in
Compatible Bat ID software*	AN, BE, KP	AN, BE, KP	KP	KP, SB	KP, SB	KP, SB

*Analook = AN; BCID-East = BE; Kaleidoscope PRO = KP; Sonobat = SB

Anabat SD-2 detectors are frequency dividing (FD) detectors that provide a broadband frequency down-conversion to generate audio signals with frequencies directly related to those the bat is producing (Corben 2014). The nature of the data generated by Anabat detectors is ideally suited to analysis using Zero-Crossings Analysis (ZCA). The ZCA system counts incoming echolocation calls (pulses) along their oscillations between positive and negative values each time a sound wave passes the zero point at a present number of crossings (i.e., Division Ratio, often 8 or 16), and a time measurement (time-frequency) is made allowing representative species-specific frequencies to be recorded, thus providing efficient analysis of representative call parameters for species identifications (Corben 2014). The Anabat with attached PDA screen provides near instant renderings of the time-frequency portions of bat calls so bats can be observed while sonograms of their calls can be displayed. This aids in identifying bats to species while in the field or during analysis with the Analook-W software program.

The BatBox Duet was used to scan sites for early bat calls prior to initiating recording activities at active survey sites. The Batbox Duet is a dual-functioning bat detector, with both heterodyne and frequency division, which has been designed for single-handed operation. By recording from the frequency division output, no bat can be missed, regardless of the frequency set on the digital counter. The Duet listens to the entire ultrasonic range between 17kHz and 120kHz. This detector also measures the amplitude of the sonar before dividing by ten and then reinstates it at the output. This creates an identical waveform to the original signal but reduces the pitch to an audible frequency (BatBox Ltd. 2015).

The SongMeter SM2BAT+, SM3BAT, and EM3+ bat detectors (Wildlife Acoustics) are versatile and can record frequency-divided (zero-crossing) bat calls, and are also a full-spectrum detector capable of capturing all frequency-time and amplitude-time components of high-frequency bat echolocation. That is, these detectors capture the entire soundscape of an incoming echolocation call either by direct recording methods which instantly digitize the audio, or by time-expansion methods which lower the call in frequency and expand it in time for recording and/or playback in quasi-real-time performance. The main benefit of full-spectrum recordings is that they contain not only the time-frequency components of the bat call, but also the time-amplitude components, including multiple harmonics when present. Thus the information recorded by full-spectrum processes is far richer and has vastly more content upon which to make a confident identification. (http://www.wildlifeacoustics.com/products/song-meter-sm2-bat-plus/training-videos accessed 3/15/2015).

The quantity of echolocation passes recorded is an index of activity and does not necessarily reflect the number of bats being recorded, i.e., one bat can be recorded more than one time (Broders 2003). During 2014, DOEO employed two methods for recording ORR bat calls:

1. Active survey (attended) at fixed-point location(s): Bat echolocation calls were *actively* monitored (i.e., attended) between dusk and midnight (O'Farrell et al. 1999, Sherwin et al. 2000, Johnson et al. 2002). At each location, we aimed the detector toward the sky in the four cardinal directions (45º angle from the horizon) until bat activity was acquired. Then, we oriented the detector towards the general direction of the bat and following its flight path, recorded echolocation calls until the signal was lost. Every attempt was made to capture as complete a call sequence as possible including the search, approach, and feeding buzz segments. Search phase calls are best suited for the acoustical identification of bats because they are the most commonly encountered in the field and have been shown to have species-specific characteristics (Allen et al. 2007). Detectors or detached microphones were extended on tripods or painter poles wherever possible to reduce ground clutter and ultrasonic insect noise (Weller and Zabel 2002). Excessive clutter, such as deploying detectors in dense vegetation, was avoided (detectors were operated in the open as much as possible). We avoided acoustical sampling during evenings when bat activity was likely to be low due to meterological conditions such as high winds, precipitation or temperatures below 10° C (Wear 2004, Ford et al. 2005, Schirmacher et al. 2007).

2. Passive survey (unattended) at fixed-point location(s): Bat echolocation calls were also collected *passively* by deploying the detectors unattended overnight (i.e., 1-3 nights) pre-programmed to record dusk to dawn (Martin and Britzke 2010). Anabat SD-2 detector systems deployed in the field for remote, passive sampling were housed in waterproof containers with an aperture through which the microphone was fitted (Britzke et al. 2010). Detectors were deployed 5-10 feet above the ground on tripods or painter poles to reduce recording ultrasonic insect noise and ground clutter (Weller and Zabel 2002). High clutter areas (i.e., dense vegetation) were avoided to reduce recording ultrasonic insect & ground clutter noise (Weller and Zabel 2002). The Titley Roost Logger™ detector was used to monitor bats at cave sites and usually deployed for 3-5 consecutive

nights. Care was taken during site selection to minimize exposure of the expensive equipment to possible theft or vandalism.

Bat Call Analysis Software Programs

Bat detectors can detect, display, and record the echolocation calls of bats which have a characteristic frequency. These calls can also be displayed as sonograms which can be analyzed and compared to find differences in the calls that an individual bat makes, such as during feeding, socializing, and navigating as well as differences between various species of bats (Ammerman 2012).

Bat call files obtained from the detectors were analyzed with specialized bat identification software [i.e., Kaleidoscope PRO, Wildlife Acoustics, Inc., Concord, MA; Analook-W, Titley Scientific, Columbia, MO] to enable acoustic identification of species. Kaleidoscope PRO has been sanctioned by the USFWS as candidate automated software which has passed the rigorous USFWS standardized test/validation process. The automated programs use a reference library of bat pulses from bats for comparison with species whose identification is unknown, and, using algorithms, assign a probability of identification to unknown bat calls. This method of comparison and analysis decreases chances of false positive identifications, but allows overlapping calls or calls which contain noise to be rejected as NOID(no identification), or calls unidentifiable to species (McCracken et al. 2013). Search phase calls are best suited for the acoustical identification of bats because they are the most commonly encountered in the field and have been shown to have species-specific characteristics (Allen et al. 2007). However, it is not always possible to collect good quality search phase calls which depend on the amount of field clutter, detector/microphone orientation, insect noise, and poor weather conditions.

In the Analook-W software program (Titley Scientific), bat call files can be displayed as sonograms which can be analyzed and compared to find differences in the calls that an individual bat makes, such as during feeding, socializing, and navigating, as well as differences between various species of bats (Ammerman 2012). This software is most compatible with Anabat detectors, but also allows analysis of files recorded by SM2BAT+ recording in native zero-cross mode. Any full spectrum file can be converted to ZC format and viewed in Analook. However, as mentioned above, sound features such as harmonics and peak frequency are lost. Analook provides a full range of parameter extraction and filtering capabilities for making species identification classifications (Corben 2014).

The Kaleidoscope Pro automated bat identification software package allows users to run their raw data from an SM2BAT+, SM3BAT, EM3+ unit, or any other bat detector on the market today including Anabat files, and it will output an automatic species identification classification for each recording. Kaleidoscope Pro saves users enormous amounts of time which would otherwise be spent viewing and post-processing calls, and provides standardized survey results that can be applied across multiple habitats, by various field technicians, and over many years. This software accepts zero crossing and full spectrum recordings, in either WAV or WAC file formats, and will automatically and accurately identify bat recordings to species using a built-in call library. The software automatically creates a summary report that is useful for compiling occupancy data and easily outputting detailed results from deployments (www.wildlifeacoustics.com/products/kaleidoscope-software/webinars accessed 3/15/2015).

Caveats: Bat Auto-ID software has its limitations...it is only as good as the input data. Even high quality recordings are not always identifiable to species. So, the bottom line is we cannot always accept auto-ID output blindly. Although there is considerable debate about the accuracy of bat detectors and automated identification software programs based solely upon echolocation calls, it has been shown that, with experience, the number of 'false-positives' or misidentifications is negligible, and questionable calls must be listed as unidentifiable (Barclay 1999, O'Farrell et al. 1999, Ammerman et al. 2012).

For example, the occasional misidentification of Little Brown calls as Indiana bat calls requires very careful follow-up analysis of the field data. This is because Little Brown and Indiana bats have significant overlap in discrete parameters such as call duration, characteristic frequency, start slope, slope at characteristic frequency, and cumulative normalized slope such that these species sometimes cannot be differentiated (Szewczak 2011). Figure 38 illustrates this overlap of Indiana bat (MYSO) and Little Brown bat (MYLU) call characteristic frequencies (octaves/second) plotted vs. duration (milliseconds; Agranat 2012).

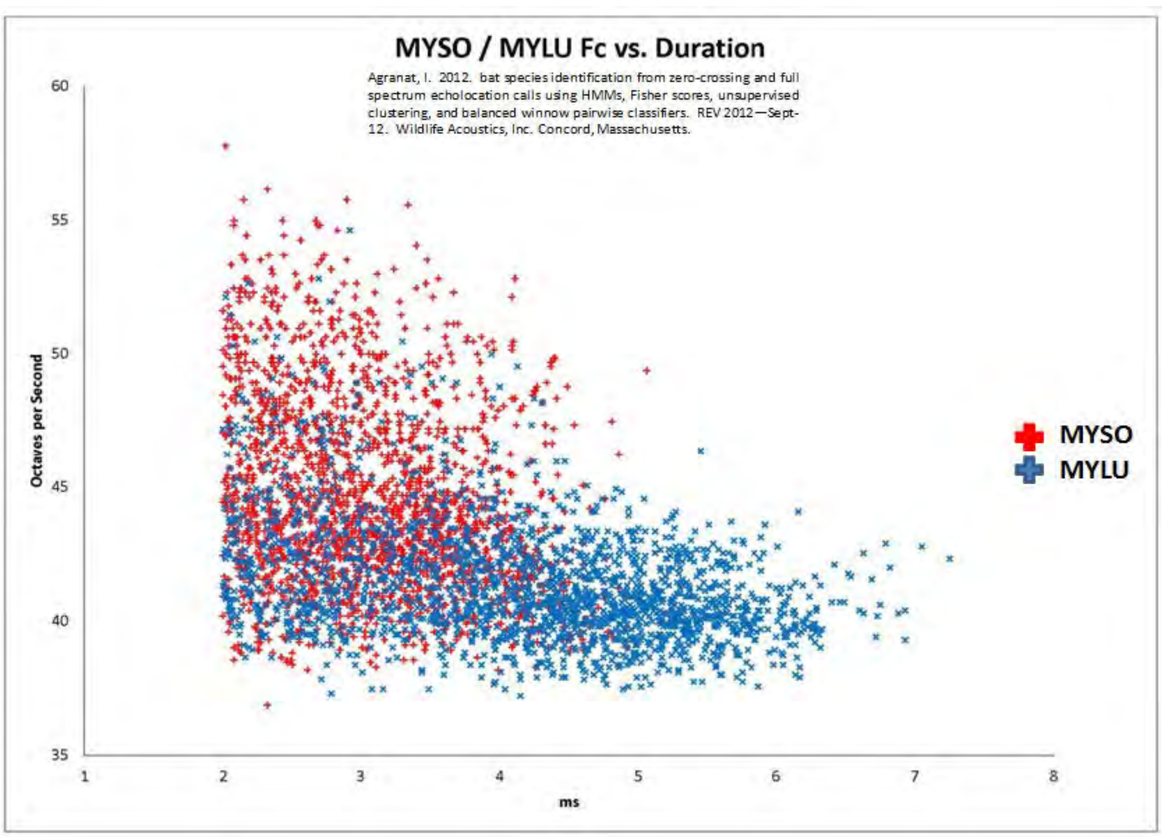


Figure 38

Given these limitations, it is equally important to consider the advantages of using bat detectors to record echolocation calls and application of automated software programs to identify those recorded calls. Bat detectors are ideal for long-term monitoring and censuses of bats and are effective for detecting species that are difficult to catch with mist nets or harp traps (Barataud 1998, Pauza and Pauziene 1998, Ammerman et al. 2012). The application of bat ultrasonic acoustic detectors and automated identification of recorded calls has allowed ecologists to quickly and efficiently characterize and inventory bat communities at multiple areas (O'Farrell and Gannon 1999, Owen et al. 2004, Hughes et al. 2011). The greatest advantage is that bat captures or disturbance of bat colonies is not necessary.

Study Site

The study was conducted on the Oak Ridge Reservation (ORR) in Anderson and Roane counties of east Tennessee. The ORR consists of approximately 34,500 acres (14,000 ha) and is nestled in the valley and ridge physiographic province and the underlying geology consists of thrust faulted Cambro-Ordovician age sedimentary rocks such as limestones, siltstones, shales and dolostones. 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. More than 20 caves have been identified on the ORR and most are developed within dolostones of the Knox Group. Mitchell et al. (1996) surveyed seven of the caves (Copper Ridge, Flashlight Heaven, Walker Branch, Big Turtle, Little Turtle, Pinnacle, and Bull Bluff), but no gray bats were found. There is an unverified report of ten gray bats roosting in Little Turtle Cave in September 1996 (Webb 2000). Therefore, acoustic bat surveys of ORR cave entrances were conducted on multiple nights to determine species, if present. We should note that ORR caves were not entered at any time due to wildlife health concerns.

Bat acoustic monitoring sites were selected based upon satellite imagery, topographic maps, consultation with the Environmental Sciences Division at the Oak Ridge National Laboratory, the Tennessee Wildlife Resources Agency (TWRA), TDEC Division of Natural Areas, and by following the U. S. Fish & Wildlife Service (USFWS) Indiana bat protocol (USFWS 2011, 2013). Additional site selection criteria included: likely flight paths and roosting/foraging habitats as described in the scientific literature (Barbour and Davis 1969, La Val et al. 1977, Lewis 1995, Kuenzi and Morrison 1998, Racey 1998, Grindal and Brigham 1999, Murray et al. 1999,Adam and Hayes 2000, Johnson et al. 2002, Henry et al. 2002, Jones et al. 2004, Szewczak 2004, Ford et al. 2005, Menzel et al. 2005, Manley et al. 2006, Ormsbee et al. 2007, Schirmacher et al. 2007, Daniel et al. 2008, Menzel et al. 2010, Timpone et al. 2010, Britzke et al. 2011).

DOEO monitored bats at 81 sites during 2014 including:

- Haul Road (ETTP truck scales to Y-12 Bear Creek Burial Grounds)
- Blair Road (ETTP)
- Blair Road quarry
- Perimeter Road (ETTP)
- Building K-1073 (ETTP)
- Copper Ridge Cave (Tower Shielding area, ORNL)
- Shagbark hickory and dead snags (potential Indiana bat roosting trees)
- Poplar Creek (ETTP area)
- Dyllis Orchard greenway (Black Oak Ridge Conservation Easement)

DOEO conducted active surveys (attended) recording bat calls from dusk until midnight and passive surveys (unattended) involving deployment of pre-programmed detectors overnight to record bat calls from dusk until dawn.

Results

TDEC Division of Remediation staff continued to monitor and record bat echolocation calls during the second year of the bat inventory and field monitoring project in 2014. The field season began in late April and continued through late October. The goal was to provide much needed information to address data gaps where there is little, no, or un-organized bat species data. The investigation was especially designed to identify all bat species but also to determine locations where federally-listed endangered species (i.e., Indiana and Gray bats) and the to-be-listed Northern Long-eared bat may be present on the ORR. Bats were monitored using acoustic bat call recording equipment, thus the study did not involve bat captures. Further, we co-deployed detectors with the ORNL Environmental Sciences Division bat ecology staff at several locations in the Tower Shielding area including Copper Ridge Cave. For purposes of the 2014 bat survey, the study area was subdivided into 12 sections:

I. ETTP: Haul Road / Blair Road
II. ETTP: Haul Road / Flannagan Road
III. ETTP: Blair Road / Poplar Creek Greenway @ East Fork Poplar Creek bridge
IV. Haul Road (west Bear Creek Valley) / Highway 95 overpass
V. East Dyllis Orchard area (Blackoak Ridge) / Perimeter Road
VI. Central Dyllis Orchard area (Blackoak Ridge)
VII. West Dyllis Orchard area (Blackoak Ridge)
VIII. ETTP: K-1073 building perimeter
IX. Tower Shielding Area (ORNL)
X. Haul Road (Bear Creek Burial Grounds area/Y-12 National Security Complex)
XI. Haul Road (Reeves Road area)
XII. Reference sites (City of Oak Ridge)

Important note: At the beginning of each section, the following background information is provided:

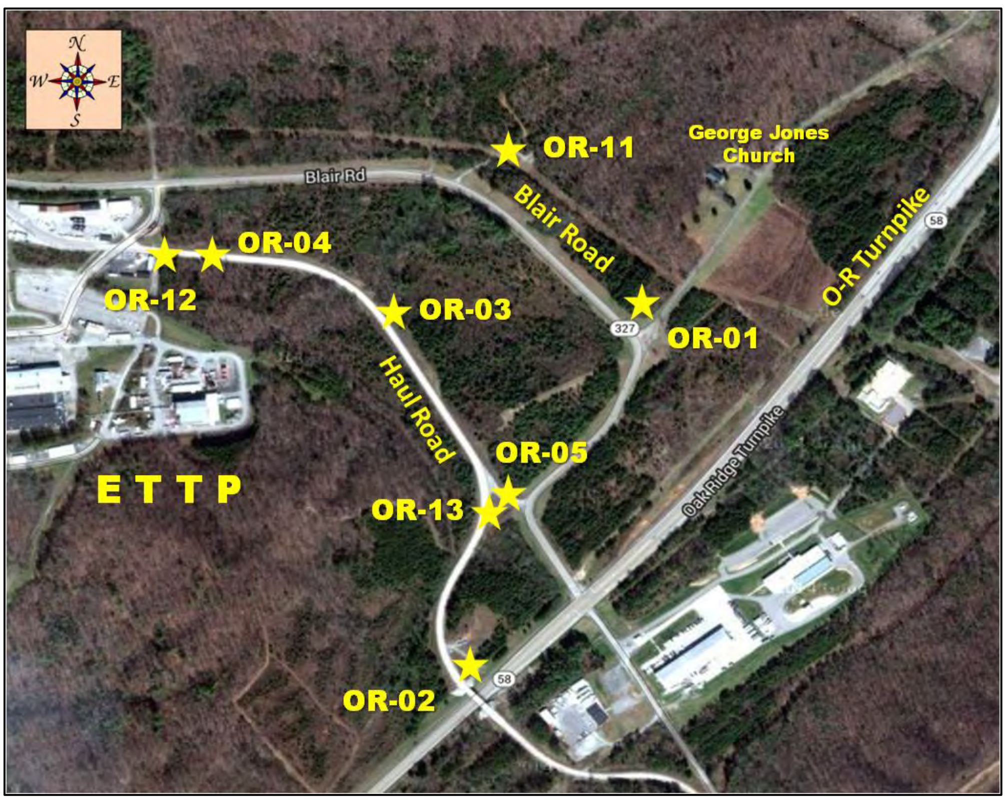
(1) Map showing location of acoustic survey sites (field sites are numbered as follows: OR-01, OR-02, OR-03, etc.),
(2) Table with field data for each site [GPS coordinates, site description, date of survey, time of survey, detector(s) deployed],
(3) Table with bat survey output data for each site (number of bat calls by species and additional software output).

Following the introductory map and tables for each section, data for every individual site is presented as a pie chart (number of bat calls per species) with a corresponding site photograph to the right of every pie chart. Each pie chart and corresponding site photograph is numbered using the survey site reference number, that is, OR-01 chart/OR-01 image, OR-02 chart/OR-02 image, OR-03 chart/OR-3 image, etc. In the bat survey output tables, note that the numbers in each *bat species detected* cell represent the number of bat calls recorded at each monitoring station, not the number of bats present. *Blank boxes* = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A *call* is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). *Pulses* are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. *Noise* =

not bat calls; likely insect or mechanical noise. Bat call frequency indicated as *Low (≤ 25kHz), Mid (25-35 kHz), or Myotis* (≥ 40kHz). All bat files were processed using the Kaleidoscope PRO automated identification software program.

Section I: ETTP: Haul Road / Blair Road

Eight sites were actively monitored for an average of three hours/night to record ultrasonic bat calls on Section One; six sites were investigated along the Haul Road between the truck scales and the Oak Ridge Turnpike bridge overpass and two sites along Blair Road (Map 1, Table 4). These sites were surveyed with Anabat SD-2 detectors on 5/21/2014 (5 sites) and 6/16/2014 (3 sites). Overall bat activity was moderate as a combined total of 482 bat calls were identified to species by the Kaleidoscope PRO program and 46 additional bat calls were recorded, but not identified (Table 5). The dominant species detected in this section was the Eastern Red bat (180 calls), Evening bat (184 calls), and Tri-colored bat (59 calls). In Section One, the highest number of bat calls were recorded at site OR-01 (289 total bat calls) at the Blair Road curve (pullover) near the bar-gated access road to George Jones Church. Site OR-05 (Haul Road access from Blair Road) was surveyed on 5/21/2014 and 14 bat calls were recorded; a follow-up survey (OR-13) at the same location on 6/16/2014 yielded no bat calls. Endangered species activity was low in this entire area as only three combined Gray bat calls were recorded. After Tables 4 & 5, there is a series of plates listed by site identification number as 'OR-01 chart/image' through 'OR-13 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 1

Table 4

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-1	35.93679	-84.373573	ETTP/Blair Road (pullover on curve near church)	5/21/2014	4	Anabat SD-2
OR-2	35.933336	-84.374694	ETTP/Haul Road near O-R Turnpike bridge overpass	5/21/2014	3	Anabat SD-2
OR-3	35.93705	-84.377736	ETTP/Haul Road (1.0 mile marker)	5/21/2014	3	Anabat SD-2
OR-4	35.938006	-84.380375	ETTP/Haul Road east of weigh station (scales)	5/21/2014	3	Anabat SD-2
OR-5	35.934566	-84.376051	ETTP/Blair Road (curve at Haul Road bar-gate)	5/21/2014	2	Anabat SD-2
OR-11	35.939343	-84.375547	ETTP/Blair Road/rain gauge station access road (utility ROW)	6/16/2014	3	Anabat SD-2
OR-12	35.937858	-84.381276	ETTP/Haul Road near weigh station (scales)	6/16/2014	3	Anabat SD-2
OR-13	35.934331	-84.376116	ETTP/Blair Road (curve at Haul Road bar-gate)	6/16/2014	3	Anabat SD-2

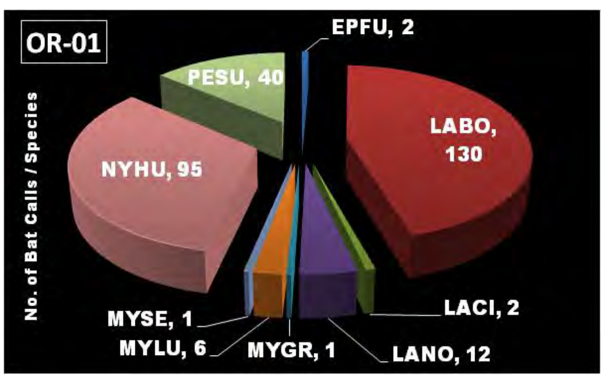
Table 5

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-01	2	130	2	12	1		6	1		95	40		28	44	16	265	8
OR-02		1	3	3						4	5	2	4	12	8	10	
OR-03		6		3	1		1	1		6	1		6	22	3	13	3
OR-04	1	14		12	1					9	4		3	20	13	27	1
OR-05		8					1			2	3		1	35		13	1
OR-11	1	13					1	3		67	4		2	12	1	84	4
OR-12	1	8								1	2		2	16	1	13	
OR-13	no bats					no bats					no bats						
subtotals	5	180	5	30	3		9	5		184	59	2	46	161	42	425	17

[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

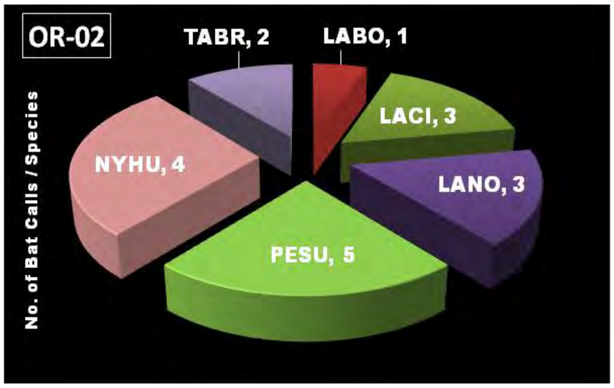
Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)



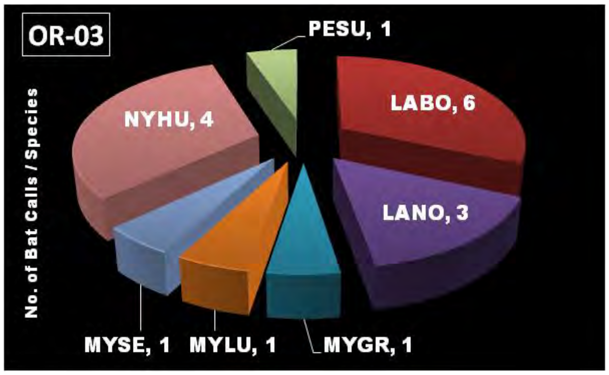
OR-01 chart

OR-01 image



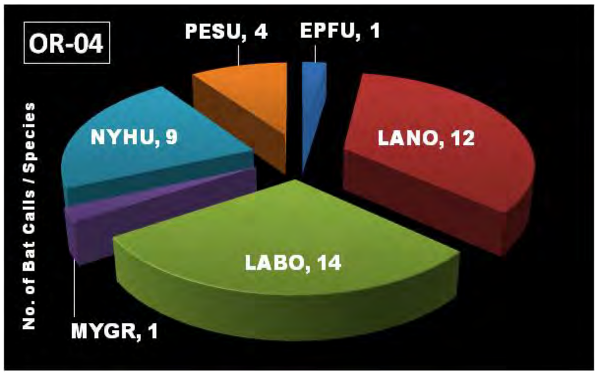
OR-02 chart

OR-02 image

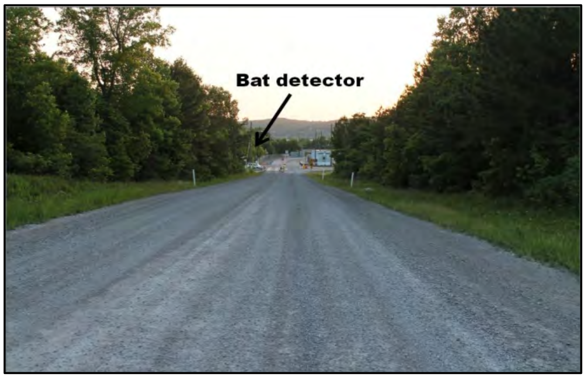


OR-03 chart

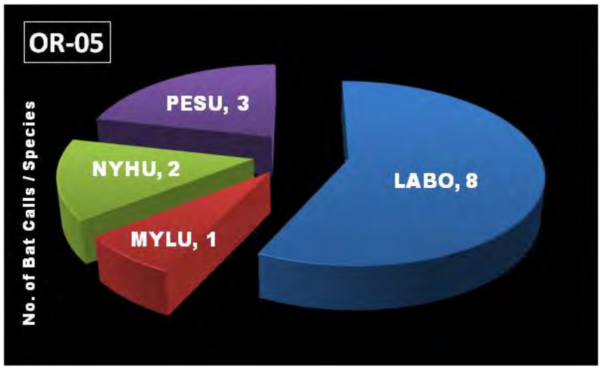
OR-03 image



OR-04 chart

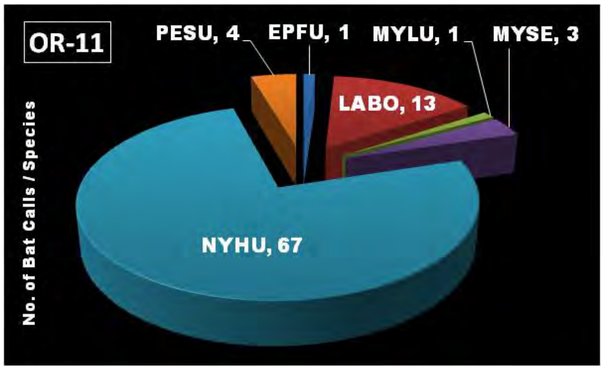


OR-04 image

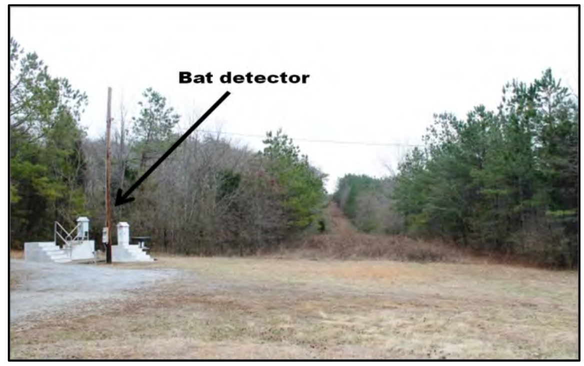


OR-05 chart

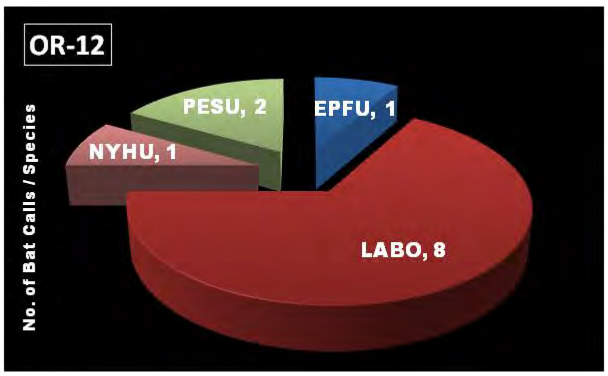
OR-05 image



OR-06 chart



OR-06 image



OR-12 chart

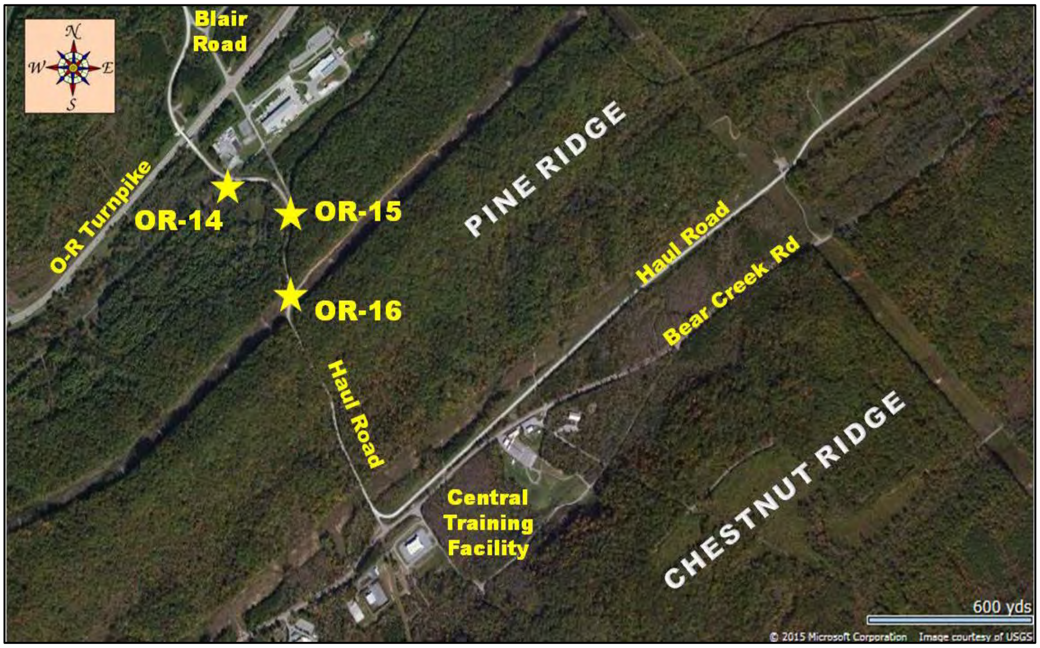
OR-12 image

OR-13 chart

OR-13 image

Section II: ETTP: Haul Road / Flannagan Road

Three sites were actively monitored for approximately three hours to record ultrasonic bat calls on Section Two. Surveying was conducted along the Haul Road (Flannagan Road) between the Oak Ridge Turnpike and the forested crest of Pine Ridge to the south. These sites were surveyed with Anabat SD-2 and EchoMeter EM3+ detectors on 6/16/2014. Overall, bat activity was light as only a combined total of 83 bat calls were identified to species by the Kaleidoscope PRO program and 48 additional bat calls were recorded, but not identified. The dominant species detected was the Eastern Red bat (26 calls) and the Evening bat (42 calls). In Section Two, the highest number of bat calls was recorded at site OR-14 (64 total bat calls) located at a bar-gated access road (junction with Haul Road) leading west into the old Happy Valley construction camp. No endangered species bat calls were recorded in this area. After Tables 6 & 7 (below here), there is a series of plates listed by site identification number as 'OR-14 chart/image' through 'OR-16 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 2

Table 6

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-14	35.930487	-84.374683	Haul Road at bar-gated access road to old "Happy Valley" site	6/16/2014	3	Anabat SD-2
OR-15	35.929536	-84.372307	Haul Road at base of Pine Ridge at jct of Old Flannagan Road	6/16/2014	3	Anabat SD-2
OR-16	35.927451	-84.37235	Haul Road at crest of Pine Ridge at powerline ROW	6/16/2014	3	EchoMeter EM3+

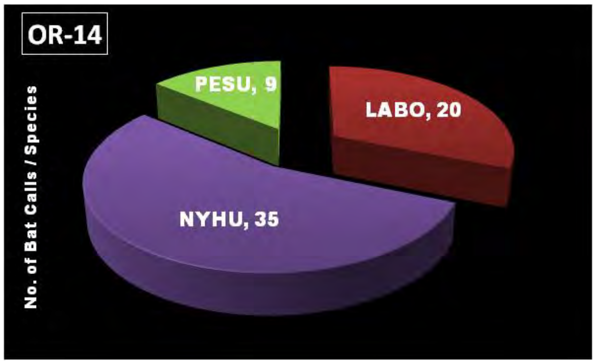
Table 7

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-14		20								35	9		1	20		64	
OR-15		6		1			1			6	2		9	506	1	14	1
OR-16	1									1	1		38	30	1	2	
subtotals	1	26		1			1			42	12		48	556	2	80	1

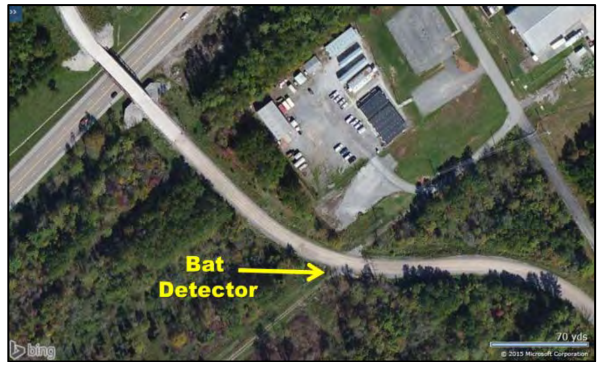
[1]**Notes:** The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, not the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

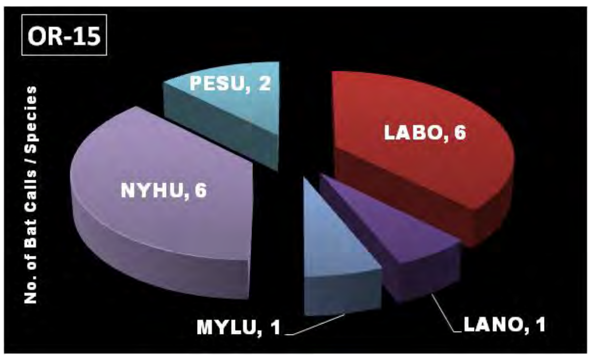
Site Specific Bat Call Data/Pictures (Plates)



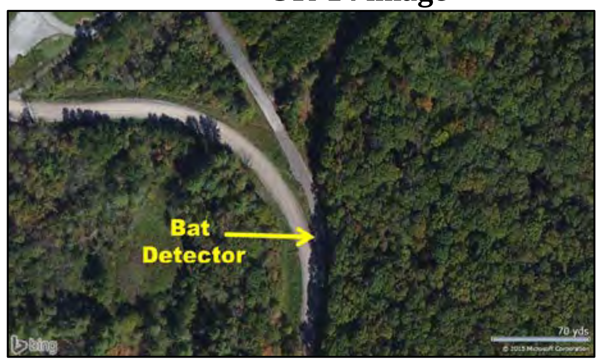
OR-14 chart



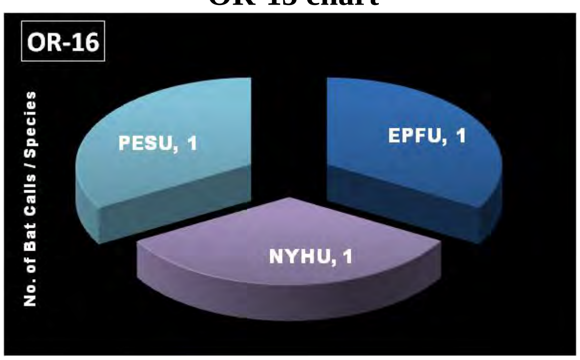
OR-14 image



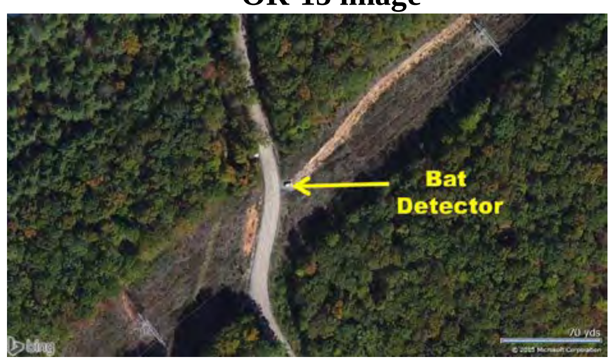
OR-15 chart



OR-15 image



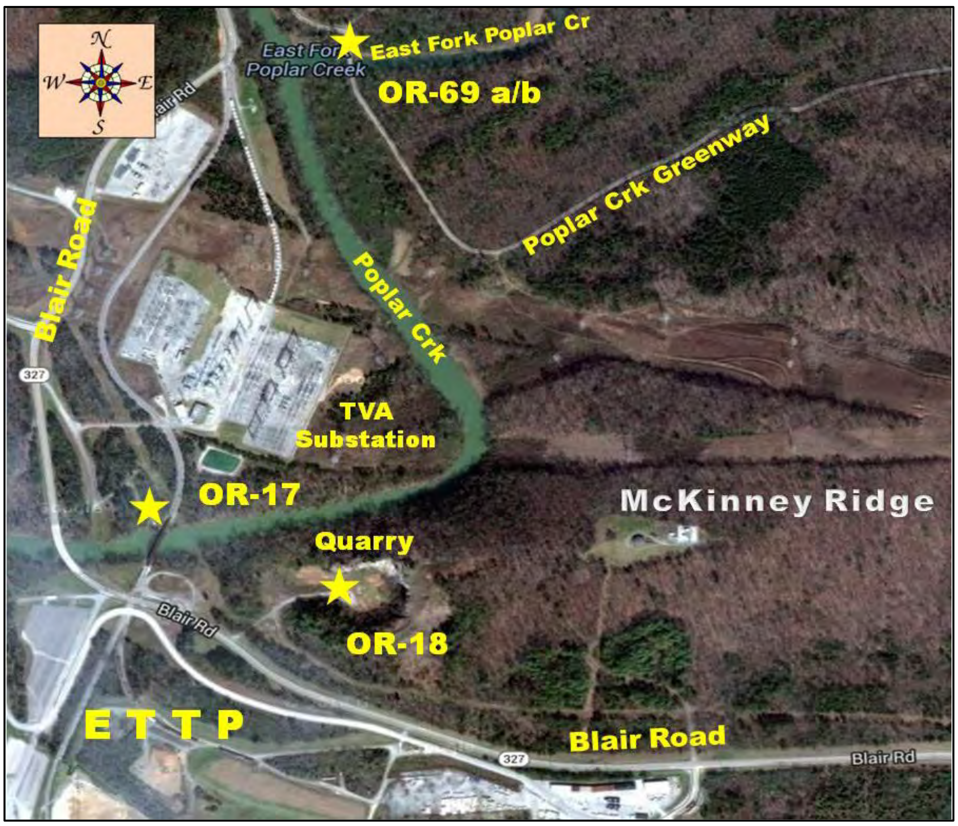
OR-16 chart



OR-16 image

Section III: Blair Road / Poplar Creek Greenway

Three sites were actively monitored for approximately three hours to record ultrasonic bat calls on Section Three. On 6/17/2014, we actively monitored with Anabat SD-2 detectors at Poplar Creek near the old RR bridge (ETTP area) and at Blair Road quarry. There is a known cave located north of the quarry on rocky bluffs above Poplar Creek. On 8/7/2014, we surveyed the Poplar Creek greenway bridge (at its confluence with East Fork Poplar Creek) using two detectors, Anabat SD-2 and the SongMeter SM2BAT+. Overall, bat activity was moderate as a combined total of 249 bat calls were identified to species by the Kaleidoscope PRO program and 152 additional bat calls were recorded, but not identified. The dominant species detected were the Eastern Red bat (33 calls), Hoary bat (68 calls), and the Tri-colored bat (50 calls). In Section Three, the highest number of bat calls recorded was at sites OR-18 (95 calls) and OR-69b (98 calls); OR-18 is the quarry site and OR-69 is the Poplar Creek/EFPC site. A total of 45 endangered Gray bat calls were recorded in Section Three, with the majority (42 calls) recorded at site OR-69b (bridge at confluence of EFPC with Poplar Creek). Gray bats prefer to forage for insect prey over water and it is possible these bats are roosting and emerged from several caves located <1.5 miles from this location. For quality control and to compare detector results, we monitored with one Anabat SD-2 and one SM2BAT+ at the Poplar Creek/EFPC site (OR-69a/b). Kaleidoscope PRO identified 98 bat calls and 46 no identifications from the Anabat SD-2 files, and 30 identified bat calls and 89 no identifications from the SongMeter SM2BAT+ files. It appears that the Anabat SD-2 recorded calls with sufficient call characteristics (i.e., search, approach, feeding buzz) to enable a greater number of species identifications (instead of no identifications) compared to the SongMeter SM2BAT+. After Tables 8 & 9 (below here), there is a series of plates listed by site identification number as 'OR-17 chart/image' through 'OR-69b chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 3

Table 8

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-17	35.942531	-84.389795	ETTP/Blair Rd/ Poplar Creek shore near old RR bridge	6/17/2014	3	Anabat SD-2
OR-18	35.941532	-84.387306	ETTP/Blair Road quarry	6/17/2014	3	Anabat SD-2
OR-69	35.949515	-84.386737	Poplar Creek trail jct w/ East Fork Poplar Creek (bridge)	8/7/2014	2	Anabat SD-2 / SongMeter SM2BAT+

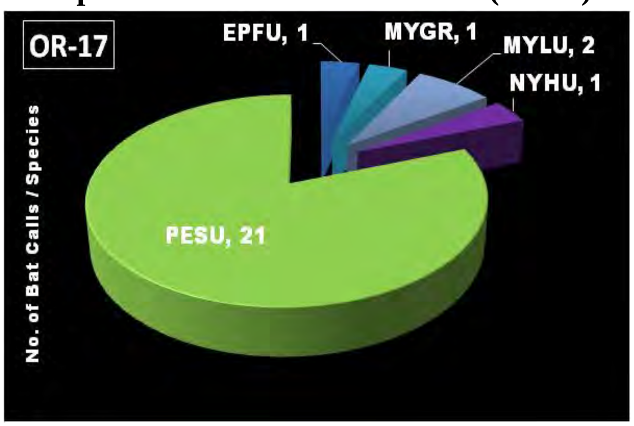
Table 9

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-17	1				1		2			1	21		5	12	1	22	3
OR-18	5	4	65	14						4	3		12	49	84	11	
OR-69a	2	9			2	1	1	1		6	8		89	31	2	23	5
OR-69b	10	20	3		42		2			3	18		46	89	13	41	44
subtotals	18	33	68	14	45	1	5	1		14	50		152	181	100	97	52

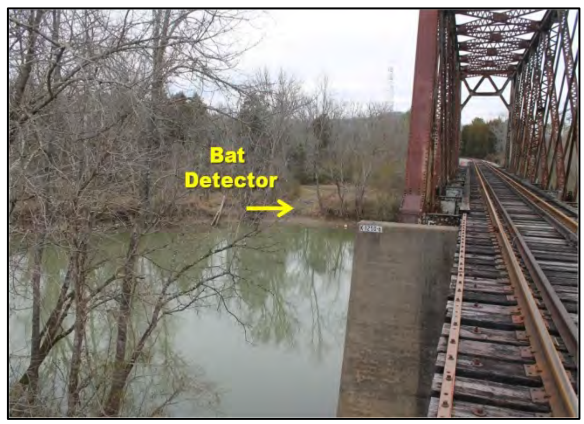
[1]**Notes:** The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, __not__ the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

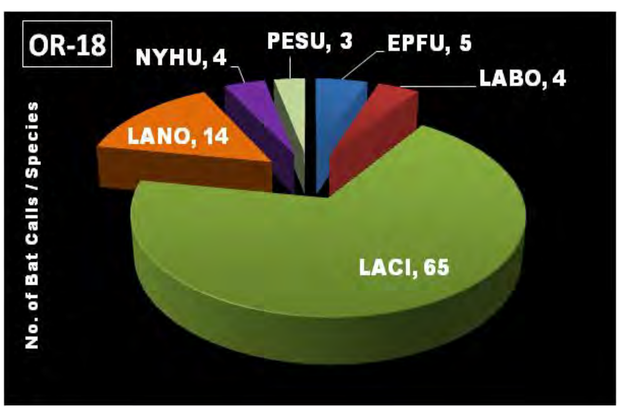
Site Specific Bat Call Data/Pictures (Plates)



OR-17 chart

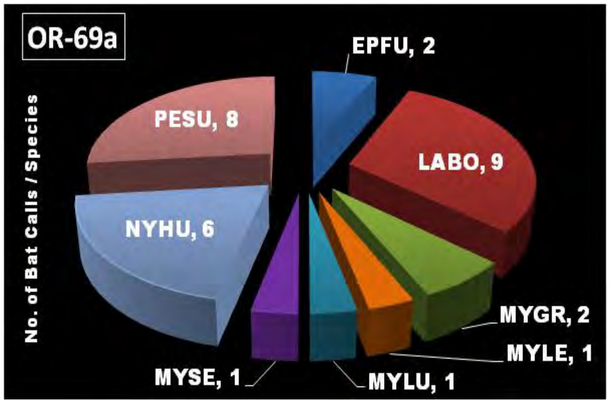


OR-17 image



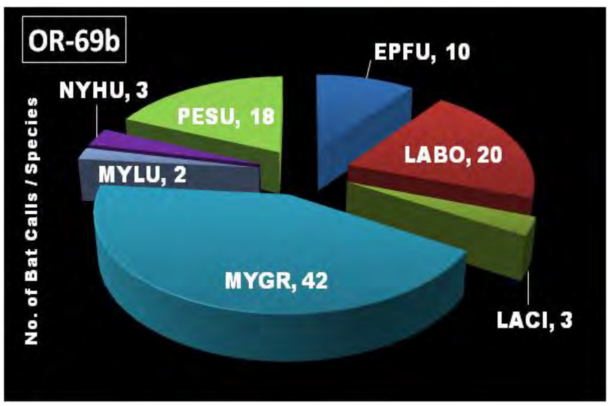
OR-18 chart

OR-18 image



OR-69a chart

OR-69a image

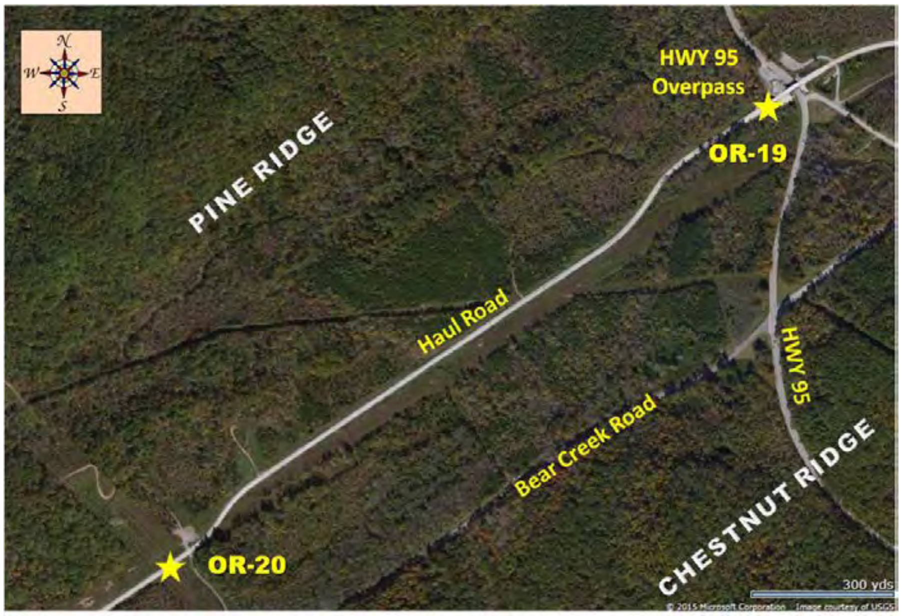


OR-69b chart

OR-69b image

Section IV: Haul Road (central area) near Highway 95 Overpass

Two Haul Road sites were monitored on 6/17/2014 with Anabat SD-2 detectors to record ultrasonic bat calls on Section Four. We deployed one Anabat SD-2 (preprogrammed to passively record dusk-dawn) at the Highway 95 overpass bridge (OR-19). The second detector was used to actively monitor along the Haul Road at the junction of two powerline ROWs (OR-20). Overall, bat activity was light at both sites as a combined total of 130 bat calls were identified to species by the Kaleidoscope PRO program and 29 additional bat calls were recorded, but not identified. The dominant species detected at the overnight site (OR-19) included the Evening bat (11 calls), Hoary bat (14 calls), and the Tri-colored bat (14 calls). The dominant species at site OR-20 was the Tri-colored bat (29 calls). A total of 4 endangered Gray bat calls were recorded at the overnight site (Hwy 95 overpass bridge). They may have been foraging over Bear Creek located beneath the bridge. After Tables 10 & 11 (below here), there is a series of plates listed by site identification number as 'OR-19 chart/image' through 'OR-20 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 4

Table 10

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-19	35.93844	-84.341097	Haul Road at HWY 95 overpass bridge	6/17/2014	overnight	Anabat SD-2
OR-20	35.930622	-84.353971	Haul Road (west of Hwy 95) at powerline ROW jct.	6/17/2014	3	Anabat SD-2

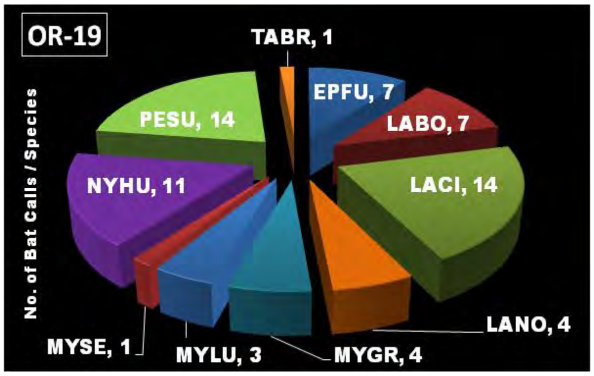
Table 11

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-19	7	7	14	4	4		3	1		11	14	1	6	46	26	32	8
OR-20	5	7	1	4			9	5		4	29		23	26460	1	14	1
subtotals	12	14	15	8	4		12	6		15	43	1	29	26506	27	46	9

[1]**Notes:** The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, not the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

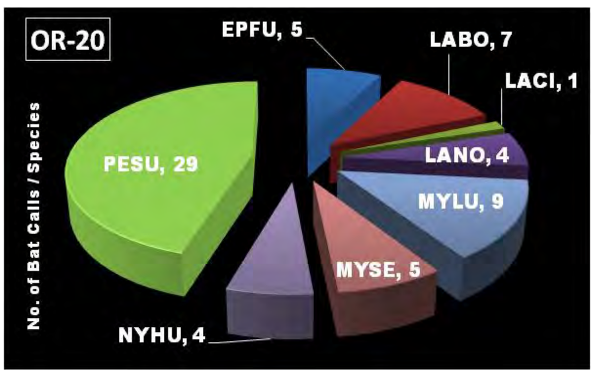
Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)

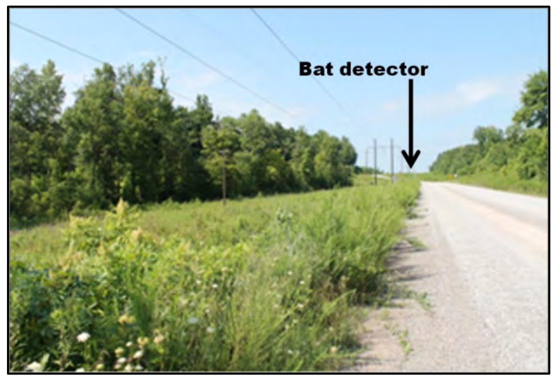


OR-19 chart

OR-19 image



OR-20 chart

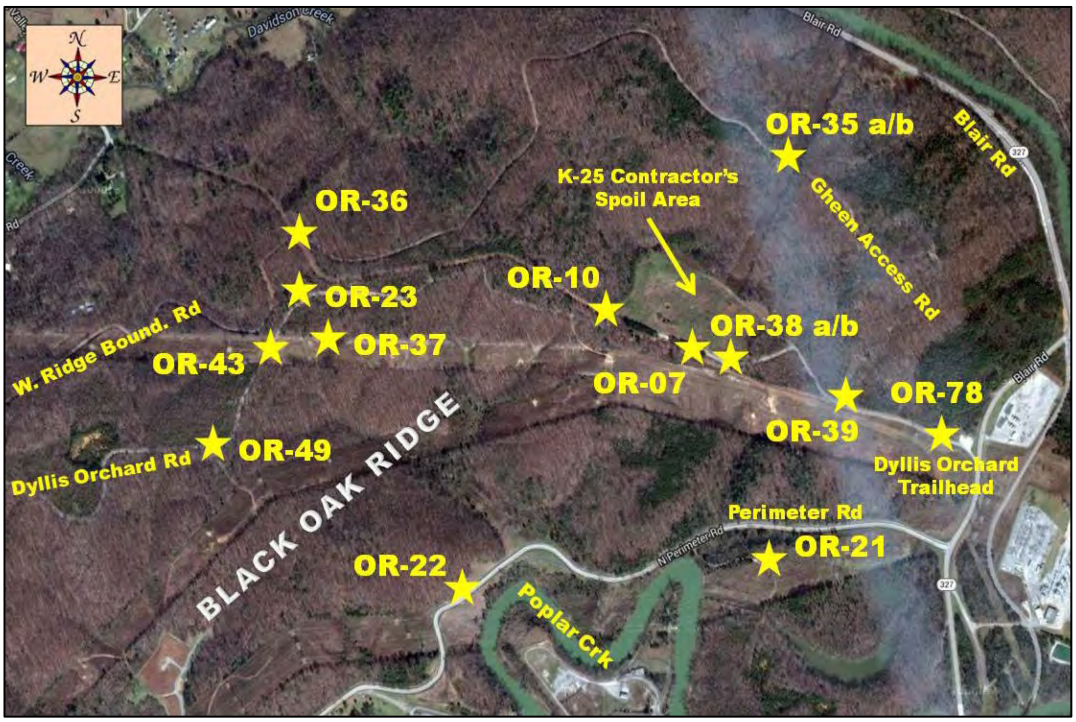


OR-20 image

Section V: East Dyllis Orchard Road (greenway) / Perimeter Road

Section Five consists of the eastern section of the Dyllis Orchard greenway on Black Oak Ridge (Black Oak Ridge Conservation Easement/BORCE) situated north of ETTP. The area is a mix of forest, utility right-of-ways (ROWs), gravel access roads, pre-Manhattan orchards, a woodland hiking/cycling trail (Twisted Beech Trail), and an old landfill site (K-25 Contractor's Spoil Area). The area is also characterized by a rich flora of wildflowers and ferns. There are several pre-Manhattan home sites in this section including the site of a former apple packing depot (site OR-49). Thirteen sites were actively monitored between 6/6/2014-7/26/2014 with Anabat SD-2 detectors at 11 sites and a mix of detectors (Anabats, SongMeter SM2BAT+, SM3BAT) at 2 sites to record ultrasonic bat calls on Section Five. Average survey time was 3.5 hours (dusk to approximately midnight). Overall, bat activity was heavy as a combined total of 1129 bat calls were identified to species by the Kaleidoscope PRO program and 258 additional bat calls were recorded, but not identified. The overall dominant species detected at all sites included the Big Brown bat (420 calls), Eastern Red bat (175 calls), and the Tri-colored bat (197 calls). Insect noise was prevalent at three sites with 885, 1960, and 840 noise files recorded at OR-23, OR-49, and OR-43 respectively. We detected a combined total of 131 *Myotis* spp. calls recorded from all sites. A total of nine endangered species calls (Gray bat, Indiana bat) were recorded at the OR-49 site (former apple packing/shipping depot).

For quality control and to compare detector results, we tested deployment of two Anabat SD-2s at site OR-35 (detectors oriented in opposite directions), and compared the Anabat SD-2 with the SongMeter SM3BAT at site OR-38 (detectors oriented in opposite directions). The results for both tests did not compare favorably, so the assumption is made that the difference in directional orientation of the respective microphones accounts for the discrepancies. Future QA/QC tests will be conducted with detectors oriented in the same direction. Kaleidoscope PRO identified 98 bat calls and 46 no identifications from the Anabat SD-2 files, and 30 identified bat calls and 89 no identifications from the SongMeter SM2BAT+ files. After Tables 12 & 13 (below here), there is a series of plates listed by site identification number as 'OR-07 chart/image' through 'OR-78 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of the 13 survey sites.



Map 5

Table 12

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-7	35.94935	-84.397767	Dyllis Orchard Road/ open field @ K25 landfill	6/6/2014	3	Anabat SD-2
OR-10	35.949866	-84.399628	Dyllis Orchard Rd/ southwest corner of K-25 landfill	6/6/2014	2	Anabat SD-2
OR-21	35.945215	-84.39605	Perimeter Road at powerline acc. rd near oxbow lake	6/17/2014	3	Anabat SD-2
OR-22	35.944451	-84.40341	Perimeter Rd on ridgetop overlooks ETTP (Clinch R.)	6/17/2014	2	Anabat SD-2
OR-23	35.950227	-84.407208	Dyllis Orchard Road / jct. w/ access road	6/21/2014	5	Anabat SD-2
OR-35 a & b	35.952728	-84.395406	Jct of Gheen Access Rd w/ West Boundary Ridge Rd	7/3/2014	4	Anabat SD-2 (2 units)
OR-36	35.95133	-84.40738	Dyllis Orchard: W. Bound Ridge Rd @ gas pipeline ROW	7/3/2014	4	Anabat SD-2
OR-37	35.949211	-84.408002	Dyllis Orchard Rd / powerline ROW	7/3/2014	4	Anabat SD-2
OR-38 a & b	35.949011	-84.397112	Dyllis Orchard Rd: K-25 landfill @ powerline ROW (field)	7/3/2014	4	Anabat SD-2 / SongMeter SM3BAT
OR-39	35. 948294	-84.394258	Dyllis Orchard Road jct w/ Gheen Access Road / ROW	7/3/2014	3	SongMeter SM2BAT+
OR-43	35.949254	-84.407991	Dyllis Orchard Road at powerline ROW	7/15/2014	3	Anabat SD-2
OR-49	35.947413	-84.409418	Dyllis Orchard Rd /former apple storehouse acc. road	7/26/2014	4	Anabat SD-2
OR-78	35.947447	-84.391361	Dyllis Orchard Greenway at bargate near trailhead	7/15/2014	2	Anabat SD-2

Table 13

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-07		2	2	1	2		1	1		2	1		0	8	3	5	4
OR-10	2	19					1	6		28	19		6	15	2	66	7
OR-21			1								3			14	1	3	
OR-22			1								1				1	1	
OR-23	18	3		8			2			9	14		12	885	26	26	2
OR-35a	8	8	2	4	2		10			4	28		10	412	14	40	12
OR-35b	32	4	6	2				2		2	32		8	42	40	38	2
OR-36	224	23		5			3			29	9		4		229	61	3
OR-37	20	24	4	4			4	4		18	14		6	126	28	56	8
OR-38a	4	8	4	2						2	6		2	46	10	16	
OR-38b	18	8	2				6	10		6	40		155	149	20	54	16
OR-39	4			2									6	8	6		
OR-43	21	13	35	2			3	6		7	15		6	840	58	35	9
OR-49	69	60		2	4		31	30	1	9	14		41	1960	71	83	66
OR-78		3		1			1	1			1		2	1	1	4	2
subtotals	420	175	57	33	8		62	60	1	116	197		258	4506	510	488	131

[1]**Notes:** The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz).** All bat files were processed using the Kaleidoscope PRO automated identification software program.

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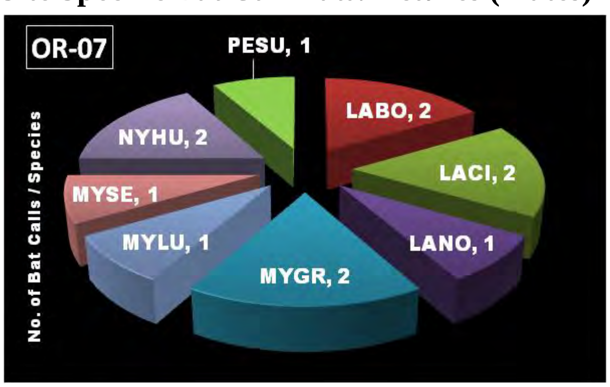
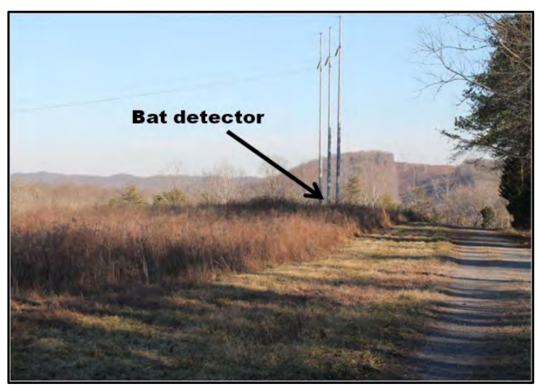
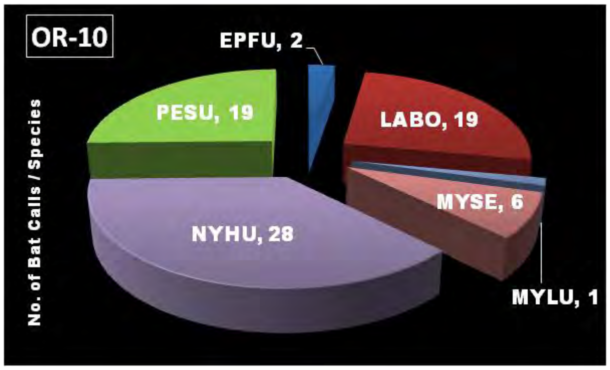
Site Specific Bat Call Data/Pictures (Plates)



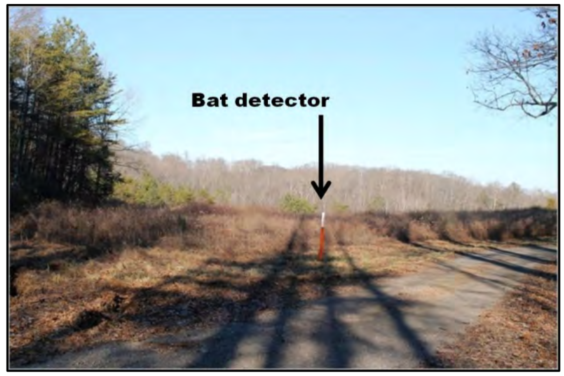
OR-07 chart



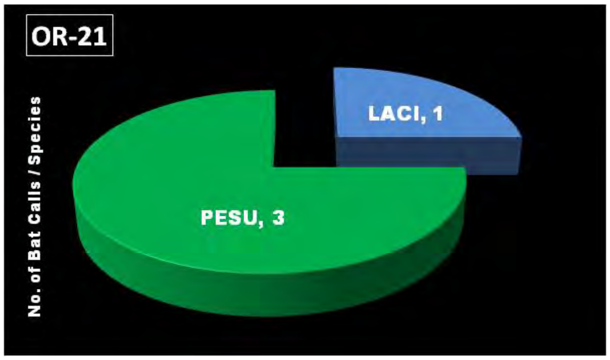
OR-07 image



OR-10 chart

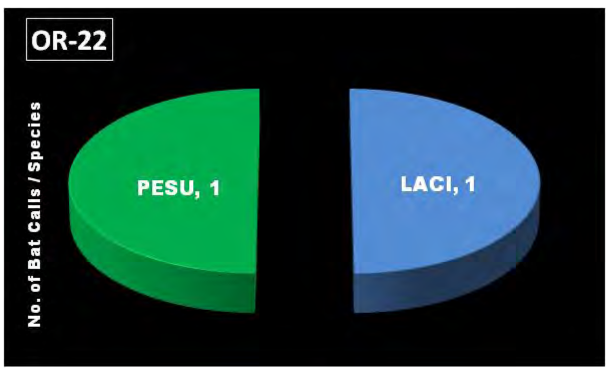


OR-10 image



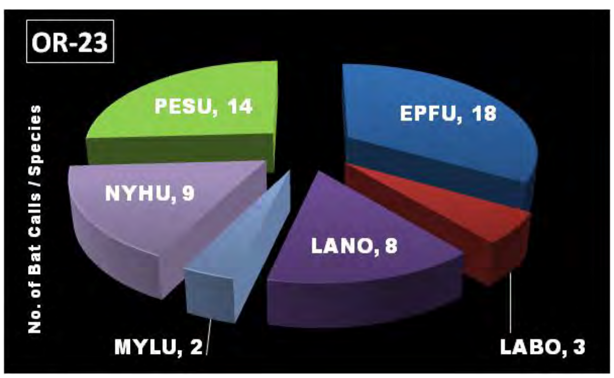
OR-21 chart

OR-21 image



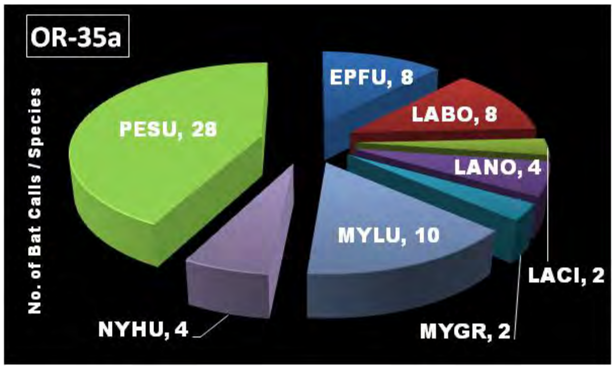
OR-22 chart

OR-22 image



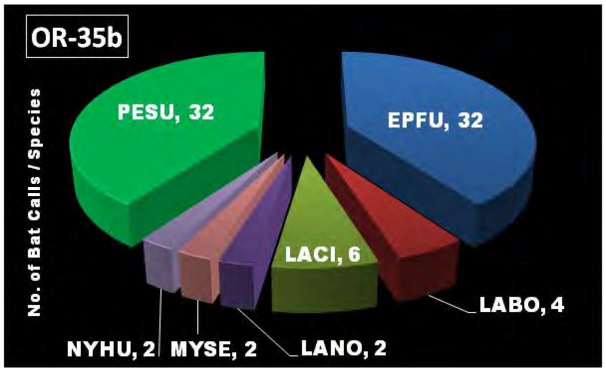
OR-23 chart

OR-23 image

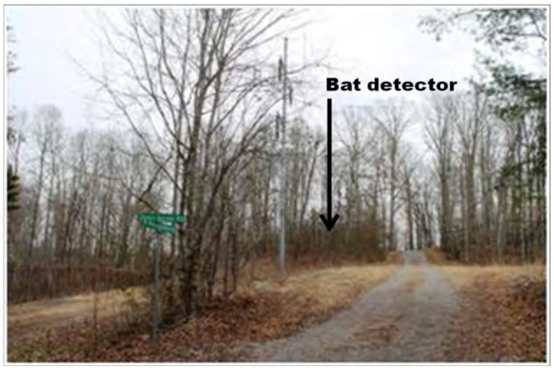


OR-35a chart

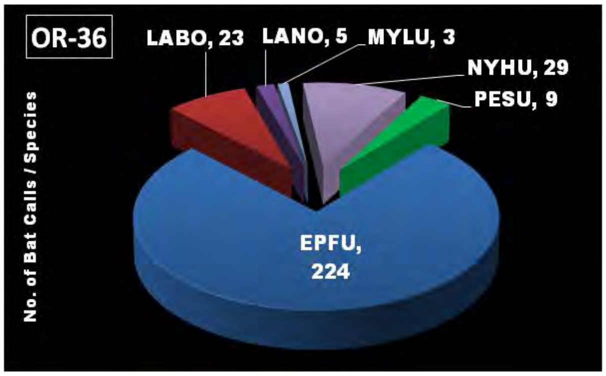
OR-35a image



OR-35b chart

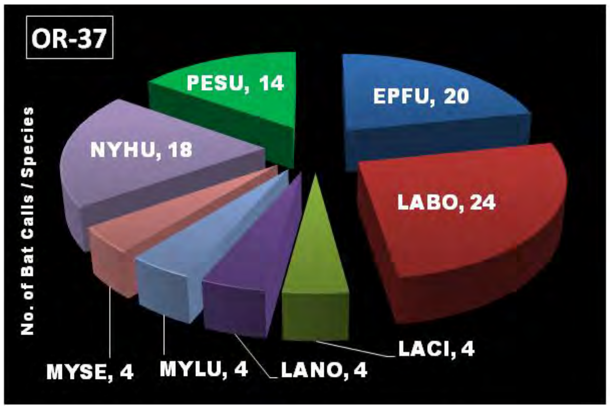


OR-35b image

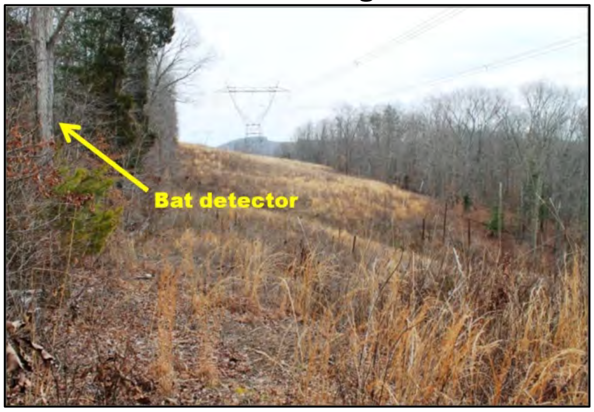


OR-36 chart

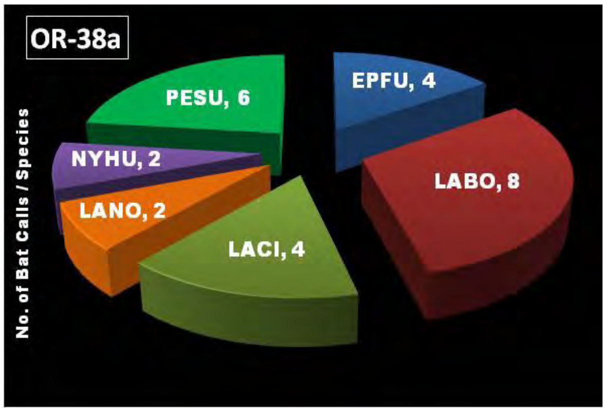
OR-36 image



OR-37 chart

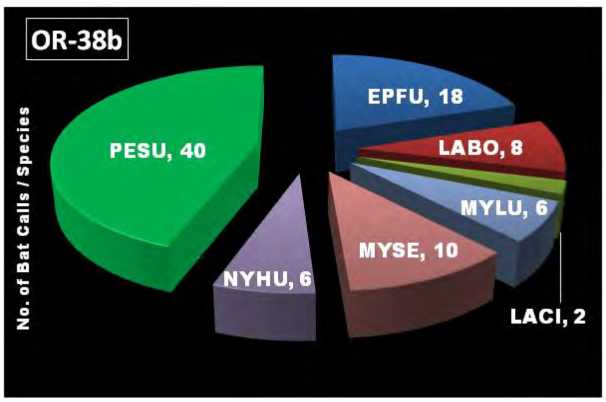


OR-37 image



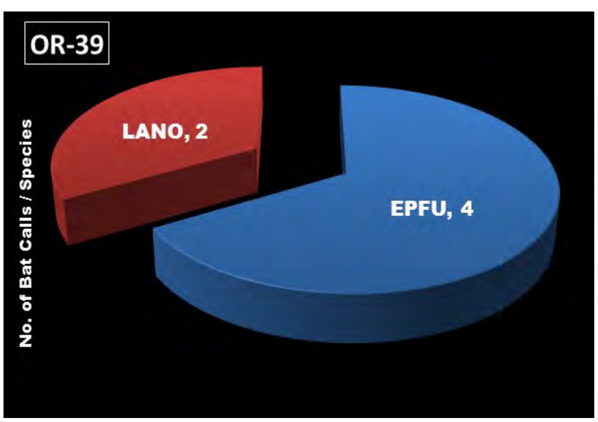
OR-38a chart

OR-38a image



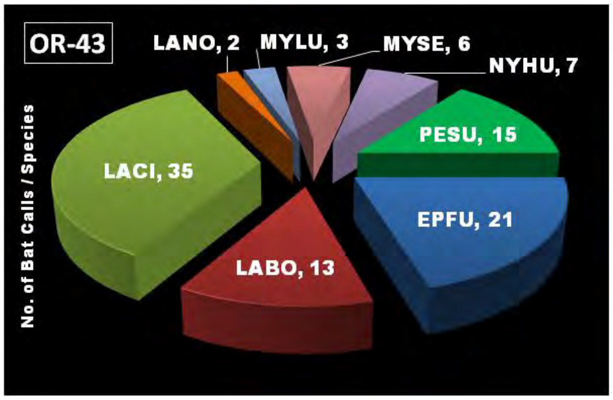
OR-38b chart

OR-38b image

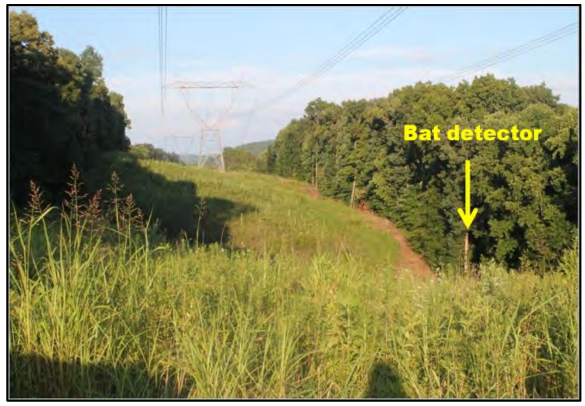


OR-39 chart

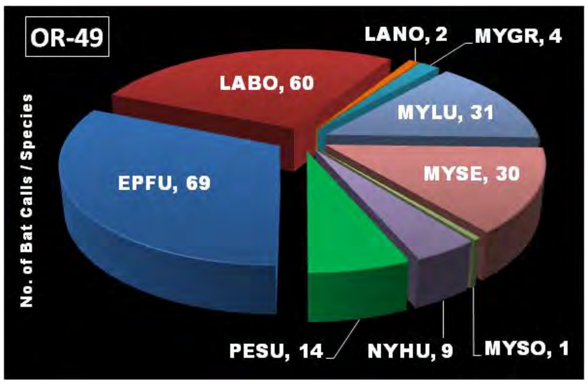
OR-39 image



OR-43 chart

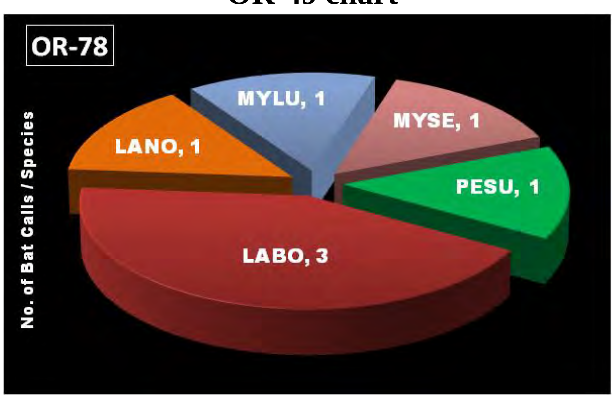


OR-43 image

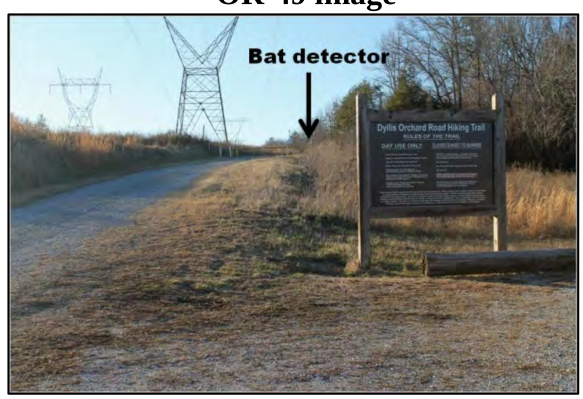


OR-49 chart

OR-49 image



OR-78 chart

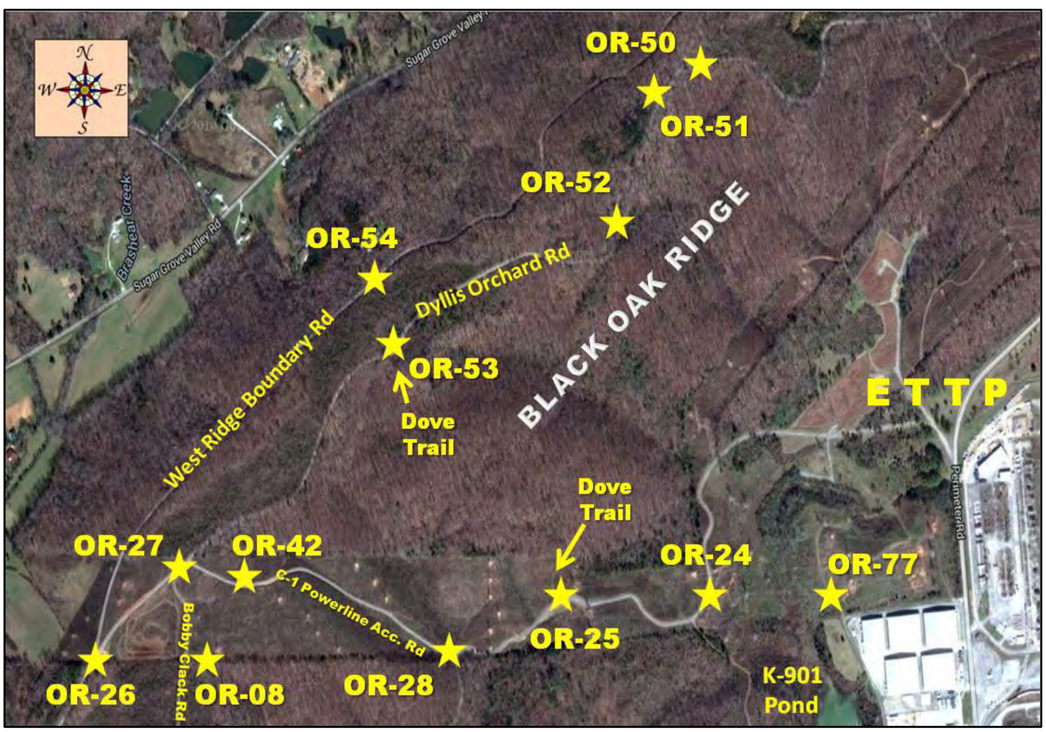


OR-78 image

Section VI: Central Dyllis Orchard Road (greenway)

Section Six consists of the central section of the Dyllis Orchard greenway on Black Oak Ridge (Black Oak Ridge Conservation Easement) situated north of ETTP. The area is a mix of forest, utility right-of-ways (ROWs), gravel access roads, a woodland hiking trail (Dove Trail), and pre-Manhattan orchards. There are several pre-Manhattan home sites in this section. The area is also characterized by a rich flora of wildflowers and ferns. Thirteen sites were monitored between 6/6/2014-9/17/2014 with Anabat SD-2 and SongMeter SM2BAT+ detectors; of these, 12 were actively monitored for approximately 3.5 hours (dusk-midnight) each to record ultrasonic bat calls on Section Six. Station OR-77 (K-901 Pond drainage basin) was monitored passively from dusk-dawn. Overall, bat activity was heavy as a combined total of 962 bat calls were identified to species by the Kaleidoscope PRO program and 225 additional bat calls were recorded, but not identified. The dominant species detected at all sites included the Big Brown bat (194 calls), Eastern Red bat (207 calls), Little Brown bat (135 calls), Northern Long-eared bat (202 calls), and the Evening bat (106 calls). Insect noise was prevalent at three sites with 1610, 2570, and 928 noise files recorded at OR-51, OR-52, and OR-54 respectively; the noise is likely due to evening insect activity, cicadas, etc. We detected a combined total of 350 *Myotis* spp. calls (mainly Little Brown and Northern Long-eared bats) recorded from all sites. Given the greatest number of *Myotis* bat calls (165) were recorded at monitoring site OR-52 along the forested Dyllis Orchard Road, where are all these *Myotis* bats coming from? Recall that *Myotis* species are predominantly cave bats. There are no documented caves within 0.5-1.0 mile of this site, but it is within 3-5 miles of several known cave locations where these bats may roost; or, is there an unknown cave much closer to this site? We recorded 12 endangered species calls (Gray bat, Indiana bat) from locations on a ridgetop (powerline ROW, OR-30) and near the Clinch River (OR-33).

