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Data Base Management Activities for the Remedial Action Program at ORNL: Calendar Year 1989

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ACRONYMS AND INITIALISMS

AA	Alternative Assessments
ACD	Analytical Chemistry Division
ATDD	Atmospheric Turbulence and Diffusion Division
BMAP	Biological Monitoring and Abatement Program
BNI	Bechtel National, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCONS	Construction data for CERCLA wells
CH2M Hill	CH2M Hill, Oak Ridge, Tennessee
CHWM	Center for Hazardous Waste Management
-CONS	Construction data
CWA	Clean Water Act
DIMS	Data and Information Management System
EMC	Environmental Monitoring and Compliance
EPA	U.S. Environmental Protection Agency
ESD	Environmental Sciences Division
FS	Feasibility Study
GIS	Geographic Information System
HASRD	Health and Safety Research Division
HF	Hydrofracture
HFCONS	Construction data for hydrofracture wells
HFIR	High-Flux Isotope Reactor
HHMS	Hydrostatic head monitoring station
HHMSCONS	Construction data for HHMS wells
HMIX	Hazardous Materials Information Exchange
HRE	Homogeneous Reactor Experiment
ID	Identification Code
ISV	In situ vitrification
MB	Melton Branch

MCI	Mining Consultants, Inc.
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NWT	Northwest Tributary
OHF	Old Hydrofracture Facility
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PA/SI	Preliminary Assessment and Site Investigation
PCB	Polychlorinated biphenyl
PIEZ	Piezometer
PIEZCONS	Construction data for piezometer wells
PP	Priority pollutant
PRAP	Pre-Remedial Action Program
PRAPCONS	Construction data for PRAP wells
RAP	Remedial Action Program
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigations
RI/FS	Remedial Investigation Feasibility Study
SDWA	Safe Drinking Water Act
SIF	Standard Interfacing Format
SLB	Shallow Land Burial
STP	Sewage Treatment Plant
SWMU	Solid Waste Management Unit
SWSA	Solid Waste Storage Area
TARA	Test Area for Remedial Action
TARACONS	Construction data for wells in TARA
TOC	Total organic carbon
TOX	Total organic halides

TRU	Transuranic
TTO	Total toxic organics
USGS	U.S. Geological Survey
UT	University of Tennessee
WAG	Waste Area Grouping
WOC	White Oak Creek
WOD	White Oak Dam
WOL	White Oak Lake
WQ	Water Quality
WQCONS	Construction data for water quality wells

ACKNOWLEDGMENTS

The Remedial Action Program (RAP) Data and Information Management System (DIMS) would not have been possible without the cooperation of numerous investigators and agencies collecting data related to the Oak Ridge National Laboratory. The authors appreciate the willingness of these sources to share data files; acknowledgment of these contributions is made throughout this report. In addition, various users of the data base have helped to ensure its quality and have provided suggestions to improve its usefulness. The authors express their appreciation to Linda J. Allison and Diana S. Wickliff for their critical review of the report.

ABSTRACT

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The Oak Ridge National Laboratory (ORNL) Remedial Action Program (RAP) was established in 1985 in response to state and federal regulations requiring comprehensive control over facility discharges and cleanup of contaminated sites. A computerized Data and Information Management System (DIMS) was developed for RAP to (1) provide a centralized repository for data pertinent to RAP and (2) provide support for the investigations and assessments leading to the long-term remediation of contaminated facilities and sites.

The current status of DIMS and its role in supporting RAP during 1989 are described. The DIMS consists of three components: (1) the Numeric Data Base, (2) the Bibliographic Data Base, and (3) the Records Control Data Base. This report addresses all three data bases, but focuses on the contents of the Numeric Data Base. Tables and figures summarize the types of data currently available, describing where and when the data were collected. Significant progress was made last year with the geographic information system (GIS) and ARC/INFO[1], which can be interfaced with SAS/GRAPH[2] to provide combined mapping and statistical graphic products. Several thematic layers of GIS data for the Oak Ridge Reservation are now available.

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[1]ARC/INFO is a registered trademark of Environmental Systems Research Institute, Redlands, California.

[2]SAS is a registered trademark of SAS Institute, Cary, North Carolina.

1. INTRODUCTION

Radioactive and/or hazardous materials have been handled at Oak Ridge National Laboratory (ORNL) for more than 40 years. Research, development, and waste management activities conducted during this time have resulted in contamination of facilities and the environment. Such areas include Solid Waste Storage Areas (SWSAs), waste ponds and seepage pits, radioactive waste processing and transfer facilities, research laboratories, dedicated environmental research sites, experimental reactors, radioisotope development facilities, the surrounding environments, and off-site contamination of the Clinch River and Watts Bar Reservoir.

ORNL has had a continuing responsibility to monitor and control these contaminated areas to ensure that on-site personnel exposures and off-site releases are maintained within applicable Department of Energy guidelines. Over the past several years, however, significant federal and state environmental legislation has been enacted to provide more comprehensive control over facility discharges and the cleanup of contaminated sites. The ORNL Remedial Action Program (RAP) was established in 1985 in response to specific state and federal regulations mandating corrective measures at areas contaminated with radioactive and/or hazardous chemicals. The most important legislative acts currently governing ORNL remedial actions are the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Clean Water Act (CWA), and the Safe Drinking Water Act (SDWA).

The Oak Ridge Reservation (ORR), on which ORNL is located, was recently listed on the CERCLA National Priority List (NPL). Associated with the NPL is the ORR Federal Facility's Agreement, which provides direction for remedial action on the ORR and prescribes that a reservation-wide consolidated data base be developed. Regulatory agencies will also be requesting various types of data as a result of ORR's inclusion on the NPL. The implications to the ORNL RAP data base will be determined when the purpose and structure of the consolidated data base have been more fully defined.

The majority of the ORNL contaminated sites are currently being treated as RCRA solid waste management units (SWMUs). Because of the large number of sites (more than 250, many of which are located close to one another) and the proven hydrologic interconnections between many of these sites, monitoring and assessment of individual sites

was shown to be impractical. Therefore, the SWMUs were divided into 20 waste area groupings (WAGs) on the basis of geographic and hydrologic information (Fig. 1).

According to Section 3004(u) of RCRA, all SWMUs must be evaluated to determine whether they are sources of continuing releases of hazardous substances into the environment. Similar requirements are imposed for off-site contamination under RCRA Section 3004(v). Investigations have been and will continue to be conducted to characterize the extent of contamination so that possible maintenance and ultimately corrective actions can be implemented. Environmental data collected in support of other programs at ORNL are also applicable to RAP. Collectively, these studies are generating a voluminous amount of data.

Because implementation of RAP is controlled by regulatory agencies, information generated by the program must be retained to support any future legal or administrative actions that may be taken. These actions may not occur for years after the data have been collected; thus, it is crucial that a management system be maintained for identifying, logging, and filing project data and records and for assisting in the search and retrieval of such information. To meet these needs, a Data and Information Management System (DIMS) has been developed for RAP.

DIMS consists of three components: (1) the Bibliographic Data Base, (2) the Records Control Data Base, and (3) the Numeric Data Base. The Bibliographic Data Base and associated hardcopy reference collection serve as a repository for all reports published as a result of the program, as well as for other pertinent publications. The Records Control Data Base serves as an index for the retrieval of unpublished information generated by the program, such as correspondence, project plans, field notebooks, and chain-of-custody records. The Numeric Data Base serves as a central repository for technical data generated by the program and for applicable data from other studies. Such data will be used to evaluate the condition of the environment as it relates to the ORNL's past waste management practices and research activities. Ultimately, analyses based on these data will be used to justify decisions regarding corrective action.

The current regulatory compliance effort involves a sequential approach to conducting (1) Preliminary Assessments and Site Investigations (PA/SI) for each WAG, (2) Remedial Investigations (RI) and Alternative Assessments (AA) for WAGs determined to be contaminated, and (3) Feasibility Studies (FS) for determining corrective actions to be

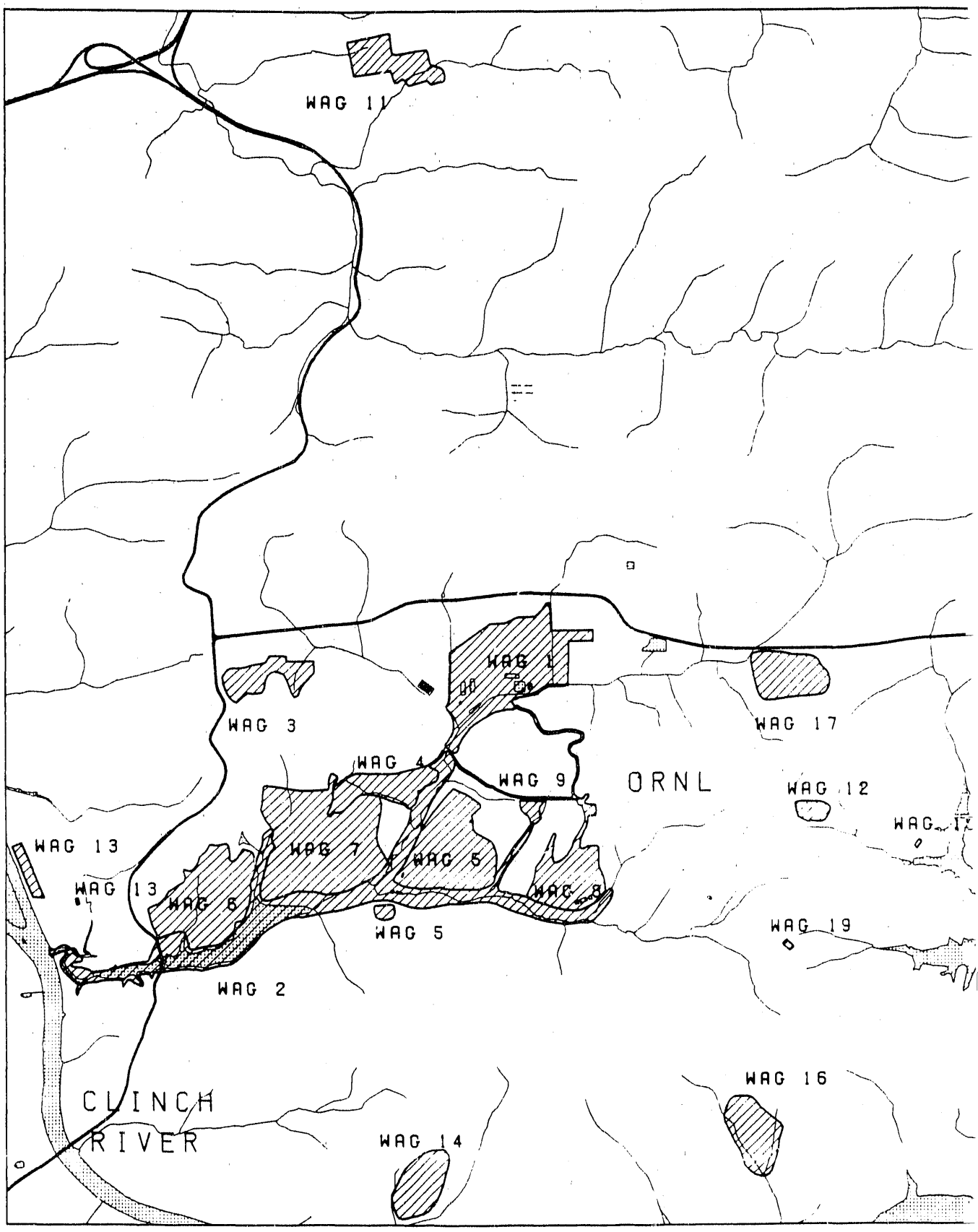
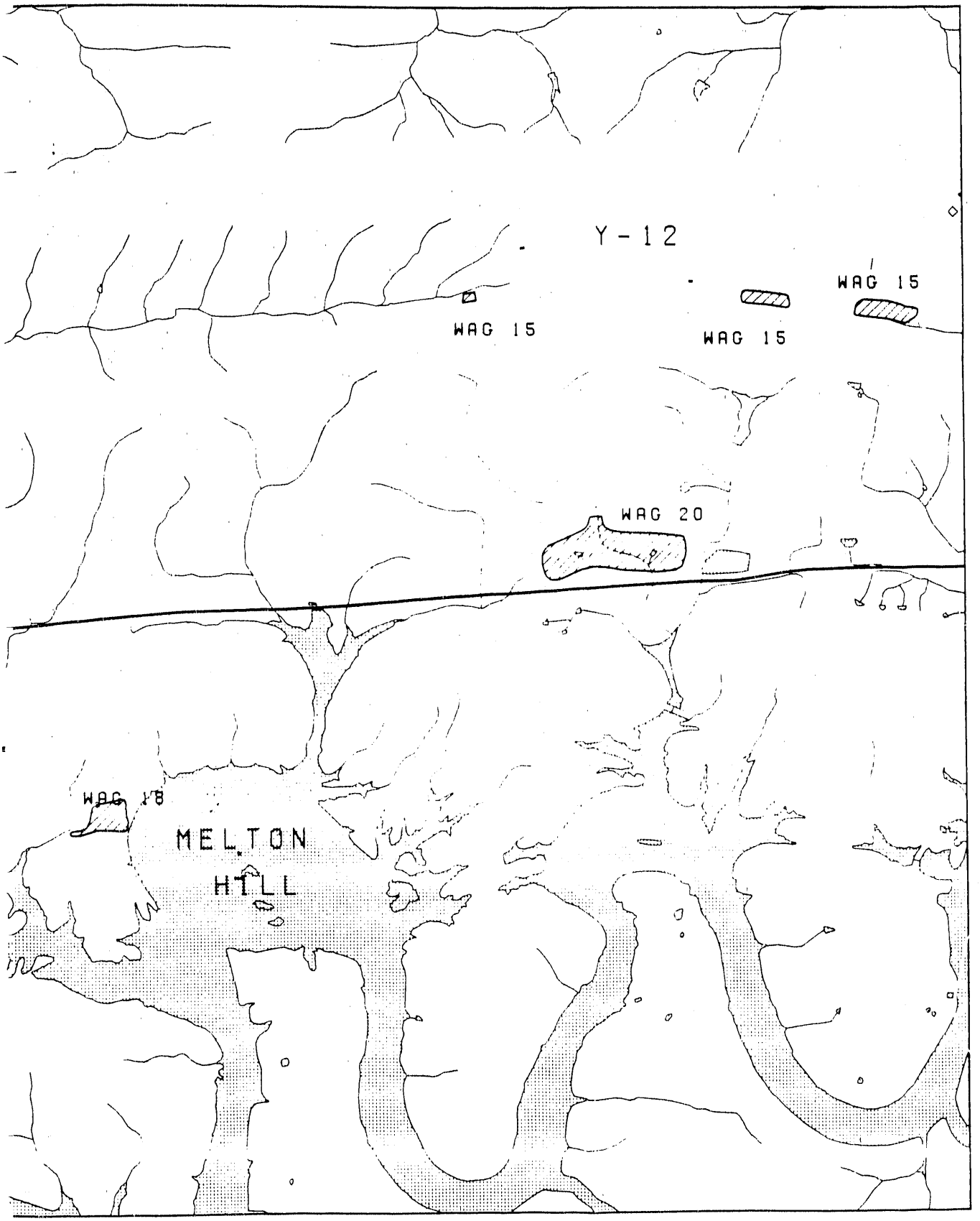


Fig. 1. Oak Ridge National Laboratory's active and inactive waste management areas, contaminated fa



ilities, and potential sources of contaminants have been divided into 20 waste area groupings (WAGs).

implemented at the contaminated WAGs (Fig. 2). In addition, National Environmental Policy Act (NEPA) compliance issues are presently being addressed. The program also conducts routine maintenance, surveillance, and interim corrective actions at sites awaiting final closure; performs technology demonstrations to evaluate decommissioning or closure techniques under field conditions; and designs and implements site and facility closures

The RI, AA, and FS phases of the program (collectively referred to as the RI/FS process) are being implemented with significant subcontracted assistance; field investigations for this RI/FS process began in late 1988. The primary RI/FS subcontractor, Bechtel National, Inc. (BNI), has created a RI/FS Data Base to manage data generated by their studies. These data are being incorporated into the RAP Numeric Data Base as studies are completed.

This report summarizes the status of the DIMS and its role in supporting RAP during calendar year 1989. It focuses on a description of the contents of the Numeric Data Base; previous reports (Voorhees et al. 1986, 1988, 1989) describe its design, development, organization, data management techniques, quality assurance, accessibility, security, etc. Work performed in 1989 for the Records Control and Bibliographic data bases is also briefly described.

Data per se will not be presented in this report. Rather, the primary objective is to let the reader know what kind of data is available, the geographic areas for which data have been collected, and the period of time for which data are available. This information is summarized in tables and figures.

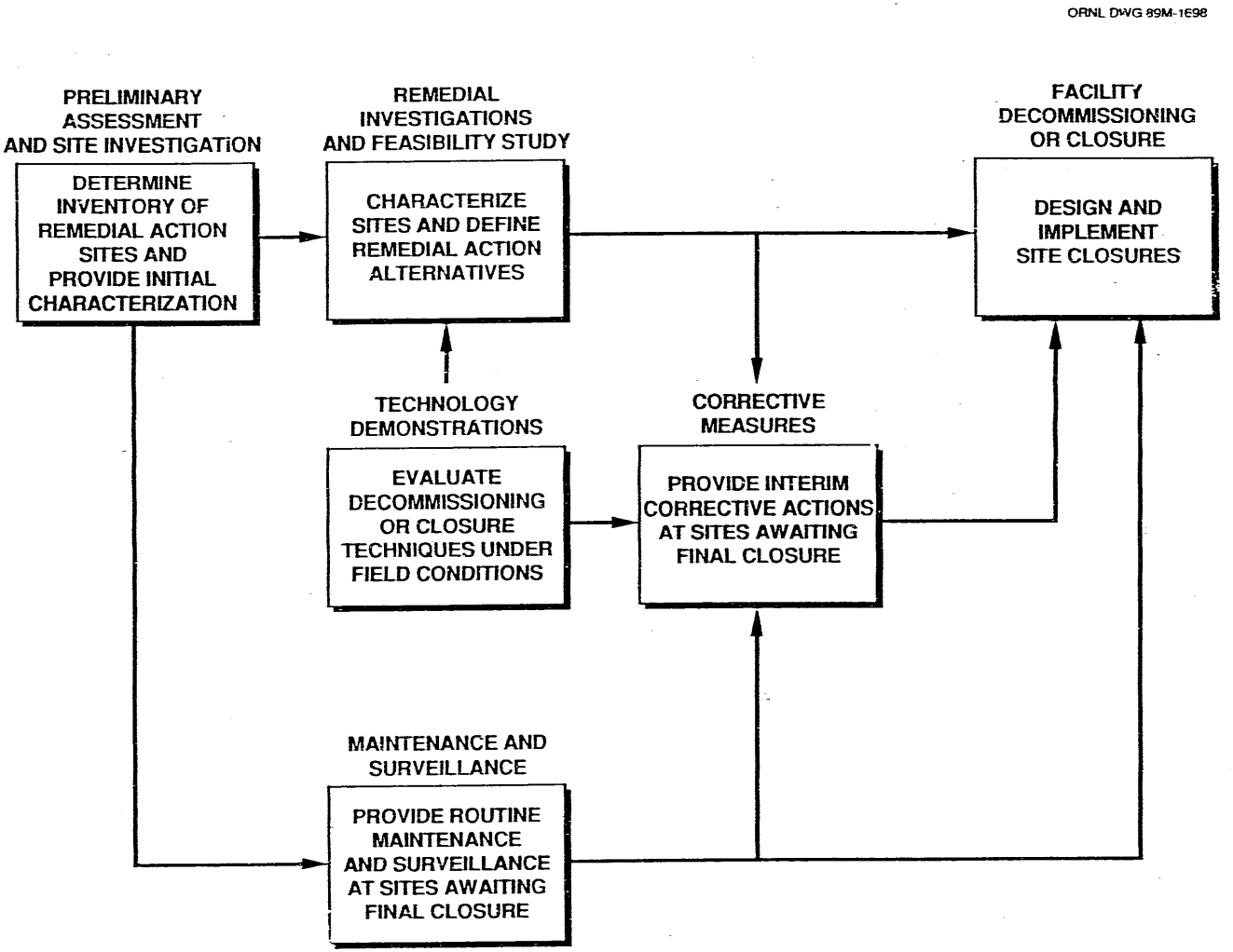


Fig. 2. Oak Ridge National Laboratory Remedial Action Program implementation flowchart.

2. NUMERIC DATA BASE

The RAP Numeric Data Base serves as a central repository for technical data related to the program. The data base was designed to take advantage of computer systems as an aid in acquiring, checking, and processing data so that accurate information is available for analysis and assessment. The data base principally uses SAS[1] software installed on IBM and VAX mainframe computers and on several PCs used by data management staff. Other software is used to manage lengthy descriptive documentation of the data sets, administrative or record-keeping tasks, and some forms of data entry. For these tasks, software such as dBASE III Plus, Lotus 1-2-3, and WordPerfect are used. Files created in dBASE and Lotus can be transferred directly into PC-based SAS data sets and subsequently uploaded to a mainframe computer.

A geographic information system (GIS), using ARC/INFO[2] software, is used to analyze and present spatially oriented data. ARC/INFO allows the user to combine and subset descriptive data associated with spatially defined data and provides complete graphic and mapping capabilities

The general structure of the Numeric Data Base consists of a collection of SAS libraries, with each library containing one or more SAS data sets. The manner in which the data sets are organized allows the investigator for a particular task to easily access his or her own data yet restricts access to other data within the data base. However, some types of data, such as precipitation and surface discharge, come from several sources and may be applicable to several tasks; these data are cataloged in separate libraries according to the type of data. For the purposes of describing the contents of the RAP Numeric Data Base, the libraries have been grouped into the following data categories:

- well construction,
- groundwater,
- surface water,

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[1]SAS is a registered trademark of SAS Institute, Inc., Cary, North Carolina.

[2]ARC/INFO is a registered trademark of Environmental Systems Research Institute, Redlands, California.

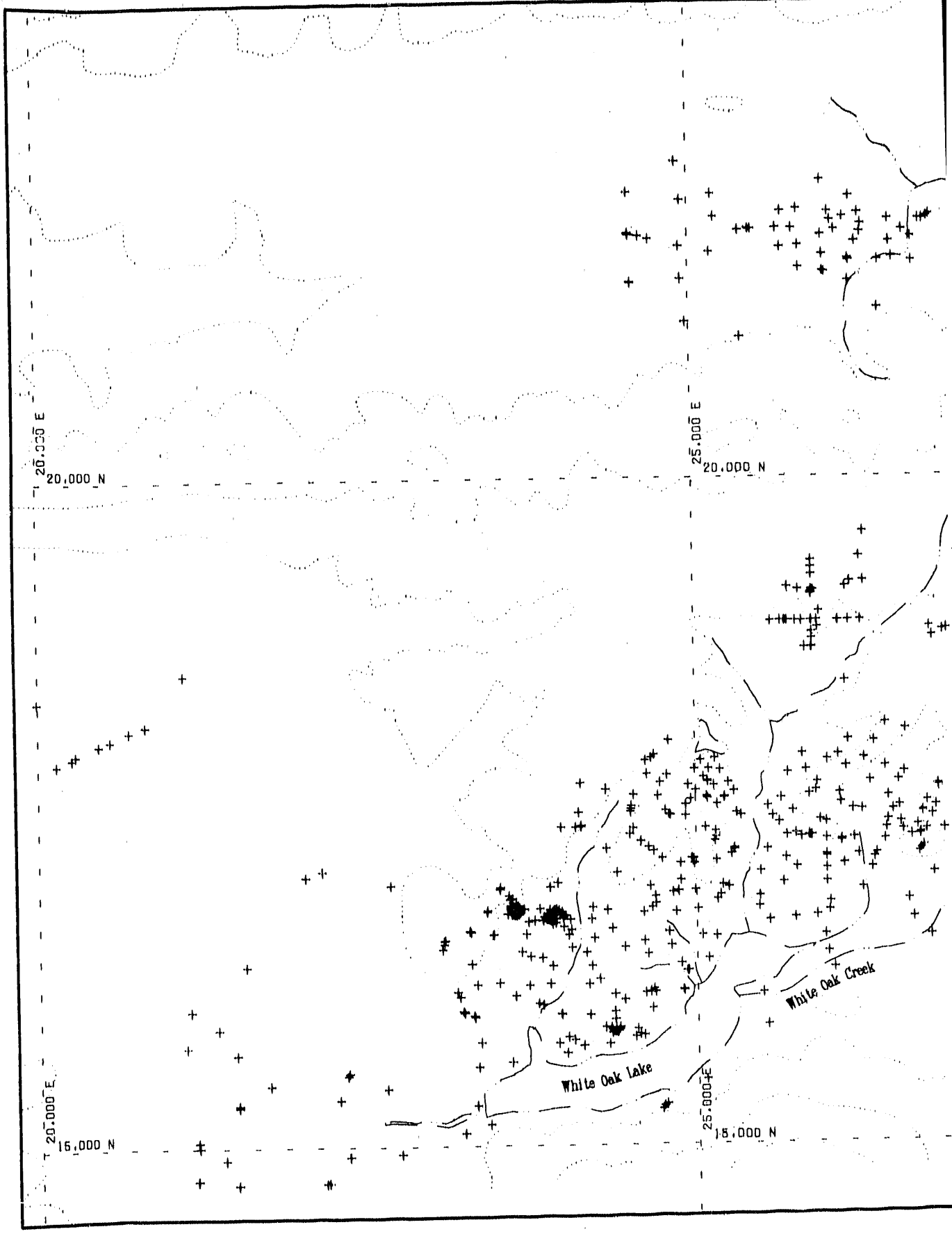
- meteorological,
- contaminant characterization,
- maintenance and surveillance,
- biological monitoring,
- technology demonstrations, and
- miscellaneous.

