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MARTIN MARIETTA

ENVIRONMENTAL SURVEILLANCE OF THE OAK RIDGE RESERVATION AND SURROUNDING ENVIRONS DURING 1985

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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LIST OF ACRONYMS

ADI	acceptable daily intake
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
BCK	Bear Creek kilometer
BCVWDA	Bear Creek Valley Waste Disposal Area
BOD	biochemical oxygen demand
CDI	calculated daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COD	chemical oxygen demand
CPCF	Central Pollution Control Facility
CRBRP	Clinch River Breeder Reactor Project
CRK	Clinch River kilometer
CWDF	Central Waste Disposal Facility
DO	dissolved oxygen
DOE-ORO	Department of Energy-Oak Ridge Operations
EFPC	East Fork Poplar Creek
EFPCK	East Fork Poplar Creek kilometer
EML	Environmental Measurements Laboratory
EPA	Environmental Protection Agency
ETF	Engineered Test Facility
FDA	Food and Drug Administration
FRC	Federal Radiation Council
GPP	General Plant Project
HFIR	High Flux Isotope Reactor
ICRP	International Committee on Radiological Protection
INAA	instrumental neutron activation analysis
LLW	low-level radioactive waste
MBAS	methylene blue absorbing substances
MDL	minimum detectable limit
MPC	maximum permissible concentrations
MSL	mean sea level
MSRE	Molten Salt Reactor Experiment
NAS	National Academy of Sciences
NASN	National Air Sampling Network
NBS	National Bureau of Standards

NESHAP	National Emission Standards for Hazardous Air Pollutants
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NSPP	Nuclear Safety Pilot Plant
ORAU	Oak Ridge Associated Universities
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORTF	Oak Ridge Task Force
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PWTP	Process Waste Treatment Plant
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RSD	relative standard deviation
SAR	safety analysis report
SOP	standard operating procedure
STP	Sewage Treatment Plant
SWSA	Solid Waste Storage Area
TCMP	Toxicity Control and Monitoring Program
TDHE	Tennessee Department of Health and Environment
TDS	total dissolved solids
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TRE	total rare earths
TRU	transuranics
TSP	total suspended particulates
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
UID	unidentified alpha
UNC	United Nuclear Corporation
USGS	United States Geological Survey
WOC	White Oak Creek
WOCK	White Oak Creek kilometer
Y-12	Oak Ridge Y-12 Plant

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EXECUTIVE SUMMARY

This calendar-year 1985 annual report on environmental surveillance of the Department of Energy's (DOE) Oak Ridge Reservation (ORR) and the surrounding environs reflects substantial changes in both content and organization from its predecessors.

Continuing improvements in Reservation-wide monitoring programs, in monitoring instrumentation and information management, and in the range and scope of regular observations and special studies have made possible a more comprehensive and detailed report of the environmental impacts of discharges and effluents from the major Oak Ridge production and research facilities than was possible previously.

To that end, the report brings together for the first time measurements of actual concentrations of chemicals and radioactivity in the environment for the current (1985) reporting period and summary data on historic (40-year) uranium releases from the three-site complex consisting of the Oak Ridge Y-12 Plant, Oak Ridge National Laboratory (ORNL), and Oak Ridge Gaseous Diffusion Plant (ORGDP).

Both current radionuclide and historic uranium-release data are used as the basis for calculating estimated radiation doses for the maximally exposed individual in the vicinity of the Oak Ridge complex, total population exposures within an 80-km (50-mile) radius, and the associated health impacts on a current as well as historic basis. The latter are presented with a review of the assumptions and limitations that underlie such dose modeling calculations and risk estimates. Also, evaluations are provided of environmental chemical measurements.

Traditional monitoring data, based on observed levels of contamination at a network of on- and off-site observation stations, have been augmented by the inclusion of a separate chapter documenting the types and levels of airborne and waterborne effluents discharged at the source. Data have also been included to describe current on-site disposal and off-site shipments of radioactive and hazardous chemical wastes.

As in the past, the main body of the report reflects results from regular year-round sampling and analysis of air, water from surface streams, groundwater, creek sediment, biota, and soil for both radioactive and nonradioactive (including hazardous) materials. Among other features introduced or expanded upon in the 1985 report are:

- A review of selected major environmental actions and occurrences during the year
- A summary listing of monitoring and sampling activities that describes the network of local, on-site, and regional observation stations from which monitoring data are derived
- Results of environmental surveillance and monitoring carried out within the Oak Ridge community

- Special environmental studies and technical reviews, including reports of Oak Ridge Task Force activities under the direction of the State of Tennessee Division of Water Management
- Quality assurance and technical reviews of the radiological and nonradiological monitoring programs at the Y-12 Plant, ORNL, and ORGDP

The objectives of this report are to:

- *Report 1985 monitoring data for the ORR and surrounding environs that may have been affected by operations on the ORR.*
- *Provide detailed information on the ORR for the reader.*
- *Provide detailed information on input and assumptions used in all calculations so the reader could repeat these calculations.*
- *Integrate monitoring data and related studies in one document that is intended to highlight the information contained in many documents.*
- *Provide trend analyses, where possible, to indicate increases and decreases in concentrations and/or discharges.*
- *Provide general information on the ORR and quality assurance that can be referenced in future reports.*

The document is organized in the following manner:

- *Executive Summary—Intended to highlight 1985 environmental conditions and monitoring data from each section.*
- *Section 1: Introduction and General Information—Intended to provide the reader with general information about the ORR and surrounding areas; this report may be referenced in future documents.*
- *Section 2: Effluent and On-Site Discharges—Intended to provide the reader with estimates of the 1985 discharges to air and water, materials disposed of on site or shipped off site for disposal, and historic releases of uranium.*
- *Section 3: Calculation of Potential Radiation and Chemical Dose to the Public—Intended to provide the reader with estimates of the doses for radiological discharges and for radiological and chemical environmental measurements.*
- *Section 4: Monitoring Data—Intended to provide the reader with 1985 monitoring data and trends in data.*
- *Section 5: Special Studies, Unusual Occurrences, and Technical Review—Intended to provide readers with highlights of studies on monitoring, characterization, and cleanup activities that were completed and reported on in 1985. This section also provides brief reviews of the unusual occurrences at the three Oak Ridge plants during 1985, and, finally, provides highlights of the review of waste management at ORNL that was reported on in 1985.*

- *Section 6: Quality Assurance and Technical Reviews—Intended to provide readers with highlights of the environmental monitoring quality assurance program and of the reviews of quality assurance programs during 1985. Also included is the QA Program that was developed in 1985. (This is the only publication that describes this newly developed program; it will thus be referenceable in future reports.)*
- *Section 7: Oak Ridge Task Force Activities—Intended to provide readers with highlights of the Task Force monitoring reports. This Task Force was established to determine the impact of DOE residual off-site contamination.*
- *Section 8: Environmental Surveillance and Monitoring of the Oak Ridge Community Provided by Oak Ridge Associated Universities—Intended to provide the reader with monitoring data from the Oak Ridge community monitoring program, data which are being collected to support the Oak Ridge Task Force study and to respond to community sampling requests.*

This report has been organized to flow as follows:

General information on the ORR → Discharges to the environment → Dose calculations from these discharges → Monitoring data and trends → Special related studies → Quality assurance program for monitoring → Task Force monitoring → Oak Ridge community monitoring.

MONITORING SUMMARY

Routine monitoring and sampling for radiation, radioactive materials, and chemical substances on and off the Oak Ridge Reservation are used to document compliance with appropriate standards, identify undesirable trends, provide information for the public, and contribute to general environmental knowledge.

Regional stations located at distances of up to 140 km (90 miles) from the ORR provide a basis for determining conditions beyond the range of potential influence of the three Oak Ridge installations. Stations within the Reservation, around the perimeters and within each plant site, and in residential and community areas document conditions in areas occupied and visited by the public and potentially affected by the Oak Ridge operations.

In all, during 1985 some 115,000 analyses of environmental samples were completed as part of the Reservation-wide and regional monitoring program. Included were approximately 61,000 air, 41,000 surface water, 8,090 groundwater, 2,400 wastewater, 80 fish, 231 soil, 132 grass, 36 pine needle, 360 sediment, and 80 external gamma analyses.

CURRENT RELEASES (1985)

Most gaseous wastes are released through stacks that are the endpoints of air-cleaning systems that remove radioactivity present either as solids (particulates) or as an absorbable gas. Discharges to the atmosphere come from 1749 emission points at the three installations, 1200 of which are small hoods and vents at ORNL.

1985 Airborne Releases

Radioactive

The total 1985 airborne discharge of nearly 59,000 Ci of radioactivity is accounted for almost totally by tritium and by two inert gases, xenon and krypton, which have little or no interaction with the terrestrial biosphere, including humans. Annual curie releases were:

Radionuclide	Discharge (Ci)
Uranium	0.10
Iodine-131	0.086
Tritium	20,000
Xenon-133	32,000
Krypton-85	6,600
Technetium-99	0.0030

Nonradioactive

Two of the most significant nonradioactive materials released to the atmosphere are fluorides and organics. Fluoride releases from ORGDP in 1985 were measured at 28 kg; the hydrogen fluoride released from Y-12 during 1985 was estimated to be 21,960 kg. The estimated 1985 releases of trichloroethane, perchlorethylene, methylene chloride, and acetone were 270,000 kg. Other nonradioactive materials released to the atmosphere are listed in Table 2.1.3.

1985 Surface Stream Releases

Radioactive

Radioactive discharges to surface streams were dominated by tritium (3700 curies in 1985). Only one other radionuclide, strontium-90, was released in quantities of more than one curie. The 3-Ci total for 1985 reflected, in part, two events in which subsurface soil contamination in the vicinity of waste management facilities was mobilized and moved into the White Oak Creek drainage. Total curie discharges by isotope were:

Radionuclide	Discharge (Ci)
Cesium-137	0.42
Cobalt-60	0.62
Tritium	3,700
Ruthenium-106	0.01
Strontium-90	3.0
Technetium-99	0.0327
Uranium	0.62
Transuranics	0.008

Nonradioactive

Estimates of nonradioactive releases to surface streams were not available for this report. Chemical release data reports are being generated and will be published in 1986. Environmental concentrations in surface streams are reported in this report.

1985 Disposal Activities

Radioactive

Radioactive wastes placed in retrievable storage during 1985, primarily at ORNL, contained 988 Ci of activity. Another 11,981 Ci of activity was disposed of by land burial on the Oak Ridge Reservation.

Nonradioactive

About 43 million kg of nonradioactive and nonhazardous solid waste was disposed of during 1985. Another 16 million kg of hazardous and/or special waste was disposed of during 1985.

Historic Uranium Releases

The releases of uranium to the atmosphere from 1944 through 1984 are estimated to be 28 Ci (16,316 kg); to water, 128 Ci (196,467 kg); and disposal, 6,598 Ci (16,032,750 kg). This is a total of 6,706 Ci (16,245,533 kg).

DOSE ESTIMATES (RADIATION AND CHEMICALS)

For the first time, this report estimates the impact on human health not only from radionuclide releases to the environment (air and water), as in the past, but also from the discharge of nonradioactive chemicals present in surface water and air. Also, those chemicals in groundwater that require more study because they were identified during a screening process are listed. Estimated health effects also have been calculated, again on the basis of dose modeling techniques, for historic (1944–84) releases of uranium.

Radioactive

During 1985, the Department of Energy issued *Radiation Standards for Protection of the Public in the Vicinity of DOE Facilities.* The effective date of these standards was July 1, 1985. It is stated in this publication that the effective dose equivalent for any member of the public from all routine DOE operations (natural background and medical exposures excluded) shall not exceed the values given below.

All pathways	Effective dose equivalent (millirem/year)	(millisievert/year)
Occasional annual exposures	500	5
Prolonged period of exposure (longer than 5 years)	100	1
Air pathway only (Limits of 40 CFR Pt. 61, Subpart H)	**Dose equivalent (millirem/year)**	**(millisievert/year)**
Whole body dose	25	0.25
Any organ	75	0.75

It is also stated in this DOE standard that DOE facilities with airborne releases subject to 40 CFR Pt. 61, Subpart H must use the AIRDOS-EPA model unless otherwise approved by EPA. AIRDOS-EPA was used for the calculations in this report.

Potential pathways of exposure to humans from radioactive effluents released from the Oak Ridge complex were considered in the calculation of the maximum potential dose to the public. The exposure routes included direct radiation, inhalation of gaseous effluents, and consumption of milk, water, and fish.

From the above data, the calculated probabilities of potential health effects (fatal cancers) are 0.1 for ORGDP and 1.4 for the Y-12 Plant. The probabilities estimate the likelihood of one fatal cancer occurring within an 80-km radius. The most probable health effect from inhaling airborne uranium is lung cancer. From all causes, 11,000 lung cancers are estimated to occur within this radius over the past 40-year period.

Health criteria for water are such that chemical intake from consumption of 2 L per day would not exceed the acceptable daily intake. Ratios of the calculated daily intake to that acceptable intake provide the basis for estimating the specific risk of developing cancer over a human lifetime (of 1 in 100,000).

Daily intakes of chemicals (in milligrams per day) were calculated on the basis of results from surface water and air sampling on the ORR. In surface waters, increased risks appear (based on monitored concentrations in the vicinity of ORGDP) to be present only from nickel. Ratios are at or below 1 (meaning a maximum risk of 1 in 100,000) at all other Reservation and perimeter monitoring points, including the East and West Forks of Poplar Creek and Bear Creek. Groundwater sampling at locations throughout burial ground and landfill areas as well as settling basins (such as the S-3 Ponds) reflects concentrations that require more study. Substances that require more study are beryllium, methylene chloride, tetrachloroethane, cadmium, lead, nickel, silver, zinc, PCBs, and chloroform. All the air concentration ratios were below 0.2.

The whole-body dose resulting from direct radiation, assuming an exposure of 240 hours per year, to a "hypothetical maximally exposed individual" at the site boundary location of maximum potential exposure was 5 millirem. This site is located along the Clinch River just above Clinch River kilometer 33. The maximum potential dose to the public during 1985 as a consequence of Oak Ridge gaseous effluents was 2 millirem and 8.3 millirem to the critical organ (lung).

Ingestion of 1 L of locally produced milk per day for one year would result in a maximum committed effective dose to an individual of 0.01 millirem and 0.2 to the bone (endosteal cells). The annual dose from ingestion of 2.2 L of treated water per day for one year from the Kingston filtration plant would be 0.12 millirem for the committed effective dose equivalent, 1.5 millirem to bone, and 0.67 millirem to kidney. Consumption of 20 kg of bass muscle per year from the Clinch River system gave the highest average effective dose equivalent (1.3 millirem) via the aquatic pathway. The annual dose equivalent to the endosteal cells from the consumption of an average bass sample from this location was 3.5 millirem. Consumption of 10 kg of carp patties (flesh and bone) containing the maximum amount of strontium-90 would result in a committed effective dose equivalent of 0.6 millirem and 6 millirem to the bone.

For each of the three Oak Ridge facilities in 1985, potential radiation doses were calculated for the nearest resident off-site individual. Effective doses, and critical organ doses representing the 50-year dose commitment in millirem from 1985 releases, were:

	Effective dose[a] (millirem)	Critical organ
Y-12 Plant	1.7	8.3 (lung)
ORNL	0.2	0.35 (stomach wall)
ORGDP	0.00068	0.0161 (bone)
Maximum from all sites	2.0	8.6 (lung)

[a] Dose calculations using air concentrations are within a factor of 3 of the AIRDOS models.

Calculations are based on radioactivity emission data from each site, local meteorological data, and dose conversion factors based on guidelines of the International Commission on Radiological Protection. The above figures translate into an added lifetime fatal cancer risk, in the case of the highest exposure to a resident living 570 m north-northwest of the Y-12 Plant, of 0.00000028.

For the average Oak Ridge resident, the average committed dose equivalent was less than 2 millirem. The primary contributor to the dose was airborne releases of uranium from the Y-12 Plant. For comparison with these estimates, the average annual background radiation dose, from natural as well as man-made sources, is 200 millirem for an individual. Included in this total are about 30 millirem from cosmic rays, 30 millirem from potassium-40 (naturally present in all human and animal tissue), 80 millirem from radon, and 60 millirem from other sources.

Based on historic releases of uranium from the three sites, total radiation doses have been calculated for the population of approximately 830,000 within an 80-km radius of the ORR. This leads to estimates of accumulated doses of 850 person-rem for releases from ORGDP and 11,377 person-rem from the Y-12 Plant—a total of 12,227 person-rem. This represents about 0.30% of the estimated exposure of 4 million person-rem for this population from natural sources over the same period.

Air

Radioactive

The DOE concentration guides for air and water are being replaced with committed dose equivalents per unit intake (inhalation and ingestion). The impact of air concentration is addressed in Sect. 3.

Nonradioactive

- Fluoride concentrations were well below standards
- Suspended particulate concentrations were all less than 76% of standards
- Sulfur dioxide concentrations were all well below standards
- Lead was the only trace metal that needs to be investigated further; the highest concentration was 49% of the standard

Surface Water

Radioactive

The impacts of water concentrations are addressed in Sect. 3.

Nonradioactive

- Mercury concentrations exceeded the criterion at White Oak Creek, Melton Branch, East Fork Poplar Creek, and Bear Creek
- Concentrations of zinc exceeded the criterion at White Oak Creek, Melton Branch, ORGDP sanitary water pumping station, ORGDP recirculating pumping station, Poplar Creek, and East Fork Poplar Creek
- Concentrations of lead exceeded the criterion at ORGDP sanitary water pumping station, ORGDP recirculating pumping station, Clinch River downstream from ORGDP, and Poplar Creek
- The parameters measured as part of the ORGDP NPDES and percentage of compliance are as follows:

Discharge	Parameter	Percent of compliance
K-1700	Aluminum	91
	Suspended solids	99
	Zinc	99
	Cadmium	99
	All others	100
K-1203	Fecal coliform	98
	Suspended solids	99
	All others	100
K-1007-B	COD	93
	All otherws	100
K-901-A	Chromium	71
	All others	100
Sanitary Water Plant	All	100

- The parameters measured as part of the Y-12 NPDES and the percentage of compliance are as follows:

Discharge	Parameter	Percent of compliance
Kerr Hollow Quarry	All	100
Rogers Quarry	Oil and grease	96
	pH	91
	Settleable solids	96
	Total suspended solids	98
	Ammonia	97
New Hope Pond	Cadmium	94
	Copper	94
	Dissolved oxygen	97
	Mercury	91
	Nitrogen	94
	Oil and grease	94
	pH	96
	Settleable solids	96
	Surfactants	98
	All others	100
304	All	100
305	pH	87
	All others	100
306	Oil and grease	87
	Total suspended solids	87
	All others	100
Category I outfalls	All	100
Category II outfalls	pH	98
	All others	100
Category III outfalls	pH	90
Category IV outfalls	pH	97
623	pH	100
S-3 Ponds liquid treatment facility	Cyanide	99
	Total suspended solids	99
	All others	100
508	Mercury	50
	All others	100
510	Biochemical oxygen demand	75
	Oil and grease	33
	All others	100
Miscellaneous	pH	58
	All others	100

- The parameters measured as part of the ORNL NPDES and the percentage of compliance are as follows:

Discharge	Parameter	Percentage of compliance
White Oak Creek	Dissolved oxygen	99
	pH	99.7
	All others	100
Melton Branch	Dissolved solids	99.7
	All others	100
Sewage Treatment Plant	Ammonia	58
	BOD	90
	Residual chlorine	96
	Suspended solids	87
	All others	100

Groundwater

Parameters that exceeded drinking water standards at each site were:

Location	Parameters
ORNL	Gross alpha, gross beta, lead, fecal coliform, nitrate
Y-12	Gross alpha, gross beta, pH, arsenic, cadmium, chromium, lead, mercury
ORGDP	Gross alpha, pH, cadmium, lead

To a large extent this is a function of what was analyzed and may not reflect all potential problems.

1985 IN REVIEW

As reflected in the many special studies and evaluations summarized in the body of this report, the year 1985 saw an unprecedented effort directed toward assessment of waste-management alternatives and characterization of environmental problems on a Reservation-wide basis. At the same time, major environmental restoration activities and upgrades of waste management and site monitoring capabilities were under way.

In late June, the Department of Energy's Oak Ridge Operations issued a report on historic releases of uranium to the environment from all of its sites, including the three Oak Ridge facilities. At the same time, work was begun to prepare a report summarizing data on historic releases of all other radioactive materials and another summarizing historic chemical releases.

During 1985, the Oak Ridge complex initiated a survey that built on extensive previous reviews of the potential for incidents having major health or safety impacts. The purpose was to identify and reexamine potential incidents that could cause large numbers of casualties, to evaluate the adequacy of existing prevention/response systems, and to identify areas where improvements are possible.

In response to the results of technical and regulatory reviews, a decision was made to examine a range of alternatives to the proposed Central Waste Disposal Facility, which had been planned for a site on Chestnut Ridge near the western boundary of the Oak Ridge Reservation. This site had been proposed for future disposal of low-level radioactive wastes originating at all three Oak Ridge sites.

A panel of the Board on Radioactive Waste Management of the National Research Council completed its two-year review of waste management practices at ORNL and concluded that these practices have kept off-site doses low and do not present a health hazard.

An independent Environmental Advisory Committee appointed by Martin Marietta Energy Systems, Inc. (with representatives of the Oak Ridge community, public interest groups, universities, and industry and from professionals in the fields of health sciences, environmental quality, natural resources, engineering, and law) continued its systematic review of the environmental situation at the the three Oak Ridge installations.

The interagency Oak Ridge Task Force began the publication of reports of its instream contaminant study dealing with five tasks: collection of water quantity and quality data for predicting sediment transport; sediment volume and contaminant characterization; transport and fate of sediment in East Fork Poplar Creek; contamination concentrations in fish; and summary and implications.

DOE issued final reports documenting reviews of both radiological and nonradiological effluent and environmental monitoring programs conducted at the Y-12 Plant, ORNL, and ORGDP. Action plans have been developed for recommended corrective actions at each site.

Major long-term remedial environmental restoration and facilities upgrade programs were under way at the Y-12 Plant and ORNL to respond to identified needs for improved methods of waste isolation, disposal, and treatment.

During 1985, plans were developed to drill more than 1000 new shallow groundwater monitoring wells; more than 200 of these have been completed at Y-12 and are now in use to monitor groundwater movements and improve understanding of water quality on the Oak Ridge Reservation.

The $5 million Central Pollution Control Facility was completed; its purpose is to remove metals and organic compounds and neutralize acids and caustics in wastewaters from the Y-12 Plant. This is the first of several major waste treatment and storage facilities planned or under construction at Y-12. In full operation, this facility will treat approximately one million gallons per year of wastewater from Y-12's metal fabrication and machining operations.

The Y-12 Plant began the discharge of fully treated water from the former S-3 Ponds into East Fork Poplar Creek. The four ponds, located at the west end of the Plant, had been used for more than 32 years to accept and act as a holding basin for nitrate-bearing liquid wastes containing low concentrations of heavy metals and other contaminants from Y-12 operations. As part of a major cleanup effort, water in the ponds has been neutralized and denitrified in situ using bacterial cultures. Final treatment allows it to meet stringent permit guidelines in a new $1.4 million "polishing" facility before it is discharged as crystal-clear water to the creek.

A new National Pollutant Discharge Elimination System (NPDES) permit was issued by the Environmental Protection Agency on May 24, 1985, for the Y-12 Plant. It imposes a variety of environmental monitoring requirements for compliance, including more than 234 specified outfalls where routine effluent monitoring will be done for specific parameters. Many of the requirements for the permit are based on biological and toxicological monitoring programs. This represents an approximately 100-fold increase in sampling requirements. In addition, some 600 new air quality permits have been established as part of a comprehensive air discharge permitting program.

At ORGDP, a new groundwater monitoring system consisting of a network of shallow wells was placed in operation. ORGDP also is the site for construction of a new Toxic Substances Control Act (TSCA) incinerator to destroy uranium-contaminated PCB waste and hazardous organic materials. Designed to provide disposal capabilities for seven DOE facilities, and scheduled to begin fully licensed operation in 1987, this facility will utilize a highly instrumented kiln and secondary combustion chamber equipment as well as a state-of-the-art off-gas treatment system to meet or exceed TSCA regulations for disposal of these types of wastes.

A concrete batch plant is under construction at ORGDP that will provide a facility for encapsulation of low-level radioactive-waste-bearing materials to be stored until any DOE decisions on disposal alternatives are made.

Twice in 1985, elevated levels of strontium-90 were detected in White Oak Creek, the principal drainage for the ORNL Bethel Valley Complex. The first, in January, was traced to a broken low-level waste line and the second, in November, to a construction pit where an air exhaust duct was exposed to water from a broken storm sewer line. The latter resulted in a temporary suspension of water intake at ORGDP and use of alternative drinking water supplies until corrective actions had been completed.

ORNL placed in operation a new Waste Operations Control Center that automates and integrates waste management and control functions on a site-wide basis. Construction was completed on a new Laboratory Emergency Response Center at ORNL, to become operational in 1986, which will further integrate and strengthen all environmental surveillance functions and response capabilities.

The $1.5 million Sewage Treatment Plant at ORNL, which became operational in late August, represents a significant step toward bringing the Laboratory into full compliance with state and federal standards for sanitary wastewater effluents. The extended aeration and filter system, with a 36-hour treatment time, replaces a two-stage lagoon system that proved to be inefficient and had resulted in many noncompliances with NPDES limits for ammonia, biochemical oxygen demand, total residual chlorine, and suspended solids.

Under the newly established Environmental Restoration and Facilities Upgrade Program, ORNL has the dual goal of reducing discharges and accelerating compliance. Long-term tasks include characterization, remedial action, and decontamination and decommissioning of facilities no longer in use. The comprehensive program will include improved facilities for waste treatment, disposal, storage, and monitoring.

DOE anticipates the issuance in 1986 of updated NPDES permits under the Clean Water Act for ORNL, which will increase the number of units/effluents operating under permit from the present 3 monitoring points to 150.

DOE advised federal and state regulatory agencies that it would accelerate efforts to evaluate alternatives to the hydrofracture process used since the 1960s for permanent disposal of certain classes of ORNL-generated liquid radioactive wastes. This was prompted by local groundwater contamination and by pending federal and state regulations that would severely restrict all types of deep well injection of hazardous chemicals and radioactive wastes.

Thirteen new, fully automated air monitoring stations were deployed on the Oak Ridge Reservation as part of an upgrade of this network, which complements individual site and remote air monitoring capabilities.

Under a cooperative agreement reached in November 1984 between DOE and TWRA, the DOE Reservation was established as the TWRA-managed Oak Ridge Wildlife Management Area. A TWRA resident officer assumed his responsibilities in 1985.

Five public deer hunts conducted by the Tennessee Wildlife Resources Agency (TWRA) during the last quarter of 1985 provided the opportunity for an unprecedented radiological survey of the growing Reservation deer population. Successful hunters were requested to bring their field-dressed deer, with the liver, to the TWRA checking station for monitoring. Of the 926 deer harvested, only 7 were retained—all because of strontium-90 concentrations that exceeded the screening limit (25-millirem annual dose to the hunters or their families from consumption of the deer meat). A rapid screening technique also was used to measure the concentrations of cesium-137 and other gamma-emitting radionuclides in deer muscle.

1. INTRODUCTION AND GENERAL INFORMATION

Each year since 1972, a report has been prepared on the environmental monitoring activities for the Department of Energy (DOE) facilities in Oak Ridge, Tennessee, for the previous calendar year. Before 1972, the individual facilities published quarterly and annual progress reports that contained some environmental monitoring data.

This calendar-year 1985 annual report on environmental surveillance of the DOE's Oak Ridge Reservation (ORR) and the surrounding environs reflects substantial changes in both content and organization from its predecessors. The objectives of this report are to:

- *Report 1985 monitoring data for the ORR and surrounding environs that may have been affected by operations on the ORR.*
- *Provide detailed information on the ORR for the reader.*
- *Provide detailed information on input and assumptions used in all calculations so the reader could repeat these calculations.*
- *Integrate monitoring data and related studies in one document that is intended to highlight the information contained in hundreds of documents.*
- *Provide trend analyses, where possible, to indicate increases and decreases in concentrations and/or discharges.*
- *Provide general information on the ORR and quality assurance that can be referenced in future reports.*

The document is organized in the following manner:

- *Executive Summary—Intended to highlight 1985 environmental conditions and monitoring data from each section.*
- *Section 1: Introduction and General Information—Intended to provide the reader with general information about the ORR and surrounding areas. This report may be referenced in future documents.*
- *Section 2: Effluent and On-Site Discharges—Intended to provide the reader with estimates of the 1985 discharges to air and water, materials disposed of on site or shipped off site for disposal, and historic releases of uranium.*
- *Section 3: Calculation of Potential Radiation and Chemical Dose to the Public—Intended to provide the reader with estimates of the doses for discharges.*
- *Section 4: Monitoring Data—Intended to provide the reader with 1985 monitoring data and trends in data.*
- *Section 5: Special Studies, Unusual Occurrences, and General Reviews—Intended to provide readers with highlights*

of studies on monitoring, characterization, and cleanup activities that were completed and reported on in 1985. This section also provides brief reviews of the unusual occurrences at the three Oak Ridge plants during 1985, and, finally, provides highlights of the review of waste management at ORNL that was reported on in 1985.

- *Section 6: Quality Assurance and Technical Reviews—Intended to provide readers with highlights of the environmental monitoring quality assurance program and of the reviews of quality assurance programs during 1985. Also included is the QA Program that was developed in 1985. (This is the only publication that describes this newly developed program; it will thus be referenceable in future reports.)*
- *Section 7: Oak Ridge Task Force Activities—Intended to provide readers with highlights of the Task Force monitoring reports. This Task Force was established to determine the impact of off-site residual contamination.*
- *Section 8: Environmental Surveillance and Monitoring of the Oak Ridge Community Provided by Oak Ridge Associated Universities—Intended to provide the reader with monitoring data from the Oak Ridge community monitoring program. These data are being collected to support the Oak Ridge Task Force and to respond to community requests.*

This report has been organized to flow as follows:

General information on the ORR → Discharges to the environment → Dose calculations from these discharges → Monitoring data and trends → Special related studies → Quality assurance program for monitoring → Task Force monitoring → Oak Ridge community monitoring.

The environmental monitoring program for 1985 included sampling and analysis of air, water from surface streams, groundwater, creek sediment, biota, and soil for both radioactive and nonradioactive (including hazardous) materials. Special environmental studies that were conducted in the Oak Ridge area are included in this report, primarily as abstracts or brief summaries. A summary of the 1985 environmental monitoring and surveillance of the Oak Ridge community by Oak Ridge Associated Universities (ORAU) is included as Sect. 8.

Brief descriptions of the Oak Ridge area and the three DOE facilities are provided here to enhance the reader's understanding of the direction and substance of the environmental monitoring program for Oak Ridge. Figure 1.1 is a map showing the location of Oak Ridge in Tennessee and its relationship to the geographic region.

1.1 OPERATIONS ON THE OAK RIDGE RESERVATION

The ORR contains three major operating facilities: ORNL, the Y-12 Plant, and ORGDP. These three facilities are located on the map of the ORR shown in Fig. 1.1.1. The administrative units on the ORR are shown in Table 1.1.1. In addition, two smaller DOE facilities are in the Oak Ridge area: the Scarboro Facility (formerly the Comparative Animal Research Laboratory) and ORAU, both of which are operated by ORAU.

ORNL, located toward the west end of Bethel Valley, is a large, multipurpose research laboratory whose basic mission

ORNL–DWG 86 8710

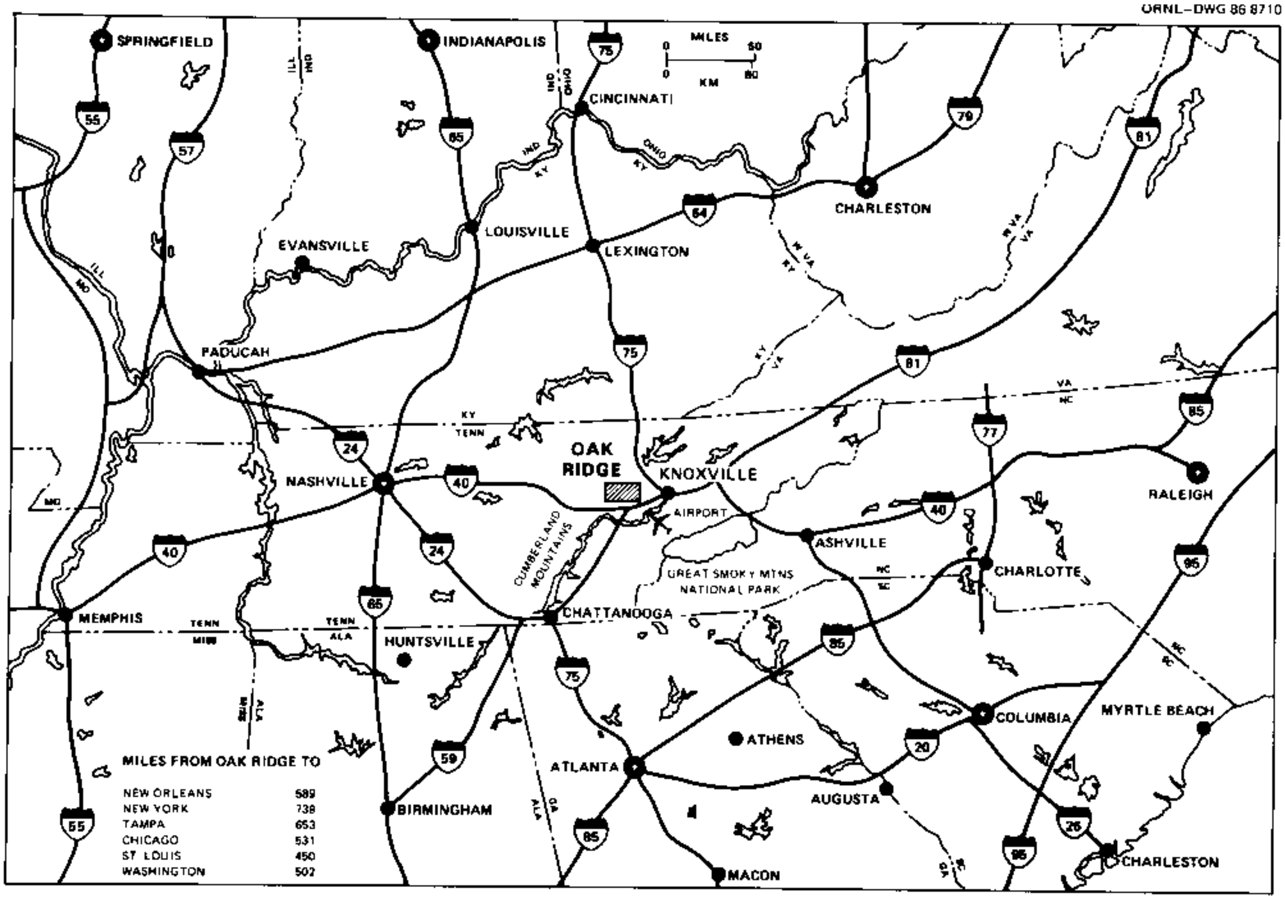

Fig. 1.1. Map showing location of Oak Ridge in Tennessee and relationship to geographic region.

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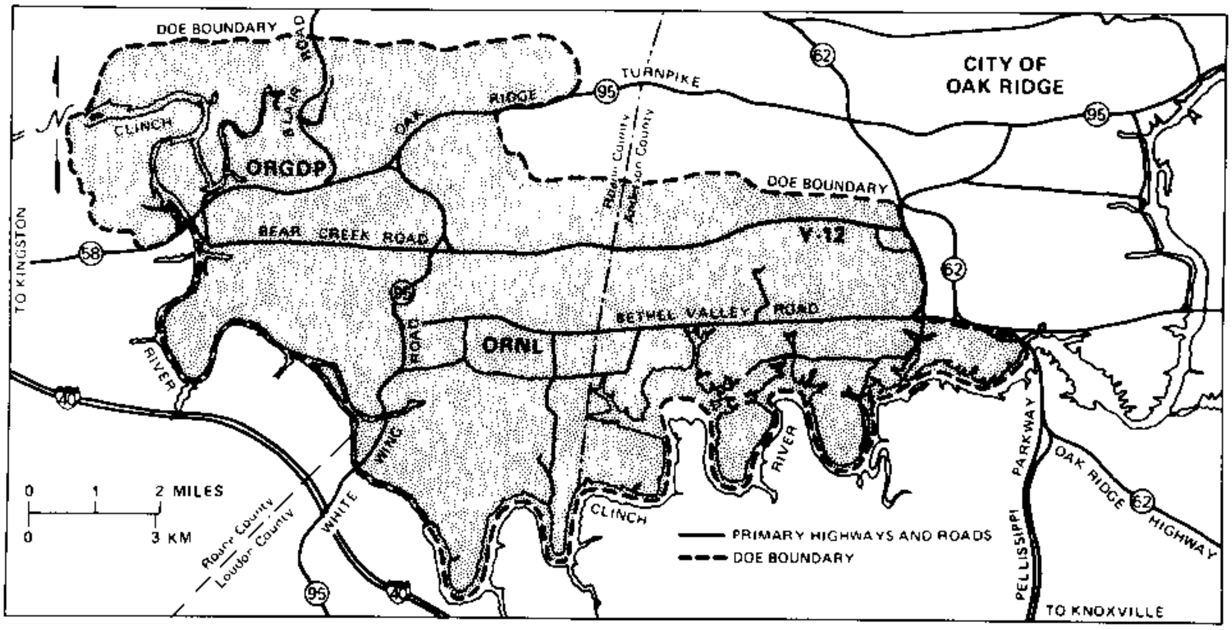

Fig. 1.1.1. Map showing the Department of Energy's Oak Ridge Reservation.

Table 1.1.1. Administrative[a] units on the ORR in 1985

Description	Forested area (ha)[b]	Total area (ha)
Resource management[c]	12,221 (30,185)[d]	14,050 34,705)
ORNL primary plant complex[e]	4 (10)	147 (364)
Y-12 primary plant complex[e]		352 (870)
ORGDP primary plant complex[e]		405 (1,000)
Scarboro Facility (ORAU-DOE)	81 (200)	432 (1,067)
Total	12,306 (30,395)	15,508 (38,306)

[a] Administrative units are those units that are managed by a major installation or by central Energy Systems.

[b] Hectare (ha) = 2.47 acres.

[c] Resource Management is the unit managed by central Energy Systems.

[d] Numbers in parentheses denote acres.

[e] Primary plant complexes within fenced areas and facilities outside but adjoining the fenced areas.

is to expand knowledge, both basic and applied, in all areas related to energy. To accomplish this mission, ORNL conducts research in all fields of modern science and technology. ORNL's facilities include nuclear reactors, chemical pilot plants, research laboratories, radioisotope production laboratories, and support facilities.

Until the summer of 1985, the primary mission of the ORGDP was the enrichment of uranium hexafluoride (UF_6) in the ^{235}U isotope. The plant has now been placed in "ready standby" for possible future uranium enrichment. Other remaining missions include advanced enrichment technique research and development, various analytical laboratory programs, engineering support, computer support, and various waste treatment services. Several new waste treatment facilities are now under construction.

The Y-12 Plant, which is immediately adjacent to the City of Oak Ridge, has five major responsibilities: (1) to produce nuclear weapons components, (2) to process source and special nuclear materials, (3) to provide support to the weapons design laboratories, (4) to provide support to other Energy Systems installations, and (5) to provide support to other government agencies. Activities associated with these functions include production of lithium compounds, recovery of enriched uranium from scrap material, and fabrication of uranium and other materials into finished parts and assemblies. Fabrication operations include vacuum casting, arc melting, powder compaction, rolling, forming, heat treating, machining, inspection, and testing.

Operations associated with the DOE research and production facilities in Oak Ridge give rise to several types of waste materials. Radioactive wastes are generated from nuclear research activities, reactor operations, pilot plant operations involving radioactive materials, isotope separation processes, uranium enrichment, and uranium processing operations. Nonradioactive (including hazardous) wastes are generated by normal industrial-type support facilities and operations that include water demineralizers, air conditioning, cooling towers, acid disposal, sewage plants, and steam plants.

Nonradioactive solid wastes are buried in the Centralized Sanitary Landfill II or in designated burial areas. Hazardous wastes are shipped to approved disposal sites or stored on site. Radioactive solid wastes are buried in disposal sites and placed in retrievable storage units either above or below ground, depending on the type and quantity of radioactive material present and the economic value involved.

Gaseous wastes generally are treated by filtration, electrostatic precipitation, and/or chemical scrubbing techniques before they are released to the atmosphere.

Liquid radioactive wastes are not released but are concentrated and contained in tanks for ultimate disposal. After treatment, process water, which may contain small quantities of radioactive or chemical pollutants, is discharged to White Oak Creek, Poplar Creek, East Fork Poplar Creek, and Bear Creek, which are small tributaries of the Clinch River.

1.2 GEOLOGIC AND TOPOGRAPHIC SETTING

A physiographic map of Tennessee is shown in Fig. 1.2.1. The ORR is located in East Tennessee in valleys that lie between the Cumberland Mountains to the northwest and the Great Smoky Mountains to the southeast, in the Valley and Ridge Physiographic Province of the Appalachian Mountains. The province, which is 13 to 20 km wide in this area, extends approximately 2000 km from the Canadian St. Lawrence lowland into Alabama. Bounded by the Appalachian Plateau Province to the west and the Blue Ridge Province to the east, the Valley and Ridge Province is a complex zone characterized by a succession of southwest-trending ridges and valleys. A geologic map of the ORR is shown in Fig. 1.2.2. The characteristic topography of the Oak Ridge area is influenced by the underlying geologic structures and differential erosion. Compressive forces that produced folding and thrusting created a southeast dip to nearly all the units on the ORR.[1] The ridges remain because they consist of relatively resistant material such as dolomite, cherty limestone, and shaly sandstone. Valleys develop in areas of more soluble limestone and easily eroded shale.

A stratigraphic column of the units present on the ORR is presented in Table 1.2.1. All of the formations are of sedimentary origin, either chemical (limestone and dolomite) or clastic (sandstone and shale). From oldest to youngest, they include the Rome Formation, the Conasauga Group, the Knox Group, the Chickamauga Limestone, the Sequatchie Formation, the Rockwood Formation, the Chattanooga Shale, the Maury Formation, and the Fort Payne Chert. Table 1.2.2 is a generalized geologic section of the bedrock formations in the Oak Ridge area.[4]

Elevations range from 226 to 415 m above mean sea level—a maximum relief of 189 m. The area includes gently sloping valleys and rolling-to-steep ridges. The Tennessee Valley Authority's (TVA) Melton Hill and Watts Bar reservoirs on the Clinch River form the southern, eastern, and western boundaries of the ORR, and

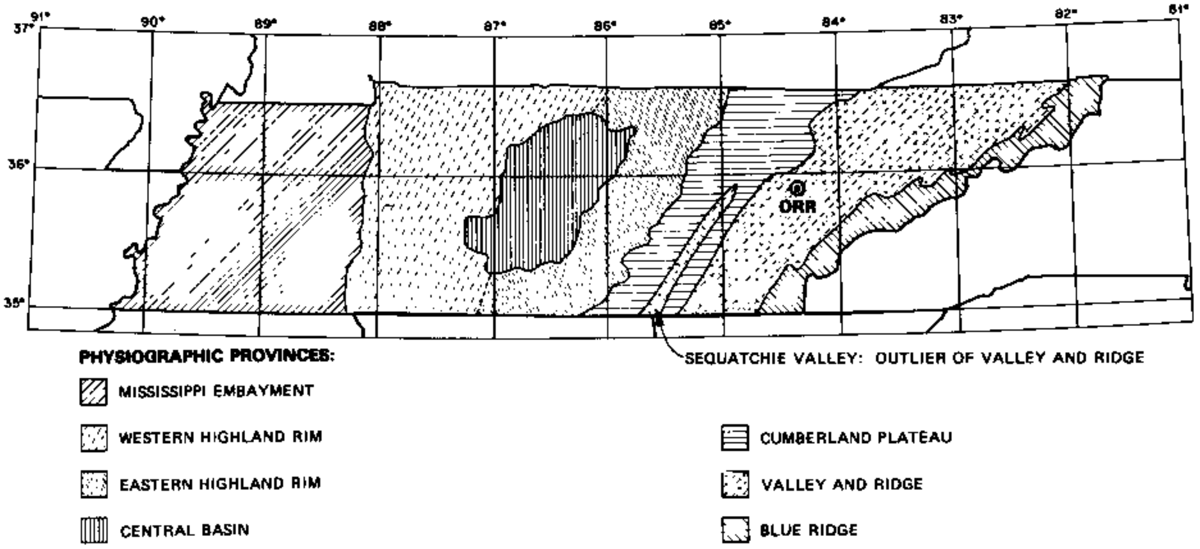

Fig. 1.2.1. Physiographic map of Tennessee. Source: Ref. 2.

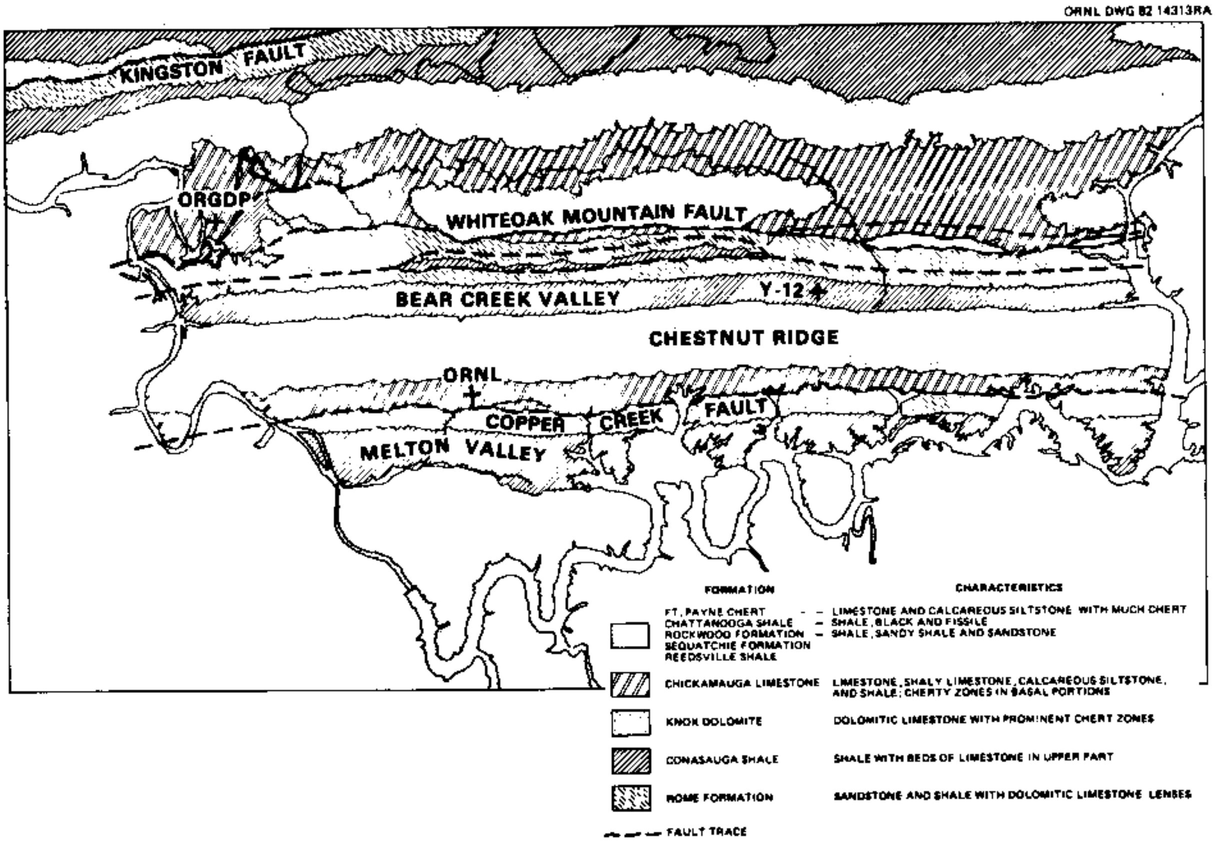

Fig. 1.2.2. Geologic map of the Department of Energy's Oak Ridge Reservation. Source: Ref. 3.

because of its heterogeneous composition. The Maynardville limestone in Bear Creek Valley often contains cavities that are several meters wide and extend for at least 30 to 40 m below the surface.[5] The capacity to transmit water is facilitated by these numerous large solution openings, and springs are particularly common at the Knox and Conasauga interface.[3]

In the Conasauga Shale, weathering processes have removed much of the limestone, leaving soils comprised of thin residual layers of siltstone that often exhibit extreme folding and faulting. These soils have a low primary (intergranular) porosity and, thus, low storage capacity. Most water that infiltrates through the surface moves laterally in the upper weathered zone to collecting streams; thus, the rate of recharge to the water table aquifer is low.

The Knox Group extends from the top of the Maynardville Limestone to the marked disconformity between Lower and Middle Ordovician rocks.

The Knox Group is the principal aquifer of the Oak Ridge area and of East Tennessee. The extensive water storage capacity of this geologic unit is due to fractures of bedrock enlarged by dissolution of the dolomites.[5] Some of these openings even attain cavernous proportions. Sinkholes occur frequently in the Knox Group outcrop belts, and many sizeable springs arise from the base of the ridges underlain by the Knox Group. Depths to the water table reach 40 m at the ridge tops.[3] The position of the water table commonly coincides with the interface between bedrock and the residual clay overburden. The residual material, which is the thickest soil mantle in the area and varies in depth from 10 to 40 m, actually provides the major area for this unit's groundwater storage. This huge thickness of overburden has a high infiltration capacity, which also tends to minimize overland runoff and maximize recharge.[7] In most instances, ridges underlain by the Knox Group also define the watershed divides of the area, which is true of most ridges. The mean yield of springs and wells in the Knox Group used for public and industrial water supplies is 0.017 m^3/s (270 gpm), making it a good water supply.[8] Springs arising from the Knox are common, especially at the Knox-Conasauga contact.[8] No estimate is available for mean well yield of domestic water wells in the Knox Group.

The Chickamauga Group is between 450 and 600 m thick in the Oak Ridge vicinity and consists of alternating limestone and siltstone/mudstone lithologies.[6] The Chickamauga Limestone underlies Bethel and East Fork valleys. Sinkholes are present on the Chickamauga but are not numerous or large in size.[9] Large solution cavities do not generally occur; most openings are only a few centimeters wide. The clay-rich residuum restricts most infiltration, and water storage is predominantly in near-surface (<30 m deep) openings in the bedrock. Total water flow and rate are relatively small.[9] Solution features appear to decrease with depth, which suggests that deep flow is very limited in the Chickamauga.[10]

Generally, groundwater flow on the ORR basically follows water table conditions. Hence, groundwater levels parallel topographic contours, with joints and fractures controlling flow direction. Recharge is derived primarily from precipitation, and groundwater discharge is through evapotranspiration, springs, and streams.

The characteristics of the various soil

series reported to be on the ORR are discussed in Sect. 4.9. The major soils are generally silty (grain size 0.06 to 0.002 mm) rather than sandy or clayey. They are very permeable and well drained. However, the dominant clay content of the subsoils outweighs this permeability, and the drainage of this region is characterized by low permeability and fast runoff. The extensive clay subsoils channel much of the hydrological input into surface flow.[11]

As in most areas, groundwater discharge contributes to the base flow of surface streams that ultimately augment the Clinch River water supply. The Clinch River is a major drainage feature of the area, and its base flow is determined by groundwater discharges to the surface water system. The low water table elevation in areas near the river is expected to be controlled by the river level elevation, which is true in most surface stream areas. It is unlikely that significant groundwater flow could pass beneath the Clinch River except in the instance of extensive well pumping on one side, which could lower the local water table.

Depth to the water table varies both spatially and temporally. At a given location, depth to water is generally greatest during the October-December quarter and least during the January-March quarter.[11]

In Bethel Valley, depth to the water table ranges from 0.3 to 11 m (1 to 35 ft), whereas in Melton Valley the range is from 0.3 to 20 m (1 to 67 ft). Seasonal fluctuations tend to be greatest beneath hillsides and near groundwater divides. As much as 4.5-m (15-ft) seasonal variation has been reported for Melton Valley, which is in the Conasauga Group.

Water table maps may be indicative of the direction of groundwater movement, at least in the near-surface, weathered zone of rock units. Deeper in the groundwater flow system, in relatively unweathered rock, water movement is controlled by the orientation of secondary openings.[9] Insufficient information is known about the distribution of secondary openings, especially in carbonate rocks, to accurately predict groundwater movement.[10]

As in most cases, groundwater flow in the residual soil is generally toward the individual streams of the surface-drainage network. In Bethel Valley, groundwater in the Chickamauga Limestone moves through small solution channels. Although the rate of groundwater flow in the area is not known, the direction and pattern of this flow in Bethel Valley are essentially subdued replicas of the topography. Thus, water flows from areas of high elevation to those of low elevation, and the principal movement is in directions normal to the contour lines. The lay of the land is such that drainage at and below the surface of Bethel Valley apparently converges to feed White Oak Creek and White Oak Lake. An exception occurs in the western end of Bethel Valley, where the groundwater west of a groundwater divide flows west into the Raccoon Creek drainage basin rather than into White Oak Creek.

The groundwater system in Melton Valley basically has a very shallow active zone.[12] This system is not unusual and is characterized by highest permeability for groundwater flow near the surface and declining permeability with depth. Although quantitative studies of near-surface groundwater flow during storm events are still in progress, it appears that most subsurface flow occurs in a near-surface region that extends to a depth of less than about 5 m. The general hydrologic picture is that of rather closely coupled surface water and groundwater systems in which circulation is rather shallow and much of the movement occurs in the near-surface zone during the wetter part of the year (late November through April).

Contaminated plume movement has been a major topic of studies in Melton Valley. The traditional concept of a subsurface contamination plume as a primary pathway for contaminant migration is not appropriate in this instance. The hydraulic conductivity of the less-weathered material is about 2 cm/d, whereas the near-surface zone is characterized by 20- to 40-cm/d (or higher) hydraulic conductivities. Furthermore, the distribution coefficients (Kd) for most radionuclides in the Conasauga Group (shales) are rather high, which suggests that any deep migration would occur at a very slow rate. The primary pathway for contaminant migration, where it occurs, is thought to be via the bathtub effect (i.e., a trench collects enough water to cause an overflow at the downstream end). Thus, subsequent movement is emergence at the surface followed by runoff downhill. A variation of that process is movement of shallow subsurface flow in fill material along and just above the interface with natural materials underlying the fill. Thus, the nature of the groundwater system suggests that long-range subsurface flow is not likely for most areas because of the low permeability of formations.

1.3.2 Groundwater Use

The major portion of the industrial and drinking water supply in the Oak Ridge area is taken from surface water sources. However, single-family wells are common in adjacent rural areas not served by public water supply systems. As in most of East Tennessee, groundwater on the ORR and in areas adjacent to the ORR occurs primarily in fractures in the rocks. Other than those adjacent to the City of Oak Ridge, most of the residential wells in the immediate area are south of the Clinch River. The characteristics of some domestic wells and springs in areas adjacent to the City of Oak Ridge and the ORR are given in Table 1.3.1. The locations of some water wells in the Oak Ridge vicintity are shown in Fig. 1.3.1. Wells shown are those for which the Tennessee Department of Water Resources keeps well logs that include well location, elevation, and depth to water. Additional wells exist within the regions shown, but they either have not been reported to the state or were incompletely reported.

Over 100 water supply wells and springs are located within 16 km of the ORR. Studies have indicated that the incised meander of the river in bedrock represents a major topographic feature that prevents any groundwater flow from passing beneath the river.[8]

Several industrial groundwater supplies exist within about 32 km of the ORR,[12] as indicated by the data in Table 1.3.2. Three of these supplies are about 15 km from the center of the ORR, and the nearest is at the Charles H. Bacon company in Lenoir City, Tennessee. An estimated average of 320 m^3 (85,000 gal) is obtained daily from this supply,[13] which is located about 15 km south-southeast of the ORR. A daily average of about 38 m^3 (10,000 gal) is obtained from the well supplying the Lenoir City Car Works, which is about 15 km south of the ORR, as well as the one supplying the Ralph Rogers Company, which is approximately 15 km northeast of the ORR. Other industrial groundwater supplies are farther from the ORR.

Table 1.3.1. Characteristics of some domestic wells and springs near the city of Oak Ridge and south of the Clinch River in the vicinity of the ORR

County	Distance to nearest post office (km)	Topographic position	Altitude (m)	Depth (m)	Geological material	Yield (m^3/s)
Anderson	Oak Ridge[a]					
	4.8 N	Valley	259	S[b]	Shale	0.00063
	2.4 NW	Valley	258	31	Shale	U[c]
	3.2 NE	Slope	308	92	Dolomite	U
	2.4 E	Slope	250	62	Limestone	U
	5.6 NE	Slope	259	16	Shale	U
	6.4 E	Slope	259	16	Shale	U
	2.4 W	Valley	249	6	Shale	U
Knox	Byington					
	6.4 W	Slope	259	19	Shale	U
	6.4 W	Valley	262	S	Dolomite	0.028
	8.0 W	Slope	256	20	Dolomite	0.00038
	8.0 W	Valley	235	S	Dolomite	0.032
	11.3 W	Valley	236	S	Dolomite	0.019
	Martel					
	9.7 N	Slope	274	56	Dolomite	U
	Oak Ridge[a]					
	8.0 SW	Valley	256	18	Shale	U
Loudon	Martel					
	8.9 NW	Ridge	233	19	Dolomite	0.00013
	Lenoir City					
	10.5 NW	Slope	294	31	Dolomite	U
Roane	Lenoir City					
	14.5 NW	Valley	236	7	Shale	U
	12.9 NW	Hilltop	348	79	Dolomite	U
	12.1 NW	Slope	247	20	Shale	U
	10.5 NW	Slope	282	24	Dolomite	U
	10.5 NW	Slope	252	4	Dolomite	U
	9.7 NW	Valley	267	S	Dolomite	0.063
	Kingston					
	11.3 E	Slope	235	13	Shale	U
	11.3 E	Valley	261	6	Shale	U

[a] Jackson Square.

[b] S = spring.

[c] U = unknown.

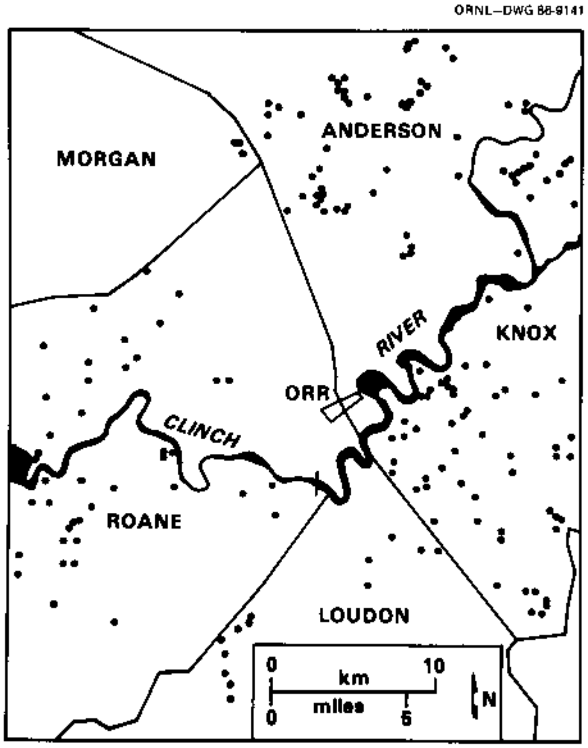

Fig. 1.3.1. Locations of water wells in the Oak Ridge vicinity.

There are 17 public groundwater supplies located within a 35-km radius of the ORR. These 17 public groundwater supplies, their sources, and their distances from the ORR are given in Table 1.3.3. Of these sources, the closest to the ORR is the Allen Fine Spring, which supplies the Dixie-Lee Utility District in Loudon County. This groundwater source is about 11 km southeast of the ORR, and it serves approximately 6700 people with an average of about 1500 m^3 (400,000 gal) of water per day. The well that serves the Edgewood Center in Roane County is about 12 km southwest of the ORR, and the spring that supplies the Cumberland Utility District of Roane and Morgan counties is approximately 13 km west of the ORR.

Connections between off-site and on-site groundwater sources are being investigated by the USGS. Because of the stra-

Table 1.3.2. Industrial groundwater supplies within about 32 km of the ORR

Industrial water user	Yield (m^3/s)	Source	Probable water-bearing formation	Distance from ORR (km)
Charles H. Bacon Co. (Lenoir City)	0.0037	Well	Knox	14.5 SSE
Lenoir City Car Works	0.00044	Well	Chickamauga	15.0 S
Ralph Rogers Co.	0.00044	Well	Conasauga	15.1 NE
Charles H. Bacon Co. (Loudon)	0.015	Spring[a]	Knox	20.4 S
Envirodyne Industry, Inc. (Loudon)	0.14	Spring[b]	Chickamauga	21.2 S
John J. Craig Co.	0.00057	Well Spring	Knox	24.9 SSE
Tennessee Forging Steel	0.001	Well Pond	Knox	30.6 W
Morgan Apparel Co.		Well	Knox	30.7 NW
Stone and Webster		Well	Conasauga	0.016 NW
TVA		Well	Knox	0.016 WNW

[a] Primary source.

[b] Secondary source.

Table 1.3.3. Public groundwater supplies within about 35 km of the ORR[a]

Public water user	People served	Yield (m^3/s)	Source	Probable water-bearing formation	Distance from ORR (km)
Oliver Springs	4,000	0.013	Spring	Knox	16.9 NNE
Dutch Valley Elementary School	140	0.00012	Well	Rome	22.5 NNE
First Utility District of Anderson County	3,600	0.012	Spring	Conasauga	21.4 NE
West Knox Utility District	15,000	0.057	Well[b]	Knox	22.5 E
Dixie-Lee Utility District	6,700[c]	0.018	Spring	Knox	10.9 SE
Piney Utility District	2,000	0.003	Spring	Knox	23.2 S
Loudon	5,200	0.025	Spring[d]	Knox	23.5 SSW
Philadelphia	300	0.00026	Well	Knox	28.2 SSW
Edgewood SE Center	100	0.00017	Well	Knox	12.2 SW
Paint Rock Elementary School	250	0.00022	Well	Rome	26.9 SW
Midway High School	500	0.00057	Spring	Chickamauga	27.0 SW
Kingston	5,000	0.014	Spring[e]	Conasauga	18.8 WSW
Rockwood	10,000	0.062	Spring[e]	Knox	34.6 WSW
Cumberland Utility District of Rome and Morgan Cos.	4,300	0.0078	Spring[e]	Knox	12.9 W
Midtown	2,500	0.0047	Well	Rome	26.4 W
Brushy Mountain State Honor Farm	200	0.0000088	Well		27.7 NW
Plateau Utility District	2,300	0.0090	Well		28.2 NW

[a] Source: Ref. 8.

[b] Secondary source.

[c] Includes Martel Utility District.

[d] Half supply.

[e] Primary source.

tigraphic and structural control of groundwater flow in the region, groundwater beneath the ORR is expected to migrate along strike and discharge to surface water bodies. There is a low probability of groundwater migration from the ORR to off-site wells.

The importance of the Knox Group as a regional aquifer is apparent from its wide use among the public and industrial groundwater users. The mean Knox spring and well yields estimated from water use figures included in Tables 1.3.1 and 1.3.2 are about 0.017 m^3/s (270 gpm). Reliable estimates of the mean yield to domestic wells in the Knox Group are not available. Yields are expected to vary widely depending on the size and extent of cavity systems encountered by individual wells. Water from the Chickamauga Group is also used on the ORR.

1.4 CLIMATE

The mountains on the east and the Cumberland Plateau on the west have a protecting and moderating influence on the region's climate. As a result, it is milder than the more continental climate found just to the west on the Plateau or on the eastern side of the Smoky Mountains. The prevailing winds follow the general topographic trend of the ridges: daytime, up-valley winds come from the southwest; nighttime, down-valley winds come from the northeast. The Smoky Mountains to the southeast provide general sheltering; severe storms such as tornadoes or high-velocity windstorms are rare. Similarly, the mountains divert hot, southerly winds that develop along the southern Atlantic coast.

In the fall, slow-moving high-pressure cells suppress rain and, while remaining nearly stationary for many days, provide outstanding fine, mild weather. Year-round mean temperatures are about 15°C (58°F), with a January mean of about 3.5°C (38°F) and a July mean of about 25°C (77°F). Temperatures of 38°C (100.4°F) or higher and −18°C (−0.4°F) or below are unusual. Low-level temperature inversions occur during about 56% of the hourly observations. Table 1.4.1 summarizes the climatic conditions of the Oak Ridge area.

Table 1.4.1. Monthly climatic summary for the Oak Ridge area based on a 20-year period[a]

Month	Temperature			Precipitation	
	Max	Min	Mean	Rain	Snow
	°C[b]	°C	°C	cm	cm
January	9.3	−1.8	3.3	13.5	8.6
February	10.7	−0.8	4.9	13.5	6.6
March	14.8	2.4	8.6	14.2	3.3
April	21.7	8.3	15.0	11.2	0.03
May	26.2	12.5	19.3	9.1	0.0
June	29.6	17.1	23.3	10.2	0.0
July	30.7	19.1	24.9	14.2	0.0
August	30.4	18.4	24.4	9.7	0.0
September	27.5	14.8	21.2	8.4	0.0
October	21.8	8.4	15.2	6.8	1.5
November	14.3	2.2	8.3	10.7	1.3
December	9.3	−0.8	4.3	14.5	6.4
Annual		14.4		135.9	26.2

[a] Source: Ref. 14.

[b] °C = (°F − 32) × 5/9.

1.5 PRECIPITATION

Precipitation, the driving mechanism of the hydrologic system, is plentiful on the ORR. The mean annual rainfall is about 138.2 cm (54.4 in.) based on 1948–1985 precipitation data.[14] Mean annual precipitation ranges from more than 147 cm (58 in.) in the northwest section of central eastern Tennessee to about 117 cm (46 in.) in the northeast section.[10] Rainfall is at a maximum near the Cumberlands and decreases from northeast to southeast, reaching a minimum at the foot of the Smoky Mountains.

Precipitation is not evenly distributed through time. Precipitation also varies on an annual scale (Fig. 1.5.1). The winter months are characterized by passing storm fronts, and this is the period of highest rainfall. Winter storms are generally of low intensity and long duration. Another peak in rainfall occurs in July when short, heavy rains associated with thunderstorms are common. Precipitation in 1985 was 107.7 cm.

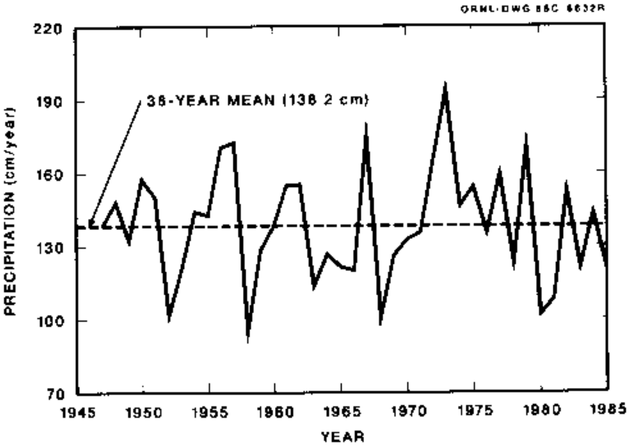

Fig. 1.5.1. Annual precipitation history of Oak Ridge, Tennessee (1948–1985).

1.6 EVAPOTRANSPIRATION AND RUNOFF

Loss of water to the atmosphere by evapotranspiration is about 76 cm (30 in.) annually, or about 55% of the total annual precipitation. Evapotranspiration is at a maximum from July to September, during the vegetation growing season. Seasonal relationships between evapotranspiration and precipitation are reflected in seasonal patterns of runoff to streams. Runoff is greatest in the winter, when evapotranspiration is low and precipitation is high. Precipitation not lost as evapotranspiration or quick runoff to streams percolates through the soil and eventually recharges the groundwater system.

The topography of the area is such that all drainage from the ORR flows into the Clinch River, which has its headwaters in southwestern Virginia and flows southwest to its mouth near Kingston, Tennessee. The Clinch River flow is regulated by several dams that provide reservoirs for flood control, electric power generation, and recreation. The principal tributaries through which liquid effluents from the plant areas reach the Clinch River are White Oak Creek, Bear Creek, East Fork Poplar Creek, and Poplar Creek.

1.7 SURFACE WATER

Surface water in the Tennessee Valley region supplies water to most nonrural areas. This section includes discussions of stream classification, surface water hydrology, and watershed characteristics.

1.7.1 Stream Classification

The Clinch River is the major surface water area that receives discharges from the Oak Ridge installations. Four TVA reservoirs influence the flow and/or water levels of the lower Clinch: Norris and Melton Hill on the Clinch River and Watts Bar and Fort Loudon on the Tennessee River.

The area on and around the ORR has no streams classified as scenic rivers or otherwise "sensitive" areas.[15] The water bodies are classified by use. Table 1.7.1 gives the use classifications for streams in or near the ORR. Classifications are based on water quality.[16]

1.7.2 Surface Water Hydrology

Figure 1.7.1 shows the location of surface water bodies in the vicinity of the ORR and the location of DOE facilities. The ORR is bounded on the south and west by a 63-km (39-mile) stretch of the Clinch River. Melton Hill Dam is located on the Clinch River at Clinch River kilometer (CRK) 37.2 (CRM 23.1), forming the Melton Hill Reservoir. Several major embayments bound the ORR; the largest is the Bearden Creek Embayment with an approximate surface area of 48 ha (120 acres). Other embayments include Walker Branch, McCoy Branch, and Scarboro Creek.

Both groundwater and surface water are drained from the ORR by a network of small tributaries of the Clinch River, as shown in Fig. 1.7.2. At Kingston, Tennessee, the Clinch drains into the Tennessee River, the seventh largest in the United States. Water levels on the Clinch are regulated by the TVA, and fluctuations on the river have an impact on the tributary streams and creeks draining the ORR.

The three DOE facilities, ORGDP, Y-12, and ORNL, each affect a different subbasin of the Clinch River. Drainage from the Y-12 Plant enters both Bear Creek and East Fork Poplar Creek. ORGDP drains predominantly into Poplar Creek, and ORNL has its greatest impact on White Oak Creek and Melton Branch. Hydrologic data are extensive for the above-mentioned streams because of their size and relationship to DOE facilities. Walker Branch has also been intensely studied as an undisturbed watershed. The location and drainage areas of Clinch River tributaries are listed in Table 1.7.2. Table 1.7.3 lists watershed areas of these streams, and Table 1.7.4 lists their flow characteristics.

1.7.3 Watershed Characteristics

The Clinch River has its headwaters near Tazewell, Virginia, and empties into the Tennessee River at Kingston, Tennessee. The Clinch watershed comprises about 11% of the Tennessee River Watershed. Three dams operated by TVA control the flow of the Clinch River. Norris Dam, built in the 1930s, is approximately 50 km (31 miles) upstream from the ORR. Melton Hill Dam, completed in 1963, controls the flow of the river near the ORR. Its primary function is not flood control but power generation.[8] Watts Bar Dam is located on the Tennessee River, but it affects the flow of the lower reaches of the Clinch.

The average discharge at the Melton Hill Dam between 1963 and 1979 was 150 m^3/s (5280 cfs). The average summer (June to September) discharge was 134 m^3/s (4720 cfs).[8] The maximum reported discharge for the dam is 1215 m^3/s (42,900 cfs).[21] Power is not constantly generated at the Melton Hill Dam, so water flow in the Clinch is pulsed. Periods of zero flow are followed by hours of flow up to about 560 m^3/s (20,000 cfs). Pulsation of flow in the Clinch affects the tributaries on the ORR. During periods of power generation, backflow may occur into White Oak Creek.[8] Periods of no flow over the dam have lasted as long as 29 days, and the

Table 1.7.1. Use classification for streams in or around the ORR[a]

Stream	Description	DOM[b]	IND[c]	FISH[d]	REC[e]	IRR[f]	LW&W[g]	NAV[h]
Clinch River	km 7.0-19.2 (Poplar Creek)	X	X	X	X	X	X	X
Poplar Creek	km 0.0–0.8		X	X	X	X	X	
Poplar Creek	km 0.8–2.1			X		X	X	
Poplar Creek	km 2.1–8.8			X	X	X	X	
East Fork Poplar Creek	km 0.0–7.7			X	X	X	X	
Bear Creek	km 0.0 to origin			X	X	X	X	
East Fork Poplar Creek	km 7.7–13.3			X		X	X	
East Fork Poplar Creek	km 13.3-dam at Y-12			X	X	X	X	
Poplar Creek	km 8.8–19.8			X	X	X	X	
Poplar Creek	km 19.8–23.0			X		X	X	
Indian Creek	At Poplar Creek (km 22.9); km 0.0–origin			X	X	X	X	
Poplar Creek	km 23.0–origin			X	X	X	X	
Clinch River	km 19.2–32.0	X	X	X	X	X	X	
White Oak Creek	km 0.0–origin			X			X	
Melton Branch	km 0.0–origin			X			X	
Clinch River	km 32.0–63.4	X	X	X	X	X	X	X
Clinch River	km 63.4–65.8	X	X	X	X	X	X	X
Scarboro Creek	km 0.0–1.6			X	X	X	X	
Scarboro Creek	km 1.6–2.1			X		X	X	
Scarboro Creek	km 2.1–origin			X	X	X	X	
Clinch River	km 65.8–74.7	X	X	X	X	X	X	X
All other tributaries in the Clinch River Basin, named and unnamed, that have not been specifically treated shall be classified				X	X	X	X	

[a] Source: Ref. 16.
[b] DOM = Domestic water supply
[c] IND = Industrial water supply
[d] FISH = Fish and aquatic life
[e] REC = Recreation
[f] IRR = Irrigation
[g] LW&W = Livestock watering and wildlife
[h] NAV = Navigation

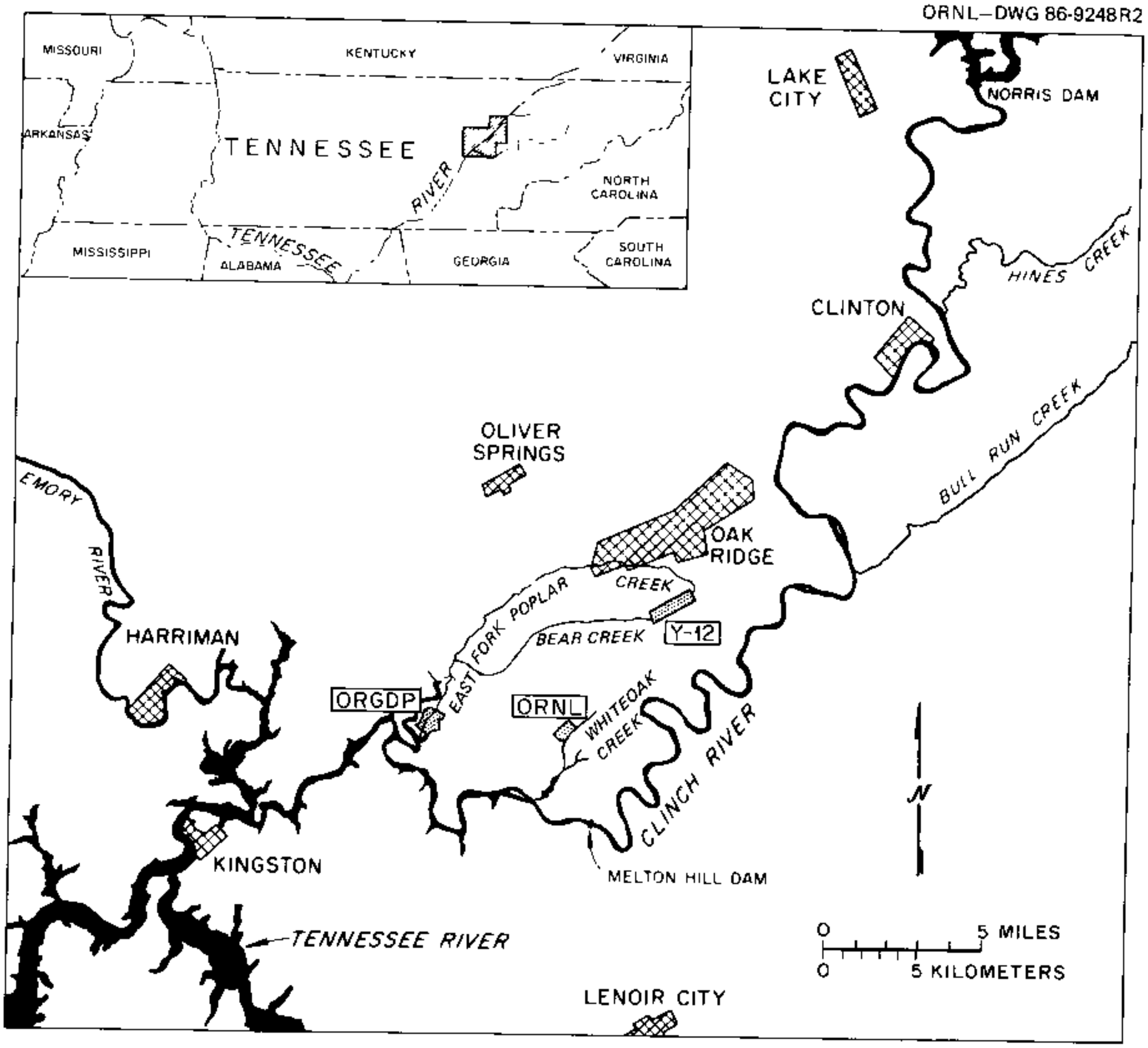

Fig. 1.7.1. Location map of major surface water bodies in the vicinity of the ORR.

average number of days of no flow per year is 13. During flood conditions, water velocities may be hazardous and may reach 2.1 m/s (7 ft/s).[22]

White Oak Creek (WOC) drains an area of 17 km^2 (6.5 $mile^2$) in Bethel and Melton valleys. Runoff from most of ORNL, including all burial grounds, reaches WOC, either directly or via one of its tributaries. The potential for contamination in WOC is great, so it has been the most studied and monitored stream on the ORR.

The headwaters of WOC are on the crest of Chestnut Ridge, and the mouth is at CRK 33.5 (CRM 20.8). The total elevation drop from headwaters to mouth is about 146 m (479 ft). After leaving Chestnut Ridge, WOC flows parallel to bedrock strike down Bethel Valley, then cuts perpendicular to strike through a gap in Haw Ridge and enters Melton Valley,

ORNL–DWG 86 8717R

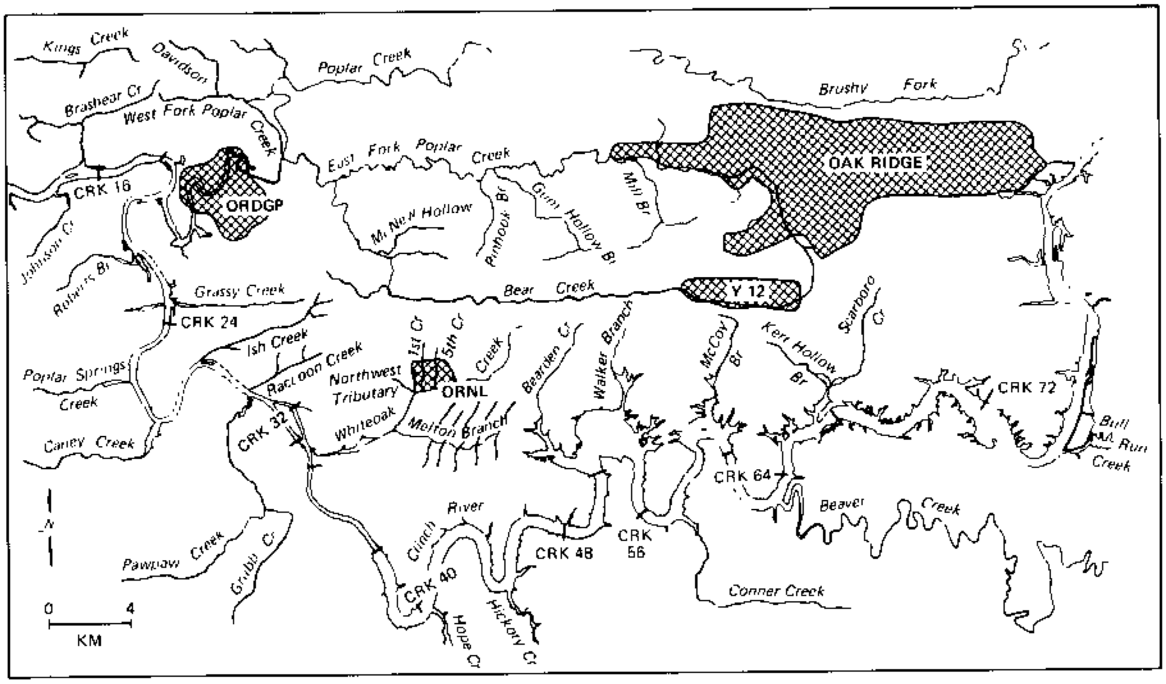

Fig. 1.7.2. Location map of ORR tributaries.

where it is joined by its major tributary, Melton Branch, at WOCK 2.49 (WOCM 1.55). A dam 1 km (0.6 mile) above the mouth of WOC controls the stream's flow and allows monitoring of contaminants. The dam, which forms White Oak Lake, was originally built in 1943 and constructed of earth. A new structure was completed in 1983 with increased reinforcement and a new sluiceway. The new facility allows more accurate flow measurements to be taken and will be able to withstand and monitor flooding conditions with a 50-year return period. Below the dam, WOC is affected by water levels in the Clinch River. As a result, reversals of flow in White Oak embayment have been observed.[10]

Groundwater discharged from the Knox Dolomite (which underlies Chestnut Ridge) and the Chickamauga Limestone (which underlies Bethel Valley) contributes to stream flow in WOC, supplying most of WOC's baseflow. Little groundwater inflow occurs in the rest of the stream course, which is underlain by the Rome Formation (Haw Ridge) and the Conasauga Group (Melton Valley). WOC is sometimes dry, but flow is augmented by discharges from the ORNL wastewater treatment plant. Ninety percent of the time, flow in WOC is greater than 0.01 m^3/s (0.21 cfs); 50% of the time it is greater than 0.03 m^3/s (0.90 cfs); 10% of the time it is greater than 0.14 m^3/s (5 cfs).[10] WOC is heavily monitored to collect flow and water quality information.

Bear Creek drains an area of approximately 19.2 km^2 (7.4 $mile^2$). At the gauging station the drainage area is 18.5 km^2 (7.15 $mile^2$). About 65% of the drainage basin is wooded, and the rest is primarily abandoned pasture. The headwaters of

Table 1.7.2. Location and drainage areas of Clinch River tributaries

Stream	Mouth location	Drainage area (km^2)
Powell River	CRK[a] 142.9	2430[b]
Big Creek	CRK 133.5	174[b]
Coal Creek	CRK 120.7	95[b]
Hinds Creek	CRK 105.9	165[b]
Bull Run Creek	CRK 75.1	270[b]
Beaver Creek	CRK 63.7	234[b]
Conner Creek	CRK 57.1	16.6[b]
Walker Branch	CRK 53.1	3.89[b]
Hickory Branch	CRK 45.7	17.9[b]
Melton Branch	WOCK[c] 2.49	3.83[b]
White Oak Creek	CRK 33.5	15.5–16.5[b,d,e]
Raccoon Creek	CRK 31.24	1.2[d,f]
ISH Creek	CRK 30.6	0.9[e,g]
Caney Creek	CRK 27.2	21.4[e]
Poplar Springs Creek	CRK 25.9	7.8[d]
Grassy Creek	CRK 23.2	5.0[d]
Bear Creek	EFPCK[h] 2.36	19.2[a]
East Fork Poplar Creek	PCK[i] 8.8	77[a]
Poplar Creek	CRK 19.3	352[d,e,f]
Emory River	CRK 7.1	2240[b]

[a] CRK = Clinch River kilometer.
[b] Source: Ref. 11.
[c] WOCK = White Oak Creek kilometer.
[d] Source: Ref. 17.
[e] Source: Ref. 18.
[f] Source: Ref. 19.
[g] Source: Ref. 12.
[h] EFPCK = East Fork Poplar Creek kilometer.
[i] PCK = Poplar Creek kilometer.

Bear Creek are on the Y-12 Plant site. Bear Creek does not drain the main site of Y-12, but does drain the waste disposal areas. The creek flows west down Bear Creek Valley (primarily underlain by Conasauga Group) and then flows north, where it empties into East Fork Poplar Creek (EFPC) at EFPCK 2.36 (EFPCM 1.47). The drainage pattern is a good example of trellis drainage patterns typical of the Valley and Ridge Province.[12]

EFPC drains an area of about 77.7 km^2 (30 mile^2), including most of the Y-12 site and a portion of the City of Oak Ridge. The headwaters of the creek are at the Y-12 Plant, where flow is controlled by New Hope Pond, a small [(~2 ha (5.0 acres)] settling basin on the east side of the plant. The average gradient along

Table 1.7.3. Oak Ridge watershed areas

Tributary	Confluence location (CRK)[a]	Total basin area (km^2)	Average annual discharge (m^3/s)[b]
Poplar Creek	19.3	352	4.7 (165),[c] 5.0 (176),[d] 6.5 (228)[e]
East Fork Poplar Creek	NA[f]	77	1.4 (49),[c] 1.5 (52),[d] 1.5 (52)[e]
Bear Creek	NA	19	
White Oak Creek	33.5	17[g]	0.38 (13.5)[g,h]
Melton Branch	NA	3.8	0.07 (2.5)[i]
Walker Branch	NA	3.9	
Raccoon Creek	31.4	1.2[j]	NA
Ish Creek	30.6	0.9[k]	0.05 (2)[k]
Coney Creek	27.2	21.4	0.40 (14)
Poplar Springs Creek	25.9	7.8	0.41 (5)
Grassy Creek	23.2	5.0	0.08 (3)

[a] CRK 0.0 is at the confluence with the Tennessee River.

[b] Discharge in cfs in parentheses.

[c] At mouth of Poplar Creek and Clinch River. Source: Ref. 11.

[d] Source: Ref. 20.

[e] Period of record: 1960–1977. Value represents the sum of the average annual discharge of West Fork Poplar Creek (4.98 m^3/s or 176 cfs) and East Fork Poplar Creek (1.47 m^3/s or 52 cfs). Source: Ref. 17 and Ref. 21.

[f] Not applicable.

[g] At White Oak Dam. Source: Ref. 18.

[h] Estimated for the period 1953–55 and 1960–63 (five water years).

[i] Source: Ref. 11.

[j] Source: Ref. 19.

[k] At 0.56 km above the mouth. Source: Ref. 12.

EFPC is about 4 m/km (21 ft/mile). Channel width varies along the creek's course from 3 to 4.6 m (10 to 15 ft) near Y-12 to 7.6 m (25 ft) farther downstream.[15]

EFPC empties into Poplar Creek at PCK 8.8 (PCM 5.47) after traversing East Fork Valley. The valley is underlain by Chickamauga Limestone, but a large portion of the basin is underlain by the Knox Dolomite. Flow in EFPC is augmented by about 0.34–0.68 m^3/s (12–24 cfs) of wastewater from Y-12 and 0.08–0.28 m^3/s (3–10 cfs) of water from the sewage treatment plant of the City of Oak Ridge.[12]

Poplar Creek has the largest drainage basin of any stream on the ORR [352 km^2 (136 $mile^2$)]. The western half of the basin lies in the Cumberland Mountains of the Appalachian Plateau, and the eastern half is in the Valley and Ridge Province. Of all the basins in the ORR area, the Poplar Creek basin has the greatest topographic relief. The elevation at the western drainage divide is 975 m (3200 ft) above MSL; where Poplar Creek enters the Clinch at CRK 19.3 (CRM 12.0), the elevation is 224 m (735 ft) above MSL.

Approximately 65% of the basin is wooded; the remainder is predominantly cultivated or pasture.[22] Most of the Poplar Creek basin is underlain by shales and sandstones that yield little water. A small portion of the basin is underlain by the highly productive Knox Dolomite.[12]

Although the entire Poplar Creek

Table 1.7.4. Flow characteristics of some major tributaries on the ORR[a]

Stream	Gauge location	Discharge					Period of record
		Max		Min		Average (m^3/s)	
		(m^3/s)	Date	(m^3/s)	Date		
Melton Branch	MBK[b] 0.15	6.85	03/11/62	0	09/02/62	0.07	1955–1963
White Oak Creek	WOCK[c] 2.65	18.2	08/30/50	0	09/16/61	0.27	1950–1953 1955–1963
White Oak Creek	WOCK[c] 0.96	18.9	12/29/54	0	(During power releases from Melton Hill Dam)	0.38	1950–1953 1955–1963
East Fork Poplar Creek	EFPCK[d] 5.31	73.9	07/06/67	0.37	08/16/69	1.37	1960–1970
Bear Creek	BCK[e] 1.29	16.8	03/12/63	0.01	08/12–14/62		
Poplar Creek	Mouth	180	03/12/63	0.14	10/27/63	4.67	1961–1965

[a] Source: Ref. 17.
[b] MBK = Melton Branch kilometer.
[c] WOCK = White Oak Creek kilometer.
[d] EFPCK = East Fork Poplar Creek kilometer.
[e] BCK = Bear Creek kilometer.

drainage basin does not lie within the ORR, it does receive drainage directly from ORGDP and indirectly from ORGDP and Y-12 via EFPC. The gauging station for Poplar Creek is at its mouth; thus, water from all parts of the drainage basin is monitored. Coal mining on the Cumberland Plateau affects water quality at the monitoring station.[10] As well as having the largest basin, Poplar Creek also has the greatest flow.

The Walker Branch Watershed is a small catchment that has been, and continues to be, intensely studied. Scientists are using Walker Branch as an undisturbed watershed. Much of the work involves nutrient cycling, which includes detailed hydrologic studies. The watershed is underlain by the Knox Group and drains a portion of Chestnut Ridge. Walker Branch empties into the Clinch at CRK 53.1 (CRM 33.0). The basin is small, about 0.98 km^2 (0.38 mile^2).[24]

Some of the hydrologic data collected at Walker Branch suggest that the average loss of precipitation to stream flow was ~56.5% during the period July-June, 1969–1971; 57.1 cm/year of water is lost as evapotranspiration and net change in groundwater storage; and evapotranspiration is estimated to be about 45% of total precipitation. The watershed is small but may be representative of the many small catchments on the Knox Dolomite that are found within the ORR.[24]

1.7.4 Water Use

There are nine public water supply systems serving about 91,500 people that withdraw surface water within a 32-km (20-mile) radius of the ORR, as listed in Table 1.7.5. Of these nine supply systems, only one is downstream of the ORR outfall. The intake for Kingston is located at Tennessee River kilometer 914.2 (TRM 568.2), about 0.6 km (0.4 mile) above the confluence of the Clinch and Tennessee rivers and 34.1 km (21.2 miles) below the ORR outfall. As indicated in Table 1.7.5, Kingston withdraws approximately 9% of its average daily supply from the Tennessee River. The city of Rockwood withdraws about 1% of its average daily supply from Watts Bar Reservoir. Its intake is located 2 km (1.3 miles) from the mouth of King Creek embayment near TRK 890 (TRM 553).

Surface water is used by facilities on the ORR as a means for wastewater discharge as well as for a source of water supply. Industrial water withdrawals from the Clinch-Tennessee River system surrounding the ORR are listed in Table 1.7.6.

Point discharges from Y-12 include (1) overflow from Kerr Hollow Quarry, which is used for disposal of reactive metals, to Scarboro Creek at km 1.1 (mile 0.7); (2) overflow from Rogers Quarry, which is used for fly ash disposal and disposal of nonreactive metal parts, to km 3.4 (mile 2.1) of McCoy Branch; (3) approximately 0.24 m^3/s (5.4 × 10^6 gal/d) of wastewater from the Y-12 Plant, primarily cooling water, to EFPC at or above km 23.5; and (4) surface runoff from the southwestern portion of the Y-12 site and seepage from lagoons previously used for acid wastes, to Bear Creek at or above km 4.8 (mile 3.0).

Discharges from ORGDP in approximate amounts are (1) 0.105 L/s (1.7 gpm) of water from the nickel plating facility to km 4.3 (mile 2.7) of Poplar Creek; (2) less than 2.2 L/s (3.5 gpm) of steam condensate to Poplar Creek at km 4.0 (mile 2.4); (3) 0.028 m^3/s (0.64 × 10^6 gal/d) of treated sanitary waste, plus

Table 1.7.5. Public supply surface water withdrawals within about 32 km of the ORR[a]

Public supply system	Population served (thousand)	Average withdrawal rate (m^3/s)	Withdrawal source and location	Distance from ORR (km)
Clinton	6.2	0.03	CRK[b] 106.7	25.1
Harriman	10.0	0.10	ERK[c] 20.8	21.7
Kingston	5.0	0.014[d]	TRK[e] 914.2	20.9
Lenior City	6.6	0.04	TRK 967.5	16.6
Loudon	5.2	0.03[f]	TRK 953.0	21.7
Anderson County Utility Board	8	0.03	CRK 89.3	14.5
Cumberland Utility District of Roane and Morgan counties	4.3	0.008[g]	LEREK[h] 3.5	14.0
First Utility District of Knox County	10.5	0.05	SCEK[i] 2.7	18.7
Hallsdale-Powell Utility District	28.7	0.07[j]	BRCEK[k] 2.1	18.2
West Knox County Utility District	15.0	0.06[l]	CRK 74.2	16.3

[a] Source: Refs. 10 and 11.
[b] CRK = Clinch River kilometer.
[c] ERK = Emory River kilometer.
[d] Secondary source (9%); spring (91%).
[e] TRK = Tennessee River kilometer.
[f] Half source (50%); spring (50%).
[g] Secondary source (5%); spring (95%).
[h] LEREK = Little Emory River Embayment kilometer.
[i] SCEK = Sinking Creek Embayment kilometer (Tennessee River).
[j] Primary source (70%); spring (30%) (outside 25-km radius).
[k] BRCEK = Bull Run Creek Embayment kilometer (Clinch River).
[l] Primary source (90%); well (10%).

classified waste, to Poplar Creek at km 4.3 (mile 2.7); (4) surface runoff and some cooling water amounting to 0.1 m^3/s (2.2×10^6 gal/d) discharging to Poplar Creek at km 2.4 (mile 1.5); (5) 0.0004 m^3/s (0.1×10^6 gal/d) of water from sludge and backwash systems associated with the potable water system, to Clinch River at km 23.2 (mile 14.5); (6) pond effluent from various sources, to Poplar Creek near km 7.2 (mile 4.5); and (7) treated cooling water to the Clinch River at km 18.2 (mile 11.4).

All discharges from ORNL are received by the WOC drainage. One waste stream discharged to Melton Branch is a blowdown from the recirculating cooling water system at the High Flux Isotope Reactor (HFIR). All discharge from Melton Branch to WOC is monitored at a sampling station located at km 0.16 (mile 0.1) of Melton Branch. Discharges directly

Table 1.7.6. Industrial water withdrawals from the Clinch-Tennessee River system[a]

Industrial water user	Average withdrawal rate (m^3/s)	Withdrawal source and location		River distance from mouth of White Oak Creek (km)
Withdrawals above White Oak Creek (mouth of CRK[b] *33.5)*				
Modine Manufacturing Co.	0.05	CRK	103.7	71.2
Tennessee Valley Authority Bull Run Steam Plant	25	CRK	77.2	43.7
U.S. Department of Energy ORNL, Y-12, Scarboro Facility, and City of Oak Ridge	0.96[c]	CRK	66.8	33.3
Withdrawals below White Oak Creek				
ORGDP	0.13[c]	CRK	23.3	10.2
ORGDP	0.54[d]	CRK	18.5	15.0
Tennessee Valley Authority Kingston Steam Plant	61.3	ERK[e]	2.9	29.6
Watts Bar hydro plant, lock, and steam plant	0.02	TRK[f]	851.5	94.5

[a] Source: Refs. 10 and 11.
[b] CRK = Clinch River kilometer.
[c] Process and potable water.
[d] Cooling water makeup only.
[e] Emory River kilometer.
[f] Tennessee River kilometer.

to WOC include (1) about 0.005 m^3/s (0.12×10^6 gal/d) to 0.01 m^3/s (0.24×10^6 gal/d) of treated domestic (sanitary) waste at WOCK 3.7 (WOCM 2.3); (2) cooling water; (3) cooling tower blowdown; (4) demineralizer regeneration wastes; (5) discharges from the low-level radioactive waste collection and ion exchange treatment system; (6) surface drainage from the main Laboratory area; and (7) discharge from process building areas. Water flow and quality are monitored at WOCK 2.6 (WOCM 1.6). Minimum flows in WOC are due predominantly to ORNL discharges.

Essentially all water used on the ORR is imported from the Clinch River. Any water not consumed is discharged to streams on the ORR. Very few streams on the ORR do not receive waste in some form, either as direct discharge, surface runoff, or groundwater discharge.

1.8 CHEMICAL AND PHYSICAL PROCESSES OF THE ATMOSPHERE

Chemically, the atmosphere is a mixture of gases, concentrations of which vary from trace levels to the 78% of the atmosphere that consists of nitrogen (N_2). Physically, the most significant feature of the atmosphere is its constant motion as a result of thermal energy produced by the unequal heating of the earth by the sun. This solar energy is the driving force for many complex physical, chemical, and biological processes that occur on or near the earth's surface.[25]

In the initial dispersion process from point or area sources, pollutants are released into the ambient air, where their transport and subsequent dilution depend on local meteorological phenomena and the influence of topography. In the Oak Ridge area, dispersion processes are influenced by meteorological phenomena such as wind (speed and direction), turbulence, and atmospheric stability.

The temporal changes of wind direction and speed resulting from the weather systems can be combined to determine the wind climatology of the Oak Ridge area. Of all the climatology data, those on the wind are of the most significance for atmospheric transport and diffusion. One of the most useful climatological presentations of wind data is the wind rose.[26]

A wind rose (ORR wind roses are given in Sect. 3.3) is a circle from whose center emanate lines representing the direction from which the wind blows. The length of each line is proportional to the frequency of the wind from that particular direction; the frequency of calm conditions may be entered in the center. Data are given for eight primary and eight secondary directions of the compass. Wind speed is divided into ranges.

1.9 ENVIRONMENTAL MONITORING AND SAMPLING SUMMARY

Routine monitoring and sampling for radiation, radioactive materials, and chemical substances on and off the ORR are used to document compliance with appropriate standards, identify trends, provide information for the public, and contribute to general environmental knowledge. The surveillance program assists in fulfilling the DOE policy of protecting the public, employees, and environment from harm that could be caused by its activities and reducing negative environmental impacts to the greatest degree practicable. Environmental monitoring information complements data on specific releases, trends, and summaries. A summary of routine environmental monitoring on the ORR is given in Table 1.9.1 for a wide range of environmental media.

Monitoring and sampling locations for various types of measurements are organized into eight groups:

(1) Regional stations located at distances up to ~140 km (~75 miles) from the ORR to provide a basis for determining conditions beyond the range of potential influence of these installations.

(2) Stations located within the ORR and in some residential and community areas to document conditions in areas occupied and visited by the public and potentially affected by these installations.

Table 1.9.1. Routine environmental monitoring on the Oak Ridge Reservation

Number of stations	Sampling period or type	Sampling frequency	Analysis frequency	Analyses
			Air	
39	Continuous	Weekly	Weekly	Gross alpha, gross beta, rainout, ^{131}I, ^{3}H
14	Continuous	Weekly	Quarterly	Specific radionuclides
22	Continuous	Continuous	Continuous	Fallout beta-gamma, alpha
5	24-h	Bimonthly	Bimonthly	Suspended particulates
39	Continuous	Continuous	Continuous	Gross particulate beta-gamma
11	Composite	Continuous	Weekly	Gross alpha, gross beta, uranium isotopes
11	Composite	Continuous	Weekly	Fluoride
11	Continuous	7 d/month	Monthly	Fluoride
2	Composite	24-h/6-d	Weekly	TSP
2	Continuous	Continuous	Continuous	SO_2
4	24-h	Quarterly	Quarterly	Metals
6	24-h	Weekly	Weekly	Suspended particulates
9	Continuous	21 week	21 week	Suspended particulates
2	Continuous	15-min	Hourly	SO_2
6	Continuous	Weekly	Weekly	Fluoride, total U, chromium
8	60-h	Quarterly	Quarterly	Metals
11	Composite	Continuous	Weekly	Fluoride
11	Composite	Continuous	Weekly	Uranium isotopic, gross alpha, gross beta
2	Continuous	Continuous	Continuous	SO_2
2	Composite	24-h/6-d	Weekly	TSP
			Water	
4	Continuous	Continuous	Continuous	Flow
1	Monthly	Monthly	Monthly	NH_4
2	Weekly	Weekly	Weekly	BOD
1	Weekly	Weekly	Weekly	COD
1	Weekly	Weekly	Monthly	COD
1	Weekly	Weekly	Quarterly	COD
1	24-h	Monthly	Monthly	Al, dissolved solids, nitrates
1	24-h	Monthly	Monthly	Cr, dissolved solids, F, phosphate, MBAS, total N, Zn
1	24-h	Monthly	Quarterly	Li
1	Weekly	Weekly	Weekly	Dissolved solids
2	Daily	Daily	Daily	DO, pH
2	Weekly	Weekly	Weekly	DO, pH

Table 1.9.1 (continued)

Number of stations	Sampling period or type	Sampling frequency	Analysis frequency	Analyses
4	Weekly	Weekly	Weekly	Suspended solids
2	Weekly	Weekly	Weekly	Settleable solids
1	Monthly	Monthly	Monthly	Oil, grease
1	Quarterly	Quarterly	Quarterly	Oil, grease
1	Weekly	Weekly	Weekly	NO_3, cyanide, flow, COD, SO_4
2	Weekly	Weekly	Weekly	Settleable solids, DO, F, Al, Cl
3	Weekly	Weekly	Weekly	Cr
4	Weekly	Weekly	Weekly	Suspended solids, oil, grease
1	Monthly	Monthly	Monthly	Suspended solids, NH_4
2	Monthly	Monthly	Monthly	BOD, fecal coliform
8	Daily	Daily	Daily	pH
1	Composite grab	Weekly	Weekly	Oil, grease, BOD, COD, TDS, NO_3-N, TSS, conductivity, DO, turbidity, pH
2	Grab	Monthly	Monthly	Oil, grease, TSS, metals, pH, Hg
2	Instantaneous	Daily	Daily	Flow
78	Instantaneous	Yearly	Yearly	Flow
77	Grab	Yearly	Yearly	pH
82	Instantaneous	Quarterly	Quarterly	Flow
82	Grab	Quarterly	Quarterly	Temperature, pH
17	Instantaneous	Yearly	Yearly	Flow
18	Grab	Weekly	Weekly	pH
1	Instantaneous	Weekly	Weekly	Flow
2	Composite	Daily	Daily	Metals, TTD, TSS, pH, color, NO_3-N, SO_4, F, Hg, MBAS, PO_4, Cl
2	Grab	Daily	Daily	Temperature, CN, Oil, grease, phenols
1	Grab	Weekly	Weekly	pH, DO, TSS, TDS, volatile organics, metals, PCB, Phenols, CN, F, N-NO_3, U, % ^{235}U, ^{241}Am, ^{237}Np, $^{238,239/240}Pu$, ^{99}Tc
1	Grab	Monthly	Monthly	Metals, Li, TSS, temperature, pH, Hg
4	Continuous	Continuous	Continuous	Flow
1	Grab	Weekly	Weekly	TSS, COD, SO_4, turbidity, temperature, oil, grease, metals, Hg, pH, settleable solids
1	Composite	Weekly	Weekly	Ammonia, F, MBAS, TDS, oil, grease, TSS, N-total, Hg, metals, temperature, pH, BOD, COD, settleable solids, volatile organics

Table 1.9.1 (continued)

Number of stations	Sampling period or type	Sampling frequency	Analysis frequency	Analyses
2	24-h	2/week	2/week	COD, suspended solids
1	24-h	Weekly	Weekly	COD
1	24-h	4/week	4/week	COD, suspended solids, temperature, turbidity
1	Grab	Weekly	Weekly	Suspended solids, Al, SO_4
2	Grab	Weekly	Weekly	Oil, grease
1	Grab	2/week	2/week	Oil, grease
1	Grab	Weekly	Weekly	Perchloroethylene, trichloroethane, methylene chloride, trichloroethylene
1	Grab	2/week	2/week	Perchloroethylene, trichloroethane, methylene chloride, trichloroethylene
2	24-h	Weekly	Weekly	Total Cr
1	24-h	2/week	2/week	Total Cr, Dissolved solids, F, NO_3-N, Be, Cd, Hg, Se, Ag, Pb, Zn
1	24-h	Weekly	Weekly	Be, Cd, Hg, Se, Ag, Pb, Zn
4	Continuous	Continuous	Continuous	pH
2	24-h	Weekly	Weekly	F
2	Grab	Daily	Daily	Dissolved oxygen
2	Grab	Quarterly	Quarterly	Total halomethanes
1	24-h	2/week	2/week	Al
1	24-h	3/week	3/week	Ammonia Nitrogen, BOD-5, suspended solids
1	Grab	3/week	3/week	Fecal coliform
1	Grab	5/week	5/week	Settleable solids
6	Daily	Daily	Daily	Flow
6	Grab	Weekly	Monthly	Cd, Cr, Ni, Pb, Zn, U, Te
3	Grab	Monthly	Monthly	CN, F, Hg, NO_3-N, SO_4, TSD
1	24-h	Monthly	Monthly	CN, F, Hg, NO_3-N, SO_4, TSD
			Fish	
4	Annually	Annually	Annually	^{90}Sr, ^{137}Cs, ^{60}Co, ^{238}Pu, ^{239}Pu, ^{234}U, ^{235}U, ^{238}U, Hg, PCBs
1	Quarterly	Quarterly	Quarterly	^{90}Sr, ^{137}Cs, ^{60}Co, ^{238}Pu, ^{239}Pu, ^{234}U, ^{235}U, ^{238}U, Hg, PCBs

Table 1.9.1 (continued)

Number of stations	Sampling period or type	Sampling frequency	Analysis frequency	Analyses
			Soil	
10	Semiannually	Semiannually	Semiannually	^{90}Sr, ^{137}Cs, ^{138}Pu, ^{239}Pu, ^{238}U, ^{234}U, ^{235}U
7	Annually	Annually	Annually	^{90}Sr, ^{187}Cs, ^{238}Pu, ^{239}Pu, ^{238}U, ^{234}U, ^{235}U
13	Semiannually	Semiannually	Semiannually	F, total U
			Grass	
7	Annually	Annually	Annually	^{90}Sr, ^{187}Cs, ^{238}Pu, ^{239}Pu, ^{238}U, ^{234}U, ^{235}U
10	Semiannually	Semiannually	Semiannually	^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{238}U, ^{234}U, ^{235}U
17	Semiannually	Semiannually	Semiannually	F, total U
			Pine needles	
13	Semiannually	Semiannually	Semiannually	F, total U
10	Annually	Annually	Annually	F, total U
			Stream sediment	
14	Semiannually	Semiannually	Semiannually	U, Hg, Pb, Ni, Cu, Zn, Cr, Mn, Al
8	Semiannually	Semiannually	Semiannually	Th, Cd
			Milk	
4	Semiannually	Semiannually	Semiannually	^{90}Sr, ^{131}I
5	Bimonthly	Bimonthly	Bimonthly	^{90}Sr, ^{131}I
			TLDs	
5	Bimonthly	Bimonthly	Bimonthly	External gammas
9	Semiannually	Semiannually	Semiannually	External gammas
2	Semiannually	Semiannually	Semiannually	External gammas
7	Quarterly	Quarterly	Quarterly	External gammas
			Groundwater	
18	Quarterly	Quarterly	Quarterly	Metals, NO_3, endrin, lindane, methoxychlor, toxaphene, 2,4-D, 2,4,5-TP silvex, Ra, gross alpha, gross beta, ^{60}Co, ^{137}Cs, fecal coliform, Cl, Fe, Mn, phenols, Na, SO_4, pH, conductivity, total organic carbon, total organic halogen
20	Quarterly	Quarterly	Quarterly	Metals, volatile organics, pesticides, Kjeldahl nitrogen, NO_3-N, PCBs, phenols, TOC, SO_4, gross alpha, gross beta, total U, ^{235}U, Th, pH, base-neutral organics

Table 1.9.1 (continued)

Number of stations	Sampling period or type	Sampling frequency	Analysis frequency	Analyses
6	Annually	Annually	Annually	Metals, volatile organics, pesticides, Kjeldahl nitrogen, NO_3-N, PCBs, phenols, TOC, SO_4, gross alpha, gross beta, total U, ^{235}U, Th, pH, base-neutral organics
6	Grab	Annually	Annually	Heavy metals, volatile organics, TKN, Hg, Se, Cl, CN, F, NO_3, phenols, SO_4, PCBs, pH, TOC, color, coliform, specific conductance, gross alpha, gross beta, U, % ^{235}U, Th, ^{237}Np, $^{238,239/240}$Pu
11	Quarterly	Quarterly	Quarterly	Metals, pesticides, NO_3-N, TOC, TOX, gross alpha, gross beta, total U, ^{235}U, phenols, fecal coliform, total coliform, pH, conductivity
24	Grab	Quarterly	Quarterly	Metals, Hg, Se, CN, TKN, NO_3-N, PCBs, pH, TOC, specific conductance, volatile organics, gross alpha, gross beta, U, % ^{235}U, Th
3	Grab	Quarterly	Quarterly	Metals, Hg, Se, Cl, F, TKN, NO_3-N, phenols, SO_4, PCBs, pH, TOC, coliform, color, specific conductance, gross alpha, gross beta, U, % ^{235}U, Th, ^{99}Tc
			Wastewater	
12	Grab	Daily	Monthly	^{90}Sr, gross alpha, gross beta, gamma scan
1	Grab	Monthly	Monthly	Gross alpha, gross beta, gamma scan
6	Grab	Monthly	Monthly	Hg, NO_3, P, Zn, Cr
3	Grab	Quarterly	Quarterly	^{137}Cs, ^{60}Co, gamma scan
4	Composite	24-h/month	Monthly	Heavy metals, BOD, Hg, oil and grease, suspended particulates, pH, TKN, PCB, temperature, gross alpha, gross beta, U, % ^{235}U, Th, ^{234}U, ^{238}U, ^{237}Np, $^{238,239/40}$Pu, ^{60}Co, ^{137}Cs

(3) Perimeter stations located on the boundaries of the ORGDP to document conditions in areas on its boundaries.

