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OF

ENVIRONMENT AND CONSERVATION

DOE OVERSIGHT DIVISION

ENVIRONMENTAL MONITORING REPORT

JANUARY through DECEMBER 2012

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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 2012 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's (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, a number of DOE operations on the Oak Ridge Reservation (ORR) continue to have the potential to emit hazardous metals. The HAPs monitoring program has continued as an independent monitoring effort performed by TDEC's Division of Remediation to provide data on hazardous metals in ambient air on the ORR and as independent verification of DOE's monitoring at ETTP. Monitoring with high-volume air samplers was conducted for arsenic, beryllium, cadmium, total chromium, lead, nickel, and uranium. Across the ORR, levels of metals in 2010 and in 2011, other than arsenic and chromium, remained at 2008-2009 levels or increased slightly. Results for 2012 indicate little overall change, although arsenic and lead levels appear to have decreased. With the possible exception of chromium during the third quarter at Y-12, analytical results for all metals were below regulatory standards and risk-specific dose levels. The total chromium analysis was slightly above a risk-specific dose for hexavalent chromium, but below the risk-specific dose for trivalent chromium and the current laboratory quantification value for the analytical method used. This project will continue to monitor for concentrations of hazardous metals in Oak Ridge Reservation (ORR) ambient air at ETTP, X-10 and Y-12. The goal is to provide independent air monitoring to assure protection of human health and the environment around the ORR.

RadNet Air Monitoring on the Oak Ridge Reservation

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 (NAREL) in Montgomery, Alabama. In 2012, as in past years, the data for each of the five RadNet air monitors exhibited similar trends and concentrations. The results for 2012 do not indicate a significant impact on the environment or public health from Oak Ridge Reservation emissions.

Fugitive Radioactive Air Emission on the Oak Ridge Reservation

The DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation uses mobile high-volume air samplers to monitor for airborne releases of radioactive contaminants from remedial and waste disposal activities on the Department of Energy's Oak Ridge Reservation. The results are compared to background measurements in order to determine if releases have occurred and to limits provided in the Clean Air Act (CAA) in order to assess compliance with associated emission standards. In 2012, DOE Oversight deployed eight of the air monitors in the program. One of the samplers was stationed to collect background information and a second to monitor the disposal of radioactive waste at the Environmental Management Waste Management Facility. The remaining samplers were positioned to monitor remedial activities at the East Tennessee Technology Park, the Oak Ridge National Laboratory, and the Y-12 National Security Complex. Monitored activities included the decommissioning and demolition of contaminated facilities. These facilities were constructed during World War II to manufacture enriched uranium, plutonium, and other radioisotopes used to produce the first atomic weapons. Remediation of associated waste disposal facilities (i.e., Tank W-1A soils and K-1070-B Old Classified Burial Ground) was also monitored. Findings indicate that fugitive releases occurred during 2012, but the concentrations were well below the CAA standards.

Perimeter Air (Low Volume) Monitoring on the Oak Ridge Reservation

The Tennessee Department of Environment and Conservation's Division of Remediation performs radiochemical analysis on samples collected from ten perimeter air monitoring stations located at exit pathways for airborne releases from the Department of Energy (DOE) Oak Ridge Reservation. The results are compared to background measurements and to standards prescribed by the Clean Air Act. Data derived from this program, along with that generated by the other division air monitoring programs, provides information used to assess the impact of DOE activities on the local environment and public health. In 2012, the results for samples collected from the perimeter air monitors were similar to those collected at the background station and were well below Clean Air Act standards.

RadNet Precipitation Monitoring on the Oak Ridge Reservation

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. Gross beta analysis for the RadNet precipitation program was discontinued in 2010 and tritium analysis was discontinued in 2012. Analysis for gamma radionuclides is performed on each composite monthly sample and will continue to be monitored. As much of the 2011 data was not yet available from EPA at the time of the last report, the 2011 tritium results are included in this report, as are the tritium results since the program's inception at each of the three sites on the reservation. The tritium data for samples from the RadNet precipitation monitors varied considerably throughout the time periods monitored for each site as well as from site to site. Since there is not a regulatory limit for radioisotopes in precipitation, the results from ORR sampling are compared to data from other sites nationwide and to EPA's drinking water limits. The tritium in precipitation results from the ORR RadNet sampling were generally higher than the national average for all other RadNet precipitation sites, but were often not the highest overall values seen in the nation. While the Oak Ridge Reservation did generally have higher tritium values in precipitation samples, the stations were located in areas near nuclear sources while most of the other stations in the RadNet precipitation program monitoring tritium were located near major population centers, with no major sources of radiological contaminants nearby. Regardless, the tritium levels seen in the precipitation samples collected at the RadNet sites on the ORR were all well below the EPA drinking water limits, as were the other isotopes measured in the program. It should be noted, the EPA drinking water limits pertain to drinking water, not precipitation, and are only used here as a possible indicator of an issue.

BIOLOGICAL MONITORING

Benthic Macroinvertebrate Monitoring

The biotic integrity of streams originating on the Oak Ridge Reservation (ORR) was determined during 2012 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, five reference stream stations were sampled. Benthic samples were collected and processed following the State of Tennessee standard operating procedures for macroinvertebrate surveys. 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 in all four 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.

Periphyton Monitoring

Diatom communities colonizing artificial substrates were sampled to assess the water quality and ecological condition of Bear Creek impacted by Department of Energy (DOE) activities on the Oak Ridge Reservation, especially the tributaries around the Environmental Management Waste Management Facility (EMWMF). Periphyton samples were collected from artificial substrates between June and December 2012 at four impacted Bear Creek sites. The goal was to use diatoms as biomonitoring tools for the ecological assessment and scoring of the water quality and to examine the recovery of Bear Creek as compared to historical periphyton data extracted from a reference stream. Water quality parameters (i.e., conductivity, pH, etc.) were also collected during each sampling event. Results presented include the diatom bioassessment index (calculated from six metrics), photosynthetic light data, stream water quality data (i.e., conductivity, metals), and diatom community composition.

Index results showed that the headwater BCK 12.3 site scored a 72.93 (no units), then the score increased to 78.61 at BCK 11.5, indicating better water quality. However, the next site downstream of BCK 11.5 dropped to 72.45 at BCK 10.6, inferring a possible impact from the north tributaries into Bear Creek. Lastly, the score increased again to 80.79 at the downstream BCK 9.6, suggesting improving water quality conditions along a longitudinal stream gradient with distance from the Y-12 Plant sources of pollution. Pollution sensitive diatoms in Bear Creek become more dominant downstream with distance from the pollution source.

Canada Geese Monitoring

In June 2012, the Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (DOE-O) conducted oversight of the annual Canada geese (*Branta canadensis*) Oak Ridge Reservation (ORR) Surveillance Program. The objective of this study was to determine if geese are becoming contaminated on the ORR. The captured geese were transported to the Tennessee Wildlife Resources Association (TWRA) game check station on Bethel Valley Road to undergo live screenings for radioactive contamination. None of the geese captured this year showed elevated gamma counts exceeding the 5 pCi/g game release level. Since no contaminated geese were captured, the DOE-Oversight Office did not conduct additional offsite sampling of Canada Geese.

Aquatic Vegetation Monitoring on the Oak Ridge Reservation

The Aquatic Vegetation Sampling program collects vegetation at locations near or in water, usually 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 activity, gross beta activity, and for gamma radionuclides and is compared to the radiological analysis of vegetation taken from background locations. The sampling conducted during 2012 suggests limited areas of elevated radionuclide concentrations in the vegetation associated with surface water on the ORR.

Threatened and Endangered Species Monitoring

The 2012 TDEC DOE-O plant survey characterizes the 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 of the BORCE. Although specific locations of plant species will not be listed in this report, a virtual tour of species identified and documented during 2012 is presented. Results list plant species, their respective scientific names, and, if applicable, their state and federal status. A total of 38 species were identified including 12 ferns, one tree (American chestnut sprouts), three shrubs, and 22 herbaceous plants. Of these, nine are state-listed species and one is federally-listed. Thus the majority of plants that were documented during 2012 are not T&E species, but collectively represent the tremendous wealth of floral diversity present on the ORR.

Twelve species of bats were documented based upon echolocation recordings and bat identification software. Staff tentatively identified the federally-endangered Gray bat at 19 locations, and the federally-endangered Indiana bat at six locations. These are important findings given the lack of previous information regarding the federally-endangered bats on the ORR. Work in 2013 will concentrate on confirmation of these identifications and distributions on the Oak Ridge Reservation.

White-tailed Deer Monitoring Program on the Oak Ridge Reservation

The DOE-Oversight Office of the TDEC Division of Remediation (TDEC DOEO) continued deer capture activities on the Oak Ridge Reservation (ORR) during 2012. The goal was to chemically immobilize deer and install global positioning system (GPS) collars 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, piscavores), subsisting in habitats impacted by industrial pollution, are ingesting environmental contaminants from their respective food chains. Humans could potentially be at risk due to unwittingly consuming contaminated game meat and fish which have bioaccumulated metals and other contaminants from the environment. 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 potentially significant vector for contaminant exposures to the public. This project is part of a multiyear investigation. Previous 2011 GPS collar investigations and results suggest a young buck swam across the Clinch River from ORNL into Knox County. White-tailed deer may temporarily leave their home range during the rut season, or to avoid hunting pressure and other anthropogenic disturbances, and may wander into urban areas to forage. During 2012, office staff captured and collared four deer, one in the city of Oak Ridge and three in Melton Valley. Two collars were retrieved and GPS fix data was downloaded and home ranges (and excursions from core area) were determined from the recovered collar data and presented herein. Hair samples were collected from each captured animal to test for heavy metals. This investigation includes laboratory testing for metals data on deer tissue and hair. There is a considerable variability with the metals reported for deer hair. It is difficult to determine the specific source of the metal contaminants from this initial investigation; however, contaminants may be bioaccumulated in deer tissues during ingestion of contaminated browse and soil (i.e., mineral licks).

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) is expanding its oversight of DOE facilities' safe drinking water programs. The scope of the office's independent sampling includes oversight of potable water quality potentially impacted by DOE's legacy contamination on the ORR. In 2012, TDEC conducted oversight of the potable water distribution systems and the water quality at ORR facilities. The 2012 results of this oversight revealed that the three reservation systems provide water that meets state regulatory levels.

RadNet Drinking Water on the Oak Ridge Reservation

The RadNet program was developed by the U.S. Environmental Protection Agency to monitor potential pathways for significant population exposures from routine and accidental releases of radioactivity from major sources in the United States (U.S. EPA, 1988). 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 a 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 ETTP Water Treatment

Plant, all results generated by the program have remained below regulatory criteria since its inception in 1966.

GROUNDWATER MONITORING

Groundwater Monitoring for the Oak Ridge Reservation and Its Environs

The Tennessee Oversight Agreement requires the state of Tennessee to provide independent monitoring and oversight to verify Department of Energy (DOE) data and to assess the effectiveness of DOE contaminant control systems on the Oak Ridge Reservation (ORR) and its environs. In 2012, Tennessee Department of Environment and Conservation (TDEC) DOE Oversight (DOE-O) monitored groundwater parameters at springs and collected samples for analysis, to assess the groundwater quality adjacent to and within the ORR. Data were gathered from electronic loggers at three springs, confirming that conduits, rapid non-darcian velocities, sinking streams, and deep complicated flow paths are involved around the ORR. Groundwater samples were collected at one residential well, one monitoring well, one surface water location, and from eleven springs. Samples were analyzed for radiochemicals, inorganics, volatile organic aromatics (VOAs) and in selected locations for stable nitrogen and oxygen isotopes. RWA-119 did show a result for copper that exceeded the 90^{th} National Water Quality Assessment (NWQA) percentile value (0.0123 mg/L). Pump House Well, (sampled twice) did not report any constituents above the screening criteria. Given the close proximity of Pump House Well to known groundwater contamination it will remain a concern and a target for future sampling. No significant results were reported from the one surface sample obtained from Scarboro Creek. Bootlegger Spring has continued to show characteristic VOAs (dichloroethene, dichloroethane, and trichloroethene) below applicable Maximum Contaminant Levels (MCLs). At spring SS-4 on the ORR, nitrate, uranium, gross alpha and gross beta were detected at concentrations exceeding the screening criteria. At GW-214 inorganic constituents were detected above the NWQA 90^{th} percentile, similar to areas on and off the ORR. Determining the source (natural or anthropogenic) of inorganic constituents is always problematic, particularly considering the limited data collected in Bear Creek Valley. Further work is needed to determine the source and possibly the distribution of constituents detected.

RADIOLOGICAL MONITORING

Facility Survey Program and Infrastructure Reduction Work Plan

The historic release of chemical and radiological materials from buildings and other facilities on the Department of Energy's Oak Ridge Reservation has led to elevated levels of contaminants in regional terrestrial and aquatic ecosystems. In an effort to understand more about the sources of these contaminants, the DOE-Office investigates the historic and present-day potential for release of contaminants from facilities through its Facility Survey Program. During its nineteen-year history the program has examined 202 facilities and found that forty-three percent (86) have either contributed to, or pose a relatively high potential for, release of some contaminant to the environment. These facilities are referred to as "high rankers" in the program's Potential for Environmental Release database. 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 2012 no facilities were removed due to the expiration of available American Recovery and Reinvestment Act funds.

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 in Bear Creek Valley for disposal. To account for wastes that may have originated from trucks in transit, personnel from the Tennessee Department of Environment and Conservation perform walkover inspections of the road and associated access roads weekly. Items noted are surveyed for radiological contamination, documented, and their description and location submitted to DOE for disposition. During 2012 a number of items were noted that had potentially fallen from trucks transporting waste to the EMWMF, but none 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

The Tennessee Department of Environment and Conservation began monitoring ambient radiation levels on the Oak Ridge Reservation in 1995. The program provides 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 the state dose limit for members of the public. While all the doses reported for 2012 at off-site locations were below the dose limit for members of the public, several locations 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.

Real Time Monitoring of Gamma Radiation on the Oak Ridge Reservation

In 2012, the Tennessee Department of Environment and Conservation placed gamma radiation exposure rate monitors at six locations on the Department of Energy's Oak Ridge Reservation. These units measure and record gamma radiation levels at predetermined intervals over extended periods of time, 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 2012, six locations were monitored in the program, including: three remedial sites at the Oak National Laboratory; the 7000 Area Truck Monitor; the exhaust stack of the Spallation Neutron Source; 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.

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). The Tennessee Department of Environment and Conservation, Department of Energy Oversight Office's Radiological Monitoring and Oversight Program conducted independent radiological monitoring of these surplus materials prior to each auction/sale. During 2012, a total of seven inspection visits were conducted at the ORR facilities. Four visits were made for ORNL sales and three visits were made for Y-12 sales. No sales were conducted at the East Tennessee Technology Park (ETTP) facility. A total of sixteen items, eleven at ORNL and, five at Y-12 were observed that required further evaluation. All sixteen of these items exhibited elevated alpha and beta radioactivity, and were withdrawn from the sales until further evaluations were conducted.

Monitoring of Waste at the Environmental Management Waste Monitoring Facility Using a Radiation Portal Monitor

The EMWMF was constructed for the disposal of low level radioactive waste and hazardous waste generated by remedial activities on the DOE's Oak Ridge Reservation. The facility is operated under CERCLA authority 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 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 2012, three sets of anomalous measurements that could not be explained by preliminary information were submitted to DOE Oversight's Audit Team and are currently under review.

SURFACE WATER MONITORING

Environmental Monitoring at the Environmental Management Waste Management Facility

The Tennessee Oversight Agreement requires the state of Tennessee to provide monitoring in order to verify Department of Energy (DOE) data and to assess the effectiveness of DOE contaminant control systems on the Oak Ridge Reservation. During 2012, the Tennessee Department of Environment and Conservation's (TDEC), Division of Remediation, DOE Oversight Office monitored groundwater elevations, effluents, surface water runoff, and sediments at DOE's Environmental Management Waste Management Facility (EMWMF). The monitoring has shown the potential for groundwater levels to be above a required ten foot geologic buffer along the north and northeast portion of the disposal cells. An incursion near Piezometer PP-02 was also identified from the 2011 water level data. Additional monitoring is warranted to determine if the incursion near PP-02 is due to issues with the underdrain, the northern trench drain, or a function of the additional waste cells. Results from radiological water samples indicate that radionuclides are being discharged from operations conducted at EMWMF. However, those discharges are in compliance under TDEC Rule 1200-2-11-.16. Results of radiochemical analysis of sediment samples indicate that radiological discharges are not substantially impacting the sediments of NT-5 and Bear Creek.

Ambient Sediment Monitoring

Sediment samples from several Clinch River and Poplar Creek sites were analyzed for metals, toxicity and radiological parameters. The mercury levels in all of the Clinch River sediment samples were less than the Probable Effects Concentration (PEC) of 1.06 mg/kg (range is from 0.015 to 0.70 mg/kg) (MacDonald et al. 2000). Poplar Creek mercury values all exceed the PEC (range from 1.90 mg/kg to 22 mg/kg). Although cesium-137 can be detected in Clinch River sediment samples taken downstream of the mouth of White Oak Creek, the levels are low and do not pose a threat to human health. Sediment toxicity testing showed no significant differences (p=0.05) between samples and pooled reference sites (Clinch River Mile [CRM] 52.6, CRM 41.2, CRM 35.5). Reference sites did not differ significantly from one another in survival or growth. The result at CRM 10.0 (63.8 % survival) was significantly different (p=0.05) from the laboratory control group (88.8% survival).

Ambient Surface Water Monitoring

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 on or adjacent to the ORR. Relative to the four ORR watersheds, *Bear Creek (BCK)*, *East Fork Poplar Creek (EFK)*, *Mitchell Branch (MIK)*, and *White Oak Creek (WCK) / Melton Branch (MEK)*, legacy Department of Energy (DOE) ORR operations have released contaminants to their respective surface waters with mainly these three major chemical families, volatile and semi-volatile organic compounds, heavy metals, and radionuclides. Relative to this study, these types of chemicals are classified as contaminants of concern (COC). The above four impacted ORR watersheds, (*BCK*, *EFK*, *MIK*, and *WCK / MEK*) flow either indirectly via Clinch River tributaries/watersheds or directly into the Clinch River. Relative to this study, additional Clinch River ORR tributaries/watersheds of interest are *McCoy Branch (MCM)*, *Raccoon Creek (RCM)*, *Grassy Creek (GCM)*, *Poplar Creek (PCM)*, and *Clear Creek (CCM, ecoregion reference tributary)*. Relative to the area of the Clinch River which is near the ORR, the 2012 Ambient Surface Water data results indicate that the Clinch River's surface water is currently not exceeding Tennessee Water Quality Criteria or DOE Preliminary Remediation Goals

Surface Water (Physical Parameters) Environmental Monitoring

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 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 2012, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-O, or the office), collected ambient water quality data at six ORR stream locations and one offsite reference stream location. In addition, Upper East Fork Poplar Creek was instrumented with continuous water quality data loggers to observe water quality data during a planned water augmentation shutoff and to determine if water quality parameters are impacted during fish kills. The effect of the augmentation was a slight decrease in specific conductivity. No discharges or fish kills were observed during the continuous monitoring.

Ambient Trapped Sediment Monitoring

In order to monitor for changes in contaminant flow through sediment transport, passive sediment samplers (traps) were deployed at three locations in Poplar Creek and at one location on the Clinch River. Of four samplers deployed, only the one at Poplar Creek Mile (PCM) 2.2 was retrievable. This sample exceeded the consensus-based sediment quality guidelines (CBSQGs) Probable Effects Concentration (PEC) (1.06 mg/kg) for mercury (3.6 mg/kg). 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 effect concentrations (TECs) are concentrations below which adverse effects are not expected to occur (Ingersoll *et al.* 2000). None of the other data from this sample exceeded the Threshold Effects Concentration (TEC).

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
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
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)
ED1, ED2, ED3	Economic Development Parcel 1, Parcel 2, and Parcel 3
EFPC	East Fork Poplar Creek
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)
ET&I	Equipment Test and Inspection
ETTP	East Tennessee Technology Park

FDA	U. S. Food and Drug Administration
FFA	Federal Facilities Agreement
FRMAC	Federal Radiation Monitoring and Assessment Center
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)
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
l	liter
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
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
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
NEPA	National Environmental Policy Act
ng	nanogram

NIC	Not In Compliance
NESHAPs	National Emissions Standards for HAPs
NNSS	Nevada National Security Site (formerly the Nevada Test Site, NTS)
NOAEC	No Observable Adverse Effect Concentration (to Tested Organisms)
NOV	Notice of Violation
NPDES	National Pollution Discharge Elimination System
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
PAM	Perimeter Air Monitor
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
RSE	Remedial Site Evaluation
SLF	Sanitary Landfill
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
TDEC	Tennessee Department of Environment and Conservation
TDS	Total Dissolved Solids
TIE	Toxicity Identification Evaluation
TLD	Thermoluminescent Dosimeter
TMI	Tennessee Macroinvertebrate Index
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
TWQC	Tennessee Water Quality Criteria
TWRA	Tennessee Wildlife Resources Agency
UCOR	URS/CH2M Oak Ridge LLC (Current EM Prime Contractor)
U.S.	United States
UT-Battelle	University of Tennessee-Battelle (ORNL Prime Contractor)
VOA	Volatile Organic Analytes
VOC	Volatile Organic Compound
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

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 2012 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. 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.

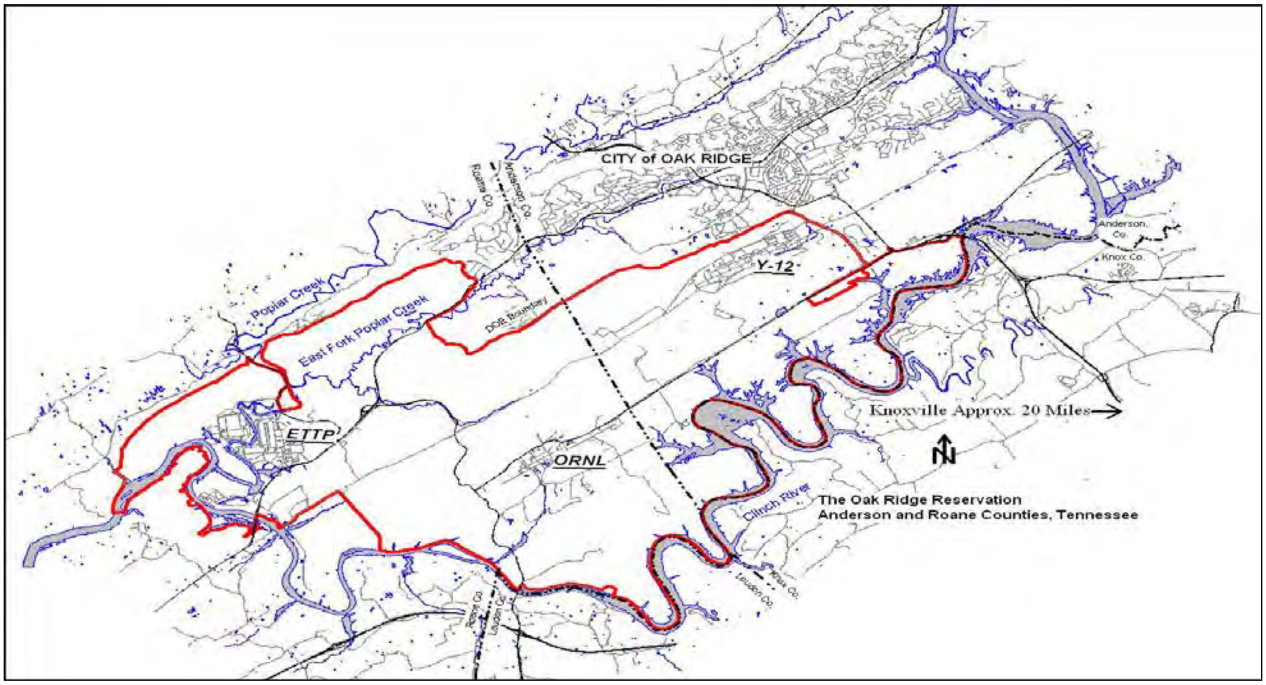

Figure 1: The Oak Ridge Reservation

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.

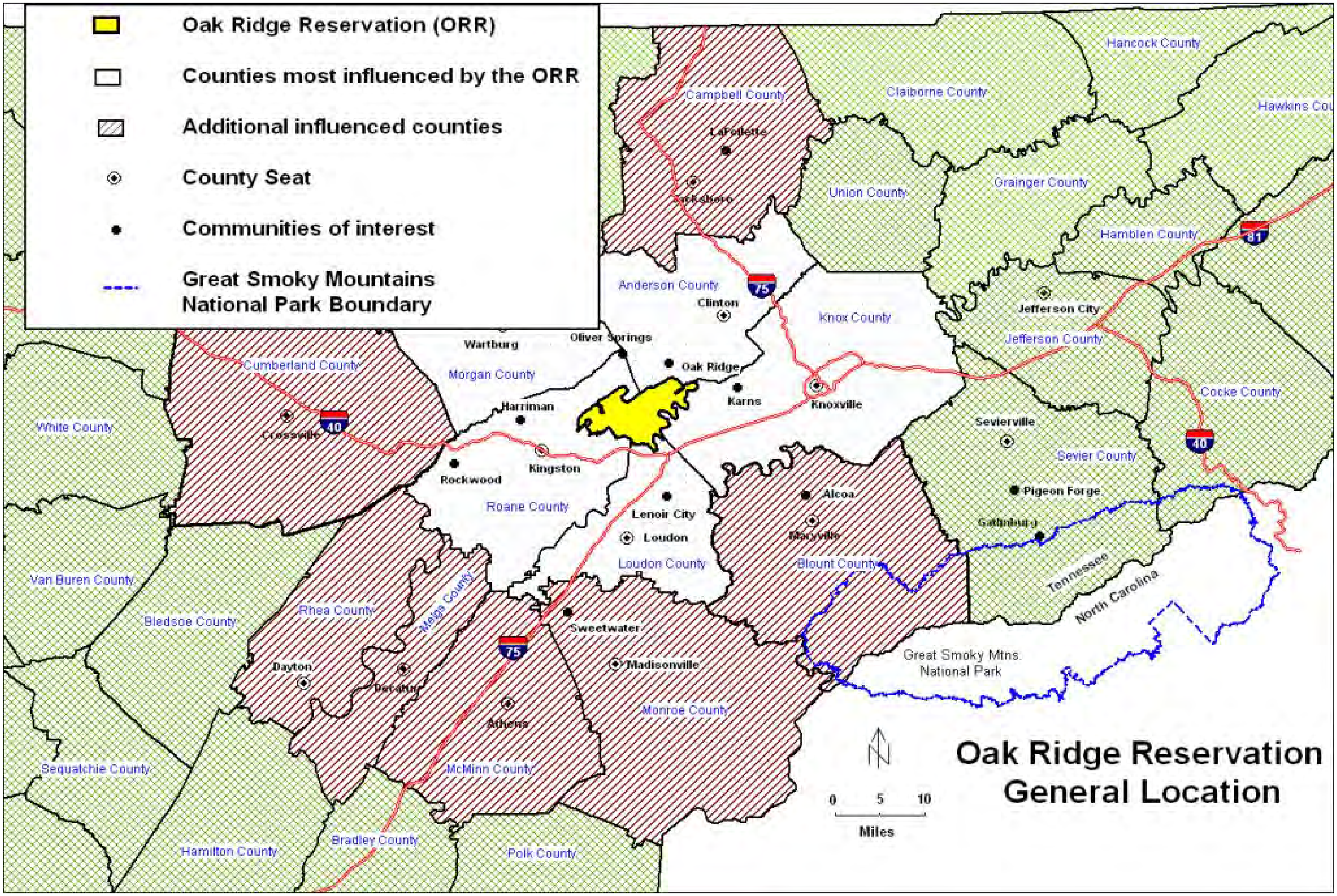

Figure 2: Location of the Oak Ridge Reservation in relation to surrounding counties

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.

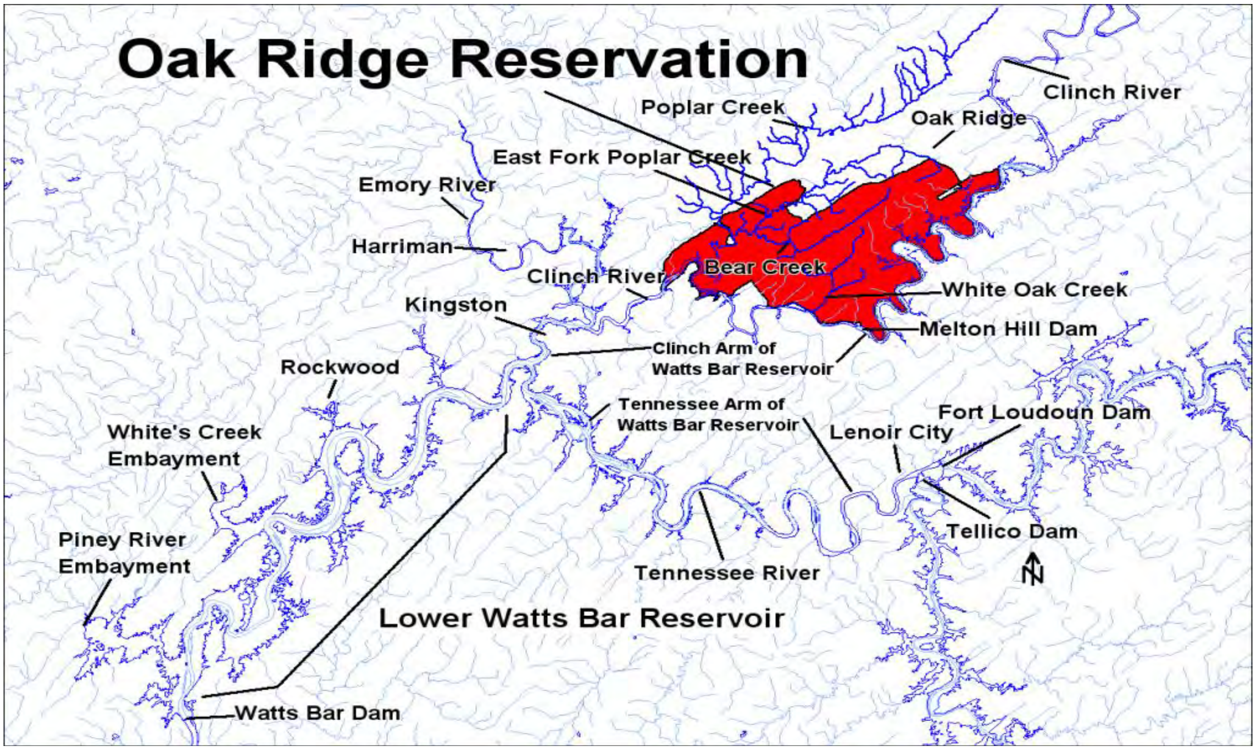

Figure 3: Watts Bar Reservoir

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 Author: Sid Jones

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, a number of DOE operations on the Oak Ridge Reservation (ORR) continue to have the potential to emit hazardous metals. The HAPs monitoring program has continued as an 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. Monitoring with high-volume air samplers was conducted for arsenic, beryllium, cadmium, total chromium, lead, nickel, and uranium. Across the ORR, levels of metals in 2010 and in 2011 other than arsenic and chromium remained at 2008-2009 levels or increased slightly. Results for 2012 indicate little overall change, although arsenic and lead levels appear to have decreased. With the possible exception of chromium during the third quarter at Y-12, analytical results for all metals were below regulatory standards and risk-specific dose levels. The total chromium analysis was slightly above a risk-specific dose for hexavalent chromium, but below the risk-specific dose for trivalent chromium and the current laboratory quantification value for the analytical method used. This project will continue to monitor for concentrations of hazardous metals in Oak Ridge Reservation (ORR) ambient air at ETTP, X-10 and Y-12. The goal is to provide independent air monitoring to assure protection of human health and the environment around the ORR.

Introduction

Title III of the Clean Air Act Amendments (CAAAs) identified 189 toxic chemicals. These chemicals, called hazardous air pollutants (HAPs), are associated with adverse health effects and are used widely in a variety of industries. Major stationary sources of HAPs are subject to the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) found in Title III of the CAAAs of 1990. Rather than set NESHAPs limits for each pollutant, the 1990 CAAAs directed the Environmental Protection Agency (EPA) to set technology-based standards using maximum achievable control technologies (MACT) for 175 source categories to achieve reductions of routine emissions of toxic air pollutants.

In 1997, concerns were raised by members of the public regarding potential health effects due to possible concentrations of HAPs in the ambient air on and around the ORR, specifically near the Toxic Substances Control Act Incinerator (TSCAI) at the East Tennessee Technology Park (ETTP). The Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office's (DOE-O) Hazardous Air Pollutants (HAPs) monitoring program was developed to provide monitoring of hazardous metals in air at ETTP and to verify the

Department of Energy's (DOE) HAPs monitoring program, which was restricted to monitoring for metals at the ETTP site. In response to these concerns, the division's Waste Management (WM) program developed a more comprehensive monitoring program for the ORR to determine what effects, if any, DOE operations were having on levels of hazardous metals in the ambient air on and around the reservation. This program was designed to provide a verification of monitoring results reported by the DOE and to extend the range of monitoring beyond the East Tennessee Technology Park area to other sites on the reservation. Background data were collected at a site located near Norris Lake in 1997. These data were used to establish a baseline for the area surrounding the ORR. A change in analytical methods initiated in 2006 by the Tennessee Department of Health (TDH) Environmental Laboratories resulted in lower limits for detection and quantification of all metals. Over the past five years, samples have been composited for quarterly analysis rather than analyzed weekly, consistent with the procedure used by the DOE program for monitoring of metals at the ETTP site. The program continues as a part of the independent monitoring around the ORR carried out by TDEC's Division of Remediation (DOR), DOE-O Office under authority of the Tennessee Oversight Agreement between TDEC and DOE. Air monitoring data generated by this program and by DOE are reviewed to refine or change sampling techniques, analytical methods, or location of samplers.

ETTP

The ambient air-sampling at this site has been primarily conducted at stations co-located with DOE monitors K-2 (Blair Rd opposite the TSCA Incinerator), Perimeter Air Monitor K-42 (next to Poplar Creek) and Perimeter Air Monitor K-35 (Gallaher Road Bridge area). The locations of these monitoring stations are shown in Figure 1. Sampling was at Blair Road exclusively from 2005 until the third quarter of 2012, primarily to facilitate comparison with a co-located DOE sampler. Additional factors in selecting locations were the availability of a power source and monitoring data reported by the DOE in the Annual Site Environmental Report (ASER). These data indicated that both lead and uranium average values were typically highest at the K-2 (as opposed to the K-35 or K-42) site. In 2012, the sampler was moved to the K-11 site shown in Figure 1. This site is in closer proximity to the demolition activities that potentially constitute the primary source of HAPs emissions following closure of the TSCA incinerator in 2009. Metals results reported for four sites at ETTP in the 2011 ASER indicate that the K-11 monitoring station typically records the highest values for both metals and radionuclides.

X-10 (ORNL)

Monitoring at ORNL was resumed in 2008 after being temporarily discontinued in 2007 due to relocation of the power supply. The location of the sampler has remained on the main ORNL campus facility near the Tank W1A (Core Hole 8) removal action (where it was moved in 2006) to monitor airborne radionuclides. Remedial work at the Tank W1A site continued into 2012, and the sampler was left at the site throughout the year as it was located near demolition projects that had the potential to create fugitive emissions of HAPs metals and radionuclides. The sampler location (X-10 CH-8) and the historical monitoring sites at the east end and west end of the plant are shown in Figure 2.

Y-12

For the past five years, air monitoring at Y-12 was conducted at the station located at the east end of this facility. The old sampling station located south of the Lake Reality area was abandoned when the Y-12 plant needed to expand parking in this area. The air monitor was relocated about 1000 feet to the north near Station 17 on East Fork Poplar Creek, as shown in Figure 3, during the summer of 2012. The monitoring site at the west end of Y-12, also shown, is west of the main plant area north of Bear Creek Valley Road.

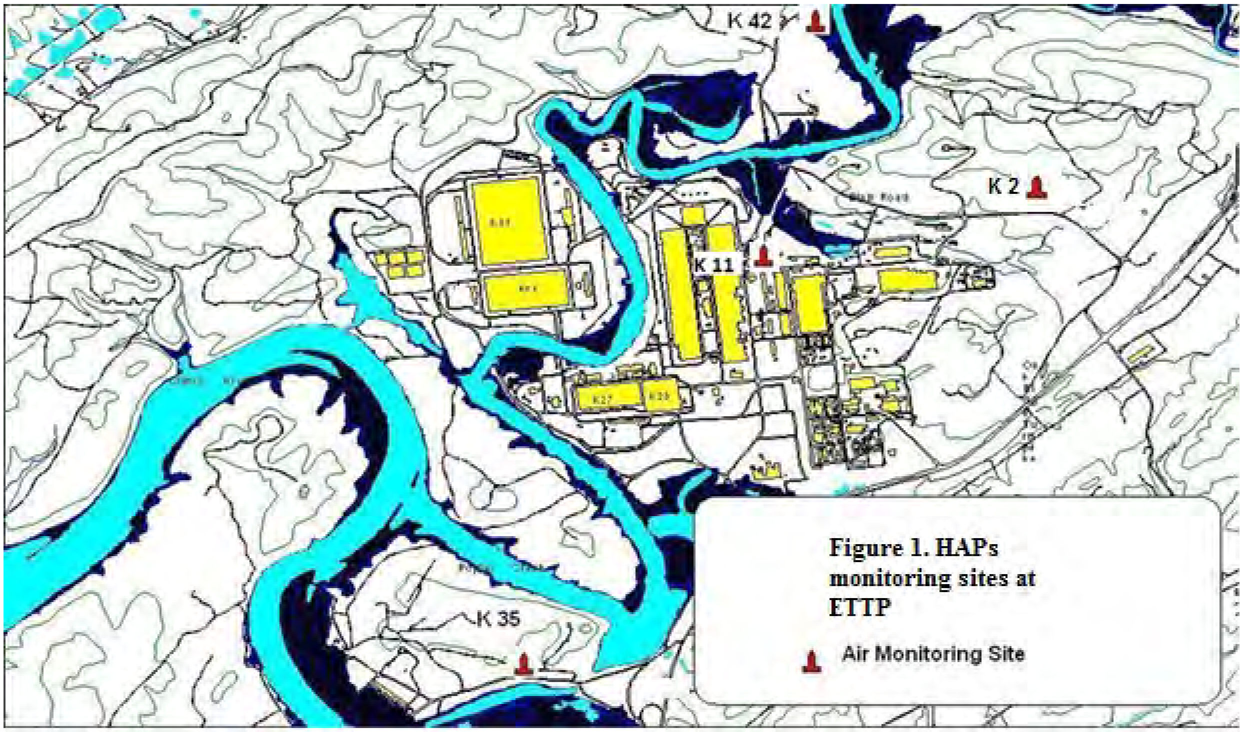

Figure 1: ETTP HAPs Sampling Locations

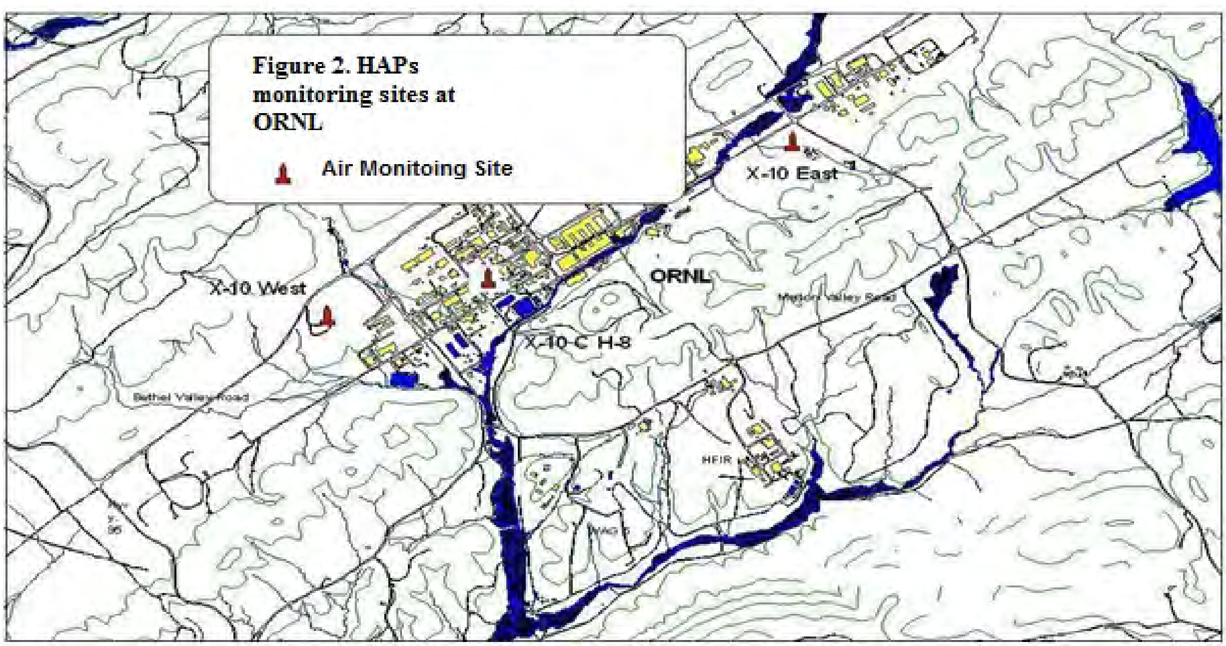

Figure 2: ORNL HAPs Sampling Stations

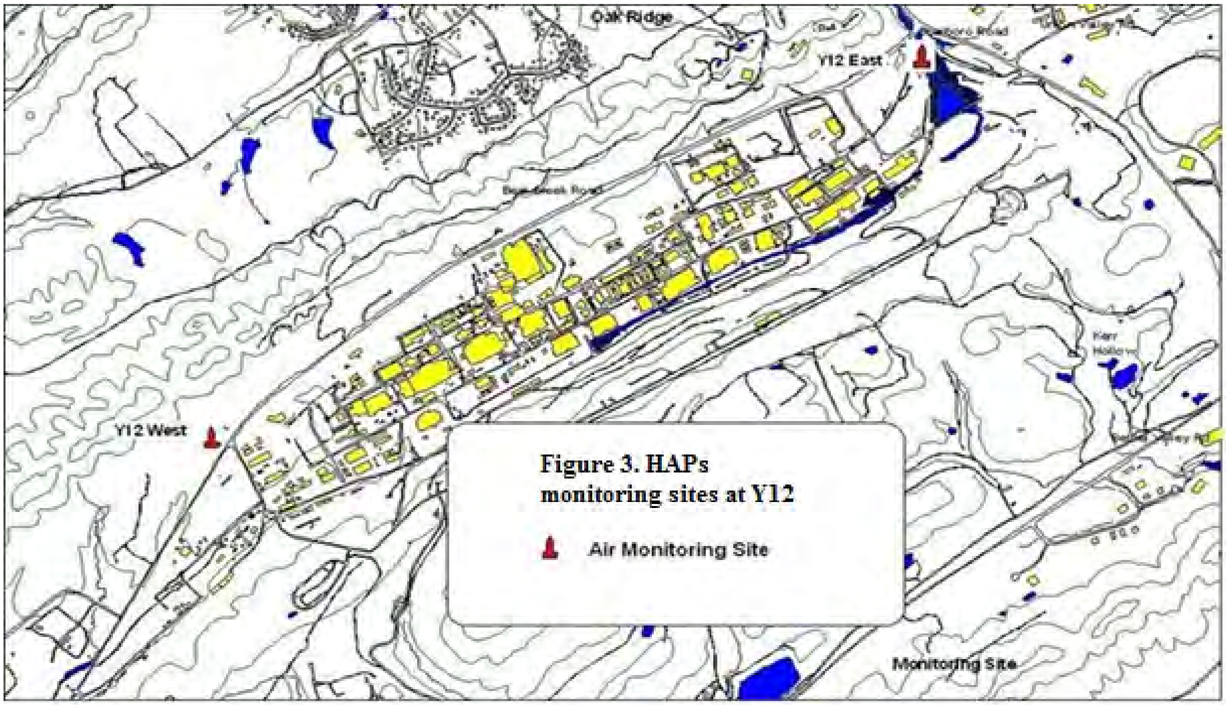

Figure 3: Y-12 HAPs Sampling Locations

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 concentration of HAPs metal in ambient air. As stated above, the ORNL monitor was 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. 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. Filter samples were collected on a weekly basis and mailed to the state (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. Table 1 lists the frequency of sample collection and analysis during 2012. In 2012, quarterly composites made from weekly samples from the three sites were sent to the TDH laboratory for analysis. The office retained a portion of each filter and, hence, the ability to analyze archived weekly samples. Throughout 2012, the

HAPs program 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 split samples at the ETTP and Y-12 sites.

Table 1: HAPs Metals Ambient Air Sampling Schedule at ETTP, ORNL and Y-12 for 2012

Monitoring period	Sampling Locations	Sampling period	Collection frequency	Analysis frequency
12/31/11-12/29/12	K2	Continuous	Weekly	Quarterly
12/31/11-12/29/12	X-10 CH8	Continuous	Weekly	Quarterly
12/31/11-12/29/12	Y-12 E	Continuous	Weekly	Quarterly

Results and Discussion

Quarterly lead results were determined from composite analyses of continuous weekly samples from stations K-2 and K-11 at the ETTP site, Y-12 E at the Y-12 site, and from the Core Hole 8 station at ORNL. Lead analytical results are summarized in Table 2 and are compared with the national quarterly ambient air quality standard, revised in 2008 to 0.15 μg/m^3. The 2012 results were generally lower than in the last few years, with a maximum of 5% of the quarterly standard.

At the time of this report, the ORR Annual Site Environmental Report (ASER) for 2012 was not available. Analytical results for lead generated from the HAPs monitoring program over the past five years at all three ORR sites were generally comparable with the concentrations reported by DOE in the ASER for the ETTP site. The 2011 ASER reported lead around ETTP at levels between 0.001 and 0.01 μg/m3. The change in analytical technique from inductively coupled plasma (ICP) to inductively coupled plasma - mass spectrometry (ICP-MS) by the Tennessee Department of Health (TDH) Environmental Laboratory in Nashville may have resulted in better resolution at low values. Reported concentrations of lead for 2007, the first year ICP-MS was used, were typically one half to one third those reported for most of the previous years. In 2012, average lead values decreased at all sites from 2011.

Table 2: Lead Concentration in Ambient Air in 2012 at ETTP, Y-12 and ORNL

Site	Quarterly composite sample results (μg/m3)				Max quarterly result (μg/m3)	Max percent of quarterly standard (μg/m3)*
	1	2	3	4		
ETTP	0.0024	0.0023	0.0081	0.002	0.0081	5%
Y-12	0.0026	0.0031	0.0024	0.0012	0.0031	2%
ORNL	0.0026	0.0028	0.002	0.0027	0.0028	2%

*National air quality standard for lead is 0.15 μg/m3 quarterly arithmetic average.

Analytical results for 2012 of all hazardous metals except lead are summarized in Tables 3 through 5. Averages are calculated using the laboratory minimum detection limit (MDL) when the sample concentration is less than this value. The quarterly results for 2012 are given in Tables 6-8. As there are no current Tennessee or national ambient air quality standards for these hazardous air pollutants, concentrations were compared to risk-specific doses and reference air concentrations as listed in Appendix V of Part 266, Title 40 of the U.S. Code of Federal

Regulations (40 CFR 266). Estimated results for total chromium at Y-12 during the third quarter of 2012 were slightly above the annual concentration guide for chromium in the +6 oxidation state (Cr VI), but at levels well below the guide for chromium in the +3 state (Cr III).

Table 3: Summary Table of Hazardous Air Pollutant Carcinogenic Metals Concentration in Ambient Air at the Y-12 East Site for 2012

Analyte	Ambient air concentration (μg/m3)			Minimum quantitation limit (μg/m3)	Minimum detection limit (μg/m3)
	Annual average concentration	Quarterly Maximum	Annual concentration guideline		
Arsenic	0.00070	0.00110	0.0023[a]	0.0037	0.00032
Beryllium	0.00002	0.00006	0.004[a]	0.00005	0.00001
Cadmium	0.00014	0.00018	0.0056[a]	0.00005	0.00002
Chromium	0.00084	0.00093J	0.00083[a] Cr-VI 1000.0[a] Cr-III	0.0037	0.00081
Nickel	0.00039	0.00056	0.042[a]	0.00005	0.00001
Uranium	0.00005	0.00012	0.15[b]	0.00004	0.000001

[a] Risk-specific doses for As, Be, Cd, Cr-VI, and Ni and the reference air concentration for Cr-III as listed in 40 CFR 266.
[b] DOE Order 5400.5 Derived Concentration Guide (DCG) for naturally occurring uranium is an annual concentration of 1E-01 pCi/m3, which is equivalent to 100 mrem annual inhalation dose. This is equivalent to 0.15 μg/m3 assuming mass-to-curie concentration conversion for natural uranium assay of 0.717% 235U.
J concentration is less than quantitation limit

Table 4: Summary Table of Hazardous Air Pollutant Carcinogenic Metals Concentration in Ambient Air at the X-10 Core Hole 8 Site for 2012

Analyte	Ambient air concentration (μg/m3)			Minimum quantitation limit (μg/m3)	Minimum detection limit (μg/m3)
	Annual average concentration	Quarterly Maximum	Annual concentration guideline		
Arsenic	0.00078	0.00087	0.0023[a]	0.0037	0.00032
Beryllium	0.000025	0.00004	0.004[a]	0.00005	0.00001
Cadmium	0.00015	0.00018	0.0056[a]	0.00005	0.00002
Chromium	0.00081	0.00081	0.00083[a] Cr-VI 1000.0[a] Cr-III	0.0037	0.00081
Nickel	0.000445	0.00051	0.042[a]	0.00005	0.00001
Uranium	4.25E-05	0.000073	0.15[b]	0.00004	0.000001

[a] Risk-specific doses for As, Be, Cd, Cr-VI, and Ni and the reference air concentration for Cr-III as listed in 40 CFR 266.
[b] DOE Order 5400.5 Derived Concentration Guide (DCG) for naturally occurring uranium is an annual concentration of 1E-01 pCi/m3, which is equivalent to 100 mrem annual inhalation dose. This is equivalent to 0.15 μg/m3 assuming mass-to-curie concentration conversion for natural uranium assay of 0.717% 235U.
J concentration in sample is less than quantitation limit

Other metals were detected at levels less than concentration guidelines (guidelines based on risk-specific doses are also listed in Tables 3 through 5). With the possible exception of chromium VI, arsenic continues to be the primary contributor to risk from hazardous metals in ambient air around the ORR. DOE results for metals monitoring at ETTP reported in the ASER also consistently showed arsenic to be the lead contributor to risk. Current minimum quantitation limits remain higher than risk-specific values for both arsenic and chromium VI, and analyses on blank filters for 2012 show trace amounts of lead, nickel and chromium. Results for blanks included in Tables 6 -8 were computed using either the results or the detection limits on blank filters and the mean volume of air passing through filters at each site in 2012. Chromium, nickel, and lead were detected on blank filters in 2012.

Table 5: Summary Table of Hazardous Air Pollutant Carcinogenic Metals Concentration in Ambient Air at the ETTP (K-2 and K-11 sites) for 2012

Analyte	Ambient air concentration (μg/m3)			Minimum quantitation limit (μg/m3)	Minimum detection limit (μg/m3)
	Annual average concentration	Quarterly Maximum	Annual concentration guideline		
Arsenic	0.000963	0.0012	0.0023[a]	0.0037	0.00032
Beryllium	0.000015	0.00003	0.004[a]	0.00005	0.00001
Cadmium	7.75E-05	0.00015	0.0056[a]	0.00005	0.00002
Chromium	0.00081	0.00081	0.00083[a] Cr-VI 1000.0[a] Cr-III	0.0037	0.00081
Nickel	0.00046	0.00067	0.042[a]	0.00005	0.00001
Uranium	3.63E-05	0.000053	0.15[b]	0.00004	0.000001

[a] Risk-specific doses for As, Be, Cd, Cr-VI, and Ni and the reference air concentration for Cr-III as listed in 40 CFR 266.
[b] DOE Order 5400.5 Derived Concentration Guide (DCG) for naturally occurring uranium is an annual concentration of 1E-01 pCi/m3, which is equivalent to 100 mrem annual inhalation dose. This is equivalent to 0.15 μg/m3 assuming mass-to-curie concentration conversion for natural uranium assay of 0.717% 235U.
J concentration in sample is less than quantitation limit

Table 6: Hazardous Air Pollutant Metals Concentrations in Ambient Air at Y-12 in 2012

Analyte	Quarterly composite sample results (μg/m3)				Results for blanks based on mean volume (μg/m3)	Maximum percent of guideline (μg/m3)*
	Quarter 1	Quarter 2	Quarter 3	Quarter 4		
Arsenic	0.00032J	0.0011J	0.00094J	0.00044J	6E-05	47.8
Beryllium	0.00001U	0.00001U	0.000057	0.00001U	2.03E-05	1.4
Cadmium	0.00018	0.00014	0.00018	0.000062	4.06E-05	3.2
Chromium	0.00081U	0.00081U	0.00093J	0.00081U	0.000318	112.0
Nickel	0.00033	0.00045	0.00056	0.00022	0.000132	1.3
Uranium	0.000027J	0.000028J	0.00012	0.000026J	0.000132	0.1

U - Not detected in sample
J - concentration in sample is less than quantitation limit.
* Concentration guidelines, detection and quantitation limits are listed in Tables 3 through 5 above

As stated above, results from the ORR Annual Site Environmental Report (ASER) for 2012 are not available at this time. However, analytical results generated by the HAPs monitoring program over the past five years were compared with results for past years reported in the 2011 ASER. The ASER data indicated sporadic detection of hazardous air pollutant metals at ETTP, with no quarterly concentrations exceeding the risk-specific doses. ASER data show a general increase in metals concentration in 2007, lower values through 2010, and an increase in 2011. TDEC data prior to 2006 include some weekly concentrations that significantly exceed both the more recent TDEC results and the averages reported by DOE for total chromium. Some of these TDEC results were higher than the risk-specific dose level for chromium VI, although significantly below standards for chromium III. Laboratory analyses for the air data reported in the DOE ASER were done using inductively coupled plasma mass spectrometry (ICP-MS), perhaps with better detection or quantification limits than those done by the TDH laboratory prior to 2007. Quality of the older TDEC data suffered from relatively high detection limits for most metals. Many results were non-detect, making meaningful comparison with DOE data impossible. Nickel was not included as a monitoring parameter in the ASERs.

Table 7: Hazardous Air Pollutant Metals Concentrations in Ambient Air at X-10 in 2012

Analyte	Quarterly composite sample results (µg/m3)				Results for blanks based on mean volume (µg/m3)	Maximum percent of guideline (µg/m3)*
	Quarter 1	Quarter 2	Quarter 3	Quarter 4		
Arsenic	0.00071J	0.00082J	0.00072J	0.00087J	5.61947E-05	37.8
Beryllium	0.00001U	0.00001U	0.00004J	0.00004J	1.9007E-05	1.0
Cadmium	0.00013	0.00014	0.00015	0.00018	3.80141E-05	3.2
Chromium	0.00081U	0.00081U	0.00081U	0.00081U	0.000297501	97.6
Nickel	0.00035	0.00051	0.00049	0.00043	0.000123959	1.2
Uranium	0.000012J	0.000015J	0.000073	0.00007	0.000123959	0.0

U - Not detected in sample
J - concentration in sample is less than quantitation limit.
* Concentration guidelines, detection and quantitation limits are listed in Tables 3 through 5 above

Table 8: Hazardous Air Pollutant Metals Concentrations in Ambient Air at ETTP in 2012

Analyte	Quarterly composite sample results (µg/m3)				Results for blanks based on mean volume (µg/m3)	Maximum percent of guideline (µg/m3)*
	Quarter 1	Quarter 2	Quarter 3	Quarter 4		
Arsenic	0.00099J	0.0012J	0.00093J	0.00073J	5.89E-05	52.2
Beryllium	0.00001U	0.00001U	0.00001U	0.00003J	1.99E-05	0.8
Cadmium	0.00013	0.00015	0.000015	0.000015	3.99E-05	2.7
Chromium	0.00081U	0.00081U	0.00081U	0.00081U	0.000312	97.6
Nickel	0.00032	0.00031	0.00067	0.00054	0.00013	1.6
Uranium	0.000018J	0.000032J	0.000042	0.000053	0.00013	0.0

U - Not detected in sample
J - concentration in sample is less than quantitation limit.
* Concentration guidelines, detection and quantitation limits are listed in Tables 3 through 5 above

Conclusions

The results of the 2012 HAPs monitoring conducted by TDEC at ETTP, ORNL and Y-12 sites indicate possible elevated levels of chromium VI during the third quarter at the Y-12 monitoring station. Exact levels are uncertain, as current minimum quantitation limits for total chromium are higher than risk-specific values for chromium VI, and the chromium analysis does not distinguish between the two common oxidation states of chromium (III and VI). Analyses on blank filters show trace amounts of chromium, as well as lead and nickel, but at values too low to greatly influence results. All other HAPs metals of concern were measured at annual average concentrations below the annual risk specific guidelines as prescribed in 40 CFR 266 and DOE Order 5400.5 This project has been re-authorized to continue into 2013. The monitors will remain at the east Y-12 sampling site, K-11 at ETTP, and in the X-10 main campus area through 2013 unless changes in DOE operations dictate a change in monitoring locations. Samples will continue to be taken each week by the radiological monitoring program following the standard operating procedures for air monitoring. Filters will be split and composited for quarterly analysis.

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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 2012, as in past years, the data for each of the five RadNet air monitors exhibited similar trends and concentrations. The results for 2012 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 four 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 perimeter and fugitive air monitoring programs (described in associated reports) focus on monitoring exit pathways off the reservation and 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 the other two programs, targets specific operations such as the High Flux Isotope Reactor (HFIR) and provides independent verification of both state and DOE monitoring data.

Methods and Materials

The approximate 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, 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.

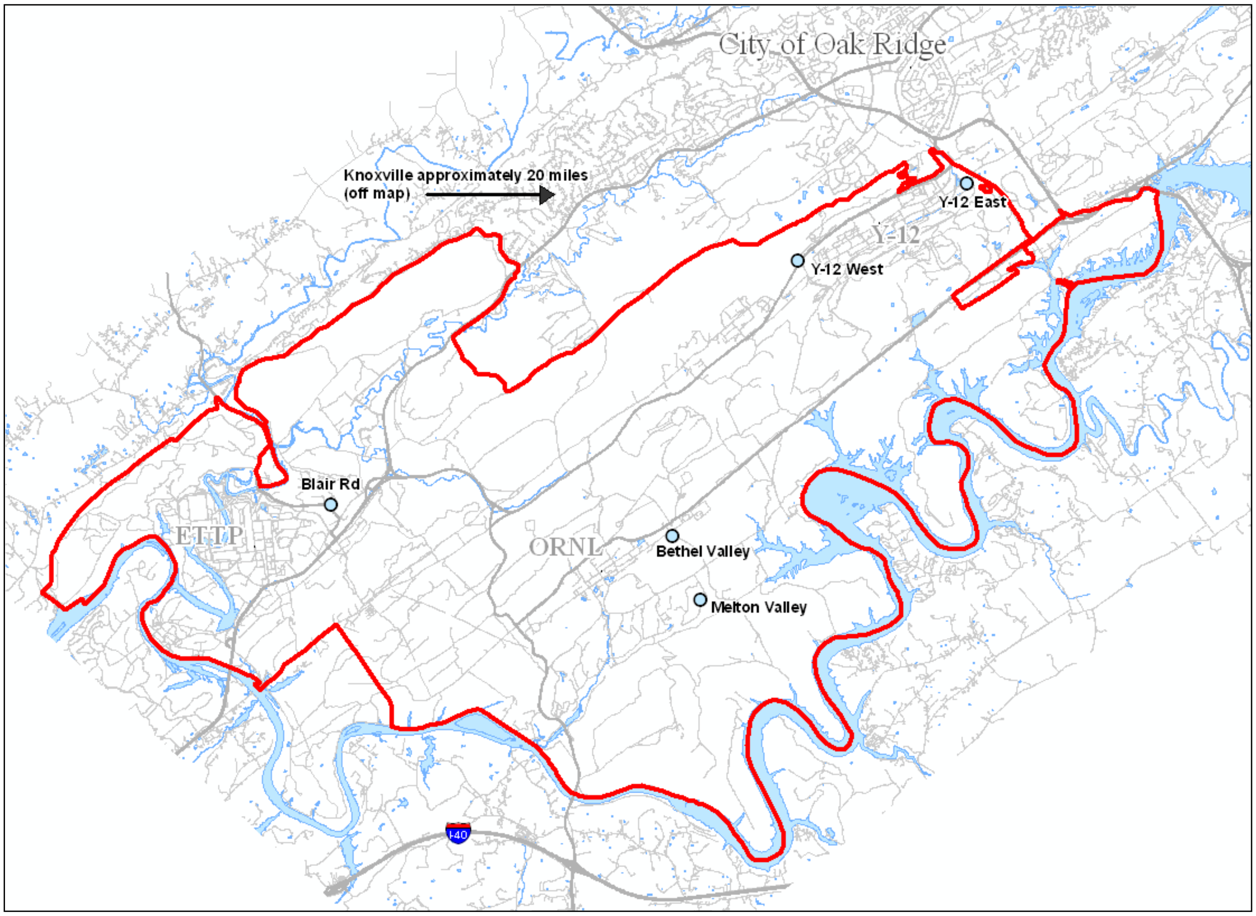

Figure 1: Approximate locations of air stations monitored by TDEC on the Oak Ridge Reservation in association with EPA's RadNet air monitoring program

The results of NAREL's analyses 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).

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 compared to background data from the fugitive monitoring program and to the Clean Air Act (CAA) environmental limit for strontium-90, as it is a pure beta emitter with a conservative limit. The background sampler for the fugitive program is located at Fort Loudoun Dam in Loudon County and samples are collected on a weekly basis.

Results and Discussion

As seen in Figure 2, the results for the gross beta analysis in 2012 were similar for each of the five ORR RadNet monitoring stations and most were lower than, but similar to the results reported for the Fugitive Air Monitoring Program background station. The 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. The gross beta results for the five ORR RadNet air stations are all well within the normal range for RadNet gross beta air results from across the nation. The 2012 results are also all well below 1.0 pCi/m^3, which is the screening level requiring further analysis.

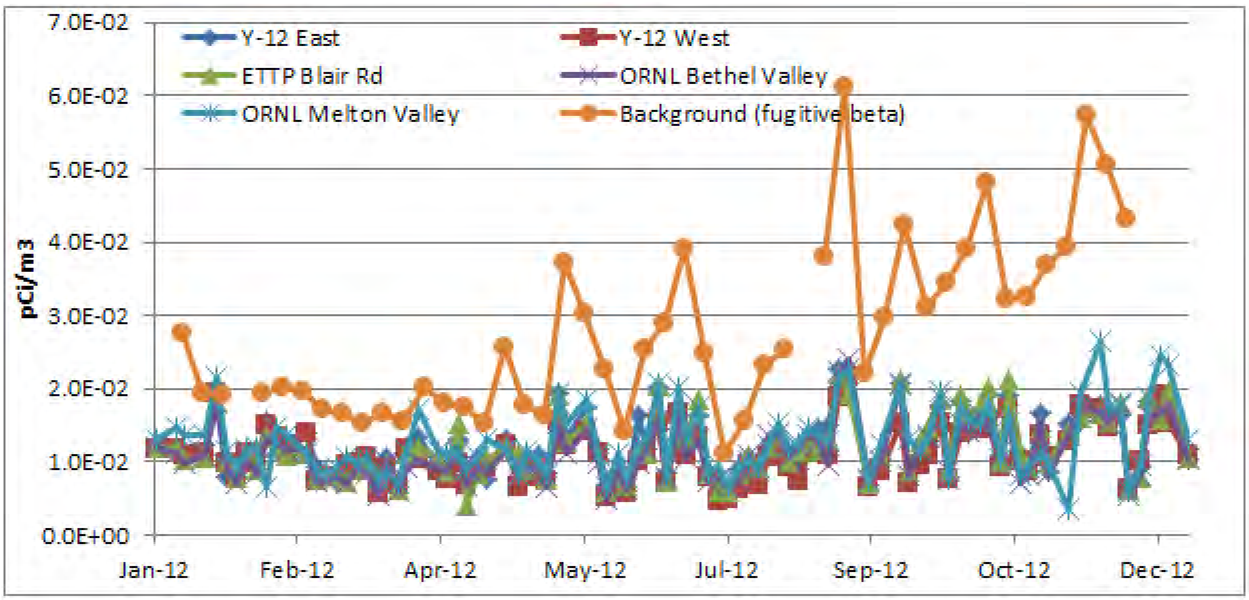

Figure 2: 2012 Gross beta results from air samples taken on the ORR in association with EPA's RadNet air monitoring program and background measurements from the DOE-O Office's fugitive air monitoring program

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 2012 average gross beta results for each of the five stations in the ORR RadNet Program, the average background concentration measured at Fort Loudoun Dam by the DOE-O Office's Fugitive Air Monitoring Program, 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.

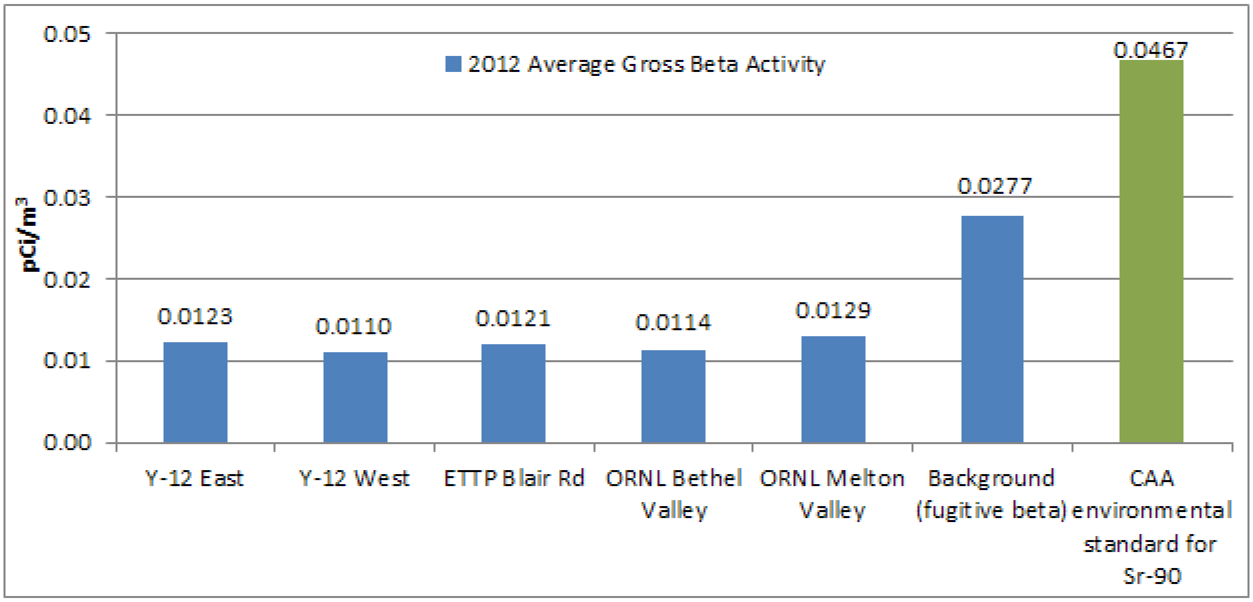

Figure 3: 2012 Average gross beta results for air samples taken on the ORR in association with EPA's RadNet air monitoring program

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 background measurements taken from the DOE-O Office's Fugitive Air Monitoring Program for 2012 (CAA value for Sr-90 [0.019 pCi/m^3] + annual average gross beta = 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 background station for the Fugitive Air Monitoring Program, which operates at a similar flow rate to the RadNet air program. 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 results at all the RadNet air stations in 2012 are 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 2012 were slightly lower overall at the Y-12 West station and slightly higher at the ORNL Melton Valley location. The average results from each of the ORR RadNet monitoring stations fall well below the strontium-90 limit (Figure 3).

In 2012, none of the gross beta results reported for the program exceeded the screening level (1.0 pCi/m^3) that would have required analysis by gamma spectrometry. The 2012 results for the uranium and plutonium analysis performed on annual composites of the air filters were not available at the time of this report: however, the 2011 results can be seen in Table 2.

Table 2: 2011 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	CAA standards (amount above background)
Pu-238	-3.00E-07	-6.80E-07	-7.00E-08	-2.40E-07	-7.00E-08	2.10E-03
Pu-239	-1.00E-07	0.00E+00	3.30E-07	0.00E+00	2.00E-07	2.00E-03
U-234	2.96E-05	9.32E-05	5.86E-05	2.98E-05	6.20E-06	7.70E-03
U-235	4.10E-06	5.60E-06	4.70E-06	2.14E-06	1.93E-06	7.10E-03
U-238	9.30E-06	1.56E-05	1.38E-05	7.10E-06	5.38E-06	8.30E-03

While the annual composite uranium and plutonium values would generally be compared to similar analyses at a background location, this data was not available. However, even assuming a background of zero, values seen were well below CAA limits.

Conclusion

As in the past, the gross beta results for each of the five RadNet air monitoring stations exhibited similar trends and concentrations. The available RadNet data for 2012 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 Authors: Gary Riner, Howard Crabtree

Abstract

The DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation uses mobile high-volume air samplers to monitor for airborne releases of radioactive contaminants from remedial and waste disposal activities on the Department of Energy's Oak Ridge Reservation. The results are compared to background measurements for determining if releases have occurred and to limits provided in the Clean Air Act (CAA) in order to assess compliance with associated emission standards. In 2012, DOE Oversight deployed eight of the air monitors in the program. One of the samplers was stationed to collect background information and a second to monitor the disposal of radioactive waste at the Environmental Management Waste Management Facility. The remaining samplers were positioned to monitor remedial activities at the East Tennessee Technology Park, the Oak Ridge National Laboratory, and the Y-12 National Security Complex. Monitored activities included the decommissioning and demolition of contaminated facilities constructed during World War II. These facilities were built to manufacture enriched uranium, plutonium, and other radioisotopes used in the production of the first atomic weapons. Remediation of associated waste disposal facilities (i.e., Tank W-1A soils and K-1070-B Old Classified Burial Ground) was also monitored. Findings indicate that fugitive releases occurred during 2012, but the concentrations were well below the CAA standards.

Introduction

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). Sampling in the program focuses on locations where there is a potential for the airborne release of radioactive air emissions from non-point sources of contaminants (i.e., fugitive emissions), such as remedial and waste management activities. In 2012, the reservation samplers were used to monitor: the decontamination and demolition of uranium enrichment facilities at the East Tennessee Technology Park (ETTP); central campus removal actions at the Oak Ridge National Laboratory (ORNL); footprint reduction activities at the Y-12 nation Security Complex (Y-12); and disposal of radioactive waste at the Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley.

To monitor the emissions, seven air samplers have been mounted on trailers or elevated platforms and positioned near these locations or activities of interest. An eighth sampler has been stationed at Fort Loudoun Dam in Loudon County to collect background information. When the results are compared, samples taken from the reservation stations that have no contribution from reservation sources (other than those that occur naturally) should be similar to the background data. Conversely, results exhibiting significantly higher concentrations of radioactive contaminants are indicative of a release subject to the provisions of the Clean Air Act (CAA). In this regard, Title 40 Code of Federal Regulations Part 61, Subpart H, of the CAA limits DOE radiological emissions to quantities that would not cause a member of the public to receive an effective dose equivalent greater than 10 millirem (mrem) in a year. In addition, DOE is required to meet provisions of the law that require all radioactive emissions to be as low as reasonably achievable (ALARA).

Methods and Materials

The project's eight high-volume air samplers use 8x10-inch, glass-fiber filters to collect particulates from air, which is drawn through the units at a rate of approximately 35 cubic feet per minute. To help assure the accuracy of the measurements, airflow through each sampler is calibrated quarterly, using a Graseby General Metal Works Variable Resistance Calibration Kit. The filters are collected weekly and shipped to the State of Tennessee's Environmental Laboratory in Nashville, Tennessee, for analysis. Analyses requested are based on the radionuclides of concern for the location being monitored and previous findings. Consequently, the analyses vary for the different locations. The locations of the monitoring stations are depicted in Figure 1 and current analysis is provided in Table 1, along with the sampling locations and the activities being monitored.

After the results are received from the laboratory, data from the reservation samplers are compared to the background results (to assess if a release has occurred) and screening levels set by the CAA to determine if additional analysis is warranted. Since the CAA does not provide standards for gross analysis, gross alpha and beta results when used are compared to the standards for uranium-235 and strontium-90 respectively. These radionuclides are found routinely on the reservation and have some of the more restrictive limits provided in the act. If the results exceed the screening levels, additional analysis is performed to identify the specific radionuclides responsible for the elevated results and the data is reevaluated based on the isotopic analysis.

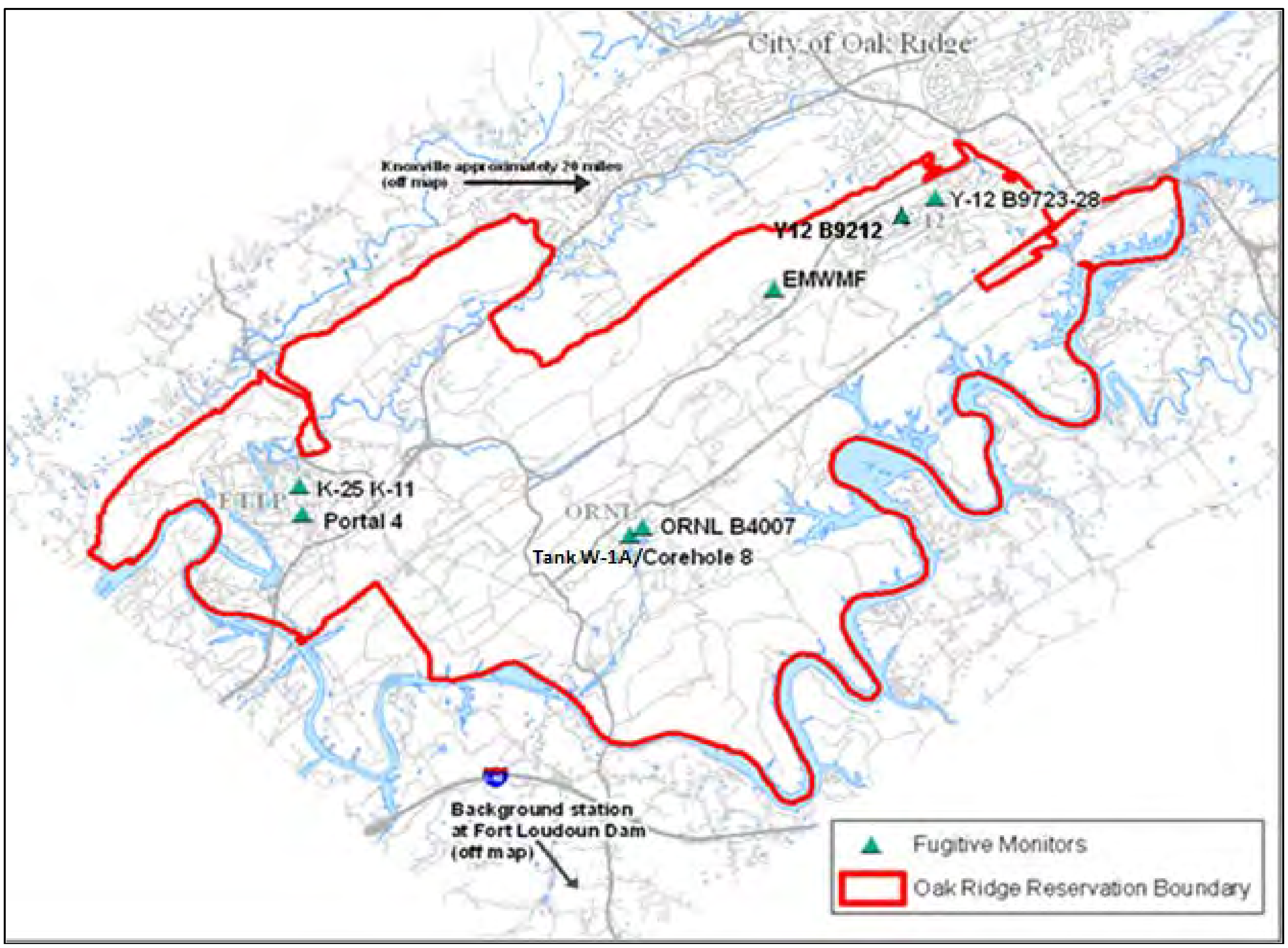


Figure 1: Approximate locations of sites monitored for fugitive air emissions in 2012

Table 1: Current fugitive air emission monitoring stations and associated radiochemical analysis

Monitoring Station	Activity Monitored	Frequency		Analysis			
		Sampling	Analysis	Gross Alpha & Beta	Uranium Isotopes	Gamma Spectrometry	Technetium-99
Y-12: Building 9723	Y-12 facility reduction activities	weekly	biweekly composite		X		
Y-12 Building 9212	Y-12 facility reduction activities	weekly	biweekly composite		X		
ETTP: K-25 K-11	K-25 D&D, K-1070B Burial Ground remediation	weekly	biweekly composite		X		X
ETTP: Portal 4	K-25 & K-27 D&D	weekly	biweekly composite		X		X
ORNL: Tank W1A/Core Hole 8	ORNL central campus remediation	weekly	weekly	X		X	
ORNL: B4007	ORNL central campus remediation	weekly	weekly	X		X	
EMWMF	Disposal of radioactive waste	weekly	weekly	X		X	
Fort Loudoun Dam (Loudon County)	Background	weekly	weekly	X		X	
			biweekly composite				

Results and Discussion

East Tennessee Technology Park and Y-12 National Security Complex

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 technetium-99 and other fission and activation products are also present, due to the periodic processing of recycled uranium obtained from spent nuclear fuel. 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 biweekly for radiochemical analysis, Current analysis includes uranium U-234, U-235, U-238, and technitum-99, with additional analysis performed, if warranted.

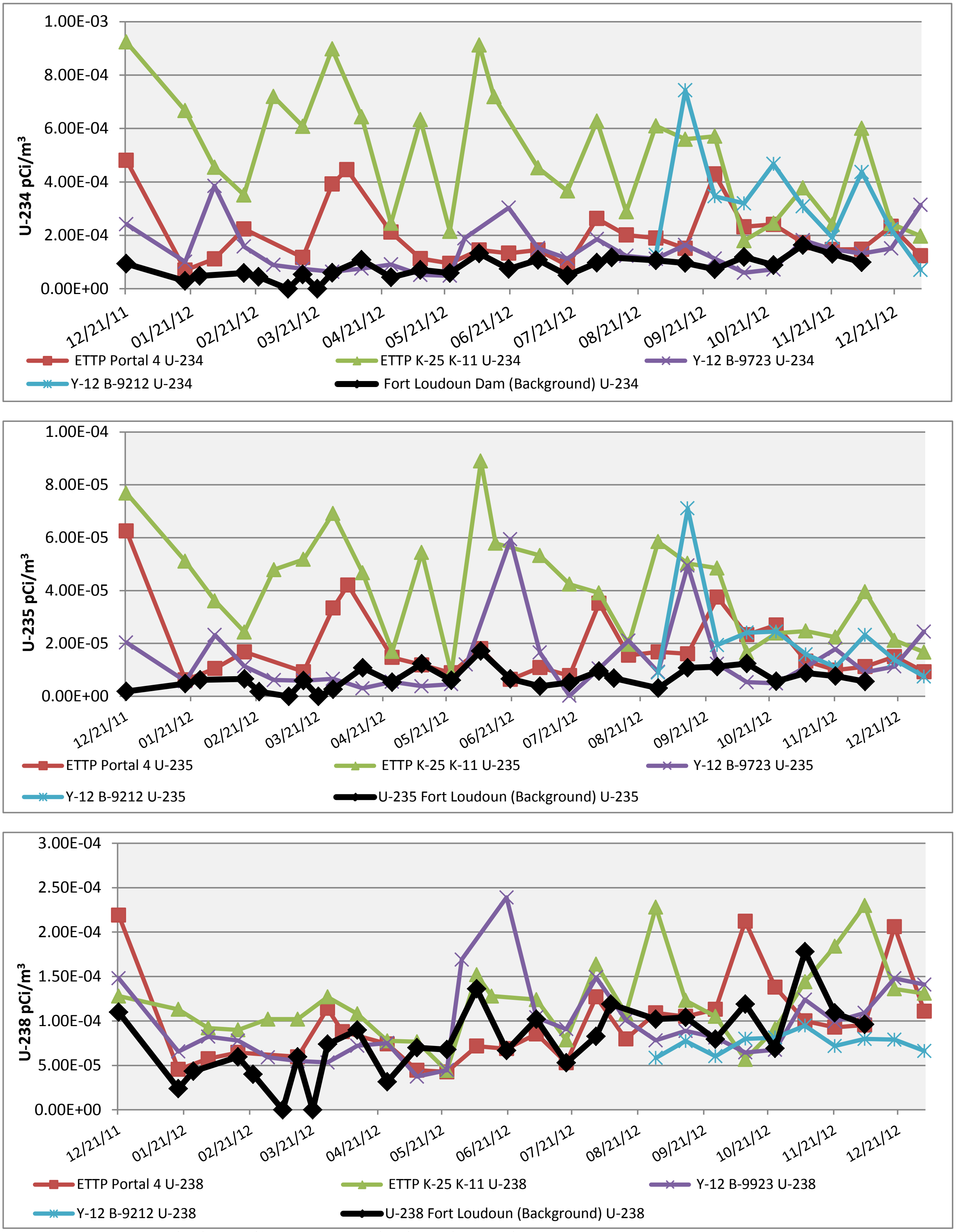
The K-25 K-11 air sampler was positioned next to the northeast end of the K-25 Process Building in March 2008 to monitor D&D of the facility and remedial activities at the adjacent K-1070-B Old Classified Burial Ground. The K-25 Process Building housed the first production facility built to produce highly enriched uranium by the gaseous diffusion process. The largest building in the nation when it began operations in 1945, the building stood four stories high and covered approximately 40 acres. Demolition of the facility began in 2008 and has continued through subsequent years, with only a portion of the east wing (the purge cascades) remaining to be addressed. The five acre K-1070-B Old Classified Burial Ground operated from the late 1950s through 1976 and was used to dispose of radioactively contaminated classified equipment from the S-50 Thermal Diffusion Plant, the K-1131 Feed Plant, and the K-25, K-27, and K-29 Uranium Processing Buildings. The second air sampler at ETTP (ETTP Portal 4) was placed at the southeast end of the K-25 Process Building in May 2006 and has also been used to monitor emissions from the demolition of the K-25 facility, as well as D&D of the K-27 Process Building. The K-27 facility is a 383,000 square foot gaseous diffusion sister facility to the K-25 Process facility.

The Y-12 Plant was also constructed during World War II to enrich uranium in the U-235 isotope, in this case by the electromagnetic separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, to conduct lithium/mercury enrichment operations, to manufacture components for nuclear weapons, to dismantle nuclear weapons, and to store enriched uranium. The Y-12 B9723 air monitor was located centrally at Y-12 (near building 9723) in July of 2010 to monitor the D&D of 112 contaminated facilities included in the Y-12 Integrated Facilities Disposition Project. A second air monitor was stationed east of Building 9212 outside of the limited area at Y-12 in September of 2012 to monitor footprint reduction activities. Associated remedial activities monitored in 2012 included: the Old Salvage Yard and Exposure Unit 9 Soils Removal Actions and pre-demolition activities at the Alpha 5 facility. Samples were collected weekly from the two samplers and composited biweekly for radiochemical analysis. Current analysis includes uranium U-234, U-235, and U-238.

The results of the uranium analysis performed on samples collected at ETTP and Y-12 are provided in Figure 2, along with the background measurements. To a large degree, the fluctuations that can be observed in the figures are attributable to regional weather conditions (e.g., wind and rain) that increase or decrease the amount of particulates in the air and, thereby, the amount deposited on the sampling filters. If there have been no releases, the data from the background and ORR samplers should be relatively similar, given allowances for local conditions and analytical uncertainties. Results that significantly exceed the measurements at the background station are considered indicative of a release. As can be noted in the charts in Figure 2, the results for many of the samples are elevated above background levels, indicating uranium releases are occurring. The ratios of the isotopes suggest the releases are of enriched uranium. However, the levels measured are a relatively small percentage of the CAA standards, as shown in Table 2.

Table 2: 2012 Average activities for uranium isotopes measured at ETTP, Y-12, and the background stations in the Fugitive Air Monitoring (pCi/m^3)

Analyte	Average Result	CAA Standard	Percent of Standard
K-25 K-11 (ETTP)			
Uranium 234	3.94E-04	7.70E-03	5.12%
Uranium 235	3.19E-05	7.10E-03	0.45%
Uranium 238	3.87E-05	8.30E-03	0.47%
Portal 4 (ETTP)			
Uranium 234	1.08E-04	7.70E-03	1.40%
Uranium 235	9.73E-06	7.10E-03	0.14%
Uranium 238	1.20E-05	8.30E-03	0.14%
Y12 Building 9723-28 (Y-12)			
Uranium 234	5.64E-05	7.70E-03	0.73%
Uranium 235	6.13E-06	7.10E-03	0.09%
Uranium 238	1.29E-05	8.30E-03	0.16%
Y-12 Building 9212 (Y-12)			
Uranium 234	2.38E-04	7.70E-03	3.09%
Uranium 235	1.45E-05	7.10E-03	0.20%
Uranium 238	-7.40E-06	8.30E-03	-0.09%



ETTP (East Tennessee Technology Park); Y-12 (Y-12 National Security Complex)

Figure 2: Uranium-234, 235, & 238 results for air monitoring at ETTP, Y-12, and the Fort Loudoun Dam background station

Oak Ridge National Laboratory

As with the other ORR installations, construction of the X-10 Plant (now known as the Oak Ridge National Laboratory) began in 1943. While the K-25 and Y-12 Plants' initial missions were the production of enriched uranium, the ORNL site focused on reactor research and the production of plutonium and other activation and fission products, 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 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, in addition to uranium and plutonium isotopes. Some of these facilities are considered the highest risk facilities at ORNL, due to their physical deterioration, the presence of loose contamination, and their close proximity to pedestrian/vehicular traffic, privately funded facilities, and active ORNL facilities. Over the last few years, a concerted effort has been made to D&D these facilities and remediate associate sites. Two of the fugitive air monitors are currently positioned to monitor associate remedial efforts: one to the southwest at the Tank the W1A/Core Hole 8 removal action, which was completed in 2012, and the other at Building B4007, which is just northeast of the ongoing D&D of the 3026 Radioisotope Development Laboratory (a time-critical removal action).

Tank W-1A was a 4,000 gallon stainless steel underground storage tank in the ORNL's North Tank Farm, near the center of the facility's main campus. The tank was commissioned in 1951 to collect and store waste from isotope separation and high-radiation analytical laboratories. In 1986, W-1A was decommissioned and the tank emptied, due to concerns that leaking transfer lines leading to the tank were a major contributor to the Core Hole 8 groundwater plume. A CERCLA action to remove W-1A and adjacent soils was initiated in 2001, but suspended after radiation levels were encountered in adjacent soils that were much higher than had been anticipated. Associated contaminants and the maximum levels reported include strontium-90 (842,000 pCi/g), cesium-137 (7,200,000 pCilg), plutonium-239/240 (11,000 pCi/g), americium-24l (90,000 pCi/g), curium-244 (40,000 pCi/g), and uranium-233 (519,000 pCi/g) (BJC 2002). The Tank W-1A Removal Action was resumed in September of 2011 and continued into the spring of 2012.

The 3026 Radioisotope Development Laboratory consists of two facilities that share a common wall (3026-C & 3026-D), 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. 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 to 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 3026 C&D facilities, by the condition of the structures, and by the location of the facilities, a time-critical removal action was initiated in 2009 to include demolition of the 3026 wooden frame structure and the stabilize 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. The 3026-D hot cell demolition is scheduled for completion in 2013, although higher than expected radiation levels have hindered the project. Due to the nature of historical operations in the faculties, potential contaminants include a long list of radionuclides: 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).

Environmental Management Waste Management Facility (EMWMF)
The EMWMF was constructed in 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 suppress dispersion of contaminants by the wind, the EMWMF uses an alternate daily cover (a fixative) rather than clean soils, as is practiced at most disposal facilities. To monitor the air emissions at the EMWMF, a mobile air sampler was placed at the southeast corner of the facility in December of 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 performed as warranted. The results, which are presented Figures 3 and 4, were all consistent with background level, as were the results for the gamma spectrometry.

Due to the long list of potential contaminants at the ORNL Tank W-1A/Core Hole 8, at ORNL B4007, and at the EMWMF locations, gross alpha, gross beta, and gamma spectrometry analysis were used to screen samples, with the intent to perform the more costly isotopic analysis if elevated gross results were noted. The results, presented in Figures 3 and 4, were all consistent with background level, as were those for gamma spectrometry. The annual average concentrations of gross alpha and beta results for each of the three ORR stations were slightly less than the average at the Fort Loudoun Dam background station.

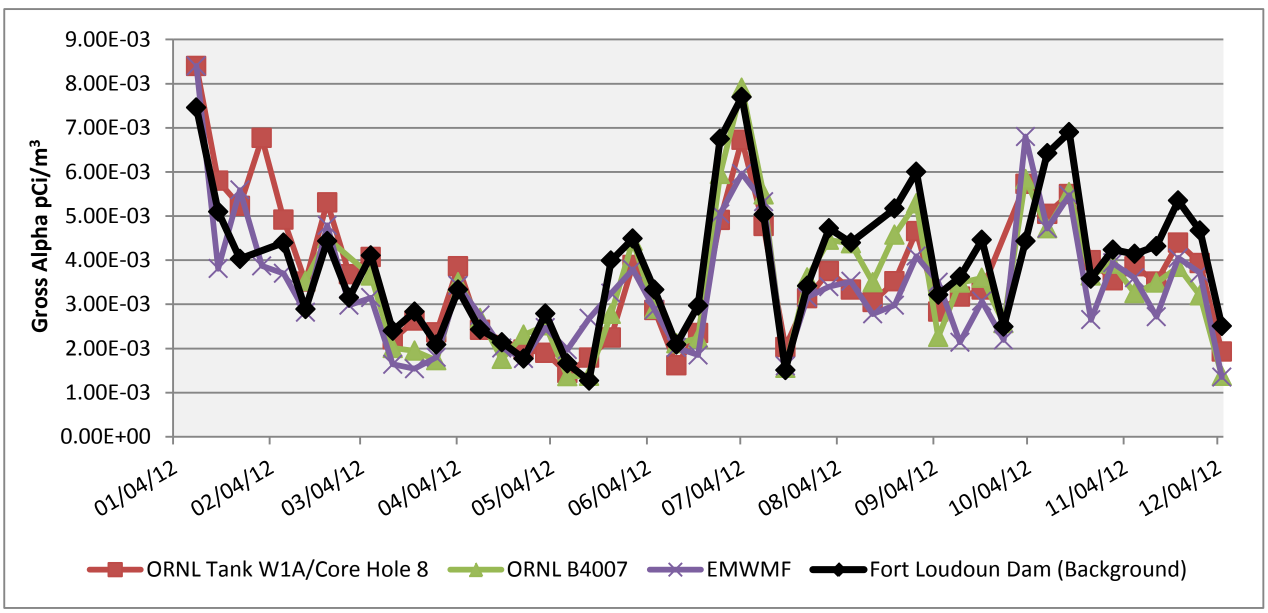


Figure 3: Gross alpha results for air monitoring at ORNL, the EMWMF, and the Fort Loudoun Dam background station

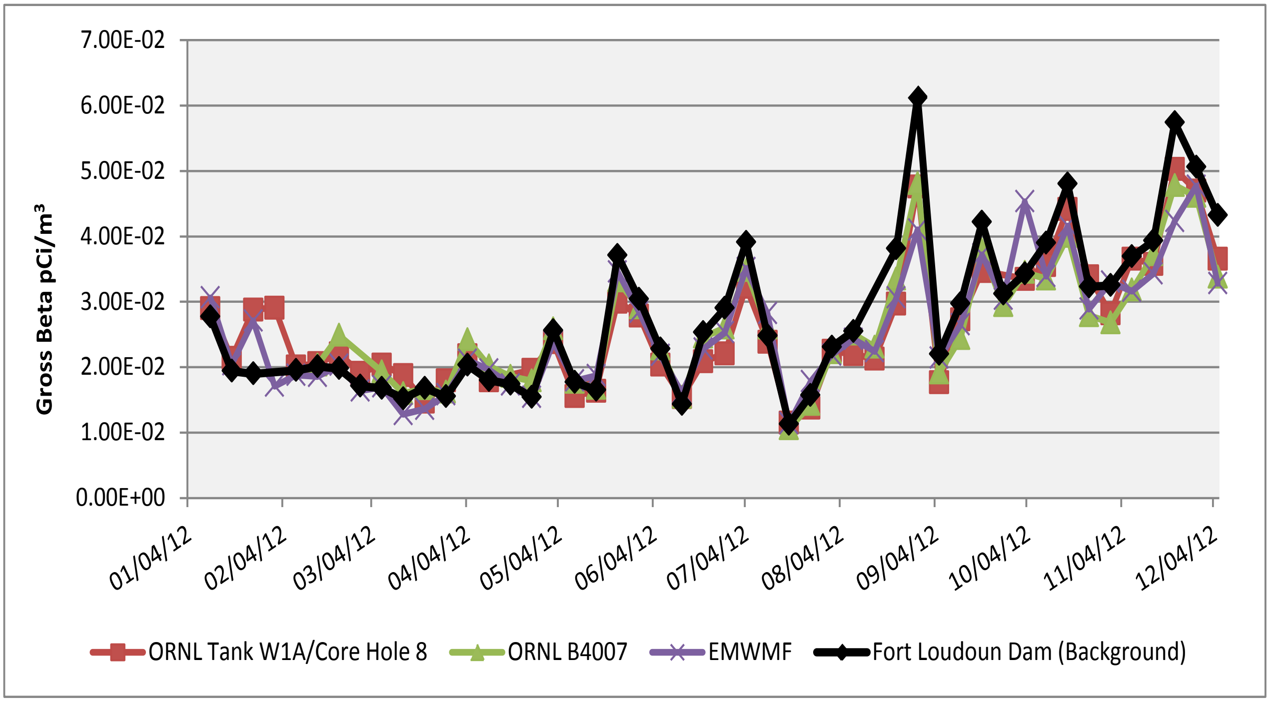


Figure 4: Gross beta results for air monitoring at ORNL, the EMWMF, and the Fort Loudoun Dam background station

Conclusion

Results for 2012 Fugitive Air Monitoring Program were consistent with background measurements for samples collected at monitoring stations located at the Oak Ridge National Laboratory and at the Environmental Management Waste Management Facility. Uranium isotopes-were reported significantly above background levels for the samples collected from the East Tennessee Technology Park and from the Y-12 National Security Complex, indicating releases are occurring. The ratios of the uranium isotopes in the samples suggest the uranium has been enriched. However, the annual average concentrations for these locations were all well below the limits specified for the isotopes in the Clean Air Act.