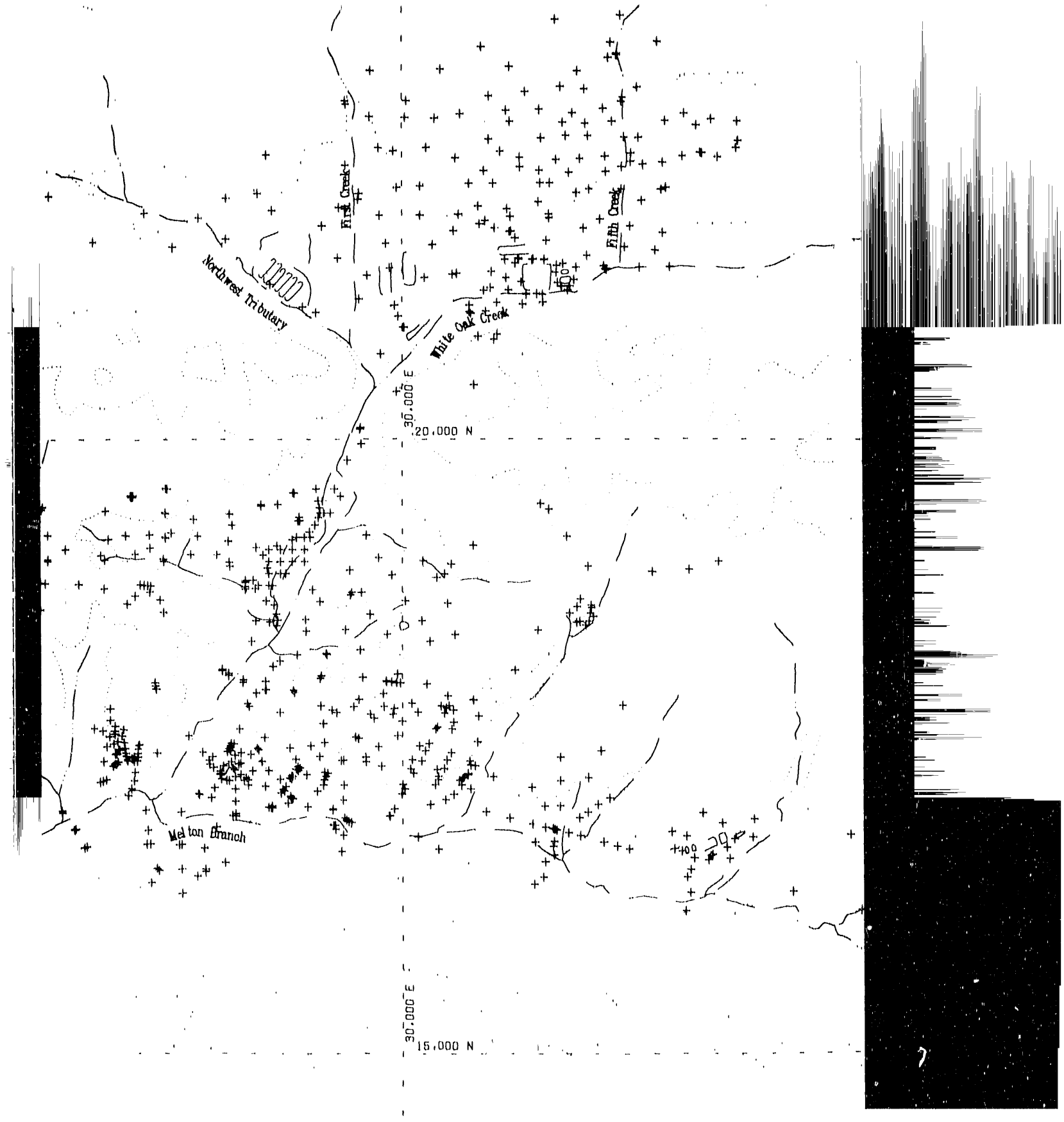
In this report, the contents of the Numeric Data Base are presented with respect to this organization (Sects. 2 1-2 10). In addition, rather than discussing only what was added to the data base in 1989, this report provides a comprehensive description of the contents of the entire data base. Although some of the information presented in last year's annual report (Voorhees et al. 1989) will be repeated, it is believed that the resulting report will be of more benefit to the user. In addition, the development of SAS format files (Sect. 2.11) and the role of the GIS (Sect. 2.12) are also discussed.

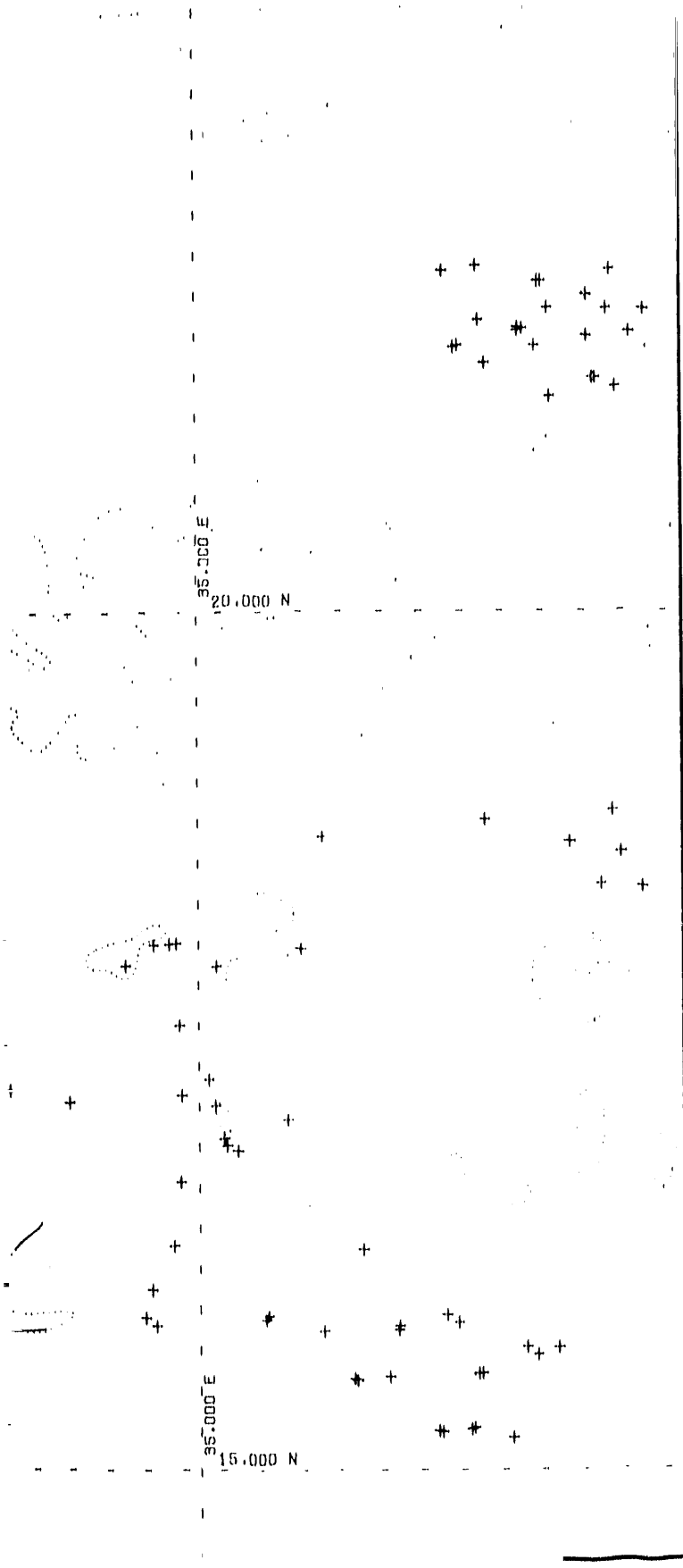
The Numeric Data Base contains more than 150 SAS data sets with a total of more than 6 5 million data entries. Contaminant characterization data occupy the majority of the data base in terms of space because of the large number of analyses associated with a single sample; however, the other categories of data are just as important and represent a significant amount of information, as discussed below.

2.1 WELL CONSTRUCTION INFORMATION

More than 1350 observation wells have been drilled in the vicinity of ORNL during its 45-year history. As indicated by Fig. 3, which simply shows the geographic extent of the wells, a fairly broad coverage exists for the ORNL area. The wells were drilled at different times and for different purposes, so there is some variation in the parameters recorded during construction. Construction data (-CONS) for these wells have been recorded in eight SAS data sets (Table 1) on the basis of the general installation date and/or general purpose and can easily be combined into a single data set as needed. Well construction


20,000 E
25,000 E
20,000 N
20,000 E
25,000 E
16,000 N
15,000 N
White Oak Lake
White Oak Creek


First Creek
Fifth Creek
Northwest Tributary
White Oak Creek
100
30,000 E
20,000 N
Melton Branch
100
30,000 E
15,000 N



Legend

Sites

+ Well Locations

Lines

- - - X-10 Grid, 1000 ft Interval

—— — Creeks, Ponds, and Basins Contours, 100 ft Interval (approx)

Map Scale 1:12000
March 1989

Fig. 3.

Locations of All Wells in the Remedial Action Program Numeric Data Base.

Table 1. SAS data sets of well construction parameters

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCI.MAI25255.SAS.ERFU2	Well construction data			
PIEZCONS	Construction data on piezometer wells installed by RAP	05DEC85 - 21JUL87	348	33
WQCONS	Construction data on water quality wells installed by RAP	19JUL85 - 01JUL87	77	40
PRAPCONS	Construction data on monitoring wells installed before establishment of RAP	1949 - 1983	763	32
HHMSCONS	Construction data on hydrostatic head monitoring stations installed by RAP	17MAR86 - 07APR88	31	43
HFCONS	Construction data on hydrofracture wells installed before establishment of RAP	1959 - 1984	89	27
CERCONS	Construction data on water quality wells installed by RAP to comply with CERCLA	08JAN85 - 15MAR85	13	25
TARACONS	Construction data on wells installed by RAP in the Test Area for Remedial Action study area	13MAR87 - 15APR87	13	32
UWCONS	Construction data on wells installed by USGS, u-series wells	23OCT85 - 19FEB87	28	38

[a]Definitions:
RAP = Remedial Action Program;
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.

data sets are updated periodically because of plugging and abandonment activities and because of changes in measure point elevations caused by damaged well casings. Well construction parameters for 28 wells (U-series wells) installed by the U.S. Geological Survey (USGS) were added to the data base in 1989.

Nearly all of the older, pre-RAP (PRAP) wells (Table 1, PRAPCONS) are located in the vicinity of the SWSAs and the Pits and Trenches Area (Fig. 1, WAGs 3-7). Many of the older wells in the ORNL Main Plant Area (Fig. 1, WAG 1) have been destroyed or damaged by construction activities. Therefore, RAP installed more than 330 piezometer (PIEZ) wells to obtain basic geologic and hydrologic data as an aid in determining suitable locations for and design of water quality monitoring wells required by RCRA (Table 1, PIEZCONS).

The piezometer well locations were selected to supplement the available information from existing wells in the burial grounds and to establish a basic network for gathering groundwater data in other WAGs. Most of the wells were shallow, drilled only until aquifer inflow was detected. Some wells, however, were drilled to reach deeper aquifers in order to determine both the potentiometric heads of water-bearing zones at these levels and the vertical hydraulic gradients; at some locations, pairs of piezometer wells were installed for these purposes.

The hydrofracture (HF) wells are located in four distinct areas associated with the experimental and operational hydrofracture sites in Melton Valley (Table 1, HFCONS). As with the older (PRAP) wells discussed previously, the information for these wells came from various documented and undocumented sources, including ORNL and USGS publications, borehole geophysical logs, and personal communications.

In accordance with the U.S. Environmental Protection Agency (EPA) regulations (40 CFR, Part 265, Subpart F), 77 water quality (WQ) wells have been installed in the ORNL area. Eight of the wells are located in WAG 8, 30 in WAG 6, and 39 in WAG 1. The wells are classified as upgradient (reference), downgradient, or internal WAG characterization wells, depending on their position in relation to the general direction of groundwater flow. During the first year, these wells (Table 1, WQCONS) were sampled quarterly, but the samples become less frequent (semiannual), depending upon the results of the analyses (Sect. 2.2.2). An additional 98 water quality wells, in various stages of development, are part of the 171 that have been or will be installed at the perimeters of

the WAGs. Construction information for these wells will be entered into the data base as they are completed.

A series of hydrostatic head monitoring stations (HHMS) has been installed in the Pits and Trenches Area and SWSA 6 in order to characterize water levels, geology, and water quality in and surrounding these waste management areas (Table 1, HHMSCONS). Each HHMS consists of a cluster of three telescoping wells of varied depths, spaced approximately 25 ft apart. The deepest well was drilled to approximately 400 ft; the depths of the intermediate and shallow wells are approximately 200 and 80 ft, respectively. Data from these wells provide information on the vertical and lateral distribution of hydraulic head and thus characterize deeper flow systems that have potential for transporting groundwater contaminants. These data will support two- and three-dimensional groundwater simulation models and will supplement the ORNL groundwater monitoring network in general.

Thirteen wells installed to meet CERCLA requirements are located adjacent to three impoundments: the 3513 pond, the Old Hydrofracture Facility (OHF) pond, and the Homogeneous Reactor Experiment (HRE) pond. Thirteen wells were also installed in the Test Area for Remedial Action (TARA) located in SWSA 6 for the purpose of studying trench closure alternatives. Data sets containing construction information for these wells have been developed (Table 1, CERCONS and TARACONS).

Twenty-eight wells were constructed by the USGS (Table 1, UWCONS) for use in describing the groundwater flow system in Melton Valley (Zehner 1989). Water level data were recorded continuously at most of these wells until the end of the 1988 water year.

The locations of all wells in the ORNL area, along with their well identifiers (IDs) are shown in a series of detailed maps presented in Appendix A of Voorhees et al. (1989). The type and extent of data associated with these wells are presented in Appendix B of Voorhees et al. (1989).

Various geophysical logging procedures and hydrogeological tests were performed on several groups of wells and recently drilled core holes. Nine USGS U-wells were caliper, gamma, neutron, and density logged at nine separate ORNL locations to provide additional lithologic and stratigraphic information (Tucci and Hanchar 1989). ASCII files of these logs have been obtained from the USGS (Table 2). Similarly, 11 HHMS wells have been logged for a variety of geophysical characteristics. Only the deepest well of each

Table 2. PC data sets of geophysical data

Data type	Data description	Date	Format
U-Well Geophysical Logs (36 files)	Data from caliper, gamma, neutron, and density logs for 9 USGS wells	Oct86 - Mar87	ASCII
HHMS Geophysical Logs (11 files)	Data from various logs for 11 wells		Lotus 1-2-3
WAG 1 Core Holes Packer Tests (40 files)	Data from 6-10 tests for each of 5 core holes		ASCII

HHMS cluster was logged. The types of logs available and a comparison of logs taken for wells 1-7 vs. wells 8-11 are shown in Table 3. These well logs are available as Lotus 1-2-3 files. Five core holes were drilled in WAG 1 to obtain stratigraphic information and characterize the underlying aquifers. Packer tests were performed at selected depths to determine the hydroconductivity and transmissivity of the isolated strata. Results of these tests are available as ASCII files (Table 2). Numerous wells have also been "slug" tested to determine the hydroconductivity and transmissivity of the open interval. These results are included in the construction data sets (Table 1) of the various well types.

2.2 GROUNDWATER

Groundwater hydrology and water quality data sets in the RAP Numeric Data Base are described in Table 4.

2.2.1 Groundwater Hydrology

Periodic depth-to-water measurements have been and continue to be made at selected piezometer wells installed by RAP (Table 1, PIEZCONS) and at selected older wells (Table 1, PRAPCONS). The objectives of such monitoring are to (1) determine the configuration of the water table, the directions of groundwater movement, and both the lateral and the vertical hydraulic gradients in the WAGs; (2) assess short-term water level changes resulting from periods of precipitation (aquifer recharge) and drought; (3) determine the amount of seasonal fluctuation of the water level in wells; and (4) track long-term water level trends in representative wells to detect effects of climatic change and human activities.

In conjunction with the water level measurements, ORNL has periodically observed selected seeps and stream check points in the ORNL area (Table 4, STRMCHK). This qualitative information is used in the study of groundwater hydrology, particularly for developing water table contour maps.

In addition to the periodic water level measurements made by ORNL, USGS operated continuous water level recorders on approximately 90 wells in the ORNL vicinity through 1988 (Table 4, CY85 - CY88). Monitored wells included the HHMS wells, the USGS U-series wells, and a few of the PRAP wells (see Sect. 2.1). Daily mean water levels, calculated from hourly unit values, have been retrieved from the USGS computer

Table 3. Available geophysical logs for HHMS Wells 1-7 and 8-11

Wells 1-7		Wells 8-11		
Log	Units	Log	Units	Description of log
DEPTH	FEET	DEPT	FEET	DEPTH IN WELL
SP	MV	SP	MV	SPONTANEOUS POTENTIAL
GR	API	GR	API	GAMMA RAY
NEUTRON	CPS	SND	CPS	RAW NEUTRON DATA
*	*	NEUT	NAPI	NEUTRON
*	*	NOISE	CPS	NOISE
CALIPER	IN	CALI	IN	X-CALIPER
*	*	CAL2	IN	Y-CALIPER
TEMP	F	TEMP	F	TEMPERATURE
DIFFTEMP	F	DTEM	F	DIFFERENTIAL TEMPERATURE
SHORTNORM	OHMM	*	*	RESISTIVITY
LONGNORM	OHMM	*	*	RESISTIVITY
*	*	ILM	OHMM	IL-MEDIUM RESOLUTION
*	*	ILD	OHMM	IL-DEEP RESOLUTION
ITT	USEC/F	DT	USEC/F	3'-5' DELTA TIME (SONIC)
*	*	AMPL	MV	AMPLITUDE (SONIC)
POROSITY	%	*	*	NEUTRON POROSITY
*	*	SNL	PU	NEUTRON POROSITY
BULK DENS	G/CM[c]	RHOB	G/CM[c]	BULK DENSITY
*	*	DRHO	G/CM[c]	BULK DENSITY CORRECTION
*	*	FFDC	CPS	FAR DENSITY COUNTS
*	*	NFDC	CPS	NEAR DENSITY COUNTS
SPRESIST	OHMS/IN	SPRESIST[a]	OHMS/IN	SINGLE-POINT RESISTANCE
*	*	TENS	MV	LINE TENSION
*	*	LSPD	FEET/MI	LINE SPEED
*	*	CL3A	OHMM	LL3 AVG BH CORRECTION
*	*	CLI3	OHMM	LL3 UNAVG BH CORRECTION
*	*	LL3	OHMM	LATEROLOG 3, UNAVG NOCORR
*	*	BL3A	OHMM	LL3 AVG WITH BHC
*	*	R[b]	?	?
TELEVIEWER[c]				
		VARIABLE DENSITY[d]		
DEVIATION[e]		AZIMUTH & DEGREES		

* = No corresponding log.
[a]Logged by ORNL, results in hardcopy form.
[b]Not used by ORNL.
[c]Wells 1-7 photographs currently reside with Principal Investigator; Wells 8-11 polaroids currently reside with Principal Investigator.
[d]Wells 8-11, hardcopy only, resides with Principal Investigator.
[e]Wells 1-11, logged by ORNL, results currently in hardcopy form.

Table 4. SAS data sets of groundwater data

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCI.MAIP25255.SAS.ERFU2	ORNL water-level measurements			
PZ85_86	Depth-to-water measurements conducted at piezometer wells 1985-1986	06FEB85 - 31DEC86	4,005	12
PZ87	Depth-to-water measurements conducted at piezometer wells in 1987	07JAN87 - 31DEC87	5,709	12
PZ88	Depth-to-water measurements conducted at piezometer wells in 1988	04JAN88 - 27DEC88	5,383	12
PZ89	Depth-to-water measurements conducted in piezometer wells in 1989	02JAN89 - 31DEC89	2,721	12
TEMPCHK	Temperature and specific conductance measured at selected piezometer wells	03MAR88 - 01FEB90	1,432	9
PZTEMPER	Probe depth and field-measured depth of the well for wells in TEMPCHK	03MAR88 - 26OCT88	57	6
STRMCHK	Records of wet or dry conditions at various seeps or stream check points; data used in support of depth-to-water measurements	18JUL86 - 29JUN88	297	8
GW5888	Periodic water-level measurements collected by the USGS; primarily historical data	20JUN50 - 28JUN88	24,335	7
ENVSCI.LDV25255.SAS.GSWELLS	USGS water-level measurements for wells equipped with continuous recorders			
CY85	Calendar year 1985 data	01OCT85 - 31DEC85	3,890	7
CY86	Calendar year 1986 data	01JAN86 - 31DEC86	21,089	8
CY87	Calendar year 1987 data	01JAN87 - 31DEC87	28,550	8
CY88	Calendar year 1988 data	01JAN88 - 31DEC88	20,349	8
CY89	Calendar year 1989 data	01JAN89 - 31JAN89	155	8
ENVSCI.LDV25255.SAS.KIFIELDV	Groundwater contaminant scoping survey, ORNL Main Plant Area and SWSA 3			
ACD1	Results of anion, cation, alkalinity, volatile organic, total organic carbon, and radiological analyses	15APR86 - 21OCT86	3,938	18
FIELD1	Sample date, well IDs, pH, specific conductance, and temperature results	15APR86 - 21OCT86	56	9

Table 4 (continued)

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCLLDV25255.SAS.TORAN	Groundwater samples taken from 19 HHMS wells			
ACD1	Results of cation, anion, total organic carbon, and radiological analyses	23FEB87 - 31JUL87	986	19
FIELD1	Characterization of groundwater quality around the Waste Holding Basin (pond 3513) and ponds associated with the Old Hydrofracture Facility and the Homogeneous Reactor Experiment			
GDW_M	Groundwater monitoring well samples analyzed for cations, anions, fecal coliforms, mercury, polychlorinated biphenyls, pesticides, phenols, and radiological activity	06FEB85 - 28JUL87	1,866	29
W_COMP_M	Groundwater monitoring well samples analyzed for dissolved oxygen, pH, specific conductance, temperature, total organic carbon, and total organic halides; multiple sample results used to compare wells	06FEB85 - 27JUL87	1,081	29
WELL_88	Field data from monitoring wells	29JUL88 - 09AUG88	13	34
ENVSCLLDV25255.SAS.GWQUAL	RCRA water quality monitoring wells established for detection of groundwater contamination; data provided by EMC/ORNL			
FIELD85	Specific conductivity, pH, and temperatures	18SEP85 - 02JAN86	756	9
DIS85	Dissolved metals; filtered samples	18SEP85 - 07JAN86	418	13
TOT85	Total metals, organics, and anions; unfiltered samples	18SEP85 - 07JAN86	1,402	14
FIELD86	Specific conductivity, pH, and temperatures	17MAR86 - 10DEC86	924	9
DIS86	Dissolved metals; filtered samples	17MAR86 - 10DEC86	495	13
TOT86	Total metals, organics, and anions; unfiltered samples	17MAR86 - 10DEC86	1,734	14
FIELD87	Specific conductivity, pH, and temperature	09MAR87 - 04DEC87	693	9
DIS87	Dissolved metals;filtered samples	09MAR87 - 17MAR87	264	13

Table 4 (continued)

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
TOT87	Total metals, organics, and anions; unfiltered samples	09MAR87 - 04DEC87	1,108	14
FIELD88	Specific conductivity, pH, and temperature	05JUN88 - 20DEC88	1,656	16
DIS88	Dissolved metals; filtered samples	05JUN88 - 04NOV88	660	21
TOT88	Total metals, organics, and anions; unfiltered samples	05JUN88 - 20DEC88	12,600	21
FIELD89	Specific conductivity, pH, and temperature	11JAN89 - 20JUN89	2,755	16
DIS89	Dissolved metals; filtered samples	11JAN89 - 19OCT89	2,277	22
TOT89	Total metals, organics, and anions; unfiltered samples	11JAN89 - 19OCT89	18,284	22

[a]Definitions:
ORNL = Oak Ridge National Laboratory;
USGS = U.S. Geological Survey;
SWSA = Solid Waste Storage Area;
HHMS = Hydrostatic Head Monitoring Station;
RCRA = Resource Conservation and Recovery Act;
EMC = Environmental Monitoring and Compliance.

system in Nashville. In addition, periodic groundwater elevation measurements conducted by the USGS are available from the RAP Numeric Data Base (Table 4, GW5888). These measurements collected primarily in the mid to late 1970s, date back to 1950 and are therefore of historical interest. The extent of USGS water level data in the RAP Numeric Data Base was summarized in Appendix B of Voorhees et al. (1989).