(4) On-site stations located on ORGDP site areas accessible only to employees or authorized visitors.

(5) Perimeter stations located on the boundaries of ORNL to document conditions in areas on its boundaries.

(6) On-site stations located on ORNL site areas accessible only to employees or authorized visitors.

(7) Perimeter stations located on the boundaries of the Y-12 Plant to document conditions in areas on its boundaries.

(8) On-site stations located on Y-12 site areas accessible only to employees or authorized visitors.

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2. EFFLUENT AND ON-SITE DISCHARGES

This section provides a review of releases to the environment from the three Oak Ridge Energy Systems installations. This review is divided into two major sections: the 1985 effluents, and historical effluents and on-site discharges. Historical data are for radioactive wastes only; 1985 data are for radioactive and nonradioactive waste.

2.1 1985 RELEASES AND 1981 THROUGH 1985 TRENDS IN RELEASES TO THE ENVIRONMENT

This section provides a brief review of the 1985 releases of radionuclides and chemicals to the environment from the three Oak Ridge Energy Systems installations. In addition, an inventory of disposal activities is given.

2.1.1 Environmental Point Discharges to the Atmosphere

Most gaseous wastes are released to the atmosphere through stacks. A summary of the air emission inventory for the Oak Ridge Energy Systems installations is given in Table 2.1.1. There are 1749 emission points at the three Oak Ridge installations, 1200 of which are small hoods and vents at ORNL. Radioactivity may be present in waste streams as a solid (particulates), as an absorbable gas (such as iodine), or as a nonabsorbable species (such as noble gas). Nonradioactive gaseous waste may also be solid (particulates) or gas (such as fluorine). Table 2.1.2 summarizes the combined 1985 point discharges of radionuclides from the three Energy Systems Oak Ridge plants. Table 2.1.3 summarizes the combined 1985 chemical emissions to the atmosphere from the three Oak Ridge plants.

The total curies of uranium discharged from these plants to the atmosphere from 1981 through 1985 ranged from a high of 0.19 Ci (1980) to a low of 0.10 Ci (1.9 kg) (1985). The 0.10 Ci discharged in 1985 represents a 23% decrease over the 0.13 Ci released in 1984. The total discharges of uranium to the atmosphere from 1981 through 1985 are shown in Fig. 2.1.1.

The total curies of tritium (^{3}H) discharged to the atmosphere from 1981 through 1985 ranged from a high of 33,000 Ci (1984) to a low of 11,000 Ci (1981). The 20,000 Ci discharged in 1985 represents a 40% decrease over the 33,000 Ci released in 1984. This decrease is the result of diminished ^{3}H isotope work. Some of the differences in ^{3}H discharges may be the result of the measurement method. The first year ^{3}H was measured was 1984; before then, discharges were estimated from inventories. The total discharges of ^{3}H to the atmosphere from 1981 through 1985 are shown in Fig. 2.1.2.

Table 2.1.1. 1985 summary of air emission inventory

Type of emission	Number of discharge points for each type of emission
Y-12[a]	
Enriched uranium	51
Depleted uranium	65
Particulates	92
Sulfur dioxide	5
Nitrogen oxide	77
Organic compounds	109
Carbon monoxide	6
Fluoride	9
Hazardous materials (Be, Hg, etc.)	14
Miscellaneous pollutants[b]	45
Total (Y-12)	473
ORNL	
Radionuclide[c]	7
Sulfur dioxide	1
Particulates	1
Miscellaneous pollutants[c]	1200[d]
Total (ORNL)	1,209
ORGDP[e]	
Uranium and technetium	8
Fluoride	9
Particulates	17
Volatile organic compounds	18
Sulfur dioxide	3
Nitrogen oxides	5
Carbon monoxide	2
Hydrochloric acid	2
Miscellaneous pollutants[b]	3
Total (ORGDP)	67
Grand total	1,749

[a] Many emission points emit more than one pollutant.

[b] Estimated emission quantities are given in Table 2.1.3.

[c] Radionuclides emitted from Stack 2026, Stack 3020, Stack 3039, Building 5505 vent, Stack 7025, Stack 7911, and small discharges from ORNL facilities at Y-12.

[d] Hoods and vents.

[e] Inventory includes only those emission locations that the facility operated during 1985.

Table 2.1.2. 1985 point discharges of radionuclides to the atmosphere from the three Oak Ridge installations

Radionuclide	Discharge (Ci)
Uranium[a]	0.10 (1.9 kg)
Iodine-131 (^{131}I)	0.086
Tritium (^{3}H)	20,000
Xenon-133 (^{133}Xe)[b]	32,000
Krypton-85 (^{85}Kr)[b]	6,600
Technetium-99 (^{99}Tc)	0.0030
UID[c]	0.00000060
Total	59,000

[a] Uranium of varying enrichments/curie quantities calculated using the appropriate specific activity for material released.

[b] Upper-limit values based on direct radiation measurements in the stack gas stream and an assumed mixture of noble gases.

[c] Unidentified alpha.

Table 2.1.3. Estimates of 1985 emissions of gaseous chemicals to the atmosphere[a]

Chemical	Amount (kg)
Acetylene	1,300
Alcohol	380,000
Ammonia	380
Argon	160,000
Mixed gases[b]	4,600
Carbon monoxide	51
Carbon dioxide (gas)	1,500
Carbon dioxide (solid)[c]	130,000
Chlorine	1,400
Fluorocarbons	12,000
Fluorine, hydrogen fluoride	22,000
Freon	110,000
Gaseous halogens and halogenated particulates	3,300
Gaseous and particulate fluorides	10,900
Gaseous chlorides	27
Steam plant discharges (particulates, sulfur dioxide, nitrogen oxides, carbon monoxide, hydrocarbons)	850,000
Helium	2,300
Hydrogen	350,000
Hydrogen sulfide	12
Methane	25
Nitrogen (gas)	19,000
Oxygen (gas)	8,400
Oxygen (liquid)[c]	61,000
Propane	2,500
Sulfur hexafluoride	4,700
Trichloroethane, perchlorethylene, methylene chloride, acetone	270,000
Total	2,700,000

[a] Source: Refs. 1 and 2.

[b] The major constituent is argon.

[c] Volatized from this form.

The total curies of xenon-133 discharged to the atmosphere from 1981 through 1985 ranged from a high of 72,700 Ci (1984) to a low of 32,000 Ci (1985). The 32,300 Ci discharged in 1985 represents a 55% decrease over the 73,000 Ci released in 1984. The total discharge of xenon to the atmosphere from 1981 through 1985 is shown in Fig. 2.1.3.

The total curies of krypton-85 discharged to the atmosphere from 1981 through 1985 ranged from a high of 14,900 Ci (1984) to a low of 6600 Ci (1985). The 6600 Ci discharged in 1985 represents a 56% decrease over the 15,000 Ci released in 1984. The total discharge of krypton to the atmosphere from 1981 through 1985 is shown in Fig. 2.1.4. The indicated decrease in the noble gases (^{133}Xe and ^{85}Kr) discharged was partly the result of better measurements and a decrease in processing of short-lived fission products.

The total curies of iodine-131 discharged to the atmosphere from 1981 through 1985 ranged from a high of 0.5 Ci (1981) to a low of 0.050 Ci (1983).

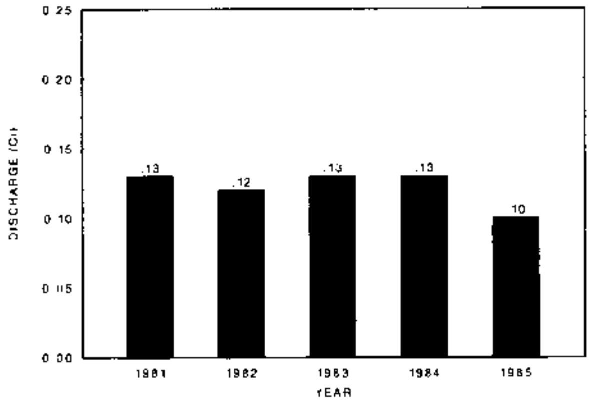

Fig. 2.1.1. Total discharges of uranium to the atmosphere, 1981–1985.

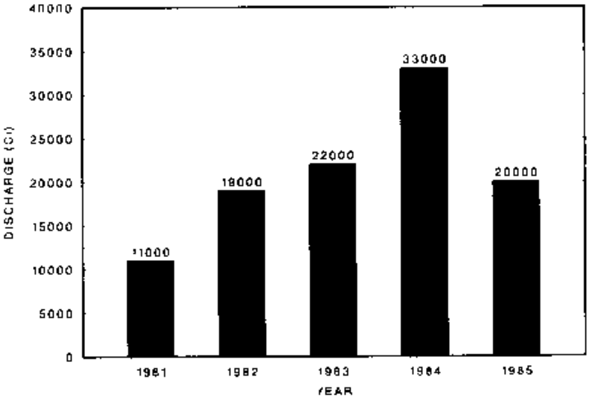

Fig. 2.1.2. Total discharges of tritium to the atmosphere, 1981–1985.

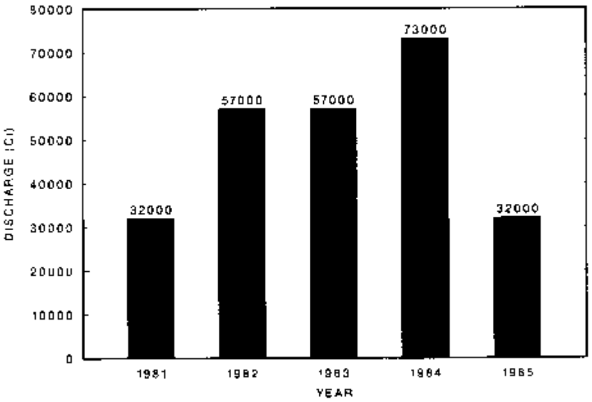

Fig. 2.1.3. Total discharges of xenon-133 to the atmosphere, 1981–1985.

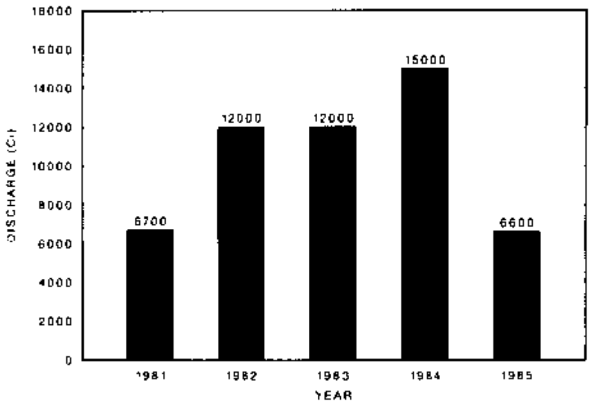

Fig. 2.1.4. Total discharges of krypton-85 to the atmosphere, 1981–1985.

The 0.086 Ci discharged in 1985 represents a 14% decrease over the 0.1 Ci released in 1984. The total discharges of ^{131}I to the atmosphere from 1981 through 1985 are shown in Fig. 2.1.5. The ^{131}I discharges have remained fairly constant since 1982. Apparent decreases in ^{131}I are probably not real but rather a result of improved analytical techniques. During 1984 more sensitive sample counting techniques were employed, which resulted in lower detection limits. This in turn resulted in an overall decrease in the average value.

The total curies of technetium-99 discharged to the atmosphere from 1981 through 1985 ranged from a high of 0.04 Ci (1981) to 0.003 Ci (1985). The 0.003 Ci discharged in 1985 represents an 85% decrease from the 0.02 Ci released in 1984. The total discharges of ^{99}Tc to the atmosphere from 1981 through 1985 are shown in Fig. 2.1.6. A significant decrease occurred in 1985 possibly because ORGDP was placed in a standby mode of operation.

Two of the most significant nonradioactive materials released to the atmosphere are fluorides and organics. The fluorides

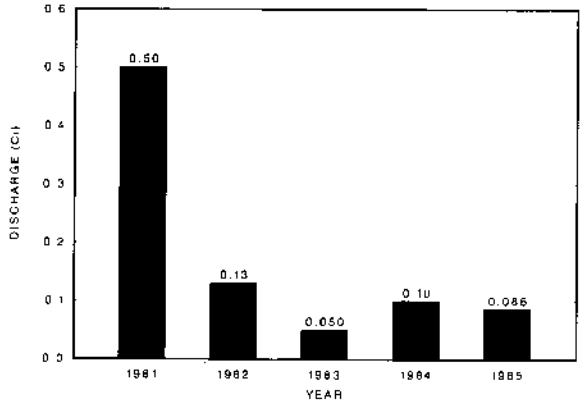

Fig. 2.1.5. Total discharges of iodine-131 to the atmosphere, 1981–1985.

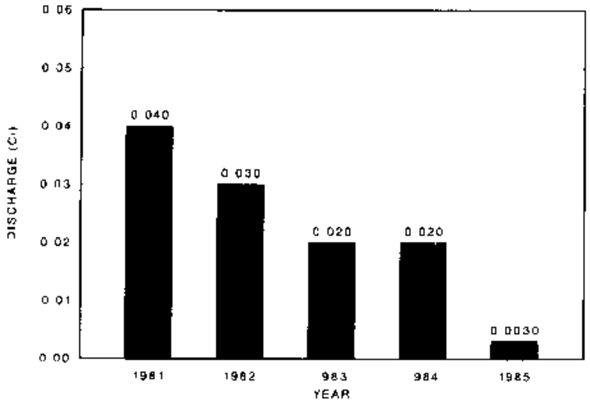

Fig. 2.1.6. Total discharges of technetium-99 to the atmosphere, 1981–1985.

released from ORGDP to the atmosphere from 1981 through 1985 ranged from a high of 91.1 kg (1983) to a low of 26 kg (1981). The 28 kg discharged in 1985 represents a 39% decrease from the 47 kg released in 1984 and was possibly a result of ORGDP being placed in standby. The total fluorides discharged to the atmosphere from 1981 through 1985 are shown in Fig. 2.1.7. The total hydrogen fluoride discharges from Y-12 to the atmosphere from 1981 through 1985 are shown in Fig. 2.1.8. Table 2.1.3 also shows 270,000 kg of organics released to the air.

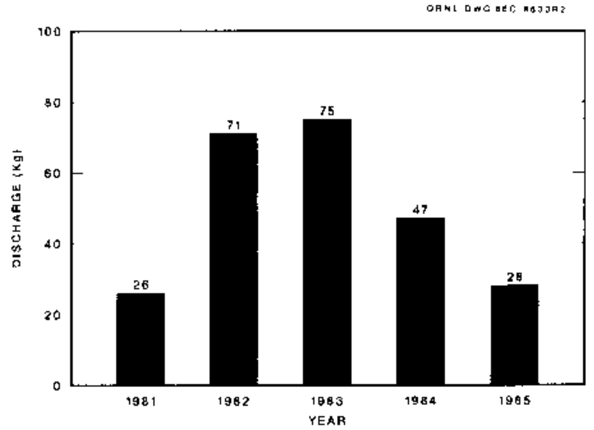

Fig. 2.1.7. Total discharges of fluorides from ORGDP to the atmosphere, 1981-1985.

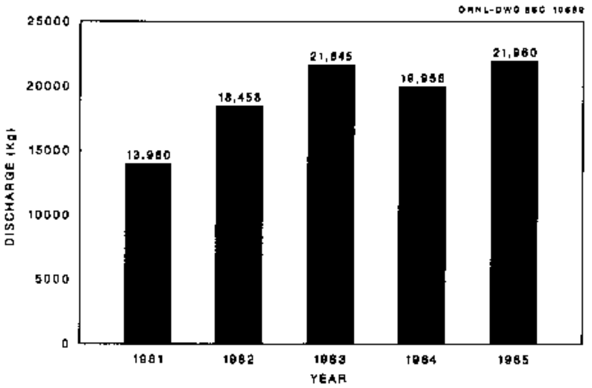

Fig. 2.1.8. Total discharges of hydrogen fluoride from Y-12 to the atmosphere, 1981-1985.

2.1.2 Environmental Discharges to Water

The discharges of radionuclides to surface streams for 1985 are shown in Table 2.1.4.

The total curies of tritium discharged to surface water from 1981 through 1985 ranged from a high of 6400 Ci (1984) to a low of 2900 Ci (1981). The 3700 Ci discharged in 1985 represents a 42% decrease from the 6400 Ci released in

Table 2.1.4. 1985 discharges of radionuclides from Oak Ridge installations to surface streams

Radionuclide	Discharge (Ci)
Cesium-137 (^{137}Cs)	0.42
Cobalt-60 (^{60}Co)	0.62
Tritium (^{3}H)	3700
Iodine-131 (^{131}I)	ND[a]
Ruthenium-106 (^{106}Ru)	<0.01
Strontium-90 (^{90}Sr)	3.0
Technetium-99 (^{99}Tc)	0.033
Total uranium	0.62 (0.924 kg)
Thorium-232 (^{232}Th)	ND
Transuranics[b]	0.008

[a] Not detected.

[b] Value based on gross transuranic alpha emitter analysis.

1984. This decrease is due in part to the fact that there was less precipitation in 1985 than in 1984. The total discharges of ^{3}H to surface streams from 1981 through 1985 are shown in Fig. 2.1.9.

The total strontium-90 and technetium-99 discharged to the surface water from 1981 through 1985 ranged from a high of 3.0 Ci (1985) and 17 Ci (1983) to a low of 1.5 Ci (1981) and 0.033 Ci (1985), respectively. The 3.0 Ci ^{90}Sr discharged in 1985 represents a 15% increase over the 2.6 Ci released in 1984. This increase primarily is due to the two radionuclide spills that occurred in 1985 (Sect. 5.2). The 0.033 Ci of ^{99}Tc discharged in 1985 represents an 88% decrease from the 0.29 Ci released in 1984. This decrease may be due to ORGDP being placed in standby in 1985. The total discharges of ^{90}Sr and ^{99}Tc to surface streams from 1981 through 1985 are shown in Fig. 2.1.10.

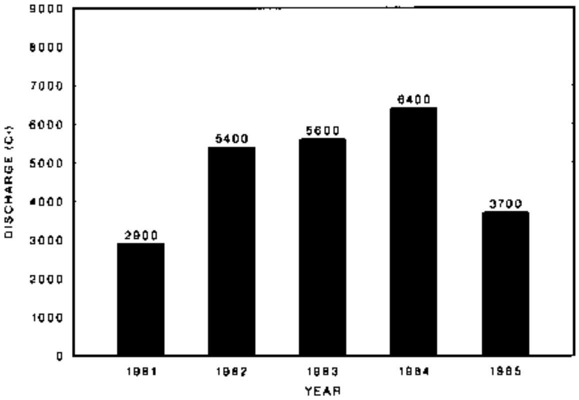

Fig. 2.1.9. Total discharges of tritium to surface waters, 1981-1985.

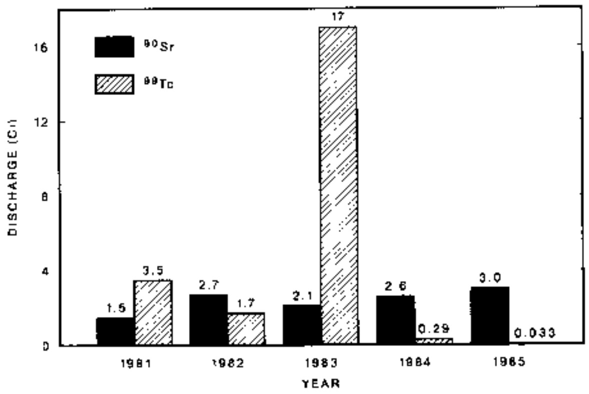

Fig. 2.1.10. Total discharges of strontium-90 and technetium-99 to surface waters, 1981–1985.

The total curies of cobalt-60 and cesium-137 discharged to surface water from 1981 through 1985 ranged from a high of 0.96 Ci (1982) and 1.5 Ci (1982) to a low of 0.17 Ci (1984) and 0.23 Ci (1981), respectively. The 0.62 Ci of ^{60}Co discharged in 1985 represents a 265% increase over the 0.17 Ci discharged in 1984. This increase may be due to better sampling equipment and methods, or it could be related to the radionuclide spills (Sect. 5.2). The 0.42 Ci of ^{137}Cs in 1985 represents a 25% decrease from the 0.56 Ci released in 1984. The decrease may be a result of less precipitation in 1985 compared with 1984, which may have resulted in less movement of ^{137}Cs in the ground.

The total discharges of ^{60}Co and ^{137}Cs to surface streams from 1981 through 1985 are shown in Fig. 2.1.11.

The total curies of uranium and ^{106}Ru discharged to surface water from 1981 through 1985 are shown in Fig. 2.1.12. The total curies of transuranics and ^{131}I discharged to surface water from 1981 through 1985 are shown in Fig. 2.1.13. The total curies of ^{232}Th discharged to surface water from 1981 through 1985 are shown in Fig. 2.1.14. The increase in uranium shown in Fig. 2.1.12 is under investigation.

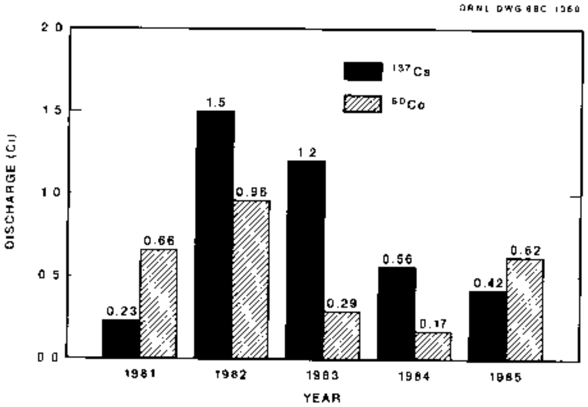

Fig. 2.1.11. Total discharges of cobalt-60 and cesium-137 to surface waters, 1981–1985.

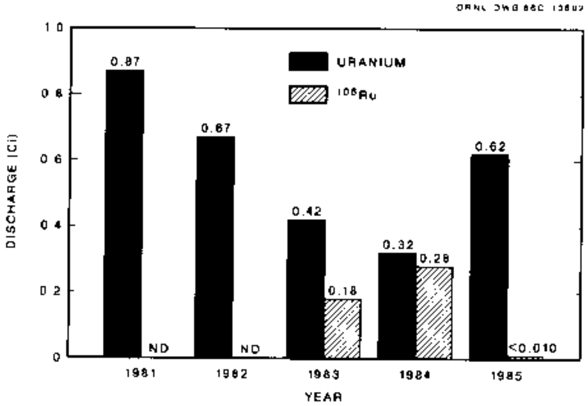

Fig. 2.1.12. Total discharges of uranium and ruthenium-106 to surface waters, 1981–1985.

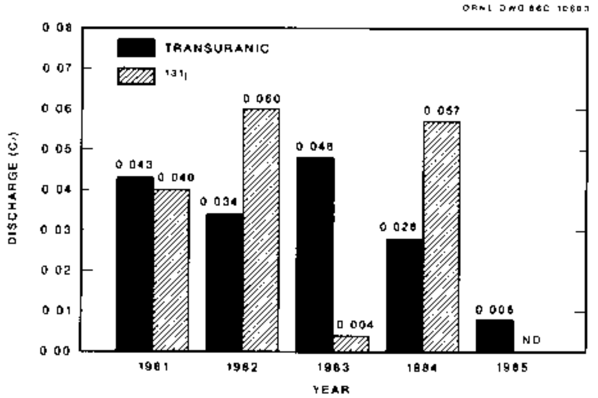

Fig. 2.1.13. Total discharges of transuranics and iodine-131 to surface waters, 1981–1985.

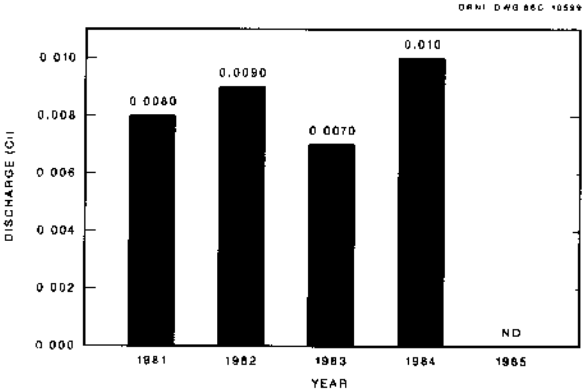

Fig. 2.1.14. Total discharges of thorium-232 to surface waters, 1981–1985.

2.1.3 On-Site Disposal and Off-Site Shipments of Waste

Radionuclides contained in waste placed in retrievable storage are shown in Table 2.1.5. During 1985, 990 Ci was placed in retrievable storage. Radionuclides contained in buried waste for 1985 are shown in Table 2.1.6. During 1985, 11,900 Ci was buried. Nonradioactive solid wastes disposed of in 1985 are listed in Table 2.1.7. During 1985, 43,000,000 kg of waste was disposed of at the three Oak Ridge installations. The hazardous and/or special waste disposal activities for the three

Table 2.1.5. Radionuclide content of waste placed in retrievable storage during 1985

Isotope	Curies
Americium-241 (^{241}Am)	0.004
Californium-252 (^{252}Cf)	7.8
Curium-242 (^{242}Cm)	3.0
Curium-243 (^{243}Cm)	46
Curium-244 (^{244}Cm)	3.1
Neptunium-237 (^{237}Np)	0.0048
Plutonium-238 (^{238}Pu)	190
Plutonium-239 (^{239}Pu)	96
Uranium-233 (^{233}U)	8.0
UID[a]	38
Cesium-137 (^{137}Cs)	87
Europium-152 (^{152}Eu)	0.001
Europium-154 (^{154}Eu)	0.001
Gadolinium-153 (^{153}Gd)	0.5
Strontium-90 (^{90}Sr)	500
Uranium-235 (^{235}U)	3.4
Total	990

[a] UID = unidentified alpha.

Table 2.1.6. Radionuclide content of buried waste
1985

Isotope	Curies[a]
Carbon-14 (^{14}C)	31
Cobalt-60 (^{60}Co)	6,600
Cesium-137 (^{137}Cs)	100
Europium-152 (^{152}Eu)	57
Europium-154 (^{154}Eu)	49
Tritium (^{3}H)	530
Uranium-238 (^{238}U)	19[b]
UID[c]	910
Plutonium-239 (^{239}Pu)	61
Thorium-232 (^{232}Th)	100
Uranium-235 (^{235}U)	6.0[d]
Americium-241 (^{241}Am)	13
Curium-244 (^{244}Cm)	5.5
Cesium-134 (^{134}Cs)	1.20
Germanium-68 (^{68}Ge)	0.25
Krypton-85 (^{85}Kr)	3.0
Ruthenium-106 (^{106}Ru)	3300
Strontium-90 (^{90}Sr)	77
Uranium-232 (^{232}U)	1.0
Uranium-233 (^{233}U)	3.0
Americium-241 (^{241}Am)	0.0026
Americium-243 (^{243}Am)	0.0001
Berkelium-249 (^{249}Bk)	0.0001
Californium-252 (^{252}Cf)	0.0021
Neptunium-237 (^{237}Np)	0.00050
Total	11,900

[a] A total 51 Ci of short-half-life materials was also disposed of during 1985.

[b] 2079 g.

[c] UID = unidentified alpha.

[d] 173 g.

Table 2.1.7. Nonradioactive waste disposal activities 1985

Waste category	Quantity (kg)	Treatment, storage or disposal
	ORGDP	
Scrap metal	630,000	Public sale
Sanitary	740,000	Centralized Sanitary Landfill II
Demolition	310,000	Centralized Sanitary Landfill II
Fly ash	720,000	Centralized Sanitary Landfill II
Total ORGDP	2,400,000	
	ORNL	
Tires	5,200	Public sale
Batteries	1,300	Public sale
Scrap metal	280,000	Public sale
Paper products	120,000	Public sale
Construction materials	3,600,000	ORNL contractor's landfill
Fly ash	11,000,000	ORNL contractor's landfill
Coal-pile runoff sludge	50,000	ORNL contractor's landfill
Sanitary	1,100,000	Centralized Sanitary Landfill II
Total ORNL	16,200,000	
	Y-12	
Sanitary and industrial	4,200,000	Centralized Sanitary Landfill II
Fly ash	18,000,000	Roger's Quarry
Scrap metal and tires	2,447,000	Public sale
Batteries	33,700	Public sale
Total Y-12	24,700,000	
Grand total	43,300,000	

installations in 1985 are listed in Table 2.1.8. The total hazardous and/or special waste handled at these installations was 16,000,000 kg.

2.2 HISTORICAL RELEASES OF RADIOACTIVITY TO THE ENVIRONMENT

This section provides a summary of the releases of radionuclides from the three Energy Systems installations in Oak Ridge. In addition, a summary inventory of radioactivity disposed of by shallow land burial and other techniques is given.

The total uranium releases to the environment from the three Oak Ridge installations from 1944 through 1984 are given in Table 2.2.1. Over 28 Ci (16,316 kg) was released to the atmosphere during this period. From 1944 through 1984, 128 Ci (196,467 kg) was released to water. Total solids disposed of from 1944 through 1984 were 6,598.9 Ci (16,032,750 kg). Other radionuclide release reports and chemical release reports are scheduled to be published in 1986.

Table 2.1.8. Hazardous and/or special waste disposal activities 1985

Waste category	Quantity (kg)	Treatment/Storage/Disposal
	ORGDP	
Nitric acid	1,200	Y-12 Plant
Electroless nickel solution	12,000	Y-12 Plant
Y-12 returned waste	1,700,000	Y-12 Plant
Waste chemicals	16,000	Commercial off-site disposal
Laboratory chemicals (includes H_2O for disposal process)	4,300,000	Storage
Laboratory chemicals	2,100,000	Storage
Solvents and oils (radiation-contaminated)	160,000	Storage for TSCA incinerator
Total ORGDP	8,290,000	
	ORNL	
Asbestos material	13,000	SWSA No. 6[a]
PCB-contaminated waste	19,000	Commercial off-site disposal
Laboratory chemicals	49,000	Commercial off-site disposal
Chemicals	57,000	On-site treatment and recycle
Radiation-contaminated waste	13,000	On-site storage
Total ORNL	150,000	
	Y-12 Plant liquids	
Waste oil	58,400	On-site storage
Waste solvents	70,600	On-site storage
Waste oil	193,600	Public sale
PCB liquid waste	327,900	Commercial off-site disposal
PCB liquid waste	50,600	On-site storage
RCRA lab packs	58,300	Commercial off-site disposal
RCRA waste chemicals	261,800	On-site storage
Total Y-12 liquids	1,021,200	
	Y-12 Plant solids	
DOT ORMB wastes	3,560,000	On-site storage
PCB solid waste	137,000	Commercial off-site disposal
PCB solid waste	118,000	On-site storage
Classified waste	580,000	On-site storage
Asbestos waste (non-rad)	46,300	Centralized Sanitary Landfill II
Asbestos waste (rad)	57,200	Bear Creek Burial Grounds
Uranium-contaminated waste	2,150,000	Bear Creek Burial Grounds
Total Y-12 solids	6,6,50,000	
Total Y-12	7,700,000	
Grand Total (Y-12, ORNL, ORGDP)	16,000,000	

[a] Solid Waste Storage Area No. 6—shallow land burial.

Table 2.2.1. Total uranium[a] releases to the environment 1944–1984

Plant	Radioactivity[a] (Ci)	Mass[a] (kg)
Airborne emissions		
ORGDP[b,c]	15.61	10,516
Y-12[d,e]	13.36	5,800
Total	28.97	16,316
Liquid effluent		
ORGDP[b,c]	14.54	16,467
Y-12[d,e]	113.54	180,000
Total	128.08	196,467
Contained in solid waste[c]		
ORGDP[b]	24.25	32,750
Y-12[c]	6,524.65	16,000,000
Total	6,598.9	16,032,750
Grand total	6,755.95	16,245,533

[a] Number reported as in references; not rounded.

[b] Source: Ref. 3.

[c] Source: Ref. 4.

[d] Corrected data. Source: Ref. 5.

[e] Source: Ref. 6.

REFERENCES FOR SECT. 2

1. J. Boyle et al., *Environmental Analysis of the Operation of Oak Ridge National Laboratory (X-10 Site)*, ORNL-5870, Oak Ridge National Laboratory, November 1982.
2. B. A. Kelly, *Resource Management Plan for the U.S. Department of Energy Oak Ridge Reservation, Vol. 15: Waste Management*, ORNL-6026/V15, Oak Ridge, Tenn., July 1984.
3. L. W. Long and J. G. Rogers, *ORGDP Uranium Discharges*, K/HS-69, Oak Ridge, Tenn., May 1985.
4. Personal communication, J. G. Rogers, March 1986.
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6. Personal communication, E. Owings, March 1986.

3. CALCULATION OF POTENTIAL RADIATION AND CHEMICAL DOSE TO THE PUBLIC

3.1 INTRODUCTION

The calculation of potential radiation dose and chemical dose to the public requires the use of models of varying degrees of complexity that represent the movement of materials through the environment from the source to humans. These models attempt to take into account the nature and physical and chemical characteristics of the materials, as well as their methods of release. The models then attempt to reflect the characteristics of the environment and of humans that influence the consequent exposure of individuals and groups.[1,2]

Potential pathways of human exposure from effluents released by the operations of the DOE Oak Ridge facilities that are considered in dose estimates are presented in Fig. 3.1.1. Only the principal pathways for exposure are included. The radiation doses received by a tissue or organ from the various pathways are weighted and then summed to estimate the total risk. This assumes that (1) a linear relationship (without threshold) exists between dose and the probability of an effect and (2) the severity of each type of effect is independent of dose. These assumptions are based on the recommendations of the International Commission on Radiological Protection (ICRP).[1,2]

These calculations require a number of inputs; for example, to calculate dose from airborne releases the input parameters are: emissions data, meteorological data, and demographical data.

3.2 CALCULATIONS OF POTENTIAL RADIATION DOSE TO THE PUBLIC

The data in this report can be divided into two broad categories: measured emission rates and environmental concentrations. At very low levels, health effects and actual doses cannot be directly measured; therefore, measured quantities are used as input for mathematical models that predict health effects and doses. There are several types of models available: (1) atmospheric dispersion; (2) water transport; (3) transport through the food chain; (4) human intake of radionuclides for air, food, and water; (5) conversion of human intake to doses; and (6) conversion of doses to health effects.

There is frequently even less correlation between the size of effluent releases and concentration measurements. The rise and fall of the yearly quantities of effluents often do not coincide with the rise and fall of the measurements that are supposed to reflect those effluents. There are many possible reasons for this lack of correlation—weather patterns, possible inappropriate placement of the monitoring stations with respect to where

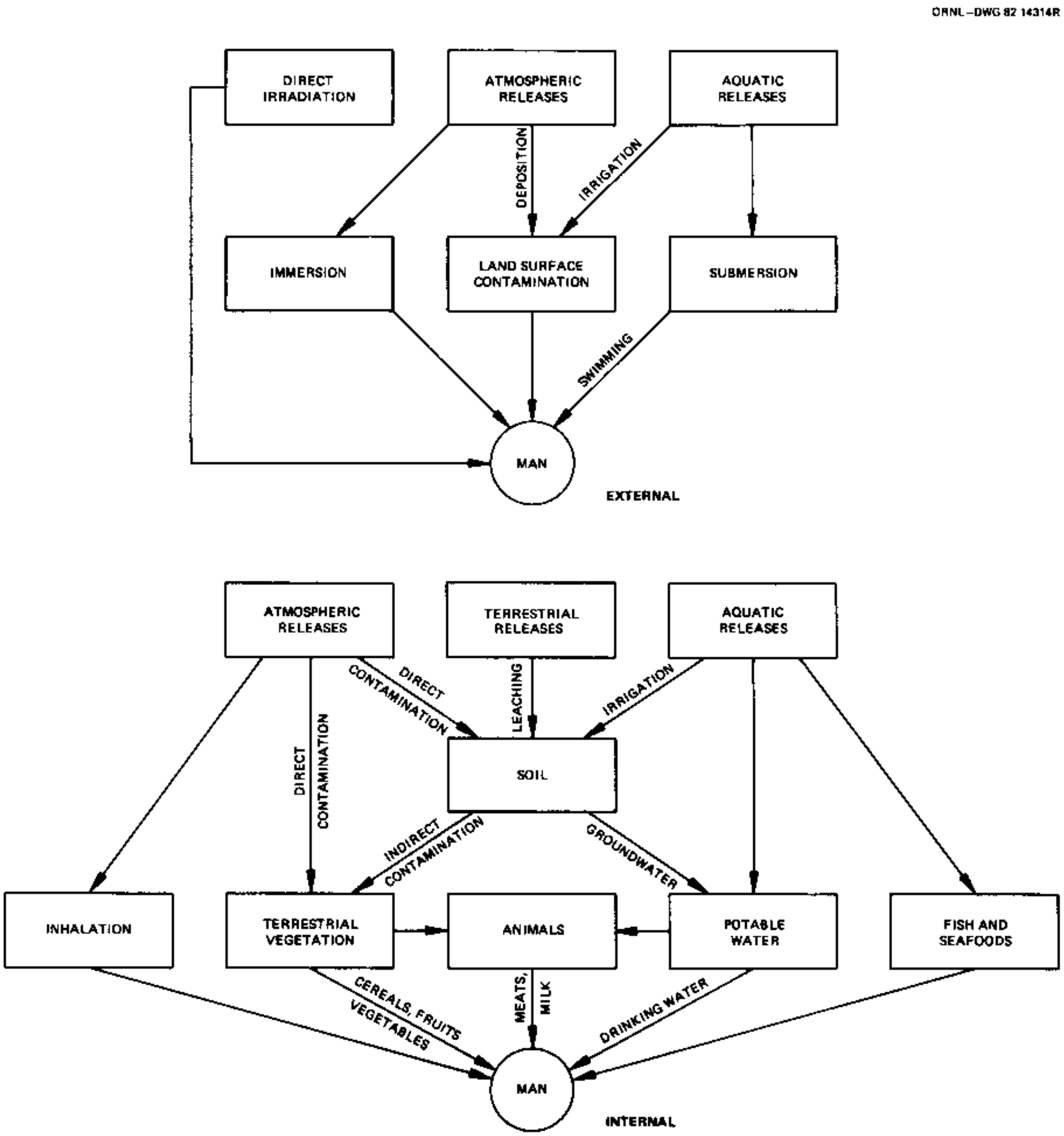

Fig. 3.1.1. Exposure pathways to humans.

the effluents are discharged, and so on. As well, measurements are in many cases so close to background concentrations that they are affected by only the largest variations in effluent discharges.

3.2.1 Regional Demography

Except for the City of Oak Ridge, the land within 8 km of the ORR is predominantly rural, used largely for residences, small farms, and pasturage of cattle. Fishing, boating, water skiing, and swimming are favorite recreational activities in the area. The approximate location and population (1980 census data) of the towns nearest the ORR are Oliver Springs (pop. 3600), 11 km to the northwest; Clinton (pop. 5300), 16 km to the northeast;

Lenoir City (pop. 5400), 11 km to the southeast; Kingston (pop. 4400), 11 km to the southwest; and Harriman (pop. 8300), 13 km to the west. Knoxville, the major metropolitan area nearest Oak Ridge, is located about 40 km to the east and has a population of about 183,000. A directional 80-km population distribution map, which is used to calculate population dose later in this section, is shown in Figs. 3.2.1 and 3.2.2. It should be noted that the center of these figures is the center of the ORR and that most of the 10-km area of these figures is the ORR. Fewer than 5000 people live within those 10 km. Table 3.2.1 lists cities and population centers within 80 km of the ORR.

ORNL DWG 86-8712

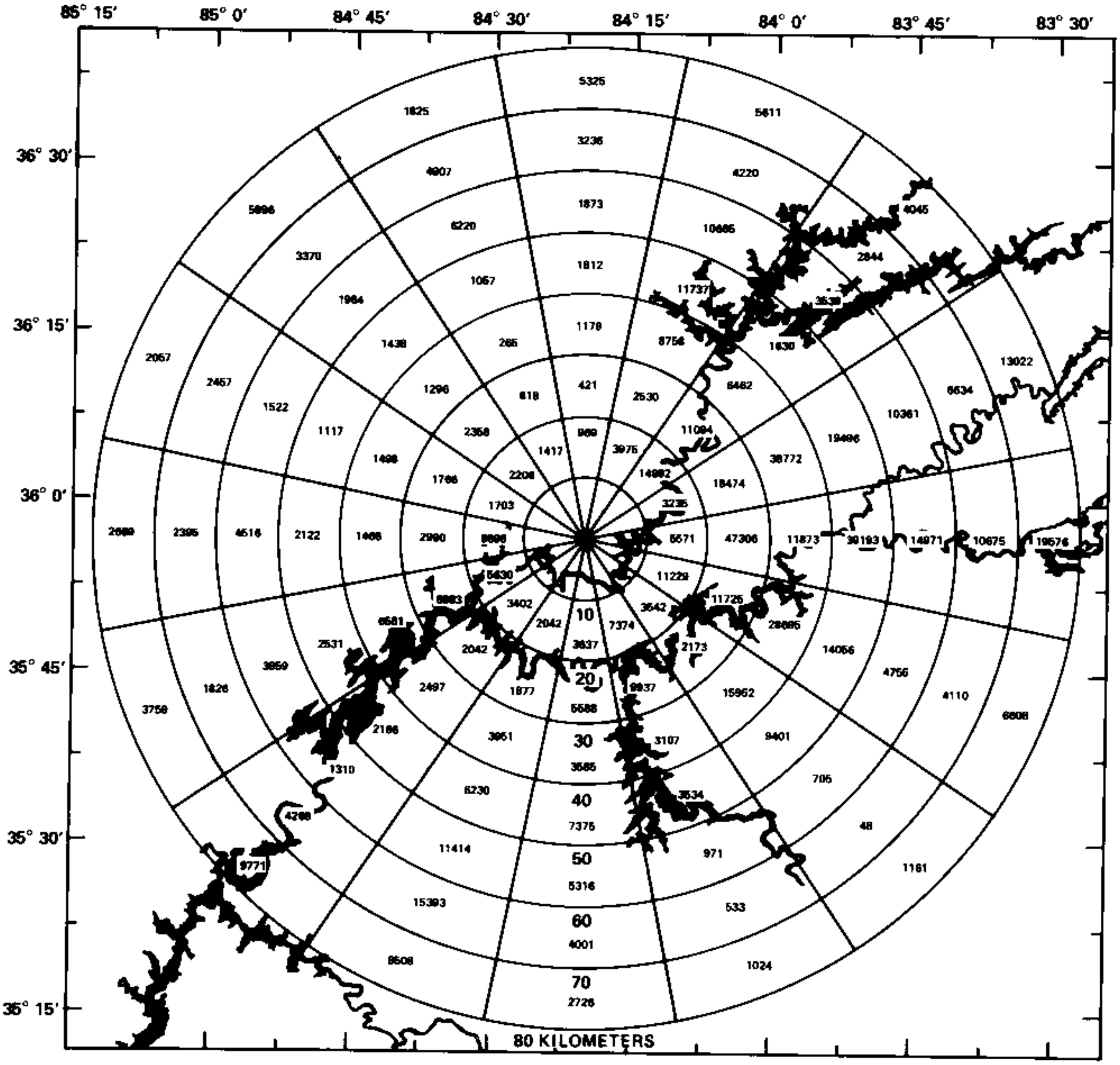

Fig. 3.2.1. Population densities from the center of the Oak Ridge Reservation, based on 1980 census data.

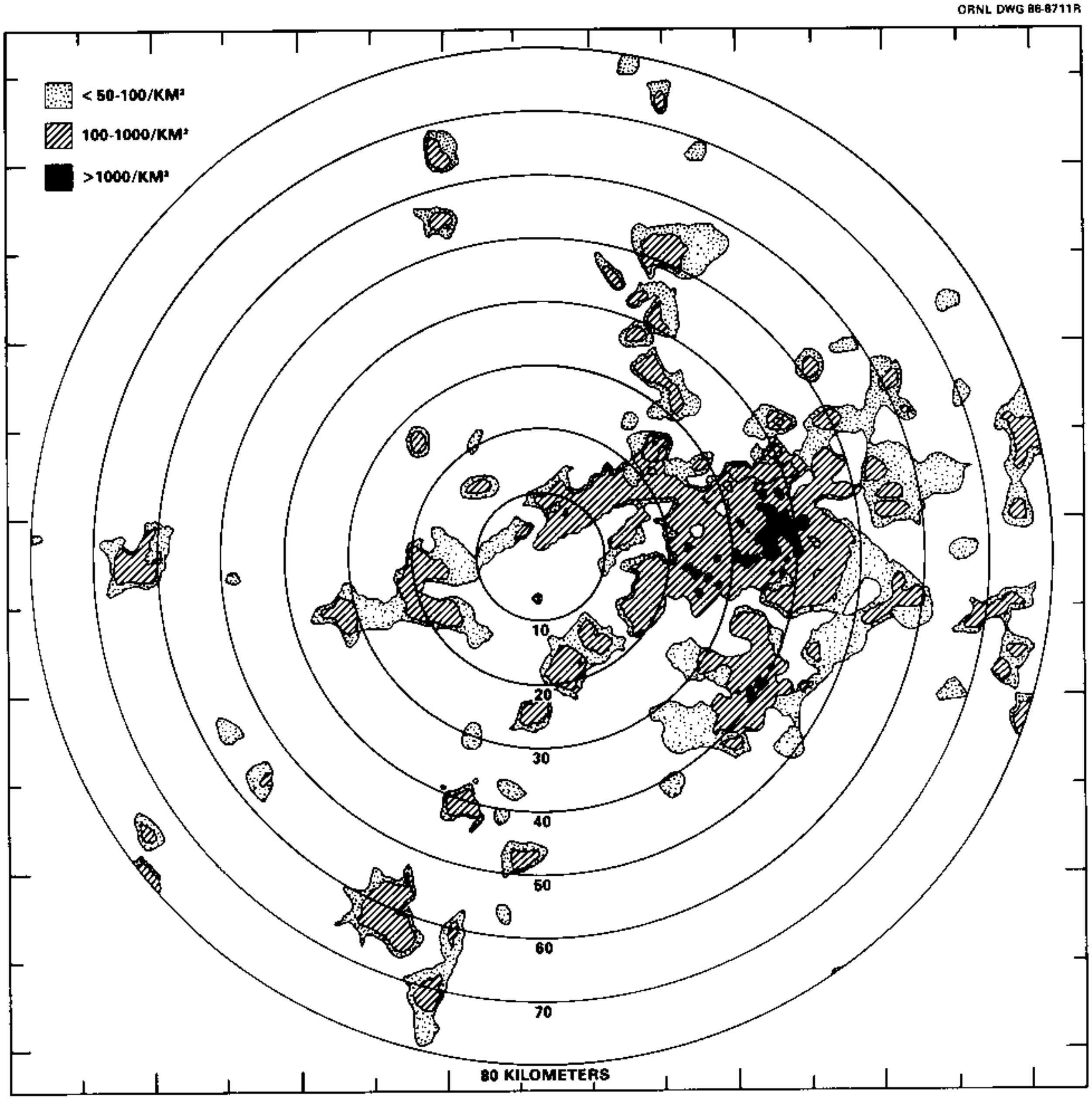

Fig. 3.2.2. Population densities by section of the East Tennessee area, based on 1980 census data.

3.2.2 Meteorological Processes

Construction of a network of meteorological observation towers was finished during 1985 with the completion of the two new towers at the Y-12 Plant. This network consists of one 60-m tower at ORGDP (tower 1), one 100-m tower (tower 2) and two 30-m towers (towers 3 and 4) on the ORNL site, one 100-m tower (tower 5) and one 60-m tower (tower 6) on the Y-12 Plant site, one rain collector and ground-level wind vanes (tower 7) on the National Oceanographic and Atmospheric Administration (NOAA) site, one 100-m tower (tower 8) located at Walker Branch

Table 3.2.1. Population of central East Tennessee towns[a]

Town/city	Population
Anderson County	
Clinton	5,245
Lake City	2,335
Norris	1,374
Oak Ridge	27,662
Oliver Springs	3,600
Blount County	
Friendsville	694
Alcoa	6,870
Maryville	17,478
Knox County	
Knoxville	183,139
Loudon County	
Greenback	546
Lenoir City	5,446
Loudon	3,940
Morgan County	
Wartburg	761
Roane County	
Harriman	8,303
Kingston	4,441
Rockwood	5,767
Sevier County	
Sevierville	4,566
Union County	
Luttrell	962
Maynardville	924
Campbell County	
Caryville	2,039
Jellico	2,769
Jacksboro	1,620
LaFollette	8,176

[a]Source: Ref. 3.

watershed, and one 110-m tower (tower 9) on the Clinch River Breeder Reactor Project (CRBRP) site. The Y-12 towers (towers 5 and 6) were completed in late 1985; complete data were not available to complete 1985 wind roses for these towers. Towers 7 and 8 are equipped for research; however, the real-time data could be used as needed but are not useful for routine plant release calculations. The CRBRP tower (tower 9) data collection system is inoperative; thus 1985 data are not available. The locations of these towers on the ORR are shown on the map in Fig. 3.2.3. The wind roses for the 10-m and 60-m levels of the 60-m meteorological tower (1) are given in Figs. 3.2.4 and 3.2.5, respectively. Figures 3.2.6, 3.2.7, and 3.2.8 are the wind roses at the 10-m, 30-m, and 100-m levels, respectively, for the 100-m meteorological tower (2). The wind roses at the 10-m and 30-m levels for 30-m towers 3 and 4 are given in Figs. 3.2.9, 3.2.10, 3.2.11, and 3.2.12, respectively.

Examination of the annual wind roses reveals that the prevailing winds are almost equally split into two directions that are 180 degrees apart: one prevailing direction is from the SW to WSW sector, and the other prevailing direction is from the NE to ENE sector. The reason the winds are so strongly aligned along these directions is due to the channeling effect induced by the ridge and valley structure of the area. The ridges and valleys within the ORR are oriented along a WSW-ENE line (with respect to true north). This orientation causes the winds at the lower layers of the atmosphere to flow along the valleys without crossing the ridges. Note that the alignment of winds is not so pronounced at tower 1, which is located in a relatively open area where the ridges

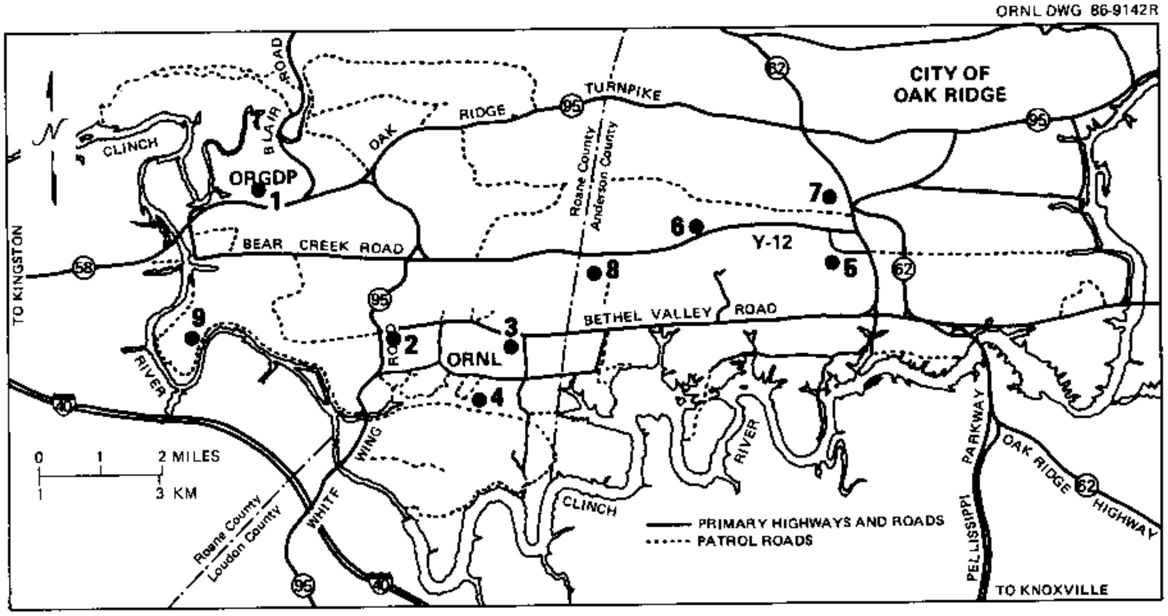

Fig. 3.2.3. Locations of meteorological towers on the Oak Ridge Reservation.

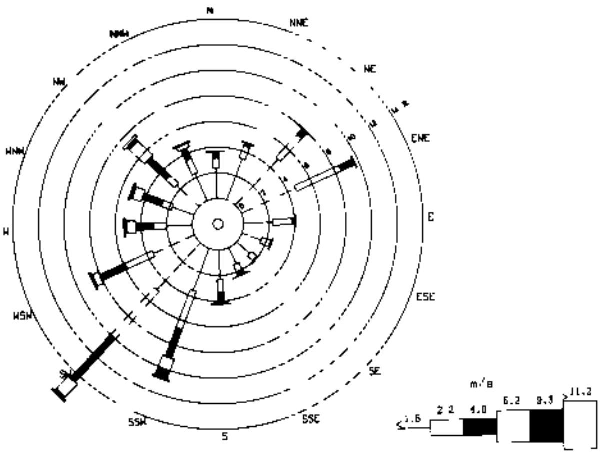

Fig. 3.2.4. 1985 annual wind rose at 10-m level of meteorological tower 1.

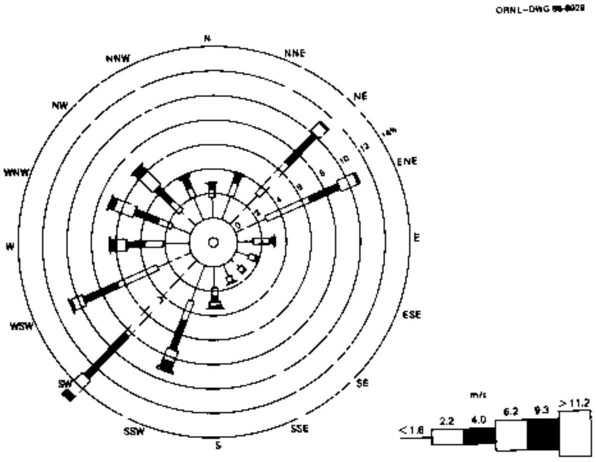

Fig. 3.2.5. 1985 annual wind rose at 60-m level of meteorological tower 1.

are not as high or structured. Another feature clearly observed on the wind roses is that the wind speeds increase with height (tower level) at each of the towers. On the average the wind speeds can be expected to increase steadily from ground level to 100 m.

3.2.3 1985 Radiation Dose and Risk Calculations

Introduction

The International Commission on Radiological Protection (ICRP) had formerly stated that when one or more than

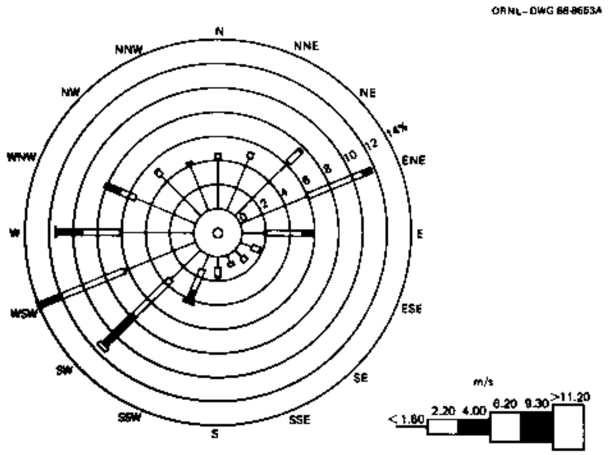

Fig. 3.2.6. 1985 annual wind rose at 10-m level of meteorological tower 2.

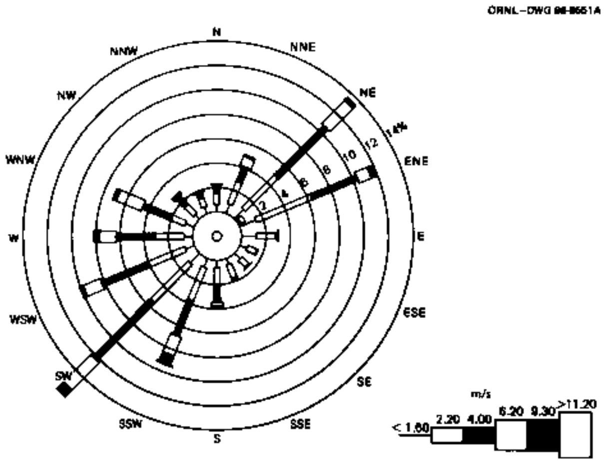

Fig. 3.2.8. 1985 annual wind rose at 100-m level of meteorological tower 2.

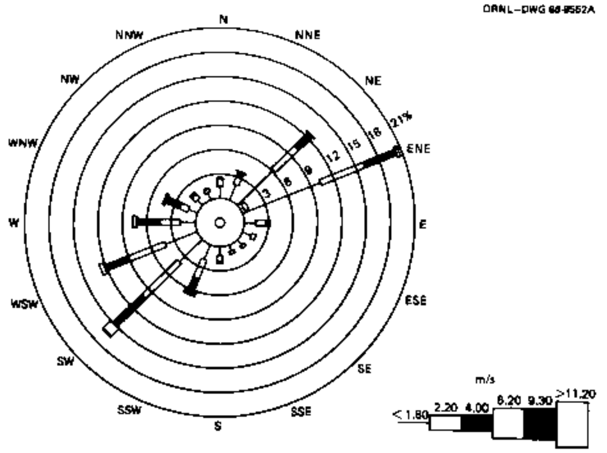

Fig. 3.2.7. 1985 annual wind rose at 30-m level of meteorological tower 2.

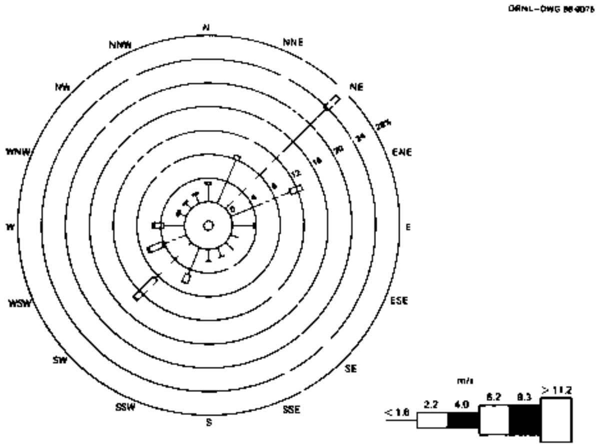

Fig. 3.2.9. 1985 annual wind rose at 10-m level of meteorological tower 3.

one organ of the body is exposed, the irradiation of one particular organ or tissue is likely to be of greatest importance because of (1) the dose it received, (2) its sensitivity to radiation, or (3) the importance to health of any damage that results. This tissue or organ was referred to as the critical organ. The ICRP now recommends a procedure that takes into account the total risk attributable to the exposure of all tissues irradiated. This dose is now referred to as the effective dose equivalent.

Exposures to radionuclides that originate in the effluents released from the DOE facilities in Oak Ridge were converted to estimates of radiation dose to individuals using models and data presented in publications of the ICRP,[1,2,4,5] other recognized literature on radiation protection,[6-8] and computer programs incorporating some of these models and

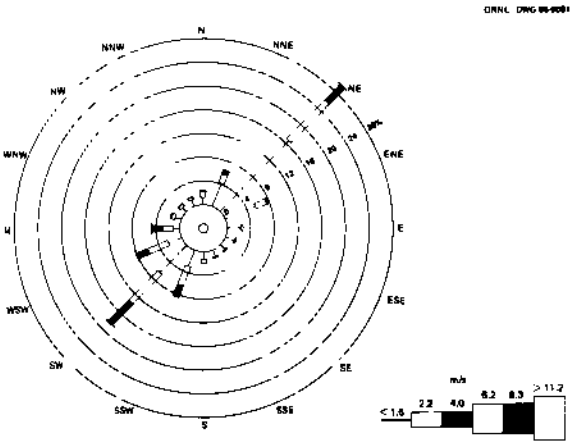

Fig. 3.2.10. 1985 annual wind rose at 30-m level of meteorological tower 3.

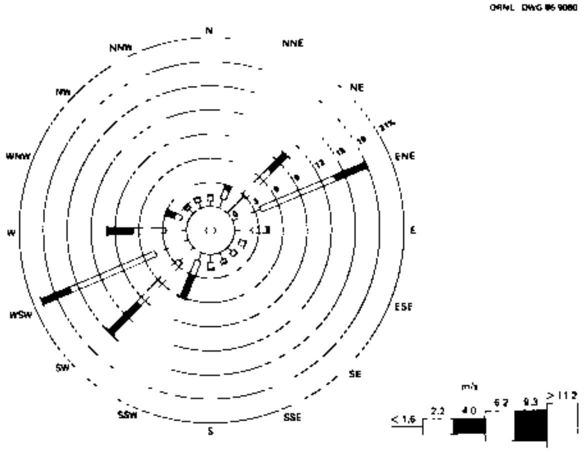

Fig. 3.2.12. 1985 annual wind rose at 30-m level of meteorological tower 4.

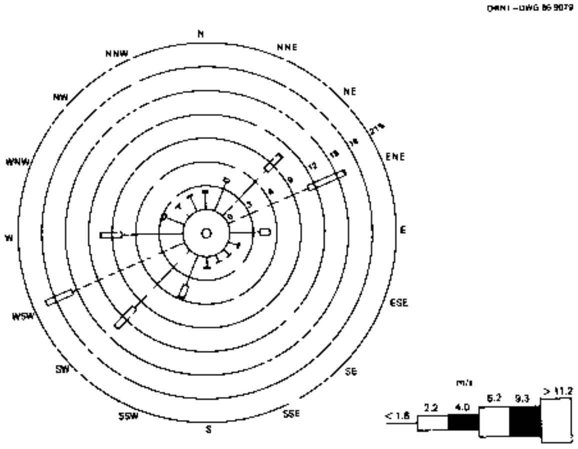

Fig. 3.2.11. 1985 annual wind rose at 10-m level of meteorological tower 4.

data.[9-10] Radioactive material taken into the body by inhalation or ingestion will continuously irradiate the body until it is removed by processes of metabolism or radioactive decay; thus, the estimates for internal dose are called "dose commitments," because they are obtained by integrating over the assumed remaining lifetime (50 years) of the exposed individual.[5]

The radiation doses to the total body and to the internal organs from external exposure to penetrating radiation are approximately equal, but they vary considerably for internal exposures because some radionuclides concentrate in certain organs of the body. For this reason, estimates of radiation to the major organs such as (but not limited to) thyroid, lungs, bone, liver, kidneys, and gastrointestinal tract were considered for various pathways of exposure. These estimates were based on parameters applicable to an average adult.[5] The population dose estimate in person-rems is the sum of the committed effective dose equivalents to exposed individuals within an 80-km radius of the DOE Oak Ridge facilities.

Gaseous effluents are discharged from several locations within each of the DOE facilities in Oak Ridge. For purposes of calculation, the gaseous discharges are assumed to occur from only one vent each at Y-12 and ORNL and two vents at ORGDP. As suggested by the EPA, no plume rise resulting from momentum (zero velocity stack discharge) was incorporated into the modeling program for Y-12, which has caps or vents out the sides of buildings. Meteorological data collected at the ORNL plant in 1985 were used for dispersion calculations for the ORNL and Y-12 sites; meteorological wind data at ORGDP collected in 1985 were used for the ORGDP site (See Sect. 3.2.2). Concentrations of radionuclides in air and deposited on the ground were estimated at distances up to 80 km from the DOE facilities using the Gaussian plume model developed by Pasquill[11] and Gifford[12] that has been incorporated in a computer program.[13-16]

Calculation of potential radiation dose to the public from airborne releases

Potential radiation doses to the nearest resident off-site individual, to the nearest population groups and to the population within 80 km of the Y-12 Plant were calculated. The calculations were made using computerized dispersion modeling techniques developed under the sponsorship of the EPA. The computer codes utilize Y-12 Plant radioactivity emission data for 1985 (See Section 2.1), local meteorological data from the meteorological tower at ORNL (see Section 3.2.2), and dose conversion factors based on guidelines of the ICRP. Organ weighting factors used in estimating effective 50-year dose commitments are based on ICRP recommendations and are also those used by the EPA. A whole-body dose equivalent was estimated for comparison with the NESHAP regulatory limit of 25-millirem whole-body dose. The whole-body dose equivalent resulting from radionuclides that are not deposited throughout the body is zero for internal exposure.[17] The 50-year dose conversion factors for inhalation are given in Table 3.2.2 and for ingestion are given in Table 3.2.3. The

Table 3.2.2. 50-year dose conversion factors[a]—inhalation

Radionuclide (solubility)		rem/μCi				
		Bone[b]	Lung[c]	Kidney	Thyroid	Stomach wall
^{3}H		0.000099	0.000125	0.000129	0.000124	0.000125
^{85}Kr		0.00000049	0.00000299	0.00000049	0.00000049	0.000000245
^{99}Tc		0.000176	0.0018	0.000176	0.00454	0.00927
^{131}I		0.000198	0.00344	0.000118	1.08	0.000257
^{133}Xe		0.00000050	0.00000196	0.000000564	0.000000571	0.000000312
^{234}U	(D)	39.7	1.66	16.9	0.0986	0.0986
	(W)	11.9	95	7.42	0.0432	0.045
	(Y)	4.05	938	1.69	0.00985	0.0122
^{235}U	(D)	40.2	1.54	15.7	0.096	0.0956
	(W)	17.6	88	6.88	0.042	0.045
	(Y)	3.95	868	1.57	0.0155	0.034
^{238}U	(D)	36.1	1.47	15.1	0.0886	0.0884
	(W)	15.8	84.2	6.65	0.000633	0.0412
	(Y)	3.53	833	1.51	0.0105	0.0183
^{244}Cm	(W)	4860	127	6.04	6.04	6.0

[a] Dose factors as they appear in EPA Clean Air Act tapes. Note: Number of significant figures based on what was used from the tapes.

[b] Endosteal cells of the bone.

[c] Pulmonary region of the lung.

Table 3.2.3. 50-year dose conversion factors[a]—ingestion

Radionuclide (solubility)		rem/μCi				
		Bone[b]	Lung[c]	Kidney	Thyroid	Stomach wall
^{3}H		0.0000656	0.0000836	0.000086	0.0000828	0.000108
^{85}Kr		[d]	[d]	[d]	[d]	[d]
^{99}Tc		0.000231	0.000231	0.000231	0.00598	0.0125
^{131}I		0.000288	0.000367	0.000174	1.67	0.00109
^{133}Xe		[d]	[d]	[d]	[d]	[d]
^{234}U	(D)	4.06	0.0097	1.7	0.0384	0.011
	(W)	4.06	0.0097	1.7	0.0384	0.011
	(Y)	0.163	0.000384	0.0662	0.000384	0.0045
^{235}U	(D)	3.93	0.0377	1.5	0.0375	0.011
	(W)	3.93	0.0377	1.5	0.0375	0.011
	(Y)	0.157	0.000387	0.0613	0.000376	0.00455
^{238}U	(D)	3.52	0.0346	1.5	0.0346	0.0049
	(W)	3.52	0.0346	1.5	0.0346	0.0049
	(Y)	0.141	0.000346	0.0592	0.000346	0.00398
^{244}Cm	(W)	40.0	0.050	0.050	0.050	0.0546

[a] Dose factors as they appear in EPA Clean Air Act tapes. Note: Number of significant figures based on what was used from the tapes.

[b] Endosteal cells of the bone.

[c] Pulmonary region of the lung.

[d] Dose factor of 0.

dose-rate conversion factors for air immersion are given in Table 3.2.4 and for ground surfaces are given in Table 3.2.5.

A total of 0.1 Ci of uranium was released by Y-12 in 1985. Because the chemical composition and assay are unavailable, it is assumed that the uranium was all ^{234}U with one-third of the total release chemically soluble in the lung (D-solubility), one-third moderately soluble (W-solubility), and one-third insoluble (Y-solubility). The uranium was released at a height of 20 m.

The whole-body dose equivalents are included in Table 3.2.6. The whole-body dose is estimated to be 0.000016 millirem (well below the 25-millirem limit).

Also included in Table 3.2.6 are the effective 50-year dose commitments and various organ doses that result from both internal and external exposure. Ingestion doses were calculated assuming that, for the nearest resident located approximately 570 m in the north-northwest direction, one-third of his food was grown in his own back yard and two-thirds was imported from outside the 80-km region (i.e., uncontaminated). The primary pathway of exposure is inhalation.

For population doses, it was again assumed that one-third of the food consumed was grown locally and two-thirds was imported. The whole-body dose equivalent to the population within 80 km was estimated to be 0.00042 person-rem (external dose only). The effective 50-year dose commitment to the population is 33 person-rem (weighted sum dose), due primarily to inhalation.

The whole-body dose equivalents from

Table 3.2.4. Dose-rate conversion factors[a]—air immersion

Radionuclide	millirem-cm^3/μCi-year				
	Bone[b]	Lung[c]	Kidney	Thyroid	Stomach wall
^{3}H	*d*	*d*	*d*	*d*	*d*
^{85}Kr	11,400,000	9,730,000	9,470,000	12,100,000	8,950,000
^{99}Tc	3,650	2,090	1,930	3,070	1,820
^{131}I	2,020,000,000	1,640,000,000	1,590,000,000	2,070,000,000	1,500,000,000
^{133}Xe	230,000,000	130,000,000	130,000,000	200,000,000	110,000,000
^{234}U	710,000	411,000	374,000	607,000	337,000
^{235}U	936,000,000	632,000,000	591,000,000	851,000,000	570,000,000
^{238}U	451,000	250,000	219,000	377,000	199,000
^{244}Cm	169,000	96,900	52,500	138,000	59,600

[a] Dose factors as they appear in EPA Clean Air Act tapes. Note: Number of significant figures based on what was used from the tapes.

[b] Endosteal cells of the bone.

[c] Pulmonary region of the lung.

[d] Dose factor of 0.

Table 3.2.5. Dose-rate conversion factors[a]—ground surface

Radionuclide	millirem-cm^2/μCi-year				
	Bone[b]	Lung[c]	Kidney	Thyroid	Stomach wall
^{3}H	*d*	*d*	*d*	*d*	*d*
^{85}Kr	2,350	2,010	1,950	2,490	1,840
^{99}Tc	0.862	0.492	0.455	0.725	0.429
^{131}I	429,000	347,000	336,000	437,000	318,000
^{133}Xe	62,900	35,600	38,500	57,000	29,700
^{234}U	295	174	100	231	111
^{235}U	207,000	139,000	131,000	188,000	126,000
^{238}U	209	121	58.5	157	72.1
^{244}Cm	205	124	20.7	159	56.2

[a] Dose factors as they appear in EPA Clean Air Act tapes. Note: Number of significant figures based on what was used from the tapes.

[b] Endosteal cells of the bone.

[c] Pulmonary region of the lung.

[d] Dose factor of 0.

ORNL releases are included in Table 3.2.6. Because uranium is not deposited throughout the body, this dose is only from external exposure. These whole-body dose equivalents result from uranium ground deposition and immersion in air.

Table 3.2.6. Calculated dose from airborne releases and risks to the nearest resident

	Dose[a] millirem (millisievert)						Fatal cancer cancer risk[e]
	Whole-body dose	Effective[b] dose	Bone[c]	Kidney	Lung[d]	Stomach wall	
				Y-12[f,g]			
	0.000016 (0.00000016)	1.7 (0.017)	0.78 (0.0078)	0.32 (0.0032)	8.3 (0.083)	0.0020 (0.000020)	0.000000028
				ORNL[h,i]			
	0.2 (0.002)	0.2 (0.002)	0.26 (0.0026)	0.31 (0.0031)	0.3 (0.003)	0.35 (0.0035)	0.000000033
				ORGDP[j,k]			
K-402-9	0.0000026	0.00028	0.0048	0.0020	0.00015	0.00081	0.000000000046
K-1420	0.0000040	0.00040	0.011	0.0046	0.00032	0.000033	0.000000000066
Total	0.0000066	0.00068	0.016	0.0066	0.00047	0.00084	0.0000000067
				Max			
	~0.2 (0.002)	<2 (0.02)	~1 (0.01)	<1 (0.01)	<9 (0.09)	<0.4 (0.004)	<0.00000006

[a] Fifty-year dose commitment.

[b] Weighted sum dose.

[c] Endosteal cells of the bone.

[d] Pulmonary region of the lung.

[e] Risk from one-year exposure was calculated using methods from Ref. 17.

[f] Nearest resident is 570 m NNW.

[g] Whole-body doses for uranium are from external doses only because it is not deposited throughout the body. Uranium considered one-third chemically soluble in lung (D-solubility), one-third moderately soluble (W-solubility), and one-third insoluble (Y-solubility).

[h] Nearest resident is 3048 m WSW.

[i] Whole-body doses for iodine, xenon, and krypton are from external doses only since they are not deposited throughout the body. The dose from ^3H includes internal as well as external pathways.

[j] Nearest resident is 3000 m WSW.

[k] Whole-body are doses from external doses only since they are not deposited throughout the body.

The whole-body dose is estimated to be 0.2 millirem (well below the 25-millirem limit). This dose includes external doses from all of the nuclides released plus the internal contribution from ^{3}H. Also included in Table 3.2.6 are the effective 50-year dose commitments and various organ doses that result from both internal and external exposure. Ingestion doses were calculated assuming that, for the nearest resident located approximately 3048 m in the west-southwest direction, one-third of the food consumed was grown in his own back yard and two-thirds was imported from outside the 80-km region (i.e., uncontaminated). The effective 50-year dose commitment is estimated to be 0.2 millirem. The primary pathway of exposure is ingestion; inhalation and air immersion also make significant contributions. The radionuclides contributing to the effective dose are ^{3}H and ^{133}Xe. The whole-body dose equivalent from ^{3}H includes both external and internal pathways because ^{3}H is considered deposited throughout the body.

For population doses, it was again assumed that one-third of the food consumed was grown locally and two-thirds was imported. The whole-body dose equivalent to the population within 80 km was estimated to be 7.2 person-rem (external dose from all nuclides plus the internal dose from ^{3}H). The effective 50-year dose commitment to the population is 7.3 person-rem (weighted sum dose), due primarily to inhalation.

Thus, the whole-body dose equivalent from all radionuclide releases at ORGDP results from external exposure only (i.e., ground deposition and immersion in air). Stacks K-1420 and K-402-9 were treated as separate release points. The estimated source terms for each stack are included in Table 3.2.7.

The whole-body dose equivalents from radionuclides released from both stacks are included in Table 3.2.6. The total whole-body dose is estimated to be 0.0000067 millirem (well below the 25-millirem limit). This dose is from external exposure from all of the nuclides released.

Also included in Table 3.2.6 are the effective 50-year dose commitments and various organ doses that result from both internal and external exposure. Ingestion doses were calculated assuming that, for the nearest residents located approximately 3000 m in the west-southwest direction, one-third of their food was grown in their own back yards and two-thirds was imported from outside the 80-km region (i.e., uncontaminated). The total effective 50-year dose commitment is estimated to be 0.00068 millirem. The primary pathway of expo-

Table 3.2.7. 1985 stack and release data for ORGDP[a]

Stack	Height (m)	Assay[b] (%)	Emissions (Ci/year)			
			^{234}U	^{235}U	^{238}U	^{99}Tc
K-402-9	23.0	3.2	0.00027	0.000015	0.000072	0.0030
K-1420	7.6	1.0	0.00041	0.000021	0.00033	*c*

[a] Uranium considered chemically soluble in lung (D-solubility).

[b] Percent enrichment of U-235.

[c] No ^{99}Tc released.

sure is ingestion; inhalation and air immersion also make contributions. The radionuclides contributing to the dose are primarily ^{234}U and ^{99}Tc from stack K-402-9, and ^{234}U from stack K-1420. Table 3.2.8 lists the effective 50-year dose commitment within the 80-km region.

Table 3.2.8. Effective 50-year person-rem dose commitment to population within 80 km

Installation	Person-rem	Person-Sievert
Y-12 Plant	33	0.33
ORNL	7.2	0.072
ORGDP	<0.00015	<0.00015
Total	<41	<0.41

Doses from drinking water

Water is sampled at White Oak Dam to determine discharges of radionuclides to the Clinch River. Based on radionuclide concentrations measured at White Oak Dam and the dilution afforded by the Clinch River (assuming complete mixing), a 0.2-millirem calculated effective dose equivalent results from consumption of Clinch River water at CRK 33.3. This is based on the adult liquid requirement (730 L/year) and the concentration in water taken at location W2 (see Sect. 4.3). Water is also sampled at the inlet to the ORGDP water plant, which is the closest (14 km) nonpublic water supply downstream from DOE discharges. Assuming that (1) the water is consumed at a rate of 730 L/year and (2) the treated water contains the same amount of radionuclides as the sampled inlet water, the calculated committed effective dose equivalent would be 0.32 millirem. The public water supply closest to the DOE facilities' liquid discharges is located about 26 km downstream at Kingston, Tennessee. The intake to the water filtration plant is located on the Tennessee River about 0.8 km upstream from the confluence of the Clinch and Tennessee rivers. Normally, Tennessee River water is used for the Kingston water supply, but under certain conditions backflow can occur. Under backflow conditions, Clinch River water may move upstream in the Tennessee River and be used as the source of water for the Kingston filtration plant. Measurements of treated river water samples taken at the Kingston filtration plant indicated that the maximum dose resulting from the ingestion of the adult daily requirement (730 L/year) is 1.5 millirem to the bone's endosteal cells and 0.12 millirem for the committed effective dose equivalent. The annual effective dose equivalent from drinking ORNL tap water (derived from Melton Hill Lake) was 0.73 millirem to the bone's endosteal cells and 0.070 millirem for the committed effective dose equivalent. Estimated radiation doses from ingestion of water are given in Table 3.2.9. The highest effective total-body dose (5.5 millirem) assumed drinking 730 L/year of water from East Fork Poplar Creek. No one is known to drink any water from East Fork Poplar Creek—this is the worst-case assumption.

Calculation of potential radiation dose to the public from ingestion of Clinch River fish

Fish were collected and analyzed, and results are given in Sect. 4.5. The calculations were based on concentrations of eight radionuclides in the flesh of bluegill, bass, and carp. The calculated doses depend on the multiplication of an assumed rate of ingestion of 20 kg of fish

Table 3.2.9. Doses from drinking water[a]

Location	Dose[b] millirem (millisievert)									
	Effective total-body[c]		Bone[d]		Kidney		Liver		Stomach wall	
Melton Hill Dam	0.32	(0.0032)	1.3	(0.013)	1.2	(0.012)	0.20	(0.0020)	0.30	(0.0030)
Gallaher process water	0.32	(0.0032)	2.5	(0.025)	1.1	(0.011)	0.18	(0.0018)	0.22	(0.0022)
Kingston	0.12	(0.0012)	1.5	(0.015)	0.67	(0.0067)	0.020	(0.00020)	0.020	(0.00020)
ORNL tap water	0.070	(0.00070)	0.73	(0.0073)	0.98	(0.0098)	0.013	(0.00013)	0.013	(0.00013)
East Fork Poplar Creek	5.5	(0.055)	22	(0.22)	86	(0.86)	0.13	(0.0013)	0.60	(0.0060)
Clinch River km 33.3	4.1	(0.041)	3.0	(0.30)	3.8	(0.038)	3.9	(0.039)	4.9	(0.049)

[a] Yearly intake of 730 L.

[b] Fifty-year dose commitment.

[c] Weighted sum dose.

[d] Endosteal cells of the bone.

Table 3.2.10. 50-year committed dose-equivalent conversion factors used for fish calculations

Radionuclide	millirem/pCi ingested ORNL[a]	EPA[b]
^{60}Co	0.000027	0.000025
^{90}Sr	0.00014	0.00013
^{137}Cs	0.00005	0.000047
^{234}U	0.00028	0.00027
^{235}U	0.00027	0.00026
^{238}U	0.00025	0.00024
^{238}Pu	0.004	0.0038
^{239}Pu	0.0044	0.0043

[a] Source: Ref. 18.

[b] EPA tapes.

flesh in a year and the dose conversion factors given in Table 3.2.10 for the ingestion of each of the eight radionuclides. The 50-year committed effective dose equivalents from consumption of Clinch River fish are given in Table 3.2.11 and the sums over all radionuclides are given in Table 3.2.12. These results indicate that the highest doses are at Clinch River kilometer (CRK) 33.3.

From the analysis of edible tissue parts of the fish, the maximum 50-year committed effective dose equivalent to an individual is estimated to be 1.2 millirem. This dose was estimated using bass collected at CRK 33.3. The primary radionuclides contributing to the dose are ^{137}Cs and ^{90}Sr. The second highest effective dose equivalent was calculated to be 0.64 millirem from ingestion of bluegill caught at CRK 33.3. The primary radionuclides contributing to this dose were ^{137}Cs and ^{90}Sr.

A better estimate of the maximum potential dose from the aquatic (fish) pathway is derived from the annual average effective dose equivalents. The radionuclides contributing primarily to this dose were ^{137}Cs and ^{90}Sr.

Fish samples taken from Melton Hill Lake (CRK 40.0) were analyzed to determine background conditions. Bass caught and consumed from this location would yield an effective dose equivalent of 0.06 millirem. Fish caught from other locations in the Clinch River and ingested

Table 3.2.11. 50-year committed effective dose-equivalent from consumption of Clinch River fish

		Radionuclide							
Location	Fish species	^{60}Co	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu
					Dose (millirem)[a]				
Clinch River km 40.0									
	Bass	0.0	0.0029	0.013	0.0035	0.00018	0.0021	0.000079	0.000079
	Bluegill	0.0	0.0037	0.022	0.011	0.0012	0.0049	0.00015	0.000097
	Carp	0.0	0.029	0.012	0.0091	0.0020	0.0041	0.000055	0.000018
Clinch River km 33.3									
	Bass	<0.0053	0.13	1.2	0.0068	0.0012	0.0024	0.000095	0.000044
	Bluegill	0.0075	0.34	0.64	0.015	0.0019	0.0056	0.000095	0.00014
	Carp	<0.0033	0.13	0.22	0.005	0.00075	0.003	0.000071	0.00061
Clinch River km 19.2									
	Base	<0.0015	0.014	0.1	0.0056	0.00069	0.0034	<0.000063	<0.000062
	Bluegill	<0.0035	0.051	0.037	0.029	0.0026	0.014	<0.00017	0.00047
	Carp	<0.0017	0.037	0.029	0.018	0.0015	0.013	0.0001	0.00047
Clinch River km 16.0									
	Bass	<0.0011	0.013	0.13	0.0043	0.00051	0.0035	0.0021	0.00039
	Bluegill	0.0044	0.027	0.069	0.011	0.00064	0.0056	0.0011	0.00033
	Carp	0.017	0.063	0.019	0.0079	0.0008	0.0038	0.00034	0.00015
Clinch River km 8.0									
	Bass	<0.00086	0.013	0.099	0.0056	0.0011	0.0028	0.0017	0.00073
	Bluegill	<0.0025	0.068	0.042	0.0096	0.00069	0.0082	0.00013	0.00063
	Carp	<0.00075	0.077	0.047	0.0079	0.00085	0.0061	0.00037	0.000071
Clinch River km 3.2									
	Bass	<0.0010	0.00088	0.046	0.0036	0.00075	0.0019	0.000032	0.00078
	Bluegill	<0.0026	0.088	0.034	0.012	0.0020	0.0061	0.00020	0.000097
	Carp	<0.00097	0.0071	0.055	0.0056	0.00040	0.0033	0.00051	0.000062

[a] Millirem = 0.01 millisievert.

would result in significantly lower effective doses than the annual average dose from bass at CRK 33.3.

Because individuals in the past have been known to consume carp patties prepared by grinding the fish flesh and bone, concentrations in carp bone were determined (Sect. 4.5). These patties contain all bones (including back and rib) but not including the head, skin, and fins. Because no data are available on the quantities of carp patties that might be consumed by an individual in a year, 10 kg/year was assumed. As would be expected, carp caught at CRK 33.3 (the confluence with White Oak Creek) had the highest concentration of ^{90}Sr in bone. Consumption of 10 kg of fish patties containing the maximum amount of ^{90}Sr would result in a committed effective dose equivalent of 0.6 millirem and a committed dose equivalent to the bone (endosteal

Table 3.2.12. Total 50-year committed effective dose-equivalent from ingestion of Clinch River fish[a]

Location	Fish species	Dose (mrem)[b]	Dose (msv)[c]
Clinch River	km 40.0		
	Bass	0.22	0.0022
	Bluegill	0.043	0.00043
	Carp	0.056	0.00056
Clinch River	km 33.3		
	Bass	1.3	0.013
	Bluegill	1.0	0.010
	Carp	0.36	0.0036
Clinch River	km 19.2		
	Bass	0.13	0.0013
	Bluegill	0.14	0.0014
	Carp	0.1	0.001
Clinch River	km 16.0		
	Bass	0.16	0.0016
	Bluegill	0.12	0.0012
	Carp	0.11	0.0011
Clinch River	km 8.0		
	Bass	0.12	0.0012
	Bluegill	0.13	0.0013
	Carp	0.14	0.0014
Clinch River	km 3.2		
	Bass	0.055	0.00055
	Bluegill	0.15	0.0015
	Carp	0.073	0.00073

[a] Total 50-year committed effective dose-equivalent summed over all radionuclides per location and fish species..

[b] Millirem.

[c] Millisievert.

cells) of 6 millirem. This is based on an assumption that 10% of a carp patty is bone.

Maximum direct radiation exposure

The point of maximum potential ("fence-post") direct radiation exposure on a site boundary is located along the bank of the Clinch River at external gamma radiation measurement location T51 (Sect. 4.2). The maximum dose results primarily from "sky shine" from an experimental plot in the ^{137}Cs field (0800 area). This dose equivalent was calculated to be 250 millirem, assuming that an individual remained at this point 24 h/d for the entire year (worst case). The probability of exposure at this location is considered remote because the area is normally accessed by boat. The total-body dose to a "hypothetical maximally exposed individual" at the same location was calculated using a more realistic upper limit residence time of 250 h/year. The calculated dose equivalent under these conditions was 7.3 millirem, which represents a probable upper limit of exposure (assuming 5 h/week fishing at this location).

Dose from consumption of milk

An important contribution to dose from radioactivity within the terrestrial food chain is through the atmosphere→pasture→cow→milk pathway. Measurements of ^{90}Sr, the principal radionuclide entering this pathway, indicate that the maximum effective dose to an individual in the immediate area from ingestion of 1 L of milk per day is less than 0.01 millirem effective dose equivalent and 0.2 millirem to the critical organ, bone endosteal cells. The average concentrations for the remote stations were assumed to be derived from background radioactivity and were subtracted from the perimeter station data. Another radionuclide of concern in milk is ^{131}I; analysis for ^{131}I was negative. Both of these doses were rounded to one significant digit. Data used for these calculations are given in Sect. 4.7.

Summary of effective and critical organ doses and five-year trends

A summary of the 1985 effective and critical organ doses from each of the pathways is given in Table 3.2.13. The effective and critical organ doses for the inhalation pathway for 1981 through 1985 are shown in Figs. 3.2.13 and 3.2.14, respectively. The effective and critical organ doses from consumption of milk for 1981 through 1985 are given in Figs. 3.2.15 and 3.2.16, respectively. The effective and critical organ doses for ingestion of fish for 1981 through 1985 are given in Figs. 3.2.17 and 3.2.18, respectively. Effective and critical organ doses for drinking water at Kingston, Tenn., for 1981 through 1985 are given in Figs. 3.2.19 and 3.2.20, respectively. Direct radiation doses for 1981 through 1985 are shown in Fig. 3.2.21.

Radiation exposure calculations for historical releases (1946–1984) and estimated human health impact

The total radiation exposure of all residents within 24 km and 80 km (15 and 50 miles) of ORGDP has been calculated based on total uranium emissions recorded from 1946 through 1984 and other radionuclide emissions recorded from 1974 through 1984. Table 3.2.14 shows the human health impacts from these releases. These data indicate a total of approximately 1200 person-rem effective dose over those periods for an 80-km radius and approximately 200 person-rem effective dose for a 24-km radius from ORGDP. This compares with the expected total population effective dose of 4,900,000 person-rem from natural sources of radiation in the same 80-km radius and approximately 800,000 person-rem from natural sources of radiation for the 24-km radius. These latter calculations take into account the increasing population since 1946 and an average annual background dose per person of 200 millirem. Potential health effects (fatal cancers) were estimated by multiplying the total population dose of 1200 person effective dose rem by 1.65×10^{-4} (0.000165) health effects per person-rem. The resulting estimate is a 0.2 probability of one health effect occurring. This means that a 0.2 probability of one fatal cancer occurring exists within an 80-km radius of ORGDP as a result of the total emissions (Sect. 2.2). A value of 1.0 would mean that approximately one fatal cancer, somewhere within an 80-km radius of ORGDP could occur as a result of known uranium and radionuclide discharges from ORGDP in the last 39 years. The most likely pathway of exposure to people within this 80-km radius is inhalation. The most probable health effect from inhaling airborne uranium and radionuclides is lung cancer. From all causes, 11,000 lung cancers are expected to occur within this 80-km radius of ORGDP in 39 years. Based on these calculations, of the 11,000 lung cancers, it is unlikely that one fatal cancer could be attributed to radionuclide and uranium releases from ORGDP.

Another way to consider the impact to the public regarding uranium and radionuclide releases from ORGDP is to determine the yearly dose to those members of the public receiving the maximum exposure. Calculations of the dose for measured uranium and all other radionuclide discharges in 1985 to the maximally exposed members of the public indicate that less than 1 millirem of effective total-body dose occurred. This is

Table 3.2.13. **Summary of the estimated radiation dose to an adult during 1985 at locations of maximum exposure**

Pathway	Location	Effective dose millirem (millisievert)[a]	Critical organ millirem (millisievert)[a]
Gaseous effluents Inhalation plus direct radiation from air, ground, and food chains	Nearest resident to Y-12 (370 m NNW)	1.7 (0.017)	8.3 (0.083) (Lung)
	Nearest resident to ORNL (3048 M WSW)	0.2 (0.002)	0.35 (0.0035) (Stomach wall)
	Nearest resident to ORGDP (3000 M WSW)	0.00068 (0.0000068)	0.016 (0.00016) (Bone)
	Maximum from all three facilities	~2 (~0.02)	~8.6 (0.0086) (Lung)
Terrestrial food chain (Milk)	Milk sampling Stations (^{90}Sr only)	0.01 (0.0001)	0.2 (0.002) (Bone)
Liquid effluents			
Aquatic food chain	Clinch River System		
Flesh		1.3 (0.013)	3.5 (0.035) (Bone)
Patties		0.6 (0.006)	6.0 (0.060) (Bone)
Drinking water	Clinch River km 40.0	0.32 (0.0032)	1.3 (0.013) (Bone) 1.2 (0.012) (Kidney)
	Clinch River km 33.3	4.1 (0.041)	3.0 (0.030) (Bone) 3.8 (0.038) (Kidney) 3.9 (0.039) (Liver) 4.9 (0.049) (Stomach wall)
	Clinch River km 19.2 ORGDP	0.32 (0.0032)	2.5 (0.025) (Bone) 1.1 (0.011) (Kidney)
	ORNL tap water	0.070 (0.00070)	0.73 (0.0073) (Bone) 0.98 (0.0098) (Kidney)
	Kingston	0.12 (0.0012)	1.5 (0.015) (Bone) 0.67 (0.0067) (Kidney)
Direct radiation along water, shores, and mud flats	Clinch River km 33.3 to 33.0	7.3 (0.073) (250 h/year)	

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[a] Millisievert = 100 millirem.

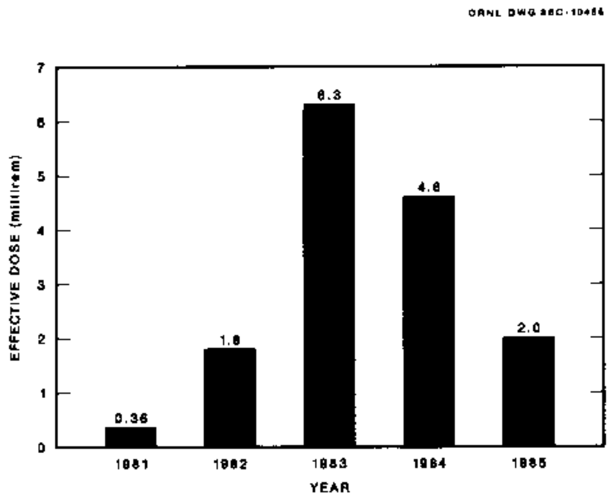

Fig. 3.2.13. Effective dose from inhalation pathway, 1981–1985.

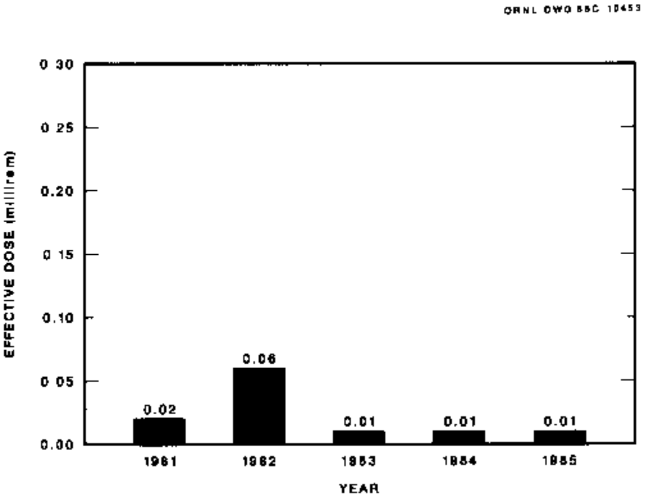

Fig. 3.2.15. Effective dose from milk consumption, 1981–1985.

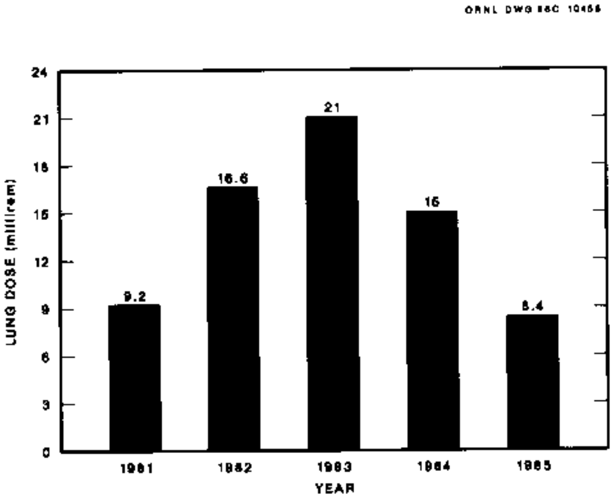

Fig. 3.2.14. Critical organ dose from inhalation pathway, 1981–1985.

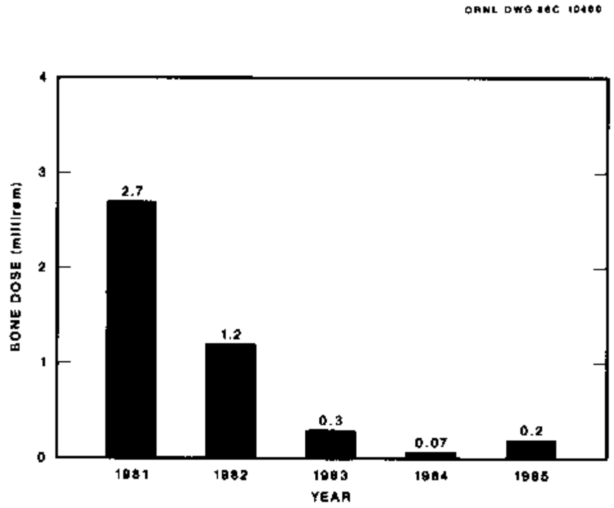

Fig. 3.2.16. Critical organ dose from milk consumption, 1981–1985.

compared with an effective total-body dose for each person of about 200 millirem per year from natural background radiation. Dose estimates for ORGDP were made using the AIRDOS mathematical model. All major pathways of exposure from airborne releases (inhalation, ingestion, and direct radiation) were considered in the calculations.

The total radiation exposure of all residents within 80 km of the Y-12 Plant has been calculated based on enriched uranium airborne emissions recorded from 1944 to 1984 plus estimated airborne emissions from other sources (see Sect. 2.2). These data indicate a total of 11,377 person-rem over that period compared with the expected total population dose of

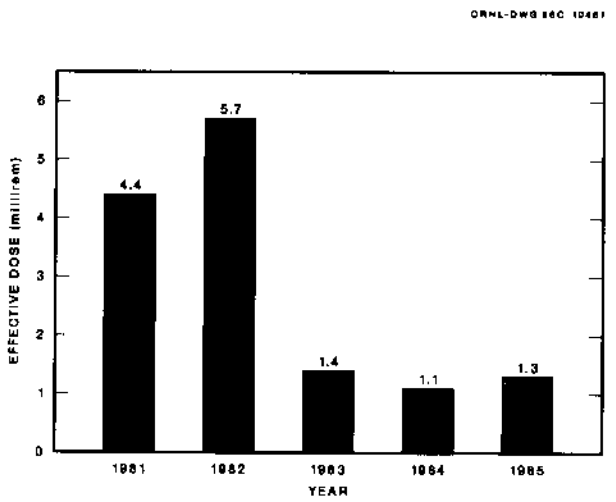

Fig. 3.2.17. Effective dose from ingestion of fish, 1981–1985.

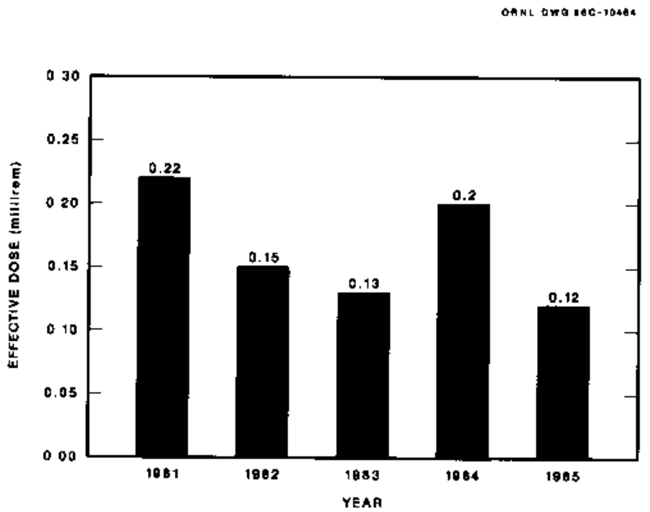

Fig. 3.2.19. Effective dose from water (Kingston) consumption, 1981–1985.

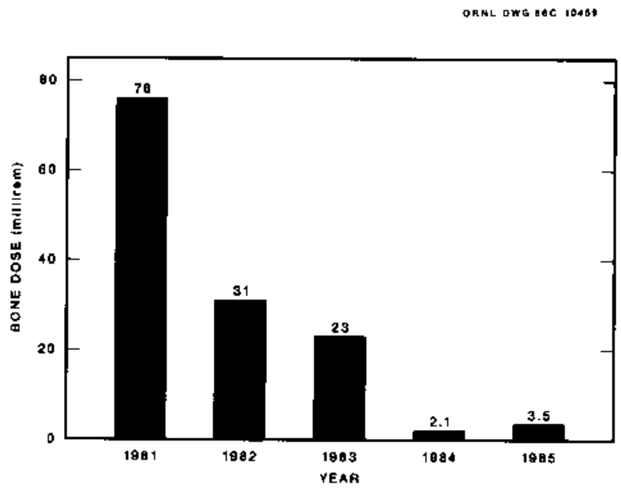

Fig. 3.2.18. Critical organ dose from fish ingestion, 1981–1985.

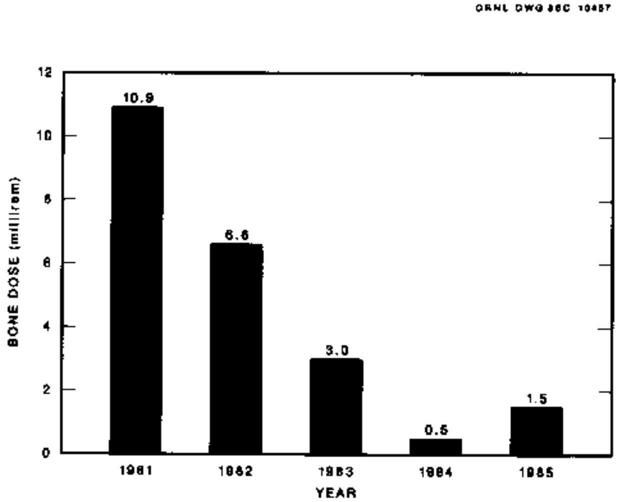

Fig. 3.2.20. Critical organ dose from water (Kingston) consumption, 1981–1985.

4,900,000 person-rem from natural sources of radiation in the same 80-km radius. This latter calculation takes into account the increasing population since 1944 and an average annual background dose per person of 200 millirem. Potential health effects (fatal cancers) were estimated by multiplying the total population dose (11,377 person-rem) by 1.65×10^{-4} (0.000165) health effects per rem. The resulting estimate of 1.4 health effects can be interpreted to mean that approximately one fatal cancer could occur as a result of historic uranium discharges. This possible fatal cancer could occur somewhere in an 80-km radius of the Y-12 Plant. These data are given in Table 3.3.15.

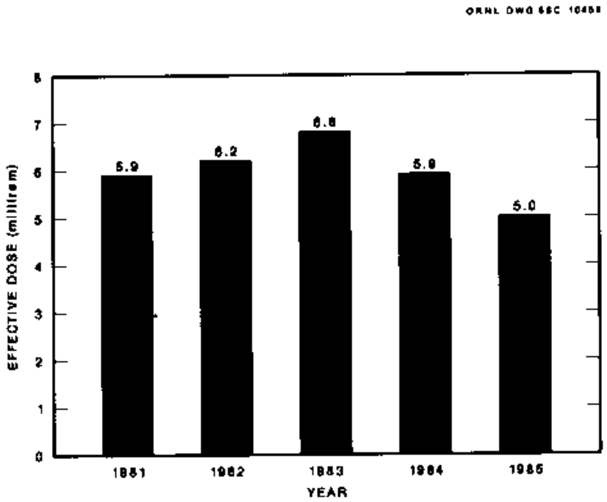

Fig. 3.2.21. Direct radiation doses, 1981–1985.

3.2.4 Dose Modeling and Its Limitations

Models use data and assumptions to make predictions. These predictions may or may not agree with measurements; however, because doses and health effects at these concentrations are below current measurement techniques, models must be used. Needed are data and assumptions about meteorology, population distributions, how radioactive material gets into the body and what it does once it gets there, and a host of other parameters.