After Tables 14 & 15 (below here), there is a series of plates listed by site identification number as 'OR-08 chart/image' through 'OR-77 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of the 13 survey sites.



Map 6

Table 14

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-8	35.936946	-84.428022	Dyllis Orchard/ Bobby Clack Road at powerline ROW	6/6/2014	3	Anabat SD-2
OR-24	35.937849	-84.414922	ETTP/C-1 Powerline Road overlooks K-901 Pond basin	6/21/2014	4	Anabat SD-2
OR-25	35.93798	-84.418559	Dyllis/Lower jct. of Dove Trail w/ C-1 Powerline Road	6/21/2014	4	Anabat SD-2
OR-26	35.93705	-84.430393	Dyllis Orchard Rd jct w/ W. Ridge Boundary Rd (ROW)	6/21/2014	3	Anabat SD-2
OR-27	35.938492	-84.427947	ETTP/Dyllis Orchard Rd jct w/ C-1 Powerline Acc. Rd.	6/21/2014	2	Anabat SD-2
OR-28	35.936955	-84.421338	ETTP/Raby Road jct w/ C-1 Powerline Access Rd	6/21/2014	2	Anabat SD-2
OR-42	35.938136	-84.426574	Dyllis Orchard: C-1 Powerline Access Road (ridge)	7/15/2014	3	Anabat SD-2
OR-50	35.94642	-84.41549	Dyllis Orchard Road at curve	7/26/2014	4	Anabat SD-2
OR-51	35.94604	-84.41604	Dyllis Orchard Road at straight-away	7/26/2014	4	Anabat SD-2
OR-52	35.94387	-84.417317	Dyllis Orchard Road / east of DOE warning siren	7/26/2014	4	Anabat SD-2
OR-53	35.94175	-84.42318	Dyllis Orchard Road @ upper Dove Trail (trailhead jct)	7/26/2014	4	SongMeter SM2BAT+
OR-54	35.943148	-84.42328	Dyllis Orchard/West Ridge Boundary Rd (straight-away)	7/26/2014	3	Anabat SD-2
OR-77	35.937493	-84.412154	ETTP/ field west of Fissile Control Bldg (K-901 Pond)	9/17/2014	overnight	SongMeter SM2BAT+

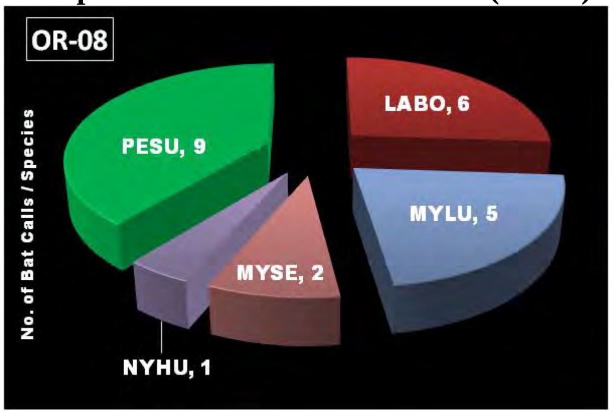
Table 15

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-08		6					5	2		1	9		8	414		16	7
OR-24	5	1		1							2			41	6	3	
OR-25	no bats					no bats					no bats						
OR-26											1			218		1	
OR-27			3										1	5	3		
OR-28	12		1	9									1	20	22		
OR-42	2	1						1			5		4	38	2	6	1
OR-50	31	32	1	2	2	1	21	23		2	1		19		34	35	47
OR-51	28	32		1	2		26	36		16	5		33	1610	29	53	64
OR-52	37	103		1	2		59	102	2	76	16		115	2570	38	195	163
OR-53	no bats					no bats					no bats						
OR-54	72	19		2	1		22	33		5	7		26	928	74	31	56
OR-77	7	13	2	1	3		2	5		6	35		18	143	10	54	10
subtotals	194	207	7	17	10	1	135	202	2	106	81		225	5987	218	394	348

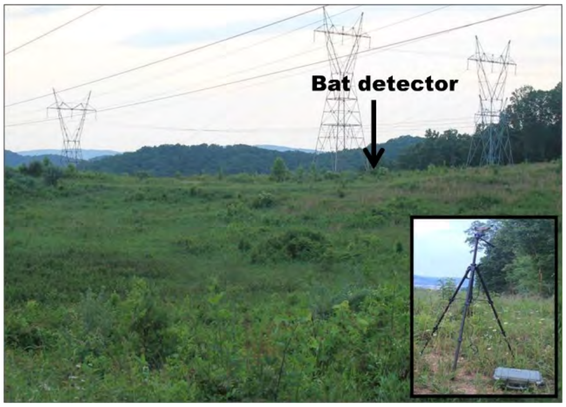
[1]Notes: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, not the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** (≥ 40kHz). All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

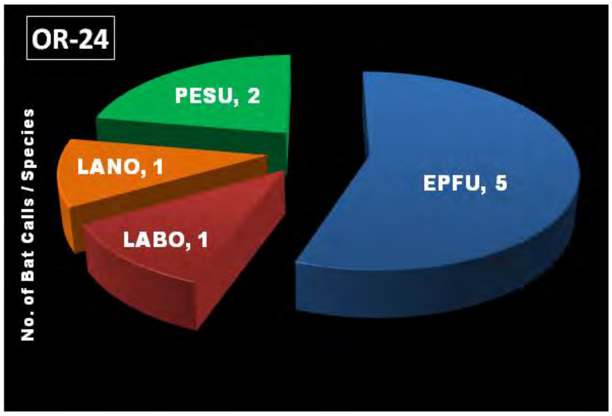
Site Specific Bat Call Data/Pictures (Plates)



OR-08 chart



OR-08 image

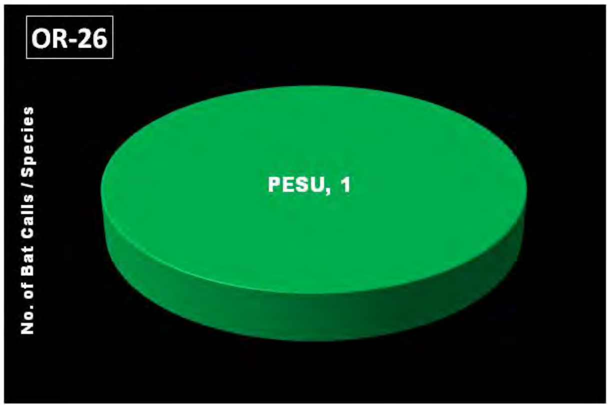


OR-24 chart

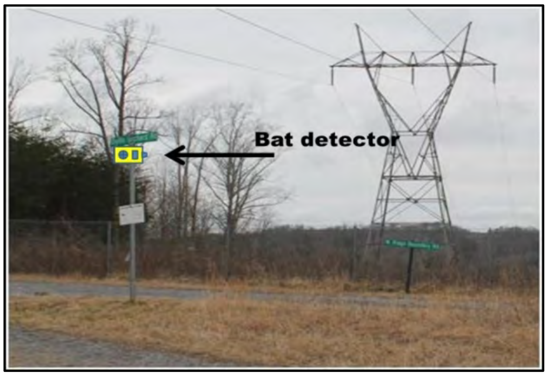
OR-24 image

OR-25 chart

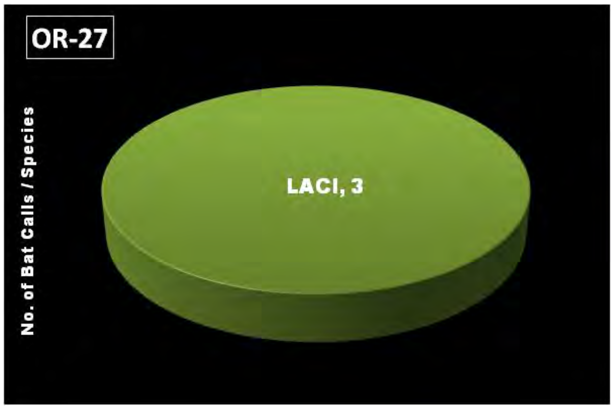
OR-25 image



OR-26 chart

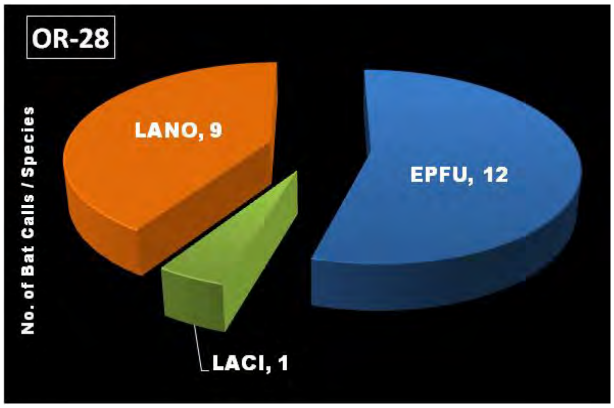


OR-26 image



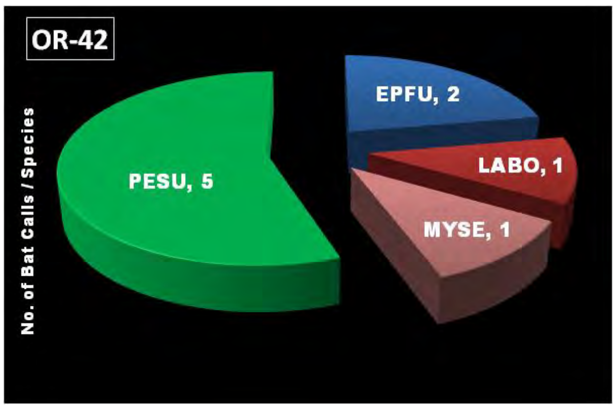
OR-27 chart

OR-27 image

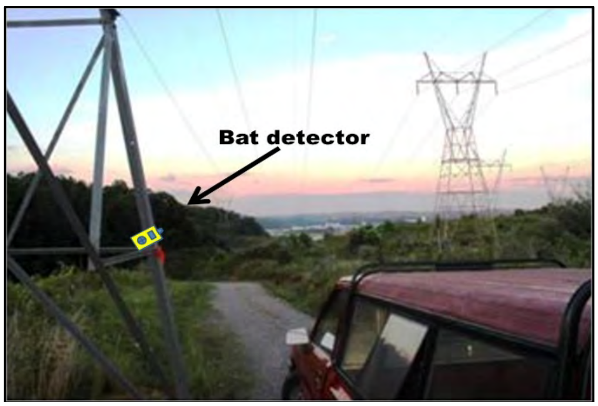


OR-28 chart

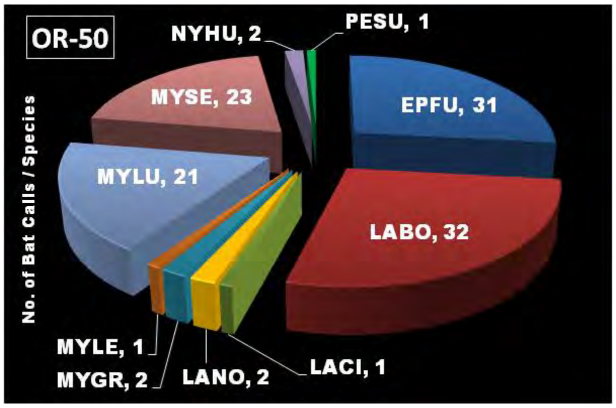
OR-28 image



OR-42 chart

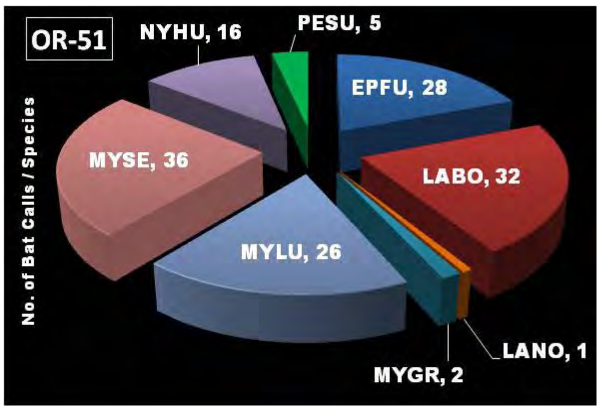


OR-42 image

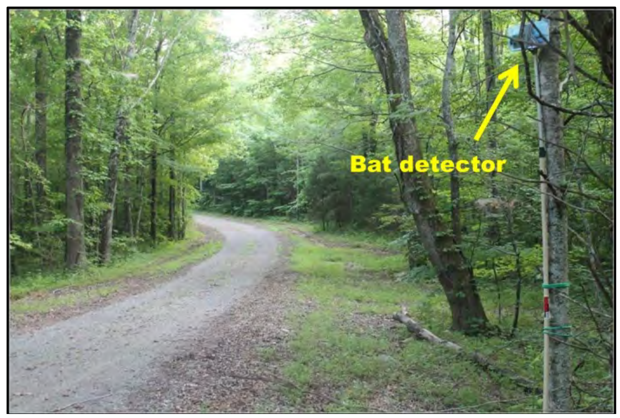


OR-50 chart

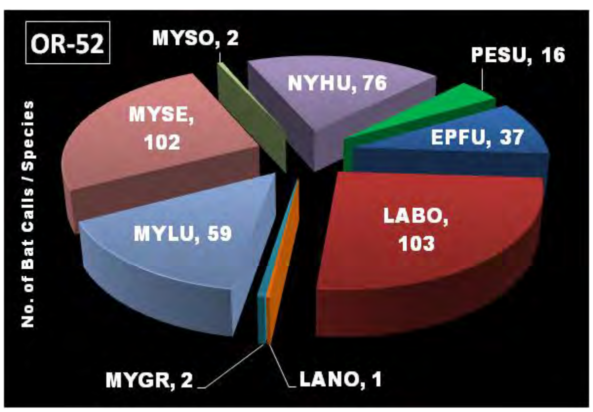
OR-50 image



OR-51 chart



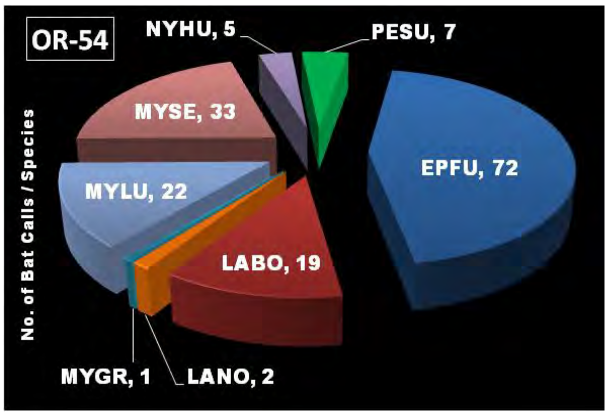
OR-51 image



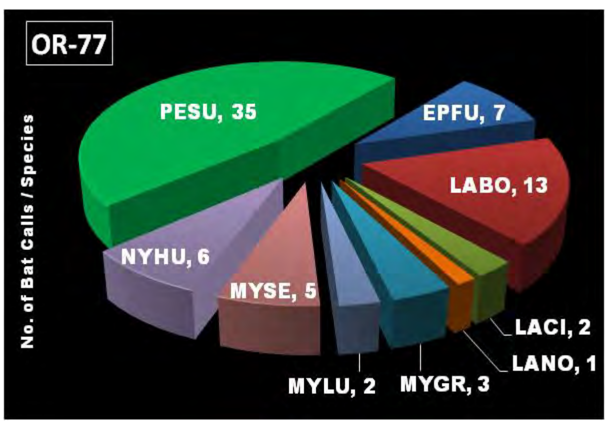
OR-52 chart

OR-52 image

OR-53 chart **OR-53 image**



OR-54 chart **OR-54 image**

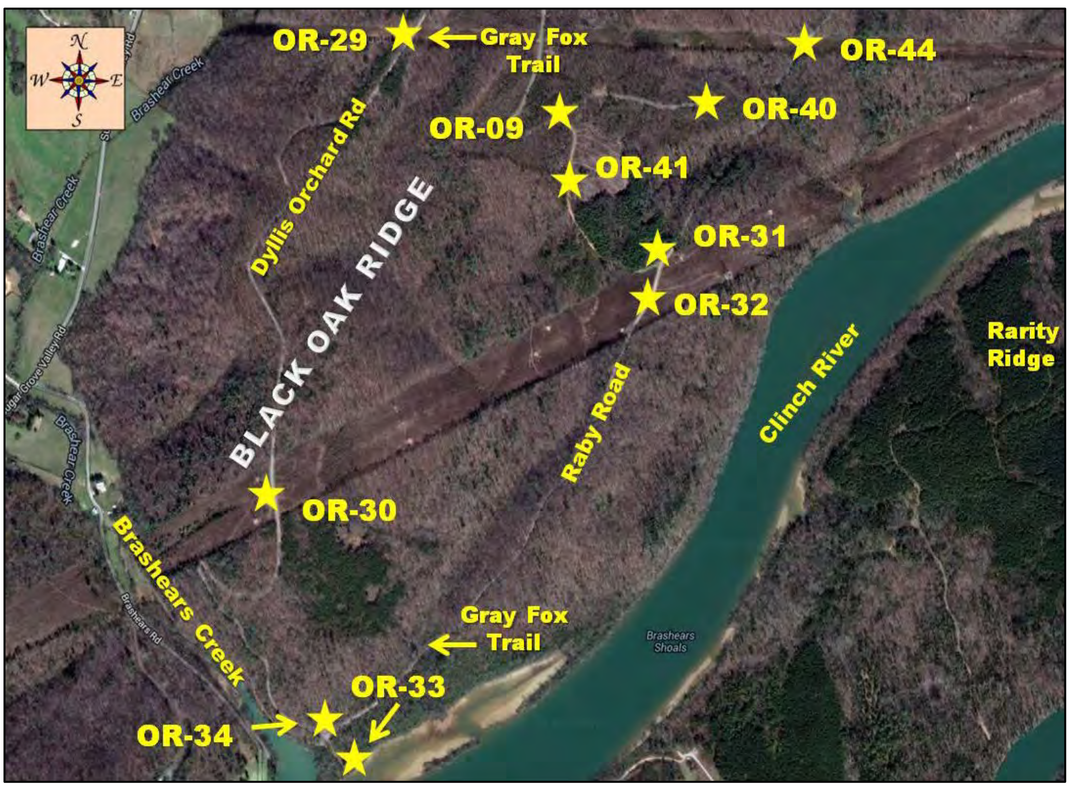


OR-77 chart **OR-77 image**

Section VII: West Dyllis Orchard Road (greenway)

Section Seven consists of the western section of the Dyllis Orchard greenway on Black Oak Ridge (Black Oak Ridge Conservation Easement) situated northwest of ETTP. The area is a mix of forest, utility right-of-ways (ROWs), gravel access roads, a woodland hiking trail (Gray Fox Trail), and pre-Manhattan orchards. There are several pre-Manhattan home sites in this section. The area is also characterized by a rich flora of wildflowers and ferns. Ten sites were actively monitored for an average of 3.5 hours each between 6/6/2014-7/15/2014 with Anabat SD-2 at eight sites, SongMeter SM2BAT+ at one site, and EchoMeter EM3+ at one site to record ultrasonic bat calls on Section Seven. Overall, bat activity was heavy as a combined total of 656 bat calls were identified to species by the Kaleidoscope PRO program and 1377 additional bat calls were recorded, but not identified. The overall dominant species detected at all sites included the Big Brown bat (193 calls) and Tri-colored bat (323 calls). Insect noise was prevalent at two sites with 509 and 935 noise files recorded at OR-09 and OR-40 respectively. We detected a combined total of 40 *Myotis* spp. calls recorded from all sites. The two most active sites included OR-33 (221 total calls) and OR-44 (145 total calls). We recorded three endangered species calls (Gray bat, Indiana bat) collected at OR-30 and OR-33.

After Tables 16 & 17 (below here), there is a series of plates listed by site identification number as 'OR-09 chart/image' through 'OR-44 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of the ten survey sites.



Map 7

Table 16

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-9	35.933992	-84.427872	Dyllis Orchard/ B. Clack Rd jct. w/ cemetery acc. road	6/6/2014	3	Anabat SD-2
OR-29	35.935556	-84.431477	Dyllis Orchard Rd at jct of Gray Fox Trail	6/30/2014	4	Anabat SD-2
OR-30	35.92699	-84.435124	Dyllis Orchard Rd powerline ROW/Brashears Rd below	6/30/2014	4	Anabat SD-2
OR-31	35.931247	-84.425511	Dyllis Orchard area: jct Raby Rd w/ B. Clack Rd / ROW	6/30/2014	3	Anabat SD-2
OR-32	35.930517	-84.425855	Dyllis Orchard area: Raby Road powerline tower	6/30/2014	4	SongMeter SM2BAT+
OR-33	35.921751	-84.43314	Dyllis Orchard: Raby Road curve / Clinch R. shore	6/30/2014	3	Anabat SD-2
OR-34	35.922499	-84.433622	Dyllis Orchard area: Raby Road curve at ridge base	6/30/2014	3	Anabat SD-2
OR-40	35.934262	-84.424245	Dyllis Orchard area: old cemetery east of B. Clack Rd	7/15/2014	4	Anabat SD-2
OR-41	35.93262	-84.427657	Dyllis Orchard area: large open field along B. Clack Rd	7/15/2014	4	Anabat SD-2
OR-44	35.935408	-84.421864	Dyllis Orchard area: Raby Road south of C-1 Powerline	7/15/2014	3	EchoMeter EM3+

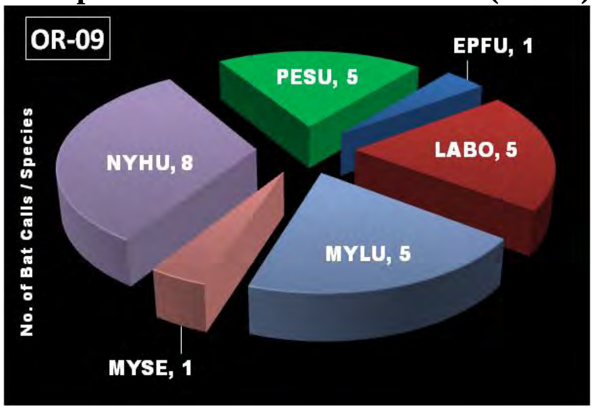
Table 17

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-09	1	5					5	1		8	5		11	509	1	18	6
OR-29	41	2	1	4						2	6		4	37	46	10	
OR-30	1			1					1	2	5		2	14	2	7	1
OR-31	14		1	1							12			24	16	12	
OR-32	11		1										37	15	12		
OR-33	1	12		2	2		1	4			199		21	75	3	211	7
OR-34	24	8	6					1		2	38		5	34	30	48	1
OR-40	15	11	1	2			8	6		3	21		10	935	18	35	14
OR-41	1	2								5	5		2	294	1	12	
OR-44	84	10		4			2	9		4	32		1285	296	88	46	11
subtotals	193	50	10	14	2		16	21	1	26	323		1377	2233	217	399	40

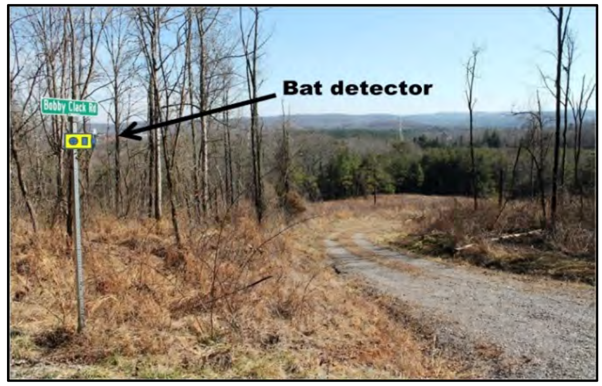
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

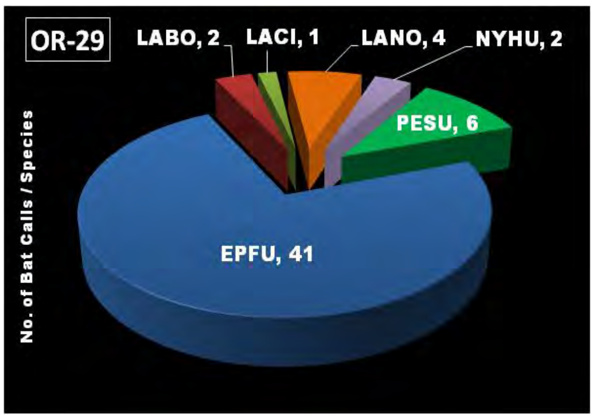
Site Specific Bat Call Data/Pictures (Plates)



OR-09 chart

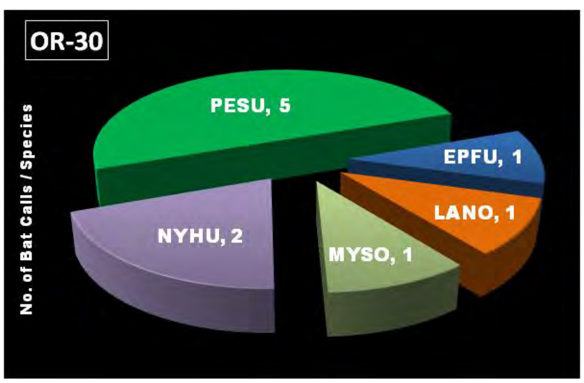


OR-09 image



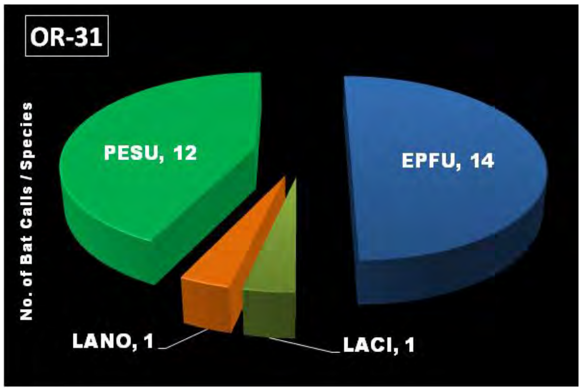
OR-29 chart

OR-29 image



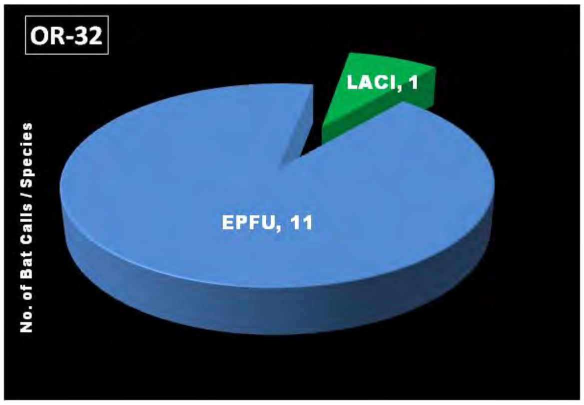
OR-30 chart

OR-30 image

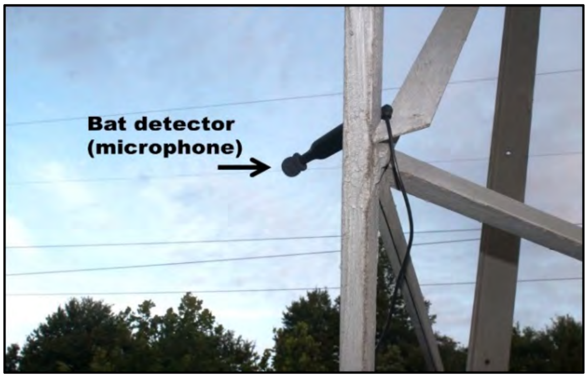


OR-31 chart

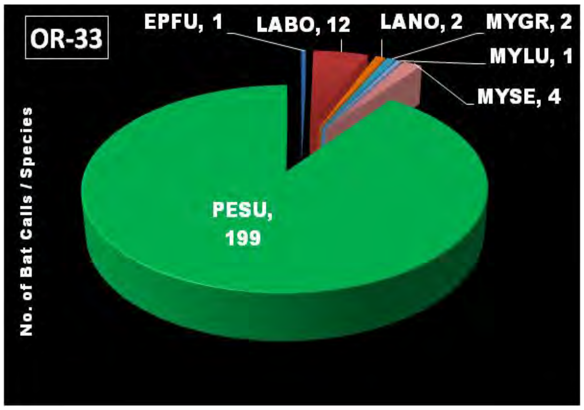
OR-31 image



OR-32 chart

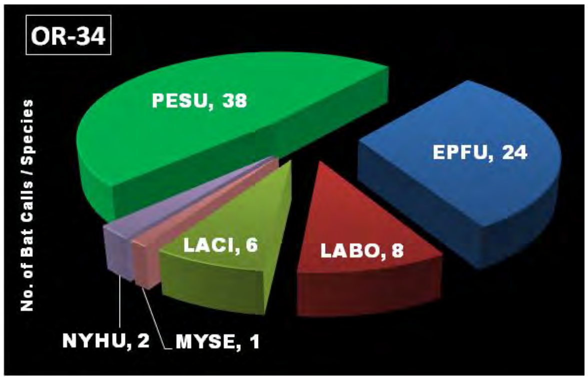


OR-32 image



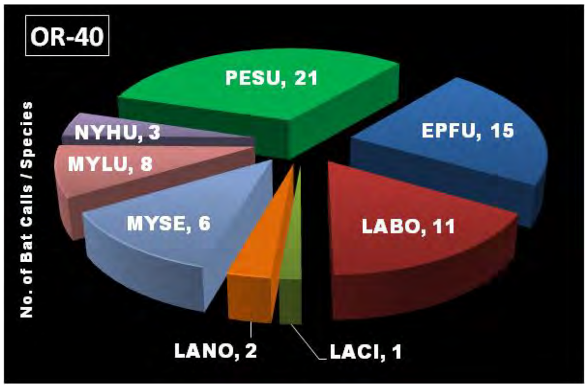
OR-33 chart

OR-33 image



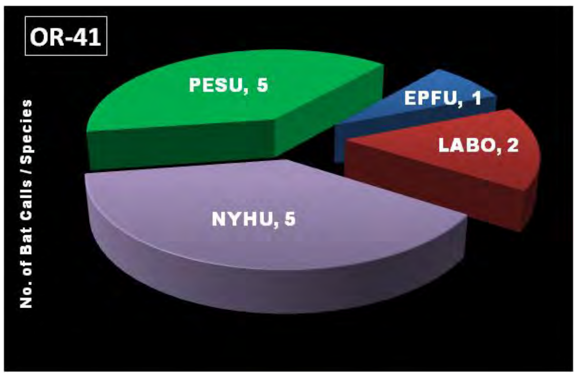
OR-34 chart

OR-34 image

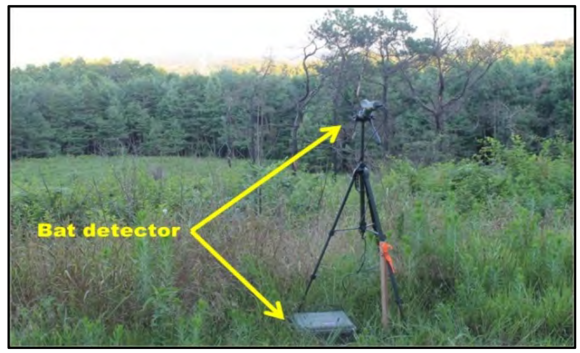


OR-40 chart

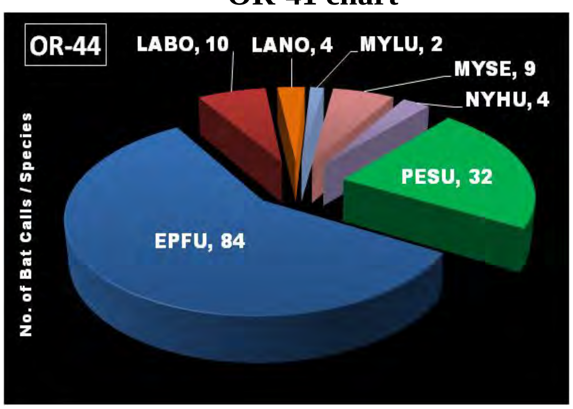
OR-40 image



OR-41 chart



OR-41 image



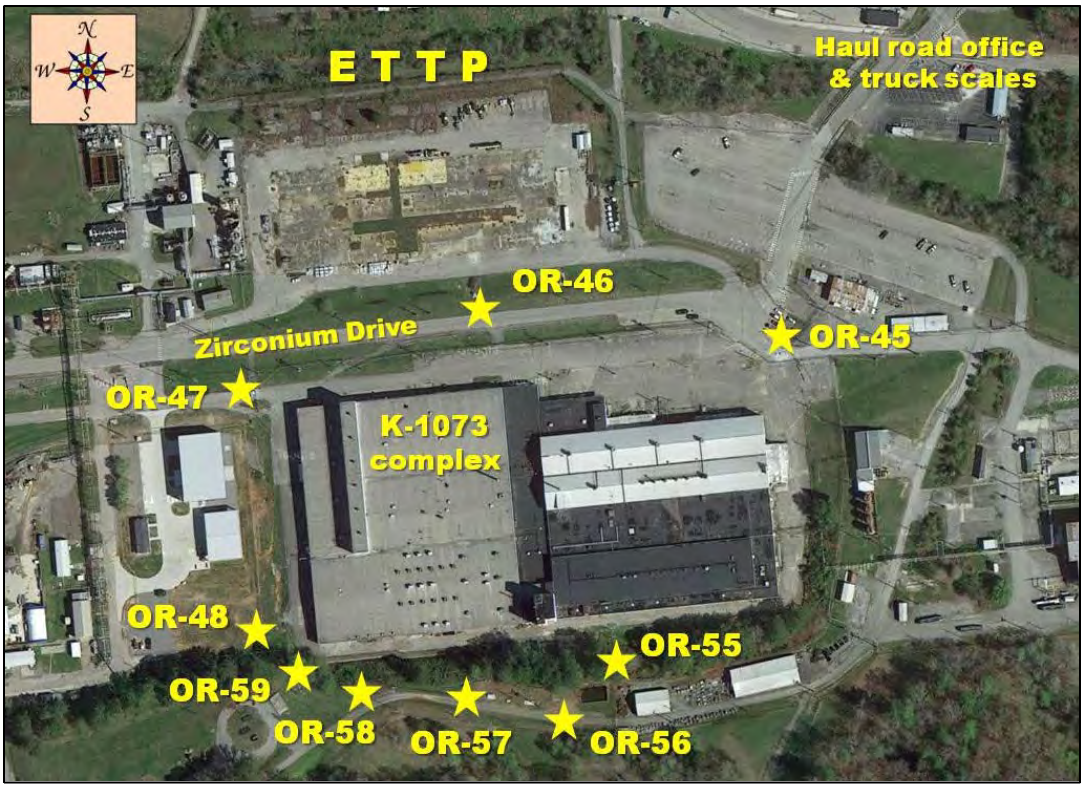
OR-44 chart

OR-44 image

Section VIII: ETTP / K-1073 building (perimeter of facility)

Section Eight consists of perimeter surveys of building K-1073 at the ETTP facility. The survey was initiated at the request of the office environmental restoration manager to determine if endangered bats may be roosting in the abandoned structure. Nine sites were actively monitored overnight (dusk-dawn) on 7/15/2014 and 7/29/2014 with a combination of Anabat SD-2, SongMeter SM2BAT+, and SongMeter SM3BAT detectors to record ultrasonic bat calls around the building perimeter. Overall, bat activity was heavy as a combined total of 1243 bat calls were identified to species by the Kaleidoscope PRO program and 23 additional bat calls were recorded, but not identified. However, the majority of bat activity was around the southwest portion of the K-1073 building: sites OR-57 (260 calls), OR-58 (689 calls), OR-59 (236 calls). This is an indication that bats may be emerging from the SW side of the building at dusk and returning around dawn to their roosting habitat inside the building. Dominant species detected for all sites included the Eastern Red bat (683 calls) and Evening bat (497 calls). If bats are indeed using the building as a summer roost, then it is likely the Evening bats because they are known to roost in buildings and the Eastern Red bats are primarily tree bats and are almost never found roosting in buildings (Ammerman et al. 2012). We detected a combined total of 13 *Myotis* spp. calls recorded from all sites. We did not detect endangered species bat calls.

After Tables 18 & 19 (below here), there is a series of plates listed by site identification number as 'OR-45 chart/image' through 'OR-59 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of thenine survey sites.



Map 8

Table 18

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-45	35.936703	-84.382843	K-1073 Bldg. (ETTP) / Zirconium Drive	7/15/2014	overnight	Anabat SD-2
OR-46	35.93685	-84.384656	K-1073 Bldg. (ETTP) / Zirconium Drive	7/15/2014	overnight	SongMeter SM3BAT
OR-47	35.936455	-84.386104	K-1073 Bldg. (ETTP) / Zirconium Dr. / old guardshack	7/15/2014	overnight	SongMeter SM2BAT+
OR-48	35.935243	-84.386024	K-1073 Bldg. (ETTP) / southwest side on embankment	7/15/2014	overnight	SongMeter SM3BAT
OR-55	35.935295	-84.383739	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	SongMeter SM3BAT
OR-56	35.934935	-84.384227	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	Anabat SD-2
OR-57	35.935048	-84.384409	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	SongMeter SM3BAT
OR-58	35.935052	-84.385514	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	Anabat SD-2
OR-59	35.935061	-84.385793	K-1073 Bldg. (ETTP) / south side of building	7/29/2014	overnight	SongMeter SM2BAT+

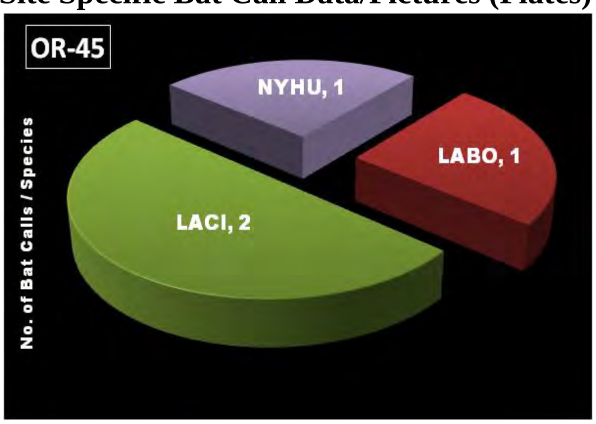
Table 19

SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
OR-45		1	2							1			2	40	2	2	
OR-46	1	3	2	2				1		2	1	1	1	2	6	6	1
OR-47											1			4		1	
OR-48		2					2				1		3	10		3	2
OR-55		4		1			5			1			5	42	1	5	5
OR-56	1	12	1				1			7	2		3	34	2	21	1
OR-57		99	1	3			1			152	3	1	25	57	5	244	1
OR-58		473		9			2			195	10		28	91	9	678	2
OR-59		89	1	3			1			139	2	1	23	57	5	230	1
subtotals	2	683	7	18			12	1		497	20	3	23	57	30	1190	13

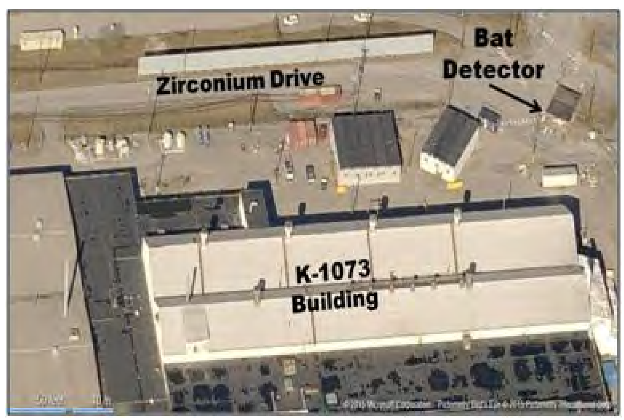
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

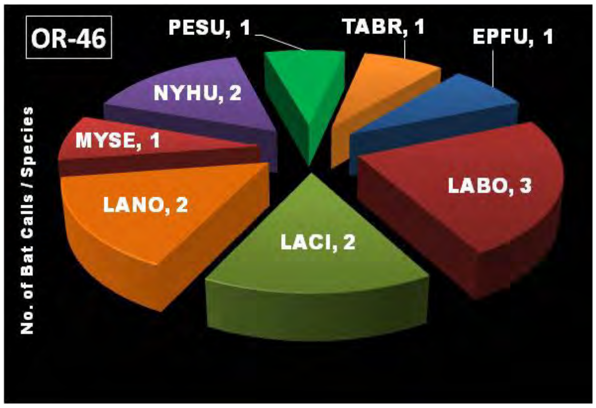
Site Specific Bat Call Data/Pictures (Plates)



OR-45 chart

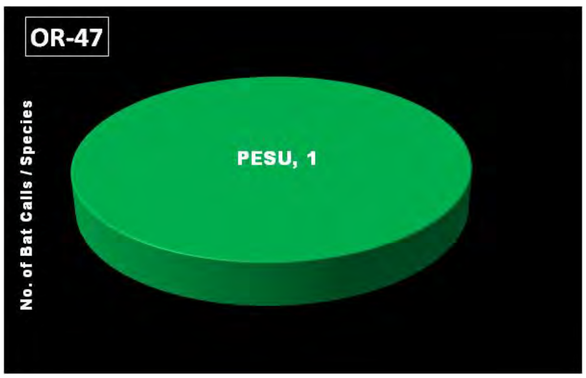


OR-45 image



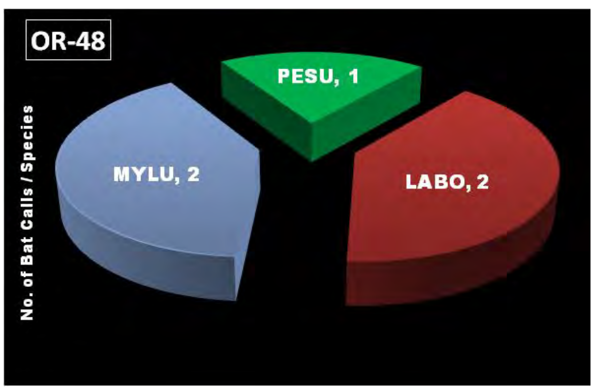
OR-46 chart

OR-46 image



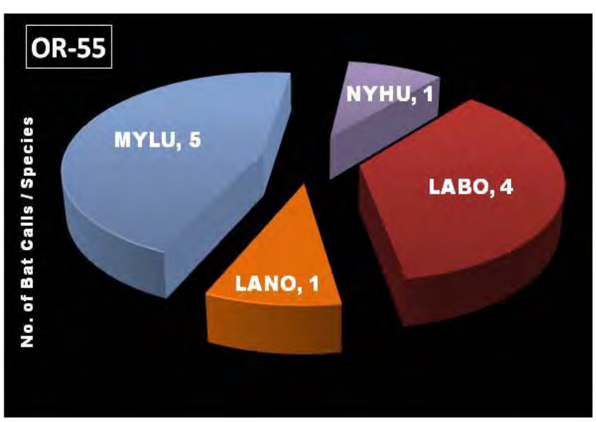
OR-47 chart

OR-47 image

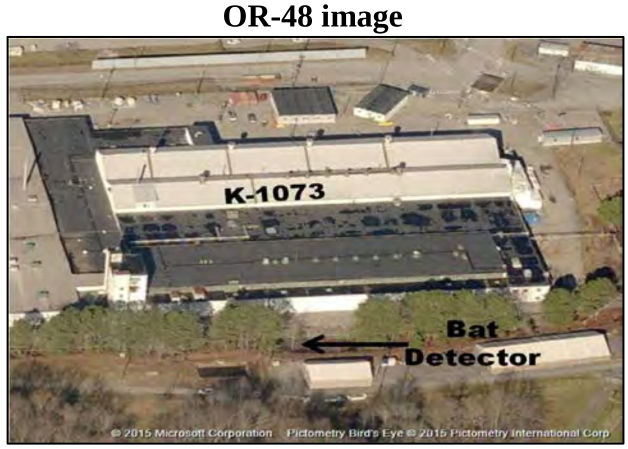


OR-48 chart

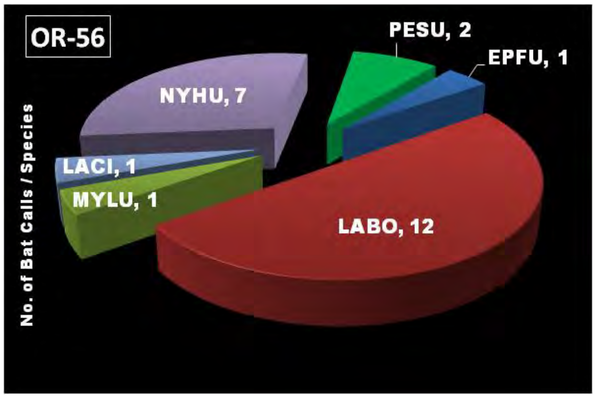
OR-48 image



OR-55 chart

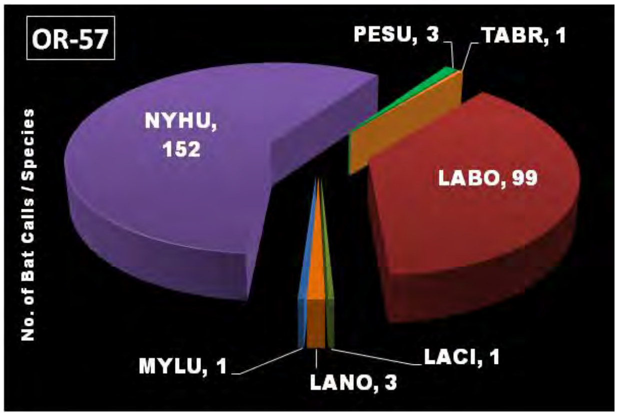


OR-55 image



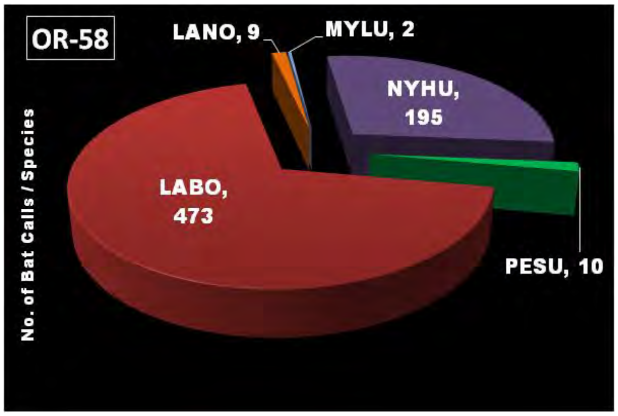
OR-56 chart

OR-56 image



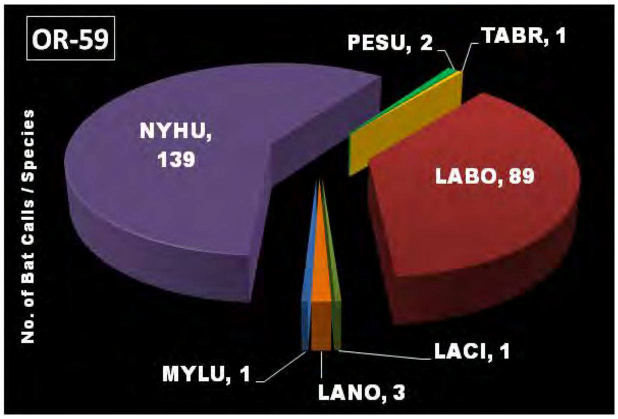
OR-57 chart

OR-57 image



OR-58 chart

OR-58 image



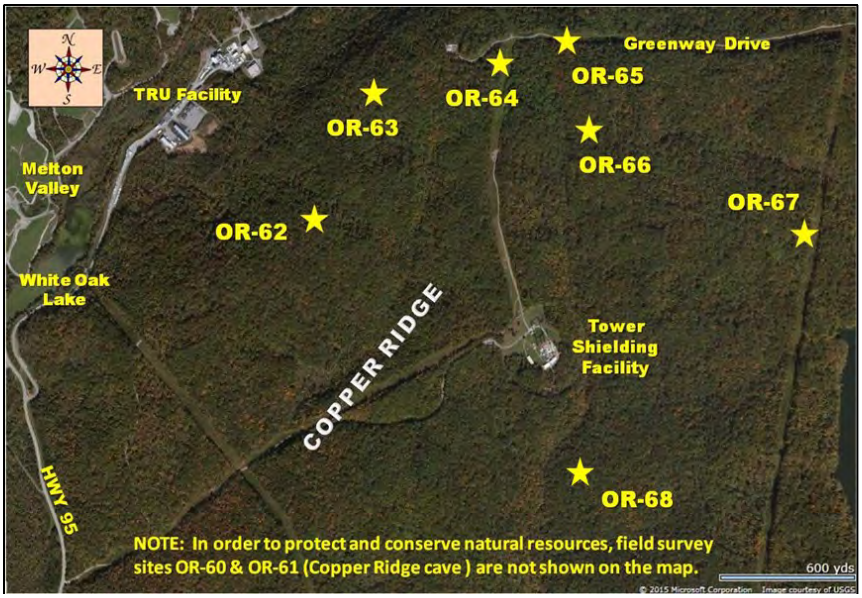
OR-59 chart

OR-59 image

Section IX: Tower Shielding Area (ORNL)

Section Nine surveys were conducted in the Tower Shielding area of Chestnut Ridge. The majority of this area is forested with lush vegetation and mature oak-hickory trees such as shagbark hickories, an important roost tree for female Indiana bats (endangered species). There are gravel access roads, powerline ROWs, a cell tower facility, caves, and the Tower Shielding facility. The area is also rich with wildlife, wildflowers and fern species. The survey was carried out in cooperation with the ORNL Environmental Sciences Division; detectors were co-deployed at several survey locations including Copper Ridge cave. Nine sites were passively monitored overnight (dusk-dawn) on 8/4/2014 and 9/5/2014 with a combination of Anabat SD-2, SongMeter SM2BAT+, and SongMeter SM3BAT detectors to record ultrasonic bat calls. Overall, bat activity was heavy as a combined total of 1353 bat calls were identified to species by the Kaleidoscope PRO program and 1680 additional bat calls were recorded, but not identified. At the location of monitoring site OR-60 (Greenway Drive, gravel access road), we did not catch any bat calls with our detector. Dominant species detected for all sites included the Big Brown bat (285 calls), Eastern Red bat (243 calls), Gray bat (176 calls), Little Brown bat (153 calls), Northern Long-eared bat (148 calls), Evening bat (179 calls), and the Tri-colored bat (152 calls). Insect noise was prevalent at two sites with 2931 and 12,182 noise files recorded at OR-60 and OR-64 respectively. We detected a combined total of 486 *Myotis* spp. calls recorded from all sites. A combined total of 184 endangered species bat calls were recorded (Gray bats, Indiana bats) from nine sites. Surprisingly, the majority of Gray bat calls were recorded near dead tree snags along Greenway Drive at site OR-65 (44 calls) and site OR-66 (75 calls). However, we did record 24 Gray bat calls and three Indiana bat calls at the location of Copper Ridge cave (sites OR-60, OR-61). In fact, we executed a QA/QC test at the cave by deploying one Anabat SD-2 and one SongMeter SM2BAT+ approximately 75 feet apart with both detector microphones oriented towards the cave entrance. When we ran the respective bat files through the Kaleidoscope PRO program, the output indicated 625 bat call identifications (+263 no IDs) were determined for the Anabat SD-2 files (site OR-61), but only 163 bat call identifications (+93 no IDs) were determined for files recorded with the SongMeter SM2BAT+ (site OR-60).

After Tables 20 & 21 (below here), there is a series of plates listed by site identification number as 'OR-60 chart/image' through 'OR-68 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right. Due to the volume of sites and data, the reader is directed to the self-explanatory plates below for additional specific bat call data for each of the nine survey sites.



Map 9

Table 20

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-60	X	X	Tower Shielding / Copper Ridge Cave (codeployed w/ ORNL)	8/4/2014	overnight	SongMeter SM2BAT+
OR-61	X	X	Tower Shielding / Copper Ridge Cave (codeployed w/ ORNL)	8/4/2014	overnight	Anabat SD-2
OR-62	35.903477	-84.31096	Tower Shielding / gravel access road (codeployed w/ ORNL)	8/4/2014	overnight	Anabat SD-2
OR-63	35.90726	-84.30887	Tower Shielding / gravel access road (codeployed w/ ORNL)	8/4/2014	overnight	SongMeter SM2BAT+
OR-64	35.907667	-84.302999	Tower Shielding / gravel access road	8/4/2014	overnight	Anabat SD-2
OR-65	35.909839	-84.297216	Tower Shielding / Greenway Drive near dead snags	9/5/2014	overnight	SongMeter SM2BAT+
OR-66	35.90474	-84.297401	Tower Shielding / Johnson Road near dead snags	9/5/2014	overnight	SongMeter SM2BAT+
OR-67	35.90306	-84.28861	Tower Shielding / Johnson Road at powerline ROW	9/5/2014	overnight	SongMeter SM3BAT
OR-68	35.89243	-84.29944	Tower Shielding / Deep Hollow Trail / Gravel Hill Cem	9/5/2014	overnight	SongMeter SM3BAT

Table 21

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-60	no bats					no bats					no bats						
OR-61	3	27			8	1	19	64	3	6	32		93	2931	3	65	95
OR-62	214	129	1	2	16		46	15		164	38		263	4	217	331	77
OR-63	7	10		1	6		23	26	5		25		1060	22	8	35	60
OR-64	31	44			11		18	30		9	33		71	12182	31	86	59
OR-65	25	10			44		26	6			8		85	119	25	18	76
OR-66	4	21			75		13	5			16		102	148	4	37	93
OR-67	1													36	1		
OR-68		2	4		16		8	2					6	168	4	2	26
subtotals	285	243	5	3	176	1	153	148	8	179	152		1680	15610	293	574	486

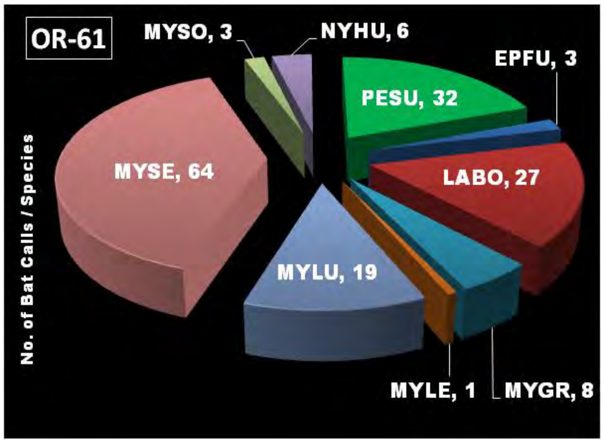
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)

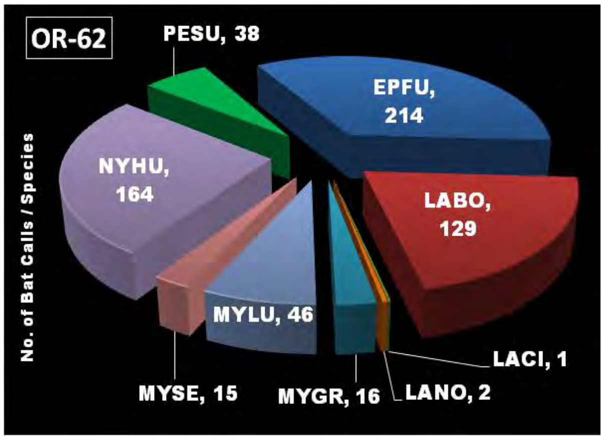
OR-60 chart

OR-60 image



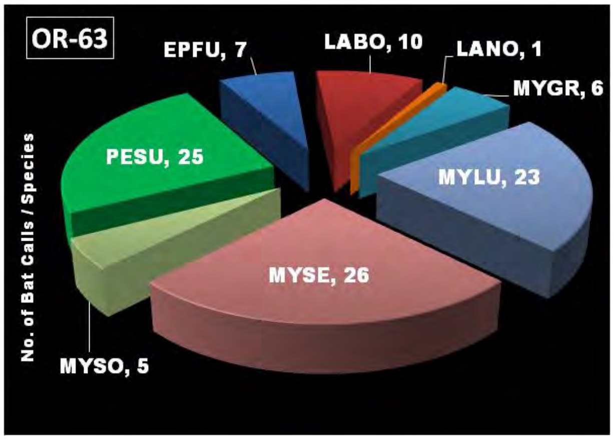
OR-61 chart

OR-61 image



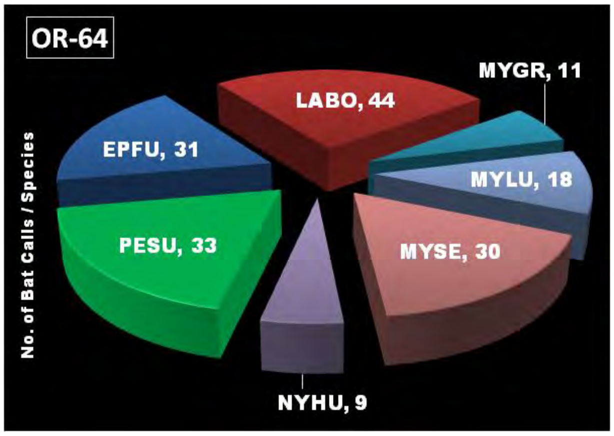
OR-62 chart

OR-62 image

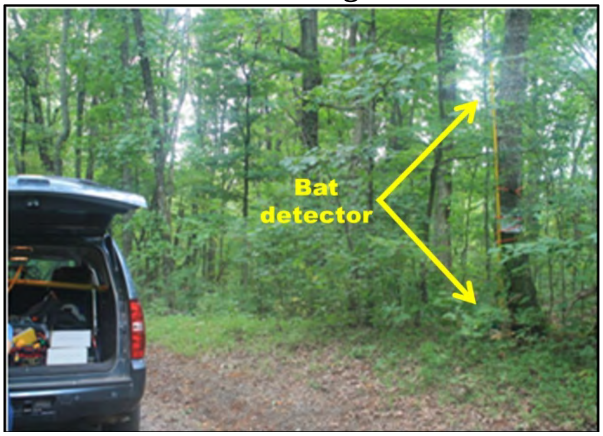


OR-63 chart

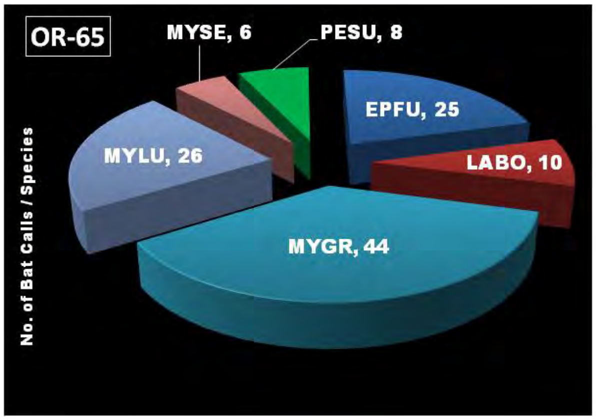
OR-63 image



OR-64 chart

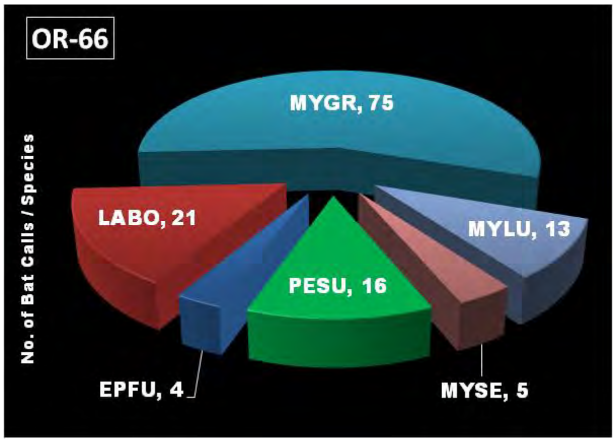


OR-64 image



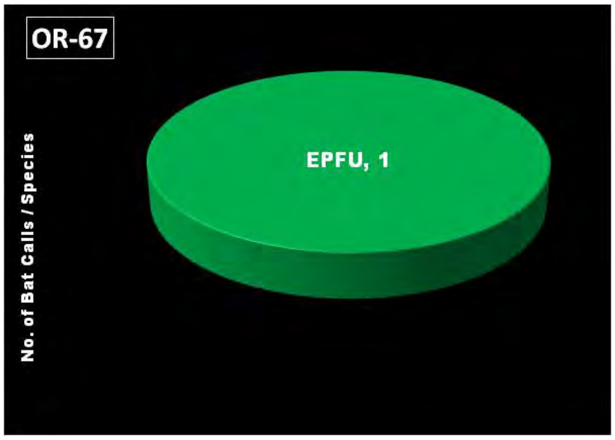
OR-65 chart

OR-65 image

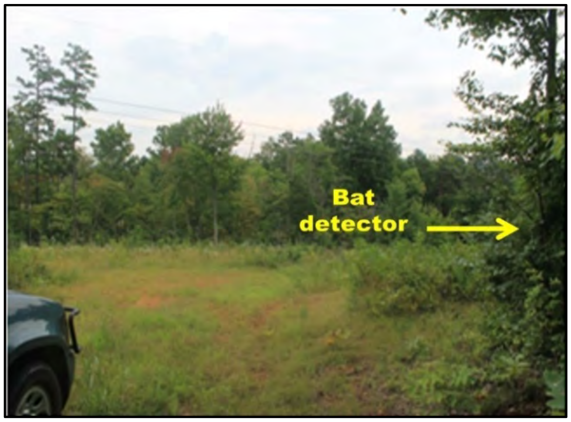


OR-66 chart

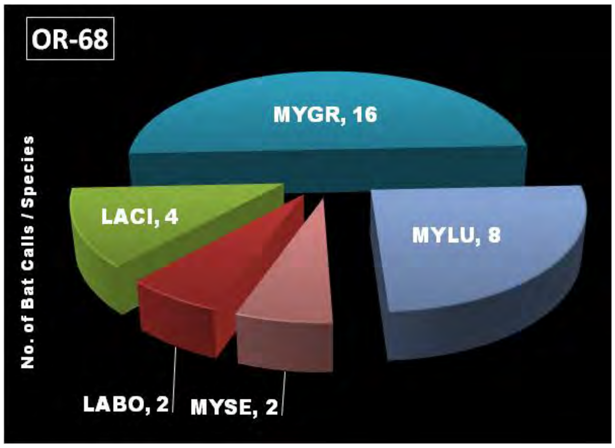
OR-66 image



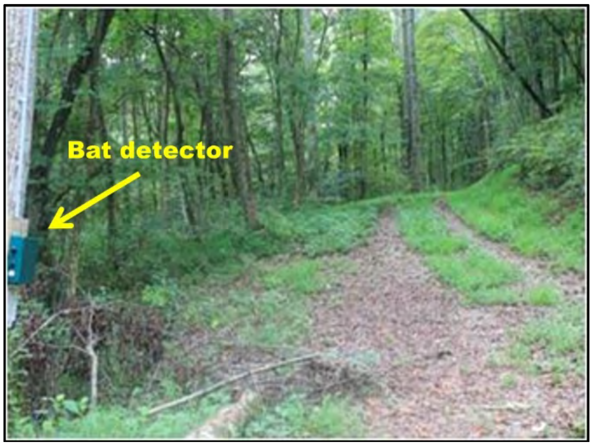
OR-67 chart



OR-67 image



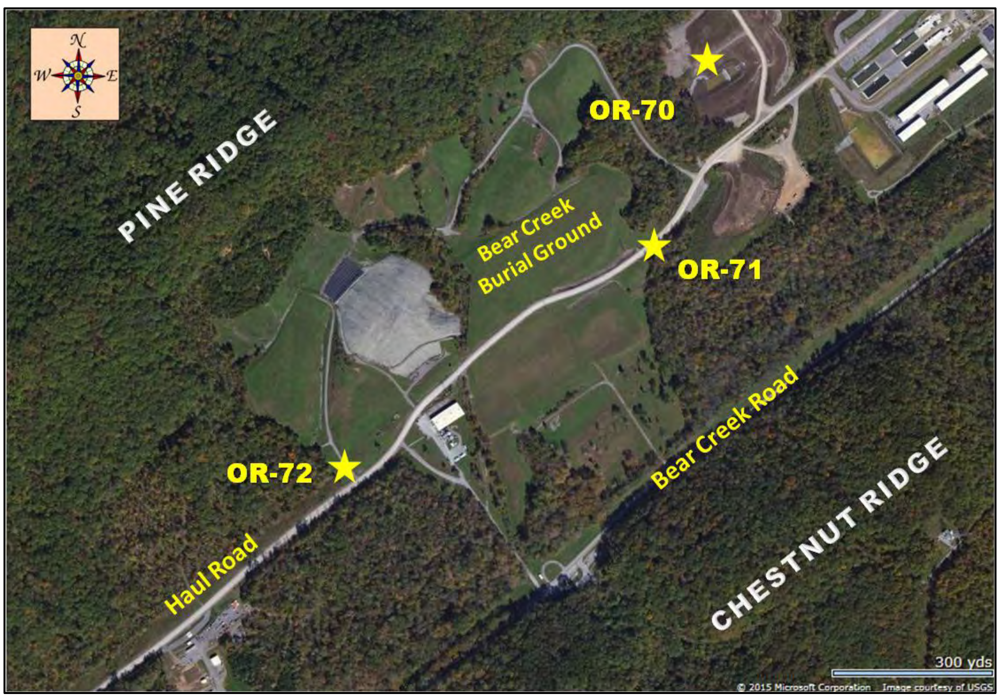
OR-68 chart



OR-68 image

Section X: Haul Road (Bear Creek Burial Grounds area)

Section Ten surveys were executed in Bear Creek Valley west of the Y-12 National Security Complex. The majority of this area is industrial with a huge contaminated landfill (Bear Creek Burial Grounds), the Haul Road, additional access roads, and surrounded by forest/field edge. Three sites were passively monitored overnight (dusk-dawn) on 9/10/2014 with a combination of Anabat SD-2 and SongMeter SM3BAT detectors to record ultrasonic bat calls. Overall, bat activity was quite sparse as a combined total of ten bat calls were identified to species by the Kaleidoscope PRO program and ten additional bat calls were recorded, but not identified. Species were only detected at one of the three sites including the Eastern Red bat (one call), Hoary bat (two calls), Little Brown bat (one call), Silver-haired bat (one call), and the Tri-colored bat (five calls). Insect noise was prevalent at two sites with 10,902 and 3492 noise files recorded at OR-70 and OR-71 respectively. We detected a combined total of one *Myotis* spp. call recorded from all sites. No endangered species bat calls were detected. After Tables 22 & 23 (below here), there is a series of plates listed by site identification number as 'OR-70 chart/image' through 'OR-72 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 10

Table 22

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-70	35.968134	-84.293171	Haul Road/ large field near pond & GW monitoring wells	9/10/2014	overnight	Anabat SD-2
OR-71	35.965286	-84.294244	Haul Road/ southeast corner of BCBG at fence corner	9/10/2014	overnight	Anabat SD-2
OR-72	35.961751	-84.300123	Haul Road/ southwest corner of BCBG at fence corner	9/10/2014	overnight	SongMeter SM3BAT

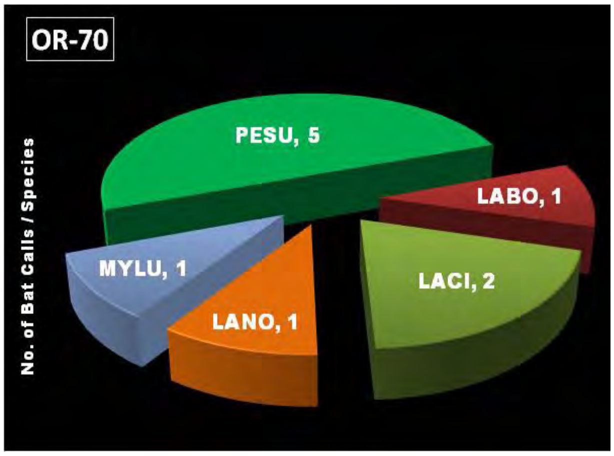
Table 23

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-70		1	2	1			1				5		10	10902	3	6	1
OR-71	no bats					no bats					no bats			3492			
OR-72	no bats					no bats					no bats			26			
subtotals	0	1	2	1			1				5		10	14420	3	6	1

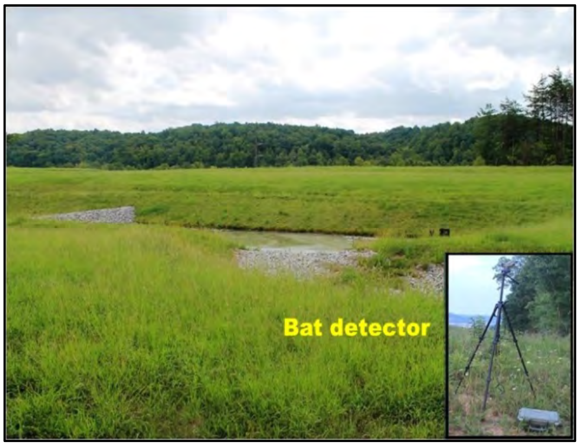
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)

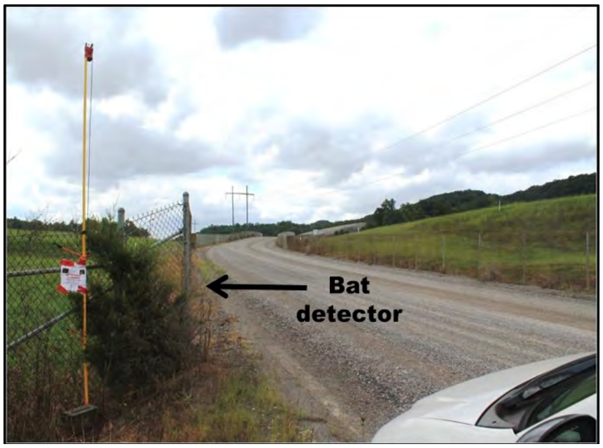


OR-70 chart

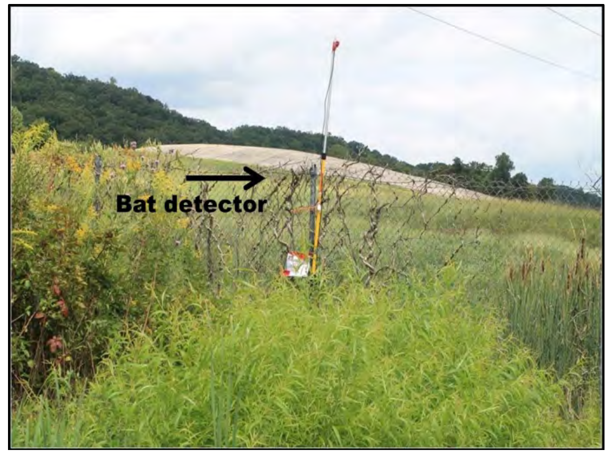


OR-70 image

OR-71 chart



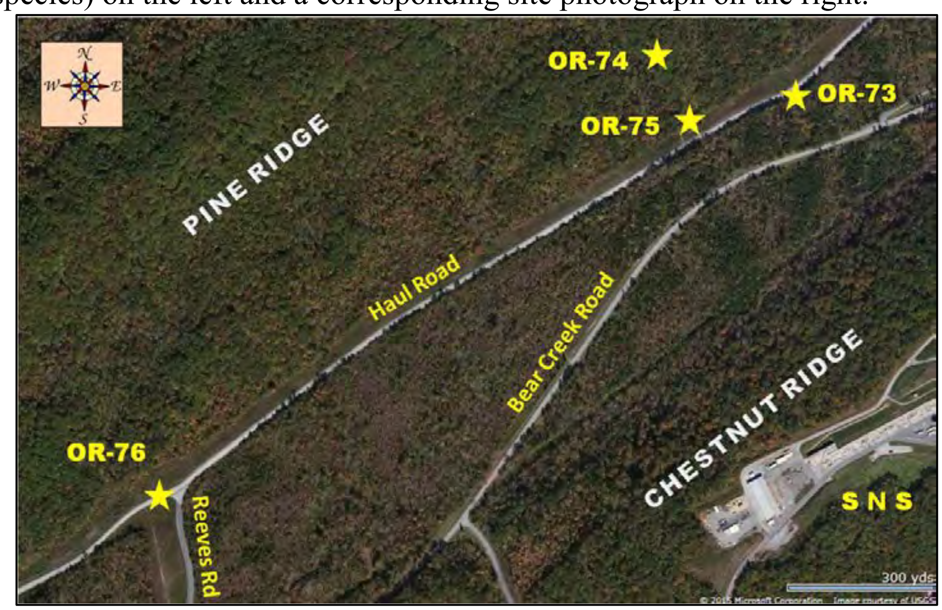
OR-71 image



OR-72 chart **OR-72 image**

Section XI: Haul Road (Reeves Road area)

Section Eleven surveys were conducted in Bear Creek Valley west of the Y-12 National Security Complex. The majority of this area is also industrial, including the Haul Road and Reeves Road, but surrounded by heavy forest. Four sites were passively monitored overnight (dusk-dawn) on 9/10/2014 with a combination of Anabat SD-2, SongMeter SM2BAT+, and SongMeter SM3BAT detectors to record ultrasonic bat calls. Overall, bat activity was quite sparse as a combined total of eight bat calls were identified to species by the Kaleidoscope PRO program and 11 additional bat calls were recorded, but not identified. Species were only detected at two of the four sites including the Northern Long-eared bat (one call) and the Little Brown bat (seven calls. Insect noise was prevalent at one site with 28,721 noise files recorded at OR-75 (deployed in a wetland). We detected a combined total of eight *Myotis* spp. call recorded from all sites. No endangered species bat calls were detected. After Tables 24 & 25 (below here), there is a series of plates listed by site identification number as 'OR-73 chart/image' through 'OR-76 chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 11

Table 24

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-73	35.957531	-84.305949	Haul Road/ south of road along stream drainage/wetland	9/10/2014	overnight	SongMeter SM2BAT+
OR-74	35.957687	-84.309533	Haul Road/ Douglas Cemetery north of Haul Rd	9/10/2014	overnight	SongMeter SM2BAT+
OR-75	35.956419	-84.30891	Haul Road/ wetland adjacent to Douglas Cem acc. road	9/10/2014	overnight	Anabat SD-2
OR-76	35.950183	-84.320025	Haul Road/ junction with Reeves Road	9/10/2014	overnight	SongMeter SM3BAT

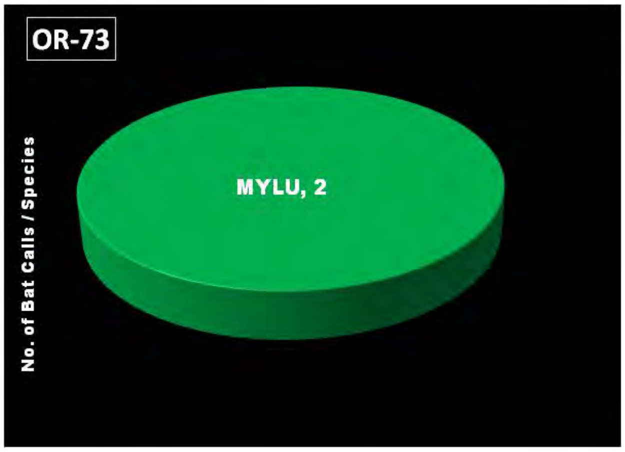
Table 25

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-73							2						6	64			2
OR-74	no bats					no bats					no bats			40			
OR-75							5	1					5	28721			6
OR-76	no bats					no bats					no bats			12			
subtotals							7	1					11	28837			8

[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

Site Specific Bat Call Data/Pictures (Plates)

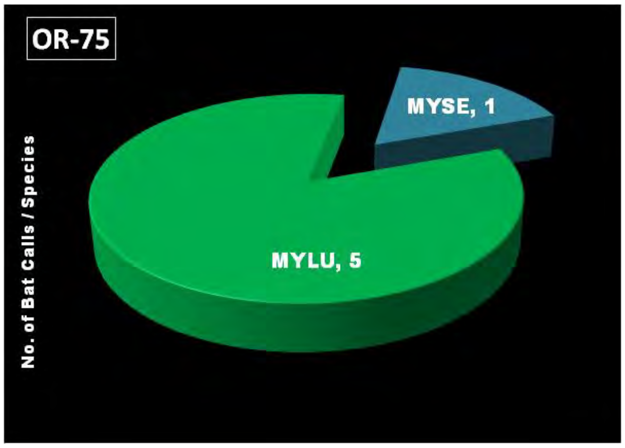


OR-73 chart

OR-73 image

OR-74 chart

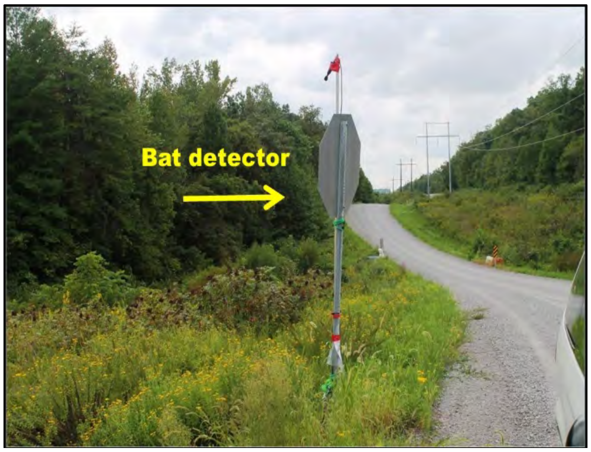
OR-74 image



OR-75 chart

OR-75 image

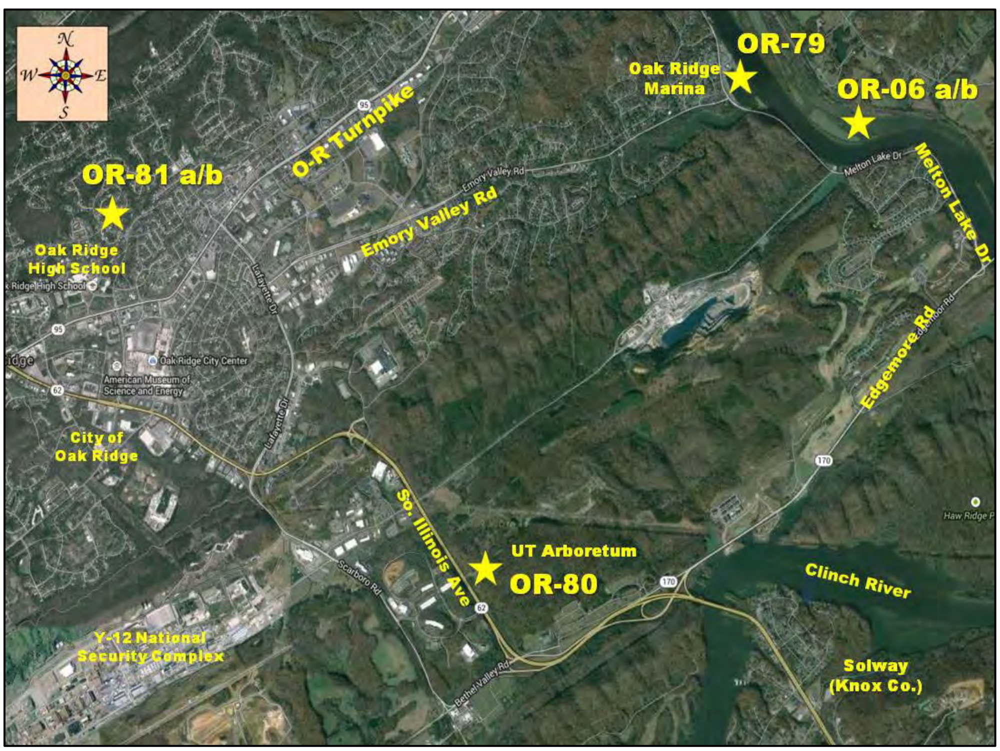
OR-76 chart



OR-76 image

Section XII: Reference Sites (City of Oak Ridge)

Section Twelve surveys were conducted at reference sites in the City of Oak Ridge including two Clinch River sites, the University of Tennessee Arboretum, and a residential neighborhood near Oak Ridge High School. Four sites were actively monitored for approximately three hours between dusk and midnight on 4/23/2014 and 9/4/2014 with a combination of Anabat SD-2s and the EchoMeter EM3+ detectors to record ultrasonic bat calls. At site OR-6a/6b, bat calls were recorded (w/ two Anabats) using a canoe to access a backwater area of the Clinch River near the Oak Ridge Marina; watercraft courtesy of Mr. Gareth Davies. Overall, bat activity was moderate as a combined total of 655 bat calls were identified to species by the Kaleidoscope PRO program and 80 additional bat calls were recorded, but not identified. Dominant species detected included Big Brown bat (123 calls) and the Tri-colored bat (299 calls). Species were only detected at two of the four sites including the Northern Long-eared bat (one call) and the Little Brown bat (seven calls). Insect noise was prevalent at one site with 28,721 noise files recorded at OR-75 (deployed in a wetland). We detected a combined total of 33 *Myotis* spp. calls recorded from all sites. We recorded seven endangered species bat calls (Gray bats) from sites OR-06 and OR-79. After Tables 26 & 27 (below here), there is a series of plates listed by site identification number as 'OR-06a chart/image' through 'OR-81b chart/image' which characterizes each bat survey site with a pie chart (bat calls detected per individual species) on the left and a corresponding site photograph on the right.