2.2.2 Groundwater Quality

Groundwater quality at ORNL has been studied through both regulatory monitoring programs (routine sampling) and scoping surveys (one-time sampling efforts). The groundwater contaminant scoping surveys listed in Table 4 were conducted by R. H. Ketelle for the Main Plant area (WAG 1) and SWSA 3 (WAG 3); by D. W. McCrackin for the White Oak Creek floodplain (WAG 2); and by L. E. Toran for the Pits and Trenches area (WAG 7), SWSA 6 (WAG 6), and near White Oak Lake (WAG 2). Ketelle and McCrackin analyzed unfiltered water samples taken from the piezometer wells installed by RAP. Water samples from this one-time sampling effort were analyzed for cations, anions, alkalinity, volatile organics, total organic carbon (TOC), and radionuclides. Field pH, specific conductivity, and temperature were also recorded. Toran also conducted a one-time sampling of 19 HHMS wells. Toran's samples were filtered and analyzed for alkalinity, cations, anions, TOC, fluorescein (drilling fluid tracer), and radiological contaminants, as well as field pH, specific conductivity, redox, and temperature.

F. G. Taylor also conducted a contaminant scoping survey that included groundwater samples. Because he sampled cores from White Oak Lake as well as seeps from the SWSAs and the Pits and Trenches Area, his study is discussed further in Sect. 2.5 (Contaminant Characterization).

Water quality wells installed by RAP (Table 1, WQCONS) are monitored by ORNL's Environmental Monitoring and Compliance (EMC) Department in accordance with EPA regulation (40 CFR Part 265, Subpart F). The results of these analyses are summarized and reported to the regulatory authorities by EMC, and copies of the electronic data are made available to RAP data management. The data, which are organized by calendar year in the RAP Numeric Data Base, are grouped according to the types of analyses: (1) dissolved metals in filtered samples; (2) total metals, organics, and anions in unfiltered samples; and (3) pH, specific conductivity, and temperature (Table 4).

Monitoring of wells installed around pond 3513, OHF, and HRE (Table 1, CERCONS) began in February 1985, in compliance with CERCLA. The samples were analyzed for cations, anions, fecal coliforms, mercury, polychlorinated biphenyls (PCBs), pesticides, phenols, and radiological contaminants. Multiple sample results for dissolved oxygen, pH, temperature, specific conductance, TOC, and total organic halides (TOX) were used in comparing wells. Sampling was discontinued in 1986 but was resumed in 1987 because of the potential presence of RCRA-listed toxic metals and fecal coliforms. Corresponding studies to characterize the contents of the pond water, pond sediments, and underlying strata are discussed in Sect. 2.5.

2.3 SURFACE WATER

Surface water hydrology and water quality data sets in the RAP Numeric Data Base are described in Table 5. Surface water quality is also studied as part of ORNL's Biological Monitoring and Abatement Program (BMAP) (Sect. 2.7).

2.3.1 Surface Water Hydrology

Data on surface discharge in the Oak Ridge area are collected and managed by staff in ORNL's Environmental Sciences Division (ESD), EMC, and the USGS using a variety of methods and data management software. Average daily flow from three EMC stations and nine USGS stations (Fig. 4) in the vicinity of ORNL are assembled by RAP data management staff, who organized these data into SAS data sets according to calendar year. The raw EMC data are total flows read once a day, whereas the USGS data are average daily flows calculated from stage height readings made at 15-min intervals. Data from eleven additional USGS stations in the vicinity of the Oak Ridge Reservation (ORR) are also included in the data base. The period of record for observations in the RAP Numeric Data Base is shown in Table 6. In addition to the flow data, descriptive information (type of gage and collection frequency) for each monitoring station is recorded in a separate SAS data set (Table 5, FLOW_LOC).

2.3.2 Surface Water Quality

The EMC Department routinely monitors water quality at three surface water sites in White Oak Creek and its tributaries and nine point source discharges, in accordance

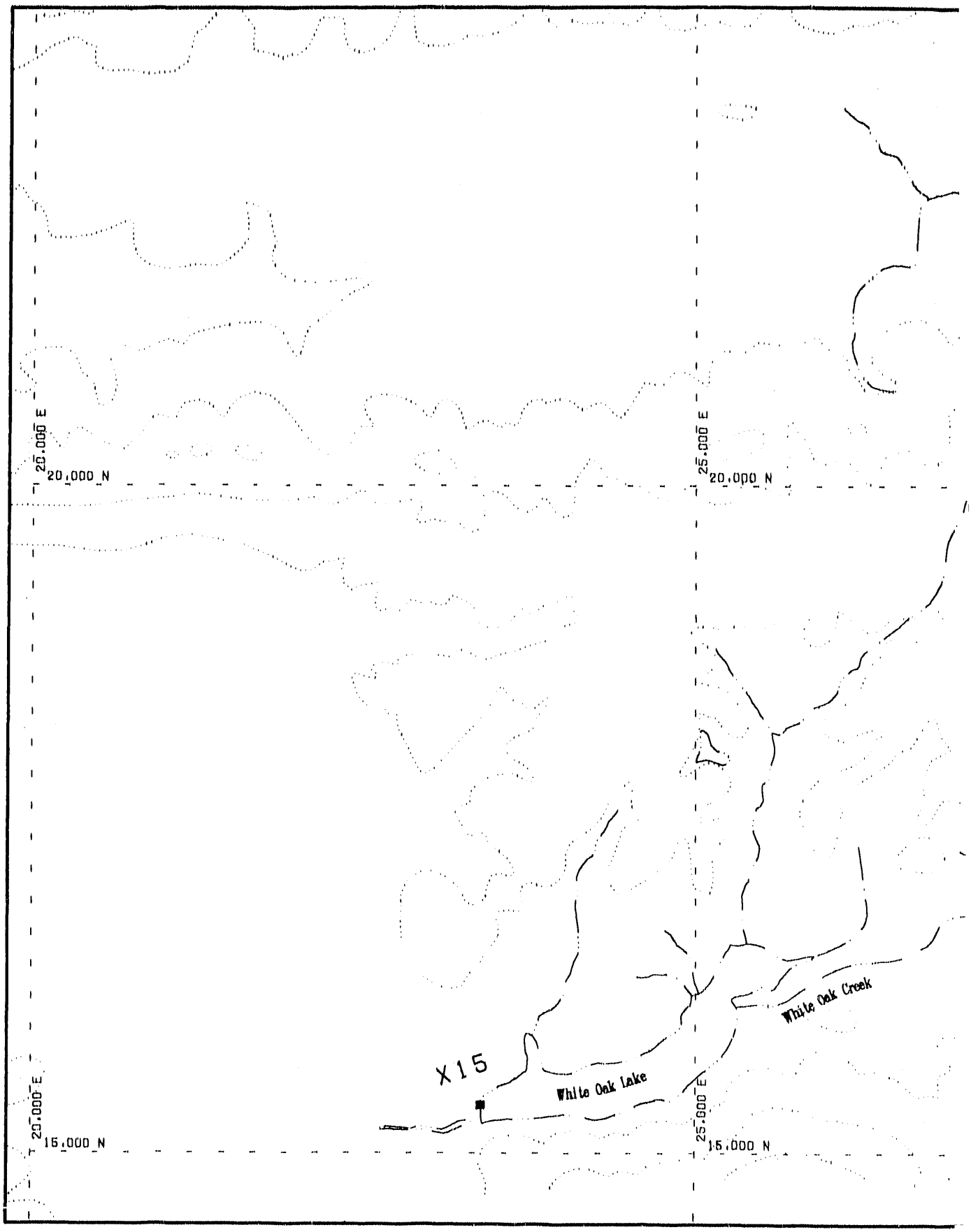
Table 5. SAS data sets of surface water data

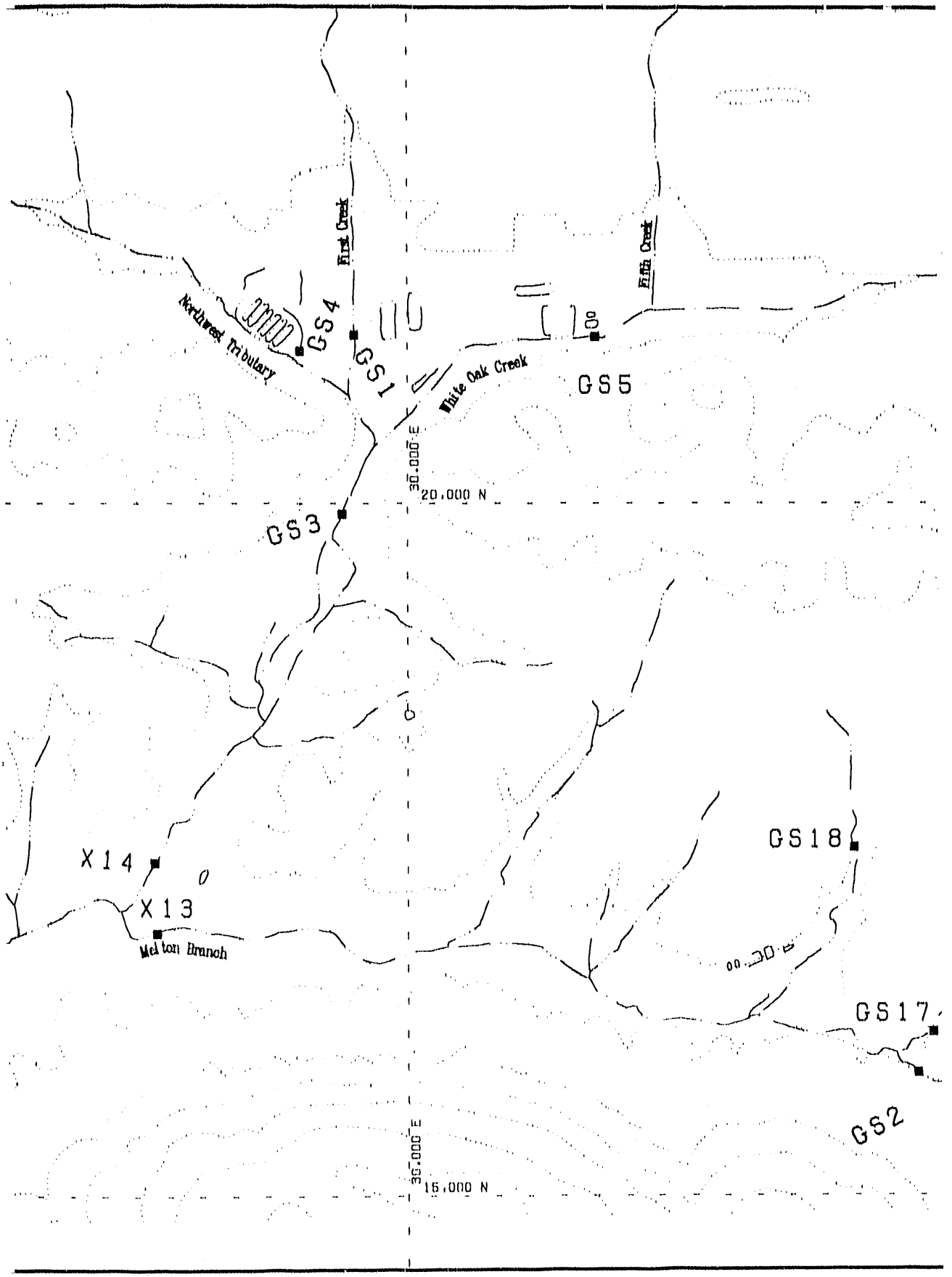
SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCI.LDV25255.SAS.FLOW	Mean daily surface discharge data collected by EMC/ORNL and USGS			
FLOW_LOC	Station description information	--	34	24
CY84	Calendar year 1984 flow data	01OCT84 - 31DEC84	276	5
CY85	Calendar year 1985 flow data	01JAN85 - 31DEC85	3,407	5
CY86	Calendar year 1986 flow data	01JAN86 - 31DEC86	4,308	5
CY87	Calendar year 1987 flow data	01JAN87 - 31DEC87	7,140	5
CY88	Calendar year 1988 flow data	01JAN88 - 31DEC88	7,668	5
CY89	Calendar year 1989 flow data	01JAN89 - 31DEC89	8,053	5
ENVSCI.LDV25255.SAS.SWQUAL	Surface water quality data collected by EMC/ORNL			
SWCHM85	Calendar year 1985 water chemistry data	01JAN85 - 31DEC85	5,211	9
SWCHM87	Calendar year 1987 water chemistry data	02JAN87 - 31DEC87	6,643	9
SWCHM88	Calendar year 1988 water chemistry data	04JAN88 - 30DEC88	6,990	9
SWCHM89	Calendar year 1989 water chemistry data	03JAN89 - 29DEC89	7,877	9
RADS87	Calendar year 1987 radiological concentrations in surface water	31JAN87 - 05FEB88	1,265	18
RADS88	Calendar year 1988 radiological concentrations in surface water	29DEC87 - 30JAN89	1,513	23
RADS89	Calendar year 1989 radiological concentrations in surface water	29DEC88 - 06DEC89	916	26
DIS87	Calendar year 1987 radiological discharges	JAN87 - FEB88	191	25
DIS88	Calendar year 1988 radiological discharges	DEC87 - JAN89	292	25
DIS89	Calendar year 1989 radiological discharges	DEC88 - OCT89	212	26
DAS86_87	Stream flow, pH, temperature, conductivity, turbidity, dissolved oxygen, and beta and gamma activity; hourly values during calendar years 1986 and 1987	01OCT86 - 31DEC87	334,945	7
DAS88	Stream flow, pH, temperature, conductivity, turbidity, dissolved oxygen, and beta and gamma activity; hourly values during calendar year 1988	01JAN88 - 31DEC88	295,092	7

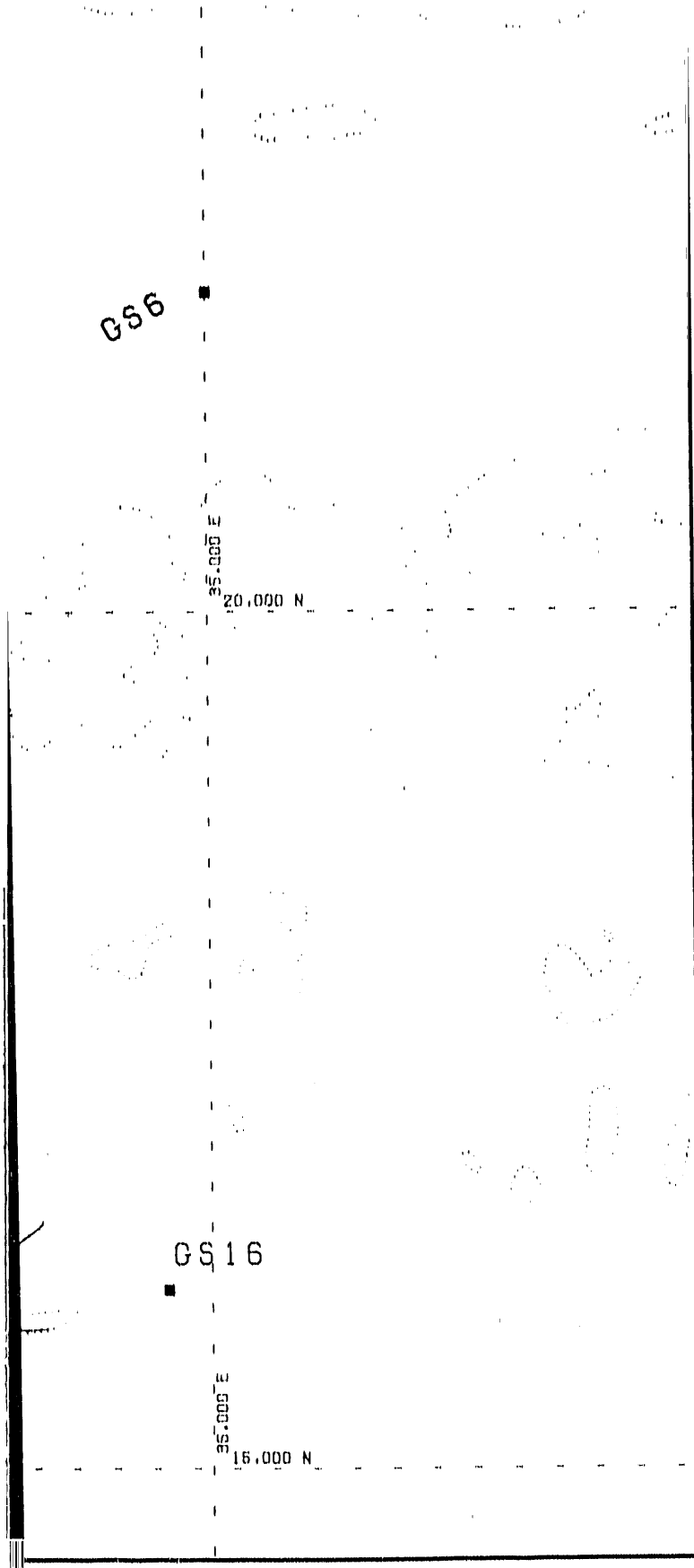
Table 5 (continued)

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
DAS89	Stream flow, pH, temperature, conductivity, turbidity, dissolved oxygen, and beta and gamma activity; hourly values during calendar year 1989	01JAN89 - 30DEC89	256,416	7

[a]Definitions:
EMC = Environmental Monitoring and Compliance;
ORNL = Oak Ridge National Laboratory;
USGS = U.S. Geological Survey.


20,000 E
25,000 E
20,000 N
20,000 N
X15
White Oak Lake
White Oak Creek
20,000 E
25,000 E
15,000 N
15,000 N


First Creek
Fifth Creek
Northwest Tributary
White Oak Creek
GS4
GS1
GS5
GS3
GS18
GS17
GS2
X14
X13
Melton Branch
30,000 E
20,000 N
15,000 N



Legend

Sites

■ Surface Discharge Sites

Lines

- - - X-10 Grid, 1000 ft Interval

——— Creeks, Ponds, and Basins

····· Contours, 100 ft Interval (approx)

Map Scale 1:12000
March 1989

Fig. 4.

Locations of Surface Discharge Monitoring Sites for which Data Exist in the Remedial Action Program Numeric Data Base.

Table 6. Number of surface discharge values (mean daily flow) in the Remedial Action Program Numeric Data Base

Site ID[a]	Station name[b]	Number of observations				
		1985	1986	1987	1988	1989
GS1	FIRST CREEK	-	-	334	366	346
GS2	MELTON BRANCH NEAR MELTON HILL (CENTER 7)	275	365	365	366	365
GS3	WOC BELOW MELTON VALLEY DR. (7500B)	275	365	365	366	361
GS4	NORTHWEST TRIBUTARY	-	-	254	366	357
GS5	PARSHALL FLUME. WHITE OAK CREEK	-	31	365	366	365
GS6	WHITE OAK CREEK NEAR MELTON HILL	-	-	268	366	365
GS7	BEAR CREEK AT STATE HIGHWAY 95	306	365	365	366	344
GS8	BEAR CREEK AT PINE RIDGE NEAR WHEAT	-	98	365	366	365
GS9	BEAR CREEK NEAR WHEAT	-	98	365	366	365
GS10	BEAR CREEK TRIB AT BEAR CREEK RD NEAR WHEAT	-	98	365	366	356
GS11	BEAR CREEK TRIB NEAR WHEAT	-	98	365	366	273
GS12	BEAR CREEK TRIB AT HWY 95 NEAR WHEAT	-	98	365	366	273
GS13	CLINCH RIVER AT MELTON HILL DAM (TAILWATER)	363	363	365	366	273
GS14	POPLAR CREEK NEAR OAK RIDGE	365	365	365	366	273
GS15	EAST FORK POPLAR CREEK NEAR OAK RIDGE	365	365	365	182	-
GS16	MELTON BRANCH TRIB (EAST SEVEN) NR OAK RIDGE. TN	-	-	150	366	342
GS17	MELTON BRANCH TRIB (CENTER SEVEN) NR OAK RIDGE. TN	-	-	150	366	365
GS18	MELTON BRANCH TRIB (WEST SEVEN) NR OAK RIDGE. TN	-	-	128	366	273
GS19	SCARBORO CR TRIB NR HAW RIDGE NR O.R. (UPSTREAM)	-	-	-	-	234
GS20	SCARBORO CR TRIB NR OAK RIDGE (DOWNSTREAM)	-	-	-	-	247

Table 6 (continued)

Site ID[a]	Station name[b]	Number of observations				
		1985	1986	1987	1988	1989
X13	MELTON BRANCH ABOVE WHITE OAK CREEK CONFLUENCE	365	280	250	249	249
X14	WHITE OAK CREEK ABOVE MELTON BRANCH CONFLUENCE	365	280	250	246	249
X15	WHITE OAK CREEK AT WHITE OAK DAM	365	280	250	249	249

[a]The U.S. Geological Survey site IDs are as follows:

GS1 = 03536450	GS7 = 03538270	GS13 = 03535912	GS19 = 0353102
GS2 = 03537100	GS8 = 03538273	GS14 = 03538225	GS20 = 0353103
GS3 = 03536550	GS9 = 035382673	GS15 = 03538250	
GS4 = 03536440	GS10 = 035382672	GS16 = 03537050	
GS5 = 03536380	GS11 = 035382677	GS17 = 03537200	
GS6 = 03536320	GS12 = 03538272	GS18 = 03537300	

Sites labeled X13, X14, and X15 are monitored by the Oak Ridge National Laboratory.

[b]These specific station names are used in the data sets.

with the National Pollutant Discharge Elimination System (NPDES) permit issued to ORNL. Summaries of the NPDES data are published quarterly by EMC (e.g., Daniels et al. 1989). Monitoring sites are shown in Fig. 5. The data set describing the surface water stations (see Sect. 2.3.1) defines the site IDs. The water chemistry data are organized by calendar year in the RAP Numeric Data Base.

Radiological concentrations in surface water monitored by EMC are also available from the RAP Numeric Data Base. Water samples are collected regularly from more than 20 stations (Table 7); the stream sampling locations are shown in Fig. 6. Stations, collection and analyses frequencies, and specific analyses may change over time. Details of this monitoring activity are presented in EMC's quarterly reports (e.g., Daniels et al. 1989).

EMC also operates a Data Acquisition System (DAS) to obtain real-time data on surface flow, pH, temperature, conductivity, turbidity, dissolved oxygen, and beta and gamma activity (in counts per min) at NPDES stations X13, X14, and X15 (Fig. 5). Hourly summaries of these data are periodically retrieved for the RAP Numeric Data Base. DAS is designed and operated to detect changes in these parameters that may reflect abnormal plant operations. These data should be used with caution. Irregularities can occur due to abnormal plant operations or a malfunctioning sensor; however, the data are not flagged accordingly.