The problem is not unique to calculations dealing with public radiation dose. To estimate air pollution and its effects, the EPA and other groups use complex models. Oceanographers employ similarly complicated models to project ocean and weather conditions. In general, determining the overall effect of substances moving through air, water, and land will require some type of modeling.

All of the DOE facilities evaluated have monitoring stations. However, they do not have enough stations to precisely state the air concentrations at every point within an 80-km (50-mile) radius of these facilities. It might take thousands of these stations to make measurements, so a model has to estimate concentrations in places where there are no stations. There is often a difference of a factor of 2 or

Table 3.2.14. Health effects from ORGDP releases of uranium 1944–1984

	Population within 80 km (50 miles)
Average annual dose	~20 person-rem
Percentage of background	0.02
Accumulated dose (39 years)	~850 person-rem
Health effects (fatal cancers)	0.1
	Population within 24 km (15 miles)
Average annual dose	~4 person-rem
Percentage of background	0.02
Accumulated dose (39 years)	~170 person-rem
Health effects (fatal cancers)	0.02

Table 3.2.15. Health effects from Y-12 releases of uranium 1944–1984[a]

	Population within 80 km (50 miles)
Average annual dose	~285 person-rem
Percentage of background	0.16
Accumulated dose (40 years)	~11,377 person-rem
Health effects (fatal cancers)	1.4

	Population within 24 km (15 miles)
Average annual dose	~145 person-rem
Percentage of background	0.31
Accumulated dose (40 years)	~5,790 person-rem
Health effects (fatal cancers)	0.72

[a] All doses are effective total-body dose equivalent.

more between measured and modeled levels.

One area where modeling is especially useful is in estimating the dose to the maximally exposed person. Using the effluent data in combination with the concentration measurements alone will not identify the location of the hypothetical person or what dose he or she receives. A mathematical model can do this more inexpensively than other methods.

In summary, there are many fundamental limitations to any mathematical dose model. Yet there are other limitations, possibly as fundamental, in interpreting some of the concentration and effluent measurements made on radionuclides. As a result, none of the data or models used here can be (or are) considered perfect.

A mathematical model is needed to estimate the total radiation dose incurred by the population (population dose) surrounding a DOE discharging facility, as well as to estimate the maximum dose received by any individual member of the public.

The AIRDOS-EPA model (referred to as AIRDOS) is one of a number of computer codes used to estimate radiation dose to the public from airborne emissions. Liquid effluents and releases from the burial of solid wastes have to be evaluated by other models.

The advantages of the AIRDOS model are two-fold. First, it agrees reasonably well—usually within a factor of 2 or 3—with measurements of radioactivity concentrations in air at the locations where it has been tested. Second, the EPA has used it in setting some of its air quality requlations.

The AIRDOS model calculates annual doses to the public by estimating radionuclide concentration in air; the rate of deposition of these radionuclides to the ground; their concentration on the ground; concentrations in streams into which radionuclides have fallen; human intake of radionuclides by inhalation; concentration in meat, milk, and fresh vegetables grown in areas where the radionuclides have fallen; and doses to humans from eating this food and breathing this air and drinking this water.

The dispersion of radionuclides into the air from their original source is described mathematically by using a so-called

Gaussian plume model. This type of model is common. It is mandated for many regulatory applications by the EPA and is found in various forms in a variety of "preferred" or "alternative" dispersion models. The governing dispersion parameters used in this model have been studied extensively.

AIRDOS has been used in a validation study around the Savannah River Plant at Aiken, South Carolina, and ORNL. Results indicate that the annual predicted ground-level air concentrations exceeded the observed value for each of the 13 stations examined. The average factor of overprediction was about 2. This suggests that the likelihood of AIRDOS underpredicting doses is probably small. Potential underprediction, or lack of conservatism, is usually avoided by risk analysts whenever possible. AIRDOS is available to the public through the Radiation Shielding Information Center at ORNL.[13]

Some of the major assumptions, both numerical and otherwise, used in the AIRDOS model follow.

(1) The population within 80 km of the ORR was used to calculate total dose. The 1980 census showed about 800,000 people within this radius for the three major DOE facilities in Anderson and Roane counties. The 80-km radius is commonly used in radiological dose assessment calculations.

The radionuclide discharges in this report are historic in nature, going back in at least one instance to 1946. It clearly is inappropriate to use present population numbers in evaluating the releases of decades ago. Estimates of the population around the facilities were based on censuses going back to 1940, with appropriate interpolation. Because population data on areas smaller than counties are difficult to obtain for the years before 1970, the distribution in direction about the facilities in the 1980 census was assumed to prevail in earlier years.

(2) The direction and speed of the wind clearly affect where and when the radionuclides fall. To avoid the complication of daily or weekly wind data, an annual compilation for the year 1985 was used for Y-12, ORNL, and ORGDP. It is then assumed that this year is representative of previous and subsequent years.

(3) Most people spend 80-90% or more of their lives indoors. This will tend to reduce the intake of radionuclides due to breathing outdoor air, although their dose reduction may be reversed by breathing indoor-generated radon, which has nothing to do with DOE facilities. The AIRDOS model assumes that the entire population lives outdoors continually, thus maximizing potential radionuclide intake. This is another example of conservatism, or the likely overestimation of dose.

(4) There are few people left who produce all their meat and vegetables. The AIRDOS model assumes that 30% of food eaten in this region originates there, and that the rest is imported from outside.

(5) The size of the radionuclide particles, or the dust particles to which they are attached, is significant in estimating radiation dose. In general, the smaller the particles, the more they stay in the lung, and the greater the dose to the lung. Larger particles are removed in the nasal region. Because inhalation usually is one of the largest sources of dose, the particle size assumption is crucial to model results. In the calculations, a representative radius of one micron was assumed. (A micron is one millionth of a meter, or about one-hundredth the thickness of this page.)

(6) The degree of solubility of the radionuclides affects the behavior of

radionuclides in the body. The faster they dissolve in water, the faster they move away from the lungs to other parts of the body. The dose to other organs then depends on the solubility. For ORGDP, it was estimated that 90% of the particles were very soluble by the time they entered the body, and 10% were of medium solubility. For the Y-12 Plant, it was estimated that equal numbers of particles fall in the high, medium, and low solubility classes. These estimates are based on the chemical nature of the radionuclides emitted from each plant.

(7) The dose to organs of the body depends on the length of time the radionuclides remain in the organ. For some radionuclides, natural elimination removes them within hours or days; for others, the radionuclides may remain for many years, irradiating the organ in question over this time. In these calculations, a cutoff period of 50 years was assumed as the longest period considered.

(8) The AIRDOS model considers only airborne releases. Yet this report shows data on liquid effluents and concentrations. Should they be included in the dose calculations?

It is stated in a 1979 publication[19] that the dose equivalents from ingestion of waterborne radionuclides deposited in streams from airborne releases by all DOE facilities were less than 1% of the dose equivalents from inhalation of airborne radionuclides. More recent calculations suggest that, on the basis of measured effluents into nearby creeks and rivers from the Oak Ridge facilities, dose equivalents from waterborne radionuclides are about 1 to 2% of the dose equivalents of airborne radionuclides. Even these small ratios are probably higher than reality, since it was assumed that no radionuclides are removed from the water by a process such as water treatment plants before they get to the consumer. Some radionuclides undoubtedly are. If these studies are any indication of the relative impact of the ratio of waterborne to airborne uranium effects, then it is reasonable not to include waterborne radioactive doses, at least to a first approximation.

Almost the same point can be made about burial of solid wastes. The largest source of radioactivity from the Oak Ridge facilities, both in terms of weight and curies of activity, is solid wastes. The dose produced from these wastes will depend on how much radioactivity moves from these wastes into water that is subsequently used by the public. Based on measurements, in almost all cases the amount is close to zero. Preliminary calculations done for other locations have confirmed that the doses produced from radionuclide migration from solid wastes, at their present measured levels, will be extremely small in comparison with airborne-related doses.

(9) The size of the dose from natural radiation background, present regardless of the existence of DOE facilities, does not enter into AIRDOS calculations. However, because the population dose computed by AIRDOS can be compared with that of the background dose, a few words about the assumptions are in order.

Background radiation varies somewhat with location. The higher the population is above sea level, the higher the dose from cosmic rays from outer space. The more uranium and thorium in earth or rocks, the higher the background. As an example, the U.S. average background of 200 millirem per year (effective total-body dose) was assumed, to be made up of

(a) about 30 millirem from cosmic rays, (b) 30 millirem from potassium in the body, (c) 80 millirem from radon, and (d) 60 millirem from other sources.[17] A population of one million would then receive a total annual dose of 1,000,000 × 0.200 = 200,000 person-rem.

3.3 REVIEW OF ASSUMPTIONS FOR HEALTH EFFECTS

A key assumption in this analysis is that cancers are statistical in nature. That is, a particular person or persons cannot be identified as having contracted cancer as a result of emissions from the Oak Ridge facilities. All that can be stated is that there may be X deaths, where X is the number or numbers in the main body of this report.

In this sense, the problem is the same as that facing those who have estimated the risk associated with smoking cigarettes. In general, those who will fall victim to cigarette-induced lung cancer, heart disease, or other ailments cannot be named. In some extreme cases, when, for example, someone who has been smoking 4 packs a day for 40 years contracts lung cancer, it can be said with virtual certainty that cigarettes are the cause. But there are other instances where an extremely heavy cigarette smoker does not contract lung cancer. As a result, there is no list of names of these who have been felled by cigarettes.

Because the health effects due to radionuclide inhalation or ingestion are not peculiar to those radionuclides, the cancer cases that are due to this source cannot be identified. If cancer were both rare and attributable mostly to radiation, it could be done. At present, it cannot.

In this report, the final results in terms of health effects are expressed as partial or fractional fatal cancers. The number of health effects due to releases may be shown as 0.7 to 0.9, for example. This fractional value comes about because of the nature of the mathematical model.

Obviously, there is no such thing as a partial death. In terms of this report, the meaning of these numbers can be visualized as follows: suppose that the radioactive releases producing 0.1 death for a given site had been duplicated in ten sites, each with exactly the same geography, meteorology, and so on. Within these ten sites, there would have been a strong chance that almost all would have shown no extra cancer resulting from radionuclide releases, a slight chance that one or two sites would have shown one extra cancer, and an almost vanishing chance that one site would have shown two or more. In the language of the mathematician, the fractional values represent the average of a Poisson distribution.

There is considerable uncertainty in the results and conclusions of health effects studies. In most instances, if not all, these uncertainties probably overestimated rather than underestimated the health effects.

A thorough discussion of all the potential uncertainties would take up considerable room and require much technical detail. For brevity, just a few major sources of uncertainty are noted.

(1) The single number chosen for converting person-rems into fatal cancers (0.000125 deaths per person-rem) and genetic effects (0.000040 deaths per person-rem) is 0.000165 deaths per person-rem,[17] which may give the illusion of precision. Radiation scientists working on International Commission on Radiological Protection Committees generally believe that this value forms an upper

limit.[3] The lower limit is unknown, although some scientists feel it may be as low as zero. While the band of uncertainty cannot be defined mathematically as yet, the fact that it exists makes the overall results less than precise. The number of cancer deaths estimated in this report is considered an estimate because we don't know all historic radioactive releases.

(2) The entire mathematical modeling process is itself subject to much uncertainty. The physical spread of radionuclides through air and water and into bodies and specific organs is a complicated process. Some of the specific areas of uncertainty are outlined in the section on the AIRDOS model (Sect. 3.2.4), which in these respects is similar to other models. The uncertainties include population questions, shielding of humans from radiation, the degree of radiation in food, how body organs react to radiation, the solubility of radionuclides in the body, etc. It is nearly impossible to estimate the overall degree of uncertainty produced as a result of these individual uncertainties. The scientists consulted on this question feel that because of the stringent (or conservative) assumptions used in the model, it will almost certainly yield an overestimate of the population dose.

(3) Much of the data on emissions to air, water, and land is itself uncertain. In the past, the present level of measurement and analysis was sometimes not achieved. This in turn led to estimates, rather than measurements, being made occasionally.

While past measurements are not always up to today's standards because of technical capabilities, these values must be estimates. Unfulfillable desires, or annoying uncertainties, were, are, and will be with us these measurements.

(4) Similar statements about uncertainty can be made about the environmental, as contrasted to the effluent, measurements. Over the years, measurement techniques have improved dramatically. These improvements have made earlier measurements relatively uncertain in retrospect. Since the samples are no longer available, there is no way the measurements can be redone using more precise and accurate techniques.

(5) There are three isotopes of uranium, with atomic weights of 234, 235, and 238, that can be emitted from DOE installations. The dose incurred by the public will depend largely on their proportion. In some cases, especially in air emissions, these proportions are or were not precisely known.

(6) There is a time delay associated with any cancers induced from the calculated radiation dose. This uncertainty in terms of time is not of the same nature as those that deal with quantity. Yet it produces uncertainty in the conclusions to be drawn. The implication may have been given in the calculations that any health effects occur shortly after the radionuclides enter the body of the person who will eventually die. This is not the case. While the time delay in the effect depends on the type of cancer induced, specialists have estimated a delay of between 5 and 30 years between the time the dose is received and when the fatal cancer appears. A fatal cancer produced as a result of a dose in 1946, by this estimation, may have shown up as early as 1951 or as late as 1976. Similarly, a dose of today may show up in cancer mortality tables as early as 1990 or as late as 2015. The type of fatal cancer that will be produced, or when it will occur, is not known. Because a natural way of thinking is to assume that effects follow shortly after

cause, the question of time delays produces uncertainty in linking the two.

In summary, these are some of the major and minor sources of uncertainties in both the data and the calculations based on them. Some, like those associated with modeling and the ratio of dose to health effects, probably overlap. Others, like changes in instrumentation and measurement over the years, probably are smaller areas of uncertainty. While it would be desirable to be able to say, as the statisticians do, that the results have a plus-or-minus of so much attached to them, it cannot be done. The uncertainties are of such a disparate nature that at present they cannot be combined mathematically.

The number of cancer deaths varies strongly from year to year and place to place.[20] Table 3.3.1 shows the variation in cancer mortality among both white and non-white males around Anderson and Roane counties, Tennessee (the site of the Y-12 Plant, ORNL, and ORGDP), for the years 1960–69 and 1970–79. Note that this is the total mortality, including dozens of specific types of cancer. This is not the *incidence* of cancer, which would include both fatal and non-fatal cases. It is likely that about the same conclusions would be drawn for data on cancer incidence among the same two groups.

Statistical tests can be performed to estimate how variable these numbers are with respect to the estimated fatal cancers due to the DOE facilities. However, a mere scanning of the numbers shows that trying to detect one death caused by radionuclides from these facilities would be futile, given the apparently natural variation in cancer mortality. The number of deaths often changes substantially from one decade to the next. The variation would be even greater if particular years were compared with each other rather than decades.

Because of the low radiation dose calculated, the mathematical model cannot be used to predict which county or counties

Table 3.3.1. Total cancers around Anderson and Roane counties, Tennessee[a]

Counties	White males		Non-white males		Population (thousands)	
	1960–69	1970–79	1960–69	1970–79	1960	1970
Anderson	332	523	18	29	60	60
Blount	344	560	26	37	58	64
Campbell	247	347	6	2	28	26
Claiborne	169	219	3	3	19	19
Jefferson	152	200	11	8	21	25
Knox	1677	2430	228	296	251	276
Loudon	173	235	9	7	24	24
Morgan	91	133	0	0	14	14
Roane	233	355	14	18	39	39
Scott	91	149	2	0	15	15
Sevier	168	298	1	2	24	28
Union	51	64	0	0	8.5	9.1

[a] Source: Ref. 20.

would suffer the one or fewer cancer deaths. It is then close to impossible, on the basis of Table 3.3.1, to detect mathematically an increase in cancer deaths of the order of one or fewer, or to identify in which county or counties this increase occurred.

It may be contended that this conclusion is drawn only because the total number of cancer deaths was considered. If the cancer or cancers produced by radionuclide discharges were concentrated in one or more body organs that otherwise had a low incidence of cancer mortality, detection of changes in rates resulting from discharges of radionuclides from DOE facilities would be easier, in principle. For example, lip cancers produced about 1 in 915 U.S. cancer deaths from 1950 to 1969.[20] If cancers caused by discharges from the Oak Ridge facilities were concentrated on a specific organ like this, which constitutes a small part of total cancer mortality, it would be possible to detect more easily the statistical effect of these facilities.

On the basis of present knowledge, this is highly unlikely. For example, the AIRDOS mathematical model predicts that most cancers caused by airborne releases of radioactivity will occur in the lung. About 14%, or 1 in 7, of all cancer deaths from 1950 to 1969 occurred in the trachea, bronchus and lung.

Table 3.3.2 shows data similar to those of Table 3.3.1, except that only lung cancer deaths are considered. The total number of deaths is substantially smaller than that of Table 3.3.1 because lung (and related) cancer deaths are only one segment of total cancer deaths. However, the same difficulty in identifying cancer deaths of the order of one recurs. There is so much natural variation in the numbers that we cannot state with any degree of certainty how many excess lung cancer deaths have occurred, or where they occurred. For example, Sevier County

Table 3.3.2. Lung, trachea, and bronchus cancer deaths around Anderson and Roane counties, Tennessee[a]

Counties	White males		Non-white males		Population (thousands)	
	1960–69	1970–79	1960–69	1970–79	1960	1970
Anderson	112	215	6	9	60	60
Blount	104	204	5	12	58	64
Campbell	74	157	1	0	28	26
Claiborne	63	83	2	1	19	19
Jefferson	28	62	1	1	21	25
Knox	489	922	60	113	251	276
Loudon	50	86	3	0	24	24
Morgan	20	64	0	0	14	14
Roane	72	142	2	7	39	39
Scott	18	63	1	0	15	15
Sevier	41	104	1	0	24	28
Union	12	26	0	0	8.5	9.1

[a] Source: Ref. 20.

lung cancer deaths for white males rose by 63 during the course of one decade. It should be noted that lung cancer deaths throughout the entire country went up substantially during this period. Table 3.3.1 reflects this national increase. Subdividing the total cancer death rate by sites in the body where cancers occur will still not allow a definitive conclusion that these rates have changed as a result of ORR discharges.

Finally, it might be contended that the overall cancer rates, as opposed to total deaths, may be higher than the national average because of radionuclide emissions from the Oak Ridge facilities. This is not the case; the ratio of total county cancer rates to the U.S. or state average varies considerably, and with a good degree of randomness geographically. The natural variability in county cancer mortality rates arises as a result of a host of environmental and human factors. The information in Figs. 3.2.1 and 3.2.2 suggests that most of these rates are not substantially above national or state averages.

The precise conclusions of this report will of course depend on the quantities of radionuclides involved. However, some general conclusions can be drawn.

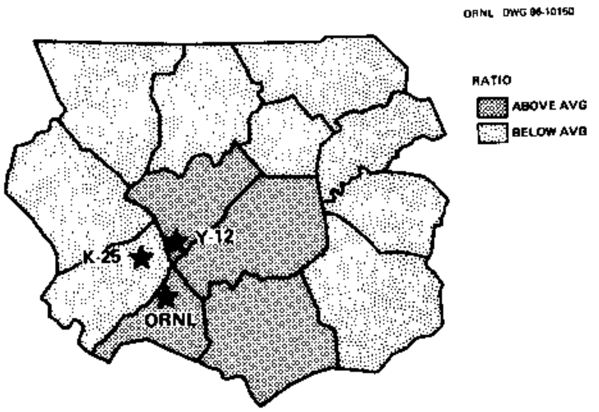

Fig. 3.3.1. Ratio of county total cancer mortality rate of the Oak Ridge area to the national average for white males, 1970–1979. Source: Ref. 20.

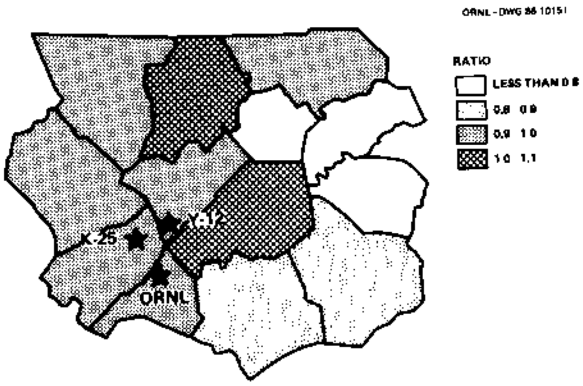

Fig. 3.3.2. Ratio of county total cancer mortality rate of the Oak Ridge area to the national average for non-white males, 1970–1979. Source: Ref. 20.

First, any fatal cancers that result from radionuclide discharges will be small compared with other sources of cancer. In addition, the number of these cancers will be very small compared with most other societal risks.

Second, there is no way that we can identify the victim or victims of these cancers, assuming that there is one or more. Cancer is too common. Lung cancer, probably the type produced by these radionuclide discharges, is also relatively common, especially among smokers.

Third, there is considerable variation in cancer death rates from year to year and place to place. This makes identifying the area where any effects are likely to happen almost impossible, given the low level of the health effects to be expected.

Fourth, there is considerable uncertainty in both the models used and some of the numbers fed into those models. From the viewpoint of public policy, these uncertainties will likely be in the direction of overestimating, rather than underestimating, these risks.

Emissions were higher in the past, before the implementation of the better control measures used today. Yet the cumulative risk produced by both present and past emissions has been small in comparison with those normally accepted by society.

3.4 CALCULATIONS OF POTENTIAL CHEMICAL DOSE TO THE PUBLIC

Health criteria for water were set such that chemical intake from consumption of 2 L of water per day would not exceed the acceptable daily intake (ADI). For noncarcinogenic toxic chemicals, the safe level of exposure is the intake of a toxicant (measured in micrograms per day) that is not anticipated to result in any adverse effects after chronic exposure to the general human population, including sensitive subgroups.[21] For carcinogenic chemicals, there is no accepted threshold limit. For the purposes of this document a specific risk of developing cancer over a human lifetime of one in one hundred thousand was used to establish acceptable levels of exposure to carcinogens.[21] In this section of the report the term "ADI" is used to represent an "allowable daily intake" for both carcinogens and noncarcinogens. For example, in establishing water quality criteria for the priority pollutants, EPA used the following relationship:

$$C_w = ADI/I_w$$

where

C_w = water quality criteria level ($\mu g/L$),
ADI = EPA-established value for an "acceptable daily intake" ($\mu g/d$), and
I_w = EPA-assumed value for the daily water consumption (2 L/d);

The review of water quality criteria documents appears in Ref. 22.

Table 3.4.1 lists the calculated daily intake (CDI) of chemicals from surface water on and off the ORR. One of the normal assumptions used for these types of calculation is the consumption of 2 L per day of raw water taken out of stream. The likelihood of that being the case is small. Therefore, the values given in Table 3.4.1 are overestimates of the intake. Table 3.4.2 lists the calculated daily intake of chemicals from air on the ORR. Chemicals with analytical detection limits below the EPA ADI were not included in these tables.

If the CDI/ADI ratio is less than one, then an unacceptable level of risk would result from exposure to ORR surface water or air. Such is the case for all chemicals in Table 3.4.1 and 3.4.2, except nickel. Nickel is a noncarcinogenic toxic substance that exhibits the largest CDI/ADI ratio in Table 3.4.1. Thus, the consumption of 2 L of water per day exceeds the daily intake by a factor of 1.2.

This analysis was also used for groundwater. However, no one drinks 2 L per day of water from the groundwater in the disposal areas. Therefore, this analysis for groundwater should be looked at screening purposes. It indicates those chemicals that require more detailed review: beryllium, lead, nickel, silver, zinc, PCBs, chloroform, methylene chloride, and tetrachloroethane. Table 3.4.3 lists the chemicals that need further investigation. Chemicals with analytical detection limits below the EPA ADI were not included in these tables.

Table 3.4.1. Calculated daily intake of chemicals from ORR surface water

Chemical	Acceptable daily intake (ADI) (mg/d)	Calculated daily intake (CDI) (mg/d)	CDI/ADI ratio
Surface water from ORGDP pumping station			
Lead	0.10	0.076	0.76
Zinc	10.0	0.7	0.07
Nickel	0.29	0.12	0.41
Surface water from ORGDP recirculating station			
Cadmium	0.057	.016	0.28
Lead	0.1	0.02	0.20
Zinc	10.0	0.84	0.080
Mercury	0.023	0.004	0.17
Nickel	0.29	0.36	1.2
Surface water from downstream of ORGDP			
Lead	0.10	0.042	0.42
Zinc	10.0	0.1	0.01
Mercury	0.023	0.002	0.087
Nickel	0.29	0.36	1.2
Surface water from Poplar Creek above Blair Bridge			
Lead	0.1	0.024	0.24
Zinc	10.0	0.46	0.046
Nickel	0.29	0.12	0.41
Surface water from Poplar Creek near Clinch River			
Lead	0.1	0.032	0.32
Zinc	10.0	2.0	0.20
Nickel	0.29	0.16	0.55
Surface water from West Fork Poplar Creek			
Lead	0.01	0.054	0.54
Zinc	10.0	0.14	0.014
Nickel	0.29	0.16	0.55
Surface water from East Fork Poplar Creek			
Mercury	0.023	0.0078	0.34
Nickel	0.29	0.3	1.0
Zinc	10.0	0.18	0.018
Surface water from Bear Creek			
Mercury	0.023	0.0068	0.30
Nickel	0.29	0.16	0.55
Zinc	10.0	0.04	0.004

Table 3.4.2. Calculated daily intake of chemicals from ORR air

Chemical	Acceptable daily intake (ADI) (mg/d)	Calculated daily intake (CDI) (mg/d)	CDI/ADI ratio
Chromium	0.1	.001[a]	0.01
Nickel	0.29	.001[b]	0.003
Copper	2.0	.01[c]	0.005
Lead	0.1	.02[d]	0.2

[a] Maximum chromium concentration in air from Table 4.1.19.

[b] Maximum nickel concentration in air from Table 4.1.20.

[c] Maximum copper concentration in air from Table 4.1.23.

[d] Maxium lead concentration in air from Table 4.1.24.

Table 3.4.3. Chemicals in ORR groundwater that require more study

Chemical
Groundwater data. United Nuclear disposal site[a]
Beryllium
Methylene chloride
Tetrachloroethane
Groundwater data Chestnut Ridge sediment disposal basin[b]
Beryllium
Lead
Nickel
Silver
Zinc
PCB
Chloroform
Methylene chloride
Tetrachloroethane
Groundwater data: classified burial grounds[c]
Beryllium
Methylene chloride
Tetrachloroethane
Groundwater data: Centralized Sanitary Landfill II[d]
Beryllium
Methylene chloride
Tetrachloroethane
Groundwater data S-3 Ponds[e]
Beryllium
Cadmium
Nickel
Methylene chloride
Tetrachloroethane
Groundwater data: Bear Creek burial grounds[f]
Beryllium
Methylene chloride
Tetrachloroethane
Groundwater data. ORGDP wells[g]
Lead
Groundwater data: 3524 ponds—ORNL[h]
Lead
Groundwater data: 7905-7908 ponds—ORNL[i]
Lead

[a] Maximum values in groundwater for Table 4.4.9.

[b] Maximum values in groundwater for Table 4.4.10

[c] Maximum values in groundwater for Table 4 4 11

[d] Maximum values in groundwater for Table 4 4 6

[e] Maximum values in groundwater for Table 4.4.7.

[f] Maximum values in groundwater for Table 4 4 8.

[g] Maximum values in groundwater for Tables 4.4 1-4.4 2.

[h] Maximum values in groundwater for Table 4.4 1.

[i] Maximum values in groundwater for Table 4.4.2

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4. MONITORING DATA

Environmental monitoring data for 1985 are summarized in subsequent tables. In general, the tables give the number of samples collected at each station or location and the maximum, minimum, and average values of substances detected. The 95% confidence coefficients (CCs) were calculated from the standard deviation of the sample average (assuming a normal frequency distribution) and are an indication of how close the sample average is to the true average value.

Where possible, average values were compared with applicable guidelines, criteria, or standards as a means of evaluating the impact of effluent releases and environmental concentrations. Stream concentrations of nonradioactive pollutants have generally been compared with the most recent TDHE water quality criteria for fish and aquatic life in freshwater streams. Liquid effluent monitoring data have been compared with the limits specified in the National Pollutant Discharge Elimination System (NPDES) permits issued to the Oak Ridge installations by the EPA. In the case of particulates in air, the geometric average and standard deviation were calculated because the applicable standards are based on the geometric average.

Data below the minimum detectable limit (MDL) are expressed as less than the MDL. In computing average values, sample results below the MDL were assigned the MDL, and the resulting average value is expressed as less than the computed value.

In the past, radionuclide concentrations in various media were compared with DOE concentration guides. The EPA has not issued concentration guides or standards. Instead, EPA recently issued radiation dose limits that apply to the dose received by the public as a result of airborne emissions from DOE facilities. The EPA has also issued dose limits for the ingestion of drinking water. The EPA standards are more stringent than the guides issued by DOE because they are largely based on limiting public exposures to levels that were considered to be "as low as reasonably achievable" (ALARA). This ALARA concept is a part of the DOE regulations, but it is not specifically quantified. In addition, DOE and EPA have standards for the protection of the public. In this report (see Sect. 3), potential doses are calculated from the inhalation of air, and the ingestion of water, fish, and milk have been calculated based on EPA's methodology.[1] Dose rates were compared with EPA standards when these were available. No specific standards or criteria are in general use for radionuclides or chemicals in sediments, vegetation, fish, or other edibles. Acceptable levels may be determined, nevertheless, on the basis of ensuring that the applicable exposure limit is not exceeded through the sum of all pathways to individuals or to suitable samples of the exposed population. DOE has promulgated new standards that will be consistent with the most recent recommendations of the National Council on Radiation Protection and Measurements.

4.1.1 General—Air

Historically there have been five systems for monitoring air at the Oak Ridge DOE facilities: (1) stations around the perimeter of the Y-12 Plant; (2) stations around the perimeter of the ORGDP plant; (3) stations around the ORR formerly identified as perimeter air monitors; (4) stations inside the ORNL plant boundary, formerly identified as ORNL local air monitors; and (5) stations outside the ORR at distances of from 19 to 121 km, designated as remote air monitors.

During the past calendar year, several committees and audit teams have reviewed the DOE Oak Ridge air monitoring systems. Based on their findings, and in an effort to better describe impacts at each of the plant's boundaries, ORNL regrouped its former LAM and PAM stations into (1) ORNL perimeter stations, consisting of numbers A3, A7, A9, A21, and A22 (see Fig. 4.1.1) and (2) Oak Ridge Reservation stations, consisting of numbers A31, A32, and A33 through A41 (see Fig. 4.1.2). In order to make the numbering system consecutive and consistent, each station was also renumbered. This new system is shown in Table 4.1.1. For calendar year 1985, only A3, A9, and A21 of the ORNL perimeter stations were sampled for radionuclides in air. However, external gamma radiation was also measured at stations A21 and A22.

In 1985 a technical review was conducted of the air monitoring systems used by Energy Systems. One of the recommendations made was that the air monitoring stations be renumbered to make them consecutive and consistent throughout the facilities. This renumbering is reflected in this report as follows: ORNL stations are designated A1–A30;

ORNL DWG 86 9120R

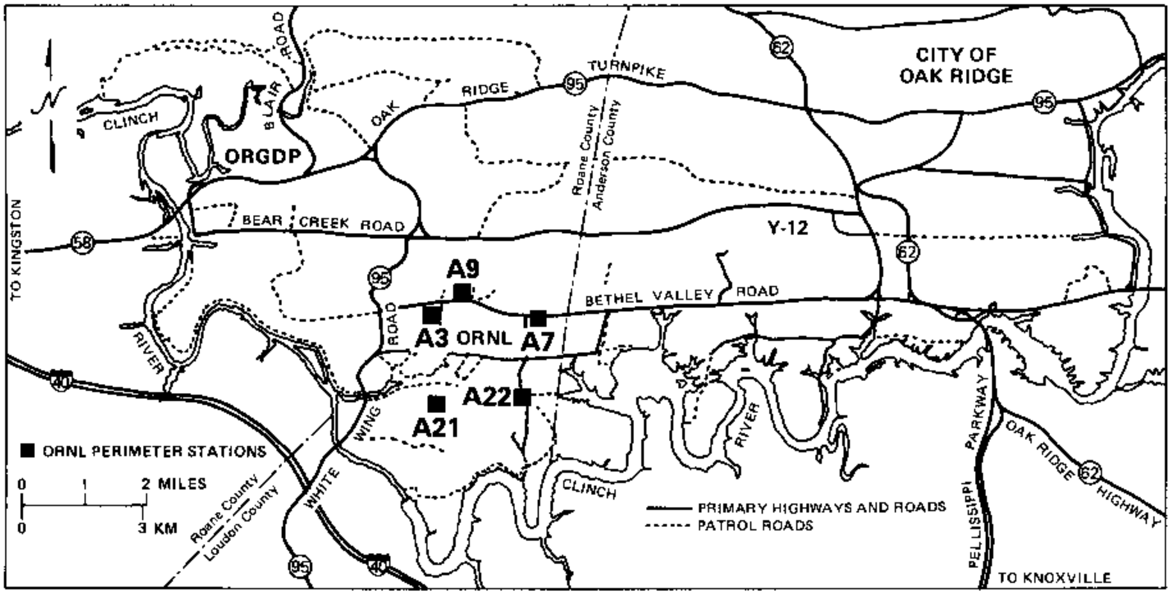

Fig. 4.1.1. Location map of perimeter air monitoring stations around ORNL.

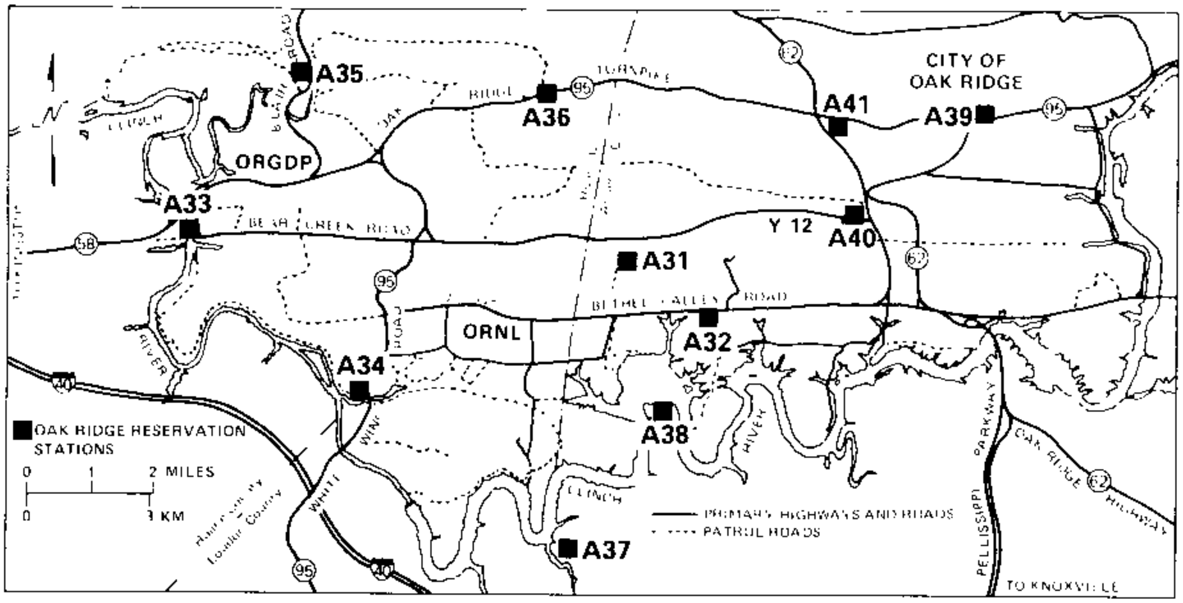

Fig. 4.1.2. Location map of the Oak Ridge Reservation air monitoring stations.

ORR stations are A31–A50; remote stations are A51–A60; Y-12 Plant stations are A61–A80; and ORGDP stations are A81–A100. There are more numbers assigned than there are stations at present, which allows additional stations to be added in the future without effect on the numbering system.

The ORR air monitoring system consists of ten stations (A31 through A41) that are, with one exception, outside the ORNL, Y-12, and ORGDP plant boundaries but inside the ORR boundary. These provide data for evaluating releases from Oak Ridge facilities to the immediate environment. The locations of the ORR air monitoring stations are shown in Fig. 4.1.2. The remote air monitoring system consists of seven stations (A51 through A57) that are outside the ORR at distances of from 19 to 121 km. The locations of the remote air monitoring stations are shown in Fig. 4.1.3. This system provides background data to aid in evaluating local conditions and fallout data.

4.1.2 Radioactive

Most gaseous wastes are released to the atmosphere through stacks. Radioactivity may be present in gaseous waste streams as a solid (particulates), as an absorbable gas (iodine), or as a nonabsorbable species (noble gas). Most gaseous wastes that may contain radioactivity are processed to reduce the radioactivity to acceptable levels before they are discharged. Stacks are monitored routinely for radionuclides of concern at each of the three Oak Ridge plants. In addition to stack discharges, there are potential airborne releases from burial grounds (e.g., ^{3}H and ^{14}C) and from uranium chip fires at Y-12.

All radioactive noble gases originate from ORNL and are monitored with a real-time (continuous) monitor with an electronic integrator. The majority (about 99%) of the ^{3}H (tritium) discharged during CY 1985 came from the isotope production facilities at ORNL and was released through stack 3039. The remaining ^{3}H comes from the ^{3}H target facility

Table 4.1.1. Listing of old and new numbers of air monitoring stations

ORNL stations		Y-12 stations		ORGDP stations	
Old number	New number	Old number	New number	Old number	New number
1	A1	1	A61	F1	A81
2	A2	2	A62	F2	A82
3	A3	3	A63	F4	A84
4	A4	4	A64	F5	A84
5	A5	5	A65	F6	A85
6	A6	6	A66	SP1	A86
7	A7	7	A67	SP2	A87
Vacant	A8	8	A68	SP3	A88
9	A9	8	A68	SP3	A88
10	A10	9	A69	SP4	A89
11	A10	10	A70	SP5	A90
12	A11	11	A71	SP6	A90
13	A13	12	A72	SP7	A92
14	A14	Vacant—A73 through A80		SP8	A93
15	A15			SP9	A94
16	A16			SP10	A95
17	A17			SP11	A96
18	A18			SP12	A97
19	A19			Vacant—A98 through A100	
20	A20				
21	A21				
22	A22				
Vacant—A23 through A30					

ORR stations		Remote stations	
Old number	New number	Old number	New number
8	A31	51	A51
23	A32	52	A52
33	A33	53	A53
34	A34	55	A54
35	A35	56	A55
36	A36	57	A56
37	A37	58	A57
38	A38	Vacant—A58 through A60	
39	A39		
40	A40		
41	A41		
Vacant—A42 through A50			

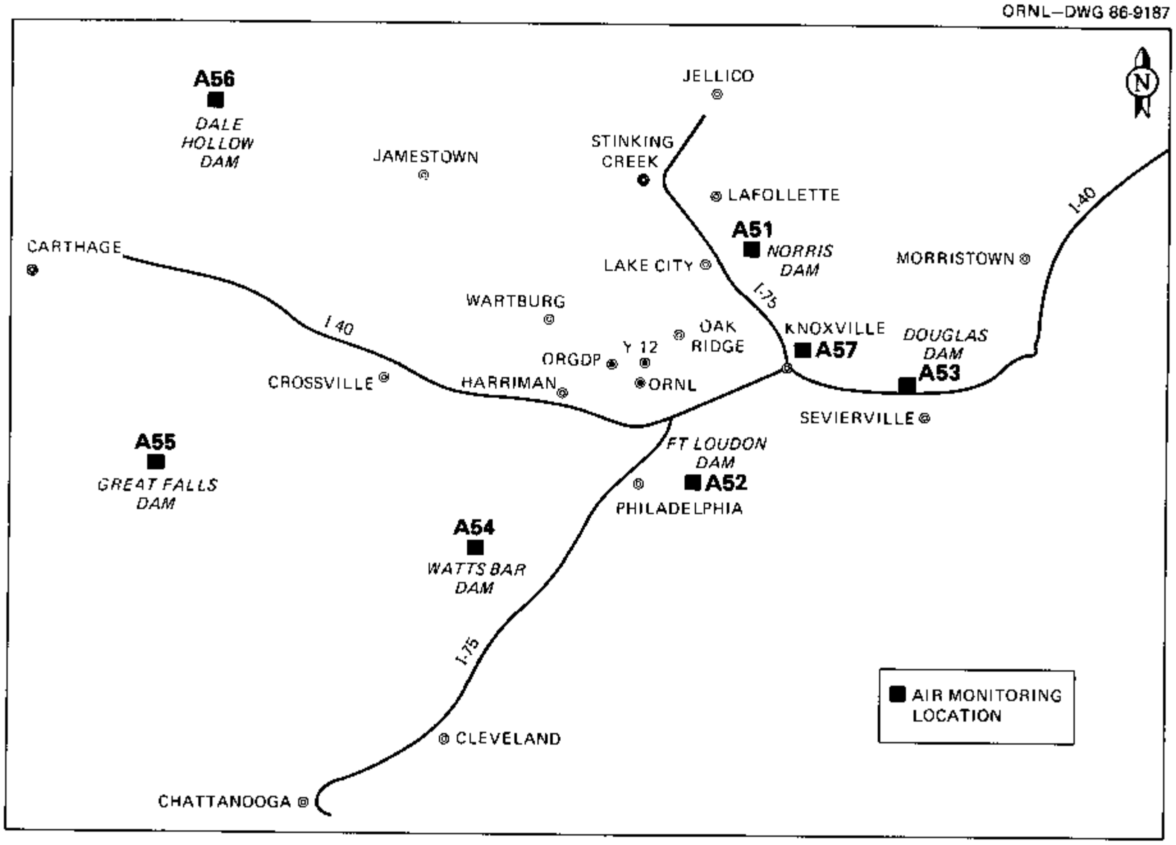

Fig. 4.1.3. Location map of the remote air monitoring stations.

through stack 7025 at ORNL. Tritium is measured with a real-time monitor at stack 3039 and with silica gel samplers at stack 7025.

Alpha and beta particles are measured in filters, and ^{131}I is absorbed onto charcoal samplers that are collected three times per week from stack 3039 and weekly from five other stacks at ORNL. Iodine-131 discharges come from the two main stacks at ORNL (3039 and 7911) and result from the processing of fuel elements and the production of medical isotopes.

The majority of the the uranium discharged to the atmosphere comes from the Y-12 Plant. It is currently measured using particulate samplers. Several projects were initiated by the Y-12 Plant during 1985 to upgrade the monitoring and treatment facilities of stack effluents, and further improvements are planned. ORGDP also measured air discharges for uranium and ^{99}Tc using Boyce-Thompson bubblers for the largest radionuclide emission point, the purge cascade. This facility's operation was placed in standby/shutdown mode about midyear. There are presently no uranium or ^{99}Tc emissions from this source.

In addition to monitoring stack discharges to the atmosphere, atmospheric concentrations of materials occurring in the general environment of East Tennessee are measured by several monitoring systems.

Sampling for radioactive particulates was carried out by directing air continuously through filter papers. Filter papers from the perimeter and remote systems were analyzed weekly by gross alpha and beta counting techniques and composited quarterly by system for specific radionuclide analysis. One exception is that for stations A36, A40, and A41 there is enough material to analyze the filters from a quarter for each station.

Airborne ^{131}I was monitored in the immediate environment at the ORR stations (A31 through A41) by continuously directing air through cartridges containing activated charcoal. Gamma spectrometry was used to measure ^{131}I.

The ORGDP's five ambient air monitors (A81 through A85) surround the plant beyond the boundary fence, as shown in Fig. 4.1.4; these monitors are used to measure ambient uranium concentrations and other parameters of interest. The results from the weekly composite samples are evaluated monthly by station for uranium and the other parameters. The 1985 summary of these results is shown in Table 4.1.2.

Eleven perimeter air monitors surround the Y-12 Plant at or near the boundary fence, as shown in Fig. 4.1.5; these monitors are used to measure ambient uranium concentrations, gross alpha, gross beta, and other parameters of interest at the boundary. The results from the weekly samples were composited quarterly by station and evaluated for uranium, gross alpha, and gross beta. Station A72 is used only for monitoring suspended particulates.

Concentrations of radioactive materials in air in Oak Ridge and the surrounding areas for 1985 are given in Tables 4.1.2 through 4.1.12.

Table 4.1.3 gives the concentration of long-lived gross alpha and beta activity in air for the Y-12 Plant perimeter. The yearly averages for gross alpha ranged from 6.9 to 26 × 10^{-15} μCi/mL and for gross beta ranged from 19 to 32 × 10^{-15} μCi/mL.

The long-lived gross alpha and beta activity in air in the ORNL perimeter air monitoring stations (Fig. 4.1.1) is given in Table 4.1.4; all values for gross alpha are less than (<) values and those for the gross beta range from 26 to 41 × 10^{-15} μCi/mL.

Table 4.1.5 gives the concentration of long-lived gross alpha and beta activity in air for the ORR air monitoring locations. All gross alpha results were less than (<) values, and the gross beta ranged from 13 to 27 × 10^{-15} μCi/mL. Concentrations of long-lived gross alpha and beta for the remote air monitoring stations are given in Table 4.1.6. All gross alpha results were less than (<) values, and the gross beta ranged from 11 to 36 × 10^{-15} μCi/mL.

The average gross beta concentrations for 1985 from particulates in air measured by both the ORR and the remote monitoring systems have remained essentially constant since 1981, except for the first half of 1981 (Fig. 4.1.6). The increase in activity measured during 1981 was attributed to the presence of weapons-test debris in the atmosphere. The average gross alpha concentrations in the perimeter and remote monitoring systems have also remained fairly constant since 1981 (Fig. 4.1.7). Gross beta values on gummed papers for ORNL perimeters, ORR stations, and Oak Ridge remote stations are given in Table 4.1.7. The mean concentrations for all systems are the same.

Apparent decreases in gross beta concentrations for 1985 as measured by the ORR and remote stations (Fig. 4.1.6) are

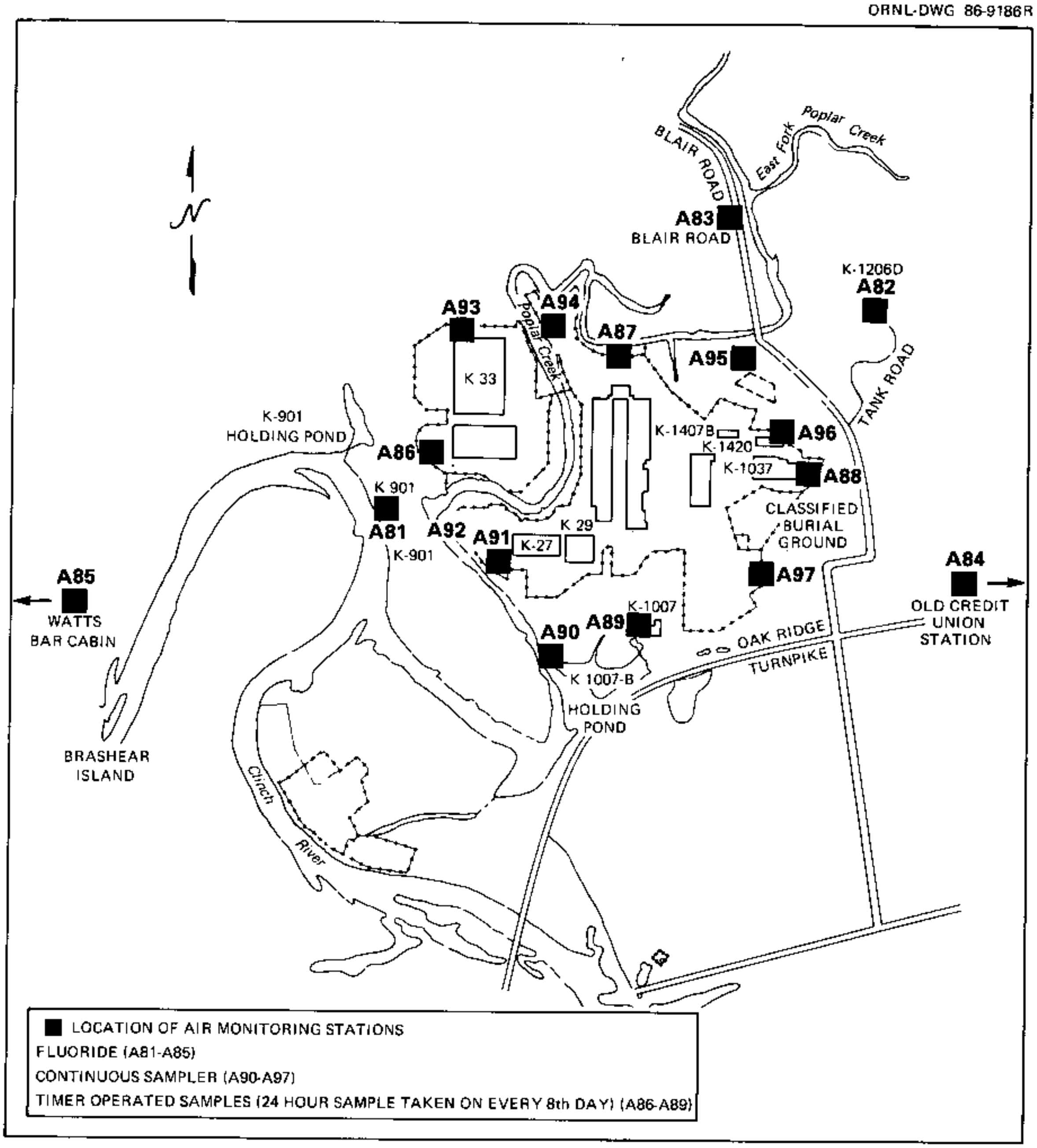

Fig. 4.1.4. Location map of the perimeter air monitoring stations around ORGDP.

probably due to changes in measuring concentrations at the detection limit. In past years, if the concentration was below the detection limit, the analyst did not report any data. Consequently, averages were calculated with only those data above the detection limits, which resulted in higher averages. It also appears that average gross alpha concentrations at these locations have increased (Fig. 4.1.7). However, in the past zeroes were recorded if the data were below detection. Zeroes were used in calculation of the averages, therefore underestimating the concentration.

Table 4.1.2. 1985 uranium in air

Location[a]	Number of samples	Concentration ($\mu g/m^3$)		
		Weekly max	Monthly max av	Yearly av
A81	50	0.019	<0.010	<0.0030 ± 0.0010[b]
A82	49	0.030	<0.0090	<0.0030 ± 0.0010
A83	48	0.021	<0.0070	<0.0030 ± 0.0010
A84	40	0.033	<0.0080	<0.0030 ± 0.0020
A85[c]	50	0.046	0.017	<0.003 ± 0.0020

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] ± value is the 95% confidence coefficient about the average.

[c] Location of A85 is 8 km west of ORGDP and is shown in Fig. 4.1.4.

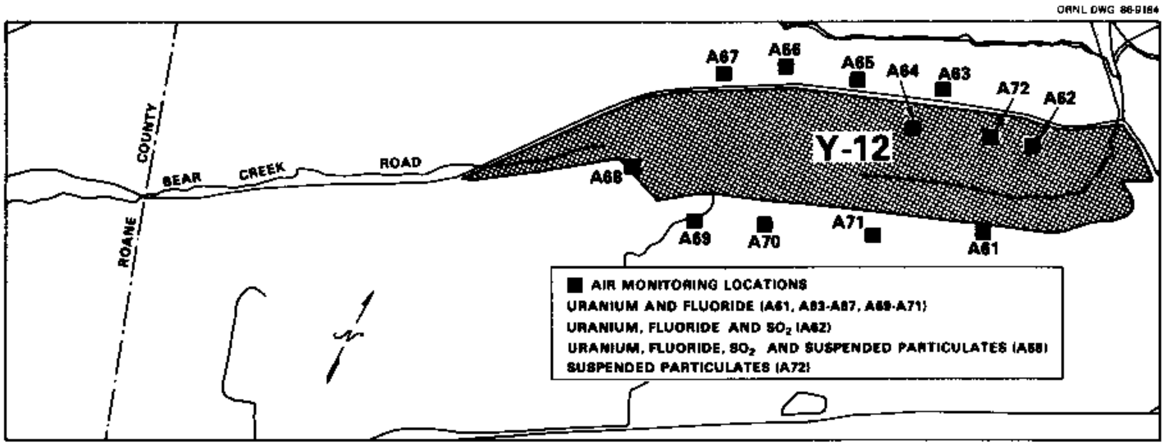

Fig. 4.1.5. Location map of the perimeter air monitoring stations around the Y-12 Plant.

During the past calendar year, quality assurance in the laboratory was increased to provide a lower limit of detection. These values were then used in the calculation of the averages.

Long-lived gross beta activity was not detected on 97%, 68%, and 62% of the filters analyzed at the ORNL perimeter, ORR, and remote stations, respectively. The highest average gross beta concentrations occur at the northern border of ORNL at station A9. There are no statistically significant differences in the average gross beta concentrations at the ORR and remote stations.

There was no long-lived gross alpha activity above the detection limit on any of the approximately 1000 filter papers analyzed. The variability in the concentrations in Fig. 4.1.7 may be caused by variability in the air flow through the filter.

Table 4.1.3. 1985 air monitoring data: long-lived gross alpha and beta activity in air (composite samples)

Location[b]	Concentration $(10^{-15}\,\mu\text{Ci/mL})$[a]					
	Gross alpha			Gross beta		
	Quarterly max	Quarterly min	Yearly av	Quarterly max	Quarterly min	Yearly av
A61	9.9	5.5	6.9	22	17	19
A62	9.8	6.3	8.2	25	17	20
A63	20	10	16	29	19	24
A64	31	14	26	44	23	32
A65	22	10	16	30	21	25
A66	16	8.0	11	27	18	21
A67	14	7.6	9.9	29	19	23
A68	21	8.3	13	29	17	22
A69	35	9.8	17	26	16	20
A70	14	6.0	8.6	25	17	20
A71	18	4.2	8.9	23	17	19

[a] To convert from $10^{-15}\,\mu\text{Ci/mL}$ to $10^{-11}\,\text{Bq/mL}$ multiply the number in table by 3.7.

[b] See Fig. 4.1.5 (Y-12 Plant perimeter).

Table 4.1.4. 1985 air monitoring data: long-lived gross alpha and beta activity

Location[b]	Concentration $(10^{-15}\,\mu\text{Ci/mL})$[a]									
	Number of samples	Gross alpha				Number of samples	Gross beta			
		Max	Min	Av	95%[c] CC		Max	Min	Av	95% CC
A3	52	<25	<12	<18	0.66	52	26	<12	<18	0.79
A7	51	<41	<9.1	<12	1.3	51	41	<9.1	<12	1.3
A9	52	<31	<9.4	<21	1.4	52	35	<9.4	<21	1.5
Network summary	155	<41	<9.1	<17	0.89	155	41	<9.1	<17	0.92

[a] To convert from $10^{-15}\,\mu\text{Ci/mL}$ to $10^{-11}\,\text{Bq/mL}$ multiply the number in table by 3.7.

[b] See Fig. 4.1.1 (ORNL perimeter).

[c] 95% confidence coefficient about the average.

Table 4.1.5. 1985 air monitoring data: long-lived gross alpha and beta activity

Location[b]	Concentration $(10^{-15}\ \mu\text{Ci/mL})$[a]									
	Number of samples	Gross alpha				Number of samples	Gross beta			
		Max	Min	Av	95% CC[c]		Max	Min	Av	95% CC
A31	52	<16	<8.5	<9.4	0.33	52	16	<8.5	<9.4	0.33
A32	52	<5.2	<4.5	<4.9	0.035	52	16	<4.5	<5.6	0.62
A33	52	<5.1	<4.1	<4.7	0.065	52	10	<4.1	<5.2	0.31
A34	52	<4.9	<4.1	<4.6	0.045	52	27	<4.1	<5.6	0.94
A35	52	<4.1	<3.3	<3.7	0.068	52	17	<3.3	<5.3	0.70
A36	52	<4.1	<3.8	<3.9	0.041	52	13	<3.8	<6.7	0.75
A37	52	<7.4	<3.5	<4.2	0.14	52	18	<3.5	<6.0	0.80
A38	52	<4.1	<3.3	<3.9	0.052	52	18	<3.3	<5.7	0.79
A39	51	<4.4	<3.8	<4.1	0.033	51	13	<3.8	<4.8	0.54
A40	49	<13	<9.1	<1.0	0.29	49	20	<9.1	<11	0.52
A41	37	<11	<9.8	<10	0.16	37	21	<9.8	<11	0.71
Network summary	553	<16	<3.3	<5.7	0.12	553	27	<3.3	<6.8	0.66

[a] To convert from $10^{-15}\ \mu\text{Ci/mL}$ to 10^{-11} Bq/mL multiply the number in table by 3.7.
[b] See Fig. 4.1.2 (ORR perimeter).
[c] 95% confidence coefficient about the average.

Table 4.1.6. 1985 air monitoring data: long-lived gross alpha and beta activity

Location[b]	Concentration $(10^{-15}\ \mu\text{Ci/mL})$[a]									
	Number of samples	Gross alpha				Number of samples	Gross beta			
		Max	Min	Av	95% CC[c]		Max	Min	Av	95% CC
A51	13	<7.2	<5.5	<6.2	0.34	13	11	<5.4	<6.7	0.82
A52	42	<9.1	<4.2	<5.0	0.34	42	24	<4.2	<6.6	1.2
A53	28	<6.0	<4.8	<5.3	0.083	28	34	<4.8	<12.0	3.5
A54	47	<6.1	<5.1	<5.5	0.085	47	17	<5.1	<6.7	0.77
A55	48	<4.9	<4.1	<4.4	0.075	48	28	<4.1	<6.4	1.2
A56	48	<12	<3.5	<4.1	0.36	48	21	<3.5	<5.3	0.94
A57	32	<4.1	<4.1	<4.1	0.0	32	36	<4.1	<8.4	2.5
Network summary	258	<12	<3.5	<4.8	0.12	258	36	<3.5	<7.2	0.66

[a] To convert from $10^{-15}\ \mu\text{Ci/mL}$ to 10^{-11} Bq/mL multiply the number in table by 3.7.
[b] See Fig. 4.1.3 (remote stations).
[c] 95% confidence coefficient about the average.

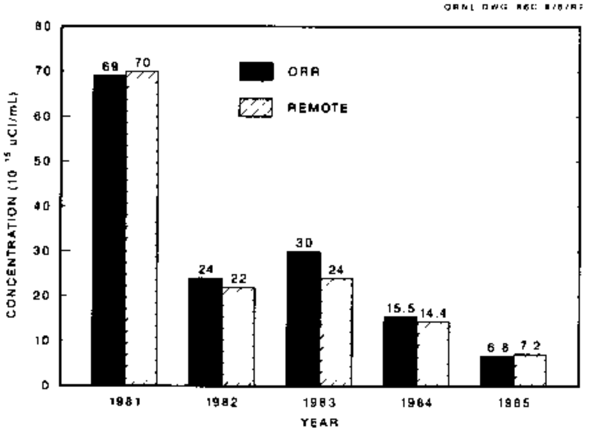

Fig. 4.1.6. Average gross beta concentrations for ORR and remote systems.

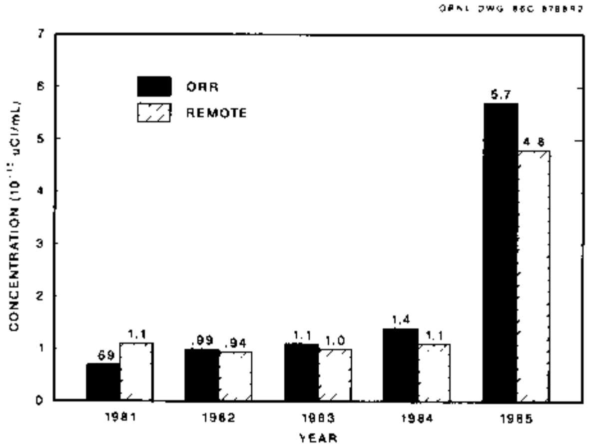

Fig. 4.1.7. Average gross alpha concentrations for ORR and remote systems.

Average gross beta concentrations from radioactive fallout for each of the air monitoring networks was the same (6.4×10^{-6} μCi/ft^2). Radioparticulate beta was detected on gummed papers in only 4% of the samples at all networks combined.

The results of specific radionuclide analyses of composited filters are given in Table 4.1.8. Differences in the average concentrations of specific radionuclides on ORR composite air filters (Table 4.1.8) from previous years are primarily due to the removal of the filters from stations A40 and A41 from the composite analyses. The majority of the uranium on air filters is produced by Y-12. Concentrations of specific radionuclides from the remote stations are similar to those measured during 1984 (Table 4.1.8). In general, activity levels were somewhat lower than those in 1984, except for ^{234}U levels, which were higher during 1984 at both the remote and perimeter stations. The uranium concentrations for stations A61 through A66 and A67 through A71 for 1983, 1984, and 1985 are shown in Figs. 4.1.8 and 4.1.9, respectively.

The results of uranium analysis of the composited filters from the air monitoring stations around the Y-12 Plant are given in Tables 4.1.9 and 4.1.10. The highest concentrations of uranium isotopes occur at ORR station A40 (Table 4.1.11). The highest uranium concentrations were found in the prevailing wind direction. Average concentrations were about the same during 1985 as in 1984. The specific uranium activity for selected ORR stations is given in Table 4.1.11. Concentrations of ^{131}I measured by the perimeter air monitoring system have remained essentially unchanged since 1980 and are shown Table 4.1.12.

4.1.3 Nonradioactive

Environmental air samples were taken for the determination of fluorides and suspended particulates around ORGDP and Y-12 and for SO_2 around Y-12. Fluorides, suspended particulates, and SO_2 are not monitored around ORNL because no operations are under way that require it under the Clean Air Act or state air regulation. No monitoring is required because ORNL releases of particulates from the steam plant are 818 kg (0.9 t) and releases of SO_2 are 4091 kg (4.5

Table 4.1.7. 1985 gross beta on gummed papers

Location	Number of samples	Concentration (10^{-4} μCi/ft^2)[a]			
		Max	Min	Av	95% CC[b]
ORNL perimeter stations[c]					
A3	52	16	<6.0	<6.2	0.39
A7	52	28	<6.0	<6.9	1.1
A9	52	10	<6.0	<6.1	0.17
Network summary	156	28	<6.0	<6.4	0.38
Oak Ridge Reservation stations[d]					
A31	52	18	<6.0	<6.3	0.49
A32	52	47	<6.0	<6.9	1.6
A33	52	10	<6.0	<6.1	0.15
A34	52	7	<6.0	<6.0	0.038
A35	52	38	<6.0	<6.7	1.2
A36	52	34	<6.0	<6.9	1.2
A37	52	10	<6.0	<6.1	0.15
A38	52	26	<6.0	<6.6	0.79
A39	52	<6.0	<6.0	<6.0	0.0
A40	52	17	<6.0	<6.5	0.58
Network summary	520	47	<6.0	<6.4	0.26
Oak Ridge remote stations[e]					
A51	44	<6.0	<6.0	<6.0	0.00
A52	41	30	<6.0	<6.6	1.2
A53	32	7.0	<6.0	<6.0	0.063
A54	46	23	<6.0	<6.4	0.74
A55	47	66	<6.0	<7.4	2.6
A56	52	22	<6.0	<6.4	0.65
A57	35	<6.0	<6.0	<6.0	0.0
Network summary	297	66	<6.0	<6.4	0.46

[a] To convert from 10^{-4} μCi/ft^2 to Bq/m^2 multiply number in table by 0.33.

[b] 95% confidence coefficient about the average.

[c] See Fig. 4.1.1.

[d] See Fig. 4.1.2.

[e] See Fig. 4.1.3.

t) annually. Because sulfur compounds are released from ORR installations, SO_2 in the environment is being monitored.

A variety of sulfur compounds are released to the atmosphere from both natural and anthropogenic sources.[2] Among the most important are the sulfur oxides (SO_x), which are produced when fossil fuels containing inorganic sulfides and organic sulfur are combusted. Of the four known monomeric sulfur oxides, only SO_2 is found at appreciable levels in the gas phase in the troposphere. Sulfur trioxide (SO_3) is emitted directly into the

Table 4.1.8 1985 continuous air monitoring data for specific radionuclides (composite samples)

Radionuclide	Concentration $(10^{-15}\,\mu Ci/mL)^a$					
	Oak Ridge Reservation stations[b]			Oak Ridge remote stations[c]		
	Quarterly max	Quarterly min	Quarterly av	Quarterly max	Quarterly min	Quarterly av
^{90}Sr	0.18	0.0055	0.062	0.15	0.018	0.059
^{137}Cs	0.048	<0.016	<0.038	0.061	<0.029	<0.040
^{230}Th	0.045	0.012	0.026	0.043	0.022	0.032
^{232}Th	0.030	0.012	0.020	0.040	0.020	0.032
^{234}U	0.32	0.12	0.22	0.24	0.055	0.11
^{235}U	0.029	0.0076	0.018	0.023	0.0039	0.093
^{238}U	0.092	0.033	0.068	0.056	0.026	0.037
^{238}Pu	0.0014	<0.00014	<0.00060	0.00043	<0.000040	<0.00030
^{239}Pu	0.0032	0.00063	0.0017	0.0030	<0.00030	<0.0017

[a] To convert from $10^{-15}\,\mu Ci/mL$ to 10^{-11} Bq/mL multiply the number in table by 3.7.
[b] See Fig. 4.1.2.
[c] See Fig. 4.1.3.

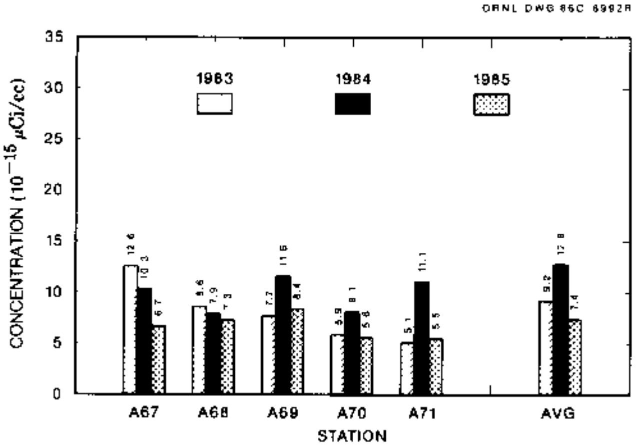

Fig. 4.1.8. Concentrations of uranium in air at locations A61 through A66.

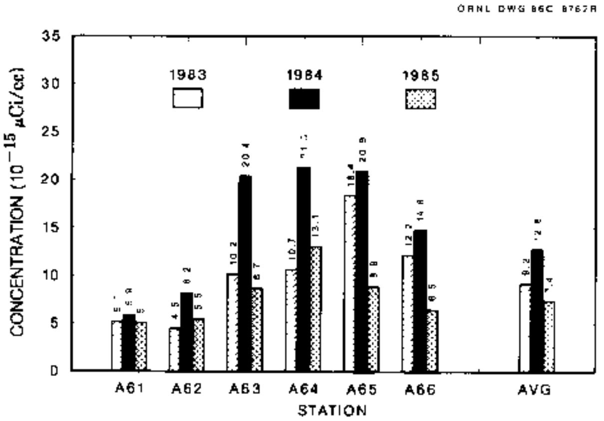

Fig. 4.1.9. Concentrations of uranium in air at locations A67 through A71.

atmosphere in fossil fuel combustion and is produced by the oxidation of SO_2 in the atmosphere.

The uranium enriching processes employed in the United States are gaseous diffusion and gas centrifuge. Both require that the uranium be in a gaseous compound, uranium hexafluoride (UF_6). Much of this UF_6 inventory is processed in systems that operate below atmospheric pressure and, therefore, present no significant UF_6 release potential. Uranium hexafluoride reacts rapidly with moisture in the air, forming uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF). Uranium compounds such as UO_2F_2 and UF_6 exhibit both chemical toxicity and radiological effects, while HF exhibits only chemical toxicity. Other toxic

Table 4.1.9. 1985 air monitoring data: ^{234}U and ^{235}U (composite samples)

Location[b]	Concentration (10^{-15} μCi/mL)[a]					
	^{234}U			^{235}U		
	Quarterly max	Quarterly min	Yearly av	Quarterly max	Quarterly min	Yearly av
A61	5.2	3.2	4.5	0.19	0.14	0.16
A62	5.6	3.2	4.6	0.22	0.16	0.19
A63	12	6.4	11	0.75	0.17	0.48
A64	22	12.0	19	1.1	0.55	0.87
A65	16	6.9	11	0.44	0.35	0.40
A66	9.2	4.0	6.3	0.33	0.13	0.21
A67	7.1	5.1	6.0	0.27	0.10	0.20
A68	14	4.1	7.3	0.59	0.10	0.31
A69	25	7.2	12	0.85	0.060	0.39
A70	7.8	2.8	4.7	0.35	0.10	0.22
A71	10	1.7	5.0	0.39	0.11	0.21

[a] To convert from 10^{-15} μCi/mL to 10^{-11} Bq/mL multiply the number in table by 3.7.

[b] See Fig. 4.1.5 (Y-12 Plant).

Table 4.1.10. 1985 air monitoring data: ^{236}U and ^{238}U (composite samples)

Location[b]	Concentration (10^{-15} μCi/mL)[a]					
	^{236}U			^{238}U		
	Quarterly max	Quarterly min	Yearly av	Quarterly max	Quarterly min	Yearly av
A61	0.23	0.05	0.13	0.34	0.15	0.24
A62	0.29	0.11	0.21	0.41	0.26	0.33
A63	0.40	0.31	0.35	0.77	0.19	0.51
A64	0.75	0.33	0.54	1.69	0.10	0.73
A65	0.58	0.17	0.38	0.86	0.34	0.69
A66	0.75	0.67	0.27	0.77	0.34	0.49
A67	0.29	0.09	0.19	0.81	0.32	0.55
A68	0.37	0.14	0.23	1.17	0.28	0.83
A69	0.49	0.29	0.40	0.44	0.22	0.35
A70	0.20	0.080	0.12	0.47	0.30	0.38
A71	0.33	0.050	0.19	0.25	0.11	0.23

[a] To convert from 10^{-15} μCi/mL to 10^{-11} Bq/mL multiply the number in table by 3.7.

[b] See Fig. 4.1.5 (Y-12 Plant).

Table 4.1.11. 1985 continuous air monitoring data: uranium (composite samples)

Location[b]		Concentration (10^{-15} μCi/mL)[a]		
		^{234}U	^{235}U	^{238}U
A36	Max	0.75	0.10	0.38
	Min	0.35	0.02	0.18
	Av	0.51	0.06	0.24
A40	Max	3.5	0.26	0.96
	Min	0.77	0.07	0.20
	Av	1.9	0.14	0.47
A41	Max	1.3	0.18	0.32
	Min	0.84	0.04	0.22
	Av	0.97	0.11	0.25

[a] To convert from 10^{-15} μCi/mL to 10^{-11} Bq/mL multiply the number in table by 3.7.

[b] See Fig. 4.1.2 (ORR).

substances that may be present in the gaseous diffusion plants—in much smaller quantities—include chlorine (Cl_2), chlorine trifluoride (ClF_3), fluorine (F_2), uranium tetrafluoride (UF_4), and technetium (Tc) compounds.

Once released into the atmosphere, these toxic materials remain airborne for various lengths of time depending on atmospheric conditions and the properties of the material. Individuals exposed to these airborne toxicants may suffer varying health effects depending on the concentration of the toxicant, the duration of the exposure, and the sensitivity of the individual.

Typical chemical reactions of some of these compounds released to the atmosphere are:

$$UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF + \text{heat}$$

$$16\,ClF_3 + 27\,H_2O \rightarrow 10\,ClO_2 + 48\,HF + HCl + 5HOCl + O_2 + \text{heat}$$

$$2F_2 + 2H_2O \rightarrow 4HF + O_2 + \text{heat}$$

$$3HF \rightleftarrows (HF)_3 + \text{heat}$$

$$6\,HF \rightleftarrows (HF)_6 + \text{heat}$$

Fluoride sampling locations around ORGDP are indicated in Fig. 4.1.4 by A81 through A85 (A85 is located about 8 km from ORGDP, upwind of the predominant wind direction).

In the past, Y-12's fluoride sampling was conducted at a limited number of sites. In 1985 the fluoride monitoring program was expanded to include 11 stations (Fig. 4.1.5). These perimeter ambient air stations are run continuously. Fluoride sampling is conducted for seven consecutive days each month. Atmospheric fluoride is collected by absorbing the fluoride on 50-mm-diam filters treated with potassium carbonate. This method is applicable to the measurement of gaseous and water-soluble particulate fluoride in the atmosphere. The lowest amount of fluoride reported is 5 μg per sample. The 1985 fluoride data reported in Table 4.1.13 show that the ambient fluoride concentrations around the Y-12 Plant are on the average less than 1% of the Tennessee air pollution control criteria. The ambient fluoride around ORGDP is also well below state criteria, and most of it is brought in with the prevailing winds.

Suspended particulates were measured in the ORGDP area at locations A86 through A97, as shown in Fig. 4.1.4. Locations A86 through A89 are sampled for particulates for 24 h every sixth day. Locations A90 through A97 are continuous air monitors; the filter paper is analyzed for particulates approximately every 48 to 72 h.

The Y-12 Plant monitors suspended particulates in ambient air at two locations at the east and west ends of the Plant (Fig. 4.1.5). Sampling for suspended

Table 4.1.12. 1985 iodine-131 in air

Location	Number of samples	Concentration $(10^{-16}\ \mu Ci/mL)$[a]			
		Max	Min	Av	95% C[b]
ORNL perimeter stations[c]					
A3	52	63	<5.3	<36	5.1
A7	51	110	<4.1	<29	5.7
A9	52	110	<3.6	<47	6.7
Network summary	155	110	<3.6	<37	3.6
Oak Ridge Reservation stations[d]					
A31	52	51	<3.4	<20	3.2
A32	52	28	<1.9	<12	1.6
A33	52	28	<1.7	<11	1.6
A34	52	19	<1.8	<11	1.2
A35	52	13	<1.3	<7.5	1.1
A36	52	33	<1.5	<10	1.4
A37	52	28	<1.4	<10	1.4
A38	52	14	<1.5	<8.9	1.2
A39	51	16	<1.5	<10	1.1
A40	49	51	<3.5	<26	3.1
A41	37	38	<3.8	<25	3.0
Network summary	553	51	<1.3	<14	0.76

[a] To convert from $10^{-16}\ \mu Ci/mL$ to 10^{-12} Bq/mL multiply the number in table by 3.7.

[b] 95% confidence coefficient about the mean average.

[c] See Fig. 4.1.1.

[d] See Fig. 4.1.2.

particulates consists of drawing air through a preweighed Whatman 41 filter paper for 24 h every 6 d. Before it is weighed, each filter paper is allowed to equilibrate in a humidity-controlled atmosphere. At the end of the 24-h sampling period, the filter papers are again allowed to equilibrate before they are reweighed. From the weight differential due to particle accumulation, sampling time, and air flow, the particulate concentration (expressed in $\mu g/m^3$) can be calculated. These values are compared with the Tennessee primary and secondary ambient air standards. The Y-12 Plant and ORGDP data for 1985 are reported in Table 4.1.14. If a sample is found to exceed the state standard, the filter is studied under a high-powered microscope to determine the type of material. If the majority of the filter is covered with road dust, insect parts, pollen, or other fugitive particles, the State has not considered it a violation.

During 1985, five filters for both Y-12 Plant monitors exceeded either the primary or secondary standard. The highest percentage of the primary standard was 36 and of the secondary standard was 40 for the ORGDP monitors. The highest percentage of the primary standard was 76 and of the secondary standard was 95 for the Y-12 monitors. None of these values show that the standards were

Table 4.1.13. 1985 fluorides in air[a]

Location	Number of samples[b]	Concentration ($\mu g/m^3$): Concentration for averaging interval, max		Concentration ($\mu g/m^3$): Annual av	95% CC[c]	Number of times standard exceeded[b]	
		7 d	30 d			7 d	30 d[d]
A81[e]	50	0.18	< 0.08	< 0.04	0.01	0	0
A82[e]	50	0.11	0.08	< 0.05	0.01	0	0
A83[e]	49	0.15	< 0.06	< 0.04	0.01	0	0
A84[e]	39	0.09	< 0.06	< 0.04	0.01	0	0
A85[f]	51	0.12	0.08	< 0.04	0.01	0	0
A61[g]	11	< 0.1		< 0.1	0.01	0	0
A62[g]	12	< 0.1		< 0.1	0.01	0	0
A63[g]	11	< 0.1		< 0.1	0.01	0	0
A64[g]	12	< 0.1		< 0.1	0.01	0	0
A65[g]	12	< 0.1		< 0.1	0.01	0	0
A66[g]	11	< 0.1		< 0.1	0.01	0	0
A67[g]	11	< 0.1		< 0.1	0.01	0	0
A68[g]	12	< 0.1		< 0.1	0.01	0	0
A69[g]	11	< 0.1		< 0.1	0.01	0	0
A70[g]	11	< 0.1		< 0.1	0.01	0	0
A71[g]	11	< 0.1		< 0.1	0.01	0	0

[a] Data are not amenable to comparison with 12-h or 24-h standard; 6-d or 7-d sample period compared with 7-d averaging interval. See text for method of measurement. These stations are not sited in accordance with 40 CFR Pt. 58 and are not satisfactory for judging compliance with ambient air quality standards.

[b] Samples are continuous; analyses are conducted on 7-d composites.

[c] 95% confidence coefficient about the average.

[d] Tennessee air pollution control (gaseous) for averaging intervals: 1.6 $\mu g/m^3$ for 7 d and 1.2 $\mu g/m^3$ for 30 d. All values are maximum—not to be exceeded more than once per year.

[e] See Fig. 4.1.4 (ORGDP).

[f] Station A85 is approximately 8 km from ORGDP, upwind of the prevailing wind direction; may be considered representative of general ambient background concentration.

[g] See Fig. 4.1.5 (Y-12).

exceeded. Total particulate concentrations are given in Table 4.1.14. One important factor in the determination of total particulates is the air volume, which is given in Table 4.1.15 for these ORGDP stations. Thus, filters were checked and only 1 of the 10 was found to not contain fugitive particles in sufficient quantity. This one sample contained a high percentage of carbon particles which, upon further investigation, was traced back to the operation of the steam plant. This sample exceeded the primary standard but was not significant enough to cause a violation of the annual geometric mean.

During 1985, a review of the locations of the Y-12 Plant total suspended particulate (TSP) monitors was conducted. Due

Table 4.1.14. 1985 suspended particulates in air

Location	Number of samples	24-h concentration ($\mu g/m^3$)				Percentage of standard AGM[b,c]	
		Max	Min	Geometric mean	95% CC[a]	PR	SC
A86[d]	33	71	1.9	24	7.6	32	40
A87[d]	45	78	2.0	20	5.0	27	33
A88[d]	43	110	2.9	27	9.6	36	45
A89[d]	38	75	3.2	24	5.9	32	40
A90[d]	92	73	1.1	17	2.5	23	28
A91[d]	97	101	0.44	14	2.7	19	23
A92[d]	99	37	0.75	12	1.9	16	20
A93[d]	95	39	0.66	12	1.8	15	19
A94[d]	75	45[e]	0.99	15	4.6	20	25
A95[d]	98	46	0.77	14	2.2	19	23
A96[d]	95	53	1.6	15	2.2	20	25
A97[d]	19	195[e]	2.9	16	23	20	25
A68[f]	53	510	0.74	35		76	95
A72[f]	52	487	1.3	57		47	58

[a] 95% confidence coefficient about geometric mean.

[b] PR STD = Primary standard = 260 $\mu g/m^3/24$ h;
SC STD = Secondary standard = 150 $\mu g/m^3/24$ h.

[c] Geometric mean = annual geometric mean (AGM):
Primary standard = 75 $\mu g/m^3$;
Secondary standard = 60 $\mu g/m^3$.

[d] These stations are not sited in accordance with 40 CFR Pt. 58 and are not fully satisfactory for judging compliance with ambient air quality standards. See Fig. 4.1.4 (ORGDP).

[e] This sample exceeds the SC STD of 150 $\mu g/m^3/24$ h.

[f] See Fig. 4.1.5 (Y-12).

to the close proximity of the west monitor (A68) to the fire training center, dirt roads, and devegetated hillsides, it was determined that the present location was inappropriate for monitoring ambient air. A new, more appropriate location was sited, and the west TSP monitor will be relocated during 1986.

In general the TSP concentrations for Y-12 were much lower during 1985 than in previous years. It is believed that the primary reason for the reduced suspended particulates was the addition of the new baghouse filter systems installed at the Y-12 steam plant.

Sulfur dioxide (SO_2) monitoring is conducted continuously at two stations at the Y-12 Plant (Fig. 4.1.5). These two stations are identical except for their location. Ambient air is pumped into pulsed ultraviolet fluorescence analyzers that are connected to recording units housed in temperature-controlled shelters. They are calibrated weekly to ensure that they remain within the ±15% drift allowed by the state. The Y-12 Plant is the only plant

Table 4.1.15. 1985 air monitoring data for volume of air drawn through filters

Location[a,b]	Volume/sample (m^3)		
	Max	Min	Geometric[c] mean
A86	3,410	1,360	2,510
A87	4,064	1,700	2,390
A88	2,835	1,100	2,020
A89	3,460	1,550	1,800
A90	15,300	3,240	6,780
A91	16,300	3,050	7,520
A92	16,600	3,260	7,740
A93	15,700	3,870	7,590
A94	16,000	850	6,610
A95	13,900	2,970	6,540
A96	20,300	2,945	7,220

[a] Fig. 4.1.4 (ORGDP).

[b] A97. Due to equipment malfunction, no quarterly samples were taken at this location.

[c] Geometric mean = annual geometric mean.

that must monitor SO_2. The TDHE conducts a quarterly audit of each system. During the third quarter of 1985, both stations showed a poor correlation with the state's standard. During this time, difficulty with the fluorescence tube was experienced, and it was difficult to maintain the calibration of the instruments. The tubes have since been replaced and calibration has been maintained.

Concentrations of SO_2 are recorded hourly for each month. The day is averaged and compared with the 3- and 24-h ambient air standards. Table 4.1.16 lists the maximum 3-h, maximum 24-h, and monthly and annual averages (mg/L) for both stations at Y-12. On the average, the 1985 ambient air sulfur dioxide values were only about 20% of the state standards. No violations of the 3- or 24-h standards occurred in 1985. The highest values at either station for SO_2 were only about 30% of the standards.

Air monitoring data for fluorides, suspended particulates, and SO_2 are presented in Tables 4.1.13 through 4.1.16. The data indicate that measured environmental concentrations of fluorides and SO_2 were in compliance with applicable standards.[3] However, suspended particulates at Y-12 and ORGDP have occasionally exceeded standards.

These standards are not applicable at ORGDP because the sampling stations are on site, near roads, and close to the ground. These stations, therefore, are not fully satisfactory for judging compliances with the ambient air quality standards because they are not sited in accordance with 40 CFR Pt. 58. Even though they are not applicable, a thorough investigation of the suspended particulate exceedance was conducted to determine the cause. Meteorological data from the ORGDP tower were used in conjunction with all applicable log entries from the ORGDP analytical laboratory and from several ORGDP operations. Despite these efforts there is no conclusive evidence to determine the causes of this exceedance.

The fluoride concentrations are given in Table 4.1.13; the State of Tennessee standard was not exceeded during 1985. Sulfur dioxide concentrations are given in Table 4.1.16. These concentrations are given by month. None of the maximum 3-h-average, max 24-h, or monthly average standards were exceeded. All maximum 24-h averages were <30% of the standard. Operating hours of SO_2 stations are important for determining SO_2 concentrations. For stations A62 and A68 the hour/month operating time is given in Table 4.1.17.

For several decades, chromium compounds have been known to be

Table 4.1.16. 1985 sulfur dioxide[a] in air

Month	Concentration (mg/L)					
	Max 3-h av		Max 24-h av		Monthly av	
	Station[b]					
	A62	A68	A62	A68	A62	A68
January	0.096	0.029	0.049	0.013	0.015	0.005
February	0.085	0.067	0.033	0.028	0.010	0.006
March	0.078	0.052	0.031	0.026	0.012	0.006
April	0.038	0.009	0.018	0.005	0.007	0.003
May	0.041	0.008	0.011	0.004	0.005	0.002
June	0.015	0.008	0.011	0.006	0.004	0.002
July	0.048	0.008	0.014	0.006	0.006	0.002
August	0.046	0.009	0.016	0.005	0.006	0.003
September	0.039	0.015	0.014	0.008	0.006	0.004
October	0.021	0.034	0.012	0.022	0.006	0.004
November	0.063	0.036	0.028	0.015	0.010	0.006
December	0.082	0.021	0.038	0.009	0.017	0.005
Annual arithmetic average					0.009	0.004

[a] Tennessee ambient air standards are 0.5 mg/L for the maximum 3-h average, 0.14 mg/L for the maximum 24-h average, and 0.03 mg/L for the annual arithmetic average. All maximum 24-h averages were < 30% of the standard.

[b] See Fig. 4.1.5 (Y-12 Plant).

carcinogenic.[4] Chromium (Cr) is never found in pure form in nature. It is usually associated with iron oxide, silica, and magnesium oxide. Chromium metal itself and trivalent chromium compounds are fairly stable and relatively nontoxic.[5] However, the water-soluble hexavalent compounds are extremely irritating, corrosive, and toxic to human body tissue.[6] Insoluble chromium compounds are retained in the lungs.[7] Airborne chromium levels around ORGDP are monitored because of the use of chromium materials in the cooling towers. Airborne concentrations at stations A81 through A85 are given in Table 4.1.18 and at stations A86 through A97 in Table 4.1.19. The maximum concentration of the 231 samples collected at stations A81 through A85 was 0.065 $\mu g/m^3$ and of the 44 samples collected from stations A86 through A97 was 0.060 $\mu g/m^3$. These maximum concentrations can be compared with the national ambient air concentrations of chromium,[5] ranging from 0.15 $\mu g/m^3$ to a high of 0.35 $\mu g/m^3$.

Nickel metal is relatively nontoxic.[8] Humans are not naturally exposed to the inhalation of atmospheric nickel, with the possible exception of nickel from volcanic emanation.[8] Emissions from the combustion of fossil fuels are a major source of

Table 4.1.17. 1985 operating data on sulfur dioxide stations

Month	Maximum (h/month)	Operating hours (%) Station[a] A62	Operating hours (%) Station[a] A68
January	744	730 (99)[b]	720 (97)
February	672	660 (99)	640 (96)
March	744	720 (97)	700 (95)
April	720	710 (99)	620 (86)
May	744	640 (87)	560 (76)
June	720	500 (69)	670 (93)
July	744	540 (73)	730 (99)
August	744	580 (78)	740 (100)
September	720	711 (99)	710 (99)
October	744	726 (99)	740 (100)
November	720	708 (99)	710 (99)
December	744	608 (82)	740 (100)

[a] See Fig. 4.1.5 (Y-12 Plant perimeter).

[b] Numbers in parentheses denote percentage of full-time operating hours.

atmospheric nickel, which is usually in the form of particles.[10] Concentrations of airborne nickel around ORGDP are determined using high-volume filter samplers. The results of these measurements are given in Table 4.1.20. Maximum concentrations of samples collected at stations A86 through A96 ranged from 0.0050 to 0.068 μg/m^3. These concentrations can be compared with those maximum values ranging from 0.0060 to 0.012 μg/m^3 determined by the National Air Sampling Network (NASN)[10] in Knoxville, Tennessee, from 1965 to 1969. There are no national or state standards for nickel. Maximum concentrations at stations A86, A88, A94, and A95 were higher than those determined by the NASN.

Titanium (Ti) is a trace metal for which there is little information available on biologic action. No toxicity has been determined for titanium at levels present in the air.[11] Airborne concentrations of titanium around ORGDP were determined during 1985 and are reported in Table 4.1.21. Maximum concentrations range from a low of 0.0031 to a high of 0.29 μg/m^3, which can be compared with values recorded in the general atmosphere of a low of <0.01 to a high of 0.3 μg/m^3 (Ref. 12). All concentrations around ORGDP are within atmosphere measurements determined at other locations. There are no national or state standards for airborne titanium.

The chemical behavior of manganese in the environment is similar to that of iron.

Table 4.1.18. 1985 chromium in air

Location[a]	Number of samples	Concentration (μg/m^3) Max	Concentration (μg/m^3) Max av	Concentration (μg/m^3) Yearly av
A81	49	0.048	<0.025	<0.016 ±[b] 0.0030
A82	49	0.027	<0.017	<0.014 ± 0.0020
A83	48	0.025	<0.018	<0.015 ± 0.0020
A84	37	0.065	<0.031	<0.016 ± 0.0050
A85	48	0.049	<0.024	<0.015 ± 0.0030

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] ± value is the 95% confidence coefficient about the average.

Table 4.1.19. 1985 chromium in air

Location[a]	Number of samples	Concentration ($\mu g/m^3$)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	0.059	0.00080	0.0073	0.048
A87	4	0.017	0.0012	0.0043	0.0074
A88	4	0.030	0.0015	0.0067	0.022
A89	4	0.015	0.0011	0.0069	0.0111
A90	4	0.0068	0.00070	0.0029	0.0046
A91	4	0.0040	0.00060	0.0015	0.0027
A92	4	0.0046	0.00060	0.0023	0.0031
A93	4	0.0040	0.0028	0.0035	0.0017
A94	4	0.0054	0.0043	0.0047	0.0015
A95	4	0.039	0.00050	0.0044	0.032
A96	4	0.0070	0.0039	0.0059	0.0024
A97[c]	1	0.0007	0.0007	0.0007	0.00

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, one quarterly sample was taken from this location.

Table 4.1.20. 1985 nickel in air

Location[a]	Number of samples	Concentration ($\mu g/m^3$)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	0.040	0.0012	0.0067	0.0287
A87	4	0.0081	0.0012	0.0041	0.0048
A88	4	0.0569	0.0015	0.0104	0.0455
A89	4	0.0246	0.0005	0.0046	0.0188
A90	4	0.0077	0.0003	0.0028	0.0063
A91	4	0.0061	0.0006	0.0019	0.0051
A92	4	0.0060	0.0003	0.0018	0.0041
A93	4	0.0056	0.0003	0.0017	0.0074
A94	4	0.0128	0.0036	0.0062	0.0121
A95	4	0.0681	0.0005	0.0067	0.0571
A96	4	0.0116	0.00412	0.0071	0.0060
A97[c]	1	0.0014	0.0014	0.0014	0.00

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, only one quarterly sample was taken from this location.

Table 4.1.21. 1985 titanium in air

Location[a]	Number of samples	Concentration ($\mu g/m^3$)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	0.295	0.0040	0.032	0.243
A87	4	0.040	0.0082	0.023	0.023
A88	4	0.088	0.0102	0.038	0.055
A89	4	0.077	0.0105	0.034	0.051
A90	4	0.051	0.0013	0.015	0.040
A91	4	0.040	0.0013	0.072	0.032
A92	4	0.038	0.0011	0.012	0.029
A93	4	0.040	0.0167	0.024	0.031
A94	4	0.044	0.0257	0.031	0.025
A95	4	0.041	0.0015	0.014	0.031
A96	4	0.070	0.0106	0.027	0.043
A97[c]	1	0.014	0.0140	0.014	0.00

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, only one quarterly sample was taken from this location.

Atmospheric presence of manganese promotes the conversion of sulfur dioxide to sulfur trioxide and then to sulfuric acid.[13] The major route of absorption by humans is by inhalation. There are no national or state environmental ambient air standards for manganese. Airborne concentrations of manganese around ORGDP were determined during 1985 and are reported in Table 4.1.22. Maximum concentrations at these locations range from a low of 0.004 to a high of 0.29 $\mu g/m^3$. These concentrations can be compared with measurements made in 1965 in nonurban and urban areas of the United States[10] with a low of 0.004 to a high of 0.019 $\mu g/m^3$ in the nonurban areas and a low of 0.01 to a high of 0.57 $\mu g/m^3$ in the urban areas. All stations exceeded the high value for nonurban areas, but none exceeded the high value within urban areas. The National Academy of Sciences[13] stated that these concentrations of manganese in ambient air appear to provide a substantial factor of safety to the population, except to groups that are close to point sources of large emissions.

Copper is essential to human life and health and, like all heavy metals, it is potentially toxic. Atmospheric levels of copper have not been proven to pose a risk to human health; hence, no emission or ambient air standards for copper have been established.[14] Airborne concentrations of copper around ORGDP were determined during 1985 and are reported in Table 4.1.23. Maximum concentrations at these locations ranged from a low of 0.005 to a high of 0.240 $\mu g/m^3$. These concentrations can be compared with measurements made by the NASN[10] in 1966

Table 4.1.22. 1985 manganese in air

Location[a]	Number of samples	Concentration (μg/m^3)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	0.295	0.0008	0.0130	0.26
A87	4	0.040	0.0008	0.0083	0.031
A88	4	0.040	0.0010	0.0119	0.036
A89	4	0.060	0.00050	0.0097	0.049
A90	4	0.034	0.00070	0.0062	0.029
A91	4	0.016	0.00060	0.0032	0.012
A92	4	0.023	0.00060	0.0049	0.020
A93	4	0.020	0.0028	0.0096	0.025
A94	4	0.027	0.0043	0.016	0.030
A95	4	0.029	0.00080	0.0059	0.021
A96	4	0.029	0.0018	0.0086	0.027
A97[b]	1	0.0049	0.0049	0.0049	0.00

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, only one quarterly sample was taken from this location.

Table 4.1.23. 1985 copper in air

Location[a]	Number of samples	Concentration (μg/m^3)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	0.0797	0.0040	0.0152	0.0610
A87	4	0.242	0.0041	0.0305	0.196
A88	4	0.0495	0.0025	0.0191	0.0366
A89	4	0.0768	0.0026	0.0163	0.0585
A90	4	0.0135	0.0011	0.0039	0.0096
A91	4	0.0051	0.0006	0.0015	0.0035
A92	4	0.0060	0.0006	0.0028	0.0043
A93	4	0.0056	0.0036	0.0043	0.0026
A94	4	0.0086	0.0023	0.0052	0.0085
A95	4	0.0773	0.0008	0.0096	0.0829
A96	4	0.0077	0.0018	0.0037	0.0041
A97[c]	1	0.0035	0.0035	0.0035	0.00

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, only one quarterly sample was taken from this location.

indicating a range of airborne copper concentrations from 0.01 to 0.257 μg/m^3 in rural and urban communities. All of the concentrations around ORGDP were within the NASN concentrations.

Lead-containing material is introduced into the environment from a variety of sources.[15] Natural sources apparently contribute only insignificantly to current concentrations of lead in the atmosphere.[16] Natural concentrations have been estimated to be about 0.0005 μg/m^3. The national ambient air quality standard for lead is 1.5 μg/m^3 for a three-month average. Airborne concentrations of lead around ORGDP were determined during 1985 and are reported in Table 4.1.24. Maximum concentrations of lead at these locations range from a low of 0.03 to a high of 0.74 μg/m^3. The maximum percentage of the lead standard was 49. The sources of this lead will be evaluated during 1986.

The concentrations of silicon, molybdenum, magnesium, iron, and aluminum around ORGDP are given in Tables 4.1.25 through 4.1.29, respectively. No standards have been identified for these pollutants.

Table 4.1.24. 1985 lead in air

Location[a]	Number of samples	Concentration (μg/m^3)				Maximum percentage of standard[c]
		Max	Min	Av	95% CC[b]	
A86	4	0.737	0.002	0.058	0.640	49
A87	4	0.121	0.002	0.032	0.099	8
A88	4	0.255	0.003	0.054	0.246	17
A89	4	0.196	0.003	0.048	0.188	13
A90	4	0.169	0.003	0.031	0.130	11
A91	4	0.100	0.001	0.014	0.081	7
A92	4	0.116	0.004	0.025	0.109	8
A93	3	0.087	0.028	0.046	0.080	6
A94	3	0.15	0.043	0.066	0.161	10
A95	4	0.136	0.002	0.024	0.107	9
A96	4	0.141	0.002	0.029	0.114	9
A97[d]	1	0.025	0.025	0.025	0.00	2

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the average.

[c] Standard = 1.5 μg/m^3 per quarter.

[d] Due to equipment malfunction, only one quarterly sample was taken from this location.

Table 4.1.25. 1985 silicon in air

Location[a]	Number of samples	Concentration (μg/m^3)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	5.90	0.05	0.63	5.14
A87	4	0.96	0.08	0.40	0.70
A88	4	2.04	0.08	0.53	1.48
A89	4	3.12	0.07	0.57	2.46
A90	4	2.06	0.03	0.35	1.62
A91	4	1.60	0.03	0.21	1.33
A92	4	1.53	0.03	0.28	1.18
A93	4	1.59	0.54	0.78	1.54
A94	4	1.75	0.54	0.93	1.61
A95	4	1.64	0.04	0.42	1.23
A96	4	2.81	0.12	0.65	2.04
A97[c]					

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, no quarterly sample were taken on this monitor.

Table 4.1.26. 1985 molybdenum in air

Location[a]	Number of samples	Concentration (μg/m^3)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	0.0052	0.0001	<0.0009	0.0078
A87	4	<0.0011	0.0008	<0.0009	0.0004
A88	4	<0.0010	0.0001	<0.0004	0.0014
A89	4	<0.0012	0.0001	<0.0003	0.0017
A90	4	0.0007	<0.0001	<0.0002	0.0005
A91	4	<0.0003	<0.0001	<0.0001	0.0002
A92	4	0.0005	<0.0001	<0.0001	0.0004
A93	4	<0.0004	<0.0001	<0.0002	0.0004
A94	4	<0.0004	<0.0002	<0.0002	0.0003
A95	4	<0.0004	<0.0001	<0.0001	0.0002
A96	4	0.0006	<0.0002	<0.0003	0.0003
A97[c]	1	<0.0014	<0.0014	<0.0014	0.00

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, only one quarterly sample was taken from this location.

Table 4.1.27. 1985 magnesium in air

Location[a]	Number of samples	Concentration ($\mu g/m^3$)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	1.5	0.0080	0.069	1.3
A87	4	0.202	0.010	0.055	0.14
A88	4	0.442	0.013	0.11	0.33
A89	4	0.301	0.013	0.082	0.24
A90	4	0.26	0.0030	0.055	0.22
A91	4	0.20	0.0030	0.031	0.16
A92	4	0.12	0.0030	0.037	0.098
A93	4	0.10	0.056	0.082	0.064
A94	4	0.13	0.11	0.12	0.032
A95	4	0.14	0.0040	0.046	0.12
A96	4	0.18	0.0090	0.061	0.13
A97[c]	1	0.017	0.017		

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, only one quarterly sample was taken from this location.

Table 4.1.28. 1985 iron in air

Location[a]	Number of samples	Concentration ($\mu g/m^3$)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	2.9	0.020	0.18	2.55
A87	4	0.32	0.020	0.11	0.22
A88	4	0.36	0.040	0.16	0.23
A89	4	0.48	0.030	0.14	0.34
A90	4	0.13	0.020	0.07	0.08
A91	4	0.10	0.010	0.04	0.07
A92	4	0.19	0.010	0.06	0.13
A93	4	0.20	0.060	0.10	0.19
A94	4	0.27	0.11	0.16	0.22
A95	4	0.25	0.010	0.04	0.21
A96	4	0.25	0.090	0.16	0.11
A97[c]			0.63	0.63	0.00

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, only one quarterly sample was taken from this location.

Table 4.1.29. 1985 aluminum in air

Location[a]	Number of samples	Concentration ($\mu g/m^3$)			
		Max	Min	Geometric mean	95% CC[b]
A86	4	5.53	0.030	0.40	4.7
A87	4	0.81	0.040	0.25	0.56
A88	4	0.90	0.050	0.32	0.62
A89	4	1.6	0.050	0.40	1.2
A90	4	0.67	0.010	0.17	0.59
A91	4	0.14	0.010	0.09	0.30
A92	4	0.93	0.010	0.14	0.76
A93	4	0.40	0.080	0.24	0.49
A94	4	0.54	0.21	0.37	0.42
A95	4	0.60	0.010	0.15	0.49
A96	4	0.70	0.040	0.27	0.57
A97[c]	1	0.13		0.13	0.00

[a] See Fig. 4.1.4 (ORGDP perimeter).

[b] 95% confidence coefficient about the geometric mean (GM ÷/× 95% CC).

[c] Due to equipment malfunction, only one quarterly sample was taken from this location.

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4.2 EXTERNAL GAMMA RADIATION

External gamma radiation measurements are made to confirm that routine radioactive effluents from the Oak Ridge facilities are not significantly increasing external radiation levels above normal background. Measurements are also made in the few relatively small areas accessible to the public where current or past operations could cause radiation levels to be elevated. In addition, the monitoring network can be used to assess the impact of unusual occurrences.

For purposes of measuring external radiation on the ORR, the stations were divided into three groups: those around the perimeter of ORNL (Fig. 4.2.1), those that monitor the ORR (Fig. 4.2.2), and those around the perimeter of ORGDP (Fig. 4.2.3). As a result of technical reviews of environmental monitoring programs during 1985, monitoring locations were renumbered to make them consecutive and consistent. A list showing the old and new numbering systems is given in Table 4.2.1. This differentiation made it possible to determine whether levels around ORNL and ORGDP were significantly higher than those throughout the

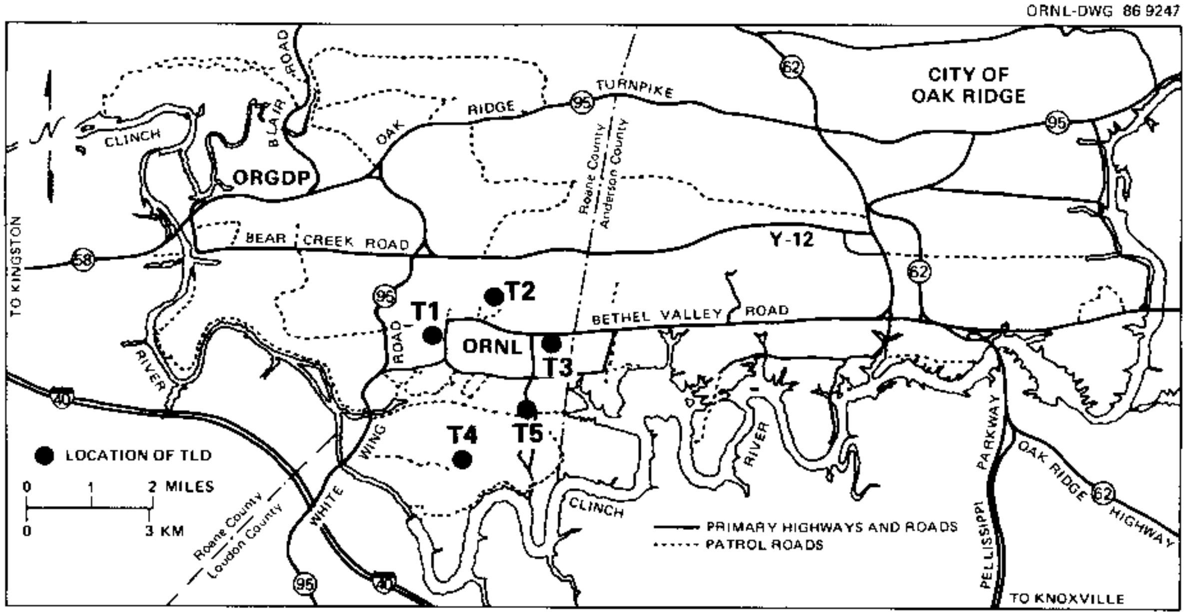

Fig. 4.2.1. Location map of TLDs around the perimeter of ORNL.

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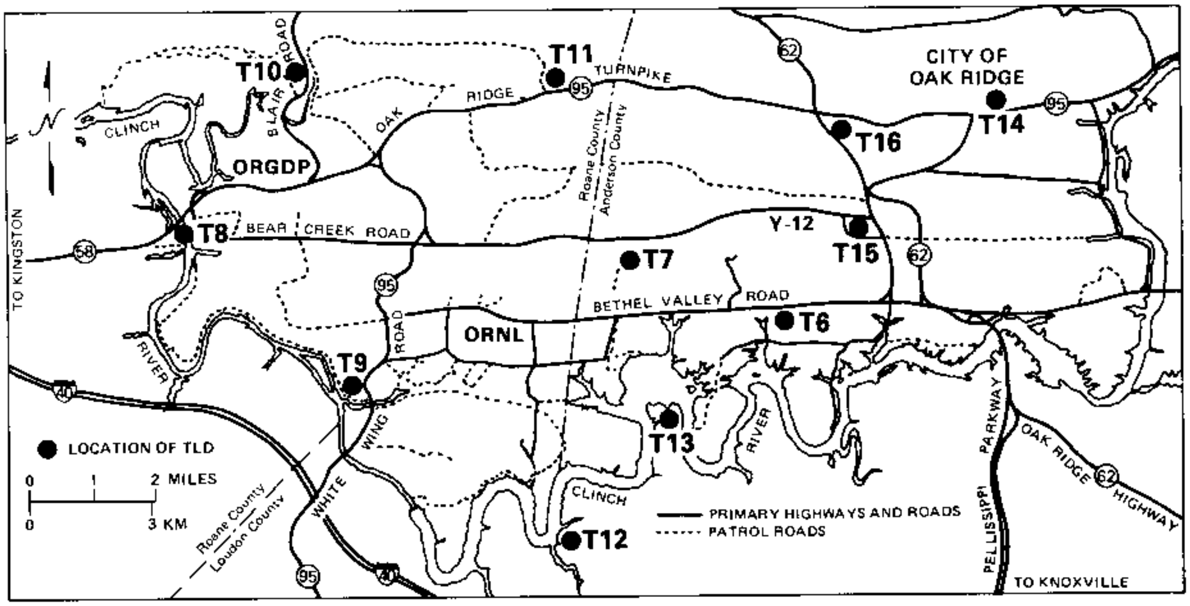

Fig. 4.2.2. Location map of TLDs on the Oak Ridge Reservation.

