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ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1984

on

RADIOLOGICAL AND NONRADIOLOGICAL PARAMETERS

to

UNITED STATES DEPARTMENT OF ENERGY
CHICAGO OPERATIONS OFFICE

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

APPENDIX

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

FOREWARD

This report was prepared by Nuclear Service's Environmental Health Physics group. The radiological monitoring data were supplied by environmental and operational health physics staff. The nonradiological data were compiled by the environmental protection representative of the Facilities' Engineering and Operation Section. The radioanalyses of environmental air and water samples for gross radioactivity and gamma isotopic determinations were performed by Radiochemistry services, Nuclear Services Section.
Radioanalyses of air, water, grass, soil, food crop and soil samples for specific radionuclides were performed by the Eberline Instrument Corporations' Radiochemistry Laboratory, Albuquerque, New Mexico. Nonradiological analyses of environmental water samples were performed by the Columbus Water and Chemical Testing Laboratory, Columbus, Ohio.

SUMMARY

Environmental data collected during CY-1984 show continued compliance by Battelle Columbus Laboratories with all applicable state and federal regulations.

In addition to the routine monitoring of liquid and atmospheric emissions at the King Avenue and West Jefferson nuclear sites, data were collected for various environmental media including air, water, grass, fish, food crop, sediment and soil. These samples were taken from the area surrounding the West Jefferson Nuclear Site.

In general, off-site levels of radionuclides attributable to the West Jefferson nuclear operation were indistinguishable from background levels. The data are summarized as follows.

West Jefferson nuclear operations during 1984 caused no distinguishable impact on concentrations of airborne radionuclides or on external radiation doses measured adjacent to the nuclear site or at the West Jefferson site boundary. (See page 28, Table 3 and page 37, Table 12.)

Radionuclides observed in food crop, grass, creek bottom sediment, and soil samples were all attributed to either atmospheric nuclear tests or natural sources. (See pages Tables 6, 7, 8, 9, 10, and 11).

Low level concentrations of a few radionuclides released to Darby Creek from the West Jefferson nuclear site were all less than 9.2% of the respective concentration guide for an individual radionuclide released to an unrestricted area. Concentrations observed at down-stream sampling locations were statistically indistinguishable from background levels. (See page 29, Table 4 and page 43, Table 18).

The estimated radiological dose resulting from the nuclear operation at the West Jefferson site was calculated for the maximum individual, nearest residence and population groups, and the integrated fifty mile population surrounding the site. (The maximum individual is a hypothetical person situated as to receive the maximum radiation exposure possible.) These dose calculations take into account both the measurable levels of environmental contaminants and the impact of radionuclides known to have been released but not found in detectable concentrations during the years environmental sampling program. The doses are summarized as follows:

The 70-year dose commitment computations for the "maximum individual, nearest resident and population groups" and the 80-km (50 mile) population have been prepared and are included in the dose evaluation section of this report. Three modes of exposure were considered in the calculations of the 70-year dose commitment: (1) chronic inhalation of radioactive mixture using an atmospheric diffusion model; (2) chronic ingestion of a radioactive mixture through terrestrial and (3) aquatic pathways. (See pages 50, 51, 52, 53, 54, 55, Tables 25, 26, 27, 28, 29, 30).

The whole body dose commitment for the "maximum individual" during CY 1984, was calculated to be 91.01 mrem. This estimate includes the external radiation exposure in excess of that received from normal background levels as well as contributions from airborne and aquatic recreation pathways. A discussion of how the dose commitment for maximum individual was calculated is given in the text on page 23.

The maximum organ dose commitment received by the maximum individual from all pathways was 0.072 mrem/yr to the skin from Krypton-85. These doses can be compared with the standards given in DOE Order 5481.1 Chapter XI of 500 mrem/yr for the whole body and 3000 mrem/yr for the skin. (See pages 37, 38, 50, Tables 12, 13, 25).

Airborne emissions from the West Jefferson nuclear site resulted in a whole body dose commitment to the population within 80-km (50 mile) radius of the nuclear site of about 9.1×10^{-6} person-rem. Liquid effluents during 1984 contributed approximately 4.8×10^{-2} person-rem to the total population dose. This estimate may be compared with the approximate 2.08×10^{5} person rem/yr received annually from natural background radiation. (See pages 54, 55, Tables 29, 30).

The average "fence-post" exposure as measured by TLD stations during 1984, was 91.0 mrem/yr (0.010 mrem/hr) above background at a location just outside the security fence on the east side of the JN-1 Hot Cell Facility. Radiation from the Hot Cell radioactive waste handling facilities was primarily responsible for the slight increase in background radiation levels. (See page 38, Table 13.) A discussion of how the average "fence post" exposure was obtained is given in the text on page 23.

Releases of low-level concentrations of radioactivity to the Columbus municipal sewerage system from the Building 3 (U-235 Processing Facility) were less than 3.2% of the concentration guide for discharges of mixtures into sanitary sewerage systems. (See page 39, Table 14.)

Discharges of sanitary water from the West Jefferson nuclear site into Darby Creek under the National Pollution Discharge Elimination System (NPDES) permit were all within the parameter limits specified in Ohio EPA Permit No. N404-CD (See Page 30, Table 5.)

SITE AND FACILITY DESCRIPTION

The activities performed under Contract No. W-7405-ENG-92 are conducted at BCL's King Avenue Site and the West Jefferson (Nuclear Science Area) Site. A 50-mile area map showing both sites is presented in Figure 1. Figure 2 and 3 show property boundaries. Various NRC licensed activities are also conducted at both sites but are not addressed in this report. However, the effluents considered in this report are a result of both contract and license activities.

Site Descriptions

The BMI King Avenue Facility is located at 39 degrees 59'N, 83 degrees 03'W in the western central portion of the city of Columbus, Ohio. The ten-acre plot, accommodating twenty-one buildings, is bounded on the north by King Avenue, Perry Street to the east, Fifth Avenue to the south and the Olentangy River to the West. Figure 7 is an expanded view of the BMI King Avenue Facility. Building 3 houses the uranium processing activities at the King Avenue Facility.

The West Jefferson Site is located at 39 degrees 58'N, 83 degrees 15'W, approximately 15 statute miles west of the BMI King Avenue Facility. The West Jefferson Site consists of a 1,000 acre tract which accommodates the Engineering Area in the southeastern portion, the Experimental Ecology Area in the east central portion and the Nuclear Sciences Area in the northern portion. The northern boundary of the Site lies approximately one mile south of Interstate Highway 70 and extends from the Georgesville-Plain City Road eastward to the Big Darby Creek. The eastern boundary of the Site roughly parallels the valley of the Big Darby Creek southward to the Conrail tracks which constitute the southern boundary. The Georgesville-Plain City Road defines the western boundary of the Site.

The Nuclear Sciences area, the focus of interest at the West Jefferson Site, is adjacent to the Site's northern boundary. As illustrated in Figure 6 it consists of a ten-acre fenced area enclosing a guardhouse, four buildings and two other small structures on a flat bluff above Battelle Lake to the south and Big Darby Creek to the east. The eastern edge of the bluff drops rather abruptly from an average elevation of 910 feet to 870 feet msl, then more gradually to the 860 foot elevation of the Big Darby Creek Floodplain. The land to the north, west, and south, to a distance of two miles, is essentially cleared farmland, although there is one narrow wooded area along the northern portion of the fence around the Nuclear Sciences Facility, and another wooded area about 1,000 feet to the northeast. To the east, within the Big Darby Floodplain and along the bluffs to the east of the Creek, the land is heavily vegetated with deciduous trees, scrub and high grasses.

Demography

The area within a two-mile radius of the BMI King Avenue Facility to the east and south can be characterized as, high-density residential. The Ohio State University, with a student enrollment of 53,278, is adjacent to the BMI King Avenue Facility on the north. The area west of the Olentangy River consists mainly of small business and light industrial properties with scattered residential patches. Table 29 shows the population within a fifty-mile radius of the King Avenue Facility.

The area immediately adjacent to the West Jefferson Site has a low population density. Figure 12 shows the population distribution, by direction and distance, within 50 miles of BMI West Jefferson. The nearest residences to the Nuclear Sciences area are two houses located 2,500 feet to the northwest and southwest, respectively. A Girl Scout Camp, Camp Ken Jockety, is located on a bluff on the east side of the Big Darby Creek at a distance of 1,500 feet. Four thousand feet to the southeast, on the eastern side of the Big Darby Creek, the Lake Darby Estates residential subdivision (Figure 3) is under construction. A total of 965 single family units are planned. A second subdivision, West Point, planned for the area east of the Lake Darby Estates and Hubbard Road, is to have 1,835 housing units by 1985.

There are 18 industries located within the ten-mile radius. Of these, there are only four that employ more than 100 people. These are White-Westinghouse Electric Corporation, General Motors, Janitrol Aircraft, and Capital Manufacturing Company. Each of these is located at least 8 miles from the Facility. Closest to the site are three small industries within West Jefferson that individually employ less than 60 people. The primary agricultural activity in the area is raising field crops such as corn and soybeans. Approximately 10% of the land area in agricultural use is devoted to pasturing beef and dairy herds.

During the last 17 years two major highways, I-70 and I-270, have been completed near the West Jefferson Site. The junction of these highways, which occurs near the eastern edge of the ten-mile perimeter around the Nuclear Sciences Area, has proven to be a popular area for industrial growth. It is estimated that the industrial population has shown an increase equivalent to that of the general population in this area; i.e., two and one-half times the ten-mile population distribution for 1965. Most of the growth has taken place near the outer limits of Columbus; however, the larger employers, e.g., General Motors and White-Westinghouse, have actually decreased their number of employees.

Climatology

Climatology of the south-central Ohio region may be described as continental-temperate. As such, the region is subject to a wide seasonal range in temperature. Summers are quite warm with the mean temperature for the

months of June, July, and August being 73.3°F. Temperatures of 90°F or above are expected for about 15 days during these months. The mean for the months of December, January, and February is 31.2°F. The number of days per year with temperatures below 32°F and below 0°F are 122 and 4, respectively. Precipitation is distributed fairly uniformly during the year although 60% falls during the spring-summer seasons. The annual monthly average rainfall is about 3.5 inches and the greatest recorded rainfall for ary 24 hour period was 3.87 inches in July of 1947.

Changeable wind directions are characteristic of the region due to the incursion of maritime tropical air masses from the Gulf of Mexico and outbreaks of continental polar air masses from Canada. Warm air mass inversion is most common during the later spring and summer and frequently results in frontal showers and thundershowers. Tropical air mass thunderstorms are also common during the summer and are frequently accompanied by high winds. Additionally, it is not uncommon for hot air mass thunderstorm development to be sufficiently strong to spawn tornado activity. Cold fronts that invade the region, principally during the late fall, winter, and early spring also bring showers and thunderstorms.

During the late spring fast moving cold fronts, with large temperature discontinuities ahead of and behind the frontal surface, travel through the region and are often accompanied by thunderstorms and frequently by tornadic activity. Of the 567 tornadoes recorded within 144 miles of the BMI Facilities during the period 1950-1975, one hundred sixty-three have occurred in the month of April.

The regional climatological data gathered by the National Weather Service at Port Columbus, seven miles east-northeast of the King Avenue Facility, is generally representative of the local climatological conditions at the Columbus Site. A local meteorol gy station is maintained at the West Jefferson Site. The data collected by the local station are used for long-term comparison with the Port Columbus data. Table 32 summarizes the windspeed and direction at the West Jefferson Site for 1983.

Geology

The arrangement of geological strata in the BMI Facilities area consists of glacial till and outwash with formations of clay, sands, and gravel. The sands and gravel of the outwash are found in scattered, thin, discontinuous lenses within the till which is composed of unstratified clay containing fragments of rock. The unglaciated basement formations in the West Jefferson area, at depths of from about 80 to 100 feet, consist of nearly horizontal beds of limestone, dolomite and shale several hundreds of feet thick. Surface soils consist of patches and mixtures of: Brookston Silty Clay Loam, Crosby Silt Loam, Lewisburg Silt Loam, Celina Silt Loam and Miamian Silt Loam. The greatest portion of the surface soils is represented by the

Brookston-Crosby association with little more than traces representing the remaining types. All of these soil types exhibit relatively low permeability and all grade into till clay at depths of 55 to 60 inches where the impermeability of the near-surface geology nearly precludes further percolation.

There have been no recorded earthquakes within 50 miles of the area of interest, although in 1937 a strong quake was experienced at Anna, Ohio, a little over 50 miles to the northwest of the West Jefferson Site. The Columbus-West Jefferson areas are, however, considered to be in an aseismic region. The BMI facilities are in a Zone 1 risk area.

Hydrology

There are two aquifers, or sources of water, in the site area. The shallow aquifer is, of course, the dense clay till. The deep, or principal, acquifer is the limestone bedrock underlying the till. Earlier wells in the site area ranged in depth from 10 to 40 feet, which placed them in the glacial deposits. Till is not very permeable and yields water slowly. The effective velocity of water moving through clay under a hydraulic gradient of one percent is reported to be less than 0.004 foot per day; for water moving through silt, sand, and loess under the same gradient, the rate is about 0.0042 to 0.065 foot per day. Water movement in the till at the Battelle site is probably within the range of the former figure, since the hydraulic gradient of the water table in the area is only slightly greater than one percent.

The present wells at the Battelle facility lie below the surface of the bedrock. The north well is 130 feet deep, the centrally located well in the Life Sciences area is 162 feet deep, and the south well is 138 feet deep. Bedrock was encountered at approximately 103 feet below the surface in drilling these wells.

A man-made hydrologic feature of the site is the artificial lake covering an area of about 25 acres that was formed by damming Silver Ditch south of, and down gradient from, the Nuclear Sciences area. The normal surface elevation of the lake is 888 feet MSL.

The source of ground water in the site area is local precipitation. Recharge to the shallow aquifer takes place relatively uniformly over the area. Contours of the water table, which are about 40 feet below the surface, are a subdued replica of the surface topography. Ground water moves downslope at right angles to the contours and follows a path similar to surface runoff. At the Nuclear Sciences area surface runoff moves downslope into the lake, thence through the controlled dam on the site into Big Darby Creek. All ground water in the site area, and that entering on the site, is already near its place of discharge.

Test borings carried out in 1970 for an addition to the Hot Laboratory reaffirmed the geology described above. Only isolated pockets of water were encountered during that boring and foundation-piling excavation operations. These pockets were readily pumped out and remained dry, which indicated that there is no interconnection of the pockets with the lake.

Flood hydrology calculation for the lake indicated a capacity of releasing water that was about three times the inflow rate measured during the January 1959 floods. It can be concluded that the lake has not adversely affected the hydrology of the area.

Big Darby Creek accounts for the principal surface water flow. Normal flow at the Darbyville gauging station, the only continuous recording gauge on Darby Creek, 40.46 river miles south of the West Jefferson Facility, is 430 cubic feet per second (cfs).

Background Radiological Characteristics

Based on aeroradioactivity measurements of the region including the BMI facilities, it is estimated that the natural terrestial background for area surrounding BMI is 60 mrm/year.[11] This number is equal to the average natural terrestrial background for the U.S. The cosmic background for the State of Ohio is averaged to be 50 mrem/year, compared to a U.S. average of 45 mrem/year. The estimate for natural whole-body internal background is considered to be 25 mrem/year for the U.S. with only minor regional variations.[12] Based on these figures, the total natural background near the BMI facilities is estimated to be approximately 135 mrem/year, as compared with an average of 130 mrem/year for the U.S. as a whole. Table 12 gives the local external background radiation levels measured at the West Jefferson Site during 1984.

Facility Descriptions

The center of nuclear activities at the BMI King Avenue Site is the U-235 Processing Facility, located on the first floor of Building 3. It is the nuclear materials management point for all transactions involving nuclear material at the King Avenue Site. Figure 7 shows the location of Building 3 in the King Avenue Site building complex.

At the BMI West Jefferson Nuclear Sciences Area, the major operation involvled is research on the properties of irradiated materials. This work is performed in the Hot Cell Laboratory (JN-1) and involves examination and testing of irradiated reactor fuel, nuclear pressure vessel material, and fuel cladding material. The experiments serve to collect data for the development or testing of theories about material performance under irradiation conditions. Nuclear support activities are conducted in the Administrative Building (JN-2) and the retired Battelle Research Reactor (JN-3). Figure 4 shows the locations of these nuclear facilities in the Nuclear Sciences Area building complex.

The King Avenue Site

The U-235 Processing Facility is located in Building 3 of the King Avenue Site. Building 3 was constructed in the mid 50's. It served until the late 60's as an exclusion area specifically designed for the processing and storing of unirradiated enriched uranium utilized on various government and industrial R&D programs. Presently Building 3 is used for several activities, but access to the U-235 processing area is limited and entry doors to the area are alarmed. The vault is used for the temporary storage of limited quantities of unirradiated enriched uranium. The area is also used for the receiving, storing, waste processing and packaging for shipment of source materials.

The major piece of processing equipment located in the area is an electric calcine furnace which is used for the reduction of scrap or waste to an oxide residue suitable for shipping to either a waste disposal site or scrap reprocessor. The furnace consists of a closed system muffle and glove-box combination. The exhaust system for the furnace is arranged so that room temperature air is drawn into and mixed with the hot exhaust gases within a blending box. The semi-cooled exhaust gases are then drawn through a water scrubber system which is equipped with a re-circulating water system. After passing through the scrubber, the washed exhaust gases flow through a bank of absolute filters and are then exhausted to the outside atmosphere through a blower and duct opening on the roof.