2.4 PRECIPITATION

Precipitation data in the Oak Ridge area are collected and managed by several investigators using a variety of methods and data management software. Total daily precipitation data from 25 sites--11 EMC, 10 ESD, 3 USGS, and 1 ATDD (Fig. 7)--are assembled into SAS data sets organized by calendar year (Table 8). The period of record for observations for each site in the RAP Numeric Data Base is shown in Table 9. In addition to the precipitation data, a SAS data set records descriptive information for each monitoring site (Table 8, PCIP_LOC). Selected information from this data set is presented in Table 10.

2.5 CONTAMINANT CHARACTERIZATION

Initial site investigations focused on the use of scoping surveys to characterize the environment with respect to the presence of radionuclides and hazardous chemicals. In

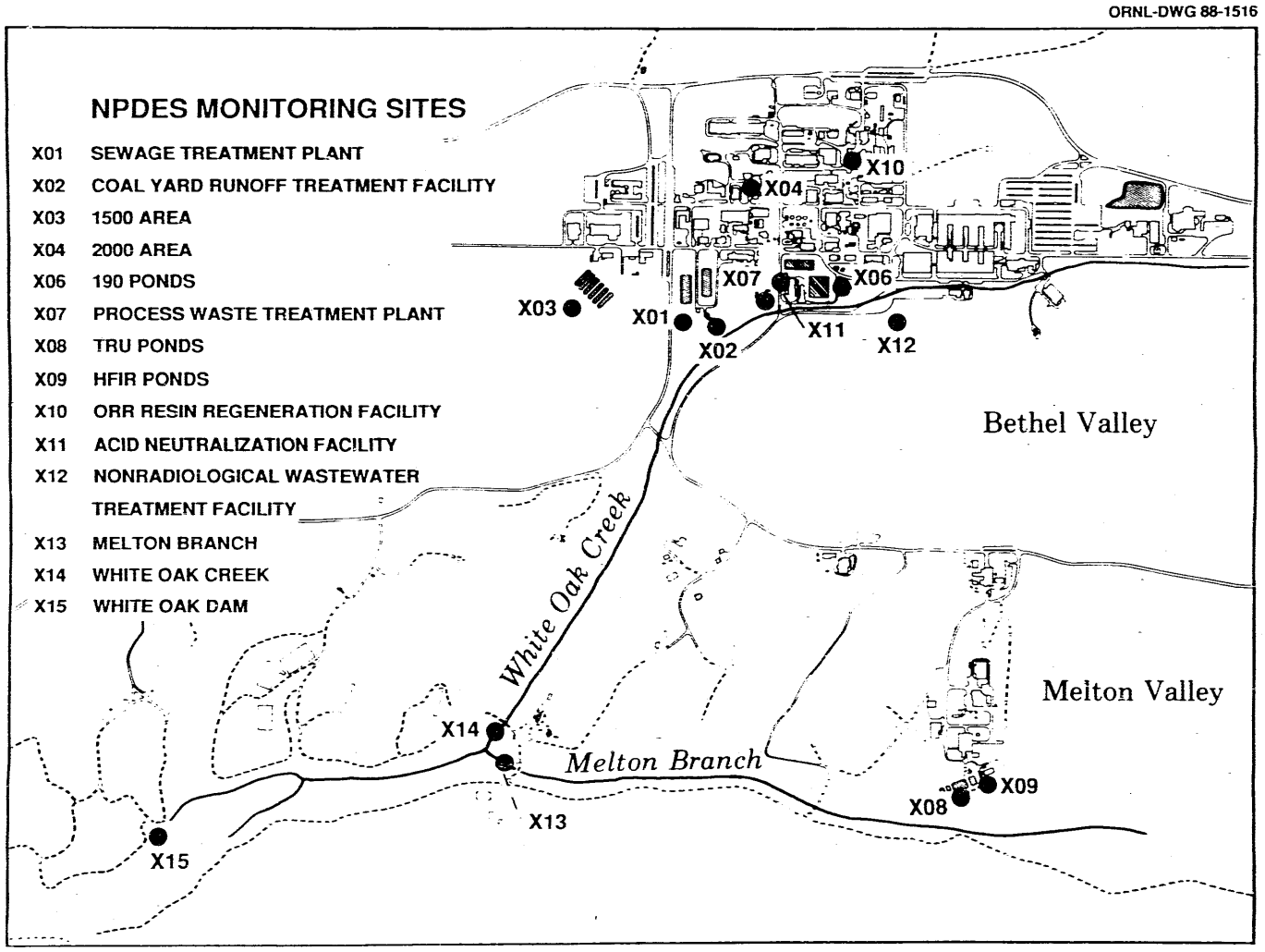


Fig. 5. Locations of monitoring sites for the National Pollutant Discharge Elimination System permit.

Table 7. Summary of collection and frequencies of radiological analyses of surface water and tap water samples

Station[a]	Parameter[b]	Collection frequency	Type	Analysis frequency
2190 Ponds	Gamma scan, gross alpha, and gross beta	Weekly	Flow proportional	Monthly
1500 Area, 3518	Gross alpha and gross beta	Weekly	Flow proportional	Monthly
2000 Area, STP	Gamma scan, gross beta, and total Sr	Weekly	Flow proportional	Monthly
3544	Gross alpha, gross beta, gamma scan, and total Sr	Weekly	Flow proportional	Monthly
7500 Bridge	Gamma scan and total Sr	Daily	Time proportional	Daily
7500 Bridge, MB1, WOC, MB2	Gamma scan, total Sr, and ^{3}H	Weekly	Flow proportional	Monthly
First Creek, Fifth Creek, Raccoon Creek	Gamma scan and total Sr	Weekly	Grab	Monthly
Gallaher, Kingston	^{3}H, ^{60}Co, ^{137}Cs, gamma scan, gross alpha, gross beta, Pu, total Sr, and U	Weekly	Grab	Quarterly
HFIR Ponds	Gamma scan, gross alpha, and gross beta	After discharge	Flow proportional	Monthly
Melton Hill Dam	^{241}Am, ^{244}Cm, ^{60}Co, ^{137}Cs, gross alpha, Pu, Th, U, total Sr, and ^{3}H	Weekly	Flow proportional	Quarterly
NWT	Gamma scan and total Sr	Weekly	Flow proportional	Monthly
ORNL Tap	^{60}Co, ^{137}Cs, gross alpha, gross beta, Pu, total Sr, and U	Daily	Grab	Quarterly

Table 7 (continued)

Station[a]	Parameter[b]	Collection frequency	Type	Analysis frequency
ORR	^{60}Co, ^{137}Cs, gross alpha, and gross beta	After discharge	Flow proportional	Monthly
WOC Headwaters	^{241}Am, ^{244}Cm, ^{60}Co, ^{137}Cs, gross alpha, total Sr, ^{3}H, Pu, Th, and U	Weekly	Grab	Monthly
WOD	^{241}Am, ^{244}Cm, ^{60}Co, ^{137}Cs, gross beta, Pu, total Sr, and ^{3}H	Weekly	Flow proportional	Weekly
TRU Ponds	Gross beta	After discharge	Flow proportional	Monthly

[a]Definitions:
STP = Sewage treatment plant;
MB = Melton Branch;
WOC = White Oak Creek;
HFIR = High-Flux Isotope Reactor;
NWT = Northwest Tributary;
ORNL = Oak Ridge National Laboratory;
ORR = Oak Ridge Reservation;
WOD = White Oak Dam;
TRU = Transuranic.

[b]Total radioactive Sr (^{89}Sr + ^{90}Sr).

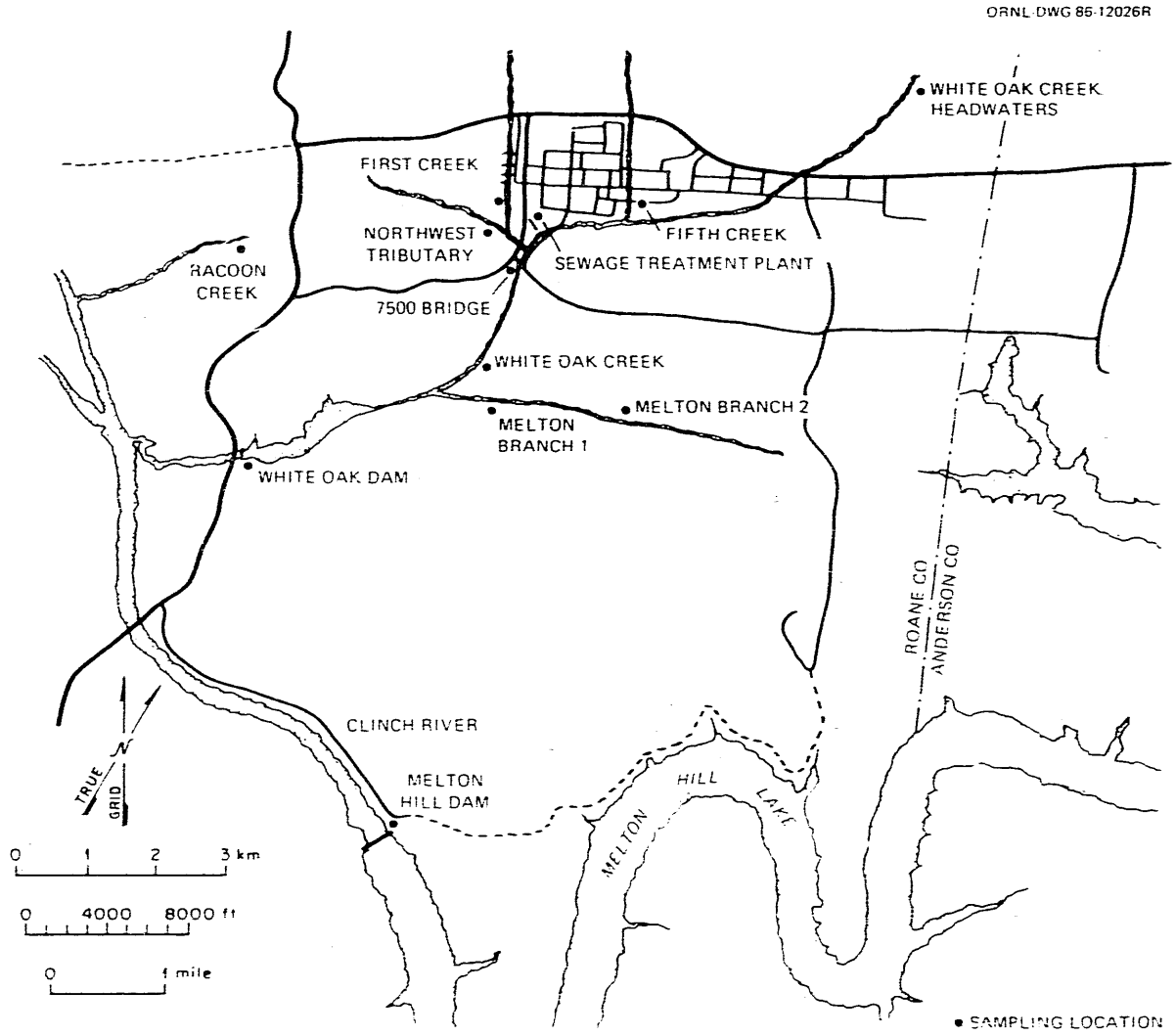


Fig. 6. Locations of Oak Ridge National Laboratory surface water radiological monitoring sites.

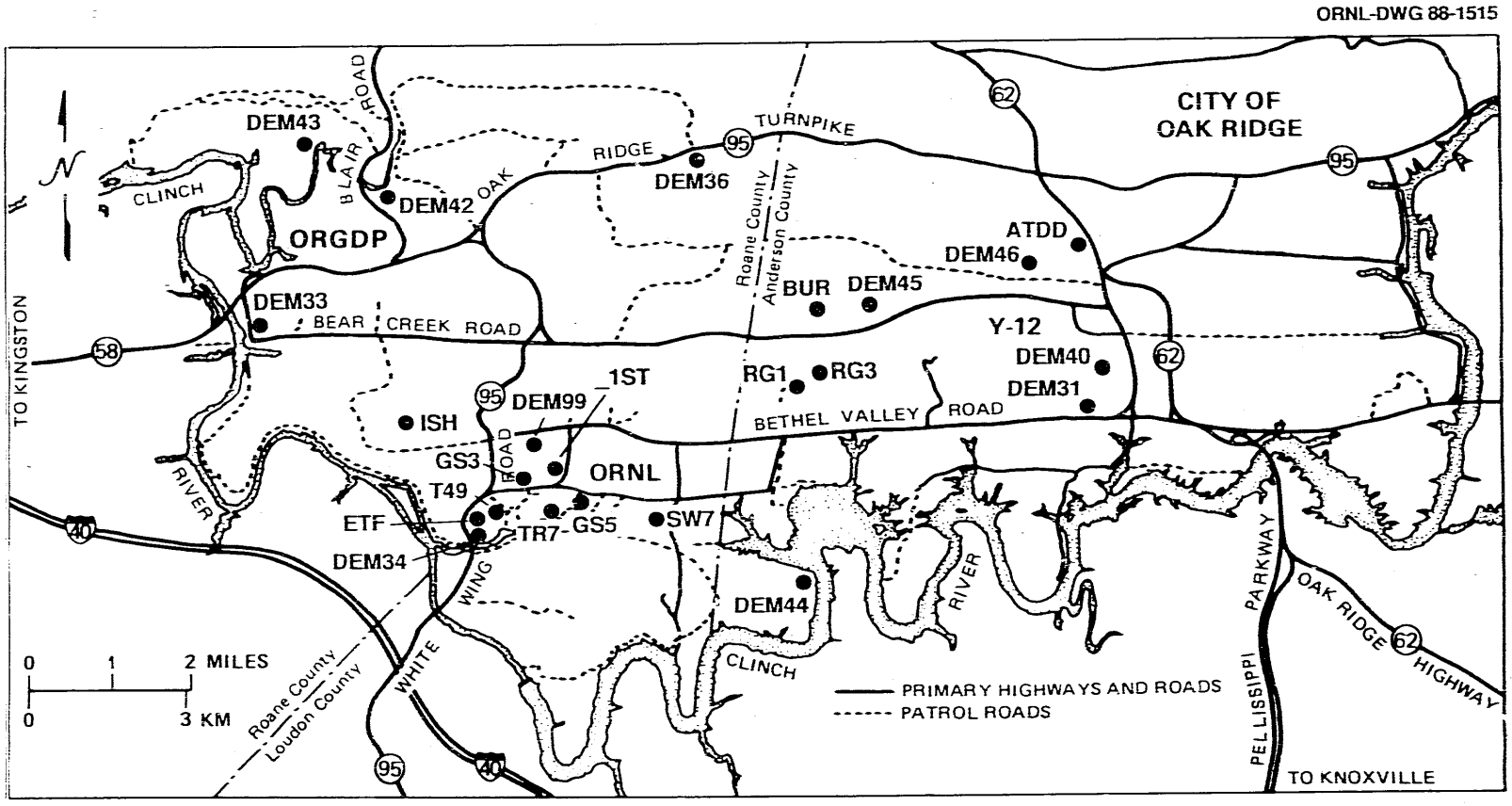


Fig. 7. Locations of precipitation monitoring site for which data exist in the Remedial Action Program Numeric Data Base.

Table 8. SAS data sets of meteorological data

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCI.LDV25255.SAS.PRECIP	Daily precipitation data collected by ESD/ORNL, EMC/ORNL, and USGS			
PCIP_LOC	Station description information	- -	25	22
CY76	Calendar year 1976 data	01JAN76 - 31DEC76	732	5
CY77	Calendar year 1977 data	01JAN77 - 31DEC77	730	5
CY78	Calendar year 1978 data	01JAN78 - 31DEC78	730	5
CY79	Calendar year 1979 data	01JAN79 - 31DEC79	730	5
CY80	Calendar year 1980 data	01JAN80 - 31DEC80	875	5
CY81	Calendar year 1981 data	01JAN81 - 31DEC81	1,095	5
CY82	Calendar year 1982 data	01JAN82 - 31DEC82	1,459	5
CY83	Calendar year 1983 data	01JAN83 - 31DEC83	2,190	5
CY84	Calendar year 1984 data	01JAN84 - 31DEC84	2,280	5
CY85	Calendar year 1985 data	01JAN85 - 31DEC85	2,920	5
CY86	Calendar year 1986 data	01JAN86 - 31DEC86	6,761	5
CY87	Calendar year 1987 data	01JAN87 - 31DEC87	6,316	5
CY88	Calendar year 1988 data	01JAN88 - 31DEC88	7,960	5
CY89	Calendar year 1989 data	01JAN89 - 31DEC89	7,247	5
ORT51_60	Oak Ridge Townsite, 1951-1960	01JAN51 - 31DEC60	3,653	5
ORT61_70	Oak Ridge Townsite, 1961-1970	01JAN61 - 31DEC70	3,652	5
ORT71_75	Oak Ridge Townsite, 1971-1975	01JAN71 - 31DEC75	1,826	5
ENVSCI.MJG25255.SAS.MET	Daily meteorological data collected at ORNL Tower C, including wind speed and direction, air temperature, and relative humidity			
METC_Y88	Calendar year 1988 data	01JAN88 - 31DEC88	8,697	35
METC_Y89	Calendar year 1989 data	01JAN89 - 31DEC89	8,496	35
METC_Y90	Calendar year 1990 data	01JAN90 - 31DEC90	743	35

[a]Definitions:
ESD = Environmental Sciences Division;
ORNL = Oak Ridge National Laboratory;
EMC = Environmental Monitoring and Compliance;
USGS = U.S. Geological Survey.

Table 9. Precipitation data (daily totals) in the Remedial Action Program Numeric Data Base

Site ID[a]	Site name[b]	Number of observations by year														
		1950 to 1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
_1ST	First Creek	–	–	–	–	–	–	–	–	–	–	–	–	184	366	365
ATDD	ATDD/NOAA	9,125	366	365	365	365	366	365	365	365	366	365	365	365	366	365
BUR	Bear Creek Burial GD	–	–	–	–	–	–	–	–	–	–	365	365	365	366	365
DEM31	Kerr Hollow	–	–	–	–	–	–	–	–	–	–	–	297	173	357	270
DEM33	Gallaher (Near K-25)	–	–	–	–	–	–	–	–	–	–	–	288	209	344	166
DEM34	White Oak Dam	–	–	–	–	–	–	–	–	–	–	–	293	179	353	219
DEM36	Oak Ridge Turnpike	–	–	–	–	–	–	–	–	–	–	–	302	173	362	140
DEM40	Y-12 (East)	–	–	–	–	–	–	–	–	–	–	–	317	199	360	166
DEM42	Blair Road (K-25)	–	–	–	–	–	–	–	–	–	–	–	320	206	362	76
DEM43	K-25 Penmeter	–	–	–	–	–	–	–	–	–	–	–	307	210	350	81
DEM44	DOSAR Facility	–	–	–	–	–	–	–	–	–	–	–	326	210	348	270
DEM45	Y-12 (West)	–	–	–	–	–	–	–	–	–	–	–	283	210	333	7
DEM46	Scarboro Facility	–	–	–	–	–	–	–	–	–	–	–	75	137	–	–
DEM99	Met Tower C	–	–	–	–	–	–	–	–	–	–	–	–	242	–	–
ETF	SWSA 6	–	–	–	–	–	143	365	365	365	366	365	365	365	366	365
GS3	USGS/SWSA 3	–	–	–	–	–	–	–	–	–	85	365	365	365	366	65
GS5	USGS/SWSA 5	–	366	365	365	365	366	365	365	365	366	365	365	365	366	65
ISH	Ish Creek	–	–	–	–	–	–	–	12	365	366	365	365	365	366	365
RG1	Walker Branch Gage #1	–	–	–	–	–	–	–	176	365	366	365	365	365	366	365
RG3	Walker Branch Gage #3	–	–	–	–	–	–	–	176	365	366	365	365	365	366	365
SW4	SWSA 4	–	–	–	–	–	–	–	–	–	–	–	–	–	184	365
SW7	Center 7 Creek Wshed	–	–	–	–	–	–	–	–	–	–	–	365	365	366	365
TR7	TRENCH 7	–	–	–	–	–	–	–	–	–	–	–	365	181	–	–
T49	49 TRENCH (SWSA 6)	–	–	–	–	–	–	–	–	–	–	–	303	365	366	365
7500B	USGS/7500 Bridge	–	–	–	–	–	–	–	–	–	–	–	–	153	366	359

[a]Site IDs were assigned by the Remedial Action Program.
[b]These specific site names are used in the data sets:
ATDD = Atmospheric Turbulence and Diffusion Division
K-25 = Oak Ridge Gaseous Diffusion Plant
NOAA = National Oceanic and Atmospheric Administration
SWSA = Solid Waste Storage Area
USGS = U.S. Geological Survey
Y-12 = Oak Ridge Y-12 Plant

Table 10. Station descriptions for precipitation-monitoring sites generated from the SAS data set

Site ID[a]	Site name[b]	Type of gage	Collection frequency	Smallest unit of measure
_1ST	FIRST CREEK	BELFORT WEIGHING	10 MINUTES[c]	.01"
ATDD	NOAA/ATDD OAK RIDGE	BELFORT WEIGH & STICK GAGE	HOURLY	.01"
BUR	BEAR CREEK BURIAL GD	BELFORT WEIGHING	10 MINUTES[c]	.01"
DEM31	KERR HOLLOW	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM33	GALLAHER (NEAR K-25)	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM34	WHITE OAK DAM	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM36	OAK RIDGE TURNPIKE	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM40	Y-12 (EAST)	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM42	BLAIR ROAD (K-25)	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM43	K-25 PENMETER	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM44	DOSAR FACILITY	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM45	Y-12 (WEST)	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM46	SCARBORO FACILITY	BELFORT HEATED TIP BUCKET	10 MINUTES	.01"
DEM99	MET TOWER C	MRI TIPPING BUCKET	HOURLY	.01"
ETF	SWSA 6	BELFORT WEIGHING	10 MINUTES[c]	.01"
GS3	USGS/SWSA 3	BELFORT WEIGHING	DAILY	.01"
GS5	USGS/SWSA 5	ELECT. TIPPING BUCKET	DAILY	.01"
ISH	ISH CREEK	BELFORT WEIGHING	10 MINUTES[c]	.01"
RG1	WALKER BRANCH GAGE #1	BELFORT WEIGHING	10 MINUTES[c]	.01"
RG3	WALKER BRANCH GAGE #3	BELFORT WEIGHING	10 MINUTES[c]	.01"
SW4	SWSA 4	BELFORT WEIGHING	10 MINUTES[c]	.01"
SW7	CENTER 7 CREEK WSHED	BELFORT WEIGHING	10 MINUTES[c]	.01"
TR7	TRENCH 7	BELFORT WEIGHING	10 MINUTES[c]	.01"
T49	49 TRENCH (SWSA 6)	BELFORT WEIGHING	10 MINUTES[c]	.01"
7500B	USGS/7500 BRIDGE	TIPPING BUCKET	15 MINUTES	.01"

[a]Site IDs were assigned by the Remedial Action Program.

[b]These specific site names are used in the data sets:
ATDD = Atmospheric Turbulence and Diffusion Division
K-25 = Oak Ridge Gaseous Diffusion Plant
NOAA = National Oceanic and Atmospheric Administration
SWSA = Solid Waste Storage Area
USGS = U.S. Geological Survey
Y-12 = Oak Ridge Y-12 Plant

[c]Data are stored in breakpoint format: level of resolution is 10 min.

addition to the groundwater scoping surveys discussed in Sect. 2.2.2, several other studies have been or are being conducted to characterize contaminants in the ORNL area (Table 11).

Drill cuttings taken during the installation of water quality wells in 1985 were analyzed for pesticides, organics, and radiological contaminants. In 1987 and 1988, an additional 55 WAG perimeter water quality wells were completed. Samples of drill cuttings and drilling water periodically taken during the installation of these wells were analyzed for cations, anions, and radionuclides. During the drilling of cores in White Oak Dam to determine its structural integrity, soil samples were collected near the saturation zone. These samples were analyzed only for cations and radiological activity. Drill cuttings taken during installation of wells around impoundments 3513, OHF, and HRE were analyzed for radioactivity only.

One of the first field studies in the program to characterize the environment over a broad area of the ORNL complex was conducted by F. G. Taylor in 1985. A total of 31 PRAP wells, 4 seeps, and 3 cores from White Oak Lake were analyzed for metals, organic compounds, and radionuclides. Results from this preliminary contaminant scoping survey were used to characterize the environmental contamination and to assess ORNL's remedial action needs and priorities.