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Perimeter Air (Low Volume) Monitoring on the Oak Ridge Reservation

Principal Author: Howard Crabtree, Gary Riner

Abstract

The Tennessee Department of Environment and Conservation's Division of Remediation, DOE Oversight Office performs radiochemical analysis on samples collected from ten perimeter air monitoring stations located at exit pathways for airborne releases from the Department of Energy (DOE) Oak Ridge Reservation. The results are compared to measurements collected at a background station and to standards prescribed by the Clean Air Act. Data derived from this program, along with that generated by the other division air monitoring programs, provides information used to assess the impact of DOE activities on the local environment and public health. In 2012, the results for samples collected from the perimeter air monitors were similar to those collected at the background station and well below Clean Air Act standards.

Introduction

The Tennessee Department of Environment and Conservation's Division of Remediation, DOE Oversight Office performs radiochemical analysis of samples collected from ten low-volume air monitors stationed at exit pathways for airborne releases from the Department of Energy (DOE) Oak Ridge Reservation (ORR). The results are compared to background measurements and standards provided in the Clean Air Act (CAA). Data from this program, along with information derived from the division's Fugitive and RadNet Air Monitoring Programs, are used to:

- identify and characterize unplanned releases on the reservation,
- verify data reported by DOE and its contractors, and
- assess the impact of DOE activities on the public health and environment

Methods and Materials

The eleven low-volume air samplers used in the program are owned by the Department of Energy and DOE contractors are responsible for their maintenance and calibration. Nine of the samplers are components of DOE's ORR Ambient Air Monitoring Program. Samples from these stations are collected by DOE contractors and provided to division personnel for analysis. The remaining samplers were dispositioned for state use by DOE, after the Y-12 fugitive air monitoring program was discontinued. DOE-O staff members collect the samples from Y-12 stations.

All of the air samplers used in the program are run continuously and each uses a forty-seven millimeter borosilicate glass fiber filter to collect particulates as air is pulled through the unit. The ORR monitors employ a pump and flow controller to maintain airflow through the filters at approximately two standard cubic feet per minute. The Y-12 monitors use a pump and rotometer, which are set to average approximately two standard cubic feet per minute. The filters from each of the air samplers are collected biweekly and shipped to the state's radiochemical laboratory for analysis. Gross alpha and gross beta analyses are performed on each of the samples, with additional analysis performed if warranted.

The locations of the eleven air monitoring stations used in the program are listed in Table 1. Ten of the stations are located around the perimeter of the ORR and Y-12 facility (Figure 1). The eleventh site is a background station located near Fort Loudoun Dam in Loudon County.

Table 1: Perimeter Air Monitoring Stations

Station	Location	County
4	Y-12 East at Portal 2	Anderson
8	Y-12 Portal 17 at Outbuilding 9990 (3rd St. and South Patrol Rd.)	Anderson
35	East Tennessee Technology Park Southwest on West Connector Rd.	Roane
37	Bear Creek at Y-12 / Pine Ridge	Roane
38	Westwood Community (Wisconsin Ave. and Whippoorwill Dr.)	Roane
39	Cesium Fields at Oak Ridge National Laboratory Services	Roane
40	Y-12 East (at entrance to Y-12)	Anderson
42	East Tennessee Technology Park North off Blair Rd.	Roane
46	Scarboro Community (South Dillard Ave.)	Anderson
48	Deer Check Station on Bethel Valley Rd.	Anderson
52	Fort Loudoun Dam (Background Station)	Loudon

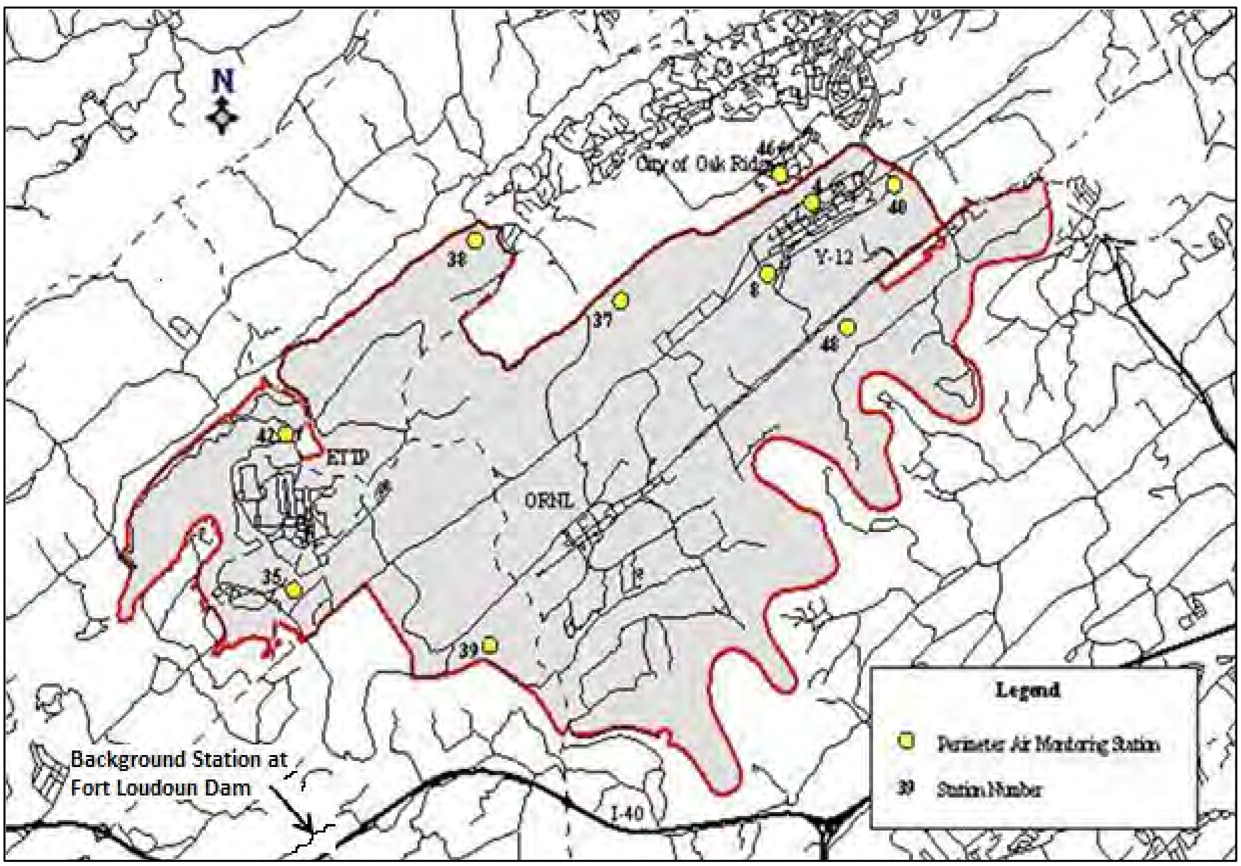

Figure 1: Approximate Location of Perimeter Air Monitoring Stations on the ORR

Results and Discussion

All the December 2012 results had not been received from the laboratory at the time of this report, so a twelve-month moving average was used to compare the radiochemical results to the annual dose limits specified in the Clean Air Act. Figures 2 and 3 chart the gross alpha and gross beta measurements for the twelve-month period that runs from 12/06/2011 through 12/04/2012.

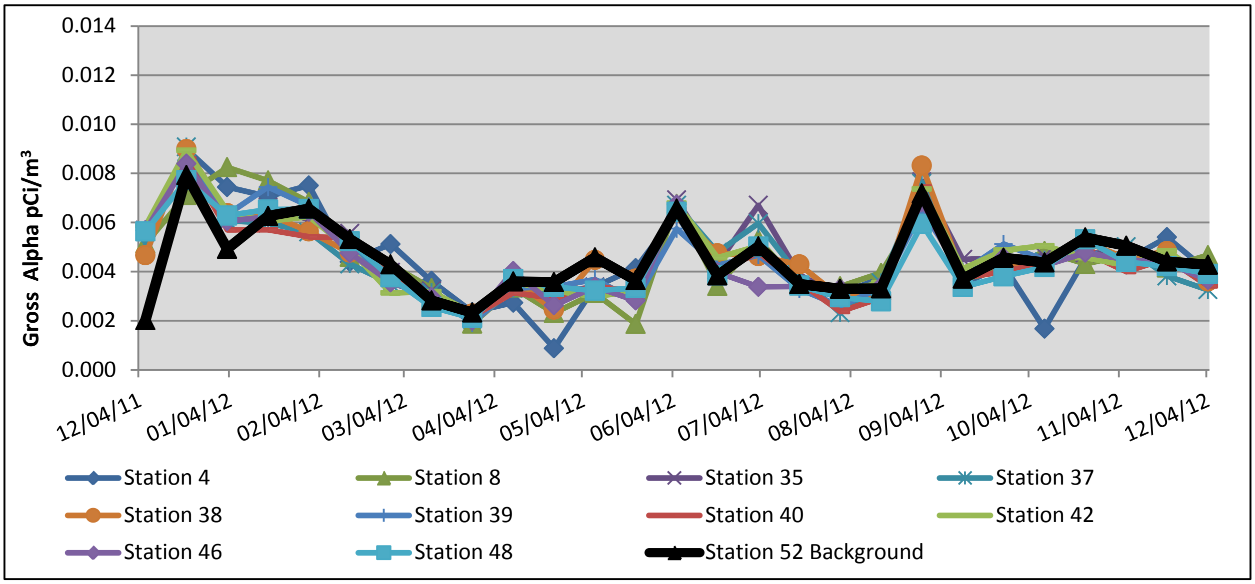

Figure 2: Gross Alpha Results for Perimeter Air Monitoring Stations (12/06/2011-12/04/2012)

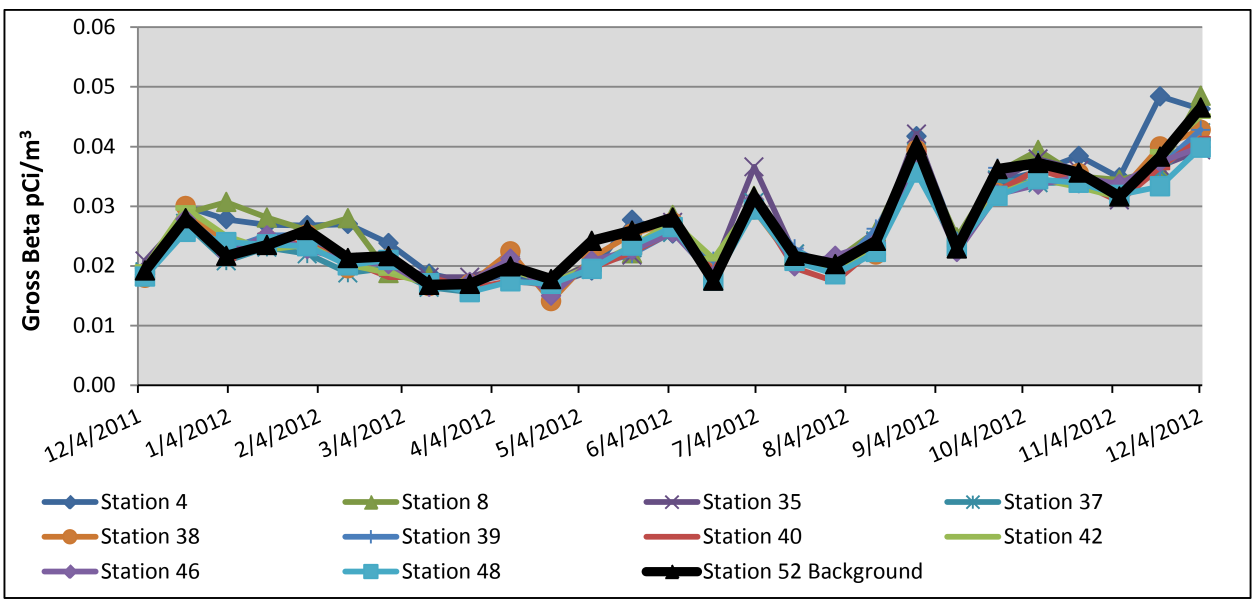

Figure 3: Gross Beta Results for Perimeter Air Monitoring Stations (12/06/2011-12/04/2012)

As can be observed in Figures 2 and 3, the results of the radiochemical analysis of samples taken at the ORR perimeter air monitoring stations during the twelve-month period were very similar to those reported for the background station. The fluctuations that can be seen in the data to a large degree can be attributed to natural phenomena or changing environmental conditions that increase or decrease the amount of particulate deposited on the sampling filters. For example, concentrations of radionuclides in the uranium and thorium decay series may increase because soils in which they naturally occur have been dispersed in the air as a consequence of dry conditions, heavy winds, and/or local activities (e.g., construction). Conversely, precipitation can remove materials suspended in the air reducing the concentration of contaminants deposited on the air filters.

The Clean Air Act specifies that exposure from radioactive materials released into the air from DOE facilities shall not cause members of the public to receive an effective dose equivalent greater than 10 mrem in a year above background measurements. Compliance with this standard is generally assessed for point-source emissions that employ air dispersion models to predict doses at off-site locations. In addition, the CAA provides environmental concentrations for radionuclides equivalent to a dose of 10 mrem/year. Staff compare the measurements from the perimeter air monitoring stations to the environmental concentrations in the CAA to assess compliance with the act.

Because the hazards associated with the various radionuclides differ significantly, the CAA requires specific analysis of each radionuclide determined to be of concern. The CAA standards do not include limits for gross alpha and gross beta activities, which represent the total alpha or beta activity for all radionuclides in the sample. Nevertheless, the more economical gross measurements, when treated as surrogates for the more hazardous isotopes, provide an effective screening mechanism to determine if further evaluation is warranted. The standards used in the program to screen the data are uranium-235 (primarily an alpha emitter) and strontium-90 (a beta emitter). Both have relatively restrictive limits and both are routinely encountered on the reservation. It should be noted that it is highly unlikely that these isotopes would be responsible for more than a small proportion of the gross activities reported for the samples.

Figures 4 and 5 on the following page show the average results for gross alpha and gross beta measured at each of the perimeter air monitoring stations during the period under consideration. The CAA environmental standards for uranium-235 and strontium-90 are provided for comparison. Since the CAA standards only apply to the dose above background, the limits represented in Figures 4 and 5 have been adjusted to include the average gross alpha and gross beta measurements taken at the background station (station 52). As can be seen in the charts, the twelve month average concentration for each perimeter air monitoring station was well below the referenced limit.

Conclusion

The results from 2012 radiochemical analysis of samples taken at ORR perimeter air monitoring stations were similar to those reported for the background station at Fort Loudoun Dam in Loudon County. While all results from December sampling events were not available at the time of this report, available data for the perimeter air monitor station were well below Clean Air Act standards.

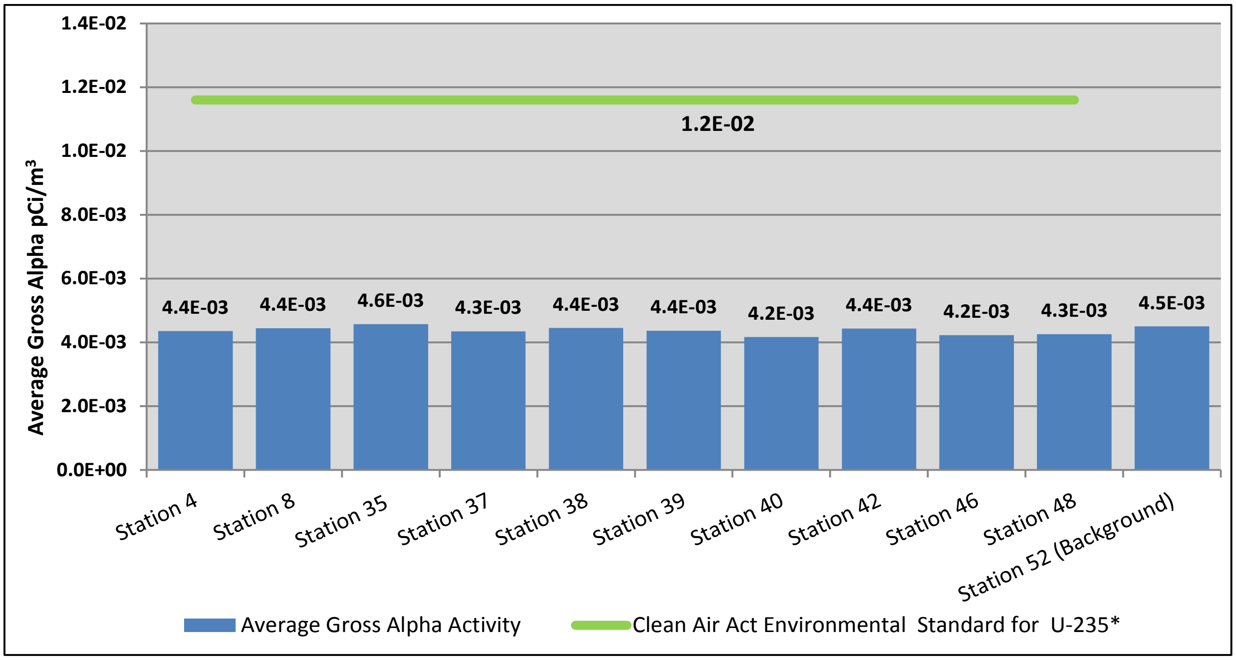

Figure 4: Average Gross Alpha Results for Perimeter Air Monitoring Stations (12/06/2011-12/04/2012)

*The standards provided by the Clean Air Act apply to the dose above background: therefore, the uranium-235 standard provided for reference in the chart has been adjusted to include the background measurement. This standard is provided for comparison only. It is unlikely the isotope would contribute significantly to the gross activity reported.

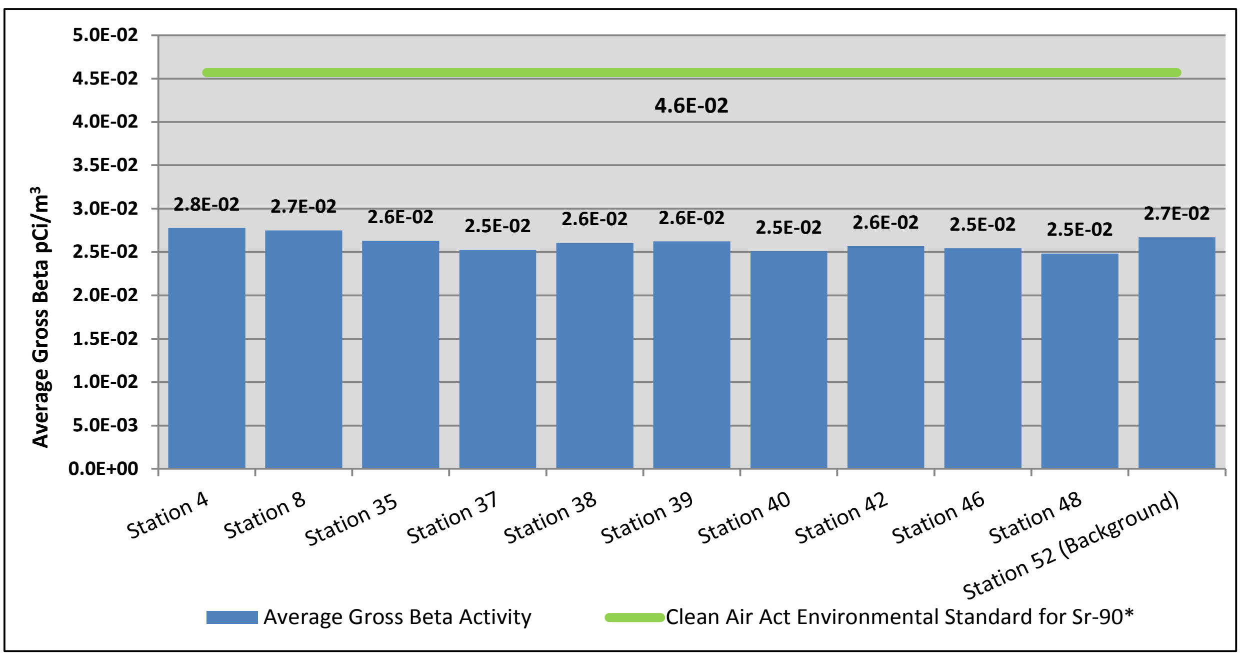

Figure 5: Average Gross Beta Results for Perimeter Air Monitoring Stations (12/06/2011-12/04/2012)

*The standards provided by the Clean Air Act apply to the dose above background: therefore, the strontium-90 standard provided for reference in the chart has been adjusted to include the background measurement. This standard is provided for comparison only. It is unlikely the isotope would contribute significantly to the gross activity reported.

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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. Gross beta analysis for the RadNet precipitation program was discontinued in 2010 and tritium analysis was discontinued in 2012. Analysis for gamma radionuclides is performed on each composite monthly sample and will continue to be monitored. As much of the 2011 data was not yet available from EPA at the time of the last report, the 2011 tritium results are included in this report, as are the tritium results since the program's inception at each of the three sites on the reservation. The tritium data for samples from the RadNet precipitation monitors varied considerably throughout the time periods monitored for each site and from site to site. Since there is not a regulatory limit for radioisotopes in precipitation, the results from ORR sampling locations are compared to data from other sites nationwide and to EPA's drinking water limits. The tritium in precipitation results from the ORR RadNet sampling locations were generally higher than the national average for all other RadNet precipitation sites, but were often not the highest overall values seen in the nation. While the Oak Ridge Reservation did generally have higher tritium values in precipitation samples, the stations were located in areas near nuclear sources while most of the other stations in the RadNet precipitation program monitoring tritium were located near major population centers, with no major sources of radiological contaminants nearby. Regardless, the tritium levels seen in the precipitation samples collected at the RadNet sites on the ORR were all well below the EPA drinking water limits, as were the other isotopes measured in the program. It should be noted, the EPA drinking water limits pertain to drinking water, not precipitation, and are only used here as a possible indicator of an issue.

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 (TDEC) Division of Remediation monitor precipitation on the Department of Energy 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 location of the precipitation samplers.

Small amounts of tritium are produced naturally, but the isotope is also released as water vapor in reactor effluents and from the evapotranspiration associated with buried wastes. Based on this knowledge, the initial precipitation monitor provided by EPA was placed 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, which is the major source area for tritium on the ORR. The second precipitation monitor was placed off of Blair Road, near the TSCA Incinerator east of ETTP to monitor contaminants burned in the incinerator and those from demolition activities at ETTP. While the TSCA Incinerator closed at the beginning of December 2009, this station still monitors continuing demolition activities at ETTP. The third station is used to monitor the Y-12 facility. It also provides an indication of any tritium traveling towards the city of Oak Ridge from Melton Valley, where elevated tritium levels have been detected. While gross beta analysis for the RadNet precipitation program was discontinued in 2010 and tritium analysis was discontinued in 2012, analysis for gamma radionuclides is performed on each composite monthly sample and will continue to be monitored.

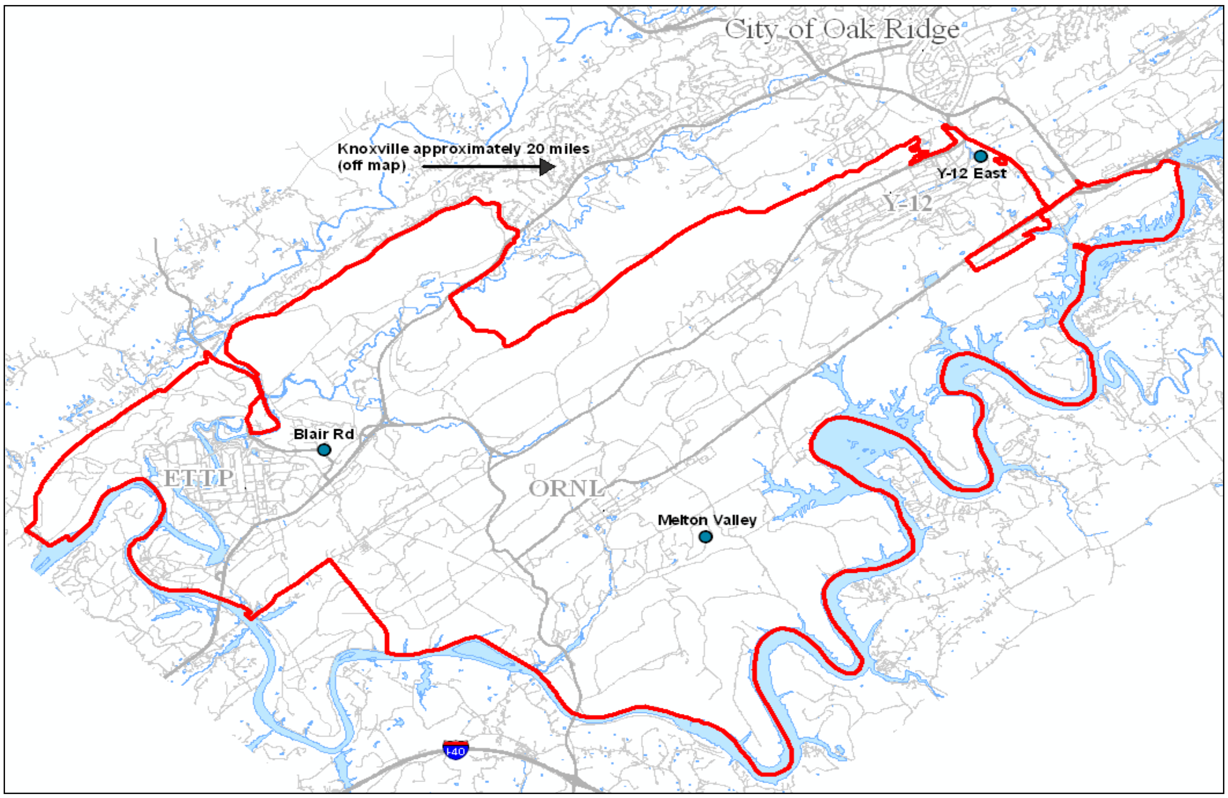

Figure 1: Locations of the RadNet Precipitation Samplers on the Oak Ridge Reservation

Since there are no regulatory limits for radiological contaminants in precipitation, the results of the tritium analyses can be compared to results seen at other RadNet precipitation stations across the nation. For further perspective, one can compare the results 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 limit for tritium, a beta emitter, is 20,000 pCi/L. The samples are also analyzed for gamma radionuclides, though 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 the maximum contaminant levels (MCLs) or derived concentrations of beta and photon emitters in drinking water that EPA uses as limits, for some isotopes.

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®) when a minimum of one liter of precipitation has accumulated in the collection bucket. 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. Prior to 2010, the composite samples were also analyzed for gross beta, and prior to 2012, monthly samples were analyzed for tritium.

The results of NAREL's analyses are provided to TDEC annually and 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, and to appraise conditions on the Oak Ridge Reservation compared to other locations in the RadNet program.

Results and Discussion

The RadNet precipitation data for tritium were only available through 2011, as tritium analysis was discontinued starting in 2012. Consequently, the tritium data since 2005 has been included in order to show the tritium data since the program's inception on the ORR for each station. As can be seen in Figure 2, the results of the monthly tritium analyses on the precipitation samples taken at the three ORR precipitation stations vary considerably by station and by month. Figure 3 has also been included to show more detailed tritium results for 2011, since those results were only available through January 2011 in last year's report. The values reported reflect the original counts minus the values obtained by counting a laboratory blank (instrument background). When the original counts are close to the values of the blank, it is possible to obtain negative values, due to the random nature of radioactive decay. While negative radioactivity is physically impossible, the inclusion of negative results allows better statistical analysis of the data.

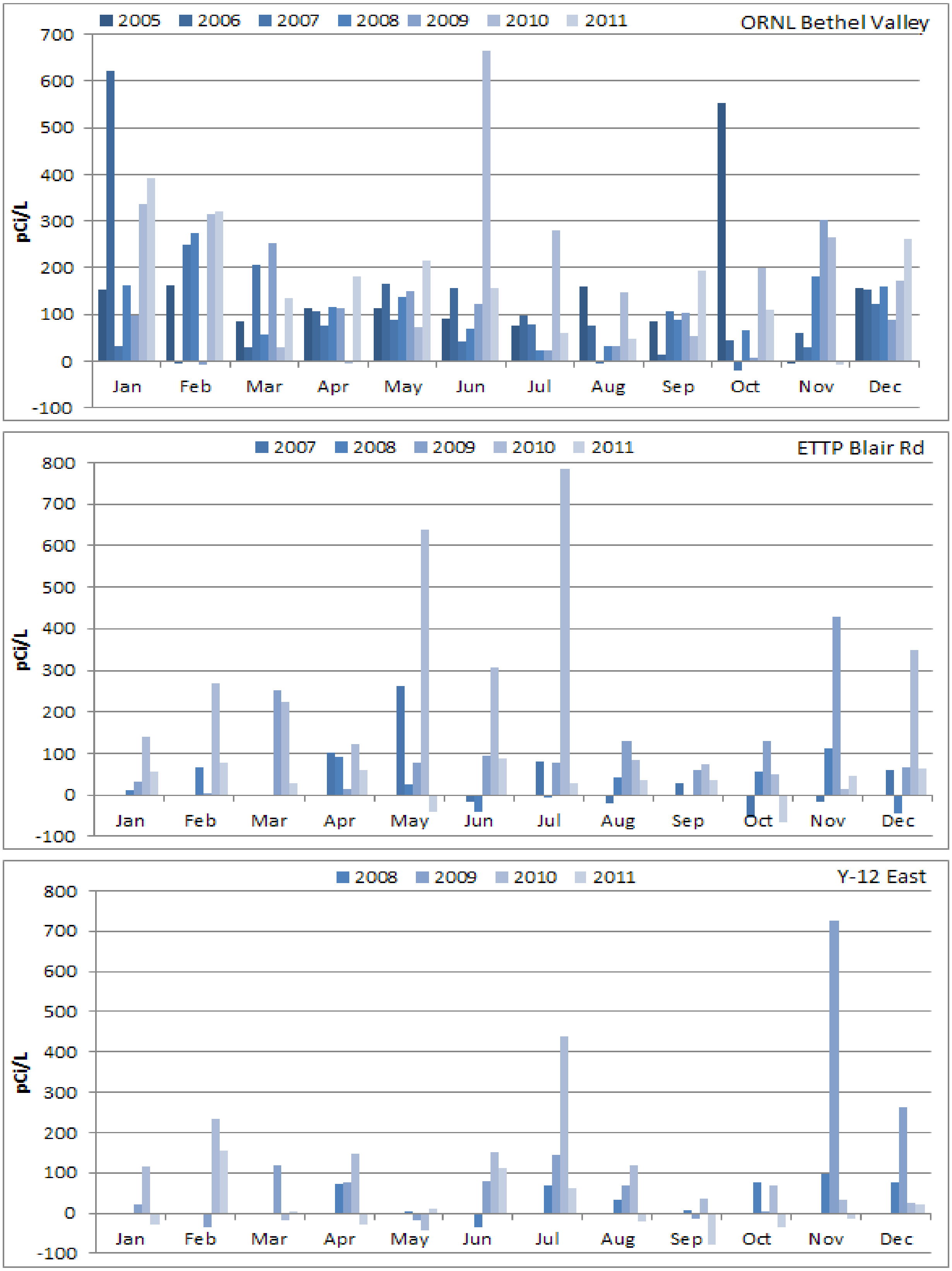

Figure 2: Monthly Tritium Results from Precipitation Samples Taken at Melton Valley (ORNL), Blair Road (ETTP), and Y-12 East through 2011

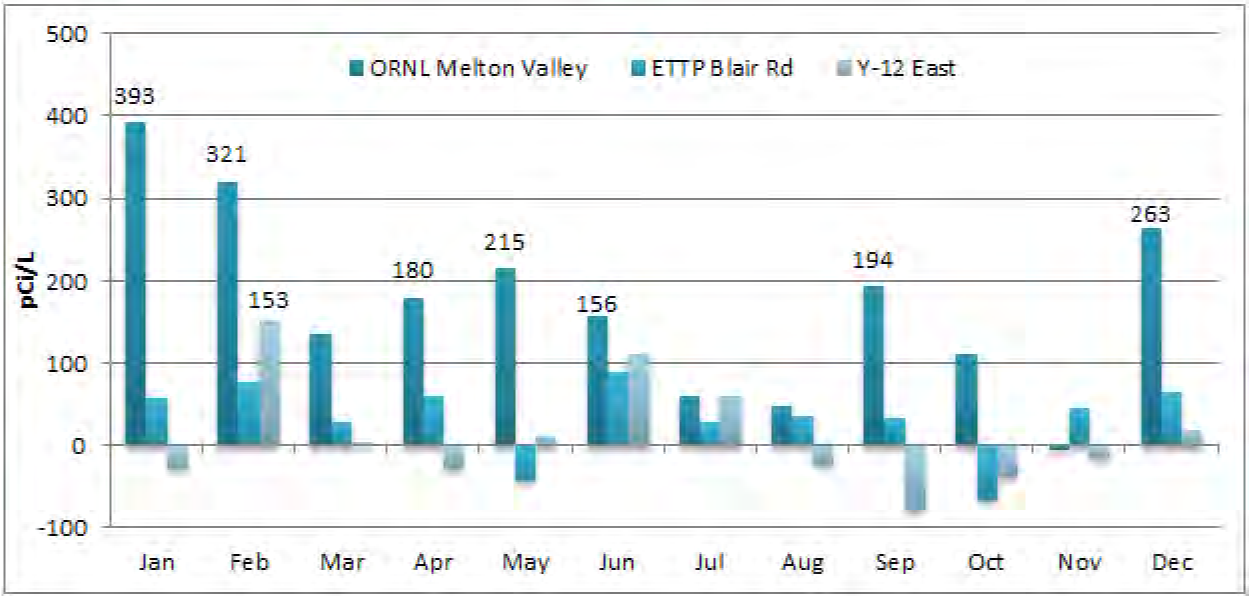

Figure 3: Monthly Tritium Results from Precipitation Samples Taken at Melton Valley (ORNL), Blair Road (ETTP), and Y-12 East in 2011 (with values above detection limits labeled)

To put the data from Figures 2 and 3 into perspective, it is helpful to compare it to values seen at other sites nationwide as well as to drinking water limits. Table 2 presents the national 2011 RadNet precipitation tritium values with results greater than the minimum detectable concentration (MDC). The average MDC for the 2011 samples was about 150 pCi/L. Here, the MDC reflects the ability of the radiological analysis to detect the I-131 for that sample with 95% confidence. There were 34 stations in 24 states with analysis results for tritium in 2011 in EPA's RadNet Precipitation program. Of the twelve samples from across the nation with results above the MDC, eight of those were from sites on the ORR.

Table 2: 2011 Tritium in Precipitation with Results Greater than the MDC

State	Station Location	Month	Result (pCi/L)
CA	Richmond	May-11	262
CA	Richmond	Dec-11	727
MN	Welch	Jun-11	480
TN	Oak Ridge- Melton Valley (ORNL)	Jan-11	393
TN	Oak Ridge- Melton Valley (ORNL)	Feb-11	321
TN	Oak Ridge- Melton Valley (ORNL)	Apr-11	180
TN	Oak Ridge- Melton Valley (ORNL)	May-11	215
TN	Oak Ridge- Melton Valley (ORNL)	Jun-11	156
TN	Oak Ridge- Melton Valley (ORNL)	Sep-11	194
TN	Oak Ridge- Melton Valley (ORNL)	Dec-11	263
TN	Oak Ridge- Y-12	Feb-11	153
VA	Lynchburg	Feb-11	225

The highest concentration of tritium seen during 2011 on the Oak Ridge Reservation (393 pCi/L) was much less than that of the highest value seen during 2011 throughout the rest of the RadNet program (Table 2). The highest national value for 2011 was in December from Richmond, California (727 pCi/L).

The ORR sampling locations are near known nuclear sources (a reactor, a nuclear waste burial grounds, and the demolition of radiologically contaminated facilities), while the other stations are largely placed near major population centers; therefore somewhat elevated tritium values are not surprising. Also, it is important to look at the drinking water limits for tritium for greater perspective. Since there are no regulatory limits for radiological contaminants in precipitation, one can compare the values to drinking water limits used by EPA as a conservative limit. The limit for tritium in drinking water is 20,000 pCi/L. The ORR sample results seen through 2011 are well below this limit.

Starting in 2010 there was no longer any analysis completed for gross beta in the monthly composite precipitation samples. Prior to this change in analysis, the gross beta results at the Oak Ridge Reservation locations (near Oak Ridge) were similar to, but often less than, average gross beta results from around the nation.

For 2012, gamma spectrometry analysis was available through December. Since the 2011 data was only available through July in the last report, Table 3 has been included to show the 2011 gamma data for the last six months of 2011 and Table 4 has been included to show the 2012 gamma data.

Table 3: The Highest Value for Select Isotopes at Each of the ORR Precipitation Stations (July –December 2011), Compared to EPA Drinking Water Limits (MCLs), in pCi/L

	Highest Value at each Station			EPA limit
Isotope	ORNL Melton	ETTP Blair Rd	Y-12 East	MCL
Be-7	ND	83	57	6,000
Co-60	0.5	0.17	0.28	100
Cs-137	0.37	0.55	0.11	200

Table 4: The Highest Value for Select Isotopes at Each of the ORR Precipitation Stations in 2012, Compared to EPA Drinking Water Limits (MCLs), in pCi/L

	Highest Value at each Station			EPA limit
Isotope	ORNL Melton	ETTP Blair Rd	Y-12 East	MCL
Be-7	112	95	66	6,000
Co-60	0.18	0.41	0.54	100
Cs-137	0.46	0.52	0.67	200

Overall, the highest values seen for beryllium-7 (Be-7), cobalt-60 (Co-60), and cesium-137 (Cs-137) 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 cobalt-60 and cesium-137 results for 2012 were non-detects, with the result less than the minimum detectable concentration (MDC). The average MDC for the 2012 cobalt-60 samples was 1.16 pCi/L and was 1.42 pCi/L for cesium-137. There are not regulatory limits for radionuclides in precipitation. The comparison to EPA's drinking water limits is just used as an indicator of possible issues.

Conclusion

While the average tritium values at all three Oak Ridge Reservation precipitation sampling sites were higher than the national average for 2011, the other sampling locations are located near major population areas and the ones on the Oak Ridge Reservation are near nuclear sources. While there is not a regulatory limit for tritium in precipitation, the limit for tritium in drinking water is 20,000 pCi/L. The levels found in precipitation at RadNet precipitation stations throughout the United States are considerably lower than the EPA limit. Since the drinking water limits are restrictive to protect public health, the levels of tritium in precipitation on the Oak Ridge Reservation are unlikely to pose a hazard to the public or the environment. The 2012 gamma data also shows results well below EPA drinking water limits and often below detection limits. This data indicate that levels of 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 Author: Gerry Middleton

Abstract

The biotic integrity of streams originating on the Oak Ridge Reservation (ORR) was determined during 2012 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, five reference stream stations were sampled. Benthic samples were collected and processed following the State of Tennessee standard operating procedures for macroinvertebrate surveys. 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 in all four 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 and 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

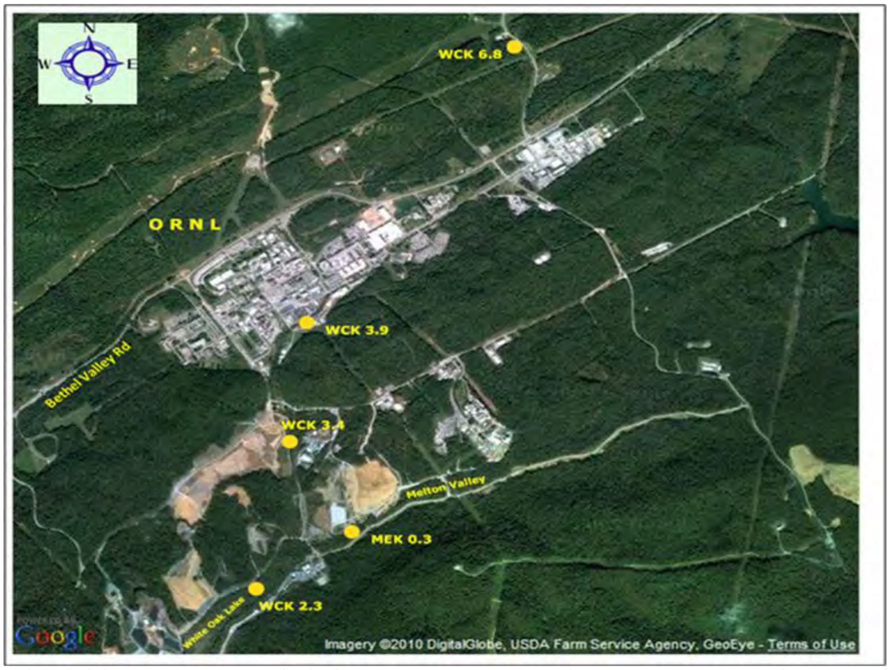
The Oak Ridge Reservation (ORR) is a 33,515-acre site owned and operated by the US Department of Energy (DOE) that is nestled in the ridge and valley physiographic province of east Tennessee (Anderson and Roane counties). Geologically, the ORR bedrock consists of thrust faulted and folded lithostratigraphic 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 April 15, 2012, and June 15, 2012, using the current US Environmental Protection Agency, US Geological Survey, and Tennessee Department of Environment and Conservation, Division of Water Pollution Control standard operating procedures for macroinvertebrates (Barbour et al. 1999, Moulton et al. 2000, TDEC 2006, 2011). Thirteen stream stations were sampled during 2012 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	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 0.3	thin canopy	MELTO000.2RO

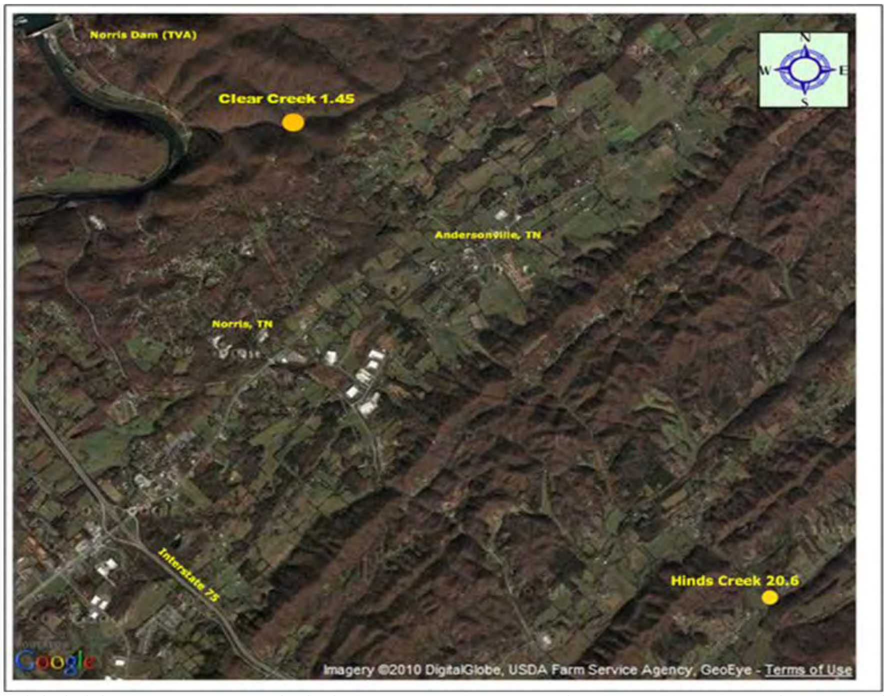


DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 1: 2012 Benthic Sites at ORNL (White Oak Creek / Melton Branch)

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

Figure 2: 2012 Benthic Sites at Upper East Fork Poplar Creek

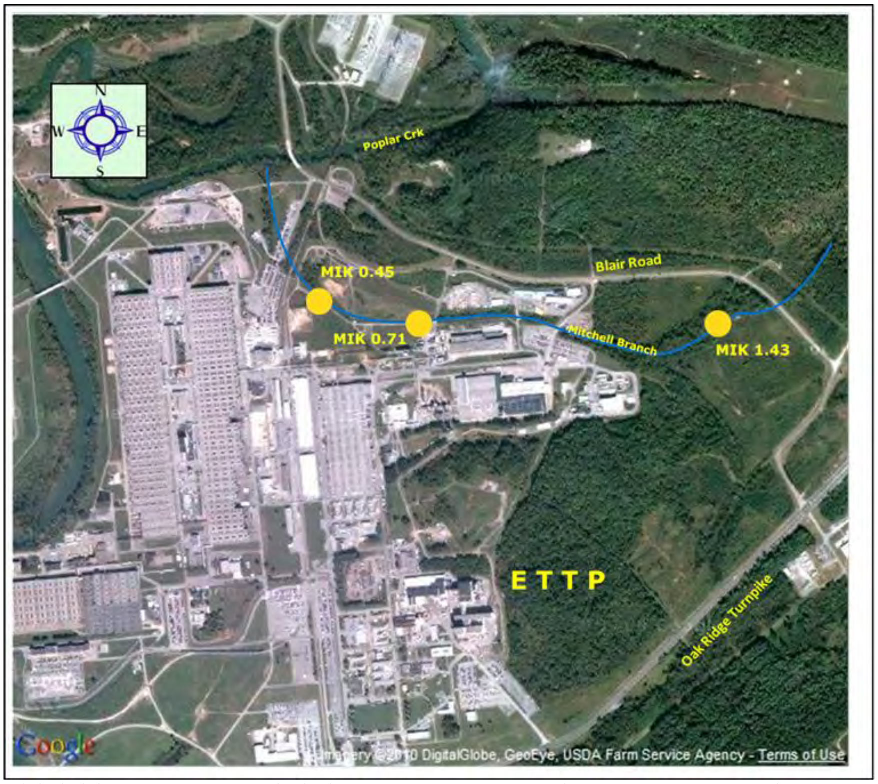


DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 3: 2012 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: 2012 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: 2012 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 a kicking and sweeping motion 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 85% 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.

Lastly, surface water samples were collected from each 2012 benthic sampling location. The laboratory results are presented in Appendix A. Personnel safety while conducting field and laboratory work followed the guidelines of the TDEC DOE-Oversight Office Health and Safety Plan (Yard 2011).

Figure 6: Kick net sampling

Figure 7: Rinsing organisms

Figure 8: Picking organisms from net

Laboratory Processing

Due to the potential for radioactive contamination associated with the lower White Oak Creek / Melton Branch sediments, 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) 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 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 for 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. Seven 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, and % Nutrient Tolerant organisms (Table 2, Hilsenhoff 1982, 1987, 1988, KDOW 2009, TDEC 2006, 2011). The EPTs are pollution-sensitive to environmental contamination and the OCs are pollution-tolerant. Once values were obtained for the seven metrics during laboratory analysis, a score of 0, 2, 4, or 6 was given to each metric based on comparison to the metric target values for Bioregion 67F, the reference ecoregion for Oak Ridge Reservation streams. The seven scores were totaled and the overall Tennessee Macroinvertebrate Index score (TMI) was compared to the Target Macroinvertebrate Index Score (i.e., TMI=32) for Bioregion 67F (TDEC 2011). The biological condition rating of the sampling site was estimated within the range of Non-Supporting/Severely Impaired (TMI ≤ 10) to Supporting/Non-Impaired (TMI ≥ 32, TDEC 2006).

Three of the seven metrics, Taxa Richness, EPT Richness, and Number of Intolerant Taxa, were calculated based on genus level identifications. A score of 1, 3, or 5 was assigned to each metric based on comparison to the metric target values for Bioregion 67F. The three scores were totaled to determine the overall scoring value. A Severely Impaired (partially or not supporting system) assessment was given if the overall score was 5 or less. A score of 6-10 indicated the results were ambiguous and additional data was needed. The site was considered Non-impaired (supporting) if the score was 11-15. A description of the metrics and the equations used to calculate the TMI scores can be obtained by referencing the TDEC standard operating procedure (TDEC 2011). 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
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	% 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

Results and Discussion

Semi-quantitative Assessments (SQKICK Sample Results)

<u>East Fork Poplar Creek</u>

Benthic laboratory results (i.e., metric values, metric scores, overall TMI scores and biological condition ratings) are presented in Table 3 for 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 improve with longitudinal downstream distance from the Y-12 Plant.

Benthic water quality assessments, especially comparing taxa from upstream to downstream sampling sites, may be confounded by natural, longitudinal variation among impacted streams (Clements and Kiffney 1995, Clements et al. 2000). It is also important to note that in the upstream EFK headwaters, make-up flow water added to EFK from the Clinch River is likely influencing water quality. Nevertheless, taxa richness, EPT richness, and %EPT-Cheum increased with distance from the East Fork Poplar Creek headwater site (station EFK 25.1) downstream to station EFK 6.3 (Table 3; distance of 18.8 km). However, one taxon proved to be confounding to explain. The moderately pollution-tolerant, net-spinning caddisfly, *Cheumatopsyche* sp. (*Trichoptera,* Lenat 1993, Alexander and Smock 2005), comprised 38.10% of the benthic population at EFK 25.1, then decreased significantly downstream to 14.55% of the benthic population at EFK 23.4. Interestingly, even further downstream the *Cheumatopsyche* sp. population increased to 41.67% and 37.13% of the population at EFK 13.8, and EFK 6.3 respectively (Figures 6-10). This enigma might be partially explained by the outfall from the City of Oak Ridge (COR) sewage treatment plant (i.e., flux of nutrients) in the vicinity of EFK 13.8. Organic pollution in streams and rivers usually changes the community structure when the most sensitive species disappear and increase the relative abundance of the more tolerant groups (Mason 1991). Furthermore, research by Pollard and Yuan (2006) determined that *Cheumatopsyche* spp. can be present in significant populations within streams impacted by low, medium and high concentrations of heavy metals. Indeed, the UEFK sampling stations exhibit water quality issues with elevated mercury concentrations associated with Y-12 Plant outfalls. Hickey and Clements (1998) determined that moderately impacted streams often have a high abundance of net-spinning caddisflies, so it is not surprising that *Cheumatopsyche* sp. was a dominant taxon at all EFK stations. In contrast, the CCK 1.45 and GHK 20.6 reference streams consisted of only 1.93% and 9.26% *Cheumatopsyche* sp. respectively. To recap, the mean population of *Cheumatopsyche* sp. for all 5 EFK stations = 30.88%, whereas the mean population for the two reference stations = 5.59%, so this taxon is 5.5X greater in EFK vs. the reference sites.

Table 3: Metric Values, Scores and Biological Condition Ratings for East Fork Poplar Crk

2012 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	16	2	26	4	26	4	29	6	29	6
EPT Richness	4	2	5	2	4	2	6	2	9	4
% EPT-Cheum	5.16	0	21.85	2	11.74	0	27.63	2	22.78	2
% OC	48.41	4	51.82	2	58.22	2	19.3	6	23.21	6
NCBI	5.59	4	5.19	4	5.49	4	5.18	4	5.18	4
% Clingers	63.1	6	56.3	6	54.93	6	60.09	6	67.51	6
% Nutrient Tolerant	65.08	2	37.82	4	52.11	4	47.59	4	40.08	4
INDEX SCORE (Tenn. Macro. Index)		20		24		22		30		32
RATING		C		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)									

Results for the Tennessee Macroinvertebrate Index (TMI) are presented in Table 3 for both UEFK and LEFK stream sampling stations. Scores calculated from the 7 metrics include EFK 25.1 (TMI = 20, rating = C, partially supporting/moderately impaired), EFK 24.4 = 24 (TMI = 24, rating = B, partially supporting/slightly impaired), and EFK 23.4 (TMI = 22, rating = B, partially supporting/slightly impaired). This outcome suggests improving water quality conditions between stations EFK 25.1 and 24.4, but additional downstream impacts that originate within the Y-12 Plant (i.e., Hg) have to some extent compromised the downstream station, EFK 23.4. The fact that all three of these UEFK monitoring stations are within the footprint of the Y-12 Plant operations and associated industrial outfalls, makes the confounding results seen in the biological data not surprising. In contrast, the two LEFK stations, EFK 13.8 (TMI = 30, rating = B, partially supporting/slightly impaired) and EFK 6.3 (TMI = 32, rating = A, supporting/non-impaired), exhibited higher taxa richness, EPT richness, and % clingers compared to the UEFK stations.

Although our benthic data suggests improving water quality conditions at East Fork Poplar Creek (with increasing distance from the headwater source of pollution at Y-12 Plant), four out of five EFK stations scored below the Bioregion 67F Target Macroinvertebrate Index score (TMI=32, TDEC 2006, 2011), indicating some impairment. It should be noted that water quality in upper UEFK has been largely influenced by make-up water flow from the Clinch River that is added upstream of the EFK 25.1 station. Despite this water quality alteration, metrics such as % OC (% of oligochaetes and chironomids present in sample) decreased from a range of 48.41-58.22% in the UEFK stations to 19.3-23.21% in the downstream LEFK stations. Further, the % NUTOL (% organisms present in samples that are tolerant of pollution) decreased from 65.08% at the headwater EFK 25.1 station to 40.08% at the downstream EFK 6.3 station. Because oligochaetes and chironomids are a pollution-tolerant group, aquatic ecologists expect that the % OC will be higher in polluted habitats; however, there being fewer tolerant taxa downstream is also indicative of some sort of a problem at EFK 6.3. Although a large part of the impacts can be attributed to inputs from Y-12 and the city of Oak Ridge Sewage Treatment Plant, an appreciable amount of impact is probably coming from non-point source runoff. A large part of LEFK is urbanized and receives a great deal of storm water runoff. (It would be interesting to know what type of storm water chemistry data Oak Ridge must provide to the state).

Figures 9-13 document the dominant macroinvertebrate taxa present in all UEFK and LEFK sampling stations, whereas Figures 14-15 represent the Clear Creek (CCK 1.45 Ref) and Hinds Creek (HCK 20.6 Ref) reference stations. Please note that all *dominant taxa figures* throughout this document include a “taxon” labeled as X-Taxa (Other); this represents the balance of taxa found in each sample that, individually, only tallied a very small % of the total assemblage/site. Dominance by one organism (i.e., one genus, order or family) at a benthic sampling station is often an indication of impaired water quality. Accordingly, we tested the hypothesis that highly impacted streams are often dominated by chironomids (Order: *Diptera*, Family: *Chironomidae*; Hickey and Clements 1998, Maret et al. 2003). Figure 16 summarizes non-midge vs. midge taxa by EFK stream site (upstream to downstream) and compares to the CCK reference. In UEFK (EFK 25.1, EFK 24.4, & EFK 23.4), non-midge taxa accounted for 51.64-59.66% of the macroinvertebrate community whereas midge taxa ranged from 40.33-48.35%. In LEFK (EFK 13.8 & EFK 6.3), non-midge taxa accounted for 80.59-81.14% of the macroinvertebrate community whereas midge taxa made up 18.85-19.40%. Lastly, the macroinvertebrate population at the CCK reference site consisted of 97.80% non-midges and only 2.19% midges. These results suggest that impacted streams indeed exhibit greater numbers of chironomids compared to less-impacted and reference streams.

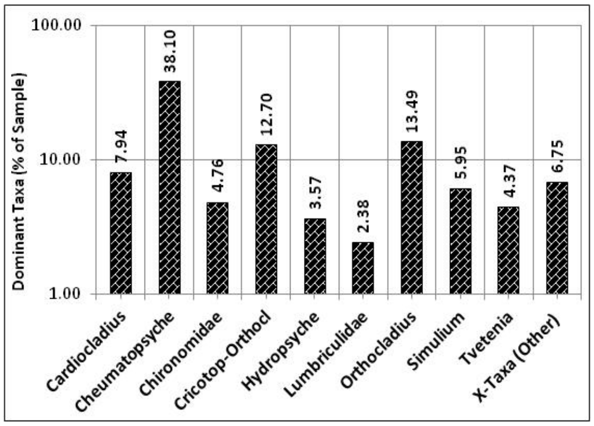


Figure 9: Dominant taxa (%) in EFK 25.1

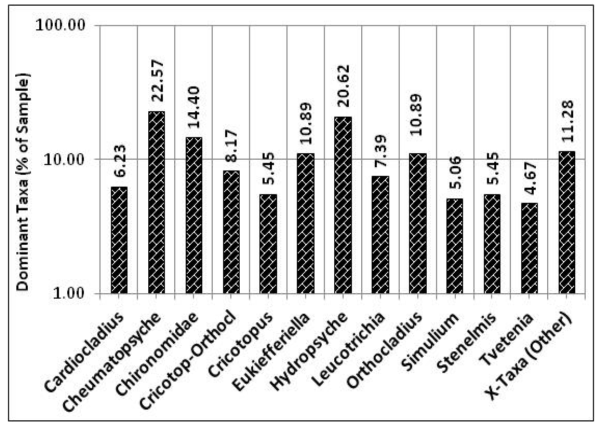


Figure 10: Dominant taxa (%) in EFK 24.4

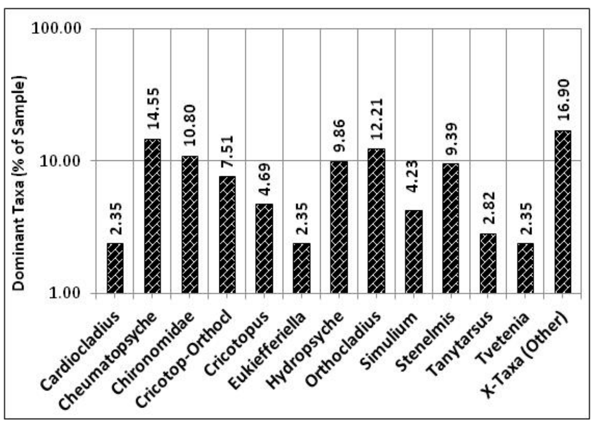


Figure 11: Dominant taxa (%) in EFK 23.4

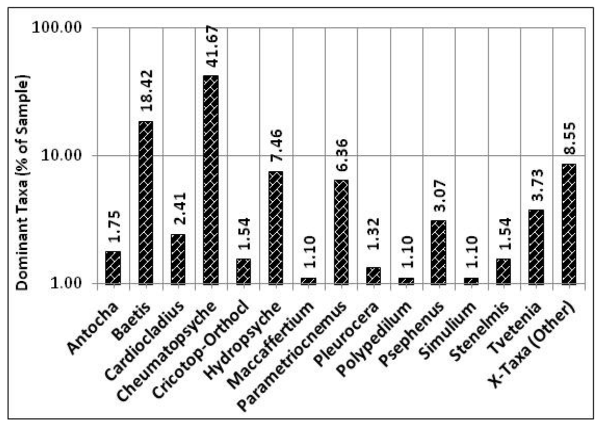


Figure 12: Dominant taxa (%) in EFK 13.8

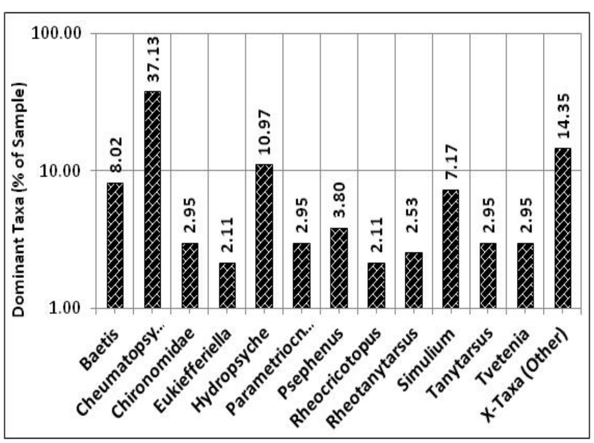


Figure 13: Dominant taxa (%) in EFK 6.3

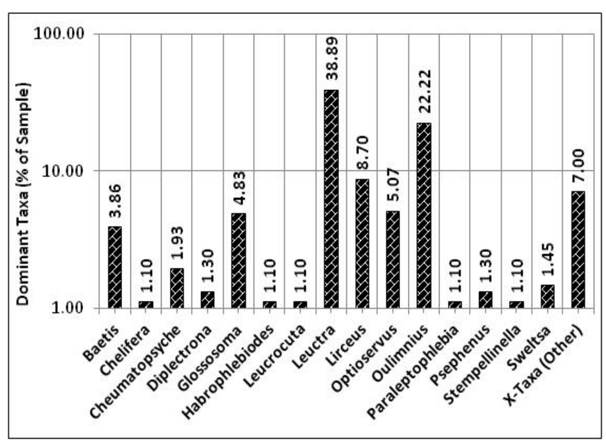


Figure 14: Dominant taxa (%) in CCK 1.45 Reference

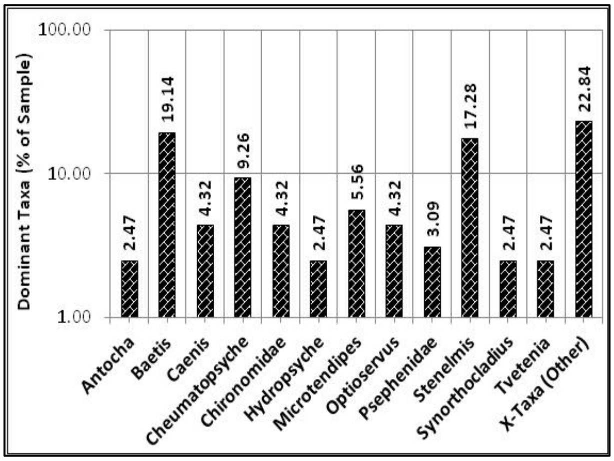


Figure 15: Dominant taxa (%) in HCK 20.6 Reference

Figure 16: %Midge / %Non-Midge in EFK & CCK Reference

A toxic stressor likely eliminates sensitive species from an assemblage, thereby leaving a subset of the initial species pool that is tolerant of the stressor (Hilsenhoff 1987, Yuan 2004). The mayfly *Baetis* sp. (*Ephemeroptera*) was present at only <1% of the total benthic population at the upstream EFK 25.1 station, but steadily increased downstream to >30% of the total population at EFK 6.3 station. *Baetis* spp. are known to be typically present in moderately polluted streams conditions (Hilsenhoff 1982, 1987, Klemm et al. 1990, Mandaville 2002).

In contrast, the Hinds Creek and Clear Creek reference sites (Table 4) exhibited Tennessee Macroinvertebrate Index scores of TMI = 36 (A, supporting/non-impaired) and TMI = 40 (A, supporting/non-impaired) respectively, thus exceeding the Bioregion 67F Target Macroinvertebrate Index score (TMI = 32), suggesting superior water quality at these reference streams as compared to East Fork Poplar Creek. For example, Taxa Richness and EPT Richness values ranged from 32-35 and 12-17 respectively at the reference streams compared to a value range of 16-26 (Taxa Richness) and 4-5 (EPT Richness) at the EFPC stations. At the CCK 1.45 reference station (Figure 14), *Leuctra* sp. (*Plecoptera*) and *Oulimnius latiusculus* (*Coleoptera*), are generally pollution-sensitive taxa indicative of high water quality (Hilsenhoff 1982, 1987, Klemm et al. 1990, Mandaville 2002) and comprise 36.89% and 22.22% respectively of the population at this reference site.

For 2012, the Tennessee Macroinvertebrate Index (TMI) scores comparing EFK 25.1 (TMI = 20, Rating = C) to EFK 6.3 (TMI = 32, Rating = A) suggests improving water quality conditions with distance downstream from the Y-12 source of pollution (until an additional downstream perturbation degenerated the system such as the COR sewage outfall or scouring of the substrates due to storm surge).

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

2012 RESULTS	Clear Creek Reference			Hinds Creek Reference			
Stream station	CCK 1.45			HCK 20.6			
METRIC	VALUE	SCORE		VALUE	SCORE		
Taxa Richness	32	6		35	6		
EPT Richness	17	6		12	6		
% EPT-Cheum	55.31	6		32.1	4		
% OC	2.9	6		25.31	6		
NCBI	2.28	6		4.52	6		
% Clingers	42.03	4		51.85	4		
% Nutrient Tolerant	10.63	6		36.42	4		
INDEX SCORE (Tenn. Macro. Index)		40			36		
RATING		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)						

Mitchell Branch

Table 5 presents the metric values, scores and biological condition ratings for Mitchell Branch. From the headwater MIK 1.43 reference station, the Taxa Richness, EPT Richness and % EPT-Cheum metrics all decreased downstream suggesting deteriorating water quality conditions at MIK 0.71 and MIK 0.45 compared to the upstream reference. The %OC and the NCBI metrics increased downstream also suggesting impaired water quality in the lower reaches of Mitchell Branch compared to the headwater reference. As expected, the headwater MIK 1.43 reference station (TMI=40, rating: A, supporting, non impaired) scored higher than both the downstream stations, MIK 0.71 (TMI=28, rating: B, partially supporting, slightly impaired) and MIK 0.45 (TMI=22, partially supporting, slightly impaired). Mitchell Branch continued to indicate signs of impaired conditions with two of three index scores well below the Bioregion 67F target Tennessee Macroinvertebrate Index score (TMI = 32, TDEC 2011). The reference station exceeded the target score.

Figures 17-19 illustrate the taxonomic composition of the Mitchell Branch macroinvertebrate population from upstream to downstream. The headwater MIK 1.43 macroinvertebrate community was dominated by pollution-sensitive EPT taxa such as *Diplectrona modesta* (16.03%), *Habrophlebiodes* sp. (10.94%), and *Leuctra* sp. (9.41%). Further downstream, the MIK 0.71 macroinvertebrate community was dominated by *Caecidotea* sp. (*Isopoda*, 12.93%), *Cheumatopsyche* sp. (*Trichoptera*, 12.07%), *Simulium* sp. (*Diptera*, 15.09%), and *Stenelmis* sp. (*Coleoptera,* 10.34%), with all four taxa being somewhat to very pollution tolerant. The lowermost downstream station, MIK 0.45, was dominated by pollution-tolerant taxa including *Chironomidae* (unidentified midges, 8.29%), *Cricotopus* sp. (midge, 6.74%), *Orthocladius* sp.

(midge, 8.81%), *Simulium* sp. (*Diptera,* 18.06%), and *Tanytarsus* sp. (midge, 7.25%). Taxa from the subfamily *Orthocladiinae* (*Cricotopus* sp., *Orthocladius* sp., etc.) constitute a combined 19.18% of the total assemblage at the downstream MIK 0.45 station. Highly impacted streams typically may be dominated by orthoclad chironomids (Hickey and Clements 1998, Maret et al. 2003). We also found that the % composition of midge taxa increased steadily downstream from 23.91% of the total macroinvertebrate assemblage at MIK 1.43 to 60.62% of the assemblage at MIK 0.45 (Figure 20). Overall, our 2012 Mitchell Branch macroinvertebrate analysis results indicate deteriorating water quality conditions exist downstream from the headwater reference station.

Table 5: Metric Values, Scores and Biological Condition Ratings for Mitchell Branch

2012 RESULTS		**MITCHELL BRANCH**						
Stream station		MIK 1.43		MIK 0.71		MIK 0.45		
METRIC		VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	
Taxa Richness		47	6	32	6	33	6	
EPT Richness		12	6	8	4	3	0	
% EPT-Cheum		50.13	6	12.93	0	5.18	0	
% OC		25.19	6	29.31	4	65.8	2	
NCBI		3.56	6	5.43	4	5.46	4	
% Clingers		42.2	4	50.0	4	40.41	4	
% Nutrient Tolerant		23.16	6	28.88	6	26.94	6	
INDEX SCORE (Tenn. Macro. Index)			40		28		22	
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)							

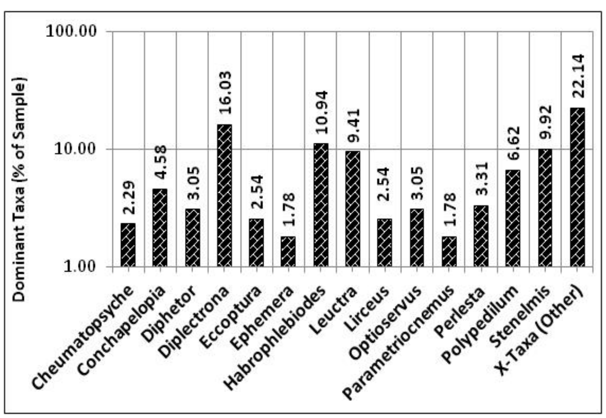


Figure 17: Dominant taxa (%) in MIK 1.43

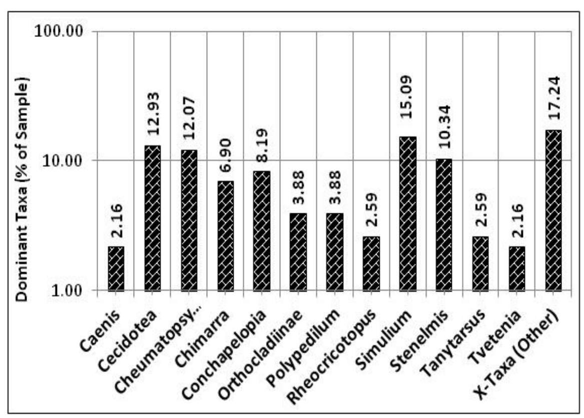


Figure 18: Dominant taxa (%) in MIK 0.71

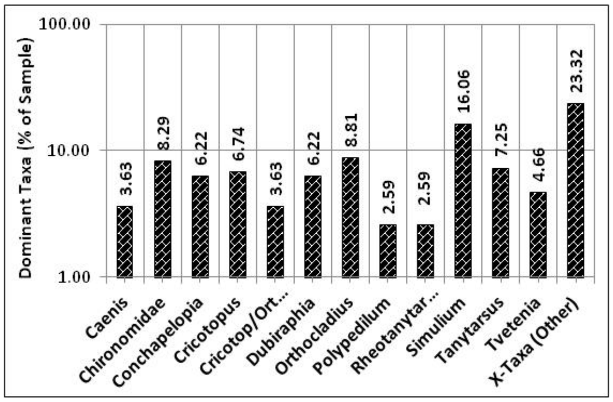


Figure 19: Dominant taxa (%) observed in MIK 0.45

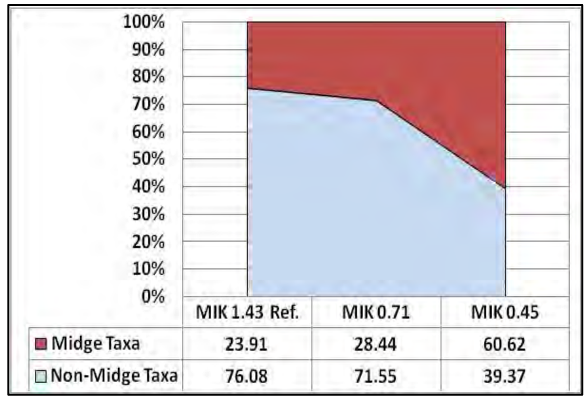


Figure 20: %Midge / %Non-Midge in MIK stations

Bear Creek

Continued poor water quality conditions are forecast for the upper Bear Creek site per the 2012 benthic laboratory data (Table 6). The headwater BCK 12.3 station received a Tennessee Macroinvertebrate Index score (TMI = 18, rating of C, partially supporting/moderately impaired) compared to the downstream BCK 9.6 which had an unexpected yet excellent result (TMI score = 32, rating of A, supporting/non impaired). This is a slightly better TMI score at BCK 12.3 compared to the 2011 result (TMI = 14, rating C). Nevertheless, the BCK 9.6 station matched the requirements of the Bioregion 67F Target Macroinvertebrate Index score, TMI=32 (TDEC 2011). Accordingly, the Taxa Richness, EPT Richness, % EPT-Cheum, and % Clinger metrics all increased significantly downstream, whereas the NCBI and % Nutrient Tolerant metrics decreased as expected. These results suggest surprisingly improved water quality conditions downstream at BCK 9.6 (compared to 2011 result of TMI = 28, B rating) with distance from the stressed headwater conditions at BCK 12.3. However, four pollution-intolerant taxa (*Pycnopsyche* sp., *Chimarra* sp., *Psilotreta* sp. and *Neophylax* sp.) were found in 2012 at the headwater BCK 12.3 site.

Table 6: Metric Values, Scores and Biological Condition Ratings for Bear Creek.

2012 RESULTS	BEAR CREEK						
Stream station	BCK 12.3		BCK 9.6				
METRIC	VALUE	SCORE	VALUE	SCORE			
Taxa Richness	23	4	36	6			
EPT Richness	7	4	11	6			
% EPT-Cheum	8.08	0	11.7	0			
% OC	7.52	6	11.4	6			
NCBI	6.83	2	5.1	4			
% Clingers	23.12	2	64.33	6			
% Nutrient Tolerant	79.67	0	50.58	4			
INDEX SCORE (Tenn. Macro. Index)		18		32			
RATING		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)						

Pollution-tolerant taxa such as *Lirceus* sp. (*Isopoda*) and *Stenelmis* sp. (*Coleoptera*, Hilsenhoff 1982, 1987, Klemm et al. 1990, Mandaville 2002) comprised 66.30% and 8.91% of the total macroinvertebrate assemblage at BCK 12.3. Dominance by one organism (i.e., one genus, order or family) at a benthic sampling station is often an indication of impaired water quality. *Lirceus* sp. dropped to 13.16% of the assemblage at BCK 9.6, and EPT taxa such as *Cheumatopsyche* sp. and *Diphetor hageni* combined to generate >38% of the assemblage at this station. Hickey and Clements (1998) determined that moderately impacted streams often have a high abundance of net-spinning caddisflies. Additional details of the taxonomic composition of the respective BCK macroinvertebrate populations can be observed in Figures 21-22; the reference stream taxonomic data is presented in Table 7 and Figures 23-24.

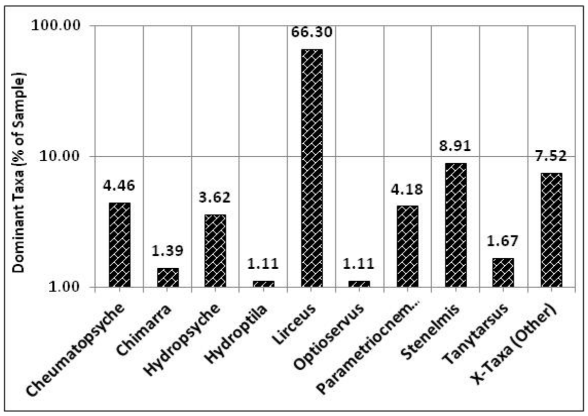


Figure 21: Dominant taxa (%) in BCK 12.3.

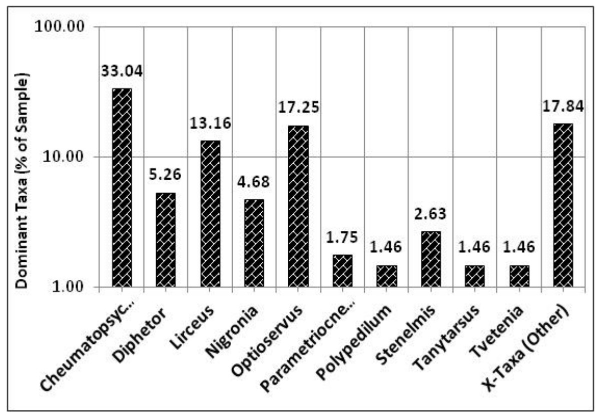


Figure 22: Dominant taxa (%) in BCK 9.6.

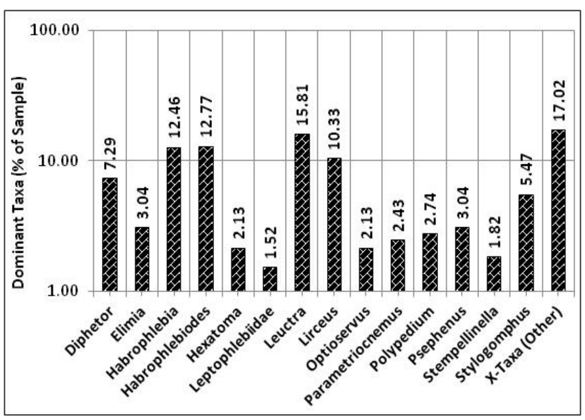


Figure 23: Dominant taxa (%) in GHK 2.9 Ref.

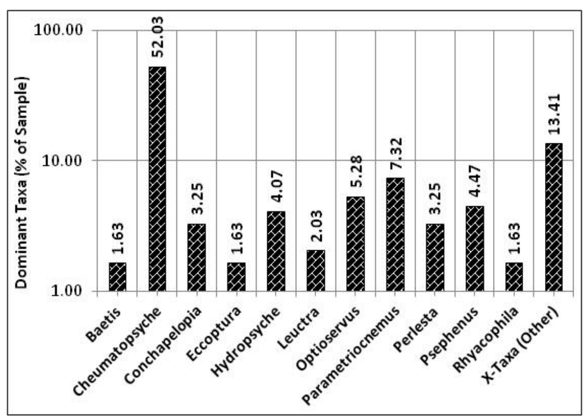


Figure 24: Dominant taxa (%) in MBK 1.43 Ref.

Dominant taxonomic assemblages of the Gum Hollow 2.9 reference stream includes the generally pollution-sensitive to moderately tolerant EPT taxa *Diphetor hageni* (*Ephemeroptera*, 7.29% of the composition), *Habrophlebia vibrans* (Ephemeroptera, 12.46% of the composition), *Habrophlebiodes* sp. (*Ephemeroptera*, 12.77% of the composition), and *Leuctra* sp. (*Plecoptera*, 15.81% of the composition). The major taxa comprising the Mill Branch 1.6 reference station composition includes a mix of pollution-sensitive to moderately tolerant EPT taxa such as *Baetis* sp. (*Ephemeroptera*), *Cheumatopsyche* (*Trichoptera*, 52.03% of the composition), *Eccoptura xanthenes* (*Plecoptera*), *Hydropsyche* sp. (*Trichoptera*), *Leuctra* sp. (*Plecoptera), Perlesta* sp. (*Plecoptera*), and *Rhyacophila* sp. (*Trichoptera*). Situated to the north of Bear Creek, outfall from three tributaries (NT-3, NT-4, NT-5) drains the Environmental Management Waste Management Facility (EMWMF) and enters Bear Creek between the two monitoring stations (BCK 12.3 and BCK 9.6). It is presently unclear if these north tributaries are impacting benthic communities in Bear Creek, thus continued benthic sampling and associated investigations during 2013 will be necessary to determine and solidify Bear Creek water quality issues, and if conditions are improving (or deteriorating).

Table 7: Metric Values, Scores and Biological Condition Ratings for Reference Sites

2012 RESULTS	Gum Hollow Branch Ref.			Mill Branch Reference			
Stream station	GHK 2.9			MBK 1.6			
METRIC	VALUE	SCORE		VALUE	SCORE		
Taxa Richness	37	6		33	6		
EPT Richness	11	6		16	6		
% EPT-Cheum	63.29	6		19.11	2		
% OC	16.08	6		13.82	6		
NCBI	3.35	6		4.93	4		
% Clingers	13.29	0		78.5	6		
% Nutrient Tolerant	19.23	6		54.47	2		
INDEX SCORE (Tenn. Macro. Index)		36			32		
RATING		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)						

Compared to the reference streams [Gum Branch 2.9 (GHK 2.9) & Mill Branch 1.6 (MBK 1.6), Table 7], BCK 12.3 demonstrated a 43-60% decrease in Taxa Richness, and %EPT-*Cheum* was 1.6 to 8 times greater in GHK 2.9 and MBK 1.6, respectively, than in upper Bear Creek. BCK 12.3 also exhibited four times greater nutrient-tolerant taxa (% Nutrient Tolerant metric) than present in Gum Branch 2.9 reference site, thus further supporting the assessment of impairment in upper Bear Creek. However, intermittently, very low water levels at BCK 12.3 may be an important factor affecting water quality. We have also noted large filamentous algal blooms at the BCK 12.3 station in springtime (April-May) which may temporarily affect benthic communities.

<u>White Oak Creek and Melton Branch</u>

The highest Tennessee Macroinvertebrate Index (TMI) score and rating for the White Oak Creek (WCK) watershed was at the upstream, headwater WCK 6.8 reference (TMI = 40, A, supporting/non-impaired), which exceeds the requirements of the Bioregion 67F Target Macroinvertebrate Index score (TMI = 32, TDEC 2011). The downstream locations at WCK 3.9, WCK 3.4 and WCK 2.3 received slightly lower TMI scores indicating partially supporting/slightly impaired biotic conditions (TMI = 30, 30 & 28 respectively, Rating = B's, Tables 8-9). Surprisingly, the MEK 0.3 site (TMI = 32, rating A) meets the Bioregion 67F Target Macroinvertebrate Index (TMI = 32) suggesting reference water quality conditions. However, these results are similar to 2011 TMI scores suggesting continued stable water quality and biotic conditions within the White Oak Creek watershed benthic community. Taxa Richness, EPT Richness, and % EPT-Cheum metrics were greater at the headwater WCK 6.8 reference compared to the downstream WCK/MEK stations. The % OC and % Nutrient Tolerant metrics increased downstream with longitudinal distance from the headwater reference. This outcome demonstrates biotic changes with longitudinal distance from the upstream reference (WCK 6.8) through the Oak Ridge National Laboratory (ORNL) downstream into Melton Valley. Interestingly, the Melton Branch (MEK 0.3) station had the highest % Clingers (76.43%) of all sites.

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

2012 RESULTS	WHITE OAK CREEK							
Stream station	WCK 6.8		WCK 3.9		WCK 3.4		WCK 2.3	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	38	6	25	4	19	4	30	6
EPT Richness	16	6	3	0	3	0	8	4
% EPT-Cheum	59.77	6	53.23	6	57.68	6	12.61	0
% OC	6.32	6	22.05	6	14.94	6	24.35	6
NCBI	4.69	6	4.84	6	4.78	6	5.01	4
% Clingers	45.4	4	21.29	2	23.24	2	53.48	4
% Nutrient Tolerant	13.2	6	19.77	6	16.18	6	35.65	4
INDEX SCORE (Tenn. Macro. Index)		40		30		30		28
RATING		A		B		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)							

Table 9: Metric Values, Scores and Biological Condition Ratings for White Oak Creek

2012 RESULTS	Melton Branch					
Stream station	MEK 0.3					
METRIC	VALUE	SCORE				
Taxa Richness	29	6				
EPT Richness	10	6				
% EPT-Cheum	16.38	2				
% OC	14.89	6				
NCBI	5.15	4				
% Clingers	76.43	6				
% Nutrient Tolerant	55.58	2				
INDEX SCORE (Tenn. Macro. Index)		32				
RATING		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)					

Figures 25-29 provide snapshots of the main taxa comprising the population of the macroinvertebrate communities in WCK/MEK watershed. The WCK 6.8 reference is characterized by 11 pollution intolerant taxa occur at WCK 6.8. Examples of these include *Diplectrona modesta*, *Rhyacophila* spp., *Tallaperla* sp., *Psilotreta* sp., *Goera* sp., *Glossosoma* sp., *Elimia* sp. *Habrophlebiodes* sp. (6.90% of the population, *Ephemeroptera*), *Leuctra* sp. (32.18% of the population, *Plecoptera*), *Optioservus* sp. (12.36% of the population, *Coleoptera*), *Psephenus herricki*. Note: *Cheumatopsyche* sp. is not sensitive (Hilsenhoff 1982, 1987, Klemm et al. 1990, Mandaville 2002).

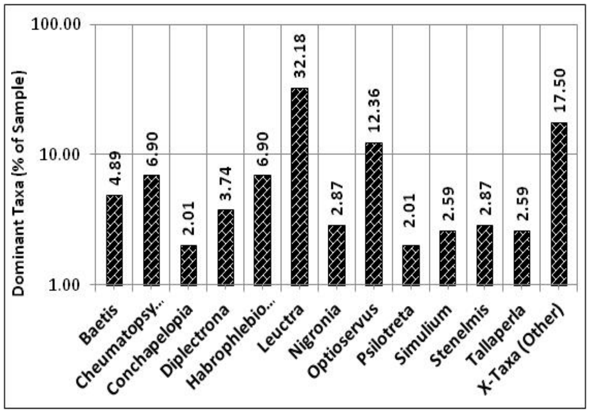


Figure 25: Dominant taxa (%) in WCK 6.8 Reference

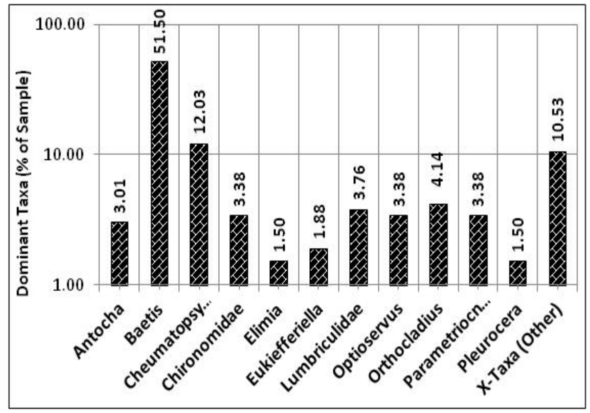


Figure 26: Dominant taxa (%) in WCK 3.9

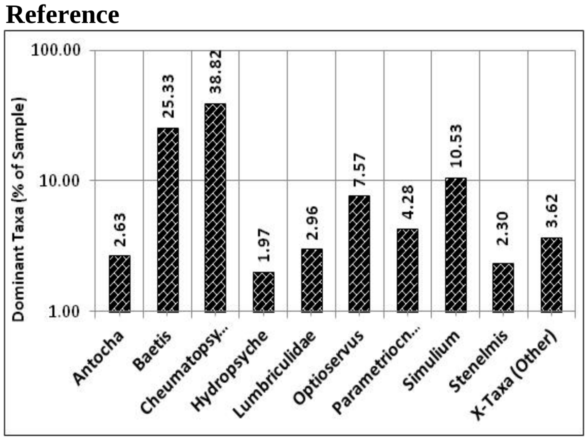


Figure 27: Dominant taxa (%) in WCK 3.4.

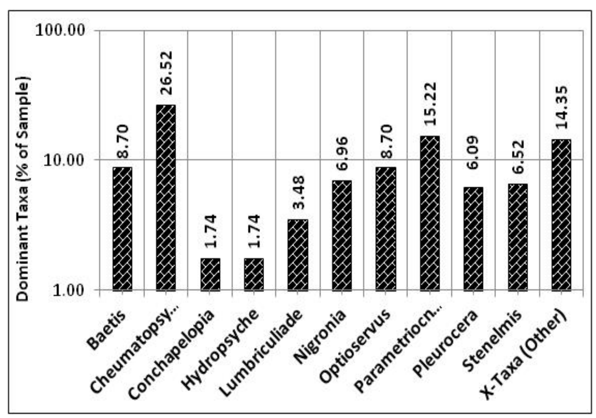


Figure 28: Dominant taxa (%) in WCK 2.3.

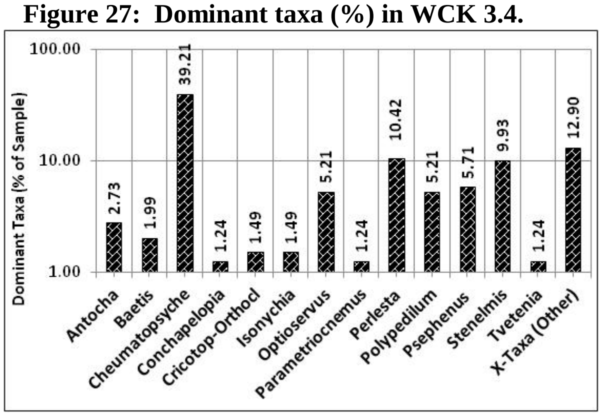


Figure 29: Dominant taxa (%) observed in MEK 0.3.

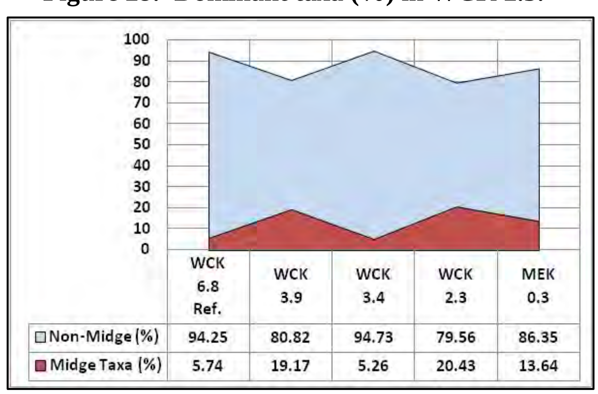


Figure 30: %Midge / %Non-Midge in WCK / MEK

Major taxa at the next downstream site, WCK 3.9, predominantly included the EPT taxa *Baetis* sp. (51.50% of the population, *Ephemeroptera*) and *Cheumatopsyche* sp. (12.03% of the population). Dominance by a few organisms (i.e., genera, order or family) at a benthic sampling station is often an indication of impaired water quality. *Baetis* sp. are known to be typically present in moderately polluted stream conditions (Hilsenhoff 1982, 1987, Klemm et al. 1990, Mandaville 2002). Significant at WCK 3.9 in 2012 was the discovery of a fairly mature specimen of *Diplectrona modesta* (pollution sensitive).

Dominant taxa at WCK 3.4 again includes *Baetis* sp. (25.33% of the population, *Ephemeroptera*) and the net-spinning caddisfly *Cheumatopsyche* sp. (38.82% of the population, *Trichoptera*), and additional taxa included *Optioservus* sp. (7.57% of the population, *Coleoptera*) and *Simulium* sp. (10.53% of the population, *Diptera*). Major taxa at WCK 2.3 included *Baetis* sp. (8.70% of the population, *Ephemeroptera*), *Cheumatopsyche* sp. (26.52% of the population, *Trichoptera*), *Nigronia* sp. (6.96% of the population, Megaloptera), *Optioservus* sp. (6.72% of the population, *Coleoptera*), and *Parametriocnemus* sp. (15.22% of the population, *Chironomidae*).

The dominant taxa at the White Oak Creek tributary (i.e., Melton Branch 0.3; MEK 0.3) consisted of the caddisfly *Cheumatopsyche* sp. (39.21% of the population, *Trichoptera)*, *Optioservus* sp. (5.21% of the population, *Coleoptera*), *Perlesta* sp. (10.42% of the population, *Plecoptera)*, Polypedilum (5.21% of the population, *Chironomidae*), *Psephenus herricki* (5.71% of the population, *Psephenidae*), and *Stenelmis* sp. (9.93% of the population, *Coleoptera*).