Map 12

Table 26

Site No.	Latitude	Longitude	Site description	Date(s)	Survey time (hrs)	Detector
OR-6	36.029631	-84.182138	Reference site: Clinch River near Oak Ridge Marina	5/28/2014	2	Anabat SD-2 (2 units)
OR-79	36.033761	-84.193125	Reference site: Oak Ridge Marina at Clinch River	9/4/2014	2	Anabat SD-2
OR-80	35.994188	-84.219475	Reference site: U. of Tennessee Arboretum (Oak Ridge)	4/23/2014	2	Anabat SD-2
OR-81	36.021267	-84.258571	Ref. site: East Pawley Ln near Oak Ridge High School	6/6/2014	4	Anabat SD-2 / EchoMeter EM3+

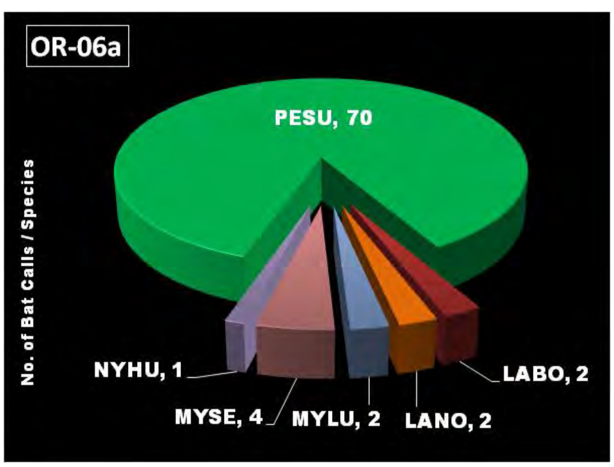
Table 27

	BAT TAXA DETECTED[1]												ADDITIONAL SOFTWARE OUTPUT[1]				
SITE #	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
OR-06a		2		2			2	4		1	70		13	12	2	73	6
OR-06b		5	1	3	5		2	3		1	49		8	31	4	55	10
OR-79	1	2	1	1	2					1	137		4	22	3	140	2
OR-80	33	8	1	5			4	4		3	12		6	24	39	23	8
OR-81a	10	12	22	3			1	3		12	16	2	12	317	27	30	4
OR-81b	79	19	40	42			2	1		10	15	1	37	789	162	44	3
subtotals	123	48	65	56	7		11	15		28	299	3	80	1195	237	365	33

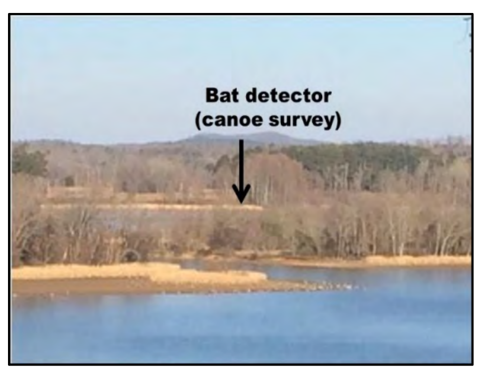
[1]**Notes**: The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The **red color** bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** **(≥ 40kHz)**. All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

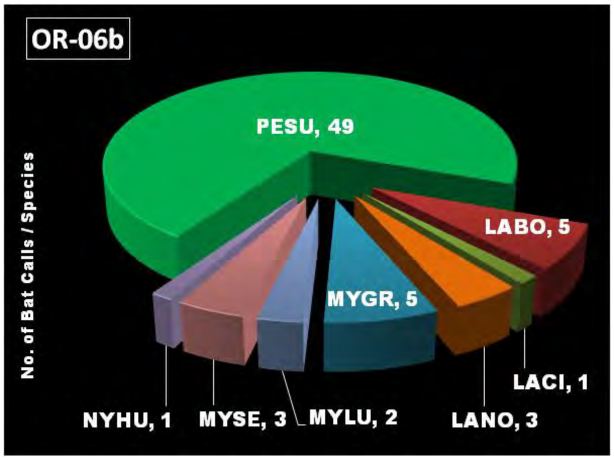
Site Specific Bat Call Data/Pictures (Plates)



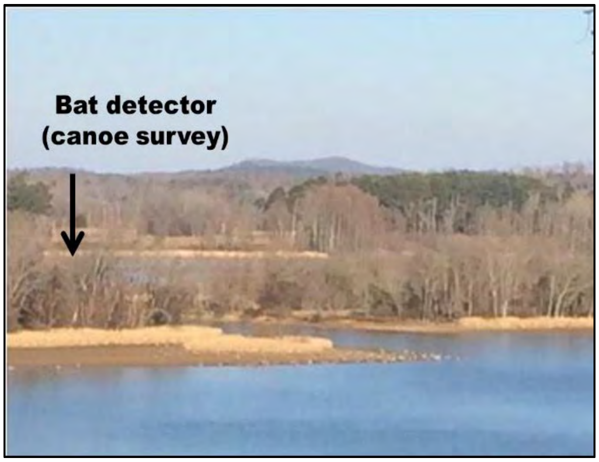
OR-06a chart



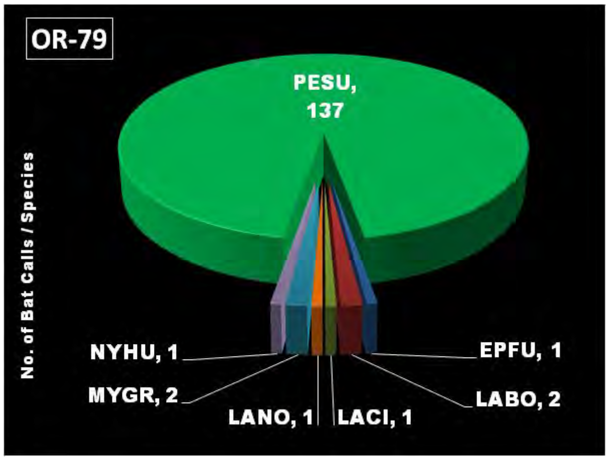
OR-06a image



OR-06b chart

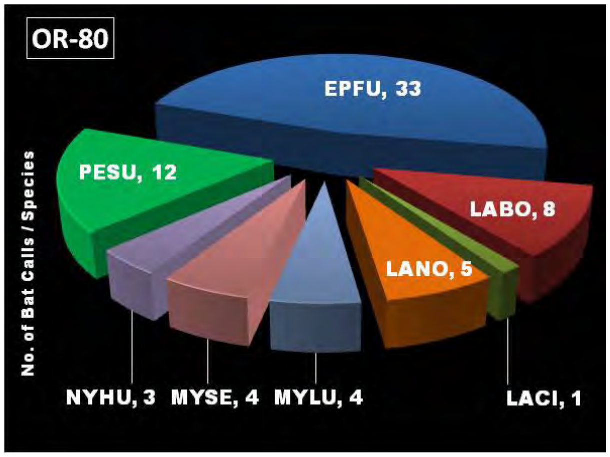


OR-06b image



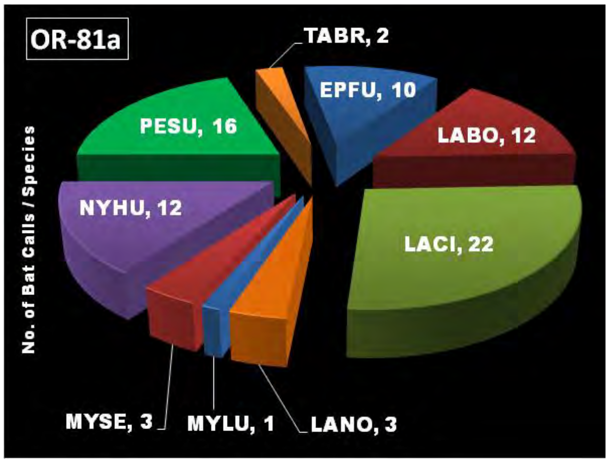
OR-79 chart

OR-79 image



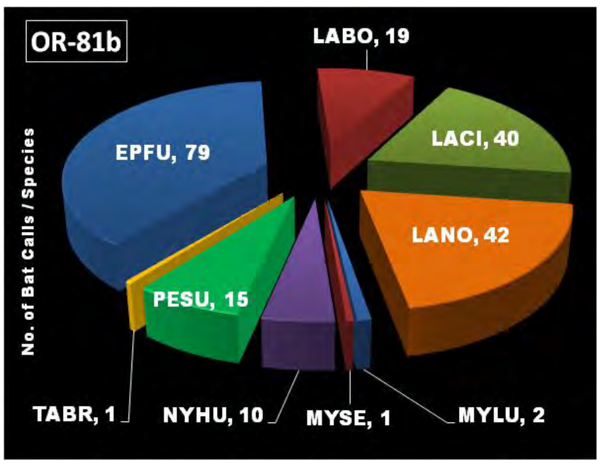
OR-80 chart

OR-80 image



OR-81a chart

OR-81a image



OR-81b chart

OR-81b image

Discussion

We conducted acoustic surveys over 108 survey nights during 2014, and recorded approximately 12,000 files of bat acoustic data collected from 81 ORR field stations. The bat call files were processed with specialized, automated bat identification software (Kaleidoscope PRO) yielding 6,960 bat identifications (Table 28). An additional 4006 bats were detected but not identified to species due to poor call quality, inclement weather conditions or field clutter. Kaleidoscope PRO output data revealed that >100 bat calls were recorded at 21 sites, >200 calls were recorded at ten sites, >300 calls were recorded at three sites, and >600 calls were recorded at two sites (OR-58 and OR-62).

Twelve bat species were detected on the ORR including: *Eptesicus fuscus* (Big Brown bat), *Lasiurus borealis* (Eastern Red bat), *Lasiurus cinereus* (Hoary bat), *Lasionycteris noctivagans* (Silver-haired bat), *Myotis grisescens* (Gray bat), *Myotis leibii* (Eastern Small-footed bat), *Myotis lucifugus* (Little Brown bat), *Myotis septentrionalis* (Northern Long-eared bat), *Myotis sodalis* (Indiana bat), *Nycticeius humeralis* (Evening bat), *Perimyotis subflavus* (Tricolored bat; Eastern Pipistrelle), and *Tadarida brasiliensis* (Brazilian Free-tailed bat). Of these species, the Eastern Red bat (24%), Big Brown bat (18%), Tricolored bat (18%), and the Evening bat (17%) were the dominant combined species detected at all sites (Figure 39). Approximately 5% of all bats detected were federally-listed endangered species (Indiana bat, Gray bat). The Tower Shielding study site turned out to be the hot spot for endangered bat species as 184 combined calls were recorded (Gray bats, Indiana bats).

We calculated bat call frequency data teased out of the Kaleidoscope PRO output for all species per all 81 sites (see Figure 40). Mid-frequency bat calls (25-35 kHz) represented the dominant frequency range (59% of the total calls) for all 81 sites combined. Mid-frequency bats include Eastern Red bat, Evening bat, and the Tri-colored bat. Low-frequency bats (<25 kHz) were next with 24% of the total calls; these bats include Big Brown bat, Silver-haired bat, Hoary bat, and the Brazilian Free-tailed bat. Lastly, the Myotis-frequency bats (≥40 kHz) represented 17% of all calls; these bats include Gray bat, Indiana bat, Eastern Small-footed bat, Little Brown bat, and the Northern Long-eared bat. Incidentally, this ORR frequency outcome compares very closely with frequency results form a concurrent 2014 State Parks bat study at Cove Lake State Park where mid frequency = 59%, low frequency = 30%, and Myotis frequency = 11% (Middleton 2015).

Large portions of the ORR remain un-surveyed. These include the mainly forested National Environmental Research Park (NERP), west Bear Creek Valley, White Wing area (Hembree marsh), sections of ETTP, Tower Shielding area, Walker Branch, and Chestnut Ridge (ORNL). Our 2014 study, along with a concurrent ORNL Environmental Science Division bat project, continued to add data for the first long-term, large-scale acoustic bat community investigation on the ORR. Information gained from this bat inventory addressed missing data gaps but also provided critical occurrence information for the endangered species and for the Northern Long-eared bat listing which is in process by the US Fish and Wildlife Service.

Table 28

	BAT TAXA DETECTED													ADDITIONAL COMBINED DATA OUTPUT				
BATS →	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	TOTAL BAT CALLS	NOID	NOISE	LOW FREQ	MID FREQ	MYOTIS FREQ
BAT CALL SUBTOTALS	1253	1660	241	195	255	3	424	460	12	1207	1241	9	6960	4006	60283	1698	4108	1154

[1]**Notes:** The numbers in each ***bat species detected*** cell represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. ***Blank boxes*** = no bat calls recorded. The red color bars represent the number of bat calls within a cell; the longer the bar, the greater the number of bat calls. A ***call*** is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). ***Pulses*** are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. ***Noise*** = not bat calls; likely insect or mechanical noise. Bat call frequency indicated as ***Low (≤ 25kHz), Mid (25-35 kHz), or Myotis*** (≥ 40kHz). All bat files were processed using the Kaleidoscope PRO automated identification software program.

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat). NOID = Unidentified bat species.

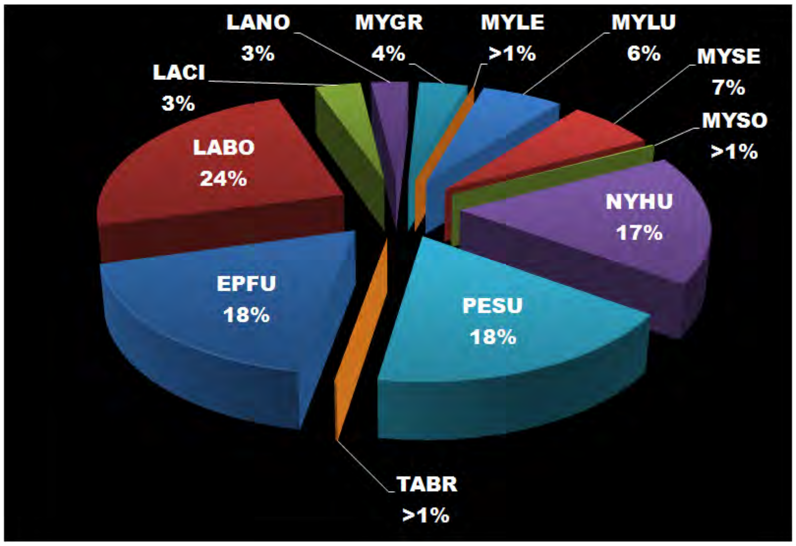


Figure 39: Summary Pie Chart
Combined 2014 Bat Calls Per Species (%)

Taxonomic Codes: EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat).

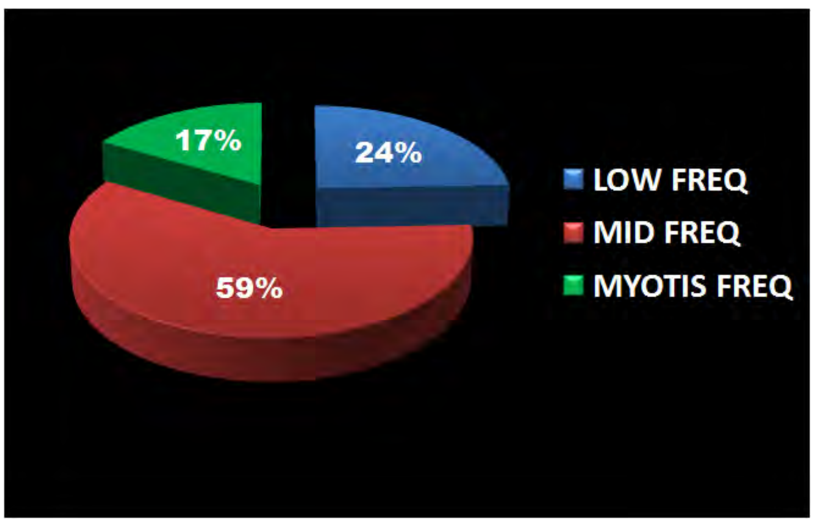


Figure 40: Summary Pie Chart
Combined 2014 Bat Calls Per Frequency (%)

Low Frequency bat calls (characteristic frequency <25 kHz): EPFU = *Eptesicus fuscus* (Big Brown Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat); **Mid Frequency bat calls (characteristic frequency ~25-35 kHz):** LABO = *Lasiurus borealis* (Eastern Red Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle); **Myotis Frequency bat calls (characteristic** frequency ≥40 kHz): MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat).

Summary

- TDEC DOR monitored 81 sites on the ORR with acoustic detectors (27 of 81 survey sites were monitored dusk to dawn)

- Monitored wetlands, caves, rocky ledges, trails, stream riparian, lake shore, buildings, shagbark hickories, gravel access roads, forest edge, powerline ROWs, and open fields
- Recorded/processed >12,000 bat call files collected during 108 survey nights
- Approximately 6,960 bats were identified to species; >4,000 were not identified
- >60,000 combined noise files were recorded (predominantly evening insects, cicadas)
- Bat calls were not detected at eight of 81 field monitoring stations
- We detected 12 of the 16 bat species known to Tennessee (EPFU, LABO, LACI, LANO, MYGR, MYLE, MYLU, MYSE, MYSO, NYHU, PESU, & TABR)
- Endangered bats were detected at 29 of 81 sites surveyed
- Gray bats detected at 24 of 81 sites surveyed
- Indiana bats detected at five of 81 sites surveyed
- Northern Long-eared bat detected at 40 of 81 sites (under consideration for listing as a federally endangered species)
- The forested NERP area of the ORR remains largely uncovered by acoustic surveys
- Mid-frequency bats (LABO, NYHU, & PESU) dominated the call frequencies
- >480 Myotis species calls were recorded at the Tower Shielding area (nine study sites combined)
- ≥350 Myotis-combined species calls were recorded in the central Dyllis Orchard area (13 study sites northwest of ETTP on Black Oak Ridge); within 3-5 miles of several known caves which could provide summer roosts for Gray bats
- ≥130 Myoti- combined species calls were recorded in the eastern Dyllis Orchard area (13 study sites northwest of ETTP on Black Oak Ridge); within 1-3 miles of several known caves which could provide summer roosts for Gray bats
- Endangered species hotspot: We documented 176 MYGR and 8 MYSO bat calls in the Tower Shielding area; bat detector was deployed near shagbark hickory trees and dead snags along Greenway Drive (these trees often used as bat roosts)

Legend: EPFU = Big Brown bat, LABO = Eastern Red bat, LACI = Hoary bat, LANO = Silver-haired bat, MYGR = Gray bat, MYLE = Eastern Small-footed bat, MYLU = Little Brown bat, MYSE = Northern Long-eared bat, MYSO = Indiana bat, NYHU = Evening bat, PESU = Tri-colored bat (Pipistrelle), and TABR = Brazilian Free-tailed bat.

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Threatened and Endangered Species Monitoring

Principal Author: Gerry Middleton

Abstract

Protection and stewardship of threatened, endangered and rare species (i.e., the overall biodiversity) in their natural habitat is a major priority to enable their long-term survival as invaluable natural resources on the US Department of Energy's (DOE) Oak Ridge Reservation (ORR). In support of this mission, the Tennessee Department of Environment and Conservation, Division of Remediation (TDEC DOR) provided monitoring and mapping of the biodiversity of the natural resources (flora and fauna) on the ORR. Further, office staff lends field biology assistance and support to the Resource Management Division (Natural Areas Program, Bureau of Parks and Conservation) and the Tennessee Wildlife Resources Agency (TWRA) at ORR natural areas and TWRA-managed sites [i.e., Black Oak Ridge Conservation Easement (BORCE) and the Three Bends Area]. During 2014, office staff monitored flora and fauna (i.e., predominantly bat acoustic surveys) on trails and off-trail areas of the BORCE and other areas of the ORR. Several new populations of TDEC-listed and non-listed flora and fauna were identified. A new aspect of the project, initiated in 2013, is the field mapping and documentation of American Chestnut sprouts (*Castanea dentata*) on the ORR.

Introduction

The Oak Ridge Reservation was acquired by the federal government in the 1940s, and approximately 25,000 acres have remained undeveloped in a relatively natural state (Mitchell et al. 1996). Approximately 20,000 acres of the ORR have been designated a DOE National Environmental Research Park (NERP), an International Biosphere Reserve, and part of the Southern Appalachian Man and the Biosphere Cooperative (Baranski 2009).

The ORR's diverse plant and animal life is situated in a relatively intact ecosystem that is highly diverse when compared with surrounding areas in the same physiographic province (Mann et al. 1996). The ORR, consisting of the Oak Ridge NERP and associated lands surrounding DOE facilities at Oak Ridge, Tennessee, is about 15,000 ha of mostly contiguous native forest in the valley and ridge province (Mann et al. 1996). Additional ORR geomorphic and topographic features supporting rare plant communities include wetlands, karst features (caves), rocky bluffs, limestone cedar barrens, and extensive forested areas (Awl 1996). About 70% of the ORR is in forest cover and less than 2% remains as open agricultural fields. Communities are generally characteristic of the intermountain regions of Appalachia (Mann et al. 1996). Oak-hickory forest, which is most widely distributed on ridges and dry slopes, is the dominant association. Minor areas of other hardwood forest cover types are found throughout the ORR; these include northern hardwoods, a few small natural stands of hemlock or white pine, and floodplain forests (Mann et al. 1996). There are several TDEC-designated natural areas on the ORR.

Approximately 25 miles of greenway trails are available for hiking, running and bicycling on the Black Oak Ridge Conservation Easement (BORCE, Figure 1) which consists of about 3000 acres of mainly forested uplands including the Dyllis Orchard greenway trail (opened to the public in October 2007).

The 3,000 acre site is subdivided into three main management units: (1) the natural area section situated north of the ED-1 industrial park site known as the East Black Oak Ridge Conservation Easement (EBOR) area (Figure 2) which includes ~1,300 acres, (2) the area north of the ETTP known as the West Black Oak Ridge Conservation Easement (WBOR; Figure 3) which includes ~1,500 acres, and (3) the McKinney Ridge section with ~230 acres. The north, east and west perimeter of the EBOR is a former patrol gravel road that is known as the North Boundary Greenway trail.

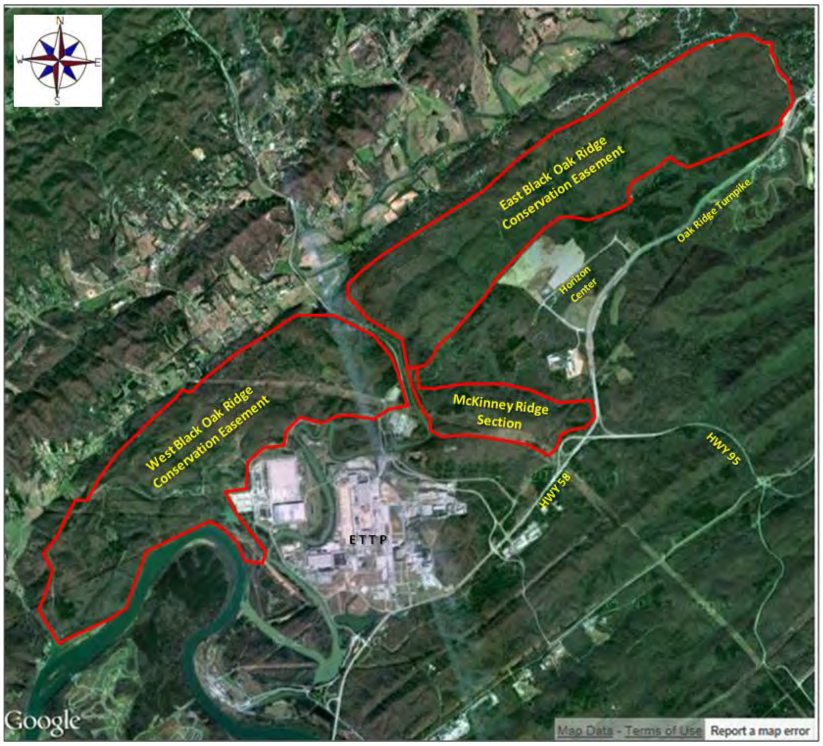


Figure 1: Black Oak Ridge Conservation Easement (BORCE, 3,000 acres; red line approx. BORCE boundary)

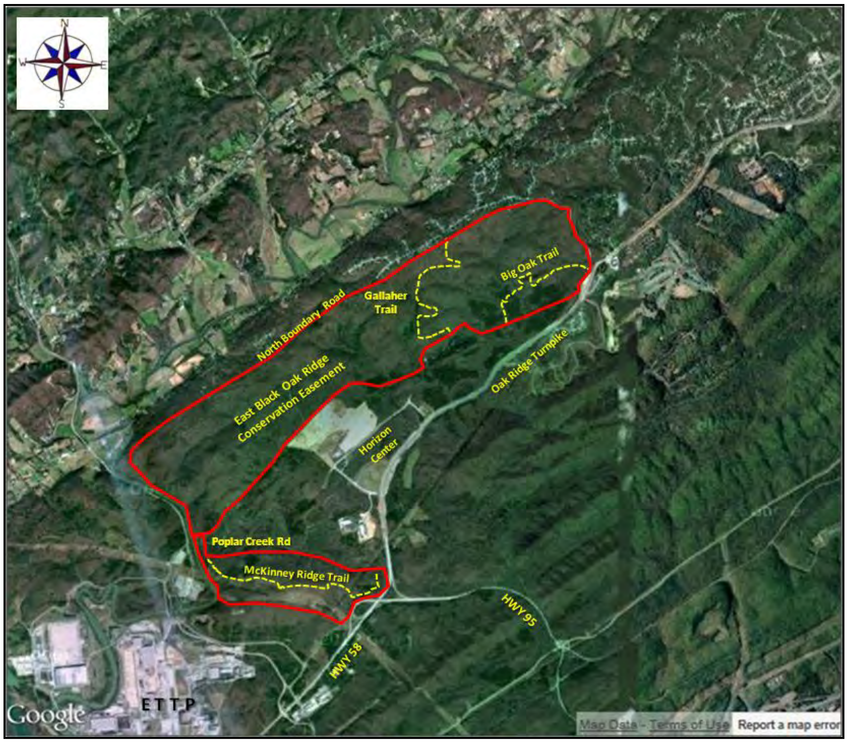


Figure 2: East BORCE (+ McKinney Ridge) and trails surveyed (yellow dashed lines) during 2012 for rare plant species

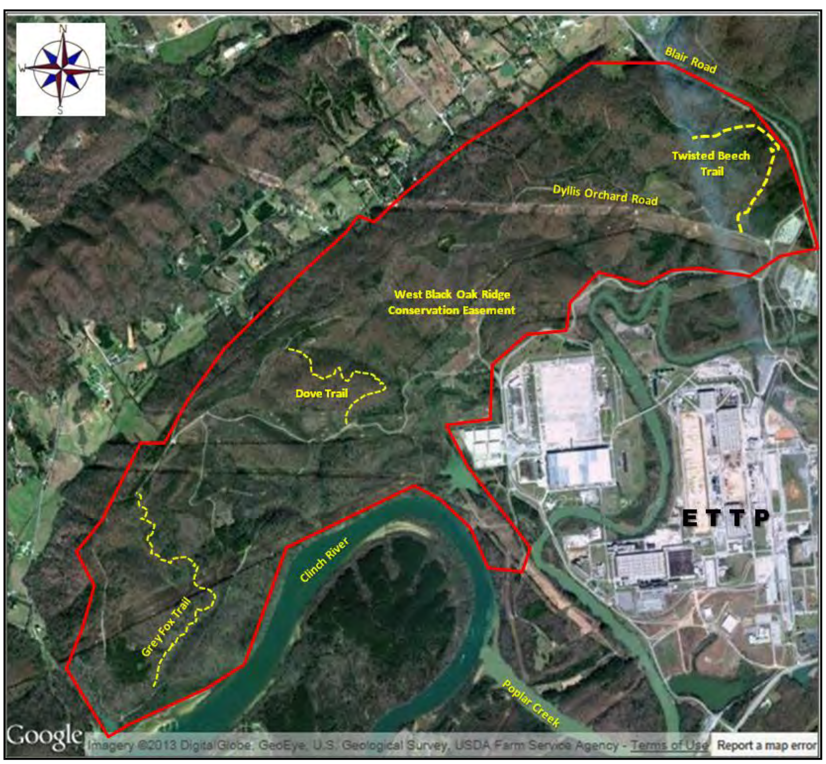


Figure 3: West BORCE and trails surveyed (yellow dashed lines) during 2012 for rare plant species

Objectives

- Monitor, conserve and protect the natural resources on the ORR
- Monitor and map populations of state- and federally-listed threatened and endangered plant and animal species (i.e., T&E species) on the BORCE and ORR
- Characterize and document presence of sensitive plant populations (non-listed species) on the BORCE and ORR
- Coordinate T&E species field projects with sister Tennessee agencies such as the TDEC Division of Natural Areas (TDEC DNA) and the Tennessee Wildlife Resources Agency (TWRA)
- Report Oak Ridge Reservation T&E field results to the US Department of Energy (US DOE), TDEC DNA, TWRA, and the US Fish and Wildlife Service (USFWS)
- Monitor, protect, and preserve the biodiversity of the ORR
- Continue field inventory of American Chestnuts (*Castanea dentata*)

The project incorporated the office's oversight role of environmental surveillance and monitoring. The Tennessee Oversight Agreement mandates a comprehensive and integrated monitoring and surveillance program for all media (i.e., air, surface water, soil sediments, groundwater, drinking water, food crops, fish and wildlife, and biological systems) and the emissions of any materials (hazardous, toxic, chemical, radiological) on the ORR and environs (TDEC 2011). Additionally, several federal and state laws support this effort: (1) the federal Endangered Species Act of 1973 (ESA), as amended, provides for the inventory, listing, and protection of species in danger of becoming extinct and/or extirpated, and conservation of the habitats on which such species thrive; (2) the National Environmental Policy Act (NEPA), requires that federally-funded projects avoid or mitigate impacts to listed species; (3) the Tennessee Rare Plant Protection and Conservation Act of 1985 (Tennessee Code Annotated Title 11-26, Sects. 201-214), provides for a biodiversity inventory and establishes the State list of endangered, threatened, and special concern taxa; and (4) National Resource Damage Assessments (NRDA) as directed by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by SARA (Superfund Amendments and Reauthorization Act of 1986), relates to damages to natural resources on the ORR.

Currently, there are 21 federally-listed vertebrate and invertebrate species in Anderson and Roane counties, home of the Oak Ridge Reservation. Of these species, there are 17 mollusks, three fish, and one mammal. Also, there are an additional 48 vertebrate and invertebrate species listed by the state of Tennessee for Anderson and Roane as either threatened (n= 6), endangered (n= 20), or deemed in need of management (n= 22). Tennessee also lists 12 species as "rare, not state listed". Several raptors are listed as deemed in need of management such as the bald eagle, barn owl, and the sharp-shinned hawk. The bald eagle (*Haliaeetus leucocephalus*) was officially removed from the federally threatened list on August 8, 2007. Eagles continue to be protected by the 1940 Bald and Golden Eagle Protection Act and the 1918 Migratory Bird Treaty Act. Bald eagles are occasionally sighted on the ORR, and a breeding pair was nesting adjacent to Poplar Creek in the vicinity of the ETTP during 2011-2012.

The Tennessee Department of Environment and Conservation Division of Natural Areas (TDEC-DNA) list eight mammal species as "deemed in need of management": Allegheny woodrat, Cinereus shrew, long-tailed shrew, meadow jumping mouse, smoky shrew, southeastern shrew, southern bog lemming, and the woodland jumping mouse. The Gray bat and Indiana bat are listed by both TDEC-DNA and the USFWS as endangered (state- and federally-listed species).

Previously, the single federally-listed mammal species known to occur on the ORR was the Gray Bat (*Myotis grisescens*, state- and federal-listed endangered). However, during the summer of 2013, an ORNL/UT team captured a male Indiana Bat during mist-netting activities at Freels Bend (*Myotis sodalis*, state- and federal-listed endangered). This is the first time since 1950, that a federally-endangered Indiana bat has been confirmed and documented on the ORR. For additional information regarding 2013 ORR bat studies, see TDEC report: *Acoustic Monitoring of Bat Echolocation Calls on the Oak Ridge Reservation (Pilot Study)* in the 2013 Environmental Monitoring Report (TDEC 2014), and the ORNL Environmental Sciences Division report: Bat Summer Report for ORNL: Bat Species Distribution on the Oak Ridge Reservation with Emphasis on the Endangered Indiana Bat, Summer 2013 (McCracken et al. 2013).

Methods

Previous vascular plant investigations have covered much of the ORR (Mann et al. 1985, Cunningham et al. 1993, Rosensteel and Trettin 1993, King et al. 1994, Awl et al. 1996), but some areas of the BORCE remain unmapped. During the spring and summer of 2014, TDEC conducted field botany walk-over excursions on trails and backcountry sections of the BORCE. Geomorphic habitats such as small drainage ravines, floodplains, wetlands, watersheds, cedar barrens, rock outcroppings, cliffs, and karst features (springs, caves, sinkholes) were surveyed for rare plant taxa. Field locations of rare plants were mapped and located using a Global Positioning System (GPS) hand-held field unit (Garmin®). Using a grid system based on 10-meter centers, the plan was to identify all plant taxa in the forest canopy, subcanopy, shrub, herbaceous, and groundcover layers. Photographs of plants were taken to document sensitive communities and rare species. Field monitoring methods and health and safety procedures generally followed the guidelines in the TDEC DOE-O Health and Security Plan (Yard 2013).

Vascular plant and fungi identifications required the use of the following sources and taxonomic keys: Radford et al. 1968, Mickel 1979, Prescott 1980, Lincoff 1981, Cobb 1984, Lellinger 1985, Wofford 1989, Gleason & Cronquist 1991, Chester et al. 1993, Chester et al. 1997, Holmgren et al. 1998, Smith 1998, Barron 1999, Foster and Duke 2000, Carman 2001, Wofford & Chester 2002, Phillips 2005, Bessette et al. 2007, Weakley 2007, and Ostry et al. 2010.

Results

During 2014, TDEC DOR field staff re-surveyed and characterized sections of the BORCE exhibiting rich diversity of species observed on woodland trails (i.e., Big Oak trail, Gallaher trail, McKinney Ridge trail, Twisted Beech trail, Dove trail, Gray Fox trail) and off-trail areas. For the protection of natural resources, specific locations of protected plant species will not be listed in this report, but we herein present a virtual tour of all fauna and flora species identified and documented during 2014 (Figures 4-102). The results also include pre-2014 species information deemed to be a significant part of the ORR biodiversity (i.e., diatoms, testate amoebae). Also, plant species, their respective scientific names, and, if applicable, their state and federal status are listed. The majority of plants and animals that were documented during 2014 are non-T&E species, but collectively represent the tremendous biodiversity of natural resources present on the ORR. The final section of the report presents information regarding surveys of the American Chestnut on the ORR.

Accordingly, the results consist of two main parts: (1) ORR fauna, and (2) ORR flora.

I. ORR Fauna

The goal is to demonstrate the vast biodiversity, from microscopic fauna to large mammals, that characterizes the ORR ecosystem including elements of the NERP. Here we present records for 9 biological groups as follows:

1. Amoebozoa
   a) Diatoms (*Bacillariophyta*)
   b) Slime mold (*Mycetozoa*; Bauldauf and Doolittle 1997)
   c) Testate amoebae (*Cercozoa*; Cavalier-Smith 1998a, 1998b, 2002, 2003, Adl et al. 2005, Howe et al. 2011)
2. Amphibians (Phylum = *Chordata*, Superclass = *Tetrapoda,* Class = *Amphibia*, Order = *Anura*)
3. Butterflies (Phylum = *Arthropoda*, Class = *Insecta*, Superorder = *Panorpida*, Order = *Lepidoptera*)
4. Lizards (Phylum = *Chordata*, Superclass = *Tetrapoda*, Class = *Reptilia*, Order = *Squamata*)
5. Mammals (Phylum = Chordata, Superclass: *Tetrapoda*, Class = *Mammaliaformes* Class = *Mammalia*)
6. Millipedes (Phylum = *Arthropoda*, Class = *Diplopoda*, Order = *Polydesmida*)
7. Snakes (Phylum = *Chordata*, Superclass = *Tetrapoda*, Class = *Reptilia*, Order = *Squamata*, Class = *Ophidia*, Subgroup: *Serpentes*)
8. Turtles (Phylum = *Chordata*, Class = *Reptilia*, Order = *Testudines*)
9. Dragonflies (Phylum = *Arthropoda*, Class = *Insecta*, Order = *Odonata*, Suborder = *Anisoptera*)

❖ 1a. *Amoebozoa* (Diatoms: *Bacillariophyta*)

Diatoms and other microscopic algae form a major component of the base of the aquatic food web of streams such as Bear Creek, East Fork Poplar Creek, Mitchell Branch, and White Oak Creek. Although diatoms were not sampled in 2014, below are examples of the biodiversity of taxa formerly collected and identified on the ORR.

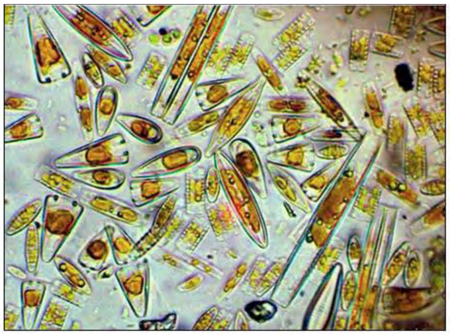


Figure 4: Diatom biomass (100X)

Figure 5: *Gomphonema* / *Cymbella* spp.

Figure 6: *Navicula radiosa*

Figure 7: *Gyrosigma* sp.

Figure 8: *Surirella* sp.

Figure 9: *Rhopalodia* sp.

Figure 10: *Stauroneis* sp.

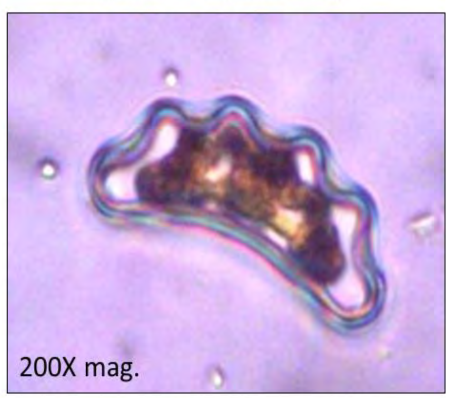


Figure 11: *Amphicampa* sp.

Figure 12: *Amphora* sp.

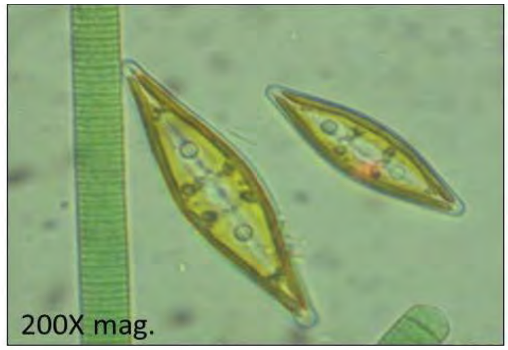


Figure 13: *Stauroneis* sp.

Figure 14: *Cymbella* sp.

Figure 15: *Epithemia* sp.

Figure 16: *Caloneis* sp. 1

Figure 17: *Caloneis* sp. 2

Figure 18: *Campylodiscus* sp.

Figure 19: *Pinnularia* sp.

❖ 1b. *Amoebozoa*: Slime mold (*Mycetozoa*; Bauldauf and Doolittle 1997)

Slime molds, with traits of both fungi and animals, are actually not fungi but are classified as *Mycetozoa*. Slime molds consist of three distinct groups: (1) the true or plasmodial slime molds are amoeboflagellates, most of which develop into large, reticulate plasmodia with synchronously dividing nuclei; (2) the cellular slime molds are strictly amoeboid, and, under conditions of nutrient starvation, aggregate to form large, motile, multicellular slugs, and (3) the *Protostelia* are mostly microscopic but morphologically diverse organisms, with different taxa exhibiting various combinations of slime mold traits (Baldauf and Doolittle 1997). All *Mycetozoa* share a structurally similar fruiting body consisting of a cellulosic stalk of one to many sterile cells supporting the spore-bearing sori (Olive and Stoianovitch 1975).

Mycetozoa have very complex life cycles involving multiple forms and stages. They begin life as a slimy mass following generation from spores and cell multiplication which creates protoplasm with the amoeba-like ability for locomotion and ingesting nutrients (Lincoff 1981, Barron 1999), and are organized within the *Amoebozoa*. The slime mold propels itself via protoplasmic streaming, a series of expansions and contractions which also facilitates engulfment of prey items by surrounding the target object with gelatinous pseudopods extending from the plasmodium, or body (Lincoff 1981). Slime molds, after reaching the mature or fruiting stage, develop stalks and reproductive spore cases. When conditions become unfavorable, these slime molds form sporangia (i.e., clusters of spores), often on the tips of stalks. Spores from the sporangia are dispersed to new habitats, germinate into small amoebae, and the life cycle begins again (Poinar and Waggoner 1992). Although not monitored specifically for this natural resource project, the examples shown below were observed during a concurrent 2014 project (Fungi Monitoring on the ORR).

Figure 20: Wolf's milk slime (*Lycogala* aff. *epidendrum*)

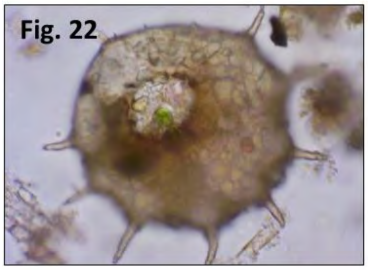
Figure 21: Dog vomit slime (*Fuligo* sp.?)

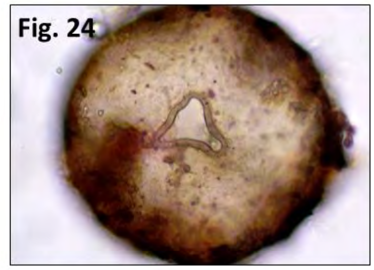
- 1c. *Amoebozoa Testate amoebae* (*Cercozoa*; Cavalier-Smith 1998a, 1998b, 2002, 2003, Adl et al. 2005, Howe et al. 2011)

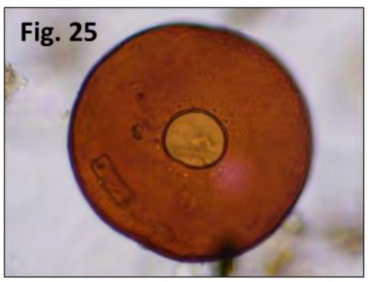
Cercozoa include many of the most abundant and therefore ecologically significant group of soil and aquatic protozoa including testate amoebae (Cavalier-Smith 1998a, 1998b, 2002, 2003, Cavalier-Smith and Chao 2003, Bass and Cavalier-Smith 2004, Adl et al. 2005, Howe et al. 2011). The testate amoebae are microscopic organisms that produce shells, or tests, either by secreting them, as in the case of *Euglypha*, or by accreting them from appropriately sized particles encountered on their travels, such as *Difflugia*. The decay-resistant test, or shell, can be identified to species in most cases and recovered from sediments in quantities sufficiently large to permit estimation of relative abundance (Booth 2001).

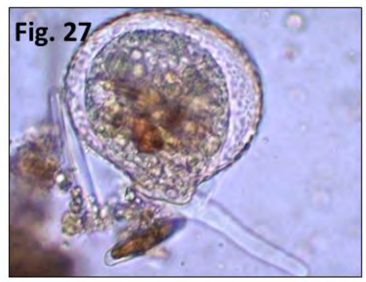
Testate amoebae (Protozoa: *Rhizopoda*) are common inhabitants of moist soils, wetlands, and lacustrine habitats (Tolonen 1986, Warner 1990). Their tests, or shells, are decay-resistant which protects the cell from desiccation and predation. This adaptation also makes them excellent ambush predators. The shell may be proteinaceous, siliceous, or calcareous and may incorporate extraneous materials such as fungal hyphae, diatoms, and mineral grains (Ogden and Hedley 1980). The morphology of tests is usually unique, allowing species level identification (Ogden and Hedley 1980, Tolonen 1986, Warner 1990). Amoeba tests are especially abundant and well-preserved in peats, sphagnum mosses and other habitats (Meisterfeld 1977). Although not monitored specifically for this natural resource project, the testate amoebae biodiversity examples shown below were collected during previous years' sampling of periphyton in ORR streams (Periphyton Project, TDEC 2009, 2010, 2011, 2012, 2013). At that time, testate amoebae taxa were identified along with the microscopic diatoms and algae comprising the periphyton community. Examples of the biodiversity of ORR Cercozoa are shown in Figures 22-39.

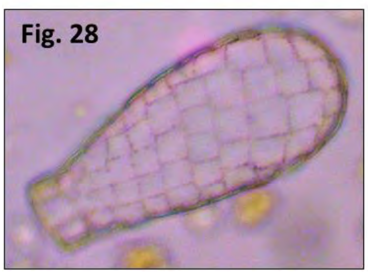
Pseudopods are seen extending from the aperature of the test (*Nebela* species) in Figure 27. The following testate amoebae genera are represented:

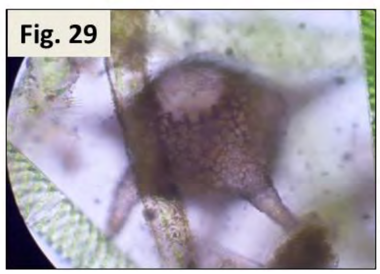












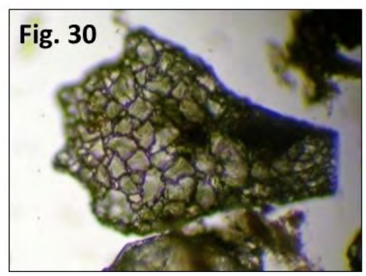


Figure legend:
22 = *Centropyxis* sp.
23 = *Nebela* sp.
24 = *Trigonopyxis* sp.
25 = *Arcella* sp.
26 = *Hyalosphenia* sp.
27 = *Nebela* sp. (w/ pseudopodia)
28 = *Quadrulella* sp.
29 = *Difflugia corona*
30 = *Difflugia oblonga* / *D. nodosa*.

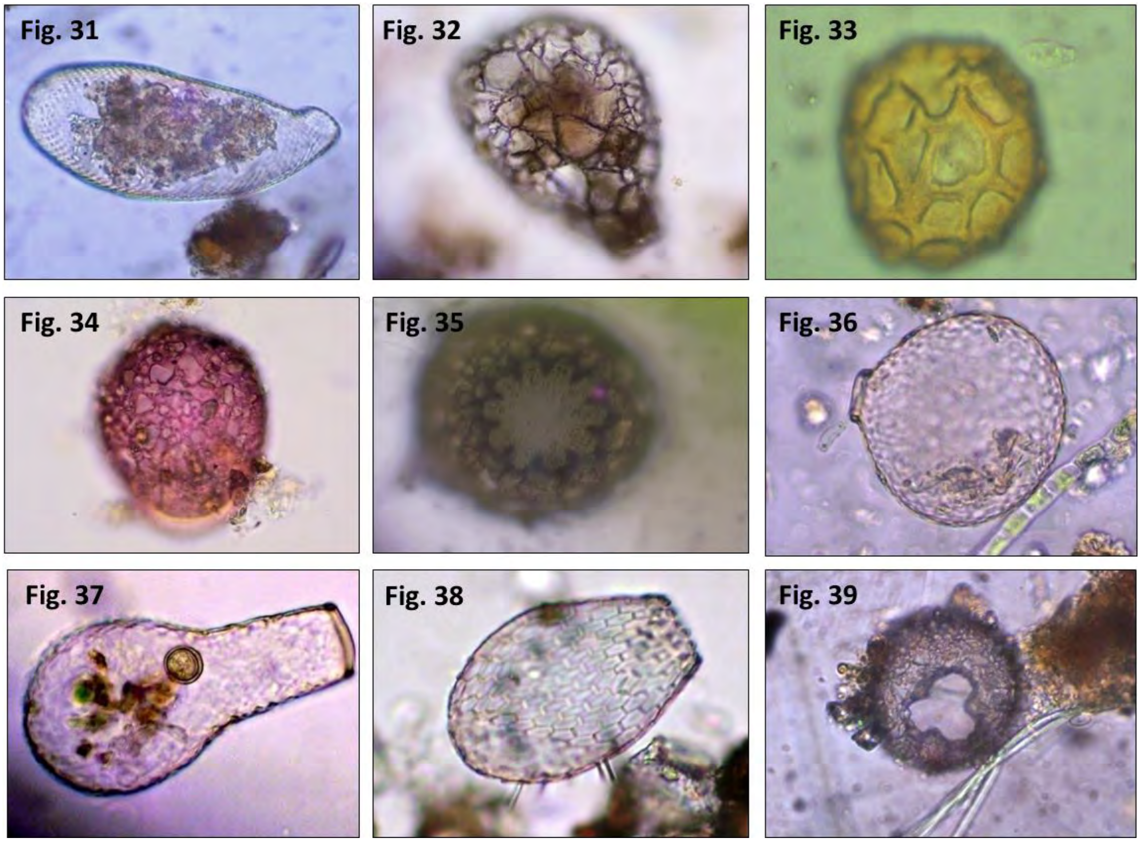


Figure legend:
31 = *Cyphoderia* sp.
32 = *Difflugia* sp.
33 = *Arcella* sp.
34 = *Heleopera* sp.
35 = *Difflugia corona*
36 = *Nebela* sp.
37 = *Nebela lageniformis*
38 = *Assulina* sp.
39 = *Difflugia lobostoma*.

- 2. Amphibians (Phylum = *Chordata*, Superclass = *Tetrapoda*, Class = *Amphibia*)

Two amphibian species were documented during 2014 TDEC DOR surveys on the ORR (Black Oak Ridge Conservation Easement) including the gray treefrog (Hyla versicolor) and Cope's gray treefrog (*Hyla chrysoscelis*).

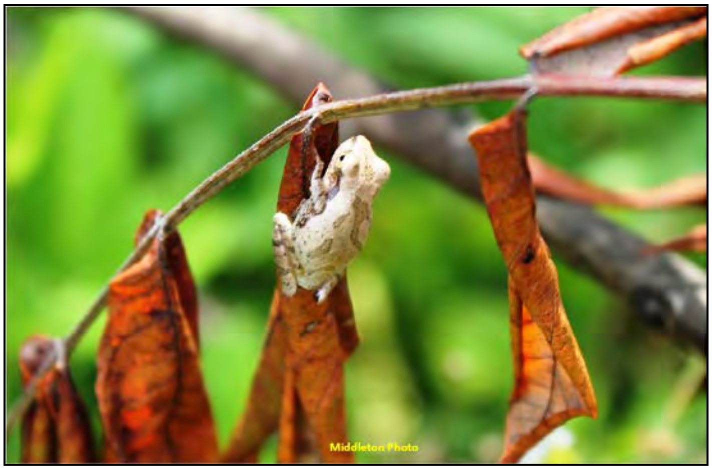


Figure 40: Gray treefrog (*Hyla versicolor*)

Figure 41: Cope's gray treefrog (*Hyla chrysoscelis*)

- ❖ 3. Butterflies (Phylum = *Arthropoda*, Class = *Insecta*, Superorder = *Panorpida,* Order = *Lepidoptera*)

The female eastern tiger swallowtail butterfly (*Papilio glaucus*) may exhibit one of two different facades. Females may assume either a yellow form (Fig. 42) similar to the male or a black, darkly striped morph (Fig. 43). These occur in abundance on the ORR, feed on nectar, and pollinate wildflower species including slender blazing star (*Liatris* sp.), butterfly weed, and yellow asters.

Figure 42: *Papilio glaucus*
(perched on slender blazing star)

Figure 43: *Papilio glaucus* (dark morph)

Additional ORR biodiversity include skippers, fritillaries, and moths (Figs. 44-47). These are but a few of the many species documented during the 2014 TDEC DOR surveys of ORR fauna on the Black Oak Ridge Conservation Easement.

Figure 44: White-spot skipper butterfly
(*Epargyreus clarus*)

Figure 45: *E. clarus* larva

Figure 46: Fritillary butterfly (Nymphalidae)

Figre 47: Luna moth (*Actias luna*)
Family = Saturniidae

❖ 4. Lizards (Phylum = *Chordata*, Superclass = *Tetrapoda*, Class = *Reptilia*, Order = *Squamata*)

Field surveys conducted in 2014 by TDEC DOR documented the eastern fence lizard (*Sceloporus undulatus*, Family Phrynosomatidae) on the Black Oak Ridge Conservation Easement. It is a medium-sized species of lizard found along forest edges, rock piles, and rotting logs or stumps in the eastern United States. According to a study published in 2009, eastern fence lizards in parts of the United States have adapted to have longer legs and new behaviors over the past 70 years to escape the exotic red fire ant, which can kill the lizard in under a minute. Fire ants from South America, *Solenopsis invicta*, were introduced to the United States accidentally in the 1930s and have been spreading north into Tennessee and elsewhere building huge mounds. The pesky creatures are known to attack and inject venom into fence lizards, both those that wander onto ant mounds and even those far away from a mound, and consume them alive (LiveScience 2009).

Figure 48: Eastern Fence Lizard

❖ **5.** Mammals (Phylum = *Chordata*, Superclass: *Tetrapoda*, Clade = *Mammaliaformes* Class = *Mammalia*)

The ORR provides habitat for game animals such as white-tailed deer (*Odocoileus virginianus*, Figure 49) and wild turkey. In addition, top predators such as the bobcat mating pair (*Lynx rufus*, Figure 50) were documented during a 2013 TDEC DOR field survey.

Figure 49: White-tailed deer **Figure 50: Bobcats (*Lynx rufus*, family: Felidae)**

Mammals that are nocturnal insect-predators on the ORR include a diverse bat community. Species that have been documented with both acoustic and mist-net surveys include the federally endangered Gray bat and Indiana bat (Figs. 51-52). A male Indiana bat and a Gray bat were captured on the ORR during a mist survey in June 2013 at Freels Bend (McCracken et al. 2013). Additional bat species documented during 2014 ORR acoustic surveys include the eastern red bat (Fig. 53), hoary bat, little brown bat, northern long-eared bat (Fig. 54), silver-haired bat (Fig. 55), big brown bat (Fig. 56), tri-colored bat, evening bat, Brazilian free-tailed bat, eastern small-footed bat, southeastern bat, and possibly the Townsend's big-eared bat. For more information regarding ORR bats, see "2013 Monitoring and Inventory of Bats on the ORR" (TDEC 2014).

Figure 51: Gray bat **Figure 52: Indiana bat**

Figure 53: Eastern Red bat

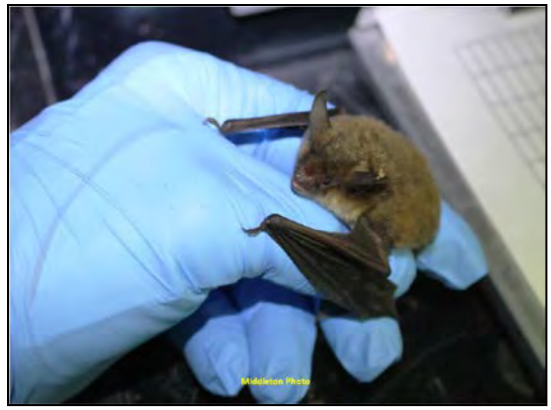


Figure 54: Northern Long-eared bat

Figure 55: Silver-haired bat

Figure 56: Big Brown bat

- 6. Millipedes (Phylum = *Arthropoda,* Class = *Diplopoda*, Order = *Polydesmida*)

Millipedes are arthropods in the class *Diplopoda* and are characterized by having two pairs of jointed legs on most body segments. Each double-legged segment is a result of two single segments fused together as one. Millipedes are a significant component of the ORR web of life. Most millipedes are slow-moving detritivores, eating decaying leaves and other dead plant matter. Some eat fungi or suck plant fluids, and a small minority are predatory. Millipedes are some of the oldest known land animals, first appearing in the Silurian period (420-440 mya; Shear and Edgecombe 2010). Due to their lack of speed and their inability to bite or sting, millipedes' primary defense mechanism is to curl into a tight coil thus protecting their delicate legs inside an armoured exoskeleton. Many species also emit various foul-smelling liquid secretions through microscopic holes called ozopores (the openings of "odoriferous" or "repugnatorial glands"), along the sides of their bodies as a secondary defense. These secretions may include alkaloids, benzoquinones, phenols, terpenoids, and/or hydrogen cyanide, among many others (Blum and Woodring 1962). Some of these substances are caustic and can burn the exoskeleton of ants and other insect predators, and the skin and eyes of larger predators. When handled, this species emits an odor similar to almonds or cherry cola.

Figure 57: Millipede couple (Family: Euryuridae)

- 7. Snakes (Phylum = *Chordata,* Superclass = *Tetrapoda*, Class = *Reptilia,* Order = *Squamata*, Clade = *Ophidia*, Subgroup: *Serpentes*)

The TDEC DOR field survey documented a gray ratsnake (Fig. 58) on the Black Oak Ridge Conservation Easement during 2014. Although numerous other snake species are known to occur on the ORR, including the venomous Copperhead (hemotoxic venom; Fig. 59), no other snake species were recorded during the field season. An agile climber, ratsnakes are at home from the ground to the tree tops in many types of hardwood forest and cypress stands, along tree-lined streams and fields, and even barns and sheds in close proximity to people. Within its range, almost any environment rich in rodents, and vertical escape options, proves a suitable habitat for the gray ratsnake. As scent-hunters these powerful constrictors feed primarily on rodents, birds, and their eggs as adults, while neonates and juveniles prefer a diet of frogs and lizards. When startled, this species, like other ratsnakes, stops and remains motionless with its body held in a series of wave-like kinks. The gray ratsnake will defend itself by raising its head and bluffing a strike. These animals are very important for the ORR web of life, especially for control of rats and mice, keeping things in balance (modified from http://en.wikipedia.org/wiki/Gray_ratsnake, accessed April 1, 2015).

Figure 58: Gray/Black Ratsnake (*Pantherophis* sp.)

Figure 59: Copperhead (*Agkistrodon contortrix*)…Danger-Danger!!

- ***8.*** Turtles (Phylum = *Chordata*, Class = *Reptilia*, Order = *Testudines*)

The Eastern box turtle (*Terrapene carolina carolina*; Fig. 60) is a subspecies within a group of hinge-shelled turtles, normally called box turtles, native to the eastern part of the United States. The eating habits of eastern box turtles vary greatly due to individual taste, temperature, lighting, and their surrounding environment. Unlike warm-blooded animals, their metabolism doesn't drive their appetite, instead, they can just lessen their activity level, retreat into their shells and halt their food intake until better conditions arise. In the wild, eastern box turtles are opportunistic omnivores and will feed on a variety of animal and vegetable matter (i.e., earthworms, snails, slugs, grubs, beetles, caterpillars, grasses, fallen fruit, berries, mushrooms,

flowers, duck weed, and carrion). Box turtles are also known to have consumed poisonous fungi making their flesh inedible
(modified from: http://en.wikipedia.org/wiki/Eastern_box_turtle, accessed April 1, 2015).

Figure 60: Eastern box turtle (*Terrapene c. carolina*; family *Emydidae*)

- 9. Dragonflies (Phylum = *Arthropoda*, Class = *Insecta*, Order = *Odonata*, Suborder = *Anisoptera*)

Dragonflies are predators, both during the aquatic larval stage, when they are known as nymphs, and as flying adults. Up to several years of the insect's life is spent as a nymph living in freshwater; the adults may be on the wing for just a few days or weeks. Fossils of very large dragonfly ancestors in the Protodonata are found from 325 million years ago in Upper Carboniferous rocks; these had wingspans of up to 750 mm. Dragonflies, often used as macroinvertebrate biometrics for rapid bioassessment surveys, are important environmental indicators of stream water quality (modified from: http://en.wikipedia.org/wiki/Dragonfly, accessed April 1, 2015). The dragonflies shown below are the two sexes of the dimorphic eastern pondhawk (*Erythemis simplicicollis*), the male is blue (Fig. 61) and the female is green (Fig. 62; J. Wojtowicz, personal communication, 6 April 2015).
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Figure 61: Eastern pondhawk (male) (*Erythemis simplicicollis*)

Figure 62: Eastern pondhawk (female) (*E. simplicicollis*)

II. ORR Flora

The goal is to demonstrate the vast biodiversity of flora that characterizes the ORR ecosystem including elements of the NERP. Here we present a virtual tour of 2014 records of cryptogams (non-seed, spore producing plants) and phanerogams (flowering seed plants) found on the ORR.

❖ **CRYPTOGAMS (Non-seed, spore-producing plants): FERNS**

Figure 63: Adder's tongue fern (*Ophioglossum* sp.)

Figure 64: Netted-chain fern (*Woodwardia aerolata*)

Figure 65: Resurrection fern (*Pleopeltis polypodioides*)

Figure 66: Broad beech fern (*Phegopteris hexagonoptera*)

Figure 67: Shining clubmoss (*Huperzia lucidula*)

Figure 68: Ground cedar (*Lycopodium sp.*)

Figure 69: Cliffbrake fern (*Pellaea atropurpurea*)

Figure 70: Rattlesnake fern (*Botrypus virginianus*)

Figure 71: Marginal wood fern (*Dryopteris marginalis*)

Figure 72: Maiden-hair fern (*Adiantum pedatum*)

Figure 73: Walking fern (*Asplenium rhizophyllum*)

Figure 74: Cinnamon fern (*Osmundastrum cinnamomeum*)

❖ *CRYPTOGAMS (Non-seed, spore-producing plants): FUNGI*

Figure 75: *Marasmius rotula* mushroom

Figure 76: Blue milky cap (*Lactarius* sp.)

Figure 77: ***Amanita sp*****. mushroom**

Figure 78: Coral Fungi (Clavariaceae)

Figure 79: Jelly Fungi (*Exidia alba*)

Figure 80: Sulfur polypore (*Laetiporus*)

Figure 81: British soldier lichen (*Cladonia*)

Figure 82: Jack-o-lantern (*Omphalotus*)

Figure 83: Black cup fungus (*Craterellus*)

Figure 84: Bearded-tooth (*Hericium* sp.)

❖ *PHANEROGAMS—FLOWERING SEED PLANTS (ANGIOSPERMS / SPERMATOPHYTES):*

The following seed-producing vascular plants were observed during 2014 TDEC DOR field excursions. Here we present a virtual tour of 2014 records of phanerogams (flowering seed plants) found on the ORR.

Figure 85: Mountain mint (*Pycnanthemum* sp.)

Figure 86: Indian pipes (parasitic) (*Monotropa uniflora*)

Figure 87: Yellow Leafcup Aster
(*Smallanthus uvedalia*)

Figure 88: Large-flowered Trillium
(*Trillium grandiflorum*)

Figure 89: Mist flower
(*Conoclinium coelestinum*)

Figure 90: Red Trillium
(*Trillium erectum*)

Figure 91: Pink lady slipper
(*Cypripedium acaule*)

Figure 92: Dwarf-crested iris
(*Iris cristata*)

Figure 93: Wild clematis (*Clematis* sp.)

Figure 94: Fire pink (*Silene virginica*)

Figure 95: Mountain laurel (*Kalmia latifolia*)

Figure 96: Butterfly weed (*Asclepias tuberosa*)

Figure 97: Ginseng (*Panax quinquefolius*) (TDEC-listed "Special Concern")

Figure 98: Squaw root/bear corn (parasitic) (*Conopholis americana*)

Figure 99: Showy orchis (*Galearis spectabilis*)

Figure 100: Little brown jug (*Hexastylis arifolia*)

Figure 101: Sedum (*Sedum ternatum*)

Figure 102: Witch hazel (*Hamamelis virginiana*)

❖ *American Chestnut Survey*

Initiated in 2013, TDEC DOR continued in 2014 with an American Chestnut (*Castanea dentata*) survey on the Black Oak Ridge Conservation Easement. Before the species was devastated by the chestnut blight, a fungal disease, it was one of the most majestic and important forest trees throughout its range. There are now very few mature specimens of the tree within its historical range, although many small shoots of the former live trees remain (Figures 103-104). Many seedlings emerge from old *Castanea dentata* stumps. TDEC DOR is documenting field locations of *C. dentata* sprouts, shoots, and saplings to develop a baseline of American Chestnut data for the ORR (Fig. 105). Field staff measured one *C. dentata* tree sapling height at 18 feet (5.5 meters) with a corresponding 13 foot (4 meters) crown width on the Gray Fox Trail (Black Oak Ridge Conservation Easement), while all other measured tree diameters were less than 2.5 inches (6.35 cm; *see* Table 1).

Figure 103: *Castanea dentata* sprout

Figure 104: *Castanea dentata* sapling

Figure 105: Recording field measurements (height, width of crown, etc.)

Table 1: American Chestnut field measurements

Gray Fox Trail	Height (m)	Canopy Width (m)	Caliper (diameter) (cm)
mean	1.21	1.35	1.64
range	0.2-5.5	0.35-3.5	0.4-5.4

Concluding Remarks
Botanical fieldwork remains to be completed on the ORR and all 3000 acres of the BORCE, particularly to map additional rare habitat and associated plant communities, American Chestnut locations, and document exotic pest-plant invasions. TDEC DOE-O staff will continue to report new rare plant findings to the Resource Management Division (RMD, Natural Areas Program and Natural Heritage Inventory Program) and to the TWRA, and provide field support as needed. Specific information relating to RMD programs is available by contacting: Brian Bowen, Program Administrator, State Natural Areas Program, telephone: (615) 532-0436, brian.bowen@.tn.us; or Silas Mathes, Data Manager, Natural Heritage Inventory Program, telephone: (615) 532-0440, silas.mathes@tn.gov. Alternatively, the RMD representative for the ORR is Lisa Huff, East Tennessee Stewardship Ecologist, Knoxville Field Office, telephone: (865) 594-5601, lisa.huff@tn.gov. The Natural Heritage Inventory Program contact for threatened and endangered animal species is David Withers, Zoologist, (615) 532-0441, david.withers@tn.gov.

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Aquatic Vegetation Monitoring on the Oak Ridge Reservation

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Abstract

As a part of its obligations under the Tennessee Oversight Agreement, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation conducts monitoring of aquatic vegetation on and near the Department of Energy's Oak Ridge Reservation. In this program, DOE Oversight staff members collect vegetation at locations near or in water with the potential for radiological contamination. If surface water bodies have been impacted by radioactivity, aquatic organisms in the immediate vicinity may uptake radionuclides, bioaccumulating radiological contaminants. The vegetation is analyzed for gross alpha, gross beta and for gamma radionuclides and is compared to the radiological analysis of vegetation taken from background locations. The sampling conducted during 2014 suggests limited areas of elevated radionuclide concentrations in the vegetation associated with surface water on the Oak Ridge Reservation. In 2014, mercury analysis was also completed at multiple locations on the Oak Ridge Reservation. Mercury results above detectable levels were seen at some locations, but were not elevated.

Introduction

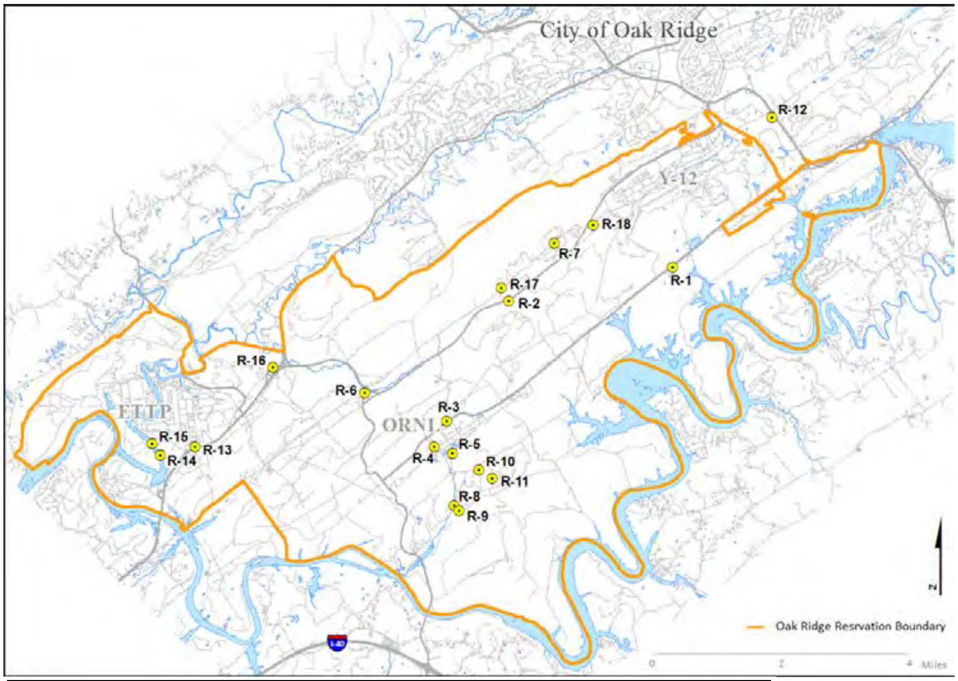
The the DOE Oversight Office of the Division of Remediation conducts monitoring of aquatic vegetation on and near the Department of Energy's Oak Ridge Reservation (ORR). Aquatic vegetation (e.g., watercress and cattails) can be bioaccumulators and due to this, they can be potential pathways by which contaminants infiltrate the ecosystem and food chain creating ecological and human health risks. If an emerging spring or stream is impacted by radiological contaminants, these substances can be deposited in the sediment. The plants may then uptake the radionuclides from the water or the sediment. Since many plants uptake and accumulate calcium naturally, they may also uptake the radionuclide strontium-90, which is similar to calcium chemically. Other radionuclides and metals may also be accumulated in the plant tissue if present in the water or sediments.

Methods and Materials

Two sets of vegetation samples were collected in 2014, one set in areas there was thought to be a greater potential for radiological contamination and one set in areas thought to have a greater potential for mercury contamination. Samples were taken by collecting at least one gallon of vegetation, including minimal other debris. Samples were then scanned with a radiological instrument for beta and gamma radiation, double-bagged in re-sealable plastic bags, labeled, and transported on ice to the state environmental laboratory in Knoxville. The Knoxville Regional Laboratory forwarded all samples to the State of Tennessee Department of Health Environmental Laboratory in Nashville for analysis.

Eighteen sites, including a background location, were sampled and analyzed for basic radiological contamination. Samples collected for radiological analysis were analyzed for gross alpha, gross beta, and gamma radionuclides. Samples were collected near Oak Ridge Reservation surface water sites, including springs, creeks, and wetlands to determine if radioactive contaminants have accumulated in the associated vegetation. The majority of vegetation samples collected for radiological analysis consisted of watercress (*Nasturtium officinale)* or cattails

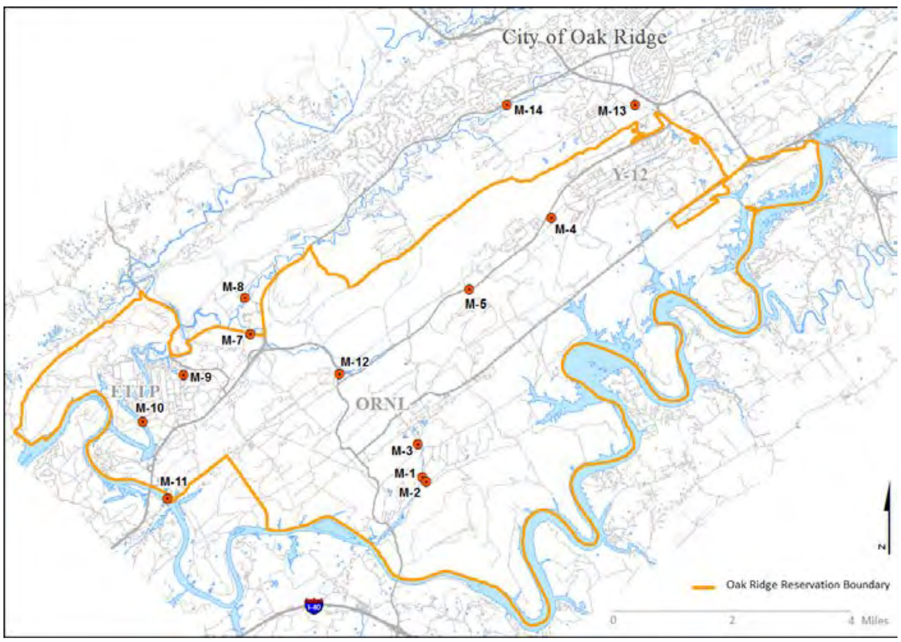
(*Typha* sp.), but there were three samples that consisted of other vegetation types: one was sweet flag (*Acorus calamus*), another was flag iris (*Iris pseudacorus*), and the third was jewelweed (*Impatiens capensis*). The species sampled were determined based on what was available at the desired sampling locations. Watercress and cattails have been used in previous years and seem to be good at bioaccumulating contaminants. The locations of the samples analyzed for radiological contaminants are shown and listed in Figure 1.



Site	Location	Vegetation
R-1	ORNL Spring Creek, near east guard check	watercress
R-2	Y-12 SS-5 Spring, below blue hole	watercress
R-3	ORNL Solar Panel Spring	watercress
R-4	ORNL First Creek, above Central Ave bridge	watercress
R-5	ORNL SWSA1 south drainage ditch	cattail
R-6	Y-12 Bear Creek wetland, near HWY 95	cattail
R-7	Y-12 EMWMF, below underdrain	cattail
R-8	ORNL Melton Valley, White Oak Creek weir	cattail
R-9	ORNL Melton Valley, ditch below New Hydrofrac	cattail
R-10	ORNL Melton Valley, wetland behind HRE	cattail
R-11	ORNL Melton Valley, HFIR drainage	cattail
R-12	Cattail/Sweet Flag Spring- Illinois and Union Valley	sweet flag
R-13	ETTP K-1007 P4 pond NW	cattail
R-14	ETTP K-1007 P1 pond near weir	cattail
R-15	ETTP Poplar Creek, below SD-440	flag iris
R-16	Background- roadside wetland	cattail
R-17	Y-12 Bear Creek, NT-8, upstream of haul road	jewelweed
R-18	Y-12 Bear Creek, below S-2	cattail

Figure 1: 2014 Aquatic Vegetation Sites Sampled for Radiological Contamination

Metals analysis for mercury was performed on the second set of samples. Mercury analysis was completed for vegetation sampled from fourteen locations, including one background location. The vegetation samples collected for mercury analysis consisted of mixed floodplain vegetation from near the edges of water sources, mainly creeks. A similar method to that used for FRMAC (Federal Radiological Monitoring and Assessment Center) vegetation sampling was used, though an area large enough to fill a gallon bag was sampled. The 2014 variation in methodology for samples collected for mercury analysis from that used for the samples collected for radiological analysis was due to low levels of mercury being seen using this methodology for the 2013 samples. Since higher mercury results were seen in a pilot project deer browse study in 2010, another approach using floodplain vegetation from the areas of interest was used. Sampling mixed floodplain vegetation allowed for a wider variety of locations of potential interest to be sampled by not being limited by vegetation type. The locations of the samples analyzed for mercury are shown and listed in Figure 2.



Site	Location
M-1	ORNL Melton Valley, White Oak Creek
M-2	ORNL Melton Valley, Melton Branch
M-3	ORNL Melton Valley Rd, White Oak Creek
M-4	Y-12, Bear Creek S-2
M-5	Y-12, Bear Creek below NT-8, near SS-5
M-6	BACKGROUND, Upper Poplar Creek
M-7	Greenway access Bear Creek
M-8	East Fork Poplar Creek, below Novus Rd
M-9	ETTP Mitchell Branch, below SD-170
M-10	Poplar Creek, below ETTP
M-11	Clinch River, near Bear Creek Rd
M-12	Bear Creek Floodplain, near Highway 95
M-13	East Fork Poplar Creek, near NOAA
M-14	East Fork Poplar Creek, near Grocery Outlet

Figure 2: 2014 Aquatic Vegetation Sites Sampled for Mercury Contamination

Results and Discussion

Radiological 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 to protective measures should be considered (FDA 1998). These values are meant to be very protective in the case that a nuclear incident occurs and food is radioactively contaminated. They are specific to certain radionuclides and are not directly comparable to gross alpha, gross beta, and gamma activity, which were the analyses run on the vegetation samples for this project. A potentially more useful comparison is to the levels of alpha, beta, and gamma seen at a background location or other samples with very low levels of radionuclides. Generally, this is done by looking at results of more than twice background levels as being elevated, at least at environmental levels.

Staff gathered eighteen vegetation samples for radiological analysis during May of 2014. Table 1 provides the results of the radiochemical analysis of these vegetation samples. Samples were collected at each of the three larger sites or areas on the Oak Ridge Reservation: Oak Ridge National Laboratory (ORNL), Y-12, and East Tennessee Technology Park (ETTP), formerly known as the K-25 site. 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 and blue bars shown in Table 1 for gross alpha and gross beta, respectively, are to visually assist you in seeing which values are lower and which are higher; the longer the bar, the higher the result. The values representing two times those seen at the background locations for each vegetation type are shown at the bottom of the table for further comparison, but since they are not actual results, they are not compared by the blue and yellow bars. Values greater than twice background are shown in bold to make them easier to find in the tables below. The data suggest limited areas of elevated radionuclide concentrations in the aquatic vegetation on the Oak Ridge Reservation.