The reduced residues and ash, after being burned and cooled, are dumped into plastic bags within the gove-box. This gove-box is an exhausted, closed system and therefore the system operating pressure is negative to the room pressure. This prevents any problem of contamination in the surrounding area exterior to the system.

This calcine system can be used for the reduction to oxide of limited quantities of unirradiated enriched uranium scrap. The removal of enriched uranium ash and residues from the glove-box is accomplished by dumping the material into a hopper built into the floor of the glove-box. This hopper feeds into a pipe over which a steel can is attached. The residue drops directly into this can which, when full, is remov d and a lid applied and sealed for shipment.

The area is also the central gathering and packaging spot for low-level radioactive contaminated waste. The area also served as a receipt and shipping, sampling, and measurement area for shipments of both source materials and small quantities of unirradiated uranium which are to be, or have been, utilized on programs being performed at the BMI King Avenue Site.

The West Jefferson Site

As shown in Figure 4, there are four principal buildings at the West Jefferson Nuclear Sciences area: JN-1, the Hot Laboratory; JN-2, the Administrative Building; JN-3, a retired Research Reactor; JN-4, the Hazardous Material Lab (Retired Plutonium Laboratory). Each of these facilities is described in the following paragraphs.

Hot Laboratory, JN-1

This laboratory, containing approximately 22,000 square feet of space, is considered to be one of the most completely equipped such installations available to the nuclear community. The Hot Laboratory is capable of providing research and technical assistance in the areas of:

- Power reactor fuel performance evaluations
- Pressure vessel irradiation surveillance capsule examinations and evaluations
- Postirradiation examinations of nuclear materials and components
- Radiation source encapsulation, and
- Physical and mechanical property studies of irradiated materials and structures.

The Hot Laboratory consists of a large high energy cell and connecting pool capable of handling complete power reactor fuel assemblies, five smaller cells, and supporting facilities. The smaller cells are the high-level and low-level cells, the two mechanical test cells, and a segmented alpha gamma cell. The supporting facilities include areas for cask handling, solid and liquid-waste disposal, contamination control, equipment decontamination, and other miscellaneous operations.

Administrative Building, JN-2

This building was designed and constructed for use as a critical assembly laboratory. It was used for critical experiments from 1957 through 1963. Since the cessation of critical experiments, the facility has been used for several nuclear related projects including direct conversion concepts, irradiation experiment assembly, and special nuclear materials handling. The operating license was terminated in 1970.

Offices and small laboratories are used by nuclear supporting services staff including Section Administration, Health Physics Services, Nuclear Materials Accountability, Quality Assurance, and Instrument Maintenance. These activities are the major building activities at this time. The building also currently houses the vault, used for storage of special nuclear materials, and a radiochemistry laboratory utilized for the assay of routine health physics samples and low activity irradiated materials study specimens.

Battelle Research Reactor, JN-3

The Battelle Research Reactor began operations October 29, 1956, but those operations were terminated on December 31, 1974, and dismantling initiated. The dismantling was completed without incident during 1975 and the license changed to a possession only status. Storage of waste awaiting shipment for burial is the only licensed activity conducted in JN-3 at this time.

Hazardous Material Laboratory, JN-4

Building JN-4 was built in 1960 to house activities in plutonium research and processing. These operations were terminated in 1978 and dismantling initiated. The dismantling is nearing completion and has been conducted without incident. A hazardous materials study laboratory has been approved for operation in JN-4. These activities involve non-radioactive material only.

Radiological Waste

The processing of liquid waste from nuclear operations at the West Jefferson site involves the collection of contaminated liquid in holding tanks and concentrating using an evaporator. All laboratory sink and floor drains in the nuclear facilities are connected to holding tanks. Only office area and restroom drains are connected to the sanitary drain system. Contaminated liquids are solidified and the solid waste disposed of by a licensed disposal contractor.

Therefore liquids which could potentially contain radioactive materials from these facilities are contained thus preventing the accidental release of radioactive materials to the sanitary sewer system. Highly contaminated liquids are mixed (remotely if required) with a solidifying agent and disposed of separately rather than being permitted to mix with large volumes of mildly contaminated liquids in the holdup tanks.

Liquid wastes from the King Avenue site include solutions and, possibly, waste water from the U-235 processing area. All liquid waste from the U-235 processing are solidified for disposal. Quality assurance procedures insure that no solution is discharged to the sewer systems without approval of the Radiological Safety Committee.

Solid radiological wastes from operations at the King Avenue site are collected, compacted if necessary, and packaged for shipment to a licensed disposal site. Solid waste from the West Jefferson site is from many sources. Examples of solid waste are the HEPA filters and disposal cartridge water filters, the spent ion-exchange resins, disposable clothing or other supplies consumed and contaminated in the laboratories, and gloves from the gove boxes. The transportation of solid waste to commercial disposal sites is performed in accordance with 49 CFR and 10 CFR.

Any releases of gaseous wastes to the environment are carefully controlled and dispersed to ensure that concentrations are as low as practicable within recommended standards. Radionuclides in particulate form are removed from exhaust stack effluents by the use of high-efficiency particulate air (HEPA) filters. The air effluents are filtered first at the points of operations, i.e., gloveboxes, hoods, test cells, and finally at the stack release point by one or two banks of HEPA filters in series. Radioactive gases present in fuel pins under examination at the Hot Cell Facility are drawn off for subsequent disposal with solid wastes. The residual gases trapped in the fuel matrix or otherwise released is monitored continuously by effluent monitors.

Constant air monitors are located throughout the laboratory. They monitor the environmental air for alpha-, beta-, and gamma-emitting particulate matter. These air monitors, upon detection of radiation exceeding a preset level, will activate the alarm bell.

The hot laboratory has two separate exhaust stack systems. One for JN-1A; one for JN-1B. There are two significant differences in the two systems. First, the JN-1A system consists of five individual stacks; the JN-1B system uses only one large stack. The other difference in the two systems is that the JN-1B system contains a large I-131 charcoal trap.

For the JN-1A stacks a single AM-2 constant air monitor is used. This instrument has three channels; one monitors for alpha particulate, one for beta-gamma particulate, and one for gaseous effluent. Any of the three channels will activate the alarm and shut off the exhaust fan for the high level, low level, and alpha-gamma (basement) cells.

For the JN-1B stack there are four separate CAMs, alpha particulate, beta-gamma particulate, gaseous effluent and Iodine-131. Any of the four instruments will activate the alarm, shut down all exhaust fans for the HEC and close the butterfly valves so no more air can be drawn from the cell. In the event that the I-131 monitor activates the alarm, two additional operations take place; an exhaust fan is started and a diversion damper opens causing any exhaust air to flow through the charcoal trap.

Although the two stack monitoring and control systems operate independently, they function on a similar basis. The alarm set point of each instrument is set at a level based upon regulatory values of RCG in DOE Order 5480.1 for various radiation species in uncontrolled areas. Alpha particulate monitors are set on the basis of the RCG for Pu-239, beta-gamma particulate monitors, on the basis of the RCG for Sr-90. Effluent monitors are set on the basis of the RCG for Kr-85m and the I-131 monitor is set on the basis for that isotope.

For each monitor, if the concentration in the stacks equals or exceeds the applicable RCG level then an alarm and corresponding action is taken. Under this procedure the activity in uncontrolled areas will remain less than the values in DOE Order 5480.1.

Ventilation in the JN-2 storage vault and the radiochemistry laboratory is provided by separate exhaust fans that are designed and operated in a manner to maintain a negative pressure atmosphere and to provide adequate air exchange in the radiochemistry laboratory. The air exhausts for the storage vault and the radiochemistry laboratory are made up of 9-inch diameter ducts that empty into large volume plenums to which two 24" x 12" absolute filters are sealed. The exhaust stack for the storate vault is equipped with alarmed continuous alpha monitoring to detect the release of any radioactive matter.

ENVIRONMENTAL MONITORING

The impact of operations on the health and safety of the public is evaluated routinely by an environmental monitoring program which has been in existence since 1955. The basic objective of the environmental monitoring program is to evaluate the effectiveness of the waste management program in maintaining the concentrations of radioactive and non-radioactive wastes so that effluent levels are maintained as low as reasonably achievable and well within applicable standards. All effluents involving polluting materials are contained within the operating facilities to the extent possible and are disposed of as packaged wastes by authorized services.

West Jefferson Site

Air Radioactive

In-stack air samplers continuously monitor the exhaust stack effluent release from each facility to assess the effectiveness of systems controlling airborne emissions. Eight continuous stack monitors ensure detection of any inadvertent release of radioactive materials and provide

data for the prompt assessment of the environmental impact, if any, (See Figure 4). Particulate samples of the effluent are collected from each exhaust stack. The particulate samples are collected on two types of filter paper, GVB-60 and Type E glass fiber. The air is sampled at an average rate of 2.8 x 10^4 cm^3/min. The filters are changed weekly, which represents average sample volume of 285.5 m^3.

Analyses are performed on a weekly basis for gross alpha and gross beta for stacks 001 through 004, 006, 012, 013, and 014. The results reported represent total average annual concentrations at the stack and also at the site boundary as calculated from stack sample data. The site boundary concentrations, reported in Tables 1 and 2, for the various exhaust stack locations were calculated by multiplying the individual stack concentration by the atmospheric dispersion parameter computed for the site boundary.

The site boundary atmospheric dispersion parameter was obtained using the atmospheric dispersion model incorporated in computer code Dacrin, (see reference 9, page 24).

The cumulative average concentration of the alpha and beta mixture, emitted from stacks 001 through 004, 012, 006, 013, and 014 was less than 0.01% of the RCG value at the site boundary. The results are summarized in Table 2.

Based on routine monthly gamma ray analyses of in-line system charcoal gas sampling cartridges installed in stacks 001 and 002 the cumulative average, concentration of iodine-131 was less than 3 x 10^{-9}% of the RCG value at the site boundary. The air is monitored at a rate of 1.3 x 10^5 cm^3/min. This represents a weekly average sample volume of 1.3 x $10^3 m^3$.

The cumulative average concentration of krypton-85 released from stacks 001, 002 and 013 was less than 0.0004% of the RCG value at the site boundary. The concentrations were calculated by using strip chart recorder data from the gaseous monitors on exhaust stacks 001, 002 and 013. The results are summarized in Table 2. (There is a discussion of RCG's in the appendix of this report.)

Identification of radionuclides in the JN-1 stack particulate emissions from stacks 001 through 004, 013, and 014 was made by monthly gamma spectrometric analyses and specific radiochemistry analyses of weekly stack air sample filters composited over a 4-week period. Gamma

spectrometric analyses were performed using an intrinsic germanium detector coupled to a Canberra Model 8180 multi-channel analyzer. The concentrations of the radionuclides identified were all less than 3.1 x 10^{-6}% of the applicable RCG values at the site boundary, (see Table 3).

Supplementary air sampling was performed at four site boundary locations during 1984 (see Figure 6). These air samples were collected continuously and analyzed on a weekly basis for gross alpha and beta activities. The average concentrations of activity at each of the site boundary locations were all lower than the average gross alpha and beta activities found at 6 off-site background air sampling locations surveyed weekly at distances varying 5 to 44 miles from the Nuclear Sciences Area, (see page 40, Table 15). Quarterly composite air samples from the four site boundary locations were analyzed for ^{238}Pu, ^{239}Pu, ^{90}Sr and ^{137}Cs. The concentrations were all less than 9.0 x 10^{-7}% of the respective RCG values, (see Table 16).

Water Radioactive

A sanitary sewerage system, which is operated in accordance with State of Ohio regulations under NPDES permit No. N404-CD, handles all sanitary sewerage generated on the West Jefferson Site. The liquids are first treated in a 2,500-gallon septic tank and then released to a 2,160-sq-foot contained sand and gravel filter bed. From the filter bed the effluent goes to a chlorinating system prior to release to Big Darby Creek.

Sampling of all liquid effluents, from the Nuclear Sciences Area to Big Darby Creek, is performed using a continuous water sampling system. The effluents consist of the liquid discharge from the 2,160-ft^2 filter bed, (see Figure 4). The effluent samples are analyzed weekly for gross alpha and beta activity in suspended and dissolved fractions. Any sample exceeding 3 x 10^{-8} μCi/ml* receives a supplementary gamma isotopic (GeLi) analysis and/or an alpha spectrometric analysis as appropriate.

The weekly samples are held, composited, and receive gamma spectrometric analyses as well as specific analyses for plutonium-239, plutonium-238, iodine-129, strontium-90, radium-226, and radium-228 at the end of each month. The concentrations of gross alpha and gross beta activity in suspended and dissolved fractions as well as the concentrations of specific radionuclides identified in the sample are summarized in Table 4. In most cases the activity in the samples is due to a mixture of nuclides. The average concentration of the mixture was 9.13% of the RCG. The average concentrations of identified radionuclides in the mixture were 9.17% of the RCG for iodine-129, 0.001% of the RCG for plutonium-238, 0.0006% for plutonium-239, 0.53% of the RCG for strontium-90, 0.017% of the RCG for cesium-1, 0.77% of the RCG for radium-226, 1.43% of the RCG for the radium-228 0.023% for lead-212, 0.008% for actinium-228 and 0.016% for uranium-235.

Weekly tap water samples are collected at the Nuclear Sciences Area to verify compliance with applicable water quality standards for radioactivity in drinking water. The weekly tap water samples are composited and analyzed monthly for gross alpha and beta activity in suspended and dissolved fractions. Any sample exceeding 3 x $10^{-8}$$\mu$Ci/ml* receives a supplementary gamma isotopic (GeLi) analysis and/or an alpha spectrometric analysis as appropriate. A 200 ft. deep well provides the tap water supply for the Nuclear Sciences Area. The average concentrations of gross alpha and gross beta activities in the dissolved and suspended fractions for 1984 were 25% of the RCG for unidentified radionuclides in an uncontrolled area.

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* RCG value for unidentified radionuclides in unknown concentrations released to an uncontrolled area, DOE Order 5480.1, Chapter XI, Attachment XI-1.[5]

Supplementary water samples are collected weekly 20 yards above and 20 yards below the sanitary drain outfall at Darby Creek. Weekly water samples are also collected below the Battelle Lake dam and at the drain spillway at Darby Creek, (see Figure 6). The supplementary water samples are analyzed weekly for mixed alpha and beta activity. The average concentrations of total activity in the down stream water samples and the below dam water samples were all less than 33% of the RCG (3×10^{-8} μCi/ml) for release of mixed alpha and beta activity to uncontrolled areas and showed no significant difference from the upstream control sample, (see Table 18).

Water Nonradioactive

Presently, liquid effluents discharged from the West Jefferson Facility are subject to the restrictions of our National Pollutant Discharge Elimination System (NPDES) Permit. Battelle monitors and reports on a monthly basis to the Ohio Environmental Protection Agency (OEPA). Table 5 includes a list of the parameters for which BCL is presently required to analyze and report.

The data listed in Table 5 represents an average of the monthly data collected during the twelve month period commencing January 1, 1984, and ending December 31, 1984, and are required under the limits or restrictions set forth in BCL's NPDES Permit. The table serves to illustrate actual performance against those limits or restrictions defined in BCL's permit.

The data provided for the North Sanitary Sewer were obtained in accordance with the BCL NPDES Permit No. N404-CD, application number OH0005461 issued by the OEPA. The conditions of BCL's NPDES Permit were determined by the Ohio EPA following an extensive study of the Scioto River Basin, of which Battelle's West Jefferson Site is a part. As the discharges are within the allowable discharge limits, the data reflect the effectiveness of BCL's waste water management.

Grass and Food Crops Radioactive

Grass and food crop samples are collected from the surrounding area. The intent of this portion of the Environmental Monitoring Program is to determine whether there is uptake and concentration of radionuclides by plant or animal life. Where possible, sampling sites are chosen at maximum deposition locations predicted by meterological studies. Grass and food crop (soybean or field corn) samples are collected at varying distances and directions within a 5-mile radius of the Nuclear Sciences Area as shown in Figure 5. Sampling locations falling into the same directional quadrant of the nuclear site are composited. The samples are analyzed for plutonium-239, plutonium-238, and strontium-90. A qualitative analysis by gamma scan (GeLi) is also performed. The results of the grass and food crop analyses are summarized in Table 6 and 7. The maxiumum concentration of strontium-90 detected in grass samples was

0.11 ± 0.2 pCi/g located in the North Quadrant. The average concentration of strontium-90 in field corn samples was 0.01 ± 0.01 pCi/g and <0.01 pCi/g for cesium-137. Plutonium-238 and plutonium-239 average concentrations were 0.00 ± 0.01 pCi/g for all samples taken of grass and food crops.

Sediment Radioactive

Silt samples are collected semiannually at two locations; i.e., Darby Creek 20 yards above and 20 yards below the point of sanitary effluent release to Darby Creek, (See Figure 4). The purpose of collecting silt samples is to estimate the inventory of certain radionuclides deposited in this waterway and document for future reference. The silt samples are collected to a depth of 2.5 cm using a 10 cm soil plugging tool fitted with a gate valve. Prior to analysis, the samples are air dried and then blended in a pulverizing mill. The silt samples are analyzed for plutonium-239, plutonium-238, and strontium-90. A quantitative gamma isotopic (GeLi) analysis is also performed. The results of the analyses are summarized in Table 8. Concentrations of strontium-90 in silt samples collected above the effluent release point averaged 0.07 ± 0.01 pCi/g and 0.08 ± 0.02 pCi/g below; for plutonium 238, 0.02 ± 0.02 pCi/g, and for plutonium-239, 0.02 ± 0.02 pCi/g and 0.03 ± 0.03 pCi/g, respectively. Cesium-137 averaged 0.6 ± 0.1 pCi/g above and below the release point.