ORR or in remote areas (Fig. 4.2.4). External gamma radiation measurements are made routinely around ORNL and ORGDP, at ORR air monitoring stations, along Poplar Creek, along the Clinch River, and at the remote monitoring stations using thermoluminescent dosimeters (TLDs) suspended 1 m above the ground and/or with hand-held scintillation detectors. Calcium fluoride TLDs are used at all stations except those around the ORNL perimeter and along the Clinch River. Calcium fluoride TLDs are used in areas where the radiation levels are expected to be near background. Two dosimeters are placed in each container at the ORR perimeter and remote sites, and three are placed in each container at the other sites. Dosimeters at the ORR perimeter stations were collected and analyzed monthly; those at the remote stations and the ORNL perimeter stations, semiannually; and those along the Clinch River, quarterly. The dose calculations for these external gamma radiation measurements are given in Sect. 3.

Data on the average external gamma radiation for the ORNL perimeter, ORR, and remote stations are given in Table 4.2.2 and for the ORGDP stations for 1984 and 1985 in Table 4.2.3. A considerable variation in background levels is normally experienced in East Tennessee, depending on elevation, topography, and geological character of the surrounding soil.[1] There were no statistically significant differences in the average radiation measurements at the ORGDP perimeter stations, the ORR stations, or the remote stations. The average external radiation at ORNL was statistically higher than at other stations. Over the past five years (1981-1985), the average external gamma radiation background levels measured were 10.0 and 7.9 μR/h at the ORR perimeter and remote monitoring stations, respectively. These calculated overall averages are based on yearly (1981-1985)

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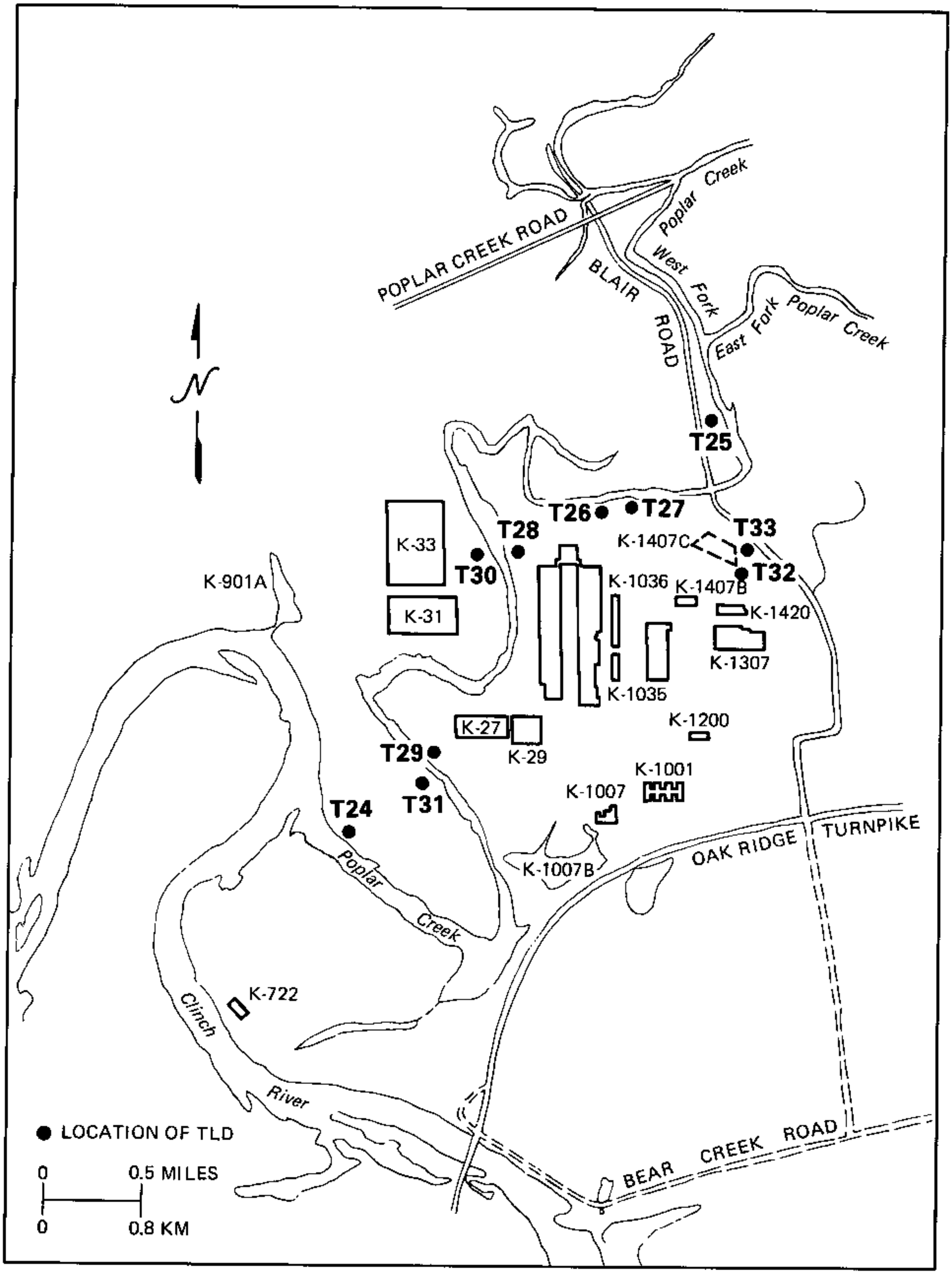

Fig. 4.2.3. Location map of TLDs around the perimeter of ORGDP.

Table 4.2.1. Listing of old and new numbers of TLD sampling stations

ORGDP[a]		ORNL perimeter		ORR		Remote		EFPC	
Old	New	Old	New	Old	New	Old	New	Old	New
76	T24	3	T1	8	T6	51	T17	01	T34
77	T25	7	T3	23	T7	52	T18	02	T35
78	T26	9	T2	33	T8	53	T19	03	T36
79	T27	21	T4	34	T9	55	T20	05	T37
80	T28	22	T5	35	T10	56	T21	07	T38
81	T29			36	T11	57	T22	10	T39
82	T30			37	T12	58	T23	11	T40
83	T31			38	T13			12	T41
84	T32			39	T14			13	T42
85	T33			40	T15			14	T43
				41	T16			15	T44

[a]Note: ORGDP moved some of these stations less than 2 m from previous location in 1985.

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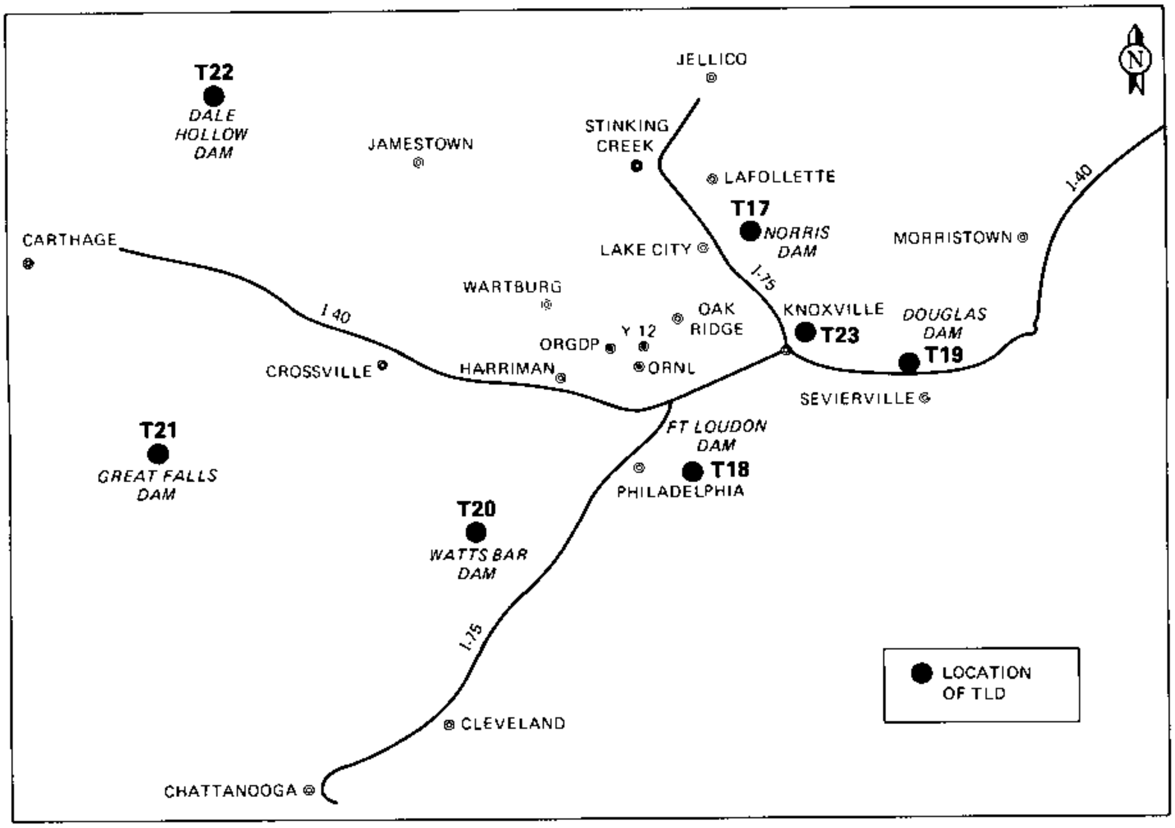

Fig. 4.2.4. Location map of TLDs at remote locations.

Table 4.2.2. 1985 external gamma radiation measurements T1 through T23

Location	No. of measurements[a]	μR/h			
		Max	Min	Av	95% CC[b]
		ORNL perimeter stations[c]			
T1	6	18	11	14	2.2
T2	6	15	12	13	0.80
T3	6	13	9.8	12	1.2
T4	6	20	11	14	2.5
T5	6	19	13	15	1.8
Overall	30	20	9.8	14	0.88
		Oak Ridge Reservation stations[d]			
T6	6[e]	16	9.8	12	1.6
T7	3[e]	9.8	8.8	9.3	0.56
T8	24	21	2.4	9.6	1.8
T9	24	21	4.1	12	1.6
T10	24	13	2.8	7.9	1.2
T11	24	15	4.8	8.5	1.0
T12	24	14	3.7	7.8	1.0
T13	24	20	4.1	8.4	1.4
T14	24	13	3.3	8.8	1.2
T15	24	13	5.3	9.1	0.91
T16	20	16	4.2	11	1.3
Overall	221	21	2.4	9.3	0.45
		Remote stations[f]			
T17	4	7.3	5.2	6.4	0.86
T18	4	9.2	4.3	6.8	2.0
T19	4	8.7	7.8	8.4	0.39
T20	4	8.0	6.8	7.5	0.62
T21	4	8.8	6.0	7.4	1.4
T22	4	10	7.0	8.9	1.5
T23	4	14	11	13	1.6
Overall	28	14	4.3	8.3	0.89

[a] Two measurements are taken per station for each time interval except for the ORNL perimeter stations, for which there are three measurements. Two or three dosimeters are placed in each container to obtain these measurements.

[b] 95% confidence coefficient about the average.

[c] See Fig. 4.2.1.

[d] See Fig. 4.2.2.

[e] Samples were analyzed semiannually with three measurements taken per station for each time interval. Station T7 samples for the second half of 1985 were not reported because they became wet during the sampling period.

[f] See Fig. 4.2.4.

Table 4.2.3. 1984 and 1985 external gamma radiation measurements T24 through T33

Location[a]	No. of measurements	μR/h			
		1985 [b]			
		Max	Min	Av	95% CC[c]
T24	12	12 16	4.2 9.4	8.9 12	1.7 1.2
T25	12	14 13	4.2 8.2	8.5 11	2.0 1.1
T26	12	18 20	5.3 14	12 17	3.0 0.86
T27	12 9[b]	23 21	7.9 14	15 18	3.2 1.3
T28	12 9	13 15	3.0 8.2	8.5 11	2.1 1.4
T29	9 12	17 19	6.5 10	13 14	2.5 1.8
T30	12	12 15	4.1 8.6	8.2 11	1.8 1.5
T31	12	11 17	5.4 9.0	8.2 13	1.3 1.6
T32	12	16 19	3.6 12)	10 15	2.7 1.3
T33	12 9	13 16	4.1 8.2	8.6 12	1.9 1.9
Overall	117	23 21	3.0 8.2	9.9 13	0.80 0.62

[a] See Fig. 4.2.3 (ORGDP).

[b] 95% confidence coefficient about the average.

averages assuming an equal number of samples. The five-year data are shown in Table 4.2.4.

External gamma radiation measurements were made along the stream course of East Fork Poplar Creek (EFPC) to evaluate potential external exposure from radioactivity that may be contained in the sediments as a result of effluent releases from Y-12. The locations of these TLDs are shown in Fig. 4.2.5. The external gamma radiation measurements along EFPC are given in Table 4.2.5. Measurements were just for April 4 to August 20, 1985, with only two measurements made. Thus, these data are questionable. Measurements were also made along the bank of the Clinch River (Watts Bar Lake) from the mouth of White Oak Creek for several hundred yards downstream to evaluate gamma radiation levels resulting from effluent releases from ORNL and "sky shine" from an experimental radioactive cesium plot located near the river bank. The locations of these TLDs are shown in Fig. 4.2.6. The external gamma radiation levels along the bank of the Clinch River ranged from 5.4 to 40 μR/h, as shown in Table 4.2.6. Measurements are made at these locations in order to estimate the maximum exposure to an individual. The average background level determined at the remote stations can be subtracted from the measured gamma radiation levels to determine the incremental increases resulting from plant operations.

Table 4.2.4. External gamma radiation measurements 1981–1985 T6-T23

Location	µR/h				
	1981	1982	1983	1984	1985
			Oak Ridge Reservation stations[a]		
T6	9.7 ± 0.5[b]	8.0 ± 1.0	11 ± 1.1	c	12 ± 1.6
T7	12 ± 0.6	13 ± 2.8	14 ± 1.0	11 ± 1.2	9.3± 0.56
T8	0.7 ± 0.6	10 ± 1.7	10 ± 1.0	8.4 ± 0.76	9.6 ± 1.8
T9	18 ± 2.5	17 ± 4.0	17 ± 1.3	9.9 ± 1.3	12 ± 1.6
T10	8.5 ± 0.5	10 ± 4.0	9.8 ± 0.9	7.9 ± 0.72	7.9 ± 1.2
T11	8.1 ± 0.6	9.5 ± 2.6	9.4 ± 1.0	7.8 ± 0.52	8.5 ± 1.0
T12	7.9 ± 1.0	9.6 ± 2.2	8.7 ± 0.8	7.3 ± 0.68	7.8 ± 1.0
T13	19 ± 0.6	11 ± 4.0	9.7 ± 0.9	8.0 ± 1.2	8.4 ± 1.4
T14	9.0 ± 0.7	12 ± 4.2	9.9 ± 0.9	7.6 ± 0.86	8.8 ± 1.2
T15	ND[d]	ND	8.7 ± 0.4	7.9 ± 0.66	9.1 ± 0.91
T16	ND	ND	11[e]	10 ± 0.76	11.0 ± 1.3
Average	10 ± 2.0	11 ± 1.9	11 ± 0.7	8.6 ± 0.34	9.3 ± 0.45
			Oak Ridge remote stations[f]		
T17	5.8 ± 0.9	5.8 ± 1.6	7.1 ± 1.6	6.8 ± 0.20	6.4 ± 0.86
T18	7.3 ± 1.7	7.3 ± 1.8	7.3 ± 0.6	8.1 ± 0.50	6.8 ± 2.0
T19	7.7 ± 1.1	7.5 ± 2.0	8.0 ± 0.6	9.1 ± 0.84	8.4 ± 0.39
T20	ND	ND	6.8 ± 0.2	7.8 ± 0.10	7.5 ± 0.62
T21	7.3 ± 0.1	5.2[d]	6.9 ± 1.5	6.4 ± 1.7	7.4 ± 1.4
T22	7.7 ± 1.2	7.2 ± 3.0	7.9 ± 1.1	11 ± 3.3	8.9 ± 1.5
T23	11 ± 0.5	11 ± 2.6	11 ± 0.4	11 ± 1.0	13 ± 1.6
Average	7.6 ± 1.1	7.2 ± 1.4	7.8 ± 1.6	8.7 ± 0.86	8.3 ± 0.89

[a] See Fig. 4.2.2.

[b] ± is 95% confidence coefficient about the average.

[c] Station was not part of ORR System in 1984.

[d] No data available.

[e] Only one measurement was taken here.

[f] See Fig. 4.2.3.

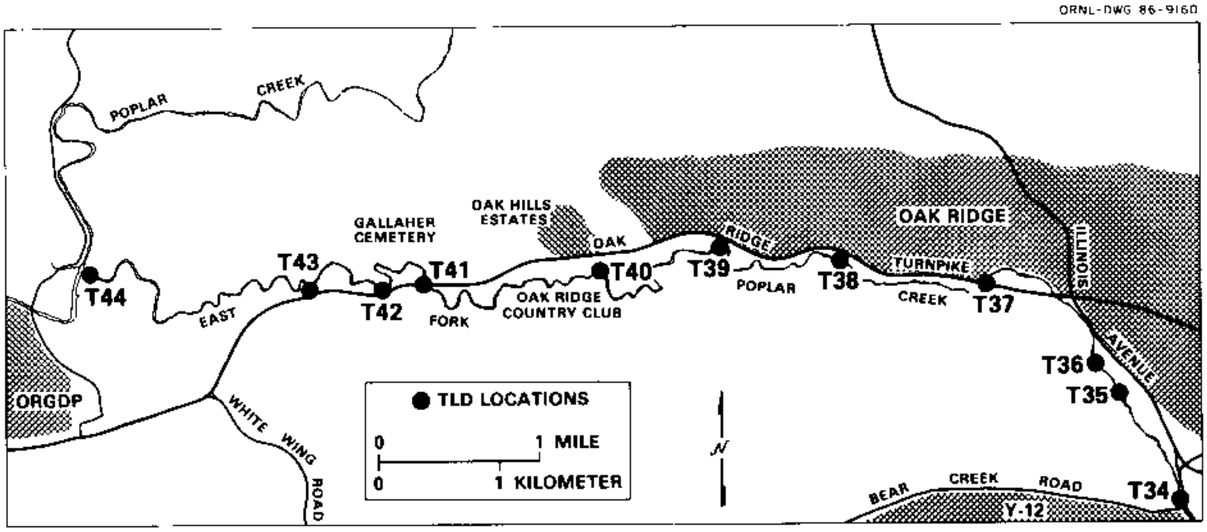

Fig. 4.2.5. Location map of TLDs along East Fork Poplar Creek.

Table 4.2.5. 1985 external gamma radiation measurements T34 through T44

Location[a]	No. of measurements[b,c]	μR/h			
		Max	Min	Av	95% CC[d]
T34	2	5.3	5.2	5.2	0.6
T35	2	7.1	6.0	6.5	7.0
T36	2	DN[e]	DN	DN	
T37	2	8.6	7.2	7.9	8.9
T38	2	7.9	6.6	7.2	8.3
T39	2	6.9	6.0	6.5	5.8
T40	2	4.9	4.2	4.5	4.5
T41	2	6.4	4.8	5.6	10
T42	2	6.1	5.5	5.8	3.8
T43	2	5.1	5.1	5.1	0.0
T44	2	9.8	4.3	7.1	35
Overall	22	9.8	4.2	6.2	0.65

[a] See Fig. 4.2.5 (EFPC).

[b] TLDs in field from April 4 to August 20, 1985.

[c] Two dosimeters per container.

[d] 95% confidence coefficient about the average. Inappropriate to calculate with only 2 data points.

[e] Data not given because TLD chips got wet, thus invalidating data.

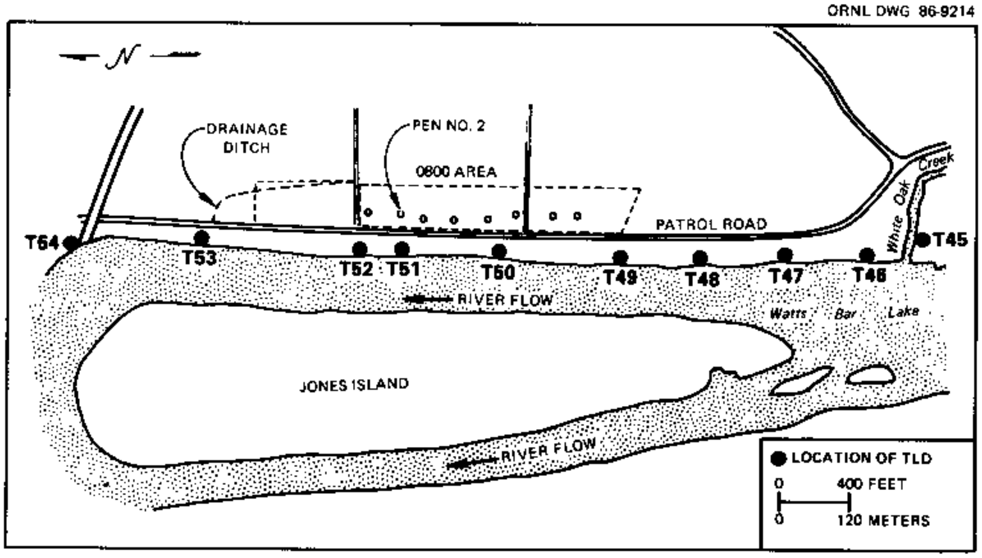

Fig. 4.2.6. Location map of TLDs along the Clinch River.

Table 4.2.6. 1985 external gamma radiation measurements along the Clinch River

Location[a]	No. of measurements[b]	μR/h			
		Max	Min	Av	95% CC[c]
T45	22	21	5.4	12	1.7
T46	22	26	5.8	14	2.3
T47	12	13	9.2	11	0.66
T48	12	15	10	12	0.79
T49	9	40	16	24	7.3
T50	12	37	19	27	3.5
T51	12	37	25	29	2.1
T52	12	28	20	23	1.5
T53	12	19	13	15	1.2
T54	12	13	9.2	11	0.76
Overall	137	40	5.4	17	1.4

[a] See Fig. 4.2.6.

[b] Two dosimeters placed in each container at locations T45 and T46; three dosimeters placed in each container at all other locations. The TLDs were collected and analyzed monthly at locations T45 and T46 and quarterly at all other locations.

[c] 95% confidence coefficient about the average.

REFERENCES FOR SECT. 4.2

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4.3 SURFACE WATER

4.3.1 General Surface Water Quality

The surface waters of the ORR are of a calcium-magnesium/bicarbonate chemical type, reflecting the abundance of limestone and dolomite bedrock in the watershed areas. Hardness is generally moderate; total dissolved solids concentrations usually range between 100 and 250 mg/L.[1]

Water quality in ORR streams is affected by wastewater discharges and by groundwater transport of contaminants from land disposal of waste. Though bedrock characteristics differ somewhat among the watersheds of these streams, the observed differences in water chemistry are not attributed to geologic variation but to different contaminant loadings. For example, East Fork Poplar Creek shows higher levels of several substances than any other stream, probably reflecting the influence of effluents from the Y-12 Plant and from the City of Oak Ridge municipal wastewater treatment facility.

Quality of water in the Clinch River is affected by ORR activities, by contamination introduced upstream of the ORR, and by flow regulation at TVA dams. In general, stream impoundment results in increased water temperatures and retention of sediments and adsorbed contaminants in impoundments. Intermittent release of water from dams causes scouring of the river channel downstream from the dam, as has occurred downstream from Melton Hill Dam, where bedrock is exposed on the river bed.[2] In the vicinity of the ORR, temperature increases are ameliorated by the practice of releasing cold bottom water from Norris Dam and thus maintaining cool water temperatures in Melton Hill Reservoir.[3]

Several institutions routinely monitor water quality in the Clinch River. Both TVA and the U.S. Geological Survey (USGS) monitor water quality just below Melton Hill Dam. The Tennessee Department of Public Health maintains a monitoring station at CRK 16.3 (3.2 km below the mouth of Poplar Creek and ORGDP).

Water quality measurements are made at a number of stations operated by Energy Systems for DOE. As a result of technical reviews of environmental monitoring programs during 1985, the numbering system was redone to make it consecutive and consistent. This new numbering system is shown in Table 4.3.1.

4.3.2 Radioactive Water Quality

Water samples were collected and analyzed regularly for radiological content from the following stations:

(1) Melton Hill Dam (station W1, Fig. 4.3.1)—in the Clinch River 3.7 km above the White Oak Creek outfall. This is a background or reference point. Flow proportional samples were collected daily and composited for quarterly analysis.

Table 4.3.1. Listing of identifications and new numbers of surface water sampling stations[a]

Location	New station number
Melton Hill Dam	W1
Confluence of White Oak Creek	W2
White Oak Dam (WOD)	W3
Melton Branch (MB)	W4
White Oak Creek (WOC)	W5
East weir WOC	W6
West weir WOC	W7
HFIR/TRU	W8
NSPP	W9
7500 bridge	W10
Northwest Tributary	W11
First Creek	W12
STP	W13
PWTP	W14
3500 (190 ponds) Ponds	W15
Flume Station 2	W16
Fifth Creek	W17
Raccoon Creek	W18
Ish Creek	W19
ORGDP sanitary water	W20
Poplar Creek above Blair Bridge	W21
Poplar Creek near Clinch River	W22
West Fork Poplar Creek	W23
East Fork Poplar Creek	W24
Bear Creek[b]	W25
K-1515	W26
K-710-A	W27
K-901-A	W28
K-1007-B	W29
K-1203	W30
K-1700	W31
Upper Bear Creek	W32
Kerr Hollow 301	W33
Rogers Quarry 302	W34
New Hope Pond 303	W35
Bear Creek 304	W36
Oil Pond 1-305	W37
Oil Pond 2-306	W38
Steam Plant Flyash Sluice Water 623	W39
S-3 Ponds Liquid Treatment Facility 507	W40
Mobile Waste Water Treatment Facility 508	W41
Waste Coolant Processing Facility 510	W42
Central Pollution Control Facility (CPCF) 501	W43
Poplar Creek[b]	W44
Kingston Water Plant	W45

[a] This new numbering system is being put in place for CY 1985. Most of these stations did not have old numbers.

[b] Future location.

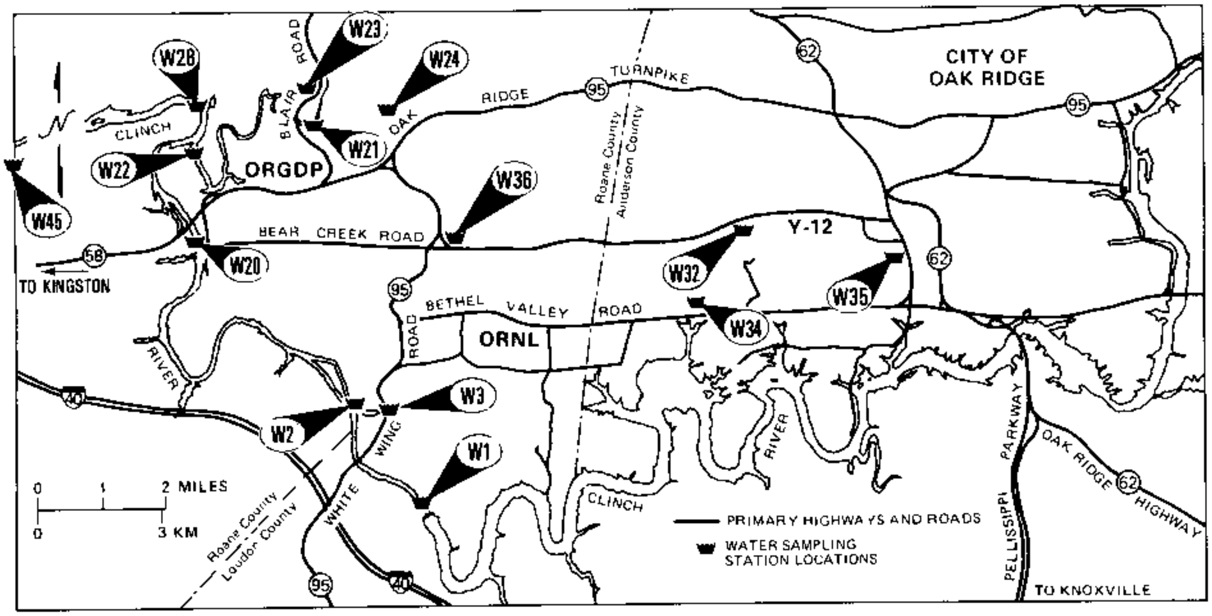
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Fig. 4.3.1. Location map of water sampling locations W1 through W3 and W21 through W25 and W33, W36 and W44.

(2) Confluence of White Oak Creek and the Clinch River (station W2, Fig. 4.3.1)—represents the closest point of access by the public. Time proportional samples were collected daily and composited for weekly analysis.

(3) White Oak Dam (station W3, Fig. 4.3.1)—ORNL discharge point from White Oak Creek to Clinch River. Flow proportional samples were collected daily and composited for weekly analysis.

(4) ORNL tap water—a reference sample. Samples were collected daily and composited for quarterly analysis.

(5) ORGDP sanitary water (station W20, Fig. 4.3.1)—10 km downstream from the confluence of White Oak Creek and the Clinch River. A grab sample was collected and analyzed quarterly.

(6) Water plant near Kingston (station W45, Fig. 4.3.1)—downstream from the entry of White Oak Creek. A sample was collected daily and composited for quarterly analysis.

(7) A number of additional water sampling stations in WOC and Melton Branch, Bear Creek, and Poplar Creek.

Fission product radionuclide concentrations were determined by specific radionuclide analysis and gamma spectrometry. Uranium analysis was by the fluorometric method or mass spectrometry. Transuranic alpha emitters were determined by chemical chromatography and alpha spectrometry.

Concentrations of radionuclides of primary concern are shown in Tables 4.3.2 and 4.3.3. Concentrations determined at

Table 4.3.2. 1985 concentrations of radionuclides in surface streams and tap water

Location[a]	No. of samples	Value	^{60}Co		^{137}Cs		^{3}H		^{90}Sr	
			(10^{-9} µCi/mL)[c]	(10^{-5} Bq/mL)[d]	(10^{-9} µCi/mL)[c]	(10^{-5} Bq/mL)[d]	(10^{-6} µCi/mL)[c]	(10^{-4} Bq/mL)[d]	(10^{-9} µCi/mL)[c]	(10^{-5} Bq/mL)[d]
Melton Hill Dam (W1)	4[b]	Max	<0.27	<1.0	2.1	7.8	5.1	19	1.4	5.1
		Min	<0.27	<1.0	0.27	1.0	0.0	0.0	0.081	0.30
		Av	<0.27	<1.0	1.1	4.1	2.5	9.3	0.79	2.9
ORGDP process water (W20)	4	Max	0.22	0.81	0.32	1.2	5.3	20	3.2[e]	12
		Min	0.11	0.41	0.081	0.30	0.38	1.4	0.46	1.7
		Av	0.14	0.52	0.17	0.63	2.5	9.3	1.9	7.0
Kingston (W45)	4	Max	0.16	0.59	0.081	0.30	0.48	1.8	3.2	12
		Min	0.054	0.20	0.054	0.20	0.0	0.0	0.16	0.59
		Av	0.099	0.37	0.072	0.27	0.12	0.44	1.2	4.4
ORNL tap water	4	Max	0.11	0.41	0.11	0.41	0.0	0.0	1.1	4.1
		Min	0.081	0.30	0.081	0.30	0.0	0.0	0.027	0.099
		Av	0.099	0.37	0.090	0.33	0.0	0.0	0.42	1.6
Confluence of White Oak Creek and Clinch River (W2)	52	Max	170	630	1500	5,600	350	1,300	350	1,300
		Min	<0.81	3.0	<1.6	<5.9	5.4	20	1.4	720
		Av	<10	<37	<46	470	62	230	52	190
White Oak Dam (W3)	52	Max	1,900	7000	650	2,400	780	2,900	3,500	13,000
		Min	5.0	19	6.9	26	83	300	110	410
		Av	63	230	42	160	350	1,300	300	1,100

[a] See Fig 4.3.1.

[b] Except for ^{3}H—only 2 samples.

[c] µCi = 10^{-6} Ci = 3.7×10^{-4} d/s.

[d] Bq = Becquerel = 1 d/s.

[e] Sample had a high (about 100%) counting uncertainty which also affected the average value.

Table 4.3.3. 1985 concentrations of alpha emitters in surface streams and tap water

Location[a]	No. of samples	Value	^{239}Pu $(10^{-12}\,\mu\text{Ci/mL})^b$	^{234}U $(10^{-9}\,\mu\text{Ci/mL})^b$	^{235}U $(10^{-12}\,\mu\text{Ci/mL})^b$	^{236}U $(10^{-12}\,\mu\text{Ci/mL})^b$	^{238}U $(10^{-12}\,\mu\text{Ci/mL})^b$	TRU[c] $(10^{-9}\,\mu\text{Ci/mL})^b$
Melton Hill Dam (W1)	3	Max	<3.0	0.18	5.4	0.78	93	NA[d]
		Min	<3.0	0.051	1.7	0.14	74	
		Av	<3.0	0.12	3.8	0.35	82	
ORGDP process water (W20)	3	Max	<3.0	0.13	4.0	0.16	84	NA
		Min	<3.0	0.076	2.3	0.12	48	
		Av	<3.0	0.11	3.4	0.14	71	
Kingston (W45)	3	Max	<3.0	0.14	2.0	0.37	87	NA
		Min	<3.0	0.052	0.48	0.18	32	
		Av	<3.0	0.086	1.4	0.28	53	
ORNL tap water	3	Max	<3.0	0.16	4.5	0.18	100	NA
		Min	<3.0	0.11	3.6	0.057	35	
		Av	<3.0	0.13	3.9	0.10	75	
White Oak Dam (W3)	52	Max	NA	NA	NA	NA	NA	2.1
		Min	NA	NA	NA	NA	NA	0.081
		Av	NA	NA	NA	NA	NA	0.71

[a] See Fig. 4.3.1.

[b] $\mu\text{Ci} = 10^{-6}\,\text{Ci} = 3.7 \times 10^{-4}\,\text{d/s}$.

[c] TRU = transuranics.

[d] Not analyzed.

Note: The companion table (4.3.4) gives the same values in Bq/mL.

Table 4.3.4. 1985 concentrations of alpha emitters in surface streams and tap water

Location[a]	No. of samples	Value	^{239}Pu (10^{-8} Bq/mL)[b]	^{234}U (10^{-5} Bq/mL)[b]	^{235}U (10^{-8} Bq/mL)[b]	^{236}U (10^{-8} Bq/mL)[b]	^{238}U (10^{-8} Bq/mL)[b]	TRU[c] (10^{-5} Bq/mL)[b]
Melton Hill Dam (W1)	3	Max	<11	0.67	20	2.9	340	NA[d]
		Min	<11	0.19	6.3	0.52	270	
		Av	<11	0.44	14	1.3	300	
ORGDP process water (W20)	3	Max	<11	0.48	15	0.59	310	NA
		Min	<11	0.28	8.5	0.44	180	
		Av	<11	0.41	13	0.51	260	
Kingston (W45)	3	Max	<11	0.52	7.4	1.4	320	NA
		Min	<11	0.19	1.8	0.67	120	
		Av	<11	0.32	5.2	1.0	196	
ORNL tap water	3	Max	<11	0.59	17	0.67	370	NA
		Min	<11	0.41	13	0.21	130	
		Av	<11	0.48	14	0.37	280	
White Oak Dam (W3)	52	Max	NA	NA	NA	NA	NA	NA
		Min	NA	NA	NA	NA	NA	NA
		Av	NA	NA	NA	NA	NA	NA

[a] See Fig. 4.3.1.

[b] Bq = Becquerel = 1 d/s.

[c] TRU = transuranics.

[d] Not analyzed.

the Clinch River sampling stations (W20 and W45) downstream from the confluence of White Oak Creek and Poplar Creek, respectively, and the Clinch River showed a marked decrease for beta and gamma emitters, many of which were below analytical detection limits (Table 4.3.2). Similar comparison was not made for alpha emitters for lack of information. Average concentrations of alpha, beta, and gamma emitters from ORGDP process water (W20) and the Kingston Water Plant (W45) are in the same range as the reference points (W1 and ORNL tap), shown in Tables 4.3.2 through 4.3.4. (Table 4.3.3 shows alpha emitters in μCi/mL; Table 4.3.4 shows alpha emitters in Bq/mL. However, average concentrations of beta-gamma emitters at White Oak Dam (station W3) and average concentrations of ^{3}H at the White Oak Creek confluence (Station W2) decreased significantly from 1984 values.

Analysis of water samples collected at the confluence of White Oak Creek and the Clinch River (W2, Fig. 4.3.1) showed that average ^{60}Co, ^{90}Sr, and ^{3}H concentrations were somewhat less than those measured at White Oak Dam (W3, Fig. 4.3.1); however, ^{137}Cs was about the same. Concentrations at this confluence point are dependent on the relative levels and flows of the creek and river in addition to the quantity of activity being discharged from White Oak Dam. Concentrations were determined at this location because it represents the closest point of access by the public to White Oak Creek.

To estimate discharges of radionuclides from ORNL to White Oak Creek and the Clinch River, daily flows were measured at White Oak Dam (W3) and the Clinch River at Melton Hill Dam (W1), 3.7 km above the White Oak Creek outfall. Monthly flows at these two stations are shown in Table 4.3.5. The average monthly dilution factor of Clinch River flow to White Oak Creek flow varied between 108 and 540 during 1985, as shown in column 4 of Table 4.3.3. The contribution of ^{90}Sr from various ORNL areas is given in Tables 4.3.6 and 4.3.7. Figure 4.3.2 is a flow diagram of the water sampling stations on WOC and Melton Branch. Figure 4.3.3 shows the locations of these sampling stations.

The Y-12 Plant conducts a flow proportional sampling program for radioactive contaminants on East Fork Poplar Creek (EFPC) at the effluent of New Hope Pond (W35, Fig. 4.3.4) and on Bear Creek where it intersects with Highway 95 (W25, Fig. 4.3.1). All samples are composited on a monthly basis and analyzed for gross alpha, gross beta, total uranium, percent ^{235}U, and thorium. This sampling is performed to assess the amount of uranium being discharged through liquid effluents as a result of the operations at Y-12. It is reported to DOE in the Radioactive Discharge Summary Report each year.

These additional water samples were collected for radiochemical analyses at the outlet of New Hope Pond (W35, Fig. 4.3.4) on East Fork Poplar Creek (W24, Fig. 4.3.1, Table 4.3.8), in Bear Creek (W25, Table 4.3.9), and in Poplar Creek (W21 and W22). Flow proportional samples were collected at Stations W35 and W25. Grab samples were collected weekly at W21 and W22. All samples were composited for monthly analyses.

The following average uranium concentrations are noted for East Fork Poplar Creek (W24, Table 4.3.8 and Fig. 4.3.2), Bear Creek (W24, Table 4.3.9 and Fig. 4.3.1), the Clinch River (W1, W20, and W45, Table 4.3.3 and Fig. 4.3.3), and Poplar Creek (Table 4.3.10 and Fig. 4.3.1). The increases in uranium discharges are

Table 4.3.5. 1985 flow in the Clinch River and White Oak Creek

Month	Flow (10^9 Liters)		Average ratio[b]
	Clinch River (W1)[a]	White Oak Creek (W3)[a]	
January	460	1.1	540
February	230	1.1	230
March	180	0.70	250
April	82	0.78	108
May	110	0.72	150
June	140	0.61	220
July	300	0.98	305
August	390	1.7	330
September	310	0.58	540
October	230	0.90	260
November	140	0.96	160
December	200	0.56	350

[a] See Fig. 4.3.3.

[b] Ratio of Clinch River to White Oak Creek flow is calculated weekly and averaged for the month.

being investigated. Doses from these concentrations are given in Sect. 3. Quantities of radionuclides discharged to surface streams for the past five years are given in Sect. 2.1. The discharge values reported in Sect. 2.1 are approximately equivalent to 0.39 Ci of uranium discharged to EFPC and 0.13 Ci to Bear Creek.

Rainwater samples are collected for radioactivity analyses on ORR and at remote locations shown in Figs. 4.3.5 and 4.3.6, respectively. Trends in the gross beta activity in rainwater (Table 4.3.4) collected at ORR stations over the past seven years are shown in Fig. 4.3.7. Many of the measured activities for the remote and perimeter stations were at or near the limits of detection. Activities at the remote stations have been consistently higher than at the perimeter stations. Mean values in 1985 were higher than in 1984, but lower than in some previous years (1980 and 1981).

4.3.3 Nonradioactive Water Quality

Water samples are collected for analysis of nonradioactive substances at many locations on and off the ORR. Samples are composited for monthly analyses; $NO_3(N)$ values are determined from a monthly grab sample. EPA-approved methods are used for the determination of chemicals in water. Concentrations of chemicals in streams and creeks on or around the ORR are determined as reviewed in this Section. These concentrations have been compared with Tennessee's in-stream allowable concentrations that are based on the long-term protection of domestic water supply, fish and aquatic life, and recreation classifications and recommendations made by the TDHE to DOE Oak Ridge Operations.[5] Concen-

Table 4.3.6. Average contribution of ^{90}Sr from various ORNL areas 1979–1982

Area	1979		1980		1981		1982	
	10^9 pCi/mo[a]	Percent[b]	10^9 pCi/mo[a]	Percent[b]	10^9 pCi/mo[a]	Percent[b]	10^9 pCi/mo[a]	Percent[b]
Measured contributors								
Measured flume (W16)	15	6.3	10	6.1	13	10.6	13	5.4
Measured 3539 & 3540 ponds (W15)	1.0	0.40	2.4	1.4	0.40	0.3	0.20	0.1
Measured Process Waste Treatment Plant (PWTP) (W14)	2.9	1.2	1.9	1.1	2.7	2.2	0.50	0.2
Measured Sewage Treatment Plant (STP) (W13)	11	4.8	15	9.1	18	14.8	36	15.7
(Sum) ORNL operations	30	12.7	30	17.7	34	27.9	50	21.4
Measured station 2A (W10)	70	30	77	46.4	72	58.9	120	49.8
Measured station 3 (W5)	170	71.5	110	65.1	100	84.4	180	77.1
Measured HFIR/TRU (W8)	0.20	0.10	0.20	0.10	0.30	0.30	0.90	0.4
Measured NSPP/MSRE (W9)	6.6	2.8	4.8	2.9	3.3	2.7	9.0	3.9
(Sum) Melton Branch	6.8	2.9	5.0	3.0	3.6	3.0	9.9	4.3
Measured station 4 (W4)	67	28.5	52	31.2	17	14.1	50	21.5
Measured east weir (W6)	NA		0.30	0.20	1.0	0.80	0.10	0.10
Measured west weir (W7)	NA		5.9	3.6	1.0	0.8	3.1	1.3
(Sum) total pits			6.2	3.8	2.0	1.6	3.2	1.4
Total effluents (sum of Station W5, Station W4, and pits)	240		170		120		230	
Measured White Oak Dam station (W3)	200		125		123		225	
Inferred contributors								
Burial grounds 1, 3 and floodplain (station W10, minus ORNL operation)	40	17	48	30	38	31	66	29
Burial ground 4 (W5 minus W10)	99	42	31	20	31	26	63	28
Burial ground 5 (W4 minus Melton Branch)	60	26	47	29	14	11	40	18
Total	200	85	130	79	80	68	170	75

[a] To convert from 10^9 pCi/mo to 10^7 Bq/mo, multiply by 3.7.

[b] Percent of total effluents.

Source: Developed from J. H. Coobs, ORNL, personal communications, November 14, 1983, and January 5 and February 8, 1984.

Table 4.3.7. Average contribution of ^{90}Sr from various ORNL areas 1983–1985

Area	1983		1984		1985	
	10^9 pCi/mo[a]	Percent[b]	10^9 pCi/mo[a]	Percent[b]	10^9 pCi/mo[a]	Percent[b]
Measured contributors						
Measured flume (W17)	10	4.0	7.8	4.9	20	8.3
Measured 3539 & 3540 ponds (W15)	0.20	0.10	0.40	0.25	7.2	3.0
Measured Process Waste Treatment Plant (PWTP) (W14)	0.30	0.10	0.40	0.25	33	14
Measured Sewage Treatment Plant (STP) (W13)	20	7.9	12	7.5	33	14
(Sum) ORNL operations	31	12	21	13	93	39
Measured station 2A (W10)	85	33	72	45	160	67
Measured station 3 (W5)	170	66	110	69	200	83
Measured HFIR/TRU (W8)	6.1	2.4	0.49	0.31	0.24	0.1
Measured NSPP/MSRE (W9)	4.9	1.9	5.2	3.3	4.8	2.0
(Sum) Melton Branch	11	4.3	5.7	3.6	5.0	2.1
Measured station 4 (W4)	82	33	44	28	32	
Measured east weir (W6)	0.10	0.10	0.14	0.088	0.093	0.03
Measured west weir (W7)	3.6	1.4	5.1	3.2	2.4	1.0
(Sum) Total pits	3.7	1.5	5.2	3.3	2.5	1.0
Total effluents (sum of Station W5, Station W4, and pits)	260		160		240	
Measured White Oak Dam station (W3)	208		216		250	
Inferred contributors						
Burial grounds 1, 3 and floodplain (station W10, minus ORNL operation)	54	22	51	32	71	30
Burial ground 4 (W5 minus W10)	85	33	38	24	40	17
Burial ground 5 (W4 minus Melton Branch)	71	29	38	24	27	11
Total	210	84	130	79	140	58

[a] To convert from 10^9 pCi/mo to 10^7 Bq/mo, multiply by 3.7.

[b] Percent of total effluents.

Source: Personal communication from L. Lasher (March 1986).

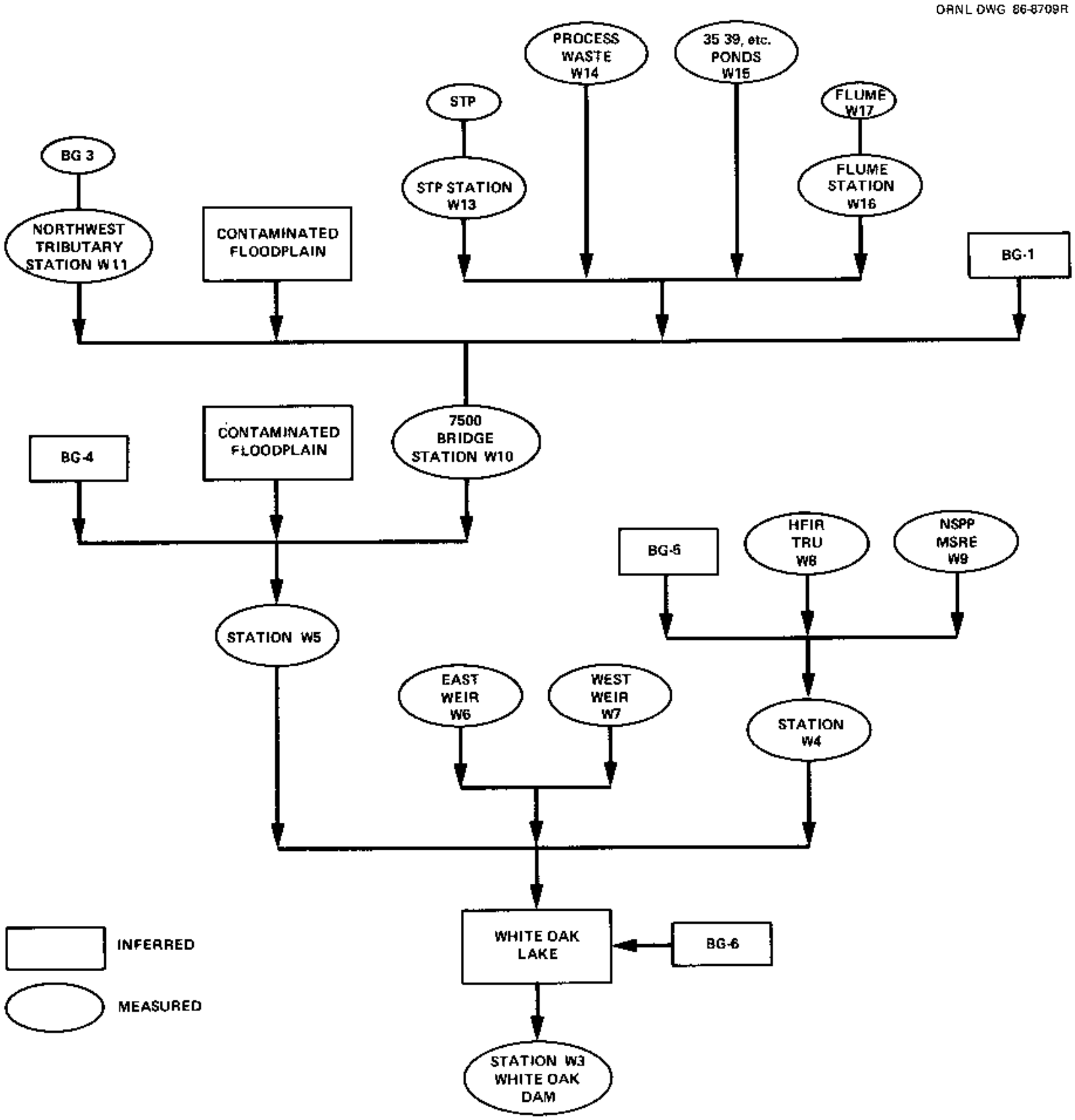

Fig. 4.3.2. Flow diagram of sampling stations on White Oak Creek and Melton Branch.

trations of chemicals in the outlet for the ORGDP sanitary water plant are compared with Tennessee water quality criteria for domestic water supply.

In some cases, the maximum concentrations recommended by the State and EPA is below the detection limit using the most sensitive EPA-approved method. Those chemicals whose detection limits exceeded Tennessee's criteria include mercury, cadmium, and lead. The average concentrations of the other chemicals may easily be compared with Tennessee criteria. Chromium, cyanide, sulfates, nickel, and total dissolved solids (TDS) were all within the Tennessee criteria

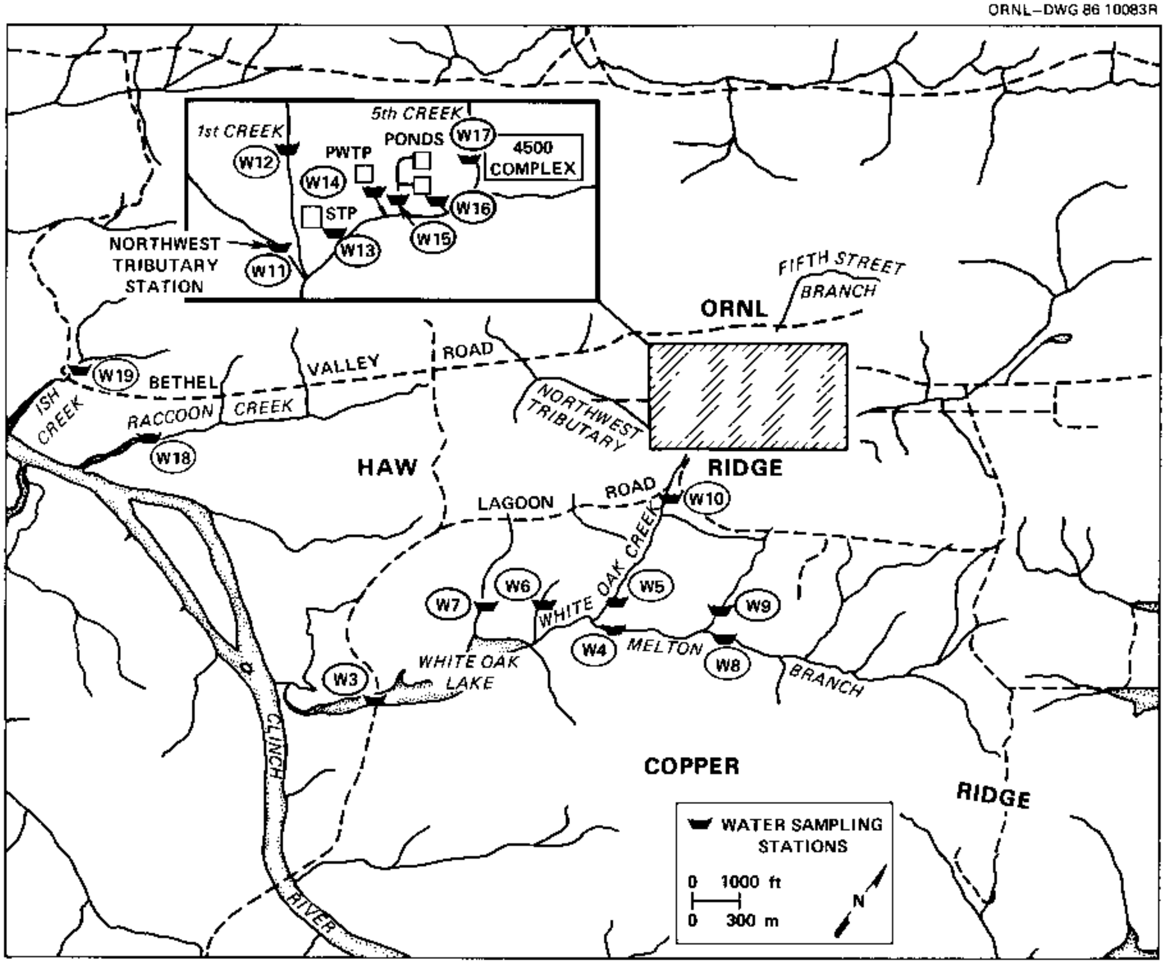

Fig. 4.3.3. Location map of sampling stations on White Oak Creek and Melton Branch.

(Tables 4.3.12 through 4.3.24). The zinc concentrations in water at White Oak Creek, Melton Branch and the Clinch River are given in Table 4.3.12. Other average concentrations that approached or exceeded the criteria include: $NO_3(N)$ at the confluence of White Oak Creek and the Clinch River (Table 4.3.13) and zinc and lead in East Fork Poplar Creek (Table 4.3.23). Average concentrations of fluoride were 90% of the Tennessee criteria at one location (Table 4.3.23). Mercury concentrations in White Oak Creek, Melton Branch, and the Clinch River are given in Table 4.3.14. Concentrations of chromium at the Melton Hill Dam stations are given in Table 4.3.15.

A better guideline for those chemicals whose detection limit exceeds the Tennessee criteria was to compare stream water affected by the Oak Ridge facilities with waters above the facilities. Water samples were collected from above Melton Hill Dam and analyzed for many of EPA's priority pollutants. Results are given in Table 4.3.16.

The chemical water quality data for the ORGDP sanitary water pumping station are given in Table 4.3.17. Table 4.3.18 lists the chemical water quality data for

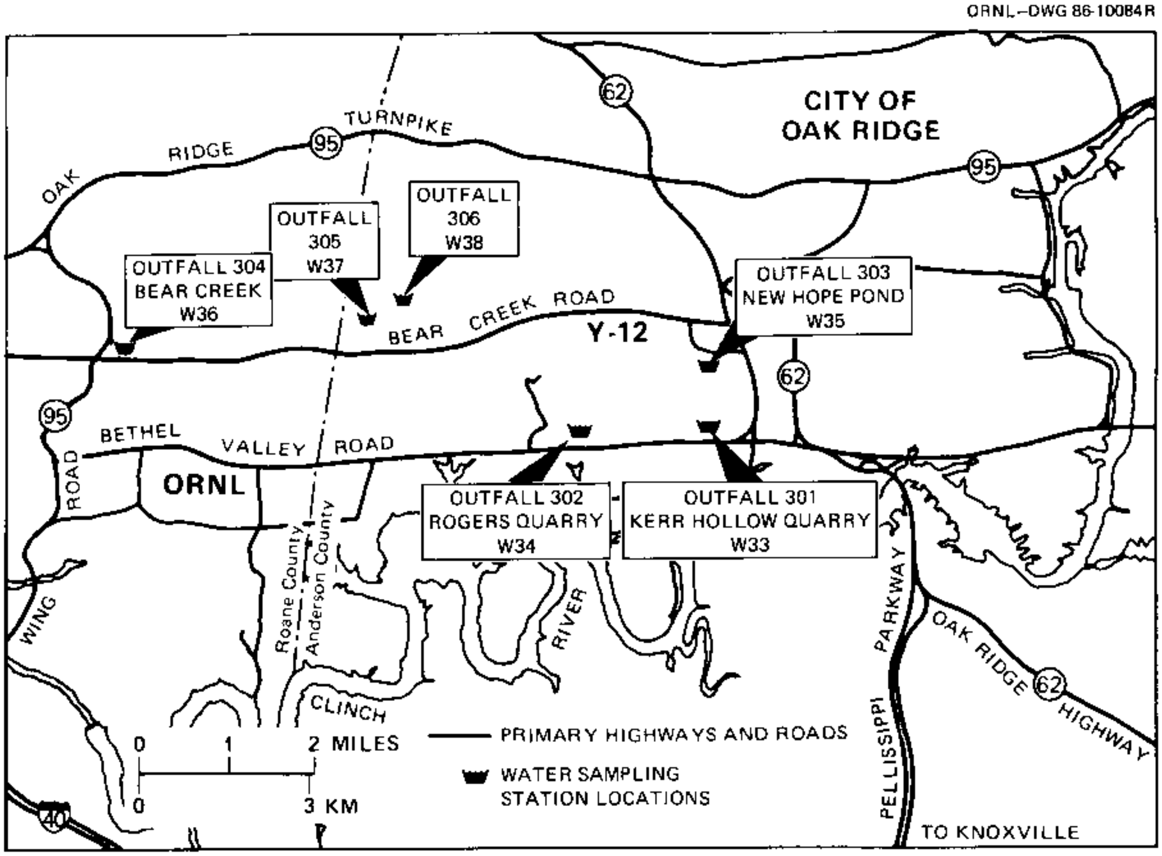

Fig. 4.3.4. Location map of Y-12 NPDES points W33 through W38.

the ORGDP recirculating pumping station. Chemical water quality data for the Clinch River downstream from ORGDP are given in Table 4.3.19. The 1985 chemical water quality data for Poplar Creek above Blair Bridge are given in Table 4.3.20. Table 4.3.21 lists the 1985 chemical water quality data for Poplar Creek near the Clinch River. The 1985 chemical water quality data for West Fork Poplar Creek on Blair Road are given in Table 4.3.22. Chemical water quality data for East Fork Poplar Creek are given in Table 4.3.23. Chemical water quality data for Bear Creek are given in Table 4.3.24.

Average chemical concentrations on or around the ORNL area are within TDHE criteria, except for mercury and zinc. The average zinc concentration slightly exceeded the criteria at White Oak Creek (Table 4.3.12). Average mercury concentrations exceeded TDHE criteria at all stations except Melton Hill Dam (Table 4.3.14).

NPDES permits under the Clean Water Act were issued by the EPA for each of the Oak Ridge facilities in 1975. The permits established a number of discharge locations at each installation and listed specific concentration limits and/or monitoring requirements for a number of parameters at each discharge location. A new NPDES permit was issued to ORGDP in February 1984. The sampling locations are shown in Fig. 4.3.8. Tables 4.3.23 through 4.3.28 list the

Table 4.3.8. 1985 radiochemical water quality for East Fork Poplar Creek[a]

Parameter	No. of samples	Concentration			Unit
		Max	Min	Av	
Gross alpha	12	60 (220)	9.4 (35)	28.7	pCi/L[b] (10^{-2} Bq/L)[c]
Gross beta	12	120 (450)	<4.0 (15)	<34.0 (126)	pCi/L (10^{-2} Bq/L)
Uranium	12	0.268	0.002	0.043	mg/L
^{235}U	12	1.2	0.43	0.76	% of total U
Thorium	12	0.037	<0.003	<0.010	mg/L

[a] Fig. 4.3.1, Station W24. Total flow: 13 billion L/year.
[b] pCi = 10^{-12} Ci = 0.01 disintegration per second.
[c] Bq = Becquerel = 1 disintegration per second. Becquerels are in ().

Table 4.3.9. Radiochemical water quality for Bear Creek[a]

Parameter	No. of samples	Concentration			Unit
		Max	Min	Av	
Gross alpha	12	48 (180)	<1 (<3.7)	<22 (<81)	pCi/L[b] (10^{-2}Bq/L)[c]
Gross beta	12	340 (1300)	<4 (<15)	<67 (<250)	pCi/L (10^{-2}Bq/L)
Uranium	12	0.088	0.046	0.061	mg/L
^{235}U	12	0.57	0.30	0.40	% total Uranium
Thorium	12	0.016	<0.003	<0.008	mg/L
^{237}Np	11	6.5 (24)	<6.0 (22)	<6.0 (<22)	pCi/L (10^{-2}Bq/L)
^{99}Tc	11	<0.3 (<1.1)	<0.3 (<1.1)	<0.3 (<1.1)	pCi/mL (10^{-2}Bq/L)
$^{239/240}$Pu	11	0.91 (3.4)	<0.2 (<0.74)	<0.26 (0.96)	pCi/L (10^{-2}Bq/L)

Total flow: 3.8 billion L/year.
[a] Fig. 4.3.1 Station W25.
[b] pCi = 10^{-12} Ci = 0.01 disintegration per second.
[c] Bq = Becquerel = 1 disintegration per second. Becquerel are in ( ).

Table 4.3.10. 1985 concentrations of uranium in surface streams

Location[c]	No. of samples	Concentration (pCi/L)[a](10^{-2} Bq/mL)[b]			
		Max	Min	Av	95% CC[d]
W21	11	13.7 (139)	<3.8 (<14)	<4.9 (<18)	0.002 (0.0074)
W22	11	5.3 (19)	<3.8 (<14)	<3.9 (<14)	0.000 (0.000)
W23	11	4.6 (17)	<0.8 (<3.0)	<3.6 (<14)	0.001 (0.0037)
W20	11	<3.8 (<14)	<3.8 (<14)	<3.8 (<14)	0.00 (0.00)
W32	10	3.8 (14)	<3.8 (<14)	<3.8 (<14)	0.00 (0.00)
W45	11	3.8 (14)	<0.8 (<3.0)	<3.5 (<13)	0.001 (0.0037)

[a] pCi = 10^{-12} Ci = 0.01 disintegration per second.
[b] Bq = Becquerel = 1 disintegration per second. Becquerel/L are in ().
[c] See Fig. 4.3.1.
[d] 95% confidence coefficient about the average.

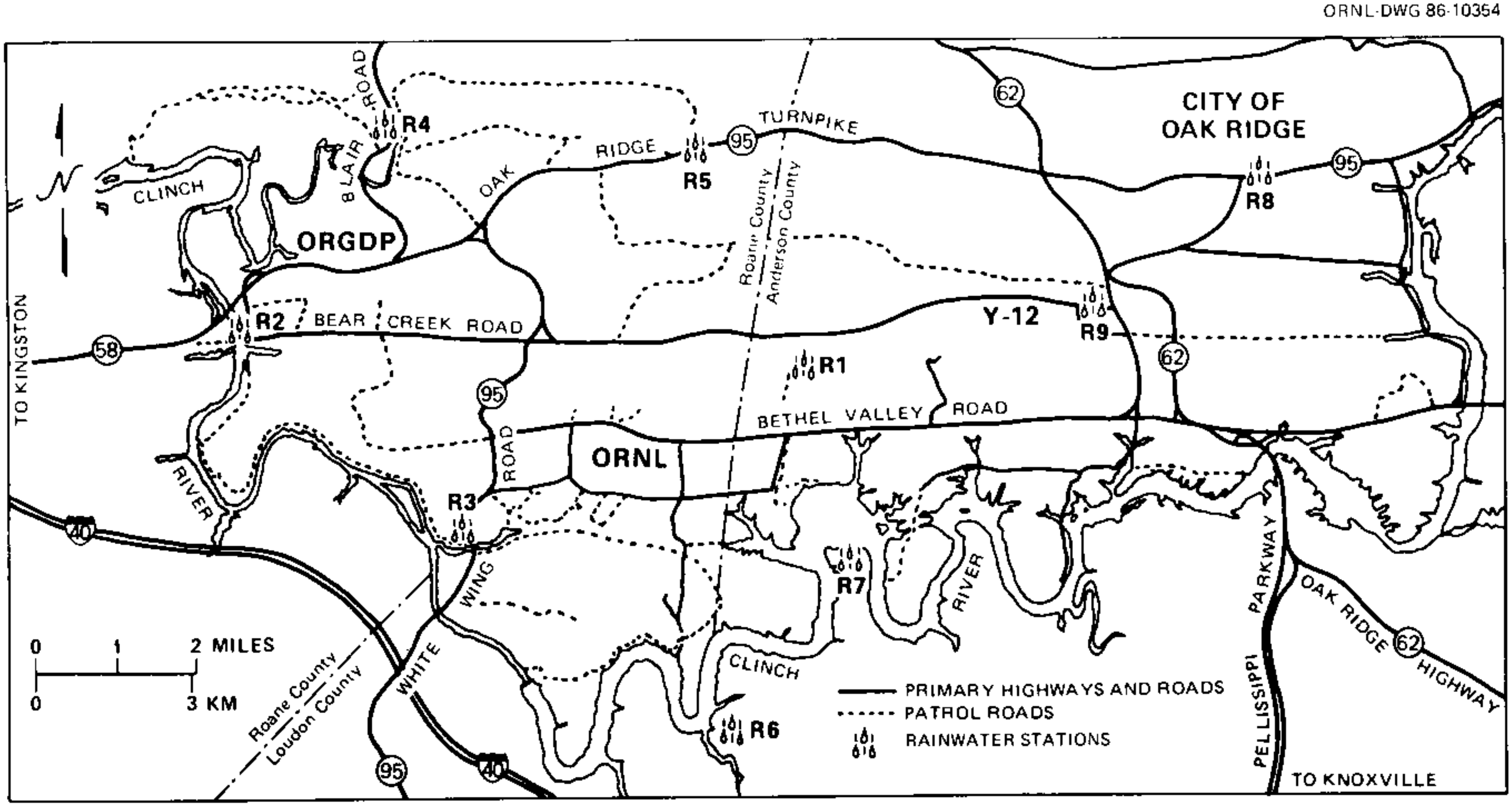

Fig. 4.3.5. Location map of ORR rainwater sampling stations.

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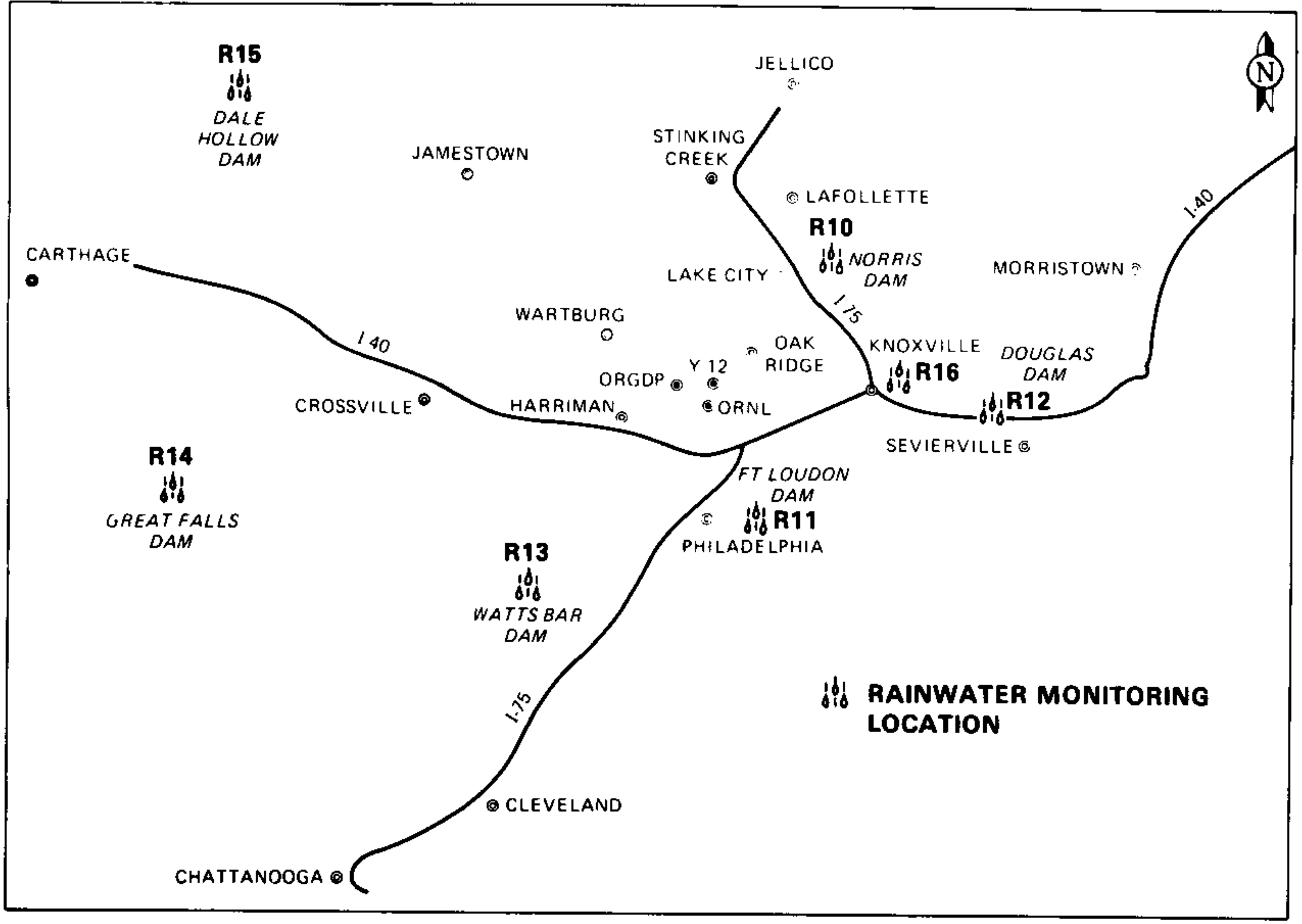

Fig. 4.3.6. Location map of remote rainwater sampling stations.

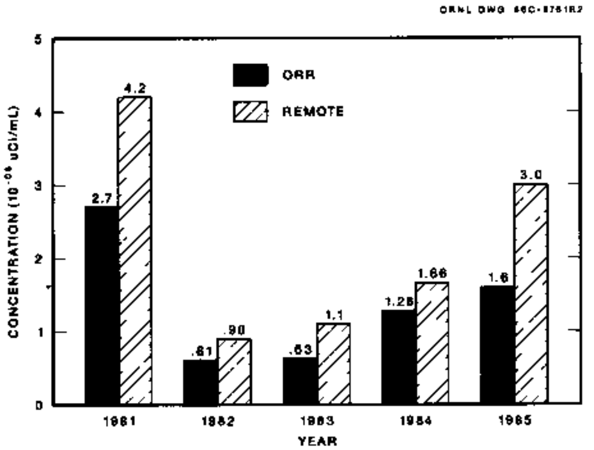

Fig. 4.3.7. Beta activity in rainwater.

discharge locations at each installation, the parameters at each location for which limits have been established, the permit limits for each parameter, and the percentage of compliance achieved.

The present ORGDP NPDES permit was issued in February 1984 and expires in February 1989. Compliance with this permit is shown in Table 4.3.25. Three parameters—aluminum at the K-1700 discharge, COD at K-1007-B holding pond, and chromium in the K-901-A holding pond—have had less than 95% of their measurements in compliance.

Table 4.3.11. 1985 long-lived gross beta in rainwater

Station number	No. of samples	Concentration $(10^{-8}\mu Ci/mL)$[a]$(10^{-4}Bq/mL)$[b] Max	Min	Av	95% CC[c]
		Oak Ridge Reservation Stations[d]			
R1	40	2.6 (9.6)	<1.4 (<5.2)	<1.5 (<5.5)	0.081 (0.30)
R2	39	2.7 (9.9)	<1.4 (<5.2)	<1.5 (<5.5)	0.10 (0.37)
R3	43	2.3 (8.5)	<1.4 (<5.2)	<1.6 (<5.9)	0.079 (0.29)
R4	38	3.0 (11)	<1.4 (<5.2)	<1.6 (<5.9)	0.14 (0.52)
R5	38	2.8 (10)	<1.4 (<5.2)	<1.6 (<5.9)	0.12 (0.4)
R6	40	3.8 (14)	<1.4 (<5.2)	<1.7 (<6.3)	0.16 (0.63)
R7	38	3.6 (13)	<1.4 (<5.2)	<1.8 (<6.7)	0.19 (0.70)
R8	42	3.6 (13)	<1.4 (<5.2)	<1.7 (<6.3)	0.14 (0.52)
R9	28	3.6 (13)	<1.4 (<5.2)	<1.8 (<6.7)	0.22 (0.81)
Network summary	348	3.8 (18)	<1.4 (<5.2)	<1.6 (<5.9)	0.048 (0.18)
		Remote Stations[e]			
R10	42	5.4 (20)	<1.4 (<5.2)	<3.0 (<11)	0.20 (0.74)
R11	37	7.0 (26)	<2.8 (<10)	<3.0 (<11)	0.23 (0.85)
R12	25	<2.8 (10)	<2.8 (<10)	<2.8 (<10)	0.0 (0.0)
R13	38	4.8 (18)	<2.1 (7.8)	<3.0 (<11)	0.14 (0.52)
R14	36	4.3 (16)	<2.8 (<10)	<3.0 (<11)	0.11 (0.40)
R15	43	5.4 (20)	<1.4 (<5.2)	<3.0 (<11)	0.17 (0.63)
R16	28	12 (44)	<2.8 (<10)	<3.2 (<12)	0.63 (2.3)
Network summary	249	12 (44)	<1.4 (<5.2)	<3.0 (<11)	0.094 (0.35)

[a] $\mu Ci = 10^{-6} Ci = 3.7 \times 10^{-4}$ disintegration per second.

[b] Bq = Becquerel = 1 disintegration per second. Becquerel/mL are in ( ).

[c] 95% confidence coefficient about the average.

[d] See Fig. 4.3.5.

[e] See Fig. 4.3.6.

Table 4.3.12. 1985 concentration of zinc in surface water

Location	No. of samples	Concentration (mg/L)				Percentage of criterion[b]
		Max	Min	Av	95% CC[a]	
Flume (W16)	12	0.10	0.04	0.069	0.011	<140
3539 and 3540 pond discharges (W15)	12	0.29	0.07	0.13	0.034	<260
Melton Branch[c] (W4)	12	0.17	<0.02	<0.066	0.024	<140
White Oak Creek[c] (W5)	12	0.12	0.03	0.061	0.015	<120
White Oak Dam[c] (W3)	12	0.07	<0.01	<0.029	0.0094	<58
Melton Hill Dam[d] (W1)	12	<0.02	<0.01	<0.018	0.0026	<35
Clinch River[d] (W20)	12	0.02	<0.01	<0.018	0.0026	<35

[a] 95% confidence coefficient about the average.

[b] Criterion is 0.05 mg/L.

[c] See Fig. 4.3.3.

[d] See Fig. 4.3.1.

Table 4.3.13. 1985 concentrations of nitrate nitrogen in surface water

Location	No. of samples	Concentration (mg/L)				Percentage of criterion[b]
		Max	Min	Av	95% CC[a]	
Flume (W15)	11	3.0	0.8	1.7	0.41	17
3539 and 3540 pond discharges (W15)	11	73	1.0	19	16	<200
Melton Branch[c] (W4)	11	10	0.71	4.2	1.7	42
White Oak Creek[c] (W5)	11	23	3.9	9.7	3.1	97
White Oak Dam[c] (W3)	11	16	0.5	8.5	2.7	85
Melton Hill Dam[d] (W1)	11	2.0	<0.1	<1.2	0.39	<12
Clinch River[d] (W20)	11	5.8	<0.1	<2.2	1.1	<22

[a] 95% confidence coefficient about the average.

[b] Criterion is 10 mg/L.

[c] See Fig. 4.3.3.

[d] See Fig. 4.3.1.

Table 4.3.14. 1985 concentration of mercury in surface water

Location	No. of samples	Concentration (mg/L)				Percentage of criterion[b]
		Max	Min	Av	95% CC[a]	
Flume (W15)	12	0.0003	<0.00005	<0.00012	0.000043	<250
3539 and 3540 pond discharges (W15)	12	0.059	0.013	0.011	0.0094	<22000
Melton Branch[c] (W4)	12	0.0001	<0.00005	<0.000054	0.000008	<110
White Oak Creek[c] (W5)	12	0.0006	<0.00005	<0.00023	0.000097	<470
White Oak Dam[c] (W3)	12	0.0003	<0.00005	<0.00011	0.000042	<220
Melton Hill Dam[d] (W1)	12	<0.00005	<0.00005	<0.00005	0.0	<100
Clinch River[d] (W20)	12	0.0001	<0.00005	<0.000058	0.00001	<120

[a] 95% confidence coefficient about the average.

[b] Criterion is 0.00005 mg/L.

[c] See Fig. 4.3.3.

[d] See Fig. 4.3.1.

Table 4.3.15. 1985 concentration of chromium in surface water

Location	No. of samples	Concentration (mg/L)				Percentage of criterion[b]
		Max	Min	Av	95% CC[a]	
Flume (W15)	12	<0.01	<0.002	<0.0053	0.0014	<11
3539 and 3540 pond discharges (W15)	12	0.12	<0.005	<0.032	0.023	<64
Melton Branch[c] (W4)	12	<0.01	<0.002	<0.0053	0.0014	<11
White Oak Creek[c] (W5)	12	<0.01	<0.004	<0.0055	0.0012	<11
White Oak Dam[c] (W3)	12	<0.015	<0.004	<0.0079	0.0022	<16
Melton Hill Dam[d] (W1)	12	<0.01	<0.002	<0.0053	0.0014	<11
Clinch River[d] (W20)	12	<0.01	<0.002	<0.0053	0.0014	<11

[a] 95% confidence coefficient about the average.

[b] Criterion is 0.05 mg/L.

[c] See Fig. 4.3.3.

[d] See Fig. 4.3.1.

Table 4.3.16. 1985 concentrations of various parameters measured in water collected above Melton Hill Dam[a]

Parameter	Concentration (mg/L)		
	Third quarter	Fourth quarter	Av
Benzene	ND[b]	<0.10	NA[c]
Bromoform	<0.010	<0.010	<0.010
Carbon tetrachloride	ND	<0.10	NA
Chlorobenzene	ND	<0.10	NA
Chlorodibromomethane	<0.010	<0.010	<0.010
Chloroform	<0.010	0.020	<0.015
Dichlorobromomethane	<0.010	<0.010	<0.010
Bis(2-ethylhexyl)phthalate	<0.010	ND	NA
1,1-Dichloroethane	ND	<0.16	NA
Butylbenzylphthalate	<0.010	ND	NA
1,2-Dichloroethane	ND	<0.10	NA
1,2-Dichloropropane	ND	<0.16	NA
1,2-Dichloropropylene	ND	<0.1	NA
Ethylbenzene	ND	<0.1	NA
2,4-D	<0.00010	ND	NA
Methylene chloride	ND	<0.10	NA
1,1,2,2-Tetrachloroethane	ND	<0.10	NA
Diethylphthalate	<0.010	ND	NA
Tetrachloroethylene	ND	<0.010	NA
Toluene	ND	<0.10	NA
Di-N-Butylphthalate	<0.010	ND	NA
1,2-Trans-dichloroethylene	ND	<0.10	NA
1,1,1-Trichloroethane	<0.18	<0.10	<0.14
1,1,2-Trichloroethane	ND	<0.10	NA
Trichloroethylene	ND	<0.010	NA
Naphthalene	<0.050	ND	NA
Ag	<0.050	<0.050	<0.050
Al	1.9	<0.20	<1.1
Alkalinity	81	27	54
As	0.90	<0.10	0.50
Asbestos	0.30	<0.30	<0.30
B	3.3	<0.080	1.7
Ba	0.054	0.028	0.041
Be	<0.0020	<0.0020	<0.0020
BOD	<5.0	<5.0	<5.0
Br	<5.0	<5.0	<5.0
Ca	24	37	31
Cd	<0.0050	<0.0050	<0.0050
Cl	4.0	4.0	4.0
CN	<0.0020	<0.0020	<0.0020
CO	<0.010	<0.010	<0.010
CO_3	0.00	0.00	0.00
COD	5.0	1.0	3.0

Table 4.3.16. (continued)

Parameter	Concentration (mg/L)		
	Third quarter	Fourth quarter	Av
Cr	<0.040	<0.040	<0.040
Cu	<0.020	<0.020	<0.020
F	<1.0	<1.0	<1.0
Fe	0.050	<0.030	<0.040
Fecal coliform	0.00	14	7.0
Ga	<0.30	<0.30	<0.30
Hardness	99	13	56
HCO_3	81	27	54
Hf	<0.040	0.040	<0.040
K	1.7	ND	ND
Li	<0.2	<0.2	<0.2
Mg	9.8	10	9.9
Mn	0.012	0.0096	0.011
Mo	<0.040	0.040	<0.040
Na	8.0	5.4	6.7
Ni	<0.060	<0.060	<0.060
NO_3	<5.0	<5.0	<5.0
Oil and grease	2.0	<2.0	<2.0
P	<0.30	<0.30	<0.30
Pb	<0.20	<0.20	<0.20
Phenols (total)	<0.001	0.0040	<0.0025
Phthalates	<0.010	ND	NA
PO_4	<5.0	<5.0	<5.0
Sb	<0.20	<0.20	<0.20
Se	<0.20	<0.20	<0.20
Settleable solids	<0.10	<0.10	<0.10
Si	0.78	1.7	1.2
Silvex	<0.000050	ND	NA
SO_4	22	24	23
Sr	0.071	0.079	0.075
Suspended solids	ND	<5.0	NA
Total dissolved solids	13	24	19
Ti	0.020	<0.020	<0.020
True color	4.0	ND	NA
Total suspended solids	<5.0	ND	NA
TTO	0.10	ND	NA
U	ND	<0.001	NA
V	0.011	<0.010	0.011
Zn	<0.020	<0.020	<0.020
Zr	<0.020	<0.020	<0.020

[a] Location W1, Fig. 4.3.1.

[b] No data available.

[c] Not applicable.

Table 4.3.17. 1985 chemical water quality data for the ORGDP sanitary water pumping station[a]

Substance	No. of samples	Concentration (mg/L)				Criteria[c]	Percentage of criteria
		Max	Min	Av	95% CC[b]		
Cd	12	<0.0020	<0.0020	<0.0020	0.00	0.000025	*d*
Cr	12	0.030	<0.010	<0.010	0.0030	0.05	<23
CN	12	0.0040	<0.0020	<0.0020	0.00	0.0035	<11
No$_3$(N)	12	0.58	0.29	0.41	0.060	10	4
Pb	12	0.38	<0.0040	<0.0070	0.0060	0.0038	<15
SO$_4^{2-}$	12	25	21	23	0.90	250	9
TDS[e]	12	1500	40	240	220	500	49
Zn	12	0.35	0.020	0.084	1.5	0.05	17
F$^-$	12	0.28	<0.010	0.15	0.020	1.4-2.4[f]	<11
Hg	12	<0.0010	<0.00020	<0.0010	0.00	0.00005	*d*
Ni	12	0.060	<0.010	<0.020	0.010	0.1	<18

[a] Location W27, Fig. 4.3.3.

[b] 95% confidence coefficient about the average.

[c] Tennessee Water Quality Criteria for domestic water supplies.

[d] When max, min, and av values were all less than (<) values, no percentages of criteria were determined because this is an indication that criteria are below the analytical lower limit of detection.

[e] Total dissolved solids.

[f] Temperature dependent. Below 12°C maximum fluoride concentration is 2.4 mg/L; above this, the maximum concentration is 1.4 mg/L.

The aluminum noncompliances at K-1700 (outfall 001) are intermittent conditions that occur occasionally during periods of heavy rainfall and subsequent heavy runoff. Samples have been collected from the streams that feed the K-1700 holding pond in an attempt to locate the source of the aluminum. A potential source is the clay, which has a high content of natural aluminum that would be carried to the streams as suspended solids during periods of heavy rain. Sampling will continue during 1986.

The noncompliances at K-1007-B (outfall 006) are due to increased COD loading. This occurs during periods of heavy rainfall, which deposits naturally occurring organic decomposition products into the K-1007-B holding pond. These conditions will continue to cause noncompliances in the future.

The total chromium violations at K-901-A (outfall 007) were due to the resuspension of colloidal hexavalent chromium compounds. This condition was believed to be associated with the low operating levels resulting from the shutdown of the gaseous diffusion cascade. Because of the reduced power levels, the concentration of polymers required to maintain the chromium ions in the trivalent state was changed, thus causing a colloidal suspension of the hexavalent chromium ions in the pond. The

Table 4.3.18. 1985 chemical water quality data for the ORGDP recirculating pumping station[a]

Substance	No. of samples	Concentration (mg/L)				Criteria[c]	Percentage of criteria
		Max	Min	Av	95% CC[b]		
Cd	11	0.0030	<0.0020	<0.0020	0.00	0.000025	<8000
Cr	11	0.020	<0.010	<0.0120	0.0020	0.05	<24
CN	12	0.0040	<0.0020	<0.0030	0.00050	0.0035	<86
$NO_3(N)$	12	0.71	0.25	0.45	0.084	10	5
Pb	11	0.010	<0.0040	<0.0050	0.0010	0.0038	<132
SO_4^{2-}	12	32	21	25	1.7	250	10
TDS[d]	12	1400	120	300	210	500	60
Zn	11	0.42	<0.020	<0.080	0.067	0.05	<160
F^-	12	0.34	<0.020	<0.16	0.05	1.4–2.4[e]	16
Hg	12	0.0020	<0.00020	<0.0010	0.00	0.00005	<2000
Ni	11	0.060	<0.010	<0.020	0.010	0.1	<20

[a] Location W28, Fig. 4.3.8.

[b] 95% confidence coefficient about the average.

[c] Tennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

[d] Total dissolved solids.

[e] Temperature dependent. Below 12°C maximum fluoride concentration is 2.4 mg/L; above this, the maximum concentration is 1.4 mg/L.

immediate corrective action was to seed the pond with the polymer to induce precipitation. A plan was then developed to adjust the polymer feed rates to prevent future conversion of the hexavalent chromium. Since these actions were taken in August 1985, there has been no resuspension of the hexavalent chromium.

The Y-12 Plant surface water monitoring programs for nonradioactive substances consist primarily of sampling the sanitary sewer wastewaters and discharges covered under the NPDES permit. The NPDES program alone covers over 236 outfalls varying in source from wastewater treatment facilities to precipitation runoff (Figs. 4.3.4 and 4.3.9). This is a result of the new NPDES permit issued to the Y-12 Plant on May 24, 1985. In comparison, the former permit contained four discharge monitoring locations. The parameters and limits for the new permit are based on best management practices and in-stream water protection criteria. In most cases the limits are much more stringent than before and compliance is based on mass loading as well as on concentration values.

Tables 4.3.23 and 4.3.24 show the concentration of chemicals in EFPC and Bear Creek, respectively, as compared with Tennessee's in-stream allowable concentrations, which are based on the long-term protection of domestic water supply, fish and aquatic life, and recreation classifications. Many of the substances are monitored under the NPDES permit,

Table 4.3.19. 1985 chemical water quality data for the Clinch River downstream from ORGDP[a]

Substance	No. of samples	Concentration (mg/L)				Criteria[c]	Percentage of criteria
		Max	Min	Av	95% CC[b]		
Cd	12	<0.0020	<0.0020	<0.0020	0.00	0.000025	*d*
Cr	12	0.030	<0.010	<0.012	0.0030	0.05	<23
CN	12	0.0050	<0.0020	<0.0030	0.0010	0.0035	<79
$NO_3(N)$	12	0.61	0.18	0.37	0.071	10	3.7
Pb	12	0.021	<0.0040	<0.0060	0.25	0.0038	<156
SO_4^{2-}	12	26	16	22	1.5	250	9
TDS[e]	12	1100	130	230	150	500	45
Zn	12	0.050	<0.020	<0.030	0.010	0.05	<57
F^-	12	0.27	<0.010	<0.15	0.040	1.4–2.4[f]	<15
Hg	12	0.0010	<0.00020	<0.0010	0.00	0.00005	<2000
Ni	12	0.18	<0.010	<0.040	0.030	0.1	35

[a] Location W45.

[b] 95% confidence coefficient about the average.

[c] Tennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

[d] When max, min, and av values were all less than (<) values, no percentages of criteria were determined because this is an indication that criteria are below the analytical lower limit of detection.

[e] Total dissolved solids.

[f] Temperature dependent. Below 12°C maximum fluoride concentration is 2.4 mg/L; above this, the maximum concentration is 1.4 mg/L.

which has less stringent limits than those listed in the tables. Consideration must also be given to the fact that some of the criteria limits are well below the reportable detection limits and analytical capabilities of the laboratories.

The locations of the ten major Y-12 NPDES discharge points are shown in Figs. 4.3.4 and 4.3.9. The remaining outfalls lie within the various categories listed in Table 4.3.26. This table lists the effluent limits as they appear in the May 1985 revision of the Y-12 Plant NPDES permit. However, the Percent of Compliance Column reflects the whole year and not just the last eight months (May to December). Many of the noncompliances reported in Table 4.3.26 were experienced prior to the effective date of the revised permit.

In mid-1983, a program to collect weekly grab samples at station W32 (Fig. 4.3.1) was initiated and was continued during 1985 (Table 4.3.24). Station W32 is located near the headwaters of Bear Creek and is influenced by discharges from the S-3 Ponds at Y-12. The disposal of plating shop and other liquid wastes at the S-3 Ponds was discontinued in March 1984 and neutralization activities in preparation for closure were initiated. Since that time, heavy metal concentrations at W32 have decreased significantly.

The locations of the ORNL NPDES points are shown in Fig. 4.3.3. NPDES permits were issued by the EPA to DOE-

Table 4.3.20. 1985 chemical water quality data for Poplar Creek above Blair Bridge[a]

Substance	No. of samples	Concentration (mg/L)				Criteria[c]	Percentage of criteria
		Max	Min	Av	95% CC[b]		
Cd	12	<0.0020	<0.0020	<0.0020	0.00	0.000025	*d*
Cr	12	0.030	<0.010	<0.013	0.0035	0.05	<26
CN	12	0.015	<0.0020	<0.0030	0.0020	0.0035	<86
$NO_3(N)$	12	1.5	0.21	1.0	0.22	10	10
Pb	12	0.012	<0.0040	<0.014	0.019	0.0038	<368
SO_4^{2-}	12	46	34	40	0.56	250	16
TDS[d]	12	550	100	190	68	500	38
Zn	12	0.23	0.020	0.090	0.50	0.05	180
F^-	12	0.30	0.060	0.22	0.47	1.4–2.4[e]	16
Hg	12	<0.0010	<0.00020	<0.0010	0.00	0.00005	*d*
Ni	12	0.060	<0.010	<0.020	0.010	0.1	<20

[a] Location W21, Fig. 4.3.1.

[b] 95% confidence coefficient about the average.

[c] Tennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

[d] When max, min, and av values were all less than (<) values, no percentages of criteria were determined because this is an indication that criteria are below the analytical lower limit of detection.

[e] Temperature dependent. Below 12°C maximum fluoride concentration is 2.4 mg/L; above this, the maximum concentration is 1.4 mg/L.

ORO to discharge to and monitor nonradiological substances in streams near ORNL in 1975. The permits established three discharge locations at ORNL (White Oak Creek, Melton Branch, and the Sewage Treatment Plant) and listed specific concentration limits and/or monitoring requirements for a number of parameters at each discharge location. ORNL achieved compliance of 99 to 100% for all effluent parameters at both White Oak Creek and Melton Branch (Table 4.3.28). At the sewage treatment plant (STP), less than 100% compliances were documented for ammonia (58%), BOD (90%), residual chlorine (96%), and suspended solids (87%). When compared with the compliances achieved in 1984, a trend of improvement was observed. This improvement is the result of the new Sewage Treatment Plant, which was completed in August 1985 and has been in use at ORNL since September 4, 1985. This new plant has the capacity for an average flow of 1,134,000 L/d and has the design capability for surges as high as 2,835,000 L/d. The treatment system consists of an aeration tank, a final clarifier, sludge holding and recirculation equipment, mixed media filter equipment, and sludge wastage piping. Effluent from the new treatment plant has been directed from the filter to the chlorination system. The noncompliances before and after the startup of the new sewage treatment plant are shown in Fig. 4.3.10. Discharge

Table 4.3.21. 1985 chemical water quality data for Poplar Creek near the Clinch River[a]

Substance	No. of samples	Concentration (mg/L)				Criteria[c]	Percentage of criteria
		Max	Min	Av	95% CC[b]		
Cd	12	<0.0020	<0.0020	<0.0020	0.00	0.000025	
Cr	12	0.030	<0.010	0.013	0.0040	0.05	<26
CN	12	0.0030	<0.0020	<0.0020	0.00	0.0035	<57
NO_3(N)	12	0.93	0.35	0.69	0.11	10	7
Pb	12	0.016	<0.0040	<0.0050	0.0040	0.0038	<132
SO_4^{2-}	12	36	26	33	2.1	250	13
TDS[d]	12	1300	14	230	190	500	46
Zn	12	1.0	0.020	0.040	0.020	0.05	80
F^-	12	0.32	<0.10	<0.23	0.040	1.4–2.4[e]	<17
Hg	12	<0.0010	<0.00020	<0.0010	0.00	0.00005	
Ni	12	0.080	<0.010	0.030	0.010	0.1	<30

[a] Location W45, Fig. 4.3.1.

[b] 95% confidence coefficient about the average.

[c] Tennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

[d] Total dissolved solids.

Table 4.3.22. 1985 chemical water quality data for West Fork Poplar Creek on Blair Road[a]

Substance	No. of samples	Concentration (mg/L)				Criteria[c]	Percentage of criteria
		Max	Min	Av	95% CC[b]		
Cd	12	<0.0020	<0.0020	<0.0020	0.00	0.000025	*d*
Cr	12	0.020	<0.010	<0.010	0.00	0.05	<20
CN	12	0.0050	<0.0020	<0.0030	0.0010	0.0035	<86
NO_3(N)	12	0.50	0.17	0.32	0.060	10	3.2
Pb	12	0.027	<0.0040	0.0090	0.0050	0.0038	<237
SO_4^{2-}	12	63	34	39	7.0	250	16
TDS[e]	12	780	100	200	100	500	40
Zn	12	0.070	0.020	0.040	0.010	0.05	80
F^-	12	0.27	<0.10	<0.17	0.040	1.4–2.4[e]	<12
Hg	12	<0.0010	<0.00020	<0.0010	0.00	0.00005	*d*
Ni	12	0.080	<0.010	<0.020	0.010	0.1	<20

[a] Location W23, Fig. 4.3.1.

[b] 95% confidence coefficient about the average.

[c] Tennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

[d] When max, min, and av values were all less than (<) values, no percentages of criteria were determined because this is an indication that criteria are below the analytical lower limit of detection.

[e] Total dissolved solids.

Table 4.3.23. 1985 chemical water quality data for East Fork Poplar Creek[a]

Paremeter	No. of samples	Concentration (mg/L)				Criteria[c]	Percentage of criteria
		Max	Min	Av	95% CC[b]		
Hg	12	0.0039	0.0006	0.0018		0.00005	3600
TSS	12	66	<5.0	<20		NC[d]	
TDS[e]	12	340	150	240		500	48
Cl	12	190	13	34		250	14
CN	12	0.006	<0.002	<0.003		0.0035	<85
F^-	12	1.0	0.8	0.9		1.0	90
MBAS	12	<0.05	<0.05	<0.05		NC	
TKN	12	10	0.3	1.4		NC	
$NO_3(N)$	12	34	1.4	6.9		10	69
SO_4^{2-}	12	80	44	58		250	23
Turbidity	12	17	0.7	7.9		NC	
Ag	12	0.03	<0.01	<0.01		NC	
Al	12	1.2	0.07	0.3		NC	
As	12	<0.06	<0.06	<0.06		NC	
B	12	0.07	0.02	0.04		NC	
Ba	12	<0.2	<0.2	<0.2		NC	
Be	12	<0.0005	<0.0005	<0.0005		NC	
Ca	12	47	33	39		NC	
Cd	12	<0.002	<0.002	<0.002		0.000025	f
Ce	12	<0.03	<0.03	<0.03		NC	
Co	12	<0.002	<0.002	<0.002		NC	
Cr	12	<0.01	<0.01	<0.01		0.05	f
Cu	12	0.09	0.006	0.019		0.02	95
Fe	12	1.3	0.06	0.6		NC	
Ga	12	<0.04	<0.04	<0.04		NC	
K	12	2.6	1.3	1.9		NC	
La	12	<0.01	<0.01	<0.01		NC	
Li	12	0.03	0.01	0.02		NC	
Mg	12	11	8.2	9.5		NC	
Mn	12	0.22	0.01	0.08		NC	
Mo	12	<0.1	<0.1	<0.1		NC	
Na	12	36	8.9	16		NC	
Nb	12	<0.02	<0.02	<0.02		NC	
Ni	12	0.15	<0.01	<0.02	0.1		
P	12	0.3	0.11	0.2	NC		
Pb	12	<0.01	<0.01	<0.01		0.0038	f
Sc	12	<0.001	<0.001	<0.001		NC	
Sr	12	0.12	0.09	0.17		NC	
Th	12	<0.02	<0.02	<0.02		NC	
Ti	12	0.017	<0.001	<0.008		NC	
V	12	<0.003	<0.003	<0.003			
Y	12	0.002	<0.001	<0.001			
Zn	12	0.09	<0.02	<0.05		0.05	<100
Zr	12	0.002	<0.001	<0.001			

[a] Location W24, Fig. 4.3.1.

[b] 95% confidence coefficient about the average.

[c] Tennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

[d] NC = No criteria available.

[e] Total dissolved solids.

[f] When max, min, and av values were all less than (<) values, no percentages of criteria were determined because this is an indication that criteria are below the analytical lower limit of detection.

Table 4.3.24. 1985 chemical water quality data for Bear Creek[a]

Paremeter	No. of samples	Concentration (mg/L)				Criteria[c]	Percentage of criteria
		Max	Min	Av	95% CC[b]		
Hg	12	0.0034	<0.00050	<0.001		0.00006	<2000
TSS	10	63	<2.0	<20		NC[d]	
TDS	10	280	190	231		500	46
Cl	12	22	9.0	14		250	6
CN	12	0.007	<0.002	<0.003		0.0035	<85
F^-	12	1.5	0.1	0.3		90	30
MBAS	12	<0.05	<0.05	<0.05		NC	
TKN	12	0.54	<0.2	<0.4		NC	
NO_3(N)	12	24	6.6	12		10	124
SO_4^{2-}	12	36	13	22		250	9
Turbidity	12	44	3.2	12		NC	
Ag	12	0.04	<0.01	<0.01		NC	
Al	12	3.0	0.12	0.74		NC	
As	12	<0.06	<0.06	<0.06		NC	
B	12	0.39	0.19	0.27		NC	
Ba	12	<0.2	<0.2	<0.2		NC	
Be	12	<0.0005	<0.0005	<0.0005		NC	
Ca	12	64	35	47		NC	
Cd	12	<0.002	<0.002	<0.002		0.000025	*f*
Ce	12	<0.03	<0.03	<0.03		NC	
Co	12	<0.002	<0.002	<0.002		NC	
Cr	12	<0.01	<0.01	<0.01		0.05	*f*
Cu	12	0.13	<0.004	<0.031		0.02	<1550
Fe	12	2.3	0.08	0.63		NC	
Ga	12	<0.04	<0.04	<0.04		NC	
K	12	2.2	0.70	1.5		NC	
La	12	<0.01	<0.01	<0.01		NC	
Li	12	0.14	0.07	0.10		NC	
Mg	12	15	7.8	11		NC	
Mn	12	0.09	<0.01	<0.03		NC	
Mo	12	<0.01	<0.01	<0.01		NC	
Na	12	11	3.8	5.9		NC	
Nb	12	<0.02	<0.02	<0.02		NC	
Ni	12	0.08	<0.01	<0.02		0.1	<20
P	12	<0.03	<0.03	<0.03		NC	
Pb	12	<0.01	<0.01	<0.01		0.0038	*f*
Sc	12	0.001	<0.001	<0.001		NC	
Sr	12	0.15	0.078	0.106		NC	
Th	12	<0.02	<0.02	<0.02		NC	
Ti	12	0.022	<0.001	<0.009		NC	
V	12	0.004	<0.003	<0.003		NC	
Y	12	0.001	<0.001	<0.001		NC	
Zn	12	0.02	<0.02	<0.02		0.05	<40
Zr	12	0.002	<0.001	<0.001		NC	

[a] Location W25, Fig. 4.3.1.

[b] 95% confidence coefficient about the average.

[c] Tennessee stream standards based on protection of domestic water supply, fish and aquatic life, and recreation classifications.

[d] NC: no criteria available.

[e] Total dissolved solids.

[f] When max, min, and av values were all less than (<) values, no percentages of criteria were determined because this is an indication that criteria are below the analytical lower limit of detection.

Table 4.3.25. 1985 National Pollutant Discharge Elimination System (NPDES) compliance at ORGDP

Discharge point	Effluent parameters	Effluent limits: Monthly av (mg/L)	Effluent limits: Daily max (mg/L)	Effluent limits: Monthly av (kg/d)	Effluent limits: Daily max (kg/d)	Percentage of measurements in compliance
001						
(K-1700 discharge)	Aluminum		1.0		16	91
	Chromium	0.050	0.080	0.80	1.2	100
	Nitrate - N		20		310	100
	Suspended solids[a]	30	50	470	780	99
	Oil and grease	10[b]	15	160	230	100
	pH, units		6.0–9.0			100
	Perchloroethylene	0.12	0.21	1.9	3.3	100
	Trichloroethane	0.11		1.7		100
	Methylene chloride	0.035		0.54		100
	Trichloroethylene	0.41	0.61	6.4	9.5	100
	Lead	0.0080	0.93	0.12	14	100
	Zinc	0.12	1.5	1.86	246	99
	Total halomethanes	1.2	2.1	19	32	100
	Beryllium	0.0010	0.0020	0.016	0.032	100
	Cadmium	0.0040	0.010	0.060	0.16	99
	Mercury	0.0013	0.011	0.021	0.17	100
	Selenium	0.12	0.31	1.9	4.8	100
	Silver	0.014	0.027	0.22	0.42	100
005						
(K-1203 Sanitary Treatment Facility)[c]	Ammonia nitrogen	5.0	7.0	12	17.3	100
	BOD	15	20	37	49.5	100
	Chlorine residual		0.24			100
	Dissolved oxygen	5.0[b]				100
	Fecal coliform, No./100 mL	200	400			98
	pH, units		6.0–9.0			100
	Suspended solids	30	45	74	110	99
	Settleable solids, mL/L		0.50			100
	Beryllium	0.0010	0.0020	0.0020	0.0050	100
	Cadmium	0.0040	0.010	0.010	0.025	100
	Mercury	0.0013	0.011	0.0030	0.027	100
	Selenium	0.12	0.31	0.30	0.77	100
	Silver	0.014	0.027	0.035	0.067	100
	Lead	0.008	0.93	0.02	2.30	100
	Zinc	0.12	1.52	0.30	3.76	100
	Perchloroethylene	0.12	0.21	0.30	0.52	100
	Trichloroethane	0.11		0.27		100
	Methylene chloride	0.035		0.087		100
	Trichloroethylene	0.41	0.61	1.01	1.51	100
	Total halomethanes	1.23	2.05	3.04	5.07	100

Table 4.3.25 (continued)

Discharge point	Effluent parameters	Effluent limits				Percentage of measurements in compliance
		Monthly av (mg/L)	Daily max (mg/L)	Monthly av (kg/day)	Daily max (kg/day)	
006 (K-1007-B Holding Pond)	COD	20	25	120	150	93
	Chromium (total)		0.050		0.30	100
	Dissolved oxygen	5.0[b]				100
	Fluoride	1.0	1.5	6.1	9.1	100
	Oil and grease	10	15	61	91	100
	pH, units		6.0–9.0			100
	Suspended solids[a]	30	50	182	304	100
007 (K-901-A Holding Pond)	Chromium (total)		0.05		0.68	71
	Fluoride	1.0	1.5	4.2	6.3	100
	Oil and grease	10	15	42	63	100
	pH, units		6.0–10			100
	Suspended solids[a]	30	50	125	210	100
009 (Sanitary Water Plant)	Suspended solids[a]	30	50	34	51	100
	Aluminum	5.0	10	5.7	11	100
	Sulphate		1400		1600	100
	pH, units		6.0–9.0			100

[a] Limit applicable only during normal operations. Not applicable during periods of increased discharge due to surface run-off resulting from precipitation.

[b] Daily minimum.

[c] Because of the small flow rates at the K-710 sanitary treatment facility, (discharge point W27), a rapid sand filter was installed May 1, 1978, eliminating the surface discharge and the need for monitoring.

limits will be more restrictive, and new permit points and parameters will be added.