Table 1: Results for Radiochemical Analysis of 2014 Vegetation Samples (pCi/g wet weight)

station	location	gross alpha	gross beta	gamma					
				Cs-137	K-40	Pb-212	Pb-214	Bi-214	Th-234
R-10	ORNL Melton Valley, wetland behind HRE	**3.0**	**53.9**		4.24				
R-17	Y-12 Bear Creek, NT-8, upstream of haul road	**3.9**	**8.9**		2.87				5.78
R-11	ORNL Melton Valley, HFIR drainage	0.42	**6.3**						
R-8	ORNL Melton Valley, White Oak Creek weir	0.28	**5.6**	2.78	1.86				
R-15	ETTP Poplar Creek, below SD-440	0.33	2.8		3.92				
R-18	Y-12 Bear Creek, below S-2	0.23	2.7		3.52				
R-12	Cattail/Sweet Flag Spring- Illinois and Union Valley	0.4	2.5		3.64				
R-5	ORNL SWSA1 south drainage ditch	0.20	2.3		3.32				
R-16	Background- roadside wetland	0.26	2.3		3.56				
R-7	Y-12 EMWMF, below underdrain	0.22	2.2		3.24				
R-9	ORNL Melton Valley, ditch below New Hydrofrac	0.22	2.0		2.62				
R-13	ETTP K-1007 P4 pond NW	0.27	2.0		2.58				
R-2	Y-12 SS-5 Spring, below blue hole	0.22	1.9		2.11			0.154	
R-3	ORNL Solar Panel Spring	0.26	1.8		2.86	0.034		0.068	
R-14	ETTP K-1007 P1 pond near weir	0.17	1.8		1.16				
R-4	ORNL First Creek, above Central Ave bridge	0.15	1.6		2.29				
R-6	Y-12 Bear Creek wetland, near HWY 95	0.14	1.4		2.69				
R-1	ORNL Spring Creek, near east guard check	0.11	1.0		2.38		0.091	0.113	
	2X BG	0.52	4.6		7.12				

bold# more than 2x background black# above detection limits

The highest levels of gross alpha and gross beta activity for 2014 were from samples collected at R-10 and R17. The R-10 sample was collected at the edge of the wetland area behind the old Homogeneous Reactor Experiment site (HRE) in ORNL's Melton Valley and was collected near but not at the exact location of the previous two years as there were not enough cattails to make of a full gallon sample at the location used in 2012 and 2013. That original location had the highest level of gross alpha gross beta activity for the 2012 and 2013 aquatic vegetation sampling years. In Table 2, the gross alpha and gross beta values for this site can be seen for 2012 and 2013 and compared to the values seen in 2014 from the nearby location. Gross alpha levels were similar for all years but the levels of gross beta seen at the 2014 sampling location were much lower than those seen at the first location sampled in 2012 and 2013. While worth noting, contamination has long been an issue at this site. The R-10 sample also had elevated gross alpha (3.9 pCi/g) and gross beta (8.9 pCi/g) levels, with gross alpha levels greater than those seen at the HRE wetland. This site is along North Tributary 8 (NT-8) in Bear Creek Valley and is located downstream of burial grounds, which are presumably the source of the contamination in the vegetation sampled.

Table 2: Gross Alpha and Gross Beta Analysis at HRE Wetland (pCi/g wet weight)

	gross alpha	gross beta
2012	2.5	189
2013	3.2	213
*2014	3.0	53.9

* similar but not exact location

Two other sites sampled for radiological contamination in vegetation also had gross beta levels that were greater than two times background, stations R-11 and R-8. Both are located at ORNL in Melton Valley. R-11 was a new location and was from a roadside wetland with cattails, downhill from the High Flux Isotope Reactor (HFIR) experiment buildings. R-8 was upstream of the White Oak Creek Weir and has been sampled previously. In 2013, that location was sampled twice in the same area harvesting cattails, once was in the summer and once in the fall. In the summer of 2013, the gross beta level was 11.2 pCi/g and in the fall sample the gross beta level was 11.8 pCi/g. For comparison, the gross beta level was 5.6 pCi/g in the 2014 sample. While there may appear to be some natural attenuation at some of the sampling sites, it can be hard to tell when only taking one or two samples a year. Decreased levels could be indicative of greater rainfall and thus greater dilution of the contaminants, the removal of sources of radiological contaminants, natural attenuation, or they could also just be a single low result.

There are various complicating factors in trying to interpret the data from a sampling project like this. Complicating factors include: only having one or two samples per location per year so that variation is not completely accounted for; the vegetation could be at different stages of development, even if sampled at the same time of year; the time of the sampling could be different; the amount of precipitation just before collection and throughout the growing season varies; and the type of vegetation could affect the result as certain types of vegetation are better bioaccumulators for various contaminants. Also, having more than one type of vegetation in an area could allow another vegetation type that is not being sampled to preferentially absorb the contaminant of interest so that it would not be detected in the vegetation sampled or at least in lower concentrations than expected based on the levels of contamination present. Many of these variables are difficult to control, especially with a limited number of samples and types of sampling media.

A modest effort was made in 2013 to get a better understanding of a couple of these variables. Findings are discussed here and, in more detail, in last year's Environmental Monitoring Report. First, a number of different types of vegetation were sampled, usually with a corresponding background location. A quick survey with radiological instruments was also conducted at the site with the most elevated gross alpha and beta results to determine if one vegetation type seemed to be accumulating more radioactive contamination. This quick survey seemed to indicate that cattails were very effective bioaccumulators, but they were not always present for sampling at all locations. Another method used in 2013 was to sample a couple of vegetation types at one location for comparison. Again, this test could be complicated by one vegetation type out-competing the other for the contaminant in question. It could also be misleading if one vegetation type is located slightly closer to the source of the contamination, or receives a different flow of water or sediments containing the contamination, had roots at different depths, oraccumulates certain contaminants but not others, among other issues. Sampling two vegetation types in one area was done four times in 2013. This was done at First Creek at ORNL with willow and watercress, where the willow appeared to be the better bioaccumulator. At the ORNL Melton Valley wetland behind HRE, the cattail sample showed significantly more gross beta and gross alpha contamination than the willow sample. Two of the nearby sampling types were sampled twice each in 2013. This was done at the site above the lower White Oak Creek weir in Melton Valley on July 23 and October 8. The sampling locations were across White Oak Creek from each other and one was a cattail sampling location and the other a willow sampling location. The results appeared to be similar between the two times of year but with the gross beta results being a little higher in the fall and the gross alpha results being a little higher in the summer. The cattails appeared to bioaccumulate more gross alpha and more gross beta in the summer, while the willow showed greater bioaccumulation for gross beta in the fall. Again, there are many complicating factors and not much data for comparison.

Mercury Analysis

Metals analysis was completed for fourteen vegetation samples for mercury in June of 2014. Samples were collected at each of the three larger sites or areas on the Oak Ridge Reservation: Oak Ridge National Laboratory (ORNL), Y-12, and East Tennessee Technology Park (ETTP), formally known as the K-25 site, as well as areas potentially contaminated from these sites but off of the Oak Ridge Reservation. Testing for mercury was done because of the great interest in mercury contamination from Y-12 and the potential for mercury contamination to be present at any of the sites on the Oak Ridge Reservation. Also, in the 2010 EMR, there were elevated levels of mercury reported in some deer browse samples. The results of the 2014 mercury sampling effort can be seen in Table 2. The red bars shown in Table 2 are to visually assist you in seeing which values are lower and which are higher; the longer the bar, the higher the result.

Table 2: Results for Mercury Analysis of 2014 Vegetation Samples (mg/kg)

Site	Location	result	*	unit
M-13	East Fork Poplar Creek, near NOAA	0.110		mg/kg
M-4	Y-12, Bear Creek S-2	0.083		mg/kg
M-14	East Fork Poplar Creek, near Grocery Outlet	0.072		mg/kg
M-10	Poplar Creek, below ETTP	0.048		mg/kg
M-8	East Fork Poplar Creek, below Novus Rd	0.033		mg/kg
M-3	ORNL Melton Valley Rd, White Oak Creek	0.031		mg/kg
M-5	Y-12, Bear Creek below NT-8, near SS-5	0.023		mg/kg
M-1	ORNL Melton Valley, White Oak Creek	0.020		mg/kg
M-9	ETTP Mitchell Branch, below SD-170	0.014	D	mg/kg
M-2	ORNL Melton Valley, Melton Branch		U	mg/kg
M-6	BACKGROUND, Upper Poplar Creek		U	mg/kg
M-7	Greenway access Bear Creek		U	mg/kg
M-11	Clinch River, near Bear Creek Rd		U	mg/kg
M-12	Bear Creek Floodplain, near Highway 95		U	mg/kg

* D - detected, but not quantifiable   U - undetected

The 2014 mercury results for the analyzed vegetation samples were all well below the EPA and TDEC precautionary advisory level of 0.30 mg/kg, as they were for the vegetation samples collected in 2013. This was the case despite the change in procedure which aimed to sample sites more likely to have mercury contamination. The 0.30 mg/kg screening value is used for fish consumption advisories though, not vegetation as there do not appear to be regulatory limits for mercury in vegetation. Of interest are the locations where mercury was clearly detected in the vegetation. The Y-12 site is the headwaters for both East Fork Poplar Creek and Bear Creek and is also the location where much mercury has been released to the environment. Unsurprisingly, three of the eight locations where mercury was detected were located downstream from Y-12 along East Fork Poplar Creek and two more were located downstream of Y-12 along Bear Creek. One was located downstream of ETTP along Poplar Creek, which is fairly large at that point, providing much dilution. And two more were located at ORNL at two different points along White Oak Creek, with the one farther upstream having higher levels of mercury as would be expected as it is be closer to potential sources and receiving less dilution. Two locations sampled that were farther down Bear Creek, farther from the sources and with more dilution, did not detect any mercury, including the location where it is near a local greenway trail.

Conclusions

The data collected suggests limited areas of elevated radionuclide concentrations in the aquatic vegetation on the Oak Ridge Reservation. Future sampling activities will focus on identifying areas of potential radiological contamination from past and current activities on the Oak Ridge Reservation to evaluate the potential for bioaccumulation of radionuclides in vegetation from the associated surface waters. Areas with previously elevated sampling results will likely continue to be monitored. The mercury analysis indicated some areas where mercury was detected in floodplain vegetation due to contamination on the three sites on the Oak Ridge Reservation, but these results were well below levels used for mercury advisory levels in fish tissue. Sampling for mercury contamination will be discontinued in 2015, focusing instead on radiological contaminants. The sampling methodology employed for the 2014 mercury samples was quite useful in expanding the types of locations where samples could be collected. This methodology will be used for some of the collection and site selection of vegetation samples collected in 2015 for radiological analysis. These samples will be used for comparison to the methodology used in 2014 where both types of samples can be collected and will be used solely in other locations of interest where only mixed floodplain vegetation is available and could not previously be sampled due to lack of the desired vegetation. In fact, many of the 2014 mercury sampling locations are likely to be used in 2015, but only for collection of samples for radiological analysis.

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DRINKING WATER MONITORING

Sampling of Oak Ridge Reservation Potable Water Distribution Systems

Principal Author: Robert B. Bishop

Abstract

As the three Department of Energy (DOE) Oak Ridge Reservation (ORR) plants become more accessible to the public, the Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (the office) continues its oversight of DOE facilities' safe drinking water programs. The scope of the office's independent sampling includes oversight of potable water quality on the ORR. In 2014, TDEC conducted oversight of the potable water distribution systems and the water quality at ORR facilities. The 2014 results of this oversight revealed that the three reservation systems provide water that meets state regulatory levels.

Introduction

Public consumption of the water on the Oak Ridge Reservation (ORR) continues to increase. Oak Ridge National Laboratory (ORNL) has always hosted foreign dignitaries and accommodated visiting scientists in an openly cooperative manner. In order to facilitate technology transfer, work for non-governmental sectors, and utilization of surplus buildings by private companies, security has been relaxed or reprioritized in recent years at some portions of the sites, most notably at East Tennessee Technology Park (ETTP). In turn, the composition of the workforce at the ORR has changed substantially. Y-12 continues to allow only limited public visitation. Current facility use involves a substantial public presence at ETTP and ORNL. Y-12's public presence is not as vast as it is at ETTP or ORNL.

Methods and Materials

The oversight included random inspections of ORNL and Y-12 to check free residual chlorine levels of the distribution systems at ORNL and Y-12.

Results and Discussion

Y-12

Five routine inspections were made at Y-12 during 2014. The inspections focused on the facility's free chlorine residual levels. The dates for the inspections were as follows: June 18, July 21, September 4, November 3 and December 9. The chlorine residual levels were in compliance with drinking water regulations.

ORNL

Six routine inspections were made at ORNL during 2014. The inspections again focused on the facility's free chlorine residual levels. The dates for the inspections were as follows: March 28, June 18, July 21, September 4, November 3 and December 9. The chlorine residual levels were in compliance with drinking water regulations.

ETTP

No routine inspections were made at ETTP in 2014. Staff review compliance reports provided by DOE to the TDEC Division of Water Resources.

Conclusion

The results of the inspections and document reviews revealed that the three potable distribution systems for the ORR provide water that meets state regulatory levels. However, the potential exists for a cross connection between the distribution systems and contamination from the surrounding environmental media when breaks/leaks occur in the system.

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RadNet Drinking Water on the Oak Ridge Reservation

Principal Author: Natalie Pheasant

Abstract

The RadNet program was developed by the U.S. Environmental Protection Agency 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 program focuses on nuclear sources and population centers. The RadNet Drinking Water Program in the Oak Ridge area provides for radiochemical analysis of finished water at five public water supplies located near and on the Oak Ridge Reservation. In this effort, quarterly samples are taken by staff from the Tennessee Department of Environment and Conservation and analysis for radiological contaminants is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory in Montgomery, Alabama. Analyses include tritium, iodine-131, gross alpha, gross beta, strontium-90, and gamma spectrometry, with further analysis performed when warranted. While results for tritium, gross beta, and strontium-90 have tended to be slightly higher at the East Tennessee Technology Park Water Treatment Plant, all results generated by the program have remained below regulatory criteria, since its inception in 1996.

Introduction

Radioactive contaminants released on the Oak Ridge Reservation (ORR) can potentially enter local streams and be transported to the Clinch River. While monitoring of the river and local water treatment facilities has indicated that concentrations of radioactive pollutants are below regulatory standards, a concern that area water supplies could be impacted by ORR pollutants remains. In 1996, the Tennessee Department of Environment and Conservation (TDEC) began participation in the Environmental Protection Agency's (EPA) Environmental Radiation Ambient Monitoring System, which is now called RadNet. RadNet is a national network of monitoring stations that collects samples to check for radiological contamination. The RadNet Drinking Water Program provides quarterly radiological sampling of finished water at public water supplies near major population centers and nuclear sources throughout the United States. The RadNet program is designed to:

- monitor pathways for significant population exposure from routine and accidental releases of radioactivity,
- provide data indicating additional sampling needs or other actions required to ensure public health and environmental quality and,
- serve as a reference for data comparisons (U.S. EPA, 1988).

The RadNet program also provides a mechanism to evaluate the impact of DOE activities on area water systems and to supplement DOE monitoring, providing independent third party analysis.

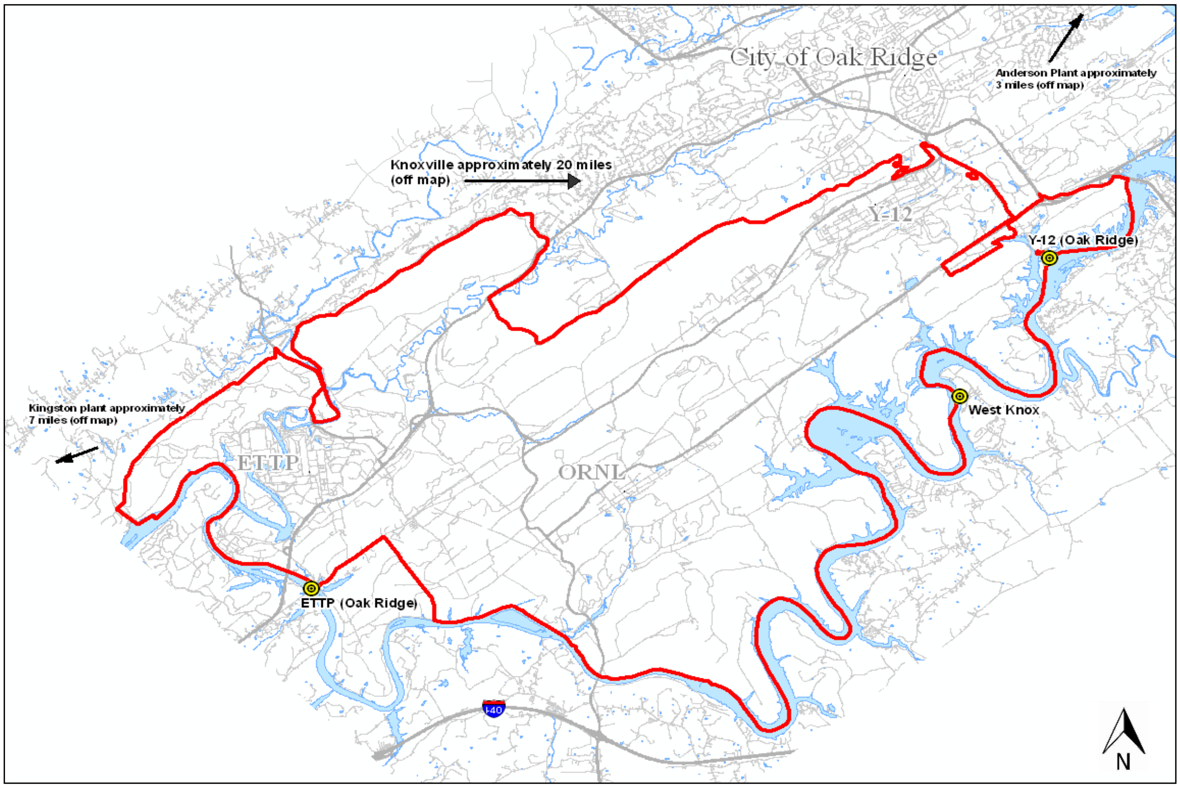
Methods and Materials

In the Oak Ridge RadNet Drinking Water Program, EPA provides radiochemical analysis of finished drinking water samples taken quarterly by TDEC staff at five public water supplies located on and in the vicinity of the ORR. The samples are collected using procedures and supplies prescribed by EPA protocol (U.S. EPA, 1988; U.S. EPA, 2013). The samples are analyzed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama. The analytical frequencies and parameters are provided in Table 1.

Table 1: RadNet Drinking Water Analyses

ANALYSIS	FREQUENCY
Tritium	Quarterly
Iodine-131	Annually on one individual sample/sampling site
Gross Alpha, Gross Beta, Strontium-90, Gamma Scan	Annually on composite samples
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

The five locations sampled in the Oak Ridge area for the program are the Kingston Water Treatment Plant, the East Tennessee Technology Park (ETTP) Water Treatment Plant (run by the city of Oak Ridge), the West Knox Utility District Water Treatment Facility, the Y-12 Water Treatment Plant (run by the city of Oak Ridge), and the Anderson County Water Authority Water Treatment Plant. Figure 1 depicts the locations of the raw water intakes associated with these facilities.



The results of NAREL's analyses are provided to TDEC annually. Nationwide data is available at NAREL's website in the Envirofacts RadNet Searchable Database, via either a simple or customized search (websites listed in references).

Results and Discussion

A large proportion of the radioactive contaminants that are transported off the ORR in surface water enter the Clinch River by way of White Oak Creek, which drains the Oak Ridge National Laboratory 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 the dilution provided by the river. With exceptions, contaminant levels are 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.

Since the ETTP Water Treatment Plant (transferred to the city of Oak Ridge on May 29, 2008) is the closest water supply downstream of White Oak Creek (approximately 6.5 river miles), this facility would be expected to exhibit the highest concentrations of radioactive contaminants of the five utilities monitored by the ORR RadNet Drinking Water program. The ETTP Water Treatment Plant, run by the city of Oak Ridge, was permanently closed at the end of September 2014, so data is only available for the first three quarters of 2014 for this location. Conversely, the Anderson County facility (located upstream of the reservation) would be expected to be the least vulnerable of the facilities to ORR pollutants. The data collected since the Oak Ridge RadNet program began in July of 1996, indicates that this is the case. However, all results for the five water treatment facilities have remained well below applicable Maximum Contaminant Levels (MCL) drinking water standards set by EPA (Table 2).

Table 2: EPA Drinking Water Standards (pCi/L)

Isotope	MCL
Iodine-131	3 pCi/L
Strontium-90	8 pCi/L
Tritium	20,000 pCi/L
Cobalt-60	100 pCi/L
Cesium-137	200pCi/L

All four quarters of tritium results were available from NAREL for 2014. These data are similar to the results received in past years. NAREL typically performs tritium analysis on each of the quarterly samples taken at the facilities in the program. The 2014 tritium results are shown in Table 3, along with the last quarter of the 2013 data. 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 in 2014 from each of the five area water treatment plants, all but one was below detection limits. The result above the detection limits for the 2014 samples is in bold in Table 3, while those results below detection limits are shown in gray. Historically, the results of the tritium analyses are often below detection limits. The results for tritium at the five sites since the program's inception range from undetected to 1,000 pCi/L. The drinking water standard for tritium is 20,000 pCi/L, so even the highest levels of tritium that have been detected by this program in the Oak Ridge area are well below this limit.

Since the net tritium results are obtained by subtracting the value of a tritium-free sample from that of the actual sample, negative numbers can be present. For a group of samples with no tritium, the results (positive and negative) should be distributed symmetrically around 0 pCi/L. Negative values are especially useful for unbiased statistical data, but can also be used to get a better picture of the range of results. The same is true for the analysis of other isotopes.

Table 3: Quarterly Tritium Results from the Five Water Treatment Facilities in pCi/L

	2013	2014 RadNet Drinking Water - Tritium			
	QTR 4	QTR 1	QTR 2	QTR 3	QTR 4
Anderson	-36	52	-7	117	58
Y-12 (OR)	-67	34	49	15	-30
West Knox	-34	-22	9	-4	-17
ETTP (OR)	0	-35	**368**	-37	closed
Kingston	-49	9	65	88	73

Note: Values above the detection limits in bold, values below detection limits are in gray. The ETTP location was closed at the end of September 2014.

I-131 analysis is performed on one sample per location each year. I-131 analysis for 2014 was done for one quarter at each of the five stations. All results were below detection limits, as can be seen in Table 4.

Table 4: I-131 Results from the Five Water Treatment Facilities in pCi/L

Anderson	QTR 4	-0.14
Y-12 (OR)	QTR 4	0.1
West Knox	QTR 4	0.21
ETTP (OR)	QTR 3	-0.03
Kingston	QTR 4	0.08

Note: Values below detection limits are in gray

Gross alpha, gross beta, gamma and strontium-90 analyses are performed annually on a composite of the quarterly samples taken from each of the five monitored facilities. Results of the 2014 composite analyses are not yet available, as it can be well into the following year before they are able to be composited. The 2013 annual composite results are now available and are noted below.

In 2013, there were no gross alpha results above detection limits and no gross beta results above detection limits (the average detection limit for the 2013 gross alpha results was 3.1 pCi/L and 4.3 pCi/L for the gross beta results). EPA's drinking water standard for gross alpha in drinking water is 15 pCi/L (MCL). The five samples from 2013 were all well below this amount. 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. While there are no drinking water limits for gross beta, one can use strontium-90 limits as a conservative comparison, although strontium-90 is unlikely to make up a large percentage of the total gross beta, if any. The gross beta results for the 2013 annual composites from drinking water sampling location near and on the ORR fell well below EPA's drinking water standard for strontium-90 (limit 8.0 pCi/L).

The gamma spectrometry on the annual composites for 2013 showed no values above detection limits. This was the case for cobalt-60 (Co-60), cesium-137 (Cs-137), radium-228 (Ra-228), and potassium-40 (K-40). The MCL for cobalt-60 is 100 pCi/L and the MCL for cesium-137 is 200 pCi/L. The 2013 results were well below these EPA drinking water standards and in fact even below detection limits.

The annual composite analysis for strontium-90 of drinking water samples for 2014 was not yet available at the time this report was written. The data from 2013 all fell below the minimum detectable amounts. The highest strontium-90 in 2013 was 0.33 pCi/L (from West Knox). This was well below the 8.0 pCi/L EPA drinking water limit for strontium-90.

All samples analyzed from this program for the Oak Ridge area since its inception have been well below the associated drinking water standards and often even below detection limits.

Conclusion

Radioactive contaminants migrate from the ORR to the Clinch River, which serves as a raw water source for area public drinking water supplies. The impact of these contaminants is diminished by the dilution provided by 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. Gross beta, strontium-90, and tritium, while below drinking water standards, have tended to have higher levels in samples taken from the ETTP Water Treatment Plant than at the other facilities monitored by the program. This is not surprising as the ETTP Water Treatment Plant is the closest facility downstream of White Oak Creek, which is the major pathway for radiological pollutants entering the Clinch River from the ORR. However, this treatment plant was closed at the end of September 2014 and will no longer be included in analyses after the 2014 data are available.

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RADIOLOGICAL MONITORING

Facility Survey Program and Infrastructure Reduction Work Plan

Principal Authors: Dave Thomasson and Don Gilmore

Abstract

Like other Department of Energy (DOE) research facilities across the nation, the Oak Ridge Reservation (ORR) released large quantities of hazardous chemicals and radiological contamination into the surrounding environment during nearly five decades of nuclear weapons research and development. Since most of this contamination was released directly from operational buildings, the Tennessee Department of Environment and Conservation's Department of Energy Oversight Office developed a Facility Survey Program to document the full histories of facilities on the reservation. The survey program examines each facility's physical condition, process history, inventory of hazardous chemical and radioactive materials, relative level of contamination, past contaminant release history and, present-day potential for release of contaminants to the environment under varying conditions ranging from catastrophic (i.e. earthquake) to normal everyday working situations. This broad-based assessment supports the objectives of Section 1.2.3 of the Tennessee Oversight Agreement, which was designed to inform local citizens and governments of the historic and present-day character of all operations on the reservation. This information is also essential for local emergency planning purposes. Since 1994, the office's survey team has characterized 206 facilities and found that forty-two percent have either historically released contaminants, or pose a relatively high potential for release of contaminants to the environment today. In many cases, this high potential-for-release is related to legacy contamination that escaped facilities through degraded infrastructures over decades of continuous industrial use (e.g. leaking underground waste lines, substandard sumps and tanks, or unfiltered ventilation ductwork). Since the inception of the program, DOE corrective actions, including demolitions, have removed thirty-nine facilities from the office's list of high Potential Environmental Release (PER) facilities. In 2013, no facilities were removed due to the expiration of American Recovery and Reinvestment Act funds.

Beginning in 2002, facility survey staff also began focusing some of their efforts on the oversight of facilities slated for demolition and/or decontamination at ORNL and Y-12. This activity was in response to formal, accelerated infrastructure reduction (demolition) programs at each of those sites. After a downturn in demolition activities in 2008 due to funding short falls, activity was escalated in 2009 with the inception of the American Recovery and Reinvestment Act (ARRA). During 2012, ARRA money expired and D&D activities came to a halt. Due to staff reorganization, retirements, and staffing priorities, this project had no reportable work completed in 2014. Evaluation and characterization of the facilities intended to be demolished has been reassigned to the Federal Facility Agreement Program within the DOE-O office. This project reassignment is intended to streamline the work effort in evaluating FFA remedial/removal work documentation and the work prioritization process.

Introduction

The Tennessee Department of Environment and Conservation's Department of Energy Oversight Office (DOE-O), in cooperation with the U.S. Department of Energy and its contractors, operates a facility survey program on the Oak Ridge Reservation (ORR). The DOE-O survey program provides a comprehensive, independent characterization of facilities on the ORR based on their operational history, present mission, physical condition, inventories of radiological and/or hazardous materials, degree of contamination, contaminant release history, and potential for release of contaminants to the environment.

The goal of the program is to fulfill part of the commitments agreed to by the State of Tennessee and the Department of Energy in Section 1.2.3 of the Tennessee Oversight Agreement, which states that "*Tennessee will pursue the initiatives in attachments A, C, E, F, and G. The general intent of these action items is to continue Tennessee's: (1) environmental monitoring, oversight and environmental restoration programs; (2) emergency preparedness programs; and (3) delivery of a better understanding to the local governments and the public of past and present operations on the ORR and potential impacts on the human health and/or environment by the Oak Ridge Reservation*." As part of this larger endeavor, the facility survey program is designed to provide a detailed assessment of all potential hazards affecting or in any way associated with facilities on the Oak Ridge Reservation. To meet this objective, survey team members walk through each facility and gather information that is recorded in a database that allows the team to characterize facilities and evaluate their potential for release of contaminants to the environment (PER). The conditions of facilities are considered within a variety of environmental conditions ranging from catastrophic (i.e. tornado, earthquake) to normal everyday working situations. From an emergency preparedness perspective such information is essential.

In 2002, the Department of Energy instituted a formal, accelerated D&D program aimed at facility reduction through demolition. Facility survey staff responded to this activity by making facility visits and conducting external inspections of each facility prior to and during demolition.

Methods and Materials

The criteria used in the selection of facilities to be surveyed include 1) position of facility in S&M/D&D programs; 2) physical condition of facility; 3) perceived levels of contamination; 4) types or quantities of inventories (hazardous or radiological); and 5) special circumstances (incidents, public or other agency request, or other unforeseen situations).

Using standard radiation survey instruments, inventory data, and historical documentation, staff members walked through each facility and recorded information in a questionnaire format. Based on these results and professional judgment, staff then ranked the potential for release of contaminants to the environment (PER) for each facility by scoring 0 (least potential) to 5 (greatest potential) for each of 10 "categories." Tables 1 and 2 illustrate the scoring guidelines for potential environmental release, and the categories to be scored.

As facilities are surveyed, scored, and compared with each other, a relative "potential for environmental release" will emerge. Staff will revisit these facilities at their discretion to evaluate changing conditions. Individual facility survey reports are delivered to DOE where they can be used to help prioritize D&D activities and corrective actions.

Table 1: Potential for Environmental Release Scoring Guidelines

Score	Score is based on observations in the field and the historic and present-day threat of contaminant release to the environment/building and/or ecological receptors.
0	No potential: no quantities of radiological or hazardous substances present.
1	Low potential: minimal quantities present, possibility of an insignificant release, very small probability of significant release, modern maintained containment.
2	Medium potential: radiological or hazardous substances present, structures stable in the near to long term, structures have integrity but are not state-of-the-art, adequate maintenance.
3	Medium potential: structures unstable, in disrepair, containment failure clearly dependent on time, integrity bad, maintenance lacking, containment exists for the short term only.
4	High potential: radiological or hazardous substances present. Containment for any period of time is questionable; migration to environment has not started.
5	Radiological or hazardous substance containment definitely breached, environmental/interior pollution from structures detected, radiological and/or hazardous substances in inappropriate places like sumps/drains/floors, release in progress, or radiological exposure rates above Nuclear Regulatory Commission (NRC) guidance.
Note: A score of 0 or 1 designates a low Potential Environmental Release rank; a score of 2 or 3 designates a moderate rank; a score of 4 or 5 designates a high rank.	

Table 2: Ten Categories Scored

1.	Sanitary lines, drains, septic systems
2.	Process tanks, lines, and pumps
3.	Liquid Low-level Waste tanks, lines, sumps, and pumps
4.	Floor drains and sumps
5.	Transferable radiological contamination
6.	Transferable hazardous materials contamination or waste
7.	Ventilation ducts and exit pathways to create outdoor air pollution
8.	Ventilation ducts and indoor air/building contamination threat
9.	Elevated radiation exposure rates inside the facility
10.	Elevated radiation exposure rates outside the facility

Discussion and Results

Due to staff reorganization, retirements, and staffing priorities no reportable work completed on this project in 2014. A discussion of the program and project follows.

The Facility Survey Program entered its twentieth year in January 2013. Since the beginning of the program, many facilities at ETTP have been privatized. In accordance with past office policy, an individual survey conducted on a facility at ETTP that has been leased to private industry might only address those portions of the facility that are leased. Consequently, some older reports may not include adjacent areas in the same facility or related facilities. These adjacent areas and related facilities may be contaminated and/or exhibit infrastructure problems that are not reflected in the report. Therefore, when reviewing these reports, it is important to look for the phrase “leased area of the facility.” This phrase indicates that the survey report covers only the leased area of the facility specifically, and is not intended to assess the entire facility or related facility problems (such as drain lines) that may exist outside of the leased area.

Since program staff members are continually in the process of evaluating DOE corrective actions taken to address facility concerns, any current ranking may not reflect the most recent corrective actions. Since the inception of the FSP, corrective actions (mostly demolitions), have removed thirty-nine facilities (X3550, X2017, X3525, X7823-A, X7827, X7819, X3505, X7055, X7700, X7700C, X7701, X2011, X3085, Y9404-3, Y9208, Y9620-2, Y9616-3, Y9959, Y9959-2, Y9736, Y9720-8, Y9201-3, Y9738, Y9769, Y9210, Y9224, Y9211, K1025-A, K1025-B, K1015, K1004-E, K1004-A, K1004-B, K1098-F, K1200-C and K1401-L3) from the office's list of "high" Potential Environmental Release facilities.

Table 3: Facility Survey Program Summary

Survey Year	Total Facilities Surveyed	High PER Facilities	Removed from High PER list	Facilities Resurveyed	D & D Visits
1994	15	9	0	0	0
1995	35	11	0	0	0
1996	34	9	0	0	0
1997	23	8	0	0	0
1998	8	3	1	2	0
1999	14	3	0	0	0
2000	14	5	3	0	0
2001	17	8	1	1	0
2002	8	5	5	0	90
2003	4	4	0	0	236
2004	0	0	2	1	463
2005	4	2	7	0	380
2006	2	2	7	4	123
2007	7	7	1	0	99
2008	0	0	0	1	15
2009	3	2	1	0	30
2010	7	5	6	0	30
2011	4	2	5	0	28
2012	3	1	0	1	22
2013	4	0	0	0	20
Totals	**206**	**86**	**39**	**10**	**1536**

Description of the 53 Highest Scoring Facilities (1994-2013)

The PER database attempts to reflect the overall condition of a facility and the potential for release of contaminants to the environment. However, it is not the total score of the ten categories that is always the best indicator of potential for environmental release. Rather, what appears to be the most accurate indicator is the number of categories for which a facility scores a four or five. Of the 206 facilities scored since 1994, 86 stood out with one or more categories scoring a four or five (Table 3). The remaining 53 high-scoring facilities are arranged in descending order of total numbers of fours and fives in the PER database (Table 4).

Table 4: Potential for Environmental Release for High-Scoring Facilities

Scoring	1	2	3	4	5	6	7	8	9	10		
BUILDING	**DRAIN LINES SANI.**	**TANKS LINES PROC.**	**TANKS LINES LLLW**	**SUMPS DRAINS FLOOR**	**TRANSF RAD. CONT.**	**TRANSF HAZ. CONT.**	**VENT TO OUTSIDE AIR**	**VENT INSIDE SYSTEM**	**INT.EXP. RAD. SURVEY**	**O. EXP. RAD. SURVEY**	**NUMBER OF 4 and 5's**	**SURVEY YEAR**
X3508	4	4	4	4	4	5	0	4	5	4	9	2009
X3003	4	4	4	4	5	1	2	2	5	4	7	2010
*X3550	0	0	0	0	0	0	0	0	0	0	0	2006
X3029	0	4	4	5	5	5	1	4	5	5	8	2007
X3033	1	4	4	4	4	5	3	2	5	5	7	2007
X3028	0	4	4	3	4	4	4	5	5	3	7	1997
X4507	1	4	4	4	4	5	2	2	5	4	6	2009
X3517	3	5	5	2	5	3	4	2	5	5	6	2005
Y9731	4	5	1	4	3	5	5	5	3	2	6	2003
K1037-C	0	0	0	0	5	5	5	5	5	4	6	1998
X7019	0	0	0	0	5	5	0	0	5	5	0	2011
X3030	1	5	5	5	4	5	1	1	1	3	5	2007
X3031	1	4	4	4	4	5	1	1	1	2	5	2007
X3118	1	4	4	4	4	5	1	1	1	2	5	2007
X3033A	0	4	4	4	4	5	3	3	2	2	5	2007
Y9401-2	1	4	1	4	1	5	4	4	1	0	5	2001
Y9204-3	3	5	2	3	4	5	4	4	2	1	5	2000
X3019-B	2	2	5	3	2	3	4	4	4	4	5	1995
K633	3	5	1	4	5	5	2	5	4	5	5	2002
X3032	0	4	4	4	2	5	3	3	2	2	4	2007
Y9201-4	2	5	0	2	2	4	5	5	2	1	4	1998
X3005	2	3	3	2	3	5	3	5	5	4	4	2006
K1004-J	5	5	0	4	3	0	0	0	1	1	3	2000
Y9203	4	2	0	4	2	4	2	2	2	0.5	3	1995
X2545	0	3	5	0	4	2	3	0	0	4	3	1995
X3020	0	0	5	5	5	0	2	0	0	1	3	1997
X3108	0	0	5	5	5	0	2	2	2	2	3	1997
X2061	0	0	0	0	5	5	3	3	5	0	3	2010
X3018	0	0	0	0	5	0	2	5	5	0	3	2011
X3091	0	0	5	5	5	1	2	2	3	2	3	1997
Y9743-2	0	3	0	5	3	5	2	2	2	1	2	2001
X3592	0	3	3	2	4	4	3	3	3	2	2	2001
X3504	1	3	0	4	5	0	2	1	2	2	2	2001
X2531	1	1	2	1	5	2	2	1	2	4	2	2001
Y9213	3	1	5	3	3	5	1	1	1	1	2	2000
*X3026	2	3	5	4	3	0	0	0	1	1	2	2005
X3001	3	1	2	3	3	2	4	4	3	3	2	1995
K1200-S	2	3	0	3	3	2	3	4	2.5	4	2	1995
X7706	4	3	0	4	2	0	2	2	2	2	2	1996
X7707	4	0	0	4	2	3	2	2	0	0	2	1996
X7720	0	0	0	0	4	0	0	0	0	4	2	1997

Scoring	1	2	3	4	5	6	7	8	9	10		
BUILDING	**DRAIN LINES SANI.**	**TANKS LINES PROC.**	**TANKS LINES LLLW**	**SUMPS DRAINS FLOOR**	**TRANSF RAD. CONT.**	**TRANSF HAZ. CONT.**	**VENT TO OUTSIDE AIR**	**VENT INSIDE SYSTEM**	**INT.EXP. RAD. SURVEY**	**O. EXP. RAD. SURVEY**	**NUMBER OF 4 and 5's**	**SURVEY YEAR**
*X3085	0	0	0	0	0	0	0	0	0	0	0	1994
X7602	0	2	0	2	4	2	1	3	2	1	1	1997
K1220-N	0	2	0	0	3	2	2	4	2	3	1	1995
X3002	0	2	0	2	3	1	2	3	4	1	1	1996
Y9207	2	0	0	1	1	4	3	1	1	0	1	1995
X7700-B	0	0	0	0	3	0	2	0	0	4	1	1996
*X2011	0	0	0	0	0	0	0	0	0	0	0	2010
*X2017	0	0	0	0	0	0	0	0	0	0	0	2010
X7019	0	0	0	0	0	5	0	5	4	5	3	2011
X7025	3	3	3	0	0	0	0	0	5	4	2	2011
X7048	0	0	0	0	0	0	0	0	3	0	0	2011
Y9401-1	0	0	0	0	5	0	0	0	5	4	3	2011

*Facility demolished.
**Facility partially demolished (see text entry).

Conclusion

When facility concerns are noted by the DOE-O office, they are relayed to the Department of Energy via the Facility Survey Report so that corrective actions can be formulated. To date, many corrective actions and demolitions have occurred. A total of thirty-nine facilities have been removed from the office's list of high Potential Environmental Release facilities. Those concerns that have not been corrected to the extent that the office has reduced the Potential Environmental Release score to less than a "4" are reflected in this report. The rankings are changed when written documentation is received by the office from DOE. Since the evaluation of corrective actions is an ongoing, time-consuming process, present scores may in some cases not reflect the most recently completed corrective actions. Due to staff reorganization, retirements, and staffing priorities, this project had no reportable work completed in 2014. Evaluation and characterization of the facilities intended to be demolished has been reassigned to the Federal Facility Agreement Program within the DOE-O office. This project reassignment is intended to streamline the work effort in evaluating FFA remedial/removal work documentation and the work prioritization process.

References

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Haul Road Radiological Surveys

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Abstract

The Haul Road was constructed for, and is dedicated to, trucks transporting CERCLA radioactive and hazardous waste from remedial activities on the Oak Ridge Reservation to the Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley for disposal. To account for wastes that may have blown or dropped from the trucks in transit, personnel from the Tennessee Department of Environment and Conservation perform walk-over inspections of the different segments of the nine-mile road Haul Road and associated access roads weekly. Anomalous items noted are surveyed for radiological contamination, documented, and their description and location submitted to DOE for disposition. During 2014, twenty-two items that had potentially fallen from trucks transporting waste to the EMWMF were documented. None of the items exhibited radioactivity in excess of free release limits and all were removed expeditiously after being reported to the Department of Energy.

Introduction

The Tennessee Department of Environment and Conservation's Division of Remediation DOE Oversight Office (DOEO), with the cooperation of the U.S. Department of Energy (DOE) and its contractors, perform weekly surveys of the Haul Road and other roads used to transport waste on the Oak Ridge Reservation (ORR). The Haul Road was constructed for and is dedicated to trucks transporting Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) radioactive and hazardous waste from remedial activities on the Oak Ridge Reservation (ORR) to the Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley for disposal. To account for wastes that may fall or be blown from the trucks in transit, DOE Oversight personnel perform walk-over inspections of different segments of the nine-mile long Haul Road and associated access roads weekly (weather permitting). Anomalous items noted along the roads are scanned for radiation, logged, marked with contractor's ribbon, and their description and location submitted to DOE for disposition. If anomalous items remain from previous inspections, they are included in subsequent reports, until removed or DOE advises the items have been found to be free of radioactive or hazardous contamination.

Methods and Materials

As previously noted, the nine-mile long Haul Road is surveyed in segments, typically consisting of one to two miles on a weekly basis (weather permitting). For safety, and by agreement with DOE and its contractors, staff members performing the inspections log in to at the East Tennessee Technology Park transportation hub and advise site personnel they intend to enter the road to perform the survey. The DOE contractor responsible for the road briefs staff members on any known conditions that could present a safety hazard and provides a two-way radio to office staff to maintain communication should unforeseen conditions arise 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 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 less 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 surface is used to scan for radioactive contaminants as the walk-over proceeds. A Ludlum 2224 Scaler with a Model 43-93 Alpha/Beta dual detector is used to investigate potential contamination on the road surfaces or anomalous items noted along the road that may be associated with waste shipments. Other radiological instruments available to staff are used as warranted (Table 1). Any areas or items with contamination levels exceeding 200 dpm/100 cm^2 removable beta, 1000 dpm/100 cm^2 total beta, 20 dpm/100 cm^2 removable alpha, and / or 100 dpm/100 cm^2 total alpha require further investigation.

Anomalous items found during the survey are marked with contractor’s ribbon at the side of the road and a description of the item and its location logged and reported to DOE and its contractors for disposition. A survey form or equivalent is maintained for each walk-over survey and is retained at the office’s Oak Ridge office. When staff members return to the road for the next weekly inspection, they perform a follow-up inspection of items found and reported in 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.

Table 1: DOE Oversight Office Portable Radiation Detection Equipment

Radiological Detection Instruments	Radiological Detection Probes	Radioactivity Measured
Ludlum Model 2221 Scaler Ratemeter	Ludlum Model 44-10 2x2” NaI Gamma Scintillator	Gamma
Ludlum Model 2224 Scaler / Ratemeter	Ludlum 43-93 Alpha / Beta Scintillation Detector	Alpha, Beta
Ludlum Model 3 Survey Meter	Ludlum Model 44-9 Pancake G-M Detector	Alpha, Beta, Gamma
Ludlum Model 3 Survey Meter	Ludlum Model 43-65 50 cm^2 Alpha Scintillator	Alpha
Ludlum Model 48-2748	Gas proportional detector Floor Monitor	Alpha, Beta
Bicron Micro Rem	Internal 1x1” NaI Gamma Scintillator	Tissue Dose Equivalent, Gamma (μRem/hr)
Identifinder-NGH	Isotopic Identifier and Ratemeter	Gamma Spectroscopy and Dose Rate Meter

Results and Discussion

The Haul Road walk-over surveys identified 22 items in 2014, potentially originating from hazardous and / or radioactive waste being transported to the EMWMF. No surface contamination readings exceeded free release limits and all ambient high energy gamma readings were within the range of normal background for the area. The items were marked as previously described; DOE notified of the findings, and the material was removed by DOE's contractors expeditiously.

Conclusions

The weekly inspections of the roads used to haul waste to the EMWMF, indicate waste items routinely fall or are blown from trucks transporting the waste. Based on these findings, it is planned to continue the Haul Road Survey Program in 2015.

References

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Ambient Gamma Radiation Monitoring on the Oak Ridge Reservation Using Environmental Dosimetry

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Abstract

The Tennessee Department of Environment and Conservation began monitoring ambient radiation levels on the Oak Ridge Reservation in 1995. The program provides conservative estimates of the dose to members of the public from exposure to gamma and neutron radiation attributable to Department of Energy activities on the reservation and baseline values for measuring the need and effectiveness of remedial activities. In this effort, environmental dosimeters have been placed at selected locations on and near the reservation. Results from the dosimeters are compared to background values and to the state dose limit for members of the public. While all the doses reported in 2014 at off-site locations were below the dose limit for members of the public, several locations on the reservation that are considered to be potentially accessible to the public had results in excess of the limit. As in the past, doses above 100 mrem were associated with various sites located in access-restricted areas of the reservation.

Introduction

Radiation is emitted by various radionuclides that have been produced, stored, and disposed on the Department of Energy's (DOE) Oak Ridge Reservation (ORR), since the Manhattan Era of World War II. Associated contaminants are evident in ORR facilities and surrounding soils, sediments, and waters. In order to assess the risks posed by these radioactive contaminants, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation began monitoring ambient radiation levels on and in the vicinity of the ORR in 1995. The program 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; and
- Information relative to the unplanned release of radioactive contaminants.

In this effort, environmental dosimeters are used to measure the radiation dose attributable to external radiation at selected monitoring stations. Associated data are compared to background values and to the state's primary dose limit for members of the public.

Methods and Materials

The dosimeters used in the program are obtained from Landauer, Inc., of Glenwood, Illinois. Each of the dosimeters uses an aluminum oxide photon detector to measure the dose from gamma radiation (minimum reporting value = 1 millirem (mrem). At locations where there is a potential for the release of neutron radiation, the dosimeters also contain an allyl diglycol carbonate based neutron detector (minimum reporting value = 10 mrem). The dosimeters are collected quarterly and shipped to the vendor for processing.

To account for exposures received in transit, control dosimeters are provided with each shipment of dosimeters received from the Landauer Company. These dosimeters are stored in a lead container (lead pig) at the DOE Oversight Office during the monitoring period and returned to Landauer for processing with the associated field deployed dosimeters. Any dose reported for the control dosimeters is subtracted from the results for the field-deployed dosimeters prior to being reported.

As the quarterly data are received from the vendor, DOE Oversight staff review the results and compile a quarterly report, which is distributed to DOE and other interested parties. At the end of the year, the quarterly results are summed for each location and the resultant annual dose compared to background values and to the state's primary dose limit for members of the public (100 mrem/year above background concentrations and medical applications). Each year, a report of the results and findings is compiled and presented in DOE Oversight's annual Environmental Monitoring Report.

Results and Discussion

The Atomic Energy Act exempts DOE from outside regulation of radiological materials at its facilities, but requires DOE to manage these materials in a manner protective of the public health and the environment. Since access to the reservation has, in the past, been predominately restricted to employees of DOE or their contractors, locations within the fenced areas of the reservation have traditionally been viewed as inaccessible to the general public. With the reindustrialization and revitalization of portions of the reservation, there has been an influx of workers employed by businesses not directly associated with DOE operations and, in some cases, property deeded to private entities within the reservation boundaries. Under state regulations, a member of the public is considered to be any individual, unless employed to perform duties that involve exposures to radiation. The state regulations go on to limit the dose to members of the public to 100 mrem/year (above background and medical applications) and the release of radiation in unrestricted areas to a dose of two mrem in any one-hour period. In this context, a restricted area is defined as an area with access limited for the purpose of protecting 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 was exposed to the same level of radiation for eight hours a day for the approximately 220 working days in a 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 in the program are based on the exposure an individual would receive if he or she remained at the monitoring station twenty-four hours a day for one year (8,760 hours). Since this is very unlikely, the doses reported should be viewed as conservative estimates of the maximum dose an individual could receive at each location.

Table 1 (attached) provides the dosimetry results for 2014, along with the total dose in 2013 for comparison. It should be noted here that none of the neutron dosimeters recorded a dose during the 2014 calendar year. The results have been organized according to location and are summarized below. Figures 1 to 9 are also provided to help the reader more easily visualize comparative data for the past five years of dosimeter data (years 2010 through 2014). Not all stations have the entire five years of data. Some of the dosimeters were moved to different stations during a particular monitoring year. An attempt will be made in this report to highlight all instances where data is not complete for a station. Tables 2 to 10 provide descriptions for the location of each dosimeter.

Table 1: 2014 Dosimeter Results

2014 Results for TDEC monitoring on the Oak Ridge Reservation using Environmental Dosimetry								
Dosimeter Designation (Dosimeter number)	**Location** *Optically Stimulated Luminescent Dosimeter (OSLs) and neutron dosimeters are reported quarterly.*	**Type of Radiation**	**Dose Reported for 2014 in mrem** *M = Below Minimum Reportable Quantity*				**2014 Total Dose ****	**2013 Total Dose ****
			1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
Off Site								
A-11 (9)	Norris Dam Air Monitoring Station (Background)	Gamma	M	6	M	5	22	12
A-12 (86)	Loudoun Dam Air Monitoring Station (Background)	Gamma	M	4	M	4	16	15
A-13 (86a)	Loudoun Dam Air Monitoring Station (Background)	Gamma	M	5	M	3	16	
		Neutron	M	M	M	M		11
A-14 (66)	Emory Valley Greenway	Gamma	M	14	M	12	52	50
A-15 (80)	Elza Gate	Gamma	M	3	M	2	10	13
A-16 (65)	California Ave.	Gamma	M	4	M	2	12	12
A-17 (64)	Cedar Hill Greenway	Gamma	M	6	M	3	18	12
A-18 (63)	Key Springs Road	Gamma	M	3	M	2	10	20
A-19 (62)	East Pawley	Gamma	M	5	M	5	20	21
A-21 (67)	West Vanderbilt	Gamma	M	8	M	6	28	29
A-22 (70)	Scarboro Perimeter Air Monitoring Station	Gamma	3	7	M	7	28	32
A-23 (91)	Emory Valley Pump House	Gamma	7	19	M	18	74	65

East Tennessee Technology Park									
C-10 (43)	K-1401 Building (West Side)	Gamma	M	7	M	7	28	28
C-12 (48)	K-1420 Building	Gamma	5	2	M	M	4	5
C-17 (44)	K-25 Building	Gamma	4	2	M	M	4	14
C-18 (160)	K-27 Building (Southwest Corner)	Gamma	M	3	M	1	8	11
C-19 (159)	K-27 Building (South Side)	Gamma	M	2	M	1	6	11
C-20 (158)	K-27 Building (Southeast Corner)	Gamma	4	0	M	2	4	11
C-21 (155)	K-27 Building (Northwest Corner)	Gamma	5	7	M	6	26	29
C-22 (156)	K-27 Building (North Side)	Gamma	M	4	M	4	16	18
C-23 (157)	K-27 Building (Northeast Corner)	Gamma	M	2	M	1	6	8
C-24 (16)	K-901 Pond	Gamma	7	4	M	3	14	19
C-25 (15)	K-1070-A Burial Ground	Gamma	M	4	M	3	14	22
C-27 (79)	ED1 On Pole	Gamma	Absent	7	M	6	26	22
C-28 (58)	K-25 Portal 5	Gamma	M	5	M	4	18	15
C-29 (177)	TSCA West Gate	Gamma	M	3	Absent	1	8	14
C-30 (178)	TSCA North Gate	Gamma	M	2	M	2	8	16
C-40 (72)	ETTP Visitors Overlook	Gamma	4	12	M	10	44	30
C-41 (45)	K-770 Scrap Yard	Gamma	M	2	M	M	4	6
C-42 (47)	Bear Creek Road ~ 2800 Feet From Clinch River	Gamma	13	26	M	23	98	89
C-43 (11)	Grassy Creek Embayment On The Clinch River	Gamma	M	Absent	M	3	12	16
C-44 (21)	White Wing Scrap Yard	Gamma	M	12	M	Absent	48	40
C-50 (179)	Uranium Storage Yard (East)	Gamma	M	5	M	6	22	20
C-51 (180)	Uranium Storage Yard (South)	Gamma	M	17	M	14	62	63
C-52 (181)	Uranium Storage Yard (South)	Gamma	3	16	M	14	60	61
C-53 (182)	Uranium Storage Yard (West)	Gamma	M	13	3	11	48	53

Oak Ridge National Laboratory

D-10 (20)	Freels Bend Entrance	Gamma	M	4	M	2	12	13
D-12 (69)	Graphite Reactor	Gamma	3	10	M	12	44	29
D-13 (167)	South Side Of Central Ave.	Gamma	17	20	M	21	82	94
D-14 (166)	North Side Of Central Ave. Building 3038	Gamma	63	40	59	M	80	58
D-15 (41)	Not Deployed	Gamma	M	2	M	4	12	12
D-16 (30)	X-3513 Impoundment	Gamma	M	8	M	7	30	22
D-17 (28)	White Oak Dam @ Highway 95	Gamma	M	4	M	3	14	8
D-18 (34)	SWSA 6 On Fence @ Highway 95	Gamma	M	6	M	4	20	15
D-19 (75)	Hot spot on Haw Ridge	Gamma	23	46	8	41	174	170
D-20 (25)	Molten Salt Reactor Experiment	Gamma	137	175	75	114	578	695
D-21 (27)	White Oak Creek Weir @ Lagoon Rd	Gamma	24	41	M	37	156	132
D-22 (24)	Building X-7819	Gamma	4	9	M	6	30	26
D-23 (35)	Confluence of White Oak Creek & Melton Branch	Gamma	91	114	12	114	456	471
D-24 (56)	Old Hydrofracture Pond	Gamma	M	17	M	13	60	58
D-26 (23)	SWSA 5 (South 7828)	Gamma	M	2	M	3	10	18
D-27 (46)	Homogeneous Reactor Experiment Site	Gamma	M	5	M	2	14	17
D-28 (22)	High Flux Isotope Reactor	Gamma	M	9	M	8	34	31
D-30 (55)	SWSA 5 TRU Waste Trench	Gamma	12	36	M	36	144	108
D-31 (87)	SWSA 5 Near Storage Tank Area	Gamma	12	29	5	28	114	
		Neutron	M	M	M	M		248
D-32 (168)	New Hydrofracture Facility	Gamma	79	99	99	106	410	414
D-33 (169)	Melton Valley Haul Road Near Creek	Gamma	135	160	179	155	630	670
D-34 (170)	Cask Storage Containment Area	Gamma	1,278	1,372	1299	1,310	5,364	5,961
D-35 (171)	Building 3038 N	Gamma	70	85	61	103	376	642
D-36 (172)	Building 3607 Material Storage Area	Gamma	2,995	3,331	3394	3,170	13,002	14,552
D-37 (173)	TH4 Tank	Gamma	155	121	72	140	522	561

D-38 (174)	Hot Storage Garden (3597)	Gamma	1,007	1,032	1,151	1,141	4,346	4,853
D-39 (175)	Building 3618	Gamma	67	Absent	M	88	312	324
D-40 (84)	Tower Shielding Facility @ Gate (West)	Gamma	M	5	2	78	18	23
D-41 (85)	Tower Shielding Facility (North Side)	Gamma	M	6	M	4	18	13
D-42 (176)	Neutralization Plant	Gamma	727	1,050	2541	3	7,520	4,958
D-50 (68)	White Oak Creek @ Coffer Dam	Gamma	M	2	M	2,710	4	0
D-51 (26)	Cesium Fields	Gamma	3	8	M	M	28	30
D-52 (31)	Cesium Forest Boundary	Gamma	8	18	M	6	66	78
D-53 (31a)	Cesium Forest Boundary (Duplicate)	Gamma	M	19	M	15	64	61
D-54 (32)	Cesium Forest On Tree	Gamma	2,520	2,754	2,899	2,326	10,160	14,764
D-55 (33)	Cesium Forest Satellite Plot	Gamma	92	94	19	76	340	392
D-60 (183)	ORNL Melton Valley Trench 7	Gamma	M	13	M	12	50	53
D-61 (184)	Not Deployed	Gamma	3	M	5	M	0	2
	Not Deployed	Neutron	M	M	M	M		
D-62 (185)	ORAU Pumphouse Road (3rd And 4th Quarter Only)	Gamma	13	14	8	8	44	51
		Neutron	M	M	M	M		
Spallation Neutron Source								
D-70 (53)	Central Exhaust Facility	Gamma***	41	169	38	63	464	178
		Neutron	M	M	M	M		
D-71 (93)	Ring Building Perimeter Fence	Gamma	M	12	M	4	32	24
		Neutron	M	M	M	M		
D-72 (17)	Beam Dump Bldg # 8520	Gamma	M	8		6	28	18
		Neutron	M	M	M	M		
D-73(73)	SNS Water Tower (Overlook) North	Gamma	2	12	M	5	34	22
D-74 (101)	LINAC Beam Tunnel Berm West (#1)	Gamma	M	8	8	6		32
		Neutron	M	M	M	M	28	

D-75 (102)	LINAC Beam Tunnel Berm (#2)	Gamma	M	11	M	7	36	31
		Neutron	M	M	M	M		
D-76 (103)	LINAC Beam Tunnel Berm (#3)	Gamma	M	7	M	6	26	29
		Neutron	M	M	M	M		
D-77 (100)	LINAC Beam Tunnel Berm (#4)	Gamma	9	10	8	8	36	29
		Neutron	M	M	M	M		
D-78 (99)	LINAC Beam Tunnel Berm (#5)	Gamma	M	8		6	28	35
		Neutron	M	M	M	M		
D-79 (98)	LINAC Beam Tunnel Berm (#6)	Gamma	2	11	M	9	40	41
		Neutron	M	M	M	M		
D-30 (97)	LINAC Beam Tunnel Berm East (#7)	Gamma	Absent	9	M	5	28	34
		Neutron	Absent	M	M	M		
D-81 (74)	SNS Cooling Tower South	Gamma	M	5	M	2	14	19
D-82 (52)	Target Bldg West	Gamma	M	13	M	7	40	8
		Neutron	M	M	M	M		
D-83 (51)	Target Bldg South	Gamma	M	4	M	2	12	6
		Neutron	M	M	M	M		
D-84 (12)	Target Bldg East	Gamma	M	8	M	2	20	13
		Neutron	M	M	M	M		
D-85 (104)	SNS Administrative Building	Gamma	5	3	M	2	10	7
		Neutron	M	M	M	M		
Y-12 National Security Complex								
B-10 (71)	Y-12 East Perimeter Air Monitoring Station	Gamma	M	5	M	4	18	14
B-11 (39)	Y-12 @ back side of Walk In Pits	Gamma	M	7	M	4	22	20
B-12 (38)	Y-12 Uranium Oxide Storage Vaults	Gamma	M	5	M	4	18	19

Environmental Management Waste Management Facility

B-23 (90)	Waste Cell Perimeter Fence @ Gate	Gamma	M	5	M	2	14	19
B-24 (92)	Contact Water Ponds Fence @ Gate	Gamma	3	5	M	3	16	24
B-25 (105)	Contact Water Ponds Fence (Northwest Side)	Gamma	11	11	M	10	42	52
B-26 (106)	Contact Water Ponds Fence (Northeast Side)	Gamma	M	11	M	10	42	41
B-29 (109)	Contact Water Ponds Fence (Southeast Side)	Gamma	11	12	M	10	44	40
B-30 (110)	Contact Water Ponds Fence (Southwest Side)	Gamma	2	12	M	9	42	49
B-32 (112)	Contact Water Tanks Fence (Northeast Side)	Gamma	7	7	M	5	24	31
B-33 (113)	Contact Water Tanks Fence (Northwest Side)	Gamma	M	6	M	6	24	23
B-36 (116)	Contact Water Tanks Fence (Southwest Side)	Gamma	M	10	M	9	38	42
B-37 (117)	Contact Water Tanks Fence (Southeast Side)	Gamma	M	10	M	9	38	34
B-38 (118)	Waste Cell Perimeter Fence (Southeast Corner)	Gamma	5	11	M	10	42	37
B-39 (119)	Waste Cell Perimeter Fence (South Side)	Gamma	M	11	M	9	40	38
B-40 (120)	Waste Cell Perimeter Fence (South Side)	Gamma	M	10	M	8	36	45
B-41 (121)	Waste Cell Perimeter Fence (South Side)	Gamma	M	12	M	8	40	48
B-42 (122)	Waste Cell Perimeter Fence (South Side)	Gamma	M	12	M	9	42	46
B-43 (123)	Waste Cell Perimeter Fence (South Side)	Gamma	M	14	M	11	50	51
B-44 (124)	Waste Cell Perimeter Fence (South Side)	Gamma	M	15	M	10	50	56
B-45 (125)	Waste Cell Perimeter Fence (South Side)	Gamma	10	14	M	10	48	47
B-46 (126)	Waste Cell Perimeter Fence (South Side)	Gamma	12	12	1	9	42	45
B-47 (127)	Waste Cell Perimeter Fence (South Side)	Gamma	5	12	19	12	48	55
B-48 (128)	Waste Cell Perimeter Fence (South Side)	Gamma	7	9	25	5	28	26
B-49 (129)	Waste Cell Perimeter Fence (Southwest Corner)	Gamma	3	14	24	10	48	51
B-50 (130)	Waste Cell Perimeter Fence (West Side)	Gamma	M	13	23	9	44	56
B-51 (131)	Waste Cell Perimeter Fence (West Side)	Gamma	M	11	50	10	42	53
B-52 (132)	Waste Cell Perimeter Fence (West Side)	Gamma	2	13	34	9	44	43
B-53 (133)	Waste Cell Perimeter Fence (West Side)	Gamma	M	11	19	10	42	40

B-54 (134)	Waste Cell Perimeter Fence (West Side)	Gamma	M	12	25	10	44	49
B-55 (135)	Waste Cell Perimeter Fence (West Side)	Gamma	10	14	14	10	48	42
B-56 (136)	Waste Cell Perimeter Fence (NW Corner)	Gamma	7	15	16	10	50	49
B-57 (137)	Waste Cell Perimeter Fence (North Side)	Gamma	6	12	M	9	42	45
B-58 (138)	Waste Cell Perimeter Fence (North Side)	Gamma	10	13	M	10	46	53
B-59 (139)	Waste Cell Perimeter Fence (North Side)	Gamma	8	12	M	8	40	48
B-60 (140)	Waste Cell Perimeter Fence (North Side)	Gamma	M	14	M	11	50	47
B-61 (141)	Waste Cell Perimeter Fence (North Side)	Gamma	2	14	M	11	50	46
B-62 (142)	Waste Cell Perimeter Fence (North Side)	Gamma	7	10	M	8	36	35
B-63 (143)	Waste Cell Perimeter Fence (North Side)	Gamma	13	12	M	10	44	52
B-64 (144)	Waste Cell Perimeter Fence (North Side)	Gamma	13	12	M	9	42	48
B-65 (145)	Waste Cell Perimeter Fence (North Side)	Gamma	M	12	2	10	44	45
B-66 (146)	Waste Cell Perimeter Fence (North Side)	Gamma	5	12	M	10	44	41
B-67 (147)	Waste Cell Perimeter Fence (NE Corner)	Gamma	3	12	M	9	42	41
B-68 (148)	Waste Cell Perimeter Fence (East Side)	Gamma	M	9	M	6	30	30
B-69 (149)	Waste Cell Perimeter Fence (East Side)	Gamma	6	11	13	8	38	38
B-70 (150)	Waste Cell Perimeter Fence (East Side)	Gamma	10	11	M	10	42	46
B-71 (151)	Waste Cell Perimeter Fence (East Side)	Gamma	M	10	M	8	36	46
B-72 (152)	Waste Cell Perimeter Fence (East Side)	Gamma	M	9	2	7	32	37
B-73 (153)	Waste Cell Perimeter Fence (East Side)	Gamma	11	12	2	9	42	45
B-74 (154)	Waste Cell Perimeter Fence (East Side)	Gamma	M	12	13	9	42	46

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 NRC limit for a decommissioned facility is 25 mrem/yr.

NEW = Data for the period does not exist for this station is new.

M = Below minimum reportable quantity (1 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.
Values in Red: Values for the 1st and 3rd Quarter Dosimeters have been highlighted in red because of questions as to the accuracy of the data. Control dosimeters for each of these two quarters were excessively high indicating that the package of dosimeters may have been x-rayed during shipping.

Since all data are viewed based on a year-long estimate of exposure, certain adjustments were made to the data to estimate a full year's data for those situations where data was incomplete due to missing dosimeters, less than one-year deployment periods, and instances where certain quarters of data were eliminated due to 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. The high readings of these control dosimeters is likely indicative of the package with dosimeters having been X-rayed most probably on its return to Landauer, Inc. for processing. The first and third quarter data for 2014 were considered to be anomalous (i.e., extremely high control dosimeter readings) and had to be adjusted accordingly (see below) to estimate values for a full year.

The following adjustments to the data were made as needed. In instances where only one to three quarters of data were available either due to missing dosimeters, less than year-long deployment or quarters of anomalous data, the available data was estimated to the full year by multiplying available data by the appropriate factor. In instances where the result for a given dosimeter was returned as "M" (i.e., < 1 mrem) the value for that quarter was assumed to be zero.

Stations off the Oak Ridge Reservation

In 2014, the results for off-site locations ranged from 10 to 74 mrem/year. The highest results reported for off-site locations were for station A-23 (74 mrem), and station A-14 (52 mrem). Station A-14 is located adjacent to the Emory Valley Greenway approximately one hundred feet from the Emory Valley Pump Station and Station A-23 is on the fence surrounding the pump station. It is believed the slightly elevated results (compared to other off-site locations) may be an artifact of the use of sediments from the East Fork Poplar Creek Flood Plain downstream of Y-12 as fill during the construction of portions of the Oak Ridge sewer system (1982, MMES). Table 2 provides the identity of the stations and Figure 1 depicts the results for dosimeter data for the period 2010-2014.

Table 2: Off-Site Dosimeter Stations

Station	Description
A-11	Norris Dam Air Monitoring Station (Background)
A-12	Loudoun Dam Air Monitoring Station (Background)
A-13	Loudoun Dam Air Monitoring Station (Background)
A-14	Emory Valley Greenway
A-15	Elza Gate
A-16	California Ave.
A-17	Cedar Hill Greenway
A-18	Key Springs Road
A-19	East Pawley
A-21	West Vanderbilt
A-22	Scarboro Perimeter Air Monitoring Station
A-23-a	DOE-Oversight Office filing cabinet
A-23	Emory Valley Pump House

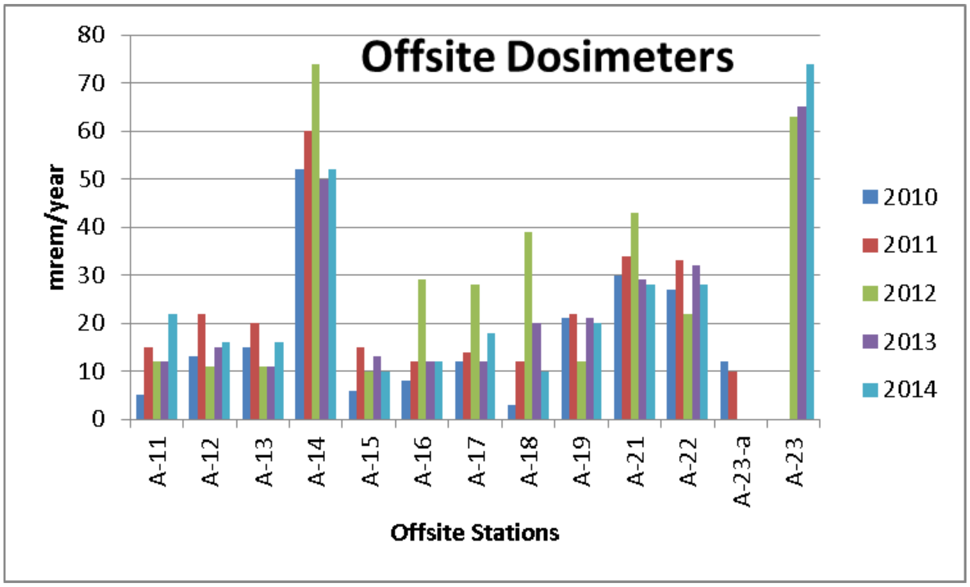

Figure 1: Off-Site Dosimeter Stations

East Tennessee Technology Park (ETTP)

The K-25 Gaseous Diffusion Plant, now known as the East Tennessee Technology Park (Horizon Center), 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 activities at the site 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 shut down in 1987. The focus subsequently turned to remediation of the site and its reindustrialization, with a long-term goal of transitioning ETTP into an industrial park. Under the reindustrialization program, portions of ETTP may be leased or sold to private entities for use or development. During 2014, the results for dosimeters stationed at ETTP ranged from 4 to 98 mrem/year. The highest results were at stations C-40 (44 mrem/year), C-42 (98 mrem/year), C-44 (48 mrem/year), C-51 (62 mrem/year), C-52 (60 mrem/year), and C-53 (48 mrem/year). Station C-42 (highest reading) is located just off of the ETTP reservation on Bear Creek Road across from an active waste handling business. Otherwise the results were similar to background values.

Although the readings might at first seem high, it should be remembered that an individual would have to remain at the given station for 24-hours a day for the entire year to receive the measured dose.

Table 3 provides the identity of the stations and Figure 2 depicts the results for dosimeter data for the period 2010-2014.

Table 3: ETTP Dosimeter Stations

Station	Description	Site	Description
C-10	K-1401 Building (West side)	C-28	K-25 Portal 5
C-12	K-1420 Building	C-29	TSCA West Gate
C-17	K-25 Building	C-30	TSCA North Gate
C-18	K-27 Building (SW Corner)	C-40	ETTP Visitors Overlook
C-19	K-27 Building (South Side)	C-41	K-770 Scrap Yard
C-20	K-27 Building (SE Corner)	C-42	Bear Creek Road ~ 2800 Feet From Clinch River
C-21	K-27 Building (NW Corner)	C-43	Grassy Creek Embayment On The Clinch River
C-22	K-27 Building (North Side)	C-44	White Wing Scrap Yard
C-23	K-27 Building (NE Corner)	C-50	ETTP Uranium Storage Yard (East)
C-24	K-901 Pond	C-51	ETTP Uranium Storage Yard (South)
C-25	K-1070-A Burial Ground	C-52	ETTP Uranium Storage Yard (South)
C-27	ED1 On Pole	C-53	ETTP Uranium Storage Yard (West)

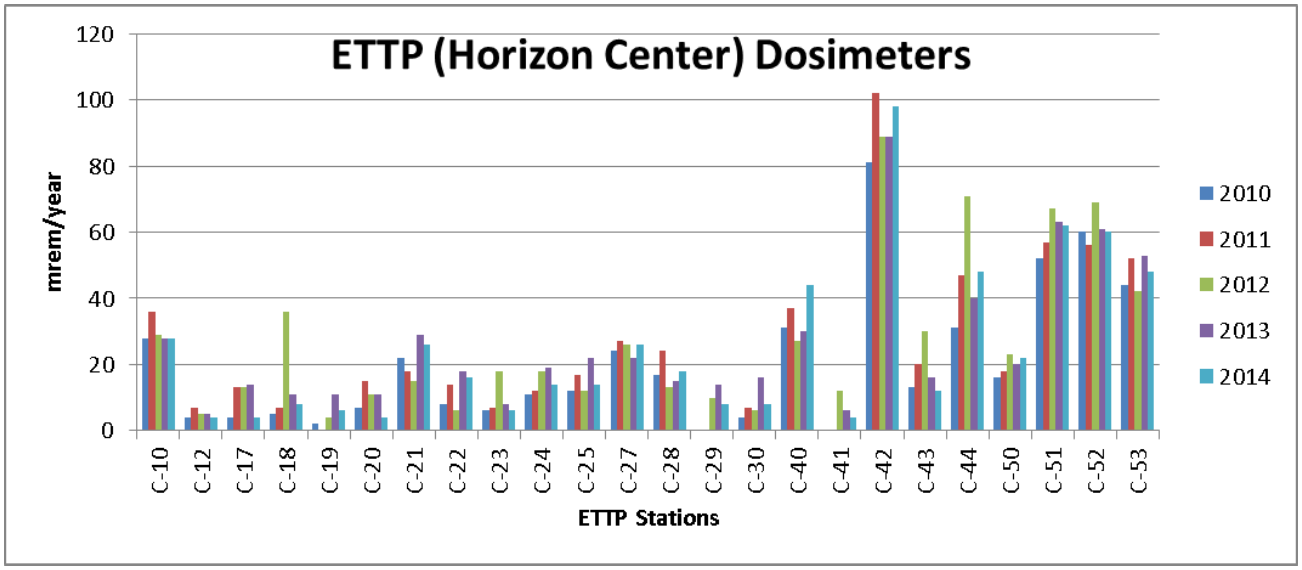

Figure 2: ETTP Dosimeter station readings

The Y-12 National Security Complex (Y-12)

Similar to K-25, the Y-12 Plant was constructed during World War II to produce enriched uranium by the electromagnetic separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, conduct lithium/mercury enrichment operations, manufacture components for nuclear weapons, dismantle nuclear weapons, and store enriched uranium. In addition to this, a number of Y-12 buildings were utilized by ORNL staff for various pursuits including animal studies, research on the Molten Salt Reactor Experiment, production of radioactive isotopes, and the Aircraft Nuclear Propulsion Program. Due to the nature of its mission, the Y-12 plant is the least accessible to members of the public of the three Oak Ridge facilities. There are three locations within the Y-12 complex currently being monitored. These are the Uranium Oxide Storage Vaults, the Walk-In Pits, and the East Perimeter Air Monitoring Station. The results for the Y-12 locations ranged from 18 to 22 mrem/year. These low levels are not unexpected as the majority of the material handled at Y-12 emit primarily alpha and beta (not gamma) radiation.

Table 4 provides the identity of the stations and Figure 3 depicts the results for dosimeter data for the period 2010-2014.

Table 4: Y-12 Dosimeter Stations

Station	Description
B-10	Y-12 East Perimeter Air Monitoring Station
B-11	Y-12 @ back side of Walk In Pits
B-12	Y-12 Uranium Oxide Storage Vaults

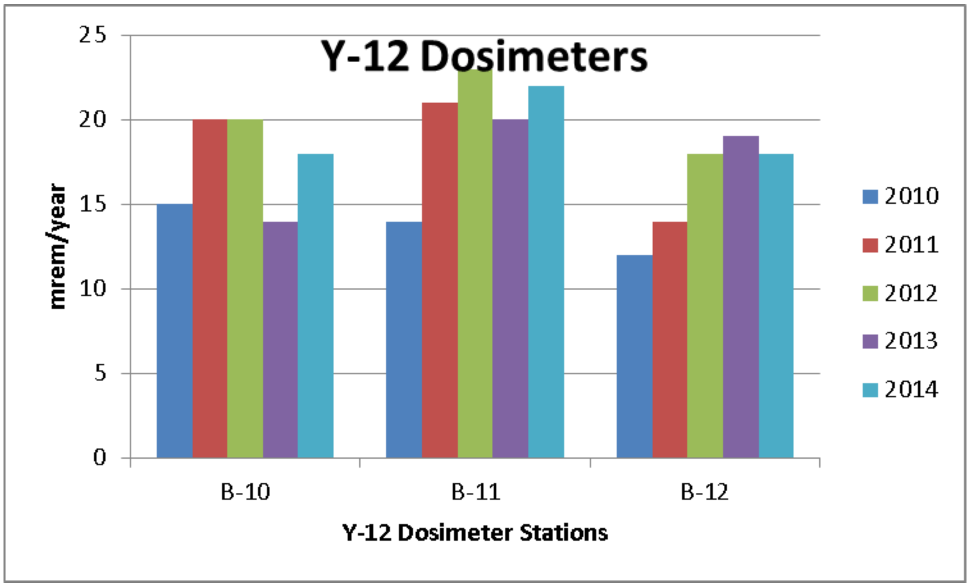

Figure 3: Y-12 Dosimeter stations readings

Environmental Management Waste Management Facility (EMWMF)
Located immediately to the west of the Y-12 complex (in the Bear Creek Valley), the Environmental Management Waste Management Facility was constructed in 2002 to dispose of radioactive and hazardous waste generated by remedial activities from all three plants on the ORR. The facility is operated under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and waste approved for disposal is limited by waste acceptance criteria agreed upon by DOE, the State, and EPA. Monitoring stations have been established at the boundary of the waste disposal cells and at secondary waste management systems (contact water ponds. For the purposes of this report, the dosimeters surrounding the EMWMF waste cells and those surrounding the contact water ponds are discussed separately.

During 2014, the results for the contact water pond dosimeters ranged from 14 to 44 mrem/year. Dosimeters surrounding the EMWMF waste cells ranged from 28to 50 mrem/year.

Table 5 provides the identity of the stations and Figure 4 depicts the results for dosimeter data for the contact water ponds for the period 2010-2014. Table 6 provides the identity of the stations and Figure 5 depicts the results for dosimeter data for the EMWMF waste cell for the period 2010-2014.