Interestingly, the lower sites within the White Oak Creek watershed (WCK 3.4, WCK 2.3 and MEK 0.3) were each dominated by downstream-increasing numbers of *Cheumatopsyche* sp. (*Trichoptera*) ranging from 6.9-12.03% of the total assemblages at the upstream WCK 6.8 and WCK 3.9 stations, to 26-39% of the assemblages at the downstream WCK 3.4, WCK 2.3 and MEK 0.3 stations. Moderately impacted streams often have a high abundance of net-spinning caddisflies (Hickey and Clements 1998), so it is not surprising that *Cheumatopsyche* sp. (moderately tolerant of pollution, *Trichoptera*, Hilsenhoff 1982, 1987, Klemm et al. 1990, Mandaville 2002) was a dominant taxon.

Lastly, Figure 30 represents a comparison of total % non-midge taxa vs. % midge taxa recorded in WCK/MEK stations. Non-midge taxa comprised >94% of the assemblages present at the WCK 6.8 reference and the downstream WCK 3.4, whereas the other 3 WCK/MEK sites were represented by 79-86% non-midge taxa. The highest % of midge taxa was determined at WCK 3.9 (19.17% of the total population) and WCK 2.3 (20.43% of the total population). Results from continued future sampling at the WCK watershed will be useful in assessing the effectiveness of ongoing ORNL remedial activities in Bethel and Melton Valleys.

Quality Control Results

Only one duplicate sample was collected as a quality control test during 2012. Per Table 10, the Gum Hollow 2.9 duplicate sample returned remarkably similar results compared to its twin sample. There were some differences in the taxa richness, % EPT, % Nutrient Tolerant and % Clingers between the original samples and respective duplicates. More importantly, the index scores and subsequent ratings matched extremely well between originals and duplicates. This outcome suggests that the taxonomists achieved good reproducibility overall among all samples.

Table 10: Metric Values, Scores & Biological Condition Ratings for Quality Control Duplicates

2012 RESULTS	Gum Hollow Ref. Duplicate	
Stream station	GHK 2.9 Dup.	
METRIC	VALUE	SCORE
Taxa Richness	38	6
EPT Richness	16	6
% EPT-Cheum	68.14	6
% OC	13.57	6
NCBI	2.2	6
% Clingers	20.35	2
% Nutrient Tolerant	10.32	6
INDEX SCORE (Tenn. Macro. Index)		38
RATING		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 impacted streams on the Oak Ridge Reservation is less than optimal compared to reference conditions. Of all sites sampled during 2012, two headwater locations, BCK 12.3 and EFK 25.1, received the lowest Tennessee Macroinvertebrate Index scores and ratings, partially supporting/moderately impaired (TMI = 18-20, C rating). This is not surprising in light of the fact that each headwater stream continues to receive impacts (i.e., metals, nutrients) from within the confines of the Y-12 Plant. The remaining ORR stream sites had biological condition ratings of partially supporting systems with slight to moderate impairment. Surface water sampling results indicate that mercury continues to be persistent in East Fork Poplar Creek; elevated nutrient concentrations, uranium and strontium, and high conductivity continue to persist in upper Bear Creek, and elevated gross alpha, gross beta, plus mercury and nutrients persist in White Oak Creek.

Future benthic monitoring will test for the potential confounding perturbations associated with tributary outfall into Bear Creek associated with the EMWMF waste cell operations. 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.

A searchable database (Microsoft® Access 2010) of all 2010-2012 benthic taxa collected and identified from ORR streams is available upon request.

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Periphyton Environmental Monitoring

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Abstract

Diatom communities colonizing artificial substrates were sampled to assess the water quality and ecological condition of Bear Creek. These communities were impacted by Department of Energy (DOE) activities on the Oak Ridge Reservation, especially the tributaries around the Environmental Management Waste Management Facility (EMWMF). Periphyton samples were collected from artificial substrates between June and December 2012 at four impacted Bear Creek sites. The goal was to use diatoms as biomonitoring tools for the ecological assessment and scoring of the water quality and to examine the recovery of Bear Creek as compared to historical periphyton data extracted from a reference stream. Water quality parameters (i.e., conductivity, pH, etc.) were also collected during each sampling event. Results presented include the diatom bioassessment index (calculated from six metrics), photosynthetic light data, stream water quality data (i.e., conductivity, metals), and diatom community composition.

Introduction

Periphyton is an assemblage of algae, fungi, bacteria and other organisms (i.e., micro-community) that colonize benthic substrates in aquatic ecosystems and are primary producers in the aquatic food chain (Stevenson et al. 2002, Carr et al. 2005). Important components of the periphyton community are diatoms (*Bacillariophyceae)*, which are unicellular photosynthetic protists with frustules constructed of silicon sequestered from the water column (Round et al. 2007). Periphytic diatoms exist within narrow environmental conditions (light, temperature, pH, turbidity, water chemistry), and are thus powerful indicators of different levels and causes of anthropogenic stress due to industrial pollution and high nutrient loads (Lange-Bertalot 1979, Sabater et al. 1987, Dixit et al. 1992, Bahls 1993, Stevenson et al. 2002, Gold et al. 2003, Wehr and Sheath 2003, Smol 2008).

Communities of benthic algae (periphyton) contain many taxa that exhibit individual tolerances to anthropogenic stress such as elevated concentrations of metals and nutrients in streams and lakes (Genter et al. 1988, Pérès 1996, St-Cyr 1997, Medley and Clements 1998, Ivorra et al 1999). Previous studies have documented negative impacts to periphyton communities in response to industrial pollution with several species being extirpated and never reappearing, whereas others were more resistant to pollution and remained (Ruggiu et al. 1998, Guilizzoni et al. 2001). Thus, community composition of periphyton can be useful in identifying degraded water quality conditions (Genter et al. 1988).

Methods and Materials

Study Site

Periphyton was collected during 2012 at four benthic locations in Bear Creek Valley [BCK km 12.3, BCK 11.5 (North Tributary 3 (NT-3) confluence, BCK 10.6 (North Tributary 5 (NT-5), & BCK km 9.6); Table 1] to quantify and evaluate Oak Ridge Reservation (ORR) diatom community composition and taxa richness. Samples were collected from artificial substrates six times (June, July, September, October, November, December). Historical diatom information was also integrated from the Hinds Creek km 20.6 site (Andersonville, TN area) for reference stream data.

Table 1: 2012 Periphyton Study Sites (including light & biomass)

Station (stream km)	Description	Vegetation Cover	Minimum / Maximum Light Intensity (units = Lux)	June 2012 Cell Density (Biomass; units = cells/cm^2)
BCK 12.3	Bear Creek km 12.3 (headwaters)	75% canopy cover	120,000-140,000	2,037,707
BCK 11.5	Bear Creek km 11.5 near NT-3 outfall	50% canopy cover	220,000-275,000	2,337,695
BCK 10.6	Bear Creek km 10.6 near NT-5 outfall	100% canopy cover	30,000-150,000	1,123,445
BCK 9.6	Bear Creek km 9.6	100% canopy cover	42,000-74,000	1,133,529

Lux is defined as the measure of luminous flux per unit area (luminous emittance); 1 Lux = 1 lumen/m^2.

Bear Creek Valley (BCV) represents topography characteristic of the east Tennessee ridge and valley physiographic province. The Bear Creek headwaters originate from a topographical surface-water divide within the restricted confines of the Y-12 Plant, flows west through BCV, and ultimately is tributary to East Fork Poplar Creek (EFK, TDEC 2006). The Environmental Management Waste Management Facility (EMWMF) which began receiving wastes in 2003 is a solid waste landfill composed of cells approved for receipt of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) low level radioactive wastes, RCRA hazardous wastes, and polychlorinated biphenyl (PCB) wastes (TDEC 2008). It is an above-grade waste disposal facility located in Bear Creek Valley just west of the Y-12 Complex (Figure 1). In addition to the disposal cells, the EMWMF consists of a leachate collection and transfer facility, support facilities, access roads, stormwater retention basins, and monitoring and security systems. One of the goals of this project was to investigate potential impacts to biological communities from NT-3 and NT-5 into Bear Creek.

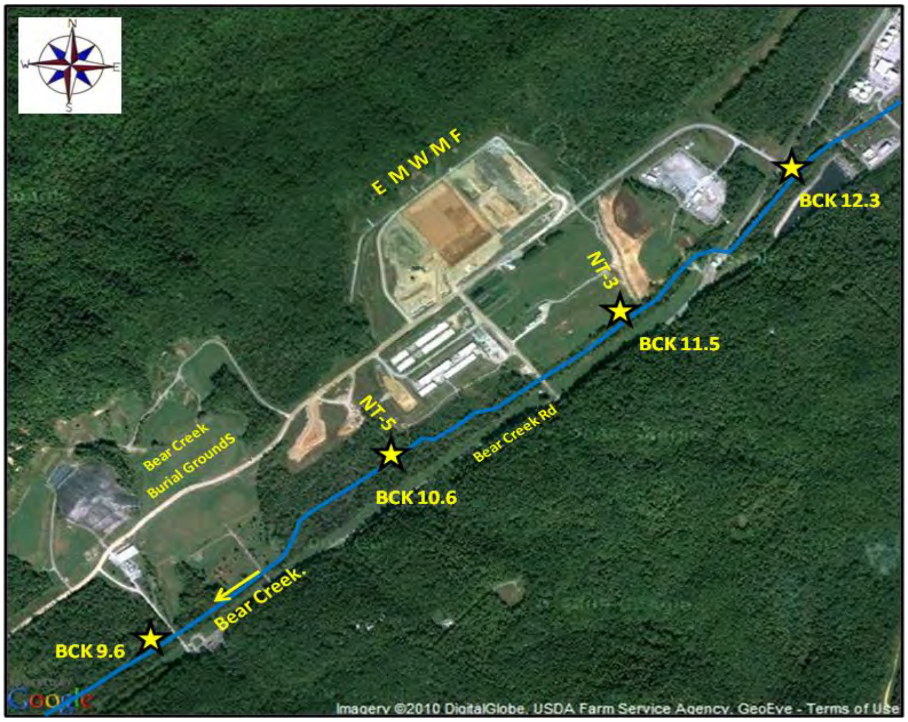


Figure 1: EMWMF facility and Bear Creek periphyton sampling locations (yellow arrow indicates direction of stream flow)

Artificial Substrates

Characterization of diatom taxa present in a sample and their disproportionate abundance can be analyzed to determine biotic integrity and diagnose specific stressors (Davis and Simon 1995). Artificial substrates are commonly used to quantify diatom communities in aquatic systems which colonize substrates rapidly (Kevern et al. 1966, Korte and Blinn 1983, Deniseger et al. 1986, Stevenson and Pan 1999, Lane et al. 2003). Introduced or artificial substrates provide precise assessments of diatom populations in streams with highly variable environmental conditions, create a standardized or uniform surface for periphyton growth, and minimize problems associated with substrate comparability among sampling stations (Porter et al.1993, Stevenson and Pan 1999, Stevenson et al. 2002, Lane et al. 2003). The goal was to obtain a sample that is a miniature replica of the standing crop of periphytic algae that is present at each site (Bahls 1993). After initial placement of artificial substrates, 2-4 weeks were allowed for periphyton recruitment and colonization before leadoff tile samples were collected (Aloi 1990, Porter et al. 1993, Barbour et al. 1999, KDOW 2002).

Artificial substrates were constructed of standard red masonry bricks (w/ 10-holes) and 12 beige ceramic tiles (23.04 centimeter square [cm^2] each) that were affixed to the top of each brick with silicon glue. Bricks (with tiles face-up) were secured to the streambed (i.e., fairly deep riffles) by driving 1.5-foot sections of rebar approximately 1-foot deep into the substrate (Hill and Middleton 2006). Thus, to prevent loss of the artificial substrates during storm surge events, one of the holes of the masonry brick was fitted over the top of the rebar, slid down, and submerged. At each BCK sampling site, the colonized brick was raised from the streambed, and one colonized tile was randomly selected and carefully pried off with a pocketknife. The tile sample was placed in a labeled plastic container, creek water was added to cover the tile, and the container was sealed and packed in an ice chest for transport to the laboratory. Once tiles were extracted, the brick was re-submerged to its original position and orientation in the creek for future sampling. Upon returning to the laboratory, samples were stored in dark refrigeration at 4°C until processing (less than or equal to 24 hours, Flotemersch et al. 2006).

Water Quality and Photosynthetic Light

Ambient water parameters were measured at each location using the YSI® 556 Water Quality Meter (pH, temp, conductivity, dissolved oxygen). Field data were recorded in a logbook at each sampling site. HOBO® light meters (Onset Computer Corporation) were deployed in July 2012 for one week to characterize photosynthetic light received as an estimate of canopy cover at each sampling station. Surface water quality laboratory data (i.e., nutrients, metals, radiological) were sequestered from a sister benthic project for inclusion in this report.

Field sampling methods and protocols employed during this project included Tennessee Department of Environment and Conservation's Quality System Standard Operating Procedure for Periphyton Stream Surveys (TDEC 2010), U.S. EPA's Periphyton Sampling Protocol (Barbour et al. 1999), the Kentucky Division of Water (KDOW 2008, 2009), the New Jersey Protocol Manual (Ponader & Charles 2005), and the United States Geological Survey (USGS) Methods for Collecting Algal Samples as Part of the National Water Quality Assessment Program (Moulton et al. 2002).

Laboratory Processing

Periphyton was brushed from tiles and carefully rinsed with 20-25 milliliter (mL) deionized water into a clean laboratory pan. The initial slurry volume of each sample was carefully measured in a graduated cylinder and recorded in the laboratory logbook. Using a clean funnel, the resultant algal slurry was poured into 30 m; dark brown Nalgene® high density polyethylene bottles. The slurry was preserved with three drops of Lugol's solution and kept in cold, dark storage (4°C) until identification and quantification of taxa (Wunsam et al. 2002, Hill et al. 2009) could be completed. Sample identification labels with site specific information was attached to each slurry sample container. Laboratory sample preparation protocols follow the methods of Bahls (1993), Barbour et al. (1999), KDOW (2008, 2009), and Moulton et al. (2002).

Staff enumerated periphyton taxa to genus using a Zeiss® (Carl Zeiss Microimaging, Inc., Thornwood, NY, USA) inverted microscope at 400X magnification (Utermöhl 1958, Gillett et al. 2009). The Olympus® BH-1 stereo microscope was also used for viewing permanently mounted diatom slides at 1000X magnification (oil immersion). Several periphyton studies have reported that generic-level identifications explain a larger portion of environmental variance than species classification (Chessman et al. 1999, Hill et al. 2001, Wunsam et al. 2002, Bellinger et al. 2006, Wang et al. 2005, 2006). Staff enumerated genera abundance of algal taxa within 10 fields-of-view (FOV). If <500 cells were observed in 10 FOV, then additional genera were counted until 500 cells were obtained. Algal filaments were also counted, where a 10-µm segment was considered equivalent to one cell for consistent enumeration (Alverson et al. 2003, Brierley et al. 2007, KDOW 2008). If observed, the occurrence of aberrant diatom shapes, such as indentations or unusual bending of the frustules, was noted because this is an indication of heavy metal stress (McFarland et al. 1997, Ruggiu et al. 1998, Gold et al. 2003, Cattaneo et al. 2004). Diatoms and non-diatom taxa were to have been keyed-out to the generic level including identifications to the species level using the keys of Smith (1950), Patrick and Reimer (1966, 1975), Prescott (1978), and Wehr and Sheath (2003).

Bioassessment Metrics

According to the guidance presented in the Quality System Standard Operating Procedure for Periphyton Stream Surveys (TDEC 2010), the TDEC Diatom Bioassessment Index (DBI) was used to determine water quality scores as calculated from six taxonomically-derived metrics to make inferences on the environmental conditions at each impacted Bear Creek sampling site (Winter and Duthie 2000, KDOW 2008, 2009). What is a metric? A metric is a quantifiable attribute or characteristic of the aquatic community that is ecologically relevant and responds predictably along an environmental disturbance gradient (Barbour et al. 1995, Karr and Chu 1999, US EPA 1996). Typically, several metrics are combined to obtain a composite index that has greater utility than each of the component metrics. The TDEC-DBI is similar to the indices for fish and macroinvertebrates in streams (Karr 1981, Hilsenhoff 1982, 1987) in that it is a multimetric index (Table 2). Basically, the diatom enumeration data is plugged into the metrics and calculated. Each individual metric provides a sub-score which is then assigned a calculated score (range 0-100) based upon the standard metric value (95^{th} percentile thresholds for each metric). The mean of the six metrics is the final TDEC-DBI score that characterizes the periphyton assemblage and ecological integrity of each stream site (Bahls 1993, Griffith et al. 2002, KDOW 2008, 2009). Further details describing the Kentucky Index can be found in KDOW (2008).

Table 2: TDEC-WPC Diatom Bioassessment Index (TDEC 2010)

DIATOM BIOASSESSMENT INDEX (METRICS) **TDEC DIVISION OF WATER POLLUTION CONTROL**
(1) **Total Number of Diatom Taxa (TNDT)** = total number of periphyton taxa identified in a sample; this number also indicates an estimate of diatom taxa richness. The TNDT is expected to decrease with increasing pollution.
(2) **Shannon Diversity (H')** = index to characterize species diversity (species proportion for all species in a particular ecosystem). Using this metric, H'=0 when only 1 species is present in the biotic assemblage (i.e., poor water quality), and H' is at its maximum when all individuals are evenly distributed among a population (i.e., clean water quality).
(3) **Pollution Tolerance Index (PTI)** = each taxa is assigned a tolerance value based on their tolerance to increased pollution; tolerance values range from 1 (most tolerant) to 4 (most sensitive). The tolerance values are derived from periphyton protocols of the Kentucky Division of Water (2008, 2009). Low PTI scores reflect impaired water quality whereas higher scores reflect clean water quality conditions.
(4) ***Cymbella* Group Richness (CGR)** = Total number of taxa from the following genera: *Cymbella, Cymbopleura, Encyonema, Encyonemopsis, Navicella, Pseudoencyonema*, & *Reimeria.* As water pollution increases, the CGR score is expected to decrease.
(5) ***Fragilaria* Group Richness (FGR)** = Total number of taxa from the following genera: *Ctenophora, Fragilaria, Fragilariforma, Pseudostaurosira, Punctastriata, Stauroforma, Staurosira, Staurosirella, Synedra*, & *Tabularia.* As water pollution increases, the FGR score is expected to decrease.
(6) **% *Navicula, Nitzschia, Sururella* (%NNS)** = The sum of the relative abundances of all *Navicula, Nitzschia*, & *Sururella* taxa. The relative abundances of these 3 main taxa within an assemblage reflect the degree of sedimentation at a reach. As sedimentation increases, the %NNS is expected to increase.

Results and Discussion

Photosynthetic Light

HOBO® light meter data indicates that the BCK 11.5 site received the greatest intensity of sunlight (maximum = 275,000 lux) whereas BCK 9.6 (maximum = 74,000 lux) received the least light intensity (Table 1, Figures 2-5). The lux is a very small unit of illuminance in the International System of Units and is defined in terms of lumens per meter squared (lm/m^2). One lux is roughly equivalent to 1.46 milliwatt (1.46×10^{-3} W) of radiant electromagnetic (EM) power. Light is prominent among the abiotic factors that may limit primary production in aquatic systems (i.e., biomass). Shading (turbidity) presents serious challenges for effective photosynthesis among primary producers (Hill et al. 1995). Periphyton biomass and productivity are much greater when light intensity is elevated during all seasons (Rosemond et al. 2000). For example, results suggest that the greatest periphyton biomass was recorded at the BCK 11.5 (biomass = 2,337,695 cells/cm^2), also the same site receiving the largest intensity of sunlight.

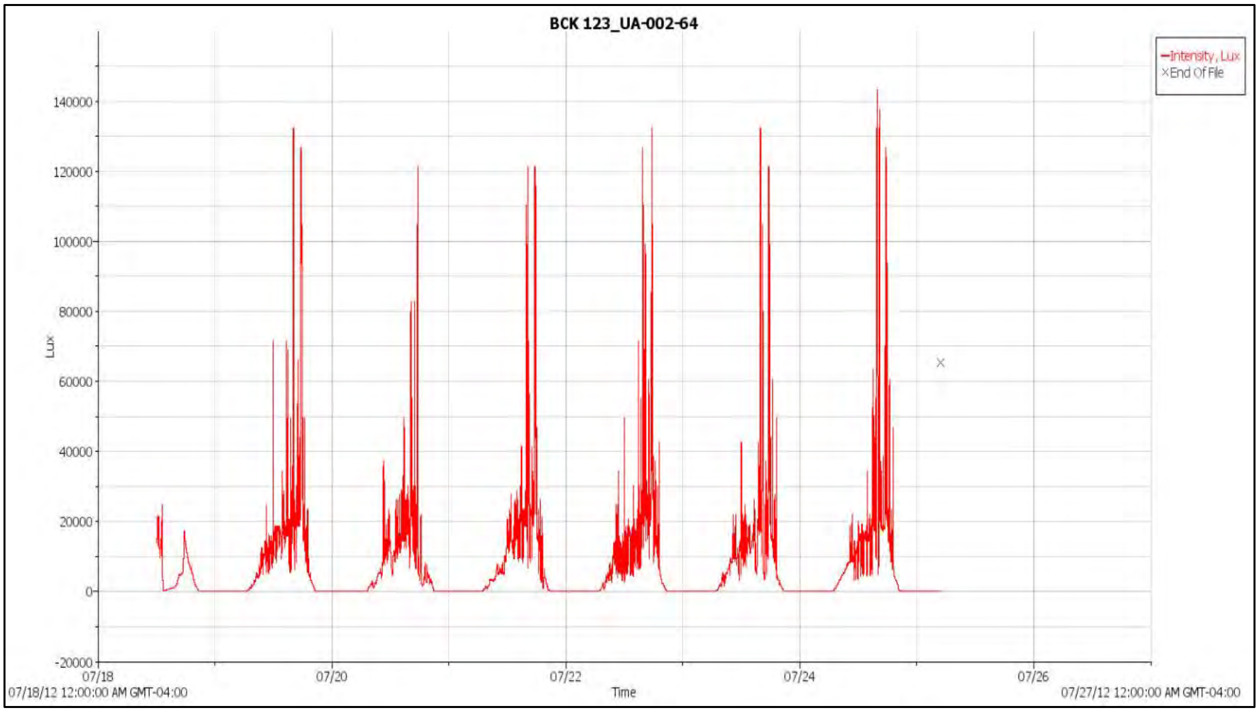


Figure 2: Photosynthetic Light Data (HOBO®; units = LUX) at BCK km 12.3 Periphyton Station (headwaters; ~75% riparian cover)

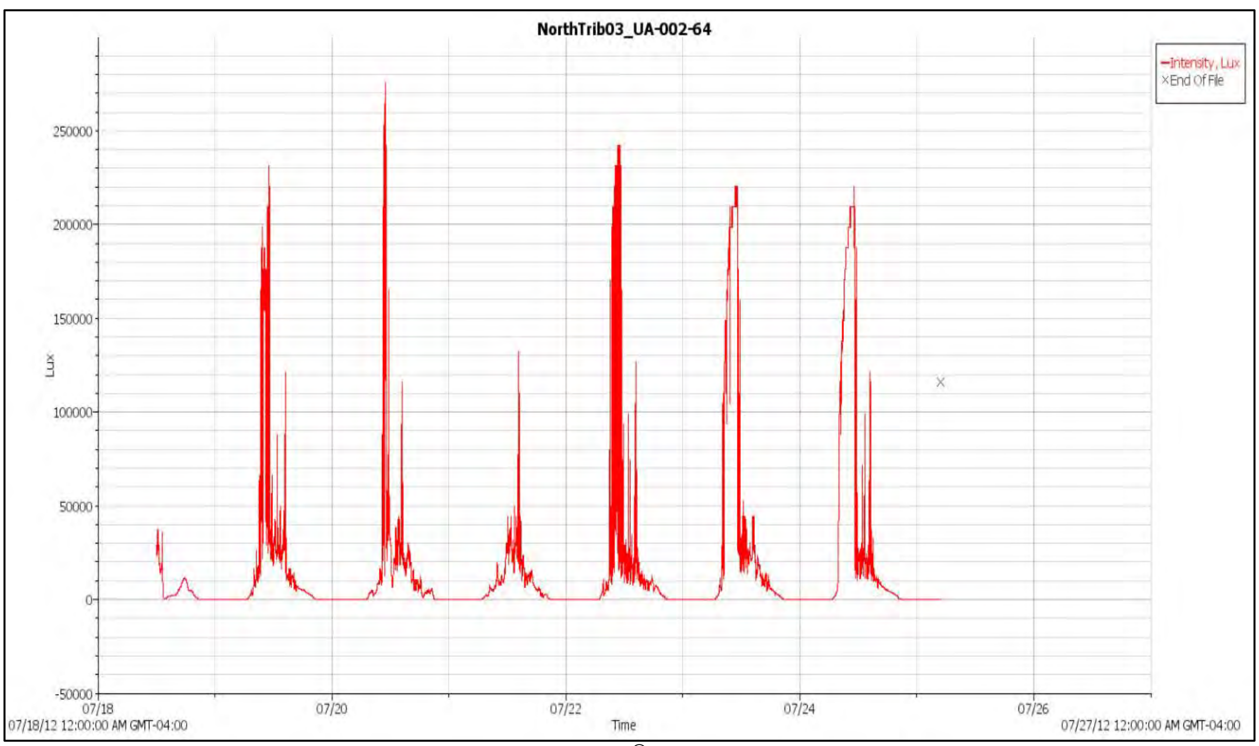


Figure 3: Photosynthetic Light Data (HOBO®; units = LUX) at BCK km 11.5 Periphyton Station (near outfall of North Tributary 3; ~50% riparian cover)

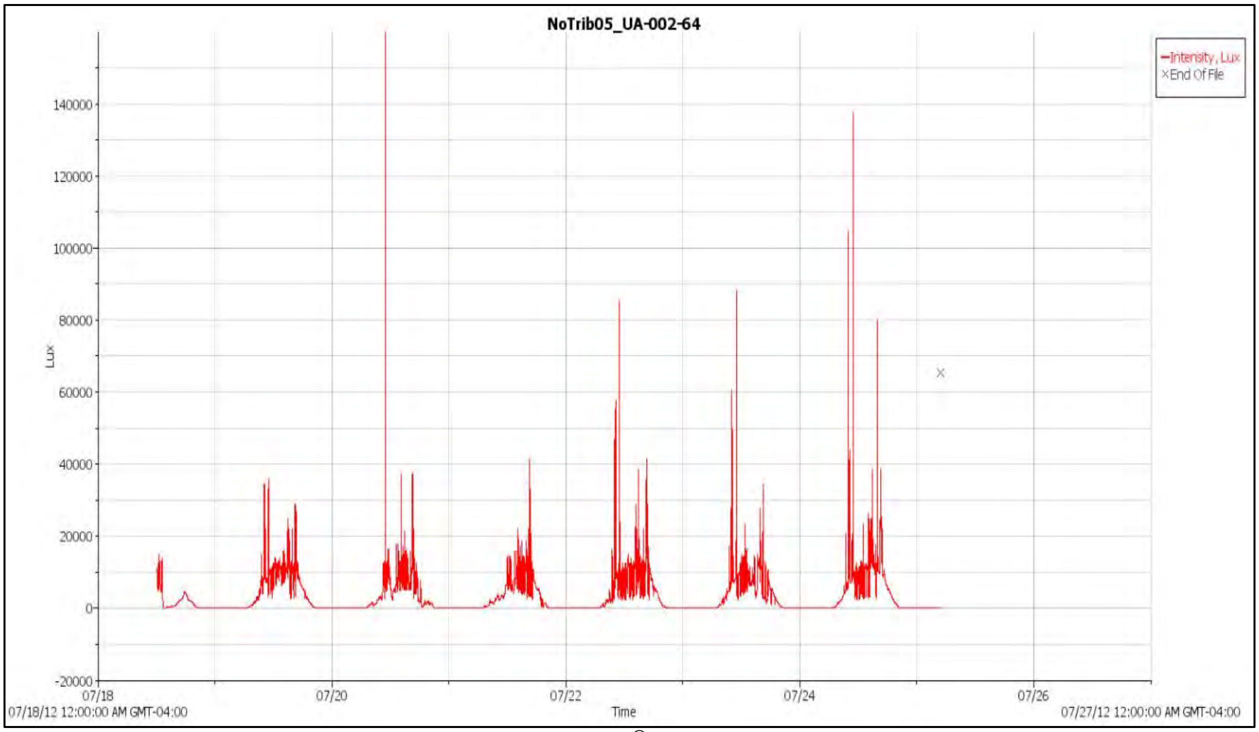


Figure 4: Photosynthetic Light Data (HOBO®; units = LUX) at BCK km 10.6 Periphyton Station (near outfall of North Tributary 5; ~75% riparian cover)

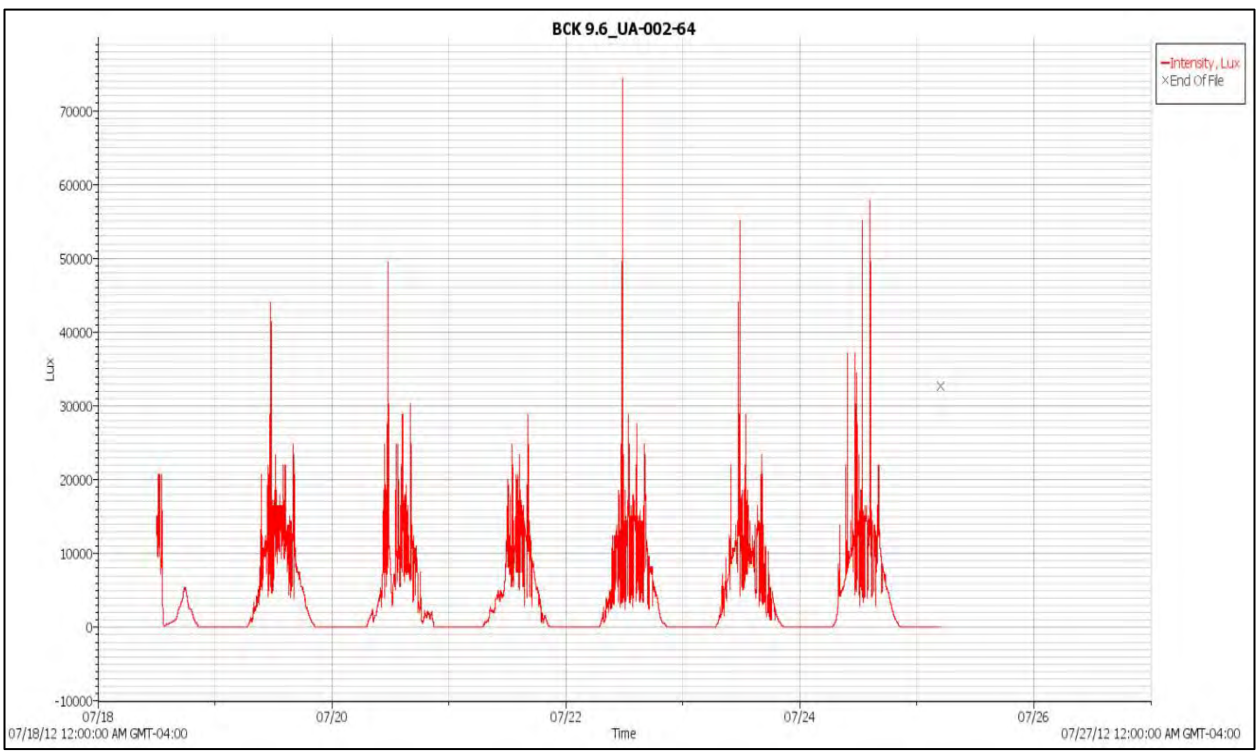
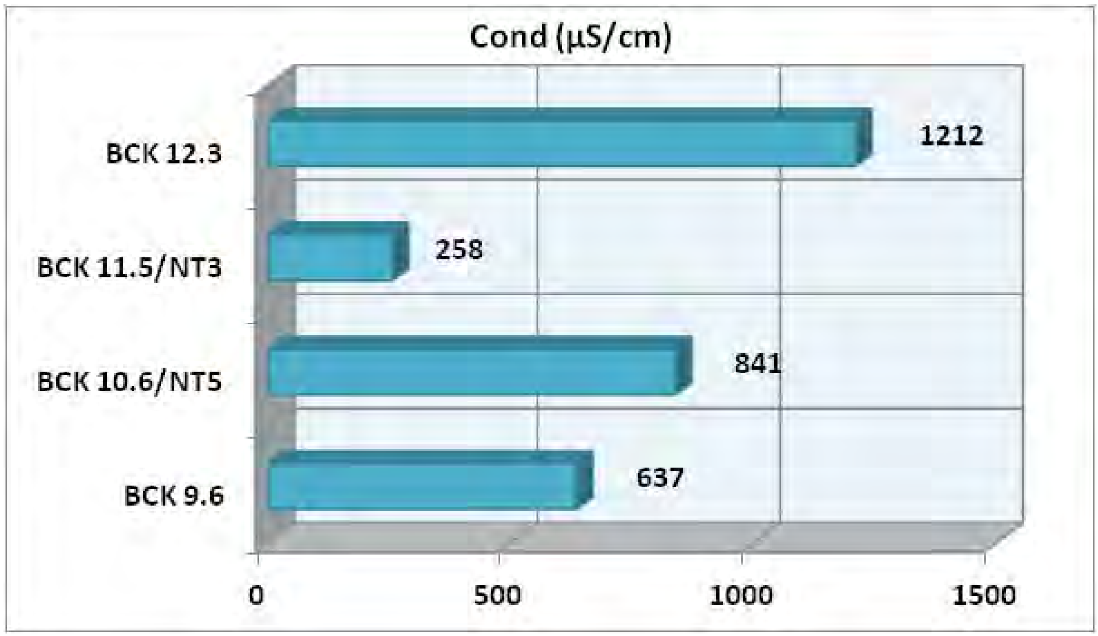


Figure 5: Photosynthetic Light Data (HOBO®; units = LUX) at BCK km 9.6 Periphyton Station (downstream site; ~100% riparian cover)

Water Quality and Environmental Stressors

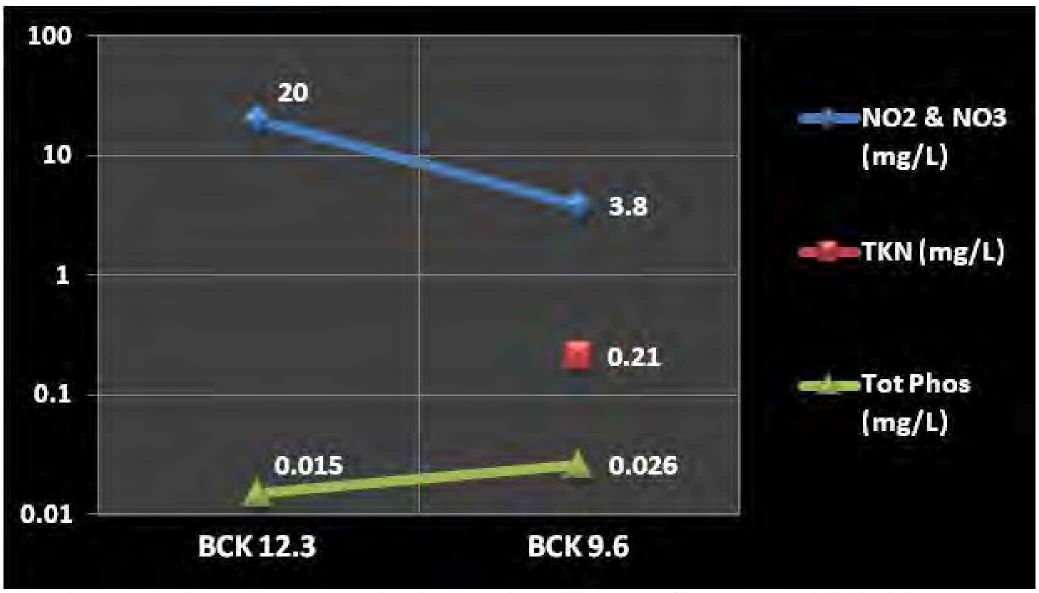
Stressors such as industrial and organic pollution can have significant impacts on water quality, which can influence aquatic food web structuring (Vitousek et al. 1997, Brennan and Withgott 2004). Environmental stressors such as elevated water conductivity can have significant impacts on algae distribution, particularly on diatoms and desmids (Coesel 1986, Alles et al. 1991, Dell'Uomo 1992, Coesel and Kooijman-Van Blokland 1994). Figure 6 reveals that the highest conductivity was recorded at BCK 12.3 (mean=1212 mircoSiemens per centimeter [µS/cm]), the headwater site that is in the proximity of the S-3 Ponds. These ponds are a source of nitrate contaminants from previous Y-12 Plant operations. Although conductivity decreased to 258 µS/cm (mean) at the downstream BCK 11.5 site, possible additional impacts from the NT-3 and NT-5 outfalls drove the mean conductivity back up to 841 µS/cm at the BCK 10.6 sampling site. It is hypothesized that the high overall conductivities recorded in upper BCK influenced the distribution of periphyton taxa that colonized substrates here.



Cond - Conductivity; µS/cm- microSiemens per centimeter

Figure 6: YSI® 556 Water Quality Meter Stream Monitoring Data

Nutrient enrichment frequently changes the structure and function of aquatic systems by affecting related components such as water chemistry, macrioinvertebrates, and periphyton (Smith et al. 1999). Nutrient inputs can cause algal blooms, increase biological oxygen demand, and decrease available dissolved oxygen (Anderson and Garrison 1997, Hooda et al. 2000, Sabater et al. 2000, Dunne et al. 2005). Changes in algal biomass and taxa composition can cause trophic cascades that have irreversible effects on aquatic community structure and function (Bourassa and Cattaneo 2000, Chase 2003, Jones and Sayer 2003). Figure 7 represents mean nutrient laboratory data for samples collected at the BCK sites during 2012. Nitrates (NO_2 & NO_3) decreased from 20 mg/L at the headwater BCK 12.3 site to 3.8 mg/L at the downstream BCK 9.6; but in contrast, both Total Kjeldahl Nitrogen (TKN) and total phosphorus increased downstream. It is hypothesized that elevated nitrates at the headwater BCK 12.3 site influenced the higher distribution of pollution-tolerant diatom taxa there. Then, increasing pollution-sensitive diatom populations downstream were a response to decreasing nitrate concentrations at BCK 9.6. Thus, the results indicate that excessive nutrients result in degraded water quality and increased impacts on algal communities, generally agreeing with other studies (Smith et al. 1999, Stoermer and Smol 1999, Carrick and Lowe 2007, Rader and Richardson 1992, Pan et al. 2000, McCormick et al. 2001). Shifts in genera composition and abundance of diatoms and other freshwater algae can be used to infer rapid community response to environmental change in aquatic systems and biomass (Sullivan 1999, Stevenson et al. 2002). Winter and Duthie (2000) determined that nutrient concentrations indirectly alter the composition of diatom communities; they found that *Achnanthidium* was high in abundance in lowland streams with high total phosphorus (TP) concentrations.



NO2-Nitrite; NO3- nitrate; tot phos - total phosphorus; mg/L - milligrams per liter; TKN - total kjeldahl nitrogen.

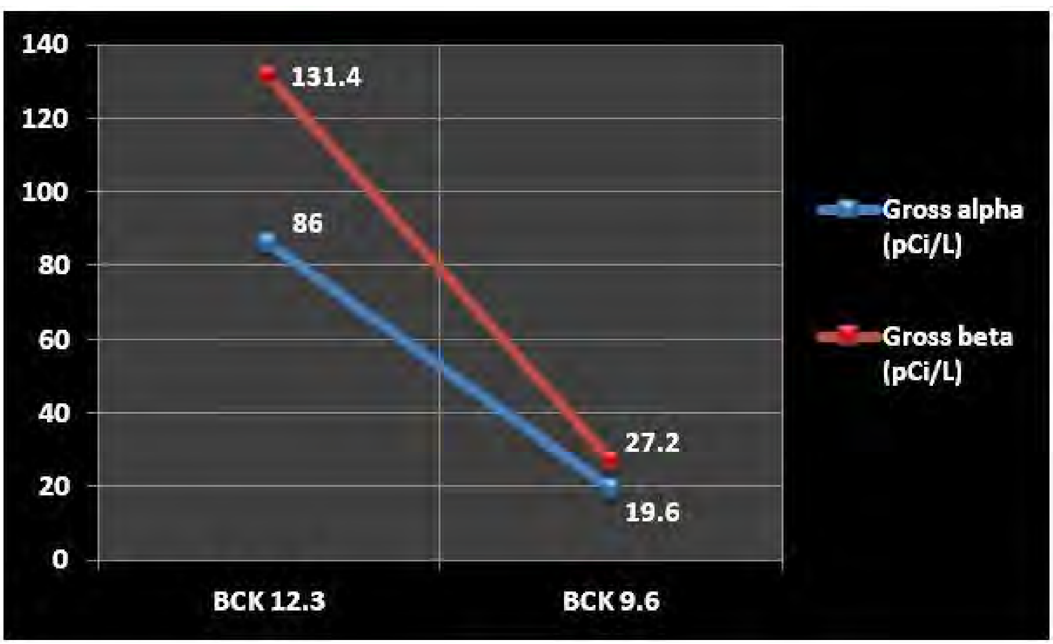
Figure 7: Bear Creek Surface Water Laboratory Analysis: Nutrients

Metal contamination may drive succession in some algal communities towards pollution-tolerant species (Gustavson and Wangberg 1995), and result in a decrease in species diversity (Leland and Carter 1984, Medley and Clements 1998). Mercury (Hg), especially the toxic methyl mercury (MeHg), is a significant environmental contaminant that accumulates to hazardous levels in fish and benthic organisms (Hill et al. 1995). Pérès et al. (1997) observed that the toxic organic compound, MeHg led to a marked reduction in diatom cell density and species composition, and inorganic Hg(II) in aquatic systems has a negative effect on diatom cell division. Medley and Clements (1998) reported that diatom communities in streams near metals contamination sources (cadmium [Cd], copper [Cu], zinc [Zn]) were dominated by early successional and metals-tolerant species. Although Hg was not detected in 2012 Bear Creek surface water samples, it was noticed that Cd concentrations were 237 micrograms per liter (µg/L) at the headwater BCK 12.3 site but decreased to 59.5 µg/L at the downstream BCK 9.6 site (Figure 8). Austin and Deniseger (1985) observed in stream experiments that Cd-sensitive diatom taxa (e.g., *Asterionella formosa*, *Tabellaria fenestrata, T. flocculosa, Achnanthidium minutissimum*) became more abundant with distance downstream from the source of Cd pollution. It was found that the population of *Achnanthidium* was greater at the downstream site compared to the headwater site, so Cd could have been a factor in this diatom response.

Cd - cadmium; Cu - copper; Fe - Iron; Pb - Lead; Mn - manganese; Zn - Zinc; µg/L - micrograms per liter

Figure 8: Bear Creek Surface Water Laboratory Analysis: Metals

Figure 9 presents the radiological data for Bear Creek. Although gross alpha and gross beta were detected in Bear Creek surface water samples at elevated concentrations of 86.0 picocuries per liter (pCi/L) and 131.4 pCi/L, respectively. There is no clear evidence to support additional impact on the periphyton community due to these perturbations. The scientific literature is lacking for studies investigating the impacts of radionuclides on periphyton communities.

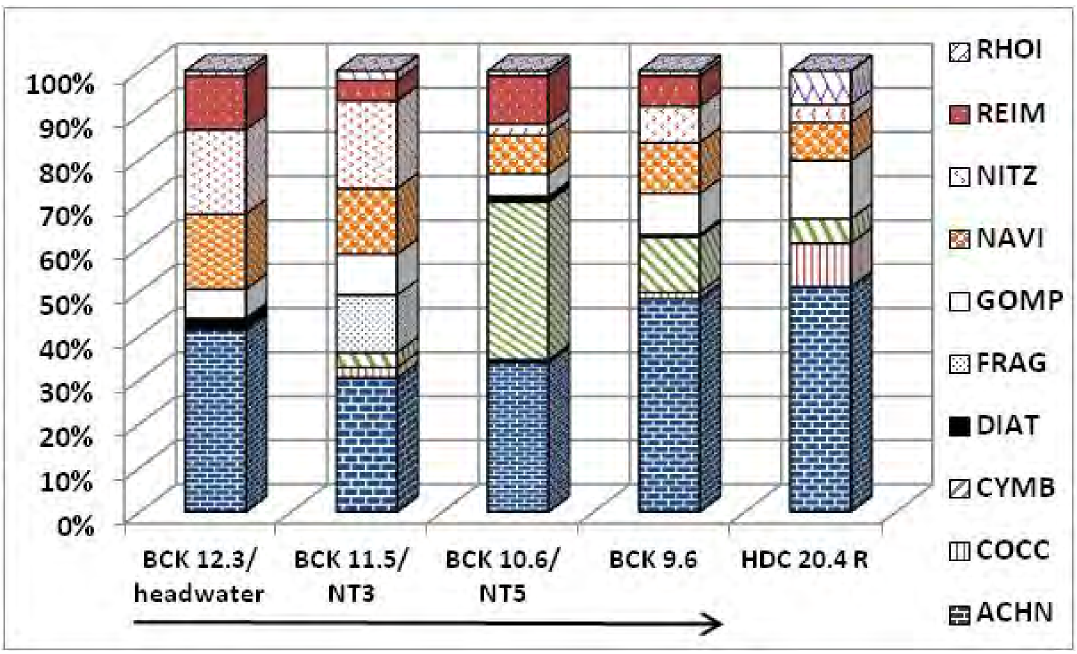


pCi/L - picocuries per liter

Figure 9: Bear Creek Surface Water Sample Analysis: Radiological

Responses of Periphyton Taxa

Diatom taxa responded to impacts in Bear Creek by exhibiting increasing relative abundance and distributions of pollution-tolerant diatoms in the upper BCK sites. In contrast, pollution sensitive diatoms became more dominant and increased their relative abundance at the downstream sites which compared well with the reference stream data (Figure 10). The pollution sensitive diatoms *Achnanthidium, Cocconeis*, and *Rhoicosphenia* demonstrated increasing dominance of the overall diatom population downstream, especially at the BCK 9.6 site compared to the headwater BCK 12.3 site. Alternatively, the pollution-tolerant diatoms *Navicula* and *Nitzschia* were considerably more abundant at the headwater BCK 12.3 site compared to the downstream BCK 9.6 site and the HCK 20.4 reference site. High proportions of the genus *Navicula* (including *N. cryptocephala*) within a population generally suggest degraded water quality (Palmer 1969, Biggs et al. 1998). Many species of the genus *Nitzschia* are recognized as indicators of organic enrichment or pollution of the water in which they are found (Lowe 1974, Wehr and Sheath 2003, Jafari and Gunale 2006) and as indicators of environmental disturbances (siltation index, Bahls 1993).



Legend: ACHN = Achnanthidium (S), COCC = Cocconeis (S), CYMB = Cymbella (S), FRAG = Fragilaria (S), GOMP = Gomphonema (T), NAVI = Navicula (T), NITZ = Nitzschia (T), REIM = Reimeria (S), & RHOI = Rhoicosphenia (S). T= pollution tolerant, S = pollution sensitive; Arrow indicates direction of flow in Bear Creek

Figure 10: Dominant Taxa of Periphyton Assemblages in Bear Creek and Hinds Creek (Reference) Sampling Stations

The pollution-sensitive indicator taxon, *Achnanthidium*, is presented in Figure 11 with its percent composition of the entire assemblage at each BCK site and reference. Note that the percent (%) *Achnanthidium* ranges from 25.79-31.49% of the population at the upper BCK sites compared to 43.95% and 45.50% at BCK 9.6 and the HDC 20.4 reference respectively. The response of these pollution sensitive diatoms at the lower BCK site suggests improving water quality downstream. Several researchers having observed decreasing abundances of *Achnanthidium* in polluted sites (Besch et al. 1972, Rushforth et al. 1981, Sabater 2000, Round et al. 2007, Kelly et al. 2008), and this species responded robustly as an indicator of polluted water conditions in impacted Bear Creek sites.

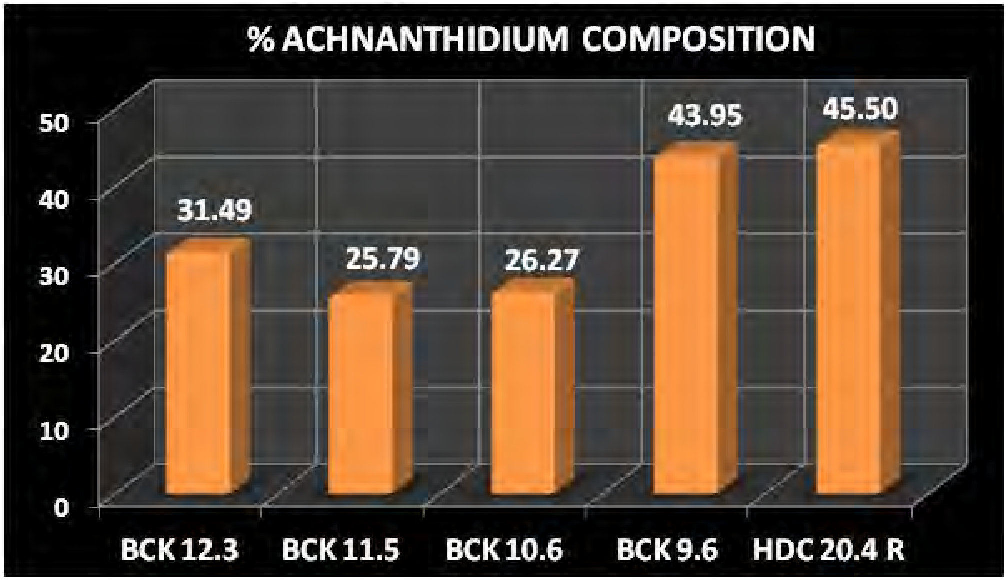
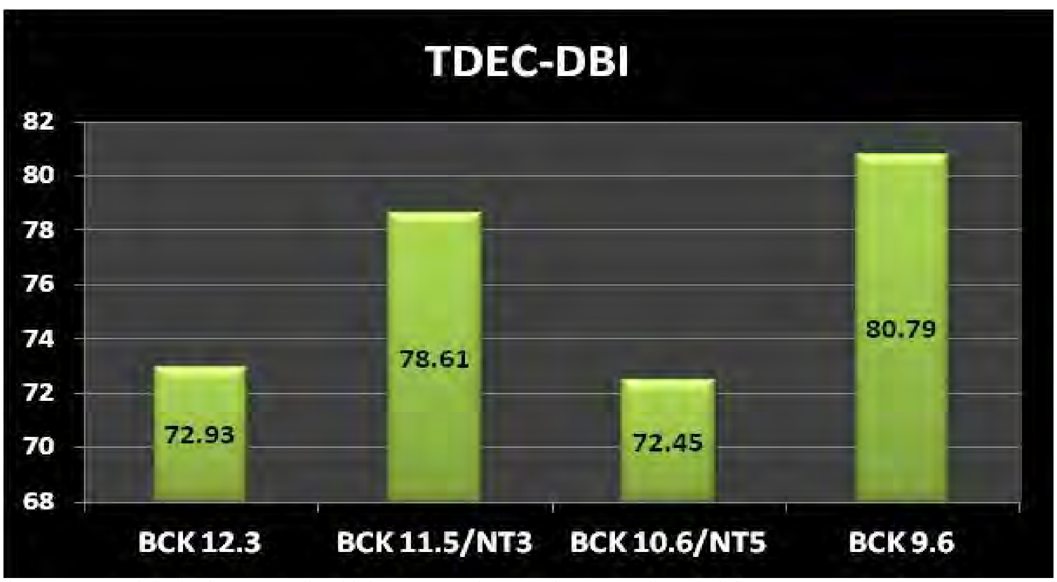


Figure 11: The % Composition of the Pollution-sensitive Diatom, *Achnanthidium* (indicator taxon), at Each Bear Creek Monitoring Station in Comparison to Historical Data Collected from the Hinds Creek Reference Stream

TDEC Diatom Bioassessment Index

The TDEC-DBI results determined that the headwater BCK 12.3 site scored a 72.93 (no units), then the score increased to 78.61 at BCK 11.5 indicating better water quality (Figure 12). However, the next site downstream of BCK 11.5 dropped to 72.45 at BCK 10.6, inferring a possible impact from the north tributaries into Bear Creek. Lastly, the score increased again to 80.79 at the downstream BCK 9.6 suggesting improving water quality conditions along a longitudinal stream gradient with distance from the Y-12 Plant sources of pollution.



(lower scores = impaired water quality, higher scores = improved water quality conditions, TDEC 2010).

Figure 12: Results for the TDEC Diatom Bioassessment Index

Pollution-Sensitive/Pollution-Tolerant Diatoms

Pie-charts characterizing the pollution sensitive diatoms vs. pollution tolerant diatoms in the headwater BCK 12.3 site (Figure 13, Table 3) and downstream BCK 9.6 site were generated (Figure 14). Interestingly, the headwater site is characterized by 2% non-diatom algae, 57% pollution-sensitive and 41% pollution-tolerant diatoms, whereas the downstream site is comprised by 3% non-diatom algae, 70% pollution-sensitive and 27% pollution-tolerant diatoms. This supports the hypothesis that pollution sensitive diatoms in BCK become more dominant downstream with distance from the pollution source.

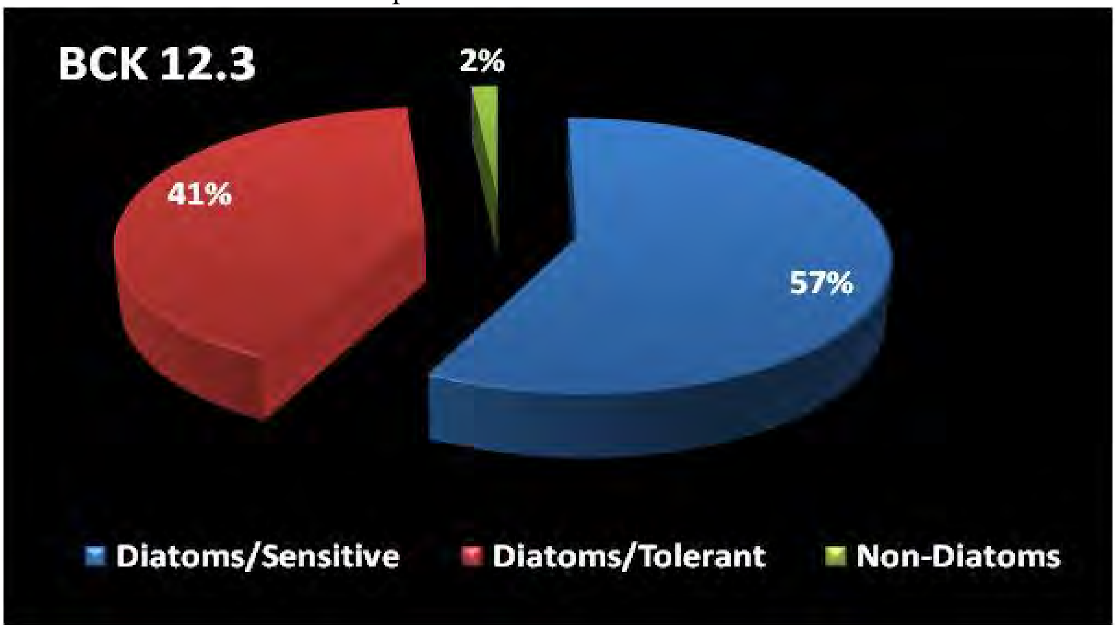


Figure 13: Comparison of Pollution-sensitive Diatoms vs. Pollution-tolerant Diatoms Characteristic of the Headwater BCK 12.3 Sampling Station

PERIPHYTON FAMILIES AND TAXA PRESENT IN OAK RIDGE RESERVATION STREAMS				
DIATOMS	DIATOMS	DIATOMS	DIATOMS	DIATOMS
ACHNANTHACEAE	**COSCINODISCACEAE**	**CYMBELLACEAE**	**EPITHEMIACEAE**	**GOMPHONEMATACEAE**
Achnanthidium (S)	Coscinodiscus (T)	Amphora (S)	Denticula (S)	Gomphonema (T)
Cocconeis (S)	Melosira (T)	Cymbella (S)	Epithemia (T)	Reimeria (S)
Rhoicosphenia (S)		Encyonema (S)	Rhopalodia (T)	
DIATOMS	DIATOMS	DIATOMS	GREEN ALGAE	BLUE-GREEN BACTERIA
NAVICULACEAE	**NITZSCHIACEAE**	**SURIRELLACEAE**	**CHLOROPHYTA**	**CYANOPHYTA**
Diploneis (S)	Hantzschia (T)	Campylodiscus (T)	Chlorella (T)	Anabaena (T)
Frustulia (S)	Nitzschia (T)	Cymatopleura (T)	Cosmarium (S)	Anacystis (T)
Gyrosigma (T)		Surirella (T)	Desmidium (S)	Chroococcus (T)
Navicula (T)			Oedogonium (T)	Cylindrospermum (T)
Neidium (S)			Pediastrum (T)	Gloeotrichia (T)
Pinnularia (S)			Scenedesmus (T)	Microcystis (T)
			Spirogyra (S)	Oscillatoria (T)
			Staurastrum (S)	Phormidium (T)
			Stigeoclonium (S)	Scytonema (T)
EUGLENOIDS				
EUGLENOPHYTA				
Euglena (T)		NOTE:		
Phacus (T)		"S" = Pollution Sensitive		
Trachelomonas (T)		"T" = Pollution Tolerant / Moderately Poll. Tolerant		

Table 3: Periphyton Taxonomic Families and Genera in ORR Streams

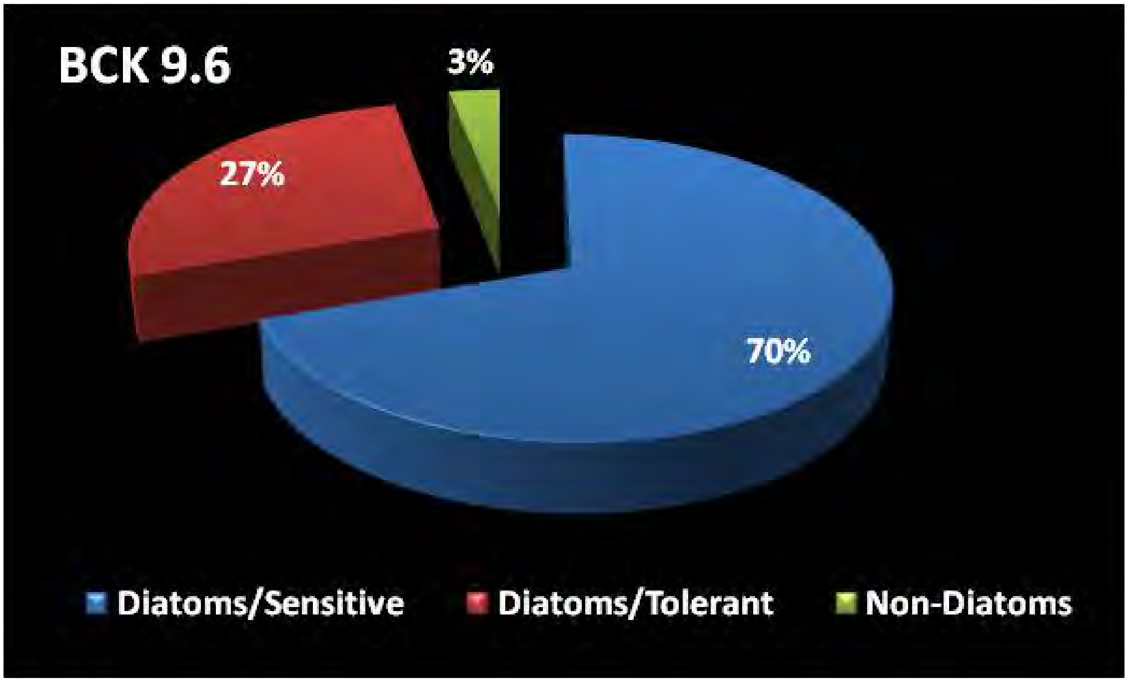


Figure 14: Comparison of Pollution-sensitive Diatoms vs. Pollution-tolerant Diatoms Characteristic of the Downstream BCK 9.6 Sampling Station

Summary and Conclusions

Periphyton samples were collected from artificial substrates six times during 2012 at four impacted Bear Creek sites. Site specific data such as conductivity, water chemistry and photosynthetic light was also measured. Following sample collection and sample preparation, diatoms and other algae were identified to the generic-level and enumerated. Periphyton data were plugged into a series of six metrics to score water quality for each stream site to calculate the TDEC-DBI for each BCK stream site for comparison to the reference stream (HDC 20.4). The following bullets characterize the conclusions:

- The greatest periphyton biomass was recorded at the BCK 11.5 (biomass = 2,337,695 cells/cm²), and is also the site receiving the greatest intensity of sunlight (275,000 lux) due to the ≤50% canopy cover. Light is prominent among the abiotic factors that may limit primary production in aquatic systems (i.e., biomass), and shading (turbidity) presents serious challenges for effective photosynthesis among primary producers (Hill et al. 1995). Periphyton biomass and productivity are much greater when light intensity is high (Rosemond et al. 2000).

- The highest conductivity was recorded at BCK 12.3 (mean=1212 µS/cm), the headwater site that is in the proximity of the S-3 Ponds, a source of nitrate contaminants from previous Y-12 Plant operations. Although the conductivity decreased to 258 µS/cm (mean) at the downstream BCK 11.5 site, possible additional impacts from the NT-3 and NT-5 outfalls drove the mean conductivity back up to 841 µS/cm at the BCK 10.6 sampling site. It is hypothesized that the high overall conductivities recorded in upper BCK influenced the distribution of periphyton taxa that colonized substrates upstream.

- Nitrates (NO_2 & NO_3) in BCK surface water samples decreased from 20 mg/L at the headwater BCK 12.3 site to 3.8 mg/L at the downstream BCK 9.6. It is hypothesized that elevated nitrates at the headwater BCK 12.3 site influenced the higher distribution of pollution-tolerant diatom taxa there. Then, increasing pollution-sensitive diatom populations downstream were a response to decreasing nitrate concentrations at BCK 9.6. Thus, the results indicate that excessive nutrients resulted in degraded water quality and increased impacts on algal communities, generally agreeing with other studies (Smith et al. 1999, Stoermer and Smol 1999, Carrick and Lowe 2007, Rader and Richardson 1992, Pan et al. 2000, McCormick et al. 2001).

- Laboratory results for surface water samples revealed that Cd concentrations was 237 µg/L at the headwater BCK 12.3 site, but decreased to 59.5 at the downstream BCK 9.6 site. Austin and Deniseger (1985) observed in stream experiments that Cd-sensitive diatom taxa (e.g., *Asterionella formosa*, *Tabellaria fenestrata, T. flocculosa, Achnanthidium minutissimum*) became more abundant with distance downstream from the source of Cd pollution. It was found that the population of the pollution-sensitive diatom *Achnanthidium* was greater at the downstream site compared to the headwater site, so Cd could have been a co-factor in this diatom response.

- Although gross alpha and gross beta were detected in Bear Creek surface water samples at elevated concentrations of 86.0 pCi/L and 131.4 pCi/L respectively, there is no clear evidence to support additional impact on the periphyton community due to these perturbations.

- Diatom taxa responded to impacts in Bear Creek by exhibiting increasing relative abundance and distributions of pollution-tolerant diatoms in the upper BCK sites. In contrast, pollution-sensitive diatoms became more dominant and increased their relative abundance at the downstream sites which compared well with the reference stream data. The pollution-sensitive diatoms *Achnanthidium, Cocconeis*, and *Rhoicosphenia* demonstrated increasing dominance of the overall diatom population downstream, especially at the BCK 9.6 site compared to the headwater BCK 12.3 site. Alternatively, the pollution-tolerant diatoms *Navicula* and *Nitzschia* were considerably more abundant at the headwater BCK 12.3 site compared to the downstream BCK 9.6 site and the HCK 20.4 reference site.

- Three lines of evidence (i.e., diatom responses) support improving water quality in downstream BCK with longitudinal distance from the source of Y-12 Plant pollution:

(1) *Achnanthidium* ranges from 25.79-31.49% of the population at the upper BCK sites compared to 43.95% and 45.50% at BCK 9.6 and the HDC 20.4 reference respectively.

(2) The TDEC-Diatom Bioassessment Index results solidify the observation that improving water quality conditions exist in BCK along a longitudinal stream gradient with distance from the Y-12 Plant source of pollution. However, it is clear there are likely impacts in the vicinity of BCK 11.5 and BCK 10.6 from the combined NT-3 and NT-5 outfalls.

(3) The BCK 12.3 headwater site is characterized by 2% non-diatom algae, 57% pollution-sensitive and 41% pollution-tolerant diatoms, whereas the downstream BCK 9.6 site is comprised by 3% non-diatom algae, 70% pollution-sensitive and 27% pollution-tolerant diatoms.

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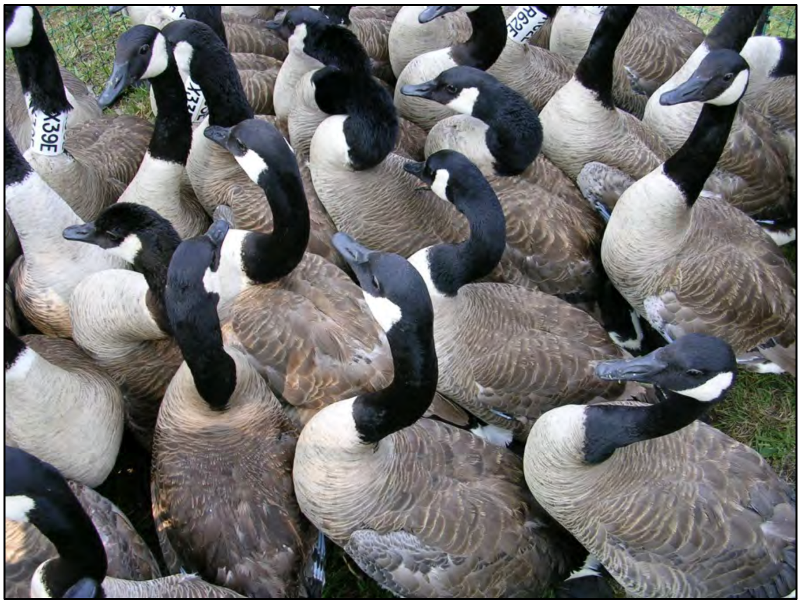
Canada Geese Monitoring

Principal Author: Gerry Middleton



Abstract

In June 2012, the Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (DOE-O) conducted oversight of the annual Canada geese (*Branta canadensis*) Oak Ridge Reservation (ORR) Surveillance Program. The objective of this study was to determine if geese are becoming contaminated on the ORR. The captured geese were transported to the Tennessee Wildlife Resources Association (TWRA) game check station on Bethel Valley Road to undergo live screenings for radioactive contamination. None of the geese captured this year showed elevated gamma counts exceeding the 5 pCi/g game release level. Since no contaminated geese were captured, the DOE-Oversight Office did not conduct additional offsite sampling of Canada Geese.

Introduction

A large population of Canada geese, both resident and transient, frequents the Oak Ridge Reservation (ORR, Crabtree 1998). The thriving goose population locally makes this bird an easily accessible food for area residents that hunt. Geese with elevated levels of cesium 137 (^{137}Cs) in muscle tissue have been found on the ORR (MMES 1987 and Loar 1994). Geese prefer to eat grass, but will also eat water plants including root nodules from bottom sediment (MMES 1987). Studies in the 1980s demonstrated that geese associated with the contaminated ponds/lakes on the ORR can accumulate radioactive contaminants quickly and that contaminated geese frequent offsite locations (Loar 1990, Waters 1990, MMES 1987). An annual goose roundup is conducted by the ORR Surveillance Program in the June-July timeframe when the birds are in molt and generally cannot fly, thus enabling easy captures.

During the annual roundup, the Department of Energy (DOE), Oak Ridge National Laboratory (ORNL) Environmental Protection and Waste Services, ORNL Analytical Chemistry Division, ORNL summer interns, university staff and graduate students, and Tennessee Wildlife Resource

Agency (TWRA) staff form field teams to capture geese on the ORR and perform whole body screenings on them to determine if the birds are radioactively contaminated. During the 1998 roundup, 38 geese at ORNL contained ^{137}Cs concentrations that exceeded the game release limit of 5 picocuries per gram (pCi/g) (ORNL 1998). A subsequent study in September 1998 found elevated levels of ^{137}Cs in grass and sediment at two stretches of White Oak Creek south of 3513 Pond and in grass around the 3524 pond (ORNL 1998). In 2002, three young-of-the-year geese from the west end of ORNL were found to have ^{137}Cs levels greater than (>) 5 pCi/g and were retained. From 2003 through 2012, no geese were found to have exceeded the ^{137}Cs game release level.

The Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (DOE-O) has a sampling plan that is implemented when geese with elevated gamma readings are detected during the annual roundup. If any geese with elevated gamma readings are detected (>5 pCi/g ^{137}Cs), arrangements are made to sample geese that are found in the vicinity of the ORR on non-DOE property. This is to determine if contaminated geese are leaving the reservation and are presenting a risk to area hunters.

Methods and Materials

Under the overall supervision of the TWRA, field teams erect temporary enclosures to retain geese at scouted ORR sites where geese were predetermined to be present. Once at the trapping site, field teams then surround the geese, slowly tighten the encirclement and reduce their routes of escape, thus herding them into the enclosure (Figure 1). After being herded into the enclosure, each goose is pre-scanned by a radiological control technician and then placed into cages for transport to the deer checking station on Bethel Valley Road (Figures 2 and 3). At the checking station, each goose is placed into a cardboard box which is sealed, weighed, and then inserted into a shielded Sodium Iodide (NaI) counter where they are live-scanned with a whole body counter for a 5-minute count to detect the presence of radionuclides, particularly ^{137}Cs (Figure 4). If the captured geese are determined to have gamma counts less than 5 pCi/g game release level, they are removed from the box and banded. Lastly, they are placed back into the cages for transport offsite. Field work was completed following the TDEC Health and Safety Plan (Yard 2011).

Figure 1: Geese collected into enclosure

Figure 2: Each goose pre-scanned by radcon technician

Figure 3: Geese transported to TWRA check station

Figure 4: Goose boxed for 5-minute count

Results and Discussion

During the June 2012 roundup, 39 geese were captured and none were retained that exceeded the game release limit (ORNL 1998). Geese were captured at the following locations:

- EGCR site (Oak Ridge National Laboratory)
- Edgemore boat ramp (Oak Ridge)
- Clark Center Park (Oak Ridge)

All captured geese were transported and relocated to an offsite TWRA wildlife management area in Greene County, Tennessee. Since none of the birds analyzed showed signs of contamination, no additional offsite sampling was conducted by DOE-O staff.

Conclusion

The sites selected for goose trapping this year were considered to be in areas where geese have 1) access to DOE contaminated areas and 2) a potential for becoming contaminated. Although none of the birds analyzed showed signs of contamination, historical information suggests that this species is still susceptible to ORR sources of contamination. However, indications are that geese are not currently picking up significant levels of ORR contamination (i.e., >5 pCi/g).

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Aquatic Vegetation Sampling 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. The Aquatic Vegetation Sampling program collects vegetation at locations near or in water, usually 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 2012 suggests limited areas of elevated radionuclide concentrations in the vegetation associated with surface water on the ORR.

Introduction

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. 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. Watercress, a floating, rooted, aquatic plant was selected where available because it can be used as a human food source and is often present at or downstream of springs. If emerging spring water is impacted by radionuclides, these substances can be deposited in the sediment. The plants may then uptake the radionuclides from the water and or the sediment. Cattails were also sampled in 2012 and are generally found in or near surface water, often in wetlands, and can also uptake radionuclides from the water and or sediment. Since both watercress and cattails uptake and accumulate calcium naturally, they may also uptake the radionuclide strontium-90, which is similar to calcium chemically. Other radionuclides may also be accumulated in the plant tissue if present in the water or soils.

Fourteen sites, including a background location for each vegetation type (watercress and cattails), were sampled in 2012. The approximate locations are shown in Figure 1 and described in Table 1. Samples were collected from Oak Ridge Reservation surface water sites, including springs, creeks, and wetlands to determine if radioactive contaminants have accumulated in the associated vegetation.

Methods and Materials

Aquatic vegetation samples are taken by collecting at least one gallon of vegetation, including roots but minimal other debris. The samples are 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 forwards all radiological samples to the State of Tennessee Department of Health Environmental Laboratory in Nashville for analysis. Samples are analyzed for gross alpha, gross beta, and gamma radionuclides. Additional analysis may be performed if merited.

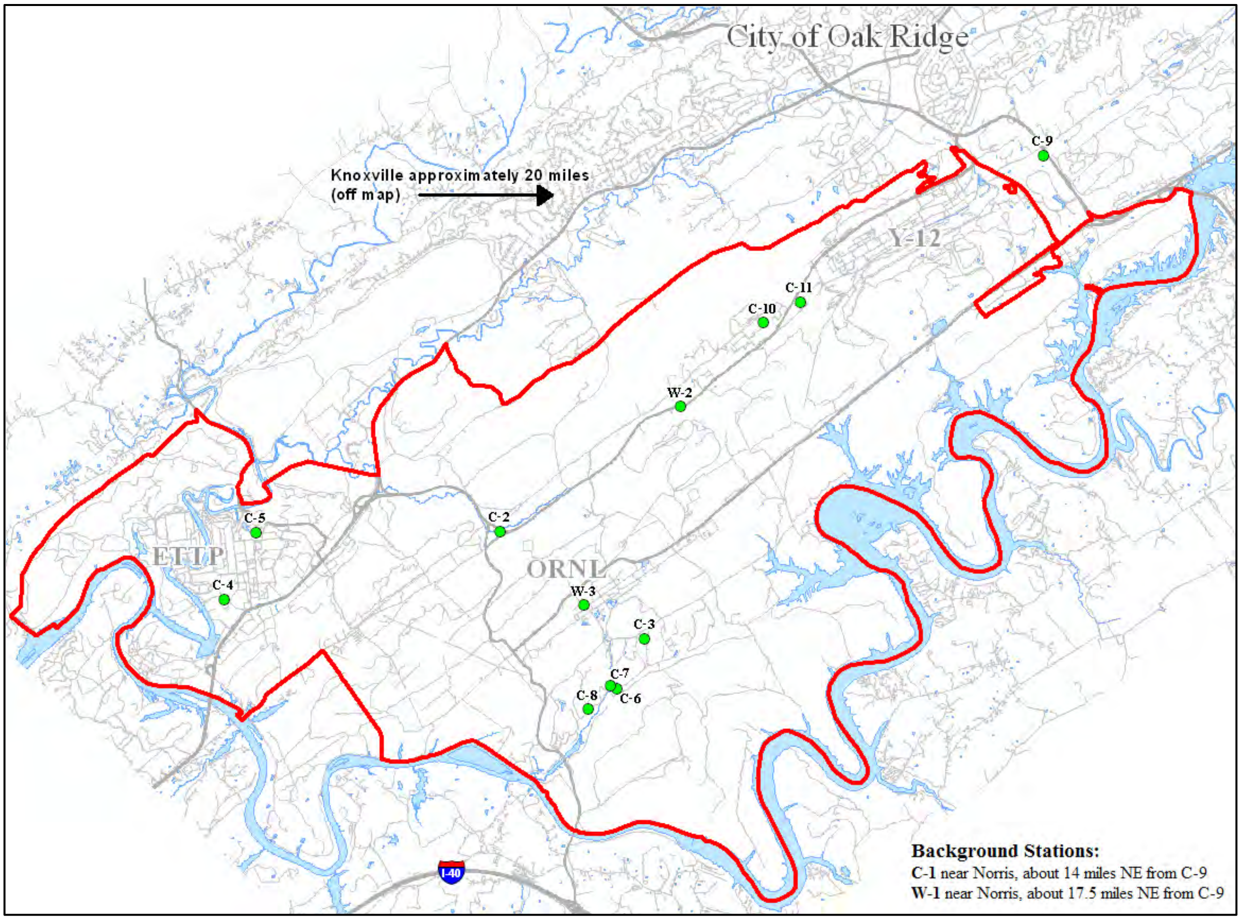

Figure 1: Location Map of Aquatic Vegetation Sites Sampled in 2012

Table 1: 2012 Cattail and Watercress Sampling Locations

Cattail Sampling Locations		
C-1	off site/background	Riner Farm pond
C-2	Y-12/Bear Creek	SS-7 spring area
C-3	ORNL/Melton Valley	wetland behind HRE
C-4	ETTP	K-1007 pond 1, outfall 490
C-5	ETTP	Mitchell Branch downstream of CNF
C-6	ORNL/Melton Valley	above Melton Branch weir
C-7	ORNL/Melton Valley	above lower White Oak Creek weir
C-8	ORNL/Melton Valley	above old weir at MVHR mile 2.6
C-9	off site/Y-12	Union Valley cattail spring
C-10	Y-12/Bear Creek	NT-3 between BYBY and EMWMF
C-11	Y-12/Bear Creek	wetland downstream of S-2

Watercress Sampling Locations		
W-1	off site/background	Norris Municipal Watershed spring
W-2	Y-12/Bear Creek	SS-5 spring
W-3	ORNL/Bethel Valley	1st Creek above Central Ave bridge

Results and Discussion

The objectives of this oversight activity and study are to detect and characterize radionuclides bioaccumulated by aquatic vegetation in and near ORR surface water. Staff gathered fourteen aquatic vegetation samples during 2012. All samples were collected in the fall of 2012, from 9/11/12 to 11/6/12. Tables 2 and 3 provide the results of the radiochemical analysis of each sample collected. The data suggests limited areas of elevated radionuclide concentrations in the aquatic vegetation on the ORR.

The yellow and blue bars shown in Tables 2 and 3 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 watercress alpha and beta values (Table 2) are compared separately from the cattail alpha and beta values (Table 3). The values representing two times those seen at the background locations for each vegetation type are shown at the bottom of each 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.

Table 2: Results for Radiochemical Analysis of 2012 Watercress Samples (pCi/g wet weight)

	site	gross α	gross β	K-40	Pb-214	Bi-214	Cs-137	Pb-212
W-1	Norris Municipal Watershed spring	0.479	2.990	3.22	0.056	0.087		
W-2	SS-5	0.356	2.241	2.54	**0.269**	**0.251**		
W-3	1st Creek above Central Ave bridge	0.612	**6.640**	2.35		0.058	0.382	0.044
	2x background:	0.958	5.98	6.44	0.112	0.174		

values greater than 2x background in bold; not detected in sample; background location

Table 3: Results for Radiochemical Analysis of 2012 Cattail Samples (pCi/g wet weight)

	site	gross α	gross β	K-40	Pb-214	Bi-214	Cs-137	Co-60	Tl-208	Pb-212	Be-7
C-1	Pond on Riner Farm	0.531	2.890	4.30							
C-2	SS-7 area	0.270	4.310	3.60	0.322	0.35			0.048		
C-3	wetland behind HRE	**2.505**	**189.38**	2.26							
C-4	K-1007 Pond 1, outfall 490	-0.024	**15.76**	2.04	0.113	0.153				0.071	
C-5	Mitchell Branch downstream of CNF	0.084	2.160	3.06					0.079		
C-6	above Melton Branch weir	0.172	**6.100**		0.199	0.297				0.068	
C-7	above lower White Oak Creek weir	**1.49**	**37.35**	4.33	0.71	0.73	57.30				
C-8	above old weir at MVHR mile 2.6	0.75	**44.81**	5.65	0.31		0.48	0.746		0.201	
C-9	Union Valley cattail spring	0.220	2.647	3.72		0.072				0.060	0.53
C-10	NT-3 between BYBY and EMWMF	0.568	4.627	3.96	0.169	0.176					0.81
C-11	wetland downstream of S-2	0.87	**6.0**	3.06		0.079					
	2x background:	1.062	5.78	8.6							

values greater than 2x background in bold; not detected in sample; background location

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 and are specific to certain radionuclides, not gross alpha, gross beta, and gamma activity. Perhaps more useful for comparison are the background levels of radionuclides for each vegetation type.

The highest level of gross alpha activity (2.505 pCi/g) and the highest level of gross beta activity (189.38 pCi/g) for the 2012 aquatic vegetation sampling program were both found in the sample collected at the edge of the wetland area behind the old Homogeneous Reactor Experiment site (HRE) in ORNL's Melton Valley. However, contamination has long been an issue at this site. A number of other sampling locations also had gross beta levels more than twice that found at the background location and one other site had a gross alpha level more than twice that found at the background location. Values greater than twice background are in bold in Tables 2 and 3. The seven locations with gross beta levels more than twice background in 2012 were: (W-3) First Creek above the Central Ave bridge at the west end of the ORNL campus, (C-4) K-1007 Pond 1 at outfall 490 at ETTP, the wetland downstream of S-2 at Y-12, and four locations in Melton Valley, south of the main ORNL campus (C-3, C-6, C-7, C-8). The two locations with gross alpha levels more than twice background in 2012 were C-3 and C-7, both in Melton Valley. C-3 was located behind HRE and C-7 was located above the lower White Oak Creek weir.

Further analysis for strontium-90 was requested for the sample with the highest detected gross beta activity (189.38 pCi/g near HRE). The result of the strontium-90 analysis was 60.02 pCi/g.

Conclusions

The data collected suggests limited areas of elevated radionuclide concentrations in the aquatic vegetation on the ORR. Future sampling activities will focus on identifying areas of concern within the ORR to evaluate the potential for bioaccumulation of radionuclides in the vegetation of surface waters of the ORR. Areas with previously elevated sampling results will be evaluated to determine if natural attenuation is occurring.

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Threatened and Endangered Species Monitoring

Abstract
Protection of threatened, endangered and rare species in their natural habitat is a major priority to enable their long-term survival and provide effective stewardship of 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, DOE-Oversight Office, (TDEC DOE-O) provided monitoring, mapping, inventory and oversight of natural resources (flora and fauna), reviewed DOE environmental documents, and conducted field assessments of threatened, endangered and rare plant and animal species. Another goal is documentation and mapping of pest-plant invasion areas on the ORR for future eradication efforts. Staff of TDEC DOE-O lends field biology assistance to the Resource Management Division (Natural Areas Program, Bureau of Parks and Conservation) and the Tennessee Wildlife Resources Agency (TWRA) for threatened and endangered (T&E)/Rare Species mapping and inventory at ORR natural areas and TWRA-managed sites [i.e., Black Oak Ridge Conservation Easement (BORCE) and the Three Bends Area]. 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, during 2012, TDEC DOE-O staff mapped plant species diversity on trails and off-trail areas of the BORCE, and also collected baseline acoustical field data for identification of bat species in the City of Oak Ridge, the University of Tennessee (UT) Arboretum, and public access areas of the ORR. Accordingly, field data is presented in two main sections: ORR fauna and ORR flora.

Introduction
The Oak Ridge Reservation (ORR) 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 Reservation have been designated a Department of Energy (DOE) National Environmental Research Park, 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 National Environmental Research Park and associated lands surrounding DOE facilities at Oak Ridge, Tennessee, is about 15,000 hectares 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 an area of old growth forest. 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 numerous Tennessee Department of Environment and Conservation (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 BORCE area (Figure 2) which includes ~1,300 acres, (2) the area north of the East Tennessee Technology Park (ETTP) known as the West BORCE area (Figure 3) which includes ~1,500 acres, and (3) the McKinney Ridge section with ~230 acres. The north, east and west perimeter of the East BORCE area is a former patrol gravel road that is known as the North Boundary Greenway trail.

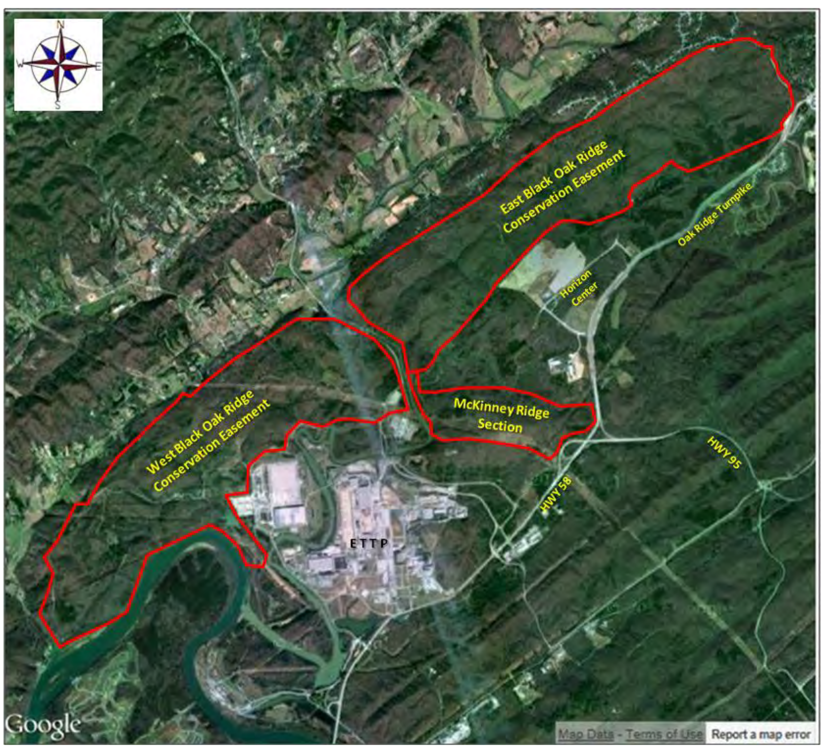

Figure 1: Black Oak Ridge Conservation Easement (3,000 acres; red line approx. boundary)

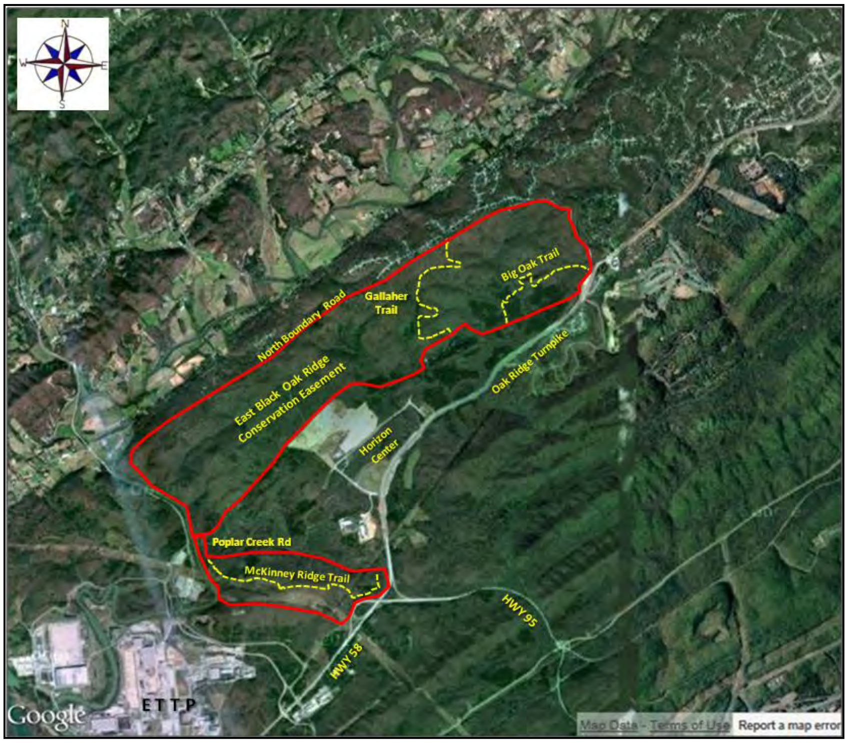

Figure 2: East Black Oak Ridge Conservation Easement, McKinney Ridge and trails surveyed (yellow dashed lines are trails surveyed during 2012 for rare plant species)

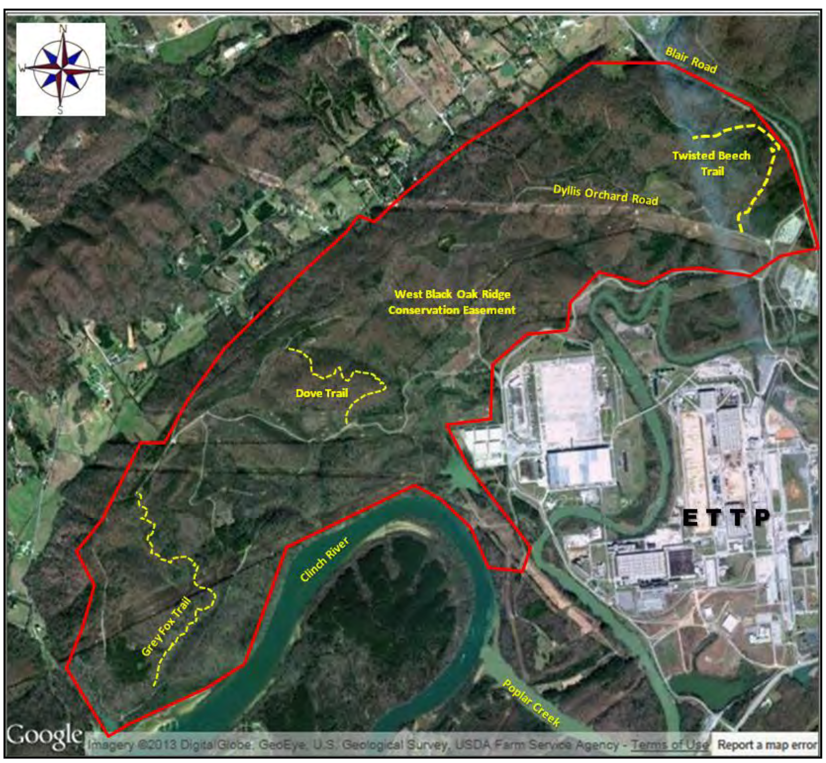

Figure 3: West Black Oak Ridge Conservation Easement and trails surveyed (yellow dashed lines are trails surveyed during 2012 for rare plant species)

ORR Fauna

Objectives

- Monitor and map populations of state- and federally-listed threatened and endangered (T&E) animal species within the 3,000 acres of the BORCE.
- Characterize and document presence of T&E species on the Oak Ridge Reservation.
- Coordinate T&E species field projects with sister Tennessee agencies such as the TDEC Division of Natural Areas (DNA) and the Tennessee Wildlife Resources Agency (TWRA).
- Report Oak Ridge Reservation T&E field results to the DOE and the US Fish and Wildlife Service (USFWS).
- Protect and preserve the animal biodiversity of the ORR.

The project incorporated the office's oversight role of environmental surveillance and monitoring. Additionally, several federal and state laws support this effort. 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 for the conservation of the habitats on which such species thrive. The National Environmental Policy Act (NEPA), requires that federally-funded projects avoid or mitigate impacts to listed species. 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. National Resource Damage Assessments (NRDA), as directed by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, and as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), is concerned with damages to natural resources on the ORR.