Table 4.3.26. 1985 National Pollutant Discharge Elimination System (NPDES) compliance at the Y-12 Plant

Discharge point	Effluent parameter	Effluent limits				Percent of compliance
		Daily av (kg/d)	Daily max (kg/d)	Daily av (mg/L)	Daily max (mg/L)	
301 (Kerr Hollow Quarry)	Lithium				5.0	100
	pH units			>6.5	<8.5	100
	Total suspended solids			30.0	50.0	100
	Temperature, °C				30.5	100
	Zirconium				3.0	100
302 (Rogers Quarry)	Oil and grease			10.0	15.0	96
	pH units			>6.5	<8.5	91
	Settleable solids, mL/L				0.5	96
	Total suspended solids			30.0	50.0[a]	98
	Temperature, °C				30.5	100
303 (New Hope Pond)	Ammonia (as N)				1.6	97
	Cadmium, total			0.0025	0.0035	94
	Chromium, total			0.05	0.08	100
	Copper, total			0.015	0.022	94
	Dissolved oxygen			5.0[b]		97
	Dissolved solids				2000	100
	Fluoride			1.5	2.0	100
	Lead, total			0.012	0.17	100
	Lithium, total				5.0	100
	Mercury, total			0.0035	0.0080	91
	Nitrogen, total (as N)				20.0	94
	Oil and grease			10.0	15.0	94
	pH units			>6.5	<10.0	96
	Settleable solids (mL/L)				0.50	96
	Surfactants (as MBAS)			5.0	8.0	98
	Total suspended solids				20.0[c]	100
	Temperature, °C				30.5	100
	Zinc, total			0.20	0.30	100
304 (Bear Creek)	Oil and grease			10.0	15.0	100
	pH units			>6.5	<8.5	100
305 (leaking burial grounds and wet weather springs—Oil Pond #1)	Oil and grease			10.0	15.0	100
	pH units			>6.5	<8.5	87
	Total suspended solids			30.0	50.0	100
306 (seepage from burial pit and surface water runoff—Oil Pond #2)	Oil and grease			10.0	15.0	87
	pH units			>6.5	<8.5	100
	Total suspended solids			30.0	50.0	87
Category I outfalls (precipitation runoff and small amounts of groundwater)	pH units			>6.5	<8.5	100
Category II Outfalls (cooling waters, condensate,	pH units			>6.5	<8.5	98
	Temperature[d]					100

Table 4.3.26 (continued)

Discharge point	Effluent parameter	Effluent limits				Percent of compliance
		Daily av (kg/d)	Daily max (kg/d)	Daily av (mg/L)	Daily max (mg/L)	
precipitation runoff, and building, roof, and foundation drains)						
Category III Outfalls (process wastewaters)	pH units			>6.5	<8.5	90
Category IV Outfalls (untreated process wastewaters)	pH units			>6.5	<8.5	97
623 (Steam Plant Fly Ash Sluice Water)	pH units			>6.5	<8.5	100
507 (S-3 Ponds Liquid Treatment Facility)	Cadmium, total	0.14	0.38	0.26	0.69	100
	Chromium, total	0.93	1.5	1.7	2.77	100
	Copper, total	1.13	1.84	2.07	3.38	100
	Cyanide, total	0.35	0.65	0.65	1.20	99
	Lead, total	0.23	0.38	0.43	0.69	100
	Nickel, total	1.30	2.17	2.38	3.98	100
	Oil and grease	14.2	28.4	26.0	52.0	100
	pH units			>6.0	<9.0	100
	Silver, total	0.13	0.23	0.24	0.43	100
	Temperature, °C				30.5	100
	Total suspended solids	16.9	32.7	31.0	60.0	99
	Total toxic organics		1.16		2.13	100
	Zinc, total	0.81	1.42	1.48	2.61	100
508 (Experimental Mobile Wastewater Treatment Facility)	Mercury, total			0.002	0.004	50
	pH units			>6.5	<9.0	100
	Total suspended solids			30.0	45.0	100
510 (Waste Coolant Processing Ffacility)	Biochemical oxygen demand	1.33	2.65			75
	Oil and grease			15.0	20.0	33
	pH units			>6.5	<9.0	100
	Temperature, °C				30.5	100
	Total suspended solids				100.0	100
Miscellaneous discharges (cooling tower blowdown)	Chromium, total				1.0	100
	Copper, total			0.5	1.0	100
	Free available chlorine			0.2	0.5	100
	pH units			>6.5	<8.5	58
	Temperature, °C			35	38	100
	Zinc, total			0.5	1.0	100

Table 4.3.26 (continued)

Discharge point	Effluent parameter	Effluent limits				Percent of compliance
		Daily av (kg/d)	Daily max (kg/d)	Daily av (mg/L)	Daily max (mg/L)	
Miscellaneous discharges	pH units			>6.5	<8.5	0
(demineralizers)	Total suspended solids			30	50	0

[a] Limit not applicable during periods of increased surface runoff resulting from precipitation.

[b] Daily minimum.

[c] If discharge volume exceeds 8.0 × 10^6 gal/d as a result of precipitation, daily maximum is 100 mg/L.

[d] Temperature shall be controlled such that the stream temperature standards delineated in the General Water Quality Criteria for the Definition and Control of Pollution in the Waters of Tennessee, as amended, are not violated as a result of this discharge.

Table 4.3.27. 1985 monitoring for upper Bear Creek[a]

Parameter	No. of samples	Concentration (mg/L)		
		Max	Min	Av
pH[b]	52	7.6	6.3	6.8
Dissolved oxygen	52	8.8	2.0	6.1
Suspended solids	52	190	<5.	<21.8
Total dissolved solids	53	6500	210	3077
Chloroform	53	<0.010	<0.010	<0.010
Methylene chloride	53	0.077	<0.010	<0.036
Perchloroethylene	53	0.097	<0.010	<0.012
Trichloroethylene	53	<0.010	<0.010	<0.010
Trichloroethane	53	0.02	<0.010	<0.011
PCB	53	0.0042	<0.0005	<0.0006
Phenol	53	0.034	<0.0010	<0.0030
^{241}Am[c]	53	<3	<3	<3
^{237}Np[c]	53	32	<6	<7
^{238}Pu[c]	53	0.51	<0.2	<0.21
^{240}Pu[c]	53	2.5	<0.2	<0.2
^{99}Tc[d]	53	2.0	<0.3	0.6
^{235}U[e]	53	0.54	0.29	0.35
Ag	53	0.04	<0.01	<0.01
Al	53	5.8	0.12	0.78
As	53	<0.06	<0.06	<0.06
B	53	0.14	<0.02	<0.11
Ba	53	<0.2	<0.2	<0.2
Be	53	0.0018	<0.0005	<0.0005
Ca	53	660	96	446
Cd	53	0.031	0.004	0.015

Table 4.3.27 (continued)

Parameter	No. of samples	Concentration (mg/L)		
		Max	Min	Av
Ce	53	<0.03	<0.03	<0.03
CN	52	0.054	<0.002	<0.006
Co	53	0.007	<0.002	<0.004
Cr	53	0.01	<0.01	<0.01
Cu	53	0.043	<0.004	<0.006
F	52	10	<0.1	<1.1
Fe	53	2.3	<0.06	<0.28
Ga	53	0.06	<0.04	<0.04
Hg	53	0.019	<0.0005	<0.0019
K	53	19	4.8	11
La	53	<0.01	<0.01	<0.01
Li	53	0.09	0.01	0.03
Mg	53	190	14	87
Mn	53	12	1.1	4.8
Mo	53	<0.1	<0.1	<0.1
Na	53	570	60	163
Nb	53	0.09	<0.02	<0.03
Ni	53	0.28	<0.01	<0.03
N-NO_3	52	1300	45	433
P	53	0.08	<0.03	<0.03
Pb	53	<0.01	<0.01	<0.01
Sc	53	0.002	<0.001	<0.001
Sr	53	2.0	0.36	1.06
Th	53	<0.02	<0.02	<0.02
Ti	53	0.024	<0.011	<0.002
U	53	1.36	0.22	0.947
V	53	0.01	<0.003	<0.003
Y	53	0.027	<0.001	<0.003
Zn	53	0.07	<0.02	<0.02
Zr	53	0.005	<0.001	<0.001

[a] See Fig. 4.3.1 Station W25.

[b] pH units.

[c] pCi/L.

[d] pCi/mL.

[e] %.

Table 4.3.28. 1985 National Pollutant Discharge Elimination System (NPDES) compliance at ORNL

Discharge point	Effluent parameters	Effluent limits: Daily av (mg/L)	Effluent limits: Daily max (mg/L)	Percentage of measurements in compliance
001 (White Oak Creek)	Dissolved oxygen	5[a]		99
	Dissolved solids		2000	100
	Oil and grease	10	15	100
	Total chromium		0.05	100
	pH, units		6.0–9.0	99.7
002 (Melton Branch)	Total chromium		0.05	100
	Dissolved solids		2000	99.7
	Oil and grease	10	15	100
	pH, units		6.0–9.0	100
003 (Sewage treatment plant)	Ammonia (as N)		5	58
	BOD		20	90
	Residual chlorine		0.5–2.0	96
	Fecal coliform, No./100 mL	200[b]	400[c]	100
	pH, units		0.5–2.0	100
	Suspended solids		30	87
	Settleable solids, mL/L		0.5	100

[a] Minimum.

[b] Monthly average.

[c] Weekly average.

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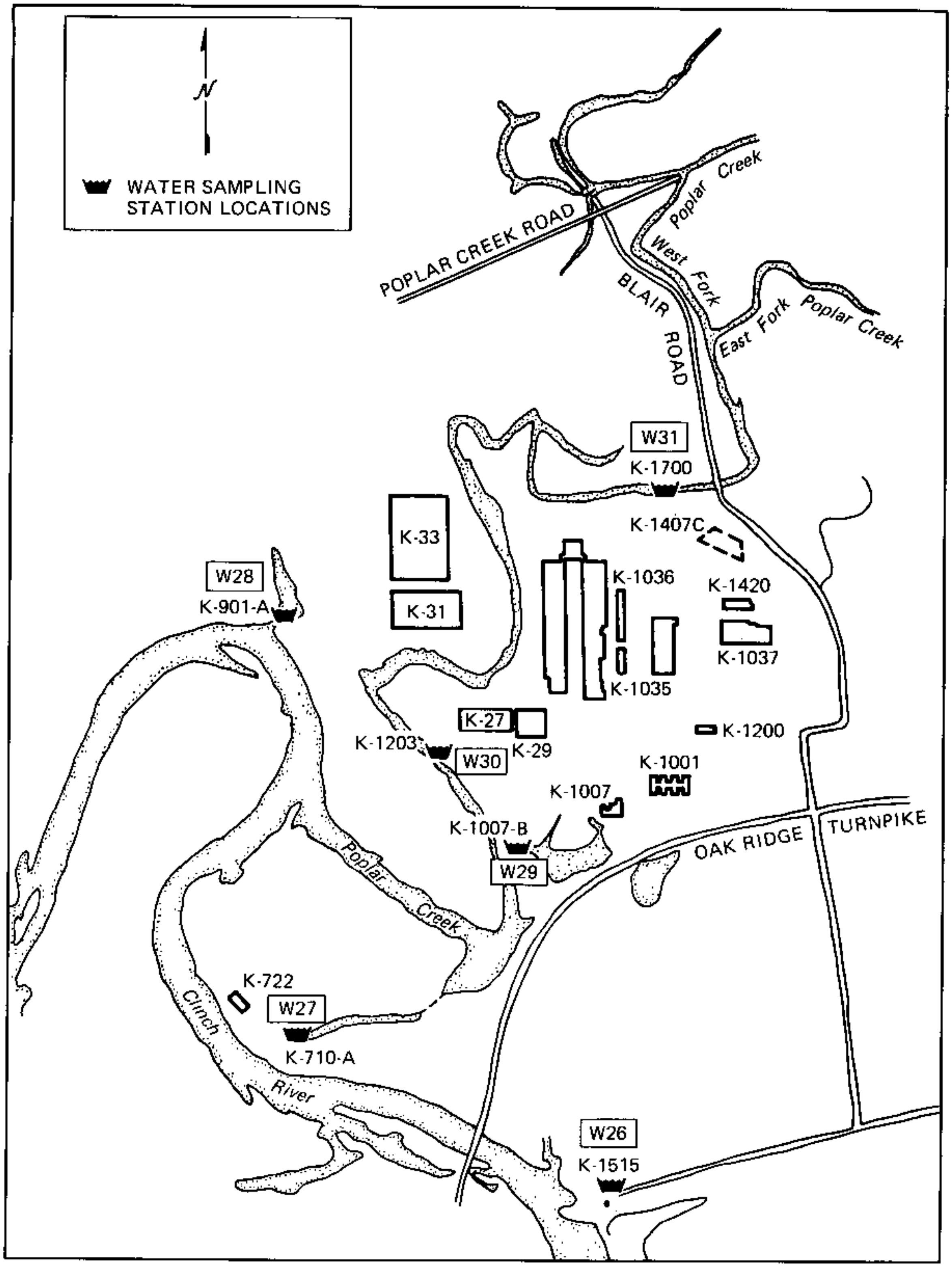

Fig. 4.3.8. Location map of ORGDP NPDES points.

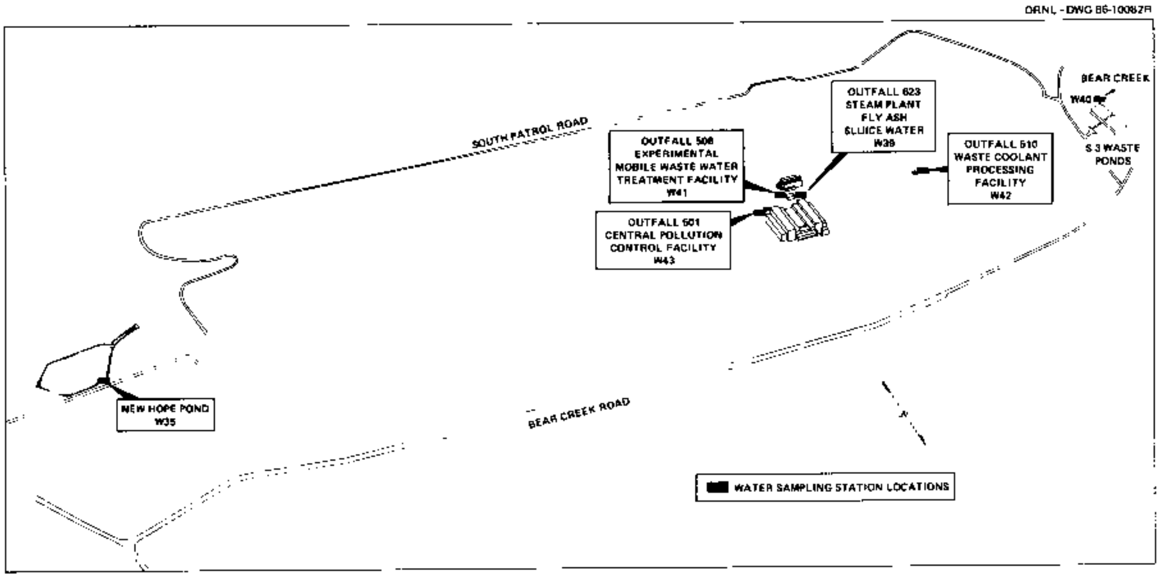

Fig. 4.3.9. Location map of Y-12 NPDES points W35 and W39 through W43.

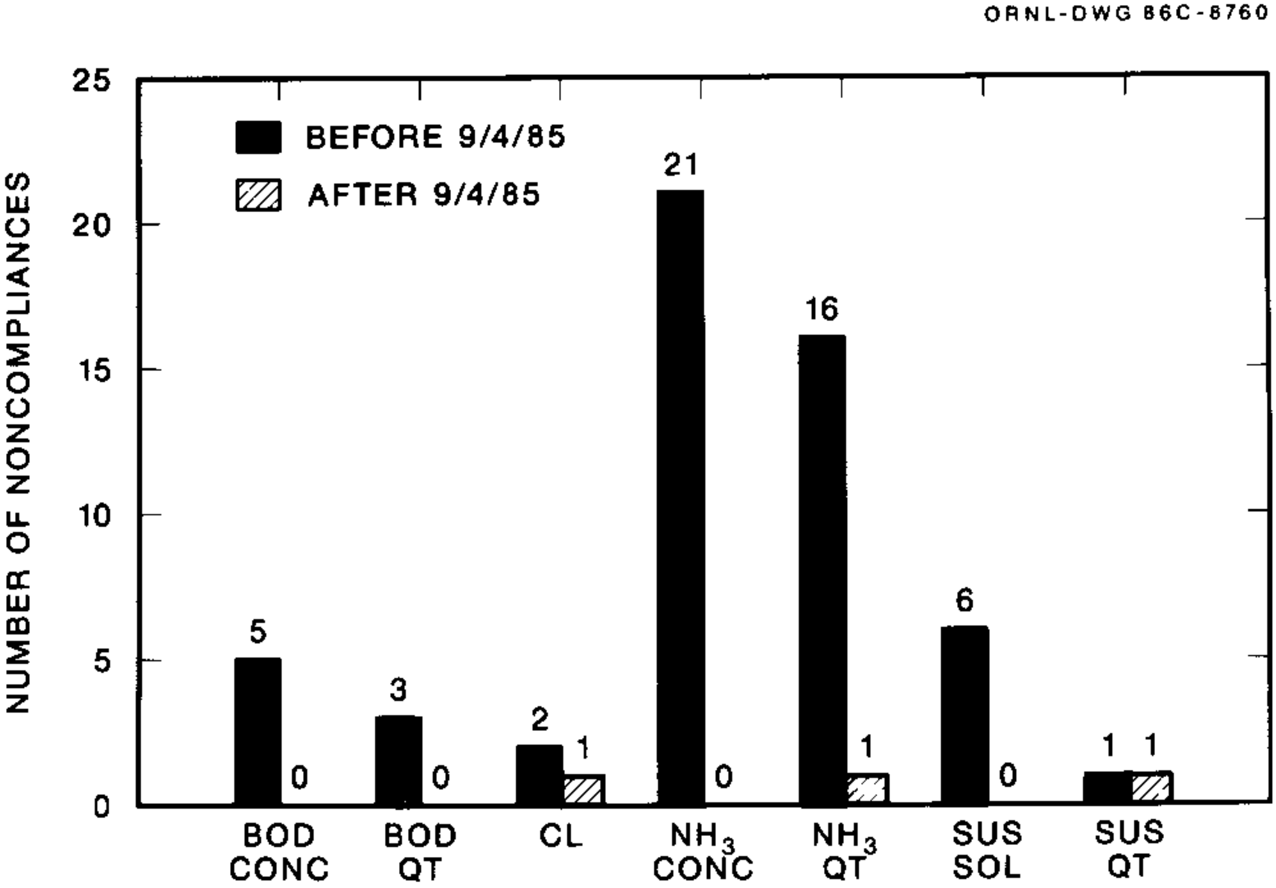

Fig. 4.3.10. Number of noncompliances before and after the startup of the sewage treatment plant at ORNL.

4.4 GROUNDWATER

The Oak Ridge Task Force (Sect. 7) is attempting, through the USGS, to determine whether a significant potential exists for off-site groundwater contamination from Y-12 Plant operations. The hydrologic flow structure is such that any groundwater flow that occurs is likely to be in a northeasterly or southwesterly direction (along strike) rather than across formations. Furthermore, the terrain generally slopes downward to the southeast. Thus, the likely direction for any deep groundwater flow would be to the southwest, toward the Clinch River from ORR storage areas, and then into the Clinch, which would be the discharge point for groundwater flow in the area. Finally, the most significant factor to consider is the rate of movement of groundwater and radionuclides in the Conasauga, Chickamauga, and Knox groups formations underlying ORR disposal areas.

The EPA has established regulations in 40 CFR Pt. 265, Subpart F, which require the owners/operators of hazardous waste facilities to monitor the groundwater beneath their facilities. The ORNL facility has a groundwater network consisting of 18 monitoring wells located within three surface impoundment areas: impoundments 3524, 7905 through 7908, and 3539 and 3540. The locations of sampling wells around ponds 3524, 3539, and 3540 are shown in Fig. 4.4.1. Figure 4.4.2 shows the location of sampling wells around ponds 7905, 7906, 7907, and 7908. The 3524 area consists of wells 31-001, 31-002, 31-003, and 31-004; the 7900 area consists of wells 32-001, 32-002, 32-003, 32-005, 33-001, 33-002, and 33-003; and the 3539 and 3540 ponds area consists of wells 31-005, 31-006, 31-007, 31-008, 31-009, 31-010, and 31-012. The wells are also classified as up-gradient (reference) or down-gradient, depending on their location relative to the waste management facility and hydrological setting. The up-gradient wells (31-001, 31-007, 31-009, 32-001, and 33-001) were located so as to provide groundwater samples that would not be affected significantly by possible leakage from the facility. The down-gradient wells (those not listed as up-gradient) were located immediately adjacent to the waste management facility. Samples collected at these wells represented the quality of the groundwater at the point of compliance. One blank (distilled, deionized water) sample labeled as 31-013 and one sample labeled as 32-000 and spiked with some of the parameters listed in Tables 4.4.1 through 4.4.3 were submitted for quality assurance.

Water samples were collected during two periods from each well and analyzed for the constituents listed in Tables 4.4.1 through 4.4.3. The data required by EPA and the State of Tennessee fall into three categories: (1) drinking water parameters (As, Ba, Cd, Cr, F, Pb, Hg, NO_3, Se, Ag, endrin, lindane, methoxychlor, toxaphene, 2,4-D, 2,4,5-TP silvex, Ra, gross alpha, gross beta, ^{60}Co, ^{137}Cs, and fecal coliform), (2) water quality parameters (Cl, Fe, Mn, phenols, Na, and SO_4); and (3) groundwater contamination parameters (pH, specific conductivity, total organic carbon, and total organic halogen). Seven measurements per well were recorded for pH, specific conductivity, and temperature, and four measurements were recorded for total organic carbon and total organic halogen during each period as specified in the regulation. For all other parameters, one sample per sampling period was collected from each well.

The analytical values for the parameters in the drinking water category were

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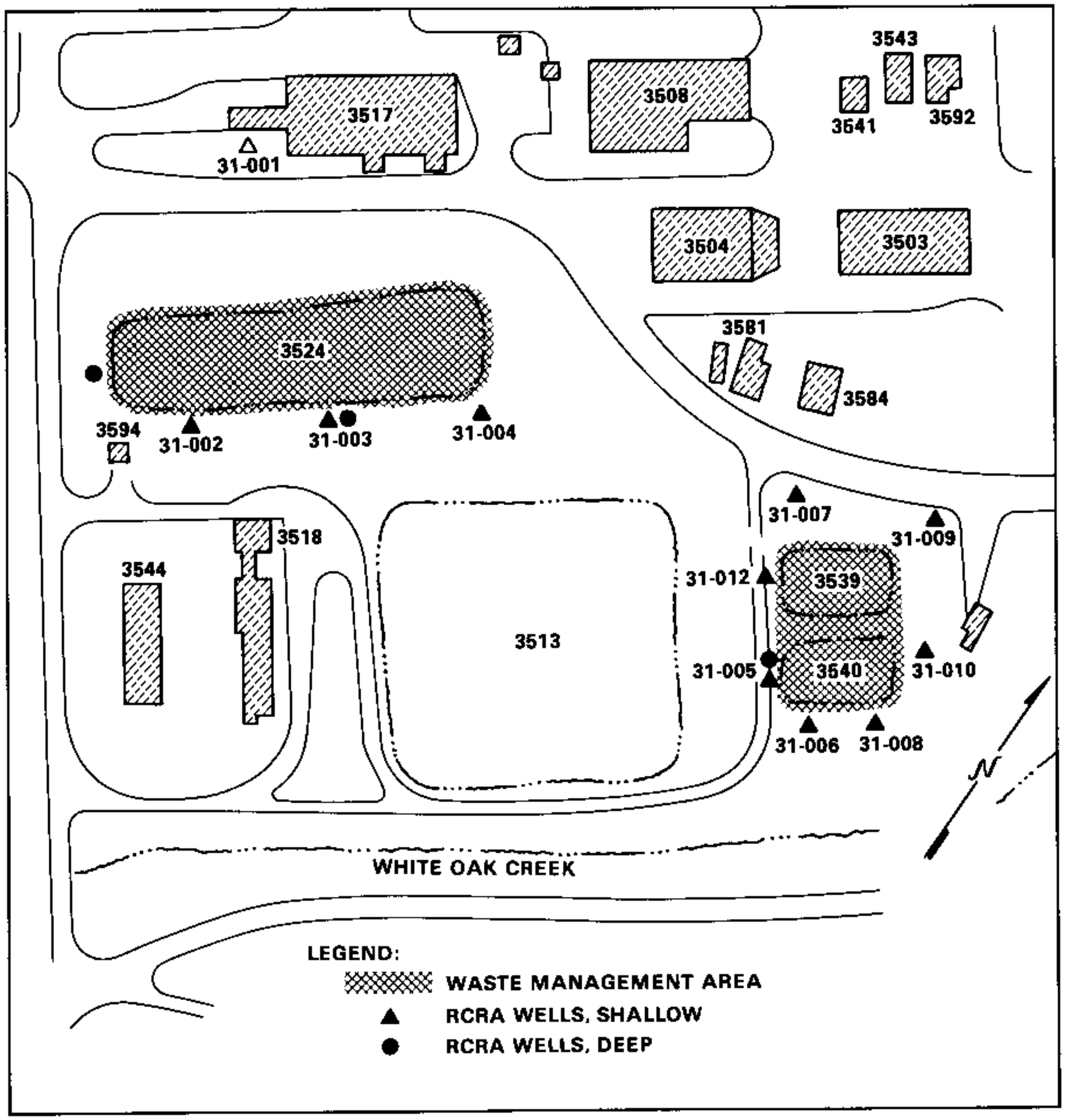

Fig. 4.4.1. Locations of sampling wells around ponds 3524, 3539, and 3540.

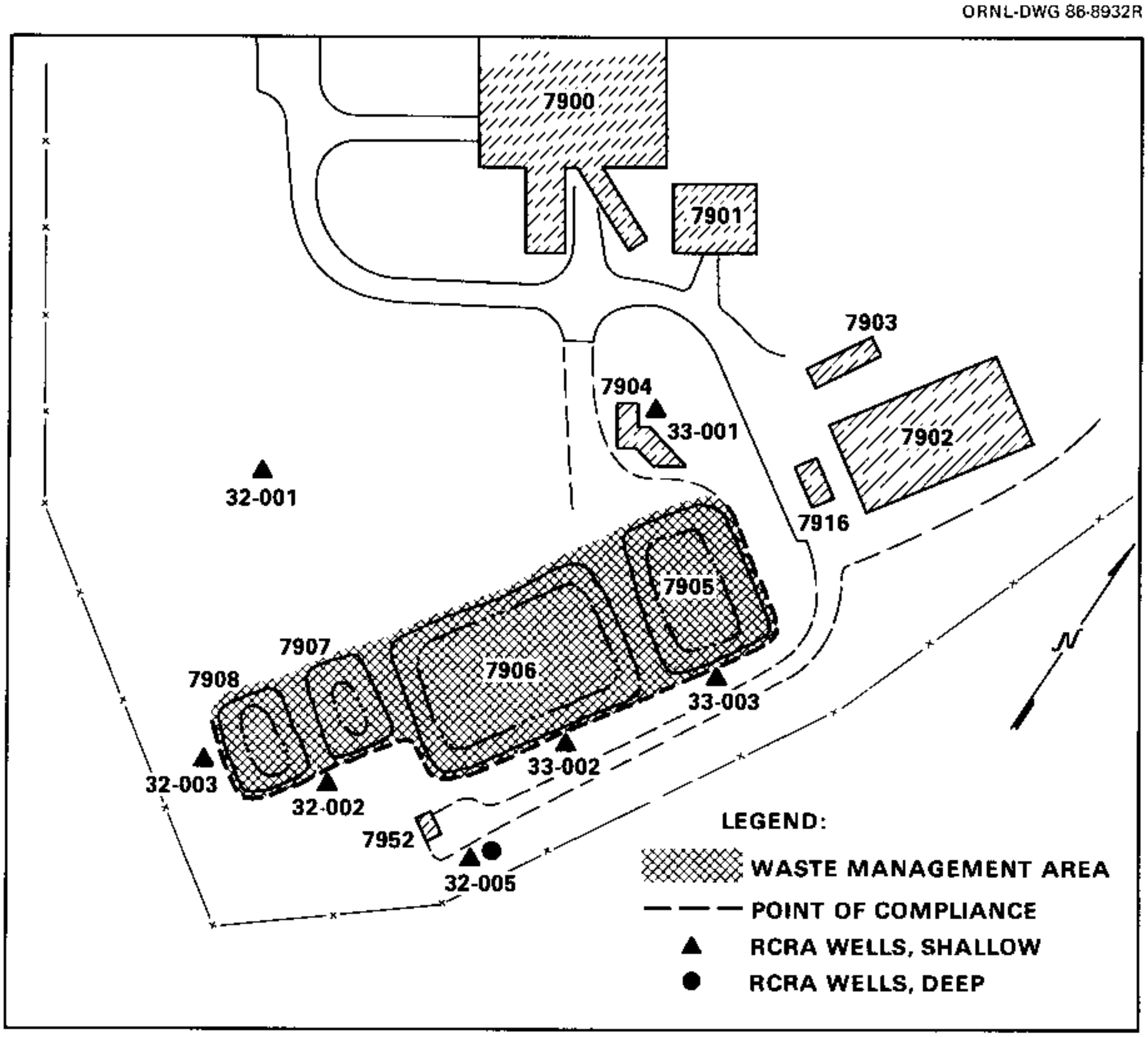

Fig. 4.4.2. Locations of sampling wells around ponds 7905, 7906, 7907, and 7908.

compared with the EPA Interim Primary Drinking Water Standards. The values for several of the up-gradient and down-gradient wells exceeded the standards for gross alpha, Pb, fecal coliform, and NO_3 (Table 4.4.4). The values for gross beta at all wells exceeded the standard during at least one of the sampling periods.

Groundwater was sampled from wells in SWSAs 4, 5, 6, and the pits and trenches area at ORNL (Figs. 4.4.3 through 4.4.6). Wells were selected for semiannual sampling from a group of about 100 monitoring wells, based on studies conducted by the Environmental Sciences Division at ORNL, historical data, and surface water flow patterns. Reference wells in the SWSAs are hydraulically up-gradient from the waste storage area (wells 189 and 313, Figs. 4.4.3–4.4.6). They should be considered only as reference wells and not as background wells because they are located in the SWSA and do receive surface runoff. During 1985, samples were analyzed for gamma emitters, gross alpha activity, ^3H,

Table 4.4.1. 1985 concentration of parameters in wells around 3524 area[a]

Parameter	No. of samples	Concentration (mg/L)			
		Max	Min	Av	95% CC[b]
2,4,5-TP silvex	8	<0.01	<0.01	<0.01	0.0
2,4-D	8	<0.01	<0.01	<0.01	0.0
Ag	8	<0.005	<0.005	<0.005	0.0
As	8	<0.01	<0.01	<0.01	0.0
Ba	8	<1.0	<1.0	<1.0	0.0
Cd	8	<0.002	<0.002	<0.002	0.0
Cl	8	12	4.7	7.2	1.7
^{60}Co	4	0.013	<0.01	<0.011	0.011
Cr	8	<0.020	<0.02	<0.02	0.0
^{137}Cs	4	0.013	<0.008	<0.011	0.002
Endrin	8	<0.0002	<0.0002	<0.0002	0.0
F	8	<1.0	<1.0	<1.0	0.0
Fe	8	2.1	0.09	0.59	0.48
Fecal coliform[c]	8	14	0	1.7	3.5
Gross alpha[d]	8	1.4	0.0016	0.26	0.36
Gross beta[d]	8	5.1	<0.0027	<0.95	1.3
Hg	8	<0.0001	<0.0001	<0.0001	0.0
Lindane	8	<0.002	<0.002	<0.002	0.0
Methoxychlor	8	<0.008	<0.008	<0.008	0.0
Mn	8	3.5	0.22	1.5	1.0
Na	8	22	15	19	2.0
NO$_3$	8	<5.0	<5.0	<5.0	0.0
Pb	8	0.053	<0.02	<0.028	0.01
pH[e]	56	7.7	7.0	7.4	0.048
Phenols	8	<0.001	<0.001	<0.001	0.0
Ra (total)[d]	8	0.0008	<0.0001	<0.0003	0.0002
Se	8	<0.005	<0.005	<0.005	0.0
SO$_4$	8	110	14	53	24
Specific conductivity[f]	56	0.45	0.03	0.26	0.028
Temperature[g]	56	25	8.8	19	1.3
Total organic carbon	32	4.1	1.3	2.5	0.3
Total organic halides	32	0.052	0.013	0.032	0.0038
Toxaphene	8	<0.005	<0.005	<0.005	0.0

[a] See Fig. 4.4.1 (ORNL).

[b] 95% confidence coefficient about the average.

[c] Units are colonies per 100 mL.

[d] Units are pCi/mL.

[e] Values in pH units.

[f] Units are in μmho/cm.

[g] Units are in °C.

Table 4.4.2. 1985 concentration of parameters in wells around 7905–7908 area[a]

Parameter	No. of samples	Concentration (mg/L)			
		Max	Min	Av	95% CC[b]
2,4,5-TP silvex	14	<0.01	<0.01	<0.01	0.0
2,4-D	14	<0.01	<0.01	<0.01	0.0
Ag	14	<0.005	<0.005	<0.005	0.0
As	14	<0.01	<0.01	<0.01	0.0
Ba	14	<1.0	<1.0	<1.0	0.0
Cd	14	<0.002	<0.002	<0.002	0.0
Cl	14	33	2.0	13	4.3
^{60}CO	7	0.076	0.0059	0.026	0.019
Cr	14	<0.02	<0.02	<0.02	0.0
^{137}Cs	7	<0.016	<0.0027	<0.0093	0.0033
Endrin	14	<0.0002	<0.0002	<0.0002	0.0
F	14	<1.0	<1.0	<1.0	0.0
Fe	14	2.2	<0.05	<0.42	0.3
Fecal coliform[c]	15	10	0.0	1.1	1.4
Gross alpha[d]	14	1.8	0.0016	0.14	0.25
Gross beta[d]	14	2.0	0.003	0.17	0.29
Hg	14	<0.0001	<0.0001	<0.0001	0.0
Lindane	14	<0.002	<0.002	<0.002	0.0
Methoxychlor	14	<0.008	<0.008	<0.008	0.0
Mn	14	0.98	0.04	0.25	0.15
Na	14	44	3.4	12	6.2
NO_3	14	39	<5.0	<13	7.1
Pb	14	0.13	<0.02	<0.028	0.016
pH[e]	98	8.3	7.0	7.6	0.07
Phenols	14	0.006	<0.001	<0.0014	0.0007
Ra (total)[d]	14	0.0014	<0.0003	<0.0004	0.0002
Se	14	<0.005	<0.005	<0.005	0.0
SO_4	14	150	<5.0	<54	25
Specific conductivity[f]	98	0.31	0.01	0.15	0.017
Temperature[g]	98	25	11	17	0.56
Total organic carbon	56	1.6	0.8	1.1	0.057
Total organic halides	56	0.038	0.005	0.02	0.0022
Toxaphene	14	<0.005	<0.005	<0.005	0.0

[a] See Fig. 4.4.2 (ORNL).

[b] 95% confidence coefficient about the average.

[c] Units are colonies per 100 mL.

[d] Units are pCi/mL.

[e] Values in pH units.

[f] Units are in µmho/cm.

[g] Units are in °C.

Table 4.4.3. 1985 concentration of parameters in wells around 3539 and 3540 ponds[a]

Parameter	No. of samples	Concentration (mg/L)			
		Max	Min	Av	95% CC[a]
2,4,5-TP silvex	14	<0.01	<0.01	<0.01	0.0
2,4-D	14	<0.01	<0.01	<0.01	0.0
Ag	14	<0.005	<0.005	<0.005	0.0
As	14	<0.01	<0.01	<0.01	0.0
Ba	14	<1.0	<1.0	<1.0	0.0
Cd	14	<0.002	<0.002	<0.002	0.0
Cl	14	13	5.2	7.6	1.1
^{60}CO	7	0.017	<0.011	<0.012	0.002
Cr	14	<0.02	<0.02	<0.02	0.0
^{137}Cs	7	0.016	<0.008	<0.01	0.003
Endrin	14	<0.0002	<0.0002	<0.0002	0.0
F	14	<1.0	<1.0	<1.0	0.00
Fe	14	8.7	0.052	2.3	1.2
Fecal coliform[c]	14	0.0	0.0	0.0	0.0
Gross alpha[d]	14	0.013	0.0011	0.0048	0.0021
Gross beta[d]	14	0.07	0.0022	0.018	0.012
Hg	14	<0.0001	<0.0001	<0.0001	0.0
Lindane	14	0.04	<0.002	<0.0021	0.0003
Methoxychlor	14	<0.008	<0.008	<0.008	0.0
Mn	14	8.9	0.65	5.0	1.9
Na	14	37	4.6	11	5.0
NO_3	14	<5.0	<5.0	<5.0	0.0
Pb	14	0.034	<0.02	<0.02	0.002
pH[e]	98	7.5	6.5	7.0	0.04
Phenols	14	0.002	0.0	<0.001	0.0002
Ra (total)[d]	14	0.0008	<0.0003	<0.0004	0.0001
Se	14	<0.005	<0.005	<0.005	0.0
SO_4	14	210	<5.0	<61	36
Specific conductivity[f]	98	0.78	0.01	0.36	0.036
Temperature[g]	98	29	13	19	0.63
Total organic carbon	56	6.6	2.3	4.3	0.34
Total organic halides	56	0.062	0.009	0.037	0.0036
Toxaphene	14	<0.05	<0.005	<0.005	0.0

[a] See Fig. 4.4.1 (ORNL).

[b] 95% confidence coefficient about the average.

[c] Units are colonies per 100 mL.

[d] Units are pCi/mL, to convert to 10^{-2} Bq/mL multiply value in table by 3.7.

[e] Values in pH units.

[f] Units are in μmhos/cm.

[g] Units are in °C.

Table 4.4.4. Concentrations of parameters whose values exceed standards in groundwater wells on the ORNL site

Well[a] ID	Date	Parameters				
		Gross alpha (pCi/mL)[b]	Gross beta (pCi/mL)[b]	Pb (mg/L)	Fecal coliform (colonies/100 mL)	NO$_3$ (mg/L)
Standard[c]		0.015	0.0035	0.05	1	10
31-001	9/18/85	*d*	0.04	*d*	*d*	*d*
	12/26/85	0.02	0.064	*d*	*d*	*d*
31-002	12/27/85	0.68	2.4	*d*	*d*	*d*
31-003	12/27/85	1.4	5.1	*d*	*d*	*d*
31-004	9/18/85	*d*	0.01	0.053	*d*	*d*
	12/29/85	*d*	*d*	*d*	14	*d*
	12/30/85	*d*	0.0081	*d*	*d*	*d*
31-005	9/19/85	*d*	0.07	*d*	*d*	*d*
	12/23/85	*d*	0.038	*d*	*d*	*d*
31-006	9/19/85	*d*	0.0078	*d*	*d*	*d*
	12/23/85	*d*	0.0051	*d*	*d*	*d*
31-007	9/19/85	*d*	0.0081	*d*	*d*	*d*
31-008	9/19/85	*d*	0.0038	*d*	*d*	*d*
	12/23/85	*d*	0.0046	*d*	*d*	*d*
31-009	9/19/85	*d*	0.0076	*d*	*d*	*d*
31-010	9/19/85	*d*	0.051	*d*	*d*	*d*
	12/20/85	*d*	0.043	*d*	*d*	*d*
31-012	9/19/85	*d*	0.0095	*d*	*d*	*d*
31-013	9/26/85	*d*	0.014	*d*	*d*	*d*
	12/19/85	*d*	0.0041	*d*	*d*	*d*
32-001	9/24/85	*d*	0.0086	*d*	4	*d*
32-002	9/26/85	*d*	0.0095	*d*	2	*d*
32-003	9/26/85	*d*	0.059	0.13	*d*	*d*
	1/2/86	*d*	0.0096	*d*	*d*	*d*
32-005	9/25/85	*d*	0.0084	*d*	10	*d*
	1/2/85	0.21	0.26	*d*	*d*	*d*
33-001	12/29/85	*d*	0.0041	*d*	*d*	*d*
33-002	9/25/85	*d*	0.038	*d*	*d*	28
	12/29/85	*d*	0.0049	*d*	*d*	28
33-003	9/24/85	*d*	0.046	*d*	*d*	36
	12/29/85	1.8	2.0	*d*	*d*	39

[a] See Figs. 4.4.1 and 4.4.2.

[b] To convert from pCi/mL to 10^{-2} Bq/mL multiply value in table by 3.7.

[c] EPA Interim Primary Drinking Water Standard.

[d] Samples do not exceed standard.

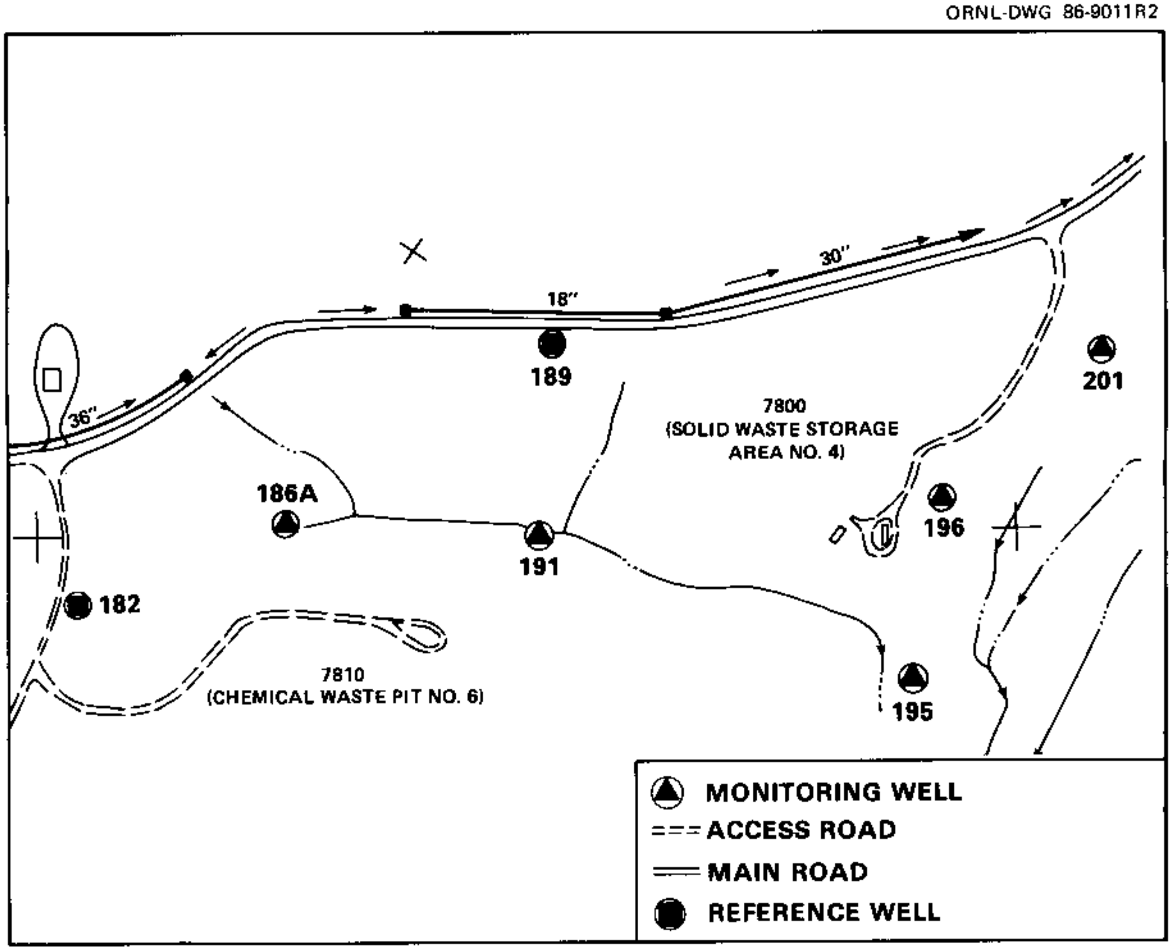

Fig. 4.4.3. Locations of sampling wells near Solid Waste Storage Area 4.

and ^{90}Sr. Data on the concentrations of radionuclides measured in the monitoring and reference wells are presented in Table 4.4.5. Concentrations of radionuclides measured in wells during the two sampling periods were highly variable and therefore make comparisons impossible.

Each waste disposal facility operated by Y-12 has a groundwater monitoring network of wells that consists of at least one well hydraulically up-gradient and three down-gradient from the facility. Water samples are collected from these wells and analyzed each quarter. Analytical results are compared with the EPA and TDHE constituents mentioned earlier. Figure 4.4.7 shows the location of monitoring wells used during 1985.

The Centralized Sanitary Landfill II is located on a small hill on the southern slope of Chestnut Ridge. This facility receives sanitary waste from all three facilities. It is surrounded by three wells that are monitored quarterly along with the other disposal facility wells. Above-normal levels of gross alpha, gross beta, and coliform bacteria were detected in one set of samples during 1985. The data

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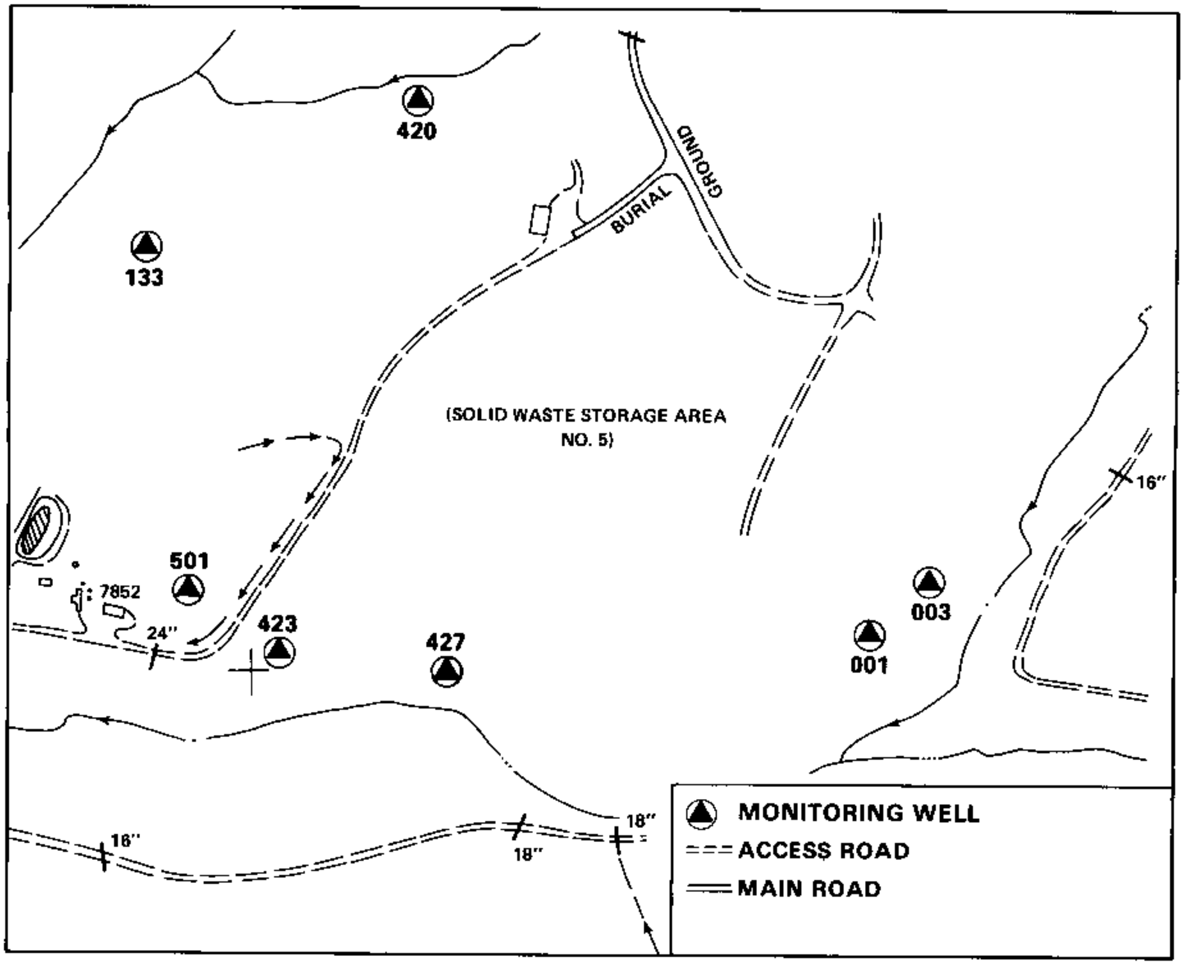

Fig. 4.4.4. Locations of sampling wells near Solid Waste Storage Area 5.

for this facility are reported in Table 4.4.6.

The S-3 Ponds are located adjacent to the west end of the Y-12 Plant at the topographic divide separating the headwaters of Bear Creek to the west from the headwaters of East Fork Poplar Creek to the east. They consist of four unlined impoundments covering an area of approximately 120 m by 120 m. Although the S-3 Ponds are no longer used for waste disposal, monitoring of the groundwater continues in addition to other studies. Groundwater, surface water, and soils at and near the S-3 Ponds show varying levels of contamination. During 1985 at least one groundwater analysis indicated levels of barium, cadmium, chromium, lead, mercury, and nitrate above the EPA Interim Primary Drinking Water Standard. Gross alpha and gross beta contamination were also detected. The 1985 data are reported in Table 4.4.7.

The Bear Creek Valley Waste Disposal Area (BCVWDA) is located on the southern flank of Pine Ridge approximately 3.2 km west of Y-12. The area consists of several principal sites, many of which are no longer used for waste disposal. Topography suggests that the general direction

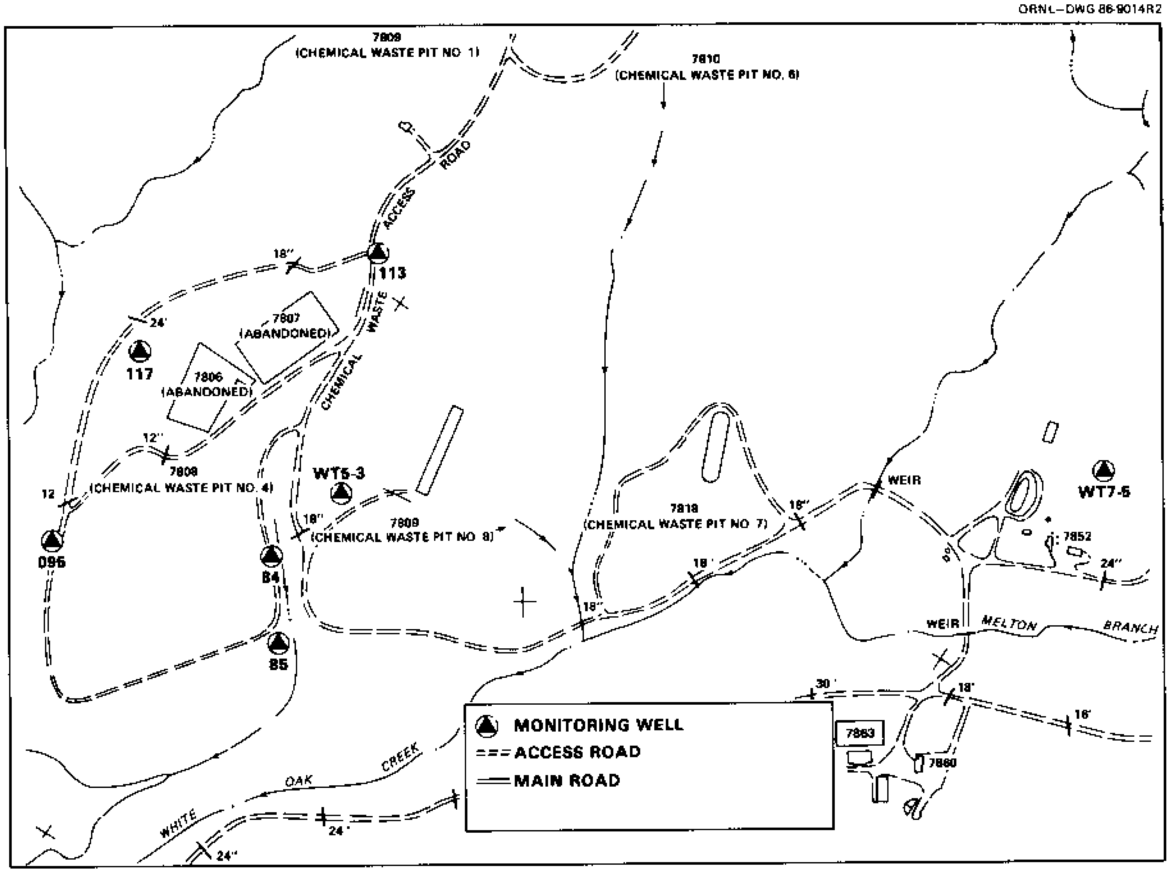

Fig. 4.4.5. Locations of sampling wells near pits.

of flow is southwesterly toward Bear Creek. Water level measurements indicate that there are upward components of groundwater flow in most of the burial grounds area.

Investigations by Geraghty & Miller[8] show that contaminants entered surface waters and groundwaters from each of the three principal waste disposal areas in the BCVWDA. The main contaminants found were volatile organic compounds, nitrate, oils, heavy metals, and radioactive substances. Plumes of groundwater contamination have been defined at all three principal disposal sites. Generally, the contaminated groundwater extends only a few tens of meters away from the waste sources, except at the S-3 Ponds, where nitrate contamination in ground water has been detected about 620 m from the source. Volatile organic compounds have been detected to depths of 62 m at both burial grounds and at the Oil Landfarm and to a depth of about 37 m at the S-3 Ponds. In 1985, additional deep monitoring wells were installed to determine whether contamination extends below those depths.

Sampling of wells located in the BCVWDA indicates levels of arsenic, cadmium, lead, and mercury exceeding the EPA drinking water standards. These data are reported in Table 4.4.8.

Geraghty & Miller reported that the contamination in the BCVWDA poses no direct threat to drinking water supplies

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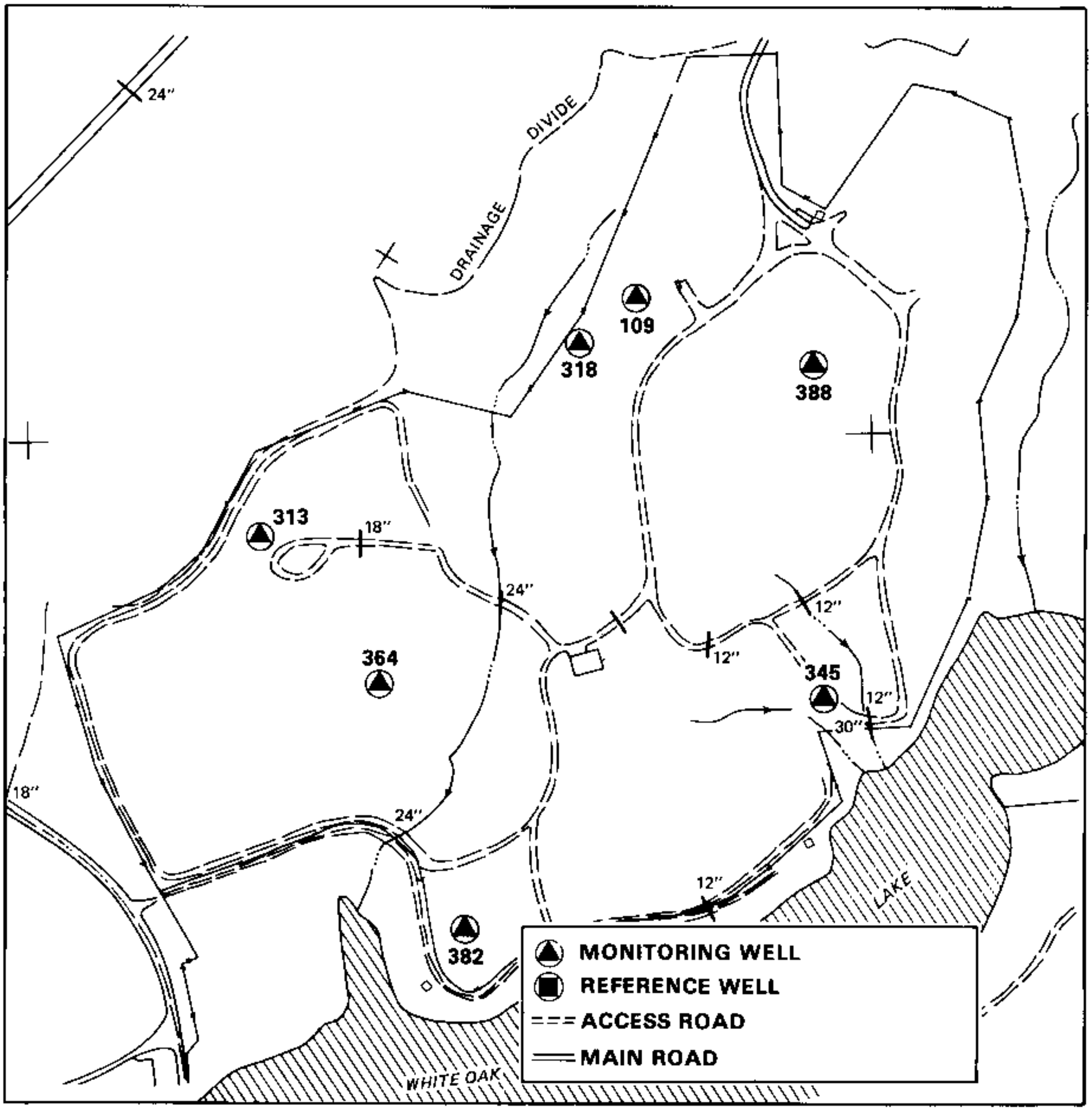

Fig. 4.4.6. Locations of sampling wells near Solid Waste Storage Area 6.

inasmuch as Bear Creek is not utilized for that purpose and the nearest water-supply wells are in other valleys across the ridges to the north and south.[8]

There are three other waste disposal sites located at the crest of Chestnut Ridge—the United Nuclear Corporation (UNC) site, the Classified Burial Grounds, and the Chestnut Ridge Sediment Disposal Basin. Although some gross alpha and gross beta contamination was detected during 1985, all other constituents of the EPA Standards were found to be within the standards.

Groundwater sampling results around the United Nuclear disposal site, located on Chestnut Ridge, are given Table 4.4.9. The results of groundwater sampling

Table 4.4.5. 1985 groundwater monitoring of radionuclides around ORNL solid waste storage areas

Parameter	No. of Samples	Concentration (10^{-8} μCi/mL)[a]		
		Max	Min	Av[a]
		Solid Waste Storage Area 4[b]		
^{60}Co	8	0.54	<0.27	<0.49
^{137}Cs	8	2.3	<0.27	<0.82
Gross alpha	8	170	2.7	32
^{3}H	8	200,000	1,100	34,000
^{90}Sr	8	2,500	30	660
		Solid Waste Storage Area 5[c]		
^{60}Co	11	3.0	<0.27	<0.80
^{137}Cs	11	2.7	<0.27	<0.97
Gross alpha	11	95	<1.1	<21
^{3}H	11	7,300,000	2,000	2,000,000
^{90}Sr	11	1,400	1.8	480
		Solid Waste Storage Area 6[d]		
^{60}Co	6	0.54	<0.27	<0.50
^{137}Cs	6	1.6	<0.27	<0.58
Gross alpha	6	5.4	<1.4	<3.7
^{3}H	6	6,200	190	2,100
^{90}Sr	6	8.4	0.35	2.3
		Pits and trenches[e]		
^{60}Co	8	2,000	<0.54	<580
^{137}Cs	8	3.2	<0.27	<1.8
Gross alpha	8	130	0.54	33
^{3}H	8	14,000	2,200	8,600
^{90}Sr	8	12	0.22	3.2
		Reference wells[f]		
^{60}Co	4	0.54	<0.54	<0.54
^{137}Cs	4	1.1	<0.27	<0.58
Gross alpha	4	6.2	1.6	3.5
^{3}H	4	250	120	170
^{90}Sr	4	3.2	0.19	1.4

[a] To convert from 10^{-8} μCi/mL to 10^{-4} Bq/mL multiply value in table by 3.7.

[b] See Fig. 4.4.3.

[c] See Fig. 4.4.4.

[d] See Fig. 4.4.6

[e] See Fig. 4.4.5.

[f] See Figs. 4.4.3 and 4.4.6.

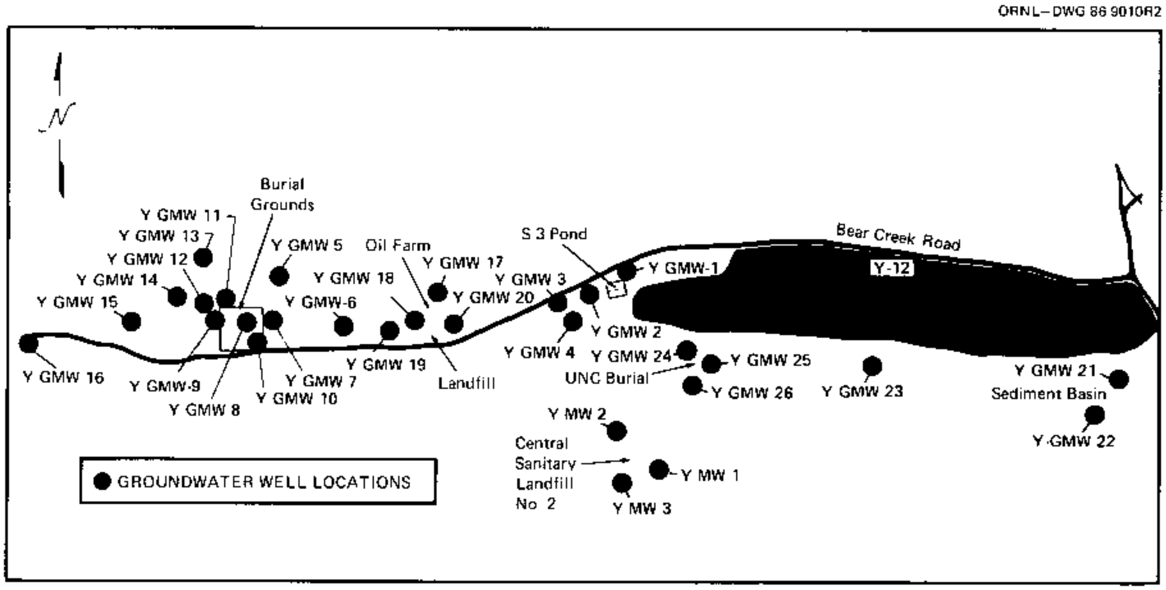

Fig. 4.4.7. Locations of sampling wells near waste areas.

Table 4.4.6. Groundwater monitoring for Centralized Sanitary Landfill II[a]
1985

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
1,1-Dichloroethane	8	<0.01	<0.01	<0.01
1,2-Dichloroethane	8	<0.01	<0.01	<0.01
1,1,1-Trichloroethane	8	0.058	<0.01	<0.016
1,1,2-Trichloroethane	8	<0.01	<0.01	<0.01
Fluoride	11	<0.1	<0.1	<0.10
Color (in apparent color units)	11	2500	<5.0	<268
MBAS	11	<0.05	<0.05	<0.05
Gross beta (pCi/L)	11	120	<4.0	<27
Uranium	11	<0.001	<0.001	<0.001
^{235}U (%)	11	<2.0	<2.0	<2.0
Niobium	11	<0.02	<0.02	<0.02
Phosphorous	11	0.12	<0.03	<0.046
Scandium	11	0.004	<0.001	<0.0018
Thorium	11	<0.02	<0.02	<0.02
Yttrium	11	0.02	<0.001	<0.0051
Gross alpha (pCi/L)	11	70	<1.0	<14.8
Conductivity (μmho/cm)	11	590	300	380
Sulfate	11	<10	1.5	<7.1
Chloride	11	20	<2.0	<7.8
Nitrate (N)	11	0.5	0.1	0.26
Total Kjeldahl nitrogen	11	<0.2	<0.2	<0.2
Total organic carbon	11	10	<2.0	<4.27

Table 4.4.6. (continued)

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
Total plate count (colonies/100 mL)	11	8.0	<1.0	<2.36
Aluminum	11	11	<0.050	<2.4
Arsenic	11	<0.060	<0.060	<0.060
Barium	11	<0.20	<0.20	<0.20
Beryllium	11	0.0030	<0.00050	<0.0010
Boron	11	<0.020	<0.020	<0.020
Cadmium	11	<0.0020	<0.0020	<0.0020
Calcium	11	87	30	45
Chromium	11	0.010	<0.010	<0.010
Cobalt	11	0.0040	<0.0020	<0.0023
Copper	11	0.013	<0.0040	<0.0064
Iron	11	10	<0.060	<2.6
Lead	11	0.010	<0.010	<0.010
Lithium	11	0.020	<0.010	<0.011
Magnesium	11	23	8.3	14
Manganese	11	0.22	<0.010	<0.064
Molybdenum	11	<0.10	<0.10	<0.10
Nickel	11	0.010	<0.010	<0.010
Selenium	11	<0.0020	<0.0020	<0.0020
Silver	11	<0.010	<0.010	<0.010
Sodium	11	7.6	0.50	2.8
Strontium	11	0.083	0.018	0.037
Titanium	11	0.047	<0.0010	<0.019
Vanadium	11	0.026	<0.0030	<0.0075
Zinc	11	0.070	<0.020	<0.030
Cerium	11	0.040	<0.030	<0.031
Gallium	11	<0.040	<0.040	<0.040
Lanthanum	11	0.020	<0.010	<0.011
Potassium	11	3.5	0.20	1.3
Zirconium	11	0.0080	<0.0010	<0.0025
Phenols	11	<0.0010	<0.0010	<0.0010
Mercury	11	0.0010	<0.00050	<0.00073
PCB (all detectable Aroclors)	3	<0.00050	<0.00050	<0.00050
Chloroethane	11	<0.010	<0.010	<0.010
Chloroform	11	<0.010	<0.010	<0.010
Bromomethane	11	<0.010	<0.010	<0.010
Chloromethane	11	<0.010	<0.010	<0.010
Methylene chloride	11	0.040	<0.010	<0.015
Tetrachloroethene	11	0.026	<0.010	<0.013
Toluene	11	0.011	<0.010	<0.010
Xylene	6	<0.010	<0.010	<0.010
pH (units)	11	8.3	7.3	7.7
Total N	11	<0.70	<0.30	<0.46

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[a] The Centralized Sanitary Landfill II is located on the Y-12 site and locations of wells are shown in Fig. 4.4.7.

[b] Unless otherwise stated in variable and name.

[c] 95% confidence coefficient about the mean.

Table 4.4.7. Groundwater monitoring, S-3 Ponds[a]
1985

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
1,1-Dichloroethane	12	<0.010	<0.010	<0.010
1,2-Dichloroethane	12	<0.010	<0.010	<0.010
1,1,1-Trichloroethane	12	<0.010	<0.010	<0.010
1,1,2-Trichloroethane	12	<0.010	<0.010	<0.010
Gross beta (pCi/L)	16	1100	<4.0	<385
Uranium	16	0.56	<0.0010	<0.20
^{235}U (%)	16	<2.0	0.31	<0.77
Niobium	16	0.090	<0.020	<0.036
Phosphorus	16	0.68	<0.030	<0.083
Scandium	16	0.038	<0.0010	<0.0038
Thorium	16	0.070	<0.020	<0.023
Yttrium	16	0.40	<0.0010	<0.086
Gross alpha (pCi/L)	16	500	<1.0	<166
Conductivity (μmho/cm)	16	9200	430	3990
Nitrate (N)	16	1800	<0.10	<485
Total Kjeldahl nitrogen	16	7.8	<0.20	<1.1
Total organic carbon	16	16	<2.0	<7.6
Aluminum	16	190	<0.050	<21
Arsenic	16	<0.060	<0.060	<0.060
Barium	16	7.2	<0.20	<2.1
Beryllium	16	0.025	<0.00050	<0.0057
Boron	16	0.16	<0.020	<0.049
Cadmium	16	0.056	<0.0020	<0.013
Calcium	16	650	47	338
Chromium	16	0.16	<0.010	<0.020
Cobalt	16	0.13	<0.0020	<0.033
Copper	16	0.085	<0.0040	<0.015
Iron	16	100	<0.060	<8.8
Lead	16	0.050	<0.010	<0.016
Lithium	16	0.26	<0.010	<0.039
Magnesium	16	190	9.5	72
Manganese	16	12	0.17	3.4
Molybdenum	16	<0.10	<0.10	<0.10
Nickel	16	0.52	<0.010	<0.13
Selenium	16	<0.0020	<0.0020	<0.0020
Silver	16	<0.010	<0.010	<0.010
Sodium	16	140	8.4	51
Strontium	16	5.2	0.11	1.7
Titanium	16	0.13	<0.0010	<0.017
Vanadium	16	0.13	<0.0030	<0.013
Zinc	16	0.22	<0.020	<0.067
Cerium	16	0.34	<0.030	<0.10
Gallium	16	0.13	<0.040	<0.046
Lanthanum	16	0.26	<0.010	<0.064

Table 4.4.7. (continued)

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
Potassium	16	49	1.5	11
Zirconium	16	0.055	<0.0010	<0.0059
Cyanide	16	0.014	<0.0020	<0.0040
Mercury	15	0.0090	<0.00050	<0.0028
PCB (all detectable Aroclors)	16	<0.00050	<0.00050	<0.00050
Chloroethane	16	<0.010	<0.010	<0.010
Chloroform	16	<0.010	<0.010	<0.010
Bromomethane	16	<0.010	<0.010	<0.010
Chloromethane	16	<0.010	<0.010	<0.010
Methylene chloride	16	0.084	<0.010	<0.019
Tetrachloroethene	16	0.018	<0.010	<0.011
Toluene	16	<0.010	<0.010	<0.010
Xylene	8	<0.010	<0.010	<0.010
pH (units)	16	7.6	4.5	6.5
Total N	16	<1800	<0.30	<486

[a] The S-3 Ponds are located on the Y-12 site, and locations of wells are shown in Fig. 4.4.7.

[b] Unless otherwise stated in variable and name.

[c] 95% confidence coefficient about the mean.

around Chestnut Ridge sediment disposal basin are given in Table 4.4.10. Results of groundwater sampling around the classified burial grounds located on Chestnut Ridge are given in Table 4.4.11. Concentrations of parameters whose values exceed standards in wells at Y-12 are given in Table 4.4.12.

During 1985, Y-12 installed and developed additional wells both in Bear Creek Valley and on Chestnut Ridge. These wells were installed to further investigate and characterize regional groundwater conditions as well as to provide additional monitoring capabilities. Y-12 will be conducting several investigative studies during the next year.

The original 21 groundwater wells at ORGDP were not sampled in 1985. These monitoring wells are of questionable reliability and the data collected from them have not been sufficiently consistent to determine trends or to identify the direction of contaminant migration, if any, from the monitored areas. The existing monitoring well system is judged to be inadequate to monitor the active and inactive waste disposal sites.[9]

Currently, a new groundwater protection program is being implemented at the ORGDP. Energy Systems personnel are providing multidisciplinary support to the ORGDP Environmental Management Staff in establishing a formal groundwater monitoring program. This support includes updating the geologic map of ORGDP. Using this information, a consultant/contractor is now on site,

Table 4.4.8. Groundwater monitoring for Bear Creek burial grounds[a]
1985

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
1,1-Dichloroethane	36	1.4	<0.010	<0.087
1,2-Dichloroethane	36	0.044	<0.010	<0.012
1,1,1-Trichloroethane	36	0.28	<0.010	<0.028
1,1,2-Trichloroethane	36	<0.010	<0.010	<0.010
Fluoride	22	0.20	<0.10	<0.11
Color (in apparent color units)	19	1200	<5.0	<99
MBAS	16	<0.050	<0.050	<0.050
Gross beta (pCi/L)	46	830	<4.0	<39.8
Uranium	46	0.018	<0.0010	<0.0025
^{235}U (%)	46	3.0	0.49	1.7
Niobium	46	0.050	<0.020	<0.021
Phosphorus	46	0.66	<0.030	<0.064
Scandium	46	0.013	<0.0010	<0.0014
Thorium	46	0.030	<0.020	<0.020
Yttrium	46	0.016	<0.0010	<0.0019
Gross alpha (pCi/L)	46	410	<1.0	<28.8
Conductivity (μmho/cm)	45	1500	85	512
Sulfate	21	230	5.0	41.5
Chloride	22	91	<2.0	<26
Nitrate (N)	46	2.2	<0.10	<0.31
Total Kjeldahl nitrogen	46	34	<0.10	<1.1
Total organic carbon	46	37	<2.0	<6.1
Total plate count (colonies/100 mL)	44	230000	<1.0	<7900
Aluminum	46	15	<0.050	<1.6
Arsenic	46	0.090	<0.060	<0.061
Barium	46	0.90	<0.20	<0.27
Beryllium	46	0.0050	<0.00050	<0.00070
Boron	46	0.71	<0.020	<0.084
Cadmium	46	0.017	<0.0020	<0.0026
Calcium	46	160	13	63
Chromium	46	0.020	<0.010	<0.010
Cobalt	46	0.016	<0.0020	<0.0035
Copper	46	0.24	<0.0040	<0.015
Iron	46	26	<0.060	<2.44
Lead	46	0.12	<0.010	<0.018
Lithium	46	0.210	<0.0100	<0.0270
Magnesium	46	24	0.10	8.97
Manganese	46	3.5	<0.010	<0.31
Molybdenum	46	<0.10	<0.10	<0.10
Nickel	46	0.15	<0.010	<0.020
Selenium	46	<0.0020	<0.0020	<0.0020

Table 4.4.8. (continued)

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
Silver	46	0.040	<0.010	<0.012
Sodium	46	29	0.60	7.58
Strontium	46	2.6	0.016	0.44
Titanium	46	0.055	<0.0010	<0.014
Vanadium	46	0.029	<0.0030	<0.0045
Zinc	46	7.6	<0.020	<0.20
Cerium	46	0.050	<0.030	<0.030
Gallium	46	0.20	<0.040	<0.044
Lanthanum	46	<0.010	<0.010	<0.010
Potassium	46	18	0.60	3.17
Zirconium	46	0.026	<0.0010	<0.0020
Cyanide	30	0.18	<0.0020	<0.013
Phenols	22	0.0050	<0.0010	<0.0014
Mercury	46	0.0070	<0.00050	<0.0014
PCB (all detectable Aroclors)	46	0.0020	<0.00050	<0.00050
Chloroethane	46	0.015	<0.010	<0.010
Chloroform	46	0.033	<0.010	<0.011
Bromomethane	45	<0.010	<0.010	<0.010
Chloromethane	46	<0.010	<0.010	<0.010
Methylene chloride	46	0.083	<0.010	<0.016
Tetrachloroethene	46	7.3	<0.010	<0.37
Toluene	46	0.015	<0.010	<0.010
Xylene	14	<0.010	<0.010	<0.010
pH (units)	46	12	6.2	7.6
Total N	46	36	<0.20	<1.4

[a] The Bear Creek burial grounds are located on the Y-12 site, and locations of wells are shown in Fig. 4.4.7.

[b] Unless otherwise stated in variable and name.

[c] 95% confidence coefficient about the mean.

designing the actual groundwater monitoring plan. The required wells have been installed and approved by the TDHE and the EPA.

As a part of this program, new exploratory wells were installed around the K-1407-B and K-1407-C holding ponds in 1985, and more wells are scheduled to be placed around the Classified Burial Ground and other areas at ORGDP where applicable. The current schedule calls for completion of the initial assessment of groundwater quality at ORGDP Resource Conservation and Recovery Act (RCRA) facilities around the end of FY 1987.

The locations of the wells around K-1407-B and K-1407-C ponds at ORGDP are shown in Fig. 4.4.8, and the sampling

Table 4.4.9. Groundwater monitoring for United Nuclear disposal site[a]
1985

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
1,1-Dichloroethane	6	<0.010	<0.010	<0.010
1,2-Dichloroethane	6	<0.010	<0.010	<0.010
1,1,1-Trichloroethane	6	<0.010	<0.010	<0.010
1,1,2-Trichloroethane	6	<0.010	<0.010	<0.010
Gross beta	8	75	<4.0	<25.4
Uranium	8	<0.0010	<0.0010	<0.0010
^{235}U (%)	8	<2.0	<2.0	<2.0
Niobium	8	<0.020	<0.020	<0.020
Phosphorus	8	0.14	<0.030	<0.053
Scandium	8	0.0020	<0.0010	<0.0011
Thorium	8	<0.020	<0.020	<0.020
Yttrium	8	0.0050	<0.0010	<0.0024
Gross alpha	8	17	<1.0	<7.5
Conductivity (μmho/cm)	8	520	140	321
Nitrate (N)	8	1.2	<0.10	<0.48
Total Kjeldahl nitrogen	8	0.20	<0.20	<0.20
Total organic carbon	8	6.0	<2.0	<3.38
Aluminum	8	2.8	0.060	0.89
Arsenic	8	<0.060	<0.060	<0.060
Barium	8	<0.20	<0.20	<0.20
Beryllium	8	0.0010	<0.00050	<0.00070
Boron	8	<0.020	<0.020	<0.020
Cadmium	8	<0.0020	<0.0020	<0.0020
Calcium	8	48	12	29
Chromium	8	0.010	<0.010	<0.010
Cobalt	8	0.0020	<0.0020	<0.0020
Copper	8	0.011	<0.0040	<0.0052
Iron	8	3.7	0.070	1.14
Lead	8	0.040	<0.010	<0.015
Lithium	8	0.010	<0.010	<0.010
Magnesium	8	25	4.6	15
Manganese	8	0.12	<0.010	<0.044
Molybdenum	8	<0.10	<0.10	<0.10
Nickel	8	<0.010	<0.010	<0.010
Selenium	8	<0.0020	<0.0020	<0.0020
Silver	8	<0.010	<0.010	<0.010
Sodium	8	3.7	0.60	2.0
Strontium	8	0.045	0.018	0.029
Titanium	8	0.022	<0.0010	<0.0087
Vanadium	8	0.0090	<0.0030	<0.0050
Zinc	8	0.140	<0.020	<0.049
Cerium	8	<0.030	<0.030	<0.030
Gallium	8	<0.040	<0.040	<0.040

Table 4.4.9. (continued)

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
Lanthanum	8	<0.010	<0.010	<0.010
Potassium	8	5.8	0.70	2.99
Zirconium	8	0.003	<0.0010	<0.0015
Mercury	8	0.0010	<0.00050	<0.00084
PCB (all detectable Aroclors)	8	<0.00050	<0.00050	<0.00050
Chloroethane	8	<0.010	<0.010	<0.010
Chloroform	8	<0.010	<0.010	<0.010
Bromomethane	8	<0.010	<0.010	<0.010
Chloromethane	7	<0.010	<0.010	<0.010
Methylene chloride	8	0.026	<0.010	<0.015
Tetrachloroethene	8	0.74	<0.010	<0.10
Toluene	8	<0.010	<0.010	<0.010
Xylene	4	<0.010	<0.010	<0.010
pH (units)	8	9.1	7.4	8.2
Total N	8	<1.4	<0.30	<0.68

[a] Locations of wells are shown in Fig. 4.4.7.

[b] Unless otherwise stated in variable and name.

[c] 95% confidence coefficient about the mean.

Table 4.4.10. Groundwater monitoring for Chestnut Ridge Sediment Disposal Basin[a]
1985

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
1,1-Dichloroethane	5	<0.010	<0.010	<0.010
1,2-Dichloroethane	6	<0.010	<0.010	<0.010
1,1,1-Trichloroethane	6	<0.010	<0.010	<0.010
1,1,2-Trichloroethane	6	<0.010	<0.010	<0.010
Gross beta (pCi/L)	8	93	<4.0	<27
Uranium	8	<0.0010	<0.0010	<0.0010
^{235}U (%)	8	<2.0	<2.0	<2.0
Niobium	8	<0.020	<0.020	<0.020
Phosphorus	8	0.090	<0.030	<0.049
Scandium	8	0.0030	<0.0010	<0.0014
Thorium	8	<0.020	<0.020	<0.020
Yttrium	8	0.020	<0.0010	<0.0080
Gross alpha (pCi/L)	8	82	<1.0	<21.4
Conductivity (μmho/cm)	8	320	21	190
Nitrate (N)	8	0.90	0.40	0.55

Table 4.4.10. (continued)

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
Total Kjeldahl nitrogen	8	<0.20	<0.20	<0.20
Total organic carbon	8	6.0	2.0	3.6
Aluminum	8	7.0	0.19	2.14
Arsenic	8	<0.060	<0.060	<0.060
Barium	8	<0.20	<0.20	<0.20
Beryllium	8	0.0010	<0.00050	<0.00050
Boron	8	0.090	<0.020	<0.033
Cadmium	8	<0.0020	<0.0020	<0.0020
Calcium	8	33	0.60	15
Chromium	8	0.030	<0.010	<0.013
Cobalt	8	0.017	<0.0020	<0.0069
Copper	8	0.45	<0.0040	<0.10
Iron	8	6.8	0.21	2.8
Lead	8	0.040	<0.010	<0.020
Lithium	8	0.030	<0.010	<0.014
Magnesium	8	17	0.50	8.2
Manganese	8	0.65	<0.010	<0.23
Molybdenum	8	<0.10	<0.10	<0.10
Nickel	8	0.030	<0.010	<0.016
Selenium	8	<0.0020	<0.0020	<0.0020
Silver	8	<0.010	<0.010	<0.010
Sodium	8	1.20	0.50	0.80
Strontium	8	0.013	0.0020	0.0075
Titanium	8	0.040	0.0010	0.02
Vanadium	8	0.016	<0.0030	<0.0072
Zinc	8	0.88	<0.020	<0.18
Cerium	8	<0.030	<0.030	<0.030
Gallium	8	<0.040	<0.040	<0.040
Lanthanum	8	0.010	<0.010	<0.010
Potassium	8	1.0	0.40	0.64
Zirconium	8	0.0050	<0.0010	<0.0030
Cyanide	8	<0.0020	<0.0020	<0.0020
Mercury	8	0.0020	<0.00050	<0.00080
PCB (all detectable Aroclors)	8	<0.00050	<0.00050	<0.00077
Chloroethane	8	<0.010	<0.010	<0.010
Chloroform	8	<0.010	<0.010	<0.010
Bromomethane	8	<0.010	<0.010	<0.010
Chloromethane	8	<0.010	<0.010	<0.010
Methylene chloride	8	0.018	<0.010	<0.011
Tetrachloroethene	8	0.034	<0.010	<0.015
Toluene	8	<0.010	<0.010	<0.010
Xylene	4	<0.010	<0.010	<0.010
pH (units)	8	8.1	5.2	6.7
Total N	8	<1.1	<0.60	<0.75

[a] Locations of wells are shown in Fig. 4.4.7.

[b] Unless otherwise stated in variable and name.

[c] 95% confidence coefficient about the mean.

Table 4.4.11. Groundwater monitoring for classifed burial grounds[a]
1985

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
1,1-Dichloroethane	3	0.083	<0.010	<0.048
1,2-Dichloroethane	3	<0.010	<0.010	<0.010
1,1,1-Trichloroethane	3	0.92	0.21	0.46
1,1,2-Trichloroethane	3	<0.010	<0.010	<0.010
Gross beta	4	680	<4.0	<179
Uranium	4	0.0040	<0.0010	<0.0017
^{235}U (%)	4	2.5	<2.0	<2.1
Niobium	4	<0.020	<0.020	<0.020
Phosphorus	4	0.040	<0.030	<0.033
Scandium	4	<0.0010	<0.0010	<0.0010
Thorium	4	<0.020	<0.020	<0.020
Yttrium	4	0.0020	<0.0010	<0.0012
Gross alpha	4	110	12	54.5
Conductivity (μmho/cm)	3	390	370	383
Nitrate (N)	4	0.50	0.30	0.40
Total Kjeldahl nitrogen	4	<0.20	<0.20	<0.20
Total organic carbon	4	7.0	<7.0	<4.9
Aluminum	4	0.66	<0.050	<0.27
Arsenic	4	<0.060	<0.060	<0.060
Barium	4	<0.20	<0.20	0.20
Beryllium	4	0.0010	<0.00050	<0.00050
Boron	4	0.83	0.020	0.27
Cadmium	4	<0.0020	<0.0020	<0.0020
Calcium	4	37	33	35
Chromium	4	0.010	<0.010	<0.010
Cobalt	4	<0.0020	<0.0020	<0.0020
Copper	4	0.0060	<0.0040	<0.0045
Iron	4	1.2	<0.060	<0.42
Lead	4	<0.010	<0.010	<0.010
Lithium	4	0.050	<0.010	<0.020
Magnesium	4	20	18	19
Manganese	4	0.040	<0.010	<0.018
Molybdenum	4	<0.10	<0.10	<0.10
Nickel	4	<0.010	<0.010	<0.010
Selenium	4	<0.0020	<0.0020	<0.0020
Silver	4	<0.010	<0.010	<0.010
Sodium	4	2.2	0.60	1.1
Strontium	4	0.016	0.011	0.014
Titanium	4	0.0090	<0.0010	<0.0065
Vanadium	4	<0.0030	<0.0030	<0.0030
Zinc	4	0.050	<0.020	<0.030
Cerium	4	<0.030	<0.030	<0.030
Gallium	4	<0.040	<0.040	<0.040
Lanthanum	4	<0.010	<0.010	<0.010

Table 4.4.11. (continued)

Parameter	No. of samples	Concentration (mg/L)[b]		
		Max	Min	Av
Potassium	4	0.90	0.60	0.70
Zirconium	4	0.0010	<0.0010	<0.0010
Mercury	4	0.0010	<0.00050	<0.00075
PCB (all detectable Aroclors)	4	<0.00050	<0.00050	<0.00050
Chloroethane	4	<0.010	<0.010	<0.010
Chloroform	4	<0.010	<0.010	<0.010
Bromomethane	4	<0.010	<0.010	<0.010
Chloromethane	4	<0.010	<0.010	<0.010
Methylene chloride	4	0.017	<0.010	<0.012
Tetrachloroethene	4	0.070	<0.010	<0.025
Toluene	4	<0.010	<0.010	<0.010
Xylene	2	<0.010	<0.010	<0.010
pH (units)	4	7.7	7.3	7.5
Total N	4	<0.70	<0.50	<0.60

[a] Locations of wells are shown in Fig. 4.4.7.

[b] Unless otherwise stated in variable and name.

[c] 95% confidence coefficient about the mean.

results for December 1985 are shown in Tables 4.4.13 and 4.4.14, respectively. Concentration of parameters whose value exceed standards in wells at ORGDP are given in Table 4.4.15.

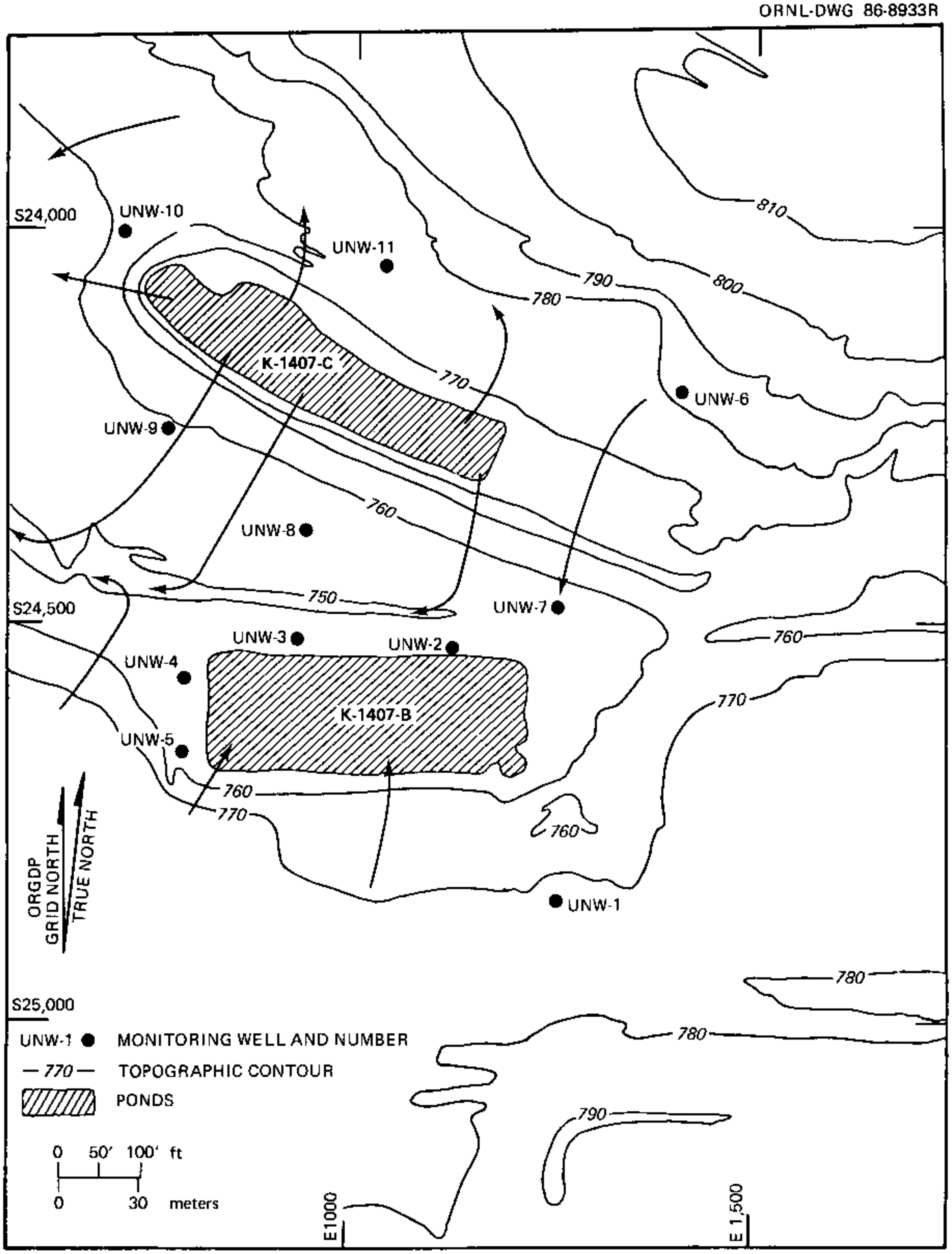

Fig. 4.4.8. Locations of sampling wells around surface impoundments.

Table 4.4.12. Concentrations of parameters whose values exceed or equal standards in groundwater wells on the Y-12 site

Location	Parameters							
	Gross alpha (pCi/L)	Gross beta (pCi/L)	pH (pH units)	mg/L				
				Arsenic	Cadmium	Chromium	Lead	Mercury
Standard[a]	15	0.35	6.5–8.5	0.050	0.010	0.050	0.050	0.002
Centralized Sanitary Landfill II[b]	70 (max) <15 (av)	120 (max) <27 (av)	*c*	*c*	*c*	*c*	*c*	*c*
S-3 Ponds[d]	500 (max) <166 (av)	1100 (max) 385 (av)	4.5	*e* *e*	0.056 (max) <0.013 (av)	0.16 (max) 0.020 (av)	0.050 (max) <0.016 (av)	0.0090 (max) 0.0028 (av)
Bear Creek burial grounds[f]	410 (max) <28.8 (av)	830 (max) <39.8 (av)	12.0 (max) 6.2 (min) 7.6 (av)	0.090 (max) <0.061 (av)	0.017 (max) 0.0026 (av)	*c* *c*	0.12 (max) <0.018 (av)	0.0070 (max) <0.0014 (av)
United Nuclear disposal site[g]	17 (max) 7.5 (av)	75 (max) 25.4 (av)	9.1 (max) 7.4 (min) 8.2 (av)	*e* *e*	*c*	*c*	*c*	*c*
Chestnut Ridge sediment disposal basin[h]	82 (max) <21.4 (av)	73 (max) <27 (av)	5.2 (min) 6.7 (av)	*e* *e*	*c*	*c*	*c*	0.0020 (max) 0.00080 (av)
Classified burial grounds[i]	110 (max) 54.5 (av)	680 (max) <179 (av)	*c*	*e* *e*	*c*	*c*	*c*	*c*

[a] National Interim Primary Drinking Water Standards, 40 CFR Part 141 and National Secondary Drinking Water Standards, 40 CFR Part 143.

[b] See Table 4.4.6 for data.

[c] Samples do not exceed standard.

[d] See Table 4.4.7 for data.

[e] When max, min, and av values are less than (<) values, no value is shown in this table because they are an indication that criteria are below the analytical lower limit of detection.

[f] See Table 4.4.8 for data.

[g] See Table 4.4.9 for data.

[h] See Table 4.4.10 for data.

[i] See TAble 4.4.11 for data.

Table 4.4.13. Groundwater monitoring well data around K-1407-B pond[a]
1985

Parameter[d]	Concentration (mg/L)[b]				
	Well identification[c]				
	UNW-1[e]	UNW-2	UNW-3	UNW-4	UNW-5
Aluminum	4.1	0.52	1.0	0.90	0.15
Antimony	<0.050	<0.050	<0.050	<0.050	<0.050
Arsenic	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Barium	0.17	0.055	0.91	0.020	0.30
Beryllium	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Boron	0.020	0.024	0.056	0.029	0.019
Cadmium	<0.0030	<0.0030	<0.0030	0.0030	<0.0030
Calcium	46	190	230	140	160
Chloride	16	137	274	66	199
Chromium	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	0.020	<0.0050	0.0053	<0.0050	0.011
Copper	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
Iron	6.2	0.60	1.7	1.4	18
Lead	0.006	0.004	<0.004	0.005	<0.004
Lithium	0.0048	<0.0040	0.0048	0.0058	<0.0040
Magnesium	19	23	37	16	19
Manganese	6.5	0.20	6.7	0.40	19
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Molybdenum	<0.010	<0.010	<0.010	<0.010	<0.010
Nickel	0.015	<0.010	0.024	<0.010	<0.010
Niobium	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070
Nitrate (as nitrogen)	<0.11	2.6	<0.11	<0.11	<0.11
Phenols	0.002	0.002	0.003	0.003	0.002
Phosphorus	0.25	0.24	<0.20	<0.20	0.45
Potassium	2.8	2.9	3.9	2.9	1.9
Selenium	<0.005	<0.005	<0.005	<0.005	<0.005
Silicon	7.5	6.0	6.6	8.7	6.5
Silver	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060
Sodium	6.9	42	140	23	14
Strontium	0.13	0.24	0.47	0.23	0.41
Sulfate	30	190	455	58	5
Thallium	<0.01	<0.01	<0.01	<0.01	<0.01
Thorium	<0.20	<0.20	<0.20	<0.20	<0.20
Titanium	0.16	0.017	0.031	0.049	0.0083
Total organic carbon	90	110	80	85	255
Total organic chloride	23	200	290	127	350
Uranium	0.007	0.006	0.007	0.009	0.009
Vanadium	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Zinc	0.062	0.062	0.051	0.16	0.066
Zirconium	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Table 4.4.13 (continued)

Parameter[f]	Well identification UNW-1	UNW-2	UNW-3	UNW-4	UNW-5
2,4-D	<1.0	<1.0	<1.0	<1.0	<1.0
Endrin	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride	0.12	0.06	0.06	0.07	0.11
Lindane	<0.01	<0.01	<0.01	<0.01	<0.01
Methoxychlor	<0.04	<0.04	<0.04	<0.04	<0.04
Silvex	<0.1	<0.1	<0.1	<0.1	<0.1
Toxaphene	<1.0	<1.0	<1.0	<1.0	<1.0

Parameter	Well identification UNW-1	UNW-2	UNW-3	UNW-4	UNW-5
Alpha activity, pCi/L	72.41	79	61.43	47.39	28.65
Beta activity, pCi/L	98.83	2027	96.40	63.60	44.95
Conductivity, μmho/cm	320	800	1600	800	1000
Fecal coliform bacteria	NF[g]	NF	NF	NF	NF
Temperature, °C	19	17	16.5	18	16
Total coliform bacteria	NF	NF	NF	NF	NF
Total radium, pCi/L	<0.0037	<0.0037	<0.0037	<0.0037	<0.0037
Uranium-235, wt %	IU[h]	IU	IU	1.35	IU
pH, units	5.92	6.39	6.16	6.66	6.20

[a] The K-1407-B pond is on the ORGDP site.

[b] Based on one quarterly sample (December 1985).

[c] Locations of wells shown in Fig. 4.4.8.

[d] Expressed in mg/L.

[e] Up-gradient well; all other wells are down-gradient.

[f] Expressed in μg/L.

[g] Not found.

[h] Insufficient uranium for assay analysis.

Table 4.4.14. Groundwater monitoring well data around K-1407-C pond[a]
1985

	Concentration (mg/L)[b]					
	Well identification[c]					
Parameter[d]	UNW-6[e]	UNW-7	UNW-8	UNW-9	UNW-10	UNW-11
Aluminum	1.1	1.0	0.68	0.55	0.75	1.4
Antimony	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Arsenic	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Barium	0.016	0.12	0.055	0.16	0.16	0.061
Beryllium	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Boron	<0.0040	0.032	0.017	0.031	0.027	0.042
Cadmium	<0.0030	<0.0030	<0.0030	0.0050	<0.0030	0.011
Calcium	61	77	70	140	110	48
Chloride	4	158	35	208	36	3.9
Chromium	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt	<0.0050	0.015	<0.0050	0.058	0.0051	<0.0050
Copper	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	0.0075
Iron	2.1	4.1	0.74	11	15	1.7
Lead	0.046	<0.004	0.004	0.004	0.007	0.334
Lithium	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
Magnesium	11	17	6.3	23	19	6.6
Manganese	0.20	9.0	0.089	22	7.3	0.18
Mercury	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Molybdenum	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nickel	<0.010	0.012	<0.010	0.013	0.013	<0.010
Niobium	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070
Nitrate (as nitrogen)	0.16	<0.11	<0.11	<0.11	<0.11	5.3
Phenols	<0.001	0.008	0.002	0.004	<0.001	0.008
Phosphorus	<0.20	0.22	<0.20	0.24	0.38	<0.20
Potassium	2.7	3.2	5.5	6.8	3.4	3.5
Selenium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silicon	5.0	4.5	7.6	4.5	3.6	6.1
Silver	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060	<0.0060
Sodium	1.8	190	5.2	100	31	3.2
Strontium	0.053	0.15	0.094	0.26	0.17	0.069
Sulfate	6	67	10	116	20	12
Thallium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Thorium	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Titanium	0.0088	0.019	0.023	0.0098	0.023	0.026
Total organic carbon	120	360	300	155	195	45
Total organic chloride	1.7	1750	410	132	19	39
Uranium	0.010	0.011	0.006	0.007	0.007	0.006
Vanadium	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Zinc	0.089	0.034	0.037	0.051	0.12	0.17
Zirconium	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050

Table 4.4.14 (continued)

Parameter[f]	UNW-6	UNW-7	UNW-8	UNW-9	UNW-10	UNW-11
	Well identification					
2,4-D	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Endrin	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fluoride	0.09	0.05	0.04	0.04	0.12	0.09
Lindane	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Methoxychlor	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Silvex	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Toxaphene	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

Parameter	UNW-6	UNW-7	UNW-8	UNW-9	UNW-10	UNW-11
	Well identification					
Alpha activity, pCi/L	60.18	59.32	30.86	24.77	25.51	26.34
Beta activity, pCi/L	85.32	109	65.14	43.51	36.76	36.40
Conductivity, μmho/cm	245	1100	380	1100	700	245
Fecal coliform bacteria	NF[g]	NF	NF	NF	NF	NF
Temperature, °C	24	15	15	20	22	16
Total coliform bacteria	NF	NF	NF	NF	NF	NF
Total radium, pCi/L	<0.0037	<0.0037	<0.0037	<0.0037	<0.0037	<0.0037
Uranium-235, wt %	IU[h]	IU	IU	IU	IU	1.02
pH, units	6.46	6.43	6.45	6.64	6.05	6.05

[a] The K-1407-C pond is on the ORGDP site.

[b] Based on one quarterly sample (December 1985).

[c] Locations shown in Fig. 4.4.8.

[d] Expressed in mg/L.

[e] Up-gradient well; all other wells are down-gradient.

[f] Expressed in μg/L.

[g] Not found.

[h] Insufficient uranium for assay analysis.

Table 4.4.15. Concentrations of parameters whose values exceed or equal standards in groundwater wells on the ORGDP site

Location	Parameters			
	Gross alpha (pCi/mL)	pH (pH units)	Cadmium (mg/L)	Lead (mg/L)
Standard[a]	15	6.5-8.5	0.01	0.05
UNW-1[b]	72.4	5.9 (min)	*b*	*b*
UNW-2[b]	79	*b*	*b*	*b*
UNW-3[b]	61.4	*b*	*b*	*b*
UNW-4[b]	47.4	*b*	*b*	*b*
UNW-5[b]	28.7	*b*	*b*	*b*
UNW-6[c]	60.1	6.5 (min)	*c*	*c*
UNW-7[c]	59.3	6.4 (min)	*c*	*c*
UNW-8[c]	30.9	6.5 (min)	*c*	*c*
UNW-9[c]	24.8	*c*	*c*	*c*
UNW-10[c]	25.5	6.1 (min)	*c*	*c*
UNW-11[c]	26.3	6.1 (min)	0.011	0.334

[a] 40 CFR 265 uses National Interim Primary Drinking Water Standards (40 CFR Pt. 141) for establishing groundwater quality and National Secondary Drinking Water Standards (40 CFR Pt. 143) as indicators of groundwater contamination.

[b] See Table 4.4.13 for data.

[c] See Table 4.4.14 for data.

REFERENCES FOR SECT. 4.4

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3. *Clinch River Breeder Reactor Plant: Preliminary Safety Analysis Report,* Docket No. 50-537, 1975, Amemdment 34, Project Management Corporation, February 1977.

4. W. M. McMaster, *Geologic Map of the Oak Ridge Reservation, Tennessee,* ORNL-TM-713, Oak Ridge National Laboratory, 1963.

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Y/SUB/85-00206C/3, Tampa, Fla., June 1985.

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4.5. BIOLOGICAL MONITORING: FISH

Fish from the Clinch River are routinely collected for tissue analyses of radionuclides, mercury, and PCBs. The six sampling locations along the Clinch River include the following river kilometers (CRK): (1) 40.0, which is above Melton Hill Dam and serves as a reference location; (2) 33.3, which is the major point where discharges from ORNL into White Oak Creek meet the Clinch River; (3) 19.2, which is the point where discharges from ORGDP and Y-12 (East Fork Poplar and Bear creeks) into Poplar Creek meet the Clinch River; (4) 16.0 and (5) 8.0, which are both downstream from the three Oak Ridge installations; and (6) 3.2, which serves as the downstream reference point for monitoring the impact of the Oak Ridge facilities. The fish sampling locations are shown in Fig. 4.5.1. Six families of fish are collected at these CRK stream locations: (1) Centrarchidae—smallmouth bass (*Micropterus dolomieui*), largemouth bass (*M. salmoides*), bluegill (*Lepomis macrochirus*), and white crappie (*Pomoxis annularis*); (2) Cyprimidae—carp (*Cyprinus carpio*); and (3) Clupeidae—gizzard shad (*Dorosoma cepedianum*); (4) *Ictaluidae*—channel catfish (*I. punctatus*).

During 1985, the fish program was modified to increase sampling efficiency. Previously, the large numbers of individual fish required for analysis were difficult to collect at the specified locations and times. At the beginning of 1985, six species were collected at CRK 19.2 and analyzed for mercury. Based on these data and historical data on radionuclides, three species of fish were selected for future analyses of mercury and radionuclides during 1985: bass (*Micropterus sp.*), a highly prized game fish[1] in East Tennessee; bluegill (*Lepomis macrochirus*), a sport fish;[1] and carp (*Cyprinus carpio*), a bottom feeder. These three species serve as representative organisms for determining impacts of plant operations. Only carp were collected and analyzed by ORNL for PCBs because previous studies by Energy Systems[2] indicate that carp accumulate PCBs to higher levels than bass and sunfish and that they make a more conservative species to monitor. Studies by TVA[3] also indicate that carp and channel catfish accumulate PCBs to higher levels than bass and sunfish.

Radionuclide concentrations are determined on a composite sample of from 6 to 12 fish, whereas mercury and PCB concentrations are determined in individual fish. Scales, head, and entrails are removed from each fish before samples are obtained. A fresh flesh sample is taken for mercury and PCB determinations. Composite flesh samples are ashed and analyzed by gamma spectrometry and radiochemical techniques for the radionuclides that contribute most to the potential radiation dose to humans. Because some radionuclides concentrate in bone (both in fish and human bones) and because they are discharged through the water pathway, bone samples from carp were analyzed for radionuclides.

ORNL-DWG 86-8811R

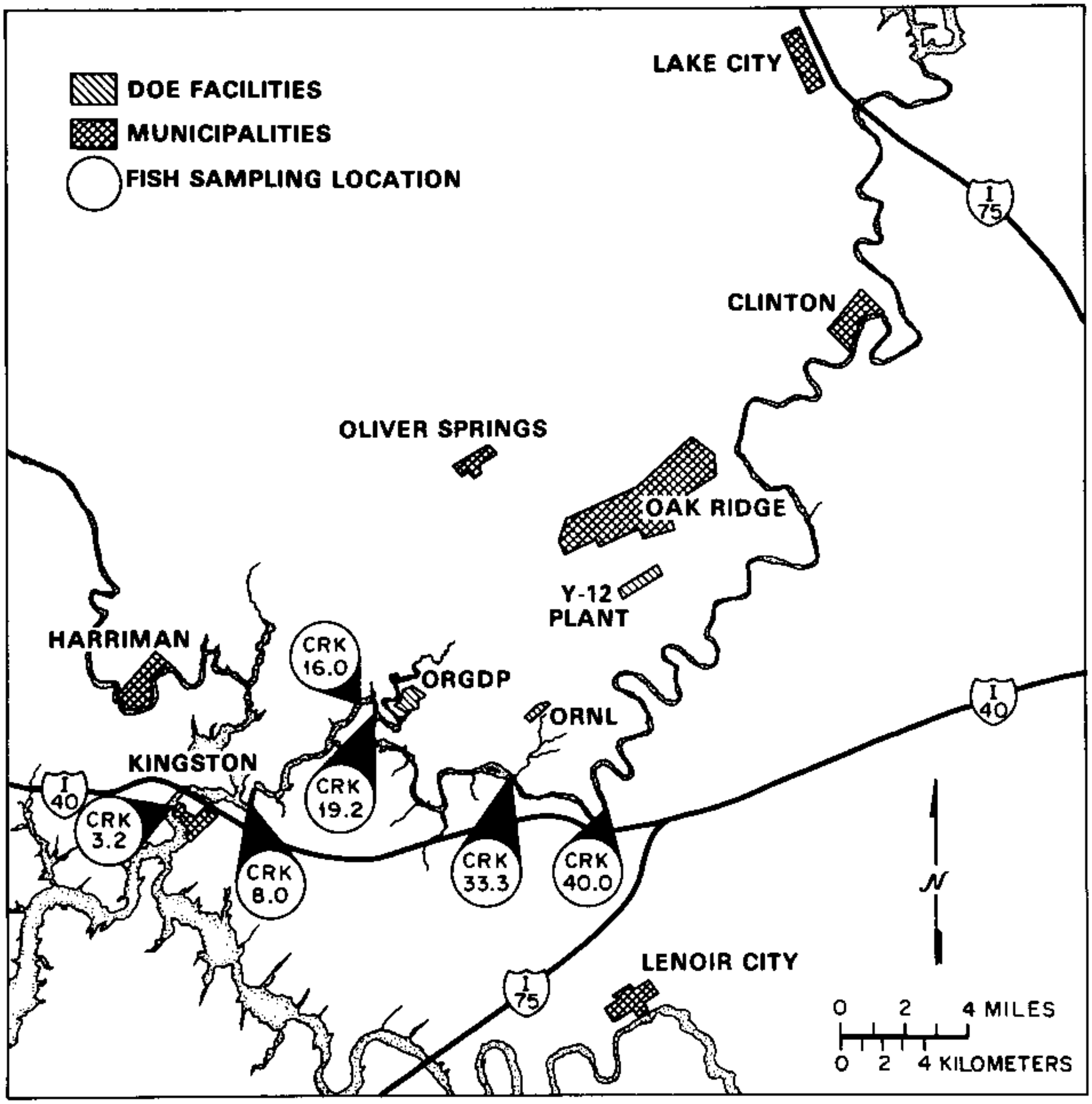

Fig. 4.5.1. Map showing 1985 fish sampling locations.