Table 5: Contact Water Pond Dosimeters

Station	Description
B-23	Waste Cell Perimeter Fence @ Gate
B-24	Leachate Collection Tanks @ Gate
B-25	Contact Water Ponds Fence (NW Side)
B-26	Contact Water Ponds Fence (NE Side)
B-29	Contact Water Ponds Fence (SE Side)
B-30	Contact Water Ponds Fence (SW Side)
B-32	Contact Water Tanks Fence (NE Side)
B-33	Contact Water Tanks Fence (NW Side)
B-36	Contact Water Tanks Fence (SW Side)
B-37	Contact Water Tanks Fence (SE Side)

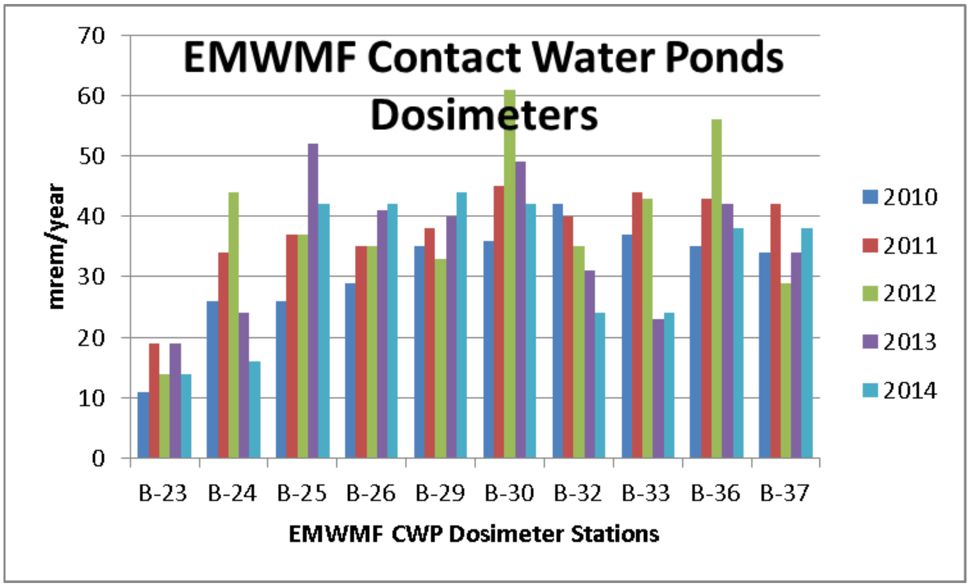

Figure 4: Contact Water Ponds Dosimeter station readings

Table 6: EMWMF Waste Cell Dosimeters

Station	Description	Station	Description
B-38	Waste Cell Perimeter Fence (SE Corner)	B-57	Waste Cell Perimeter Fence (North Side)
B-39	Waste Cell Perimeter Fence (South Side)	B-58	Waste Cell Perimeter Fence (North Side)
B-40	Waste Cell Perimeter Fence (South Side)	B-59	Waste Cell Perimeter Fence (North Side)
B-41	Waste Cell Perimeter Fence (South Side)	B-60	Waste Cell Perimeter Fence (North Side)
B-42	Waste Cell Perimeter Fence (South Side)	B-61	Waste Cell Perimeter Fence (North Side)
B-43	Waste Cell Perimeter Fence (South Side)	B-62	Waste Cell Perimeter Fence (North Side)
B-44	Waste Cell Perimeter Fence (South Side)	B-63	Waste Cell Perimeter Fence (North Side)
B-45	Waste Cell Perimeter Fence (South Side)	B-64	Waste Cell Perimeter Fence (North Side)
B-46	Waste Cell Perimeter Fence (South Side)	B-65	Waste Cell Perimeter Fence (North Side)
B-47	Waste Cell Perimeter Fence (South Side)	B-66	Waste Cell Perimeter Fence (North Side)
B-48	Waste Cell Perimeter Fence (South Side)	B-67	Waste Cell Perimeter Fence (NE Corner)
B-49	Waste Cell Perimeter Fence (SW Corner)	B-68	Waste Cell Perimeter Fence (East side)
B-50	Waste Cell Perimeter Fence (West Side)	B-69	Waste Cell Perimeter Fence (East side)
B-51	Waste Cell Perimeter Fence (West Side)	B-70	Waste Cell Perimeter Fence (East side)
B-52	Waste Cell Perimeter Fence (West Side)	B-71	Waste Cell Perimeter Fence (East side)
B-53	Waste Cell Perimeter Fence (West Side)	B-72	Waste Cell Perimeter Fence (East side)
B-54	Waste Cell Perimeter Fence (West Side)	B-73	Waste Cell Perimeter Fence (East side)
B-55	Waste Cell Perimeter Fence (West Side)	B-74	Waste Cell Perimeter Fence (East side)
B-56	Waste Cell Perimeter Fence (NW Corner)		

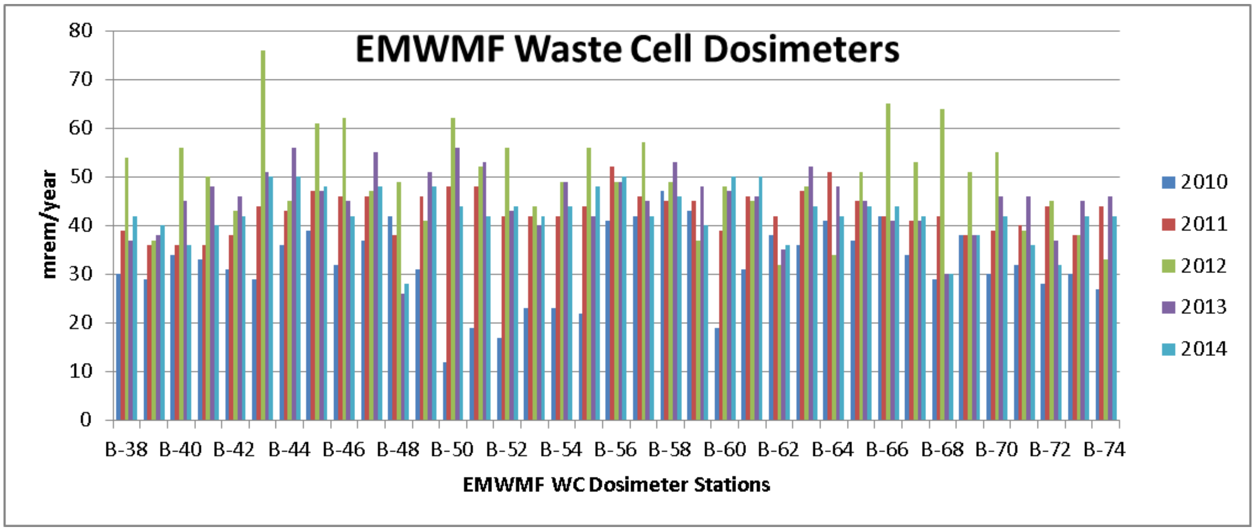

Figure 5: EMWMF Waste Cell Dosimeter station readings

Oak Ridge National Laboratory (ORNL)

Like the K-25 and Y-12 facilities, ORNL was also established during the World War II Manhattan Era. Its war time 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 later other ORNL and Hanford reactors. Over the years, thirteen reactors were constructed and operated at the ORNL site, including the currently active High Flux Isotope Reactor. Since its inception, ORNL has evolved into DOE's largest multi-program national science and energy laboratory. As such, it hosts thousands of visitors a year. In addition, land adjacent to ORNL's main campus has been deeded to organizations outside of DOE; buildings have been constructed using private funds; and facilities are now occupied by non-DOE contractors (ORAU, 2003). Many of the facilities constructed during World War II and the cold war eras that remain are highly contaminated and have fallen into disrepair, complicating remediation. Access to the site is controlled for security purposes, but admittance is allowed with the appropriate visitor's pass and associated training. Within the access controlled areas, certain locations have been designated as radiation areas and access is restricted for safety, including legacy burial grounds and associated facilities.

Due to the nature of some of the radioactive contaminants at ORNL (e.g., high energy gamma emitters), the highest dose rates in the dosimetry program are typically associated with ORNL stations. The dose rates measured at ORNL in 2014 ranged from 4 to 13,002 mrem/year for the year. It should be reiterated that the dose rates reported here reflect the dose that could be received if a hypothetical person remained at the monitoring station for 24 hours a day for the 365 days in a year. Consequently, the results are conservative estimates of the *potential* dose at the monitoring locations, which are used to identify locations that merit further evaluation. The actual dose any individual would receive is dependent on the time spent at the location, which in all cases would be a fraction of that assumed for the dose estimates.

In 2014, seventeen monitoring stations at ORNL had results exceeding 100 mrem over the year. Six of these sites are located on the main campus of ORNL but are away from the most heavily traveled areas of the facility (Table 7 and Figure 6). Nine of these sites are located in the considerably less traveled ORNL Melton Valley Area (Table 8 and Figure 7). Two of these sites are sites are in the Cesium Forest located considerably south of the Melton Valley (Table 9 and Figure 8).

Table 7: ORNL Campus Dosimeter > 100 mrem/year.

Description	Station	mrem/year 2014
Building 3038 N	D-35	376
Building 3607 Material Storage Area	D-36	13002
TH4 Tank	D-37	522
Hot Storage Garden (3597)	D-38	4346
Building 3618	D-39	312
Neutralization Plant	D-42	7520

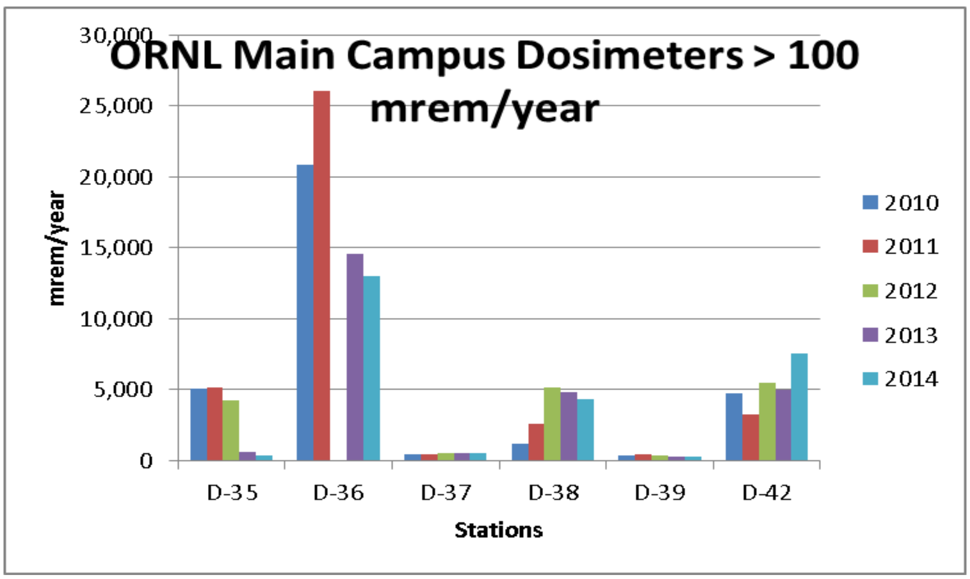

Figure 6: ORNL Main Campus Dosimeters > 100 mrem/year

Table 8: ORNL Melton Valley Dosimeters > 100 mrem/year

Station	Description	mrem/year 2014
D-19	Haw Ridge @ Melton Valley Access Rd.	174
D-20	Molten Salt Reactor Experiment	578
D-21	White Oak Creek Weir @ Lagoon Rd	156
D-23	Confluence of White Oak Ck & Melton Branch	456
D-30	SWSA 5 TRU Waste Trench	144
D-31	SWSA 5 near Storage Tank Area	114
D-32	New Hydrofracture Facility	410
D-33	Melton Valley Haul Road Near Creek	630
D-34	Cask Storage Containment Area	5364

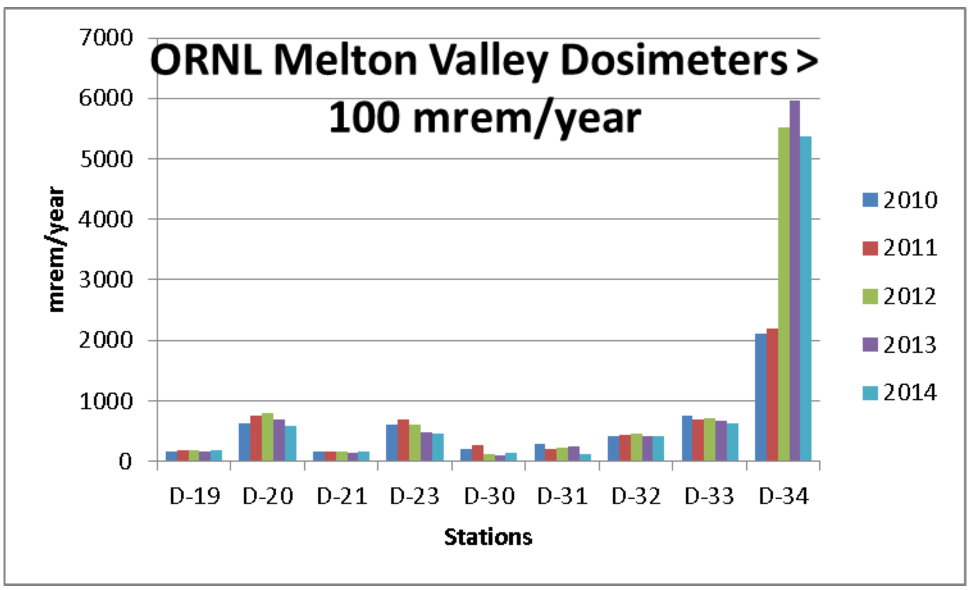

Figure 7: ORNL Melton Valley Dosimeters > 100 mrem/year

Table 9: ORNL Dosimeters > 100 mrem/year south of Melton Valley

Description	Station	mrem/year
Cesium Forest @ Base Of Tree	D-54	10160
Cesium Forest Satellite Plot	D-55	340

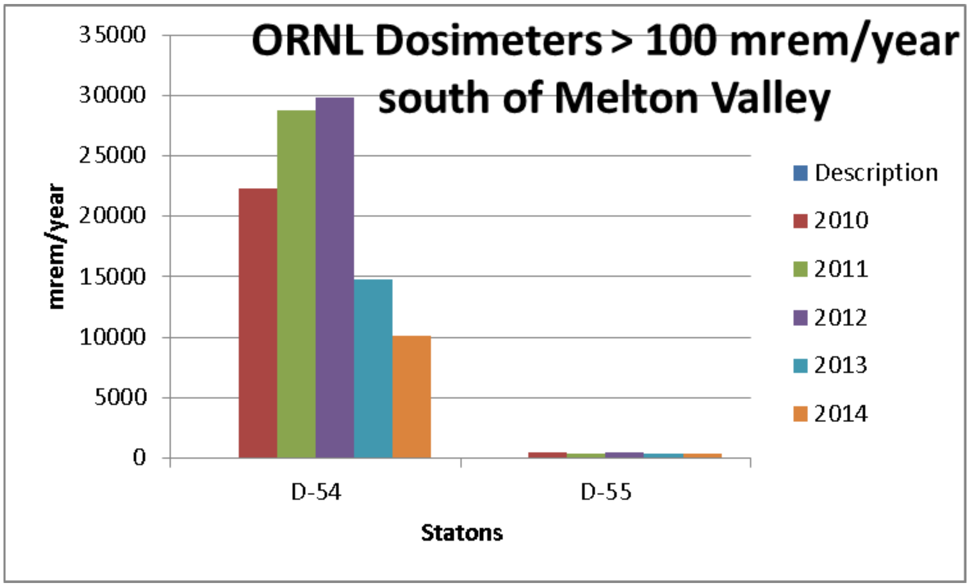

Figure 8: ORNL Dosimeters > 100 mrem/year south of Melton Valley

Unlike previous years, the highest dose reported in the program for 2014 (13,002 mrem) was at station D-36 (station 172 in last year's report), which is located on the main ORNL campus at the building 3607 Materials Storage Area. In last year's report, Station D-54 (station 32 in last year's report) a dosimeter located at the base of a tree in the Cesium Forest had the highest annual reading. In 1962, a group of trees at this location 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). The Cesium Forest is located in a remote, gated area of the Reservation and is posted as a radiation area. The dosimeter, which is placed on or very near the trunk of the tree, is exchanged remotely with the assistance of ORNL personnel. It should be noted that variability in the results noted in Table 1 is primarily due to the inexact nature of the remote apparatus (the dosimeter) being placed near the tree. Problems with first and third quarter results for the dosimeters in 2014, as well as the fact that the dosimeter had been moved away from the tree perhaps by winds in the fourth quarter, may have led to the lower value for the year.

There were two stations reading greater than 100 mrem/year in 2013, which were below 100 mrem/year in 2014. These include station D-14, North side of Central Avenue (station 166 in the 2013 report), and station D-52, Cesium Forest Boundary (station 31 in the 2013 report). Part of the reason for these stations falling below the 100 mrem/year level may have been the problems with the dosimeter data for the first and third quarters of 2014 which necessitated projecting values for the year using only second and fourth quarter data.

Overall, the dose rates at the above locations decreased in 2014 when compared to 2013 results. Most of these locations are associated with legacy facilities that are either undergoing or are scheduled for remediation. As the clean-up continues, the dose rates measured are expected to be further reduced.

Dosimeter data for stations at ORNL (except stations at SNS which are treated separately) with lower than 100 mrem/year in 2014 are presented in Table 10 and Figure 9. During 2010 to 2012 Station D-14 (North Side of Central Ave) had annual values greater than 100 mrem/year. Although below 100 mrem/year during 2014, care should be taken in this interpretation since problems with 1st and 3rd quarter data necessitated annual estimation based on two quarters of data.

Table 10: Stations at ORNL (except SNS) with Dosimeter annual readings less than 100 mrem/year

Station	Description	Station	Description
D-10	Freels Bend Entrance	D-27	Homogeneous Reactor Experiment Site
D-12	Graphite Reactor	D-28	High Flux Isotope Reactor
D-13	South Side Of Central Ave.	D-40	Tower Shielding Facility @ West Gate
D-14	North Side Of Central Ave.	D-41	Tower Shielding Facility @ North Gate
D-16	Southside Ave. Parking Lot (Old X-3513 Impoundment)	D-50	White Oak Creek @ Coffer Dam
D-17	White Oak Dam @ Highway 95	D-51	Cesium Fields @ Clinch River
D-18	SWSA 6 On Fence @ Highway 95	D-52	Cesium Forest Boundary
D-22	Building X-7819	D-53	Cesium Forest Boundary (Duplicate)
D-24	Old Hydrofracture Pond	D-60	ORNL Melton Valley Trench 7
D-26	SWSA 5 (South 7828)	D-62	ORAU Pumphouse Road

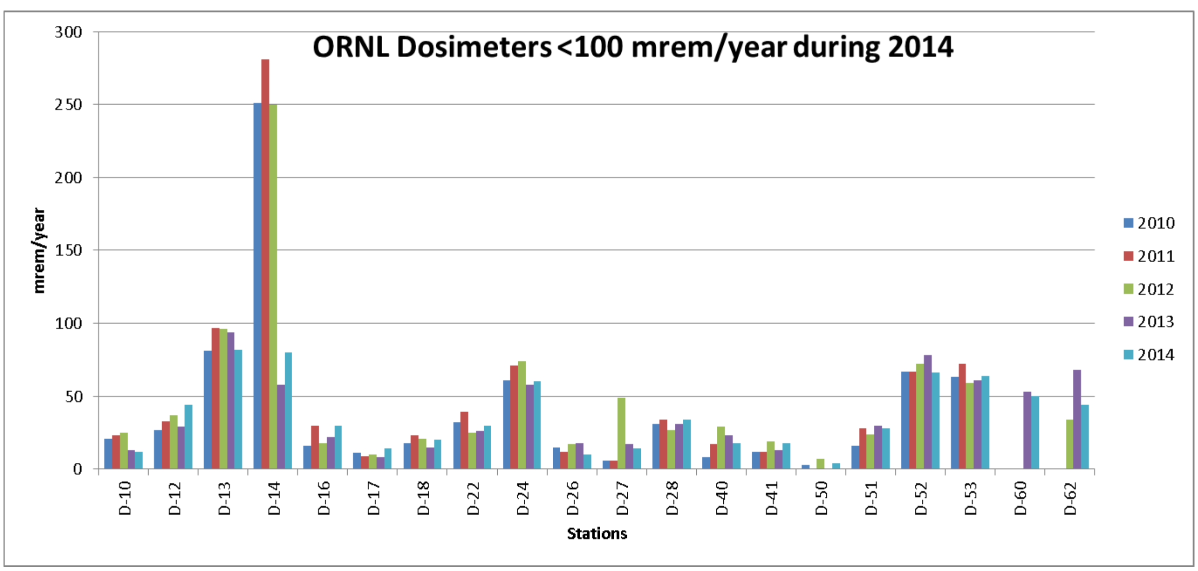

Figure 9: Stations at ORNL (excepting SNS) with Dosimeter annual readings less than 100 mrem/year

While all the locations exceeding 100 mrem warrant continued monitoring, special attention needs to be given to the materials storage area at Building 3607, south of the irradiated fuels building (Building 3525), which had an annual dose of 13,002 mrem. Vehicles often park next to the monitoring station, which is located at the radiation boundary of the storage area.

Spallation Neutron Source (SNS)

Located near the ORNL main campus, the SNS is a one-of-a-kind research facility that produces the most intense pulsed-neutron beam in the world. During the process, electrons are removed from hydrogen ions in a linear particle accelerator (linac) which converts the ions into protons. The protons are passed into an accumulator ring, which releases them as high-energy pulses directed toward a liquid mercury target. When the protons strike the nucleus of the mercury atoms, neutrons are "spalled" or thrown off, along with other spallation products. Radiation is generated throughout the process, as protons interact with the nuclei of other atoms, converting the struck nuclei into different isotopes, which are often radioactive. DOE Oversight staff have located dosimeters outside the linac, accumulator ring, target building, central exhaust stack, and other locations of interest. During 2014, the results ranged from 10 to 464 mrem/year. The only result to exceed 100 mrem in 2014 was for a dosimeter located on the central exhaust stack (464 mrem/year). It might be noted here that this was more than twice the reading obtained in 2013 (178 mrem/year). Of interest in this regard is that during the second and third quarters of calendar year 2014 the SNS beamline was run at record power levels until it was necessary to shut it down to replace a failed target. Future plans are to run the beamline at more moderate power levels in order to avoid premature failure of targets.

Conclusion

Overall, the radiation doses measured in the Environmental Dosimetry Program in 2014 decreased or remained statistically the same as in 2013. A total of eighteen locations exceeded the 100 mrem screening level over the year: seventeen at ORNL and one at SNS. The majority of these sites were associated with legacy facilities undergoing or scheduled for remediation, which is expected to significantly lower the measured doses as the clean-up progresses.

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Real Time Monitoring of Gamma Radiation on the Oak Ridge Reservation

Principal Author: Gary Riner

Abstract

In 2014, the Tennessee Department of Environment and Conservation placed gamma radiation exposure rate monitors at five locations on the Department of Energy's Oak Ridge Reservation. These units measure and record gamma radiation levels at predetermined intervals over extended time periods, providing an exposure rate profile that can be correlated with activities and/or changing conditions. Monitoring with the units focuses on the measurement of exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods and/or where there is a potential for an unplanned release of gamma emitting radionuclides to the environment. In 2014, five locations were monitored in the program: the Oak Ridge National Laboratory (ORNL) Central Campus Remediation; the exhaust stack at the Spallation Neutron Source Facility; the Molten Salt Reactor at the ORNL; the Environmental Management Waste Management Facility; and a background station located at Fort Loudoun Dam in Loudon County. All results were below limits specified by state and Nuclear Regulatory Commission regulations, which require their licensees to conduct operations in such a manner that the external dose in any unrestricted area does not exceed 2.0 millirem (2,000 μrem) in any one-hour period.

Introduction

The Department of Energy (DOE) Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation has deployed gamma radiation exposure rate monitors equipped with microprocessor-controlled data loggers on the Oak Ridge Reservation (ORR) since 1996. While the environmental dosimeters used in the office's ambient radiation monitoring program provide the cumulative dose over the time period monitored, the results cannot account for the specific time, duration, and magnitude of fluctuations in the dose rates. Consequently, when using dosimeters alone, a series of small releases cannot be distinguished from a single large release. The exposure rate monitors measure and record gamma radiation levels at predetermined intervals (e.g., minutes) over extended periods of time, providing an exposure rate profile that can be correlated with activities and/or changing conditions. The instruments have primarily been used to record exposure rates during remedial and waste management activities to supplement the integrated dose rates provided by the office's environmental dosimetry program.

Methods and Materials

The exposure rate monitors deployed in the 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 1 μrem/hour to 1 rem/hour at predetermined intervals (one minute to two hours). The results reported are the average of the measurements recorded by the two Geiger Mueller detectors, but data from either detector can be accessed if needed. Information recorded by the data loggers is downloaded to a computer using an infrared transceiver and associated software.

Monitoring in the program focuses on the measurement of exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods and/or there is a potential for an unplanned release of gamma-emitting radionuclides to the environment. Candidate monitoring locations include remedial activities, waste disposal operations, pre and post operational investigations, and emergency response activities. Results recorded by the monitors are evaluated by comparing the data to background measurements and state radiological standards. In 2014, the exposure rate monitors were used to monitor gamma emissions at the five locations listed below and depicted in Figure 1.

- Fort Loudoun Dam (background location)
- Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley southwest of the Y-12 National Security Complex
- Oak Ridge National Laboratory (ORNL) Central Campus Remediation (Radioisotope Development Lab Removal Action)
- ORNL Molten Salt Reactor Experiment (MSRE)
- Spallation Neutron Source (SNS) exhaust stack

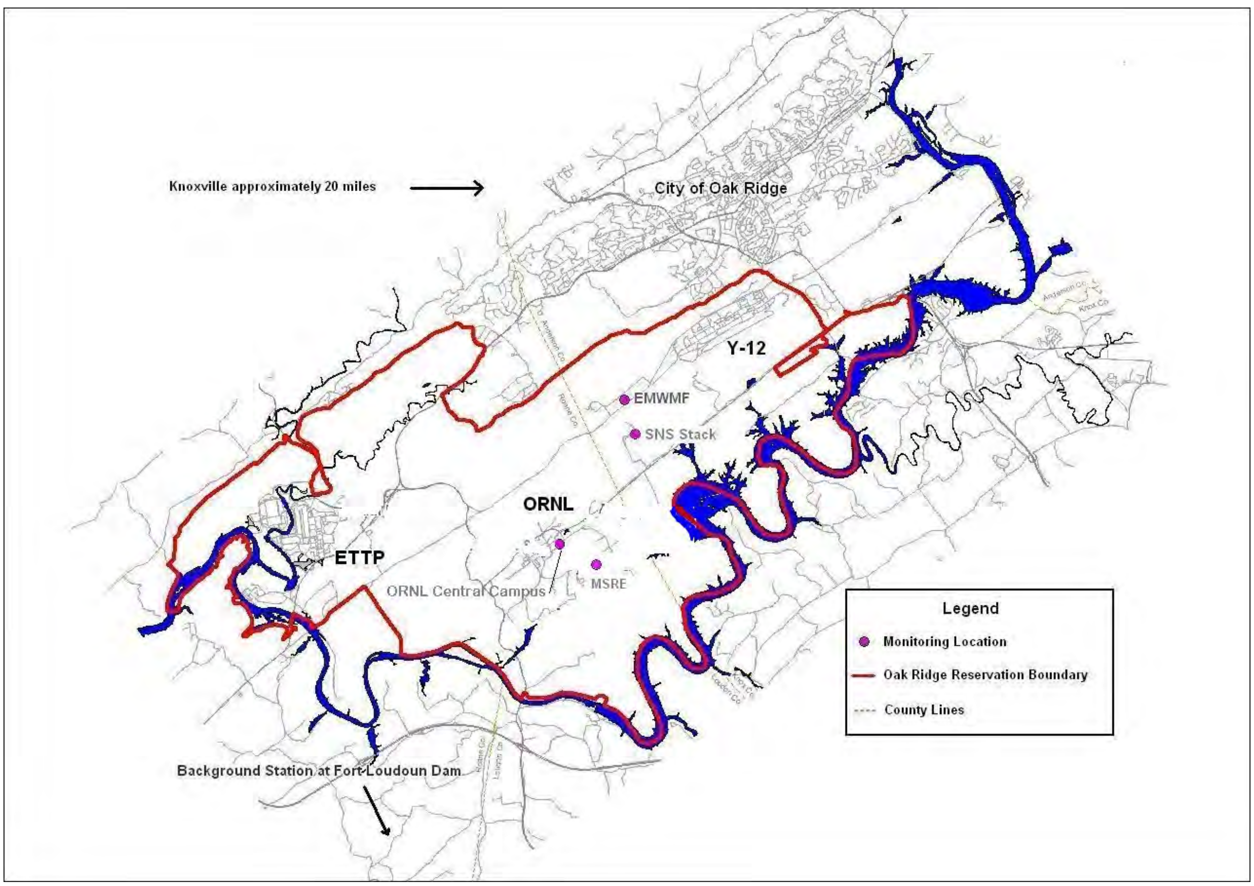


Figure 1: Gamma exposure rate monitoring locations in 2014

Results and Discussion

The amount of radiation an individual can be exposed to is restricted by state and federal regulations. The primary dose limit for members of the public specified by these regulations is a total effective dose equivalent of 100 mrem in a year. Since there are no agreed upon levels where exposures to radiation constitute zero risk, radiological facilities are also required to maintain exposures as low as reasonably achievable (ALARA). Table 1 provides some of the more commonly encountered dose limits.

Table 1: Commonly encountered dose limits for exposures to radiation

Dose Limit	Application
5,000 mrem/year	Maximum annual dose for radiation workers
100 mrem/year	Maximum dose to a member of the general public
25 mrem/year	Limit required by state regulations for free release of facilities that have been decommissioned
2 mrem in any one hour period	The state limit for the maximum dose in an unrestricted area in any one hour period

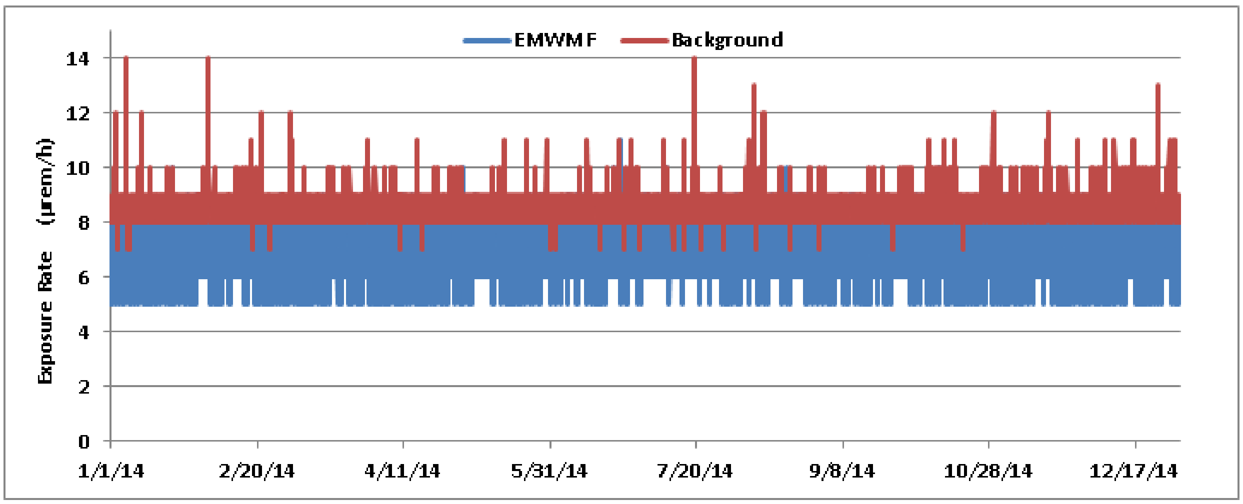
The unit used to express the limits (rem) refers to the dose of radiation an individual receives (the amount of radiation absorbed by the individual). For alpha and neutron radiation, the measured quantity of exposure, roentgen (R), is multiplied by a quality factor to derive the dose. For gamma radiation, the roentgen and the rem are generally considered equivalent. The more familiar unit, rem, is used in this report to avoid confusion. It is important to note that the monitors used in this program only account for the doses attributable to external exposures from *gamma* radiation. Any dose contribution from alpha, beta, or neutron radiation would be in addition to the measurements reported.

Fort Loudoun Dam Background Station

On average, individuals in the United States receive a dose of approximately 300 mrem in a year from naturally occurring radiation. Most of this dose is from internal exposures received as a result of breathing radon and associated daughter radionuclides. Background exposure rates fluctuate over time due to various phenomena that alter the quantity of radionuclides in the environment and/or the intensity of radiation being emitted by these radionuclides. For example, the gamma exposure rate above soils saturated with water after a rain are expected to be lower than the rate over dry soils because the moisture shields radiation released by terrestrial radionuclides. To better assess exposure rates measured on the reservation and the influence that natural conditions have on these rates, office staff maintain one of the office's gamma monitors at Fort Loudoun Dam in Loudon County to collect background information. The background results are provided on Figures 2 through 5. During the 2014 calendar year, exposure rates averaged 8.6 µrem/hour and ranged from 7 to 14 µrem/hour, which is equivalent to a dose of approximately 76 mrem/year.

The Environmental Management Waste Management Facility (EMWMF)

The EMWMF was constructed in Bear Creek Valley (near the Y-12 Plant) to dispose of wastes generated by CERCLA activities on the ORR. The EMWMF relies on a waste profile provided by the generator to characterize waste disposed of in the facility. This profile is based on an average of the contaminants in a waste lot. Since the size of waste lots can vary from a single package to many truckloads of waste, the averages reported are not necessarily representative of each load of waste transported to the facility. That is, some loads may have highly contaminated wastes, while other loads may contain very little contamination. Historically, the exposure rate monitors were used to identify waste potentially exceeding waste acceptance criteria as it was transported into the disposal cells, which was subject to audit. In 2011, the office replaced the unit with a radiation portal monitor (RPM). One of the exposure-rate monitors was returned to the site and placed alongside the RPM to assess the performance of each and confirm associated results. Measurements taken averaged 6.8 μrem/hour and ranged from 5 to 11 μrem/hour, which was very similar to the background measurements collected during the period (Figure 2).



The state dose limit in an unrestricted area is 2 mrem (2,000 μrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 μrem) in a year.

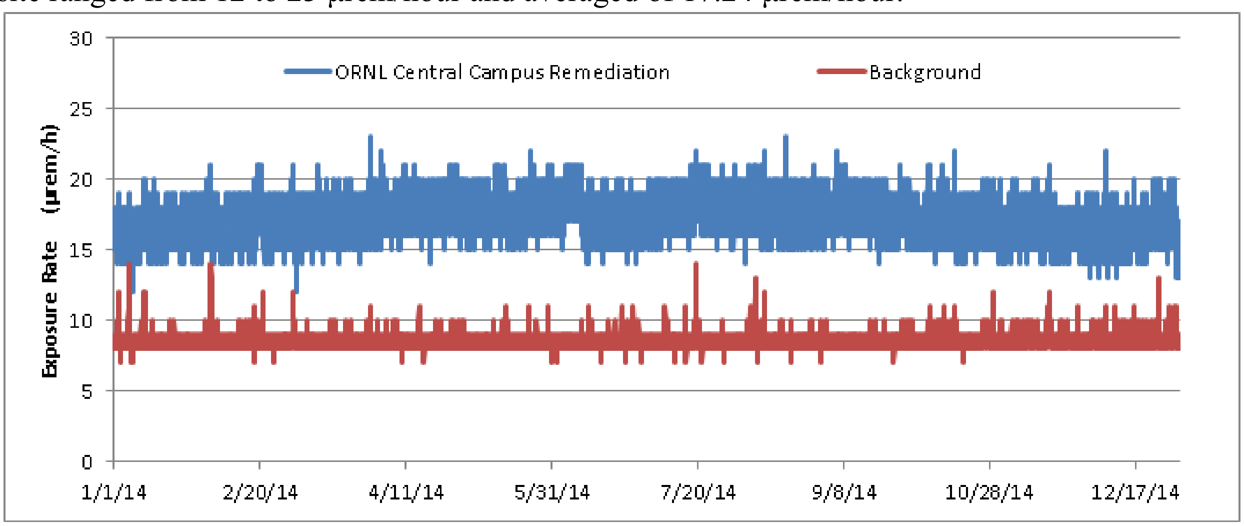
Figure 2: 2014 Results of gamma exposure-rate monitoring at the weigh-in station for the Environmental Management Waste Management Facility and at the background station

ORNL Central Campus Remediation/Building 3026 Radioisotope Development Lab

Monitoring of the ORNL Central Campus Remediation began 09/01/2011 and continued through 2014. Concerns include potential releases during the demolition of high risk facilities centrally located on ORNL's main campus in close proximity to pedestrian and vehicular traffic, privately funded facilities, and active ORNL facilities. Many of these facilities were constructed during the Manhattan Era to produce radioisotopes in support of the development of the first nuclear weapons and later for medical research and commercial applications. Among these facilities is the Radioisotope Development Laboratory, a wooden structure comprised of the 3026-C and 3026-D facilities, which are being addressed as a CERCLA time critical removal action.

The 3026 facilities were constructed in the 1940s to house operations for the separation of barium-140 from uranium fuel slugs irradiated in ORNL's Graphite Reactor and, later in the Hanford reactors. Over the years, the facilities were modified for various uses, including the separation of radioisotopes from liquid wastes generated by the processing of irradiated fuel elements for uranium and plutonium in the 3019 Radiochemical Chemical Development Lab. In the 1960s, 3026-C was equipped to enrich Krypton-85 by thermal diffusion and, in the 1970s, a tritium lab was added to package, store, and test radio-luminescent lights. 3026-D was modified in the 1960s to support processing of fuel from the Sodium Reactor Experiment and examine irradiated metallurgical reactor components. Both facilities were shut down in the late 1980s. In the interim, the wood frame structures experienced significant physical deterioration, to the point of failure. As a consequence of the hazards presented by radioactive contamination present in the facilities, the condition of the structures, and their location, a time-critical removal action was initiated in 2009 to include demolition of the 3026 wooden frame structure and stabilization of the hot cells contained in each of the two facilities. The 3026 wooden superstructure was demolished in 2010 and demolition of the 3026-C hot cells was completed in 2012. The 3026-D hot cell demolition was completed in 2013, although higher than expected radiation levels hindered the project. Due to the nature of historical operations in the facilities, potential contaminants include a long list of radionuclides including cesium-137, strontium-90, carbon-14, nickel-59 & 63, iron-55 & 59, krypton-85, promethium-147, silver-110m, tritium, technetium-99, zinc-65, americium-241, and neptunium-239, along with isotopes of europium (153, 154, & 155), plutonium (239, 240, & 241), and uranium (233, 234, 235, 236, & 238).

One of the office's exposure-rate monitors was at placed at the 3026 demolition site on 01/11/2012 (prior to the demolition of the 3026-C hot cell) and has remained at the site through 2014. In 2012, the levels of gamma radiation measured ranged from 12 to 88 µrem/hour and averaged of 24.7 µrem/hour. As the removal action turned to the more contaminated 3026-D hot cells in 2013, the exposure rates increased substantially then declined near the end of the year as the waste was removed for disposal (Figure 3). During 2014, gamma radiation measured at the site ranged from 12 to 23 µrem/hour and averaged of 17.24 µrem/hour.



The state dose limit in an unrestricted area is 2 mrem (2,000 µrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 µrem) in a year.

Figure 3: 2014 Results of gamma exposure rate monitoring at the ORNL Central Campus Removal Action and at the background station

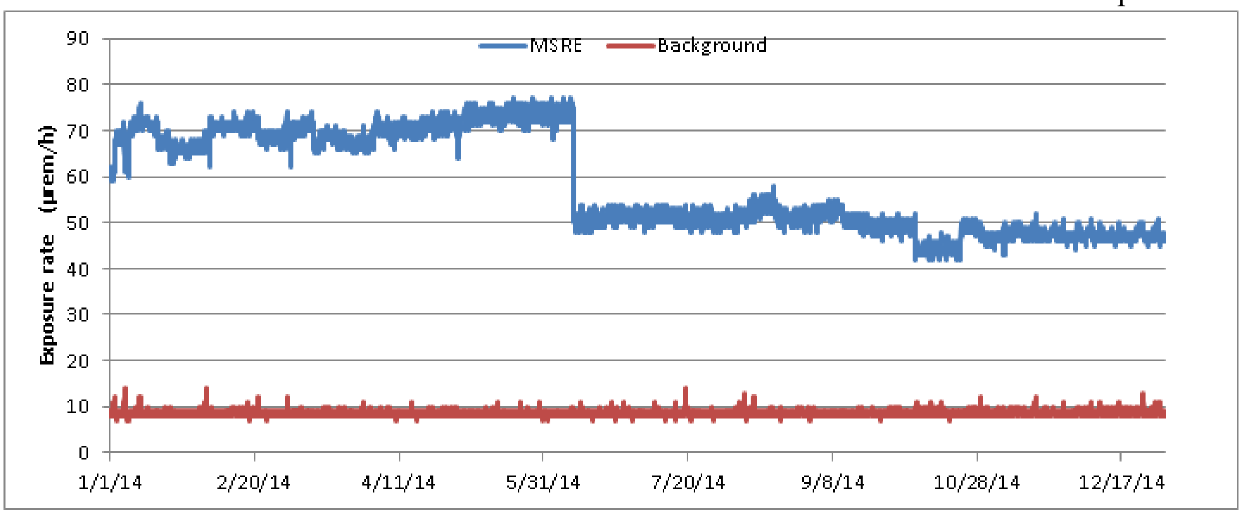
Molten Salt Reactor Experiment (MSRE)

The concept of a molten salt reactor was first explored at ORNL in association with a 1950s campaign to design a nuclear powered airplane. After interest in an atomic airplane subsided, the

MSRE was constructed to evaluate the feasibility of applying the technology to commercial power applications. The concept called for circulating uranium fluoride (the fuel) dissolved in a molten salt mixture through the reactor vessel. The MSRE achieved criticality (a chain reaction resulting in a release of radiation) in 1965 and was used for research until 1969.

When the reactor was put into shutdown mode, the molten fuel salts and flush salts were transferred to drain tanks and allowed to solidify. In 1994, an investigation of the MSRE revealed elevated levels of uranium hexafluoride and fluorine gases throughout the off-gas piping connected to the drain tanks. Among other problems, uranium had migrated through the system to the auxiliary charcoal bed, creating criticality concerns. Actions were taken subsequently taken to stabilize the facility and a CERCLA Record of Decision was issued in July 1998, requiring the removal, treatment, and safe disposition of the fuel and the flushing of salts from the drain tanks.

From 11/01/2012 through the end of 2014, the office has recorded gamma exposure rates with a gamma monitor that was placed near the gate where trucks containing radioactive materials (e.g., fuel removed from the drain tanks) exit the MSRE. The location is also near a radiation area that is used to store equipment used in the remediation. During the 2014 monitoring period, the average exposure rate measured ranged from was 42 to 77 μrem/hour and averaged 58.5 μrem/hour (Figure 4). The major source of the radiation measured appears to be a salt probe stored in the radiation area adjacent to the monitoring station. The drop in rate, observed in early June is believed to be due the removal of some radioactive material stored near the salt probe.



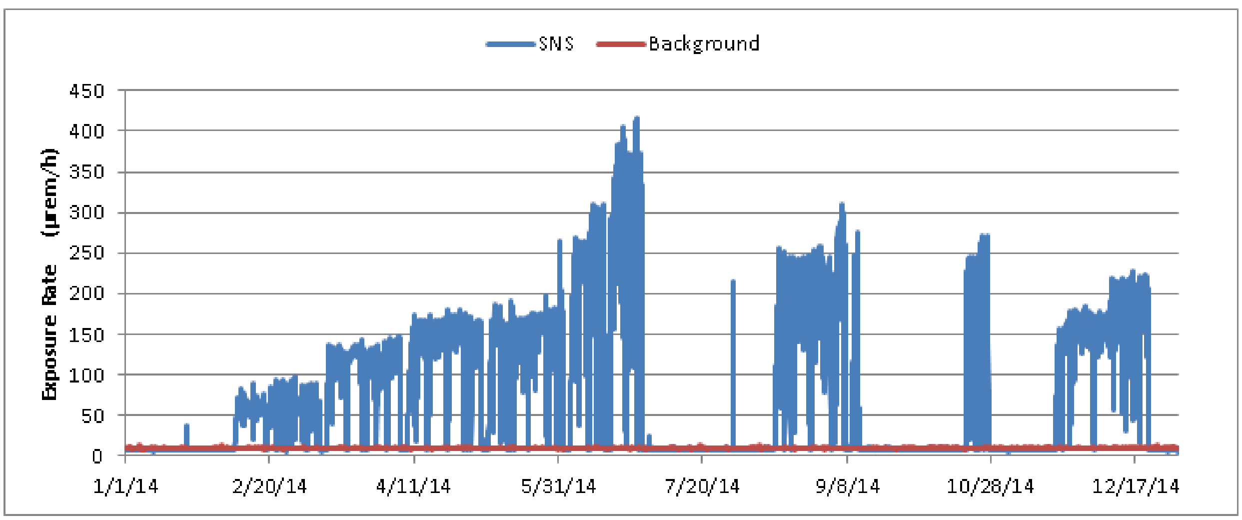
The state dose limit in an unrestricted area is 2 mrem (2,000 μrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 μrem) in a year.

Figure 4: 2014 Results of gamma exposure rate monitoring at the ORNL MSRE and at the background station

Spallation Neutron Source (SNS)

The SNS is a one of a kind research facility that produces the most intense pulsed-neutron beams in the world. The facility was designed and built in partnership with six DOE national laboratories, including Lawrence Berkeley in California, Los Alamos in New Mexico, Argonne in Illinois, Brookhaven in New York, Thomas Jefferson in Virginia, and ORNL in Tennessee. In the most of basic terms, the 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 very high energies and passed through a magnetic foil that strips off the electrons, converting the ions into 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, and released to the atmosphere through the central exhaust stack.

To assess the gamma component of air releases from the SNS, one of the office's exposure rate monitors has been located on the central exhaust stack used to vent air from process areas inside the linac and target building. As might be expected, the exposure rates vary with the operational status of the accelerator. During periods when the accelerator is not on line, the rate is similar to background measurements, with much higher levels recorded during operational periods. The exposure rates measured in 2014 ranged from 5 to 417 μrem/hour and averaged 148.45 μrem/hour (Figure 5).



The state dose limit in an unrestricted area is 2 mrem (2,000 μrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 μrem) in a year.

Figure 5: 2014 Results of gamma exposure rate monitoring at the SNS stack and at the background station

Conclusion

The use of gamma radiation exposure rate monitors equipped with microprocessor controlled data loggers has proven to be a flexible and reliable method for monitoring gamma radiation on the reservation. Based on the data collected in 2014, the following conclusions were reached.

- Environmental Management Waste Management Facility gamma levels were consistent with background measurements.

- ORNL Central Campus D&D (3000 Area) gamma levels were within anticipated levels.
- Measurements taken at the MSRE were not indicative of any releases during the period. Exposure levels measured during the year have been attributed to a contaminated salt probe stored near the monitor.
- Gamma levels at SNS were within expected levels and consistent with measurement collected in previous years.

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Surplus Material Verification

Principle Author: John Wojtowicz

Abstract

The Department of Energy (DOE) offers a wide range of surplus items for auction/sale to the general public on the Oak Ridge Reservation (ORR). The Tennessee Department of Environment and Conservation, Department of Energy Oversight Office's Monitoring and Oversight Program conducted independent radiological monitoring of these surplus materials prior to each auction/sale. During 2014, a total of six inspection visits were conducted at the ORR facilities. Two visits were made for ORNL sales and four visits were made for Y-12 sales. No sales were conducted at the East Tennessee Technology Park (ETTP) facility. Only one item of potential concern was found at the Y-12 auction.

Introduction

The Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (the office; DOE-O), in cooperation with the U.S. Department of Energy (DOE) and its contractors, conducts radiological surveys of surplus materials that are destined for sale to the public on the 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 public auction/sale. The office, as part of its larger radiological monitoring role on the reservation, conducts these surveys to help ensure that no potentially contaminated materials reach the public. In the event that elevated radiological activity is detected (greater than twice background), a quality control check is made with a second meter (if possible). If both meters show elevated activity, the office immediately reports the finding to the responsible supervisory personnel of the surplus sales program. Later, readings are converted to dpm/100 cm2 (dpm = disintegrations per minute) and included in a report for the survey. TDEC-DOE Oversight then follows the response of the sales organizations to see that appropriate steps (removal of items from sale, resurveys, etc.) are taken to protect the public.

Methods and Materials

Staff members make biased surveys of items using standard radiological monitoring meters; sodium iodide for gamma radiations and Zinc Sulfide scintillator (alpha)/plastic scintillator (beta)/dual-detection, or equivalent meters. The alpha/beta scintillator dual-detection meters have been found to be the most likely to find increased activity (i.e., most increased activity found is either alpha or beta). Inspections are scheduled just prior to sales after the material has been staged. Items range from furniture and equipment (shop, laboratory and computer) to vehicles and construction materials. Particular attention is paid to items originating from shops and laboratories. Where radiological release tags are attached, radiation clearance information is compared to procedural requirements. If any contamination is detected during the on-site survey, the surplus materials manager is notified immediately.

Staff also reviewed DOE Policy 458.1 to evaluate whether DOE's surplus sales procedures meet the intent of the Policy. According to DOE Policy 458.1, the following requirements must be met in releasing materials to the public:

Public Notification of Clearance of Property.

(a) Field Element Managers must, as appropriate, incorporate information on site clearance policies and protocols, process knowledge decisions, approved Authorized Limits, any approved revised Authorized Limits, use of pre-approved Authorized Limits, and property control and clearance programs into effective site public notification and communications programs.

(b) Information on approved Authorized Limits, any approved revised Authorized Limits, use of pre-approved Authorized Limits, results of radiological monitoring and surveys of cleared property with type and quantity of property cleared, and independent verification results must be summarized in the Annual Site Environmental Report.

(c) The responsible field element must make documentation on clearance of property available to the public and to the property owner or recipient as appropriate.

Staff will be tracking whether these requirements of DOE Policy 458.1 are being implemented in Oak Ridge.

Results and Discussion

A total of six inspections were conducted during 2014, two at ORNL and four at Y-12. No sales were held at ETTP. Elevated levels of alpha and beta radiological contamination requiring further evaluation were discovered on one item at Y-12 during the DOE-O surveys.

Items of concern are reevaluated ORNL/Y-12 to ensure that they meet the appropriate Y-12 or ORNL release criteria for release of items to the public. The elevated levels of activity are often determined to be due to an accumulation of radon.

Initial inspection of DOE's following of DOE Policy 458.1, showed a first-time coverage of the basic clearance procedures in the Annual Site Environmental Report (ASER) for 2013. Further study needs to be conducted on the existence of "effective site public notification and communications programs" and the making of documentation on clearance of property available to the public and to the property owner or recipient as appropriate.

Conclusion

During 2014, hundreds of surplus materials items were sold through ORNL and Y-12 surplus sales organizations in separate sales events. And while DOE does a good job of preventing radiological contamination from reaching the public, minor radiological contamination may occasionally be found to be associated with sales items.

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Monitoring of Waste at the Environmental Management Waste Management Facility (EMWMF) using a Radiation Portal Monitor

Principal Author: Gary Riner, Howard Crabtree

Abstract

The Environmental Management Waste Management Facility (EMWMF) was constructed for the disposal of low level radioactive waste and hazardous waste generated by remedial activities on the Department of Energy's (DOE) Oak Ridge Reservation. The facility is operated under the authority of CERCLA and is required to comply with regulations contained in the Record of Decision authorizing the facility. Only radioactive waste with concentrations below limits imposed by waste acceptance criteria (WAC) agreed to by Federal Facilities Agreement (FFA) parties are authorized for disposal in the facility. To help ensure compliance with the WAC, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation has placed a radiation portal monitor (RPM) at the check-in station for trucks transporting waste into the facility. As the waste passes through the portal, radiation levels are measured and monitored by DOE Oversight staff. When anomalies are noted, DOE and EMWMF personnel are notified and basic information on the nature and source of the waste passing through the portal at the time of the anomaly is reviewed. If the preliminary review fails to identify a cause for the anomalous results, associated information is provided to DOE Oversight's Audit Team for review and disposition. In 2014, the only anomalies observed in the results were due to a nuclear density gauge which contains sealed cesium-137 and americium-241 sources. The density gauge is not a waste, but a tool transported into the EMWMF disposal cells as needed and is otherwise stored outside the facility.

Introduction

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). Only low level radioactive waste, as defined in TDEC 0400-02-11.03(21), with concentrations below limits imposed by Waste Acceptance Criteria (WAC), and agreed to by FFA parties, 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 it supervises. This includes waste characterization and approval for disposal in the EMWMF (DOE, 2001). The state and EPA oversee and audit associated activities, including decisions authorizing waste lots for disposal.

To help ensure compliance with the WAC, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation (DOE-Oversight) placed a Radiation Portal Monitor (RPM) at the check-in station for trucks transporting waste into the EMWMF for disposal. As the trucks pass through the portal, gamma radiation levels are measured and transmitted to a secure website monitored by DOE Oversight staff and available to DOE and its authorized contractors for review. When anomalous measurements are observed, DOE is notified. Basic information as to the nature and source of the waste passing through the portal at the time of the measurements are obtained from EMWMF personnel. If preliminary information indicates the facility's WAC may have been violated, the information is submitted to DOE Oversight's Audit Team for review and disposition.

Methods and Materials

A Canberra RadSentry Model S585 portal monitor is used in the program. 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 located on each side of the road at the check-in station for trucks hauling waste into the disposal area (Figure 1). 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, analyzed, and uploaded to a secure website, along with associated information (e.g., date, time, and background measurements). Data on the website is monitored by TDEC staff and available for review by DOE and their authorized contractors. If radiation levels exceed a predetermined level, the RPM sends an alert notification to TDEC staff members by email. When an alert notification is received or anomalies are noted in review of the data, 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. If available information suggests WAC may have been violated, the information is submitted to DOE Oversight's Audit Team for review and disposition. The Audit Team is led by DOE Oversight's Waste Management program with support provided by other Oversight programs as required.

Figure 1: TDEC Portal Monitor at the Environmental Management Waste Management Facility

Results and Discussion
Over the 70 years since the ORR was established, a variety of production and research activities have generated numerous radioactive wastes, most of which are eligible for disposal at the EMWMF. Contaminants include activation and fission products (from isotope production facilities, reactor operations, and nuclear research at the Oak Ridge National Laboratory), as well as uranium (U), technetium-99 (Tc-99), and associated radionuclides (generated by uranium enrichment operations and the manufacturing of nuclear weapons components at the K-25 and Y-12 plants respectively). As these radionuclides decay, they emit one or more types of ionizing radiation.[4] Of these, three are most often considered of concern at the EMWMF: alpha (large positively-charged particles), beta (smaller negatively-charged electrons), and gamma/x-rays (small packets of energy called photons). Due to their size, weight, and charge, alpha and beta particles tend to interact with nearby atoms over short distances. Consequently, alpha and beta radiation are easily shielded and would not be expected to penetrate the steel side walls of truck beds carrying waste into the EMWMF for disposal. To a large degree, the waste can also shield itself. However, gamma radiation is pure electromagnetic energy with no mass or charge, capable of traveling long distances through various materials before depleting its energy. The radiation portal monitor is only capable of measuring gamma radiation.

Most radionuclides emit gamma radiation, although the frequency of emissions and associated energies vary, depending on the nuclear characteristics of the particular radionuclide. Radionuclides that are predominately alpha emitters emit gamma less frequently than beta emitters. Radionuclides considered pure alpha or beta emitters only give off gamma radiation a very small percentage of the time, or not at all. The waste lots disposed in the EMWMF contain mixtures of radionuclides that, as a whole, emit all three kinds of radiation. Since there are no pure gamma emitters, it is assumed for screening purposes that anomalous increases in gamma measurements are accompanied by increased alpha/beta radiation and concentrations of associated radionuclides. The higher the energy of the gamma emissions, the more likely the gamma photons of any given radioisotope will penetrate through the waste and truck bed to be counted by the portal monitor's detectors. The higher the frequency of emissions and concentrations of gamma emitting radioisotopes in the waste, the greater the number of counts measured (the count rate).

To a large degree, the mixture of radionuclides in wastes from the different ORR facilities are characteristic of the primary mission at each site. For example, wastes from ORNL typically include a long list of man-made radionuclides produced by irradiating uranium in reactors, along with their progeny (radionuclides to which they decay). Included in this mix are the most prolific gamma emitters typically found on the ORR (e.g., cesium-137, cobolt-60), along with many other radionuclides produced during nuclear reactions. Consequently, ORNL wastes are expected to have higher count rates than the other sites and, typically, a larger variety of isotopes in the mix. Conversely, uranium isotopes and technetium-99 are the dominant radionuclides in waste from the East Tennessee Technology Park (ETTP) and Y-12 facilities. Uranium isotopes are primarily alpha emitters and technetium-99 is a pure beta emitter. Decay products of uranium are removed during processing of the ore, so only the immediate progeny of the uranium isotopes that grow-in over relatively short time periods are generally present in ETTP and Y-12 wastes

[4] *Ionizing radiation* is any form of radiation that has enough energy to knock electrons out of atoms or molecules, creating ions.

(e.g., thorium-231, thorium-234, and protactinium-234m). As a result, the count rates are expected to be much lower and the anomalies more difficult to detect. When reviewing the results generated by the RPM, staff attempt to identify deviations from the norm, which, for the reasons above, change from site to site and from waste lot to waste lot. In most cases, the anomalous results can be resolved based on preliminary information; in others it cannot. In such instances, the results and preliminary information is submitted to the DOE Oversight Audit Team, for disposition.

In 2014, no anomalies were noted in any of the wastes delivered from the three ORR facilities, much of which consisted of demolition material from the Deactivation and Decommissioning (D&D) of the K-25, K-27, and K-33 Process Buildings at ETTP. These facilities housed production facilities for the enrichment of uranium, initially for nuclear weapons and later to fuel commercial and government owned reactors. In most cases, a large proportion of the demolition waste is clean material mixed with surficially contaminated material during the demolition process. So the concentrations would be expected to be low, compared to process equipment, which typically contains the higher concentrations of contaminants. While there were no anomalous increases observed in the results, it was noted that in some instances the measurements for ETTP wastes were less than the background measurements reported by the RPM. There were also fewer clean soils carried into the site for fill. The only anomalies observed in the results during 2014 where due to a nuclear density gauge which contains sealed and shielded cesium-137 and americium-241 sources. This instrument is used to measure compaction of the waste, a requirement to assure stability of the facility over time. The density gauge is not a waste, but a tool transported into the EMWMF disposal cells as needed and is otherwise stored outside the facility.

Conclusions

In 2014, most of the waste delivered to the EMWMF for disposal was derived from the demolition of uranium enrichment facilities at ETTP, constructed to produce uranium enriched in the U-235 isotope for nuclear weapons and, later, to fuel commercial and government owned reactors. Associated contaminants were primarily uranium isotopes (predominantly alpha emitters) and Tc-99 (a pure beta emitter). As might be expected, the radiation levels measured were low. The only elevated results observed were due to a nuclear density gauge that contains sealed and shielded cesium-137 and americium-241 sources used to measure compaction of the waste. The density gauge is not a waste, but a tool transported into the EMWMF disposal cells as needed and is otherwise stored outside the facility.

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SURFACE WATER MONITORING

Monitoring of Liquid Effluents, Surface Water, and Groundwater and Sediments at the Environmental Management Waste Management Facility

Principle Authors: Robert Storms, Wesley White

Abstract

The Tennessee Oversight Agreement requires the State of Tennessee to provide monitoring to verify Department of Energy (DOE) data and to assess the effectiveness of DOE contaminant control systems on the Oak Ridge Reservation. During 2014, the Tennessee Department of Environment and Conservation's (TDEC) DOE Oversight Office monitored groundwater elevations, effluents, and surface water runoff at DOE's Environmental Management Waste Management Facility (EMWMF). The monitoring has shown the potential for groundwater levels to be above the geologic buffer along the north and northeast portion of the disposal cells. A groundwater incursion below the waste liner and near PP-01 was identified from the 2011 water level data. This incursion has progressed through time. Additional monitoring is warranted to determine if the incursion near PP-01 is due to issues with the underdrain, the northern trench drain, pore pressure from waste loading of the landfill, or a function of the additional waste cells. Results from radiological water samples suggest that radionuclides are being discharged from operations conducted at EMWMF. However, those discharges are in compliance under TDEC Rule 1200-2-11-.16.

Introduction

The Tennessee Oversight Agreement requires the State of Tennessee to provide monitoring to verify Department of Energy (DOE) data and to assess the effectiveness of DOE contaminant control systems on the Oak Ridge Reservation (ORR). During 2014, Tennessee Department of Environment and Conservation's (TDEC) DOE Oversight Office (DOE-O) monitored groundwater elevations, effluents, and surface water runoff at DOE's Environmental Management Waste Management Facility (EMWMF). This facility was constructed to dispose of waste generated by remedial activities on the ORR and is operated under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). While the facility holds no permit from any state or federal agency, it is required to comply with applicable or relevant and appropriate requirements (ARARs) in the CERCLA Record of Decision (DOE, 1999) and with requirements associated with responsibilities delegated to the DOE by the Atomic Energy Act.

While the availability of onsite disposal capacity of the EMWMF has expedited remedial activities, the East Tennessee region presents some environmental challenges for landfill design, including the height of the groundwater table, the quantity of surface water runoff, and the porosity of local soils. Modifications to the initial design of the landfill included the installation of a French drain under the facility to lower the water table, which had risen to levels that approached the liner of the disposal cells. Issues with pooling effluent (contact water), a mixture of rainwater runoff and drainage from wastes, required a modification of procedures. The water is sampled, and, based on results, either released to a ditch that discharges into a sediment basin or sent for treatment at the Oak Ridge National Laboratory (ORNL) Process Waste Treatment Facility. The sediment basin discharges to a local tributary of Bear Creek.

It is the intent of this project to verify that the design, operations, and associated contaminant control mechanisms of the facility are consistent with criteria agreed to by the state, the Environmental Protection Agency (EPA), and DOE.

Methods and Materials

To verify that the EMWMF is meeting its design, a program was initiated to monitor discharges and groundwater locations. This program includes reviewing groundwater elevations, monitoring groundwater response with respect to precipitation and observing water quality parameters at two discharge locations. We will also be collecting analytical radiological water samples at EMWMF-1 (GW-918), EMWMF-2, EMWMF-3, EMWMF-4B, EMWNT-3A, EMWNT-5, during discharges from the Contact Water Ponds (CWPs) and the Contact Water Tanks (CWTs). In addition, sediment samples from the Sediment Basin are collected when conditions allow. No sediment samples were collected in 2014. However, the Ambient Trapped Sediment Monitoring Program looked at NT-5 just below the V-Weir. The results of that study are discussed with that program. The radiological sample locations for 2014 are provided in Figure 1.

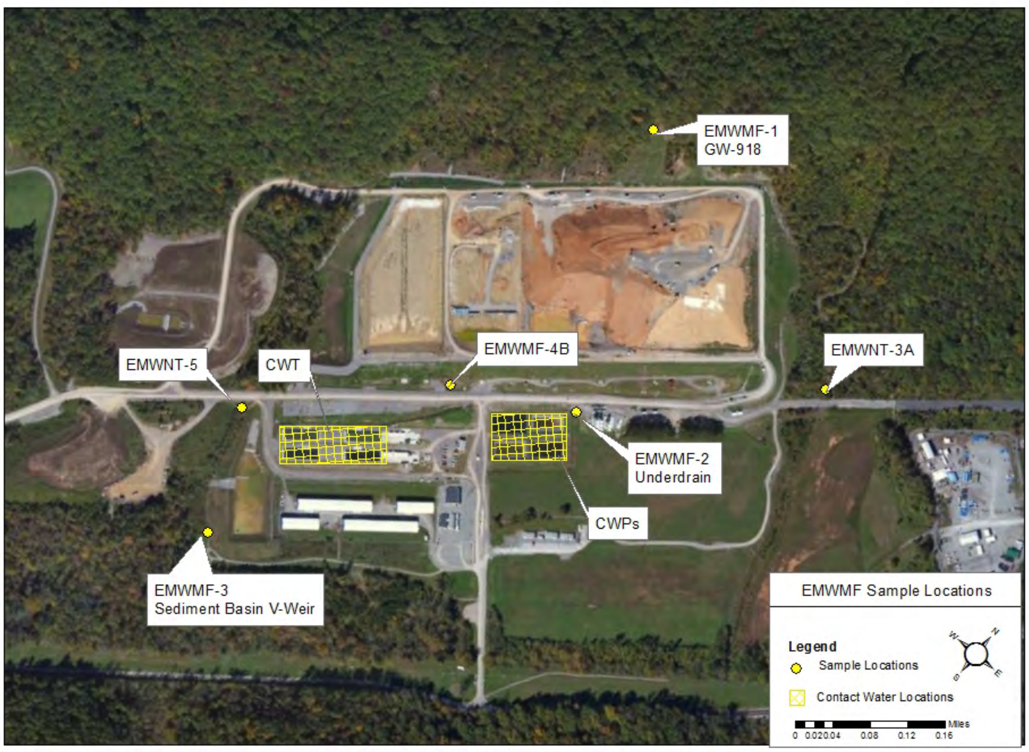


Figure 1: Radiological Sample Locations

Groundwater Review

Prior to the construction of the EMWMF, Federal Facilities Agreement (FFA) parties agreed on a contingency plan to be implemented if the water table rose to within ten feet of the liner (the fundamental barrier that prevents contaminants from migrating out of the facility into the groundwater) [URS/CH2M Oak Ridge (UCOR), 2012]. The intent of the contingency plan was to prevent the liner from damage caused by hydrostatic pressures from the water table rising to levels above the liner. In 2003, state geologists, taking water level measurements near the filled NT-4 channel, observed the water table had risen into the ten-foot buffer below the facility. DOE was advised and the contingency plan was implemented. The continued rise of the water table subsequently led to the construction of a French drain running north to south underneath the facility and a northern trench drain to lower the water table that had periodically risen to the facility's liner in some areas.

This groundwater review obtained data collected from UCOR (available on the Oak Ridge Environmental Information System - OREIS). Therefore, the data reviewed is from the previous year. The data is analyzed to determine its validity, and is then contoured utilizing a surface contouring program (Surfer®). Engineering data was utilized to contour a surface feature ten feet below the top of the geologic buffer (a 10-foot soil buffer below the liners) and, data from the underdrain installation was utilized to further refine the groundwater contours.

To further understand how the groundwater responds seasonally and to precipitation events, the state fitted seven monitoring wells with piezometers at EMWMF, using HOBO U20 water level and U24 conductivity loggers. The Oversight Office installed the data loggers to monitor GW-918, GW-947, GW-916, GW-952, GW-927, GW-917, and GW-922 (with an option to move the data loggers at GW-922 to GW-925 during the year). In addition to obtaining information at EMWMF for groundwater, the water level and conductivity information will be useful in assessing the groundwater at the proposed Environmental Management Disposal Facility (EMDF). The EMDF facility is proposed just east of EMWMF. The locations of the monitoring wells or piezometers for continuous monitoring are provided in Table 1 and Figure 2. The data loggers are set up to record temperature, conductivity, and pressure (water level) at five-minute intervals.

Table 1: Continuous groundwater monitoring locations

Table 1. Continuous Groundwater Monitoring Locations		
Well/Piezometer	Total Depth from Ground Surface (feet)	Rationale
GW-918	33.00	Will help understand hydrogeologic conditions along Pine Ridge.
GW-947	47.68	The fluctuating seasonal groundwater levels have been near, at, or above the ground surface.
GW-952	45.00	Seasonal fluctuation in groundwater levels have been observed.
GW-916	36.00	Is close to a seep and an existing wetland near EMDF.
GW-917	51.00	Wells GW-917 and GW-927 have shown an upward gradient.
GW-927	92.00	Wells GW-917 and GW-927 have shown an upward gradient.
GW-922	46.00	Very little water groundwater fluctuations have been previously observed, near NT-4 - see how lower NT-4 responds seasonally and to rain events.
GW-925	148.00	This well is hydraulically connected to NT-4 (water levels decreased when underdrain was installed) - see how NT-4 responds to rain events and other variations.

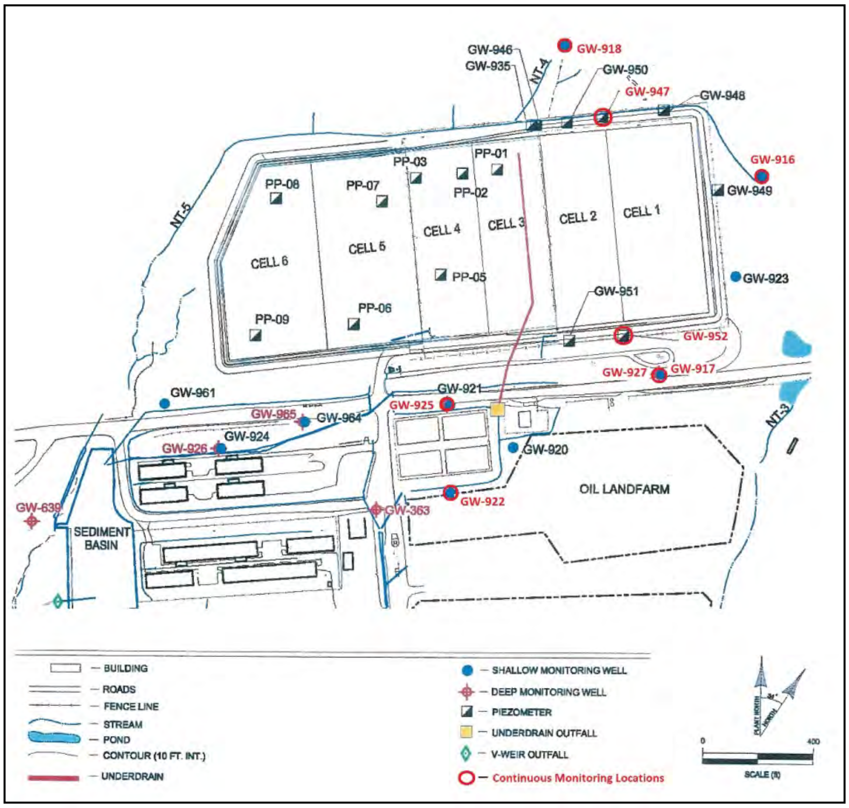


Figure 2: Groundwater Continuous Monitoring Locations

Water Quality Parameters

Water quality parameters were taken at two locations at EMWMF: EMWMF-2 (Underdrain) and EMWMF-3 (Sediment Basin V Weir Discharge). Water quality parameters were collected utilizing a YSI Professional Plus and an In-Situ® Troll 9500 multiparameter water quality monitoring meter. The YSI Professional Plus has been used throughout the year on a scheduled basis. The In-Situ® Troll 9500 was utilized at the EMWMF-2 from January 1 through December 31. Another In-Situ® Troll 9500 was deployed at EMWMF-3 to monitor the sediment basin discharge from April 22 to December 23. Parameters monitored include temperature, specific conductivity, pH, dissolved oxygen (DO), turbidity, and discharge flow rate.

Results and Discussion

Groundwater Review

A groundwater review was performed in 2014 based on historical data up to August 2013. The groundwater elevation data and the geologic buffer (10 feet below the top) were modeled utilizing Surfer®. The resulting groundwater potentiometric contours were compared against ten feet below the top of the geologic buffer to show areas that might intersect. Figure 3 shows the groundwater potentiometric contours for the highest groundwater elevations in 2013 (May), the bottom of the geologic buffer contours, and the areas of potential incursion of groundwater within ten feet from the top of the geologic buffer. The modeling yielded similar results for all four quarters of water level data. However, the groundwater incursion near piezometer PP-01 and PP-02 is increasing in size with each quarterly measurement. This change could be caused by several different factors and all are speculative at this time. Further monitoring of this situation is warranted.

When comparing the Surfer® groundwater potentiometric contours with the geologic buffer contours, generally the water elevations are below the agreed upon 10-foot buffer. Unfortunately, the data for the northeastern portion of the disposal cells is limited. An additional well would be necessary to properly define the groundwater potentiometric surface for disposal cells one and two. However, any additional wells to refine the water elevation data for these two disposal cells are not recommended as it could compromise the integrity of the already filled disposal cells. A well (GW-949) along the east side was considered dry, and as a function of Surfer®, GW-950, GW-947, and GW-948 groundwater elevations are providing a local bias for the contouring. This bias along with a need for more groundwater level data from the northern drainage trench makes it difficult to generate an accurate model, thus the observed incursion. The incursion (shown in figures 4 through 6), that includes piezometers PP-01 and PP-02 was examined and could be due to several factors. Additional monitoring is warranted to determine if it is due to the construction of cells 5 and 6. Other potential causes include issues with the underdrain, a leaky cell liner, waste cell loading of the underlying geology creating a damming effect from Pine Ridge, or waste cell loading increasing the pore pressure of the piezometers.