In 1985 T. E. Cerling also conducted a contaminant scoping survey which focused on streambed materials and water in White Oak Creek and tributaries. The objectives of his study were to provide a basis for ranking areas in need of corrective action and to identify sites where further studies are needed to characterize contaminant migration in the White Oak Creek watershed. The samples were analyzed for metals, anions, pesticides, organics, and radionuclides. Cerling continued to sample additional streambed sediments and a few selected PRAP wells in 1986, and in the spring of 1987 he evaluated whether there were continuing releases of contaminants within WAGs at ORNL. The primary purpose of the WAG scoping survey was to provide information requested in the ORNL Hazardous Waste Facility's draft permit under provisions of Section 3004(u) of RCRA. The results of Cerling's studies supported (1) recommendations to regulatory agencies about WAGs that require cleanup under RCRA and (2) a ranking of the WAGs on the basis of the magnitude of potential releases.

Table 11. SAS data sets on contaminant characterization studies

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCI.LDV25255.SAS.HUPTV	Characterization of soil (drill cuttings) at water quality wells installed by RAP			
ACD	Pesticides, semivolatile organics, anions, cations, and radiological analyses	16JUL85 02MAR88	6,425	21
FIELD	Date sampled, well ID, sample ID, and core sample depth	16JUL85 - 02MAR88	130	11
WOD	Cation and radiological analyses of drill cuttings taken during WOD integrity study	06JAN88 - 21JAN88	332	18
ENVSCI.LDV25255.SAS.STANSV	Characterization of soil at wells installed around impoundments 3513, OHF, and HRE			
SOIL	Well drilling cuttings analyzed for radiological activity	07JAN85 - 13MAR85	26	20
SOIL2	Radiological analyses of soil samples taken near pond 3513	02APR86	88	21
CORES	Radiological analyses of rock cores beneath impoundments 3513 and OHF	10SEP86 - 28OCT86	279	23
ENVSCI.LDV25255.SAS.TAYLORV	Contaminant scoping survey of wells and seeps in the Solid Waste Storage Areas, the Pits and Trenches, and in sediment cores from White Oak Lake			
ACD1	Cations, organics, mercury, and radiological analyses results	09JUL85 - 07NOV85	10,141	19
FIELD1	Field data including sampling date and location, sample type, sample ID, and sample depth	09JUL85 - 07NOV85	120	13
ENVSCI.LDV25255.SAS.CERLINGV	Contaminant scoping surveys of streambed materials and water			
ACD	Cations, anions, mercury, pesticides, organics, and radiological analyses results; a few alkalinity, polychlorinated biphenyls, and pH results	19JUL85 - 14MAY87	17,617	22
FIELD	Field data including sampling date and location, sample type, and sample ID	19JUL85 - 14MAY87	768	16

Table 11 (continued)

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCI.LDV25255.SAS.STANSV	Characterization of pond water and sediments at impoundments 3513, OHF, and HRE			
POND_W	Pond water, analyzed for dissolved oxygen, pH, specific conductance, temperature, total organic carbon, total organic halides, cations, anions, fecal coliforms, mercury, polychlorinated biphenyls, pesticides, phenols, and radiological activity	26JAN85 - 02NOV87	1,529	22
SEDI	Pond sediments analyzed for cations, mercury, polychlorinated biphenyls, pesticides, and radiological activity	14NOV84 - 02APR87	940	23
^{85}Sr tracer study of OHF impoundment				
SR85_T12	Level of ^{85}Sr in pond water	18MAR87 - 17MAR88	54	14
SR85_T3	Analyses of radiological activity in pond sediments	13JUL87	13	17
SR85_T5	Levels of ^{85}Sr and ^{90}Sr in pond water	18MAR87 - 17MAR88	24	14
SR85_T67	Levels of ^{137}Cs in pond water	18MAR87 - 17MAR88	53	14
ENVSCI.LDV25255.SAS.TANKS	Characterization of inactive waste storage tanks and their contents			
TANKINFO	Description of inactive waste storage tanks	--	33	27
TANKDAT1	Field sampling data; contents profile, external contamination levels, and procedural variations	02JUN88 - 03MAR89	31	25
TANKDAT2	Field sampling data; sample IDs, sample types, and sample depths	02JUN88 - 03MAR89	149	8
ACID	Tank contents analyzed for alkalinity, pH, anions, cations, volatile and semivolatile organics, PCBs, and radiological activity	02JUN88 - 26SEP88	15,365	13

[a]Definitions:
RAP = Remedial Action Program;
OHF = Old Hydrofracture Facility;
HRE = Homogeneous Reactor Experiment;
PCB = Polychlorinated biphenyl.

Characteristics of pond water and sediments at impoundments 3513, OHF, and HRE were studied by R. G. Stansfield and C. W. Francis in 1985. Sediment samples were analyzed for cations, mercury, PCBs, pesticides, and radiological activity. Water samples were analyzed for these same parameters and also for dissolved oxygen, pH, specific conductance, temperature, TOC, TOX, and fecal coliforms. Data on groundwater surrounding the ponds are contained in data sets identified in Sect. 2.2.2. The inactive waste storage tanks at ORNL were characterized to plan remedial action (Table 11) Information on the physical description of the tanks (e.g., tank location, age, size, and configuration) has been compiled. The contents of 30 accessible tanks were profiled, and samples were collected from the 27 which contained liquids and/or sludge. The liquid and sludge levels, external contamination data, and procedural information were recorded as the tanks were sampled. Sample types, the depth of the liquid or sludge sample, and the amount of surface radioactivity were noted for each sample. Chemical analyses of the samples included alkalinity, pH, anions, organics, metals, PCBs, and radiological constituents.

2.6 MAINTENANCE AND SURVEILLANCE

A series of radiological and hazardous waste scoping surveys have been and continue to be conducted by the Health and Safety Research Division (HASRD) of ORNL for the Maintenance and Surveillance Phase of the program.

The surveys include a variety of sites known to have historical contamination problems. The purpose of these surveys is (1) to identify levels of radioactive contamination and hazardous waste and (2) to determine if the concentrations of these contaminants warrant corrective actions to minimize personnel exposure and/or further surface contamination. A description of the survey methods and instrumentation is presented in Myrick et al. (1987).

Measurements taken at many of the sites include gamma exposure rate at the surface, gamma exposure rate at 1 m, and alpha and beta-gamma dose rates. In addition, soil samples were collected at selected locations and analyzed for a variety of radionuclides, metals (As, Ba, Cd, Cr, Pb, Hg, Se, and Ag), insecticides (lindane, endrin, toxaphene, and methoxychlor) and herbicides (2,4-D and 2,4,5-TP). The data sets from these surveys, which have been incorporated into the RAP Numeric Data Base, are described in Table 12.

Table 12. SAS data sets of surface radiological and hazardous waste scoping surveys

SAS library/ SAS data set	Description of library/data set	Time period	Number of observations	Number of variables
INVSCI.AXR25255.SAS.MSCAP	Results of routine maintenance and surveillance monitoring to determine the need for near-term corrective actions			
FIELD	Sampling locations	AUG86 - MAY87	220	9
BACKGRND	Background radiation concentrations	AUG86 - FEB87	24	9
REGSTNDS	Regulatory standards	--	14	4
RAD1	Gamma exposure rates	AUG86 - FEB87	407	22
RAD2	Alpha and beta-gamma activity levels	AUG86 - FEB87	47	11
SOILS	Concentrations of radionuclides, metals, and pesticides in soil samples; soil characteristics	AUG86 - MAY87	3,086	13

2.7 BIOLOGICAL MONITORING

As a condition of the NPDES permit issued to ORNL on April 1, 1986, a Biological Monitoring and Abatement Program (BMAP) was developed for White Oak Creek (WOC), selected tributaries, and the Clinch River. The BMAP consists of the following seven major tasks: (1) toxicity monitoring; (2) bioaccumulation monitoring of nonradiological contaminants in aquatic biota; (3) biological indicator studies; (4) instream ecological monitoring; (5) assessment of contaminants in the terrestrial environment; (6) radioecology of WOC and White Oak Lake; and (7) contaminant transport, distribution, and fate in the WOC embayment-Clinch River-Watts Bar Reservoir system. SAS data sets that have been incorporated into the RAP Numeric Data Base on these subjects are listed in Table 13. Many of the sampling sites are used for more than one study (Fig. 8). Thus, having these data in a common data base and format will allow information from one BMAP study to be easily related to either another study or with all data in the RAP Numeric Data Base.

2.8 TECHNOLOGY DEMONSTRATIONS

Descriptions of data sets associated with technology demonstration studies are presented in Table 14. These include the Shallow Land Burial (SLB) Closure demonstration, and the In Situ Vitrification (ISV) study.

The purpose of the SLB Closure study is to demonstrate and evaluate stabilization and closure techniques at a low-level solid waste disposal site at ORNL. The techniques include dynamic compaction, in situ grouting, and covering for a group of waste disposal trenches at TARA in SWSA 6. Current data include construction information on wells installed in the area under investigation, associated water levels, water quality, and soil gas analyses.

In situ vitrification is a potential technique for immobilization and closure of various ORNL contaminated sites. A 25-ton mass of vitrified material was produced in the field within a scale model of an old seepage trench to which stable strontium and cesium had been added as surrogates for ^{90}Sr and ^{137}Cs. Data were collected to analyze the performance of the test, and samples were taken to determine the leaching characteristics of the waste form produced in the field.

Table 13. SAS data sets on the Biological Monitoring and Abatement Program studies

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCI1.DV25255.SAS.BMAP	Data from the Biological Monitoring and Abatement Program			
Population estimates and associated data				
CG_VITAL	Banded Canada geese vital statistics	19JAN89 - 11JUL89	403	14
CG_TRACK	Canada geese tracking data	23JUN89 - 01DEC89	1,598	13
HABITFLW	Habitat description of BMAP sampling sites: flow conditions	19MAY88 - 09JUN88	1,462	10
HABITSUB	Habitat description of BMAP sampling sites: substrate characteristics	10JUN88 - 02AUG88	648	31
WCCLS1	Taxonomic and ecological classifications for WOC benthic invertebrate data	--	232	10
WCBEN1A	WOC benthic invertebrate data from monthly samples	05MAY86 - 06JUN87	7,220	13
WCFLD1A	WOC benthic invertebrate data from monthly samples, including substrate conditions, water temperature, and stream stage	05MAY86 - 06APR88	975	20
WCQL1A	WOC benthic invertebrate data from qualitative samples	01APR87	425	11
WC_AGE	WOC fish-scale age data	15MAY88 - 08DEC89	886	12
WC_CHM	WOC fish population study: water conditions	22MAY85 - 08DEC89	168	20
WC_SHK	WOC fish population study: collection specifics	22MAY85 - 08DEC89	415	21
WC_FSH	WOC fish population data: fish collected	22MAY85 - 08DEC89	27,564	16
KDUCKS	Census of waterfowl at ORGDP	13OCT88 - 09JUN89	271	18
XDUCKS	Census of waterfowl at ORNL	05AUG88 - 13DEC89	364	15
YDUCKS	Census of waterfowl at Y-12 plant	17FEB89 - 09JUN89	83	7
WOLFISH	WOL fish population survey: estimation by species	07MAY87 - 13MAY87	3,552	10
W_FOWL	Record of waterfowl sightings in Oak Ridge area	16OCT87 - 12AUG88	3,809	7
Toxicity bioassay studies				
WOCCHEM	WOC toxicity bioassay results: water chemistry	20MAR86 - 25MAR87	1,260	15
WOCCD	WOC toxicity bioassay results: Ceriodaphnia survival and reproduction	21MAR86 - 25MAR87	192	19

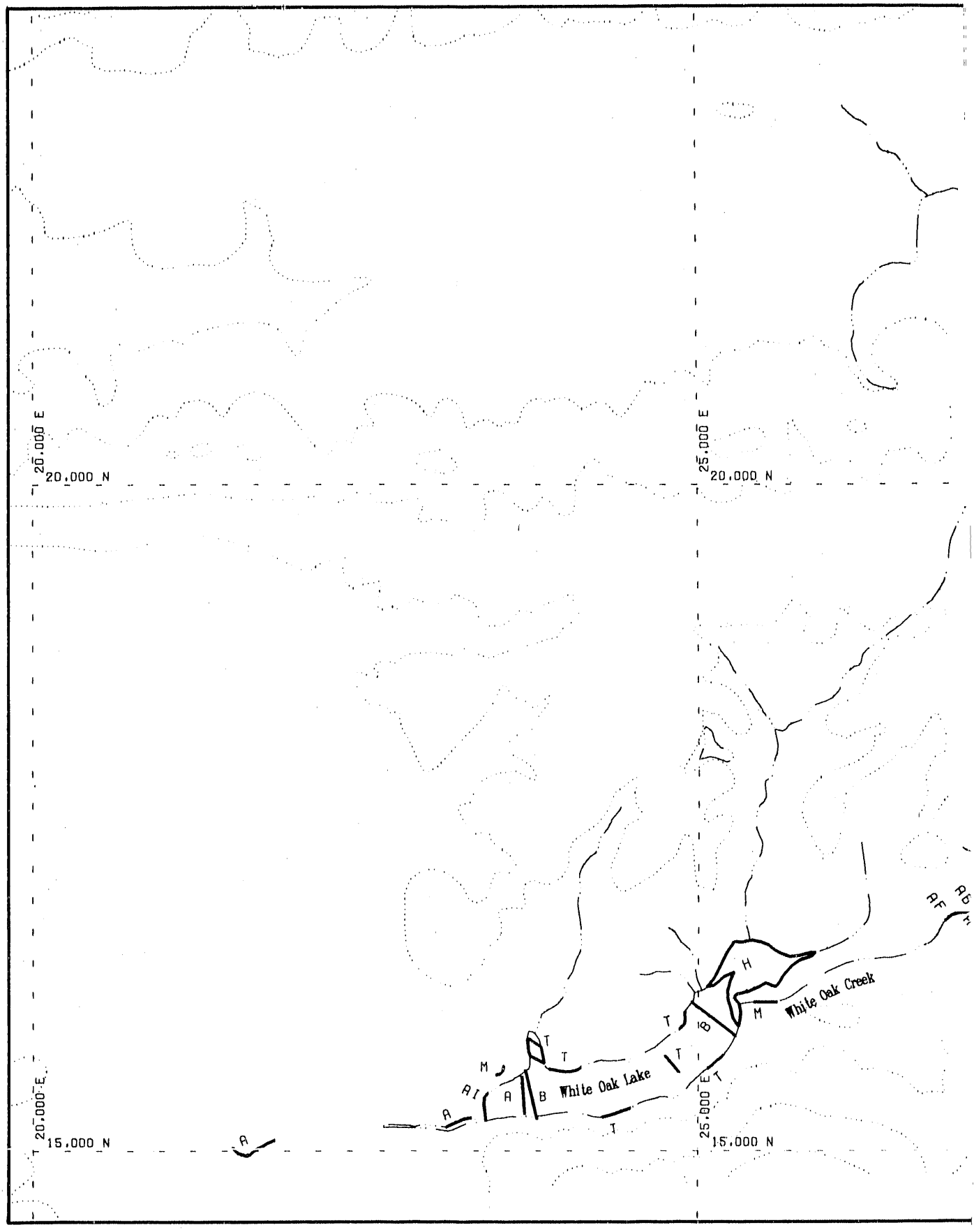
Table 13 (continued)

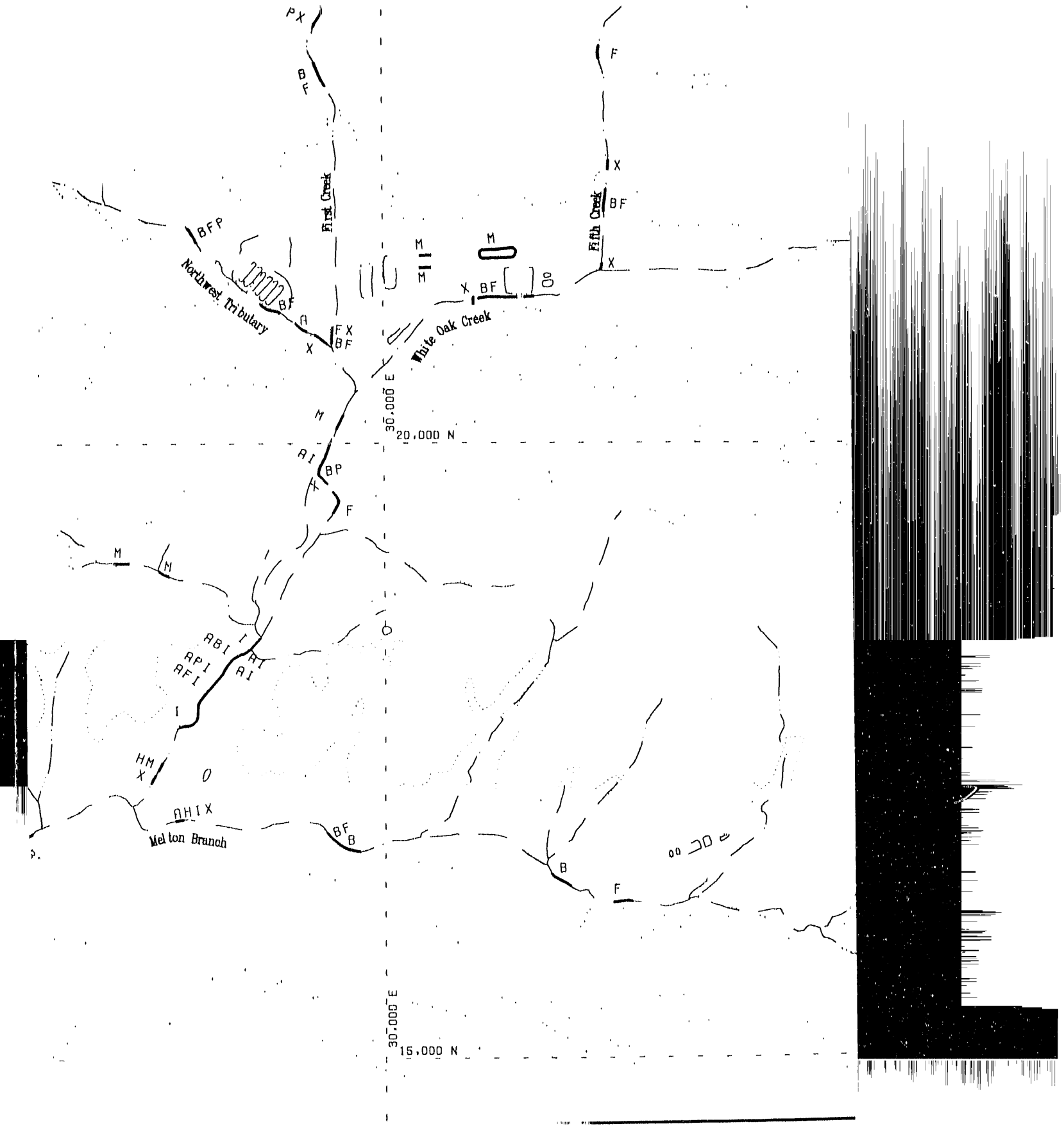
SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
WOCFHM	WOC toxicity bioassay results: fathead minnow survival and growth	27MAR86 - 26MAR87	768	12
CNTB_IND	Reference sites: physiological stress indicators	15JUN87 - 22JUN87	57	44
WOCB_IND	WOC fish: physiological stress indicators	19NOV86 - 15OCT87	160	48
CHLOROPL	WOC watershed chlorophyll-*a* and carbon uptake by periphyton	24OCT86 - 27APR89	3,158	9
WOCORGS	Organic and mercury analyses in WOC watershed	26JAN87 - 23APR87	1,504	21
WOCSURWQ	WOC surface water quality related to periphyton studies	23JUL86 - 18DEC89	8,211	21
Contaminant concentrations in biological samples				
FISH_MET	Metal analyses of fish collected from WOC, Clinch River, and reference sites	25NOV86 - 23FEB87	60	13
FISH_ORG	Organic analyses of fish collected from WOC, Clinch River, and reference sites	25NOV86 - 23FEB87	50	11
FISH_PCB	PCB and ^{90}Sr analyses of fish collected from WOC, Clinch River, and reference site.	25NOV86 - 23FEB87	50	11
FISH_RAD	Radionuclide analyses of fish taken from WOL	07MAY87	280	20
CLAM_PCB	PCE concentrations in clams exposed for one month in WOC	15JUL87 - 17AUG87	20	11
SNAPPERS	Radionuclide, mercury, and DNA analyses of common snapping turtles	20APR88 - 12JUL88	21	11
TURTLES	Radionuclide, mercury, and DNA analyses of yellow-bellied sliders	27JUL87 - 18SEP87	24	32
COOT_RAD	Total strontium in American Coots trapped at WOL	27FEB88	6	21
MAMMALS	Radionuclides in small mammals (rats and mice) collected at East Fork Poplar Creek and SWSA 4	22MAY87 - 27SEP87	129	13
MACROPHY	Radionuclides and metals in emergent macrophytes in WOC watershed	08SEP87 - 23SEP88	1,242	27
WTR_FOWL	Metals and radionuclides in Oak Ridge waterfowl	12JUL88 - 05AUG89	588	21
Off-site/Watts Bar Reservoir and Clinch River studies				
CORESTP	Tennessee State Plane coordinates for sediment core samples	--	59	3
WB_FIELD	Sediment core sample IDs, dates, depths, and weights	22JUL86 - 25SEP87	1,100	8

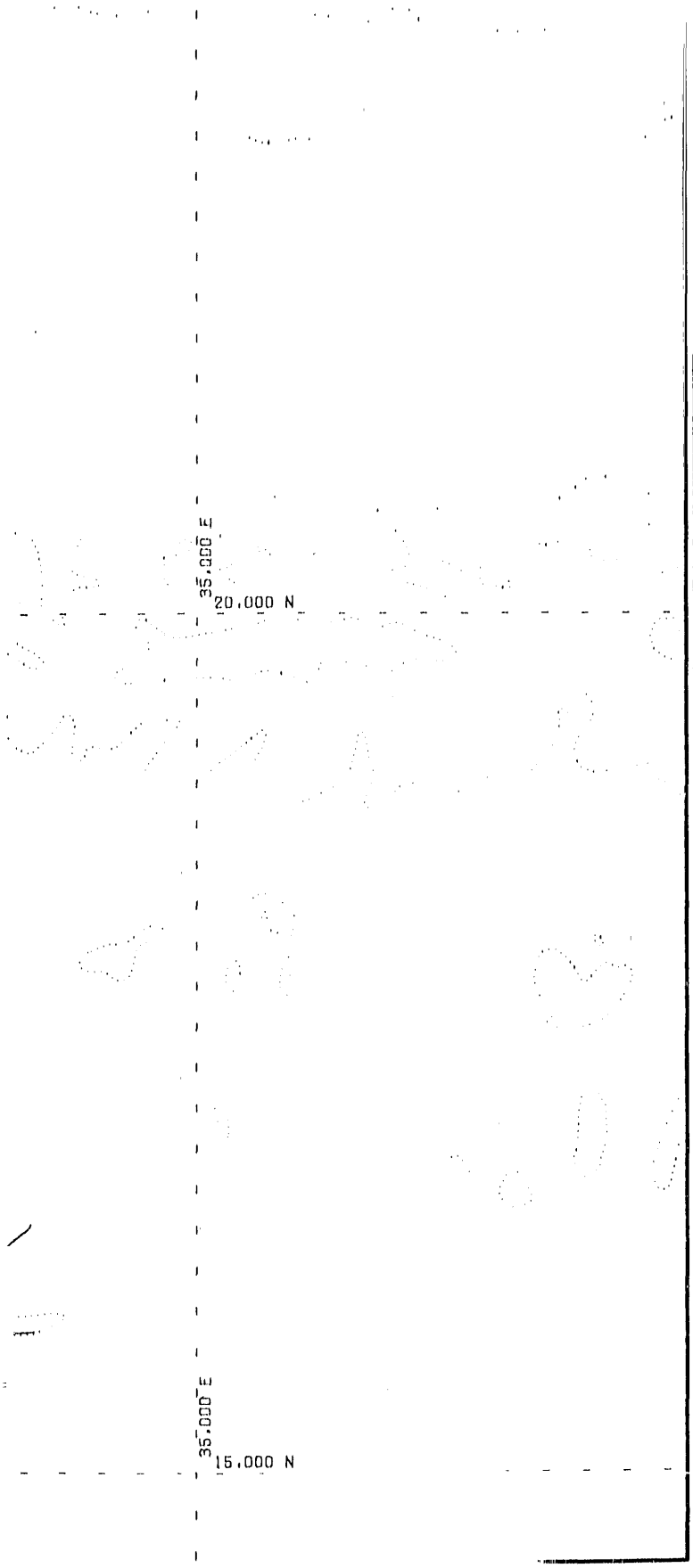
Table 13 (continued)

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
WB_CORES	Radiological analyses of sediment core samples	22JUL86 - 25SEP87	17,584	12
SED_INV	^{137}Cs and ^{7}Be inventory in sediments estimated from core samples	--	204	15

[a]Definitions:
BMAP = Biological Monitoring and Abatement Program
WOC = White Oak Creek
WOL = White Oak Lake
ORNL = Oak Ridge National Laboratory
PCB = Polychlorinated biphenyl
SWSA = Solid Waste Storage Area
ORGDP = Oak Ridge Gaseous Diffusion Plant


20,000 E
25,000 E
20,000 N
15,000 N
White Oak Lake
White Oak Creek


First Creek
Fifth Creek
Northwest Tributary
White Oak Creek
Melton Branch
30,000 E
20,000 N
15,000 N



Legend

Monitoring Codes

A = Fish, bioaccumulation
B = Benthos
F = Fish
H = Macrophytes
I = Fish, bioindicators
M = Mammals
P = Periphyton
T = Turtles
X = Ambient toxicity

Lines

- - - X-10 Grid, 1000 ft Interval

——— Creeks, Ponds, and Basins

Contours, 100 ft Interval (approx)

Map Scale 1:12000
March 1989

Fig. 8.