Soil Radioactive

Soil samples are collected annually from fourteen locations at varying distances and directions within a 5-mile radius of the Nuclear Sciences Area. Locations falling into the same directional quadrant from the nuclear site are composited, (see Figure 5). The soil samples are collected to a depth of 2.5 cm using a 10 cm soil plugging tool. Each soil sample consists of a composite of five "plugs" of soil collected at random from an area of approximately 100 m^2. Prior to analysis, the composite samples are air dried and then blended in a pulverizing mill. The soil samples are analyzed for plutonium-238, plutonium-239, and strontium-90. A qualitative analysis by gamma scan (GeLi) is also performed. The results of the analyses are summarized in Table 9. The concentration of strontium-90 in soil samples averaged 0.4 ± 0.1 pCi/g. The average concentration of plutonium-239 was 0.01 ± 0.01 pCi/g and the plutonium-238 average concentration was 0.01 ± 0.02 pCi/g for all soil samples collected. Gamma isotopic analyses of the soil samples showed the average concentration of cesium-137 to be 0.3 ± 0.1 pCi/g.

Fish Radioactive

Fish samples were collected from Darby Creek and Battelle Lake over a nine month period and composited for analyses on a quarterly basis. The fish samples were analyzed for plutonium-238, plutonium-239, and strontium-90. A quantitative gamma isotopic (GeLi) analyses was also performed. The results of the analyses are summarized in Table 11. Average concentrations

of plutonium-239 in fish samples taken from Darby Creek were 0.00 ± 0.01 pCi/g and 0.00 ± 0.01 pCi/g for plutonium-238. The average concentration of strontium-90 in fish samples taken from Darby Creek was 0.04 ± 0.01 pCi/g, and <0.1 pCi/g for cesium-137. Fish taken from Battelle Lake had average concentrations of plutonium-239 and plutonium-238 of 0.00 ± 0.01 pCi/g and 0.00 ± 0.01 pCi/g, respectively. Average concentrations of strontium-90 and cesium-137 in fish samples taken from Battelle Lake were 0.13 ± 0.01 pCi/g and <0.1 pCi/g, respectively.

Background Radiation Levels

The external radiation background levels at the West Jefferson site are continuously monitored at 40 dosimetry stations using commercially available environmental TLD packets, (see Figure 8 and 9). All TLD packets are changed and evaluated each calendar quarter. The annual average dose rate at the site boundary based on 25 parameter dosimeter stations was 0.091 rem or 18% of the 0.5 rem limit established for the general public. This value does not include contributions from natural background radiation which is estimated to be approximately 0.120 rem/yr. The results are summarized in Table 12 and 13.

KING AVENUE SITE

Water Radioactive

Sampling of all liquid discharges from the Building 3 (U-235 Processing Facility) sump to the Columbus municipal sewerage system is performed on a monthly basis, (see Figure 7). This discharge consists of the liquid wastes from the building laboratory drain systems. The building sump samples are routinely analyzed for gross alpha and gross beta activities. Any sample exceeding 4×10^{-7} µCi/ml* receives a gamma isotopic (GeLi) analysis and/or an alpha spectrometric analysis as necessary.

Sample analyses are performed monthly on the Building 3 sump samples. The concentrations of gross alpha and gross beta activity are summarized in Table 14. The average concentration of the mixture was less than 3.1% of the RCG for release to a public sanitary sewerage system. For averaging purposes, samples below the minimum detection limit are assumed to be the value of the limit.

Total releases of radioactivity during CY 1984 from the West Jefferson and King Avenue sites are summarized in Table 18.

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*RCG value for unidentified radionuclides in unknown concentrations released to a public sanitary sewerage system, DOE Order 5480.1, Chapter XI.

EVALUATION OF DOSE TO THE PUBLIC

Estimated Radiation Doses to the Public from Emissions from the Battelle West Jefferson Site During CY 1984

The BCL Environmental Monitoring Report for CY 1984 presents data which provide information for determining those sources of environmental radiation resulting from past or current nuclear activities and those due to atmospheric nuclear tests or natural radioactivity. Contributions from BCL's nuclear operations were undistinguishable from other sources with only two exceptions. These include minimal airborne releases of mixed fission products from Hot Laboratory activities and very low concentrations of mixed fission products in liquid effluents at the West Jefferson Nuclear Sciences Area. The radiological impact of BCL's nuclear activities is calculated from the quantity of radionuclides measured directly in effluents from operating facilities in 1984 from the annual deposition of airborne radionuclides on vegetation and food crops, and from residual radionuclides in stream sediment from past operations.

Atmospheric Discharges

Measured releases and ground level annual average concentrations at the site boundary during 1984 for the West Jefferson Site are summarized in Table 2. The site boundary, which determines the perimeter for uncontrolled exposure, is considered coincident with the downwind position from the facility where the annual ground level concentrations will be highest. This point is on BCL property but outside the security fence. The gross beta data in Table 2 shows that the total mixed fission product releases for 1984 amounted to 4.65 μCi with a total average concentration at the site boundary of 1.46×10^{-18} μCi/ml. Based on isotopic analyses of the stack effluents from the JN-1 facility, the principal radionuclides were determined to be cobalt-60, plutonium-239, cesium-137, lead-212, cerium-144, strontium-90, antimony-125, actinium-228, and uranium-235. The total krypton-83 emission was 2.03 Ci with a corresponding average concentration at the site boundary of 1.04×10^{-12} μCi/ml. The total plutonium-239 emissions were 0.44 μCi. Review of JN-1 facility operation for 1984 indicates that most of the gross alpha reported was due to plutonium-239. Therefore, all the alpha emissions are considered to be plutonium-239 only, with an annual average concentration at the site boundary of 1.38×10^{-19} μCi/ml. The total isotopic composition of the effluents emitted from the five stacks of the JN-1 facility was used in evaluating the off site dose to the public.

Liquid Discharges

Measured aqueous releases and effluent concentrations during 1984 for the West Jefferson Site are summarized in Table 4. The concentration values apply to the water discharged into Big Darby Creek after passage through a conventional leaching bed. Based on knowledge gained from an isotopic

inventory of radionuclide concentrations in the leaching bed, emissions should be due to very limited elution from the leach bed of contaminants that were delivered to the bed in past years. Therefore, the alpha activity is considered to be primarily uranium-238 and the gross beta activity should contain only relatively long-lived radionuclides.

Estimated Radiation Dose to the Public from Atmospheric Discharges

Calculation of Atmospheric Dispersion Parameters

In all cases on-site meteorological data were used as input to compute the annual average dispersion parameters for the site. Computer Code DACRIN programed for localized applications, was used to generate the required X/Q data for calculating dose to the maximum individual, nearest residence and population groups. Thus, annual average X/Q values were developed for a series of concentric rings extending from the site boundary out to a distance of 50 miles. (Refer to Figure 12.) The annular rings were broken down into sixteen sectors corresponding to the normal wind rose pattern. (Refer to Figure 11.)

Computation of Maximum Individual Nearest Residence and Population Group Doses

The annual radiation dose from gaseous and particulate radionuclides discharged into the atmosphere was computed for a person continuously immersed in an infinite hemispherical cloud containing the radionuclides. Tables 2 and 3 list stack concentrations used to estimate site boundary, nearest residence and population group concentrations from the X/Q data noted in the above paragraph. The radionuclide composition and concentration of the atmospheric emissions was used to compute critical organ doses assuming the more sensitive biological form (soluble or insoluble) was present. Doses arising from the alpha activity emissions were based on plutonium-239, liberated entirely as the insoluble oxide form. The annual dose estimates obtained for the maximum individual, nearest resident, and for population groups from both gaseous and particulate emissions are summarized in Tables 20, 21, 22, 23, and 24.

The estimated off-site doses listed in the tables are very low compared to the maximum permissible exposures (MPE) which have been recommended by the ICRP[4] and other groups for the general public. The MPE values recommended for an individual are: bone - 3 rem/yr, GI tract - 1.5 rem/yr, whole body - 0.5 rem/yr, skin - 3 rem/yr, thyroid - 3 rem/yr, lung - 1.5 rem/yr, and kidney - 1.5 rem/yr. The recommended values for a population group are one-third of these values. Therefore, from Table 20 it may be seen that the largest fraction of MPE occurs to the skin and is 0.003% of the recommended limits at the site boundary. In comparison, exposure of persons to natural background radiation in the area would be approximately 120 mrem/yr as measured by TLD stations. Atmospheric emissions from the site (Table 19) led to maximum estimated whole body radiation doses which are approximately 0.01% of that expected from natural background.

Computation of the 70-Year Dose Commitment for Maximum Individual, Nearest Resident, Population Groups and Integrated 50-Mile Population

The 70-year dose commitments were determined by using computer Code DACRIN based on annual meteorlogical data (Table 30), the 1980 estimated geographic distribution of the population in the various sectors around the site out to a 50-mile radius (Figure 12) and the radionuclide release data given in Table 19. Summaries of the 70-year dose commitment groups are given in Tables 23, 24, 25, 26, and 28. The values given in Table 28 may be compared against the integrated person-rem dose that would be expected for the population group due to natural background. Since the level of natural background radiation would be essentially constant over the whole area, the corresponding person-rem value is simply the product of the total population and the natural background radiation value. Using a natural background of approximately 0.120 rem/yr and a total 50-mile population figure of 1.73×10^6 produces an integrated population dose from natural background of 2.08×10^5 person-rem/yr. The total body dose commitment caused by emissions from Battelle's West Jefferson Site to the integrated 50 mile population, is less than 9.2×10^{-9}% of that due to natural background radiation.

Estimated Radiation Dose to the Public from Liquid Discharges

Radiation Dose from Swimming (External Whole Body)

It is not known if any of the area below the outfall on Big Darby Creek is used for swimming purposes; however, such use could be possible.

Swimmers are assumed to receive an external radiation dose from being submerged in water containing radionuclides which are anticipated to be present in the liquid effluent. The measured emissions at the outfall were summarized in Table 4. Only the beta releases were used in calculating the external radiation dose to potential swimmers, since the less penetrating alpha emissions do not make a singificant contribution to the total body dose. Using computer Code PABLM the estimated dose to the swimmer who might spend 8 hours in the water each week from June to September 30 were obtained. Results are given for the maximum individual, nearest resident, population groups and the integrated 50-mile population in Tables 21, 22, 23, 24, and 29.

Radiation Dose Due to Boating and Water Skiing

Big Darby Creek is too small to allow boating or other water recreation sports. Thus, there will be no dose from these activities.

Radiation Dose from Drinking Water

Water from Big Darby Creek below the outfall is not used for drinking prior to its confluence with the Scioto River according to the U.S. Geological Survey; therefore, there will be negligible dose contribution from this source.

Annual Radiation Dose from Eating Fish

There may be limited fishing in Battelle Lake and along Big Darby creek but no estimate of the extent of this activity is available. Radiation dose to man can occur from eating fish which have resided in water which contains radionuclides from the liquid effluent. The concentration of an individual radionuclide in the fish (μCi/g dry wt.) is assumed to be directly related to the concentration of the radionuclide in the water in which the fish reside multiplied by a bioaccumulation factor.[8] Computer Code PABLM was used to estimate doses from eating fish taken from Battelle Lake and Big Darby Creek to the maximum individual, nearest resident, population groups and the integrated 50-mile population. See Tables 21, 22, 23, 24 and 29. Internal radiation doses were estimated on the basis of analytical data given in Table 4 for water samples taken from liquid effluents discharged to Darby Creek.

Comparison of the data in Table 21 for the maximum individual, show that fish consumption is expected to be the dominant exposure pathway for persons from liquid emissions at the Battelle West Jefferson Site. However, individuals in this area would routinely be exposed to natural background radiation at levels of about 120 mrem/yr. Therefore, maximum doses resulting from liquid emissions from the site should have been approximately 3×10^{-5}% of that produced by natural background.

70-Year Dose Commitment

Tables 25, 26, 27, 28, 29 and 30 of this report provide estimated 70-year dose commitments to the maximum individual, nearest resident, population groups and the 80-kilometer population from one-year of exposure. Also given for terrestrial pathway exposures, is the estimated 70-year accumulated dose to the maximum individual (and the 80-kilometer population from 70-years of continuous exposure to the residual environmental contamination left by the one-year release. The radionuclide composition of effluents reported for 1984 is shown in Table 19. Since these quantities of radionuclides, when dispersed in large volumes of air and water, were generally undetectable in the off-site environment, dose models (References 9 and 10) were employed to assess the resulting radiological dose impact. Code DACRIN was used to estimate doses from chronic inhalation of a radioactive mixture using an atmospheric diffusion model. Code PABLM was used to estimate doses from the chronic ingestion of a radioactive mixture through terrestrial and aquatic pathways.

Fence Post Dose Estimate

The "fence post" dose is the maximum measured accumulative dose possible to an individual having access to an uncontrolled area, excluding ingestion and inhalation pathways. An estimated "fence post" dose of 91 mrem for 1984 was obtained by subtracting the average TLD background reading of 120 mrem (Table 12, Page 37) from the averaged annual TLD reading of 211 mrem taken from Table 13, Page 38.

Maximum Individual Dose Estimate

The total body dose commitment calculated for the "maximum individual" is estimated as 91.01 mrem for 1984 and is the summation of the following: (1) 91 mrem, representing the "fence post" dose discussed in the previous paragraph; (2) 5.25×10^{-5} mrem, representing the 70 year dose commitment due to the atmospheric inhalation pathway (Table 25, Page 50); (3) 3.10×10^{-9} mrem, representing the 70 year dose commitment due to the atmospheric ingestion pathway (Table 25, Page 50); (4) 3.20×10^{-4} mrem, representing the 70 year dose commitment from eating fish (Table 25, Page 50); (5) 2.10×10^{-10} mrem, representing the 70 year dose commitment resulting from aquatic reaction (Table 25, Page 50) and (6) 1.20×10^{-2} mrem, representing the annual whole body dose from Krypton-85 (Table 20, Page 45).

Nearest Resident and Population Group Dose Estimates

Although radiation dose estimates were calculated for a hypothetical "maximum individual", the probability of this dose occurring is extremely remote. To obtain more realistic dose estimates, computations of "real" doses to the nearest resident and nearest population groups were made and included in the EMR for CY 1984. See Tables 20, 22, 23, 24, 26, 27, and 28.

REFERENCES

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(2) Operational and Environmental Safety Division, Environmental Protection, Safety, and Health Protection Reporting Requirements, DOE Order 5484.1 U.S. Department of Energy, Washington, D.C., February 1981.

(3) Scioto River Basin Waste Load Allocation Report for the 303 (e) Continuing Planning Process for Water Quality Management.

(4) ICRP Publication 2, "Recommendations of the International Commission on Radiological Protection, Report of Committee II on Permissible Dose for Internal Radiation." Pergamon Press, 1959.

(5) Operational and Environmental Safety Division, Environmental Protection, Safety, and Health Protection Programs for DOE Operations, DOE Order 5480.1, U.S. Department of Energy, Washington, D.C., May 1980.

(6) U.S. NRC Regulatory Guide 1.109, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for Purpose of Evaluating Compliance With 10 CFR Part 50, Appendix 1."

(7) DOE/EP-0023, A Guide for Environmental Radiological Surveillance at USDOE installations, Revised July 1981.

(8) J. R. Houston, D. L. Strenge and E. C. Watson, DACRIN - A Computer Code for Calculating Organ Dose From Acute or Chronic Radionuclide Inhalation, BNWL-B-389, PNL, Richland WA, 99352, August 1975.

(9) B. A. Napier, W. E. Kennedy, Jr., and J. K. Soldat, PABLM - A Computer Program to Calculate Accumulated Radiation Doses from Radionuclides in the Environment, PNL-3209, PNL, Richland, WA, 99352, March 1980.

(10) Civil Effects Operations (LEX 59.4.23) Aeroradioactivity Surveys and A Real Geology of Parts of Ohio and Indiana (ARMS-1) May 1966.

(11) "Estimates of Ionising Radiation Doses in the United States 1960-2000", U.S. Environment Protection Agency, ORP/CSD 72-1.

Quality Assurance

Several methods are used to assure that the data collected each year are representative of actual concentrations in the environment. Extensive environmental data are collected to eliminate an unrealistic reliance on only a few results. Newly collected data are compared with historical data for each environmental medium to assure that current values are consistent with previous results. This allows for timely investigation of any unusual results. Samples are collected using identical methods near to and far from the nuclear site, as well as upstream and downstream on Darby Creek, to provide for identification of any net differences that may be attributable to the West Jefferson nuclear operations. These procedures, in conjunction with a program to demonstrate the accuracy of radiochemical analyses, assure that the data accurately represent environmental conditions.

The majority of the routine radioanalyses for the BCL environmental surveillance program are performed at the radiochemistry facility located at the West Jefferson nuclear site. Environmental samples requiring specific isotopic analysis are sent to Eberline Instrument Corporation's Albuquerque Laboratory, Albuquerque, New Mexico. Both laboratories maintain internal quality assurance programs that involve routine calibration of counting instruments, daily source and background counts, routine yield determinations of radiochemical procedures, and replicate analyses to check precision. The accuracy of radionuclide determination is assured through the use of standards traceable to the National Bureau of Standards, when available.

Assurance of the dose calculation quality is provided in the following ways. Since doses are similar from year to year, a comparison is made against past calculated doses and any differences are validated. All computed doses are double checked by the originator and by an independent third party who also checks all input data and assumptions used in calculation. Information necessary to perform all of the calculations are fully documented.