The concentrations of cesium-137 in bass, bluegill, and carp tissue are given in Fig. 4.5.2. The concentrations in bass ranged from a high of 1200 pCi/kg (CRK 33.3) to a low of 13 pCi/kg (CRK 40.0). Concentrations in bluegill ranged from a high of 640 pCi/kg (CRK 33.3) to a low of 22 pCi/kg (CRK 40.0). The concentrations in carp ranged from a high of 220 pCi/kg (CRK 33.3) to a low of <12 pCi/kg. Discharges of ^{137}Cs from ORNL operations enter the Clinch River via White Oak Creek at CRK 33.3. The concentrations of cobalt-60 in bass, bluegill, and

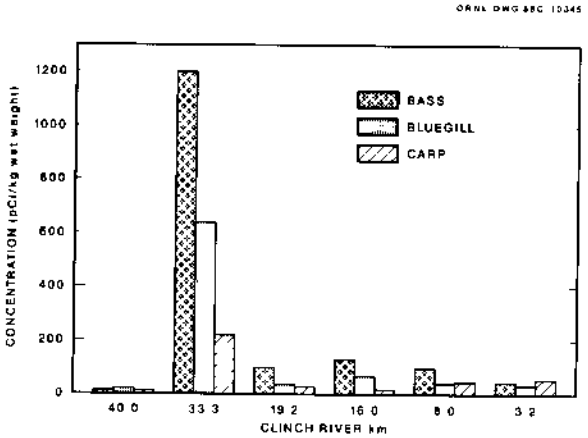

Fig. 4.5.2. Concentrations of cesium-137 in bass, bluegill, and carp tissue, 1985.

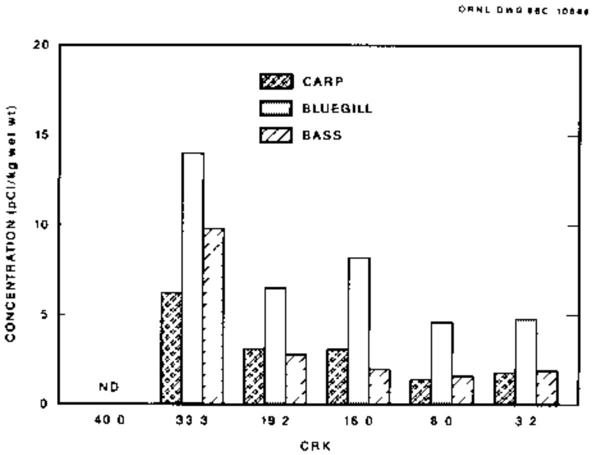

Fig. 4.5.3. Concentrations of cobalt-60 in bass, bluegill, and carp tissue, 1985.

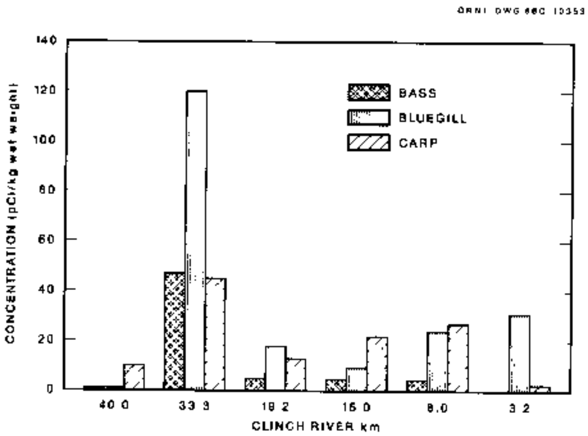

Fig. 4.5.4. Concentrations of strontium-90 in bass, bluegill, and carp tissue, 1985.

carp tissue are given in Fig. 4.5.3. The highest concentration was <9.8 pCi/kg wet wt at CRK 33.3.

The concentrations of strontium-90 in bass, bluegill, and carp tissue are given in Fig. 4.5.4. The concentrations in bass ranged from a high of 47 pCi/kg (CRK 33.3) to a low of 0.31 pCi/kg (CRK 3.2). The concentrations in bluegill ranged from a high of 120 pCi/kg (CRK 33.3) to a low of 1.3 pCi/kg (CRK 40.0). Concentrations in carp ranged from a high of 45 pCi/kg (CRK 33.3) to a low of 2.5 pCi/kg (CRK 3.2). Discharges of ^{90}Sr from ORNL operations enter the Clinch River via White Oak Creek at CRK 33.3.

The plutonium-238 concentrations in bass, bluegill, and carp tissue are given in Fig. 4.5.5. The concentrations in bass ranged from a high of 0.26 pCi/kg (CRK 16.0) to a low of 0.004 pCi/kg (CRK 3.2). The range of concentrations in bluegill was from a high of 0.16 pCi/kg (CRK 8.0) to a low of 0.012 pCi/kg (CRK 33.3). The range of concentrations in carp was from a high of 0.064 pCi/kg (CRK 3.2) to a low of 0.009 pCi/kg (CRK 33.3).

The plutonium-239 concentrations in bass, bluegill, and carp tissue are given in Fig. 4.5.6. The range of concentrations in bass was from a high of 0.089 pCi/kg (CRK 3.2) to a low of 0.005 pCi/kg (CRK 33.3). The concentrations in bluegill ranged from a high of 0.072 pCi/kg (CRK 8.0) to a low of 0.011 pCi/kg (CRK 40.0 and CRK 3.2). Concentrations in carp ranged from a high of 0.069 pCi/kg to a low of 0.002 pCi/kg (CRK 40.0).

The uranium-234 concentrations in bass, bluegill, and carp tissue are given in

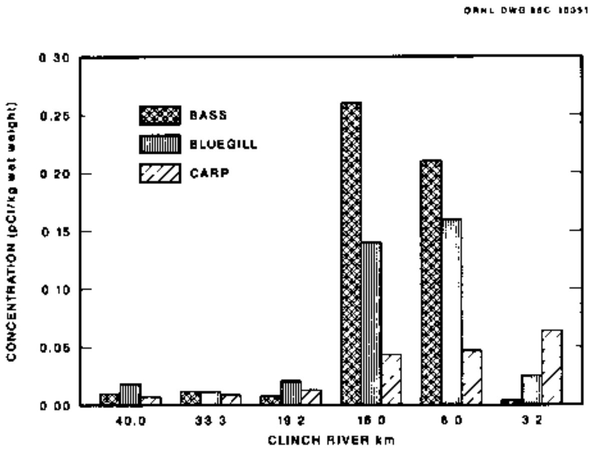

Fig. 4.5.5. Concentrations of plutonium-238 in bass, bluegill, and carp tissue, 1985.

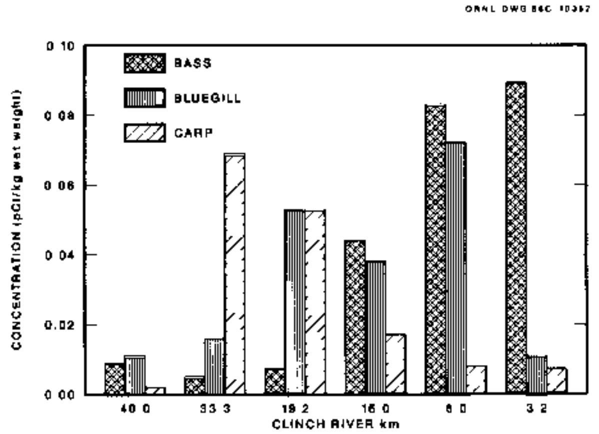

Fig. 4.5.6. Concentrations of plutonium-239 in bass, bluegill, and carp tissue, 1985.

Fig. 4.5.7. The concentrations in bass ranged from a high of 1.2 pCi/kg (CRK 33.3) to a low of 0.61 pCi/kg (CRK 40.0). Concentrations in bluegill ranged from a high of 5.1 pCi/kg (CRK 19.2) to a low of 1.7 pCi/kg (CRK 8.0). The range of concentrations in carp was from a high of 3.2 pCi/kg (CRK 19.2) to a low of 0.88 pCi/kg (CRK 33.3). CRK 19.2 is the discharge of Poplar Creek, which is the major source of ^{234}U.

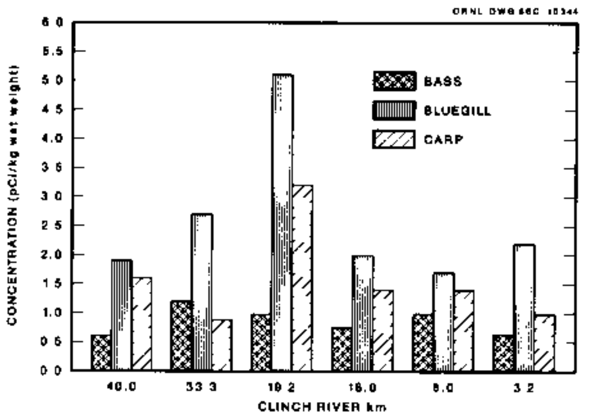

Fig. 4.5.7. Concentrations of uranium-234 in bass, bluegill, and carp tissue, 1985.

The concentrations of uranium-235 in bass, bluegill, and carp tissue are given in Fig. 4.5.8. Concentrations in bass ranged from a high of 0.23 pCi/kg (CRK 33.3) to a low of 0.034 pCi/kg (CRK 40.0). The concentrations in bluegill ranged from a high of 0.49 pCi/kg (CRK 19.2) to a low of 0.12 pCi/kg (CRK 16.0). Concentrations in carp ranged from a high of 0.37 pCi/kg (CRK 40.0) to a low of 0.076 pCi/kg (CRK 3.2).

The concentrations of uranium-238 in bass, bluegill, and carp tissue are given in Fig. 4.5.9. The concentrations in bass ranged from a high of 0.68 pCi/kg (CRK 16.0) to a low of 0.37 pCi/kg (CRK 3.2). Concentrations in bluegill ranged from a high of 2.8 pCi/kg (CRK 19.2) to a low of 0.96 pCi/kg (CRK 40.0). The range of concentrations in carp was from a high of 2.6 pCi/kg (CRK 19.2) to a low of 0.59 pCi/kg (CRK 33.3).

Carp bone concentrations of strontium-90 are given in Fig. 4.5.10. The concentrations ranged from a high of 3500 pCi/kg (CRK 33.3) to a low of 160 pCi/kg (CRK 40.0).

Concentrations of cesium-137 in carp bone are given in Fig. 4.5.11. The range of

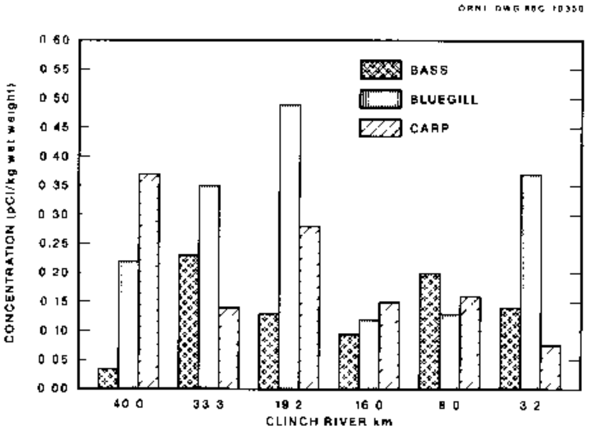

Fig. 4.5.8. Concentrations of uranium-235 in bass, bluegill, and carp tissue, 1985.

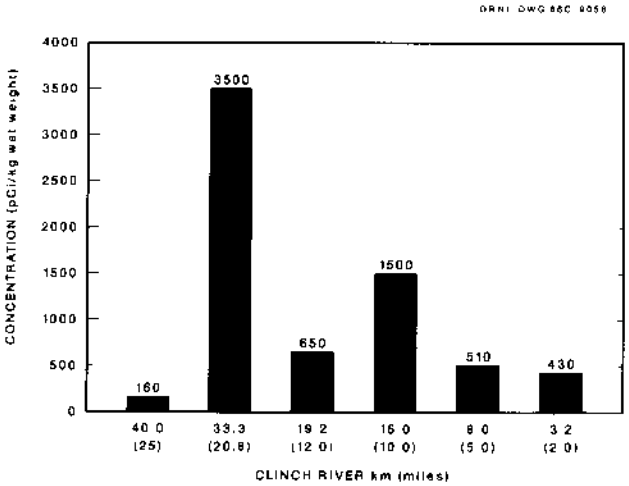

Fig. 4.5.10. Concentrations of strontium-90 in carp bone, 1985.

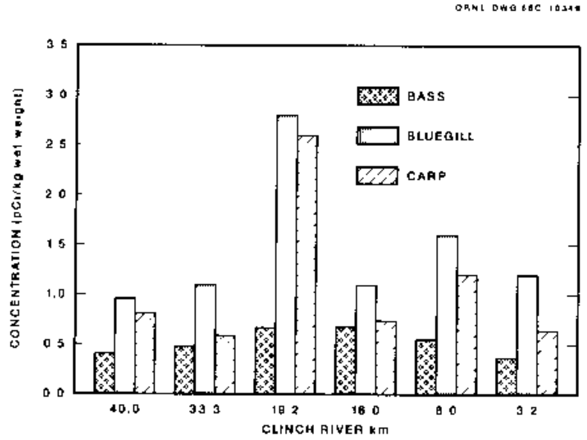

Fig. 4.5.9. Concentrations of uranium-238 in bass, bluegill, and carp tissue, 1985.

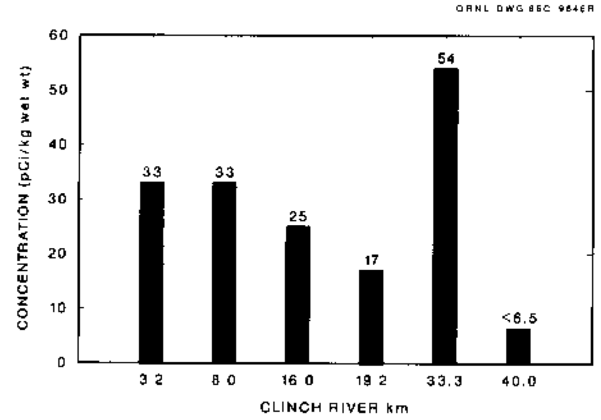

Fig. 4.5.11. Concentrations of cesium-137 in carp bone, 1985.

concentrations was from a high of 54 pCi/kg (CRK 33.3) to a low of <6.5 pCi/kg (CRK 40.0). The plutonium-238 and plutonium-239 concentrations in carp bone are given in Fig. 4.5.12. The plutonium-239 concentrations ranged from a high of 0.33 pCi/kg (CRK 8.0) to a low of 0.01 pCi/kg (CRK 40.0).

Carp bone concentrations of uranium-234, -235, and -238 are given in Fig. 4.5.13. The concentrations ranged from a high of 105 pCi/kg (CRK 19.2) to a low of 7.1 pCi/kg (CRK 40.0). The ^{235}U concentrations in carp bone ranged from a high of 7.9 pCi/kg (CRK 19.2) to a low of 2.3 pCi/kg (CRK 3.2). The ^{238}U concentrations in carp bone ranged from a high of 71 pCi/kg (CRK 19.2) to a low of 6.8 pCi/kg (CRK 40.0). The concentrations of cobalt-60 in carp bone are shown in Fig. 4.5.14. In most cases, ^{60}Co was at or below the minimum level of detection in bass, bluegill, and carp tissue.

The program for monitoring mercury in fish collected from various locations in the Clinch River was revised in 1984. Pre-

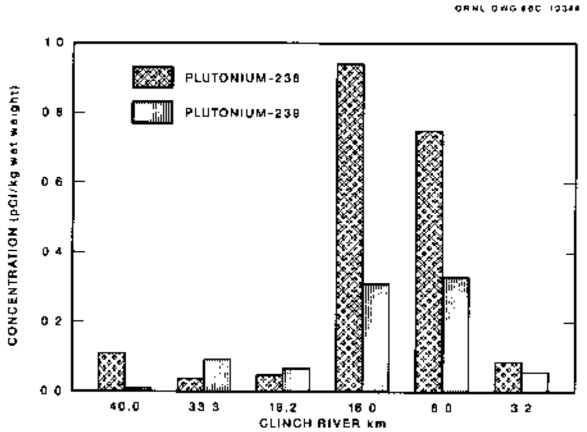

Fig. 4.5.12. Concentrations of plutonium-238 and plutonium-239 in carp bone, 1985.

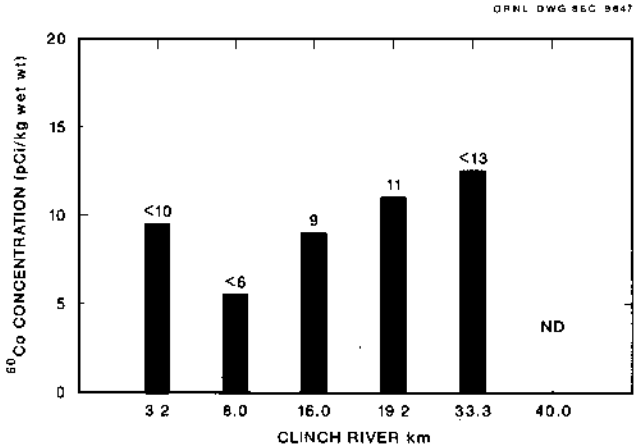

Fig. 4.5.14. Concentrations of cobalt-60 in carp bone, 1985.

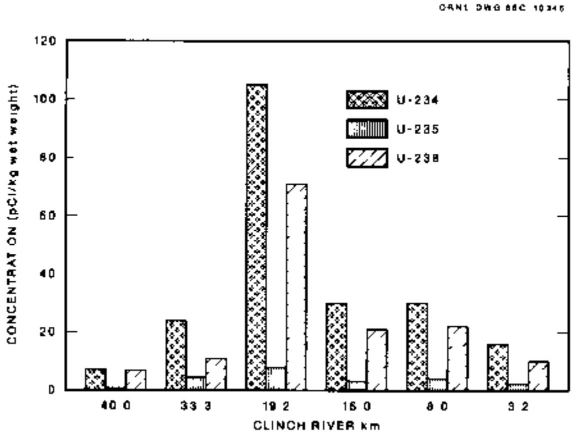

Fig. 4.5.13. Concentrations of uranium-234, uranium-235, and uranium-238 in carp bone, 1985.

viously, mercury had been measured in a composite sample of several individuals. Samples were collected in 1985 from individual fish to determine the variability of this parameter within fish commonly caught from the river. Table 4.5.1 gives a summary of mercury concentrations found in these species. All average values were below the FDA action level (1000 ng/g).[4] The highest values were from the vicinity of CRK 19.2, the approximate point where Poplar Creek enters the Clinch River (Fig. 4.5.1). Average concentrations decreased downstream with increasing distance from CRK 19.2. Table 4.5.2 lists average mercury concentrations in fish for 1981–1985, except for CRK 19.2, which is shown in the figures. Average concentrations of mercury in fish measured by TVA at CRKs 3.2, 9.6, and 17.6 are similar to those reported in Table 4.5.1 for CRKs 3.2, 8.0, 16.0, and 19.2. Mercury concentrations in fish (bass, sunfish, carp) measured by TVA were highest in tissue from East Fork Poplar Creek km 22.0. Average concentrations of total mercury in largemouth bass and redbreast sunfish from this location exceeded the FDA action level, and those in carp were at the action level. Tissue samples from Bear Creek fish did not indicate elevated mercury concentrations.

The concentrations of mercury in bass, bluegill, and carp tissue are given in Fig. 4.5.15. Concentrations in bass ranged from a high of 370 ng/g (CRK 19.2) to a low of 15 ng/g (CRK 40.0). Mercury concentrations in bluegill tissue ranged from a high of 270 ng/g (CRK 19.2 and 16.0) to a low of 23 ng/g (CRK 40.0). The concen-

Table 4.5.1. 1985 mercury concentrations in Clinch River fish

Location[a]	Species	No. of fish sampled	Concentration (ng/g wet wt)				Percentage of action level[c]
			Max	Min	Av	95% CC[b]	
CRK 3.2	Bass	6	130	80	100	19	10
	Bluegill	6	140	30	77	32	7.7
	Carp	6	130	30	72	29	7.2
CRK 8.0	Bass	6	210	130	170	28	17
	Bluegill	6	170	40	98	39	9.8
	Carp	6	370	60	150	99	15
CRK 16.0	Bass	6	360	240	305	44	31
	Bluegill	6	480	140	270	110	27
	Carp	6	630	170	290	140	29
CRK 19.2	Bass	24	1200	150	370	90	37
	Bluegill	24	540	50	270	52	27
	Catfish	3	360	100	250	160	25
	Crappie	12	430	40	150	77	15
	Carp	24	1000	40	400	120	40
	Shad	12	160	10	95	29	9.5
CRK 33.3	Bass	12	180	30	110	28	11
	Bluegill	12	280	50	93	37	9.3
	Carp	12	210	50	110	26	11
CRK 40.0	Bass	6	80	30	45	14	4.5
	Bluegill	6	40	10	23	8.4	2.3
	Carp	6	150	50	92	29	9.2

[a] See Fig. 4.5.1.

[b] 95% confidence coefficient about the average.

[c] Percentage of Food and Drug Administration action level of mercury in fish (1000 ng/g) for the average concentration.

Source: Ref. 4.

trations of mercury in carp tissue ranged from a high of 400 ng/g (CRK 19.2) to a low of 92 ng/g (CRK 40.0). Concentrations of mercury in bass, bluegill, carp, crappie, and shad by year are given in Figs. 4.5.16 and 4.5.17. All mercury concentrations are presented on a wet-weight basis.

During 1985 analyses were made to determine the PCB concentration in individual fish of several species. Summary concentration values are shown in Table 4.5.3. The highest average concentrations of PCBs in Clinch River fish were found in carp (Table 4.5.3). The average concentrations were about the same in all species at CRK 16.0, although the highest was in shad. Concentrations of PCBs were measured by TVA in fish flesh from 146 individuals representing 9 species.[2] Sixteen of these individuals (13 channel catfish and 3 carp) had levels at or above the FDA tolerance. The highest average con-

Table 4.5.2. Mercury concentrations in Clinch River fish 1985

Location[a]	Species[b]	Concentration (ng/g wet wt)				
		1981	1982	1983	1984[c]	1985[c]
CRK 8.0	Bass	133	120	120	140	170
	Bluegill	86	170	240	120	98
	Carp	289	280	340	200	150
	Crappie	401	59		38	
	Shad	73	30	30	20	
CRK 16.0	Bass	237	200	340	180	305
	Bluegill	257	150	170	190	270
	Carp	487	210	280	260	290
	Crappie	131	99	160	130	
	Shad	44	29	50	25	
CRK 33.3[d]	Bass	144	99	135	87	110
	Bluegill	117	160	110	76	93
	Carp	108	240	220	86	110
	Crappie	253[e]	43		25	
	Shad	44	19	35	20	
CRK 40.0	Bass	16	13	100	22	45
	Bluegill	57	34	30	43	23
	Carp	124	97	90	120	92
	Crappie	30			24	
	Shad	12	7	10	8.6	

[a] See Fig. 4.5.1; for data at CRK 19.2 see Figs. 4.5.17 through 4.5.21.

[b] For years 1981 through 1983, ten fish from each species were composited. During 1985, concentrations in individual fish were measured and the average is reported here.

[c] Average of individual fish.

[d] Average of quarterly samples.

[e] Average of three quarterly samples. Crappie were not collected in the second quarter.

centrations were in catfish collected from lower White Oak Creek near km 0.32; the next highest, from East Fork Poplar Creek km 22.1. These data are difficult to compare with those in Table 4.5.3 because only three catfish were collected during 1985 by the Oak Ridge facilities. Average PCB concentrations are shown in Fig. 4.5.18. All other values were below the tolerance level.

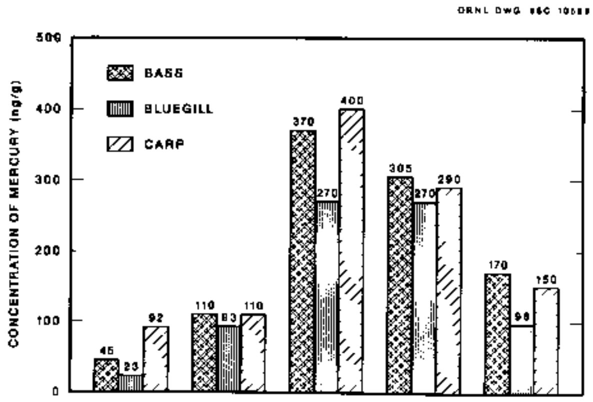

Fig. 4.5.15. Concentrations of mercury in bass, bluegill, and carp tissue, 1985.

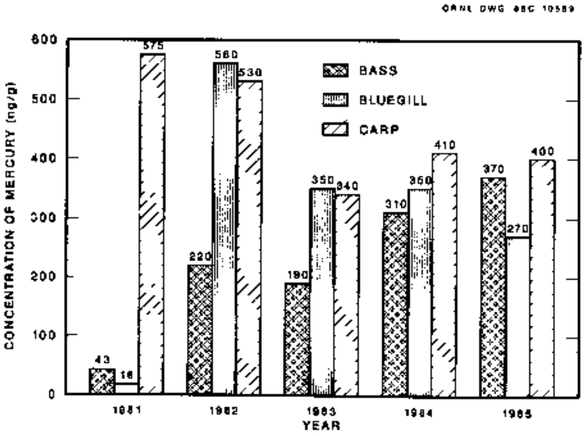

Fig. 4.5.16. Concentrations of mercury in bass, bluegill, and carp tissue, 1981–1985.

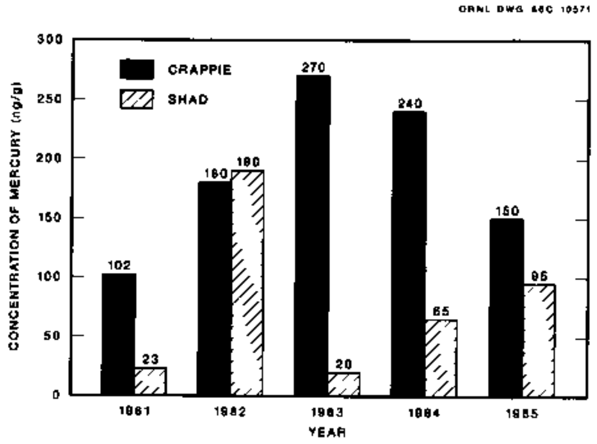

Fig. 4.5.17. Concentrations of mercury in crappie and shad tissue, 1981–1985.

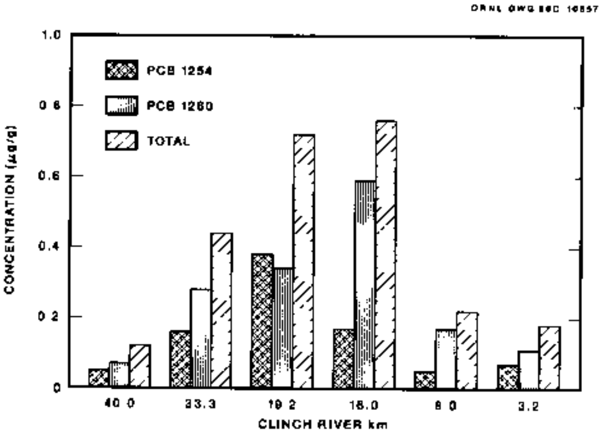

Fig. 4.5.18. Average concentrations of PCB in carp tissue, 1985.

Table 4.5.3. 1985 PCB concentrations in Clinch River Carp

Location[a]	PCB type	No. of fish sampled	Concentration (μg/g wet wt)				Percentage of tolerance[c]
			Max	Min	Av	95% CC[b]	
CRK 3.2	1254	6	0.13	<0.05	<0.07	0.03	<9
	1260	6	0.31	<0.05	<0.11	0.08	
CRK 8.0	1254	6	<0.05	<0.05	<0.05	0.0	<11
	1260	6	0.36	<0.50	<0.17	0.12	
CRK 16.0	1254	6	0.58	<0.05	<0.17	0.18	<38.5
	1260	6	1.1	0.14	0.59		
CRK 19.2	1254	17	1.4	<0.05	<0.38	0.17	<36
	1260	17	1.3	<0.05	<0.34	0.16	
CRK 33.3	1254	6	0.46	<0.05	<0.16	0.13	<22
	1260	6	0.85	<0.10	<0.28	0.24	
CRK 40.0	1254	5	<0.05	<0.05	<0.05	0.0	<6
	1260	5	0.11	<0.05	<0.07	0.02	

[a] See Fig. 4.5.1.

[b] 95% confidence coefficient about the average.

[c] Percentage of Food and Drug Administration tolerance for PCBs in fish (2 μg/g wet wt) for the average concentration. Total PCBs shown in tolerance column.

Source: Ref. 5.

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1. P. Bryan and C. E. White, "An Economic Evaluation of the Commercial Fishing in the TVA Lakes of Alabama during 1956," pp. 128-132 in *Proceedings of the Twelfth Annual Conference of the Southeastern Association of Game and Fish Commissioners*, 1958.

2. *Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, CY 1984*, ORNL-6209, August 1985, Oak Ridge, Tenn.

3. Tennessee Valley Authority, Office of Natural Resource and Economic Development, *Fish Sampling and Analysis Task 4: Instream Contaminant Study*, Chattanooga, Tenn., 1985.

4. U. S. Department of Health, Education, and Walfare, Food and Drug Administration, *Action Level for Mercury in Fish, Shellfish, Crustaceans, and Other Aquatic Animals*, 21 CFR Pt. 109, p. 3990, January 19, 1979.

5. U. S. Food and Drug Administration, *Polychlorinated Biphenyls (PCBs) in Fish and Shellfish; Reduction of Tolerances; Final Decision*, 21 CFR Pt. 109, p. 21514, May 22, 1984.

4.6 BIOLOGICAL MONITORING: DEER

Continued personal property losses and the increasing potential for human injury have prompted a more aggressive DOE aproach to reducing deer-vehicle collisions. Figure 4.6.1 indicates the total number of deer-vehicle collisions by year since 1969. Deer-vehicle collisions were not accurately recorded until 1973. Actions that have been taken and are ongoing to manage the deer population and hopefully decrease the number of deer-vehicle collisions are:

(1) "Deer-crossing" warning signs on all major roads.

(2) Numerous articles in newspapers about deer-vehicle collisions and deer habits.

(3) Trapping and removal of deer by Tennessee Wildlife Resources Agency (TWRA) Staff.

(4) Establishment of the Oak Ridge Wildlife Management Area.

(5) Placement of full-time TWRA officers on the ORR, whose major responsibility is to manage wildlife on the ORR.

(6) Completion of five 2-day public deer hunts in October, November, and December 1985.

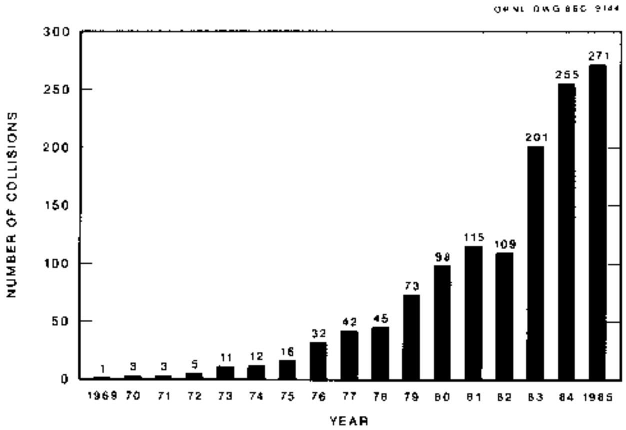

Fig. 4.6.1. Deer-vehicle collisions on the ORR, 1969–1985.

"Deer crossing" warning signs have been placed on major roads to alert drivers to the fact that deer frequently cross the road in locations between these warning signs. These signs are intended to increase driver awareness of the possibility that deer might enter the highway and will only be effective if drivers reduce speed in those areas. Based on speed checks, it is apparent that most drivers have been unwilling to decrease their speed; therefore, this has been an ineffective reduction program.

Articles have been published in newspapers and in Energy Systems employee newsletters in an attempt to inform people of deer habits such as late evening and early morning movement. Once again, this is ineffective unless drivers are willing to reduce their speed. Speed limits in these areas will be under review in 1986.

Trapping and removal of deer by TWRA has been unsuccessful because of the cost-ineffectiveness and difficulty of trapping on terrain such as the ORR. For example, between 1978 and 1983 tens of thousands of trap nights (number of traps multiplied by the number of nights) resulted in less than 200 deer being trapped and removed by TWRA staff.

In 1984 the Oak Ridge Wildlife Management area was established, and in the fall of 1985 a full-time TWRA officer was placed on the ORR. These new actions were necessary to start an effective wildlife management program.

The only successful technique for reducing the deer population to date has been the public hunts. The first public hunts on the ORR occurred during 1985. These hunts required a unique radiological survey because of the possibility of radioactive contamination from the multiple DOE facilities within the managed hunt area. The survey was conducted to ensure that the consumption of meat from the harvested animals would not result in more than a 25-millirem annual dose to the consumer. This requirement resulted in the development of a rapid screening technique to measure the concentration of ^{137}Cs and other gamma-emitting nuclides at levels less than 5 pCi/g.

Hunt areas are shown in Fig. 4.6.2. Hunters harvested 926 deer, of which 55% were bucks, for the season. In general, the bucks were considerably heavier than the does. Fifty percent of the bucks weighed more than 45.5 kg, and 77% of the does weighed between 22.7 and 45.5 kg. Only 6% of the females weighed more than 45.5 kg. There was little difference in the age distributions for the two sexes. Hunter surveys indicated a general satisfaction with the way the hunts were conducted as well as with the radiological survey. The most successful hunt was the one on November 16–17, in which 291 animals were taken.

The requirement that the radiological analyses of deer samples be performed while the hunter waited for a release led to the use of sensitive sodium iodide detectors and a counting period of 5 min. Rapid sample preparation was a concomitant necessity, and it was achieved by the use of a 30- to 40-g liver sample placed in a 5.08-cm (2-in.)-diam vial. The sample preparation was performed by TWRA officers using the liver samples brought in by the hunters. The maximum delay for any one hunter was about 45 min. This condition existed only once or twice during the entire ten days of hunting.

The ^{137}Cs concentrations exceeded 1 pCi/g in only 10 animals, and the maximum ^{137}Cs concentration was 3 pCi/g.

Because ^{90}Sr contamination was known to be a possibility in bone and antlers, checking for that nuclide was accomplished by counting a fresh surface of bone or antler with a sensitive beta detector coupled to a digital scaler. This technique led to the detection of seven contaminated animals from the harvest.

Concentrations of ^{90}Sr in those animals ranged from 35 to 250 pCi/g (fresh weight). Contaminated animals were not released. However, the hunters that killed contaminated deer were allowed to continue their hunt or to return for a subsequent one.

Follow-up analyses using standard radiochemical procedures for ^{90}Sr were conducted on a sample of the bone, liver, and muscle from those confiscated animals. Results of the quantitative measurements of ^{90}Sr in bone and ^{137}Cs in liver are shown in Table 4.6.1.

The confiscated animals were all males with the exception of #17, killed during the first hunt. In addition, the kill locations of five animals were clustered within a 4-mile^2 area to the west of ORNL at a distance of 1 to 3 miles from the western plant boundary. The remaining two animals were killed within a half-mile north of the ORGDP boundary (about 5 miles NNW from the western boundary of the ORNL facility).

Previous studies have shown the presence of both ^{125}I and ^{129}I in the thyroid glands from vehicle-killed as well as harvested deer on the ORR. The availability of material from the 1985 hunts led to a limited study of radioiodine in the herd so as to compare the environmental pool of these isotopes. Results obtained from the

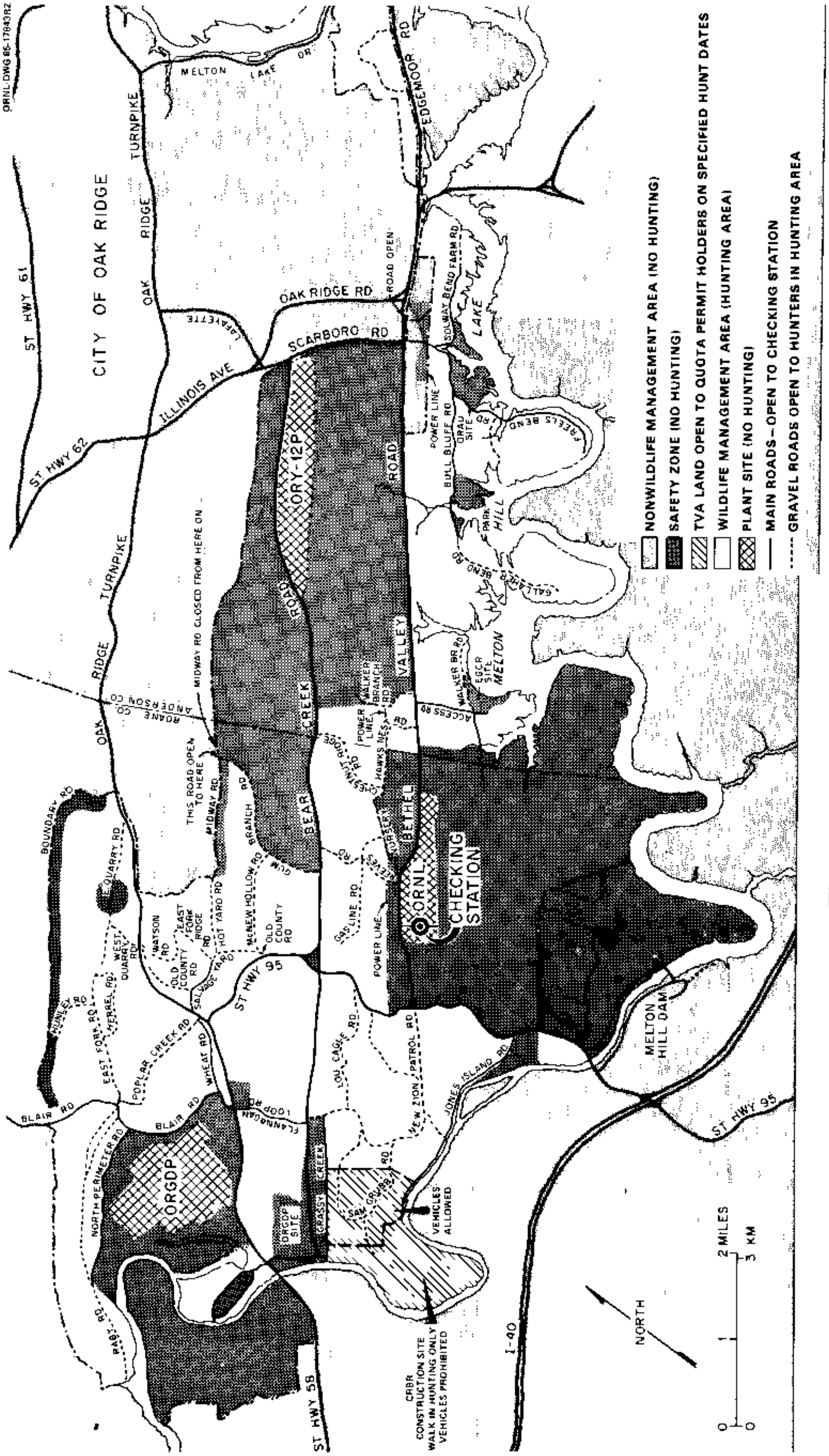

Fig. 4.6.2. 1985 ORR hunt area.

Table 4.6.1. ^{90}Sr and ^{137}Cs results from confiscated deer, 1985

ID[a]	^{90}Sr[b]	^{137}Cs[c]	Sex/Pts[d]	Weight[e]	Age[f]
17 (10/06)	150	3.7	F/0	40	2.5
11 (11/16)	170	0.6	M/7	52	2.5
104 (11/16)	120	0.3	M/5	62	2.5
171 (11/16)	170	0.3	M/3	47	1.5
57 (12/14)	260	0.0	M/9	69	3.5
4 (12/15)	35	0.0	M/3	43	1.5
41 (12/28)	NA[g]	0.0	M/6	38	1.5

[a] ID is deer No. followed by kill date.

[b] ^{90}Sr bone concentration in pCi/g (fresh weight). Note deer were kept based on ^{90}Sr and ^{137}Cs in tissue.

[c] ^{137}Cs liver concentration in pCi/g (fresh weight).

[d] Sex/Pts is the animal's sex and number of points on antlers.

[e] Weight is field dressed weight in kilograms.

[f] Age is given in years.

[g] NA indicates that the sample has not been analyzed.

nondestructive determinations via high-resolution gamma-ray spectrometry are presented in Table 4.6.2. Note that all values are given in units of pCi/g (fresh weight).

Examination of deer thyroids (Table 4.6.2) shows that the maximum ^{129}I concentrations occur in those animals initially confiscated (Table 4.6.1) for excessive ^{90}Sr concentrations. This finding suggests a possible water pathway for the ^{129}I. Previous measurements have shown that ^{125}I is evolved as a gaseous discharge at ORNL.

Iodine-131 was not detected in any of the thyroids in this collection. This was expected since the determinations for the radioiodines were not undertaken for a period of 5 to 8 weeks following the hunts.

It is not possible yet to draw a firm conclusion, but it appears that the hunts have resulted in some reduction in deer-vehicle collisions, as shown in Fig. 4.6.3.

Table 4.6.2. Radioiodine concentrations in thyroids collected during 1985 hunts

ID[a]	^{125}I	^{129}I	Sex/Pts[b]	Age[c]
17 (10/06)[d]	9.0	86	F/0	2.5
11 (11/16)[d]	2.8	4.9	M/7	2.5
104 (11/16)[d]	12.3	19	M/5	2.5
171 (11/16)[d]	6.3	17	M/3	1.5
20 (12/15)	67	1.5	M/0	0.5
44 (12/15)	3.2	<.5	F/0	2.5
47 (12/15)	5.0	<.5	M/0	0.5
64 (12/15)	11.4	<.5	M/0	0.5
41 (12/28)[d]	37	4.0	M/6	1.5
9 (12/29)	9,6	1.8	F/0	0.5
10 (12/29)	26	1.0	M/0	0.5
13 (12/29)	49	3.0	F/0	4.5
21 (12/29)	58	1.7	F/0	2.5
27 (12/29)	8.2	<.5	F/0	2.5
34 (12/29)	5.0	<.5	F/0	0.5

[a] ID is deer no. followed by kill date.

[b] Sex/Pts is the animal's sex and number of points on antlers.

[c] Age is given in years.

[d] These deer were confiscated.

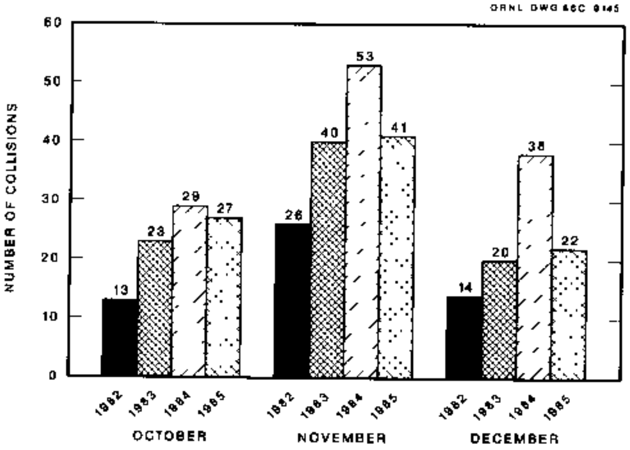

Fig. 4.6.3. Deer-vehicle collisions on the ORR for October, November, and December (1982–1985).

4.7 BIOLOGICAL MONITORING: MILK

Assessment of the dose to humans from environmental radiation sources requires the summation of the contributions of all nuclides that could be released over each identifiable pathway. One of these pathways involves the ingestion of radionuclides following their transfer from the environment to humans via food chains, such as the forage→cow→milk pathway. Milk is potentially a significant pathway for the passage of radionuclides from their point of release to humans because of the relatively large surface area that can be grazed daily by the cow, the rapid transit of milk from producer to consumer, and the importance of milk in the diet, particularly for infants and children.

The impact of this contamination on the pathway depends to a major extent on whether direct contamination of the plant surface is occurring. In the case of relatively short-lived isotopes like ^{131}I, food-chain contamination via the roots is unlikely because radioactive decay would reduce the opportunity for the isotope to pass from soil into the plants.[1] Root uptake is a slow process compared with the immediate contamination of foods that occurs when the plant surfaces become contaminated by direct deposit.[1]

A 3-year study[2] of the ^{131}I and ^{90}Sr content of milk from dairy herds grazing on well-fertilized and poorly fertilized fields found a 50% difference in the level of contamination. The radionuclide content of the milk from cattle pastured in well-fertilized fields was lower, presumably because the faster growing grass diluted the contamination present as foliar deposition.[1]

It has been shown that during the pasteurization process, there is no loss of ^{131}I (Ref. 3) and that 97% of ^{131}I activity of in-vivo labeled milk was present in the serum as inorganic iodide.[4] Any contamination that is present will also be found in any butter or cheese made from this milk.

Raw milk is monitored for ^{131}I and ^{90}Sr by the collection and analysis of samples from 9 locations within a radius of 80 km of Oak Ridge. Samples are collected approximately weekly from five stations located near the Oak Ridge area (Fig. 4.7.1). Four other stations are more remote with respect to the Oak Ridge facilities and are sampled at the rate of one station about every month (Fig. 4.7.2). Samples are analyzed by ion exchange and low-level beta counting, and the results are compared with intake guidelines specified by the Federal Radiation Council (FRC).[5]

All ^{131}I concentrations in milk from both the immediate and remote stations were below the accepted analytical detection limit of 0.011 pCi/mL. According to the FRC, concentrations in this range require adequate surveillance to confirm calculated intakes. This recommended surveillance was performed. Concentrations of ^{90}Sr in milk samples are shown in Table 4.7.1. The average ^{90}Sr concentration for the stations in the immediate Oak Ridge area was 1.4 ± 0.14 pCi/L, which is within Range I of the FRC guideline, and the average for each individual station was within the Range I category. Remote stations averaged 1.1 ± 0.51 pCi/L, and all stations were within the Range I of the FRC guideline. The average concentrations of ^{90}Sr at the immediate and remote locations from 1981 through 1985 are given in Fig. 4.7.3. The range for ^{90}Sr at the immediate location was from a high of 0.0016 pCi/mL to

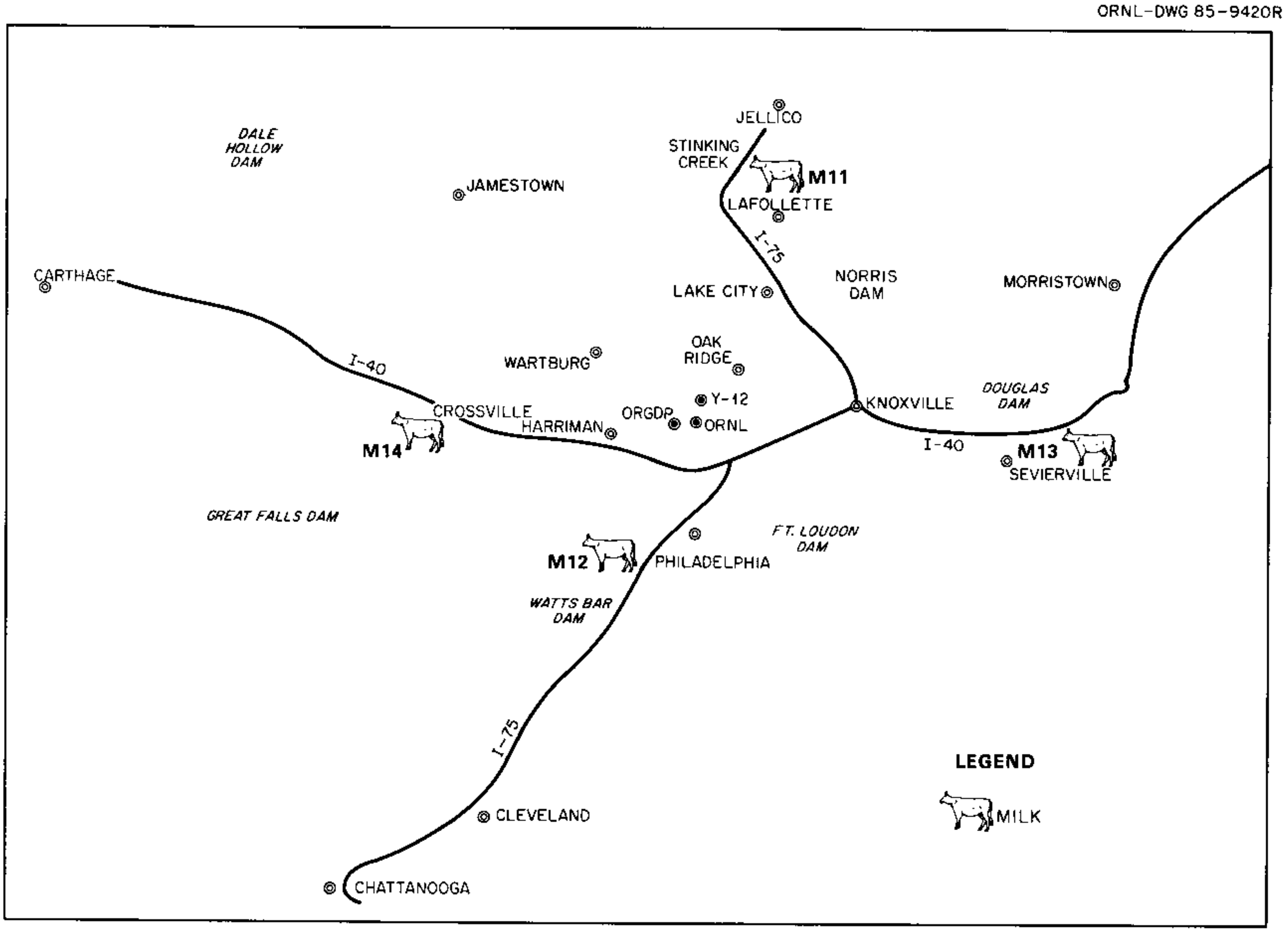

Fig. 4.7.1. Locations of milk sampling stations near the Oak Ridge facilities.

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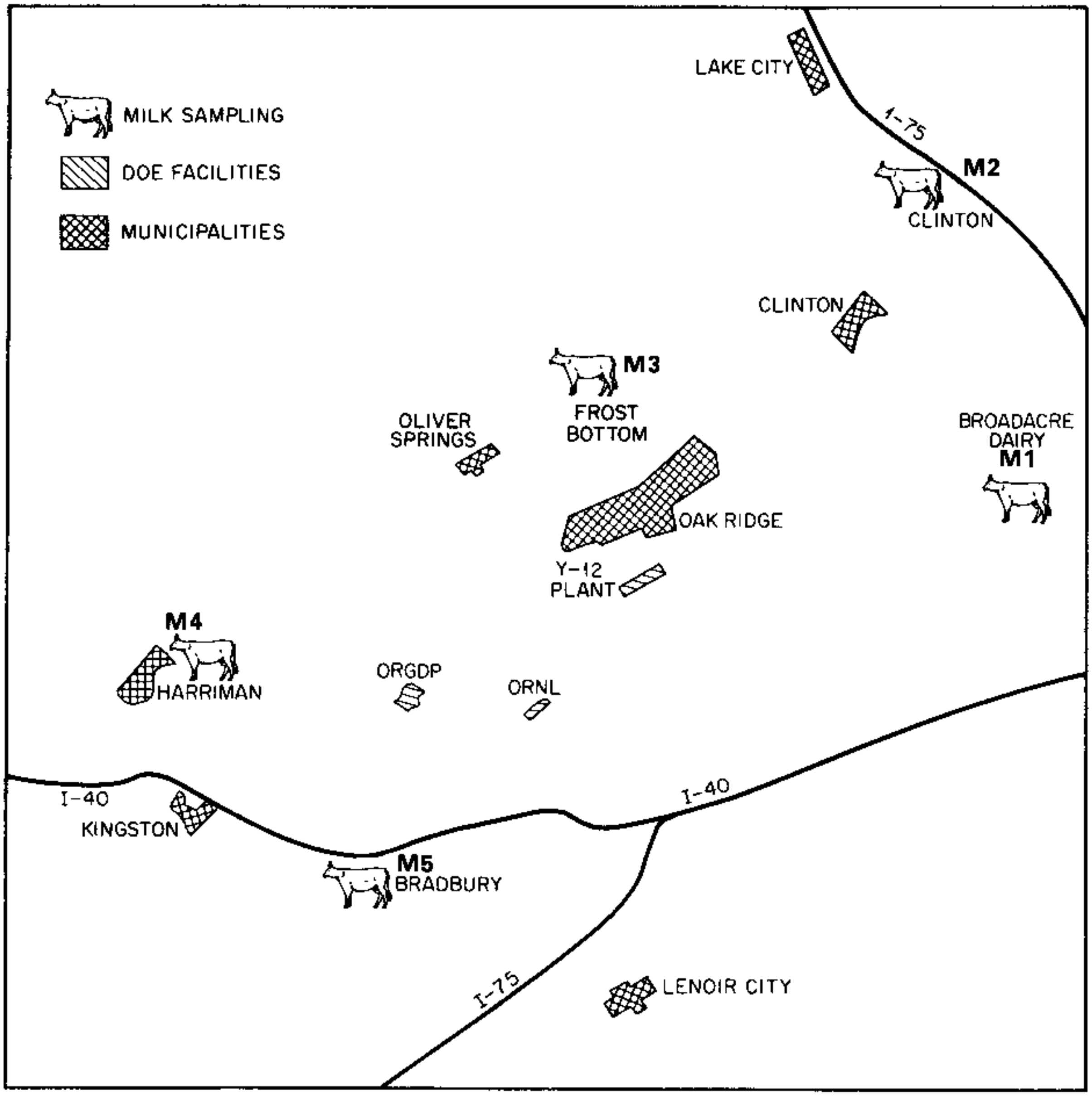

Fig. 4.7.2. Locations of milk sampling stations remote from the Oak Ridge facilities.

Table 4.7.1. 1985 concentrations of ^{90}Sr in milk[a]

Station	No. of samples	Concentration (pCi/L)				Comparison with standard[c]
		Max	Min	Av	95% CC[b]	
		Immediate environs[d]				
M1	39	1.6	0.41	1.1	0.089	Range I
M2	35	2.6	0.27	1.2	0.15	Range I
M3	39	3.0	0.81	1.9	0.19	Range I
M4	34	2.2	1.1	1.5	0.11	Range I
M5	40	2.7	0.81	1.5	0.14	Range I
Average				1.4	0.14	Range I
		Remote environs[e]				
M11	3	2.2	0.81	1.4	0.83	Range I
M12	1	1.6	1.6	1.6		Range I
M13	3	1.1	0.27	0.81	0.54	Range I
M14	4	0.81	0.54	0.68	0.16	Range I
Average				1.1	0.51	Range I

[a] Raw milk samples, except for station M1, which is a dairy.

[b] 95% confidence coefficient about the average.

[c] Applicable FRC standard, assuming 1 L/d intake: Range I, 0 to 0.02 pCi/mL, adequate surveillance required to confirm calculated intakes; Range II, 0.02 to 0.2 pCi/mL, active surveillance required; and Range III, 0.2 to 2 pCi/mL, positive control action required.

[d] See Fig. 4.7.1.

[e] See Fig. 4.7.2.

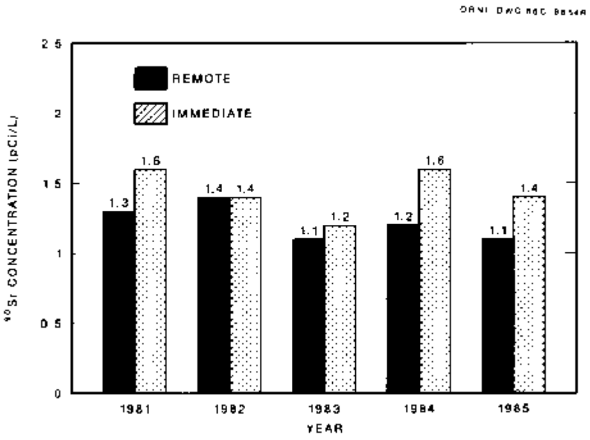

Fig. 4.7.3. Strontium-90 concentrations in milk at immediate and remote environs from 1981 through 1985.

a low of 0.0012 pCi/mL. The ^{131}I concentrations from 1981 through 1985 were all below the detection limit of 0.00045 pCi/mL.

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Powder from Milk Contaminated with ^{131}I and Its Consequences for the Environment," *Health Phys.* 47(4), 644–648 (1984).

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4.8 VEGETATION

Radionuclides and chemical pollutants introduced into the biosphere are affected by the same biogeochemical processes that cycle essential and nonessential elements within and among ecosystems. These processes determine bioaccumulation during transport of radionuclides or chemicals through terrestrial food chains. Concentrations of materials in soil are of great importance to determination of the uptake in plants through the roots (see Sect. 4.9). However, pollutants can bypass the soil and pass directly to the food chain by foliar deposition. The pollutant may then pass directly to grazing animals or humans as superficial contamination or they may be absorbed metabolically from the plant surface. Pollutants absorbed by grazing animals are transferred to the milk and meat of these animals. Foliar contamination can be removed by radioactive decay, volatilization, leaching by rain or other weathering effects, and by dying and dropping of plant parts.

Samples of grass were collected from 13 areas around ORGDP, as shown in Fig. 4.8.1. Pine needles were also collected at 5 of the locations: V2, V3, V4, V5, and V9. All samples were analyzed for uranium and fluoride. Fluorometric analysis is used for the determination of uranium, and a fluoride-selective ion electrode is used for the determination of fluorides. Data for ORGDP uranium and fluoride content in vegetation are presented in Table 4.8.1. The concentrations of fluoride in grass ranged from a high of 8.6 μg/g (V11) to a low of 2.7 μg/g (V4). Concentrations of fluoride in pine needles ranged from a high of 11 μg/g (V9) to a low of 3.6 μg/g (V3). The fluoride concentrations in grass at all sampling points were below the 30-μg/g level considered to produce adverse effects when ingested by cattle with average grazing intakes.[1] Around ORGDP, the highest uranium concentration in grass was at V11 near the contaminated scrap yard (Table 4.8.1). As shown in Figs. 4.8.2 through 4.8.5 a general decrease in both the fluoride and uranium concentrations since 1984 is indicated by the data. However, an increase in the fluoride concentrations may have occurred since 1984 in grass at locations V9 and V13, and in pine needles at V2 and V9. Since 1984, increased uranium concentrations have been observed in both grass and pine needles at V3 and in pine needles at V9.

Grass samples were also collected semiannually from 1-m plots at the ORR locations (Fig. 4.8.6), and annually at the remote locations (Fig. 4.8.7). After initial preparation,[2] the samples were analyzed by gamma spectrometry and radiochemical techniques for a variety of radionuclides, as shown in Table 4.8.2.

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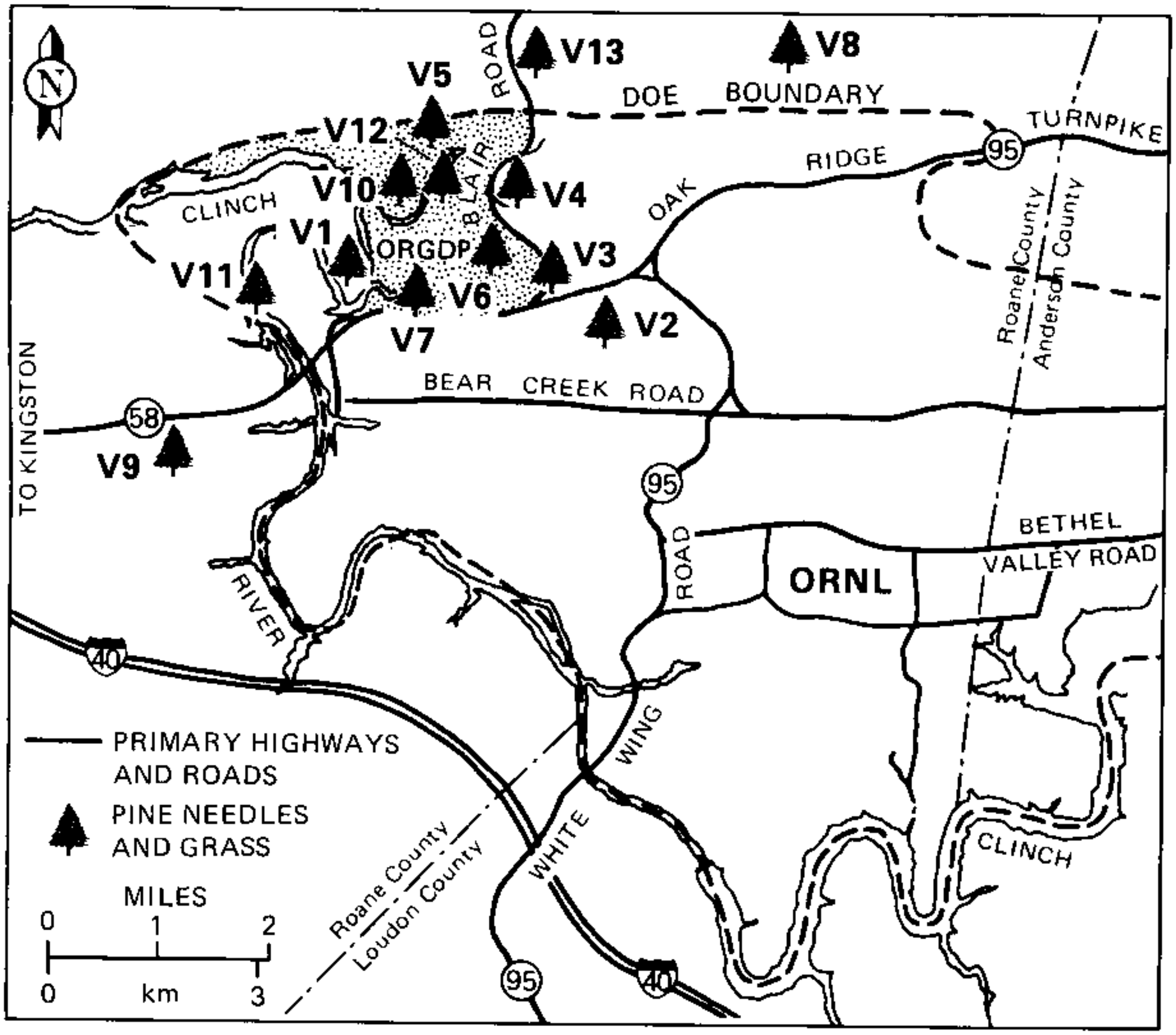

Fig. 4.8.1. Map of pine needle and grass sampling locations.

The strontium-90 concentrations in grass samples from 1981 through 1985 are shown in Fig. 4.8.8.

The cesium-137 concentrations in grass samples from 1981 through 1985 are shown in Fig. 4.8.9. There appears to have been a significant decrease in ^{137}Cs concentrations at both the ORR and remote locations since 1982.

The uranium-234, uranium-235, and uranium-238 concentrations in grass samples from 1981 through 1985 are shown in Figs. 4.8.10, 4.8.11, and 4.8.12, respectively.

The average concentrations of ^{90}Sr, ^{137}Cs, ^{239}Pu, ^{238}Pu, ^{235}U, ^{234}U, and ^{238}U are shown in Table 4.8.3.

In general, concentrations of uranium appear higher at the ORR than at the remote sites.

Table 4.8.1. 1985 vegetation sampling data[a]

Location[b]	F$^-$ concentration[c] (μg/g dry wt)		U (total) concentration[c] (μg/g dry wt)		U (total) concentration[c] (pCi/g dry wt)	
	Grass	Pine needles	Grass	Pine needles	Grass	Pine needles
V1	3.9		0.031		0.024	
V2	4.4	5.5	0.050	0.033	0.038	0.025
V3	3.0	3.6	0.17	0.30	0.131	0.224
V4	2.7	5.2	0.044	0.035	0.033	0.027
V5	3.6	4.1	0.062	0.067	0.047	0.051
V6	5.0		0.088		0.067	
V7	3.4		0.038		0.029	
V8	8.3		0.036		0.027	
V9	8.4	11	0.074	0.16	0.056	0.12
V10	7.0		0.071		0.054	
V11	8.6		2.5		1.9	
V12	3.0		0.40		0.301	
V13	5.9		0.045		0.034	

[a] An ingestion by cattle of 30 μg of fluoride per gram (dry weight) of grass for average grazing intake is considered to produce no adverse effect on the cattle.

[b] See Fig. 4.8.1.

[c] Concentration based on two sample collections.

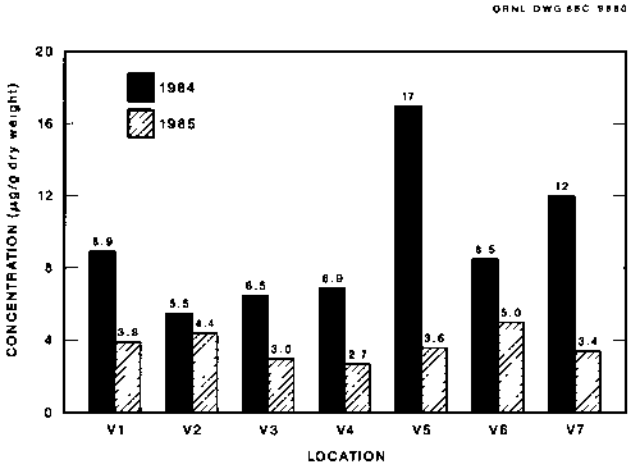

Fig. 4.8.2. Fluoride concentrations in grass at locations V1 through V7.

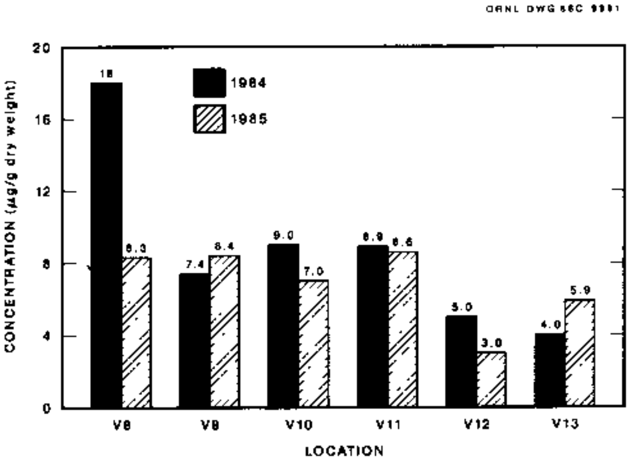

Fig. 4.8.3. Fluoride concentrations in grass at locations V8 through V13.

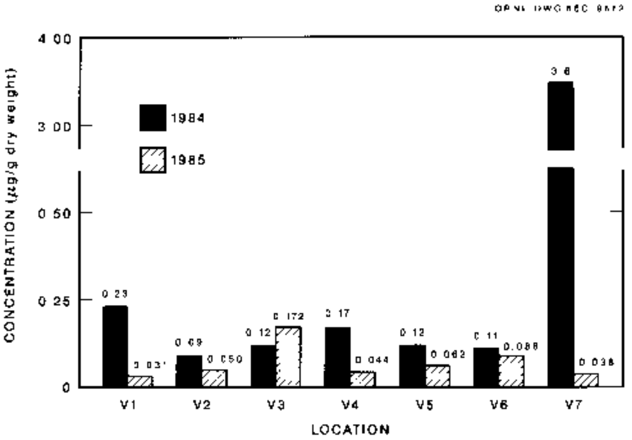

Fig. 4.8.4. Uranium concentrations in grass at locations V1 through V7.

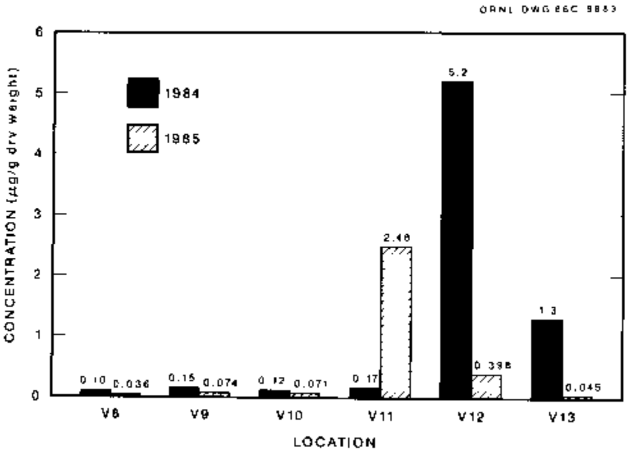

Fig. 4.8.5. Uranium concentrations in grass at locations V8 through V13.

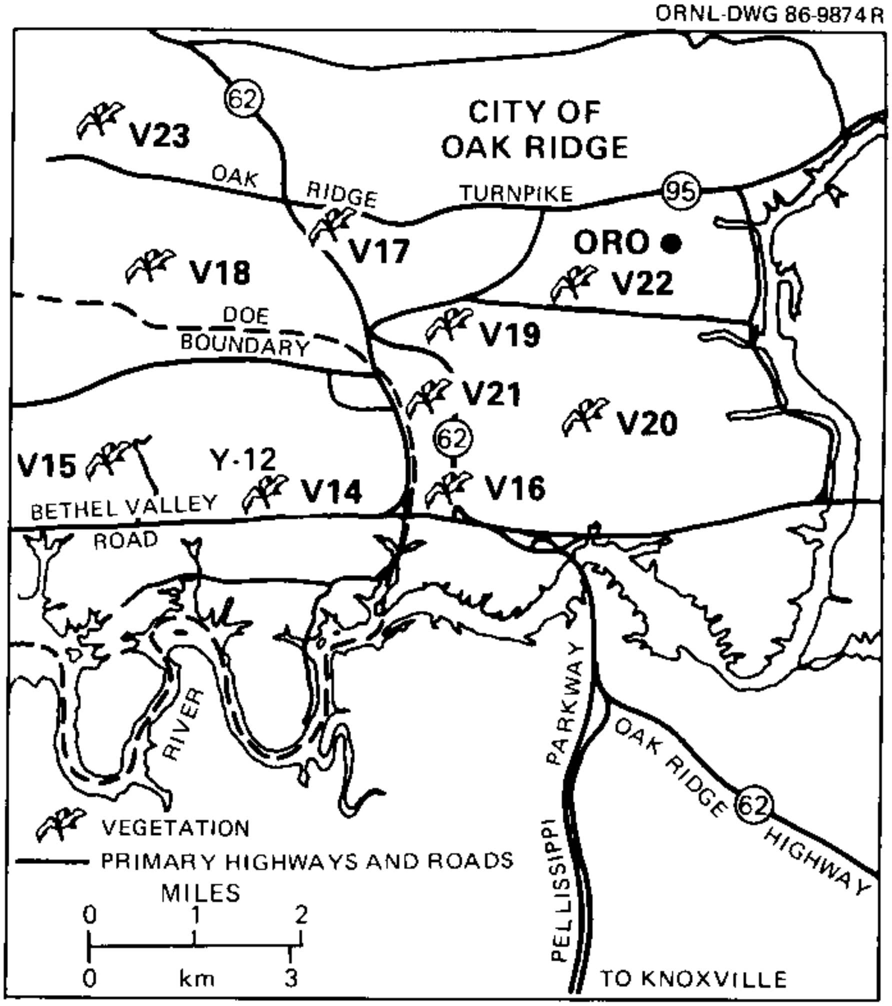

Fig. 4.8.6. Map of ORR grass sampling locations.

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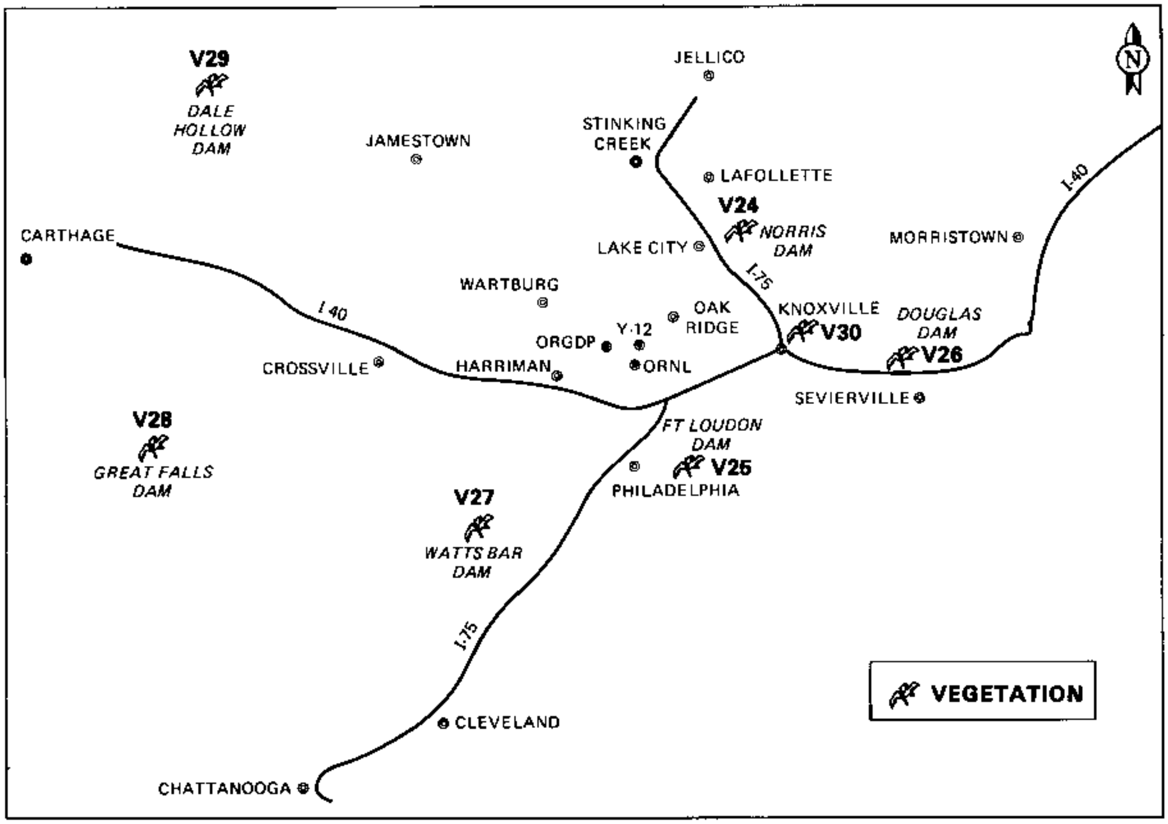

Fig. 4.8.7. Map of remote grass sampling locations.

Table 4.8.2. 1985 radioactivity in grass samples from the ORR and remote monitoring stations

Location	Concentration (pCi/g dry wt)						
	^{90}Sr	^{137}Cs	^{238}Pu	^{239}Pu	^{234}U	^{235}U	^{238}U
			ORR[a,b]				
V14	0.13	<0.019	<0.0012	<0.0005	0.11	0.0078	0.049
V15	0.16	<0.032	0.0013	0.0022	0.032	0.0027	0.015
V16	0.12	<0.022	<0.0019	<0.0006	0.039	0.0043	0.015
V17	0.13	<0.019	<0.0018	0.0009	0.030	0.0025	0.016
V18	0.12	<0.022	<0.0015	0.0005	0.042	0.0034	0.035
V19	0.089	<0.022	<0.0023	<0.0076	0.024	0.0017	0.018
V20	<0.066	<0.022	<0.0008	<0.0010	0.033	0.0019	0.014
V21	0.033	<0.019	0.0002	<0.0004	0.049	0.0023	0.028
V22	0.12	<0.018	<0.0010	0.0003	0.33	0.015	0.043
V23	0.095	<0.031	<0.0005	<0.0009	0.23	0.0085	0.032
Average	<0.093	<0.023	<0.0009	<0.0007	0.092	0.0050	0.027
			Remote[c,d]				
V24	0.076	<0.031	0.0006	0.0006	0.073	0.025	0.018
V25	0.081	0.053	0.0001	0.0003	0.041	0.0019	0.027
V26	0.089	<0.017	0.0001	0.0003	0.023	0.003	0.0076
V27	0.097	0.080	0.0008	0.0014	0.051	0.0022	0.024
V28	0.27	0.034	0.0005	0.0078	0.051	0.0041	0.0086
V29	0.24	0.024	0.0008	0.0057	0.023	0.0021	0.014
V30	0.15	0.028	0.0007	0.0014	0.092	0.007	0.054
Average	0.14	<0.024	0.0005	0.0025	0.051	0.0065	0.022

[a] See Fig. 4.8.6.

[b] Average of two samples.

[c] See Fig. 4.8.7.

[d] One sample.

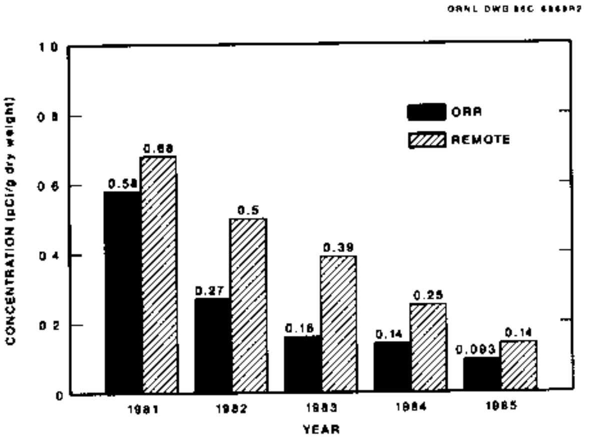

Fig. 4.8.8. Strontium-90 concentrations in grass at ORR and remote locations, 1981–1985.

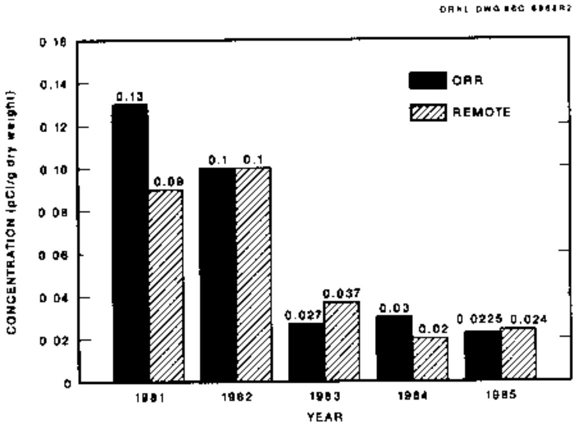

Fig. 4.8.9. Cesium-137 concentrations in grass at ORR and remote locations, 1981–1985.

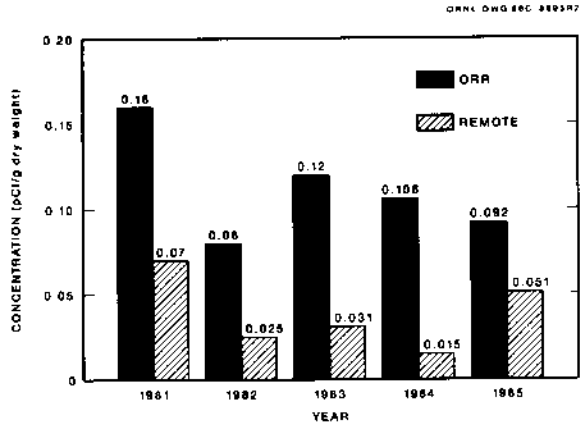

Fig. 4.8.10. Uranium-234 concentrations in grass at ORR and remote locations, 1981–1985.

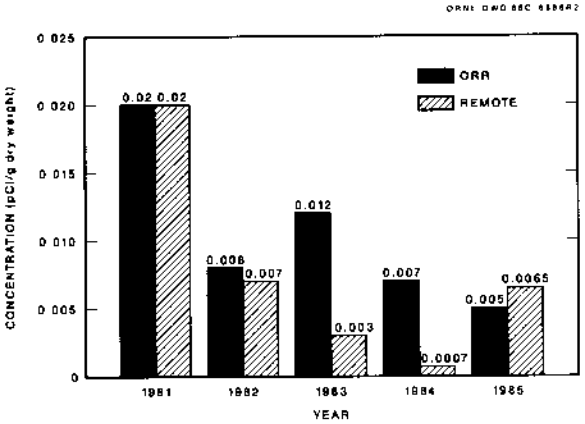

Fig. 4.8.11. Uranium-235 concentrations in grass at ORR and remote locations, 1981–1985.

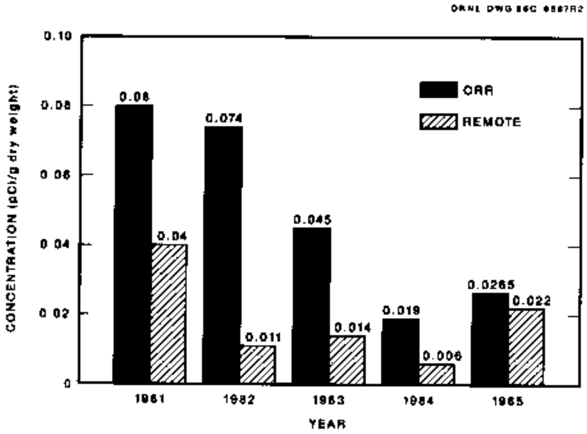

Fig. 4.8.12. Uranium-238 concentrations in grass at ORR and remote locations, 1981–1985.

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Table 4.8.3. Average concentrations of radionuclides in grass samples from ORR and remote monitoring stations[a]

Year/location[a]	Concentrations (pCi/g dry wt)						
	^{90}Sr	^{137}Cs	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu
1981							
ORR stations[b]	0.58	0.13	0.16	0.02	0.08	0.0011	0.0023
Remote stations[c]	0.68	0.09	0.07	0.02	0.04	0.0017	0.0018
1982							
ORR stations	0.27	0.10	0.08	0.008	0.074	0.0007	0.0006
Remote stations	0.50	0.10	0.025	0.007	0.011	0.0007	0.0006
1983							
ORR stations	0.16	0.27	0.12	0.012	0.45	0.0009	0.0011
Remote stations	0.39	0.037	0.031	0.0035	0.014	0.0002	0.0003
1984							
ORR stations	0.14	<0.031	0.11	0.0074	0.019	<0.0013	<0.0041
Remote stations	0.25	<0.019	0.015	<0.0007	0.006	<0.0007	<0.0013
1985							
ORR stations	0.093	0.023	0.092	0.005	0.027	<0.0009	<0.0007
Remote stations	0.14	0.024	0.051	0.0065	0.022	0.0005	0.0025

[a] See Figs. 4.8.6 and 4.8.7.
[b] Average of two samples.
[c] Single samples.

4.9 SOIL

4.9.1 Reservation Soils

The ORR is overlain primarily by residual soils and, to a much lesser extent, by alluvial soils. The alluvium, water-deposited soil, occurs on low terraces and floodplains along streambeds. Residual soils are formed in place by the weathering of their underlying rock. Decomposition of rock occurs as a result of physical weathering and chemical action. The nature of a residual soil depends on the type of source rock, solubility of the source rock components, degree of weathering, climate, vegetation, and drainage. Soils also exhibit different characteristics after being disturbed by excavation and recompaction.

The bedrock that underlies the ORR is part of the Ridge and Valley Province of the eastern overthrust belt. The ridges are made up of dolomite and limestone that have weathered over time to form fine-grained reddish soils with depths of up to 27.5 m (90 ft) and well-developed internal drainage. The valley soils are generally much shallower and are a mix of clays, silts, and weathered shale fragments.

Though some generalizations may be made about the nature of the ORR soils, the characteristics of soils are highly localized, and soil properties vary widely even within a soil series. The ORR's residual soils are generally cohesive, fine-grained clays and silty clays of medium to high plasticity. The in-situ material has a moisture content near or higher than optimum for compaction. It has generally adequate strength, but it is highly compressible and settlement under load is often the limiting soil characteristic. The ORR contains no naturally occurring concentrations of sand or gravel.

4.9.2 Soil and Environmental Pathways

Most of the food consumed by humans is grown on soils that provide elements that complicate terrestrial ecological systems. Radionuclides that occur in soil can be incorporated metabolically into plants and can ultimately find their way into the tissue of animals or they may remain in roots. In addition to root uptake, direct deposition may occur on foliar surfaces, from which contaminants may be absorbed metabolically by the plants or may be transferred directly to animals that consume the contaminated foliage. Foliar deposition is potentially a major source of food-chain contamination by both nonradioactive and radioactive substances.

Soils consist of mineral and organic matter, water, and air arranged in a complicated physicochemical system that provides the mechanical foothold for plants in addition to supplying their nutritive requirements.[1,2] When a radionuclide is added in soluble form, it can adsorb on clays and organic matter, precipitate as an oxide or hydroxide, chelate with organic compounds, or (somewhat unlikely) remain in solution. The manner in which the radionuclide is distributed among these various fractions will determine how long it will remain at the site of deposition and the extent to which it will be available for uptake by plants.[3] Uptake of a radionuclide by plants depends to a considerable degree on whether it remains within reach of the roots of plants and the extent to which it is chemically available. The relative uptake[4] of various radioelements from soils is Sr >> I > Ba > Cs, Ru > Ce > Y, Pm, Zr, Nb > Pu, U.

Guidelines for soil radionuclide concentrations are limited. Where they are available, they are defined as the limiting concentration of a radionuclide in the soil below which specified dose limits will not be exceeded.[5] Source-to-dose conversion factors for individual sites may need to be developed based on site-specific data; however, generic values have been developed.[5] The dose parameter of interest is the dose equivalent to the whole body, tissue, or organ expressed in units of millirem (see Sect. 3).

The environmental pathways by which radioactive materials in soils reach humans form a complex, interconnected network (e.g., soil → foliage → animal → humans). The most direct pathway to humans is the ingestion of soil by a child.

4.9.3 Soil Radionuclide and Fluoride Data on the ORR

The ORR and remote soil samples were collected during the same time period and from the same 1-m plots as were the grass samples (Sect. 4.8). Soil sampling is performed to allow examination of atmospheric deposition of radionuclides. Sampling locations are shown in Figs. 4.9.1 and 4.9.2, respectively. Only the top 2 cm (except at those locations around ORGDP, which are 1 cm) of the soil sample were analyzed for radionuclides. Soil samples were collected at 13 locations semiannually around ORGDP to determine concentrations of uranium and fluoride (Fig. 4.9.3). About 450 g (1 lb) of soil is collected from each location at a maximum depth of 1 cm. Fluorometric analysis is used to determine uranium levels, and a fluoride ion selective electrode is used to determine fluoride levels. Results of these analyses are found in Tables 4.9.1 and 4.9.2. The average concentrations of strontium-90 and cesium-137 in soil from 1981 through 1985 are shown in Figs. 4.9.4 and Fig. 4.9.5, respectively. The average ^{90}Sr concentration at the ORR locations ranged from a high of 0.4 pCi/g dry wt (1981) to a low of 0.17 pCi/g dry wt (1985). There was no statistical difference between 1984 and 1985. The trends since 1981 (the year of a Chinese weapons test) indicate a decrease in the average concentrations of ^{90}Sr at the ORR locations. The two highest ^{90}Sr concentrations on the ORR are at S1 and S9. Both locations are predominantly downwind from ORNL. The average ^{137}Cs concentration at the ORR locations ranged from a high of 1.3 pCi/g dry wt (1981) to a low of 0.7 pCi/g dry wt (1984). The 0.83 pCi/g in 1985 was a 19% increase over the 0.7 pCi/g in 1984. From 1981 through 1985, the concentrations at the remote locations were higher than those at the ORR locations for the same year. The trends since 1981 indicate a decrease in the average concentrations of ^{137}Cs at both the remote and ORR locations.

The concentrations of uranium-234, -235, and -238 in soil from 1981 through 1985 are shown in Figs. 4.9.6, 4.9.7, and 4.9.8, respectively. The average concentrations of ^{234}U at the ORR locations ranged from a high of 1.3 pCi/g dry wt (1985) to a low of 0.48 pCi/g dry wt (1982). The 1.3 pCi/g in 1985 was a 112% increase over the 0.6 pCi/g in 1984. Also, the average concentrations of 1.3 pCi/g at the ORR locations are 168% higher than those at the remote locations. The average concentrations of ^{235}U at the ORR locations (Fig. 4.9.7) ranged from a high of 0.11 pCi/g dry wt (1983) to a low of 0.03 pCi/g dry

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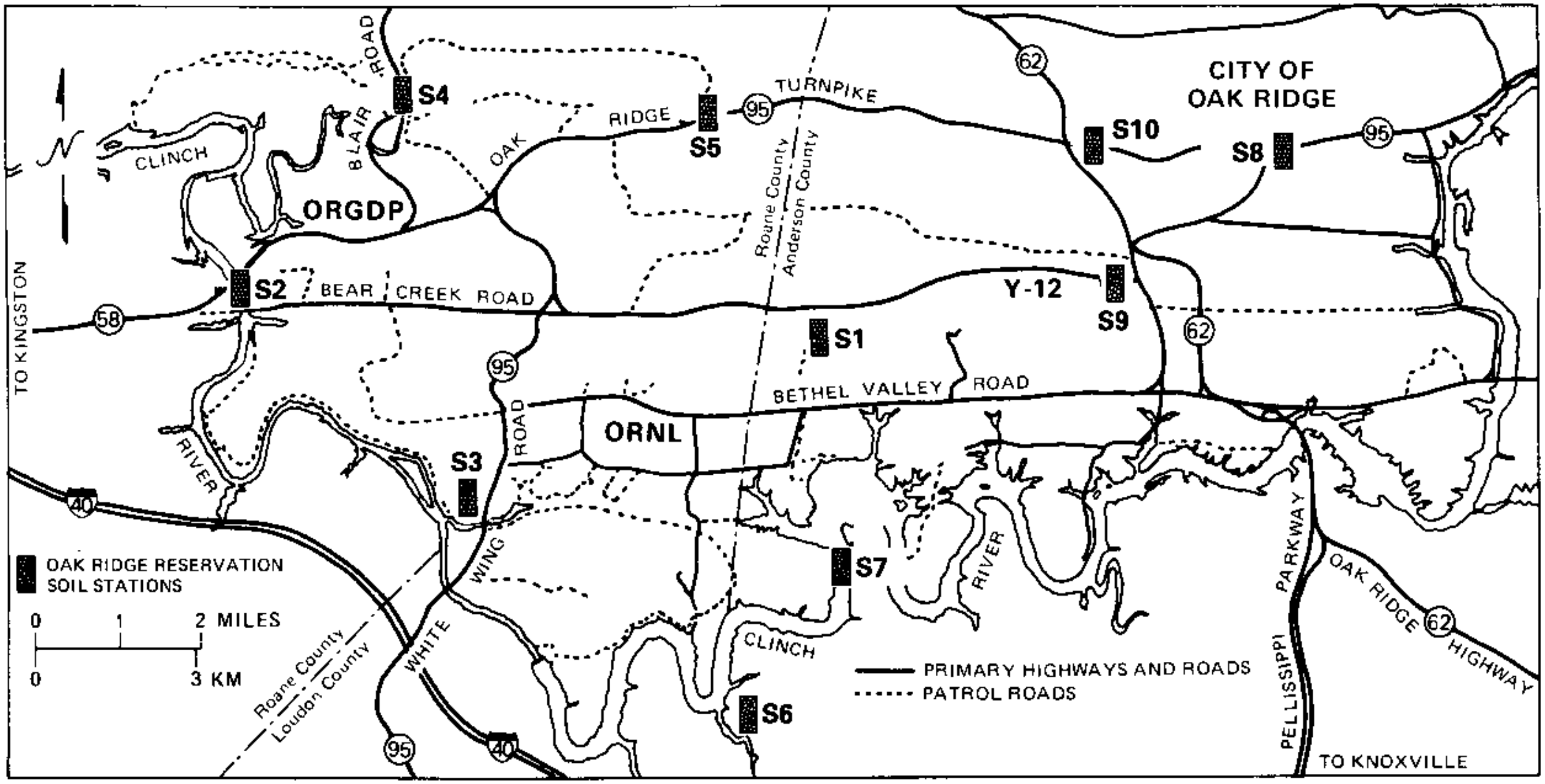

Fig. 4.9.1. Locations of ORR soil sampling areas.

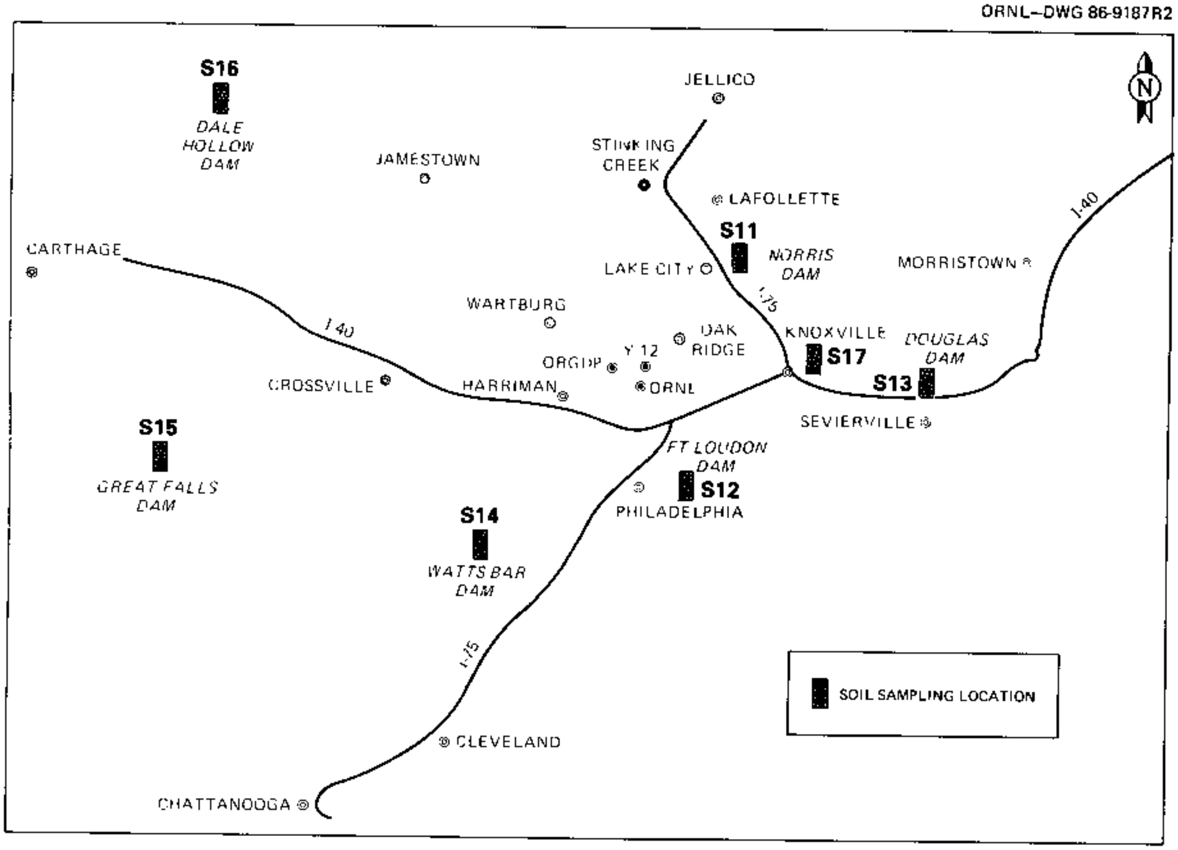

Fig. 4.9.2. Locations of remote soil sampling areas.

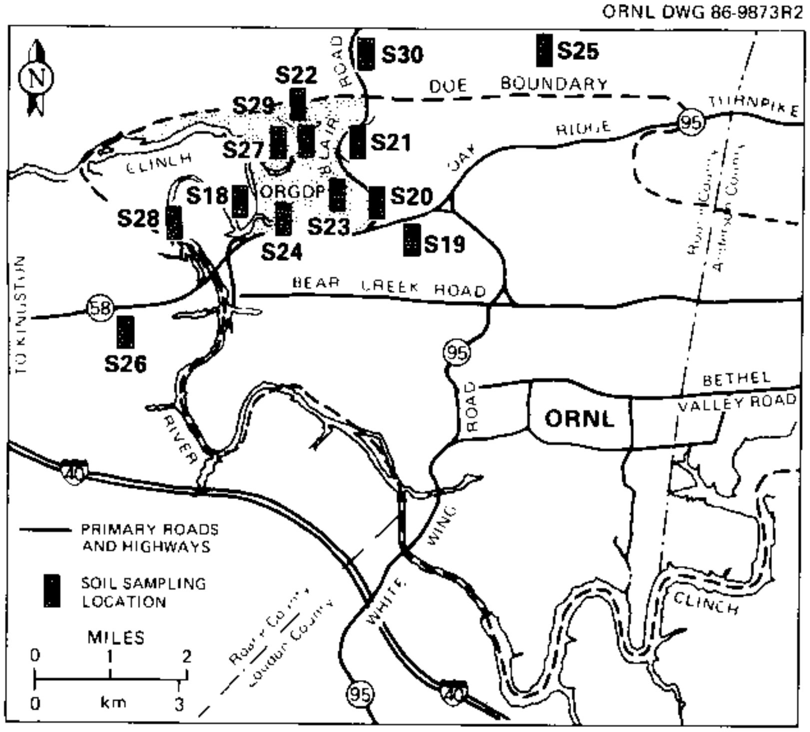

Fig. 4.9.3. Soil sampling locations around ORGDP.

Table 4.9.1. 1985 radioactivity in soil samples from Oak Ridge Reservation and remote monitoring stations

Location	Concentration (pCi/g dry wt)						
	^{90}Sr	^{137}Cs	^{238}Pu	^{239}Pu	^{234}U	^{235}U	^{238}U
			ORR[a,b]				
S1	0.28	0.92	0.00090	0.022	0.81	0.086	1.0
S2	0.10	1.8	0.0016	0.025	0.39	0.035	0.28
S3	0.10	0.080	0.00040	0.0038	0.34	0.022	0.23
S4	0.16	1.5	0.0014	0.019	0.57	0.057	0.43
S5	0.13	0.11	0.00040	0.0041	0.46	0.051	0.34
S6	0.19	1.0	0.0011	0.029	0.39	0.036	0.29
S7	0.24	0.72	0.0011	0.014	0.27	0.021	0.23
S8	0.12	0.82	0.0032	0.013	0.93	0.061	0.58
S9	0.25	1.1	0.0099	0.018	8.0	0.37	2.3
S10	0.070	0.28	0.00040	0.0041	0.54	0.055	0.39
Average	0.17	0.83	0.0020	0.015	1.27	0.080	0.60
			Remote[c,d]				
S11	0.16	0.78	0.00060	0.016	0.41	0.027	0.27
S12	0.092	0.76	0.00060	0.012	0.49	0.043	0.43
S13	0.14	0.97	0.0010	0.021	0.78	0.035	0.62
S14	0.19	1.0	0.0021	0.017	0.38	0.016	0.32
S15	0.12	1.2	0.0015	0.018	0.35	0.023	0.27
S16	0.15	1.5	0.0032	0.020	0.41	0.015	0.32
S17	0.11	1.2	0.0026	0.016	0.51	0.035	0.46
Average	0.14	1.1	0.0017	0.017	0.47	0.028	0.39

[a] See Fig. 4.9.1.

[b] Average of two samples.

[c] See Fig. 4.9.2.

[d] One sample.

wt (1981). The 0.08 pCi/g in 1985 was a 33% increase over the 0.06 pCi/g in 1984. Also, the average concentrations of 0.08 pCi/g at the ORR locations are 188% higher than those at the remote locations. The increase in ^{238}U at the remote locations from 1982 to 1983 (Fig. 4.9.8) is thought to be a result of global atmospheric deposition. The average concentrations at the ORR locations ranged from a high of 0.60 pCi/g dry wt (1985) to a low of 0.33 pCi/g dry wt (1980). The 0.60 pCi/g in 1985 was an 82% increase over 0.33 pCi/g in 1984. Also, the average concentrations of 0.60 pCi/g at the ORR locations were 54% higher than those of the remote locations.

pCi/g in 1985 was an 82% increase over 0.33 pCi/g in 1984. Also, the average concentrations of 0.60 pCi/g at the ORR locations were 54% higher than those of the remote locations.

Table 4.9.2. 1985 soil sampling data around ORGDP[a]

Location[b]	F concentration[c] (μg/g dry wt)	U (total) concentration (μg/g dry wt)	U (total) concentration (pCi/g dry wt)
S18	280	2.0	1.5
S19	440	2.5	1.9
S20	150	2.5	1.9
S21	200	1.8	1.4
S22	320	2.3	1.8
S23	74	2.0	1.5
S24	190	2.6	2.0
S25	100	1.4	1.1
S26	230	2.4	1.8
S27	200	2.9	2.2
S28	190	39	29
S29	340	7.9	6.0
S30	160	4.9	3.7

[a] Upper 1 cm of soil column.

[b] See Fig. 4.9.3.

[c] Average concentration based on semiannual collections in May and August.

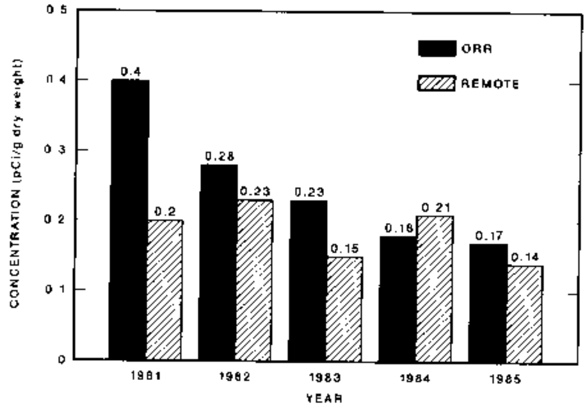

Fig. 4.9.4. Strontium-90 concentrations in soil, 1981–1985.

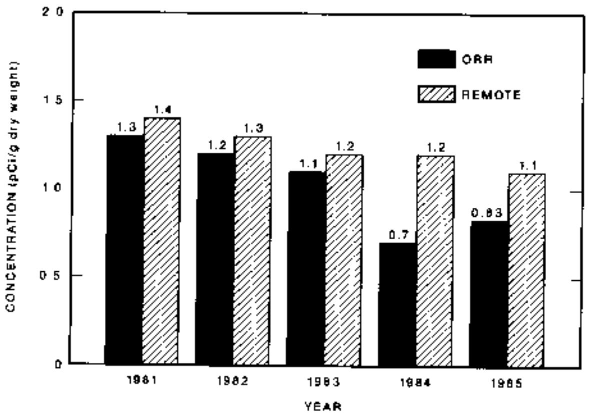

Fig. 4.9.5. Cesium-137 concentrations in soil, 1981–1985.

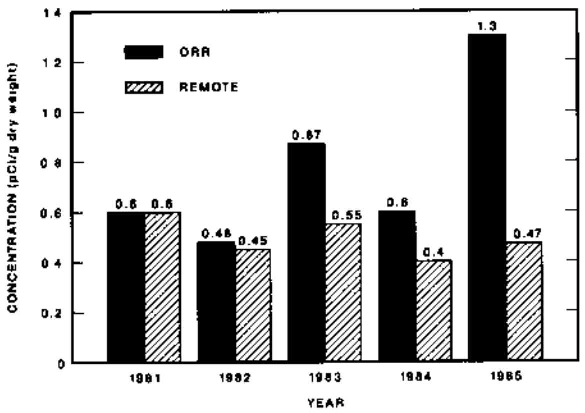

Fig. 4.9.6. Uranium-234 concentrations in soil, 1981–1985.

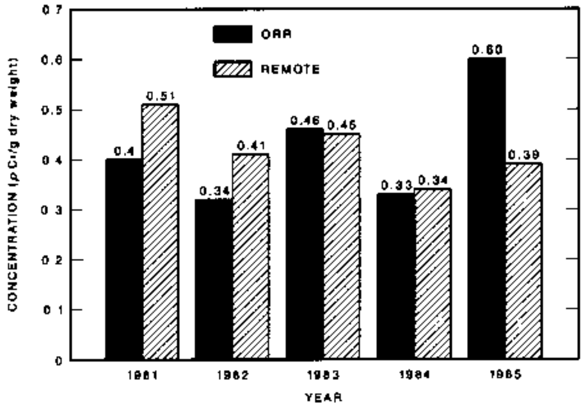

Fig. 4.9.8. Uranium-238 concentrations in soil, 1981–1985.

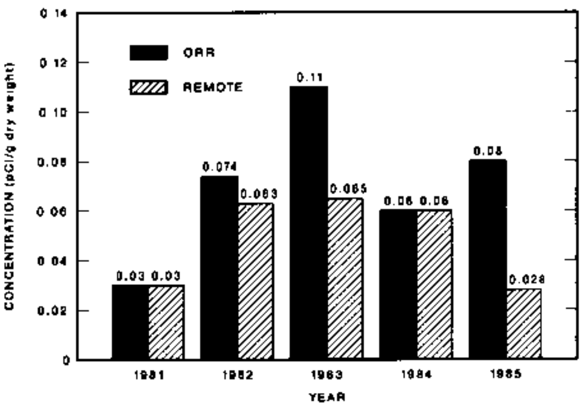

Fig. 4.9.7. Uranium-235 concentrations in soil, 1981–1985.

All uranium concentrations at the ORR show a significant increase in 1985 over 1984. The ^{234}U, ^{235}U, and ^{238}U concentrations are higher in soil near the Y-12 Plant than at other parts of ORR (Station S9, Table 4.9.1, and Fig. 4.9.1). These higher concentrations near Y-12 account for the overall average of the ORR being higher than in 1984. Uranium concentrations may be enriched at the ORR stations. The concentrations of radionuclides in soil are given in Table 4.9.1. The concentrations of radionuclides in soil from 1981 through 1985 are given in Table 4.9.3.

The fluoride and uranium concentrations in soil around ORGDP have decreased since 1984 except for S19 for fluoride and S28 for uranium. The fluoride concentrations ranged from a high of 440 μg/g dry wt (S19) to a low of 74 μg/g dry wt (S23). Concentrations at each location are shown in Figs. 4.9.9 and 4.9.10. Background levels of water-soluble fluoride in soil are 1-2 μg/g. The uranium concentrations in soil ranged from a high of 29 pCi/g dry wt (S28) to a low of 1.1 pCi/g dry wt (S25). Concentrations at each location are shown in Figs. 4.9.11 and 4.9.12. The average background uranium concentration in soil, as measured at remote stations, was about 0.9 pCi/g dry wt. High uranium concentrations at S28 (Table 4.9.2) may have resulted from the cleanup of the contaminated scrap yard rather than from atmospheric releases from ORGDP.