Sampling Sites for the Biological Monitoring and Abatement Program Studies

Table 14. SAS data sets on technology demonstration studies

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCLLDV 25255.SAS.SLB	Data associated with the SLB Closure demonstration			
TARACONS	Construction data on wells used for the SLB demonstration	01JAN77 - 15APR87	15	32
WATEREL	Manual water-level measurements for the TARA wells	21MAY87 - 21JUN88	1,056	10
W_LEVELS	Continuous water-level measurements for the TARA wells	04MAR88 -18APR89	6,868	10
FIELD	Temperature, pH, dissolved oxygen, and conductivity for TARA wells	18NOV87 - 23NOV87	15	9
WELLWQ	Results of cation, anion, and organic analyses of water from the TARA wells	18NOV87 - 23NOV87	2,070	22
ORG_VAP	Soil organic vapor analyses of cores taken in the vicinity of TARA	03MAR88 - 12APR88	221	16
SOIL_ORG	Organic analyses of soil cores taken in the vicinity of TARA	08MAR88 - 11APR88	990	19
SOIL_RAD	Radiological analyses of soil cores taken in the vicinity of TARA	03MAR88 - 12APR88	681	18
ENVSCLLDV25255.SAS.ISV	Data associated with the ISV demonstration			
OFFGAS	Dissolved and total solids, total and soluble alpha and beta, and pH measured at various sample points in the off-gas scrubbing system	25JUN87 - 05AUG87	108	15
ACD_GAS	Chemical analysis of off-gas scrubbing solutions and filters	25JUN87 - 05AUG87	3,769	21
ACD_RCK	Elemental composition of the "wastes" before and after vitrification	--	1,493	21
ORNLOFFG	Temperatures, flow rates, CO and CO_2 concentrations at various points in the off-gas scrubbing system measured over time during the ISV field demonstration	14JUL87 - 19JUL87	240	15
TEMPC	Temperature measured at thermocouples at center of the ISV site	14JUL87 - 19JUL87	2,400	8
TEMP7	Temperature measured at thermocouples placed 7 ft from center of the ISV test site	14JUL87 - 28AUG87	3,637	8
TEMP10	Temperature measured at thermocouples placed 10 ft from center of the ISV test site	14JUL87 - 28AUG87	11,712	8
POWER	Electric power consumed during the demonstration	14JUL87 - 19JUL87	76	11

[a]Definitions:
SLB = Shallow Land Burial;
TARA = Test Area for Remedial Action;
ISV = In situ vitrification.

2.9 RI/FS DATA INCORPORATED INTO THE RAP NUMERIC DATA BASE

Results of Bechtel National, Inc. (BNI) field investigations and data acquisition activities which started in late 1988 are being managed in BNI's Remedial Investigation/Feasibility Study (RI/FS) Data Base according to Data Management Project Procedures (Bechtel National, Inc. Team 1988). As technical reports describing these data are completed, copies of the data are transferred to RAP, checked for quality, and incorporated into the RAP Numeric Data Base. The data transferred thus far are listed in Table 15. Additional types of data to be transferred include well construction data, ground water elevations, well head space, gas analysis results, and radiological walkover survey data.

2.10 MISCELLANEOUS STUDIES/DATA SETS

Data sets which do not conveniently fit into any of the categories established for the RAP Numeric Data Base are listed in Table 16. These include regulatory standards, general information about the WAGs and Solid Waste Management Units (SWMUs), results of a study by Cerling to compare three extraction procedures, and an inventory of solid wastes disposed of in SWSAs 5 and 6.

2.11 FORMAT FILES

Although almost anything can be computerized in some kind of format, often it is not practical to maintain lengthy character fields in a data set that will be printed routinely. In such cases, codes are assigned to represent a data entry. For example, "04A" is the standard NPDES code for 4,6-dinitro-2-methylphenol. SAS format files have been added to the data base so that chemical names can be displayed in several ways: with the ACD abbreviation, the full name of the element or compound, the NPDES code, the Priority Pollutant code, or the Chemical Abstract Service number. Also, format files have been written to refer to (1) the geologic unit of a core segment, (2) the pipe and screen materials used in the construction of the piezometer and water quality monitoring wells, and (3) the full order names of benthic invertebrates. These files are listed in Table 17.

Table 15. RI/FS data files transferred to RAP Numeric Data Base

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
ENVSCI.LDV25255.SAS.WAG6DATA	Characterization of WAG 6 groundwater monitoring wells, soil cores, and surface water samples			
ACIDCASB	Listings of ORNL/ACD CAS-numbers, Pnames, and Rnames		284	3
COORDDB	Sample locations, grid coordinates, and elevations used for sampling		78	4
ITCOMPT	Listing of CAS numbers, common names, regulation names, and representative names used by BNI		1,533	7
GW89A	Groundwater samples from monitoring wells analyzed for dissolved solids, COD, fecal coliforms, TOC, TOX, metals, mercury, PCBs, pesticides, phenols, and radiological activity	19APR89 - 09JUN89	6,823	15
SOIL89A	Soil sampling analyses for 53 bore holes and results are for % moisture, % solids, pesticides, organics, PCBs, and radiological activity	12DEC88 - 30DEC89	12,346	16
SW89A	Surface water samples for dissolved solids, COD, TOC, TOX, metals, mercury, PCBs, pesticides, phenols, and radiological activity	08FEB89 - 09JUN89	8,362	15

[a]Definitions:
ACD = Analytical Chemistry Division
CAS = Chemical Abstract Service
COD = chemical oxygen demand
ORNL = Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
TOC = total organic carbon
TOX = total organic halides

Table 16. SAS data sets on related miscellaneous studies

SAS library/ SAS data set	Description of library/data set[a]	Time period	Number of observations	Number of variables
I2NVSCI.MJC25255.SAS.RAPIDIM				
WAO_INFO	Descriptive information about the Waste Area Groupings and Solid Waste Management Units	--	253	9
I2NVSCI.LDV25255.SAS.GWQUAL				
STAND	EPA Interim Primary Drinking Water Standards for analyses of water from RCRA wells. Parameters without standards are flagged	--	31	4
I2NVSCI.LDV25255.SAS.CERLINOV	Comparison of three extraction procedures for streambed materials			
EXTRACT	Cations analyzed for comparison of extraction procedures	--	1,970	22
FIELD	Field data including sampling date and location, sample type, sample ID, etc.	--	768	16
I2NVSCI.LDV25255.SAS.SWIMS	Solid waste information management systems (SWIMS) data from EHP Division			
MOD3SW6	Inventory of solid wastes disposed of in SWSA 6	01OCT68 - 28FEB90	18,750	40
MOD3	Inventory of solid wastes disposed of in all other SWSAs	03JAN88 - 26FEB90	3,795	40
MOD3COM	Comments from waste disposal	03JAN83 - 30DEC86	4,203	14

[a]Definitions:
EPA = U.S. Environmental Protection Agency
RCRA = Resource Conservation and Recovery Act
SWSA = Solid Waste Storage Area

Table 17. Format files for defining data entries for selected variables

Data set	Member name	Description of file[a]
ENVSCI.LDV25255.SASFMTS	(PPFMT)	File for converting from NPDES to PP codes; can be used with ACD SAS data sets
	(CASFMT)	File for converting from NPDES to CAS codes; can be used with ACD SAS data sets
	(NAMEFMT)	File for converting from abbreviations to full chemical names; can be used with ACD SAS data sets
	(DETECT)	File defining detection limits for organic compounds; can be used with ACD SAS data sets
	(GFMT)	File for printing geounit when used with the WQCONS, PIEZCONS, and HHMSCONS SAS data sets
	(SFMT)	File for printing pipe material and screen material when used with the WQCONS and PIEZCONS SAS data sets
	(ORDER)	File for converting from abbreviations of taxonomic orders of aquatic macroinvertebrates to full order name; can be used with BMAP benthic invertebrate data

[a]Definitions:
NPDES = National Pollution Discharge Elimination System;
PP = Priority Pollutants;
ACD = Analytical Chemistry Division;
CAS = Chemical Abstracts Service;
WQCONS = Construction data for water quality wells;
PIEZCONS = Construction data for piezometer wells;
BMAP = Biological Monitoring and Abatement Program.

2.12 GEOGRAPHIC INFORMATION SYSTEM DATA

Because several grid coordinate systems are used for the ORNL vicinity, a major concern in dealing with geographic data for RAP is that those who provide and/or receive such data know (1) which grid is used and (2) how to convert from one grid system to another. This topic is addressed in Sect. 2.12.1, followed by discussions of the GIS data files developed for RAP (Sect. 2.12.2) and interfacing ARC/INFO with SAS/GRAPH (Sect. 2.12.3).

2.12.1 Grid Coordinate Systems

Several map coordinate systems may be applied to the ORR, including the ORNL (X-10) Grid, the Oak Ridge Y-12 Plant (Y-12) Grid, the Oak Ridge Gaseous Diffusion Plant (K-25) Grid, the Administrative Grid (AGS), Tennessee Lambert State Plane, and latitude/longitude (lat/long) coordinates. Conversion from one system to another is not a simple matter; the accuracy of the conversion depends in part on the number and accuracy of control points used in developing the transformation equations. In 1988 a new set of transformation relationships was developed by Geophysical Service, Inc. (1988), based on 43 reference points determined on the ORR with a Global Positioning System (GPS). This method of coordinate conversions has been adopted for the ORNL RAP, replacing those transformation procedures referred to in the 1987 Annual RAP Data Management Report (Voorhees et al. 1988). A set of equations to perform these coordinate transformations is described in Appendix A.

All location data in the RAP Numeric Data Base are entered and retained in the original form. For example, if a location is surveyed in the X-10 Grid or if a sampling point is read off a map drawn in the Y-12 Grid, then these data are retained in the data set as X-10 and Y-12 grid coordinates, respectively. The conversion of location data from one grid system to another or from two grid systems into a third (such as lat/long coordinates) is done at the time it is needed.

2.12.2 Geographic Information System Data Sets

A data base of descriptions of the spatial characteristics of activities in RAP has been established in the ESD Geographic Information System (GIS). ESD's GIS operates on a VAX cluster and uses ARC/INFO software. The structure of the GIS data base for

RAP is organized at two levels. The detailed level of organization is a collection of geographic features (e.g., points, lines, and polygons) and their associated attributes (e.g., well ID, elevation, and area) and is called a "coverage." A coverage typically has geographic features that represent some common theme such as roads, wells, or streams. For the GIS data developed for RAP, these coverages are further organized into VAX subdirectories that represent a common collection of themes. For example, all of the different types of wells associated with RAP are in one VAX subdirectory.

ARC/INFO has analytical capabilities to process spatial data in either larger or smaller aggregations of data than a single coverage. These aggregations of spatial data may be either temporary or permanent. The GIS software also has the ability to spatially interrelate the features from multiple coverages. This analytical flexibility has allowed the GIS data to be stored in aggregations that best suit the needs of the remainder of the RAP Numeric Data Base and the purposes of the program.

The RAP GIS data are grouped into the following major themes:

- groundwater wells,
- biological and surface sampling locations,
- SWMUs,
- WAG boundaries,
- descriptive background features (roads, buildings, etc.), S-16A map, and digital elevation model data, and
- off-site sampling locations.

Within each of these major themes, there are one or more subthemes stored as coverages. For example, within the groundwater wells, attributes of the piezometer and CERCLA wells are stored as separate coverages. The structure of the RAP GIS data base is summarized in Table 18. Details about the contents of these coverages were presented in Appendix C of Voorhees et al. (1989) and documentation of S-16A map coverages is presented in Appendix B of this document. Digital GIS data for the S-16A map was obtained from TVA and processed into the coverages listed in Table 18. The map includes the entire ORR. BNI has digitized topography, roads, buildings, utilities, streams, and water bodies for the areas under investigation by RAP. Copies of these data sets are available

Table 18. Overview of the Remedial Action Program Geographic Information System data base structure[a]

Vax subdirectory	Coverage name	Coverage theme[b]	Number of features[c]
U3:[RQM.RAP.CORE]	COREDD	Off-site RAP sediment samples	59
(Watts Bar Sampling)	CORESITES	Off-site RAP sediment samples	48
	CORESTP	Final off-site sediment samples	59
	LAKE	Draft Watts Bar Lake outline	0
	WBLAKESTP	Watts Bar Lake outline	31
U3:[RQM.RAP.NWELLS]	ACRE4	4-acre site wells	7
(Well Locations)	ACRE4H	4-acre site wells near HF wells	7
	ACRE4P	4-acre site wells near PRAP wells	7
	CERCONS	RAP CERCLA wells	13
	HFLOC	Hydrofracture wells	89
	HFLOCWAG	Hydrofracture wells with WAGs	89
	HHLOC	Hydrostatic head monitoring wells	19
	HHLOCWAG	Hydrostatic head monitoring wells with WAGs	19
	HHMS88	Revised hydrostatic head monitoring wells	31
	HHMS88WAG	Rev. hydrostatic head monitoring wells with WAGs	31
	PCIPLOC	Precipitation monitoring sites	20
	PCIPLOCWAG	Precipitation monitoring sites with WAGs	20
	PRLOC	PRAP wells	651
	PRLOCWAG	PRAP wells with WAGs	651
	PZDECAP	Piezometer wells	331
	PZDECWAG	RAP piezometer wells with WAGs	331
	STDWELL	Stockdale wells	51
	STDWELLN	Stockdale wells nearest PRAP wells	51
	TARA	Test Area for Remedial Action wells	13
	UCONT	Continuous monitoring wells	93
	UWELLS	USGS continuous monitoring wells	28
	UCONT	USGS continuous monitoring wells with WAGs	26
	WQ88	Revised RAP RCRA water quality wells	77
	WQ88WAG	Revised RAP RCRA water quality wells with WAGs	77
	WQLOC	RAP RCRA water quality wells	22
	WQLOCWAG	RAP RCRA water quality wells with WAG	22
U3:[RQM.RAP.SAMPTS]	BIOA	Stream sampling - bioaccumulation	9
(Sampling Sites)	BIOALL	Stream sampling for biological monitoring	72
	BIOB	Stream sampling - benthos	13
	BIOF	Stream sampling - fish	12
	BIOH	Stream sampling - macrophytes	3
	BIOI	Stream sampling - bioindicators	4
	BIOL1	Stream sampling - biological monitoring	67
	BIOL4	Revised stream sampling - biological monitoring	68
	BIOL4P	Stream sampling points - biological monitoring	68
	BIOM	Stream sampling - mammals	9
	BIOP	Stream sampling - periphyton	6
	BIOT	Stream sampling - turtles	6
	BIOX	Stream sampling - ambient toxicity	10
	CER1	Cerling data - 1985	327
	CER1WAG	Cerling data - 1985 with WAG	327
	CER2	Cerling data 1986-87	365
	CER2OG	Transformed Cerling data 1986-87	63
	CER2OGWAG	Transformed Cerling data with WAGs	63
	CER2WAG	Cerling 1986-87 data with WAGs	365
	SURDIS	Surface discharge monitoring sites	9
	SURDISWAG	Surface discharge monitoring sites with WAGs	9
U3:[RQM.RAP.SWMU]	SWMU	RAP SWMU locations	205

Table 18 (continued)

Vax subdirectory	Coverage name	Coverage theme[b]	Number of features[c]
U3:[RQM.RAP.TUG]	BUILD1	Revised central ORNL buildings	39
(ORNL Maps)	BUILDS	Central ORNL buildings	39
	CREEK5	White Oak Lake and Creek	98
	CREEKDEN	Densified White Oak Lake and Creek	98
	STREETLIN	Central ORNL streets	20
U3:[RQM.RAP.WAG]	MAPFR	Overlay boundaries for WAG map	6
(WAG Maps)	SWSA1T	Historical SWSA 1 boundary	1
	WAG11RX	Revised WAG 11 location	1
	WAGX10	WAG boundaries	27
	WAGX10B	Revised WAG boundaries	27
	X10GRD5K	1000-ft grid with labels	28
	X10GRDN	1000-ft grid with annotation	70
	XGRD5K	5000-ft grid with annotation	7
LIB:[LIB.S16A]	L01	1st class road casings - casings	1,275
(S16-A Map)	L02	2nd class road casings - casings	555
	L03	not documented	2
	L04	3rd class road casings	302
	L05	4th class road casings (patterned)	18,054
	L06	trails (patterned or styled)	3,855
	L07	TVA structural profiles	370
	L08	active railroads (patterned)	1,788
	L09	inactive railroads	102
	L10	crossings (Bridges, tunnels, etc)	114
	L11	masonry dams, piers	9
	L12	tailings ponds (patterned)	132
	L13	1st class buildings	38,224
	L14	2nd class buildings	660
	L15	public service buildings	3,193
	L17	transmission lines	15,922
	L18	pipelines, above ground	895
	L20	county boundaries	569
	L21	corporate boundaries	1,775
	L22	reservation boundaries	2,419
	L23	small parks and substations	1,189
	L24	cemeteries	655
	L26	vertical control	3
	L29	Ts for woods	2
	L30	GLO - section lines	19
	L32	index topographic contours	3,235
	L33	intermediate topographic contours	12,469
	L37	disturbed surfaces	13
	L38	blue open water - blue shoreline	798
	L39	single line drains (streams)	1,068
	L41	wells, springs	3
	L42	swamps (patterned)	21
	L43	channel lines (styled)	1,706
	L45	fences (patterned or styled)	2,268
	L46	urban tint outlines	307
	L47	woods (green tint outline)	7,699
	L48	other vegetation	11
	L49	not documented	1
	L50	black misc.	1,121
	L51	blue misc.	199
	L52	brown misc.	1,054
	L53	red misc.	3
	L55	maximum probable flood	321

Table 18 (continued)

Vax subdirectory	Coverage name	Coverage theme[b]	Number of features[c]
	L56	500 year flood boundary	328
	L57	100 year flood boundary	323
	L58	Approximate probable flood boundary	320
	L59	Not Documented	32
MO:[MAP.DEMDATA]	BETHEL.USGS	Digital elevation model data for the Bethel Valley Quad map	NA

[a]Coverages sorted alphabetically by name within alphabetically-sorted VAX subdirectories.

[b]Definitions:
RAP = Remedial Action Program;
HF = Hydrofracture;
PRAP = Pre-Remedial Action Program;
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act;
WAG = Waste Area Grouping;
USGS = U.S. Geological Survey;
SWMU = Solid Waste Management Unit;
ORNL = Oak Ridge National Laboratory;
SWSA = Solid Waste Storage Area.

[c]Number of points, lines, or polygons in coverage. NA = Not applicable.

upon request. All of these data will be transferred to the RAP Numeric Data Base at the conclusion of the work.

2.12.3 Interfacing ARC/INFO with SAS/GRAPH

Environmental research and assessment activities at ORNL include the analysis of spatial and temporal patterns of ecosystem response at a landscape scale. Analysis through use of a GIS involves an interaction between the user and thematic data sets frequently expressed as maps. A portion of GIS analysis has a mathematical or statistical aspect, especially for the analysis of temporal patterns. ARC/INFO is an excellent tool for manipulating GIS data and producing the appropriate map graphics. INFO also has some limited ability to produce statistical tabulation. At ORNL we have extended our capabilities by graphically interfacing ARC/INFO and SAS/GRAPH to provide a combined mapping and statistical graphics environment (McCord and Olson 1989). With the data management, statistical, and graphics capabilities of SAS added to ARC/INFO, we have expanded the analytical and graphical dimensions of the GIS environment. Pie or bar charts, frequency curves, hydrographs, or scatter plots produced by SAS can be added to maps from attribute data associated with ARC/INFO coverages. Numerous small, simplified graphs can also become a source of complex map "symbols." These additions extend the dimensions of GIS graphics to include time, details of the thematic composition, distribution, and interrelationships. Details regarding the ARC/INFO and SAS/GRAPH interface and examples of products resulting from this work are presented in Appendix C.

3. BIBLIOGRAPHIC DATA BASE

In November 1986 work began on the development of a computerized, bibliographic data base to support the information needs of ORNL Remedial Action Program staff. The data base contains a bibliographic citation, an abstract, and various index terms and subject categories for published documents (e.g., reports, journal articles, conference papers, and theses) that relate to the ORNL Remedial Action Program. In addition to the on-line data base, a resource collection containing a paper copy of each document cited is also maintained. Availability of these resources is presented in Sect. 6.1.

The Bibliographic Data Base and hardcopy reference collection serve as a central resource for use by all staff in the ORNL Remedial Action Program and by all subcontractors to identify and access needed program documentation. The data base was designed to ensure (1) a quick and efficient retrieval of needed documents from the resource collection, (2) flexibility in creating a reference list for ORNL/RAP reports, and (3) ability to machine-sort records according to any of the 32 data fields that comprise a record in the Bibliographic Data Base.

During calendar year 1989, 415 documents were added to the Bibliographic Data Base, and 1,237 modifications were made to existing data base records. At year's end, the data base contained 6,215 records. A number of new data fields were developed during the year to permit a more efficient retrieval of needed information from the data base.

4. RECORDS CONTROL DATA BASE

Information associated with programs such as RAP, which are regulatory controlled, must be retained to support any future legal or administrative actions which may be taken. These actions may not occur for several years after the data have been collected. Thus, it is crucial that a system be developed and maintained for identifying, logging, and collating project records and for assisting in the search and retrieval of such information. The records must be sufficiently detailed to provide a complete and accurate history of both the data-gathering process and the results obtained. The ORNL/RAP Records Control Data Base and archive was established in late 1987 to serve this need.

In accordance with EPA guidance for remedial investigations (EPA 1985), the Records Control Data Base and archive is capable of (1) receiving all data/information collected or generated; (2) processing, sorting, and entering all data/information into the storage file; (3) making data/information available to users; and (4) ensuring efficiency in data/information security and disclosure.

The Records Control Data Base operates on the ADSEP (Automated Data Set Editing Program) software installed on the IBM-3033 computers at ORNL. The data base serves as an index for the retrieval of information generated by the program, including correspondence, project plans, well logs, field notebooks, and chain-of-custody forms. The system, which was established for archival purposes, was developed in cooperation with BNI, RAP's primary subcontractor, so that records generated during BNI's investigations can be easily consolidated with those from ORNL. During calendar year 1989, 1153 documents were added to the ORNL/RAP Records Control Data Base for a total of more than 1800 records.

5. OTHER INFORMATION-RELATED RESOURCES

5.1 AERIAL PHOTOGRAPHS

Aerial photography has been used extensively in analyses of local and regional land-use changes. Studies of aerial photographs taken over a period of time can reveal not only how the land was used in the past but also how the many interrelated characteristics of the environment (including land cover, aquatic habitats, soils, geomorphology, and hydrology) may have been affected by land use practices. For this reason, a collection of aerial photographs of ORR has been amassed to support the RAP studies. Photographic information should be useful to RAP investigators studying contamination at historical waste disposal sites and determining alternative approaches for corrective action. In addition, anyone requiring knowledge of historical land-use practices on the ORR should find this resource useful.