BCL also participates in the DOE sponsored Quality Assessment Program which is administrated by the Environmental Measurements Laboratory (EML) and requires the qualitative analyses of spiked air, water, soil, vegetation and tissue samples furnished by DOE/EML semiannually. The spiked media samples are analyzed by the radiochemistry facilities serving BCL and the results reported to DOE/EML for verification of accuracy.

TABLE 1. POPULATION DISTRIBUTION WITHIN
10 MILE RADIUS FROM SITE

Distance Radius	Population
1,500 feet	0
2,500 feet	4
1 mile	700
2 miles	3,500
5 miles	10,700
10 miles	116,330

TABLE 2. SUMMARY OF ATMOSPHERIC RADIOACTIVE EMISSIONS - WEST JEFFERSON SITE
CY 1984

Species	Stack Locations	Number of Stack Samples	Stack Volume 10^{10} liters/yr	Activity μCi/yr	MDL 10^{-14} μCi/ml	Range 10^{-14} μCi/ml	Stack 10^{-14} μCi/ml	Site Boundary(a) 10^{-19} μCi/ml	10^{-3} Percentage of RCG at Site Boundary(a)
Gross α	001	52	3.17	0.07	0.007	<MDL-3.78	0.21 ± 0.01	1.71 ± 0.08	10.39
Gross β	001	52	3.17	0.74	0.004	0.29-45.30	2.34 ± 0.04	19.07 ± 0.33	
Gross α	002	52	11.70	0.27	0.007	0.007-1.84	0.23 ± 0.02	1.87 ± 0.16	11.53
Gross β	002	52	11.70	3.05	0.004	0.35-36.90	2.60 ± 0.04	21.19 ± 0.33	
Gross α	003	52	3.63	0.02	0.007	<MDL-0.23	0.06 ± 0.01	0.49 ± 0.08	0.24
Gross β	003	52	3.63	0.19	0.004	0.19-1.43	0.52 ± 0.02	4.24 ± 0.16	
Gross α	004	52	1.44	0.02	0.007	<MDL-0.39	0.11 ± 0.01	0.90 ± 0.08	4.53
Gross β	004	52	1.44	0.14	0.004	0.18-3.77	1.00 ± 0.03	8.15 ± 0.24	
Gross α	013	52	1.11	0.02	0.007	0.01-0.60	0.17 ± 0.01	1.39 ± 0.08	7.42
Gross β	013	52	1.11	0.18	0.004	0.43-5.77	1.65 ± 0.03	13.45 ± 0.24	
Gross α	014	52	2.02	0.02	0.007	<MDL-1.44	0.11 ± 0.01	0.90 ± 0.08	4.24
Gross β	014	52	2.02	0.19	0.004	0.17-10.90	0.93 ± 0.03	7.58 ± 0.24	
Gross α	012	52	2.48	0.008	0.007	<MDL-0.11	0.03 ± 0.01	0.24 ± 0.08	1.83
Gross β	012	52	2.48	0.10	0.004	0.21-1.23	0.42 ± 0.02	3.42 ± 0.16	
Gross α	006	52	0.38	0.008	0.007	MDL-0.55	0.20 ± 0.02	1.63 ± 0.16	6.93
Gross β	006	52	0.38	0.06	0.004	0.37-2.86	1.50 ± 0.05	12.23 ± 0.41	
^{131}I	001	12	3.17	0.002	0.009	<MDL-0.13	0.01 ± 0.09	0.08 ± 0.73	0.00001
^{131}I	002	12	11.70	0.002	0.009	<MDL-0.23	0.02 ± 0.09	0.16 ± 0.73	0.00002
	Gaseous	Emissions		Activity μCi/yr	MDL, 10^{-8} μCi/ml	Range, 10^{-8} μCi/ml	Stack, 10^{-9} μCi/ml	Site Boundary, 10^{-13} μCi/ml	
^{85}Kr	001	(c)	3.17	1.56×10^6	0.02	0.04-20.20	49.21	40.11	1.34
^{85}Kr	002	(c)	11.70	3.32×10^4	0.02	0.02-0.11	0.28	0.23	0.002
^{85}Kr	013	(c)	1.11	4.34×10^5	0.02	<MDL-15.60	39.00	31.79	1.06

(a) Site boundary concentrations were calculated by multiplying stack concentrations by the atmospheric dispersion parameter computed for the site boundary using computer code DACRIN (See reference 9, Page 24).

(b) RCG - for mixed alpha and beta activity, 2×10^{-14} μCi/ml; ^{85}Kr 3×10^{-7} μCi/ml; ^{131}I 1×10^{-10} μCi/ml.

(c) ^{85}Kr concentration calculated by evaluation of data on strip chart recorder used with gaseous stack monitor.

TABLE 3. GAMMA EMITTING RADIONUCLIDES IDENTIFIED IN THE JN-1 (HOT LAB) STACK EMISSIONS
CY 1984

(a) Species	Stack Location Figure 4	Composite Stack (b) Samples	Volume 10^{10} liters/yr	Activity, µCi/yr	MDL, 10^{-15} µCi/ml	Range, 10^{-15} µCi/ml	Stack, 10^{-15} µCi/ml	Site (c) Boundary, 10^{-19} µCi/ml	10^{-7} Percent of (d) RCG at Site Boundary
^{60}Co	002	12	11.70	0.73	0.80	<MDL-54.90	6.22 ± 1.22	5.07 ± 0.99	1.69
	004	12	1.44	0.007	0.80	<MDL-5.86	0.49 ± 1.16	0.04 ± 0.95	0.13
	013	12	1.11	0.04	0.80	<MDL-44.30	3.69 ± 1.23	3.01 ± 1.00	1.00
^{137}Cs	001	12	3.17	0.06	1.05	<MDL-33.00	1.89 ± 1.38	1.54 ± 1.12	0.31
	002	12	11.70	0.18	1.05	<MDL-10.30	1.57 ± 1.24	1.[illegible].01	0.26
	003	12	3.63	0.009	1.05	<MDL-2.90	0.24 ± 1.33	[illegible]08	0.04
	004	12	1.44	0.046	1.05	<MDL-13.00	3.18 ± 1.30	[illegible]06	0.52
	013	12	1.11	0.004	1.05	<MDL-3.84	0.37 ± 1.27	[illegible].04	0.06
^{235}U	001	12	3.17	0.013	2.11	<MDL-5.70	0.41 ± 1.81	[illegible] ± 1.48	8.25
	002	12	11.70	0.10	2.11	<MDL-5.70	0.84 ± 3.48	[illegible]8 ± 2.84	17.00
	003	12	3.63	0.014	2.11	<MDL-4.50	0.38 ± 1.82	0.31 ± 1.48	7.75
	004	12	1.44	0.007	2.11	<MDL-6.10	0.51 ± 1.82	0.42 ± 1.48	10.50
	014	12	2.02	0.03	2.11	<MDL-11.00	1.52 ± 1.62	1.24 ± 1.32	31.00
^{144}Ce	001	12	3.17	0.07	1.45	<MDL-46.00	3.83 ± 6.58	3.12 ± 5.36	1.56
	002	12	11.70	0.32	1.45	<MDL-19.00	2.75 ± 6.26	2.24 ± 5.10	1.12
	003	12	3.63	0.12	1.45	<MDL-39.00	3.25 ± 6.61	2.64 ± 5.39	1.32
	004	12	1.44	0.58	1.45	<MDL-24.00	4.00 ± 6.29	3.26 ± 5.13	1.63
	014	12	2.02	0.64	1.45	<MDL-38.00	3.17 6.57	2.58 ± 5.35	1.29
^{125}Sb	001	12	3.17	0.78	1.01	<MDL-520.00	24.70 ± 2.92	20.13 ± 2.38	2.24
	002	12	11.70	1.47	1.01	<MDL-151.00	12.60 ± 2.80	10.27 ± 2.28	1.14
	013	12	1.11	0.043	1.01	<MDL-46.40	3.87 ± 2.73	3.15 ± 2.23	0.35
^{228}Ac	001	12	3.17	0.03	2.10	<MDL-20.00	0.95 ± 5.61	0.77 ± 4.57	0.13
	002	12	11.70	0.13	2.10	<MDL-13.00	1.08 ± 5.93	0.88 ± 4.83	0.15

(a) Only those radionuclides which contributed to critical organ doses to the maximum individual greater than 1×10^{-10} rem/yr are listed.

(b) Identification of radionuclides in stack particulate emissions was by gamma spectrometric analysis of stack particulate air filters.

(c) Site boundary concentrations were calculated by multiplying stack concentration by the atmospheric dispersion parameter computed for the site boundary using computer code DACRIN (see reference 9, page 24).

(d) RCG: ^{137}Cs 5×10^{-10} µCi/ml; ^{60}Co 3×10^{-10} µCi/ml; ^{235}U 4×10^{-12} µCi/ml; ^{144}Ce 2×10^{-10} µCi/ml; ^{228}Ac 6×10^{-10} µCi/ml; ^{125}Sb 9×10^{-10} µCi/ml.

TABLE 4. SUMMARY OF LIQUID RADIOACTIVE EMISSIONS - WEST JEFFERSON SITE (MEASURE OF EFFLUENT FROM SANITARY SEWERAGE SYSTEM INTO BIG DARBY CREEK - FIGURE 4, DESIGNATION 010)[(a)]
CY 1984

Species	Number of Samples	Activity, µCi/yr	MDL, 10^{-8} µCi/ml	Range 10^{-8} µCi/ml	Average Concentration 10^{-9} µCi/ml[(b)]	RCG 10^{-8} µCi/ml	Percentage of RCG
Gross α	52	48.40	0.05	<MDL-1.69	4.93 ± 0.21	10[(c)]	9.13
Gross β	52	41.20	0.02	<MDL-1.02	4.20 ± 0.23		
^{90}Sr	12	13.10	0.10	<MDL-0.50	1.59 ± 0.93	30	0.53
^{238}Pu	12	0.55	0.009	<MDL-0.02	0.05 ± 0.06	500	0.001
^{239}Pu	12	0.34	0.009	<MDL-0.02	0.03 ± 0.04	500	0.0006
^{137}Cs	12	40.00	0.1	<MDL-4.08	3.40 ± 9.48	2000	0.017
^{129}I	12	48.80	0.1	<MDL-1.40	5.50 ± 3.14	6	9.17
^{226}Ra	12	2.04	0.009	<MDL-0.10	0.23 ± 0.04	3	0.77
^{228}Ra	12	3.88	0.01	<MDL-0.2	0.43 ± 0.48	3	1.43
^{212}Pb	12	44.00	0.1	<MDL-4.80	4.50 ± 21.30	2000	0.023
^{228}Ac	12	53.00	0.1	<MDL-8.40	7.00 ± 44.70	9000	0.008
^{238}U	12	46.00	0.1	<MDL-5.60	4.70 ± 16.30	3000	0.016

(a) Annual average flow in Big Darby Creek = 429 cu ft/sec - 3.82×10^{11} liters/yr. Total volume of liquid effluent discharge = for CY 1984 = 7.84×10^{6} liters.
(b) Isotopic data for effluents released at this location were obtained from monthly composite samples.
(c) RCG - Mixture of alpha and beta activity; 3×10^{-8} µ Ci/ml. (If it is known that ^{129}I, ^{226}Ra, and ^{228}Ra are not present, the limiting value of 1×10^{-7} µCi/ml may be used.) See Appendix.

TABLE 5. NONRADIOLOGICAL SAMPLING FOR WEST JEFFERSON SITE

January 1, 1984 to December 31, 1984

	North Sanitary System Sewer[c]				Permit Requirements[d] Discharge Limitations			
				Kg/Day	Loading Kg/Day[e]		Concentration Other Units	
	Avg.	Max.	Min.	Avg.	30 Day	Dailey	30 Day	Dailey
Flow Rate (gal/day)	6480	10,080	4320	-			(b)	(b)
Residual Chlorine (mg/l)	0.42	0.5	0.1	0.0100			-	0.5
pH Value (S.U.)	7.33	7.77	7.11	-			6.0 to	9.0
Fecal Coliform (#/100 ml)	7.5	80.0	0.0	-			200	400
Total Suspended Solids (mg/l)	0.33	4.0	0.0	0.0055	0.49	0.99	10	20
Temperature (^{o}F)	(a)	(a)	(a)	-			-	90^{o}
B.O.D. (5 day) (mg/l)	4.17	5.0	3.4	0.1023	0.49	0.99	10	20

(a) Sample analysis for this parameter was not required by our NPDES Permit.

(b) No restrictions for flow under our NPDES Permit.

(c) Sampling site location No. 010.

(d) Permit requirement discharge limitations based on NPDES Permit #404-CD.

(e) Flow rate 0.013 mgd.

TABLE 6. SUMMARY OF GRASS ANALYSES
CY 1984

Location[a] (Direction and Distance from Nuclear Science Area)		Number of Composite Samples	pCi/g dry wt.[b] ^{90}Sr	^{238}Pu	^{239}Pu	^{137}Cs
North Quad	6.4 km (4.0 miles) 8.0 km (5.0 miles)	2	0.04 ± 0.01	0.01 ± 0.01	0.00 ± 0.01	<0.1
East Quad	1.6 km (1.0 miles) 3.2 km (2.0 miles) 6.4 km (4.0 miles) 7.2 km (4.5 miles) 8.0 km (5.0 miles)	5	0.11 ± 0.02	0.01 ± 0.02	0.02 ± 0.02	<0.2
South Quad	0.8 km (0.5 miles) 3.1 km (1.9 miles)	2	0.06 ± 0.01	0.01 ± 0.02	0.00 ± 0.01	<0.3
West Quad	4.8 km (3.0 miles) 6.4 km (4.0 miles) 8.0 km (5.0 miles)	3	0.07 ± 0.02	0.01 ± 0.01	0.00 ± 0.01	<0.3
On Site	-----------------	2	0.06 ± 0.10	0.00 ± 0.01	0.00 ± 0.01	<0.2

Note: No standards for radionuclides in grass have been established.

(a) Locations are shown in Figure 5.

(b) Minimum Detection Limit for ^{90}Sr in grass is 0.1 pCi/g dry wt.
Minimum Detection Limit for ^{238}Pu and ^{239}Pu in grass is 0.01 pCi/g dry wt.
Minimum Detection Limit for ^{137}Cs in grass is 0.1 pCi/g dry wt.

TABLE 7. SUMMARY OF FOOD CROP ANALYSES CY 1984

Type of Samples	Quadrant	Location[a] (Distance from Nuclear Sciences Area)	Number of Composite Samples	pCi/g dry wt. (b)			
				^{90}Sr	^{238}Pu	^{239}Pu	^{137}Cs
Field Corn	West West	0.74 km (2400 feet) 3.2 km (2.0 miles)	2	0.01 ± 0.01	0.00 ± 0.01	0.00 ± 0.01	<0.1
Field Corn	North North	4.0 km (2.5 miles) 8.0 km (5.0 miles)	2	0.00 ± 0.01	0.00 ± 0.01	0.00 ± 0.01	<0.1
Field Corn	South South South	4.0 km (1.5 miles) 6.4 km (4.0 miles) 8.0 km (5.0 miles)	3	0.02 ± 0.01	0.00 ± 0.01	0.00 ± 0.01	<0.1
Field Corn	On Site	-----------------	1	0.00 ± 0.01	0.00 ± 0.01	0.00 ± 0.01	<0.1

Note: No standard for radionuclides in food crops have been established.

(a) Locations are shown in Figure 5.

(b) Minimum Detection Limit for ^{90}Sr in food crops is 0.01 pCi/g dry wt.
Minimum Detection Limit for ^{238}Pu and ^{239}Pu in food crops is 0.01 pCi/g dry wt.
Minimum Detection Limit for ^{137}Cs in food crops is 0.1 pCi/g dry wt.

TABLE 8. SUMMARY OF SILT ANALYSES
CY 1984

Location[b] Figure	Number of Samples	PCi/g dry wt.[a]			
		^{90}Sr	^{238}Pu	^{239}Pu	^{137}Cs
A (20 yd above outfall)	2	0.07 ± 0.01	0.02 ± 0.02	0.02 ± 0.02	0.6 ± 0.1
B (20 yd below outfall)	2	0.08 ± 0.02	0.02 ± 0.03	0.03 ± 0.03	0.6 ± 0.1

Note: No standards for radionuclides in silt have been established.

(a) Minimum Detection Limit for ^{90}Sr and ^{137}Cs in silt is 0.01 pCi/g and 0.1 pCi/g dry wt. respectively.

Minimum Detection Limit for ^{238}Pu and ^{239}Pu in silt is 0.01 pCi/g dry wt.

(b) The collection of silt samples at these locations, where silt deposition and accumulation should be at a maximum, was based on observations of the average flow pattern of Big Darby Creek in the vicinity of the outfall.

TABLE 9. SUMMARY OF SOIL ANALYSES FOR SPECIFIC RADIONUCLIDES
CY 1984

Location[a] (Direction and Distance from the Nuclear Science Area)		Number of Composite Samples	pCi/g dry wt.[b] ^{238}Pu	^{239}Pu	^{90}Sr
North Quad	6.4 km (4.0 miles) 8.0 km (5.0 miles	2	0.00 ± 0.02	0.00 ± 0.01	0.04 ± 0.01
East Quad	1.6 km (1.0 miles) 3.2 km (2.0 miles) 6.4 km (4.0 miles) 7.2 km (4.5 miles) 8.0 km (5.0 miles)	5	0.00 ± 0.02	0.01 ± 0.01	0.04 ± 0.01
South Quad	0.8 km (0.5 miles) 3.1 km (1.9 miles)	2	0.01 ± 0.02	0.01 ± 0.01	0.04 ± 0.01
West Quad	4.8 km (3.0 miles) 6.4 km (4.0 miles) 8.0 km (5.0 miles)	3	0.01 ± 0.02	0.01 ± 0.01	0.04 ± 0.01
On Site	-----------------	2	0.01 ± 0.01	0.01 ± 0.01	0.03 ± 0.01

Note: No standards for radionuclides in soil have been established. The Environmental Protection Agency's proposed federal radiation protection guidance for exposures to transuranium elements in the environment has recommended a reference level of 0.2 $\mu Ci/m^2$ for soil contamination.