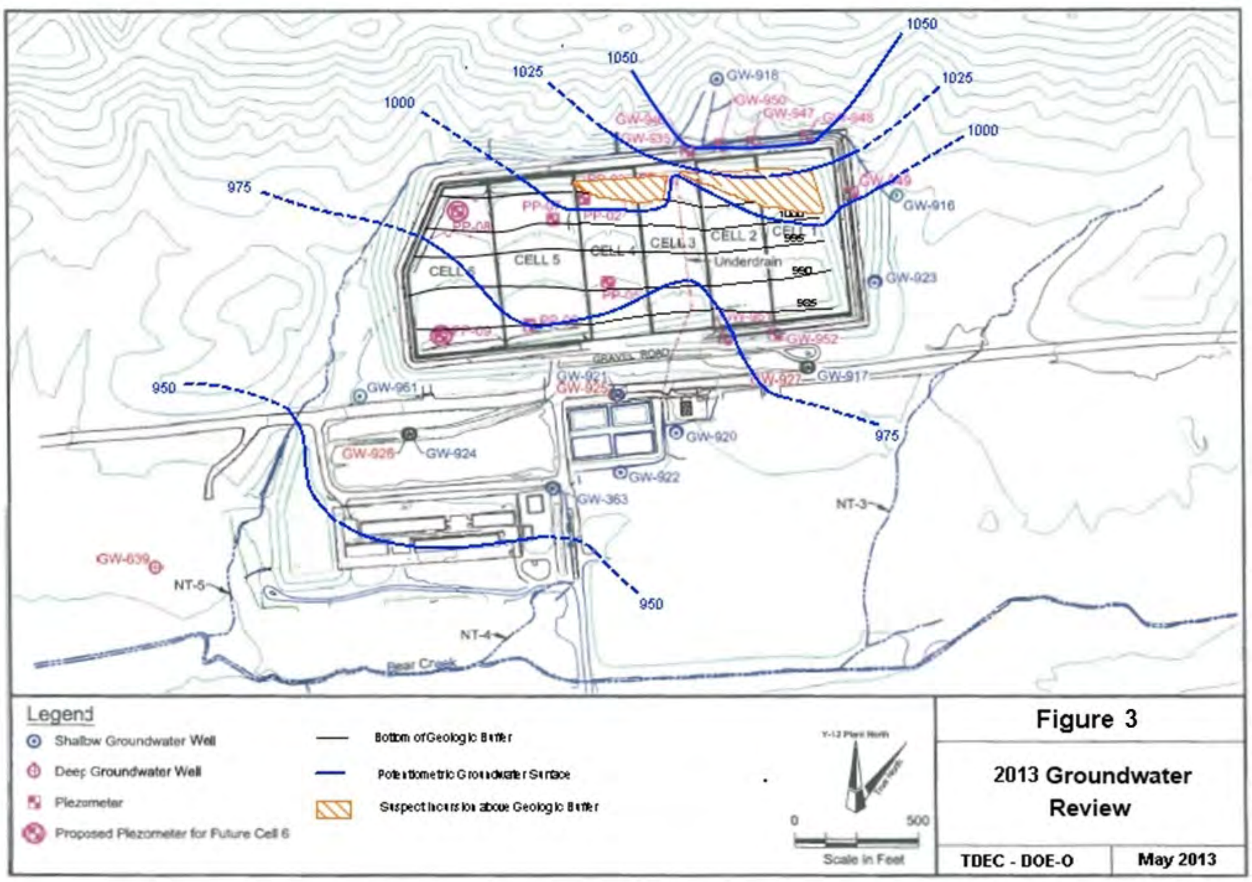


Figure 3: 2013 Groundwater Review

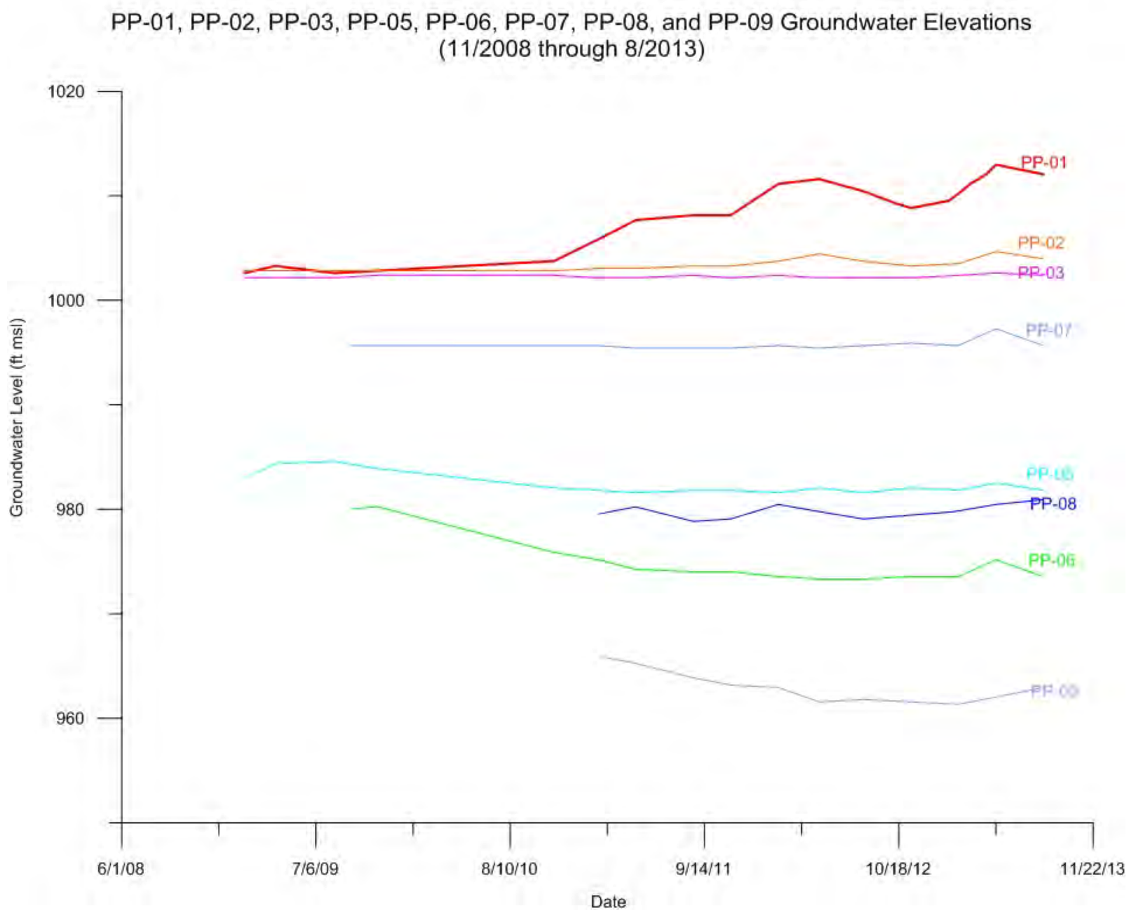
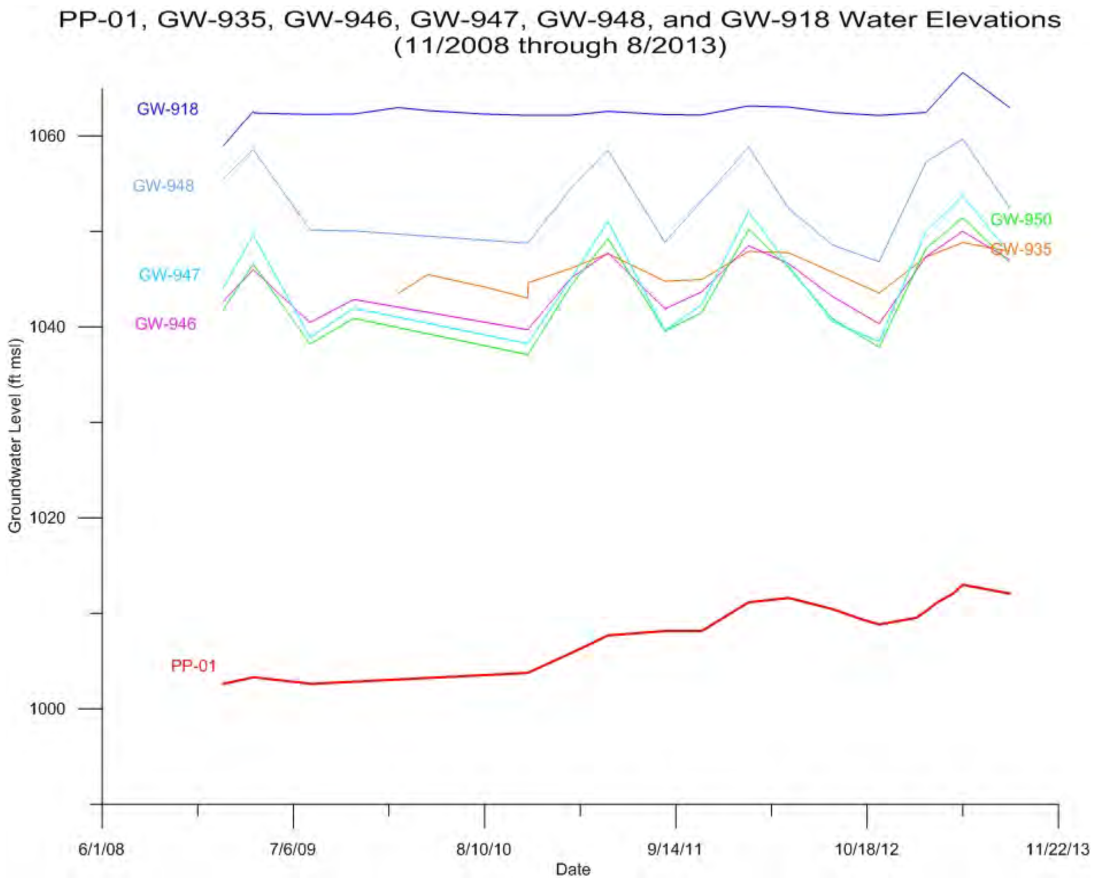
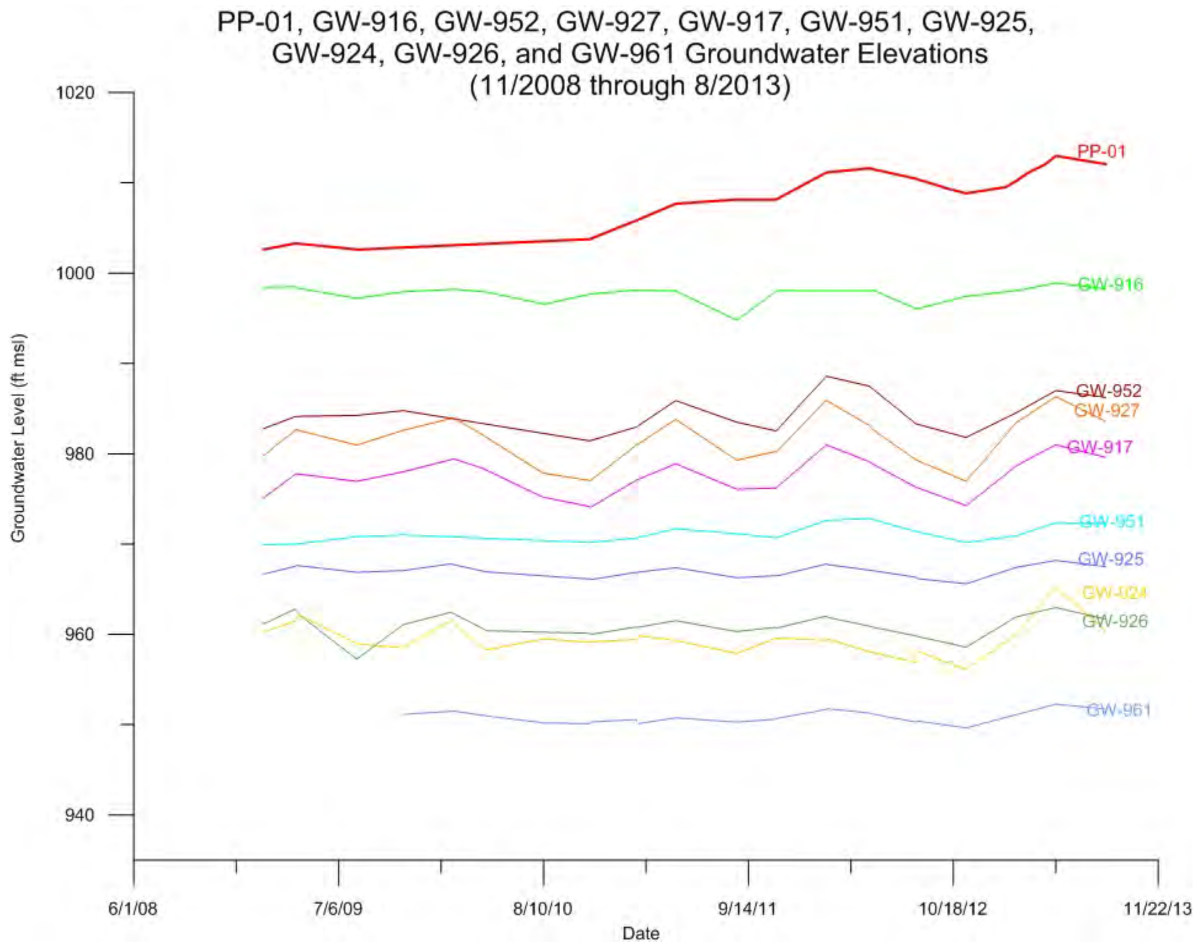


Figure 4: PP-01 water elevations in relations to piezometers at EMWMF from November 2008 to August 2013



ft msl – feet mean sea level

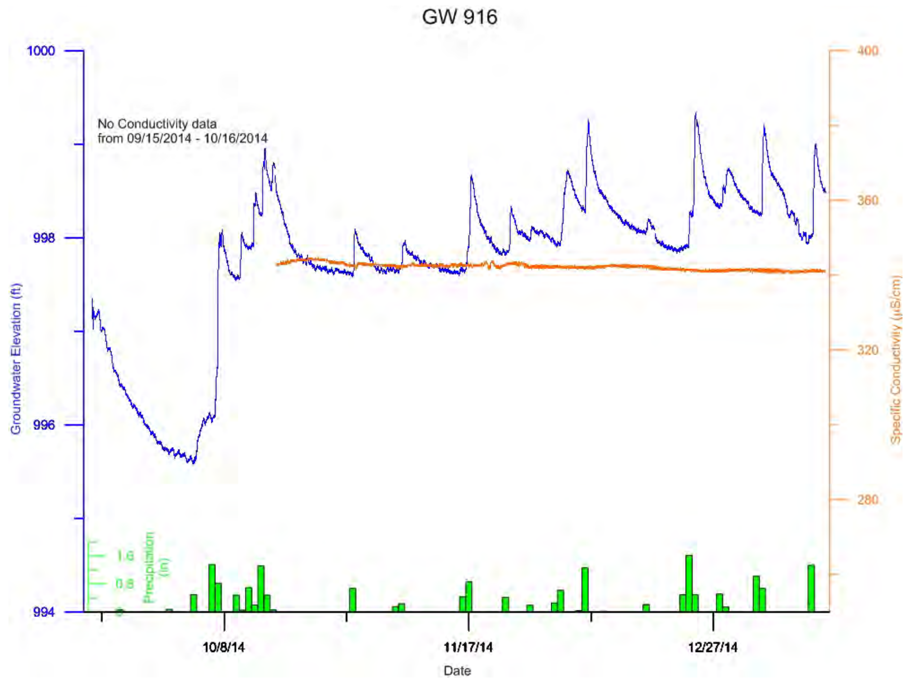
Figure 5: PP-01 water elevations in relations to upgradient wells at EMWMF from November 2008 to August 2013



ft msl – feet mean sea level

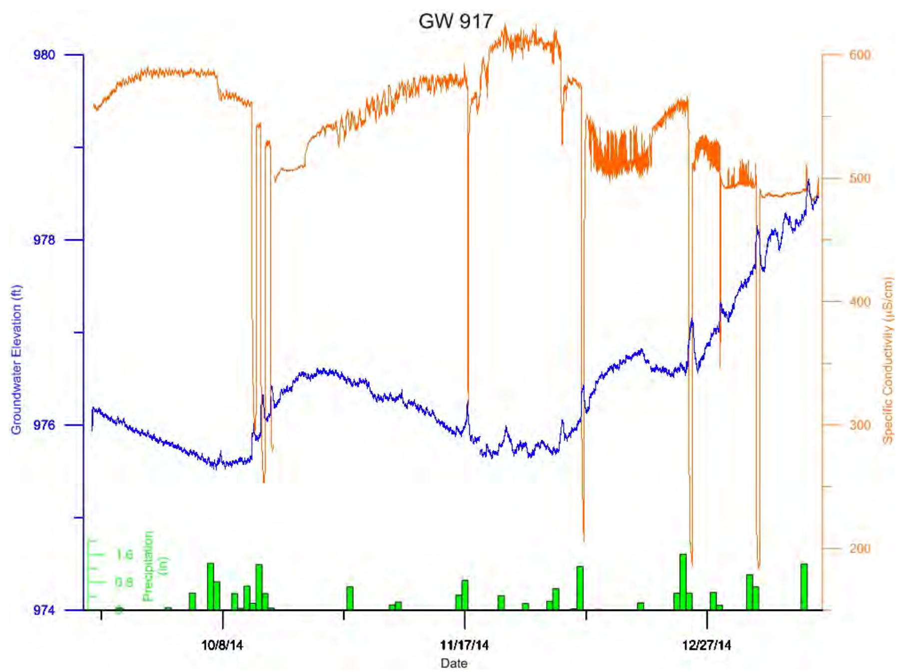
Figure 6: PP-01 water elevations in relations to downgradient wells at EMWMF from November 2008 to August 2013

In September 2014, the DOE Oversight Office instrumented seven monitoring wells or piezometers at EMWMF with HOBO U20 water level and U24 conductivity loggers. The groundwater levels and specific conductivity readings for GW 916, GW-917, GW-918, GW-922, GW-927, GW-947, and GW-952 are provided in Figures 7 through 13, respectively. A detailed evaluation of this data will be completed after a full year of data has been collected. The evaluation will be discussed in next year's Environmental Monitoring Report.



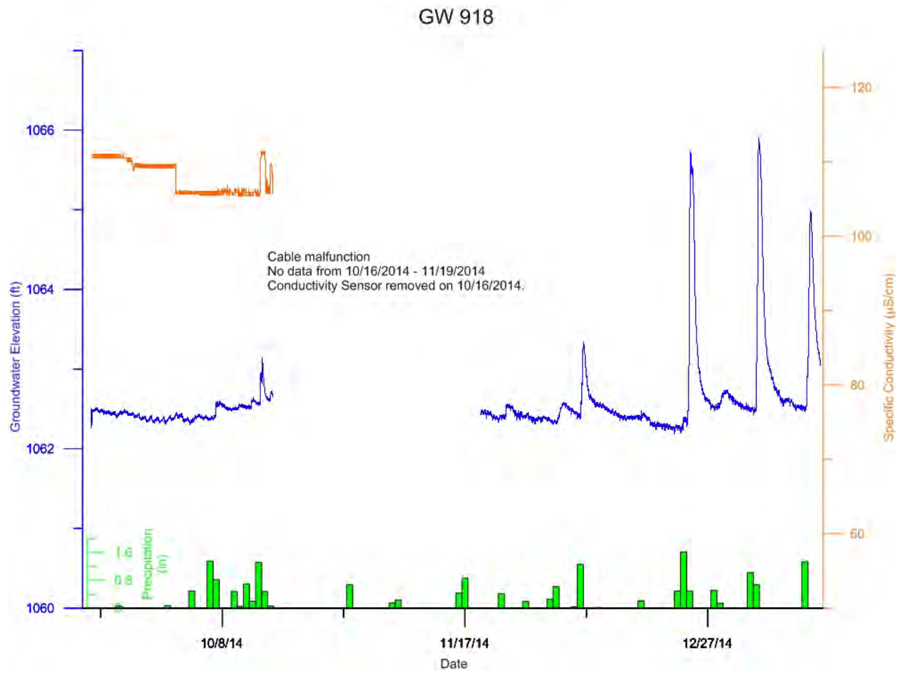
ft – feet mean sea level: **µS/cm** – microSiemens per centimeter; **in** - inches.

Figure 7: GW-916 Continuous Water Elevations and Specific Conductivity Readings (September 15, 2014 to January 14, 2015)



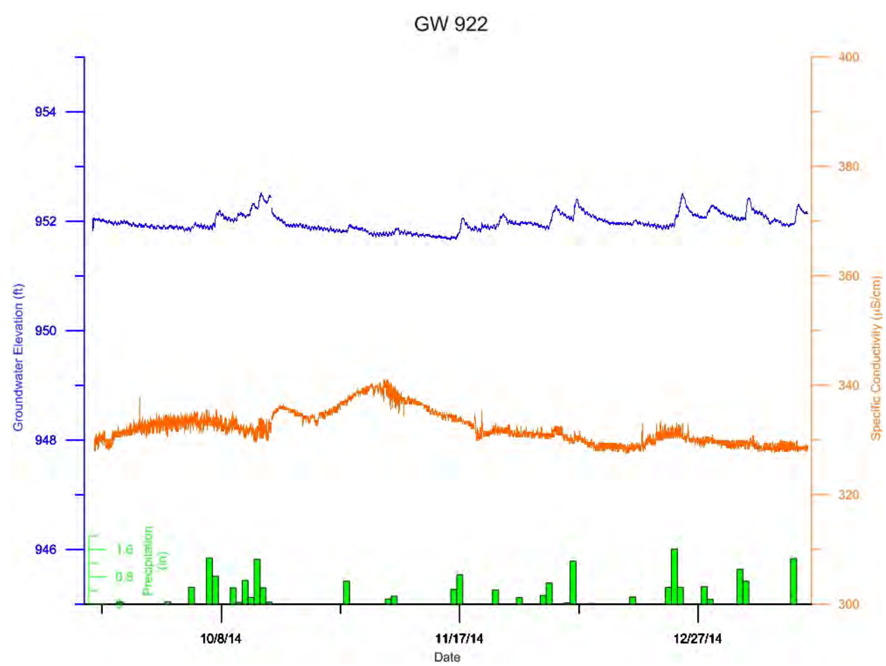
ft – feet mean sea level: **µS/cm** – microSiemens per centimeter; **in** - inches.

Figure 8: GW-917 Continuous Water Elevations and Specific Conductivity Readings (September 15, 2014 to January 14, 2015)



ft – feet mean sea level: **µS/cm** – microSiemens per centimeter; **in** - inches.

Figure 9: GW-918 Continuous Water Elevations and Specific Conductivity Readings (September 15, 2014 to January 14, 2015)

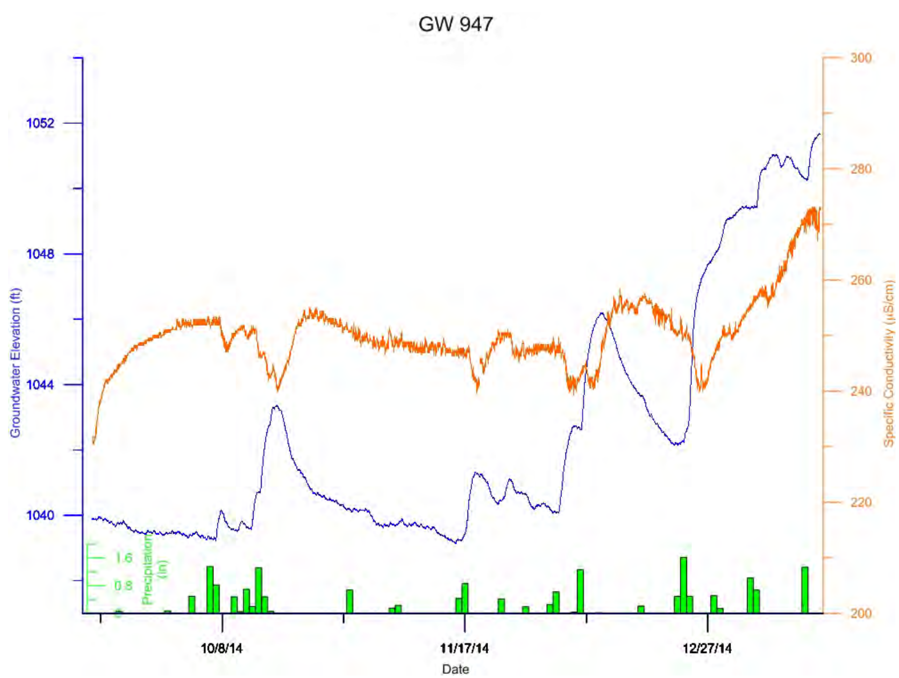


ft – feet mean sea level: **µS/cm** – microSiemens per centimeter; **in** - inches.

Figure 10: GW-922 Continuous Water Elevations and Specific Conductivity Readings (September 15, 2014 to January 14, 2015)

ft – feet mean sea level: **µS/cm** – microSiemens per centimeter; **in** - inches.

Figure 11: GW-927 Continuous Water Elevations and Specific Conductivity Readings (September 15, 2014 to January 14, 2015)



ft – feet mean sea level: **µS/cm** – microSiemens per centimeter; **in** - inches.

Figure 12: GW-947 Continuous Water Elevations and Specific Conductivity Readings (September 15, 2014 to January 14, 2015).

ft – feet mean sea level: **µS/cm** – microSiemens per centimeter; **in** - inches.

Figure 13: GW-952 Continuous Water Elevations and Specific Conductivity Readings (September 15, 2014 to January 14, 2015)

Water Quality Parameters

One or two times a week, TDEC staff recorded water quality parameters at the EMWMF-2 and EMWMF-3 with a YSI-Professional Plus water quality meter. Table 2 provides a summary of the data recorded at the two sites with the YSI-Professional Plus water quality meter.

pH is an important limiting chemical factor for aquatic life. If the water in a stream is too acidic or basic, the H+ or OH- ion activity may disrupt aquatic organism's biochemical reactions by either harming or killing the stream organisms. Streams generally have a pH value ranging from 6 to 9, depending upon the presence of dissolved substances that come from bedrock, soils and other materials in the watershed.

Dissolved Oxygen is expressed as a concentration in water. A concentration is the amount, in weight, of a particular substance per a given volume of liquid. The DO concentration in a stream is the mass of the oxygen gas present, in milligrams/liter of water or parts per million (ppm). This number can be affected by temperature, flow, aquatic life, altitude, dissolved or suspended solids or human activity.

Table 2: 2014 Data Summary of the Water Quality Parameters collected with the YSI-Pro Water Quality Meter

UNDER DRAIN

	PH			DO			COND			TEMP			ORP			
	high	low	avg	high	low	avg	high	low	avg	high	low	avg	high	low	avg	visits
Jan	6.77	6.37	6.61	7.89	3.76	5.65	553.7	515.7	533.2	14.8	13.4	14.2	410.4	196.6	264.7	9
Feb	6.58	6.47	6.52	6.33	4.64	5.56	618	516.6	541.3	15.9	13.3	14.4	356.4	213.4	263.4	7
Mar	6.67	6.48	6.55	6.09	3.9	5.17	542.4	504.3	519.8	15	14.5	14.7	266.3	202.3	233	4
Apr	6.53	6.3	6.42	5.11	2.63	3.99	544.1	497.7	520.8	16.2	15.2	15.8	237.5	129.3	205.8	8
May	6.51	6.33	6.43	3.98	1.83	3.22	526	474.4	506.5	17.4	16.1	16.5	224.7	138.8	194.4	9
Jun	6.48	6.29	6.4	1.97	0.93	1.52	620.7	484.7	515.3	17.4	16.7	17.1	208.7	149.3	186.1	7
Jul	6.76	6.47	6.56	1.67	0.98	1.43	533.1	477.5	505	18	17.4	17.6	225.4	108.8	184.6	9
Aug	6.88	6.46	6.64	1.93	1.33	1.66	505.2	470.2	489.1	18.2	17.7	17.9	241.6	192.8	214.7	9
Sep	6.81	6.4	6.55	2.88	0.94	1.61	483.4	470.4	477.5	18.2	17.7	18	266.1	166.1	202.1	9
Oct	6.65	6.43	6.55	4.67	1.8	2.91	614	475.9	525.7	18.2	16.9	17.7	325.1	207.7	263.7	8
Nov	6.76	6.19	6.52	7.34	4.41	5.95	488	393.3	457	17.4	14.9	16.2	304.1	174.3	241.1	6
Dec	6.74	6.47	6.65	6.19	3.37	4.96	540.3	490	513.1	16.3	14.9	15.8	291	206.6	240.7	7

OUT FALL

	PH			DO			COND			TEMP			ORP			
	high	low	avg	high	low	avg	high	low	avg	high	low	avg	high	low	avg	visits
Jan	8.64	7.46	7.84	17.34	12.53	14.35	1006	372.2	753.8	5.9	2.5	4.4	286.1	176.4	231.7	9
Feb	8.64	7.9	8.18	14.26	10.92	12.82	698	272.5	448.7	12.1	2	6.4	412.1	180.6	244.5	7
Mar	8.66	8.08	8.4	12.04	11.63	11.84	554.8	448.9	491.7	11.4	8.8	9.8	238.3	170.2	204.2	4
Apr	8.59	7.12	8.07	14.48	7.41	9.64	567	217.8	421.4	21.2	12.9	17.4	202.8	110.5	176.8	8
May	8.69	7.95	8.21	7.98	6.17	7.05	435.5	302	383.2	25.2	18.7	22.9	190.2	131.4	167.1	9
Jun	8.12	7.69	7.89	6.88	5.6	6.13	801	290.3	446.9	27.5	23.9	26	238.1	163.9	188.5	7
Jul	9.19	7.98	8.51	9.03	5.98	7.06	323.8	175.4	243.8	29.2	24	26.9	270.5	161.4	194.6	9
Aug	9.15	8.21	8.62	7.64	6.22	6.93	423	289.4	356.5	27.8	24.3	26.2	235.5	116.3	170	9
Sep	9.18	7.31	8.05	7.42	4.51	6.03	681	147.2	281	27.2	16.4	23.2	273.8	142.1	187.3	9
Oct	7.61	7.1	7.43	8.87	6.3	7.86	701	154.4	307.9	19.4	14.9	16.8	370.9	213.2	264.5	8
Nov	7.6	6.63	7.22	12.77	10.09	11.72	598.7	338	406.3	10	4.1	8.6	272.4	205.1	228.6	6
Dec	7.69	7.08	7.41	12.88	10.04	11.56	453.6	279.6	355.4	10.6	5.9	8.2	279.3	194.1	237.5	7

DO – Dissolved Oxygen; COND – Specific Conductivity; TEMP – temperature; ORP-Oxidation Reduction Potential

Specific Conductivity is a measure of how well water passes an electrical current. It is an indirect measure of the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron and aluminum. The presence of these substances increases the specific conductivity in water. Conversely substances like oil or alcohol will lower the specific conductivity.

Temperature of water is a controlling factor for aquatic life. It controls the rate of metabolism, reproduction activities and therefore, life cycles. Temperature can be influenced by seasonal fluctuations and flow rate.

Oxidation Reduction Potential (ORP or Redox potential), is a measurement of water's ability to oxidize contaminants. The higher the ORP, the greater the number of oxidizing agents present in the water.

In addition to the YSI-Professional Plus water quality meter whose monitoring data is listed in Table 2, an In-Situ® Troll 9500 multi-parameter water quality data logger was at EMWMF-2 from January 1, 2014 through December 31, 2014 and at EMWMF-3 from April 22, 2014 through December 23, 2014. To complement the water quality parameter graphs, a precipitation graph was created from the ORNL precipitation data collected from the meteorological station at

Y-12 West. The meteorological data was collected approximately one mile northeast from EMWMF. Graphs of EMWMF-2 and EMWMF-3 are presented in Figures 14 and 15, respectively.

At EMWMF-2 (Underdrain):
The pH was relatively constant as expected with groundwater. The DO dropped a little during the summer months as expected with slightly higher temperatures. The conductivity kept a consistent average, also expected with groundwater. 2014 data was consistent with the 2013 data.

There are three data gaps at EMWMF-2. The data gaps occurred from equipment servicing and equipment expiration. The data gap from July 22-July 24 was due to a break for equipment cleaning and calibration. The data gap from September 23-September 25 was due to a removal of a defective rugged DO sensor that failed on September 15 and calibration. The third data gap is from November 18-November 25 and was due to the replacement of the rugged DO sensor and calibration.

The parameters monitored with the In-Situ® multiparameter water quality data logger were temperature, pH, DO, specific conductivity, water surface height (calculated to discharge), and turbidity. Monitoring was to determine the integrity of the liners of the disposal cells. Any leaks in the liner should have displayed changes (whether gradual or sudden) to pH, DO, specific conductivity, and possibly discharge. Monitoring the discharge in conjunction with the surrounding groundwater levels should help determine the long term effectiveness of the underdrain. Future monitoring should be compared to see if there is a trend of these parameters occurring on an annual basis (See Figure 14).

<u>Temperature:</u>
There is a diurnal cycle (a regular 24-hour daily cycle) with the data. This fluctuation is due to the fact that the underdrain is monitoring groundwater discharge which is being exposed to atmospheric conditions at the discharge point. There is a gentle temperature increase beginning from March to early October. In October, the temperature is slightly decreasing. This gentle temperature change is expected and is seasonal.

<u>pH:</u>
The pH data has a slight diurnal cycle. Generally, the groundwater pH was between 6.4 to 6.75 standard units. The only noted peaks with the pH data were associated with a sizeable precipitation event. These pH spikes are thought to be the result of surface water runoff.

<u>Dissolved Oxygen (DO):</u>
Dissolved oxygen has a slight diurnal cycle and it varies with temperature. As the temperature decreases, more oxygen can be dissolved in solution. The DO probe appeared more sensitive to temperature and this could be due to the limited water column above the probe. Groundwater typically has low DO values. The spikes in DO were associated with the groundwater runoff during precipitation events. The lowest dissolved oxygen values were consistently recorded from June through September. The DO sensor malfunctioned on September 15 and a new sensor was installed on November 25.

Specific Conductivity:

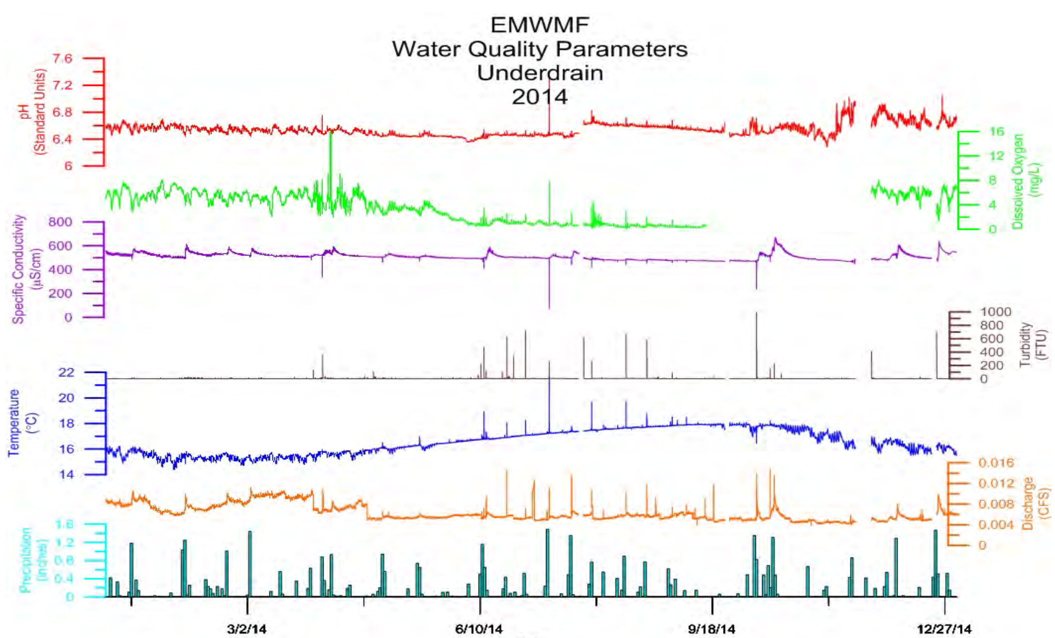
Specific conductivity varies based on the length of time the groundwater is exposed to stratigraphic units (rock formations). The specific conductivity values at the underdrain indicate a recessional curve after several major rain events. When there was a recessional curve, there was a 26-hour lag before higher conductivity values peaked for the December 6 rain event. This higher conductive groundwater (older water) is being displaced by the infiltration of fresh rainwater the hours following the precipitation event. However, there are several other rain events with no observed recessional curve. It is possible that during the dry periods (as shown during the fall of 2013). The rain water percolated into storage and did not displace the older formation water. The low specific conductivity values suggest that some surface water backs up into the underdrain during rain events.

Turbidity:

The turbidity values were somewhat misleading. EMWMF-2 is near surface water runoff, open to the atmosphere, and shallow. During all rain events, initial placement of the YSI water quality meter, or during servicing of the data logger, the turbidity values were anomalously high. The highest values do suggest that some surface water backs up into the underdrain during rain events. All other turbidity readings were consistently below 10 NTUs.

Discharge:

There is a V-weir associated with EMWMF-2. The discharge was fairly constant, with some increase during wetter periods. There were slight recessional curves noted with the discharge data with major precipitation events. For December 6, there was a six-hour lag before the highest flow rate was observed. The largest discharge peaks observed on Figure 14 were associated with precipitation events and water entering EMWMF-2 from surface water runoff.



C –Centigrade; **mg/L** – milligrams per liter; **µS/cm** – microSiemens per centimeter; **NTU** - nephelometric *turbidity units;* **CFS** – *cubic feet per second;* **in** – *inches.*

Figure 14: Water Quality Parameters (temperature, pH, DO, specific conductivity, discharge, and turbidity) and Precipitation at EMWMF-2

At EMWMF-3 (V-Weir):
The pH rose during the summer months and fell during the fall. During the summer months, pH was found to be above the release criteria (>9). High pH is attributed to algae growth (Tucker and D'Abramo, 2008). The DO dropped as the temperatures rose during the weather cycle. Conductivity displayed a spike in January. This was during a low flow period. Overall conductivity numbers were up in 2014 and data patterns were similar to 2013.

There are four data gaps at EMWMF-3. The unit was placed in service on April 22 after the threat of stagnant freezing water which might damage the probes was eliminated. The unit was pulled from this location on December 23 when there was an increased potential for the water at EMWMF-3 to freeze. The four data gaps were for equipment maintenance, cleaning, and calibration.

The parameters monitored (see Figure 15) with the In-Situ® multiparameter water quality data logger at EMWMF-3 from April 22 to December 23 were temperature, pH, DO, specific conductivity, water surface height (calculated to discharge), and turbidity.

<u>Temperature:</u>
As evident from the temperature graph, the water temperatures were elevated. The increased temperatures were expected for a surface water impoundment. The shallow surface water is affected by the ambient air temperatures. The surface water temperature increase was observed during April through September of 2014. The daily temperature fluctuations (diurnal cycle) were subdued during times when the flow at the V-weir stopped. Radiant heating from the sun at the outfall also affected temperatures. Along with the daily surface water temperature fluctuation, seasonal temperature fluctuations were observed.

<u>pH:</u>
The pH data has a pronounced diurnal cycle. The pH data can vary with temperature. Generally, the surface water pH during times of discharge varied between 6.74 and 9.78 standard units, with the average pH around 8.49 standard units. The pH was observed above 9.0 standard units at the V-Weir during discharges 83 times. The process that causes the pH exceedance explains that during the day, underwater photosynthesis exceeds respiration, so pH rises as carbon dioxide is extracted from the water. As the sun begins to set, photosynthesis decreases and eventually stops, so pH falls throughout the night as respiring organisms add carbon dioxide to the water. The daily interplay of respiration and photosynthesis caused pH to cycle up and down during a 24-hour period. Extended episodes of high pH are particularly common in ponds where filamentous algae dominate the plant community. Also, high pH in aquiculture ponds appears to occur more frequently and with greater severity in waters with low total hardness and moderate to high total alkalinity (Tucker and D'Abramo, 2008). These 83 discharges were above the storm-water release criteria noted in Table 3.

<u>Dissolved Oxygen (DO):</u>
The DO has a diurnal cycle and it varies with temperature. Generally as the temperature decreases, more oxygen is dissolved from the atmosphere to the surface water. However, at the sediment basin, DO increases as temperature increases. The observed DO increase is due to

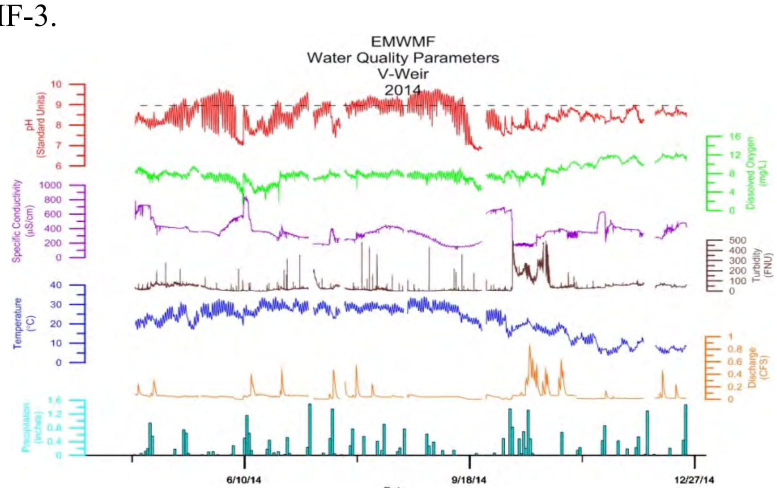
biological (photosynthesis) or rapid non-laminar flow conditions. The lower levels of DO are probably associated with the elevated atmospheric and water temperatures. The higher observed DO readings during the day help support the conclusion that the observed pH issue is biological in nature.

Specific Conductivity:
Specific Conductivity also has a slight diurnal cycle; the warmer the water, the more ions in the solution. The graph shows this fluctuation with temperature. There were also changes in conductivity due to significant rain events, the length of time the water was exposed to soil in the sediment basin, and the origin of the surface water (contact water pond discharge or precipitation).

Turbidity:
There were several peaks in the graph for turbidity which were confirmed with visual observations. There is not a release criterion for turbidity. However, the EPA proposed (then vacated said proposal) that an effluent limitation for sites that disturb 20 acres be required to comply with a turbidity limit of 280 *nephelometric turbidity units* (NTUs). The data logger recorded turbidity values above 280 NTU several times. The high turbidity values in October were related to the abnormal precipitation events from October 6 to October 16. A review of the EMWMF storm-water measures were initiated at the site, and several better management practices were implemented in order to minimize the observed high sediment loading in October.

Discharge:
The discharge at EMWMF-3 corresponded with precipitation events, Contact Water Ponds/Contact Water Tank discharges, and uncontaminated storm water discharges.

The parameters of discharge, pH, DO, and turbidity showed that there were potential issues at EMWMF-3, particularly with biological activity (high pH and DO) and surface water runoff (high turbidity). Algal blooms or mats have the potential to increase the pH above the release criteria at EMWMF-3.



C –Centigrade; **mg/L** – milligrams per liter; **µS/cm** –microSiemens per centimeter; **NTU** - nephelometric *turbidity units;* **CFS** – *cubic feet per second;* **in** – *inches.*

Figure 15: Water Quality Parameters (temperature, pH, DO, specific conductivity, discharge, and turbidity) and Precipitation at EMWMF-3

Table 3: Stormwater Monitoring Criteria	
Parameter	**Release Criteria Level**
5-day Biological Oxygen Demand	40 mg/L
Total Suspended Solids (TSS)	110 mg/L
Ammonia as Nitrogen	0.2 mg/L
Oil and Grease	30 mg/L
pH	6.0-9.0 (standard units)
Gross Alpha	15 pCi/L
Gross Beta	50 pCi/L
Radiological COCs	25% of Nuclide specific DCG from DOE Order 5400.5

(Safe Drinking Water Act, TDEC 1200-4-3-.03(3(g)) and 1200-2-11-.16)

mg/L – milligram per liter
pCi/L – picocuries per liter
COC – contaminants of concern
DCG – derived concentration guides
DOE – Department of Energy

Radiological Water Samples

Five location groupings were consistently sampled at EMWMF. The samples were analyzed for radionuclides. The analyses varied and included gross alpha, gross beta, gamma, strontium-90, technetium-99, tritium, and isotopic uranium.

EMWMF-1 (GW-918)

A total of three samples were collected at the background location, EMWMF-1. This location was co-sampled during the quarterly groundwater sampling events for EMWMF-1 at GW-918. The samples were analyzed for gross alpha, gross beta, gamma radionuclides, strontium-90, technetium-99, isotopic uranium, and tritium. Results are shown in Table 4.

Table 4: EMWMF-1 (GW918) Sample 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)
2/18/14	0	0		0.37	0.55	0.145	0
5/14/14	0	0		0.23	2.86	0.154	139
8/13/14	1.95	13.3		-0.26	0.49	0.103	0

pCi/L – picocurie per liter

EMWMF-2 (Underdrain Discharge)

A total of ten samples were collected at EMWMF-2. The samples were analyzed for technetium-99, tritium, strontium-90, and isotopic uranium. The sample results are presented in Table 5. While the levels do not raise a health concern/risk, the presence of Tc-99 activity as well as uranium will be watched closely for upward trends and potential seeps in the liner. At present, the numbers are of a very minimal concern. 2013 averages are shown for comparison purposes.

Table 5: EMWMF2 (Underdrain Discharge) Sample Results

Date	Technetium-99 (pCi/L)	Tritium (pCi/L)	Strontium-90 (pCi/L)	Uranium (pCi/L)
1/16/14	1.10	299	0.05	0.611
2/27/14	1.07	0	0.14	0.554
4/8/14	0.53	135	0.4	0.468
6/12/14	0.61	0	4.9	0.420
6/26/14	4.58	145	0.38	0.357
7/22/14	0	0	.108	0.410
8/28/14	0	142	-0.53	0.278
10/9/14	0.58	0	pending	0.320
11/14/14	0.57	61	pending	0.387
12/11/14	0.47	31	pending	0.573
2013 avg	0	102	0.47	0.590

pCi/L – picocurie per liter Pending – Data not available from the Laboratory

avg - average

EMWMF-3 (Sediment Basin Discharge)

A total of eleven samples were collected at EMWMF-3. The samples were analyzed for gross alpha, gross beta, strontium-90, technetium-99, isotopic uranium, and tritium. The sample results are presented in Table 6. The results at EMWMF-3 were elevated in all the analyses, indicating some radionuclides are being discharged at EMWMF-3.

Table 6: EMWMF-3 Sample Results (Sediment Basin Discharge)							
Date	Gross Alpha (pCi/L)	Gross Beta (pCi/L)		Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Total Uranium (pCi/L)	Tritium (pCi/L)
1/16/14	27.7	130.6		3.8	89.9	25.6	300
1/23/14	50.9	206		5.1	141.9	49.36	684
2/18/14	17.4	27.9		1.78	19.75	14.44	138
4/18/14	1.64	21.6		1.32	12.44	6.36	135
6/12/14	11.8	34.3		0.53	11.67	10.36	139
6/26/14	9.2	26.1		3.00	22.39	5.95	145
7/22/14	1.90	16.1		2.8	8.49	0.475	580
8/28/14	2.10	70.3		1.39	47.6	3.24	287
10/9/14	2.71	18.3		pending	4.98	1.90	143
11/14/14	14.2	349.0		pending	325	2.72	410
12/11/14	3.32	38.5		pending	28.7	pending	73

pCi/L – picocurie per liter   Pending – Data not available from the Laboratory

This location is subject to the release criteria shown in Table 3. There are exceedances to the gross alpha and gross beta release criteria. However, DOE Order 5400.5 establishes DCGs for radionuclides in process effluents (Table 7), which are used as reference concentrations for conducting environmental protection programs. Per DOE agreement with TDEC, annual average (sum of fractions) SOF calculations for storm-water discharge into Bear Creek are based on 25% of the 100 millirem per year DCG specified under DOE Order 5400.5, which corresponds to a SOF of 1.042. In addition to the TDEC limit for SOF, a modified annual average sum of fractions of 0.625 serves as the environmental as low as reasonably achievable (ALARA) goal for EMWMF. The storm-water SOF is calculated each calendar year using radiological contaminants of concern (COC) results reported for monthly surface water, monthly storm-water, other storm-water, quarterly surface water, and miscellaneous surface water samples collected at the discharge point of the EMWMF storm-water retention and sedimentation pond. The 2014 annual storm-water sum of factions result is 0.37, and is in compliance with the TDEC limit of 25 millirem per year (mrem/yr) specified under TDEC Rule 1200-2-11-.16.

Table 7: Derived Concentration Guides (DCGs) for selected isotopes		
Isotope	**DCG (100 mrem/year)**	**¼ of DCG (25 mrem/year)**
Tritium	2,000,000 pCi/L	500,000 pCi/L
Strontium-90	1,000 pCi/L	250 pCi/L
Technetium-99	100,000 pCi/L	25,000 pCi/L
Uranium-234	500 pCi/L	125 pCi/L
Uranium-235	600 pCi/L	150 pCi/L
Uranium-238	600 pCi/L	150 pCi/L

pCi/L – picocurie per liter mrem/year – millirem per year

EMWMF-4/4B (Uncontaminated Storm-water Discharge)

Three samples were collected at EMWMF-4B. The samples were analyzed for gross alpha, gross beta, strontium-90, total uranium, technetium-99, and tritium. The sample results are presented in Table 8.

Table 8: EMWMF-4/4B Sample 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)**
2/27/14	0	0		0.25	0.57	0.558	0
5/22/14	NA	NA		0.11	629	0.276	139
7/17/14	NA	NA		0.37	-0.58	2.39	882

NA – not analyzed pCi/L – picocurie per liter

This location is subject to the release criteria shown in Table 3, as it is discharged to EMWMF-3. The samples at EMWMF-4B did not exceed their release criteria. However, the Tc-99 activity from 5/22/14 raises a concern due to the fact that the discharge from EMWMF-4B does not come in contact with the waste. The sample is being re-analyzed to determine if the initial laboratory analysis is correct.

<u>Surface Water Runoff</u>

A total of four samples were collected at tributaries NT-3A and NT-5. The samples were analyzed for gross alpha, gross beta, strontium-90, technetium-99, isotopic uranium, and tritium. The sample results are presented in Table 9. The results from the tributaries do not indicate a concern at this time and the total uranium numbers have improved significantly when compared to 2013 data. Staff will continue to monitor the tributaries for changing conditions.

Table 9:Surface Water Results								
Station ID	Date	Gross Alpha (pCi/L)	Gross Beta (pCi/L)		Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Total Uranium (pCi/L)	Tritium (pCi/L)
NT-3A	5/8/14	0	0		0.14	0	0.519	0
NT-5	5/8/14	0	0		0.22	0.55	0.379	0
NT-3A	10/7/14	-1.824	2.6		-0.56	0	0.26	0
NT-5	10/7/14	-1.385	8.9		-0.48	1.08	0.312	0

pCi/L – picocurie per liter

The surface water runoff locations are subject to the release criteria shown in Table 3.

Contact Water Pond/Tank samples

A total of three samples were collected at the contact water ponds and/or contact water tanks. The samples were analyzed for gross alpha, gross beta, strontium-90, technetium-99, isotopic uranium, and tritium. The radionuclide sample results are presented in Table 10. The results from the CWPs or CWTs are elevated in gross alpha, gross beta, strontium-90, technetium-99, uranium, and tritium compared to background. The disposition of the contact water was based on a more detailed sampling program. Contact water was either disposed of at the ORNL Process Waste Treatment Facility or was discharged to the sediment pond. The release criterion for uranium from contact water is 480 pCi/L. All contact water pond samples met or were conditioned to meet the release criteria and were discharged to the sediment pond. The sediment pond discharge then follows the procedures discussed for EMWMF-3.

Table 10: Contact Water Pond Sample Results								
Station ID	Date	Gross Alpha (pCi/L)	Gross Beta (pCi/L)		Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Total Uranium (pCi/L)	Tritium (pCi/L)
CWP-4	2/27/14	74	318		6.8	248.3	58.71	831
CWP-2	8/5/14	-7.9	906		3.2	268.3	2.53	584
CWP-3	12/18/14	-31.5	2007		pending	1765	57.43	342

pCi/L – picocurie per liter

Pending – Data not available from the Laboratory

Conclusion

The groundwater review continues to show a potential for groundwater levels to be above the geologic buffer along the northern and northeast portion of the disposal cells. Additional wells to refine the water elevation data for disposal cells one and two are needed but not recommended. Those two disposal cells are nearly full and any intrusive activities could compromise the integrity of the disposal cell liners. Near PP-01 the water level has risen throughout the year. Further monitoring is needed to see if this incursion is stable or increasing. Additional data loggers have been installed at several wells to get a better idea of how the groundwater system behaves seasonally with regards to precipitation.

There still are problems with pH at the EMWMF-3. Continuous water quality parameters are important for documenting discharges, changing conditions, and monitoring releases at EMWMF-2 and EMWMF-3

The results from the radiological water samples suggest that radionuclides are being discharged from EMWMF-3 to NT-5 and eventually Bear Creek. However, those discharges are in compliance under TDEC Rule 1200-2-11-.16.

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Ambient Sediment Monitoring

Principle Author: John (Tab) Peryam

Abstract

Sediment samples from two Clinch River sites and five Poplar Creek sites were analyzed for metals and radiological parameters. Samples were also collected at Bear Creek, East Fork Poplar Creek, and Mitchell Branch. One of the sites, Poplar Creek Mile 7.0 (PCM 7.0/PCK 11.3), serves as a reference site; it is upstream of the mouth of East Fork Poplar Creek on Poplar Creek. Samples were analyzed for aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, and zinc. In addition, samples were analyzed for gross alpha, gross beta and gamma radionuclides.

The East Fork Poplar Creek Mile 3.9 sediment mercury value (14 mg/kg) exceeds the Consensus Based Sediment Quality Guidelines (CBSQG) Probable Effects Concentration (PEC) of 1.06 mg/kg (MacDonald *et al.* 2000). The mercury in East Fork Poplar Creek and Poplar Creek sediments results from historical activities at Y-12 and, to a lesser extent, the East Tennessee Technology Park (ETTP). East Fork Poplar Creek empties into Poplar Creek at Poplar Creek Mile 5.5; the mouth of Poplar Creek is at approximately Clinch River Mile (CRM) 12. Of the sites sampled, mercury levels were highest at East Fork Poplar Creek km 6.3 and generally decreased downstream to Poplar Creek and the Clinch River. All of the sites sampled on East Fork Poplar Creek and Poplar Creek had mercury values above the PEC.

Historical data obtained from Oak Ridge Environmental Information System (OREIS), along with 2014 Tennessee Department of Environment and Conservation (TDEC) sediment data indicate that, sometime between 2004 and 2008, sediment mercury levels increased significantly at Mitchell Branch km 0.1 (K1700). Similarly, nickel, chromium, boron, and barium concentrations increased during the same time period at this location.

The radiological sediment data show no reason for human health concerns; all parameters are well below DOE Preliminary Remediation Goals (PRGs). In 2014, cesium-137 (Cs-137) was detected in both of the Clinch River samples and in the Mitchell Branch sample. The recreational PRG for Cs-137 is 117 pCi/g [total soil/sediment Total Risk (TR) 1.0E-06] (DOE 2013). The highest Cs-137 value was 1.21 pCi/g at CRM 0.0. Gross beta activity was highest at the Mitchell Branch location (265 pCi/g).

Introduction

Sediment is an important part of aquatic ecosystems. Anthropogenic chemicals and waste materials introduced into aquatic systems often accumulate in sediments. Sediment is often a depository for contaminants such as metals, radionuclides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and agricultural chemicals. Concentrations of contaminants can be much higher in sediments than in the water column. Many aquatic organisms depend on sediment for habitat, sustenance, and reproduction. 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.

Contaminants from past Department of Energy (DOE) activities on the Oak Ridge Reservation (ORR) have made their way into several streams that feed into Poplar Creek and the Clinch River. The major pathways of concern are White Oak Creek (WOC) and East Fork Poplar Creek (EFPC). The major contaminants of concern from White Oak Creek are strontium-90 (Sr-90) and cesium-137 (Cs-137). East Fork Poplar Creek is contaminated with mercury from past activities at Y-12. In order to characterize and monitor the impact from these streams, the Tennessee Department of Environment and Conservation's DOE Oversight Office (TDEC DOE-O) sampled sediment in the Clinch River, Poplar Creek, East Fork Poplar Creek, Bear Creek and Mitchell Branch. Sediment samples were analyzed for metals and radiological parameters. TDEC DOE-O conducted sediment monitoring at ten sites in June and July 2014 (see Table 1 and Figure 1). Two sites were on the Clinch River and five sites were on Poplar Creek. In addition, East Fork Poplar Creek, Bear Creek, and Mitchell Branch were sampled. Since there are no federal or state sediment cleanup levels, the metals data were compared to Consensus-based Sediment Quality Guidelines (CBSQGs)(MacDonald et al. 2000). Radiological data were compared to DOE's Preliminary Remediation Goals (PRGs) (DOE 2013). PRGs are upper concentration limits for specific chemicals in environmental media that are intended to protect human health. PRGs are often used at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites for risk assessment (Efroymson et al. 1997).

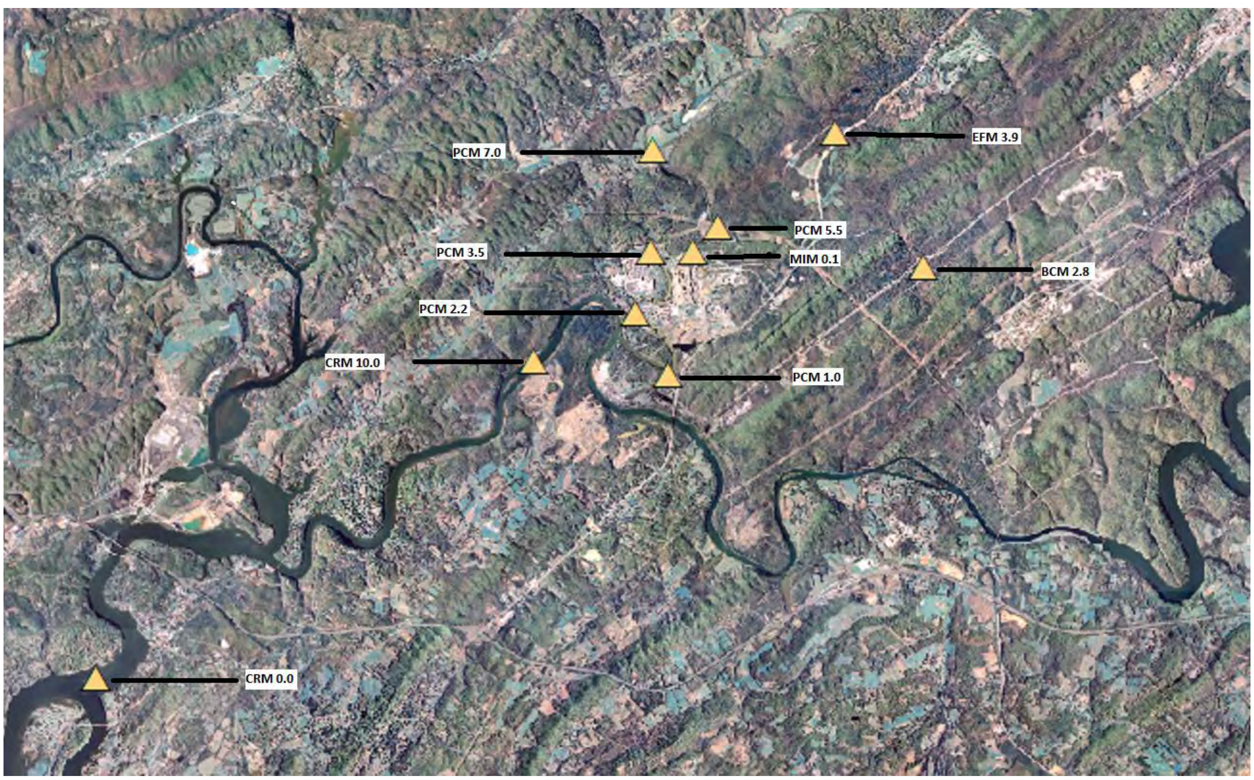

Figure 1: Sediment Sampling Sites

Methods and Materials

Sediment samples were taken during June and July using the methods described in the DOE-O Sediment Monitoring Standard Operating Procedure. At least three grabs were taken at each site; the grabs 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 aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, and zinc. In addition, samples were analyzed for gross alpha, gross beta and gamma radionuclides.

Table 1: Sampling Sites

Monitoring Location	ID	Alternate ID	Metric ID
Clinch River Mile 10.0	CLINC010.0RO	CRM 10.0	CRK 16.1
Clinch River Mile 0.0	CLINC000.0RO	CRM 0.0	CRK 0.0
Poplar Creek Mile 7.0	POPLA007.0RO	PCM 7.0	PCK 11.3
Poplar Creek Mile 5.5	POPLA005.5RO	PCM 5.5	PCK 8.9
Poplar Creek Mile 3.5	POPLA003.5RO	PCM 3.5	PCK 5.6
Poplar Creek Mile 2.2	POPLA002.2RO	PCM 2.2	PCK 3.5
Poplar Creek Mile 1.0	POPLA001.0RO	PCM 1.0	PCK 1.6
East Fork Poplar Creek Mile 3.9	EFPOP003.9RO	EFM 3.9	EFK 6.3
Bear Creek Mile 2.8	BEAR002.8RO	BCM 2.8	BCK 4.5
Mitchell Branch 0.1	MITCH000.1RO	MIM 0.1	MIK 0.1

Results and Discussion

Metals Analyses

The only metals found above the PEC were mercury and nickel (Table 2). 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 effects on benthic macroinvertebrate species only (WDNR 2003). The CBSQGs are considered to be 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 (Ingersoll *et al.* 2000).

Table 2: Summary of Metals Data

Parameter	Units	Mean	Std. Dev.	Median	Range	Min.	Max.	Count	EPA*	TEC**	PEC***
Arsenic	mg/kg	3.94	5.06	0.5	12	0	12	10	7.24	9.79	33
Barium	mg/kg	94.3	41.5	71	102	58	160	10			
Beryllium	mg/kg	0.61	0.26	0.53	0.9	0.4	1.3	10			
Boron	mg/kg	42.1	10.2	41.5	33	29	62	10			
Chromium	mg/kg	22.3	30.9	11.5	99	11	110	10	52.3	43.4	111
Mercury	mg/kg	3.24	4.18	2.35	13.97	0.03	14	10	0.13	0.18	1.06
Nickel	mg/kg	61.4	89.9	15	270	10	280	10	15.9	22.7	48.6

*USEPA. 2001. Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment. Originally published November 1995. Website version last updated November 30, 2001: http://www.epa.gov/region4/waste/ots/ecolbul.htm
**Consensus Based Sediment Quality Criteria, Threshold Effects Concentration (McDonald *et al.* 2000)
***Consensus Based Sediment Quality Criteria, Probable Effects Concentration (McDonald *et al.* 2000)

The East Fork Poplar Creek Mile 3.9 sediment mercury value (14 mg/kg) exceeds the PEC of 1.06 mg/kg (MacDonald *et al.* 2000). The mercury in East Fork Poplar Creek and Poplar Creek sediments results from historical activities at Y-12 and, to a lesser extent, East Tennessee Technology Park (ETTP). Figure 2 shows the effect of the East Fork Poplar Creek mercury contamination on the Clinch River sediments. East Fork Poplar Creek empties into Poplar Creek at Poplar Creek Mile 5.5; the mouth of Poplar Creek is at approximately Clinch River Mile (CRM) 12. Mercury levels are highest at East Fork Poplar Creek km 6.3 and generally decrease downstream. All of the sites sampled on East Fork Poplar Creek and Poplar Creek had mercury values above the PEC.

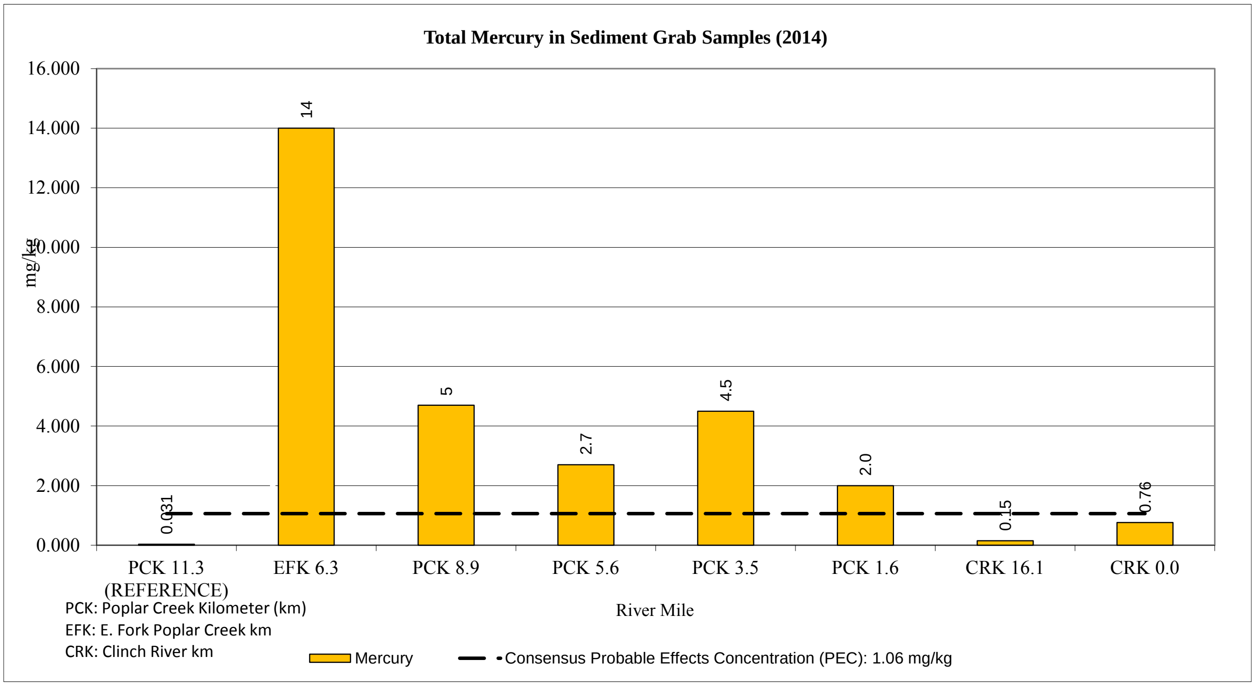

Figure 2: Mercury in Clinch River and Poplar Creek Sediment Grab Samples

Figure 3, total mercury in sediment grab samples at Mitchell Branch km 0.1 (1992-2014), gives a chronological view of changes in sediment mercury content over the years 1992 to 2014. The graph incorporates data obtained from OREIS and includes DOE Environmental Surveillance Soil & Sediment Data, DOE Remedial Effectiveness Reports, and data from DOE Environmental Monitoring Plans. Sometime between 2004 and 2008, sediment mercury levels increased significantly as can be seen in the data in Figure 3. Similarly, nickel, chromium, boron, and barium concentrations increased during the same time period at this location (Figures 4, 5, 6, and 7). This increase is due to decommissioning and demolition (D&D) activities at the ETTP site.

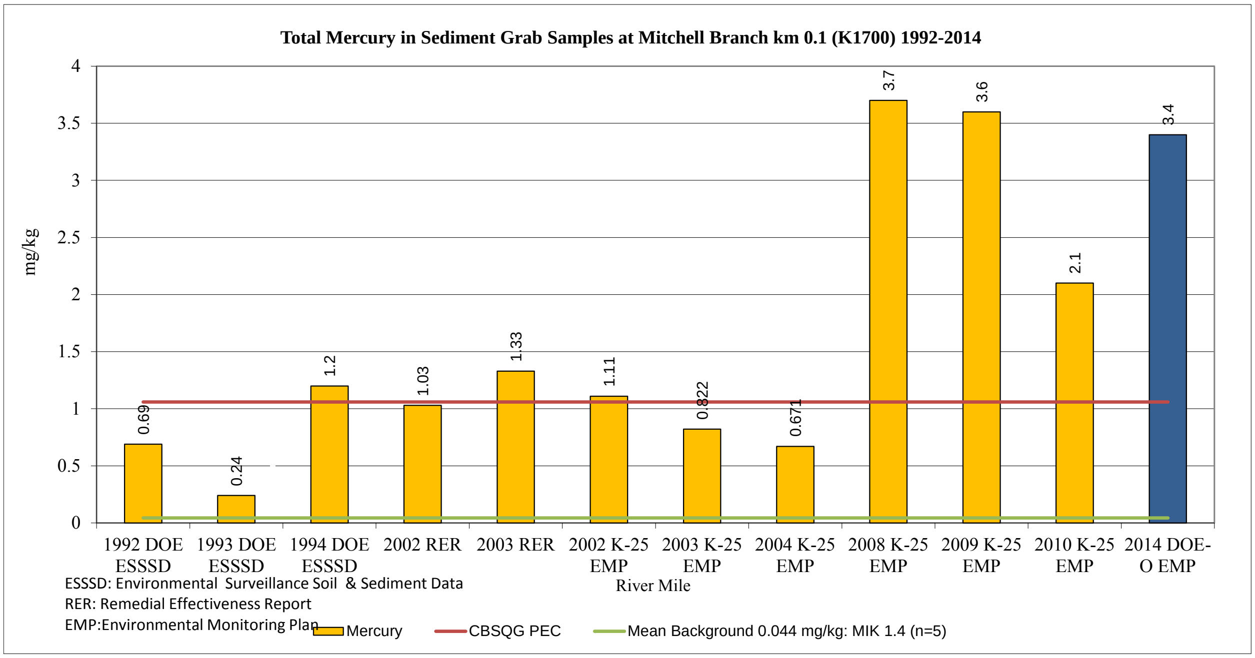

Figure 3: Total Hg in Sediment Grab Samples at Mitchell Branch km 0.1 (1992-2014)

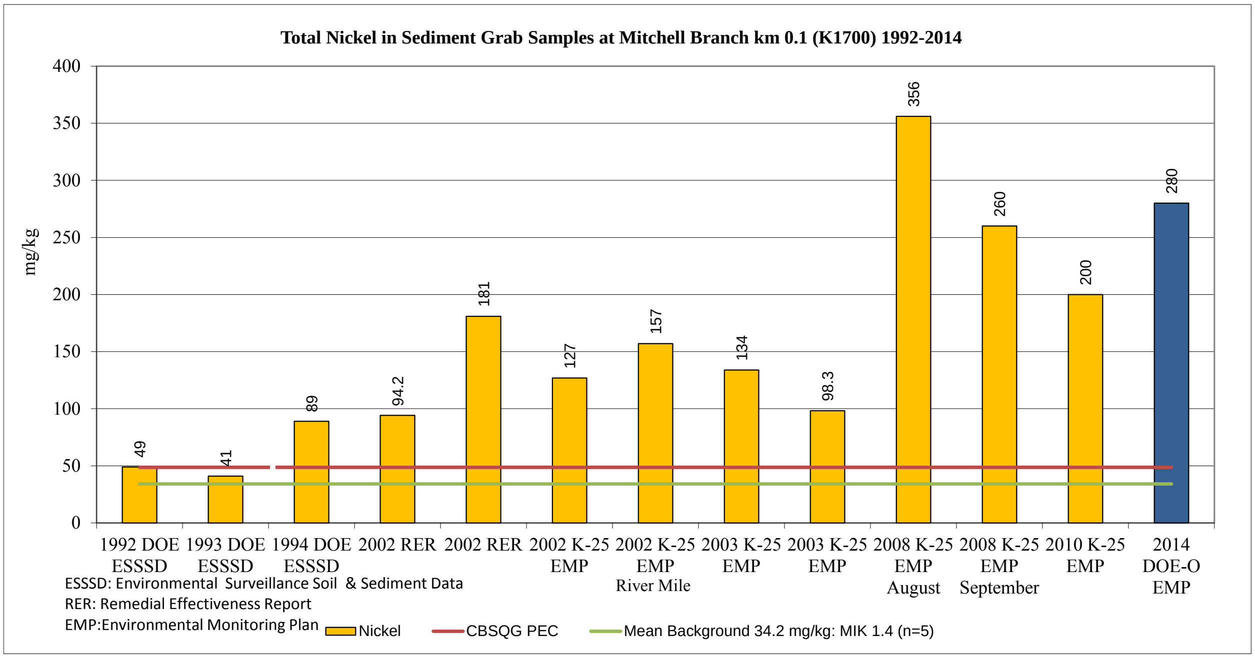

Figure 4: Nickel in Sediment Grab Samples at Mitchell Branch km 0.1 (1992-2014)

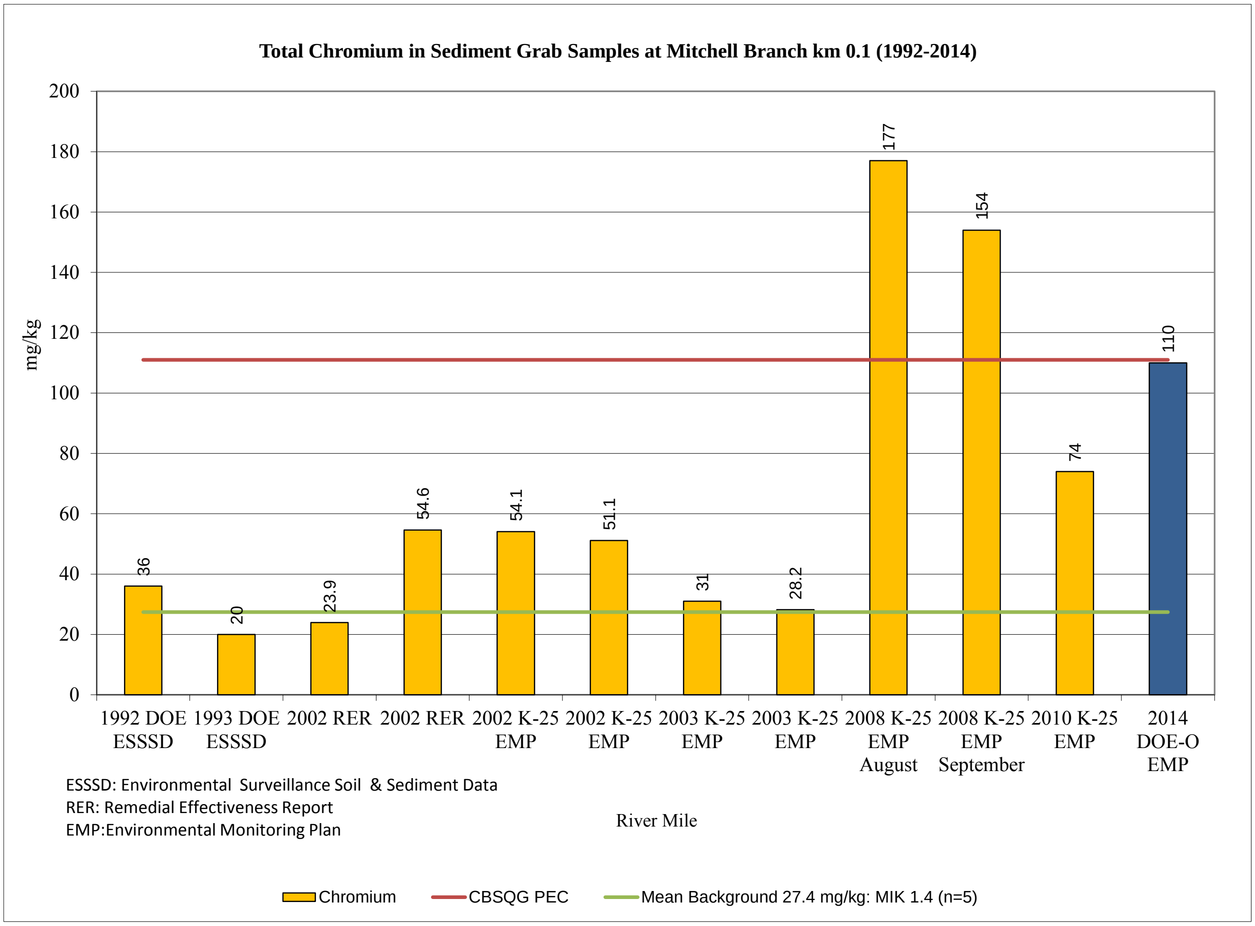

Figure 5: Temporal View of Chromium at Mitchell Branch km 0.1

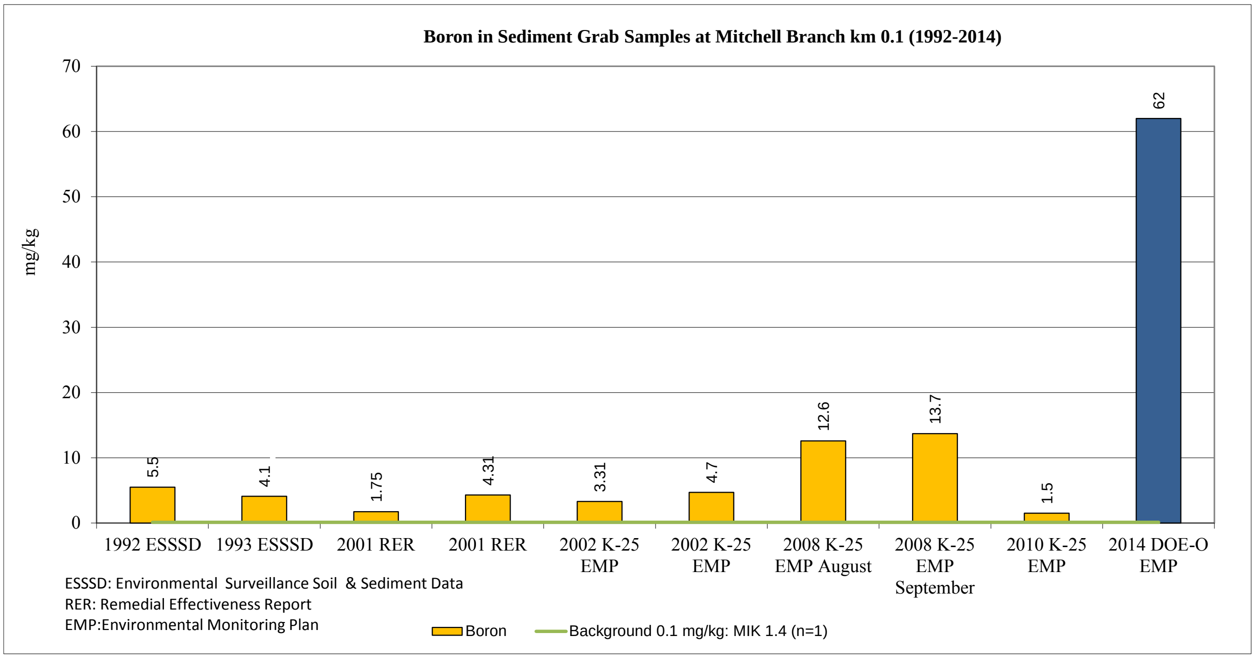

Figure 6: Temporal View of Boron at Mitchell Branch km 0.1

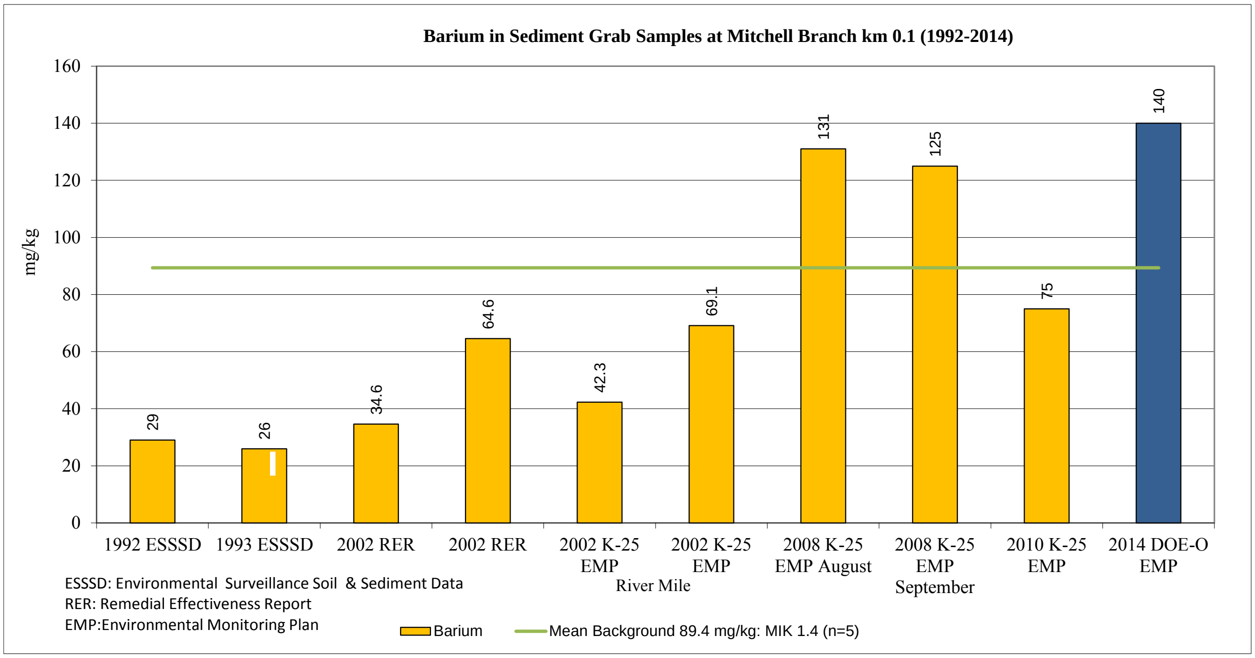

Figure 7: Temporal View of Barium at Mitchell Branch km 0.1

Radiological Analyses

The radiological sediment data show no reason for human health concerns; all parameters are well below DOE PRGs. In 2014, Cs-137 was detected in both of the Clinch River samples and in the Mitchell Branch sample. The recreational PRG for Cs-137 is 117 pCi/g (total soil/sediment TR 1.0E-06) (DOE 2013) while the highest Cs-137 value was 1.21 pCi/g at CRM 0.0. Gross beta activity was highest at the Mitchell Branch location (265 pCi/g) (Figure 8). Figures 9 and 10 show a chronological view of changes in sediment gross alpha and beta activities over the years 1992 to 2014. These graphs incorporate data obtained from OREIS and include DOE Environmental Surveillance Soil & Sediment Data and DOE Remedial Effectiveness Reports, as well as the 2014 TDEC DOE-O data.

Table 3: Summary of Radiological Data

Parameter	Units	Mean	Stand	Median	Range	Minimum	Maximum	Count
Radioactivity, alpha	mg/kg	2.214	1.5	1.94	5.16	0	5.16	10
Radioactivity, beta	mg/kg	29.48	82.8	3.6	265	0	265	10

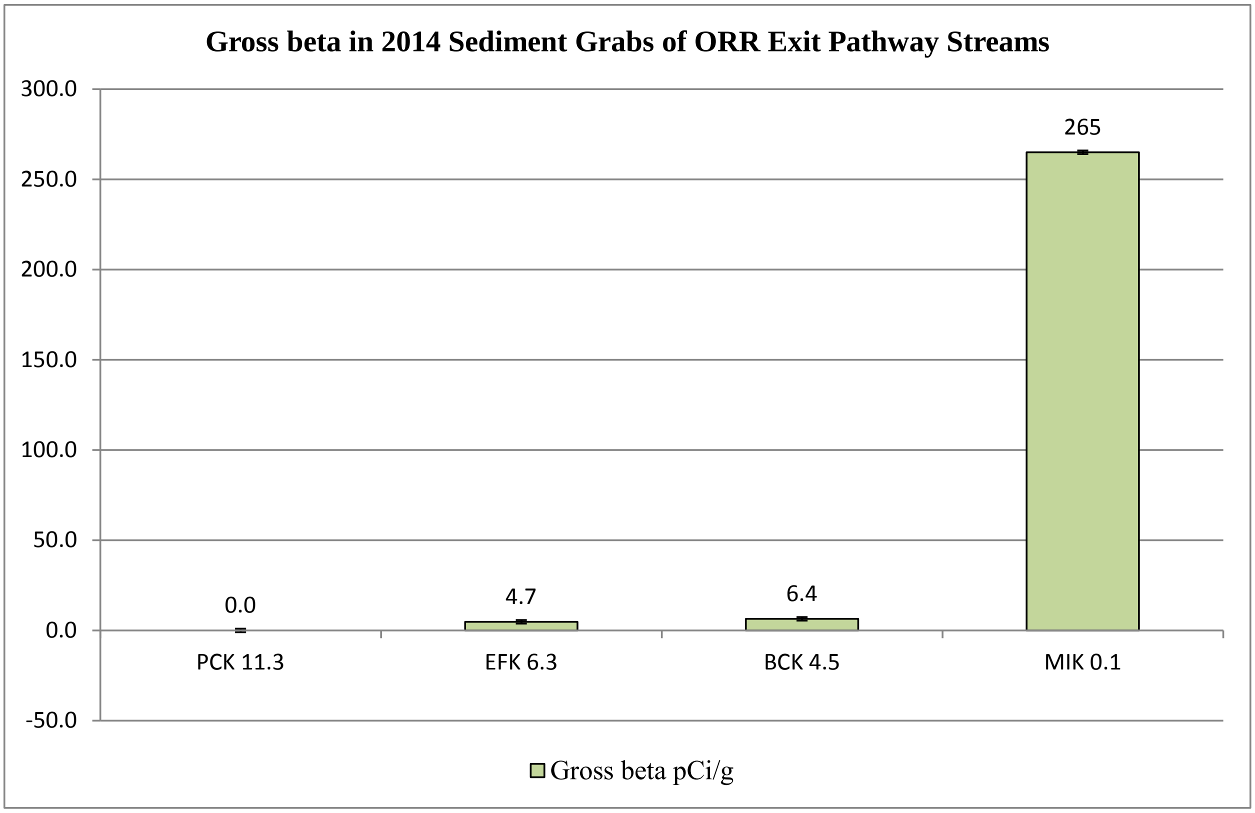

Figure 8: Gross beta in 2014 sediment grabs of ORR exit pathway streams

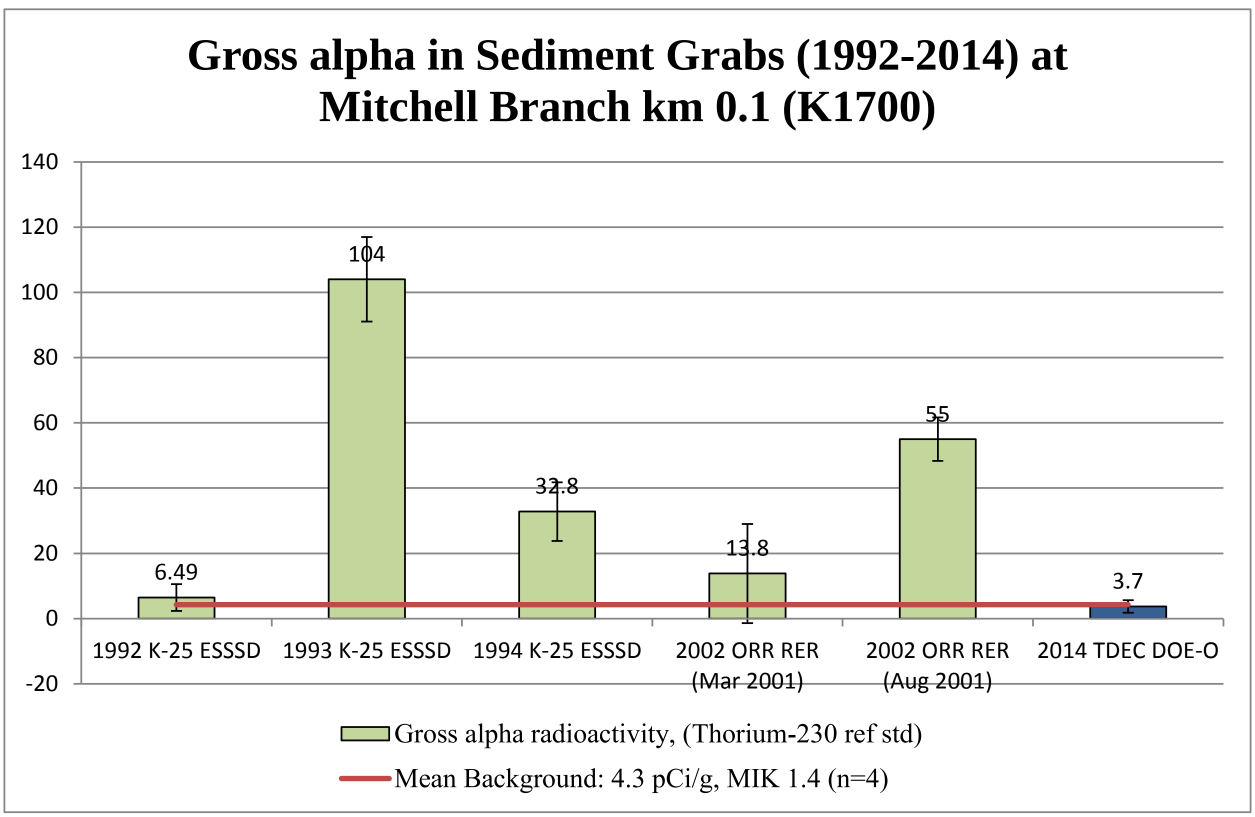

Figure 9: Gross alpha in sediment grabs (1992-2014) at Mitchell Branch km 0.1 (K1700)

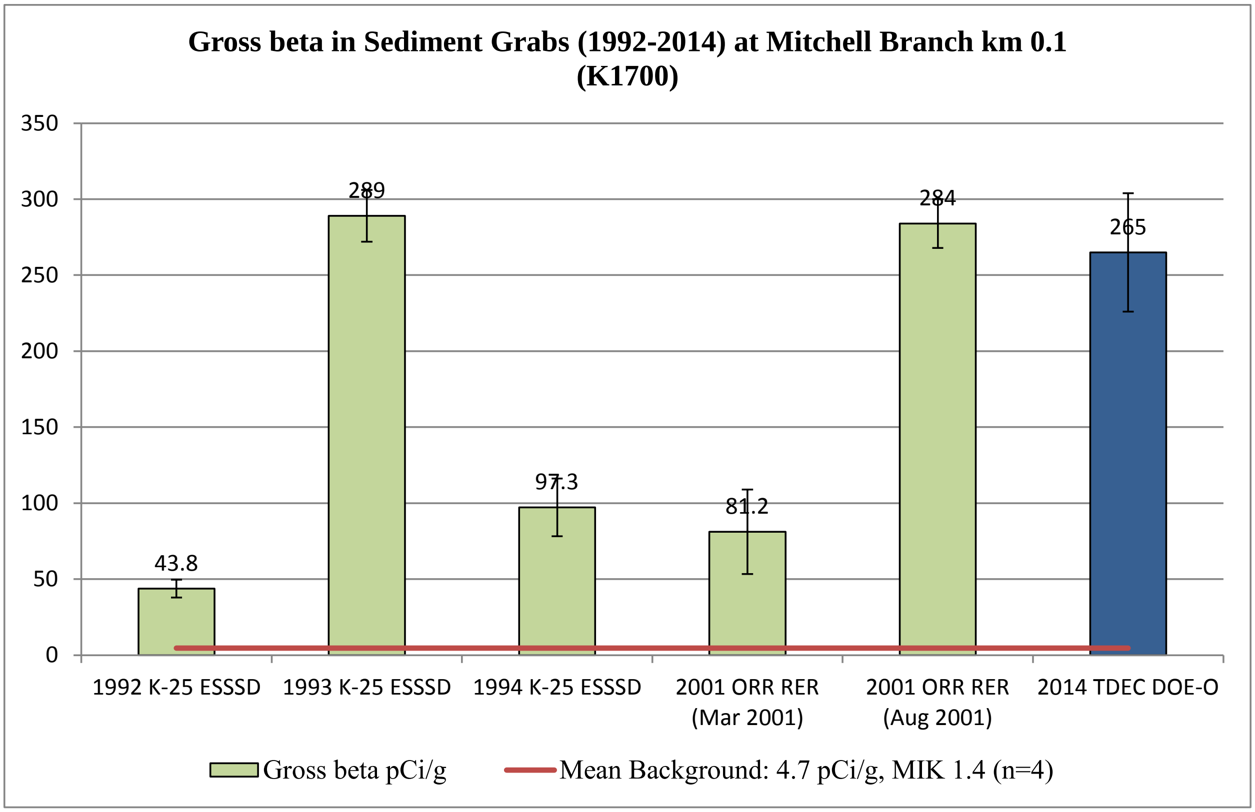

Figure 10: Gross beta in sediment grabs (1992-2014) at Mitchell Branch km 0.1 (K1700)

Conclusion

The East Fork Poplar Creek Mile 3.9 sediment mercury value (14 mg/kg) exceeds the PEC of 1.06 mg/kg (MacDonald *et al.* 2000). The mercury in East Fork Poplar Creek and Poplar Creek sediments results from historical activities at Y-12 and to a lesser extent ETTP. Figure 2 shows the effect of the East Fork Poplar Creek mercury contamination on the Clinch River sediments. East Fork Poplar Creek empties into Poplar Creek at Poplar Creek Mile 5.5; the mouth of Poplar Creek is at approximately Clinch River Mile (CRM) 12. Mercury levels are highest at East Fork Poplar Creek km 6.3 and generally decrease downstream. All of the sites sampled on East Fork Poplar Creek and Poplar Creek had mercury values above the PEC.