Table 4.9.3. Concentration of radionuclides in soil samples from ORR and remote stations

Year/ location	Concentration (pCi/g dry wt) ^{90}Sr	 ^{137}Cs	 ^{234}U	 ^{235}U	 ^{238}U	 ^{238}Pu	 ^{239}Pu
1981							
ORR stations[a,b]	0.040	1.3	0.60	0.030	0.40	0.0040	0.040
Remote stations[c,d]	1.4	0.60	0.030	0.50	0.004	0.080	ND[e]
1982							
ORR stations	0.28	1.2	0.48	0.074	0.34	0.00080	0.023
Remote stations	0.23	1.3	0.45	0.063	0.410	0.0015	0.021
1983							
ORR stations	0.23	1.1	0.87	0.11	0.46	0.00090	0.014
Remote stations	0.15	1.7	0.55	0.065	0.45	0.0013	0.016
1984							
ORR stations	0.18	0.70	0.62	0.060	0.33	<0.0010	<0.009
Remote stations	0.2	1.2	0.40	0.058	0.34	<0.0020	<0.011
1985							
ORR stations	0.17	0.83	1.3	0.080	0.60	0.0020	0.015
Remote stations	0.14	1.1	0.47	0.028	0.39	0.0017	0.017

[a] See Fig. 4.9.1.

[b] Average of two samples.

[c] See Fig. 4.9.2.

[d] Single sample.

[e] Not detected.

ORNL DWG 86C 9876

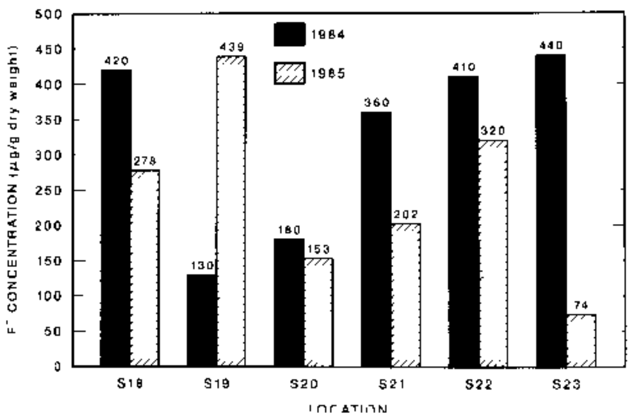

Fig. 4.9.9. Fluoride concentrations in soil (S18 through S23).

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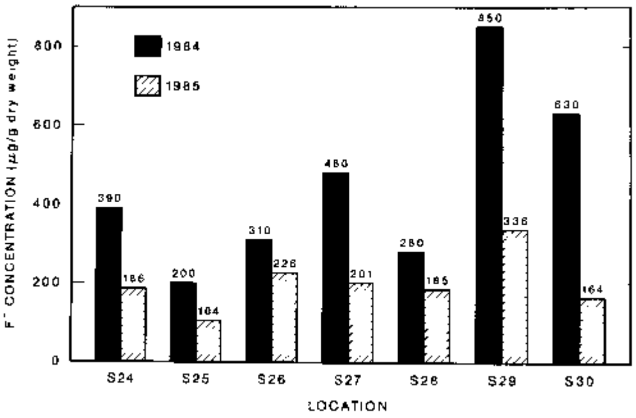

Fig. 4.9.10. Fluoride concentrations in soil (S24 through S30).

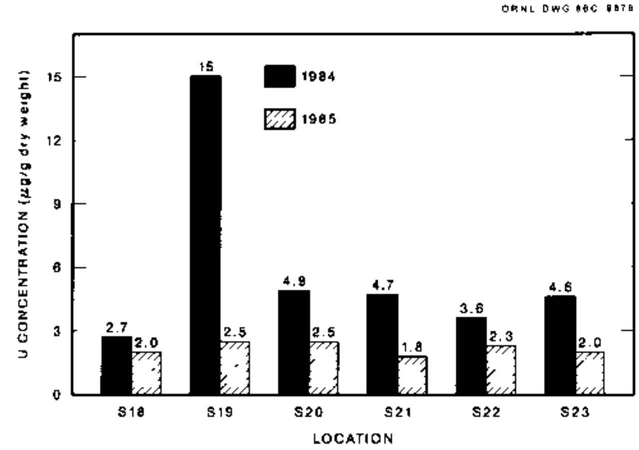

Fig. 4.9.11. Uranium concentrations in soil (S18 through S23).

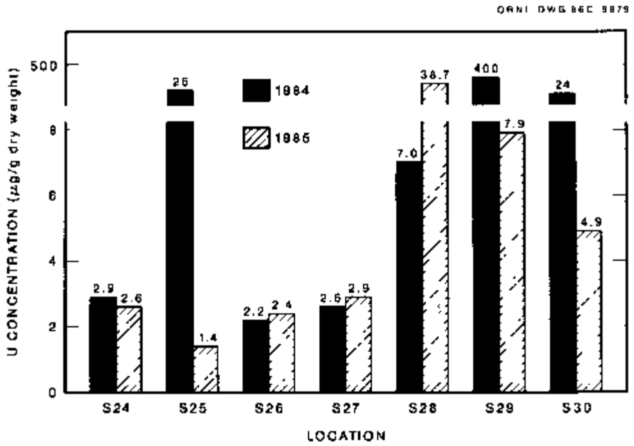

Fig. 4.9.12. Uranium concentrations in soil (S24 through S30).

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4.10 SEDIMENT

In the aquatic environment the mixing problem is difficult to model because the diffusion, physical, and biological processes are not well understood. If a pollutant is a suspended solid, it can settle to the bottom (hence the need for sediment sampling), be filtered by certain organisms, or become attached to plant surfaces. Pollutants in solution can adsorb on suspended organic and inorganic solids or be assimilated by the plants and animals. The suspended solids, dead biota, or excreta settle to the bottom and become part of the organic substrate that supports the bottom-dwelling community of organisms.[1] Possible routes[2] of trace metals (including uranium) in an aquatic ecosystem are shown in Fig. 4.10.1. The basic components[3] of the aquatic ecosystem are shown in Fig. 4.10.2.

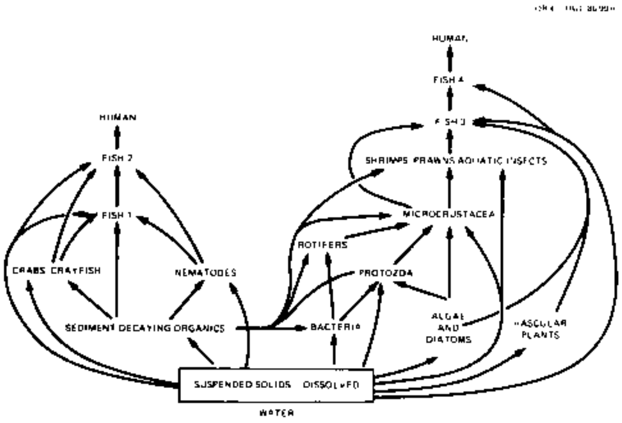

Fig. 4.10.1. Routes of trace metals in an aquatic ecosystem. Source: Ref. 2.

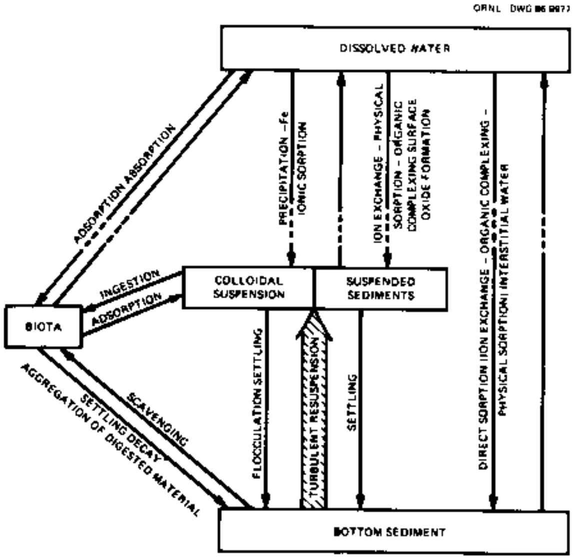

Fig. 4.10.2. Basic components of the aquatic ecosystem. Source: Refs. 3 and 4.

Sediments play a dominant role in aquatic ecology by serving as a repository for radioactive or chemical substances that pass by way of the bottom-feeding biota to the higher trophic levels.[4] Soluble pollutants introduced into a body of water reach the bottom sediment primarily by adsorption on suspended solids that later deposit on the bottom. The deposited remains of biota that have absorbed pollutants may also be an important source of radioactive and chemical pollutants that enter the food chain. In sediment studies of the Clinch River, the amounts of radioactivity contained by the suspended solids were found to be variable,[5,6] which is not surprising considering that the load of solids and particle size varies from place to place in the river and varies with time. The main mechanism of removal of dissolved matter is ion exchange on sediment surfaces; particulates with good ion exchange properties, such as most clay minerals, act as efficient scavengers and may serve to purify the water of the more readily adsorbed ions.[4] These ion exchange properties apply to ^{90}Sr and a few other contaminants. For most other contaminants, other processes are involved.

A sediment sampling program was initiated near ORGDP in 1975 to determine the concentrations of various metals in the sediment of Poplar Creek and the Clinch River. The current sampling program consists of eight sampling locations, shown in Fig. 4.10.3. All of these sediment sampling areas can be affected by effluents from the three major ORR plants because of the complex hydrology associated with hydroelectric operations at Melton Hill Dam and Watts Bar Dam. Samples were collected semiannually and analyzed by atomic absorption, inductively coupled plasma, and other methods.

The concentrations of metals in the stream sediment samples (Table 4.10.1) generally exceeded background levels of metals in remote streams, as shown in Table 7.3.2. An examination of the data shows SS7 and SS8 to have the lowest metal concentrations of the sampling stations (except for Cr at SS7). Location SS5 had the highest concentrations of lead and copper. For most of the metals, the highest concentrations occurred at stations in the creek close to ORGDP: SS2, SS3, and SS6. Metal concentrations in sediments at all stations in 1985 were lower than they were in 1984. The reason for the reduction in results is unknown; many factors may influence sediment metal concentrations, including particle size distribution, content of organic matter, and inputs from industrial and other sources. Particle size distribution and organic matter content of sediment in rivers and creeks can vary greatly from time to time and from place to place. Thus, temporal and spatial trends must be regarded cautiously unless particle size and organic matter are homogeneous among all samples being compared.

The concentrations of mercury, lead, nickel, and uranium for 1983, 1984, and 1985 are compared in this section because of the importance of pollutants to environmental impact.

The concentrations of mercury in Poplar Creek and Clinch River sediment are shown in Fig. 4.10.4. The 1985 concentrations ranged from a high of 19 μg/g (SS2) to a low of <1 μg/g (SS7 and SS8).

Figure 4.10.5 shows the concentrations of lead in Poplar Creek and Clinch River sediment. The range in 1985 was from a high of 34 μg/g (SS5) to a low of 14 μg/g (SS8).

The concentrations of chromium for 1984 and 1985 in Poplar Creek and Clinch River sediment are shown in Fig. 4.10.6. The concentrations ranged from a high of 93 μg/g (SS2) to a low of 14 μg/g (SS8). The concentrations of nickel in Poplar Creek and Clinch River sediment are shown in Fig. 4.10.7. The 1985 concentrations ranged from a high of 114 μg/g (SS2 and SS3) to a low of 14 μg/g (SS8). The concentrations of uranium in Poplar Creek and Clinch River sediment are shown in Fig. 4.10.8. The concentrations ranged from a high of 27 μg/g (SS3) to a low of 1 μg/g (SS7). The concentrations of aluminum in Poplar Creek and Clinch River sediment are shown in Fig. 4.10.9. The concentrations ranged from a high of 38,000 μg/g dry wt at SS6 to a low of 13,000 μg/g dry wt at SS8.

It is tempting to conclude from the general decrease in metal concentrations between 1984 and 1985 that various DOE activities (plant shutdown, environmental recommendations) adjacent to ORGDP

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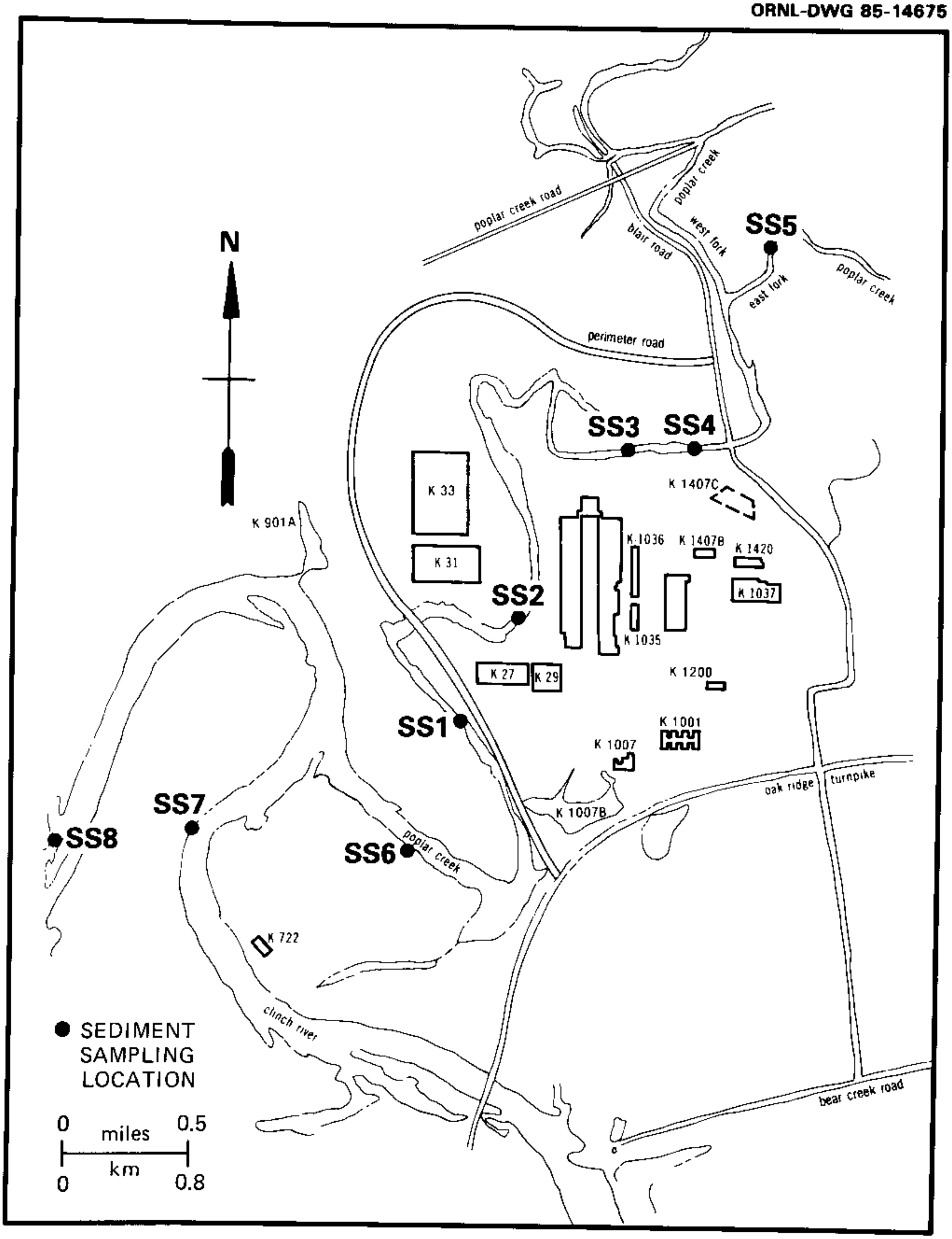

Fig. 4.10.3. Map of sediment sampling locations near ORGDP.

Table 4.10.1. 1985 concentrations of various elements in stream sediment samples near ORGDP

Station[a]	Concentration (µg/g dry wt)											
	Hg			Pb			Ni			Cu		
	Aug.	Dec.	Av.	Aug.	Dec.	Av.	Aug.	Dec.	Av.	Aug.	Dec.	Av.
SS1	1.4	3.1	16	30	17	24	72	74	73	24	33	29
SS2	13	26	19	30	26	28	131	97	110	38	60	49
SS3	1.0	8.0	<4.0	40	26	33	108	120	110	35	57	46
SS4	1.8	6.1	5.0	30	31	31	59	36	48	28	49	39
SS5	11	1.8	6.0	50	17	34	57	20	39	96	30	63
SS6	7.0	4.0	3.0	40	16	28	114	31	73	48	26	37
SS7	<1.0	<1.0	<1.0	30	7	19	37	7.1	22	0.0	9.6	13
SS8	<1.0	<1.0	<1.0	20	8	14	28	8.7	16	0.0	10	10

Station[a]	Concentration (µg/g dry wt)											
	Zn			Cr			Mn			Al		
	Aug.	Dec.	Av.	Aug.	Dec.	Av.	Aug.	Dec.	Av.	Aug.	Dec.	Av.
SS1	80	120	100	30	51	42	455	660	560	41,000	14,000	28,000
SS2	136	140	140	66	120	93	435	780	610	50,000	16,000	33,000
SS3	113	120	110	33	33	33	556	580	670	36,000	13,000	25,000
SS4	92	130	480	27	28	28	397	830	610	29,000	16,000	26,000
SS5	126	52	39	41	18	30	510	670	590	46,000	15,000	31,000
SS6	115	77	73	59	25	42	633	520	580	58,000	17,000	38,000
SS7	15	15	22	107	8.3	58	607	350	480	32,000	4,600	18,000
SS8	28	25	16	19	9.8	14	359	590	480	21,000	4,500	13,000

Station[a]	Concentration											
	(µg/g dry wt)									(pCi/g dry wt)		
	Th			Cd			Uranium			Uranium		
	Aug.	Dec.	Av.	Aug.	Dec.	Av.	Aug.	Dec.	Av.	Aug.	Dec.	Av.
SS1	<20	<20	<20	2.0	<0.03	<1.0	2.6	12	8.0	2.0	9.5	6.1
SS2	<20	<20	<20	4.0	0.93	2.0	7.6	19	13	5.8	15	10
SS3	<20	<20	<20	1.0	0.32	1.0	8.8	45	27	6.7	34	21
SS4	<20	<20	<20	1.0	1.6	1.0	4.2	4.9	5.0	3.2	3.8	3.8
SS5	<20	<20	<20	4	<0.30	<2.0	8.1	4.7	6.0	6.2	3.6	4.6
SS6	<20	<20	<20	2	<0.30	<1.0	6.3	3.3	20	4.8	2.5	15
SS7	<20	<20	<20	1	<0.30	<1.0	1.2	0.5	1.0	1.0	0.4	0.8
SS8	<20	<20	<20	1	<0.30	<1.0	0.6	2.1	1.4	0.5	1.6	1.1

[a] See Fig. 4.10.3.

[b] Concentration based on semiannual sample collections in August and December.

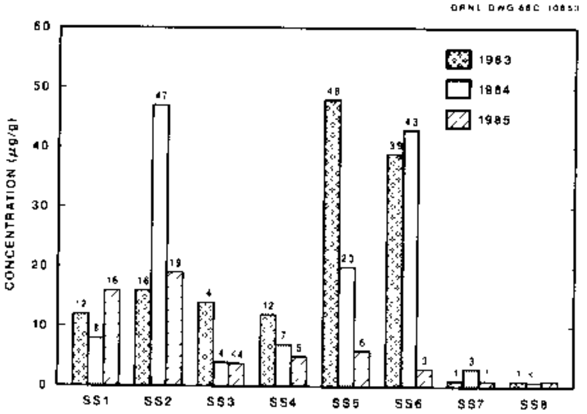

Fig. 4.10.4. Average mercury concentrations in sediment (1983, 1984, and 1985).

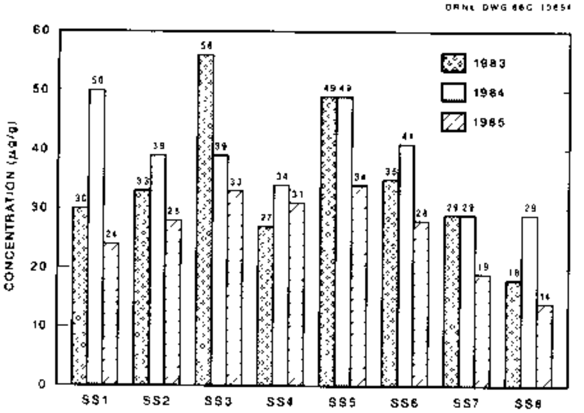

Fig. 4.10.5. Average lead concentrations in sediment (1983, 1984, and 1985).

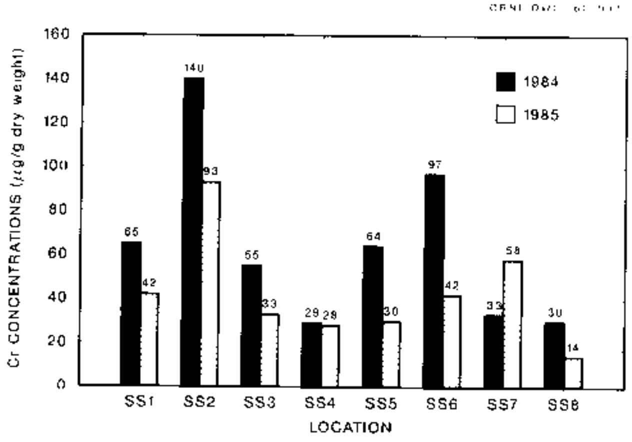

Fig. 4.10.6. Average chromium concentrations in sediment (1984 and 1985).

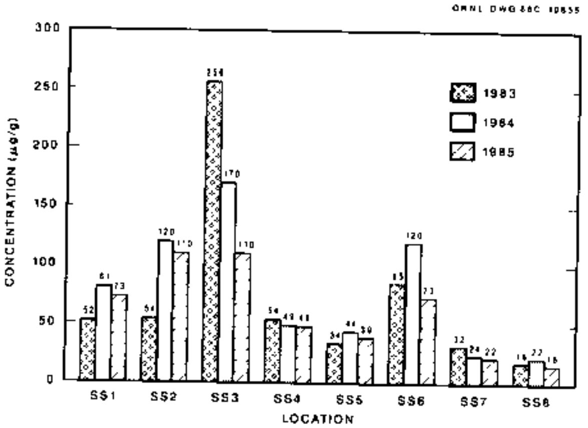

Fig. 4.10.7. Average nickel concentrations in sediment (1983, 1984 and 1985).

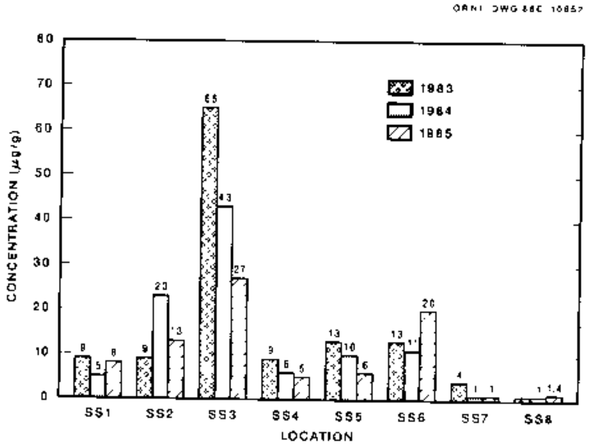

Fig. 4.10.8. Average uranium concentrations in sediment (1983, 1984, and 1985).

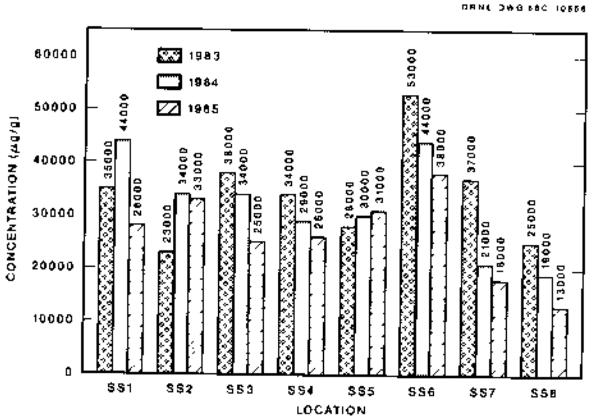

Fig. 4.10.9. Averge aluminum concentrations in sediment (1983, 1984, and 1985).

and upstream from Y-12 and ORNL sediment sampling locations have led to improved sediment quality. However, the possibility that particle size distribution and organic water content have not been homogeneous between 1984 and 1985 samples precludes such a conclusion at this time. See Sects. 5 and 7 for more information about characterization of sediment on the ORR and in upstream and downstream river reservoir systems.

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5. SPECIAL STUDIES, UNUSUAL OCCURRENCES, AND TECHNICAL REVIEW

5.1 SPECIAL STUDIES

This section contains brief summaries of special studies in late 1984 and 1985 that have been conducted or are continuing in relation to the environmental monitoring activities of the DOE Oak Ridge facilities. In addition, studies related to cleanup activities, site characterization, and improvements in monitoring and modeling capability are included. Brief synopses and references are provided for completed studies in which additional details may be found.

5.1.1 Calculational Methods for Analysis of Postulated UF_6 Releases

The Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research has for several years been conducting the Fuel Cycle Facility Safety Research Program to develop methods for analyzing postulated accidents at NRC-licensed facilities. One objective of the program being carried out by the NRC Division of Risk Analysis was to develop an Accident Analysis Handbook for use by both NRC and NRC licensees. A report has been published that provides a detailed description of calculational methods for the analysis of postulated uranium hexafluoride (UF_6) releases that were developed for inclusion in the Accident Analysis Handbook.[1]

In an earlier report[2] various accident scenarios involving postulated releases of UF_6 were identified, as were a number of calculational methods that would be useful for analyzing such postulated accidents. From among the calculational methods identified, several methods were selected as necessary for a first-order approximation of accident consequences. Reference 1 describes the implementation of most of those selected methods into a series of computer programs that can be used for analysis of postulated UF_6 releases.

When UF_6 is released from containment into moist air, it reacts with the water vapor in the air to form hydrogen fluoride (HF) and uranyl fluoride (UO_2F_2). In modeling postulated releases, UF_6 is encountered in solid, liquid, and vapor phases. HF and H_2O can exist in liquid and vapor phases, and their coexistence significantly affects their vapor pressures and liquid-phase enthalpies. Self-association (polymerization) of HF vapor also occurs. Correlations for various physical and thermodynamic properties are presented in Ref. 2. The solid-vapor composition to be expected from the flashing of UF_6 liquid is also discussed.

Because of the equilibrium phase behavior of UF_6, multiphase flow frequently occurs. A major complicating factor is the existence of the UF_6 triple point at about 22 psia, a pressure frequently lying between the pressure of UF_6 in containment and the pressure of the surroundings. The description of analysis methods for determining release rates is generalized for a multicomponent system; however, the implementation of these methods into computer models is limited to UF_6. The simulation of the phase behavior of UF_6 within containment as a function of initial conditions, mass flow rates into and out of containment, and heating rate is also discussed in Ref. 2.

Although the methods for simulating releases of UF_6 from cylinders through either a breach or a broken (or misvalved) piping system can be used for developing source terms for outdoor releases of UF_6, additional methods are needed for analyzing releases postulated to occur indoors. These methods are incorporated into compartment models. Several simple models have been developed to simulate heat transfer, flow-through ventilation system components, and deposition. Mass and energy balances within a compartment are also presented.

Four main programs that use an extensive set of common subroutines have been developed for simulating postulated accidental releases of UF_6.

- CYLIND simulates the transient release of UF_6 from containment through a breach or piping system.
- FODRFT and INDRFT are used to simulate transient behavior resulting from the release of UF_6 inside compartments ventilated by forced-draft and induced-draft ventilation systems, respectively.
- BATCH is a closed compartment model (no ventilation) with an "open-compartment" option that allows it to be used to simulate a steady-state release directly into a forced-draft ventilation system exhausting to a known pressure.

Six example problems encompassing a total of 16 cases are provided to illustrate the use of CYLIND, FODRFT, INDRFT, and BATCH. These examples include: (1) releases from cylinders (a) through a breach in the cylinder wall and (b) through a ruptured piping system, (2) releases occurring in compartments ventilated by (a) forced draft and (b) induced draft, and (3) a release into a ventilation system. Problem statements, input descriptions, and a summary of results for each example are provided.[2]

The approach used in developing the various compartment model programs lends itself to future refinement of the models used as well as to the development of more elaborate models involving multiple compartments. By virtue of its necessary inclusion in the described models as a reaction product of UF_6, the models FODRFT, INDRFT, and BATCH can also be used to simulate releases of HF.

5.1.2 Evaluation of Potential for Incidents Having Health or Safety Impacts

Operation of the large, complex DOE facilities at Oak Ridge requires the use of materials that, if not contained, have the potential for adverse health effects to humans. Some of these materials (e.g., uranium hexafluoride, hydrogen fluoride, and ammonia) are involved directly in operating processes. Others (e.g., chlorine, natural gas, and gasoline) are used in auxiliary support processes. However, throughout the lifetime of these facilities, DOE, its predecessors, and its contractors have given high priority to the safety of employees and the general public. As a result, operators of the facilities have achieved outstanding safety performance records over many years. In more recent years, the safety of employees, the public, and the environment has been elevated to a position of first priority.

About 1977, DOE initiated a highly structured Safety Analysis Report (SAR) program for nuclear-related work that is now mature and is being successfully used to assess risks and to evaluate the adequacy of safety and detection systems, administrative controls, emergency response planning, and other actions designed to minimize the likelihood of hazardous events and to effectively respond to adverse situations should they occur.

Recognizing that extensive reviews have already been performed for many operations, a survey[3] was undertaken at the initiative of Energy Systems following the accident in Bhopal, India. At the request of DOE, personnel at the facilities operated by NLO, Inc., and Goodyear Atomic Corporation (GAT) were asked to participate. The objectives were to (1) collectively identify and reexamine potential incidents that could cause large numbers of casualties, (2) evaluate the adequacy of existing prevention/response actions, and (3) identify improvements where possible.

Although this evaluation can be considered more analogous to a hazardous materials survey than to a systems analysis of the type necessary to identify accidents comparable to the one that occurred at Bhopal, its findings—along with those resulting from the SAR program—reaffirm the conclusion that the potential for an accident with consequences similar to those at Bhopal is essentially nonexistent.

The survey was made by contractor personnel under the leadership of a site representative who conducted the reviews. Evaluations were generally qualitative and based on a best-judgment approach by knowledgeable personnel representing operating, technical, safety, environmental, and emergency control/response disciplines. A review panel was formed, and this group of advisory personnel (appointed by the facility manager or laboratory director) reviewed, commented on, and challenged the team's findings.

Primary concern was given to large-impact situations whereby a single event or a series of events could be reasonably postulated to cause five or more fatalities. Attention was also focused on materials, systems, or facilities outside the formal SAR program—specifically, standard industrial hazards having very serious consequences, even though the probabilities of occurrences are low. It was further recognized that a single, manageable event occurring with or following other events might progress into a much more serious situation.

The hazard level, probability, and risk matrix concept developed for the safety analysis and review system (OR 5481.1B) was used as a general guide for this survey. However, strict adherence to this order was not required, and contractor personnel exercised considerable flexibility in conducting and presenting the site reviews. Tables prepared for the site reviews were intended to address specific site concerns as perceived by the representatives and review panels and were therefore not intended to be uniform from site to site.

In this survey, a deliberate effort was made to address real hazards having multiple-fatality potential as opposed to material releases or events that could cause perceived problems or have a public relations impact.

Seismic considerations addressed the same events as were used in the SARs. Based on a seismic activity study, seismic events for each facility were defined that would be expected to have a 10% probability of being exceeded during the remaining plant lifetimes, which corresponds to a 237-year return period. The resulting evaluation-base earthquakes were determined to be those producing ground level accelerations of 0.08 g for Oak Ridge. The facilities were evaluated at these levels.

For the gaseous diffusion plant, representatives used operating conditions close to those currently experienced or projected and, thus, some differences in analyses exist.

Conclusions

The conclusions from this study were based on the facility reviews and on extensive group discussions with both the site representatives and other personnel at each facility.

Despite the outstanding safety records that have been achieved, situations exist throughout the facilities surveyed that have the potential to cause serious injury or death to employees who are either working on a specific job or are within the immediate area. These situations include moving and connecting gas cylinders, electrical switching and maintenance operations, maintenance and operation of heavy or rotating equipment, operations involving toxic or corrosive chemicals, and other generally recognized industrial hazards. Because of the effective use of safeguards, however, such situations were not deemed to have a serious potential for multiple fatalities.

Existing safety, environmental, and risk analyses have been very effective in identifying concerns and prompting actions to reduce risk to human life. Given the size and complexity of these facilities, there are relatively few materials or situations at the sites for which credible scenarios for multiple fatalities were developed.

This survey indicates, almost invariably, that the lower the quantity of material on hand, the lower the risk of large, serious releases or events. Attention should be given to formally adopting and using an optimum working inventory philosophy for all potentially hazardous materials.

Current surveillance and detection systems provide a high probability that large releases or major events will be quickly detected. Most instrumented detection systems for chemical releases, however, are specific to recognized materials and discharge points; hence, a lower level of confidence exists that releases of unusual materials would be detected quickly.

Several materials or situations present potential hazards of general concern. Anhydrous hydrogen fluoride, chlorine, and ammonia are present in sufficiently large quantities to present significant hazards in the event of catastrophic tank or cylinder failures.

Uranium hexafluoride is utilized at all of the gaseous diffusion plants, and the rupture of a cylinder containing liquid UF_6 could have severe impacts. This concern is being addressed through the SAR program; however, employee awareness of actions to be taken in the event of a large UF_6 release should be given greater attention. Because of the somewhat isolated locations of the facilities and their large areas, on-site consequences of materials are of greatest concern. However, studies of dispersion models indicate that the combination of worst weather conditions and large releases has the potential for significant off-site impacts.

Gaseous and liquid fuels, as well as other hazardous materials, are widely used and transported throughout all of the facilities. Leakage or spills of these materials present the potential for impacting relatively large numbers of employees. These situations represent common industrial hazards and are not addressed through the SAR program.

The stockpile of UF_6 cylinders, filled before the rigid application of administrative controls (about 1975) to ensure that cylinders are free of hydrocarbon oil, represents an unknown risk in the future when the contents of these cylinders are heated to the liquid phase for transfer or processing.

The impact of seismic events on the reactors at ORNL was not included in the original SARs, and there appears to be no firm schedule for updating the SARs to include seismic evalutions although such actions are planned for the reactors that are expected to remain in operation. The impact of seismic events on stored enriched uranium at the Y-12 Plant is receiving increased attention. Corrective actions are planned, and engineering design is currently in progress.

Much of the emergency planning at the facilities presupposes that mass evacuation would not be the correct action if large material releases were to occur. However, the degree to which employees would correctly and rapidly respond to instructions to remain indoors, secure buildings, etc., has not been determined through large-scale drills. Additionally, whether the large-scale evacuation of employees beyond the facility parking lots could be effectively accomplished is unknown, should such action be necessary.

Emergency access to plant public address systems is limited to intrafacility buildings that are relatively close together. No remote tie-in capability exists at some facilities.

Large numbers of visitors who are unfamiliar with warning signals and emergency response procedures present a unique concern, especially at ORNL.

Biological work (ORNL at Y-12) was assessed by the ORNL review committee as posing no risk within the context of the multiple fatality criteria used in this survey.

Events that develop at slow or moderate rates can likely be managed by facility personnel so as to avoid large-scale, multiple-person impacts. Rapidly developing events, simultaneous events, or a rapid series of events present the most serious situations. In this sense, seismic or catastrophic failures that could initiate significant structural failures or multiple events have the most serious consequences, although the probability or occurrence may be very low.

Recommendations

This survey resulted in fresh and comprehensive internal reviews of each facility. Follow-up actions by the individual facilities should be taken to reduce risks by disposing of unused materials and reducing inventories when possible.

Additionally, the following recommendations are made:

(1) An optimum working inventory policy should be established and seriously implemented for all potentially hazardous materials. Such a policy has the potential for cost control benefits as well as for reducing the impact if a material release occurs. Special consideration should be given to scheduled reviews and inspections to ensure that unused and unnecessary inventories, however small, of hazardous materials are not retained. When required, contractor policies and procedures should be revised to formally include this action.

(2) The present survey reflects a material and inventory evaluation at a single time. Programs at all of the facilities are dynamic and variable. In addition to routine hazardous materials management activities, each facility should maintain a current listing of materials whose releases would have the potential for multiple (five or more) fatalities. A report listing the materials, inventory quantities, and changes in the inventories from the last review should be provided to senior management annually.

(3) Plans for protection of the facility population and the public in the event of major material releases should be reevaluated. The need for enhanced employee awareness or for conducting emergency drills involving employees should be evaluated by each facility. Specific attention should be given to plans to ensure visitors' safety in the event of a serious event. Assurance of a functional and available public address system should be given additional attention.

(4) Facility emergency drills and training exercises should be structured to provide greater training and instruction for the general facility population and to include some simulated situations involving multiple and rapidly progressing events. The rate-of-development component (e.g., a very dense and rapidly expanding cloud of toxic gas) should be given greater attention in emergency response training.

(5) Each facility should give deliberate attention to managing intrafacility transfers of gaseous and liquid fuels (and other hazardous materials) so as to minimize risk to the facility population.

5.1.3 Site Characterization Techniques Used at a Low-Level Waste Shallow Land Burial Field Demonstration Facility

The Environmental Sciences Division of ORNL has been investigating improved shallow land burial technology for application in the humid eastern United States. As part of this effort, a field demonstration facility (Engineered Test Facility, or ETF) has been established in SWSA 6 for the purpose of investigating the ability of two trench treatments (waste grouting before cover emplacement and waste isolation with trench liners) to prevent water-waste contact and thus minimize waste leaching. As part of the experimental plan, the ETF site has been characterized for the purpose of constructing a hydrologic model. Site characterization is an extremely important component of the waste disposal site selection process; during these activities, potential problems that might obviate the site from further consideration may be found. A report has been published that describes the ETF site characterization program and identifies and, where appropriate, evaluates those tests that are of most value in model development.[4] Specific areas covered include site geology, soils, and hydrology. The information in Ref. 4 is similar to that which will be required of a low-level waste site developer in preparing a license application for a potential site in the humid East. Only data relevant to hydrologic model development are included, anticipating that many of these same characterization methods will be used at future disposal sites with similar water-related problems.

The ETF is located in Melton Valley, approximately 2 km south of ORNL. Geologically, it is within the Copper Creek thrust block and is underlain by strata of the Middle to Late Cambrian Conasauga Group. The specific formation is the Maryville Limestone, which consists of silty limestone interbedded with mudstones and shales. The structure of the formation is highly deformed with small-scale folding, several examples of which were exposed during trench excavation at the ETF. The formation is also heavily fractured, and flow through these fractures is believed to be quite significant during periods of heavy precipitation. Soil thickness, as measured from core samples and surface geophysical techniques, ranges from 2 to 7 m, being thinnest in the vicinity of experimental wells ETF-9, -1, and -2 (above a major limestone fold) and increasing in thickness to the northwest and southwest of the ETF experimental trenches.

Major emphasis in Ref. 4 was placed on shallow (<10 m) geological characterization, because this is the depth that will contain the LLW and in which groundwater movement and fluctuations are readily observed. Of perhaps equal importance is deeper geological site characterization.

In addition to shallow geological characterization, radionuclide, chemical, and physical properties have been determined on core samples taken from a nearby site at depths of 5 to 35 m. These samples were taken from the Maryville Formation, identical to that portion of the Conasauga Group that underlies the ETF. A summary of important geologic characteristics of the ETF site is contained in Table 5.1.1.

The soil of the ETF site is described as being very shallow, even taking into account the material removed during site clearing. The underlying horizons were found to be highly leached (strongly acidic) and highly structured due to stratigraphic characteristics inherited from the bedrock. The soil's stratigraphic orientation was extremely variable in both dip and strike because of the folding and faulting. Root penetration was generally not noted below approximately 40 cm, presumably because of dense horizons and tight structure.

Measurement of distribution coefficients (Kd's) for seven radionuclides in soil samples collected from the ETF site indicates a range of 11.7 L/kg (^{125}I) to 64,100 L/kg (^{137}Cs). Extremely low Kd's ($\leq 10^{-1}$ L/kg) were not encountered for any soil samples, as might be the case with tritium. There was no observable pattern with depth for the Kd's of any of the radionuclides tested, nor were there any differences among the three profiles tested. Thus the best representation of these Kd values for unsaturated zone

Table 5.1.1. Summary of Engineered Test Facility site characteristics

Property	Unit	Value
Geology[a]		
Radionuclide, chemical, and physical properties (mean of 23 samples, 5- to 35-m depth, Maryville Limestone)		
Kd, ^{85}Sr	L/kg	63.1
Kd, ^{134}Cs	L/kg	27,400
Kd, ^{58}Co	L/kg	2,720
Kd, ^{125}I	L/kg	9.4
Kd, ^{241}Am	L/kg	27,600
Kd, Ca + Mg	L/kg	56.0
Exchangeable Ca	meq/kg	113
Exchangeable Mg	meq/kg	19.1
Exchangeable Na	meq/kg	0.3
Exchangeable acidity	meq/kg	16.0
Cation exchange capacity	meq/kg	149
pH	$-\log[H^+]$	7.6
$CaCO_3$	%	17.1
Sand	%	76
Silt	%	13
Clay	%	11
Particle density	mg/m^3	2.63
Soils[b]		
Radionuclide adsorption: mean Kd (0- to 2-m soil depth)		
^{241}Am	L/kg	5,670
^{85}Sr	L/kg	494
^{137}Cs	L/kg	64,100
^{60}Co	L/kg	782
^{125}I	L/kg	11.7
^{59}Fe	L/kg	46,800
^{51}Cr	L/kg	2,780
Chemical properties: mean (0- to 2-m soil depth)		
Exchangeable Ca	meq/kg	20
Exchangeable Mg	meq/kg	31
Exchangeable Na	meq/kg	1
Exchangeable K	meq/kg	3
Exchangeable acidity	meq/kg	154
Cation exchange capacity	meq/kg	210
Base saturation	%	26
Organic matter	%	0.37
$CaCO_3$	%	0
pH	$-\log[H^+]$	4.4
Water hardness	mM	0.12

Table 5.1.1. (continued)

Property	Unit	Value
Physical properties (0- to 2-m depth)		
Bulk density	mg/m^3	1.34
Total porosity	L/L	0.50
Sand	%	36
Silt	%	22
Clay	%	42
Clay mineralogy	Species	Illite > chlorite > vermiculite
Soil series		Montevallo
Soil classification	Family	Loamy-skeletal, mixed, thermic, shallow typic dystrochrept
Hydrology		
Climatic factors		
Precipitation, mean annual at Oak Ridge	mm	1,388
Precipitation, mean annual at ORNL	mm	1,267
Precipitation, observed 1981	mm	1,022
Precipitation, observed 1982	mm	1,295
Surface water		
Peak discharge Flume I	L/s	57.8
Peak discharge Flume II	L/s	50.8
Low flow	L/s	0
Infiltration (saturated)		
Trench cover material	cm/s	13.3×10^{-5}
Undisturbed area	cm/s	1.56×10^{-5}
Groundwater		
Aquifer characteristics		
Transmissivity (T)	m^2/min	2.54×10^{-3}
Storage coefficient (S)		~0.01
Hydraulic conductivity	cm/s	6.31×10^{-5}
Effective aquifer thickness	m	67
Effective porosity		0.03
Water chemistry	Calcium/ bicarbonate	
Unsaturated zone		
Mean saturated hydraulic conductivity	cm/s	2.0×10^{-5}

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[a] Location: Oak Ridge National Laboratory (ORNL) Solid Waste Storage Area 6; experimental trench area: 0.3 ha; Flume I drainage area: 0.65 ha; Flume II drainage area: 0.88 ha; monitoring wells: 44 .

[b] Formation: Maryville Limestone; lithology: silty limestone with interbedded mudstones and shales; strike: ~N50°E; dip: ~30°SE; structure: highly deformed by small-scale folding—heavily fractured.

modeling purposes would be the averages and the standard deviations. On a larger (30-m) depth scale extending into comparatively unweathered bedrock, there appeared to be some general decline in most radionuclide Kd's.

Cation exchange capacities averaged 210 meq/kg and were quite uniform in this characteristic. There appeared to be only a minor influence of vegetational nutrient cycling, as evidenced by the modest decline in exchangeable calcium with depth in each profile tested. A number of significant correlations were observed among the soil chemical properties. Of particular note are the correlations between exchangeable acidity and percent base saturation and pH ($r = 0.80$ and -0.72, respectively). This relationship is to be expected because the lower the soil pH, the more exchange sites that are occupied by acid cations (Al^{+3} and H^+) and, hence, the lower the percentage of these sites that are occupied by basic cations. Calcium dominated these exchangeable bases when the base saturation increased, which accounts for its high correlation ($r = 0.90$) with percent base saturation and its negative correlation with exchangeable acidity ($r = -0.73$). A summary of radionuclide, chemical, physical, and mineralogical properties for soils collected at the ETF site is contained in Table 5.1.1.

5.1.4 Y-12 Plant Air Monitoring Programs

To accurately assess the effect of Y-12 Plant operations on the region's ambient air quality, the Y-12 Plant currently has in place a comprehensive plan to upgrade stacks and its air monitoring program.[5] This program is expected to grow significantly in the next five years as the Y-12 Plant obtains hundreds of air pollution operating permits and new emission sources are added or modified. In addition, recently enacted, proposed, or considered changes in air pollution regulations,[6] such as the expansion of hazardous air pollution regulations and the regulation of airborne radionuclides, may significantly increase the air pollution monitoring requirements of the Y-12 Plant in the near future.

Air pollution monitoring at the Y-12 Plant involves three distinct but interrelated monitoring methods. The first, mandated by the Clean Air Act,[7] is source emission or stack testing. This procedure is required to ensure that air pollution control devices are operating efficiently and that permitted emission rates are not exceeded. This method of air pollution testing is very important because it specifically determines the degree of compliance with emission limitations for individual air pollution point sources. The remaining two methods of air pollution monitoring, ambient air and atmospheric dispersion modeling, attempt to determine the impact of Y-12 Plant operations on the region's air quality.

In 1985 the Y-12 Plant continued to make significant strides in defining the physical and chemical characteristics of airborne releases emitted from production stacks. The "Stack Catalog Project," initiated in 1984, was completed to provide an overall inventory and evaluation of the Y-12 Plant's ventilation stacks. Efforts are continuing to maintain an up-to-date inventory of the Y-12 Plant's ventilation systems to account for emissions stemming from inside the plant boundaries. During 1985, emphasis continued to be placed on upgrading controls on existing air pollution sources to further reduce emissions of contaminants into the atmosphere; a number of capital projects are under way at the Y-12 Plant that will reduce emissions of air contaminants. One of these projects, the Y-12 Steam Plant Improvement—Emissions Control Project, which had been ongoing for several years, was completed in 1985. The installation of new, high-efficiency, fabric-filter baghouses on all four pulverized coal boilers of the Y-12 Plant's Steam Plant was completed and has significantly reduced the amount of particulates (fly ash) released into the atmosphere. Opacity of the steam plant stack emissions is continuously monitored using light photometry. During 1984, readings that were taken before the baghouse installation indicated that visible emissions exceeded state-imposed limits. Opacity measurements taken following baghouse installation were well within compliance limits.

A comprehensive program to significantly improve monitoring and quantification of radiological air emissions from the Y-12 Plant's many process stacks was developed in 1985 and initiated under an ambitious schedule in order to meet the requirements issued by the EPA under the NESHAP program. The Y-12 Plant Airborne Radionuclide Monitoring Program involves a strategy consisting of a number of independent but interrelated program elements. The strategy combines periodic EPA stack sampling techniques with continuous stack sample collection and real-time emissions monitoring. All program elements were designed to interact to fulfill the goal of quantifying radiological air emissions and demonstrating compliance with NESHAP in the most expeditious time period possible. Approximately 120 process stacks, which serve equipment that processes enriched or depleted uranium, are involved in the program.

Progress continues to be made to quantify radiological air discharges from uranium processing exhaust stacks and significantly upgrade the emissions monitoring capabilities of the Y-12 Plant.

Stack sampling activities were initiated and are currently being conducted by the ORGDP Systems and Equipment Technology Department under contract with Y-12 to obtain an EPA-approved characterization of stack effluents from a large number of uranium processing exhausts. Many of these stacks are being lengthened or otherwise modified, and permanent stack sampling access platforms are being installed in order to meet the EPA criteria for the collection of particulate stack samples. Construction was completed in late 1985 on the first four stacks to be modified, and detailed engineering design is continuing for the modification of all remaining stacks that do not meet sampling requirements. Where possible, independent stacks are being combined and complete emissions sampling and monitoring capabilities provided in order to continuously measure potential radiological emissions in the most cost-effective manner possible.

In addition to obtaining an EPA-approved stack gas characterization of all significant Y-12 Plant uranium processing exhaust stacks, continuous emission stack samplers are being installed. The purpose is to monitor daily radiological emissions and alert operating personnel of possible emission excursions.

The major improvements in Y-12's radiological air emissions monitoring will continue through 1986. The completion of the Y-12 Plant Radionuclide Monitoring Program by February 1987 continues to be one of the highest priorities of the Y-12 Plant, with significant capital and manpower resources dedicated to its success.

The Y-12 Plant currently operates two stations within the Plant boundaries to monitor the ambient air concentrations of total suspended particulate matter and sulfur dioxide. Eleven monitoring stations located around the perimeter of the Plant are also maintained. These stations gather data on the concentrations of various uranium isotopes. In addition, efforts continued during 1985 to expand the existing perimeter system by including an ambient air monitor for the Scarboro Community of the City of Oak Ridge. This project is scheduled for completion in early 1986 and will involve installation of ambient air monitoring stations capable of sampling (1) particulates, with a high-volume sampler; (2) radionuclides, with a charcoal filter; and (3) both dry (deposition) and wet (precipitation) atmospheric fallout. Data will be collected in a digital format and the host computer will be able to calculate daily and weekly averages for all monitoring variables.

Atmospheric dispersion modeling will play an important role in the Y-12 Plant's Air Pollution Control Program. Computer-aided atmospheric dispersion modeling provides a valuable tool for determining long-range transport of air contaminants and predicting downwind ground-level concentration of materials near a source. Air pollution modeling will enable the Y-12 Plant to model emergencies and estimated effects on employees and population centers downwind of the plant. Dispersion modeling is also required in the calculations of dose equivalent rates for compliance with EPA radionuclide emissions regulations.[6]

To provide meteorological data, two meteorological towers were installed at the Y-12 Plant that have automated data collection and solid-state telemetry data transfer to a computer. A 100-m tower located near the east boundary of the plant has instrumentation at the 10-, 30-, and 100-m levels. A 60-m tower just west of the plant has monitors at the 10- and 60-m levels. Wind and other meteorological parameters will be monitored to provide data on the stability class of the atmosphere as well as wind speed and direction data essential for reliable dispersion modeling. As data from the meteorological towers and various process stacks are obtained, the Y-12 Plant, in conjunction with ORNL, will examine the development of an atmospheric dispersion modeling program for Bear Creek Valley.

5.1.5 Y-12 Plant Water Pollution Control Monitoring

The new NPDES permit issued on May 24, 1985, imposes a variety of environmental monitoring requirements for compliance. More than 236 specified outfalls require routine effluent monitoring for specific parameters. However, a large percentage of monitoring for compliance with the NPDES permit is for biological and toxicological monitoring programs.

A biological monitoring and abatement program[5] was initiated in 1985 and will be continued for at least the next five years. The Environmental Sciences Division at ORNL prepared a proposal that was submitted to the TDHE and EPA for approval. The results of the biological monitoring will determine whether the classified uses of East Fork Poplar Creek are being maintained or protected. In addition, the effluent limitations at the treatment facilities may also be modified on the basis of the results of the study.

The NPDES permit also requires a Toxicity Control and Monitoring Program (TCMP) for most of the treatment facilities, cooling tower blowdown, and all Category IV discharges (untreated process wastewaters). This evaluation consists of performing bioassay studies that provide information on the toxic potential of the identified discharges. Before the studies could be conducted, toxicity evaluation plans had to be submitted to the EPA and the TDHE for approval. At a minimum, each plan of study had to include a study implementation schedule, a consideration of waste variability, evaluation of wastewater dispersion and persistence in the receiving water, and an assessment of toxic components in the receiving water body and biota.

During 1985, the Y-12 Plant submitted and received approval on several plans and began the toxicity evaluations for several of the identified discharges. The evaluations are being performed by the Ecological Effects Group and Reservation Studies Group of the Environmental Sciences Division of ORNL. They consist of performing bioassay studies that provide information on the toxic potential of the identified discharges by exposing sensitive aquatic organisms (fathead minnows and *Ceriodaphnia*) to various concentrations of the wastewaters. From the fatality rate, growth rate, and reproductivity rate of the test organisms, the acute and chronic toxicity of the wastewater can be determined.

Toxicity evaluation studies will continue through 1986. The results of the studies will be used to determine whether the effluent limitations of the NPDES permit are adequate to protect the receiving water body and biota. If the results indicate that the wastewaters are discharged in toxic amounts, Y-12 must submit a toxicity control and implementation schedule that would include appropriate measures to reduce the discharges to acceptable levels.

The Y-12 Plant has traditionally monitored for uranium in plant effluents; PCB monitoring has recently been implemented for specific locations and processes. The reissued NPDES permit requires both a radiological and a PCB monitoring program. During 1985 a sampling program was initiated to identify and verify specific types of radioactivity at various discharges. After the initial sampling was complete, a detailed proposal was developed and submitted to TDHE, EPA, and DOE. The PCB monitoring program proposal developed and submitted in 1985 outlined a program to evaluate the entire plant and identify other possible sources of PCB contamination.

The mercury problem at the Y-12 Plant has necessitated the development and installation of an on-line monitor to measure the mercury concentrations in East Fork Poplar Creek that emanate from within the Plant boundary. The monitor is capable of (1) unattended round-the-clock operations, (2) transmitting data to a remote central monitoring facility, (3) operating routinely in the 1- to 10-ppb range, and (4) ultimately detecting less than 0.1 ppb mercury.

The monitor has been configured around (1) a commercially available mercury vapor generator, (2) an inexpensive, dedicated cold vapor atomic absorption spectrophotometer with background correction, (3) a small computer with a real-time clock, and (4) an alarm indicating abnormal mercury concentrations. As configured, the system is capable of monitoring two locations on the stream (i.e., the entrance and the exit of New Hope Pond) every hour but could be modified to monitor both locations every 15 minutes.

The Y-12 Plant sanitary sewers discharge domestic wastewater to the City of Oak Ridge sewer system. Treatment is provided by the City of Oak Ridge Wastewater Treatment Plant, located in the western part of the city near East Fork Poplar Creek. Preliminary monitoring of treatment plant sludge indicated uranium concentrations at or above background levels. Current disposition of the City of Oak Ridge sludge in land applications has led to an increased interest in evaluating the sanitary sewer waste flows leaving the Y-12 Plant for uranium.

Portable automatic samplers are being used by the Y-12 Plant Environmental Monitoring Group to collect 24-h composite samples. The four monitoring locations include the sewer lines serving the Plant's west area, the Plant's east area, the Valley Industrial Park, and the Scarboro Road sewer main.

Connections and discharges to the municipal sewer system are regulated by a sewer use ordinance[8] adopted by the Oak Ridge City Council and administered by the Oak Ridge Department of Public Works. This ordinance limits the discharge of specific pollutants to the Oak Ridge system and sets forth stringent protection criteria for industrial wastewater flows. The protection criteria establish limitations on specific metals and organic pollutants.

Based on data collected in 1984 and 1985, the Y-12 Plant sewer discharges are in compliance with both the municipal ordinance for conventional domestic pollutants and anticipated EPA pretreatment standards.[8] Several metal pollutants (copper, zinc, iron, magnesium, and cadmium) are slightly in excess of the current protection criteria limits. Composite sampling will continue to enable full compliance verification. Requests for new connections to the Y-12 Plant's sanitary sewer system are reviewed for compliance with City of Oak Ridge protection criteria and EPA pretreatment standards.

5.1.6 Biological Monitoring and Abatement Program for East Fork Poplar Creek

On May 24, 1985, an NPDES permit was issued for the Y-12 Plant. As specified in Part III(C): Special Condition No. 7 of the permit, a plan for the biological monitoring of the East Fork Poplar Creek had to be submitted to the EPA and the TDHE within 90 days of the effective date of the permit. The Biological Monitoring and Abatement Program, as outlined in Ref. 9, was developed to meet this requirement.

The proposed program will be conducted for the duration of the NPDES permit. The proposed plan is based on preliminary discussions held on October 25, 1984, and April 4, 1985, between staff of Energy Systems, DOE, EPA, and TDHE. The current plan also reflects the results obtained from a reconnaissance of the proposed sampling sites on East Fork Poplar Creek conducted on May 9, 1985, by the staff from Energy Systems and TDHE. Because the composition of existing effluent streams entering New Hope Pond will be altered shortly, baseline (pre-operational) conditions in East Fork Poplar Creek will exist only for the next few months. Consequently, preliminary studies of the fish population were initiated on May 14, 1985.

The approach to biological monitoring described in Ref. 9 represents a combination of established monitoring protocols with more innovative state-of-the-art techniques to determine regulatory compliance. Although details of the specific procedures to be used in the initial stages of program are provided, experimental designs associated with studies that will be implemented after the first year are described in less detail.[9] The overall strategy is to use the results obtained in the initial characterization studies to define the scope of future monitoring efforts. Such efforts may require more intensive sampling than initially proposed in some areas (e.g., additional toxicity testing if initial results indicate poor survival or growth) and a reduction in sampling intensity in others (e.g., reduction in benthic invertebrate sampling frequency from monthly to bimonthly or quarterly after the first year). By using the results of previous monitoring efforts to define the needs and short-term goals of future studies, an effective, integrated monitoring program can be developed to protect the ecological integrity of East Fork Poplar Creek.

5.1.7 ORGDP Groundwater Monitoring Program

The ORGDP Groundwater Monitoring Program is being designed by Geraghty & Miller, Inc. This includes site characterization of 29 Comprehensive Environmental Response, Compensation, and Recovery Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites. The work involves geohydrologic characterization of each site, and the siting, design, and installation of monitoring wells. The construction phase of the program is to be completed in 1986. A second phase, which will assess 39 additional sites, will be initiated and completed in 1986.

The Energy Systems staff will support the program by providing updated geologic maps of ORGDP and conducting a streambed survey to locate nonpoint sources of surface water contamination. This support, along with the Geraghty & Miller work, will provide an ORGDP groundwater quality assessment. With the data required from the reports and from the monitoring wells, the groundwater quality assessment will be complete at the end of FY 1987.

5.1.8 Characterization Plan for Solid Waste Storage Area 6

DOE Order 5820.2 provides policy and guidelines for the management of radioactive wastes. Both new and existing DOE waste management facilities are required to comply with this order. New facilities are required to be sited, designed, operated, and closed using criteria specified in the order; however, existing facilities must, as a minimum, comply with the operating and closure portions of the order. A report has been published[10] that reviews existing information on SWSA 6 and develops cost estimates and schedules for obtaining the site information necessary to characterize the site for later use and develop plans for its closure.

SWSA 6 is the only currently operating low-level radioactive waste (LLW) shallow land burial facility at ORNL. Examination of the operational requirements of DOE Order 5820.2 indicates that there are only a few areas in which the current operation of SWSA 6 is not in compliance. However, for its closure, the compliance requirements may be more difficult to achieve. The major obstacle to meeting the closure requirements is the lack of detailed site characterization information, such as that specified for new burial facilities, but also that required for closure of existing sites.

The identification, investigation, and cleanup of existing or abandoned waste management facilities have been mandated by CERCLA, which establishes a federal program to identify, assess, and abate uncontrolled and nonpermitted sources of the release of hazardous substances into the environment. DOE Order 5480.14 establishes a CERCLA-like program to identify and evaluate abandoned DOE waste sites and other potential sources of hazardous substance releases and to plan for their cleanup. The requirements of this order are consistent with the technical requirements of CERCLA.

Characterization of SWSA 6 is an essential step toward compliance with DOE Orders 5480.14 and 5820.2. To ensure that SWSA 6 complies with these orders, it will be necessary to establish whether sufficient data exist to characterize the geology, hydrology, soils, and climatology and, if they do not, to develop plans to obtain any additional information required. It will also be necessary to determine whether sufficient data exist to establish a source term and provide the required geochemical information for hydrologic and dosimetric calculations. Where data gaps exist, methodology for obtaining this information must be developed.

To maintain operations in SWSA 6 and comply with the closure requirements outlined in DOE Orders 5820.2 and 5480.14, it is necessary to ensure that sufficient site information is available to verify that the site will not represent a significant radiological hazard to future generations and that minimum maintenance and surveillance will be required to maintain this condition. Because SWSA 6 was established without detailed site evaluation techniques (such as those imposed on new shallow land burial sites by DOE Order 5820.2 or 10 CFR Pt. 61), a considerable portion of the site information necessary to ensure compliance was not collected before operations began and must be collected now, with burials well under way. This situation exists for essentially all of the operating and inactive DOE burial sites.

Two approaches are available for developing a characterization plan. The first, which may be more applicable to new sites, would be to gather data on all of the parameters thought to be necessary to understand the site and, using these parameters, to calculate the long-term performance of the site. In many ways, this appears to be the approach suggested for siting new facilities by DOE Order 5820.2 and 10 CFR Pt. 61, as described in Refs. 11 and 12 for NRC facilities.

The second approach, which is probably more applicable to operating facilities, would be to evaluate the concerns that have surfaced during past operations and develop a characterization plan based on these concerns. During SWSA 6 operations, it has been observed that the waste in many trenches is not isolated from water; thus, some remedial actions and corrective measures have been proposed and carried out. As a result of these observations, specific studies and measurements have been made that allow the development of hypothetical models for the performance of the site, which might be different from that assumed before operation began. This approach allows the site characterization to concentrate on the parameters required to analyze the site for future performance based on operating experience.

In the case of SWSA 6, the methodology adopted for planning the characterization of the site has been to (1) identify all existing information regarding the characteristics of the site, (2) develop conceptual models that describe our current understanding of the site, and (3) develop a plan for obtaining the additional site information required to validate the conceptual models and allow future pathways analysis and performance assessment of the site. At present, the first step in the methodology has been completed.[13]

Following collection and analysis of the site information, preliminary pathways analysis and performance assessment can be conducted to determine whether the site will meet the assumed performance objectives, and if not, what corrective measures would have to be incorporated to provide the necessary assurances that closure can be achieved.

5.1.9 Ecological Characterization of Bear Creek Watershed

Ecological studies of the Bear Creek watershed were initiated in May 1984 and continued through 1985. The proposed five-year study calls for an initial, detailed characterization of the benthic invertebrate and fish communities in Bear Creek in the first year followed by a reduction in sampling intensity during the four-year monitoring phase of the plan.

The objectives of the ecological studies on Bear Creek are (1) to assist in the development of an effective remedial action plan related to past waste disposal operation in Bear Creek Valley and (2) to evaluate the effectiveness of these actions by monitoring the ecological recovery of Bear Creek. To accomplish the short-term goal of assessing potential ecological consequences of various remedial action alternatives, studies were conducted to characterize the existing environment in Bear Creek. This characterization utilized two approaches: (1) instream sampling of the benthic invertebrate and fish communities in Bear Creek to identify spatial and temporal patterns in distribution and abundance and (2) laboratory bioassays on water samples from Bear Creek and selected tributaries to identify potential sources of toxicity to biota.

The second objective of the ecological program relates to the long-term goal of identifying and prioritizing contaminant sources and assessing the effectiveness of major remedial actions that are implemented to mitigate the impacts of past waste disposal operations in Bear Creek Valley. Following completion of the initial characterization studies, periodic monitoring will be conducted over several years.

The Bear Creek watershed has a drainage area of 19.4 km^2. Parallel northeast-trending ridges constitute the northern and southern boundaries of the watershed. Elevations in the watershed range from 230 m at the mouth of the creek to 372 m at the crest of Chestnut Ridge. The Y-12 Plant is located on the headwater divide between Bear Creek, which flows to the west of the plant, and East Fork Poplar Creek, which flows to the east. The headwaters of Bear Creek originate in the vicinity of the S-3 Ponds; the creek flows approximately 12.9 km before joining East Fork Poplar Creek.

Approximately 65% of the watershed is wooded, with pines and mixed hardwoods, and much of the remainder consists of waste disposal areas located in upper Bear Creek Valley. These include the S-3

Ponds, the Sanitary Landfill/Oil Landfarm area, and the burial grounds.

In addition to the impacts of waste disposal operations in Bear Creek Valley, the creek is also subjected to high sediment loading from construction-related activities in the upper reaches of the watershed. Currently a major source of sediment to Bear Creek is erosion and runoff from the Rust Engineering construction spoil area adjacent to the creek. The site had been used for this purpose since 1964 but was graded and seeded in 1984 and is no longer in use. During the process of grading, construction debris (primarily large pieces of concrete) was pushed into the stream, requiring relocation of the benthic invertebrate sampling site to a new location 100 m upstream.

The numerous springs that originate on the north slope of Chestnut Ridge strongly influence stream flows and temperatures in Bear Creek. In addition to their importance in stabilizing the flow regime in Bear Creek, these springs also influence its thermal regime.

Limited information is available on the past ecology of Bear Creek. The first studies were conducted in August of 1972 and 1973 and consisted of qualitative surveys of the benthic invertebrate communities. The first intensive survey of the benthic invertebrate and fish communities in Bear Creek was conducted from May 1975 through April 1976.[14] The only biological sampling conducted in Bear Creek since 1976 was a limited reconnaissance survey of small streams near the burial grounds on December 20, 1983, and January 6-8, 1984.

Although direct comparisons between these and other early studies are often limited by differences in sampling design (including site locations, frequency of sampling, and methodology), these earlier biological studies, when considered together, can provide a basis for inferences regarding the nature and significance of the ecological impacts on Bear Creek watershed more than ten years ago. This information can provide a basis for evaluating the results of the present studies to assess the degree of ecological recovery that has occurred since the mid-1970s.

Previous studies indicated that waste disposal operations at the Y-12 Plant had a significant adverse impact on the aquatic biota in Bear Creek. From the results of previous studies it is reasonable to conclude that, 10 years ago, no fish and few, if any, benthic invertebrates inhabited a reach of the creek from the headwaters at the S-3 Ponds downstream for a distance of at least 2 km (to below the Sanitary Landfill/Oil Landfarm area). Seepage from the S-3 Ponds created an acutely toxic environment characterized by low pH and high levels of many trace elements.

The ecological status of Bear Creek today differs significantly from that of 10 years ago. First, the zone of high toxicity has been substantially reduced, from more than 2 km in 1974 to a maximum of less than 1 km in 1984. Recent data from bioassays and fish sampling conducted in April 1985 suggest a possible reduction in toxicity as far upstream the S-3 Ponds area. Second, a diverse, abundant fish community presently inhabits a reach of Bear Creek adjacent to the burial grounds and Sanitary Landfill/Oil Landfarm. Although densities and number of species were low, the fish were in good condition, and the low abundance may have been the result of significant reductions in available habitat due to very low stream flows.

The recovery that has occurred can be attributed primarily to the termination of discharges to the S-3 Ponds and subsequent neutralization and denitrification of the ponds. The most significant source of impacts on biota in Bear Creek was the S-3 Ponds.

Consequently these measures represent probably the most important remedial actions that could have been taken to initiate the process of ecological recovery in upper Bear Creek.[15]

Uranium is elevated in Bear Creek, but is less than 2 ppm at all sites. Uranium exhibits acute toxicity at approximately 3 ppm in very soft water, but is far less toxic (LD_{50} $\sim$140 ppm) in hard water such as is typical of Bear Creek. Its effects are likely to be of little ecological concern in Bear Creek.

5.1.10 Remedial Alternatives for the Bear Creek Valley Waste Disposal Area

On May 26, 1983, representatives of the DOE signed a Memorandum of Understanding with the EPA and the TDHE relating to control of contamination in Bear Creek Valley Waste Disposal Area (BCVWDA) adjacent to the Y-12 Plant. This disposal area consists of three sites. Some of the studies listed below have shown that plumes of groundwater contamination have been found at all three disposal sites. In most cases, the contaminated groundwater extended only a few hundred meters (few hundred feet) away from the waste sources. The S-3 Ponds were an exception—nitrate contamination in groundwater has been detected about 670 m (2000 ft) from the source. Volatile organic compounds have been detected to depths of 60 m (200 ft) at the Burial Grounds and the Oil Landfarm and to a depth of about 37 m (120 ft) at the S-3 Ponds. Additional deep monitoring wells are being installed to determine whether contamination extends below these depths.

The contamination in the BCVWDA poses no direct threat to drinking water supplies because the nearest water supply wells are in other valleys across the ridges to the north and south.

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5.2 RELEASES OF STRONTIUM-90 TO WHITE OAK CREEK FROM THE ORNL BETHEL VALLEY COMPLEX

In late January 1985, elevated levels of ^{90}Sr were detected coming from the Sewage Treatment Plant. Results of extensive investigations indicated that a broken low-level waste line was a major source of the ^{90}Sr, which infiltrated the sanitary sewer system and was released to White Oak Creek

During a heavy rain storm in late November 1985, higher than usual levels of ^{90}Sr were detected in White Oak Creek and in the sanitary, storm, and low-level waste systems. Results of studies that followed indicated that the major source of the elevated levels of radioactivity was a construction project pit that had exposed an air exhaust duct and a storm sewer line. During the course of the heavy rain, the storm line broke and large amounts of water entered the excavation and infiltrated the air exhaust duct, which was heavily contaminated with ^{90}Sr. The contaminated water then found its way into most of the waste lines in the area and into White Oak Creek.

During the course of 1985, the total ^{90}Sr (approximately 3 Ci) released to the Clinch River by way of White Oak Creek was only slightly higher than it had been for the previous three years (2.1 to 2.7 Ci). However, in the years before 1985, the major source of release was the waste storage areas, and only on the order of 10% of total ^{90}Sr released came from the main Bethel Valley operating complex. During 1985, more than 50% of the ^{90}Sr in White Oak Creek came from Bethel Valley.

The more obvious repairs were made after both of these unusual incidents, and a continuing series of studies and upgrades are taking place.

5.3 TECHNICAL REVIEW OF THE MANAGEMENT OF RADIOACTIVE WASTE AT ORNL

This review was performed for the U.S. Department of Energy by a panel of the Board on Radioactive Waste Management under the National Research Council's Commission on Physical Sciences, Mathematics, and Resources.

In summary, ORNL's waste management practices have kept off-site doses low; some of the practices are temporary and improvised—they may not be as satisfactory in the future; reducing anticipated future releases will be difficult because the limited number of candidate waste disposal locations are characterized by topographic peculiarities; and a major ORNL accomplishment has been the demonstration that hydrofracture can be a successful method of disposal for at least low- and intermediate-level waste.

The panel obtained its information over a two-year period by examining a large body of technical literature, by making six visits to ORNL, and through briefings by representatives of government agencies and their subcontractors.

Reference 16 contains the charge to the panel; descriptions of the site, the waste that is present, and the methods used to handle it; comments on the manner in which the performance of the waste-handling system is monitored, the criteria against which performance is assessed, the panel's assessment of performance, and consideration of alternative methods for future handling of radioactive waste; and a brief comparison of ORNL with other sites. The panel's principal conclusions and recommendations are summarized below. In general, the conclusions and recommendations considered by the panel to be the most important are provided first.

Waste management planning

By virtue of its relatively long history as a leading research establishment in the nuclear programs of the United States, ORNL has had to overcome two principal handicaps in its handling of radioactive waste. First, when the Laboratory was sited, little thought was given—or realistically could have been given—to geological or hydrological factors later found to be critical to waste handling and disposal. Second, as an active facility and center of excellence, ORNL both generated and received from other sites substantial amounts of radioactive waste destined for on-site disposal using the standard, but relatively primitive, methods available during the early stages of its programs. Despite the development of a number of innovative techniques, neither of these handicaps has been overcome. While multiple burial grounds, hydrofracture sites, and special disposal areas have been constructed, used to capacity, and closed, the requirements for new disposal capacity continue to grow, problems with previous sites continue to be recognized, and areas suitable for use under current or reasonably anticipated standards and regulations remain increasingly difficult to find in the Oak Ridge area.

Current ORNL plans for the development of two large new disposal facilities—the Central Waste Disposal Facility (CWDF) on Chestnut Ridge and SWSA 7 between Haw and Copper ridges—are analyzed. CWDF plans are found to be seriously flawed hydrogeologically; SWSA 7 planning remains to be fully developed. The panel, placing itself in the position of an organization facing disposal limitations, discusses briefly some possible alternative approaches. Finally, the panel comments on plans for corrective measures at existing ORNL disposal sites and on plans for decontaminating and decommissioning selected existing facilities.

Principal conclusions

(1) The site that has been chosen for the CWDF is a poor one from hydrogeological considerations for burial of radioactive waste; however, pretreatment of already low-activity waste might reduce releases to satisfactorily low levels.

(2) Current plans for SWSA 7 represent a continuation of recent practices at SWSA 6. The panel believes that water will intrude and that radionuclides will be released. It cannot rule out the possibility that current emissions could increase.

(3) There has been no comprehensive analysis of solid waste management alternatives.

(4) The need to incur substantial costs to stabilize and/or clean up White Oak Creek sediments or to stabilize and/or clean up sediments in holding basins and ponds has not been established by the analyses provided.

(5) The Molten Salt Reactor Experiment (MSRE) facility, as it now stands, contains an inventory of highly radioactive fluoride salts that are safely contained only through the annual recombination of the radiolytically decomposed salts. The extremely toxic and corrosive nature of this inventory, and its transpor-

tability in water, represent a potential for significant radioactive contamination in the event of accidental release.

(6) Insufficient attention has been given by DOE and ORNL to policies that would limit the amounts of radioactive waste (particularly wastes containing ^{90}Sr) that must be disposed by shallow land burial at ORNL.

Principal recommendations

(1) Alternative CWDF sites that are not on karst topography should be sought—or it should be demonstrated that the potential releases would be insignificant.

(2) In view of the inadequacy (to meet projected regulatory requirements) of present burial practices and those now planned, disposal alternatives that promise better confinement of radionuclides should be considered.

(3) Solid waste management strategies should be analyzed comprehensively; a systems approach must be used to avoid creating undesirable impacts at one location while solving a problem elsewhere.

(4) Before substantial funds are expended for the cleanup and stabilization of White Oak Lake sediments, or sediments in the holding ponds and basins, an integrated assessment should be made of the costs and benefits that will be obtained.

(5) DOE should decide what is to be done with the inventory at the MSRE so that firm plans and schedules can be developed promptly for the removal, chemical separation, and disposal of the actinides, fission products, and corrosive salts that remain in the MSRE.

(6) DOE and ORNL should consider adopting policies that limit the radioactive waste that must be disposed at ORNL—by placing elsewhere projects that generate large amounts of radioactive waste, by providing incentives to reduce the amounts of radioactive waste generated, and by refusing waste from other sites.

Disposal of radioactive waste in hydraulically fractured shale

Low- and intermediate-level waste has been successfully immobilized in hydraulically fractured shale at ORNL for the past 15 years. Despite some indications of localized water migration in exceptional circumstances, the panel believes that the approach is worthy of consideration for application elsewhere and for disposal of additional types of waste—although additional research is a prerequisite to broad acceptance.

Principal conclusions

(1) Placement of low- and intermediate-level radioactive waste by hydrofracture at ORNL has been satisfactory to date.

(2) Further application of this process at ORNL requires better understanding of the effects of the emplacement on the host rocks and on the groundwater system.

(3) Application of the methodology to other waste forms and other sites has potential but must be supported by appropriate research.

Recommendations

A series of recommendations is set forth in Ref. 18 to support hydrofracture emplacement of low-level radioactive waste at ORNL and elsewhere and to support extension of the method to other waste and waste forms.

Effectiveness of ORNL waste management practices

It is clear that neither routine operations nor the several special cases identified by the panel will expose ORNL personnel or the general public to health hazards. However, if regulatory authorities further tighten allowable effluent release levels, in conjunction with the fixed size and the geological and hydrological limitations of the ORNL site, this would significantly reduce the margin for error in waste management operations.

Principal conclusions

(1) The routine off-site effluents from ORNL radioactive waste operations do not present a health hazard.

(2) During the past 20 years, ORNL has achieved large reductions in the amount of radioactive material released as process waste. These reductions cause the contribution from burial grounds and the pits and trenches area to take on greater significance. Further efforts to reduce the small amount of radioactive material released from the process waste systems do not appear to be necessary.

(3) Attempted mitigating actions such as shortening trench length, placing impervious covers over trench caps, or diverting surface water around burial trenches may provide temporary reduction in ^{90}Sr outflow, over a few years; however, the effectiveness of these measures over much longer periods of time remains to be proven.

(4) Strontium-90 appears to be the primary radionuclide that may cause effluents to exceed current or future standards for release at White Oak Dam. Any new source of ^{90}Sr buried in the near-surface shale can be expected to add to the total discharge at White Oak Dam, unless adequate measures are taken to control its release.

(5) Tritium, as the next most important contributor to off-site dose from liquid effluents, must also be disposed with more consideration given to reducing its discharge to White Oak Creek.

(6) Catastrophic washout of White Oak Creek sediments would produce 3 and 5 millirem, respectively, to people consuming drinking water and eating fish from the Clinch River.

Recommendations

(1) Before establishment of new burial grounds in the White Oak drainage basin, future releases of ^{90}Sr and ^{3}H from SWSAs 3, 4, 5, and 6 and the seepage pits and trenches must be predicted quantitatively—and shown not to exceed regulatory standards.

(2) Corrective actions should be taken on burial grounds either where release of ^{90}Sr and ^{3}H is expected to increase in the future or where a substantial decrease of current ^{90}Sr and ^{3}H release can be attained at reasonable cost.

(3) Research should be conducted with the aim of obtaining a better understanding of the implications of both the groundwater and the streambed sediment data, so that they can be coupled and put to effective use in predicting long-term trends of releases.

(4) Groundwater migration at SWSA 3 should be studied in detail to obtain a better understanding of the influence of solution cavities on radionuclide transport from burial trenches.

(5) More extensive use should be made of groundwater monitoring at SWSA 6 to

compensate for the limitations of the surface water monitoring system at that site.

(6) ORNL should determine the extent to which radionuclide migration has occurred from the pits and trenches area. This should be done through the installation of a properly located and constructed monitoring system. There should be more frequent sampling of existing and new wells, as well as gathering of data from seeps, surface water, and lysimeters.

(7) ORNL should take action to ensure that process waste pipes do not leak into the sanitary sewer system.

Regulation of radiation exposure in the United States

Operations have been conducted at ORNL for over 40 years, and throughout that time the regulatory climate has become increasingly more challenging because (1) the release limits have been continually tightened, and (2) there are more regulatory agencies with jurisdictions that appear to overlap and with requirements not always clearly defined.

Principal conclusion

The regulatory criteria that now apply and those likely to apply in the future are diverse. An example of change is the recent application of the RCRA to ORNL.

Monitoring

An extensive system is in place for the monitoring of gaseous, liquid, and solid waste at ORNL. Monitoring system data have been collected and published for many years, and system improvements have been undertaken from time to time. There remain, however, several areas in which additional monitoring should be undertaken.

Principal conclusions

(1) The present method of estimating how much radioactive material is being discharged to the Clinch River either by seepage under White Oak Dam or by SWSA 3 leakage to Raccoon Creek is inadequate.

(2) The present monitoring network fails to monitor on-site and off-site concentrations of ^{3}H in air.

Recommendations

(1) ORNL should develop modeling programs that will use geologic, hydrologic, and geochemical test results as well as other pertinent monitoring data to predict the migration of leachate from radioactive waste.

(2) A better estimate of the migration of radionuclides to the Clinch River by seepage under White Oak Dam and by leakage from SWSA 3 to Raccoon Creek should be developed.

(3) The air monitoring system should be upgraded to include on-site and off-site measurements of ^{3}H in air.

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6. QUALITY ASSURANCE AND TECHNICAL REVIEWS

6.1 RADIOLOGICAL

All the analytical laboratories at the Oak Ridge plants maintain internal control programs that use known solutions of radionuclides for calibration, instrument checks, and general procedure control. Certified standards from other DOE laboratories or from the National Bureau of Standards (NBS) are often used in such control work.

A very significant externally operated program is the Quality Assurance Program, administered by the DOE Environmental Measurements Laboratory (EML) in New York. All the plant laboratories participate in this program, which currently provides quarterly samples of five types of environmental media—soil, water, air filters, vegetation, and animal tissue—each containing from five to nine radionuclides at levels known to EML. Analytical results are returned each quarter to EML, where statistical evaluation is made and periodic reports are issued to each participant, showing how the participants' results compare with the established values and with the results of other laboratories. Participation is mandatory for parameters of concern to the particular plant and optional for parameters that do not apply.

The laboratories at the Oak Ridge plants are also general participants in voluntary national radionuclide quality assurance (QA) programs administered by other DOE sites, especially Los Alamos, New Mexico. The Oak Ridge laboratories are especially active in such programs because of their range of radionuclide interests; their analytical performance has had excellent agreement with standards.

In addition, during 1985 ORNL participated in the Eighth International Environmental Dosimeter Intercomparison Project. The ORNL means for the pre-irradiated, field, and laboratory dosimeters fell within the confidence interval for the standards.

6.2 CHEMICAL

All the analytical laboratories have established internal programs designed to provide reliable calibration of instruments and evaluation of analyst performance in the measurement of a wide range of chemical pollutants in environmental media.

Another effective external quality control (QC) program is also in place; it uses certified solutions purchased from commercial sources. Monthly samples that contain a host of common pollutants, including trace metals, residual chlorine, cyanide, phenol, nitrogen, organic carbon, grease and oil, minerals, and other impurities (all at environmental levels certified by the vendor) are sent to each laboratory quality control officer. Obtained as from unknown samples in the laboratory, the analytical results are transmitted to the Y-12 Plant Quality Division for statistical review. Periodic reports sent to each of the four laboratories compare results with the certified values and with those of the other laboratories.

All the plant laboratories participate in the National Quality Assurance Program, administered by the EPA to support the NPDES. Known standards are submitted, on a request basis, to the laboratories for analysis of parameters designated in the current permits. Results are sent to the regulator, where evaluation and followup on deficiencies at specific laboratories are coordinated. All laboratories generally perform within the EPA's acceptance range on all permit parameters. ORNL results, for example, fell within 10% of the known values in 1985, which was acceptable to the regulators. Typical performance evaluation reports for the ORNL and ORGDP NPDES programs are given in Table 6.2.1 and Table 6.2.2, respectively.

These annual performance evaluations should be viewed as "spot checks" of quality; they are not a substitute for the daily QC activities conducted by all laboratories.

6.3 GENERAL

The Energy Systems' Committee on Environmental Analysis was established in 1977 to provide a uniform basis for measuring environmental pollutants and to ensure that measurement sensitivity, quality, and methodology remain in accord with the federal and state requirements for environmental monitoring. The resulting Environmental and Effluent Analysis Manual[1] emphasizes laboratory procedures used for measuring parameters that appear on the NPDES permits or air discharge permits of any of the Oak Ridge plants. The manual details 111 analytical procedures for water, air, sediment and soil, biota, and miscellaneous media such as oil under test for reuse. Procedures for both radiological and nonradiological parameters are included. EPA-approved analytical methods are used whenever possible.

This committee also coordinates special quality control programs of interest to all plants, such as the measurement of fluorides in air or PCBs in oil. It has also been instrumental in the generation and evaluation of proposed analytical control standards, such as PCBs in transformer oil and ^{99}Tc in grass and soil. The committee has also accepted responsibility for overseeing the reliability of certain external quality control standards, including those generated and certified by a commercial source.

Quality assurance in environmental monitoring has become a well-accepted responsibility at all of the plants. The program is especially developed to keep pace with the broad surveillance responsibilities assumed by that facility for both radiological and nonradiological monitoring in the Oak Ridge area. This program includes:

(1) operating procedures for each activity;

(2) inspection lists of operating and maintenance activities;

(3) check-off frequency lists for all QA steps, such as schedules for equipment inspection and test control;

Table 6.2.1. Performance evaluation report
DMR-QA study number 005
Oak Ridge National Laboratory

Parameters	V P	Report value	True value[a]	Acceptance limits	Warning limits	Performance evaluation
Trace metals (μg/L)						
Aluminum	X	1110	1074	847–1310	909–1240	Acceptable
Arsenic	X	76.0	84.1	59.3–108	65.8–102	Acceptable
Beryllium	X	110	111	92.3–133	97.7–128	Acceptable
Cadmium	X	390	391	345–441	357–429	Acceptable
Chromium		63.0	66.2	48.9–82.5	53.2–78.2	Acceptable
Cobalt	X	670	762	628–866	661–833	Acceptable
Copper	X	650	694	606–764	626–744	Acceptable
Iron	X	1500	1558	1320–1780	1380–1720	Acceptable
Lead	X	250	250	198–300	211–287	Acceptable
Manganese	X	720	803	704–888	728–864	Check for error
Mercury	X	7.2	7.19	4.47–9.77	5.17–9.08	Acceptable
Nickel	X	300	288	244–330	255–319	Acceptable
Trace metals (μg/L)						
Selenium	X	50.0	60.6	31.5–78.9	37.8–72.6	Acceptable
Vanadium	X	433	450	361–557	390–528	Acceptable
Zinc	X	190	201	168–234	176–225	Acceptable
Miscellaneous parameters						
pH (units)		5.94	6.00	5.85–6.13	5.89–6.10	Acceptable
Total suspended soils (mg/L)		78.0	95.3	77.4–106	81.0–103	Check for error
Oil and grease (mg/L)		18.9	19.0	9.60–25.6	11.7–23.5	Acceptable
Nutrients (mg/L)						
Ammonia-nitrogen		3.1	3.10	2.42–3.72	2.58–3.56	Acceptable
Nitrate-nitrogen	X	0.16	0.152	0.0788–0.234	0.0979–0.215	Acceptable
Kjeldahl nitrogen	X	2.0	2.20	1.39–3.14	1.61–2.92	Acceptable
Total phosphorus	X	6.0	7.10	5.57–8.65	5.95–8.27	Acceptable
Nutrients (mg/L)						
Orthophosphate	X	4.3	4.39	3.76–5.10	3.92–4.93	Acceptable
Demands (mg/L)						
COD		130	128	99.9–145	106–140	Acceptable
TOC	X	53.0	50.5	37.7–61.9	41.0–58.6	Acceptable
5-day BOD		86.0	83.5	43.0–113	52.0–104	Acceptable

[a] Based upon theoretical calculations, or a reference value when necessary.

Table 6.2.2. Performance evaluation report
DMR-QA study number 005
Oak Ridge Gaseous Diffusion Plant

Parameters	V P	Report value	True value[a]	Acceptance limits	Warning limits	Performance evaluation
			Trace metals (mg/L)			
Aluminum		1180	1074	847-1310	909-1240	Acceptable
Arsenic		101	84.1	59.3-108	65.8-102	Acceptable
Beryllium		115	111	92.3-133	97.7-128	Acceptable
Cadmium		399	391	345-441	357-429	Acceptable
Chromium		69	66.2	48.9-82.5	53.2-78.2	Acceptable
Cobalt	X	736	762	628-866	661-833	Acceptable
Copper		691	694	606-764	626-744	Acceptable
Iron	X	1570	1558	1320-1780	1380-1720	Acceptable
Lead		255	250	198-300	211-287	Acceptable
Manganese	X	831	803	704-888	728-864	Acceptable
Mercury		4.0	7.19	4.47-9.77	5.17-9.08	Not acceptable
Nickel		296	288	244-330	255-319	Acceptable
Selenium		56	60.6	31.5-78.9	37.8-72.6	Acceptable
Vanadium	X	458	450	361-557	390-528	Acceptable
Zinc		207	201	168-234	176-225	Acceptable
			Miscellaneous parameters			
pH (units)		6.0	6.00	5.85-6.13	5.89-6.10	Acceptable
Total suspended solids (mg/L)		108	95.3	77.4-106	81.0-103	Not acceptable
Oil and grease (mg/L)		16.5	19.0	9.60-25.6	11.7-23.5	Acceptable
			Nutrients (mg/L)			
Ammonia-nitrogen		3.2	3.10	2.42-3.72	2.58-3.56	Acceptable
Nitrate-nitrogen		0.15	0.152	.0788-0.234	0.0979-0.215	Acceptable
Orthophosphate		4.47	4.39	3.76-5.10	3.92-4.93	Acceptable
			Demands (mg/L)			
COD		125	128	99.9-145	106-140	Acceptable
TOC		45.8	50.5	37.7-61.9	41.0-58.6	Acceptable
5-day BOD		71.0	83.5	43.0-113	52.0-104	Acceptable

[a] Based upon theoretical calculations or a reference value when necessary.

(4) documentation of compliance with QA procedures;

(5) participation in intralaboratory and interlaboratory sample-exchange programs;

(6) evaluation of the adequacy of sample preparation work and data analysis; and

(7) identification of the role, responsibilities, and authority of each staff member as related to quality assurance.

Several of the ANSI Standards[2-4] available for environmental sampling and data handling are being implemented in the environmental monitoring program. The American Chemical Society Committee on Environmental Improvement guidelines[5] on data acquisition are being considered for implementation.

Figure 6.3.1 is a schematic diagram showing a flow chart of this QA program. A sample flow and feedback loop on environmental surveillance is shown in Fig. 6.3.2. Several studies have been completed on the development of QA in environmental sampling. More detailed discussions of this QA program have been presented elsewhere.[6-11]

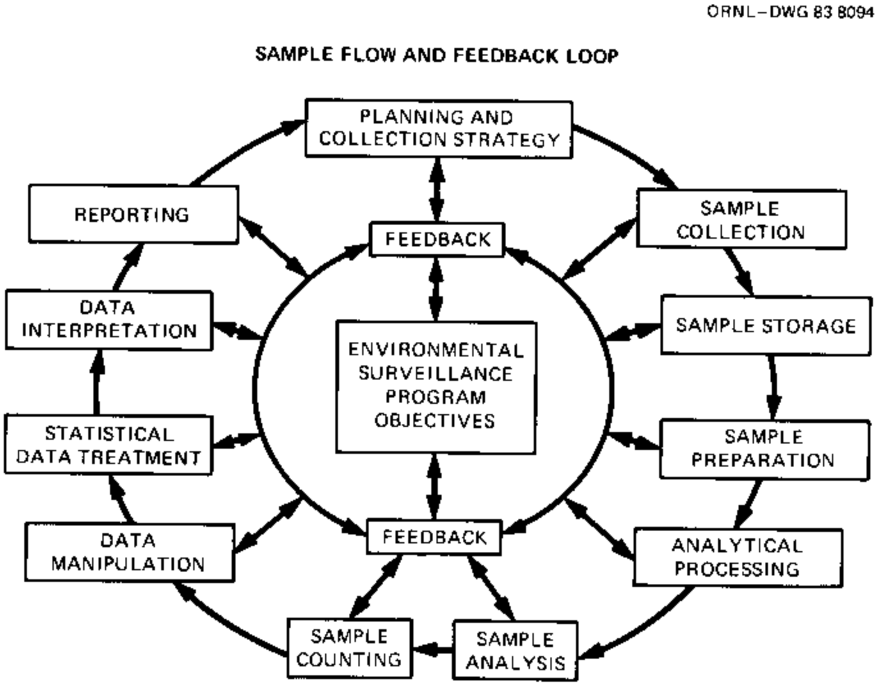

Fig. 6.3.1. Schematic diagram showing flow chart of QA program.

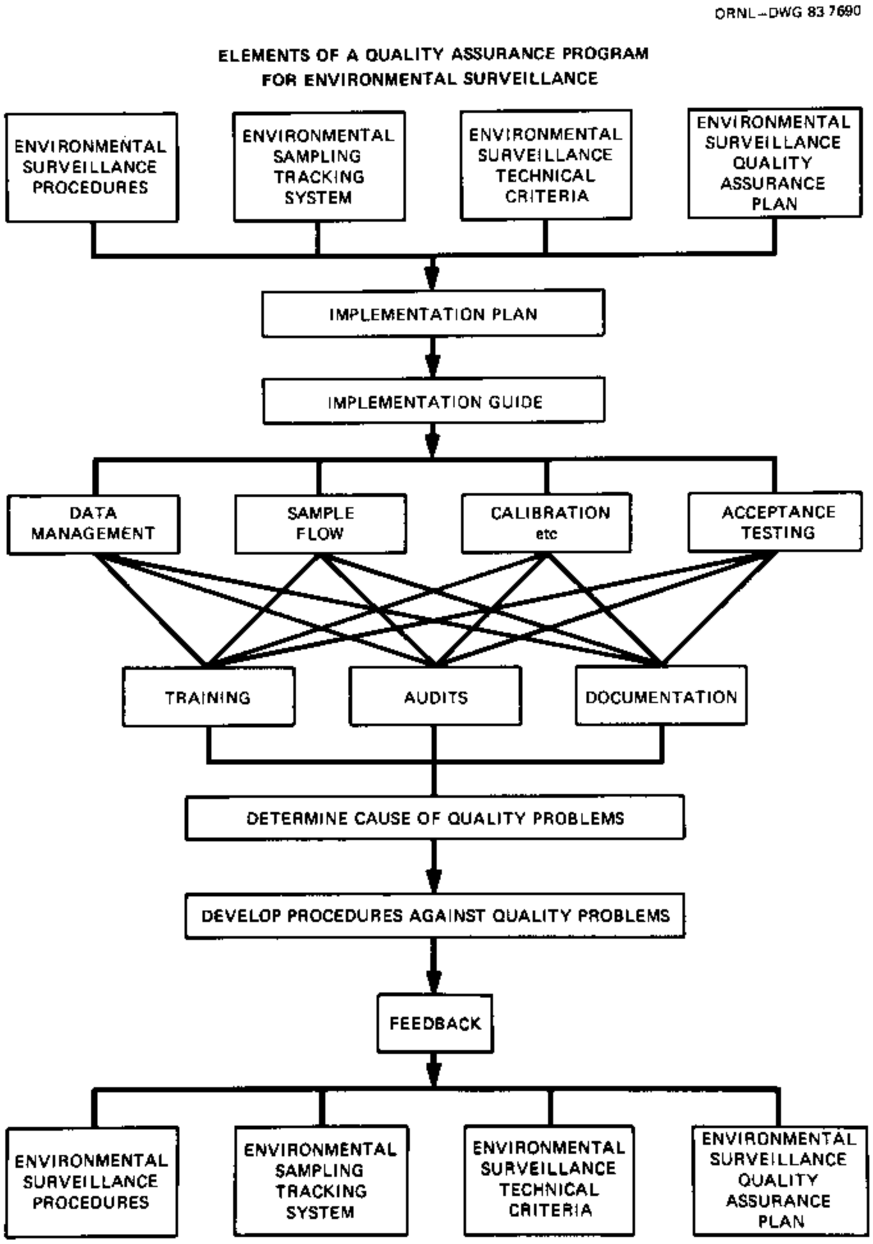

Fig. 6.3.2. Environmental surveillance sample flow and feedback loop.

6.4 EPA QUALITY ASSURANCE PERFORMANCE AUDIT INSPECTION

During the week of July 15, 1985, representatives of the EPA Region IV conducted a second performance audit to assess the reliability of the environmental monitoring database being generated by the DOE Y-12 Plant and the ORAU facility in Oak Ridge. Staff of the TDHE participated in the audit but did not generate a separate inspection report. The first audit was conducted in June 1984. The Y-12 Plant is involved in extensive sampling and analysis programs related to pollution control, and ORAU is examining the extent of pollutant migration to the community of Oak Ridge, downstream on East Fork Poplar Creek. Monitoring data collected in these efforts will serve as the basis for planning environmental remedial actions, as agreed upon in the Memorandum of Understanding between DOE and the EPA/TDHE, dated May 26, 1983.

The audit covered the field monitoring and laboratory analytical programs conducted by the Y-12 Plant, ORAU, and ORNL for soil and sediments associated with the Y-12 Plant or the Oak Ridge community and for groundwater and NPDES outfalls related to the Y-12 Plant. Separate groups inspected the field methodologies and the laboratory support functions.

The audit team found no evidence that any portion of the environmental database should be invalidated, although it made several recommendations for strengthening the quality of the program. With all of the DOE Oak Ridge facilities conducting similar programs of monitoring NPDES effluents, groundwaters, soils, and sediments, the auditors recommended that a unified document be generated to standardize the sampling methodology. A task team, including representatives of all the Oak Ridge facilities, was subsequently formed and is working toward that goal. This work is expected to result in a collection of methods, based on recommendations by the American Society for Testing and Materials and by EPA, which may serve as a standard for other DOE facilities. The review found that Y-12's NPDES self-monitoring program is now consistent with permit requirements currently in effect.

The EPA audit found that the laboratories that support the monitoring programs are providing results of generally good quality; however, several recommendations were made. Full isolation of the low-level environmental measurement work was recommended for the Y-12 Plant laboratory; the Plant is moving toward that objective. Some deficiencies in sample preservation and holding times were noted, and these have been corrected. Increased emphasis has been placed on QA documentation, records retention, and other minor deficiencies at the Y-12 Plant. The ORAU laboratory has also improved its QA procedures and has satisfied the EPA on analytical methodology since the 1985 audit. More interplant sample exchange is being implemented as a result of the EPA recommendations, and several reference materials, particularly contaminated soils, are being developed for general use in laboratory quality control.

The improvements in field and analytical methodologies will continue, and both will be subjected to internal inspections on a timely basis. It is also expected the EPA/TDHE audit of 1985 will be followed by other inspections to document that compliance with regulations is complete.

6.5 TECHNICAL REVIEW OF THE Y-12 PLANT RADIOLOGICAL EFFLUENT AND ENVIRONMENTAL MONITORING PROGRAM

An evaluation of the program for monitoring radioactive contaminants in effluents and the environment of the Y-12 Plant was conducted June 17-21, 1985, by a team organized by ORAU. This evaluation included a review and assessment of the monitoring programs, procedures, and equipment. No evidence of conditions that pose a potential danger to public health and safety was noted. In several areas, additional data should be developed to confirm an acceptable level of environmental protection.

Control and monitoring activities must be consistent with regulations and should be in accordance with methods of "accepted good practice" for comparable industries and DOE's ALARA philosophy. With respect to these criteria, some aspects of monitoring procedures, documentation, and QA are deficient. In addition, the techniques and equipment presently used for stack monitoring are such that there is considerable doubt as to the adequacy and accuracy of the air emissions data.

The findings of this review team are summarized below. The Y-12 Health, Safety, Environment, and Accountability Division staff has recognized some of the deficiencies and potential problem areas in the effluent and environmental monitoring program. In certain cases, additional evaluations and/or improvements have already been initiated. However, a comprehensive plan for identifying deficiencies and a schedule for achieving improvements related to the environmental monitoring activities have not been developed. It was also apparent the environmental monitoring staff has not had sufficient time and/or opportunity to develop familiarity with facility operations and existing emissions control equipment.

The remainder of this section summarizes findings and recommendations of this review as related to specific program areas. Further information is to be found in the report.[12] It should be noted that certain of the recommendations provide only one suggested approach; there may be alternative approaches that would be acceptable. A summary of the recommendations from the body of the report according to categories of short-term and long-term priorities is given in the Executive Summary.[12]

The environmental monitoring staff has recently been assigned additional responsibilities for effluent and environmental monitoring; however, the present staff does not have adequate expertise or manpower to conduct the comprehensive environmental program as currently assigned. This situation has been recognized, and additional professional and technical personnel are being recruited. Another problem, somewhat related to staffing, is the fragmentation of monitoring programs among several departments, without the existence of well-defined and documented responsibilities or a focal point for the program. More authority and responsibility for these programs must be assigned to the environmental monitoring staff.

Documented, detailed procedures do not exist for most of the effluent and environmental monitoring activities. Procedures and protocols covering sample collection, handling, and analysis; responsibilities; equipment descriptions; preventive maintenance; calibration; training; record keeping; and response to off-normal situations should be developed as soon as possible.

Major radioactive air emission sources at the Y-12 Plant are the 112 exhaust ventilation systems for the uranium production operations; depleted, natural, and enriched uranium isotopic distributions are possible. Not all systems are equipped with emission controls or are continuously monitored. Selection of systems for monitoring was based on earlier evaluations and may not represent present conditions. The Y-12 Plant is conducting additional characterization studies of air emissions and proposes to reduce the number of release points and provide continuous monitoring for all stacks by 1991.

Inspection of selected stack sampling systems identified a large number of deficiencies. The entire stack monitoring program is in need of re-evaluation and upgrading of sampling equipment.

A change of the major theme of the program from materials accountability to environmental compliance is needed.

Air monitoring is performed at 11 locations on the Y-12 Plant perimeter. However, the sample locations were selected without a thorough evaluation of local meteorological conditions. It is, therefore, possible that samples from the locations may not be truly representative of uranium concentrations at the Y-12 Plant perimeter. After site-specific meteorological information is available from the new Y-12 meteorological towers, modeling should be performed to confirm the suitability of these locations. Off-site monitoring stations on Pine Ridge and near the location of the maximally exposed individual are also recommended.

Analytical procedures for stack (and perimeter air) samples are adequate to detect less than 10% of the DOE unrestricted area guideline for uranium. Stack calculations are performed by computer; while the computer program uses factors such as probe loss correction and activity calculation, these have not been verified. Also, the actual sampled volume is not used for calculations. Analyses are limited to uranium; some additional analyses are needed to verify that other radionuclides, normally encountered as contaminants in recycled uranium, are not present at significant levels.

Calculations of population doses in the vicinity of the Y-12 Plant have been performed using 1985 air emissions data and the AIRDOS/DARTAB computer code. The results indicate that Y-12 is in compliance with NESHAP, but many of the parameters, such as particle size distribution, lung solubility class, accuracy of source term data, and local meteorological conditions are in question.

Monitoring of radionuclide concentrations in liquid effluents appears to be adequate, and releases are well within acceptable regulatory limits. Permit changes have increased the number of NPDES monitoring points to 236, 8 of which are believed to require monitoring for radionuclides. This has resulted in a substantial increase in manpower and equipment requirements.

Confirmation of the flow measurements at the East Fork Poplar Creek and Bear Creek stations is recommended. There is doubt about the calibration of the double weir at the Bear Creek station. Metering data of the USGS and TVA on these same streams should be obtained for comparison with Y-12 determinations. A procedure for calibration of liquid effluent sampling equipment should be developed.

A major effort is under way to characterize the geohydrology in the Y-12 site area and to provide additional locations for groundwater monitoring. Three different consulting firms have been involved in this effort. During 1985 approximately 100 new wells were added to the 29 wells already being monitored by Y-12.

Many of the older wells were installed a number of years ago. There is incomplete information regarding the construction of the wells and corresponding geology. Some of the wells have been damaged. Well casings are unsealed, and some wells do not have caps. Efforts should be made to obtain installation information on the older wells, and their condition should be upgraded where practical.

A water level contour map should be developed. This will probably require some additional wells on the main plant site, near the S-3 Ponds, along the groundwater divide, and near the exit of East Fork Poplar Creek from Bear Creek Valley. ORNL has conducted extensive geohydrologic studies of Conasauga shale formations, and this resource should be used.

New, improved well monitoring procedures were implemented in late 1984. Because of the previous sampling techniques used, there was a potential for cross-contamination of wells and samples; hence, there is some unreliability in the historic groundwater monitoring data.

Limited sampling of soils and sediments in the vicinity of Y-12 is performed by ORNL as part of the monitoring program for the ORR. This sampling is not sufficient to characterize off-site contamination along Bear Creek and in the prevailing downwind direction from the uranium production area. The limited information also does not permit establishment of patterns and trends. Additional sampling of soils and sediments within the environment of the Y-12 Plant should be conducted by the Y-12 Environmental Monitoring staff, either alone or in conjunction with ORNL.

Y-12 is committed to a comprehensive program to improve waste management technology and reduce waste volumes. Numerous studies and projects are planned or already in progress. The panel had no specific recommendation for the monitoring program as related to radioactive waste management.

Procedures for analysis of effluent and environmental samples appear adequate, although many are 5 to 7 years old and have not incorporated recent developments and state-of-the-art techniques. Most procedures are currently being revised to convert from the Union Carbide to the Energy Systems format. Appropriate upgrading of these procedures should be performed as part of the format change, and a requirement for annual review is recommended.

The Quality Division has overall Y-12 Plant QA responsibility; each division, department, or program is responsible for developing and maintaining its own internal QA/QC program. However, such programs for the activities of the environmental monitoring staff have not been developed. Specific QA/QC provisions, which are typically incorporated into individual procedures, do not exist for environmental monitoring activities because the procedures are not yet documented. Most individual analytical procedures include specific QA provisions, but there is no overall QA plan for the analytical laboratory. QA plans should be developed for the environmental monitoring and analytical programs, and specific QA/QC provisions should be incorporated into various environmental monitoring procedures as they are developed.

Environmental and effluent radioactivity data do not routinely include uncertainties. Where uncertainties are provided, they are limited to uncertainties related to statistics of radioactive decay; other possible error factors are not propagated throughout computations. (Also, some stack release data are reported as zero, rather than providing the minimum detectable level.) It is recommended that the EPA report *Upgrading Environmental Radiation Data*[13] be consulted regarding generation and use of environmental and effluent monitoring data at Y-12.

There is no documented environmental monitoring staff guidance regarding the review and acceptance (or rejection) of monitoring and analytical data; such guidance should be developed.

It is planned that environmental and effluent data will be computerized for ease of retrieval and evaluation. Programs to evaluate trends should be obtained and their use implemented.

More detailed information on this review is available in Ref. 12. Action plans to complete all of the recommendations from this review have been completed and action has begun to implement these recommendations.

6.6 TECHNICAL REVIEW OF THE ORNL RADIOLOGICAL EFFLUENT AND ENVIRONMENTAL MONITORING PROGRAM

An evaluation of the program for monitoring radioactive contaminants in effluents and the environment of ORNL was conducted June 24-28, 1985. This evaluation included a review and assessment of the monitoring programs, procedures, and equipment. No evidence of conditions that pose a potential danger to public health and safety was noted.

Control and monitoring activities must be consistent with regulations and should be in accordance with methods of accepted good practice for comparable industries and DOE's ALARA philosophy. With respect to these criteria, some aspects of monitoring procedures, documentation, and QA are deficient. In certain areas the review panel was left with the impression that ORNL is pursuing high technology monitoring approaches without a thorough evaluation of the significance of the data being generated and without an adequate assessment of the need for or applicability of selected high technology solutions to specific monitoring problems. While large expenditures are incurred for such approaches, there appears to be a tendency to skimp or cut corners in other vital areas, such as laboratory supplies and facilities. The findings of the review team are summarized below.