A total of 391 aerial photographs of ORR and its immediate vicinity were obtained from TVA for the following years: 1939, 1945, 1952, 1967, 1974, 1981, 1984, and 1985. For most years, considerable overlap of the photographs allows stereoscopic viewing. Specific information regarding dates of the photographs, scales of the prints, spatial coverage, and quality of the prints is presented in Table 19.

The photographs are available at the ESD branch of the ORNL library, in Building 1505. Because the photographs and their corresponding index maps are of varying sizes, they are specially stored. Users should request the information from the librarian.

5.2 EPA TREATABILITY DATA BASE

The U.S. Environmental Protection Agency (EPA) is developing a computerized data base containing information for treating chemicals found in various types of waters and wastewaters. The system is designed to be used as a guide to identify the effectiveness of treatment technologies for organic and inorganic compounds commonly found at hazardous waste sites. EPA's Risk Reduction Engineering Laboratory, where the data base is being developed, has emphasized the priority pollutant list (Appendix VIII of RCRA) and also those compounds found at Superfund sites. Currently there are about 825 compounds in the data base with 2,500 sets of treatability data for approximately half of the compounds.

Table 19. Descriptive information on aerial photographs of the Oak Ridge Reservation

Year	Month/Day	Scale	Number of photos	Comments
1939	November-December	Contact prints and 1" = 3,600'	26	Enlargements very poor quality; contact prints used to create index map
1945	April 5-13, August 9	Unknown	88 9	Coverage very spotty, limited to the vicinity of the Clinch River; unable to create an index map for this year
1952	April 30	1" = 3,600'	20	Good prints
1967	Dates vary, primarily March 2	Primarily 1" = 2,000', but scale not uniform throughout series	38	Monoscopic coverage in Cave Creek quadrangle indicated in orange on the index map
1974	April 19	Originally 1" = 1,000' enlarged to 1" = 1,1000'	19	Monoscopic coverage in the Cave Creek quadrangle indicated in orange on the index map
1981	February 25	1" = 1,000'	87	No comments
1984	November 7	1" = 1,000'	56	Coverage available only for southern part of reservation
1985	March 18	1" = 1,000'	48	Coverage available only for northern part of reservation

We acquired an updated copy of the Treatability Data Base in September 1989 and will retrieve information from it for specific compounds upon request.

5.3 ELECTRONIC BULLETIN BOARDS FOR HAZARDOUS MATERIALS INFORMATION

RAP data management is registered with two electronic bulletin boards (Hazardous Materials Information Exchange (HMIX) and the Center for Hazardous Waste Management (CHWM)) which contain information related to hazardous materials. These bulletin boards are briefly described in this section. Retrieval of information from these resources or assistance in accessing them is available upon request.

5.3.1 Hazardous Materials Information Exchange

The HMIX is a "hazardous materials (HAZMAT) information clearinghouse" and "exchange system" designed to provide Federal, state, local, and private-sector organizations with a means of sharing valuable and timely information about the prevention of, preparation for, and mitigation of hazardous materials emergencies. It is sponsored by the Federal Emergency Management Agency and the Research and Special Programs Administration of the U.S. Department of Transportation. The HMIX consists of

- a calendar of Federal training courses,
- public and private-sector HAZMAT information,
- a calendar of conferences,
- instructional material and literature listing,
- toll-free (800) numbers and on-line data bases,
- laws and regulations,
- contracts,
- Department of Transportation agency-specific information, and
- Federal Emergency Management agency-specific information.

In addition, a bulletin listing provides current news. An example of this listing is given in Fig. 9.

NEW BULLETINS AND ANNOUNCEMENTS

03/08/90	1	Publication Announcement
02/28/90	2	NCP Revision Issued
02/23/90	3	ATSDR Rule Sets Procedures for Determining When and How to Conduct Health Assessment & Health Effects Studies
02/16/90	4	OSHA Requests Comments on Proposed Rule for Certification of Hazardous Waste Training Programs
02/15/90	5	Hazmat Week 1990—5 Day Satellite Videocourse
02/05/90	6	Achievement Awards from the Chemical Manufacturers Assoc.
01/29/90	7	DEA Clandestine Drug Lab Guide
01/24/90	8	BATF Explosives List
01/09/90	9	New Version of CADET Available for Downloading
01/09/90	10	DOE Offers Transportation Emergency Response Course
12/21/89	11	Chemical Listings from Emergency Response Guide

BULLETINS OF CONTINUING INTEREST

02/09/89	12	Public Notice Regarding Privacy and Other Legal Matters With Respect to the HMIX Electronic Bulletin Board
02/09/89	13	Rules and Guidelines for Users of the HMIX Bulletin Board
07/19/89	14	PROCOMM Communication Fact Sheet
07/19/89	15	BITCOM Communication Fact Sheet
07/19/89	16	CROSSTALK Communication Fact Sheet
07/19/89	17	MACTERMINAL Communication Fact Sheet
07/19/89	18	SMARTCOM Communication Fact Sheet
06/09/89	19	Private Sector Criteria - HMIX
01/16/90	20	HMIX Newsletter
06/09/89	21	Information on Drug Law, Films and Literature
09/22/89	22	HMIX Table of Contents
06/09/89	23	Board Status (Help for downloading archived files)
08/23/89	24	Information on ordering the HMIX USER'S GUIDE

Fig. 9. Example of the HMIX bulletin board.

5.3.2 Center for Hazardous Waste Management

The CHWM, which is located at the Illinois Institute of Technology, Chicago, operates a bulletin board with information on hazardous waste treatment methods, remediation, environmental and human health effects, waste minimization, and training. An excerpt of the bulletin's menu follows.

========== Bulletin Menu ==========

1 - The Center for Hazardous Waste Management
2 - How to participate in this BBS
3 - Software to download
4 - Menus to download
5 - Conferences
6 - Hazardous waste RD&D Permit
7 - Superfund evaluation project

==========

The following list of file categories for which information is available was also obtained from the CHWM.

Name	Description of file category
A	ALL FILES
SOFTWR	SOFTWARE AND COMPUTERS
MISC	MISCELLANEOUS
BROCHURE	HAZARDOUS WASTES SERVICES INFO
CONSULT	LISTING OF AVAILABLE ENVIRONMENTAL CONSULTANTS
REGULAT	EPA AND STATE HAZ WASTE REGULATIONS
TREAT	PROCESSES TO TREAT HAZARDOUS WASTE
TRAIN	TRAINING AND SHORT COURSES
HEALTH	HEALTH AND TOXICOLOGY EFFECTS OF HAZ WASTE
REMED	REMEDIAL ACTION METHODS AND CONCERNS
GROUND	GROUNDWATER PROBLEMS
MINIMIZ	WASTE MINIMIZATION
CITYW	MUNICIPAL WASTE DISPOSAL CONCERNS

The following edited list was extracted from the "ALL FILES" category as an example of the type of information that can be found on the system.

File name		Size	Date	Subject
USER2.LST		9216	03-12-89	USERS WILLING TO BE CONTACTED
GARBAGE.CIT	*	2561	10-17-88	INCINERATION VS RECYCLING IN CHICAGO
RCRACAS.NOS	*	16256	08-23-88	RCRA/SARA SUBSTANCE COMPARISON W/CAS #'s
Z4TABLE.TXT	*	61696	07-19-88	DRAFT OF OSHA Z-4 HAZARDOUS SUBSTANCES
ENVLAW.CLS	*	4224	07-09-88	CLASS SYLLABUS FOR ENV'L LAW COURSE
313LIST.TXT	*	15744	07-09-88	ASCII FILE OF SARA TOXIC CHEMICALS
MANIFEST.ARC	*	32256	07-01-88	HAZ WASTE MANIFEST TRACKING SYSTEM DB3+
TOPIC_1.TXT	*	1792	05-06-88	DISCUSSION PROBLEM RE GW MONITORING
STIFF25.ARC	*	22400	04-15-88	STIFF DIAGMS FOR GWATER ION ANALYSIS
RFP.BRO	*	3248	04-01-88	RFP PROCESS FOR IN-SITU SOIL DECONTAMINANT
OSHA23.REG	*	3997	03-12-88	OSHA EXTENDS RIGHT-TO-KNOW ALL INDUSTRS
PRIORITY.REG	*	5558	02-08-88	ATSDR PRIORITY LIST OF 100 POLLUTANTS
SEMINARS	*	1280	01-28-88	ENVIRON ENGINEERING SEMINARS @ IIT
LISTU REG	*	20540	01-25-88	RCRA "U" LIST OF HAZARDOUS WASTES
LISTP REG	*	9559	01-25-88	RCRA "P" LIST OF HAZARDOUS WASTES
LISTS REG	*	3597	01-20-88	DISCUSSION OF HAZARDOUS WASTES LISTS
TRIBUNE.TOX	*	2030	01-15-88	EPA REASSESSES HAZ WASTE TOXICITY
BENZENE.HLT	*	4235	01-12-88	ATSDR TOXICOLOGY PROFILES: BENZENE
AIRBILL.REG	*	1171	01-12-88	CLEAN AIR ACT AMENDMENTS APPROVED
SURVEY2 TRT	*	2809	01-03-88	ALTERNATIVE TREATMENT PROCESS SURVEYS
SURVEY1 TRT	*	1208	01-03-88	TREATMENT PROCESSES SURVEY BOOKS

6. SERVICES AVAILABLE

Information in the RAP Data and Information Management System is available in a variety of formats depending upon the type of request and users' needs. As indicated in Sect. 4, the Records Control Data Base and archive was established primarily to organize and manage records that document the history of all programmatic actions and decisions. Because this system is not intended to be a working file, access to this information is limited to program management requests. Bibliographic information and numeric data, however, are often of use to RAP staff and their subcontractors as well as to other personnel conducting investigations on the ORR. Access to the information in these data bases is described below.

6.1 BIBLIOGRAPHIC DATA BASE

Available services pertaining to bibliographic information include:

- performing computerized literature searches of commercially available data bases,
- performing topical searches of program-sponsored computerized data bases, and
- providing assistance in locating copies of needed documents.

During the year, 778 documents or information items were provided in response to requests from ORNL staff. An additional 183 informational items were provided to the RI/FS Subcontract Team, which includes Bechtel National, Inc. (BNI), CH2M Hill, EDGe/MCI, ECE, and Lee Wan. In order to disseminate information in a timely manner, an electronic bulletin continues to be sent weekly to approximately 130 program participants and other interested parties.

In addition to paper copy, which has been the most frequently used form of output, the user can request that the information be provided in electronic form. The obvious advantage to receiving output in digital form is the elimination of the need for re-entering the information when preparing a bibliography or reference section for a report. The following options exist for receiving information in electronic form.

- electronic mail (E-mail) on the ORNL computer network,

- file transfer on the network, and
- PC diskette.

To obtain further information concerning the Bibliographic Data Base or services available, please contact

Park T. Owen
Oak Ridge National Laboratory
Building 2001, MS-6050
P. O. Box 2008
Oak Ridge, Tennessee 37831-6050

Telephone: 615/576-0568 or FTS 626-0568
Facsimile: 615/574-9888 or FTS 624-9888

6.2 NUMERIC DATA BASE

Printouts of raw and intermediate data sets, as well as computer access to the data, are provided routinely to principal investigators for information and data verification purposes (Voorhees et al. 1988). Although data analyses are the responsibility of those who collect the data, data management staff assist in such analyses upon request. Summary statistics (e.g., minimum, maximum, mean, and standard deviation), plots, graphs, and a wide variety of other outputs are available. In many cases, it is more efficient and cost effective to have RAP data management staff provide the needed statistics, assessments, tables, plots, etc., for reports prepared by RAP investigators. The RAP data management staff are familiar with the RAP Numeric Data Base as a whole and are able to provide analyses that integrate the data from various tasks within the program.

Assistance in the display and manipulation of spatial information can also be provided. For example, the GIS has been used to produce large-scale plots of the locations of piezometer and water quality wells drilled for RAP. These plots, required by state and federal regulators, were scaled to existing topographic base maps and produced as Mylar overlays. Also, the RAP GIS has the capability to convert data between several other GIS formats, including the USGS Digital Line Graph, U.S. Bureau of the Census Geographic Base File, Autocad, Intergraph, and ORNL Geographic Data Systems.

A copy of the digital data used to create the S-16A map, which covers several square miles around the ORNL site, was obtained by RAP data management. As more

base geographic data sets become available, the GIS will prove to be a valuable tool for analyzing and presenting site characterization and assessment data. These analyses will emphasize the spatial orientation of the data. For example, the GIS will allow an investigator to specify a spatially defined subset of data for groundwater wells whose locations can be plotted to any scale. Furthermore, using the GIS to draw maps to scale and checking the product against well-defined reference points have been and continue to be an effective means of verifying spatially oriented data. The GIS can also be used to display simultaneously multiple classes of data (e. g., well locations and WAG boundaries). These analyses are particularly useful to multidisciplinary projects such as RAP.

Requests for data and related products are available in any of several formats including, but not limited to the following:

- direct read access to SAS data libraries;
- computer data tapes in specified format for export to another mainframe computer;
- copies of data sets on PC diskettes in Lotus 1-2-3, dBASE III PLUS, PC-SAS, or ASCII format;
- selected data in specified format for direct inclusion in reports;
- generic printouts of selected data;
- summary tables of precipitation or flow data for selected sites;
- plots of groundwater elevation (well hydrographs);
- ORNL maps showing locations of various types of wells; and
- ORNL maps showing sampling locations for a particular study.

More than 50 specific requests for data from the RAP Numeric Data Base, mostly from ORNL staff, were filled in 1989. Requests originating outside ORNL (e.g., from EPA or the Tennessee Department of Health and Environment) must have RAP management approval. To obtain further information concerning the Numeric Data Base or to request data or related products, please contact

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Appendix A

TRANSFORMATION OF COORDINATES BETWEEN LOCAL GRIDS AND TENNESSEE STATE PLANE (NAD-83)

A set of equations to transform Tennessee State Plane coordinates (NAD-83) to any of the four local grid systems (X-10, Y-12, K-25, and Administrative) and vice versa have been developed. The equations are a result of regressions performed on coordinates transformed with the GRIDCHG program of ARC/INFO, which does any of the above transformations in an interactive mode. The advantage of the equations is that a large file (such as a SAS data set) of points can be transformed easily in a batch job. Results rounded to three decimal places duplicate results from GRIDCHG. Using the equations can result in very small errors. The GRIDCHK program of ARC/INFO is used for small study areas when very precise results are required. Note that it is also possible to go from a local grid system to another local grid system using these equations. For example, one could go from X-10 to NAD-83 and then from NAD-83 to Y-12. The source code that performed these regressions and the resulting equations are available as ASCII files upon request.

To transform coordinates from a local grid to NAD-83 or vice versa, use the following abbreviations and equations:

ADME = Administrative Easting
ADMN = Administrative Northing
K25E = K-25 Easting
K25N = K-25 Northing
N83E = Tennessee State Plane (NAD-83) Easting
N83N = Tennessee State Plane (NAD-83) Northing
X10E = X-10 Easting
X10N = X-10 Northing
Y12E = Y-12 Easting
Y12N = Y-12 Northing .

From X-10 to NAD-83 use

N83E = 0.2503207564*X10E - 0.1738489472*X10N + 747938.7187
N83N = 0.1738489495*X10E + 0.2503207580*X10N + 167169.0430

From NAD-83 to X-10 use

X10E = 2.6949843266*N83E + 1.8716793269*N83N - 2328569.966
X10N = -1.8716793217*N83E + 2.6949843092*N83N + 949383.5081

From Y-12 to NAD-83 use

N83E = 0.2496716899*Y12E - 0.1747867025*Y12N + 747982.6075
N83N = 0.1747867029*Y12E + 0.2496716897*Y12N + 167159.4460

From NAD-83 to Y-12 use

Y12E = 2.6879267567*N83E + 1.8817265786*N83N - 2325070.837
Y12N = -1.8817265825*N83E + 2.6879267583*N83N + 958186.4079

From K-25 to NAD-83 use

N83E = 0.3029123485*K25E - 0.0336026319*K25N + 744322.9777
N83N = 0.0336026310*K25E + 0.3029123490*K25N + 186597.7862

From NAD-83 to K-25 use

K25E = 3.2611536645*N83E + 0.3617658595*N83N - 2494856.315
K25N = -0.3617658495*N83E + 3.2611536593*N83N - 339253.4191

From Administrative to NAD-83 use

N83E = 0.2489592191*ADME - 0.1758057049*ADMN + 748077.4866
N83N = 0.1758057047*ADME + 0.2489592197*ADMN + 167110.1588

From NAD-83 to Administrative use

ADME = 2.6801988607*N83E + 1.8926563578*N83N - 2321278.532
ADMN = -1.8926563551*N83E + 2.6801988539*N83N + 967965.1530

Appendix B

S-16A MAP ARC/INFO COVERAGE DOCUMENTATION

B.1 INTRODUCTION

The coverages from the S-16A map digital data are stored on the ESD VAX cluster in the directory LIB:[LIB.S16A]. Each coverage consists of one level for the entire S-16A map as processed in ARC/INFO. Users of this digital data should be aware that it still contains its graphical aspect (e.g., extra lines for thick lines and shading). If line or polygon topology is desired, the coverages should be carefully edited to assure logical line and polygon relationships. Several instances of errors have been observed in the coverages. Examples include trails in the fourth class roads level (L05), stray lines in the streams level (L38), and buildings in the roads level (L04). When erroneous features are found in a level, it is not always clear if they duplicate features in the level or if they need to be moved to another level. In order to systematically record and correct coverage errors, all errors need to be reported to Raymond McCord at

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Table B.1 is a descriptive index of the S-16A map coverages. An index of coordinate grid coverages and descriptions of available annotation for the coordinate coverages are given below.

B.2 COORDINATE GRID COVERAGE

Grid lines and tic marks for several coordinate systems are in a separate coverage for the S-16A data. The information below describes that coverage.

Workspace: LIB:[LIB.S16A] Cover Name: S16AGRID

Number of tics: 4 (tics are identical to level coverages)

Level values:

level = 21	State plane tics (NAD 27)
level = 35	Longitude/latitude grid
level = 46	UTM zone 16 tics
level = 52	Background Intergraph grid
level = 53	Administrative grid lines
level = 58	State plane (NAD 27) grid lines.

Table B-1. Descriptive index of S-16A coverages

Coverage name	TVA description	Comments	Number of arcs	Number of segments
L01	1st class road casings	Thick red lines on the map (composed of 4-6 parallel arcs), interstates, Pellsippi, and state highways	1,275	6,300
L02	2nd class road casings	Secondary roads, red-dashed lines (dashing by extra arcs), i.e. Bethel Valley Road, Blair Road	555	3,702
L03	Not documented	Patterned part of one second class road, not useful	2	103
L04	3rd class road casings	Hollow parallel line roads, ORNL streets, and Oak Ridge City streets	302	53,115
L05	4th class road casings (patterned)	Double-dashed roads, and jeep trails, one arc for each symbolic dash	18,054	68,207
L06	Trails (patterned or styled)	Single-dashed trails, one arc for each dash	3,855	16,072
L07	TVA structural profiles	TVA boundary (?) that contains a "high water level" boundary for the Clinch River	370	14,276
L08	Active railroad lines (patterned)	Railroads with cross-tie pattern for arcs	1,788	6,567
L09	Inactive railroad lines	Single dashed line	102	171
L10	Crossings (bridges, tunnels, etc)	All arcs are in eastern 1/3 of map	114	177
L11	Masonry dams, piers	Melton Hill Dam, etc.	9	10
L12	Tailings ponds (patterned)	Ash disposal areas, no pattern arcs	132	703
L13	1st class buildings	Solid and hatched buildings: pattern is generated with arcs, house, apartment and office	38,224	47,602

Table B-1 (continued)

Coverage name	TVA description	Comments	Number of arcs	Number of segments
L14	2nd class buildings	Slash-patterned buildings, barn, and storage shed	660	1,282
L15	Public service buildings	Solid filled buildings, arc-generated pattern, churches and schools	3,193	4,056
L17	Transmission lines	Power lines, dashed pattern arcs, "poles" as nested triangle arcs	15,922	37,684
L18	Pipelines, above ground	Dashed line on map, patterned	895	2,468
L20	County boundaries	Part of line missing to make room for text label, patterned	569	2,163
L21	Corporate boundaries	Oak Ridge city boundary, contains several gaps	1,775	5,967
L22	Reservation boundaries	DOE Oak Ridge reservation boundary; TVA reservoir boundary, with missing gaps	2,419	12,254
L23	Small parks and substations	Not always closed polygons	1,189	2,032
L24	Cemeteries	Not always closed polygons; some arcs for cross symbol	655	951
L26	Vertical control	One bench mark	3	3
L29	T's for woods	Not useful, not plotted on map	2	10
L30	GLO - section lines	Only a few short arcs; meaning not clear	19	19
L32	Index contours	100-ft contours; no elevation information	3,235	11,6715
L33	Intermediate contours	20, 40, 60, 80-ft contours; no elevation information	12,469	445,023
L37	Disturbed surfaces	Brown mottled area on map	13	172

Table B-1 (continued)

Coverage name	TVA description	Comments	Number of arcs	Number of segments
I.38	Blue open water - blue shoreline	Blue-shaded ponds, lakes, creeks and rivers; polygon intactness uncertain	798	21,316
I.39	Single line drains	Creeks, blue line drainage features	1,068	21,862
I.41	Wells, springs	Contains only 2 or 3 features; springs are in I.51	3	26
I.42	Swamps (patterned)	Blue lines on map stores as arcs to form swamp symbol	21	34
I.43	Channel lines (styled)	Blue dashed lines in impoundments; if part of channel is adjacent shore, then lines are not repeated	1,706	5,751
I.45	Fences (patterned or styled)	Red fence lines in fields, with dashed lines	2,268	2,651
I.46	Urban tint outlines	Polygons define pink urban shaded areas	307	2,411
I.47	Woods (green tint outlines)	Boundary lines for green shaded areas	7,699	69,928
I.48	Other vegetation	Boundary lines for green dotted orchard areas	11	86
I.49	Not documented	Some map in the south central section	1	4
I.50	Black misc.	Black line features, tanks, gates, river mile, etc.	1,121	2,113
I.51	Blue misc.	Springs	199	1,962
I.52	Brown misc.	Topographic contour depression ties, should be used with I.32 and I.33 for pretty graphics	1,054	1,360
I.53	Red misc.	Tic marks along roads for labelling (?)	3	3

Table B-1 (continued)

Coverage name	TVA description	Comments	Number of arcs	Number of segments
L55	Maximum probable flood	Polygon defining flood level along Clinch River, not on published map	321	13,718
L56	500-year flood boundary	Clinch River, not on published map	328	12,425
L57	100-year flood boundary	Clinch River, not on published map	323	11,676
L58	Approx. probable flood boundary	Clinch River, not on published map	320	13,342
L59	Not documented	Partial river channel	32	1,925

*All coverages have the following identical characteristics: standard AAT attributes of length, etc.; no polygon topology; 4 tics; Fuzzy tolerance = 12.12171; and Xmin = -15367.81, Ymin = -38496.06, Xmax = 107276.7, Ymax = 82721.03.

B.3 ANNOTATION INFORMATION

Annotation contains the text labelling for coordinate values at grid lines and tic marks along the map border. Annotation may be selected by specifying the level numbers on the ANNOTEXT command. The following levels control the selection:

level = 36 Longitude and Latitude;
level = 47 UTM zone 16;
level = 54 Administrative; and
level = 59 State plane (NAD 27).

Currently, the number of annotations is 635. At this time, the text strings that compose the grid labels are converted from the standard interfacing format (SIF) file with one annotation for each character. Future editing may condense the annotations to one per text string.

B.4 COORDINATE TRANSFORMATIONS

The TRANSFORM command was used to change the coordinate system for the coverages from the converted Intergraph units to the Administrative grid system. The listing below provides the statistics on the transformation calculation.

Transformation scale: 787
RMS error: 0.1821E-03

tic ID	Input x	Input y	output x	output y	delta x	delta y
101	-70.7	569	-0.1981E+4	0.4191E+5	-0.0861	0.0977
102	6.59	631	0.7591E+5	0.4821E+5	-0.109	-0.137
103	44.0	592	0.8311E+5	0.6371E+4	0.0156	0.0181
104	-33.3	530	0.5231E+4	0.1311E+3	0.173	0.175

B.5 COORDINATE VALUES FOR S-16A TICS

Values for the S-16A map digital data are described below for all five coordinate systems. Units and direction information is included for each tic identification (ID) within a coordinate system.