Historical data obtained from Oak Ridge Environmental Information System (OREIS), along with 2014 Tennessee Department of Environment and Conservation (TDEC) sediment data indicate that, sometime between 2004 and 2008, sediment mercury levels increased significantly at Mitchell Branch km 0.1 (K1700). Similarly, nickel, chromium, boron, and barium concentrations increased during the same time period at this location.

The radiological sediment data show no reason for human health concerns; all parameters are well below DOE PRGs. In 2014, Cs-137 was detected in both of the Clinch River samples and in the Mitchell Branch sample. The recreational PRG for Cs-137 is 117 pCi/g (total soil/sediment TR 1.0E-06) (DOE 2013). The highest Cs-137 value was 1.21 pCi/g at CRM 0.0. Gross beta activity was highest at the Mitchell Branch location (265 pCi/g). A chronological view of sediment gross alpha and beta activity shows strong variability.

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Surface Water (Physical Parameters) Monitoring

Principal Authors: John (Tab) Peryam and Wesley White

Abstract

Due to the presence of areas of extensive anthropogenic point and non-point source contamination on the Oak Ridge Reservation (ORR), there exists the potential for this pollution to impact surface waters on the ORR as well as offsite aquatic systems. The local karst topography and related structural geology influences the fate and transport of contaminants that may further degrade the groundwater and surface water quality of aquatic systems adjacent to the ORR. Therefore, during 2014, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-O, or office), collected ambient water quality data at six ORR stream locations and one offsite reference stream location. In addition, continuous water quality data loggers were installed in Upper East Fork Poplar Creek and Bear Creek to observe water quality parameters to determine temporal trends.

Introduction

Two separate tasks are covered with the surface water physical parameter monitoring program. The tasks include the 1) discrete ambient surface water physical monitoring and 2) a continuous surface water physical monitoring.

Discrete Ambient Surface Water Physical Monitoring

The first task was to collect discrete ambient water quality monitoring data at seven stream sites located in several watersheds during 2014. The main ORR watersheds include portions of East Fork Poplar Creek, Bear Creek, and Mitchell Branch. Field data was also collected from Mill Branch, a small reference stream located in the City of Oak Ridge. The EFK (East Fork Poplar Creek) 13.8 km monitoring site is located outside the ORR. Specifically, it is located approximately ten kilometers (km) downstream of the Y-12 National Security Complex. The project objectives were to create a baseline of water quality monitoring data and physical stream parameters (which were measured on a monthly basis) and to determine possible water quality impairment issues. Furthermore, this monitoring task was directed toward determining long-term water quality trends, assessing attainment of water quality standards and providing background data for evaluating stream recovery due to toxicity stressors. Table 1 and Figure 1 show locations that were selected for data collection. Figure 2 shows TDEC staff conducting monitoring on the ORR.

Table 1: Discrete Ambient Surface Water Physical Monitoring Locations in Kilometers (mile equivalents)

Site	Location
EFK 23.4 (14.5)	East Fork Poplar Creek (near Y-12 east gate)
BCK 12.3 (7.6)	Bear Creek (near Y-12 west gate)
BCK 9.6 (6.0)	Bear Creek (near Walk-in Pits)
BCK 4.5 (2.8)	Bear Creek (Weir at Hwy. 95)
MIK 0.1 (0.06)	Mitchell Branch (Weir at ETTP)
EFK 13.8 (8.6)	East Fork Poplar Creek (near Big Turtle Park)
MBK 1.6 (1.0)	Mill Branch (Reference)

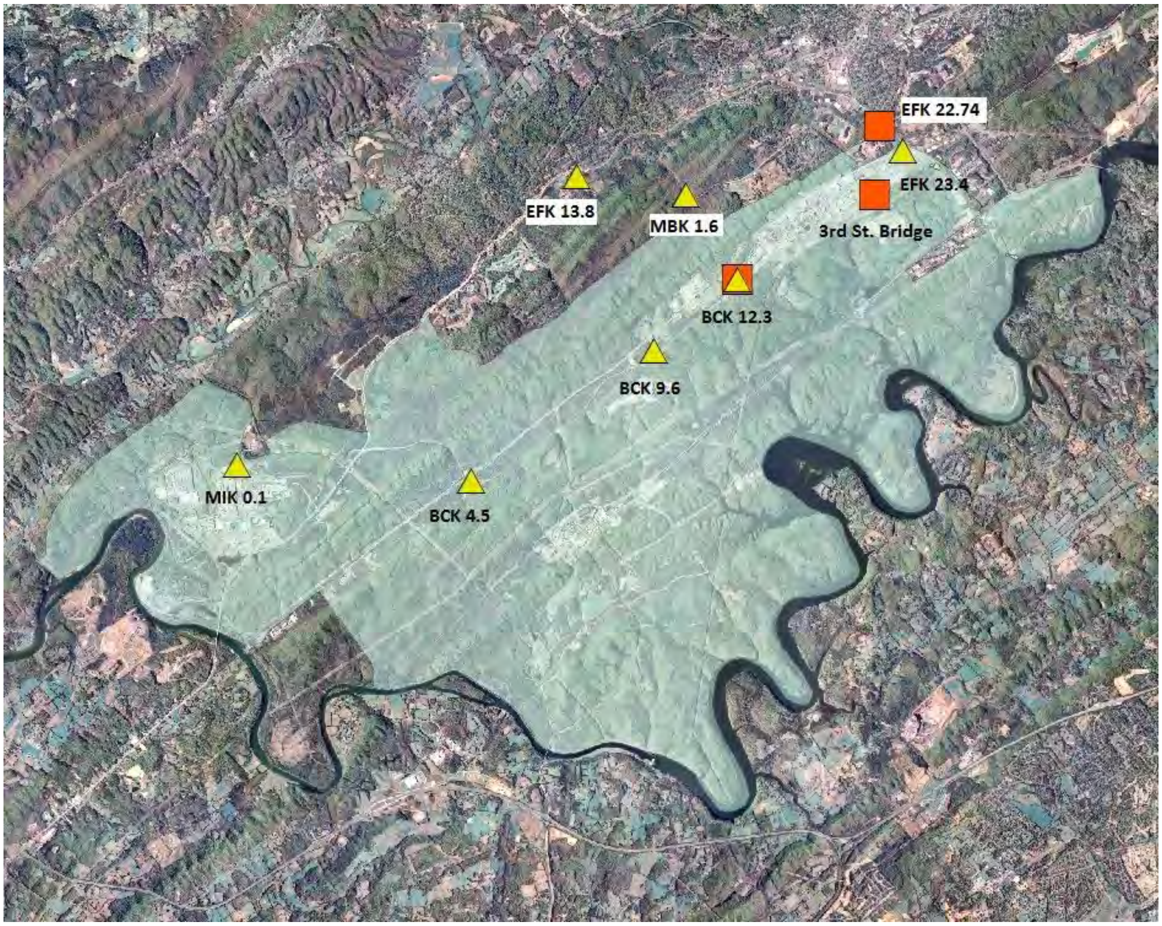


Figure 1: Oak Ridge Reservation Physical Parameter Monitoring Locations

△ Discrete Monitoring Locations
■ Continuous Monitoring Locations

Continuous Surface Water Physical Monitoring

The surface water exiting the Y-12 facility has shown a need to be monitored with greater detail. Three continuous locations were placed around Y-12 (Figure 1). Two monitoring locations are on East Fork Poplar Creek (EFPC) and a third monitoring location is on Bear Creek. The EFPC locations were selected to monitor the creek after the augmentation water was discontinued in 2014, and to determine a baseline prior to any mercury abatement work at outfall 200. The Bear Creek location was installed after reviewing the discrete data from BC 12.3. This location has shown to be impacted and there is a need to understand its temporal trends with regard to water quality.

Table 2: Continuous Surface Water Physical Monitoring Locations in Kilometers (mile equivalents)

Site	Location
Third Street Bridge [EFK 24.9 (15.5)]	East Fork Poplar Creek (at the Third Street Bridge)
EFK 22.74 (14.1)	Bear Creek (off site – water exiting Y-12)
BCK 12.3 (7.6)	Bear Creek (water exiting Y-12)

Methods and Materials

Discrete Ambient Surface Water Physical Monitoring

The measured parameters were temperature, pH, conductivity, and dissolved oxygen. Both YSI 556 MPS and YSI Professional Plus multi-parameter water quality instruments were used to collect the data. The instruments were calibrated prior to operation in the field. During each stream examination, the data was recorded in a field notebook including time, date and weather conditions. Unusual occurrences relating to stream conditions were noted.

In the event that field readings such as pH and conductivity were beyond benchmark ranges, 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 office to determine if further action is needed. Field and monitoring methods, and health and safety procedures were followed per the Tennessee Department of Health's Standard Operating Procedures (TDH 1999), and the TDEC DOE-O Health, Safety, and Security Plan (Yard 2014).

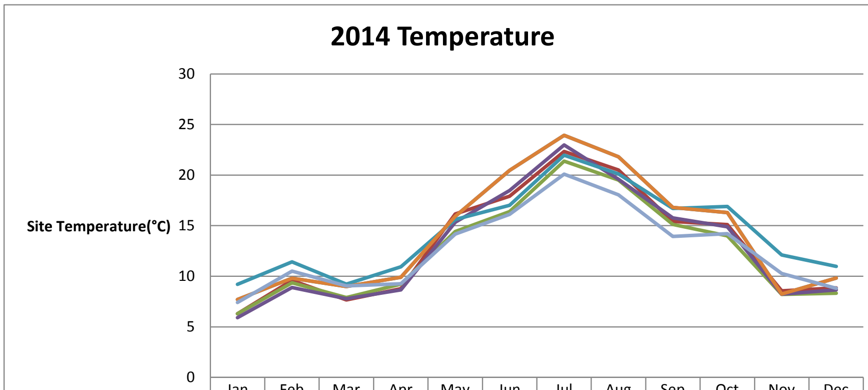
Continuous Surface Water Physical Monitoring

Continuous water quality parameters were taken at three locations at Y-12 along UEFPC. Water quality parameters were collected utilizing an In-Situ® Troll 9500 multiparameter water quality monitoring probe. An YSI-556/YSI Professional Plus was used periodically to check the performance of the In-Situ® Troll 9500. The continuous data is plotted with precipitation data collected from the nearest meteorological tower.

Results and Discussion

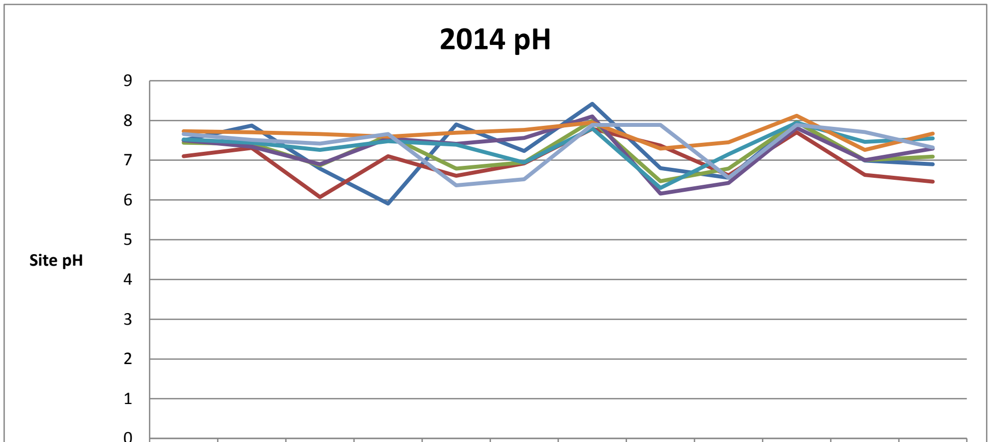
Discrete Ambient Surface Water Physical Monitoring

Field data was collected on a monthly basis from the seven monitoring sites. Figures 4 thru 7 provide monthly temperature, pH, conductivity, and dissolved oxygen data.



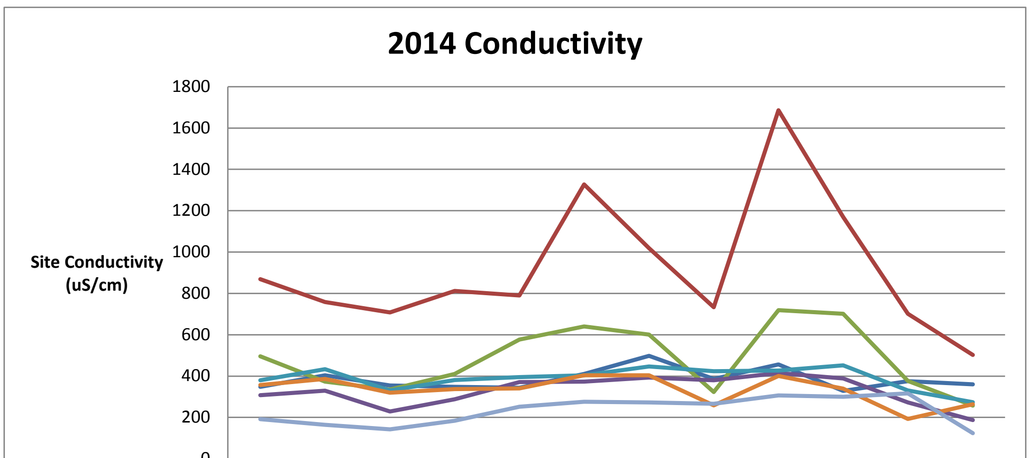
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFK 23.4	7.7	9.8	8.99	9.91	15.92	20.47	23.94	21.81	16.8	16.3	8.25	9.83
BCK 12.3	6.3	9.59	7.66	8.78	16.15	17.92	22.33	20.5	15.42	15.1	8.56	8.84
BCK 9.6	6.3	9.36	7.89	9.21	14.42	16.4	21.37	19.51	15.13	14	8.2	8.32
BCK 4.5	5.9	8.88	7.78	8.66	15.34	18.48	22.97	19.59	15.77	14.9	8.22	8.66
MIK 0.1	9.2	11.42	9.22	10.94	15.62	17.01	21.97	20.11	16.71	16.9	12.11	10.97
EFK 13.8	7.7	9.8	8.99	9.91	15.92	20.47	23.94	21.81	16.8	16.3	8.25	9.83
MBK 1.6	7.4	10.51	9.05	9.26	14.16	16.11	20.1	18.04	13.93	14.2	10.27	8.82

Figure 4: 2014 Monthly Site Temperature



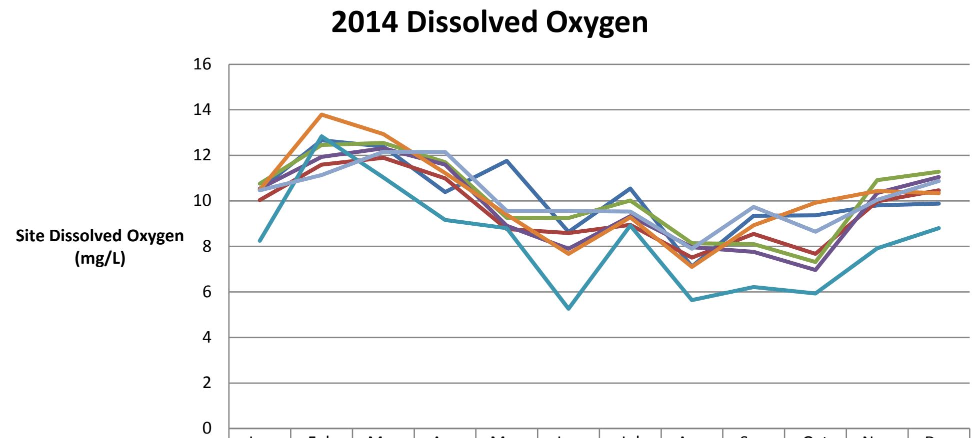
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFK 23.4	7.5	7.87	6.79	5.91	7.9	7.23	8.42	6.8	6.56	7.96	6.99	6.9
BCK 12.3	7.1	7.31	6.07	7.1	6.61	6.92	7.79	7.37	6.62	7.7	6.63	6.46
BCK 9.6	7.44	7.41	6.87	7.62	6.79	6.95	7.99	6.47	6.79	7.96	7	7.09
BCK 4.5	7.5	7.34	6.9	7.55	7.41	7.56	8.1	6.16	6.43	7.81	7	7.29
MIK 0.1	7.52	7.44	7.26	7.48	7.39	6.94	7.8	6.3	7.15	7.94	7.46	7.55
EFK 13.8	7.73	7.7	7.66	7.59	7.69	7.76	7.95	7.29	7.45	8.12	7.26	7.67
MBK 1.6	7.66	7.51	7.42	7.66	6.37	6.52	7.89	7.89	6.56	7.89	7.71	7.32

Figure 5: 2014 Monthly Site pH



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFK 23.4	348	404	355	348	344	410	498	387	456	329	376	360
BCK 12.3	869	758	708	812	790	1327	1019	733	1686	1170	701	502
BCK 9.6	495.4	373	335	410	577	640	601	323	719	701	377	257
BCK 4.5	308	330	229	288	371	373	393	380	415	389	273	187
MIK 0.1	380	433	331	381	395	404	447	424	427	452	331	274
EFK 13.8	356.9	386	320	337	341	404	404	258	401	339	193	264
MBK 1.6	192.3	164	143	184	252	276	273	266	307	300	317	124

Figure 6: 2014 Monthly Site Conductivity



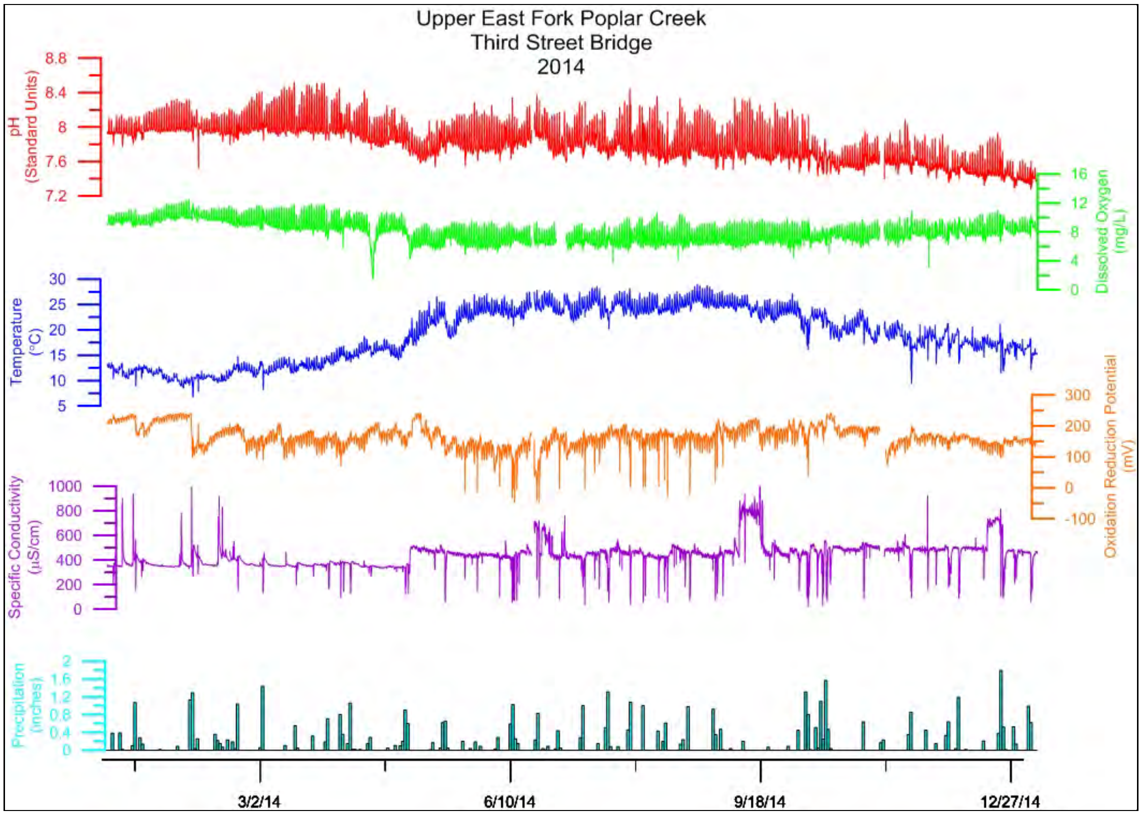
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFK 23.4	10.5	12.66	12.39	10.39	11.76	8.64	10.54	7.12	9.35	9.37	9.8	9.88
BCK 12.3	10.04	11.59	11.89	10.99	8.76	8.59	8.95	7.51	8.55	7.67	9.98	10.46
BCK 9.6	10.76	12.46	12.55	11.7	9.26	9.25	10.02	8.14	8.1	7.31	10.91	11.28
BCK 4.5	10.54	11.93	12.31	11.59	8.91	7.9	9.33	7.97	7.76	6.96	10.35	11.05
MIK 0.1	8.25	12.84	11.03	9.16	8.8	5.26	8.92	5.64	6.22	5.93	7.92	8.8
EFK 13.8	10.48	13.79	12.93	11.22	9.4	7.67	9.28	7.1	8.93	9.92	10.44	10.34
MBK 1.6	10.46	11.14	12.16	12.15	9.56	9.56	9.53	7.9	9.74	8.65	10.05	10.87

Figure 7: 2014 Monthly Site Dissolved Oxygen

Sites BCK 12.3, BCK 9.6, and BCK 4.5 (all in Bear Creek) continue to consistently exhibit elevated conductivity values. There is no Tennessee General Water Quality Criteria for Fish and Aquatic Life for conductivity. Elevated conductivity levels indicate elevated nutrient levels which suggest degraded surface water quality in Bear Creek. All three Bear Creek sites are located downstream and to the west of the legacy capped S-3 nitric acid holding ponds and the Y-12 West End water treatment facility. The S-3 capped ponds are very close to the headwaters of Bear Creek. Site BCK 12.3 is the closest site to the headwaters of Bear Creek and is located within the western area of the Y-12 complex. Site BCK 9.6 is located approximately 1 mile to the west of BCK 12.3, and site BCK 4.5 is located approximately two miles to the west of site BCK 12.3. One observes the elevated conductivity values to decrease as one travels further downstream and to the west of site BCK 12.3. It is believed that the legacy S-3 capped nitric acid holding ponds have created a groundwater plume of nutrients (likely nitrogen compounds) which has traveled to the west and migrated to the head waters of Bear Creek. It is highly likely that this groundwater nutrient/nitrogen compound plume has migrated into the surface water thus causing the elevated conductivity values in Bear Creek.

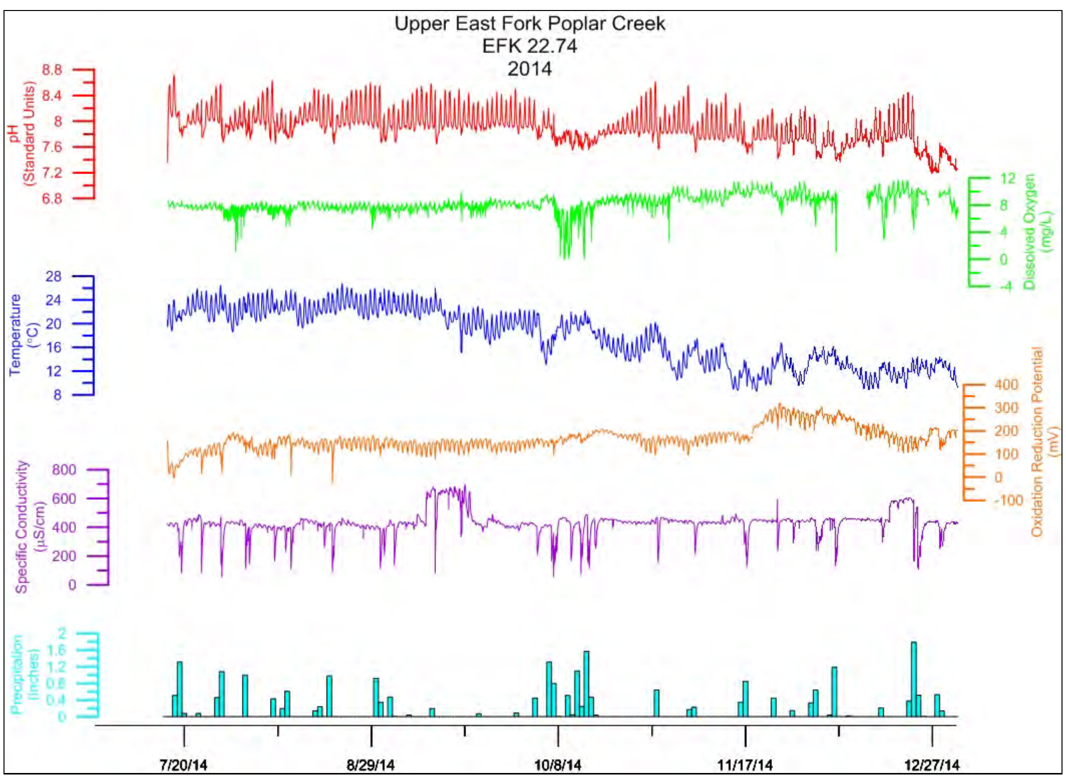
Continuous Surface Water Physical Monitoring

Data downloads and weekly checks were collected at the three continuous monitoring sites. Figures 8 thru 10 provide temperature, pH, specific conductivity, dissolved oxygen, and oxidation reduction potential data along Upper East Fork Poplar Creek at Third Street Bridge and EFK 22.74, and Bear Creek (BCK 12.3), respectively.



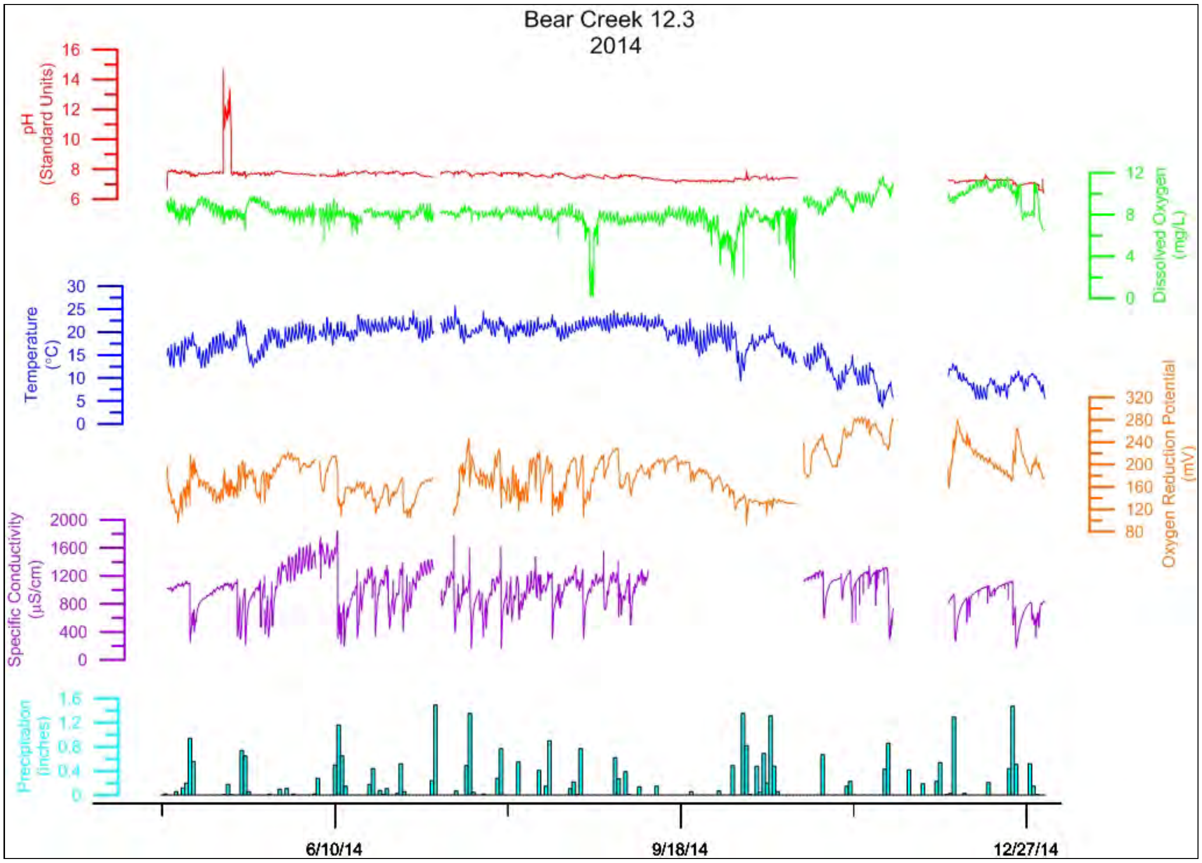
C –Centigrade; **mg/L** – milligrams per liter; **mv** = millivolts; **µS/cm** – microSiemens per centimeter

Figure 8: Water Quality Parameters (temperature, pH, DO, specific conductivity, and ORP) along Upper East Fork Poplar Creek at Third Street Bridge



C –Centigrade; **mg/L** – milligrams per liter; **mv** = millivolts; **µS/cm** – microSiemens per centimeter

Figure 9: Water Quality Parameters (temperature, pH, DO, specific conductivity, and ORP) along Upper East Fork Poplar Creek at EFK 22.74



C –Centigrade; **mg/L** – milligrams per liter; **mv** = millivolts; **µS/cm** – microSiemens per centimeter

Figure 10: Water Quality Parameters (temperature, pH, DO, specific conductivity, and ORP) at Bear Creek (BCK 12.3)

Upper East Fork Poplar Creek at Third Street Bridge

As shown in Figure 8, there are diurnal cycle for temperature, pH, ORP, and DO. There are observed decreases in conductivity during rain events along with increases in conductivity due to runoff caused by the salting of roadways during cold weather events in November, January, and February. There were three other anomalous conductivity events in June, September, and December that seemed to last for a prolonged period. The cause of the anomalous conductivity events is currently unknown and it may be due to changes in the groundwater system that feeds the springs. Upper East Fork Poplar Creek is spring-fed with no surface water augmentation. The temperature variations seem consistent with seasonal variations, which are understated due to the thermal properties of the spring water. Dissolved oxygen shows there is a consistent amount of oxygen in the system. However, in April 2014 a dip of DO was observed. The cause of this dip in DO has not been identified. None of the anomalous specific conductivity or DO readings were associated with fish kills or known discharges to the Creek.

Upper East Fork Poplar Creek at EFK 22.74

This station was first installed on July 16, 2014. This station is downstream from the Third Street Bridge location, serves for data verification and helps tracks stream recovery along EFPC. As shown in Figure 9, there are diurnal cycles for temperature, pH, ORP, and DO. The same anomalous-specific conductivity events were recorded in September and December. The dissolved oxygen readings recorded several decreases that were associated with sedimentation covering the DO sensor and not water quality. The temperature readings have greater variations due to the distance from the springs and the location is influenced from other surface water features.

Bear Creek at BCK 12.3

This station was first installed on April 22, 2014. As shown in Figure 10, there are diurnal cycles for temperature, pH, ORP, and DO. There was an anomalous spike in pH on May 8 through May 10. The pH sensor was later checked and the sensor passed all checks and calibrations. However, it should be noted that two additional spikes were observed. The pH sensors showed a failure after those spikes and the questionable data was removed from the graphs. There are different theories on the cause of the pH spikes and/or the failure of the sensors that recorded a spike that will be tested next year with the placement of two water quality data loggers at this location. If both data loggers record a pH spike, then the data is real, if only one data logger records a pH spike, then it is a sensor failure. Dissolved oxygen shows there is a consistent amount of oxygen in the system. Dips in the DO data were caused by sedimentation build up after rain events that covered up the DO sensor. BC 12.3 location is impacted by high specific conductivity from the S-3 pond area. Dips in conductivity are only recorded during rain events. Highest conductivity was observed during periods of low precipitation. The conductivity probe malfunctioned in September/October due to heavy bio-fouling of the sensor. The sensor had to be cleaned beyond the routine maintenance in order to remove the bio-fouling and to restore proper sensor performance. The questionable specific conductivity data was removed from the graphs. The ORP data is inconsistent with differing responses due to precipitation, conductivity, pH, and DO. This variability in ORP could be due to the S-3 area. However, further work with multiple data loggers at this location will have to be done to verify that response.

Conclusion

For the surface water physical parameters data, all samples met Tennessee water quality criteria for the parameters observed at the seven monitoring stations on the ORR. The elevated conductivity values observed in Bear Creek are of concern. As legacy DOE ORR pollution has negatively impacted East Fork Poplar Creek, Bear Creek, and Mitchell Branch, continued physical parameter monitoring is justified and needed at the seven monitoring creek stations.

The continuous monitoring of the physical parameters is providing a baseline of water quality parameters for how they react to changes in precipitation and other inputs along EFPC and Bear Creek. The continuous monitoring of water quality parameters has shown a potential to document conditions that may need to be addressed in the near future. There are some potential conditions that need to be confirmed along Bear Creek; additional work next year will place a confirmation data logger to determine if the pH exceedances are real and not a malfunctioning pH sensor. The office continues to monitor the streams at Y-12 to determine if fish kills or other discharges can be associated with continuous monitoring.

References

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Yard, C.R. Health, Safety, and Security Plan. Tennessee Department of Environment and Conservation, Department of Energy Oversight Office. Oak Ridge, Tennessee. 2014.

Ambient Trapped Sediment Monitoring

Principle Author: John (Tab) Peryam

Abstract

In order to monitor for changes in contaminant flow through sediment transport, passive sediment samplers (traps) were deployed at six locations: Bear Creek km (BCK) 4.5, BCK 12.3, Bear Creek North Tributary 5 (NT5), East Fork Poplar Creek km (EFK) 23.4, EFK 13.8 and EFK 6.3.

All of the samples from East Fork Poplar Creek exceeded the consensus-based sediment quality guidelines (CBSQGs) Probable Effects Concentration (PEC) (1.06 mg/kg) for mercury. 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). The CBSQGs are considered to be 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 (Ingersoll *et al.* 2000). East Fork Poplar Creek and Bear Creek mercury sediment concentrations generally decrease as one travels downstream. Conversely, the proportion of methyl mercury relative to total mercury in each sample increases downstream at both streams. The general trend for other metals (arsenic, uranium, barium, boron, chromium, nickel) at East Fork Poplar Creek is to decrease as one travels downstream from Y-12. The sample collected at BCK 4.5 provided only enough sediment to run total mercury/methyl mercury analyses, so the downstream trend for these metals has not yet been determined for Bear Creek.

Gross alpha and beta values were in normal range and do not indicate contamination. All of the gamma radionuclides detected were naturally-occurring and do not pose a threat to human health. Slight uranium-235 enrichment at the NT-5 sampling location is suggested by the data; other sampling locations did not show U-235 enrichment.

Introduction

Sediment is an important part of aquatic ecosystems. Many aquatic organisms depend on sediment for habitat, sustenance, and reproduction. Sediment is also a depository for contaminants such as metals, radionuclides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and agricultural chemicals. Concentrations of contaminants can be much higher than that 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. Past sediment sampling activities by the Tennessee Department of Environment and Conservation, Department of Energy Oversight (TDEC DOE-O) have shown that Poplar Creek has elevated levels of mercury in sediments. This mercury can be attributed to historical discharges from Y-12, and, to a lesser extent, from East Tennessee Technology Park (ETTP). This project focuses on the sediments that are currently being transported in East Fork Poplar Creek (EFPC), Bear Creek and North Tributary 5 (NT5) by utilizing passive sediment collectors.

Methods and Materials

Sediment traps were deployed at the following approximate stream locations: East Fork Poplar Creek km (EFK) 6.3, 13.8, 23.4, Bear Creek km (BCK) 4.5, 7.6 and at NT5 (Figure 1). The sediment traps were modeled after a design described by Phillips *et al.* (2000) (Figure 2). Figure 3 shows one of the sediment traps; the body is constructed of 4" polyvinyl chloride (PVC) pipe with 4" fittings. The other fitments of the trap are common items available in most hardware stores. The sediment traps are fastened to the stream bed with metal stakes; traps are oriented horizontally in an orientation parallel to the flow of the current (Figure 4). Safety caps constructed of PVC pipe are attached to tops of the metal stakes. Once deployed, the sediment traps are visited weekly for maintenance: debris is removed from the sediment trap and the inlet and outlet tubes are cleared of algae and biofilm with a brush. If stream conditions have changed such that the sediment trap is no longer functioning properly, the trap may be moved to a more suitable location in the same general area of the stream.

All of the traps were deployed for approximately six months, from May 14th to November 4th. The East Fork Poplar Creek traps, however, were sampled two times in 2014; their initial deployment was from February 6th to May 14th. They were re-deployed at the same location on May 14th, after the contents were harvested for analysis.

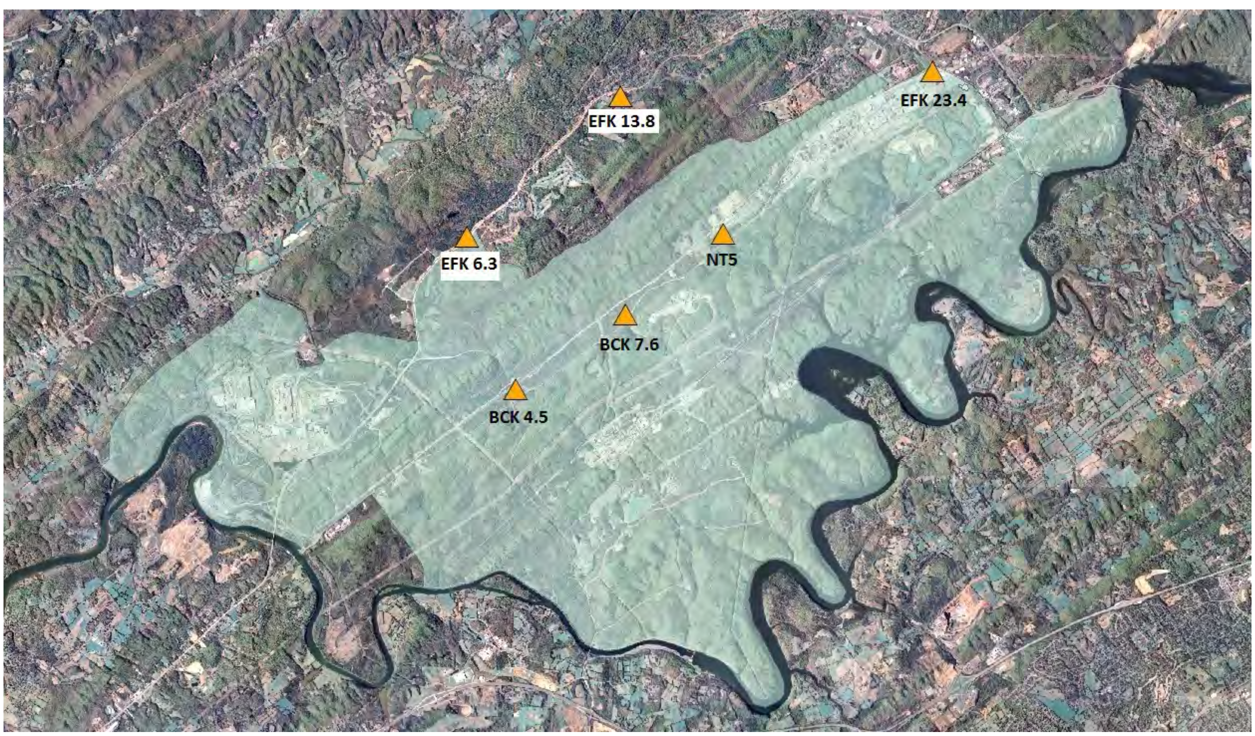
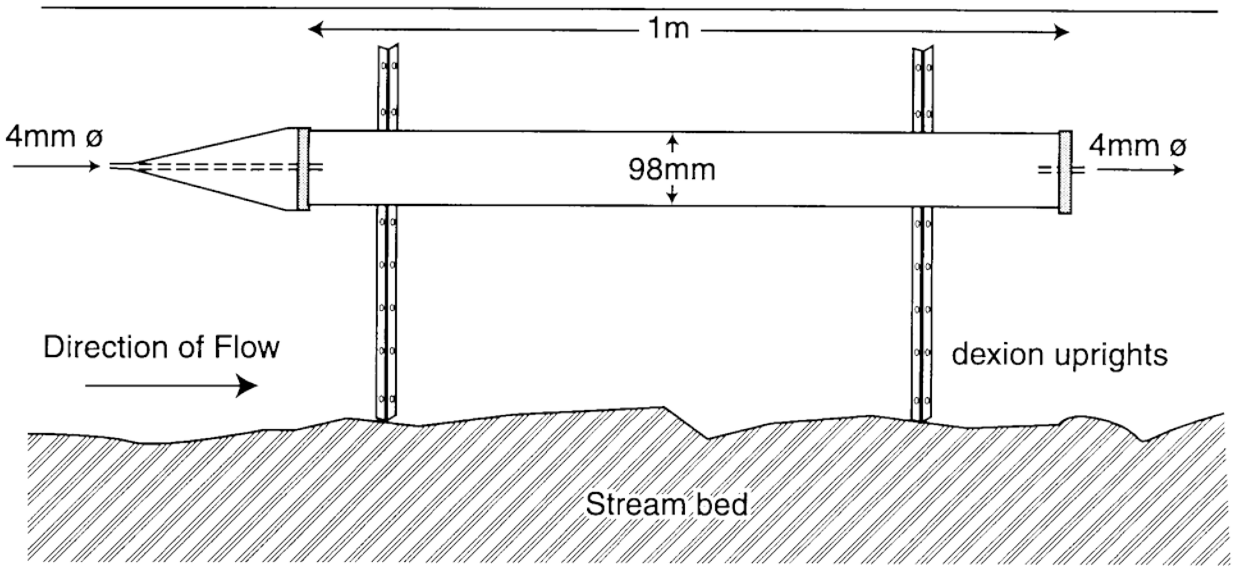


Figure 1: Sampling Site Locations



Phillips *et al.* (2000)

Figure 2: Sediment trap design

Figure 3: Photo of Sediment Trap

Figure 4: Sediment trap deployed

Results
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 effects on benthic macroinvertebrate species only (WDNR 2003). The CBSQGs are considered to be 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 (Ingersoll *et al.* 2000).

The three sediment traps at EFPC were sampled twice in 2014; the first deployment period was from 2/6/2014 to 5/14/2014 and the second deployment period was from 5/14/2014 to 11/4/2014. Analysis for the first deployment did not include methyl mercury, but it was added to the list of analytes for the second deployment. Figure 5 shows the total mercury results for the two sampling events at EFPC; the two sampling events show consistent results and readings decrease downstream from EFK 23.4. All East Fork Poplar Creek samples exceed the PEC for mercury (1.06 mg/kg). A background value of 0.04 mg/kg from Hinds Creek km 20.6 is used for comparison. Figure 6 shows the relative abundance of total mercury and methyl mercury at the three sampling sites on East Fork Poplar Creek; methyl mercury increases relative to the total mercury concentration as one travels downstream. This is similar to what is observed on Bear

Creek; as one travels downstream the ratio of methyl mercury to total mercury increases (Figure 6). The methyl mercury level at Bear Creek km 4.5 is almost as high (1.43 ng/g) as the methyl mercury level (1.52 ng/g) at East Fork Poplar Creek km 23.4. NT-5 total and methyl mercury results are shown in figure 6; results are less than the CBSQG PEC for total mercury. There is not a PEC for methyl mercury at the present time.

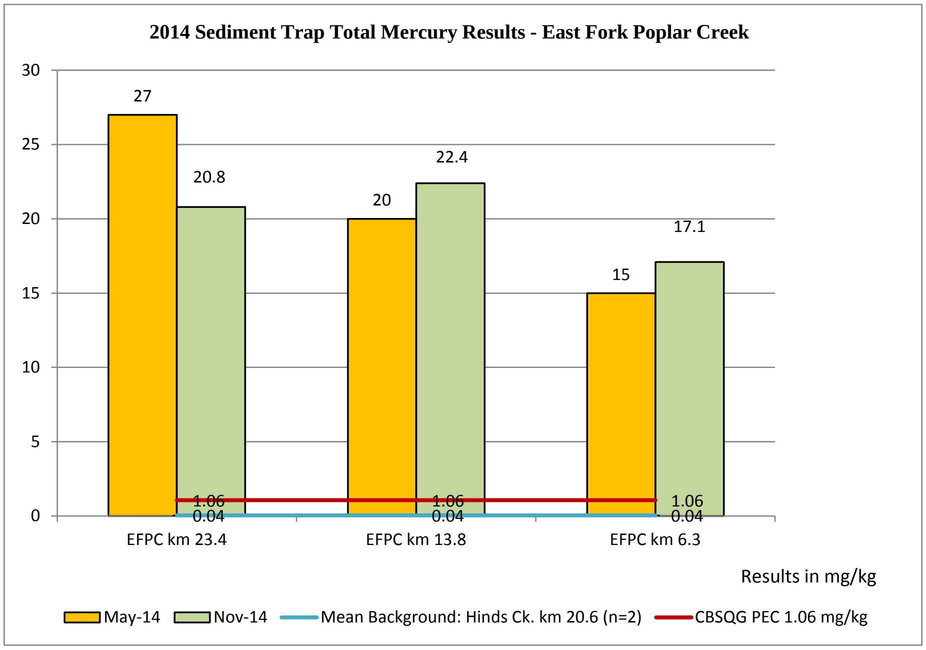


Figure 5: 2014 East Fork Poplar Creek Total Mercury Results

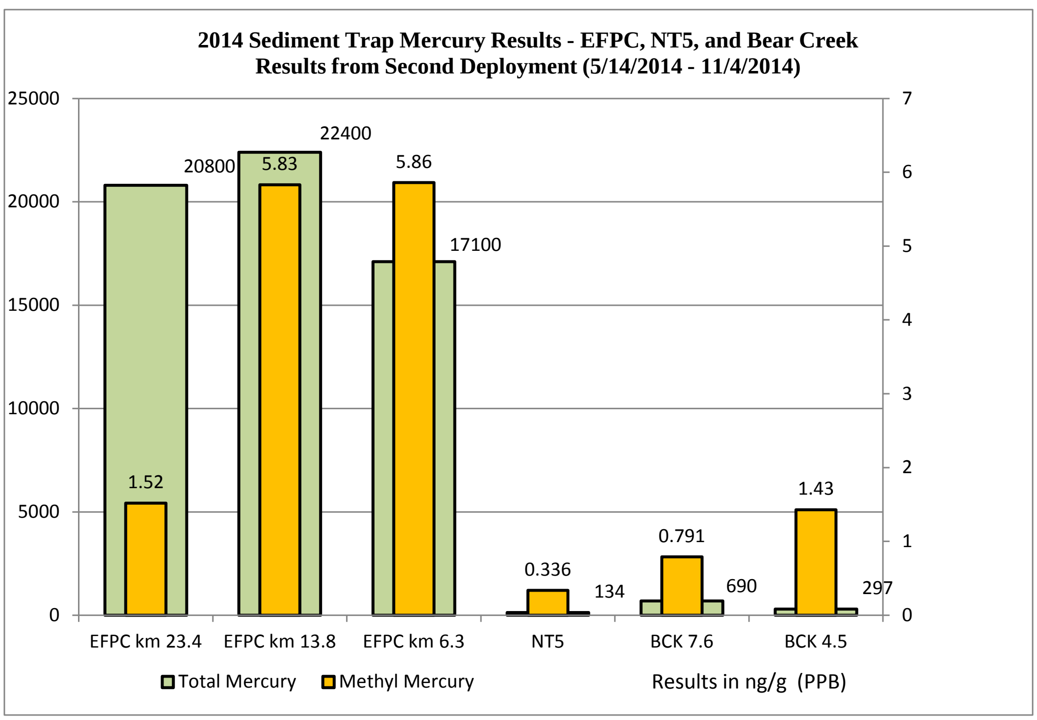


Figure 6: 2014 Bear Creek, NT5, and East Fork Poplar Creek Total and Methyl Mercury Results

Total uranium results are shown in Figure 7; uranium concentrations are higher at EFK 23.4 than at the two downstream sampling locations. Oak Ridge National Laboratory (ORNL) sediment data (1994-1996) was obtained from the Oak Ridge Environmental Information System (OREIS) for comparison to TDEC data at EFPC km 6.3. The orange bars labeled May-14 represent data from the first deployment of the sediment traps at EFPC; the traps were deployed from February 6, 2014 to May 14, 2014. The green bars labeled Nov-14 show the data from the second deployment (May 14, 2014 to November 4, 2014).

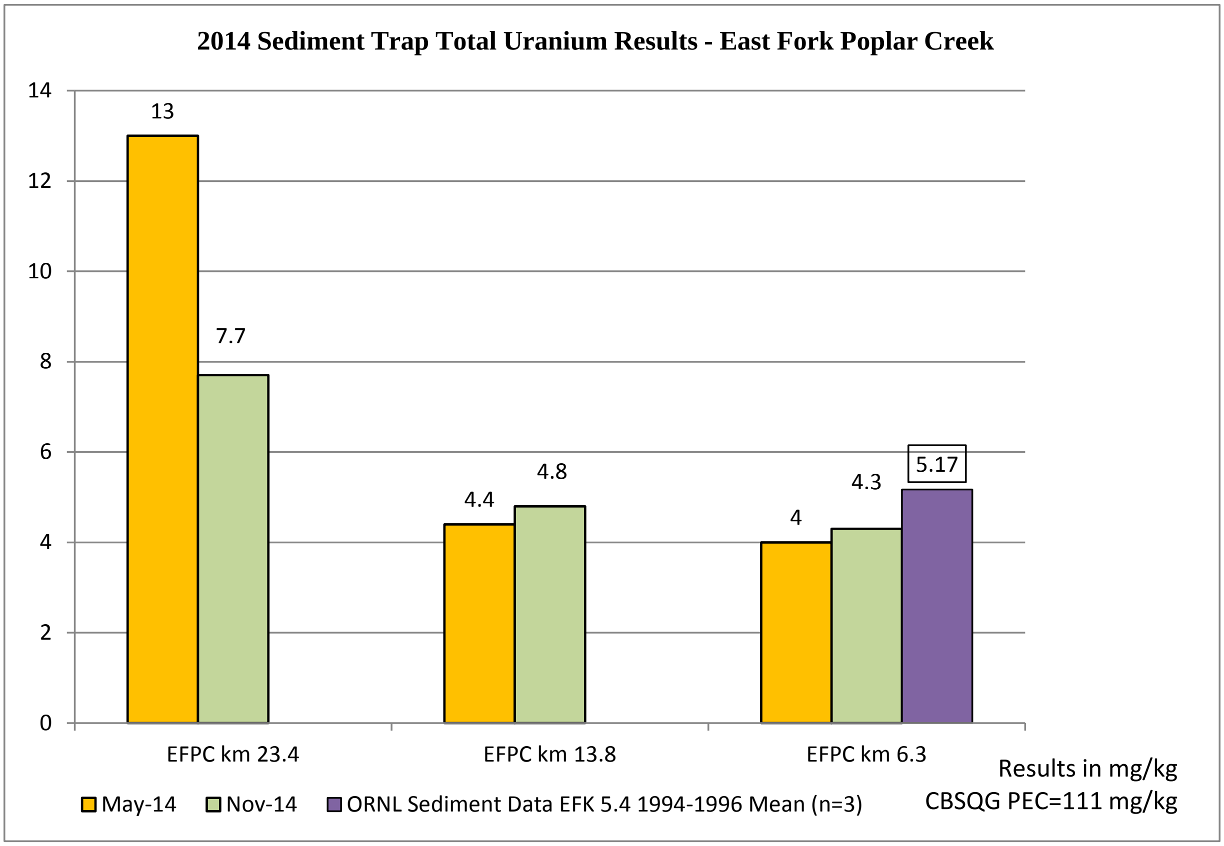


Figure 7: Sediment Trap Total Uranium Results – East Fork Poplar Creek

Figure 8 shows the downward gradient of EFPC arsenic concentrations at the three sampling sites as one goes downstream from Y-12, much like the graphs of the barium (Figure 9), chromium (Figure 10), boron (Figure 11), and nickel (Figure 12). The boron results do show a slight downward gradient downstream of Y-12, but the drop is not as pronounced as with the other metals mentioned (Figure 11). Background sediment nickel data from Clear Creek (n=8) in Anderson County is displayed in Figure 14; all of the EFPC nickel values are less than the CBSQG PEC of 48.6 mg/kg, but are considerably above background.

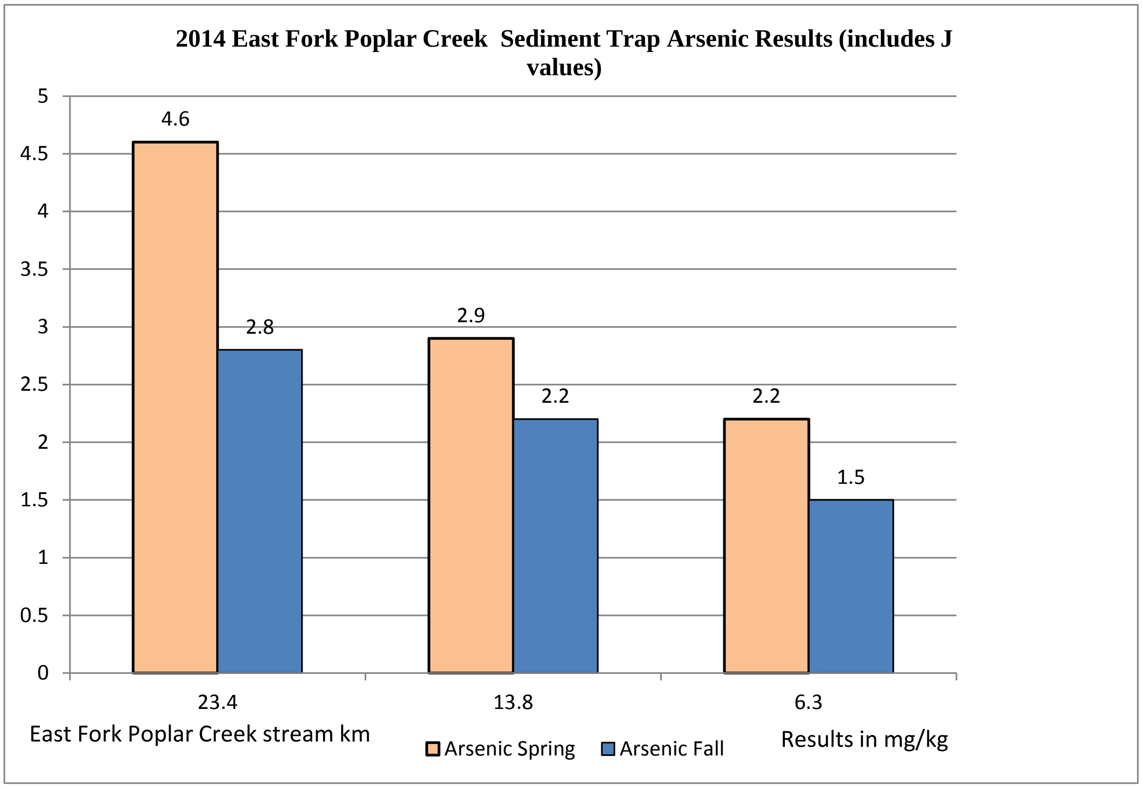


Figure 8: Sediment Trap Arsenic Results - East Fork Poplar Creek

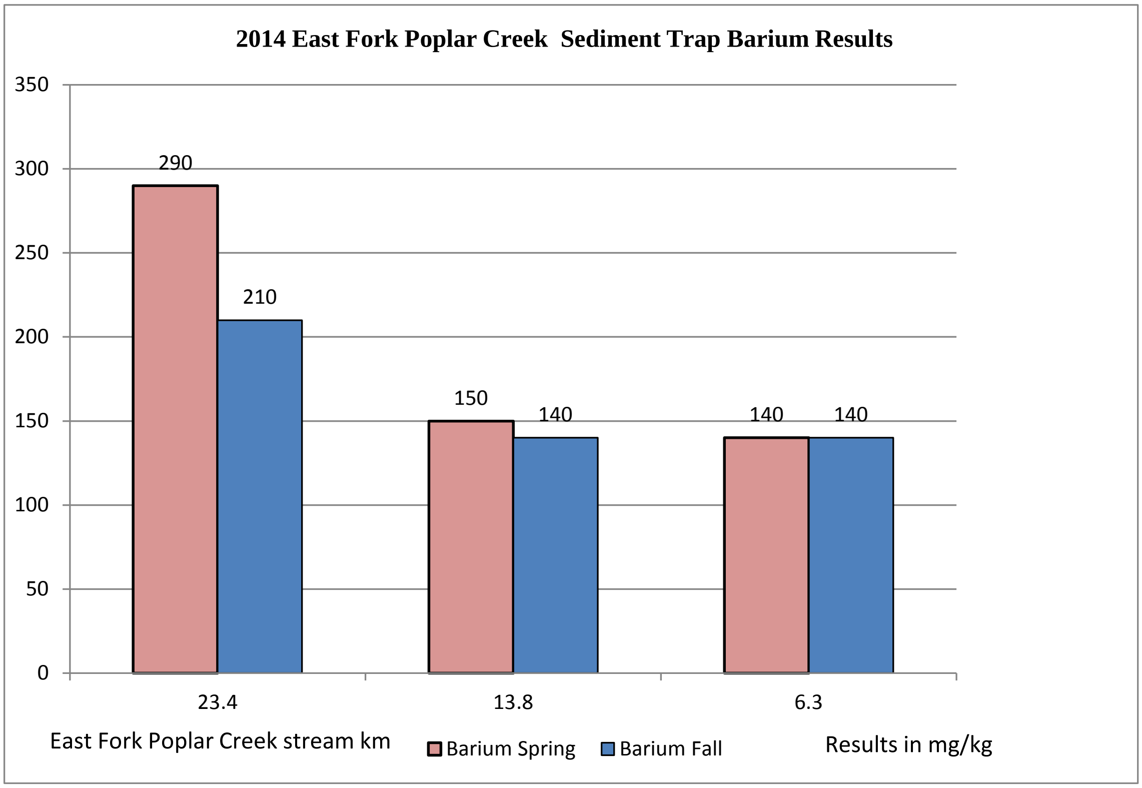


Figure 9: East Fork Poplar Creek Sediment Trap Barium Results

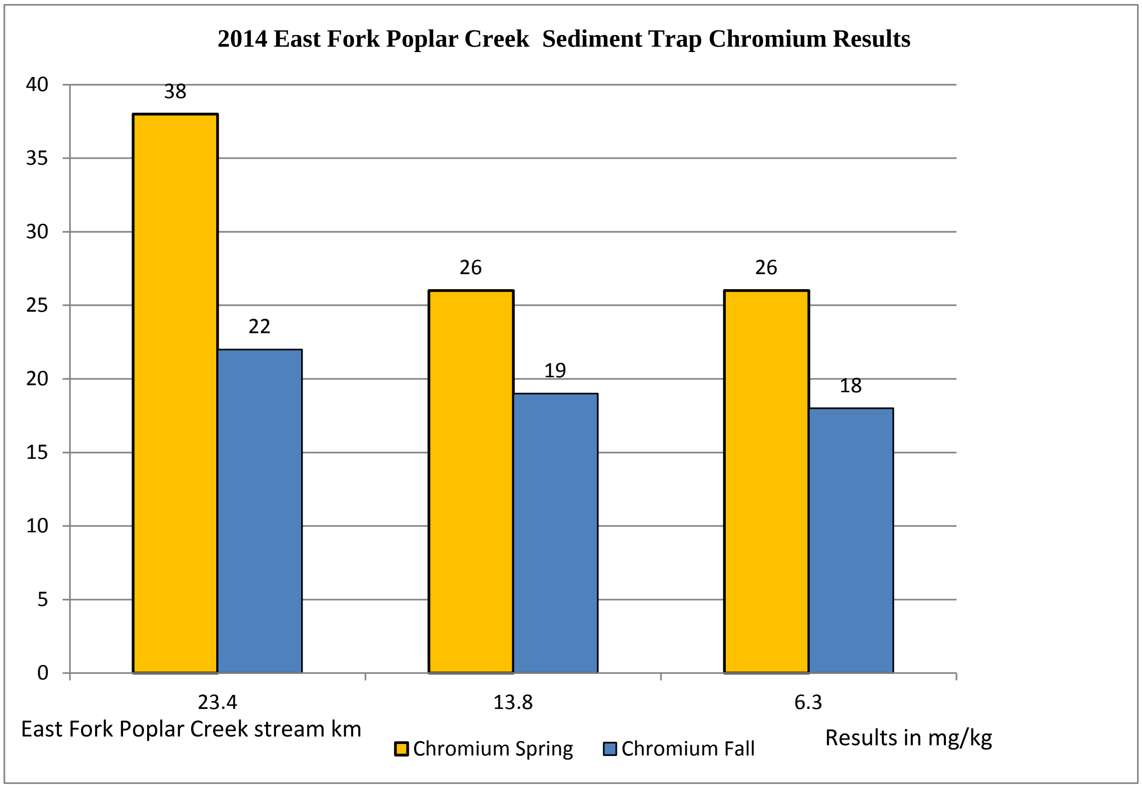


Figure 10: East Fork Poplar Creek Sediment Trap Chromium Results

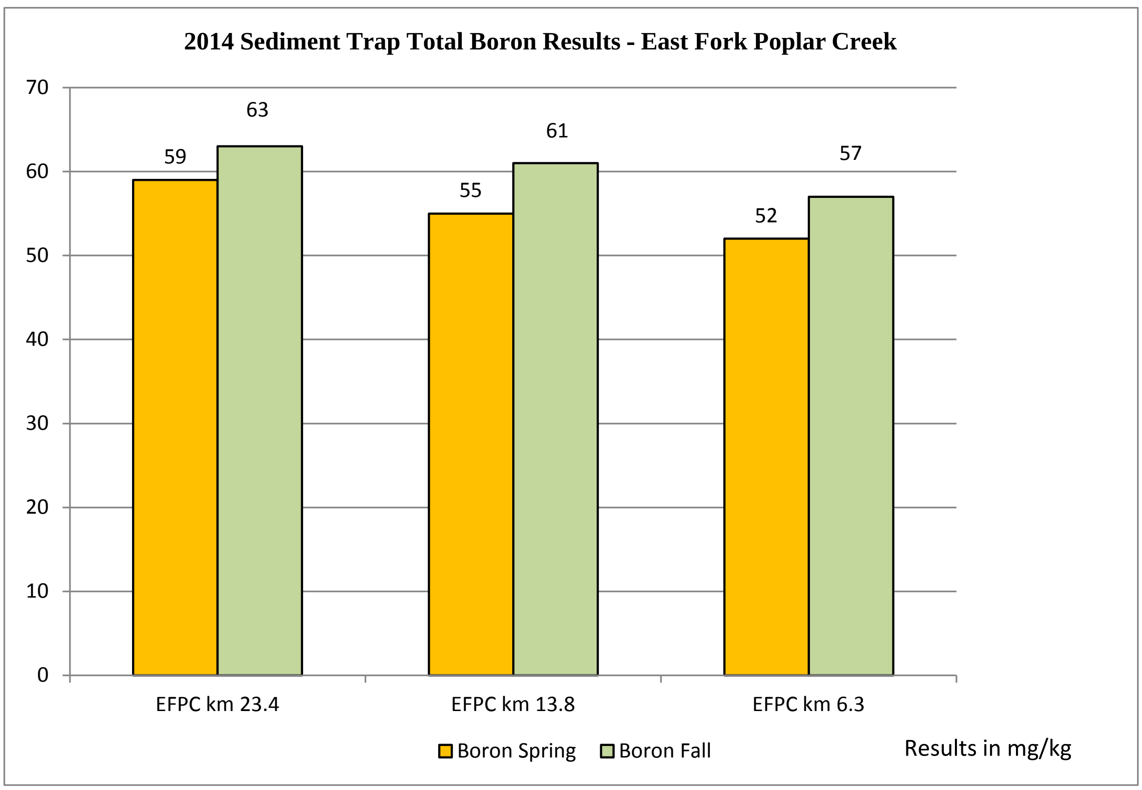


Figure 11: East Fork Poplar Creek Sediment Trap Boron Results

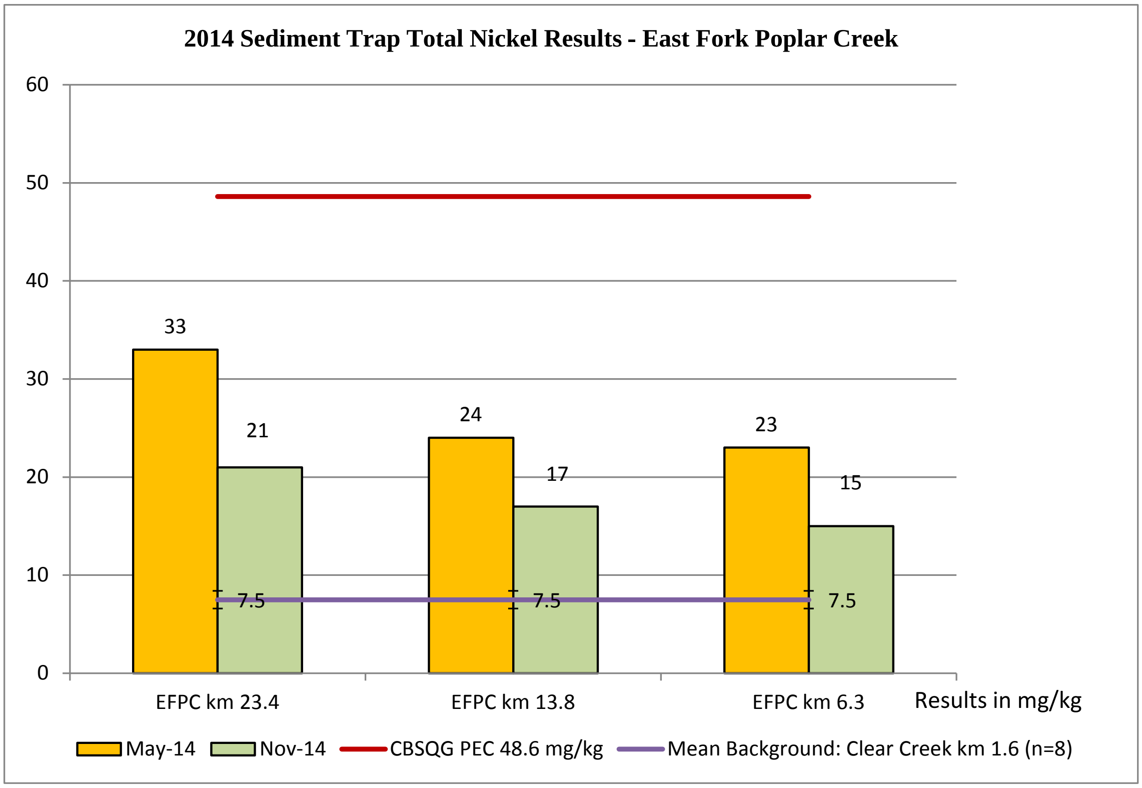


Figure 12: East Fork Poplar Creek Sediment Trap Nickel Results

Radiological Results

Radiological analyses included gross alpha, gross beta, gamma radionuclides, and uranium isotopic (see Figure 13). Gross alpha and beta values were in normal range and do not indicate contamination. All of the gamma radionuclides detected were naturally-occurring (Pb-212, K-40, etc.) and do not pose a threat to human health. Isotopic uranium analyses received for the fall harvested sediments do not suggest enrichment except at the NT5 sampling location, which indicates 3.28 to 4.56% U-235 enrichment (Rad Pro Calculator, 2015). NT5 is the main outfall for the Environmental Management Waste Management Facility (EMWMF); EMWMF has received waste resulting from ETTP decommissioning and demolition activities in recent years.

Location	Analyte	Result	Units	Uncertainty	Detection limit	Calculated U-235 Mass % Enrichment	Uncertainty Range
EFK 23.4	U-233/234	3.17E+00	pCi/g	3.91E-01	1.37E-02		
	U-235	1.95E-01	pCi/g	4.80E-02	2.13E-02	0.65	0.54 to 0.76
	U-238	3.31E+00	pCi/g	4.07E-01	1.72E-02		
EFK 13.8	U-233/234	2.02E+00	pCi/g	2.54E-01	2.24E-02		
	U-235	1.27E-01	pCi/g	3.56E-02	1.55E-02	0.69	0.57 to 0.81
	U-238	1.99E+00	pCi/g	2.51E-01	1.02E-02		
EFK 6.3	U-233/234	2.65E+00	pCi/g	3.57E-01	3.35E-02		
	U-235	1.53E-01	pCi/g	4.89E-02	3.85E-02	0.84	0.68 to 0.99
	U-238	2.13E+00	pCi/g	2.93E-01	3.10E-02		
NT5	U-233/234	9.77E+00	pCi/g	1.14E+00	1.35E-02		
	U-235	6.82E-01	pCi/g	1.09E-01	2.10E-02	3.93	3.28 to 4.56
	U-238	1.53E+00	pCi/g	2.02E-01	1.34E-02		
BCK 7.6	U-233/234	2.00E+00	pCi/g	2.68E-01	1.97E-02		
	U-235	1.39E-01	pCi/g	4.12E-02	1.57E-02	0.65	0.54 to 0.76
	U-238	4.03E+00	pCi/g	5.08E-01	1.27E-02		

Figure 13: Results of Uranium Isotopic Analyses

Conclusion

In order to monitor for changes in contaminant flow through sediment transport, passive sediment samplers (traps) were deployed at six locations: BCK 4.5, BCK 12.3, NT5, EFK 23.4, EFK 13.8 and EFK 6.3.

The general trend for total mercury at both East Fork Poplar Creek and Bear Creek is to decrease in concentration as one moves downstream from Y-12. Methyl mercury, on the other hand, increases as one goes downstream. The general trend for other metals (arsenic, uranium, barium, boron, chromium, nickel) at East Fork Poplar Creek is to decrease as one travels downstream from Y-12. All of the samples from East Fork Poplar Creek exceeded the CBSQGs PEC (1.06 mg/kg) for mercury. 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). The CBSQGs are considered to be 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).

Slight uranium-235 enrichment at the NT-5 sampling location is suggested by the data; other sampling locations did not show U-235 enrichment. Gross alpha and beta values were in normal range and do not indicate contamination. All of the gamma radionuclides detected were naturally-occurring and do not pose a threat to human health.

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Ambient Surface Water Monitoring

Principle Author: John (Tab) Peryam

Abstract

The office conducts semi-annual surface water sampling to detect possible contamination from Department of Energy (DOE) sites. Sampling is conducted at six sites on the Clinch River and four sites on tributaries of the Clinch River (McCoy Branch, Raccoon Creek, Grassy Creek, and Poplar Creek). Samples were analyzed for alpha, beta, and gamma emissions, ammonia, dissolved residue, nitrate and nitrate (NO^3 & NO^2) nitrogen, suspended residue, total hardness, total Kjeldahl nitrogen, total phosphate, arsenic, cadmium, copper, iron, lead, manganese, mercury, chromium, and zinc. Other than dissolved oxygen at Clinch River Mile (CRM) 78.7, the data were either non-detects or the values were within bounds of Tennessee Water Quality Criteria (TNWQC). Dissolved oxygen (DO) was measured at 4.35 mg/L on 10/23/2014 at Clinch River Mile (CRM) 78.7; this value is below the TNWQC of 6.0 mg/L (fish and aquatic life, trout stream). One factor that may have affected the low DO value was that the sampling location is upstream of the aerating weir dam and a short distance from Norris Dam where the discharge water comes from a great depth from Norris Lake. Strontium-90 specific analysis from the samples collected at Raccoon Creek showed 0.58 pCi/L in the second quarter and 9.2 pCi/L in the fourth quarter; the EPA strontium-90 Maximum Contaminant Level (MCL) for drinking water is 8 pCi/L. Raccoon Creek is believed to be impacted by contaminated groundwater from Solid Waste Storage Area (SWSA) 3; the primary radiological contaminant is strontium-90 (Sr-90). Radiological data, other than the Sr-90 detection mentioned previously, show nothing of concern. Gross alpha and gross beta values were typical of background conditions.

Introduction

The Oak Ridge Reservation (ORR) Clinch River tributaries of Raccoon Creek, Grassy Creek, Poplar Creek, and McCoy Branch drain into the Clinch River. The public municipalities and ORR nuclear processing industrial plants which are located in this area of the Clinch River are: the city of Norris, the city of Clinton, Knox County, the city of Oak Ridge, the Y-12 complex, the Oak Ridge National Laboratory (ORNL) (old X-10 complex), the East Tennessee Technology Park (ETTP) (old K-25 complex), and the city of Kingston. To obtain public drinking water and industrial plant processing water, all of these areas utilize the surface waters of the Clinch River. The division conducts semi-annual surface water sampling at six sites on the Clinch River and four tributary sites to detect possible contamination from ORR DOE facilities.

Sampling was conducted during May-June and October (see Table 1, Figures 1 and 2 for the sampling locations). Samples were analyzed for alpha, beta, and gamma emissions, ammonia, dissolved residue, nitrate and nitrite (NO^3 & NO^2) nitrogen, suspended residue, total hardness, total Kjeldahl nitrogen, total phosphate, arsenic, cadmium, copper, iron, lead, manganese, mercury, chromium, and zinc. In addition, samples from Raccoon Creek were analyzed for strontium-90 and technetium-99. Contaminants in surface water samples are rarely detected. The data provide an ambient data set for evaluation of possible future contaminant discharges. Data are available from the Environmental Protection Agency's (EPA) WQX/STORET database online (http://www.epa.gov/storet/).

Methods and Materials

In the spring and fall of 2014, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-Oversight), conducted surface water monitoring at six sites on the Clinch River and four Clinch River tributaries, McCoy Branch (MCM), Grassy Creek (GCM), Raccoon Creek (RCM), and Poplar Creek (PCM). The surface water samples were taken to the State of Tennessee Department of Health Laboratory (TDH) for nutrients, metals, and radionuclide analyses. YSI Professional Plus and YSI 556 multi-probe system field instruments were used to measure the parameters of pH, conductivity, dissolved oxygen, and temperature at each monitoring site. This surface water monitoring program followed the Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water (TDEC 2011). In addition, all work associated with this program was conducted in compliance with the office's 2014 Health, Safety, and Security Plan.

Table 1 lists the ten sampling locations and the samples collected during each sampling event, and Figures 1 and 2 show the sampling sites relative to the ORR map. Table 2 lists the analytical parameters of interest:

Figure 1: Surface Water Sampling Sites

Figure 2: Surface Water Sampling Locations

Table 1: Sample Locations

Project Site #	Stream Location	DWR Site	Stream Mile	Clinch River Mile	Spring Event	Fall Event
1	Clinch River	CLINC078.7AN	CRM 78.7	78.7	X	X
2	Clinch River	CLINC052.6AN	CRM 52.6	52.6	X	X
3	Clinch River	CLINC035.5AN	CRM 35.5	35.5	X	X
4	Clinch River	CLINC017.9RO	CRM 17.9	17.9	X	X
5	Clinch River	CLINC010.0RO	CRM 10.0	10.0	X	X*
7	Clinch River	CLINC041.2AN	CRM 41.2	41.2	X	X
10	*McCoy Branch	MCCOY000.9AN	MCM 0.9	37.5	X	X
18	*Raccoon Creek	RACCO000.4RO	RCM 0.4	19.5	X	X
20	*Grassy Creek	GRASS000.7AN	GCM 0.7	14.6	X	X
33	*Poplar Creek	POPLA001.0RO	PCM 1.0	12.0	X	X

Project Site# = TDEC-DOE-Ovesight Office Project Site number.