Currently, there are 21 federally-listed vertebrate and invertebrate species in Anderson and Roane counties (Table 1), home of the Oak Ridge Reservation. Of these species, there are 17 mollusks, three fish, and one mammal. There are an additional 48 vertebrate and invertebrate species listed by the state of Tennessee for Anderson and Roane as either threatened (six), endangered (20), or deemed in need of management (22, Table 1). 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 single federally-listed mammal species known to occur on the ORR is the gray bat (*Myotis grisescens*, endangered, Figure 4). The TDEC-DNA lists eight mammal species as "deemed in need of management". They are the Allegheny woodrat (*Neotoma magister*), Cinereus shrew (*Sorex cinereus*), long-tailed shrew (*Sorex dispar*), meadow

Table 1: Vertebrate and Invertebrate Species of Anderson & Roane Counties, TN

VERTEBRATE AND INVERTEBRATE SPECIES OF ANDERSON/ROANE COUNTIES, TENNESSEE**					
Common Name	Scientific Name	Category	Fed. Status	State Status	Habitat
Alabama Lampmussel	Lampsilis virescens	Mollusc	LE	E	Shoal sand & gravel substrates of small-med rivers
Allegheny Woodrat	Neotoma magister	Mammal	--	D	Outcrops, cliffs, talus, crevices, sinkholes, caves
Anthony Riversnail	Athearnia anthonyi	Mollusc	LE,XN	E	Large rivers/creeks, on cob/boul substrates adj. riffles
Ashy Darter	Etheostoma cinereum	Fish	--	T	Small to med rivers with bedrock/gravel & boulders
Bachman's Sparrow	Aimophila aestivalis	Bird	--	E	Dry open pine/oak woods; dense ground cover nests
Bald Eagle	Haliaeetus leucocephalus	Bird	--	D	Large bodies of water; sheltered roosts in winter
Barn Owl	Tyto alba	Bird	--	D	Open & partly open country; farms
Bewick's Wren	Thryomanes bewickii	Bird	--	E	Brushy areas, thickets/scrub in open & riparian wood
Berry Cave Salamander	Gyrinophilus gulolineatus	Amphibian	--	T	Aquatic cave obligate; Ridge & Valley
Birdwing Pearlymussel	Lemiox rimosus	Mollusc	LE	E	Small-med size rivers in riffles w/ sand & gravel
Black Mountain Salamander	Desmognathus welteri	Amphibian	--	D	Spring runs & perm. streams in wooded mountains
Blue Sucker	Cycleptus elongatus	Fish	--	T	Swift waters over firm substrates in big rivers
Cave Obligate Isopod	Amergoniscus nicholasi	Crustacean	--	Rare, Not State Listed	Terrestrial cave obligate; known from 2 caves
Cave Spider	Nesticus paynei	Arachnid	--	Rare, Not State Listed	Terrestrial cave associate; also found on surface
Cerulean Warbler	Dendroica cerulea	Bird	--	D	Mature deciduous forest, floodplains or mesic
Cinereus Shrew	Sorex cinereus	Mammal	--	D	Rich woodlands of many types; open fields
Cracking Pearlymussel	Hemistena lata	Mollusc	LE	E	Med-sized rivers buried in mud/sand/gravel/cobble
Dromedary Pearlymussel	Dromus dromas	Mollusc	LE	E	Med-large rivers w/ riffles & shoals
Eastern Slender Glass Lizard	Ophisaurus attenuatus longicaudus	Reptile	--	D	Dry upland areas (brushy & grassy fields); fossorial
Emerald Darter	Etheostoma baileyi	Fish	--	D	Creeks & small rivers w/ riffles of gravel or rubble
Fanshell	Cyprogenia stegaria	Mollusc	LE	E	Medium to large streams/rivers w/ sd/grav substrates
Finerayed Pigtoe	Fusconaia cuneolus	Mollusc	LE	E	Riffles of fords & shoals of mod grad streams
Flame Chub	Hemitremia flammea	Fish	--	D	Springs & spring-fed streams with lush aquatic veg
Four-toed Salamander	Hemidactylium scutatum	Amphibian	--	D	Woodland swamps/depressions/sphagnum/acid soils
Golden-winged Warbler	Vermivora chrysoptera	Bird	--	D	Early success'l habitats in Appalac. foothill regions
Gray Myotis	Myotis grisescens	Mammal	LE	E	Cave obligate all yr; likes forested areas; migratory
Green Salamander	Aneides aeneus	Amphibian	--	Rare, Not State Listed	Damp crevices in shaded ledges; beneath loose bark
Hellbender	Cryptobranchus alleganiensis	Amphibian	No Status	D	Rocky, clear creeks & rivers with large shelter rocks
Heron Rookery	Heron rookery	Rookery	--	Rare, Not State Listed	No Data
Incurved Cave Isopod	Caecidotea incurva	Crustacean	--	Rare, Not State Listed	Aquatic cave obligate; known fr 2 wet caves in E. TN
Long-tailed Shrew	Sorex dispar	Mammal	--	D	Mountainous, forested areas with loose talus
Meadow Jumping Mouse	Zapus hudsonius	Mammal	No Status	D	Open grassy fields; thick vegetation near water
Northern Pinesnake	Pituophis melanoleucus melanoleucus	Reptile	--	T	Sandy soils in pine-oak woods; dry mountain ridges
Orangefoot Pimpleback	Plethobasus cooperianus	Mollusc	LE	E	Large rivers in sd-grav-cobble substr in deep water
Payne's Cave Beetle	Pseudanophthalmus paynei	Insect	--	Rare, Not State Listed	Terrestrial cave obligate; no. R&V prov; Anderson Co.
Pink Mucket	Lampsilis abrupta	Mollusc	LE	E	Generally large river species, w/ mod-strong currents
Purple Bean	Villosa perpurpurea	Mollusc	LE	E	Creeks to med-sized rivers, headwaters, in riffles
Pyramid Pigtoe	Pleurobema rubrum	Mollusc	--	Rare, Not State Listed	Rivers with strong current & firm sand/gravel substr
Ring Pink	Obovaria retusa	Mollusc	LE	E	Large rivers in gravel/sand bars; many sites inundat'd
Rough Pigtoe	Pleurobema plenum	Mollusc	LE	E	Med-large rivers in sd, grav, & cob substr of shoals
Rough Rabbitsfoot	Quadrula cylindrica strigillata	Mollusc	LE	E	Small-med sized rivers, clear, shallow riffles; upland
Sharp-shinned Hawk	Accipiter striatus	Bird	No Status	D	Forests & open woodlands.
Sheepnose	Plethobasus cyphyus	Mollusc	LE	Rare, Not State Listed	Lrge to med-sized rivers, in riffles w/coarse sd/grav
Shiny Pigtoe	Fusconaia cor	Mollusc	LE	E	Shoals/riffles of sm-med rivers w/ mod-fast current
Slender Chub	Erimystax cahni	Fish	LT	T	Major headwater tribs to TN River/ swift-mod currents
Smoky Shrew	Sorex fumeus	Mammal	--	D	Damp wooded areas include'g conifer/mixed forests
Southeastern Shrew	Sorex longirostris	Mammal	--	D	Habitats: wet meadows, damp woods, & uplands
Southern Bog Lemming	Synaptomys cooperi	Mammal	--	D	Marshy meadows, wet balds, & rich upland forests
Spectaclecase	Cumberlandia monodonta	Mollusc	LE	Rare, Not State Listed	Med to large rivers; mud/sand/grav/cobble/bould
Spiny Riversnail	Io fluvialis	Mollusc	--	Rare, Not State Listed	Shallow waters of shoals that are well-oxygenated
Spotfin Chub	Erimonax monachus	Fish	LT,XN, PXN	T	Clear upland rivers with swift currents & boulders
Swainson's Warbler	Limnothlypis swainsonii	Bird	--	D	Mature, rich, damp, decid floodpl & swamp forests
Tangerine Darter	Percina aurantiaca	Fish	--	D	Large-mod headwater tribs to Tenn River/clear pools
Tennessee Dace	Phoxinus tennesseensis	Fish	--	D	1st order spring-fed streams of woodlands in R&V lime
Tiny Cave Beetle	Pseudanophthalmus pusillus	Insect	--	Rare, Not State Listed	Terrestrial cave obligate; northern Ridge & Valley
Valley Flame Crayfish	Cambarus deweesae	Crustacean	--	E	Primary burrower; open areas with high water tables
Wallace's Cave Beetle	Pseudanophthalmus wallacei	Insect	--	Rare, Not State Listed	Terrestrial cave obligate; Ridge & Val; Anderson Co.
White Wartyback	Plethobasus cicatricosus	Mollusc	LE	E	Presumed to inhabit river shoals & riffles; very rare
Woodland Jumping Mouse	Napaeozapus insignis	Mammal	--	D	Deciduous & coniferous forests with herbaceous cover
Yellowfin Madtom	Noturus flavipinnis	Fish	LT,XN	E	Med size to large creeks & small rivers
**Source: TDEC Division of Natural Areas Accessed 2-29-2013 http://www.tn.gov/environment/na/data.shtml					

Federal Status Codes: LE-Listed Endangered; XN-Non-essential experimental population in portion of range; PXN-Proposed non-essential experimental population in portion of range; LT-Listed Threatened.

State Status Codes: D- Deemed in need of management; E- Endangered; T- Threatened.

jumping mouse (*Zapas hudsonius*), smoky shrew (*Sorex fumeus*), southeastern shrew (*Sorex longirostris*), southern bog lemming (*Synaptomys cooperi*), and the woodland jumping mouse (*Napaeozapus insignis*). The gray bat is listed by TDEC-DNA as endangered. However, the presence of the federally-endangered Indiana bat (*Myotis sodalis*, Figure 5) on the ORR is unclear and knowledge of the overall bat community is not well known. Trees with exfoliating bark and dead or dying trees create suitable summer maternal roosting habitat for Indiana bats (*Myotis sodalis*, Callahan et al. 1997, Gardner et al. 1991, Kurta et al. 1996, Webb 2000, SAIC 2011). Thus, bottomland hardwood forest habitat in the East Fork Poplar Creek floodplain has previously been identified as potentially suitable roosting habitat for maternal colonies of the federally endangered Indiana bat (SAIC 2011). Accordingly, for 2012, bats were chosen as the primary focus for T&E animals because of the white nose syndrome (WNS) issues and the paucity of knowledge concerning bat species populations in the Oak Ridge area. Although previous bat studies have been conducted on the DOE ORR, these investigations are now infrequent and typically are only authorized by the DOE for special ORR construction projects or release of federal properties. Indeed, previous ORR bat investigations have been limited by short term 2-4 night surveys of mist-netting and acoustic surveys at project sites (i.e., to meet the requirements of section 7 of the Endangered Species Act of 1973 for threatened and endangered species), and thus no long term, intensive monitoring data is available.

Figure 4: Gray bat (*M. grisescens*)
***Federally-endangered**
Credit: R. Barbour/Smithsonian

Figure 5: Indiana bat (*M. sodalis*)
***Federally-endangered**
Credit: www.fs.fed.us/r9/wildlife/tes/indianabat.htm

Bats in the eastern United States use high frequency echolocation calls (inherent to individual species) to locate prey and navigate in their surroundings (similar to sonar; Britzke 2003). Most of these echolocation calls are above the range of human hearing. Bats are nocturnal and hibernate from November to March in our region. During summer nights, bat roost-emergence and feeding 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). They typically roost in tree cavities or under exfoliating bark of snags or live trees, where they form maternity colonies of less than 100 individuals during summer (May–July) (Caceres and Barclay 2000). Bat detectors permit nonintrusive sampling of the community by recording calls which are later analyzed with software to determine species.

White Nose Syndrome

Mortality in cave hibernating bats was first documented late in winter of 2006–2007 in caves of central New York (Figure 6). White Nose Syndrome (WNS) was the name assigned to the novel infectious disease described as the cause of the declines in hibernating bat populations because of the white powdery blooms seen on the muzzles, ears and wings of many affected bats (Tuttle 1979, Meteyer et al. 2012, Figure 7). White-nose spreads mainly through bat-to-bat contact. There is no evidence it infects humans or other animals. But spores may be carried cave-to-cave by people on clothing or gear. WNS has since spread to seven species of hibernating bats in 17 states and four Canadian provinces, killing an estimated five million bats (Zimmerman 2009, USFWS 2012). Recently published results of infectivity trials confirmed that *Geomyces destructans* is the causative agent of WNS (Lorch et al. 2011). Evidence suggests that this pathogen may have been introduced from Europe where infection with *G. destructans* is not associated with bat mortality (Puechmaille et al. 2010, Warnecke et al. 2012). *Geomyces destructans* belongs to a genus of organic decomposers, yet this fungal infection has caused catastrophic declines in cave hibernating bats that surpass any other cutaneous fungal infections of mammals documented to date (Meteyer et al. 2012). The fungus colonizes and erodes the skin of wings, ears and muzzle of bat hosts, and within weeks of emergence from hibernation an intense neutrophilic inflammatory response to *G. destructans* is generated, causing severe pathology that can contribute to death (Meteyer et al. 2012). Because the body temperature of hibernating bats ranges from 2–15°C, which closely matches optimal temperatures for the growth of *G. destructans*, as the hibernation season progresses, fungal colonization and erosion of the wing membrane can become severe (Meteyer et al. 2012). Thus, *G. destructans* potentially disrupts physiological processes that control water and electrolyte balance, torpor length and energy conservation during hibernation (Meteyer et al. 2009, Cryan et al. 2010). Histologic evidence suggests that this down-regulation of immunity also occurs in hibernating bats (Meteyer 2009, 2011), enabling the unabated growth of the cold-loving *G. destructans* and leading to the development of progressive fungal infection on the muzzle and glabrous surfaces of their body.

The federally-endangered gray bat (*Myotis grisescens*), unfortunately, is among the at-risk cave-dwelling species in the southeastern United States. Other potential at-risk species include the federally-endangered Indiana bat (*M. sodalis*), northern long-eared bat (*M. septentrionalis*), little brown bat (*M. lucifugus*), tri-colored bat (*Perimyotis subflavus*), Townsend's big-eared bat (*Corynorhinus townsendii*), Rafinesque's big-eared bat (*C. rafinesquii*), eastern small footed bat (*M. leibii*), big brown (*Eptesicus fuscus*), cave bat (*M. velifer*), and southeastern bat (*M. austroriparius*). A 2013 acoustical bat study is planned by this office to focus on the ORR, to identify species, determine roosting sites, and to monitor for WNS-infected bats.

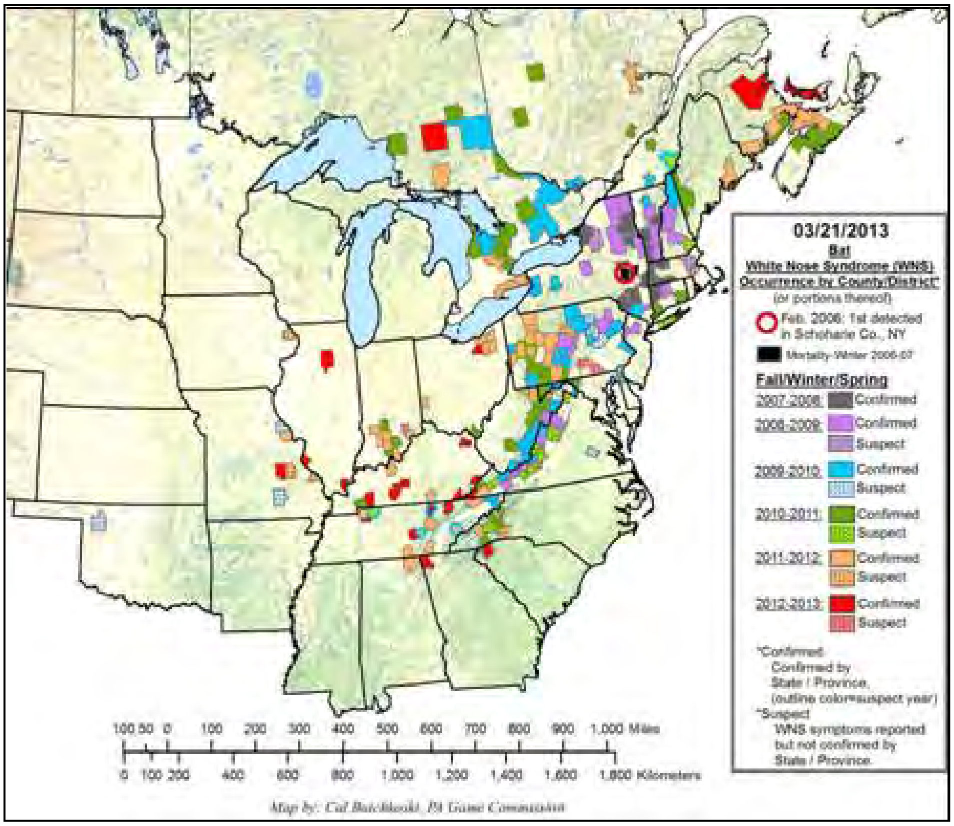

Figure 6: White Nose Syndrome Occurrence Map
Credit: Pennsylvania Game Commission

Figure 7: Bats infected with WNS
Credit: www.bats.org.uk

Methods

During 2012, background acoustical monitoring using the Anabat detector technology was conducted to document bat species present in public access areas of the ORR, and adjacent areas such as the City of Oak Ridge and the University of Tennessee (UT) Arboretum. Anabat SD-2 detectors were activated at dusk (i.e., 30 minutes past sunset) and continuously recorded bat echolocation calls for approximately 3-4 hours each evening (Wear 2004, Ford et al. 2005, Schirmacher et al. 2007). Two detectors were typically deployed to record bat calls at each site, with each detector facing in opposite directions. Detector systems placed into the field for remote, passive sampling are usually housed in waterproof containers with an aperture through which the microphone can be fitted (Britzke et al. 2010, Figure 8). Detectors were placed a few feet off the ground on camera tripods to reduce recording ultrasonic insect clutter (Weller and Zabel 2002). Field data were saved on 2-gigabit (GB) compact flash cards which were downloaded and processed using software programs such as AnalookW (Titley Scientific-USA, Columbia, MO), EchoClass (U.S. Army Corps of Engineers, Vicksburg, MS), BCID-East (Bat Call Identification-East US, Bat Call Identification, Inc., Kansas City, MO), and Kaleidoscope Pro (Wildlife Acoustics, Inc., Concord, MA) for tentative species identifications. Approximately 65 monitoring nights of data were collected from greater than 50 fixed-point survey locations between June and October. The fixed-point survey stations included gravel access roads, forest, riparian, field, trails, ponds, streams, springs, karst features, rock outcroppings, river edge, or other areas suspected of concentrated bat activity.

Figure 8: Anabat SD-2 Field Deployment in Weatherproof Housing

Results

Figures 9-13 are maps of the five main areas surveyed for bat activity during 2012, including: (1) BORCE and the Horizon Center area, (2) Melton Lake greenway/Edgemore Road bridge near Bull Run steam plant, (3) UT Arboretum, (4) Freels Bend (TWRA 3 Bends Wildlife Management Area), and (5) Bull Bluff greenway/Clark Park area.

Twelve species of bats were documented based upon the bat identification software programs described above. The federally-endangered gray bat was identified at 19 locations, and the federally-endangered Indiana bat at six locations (Table 2). These are important findings given the lack of previous information regarding the federally-endangered bats on the ORR.

Table 2: Results of the 2012 Anabat Baseline Acoustical Survey

Map #	Map reference	Site description (Anabat monitoring stations)	Bat species documented
1	BORCE/Horizon	East side Lambert Quarry (at waterline)	LABO LACI MYGR PESU
2	BORCE/Horizon	West side Lambert Quarry (ramp at waterline)	EPFU LABO LACI LANO
3	BORCE/Horizon	Hunley Road / clearing (old homesite)	EPFU LABO LANO MYGR
4	BORCE/Horizon	Pond / ED-6 area clearing	EPFU LABO LACI MYGR PESU
5	BORCE/Horizon	Northwest corner of ED-6 clearing	EPFU LABO LACI LANO
6	BORCE/Horizon	EFPC bridge @ Renovare Blvd (Horizon Ctr)	LABO LACI LANO MYGR
7	BORCE/Horizon	EFPC bridge @ Novus Drive (Horizon Ctr)	LABO MYGR PESU
8	BORCE/Horizon	Sandbar downstream of EFPC bridge/Novus Dr	EPFU LABO LACI MYGR
9	BORCE/Horizon	North Boundary trailhead /Poplar Creek Road / concrete bridge spanning Bear Creek	EPFU LABO LANO MYGR PESU
10	BORCE/Horizon	2nd concrete bridge spanning Bear Creek along North Boundary Greenway/Poplar Crk Road	EPFU LABO LACI LANO MYGR MYLU MYSO PESU
11	BORCE/Horizon	EFPC bridge along No. Boundary Greenway/ confluence of EFPC with Poplar Creek	EPFU LABO LACI LANO MYGR MYLU MYSO PESU
12	BORCE/Horizon	ED-1 wetland outfall into EFPC / sand bar	EPFU LABO LACI MYGR PESU
13	BORCE/Horizon	ED-1 small cave adjacent to gravel access road (East Fork Rd)	EPFU LABO LACI LANO MYLU
14	BORCE/Horizon	Delapidated EFPC bridge located on abandoned road southwest of Lambert Quarry	EPFU LABO LANO MYGR NYHU PESU
1	Melton Greenway	Underneath the Edgemore Road bridge	LABO MYGR MYLU MYSE
2	Melton Greenway	Backwater area of greenway (wooden plank)	MYLU NYHU
1	UT Arboretum	Central China tree collection in wetland area with small ponds adjacent to Scarboro Creek; located south of office	LABO MYGR MYSE MYSO PESU
2	UT Arboretum	Backwater pond at southeast property corner	LABO MYGR MYLE MYLU
1	Freels Bend	Freels cabin and adjacent backwater areas	EPFU LABO LACI MYGR MYLE MYLU MYSE MYSO NYHU
2	Freels Bend	Causeway south of the cabin (gravel access road) adjacent to large backwater pond	EPFU LABO LACI LANO MYGR MYLE MYLU MYSE MYSO NYHU PESU TABR
3	Freels Bend	Northern shoreline of backwater pond; approximately 100 yards from access road	LABO LACI LANO MYLU MYSO PESU
4	Freels Bend	Western shoreline of backwater pond near old homesite	LABO LANO MYLU MYSE MYSO NYHU
5	Freels Bend	Dead-end access road (hunter parking area)	EPFU LABO PESU
1	Clark Pk/Bull Bluff	McCoy Branch backwater pond north of causeway (access)	LABO LACI MYGR MYLU NYHU PESU
2	Clark Pk/Bull Bluff	Clark Park lake swimming area (cove)	LABO LACI LANO NYHU PESU
3	Clark Pk/Bull Bluff	Shoreline of Melton Lake backwater area in isthmus	LABO LACI MYGR MYLU MYSE NYHU PESU
4	Clark Pk/Bull Bluff	Shoreline of Melton Lake backwater area near Bull Bluff	LABO LACI LANO MYGR MYLU NYHU PESU

EFPC- East Fork Poplar Creek; UT - University of Tennessee; BORCE - Black Oak Ridge Conservation Easement; PK -park
Bat species: EPFU= *Eptesicus fuscus* (Big brown), LABO= *Lasiurus borealis* (Eastern red), *Lasiurus cinereus* (Hoary), *Lasionycteris noctivagans* (Silver-haired), MYGR= *Myotis grisescens* (Gray), MYLE= *Myotis leibii* (E. small-footed), MYLU= *Myotis lucifugus* (Little brown), MYSE= *Myotis septentrionalis* (N. long-eared), MYSO= *Myotis sodalis* (Indiana), NYHU= *Nycticeius humeralis* (Evening), PESU= *Perimyotis subflavus* (Tri-colored), TABR= *Tadarida brasiliensis* (Brazilian free-tailed).

Figure 9: Survey Locations for Bat Species on the Black Oak Ridge Conservation Easement / Horizon Center site

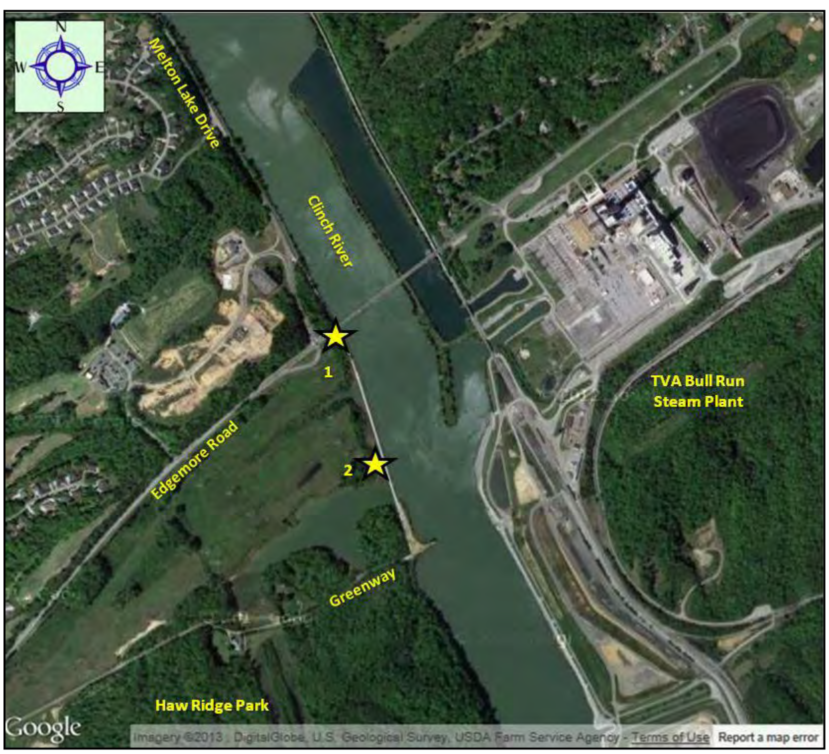

Figure 10: Survey Locations for Bat Species at the Melton Lake Greenway and Edgemore Road bridge

Figure 11: Selected Survey Locations for Bat Species at the University of Tennessee Arboretum

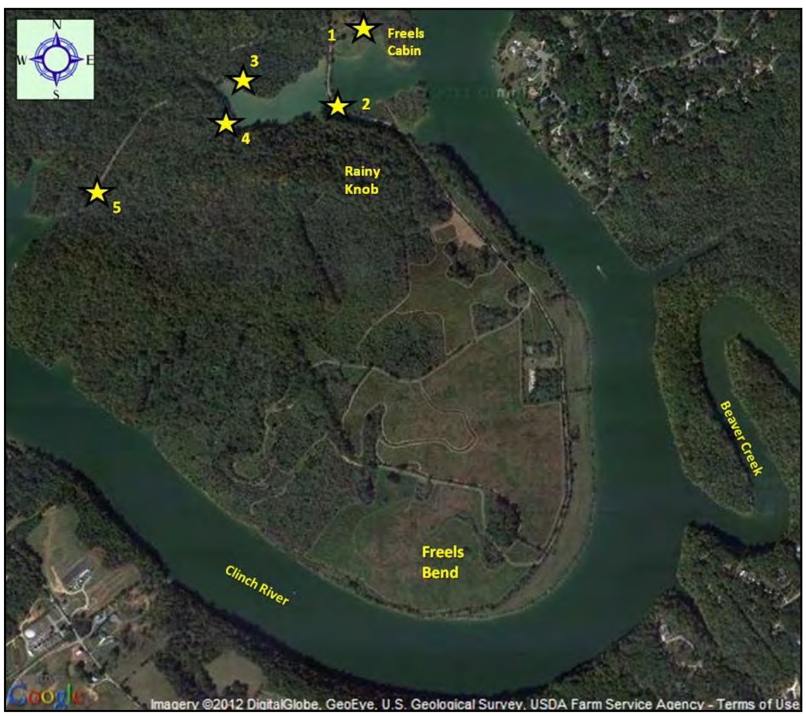

Figure 12: Survey Locations for Bat Species at Freels Bend (TWRA 3 Bends Wildlife Management Area)

Figure 13: Survey Locations for Bat Species at the Bull Bluff greenway near Clark Park

ORR Flora

Objectives

- Monitor and map populations of state- and federally-listed threatened and endangered (T&E) plant species within the 3,000 acres of the BORCE.
- Characterize and document presence of T&E species on the Oak Ridge Reservation.
- Coordinate T&E species field projects with sister Tennessee agencies such as the TDEC Division of Natural Areas (DNA) and the Tennessee Wildlife Resources Agency (TWRA).
- Report Oak Ridge Reservation T&E field results to the DOE, TWRA, and the US Fish and Wildlife Service (USFWS).
- Protect and preserve the plant biodiversity of the ORR.

The project incorporated the office's oversight role of environmental surveillance and monitoring. Additionally, several federal and state laws support this effort. 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. The National Environmental Policy Act (NEPA), requires that federally-funded projects avoid or mitigate impacts to listed species. 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. The National Resource Damage Assessments (NRDA) as directed by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), relates to damages to natural resources on the ORR.

Currently, the Hart's-tongue fern (*Asplenium scolopendrium* var. *americanum*) is the only federally listed plant species for Anderson and Roane counties (Listed Threatened, LT; Table 3). Also, there are an additional nine plant species listed by the state of Tennessee for Anderson and Roane as either threatened (4), endangered (2), or special concern-commercially exploited (3, Table 3). Plants listed by TDEC DNA as threatened include: Appalachian bugbane (*Cimicifuga rubifolia*), Canada lily *(Lilium canadense*), slender blazing-star (*Liatris cylindracea*), and tubercled rein-orchid (*Platanthera flava* var. *herbiola*). Plants listed by TDEC DNA as endangered include: Hart's-tongue fern (*A. scolopendrium* var. *americanum*) and tall larkspur (*Delphinium exaltatum*). Lastly, plants listed by TDEC DNA as special concern-commercially exploited include: American ginseng (*Panax quinquefolius*), goldenseal (*Hydrastis canadensis*), and pink lady's-slipper (*Cypripedium acaule*). Rare plant locations and their respective GPS coordinates are not provided in this report in order to protect the species from illegal poaching.

Methods

Previous vascular plant investigations have covered much of the ORR (Awl et al. 1996), but some areas of the BORCE remain unmapped. During the spring and summer of 2012, TDEC conducted field botany 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, Safety, and Security Plan (Yard, 2011).

Vascular plant identifications required the use of the following sources and taxonomic keys: Radford et al. (1968), Prescott (1980), Cobb (1984), Lellinger (1985), Wofford (1989), Gleason & Cronquist (1991), Chester et al. (1993), Chester et al. (1997), Holmgren et al. (1998), Smith (1998), Carman (2001), Wofford & Chester (2002), and Weakley (2007).

Results

The 2012 TDEC DOE-O plant survey characterizes the 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 of the BORCE. Although specific locations of plant species will not be listed in this report, a virtual tour of species identified and documented during 2012 is presented in figures 14 through 51. Results of the botanical survey are presented in Table 3 which lists plant species, their respective scientific names, and, if applicable, their state and federal status. A total of 38 species were identified including 12 ferns, one tree (American chestnut sprouts), three shrubs, and 22 herbaceous plants. Of these, nine are state-listed species and one is federally-listed. Thus the majority of plants that were documented during 2012 are not T&E species, but collectively represent the tremendous wealth of floral diversity present on the ORR.

Figure 14: Cinnamon fern
Credit: TDEC/DOEO photo

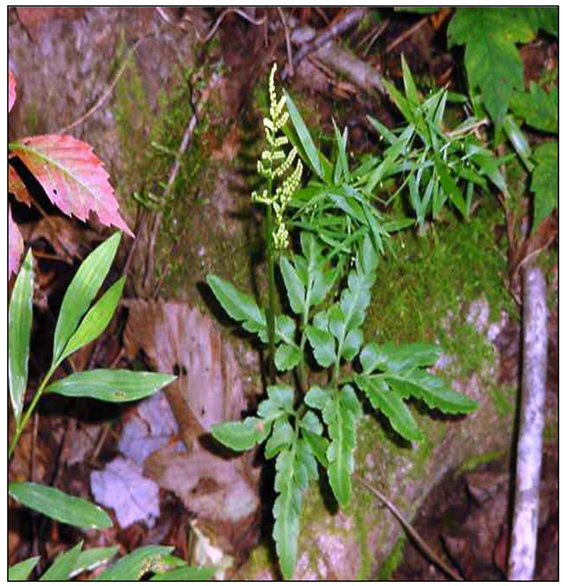

Figure 15: Grapefern (*Botrychium* sp.)
Credit: TDEC/DOEO photo

Figure 16: Sensitive fern
Credit: web.cortland.edu

Figure 17: Netted chain fern
Credit: Janet Novak

Table 3: Plants Documented on the BORCE During 2012

2012 FLORA DOCUMENTED ON THE BLACK OAK RIDGE CONSERVATION EASEMENT				
Common Name	**Scientific Name**	**Family / Group**	**Fed. Status**	**State Status**
American chestnut (sprouts)	Castanea dentata	Fagaceae		
American ginseng	Panax quinquefolius	Araliaceae		S-CE
Appalachian bugbane	Cimicifuga rubifolia	Ranunculaceae		T
Bee balm	Monarda sp.	Lamiaceae		
Broad beech fern	Phegopteris hexagonoptera	Pteridophyte		
Canada lily	Lilium canadense	Liliaceae		T
Cinnamon fern	Osmunda cinnamomea	Pteridophyte		
Cliffbrake fern	Pellaea atropurpurea	Pteridophyte		
Climbing fern	Lygodium palmatum	Pteridophyte		
Doll's eyes / White baneberry	Actaea pachypoda	Ranunculaceae		
Dutchman's breeches	Dicentra cucullaria	Fumariaceae		
False foxglove	Aureolaria sp.	Scrophulariaceae		
Goldenseal	Hydrastis canadensis	Flowering Plant		S-CE
Grapefern	Botrychium sp.	Pteridophyte		
Ground cedar	Lycopodium sp.	Pteridophyte		
Hart's-tongue fern	Asplenium scolopendrium var. americanur	Pteridophyte	LT	E
Indian pink	Spigelia marilandica	Loganiaceae		
Indian physic	Porteranthus stipulatus	Rosaceae		
Indian pipes	Monotropa uniflora	Monotropaceae		
Maidenhair fern	Adiantum pedatum	Pteridophyte		
Mountain laurel	Kalmia latifolia	Ericaceae		
Mountain mint	Pycnanthemum sp.	Lamiaceae		
Netted chain fern	Woodwardia areolata	Pteridophyte		
New Jersey tea	Ceanothus americanus	Rhamnaceae		
Passion flower	Passiflora incarnata	Passifloraceae		
Pink lady's-slipper	Cypripedium acaule	Flowering Plant		S-CE
Pinkster-bloom	Rhododendron nudiflorum	Ericaceae		
Royal fern	Osmunda regalis	Pteridophyte		
Sensitive fern	Onoclea sensibilis	Pteridophyte		
Showy orchis	Galearis spectabilis	Orchidaceae		
Slender Blazing-star	Liatris cylindracea	Flowering Plant		T
Tall Larkspur	Delphinium exaltatum	Flowering Plant		E
Trailing arbutus	Epigaea repens	Ericaceae		
Trillium	Trillium sp.	Liliaceae		
Tubercled rein-orchid	Platanthera flava var. herbiola	Flowering Plant		T
Walking fern	Asplenium rhizophyllum	Pteridophyte		
White turtlehead	Chelone glabra	Scrophulariaceae		
Yellow aster	Helianthus sp.	Asteraceae		

Federal Status Codes: LE - Listed Endangered; XN – Non-essential experimental population in portion of range; PXN – Proposed non-essential experimental population in range; LT – Listed Threatened; S-CE – Special Concern – Commercially Exploited
State Status Codes: D – Deemed in need of management; E – Endangered; T - Threatened

Figure 18: Maidenhair fern
Credit: TDEC/DOEO photo

Figure 19: Cliffbrake fern
Credit: TDEC/DOEO photo

Figure 20: Royal fern
Credit: TDEC/DOEO photo

Figure 21: Walking fern
Credit: TDEC/DOEO photo

Figure 22: Broad beech fern
Credit: TDEC/DOEO photo

Figure 23: Ground cedar
Credit: TDEC/DOEO photo

Figure 24: Hart's-tongue fern
Credit: D. Horn/UTK Herbarium

Figure 25: Climbing fern
Credit: www.caes.uga.edu

Figure 26: Passion flower
Credit: TDEC/DOEO photo

Figure 27: Dutchman's breeches
Credit: TDEC/DNA photo

Figure 28: New Jersey Tea
Credit: Daniel Reed/UTK Herbarium

Figure 29: Doll's eyes
Credit: TDEC/DNA photo

Figure 30: False-foxglove
Credit: TDEC/DOEO

Figure 31: Pink trillium
Credit: TDEC/DOEO

Figure 32: Indian pipes
Credit: TDEC/DOEO

Figure 33: Indian pink
Credit: TDEC/DOEO

Figure 34: Showy orchid
Credit: TDEC/DOEO

Figure 35: White turtlehead
Credit: TDEC/DOEO

Figure 36: Tall larkspur
Credit: TDEC/DOEO

Figure 37: Mountain laurel
Credit: TDEC / Inset: A. Heilman/UTK Herb

Figure 38: Pink ladyslipper
Credit: A. Heilman/UTK Herb

Figure 39: Goldenseal
Credit: TDEC / Inset: T. Barnes/UTK Herb

Figure 40: Pinkster bush
Credit: TDEC/DNA

Figure 41: Bee balm
Credit: TDEC/DNA

Figure 42: Mountain mint
Credit: TDEC/DNA

Figure 43: Yellow aster
Credit: TDEC/DNA

Figure 44: Trailing arbutus
Credit: TDEC/DNA

Figure 45: Ginseng
Credit: TDEC / Inset: discoverlife.org

Figure 46: Appalachian bugbane
Credit: D. Horn/UTK Herbarium

Figure 47: American chestnut sprouts
Credit: TDEC/DOEO

Figure 48: Slender blazing star
Credit: T. Barnes/UTK Herbarium

Figure 49: Canada lily
Credit: E. Lickey/UTK Herbarium

Figure 50: Indian physic
Credit: TDEC/Insert: T. Barnes/UTK Herb.

Figure 51: Tubercled rein-orchid
Credit: D. Horn/UTK Herbarium

Concluding Remarks

The detections of both federally-endangered bats (i.e., Gray bat, Indiana bat) provide significant new information to our knowledge of species present on the ORR. Additional acoustic studies are needed to further characterize ORR bat communities for future environmental assessments and ecological studies, such that the information presented to the public is factually correct. High quality Indiana bat roosting habitat on the ORR should be identified and monitored periodically (Mitchell and Martin 2002).

Botanical fieldwork remains to be completed on all 3000 acres of the BORCE, particularly to map additional rare habitat and associated plant communities, and to 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 to 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: David Withers, Zoologist, (615) 532-0441, david.withers@tn.gov.

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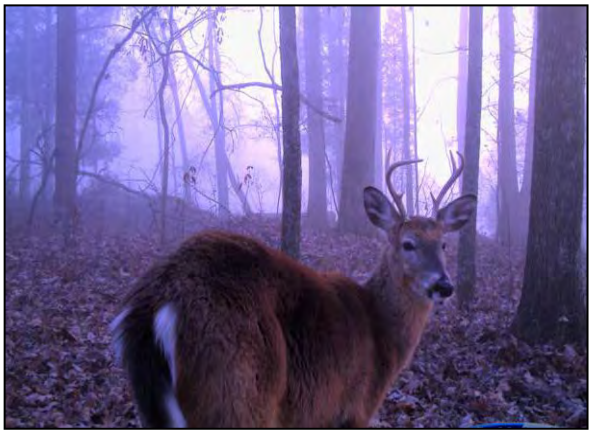
White-tailed Deer Monitoring on the Oak Ridge Reservation
Principal Author: Gerry Middleton



Credit: CuddeBack Capture™ IR Camera

Credit: TDEC-DOEO photo

Abstract
The DOE-Oversight Office (DOE-O) of the TDEC Division of Remediation (TDEC DOR) continued deer capture activities on the Oak Ridge Reservation (ORR) during 2012. The goal was to chemically immobilize deer and install global positioning system (GPS) collars 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, piscavores), subsisting in habitats impacted by industrial pollution, are ingesting environmental contaminants from their respective food chains. Humans could potentially be at risk due to unwittingly consuming contaminated game meat and fish which have bioaccumulated metals and other contaminants from the environment. 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 potentially significant vector for contaminant exposures to the public. This project is part of a multiyear investigation. Our previous 2011 GPS collar investigations and results suggest a young buck swam across the Clinch River from ORNL into Knox County. White-tailed deer may temporarily leave their home range during the rut season, or to avoid hunting pressure and other anthropogenic disturbances, and may wander into urban areas to forage. During 2012, office staff captured and collared four deer, one in the City of Oak Ridge and three in Melton Valley. Two collars were retrieved, GPS fix data was downloaded and home ranges (as well as excursions from core area) were determined from the recovered collar data and presented herein. Hair samples were collected from each captured animal to test for heavy metals. This investigation includes laboratory metals data on deer tissue and hair. There is a considerable variability with the metals reported for deer hair. It is difficult to determine the specific source of the metal contaminants from this initial investigation; however, contaminants may be bioaccumulated in deer tissues during ingestion of contaminated browse and soil (i.e., mineral licks).

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). Methylmercury (MeHg) is the most toxic and bioavailable species of Hg in affected environments where it is readily absorbed into biological organisms (Mergler et al. 2007, Cardona-Marek et al. 2009). For example, Tasca (1988) reported Hg and lead (Pb) concentrations of 17 parts per million (ppm) and 87.6 ppm respectively in hair samples of ORR white-tailed deer. Travis et al. (1989) selected road-killed deer along the Oak Ridge Turnpike, and liver and muscle samples were collected for analysis and tested for a full suite of metals. They concluded that Hg concentrations in deer meat (muscle) and liver were below levels of concern; however, they recommended that routine consumption of game from the East Fork Poplar Creek (EFPC) floodplain may result in an unacceptable risk from arsenic (As) and beryllium (Be,Travis et al. 1989). Sample and Suter II (2002) suggested that white-tailed deer foraging on vegetation and consuming ash at the Y-12 Filled Coal Ash Pond (FCAP) site (to meet their sodium dietary needs) may be at risk for uptake of arsenic and selenium. Deer are known to consume fly ash due to its high sodium content. Potentially toxic elements such as As, boron (B), cadmium (Cd), chromium (Cr), Hg, molybdenum (Mo), Pb and selenium (Se) may be found at high concentrations in coal ash, which can affect small burrowing mammals (Peles and Barrett 1997, Sample and Suter II 2002). Talmage and Walton (1993) reported Hg uptake in small mammals (e.g., shrews) in the Hg-contaminated floodplain soils of EFPC; Hg levels in kidneys of EFPC shrews ranged from 21-73 microgram per gram (µg/g), the concentration at which Hg-induced renal damage could be expected. Stevens et al. (1997) documented that mink and muskrat collected from EFPC had bioaccumulated above background levels of Hg (greater than 5 ppm).

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 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).

Global Positioning System Technology

Recent advances in tracking and telemetry technology, such as the widespread use of the GPS, have allowed scientists to collect location data for animals at an ever-increasing rate and accuracy (Pellerin et al. 2008, Tomkiewicz et al. 2010). GPS technology has increased the accuracy and precision of animal location estimates and has allowed researchers to generate more frequent and larger datasets which are useful in home range analyses (Kolodzinski et al. 2010). The more frequent sampling afforded by GPS collars is likely to capture occasional use of areas or resources that are important to an animal (Kochanny et al. 2009). Further, the absence of observer-based sampling limitations, including observations during the night and bouts of inclement weather, as well as the possibility of an evenly distributed sampling protocol throughout days and seasons, ensure a more representative sample of an animal's space use. GPS technology also extends the possibility of gathering information from remote locations for species otherwise difficult to track either because of long distance movements or because of environmental constraints (Kie et al. 2010). With increases in the duration, frequency and accuracy of observations, it may be argued that we are approaching near-perfect knowledge of the locations that an animal has visited, that is, why an animal has the home range it does (Kie et al. 2010). Considered uncritically, detailed GPS data offer the chance to describe, in increasingly minute detail, something that still cannot be explained satisfactorily (Kie et al. 2010), or heretofore that we have been unable to explore (Demma et al. 2007). If fixes are collected at a sufficiently high sampling rate, and if they are representative of space use by the animal, GPS locations can closely approximate the actual continuous path taken by an animal in near-real time (Kie et al. 2010).

White-tailed Deer Behavior and Breeding

White-tailed deer are gregarious with two basic social groups: 1) family groups centered around a matriarch with females (fawns of previous generations), and 2) 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 rubbings and scrapings 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).

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 is usually 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 less than 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 2012, the focus of this investigation was to chemically immobilize (capture) and 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 County)? If so, these animals could be hunted offsite, and once harvested, contaminated venison could unknowingly be consumed by the public. Further, if ORR deer migrate offsite and are harvested, then they also would not be scanned for radiological contamination (i.e., as per the ORR WMA deer hunt radiological scanning of deer bone and tissue).

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 2012, the study area was the ORR solid waste storage areas (SWSAs) of Melton Valley (ORNL, Figure 1). The study area in Melton Valley lies within the remediated White Oak Creek/Melton Branch watershed including a few ponds and White Oak Lake. 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. The offsite study area was the city of Oak Ridge (Figure 2).

HFIR - High Flux Isotope Reactor; SWSA - Solid Waste Storage Area

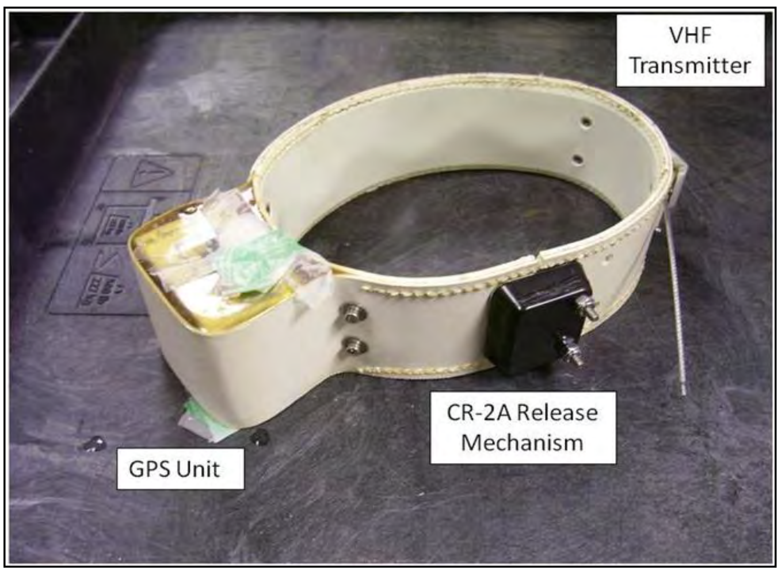
Figure 1: Oak Ridge Reservation: White-tailed Deer Project Study Area

SAIC - Science Applications International Corporation

Figure 2: City of Oak Ridge White-tailed Deer Study Area

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, Figure 3). 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 via ground triangulation by estimating azimuths from established telemetry stations using the Telonics TR-4 VHF receiver (Brinkman et al. 2002, Cox et al. 2002).



GPS - Global Positioning System; VHF- very high frequency

Figure 3: Telonics TGW-4500 GPS collar (store-on-board)

Capture Methods

White-tailed deer were captured during the winter/spring of 2012 in Melton Valley (*n*=3) and in the City of Oak Ridge (*n*=1) using two methods: 1) trap deer in clover trap and then immobilize with dart projector (within the city limits of the Oak Ridge, Figures 4-5), and 2) drive-by and dart deer (chemical immobilization) accustomed to the presence of humans in SWSAs of Melton Valley at ORNL (controlled access areas). Deer are crepuscular, thus captures were attempted during both dusk and pre-dawn hours, and morning daylight hours between 0700 and 1100. The four field team members (i.e., 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.

Figure 4: Clover trap set up.
Credit: www.und.nodak.edu

Figure 5: Releasing deer from Clover trap.
Credit: PA Game & Fish Commission

Chemical Immobilization (Anesthesia) and Handling

Of the Melton Valley deer captured and collared, one deer was darted by TWRA using the Pneu-Dart Type C, 3-cubic centimeter (cc) gel collar (Pneu-Dart, Inc., Williamsport, PA) delivered to the deer from the Pneu-Dart X-Caliber™ carbon dioxide (CO_2) projector (Pneu-Dart, Inc., Williamsport, PA) at a range of 25 yards. The other two 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 fired from a Pneu-Dart Model 389 dart projector (cartridge-powered; Pneu-Dart, Inc., Williamsport, PA, Figures 6-7). 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 (Figure 8). Delivering the dart to the neck/shoulder junction provides the fastest induction time (TDEC 2012). 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). The amount loaded in each dart will vary depending on the estimated weight of the deer. A typical dose for a 120 lb. deer is 1.5 ml of this mixture. 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).

Figure 6: 1.5-cubic centimeter PneuDart barbed dart
Credit: PneuDart, Inc., Williamsport, PA

Figure 7: PneuDart Model 389 Dart Projector
Credit: PneuDart, Inc., Williamsport, PA

Figure 8: Shoulder or hip dart placement

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 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 determined to be 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 (Figures 9-10). The equipment manager applies a sterile ophthalmic lubricant to the deer's eyes (Kjær et al. 2007, Karns et al. 2011, Figure 11), blindfolds the deer, and determines age and sex which is recorded. Next, the equipment manager quickly installed the GPS collar on the deer (Figure 12). Once the collar has been applied, the equipment manager and the handler monitored the deer vital signs (Figure 13). Once the heart rate, temperature and respiration have been measured and recorded, then the equipment manager applies the numbered ear tags (Figure 14), and removes the dart from the deer (Figures 15). On especially cold days, space blankets were sometimes used to help keep the animal warm during recovery from the immobilizing drugs (Figure 16). The data collector takes photographs and records important details pertinent to the capture (TDEC 2012).

Figure 9: Place in sternal position

Figure 10: Airway checked for obstructions

Figure 11: Apply eye ointment **Figure 12: Fit and install GPS collar**

Figure 13: Check vital signs **Figure 14: Apply numbered ear tags**

Figure 15: Dart removal

Figure 16: Keep deer warm

Figure 17: Collect hair sample (curry comb)

During recovery time, measurements of the deer were taken (i.e., length, girth) and approximately 2-5 grams of hair sample was collected with a curry-comb from the caudal or mid-dorsal region for laboratory analyses (i.e., heavy metals; Stevens et al. 1997, Duffy et al. 2005, Brookens et al. 2007, Figure 17). The deer is shown resting and recovering from the capture and drug immobilization procedure in Figure 18. Hg analysis of hair samples has been commonly used to assess accumulation of this toxic metal 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 ten minutes while the deer was immobilized. After the effects of Telazol® wear off (80 minutes), the deer was administered Tolazoline with syringe to reverse the effects of Xylazine (Figure 19). Drugged deer are usually aroused and able to walk away in 10-30 minutes after the dose of Tolazoline has been administered (Figures 20-21). Deer immobilization (captures) and handling followed the standard operating procedures per the TDEC White-tailed Deer Capture Plan (TDEC 2012), the TDEC Health and Safety Plan (Yard 2011), 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.

Figure 18: Administer reversal drug

Figure 19: Recovery from capture

Figure 20: Arousal from drugs (kicking) **Figure 21: Deer arises and walks away**

Deer Tissue Sampling

Initially, sampling of road-killed deer and predator carcasses consisted of collecting muscle, antler (if present), bone, and hair samples to test for the presence of heavy metals (As, Be, Cd, Cr, cobalt (Co), Hg, Pb, Mo, nickel (Ni), Se, strontium (Sr), uranium (U), zinc (Zn), and MeHg,). During 2012, only hair samples were collected from captured Melton Valley collared-deer for metals analyses. Hair samples were removed from the deer with stainless steel implements (i.e., curry comb). Approximately 3-5 grams of hair was removed from the caudal or mid-dorsal area of the deer and placed in plastic baggies. Labeled samples were packed in coolers for transport to the TDEC DOE-Oversight (DOE-O) laboratory for cold storage in a lockable freezer until delivery to the Tennessee Department of Health's Nashville Central Laboratory for analysis.

The Tennessee Department of Health, Environmental Laboratory and Microbiological Laboratory Organization (Laboratory Services) has expertise in a broad scope of services and analysis available to the TDEC DOE-O and other TDEC divisions statewide. General sampling and analysis methods follow Environmental Protection Agency (EPA) guidelines as listed in appropriate parts of 40 Code of Federal Regulations (CFR). Laboratory Services may subcontract certain analyses and quality control (QC) samples out to independent laboratories. Bench level Quality Assurance/Quality Control (QA/QC) records and chain-of-custody records are maintained at the Tennessee Environmental Laboratory, as are quality assurance (QA) records on subcontracted samples (TDHLS 1999). Accordingly, all tissue metals analyses (except MeHg) were conducted by Laboratory Services, Nashville, Tennessee. The MeHg tissue samples were farmed-out and analyzed by Brooks-Rand Laboratory, Seattle, Washington. The list of metals analyzed, sample collecting practices and methods followed recommendations of TWRA staff, and those of 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

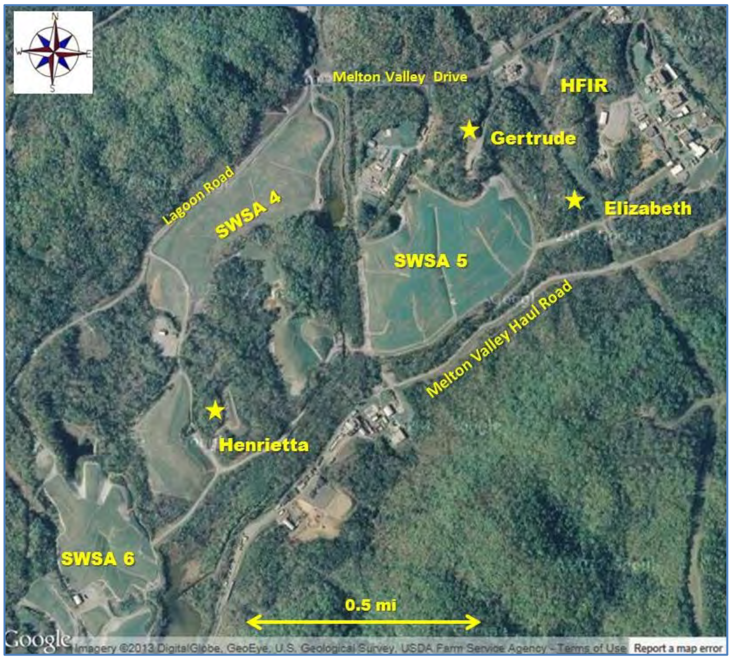
During 2012, three Melton Valley deer were chemically immobilized with a dart gun and collared in the contaminated areas of the ORNL SWSAs (Table 1). One additional deer was collared offsite in the City of Oak Ridge as a reference animal. Presented below are the 2012 deer tracking results plus 2012 deer hair laboratory metals data.

Table 1: Deer Capture Data

Deer	Date captured	Est. Age	Est. Weight (lbs.)	GPS collar	VHF freq.	Successful Pulse	Collar Release
Elizabeth	2/14/2012	3.5 yrs.	n/a	2-yr	151.415	60 bpm	1/15/2014
Gertrude	4/11/2012	2 yrs.	~120	1-yr	151.205	60 bpm	3/15/2013
Henrietta	4/18/2012	1 yr.	~90	2-yr	151.295	60 bpm	1/15/2014
Clarabelle	5/30/2012	3 yrs.	~120	1-yr	151.415	50 bpm	3/15/2013

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

The first deer was captured and collared on February 14, 2012 (a 3.5-year-old doe, code named "Elizabeth"). The next doe captured and collared unfortunately perished following release back into the wild. The collar was retrieved and later redeployed on another deer. The second deer successfully captured and collared on April 11, 2012 was a 2-year-old doe, code named "Gertrude", and the third Melton Valley deer a (1-year-old doe, code named "Henrietta") was captured and collared on April 18, 2012. Elizabeth and Henrietta were fitted with 2-year collars (drop-off date, 1/15/14) and Gertrude with a 1-year collar (drop-off date, 3/15/13). All deer and their respective locations were monitored twice-a-month with a VHF receiver to determine the condition and location of each deer. The VHF signals emitted from each collar should be 50-60 beats-per-minute (bpm) if the deer is alive and if the collar is still attached; however, a 100 bpm indicates a possible mortality or that the collar fell off the deer prematurely. Figure 22 shows the capture/collaring locations for the three Melton Valley does.



HFIR - High Flux Isotope Reactor; SWSA- Solid Waste Storage Area

Figure 22: Melton Valley Deer Capture Locations

As mentioned previously, two deer collars were scheduled to be released on March 15, 2013. Accordingly, Clarabelle's collar was retrieved near the American Centrifuge Manufacturing facilities in Oak Ridge on March 18, 2013, and Gertrude's collar was subsequently recovered in Melton Valley near the HFIR facility (High Flux Isotopic Reactor) on April 5, 2013. The remaining deployed collars will not be released from the deer until January 15, 2014 (i.e. Elizabeth and Henrietta).

Oak Ridge Urban Deer—Clarabelle

During anticipated recovery of dropped collars, it became necessary to capture Clarabelle in the City of Oak Ridge because the collar release mechanism failed. To review previous collaring events, the original collar on this deer was attached using an improvised, passive bucket snare (Figures 23-24). On July 2011, Clarabelle collared herself while feeding at the snare (Figures 25-26). According to an eye witness, she stuck her hear down into the bucket to feed and when she raised her head up, the collar was around her head and then it slid down her neck. Thus, one deer was collared without the need to trap or immobilize the animal. Unfortunately, the collar release mechanism malfunctioned at the drop-off date (January 15, 2012), and remained attached to the deer. The Telonics collar technology used on this project employs store-on-board technology (i.e., GPS fix data), and thus the data cannot be downloaded until the collar is retrieved.

Figure 23: Passive bucket snare
Credit: TDEC DOE-O photo

Figure 24: Deer feeding from bucket snare
Credit: CuddeBack Capture™ IR Camera

Figure 25: Clarabelle feeding at bucket snare
Credit: CuddeBack Capture™ IR Camera

Figure 26: Deer collared herself 3 minutes later
Credit: CuddeBack Capture™ IR Cam July 2011

To capture Clarabelle, the Clover trap method was used in an attempt to recover the collar. After the Clover trap was set up and baited with corn in a secluded, wooded section of town (i.e., good vegetation cover), the door was secured open for two weeks so that deer became accustomed to feeding in the trap. Some bait was also scattered around the door of the trap to entice deer into the trap (James and Stickles 2011). The vegetation cover served to conceal the trap from the public and also helped to reduce stress to the deer as the trap was approached by the field team to dart the deer. After the Clover trap was activated to catch a deer, any animal entering and feeding inside the trap would trip a wire releasing the door and trapping the animal inside. Once the trip wire and trap door were set, the trap was checked near dawn each morning to see if Clarabelle had been captured in an effort to reduce capture stress.

Once Clarabelle was re-captured (recapture date 5/30/12) in the Clover trap, she was darted with the projector and immobilized with drugs (procedure as described in Methods section). Interestingly, three deer were actually trapped at once, including Clarabelle. Once immobilizing drugs were administered, the field team retreated to an area out of sight of the deer in order to let the drugs take effect. After waiting for the deer to become immobilized (6-10 minutes), the plan was to quietly approach the trap, remove the old collar and install a new 1-year collar on Clarabelle. However, the trap became compromised due to the additional trapped deer thrashing about inside the trap, and just as Clarabelle was darted, she escaped the trap and then ran about ¼-mile to the south before collapsing from the drugs (Figure 27). Nevertheless, the field team found her in time to accomplish the planned mission and retrieved the old collar (i.e., 2011 deployment), and affixed the new collar on the deer (i.e., 2012 deployment, Figure 28). The field team subsequently recovered Clarabelle's second collar on March 18, 2013.

TDEC - Tennessee Department of Environment and Conservation ; SAIC - Science Application International Corporation; Dr - drive; Rd - Road.

Figure 27: Oak Ridge City Deer Capture Locations

Figure 28: A recovered Clarabelle (after being re-collared)

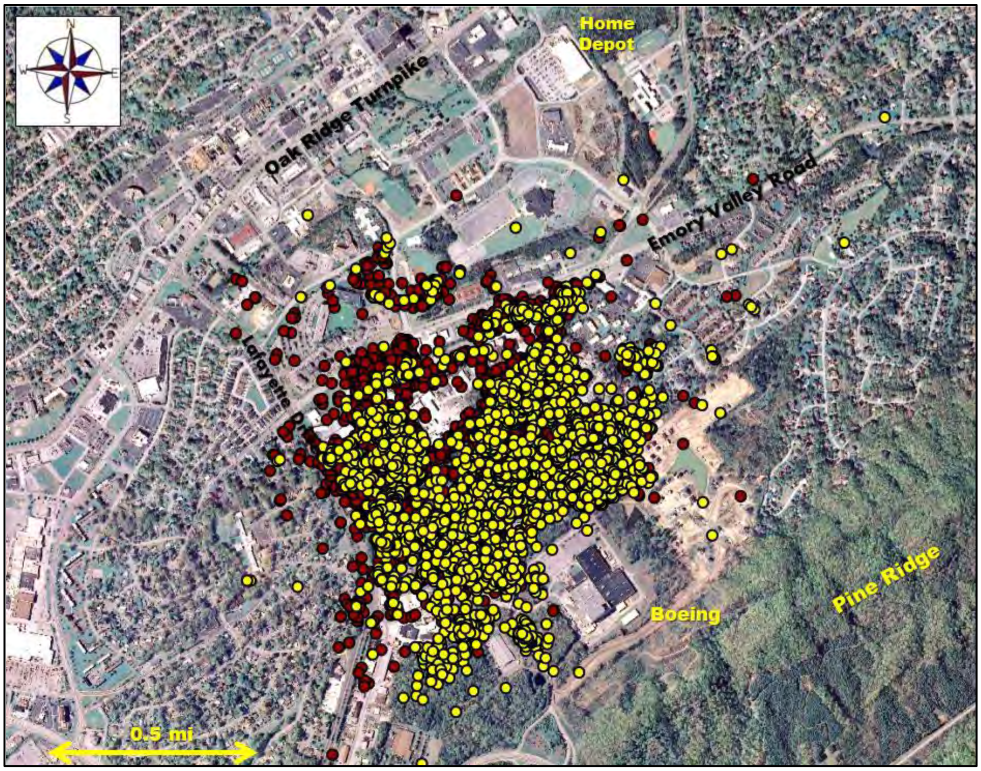
Clarabelle’s store-on-board GPS fix data were downloaded from both her two recovered collars to a computer for spatial analysis (Nelson and Sargeant 2008). The GPS fixes for each collar were imported to create maps using ArcGIS® 9.3 (Environmental Systems Research Institute, Inc., Redlands, CA, Karns et al. 2011). All data was projected in Universal Transverse Mercator (UTM) North American Datum (NAD) 1983 Zone 16 North in meters.

Figure 29 compares 2011 GPS fix data and 2012 GPS fix data from Clarabelle’s two collar deployments showing her core area in Oak Ridge. The red stars indicate the 2011 GPS fixes for the core area and the yellow stars represent the 2012 GPS fixes for the core area. Figure 30 represents her 2012 home range with excursions from the core area to the east and west; Figure 31 represents the 2012 core area within the home range. The home range of deer is defined as the area traversed in its normal activities of food gathering, mating, and caring for young (Burt 1943). The core area within the home range reflects those areas that are more intensively utilized and where the animal spends a disproportionate amount of time, presumably because conditions exist that satisfy the subsistence requirements within that area of the home range (Hodder et al. 1998, Heffelfinger 2006). Clarabelle made five short excursions from the core area during winter-spring 2012 (Table 2, Figures 32-36). She made two excursions to the west of her core area into town during December 2011 and January 2012, plus three additional excursions to the east of her core area to the Clinch River in January, February, and April 2012. There is no evidence supporting that she entered the water to swim to another location. These excursions may be partially explained by the rut season, predation pressure, or to hunting pressure (i.e., the final ORR WMA deer hunt was held in mid-December 2012). Through field team observations, this doe delivered two fawns during 2012. D’Angelo et al. (2004) documented that female white-tailed deer excursions occur in close proximity with their estrous cycles.

Table 2: Deer Excursion Data (Clarabelle-City of Oak Ridge)

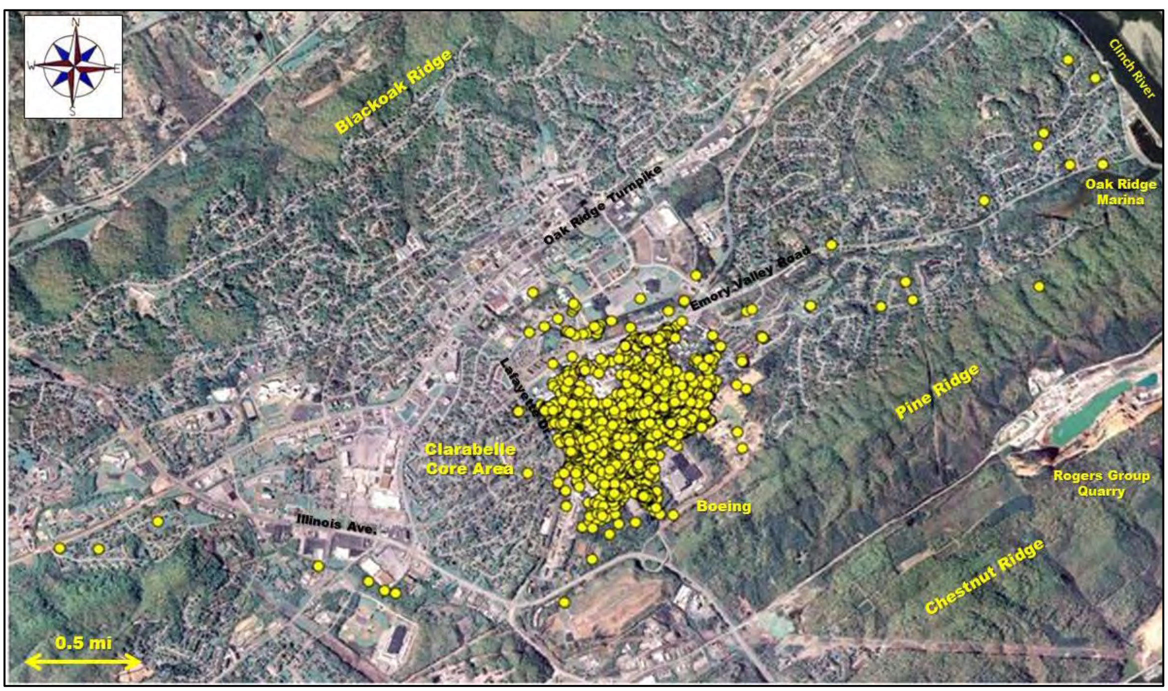
	Excursion Date(s)	**Linear Feet Traversed**	**Miles Traversed**	**Travel Time-hours**
Excursion 1	12/20/2011	26,030	4.93	10.5
Excursion 2	1/18/2012	12,778	2.42	6.0
Excursion 3	1/31-2/1/2012	25,080	4.75	13.5
Excursion 4	2/16/2012	24,710	4.68	7.5
Excursion 5	4/11/2012	29,568	5.60	9.0

In contrast, buck excursions may represent exploratory searches for estrous females (Guyse 1978, Hawkins and Klimstra 1970, Hosey 1980, Moore and Marchinton 1974), a new food source, or may be a male chasing an unreceptive female (Richardson and Petersen 1974), a male being led by an estrous female back to her core area (Cox and Le Boeuf 1977, Holzenbein and Schwede 1989), a male leading a receptive mate away from intrasexual breeding competition (Moore and Marchinton 1974), or female incitation of male competition (Cox and Le Boeuf 1977). Young females exhibiting late estrous cycles may account for an extended breeding season and may partially explain male white-tailed deer excursions during the post-breed and winter periods as they pursue additional opportunities to reproduce (Karns et al. 2011).



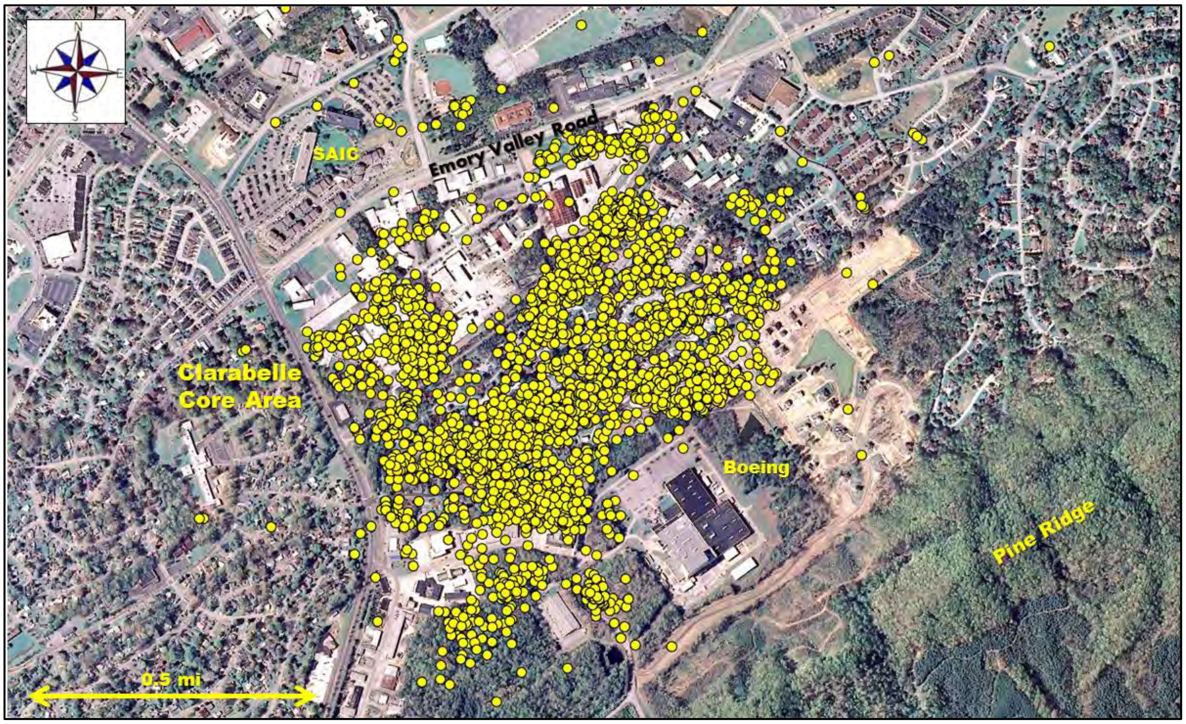
2010-2011 GPS fixes = red circles and 2011-2012 GPS fixes = yellow circles

Figure 29: 2011-2012 Clarabelle Core Area Movements Compared to 2012-2013 Core Area Movements



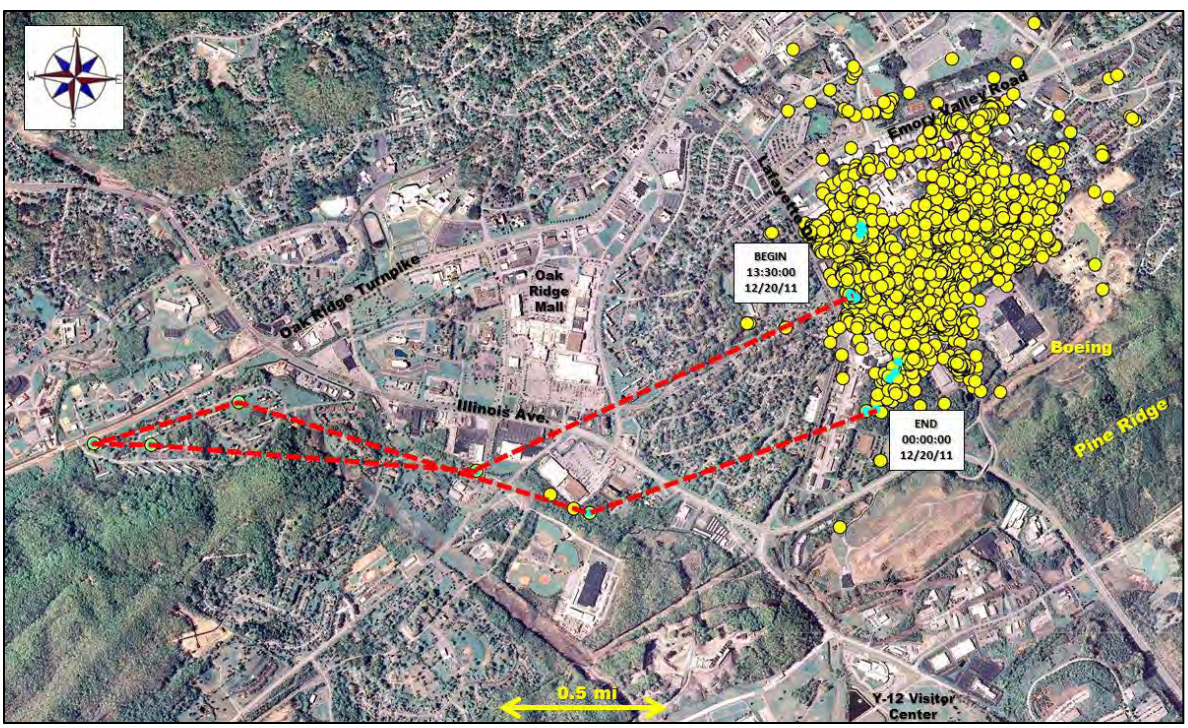
GPS fixes = yellow circles

Figure 30: Clarabelle Home Range Including Excursion Points



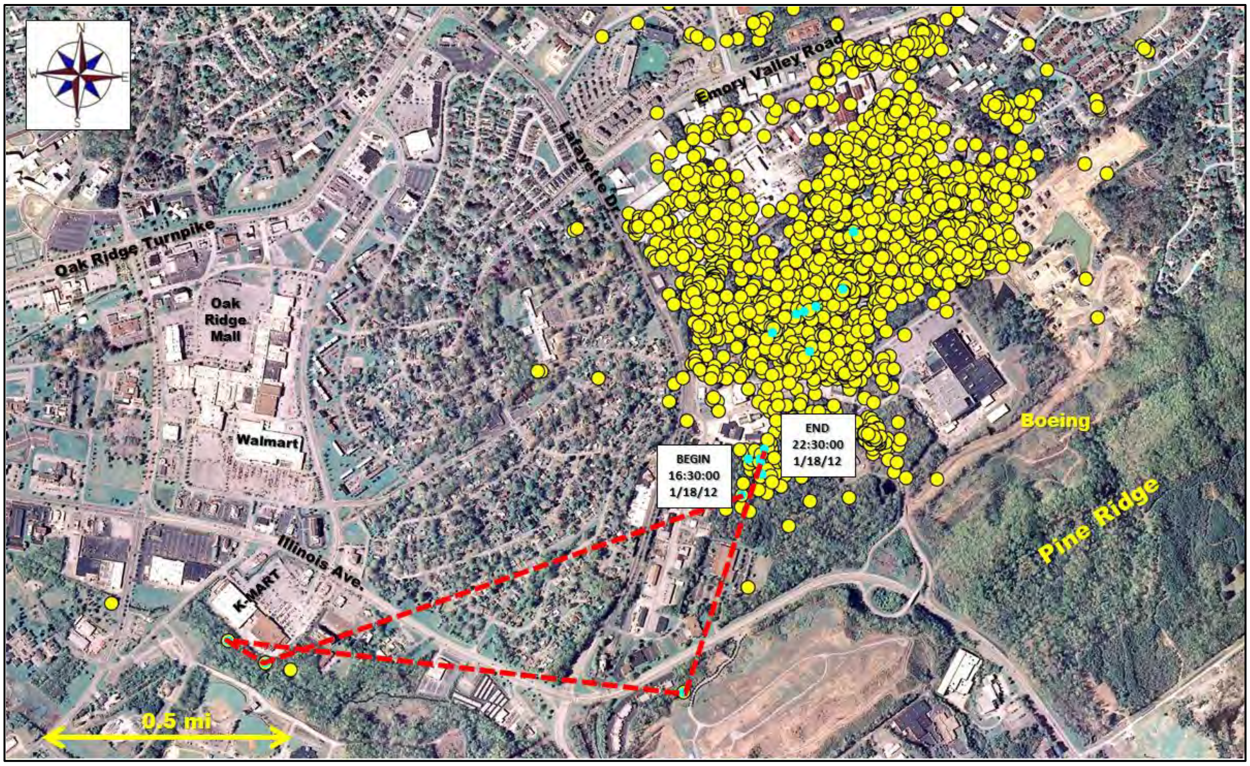
GPS fixes = yellow circles

Figure 31: Clarabelle Core Area



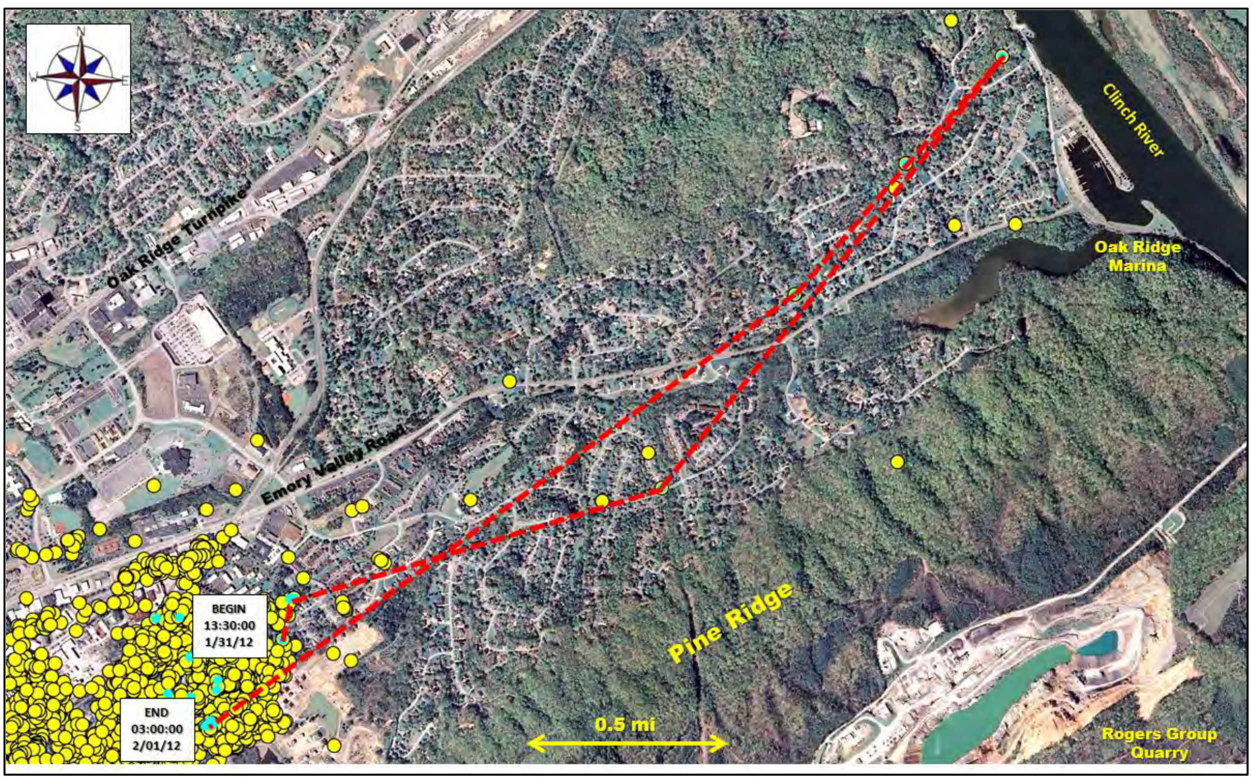
12/20/2011 excursion is the red dashed line

Figure 32: Clarabelle Excursion #1 Outside Core Area



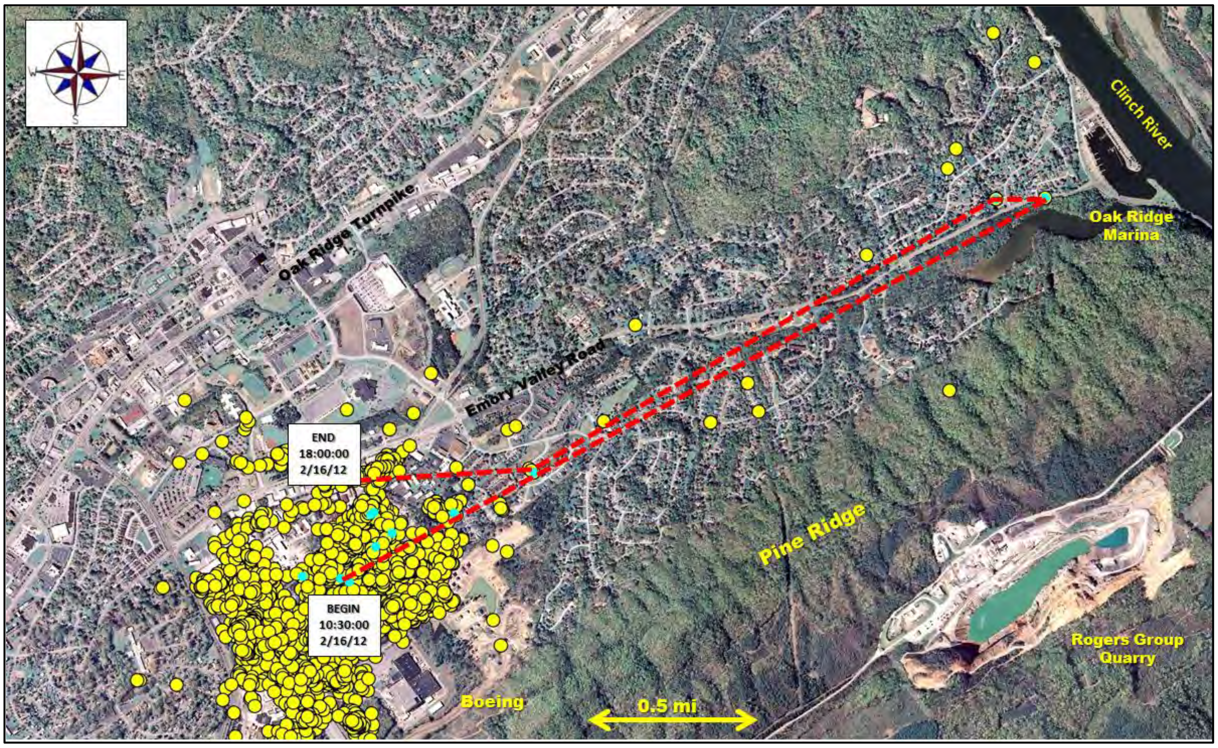
1/18/2012 excursion is the red dashed line

Figure 33: Clarabelle Excursion #2 Outside Core Area



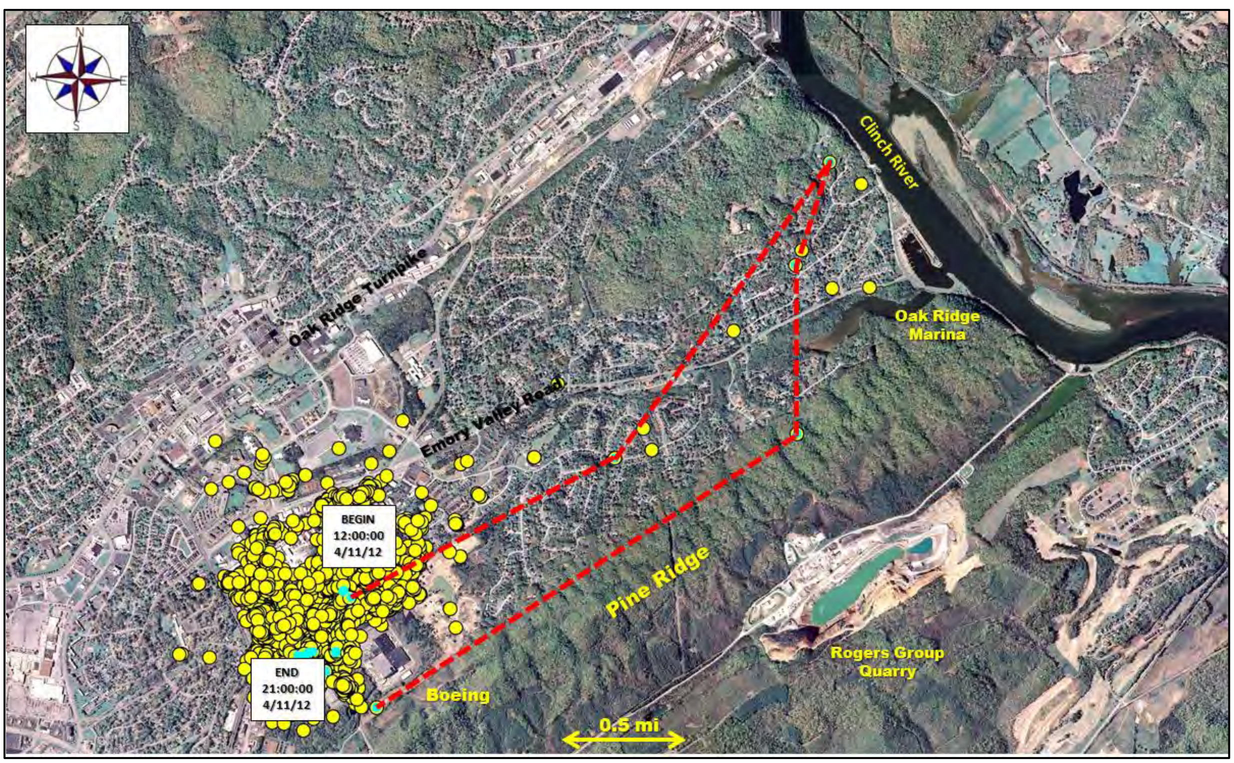
1/31-2/1/2012 excursion is the red dashed line

Figure 34: Clarabelle Excursion #3 Outside Core Area



2/16/2012 excursion is the red dashed line

Figure 35: Clarabelle Excursion #4 Outside Core Area



4/11/2012 excursion is the red dashed line

Figure 36: Clarabelle Excursion #5 Outside Core Area

Melton Valley (ORNL) Deer—Gertrude

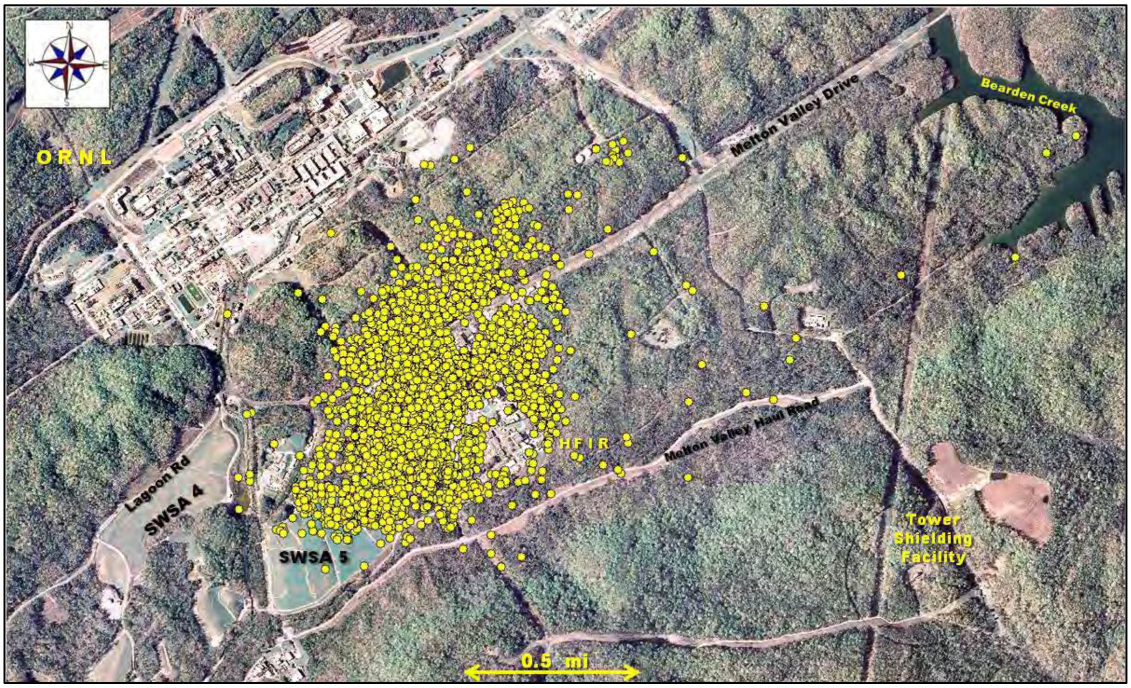
Adhering to capture procedures as described in the Methods section, Gertrude was darted, immobilized with drugs, and fitted with a new 1-year Telonics GPS collar on April 11, 2012. Her collar was retrieved (following the pre-programmed release and drop-off) on April 5, 2013 near the Oak Ridge National Laboratory's High Flux Isotopic Reactor (HFIR) in Melton Valley (Figure 37).

Gertrude's store-on-board GPS fix data was downloaded from her recovered collar to a computer for spatial analysis (Nelson and Sargeant 2008). The GPS fixes were imported to create maps using ArcGIS® 9.3 (Environmental Systems Research Institute, Inc., Redlands, CA, Karns et al. 2011). All data was projected in Universal Transverse Mercator (UTM) North American Datum (NAD) 1983 Zone 16 North in meters.

Figure 37 elucidates where Gertrude was captured (4/11/2012) and the location of collar recovery following drop-off (4/5/2013). Gertrude's home range and core areas are shown in Figures 38 and 39 respectively. The home range of deer is defined as the area traversed in its normal activities of food gathering, mating, and caring for young (Burt 1943). The core area within the home range reflects those areas that are more intensively utilized and where the animal spends a disproportionate amount of time, presumably because conditions exist that satisfy the subsistence requirements within that area of the home range (Hodder et al. 1998, Heffelfinger 2006). Gertrude made numerous excursions from her core area during 2012, but four in particular traversed the greatest distance. These four lengthy excursions all occurred within 4.5-9.0 hrs and covered a range of 2.89-3.98 miles (i.e., total distance traversed round-trip from core area), and are shown as red-dashed lines in Figures 40-43. An observation is that three out of four of Gertrude's long excursions (during July, October and November) were round-trips out of her core area to the shoreline of Melton Lake Reservoir (Bearden Creek embayment). Why? There is no evidence to support that she entered the lake to swim to another location. Through field team observations, this doe delivered two fawns during 2012.