The ORNL staff has recognized many of the deficiencies and potential problem areas and has already initiated steps for further evaluation and/or improvements. Assistance in the form of technical guidance and funding support will be required from DOE to correct some of these deficiencies.

Additional information can be found in Ref. 14. It should be noted that certain of the recommendations provide only one suggested approach and that there may be alternative approaches that would be acceptable. A summary of the recommendations from the body of the report according to categories of short-term and long-term priorities is given in the Executive Summary.[14]

The environmental monitoring staff demonstrates the attitude and initiative necessary to the achievement of an effective environmental program. The staff has adequate expertise and manpower to conduct the comprehensive environmental program as currently assigned. However, the Environmental Monitoring staff lacks familiarity with plant operations and the controls and systems in use. A somewhat related problem is the fragmentation of monitoring program activities among several organizational units, without the existence of well-defined and documented responsibilities. More authority and responsibility for these programs must be assumed by the environmental monitoring staff.

Documented procedures have been prepared for most of the effluent and environmental monitoring activities. In many cases these procedures are not currently being followed, they contradict other documents, and they are incomplete. Procedures are not revised on an established schedule or reviewed and approved by division QA and administrative personnel.

Major radioactive air emission sources at ORNL are the seven exhaust ventilation systems for the major research and production areas of the plant. All ventilation systems are equipped with emission controls and are continuously monitored. Inspection of three stack sampling systems identified a number of deficiencies and questionable procedures. General aspects of the stack monitoring program are in need of re-evaluation, including upgrading of certain sampling equipment. Air monitoring is performed at 10 locations on the plant perimeter, 23 locations within the plant perimeter, and 7 remote locations. The construction of the perimeter and remote air monitoring stations may bias the sample results because the intake and exhaust are both confined inside the shelter. The design of these units should be changed.

Monitoring of radionuclide concentrations in liquid effluents generally appears to be adequate. Since White Oak Creek is the principal transport mechanism for liquid effluents leaving the site, the sediments in WOC and White Oak Lake contain contamination that could be transported past White Oak Dam during high runoff. A study to determine the best method of sediment stabilization should be performed, and a better monitoring system for sediment migration during high flows should be implemented.

In general, the monitoring wells are in poor condition, requiring repair, cleaning, and/or capping. Additional wells are recommended in the areas of SWSAs 4, 5, and 6 to characterize the leaching of radionuclides from the trenches. The current groundwater behavior information is inadequate to evaluate the migration pathways from the site. A detailed study of the local groundwater is recommended.

The monitoring programs for other terrestrial and biological media appear to be thorough and in accordance with generally accepted or standard procedures. More definitive documentation of sampling locations and conditions would improve data reliability and sample uniformity.

ORNL is committed to a comprehensive program to improve waste management technology and reduce waste volumes. Numerous studies and projects are planned or already in progress. The panel has no specific recommendation for the monitoring program as related to radioactive waste management.

Procedures for analysis of effluent and environmental samples appear generally adequate. However, some procedures are outdated and have not incorporated state-of-the-art techniques or protocols. Appropriate upgrading of the procedures should be performed and a requirement for regularly scheduled reviews established. Use of "real world" samples for calibration and QA/QC is recommended.

Environmental and effluent radioactivity data do not routinely include uncertainties; where uncertainties are provided, they are limited to those related to statistics of radioactive decay, and other possible error factors are not propagated throughout the computations. Methods for reporting uncertainties, zeros, and negative values should be reviewed. It is recommended that the EPA report *Upgrading Environmental Radiation Data*[13] be consulted regarding generation and use of environmental and effluent monitoring data at ORNL.

The overall QA plans of ORNL and the Environmental and Occupational Safety and Analytical Chemistry divisions are commendable. Most individual procedures have specific QA provisions. However, some aspects of the environmental monitoring staff QA program have not been documented or implemented. There is a lack of documented followup on problems and malfunctions. An increase in periodic equipment operational checks and inspections and field procedure observation by environmental monitoring staff is recommended. More detailed information can be obtained from the review report.[14] Action plans have been developed to comply with these recommendations. Actions have been taken to implement these recommendations.

6.7 TECHNICAL REVIEW OF THE ORNL NONRADIOLOGICAL EFFLUENT AND ENVIRONMENTAL MONITORING PROGRAM

A technical review of ORNL's nonradiological effluent and environmental monitoring was conducted June 3 through June 7, 1985.[15] This review was conducted by Energy Systems staff members at the request of the DOE to permit interchange of expertise as well as to evaluate ORNL's program. Based on information provided, ORNL's nonradiological monitoring is extremely limited. There is only one ambient air monitor, three NPDES monitoring stations, no sediment program, no water quality groundwater monitoring wells, few RCRA samples, twice-a-year grass samples, and only PCB and mercury analysis in fish and wildlife.

Monitoring should be upgraded in several areas. Ambient air is not sufficiently sampled to reveal the presence of pollutants because there is only one nonradiological ambient sampler; a sediment sampling program needs to be implemented to complement surface water and fish and aquatic life nonradiological data; appropriate groundwater monitoring wells should be installed; and fish and wildlife analysis programs should be expanded to include bioaccumulation studies and long-term exposure effects. Programs for analysis are quite good but are very labor-intensive. Analytical laboratories need upgraded equipment. There is little indication of preparation for a substantially increased sampling and analytical load, which is evidently inevitable. There will apparently be a demand for technicians to secure and analyze samples. Additional technicians should be secured and trained sufficiently early to accommodate the increase.

Analysis of samples uses accepted methods by well-trained and competent technicians. However, with the exception of the "8600 Protocol" the analyses are not very cost-effective. Much manual work is required and Analytical Chemistry Division does not seem well equipped to routinely handle large volumes of samples in a cost-effective manner. Generally, analytical work is accurate and timely, but there is not much evidence of preparation, either in equipment or personnel, for the sample load that can be reasonably anticipated in the not-too-distant future.

Chain of custody for field samples needs to be reviewed and strengthened. A written procedure should be prepared and implemented to provide for irrefutable chain of custody. There is some evidence that current informal procedures are not always followed; therefore, control features need to be established to ensure application of all features of the procedure.

Interface between representatives of different Energy Systems plants is a valuable tool in the transfer of information. What was learned at ORNL can be of value to the other Energy Systems facilities in evaluating their programs and continuing the upgrading of environmental monitoring.

6.8 TECHNICAL REVIEW OF THE Y-12 PLANT NONRADIOLOGICAL EFFLUENT AND ENVIRONMENTAL MONITORING PROGRAM

A thorough technical review of the Oak Ridge Y-12 Plant nonradiological effluent and environmental monitoring and sampling program was conducted July 8 through 12, 1985.[16] This review was conducted by Energy Systems staff to permit interchange of expertise as well as to evaluate the Y-12 program. Based on information reviewed, Y-12 has some very strong areas such as chain-of-custody forms and compliance work on the new NPDES permit.

During the review a number of areas were revealed that need to be upgraded. This review resulted in a number of recommendations, most of which are major needs. The recommendations are divided into 18 categories. To assist in the preparation of the action plans and to help in the division of responsibility, some recommendations are repeated in several categories (e.g., QA plan). Furthermore, many of the concerns identified during this audit have been or are currently being addressed. As such, the number of recommendations is not an indication of the overall status of the Y-12 Plant nonradiological effluent and environmental monitoring program. Knowing that all of these recommendations cannot be completed at one time, a priority system for evaluation was established (from 1 to 5, with 1 being the highest priority and 5 being the lowest). Each recommendation is also divided into major or minor categories as an indication of the resources estimated to complete this recommendation. The areas needing the most improvement are air monitoring, QA/QC, field procedures, documentation, groundwater sampling, spill prevention control and countermeasures plan, and biological monitoring. Table 6.8.1 is a summary of the number of recommendations by category and by priority.

Interface between representatives of different Energy Systems plants results in valuable transfer of information. It is intended that what was learned at Y-12 can be of value to the other Energy Systems facilities in evaluating their programs and continuing the upgrading of environmental monitoring.

Table 6.8.1. Summary of recommendations

Category	Priority					Total	Resources required	
	1	2	3	4	5		Major	Minor
General recommendations								
General	11	4	2	4	1	22	16	6
Specific recommendations								
Procedure review	2	0	2	3	0	7	4	3
DOE orders	1	1	0	1	0	3	3	0
Surface water	2	2	1	1	2	8	6	2
Mercury sampling program	0	1	0	0	0	1	1	0
NPDES compliance	2	3	0	1	0	6	2	4
Emergency sampling	0	0	1	0	0	1	1	0
SPCC plan	6	4	3	0	1	14	7	7
Air monitoring	4	2	0	1	0	7	6	1
Groundwater	3	2	3	0	0	8	8	0
Sample container preparation	0	0	1	0	1	2	1	1
Analytical chemistry	2	0	1	1	0	4	3	1
Biological monitoring	1	3	2	2	2	10	8	2
QA/QC in the laboratory	1	3	1	0	0	5	5	0
QA/QC in sample preparation	0	0	1	1	0	2	2	0
QA/QC data	0	0	1	0	0	1	1	0
Sample chain of custody	0	1	1	0	0	2	2	0
Hazardous waste	0	7	4	2	0	13	10	3
Total	35	33	24	17	7	116	86	30

Source: Ref. 16

6.9 TECHNICAL REVIEW OF THE ORGDP ENVIRONMENTAL MONITORING PROGRAM

6.9.1 Overall Assessment

An environmental audit of the ORGDP was conducted by a team of NUS scientists and engineers during the week of June 3 through June 7, 1985. The team evaluated ORGDP in terms of compliance with environmental regulations and DOE orders, the adequacy of pollution control equipment, the effectiveness of environmental monitoring, and the application of QC procedures to environmental programs. The audit was conducted by observing operations, inspecting facilities, evaluating analysis and monitoring techniques, reviewing reports and data, and interviewing personnel.

Overall, the ORGDP environmental monitoring program appears to be well structured and has attempted to address all areas of air, water, and land media likely to be affected by the operations of the facility. The plant management is knowledgeable about environmental concerns and has established clear, well-defined goals to address these areas. An adequate professional staff is available to manage the environmental program.

No imminent threat to public health and safety was identified by the audit; most potential sources of emission/ effluent from the plant have been well identified and the pollution control equipment is appropriate and effective. Certain deficiencies in the environmental monitoring program, however, limit confidence in the data that are collected. These deficiencies center around the lack of an acceptable groundwater monitoring program, the validity of air monitoring data, and the representativeness of samples taken for radiological monitoring.

6.9.2 Strengths of the Program

The audit highlighted several strengths of the ORGDP environmental management program including a good understanding and implementation of regulations and orders, good identification of waste streams, and good management of pollution control facilities. These strengths result in a high rate of compliance with environmental discharge standards.

Wastewater treatment facilities are well maintained and operated, the surface water sampling program is satisfactory, and the plant has an excellent record of compliance with its NPDES discharge standards. ORGDP has a very good meteorological data collection system, a high compliance rate in meeting emission standards, and a well-managed hazardous and toxic materials control system. A comprehensive groundwater monitoring program was proposed, and a contract has been signed for a 3-year program.

The internal waste manifest system developed at ORGDP is an excellent means of tracking all radioactive and hazardous wastes. Permit applications for all the hazardous waste facilities are under preparation, and many have been completed and submitted. PCB wastes are being handled properly. Cleanup of the diked hazardous waste storage areas and the low-level radioactive metal scrap yard is near completion. A survey of past disposal practices has identified several inactive waste sites that are currently being evaluated to determine whether contaminants are being released to the environment.

The computer-aided QC system for the ORGDP laboratory has been well developed, and efforts are being undertaken for its full implementation in the near future. This system requires analysts to be disciplined and incorporates checks and balances on analytical work. Correct procedures are being employed in ORNL and ORGDP laboratories in carrying out both analyses and quality control.

Emergency procedures and contingency plans are well formulated and thoroughly documented, and they address potential emergencies that could occur at the facility. Emergency personnel understand their responsibilities and are well trained. The shift superintendent has the necessary information readily available and sufficient resources to assess emergency situations and implement mitigating and corrective actions.

6.9.3 Weaknesses of the Program

The monitoring programs for air and groundwater effluents are the primary weaknesses in the ORGDP system. Inaccurate data may be reported because of deficiencies in monitoring procedures and techniques, which may result in poor estimates of the quantities of pollutants being released.

The existing groundwater monitoring wells are poorly constructed and improperly located to determine existing groundwater quality or movement and cannot be used with a high degree of confidence to detect groundwater contamination. Evidence also points to the possibility of cross-contamination of aquifers due to poor construction techniques for these wells. Additionally, there is no current capability for determining the extent of contamination or for remediating the contamination already identified.

Ambient air and plant emission data are of questionable validity because of inaccurate flow rate measurements, inadequate sampler calibrations, and lack of quality control on data input. Data obtained by the current ORGDP and ORNL air monitoring systems are not defensible because of these problems.

ORGDP does not have complete training and inspection plans for hazardous waste facilities. Low-level radioactive waste sites (e.g., Classified Burial Ground, Scrap Metal Yard, and Radioactive Waste Incinerator) do not have contingency plans, inspection schedules, or training plans. The lithium storage areas contain deteriorated fiberboard drums with inadequate aisle space and pose potential health, safety, and environmental risks.

The chain of custody for environmental samples delivered to the ORGDP laboratory cannot be verified because there is no signature of receipt or person-to-person delivery of samples to the analyst.

Volatile organic analyses of water samples are not being completed within the EPA-prescribed holding time because of a lack of trained personnel.

Soil and vegetation monitors for radiological effluents are not properly located, resulting in data that are not representative of environmental conditions.

6.9.4 Major Recommendations

(1) A physical exchange and formal signature of receipt should be implemented by laboratory analysts to ensure proper chain of custody on all samples.

(2) The acquisition of a sufficient number of trained laboratory analysts should be expedited to ensure that volatile organic analyses are completed on time.

(3) The ambient air monitoring program should be reviewed to ensure that proper measurements are being recorded, equipment maintenance and calibration are performed, and only valid data are entered into the records.

(4) The groundwater monitoring program should be implemented as soon as possible, and an evaluation should be undertaken to determine the potential to accelerate the work and shorten the schedule. The existing monitoring wells should be plugged to preclude cross-contamination of aquifers.

(5) The lithium storage area should be upgraded to provide safe storage in accordance with hazardous waste regulations.

(6) Inspection, training, and contingency plans should be developed and implemented for all hazardous and low-level radioactive waste facilities.

(7) Radioactive effluent data collection and management should be thoroughly reexamined as part of Energy Systems' ongoing internal radioactive data evaluation. Some data that are being collected are not being reported,

and the reasons for reporting other data have not been clearly been identified. The objectives of the radiological monitoring and data management effort need to be better defined.

6.10 QA PROGRAM REQUIREMENTS FOR ENVIRONMENTAL MONITORING

6.10.1 Introduction

As a result of the 1985 technical reviews of the environmental monitoring programs, this QA section was developed. The purpose of this is to provide standards for the implementation of a cost-effective QA program plan that will provide adequate confidence that all environmental monitoring, measurement, and analysis is conducted in a controlled manner and that resulting data are judged adequate and fit for intended use in meeting regulatory and company standards with regard to environmental measurement activities.

The term "QA program plan" is defined as a written document that presents specific terms, policies, organization, objectives, functional activities and specific QA/QC activities designed to achieve the data quality goals of the specific site with regard to the site environmental monitoring program.

A QA program plan is required for each site operation within Energy Systems and will be prepared by the responsible site environmental organization. The elements of a QA program plan are:

(1) title page with provision for approval signatures;

(2) table of contents;

(3) site environmental program description (may be issued as a separate document);

(4) site environmental program organization (optional);

(5) QA objectives for measurement data in terms of precision, accuracy, completeness, representativeness, and comparability;

(6) sampling procedures;

(7) sampling custody;

(8) calibration procedures and frequency;

(9) analytical procedures;

(10) data analysis, validation, and reporting;

(11) internal QC checks and frequency;

(12) performance and system audits and frequency;

(13) preventive maintenance procedures and schedules;

(14) specific routine procedures to be used to assess data precision, accuracy, and completeness of specific measurement parameters;

(15) corrective action; and

(16) QA reports to management.

6.10.2 Responsibilities

Each site environmental organization, in close coordination with the Quality Assurance Coordinator, is responsible for the preparation of a written QA program plan for environmental measurements. Each program plan must be reviewed and approved by the site Environmental, Safety, and Health manager and the

Quality Assurance Coordinator. A copy of the approved plan will be distributed to each person who has a major responsibility for the quality of measurement data.

6.10.3 Plan Requirements

Each of the elements identified in Sect. 6.10.1 must be considered and addressed in the QA program plan. In some instances, a particular element may not be relevant to the site environmental measurement requirements. When this is the case, a brief explanation of why the element is not relevant must be included. Any regulatory or company standard operating procedures must be followed whenever available. This means regulatory approved reference, equivalent, or alternative methods must be used and their corresponding guidelines must be applied whenever they are available.

Detailed standard procedures that delineate how QA data are produced will be separately prepared and referenced in the QA program plan. Standard procedures include those for sampling (including sample custody), calibration, and analytical and routine procedures used to assess data precision, accuracy, and completeness.

The following subsections provide specific guidance pertinent to each of the elements that must comprise the QA program plan.

Title page. As a minimum, the QA program plan must be signature-approved by (1) site Environmental, Safety, and Health Manager and (2) site Environmental, Safety, and Health Quality Assurance Coordinator.

Table of contents. The QA program plan must be prepared in document control format with provisions for revision as needed. The QA program plan Table of Contents will address each of the following items: (1) introduction, (2) a serial listing of each of the QA program plan elements, and (3) a listing of any appendices that are required to augment the QA program plan as presented (i.e., standard operating procedures, etc.).

Site environmental program description. The intent of this section is to familiarize the reader with the general objectives of the program. The description need not be a comprehensive one; however, it should contain sufficient detail to allow those individuals responsible for review and approval of the QA program plan to complete their task. The site environmental program description may be issued as a separate document and referenced in this section.

Site environmental program organization. This section of the QA program plan must provide sufficient information concerning organization and responsibility of site personnel to ensure performance, reliability, and competence such that data of known quality result from work activities.

Where applicable, the following criteria must be addressed with respect to program organization and responsibility: (1) a table, chart, or flow diagram that illustrates the program organization and line authority; (2) a flow diagram or brief narrative delineating program reporting relationships; and (3) a list of key individuals, including the Quality Assurance Coordinator, and a brief outline delineating specific personnel qualifications.

QA objectives for measurement data in terms of precision, accuracy, completeness, representativeness, and comparability. The assessment of data quality is the end result of a comprehensive

QC/QA program and is comprised of five basic components: accuracy, precision, completeness, representativeness, and comparability.

Each of these parameters is quantifiable and, when appropriately collated and assessed, can produce a numerical coefficient proportional to data quality. The degree of data quality possible is strongly dependent on the size of the database from which information is derived as well as on the comprehensiveness of detail of the written protocol associated with the data generation aspects of the program. The five data quality criteria should also be addressed in terms of the following considerations, where appropriate.

Specific parameters that must be addressed with respect to data accuracy are: traceability of instrumentation, standards, samples, and data; methodology; referenced or spiked samples; and performance audits.

Examples of specific parameters which must be examined in order to evaluate precision are: replicate samples, co-located monitors, and instrument checks.

A provision that specifies the quantity of data that must be acquired in order to meet project needs as well as the percent of recovery required to ensure data adequacy must be included.

The degree with which samples extracted from industrial operations or other environmental media are representative of the media from which they are taken must be known. Examples of representativeness contingencies are:

- Where gaseous and particulate samples are concerned, all sampling plans prepared before a given measurement activity will specify the need to use either isokinetic or anisokinetic procedures as stipulated by standard EPA protocols.
- Where liquid sample acquisition is concerned, the number of aliquots to be acquired from predetermined representative areas of flow shall be specified.
- Where solid samples are concerned, the sampling plan will specify the number of solid increments that must be extracted from a given pile or waste area in order to obtain a representative section of the material being sampled.
- In some cases, acquisition of a representative sample is not possible because of the large quantities of material under consideration and/or funding constraints. In this case, the sampling plan will present best engineering judgments as to the level of representativeness implied by the kind of sampling operation employed.

A measure of the confidence with which one data set can be compared with another is considered to be an integral function associated with data quality and assessment. Important examples of data comparability are: (1) standardized siting, sampling, and analysis; (2) consistency of reporting units; and (3) standardized data format.

6.10.4 Sampling Procedures

Quality assurance in sampling is critical to the production of useful data because it must be assumed that the acquired sample is representative of the process or effluent stream under investigation. The sampling plans must be sufficiently comprehensive to ensure that this level of representativeness is obtained and, as such, combines good sampling practices with a QC program, both of which are monitored for effectiveness through the QA program. In keeping with these criteria, the sampling plans should address the following parameters, where applicable:

- Description of techniques used to select sampling sites.
- Inclusion of specific sampling procedures to be used (by reference in the case of standard procedures and by actual description of the entire procedure in the case of nonstandard procedures).
- Charts, flow diagrams, or tables delineating sampling program organization.
- A description of containers and procedures used for sample collection, transport, and storage.
- Contingencies for the preparation of sampling equipment and containers to avoid sample contamination (e.g., containers for organics should be solvent-rinsed; containers for trace metals should be acid-rinsed).
- Sample preservation methods and contingencies.
- Considerations for shipping samples promptly to the laboratory to meet recommended holding time deadlines.
- Chain-of-custody procedures.
- The use of permanently bound notebooks to record all field data and observations.

6.10.5 Sample Custody

To ensure that environmental measurement activities result in data of known quality that are complete, representative, comparable, valid, of known precision and accuracy, and legally defensible, it is necessary to use reliable chain-of-custody procedures applicable to both field sampling and laboratory operations. Following are important chain-of-custody criteria that should be addressed, where applicable, in QA program plans.

(1) Field sampling operations

- Address procedures associated with the preparation of reagents or supplies that become an integral part of the sample (e.g., filters and absorbing agents).
- A provision is necessary for recording the exact location and specific considerations associated with sample acquisition.
- Procedures associated with sample preservation must be cited.
- Pre-prepared sample labels containing all information necessary for effective sample tracking should be used in the field.
- Standardized field tracking reporting forms should be used to establish sample chain of custody in the field prior to shipment.

(2) Laboratory operations

- QA program plans should identify a sample custodian at the laboratory facility who is authorized to sign for incoming field samples, and who will verify the data entered onto the chain-of-custody records.
- The QA program should specify laboratory chain-of-custody procedures for sample handling, storage, and dispersement for analysis.

6.10.6 Calibration Procedures and Frequency

Periodic calibration of measurement systems is conducted to ensure that all data resulting from the use of these systems are consistent with an established standard of known value called the calibration standard. The QA program plan must reference specific calibration protocols that ensure the generation of reliable data. The plan discussion on calibration should address the following criteria:

- For each measurement parameter, including all pollutant measurement systems, reference the applicable standard operating procedure (SOP) or provide a description of the calibration procedure to be used.
- List the frequency planned for recalibration.
- Where applicable, list those calibration standards whose concentrations or values will be established or compared with standards of high quality.
- List the standards of high quality that will be used for traceability.

6.10.7 Analytical Procedures

Quality assurance in analysis is accomplished by:

- establishing good laboratory practices;
- maintaining a QC program; and
- monitoring the accuracy, precision, and detection limits with which results are produced.

With respect to these items, the QA program plan should reference the applicable SOP or provide a description of the analytical procedures to be used for each major measurement parameter, including all pollutant measurement systems. Where applicable, analytical procedures recognized by EPA as standard methods must be used. To ensure the consistent generation of analytical data of known quality, the QA program plan should specifically provide the following items: (1) method blank analysis, (2) calibration check sample analyses, (3) performance check analysis, and (4) method validation sample analyses.

6.10.8 Data Analysis, Validation, and Reporting

For each major measurement parameter, including all pollutant measurement systems, briefly describe the following:

- The data analysis scheme planned on collected data, including units and all equations used to calculate the concentration or value of the measured parameter.
- The principal criteria that will be used to validate data integrity during collection and reporting of data.
- The plans for treating outliners.
- The data flow or reporting scheme from collection of raw data through storage of validated concentrations.
- Key individuals who will handle the data in this reporting scheme. (If this has already been described under project organization and responsibilities, it need not be repeated here.)

6.10.9 Internal QC Checks

Internal quality control checks involve a process whereby a given measurement parameter is periodically evaluated in terms of performance reliability throughout the full scale of its measurement capability. The following actions should be taken with respect to this QA program plan element:

- Reference or describe any standard operating procedures used for the performance of internal QC checks. This may involve instrument manufacturer protocols or standard frequency check criteria integral to many standard analysis methodologies.
- For each major measurement parameter, including all pollutant measurement systems, describe the frequency and type(s) of operation check(s) planned during routine sampling and routine analysis, the established control limits, and corrective action to be initiated before measurements are continued.
- Describe the intended approach for documenting these QC checks such that the information can be made available in the event of a systems audit.

One example of an operational check is the analysis of a standard solution after every tenth analysis of routine samples and re-analysis of the ten previous samples if the operational check exceeds the established control limits.

6.10.10 Performance and Systems Audits

A system audit consists of an on-site qualitative review. The intent of a performance audit is to determine the accuracy of the total measurement system or component parts thereof.

With respect to the preparation of QA program plans for auditing contingencies, the following items should be addressed:

- List specific plans or contingencies inherent in the site organization's structure for the performance of system audits.
- List specific provisions, including a schedule, for conducting performance audits for each major measurement parameter, including all pollutant measurement systems.

6.10.11 Preventive Maintenance

It is important to specify routine inspection for preventive maintenance of facilities and equipment used in the generation of data. The following parameters should be considered with respect to this element:

- Provision of a schedule of important preventive maintenance tasks that must be carried out to minimize downtime of the measurement systems and thus increase data completeness.
- Where appropriate, a list of critical spare parts that should be on hand to minimize downtime due to parts failure.
- Indication that inspection activities will be performed by suitably qualified personnel using accepted and documented procedures in accordance with manufacturer protocols or written laboratory methods. Such documentation must include detailed descriptions of parts replaced, adjustments made, or calibration actions taken.

6.10.12 Specific Routine Procedures Used To Assess Data Precision, Accuracy, and Completeness

It is Energy Systems policy that precision and accuracy of data must be routinely assessed on all environmental monitoring and measurement data. Therefore, specific procedures to assess precision and accuracy on a routine basis on the project must be described in each QA program plan.

For each major measurement parameter, including all pollutant measurement systems, the QA program plan preparer should describe the routine procedures used to assess the precision, accuracy, and completeness of the measurement data. Include in this procedure the equations to calculate precision, accuracy and completeness, and the activity plans to gather data for the precision and accuracy calculations.

In addition, it should be noted that the results of performance audits are used to calculate accuracy (this is only one of a number of QA accuracy checks). The frequency recommended for assessment of measurement system accuracy depends on several factors, including costs. As a minimum, a performance audit should be conducted quarterly.

The QA program plan preparer should choose statistical techniques considered to be appropriate for the routine assessment of data precision, accuracy, and completeness that best suit the needs of the measurements in question.

- Central tendency and dispersion

  Arithmetic mean
  Range
  Standard deviation
  Relative standard deviation
  Geometric mean

- Measures of variability

  Accuracy
  Bias
  Precision; within laboratory, between laboratories, and laboratory bias

- Significance test

  u-test
  t-test
  F-test
  Chi-square test

- Confidence limits

- Testing for outliers

6.10.13 Corrective Action

A corrective action provision is required for every QA program plan to allow for the contingency of functional or performance error. Quality assurance parameters, such as (1) exacting personnel requirements; (2) rigid facilities, equipment, and services controls; and (3) careful attention to data generation, data processing, and data quality assessment all combine to form a comprehensvie QA protocol designed to minimize the need for corrective action. All of these QA parameters, however, contain as integral parts of their structure specifically defined feedback systems designed to indicate clearly those occasions when generated data fall below acceptable quality limits.

In those instances where corrective action is found to be necessary based on quality of acquired data, the QA program plan shall identify areas of responsibility for taking correction action as needed. Individual corrective actions relative to ongoing project activities may be implemented automatically as a result of information derived from the activity. Corrective action may also result from any of the following parameters: (1) performance audits, (2) systems audit, (3) laboratory/interfield comparison studies, and (4) failure to adhere to a QA program plan or standard procedures.

The preparer should address each of the following items in the QA program plan:

Table 7.4.3. In-stream contaminant study—Task 4 (Mercury concentrations in fish and other aquatic organisms)[a]

Sampling location/ species	Number of fish	Mercury concentration (mg/kg)	
		Mean	Range
East Fork Poplar Creek km 6.4			
Bluegill	5	0.89	0.20–1.2
Redbreast sunfish	2	0.67	0.64–0.70
Green sunfish	1	0.52	0.52
Warmouth	1	0.96	0.96
Rock bass	1	1.0	1.0
Yellow perch	1	0.93	0.93
White sucker	2	0.97	0.54–1.4
Black redhorse	1	0.57	0.57
Gizzard shad (composite)	1	0.12	0.12
Snapping turtle	4	0.95	0.41–1.4
Crayfish (composite)	1	0.29	0.29
Bear Creek km 0.64			
Bluegill	2	0.59	0.52–0.66
Redbreast sunfish	2	U[b]	U
Rock bass	10	0.31	0.17–0.43
White sucker	4	0.38	0.24–0.49
Northern hog sucker	3	0.23	0.17–0.27
Frog	1	U	U
Crayfish (composite)	1	U	U
Poplar Creek km 0.32			
Channel catfish	10	0.14	U–0.42
Largemouth bass	10	0.50	0.24–1.3
Bluegill	10	0.38	0.18–0.82
Smallmouth buffalo	7	0.93	0.13–1.7
Striped bass, hybrid	3	0.04	U–0.12
White bass	1	U	U
Sauger	2	0.84	0.37–1.3

[a] Source: Ref. 5.

[b] U = below minimum detection amount of 0.10 mg/kg.

plain of East Fork Poplar Creek are based on 394 sediment samples taken from 130 locations. The data indicate that approximately 440,000 m^3 (690,000 kg) of contaminated sediment and 77,000 pounds of mercury are contained in the channel and floodplain. About 75% of the mercury (by weight) is located in the upper third of the stream above EFPCK 15. An estimated 40 to 50% is between EFPCK 16.2 and EFPCK 18.4. Approximately 80% of the mercury is contained in 25% of the contaminated sediment with a mercury concentration exceeding 100 mg/kg.

Analysis of data from three storms and historic stream-flow records indicates

Table 7.4.4. In-stream contaminant study—Task 4 (Mercury concentrations in supplemental fish flesh samples)[a]

Sampling location/ species	Number of fish	Mercury concentration (mg/kg)	
		Mean	Range
EFPC km 22.1			
Common carp	2	0.24	0.21–0.27
Bluegill	1	1.1	1.1
EFPC km 2.7			
Common carp	2	0.88	0.82–0.93
Bluegill	2	0.63	0.60–0.65
Bear Creek km 1.9			
Rock bass	1	0.35	0.35
Northern hog sucker	2	0.31	0.25–0.37
Poplar Creek km 22.1			
Common carp	1	0.52	0.52
Golden redhorse	1	0.15	0.15
Bluegill	1	0.27	0.27
Redbreast sunfish	1	U[b]	U
Poplar Creek km 0.32			
Common carp	2	0.18	0.12–0.24
Bluegill	2	0.37	0.28–0.46
Melton Hill Dam			
Common carp	2	0.14	0.11-0.16
Bluegill	1	U	U
Redbreast sunfish	1	U	U
Clinch River km 10.9			
Common carp	2	0.34	0.21-0.47
Bluegill	2	0.14	0.13-0.14

[a] Source: Ref. 5.

[b] U = Below minimum detection limit of 0.10 mg/kg.

that approximately 15,800 kg (10,200 m^3) of sediment and 225 kg of mercury are exported annually from East Fork Poplar Creek. An estimated 34 kg of the annual mercury export comes from New Hope Pond. Thus, the net contribution of the watershed below New Hope Pond is approximately 193 kg per year. A comparison of the mercury loads between sampling stations indicates that most of this net export is contributed by the highly contaminated area between EFPCK 16 and EFPCK 22.9 (i.e., no increase in mercury load was observed below EFPCK 16.0.

Assuming a continuous net export rate of 193 kg per year, some 400 years would be required to deplete the estimated 77,200 pounds of mercury in the channel and floodplain of East Fork Poplar Creek.

- The predetermined limits for data acceptability beyond which corrective action is required for each measurement system.
- Established procedures for each measurement system to identify the corrective action that will be taken when the limits are exceeded.
- For each measurement system, the level within the organization responsible for initiating the corrective action and also the level within the organization responsible for approving the correcting action, if necessary.

6.10.14 QA Reports to Management

Each QA program plan should include provisions to keep responsible management informed on the performance of the measurement systems. A contingency is needed in the QA program plan which describes a mechanism for reports to management which address the following:

- periodic assessment of measurement data accuracy, precision, and completeness;
- results of performance audits;
- results of system audits; and
- significant QA problems and recommended solution.

6.10.15 Structural Formatting Requirements for Compilation of the QA Program Plan

Historically, environmental managers have routinely included the majority of these elements in their site environmental program. In practice, it is frequently difficult to separate important QA/QC functions and to isolate these functions from technical performance activities. For those activities where this is the case, it is not deemed necessary to replicate the narrative in the QA program plan section.

Although the QA program plan must provide individual subsections for each of the elements, it is not necessary that each of these elements be accompanied by narrative protocols. In those instances where specific QA/QC protocols are addressed as an integral part of the site environmental program, it is only necessary to cite the page number and location in the environmental program in the specific subsection designated for this purpose.

6.11 STATISTICAL TECHNIQUES USEFUL IN DATA MANIPULATION AND DATA QUALITY ASSESSMENT ACTIVITIES

6.11.1 Central Tendency and Dispersion

The arithmetic mean. The sum of all values in a measurement set (X_i), divided by the number of values summed (n). Commonly called the "average." Often denoted symbolically by a bar over the variable symbol, as "$\overline{X}$."

$$\overline{X} = \sum_{i=1}^{n} X_i/n$$

Range. The difference between the maximum and minimum values of a set of values.

$$R = X_{\max} - X_{\min}$$

A rough indication of variability, particularly when the set of values is small (<10).

Standard deviation. An indication of the dispersion of a set of numbers about the mean value. Normal (and other) distributions are expressed as a function of the standard deviation.

For a given set of values, the defining equation is:

$$s = \left[\frac{\sum_{i=1}^{n} \left(X_i - \overline{X}\right)^2}{n-1} \right]^{1/2}$$

For computation purposes, it is convenient to use:

$$s = \left[\frac{\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_i\right)^2}{n}}{n-1} \right]^{1/2}$$

Relative standard deviation, or coefficient of variation. The dispersion of a set of values, expressed as a percentage of the mean.

$$\% RSD = (s/\overline{X}) \times 100$$

6.11.2 Measures of Variability

Accuracy. The difference (either on an absolute or percentage basis) between a measured value and an assumed "true" value. The larger the difference, the lower the accuracy.

$$B = X - T \ , \quad \text{or}$$

$$\% B = \left(\frac{X-T}{T} \right) 100$$

(see "Bias")

Bias. A nonrandom measurement error: a consistent difference either between sets of results or between a measured value and a "true" value. If the latter, the bias or percent bias is measured by the relationships in "Accuracy."

Precision. A measure of agreement among individual measures of a variable, under identical or specified similar conditions. Precision may be expressed in several ways, and care must be exercised in the definition and use of precision measures.

One set of such measures follows:

(1) Within-laboratory: The within-laboratory standard deviation, s, measures the dispersion in replicate single determinations made by one laboratory team (same field operators, laboratory analyst, and equipment) sampling the same true concentration. This is also termed "repeatability."

(2) Between-laboratory: The between-laboratory standard deviation, s_b, measures the total variability in a determination resulting from determinations by different laboratories sampling the same true concentration. The between-laboratory variance, s_b^2, may be expressed as:

$$s_b^2 = s_L^2 + s^2$$

and consists of a within-laboratory variance plus a laboratory bias variance, s_L^2 (usually termed "reproducibility").

(3) Laboratory bias: The laboratory bias standard deviation,

$$s_L = \sqrt{s_b^2 - s^2} \ ,$$

is that portion of the total variability that can be attributed to differences in the field operators, analysts, and instrumentation, and to different manners of performance of procedural details left unspecified in a technique. This term measures that part of the total variability in a determination which results from the use of a technique by different laboratories, as well as from modifications in usage by a single laboratory over a period of time. The laboratory bias standard deviation is estimated from the within- and between-laboratory estimates previously obtained.

A corresponding set of relative standard deviations would be *RSD*, RSD_b, and RSD_L. These are convenient to use if the precision is proportional to the mean value of the variable.

6.11.3 Significance Tests

u-test. This test measures the significance of individual values and experimentally estimated means where the normal population has a known mean and standard deviation.

$$u = \frac{X - \bar{X}}{s} \; ,$$

where

X = individual value being tested,

$\bar{X}$ = calculated mean of experimental results, and

s = calculated standard deviation of all data in population.

u is a measure of the number of standard deviation units an individual data point is away from the mean, assuming normal distribution.

t-test. If one has an assumed "true value," however obtained, the existence of a significant bias in other measurements of this value can be defined by a t-test:

$$t = \frac{\bar{d}}{s_b/n} \; ,$$

where

t = a parameter, the magnitude of which is referenced to tabulated values. A t-value that exceeds the tabulated value for given specifications of probability and number of degrees of freedom indicates the existence (within the definition of probability specified) of a significant bias. The more stringent the probability requirements; i.e., the smaller the probability chosen, the larger the tabulated t-value;

$\bar{d}$ = the average of the signed difference between the true value and the measured values: the average bias;

s_d = the standard deviation of the signed differences, d_i; and

n = the number of measurements made.

F-test. Fisher's F-test measures the significance of two sets of data to determine the degree of statistical significance of the difference between the calculated variances. In this method, the larger variance is divided by the smaller variance and the resulting ratio is referred to as F.

$$F = \frac{s_1^2}{s_2^2} \; ,$$

where s_1 and s_2 are standard deviations of the two sets of data being tested. The F-value determined is compared with a list of F-values for the specific data sets' degrees of freedom to determine the statistical probability that the two sets of data are identical.

chi-square test. If one has a reasonable estimate of the expected standard deviation of a set of measurements, the existence of a defined "excess variability" can be tested as follows:

$$\frac{x^2}{\phi} = \frac{s_d^2}{\sigma^2[x]} ,$$

where

x^2/ϕ = a random variable with tabulated values ($\phi = n - 1$ = number of degrees of freedom), and

$\sigma^2[x]$ = the expected variance of the measurements x.

If x^2/ϕ is larger than the chosen tabulated value (with specified probability), it is concluded that the measurements are exhibiting excess variability. The chi-square test is a measure of the validity of a series of measurements based on an "expected" variability. The test is worthwhile only whenever a measurement technique has been tested thoroughly, so that a realistic expectation can be estimated.

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7. OAK RIDGE TASK FORCE ACTIVITIES

7.1 INTRODUCTION

On November 3, 1983, the Oak Ridge Task Force (ORTF), under the direction of the Tennessee Division of Water Management, approved conceptual work plans prepared by four subgroups of the ORTF. These work plans addressed potential off-site contamination problems associated with the DOE facilities near Oak Ridge, Tennessee. The conceptual work plans were transmitted to DOE on November 14, 1983. DOE subsequently authorized TVA to prepare a technical work plan covering the in-stream water, sediment, fish, and floodplain sampling approved by the task force.

7.2. WATER SAMPLING AND ANALYSIS

The first of five ORTF reports on the in-stream contaminant study, published in April 1985, presents the results of field measurements, sample collections, and laboratory analyses of surface waters downstream of the DOE facilities. Included are the results of one base-flow survey and two storm-event surveys conducted from May through November 1984. Sampling of a third storm was conducted on April 5 and 6, 1985. The results of this storm-event survey are reported in Sect. 7.3.

This section presents the water data collected and the procedures for collecting, handling, and analyzing the samples. Results are summarized in tables that include available criteria, standards, and background levels.

The purpose of the in-stream contaminant study was to define the hydrologic characteristics and mercury concentrations in East Fork Poplar Creek and Bear Creek for sediment transport predictions. Water quality samples were collected to determine the presence of other contaminants that might be added to ongoing monitoring programs. Flow measurements were made and/or water samples collected from the Clinch River, East Fork Poplar Creek, Bear Creek, Poplar Creek, and lower White Oak Creek during one base-flow condition and from East Fork Poplar Creek, Bear Creek, and Mill Branch (a tributary of East Fork Poplar Creek) during two storm-flow conditions. The results of a third storm-flow survey (conducted April 5 and 6, 1985) are reported in Sect. 7.3.

The base-flow survey consisted of field measurements and sample collections at nine stations: CRK 38.4, 36.8, 24.0, 16.0, and 10.9; EFPCK 23; BCK 11.8; WOCK 0.64; and PCK 22.1. Six of these stations were included in the Interagency Agreement approved April 30, 1984. Three stations (CRK 38.4 and 10.9, and PCK 22.1) were added in May of 1984 to provide supplemental data requested by ORNL. Base-flow field measurements included dissolved oxygen (DO), temperature, pH, conductivity, alkalinity, and water level. Laboratory analyses included selected metals, nutrients, priority pollutants, oil and grease, solids, turbidity, hardness, and radiological parameters.[1]

The storm-flow surveys involved sampling and laboratory analyses of mercury, suspended solids, turbidity, particle size distribution, specific gravity, and radiological parameters. Stream-flow and precipitation data were also collected during each storm-flow survey. Storm-flow sampling stations were located at EFPCK 22.9, 16.0, 10.9, 5.3, and 0.048; Mill Branch km 0.32 (a tributary to East Fork Poplar Creek); and BCK 0.88.

The results of field analyses (DO, temperature, pH, conductivity, and alkalinity); physical analyses (turbidity and solids); and aluminum, hardness, and nutrient analyses are summarized in Table 7.2.1. Results of metal analyses indicated that most metal concentrations were below detection limits and/or available standards and background data. Exceptions are given in Table 7.2.2. Results of significant radiological analyses are given in Tables 7.2.3 and 7.2.4.

Comparison of results of the split water samples with EPA was acceptable, especially considering the low concentrations

Table 7.2.1. In-stream contaminant study—Task 1
(Base-flow survey—field, physical, aluminum, hardness, and nutrient analyses results)[a]

Parameter (units)	East Fork Poplar Creek km 22.9	Bear Creek km 11.8	White Oak Creek km 11.8	Poplar Creek km 22.0	Clinch River km 38.4	Clinch River km 10.9
Temperature (°C)	22.4	17.0	17.6	14.0	15.5[b]	14.7[b]
Dissolved oxygen (mg/L)	8.3	9.3	6.2	9.2	12.3[b]	11.1[b]
pH (standard units)	8.1	7.9	7.4	7.7	8.3[c]	7.7[c]
Conductivity (μmho/cm)	454.0	>2000.0	395.0	230.0	280.0[b]	[d]
Alkalinity (mg/L as $CaCO_3$)	115.0	176.0	110.0	49.0	96.0	[d]
Turbidity (NTU)	3.5	1.6	22.0	[d]	[d]	[d]
Total suspended solids (mg/L)	5.0	2.0	18.0	[d]	[d]	[d]
Total volatile suspended solids (mg/L)	2.0	2.0	3.0	[d]	[d]	[d]
Hardness (mg/L as $CaCO_3$)	170.0	1000.0	160.0	[d]	[d]	[d]
Aluminum (μg/L)	60.0	140.0	205.0	[d]	[d]	[d]
Organic nitrogen (mg/L)	0.57	0.21	0.29	[d]	[d]	[d]
Total ammonia nitrogen (mg/L)	0.11	0.17	0.13	[d]	[d]	[d]
Unionized ammonia nitrogen (mg/L)	0.007	0.005	0.001	[d]	[d]	[d]
Nitrate-nitrite nitrogen (mg/L)	3.8	240.0	0.83	[d]	[d]	[d]
Total phosphorus (mg/L)	0.66	<0.01	0.18	[d]	[d]	[d]

[a] Source: Ref. 1.

[b] Mean values from a reservoir profile.

[c] Maximum values in a reservoir profile.

[d] No data.

Table 7.2.2. In-stream contaminant study—Task 1 (Base-flow survey—metal concentrations exceeding standards, criteria, or background levels)[a]

Parameter	Concentrations (μg/L)			
	East Fork Poplar Creek km 22.9	Bear Creek km 11.8	White Oak Creek km 0.64	Clinch River km 38.4
Total mercury	2.5	*c*	<0.3[a]	0.3
Total cadmium	*c*	26.0	*c*	*c*
Total chromium	*c*	*c*	9.0[a]	*c*
Total copper	*c*	15.0	*c*	*c*
Total lithium	30.0	*c*	*c*	*c*
Total nickel	*c*	69.0	*c*	*c*
Total zinc	60.0	*c*	*c*	*c*

[a] Source: Ref. 1.

[b] Mean value of field duplicate samples.

[c] No data.

obtained for most parameters. Gross alpha and gross beta analyses did not always correspond within error limits; however, this was expected because of the nonspecific nature of these analyses. The results of split sample analyses indicated that there were no significant analytical problems.

A QC program was completed during the study. The overall accuracy and precision of the data were adequate and within the interpretive requirements of this study. The QC program did, however, reveal certain limitations that must be considered when interpreting the results on the extractable organic priority pollutant data. Because of the inefficiency of the EPA-approved methods to extract many of the base/neutral and acid-extractable compounds, the reviewer of the data should realize that some of the organic compounds that were not detected by this method could be present in the environment.

7.3. SEDIMENT CHARACTERIZATION

The second ORTF report on the in-stream contaminant study was published in April 1985. It presents the results of laboratory analyses of sediment samples collected downstream of the DOE Oak Ridge facilities. The samples were collected from June through November 1984. The Task 2 report[3] presents the sediment data and the procedures for collecting, handling, and analyzing the samples. Results are summarized in tables that include available criteria, standards, and background levels. The procedures and data are discussed for clarification but the implications of the data have not been assessed.

The purposes of Task 2 of the in-stream contaminant study were (1) to define the floodplain for the maximum flood event during the period of operation of DOE

Table 7.2.3. In-stream contaminant study—Task 1
(Base-flow survey—maximum concentrations of significant radioisotopes in water samples and applicable standards and background levels)[a]

Isotope	LLD[b] (pCi/L)	Standards and background levels (pCi/L)			Concentrations of signficant isotopes: base-flow survey[f] (pCi/L)			
		Drinking water standard[c]	MPC[d]	Tenn. River[e]	White Oak Creek	Bear Creek	Clinch River	East Fork Poplar Creek
Gross alpha	2.0	15	30	4.0	11 (36%)	31 (103%)	3 (10%)	8 (25%)
Gross beta	2.4	*g*	3,000	9.6	690 (23%)	330 (11%)	4 (0.1%)	17 (0.6%)
Tritium	330	20,000	3,000,000	710	544,000 (18%)	500 (0.02%)	500 (0.02%)	400 (0.01%)
^{137}Cs	5.0	*g*	20,000	*h*	68 (0.34%)	*h*	*h*	*h*
^{60}Co	5.0	*g*	30,000	*h*	19 (0.06%)	*h*	*h*	*h*
^{90}Sr		*g*	300	*i*	*h*	*i*	0.6 (0.2%)	*i*

[a] Source: Ref. 1.

[b] Lower limit of detection as calculated by the method described in Ref. 2.

[c] Interim primary drinking water regulations as outlined in 40 CFR Pt. 141.

[d] Maximum permissible concentrations (MPC) recommended by 10 CFR Pt. 20 for nonoccupational exposure.

[e] Maximum concentrations reported by TVA in the Tennessee River samples collected in 1981–83.

[f] The percentage of the MPC value is reported in parentheses.

[g] No standard available.

[h] Isotope not identified in gamma spectral analyses.

[i] Analysis not performed.

Table 7.2.4. In-stream contaminant study—Task 1 (Storm-flow surveys—maximum concentrations of significant radioisotopes in water samples and applicable standards and background levels)[a]

Isotope	LLD[b] (pCi/L)	Standards and background levels (pCi/L)			Concentrations of significant isotopes (two storm-flow surveys)[f] (pCi/L)	
		Drinking water standard[c]	MPC[d]	Tenn. River[e]	Bear Creek	East Fork Poplar Creek
Gross alpha	2.0	15	30	4.0	8 (27%)	15 (50%)
Gross beta	2.4	*g*	3000	9.6	36 (1%)	55 (2%)
^{131}I	8.0	*g*	300	*h*	*h*	14 (5%)
^{234m}Pa		*g*		*h*	*h*	268

[a] Source: Ref. 1.

[b] Lower limit of detection as calculated by the method described in Ref. 2.

[c] Interim Primary Drinking Water Regulations as outlined in 40 CFR Pt. 141.

[d] Maximum permissible concentrations (MPC) recommended by 10 CFR Pt. 20 for nonoccupational exposure.

[e] Maximum concentrations reported by TVA in the Tennessee River samples collected from 1981–83.

[f] The percentage of the MPC value is reported in parentheses.

[g] No standard available.

[h] Isotope not identified in gamma spectral analyses.

facilities at Oak Ridge; (2) to estimate the quantity of mercury-contaminated sediment and floodplain deposits along East Fork Poplar Creek, Bear Creek, and lower White Oak Creek; (3) to measure the concentration of other contaminants in sediments downstream of DOE facilities; and (4) to obtain preliminary information on the possible transport of mercury-contaminated sediment to the Tennessee River.

The sediment sampling program involved four basic activities. The first included cross-section surveys and floodplain mapping to define the maximum flood event since 1940, the approximate beginning of DOE operations. Floodplain areas included the Clinch River from its mouth in Watts Bar Reservoir to Melton Hill Dam; Poplar Creek from its mouth at CRK 19.2 to CRK 9.0 upstream of East Fork Poplar Creek; East Fork Poplar Creek from its mouth to km 23.5 downstream of New Hope Pond; and Bear Creek from its mouth to km 12.3 downstream of the S-3 ponds.

The second activity involved the analysis of mercury concentrations in sediment (i.e., 122 cores collected in the floodplain of East Fork Poplar Creek, 19 in-stream sediment samples collected in East Fork Poplar Creek, 4 cores collected in the floodplain of Bear Creek, and 4 in-stream cores collected in lower White Oak Creek). In addition, selected cores were also analyzed for radiological parameters. Limited sampling of the Bear Creek and White Oak Creek floodplains was conducted to verify previous data[3] that suggested that mercury contamination was not extensive in these areas.

The third activity involved selective sampling of surface layer sediments at in-stream (i.e., channel bed) locations to determine the presence of other contaminants (i.e., base/neutral priority pollutants, priority pollutant metals, cyanide, phenols, PCBs, and radiological contaminants). Sixteen fine-particle sediment samples were collected from East Fork Poplar Creek, three from Bear Creek, four from lower White Oak Creek, three from Poplar Creek, five from the Clinch River (Watts Bar and Melton Hill reservoirs), and three from Norris Reservoir (background samples).

The fourth activity involved core sampling in the Clinch River and the Tennessee River. Eight core samples were collected from the Clinch River below Melton Hill Dam to determine the presence of mercury and radiological parameters. Seven core samples were collected from the Tennessee River (Watts Bar Reservoir to Guntersville Dam) to determine the presence of mercury, PCBs, and chromium.

Several metals were measured at concentrations above available criteria and/or background levels. These concentrations are summarized in Table 7.3.1. A summary of metal concentration is given in Table 7.3.2. Samples were analyzed for base/neutral priority pollutants and PCBs. A statistical summary of PCB and base/neutral compounds that had concentrations at or above the analytical detection limits is given in Table 7.3.3. The maximum concentrations of significant radionuclides are given in Table 7.3.4, and the results of radionuclide analyses are given in Table 7.3.5. A summary of the maximum concentrations of significant radionuclides is given in Table 7.3.6.

A QC program was completed with this study. As indicated by the duplicate and split sample results, the accuracy and precision for most of the sediment data are acceptable. However, the QC program did point out that (as expected) reducing the number of sample aliquots for mercury determination to collect more core samples resulted in a deterioration in the precision of the laboratory analyses. When the results of the laboratory duplicates are compared with the field duplicates, it is apparent that the most significant variability is due to natural variability in the environment. Variations in deposition patterns for sediment, even in localized areas, and the particulate nature of sediment samples, make collecting truly duplicate samples difficult and increase the value of additional core samples.

Statistically poor results were obtained on both the duplicate and split samples for the analysis of the base/neutral organic compounds. TVA's intralaboratory quality control data and discussions with EPA chemists indicate that losses of some organic compounds may have occurred during TVA's sample cleanup because of the analytical methodology currently available for the analyses of organics in sediment samples. These compounds could, therefore, be present in the environment at a higher concentration than indicated by the TVA results.

Table 7.3.1. In-stream contaminant study—Task 2 (Criteria and selected data for metals in sediments and soil)[a]

Parameter[b] (ppm)[b]	Proposed Virginia criteria[c]	Average earth's crust[d]	Mean concentrations of upper Tennessee River[e]	Mean concentrations of tributary streams to upper Tennessee River[f]	Mean concentrations of Clinch River[g]
Mercury	0.3	0.5	1.00 (<0.05–4.3)	0.25 (<0.05–0.98)	0.16[h] (<0.05–0.51)
Arsenic			12.00 (7.4–17.5)	12.20 (2.0–56.0)	8.70 (2.0–16.0)
Cadmium		0.2	5.50 (0.4–12.0)	1.80 (<0.4–11.0)	1.40 (<0.4–3.7)
Chromium		200.0	48.0 (14.0–86.0)	19.70 (5.0–46.0)	19.30 (6.3–44.7)
Lead		16.0	59.70 (<10.0–99.0)	47.90 (<3.0–300.0)	31.60 (13.1–72.0)
Nickel		100.0	33.60 (5.8–57.0)	22.40 (<3.3–70.0)	30.00 (16.0–70.0)
Silver			2.50 (0.5–5.0)	1.30 (0.4–2.1)	1.60 (1.3–2.0)
Zirconium			NA[i]	NA	NA

[a] Source: Ref. 3.

[b] Concentrations given in mg/kg (ppm), dry weight; range in parentheses.

[c] State of Virginia proposed regulation for total mercury in freshwater river sediment.

[d] Average abundance of trace elements in the crust of the earth. Source: Ref. 4.

[e] Average concentrations in river sediment for reach from Nickajack Dam to confluence of the Holston and French Broad rivers, TRMs 427 to 652; 24 sampling locations—1970 to 1983, TVA STORET data.

[f] Average concentrations in river sediment for streams tributary to the Tennessee River between miles 424 and 652; 43 sampling locations 1970 to 1981, TVA STORET data.

[g] Average concentrations in Clinch River sediment above Melton Hill Dam, CRM 23.2; 12 sampling locations—1970 to 1981, TVA STORET data.

[h] Seven of twelve samples below detection limits.

[i] Not analyzed.

7.4 FISH SAMPLING AND ANALYSIS

The fourth report[5] on the in-stream contaminant study presents the results of field measurements and laboratory analyses of fish collected downstream of the DOE Oak Ridge facilities. The Task 4 report presents the fish and aquatic animal data collected and the procedures followed for collecting, handling, and analyzing the samples. Results are summarized in tables that include available criteria, standards, and background levels. The procedures and data are discussed for clarification, but the implications of the data have not been assessed.

The purposes of Task 4 of the in-stream contaminant study were to determine contaminant concentrations in fish from selected sampling sites in Watts Bar and

Table 7.3.2. In-stream contaminant study—Task 2 (Surface layer, fine-particle sediment—summary of metal concentrations)[a]

Parameter	Concentrations (ppm)[b]											
	East Fork Poplar Creek			Bear Creek			White Oak Creek			Poplar Creek		
	Max	Min	Mean (n = 16)	Max	Min	Mean (n = 3)	Max	Min	Mean (n = 4)	Max	Min	Mean (n = 3)
Mercury	165.0	11.0	40.0	0.7	<0.1	0.3	6.0	2.2	3.3	5.9	0.1	3.4
Arsenic	14.0	3.8	6.9	11.0	4.8	6.5	12.0	5.0	8.7	11.0	7.4	8.9
Cadmium	8.2	<0.5	1.6	8.6	<0.5	8.6	2.4	0.6	1.4	3.5	2.1	2.9
Chromium	58.0	24.0	37.0	35.0	16.0	22.0	290.0	66.0	163.0	38.0	19.0	27.0
Lead	170.0	36.0	80.0	85.0	35.0	52.0	51.0	33.0	40.0	38.0	23.0	32.0
Nickel	74.0	20.0	37.0	155.0	28.0	67.0	30.0	24.0	26.0	65.0	43.0	56.0
Silver	45.0	2.0	8.0	<1.0	<1.0	<1.0	10.0	2.0	6.0	2.0	<1.0	2.0
Zirconium	590.0	350.0	448.0	500.0	430.0	500.0	480.0	260.0	365.0	470.0	220.0	340.0

Parameter	Concentrations (ppm)[a]								
	Clinch River (Watts Bar)			Background Stations					
				Clinch River (Melton Hill)			Norris Reservoir[c]		
	Max	Min	Mean (n = 4)	Max	Min	Mean (n = 1)	Max	Min	Mean (n = 3)
Mercury	2.8	0.3	0.8		<0.1	<0.1	<0.1	0.1	0.1
Arsenic	11.0	5.1	8.1	17.0	17.0	17.0	26.0	16.0	22.0
Cadmium	4.2	0.7	1.8	0.5	0.5	0.5	<0.5	<0.5	<0.5
Chromium	25.0	9.0	16.0	25.0	25.0	25.0	23.0	21.0	22.0
Lead	38.0	14.0	30.0	28.0	28.0	28.0	77.0	58.0	67.0
Nickel	38.0	14.0	21.0	36.0	36.0	36.0	28.0	24.0	26.0
Silver	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Zirconium	890.0	400.0	650.0	230.0	230.0	230.0	270.0	180.0	220.0

[a] Source: Ref. 3.

[b] ppm is equivalent to mg/kg.

[c] Values for Norris Reservoir include CRK 136 and 150 and Powell River km 9.6.

Melton Hill reservoirs, East Fork Poplar Creek, Bear Creek, Poplar Creek, lower White Oak Creek, and White Oak Lake and to obtain baseline population data from East Fork Poplar Creek and Bear Creek for future camparisons.

Fish samples were collected and analyzed to show the spatial delineation of contaminant levels in fish and to identify areas with the greatest potential risks to public health from the consumption of fish. The relative abundance and diversity of species in East Fork Poplar and Bear creeks were determined. Selected aquatic animals (frogs, snapping turtles, and crayfish) in East Fork Poplar and Bear creeks were also sampled and contaminant levels determined.

Table 7.3.3. In-stream contaminant study—Task 2 (Surface layer, fine-particle sediment—organic compound concentrations at or above analytical detection limits)[a]

Parameter (ppb)[b]	East Fork Poplar Creek				Bear Creek				White Oak Creek			
	N[c]	Max	Min	Mean	N[c]	Max	Min	Mean	N[c]	Max	Min	Mean
PCB 1254	5	2000	200	680	1	500	500	500	1	1200	1200	1200
PCB 1260	9	4000	200	850	1	900	900	900	1	1600	1600	1600
Fluoranthene	9	4600	870	1850	1	970	970	970				
Bis(2-ethylhexyl) phthalate	14	2000	700	1170					1	1600	1600	1600
Pyrene	7	850	3500	1590	1	710	710	710				
Phenanthrene	5	1200	4500	1980	1	690	690	690				
Benzo(a)pyrene	1	900	900	900								
Chrysene	1	920	920	920								
Anthracene	1	1000	1000	1000								
Benzo(a)anthracene-1,2 benzanthracene	2	1200	920	1060								

[a] Source: Ref. 3.

[b] ppb is equivalent to μg/kg.

[c] This table provides data only for the streams with concentrations above the detection limits. "N" is the number of occurrences in a particular stream for which the concentrations of a specific compound exceeded the detection limit. Max, Min, and Mean are the statistics for those concentrations at or above the detection limit only.

Table 7.3.4. In-stream contaminant study—Task 2
[Surface layer, fine-particle sampling—maximum concentrations reported for significant radioisotopes in surface sediment samples (all concentrations are pCi/g, dry wt)][a,b]

	Clinch River	East Fork Poplar Creek	Bear Creek	White Oak Creek	Poplar Creek	Norris Reservoir Control Station		Comparison data	
						Clinch River upstream	Powell River	Tennessee River[c]	Clinch River[d]
Analysis/isotope									
Gross alpha	11	160	32	3	11	4	3	15	100
Gross beta	398	110	150	6,600	60	42	37	65	91
Uranium	7	90	200	4.1	14	5.9	2.3	[e]	2.0
^{89}Sr	4	0.7	0.5	0	1	4	1	14	12.1
^{90}Sr	1.8	0.1	0.1	900	0.2	0.4	0.5	0.6	0.6
Gamma spectral analysis[e]									
^{60}Co	1.2	ND[f]	ND	184	ND	ND	ND	0.6	2.7
^{134}Cs	ND	ND	ND	1.2	ND	ND	ND	0.13	0.01
^{137}Cs	167	8.6	0.2	12,100	1.9	0.9	0.7	5.5	83
^{40}K	27	21	18	25	16	27	16	27	84
^{225}Ra	0.7	ND	ND	ND	ND	ND	ND	2.3	1.4
^{234}Th	4	23	63	ND	3.8	ND	ND	ND	ND
^{152}Eu	ND	ND	ND	8	ND	ND	ND	ND	ND
^{154}Eu	ND	ND	ND	7	ND	ND	ND	ND	ND
^{241}Am	ND	ND	ND	4	ND	ND	ND	ND	ND
^{228}Ac	2.2	2	1.8	4	1.1	2.2	1.8	2.7	2.1
^{234}Pa	ND	ND	ND	ND	ND	ND	ND	4.6	4.8
Transuranics									
^{239}Pu	0.73	0.10	0.001	1.08	0.02	*f*	*f*	*f*	*f*
^{238}Pu	0.03	0.02	0.001	0.007	<0.0002	*f*	*f*	*f*	*f*
^{241}Am	0.51	0.05	0.04	0.46	0.02	*f*	*f*	*f*	*f*
^{244}Cm	0.02	0.01	0.009	0.01	<0.0008	*f*	*f*	*f*	*f*

[a] Source: Ref. 3.

[b] Uranium reported in units of μg/g, dry weight.

[c] Maximum concentrations reported by TVA in surface sediment samples collected from the Tennessee River from 1981–83.

[d] Maximum concentrations reported by TVA in surface sediment samples collected from the Clinch River from 1974–1983.

[e] Analysis not performed.

[f] ND = not detected by gamma spectral analysis.

NOTE: The lower limits of detection for all isotopes, as described in Ref. 2, are typically 1 pCi/g, dry weight.

Mercury concentrations in fish and other aquatic organisms are given in Tables 7.4.1 through 7.4.3. Mercury concentrations were highest in fish and other aquatic animal tissue (frogs, turtles, and crayfish) for EFPCK 22.1 (Table 7.4.2). Mean levels of mercury in fish flesh samples decreased in EFPC downstream stations to below 1.0 mg/kg (Table 7.4.4). Only six fish (12% of those analyzed) were found to contain measurable priority pollutant organics other than PCBs, and only one of these contained more than one compound. Organic priority pollutant results are given in Table 7.4.5. The significant concentrations for radionuclides are given in Table 7.4.6.

A quality control program was completed with this study. The overall results of the quality control program labora-

Table 7.3.5. In-stream contaminant study—Task 2
[Mecury-contaminated sediment—maximum concentrations reported for significant radioisotopes in core samples (all concentrations are pCi/g, dry wt)][a,b]

	East Fork Poplar Creek	Bear Creek	White Oak Creek	Comparison data		
				Tennessee River[c]	Clinch River[d]	Clinch River[e]
Analysis/isotope						
Gross alpha	40	7	4	15	6.9	14
Gross beta	140	179	18,100	65	55	111
Uranium	73	167	18	*f*	*f*	5.1
^{89}Sr	0.5	0.5	12	14	2.8	3
^{90}Sr	0.2	0.2	563	0.6	6.6	0.1
Gamma spectral analysis						
^{60}Co	0.4	ND[g]	437	0.6	8.2	1.6
^{134}Cs	0.1	ND	1.7	0.13	ND	ND
^{137}Cs	2.7	0.5	46,900	5.5	370	42
^{40}K	21	22	25	27	60	44
^{226}Ra	ND	1.2	0.7	2.3	ND	0.9
^{234}Th	29	115	2	ND	ND	4
^{152}Eu	ND	ND	8.9	ND	ND	ND
^{154}Eu	ND	ND	14	ND	ND	ND
^{241}Am	ND	ND	73	ND	ND	ND
^{228}Ac	ND	1.2	0.7	2.7	ND	1.5
^{234m}Pa	41	181	ND	4.6	ND	ND
^{235}U	1.7	3.8	ND	ND	ND	ND
Transuranics						
^{239}Pu	0.07	0.002	2.6	*f*	*f*	0.10
^{238}Pu	0.10	0.001	0.49	*f*	*f*	0.01
^{241}Am	0.06	0.015	14.3	*f*	*f*	0.30
^{244}Cm	0.01	0.005	12.4	*f*	*f*	0.05

[a] Source: Ref. 3.

[b] Uranium reported in units of μg/g, dry weight.

[c] Maximum concentrations reported by TVA in surface sediment samples collected from the Tennessee River from 1981-83.

[d] Maximum concentrations reported by TVA in core sediment samples from the Clinch River from 1974-76.

[e] Maximum concentrations in Clinch River core samples collected during the in-stream contaminant study—Task 2.

[f] Analysis not performed.

[g] ND = not detected by gamma spectral analysis.

Table 7.3.6. In-stream contaminant study—Task 2 [Clinch River core sampling—maximum concentrations reported for significant radioisotopes in core samples (all concentrations are pCi/g, dry wt)][a,b]

	Clinch River in-stream	Jones and Grubb islands	Tennessee River[c]
Analysis/isotope			
Gross alpha	14	10	15
Gross beta	111	100	65
Uranium[a]	5.1	1.3	*d*
^{89}Sr	3	3	14
^{90}Sr	0.1	0.1	0.6
Gamma spectral analysis			
^{60}Co	1.6	*e*	0.6
^{137}Cs	42	3.2	5.5
^{40}K	44	44	27
^{226}Ra	0.9	0.9	2.3
^{234}Th	4	1.4	*d*
^{228}Ac	1.5	0.9	2.7
Transuranics			
^{239}Pu	0.1	0.02	*d*
^{239}Pu	0.01	<0.001	*d*
^{241}Am	0.30	0.02	*d*
^{244}Cm	0.05	0.007	*d*

[a] Source: Ref. 3.

[b] Uranium reported in units of μg/g, dry weight.

[c] Maximum concentrations reported by TVA in surface sediment samples collected from the Tennessee River from 1981–83.

[d] Analyses not performed.

[e] Isotope not identified in gamma spectral analyses.

NOTE: The lower limits of detection for all isotopes, as described in Ref. 2, are typically 1 pCi/g, dry weight, or less.

tories were excellent and within the requirments of this study. The EPA-TVA split data did, however, reveal two areas where caution should be exercised in interpreting the data. Since EPA split results for PCBs in tissue were an average of 1.4 times greater than the TVA values, a "safety factor" should be incorporated when applying the FDA limit for PCBs in fish. Significant levels of PCBs in the fish tissue also complicated the interpretation of gas chromatograph results for the presence of pesticides. Therefore, caution should be taken when using the pesticide values on tissue samples in which PCB is also present.

Table 7.4.1. In-stream contaminant study—Task 4 (Mercury concentrations in fish and other aquatic organisms)[a]

Sampling location/ species	Number of fish	Mercury concentration (mg/kg)	
		Mean	Range
Scarboro Creek			
Channel catfish	10	U[b]	U
Largemouth bass	10	0.11	U–0.44
Bluegill	10	0.06	U–0.21
McCoy Branch			
Channel catfish	9	U	U
Yellow bullhead	1	U	U
Largemouth bass	10	0.08	U–0.17
Bluegill	10	0.04	U–0.14
Melton Hill Dam			
Largemouth bass	10	0.11	U–0.23
Bluegill	9	0.02	U–0.14
White Oak Lake			
Largemouth bass	2	0.41	0.24–0.57
Bluegill	10	0.23	U–0.46
Yellow bass	7	0.07	U–0.23
White Oak Creek km 0.32			
Channel catfish	8	0.06	U–0.16
Black bullhead	2	0.06	U–0.11
Largemouth bass	5	0.13	U–0.36
Bluegill	10	0.16	U–0.56
Striped bass, hybrid	5	0.11	U–0.15
Clinch River km 17.6			
Smallmouth buffalo	10	0.46	U–1.2
Largemouth bass	10	0.34	0.19–0.58
Bluegill	10	0.16	U–0.40
Clinch River km 9.6			
Largemouth bass	10	0.31	0.20–0.56
Bluegill	10	0.19	0.12–0.33

[a] Source: Ref. 5.

[b] U = below minimum detection amount of 0.10 mg/kg.

7.5 SEDIMENT TRANSPORT

A report on sediment transport[6] was also published during 1985. Water and bedload samples were collected during three rain storms to assess the transport and fate of the mercury-contaminated sediment in East Fork Poplar Creek.

Table 7.4.2. In-stream contaminant study—Task 4 (Mercury concentrations in fish and other aquatic organisms)[a]

Sampling location/ species	Number of fish	Mercury concentration (mg/kg)	
		Mean	Range
Clinch River km 3.2			
Largemouth bass	10	0.10	U–0.26[b]
Bluegill	10	0.03	U–0.13
Emory River km 1.6			
Largemouth bass	10	0.12	U–0.32
Bluegill	10	0.05	U–0.20
Tennessee River km 915.2			
Largemouth bass	10	0.16	U–0.45
Bluegill	10	0.02	U–0.17
Sauger	2	0.30	0.30–0.30
Paddlefish	1	U	U
Tennessee River km 892.8			
Largemouth bass	10	0.05	U–0.14
Bluegill	10	0.04	U–0.18
East Fork Poplar Creek km 22.1			
Common carp	4	1.0	0.57–1.3
Largemouth bass	8	1.3	0.80–1.9
Bluegill (composite)	2	0.68	0.54–0.82
Redbreast sunfish	10	1.7	0.24–3.3
Frogs	10	1.6	U–3.0
Snapping turtles	5	0.72	0.43–1.2
Crayfish	2	0.82	0.43–1.2
East Fork Poplar Creek km 14.1			
Bluegill	6	0.80	0.51–1.0
Redbreast sunfish	10	0.96	0.64–1.4
Snapping turtle	5	0.63	0.16–1.0
Crayfish (composite)	4	0.22	0.24–0.72

[a] Source: Ref. 5.

[b] U = below minimum detection amount of 0.10 mg/kg.

Water samples from six locations were collected across the storm hydrograph and analyzed for total suspended solids, total mercury, and dissolved mercury. Peak discharges for all three storms were substantially below the 2-year recurrence interval. The water quality data show (1) relatively high sediment concentrations for the storms sampled, (2) most of the mercury appearing in the suspended form, and (3) no obvious spatial trend in total mercury concentrations.

Estimates of the quantity and distribution of mercury in the channel and flood-

Table 7.4.5. In-stream contaminant study—Task 4 (Organic priority pollutants, except PCBs in fish flesh samples)[a]

Sampling location	Fish species	Organic compound	Concentration (mg/kg)
McCoy Branch	Yellow bullhead	Di-n-butyl phthalate	1.30
	Channel catfish	4,4-DDD	0.01
East Fork Poplar Creek km 22.1	Largemouth bass	bis(2-ethylhexyl) phthalate	1.20
	Carp[b]	Aldrin	0.02
	Carp[b]	4,4-DDE	0.04
White Oak Creek km 0.32	Channel catfish	Chloroform	0.02
	Channel catfish	Chloroform	0.02

[a] Source: Ref. 5.

[b] Same fish sample.

Table 7.4.6. In-stream contaminant study—Task 4 (significant maximum concentrations for radioisotopes in fish flesh samples, pCi/g, dry wt)[a]

	NRC reporting level[b]	Tennessee River[c]	Lower limit of detection[d]	Clinch River	East Fork Poplar Creek	White Oak Lake	White Oak Embayment	Bear Creek
Analysis/isotope								
Gross alpha	*e*	5	0.1	0.07	0.9	0.05	0.07	0.02
Gross beta	*e*	45	0.1	64	74	76	40	29
^{89}Sr	*e*	1.2	0.5	0.1	0.2	0.2	−1.6[f]	*g*
^{90}Sr	*e*	0.3	0.1	0.01	0.06	0.25	1.3	*g*
Gamma spectral analysis								
^{60}Co	40	0.03	0.01	*h*	0.03	0.12	0.07	*h*
^{134}Cs	4	*h*	0.08	*h*	0.11	0.04	*h*	*h*
^{137}Cs	8	0.2	0.02	18	2.6	26	9.7	0.4
^{40}K	*d*	20	1.00	18	22	17	14	18

[a] Source: Ref. 5.

[b] Source: Ref. 8.

[c] Maximum concentrations reported by TVA in fish samples collected from the Tennessee River from 1981–1983.

[d] Lower limit of detection as determined by the method described in Ref. 2.

[e] No reporting level given.

[f] Negative value is an artifact of counting statistics and does not imply a negative activity.

Not all of the contaminated sediment is readily susceptible to erosion, however. The relative stability of the floodplain is apparent from field observation and computer simulations of floods with a 1-, 2-, 30-, and 500-year recurrence interval. Simulated velocities for extreme floods are sufficient to cause some bank erosion and allow channel transport, but floodplain velocities are not sufficient to cause significant scour and transport.

These results provide an estimate of mercury quantities, distribution, and transport. The sampling program and data analyses were designed to provide estimates for initial decisions regarding possible remedial actions. The data are not sufficient for evaluating site-specific alternatives in detail. In this context, it is obvious that the floodplain of East Fork Poplar Creek contains substantial quantities of mercury. Under natural conditions, this mercury will remain in the floodplain for many years, serving as a continual source of mercury to downstream waters. Improper disturbances of the floodplain could substantially increase erosion and the downstream transport of mercury.

7.6 SUMMARY OF IN-STREAM CONTAMINANT STUDY

The primary purpose of the in-stream contaminant study was to provide water, sediment, and fish data for identifying off-site contaminants and assessing potential public health risks. Specific objectives were:

(1) To identify the presence of contaminants in the water, sediment, and fish downstream of the DOE facilities at Oak Ridge.

(2) To estimate the quantity of mercury-contaminated sediment in East Fork Poplar Creek, Bear Creek, and lower White Oak Creek.

(3) To assess the transport and fate of the mercury contaminated sediment.

The study consisted of five tasks. Task 1 involved collecting water quantity and quality data for predicting sediment transport. Task 2 focused on sediment volume and contaminant characterization. Task 3 addressed the transport and fate of sediment in East Fork Poplar Creek. Task 4 examined contaminant concentrations in fish. Reports for these tasks have been completed and describe sampling locations, parameters, procedures, and analytical results.[1,3,5] The Task 5 report[7] summarizes the previous reports and the management implications of the results. Detailed analyses of the data (i.e., risk assessment and evaluation of possible remedial actions) are the responsibility of other subgroups of the ORTF.

In all, 1526 water, sediment, and aquatic biota samples were collected during the in-stream contaminant study. Laboratory and field analyses of these samples yielded 24,137 analytical observations. One hundred eighty-five samples were also collected from seven core locations in the Tennessee River to complement existing data on the fate of previous mercury releases.

Several sources of additional data, collected before the in-stream contaminant study, are available and were used for comparative purposes. From 1960 through 1983, TVA and other organizations collected samples in the Oak Ridge area to obtain data for various special projects (e.g., the Regional Water Management

Program, the Clinch River Breeder Reactor Project, and reservoir water quality studies). These data are available on EPA's STORET system. In 1983, ORNL collected sediment samples at 18 locations in the stream channels and floodplains of East Fork Poplar Creek, Bear Creek, White Oak Creek, Poplar Creek, and the Clinch River. This preliminary screening survey was conducted to identify contaminants with a sediment concentration sufficient to warrant further investigation.

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7. Oak Ridge Task Force, *Instream Contaminant Study—Task 5: Summary Report*, Tennessee Valley Authority, Office of Natural Resources and Economic Development, January 1986.
8. *Standard Radiological Effluent Technical Specifications for Pressurized Water Reactors*, NUREG-0472 (Draft), Rev. 3, January 1983.

8. ENVIRONMENTAL SURVEILLANCE AND MONITORING OF THE OAK RIDGE COMMUNITY PROVIDED BY OAK RIDGE ASSOCIATED UNIVERSITIES

8.1 HISTORICAL PERSPECTIVE

As a result of wastewater discharges from the Y-12 Plant, East Fork Poplar Creek and its floodplain became contaminated with materials such as mercury, uranium, thorium, chromium, and zinc. Because the extent of this contamination was not known, considerable quantities of floodplain soils and creek sediments were used throughout the community, primarily in 1982 as topsoil for portions of the new Oak Ridge sewer system. While the bulk of the mercury discharges were before 1960 and before the mid-1970s for uranium, thorium, chromium, and zinc, other pollutants have also been discharged in smaller amounts and have also accumulated in sediments and soils.

East Fork Poplar Creek fish exceed the Food and Drug Administration's action level for mercury, and the TDHE has posted the streams, warning against fishing and swimming.

In 1983, two activities were initiated to better define the potential problem with this residual contamination. The first was a sampling program in response to citizens' requests to determine whether their soil, vegetables, or well water were contaminated. This effort also was directed toward defining the extent of contamination in the community, particularly along the sewer beltway. The second activity was the establishment of the interagency Oak Ridge Task Force (ORTF). This group included representatives from DOE, the EPA, TVA, the USGS, and the City of Oak Ridge. It is chaired by a representative of the TDHE. The ORTF is collecting toxicological and environmental data with which to evaluate the potential long-term public health impact of the residual contamination and the cost versus benefit of remedial measures.[1]

The general sampling effort in 1984 consisted of (1) sampling of private residences; (2) a rapid scan of the entire length of the sewer beltway; (3) participation in the interim cleanup effort at the Civic Center area; (4) cleanup of two small areas of contaminated soil in the community; (5) a rapid scan for preliminary determination of the contamination distribution in the East Fork Poplar Creek floodplain; and (6) monitoring for radioactivity of the Oak Ridge Wastewater Treatment Facility and Emory Valley Road Pump Station. Over 2600 soil, plant, and animal samples were collected and analyzed.

8.2 CURRENT ACTIVITIES

During 1985 sampling of private properties continued, and the following were completed: interim cleanup of a private residence, rapid scan of the East Fork Poplar Creek floodplain, sampling for the Tennessee Department of Transportation for the expansion of Illinois Avenue, and sampling of a salvage yard and a lagoon on Melton Hill Lake suspected of being contaminated by the salvage yard.

8.2.1 Private Properties in the Oak Ridge Community

Cedar Hill area (Table 8.2.1 and Fig. 8.2.1). No samples were collected from private properties in this area.

Country Club area (Table 8.2.1 and Fig. 8.2.1). Sampling consisted of 23 soil samples taken from three private residences near the edge of the East Fork Poplar Creek floodplain. No vegetation samples were collected. Only soil samples collected at the edge of the East Fork Poplar Creek floodplain exceeded the TDHE interim guideline level for soil mercury of 12 ppm.

East Village area (Table 8.2.1 and Fig. 8.2.1). No samples were collected from private properties in this area.

Elm Grove area (Table 8.2.1 and Fig. 8.2.1). No samples were collected from private properties in this area.

Fairbanks Road area (Table 8.2.1 and Fig. 8.2.1). Fifteen soil samples were collected from two private properties; all were below the TDHE guidelines.

High School area (Table 8.2.1 and Fig. 8.2.1). No samples were collected from private properties in this area.

Linden School area (Table 8.2.1 and Fig. 8.2.1). Three residences were sampled, and 197 yard soil samples were collected.

Table 8.2.1. Summary of soil sampling from private property in the Oak Ridge community for 1985

Area	Number of properties	Garden	Yard	Soil mercury concen. range[a] (ppm)
Cedar Hill	0	0	0	
Country Club	3	0	23	1.7–69
East Village	0	0	0	
Elm Grove	0	0	0	
Fairbanks Road	2	0	15	0.02–0.96
High School	0	0	0	
Linden School[a]	3	0	197	0.02–600
Oak Hills	0	0	0	
Robertsville[b]	2	0	135	0.02–650
Scarboro	2	12	17	0.05–2.7
Wiltshire Estates	1	2	0	2.0–2.2
Woodland	0	0	0	
Totals	13	14	387	

[a] Includes a residence of known contamination which has been cleaned up.

[b] Includes property encompasing a contaminated portion of the East Fork Poplar Creek floodplain.

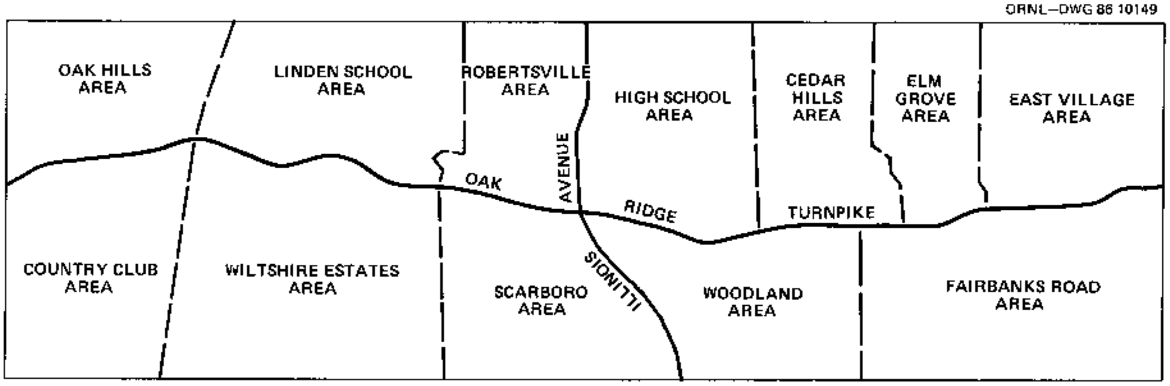

Fig. 8.2.1. Private property areas in the Oak Ridge community.

Several yard soil samples, all of which were collected from a single residence, showed mercury concentrations exceeding the TDHE guidelines. Because of the distance from the floodplain, the contamination is most likely the result of importing floodplain soil.

Oak Hills area (Table 8.2.1 and Fig. 8.2.1). No samples were collected from private properties in this area.

Robertsville area (Table 8.2.1 and Fig. 8.2.1). One hundred thirty-five samples were collected from two private properties. Both properties were partially located in the East Fork Poplar Creek floodplain. All soil samples exceeding the TDHE interim guideline value were collected on the floodplain.

Scarboro area (Table 8.2.1 and Fig. 8.2.1). Twenty-nine soil samples were collected from three residences; none exceeded the TDHE guidelines.

Wiltshire Estates area (Table 8.2.1 and Fig. 8.2.1). Two soil samples were collected from one residence. No samples exceeded the State interim guidelines.

Woodland area (Table 8.2.1 and Fig. 8.2.1). No samples were collected from private properties in this area.

Interim remedial action. Because children lived in the home located on contaminated private property, a detailed study was undertaken and completed in 1985. With the assistance of EPA, DOE requested that the soil contaminated above 100 ppm should be removed and the cleanup continue until the soil mercury concentration was 10 ppm or less. One hundred eighty-three soil samples were collected to confirm that the cleanup criteria were met. This cleanup effort is now complete.

Private property summary to date (Table 8.2.2). Since the ORAU Environmental Surveillance and Monitoring Program began in 1983, 159 private properties have been sampled. This sampling effort represents about 2% of the private properties in Oak Ridge (based on data obtained from the City of Oak Ridge's Tax Assessors Office). Although several private properties had contaminated soils, only 4 (2% of the total sampling effort) were not partially located on the floodplain proper. Three of these properties were contaminated by East Fork Poplar Creek floodplain soil being used as a soil amendment or fill. The

Table 8.2.2. Total residence sampling effort, 1983–1985 (distribution by locality)

	Number of soil samples	Number of residences	Number of vegetation samples	Number of water samples
Oak Hills	14	6	0	0
Linden School	496	58	14	0
Country Club	64	14	10	2
Robertsville	20	3	0	0
High School	41	14	3	0
Cedar Hills	8	3	0	0
Elm Grove	12	3	0	0
East Village	12	4	0	0
Scarboro	49	18	13	1
Woodland	19	7	0	0
Fairbanks Road	54	17	7	0
Wiltshire	41	12	18	0

fourth property was contaminated by runoff from the sewer beltway near Jefferson Junior High School. The sewer beltway in this area was covered with contaminated topsoil from the floodplain.

Rapid scan of the East Fork Poplar Creek floodplain. The initial design for the East Fork Poplar Creek floodplain study established transects across the creek every 100 m. Transects generally traversed the width of the floodplain with surface soil samples collected every 50 m, or at closer intervals if the transect was less than 100 m long. The survey begun in 1984 was completed in the spring of 1985. The study began where East Fork Poplar Creek crosses the Oak Ridge Turnpike to reenter the ORR near the west end of the city. The transects follow 15.85 km of the stream to where it initially leaves the Y-12 Plant site. Six hundred thirty-four soil samples have been collected with a range of soil mercury concentrations of 0.03 to 2400 ppm. The sampling effort focused on the floodplain proper; however, some of the samples were collected around the floodplain's boundary. These data are mainly used as screening information.

Core sampling. Tables 8.2.3–8.2.5 show sample number versus log number. Soil core sampling at two locations was done to construct a preliminary vertical profile of the contaminants in the East Fork Poplar Creek floodplain (Table 8.2.6). The results show that most of the mercury is located within the top 20 inches. This agrees with similar studies of the floodplain by TVA.[1]

Illinois Avenue expansion (Table 8.2.7). ORAU responded to a Tennessee Department of Transportation request for soil sampling at a future highway improvement project beginning at the intersection of Highway 62 (Illinois Avenue) and the Oak Ridge Turnpike and continuing north on both sides of the highway. Thirty-four samples were collected, and the analysis indicated soil mercury concentrations to be less than the TDHE interim guidelines.

Salvage Yard (Table 8.2.8). A salvage yard that has received scrap materials from various DOE facilities in Oak Ridge was surveyed for contamination. Two hundred sixty-six soil samples were collected using a grid design. The soil mercury concentrations ranged from 0.16 to

Table 8.2.3. Sample identification 1 through 58

Sample number	Log number	Sample number	Log number
1	85-1238A	30	85-1195B
2	85-1238B	31	85-1195A
3	85-1238C	32	85-0666
4	85-1239A	33	85-0667
5	85-1239B	34	85-0668
6	85-1239C	35	85-0669
7	85-1239D	36	85-0670
8	85-1240A	37	85-0671
9	85-1240B	38	85-0672
10	85-1240C	39	85-0676
11	85-1240D	40	85-0678
12	85-1241A	41	85-0683
13	85-1241B	42	85-0694
14	85-1241C	43	85-0695
15	85-1242A	44	85-0699
16	85-1242B	45	85-0700
17	85-1242C	46	85-0701
18	85-1242D	47	85-0702
19	85-1243A	48	85-0704
20	85-1243B	49	85-0705
21	85-1244A	50	85-0706
22	85-1244B	51	85-0709
23	85-1244C	52	85-0710
24	85-1244D	53	85-0720
25	85-1245A	54	85-0727
26	85-1245B	55	85-0742
27	85-1245C	56	85-0752
28	85-1195D	57	85-0766
29	85-1195C	58	85-0772

Table 8.2.4. Sample identification 59 through 118

Sample number	Log number	Sample number	Log number
59	85-0773	89	85-1037
60	85-0774	90	85-1039
61	85-0775	91	85-1041
62	85-0776	92	85-1043
63	85-0777	93	85-1045
64	85-0778	94	85-1047
65	85-0779	95	85-1049
66	85-0780	96	85-1072
67	85-0781	97	85-1073
68	85-0782	98	85-1074
69	85-0786	99	85-0026
70	85-0787	100	85-0192
71	85-0788	101	85-0196
72	85-0789	102	85-0233
73	85-0793	103	85-0251
74	85-0794	104	85-0259
75	85-0795	105	85-0262
76	85-0799	106	85-0374
77	85-0801	107	85-0392
78	85-0807	108	85-0412
79	85-0811	109	85-0426
80	85-0812	110	85-0443
81	85-0815	111	85-0449
82	85-0817	112	85-0454
83	85-0818	113	85-0456
84	85-0819	114	85-0461
85	85-0820	115	85-0463
86	85-0821	116	85-0468
87	85-0924	117	85-0470
88	85-0925	118	85-0475

Table 8.2.5. Sample identification 119 through 165

Sample number	Log number	Sample number	Log number
119	85-0481	149	85-1076
120	85-0487	150	85-1077
121	85-0488	151	85-1078
122	85-0492	152	85-1079
123	85-0498	153	85-1080
124	85-0509	154	85-1081
125	85-0518	155	85-1082
126	85-0523	156	85-1083
127	85-0843	157	85-1084
128	85-0852	158	85-1085
129	85-0853	159	85-1086
130	85-0854	160	85-1087
131	85-0855	161	85-0338
132	85-0861	162	85-1075
133	85-0874	163	85-1096
134	85-0879	164	85-1094
135	85-0881	165	85-1095
136	85-0887		
137	85-0896		
138	85-0898		
139	85-0912		
140	85-0917		
141	85-0280		
142	85-2586		
143	85-0487		
144	85-0498		
145	85-0695		
146	85-0700		
147	85-0784		
148	85-0790		

Table 8.2.6. Core samples from Royce Circle multiparameter analysis[a]

Element	Number of observations	Maximum value (ppm)	Minimum value (ppm)	Average (ppm)	Standard deviation
Arsenic	27	12.1	5.2	8.5	2.3
Barium	27	640	310	422	83
Beryllium	27	2.0	1.0	1.1	0.25
Cadmium	27	14	1.0	6.4	3.8
Chromium	27	100	47	71	15
Copper	27	180	26	80	33
Lead	27	140	10	78	32
Lithium	27	30	5.4	15	6.6
Mercury	27	650	3.8	173	184
Nickel	26	94	17	48	24
Selenium	27	3.0	1.0	1.8	0.62
Silver	27	12	1.0	5.1	3.3
Thorium	27	33	8.4	17	6.8
Uranium	27	40	8.7	24	8.1
Zinc	27	190	50	126	34

[a] Data represent 27 core samples varying in depth from 0 to 73 cm.

6700 ppm with 142 (~53%) of the samples exceeding the TDHE interim guidelines for mercury. In addition, several other soil contamination parameters were measured and are reported in Table 8.2.8. Several of these parameters (e.g., mercury and uranium) are elevated when compared with the equivalent data based on background soils.

Melton Hill Lagoon (Table 8.2.7). The sediments from a lagoon of the Melton Hill Reservoir, which receives the outfall from the old east end water treatment plant and possibly runoff from the previously mentioned salvage yard, were sampled. The sampling consisted of composite cores from the surface to 9 in. deep for a total of 20 samples with a sediment mercury concentration range of 0.05 to 16 ppm. Selected samples were also analyzed for uranium, and the results are reported in Table 8.2.9. With the exception of one sample, the mercury concentrations in these sediments are in the general range for background soils.

8.2.2 Multiparameter Analysis

Because of concerns that other contaminants besides mercury were released from the Y-12 Plant, multiparameter analyses have been done on a subset of soil samples. These additional analyses included uranium, barium, lead, arsenic, chromium, thorium, silver, selenium, beryllium, methyl-mercury, and PCBs. In addition to the previously discussed core samples, Table 8.2.9 presents the results of these efforts. Organic mercury compounds tend to be more toxic than the inorganic compounds. Since ORAU's routine analysis is for total mercury only, 52 samples were submitted for methyl-mercury analysis. The submitted samples' total soil mercury concentration ranged from 20 to 1400 ppm with no sample showing methyl-mercury above the detection limits of 0.1 ppm.

For comparison, several soil samples that were considered background because of location and/or mercury content were

Table 8.2.7. Miscellaneous sampling efforts conducted in Oak Ridge and surrounding environs during 1985

Area	Type	Number	Range[a]
East Fork Poplar Creek Floodplain[b]	Soil	634	0.03–2400
Illinois Ave.[b]	Soil	34	0.03–0.27
Salvage Yard[b]	Soil	266	0.16–6700
Melton Hill Lagoon	Sediment	38	0.02–16
Natural[c]	Soil		0.01–4.7

[a] Range is for mercury in parts per million (ppm).

[b] Surface sampling.

[c] Source: Reference 1: 1978 National Academy of Sciences report titled, "An Assessment of Mercury in the Environment," are: Soils 0.01–4.7 ppm

Table 8.2.8. Summary of salvage yard soils multiparameter analysis

Element	Number of observations	Maximum value (ppm)	Minimum value (ppm)	Average (ppm)	Standard deviation
Arsenic	57	145	6.1	23	22
Barium	57	1200	230	492	215
Beryllium	57	3.6	0.68	1.2	0.41
Cadmium	57	120	2.5	14	17
Chromium	55	650	40	176	110
Copper	57	5400	18	520	790
Lead	57	3800	57	1000	890
Lithium	57	24	2.7	13	4.6
Mercury	57	6700	0.48	170	890
Nickel	57	570	21	110	100
Selenium	54	1.0	1.0	2.1	1.5
Silver	55	120	1.0	6.5	17
Thorium	56	31	4.8	10	4.3
Uranium	57	600	2.8	120	140
Zinc	57	7500	63	1400	1300
PCB	19	380	4.3	96	118

submitted for multiparameter analysis. The results of these analyses are summarized in Table 8.2.9. The presence of various uranium isotopes in soils from areas in the city was also examined

8.2.3 Wastewater Analysis

Since April 1984, ORAU's Environmental Surveillance and Monitoring Program has been monitoring the sludge from the

Table 8.2.9. East Fork Poplar Creek floodplain multiparameter analysis[a]

Element	Number of observations	Maximum value (ppm)	Minimum value (ppm)	Average (ppm)	Standard deviation
Arsenic	42	15	5.9	8.7	2.0
Barium	42	700	250	420	92
Beryllium	42	3.6	0.33	1.0	0.55
Cadmium	42	40	3.1	9.3	7.3
Chromium	42	150	56	92	22
Copper	42	270	36	111	46
Lead	42	3900	47	165	590
Lithium	41	64	7.6	16	10
Mercury	42	2400	32	269	410
Nickel	42	210	22	59	34
Selenium	42	6.0	1.0	1.6	0.89
Silver	42	82	1.0	8.8	12
Thorium	42	64	7.6	21	11
Uranium	42	85	4.6	37	15
Zinc	41	510	130	191	70
PCB	27	2.1	0.2	0.59	0.43
Gross alpha	32	21	3.4	9.4	3.4
Gross beta	32	73	21	40	10

[a] Data represent 27 core samples varying in depth from 0 to 73 cm.

Oak Ridge Water Treatment Plant for ^{137}Cs and ^{60}Co. This effort was initiated because of contamination attributed to a local private facility. Table 8.2.10 presents the results of this effort for 1985. Except for the ^{60}Co value on February 25, 1985, nearly all values are close to an order of magnitude below the most restrictive levels.

Table 8.2.11 presents data from the west and east drying beds for the Oak Ridge Water Treatment Plant. Multiparameter analyses have been performed on the dry sewage sludge. These analyses included both radioactive and nonradioactive parameters and are presented in Tables 8.2.12 and 8.2.13. These data are presented on a dry weight basis, and to convert to a wet basis (actual concentration in the wastewater), the value must be multiplied by percent solids.

In an effort to relate the contaminants in the sludge from Oak Ridge to those of the sludge of the surrounding communities, sewage sludge samples were collected and analyzed with the results shown in Table 8.2.13. It might be noted that Oak Ridge is higher than the other two communities in several parameters (Ba, Cr, Cu, Hg, Se, Ag, U, I, ^{137}Cs, ^{60}Co, ^{54}Mn, and ^{134}Cs). The results are presented as dry weight.

8.2.4 Quality Assurance and Quality Control

In 1985, the EPA, the TDHE, and ORAU met in Oak Ridge to review ORAU's QA procedures. One of the results of this and the previous year's meeting was a sample exchange program. ORAU has exchanged samples with EPA and Y-12. In addition, based on ORAU's performance on analytical materials from

Table 8.2.10. Summary of the Oak Ridge Waste Water Treatment Facility Liquid Sludge from Tank #4 1985

Element	Number of observations	Maximum value (pCi/mL)	Minimum value (pCi/mL)	Average (pCi/mL)	Standard deviation
		Quarter I			
^{137}Cs	23	3.2	0.001	1.1	0.76
^{60}Co	23	35	0.008	3.7	6.9
		Quarter II			
^{137}Cs	48	1.4	0.001	0.15	0.33
^{60}Co	48	6.0	0.001	0.76	1.1
		Quarter III			
^{137}Cs	28	2.1	0.001	0.98	0.72
^{60}Co	28	5.7	0.001	2.2	1.4
		Quarter IV			
^{137}Cs	29	6.5	2.3	3.9	1.4
^{60}Co	29	9.8	1.5	3.7	1.7

Table 8.2.11. City of Oak Ridge Sludge drying beds radioactivity samples collected 8/7/85

Sample No.		Concentration (ppm)			
		^{60}Co	^{137}Cs	^{134}Cs	^{54}Mn
West Plant					
Bed #1	149	110 ± 10	26 ± 2	1.4 ± 0.7	3.0 ± 0.7
Bed #2	150	130 ± 10	30 ± 2	3.1 ± 0.8	4.3 ± 0.8
Bed #3	151	120 ± 10	32 ± 2	2.4 ± 0.7	2.0 ± 0.6
Bed #4	152	92 ± 5	16 ± 1	1.0 ± 0.6	2.3 ± 0.6
Bed #5	153	240 ± 10	94 ± 5	6.1 ± 1.1	4.3 ± 0.9
Bed #6	154	87 ± 5	15 ± 1	1.9 ± 0.6	2.0 ± 0.5
East Plant					
Bed #1	155	140 ± 10	49 ± 3	4.6 ± 0.9	3.2 ± 0.7
Bed #2	156	150 ± 10	82 ± 5	6.2 ± 1.0	3.4 ± 0.8
Bed #4	157	170 ± 10	65 ± 4	4.5 ± 0.9	4.0 ± 0.8
Bed #6	158	190 ± 10	75 ± 4	5.5 ± 1.0	2.8 ± 0.8
Bed #7	159	170 ± 10	66 ± 4	5.5 ± 1.0	3.6 ± 0.9
Bed #8	160	180 ± 10	78 ± 4	5.7 ± 1.0	3.4 ± 0.8

Table 8.2.12. Water treatment plant for sewage sludge multiparameter analysis

Dry weight basis

	Concentration (ppm)		
	2/15/85	6/4/85	9/9/85
Sample No.	161	162	163
Solids	3.0%	3.0%	3.0%
Parameter			
Arsenic	5.1 ± 0.3	33 ± 5	5.3 ± 0.3
Barium	1200 ± 100	1300 ± 100	770 ± 40
Beryllium	0.8	<1	1.0
Cadmium	1.5		10
Chromium	1100 ± 100	530 ± 30	380 ± 20
Copper	1100 ± 100	660 ± 30	660 ± 50
Lead	250	200	200
Lithium	17	4.2	16
Mercury	12 ± 1	10 ± 1	11 ± 1
Nickel	170 ± 30	83	80
Selenium	8.1 ± 1.5	<7	6 ± 1
Silver	130 ± 8	115 ± 7	96 ± 6
Thorium	3.4 ± 0.3	2.4 ± 0.3	2.6 ± 0.2
Uranium	40 ± 3	40 ± 3	25 ± 2
Zinc	3000 ± 200	2600 ± 200	2100 ± 100
Antimony	4.5 ± 0.3	4.6 ± 0.5	4.0 ± 0.2
Bromine	115 ± 6	212 ± 12	93 ± 5
Iodine	112 ± 7	115 ± 7	94 ± 6
		Concentration (pCi/g)	
^{137}Cs	30 ± 2	15 ± 1	55 ± 3
^{60}Co	60 ± 3	27 ± 2	107 ± 5
^{54}Mn	0.8 ± 0.3		3.4 ± 0.3
^{134}Cs	1.7 ± 0.4	1.4 ± 0.5	10 ± 1
^{65}Zn			3.3 ± 0.5

NBS, ORAU is now participating in the certification program for the NBS Standard Reference Materials. In 1985 representatives of the Knoxville office of the TDHE reviewed the EFPC floodplain soil sampling program and were critical of several aspects, such as adherence to the proposed work plan, definition and identification of the floodplain boundary, precision in identifying sample collection locations, and sample collection methods and documentation. Meetings among the concerned groups produced a better understanding of the problems and changes that have improved the data being generated.

Table 8.2.13. Multiparameter analyses of dried sewage sludges sampled 9/9/85

	Concentration (ppm dry wt)		
Sample No. Solids	Knoxville 164 3.7%	Lenoir City 165 17.3%	Oak Ridge 166 3.0%
Parameter			
Arsenic	5.8 ± 0.4	8.1 ± 0.5	5.3 ± 0.3
Barium	470 ± 30	570 ± 40	770 ± 40
Beryllium	2.0	1.0	1.0
Cadmium	12	8.0	1.0
Chromium	320 ± 20	270 ± 20	380 ± 20
Copper	330 ± 40	480 ± 40	600 ± 50
Lead	190	300	200
Lithium	18	14	16
Mercury	2.2 ± 0.3	3.7 ± 0.7	11 ± 1.0
Nickel	280	60	80
Selenium	2.3 ± 0.5	4 ± 1	6 ± 1.0
Silver	43 ± 3.0	18 ± 1	96 ± 6.0
Thorium	3.7 ± 0.2	3.2 ± 0.2	2.6 ± 0.2
Uranium	2.6 ± 0.2	4.0 ± 0.3	25 ± 2.0
Zinc	730 ± 40	2200 ± 100	2100 ± 100
Antimony	4.5 ± 0.3	150 ± 10	4.0 ± 0.2
Bromine	100 ± 6.0	23 ± 1.0	93 ± 5.0
Iodine	42 ± 3.0	10 ± 1.0	94 ± 6.0
		Concentration (pCi/g)	
^{137}Cs	0.07 ± 0.05	0.14 ± 0.03	55 ± 3.0
^{60}Co	<0.60	<0.050	107 ± 5.0
^{54}Mn	<0.060	<0.050	3.4 ± 0.30
^{134}Cs	<0.060	<0.050	10 ± 1.0
^{7}Be	<0.060	1.3 ± 0.2	<0.050

REFERENCE FOR SECT. 8

1. Oak Ridge Task Force, *Instream Contaminant Study—Task 2: Sediment Characterization,* Tennessee Valley Authority, Office of Natural Resources and Economic Development, April 1985.

Appendix

DEFINITIONS, UNITS, PREFIXES, AND ABBREVIATIONS

Definitions

Committed dose equivalent—The dose equivalent received for a period of 50 years resulting from the intake or deposition of a radionuclide in any one year.

Confidence interval and confidence coefficient—A confidence interval is a statement that the population parameter (usually the mean) has a value lying between two specified limits. It has the feature that, in repeated sampling, a known proportion (for instance, 95%) of the intervals computed by this method will include the population parameter. The confidence limits are the end points of the interval, and the confidence coefficient is the percentage of all possible samples of a given size yielding the confidence interval that will catch the mean. The 95% confidence coefficient for a sample can be estimated by the following: $2x\sqrt{s^2/n}$, where s^2 is the sample variance and n is the number of samples.

Critical organ—A particular organ or tissue that is likely to be of greatest importance when more than one organ is exposed because of the dose it receives, its sensitivity to radiation, or the importance to health of any damage that results.

Dose equivalent—The product of the absorbed dose to the body or an organ and the quality factor.

Effective dose equivalent—The sum of the dose equivalent received from external sources plus the sum of the committed dose equivalent to each organ multiplied by the weighting factor appropriate to each organ.

Geometric mean and standard deviation—When the variance of a population is related to the mean, a logarithmic transformation of the original data will somethimes help to stabilize the variance. A mean that is calculated on the logarithmic data and then transformed back (using the antilogarithm) to the original units is the geometric (or derived) mean.

To estimate the standard deviation about the geometric mean, the standard deviation of the logarithms is transformed back to the original data and the geometric mean is then multiplied and divided by the antilog of the standard deviation.

Quality factor—A multiplying factor for a dose equivalent to the body or an organ to allow for the additional damage caused by radiations that produce higher ionizing densities than X or gamma radiation. This factor is applicable only for purposes of radiation protection and should not be used for accidental high exposures.

Stochastic effect—Effect characterized by malignant and hereditary diseases for which the probability of an effect occuring, rather than its severity, is regarded as a function of dose without threshold.

Weighting factor—The ratio of the stochastic risk arising from exposure of a tissue to the total risk when the whole body is irradiated uniformly.

Radiation Units

Curie (Ci) and Becquerel (Bq)—Units of radioactivity that are a measure of those spontaneous, energy-emitting, atomic transformations that involve changes in the state of the nuclei of radioactive atoms. 1 Ci = 37,000,000,000 Bq.

Roentgen (R) and coulombs per kilogram (C/kg)—Units of exposure to radioactivity. 1 R = 0.000258 C/kg.

Rad and Gray (Gy)—Units of absorbed dose in any medium. 1 rad = 0.01 Gy.

Roentgen equivalent man (rem) and Sievert (Sv)—Units of dose equivalent which account for the relative biological effectiveness of a given absorbed dose. 1 rem = 0.01 Sv.

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Elements and Compounds

Ag	silver
Al	aluminum
As	arsenic
B	boron
Ba	barium
Be	beryllium
Br	bromine
Ca	calcium
Cd	cadmium
Ce	cerium
Cl	chlorine
Cl^-	chloride
CN	cyanide
Co	cobalt
Cr	chromium
Cs	cesium
Cu	copper
F^-	fluoride
Fe	iron
Ga	gallium
^3H	tritium
Hf	halfnium
Hg	mercury
I	iodine
K	potassium
Kr	krypton
La	lanthanum
Li	lithium
Mg	magnesium
Mn	manganese
Mo	molybdenum
Na	sodium
Nb	niobium
NH_3	ammonia
Np	neptunium
$NH_3(N)$	ammonia nitrogen
$NO_3(N)$	nitrate nitrogen
NO_3	nitrate
Ni	nickel
P	phosphorus
Pb	lead
PO_4^{3-}	phosphate
Pu	plutonium
Rn	radon
Ru	ruthenium
Sb	antimony
Sc	scandium
Se	selenium
Si	silicon
SO_4^{2-}	sulfate
Sr	strontium
Tc	technetium
Th	thorium
Ti	titanium
U	uranium
V	vanadium
Xe	xenon
Y	yttrium
Zn	zinc
Zr	zirconium