Stream Location = Clinch River or one of its *tributaries.

DWR Site = Division of Water Resources site designation.

Stream Mile = Specific streams' mile.

Clinch River Mile = distance (miles) of stream location from the Clinch River/Tennessee River confluence.

X = Stream Location was sampled.

* = only rad data

Table 2: Test analyses, MDLs, Units, Methods

Test	MDL	Units	Method
Digestion Metals	n.a.	n.a.	USEPA 200.2
Specific conductivity	0.1	µS/cm	USEPA 120.1
Dissolved oxygen (DO)	0.01	mg/l	USEPA 360.1
pH	0.01	None	USEPA 150.1
Temperature, water	0.01	deg C	USEPA 170.1
Nitrogen, ammonia (NH3) as NH3	0.028	mg/l	USEPA 350.1
Hardness, carbonate	1	mg/l	USEPA 130.2
Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N	0.016	mg/l	TDEC A.18.4
Dissolved Solids	10	mg/l	USEPA 160.1
Total Suspended Solids (TSS)	10	mg/l	USEPA 160.2
Nitrogen, Kjeldahl	0.14	mg/l	USEPA 351.2
Phosphate	0.0065	mg/l	TDEC A.18.9.1
Iron	varies	µg/l	USEPA 236.2
Manganese	varies	µg/l	USEPA 243.2
Zinc	varies	µg/l	USEPA 289.2
Arsenic	varies	µg/l	USEPA 206.2
Cadmium	varies	µg/l	USEPA 213.1
Chromium	varies	µg/l	USEPA 218.1
Copper	varies	µg/l	USEPA 220.1
Lead	varies	µg/l	USEPA 239.1
Mercury	varies	µg/l	USEPA 245.1

Results and Discussion

Chromium values were either non-detects or very low J values and do not present health or ecological concerns. A J value is an estimated value between the Minimum Detection Limit (MDL) and the Method Quantification Limit (MQL). Lead results were either non-detects with the exception of one sample at Grassy Creek mile 0.7. The result from this analysis showed lead at 1.4µg/L, which is well below the Tennessee Water Quality Criteria (TNWQC) of 65 µg/L for fish and aquatic life. Cadmium was not detected at any of the sites. Copper and zinc were detected at very low concentrations at several sites; the values were well below Tennessee Water Quality Criteria (TNWQC). The spring mercury figure for Poplar Creek Mile (PCM) 1.0 was 0.044J µg/L; this value is less than the TNWQC (0.051 µg/L, for recreation organisms only). Mercury contamination of Poplar Creek is a recognized problem. East Fork Poplar Creek is impacted by mercury from Y-12 and is a tributary of Poplar Creek. PCM 1.0 is located downstream of the mouth of East Fork Poplar Creek.

McCoy Branch continues to show some effects of the Filled Coal Ash Pond (FCAP) upstream; arsenic values were 3.1J µg/L and 2.9J µg/L for 2014. These figures for McCoy Branch are below the TNWQC of 10 µg/L (recreation, organisms only). Summarized metals and nutrient data are shown in Table 3. DO was measured at 4.35 mg/L on 10/23/2014 at Clinch River Mile (CRM) 78.7; this value is below the TNWQC of 6.0 mg/L (fish and aquatic life, trout stream). This sampling location is just a short distance from Norris Dam; and the water coming from the dam is from a great depth and is low in dissolved oxygen. In 1984, the Tennessee Valley Authority (TVA) installed auto venting turbines to provide for more aeration. At about the same time, they built an aerating weir dam one mile below Norris Dam. Factors that affected the low

DO value may have been that the sampling location is above the aerating weir dam and the DO measurement was taken, the dam was not generating.

Raccoon Creek is believed to be impacted by contaminated groundwater from solid waste storage area (SWSA) 3; the primary radiological contaminant is strontium-90. Strontium-90 specific analysis from the samples collected at Raccoon Creek showed 2.41 pCi/L in the second quarter and 1.42 pCi/L in the fourth quarter. These values are below the EPA strontium-90 maximum contaminant level (MCL) for drinking water of 8 pCi/L. Radiological data, other than the strontium-90 detection mentioned previously, show nothing of concern. Gross alpha and gross beta values were typical of background conditions. Radiological data are shown in Table 4.

Table 3: 2014 Surface Water Data Summary (non-radiological)

Parameter	Units	Minimum	Maximum	Mean	Median	Standard Deviation	Count	TWQC*
ammonia	mg/L	0	0.120	0.0308	0	0.0396	19	n.a.
dissolved oxygen	mg/L	4.82	13.70	8.763	8.76	1.903	19	5.0[a]
dissolved residue	mg/L	124	260	165.6	150	30.1	19	500[b]
NO_3 & NO_2	mg/L	0	2.5	0.46	0.38	0.53	19	n.a.
pH		7.21	8.17	7.702	7.655	0.268	18	5.5-9[a]
specific conductivity	µs/cm	193	448.9	292.1	289.6	56.0	19	n.a.
suspended residue	mg/L	0	18	2.5	0	5.3	19	n.a.
total hardness	mg/L	100	240	142.6	140	31.1	19	n.a.
total Kjeldahl nitrogen	mg/L	0	0.22	0.038	0	0.077	19	n.a.
total phosphate	mg/L	0	0.057	0.0153	0.015	0.0177	19	n.a.
arsenic	µg/L	0	3.6	0.35	0	1.05	19	10[c]
cadmium	µg/L	0	0	0	0	0	19	2.0[d]
chromium	µg/L	0	1.5	0.15	0	0.44	19	16[e]
copper	µg/L	0	4.2	0.49	0	0.97	19	13[d]
iron	µg/L	33	560	157.1	110	146.1	19	n.a.
lead	µg/L	0	1.4	0.07	0	0.32	19	5[f]/65[a]
manganese	µg/L	6.7	360	60.8	37	81.8	19	n.a.
mercury	µg/L	0	0.044	0.0023	0	0.0101	19	0.051[c]
zinc	µg/L	0	8.3	1.74	0	2.31	19	120[d]

*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] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 4: 2014 Radiological Surface Water Data Summary

Parameter	Mean	Minimum	Maximum	Median	Standard Deviation	Range	Count	EPA[1]
Strontium-90*	1.915	1.42	2.41	1.915	0.700	0.99	2	8
Technetium-99*	0.075	-0.55	0.7	0.075	0.88	1.25	2	900
Radioactivity, alpha	0.4315	-0.23	2.55	0	0.987	2.78	20	n.a.
Radioactivity, beta	1.98	-0.3	5.6	1.85	2.20	5.9	20	n.a.

Units are pCi/L

[1]EPA Maximum Contaminant Level for drinking water

*Detected only at Raccoon Creek

Conclusion

In 2014, there was only one case in which TNWQC were not met: dissolved oxygen at Clinch River Mile 78.7. Dissolved oxygen was measured at 4.35 mg/L on 10/23/2014 at Clinch River Mile (CRM) 78.7; this value is below the TNWQC of 6.0 mg/L (fish and aquatic life, trout stream). This sampling location is just a short distance from Norris Dam and the water discharged from the dam comes from a great depth and is low in dissolved oxygen. Factors that affected the low D.O. value may have been that the sampling location is upstream of the aerating weir dam and, at the time the measurement was taken, the dam was not generating. All other metals, nutrients, and physical parameter measurements were within acceptable limits of the TNWQC.

Raccoon Creek is impacted by contaminated groundwater from SWSA 3; the primary radiological contaminant is strontium-90. Strontium-90 specific analysis from the samples collected at Raccoon Creek showed 0.58 pCi/L in the second quarter and 9.2 pCi/L in the fourth quarter; the EPA strontium-90 maximum contaminant level (MCL) for drinking water is 8 pCi/L. Radiological data, other than the strontium-90 detection mentioned previously, show nothing of concern. Gross alpha and gross beta values were typical of background conditions, with the exception of Raccoon Creek which had a gross beta value of 22.5 pCi/L.

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Rain Event Surface Water Monitoring

Principle Author: Robert B. Bishop

Abstract

The Division of Remediation, Department of Energy Oversight Office conducted surface water sampling following a rain event of at least one inch in a 24-hour period or two inches in a 72-hour period, at stream sites on the Oak Ridge Reservation in 2014. Samples were collected during the second, third and fourth quarters following a qualifying event. Samples were not collected during the first quarter due to not being able to meet the rain event criteria. Results were consistent with results from a non-contaminated site following a heavy rain, with the exceptions of mercury at East Fork Popular Creek kilometer 23.4 and radionuclides at Storm Drain 490.

Introduction

Heavy rains may lead to point and non-point source contaminant releases to streams on the Oak Ridge Reservation (ORR). These rain events or a qualifying rain event for this program is defined as a one-inch or more of rain in a 24-hour period or two-inches or more in a 72-hour period. Qualifying rain events have the potential to mobilize contamination at greater concentrations than a rain event of lesser magnitude.

This surface water sampling program has been established to assess the degree of impact, if any, caused by heavy rain events. In 2014, eight locations were sampled after a qualifying rain event. Table 1 and Figure 1 show the Rain Event Surface Water Monitoring locations. Mill Branch serves as a reference location and is located off of the ORR. Sampling the East Fork Poplar Creek kilometer (EFK) 23.4 location will help to determine what is exiting the eastern side of Y-12 site. The White Oak Creek kilometer (WCK) 0.0 sample location is anticipated to capture surface water exiting ORNL Melton Valley and the central campus area. The Bear Creek kilometer (BCK) 4.5 sample location is intended to capture water exiting the western side of Y-12, along with Environmental Management Waste Management Facility (EMWMF) and the burial grounds. To sample the runoff along the north side of East Tennessee Technology Park (ETTP), the Mitchell Branch kilometer (MIK) 0.01 sample location was selected. The P1 Pond Weir was selected to sample the runoff along the south side of ETTP. Storm Drain (SD) 490 was added to this program to study the technetium-99 (Tc-99) release that may have occurred during the demolition activities from the K-25 building. And, SD 510 was added during the fourth quarter to see what might be exiting the demolition activities from building K-31. Figure 2 shows Tennessee Department of Environment and Conservation (TDEC) staff collecting water samples and field parameters following a 2014 storm water event.

Methods and Materials

Qualifying rain event samples were collected following rain events on May 15, 2014 (2nd quarter), July 24, 2014 (3rd quarter), October 7, 2014 and October 15, 2014 (4th quarter). Due to concerns over the preservative in the metal samples taken on October 7, metals were resampled on October 15 to ensure all sampling protocols were met. Samples were not collected during the first quarter of 2014. Figure 4 illustrates data for the four 2014 ORR vicinity storms which exceeded 1.00 inches of precipitation within a 24-hour period as recorded at the Oak Ridge Office of the National Oceanic and Atmospheric Administration Atmospheric Turbulence and

Diffusion Division Climatological data site. During the first quarter, samples could not be collected within the sample time frame after a qualifying rain event. Surface water samples collected during 2014 were analyzed for the following parameters:

Table 1. Sample Locations in Kilometers (mile equivalents)	
Site	**Location**
MBK 1.6 (1.0)	Mill Branch (Reference)
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 (at Hwy. 95)
MIK 0.1 (0.06)	Mitchell Branch (Weir at ETTP)
P1 Pond Weir	Weir located at ETTP
SD 490	Storm Drain located at ETTP
SD 510	K-31 ETTP

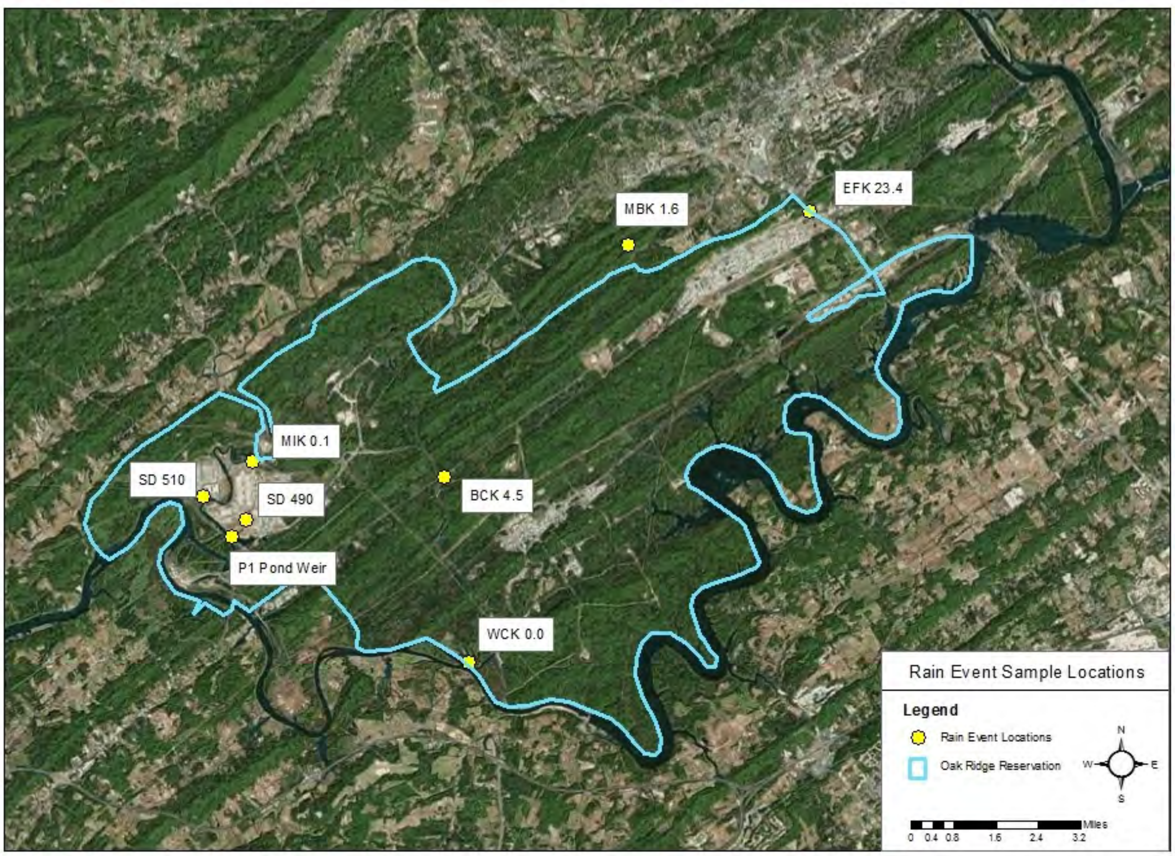

Figure 1: Rain Event Surface Water Monitoring Locations

Figure 2: Storm water sample collection at P-1 Pond Weir

Metals: Arsenic, cadmium, chromium, copper, lead, manganese, zinc, mercury and iron were sampled at all locations during each sample collection. Analysis for hexavalent chromium was conducted on samples collected at MIK 0.1, SD 490 and the P1 Pond Weir. At SD510, hexavalent chromium was sampled during the fourth quarter. Uranium was tested during the third quarter event at the P1 Pond Weir and MBK 1.6. During the fourth quarter event, uranium was tested at SD 490, P1 Pond Weir, SD 510 and MBK 1.6.

Radionuclides: At each site, for all sampling events, analysis for gamma radionuclides, gross alpha and gross beta was conducted. Strontium-90 was collected for analysis at WCK 0.0 during all events. Tritium and Tc-99 were collected for analysis at SD 490 and P1 Pond Weir during all events. Tc-99 analysis was conducted on the fourth quarter sample from SD 510.

PCBs: Starting in the fourth quarter, polychlorinated biphenyls (PCB's) were sampled for analysis at SD 510.

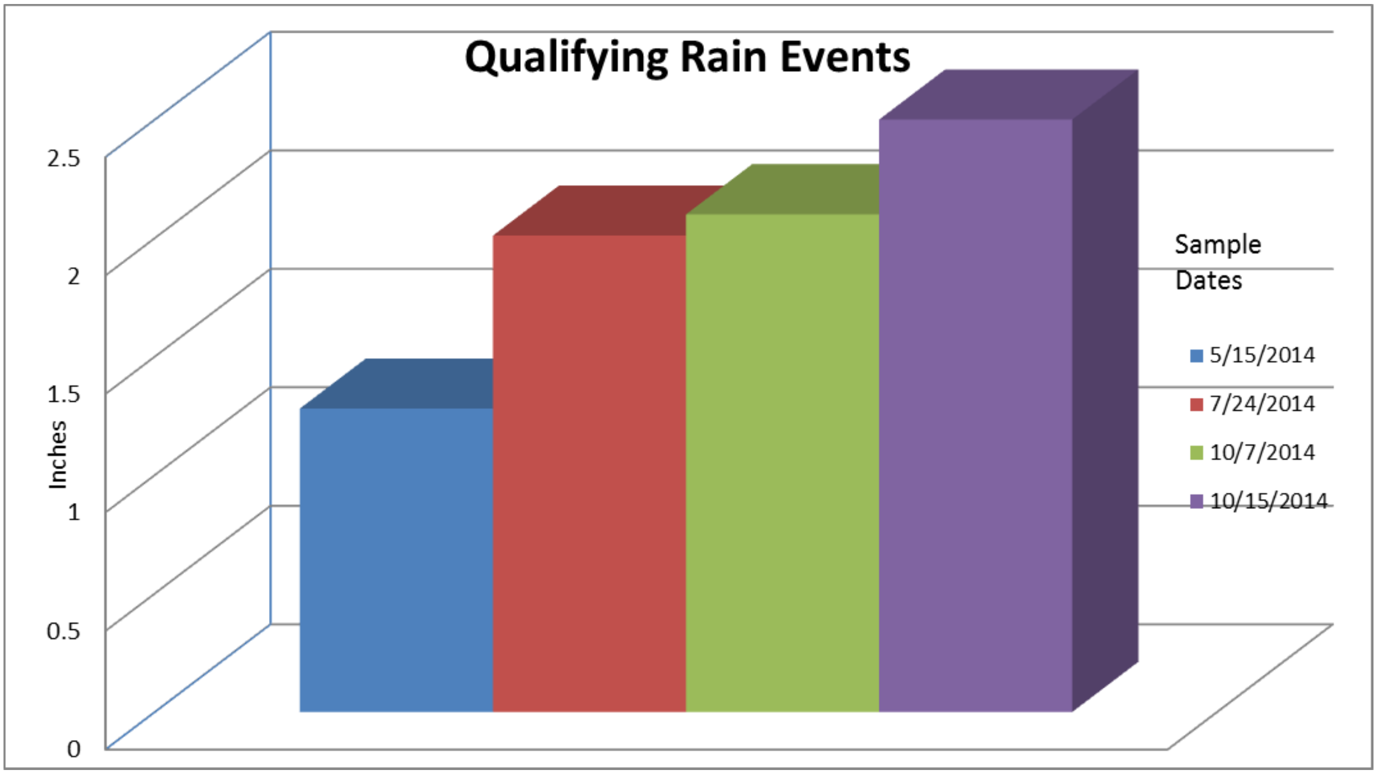

Figure 4: Qualifying Rain Events for Each Sample

Results

During Sampling, water quality parameters were measured with a YSI professional plus water quality meter. The water quality parameters are summarized in Figures 5 through 8. Tables 2 through 5 provide the results of the metal and radionuclide analysis.

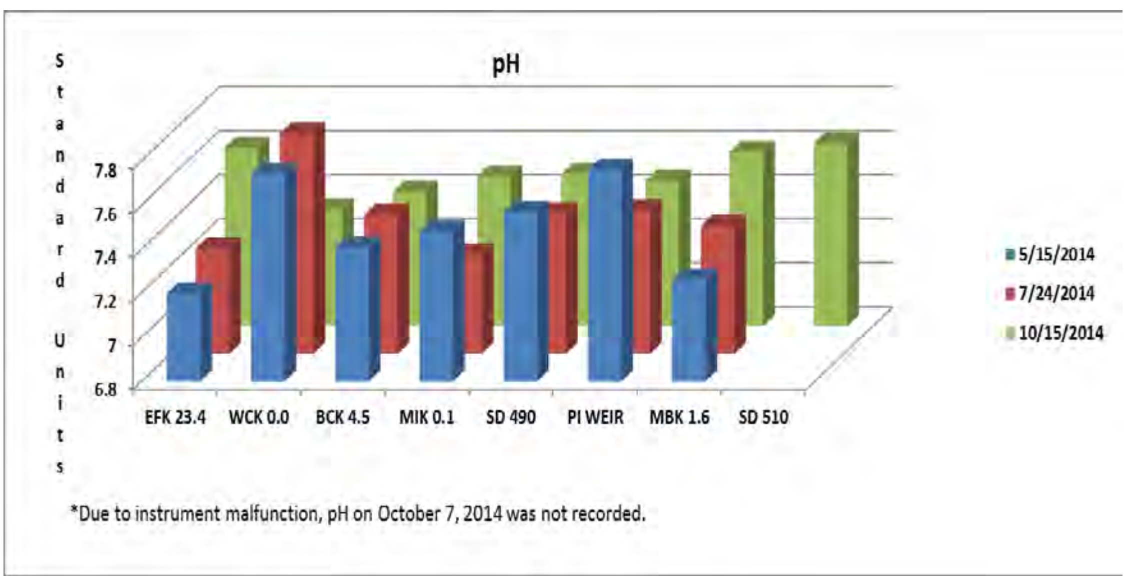

Figure 5: pH Field Measurements

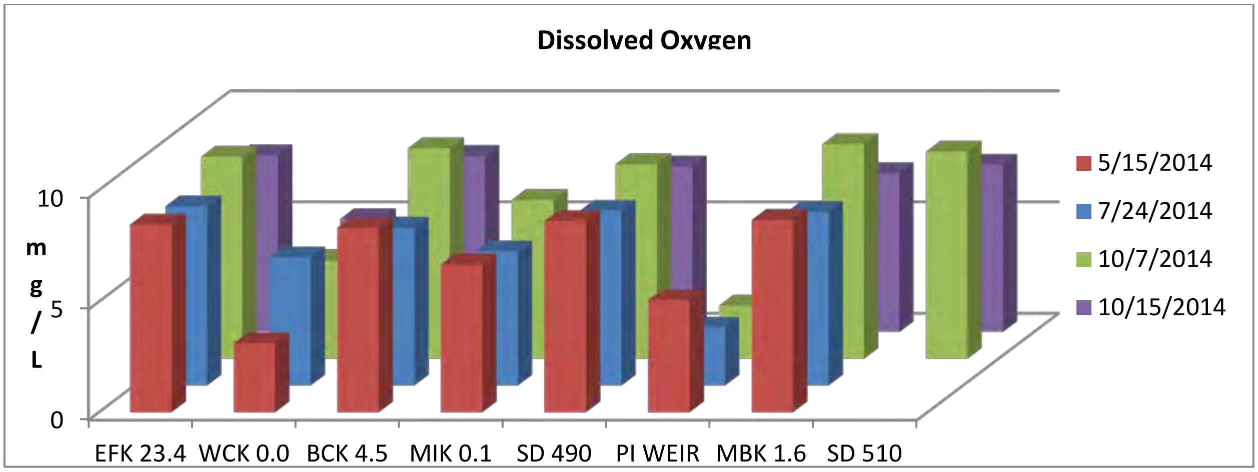

Figure 6: Dissolved Oxygen Field Measurements

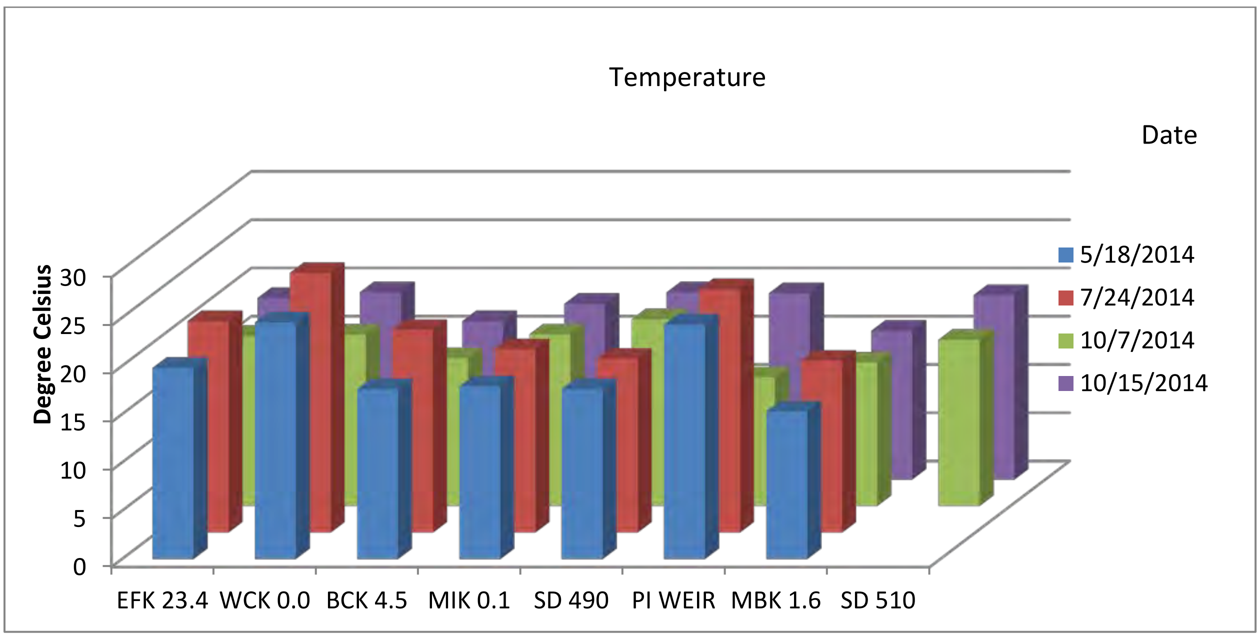

Figure 7: Temperature Field Measurements

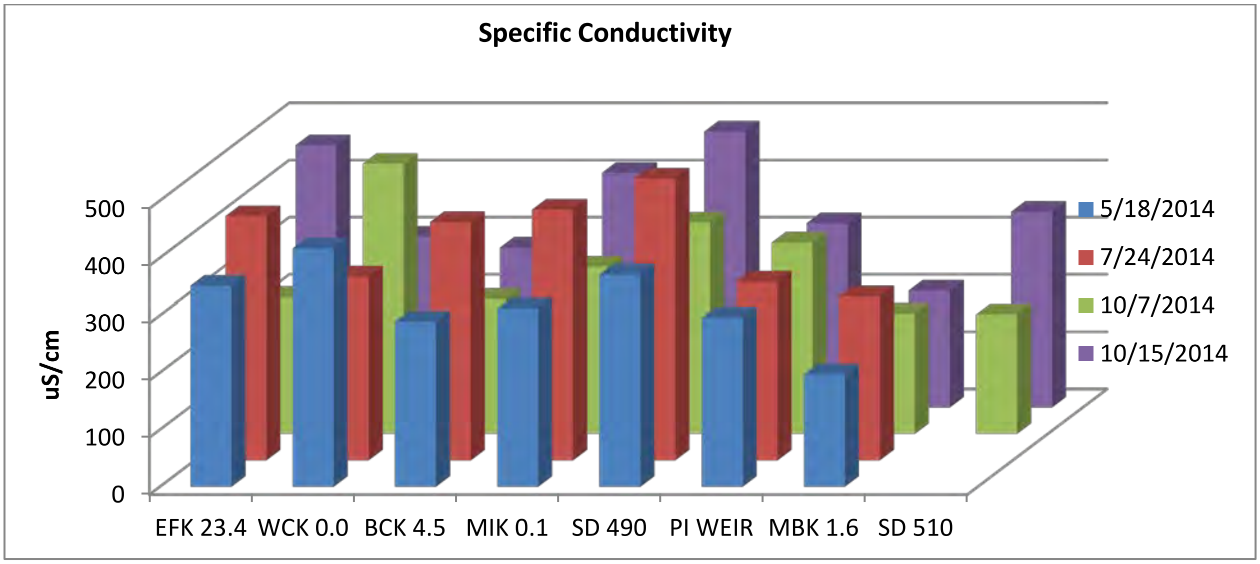

Figure 8: Specific Conductivity Field Measurements

Table 2. Results of Metals Analysis

Site	As ug/L	Cd ug/L	Cr ug/L	Cr(hex) ug/L	Cu ug/L	Fe ug/L	Pb ug/L	Mn ug/L	Hg ug/L	Zn ug/L	U ug/L
5/15/2014											
EFK 23.4	U	U	U		4.5	250	U	56	0.3	24	
WCK 0.0	1.5J	U	1.6J		1.8	520	0.77J	240	U	10	
BCK 4.5	1.1J	U	1.7J		1.9	1100	1.3	140	U	14	
MIK 0.1	0.86J	U	2.0J	U	4.3	430	1.6	89	U	17	
SD 490	0.66J	U	1.5J	U	3.3	200	2.3	78	U	38	
P1 WEIR	0.72J	U	U	U	3.2	170	U	250	U	10	
MBK 1.6	U	U	U		0.71J	560	U	56	U	7.8	
7/24/2014											
EFK 23.4	U	U	U		3.4	110	U	25	0.15J	16	
WCK 0.0	1.0J	U	1.2J		1.6	450	0.64J	120	U	8.3	
BCK 4.5	U	U	U		0.57J	210	U	72	U	3.0J	
MIK 0.1	U	U	2.4J	U	1.6	210	U	190	0.5	5.9	
SD 490	U	U	1.6J	U	1.4	140	U	180	U	5.5	
P1 WEIR	0.90J	U	U	U	U	300	U	260	U	7.2	0.22J
MBK 1.6	U	U	U		U	170	U	38	U	7.7	0.31J
10/15/2014											
EFK 23.4	U	U	2.1J		5.1	170	U	23	0.16J	12	
WCK 0.0	U	U	2.9J		3.2	990	1.2	110	U	8.8	
BCK 4.5	U	U	1.6J		1.7	1100	0.85J	56	U	4.0J	
MIK 0.1	U	U	5	U	5.8	340	U	89	U	5.8	
SD 490	U	U	2.2J	U	1.3	150	U	110	U	14	2
P1 WEIR	U	U	U	U	U	270	U	420	U	1.6J	0.27J
MBK 1.6	U	U	2.0J		2.8	510	U	36	U	2.8J	0.20J
SD 510	U	U	5.5	U	2.8	230	1.3	7.6	U	27	2.4

J - indicates the estimated value between method detection limit (MDL) and method quantitation limit (MQL)
U - undetected
Blank - Not analyzed.
ug/L - Micrograms per liter

The results for metal analysis have been consistent to previous rain event samples. 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 9 illustrates MIK 0.1 chromium concentrations sampled during storm events occurring 2009 thru 2014.

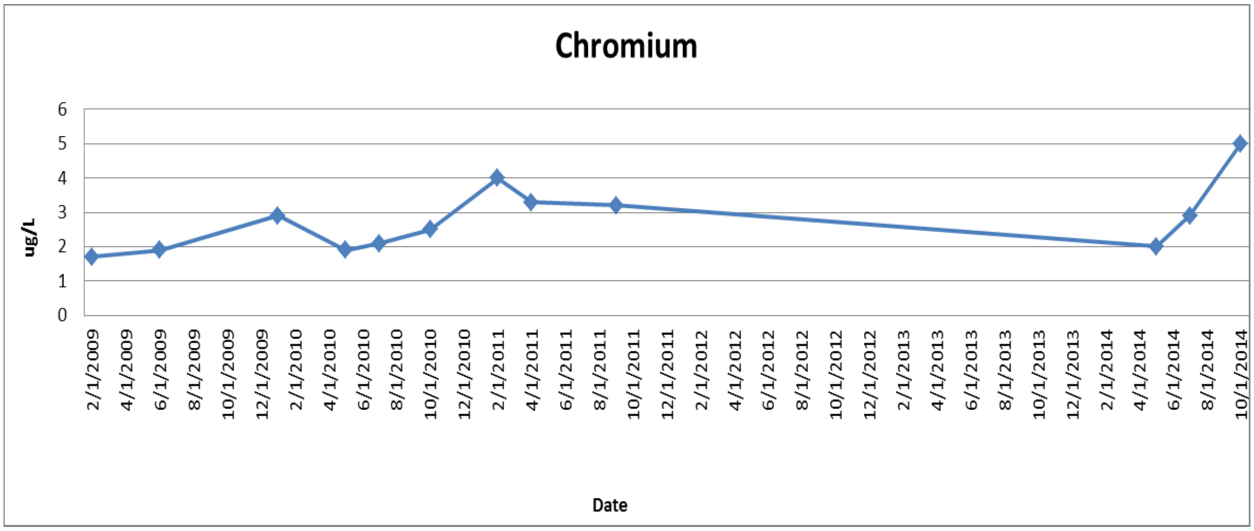

Figure 9: Chromium Concentrations from MIK 0.1 from 2009 through 2014

Site EFK 23.4 exhibited mercury concentrations which were higher than the Tennessee Water Quality Criteria (TWQC) for Recreation (Organisms only) Criterion Maximum Concentration of 0.051 ug/L. The EFK 23.4 elevated values were 0.3 ug/L (5/15/2014), 0.15 ug/L (7/24/2014) and 0.16 ug/L (10/15/2014). The elevated mercury levels at EFK 23.4 were expected, given the levels of mercury contamination present in East Fork Popular Creek. Figure 10 illustrates EFK 23.4 mercury rain events in ug/L results from years 2004 to 2014.

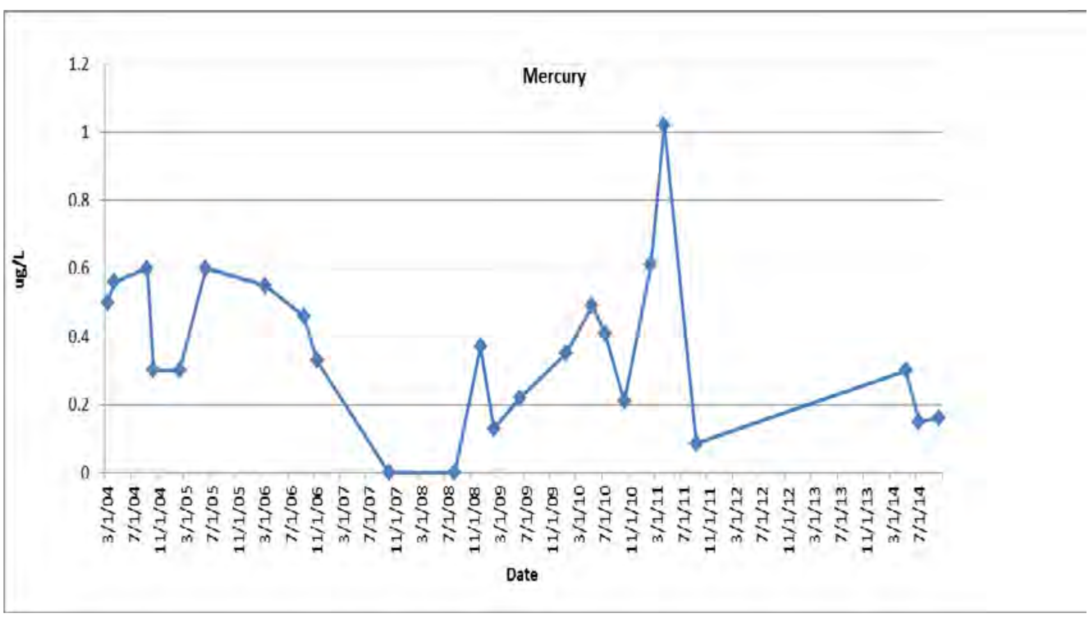

Figure 10: Mercury Concentrations from EFC 23.4 from 2004 through 2014

All samples were analyzed for Gross Alpha, Gross Beta, and gamma radionuclides. The results of the gross alpha and beta are shown in table 3. The gamma radionuclide analysis detected only naturally occurring decay products of Radon (Lead-212, Lead-214 and Bismuth-214) and therefore the gamma results are not presented.

Table 3.
Results of Gross Alpha/Beta Radionuclide Analysis

Site	Gross Alpha pCi/L	Gross Alpha Error ± pCi/L	Gross Beta pCi/L	Gross Beta Error ± pCi/L
5/15/2014				
EFK 23.4	20.2	1.8	36	3.4
WCK 0.0	12.1	1.3	98.5	6.1
BCK 4.5	9.9	1.1	15.2	2.6
MIK 0.1	7.7	1	68.1	4.3
SD 490	-29.1	2.2	1090	60
P1 WEIR	-2.49	0.83	121.6	6.3
MBK 1.6	0	0	0.75	2.4
7/24/2014				
EFK 23.4	5.37	0.99	7.6	2.7
WCK 0.0	9.8	1.2	90.9	6.1
BCK 4.5	19	2.2	19.4	3.2
MIK 0.1	5	1	87.2	7.5
SD 490	-25.3	3.3	967	93
P1 WEIR	-1.4	0.7	33.8	3.4
MBK 1.6	-0.12	0.69	2.8	2.6
10/7/2014				
EFK 23.4	9.588	0.924	9.9	2.6
WCK 0.0	7.387	1.053	122.3	7.7
BCK 4.5	6.927	0.877	28.6	2.9
MIK 0.1	10.858	1.033	45.3	3.3
SD 490	-20.589	1.403	586	28.1
P1 WEIR	-1.447	0.664	18.8	2.8
MBK 1.6	-1.779	0.617	1.3	2.5
SD 510	-1.057	0.666	45.1	3.1

Strontium-90 was sampled for analysis at WCK 0.0 due to historical evidence of contamination at this site. Table 4 provides the strontium-90 results. The strontium-90 results observed in 2014 are similar to previous results from past years. Tritium and Tc-99 were sampled at SD 490 and the P1 Pond Weir. Only Tc-99 was sampled at SD 510 (initially sampled during the fourth quarter). Tritium and Tc-99 analysis was conducted to monitor for contamination from CERCLA work in these areas. Results from the tritium and Tc-99 analyses are shown in Table 5.

Table 4. Strontium Radionuclide Results		
Site	Strontium-90 (pCi/L)	Strontium-90 Error (±pCi/L)
5/15/2014		
WCK 0.0	4.1	4
7/24/2014		
WCK 0.0	39	14
10/7/2014		
WCK 0.0	44	10

pCi/L - picocuries per liter

Table 5. Tritium and Technetium-99 Results				
Site	Tritium (pCi/L)	Tritium Error (±pCi/L)	Tc-99 (pCi/L)	Tc-99 Error (±pCi/L)
5/15/2014				
SD 490	134	38	729	19
P1 Pond Weir	135	38	112.6	3
7/24/2014				
SD 490	0	33	1107	28
P1 Pond Weir	146	39	27.83	0.87
10/7/2014				
SD 490	0	32	419	11
P1 Pond Weir	144	28	13.4	0.55
SD 510	NA	NA	33.8	1

NA - Not Analyzed

pCi/L - picocuries per liter

In late 2013, a Tc-99 release occurred while building K-25 was undergoing demolition at the ETTP, therefore 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 sanitary sewer lines and the electrical conduits in the area being investigated as potential points of pooling. If pooling of the Tc-99 has occurred, then heavy rains may provide a mode of transport to SD 490. However, the specific conductivity readings on the storm flow through SD 490 have raised the possibility that the Tc-99 has entered into the ground water system and is being flushed out through breaks in the drainage system during heavy rains. Future groundwater sampling around K-25 and the storm drains would address the Tc-99 potential for being in the groundwater.

PCB's were analyzed at SD 510 beginning in the fourth quarter of 2014. Analysis was conducted to monitor the possible contamination from CERCLA work being conducted in the area. PCB's were not detected in the submitted sample.

Conclusion

Overall, the results seem to indicate that long-term radiological contaminates continue to impact White Oak Creek and Mitchell Branch, while mercury remains a concern at East Fork Popular Creek. Until a determination is made concerning the Tc-99 in the SD 490 area, it is recommended that monitoring continue in this area.

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Benthic Macroinvertebrate Surface Water Monitoring Program

Principal Author: John (Tab) Peryam

Abstract

In May 2014, the office conducted surface water monitoring at the following Oak Ridge Reservation watersheds: Bear Creek, East Fork Poplar Creek, Mitchell Branch, and White Oak Creek/Melton Branch. In all, surface water samples were collected from eleven impacted stream sites and associated reference sites. In addition, monitoring was also conducted at Clear Creek near Norris Dam, which serves as a reference site for all the ORR watersheds. Samples were delivered to the State of Tennessee Department of Health Laboratory for nutrients, metals, and radiological analyses. Conductivity, pH, conductivity, dissolved oxygen, and temperature were measured at each monitoring site using YSI Professional Plus multi-parameter water quality instruments. The surface water data indicate that the surface water quality in the four watersheds was less than optimal when compared to reference streams. The comprehensive stream assessment scores calculated from the benthic macroinvertebrate monitoring program indicated the same conclusion.

Introduction

Due to the presence of areas of extensive anthropogenic point and non-point source contamination on the Oak Ridge Reservation (ORR), there exists the potential for this pollution to impact surface waters on the ORR and as offsite aquatic systems. The local karst topography and related structural geology influences the fate and transport of contaminants that may further degrade the groundwater and surface water quality of aquatic systems on or adjacent to the ORR. The biotic integrity of an associated aquatic system/watershed/stream is directly influenced by its surface water quality. In general, the better the surface water quality of a stream, the better its biotic integrity. This project complements the Benthic Macroinvertebrate Monitoring Project; assessment of the surface water quality of a stream 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. Relative to the four major ORR watersheds, Bear Creek (BCK), East Fork Poplar Creek (EFK), Mitchell Branch (MIK), and White Oak Creek (WCK) / Melton Branch (MEK), legacy and present Department of Energy (DOE)/ORR operations have released contaminants to their respective surface waters with mainly these major chemical families: volatile and semi-volatile organic compounds, nutrients, heavy metals, and radionuclides. These contaminants can have a detrimental effect upon the health of benthic macroinvertebrate communities. When contaminant concentrations in surface water are high enough, the total population of benthic communities can be drastically reduced. Negatively impacted benthic communities indicate a polluted, distressed stream/watershed/aquatic system.

Methods and Materials

In May 2014, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-O), conducted surface water monitoring at the following impacted ORR watersheds: BCK, EFK, MIK, and WCK. In all, surface water samples were collected from eleven impacted stream sites and associated reference sites. In addition, monitoring was also conducted at Clear Creek (CCK) near Norris Dam and at Hinds Creek to serve as a reference site for all the ORR watersheds. To enhance the evaluation of each streams' biotic integrity, the surface water sampling program was conducted in conjunction with the 2014 Benthic Macroinvertebrate Monitoring Program. Samples were delivered to the State of Tennessee Department of Health (TDH) Laboratory for nutrients, metals, and radiological analyses. Conductivity, pH, dissolved oxygen and temperature were measured at each monitoring site using YSI Professional Plus multi-parameter water quality instruments. The surface water monitoring program followed both the 2011 TDEC WPC Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water and the 2011 TDEC WPC Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys. In addition, all work associated with this program will be conducted in compliance with the office's Health, Safety, and Security Plan.

Samples were taken for the following parameters:

Inorganics: ammonia, nitrate & nitrite (NO^3 & NO^2), residue (dissolved), residue (suspended), specific conductivity, total hardness, total Kjeldahl nitrogen, total phosphorus.
Metals: arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, and zinc.
Radionuclides: gamma radionuclides, gross alpha, and gross beta.

Table 1 lists the nineteen benthic macroinvertebrate sampling locations. Figures 1-5 show locations of the benthic macroinvertebrate sampling sites. Surface water samples were collected at only eleven of the nineteen benthic macroinvertebrate sites; these sites are listed in bold and italic typeface on Table 1.

Table 1: 2014 Benthic Macroinvertebrate Sample Locations

Stream Location	TDEC-DOE-O Project Site	DWR Site
East Fork Poplar Crk	EFK 25.1	EFPOP015.6AN
East Fork Poplar Crk	EFK 24.4	EFPOP015.2AN
East Fork Poplar Crk	EFK 23.4	EFPOP014.5AN
East Fork Poplar Crk	EFK 13.8	EFPOP008.6AN
East Fork Poplar Crk	***EFK 6.3***	***EFPOP003.9RO***
Bear Creek	***BCK 12.3***	***BEAR007.6AN***
Bear Creek	***BCK 9.6***	***BEAR006.0AN***
Mitchell Branch	***MIK 1.43*** *	***MITCH000.9RO***
Mitchell Branch	MIK 0.71	MITCH000.4RO
Mitchell Branch	***MIK 0.45***	***MITCH000.3RO***
White Oak Creek	***WCK 6.8*** *	***WHITE004.2RO***
White Oak Creek	WCK 3.9	WHITE002.4RO
White Oak Creek	WCK 3.4	WHITE002.1RO
White Oak Creek	***WCK 2.3***	***WHITE001.4RO***
Melton Branch	MEK 0.3	MELTO000.2RO
White Creek	***WCM 2.3*** *	***ECO67F13***
White Wing Tributary	WWT 0.8 *	WWTRI00.05RO
Clear Creek	***CLM 1.0*** *	***ECO67F06***
Gum Hollow Branch	GHK 2.9 *	GHOLL001.8RO
Hinds Creek	***HCK 20.6*** *	***HINDS012.8AN***
Mill Branch	***MBK 1.6*** *	***FECO67I12***

Stream Location = ORR Stream/Watershed, * = Reference Stream
Surface water samples collected only at Bold/Italic sites
DWR Site = Division of Water Resources site designation

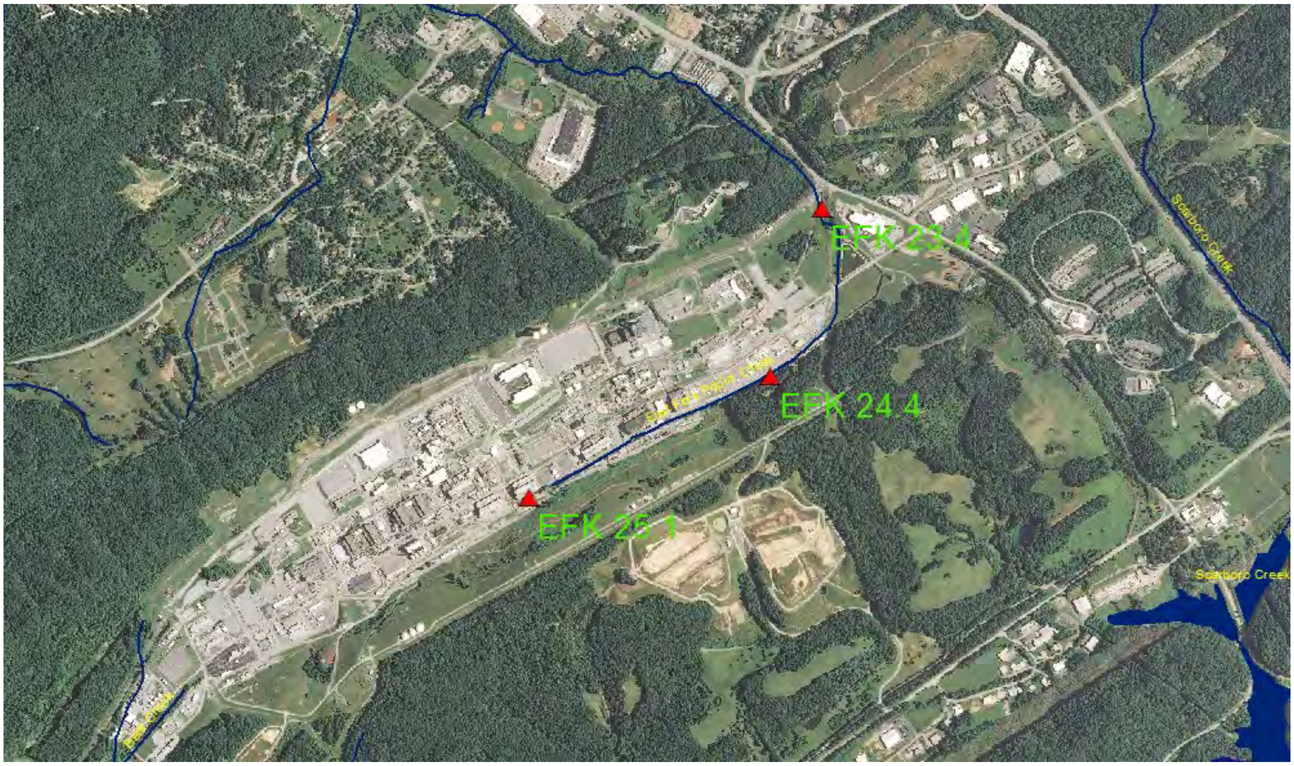

Figure 1: Upper East Fork Poplar Creek / Y-12 Plant

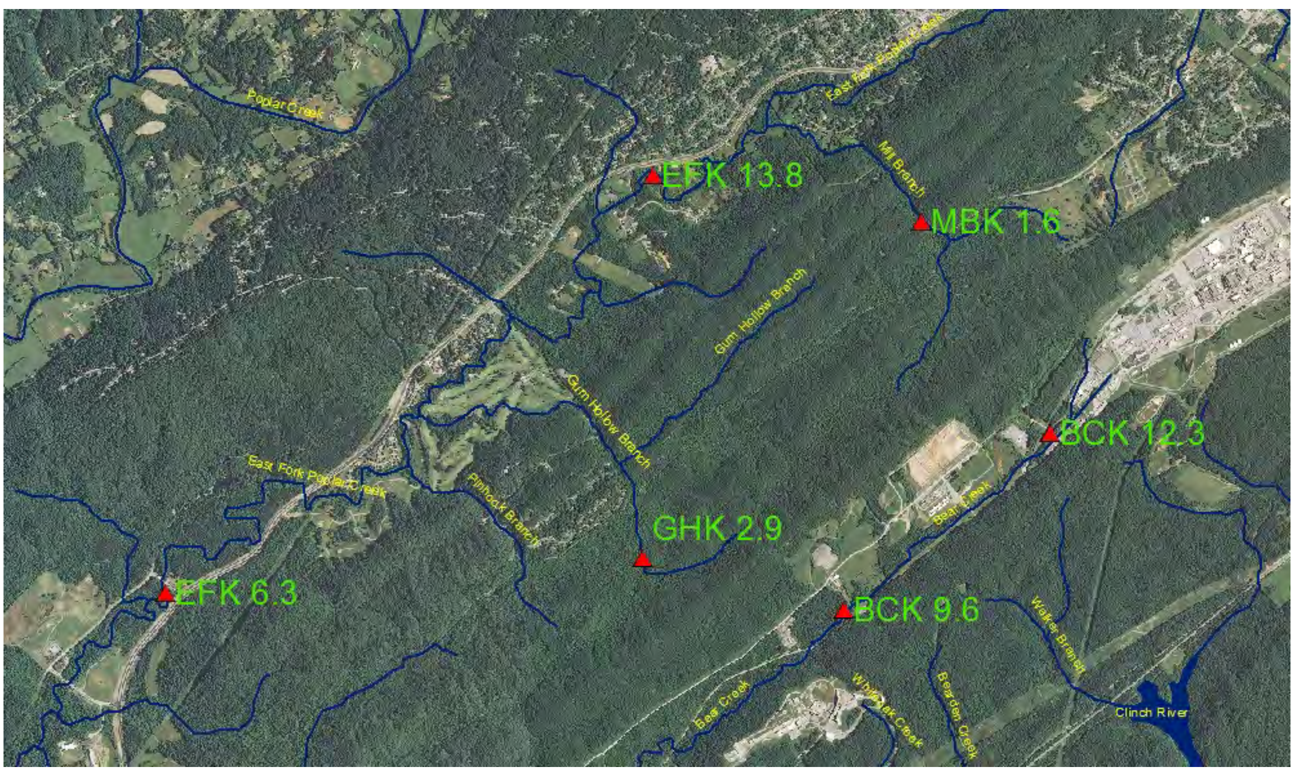

Figure 2: Lower East Fork Poplar Creek / Bear Creek Watersheds

Figure 3: Mitchell Branch Watershed (ETTP)

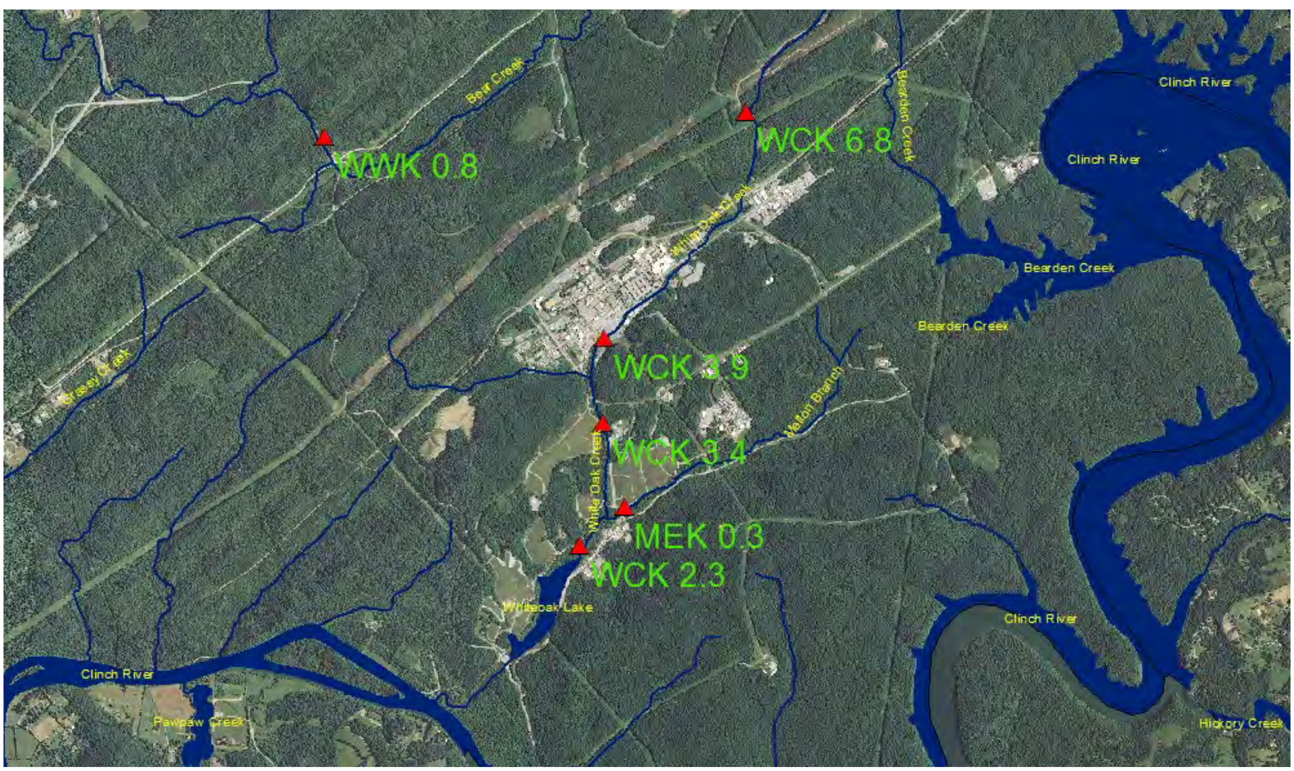

Figure 4: White Oak Creek / Melton Branch Watersheds (ORNL)

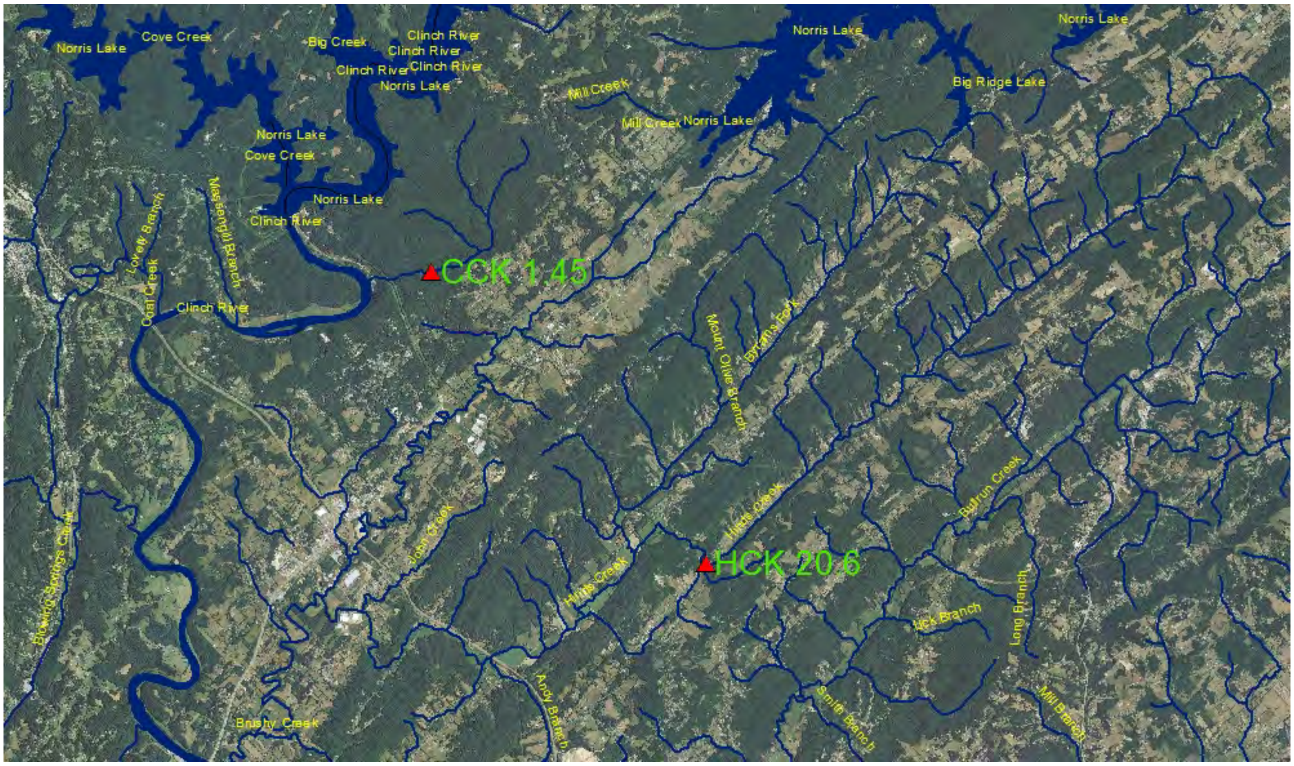

Figure 5: Clear Creek Ecoregion and Hinds Creek Reference Sites

Results and Discussion: The 2014 Benthic TDH laboratory surface water results are discussed in the following order, Bear Creek, East Fork Poplar Creek, Mitchell Branch, and White Oak Creek / Melton Branch.

Bear Creek:

Tables 2 and 3 presents a summary of the 2014 benthic surface water sample results for Bear Creek.

Table 2: 2014 Surface Water Data Summary (non-radiological)

Parameter	BCK 12.3	BCK 9.6	HCK 20.6 (ref.)	CCK 1.6 (ref.)	TWQC*	Units
pH	6.61	6.79	6.16	8.19	5.5-9[a]	None
Specific conductance	790	577	371	252.6	n.a.	uS/cm
Temperature, water	16.15	14.42	13.95	13.44	<=30.5	°C
Dissolved oxygen (DO)	0.132	9.26	9.63	10.46	5.0[a]	mg/l
Ammonia-nitrogen	U	U	U	U	n.a.	mg/l
Hardness, Ca, Mg	330	250	190	120	n.a.	mg/l
Inorganic nitrogen (nitrate and nitrite)	27	18	0.55	0.31	n.a.	mg/l
Total dissolved solids	490	340	200	160	500[b]	mg/l
Total suspended solids	16	U	U	U	n.a.	mg/l
Kjeldahl nitrogen	0.42	0.34	U	U	n.a.	mg/l
Phosphorus	0.016	U	U	U	n.a.	ug/l
Iron	1200	500	290	51	n.a.	ug/l
Arsenic	U	U	U	U	10[c]	ug/l
Cadmium	1.6	U	U	U	2.0[d]	ug/l
Chromium	U	U	1.2	U	16[e]	ug/l
Copper	0.9	0.65	0.48	U	13[d]	ug/l
Lead	U	U	U	U	5[f]/65[a]	ug/l
Manganese	270	30	47	11	n.a.	ug/l
Zinc	8.8	5.7	U	6.6	120[d]	ug/l
Mercury	U	U	U	U	0.051[c]	mg/l

*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] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 3: 2014 Bear Creek Surface Water Data Summary (radiological)

Parameter	BCK 12.3	BCK 9.6	HCK 20.6 (ref.)	CCK 1.6 (ref.)	PRG[1]
Gross alpha radioactivity, (Thorium-230 ref std)	65.6	26.5	-0.23	0	n.a.
Gross beta radioactivity, (Cesium-137 ref std)	179	26.5	5.6	0	n.a.

Units are pCi/L

[1] DOE Preliminary Remediation Goals (PRGs), Recreator: TR=1.0E-6, last updated 11/20/2013

The specific Bear Creek data results are organized relative to the directional creek flow beginning near the headwaters within Y-12 and then proceeding downstream and to the west towards the Clinch River. Relative to our specific monitoring sites, please note this directional flow where BCK 12.3 is just to the west of the Y-12 secured area and then our additional monitoring sites are to the west and downstream of BCK 12.3.

Directional Flow: BCK 12.3 (near headwater and within Y-12) $>^{West}$ BCK 9.6 (2 miles outside of Y-12) $>^{West}$ Clinch River (with reference streams of HCK 20.6, and CCK 1.6)

BCK 12.3 is just to the west of the Y-12 legacy S-3 ponds, which are now capped. The Benthic Macroinvertebrate Monitoring section in this Environmental Monitoring Report concluded that the most impaired section based on benthic data was at BCK 12.3. By the time the surface water gets to BCK 9.6, the benthic data suggest the creek is non-impaired. In the past, the S-3 ponds were used as holding basins for mainly nitric acid. It is believed that these ponds have created a contaminated groundwater plume of nutrients (likely nitrogen compounds) which has traveled to the west and migrated to the head waters of Bear Creek then migrated further downstream/west of the headwaters. Relative to the solid phase/aqueous phase equilibrium mechanism, the groundwater plume [likely predominately nitrates (NO^3) and nitrites (NO^2)] have partitioned/dissolved into the surface water of Bear Creek. Thus, in the surface water at BCK 12.3, the elevated specific conductivity values are likely due to mainly high nitrogen concentrations. Another main contamination concern in the Bear Creek watershed is the presence of uranium contamination. In the 1980s, within the Bear Creek Burial Grounds, it is estimated that approximately 20,500 tons of depleted uranium were buried. Legacy uranium contamination in the burial grounds has been remediated by employing **Comprehensive Environmental Response, Compensation, and Liability Act (**CERCLA) regulations. Current uranium waste is disposed of by employing DOE Order 435.1.

Specific data results/observations relative to specific parameters are presented below:

Non-Radiological Parameters:

1.) Compared to the reference sites, specific conductivity was elevated at BCK 12.3 (790 microSiemens per centimeter [µS/cm]), then decreased downstream/west to BCK 9.6 (577 µS/cm). In this area of Bear Creek, specific conductivity levels are typically elevated.

2.) Compared to the reference sites, total hardness, dissolved residue, iron, and manganese concentrations were the highest at BCK 12.3 and also decreased as the stream flowed downstream/west to BCK 9.6.

Radiological Parameters:

1.) Radioactive alpha concentrations were the highest at BCK 12.3 (65.6 picocuries per liter [pCi/L]), and decreased as the stream flowed downstream/west to BCK 9.6 (26.5 pCi/L). Reference sites HCK 20.6 and CCK 1.45 had alpha values of -0.23 and 0 pCi/L, respectively.
2.) Radioactive beta concentrations were the highest at BCK 12.3 (179 pCi/L), and decreased as the stream flowed downstream/west to BCK 9.6 (26.5 pCi/L). Reference sites HCK 20.6 and CCK 1.45 had beta values of 5.6 and 0 pCi/L, respectively.

East Fork Poplar Creek:
Tables 4 and 5 present a summary of the 2014 benthic surface water samples results for East Fork Poplar Creek. The Benthic Macroinvertebrate Monitoring section reported EFK 6.3, based on the benthic data, as being slightly impaired.

Table 4: 2014 East Fork Poplar Creek Surface Water Data Summary (non-radiological)

Parameter	EFK 6.3	HCK 20.6 (ref.)	CCK 1.6 (ref.)	TWQC*	Units
pH	6.31	6.16	8.19	5.5-9[a]	None
Specific conductance	396	371	252.6	n.a.	uS/cm
Temperature, water	17.95	13.95	13.44	<=30.5	°C
Dissolved oxygen (DO)	7.81	9.63	10.46	5.0[a]	mg/l
Ammonia-nitrogen	U	U	U	n.a.	mg/l
Hardness, Ca, Mg	160	190	120	n.a.	mg/l
Inorganic nitrogen (nitrate and nitrite)	4.0	0.55	0.31	n.a.	mg/l
Total dissolved solids	220	200	160	500[b]	mg/l
Total suspended solids	17	U	U	n.a.	mg/l
Kjeldahl nitrogen	0.33	U	U	n.a.	mg/l
Phosphorus	0.54	U	U	n.a.	ug/l
Iron	130	290	51	n.a.	ug/l
Arsenic	U	U	U	10[c]	ug/l
Cadmium	U	U	U	2.0[d]	ug/l
Chromium	U	1.2	U	16[e]	ug/l
Copper	2.0	0.48	U	13[d]	ug/l
Lead	U	U	U	5[f]/65[a]	ug/l
Manganese	23	47	11	n.a.	ug/l
Zinc	18	U	6.6	120[d]	ug/l
Mercury	0.058J	U	U	0.051[c]	mg/l

*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] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 5: 2014 East Fork Poplar Creek Surface Water Data Summary (radiological)

Parameter	EFK 6.3	HCK 20.6 (ref.)	CCK 1.6 (ref.)	PRG[1]
Gross alpha radioactivity, (Thorium-230 ref std)	2.61	-0.23	0	n.a.
Gross beta radioactivity, (Cesium-137 ref std)	2.4	5.6	0	n.a.

Units are pCi/L

[1] DOE Preliminary Remediation Goals (PRGs), Recreator: TR=1.0E-6, last updated 11/20/2013

The specific East Fork Poplar Creek data results are organized relative to the directional creek flow beginning near the headwaters in Y-12 and then proceeding downstream towards the Clinch River. Relative to our specific monitoring sites, please note this directional flow where EFK 25.1 is within Y-12 and just to the east of the EFK headwaters. Additional downstream monitoring sites are to the east, then north, and finally to the west of EFK 25.1.

Directional Flow*:* EFK 25.1 (near headwater and within Y-12) >^{East} EFK 24.4 (within Y-12) >^{North} EFK 23.4 (just outside of Y-12 east security gate) >^{North} EFK 13.8 (near city of Oak Ridge Waste Water Treatment Plant) >^{West} EFK 6.3 (2 miles east of ETTP) > ^{West} Clinch River (with reference streams of HCK 20.6, and eco-region CCK 1.6)

Specific data results/observations relative to specific parameters:

Non-Radiological Parameters:

1.) Nitrates and nitrites at EFK 6.3 are slightly elevated in comparison to reference sites, as is phosphorus.
2.) The mercury value was 0.058J for EFK 6.3; the TNWQC for mercury is .051 µg/L. A "J" value is an estimate between the minimum detection limit (MDL) and the method quantitation limit (MQL).

Radiological Parameters:

1. The radioactive alpha concentration at EFK 6.3 (2.61 pCi/L) was similar to that of the reference sites; reference sites HCK 20.6 and CCK 1.45 had alpha values of -0.23 and 0.0 pCi/L, respectively.
2. The radioactive beta concentration at EFK 6.3 (2.4 pCi/L) was similar to that of the reference sites; reference sites HCK 20.6 and CCK 1.45 had beta values of 5.6 and 0.0 pCi/L, respectively.

Mitchell Branch:
Tables 6 and 7 present a summary of the 2014 benthic surface water sampling results for Mitchell Branch. The Benthic Macroinvertebrate Monitoring section reported MIK 0.45, based on the benthic data, as being slightly impaired while the reference station, MIK 1.43, was non-impaired.

Table 6: 2014 Mitchell Branch Surface Water Data Summary (non-radiological)

Parameter	MIK 0.45	MIK 1.43 (ref.)	CCK 1.6 (ref.)	TWQC*	Units
pH	7.48	7.29	8.19	5.5-9[a]	None
Specific conductance	457	186	252.6	n.a.	uS/cm
Temperature, water	15.93	14.34	13.44	<=30.5	°C
Dissolved oxygen (DO)	8.67	9.6	10.46	5.0[a]	mg/l
Ammonia-nitrogen	U	U	U	n.a.	mg/l
Hardness, Ca, Mg	220	95	120	n.a.	mg/l
Inorganic nitrogen (nitrate and nitrite)	0.21	0.072	0.31	n.a.	mg/l
Total dissolved solids	260	110	160	500[b]	mg/l
Total suspended solids	U	12	U	n.a.	mg/l
Kjeldahl nitrogen	U	U	U	n.a.	mg/l
Phosphorus	U	U	U	n.a.	ug/l
Iron	190	600	51	n.a.	ug/l
Arsenic	U	U	U	10[c]	ug/l
Cadmium	U	U	U	2.0[d]	ug/l
Chromium	1.3J	U	U	16[e]	ug/l
Copper	1.2	0.52	U	13[d]	ug/l
Lead	U	U	U	5[f]/65[a]	ug/l
Manganese	79	83	11	n.a.	ug/l
Zinc	2.8	U	6.6	120[d]	ug/l
Mercury	U	U	U	0.051[c]	mg/l

*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] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 7: 2014 Mitchell Branch Surface Water Data Summary (radiological)

Parameter	MIK 0.45	MIK 1.43 (ref.)	CCK 1.6 (ref.)	PRG[1]
Gross alpha radioactivity, (Thorium-230 ref std)	9.7	2.68	0	n.a.
Gross beta radioactivity, (Cesium-137 ref std)	29.3	-3	0	n.a.

Units are pCi/L

[1] DOE Preliminary Remediation Goals (PRGs), Recreator: TR=1.0E-6, last updated 11/20/2013

The specific Mitchell Branch data results are organized relative to the directional creek flow beginning near the headwaters and then proceeding downstream and to the west towards Poplar Creek which flows into the Clinch River. Relative to our specific monitoring sites, please note this directional flow where MIK 1.43 is just to the northeast of the secured East Tennessee Technology Park (ETTP) area, previously known as K-25. Additional monitoring sites are to the west and downstream of MIK 1.43.

Directional Flow: MIK 1.43 (very near headwater and reference stream) $>^{\text{Southwest}}$ MIK 0.71 (within secured ETTP/Old K-25) $>^{\text{West}}$ MIK 0.45(within secured ETTP/Old K-25) (with reference streams of MIK 1.43 and eco-region CCK 1.45)

MIK 1.43 is just to the northwest of ETTP, previously known as K-25. In the past the K-25 industrial complex employed a gaseous diffusion process to enrich naturally occurring uranium to the various fissile uranium isotopes such as uranium-233 (^{233}U), and uranium-235 (^{235}U). Currently the old K-25 complex, now known as ETTP, is being deactivated and demolished (D&D). During the D&D, in addition to various uranium isotopes, the radionuclide, technetium-99 (^{99}Tc), has also been found. Also, the non-radiological heavy metal chromium has been found. Chromium (Cr) is a transition metal usually occurring in the environment in its trivalent (Cr^{3+}) state and to a lesser extent in its hexavalent (Cr^{6+}) state. Naturally occurring chromium is almost exclusively in the (Cr^{3+}) state, as the energy required for its oxidation to the (Cr^{6+}) state is quite high. Hence, the (Cr^{6+}) form is usually considered to be a man-made product. The toxicities of the two forms of chromium are very different. (Cr^{3+}) is generally a nontoxic, non-mobile micronutrient; however, (Cr^{6+}) is water soluble, quite toxic, and carcinogenic to human beings.

Specific data results observations relative to specific parameters:

Non-Radiological Parameters:

1.) Compared to the reference sites, specific conductivity, total hardness, and dissolved residue values/concentrations were the lower at MIK 1.43 (reference) and increased as the stream flowed downstream/west into the contaminated footprint of the ETTP / old K-25 area.
2.) Chromium was detected at MIK 0.45 (1.3J), but not detected in the two reference streams.

Radiological Parameters:

1. The radioactive alpha concentration at MIK 0.45 (9.7 pCi/L) was higher than that of the reference sites; reference sites MIK 1.43 and CCK 1.45 had alpha values of 2.68 and 0.0 pCi/L, respectively.

2. The radioactive beta concentration at MIK 0.45 (29.3 pCi/L) was higher than that of the reference sites; reference sites MIK 1.43 and CCK 1.45 had beta values of -3 and 0.0 pCi/L, respectively.

White Oak Creek / Melton Branch:
Tables 8 and 9 present a summary of the 2014 benthic surface water sampling results for White Oak Creek / Melton Branch. The Benthic Macroinvertebrate Monitoring section has reported WCK 2.3 based, on the benthic data, as being slightly impaired while WCK 6.8 was non-impaired.

The specific White Oak Creek / Melton Branch data results are organized relative to the directional creek flow beginning near the headwaters and then proceeding downstream and west into the Clinch River. Relative to our specific monitoring sites, please note this directional flow where WCK 6.8 is just to the northeast of the Oak Ridge National Laboratory (ORNL). Additional monitoring sites are to the southwest and downstream of WCK 6.8. Specifically, White Oak Creek flows southwest through ORNL and then flows west through the associated contaminated Bethel Valley Burial Grounds. Just southeast of this point, Melton Branch flows into White Oak Creek. However, before Melton Branch flows into White Oak Creek, Melton Branch has already flowed through the contaminated Melton Valley Burial Grounds which are located to the northeast of the Bethel Valley Burial Grounds. Just to the southwest of the Melton Branch/White Oak Creek confluence is site WCK 2.3. From this point White Oak Creek flows southwest into the Clinch River.

Table 8: 2014 White Oak Creek Surface Water Data Summary (non-radiological)

Parameter	WCK 2.3	WCK 6.8 (ref.)	CCK 1.6 (ref.)	TWQC*	Units
pH	6.08	6.0	8.19	5.5-9[a]	None
Specific conductance	417	249	252.6	n.a.	uS/cm
Temperature, water	17.08	14.77	13.44	<=30.5	°C
Dissolved oxygen (DO)	8.04	10.33	10.46	5.0[a]	mg/l
Ammonia-nitrogen	0.070	U	U	n.a.	mg/l
Hardness, Ca, Mg	160	120	120	n.a.	mg/l
Inorganic nitrogen (nitrate and nitrite)	1.2	0.17	0.31	n.a.	mg/l
Total dissolved solids	240	150	160	500[b]	mg/l
Total suspended solids	U	U	U	n.a.	mg/l
Kjeldahl nitrogen	0.20	U	U	n.a.	mg/l
Phosphorus	0.29	0.018	U	n.a.	ug/l
Iron	120	81	51	n.a.	ug/l
Arsenic	U	U	U	10[c]	ug/l
Cadmium	U	U	U	2.0[d]	ug/l
Chromium	U	U	U	16[e]	ug/l
Copper	2.4	U	U	13[d]	ug/l
Lead	U	U	U	5[f]/65[a]	ug/l
Manganese	39	11	11	n.a.	ug/l
Zinc	12	6.4	6.6	120[d]	ug/l
Mercury	U	U	U	0.051[c]	mg/l

*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] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 9: 2014 White Oak Creek Surface Water Data Summary (radiological)

Parameter	WCK 2.3	WCK 6.8 (ref.)	CCK 1.6 (ref.)	PRG[1]
Gross alpha radioactivity, (Thorium-230 ref std)	14.4	0	0	n.a.
Gross beta radioactivity, (Cesium-137 ref std)	109.4	0	0	n.a.

Units are pCi/L

[1] DOE Preliminary Remediation Goals (PRGs), Recreator: TR=1.0E-6, last updated 11/20/2013

Directional Flow: WCK 6.8 (very near headwater and reference stream) $>^{\text{Southwest}}$ WCK 3.9 (within secured ORNL) $>^{\text{Southwest}}$ WCK 3.4 (within secured ORNL/Bethel Valley Burial Grounds) $>^{\text{Southeast}}$ MEK 0.3 (within secured Melton Valley Burial Grounds/ORNL/ Bethel Valley Burial Grounds) $>^{\text{Southwest}}$ WCK 2.3 (within secured ORNL/Bethel Valley Burial Grounds) (with reference streams of WCK 6.8 and eco-region CCK 1.45)

WCK 6.8 is located just to the northwest of the ORNL, previously known as X-10. In the past, the X-10 industrial complex employed thirteen nuclear reactors such as the Graphite (X-10) Reactor, two aqueous homogeneous reactors, and an all-metal fast-burst reactor. All of the others were light-cooled and modulated reactors. Today, the only remaining operating reactor at ORNL is the High Flux Isotope Reactor (HFIR). Radioactive materials such as ^{233}U, ^{235}U, ^{239}Pu were employed in the operation of these nuclear reactors and to support the production of nuclear weapons at Y-12. In addition, the radionuclide, strontium-90 (^{90}Sr), is a by-product of nuclear fission reactors. Also, relative to ORNL research projects, other radionuclides were produced. In the production of these nuclear materials at ORNL, non-radiological carcinogenic organic volatiles, such as trichoroethylene (TCE), and tetrachloroethylene (PCE) were also employed.

Specific data results observations relative to specific parameters:

Non-Radiological Parameters:

1.) Phosphorus, zinc, manganese, specific conductivity, total hardness, and dissolved residue values/concentrations were lower at WCK 6.8 and CCK 1.6 (reference sites) than at WCK 2.3.

Radiological Parameters:

1.) The radioactive alpha concentration at WCK 2.3 (14.4 pCi/L) was higher than that of the reference sites; both reference sites (WCK 6.8 and CCK 1.45) had alpha values of 0 pCi/L.
2.) The radioactive beta concentration at WCK 2.3 (109.4 pCi/L) was higher than that of the reference sites; both reference sites (WCK 6.8 and CCK 1.45) had alpha values of 0 pCi/L.

Conclusion

Bear Creek: None of the non-radiological results were greater than the Tennessee General Water Quality Criteria (TWQC). In addition, none of the radiological results were greater than DOE Preliminary Remediation Goals (PRG) goals. Relative to the majority of the above observations, the main trend is that contaminant levels are highest at BCK 12.3 and decrease as Bear Creek flows downstream and to the west. It is likely that as the contaminants travel farther downstream/west, their concentrations are being decreased due to the water dilution effect.

East Fork Poplar Creek: Except for mercury, none of the other non-radiological results were greater than the TWQC. Mercury's TWQC limit in surface water is < 0.051 µg/L. This result was expected due to the Y-12 legacy mercury contamination of EFK. Nonetheless, these elevated EFK mercury values are of great concern as mercury is highly toxic to human beings.

Mitchell Branch: None of the non-radiological results were greater than the TWQC. Relative to the majority of the above observations, the main trend is that contaminant levels are lowest at MIK 1.43 and increase as Mitchell Branch flows downstream and to the west and enters the contaminated footprint of the ETTP/old K-25 complex.

White Oak Creek / Melton Branch: None of the non-radiological results were greater than the TWQC. In addition, none of the radiological results were greater than DOE PRG goals. Phosphorus, zinc, manganese, specific conductivity, total hardness, and dissolved residue values/concentrations were the lower at WCK 6.8 and CCK 1.6 (reference sites) than at WCK 2.3. The radioactive alpha and beta concentrations at WCK 2.3 (14.4 pCi/L) were higher than that of the reference sites. Both reference sites WCK 6.8 and CCK 1.45 had alpha values of 0 pCi/L.

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