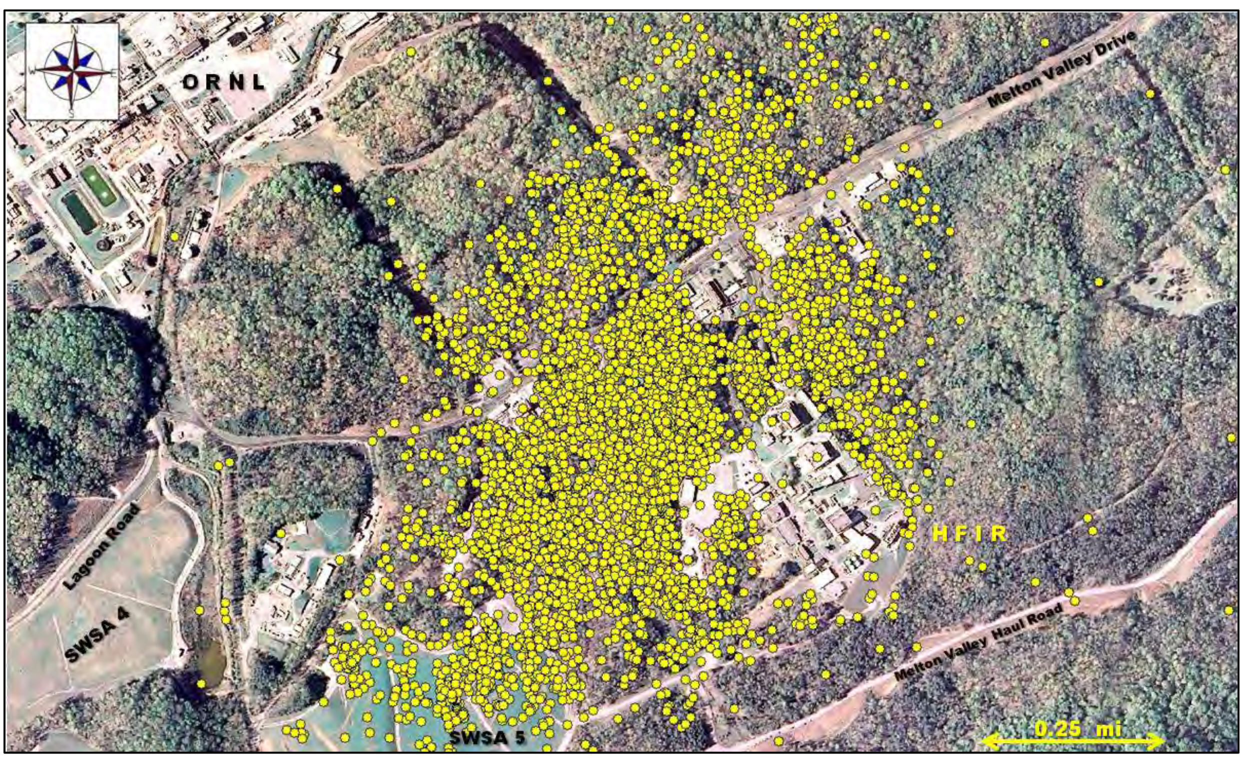
ORNL-Oak Ridge National Laboratory; SWSA-Solid Waste Storage Area; HFIR-High Flux Isotopic Reactor

Figure 37: Gertrude Capture/Collaring Location and Collar Recovery Site



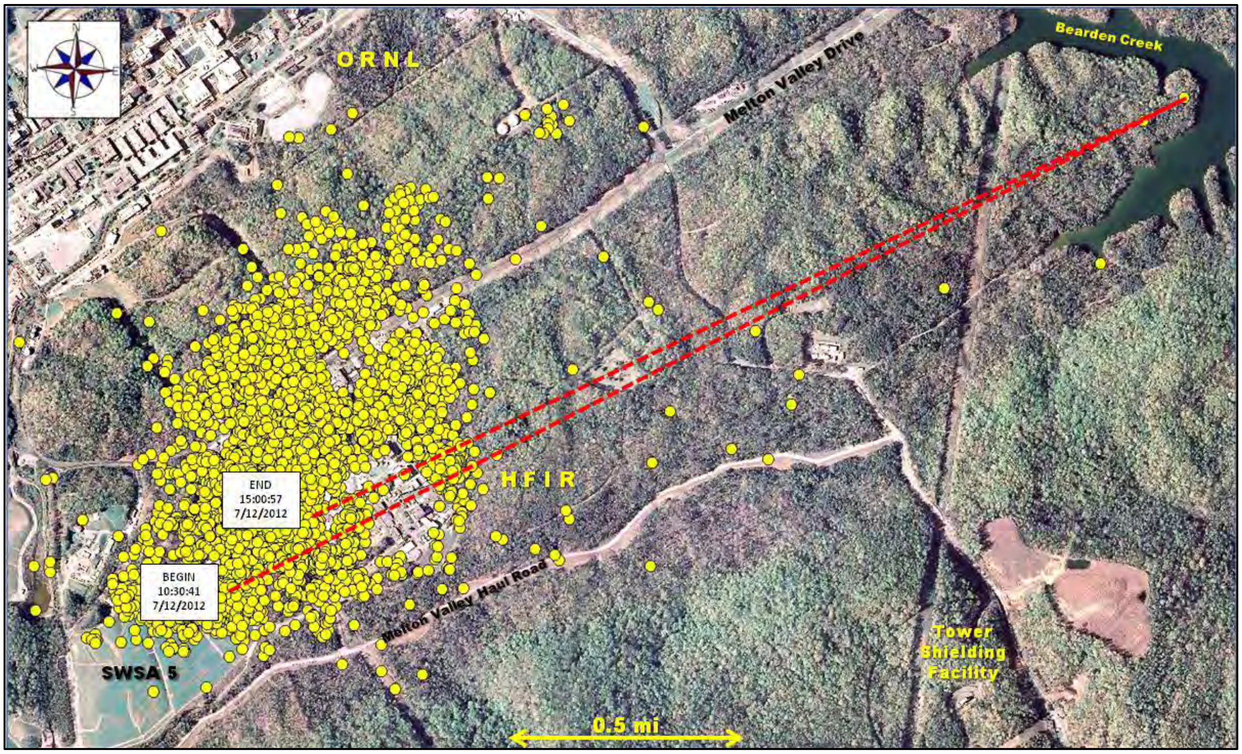
GPS fixes = yellow circles; ORNL-Oak Ridge National Laboratory; SWSA-Solid Waste Storage Area; HFIR-High Flux Isotopic Reactor

Figure 38: Gertrude Home Range Including Excursion Points (Outside core area)



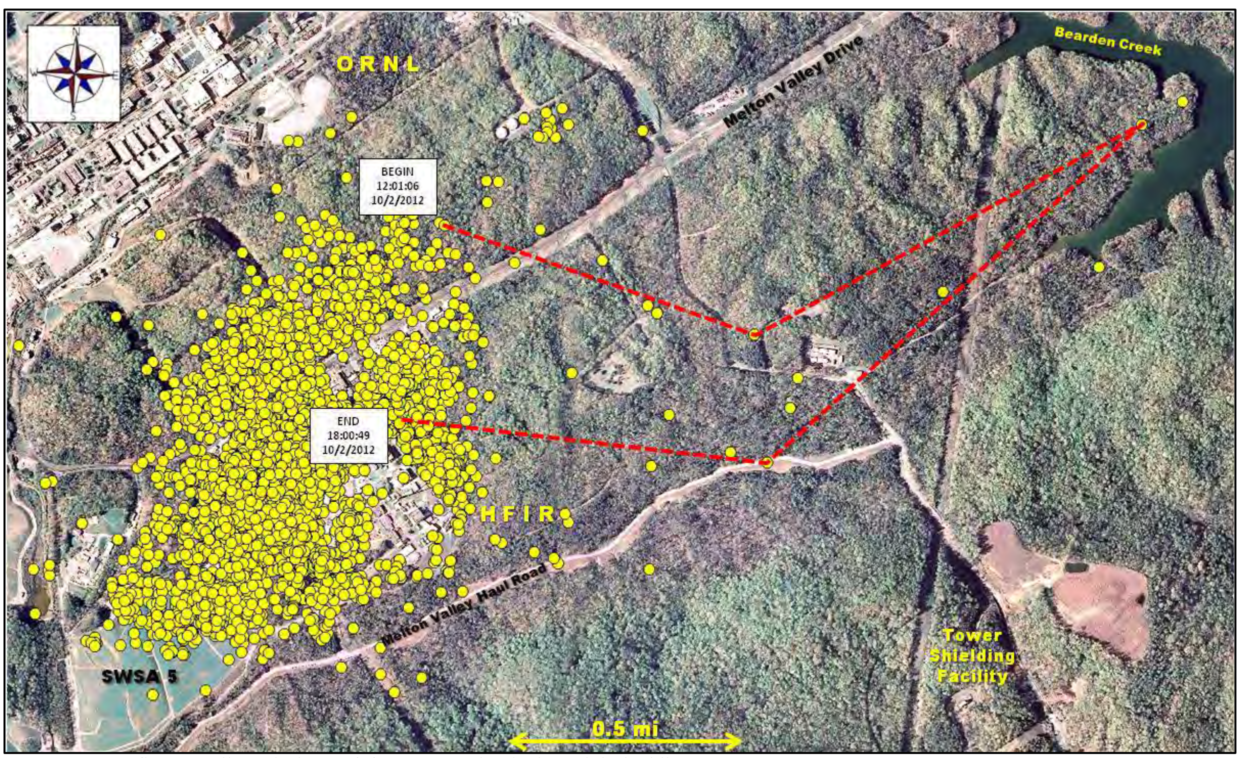
GPS fixes = yellow circles; ORNL-Oak Ridge National Laboratory; SWSA-Solid Waste Storage Area; HFIR-High Flux Isotopic Reactor

Figure 39: Gertrude's Core Area (clustered around the HFIR facility)



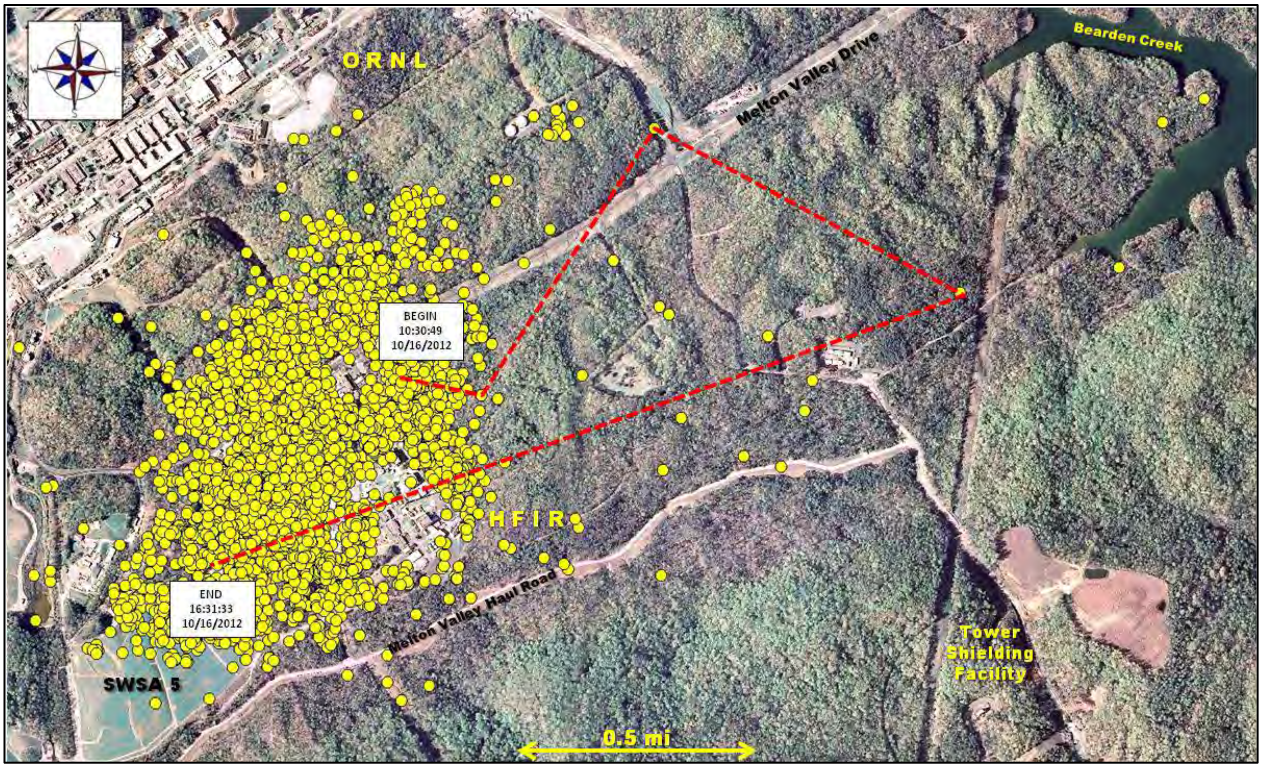
GPS fixes = yellow circles; 7/12/2012 excursion is the red dashed line

Figure 40: Gertrude Excursion #1 Outside Core Area



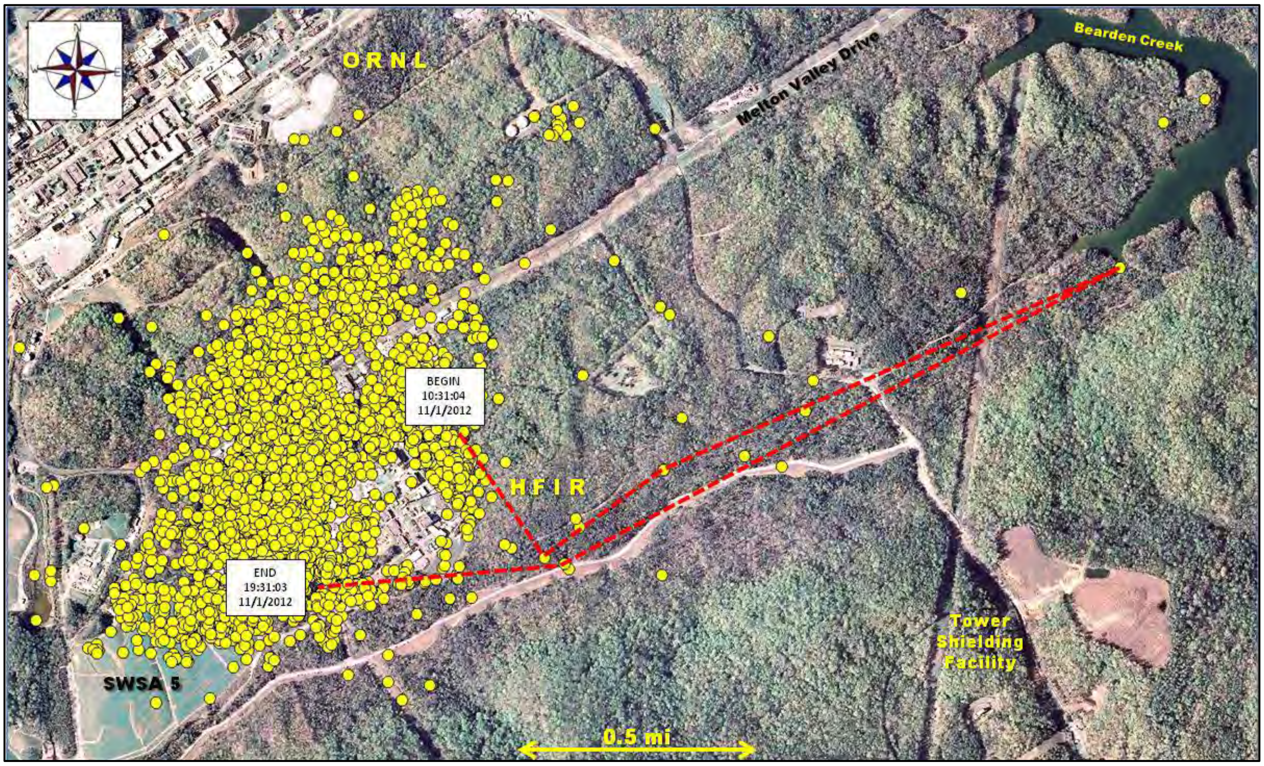
GPS fixes = yellow circles; 10/2/2012 excursion is the red dashed line

Figure 41: Gertrude Excursion #2 Outside Core Area



GPS fixes = yellow circles; 10/16/2012 excursion is the red dashed line

Figure 42: Gertrude Excursion #3 Outside Core Area



GPS fixes = yellow circles; 11/1/2012 excursion is the red dashed line

Figure 43: Gertrude Excursion #4 Outside Core Area

Deer Home-range and Excursions Outside Core Area

In previous ORR studies, the average home range for collared-deer was found to be 345 ha (852 ac), and dispersal distances of up to 33 km (20.5 mi) were recorded (Kitchings and Story 1979, Story and Kitchings 1982, 1985). In the current study, Clarabelle, the urban deer, had a core area size within her home range of 464 ac, whereas Gertrude, the Melton Valley deer, surprisingly had a smaller core area of 251 acres in 50/50 wooded and open field terrain. In contrast, the young buck (Abner), monitored in Melton Valley during 2011, had a core area of 1,025 acres in 50/50 wooded and open field terrain. Our results agree with the research of Marchinton and Hirth (1984) who determined that home ranges in white-tailed deer vary from 50-500 ha (123-1,235 ac). Thus, the Melton Valley buck core area (i.e., Abner) is 2.2 times greater than the urban doe core area (i.e., Clarabelle), and four times greater than Gertrude’s core area. Bucks usually have greater home ranges than does, and may extend their range during the rut, but home range tends to be larger in open country than in thick vegetation (Whitaker and Hamilton 1998).

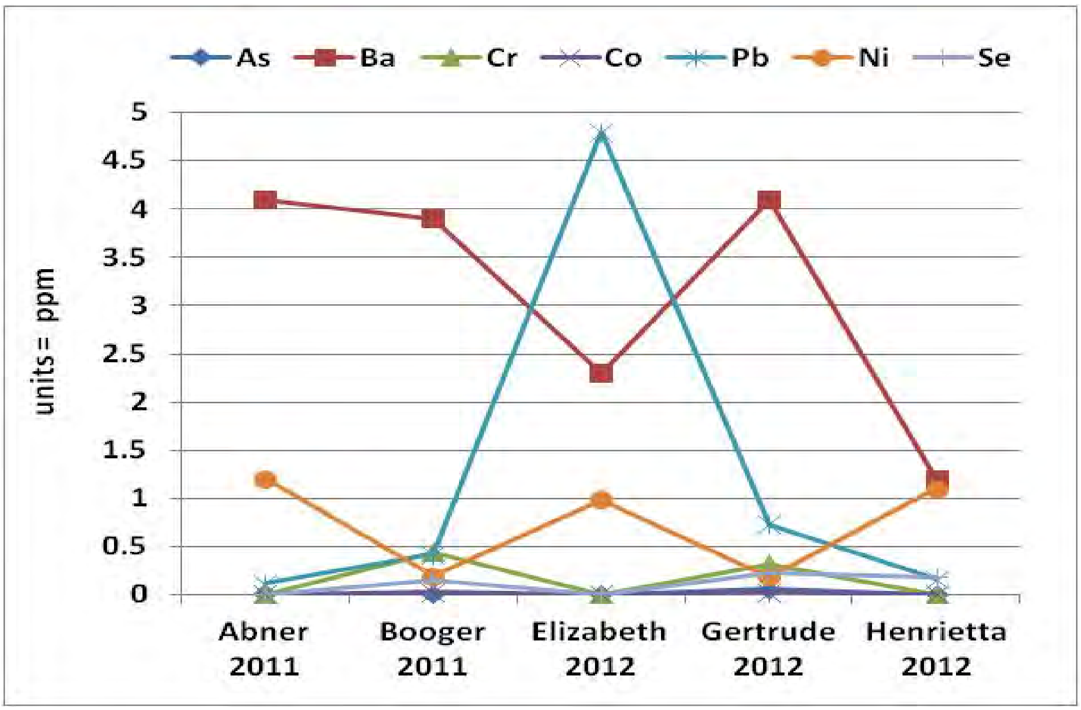
Tables 2 and 3 list linear feet and miles traversed plus travel time (in hours [hrs]) for the excursions of Clarabelle and Gertrude respectively. Clarabelle spent 46.5 total hrs on five excursions (mean = 9.3 hrs/excursion) and Gertrude spent 25.5 hrs on four main excursions (mean = 6.4 hrs/excursion). However, Abner’s (buck) mean travel distance/excursion is greater than either doe (5.9 mi vs. 3.3-4.5 mi), and he spent a total of 111 hours on four excursions (mean = 27.75 hrs/excursion). Our excursion time results are in concurrence with Tomberlin (2007) who observed that deer excursions outside their home-range may last from 6-28 hrs and cover significant distances. One last consideration, deer exhibit a deep-seated propensity for social grouping, which likely evolved as a defense against predation (Hirth 1977; Nelson and Mech 1981; Messier and Barrette 1985; Geist 1998). Deer close to other deer benefit from the vigilance of other deer, share the risk of being detected or killed, and when forced to flee predators, their multiple escape paths and motion may confuse predators (Nelson and Sargeant 2008).

Table 3: Deer Excursion Data (Gertrude-Melton Valley/ORNL)

	Excursion Date(s)	Linear Feet Traversed	Miles Traversed	Travel Time-hours
Excursion 1	7/12/2012	21,014	3.98	4.5
Excursion 2	10/2/2012	16,949	3.21	6.0
Excursion 3	10/16/2012	15,259	2.89	6.0
Excursion 4	11/1/2012	16,685	3.16	9.0

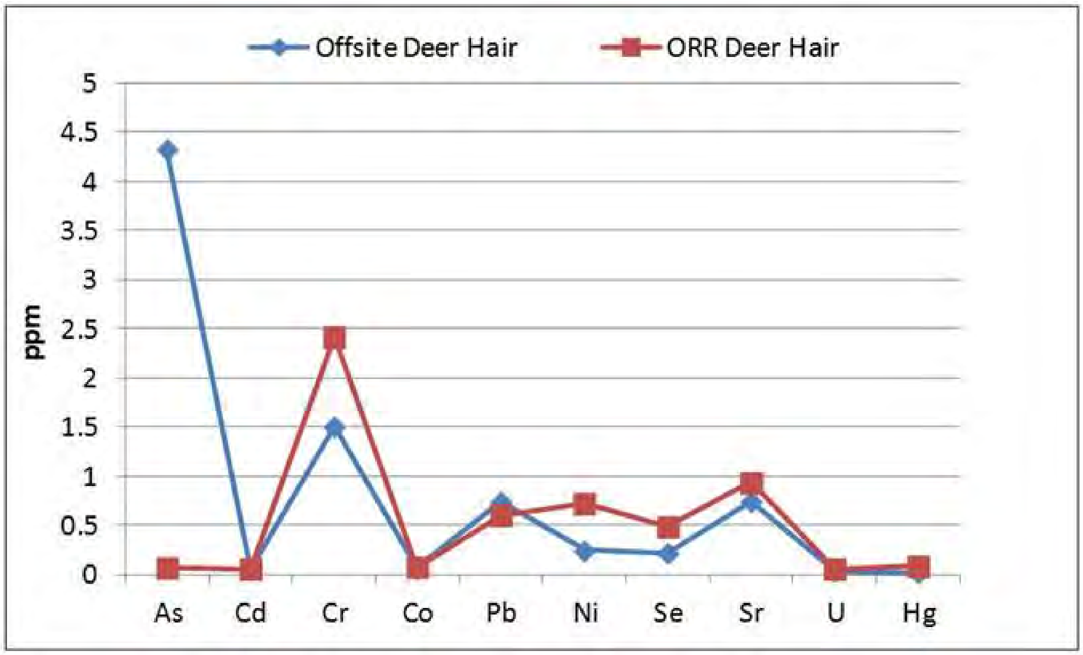
Heavy Metals Data (Deer Hair Body Burden)

Laboratory metals data for 2011-2012 collared-deer hair samples (i.e., body burden) for As, Barium (Ba), Cr, Co, Ni, Pb, and Se is presented in Figure 44. Road-kill deer hair metals sample results for 2011 are presented in Figure 45 as a comparison with 2011-2012 collared-deer hair data. Figure 46 shows the body burden of total mercury (THg) and MeHg in our 2011-2012 collared-deer hair samples compared to the 2011 road-kill deer hair THg and MeHg results (means, n=7) collected from ORR road-kill deer. Lastly, Figure 47 shows the body burden of THg and MeHg in our 2011-2012 collared-deer hair samples compared to the 2011 road-kill deer hair THg and MeHg results (means, n=17) collected from offsite road-kill deer (city of Oak Ridge). Please note that metals except THg and MeHg are reported in units of parts-per-million (ppm); THg and MeHg results are reported in units of parts-per-billion (ppb).



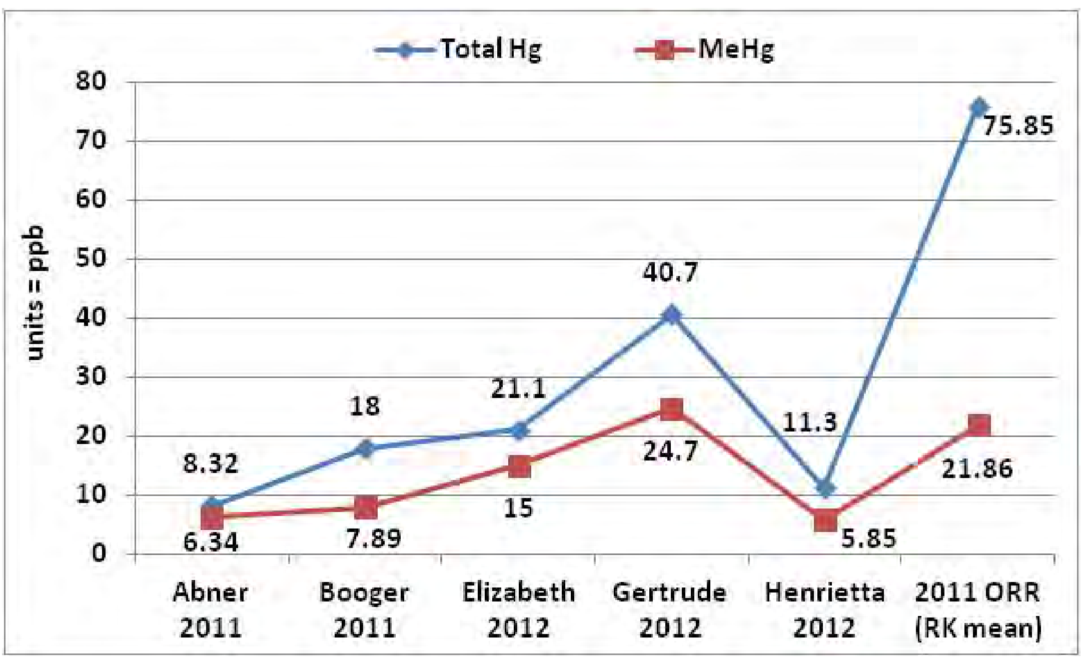
As - arsenic ; Ba - barium; Cr - chromium; Co -cobalt; Pb - lead; Ni -nickel; Se -selenium; ppm - parts per million

Figure 44: 2011-2012 Melton Valley (ORR) Collared-Deer Hair Metals Data



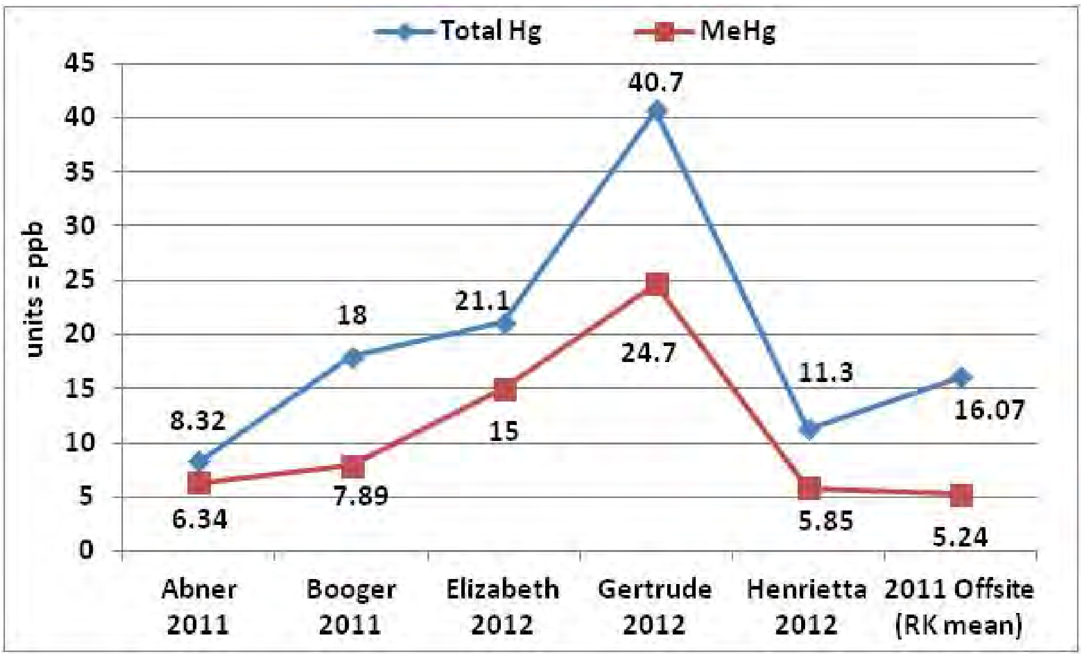
As - arsenic; Cd - cadmium; Cr - chromium; Co -cobalt; Pb -lead; Ni - nickel; Se -selenium; Sr -strontium; U -uranium; Hg -mercury; ppm - parts per million.

Figure 45: 2011 Metals Data Comparing Hair Samples Between Offsite Road-kill Deer (means, *n*=17) and ORR Road-kill Deer (means, *n*=7)



Hg - mercury; MeHg- methylmercury; ppb - parts per billion; RK mean - Road Kill mean

Figure 46: 2012 Total Mercury and Methylmercury Results Comparing Collared Deer Hair Data to Mean 2011 ORR Road-kill Deer Hair Data (*n*=7)



Hg - mercury; MeHg- methylmercury; ppb - parts per billion; RK mean - Road Kill mean

Figure 47: 2012 Collared Deer Hair Total Mercury and Methylmercury Data Compared to Mean 2011 Offsite Road-kill Deer Hair Data (*n*=17)

In Figure 44, three collared-deer hair body burden metals stand out from the rest: Ba, Pb and Ni. Barium concentrations were greater than 2.0 ppm in Abner, Booger Baby, Elizabeth and Gertrude, but less than 2.0 ppm in Henrietta. Lead concentrations were greater than 4.5 ppm in Elizabeth, but less than 1 ppm in the other four deer. Lastly, nickel was found to be greater than 1.0 ppm in Abner, Elizabeth and Henrietta, but less than 1.0 ppm in Booger Baby and Gertrude. Of the 2011 road-kill deer hair samples (Figure 45), mean Pb and Ni were less than 1.0 ppm in both the ORR and city of Oak Ridge road-kill deer hair samples. Chromium was detected at mean concentrations of 1.5 ppm and 2.5 ppm in city of Oak Ridge and ORR hair samples respectively. The body burden of As in deer hair was surprisingly present at higher concentrations of 4.0 ppm (mean) in offsite city of Oak Ridge road-kill deer hair compared to As less than 0.5 ppm (mean) for road-kill deer hair samples collected on the ORR.

Body burdens of THg and MeHg were found to be highest in Gertrude at concentrations of 40.7 ppb and 24.7 ppb respectively (Figure 46). The remaining four deer registered body burden concentrations of less than 21.1 ppb THg or MeHg. Comparatively, the body burden of THg and MeHg concentrations for ORR road-kill deer hair samples was 75.85 ppb and 21.86 ppb (means) respectively. In contrast, the body burden of THg and MeHg concentrations for city of Oak Ridge road-kill deer hair samples was considerably lower at concentrations of 16.07 ppb and 5.24 ppb respectively compared to the higher THg and MeHg concentrations detected in the ORR collared-deer and ORR deer hair results (Figure 47).

Lacking additional deer hair sampling data, and with only limited knowledge of foraging and mineral soil lick locations on the ORR, it is difficult to assess why one deer (i.e., Gertrude) has a higher body burden of THg and MeHg than other deer in the same general area of Melton Valley. Equally puzzling is the elevated Pb body burden concentration that was five times greater in the deer hair of Elizabeth than in the other four deer. Grazing wildlife (ruminants) can ingest metals either by consuming herbage (browse) that is contaminated, or by consuming contaminated soils (mineral licks, Wilkinson et al. 2003). Thus, contaminants may be bioaccumulated in deer tissues during ingestion of contaminated browse and soil (i.e., mineral licks, Grodzińska et al. 1983, Harrison and Dyer 1984, Peles and Barrett 1997, Han et al. 2006, Beyer et al. 2007).

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DRINKING WATER MONITORING

Sampling of Oak Ridge Reservation Potable Water Distribution Systems

Principal Author: Clyde E. Worthington, L.P.G.

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) is expanding its oversight of DOE facilities' safe drinking water programs. The scope of the office's independent sampling includes oversight of potable water quality potentially impacted by DOE's legacy contamination on the ORR. In 2012, TDEC conducted oversight of the potable water distribution systems and the water quality at ORR facilities. The 2012 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. 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. Oak Ridge National Laboratory (ORNL) has always hosted foreign dignitaries and accommodated visiting scientists in an openly cooperative manner. The other two facilities, ETTP and Y-12, allowed only limited public visitation until recent years. 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 2012. They focused on the facility's free chlorine residual levels. The dates for the inspections were as follows: February 29, May 30, July 30, September 26, and November 28. The chlorine residual levels were in compliance with drinking water regulations.

ORNL

Seven routine inspections were made at ORNL in 2012. They focused on the facility's free chlorine residual levels. The dates for the inspections were as follows: January 31, March 30, May 30, June 8, August 30, October 31, and December 28. The chlorine residual levels were in compliance with drinking water regulations.

ETTP

No routine inspections were made at ETTP in 2012 due to the city of Oak Ridge being responsible for 90 percent of ETTP's system. TDEC DOE-Oversight is not tasked to oversight the city of Oak Ridge's system. The other ten percent is maintained by Operations Management International (OMI) and is located in a classified area of ETTP. OMI sends a copy of their sampling results to TDEC's Division of Water Supply for regulatory purposes. TDEC DOE Oversight also gets a copy of these results. Personnel fulfilled oversight responsibilities of ETTP's facility by reviewing and filing the results from OMI.

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

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Abstract

The RadNet program was developed by the U.S. Environmental Protection Agency to monitor potential pathways for significant population exposures from routine and accidental releases of radioactivity from major sources in the United States (U.S. EPA, 1988). 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 a 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 ETTP Water Treatment Plant, all results generated by the program have remained below regulatory criteria, since its inception in 1966.

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 EPA's 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 radiological monitoring of finished water at public water supplies near nuclear facilities 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 validate DOE monitoring in accordance with the Tennessee Oversight Agreement (TDEC, 2011).

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). 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 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 approximate locations of the raw water intakes associated with these facilities.

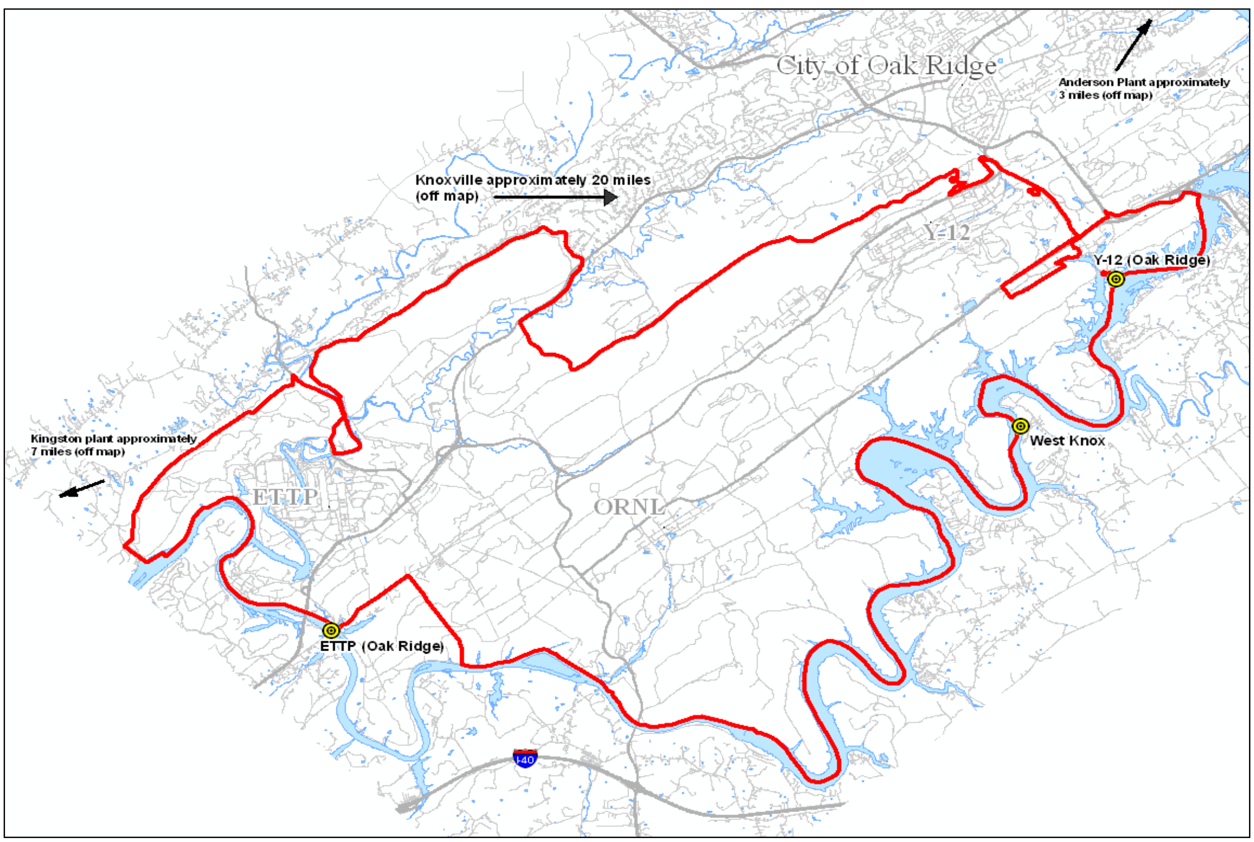

Figure 1: Approximate Locations of the Intakes for Public Water Systems Monitored in Association with EPA's RadNet Drinking Water Program

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 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. 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) for the drinking water standards set by EPA (Table 2).

Table 2: 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

Only iodine-131 and tritium results have been received from NAREL for 2012. These data are similar to the results received in past years.

NAREL performs analysis for iodine-131 each year on one sample from each facility. This was done for the fourth quarter of 2012, in October. All iodine-131 samples for 2012 (Table 3) were below detection limits for the isotope. The highest result from the five water treatment facilities sampled in this program in 2012 was 0.153 pCi/L, which was well below the corresponding drinking water limit for iodine-131 of 3 pCi/L.

Table 3: Iodine-131 Results for 2012 (fourth quarter)

Water Treatment Facility	I-131 (pCi/L)
Anderson	0.002
Y-12	0.070
West Knox	0.082
ETTP	0.153
Kingston	0.130

NAREL typically performs tritium analysis on each of the quarterly samples taken at the facilities in the program. Since only the first quarter 2011 tritium results were available last year, both the 2011 and 2012 tritium results are shown in Table 4. Analysis for tritium was not performed in the second quarter of 2011 due to the nuclear incident in Japan and a subsequent focus on analysis of mixed fission products. As a consequence, gamma spectrometry and I-131 were the only analyses performed on the second quarter samples.

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 samples taken in 2011 and 2012 from the five area water treatment plants, all but three were below detection limits. These are shaded in Table 4. 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.

Table 4: Quarterly Tritium Results from the Five Water Treatment Facilities for the First Quarter of 2011 and for 2012 in pCi/L, with Values above the Detection Limits in bold

	2011				2012			
	QTR 1	QTR 2	QTR 3	QTR 4	QTR 1	QTR 2	QTR 3	QTR 4
Anderson	-57	*	33	-4	-59	73	-46	-91
Y-12	-50	*	49	-27	-12	**139**	48	-48
West Knox	-12	*	71	40	-34	79	**386**	9
ETTP	33	*	83	33	23	**125**	57	-81
Kingston	-38	*	72	58	25	30	92	-65

* Tritium results for the second quarter 2011 were not run due to the nuclear incident in Japan

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.

Gross alpha, gross beta, 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 2012 composite analyses are not yet available, as it can be well into the following year before they are able to be composited. The 2011 annual composite results are now available, with the exception of strontium-90 and are shown in Table 5 and Table 6. The 2010 annual composite results for strontium-90 are shown in Table 7.

Table 5: 2011 Gross Alpha and Gross Beta Annual Composite Results

Water Treatment Facility	Gross Alpha (pCi/L)	Gross Beta (pCi/L)
Anderson	0.9	-0.3
Y-12	0.2	2.5
West Knox	0.4	1.6
ETTP	0.1	2.7
Kingston	0.6	3.0

In 2011, there were no gross alpha results above detection limits, and only one of the five stations had gross beta results above detection limits (Kingston 3.0 pCi/L). The MCL for gross alpha in drinking water is 15 pCi/L. The five samples from 2011 were all well below this. 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. As can be seen in Table 5, gross beta results for the 2011 annual composites from drinking water sampling location near and on the ORR fell well below the strontium-90 limit of 8.0 pCi/L.

Table 6: 2011 Gamma Annual Composite Results

Water Treatment Facility	Co-60 (pCi/L)	Cs-137 (pCi/L)	K-40 (pCi/L)
Anderson	0.00	0.03	3.80
Y-12	-0.04	-0.37	6.70
West Knox	0.52	0.23	6.40
ETTP	-0.73	-0.10	13.90
Kingston	0.09	-0.20	3.00

The gamma spectrometry on the annual composites showed no values above detection limits. This was the case for all the cobalt-60 (Co-60), cesium-137 (Cs-137), and potassium-40 (K-40) results shown in Table 6. The MCL for cobalt-60 is 100 pCi/L and the MCL for cesium-137 is 200 pCi/L. The 2011 results were well below these.

Table 7: 2010 Strontium-90 Annual Composite Results

Water Treatment Facility	strontium-90 (pCi/L)
Anderson	0.20
Y-12	0.03
West Knox	0.09
ETTP	0.22
Kingston	0.01

The annual composite analysis for strontium-90 of drinking water samples for 2011 was not yet available at the time this report was written. However, the data from 2010 (Table 7) all fell below the minimum detectable amounts. The highest strontium-90 result in 2010 for samples collected on and near the ORR was 0.22 pCi/L (from ETTP), and 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 in 1966. 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.

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GROUNDWATER MONITORING

Groundwater Monitoring for the Oak Ridge Reservation and Its Environs

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Abstract

The Tennessee Oversight Agreement requires the State of Tennessee to provide independent monitoring and oversight to verify Department of Energy (DOE) data and to assess the effectiveness of DOE contaminant control systems on the Oak Ridge Reservation (ORR) and its environs. In 2012, Tennessee Department of Environment and Conservation (TDEC) DOE Oversight Office (DOE-O) monitored groundwater parameters at springs and collected samples for analysis to assess the groundwater quality adjacent to and within the ORR. Data were gathered from electronic loggers at three springs confirming that conduits, rapid non-darcian velocities, sinking streams, and deep complicated flow paths are involved around the ORR. Groundwater samples were collected at one residential well, one monitoring well, one surface water location, and from eleven springs. Samples were analyzed for radiochemicals, inorganics, volatile organic aromatics (VOAs) and, in selected locations, for stable nitrogen and oxygen isotopes. RWA-119 did show a result for copper that exceeded the 90^{th} National Water Quality Assessment (NWQA) percentile value (0.0123 mg/L). Pump House Well, (sampled twice) did not report any constituents above the screening criteria. Given the close proximity of Pump House Well to known groundwater contamination, it will remain a concern and a target for future sampling. No significant results were reported from the one surface sample obtained from Scarboro Creek. Bootlegger Spring has continued to show characteristic VOAs (dichloroethene, dichloroethane, and trichloroethene) below applicable Maximum Contaminant Levels (MCLs). At spring SS-4 on the reservation, nitrate, uranium, gross alpha and gross beta were detected at concentrations exceeding the screening criteria. At GW-214 inorganic constituents were detected above the NWQA 90^{th} percentile, similar to areas on and off the ORR. Determining the source (natural or anthropogenic) of inorganic constituents is always problematic, particularly considering the limited data collected in Bear Creek Valley. Further work is needed to determine the source and possibly the distribution of constituents detected.

Introduction

In 2012, the Tennessee Department of Environment and Conservation (TDEC) Department of Energy (DOE) Oversight (DOE-O) Office monitored groundwater parameters at three springs, sampled one residential well, one monitoring well, one production well, eleven springs and one surface water site to assess the groundwater quality adjacent to and within the Oak Ridge Reservation (ORR). Figure 1 and Table 1 provide locations where samples were collected.

Methods and Materials

Groundwater quality assessment in and around the ORR by TDEC/DOE-O consisted of the collection and analysis of samples within and around the ORR. Samples were analyzed for radiochemicals, inorganics, volatile organic aromatics (VOAs) and at selected locations samples were obtained for stable nitrogen and oxygen isotopes. Samples were analyzed either by the state of Tennessee's Department of Health Laboratories or by contract laboratory for isotopic uranium and nitrogen. All detected compounds were screened against Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCL), EPA secondary MCLs, EPA Health Advisories, EPA Maximum Contaminant Level Goal (MCLG) (EPA, 2011), and the 90th percentile results for the National Water Quality Assessment (NWQA) United States Geological Survey (USGS) groundwater study (DeSimone 2009).

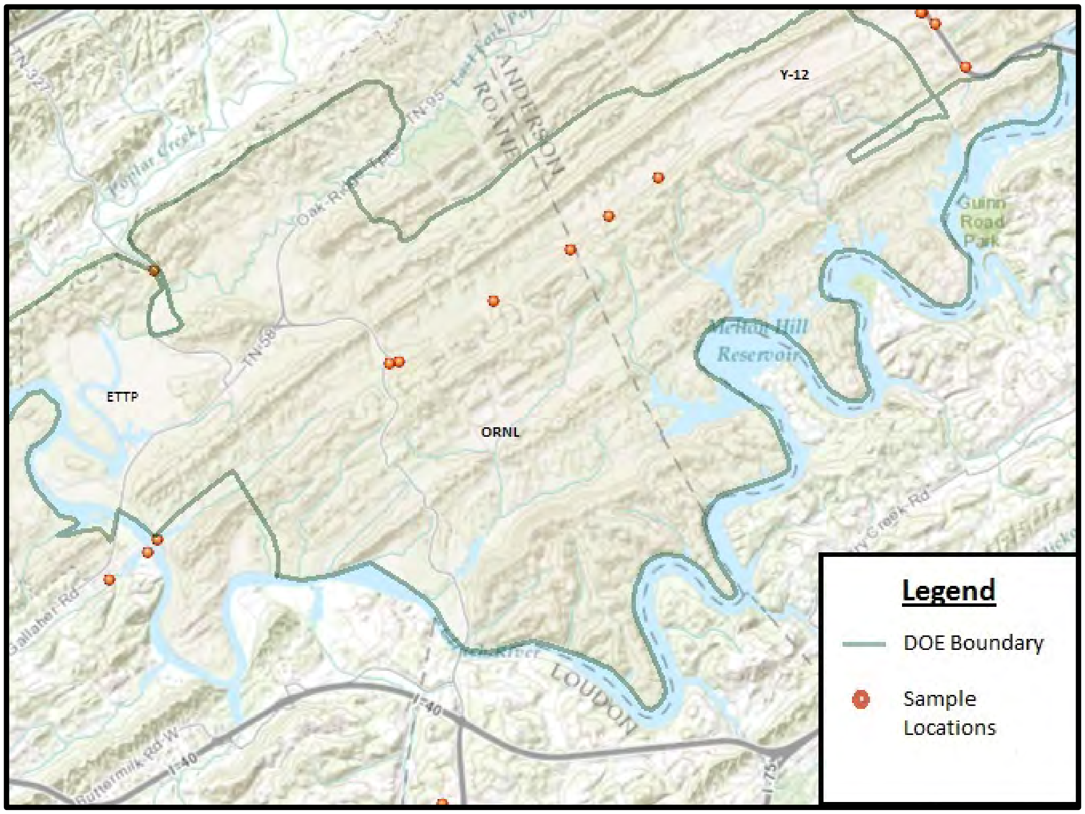


Figure 1: 2012 Well and Spring Sampling Locations

Groundwater Parameter Monitoring

Water quality parameters were continuously collected utilizing a HOBO® conductivity/temperature data logger at Gallaher spring and in the channel of the Clinch River to determine how and whether the spring responded to ambient changes. Two In-situ® Troll data loggers recorded water quality parameters for springs SS-7 and SS-8 within Bear Creek Valley on the ORR.

Residential Wells

One sample was collected from residential well RWA-119 in 2012. The sample was collected at the request of the landowner. The well is south of ORR and Interstate-40.

Tennessee Valley Authority Well

Pump House Well located along Blair Road supplies the Tennessee Valley Authority (TVA) Roane County substation located approximately two kilometers north of East Tennessee Technology Park (ETTP), with fire suppression water and water for domestic needs (ice machine) to TVA offices located at the substation.

Table 1: Sample Locations

Station	Onsite/ Offsite	Type	Sample Events	Area
10-895 Spring	ON*	Spring	1	ETTP
SS-5 Spring	ON	Spring	1	Bear Creek Valley
SS-4 Spring	ON	Spring	1	Bear Creek Valley
SS-2 Spring	ON	Spring	1	Bear Creek Valley
SS-6 Spring	ON	Spring	1	Bear Creek Valley
SS-7 Spring	ON	Spring	1	Bear Creek Valley
SS-8 Spring	ON	Spring	1	Bear Creek Valley
U Spring	OFF	Spring	1	Bear Creek Valley
Bootlegger Spring	OFF	Spring	1	UT Arboretum
Cat Tail Spring	OFF	Spring	1	Union Valley
Gallaher Spring	OFF	Spring	1	Bear Creek Valley
RWA-119	OFF	Residential Well	1	Paw Paw Valley
Pump House Well	OFF	TVA Well	2	Blair Road
GW-214	OFF	Monitoring Well	1	Bear Creek Valley
Scarboro Creek Culvert	OFF	Surface Water	1	UT Arboretum

* USGS 10-895 may or may not be on site. ORR Site boundary is hard to determine at the spring location
ETTP - East Tennessee Technology Park
TVA - Tennessee Valley Authority
USGS – United States Geological Survey
UT - University of Tennessee

Pump House Well is proximal to two known areas that have detected contamination; Contractor's Spoil Area (CSA) to the northwest, and USGS spring 10-895. Near-surface soil borings from CSA have detected semi-volatile organic compounds (SVOCs) and fuels. USGS 10-895 sampling detected trichloroethane at or near the MCLs and low levels [less than 10 picoCuries per liter (pCi/L)] of technetium 99 (Tc^{99}). The source for contamination in USGS 10-895 is not known. Given the proximity to known contaminants, and the potential pathway for human consumption, Pump House Well will remain a concern and a target for future monitoring. In addition to the sample being analyzed for radiochemicals, inorganics, and VOAs, the sample was analyzed for isotopic nitrogen and oxygen.

Monitoring Well

One sample was collected from monitoring well GW-214, located in southwest Bear Creek Valley, adjacent to and on the northeast Bank of the Clinch River. GW-214 is geologically located along strike and down gradient from Y-12 and the disposal areas in Bear Creek Valley on the ORR. GW-214 is also located across geologic strike and down dip from the ETTP water treatment plant and the ponds used for initial treatment of ETTP drinking water supplies. GW-214 is completed at 415 feet below the ground surface.

Surface Water

One surface water location on Scarboro Creek was sampled to determine if Scarboro Creek's path may reflect an unmapped linear geologic feature that could be a pathway for deeper components of Union Valley plume to be transported outside Union Valley. The Union Valley plume is currently assumed to terminate at Cattail Spring near Illinois Avenue.

Springs

A total of twelve samples were collected from eleven springs. U-spring, Gallaher Spring, SS-2, SS-4, SS-5 SS-6, SS-7, and SS-8 are located on the Maynardville Limestone formation within Bear Creek Valley (six onsite and two offsite). Of the remaining three springs that were sampled, one spring, Bootlegger, is located along Scarboro Creek within the University of Tennessee (UT) Arboretum. USGS 10-895 is located along Poplar Creek north of ETTP, and the remaining spring, Cattail, is located in Union Valley offsite and adjacent to Scarboro Road. The samples were analyzed for metals, general inorganics, radiochemicals, and volatile organics. SS-7, SS-8, and U-Spring were analyzed for stable nitrogen and oxygen isotopes.

Stable Nitrogen and Oxygen Isotopes

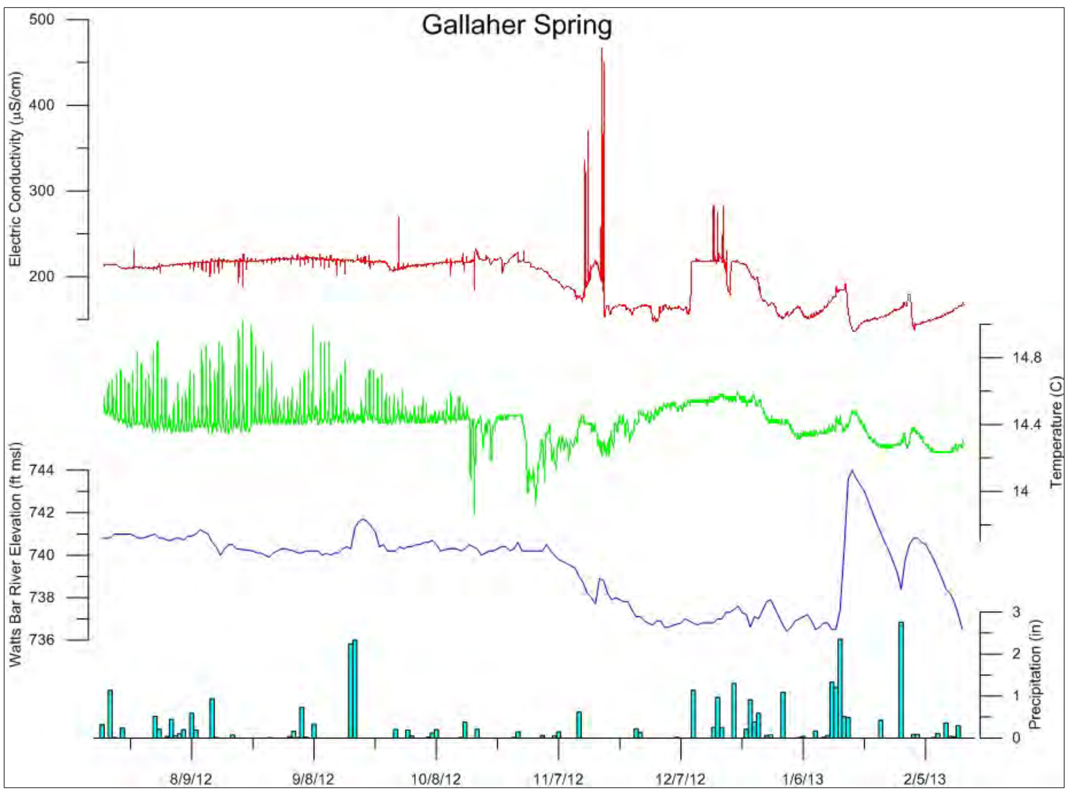
Nitrate in the environment has several different sources: atmosphere, precipitation, surface water, groundwater, soil, fertilized soil (i.e., a synthetic nitrogen reservoir) and human and animal waste. There are two naturally-occurring stable nitrogen isotopes, ^{14}N and ^{15}N. It is possible to use the concentration of the less abundant ^{15}N versus the nitrate concentration in samples to roughly evaluate and separate the different sources of nitrate (Junk and Svec, 1958). However, there is considerable overlap of these signatures and this makes data interpretation more challenging. The isotopic method is improved by not only using ^{15}N, but also the ^{18}O in the nitrate (NO_3). Oxygen has three stable isotopes, ^{16}O, ^{17}O and ^{18}O, of which ^{16}O is the most abundant and ^{18}O has a known association and abundance ratio with ^{16}O. The $^{16}O/^{18}O$ ratios in groundwater are related to recharge, flow path, precipitation and temperature. (Böttcher, et al 1990) Since there are variations in ^{18}O, using both ^{15}N and ^{18}O increases the sensitivity of the method. The isotopic method is also being used for dissolved ammonia (NH_4) using the ^{15}N in that molecule. In anoxic waters, nitrate reduces to ammonia. Stable nitrogen and oxygen isotope samples were collected for springs SS-7, SS-8, Gallaher Spring, U-Spring and GW-214 in Bear Creek Valley, and Pump House Well north of ETTP.

Discussion and Results

Groundwater Parameter Monitoring

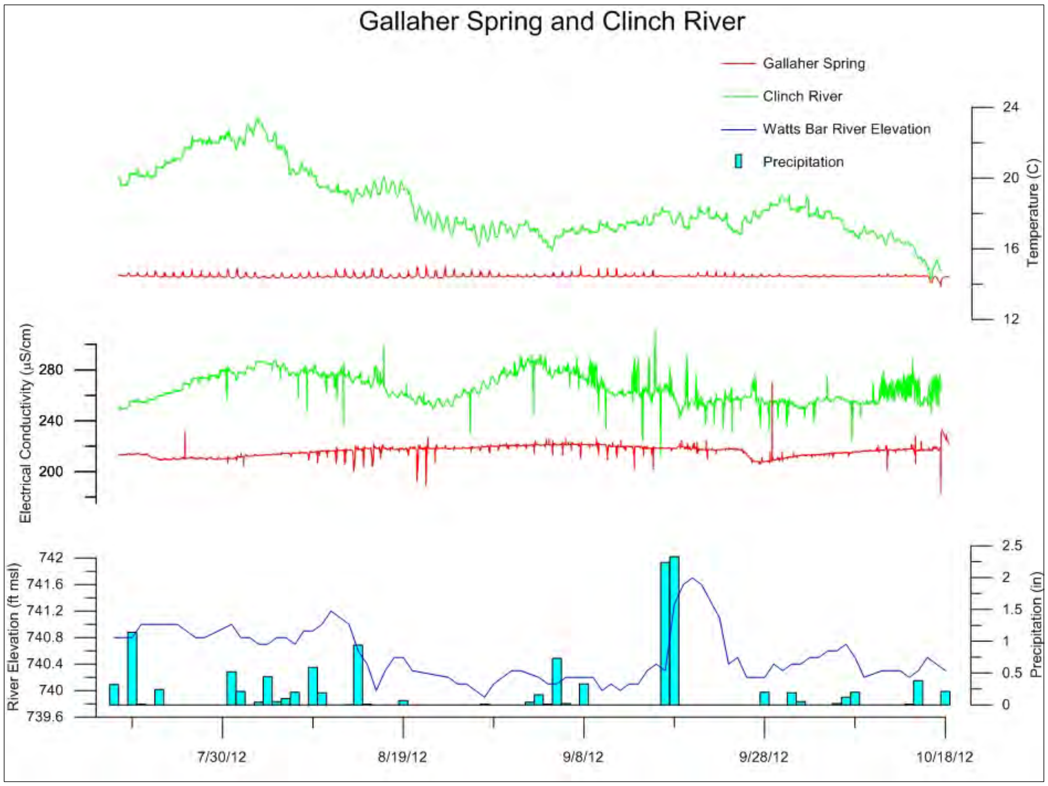
SS-7 and SS-8. Two springs (SS-7 and SS-8) in Bear Creek Valley were outfitted with In-Situ Troll® water quality data loggers. Unfortunately, beavers in the area of these springs created problems. The springs were inundated, attempts were made to drain the areas to get good water quality data but the areas were quickly dammed back up. The inundated springs dampened the springs' response to precipitation and flow. In addition, the beavers at SS-8 moved the equipment out from the spring vent and covered the equipment with mud. A review of the data only showed the results of the beaver activity. The beaver activity masked the water quality results and therefore the data could not be used.

Gallaher Spring A HOBO™ combined electrical conductivity and temperature data logger was installed on July 18, 2012. The data logger was set up to collect and record data at 15-minute intervals, and was removed on February 14, 2013. Another HOBO™ data logger was placed upstream of the Gallaher Spring at approximately mid channel (tied to a channel marker buoy) in the Clinch River from July 18, 2012 to October 17, 2012. Figures 2 and 3 provide the results for those two data loggers.



C - celcius
ft msl - feet above mean sea level
in - inches
µS/cm - microSiemens per centimeter.

Figure 2: Electric Conductivity, Temperature, Watts Bar River Elevation, and Precipitation for Gallaher Spring

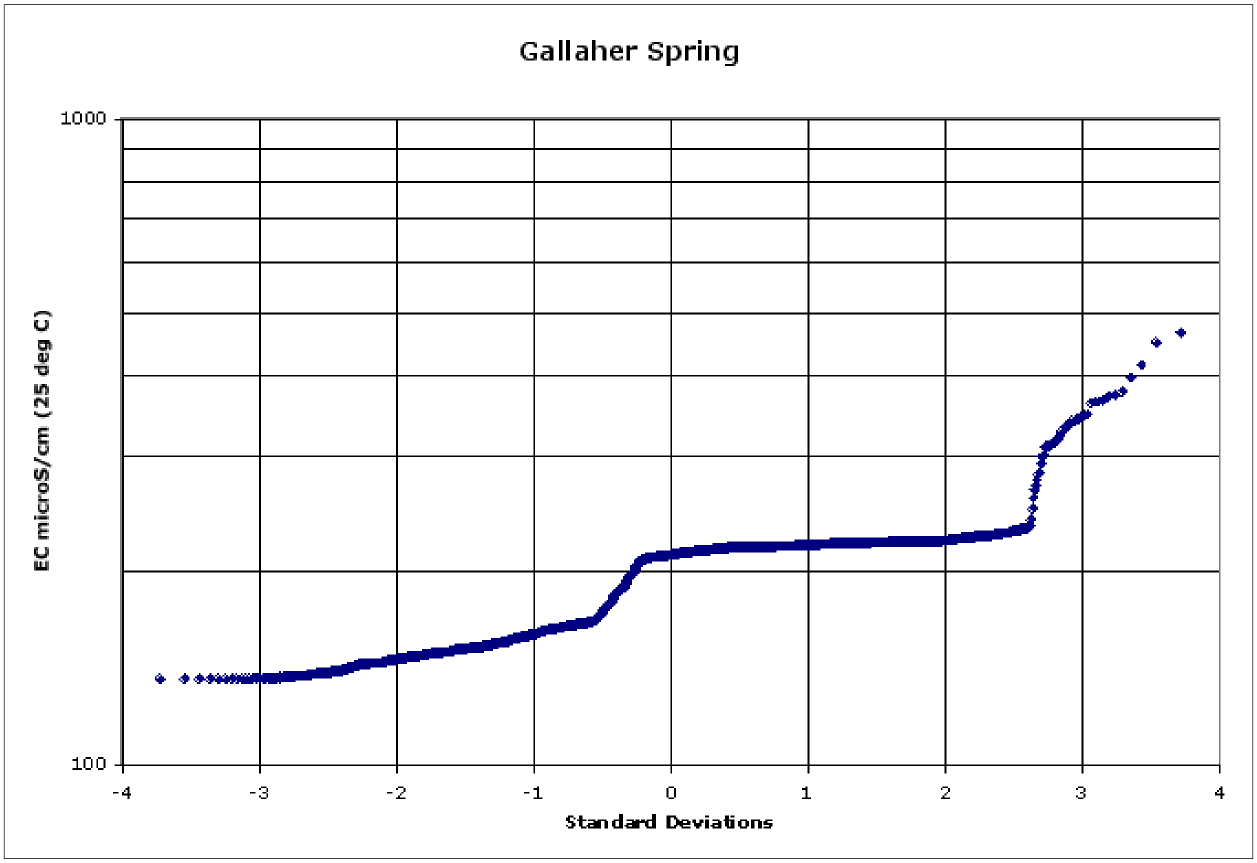


C - celcius
ft msl - feet above mean sea level
in - inches
µS/cm - microSiemens per centimeter.

Figure 3: Gallaher Spring with Clinch River Comparison

For Gallaher Spring, a graph of standard deviations versus the logarithm of electrical conductivity (Figure 4) shows several log-normal sets of data suggesting that several different water types discharged from the spring. Two large sets of values have geometric means of about 150 and 220 microSiemens per centimeter (µS/cm). These signatures suggest meteoric waters with minimal bedrock contact being recharged rapidly and flowing rapidly. Other smaller sets have geometric means of 190, 280 and 380 µS/cm. The higher electric conductivity suggests discharge of water from deeper pathways or longer residence time. In other words, Gallaher Spring discharges from a deeper pathway only part of the time, seemingly instantaneously.

These highly variable events occur below a certain lake elevation or during low pool stage that began in early November 2012. For reference, Watts Bar Stage daily stage information is shown in Figures 2 and 3. During the high pool stage, electrical conductivity varies only a small amount, while temperature shows only a diurnal effect. This lack of variability in electric conductivity is best seen in early November 2012 (as seen by two days of high rainfall in late September and a rise in the Watts Bar river elevation with no variability in the electric conductivity). When the water level in Watts Bar begins to decrease for low pool stage in November, there is increased variability with both conductivity and temperature. Rain events and a rise in water elevations of Watts Bar during low pool seem to affect electric conductivity. What appears to be happening is that the high pool water level suppresses the water quality variability.



EC - electric conductivity
microS/cm - microSiemens per centimeter.

Figure 4: Standard Deviations of Electric Conductivity for Gallaher Spring

When the Watts Bar Lake level dropped for low pool, a much smaller precipitation event seems to cause a large increase in electrical conductivity. This change in electric conductivity could be interpreted as groundwater releases from storage of deeper water feeding the spring, however the simplest explanation is that the spikes are related to an electronic or measurement malfunction in the data logger (the sharp spikes in conductivity in November and December). Of particular concern are the large, almost instantaneous increases in the electric conductivity. As seen in Figure 2, there is no corresponding change in the temperature. The problem of making simply the latter interpretation (i.e., the changes are only the result of malfunction in the instrument) and dismissing the data as real is that the data include several measurements on each excursion and that they were collected when the lake level was low. In coastal karst/carbonate settings, variability like this can occur and leads to similar interpretational challenges.

During November 2012 the electric conductivity pattern changes to one of a decrease in electrical conductivity and an increase in temperature with precipitation events or a rise in water elevation after a heavy precipitation event. This pattern is often observed in springs with sinking streams, where large volumes of low conductivity water (precipitation typically has electrical conductivity at about 15 µS/cm) recharge, flow and discharge rapidly. When a large volumes of recharging meteoric water enters the system via conduits, the lower conductive fresh water proceeds rapidly to the spring thus causing a rapid fall in electric conductivity (Newson, 1971; Worthington et al., 1992). High variation of the electrical conductivity at or following precipitation would be indicative of allogenic recharge (i.e., sinking streams) (Worthington et al., 1992). East Tennessee carbonates are not characterized by large sinking streams but still show a fairly typical variability of electrical conductivity because of rapid recharge and flow in conduits (Ketelle and Davies, 1999). The variability of electric conductivity suggests that the spring discharges both overflow and deeper waters when hydraulic conditions allow. The temperature record for Gallaher Spring is generally constant near the average annual outside temperature, suggesting that the spring is driven by conduit flow of considerable size.

An additional HOBO™ data logger was deployed in the Clinch River, in mid channel, upstream of the tributary that leads to Gallaher Spring. As shown on Figure 3, the electric conductivity and temperature values recorded by Clinch River data logger show a different pattern to that recorded by the Gallaher Spring data logger. The electric conductivity generally varies between 250 and 290 µS/cm. There is no correlation between the two data sets. The water elevation for Watts Bar Lake is also shown.

The variability of electric conductivity at Gallaher spring is complicated because of a combination of inputs from sinking streams, the interaction of the head of the river connected directly via a short surface-water channel, and possibly changes in barometric pressure.

Residential Well

RWA-119 was compared to the screening criteria. Only copper with a result of 0.027 mg/L exceeded the NWQA 90th percentile value (0.0123 mg/L). However, given the location of RWA-119 south of ORR, it is expected that this constituent likely derives from sulfide deposits within the country rock.

Tennessee Valley Authority Well

In 2012, the Pump House Well was sampled twice; the results did not report any constituents above the screening criteria.

Monitoring Well

GW-214 was co-sampled with DOE contractors on 07/19/12. Reported field parameters for pH exceeded the EPA secondary standard (pH between 6.5-8.5 standard units) with the highest reading of pH 12.24. Conductivity was 2406 µS/cm and an oxidation reduction potential (ORP) of -89.9 millivolts (mv) was reported. The sample was analyzed for metals, organics, general inorganics, radiochemicals, and nitrogen isotopes.

Monitoring results that exceeded the screening criteria are shown in table 2.

Table 2: GW-214 Results over Screening Criteria

Analyte	Result (mg/L)	Primary MCL (mg/L)	Secondary MCL (mg/L)	Health Advisories (mg/L)	MCLG (mg/L)	NWQA (mg/L)
Aluminum	0.0286	NA	0.05 to 0.2	NA	NA	**0.00528**
Boron	0.850	NA	NA	7	NA	**0.218**
Chloride	654	NA	**250**	NA	NA	**62.8**
Copper	0.0143	NA	1.0	NA	1.3	**0.0123**
Fluoride	3.2	4	**2**	NA	4	**1.1**
Lithium	0.0483	NA	NA	NA	NA	**0.0438**
Selenium	0.0134	NA	NA	NA	NA	**0.00302**
Sodium	564	NA	NA	**20***	NA	**78.7**
Thallium	0.0011	0.002	NA	NA	**0.0005**	**<0.001**
TDS	1410	NA	**500**	NA	NA	**590**

Red numbers denote the results exceeded the specific criteria.
* Not in the Health Advisory Table - listed on Drinking Water Advisory Table (for individuals on a 500 mg/kg restricted sodium diet)
MCL Maximum Contaminant Level - Primary- enforceable standard, Secondary - non enforceable guidelines for cosmetic and aesthetic effects
MCLG Maximum Contaminant Level Goals - non enforceable health goal
mg/L milligram per liter
NA not applicable
NWQA National Water Quality Assessment Program 90th concentration percentile
TDS Total Dissolved Solids
(2011 Edition of the Drinking Water Standards and Health Advisories, 2011)
(DeSimone, 2009)

Both boron and copper have been detected at elevated concentrations around former disposal areas along Bear Creek Valley (Lockheed Martin Energy Systems, 1996). The analysis from groundwater at the closed S-3 site shows all the above constituents from GW-214 to be elevated (UT-Battelle, 2001). The S-2 site could also be a source, with similar constituents to the S-3 site. In addition, elevated pH and sodium could be from the treatment ponds of the ETTP water plant. A dye sample was collected and analyzed. A very small amount of the fluorescent dye uranine (disodium fluorescein) [fluorescence peak at 512 nm] suggested it could have a source upgradient in Bear Creek Valley, Melton Valley, or Bethel Valley where numerous tracer tests have been conducted using that fluorescent tracer.

Oxidation-reduction reactions and pH determine what minerals, or more important, what species of minerals, are soluble. Unfortunately, with high or low pH and high positive or negative ORP values, one would expect to find inorganics in solution similar to those detected depending on source rocks. Therefore, we still need to determine if the inorganics detected are naturally occurring or anthropogenic.

Analysis of groundwater from GW-214 for 2012 is similar to the analysis from RWA-117 sampled in 2011. RWA-117 is located across the Clinch River, along geologic strike and down-gradient approximately three kilometers to the southwest of GW-214. RWA-117 reported a pH of 9.13, ORP of -312.09 mv, fluoride at 4.1 mg/L, sodium at 181 mg/L, and boron at 0.660 mg/L.

Determining the source (natural or anthropogenic) of the constituents is difficult with the limited data collected in Bear Creek Valley. There is a possibility that the elevated pH, sodium, boron, fluoride reported could be from former waste sites along Bear Creek Valley. Further work is needed to determine the source and possibly the distribution of constituents detected.

Surface Water

One surface water sample was collected on Scarboro Creek. All detected compounds were screened against EPA MCL, EPA secondary MCLs, EPA Health Advisories, and EPA MCLG (EPA, 2011). No compounds were detected above the screening criteria.

Unfortunately, low level VOAs are usually not found far from a groundwater discharge location. All we can determine from the sample is that groundwater from Union Valley does not discharge close to the surface water sample location. Henceforth, additional work will need to be done to determine if there is a pathway for deeper flow of a plume from Union Valley along the linear geologic feature of Scarboro Creek.

Springs

Eleven springs were sampled. The spring samples were analyzed for volatile organic compounds, metals, general inorganics, and radionuclides. Stable nitrogen and oxygen isotopes were analyzed from SS-7, SS-8, and U-Spring. Table 3 shows constituents that exceed EPA MCLs, EPA secondary MCLs, EPA Health Advisories, EPA MCLG (EPA, 2011), and the 90^{th} percentile results for the NWQA USGS groundwater study (DeSimone 2009).

The sample collection method for sampling inorganics in springs may be one of the reasons why there is aluminum, iron, and manganese in the samples. Sediments can be suspended from the sampling activities and end up in the sample jars during sample collection. The sediments are then dissolved in the water with the nitric acid preservative prior to analysis in the laboratory.

At SS-4, nitrate, uranium, gross alpha and gross beta were detected at concentrations exceeding the screening criteria. In addition to those samples that exceeded the screen criteria. Bootlegger Spring within the UT Arboretum along Scarboro Road continues to show the presence of dichloroethene, dichloroethane, and trichloroethene in 2012. The VOA results were below their respective EPA MCLs. TDEC has in the past connected the Security Pits to Bootlegger Spring with two separate dye traces(TDEC 1995, TDEC 1996).

Stable Nitrogen and Oxygen Isotopes

Stable nitrogen and oxygen isotopic data was collected for springs SS-7, SS-8, Gallaher and U-Spring in Bear Creek Valley, Pump House Well north of ETTP and GW-214. The results from Gallaher Spring are still pending analysis. The results are plotted as the permil (‰) variation (delta, ∂) of ^{15}N (from AIR [air]) versus and ^{18}O (from VSMOW [Vienna Standard Mean Ocean Water]). (Figure 5)

Table 3: Spring Results over Screening Criteria

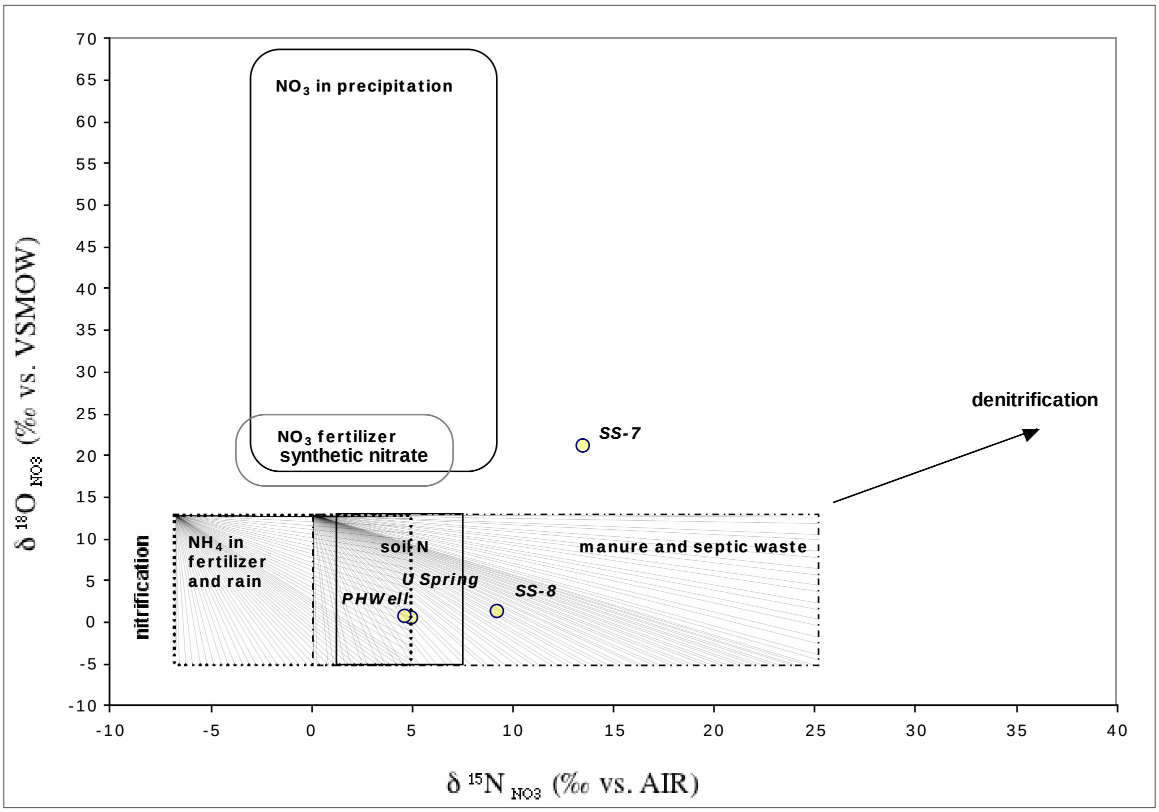
Location	Analyte	Result (mg/L)	Primary MCL (mg/L)	Secondary MCL (mg/L)	Health Advisories (mg/L)	MCLG (mg/L)	NWQA (mg/L)
SS-2	Aluminum	0.195	N/A	**0.05 to 0.2**	NA	NA	**0.00528**
SS-4	Aluminum	0.071	N/A	**0.05 to 0.2**	NA	NA	**0.00528**
SS-4	Uranium	0.0508	**0.030**	N/A	**0.02**	NA	**0.00803**
SS-4	Nitrate	11	**10**	N/A	NA	NA	NA
SS-4	Gross Alpha	20.8 pCi/L	**15** pCi/L	N/A	NA	NA	NA
SS-4	Gross Beta	72 pCi/L	**50** pCi/L*	N/A	NA	NA	NA
SS-5	Aluminum	0.058	N/A	**0.05 to 0.2**	NA	NA	**0.00528**
SS-6	Aluminum	0.314	N/A	**0.05 to 0.2**	NA	NA	**0.00528**
SS-6	Iron	0.396	N/A	**0.300**	NA	NA	1.11
SS-7	Aluminum	0.417	N/A	**0.05 to 0.2**	NA	NA	**0.00528**
SS-7	Iron	0.666	N/A	**0.300**	NA	NA	1.11
SS-8	Aluminum	0.374	N/A	**0.05 to 0.2**	NA	NA	**0.00528**
SS-8	Iron	0.583	N/A	**0.300**	NA	NA	1.11
SS-8	Manganese	0.072	N/A	**0.050**	NA	NA	0.172
U-Spring	Aluminum	0.087	N/A	**0.05 to 0.2**	NA	NA	**0.00528**
Cattail Spring	Manganese	0.370	N/A	**0.050**	NA	NA	**0.172**

Red numbers denote the results exceeded the specific criteria.
* 4 mren/yr is the MCL. However, since there is no simple conversion between mrem/year and pCi/L, EPA considers 50 pCi/L to be the level of concern for gross beta activity.
MCL Maximum Contaminant Level - Primary- enforceable standard, Secondary - non enforceable guidelines for cosmetic and aesthetic effects
MCLG Maximum Contaminant Level Goals - non enforceable health goals
mg/L milligram per liter
NA not applicable
NWQA National Water Quality Assessment Program 90th concentration percentile
pCi/L picrocuries per liter
(2011 Edition of the Drinking Water Standards and Health Advisories, 2011)
(DeSimone, 2009)

The results of the nitrogen isotopic data are shown in Figure 5. For reference, the general fields for various types of nitrate in the hydrosphere are included. As shown in Figure 5, the samples from Pump House Well, and U-Spring both plot in the soil nitrogen field. In contrast, the samples from springs SS-8 and SS-7 in Bear Creek Valley plot outside that area. These two results also exhibit denitrification shifts (i.e., to the right) with the sample from SS-7 plotting nearer the synthetic nitrate field (which includes nitric acid, fertilized soils as well as precipitation, from NO_3 air contamination from several synthetic NO_3 sources).

No nitrate was present in GW-214, the variation of ^{15}N in ammonia is -1.21, the ammonia concentration was 0.43 mg/L and it has been determined and would plot generally in a region for ^{15}N for ammonia related to fertilizer (Kendall and McDonnell, 1998) (the mean value is –0.91 +/- 1.88)

A denitrification trend would be expected, if the source is S-3 ponds, because of a large synthetic nitrate source and extensive biological denitrification treatment prior to closure (UT-Battelle, 2001). In addition, groundwaters are mixtures from different areas, which also results in mixtures of different nitrate sources, as can be seen with the SS-7 and SS-8 plotting to the right of general hydrospheric nitrate fields. SS-7, having previously documented uranium and other contamination from known sources upgradient of the spring, seems to have retained its tracer signal with some clarity. The initial data show that the nitrate analysis using ^{15}N and ^{18}O is a powerful tracer in groundwaters in and around the ORR. The Department of Energy has used these tracers effectively at the Hanford Site, Washington (Singleton et al., 2005).



VSMOW Vienna Standard Mean Ocean Water standard
AIR the standard Nitrogen ratio for air
NH_4 ammonia
N nitrogen
NO_3 nitrate
PH Well Pump House Well
‰ per mille
δ variation

Figure 5: Nitrate analysis using ^{15}N and ^{18}O

Conclusions

DOE-O groundwater monitoring in 2012 was concentrated on and offsite in Bear Creek Valley. Ancillary to the sampling in Bear Creek Valley were the TVA Pump House Well located just north of ETTP, a Residential Well RWA-119 south of the ORR. At the UT Arboretum, Bootlegger Spring and Scarboro Creek were sampled. Springs on and offsite of the reservation were monitored on a continuing basis for various water parameters.

RWA-119 did show a result for copper that exceeded the 90th NWQA percentile value (0.0123 mg/L). However, given the location of RWA-119 south of ORR, it is expected that the results for copper may be related to sulfide deposits. Pump House Well, (sampled twice) did not report any

constituents above the screening criteria. Given the close proximity of Pump House Well to known groundwater contamination it will remain a concern and a target for future sampling.
Bootlegger Spring and Scarboro Creek were each sampled once in 2012. Bootlegger Spring has been shown by TDEC dye traces to be connected to the Security Pits groundwater plume and characteristic VOAs (below applicable MCLs) continue to be reported from analysis of the spring's groundwater in 2012 (dichloroethene, dichloroethane, and trichloroethene). In the past Bootlegger Spring has exceeded MCLs and will remain in the DOE-O monitoring program (TDEC 1995, TDEC 1996).

Scarboro Creek was sampled in consideration of the possibility that an unmapped cross geologic strike feature could provide a preferential path for the Union Valley carbon tetrachloride plume to follow. No significant results were reported from the one surface sample obtained from Scarboro Creek. In general low level VOAs are usually not found far from a groundwater discharge locations. All that can be determined from the sample is that contaminated groundwater from Union Valley does not discharge close to the surface water sample location at the time the sample was obtained. Additional work will need to be done to determine if there is a pathway for deeper flow of a plume from Union Valley along the linear geologic feature of Scarboro Creek.

Results from analysis of groundwater obtained from springs on the ORR within Bear Creek Valley report a continued impact from former disposal areas on the reservation. At spring SS-4 on the reservation, nitrate, uranium, gross alpha and gross beta were detected at concentrations exceeding the screening criteria.

At GW-214 inorganic constituents were detected above the NWQA 90th percentile, similar to areas on and off the ORR. Stable nitrogen isotopic data suggests that GW-214 water contains nitrogen from fertilizer [15-N in ammonia is -1.76 ‰, no nitrate detectable]. The water also contains a very small amount of the fluorescent dye uranine (disodium fluorescein fluorescence peak at 512 nm), suggesting it could have a source upgradient in Bear Creek Valley, Melton Valley, Bethel Valley where numerous tracer tests have been conducted using that fluorescent tracer. Determining the source (natural or anthropogenic) of inorganic constituents is always problematic, particularly considering the limited data collected in Bear Creek Valley. There is a possibility that the elevated pH, aluminum, sodium, boron, fluoride, copper, lithium, selenium, and thallium reported could be from former waste sites along Bear Creek Valley. Further work is needed to determine the source and possibly the distribution of constituents detected.

The record of electric conductivity and temperature at Gallaher Spring shows the following:

- The spring is fed by sinking streams.
- When the Clinch River lake level is above a certain elevation, discharge and water-quality variability at the spring are suppressed.
- When lake level is low the spring seems to operate as a "conventional" spring fed by allogenic recharge (sinking streams) with a characteristic rapid reaction to recharge.

- There are data excursions that could or could not be real that would require additional information to correctly interpret.

Monitoring at Gallaher Spring has served to highlight the complexity of the groundwater system of the ORR. A combination of inputs from sinking streams, and interactions of the varying heads of the Clinch River produces a very complex set of changes in electrical conductivity. The variability of electric conductivity suggests that the spring discharges both overflow and deeper waters when hydraulic conditions allow. The temperature record for Gallaher Spring is generally constant at near the average annual outside temperature, suggesting that the spring is driven by conduit flow of considerable size. It is an understatement to say that this complexity makes sampling the spring to determine all the representative source areas challenging.

Should Gallaher Spring be indeed impacted by former disposal areas, it is expected that such contaminated groundwater would be associated with a deep flow system. The sampling of Gallaher Spring and other offsite locations has been frustrating. Gallaher spring has shown potentially variable source areas that react to several different hydrogeologic conditions. The changing conditions are difficult to predict. Contaminants may be present during one sampling event and absent for the next event.

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RADIOLOGICAL MONITORING

Facility Survey Program and Infrastructure Reduction Work Plan

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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 202 facilities and found that forty-three 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 2012 no facilities were removed due to the expiration of American Recovery and Reinvestment Act funds. During 2012, staff conducted five facility surveys, four at Y-12 and one at ORNL (see Table 3).

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. During 2012 staff made 22 site visits to observe D&D related activity (see Table 3). Three facility surveys were completed and sent to DOE in 2012.

Introduction

The Tennessee Department of Environment and Conservation's Department of Energy Oversight Office, in cooperation with the Department of Energy (DOE) and its contractors, conducts a Facility Survey Program (FSP) on the Oak Ridge Reservation (ORR). The program provides a comprehensive, independent assessment of active and inactive facilities on the reservation based on their 1) physical condition, 2) inventories of radiological materials and hazardous chemicals, 3) levels of contamination, and 4) operational history. The ultimate goal of the program is to fulfill 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) to provide a better understanding by the local governments and the public of past and present operations at the ORR and impacts on human health and/or the environment by the ORR*."

The overall objective of the Facility Survey Program is to provide a detailed assessment of all potential hazards affecting, or in any way associated with, facilities on the Oak Ridge Reservation. To this end, the program evaluates facilities' potential for release of contaminants to the environment under varying environmental conditions ranging from catastrophic (i.e. tornado, earthquake) to normal everyday working situations. This information is also incorporated into local emergency preparedness planning.

Methods and Materials

Survey program staff members take a historical research approach to evaluating each facility. Prior to commencing fieldwork they examine engineering documents, past contaminant release information, hazard-screening and safety basis documents, drain databases, and radiological and chemical inventory data. They then perform a walk-through of the facility with the facility manager to gather additional information and to validate information acquired from previously reviewed documents. During the field visit, calibrated, industry standard, radiation survey instruments are used to estimate radiation contamination and dose levels in and around the footprint of each facility. At the end of the document review and walk-through process, a final report is produced and information is entered into the office's Potential for Environmental Release (PER) database. This database helps the team characterize conditions at each facility based on its physical condition and potential for release of contaminants to the environment.

The PER database is composed of ten categories that relate directly to the contents and condition of the operational infrastructure within and around each facility (Table 1). Each category is assigned a score from 0 to 5 (5 reflects the greatest potential for release) for each of the ten categories. As facilities are scored, totaled, and compared with each other, a relative ranking emerges. Special circumstances, such as legacy releases and professional judgment also influence category scoring. Scores are not intended to reflect human health risk. Rather, their sole purpose is to help characterize facilities based on the conditions in and around them. This information is used within the office for information, comparison, and review purposes only.

Table 1: Categories to be 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
7.	Ventilation ducts and exit pathways to create outdoor air pollution
8.	Ventilation ducts and indoor air/building contamination threat
9.	Radiation exposure rates inside the facility elevated
10.	Radiation exposure rates outside the facility elevated

The final facility survey report notifies DOE of the office's findings so that DOE has the opportunity to respond and formulate corrective actions. When the office receives written confirmation from DOE of corrective actions taken at a specific facility, the rankings for that facility are modified accordingly in the PER database. The scoring criteria for each category are presented below in Table 2. Table 3 provides a program summary.

Table 2: Potential 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**: quantities of 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**: quantities of radiological or hazardous substances present, containment for any period of time is questionable, migration to environment has not started.
5	**Release:** 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.	

Discussion and Results

The Facility Survey Program entered its nineteenth year in January 2012. 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
Totals	**202**	**86**	**39**	**10**	**1516**

Description of the 53 Highest Scoring Facilities (1994-2012)

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 202 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).

At **Y-12**, nine facilities had at least one category score of 4 or 5: Y9731, Y9204-3, Y9201-4, Y9401-2, Y9213, Y9743-2, Y9203, Y9401-1 and, Y9207.

Facility Y9731 is the oldest facility in the Y-12 complex. It originally housed the pilot project for the prototype calutron, and the original production facilities for stabilized metallic isotopes, which were used in nuclear medicine. It received four category scores of 5, two category scores of 4, and a total score of 37. Most of the facility (outside the office area) today is not receiving preventative maintenance. Process tanks and lines have leaked radiological and hazardous materials throughout the building. Asbestos-containing pipe insulation is peeling and flaking, as is lead-bearing interior and exterior paint. The exhaust fans for the building are not HEPA filtered, and therefore pose a direct pathway to the environment.

Facility Y9204-3 (Beta 3) is one of the original isotope enrichment facilities at Y-12. It received two category scores of 5, three category scores of 4, and a total score of 33. This 250,000 square-foot facility is now inactive and locked. The largest concerns are leaking PCB-contaminated mineral oil (Z-oil), and radiological contamination. The building has not been sampled above eight feet for radiological contamination, even though the probability of finding it is great. The building historically and presently vents directly to the environment without HEPA filtration.

Facility Y9201-4 (Alpha 4) is also one of the original Y-12 uranium enrichment buildings. It received three category scores of 5, one category score of 4, and a total score of 28. The containment integrity of the original process system is weak. This has resulted in breaches that have deposited contaminants in unwanted places throughout the building. Evidence suggests that open (non-filtered) exhaust fans have also released contaminants from the interior of the building to the environment for decades. PCBs, asbestos insulation, and chipping/flaking lead-based paint are also found deposited throughout the building.

Facility Y9401-2 (Plating Shop) received four category scores of 4, one category score of 5, and a total score of 25. All of these scores relate to a variety of chemical contamination issues.

Facility Y9213 (Criticality Experiment Facility) received two category scores of 5, and a total score of 24. This facility was built in 1951 and contains two underground neutralization tanks and an underground pit. The tanks and pit present a very high potential for radiological and chemical soil contamination. The areas around the tanks have not been sampled for contamination. The facility also exhibits extensive flaking of exterior lead-based paint.

Facility Y9203 (Instrumentation, Characterization Department and Manufacturing Technology Development Center) received three category scores of 4 and a total score of 22.5. Despite much work that has been done to re-route process drains in order to prevent them from terminating in the storm sewer system, these drains now go to the sanitary sewer system. This termination still presents a potential pathway to the environment and the public.

Facility Y9743-2 (Animal Quarters) received two category scores of 5, and a total score of 23. These scores reflect the uncertainty associated with the lack of radiological and chemical sampling surveys, the complete lack of institutional and process knowledge and the fact that there are interior tanks and bottles with unknown contents. The probability of biological and chemical contamination is high. There is also a total lack of facility maintenance.

Facility Y9207 (Biology Complex) received one category score of 4, and a total score of 13. In this facility, the sinks in a radiological area drain directly to the Oak Ridge sewer system, and thus represent a potential pathway for radiological materials to the city sewage and sludge.

Facility Y9401-1 received two category scores of 5 and one category score of 4. The primary issue with this facility is radiological contamination; the furnace room is contaminated and not enterable. Also, there are small amounts of external contamination around the building from past operations.

At **ETTP,** five facilities had at least one category score of four or five: K1037-C, K633, K1200-S, K1004-J, and K1220-N.

Facility K633 received five category scores of 5, two category scores of 4 and a total score of 39. There is extensive radiological contamination throughout the building, and extensive peeling of exterior and interior paint, which contains PCBs, asbestos, and lead. External soil contamination suggests radiological material has moved to the environment.

Facility K1037-C (Nickel Smelter House) received five category scores of 5, one category score of 4, and a total score of 29. This is an old facility in general disrepair. It has numerous roof leaks and is heavily contaminated, both radiologically and chemically. Large scrubber-type vessels located on the east end of the second floor of the barrier production area contain internal radioactive contamination. Discarded contaminated equipment is stored in the building. The facility is posted as a PCB hazard. No corrective actions have been completed at this facility.

Facility K1200-S (Centrifuge Preparation Laboratory, South Bay) received two category scores of 4 and a total score of 26.5. The high score is primarily attributable to the uncertainty of radiological contamination associated with the ventilation system. The interior ductwork and portions of the roof where air is exhausted have not been surveyed for contamination. The potential for airborne release appears great. Equipment inside the facility contains uranium hexafluoride and other hazardous chemicals, and there are numerous radiologically-contaminated storage areas. Confined space entry requirements prevented the office from performing a survey of the pits below the centrifuges. The greatest release potential for contaminants would be during decontamination and decommissioning activities. *Equipment removal and cleanup is ongoing at* *this facility. It is expected that the facility will be removed from the office's "high rankers" list in the future.*

Facility K1004-J received two category scores of 5, one category score of 4, and a total score of 19. This facility was constructed in 1948 and was originally used for uranium recovery from spent fuel solutions and centrifuge research. It originally included a hot cell, reinforced concrete vaults, a 750-gallon "hot" tank, a 5,500-gallon underground low-level liquid waste tank, and a laboratory. The facility was ranked high in the PER database because of the insufficient knowledge concerning facility infrastructure. First, there is considerable uncertainty over the location and number of active storage vaults under the facility. It is also unknown whether any of these vaults contain radioactive materials or contamination. There is considerable uncertainty over drainpipe connections and their contribution of radiological and chemical contaminants to general area contamination. During 2011 all the combustibles and most other equipment was removed from this facility.

Facility K1220-N (Centrifuge Plant Demonstration Facility, North) received one category score of 4 and a total score of 18. The interior ductwork has not been surveyed for radiological contamination and the score reflects a high degree of uncertainty concerning the presence of radionuclides. Uranium residuals are present inside the centrifuge systems. After the centrifuge systems are removed and the criticality and security concerns are addressed, this facility is a candidate for reuse. No corrective actions have been conducted at this facility.

At **ORNL,** thirty-three facilities had at least one category score of four or five: X3026, X3029, X3033, X3028, X4507, X3517, X3005, X3030, X7019, X3508, X3031, X3118, X3033-A, X3019-B, X3032, X7720, X7700-B, X2545, X3020, X3108, X3091, X3592, X3504, X3001, X7706, X7707, X2531, X3002, X3003, X3018, X7602, X7019, and X7025/48.

Facility X3517 received five category scores of 5, one category score of 4, and a total score of 39. Despite these relatively high scores, the physical condition of this facility is good, and much effort has gone into decontamination and cleanup work inside the facility. Still, breaches in containment/process systems in the facility resulted in low levels of radiological contamination being distributed throughout. The liquid low level waste system has contributed radiological contamination to the soil and groundwater outside the building.

Facility X3029 (Radioisotope Production Area/Source Development Lab) received five category scores of 5, three category scores of 4, and a total score of 38. This entire hot cell facility is a posted radiological contamination zone that also contains interior, posted radiation areas. During operation, radiological contamination migrated from hot cells and found its way into floor drains and lines. There is a very high probability that this contamination migrated from drain lines and contributed to soil and ground water contamination. The facility also exhibits old, broken floor tiles (containing asbestos) and extensive peeling of lead-based interior and exterior paint. During its operation, X3029 handled Co-60, Cs-137, Sr-90, Ir-192, C-14, Tc-99, I-131, as well as other radioisotopes. The facility was shut down in the late 1960s.