(a) Locations are shown in Figure 5.

(b) Minimum Detection Limit for ^{238}Pu and ^{239}Pu in soil is 0.01 pCi/g dry wt. Minimum Detection Limit for ^{90}Sr in soil is 0.01 pCi/g dry wt.

TABLE 10. SUMMARY OF GAMMA ISOTOPIC ANALYSIS OF SOIL SAMPLES
CY 1984

Location (Direction and Distance from the Nuclear Science Area)[a]

	North Quad 6.4 Km (4.0 miles) 8.0 Km (5.0 miles)	East Quad 1.6 Km (1.0 miles) 3.2 Km (2.0 miles) 6.4 Km (4.0 miles) 7.2 Km (4.5 miles) 8.0 Km (5.0 miles)	South Quad 0.8 Km (0.5 miles) 3.1 Km (1.9 miles)	West Quad 4.8 Km (3.0 miles) 6.4 Km (4.0 miles) 8.0 Km (5.0 miles)	On Site
Number of Composite Samples	2	5	2	3	2
Nuclide	Average Concentration pCi/g (dry) wt.[b]				
^{137}Cs	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.4 ± 0.1	0.3 ± 0.1

Note: No standards for radionuclides in soil have been established.

(a) Locations are shown in Figure 5.

(b) Minimum detection limit for ^{137}Cs (in pCi/g dry wt.) is 0.1.

TABLE 11. SUMMARY OF FISH ANALYSES
CY 1984

Location[a]	Period of Collection	Number of Composite Samples	pCi/g dry wt.[b] ^{238}Pu	^{239}Pu	^{137}Cs	^{90}Sr
Darby Creek	1st qtr.	(c)				
Battelle Lake	1st qtr.	(c)				
Darby Creek	2nd qtr.	1	0.00 ± 0.01	0.00 ± 0.01	<0.1	0.10 ± 0.01
Battelle Lake	2nd qtr.	1	0.01 ± 0.01	0.00 ± 0.01	<0.1	0.09 ± 0.01
Darby Creek	3rd qtr.	1	0.00 ± 0.01	0.00 ± 0.01	<0.1	0.06 ± 0.01
Battelle Lake	3rd qtr.	1	0.00 ± 0.01	0.00 ± 0.01	<0.1	0.18 ± 0.01
Darby Creek	4th qtr.	1	0.00 ± 0.01	0.00 ± 0.01	<0.1	0.12 ± 0.01
Battelle Lake	4th qtr.	1	0.01 ± 0.01	0.00 ± 0.01	<0.1	0.12 ± 0.01

Note: No standards for radionuclides in fish have been established.

(a) Fish samples were collected from various locations within Battelle lake. Fish samples from Darby Creek were taken at various distances within 1000 ft. downstream from the sanitary outfall. (See Figure 6).

(b) Minimum Detection Limit for ^{90}Sr in fish was 0.1 pCi/g dry weight, 0.2 pCi/g dry weight ^{137}Cs, and 0.01 pCi/g dry weight for ^{238}Pu and ^{239}Pu.

(c) No fish samples were collected during the first quarter of Cy 1984.

TABLE 12. INTEGRATED EXTERNAL BACKGROUND RADIATION MEASUREMENTS WITHIN 3/4-MILE RADIUS-WEST JEFFERSON SITE CY 1984

Location and Distance(a)	Integrated TLD Measurements in Rem				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Total for Year
Southwest					
400 ft	<0.030	0.030	0.030	0.030	<0.120
2400 ft	<0.030	0.030	0.030	0.030	<0.120
4050 ft	<0.030	0.030	<0.030	0.030	<0.120
West					
500 ft	<0.030	0.030	<0.030	0.030	<0.120
2070 ft	<0.030	0.030	<0.030	0.030	<0.120
Southeast					
1200 ft	<0.030	0.030	0.030	0.030	<0.120
3300 ft	<0.030	0.030	<0.030	0.030	<0.120
South					
1200 ft	<0.030	0.030	<0.030	0.030	<0.120
1350 ft	<0.030	<0.030	<0.030	0.030	<0.120
1800 ft	<0.030	0.030	0.030	0.030	<0..120
3600 ft	<0.030	0.030	<0.030	(b)	<0.120(c)
East					
1380 ft	<0.030	0.030	0.030	0.030	<0.120
Northeast					
1200 ft	<0.030	0.030	<0.030	0.030	<0.120
Northwest					
1320 ft	<0.030	0.030	0.030	0.030	<0.120
North					
1500 ft	<0.030	0.030	<0.030	0.030	<0.120

(a) Refer Figure 8. Average background for year <0.120 Rem
(b) Dosimeter damaged. No data available.
(c) Approximate value based on estimated 4th quarter dose to TLD.

TABLE 13. INTEGRATED EXTERNAL RADIATION MEASUREMENTS AT PERIMETER SECURITY FENCE - WEST JEFFERSON SITE
CY 1984

Location and Distance[a]	Integrated TLD Measurements in Rem				
	1st Qtr.	2nd Qtr.	3rd Qtr.	4th Qtr.	Total for Year
Southwest					
100 ft JN-3	<0.030	0.030	<0.030	0.030	<0.120
150 ft JN-2	<0.030	0.030	<0.030	0.030	<0.120
175 ft JN-1	<0.030	0.040	0.040	0.060	<0.170
West					
75 ft JN-2	<0.030	0.030	0.030	0.030	<0.120
150 ft JN-3	<0.030	0.030	0.030	0.040	<0.130
Southeast					
150 ft JN-4	0.030	0.070	0.070	0.090	0.260
200 ft JN-1	<0.030	0.040	0.030	0.050	<0.150
240 ft JN-1	<0.030	0.070	0.070	0.080	<0.250
250 ft JN-1	0.040	0.100	0.070	(b)	0.300(c)
South					
150 ft JN-2	<0.030	0.030	0.030	(b)	<0.190(c)
160 ft JN-1	<0.030	0.050	0.050	0.070	<0.200
190 ft JN-1	0.060	0.100	0.070	0.100	0.330
East					
150 ft JN-4	<0.030	0.070	0.060	0.080	<0.240
230 ft JN-1	0.060	0.110	0.100	0.120	0.390
240 ft JN-1	0.070	0.110	0.100	0.150	0.430
Northeast					
150 ft JN-4	<0.030	0.050	0.040	0.060	<0.180
225 ft JN-4	<0.030	0.040	0.040	0.050	<0.160
250 ft JN-1	0.040	0.080	0.070	0.110	0.300
260 ft JN-1	0.060	0.090	0.080	0.120	0.350
275 ft JN-3	<0.030	0.030	0.030	0.040	<0.130
Northwest					
200 ft JN-4	<0.030	0.040	0.030	0.050	<0.150
250 ft JN-3	<0.030	0.030	0.030	0.040	<0.130
North					
150 ft JN-4	<0.030	0.040	0.040	0.050	<0.160
200 ft JN-4	<0.030	0.040	0.040	0.050	<0.160
300 ft JN-3	<0.030	0.040	0.030	0.040	<0.140

(a) Refer Figure 9. Average fence line dose for year 0.211 Rem
(b) Dosimeter damaged. No data available.
(c) Approximate value based on estimated 4th quarter dose to TLD.

TABLE 14. CONCENTRATION OF RADIOACTIVITY IN LIQUID DISCHARGES TO COLUMBUS MUNICIPAL SANITARY SEWAGE SYSTEM CY 1984

Nuclide	Location Figure 7	Number of Samples	Activity, μCi/yr	Concentration Range,[a] 10^{-9} μCi/ml	Concentration Average, 10^{-9} μCi/ml	Percent of RCG[b]
Gross α	005	12	720.0	1.70-20.20	5.45 ± 0.49	3.11
Gross β	005	12	922.0	3.99-13.00	6.98 ± 0.55	

(a) Minimum Detection Limit (MDL) for: gross alpha: 0.5×10^{-9} μCi/ml; gross beta: 0.6×10^{-9} μCi/ml.

(b) RCG - Mixture of alpha and beta activity: 400×10^{-9} μCi/ml.

TABLE 15. SUMMARY OF SITE BOUNDARY AIR SAMPLE ANALYSES FOR GROSS RADIOACTIVITY CY 1984

Location[a] Direction and Distance from Nuclear Sciences Area	Number of Samples	10^{-15} μCi/ml[b] Gross α[c]	Gross β[c]
North Quadrant Station (450 ft. North of JN-4 Stacks)	52	0.00 ± 0.44	0.00 ± 0.82
East Quadrant Station (400 ft. East of JN-1 Stacks)	52	0.03 ± 0.44	0.00 ± 0.82
South Quadrant Station (750 ft. South of JN-2 Stacks)	52	0.00 ± 0.44	0.00 ± 0.82
West Quadrant Station (400 ft. West of JN-2 Stacks)	52	0.00 ± 0.44	0.00 ± 0.82

(a) Locations are shown in Figure 6.

(b) Minimum Detection Limit for gross α is 1×10^{-17} μCi/ml, and 4×10^{-17} μCi/ml for gross β.

(c) The values shown for gross α and gross β indicate site boundary concentrations above background concentrations found at off-site air monitoring stations. See Table 17.

TABLE 16. SUMMARY OF SITE BOUNDARY AIR SAMPLE ANALYSES FOR SPECIFIC RADIONUCLIDES
CY 1984

Location[a] Direction and Distance from Nuclear Sciences Area	Number of Composite Samples	10^{-19} μCi/ml[b]			10^{-16} μCi/ml[b]	
		^{90}Sr	^{238}Pu	^{239}Pu	^{137}Cs	^{144}Ce
North Quadrant Station (450 ft. North of JN-4 stacks)	4	1.09 ± 0.56	0.08 ± 0.05	0.02 ± 0.02	<MDL	<MDL
East Quadrant Station (400 ft. East of JN-1 stacks)	4	1.32 ± 0.74	0.05 ± 0.14	0.06 ± 0.09	<MDL	<MDL
South Quadrant Station (750 ft. South of JN-2 stacks)	4	1.88 ± 0.71	0.02 ± 0.04	0.01 ± 0.02	0.53 ± 1.34	<MDL
West Quadrant Station (400 ft. West of JN-2 stacks)	4	1.02 ± 0.72	0.02 ± 0.04	0.01 ± 0.02	0.35 ± 1.64	5.18 ± 7.57

(a) Locations are shown in Figure 6.

(b) Minimum detection limit for ^{90}Sr is 7×10^{-20} μCi/ml, ^{238}Pu 2×10^{-21} μCi/ml, ^{239}Pu 2×10^{-21} μCi/ml, and ^{137}Cs 1×10^{-17} μCi/ml.

TABLE 17. SUMMARY OF OFF SITE AIR SAMPLE ANALYSES
CY 1984

Location[a] Direction and Distance from Nuclear Sciences Area	Number of Samples	10^{-14} µCi/ml[b]	
		Gross α	Gross β
Grandview (17.8 km east)	52	0.51 ± 0.04	2.96 ± 0.07
Chesapeake (24.4 km east)	52	0.51 ± 0.04	3.15 ± 0.08
Fairgrounds (24.8 km northeast)	52	0.58 ± 0.05	2.38 ± 0.08
Newark (70.8 km northeast	52	0.55 ± 0.04	3.12 ± 0.08
Grove City (14.5 km southeast)	52	0.50 ± 0.04	3.08 ± 0.08
New Rome (8.0 km east)	52	0.51 ± 0.04	3.04 ± 0.07

(a) Locations are shown in Figure 10.

(b) Minimum Detection Limit for gross α is 7×10^{-17} µCi/ml and 4×10^{-17} µCi/ml for gross β.

TABLE 18. SUMMARY OF ENVIRONMENTAL WATER SAMPLE ANALYSES
CY 1984

Location[(a)] Direction and Distance from Nuclear Sciences Area	Number of Samples	10^{-9} μCi/ml[(b)]	
		Gross α	Gross β
Darby Creek Upstream (18.3 m above sanitary outfall)	52	5.32 ± 0.53	5.73 ± 0.59
Darby Creek Downstream (18.3 m below sanitary outfall)	52	5.77 ± 0.51	5.72 ± 0.55
Darby Creek Downstream (186.3 m below sanitary outfall)	52	4.66 ± 0.43	4.22 ± 0.47
Battelle Lake Spillway (18.3 m below dam)	52	3.50 ± 0.40	4.62 ± 0.49

(a) Locations are shown in Figure 6.

(b) Minimum Detection Limit for gross α is 2×10^{-10} μCi/ml and 1×10^{-10} μCi/ml for gross β.

TABLE 19. RADIONUCLIDE COMPOSITION OF BCL EFFLUENTS
CY 1984

West Jefferson Site

Air	Activity (μCi)
Gross Alpha	0.44
Gross Beta	4.65
Plutonium-239	0.44
Cobalt-60	0.78
Strontium-90	0.00003
Cesium-137	0.30
Actinium-228	0.16
Lead-212	0.07
*Lead-214	0.72
*Bismuth-214	1.04
Cerium-144	0.63
Antimony-125	2.30
Krypton-85	2029200.00
Niobium-95	0.001
Uranium-235	0.16
*Potassium-40	8.08
Thallium-208	0.007

Water	Activity (μCi)
Gross Alpha	48.40
Gross Beta	41.20
Iodine-129	48.80
Strontium-90	13.10
Plutonium-238	0.55
Plutonium-239	0.34
Radium-226	2.04
Radium-228	3.88
Lead-212	44.00
*Bismuth-214	395.00
Actinium-228	53.00
*Potassium-40	98.00
Cesium-137	40.00
*Lead-214	543.00
Thallium-208	12.00
Uranium-235	46.00

King Avenue Site

Water	Activity (μCi)
Gross Alpha	720.00
Gross Beta	922.00

* Lead-214, bismuth-214 and potassium-40 are naturally occurring radionuclides which were part of the total effluent composition.

TABLE 20. SUMMARY OF ANNUAL RADIATION DOSE TO THE MAXIMUM INDIVIDUAL, NEAREST RESIDENT AND POPULATION GROUPS FROM RELEASES OF KRYPTON-85 DURING CY 1984

Critical Organ	Dose to the Maximum Individual (0.122 Km)
Total Body	1.20×10^{-2} mrem/yr
Skin	7.21×10^{-2} mrem/yr
	Dose to the Nearest Resident (0.750 Km NW)
Total Body	2.05×10^{-3} mrem/yr
Skin	1.23×10^{-2} mrem/yr
	Dose to the Nearest Population Group (Darby Estates, Population 2,000)
Total Body	9.70×10^{-4} person-rem/yr
Skin	5.82×10^{-3} person-rem/yr
	Dose to the Population Group (West Jefferson, Population 6,000
Total Body	6.71×10^{-4} person-rem/yr
Skin	4.03×10^{-3} person-rem/yr

TABLE 21. ANNUAL DOSE TO THE MAXIMUM INDIVIDUAL FROM EFFLUENTS RELEASED DURING CY 1984

	Dose (mrem/yr)					
Pathway	Whole Body	GI[(a)]	Thyroid	Kidneys	Bone	Lungs
Airborne (inhalation)	1.39 E^{-6}	2.41 E^{-6}	6.38 E^{-7}	2.64 E^{-6}	1.02 E^{-5}	1.21 E^{-3}
Airborne (ingestion)	1.10 E^{-10}	5.40 E^{-12}	1.10 E^{-11}	6.60 E^{-11}	3.90 E^{-10}	7.70 E^{-12}
Eating Fish	3.20 E^{-5}	4.70 E^{-8}	1.90 E^{-7}	1.40 E^{-5}	3.10 E^{-5}	3.10 E^{-6}
Aquatic Recreation	2.10 E^{-10}	2.10 E^{-10}	2.10 E^{-10}	2.10 E^{-10}	2.10 E^{-10}	2.10 E^{-10}

(a) Gastrointestinal tract (lower large intestine).

TABLE 22. ANNUAL DOSE TO THE NEAREST RESIDENT (0.75 KM NW) FROM EFFLUENTS RELEASED DURING CY 1984

Pathway	Dose (mrem/yr)					
	Whole Body	GI[a]	Thyroid	Kidneys	Bone	Lungs
Airborne (inhalation)	1.90 E^{-7}	4.07 E^{-7}	1.08 E^{-7}	3.55 E^{-7}	1.14 E^{-6}	1.63 E^{-4}
Airborne (ingestion)	1.10 E^{-10}	5.40 E^{-12}	1.10 E^{-11}	6.60 E^{-11}	3.90 E^{-10}	7.70 E^{-12}
Eating Fish	3.20 E^{-5}	4.70 E^{-8}	1.90 E^{-7}	1.40 E^{-5}	3.10 E^{-5}	3.10 E^{-6}
Aquatic Recreation	2.10 E^{-10}	2.10 E^{-10}	2.10 E^{-10}	2.10 E^{-10}	2.10 E^{-10}	2.10 E^{-10}

(a) Gastrointestinal tract (lower large intestine).