Coordinate system	Dir	Units	Tic ID 101	102	103	104
State Plane	E	feet	2460000	2520000	2550000	2490000
(NAD-27)	N	feet	560000	610000	580000	530000
SIF	E	rel.	-70.73	6.592	44.01	-33.312
	N	rel.	568.863	631.0	592.226	530.089
State Plane	E	meters	740211.070	758499.375	767643.773	749355.459
(NAD-83)	N	meters	177205.720	192446.433	183302.295	168061.532
Admin.	E	feet	-1976.1327	75885.5938	83087.6878	5225.8426
	N	feet	41946.5349	48181.1995	6365.8883	131.1067
X-10	E	feet	-2040.4510	75771.9719	83301.0868	5488.546
	N	feet	41512.3675	48356.0071	6597.3177	-246.4398

B.6 EVALUATION OF COORDINATE TRANSFORMATION ACCURACY

The coordinates of the S-16A Standard Interface Format (SIF) file were received in a relative graphical coordinate system. From the information on the published map, it was determined that the map was generated with a projection based on the NAD-27 data. From the annotation and lines of a coordinate grid SIF file, it was relatively simple to pick out NAD-27 and SIF coordinate values at the above grid line intersections. The NAD-83 values were calculated from the NAD-27 values by the National Geodetic Survey. A grid transformation program was used to convert the NAD-83 values to Administrative and X-10 values. This transformation program was furnished by Keith Craft as a product of the survey bench marks by a global positioning system in 1988 (Keith Craft, personal communication, 1988). The accuracy of the processing was tested to evaluate the final coordinate values in the Administrative Grid system of the intersections of the Administrative Grid lines. The following points were investigated:

Published Coordinate Values		Transformed Coordinate Values	
E	N	E	N
15000	0	14993.81	5.9
15000	50000	14995.66	50006.5
85000	5000	84994.52	5003.938
85000	45000	84995.83	45004.41
85000	50000	85996.64	50004.53

The errors between the published and the actual coordinate values are in the range of 4-6 ft. At the published map scale, this represents an error of 0.002-0.003 in. This range of errors is judged to be quite good. Part of the error is probably due to the fact that the published Administrative Grid lines on the map were generated from "old" coordinate transformation equations that were derived before the more accurate global positioning of the bench marks.

Appendix C

INTERFACING ARC/INFO WITH SAS/GRAPH: NEW DIMENSIONS FROM STATISTICAL GRAPHICS FOR GIS ANALYSIS AND INTERPRETATION

C.1 BACKGROUND

Over the past 30 years ESD has conducted numerous projects, including environmental impact assessments, environmental and ecosystem modeling and simulation, ecosystem analysis for nutrient cycling and pollutant fate and effects, radiological and hazardous waste management, regional environmental monitoring, and data analysis and interpretation. The studies have included landscape scales ranging from a single watershed to global coverage. The ecological and environmental projects have evaluated the effects and interrelationships of individual and multiple components.

In all of these categories of studies, ESD has made extensive use of computing technology for its data management, analysis, and presentation. The analytical tools frequently used with data in ESD studies include statistics, graphics, data integration, model construction and simulation, and GISs. A typical research problem will require the use of most of these analytical techniques. The chronology of a project also frequently includes several interchanges between data management, statistical analyses, and mapping with a GIS. This section presents the results of an effort to integrate the graphics from SAS statistical software with the ARC/INFO GIS software used by ESD staff (McCord and Olson 1989).

The integration of SAS/GRAPH and ARC/INFO graphics was initially done to combine two complementary classes of graphical products. SAS and SAS/GRAPH are very comprehensive software systems that ESD has used for several years to manage data, and conduct statistical analysis, and produce data-intensive graphics (i.e., graphics which depend upon the processing and display of hundreds to thousands of data values). Because of SAS's ease of use, comprehensiveness, and power, these software systems are used by the majority of ESD scientists performing data analyses. However, the mapping and GIS capabilities of SAS/GRAPH are limited. In contrast, ARC/INFO is a very comprehensive GIS and mapping software system with limited capability for statistical analysis and essentially no data-intensive graphics capability for the display of statistical analyses. (The primitive graphics tools for drawing various graphs are found in ARCPLOT, but simple graphs can require hundreds of statements.) As a result of these characteristics, we anticipated that these two systems would be very good complements to one another.

After the initial interface between these graphics systems was developed, the decision was made that the combination of map- and data-based graphs adds new dimensions to data interpretation and analysis. While the combined graphic could be

produced by simply adding a few graphs (e.g., frequency histograms and pie charts) to a map, this capability could also be used as a very sophisticated symbol generator. If the graphs are simplified (i.e., contain only very simple or no axis labelling; bold, but unpatterned symbols; and uniform size, scale, and axes ranges), then they can be made relatively small (1 cm^2). If the graphs are made small enough, then numerous (tens to hundreds) graphs can be plotted on a map as if they were symbols.

These symbols can then readily add large amounts of information and new dimensions to the data displayed. A map can display the two or three spatial dimensions of the thematic data being analyzed. The symbols from points, lines, and polygon shading can display additional categorical changes and spatial overlap of the attributes of the data in a GIS system. In addition to these features, the graphs on the map could display the following types of new details about differences between subcomponents of the thematic information:

- thematic values vs time,
- frequency distribution for sample populations,
- multivariate relationships,
- sample compositions,
- enumerated data plots or lists, and
- statistical summary tables.

C.2 APPROACH

The interface between SAS/GRAPH and ARC/INFO was developed in the following hardware and software environment:

SAS/GRAPH Hardware: IBM PC/AT, EGA monitor;
Software: PC-DOS 3.2, SAS, SAS/GRAPH 6.03.

ARC/INFO Hardware: MicroVAX 3500, Imagen 2308 laser printer, Matrix PCR film recorder;
Software: VAX/VMS 4.7a, ARC/INFO 4.01, VAX FORTRAN 4.8.

While the above specifications describe the systems used at ESD, the interface can be implemented between any hardware system(s) that can execute the current versions of SAS, SAS/GRAPH, and ARC/INFO and transfer character data.

The first step in developing the interface was to modify the specifications of the metagraphics driver provided by SAS with PROC GDEVICE (SAS 1988) to simplify the hardware capabilities assumed by the driver. The metagraphics driver can be altered to control the assumed device characteristics such as page size, resolution, number and name of colors, hardware character and symbol generation, polygon fill, hardware arc/curve generation, and hardware line types. To make the interface as universal as possible, hardware capabilities for character, symbol, line type, and curve generation were not allowed in the metagraphics device driver. The resulting output file from SAS/GRAPH then contained only instructions for pen selection, movement, and drawing. The metagraphics output file was defined to be in ASCII so that it could be transported between systems (PC to VAX) without data and record conversion problems.

After the metagraphics file from SAS is transferred to the ARC/INFO host (a VAX in this case), it is processed by a FORTRAN program that produces an ARC/INFO plot file. The program that converts the metagraphics file to ARC/INFO plot file format includes the following steps:

- unneeded SAS/GRAPH plot header information is bypassed,
- SAS page units are converted to inches,
- X and Y minimum and maximum are calculated, and
- SAS pen control commands are converted to ARC/INFO plot file syntax.

Incorporation of the graphs in ARC/INFO plot file format into a final map can be accomplished with the PLOT command in ARCPLOT. The graphs can be incorporated into a final map with or without the map composition capability of ARCPLOT. Map composition commands can be used to reposition and rescale the graphs as needed. A detailed procedure is available to document the steps required to create these enhanced products (McCord 1989).

When generating graphic symbols in SAS to be displayed by ARC/INFO, each symbol is transferred as a separate plot file. Often the plots are generated by using a SAS

BY statement with the site or plot ID value. Unique plot names which incorporate the ID can then be used to associate the symbol with map coordinates to control plotting within the ARCPLOT program. The following schematic AML program listing illustrates the cross-referencing of plot file names for graphs and the coordinates using the ID from an attribute file and calculating the BOX coordinates for the PLOT command in ARCPLOT (ESRI 1987):

```
ARCPLOT

        ... and other statements setting up map and drawing other map elements...
&S OUNIT [OPEN TEST.DAT STAT -R]
        ... TEST.DAT is a file containing ID and coordinates from PAT for plotting graphs... ... scan data file
        to determine number of record...
&DO INDEX = 1 &REPEAT %INDEX% + 1 &UNTIL %INDEX% = %COUNT%
        &S VALUE [READ %OUNIT% STAT]
                ... Read TEST.DAT to generate symbol values to be used for filename building and box
                coordinate calculation ...
        &IF [EXISTS U1:[LTS.HUSTON]THARP%ID%.PLT -FILE] &THEN
                ... Test for existence of plot file from symbolically derived name
        PLOT U1:[LTS.HUSTON]THARP%ID%.PLT BOX %XMIN% %YMIN% %XMAX% %YMAX%
                ... example of PLOT command with BOX option using generated filename and calculated BOX
                coordinates.
&END
```

If the coordinates were also stored with the attribute data in SAS, then a SAS program could be used to generate an AML program that also uses the PLOT command of ARCPLOT to position and scale the symbols. The BOX option on this PLOT command is a very useful way to control the position and size of the symbols.

C.3 EXAMPLES OF APPLICATIONS

C.3.1 Dimensions of Time

One example of the analysis incorporating the dimension of time includes a map (Fig. C-1) showing the location and water level history of monitoring wells in the White

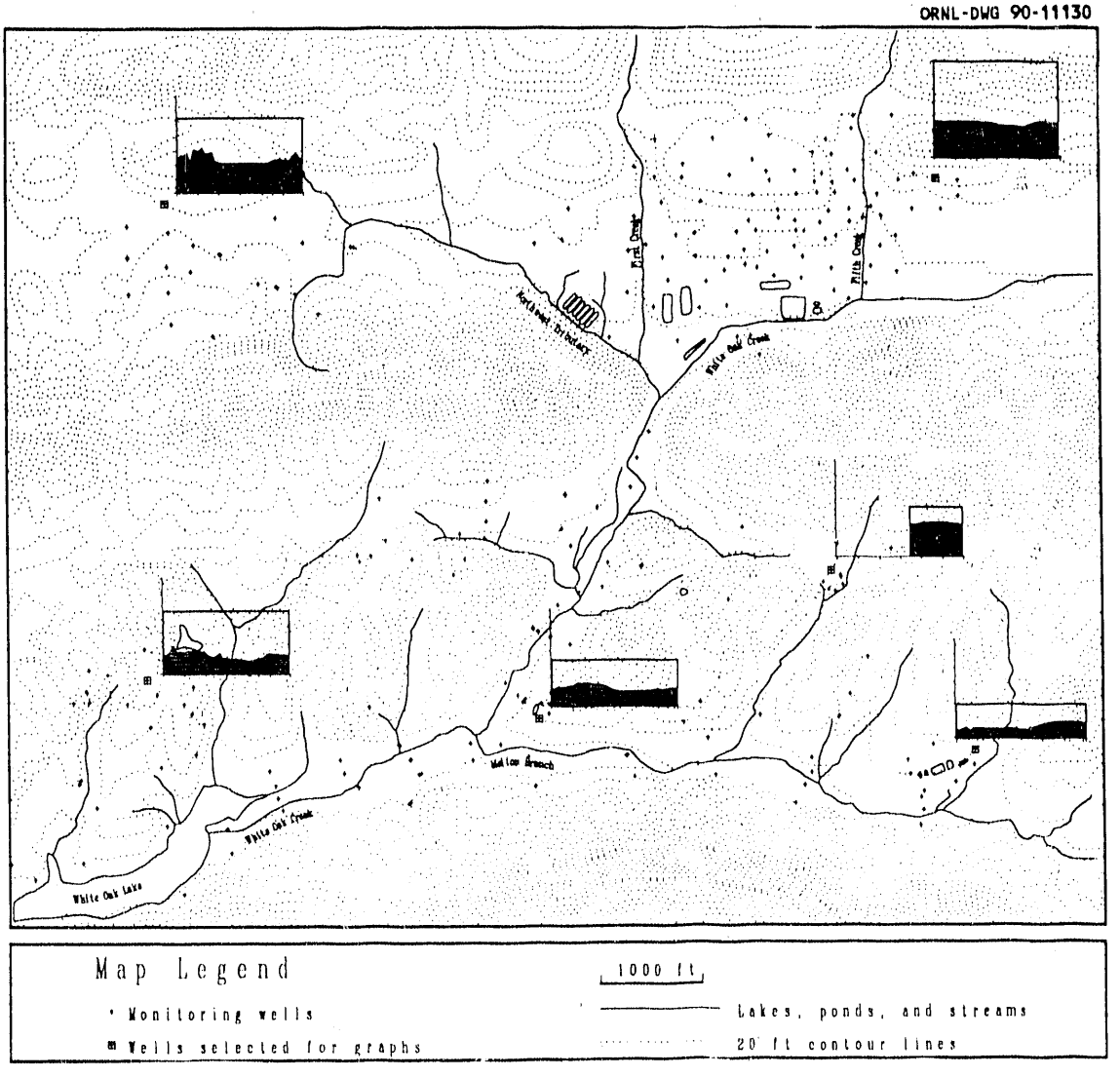

Fig. C-1. Example of plotting hydrographs for a selected subset of monitoring wells in the White Oak Creek Watershed near Oak Ridge National Laboratory. The hydrographs display data from 10/86 - 10/89. The shaded areas represent the water level and the empty area above represents the elevation to the ground surface. All of the hydrographs have the same vertical scale to illustrate the differences between the ground surface elevation and depth to the monitored water level for the wells.

Oak Creek Watershed. The line graphs of water level (Y) versus time (X) all have a uniform size and scale to show the details for the hydrographs. The dimensions of the information displayed here could be increased if more than one dependent variable was displayed on the graphs.

C.3.2 Dimensions of Composition

The map shown in Fig. C-2 displays differences in the size distribution for trees in different forest types on the Walker Branch Watershed (Dale et al. 1990). The graphs shown here are simple vertical bar charts, but other graphs reflecting sample composition or distribution could also be used. This figure is an example of one that used an AML to position and scale all of the graphs.

C.3.3 Dimensions of Interrelationships

Statistics provide the capability to determine significant differences in the relationship between two variables for several populations with analysis of covariance. Figure C-3 shows a map of the eastern United States with scatter plots containing regression lines showing the changing relationship between surface water pH and elevation for different regions studied by EPA's National Surface Water Survey (Linthurst et al. 1986). Additional dimensions describing relationships between measurements could also be displayed with three-dimensional surface displays generated in SAS/GRAPH.

C.3.4 Dimensions of Complex Symbols

Bar charts have been used as complex symbols (Fig. C-2) on a map of the Walker Branch Watershed, showing changes in the stem density for tree size classes from forest sample plots on the watershed. Other examples of graphs that can be converted to complex symbols include stacked vertical, horizontal, and three-dimensional bar charts, as well as pie charts.

C.3.5 Other Data Dimensions

Examples of other dimensions of data include the incorporation of statistical summaries, analytical results, and brief data tables on the maps. SAS/GRAPH has a GPRINT (SAS 1987) procedure that will convert any portion of text output into a

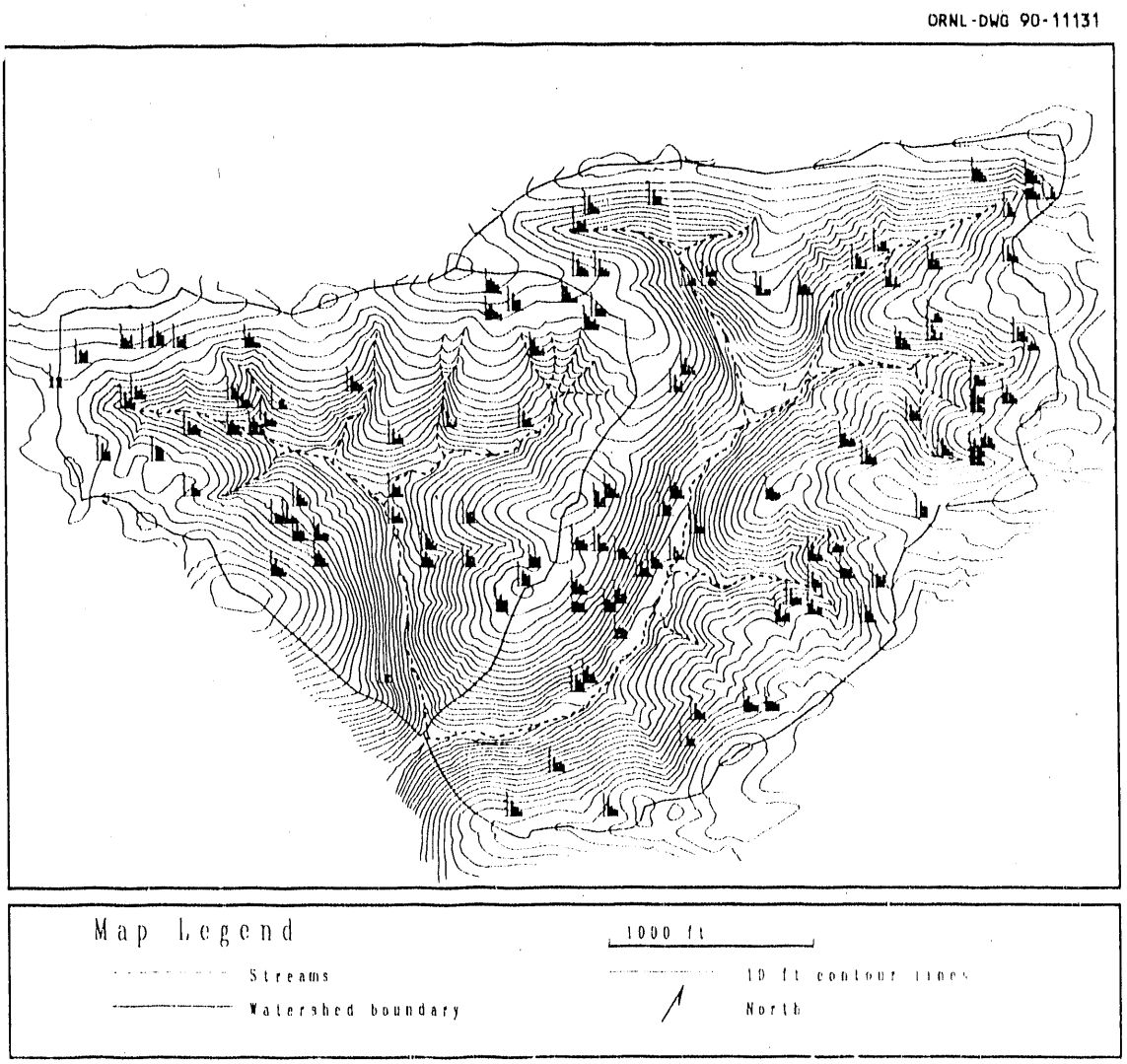

Fig. C-2. Example of plotting vertical bar charts of the log of stem density by tree size classes for forest study plots on the Walker Branch Watershed near Oak Ridge National Laboratory. The graphs are a combined example of displaying distribution and using graphs as "symbols."

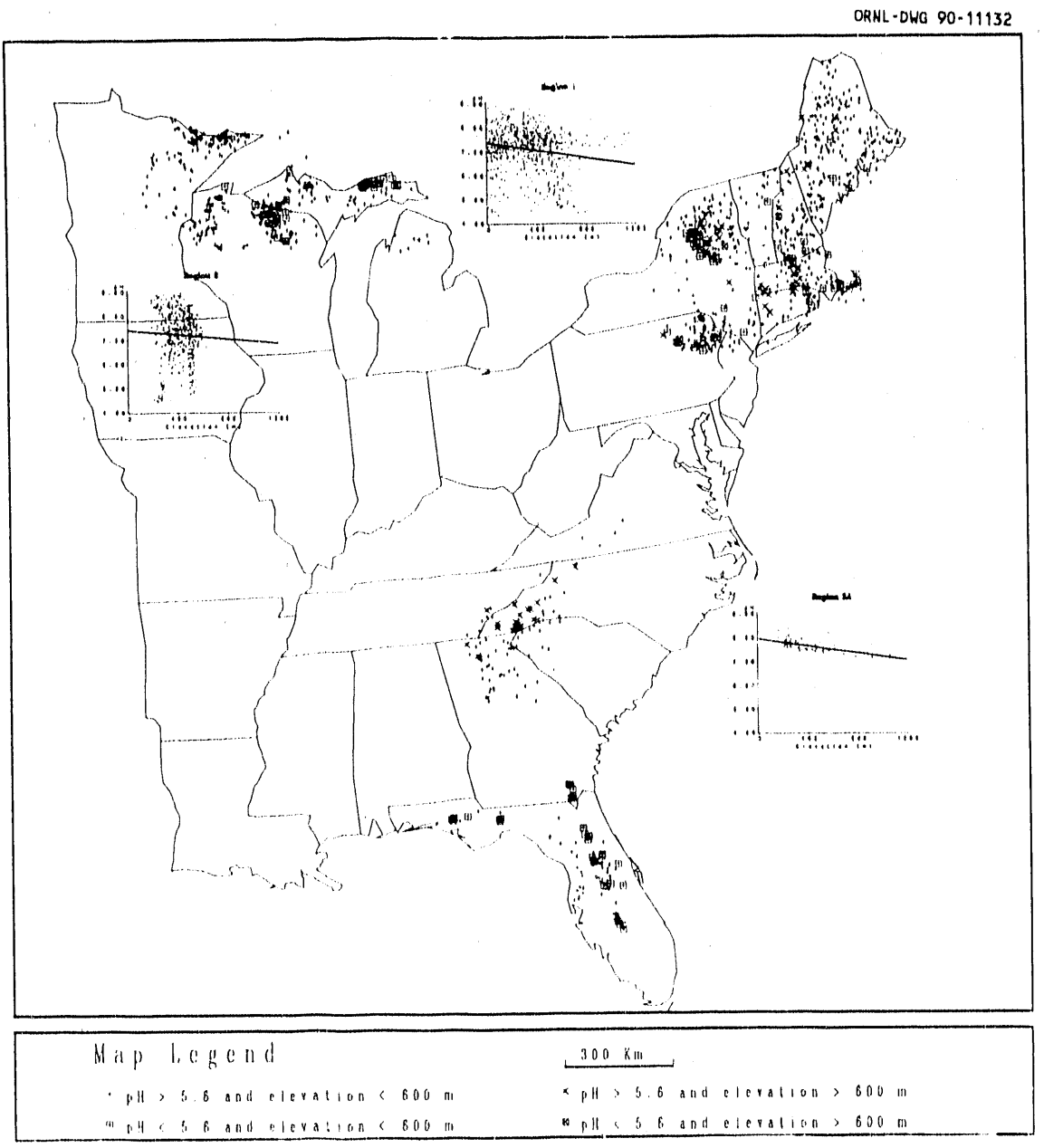

Fig. C-3. Example of scatter plots showing details of the relationship between pH and elevation by region from National Lake Survey samples. The map also shows the spatial relationship between lakes with low pH and high elevation.

graphics-based font so that it can be plotted. The conversion of portions of SAS statistical or listing outputs to graphics is a very simple procedure with PROC GPRINT. Examples of maps with this additional type of dimension have not been included here because they are best suited for poster-size maps.

C.4 SUMMARY AND CONCLUSIONS

The graphical interface between SAS/GRAPH and ARC/INFO has permitted researchers not only to add data-intensive graphs in chart form to maps but also to increase the dimensions available for display and analysis. Numerous small, simplified graphs can become a complex sort of symbol for the interpretation of changes in the details of the data. These graphs can show (1) changes in measurements over time, (2) sample composition, (3) statistical distribution, and (4) multivariate relationships. All of these details represent information beyond the spatial and categorical information displayed on the typical map produced by a GIS system. ARC/INFO and SAS/GRAPH were found to be excellent complements to each other in the production of analytical graphics.

The interface is relatively easy to use for the scientist who has an operational knowledge of SAS, SAS/GRAPH, and ARC/INFO. The major challenge in using the interface is to avoid overcrowding the final graphic product by adequately simplifying the map and the graphs to be included. Specifying the automatic page position in page units also has limitations because it presumes detailed knowledge about the location and scale of the final map product.

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