Facility X3033 (Krypton and Tritium Facility) received three category scores of 5, four category scores of 4, and a total score of 37. This is another surplus Isotope Circle facility. It was placed in standby mode in the 1990s. The facility also includes a five-foot tall cinder block containment structure that houses four, charcoal-filled stainless steel tanks used for permanent storage of Kr-85. Radiation dose rates are still relatively high around and above the top edge of the wall of this structure. During its operational history, this facility processed C-14, Kr-85, H-3 and probably other radioisotopes. The entire facility is a posted radiological contamination zone, and there is a high probability that the facility has contributed to soil and groundwater contamination via leaky process and low level wastewater collection lines. In a man-hole type of sump near the S.W. corner of the building, radiological dose rates approach 10 mR/hr. from Cs-137 contamination.

Facility X3028 received two category scores of 5, five category scores of 4, and a total score of 36. The primary issue with this facility was the relatively large quantity of radiological contamination distributed throughout the building. It also shows extensive peeling and chipping of interior wall paint that is supposed to serve as containment for plutonium contamination. Ongoing corrective actions are occurring at this facility.

Facility X3005 (Low-Intensity Test Reactor) received three category scores of 5, one category score of 4, and a total score of 35. The primary issues with this facility are activation products associated with the reactor, reactor infrastructure, and reactor shielding materials. Radioactive contamination also exists throughout the facility. A leaky roof on the eastern half of the facility has caused excessive, interior mold and mildew buildup. Another concern is the large quantities of flaking and peeling lead-based, PCB-containing paint on the interior and exterior of the building.

Facility X4507 (High-Radiation Level Chemical Development Facility) and adjoining X4556 (Filter Pit), received five category scores of 4, one category score of 5, and a total score of 35. The primary concern with this facility is radiological contamination. The entire building is a posted contamination zone, with several areas of elevated radiation dose. There are four contaminated hot cells. There was a significant curium-244 spill adjacent to Cell 4. Contamination has historically leaked from degraded low level liquid waste lines into surrounding soil and groundwater.

Facility X3508 (High-Level Alpha Radiation Lab) received seven category scores of 4, two category scores of 5, and a total score of 38. This facility has a history of beryllium use/storage. There are two separate banks of hot cells. (There are low levels of radiological contamination scattered throughout the building that generate elevated radiological dose rates.)

Facility X3019-B (High-Level Radiation Analytical Laboratory) at ORNL received four category scores of 4, one category score of 5, and a total score of 33. The primary concern with this facility is the very high levels of radiological contamination. The eight hot cells in this facility are "Very High Radiation Areas" and contain many different radionuclides from past operations. The in-cell steam pipes, the off-gas ventilation system, and the ventilation ductwork on the roof are also radiologically contaminated. Also, the laboratory off-gas ductwork located above the hot cells contains perchlorates six times above the maximum recommended by the ORNL Perchloric

Acid Committee. Perchlorates are shock sensitive and have the potential to react violently when disturbed. Signage identifying this hazard is posted.

Facility X3030 (Radioisotope Production Lab) received four category scores of 5, one category score of 4, and a total score of 31. This surplus Isotope Circle facility processed a wide range of radioisotopes during its 50-year operational history, including Co-56, Co-57, Au-198, Fe-55, Np-234, Se-75, Sr-90, Sn-119m, U-237, P-33, and Ir-192. All operations were stopped in the late 1990s. The facility contains "High Contamination" as well as "High Radiation" areas. As with most other Isotope Circle processing facilities, there is a very high probability that X3030 contributed radiological contamination to soil and groundwater via exfiltration from leaky wastewater and process lines. And like many other of these nonoperational surplus facilities, it also exhibits extensive peeling of exterior lead-based paint that is moving into the environment.
Facility X7019 (Storage Facility) received three category scores of 5 and one category score of 4. The entire facility is an airborne radiological zone and requires a respirator for entry. There is one spot of radiological contamination in the surrounding yard. The building is also a beryllium contamination zone.

Facility X3033-A (Actinide Fabrication Facility) received four category scores of 4, one category score of 5, and a total score of 31. This facility contributed to soil and groundwater contamination via leaky process and liquid low-level waste lines. Most of the remaining radiological contamination is present in small, fixed hot spots of alpha-emitting transuranics, including plutonium, americium, and curium.

Facility X3032 (Radioisotope Production Lab E) received three category scores of 4, one category score of 5, and a total of 29. These scores are primarily related to the fact that leaky process and liquid low-level waste lines contributed to soil and ground water contamination. Also, lead-based paint that was used as wall covering throughout the facility is peeling and flaking excessively.

Facility X3001 (Graphite Reactor) at ORNL received two category scores of 4, and a total score of 28. The primary concern with this facility is that there is considerable radiological contamination. The air exhaust shaft that vented the reactor pile is contaminated with cesium-137, strontium-90 and fission products. This is a source releasable to the outside environment if a fire or other event occurred in the ventilation system. Several corrective actions, such as the plugging of drains that went to the sewer system, were recently implemented at this facility.

Facility X3031 (Radioisotope Production Lab) received four category scores of 4, one category score of 5, and a total score of 27. This facility was built in 1950 as part of the Isotopes Program and was deactivated in 1997. During its active history, it processed a wide variety of radioisotopes. Today it contains fixed and removable radiological contamination located in "High Contamination" and "Radiation" areas. Leaky process and low-level waste water collection lines have contributed to soil and groundwater contamination.

Facility X3118 (Radioisotope Production Lab) received four category scores of 4, one category score of 5, and a total score of 27. The primary issues with this building are a leaky roof, a leaky process waste-water line that has contributed to soil and groundwater contamination and, flaking and peeling lead-based paint throughout the facility.

Facility X3592 (Coal Conversion Facility) received two category scores of 4, and a total score of 27. Its original mission was to explore the potential for utilizing liquefied coal as an alternative fuel source. But in later years the facility performed lithium isotope separation using massive quantities of mercury. The scores were given for transferable radiological contamination and mercury contamination found in the drains.

Facilities X7706, X7720, X7700-B and X7707 (Cooling House, Civil Defense Bunker, Below-ground Outside Source Storage Area) are all part of the Tower Shielding Complex. A survey of this group of facilities resulted in seven category scores of 4. The primary issues at this complex of facilities are soil contamination, uncovered activated and contaminated concrete rubble, and drain lines that have direct connections to the environment.

Facility X2545 (Coal Yard Runoff Collection Basins) at ORNL received one category score of 5, two category scores of 4, and a total score of 21. Orphaned, 2- and 6-inch diameter, cast iron low-level liquid waste (LLLW) lines run through the facility property, and a LLLW line box is posted as a "Radiation Area". The area has been chained off and is overgrown with vegetation. Due to the radiological postings, the cast iron LLLW lines are assumed to be degraded and leaking to the environment. ORNL Environmental Restoration staff has been notified of these lines and their condition, but TDEC has not received written confirmation concerning planned corrective actions.

Facility X2531 (Radiological Waste Evaporator Facility) received one category score of 5, one score of 4, and a total score of 21. This ranking includes X2537 (Evaporator Pit) and X2568 (HEPA filter bldg.). Even though this is a relatively clean, modern facility, it earned these scores because of several areas of transferable radiological contamination and high radiological dose rates surrounding the evaporator pit.

Facility X3504 (Geosciences Lab) received one category score of 5, one score of 4, and a total of 20. The entire building is a posted "Contamination Area". There is also underground and soil contamination outside of the building.

Facility X3026 received one category score of 5, one category score of 4, and a total score of 19. Although this building was demolished in 2009, the two banks of contaminated hot cells and building pad still remain. The hot cells were encapsulated in 2009, as was the floor. The liquid low-level waste lines to which the hot cells and building were attached remain. They historically leaked and contributed to soil contamination at the northwest corner (and elsewhere) of the facility. The subterranean, contaminated trench, once a canal, is still intact. Additional decontamination of the hot cells occurred in 2011.

Facility X3003 and ventilation stack X3018. Facility X3003 received two category scores of 5, five category scores of 4 and a total score of 35. Stack X3018 received three category scores of 5, and a total score of 17. Both facilities' scores reflect radiological contamination, exterior soil contamination zones, contaminated, underground LLLW lines and contaminated ventilation ductwork.

Facility X3002 (HEPA Filter House for the Graphite Reactor) received one category score of 4 and a total score of 18. The primary hazards associated with this building are related to the high level of airborne and other radiological contamination in the roughing filter room, the HEPA filter bank, and the ventilation system. Several corrective actions recommended by the office were implemented at this facility.

Facility X3020 (Radiological stack for bldgs. 3019A-B) received three category scores of 5 and a total score of 18. All of the major concerns noted for this facility were related to legacy features that are not part of the present-day operational infrastructure. There is an antiquated, contaminated drain line that was part of the ORNL LLLW system. This line leaked and contributed to surface and subsurface contamination of the general area from the 1940's through the 1970's. It was capped in the late 1970's, but is possibly still contributing contamination. There is also a contaminated, above-grade, single-walled concrete sump box attached to the floor drain system.

Facilities X3108 and X3091 (HEPA filter houses for buildings X3019A-B and Radiological Stack X3020) each received three category scores of 5; X3108 received a total score of 23, and X3091 received a total score of 25. These two facilities are physically connected to the X3020 stack. And like the X3020 stack situation described above, all major concerns noted with these facilities are related to their non-operational infrastructure. Associated with both facilities is a contaminated drain system that went to the LLLW system. This line leaked and contributed to general-area surface and subsurface contamination from the 1940's through the 1970's. It was capped in the late 1970's, but is possibly still contributing to contamination. Both facilities also contain significant levels of radiological contamination, considerable contaminated aboveground ductwork, and contaminated lower-level HEPA filter pits. Both facilities are non-state-of-the-art structures that are adequately maintained.

Facility X7602 (Integrated Process Development Lab.) received one category score of 4 and a total score of 17. The primary concern with this building was the extensive transferable radiological contamination throughout the facility.

Facility X7019 received four category scores of 5. The entire building is a respirator zone due to beryllium contamination. It is also radiologically contaminated. Radiological contamination has escaped into the surrounding environment in at least one place.

Facility X7025/48 received one category score of 5 and one category score of 4. These scores were assigned because of interior and exterior radiological contamination.

Conclusion

The historic release of chemical and radiological materials from buildings and other facilities on the Department of Energy's Oak Ridge Reservation has led to elevated levels of contaminants in regional terrestrial and aquatic ecosystems. In an effort to understand more about the sources of these contaminants, the DOE-O office investigates the historic and present-day potential for release of contaminants from facilities through its Facility Survey Program. During its nineteen-year history the program has examined 202 facilities and found that forty-three percent (86) have either contributed to, or pose a relatively high potential for, release of some contaminant to the environment. These facilities are referred to as “high rankers” in the program’s Potential for Environmental Release database.

In many cases, legacy contamination from degraded facility infrastructure, such as underground waste lines, substandard sumps and tanks, or ventilation ductwork, is generating high scores in the database. This will continue until deteriorating facilities are fully remediated. This is particularly the case at Oak Ridge National Laboratory where many facilities were connected to an aging, leaky underground low-level liquid waste line system. Inactive facilities that are no longer receiving adequate exterior or interior maintenance are also driving high scores. On many buildings, peeling lead-based paint is extensive, and leaky roofs are common. These conditions will only worsen as time passes if not remediated. On the other hand, formal infrastructure reduction programs that began at Y-12 and ORNL in 2002 and at ETTP in 2003 are alleviating many of these problem areas.

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.

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

Scoring Categories	**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

Table 4: (continued) Potential for Environmental Release for High-Scoring Facilities

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
*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).

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Haul Road Radiological Surveys

Principal Author: David C. Foster

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 in Bear Creek Valley for disposal. To account for wastes that may have originated from trucks in transit, personnel from the Tennessee Department of Environment and Conservation perform walkover inspections of the road and associated access roads weekly. Items noted are surveyed for radiological contamination, documented, and their description and location submitted to DOE for disposition. During 2012, a number items were noted that had potentially fallen from trucks transporting waste to the EMWMF, but none exhibited radioactivity in excess of free release limits and all were removed expeditiously after being reported to the Department of Energy.

Introduction

The DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation (the division), with the cooperation of the U.S. Department of Energy (DOE) and its contractors, conducts periodic walkover surveys of haul roads dedicated to the transport of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) radioactive and hazardous waste on the Oak Ridge Reservation (ORR). To account for CERCLA radioactive and hazardous wastes that may have originated from trucks in transit, this office, in an effort to protect the environment and the citizens of the state of Tennessee, implemented a plan to routinely survey roads on the ORR used for hauling or transporting radioactive material.

Walkover surveys are conducted on segments of the haul road (ETTP to EMWMF) on a weekly basis, weather permitting. Walkover surveys are also conducted on an "as needed" basis on other roads within the ORR (such as Reeves Road or other designated roads). Any areas or items exceeding 200 dpm/100 cm^2 removable beta, 1000 dpm/100 cm^2 total beta, 20 dpm/100 cm^2 removable alpha, and 100 dpm/100 cm^2 total alpha would require further investigation depending on the isotope(s) involved. These release limits are conservative for the most restrictive isotopes. Ambient gamma surveys of the road surface are conducted using the Ludlum Model 2221 Scaler Ratemeter with the Model 44-10 2x2 inch sodium iodide (NaI) Gamma Scintillator. Normal background with this instrument on the Oak Ridge Reservation is 5,000 - 11,000 cpm. A Ludlum 2224 Alpha/Beta dual detection meter is used to investigate surface contamination on potential CERCLA waste items found on or beside the road, and on the road surface. A survey form or equivalent is maintained for each walkover survey and is retained at the office. If any items are identified during the walkover survey, the information is directed to the TDEC Radiological Monitoring and Oversight Program Manager and corresponding DOE officials are contacted. Items noted are documented and their description and location submitted to DOE for disposition.

Methods and Materials

Procedures employed during the project are consistent with those contained in the office's work plan for the walkover survey program for field radiological surveys. The walkover surveys are conducted using a physical approach. A walkover survey of the area is conducted with the use of the office's radiological detection instruments. The instruments available for use are provided in Table 1.

Table 1: DOE Oversight Division 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 (cpm)
Ludlum Model 2224 Scaler / Ratemeter	Ludlum 43-93 Alpha / Beta Scintillation Detector	Alpha, Beta (cpm)
Ludlum Model 3 Survey Meter	Ludlum Model 44-9 Pancake G-M Detector	Alpha, Beta, Gamma (cpm)
Ludlum Model 3 Survey Meter	Ludlum Model 43-65 50 cm^2 Alpha Scintillator	Alpha (cpm)
Bicron Micro Rem	Internal 1x1" NaI Gamma Scintillator	Tissue Dose Equivalent, Gamma (µRem/hr)
Bubble Technology Industries Microspec-2	E-Probe With 2x2" NaI Gamma Scintillator	Gamma Spectroscopy (Isotope Identification)

The instrument used for gross high energy gamma detection on road surfaces is the Ludlum Model 2221 Scaler Ratemeter with the Model 44-10 2x2 inch NaI Gamma Scintillator. A Ludlum 2224 Scaler with a Model 43-93 Alpha/Beta dual detector is used to investigate potential contamination on road surfaces and items that may be associated with CERCLA hazardous and radioactive waste shipments. Other radiological instruments may be used on an "as needed" basis.

Two staff members conduct the haul road walkover survey. The staff members visually split the road into halves lengthwise and each staff member surveys one-half of the road by walking in a serpentine motion from side to side along the designated portion of road. The NaI probes are held approximately six to twelve inches above the ground's surface. Staff members also perform a visual inspection of the road and adjacent area's for items that may have originated from trucks or impacted areas for further investigation.

Areas with staining of soil surface, road surface, stressed vegetation, or items associated with CERCLA hazardous and radioactive waste shipments are noted. When an area of concern or an item is noted, staff mark the area or item with yellow ribbon to be located for further investigation and/or disposition; GPS may also be used. A survey form or equivalent is maintained for each trip and contains the state's findings for that survey. If necessary, concerns are brought to the attention of the Federal Facility Agreement (FFA) and/or the Tennessee Oversight Agreement (TOA) project managers for resolution.

Results and Discussion

The objective of this oversight activity is the detection of CERCLA hazardous and radioactive wastes that may have originated from trucks in transit. The 2012 objective consisted of weekly walkover surveys of designated segments of the haul road. The office performed a documented survey for each segment of road inspected. The purpose of the oversight activity is to determine the presence of any CERCLA hazardous and radioactive waste located on the roads used for hauling or transporting waste or material on the Oak Ridge Reservation. For 2012, no surface contamination readings exceeding free release limits were documented and all ambient high energy gamma readings were within the acceptable range of normal background for the area.

Conclusions

The continued use of roads used for hauling or transporting radioactive material on the Oak Ridge Reservation warrants the state's routine walkover surveys in order to adequately determine the potential presence or lack of any radionuclides or CERCLA waste. The plan is to continue to investigate and survey the ORR haul roads routinely and evaluate the potential for new pathways for any radionuclides or CERCLA waste to reach public roads from the ORR. As a result of continued D&D activities at the ETTP facility, the volume of waste being transported to EMWMF remained relatively constant at the 2012 level, and will continue to be monitored accordingly in 2013.

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Ambient Radiation Monitoring on the Oak Ridge Reservation Using Environmental Dosimetry

Principal Author: David C. Foster

Abstract

The Tennessee Department of Environment and Conservation began monitoring ambient radiation levels on the Oak Ridge Reservation in 1995. The program provides 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 the state dose limit for members of the public. While all the doses reported for 2012 at off-site locations were below the dose limit for members of the public, several locations 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 of on the Department of Energy (DOE) Oak Ridge Reservation (ORR). Associated contaminants are evident in ORR facilities and surrounding soils, sediments, and waters. In order to 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. This 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.
- Information relative to the unplanned release of radioactive contaminants on the ORR.

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 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 dosimeter uses an aluminum oxide photon detector to measure the dose from gamma radiation (minimum reporting value = 1 millirem (mrem). At locations where a potential for the release of neutron radiation exists, the dosimeters also contain an allyl diglycol carbonate based neutron detector (minimum reporting value = 10 mrem). Dosimeters are collected quarterly and sent to Landauer 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 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 was subtracted from the results for the field-deployed dosimeters by the vendor 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 is compared to background values and 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 are 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 to 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 office's Ambient Radiation Monitoring 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 to be the actual case, the doses reported should be viewed as conservative estimates of the maximum dose an individual would receive at each location.

Stations off the Oak Ridge Reservation

All the doses reported for monitoring stations off the reservation (e.g., residential areas) were below the 100 mrem/year dose limit for members of the public. The highest reported annual dose (89 mrem) for locations off the ORR was found near a privately owned waste processing facility near the west end of Bear Creek Road. The previous year's dose at this location was 102 mrem. Otherwise, doses reported for off-site locations were similar to the national average for natural exposures to terrestrial radiation (28 mrem/year) and cosmic sources (27 mrem/year) (NCRP, 1987).

East Tennessee Technology Park

The doses reported from ETTP and vicinity sites were all below the 100 mrem/year dose limits for members of the public

Oak Ridge National Laboratory

ORNL is unique in that land adjacent to the 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). Access to the site is controlled for security purposes, but admittance is allowed with the appropriate visitor's pass and associated health and safety training. Within the access controlled areas, certain sites have been designated as radiation areas for safety.

At ORNL there were twenty-one monitoring stations that exceeded the 100 mrem/year dose limits. Eleven of these sites are located in remote areas with access restricted to the general public. The sites are:

- The Molten Salt Reactor Experiment.
- The New Hydrofracture Facility.
- Melton Valley Haul Road.
- The Cask Storage Containment Area.
- Solid Waste Storage Area 5.
- The Solid Waste Storage Area 5 Transuranic Waste Trench.
- The confluence of White Oak Creek and Melton Branch.
- White Oak Creek Weir at Lagoon Road.
- The Hot Spot on Haw Ridge.
- The Cesium Forest satellite plot and.
- The Cesium Forest.
- North Central Avenue.
- Building 3038 North.
- Building 3607.
- TH4 Tank area.
- Hot Storage Garden.
- Building 3618.
- Neutralization Plant.
- North Tank Farm (west).
- North Tank Farm (south).
- The North Tank Farm (north).

The highest dose for 2012, 29,875 mrem for the year, was at a tulip poplar tree in ORNL's Cesium Forest (Station 32). 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). Based on the dosimetry results, it appears a significant amount of the cesium remains in the trees and local environment. The previous year's dose at the poplar tree was 28,725 mrem; the tree is in a posted radiation area. Please refer to Table 1 for the remaining values exceeding 100 mrem/year.

Several stations of particular interest on ORNL's main campus that changed from last year should be monitored closely in 2013. The materials storage area (Building 3607) south of the irradiated fuels building (Building 3525) annual dose was 16,243 mrem. Vehicles often parked next to building 3607 and the boundary of the radiation area. It should be noted, the dose at this location was reduced from that reported in 2011 (26,058 mrem) by reconfiguring the material stored at the location. Several of the locations exceeding 100 mrem/year in 2012 were due to ongoing remedial actions and are expected to decrease substantially in future reporting (e.g., the North Tank Farm stations). All twenty-one areas warrant continued monitoring, due to the potential for public exposures.

Spallation Neutron Source

With the opening of the SNS for research, the office extended the dosimeter program to cover the site. Currently 16 dosimeters are stationed at the facility to monitor the potential release of gamma or neutron radiation. The highest observed yearly dose at the site was 194 mrem from the central exhaust facility. The previous year's dose at the central exhaust facility was 81 mrem.

Y-12

In addition to the dosimeters located at EMWMF (below), 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. There were no doses reported above 100 mrem in 2012.

Environmental Management Waste Management Facility

In 2007, the dosimeter program began monitoring two locations within the EMWMF complex: the waste cell and the contact water ponds. Dosimeters have been placed on the fence around the boundary at each location. Doses did not exceed the 100 mrem dose limit at either facility for 2012.

Conclusion

Overall, the doses reported for locations monitored in the Environmental Dosimetry Program in 2012 decreased or stayed approximately the same as reported in 2011. The doses for a number of these sites are expected to decrease in 2013, as remedial activities at the locations are completed. A total of twenty-two locations (twenty-one at ORNL and one at SNS) exceeded the 100 mrem/year standard used to evaluate the results; these may need further review and/or action in 2013.

Table 1: 2012 Results from TDEC Monitoring on the Oak Ridge Reservation using Environmental Dosimeters

2012 Results for TDEC monitoring on the Oak Ridge Reservation using Environmental Dosimetry										
Station # (Dosimeter)		**Location** *Optically Stimulated Luminescent Dosimeter (OSLs) are reported quarterly & neutron dosimeters are reported semi-annually*	**Type of Radiation**	**Dose Reported for 2012 in mrem** *M = Below Minimum Reportable Quantity*				**2012 Total Dose ****	**2011 Total Dose ****
				1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
Off Site									
9	(OSL)	Norris Dam Air Monitoring Station (Background)	Gamma	3	3	6	M	12	15
86	(OSL)	Loudoun Dam Air Monitoring Station (Background)	Gamma	3	2	6	M	11	22
86a	(Neutron)	Loudoun Dam Air Monitoring Station (Background)	Gamma	3	4	4	M	11	20
			Neutron	M	M	M	M	0	M
66	(OSL)	Emory Valley Greenway	Gamma	12	14	15	33	74	60
80	(OSL)	Elza Gate	Gamma	4	2	4	NA	10	15
65	(OSL)	California Avenue	Gamma	M	4	4	21	29	12
64	(OSL)	Cedar Hill Greenway	Gamma	M	3	4	21	28	14
63	(OSL)	Key Springs Road	Gamma	2	2	3	32	39	12
62	(OSL)	East Pawley	Gamma	2	4	6	NA	12	22
67	(OSL)	West Vanderbilt	Gamma	5	8	11	19	43	34
70	(OSL)	Scarboro Perimeter Air Monitoring Station	Gamma	6	8	8	M	22	33
91	(OSL)	Corehole 8 RMSA (1st Quarter only)	Gamma	67	NA	NA	NA	67	NA
91	(OSL)	2nd Quarter at Emory Valley Pump House (2nd thru fourth quarter)	Gamma	NEW	17	18	28	63	NEW
East Tennessee Technology Park									
43	(OSL)	K-1401 Building (West side)	Gamma	7	9	9	4	29	36
48	(OSL)	K-1420 Building	Gamma	M	M	M	5	5	7
44	(OSL)	K-25 Building	Gamma	2	3	3	5	13	13
160	(OSL)	K-27 Building (SW Corner)	Gamma	Absent	3	2	31	36	7

East Tennessee Technology Park (cont.)								
159 (OSL)	K-27 Building (South side)	Gamma	M	2	2	Absent	4	M
158 (OSL)	K-27 Building (SE Corner)	Gamma	1	5	3	2	11	15
155 (OSL)	K-27 Building (NW Corner)	Gamma	2	6	6	1	15	18
156 (OSL)	K-27 Building (North side)	Gamma	M	3	3	M	6	14
157 (OSL)	K-27 Building (NE Corner)	Gamma	M	M	2	16	18	7
16 (OSL)	K-901 Pond	Gamma	4	1	4	9	18	12
15 (OSL)	K-1070-A Burial Ground	Gamma	3	4	5	M	12	17
79 (OSL)	ED1 on pole	Gamma	3	6	8	9	26	27
58 (OSL)	K-25 Portal 5	Gamma	3	5	5	M	13	24
177 (OSL)	TSCA West Gate	Gamma	M	M	3	7	10	M
178 (OSL)	TSCA North Gate	Gamma	M	4	2	M	6	7
72 (OSL)	ETTP Visitors Overlook	Gamma	7	10	10	Absent	27	37
45 (OSL)	K-770 Scrap Yard	Gamma	4	1	2	5	12	M
47 (OSL)	Bear Creek Road ~ 2800 feet from Clinch River	Gamma	20	26	26	17	89	102
11 (OSL)	Grassy Creek Embayment on the Clinch River	Gamma	5	4	5	16	30	20
21 (OSL)	White Wing Scrap Yard	Gamma	Absent	10	13	48	71	47
179 (OSL)	Uranium Storage Yard (East)	Gamma	4	6	4	9	23	18
180 (OSL)	Uranium Storage Yard (South)	Gamma	12	15	16	24	67	57
181 (OSL)	Uranium Storage Yard (South)	Gamma	10	14	15	30	69	56
182 (OSL)	Uranium Storage Yard (West)	Gamma	13	11	12	6	42	52
Oak Ridge National Laboratory								
20 (OSL)	Freels Bend Entrance	Gamma	5	7	7	6	25	23
69 (OSL)	Graphite Reactor	Gamma	5	6	6	20	37	33
167 (OSL)	South side of Central Avenue	Gamma	21	22	27	26	96	97
166 (OSL)	North side of Central Avenue, Building 3038	Gamma	68	66	71	45	250	281

Oak Ridge National Laboratory (cont.)								
41	(OSL)	North Tank Farm/ Gunite tanks	Gamma*	29	4	NA	NA	33	122
41	(OSL)	Not Deployed (3rd Quarter)	Gamma	NA	NA	N/A	N/A	0	NA
30	(OSL)	X-3513 Impoundment	Gamma	5	6	7	M	18	30
28	(OSL)	White Oak Dam @ Highway 95	Gamma	3	3	4	M	10	9
34	(OSL)	SWSA 6 on fence @ Highway 95	Gamma	4	6	5	6	21	23
75	(OSL)	Hot spot on Haw Ridge	Gamma	39	48	50	52	189	188
25	(OSL)	Molten Salt Reactor Experiment	Gamma	188	215	200	199	802	748
27	(OSL)	White Oak Creek Weir @ Lagoon Rd	Gamma	33	43	46	35	157	163
24	(OSL)	Building X-7819	Gamma	6	9	10	M	25	39
35	(OSL)	Confluence of White Oak Creek & Melton Branch	Gamma	127	169	166	151	613	700
56	(OSL)	Old Hydrofracture Pond	Gamma	14	16	20	24	74	71
23	(OSL)	SWSA 5 (South 7828)	Gamma	3	1	5	8	17	12
46	(OSL)	Homogeneous Reactor Experiment Site	Gamma	4	5	3	37	49	6
22	(OSL)	High Flux Isotope Reactor	Gamma	5	10	10	2	27	34
55	(OSL)	SWSA 5 TRU Waste Trench	Gamma	43	26	27	14	110	262
			Gamma	46	54	53	63	216	253
87	(Neutron)	SWSA 5 near storage tank area	Neutron	M	M	M	M	0	M
168	(OSL)	New Hydrofracture Facility	Gamma	92	129	113	129	463	432
169	(OSL)	Melton Valley Haul Road near creek	Gamma	157	181	181	190	709	693
170	(OSL)	Cask Storage Containment Area	Gamma***	866	1,607	1,549	1,488	5,510	2,202
171	(OSL)	Building 3038 N	Gamma	1,027	1,093	1,244	876	4,240	5,119
172	(OSL)	Building 3607 material storage area	Gamma	3,817	4,406	3,953	4,067	16,243	26,058
173	(OSL)	TH4 Tank	Gamma	153	166	89	153	561	471
174	(OSL)	Hot Storage Garden (3597)	Gamma	1,175	1,359	1,369	1,282	5,185	2,602
175	(OSL)	Building 3618	Gamma	78	101	94	106	379	425
84	(OSL)	Tower Shielding Facility @ gate (west)	Gamma	2	3	5	19	29	17
85	(OSL)	Tower Shielding Facility (North side)	Gamma	1	4	4	10	19	12

Oak Ridge National Laboratory (cont.)								
176 (OSL)	Neutralization Plant	Gamma	843	836	1,839	1,969	5,487	3,252
68 (OSL)	White Oak Creek @ Coffer Dam	Gamma	M	M	M	7	7	M
26 (OSL)	Cesium Fields	Gamma	5	4	8	7	24	28
31 (OSL)	Cesium Forest boundary	Gamma	15	21	17	19	72	67
31a (OSL)	Cesium Forest boundary (duplicate)	Gamma	14	19	19	7	59	72
32 (OSL)	Cesium Forest on tree	Gamma	7,118	8,056	7,548	7,153	29,875	28,725
33 (OSL)	Cesium Forest Satellite Plot	Gamma	93	129	125	124	471	428
183 (OSL)	North Tank Farm (West) 1st & 2nd quarters only	Gamma*	2,403	10	NA	NA	2,413	2670
183 (OSL)	Not Deployed (3rd Quarter)	Gamma	NA	NA	M	NA		
	North Tank Farm (South) 1st & 2nd quarters only	Gamma*	117	8	NA	NA	125	786
184 (Neutron)	North Tank Farm (South) 1st & 2nd quarters only	Neutron*	M	M	NA	NA	0	M
184 (Neutron)	Not Deployed (3rd Quarter)	Gamma	NA	NA	M	NA		
	Not Deployed (3rd Quarter)	Neutron	NA	NA	M	NA		
	Quart. North Tank Farm (North) 1st & 2nd quarters only	Gamma*	260	13	NA	NA	273	21,732
185 (OSL)	Quart. North Tank Farm (North) 1st & 2nd quarters only	Neutron*	M	M	NA	NA	0	M
	ORAU Pumphouse Road (3rd and 4th quarters only)	Gamma	NEW	NEW	9	8	17	NEW
185 (OSL)	ORAU Pumphouse Road (3rd and 4th quarters only)	Neutron	NEW	NEW	M	M	0	NEW
Spallation Neutron Source								
		Gamma***	55	63	29	47	194	81
53 (Neutron)	Central Exhaust Facility	Neutron	M	M	M	M	0	M
		Gamma	4	6	5	7	22	18
93 (Neutron)	Ring Building Perimeter Fence	Neutron	M	M	M	M	0	M
		Gamma	M	3	3	10	16	12
17 (Neutron)	Beamdump Bldg # 8520	Neutron	M	M	M	M	0	M
73 (OSL)	SNS Water Tower (overlook) North	Gamma	4	6	5	7	22	15

Spallation Neutron Source (cont.)								
101 (Neutron)	LINAC Beam Tunnel Berm West (#1)	Gamma	6	8	7	19	40	23
		Neutron	M	M	M	M	0	M
102 (Neutron)	LINAC Beam Tunnel Berm (#2)	Gamma	7	7	8	23	45	25
		Neutron	M	M	M	M	0	M
103 (Neutron)	LINAC Beam Tunnel Berm (#3)	Gamma	8	4	Absent	26	38	21
		Neutron	M	M	Absent	M	0	M
100 (Neutron)	LINAC Beam Tunnel Berm (#4)	Gamma	5	8	9	12	34	31
		Neutron	M	NA	M	M	0	M
99 (Neutron)	LINAC Beam Tunnel Berm (#5)	Gamma	6	4	8	7	25	24
		Neutron	M	M	M	M	0	M
98 (Neutron)	LINAC Beam Tunnel Berm (#6)	Gamma	6	8	9	12	35	25
		Neutron	M	M	M	M	0	M
97 (Neutron)	LINAC Beam Tunnel Berm East (#7)	Gamma	7	6	7	23	43	28
		Neutron	M	M	M	M	0	M
74 (OSL)	SNS Cooling Tower South	Gamma	2	2	2	8	14	13
52 (Neutron)	Target Bldg West	Gamma	M	1	M	4	5	9
		Neutron	M	M		M	0	M
51 (Neutron)	Target Bldg South	Gamma	3	1	3	11	18	4
		Neutron	M	M	M	M	0	M
12 (Neutron)	Target Bldg East	Gamma	3	4	2	18	27	7
		Neutron	M	M	M	M	0	M
104 (Neutron)	SNS Administrative Building	Gamma	2	3	2	9	16	6
		Neutron	M	M	M	M	0	M
Y-12								
71 (OSL)	Y-12 East Perimeter Air Monitoring Station	Gamma	2	4	6	8	20	20

Y-12 (cont.)									
39	(OSL)	Y-12 @ back side of Walk In Pits	Gamma	3	Absent	5	15	23	21
38	(OSL)	Y-12 Uranium Oxide Storage Vaults	Gamma	3	2	4	9	18	14
Environmental Management Waste Management Facility									
90	(OSL)	Waste Cell Perimeter Fence @ gate	Gamma	M	3	4	7	14	19
92	(OSL)	Contact Water Ponds Fence @ gate	Gamma	6	9	9	20	44	34
105	(OSL)	Contact Water Ponds Fence (NW corner)	Gamma	7	6	10	14	37	37
106	(OSL)	Contact Water Ponds Fence (North side)	Gamma	6	10	11	8	35	35
109	(OSL)	Contact Water Ponds Fence (North side)	Gamma	7	14	12	M	33	38
110	(OSL)	Contact Water Ponds Fence (NE corner)	Gamma	9	14	15	23	61	45
112	(OSL)	Contact Water Ponds Fence (SE corner)	Gamma	9	11	12	3	35	40
113	(OSL)	Contact Water Ponds Fence (South side)	Gamma	8	13	13	9	43	44
116	(OSL)	Contact Water Ponds Fence (South side)	Gamma	7	12	13	24	56	43
117	(OSL)	Contact Water Ponds Fence (SW corner)	Gamma	6	11	10	2	29	42
118	(OSL)	Waste Cell Perimeter Fence (SE corner)	Gamma	7	11	10	26	54	39
119	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	7	12	10	8	37	36
120	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	6	11	10	29	56	36
121	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	9	13	10	18	50	36
122	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	9	11	11	12	43	38
123	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	9	13	13	41	76	44
124	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	10	13	13	9	45	43
125	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	6	11	11	33	61	47
126	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	8	10	11	33	62	46
127	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	8	14	13	12	47	46
128	(OSL)	Waste Cell Perimeter Fence (South side)	Gamma	5	7	7	30	49	38
129	(OSL)	Waste Cell Perimeter Fence (SW corner)	Gamma	9	12	13	7	41	46

Environmental Management Waste Management Facility (cont.)

130 (OSL)	Waste Cell Perimeter Fence (West side)	Gamma	9	15	12	26	62	48
131 (OSL)	Waste Cell Perimeter Fence (West side)	Gamma	Absent	11	11	30	52	48
132 (OSL)	Waste Cell Perimeter Fence (West side)	Gamma	8	12	11	25	56	42
133 (OSL)	Waste Cell Perimeter Fence (West side)	Gamma	6	13	12	13	44	42
134 (OSL)	Waste Cell Perimeter Fence (West side)	Gamma	8	12	12	17	49	42
135 (OSL)	Waste Cell Perimeter Fence (West side)	Gamma	7	11	13	25	56	44
136 (OSL)	Waste Cell Perimeter Fence (NW corner)	Gamma	9	11	12	17	49	52
137 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	8	12	12	25	57	46
138 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	8	12	12	17	49	45
139 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	11	11	13	2	37	45
140 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	9	15	14	10	48	39
141 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	11	13	13	8	45	46
142 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	7	10	10	5	32	42
143 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	9	13	12	14	48	47
144 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	9	13	12	M	34	51
145 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	10	12	12	17	51	45
146 (OSL)	Waste Cell Perimeter Fence (North side)	Gamma	10	13	12	30	65	42
147 (OSL)	Waste Cell Perimeter Fence (NE corner)	Gamma	7	11	11	24	53	41
148 (OSL)	Waste Cell Perimeter Fence (East side)	Gamma	5	13	8	38	64	42
149 (OSL)	Waste Cell Perimeter Fence (East side)	Gamma	7	12	10	22	51	38
150 (OSL)	Waste Cell Perimeter Fence (East side)	Gamma	8	11	11	25	55	39
151 (OSL)	Waste Cell Perimeter Fence (East side)	Gamma	7	11	10	11	39	40
152 (OSL)	Waste Cell Perimeter Fence (East side)	Gamma	5	11	10	19	45	44
153 (OSL)	Waste Cell Perimeter Fence (East side)	Gamma	7	12	10	9	38	38
154 (OSL)	Waste Cell Perimeter Fence (East side)	Gamma	10	12	11	M	33	44

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.

*The dose reported is for the first two quarters for these stations due to completion of the Tank W-1A (Corehole-8) project and a request to remove the dosimeters by the DOE contractor to remove a fence.

** 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 by the vendor from the dose reported for each field deployed dosimeter.

*** Dosimeter was relocated to the point of highest public dose for the area being monitored or relocated to an area warranting monitoring.

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Real Time Monitoring of Gamma Radiation on the Oak Ridge Reservation

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Abstract

In 2012, the Tennessee Department of Environment and Conservation placed gamma radiation exposure rate monitors at six locations on the Department of Energy's Oak Ridge Reservation. These units measure and record gamma radiation levels at predetermined intervals over extended periods of time, 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 2012, six locations were monitored in the program, including: three remedial sites at the Oak National Laboratory; the 7000 Area Truck Monitor; the exhaust stack of the Spallation Neutron Source; 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 DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation (the office) has deployed continuously-recording exposure-rate monitors 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 continuous-exposure-rate monitors can record gamma radiation levels at short intervals (e.g., one minute), providing an exposure-rate profile that can be correlated with changing activities or conditions at a site. 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. Data from each 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 where 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 2012, the exposure rate monitors were used to monitor gamma emissions at the six locations listed below and depicted in Figure 1.

- Fort Loudoun Dam (background location).
- Oak Ridge National Laboratory (ORNL) 7000 Area Radiation Portal Monitor.
- ORNL Core Hole 8/Tank W-1A Removal Action.
- ORNL Central Campus Remediation (Radioisotope Development Lab Removal Action).
- ORNL Molten Salt Reactor Experiment (MSRE).
- Spallation Neutron Source (SNS) exhaust stack.

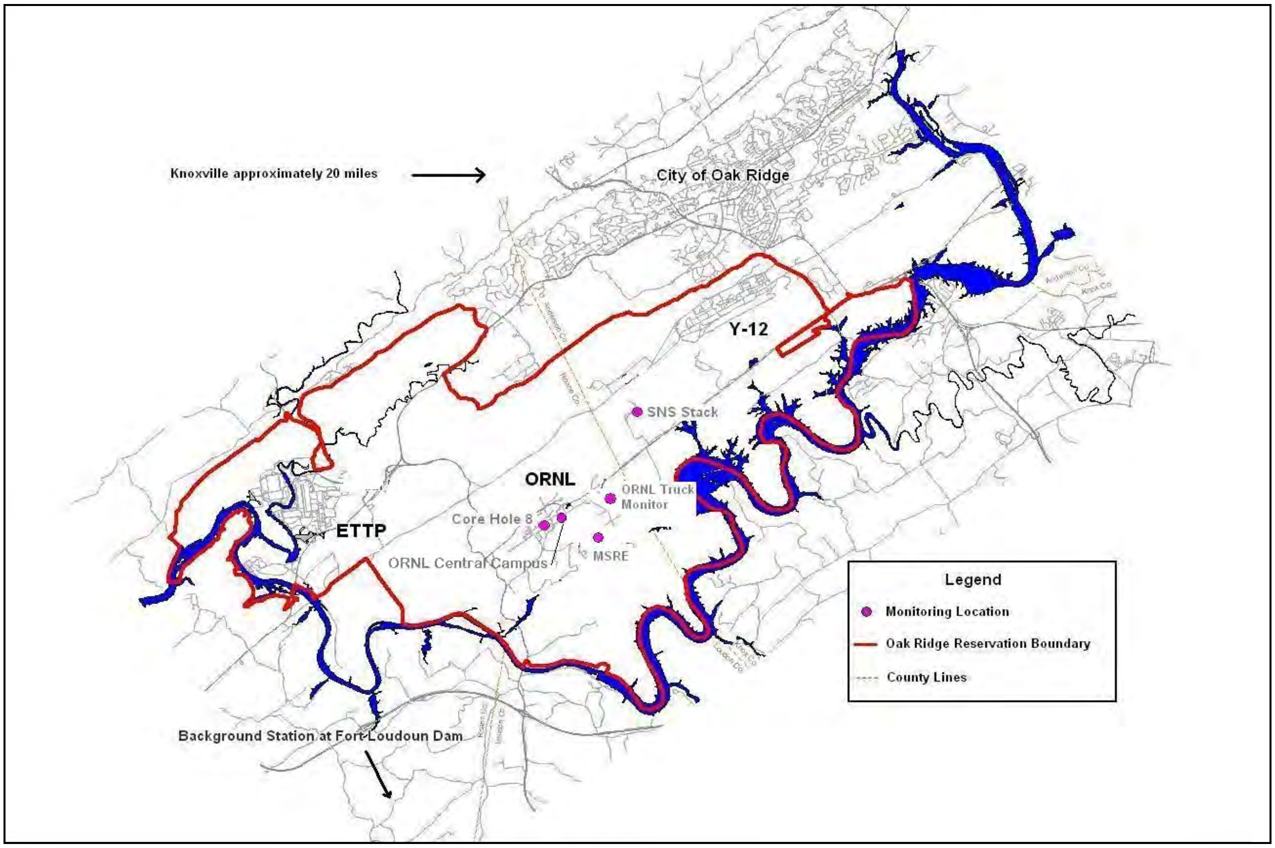


Figure 1: Gamma exposure rate monitoring locations in 2012

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

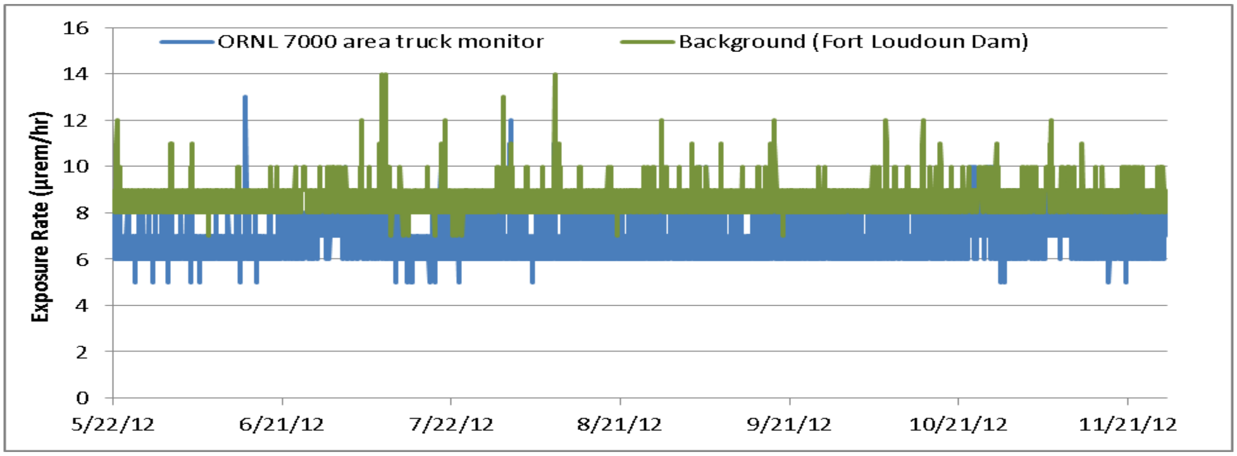
The unit used to express the limits (rem) refers to the dose of radiation an individual receives (the amount of radiation absorbed by the individual). For alpha and neutron radiation, the measured quantity of exposure, roentgen (R), is multiplied by a quality factor to derive the dose. For gamma radiation, 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/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. During the 2012 calendar year exposure rates averaged 8.7 µrem/hour and ranged from 7 to 14 µrem/hour.

The ORNL Truck Monitor (7000 Area)

The Y-12 Industrial Landfill is permitted by TDEC’s Division of Solid and Hazardous Waste Management, under the condition that no radioactive waste be disposed at the facility. To help ensure this condition of the permit is not violated, trucks transporting waste to the landfill from ORNL are screened prior to leaving the site at the 7000 area radiation portal monitor. The trucks are screened again at the landfill, prior to disposal. The office deployed one of the gamma monitors at the 7000 area truck monitor from 05/22/2012 to 11/27/2012 to measure gamma activity prior to the trucks leaving the ORNL site. Measurements recorded during the period ranged from 5 to 13 µrem/hour and averaged 6.97 µrem/hour (Figure 2), which is similar to measurements collected during the same time period at the background station.



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: 2012 Results of Gamma Exposure Rate Monitoring at the ORNL 7000 Area Truck Monitor and Background Station

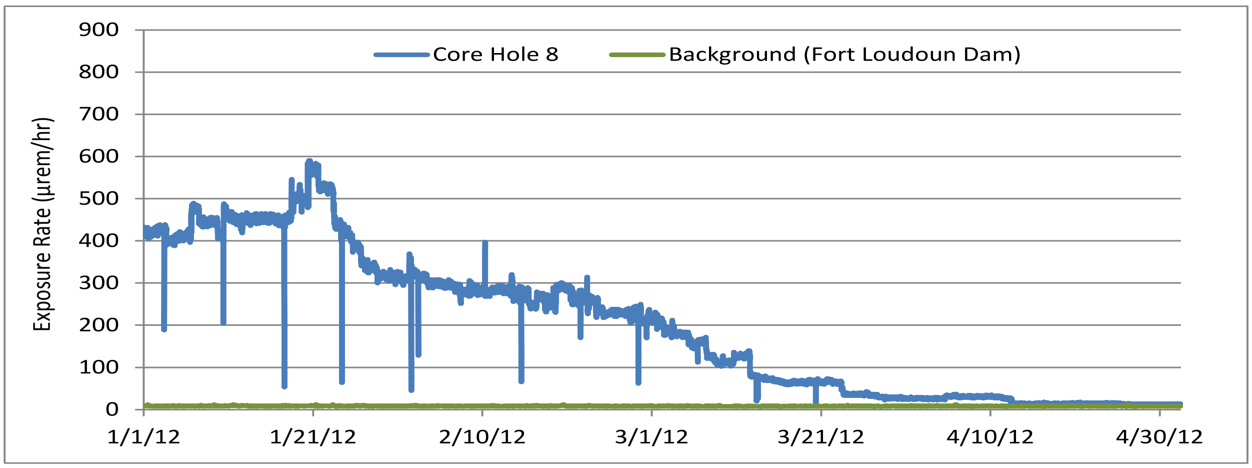
Core Hole 8/Tank W-1A at ORNL

Tank-W-1A is a 4,000 gallon stainless steel underground storage tank located in the North Tank Farm, near the center of ORNL's main campus. The tank was commissioned in 1951 to collect and store waste from isotope separation and high-radiation analytical facilities (i.e., Buildings 2026 and 3019). In 1986, W-1A was decommissioned and the tank emptied, due to concerns leaking transfer lines leading to the tank were a major contributor to the Core Hole 8 groundwater plume. The Core Hole 8 plume emanates from the North Tank Farm and migrates westward, where it enters Fifth Creek. Associated contaminants include strontium-90, americium-241, plutonium-238, 239, 240, and curium-244 (Bechtel, 1992). A CERCLA action to remove W-1A and adjacent soils was initiated in 2001, but was suspended after radiation levels were encountered in adjacent soils that were much higher than had been anticipated. Associated contaminants and the maximum levels reported include strontium-90 (842,000 pCi/g), cesium-137 (7,200,000 pCilg), plutonium-239/240 (11,000 pCi/g), americium-24l (90,000 pCi/g), curium-244 (40,000 pCi/g), and uranium-233 (519,000 pCi/g) (BJC 2002).

The Tank W-1A Removal Action was resumed in September of 2011 and continued into the spring of 2012. One of the office's exposure rate monitors was placed at the site on 07/08/2010 (prior to the beginning of the remediation) where it remained through 05/02/2012 (after the action had been completed). Background measurements collected in 2010 averaged 13 µrem/hour, with similar results reported through September of 2011. Excavation of the contaminated soils began in September of 2011 and Tank W-1A was removed on January 6, 2012. Figure 3 depicts the radiation levels measured from the beginning of the action through its completion (09/01/2011-05/01/2012). As can be noted in Figure 3, radiation levels abruptly increase in mid-September of 2011 as contaminated soils are excavated and brought to the surface (peaking at 814 µrem/hour on November 29th), then decline as the soils and tank are removed from the site for disposal. During the period, gamma exposure rates ranged from 9 to 814 µrem/hour and averaged 323 µrem/hour. At completion of the project, exposure rate measurements had returned to background levels. During the year 2012, exposure rates measured at the site ranged from 5 to 189 µrem/hour and averaged 39 µrem/hour (Figure 4).

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 (1000,000 µrem) in a year.

Figure 3: Results of Gamma Exposure Rate Monitoring During the Core Hole 8/Tank W-1A Removal Action (09/01/2011-05/01/2012)



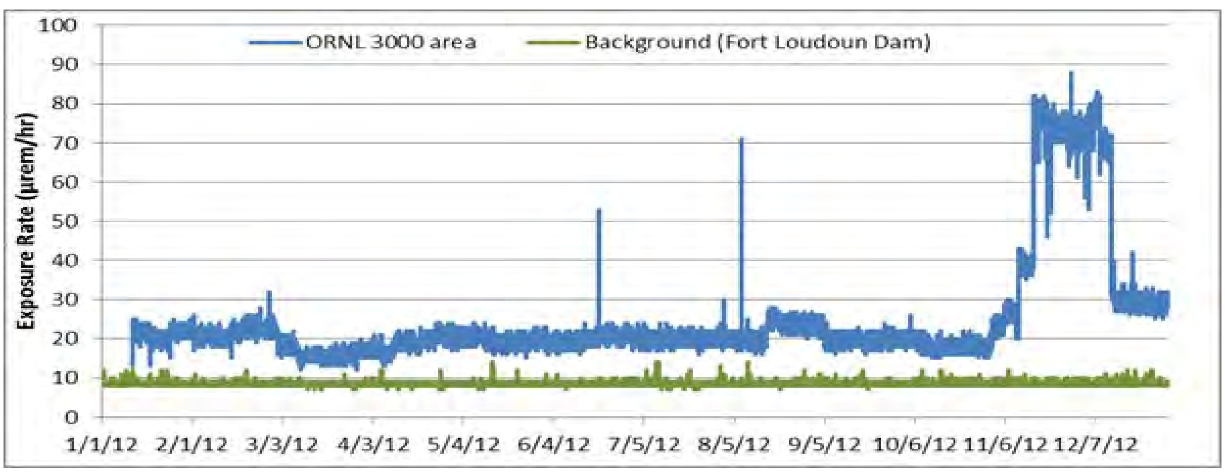
The state dose limit in an unrestricted area is 2 mrem (2,000 µrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 µrem) in a year.

Figure 4: 2012 Results of Gamma Exposure Rate Monitoring at the Core Hole 8 Removal Action and at the Background Station

ORNL Central Campus Remediation/Building 3026 (Radioisotope Development Lab)
Monitoring of the ORNL Central Campus Remediation began 01/11/2012 and continued through the year. 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 currently being addressed as CERCLA time-critical removal action items.

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 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 fuel elements for uranium and plutonium in the 3019 Building. 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 to 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 3026 C&D facilities, the condition of the structures, and the location of the facilities, 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 3026 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 is scheduled for completion in 2013, although higher than expected radiation levels have hindered the project. Due to the nature of historical operations in the facililties, 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 placed at the exit for trucks hauling waste from ORNL on 01/11/2012 (prior to the demolition of the 3026-C hot cell), where it remained throughout the year. During this time period, gamma radiation levels measured ranged from 12 to 88 µrem/hour and averaged of 24.7 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.

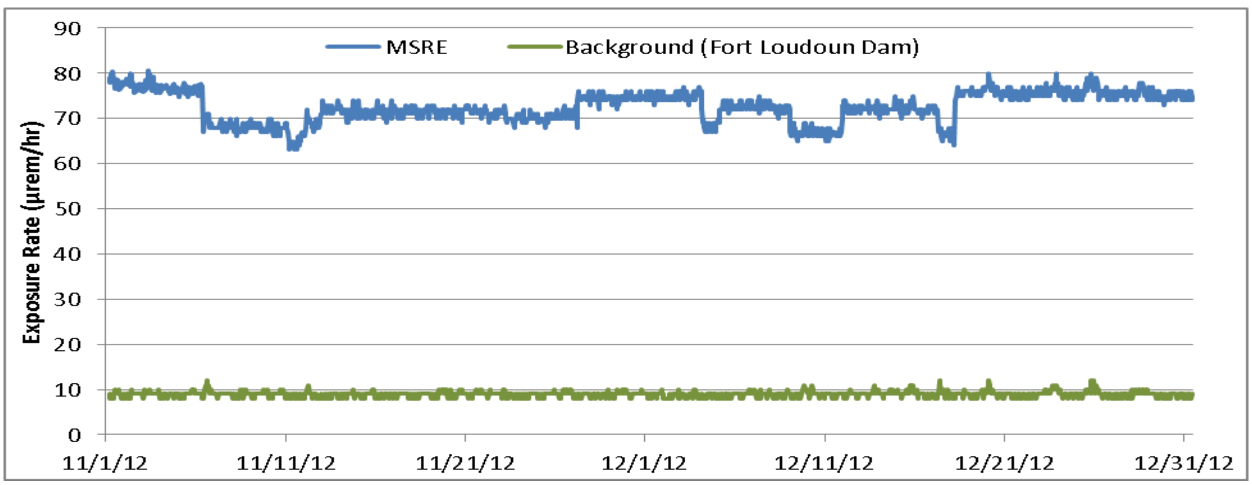
Figure 5: 2012 Results of Gamma Exposure Rate Monitoring at the ORNL Central Campus Removal Action and at the Background Station

The 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 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 until 12/31/2012, staff recorded gamma exposure rates with a monitor that was placed near the gate where trucks containing radioactive materials (fuel removed from the drain tanks) exit the MSRE and transport the materials to a storage area. During the 2012 monitoring period, the average exposure rate measured ranged from was 56 to 103 μrem/hour and averaged 76.36 μrem/hour (Figure 6).

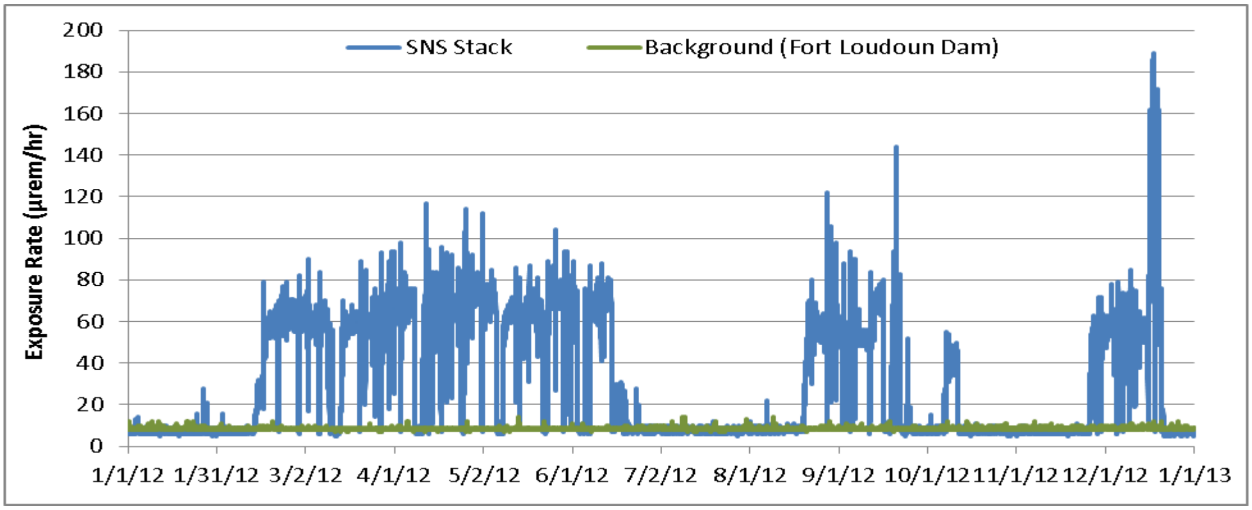


The state dose limit in an unrestricted area is 2 mrem (2,000 μrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 μrem) in a year.

Figure 6: 2012 Results of Gamma Exposure Rate Monitoring at the ORNL MSRE and at the Background Station

Spallation Neutron Source

The Spallation Neutron Source is an accelerator neutron source located on Chestnut Ridge between the ORNL and Y-12 facilities. One of the office's exposure rate monitors is located on the discharge air stack used to vent air from process areas inside the linac and target building. The exposure rate changes with operation status of the accelerator. During periods when the accelerator is not on line, the rate is typical of background for the area. Rates during 2012 ranged from 5 to 189 μrem/hour and averaged 39.25 μrem/hour (Figure 7).



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 7: 2012 Results of Gamma Exposure Rate Monitoring at the SNS stack and at the Background Station

Conclusion

The use of continuously-recording gamma-exposure monitors has proven to be a flexible and reliable method for monitoring gamma radiation on the reservation. Based on the data collected in 2012, the following conclusions were reached.

- Gamma levels at the ORNL Truck Monitor (7000 area) were consistent with background measurements.
- Measurements recorded at the Core Hole 8/Tank W-1A Removal Action during 2012 decreased as the contaminated soils excavated were removed from the site, along with Tank W-1A. Post removal measurements were less than pre activity readings.
- 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.

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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 Radiological Monitoring and Oversight Program conducted independent radiological monitoring of these surplus materials prior to each auction/sale. During 2012, a total of seven inspection visits were conducted at the ORR facilities. Four visits were made for ORNL sales and three visits were made for Y-12 sales. No sales were conducted at the East Tennessee Technology Park (ETTP) facility. A total of sixteen items, eleven at ORNL and, five at Y-12 were observed that required further evaluation. All sixteen of these items exhibited elevated alpha and beta radioactivity, and were withdrawn from the sales until further evaluations were conducted.

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. 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 cm^2 (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, 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.

Results and Discussion

A total of seven inspections were conducted, four at ORNL and three at Y-12. No sales were held at ETTP. Elevated levels of alpha and beta radiological contamination were discovered on sixteen items during the DOE-O surveys. Five observations requiring further evaluation were made at the Y-12 surplus sales facility. Upon notification by DOE-O staff, the items were removed from the auction for further review by Y-12 Radiation Control personnel. Eleven observations requiring further evaluation were made at the ORNL surplus sales. These items were also removed from the auction for further evaluation by ORNL Radiation Control.

Items removed from auctions are reevaluated to ensure that they meet the appropriate Y-12 or ORNL release criteria for release of items to the public and in the event they do, they may be later returned to the auction. The elevated levels of activity were often determined to be due to an accumulation of radon; however, in at least three of the instances, the activity was found to be due to contaminants other than radon.

Conclusion

During 2012, 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 was detected on sixteen items staged for release to the public. All sixteen of the items were removed from the auction list for further evaluation.

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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 EMWMF was constructed for the disposal of low level radioactive waste and hazardous waste generated by remedial activities on the DOE's Oak Ridge Reservation. The facility is operated under CERCLA authority 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 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 2012, three sets of anomalous measurements that could not be explained by preliminary information were submitted DOE Oversight's Audit Team and are currently under review.

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) agreed to by FFA parties is approved for disposal in the EMWMF. DOE is accountable for compliance with the WAC and has delegated responsibility to make WAC attainment decisions to its prime contractor, which it oversees. 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) emplaced 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 noted, DOE is notified. Basic information as to the nature and source of the waste passing through the portal at the time of the measurement is 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 its 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 measurement 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 lead by the DOE Oversight's Waste Management program with support from other Oversight programs and administration.

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 (ORNL), as well as uranium, technetium-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.[1] 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 or, to a large degree, the waste 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 measures 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 give off gamma a very small

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

percentage of the time, or not at all. The wastes lots disposed of 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 is 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 dominate radionuclides in waste from the 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 (e.g., thorium-231, thorium-234, and protactium-231m). As a result, the count rates are expected to be much lower and 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 2012, no anomalies were noted in wastes from the Y-12 or ETTP facilities, much of which consisted of demolition material from the 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.

The most frequent anomalies during 2012 were due to a nuclear density gauge which contains sealed and shielded cesium-137 and americium-241 sources. The 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 otherwise stored outside the facility. Measurements taken in October as the density gauge was carried past the RPM are included in Figure 1. Typically, the gauge is carried into the waste cells in one of two types of vehicles: one has a flat bed with no sidewalls that would attenuate the gamma radiation emitted by the sources: the other has sidewalls. The difference in the two measurements taken on 10/03/2012 (86,578 cps) and 10/10/23/2012 (36,545 com) is believed to reflect the attenuation of gamma emissions from by the sidewalls of the truck bed. The effect on lower energy gamma emissions would be expected to be more pronounced.

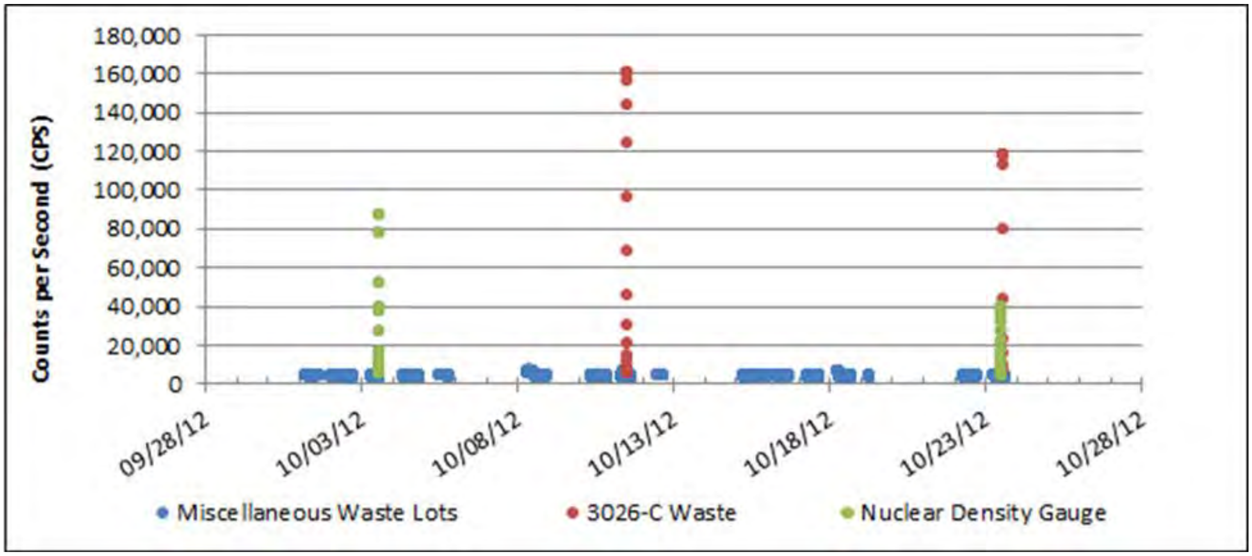

Figure 1: Measurements Recorded in October 2012 by the EMWMF Radiation Portal Monitor

The only anomalous results unresolved by preliminary information in 2012 were generated by waste derived from remedial activities at ORNL. Much of this waste was generated by the D&D of facilities constructed in the 1940s and 1950s as part of the World War II effort to develop the first nuclear weapons. In the interim, the facilities have housed a variety of operations in support of nuclear research and the production of radioisotopes.

The first anomaly (95,724 cps) occurred at 09:42 on 02/23/2012, during the delivery of waste from ORNL's Small Facilities Complex Demolition Project. Staff were advised by EMWMF personnel at the time of the alert a flatbed truck carrying heat exchangers from the 3102 facility was passing through the check-in station. While little specific information was found on the heat exchangers, preliminary information indicates that 3102 is an open pit located near the Oak Ridge Research Reactor (ORRR) that contained four heat exchangers. During operation of the ORRR, the units were used to transfer heat generated in the core of the reactor from the primary system to the secondary system. (Kuhaida, 1997). Associated information has been submitted to DOE Oversight's Waste Audit Team for consideration.

The highest RPM measurement in 2012 occurred on 10/11/2012 at 12:12 and on 10/23/2012 at 12:06 (Figure 1). EMWMF personnel advised in both instances waste passing through the portal monitor at the time of the measurements was derived from the demolition of the 3026-C facility. 3026-C was a wood frame structure constructed in the 1940s to house operations for the separation of barium-140 from uranium fuel slugs irradiated in ORNL's Graphite Reactor (ORAU, 2007). Over the years, the facility was modified for various uses, including the separation of radioisotopes from liquid wastes generated by processing of irradiated fuel elements for uranium and plutonium. 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. As a consequence of the hazards presented by radioactive contamination present in the 3026 C and the adjacent 3026-D facility, the condition of the wooden structures, and the location of the facilities, a time-critical removal action was initiated in 2009 to include demolition of the 3026 C & D superstructure and stabilization of hot cells contained in in each of the two facilities. The wooden superstructure of the facilities was demolished in 2010 and demolition of the 3026-C hot cells was completed in 2012. Due to the nature of historical operations in the facilities, potential contaminants include a long list of radionuclides including cesium-137, strontium-90, nickel-59 & 63, iron-55 & 59, krypton-85, promethium-147, silver-110m, tritium, technetium-99, americium-241, and neptunium-239, along with various isotopes of europium, plutonium and uranium. While higher levels of gamma-emitting radionuclides are typical of ORNL wastes, the levels measured on 10/11/2012 (160,815 cps) and 10/23/2012 (118,029cps) were unusually high compared to previous shipments of waste from the facility and the highest reported since the RPM was set in place in 2011. DOE Oversight's Audit Team is currently in review of associated information.

Conclusions

In 2012, much of the waste delivered to the EMWMF for disposal was derived from the demolition of facilities constructed to support the development of the first nuclear weapons, As might be expected, the gamma radiation levels measured by the EMWMF Radiation Portal Monitor were much lower for waste generated by demolition of the uranium enrichment facilities than those recorded for ORNL wastes (which typically contain the predominant gamma emitting radionuclides on the ORR). Three sets of anomalous measurements that could not be explained by preliminary information were noted in results from monitoring ORNL waste. One identified as the 3102 heat exchangers, which apparently were used to transfer heat generated in the core of the Oak Ridge Research Reactor from the primary system to the secondary system. The second and third, from waste derived from the demolition of the 3026-C Radioisotope Development Laboratory, which was used historically to separate radioisotopes from uranium irradiated in the Graphite Reactor and liquid wastes generated by processing of irradiated fuel elements for uranium and plutonium. In both cases, associated information has been provided to the DOE Oversight's Audit team for review and disposition.

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SURFACE WATER MONITORING

Monitoring of Effluents at the Environmental Management Waste Management Facility

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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 2012, the Tennessee Department of Environment and Conservation's (TDEC), Division of Remediation, DOE Oversight Office monitored groundwater elevations, effluents, surface water runoff, and sediments at DOE's Environmental Management Waste Management Facility (EMWMF). The monitoring has shown the potential for groundwater levels to be above a required ten foot geologic buffer along the north and northeast portion of the disposal cells. An incursion near Piezometer PP-02 was also identified from the 2011 water level data. Additional monitoring is warranted to determine if the incursion near PP-02 is due to issues with the underdrain, the northern trench drain, or a function of the additional waste cells. Results from radiological water samples indicate that radionuclides are being discharged from operations conducted at EMWMF. However, those discharges are in compliance under TDEC Rule 1200-2-11-.16. Results of radiochemical analysis of sediment samples indicate that radiological discharges are not substantially impacting the sediments of NT-5 and Bear Creek.

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 2012, the Tennessee Department of Environment and Conservation's (TDEC), Division of Remediation, DOE Oversight Office monitored groundwater elevations, effluents, surface water runoff, and sediments 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 at the EMWMF has expedited remedial activities on the ORR, the east Tennessee region presents 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 contaminated storm water (contact water) pooling in the waste cells required a modification of procedures. The water is sampled, and, based on results, either released to a ditch that discharges into the sediment retention basin or sent for treatment at the Oak Ridge National Laboratory Process Waste Treatment Facility. The sediment basin discharges to the NT-5 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, Environmental Protection Agency (EPA), and DOE.

Methods and Materials

To verify that the EMWMF is meeting its performance objectives, a program was initiated to monitor discharges and groundwater locations. This program includes: reviewing groundwater elevations; monitoring water quality parameters at two discharge locations; collecting sediment samples along North Tributary (NT) 5 and Bear Creek; and collecting water samples for radiochemical analysis at EMWMF-1 (GW-918), EMWMF-2, EMWMF-3, EMWMF-4B, EMWMF-6 (NT-4), and at the Contact Water Ponds (CWPs) and Tanks (CWTs). EMWMF-4, EMWMF-5, and EMWMF-3A were not sampled in 2012. The radiological sample locations are provided in Figure 1.

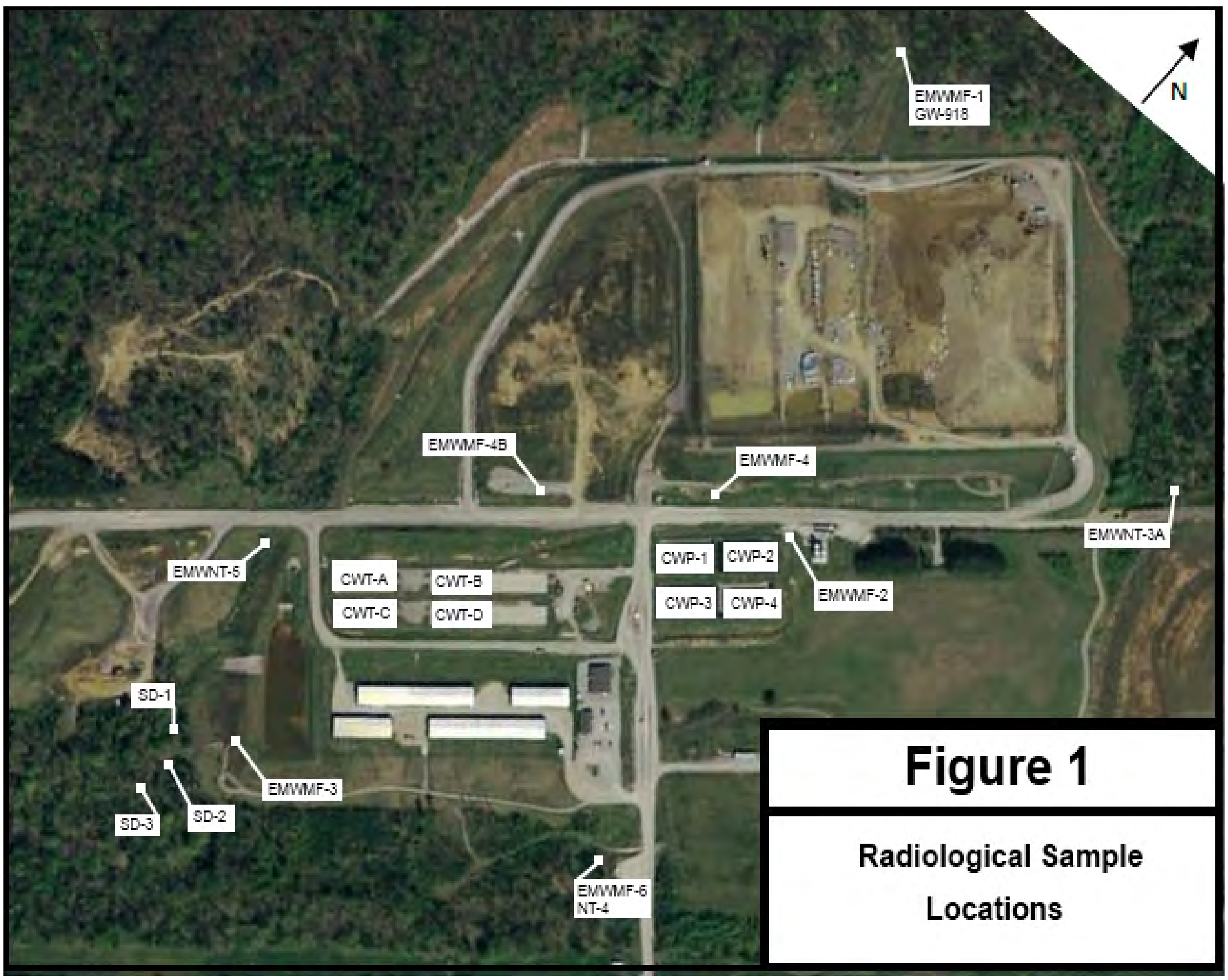


Figure 1: EMWMF Radiological Sample Locations *Google Maps (DigitalGlobe, et al., 2011*)

Groundwater Review

Prior to the construction of 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.

This groundwater review obtained data collected from UCOR and is available on Oak Ridge Environmental Information System (OREIS). Therefore, the data reviewed is from the previous year. The data is analyzed to determine its validity, and 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 ten-foot soil buffer below the liners) and data from the underdrain installation was utilized to further refine the groundwater contours.

Water Quality Parameters

Water quality parameters were taken at two locations at the EMWMF: EMWMF-2 (the underdrain) and EMWMF-3 (the discharge from the sediment retention basin v-weir). Water quality parameters were collected utilizing a YSI-556/YSI Professional Plus and an In-Situ® Troll 9500 multiparameter water quality monitoring probe. The YSI-556/YSI Professional Plus has been used throughout the year on a scheduled basis. The In-Situ® Troll 9500 was utilized at the underdrain (EMWMF-2) from March 22 through December 31. Another In-Situ® Troll 9500 was deployed at the sediment basin (EMWMF-3) to monitor discharges from March 22 to December 4. 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 2012 based on the previous year's data from UCOR. In addition, all historic water level information was collected from OREIS and reviewed to refine the site models. The groundwater elevation data and geologic buffer were modeled utilizing Surfer®. The resulting groundwater potentiometric contours were compared against the bottom of the geologic buffer to show areas that might intrude into the buffer. The modeling did not account for the northern drainage trench. This trench was designed to eliminate any potential incursions of groundwater above the geologic buffer along the northern end of the disposal cells. Figure 2 shows the groundwater potentiometric contours for August 2011, the bottom of the geologic buffer contours, and the areas of potential incursion of groundwater within 10 feet from the top of the geologic buffer. The modeling yielded similar results for all four quarters of water level data. However, the incursion near piezometer PP-02 was 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 10 feet below the top of the geologic buffer contours, generally the water elevations are below the 10 foot buffer. Unfortunately, the data for the northeastern portion of the disposal cells is limited. Modeling without the northern drainage trench suggests that the groundwater may be above the geologic buffer. An additional well would be necessary to properly define the groundwater potentiometric surface for disposal cells one and two and/or to determine the long term performance of the northern drainage trench. 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 near piezometer PP-02 is new 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 or if there are issues with the underdrain and/or the northern trench drain.

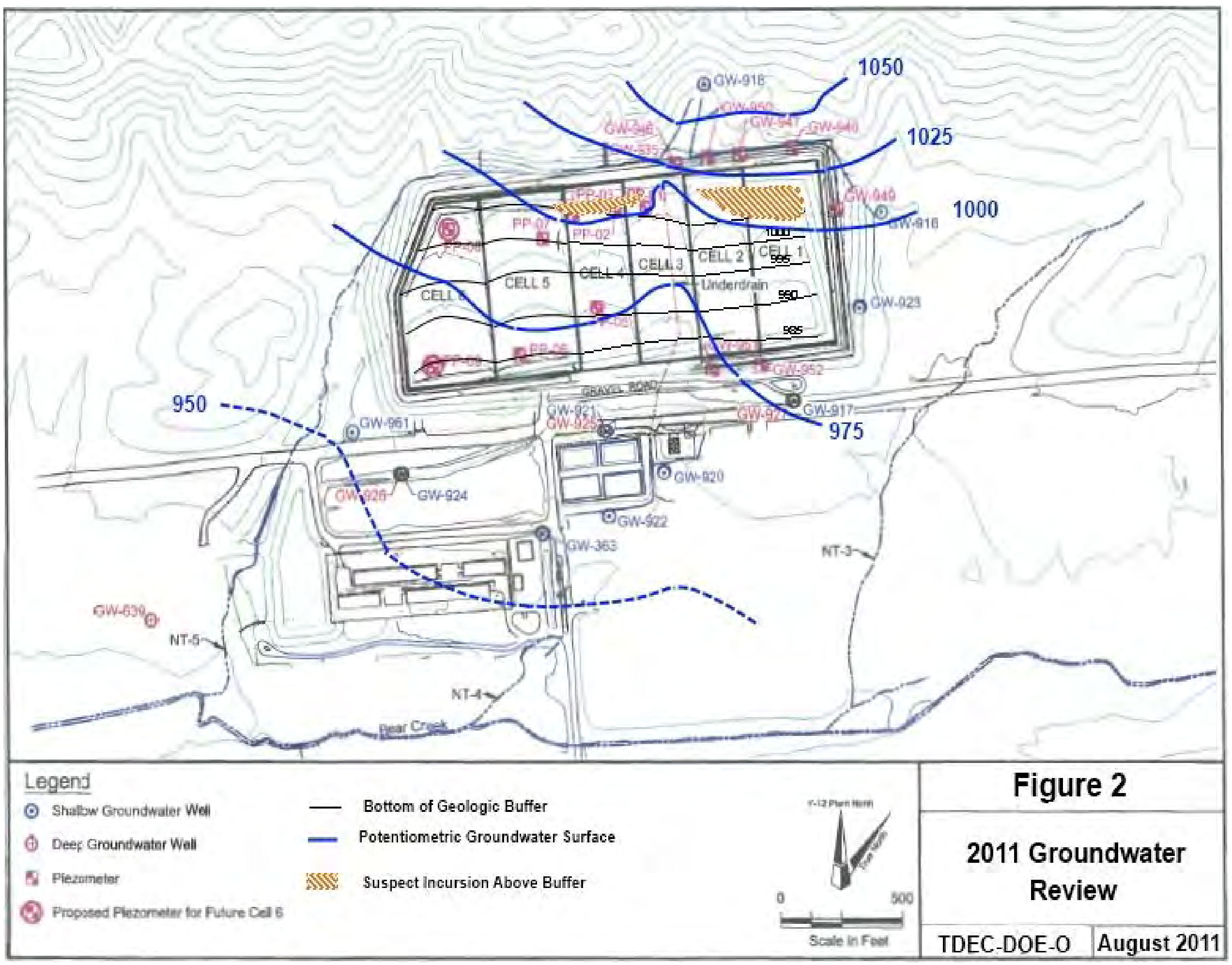


Figure 2: 2011 Groundwater Review

Water Quality Parameters

One to two times a week, TDEC staff recorded water quality parameters at the EMWMF-2 and EMWMF-3 with a YSI-556/Pro. Table 1 provides a summary of the data recorded at the two sites with the YSI-556 water quality meter.

Table 1: 2012 Data Summary of the Water Quality Parameters collected with the YSI-556/Pro Water Quality Meter

UNDER DRAIN

	PH			DO			COND			TEMP			
	high	low	avg	high	low	avg	high	low	avg	high	low	avg	visits
Jan	7.04	6.43	6.66	6.85	2.3	4.63	607	504	544	15.78	14.89	15.43	9
Feb	6.82	6.41	6.57	5.8	2.78	4.61	549	446	516	15.71	14.63	15.25	8
Mar	6.46	6.26	6.36	8.5	2.62	4.3	530	420	506	15.54	15.08	15.29	8
Apr	6.5	6.04	6.34	5.81	2.36	3.88	504	428	478	16.59	15.41	15.9	8
May	6.37	6.14	6.25	2.53	1.45	2.02	581	450	494	17.21	15.47	16.01	10
Jun	6.46	6.28	6.34	3.13	1.09	1.85	486	461	470	17.3	16.9	17.03	7
Jul	6.3	6.27	6.29	2.97	0.83	1.45	458	444	451	17.8	17.3	17.6	9
Aug	6.35	6.22	6.27	2.62	0.54	1.53	469	406	444	18.2	17.1	17.85	9
Sep	6.39	6.21	6.32	2.73	0.96	1.84	778	442	501	18.2	17.7	17.95	8
Oct	6.6	6.37	6.45	4.34	1.26	3.36	448	429	442	18.2	16.6	17.28	8
Nov	6.65	6.44	6.55	5.2	4.12	4.86	434	394	421	16.8	16	16.48	6
Dec	6.68	6.45	6.55	5.36	3.11	4.27	592	399	456	16.3	15.3	15.83	6

OUT FALL

	PH			DO			COND			TEMP			
	high	low	avg	high	low	avg	high	low	avg	high	low	avg	visits
Jan	8.45	6.8	7.62	15.41	10.14	12.9	550	240	402	9.48	4.2	6.57	9
Feb	7.95	7.42	7.66	16.38	12.4	13.9	605	223	340	9.6	5.2	7.85	8
Mar	9.59	7.21	8.45	15.03	8.3	12.6	506	159	331	22.58	11.01	16.07	9
Apr	8.85	7.67	8.03	10.86	6.73	8.51	597	429	533	20.98	14.59	18.26	8
May	8.52	7.32	7.96	8.67	5.13	6.65	648	183	348	27.18	17.67	22.21	9
Jun	8.34	7.72	8.08	6.21	5.31	5.79	754	394	595	28.5	21.6	25.2	5
Jul	x	x	x	x	x	x	x	x	x	x	x	x	0
Aug	8.06	7.62	7.84	7.14	6.48	6.81	763	487	626	26.1	21.2	23.65	2
Sep	8.16	7.8	7.94	8.36	6.43	7.35	650	122	272	21.3	14.4	18.8	4
Oct	7.95	7.62	7.71	8.91	6.44	7.95	1128	839	979	22.5	11.5	17.17	4
Nov	x	x	x	x	x	x	x	x	x	x	x	x	0
Dec	7.82	7.32	7.6	11.56	9.27	10.2	285	151	213	8.2	5	7.07	3

X – No water flow; DO – Dissolved Oxygen; COND – Specific Conductivity; TEMP - temperature

The **pH** is a measure of the acidity or alkalinity of a solution, an important limiting factor for aquatic life. If the water in a stream is too acidic or basic, the H+ or OH- ion activity may disrupt aquatic organisms' 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 of a particular substance (weight) per a given volume of liquid. The DO concentration in a stream is the mass of the oxygen present, in milligrams/liter of water or ppm. This number can be affected by temperature, flow, aquatic life, altitude, dissolved or suspended solids or human activity.

Specific Conductivity is a measure of how well water can pass through 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.

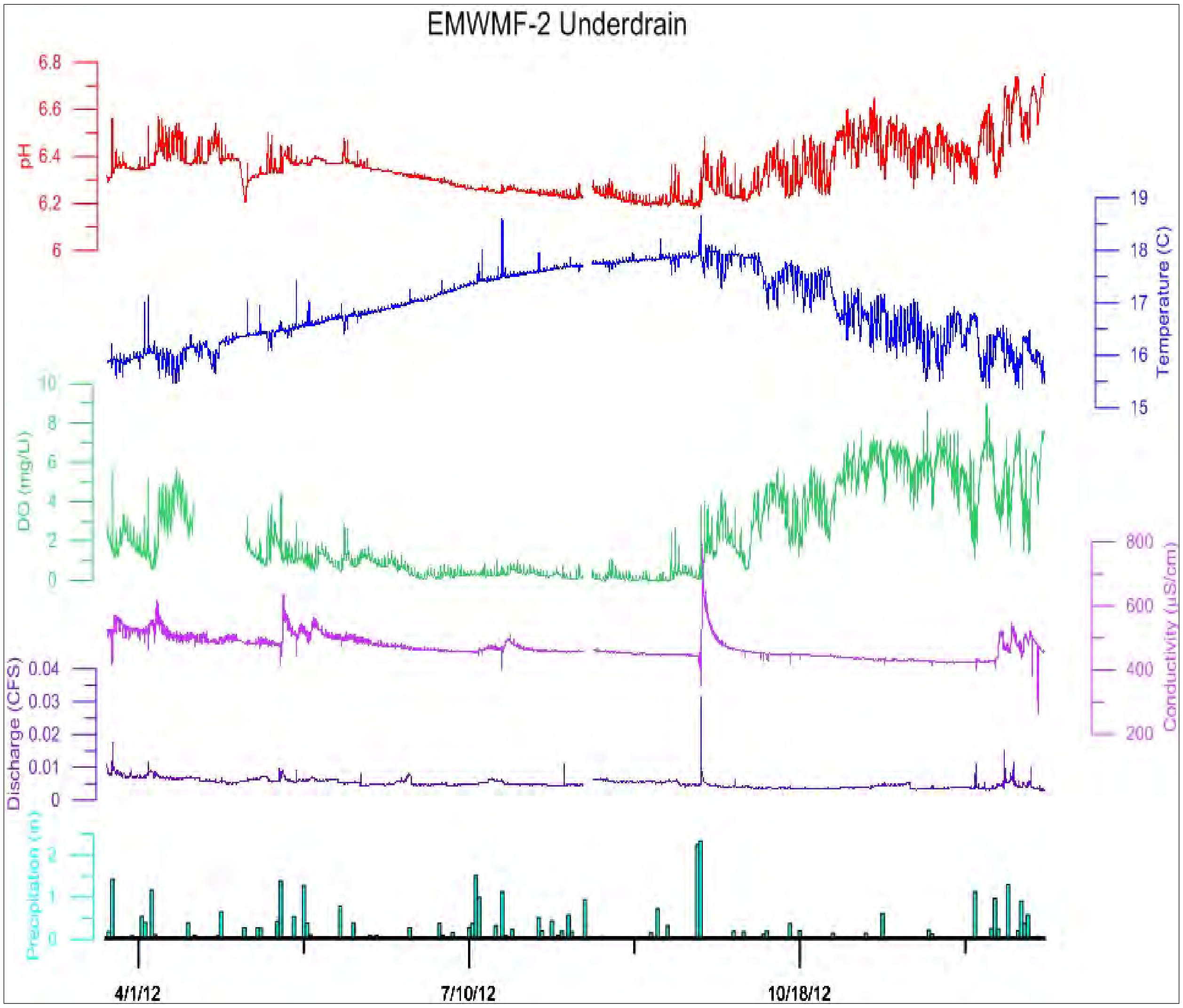
In addition to the YSI-556/YSI Professional Plus water quality meter whose monitoring data is listed in Table 1, an In-Situ® Troll 9500 multiparameter water quality data logger was placed at EMWMF-2 from March 22 through December 31 and at EMWMF-3 from March 22 through December 4. To complement the water quality parameter graphs, a precipitation graph was created from precipitation data obtained 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 3 and 4, respectively.

At EMWMF-2 (the underdrain):

The pH was relatively constant, as expected with groundwater. The DO dropped slightly during the summer months, as expected with higher temperatures. The conductivity kept a consistent average, also expected with groundwater. (See Table 1.)

There are two data gaps at EMWMF-2. The data gaps were due to equipment maintenance. The data gaps in April 17-May 1 (DO only) and August 13-16 were due to an expired DO cap and thorough cleaning/check-up/calibration of the instrument, respectively.

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 shown significant changes 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. Currently, natural conditions are being observed; however, future monitoring should be compared to these parameters (See Figure 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 3: Water Quality Parameters (temperature, pH, DO, specific conductivity, discharge, and turbidity) and Precipitation at EMWMF-2

Temperature:

There is a diel 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 mid-September. In September the temperature is slightly decreasing. This gentle temperature change is expected and is seasonal.

Hydrogen Ion Concentration (pH):

The pH data has a slight diel cycle. Generally the groundwater pH was between 6.18 to 6.75 standard units. The only noted peaks with the pH data were associated with a sizeable precipitation event. Surface water runoff was the reason for those pH spikes.

Dissolved Oxygen (DO):

Dissolved oxygen has a slight diel 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 May 28 through September 8.

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 seven- to 12-hour lag before higher conductivity values peaked. This higher conductive groundwater (older water) is being displaced from the infiltration of fresh rainwater within a few hours of the precipitation event. However, there are several other rain events with no observed recessional curve. It is possible that, during the dry periods shown in July and during the fall of 2012, the rain water percolated into storage and did not displace the older formation water.

Turbidity:

The turbidity values were recorded but are not shown in Figure 3. The turbidity values were somewhat misleading. Since EMWMF-2 is near surface water runoff, open to the atmosphere, and shallow, any disruptions were magnified. During all rain events, movement of the YSI water quality meter, or servicing of the data logger, the turbidity values were anomalously high. All other turbidity readings were consistently below 10 NTUs.

Discharge:

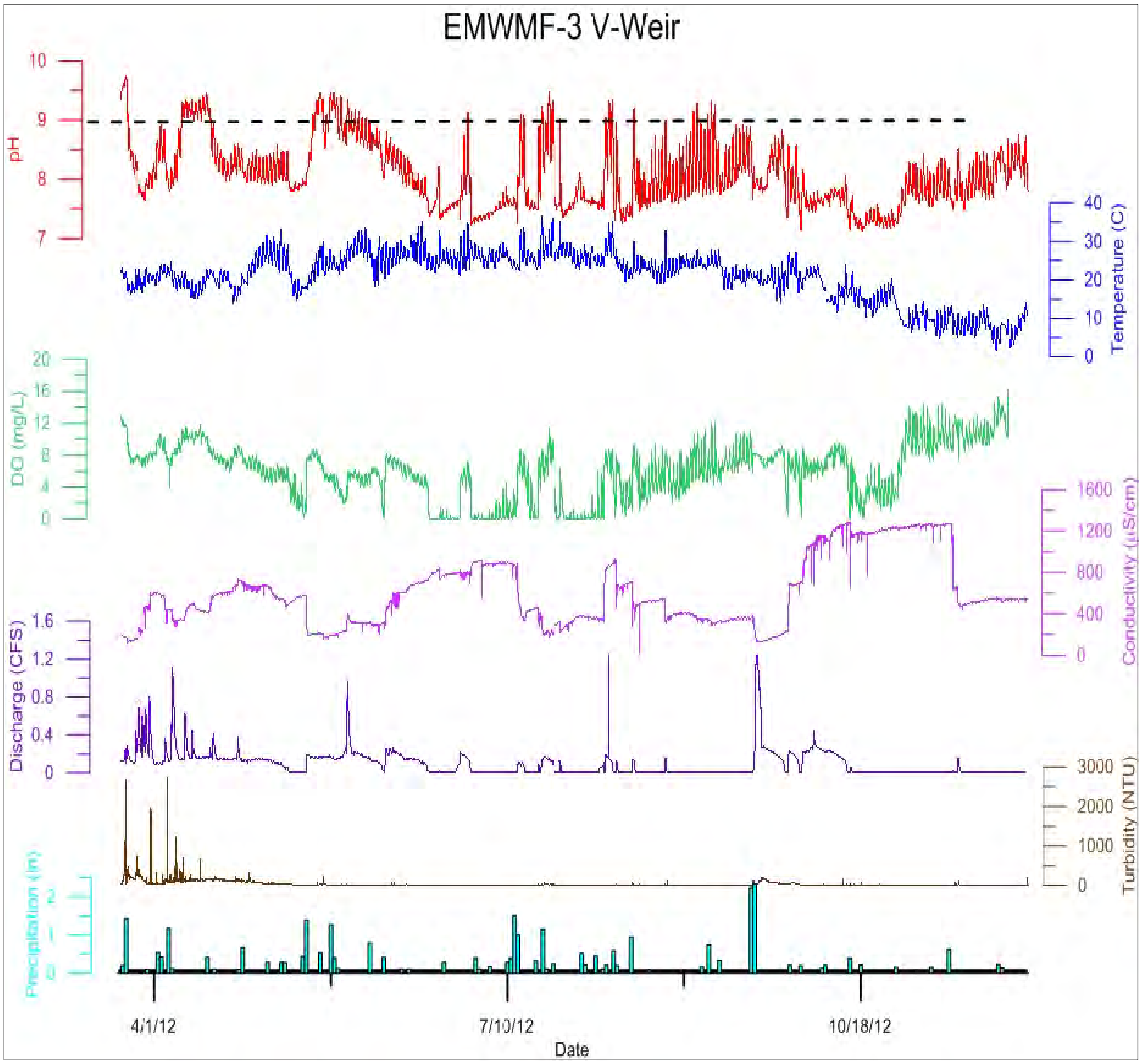
There is a V-weir associated with EMWMF-2. The discharge was fairly constant, with some increase during wetter periods. There were slight recessional curves noted with the discharge data with major precipitation events. Similar to specific conductivity, some of the precipitation events went into storage. The discharge peaks observed on Figure 3 were due to precipitation events and water entering EMWMF-2 from surface water runoff.