TABLE 23. ANNUAL DOSE TO THE NEAREST POPULATION GROUP (DARBY ESTATES) FROM EFFLUENTS RELEASED DURING CY 1984

Pathway	Dose (Person-rem)(b)					
	Whole Body	GI(a)	Thyroid	Kidneys	Bone	Lungs
Airborne (inhalation)	8.86 E^{-8}	1.93 E^{-7}	5.16 E^{-8}	1.56 E^{-7}	5.22 E^{-7}	7.58 E^{-5}
Airborne (ingestion)	2.20 E^{-10}	2.20 E^{-10}	1.08 E^{-11}	1.32 E^{-10}	7.80 E^{-10}	1.54 E^{-11}
Eating Fish	6.40 E^{-5}	9.40 E^{-8}	3.80 E^{-7}	2.80 E^{-5}	6.20 E^{-5}	6.20 E^{-6}
Aquatic Recreation	4.20 E^{-10}	4.20 E^{-10}	4.20 E^{-10}	4.20 E^{-10}	4.20 E^{-10}	4.20 E^{-10}

(a) Gastrointestinual tract (lower large intestine).

(b) Population affected: 2000

TABLE 24. ANNUAL DOSE TO THE POPULATION GROUP (WEST JEFFERSON) FROM EFFLUENTS RELEASED DURING CY 1984

Pathway	Dose (Person-rem)[b]					
	Whole Body	GI[a]	Thyroid	Kidneys	Bone	Lungs
Airborne (inhalation)	6.42 E^{-8}	1.34 E^{-7}	3.56 E^{-8}	1.13 E^{-7}	3.90 E^{-7}	5.50 E^{-5}
Airborne (ingestion)	6.60 E^{-10}	3.24 E^{-11}	6.60 E^{-10}	3.96 E^{-10}	2.34 E^{-9}	4.62 E^{-11}
Eating Fish	1.92 E^{-4}	2.82 E^{-7}	1.14 E^{-6}	8.40 E^{-5}	1.86 E^{-4}	1.86 E^{-5}
Aquatic Recreation	1.26 E^{-9}	1.26 E^{-9}	1.26 E^{-9}	1.26 E^{-9}	1.26 E^{-9}	1.26 E^{-9}

(a) Gastrointestinal tract (lower large intestine).

(b) Population affected: 6000

TABLE 25. 70 YEAR DOSE COMMITMENT FOR THE MAXIMUM INDIVIDUAL FROM EFFLUENTS RELEASED DURING CY 1984

	Dose (Rem)					
Pathway	Whole Body	GI[(a)]	Thyroid	Kidneys	Bone	Lungs
Airborne (inhalation)	$5.25\ E^{-8}$	$2.44\ E^{-9}$	$6.38\ E^{-10}$	$2.05\ E^{-7}$	$1.07\ E^{-6}$	$2.25\ E^{-6}$
Airborne (ingestion)	$3.10\ E^{-12}$	$3.80\ E^{-13}$	$1.20\ E^{-12}$	$1.80\ E^{-11}$	$2.00\ E^{-11}$	$3.10\ E^{-13}$
Eating Fish	$3.20\ E^{-7}$	$4.70\ E^{-11}$	$3.10\ E^{-10}$	$1.70\ E^{-8}$	$4.00\ E^{-7}$	$5.80\ E^{-9}$
Aquatic Recreation	$2.10\ E^{-13}$	$2.10\ E^{-13}$	$2.10\ E^{-13}$	$2.10\ E^{-13}$	$2.10\ E^{-13}$	$2.10\ E^{-13}$
Airborne (ingestion)[(b)]	$3.20\ E^{-12}$	$5.40\ E^{-15}$	$2.70\ E^{-13}$	$2.30\ E^{-11}$	$2.10\ E^{-11}$	$3.10\ E^{-13}$

(a) Gastrointestinal tract (lower large intestine).

(b) 70-year accumulated dose.

TABLE 26. 70 YEAR DOSE COMMITMENT FOR THE NEAREST RESIDENT (0.75 KM NW) FROM EFFLUENTS RELEASED DURING CY 1984

Pathway	Dose (Rem)					
	Whole Body	GI(a)	Thyroid	Kidneys	Bone	Lungs
Airborne (inhalation)	$8.92\ E^{-9}$	$4.14\ E^{-10}$	$1.08\ E^{-10}$	$3.49\ E^{-8}$	$1.82\ E^{-7}$	$3.83\ E^{-7}$
Airborne (ingestion)	$3.10\ E^{-12}$	$3.80\ E^{-13}$	$1.20\ E^{-12}$	$1.80\ E^{-11}$	$2.00\ E^{-11}$	$3.10\ E^{-13}$
Eating Fish	$3.20\ E^{-7}$	$4.70\ E^{-11}$	$3.10\ E^{-10}$	$1.70\ E^{-8}$	$4.00\ E^{-7}$	$5.80\ E^{-9}$
Aquatic Recreation	$2.10\ E^{-13}$	$2.10\ E^{-13}$	$2.10\ E^{-13}$	$2.10\ E^{-13}$	$2.10\ E^{-13}$	$2.10\ E^{-13}$
Airborne (ingestion)(b)	$3.20\ E^{-12}$	$5.40\ E^{-15}$	$2.70\ E^{-13}$	$2.30\ E^{-11}$	$2.10\ E^{-11}$	$3.10\ E^{-13}$

(a) Gastrointestinal tract (lower large intestine).

(b) 70-year accumulated dose.

TABLE 27. 70 YEAR DOSE COMMITMENT FOR THE NEAREST POPULATION GROUP (DARBY ESTATES) FROM EFFLUENTS RELEASED DURING CY 1984

	Dose (Person-rem)(b)					
Pathway	Whole Body	GI(a)	Thyroid	Kidneys	Bone	Lungs
Airborne (inhalation)	4.24 E^{-6}	1.92 E^{-7}	5.16 E^{-8}	1.66 E^{-5}	8.66 E^{-5}	1.82 E^{-4}
Airborne (ingestion)	6.20 E^{-9}	7.60 E^{-10}	2.40 E^{-9}	3.60 E^{-8}	4.00 E^{-8}	6.20 E^{-10}
Eating Fish	6.40 E^{-4}	9.40 E^{-8}	6.20 E^{-7}	3.40 E^{-5}	8.00 E^{-4}	1.16 E^{-5}
Aquatic Recreation	4.20 E^{-10}	4.20 E^{-10}	4.20 E^{-10}	4.20 E^{-10}	4.20 E^{-10}	4.20 E^{-10}
Airborne (ingestion)(c)	6.40 E^{-9}	7.60 E^{-10}	3.40 E^{-9}	4.60 E^{-8}	4.20 E^{-8}	6.20 E^{-10}

(a) Gastrointestinal tract (lower large intestine).

(b) Population affected: 2000

(c) 70-year accumulated dose.

TABLE 28. 70 YEAR DOSE COMMITMENT FOR THE POPULATION GROUP (WEST JEFFERSON) FROM EFFLUENTS RELEASED DURING CY 1984

Pathway	Dose (Person-rem)[b]					
	Whole Body	GI[a]	Thyroid	Kidneys	Bone	Lungs
Airborne (inhalation)	2.93 E^{-6}	1.36 E^{-7}	3.56 E^{-8}	1.15 E^{-5}	5.98 E^{-5}	1.26 E^{-4}
Airborne (ingestion)	1.86 E^{-8}	2.28 E^{-9}	7.20 E^{-9}	1.08 E^{-7}	1.20 E^{-7}	1.86 E^{-9}
Eating Fish	1.92 E^{-3}	2.82 E^{-7}	1.86 E^{-6}	1.02 E^{-4}	2.40 E^{-3}	3.48 E^{-5}
Aquatic Recreation	1.26 E^{-9}	1.26 E^{-9}	1.26 E^{-9}	1.26 E^{-9}	1.26 E^{-9}	1.26 E^{-9}
Airborne (ingestion)[c]	1.92 E^{-8}	2.28 E^{-9}	1.02 E^{-8}	1.38 E^{-7}	1.26 E^{-7}	1.86 E^{-9}

(a) Gastrointestinal tract (lower large intestine).

(b) Population affected: 6000.

(c) 70-year accumulated dose.

TABLE 29. 70-YEAR DOSE COMMITMENT FOR INTEGRATED 80-KILOMETER POPULATION FROM LIQUID EFFLUENTS RELEASED DURING CY 1984

Exposure Mode	Population Affected	Population Dose (Person-rem)					
		Whole Body	GI[a]	Thyroid	Kidneys	Bone	Lungs
Eating Fish	1.5×10^5	$4.80\ E^{-2}$	$7.10\ E^{-6}$	$4.60\ E^{-5}$	$2.50\ E^{-3}$	$6.00\ E^{-2}$	$8.70\ E^{-4}$
Aquatic Recreation	1.5×10^5	$3.20\ E^{-8}$	$3.20\ E^{-8}$	$3.20\ E^{-8}$	$3.20\ E^{-8}$	$3.20\ E^{-8}$	$3.20\ E^{-8}$

(a) Gastrointestinal tract (lower large intestine).

TABLE 30. 70-YEAR DOSE COMMITMENT FOR INTEGRATED 80 KILOMETER POPULATION FROM AIRBORNE EFFLUENTS RELEASED DURING CY 1984

Exposure Mode	80-Kilometer Population	Population Dose (person-rem)					
		Whole Body	GI[(a)]	Thyroid	Kidneys	Bone	Lungs
Foodstuff (ingestion)	1.73×10^6	$1.70\ E^{-7}$	$2.10\ E^{-8}$	$6.90\ E^{-8}$	$1.00\ E^{-6}$	$1.10\ E^{-6}$	$1.70\ E^{-8}$
Chronic (inhalation)	1.73×10^6	$8.91\ E^{-6}$	$4.10\ E^{-7}$	$1.06\ E^{-7}$	$3.48\ E^{-5}$	$1.82\ E^{-4}$	$3.81\ E^{-4}$
Foodstuff (ingestion)[(b)]	1.73×10^6	$1.80\ E^{-7}$	$2.10\ E^{-8}$	$9.60\ E^{-8}$	$1.30\ E^{-6}$	$1.20\ E^{-6}$	$1.70\ E^{-8}$

(a) Gastrointestinal tract (lower large intestine).

(b) 70-Year Accumulated Dose.

TABLE 31. PARAMETERS FOR WEST JEFFERSON SITE AIRBORNE RELEASE DOSE CALCULATIONS

Facility name:	JN-1 (Hot Lab)
Releases:	See Table 3
Meteorological conditions:	West Jeff meteorological station 1-year data (1/1-12/31/84), annual average
Dispersion model:	Gassian, BCL parameters
X/Q:	Maximum individual 8.15×10^{-5} sec/m^3 @ 122m SE 80-km population 7.95×10^{-9} sec/m^3
Release height:	24.2 meters effective (18.28 meters actual stack height)
Population distribution:	1.73×10^6, see Figure 12
Computer code:	DACRIN, version 1.2, Rev. 1980
Calculated dose:	Chronic inhalation, maximum individual and 80-km population, 70-year dose commitment
Files addressed:	Radionuclide Library, Rev. 1-15-81 Organ Data Library, Rev. 2-5-81
Computer code:	PABLM, version 2.1, Oct. 1980
Calculated dose:	Chronic ingestion, maximum individual and 80-km population, 70-year dose commitment
Files addressed:	Radionuclide Library, Rev. 1-15-81 Food Transfer Library, Rev. 2-27-78 Organ Data Library, Rev. 2-5-81 External Dose Factor Library. Rev. 3-15-81 Bioaccumulation Factor Library

TABLE 32. AVERAGE ANNUAL PERCENT FREQUENCY OF WIND DIRECTION AND AVERAGE WIND SPEED (M/S) FOR CY 1984

Direction		Percent	Average Speed (M/S)
N		4.2	4.6
NNE		3.8	4.1
NE		4.5	4.0
ENE		4.7	4.1
E		5.5	4.3
ESE		4.4	3.7
SE		4.7	4.2
SSE		4.0	3.9
S		5.2	4.3
SSW		7.8	4.9
SW		11.2	5.4
WSW		8.0	5.2
W		7.5	5.0
WNW		6.2	4.8
NW		5.8	4.6
NNW		3.9	4.1
CALM		8.6	---
	Total	100.0	4.1

TABLE 33. ANNUAL AVERAGE ATMOSPHERIC DISPERSION AROUND THE WEST JEFFERSON SITE FOR A 18 METER STACK HEIGHT RELEASE (UNITS ARE SEC/M^3) [(a)]

	Range in Miles (Km)									
Direction	0.5(0.8)	1.2(2.0)	2.5(4.0)	3.5(5.6)	4.5(7.2)	7.5(12)	15(24)	25(40)	35(56)	45(72)
N	3.20 E^{-5}	7.18 E^{-6}	2.04 E^{-6}	9.27 E^{-7}	7.11 E^{-7}	2.98 E^{-7}	9.61 E^{-8}	4.25 E^{-8}	2.47 E^{-8}	1.67 E^{-8}
NNE	3.59 E^{-5}	8.06 E^{-6}	2.29 E^{-6}	1.04 E^{-7}	7.98 E^{-7}	3.34 E^{-7}	1.08 E^{-7}	4.77 E^{-8}	2.77 E^{-8}	1.88 E^{-8}
NE	3.68 E^{-5}	8.26 E^{-6}	2.35 E^{-6}	1.07 E^{-6}	8.18 E^{-7}	3.43 E^{-7}	1.10 E^{-7}	4.89 E^{-8}	2.84 E^{-8}	1.93 E^{-8}
ENE	3.59 E^{-5}	8.06 E^{-6}	2.29 E^{-6}	1.04 E^{-7}	7.98 E^{-7}	3.34 E^{-7}	1.08 E^{-7}	4.77 E^{-8}	2.77 E^{-8}	1.88 E^{-8}
E	3.43 E^{-5}	7.69 E^{-6}	2.18 E^{-6}	9.91 E^{-7}	7.61 E^{-7}	3.19 E^{-7}	1.03 E^{-7}	4.55 E^{-8}	2.64 E^{-8}	1.79 E^{-8}
ESE	3.98 E^{-5}	8.93 E^{-6}	2.54 E^{-6}	1.15 E^{-6}	8.84 E^{-7}	3.71 E^{-7}	1.19 E^{-7}	5.28 E^{-8}	3.07 E^{-8}	2.08 E^{-8}
SE	3.51 E^{-5}	7.87 E^{-6}	2.24 E^{-6}	1.02 E^{-6}	7.79 E^{-7}	3.26 E^{-7}	1.05 E^{-7}	4.65 E^{-8}	2.71 E^{-8}	1.83 E^{-8}
SSE	3.78 E^{-5}	8.47 E^{-6}	2.41 E^{-6}	1.09 E^{-6}	8.39 E^{-7}	3.52 E^{-7}	1.13 E^{-7}	5.01 E^{-8}	2.91 E^{-8}	1.97 E^{-8}
S	3.43 E^{-5}	7.69 E^{-6}	2.18 E^{-6}	9.91 E^{-7}	7.61 E^{-7}	3.19 E^{-7}	1.03 E^{-7}	4.55 E^{-8}	2.64 E^{-8}	1.79 E^{-8}
SSW	3.01 E^{-5}	6.75 E^{-6}	1.92 E^{-6}	8.73 E^{-7}	6.67 E^{-7}	2.80 E^{-7}	9.02 E^{-8}	3.99 E^{-8}	2.32 E^{-8}	1.57 E^{-8}
SW	2.73 E^{-5}	6.12 E^{-6}	1.74 E^{-6}	7.91 E^{-7}	6.06 E^{-7}	2.54 E^{-7}	8.18 E^{-8}	3.62 E^{-8}	2.10 E^{-8}	1.43 E^{-8}
WSW	2.83 E^{-5}	6.36 E^{-6}	1.84 E^{-6}	8.36 E^{-7}	6.29 E^{-7}	2.64 E^{-7}	8.50 E^{-8}	3.76 E^{-8}	2.19 E^{-8}	1.48 E^{-8}
W	2.95 E^{-5}	6.61 E^{-6}	1.88 E^{-6}	8.55 E^{-7}	6.54 E^{-7}	2.74 E^{-7}	8.84 E^{-8}	3.91 E^{-8}	2.27 E^{-8}	1.54 E^{-8}
WNW	3.07 E^{-5}	6.89 E^{-6}	1.96 E^{-6}	8.91 E^{-7}	6.81 E^{-7}	2.86 E^{-7}	9.21 E^{-8}	4.07 E^{-8}	2.37 E^{-8}	1.60 E^{-8}
NW	3.20 E^{-5}	7.18 E^{-6}	2.04 E^{-6}	9.27 E^{-7}	7.11 E^{-7}	2.98 E^{-7}	9.61 E^{-8}	4.25 E^{-8}	2.47 E^{-8}	1.67 E^{-8}
NNW	3.59 E^{-5}	8.06 E^{-6}	2.29 E^{-6}	1.04 E^{-6}	7.98 E^{-5}	3.34 E^{-7}	1.08 E^{-7}	4.77 E^{-8}	2.77 E^{-8}	1.88 E^{-8}

(a) Calculated from meteorological data collected during the period 1-84 through 12-84.

TABLE 3[illegible]. BMI KING AVENUE SITE POPULATION
WITHIN 50 MILES

	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50	Total
N	1,205	4,202	8,700	7,216	8,502	26,724	7,615	11,143	15,914	24,936	116,157
NNE	2,225	8,882	10,041	10,061	9,073	36,911	8,315	9,702	8,687	13,102	116,999
NE	2,389	8,782	7,145	12,067	9,991	14,091	15,950	14,594	12,792	15,118	112,919
ENE	3,699	6,296	9,335	9,041	6,378	13,580	19,159	16,745	22,731	21,900	128,864
E	3,232	4,964	5,301	4,316	7,159	19,409	16,516	16,463	24,353	22,328	134,041
ESE	2,563	3,382	5,595	14,082	12,465	63,939	15,088	17,222	19,994	12,672	167,002
SE	4,232	2,719	7,523	17,120	17,140	16,319	19,666	18,241	18,211	9,927	131,098
SSE	1,679	3,685	6,098	10,100	14,492	21,466	12,312	11,862	13,044	10,022	104,760
S	1,346	1,797	5,940	2,969	2,229	5,673	9,019	8,323	13,122	16,497	66,915
SSW	837	1,685	6,718	9,083	4,526	17,293	10,880	8,284	10,637	14,278	84,221
SW	1,400	2,167	5,119	15,565	15,129	11,062	14,925	7,001	9,529	11,322	93,219
WSW	1,288	3,018	1,561	3,094	2,723	14,483	9,903	7,661	31,354	53,895	128,980
W	1,632	3,658	3,057	898	838	2,498	8,374	11,035	32,199	41,631	105,820
WNW	1,301	3,296	5,159	3,432	1,401	7,797	7,951	6,477	10,379	14,358	61,551
NW	1,150	2,990	5,497	5,720	7,371	6,505	9,288	7,062	9,984	13,974	69,601
NNW	963	3,363	4,383	5,132	5,540	7,463	7,956	10,381	15,148	25,452	85,781
Total	31,141	64,886	97,172	129,896	124,957	295,273	192,917	182,196	268,078	321,412	1,707,928

Total within 50 miles = 1,707,928

FIGURE 1. REGIONAL MAP FOR KING AVENUE AND WEST JEFFERSON SITES

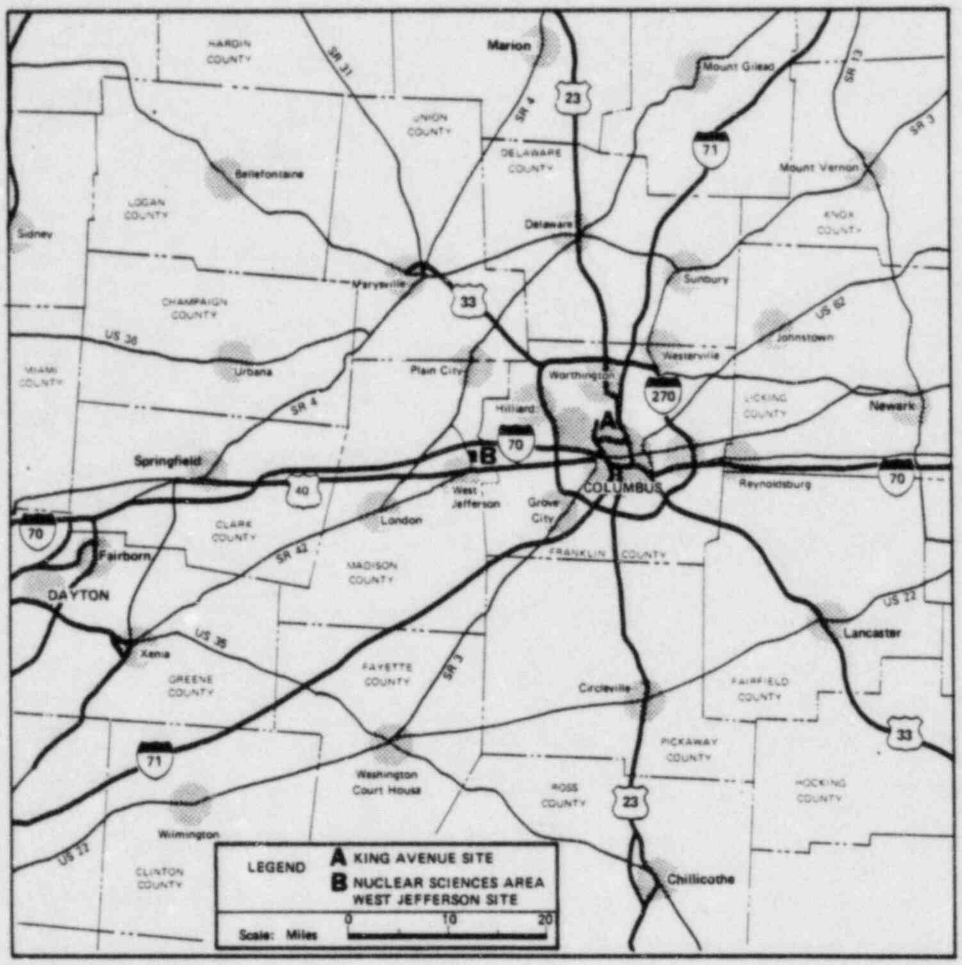


FIGURE 2. LOCAL VICINITY MAP OF KING AVENUE SITE

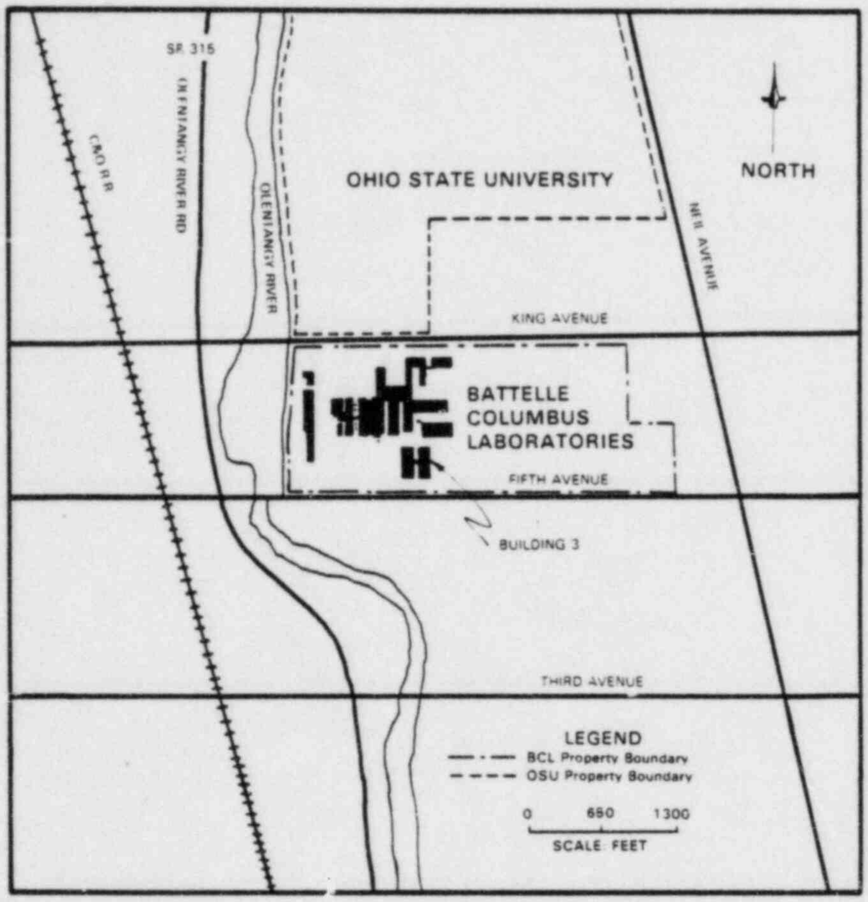


FIGURE 3. LOCAL VICINITY MAP OF NUCLEAR SCIENCES AREA WEST JEFFERSON SITE

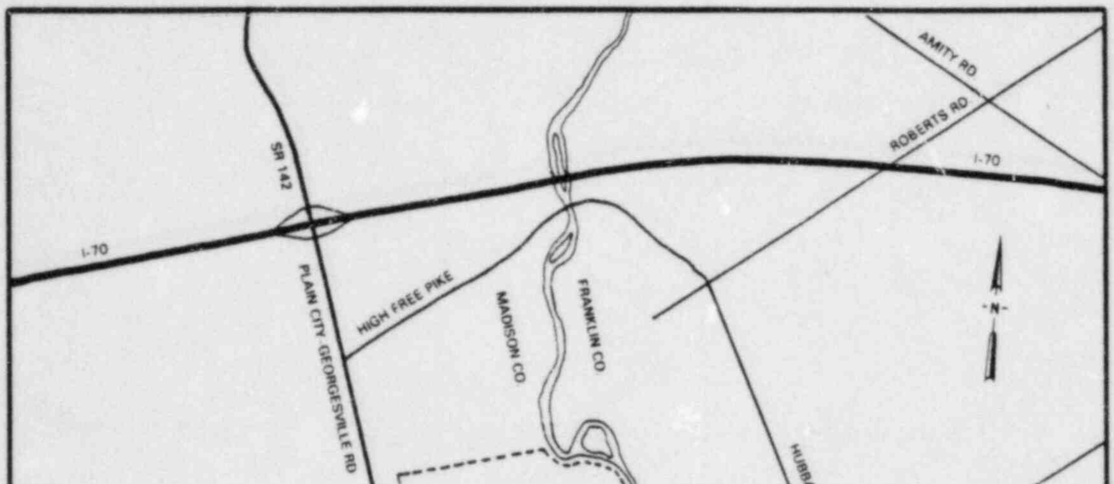


FIGURE 4. NUCLEAR SCIENCES AREA WEST JEFFERSON SITE

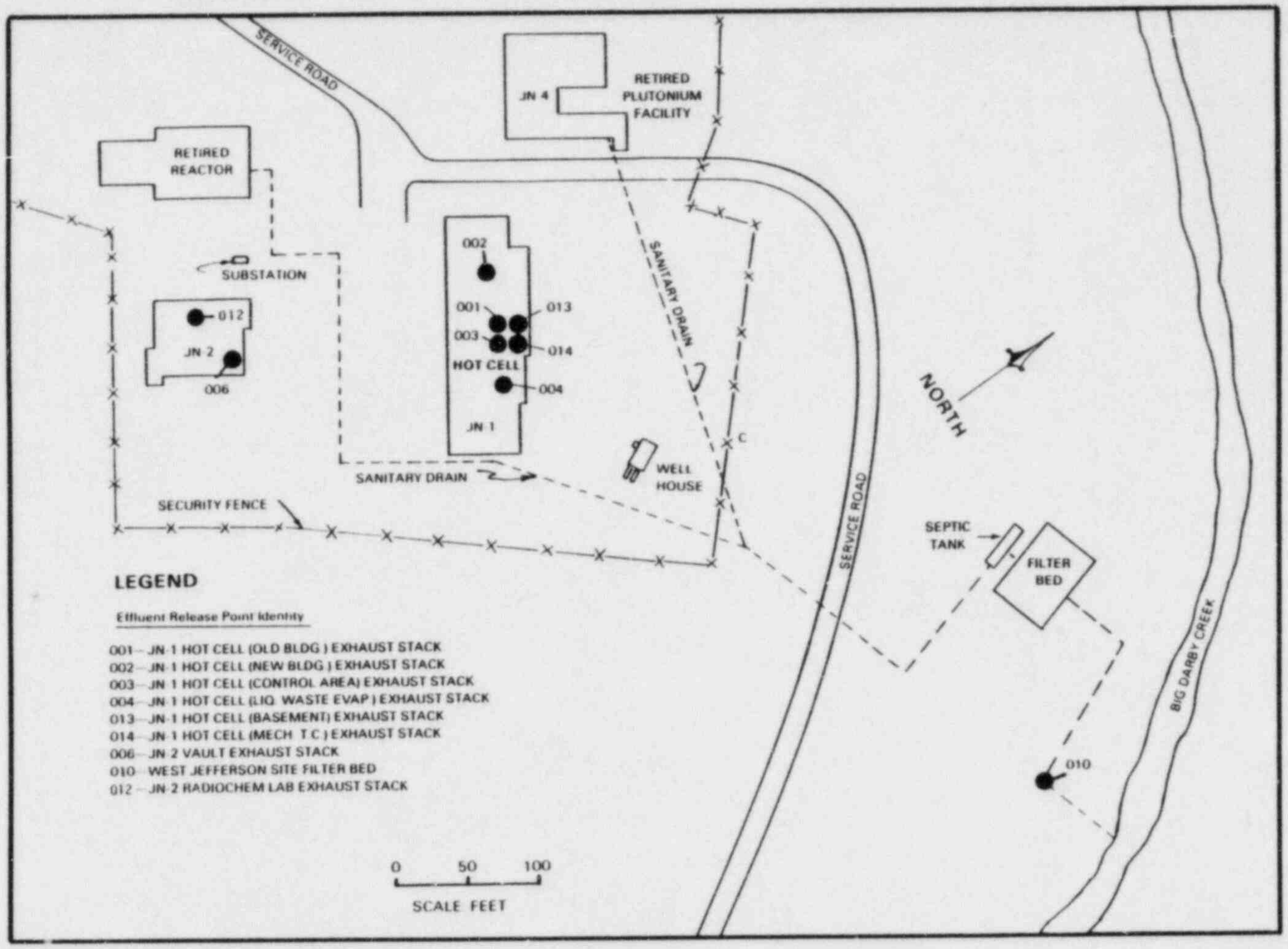


FIGURE 5. MAP OF GRASS, FOODCROP AND SOIL SAMPLING LOCATIONS

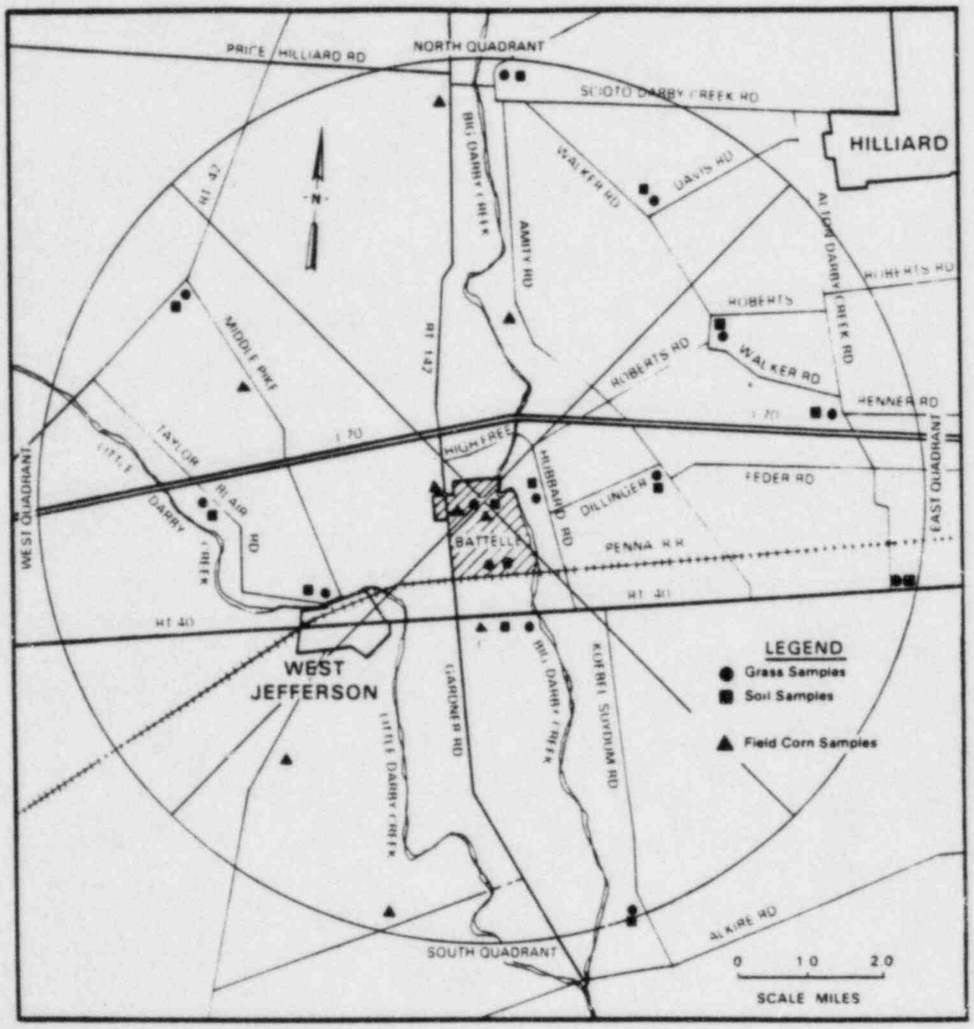


FIGURE 6. MAP OF SITE BOUNDARY AIR SAMPLING LOCATIONS AND BATTELLE LAKE AND DARBY CREEK WATER AND SEDIMENT SAMPLING LOCATIONS