At EMWMF-3 (the discharge from the sediment retention basin):

The pH was elevated in early spring due to an algal bloom. The DO dropped as the temperatures rose during the weather cycle. Conductivity displayed a spike in October. This was during a low flow period (Table 1.)

There are no data gaps at EMWMF-3. However, the unit was placed in service on March 22 after the threat of stagnant freezing water (that could potentially damage the probes) was eliminated. The unit was pulled from this location on December 4 when there was an increased potential for the water at EMWMF-3 to freeze.

The parameters monitored (see Figure 4) with the In-Situ® multiparameter water quality data logger at EMWMF-3 from March 22 to December 4 were temperature, pH, DO, specific conductivity, water surface height (calculated to discharge), and turbidity.



C –Centigrade; **mg/L** – milligrams per liter; **µS/cm** –microSiemens per centimeter; **NTU** - nephelometric *turbidity units;* **CFS** – *cubic feet per second;* **in** – *inches.*

Figure 4: Water Quality Parameters (temperature, pH, DO, specific conductivity, discharge, and turbidity) and Precipitation at EMWMF-3

<u>Temperature:</u>

As evident from the temperature graph, the water temperatures were elevated. The increased temperature was expected for a surface water impoundment when the ambient air temperatures were the highest. The ambient air temperature increase was observed during June and July of 2012. The daily temperature fluctuations (diel cycle) were amplified during times when the flow at the V-weir stopped. The temperature amplification was due to no flow (stagnant water) and radiant heating from the sun. Along with the daily temperature fluctuations, seasonal temperature fluctuations were observed.

pH:

The pH data has a pronounced diel cycle. This cycle was especially evident when there was no discharge at the V-Weir. The pH data can vary with temperature. Generally, the surface water pH during times of discharge varied between 7.13 and 9.73 standard units, with the average pH around 8.02 standard units. The pH was observed above 9.0 standard units at the V-Weir during discharge 25 times as shown in Table 2. These twenty-five discharges were above the stormwater release criteria noted in Table 3.

Table 2: pH Above 9 Standard Units

Start		Stop
3/22/12 2:20 PM		3/24/12 12:05 PM
4/8/12 4:56 PM		4/16/12 10:56 PM
5/15/12 6:26 PM		5/16/12 3:41 AM
5/16/12 1:41 PM		5/18/12 10:11 PM
5/19/12 3:56 PM		5/19/12 11:56 PM
5/20/12 10:56 AM		5/23/12 12:26 AM
5/23/12 2:41 PM		5/24/12 2:56 AM
5/25/12 1:26 PM		5/26/12 2:56 AM
5/26/12 5:26 PM		5/26/12 10:56 PM
5/27/12 4:56 PM		5/27/12 9:56 PM
5/28/12 4:26 PM		5/28/12 10:56 PM
5/29/12 5:41 PM		5/29/12 8:41 PM
5/30/12 6:41 PM		5/30/12 8:56 PM
6/28/21 5:26 PM		6/28/12 9:16 PM
7/13/12 6:06 PM		7/13/12 9:06 PM
7/14/12 3:06 PM		7/14/12 6:26 PM
7/19/12 3:06 PM		7/19/12 11:16 PM
7/21/12 12:26 PM		7/22/12 1:26 AM
7/22/12 12:16 PM		7/22/12 10:56 PM
7/24/12 7:46 PM		7/24/12 8:36 PM
8/6/12 7:16 PM		8/6/12 10:16 PM
8/7/12 2:26 PM		8/8/12 1:06 AM
8/8/12 12:46 PM		8/8/12 9:16 PM
8/14/12 4:16 PM		8/14/12 10:36 PM
8/23/12 7:06 PM		8/23/12 7:56 PM

There are possible explanations for the observed higher pH values based on the data collected with the In-Situ® Troll data logger. As observed when there was no discharge in late August and early September, the pH varied from 7.71 to 9.33 standard units. No discharges or inputs to the V-Weir were observed. This increase in pH was associated with algal growth during periods of high photosynthetic activity. Algal growth in the sediment basin, V-Weir, and in the contact water basins have all played a role in the elevated pH levels observed at the V-Weir. Several algal remedies were employed in 2012, but their effectiveness needs to be reviewed.

Dissolved Oxygen (DO):
DO has a diel cycle that 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 either due to biological (photosynthesis/algal growth) or rapid non-laminar flow conditions. However, the lower levels of DO are probably associated with the elevated atmospheric and water temperatures. The higher DO readings observed during the day helps to support the conclusion that the pH issue is biological in nature.

Specific Conductivity:
Specific conductivity also has a slight diel cycle; the warmer the water the more ions in solution. The graph shows this fluctuation with temperature. There were also changes in conductivity due to significant rain events, length of time the water was exposed to soil in the sediment basin, and 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 no release criteria 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 on March 23, 24, 26, and 27, and April 6, 7, and 8. The high turbidity values in March and April were related to the construction activities associated with cell 6.

Discharge:
The discharge at EMWMF-3 was related to precipitation events and to CWP/CWT and uncontaminated stormwater discharges. CWP/CWT releases to the sediment basin were observed on January 5, January 12, February 2, February 14, February 28, April 24, June 26, October 2, and October 4 (as noted in the respective field log).

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.

Table 3: Stormwater Monitoring Criteria (Safe Drinking Water Act, TDEC 1200-4-3-.03(3(g)) and 1200-2-11-.16)

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

mg/L – milligram per liter; pCi/L – picocuries per liter; COC – contaminants of concern; DCG – derived concentration guides;

Radiological Sediment Samples

Two sediment grab samples were collected from the sediment basin at the locations shown in Figure 1. The samples were collected to determine if any deposition of radiological contaminants has occurred in the sediment basin. One sediment sample (location SD-1) was taken in 2012 at the confluence of the EMWMF outfall and did not show evidence of contamination build-up. Samples were analyzed for gross alpha, gross beta, strontium-90, total uranium, and technetium-99. The results are provided in Table 4. The results do not indicate a concern for radioactive concentrations in the sediment basin at this time.

	Table 4: EMWMF SB-1 Sediment Results (pCi/g*)					
Station ID	**Date**	**Gross Alpha)**	**Gross Beta***	**Technetium-99**	**Strontium-90***	**Total Uranium**
SB-1	6/22/12	5.53	5.9	1.22	0	2.80
SB-2	9/14/12	5.73	11.8	1.54	.53	4.27

*picocuries per gram

Radiological Water Samples

Five location groupings were consistently sampled at EMWMF in 2012. The samples were analyzed for radionuclides. The analyses varied and could include gross alpha, gross beta, strontium-90, technetium-99, tritium, and isotopic uranium.

<u>EMWMF-1 (GW-918)</u>

A total of five samples were collected at the background location, EMWMF-1 (Table 5). 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. In addition, staff was able to sample GW-921 on one occasion which is down gradient from the cell and near strike with the CWPs.

Table 5: EMWMF-1 (GW918) Sample Results (pCi/L*)						
Date	**Gross Alpha**	**Gross Beta**	**Strontium-90**	**Technetium-99**	**Total Uranium**	**Tritium**
11/08/11	4.7	3.9	0	1.11	0.11	0
2/14/12	0.8	3.1	0	1.08	0.12	0.0
5/10/12	0.76	3.5	0	0	0.12	0
8/7/12 (GW921)	0	3.5	0.02	0.54	0.08	0.0
8/9/12	0.4	4.9	0	1.08	.23	0
11/26/12	0.9	2.6	0	0	.24	0

*pCi/L – picocuries per liter

<u>EMWMF-2 (underdrain discharge):</u>

A total of six samples were collected at EMWMF-2. The samples were analyzed for gross alpha, gross beta, technetium-99, tritium, and isotopic uranium. The sample results are presented in Table 6. The sample results are comparable to background or EMWMF-1.

Table 6: EMWMF-2 Sample Results (pCi/L*)						
Date	**Gross Alpha**	**Gross Beta**	**Technetium-99**	**Tritium**	**Strontium-90**	**Uranium**
4/12/12	0	2.8	N/A	N/A	N/A	N/A
5/10/12	1.7	2.1	0	0	0	.23
7/31/12	NA	NA	0	0	0.02	.36
8/21/12	2.4	2.1	NA	NA	NA	NA
10/2/12	NA	NA	0	0	0.35	.50
11/8/12	NA	NA	0	0	0.114	.32

*NA – not analyzed; pCi/L – picocuries per liter

EMWMF-3 (sediment basin discharge)

A total of six 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 7. The results at EMWMF-3 were elevated in the all analyses indicating some radionuclides are being discharged at EMWMF-3.

Table 7: EMWMF-3 Sample Results (pCi/L*)							
Date	**Gross Alpha**	**Gross Beta**		**Strontium-90**	**Technetium-99**	**Total Uranium)**	**Tritium**
2/14/12	39.0	13.2		0.64	9.2	23.6	346
3/29/12	52.8	8.1		0.84	NA	22.3	NA
5/15/12	1.7	4.2		0.49	1.66	1.06	0
9/18/12	2.1	3.3		0.18	0.54	0.78	139
9/27/12	14.7	18.2		1.21	6.37	7.71	684
12/11/12	9.3	12.1		0.77	1.09	8.18	0

*pCi/L – picocuries per liter

Concentrations of radionuclides released from the sediment basin outfall (EMWMF 3) to the receiving stream (NT-5) are restricted to an annual average concentration equivalent to 25 mrem in a year, based on dose limits specified in state regulations. To assess the concentration of radionuclides released from the sediment basin, FFA parties have agreed to use 25% of the Derived Concentration Guides (DCGs) contained in DOE Order 5400.5 (Table 8). The DCGs represent the concentration of specific radionuclides in water that would result in a dose equivalent to 100 mrem/year, if ingested at a rate of two liters per day over the course of year. For mixtures of radionuclides, the sum of the ratios of the observed concentration of each radionuclide to its corresponding limit must not exceed 1.0. In 2012, the results for the radionuclides measured at the sediment basin were well below the DCGs corresponding to a dose of 25 mrem in a year. Gross alpha and gross beta represent the combined dose for all alpha and beta emitters and are used as a screening tool to assess if additional analysis is warranted.

Table 8: Derived Concentration Guides (DCGs) for selected isotopes		
Isotope	**DCG (100 mrem/year)**	**25% of the 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 – picocuries per liter; mrem/year – millirem per year.

EMWMF-4/4B (uncontaminated stormwater discharge)
One sample was collected at EMWMF-4B. No water was observed discharging from EMWMF-4. The sample was analyzed for gross alpha, gross beta, strontium-90, total uranium, and tritium. The sample results are presented in Table 9. This location is subject to the release criteria shown in Table 2, as it is discharged to EMWMF-3. The sample at EMWMF-4B did not exceed release criteria.

Table 9: EMWMF-4/4B Sample Results (pCi/L*)							
Date	**Gross Alpha**	**Gross Beta**		**Strontium-90**	**Technetium-99**	**Total Uranium**	**Tritium**
11/9/11	1.4	3.9		0.27	NA	5.31	0

*NA – not analyzed; pCi/L – picocuries per liter

Surface Water
A total of three samples were collected at tributaries NT-3, NT-4. NT-5 was not sampled this year. The samples were analyzed for gross alpha, gross beta, strontium-90, technetium-99, isotopic uranium, and tritium. The sample results are presented in Table 10. At the NT-3 sampling location, all results were elevated compared to background results. It is believed these results are due to plume issuing from legacy disposal areas to the east of the site (i.e. Bone Yard/ Burn Yard or the Hazardous Chemical Disposal Area).

Table 10:Surface Water Results (pCi/L*)								
Station ID	**Date**	**Gross Alpha**	**Gross Beta**		**Strontium-90**	**Technetium-99**	**Total Uranium**	**Tritium**
NT-3	6/19/12	312	51.9		0.20	1.10	69.62	150
NT-4	6/19/12	0	1.8		0	0.55	0.91	0
NT-3	12/11/12	pending	pending		pending	pending	pending	pending

*pCi/L – picocuries per liter; Pending – Data not available from the Laboratory

Contact Water Pond/Tank samples (CWP/CWT)
The contact water pond and tanks are used to hold contaminated stormwater that collects in the waste cells. The "contact water" is sampled and based on the results, either released to the sediment retention basin or treated as leachate and sent for treatment at the ORNL Process Waste Treatment Plant. DOE's DCGs are used as the limit for releases to the sediment retention basin. A total of six samples were collected at the contact water ponds and tanks and analyzed for gross alpha, gross beta, strontium-90, technetium-99, isotopic uranium, and tritium. All results were elevated when compared to background results, but below DOE's DCGs.

Table 11: Contact Water Pond Sample Results (pCi/L*)								
Station ID	**Date**	**Gross Alpha**	**Gross Beta**		**Strontium-90**	**Technetium-99**	**Total Uranium**	**Tritium**
CWP-1	11/21/11	11	47.3		0.27	73	5.31	0
CWP-1	5/16/12	37	21.7		2.13	9.05	11.88	149
CWP-1	6/14/12	70	19.3		2.26	6.09	20.65	150
CWP-1	8/6/12	213	7.4		1.00	6.22	57.35	140
CWT-C	9/24/12	440	34.6		0.73	30.9	175.4	NA
CWP-3	9/27/12	150	40.9		pending	pending	pending	pending

*pCi/L – picocuries per liter; Pending – Data not available from the Laboratory

Conclusion

Groundwater review has shown 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. However, these two cells are nearly full and any intrusive activities could compromise the integrity of the disposal cell liners. Near PP-02 the water level has risen throughout the year. Further monitoring is needed to see if this incursion is stable or increasing.

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. Continuous monitoring does reveal conditions that require closer scrutiny and oversight and have brought changes, such as introducing algal remedies to reduce the pH at the V-Weir.

The results from the radiological water samples suggest that radionuclides are being discharged from EMWMF-3 and EMWMF-4. However, those discharges are within compliance under TDEC Rule 1200-2-11-.16. The results from radiological sediment samples suggest that radiological discharges from EMWMF-3 are not impacting the sediments of NT-5 and Bear Creek.

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Ambient Sediment Monitoring

Principle Author: John (Tab) Peryam

Abstract

Sediment samples from several Clinch River and Poplar Creek sites were analyzed for metals, toxicity and radiological parameters. The mercury levels in all of the Clinch River sediment samples were less than the Probable Effects Concentration (PEC) of 1.06 mg/kg (range is from 0.015 to 0.70 mg/kg) (MacDonald et al. 2000). Poplar Creek mercury values all exceed the PEC (range from 1.90 mg/kg to 22 mg/kg). Although cesium-137 can be detected in Clinch River sediment samples taken downstream of the mouth of White Oak Creek, the levels are low and do not pose a threat to human health. Sediment toxicity testing showed no significant differences (p=0.05) between samples and pooled reference sites (Clinch River Mile [CRM] 52.6, CRM 41.2, CRM 35.5). Reference sites did not differ significantly from one another in survival or growth. The result at CRM 10.0 (63.8 % survival) was significantly different (p=0.05) from the laboratory control group (88.8% survival).

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 DOE activities on the 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 and cesium-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 and Poplar Creek. Sediment samples were analyzed for metals, toxicity and radiological parameters. DOE-O conducted sediment monitoring at 11 sites in June, 2012 (see Table 1 and Figure 1). Seven sites were on the Clinch River and four sites were on Poplar Creek. 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).

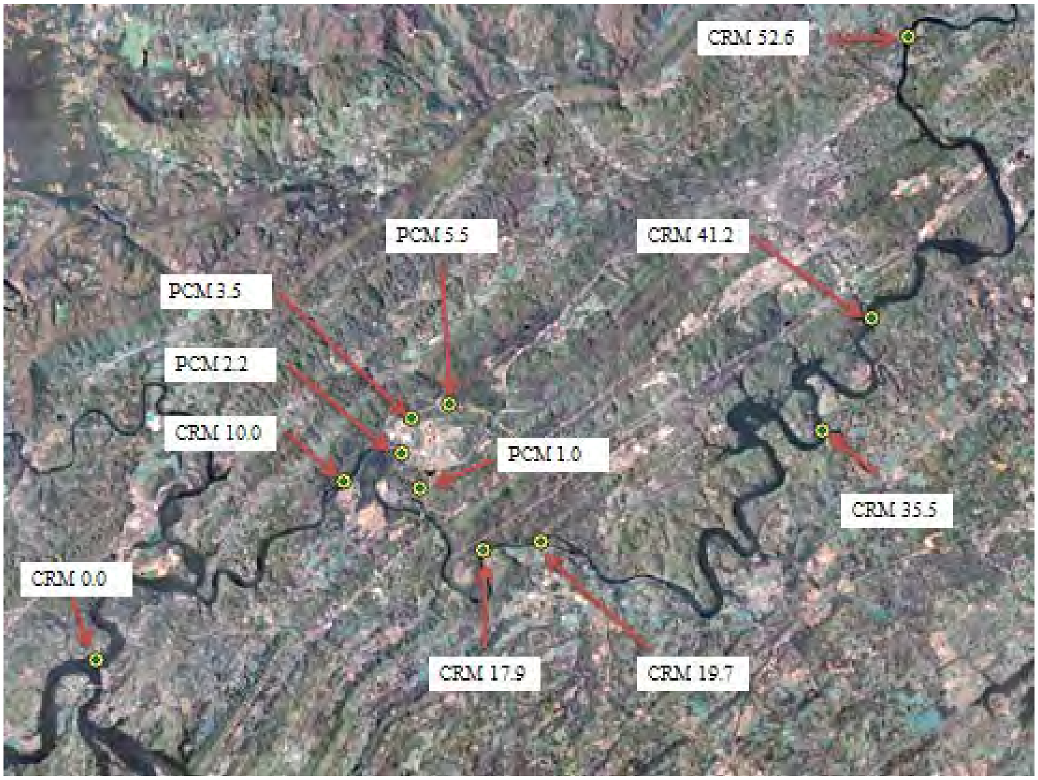

Figure 1: Sediment Sampling Sites

Methods and Materials

Sediment samples were taken during June using the methods described in the DOE-O Sediment Monitoring Standard Operating Procedure. River sediment samples were taken with a petite PONAR dredge. At least three grabs were taken at each site; the grabs were combined and containerized for transport to the analytical laboratory. Separate containers were used for metals, mercury, toxicity, and radiological samples. The Tennessee State Laboratories processed the samples, according to 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. Sediment toxicity tests were conducted by Coastal Bioanalysts, Inc. These tests were 10-day growth and survival tests (Chironomus tentans) conducted in sediment (EPA 100.2). For the purpose of toxicity testing, three of the sites upstream of DOE impacts were pooled for use as reference sites. These sites were Clinch River Mile (CRM) 52.6, CRM 41.2, and CRM 35.5. In addition, a laboratory control group was used for comparison to the sample toxicity tests.

Table 1: Sampling Sites

Location	Site	Stream Reach in Miles/tenths	Designation
Clinch River	CRM 52.6	52.6	CLINC052.6AN
Clinch River	CRM 41.2	41.2	CLINC041.2AN
Clinch River	CRM 35.5	35.5	CLINC035.5AN
Clinch River	CRM 19.7	19.7	CLINC019.7RO
Clinch River	CRM 17.9	17.9	CLINC017.9RO
Clinch River	CRM 10.1	10.1	CLINC010.1RO
Clinch River	CRM 0.0	0.0	CLINC000.0RO
Poplar Creek	PCM 5.5	5.5	POPLA005.5RO
Poplar Creek	PCM 3.5	3.5	POPLA003.5RO
Poplar Creek	PCM 2.2	2.2	POPLA002.2RO
Poplar Creek	PCM 1.0	1.0	POPLA001.0RO

CRM – Clinch River Mile PCM – Poplar Creek Mile

Results and Discussion

Metals Analyses

The 2012 arsenic value [14.2(J) ppm] at the mouth of the Clinch River (Clinch River Mile 0.0) was greater than the Threshold Effects Concentration (TEC) (9.79), but less than the Probable Effects Concentration (PEC) (33 ppm) for arsenic (MacDonald *et al.* 2000) (Table 2). A "J" value is an estimated value between the method detection limit (MDL) and the method quantitation limit (MQL). Following the Kingston Ash Spill in December 2008, arsenic levels in sediment samples at this sampling location increased (Figure 2). Based on TDEC/DOE-O's annual sediment sampling, sediment arsenic levels have not reached the PEC during the period from 2001 to 2012. The PECs are Consensus-Based Sediment Quality Guidelines (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 to 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***
Aluminum	mg/kg	5660	4147.1	5200	12740	1260	14000	11			
Arsenic	mg/kg	3.98	3.96	3.2	14.2	0	14.2(J)	11	9.8	9.79	33
Cadmium	mg/kg	0.26	0.267	0.200	0.74	0	0.74	11	0.99	0.99	4.98
Chromium	mg/kg	15.72	14.95	12.10	53.2	3.7	56.9	11	43.4	43.4	111
Copper	mg/kg	15	11.97	9.7	33.3	2.3	35.6	11	31.6	31.6	149
Iron	mg/kg	12645	5210.9	13300	15630	4470	20100	11			
Lead	mg/kg	13.68	6.52	13.40	24.5	3.5	28	11	35.8	35.8	128
Magnesium	mg/kg	1102.4	516.20	1320	1458	302	1760	11			
Manganese	mg/kg	673.0	372.9	454.0	1071	279	1350	11			
Mercury	mg/kg	3.21	6.58	0.12	21.985	0.015	22	11	0.18	0.18	1.06
Nickel	mg/kg	14.94	10.72	15.40	32.1	2.9	35	11	22.7	22.7	48.6
Zinc	mg/kg	45.78	31.71	51.9	101.4	8.6	110	11	124	121	459

*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)

RAGS Risk Assessment Guidance for Superfund

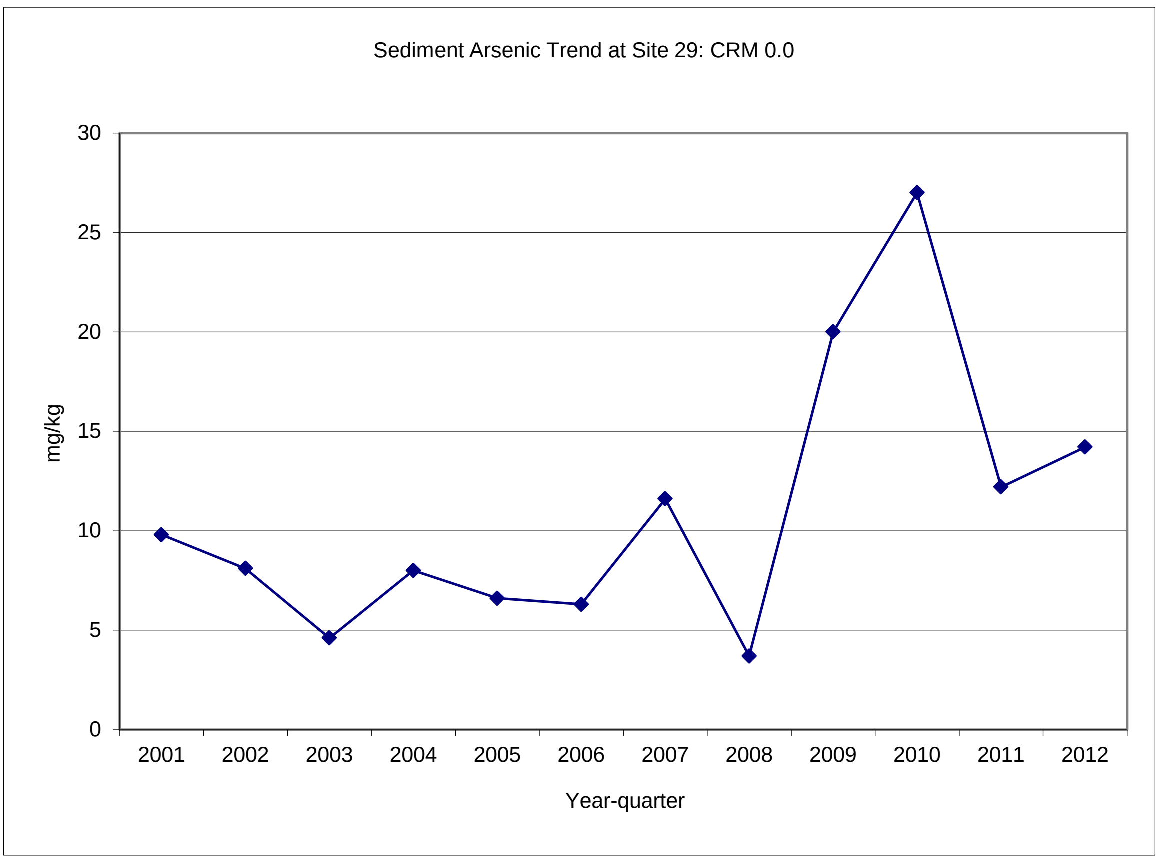

Figure 2: Arsenic at Clinch River Mile 0.0

The only metal found above the PEC was mercury (Table 2). All of the 2012 Poplar Creek sediment mercury values exceed the PEC of 1.06 mg/kg (MacDonald *et al.* 2000). The mercury values range from 1.90 mg/kg to 22 mg/kg with the greatest value at PCM 2.2 [22 mg/kg] (Figure 3). The mercury in Poplar Creek sediments results from historical activities at Y-12 and to a lesser extent ETTP. The mercury levels in Clinch River sediment samples taken below Poplar Creek are less than the PEC.

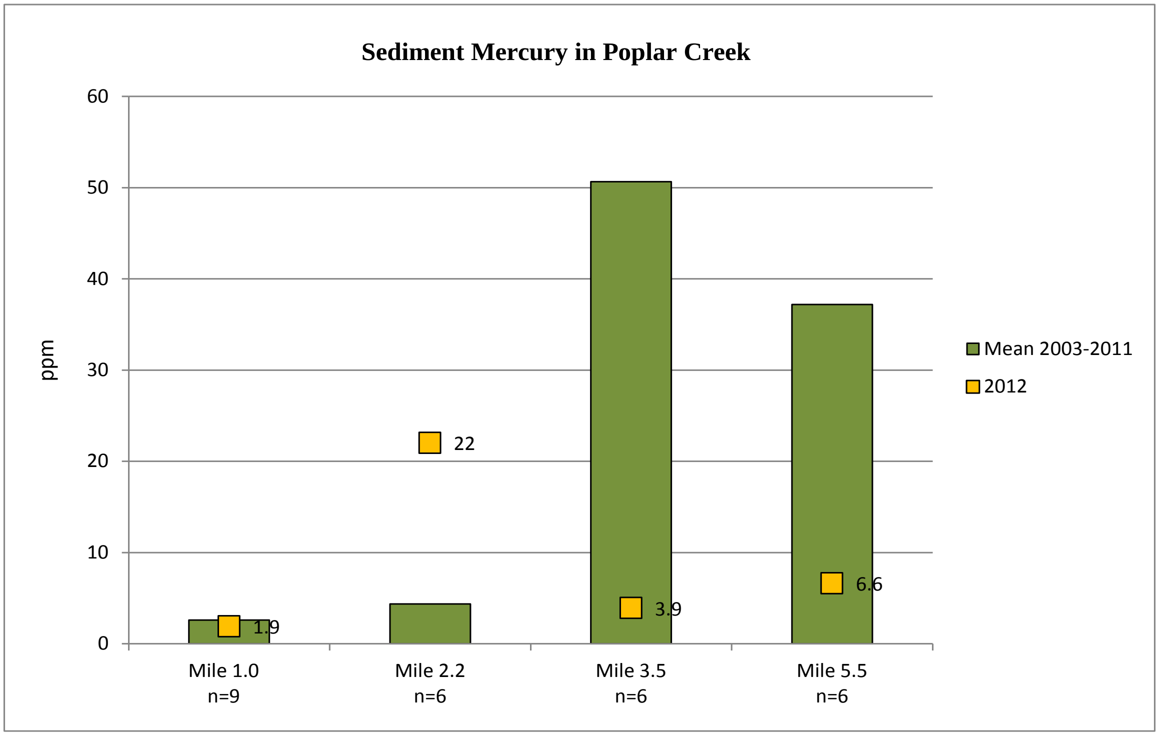

Figure 3: Mercury in Poplar Creek Sediment Grab Samples

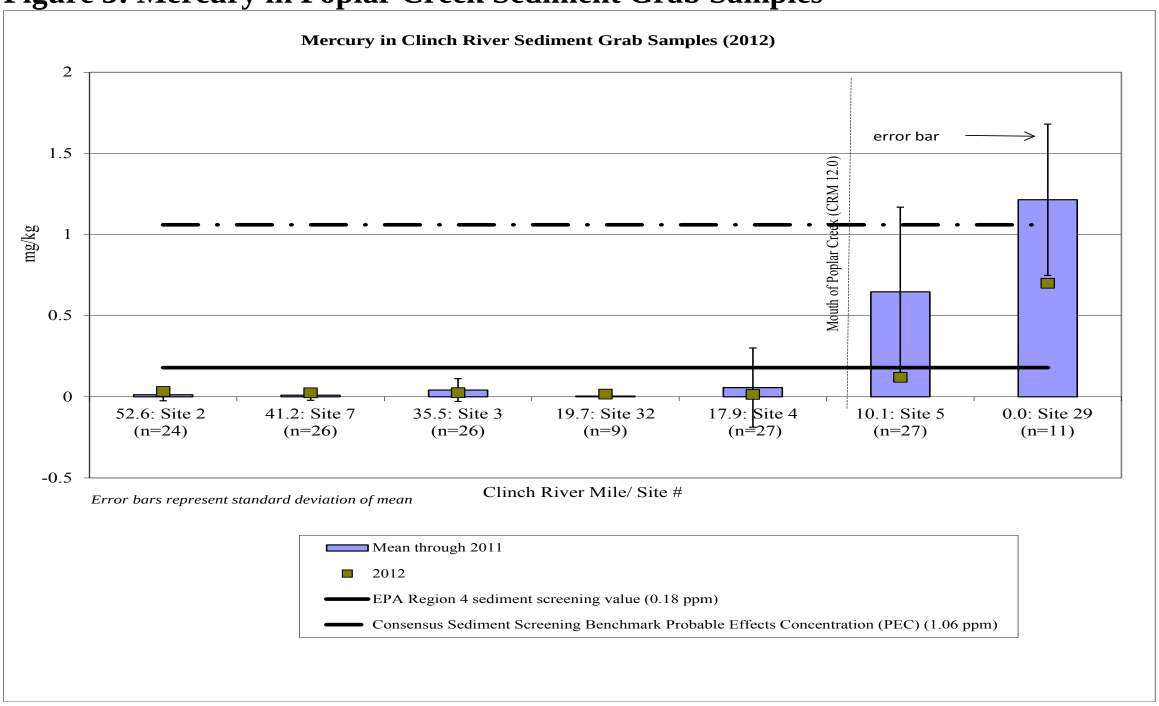

Figure 4: Mercury in Clinch River Sediment Grab Samples

Figure 4 shows the effect of the Poplar Creek mercury contamination on the Clinch River sediments. The mouth of Poplar Creek is at approximately Clinch River mile (CRM) 12 and the sampling sites downstream show mercury contamination.

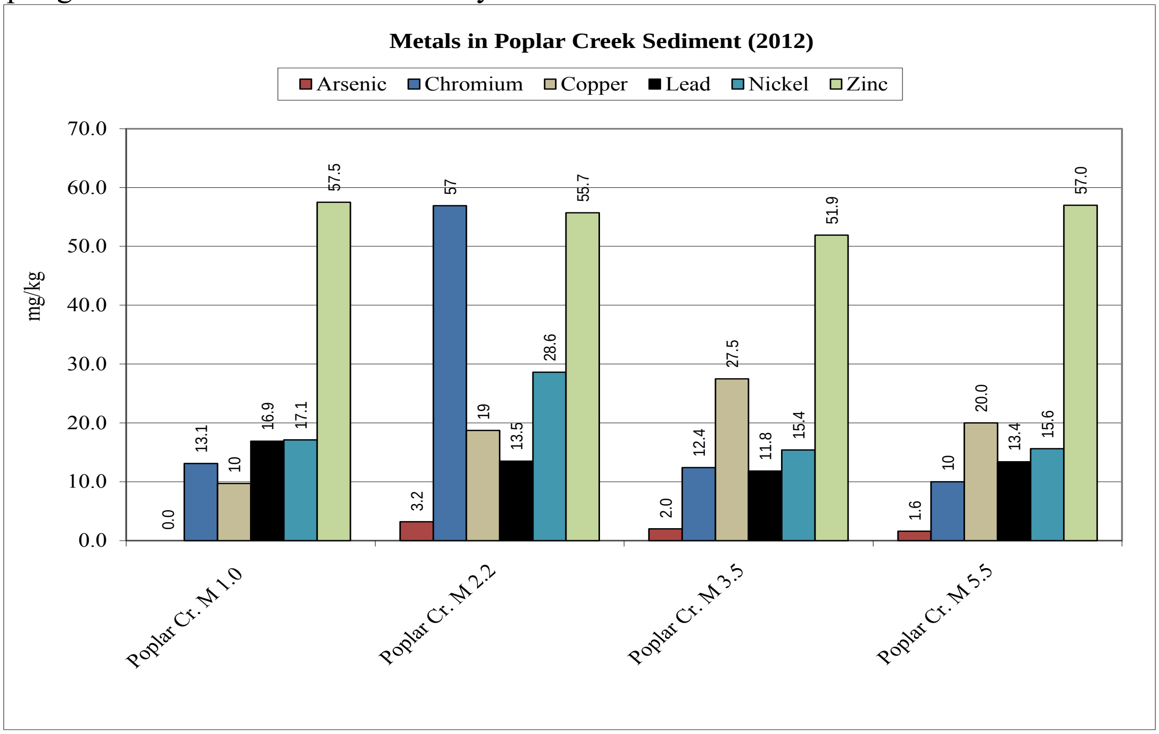

Figure 5: Metals Profile for Poplar Creek Sites

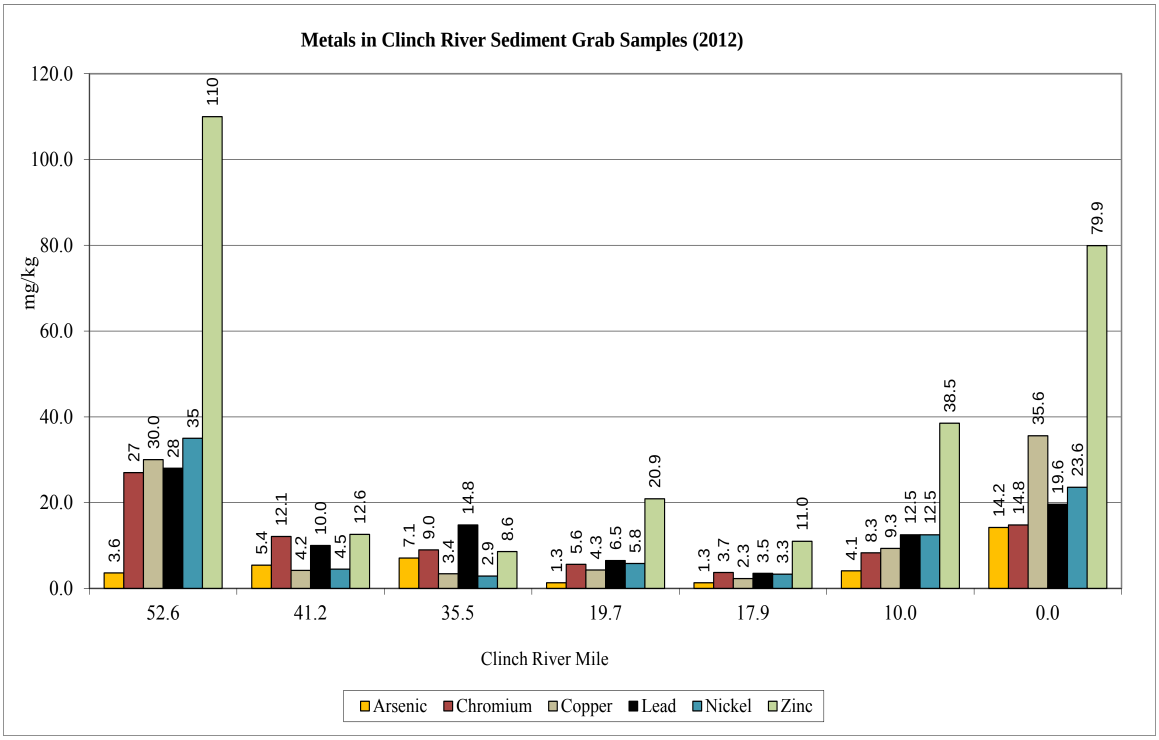

Figure 6: Metals Profile for Clinch River Sites

Figure 5, Metals in Poplar Creek Sediments (2012), shows the data for the metals arsenic, chromium, copper, lead, nickel and zinc; all values are below their respective PECs. The same is true for these metals in the samples from the Clinch River (Figure 6).

Sediment Toxicity

Sediment toxicity was predicted using consensus-based freshwater sediment quality guidelines (EPA 2000). An individual PEC Quotient (PEC-Q) was calculated for each metal by dividing the sediment concentration of each metal by the PEC for that metal. In this case, seven metals (arsenic, cadmium, chromium, copper, lead, nickel, and zinc) were included in the calculation. These individual PEC-Qs are summed, then divided by the number of metals in order to obtain a mean PEC-Q which is compared to the Consensus-Based Sediment Quality Guidelines (CBSQGs) for metals according to a method used by the State of Wisconsin (WDNR 2003). Predicting toxicity with the CBSQGs is most reliably done with total PAHs, total PCBs and the metals arsenic, cadmium, chromium, copper, lead, nickel, and zinc. The supporting data comes from testing hundreds of samples with 10- to 42-day toxicity analyses with *Hyalella azteca* (an amphipod) or 10- to 14-day toxicity analyses with the midges *Chironomus tentans* or *C. riparius* (Ingersoll et al. 2000). The measured toxicities of the samples that comprise the database mentioned previously were plotted at the midpoints of the range of the mean PEC quotient where they fell (e.g., <0.1, 0.1-0.2, 0.2-0.3). The results showed that toxicity is directly correlated with the mean PEC quotient (r^2 = 0.98). The slope of the relationship between mean PEC-Q and sediment toxicity is shown in Chart 1. (MacDonald et al. 2000). Predicted sediment toxicities were compared to actual sediment toxicity test results conducted by Coastal Bioanalysts, Inc. (Figures 7 and 8) This comparison was completed by running the 10-day growth and survival (Chironomus tentans) test recommended by the EPA (EPA 100.2/ASTM 1706).

$$Y = 101.48\left(1 - 0.36^{x}\right)$$

$$\left(Where\ x = mean\ PEC - Q\ and\ Y = toxicity\right)$$

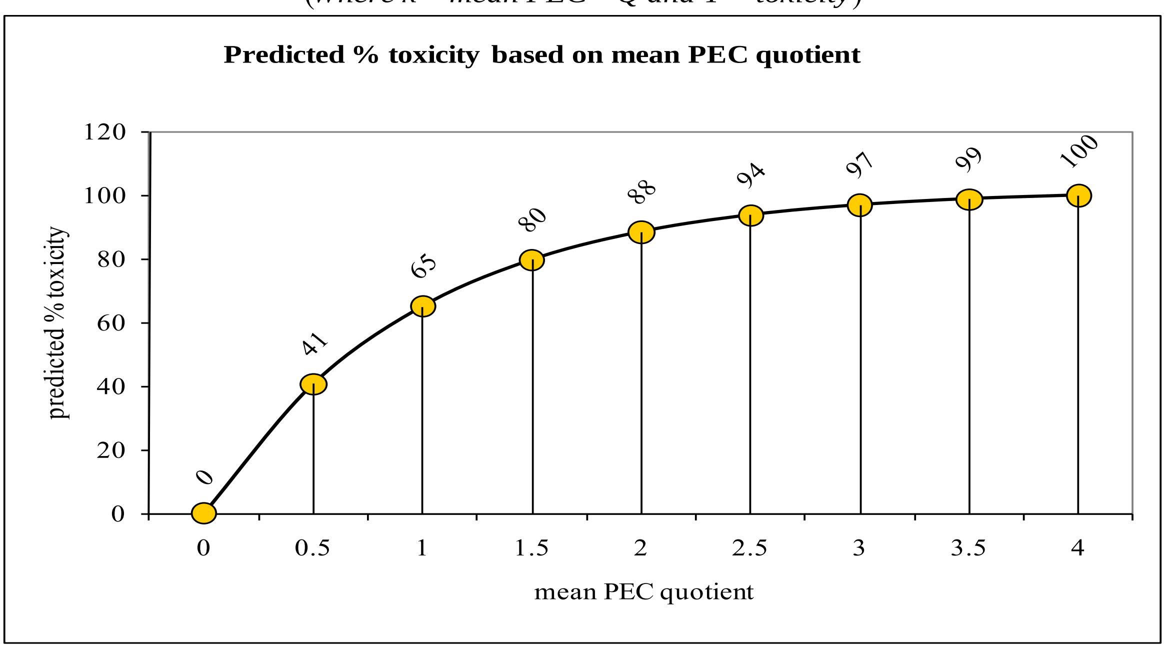

Chart 1: Predicted % toxicity based on mean PEC quotient

There were no significant differences (p=0.05) between samples and pooled reference sites (CRM 52.6, CRM 41.2, CRM 35.5). Reference sites did not differ significantly from one another in survival or growth. The result at CRM 10.0 (63.8 % survival) was significantly different (p=0.05) from the laboratory control group (88.8% survival).

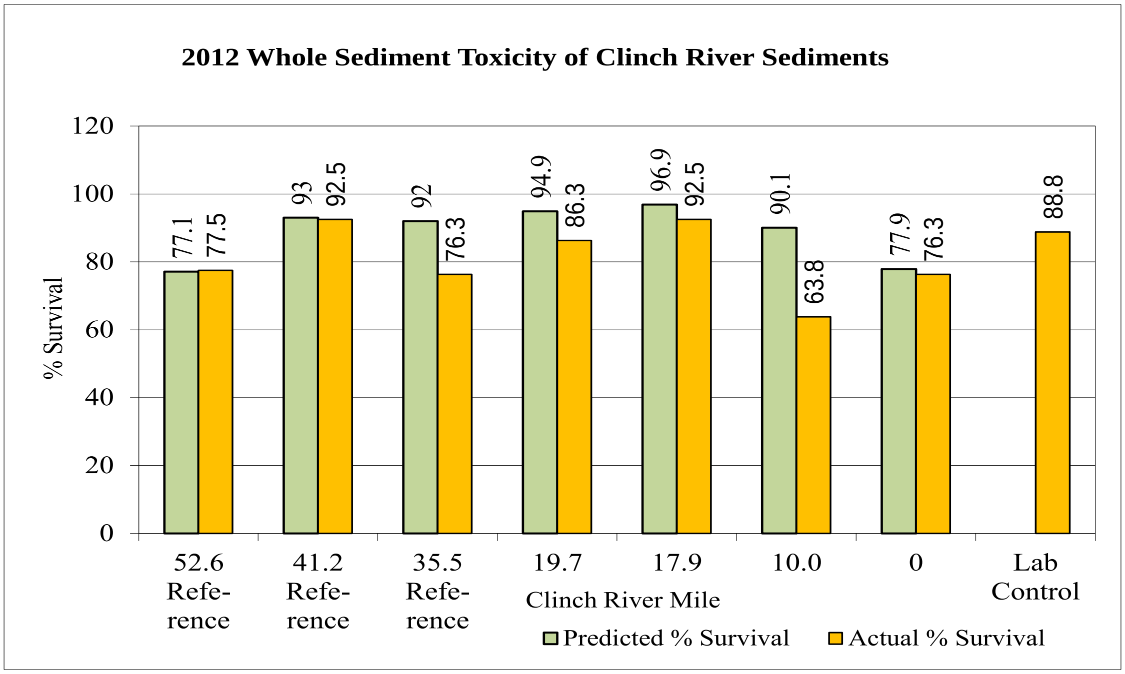

Figure 7: 2012 Whole sediment toxicity of sediments in Clinch River sediments

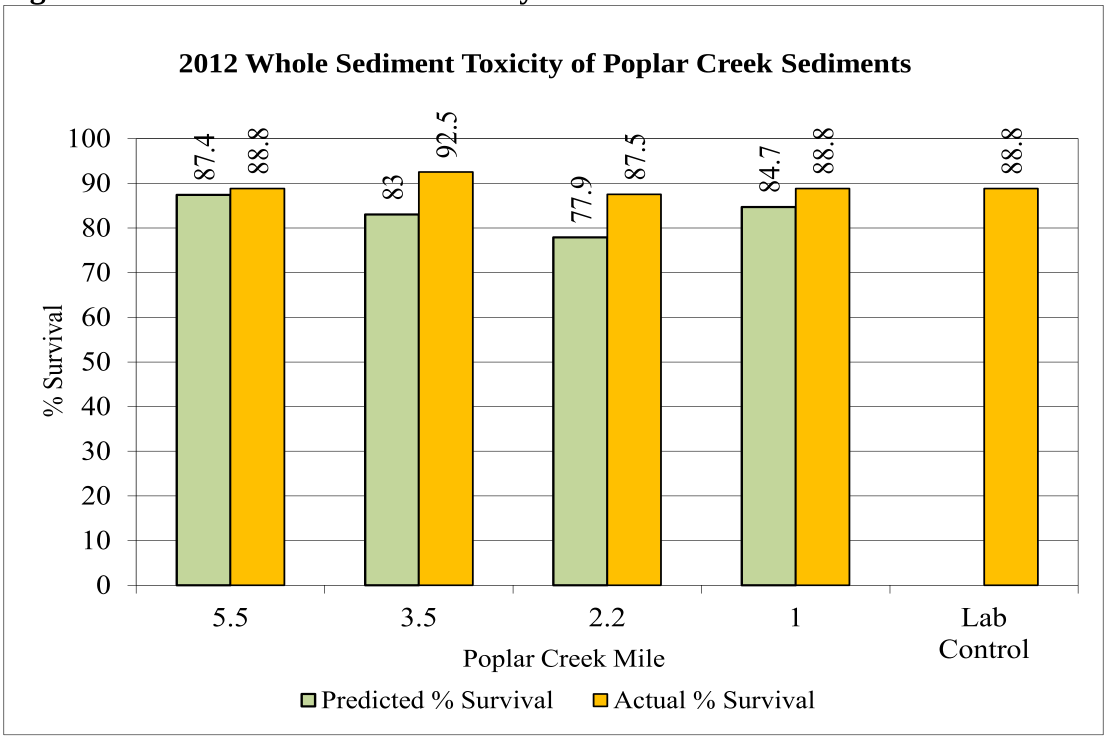

Figure 8: 2012 Whole Sediment Toxicity of Poplar Creek Sediments

Radiological Analyses

A summary of the 2012 radiological results are shown in Table 3. The radiological sediment data show no reason for human health concerns; all parameters are well below DOE PRGs. 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 2.12 pCi/g at CRM 0.0. In 2012,cCesium-137 was detected in only three of the samples: CRM 19.7 (0.65 pCi/g), CRM 10.0 (0.510 pCi/g), and CRM 0.0 (2.12 pCi/g). Cesium-137 results for the Clinch River are shown in Figure 9. Cs-137 contamination of the Clinch River from White Oak Creek is indicated by the Cs-137 sample results for the sites downstream of the mouth of White Oak Creek (CRM 20.8).

Table 3: Summary of Radiological Data

Parameter	Units	Mean	Std. Dev.	Median	Range	Min.	Max.	Count
Radioactivity, alpha	mg/kg	2.08	1.54	1.71	5.26	0	5.26	11
Radioactivity, beta	mg/kg	3.7	3.8	2.7	13.6	0	13.6	11
Potassium-40	mg/kg	10.2	7.8	11.2	27.8	0	27.8	11
Cesium-137	mg/kg	0.30	0.65	0	2.12	0	2.12	11
Thallium-208	mg/kg	0.39	0.43	0.30	1.58	0	1.58	11
Lead-212	mg/kg	1.01	0.97	0.9	3.76	0	3.76	11
Lead-214	mg/kg	1.15	1.39	0.97	5.14	0	5.14	11
Bismuth-212	mg/kg	0.34	1.12	0	3.7	0	3.7	11
Bismuth-214	mg/kg	0.95	1.64	0.49	5.64	0	5.64	11
Actinium-228	mg/kg	1.13	1.22	0.98	4.4	0	4.4	11

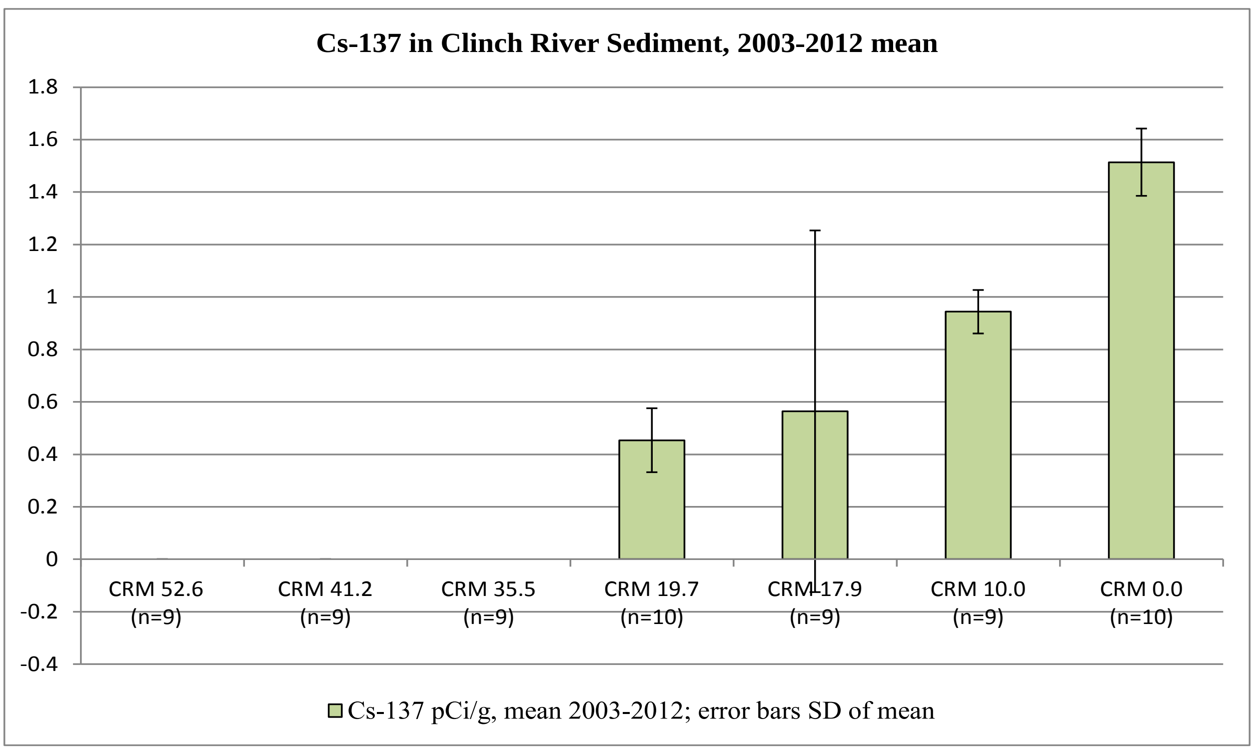

Figure 9: Cesium 137 in Clinch River Sediments

At Clinch River Mile 10.0, Cs-137 activities appear to have decreased over the 18 year span of sediment sampling from 1994 to 2012 (Figure 10). This may be due to natural radioactive decay (half-life 30 years) of Cs-137 and the deposition of fresh sediment at the sampling sites.

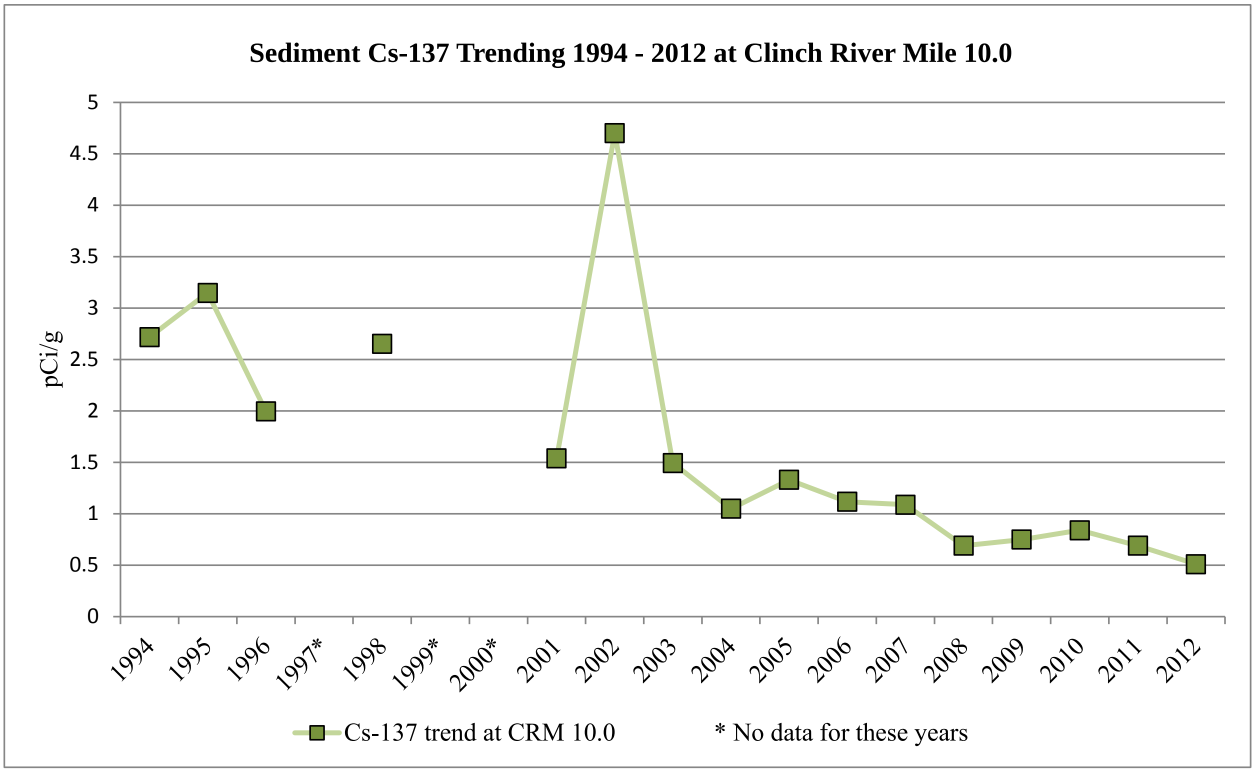

Figure 10: Cesium-137 Trending at Clinch River Mile 10.0

Conclusion

Mercury levels in the samples taken at Poplar Creek and in the Clinch River below the confluence of Poplar Creek are elevated. The mercury levels in all of the Clinch River sediment samples taken below Poplar Creek are less than the PEC of 1.06 mg/kg (MacDonald et al. 2000). The highest mercury level (0.70 mg/kg) was at Clinch River Mile 0.0. Poplar Creek mercury values all exceed the PEC (range from 1.90 mg/kg to 22 mg/kg). Mercury concentrations do not show any clear temporal trends at any of the sites sampled. The only metal found above the PEC was mercury. Other metals in both Poplar Creek and the Clinch River are below their respective PECs.

Cs-137 is found in low concentrations in the sediment at Clinch River sites below the mouth of White Oak Creek. The levels are very low and do not pose a threat to recreation or human health. At Clinch River Mile 10.0, Cs-137 activities appear to have decreased over the span of sediment sampling from 1994 to 2012. The level of contamination appears to be decreasing over time, possibly due to the radioactive decay of the Cesium-137 and the deposition of fresh sediment.

Predicted sediment toxicities were compared to actual sediment toxicity test results from Coastal Bioanalysts, Inc. testing. There were no significant differences (p=0.05) between samples and pooled reference sites (CRM 52.6, CRM 41.2, CRM 35.5). Reference sites did not differ significantly from one another in survival or growth. The result at CRM 10.0 (63.8 % survival) was significantly different (p=0.05) from the laboratory control group (88.8% survival).

Sediment data from the 2012 sampling show no levels of contamination that exceed DOE Preliminary Remediation Goals (PRGs) for recreation and, based on these criteria, do not pose a threat to human health. If in the future, these sediments are to be used for agricultural or other purposes, analysis should be performed to determine the suitability for these new purposes.

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Ambient Surface Water Monitoring

Principal Author: Andy Robinson

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 on or adjacent to the ORR. Relative to the four ORR watersheds, Bear Creek (BCK), East Fork Poplar Creek (EFK), Mitchell Branch (MIK), and White Oak Creek (WCK) / Melton Branch (MEK), legacy Department of Energy (DOE) ORR operations have possibly impacted their respective surface waters with volatile and semi-volatile organic compounds, heavy metals, and radionuclides. Relative to this study, these types of chemicals are classified as contaminants of concern (COC). The four impacted watersheds listed above flow either indirectly via Clinch River tributaries/watersheds or directly into the Clinch River. Relative to this study, additional Clinch River ORR tributaries/watersheds of interest are McCoy Branch (MCM), Raccoon Creek (RCM), Grassy Creek (GCM), Poplar Creek (PCM), and Clear Creek (CCM, ecoregion reference tributary).

Introduction

The Bear Creek, East Fork Poplar Creek, Mitchell Branch, and White Oak Creek/Melton Branch watersheds ultimately drain into the Clinch River. In addition, the ORR Clinch River tributaries of RCM, GCM, PCM, and CCM also 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. From the city of Norris (north of ORR) to the city of Kingston (south of ORR), this span of the Clinch River is approximately thirty miles in length. In addition, this Clinch River stretch is often used by swimmers, and boaters engaged in recreational activities. The DOE ORR COCs are classified into two groups, non-radiological and radiological. The main non-radiological COCs are classified as either volatile and semi-volatile organic compounds or as heavy metals, such as mercury. The radiological COCs emit all or some of the three ionizing radioactive particles of alpha, beta, and gamma rays. It's possible that the environment, ecology, and aquatic life of the Clinch River, its adjacent tributaries and associated ORR watersheds, have been impacted by these non-radiological and radiological COCs. To comprehensively evaluate the surface water quality of a watershed, tributary, or river, one must conduct an environmental sampling and monitoring program which accesses the physical and chemical properties of the surface water. Specifically, this study focused on the portion of the Clinch River and its tributaries which span approximately thirty miles from the north at Norris to the south at Kingston, Tennessee. This study provides a comprehensive evaluation of potential contamination from ORR operations. Therefore, this ambient surface water monitoring program is important and necessary in fulfilling our office's mission: to protect the environment and to ensure the health and safety of Tennessee citizens living near the ORR.

Methods and Materials

In the spring and fall of 2012, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-Oversight), conducted surface water monitoring and sampling relative to six sites located on the Clinch River and to five Clinch River tributaries, McCoy Branch (MCM), Grassy Creek (GCM), Raccoon Creek (RCM), Poplar Creek (PCM), and the eco-region reference Clinch River tributary of Clear Creek (CCM). Only seven sites were monitored and sampled during the spring, however, all eleven sites were monitored and sampled in the fall. The surface water samples were submitted to the State of Tennessee Department of Health Laboratory (TDH) for inorganic, heavy metals, and radionuclide analyses. In addition, utilizing YSI Professional Plus and YSI 556 multi-probe system (MPS) multi-parameter field instruments, the parameters of pH, conductivity, dissolved oxygen, and temperature were measured at each monitoring site. The surface water monitoring program followed both the WPC Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water (TDEC 2011) and the WPC Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (2011 TDEC). In addition, all work associated with this program was conducted in compliance with the office’s 2011 Health, Safety, and Security Plan.

Table 1 lists the eleven sampling locations and the samples collected during each sampling event, and Figure 1 shows the sampling sites relative to the ORR topographic map. Table 2 lists the analytical parameters (COC) of interest:

Table 1: 2012 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
18	*Raccoon Creek	RACCO000.4RO	RCM 0.4	19.5		X
20	*Grassy Creek	GRASS000.7AN	GCM 0.7	14.6		X
25	*Clear Creek	ECO67F06	CCM 1.0	77.7		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.

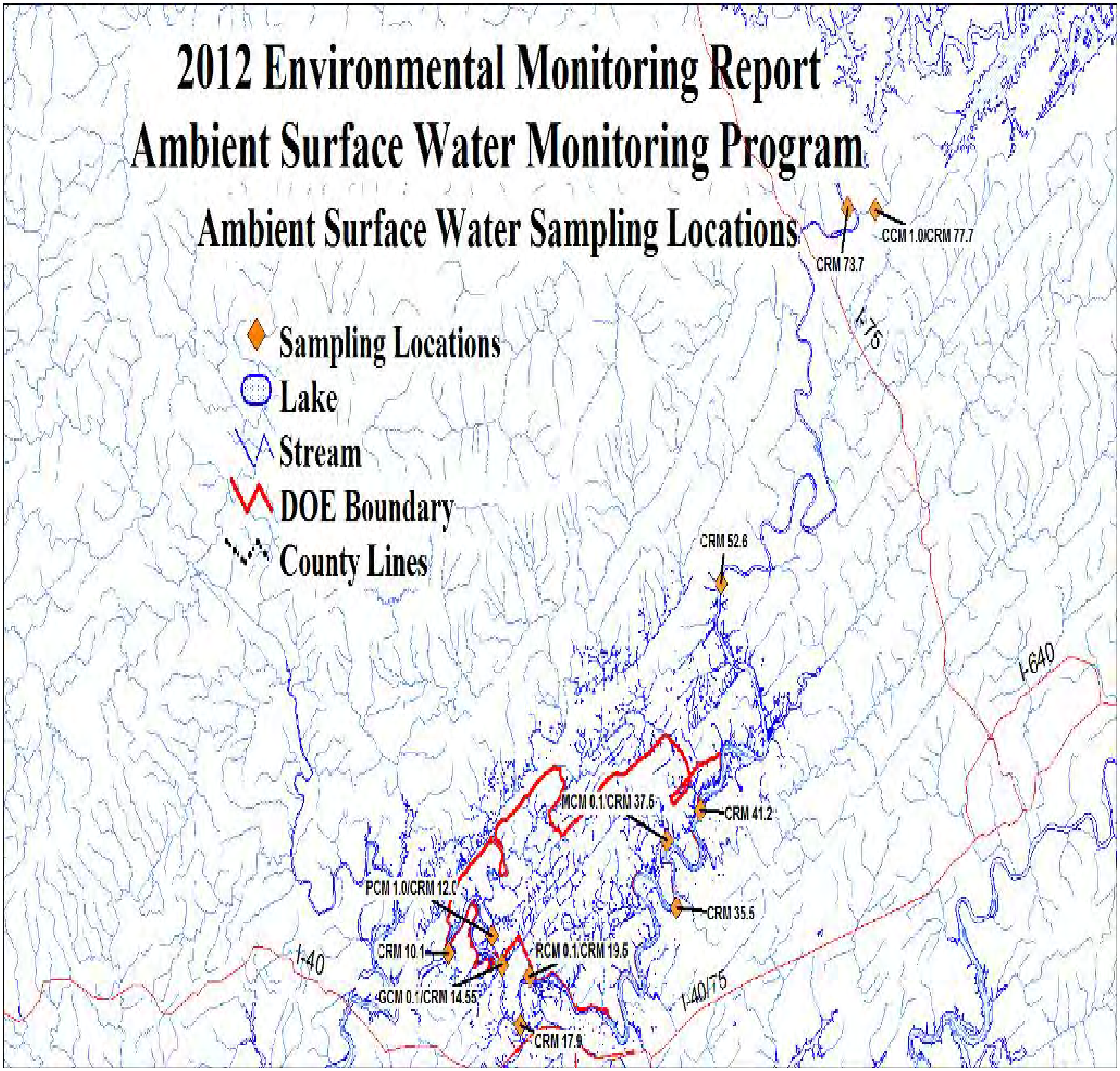

Figure 1: The Eleven Sample Locations Relative to the ORR Topographic Map

Table 2: Inorganic and Radiological Analysis Parameters

Inorganic Parameter	Units	Spring Event	Fall Event
Alkalinity	mg/L		X
Ammonia	mg/L	X	X
Chemical oxygen demand	mg/L	X	X
Chloride	mg/L		X
Dissolved oxygen	mg/L	X	X
NO2 & NO3	mg/L	X	X
pH	None	X	X
Residue, dissolved	mg/L	X	X
Residue, suspended	mg/L	X	X
Specific conductivity	µS/cm	X	X
Sulfate	mg/L		X
Temperature	deg C	X	X
Total hardness	mg/L	X	X
Total Kjeldahl nitrogen	mg/L	X	X
Total Phosphorus	mg/L	X	X
Arsenic	ug/L	X	X
Cadmium	ug/L	X	X
Calcium	mg/L		X
Chromium	ug/L	X	X
Copper	ug/L	X	X
Iron	ug/L	X	X
Lead	ug/L	X	X
Magnesium	mg/L		X
Manganese	ug/L	X	X
Mercury	ug/L	X	X
Potassium	mg/L		X
Selenium	ug/L	X	X
Sodium	mg/L		X
Zinc	ug/L	X	X

X = Paramater was analyzed.

Radiological Parameter	Units	Spring Event	Fall Event
Actinium-228	pCi/L	X	X
Bismuth-212	pCi/L	X	X
Bismuth-214	pCi/L	X	X
Cesium-137	pCi/L	X	X
Lead-210	pCi/L	X	X
Lead-212	pCi/L	X	X
Lead-214	pCi/L	X	X
Potassium-40	pCi/L	X	X
Radioactivity, alpha	pCi/L	X	X
Radioactivity, beta	pCi/L	X	X
Strontium-90	pCi/L	X	X
Technetium-99	pCi/L	X	X
Thallium-208	pCi/L	X	X

X = Paramater was analyzed.

Results and Discussion

The ambient TDH laboratory surface water final results are discussed relative to the two sampling events, spring 2012, and fall 2012. Tables 3 and 4 contain the spring 2012 surface water data summaries. Tables 5 and 6 contain the fall 2012 surface water data summaries.

Table 3: 2012 Spring Surface Water Data Summary (non-radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
Ammonia	mg/L	0.0314	0	0.078	0.033	0.078	5	n.a.
Chemical oxygen demand	mg/L	8.6	0	12	4.879	12	5	n.a.
Dissolved oxygen	mg/L	7.472	0	9.82	4.220	9.82	5	> 5.0[a]
NO2 & NO3	mg/L	0.196	0	0.41	0.20	0.41	5	n.a.
pH	None	8.386	7.65	8.74	0.442	1.09	5	between 6-9[a]
Residue, dissolved	mg/L	144	135	151	7.1	16	5	n.a.
Residue, suspended	mg/L	0	0	0	0	0	5	n.a.
Specific conductivity	µS/cm	275.2	246	293	20.4	47	5	n.a.
Temperature	°C	24.234	20.2	25.5	2.269	5.3	5	<= 30.5[a]
Total hardness	mg/L	150.6	131	174	16.0	43	5	n.a.
Total Kjeldahl nitrogen	mg/L	0.126	0	0.29	0.127	0.29	5	n.a.
Total Phosphorus	mg/L	0.0422	0.012	0.13	0.0494	0.118	5	n.a.
Arsenic	ug/L	0	0	0	0	0	5	< 10[b]
Cadmium	ug/L	0	0	0	0	0	5	< 2.0[d]
Chromium	ug/L	0.124	0	0.62	0.277	0.62	5	< 16[c]
Copper	ug/L	0.46	0	1.3	0.64	1.3	5	< 13[d]
Iron	ug/L	224.8	35	540	207.6	505	5	n.a.
Lead	ug/L	0.25	0	0.53	0.242	0.53	5	< 65[d]
Manganese	ug/L	51.76	22.7	103	34.79	80.3	5	n.a.
Mercury	ug/L	0	0	0	0	0	5	< 0.051[b]
Selenium	ug/L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Zinc	ug/L	1.5	0	3.6	1.30	3.6	5	< 120[d]

*Tennessee Water Quality Criteria:
[a]Fish and Aquatic Life (FAL), applies to all sites.
[b]Recreation (organisms only), applies to all sites.
[c]Fish and Aquatic Life (FAL), Chromium VI.
[d]Fish and Aquatic Life (FAL), applies to all sites. This value corresponds to a total hardness of 100mg/L.
n.a. = Not applicable.

Table 4: 2012 Spring Surface Water Data Summary (radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	PRG**
Actinium-228	pCi/L	0	0	0	0	0	5	7440
Bismuth-212	pCi/L	0	0	0	0	0	5	20900
Bismuth-214	pCi/L	3.88	0	10.7	5.36	10.7	5	77200
Cesium-137	pCi/L	0	0	0	0	0	5	487
Lead-210	pCi/L	0	0	0	0	0	5	16.8
Lead-212	pCi/L	0	0	0	0	0	5	593
Lead-214	pCi/L	0	0	0	0	0	5	43100
Potassium-40	pCi/L	0	0	0	0	0	5	600
Radioactivity, alpha	pCi/L	0.84	0.2	2.5	0.95	2.3	5	n.a.
Radioactivity, beta	pCi/L	2.4	0.5	3.7	1.32	3.2	5	n.a.
Strontium-90	pCi/L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Technetium-99	pCi/L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Thallium-208	pCi/L	0	0	0	0	0	5	n.a.

**DOE Preliminary Redemdiation Goals (PRG) for Radiological Parameters, Recreator: TR=1.0

Table 5: 2012 Fall Surface Water Data Summary (non-radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
Alkalinity	mg/L	148.556	118	227	32.849	109	9	n.a.
Ammonia	mg/L	0.082	0.054	0.13	0.027	0.076	9	n.a.
Chemical oxygen demand	mg/L	8.750	0	12	3.969	12	8	n.a.
Chloride	mg/L	5.000	2.1	8.7	2.092	6.6	8	n.a.
Dissolved oxygen	mg/L	9.052	7.83	10.7	0.997	2.87	9	> 5.0[a]
NO2 & NO3	mg/L	0.374	0	0.8	0.24	0.8	9	n.a.
pH	None	7.794	7.59	7.95	0.135	0.36	9	between 6-9[a]
Residue, dissolved	mg/L	185.444	141	260	43.4	119	9	n.a.
Residue, suspended	mg/L	1.444	0	13	4	13	9	n.a.
Specific conductivity	µS/cm	290.889	221	452	66.9	231	9	n.a.
Sulfate	mg/L	15.622	3.2	25	7.3	21.8	9	n.a.
Temperature	deg C	15.038	12.06	17.76	2.060	5.7	9	<= 30.5[a]
Total hardness	mg/L	151.111	130	220	27.6	90	9	n.a.
Total Kjeldahl nitrogen	mg/L	0.187	0	0.62	0.200	0.62	9	n.a.
Total Phosphorus	mg/L	0.019	0	0.089	0.0286	0.089	9	n.a.
Arsenic	ug/L	0.628	0	3.1	1	3.1	9	< 10[b]
Cadmium	ug/L	0	0	0	0	0	9	< 2.0[d]
Calcium	mg/L	44.125	35	81	15.310	46	8	n.a.
Chromium	ug/L	0.090	0	0.81	0.270	0.81	9	< 16[c]
Copper	ug/L	1.078	0.38	1.9	0.53	1.52	9	< 13[d]
Iron	ug/L	142.778	28	590	183.9	562	9	n.a.
Lead	ug/L	0.096	0	0.55	0.199	0.55	9	< 65[d]
Magnesium	mg/L	10.888	5.4	16	2.902	10.6	8	n.a.
Manganese	ug/L	40.111	10	130	38.42	120	9	n.a.
Mercury	ug/L	0.006	0	0.051	0.0170	0.051	9	< 0.051[b]
Potassium	mg/L	1.725	1.1	2.7	0.509	1.6	8	n.a.
Selenium	ug/L	0	0	0	0.000	0	1	n.a.
Sodium	mg/L	6.239	0.81	11	3.166	10.19	8	n.a.
Zinc	ug/L	1.600	0	4.8	1.78	4.8	9	< 120[d]

*Tennessee Water Quality Criteria:
[a]Fish and Aquatic Life (FAL), applies to all sites.
[b]Recreation (organisms only), applies to all sites.
[c]Fish and Aquatic Life (FAL), Chromium VI.
[d]Fish and Aquatic Life (FAL), applies to all sites. This value corresponds to a total hardness of 100mg/L.
n.a. = Not applicable.

Table 6: 2012 Fall Surface Water Data Summary (radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	PRG**
Actinium-228	pCi/L	0	0	0	0	0	9	7440
Bismuth-212	pCi/L	0	0	0	0	0	9	20900
Bismuth-214	pCi/L	68.711	0	130	41.97	130	9	77200
Cesium-137	pCi/L	0	0	0	0	0	9	487
Lead-210	pCi/L	0	0	0	0	0	9	16.8
Lead-212	pCi/L	0	0	0	0	0	9	593
Lead-214	pCi/L	35.167	0	65	21	65	9	43100
Potassium-40	pCi/L	0	0	0	0	0	9	600
Radioactivity, alpha	pCi/L	-0.144	-0.9	2.1	0.95	3	9	n.a.
Radioactivity, beta	pCi/L	4.089	0.8	9.5	2.89	8.7	9	n.a.
Strontium-90	pCi/L	0	0	0	0	0	9	265
Technetium-99	pCi/L	0	0	0	0	0	9	n.a.
Thallium-208	pCi/L	0	0	0	0	0	9	n.a.

**DOE Preliminary Redemdiation Goals (PRG) for Radiological Parameters, Recreator: TR=1.0

The following sections provide directional flow and COC information relative to the four ORR watersheds: Bear Creek, East Fork Poplar Creek, Mitchell Branch, and White Oak Creek / Melton Branch.

Watersheds

<u>Bear Creek Watershed</u>: (BCK headwater begins within the western edge of Y-12 and flows ~ 5 miles west/northwest until it empties into EFK) >$^{\text{West/Northwest}}$ East Fork Poplar Creek (EFK) (EFK headwater begins within the western edge of Y-12 and flows east thru Y-12, turns north thru Oak Ridge, turns west and exits Oak Ridge, ~ 5 miles further west of this point BCK flows into EFK, ~ 5 miles further west from this BCK/EFK confluence EFK flows into Poplar Creek) >$^{\text{West}}$ Poplar Creek (~ 3 miles further west PCM flows into Clinch River) >$^{\text{West}}$ Clinch River

The Bear Creek watershed originates within the western edge of the Y-12 nuclear processing complex. Its headwaters are very near the Y-12 legacy S-3 ponds which are now capped. In the past, these 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 and 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)] COCs have possibly partitioned/dissolved into the surface water of Bear Creek. Also, another COC 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 contamination is disposed of by employing Resource Conservation and Recovery Act (RCRA) requirements. Relative to the majority of the BCK watershed COC, the main trend is that COC levels are highest near the BCK headwaters and decrease as BCK flows downstream and to the west of Y-12.

<u>East Fork Poplar Creek Watershed</u>**:** (EFK headwater begins within the western edge of Y-12 and flows east thru Y-12, turns north thru Oak Ridge, turns west and exits Oak Ridge, ~ 10 miles further west of this point EFK flows into Poplar Creek) >$^{\text{West}}$ Poplar Creek (~ 5 miles further west PCM flows into Clinch River) >$^{\text{West}}$ Clinch River

The East Fork Poplar Creek watershed originates within the Y-12 complex and is very near the make-up water flow outfall from the Clinch River. Past and present Y-12 operations employ enriched uranium for mainly two purposes; operating nuclear reactors and producing nuclear weapons. In the complicated process of enriching uranium, the heavy metal mercury was used in vast amounts. It is believed that approximately 2.5 million pounds of mercury have contaminated the Upper East Fork Poplar Creek. Thus, the lower portions of East Fork Poplar Creek have also been contaminated with both non-radiological mercury and radiological COC. Once East Fork Poplar creek exits the Y-12 industrial complex, it then travels directly through the City of Oak Ridge. At this point it curves north/west and then flows to the west where it eventually flows into the Clinch River. The majority of the main trend in COC levels of the EFK watershed are highest near the EFK headwaters and decrease as EFK flows downstream and to the west of Y-12.

***Mitchell Branch Watershed*:** (MIK headwater begins ~ 2 miles to the east/northeast of ETTP/Old K25 and flows ~ 3 miles southwest/west/north thru ETTP/Old K-25 into Poplar Creek) $>^{\text{Southwest/West/North}}$ Poplar Creek (~ 2 miles further west PCM flows into Clinch River) $>^{\text{West}}$ Clinch River

The Mitchell Branch watershed originates 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). Relative to the radioactive decay process, ^{235}U decays to plutonium-239 (^{239}Pu). Like enriched uranium, ^{239}Pu also has radioactive fissile properties. The enriched uranium and its daughters emit the three ionizing radioactive particles of *alpha, beta*, and *gamma rays*. 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. The non-radiological heavy metal chromium has also 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. Cr^{6+} is water soluble, in large concentrations quite toxic, and carcinogenic to human beings. Relative to the majority of the MIK watershed COC, the main trend is that COC levels are lowest near the MIK headwaters and increase as MIK flows downstream and enters the contaminated footprint of the ETTP/Old K-25 complex.

***White Oak Creek / Melton Branch Watershed*:** (WCK headwater begins south of the Neutron Spallation Complex and ~ 2 miles to the northwest of ORNL, flows ~ 1 mile west thru ORNL, turns south/southwest and flows ~ 2 miles thru the Bethel Valley Burial Grounds (at this point within the Bethel Valley Burial Grounds, MEK ,which flows west thru the Melton Valley Burial Grounds, empties into WCK), from this point WCK flows ~ 2 miles west into Clinch River) $>^{\text{West}}$ Clinch River

The White Oak Creek / Melton Branch watershed originates just to the northwest of the Oak Ridge National Laboratory (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 fissile COCs such as ^{233}U, ^{235}U, and ^{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 volatile COCs, such as trichloroethylene (TCE) and tetrachloroethylene (PCE), were employed. Relative to the majority of the WCK / MEK watershed COC, the main trend is that COC levels are lowest near the WCK headwaters. They increase as WCK and MEK flow downstream and thru the ORNL/Melton and Bethel Valley Burial Grounds. They then empty directly into the Clinch River.

Sampling Sites along the Clinch River and its Tributaries
In 2012, the five Clinch River Tributaries sampled are: McCoy Branch (MCM 0.9), Grassy Creek (GCM 0.7), Raccoon Creek (RCM 0.4), Poplar Creek (PCM 1.0), and Clear Creek (CCM 1.0). The Clinch River was also sampled at six locations: CRM 78.9, CRM 52.6, CRM 41.2, CRM 35.5, CRM 17.9, and CRM 10.0.

Table 7 organizes the eleven sampling sites relative to the directional flow of the Clinch River, to the Clinch River mile, and to the Clinch River tributary. Please note that CRM 78.7, and CRM 52.6 are well north of the ORR reservation and both serve as study reference points. In addition, CRM 77.7 (Clear Creek Tributary – CCM 1.0) is also well north of the ORR, and serves as the studies' eco-reference site.

Table 7: Directional Flow of the Eleven Sampling Sites

Clinch River Direction	Southeast >	Southeast >	Southeast >	Southeast >	Southeast >	Southeast >	West >	West >	West >	West >	West >	Tennessee River
Clinch R. Mile	CRM 78.7 Ref.	CRM 77.7 (Eco-Ref.)	CRM 52.6 Ref.	CRM 41.2	CRM 37.5	CRM 35.5	CRM 19.5	CRM 17.9	CRM 14.6	CRM 12.0	CRM 10.0	
Tributary		CCM 1.0			MCM 0.9		RCM 0.4		GCM 0.7	PCM 1.0		

***<u>McCoy Branch Tributary (MCM 0.9</u>*<u>)</u>:** (MCM headwater begins in Bethel Valley ~ 5 miles to the east of ORNL. Also, the headwaters originate within the footprint of the old Y-12 Filled Coal Ash Pond and flows ~ 2 miles south to the McCoy Branch confluence / Clinch River) $>^{\text{South}}$ MCM 0.9 $>^{\text{South}}$ Clinch River

Clinch River Flow: CRM 78.7 > (CRM 77.7=CCM 1.0) > CRM 52.6 > CRM 41.2 > (CRM 37.5=MCM 0.9)

The McCoy Branch watershed is located in Bethel Valley, approximately five miles to the east of ORNL. Its headwaters are located on the top of Chestnut Ridge and originate within the footprint of the old Y-12 Filled Coal Ash Pond. From the 1950s to the 1960s, this pond was used as a settling basin for coal ash slurry resulting from the operation of the Y-12 Steam Plant. With several corrective actions, DOE remediated the Coal Ash Pond in the mid-1990s. Relative to the coal ash slurry contamination, the predominant non-radiological COC are the heavy metals of selenium, and arsenic; the predominant radiological COC is the radionuclide, thorium-228 (^{228}Th). From its headwaters within the contaminated footprint of the old Y-12 Filled Coal Ash Pond, McCoy Branch then flows approximately two miles to the south and empties directly into the Clinch River.

Specific Fall Event Data Results Observations (relative to specific COC, as MCM 0.9 was only sampled in the fall):

Non-Radiological COC:

MCM 0.9 exhibited an arsenic concentration of (3.1J microgram per liter [μg/L]). A "J" flag indicates the arsenic concentration is to be considered estimated.

Radiological COC:

None of concern.

McCoy Branch Conclusion: None of the non-radiological COC results were greater than the Tennessee General Water Quality Criteria (TWQC) (Table 5). In addition, none of the radiological COC results were greater than DOE Preliminary Remediation Goals (PRGs) (Table 6). The majority of the non-radiological and radiological COC results were of the same order as their associated reference stream COC results. The field trip and field blank quality control results were in control which indicated that the field sampling technique was correctly conducted. Relative to the sampling sites upstream of MCM 0.9, the main trend is that COC levels remained flat/constant.

<u>Grassy Creek Tributary (GCM 0.7):</u> (GCM headwater begins ~ 5 miles west of Y-12 and ~ 2 miles east of the Clinch River) $>^{\text{West}}$ GCM 0.7 $>^{\text{West}}$ Clinch River

Clinch River Flow: CRM 78.7 > (CRM 77.7=CCM 1.0) > CRM 52.6 > CRM 41.2 > (CRM 37.5=MCM 0.9) > CRM 35.5 > (CRM 19.5=RCM 0.4) > CRM 17.9 > (CRM 14.6=GCM 0.7)

The Grassy Creek watershed is located in Bear Creek Valley where its headwaters originate approximately five miles to the west of Y-12 and two miles to the east of the Clinch River. When compared with the close proximity of Bear Creek to Y-12, Grassy Creek is much further to the west of Y-12. Approximately one mile to the east of where Grassy Creek drains into Bear Creek Valley, Bear Creek curves to the north where it eventually empties into EFK. So, Bear Creek's surface water does not flow into Grassy Creek. However, as Grassy Creek watershed does drain thru the western portion of Bear Creek Valley, it is possible that legacy Bear Creek/Y-12 COCs employing groundwater pathways have migrated further west into Grassy Creek. For specific information regarding Bear Creek/Y-12 COCs, please see the ***<u>Bear Creek Watershed</u>*** section. Located approximately a half-mile to the east of where Grassy Creek flows into Bear Creek Valley, is the National Nuclear Security Administration (NNSA) security services training facility. Within this training facility is a small weapons firing range which is used by Y-12, ORNL, and ETTP security personnel. As this weapons firing range is often used by these security forces, it is possible that lead bullets have inadvertently entered into Grassy Creek.

Specific Fall Event Data Results Observations (relative to specific COC, as GCM 0.7 was only sampled in the fall):

Non-Radiological COC:
None of concern.

Radiological COC:
None of concern.

Grassy Creek Conclusion: None of the non-radiological COC results were greater than the TWQC (Table 5). In addition, none of the radiological COC results were greater than DOE PRGs (Table 6). The majority of the non-radiological and radiological COC results were of the same order as their associated reference stream COC results. The field trip and field blank quality control results were in control which indicated that the field sampling technique was correctly conducted. Relative to the sampling sites upstream of GCM 0.7, the main trend is that COC levels remained flat/constant. Specific final data results are available upon request.

<u>Raccoon Creek Tributary (RCM 0.4):</u> (RCM headwater begins approximately one mile to the west of ORNL, one mile north of the Bethel Valley Burial Grounds, and one mile east of the Clinch River) $>^{\text{Southwest}}$ RCM 0.4 $>^{\text{Southwest}}$ Clinch River

Clinch River Flow: CRM 78.7 > (CRM 77.7=CCM 1.0) > CRM 52.6 > CRM 41.2 > (CRM 37.5=MCM 0.9) > CRM 35.5 > (CRM 19.5=RCM 0.4)

The Raccoon Creek watershed is located in Bethel Valley where its headwaters are located approximately one mile to the west of ORNL, one mile north of the Bethel Valley Burial Grounds and one mile northeast of the Clinch River. Haw Ridge physically separates the Raccoon Creek watershed from the Bethel Valley Burial Grounds. However, it is possible that, via groundwater pathways, Bethel Valley Burial Grounds COCs have migrated into Raccoon Creek. For specific information regarding Bethel Valley Burial Grounds COCs, please see the ***White Oak Creek / Melton Branch Watershed*** section. Within the Bethel Valley Burial Grounds are several solid waste storage areas, SWSA, which contain both non-radiological and radiological COC.

Specific Fall Event Data Results Observations (relative to specific COC, as RCM 0.4 was only sampled in the fall):

Non-Radiological COC:

None of concern.

Radiological COC:

Compared to all the monitoring sites, only RCM 0.4 exhibited any strontium-90 with a concentration of (1.84 picocurie per liter [pCi/L]). There are no TWQC for radiological compounds. The DOE PRG for strontium-90 is 265 pCi/L.

Raccoon Creek Conclusion: None of the non-radiological COC results were greater than the TWQC (Table 5). In addition, none of the radiological COC results were greater than DOE PRGs (Table 6). The majority of the non-radiological and radiological COC results were of the same order as their associated reference stream COC results. The field trip and field blank quality control results were in control which indicated that the field sampling technique was correctly conducted. In comparison to all the study's eleven monitoring sites, only RCM 0.4 exhibited any strontium-90.

Poplar Creek Tributary (PCM 1.0): (PCM headwater begins near the Oliver Springs Walden Ridge area. PCM then flows west to southwest for approximately 20 miles until it reaches PCM 1.0 $>^{\text{West}}$ PCM 1.0 (~ 1 mile further west PCM flows into Clinch River) $>^{\text{West}}$ Clinch River

Clinch River Flow: CRM 78.7 > (CRM 77.7=CCM 1.0) > CRM 52.6 > CRM 41.2 > (CRM 37.5=MCM 0.9) > CRM 35.5 > (CRM 19.5=RCM 0.4) > CRM 17.9 > (CRM 14.6=GCM 0.7) > (CRM 12.0=PCM 1.0)

The Poplar Creek watershed originates near the Oliver Springs Walden Ridge area. For approximately twenty-one miles, Poplar Creek flows west to southwest until it flows into the Clinch River. East Fork Poplar Creek, (including the Bear Creek convergence), flows into Poplar Creek approximately ten miles upstream of the Poplar Creek/Clinch River confluence. Mitchell Branch flows into Poplar Creek approximately three miles upstream from the Poplar Creek/Clinch River confluence. Thus, the ORR watersheds of Bear Creek, East Fork Poplar Creek, and Mitchell Branch all drain into Poplar Creek. The reader will recall that all three of these watersheds have been possibly impacted with DOE ORR non-radiological and radiological COCs. For specific details regarding these three contaminated ORR watersheds, please see the above sections: ***Bear Creek Watershed***, ***East Fork Poplar Creek Watershed***, and ***Mitchell Branch Watershed***.

Specific Spring and Fall Events Data Results Observations (relative to specific COC, as *PCM 1.0 was* sampled in both the spring and fall):

Non-Radiological COC:

In the fall, only PCM 1.0 exhibited any mercury with a concentration of (0.051J ug/L). The TWQC limit for mercury is 0.051 ug/L. In the spring, PCM's sample and sample field duplicate mercury results were (less than method detection limit [MDL]). A "J" flag indicates the mercury concentration is to be considered estimated. A less-than-MDL result indicates mercury was not detected above the laboratory analysis instrument's minimum detection limit for mercury.

Radiological COC:

None of concern.

Poplar Creek Conclusion: None of the non-radiological COC results were greater than TWQC, except for the fall PCM 1.0 mercury result which was equal to the TWQC mercury limit of (<0.051 µg/L)-(Tables 3 and 5). None of the radiological COC results were greater than DOE PRGs (Tables 4 and 6). The majority of the non-radiological and radiological COC results were of the same order as their associated reference stream COC results. The field trip, field blank, and PCM 1.0 sample field duplicate quality control results were in control which indicated that the field sampling technique was correctly conducted. Relative to all of the sampling sites upstream of PCM 1.0, the main trend is that COC levels remained flat/constant. Specific final data results are available upon request.

***Clear Creek Tributary (CCM 1.0)*:** (CCM headwater begins approximately one mile to the east of the Clinch River/Norris Dam) $>^{West}$ CCM 1.0 $>^{West}$ Clinch River

Clinch River Flow: CRM 78.7 > (CRM 77.7=CCM 1.0)

The Clear Creek watershed originates approximately one mile to the east of Norris Dam which is located in Norris, Tennessee. Norris Dam is located approximately twenty-five miles northeast of the ORR. As Clear Creek is a very pristine, biologically healthy creek, it is used as the eco-region reference stream.

Specific Fall Event Data Results Observations (relative to specific COC, as CCM 1.0 was only sampled in the fall):

Non-Radiological COC and Radiological COC:

None of concern.

Clear Creek Conclusion: None of the non-radiological results were greater than the TWQC (Table 5). In addition, none of the radiological results were greater than DOE PRGs (Table 6). The majority of the non-radiological and radiological results were of the same order as CRM 78.7 reference stream results. The trip blank, field blank, quality control results were in control which indicated that the field sampling technique was correctly conducted. The CCM 1.0 data results indicate that Clear Creek remains a pristine stream. Specific final data results are available upon request.

<u>Clinch River (CRM 78.7, CRM 52.6, CRM 41.2, CRM 35.5, CRM 17.9, CRM 10.0):</u>
(CRM headwaters originates in Tazewell County, Virginia and flows southwest/west to the Tennessee River) >$^{\text{Southwest}}$ Tennessee >$^{\text{Southwest}}$ CRM 78.7 >$^{\text{Southwest}}$ CRM 52.6 >$^{\text{Southwest}}$ CRM 41.2 >$^{\text{Southwest}}$ CRM 35.5 >$^{\text{West}}$ CRM 17.9 >$^{\text{West}}$ CRM 10.0 >$^{\text{West}}$ Tennessee River

Clinch River Flow: CRM 78.7 > CRM 52.6 > CRM 41.2 > CRM 35.5 > CRM 17.9 > CRM 10.0

The Clinch River watershed originates in Tazewell County, Virginia. The Clinch River flows approximately three hundred miles southwest until it empties into the Tennessee River. This Clinch River/Tennessee River confluence is located in Kingston, Tennessee. Relative to this study the Clinch River area of interest spans from the city of Norris (~ twenty miles north of ORR) to the city of Kingston (~ ten miles south of ORR), thus this span of the Clinch River is approximately thirty miles in length. The public municipalities and ORR nuclear processing industrial plants which are located in this span 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 ORNL (old X-10 complex), the ETTP (old K-25 complex), and the city of Kingston. To obtain public drinking water industrial plant processing water, all of these areas utilize the surface waters of the Clinch River. In addition, this Clinch River stretch is often used by swimmers, and boaters engaged in recreational activities.

Specific Spring and Fall Events Data Results Observations (relative to specific COC, as CRM 78.7, CRM 52.6, CRM 41.2, CRM 35.5, CRM 17.9, CRM 10.0 were sampled in both the spring and fall):

Non-Radiological COC and Radiological COC:

1.) None of concern.

Clinch River Conclusion: None of the non-radiological COC results were greater than the TWQC (Tables 3 and 5). In addition, none of the radiological COC results were greater than DOE PRGs (Tables 4 and 6). The majority of the non-radiological and radiological COC results were of the same order as their associated reference stream COC results. The field trip, field blank, and sample duplicate quality control results were in control which indicated that the field sampling technique was correctly conducted. Relative to the six sampling sites, the main trend is COC levels remained flat/constant. Specific final data results are available upon request.

Overall Conclusion:
In short, the 2012 ambient surface water final results indicate that very low concentration levels of *arsenic*, *mercury*, and *strontium-90* were present in the Clinch River tributaries. These low level COC values compare very well to historical data. None of the non-radiological COC results were greater than the TWQC, except for the Fall Event *PCM 1.0 mercury* result which was equal to the TWQC mercury limit of (<0.051 µg/L). None of the radiological COC results were greater than DOE PRGs. There are no TWQC for radiological compounds.

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Surface Water (Physical Parameters) Monitoring

Principal Author: Andy Robinson 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 2012, 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, Upper East Fork Poplar Creek was instrumented with continuous water quality data loggers to observe water quality data during planned water augmentation shutoff and to determine if water quality parameters are impacted during fish kills. The effect of the augmentation is a slight decrease in specific conductivity. No discharges or fish kills were observed during the continuous monitoring.

Introduction

Two separate tasks are covered with the surface water physical parameter monitoring program. The tasks include the 1) planned ambient surface water physical monitoring 2) a special project during water augmentation shutoff to see if water quality parameters could be identified during reported fish kills.

Ambient Surface Water Physical Monitoring

The first task was to collect ambient, real time water quality monitoring data at seven stream sites located in several watersheds during 2012. 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 km downstream of the Y-12 National Security Complex. The project objectives were to create a baseline of water quality monitoring data, 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: Sample Locations in Kilometers (mile equivalents)

Site	Location
EFK 23.4 (14.5)	East Fork Poplar Creek (Station 17)
BCK 12.3 (7.6)	Bear Creek (near Y-12 west guard entrance)
BCK 9.0 (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)

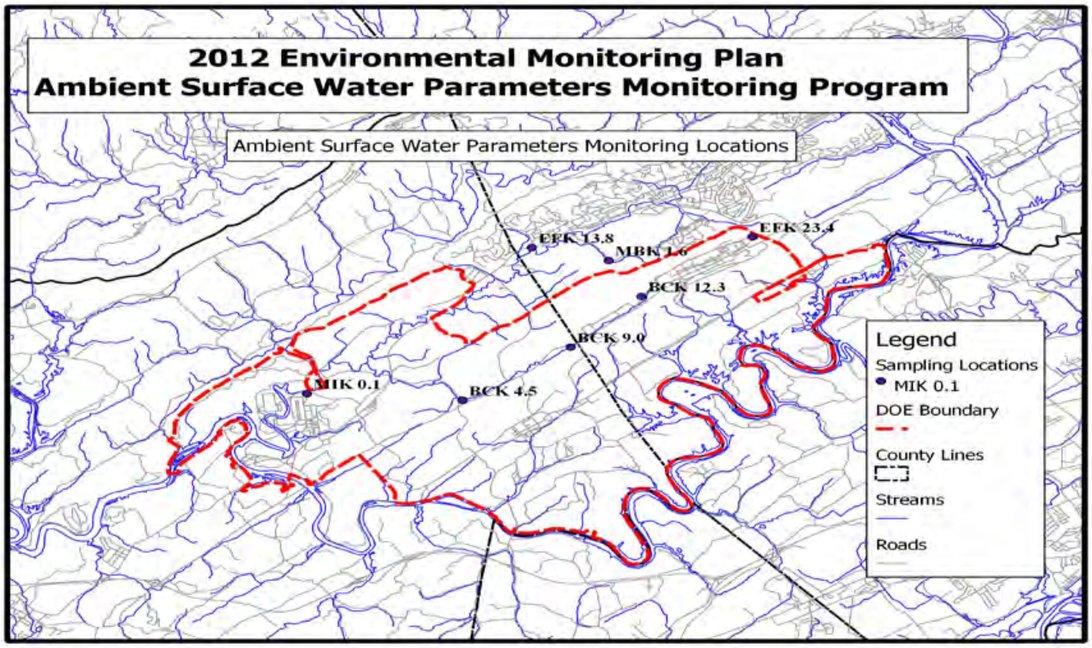


Figure 1: Oak Ridge Reservation Physical Parameter Monitoring Locations

Figure 2: TDEC staff conducting monitoring on the Oak Ridge Reservation

Upper East Fork Poplar Creek Monitoring

The second task was a special project for continuous monitoring of the Upper East Fork Poplar Creek (UEFPC).This special project was first set up to determine what effects augmentation water has on the creek and the fish. However, the task was later expanded to see if water quality conditions could be identified during fish kills.

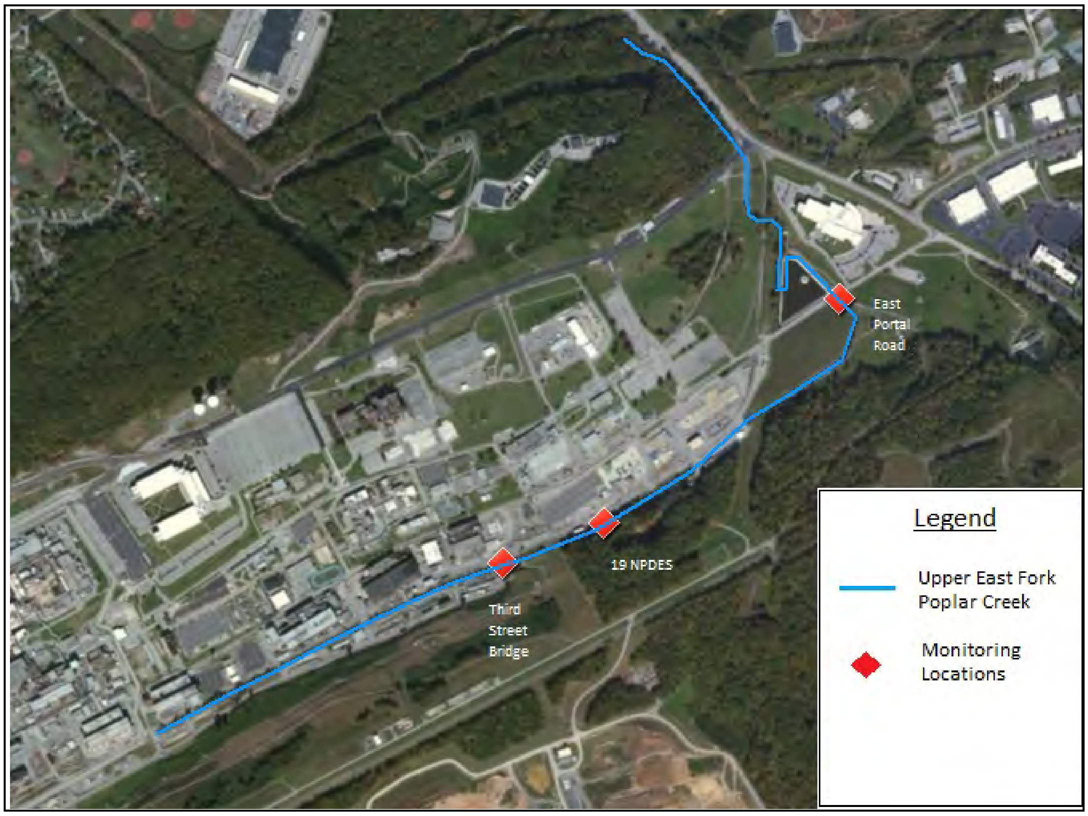


Figure 3: Upper East Fork Poplar Creek Continuous Monitoring Locations

Methods and Materials

Ambient Surface Water Physical Monitoring

The measured parameters were temperature, pH, conductivity, and dissolved oxygen. Both YSI 556 MPS and YSI Professional Plus field 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. One team member recorded the instrument readings and other field notes, while the other person operated the instrument. Unusual occurrences relating to stream conditions were duly noted.

In case field readings such as pH and conductivity were beyond benchmark ranges, then 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 2011).

Upper East Fork Poplar Creek 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.

Initially the water quality data loggers were placed along UEFPC to see what effect augmentation water (or lack thereof) has on the creek and to see if the water quality parameters could help determine conditions leading to fish kills. Two data loggers were stationed along Upper East Fork Poplar Creek beginning May 24, 2013. The first one was located near 19 National Pollutant Discharge Elimination System Outfall (NPDES) and the second one was placed downstream where UEFPC crosses East Portal Road. Parameters monitored include temperature, specific conductivity, pH, dissolved oxygen (DO), and oxidation reduction potential (ORP).

During a rain event on June 1 2012, the 19 NPDES water quality data logger was washed out of the stream bed. Henceforth that station was subsequently abandoned. During a rain event on August 4 2012, the water quality data logger at East Portal Road was damaged due to the moving currents and the concrete bottom and sides of the culvert. Subsequently, this station was abandoned.

Upon meeting Y-12 personnel, an alternate location was approved for continuous monitoring. The alternate location on UEFPC is an unused stilling well at the Third Street Bridge. The Third Street Bridge location was deployed on November 6, 2012.

Results and Discussion

Ambient Surface Water Physical Monitoring

In 2012, field data was collected on a monthly basis from the seven monitoring sites. The 2012 monthly monitoring dates were January 20th, February 13th, March 7th, April 10th, May 4th, June 8th, July 10th, August 9th, September 7th, October 5th, November 2nd, and December 7th. Within Tables 2 thru 5, one can find the summarized 2012 temperature, pH, conductivity, and dissolved oxygen data. In addition, Figures 4 thru 7 provide monthly temperature, pH, conductivity, and dissolved oxygen data.

Table 2: Summary of 2012 Temperature Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
EFK 23.4	°C	16.409	9.57	20.6	3.351	11.03	12	<= 30.5[a]
BCK 12.3	°C	14.291	4.13	22.0	6.139	17.87	12	<= 30.5[a]
BCK 9.0	°C	13.483	4.12	21.8	5.718	17.68	12	<= 30.5[a]
BCK 4.5	°C	13.844	3.81	20.1	5.668	16.29	12	<= 30.5[a]
MIK 0.1	°C	15.148	6.94	20.0	4.485	13.06	12	<= 30.5[a]
EFK 13.8	°C	15.523	5.40	23.0	6.088	17.60	12	<= 30.5[a]
MBK 1.6	°C	13.381	4.62	18.9	4.756	14.28	12	<= 30.5[a]

* Tennessee Water Quality Criteria:

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

Table 3: Summary of 2012 pH Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
EFK 23.4	none	7.856	6.74	8.18	0.399	1.44	12	between 6-9[a]
BCK 12.3	none	7.363	6.60	7.84	0.401	1.24	12	between 6-9[a]
BCK 9.0	none	7.551	6.25	8.14	0.629	1.89	12	between 6-9[a]
BCK 4.5	none	7.187	4.60	7.84	0.894	3.24	12	between 6-9[a]
MIK 0.1	none	7.275	6.27	7.59	0.370	1.32	12	between 6-9[a]
EFK 13.8	none	7.853	7.03	8.12	0.287	1.09	12	between 6-9[a]
MBK 1.6	none	7.723	7.32	8.03	0.224	0.71	12	between 6-9[a]

*Tennessee Water Quality Criteria:

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

Table 4: Summary of 2012 Conductivity Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
EFK 23.4	uS/cm	346.4	276	398	30.1	122	12	n.a.
BCK 12.3	uS/cm	1046.5	658	1646	307.4	988	12	n.a.
BCK 9.0	uS/cm	565.4	386	775	148.1	389	12	n.a.
BCK 4.5	uS/cm	346.4	263	461	66.1	198	12	n.a.
MIK 0.1	uS/cm	423.3	344	539	69.7	195	12	n.a.
EFK 13.8	uS/cm	344.1	262	401	33.9	139	12	n.a.
MBK 1.6	uS/cm	245.7	166	314	58.6	148	12	n.a.

*Tennessee Water Quality Criteria:

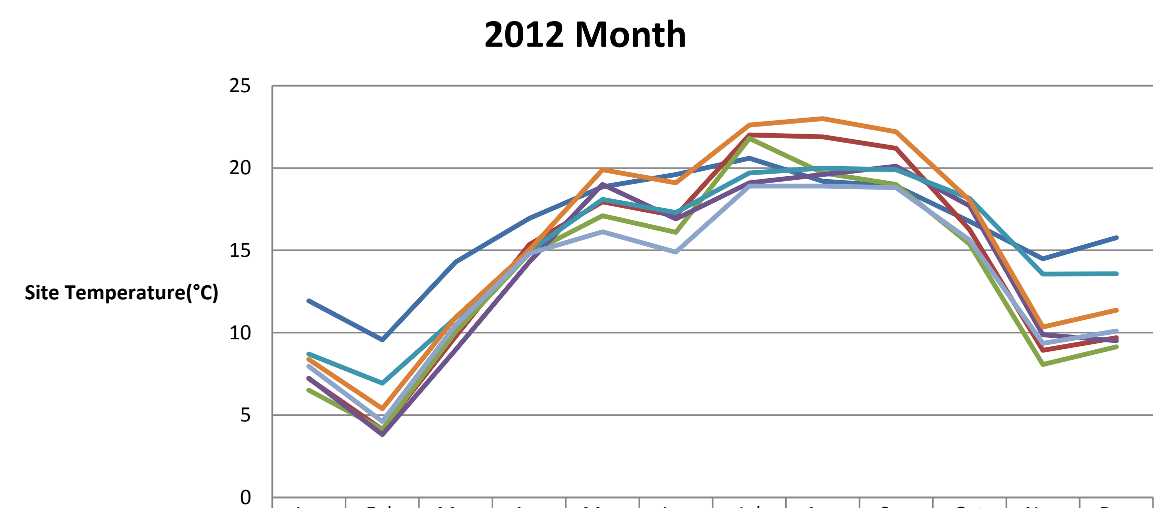
n.a. = Not applicable.

Table 5: Summary of 2012 Dissolved Oxygen Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
EFK 23.4	mg/L	10.568	8.76	14.22	1.669	5.46	12	> 5.0[a]
BCK 12.3	mg/L	9.513	5.43	13.86	2.733	8.43	12	> 5.0[a]
BCK 9.0	mg/L	10.134	6.11	13.96	2.547	7.85	12	> 5.0[a]
BCK 4.5	mg/L	8.662	4.11	14.04	3.537	9.93	12	> 5.0[a]
MIK 0.1	mg/L	7.370	2.48	13.69	3.429	11.21	12	> 5.0[a]
EFK 13.8	mg/L	10.302	6.99	14.72	2.607	7.73	12	> 5.0[a]
MBK 1.6	mg/L	10.461	7.43	14.38	2.223	6.95	12	> 5.0[a]

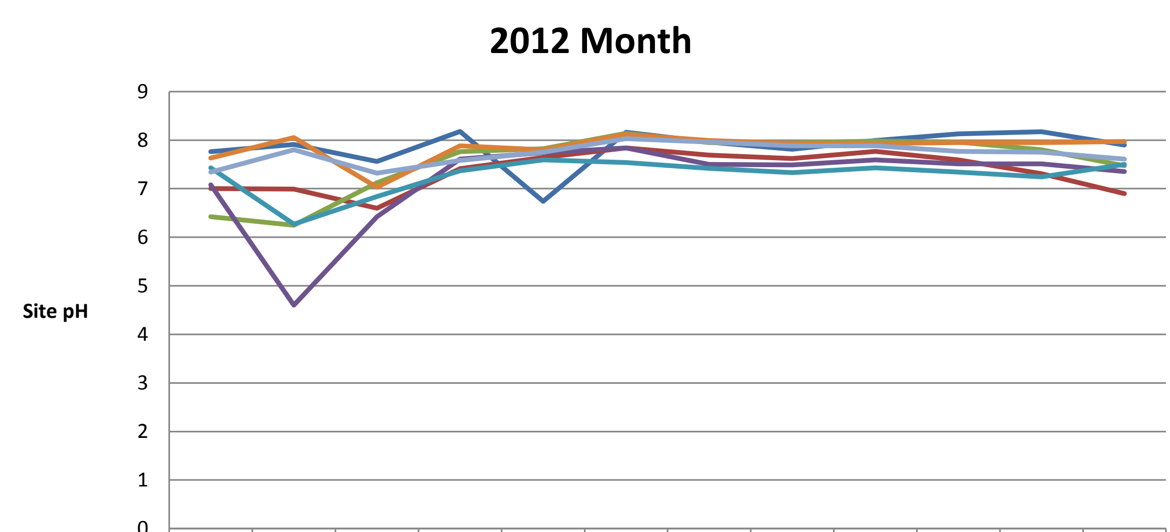
*Tennessee Water Quality Criteria:

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



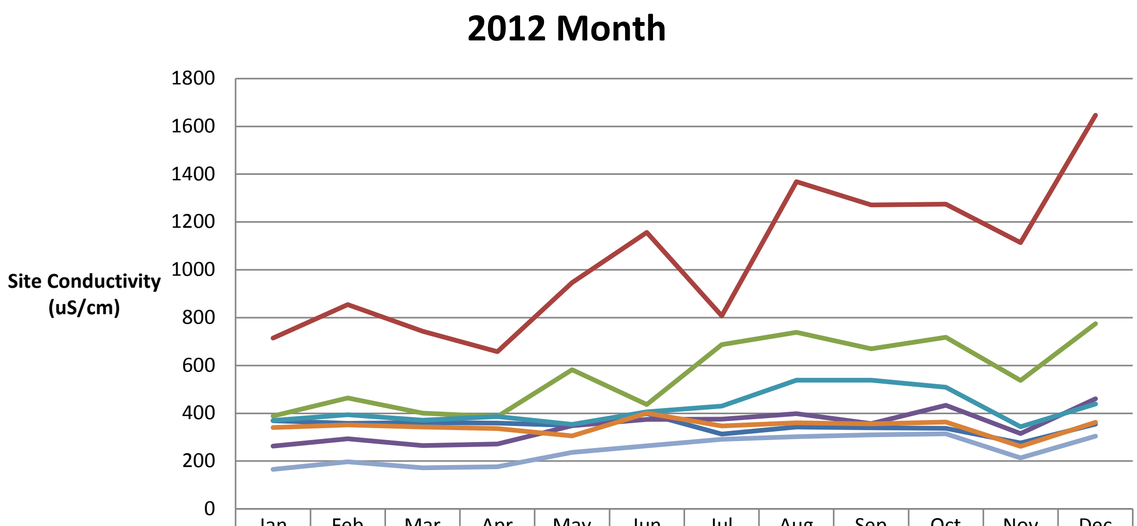
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFK 23.4	11.94	9.57	14.29	16.94	18.86	19.6	20.6	19.2	18.9	16.76	14.48	15.77
BCK 12.3	7.22	4.13	9.78	15.34	17.94	17.1	22	21.9	21.2	16.25	8.94	9.69
BCK 9.0	6.52	4.12	10.05	14.82	17.1	16.1	21.8	19.7	19	15.38	8.07	9.14
BCK 4.5	7.25	3.81	8.96	14.3	19.01	16.9	19.1	19.6	20.1	17.7	9.88	9.52
MIK 0.1	8.7	6.94	10.9	14.95	18.1	17.3	19.7	20	19.9	18.15	13.56	13.57
EFK 13.8	8.38	5.4	10.93	15.02	19.89	19.1	22.6	23	22.2	18.04	10.34	11.37
MBK 1.6	7.96	4.62	10.46	14.82	16.13	14.9	18.9	18.9	18.8	15.62	9.36	10.1

Figure 4: 2012 Monthly Site Temperature



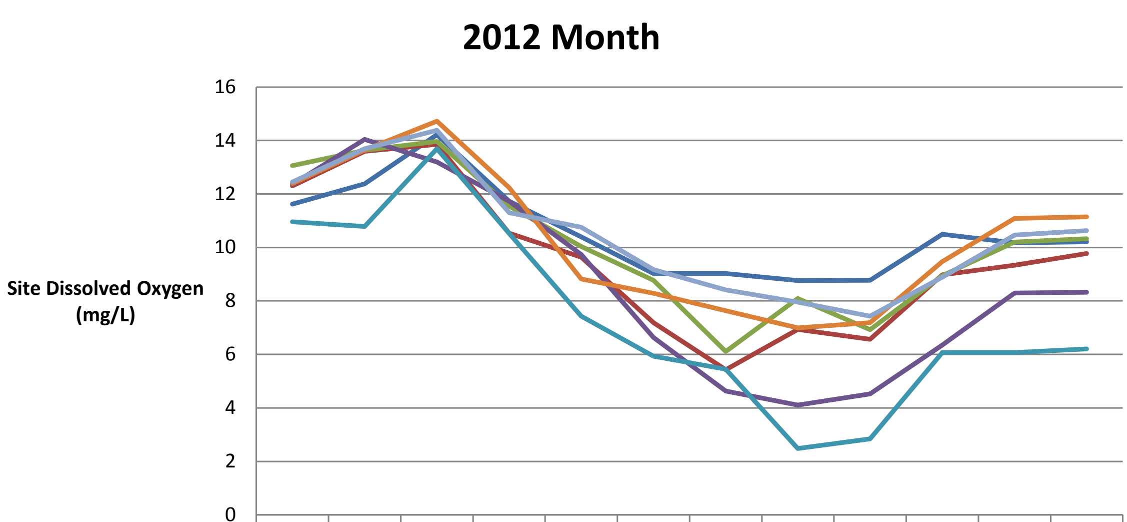
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFK 23.4	7.76	7.91	7.56	8.18	6.74	8.16	7.96	7.81	7.99	8.13	8.17	7.9
BCK 12.3	7	6.99	6.6	7.41	7.64	7.84	7.69	7.62	7.77	7.59	7.31	6.9
BCK 9.0	6.42	6.25	7.12	7.76	7.82	8.14	7.95	7.94	7.98	7.96	7.8	7.47
BCK 4.5	7.08	4.6	6.42	7.61	7.74	7.84	7.5	7.49	7.59	7.51	7.51	7.35
MIK 0.1	7.43	6.27	6.84	7.37	7.59	7.54	7.42	7.33	7.43	7.34	7.24	7.5
EFK 13.8	7.63	8.05	7.03	7.88	7.8	8.12	7.99	7.93	7.93	7.95	7.95	7.97
MBK 1.6	7.34	7.8	7.32	7.58	7.75	8.03	7.96	7.88	7.88	7.77	7.75	7.61

Figure 5: 2012 Monthly Site pH



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFK 23.4	369	358	361	359	349	398	313	343	339	337	276	355
BCK 12.3	715	855	743	658	947	1157	808	1369	1271	1275	1114	1646
BCK 9.0	389	464	401	386	582	437	687	739	670	718	537	775
BCK 4.5	263	294	265	272	348	374	375	399	357	434	315	461
MIK 0.1	370	394	371	386	354	406	430	538	539	509	344	439
EFK 13.8	341	351	343	336	306	401	347	360	356	364	262	362
MBK 1.6	166	197	172	177	237	264	291	302	310	314	214	304

Figure 6: 2012 Monthly Site Conductivity



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EFK 23.4	11.62	12.38	14.22	11.73	10.4	9.03	9.03	8.76	8.77	10.49	10.17	10.21
BCK 12.3	12.3	13.6	13.86	10.53	9.64	7.19	5.43	6.94	6.57	8.98	9.34	9.77
BCK 9.0	13.06	13.63	13.96	11.54	10.04	8.77	6.11	8.09	6.93	8.95	10.2	10.33
BCK 4.5	12.36	14.04	13.2	11.73	9.74	6.63	4.63	4.11	4.52	6.35	8.3	8.33
MIK 0.1	10.96	10.79	13.69	10.52	7.43	5.93	5.45	2.48	2.84	6.07	6.07	6.21
EFK 13.8	12.39	13.64	14.72	12.23	8.82	8.29	7.64	6.99	7.19	9.47	11.09	11.15
MBK 1.6	12.45	13.69	14.38	11.3	10.76	9.17	8.41	7.96	7.43	8.89	10.46	10.63

Figure 7: 2012 Monthly Site Dissolved Oxygen

Relative to the pH parameter, site BCK 4.5 (Bear Creek) exhibited one monthly measurement below the pH Tennessee General Water Quality Criteria for Fish and Aquatic Life Criterion Maximum Concentration of between 6 and 9. The BCK pH value was 4.6 on 02/13/2012. It is believed that this out of control value was due to an instrument malfucntion. Thus, the author recommends that the reader disregard this value.

Relative to the dissolved oxygen parameter, sites BCK 4.5 (Bear Creek) and MIK 0.1 (Mitchell Branch) exhibited a total of five monthly measurements which were below the dissoved oxygen Tennessee General Water Quality Criteria for Fish and Aquatic Life Criterion Maximum Concentration of (> 5.0 mg/L). Specifically, the out-of-control BCK 4.5 values were (4.63 mg/L – 07/10/12), (4.11 mg/L – 080912), and (4.52 mg/L – 090712). Likewise, the out-of-control MIK 0.1 values were (2.48 mg/L – 080912), and (2.84 mg/L – 090712). Due to the typically dry and hot East Tennessee summer months, both sites generally exhibit very low flow rates which can cause stagant water conditions. This, in turn, can cause low dissolved oxygen values. Relative to just the BCK 4.5 site, at various times in 2012, beaver-constructed dams at BCK 4.5 caused the creek flow to be significantlly reduced, thus transforming the BCK 4.5 area into a pond. In the hot summer months this ponding effect at BCK 4.5 sometimes resulted in stagnant water conditions which in turn likely contributed to the observed low out-of-control dissolved oxygen values. Thus, the author considers both site's low out-of-control dissolved oxygen values to be valid and of concern. For example, very low dissolved oxygen surface water concentrations (< 1.0 mg/L) could cause a fish kill. This possible serious situation would result in extremely negative impacts to the surface water quality of the associated stream and pose a health threat to the public.

Relative to the conductivity parameter, sites BCK 12.3, BCK 9.0, and BCK 4.5 (all in Bear Creek) continue to consistently exhibit elevated conductivity values. As there is no Tennessee General Water Quality Criteria for Fish and Aquatic Life Criterion Maximum Concentration for conductivity, the elevated values are not out of control; nonetheless, one should be concerned with these high values. Specifically, 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 9.0 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 dissolved into the surface water thus causing the elevated conductivity values in Bear Creek. As it is unknown when DOE (Department of Energy), remediation efforts will remedy this concerning conductivity situation; continued monitoring of Bear Creek is warranted.

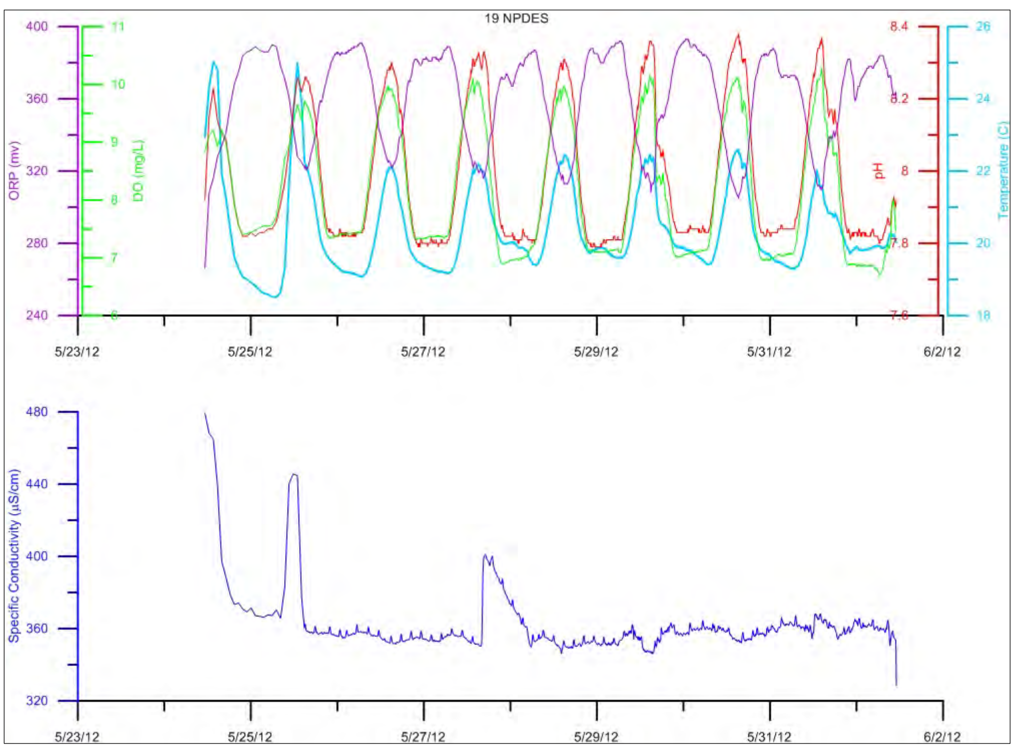
Upper East Fork Poplar Creek Monitoring

Continuous monitoring on the Upper East Fork Poplar Creek is discussed below by task of augmentation water shutoff and the individual monitoring locations for the two long term study areas.

Augmentation Water Shutoff

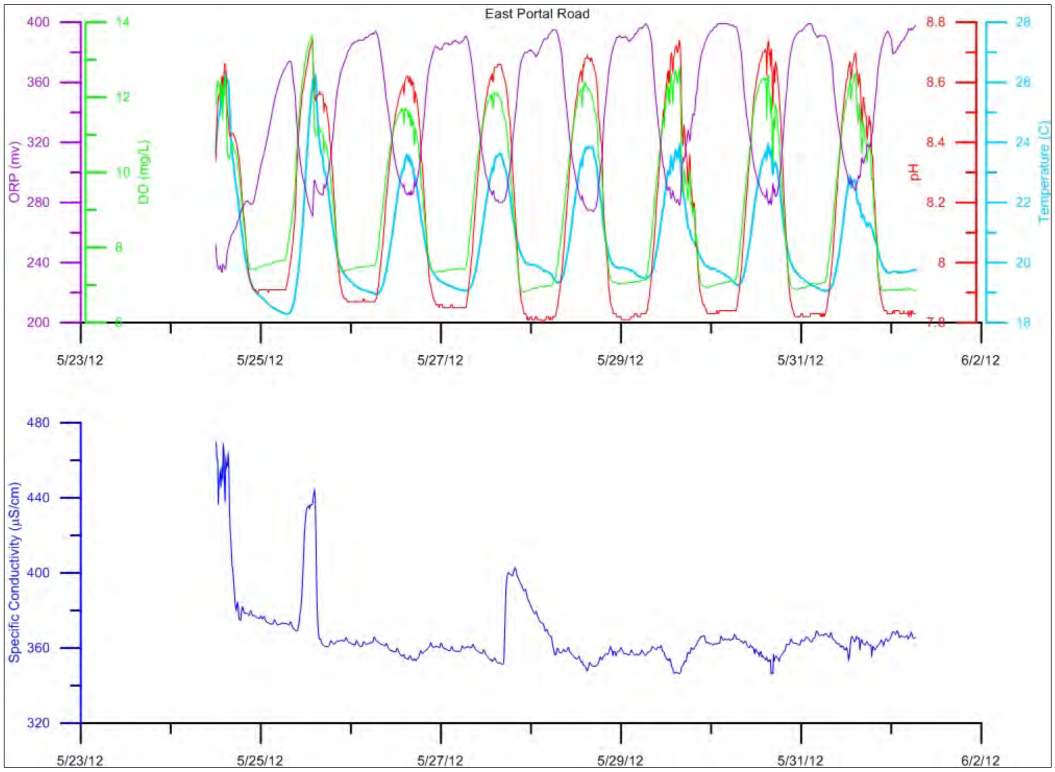
The office was notified that the augmentation water at the 200 outfall was off for maintenance. On May 24, 2012 a visual survey of UEFPC was performed. The augmentation water was off. The creek water was clear and small fish were abundant. Two water quality data loggers were placed in UEPFC where 19 NPDES and East Portal Road intersect. The parameters monitored with the In-Situ® multiparameter water quality data logger were temperature, pH, DO, specific conductivity, and ORP. On May 25, 2012 the data was downloaded and graphs were generated and are presented in Figures 8 and 9. Figure 10 shows specific conductivity and temperature for both locations.

There was a diurnal cycle for temperature, pH, ORP, and DO. The augmentation water does not have a strong effect on pH, ORP, or DO. Specific conductivity and temperature are influenced by the augmentation water. Based on the water quality graphs for 19 NPDES and East Portal locations, the effect of augmentation decreases the conductivity of the water, with one anomaly observed around May 27, 2012. On May 27, 2012, either the augmentation water was decreased and slowly ramped back up or higher conductivity waters were being discharged to UEFPC. The augmentation water's effect on temperature is as a moderator. The daily temperature fluctuations at UEFPC changed from approximately 7° Celsius (C) to 4° C.



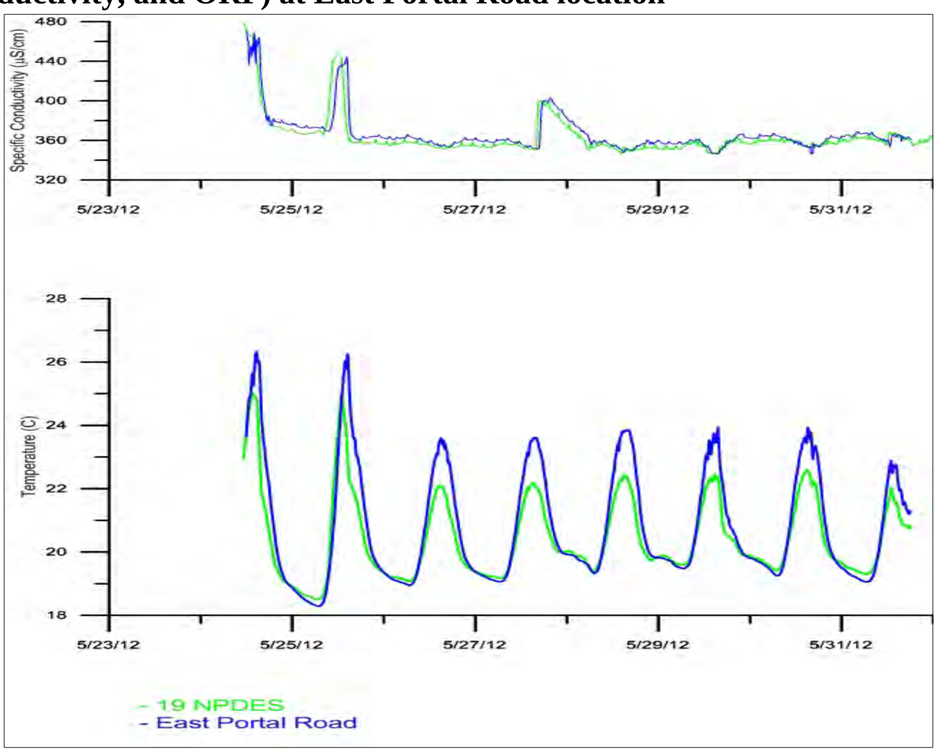
C –Centigrade; **mg/L** – milligrams per liter; **mv** = millivolts; **µS/cm** – microSiemens per centimeter

Figure 8: Water Quality Parameters (temperature, pH, DO, specific conductivity, and ORP) at the 19 NPDES Location



C –Centigrade; **mg/L** – milligrams per liter; **mv** - millevolts; **µS/cm** – microSiemens per centimeter

Figure 9: Water Quality Parameters (temperature, pH, DO, specific conductivity, and ORP) at East Portal Road location



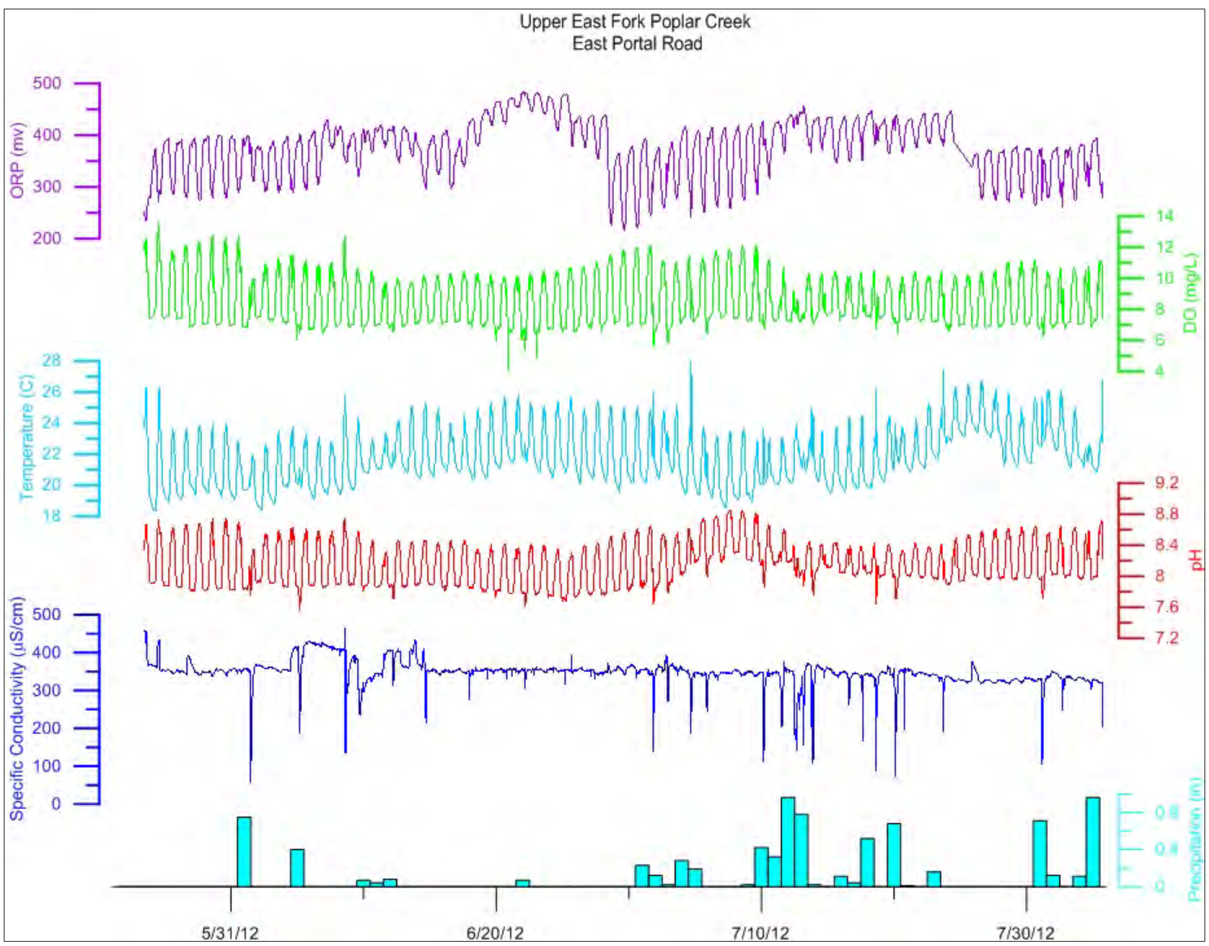
C –Centigrade; **µS/cm** – microSiemens per centimeter

Figure 10: Specific Conductivity and Temperature at 19 NPDES and East Portal Road.

Upper East Fork Poplar Creek at East Portal Road

The East Portal Road monitoring instrument was left after a rain event moved the In-Situ Troll 9500 out of the water at 19 NPDES. This instrument was left to determine if water quality parameters could record conditions that create fish kills. Unfortunately, a large rain event on August 4, 2012 was enough to cause damage to the water quality meter. The unit ceased to function just before a recorded fish kill in early September. To complement the water quality parameter graphs, a precipitation graph was created from the ORNL precipitation data from the meteorological station at Y-12 Plant Shift Superintendent office (PSS). The meteorological data was collected approximately 3500 feet west from East Portal Road and UEFPC.

The diurnal cycle for temperature, pH, ORP, and DO continues. Higher specific conductivity water was observed on May 24, May 25, May 27, June 4 through June 14, and July 25, 2012. This higher conductivity water could be due to augmentation water being shut off. There are observed decreases in conductivity during rain events. Temperature effects with higher specific conductivity were not evident. There is a small decrease in DO around June 20 along with a rise in ORP. No explanation for this change and no effect on the aquatic biota were seen during this time. Figure 11 provides all the data gathered at East Portal Road.



C –Centigrade; **mg/L** – milligrams per liter; **mv**- millivolts; **µS/cm** –microSiemens per centimeter; in – *inches.*

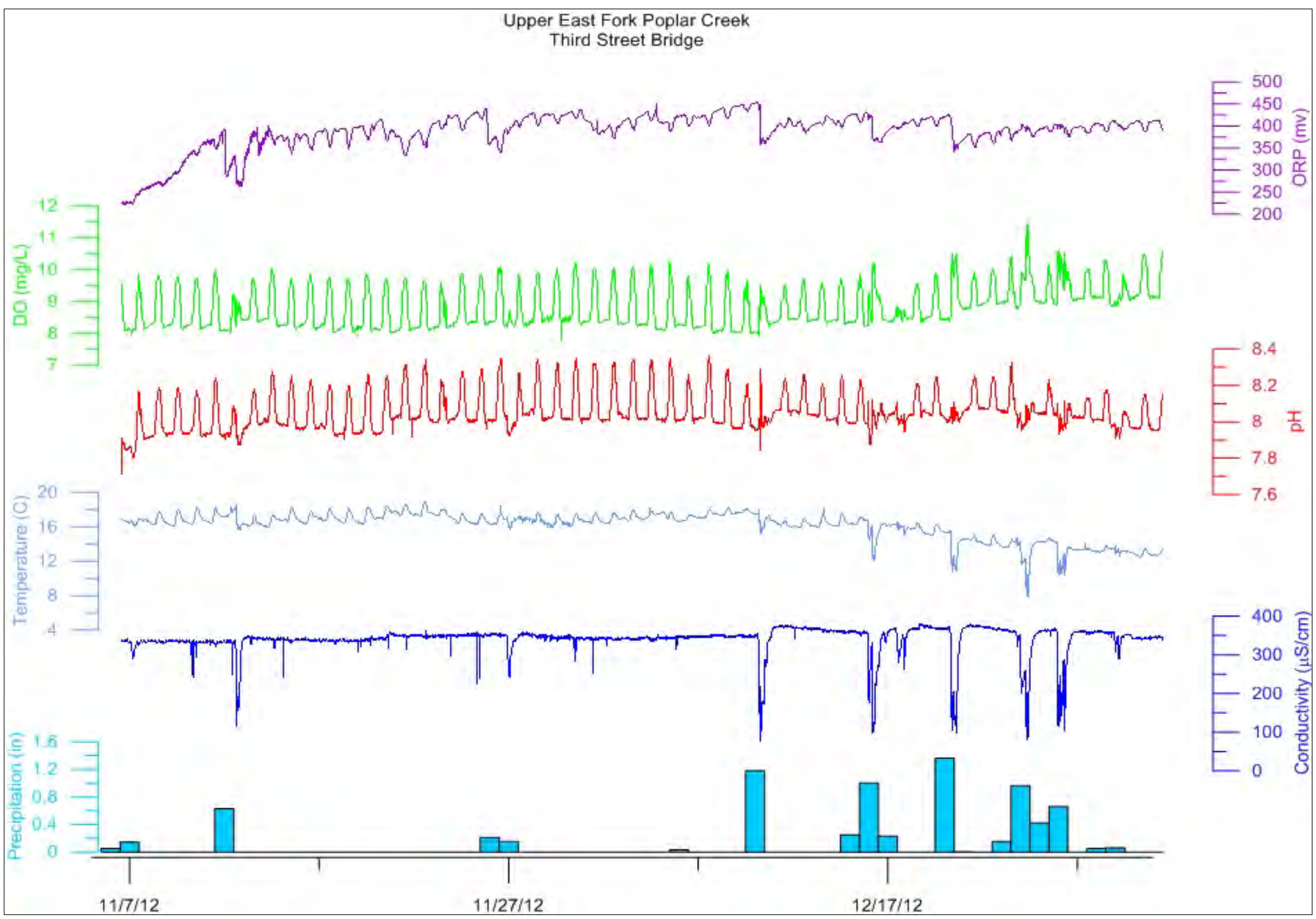
Figure 11: Water Quality Parameters (temperature, pH, DO, specific conductivity, ORP) and Precipitation at East Portal Road

Upper East Fork Poplar Creek at Third Street Bridge

Because of missing the slight fish kill in early September, a new location or building a stilling well at the East Portal Road Location was needed. Upon meeting Y-12 personnel, an alternate location was determined. An unused stilling well at the Third Street Bridge was available. On November 6, 2012 a water quality datalogger was installed. The data for this location is presented in Figure 12. To complement the water quality parameter graphs, a precipitation graph was created from the ORNL precipitation data from the meteorological station at Y-12 PSS. The meteorological data was collected approximately 1000 feet west from Third Street Bridge and UEFPC.

The diurnal cycle for temperature, pH, ORP, and DO continues. There are observed decreases in conductivity during rain events and/or other inputs. The temperature variations seem consistent with a general decrease in December due to cooler temperatures.

Currently, the office will continue to monitor to see if water quality parameters are impacted during fish kills or discharges.



C –Centigrade; **mg/L** – milligrams per liter; **mv** - millivolts; **µS/cm** –microSiemens per centimeter; in – *inches.*

Figure 12: Water Quality Parameters (temperature, pH, DO, specific conductivity, ORP) and Precipitation at Upper East Fork Poplar Creek and Third Street Bridge

Conclusion

For the surface water physical parameters, other than the low pH and dissolved oxygen values observed in Bear Creek and Mitchell Branch, the remaining data was in control relative to Tennessee water quality criteria for the parameters observed at the seven monitoring stations on the ORR. The low dissolved oxygen values in both Bear Creek and Mitchell Branch remain a concern. In addition, the elevated conductivity values observed in Bear Creek are also 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.

Along UEFPC, continuous monitoring of the physical parameters revealed the effects that augmentation water have on the stream. The office continues to monitor the stream to determine if fish kills or other discharges at Y-12 can be identified with continuous monitoring.

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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 three locations in Poplar Creek and at one location on the Clinch River. Of four samplers deployed, only the one at Poplar Creek Mile (PCM) 2.2 was retrievable. This sample exceeded the consensus-based sediment quality guidelines (CBSQGs) Probable Effects Concentration (PEC) (1.06 mg/kg) for mercury (3.6 mg/kg). 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). None of the other data from this sample exceeded the Threshold Effects Concentration (TEC).

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. TDEC DOE-O past sediment sampling activities 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, ETTP. This project focuses on the sediments that are currently being transported in the Clinch River and Poplar Creek by utilizing passive sediment collectors.

Methods and Materials

Four passive sediment samplers were deployed May of 2011 at Poplar Creek miles 2.2, 3.5, and 5.5 and at Clinch River Mile 20.8 (Table 1, Figure 1). A photo of a sediment sampler (trap) is shown in Figure 2. Only one sediment sampler (PCM 2.2) was retrieved in June of 2012; the other two on Poplar Creek could not be located while the Clinch River sampler was snagged in underwater debris and was not retrievable.

Table 1: Sampling Sites

Location	Latitude	Longitude
Poplar Creek Mile 5.5	35.94547	-084.38601
Poplar Creek Mile 3.5	35.94202	-084.40158
Poplar Creek Mile 2.2	35.93085	-084.40503
Clinch River Mile 20.8	35.89661	-084.33302

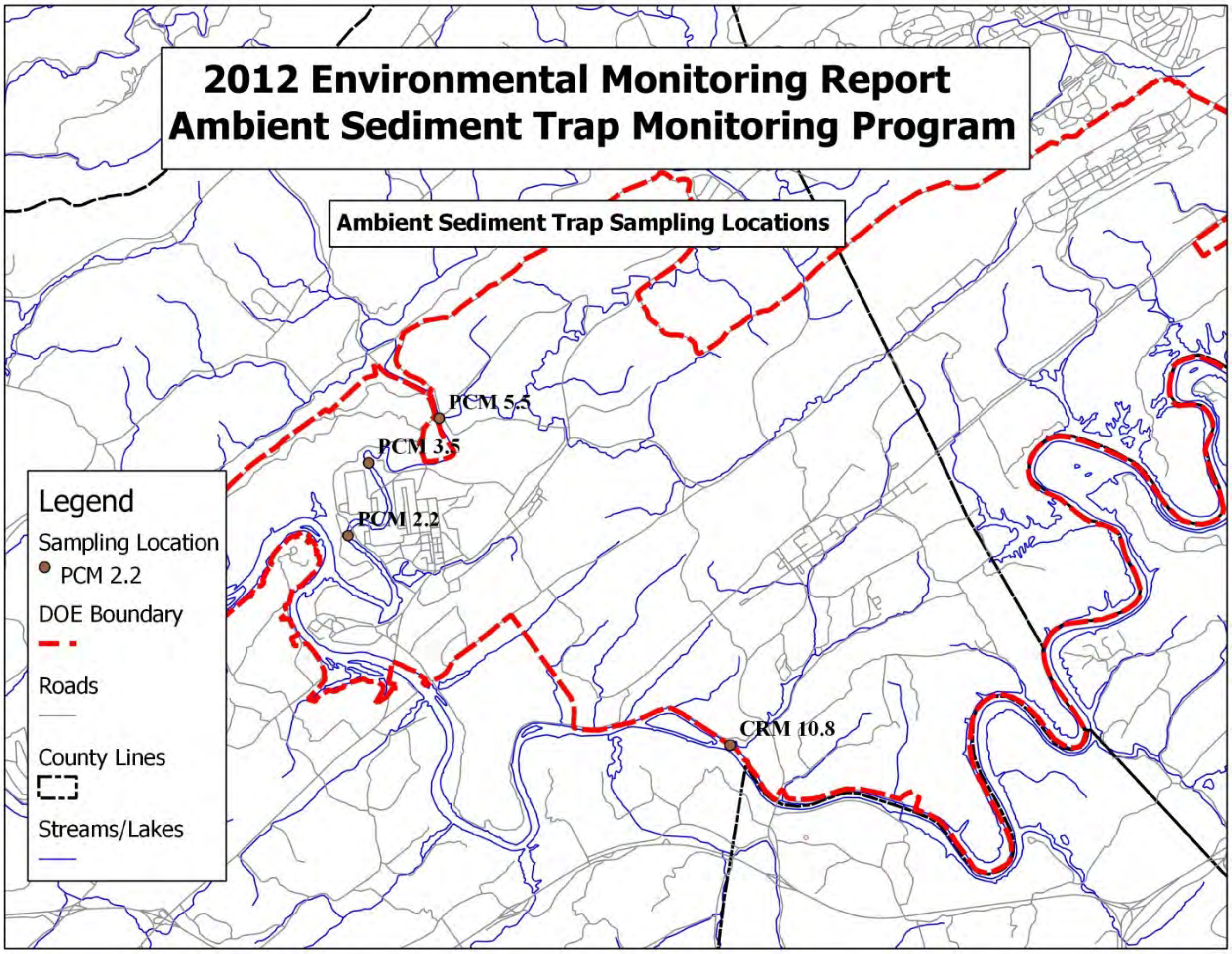

Figure 1: Sampling Site Locations

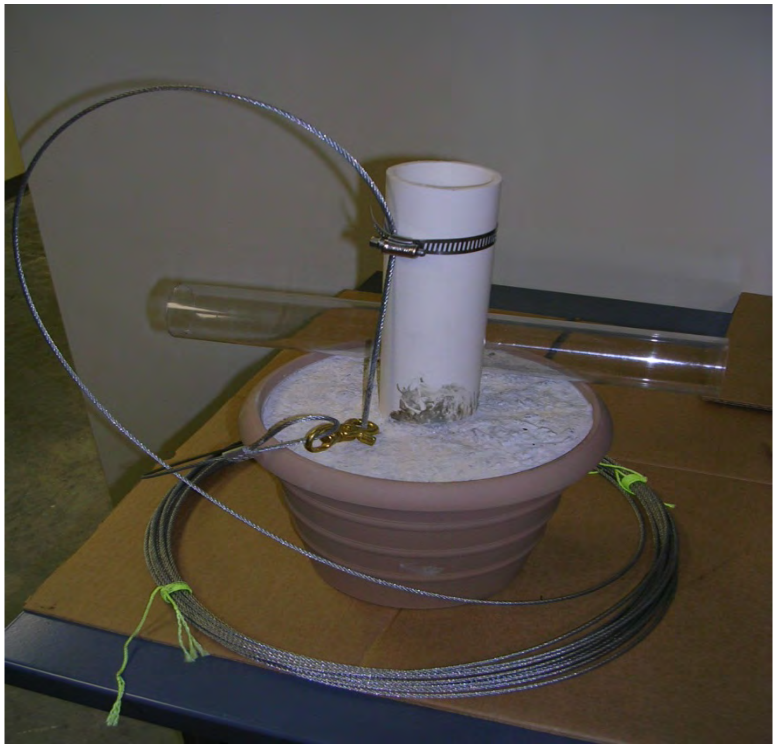

Figure 2: Photo of Sediment Trap

Results

The sediment trap metals data from Poplar Creek Mile PCM 2.2 are shown in Table 2 and Figure 3. Data from dredged samples (2006-2012) were compared to the trapped sediment results along 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 to 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 mercury PEC was exceeded at PCM 2.2 (3.6 mg/kg). The 2012 sediment trap mercury value was less than the mean of the dredged samples taken between 2006 and 2012 (n=7). None of the other sediment trap data exceeded the Threshold Effects Concentration (TEC) (table 2). Table 3 lists the data for PCM 2.2.

Table 2: PCM 2.2 Metals Data

Date Collected:	6/26/2012	**Lead**	11
Units:	mg/kg	**MDL**	0.320
Aluminum	3600	**MQL**	1.0
MDL	2.3	**Date Analyzed**	9/21/2012
MQL	10	**Magnesium**	3100
Date Analyzed	9/21/2012	**MDL**	2
Arsenic	2.6J	**MQL**	10
MDL	0.440	**Date Analyzed**	9/21/2012
MQL	5.0	**Manganese**	1500
Date Analyzed	9/21/2012	**MDL**	0.390
Cadmium	Not detected	**MQL**	1.0
MDL	0.170	**Date Analyzed**	9/21/2012
MQL	1.0	**Mercury**	3.6
Date Analyzed	9/21/2012	**MDL**	0.0180
Chromium, total	8.3	**MQL**	0.10
MDL	1.10	**Date Analyzed**	6/26/2012
MQL	2.50	**Nickel**	8.3
Date Analyzed	9/21/2012	**MDL**	0.210
Copper	7.3	**MQL**	1.0
MDL	0.330	**Date Analyzed**	9/21/2012
MQL	1.0	**Zinc**	43
Date Analyzed	9/21/2012	**MDL**	2.00
Iron	24000	**MQL**	5.0
MDL	1.08	**Date Analyzed**	9/21/2012
MQL	2		
Date Analyzed	9/21/2012		

MDL-method detection level MQL-method quantitation limit

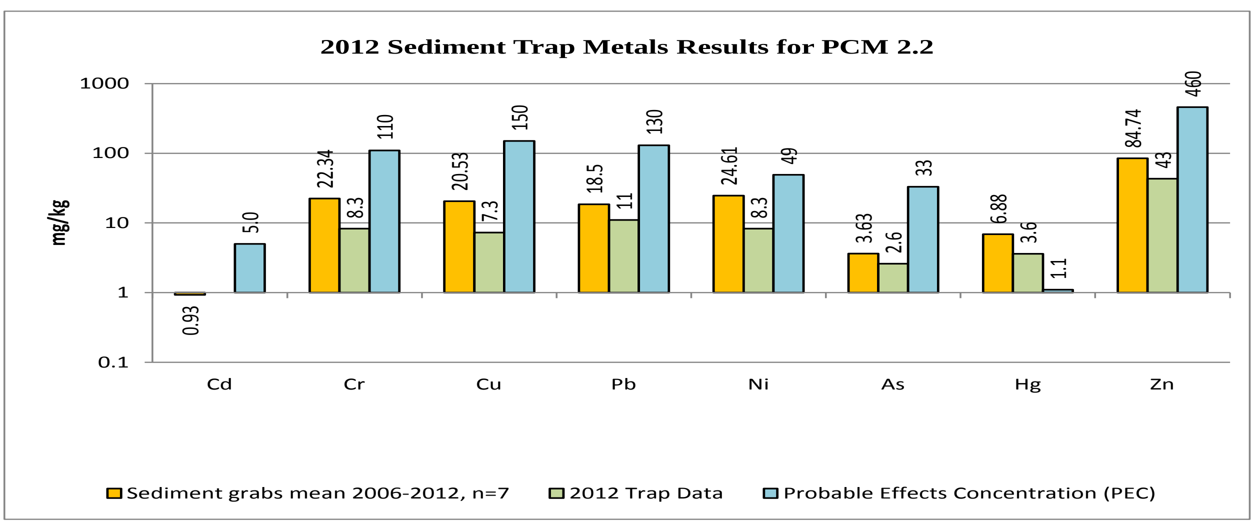

Figure 3: Sediment Trap Metals Results for PCM 2.2 (mg/kg – milligrams per kilogram)

Table 3: Sediment Quality Guideline Values for Metals

Parameter	Units*	EPA**	TEC***	MEC****	PEC*****
Arsenic	mg/kg	9.8	9.8	21.4	33
Cadmium	mg/kg	0.99	0.99	3.0	4.98
Chromium	mg/kg	43.4	43	76.5	111
Copper	mg/kg	31.6	32	91	149
Iron	mg/kg	20,000	20,000	30,000	40,000
Lead	mg/kg	35.8	36	83	128
Manganese	mg/kg	460	460	780	1100
Mercury	mg/kg	0.18	0.18	0.64	1.06
Nickel	mg/kg	22.7	23	36	48.6
Zinc	mg/kg	124	120	290	459

*mg/kg - milligrams per kilogram
** EPA Sediment Screening Values USEPA. 2001.
***Threshold Effects Concentration (TEC) (MacDonald *et al.* 2000)
Iron & Manganese TEC values from (Persaud *et al.* 1993)
****Median Effects Concentration (MEC) (MacDonald *et al.* 2000)
Iron & Manganese MEC values from (Persaud *et al.* 1993)
*****Probable Effects Concentration (MacDonald *et al.* 2000)
Iron & Manganese PEC values from (Persaud *et al.* 1993)

Conclusion

Mercury analysis of the sediment sample collected at PCM 2.2 showed the concentration to be 3.6 mg/kg, a value that exceeds the CBSQG PEC of 1.06. Values that exceed the PECs indicate that there may be adverse effects to benthic macroinvertebrates living there. The results for all of the other metals analyzed were less than their respective CBSQG TECs. This indicates that there is little impact from these metals to the benthic macroinvertebrates there. The 2012 mercury value was less than the mean of the dredged samples (6.88 mg/kg) taken between 2006 and 2012 (n=7).

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APPENDIX A

Abstract
This report is a companion to the Benthic Macroinvertebrate Monitoring Project Report in the 2012 Tennessee Department of Environment and Conservation DOE Oversight Environmental Monitoring Report. 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 on or adjacent to the ORR. The biotic integrity, "overall biological health", 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. Likewise, the worse the surface water quality of a stream, the worse its biotic integrity. When one accesses the surface water quality of a stream, one can more accurately access the stream's total overall biological health. Thus, with a comprehensive stream evaluation one can better answer the question; "is the stream clean with a healthy, diverse biological community or is the stream polluted with an unhealthy, un-diverse biological community?" In addition, this "overall biological health" stream assessment will help determine if DOE remedial activities are being effective in cleaning up polluted ORR watersheds/streams.

The 2012 final surface water data results indicated that the surface water quality in the four watersheds was less than optimal when compared to reference streams. The comprehensive stream assessment scores were calculated from the component Benthic Macroinvertebrate Monitoring Project which indicated the same conclusion. Because of this, both programs are needed to continually access the surface water quality and biological health of the major ORR area watersheds.

Introduction
This report is a companion to the Benthic Macroinvertebrate Monitoring Project Report in the 2012 Tennessee Department of Environment and Conservation DOE Oversight Environmental Monitoring Report. Because benthic macroinvertebrates are relatively sedentary and long-lived, they are excellent indicators of the biotic integrity, "overall health", of an aquatic system. In systems where the source of the toxicant is non-point (e.g. runoff or seeps) or where the combined effects of pollutants in a complex effluent exceed individual organism toxicity, 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 predominant Oak Ridge Reservation (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 three major chemical families: volatile and semi-volatile organic compounds, heavy metals, and radionuclides. These contaminants of concern (COC) can have a detrimental effect upon the health of benthic macroinvertebrate communities. In Environmental Protection Agency (EPA) laboratory toxicity tests, it has been demonstrated that heavy metals are toxic to benthic macroinvertebrates

(U.S. EPA 1992). When heavy metal concentrations in surface water are high enough, the total population of benthic communities can be drastically reduced. In fact, they may be entirely eradicated (Clements 1991). Again, negatively impacted benthic communities indicate a polluted, distressed stream/watershed/aquatic system. Such streams with poor surface water quality will have difficulty in supporting a healthy community of aquatic life including benthic macroinvertebrates and fish. And of particular concern, if a stream can't support a healthy aquatic community, then such a stream poses dangerous health risks to humans. Thus, in conjunction with the biological monitoring component, this benthic macroinvertebrate surface water monitoring program is important and necessary in fulfilling our office's mission: protecting the environment, and ensuring the health and safety of Tennessee citizens living near the ORR.

Methods and Materials

In May 2012, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-O), conducted surface water monitoring and sampling relative to the following impacted ORR watersheds: Bear Creek (BCK), East Fork Poplar Creek (EFK), Mitchell Branch (MIK), and White Oak Creek (WCK) / Melton Branch (MEK). In all, surface water samples were collected from nineteen impacted stream sites and associated reference sites. In addition, monitoring and sampling was also conducted at Clear Creek (CCK) near Norris Dam which serves as an ecoregion 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 2012 Benthic Macroinvertebrate Biological Monitoring Program. Surface water samples were collected from nineteen ORR stream sites and the samples were submitted to the State of Tennessee Department of Health (TDH) Laboratory for inorganic, heavy metals, and radionuclide analyses. In addition, utilizing YSI Professional Plus and YSI 556 Multi-Probe System multi-parameter field instruments, the parameters of pH, conductivity, dissolved oxygen, and temperature were measured at each monitoring site. 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.

The analytical parameters (COC) of interest are:

> *Inorganics:* ammonia, nitrate & nitrite (NO^3 & NO^2), residue (dissolved), residue (suspended), specific conductivity, sulfate (*East Fork Poplar Creek only*), total hardness, total Kjeldahl nitrogen, total phosphorus.
>
> *Metals:* arsenic, cadmium, chromium, copper, hexavalent chromium (*Mitchell Branch only*), iron, lead, manganese, mercury, and zinc.
>
> *Radionuclides:* gamma radionuclides, gross alpha, and gross beta.

Table 1 lists the nineteen sample locations, and Figures 1-5 shows the Benthic surface water sampling sites relative to the ORR aerial maps.

Table 1: 2012 Sample Locations

Stream Location	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
Clear Creek	CCK 1.45	ECO67F06
Gum Hollow Branch	GHK 2.9	GUM001.8RO
Hinds Creek	HCK 20.6	HINDS012.8AN
Mill Branch	MBK 1.6	FECO67I12
Stream Location = ORR Stream/Watershed		
Project Site# = TDEC-DOE-Ovesight Office Project Site number.		
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

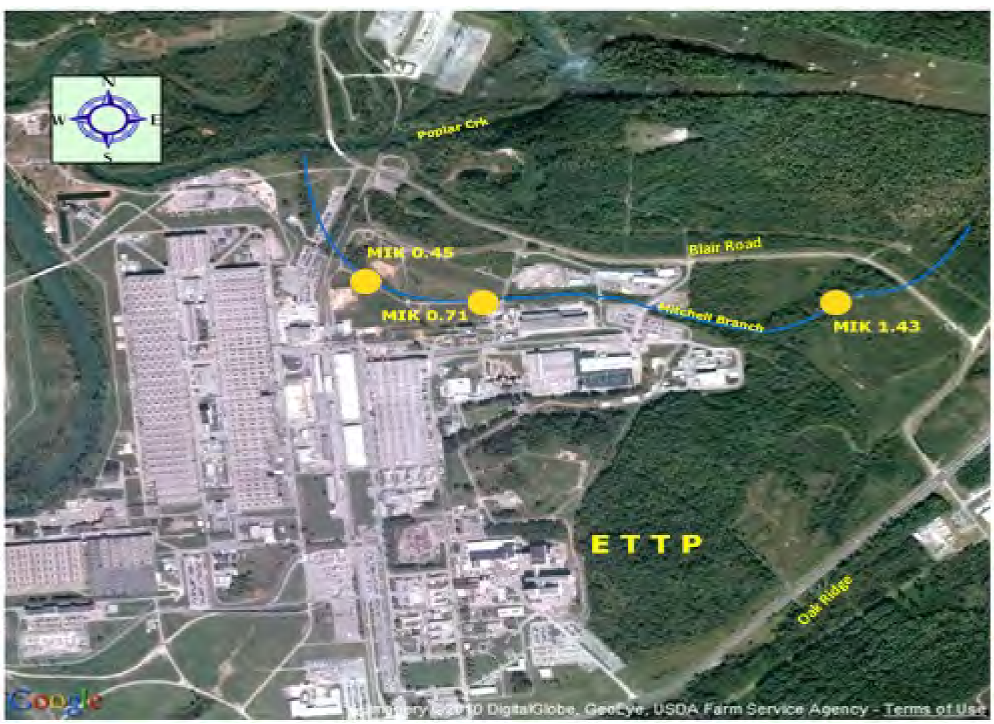

Figure 3: Mitchell Branch Watershed (ETTP)

Figure 4: White Oak Creek / Melton Branch Watersheds (ORNL)

Figure 5: Clear Creek Ecoregion and Hinds Creek Reference Sites

Results and Discussion: The 2012 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 2012 benthic surface water sample results for Bear Creek.

Table 2: 2012 Bear Creek Surface Water Data Summary (non-radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
Ammonia	mg/L	0.0165	0	0.033	0.023	0.033	2	n.a.
Dissolved oxygen	mg/L	10.245	10.18	10.31	0.092	0.13	2	> 5.0[a]
NO2 & NO3	mg/L	11.9	3.8	20	11.46	16.2	2	n.a.
pH	None	7.785	7.74	7.83	0.064	0.09	2	between 6-9[a]
Residue, dissolved	mg/L	311	203	419	152.7	216	2	n.a.
Residue, suspended	mg/L	0	0	0	0	0	2	n.a.
Specific conductivity	µS/cm	540.5	361	720	253.9	359	2	n.a.
Sulfate	mg/L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Temperature	°C	17.785	17.74	17.83	0.064	0.09	2	<= 30.5[a]
Total hardness	mg/L	261.5	217	306	62.9	89	2	n.a.
Total Kjeldahl nitrogen	mg/L	0.105	0	0.21	0.148	0.21	2	n.a.
Total Phosphorus	mg/L	0.0205	0.015	0.026	0.0078	0.011	2	n.a.
Arsenic	ug/L	0	0	0	0	0	2	< 10[b]
Cadmium	ug/L	0.48	0	0.96	0.6788	0.96	2	< 2.0[d]
Chromium	ug/L	0	0	0	0	0	2	< 16[c]
Copper	ug/L	0.44	0	0.88	0.62	0.88	2	< 13[d]
Hexavalent Chromium	mg/L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.016[c]
Iron	ug/L	417	272	562	205.1	290	2	n.a.
Lead	ug/L	0.24	0	0.48	0.339	0.48	2	< 65[d]
Manganese	ug/L	148.25	59.5	237	125.51	177.5	2	n.a.
Mercury	ug/L	0	0	0	0	0	2	< 0.051[b]
Zinc	ug/L	3.15	3.1	3.2	0.07	0.1	2	< 120[d]

*Tennessee Water Quality Criteria:

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

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

[c]Fish and Aquatic Life (FAL), Chromium VI.

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

n.a. = Not applicable.

Table 3: 2012 Bear Creek Surface Water Data Summary (radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	PRG**
Actinium-228	pCi/L	0	0	0	0	0	2	7440
Bismuth-212	pCi/L	0	0	0	0	0	2	20900
Bismuth-214	pCi/L	9.9	0	19.8	14.00	19.8	2	77200
Cesium-137	pCi/L	0	0	0	0	0	2	487
Lead-210	pCi/L	0	0	0	0	0	2	16.8
Lead-212	pCi/L	0	0	0	0	0	2	593
Lead-214	pCi/L	0	0	0	0	0	2	43100
Potassium-40	pCi/L	0	0	0	0	0	2	600
Radioactivity, alpha	pCi/L	52.8	19.6	86	46.95	66.4	2	n.a.
Radioactivity, beta	pCi/L	79.3	27.2	131.4	73.68	104.2	2	n.a.
Thallium-208	pCi/L	0	0	0	0	0	2	n.a.

**DOE Preliminary Redemdiation Goals (PRG) for Radiological Parameters, Recreator: TR=1.0

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 GHK 2.9, MBK 1.6, and eco-region CCK 1.45)

BCK 12.3 is just to the west of the Y-12 legacy S-3 ponds, which are now capped. In the past, these 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)] COC 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 COC 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 contamination is disposed of by employing Resource Conservation and Recovery Act (RCRA) requirements.

Specific data results observations relative to specific COC are presented below:

Non-Radiological COC:

1.) Compared to the reference sites, specific conductivity was elevated at BCK 12.3 (720 microSiemens per centimeter [μS/cm]), then decreased downstream/west to BCK 9.6 (361 μS/cm), and to GHK 2.9 (133 μS/cm). In this area of Bear Creek, specific conductivity levels are typically elevated and remain a health concern.
2.) Compared to the reference sites, total hardness, residue dissolved, and manganese concentrations were the highest at BCK 12.3 and also decreased as the stream flowed downstream/west to BCK 9.6.
3.) Compared to the reference sites, iron exhibited similar concentrations with a flat trend except for a higher spike concentration at BCK 9.6. It is possible that this higher concentration may be due to the nearby Environmental Management Waste Management Facility operations which have possibly dislodged soil into the watershed tributaries which flow into Bear Creek near BCK 9.6.

Radiological COC:

1.) Compared to the reference sites, radioactive alpha concentrations were the highest at BCK 12.3 (86 picocuries per liter [pCi/L]), and decreased as the stream flowed downstream/west to BCK 9.6 (19.6 pCi/L), and to GHK 2.9 (-0.01 pCi/L).
2.) Compared to the reference sites, radioactive beta concentrations were the highest at BCK 12.3 (131.4 pCi/L), then decreased as the stream flowed downstream/west to BCK 9.6 (27.2 pCi/L), and to GHK 2.9 (2.6 pCi/L).

Bear Creek Conclusion: None of the non-radiological COC results were greater than the Tennessee General Water Quality Criteria (TWQC) (Table 2). In addition, none of the radiological COC results were greater than DOE Preliminary Remediation Goals (PRG) goals (Table 3). The majority of the non-radiological and radiological COC results were of the same order as their associated reference stream COC results. The field trip and field blank quality control results were in control which indicated that our field sampling technique was correctly conducted. Relative to the majority of the above observations, the main trend is that COC levels are highest at BCK 12.3 and decrease as Bear Creek flows downstream and to the west. It is likely that as the COC travel farther downstream/west, their concentrations are being decreased due to the water dilution effect.

East Fork Poplar Creek:
Tables 4 and 5 present a summary of the 2012 benthic surface water samples results for Poplar Creek.

Table 4: 2012 East Fork Poplar Creek Surface Water Data Summary (non-radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
Ammonia	mg/L	0.2616	0	1.1	0.472	1.1	5	n.a.
Dissolved oxygen	mg/L	9.258	7.41	9.97	1.073	2.56	5	> 5.0[a]
NO2 & NO3	mg/L	2.34	1.3	3.8	0.98	2.5	5	n.a.
pH	None	7.55	6.45	7.97	0.632	1.52	5	between 6-9[a]
Residue, dissolved	mg/L	187	160	224	24.0	64	5	n.a.
Residue, suspended	mg/L	0	0	0	0	0	5	n.a.
Specific conductivity	µS/cm	365.6	316	449	55.7	133	5	n.a.
Sulfate	mg/L	28.2	21	36	5.5	15	5	n.a.
Temperature	°C	18.658	17.06	22.97	2.440	5.91	5	<= 30.5[a]
Total hardness	mg/L	323	185	808	271.7	623	5	n.a.
Total Kjeldahl nitrogen	mg/L	0.53	0	1.8	0.731	1.8	5	n.a.
Total Phosphorus	mg/L	0.1714	0.067	0.32	0.1083	0.253	5	n.a.
Arsenic	ug/L	0	0	0	0	0	5	< 10[b]
Cadmium	ug/L	0.082	0	0.41	0.1834	0.41	5	< 2.0[d]
Chromium	ug/L	0.678	0	1.5	0.683	1.5	5	< 16[c]
Copper	ug/L	2.88	1.6	4.9	1.34	3.3	5	< 13[d]
Hexavalent Chromium	mg/L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.016[c]
Iron	ug/L	156.2	100	195	46.5	95	5	n.a.
Lead	ug/L	0.258	0	0.38	0.157	0.38	5	< 65[d]
Manganese	ug/L	44.08	20	101	32.88	81	5	n.a.
Mercury	ug/L	0.396	0.12	0.81	0.3061	0.69	5	< 0.051[b]
Zinc	ug/L	12.32	3.9	26.1	8.46	22.2	5	< 120[d]

*Tennessee Water Quality Criteria:
[a]Fish and Aquatic Life (FAL), applies to all sites.
[b]Recreation (organisms only), applies to all sites.
[c]Fish and Aquatic Life (FAL), Chromium VI.
[d]Fish and Aquatic Life (FAL), applies to all sites. This value corresponds to a total hardness of 100mg/L.
n.a. = Not applicable.

Table 5: 2012 East Fork Poplar Creek Surface Water Data Summary (radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	PRG**
Actinium-228	pCi/L	0	0	0	0	0	5	7440
Bismuth-212	pCi/L	0	0	0	0	0	5	20900
Bismuth-214	pCi/L	11.92	0	24.2	11.20	24.2	5	77200
Cesium-137	pCi/L	0	0	0	0	0	5	487
Lead-210	pCi/L	0	0	0	0	0	5	16.8
Lead-212	pCi/L	0	0	0	0	0	5	593
Lead-214	pCi/L	0	0	0	0	0	5	43100
Potassium-40	pCi/L	0	0	0	0	0	5	600
Radioactivity, alpha	pCi/L	6.92	3.7	14.6	4.37	10.9	5	n.a.
Radioactivity, beta	pCi/L	6.86	4.4	14.4	4.23	10	5	n.a.
Thallium-208	pCi/L	0	0	0	0	0	5	n.a.
**DOE Preliminary Redemdiation Goals (PRG) for Radiological Parameters, Recreator: TR=1.0								

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 6.8 (2 miles east of ETTP) > West Clinch River (with reference streams of HCK 20.6, and eco-region CCK 1.45)

Specific Data Results Observations relative to specific COC:

Non-Radiological COC:

1.) Compared to both the reference and downstream monitoring sites, temperature was somewhat elevated at EFK 25.1, and then decreased downstream/west. This observation is typical and expected as the temperature of the make-up water from the Clinch River is warmer than the temperature at EFK 25.1.
2.) Compared to the reference sites, specific conductivity, ammonia, sulfate, residue dissolved, total Kjeldahl nitrogen, chromium, copper, manganese, and zinc values/concentrations were the highest at EFK 25.1 and also decreased as the stream flowed downstream/west.
3.) Compared to the reference and downstream monitoring sites, dissolved oxygen concentrations were the lowest at EFK 25.1 and increased downstream/west. From EFK 25.1 to the west, due to the increased flow from the Clinch River make-up flow, the depth of EFK becomes deeper as it travels to the west. With the combination of higher flow and greater depth/volume, this mechanism might possibly explain the trend of increasing concentrations of dissolved oxygen from the east to the west.
4.) Compared to the reference sites, total hardness concentrations indicated a flat trend at all the monitoring sites except for a sharp increase in concentration at EFK 6.3 (808 milligrams per liter [mg/L]). This unusual observation may be due to significant land excavation operations at the nearby Parcel 6 / Black Oak Easement / New Horizon area. During heavy rain events

contaminated surface water runoff from the excavated Parcel 6 area may have possibly entered this area of EFK 6.3 and increased the total hardness concentrations.

5.) Compared to the reference sites, total phosphorus concentrations were higher at EFK 25.1, then decreased at EFK 13.8, then an unexpected sharp increase in concentration was observed at EFK 6.3 (0.32 mg/L). This unusual observation may be due to significant land excavation operations at the nearby Parcel 6 / Black Oak Easement / New Horizon area. During heavy rain events contaminated surface water runoff from the excavated Parcel 6 area may have possibly entered this area of EFK 6.3 and increased the total phosphorus concentrations.
6.) Compared to the reference sites, mercury concentrations were higher at EFK 25.1 and decreased downstream/west except for an unusual sharp increase in mercury concentration at EFK 6.3. Exact values are: EFK 25.1 (0.63 µg/L), EFK 24.4 (0.25 µg/L), EFK 23.4 (0.12J µg/L), EFK 13.8 (0.17J µg/L), EFK 6.3 (0.81 µg/L), HCK 20.6 reference (less than [<] method detection limit [MDL]), and CCK 1.45 eco-region reference (< MDL). A J flag indicates the mercury concentration is to be considered estimated. A < MDL result indicates mercury was not detected above the laboratory analysis instrument's minimum detection limit for mercury. The observed increase in mercury concentration at EFK 6.3 is very unusual, and unexpected. Additional research is indicated to determine the cause of the unknown mechanism for this concerning increase in mercury at EFK 6.3.

Radiological COC:

1.) Compared to the reference sites, radioactive alpha concentrations were the highest at EFK 25.1 and decreased to a fairly flat trend downstream/west. Exact values are: EFK 25.1 (14.6 pCi/L), EFK 24.4 (5.1 pCi/L), EFK 23.4 (5.3 pCi/L), EFK 13.8 (5.9 pCi/L), EFK 6.8 (3.7 pCi/L), HCK 20.6 reference (0.2 pCi/L), and CCK 1.45 eco-region reference (0.3 pCi/L).
2.) Compared to the reference sites, radioactive beta concentrations were the highest at EFK 25.1 and also decreased to a fairly flat trend downstream/west. Exact values are: EFK 25.1 (14.4 pCi/L), EFK 24.4 (5.2 pCi/L), EFK 23.4 (5.2 pCi/L), EFK 13.8 (5.1 pCi/L), EFK 6.8 (4.4 pCi/L), HCK 20.6 reference (2.5 pCi/L), and CCK 1.45 eco-region reference (0.9 pCi/L).
3.) Bismuth-214 concentrations increased as EFK flowed downstream/west; however, this trend was weak. Exact values are: EFK 25.1 (<MDL), EFK 24.4 (17.3 pCi/L), EFK 23.4 (18.1 pCi/L), EFK 13.8 (<MDL), EFK 6.8 (24.2 pCi/L), HCK 20.6 reference (<MDL), and CCK 1.45 eco-region reference (<MDL).

East Fork Poplar Creek Conclusion: Except for mercury, none of the other non-radiological COCs were greater than the TWQC (Table 4). Mercury's TWQC limit in surface water is < 0.051 ug/L. All of the EFK monitoring site's mercury concentrations were greater than this limit. These results were 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. The highest mercury concentration was at EFK 6.3 (0.81 µg/L). This elevated value is approximately 16 times higher than the (0.051 µg/L) mercury limit. Due to this unusual and unexpected mercury result at EFK 6.3, it is reasonable for one to pose the following concerning question. Why does EFK 6.3 which is located several miles downstream of EFK 25.1 have the highest mercury concentration relative to all of our EFK monitoring sites? The answer to this question remains confounding, concerning, and currently unknown. To answer this question, additional monitoring and research is warranted relative to the mercury contamination in EFK. None of the radiological COCs were greater than DOE PRG (Table 5). The majority of non-radiological and radiological COC results were of the same order as their associated reference stream COC results. The results from the HCK 20.6 field duplicate sampling showed excellent reproducibility, thus indicating that our field sampling technique was correctly conducted. Relative to the majority of the above observations, the main trend is COC levels are highest at EFK 25.1 and decrease as the EFK flows downstream and to the west. It is likely that as the COC travel farther downstream/west, their concentrations are being decreased due to the water dilution effect. Thus, continued East Fork Poplar Creek benthic surface water monitoring is justified and warranted.

Mitchell Branch:

Tables 6 and 7 present a summary of the 2012 benthic surface water sampling results for Mitchell Branch.

Table 6: 2012 Mitchell Branch Surface Water Data Summary (non-radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
Ammonia	mg/L	0	0	0	0	0	2	n.a.
Dissolved oxygen	mg/L	9.39	9.2	9.58	0.269	0.38	2	> 5.0[a]
NO2 & NO3	mg/L	0.13	0.11	0.15	0.03	0.04	2	n.a.
pH	None	7.205	6.67	7.74	0.757	1.07	2	between 6-9[a]
Residue, dissolved	mg/L	210.5	197	224	19.1	27	2	n.a.
Residue, suspended	mg/L	0	0	0	0	0	2	n.a.
Specific conductivity	µS/cm	372.5	356	389	23.3	33	2	n.a.
Sulfate	mg/L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Temperature	°C	18.665	18.13	19.2	0.757	1.07	2	<= 30.5[a]
Total hardness	mg/L	191.5	183	200	12.0	17	2	n.a.
Total Kjeldahl nitrogen	mg/L	0.07	0	0.14	0.099	0.14	2	n.a.
Total Phosphorus	mg/L	0.059	0.048	0.07	0.0156	0.022	2	n.a.
Arsenic	ug/L	0	0	0	0	0	2	< 10[b]
Cadmium	ug/L	0	0	0	0	0	2	< 2.0[d]
Chromium	ug/L	0	0	0	0	0	2	< 16[c]
Copper	ug/L	1.1	1.1	1.1	0	0	2	< 13[d]
Hexavalent Chromium	mg/L	0	0	0	0	0	2	< 0.016[c]
Iron	ug/L	190.5	163	218	38.9	55	2	n.a.
Lead	ug/L	0	0	0	0	0	2	< 65[d]
Manganese	ug/L	99.9	74.8	125	35.50	50.2	2	n.a.
Mercury	ug/L	0	0	0	0	0	2	< 0.051[b]
Zinc	ug/L	3.15	2.9	3.4	0.35	0.5	2	< 120[d]

*Tennessee Water Quality Criteria:

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

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

[c]Fish and Aquatic Life (FAL), Chromium VI.

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

n.a. = Not applicable.

Table 7: 2012 Mitchell Branch Surface Water Data Summary (radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	PRG**
Actinium-228	pCi/L	0	0	0	0	0	2	7440
Bismuth-212	pCi/L	0	0	0	0	0	2	20900
Bismuth-214	pCi/L	6.75	0	13.5	9.55	13.5	2	77200
Cesium-137	pCi/L	0	0	0	0	0	2	487
Lead-210	pCi/L	0	0	0	0	0	2	16.8
Lead-212	pCi/L	0	0	0	0	0	2	593
Lead-214	pCi/L	0	0	0	0	0	2	43100
Potassium-40	pCi/L	0	0	0	0	0	2	600
Radioactivity, alpha	pCi/L	7.6	5.9	9.3	2.40	3.4	2	n.a.
Radioactivity, beta	pCi/L	3.45	3	3.9	0.64	0.9	2	n.a.
Thallium-208	pCi/L	0	0	0	0	0	2	n.a.
**DOE Preliminary Redemdiation Goals (PRG) for Radiological Parameters, Recreator: TR=1.0								

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 COC:

Non-Radiological COC:

1.) Compared to the reference sites, specific conductivity, total hardness, NO^2 and NO^3, residue (dissolved), and manganese values/concentrations were the lowest at MIK 1.43 and increased as the stream flowed downstream/west into the contaminated footprint of the ETTP / old K-25 area.

2.) Compared to the reference sites, iron concentrations exhibited an opposite trend where they were the highest at MIK 1.43 and decreased as the stream flowed downstream/west into the contaminated footprint of the ETTP / old K-25 area. It may be possible that an unknown mechanism is causing the iron to precipitate out of the surface water as ferric and/or ferrous iron and into the creek sediment. Further monitoring of the surface water and perhaps sampling of the creek sediment is indicated.
3.) Relative to both the reference and all monitoring sites, Cr^{6+} was not detected above its MDL.
4.) Chromium was only detected at MIK 1.43 (1.0J). All the other sites' concentrations were less than MDL for chromium.

Radiological COC:

1.) Compared to the reference sites, radioactive alpha concentrations were the lowest at MIK 1.43 (0.2 pCi/L), and increased as the stream flowed downstream/west to MIK 0.71 (5.9 pCi/L), and to MIK 0.45 (9.3 pCi/L).
2.) Compared to the reference sites, radioactive beta concentrations were the lowest at MIK 1.43 (0.4 pCi/L), and increased as the stream flowed downstream/west to MIK 0.71 (3.0 pCi/L), and to MIK 0.45 (3.9 pCi/L).
3.) Compared to the reference sites, bismuth-214 concentrations were the highest at MIK 1.43 (22.3 pCi/L), and decreased as the stream flowed downstream/west to MIK 0.71 (< MDL), and to MIK 0.45 (13.5 pCi/L).

Mitchell Branch Conclusion: None of the non-radiological COC results were greater than the TWQC (Table 6). In addition, none of the radiological COC results were greater than PRG goals (Table 7). All of the non-radiological and radiological COC results were of the same order as their associated reference stream COC results. The field trip and field blank quality control results were in control which indicated that our field sampling technique was correctly conducted. Relative to the majority of the above observations, the main trend is that COC 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. It appears that DOE's remediation efforts to eliminate chromium and its (Cr^{6+}) form have been very effective.

<u>White Oak Creek / Melton Branch:</u>

Tables 8 and 9 present a summary of the 2012 benthic surface water sampling results for White Oak Creek / Melton Branch.

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: 2012 White Oak Creek/Melton Branch Surface Water Data Summary (non-radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
Ammonia	mg/L	0.019	0	0.039	0.022	0.039	4	n.a.
Dissolved oxygen	mg/L	9.89	9.58	10.07	0.230	0.49	4	> 5.0[a]
NO2 & NO3	mg/L	1.065	0.3	1.7	0.65	1.4	4	n.a.
pH	None	8.1025	7.93	8.52	0.280	0.59	4	between 6-9[a]
Residue, dissolved	mg/L	219.5	178	244	28.9	66	4	n.a.
Residue, suspended	mg/L	0	0	0	0	0	4	n.a.
Specific conductivity	µS/cm	428	367	452	40.8	85	4	n.a.
Sulfate	mg/L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Temperature	°C	19.3025	18.93	19.86	0.413	0.93	4	<= 30.5[a]
Total hardness	mg/L	187.25	157	251	43.0	94	4	n.a.
Total Kjeldahl nitrogen	mg/L	0.19	0	0.63	0.300	0.63	4	n.a.
Total Phosphorus	mg/L	0.465	0.18	0.69	0.2344	0.51	4	n.a.
Arsenic	ug/L	0	0	0	0	0	4	< 10[b]
Cadmium	ug/L	0.1425	0	0.57	0.2850	0.57	4	< 2.0[d]
Chromium	ug/L	0.2425	0	0.97	0.485	0.97	4	< 16[c]
Copper	ug/L	2.45	0	4.4	1.88	4.4	4	< 13[d]
Hexavalent Chromium	mg/L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.016[c]
Iron	ug/L	116	79	155	39.0	76	4	n.a.
Lead	ug/L	0.0575	0	0.23	0.115	0.23	4	< 65[d]
Manganese	ug/L	19.425	10.6	24	6.27	13.4	4	n.a.
Mercury	ug/L	0	0	0	0	0	4	< 0.051[b]
Zinc	ug/L	12.7	2.8	23.3	9.34	20.5	4	< 120[d]

*Tennessee Water Quality Criteria:
[a]Fish and Aquatic Life (FAL), applies to all sites.
[b]Recreation (organisms only), applies to all sites.
[c]Fish and Aquatic Life (FAL), Chromium VI.
[d]Fish and Aquatic Life (FAL), applies to all sites. This value corresponds to a total hardness of 100mg/L.
n.a. = Not applicable.

Table 9: 2012 White Oak Creek/Melton Valley Branch Surface Water Data Summary (radiological)

Parameter	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	PRG**
Actinium-228	pCi/L	0	0	0	0	0	4	7440
Bismuth-212	pCi/L	0	0	0	0	0	4	20900
Bismuth-214	pCi/L	3.625	0	14.5	7.25	14.5	4	77200
Cesium-137	pCi/L	26.775	0	69.8	33.6	69.8	4	487
Lead-210	pCi/L	0	0	0	0	0	4	16.8
Lead-212	pCi/L	0	0	0	0	0	4	593
Lead-214	pCi/L	0	0	0	0	0	4	43100
Potassium-40	pCi/L	0	0	0	0	0	4	600
Radioactivity, alpha	pCi/L	5.15	2.5	9.9	3.27	7.4	4	n.a.
Radioactivity, beta	pCi/L	139.88	103.8	186.5	36.62	82.7	4	n.a.
Thallium-208	pCi/L	1.25	0	5.0	2.5	5.0	4	n.a.

**DOE Preliminary Redemdiation Goals (PRG) for Radiological Parameters, Recreator: TR=1.0

Directional Flow: WCK 6.8 (very near headwater and reference stream) $>^{SouthWest}$ WCK 3.9 (within secured ORNL) $>^{SouthWest}$ WCK 3.4 (within secured ORNL/Bethel Valley Burial Grounds) $>^{SouthEast}$ MEK 0.3 (within secured Melton Valley Burial Grounds/ORNL/ Bethel Valley Burial Grounds) $>^{SouthWest}$ 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 COC 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. Also in the production of these nuclear materials at ORNL, non-radiological carcinogenic organic volatile COC, such as trichoroethylene (TCE), and tetrachloroethylene (PCE) were employed. Specific Data Results Observations relative COCs:

Non-Radiological COC:

1.) Compared to the reference sites, specific conductivity, NO^2 and NO^3, and residue (dissolved) values/concentrations were the lowest at WCK 6.8, increased to WCK 3.9 and remained level to WCK 2.3, where their concentrations were the highest.
2.) Compared to the reference sites, total hardness, and iron concentrations were the highest at WCK 6.8, decreased to WCK 3.9 and remained level to WCK 2.3, where their concentrations increased to nearly the same as WCK 6.8.
3.) Compared to the reference sites, total phosphorus concentrations were the highest at WCK 6.8 and increased as the stream flowed downstream/west to WCK 6.8, where the concentration decreased.

Radiological COC:

1.) Compared to the reference sites, radioactive alpha concentrations were the lowest at WCK 6.8 and showed a weak trend where concentration increased downstream/west. Exact values are: WCK 6.8 reference (1.3 pCi/L), WCK 3.9 (3.7 pCi/L), WCK 3.4 (4.5 pCi/L), MEK 0.3 (2.5 pCi/L), WCK 2.3 (9.9 pCi/L), and CCK 1.45 eco-region reference (0.3 pCi/L).
2.) Compared to the reference sites, radioactive beta concentrations were the lowest at WCK 6.8 and showed a weak trend where concentration increased downstream/west. Exact values are: WCK 6.8 reference (1.6 pCi/L), WCK 3.9 (150.3 pCi/L), WCK 3.4 (118.9 pCi/L), MEK 0.3 (103.8 pCi/L), WCK 2.3 (186.5 pCi/L), and CCK 1.45 eco-region reference (0.9 pCi/L).
3.) Bismuth-214 was only detected at WCK 6.8 (8.3 pCi/L) and WCK 2.3 (14.5 pCi/L). All the other sites' concentrations were less than MDL.
4.) Cesium-137 was only detected at WCK 3.9 (69.8 pCi/L) and WCK 2.3 (37.3 pCi/L). All the other sites' concentrations were less than MDL.
5.) Thallium-208 was only detected at MEK 0.3 (5.0 pCi/L). All the other sites' concentrations were less than MDL.

White Oak Creek / Melton Branch Conclusion: None of the non-radiological COC results were greater than the TWQC (Table 8). In addition, none of the radiological COC results were greater than DOE PRG goals (Table 9). The majority of the non-radiological and radiological COC results were of the same order as their associated reference stream COC results. The field trip and field blank quality control results were in control which indicated that the field sampling technique was correctly conducted. In addition, the results from the MEK 0.3 field duplicate sampling showed excellent reproducibility, thus confirming that the field sampling technique was correctly conducted. Relative to the majority of the above observations, the main trend is that COC levels were highest at WCK 6.8 and increased as White Oak Creek/Melton Branch flows downstream and to the west, ultimately flowing into the Clinch River.

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