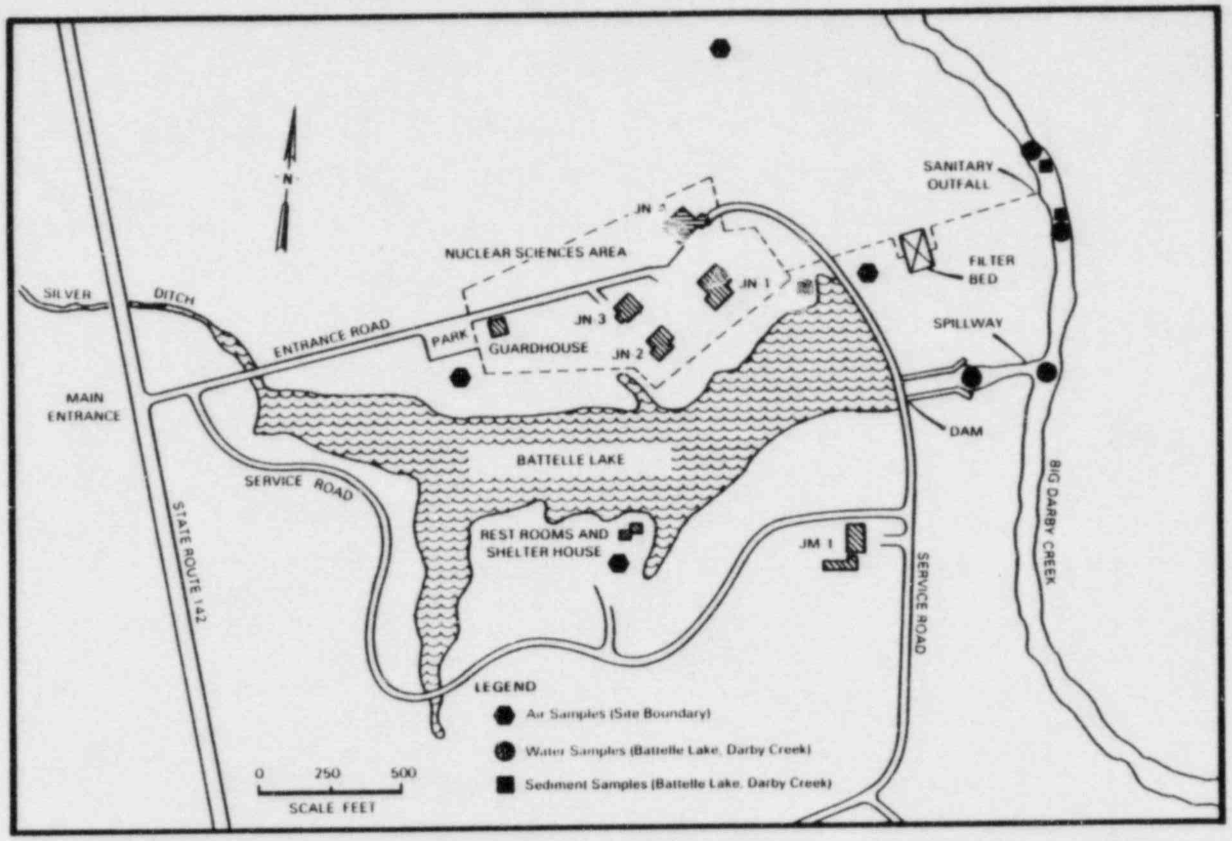


FIGURE 7. BATTELLE'S COLUMBUS LABORATORIES
KING AVENUE SITE

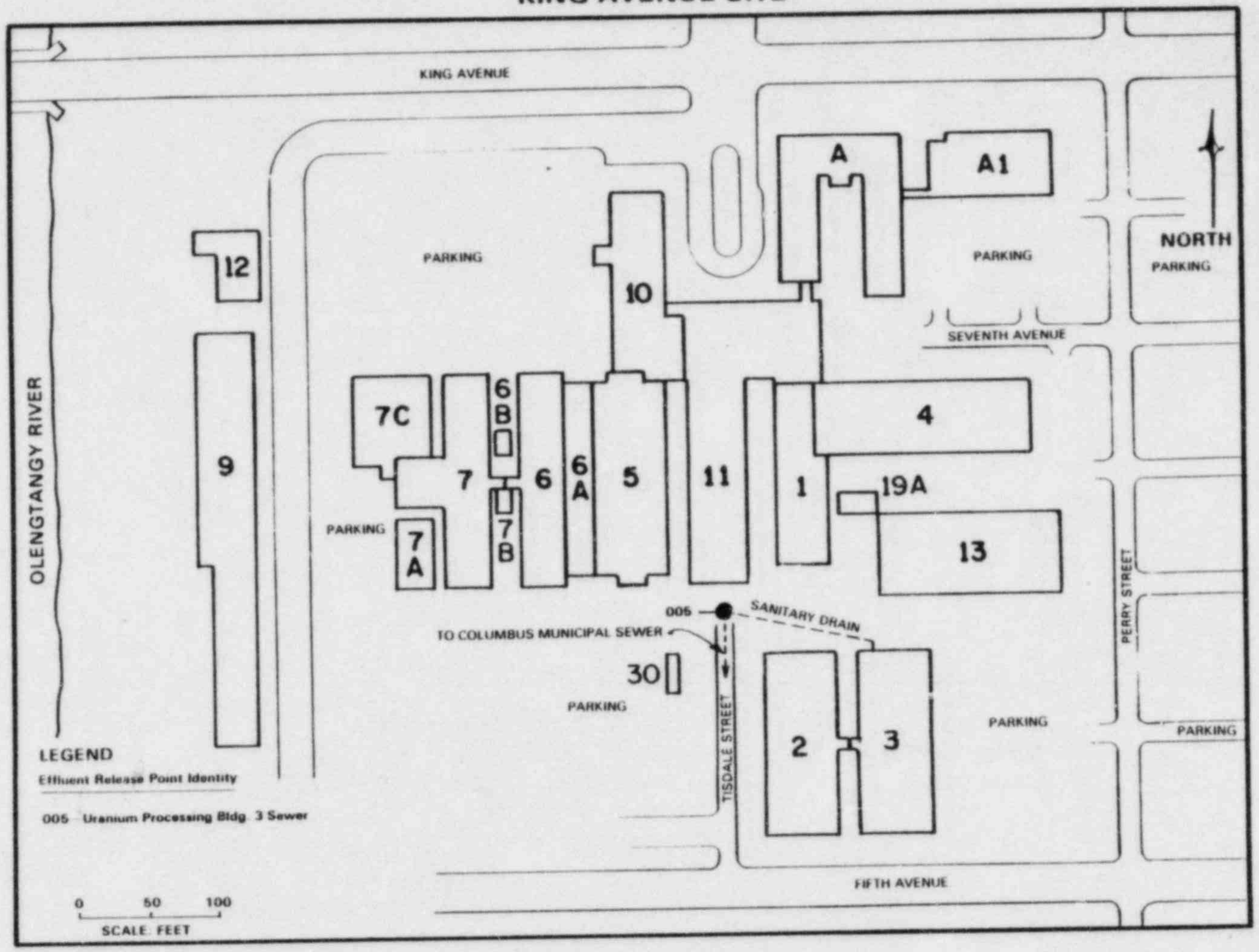


FIGURE 8. MAP OF TLD LOCATIONS WITHIN ¾ MILE RADIUS OF THE NUCLEAR SCIENCES AREA

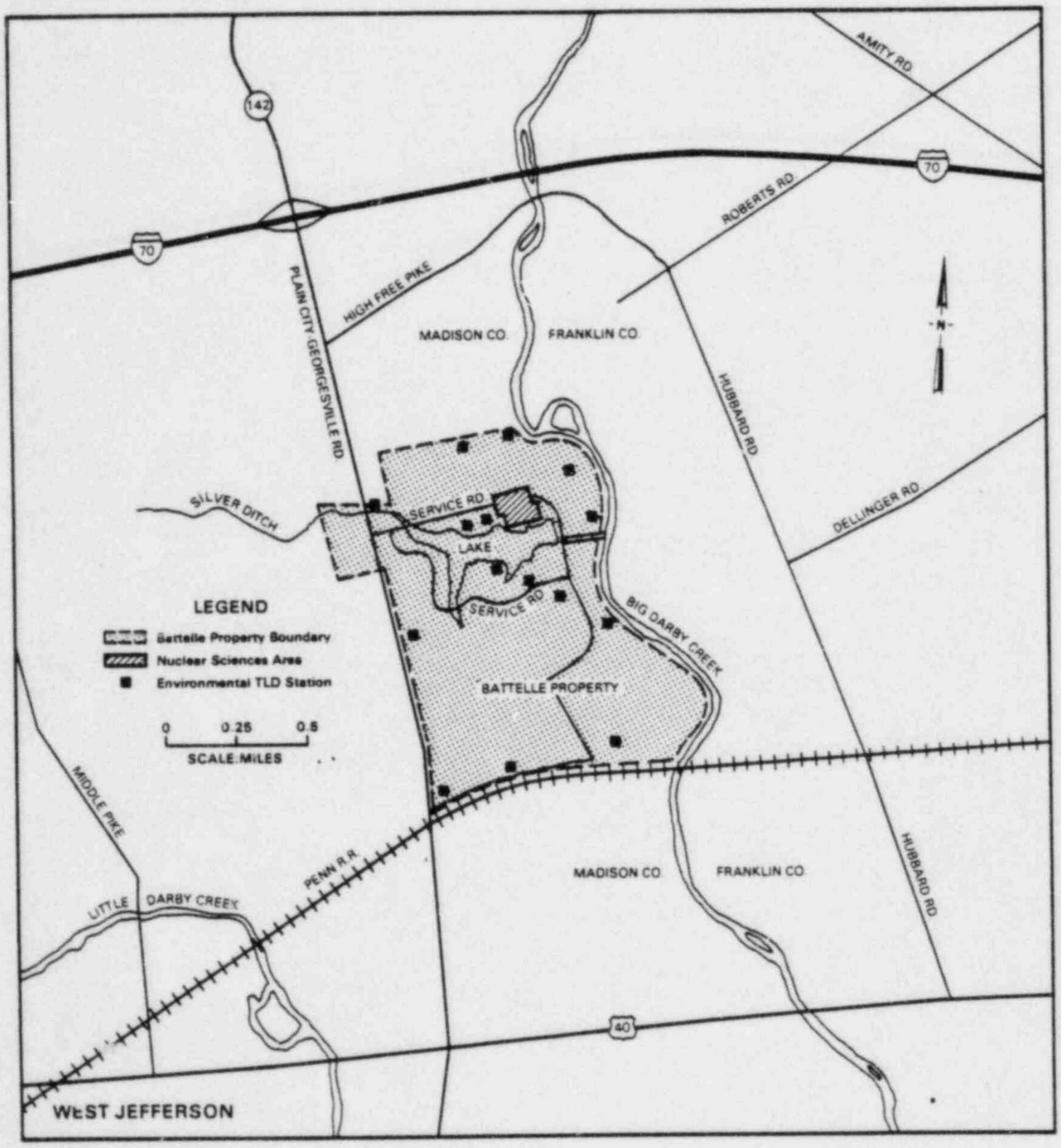


FIGURE 9. MAP OF TLD LOCATIONS AT THE PERIMETER SECURITY FENCE

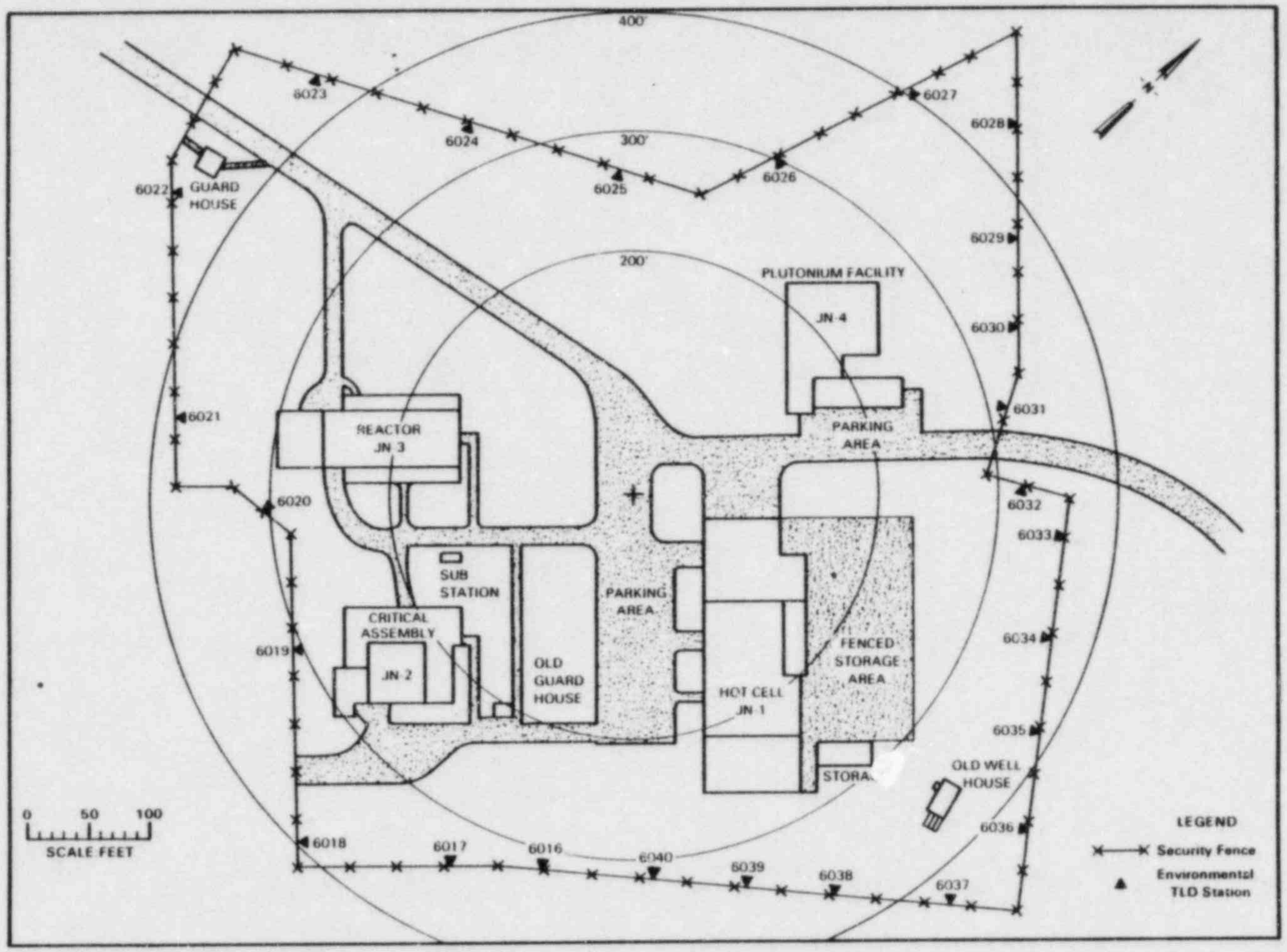


FIGURE 10. MAP OF COLUMBUS AND VICINITY SHOWING OFF SITE AIR SAMPLING LOCATIONS

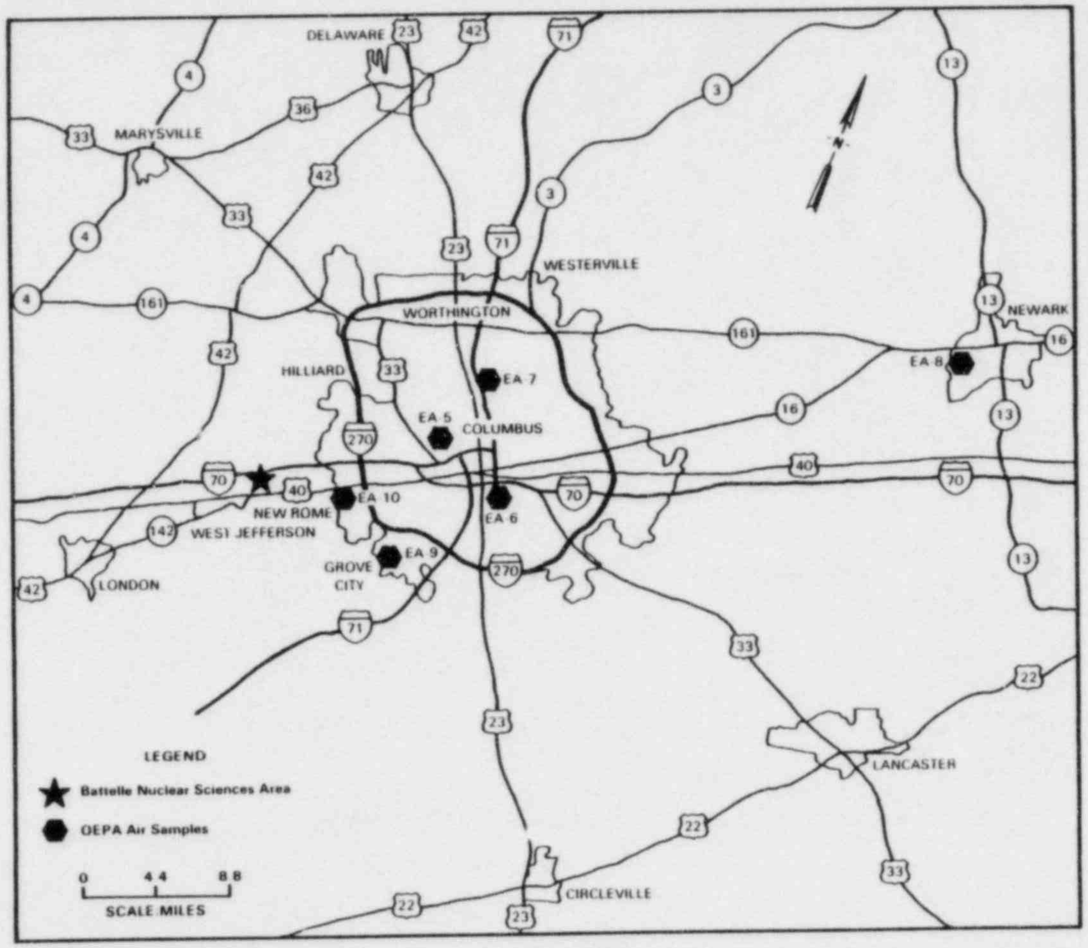


FIGURE 11. 1984 WIND ROSE PATTERN FOR WEST JEFFERSON SITE

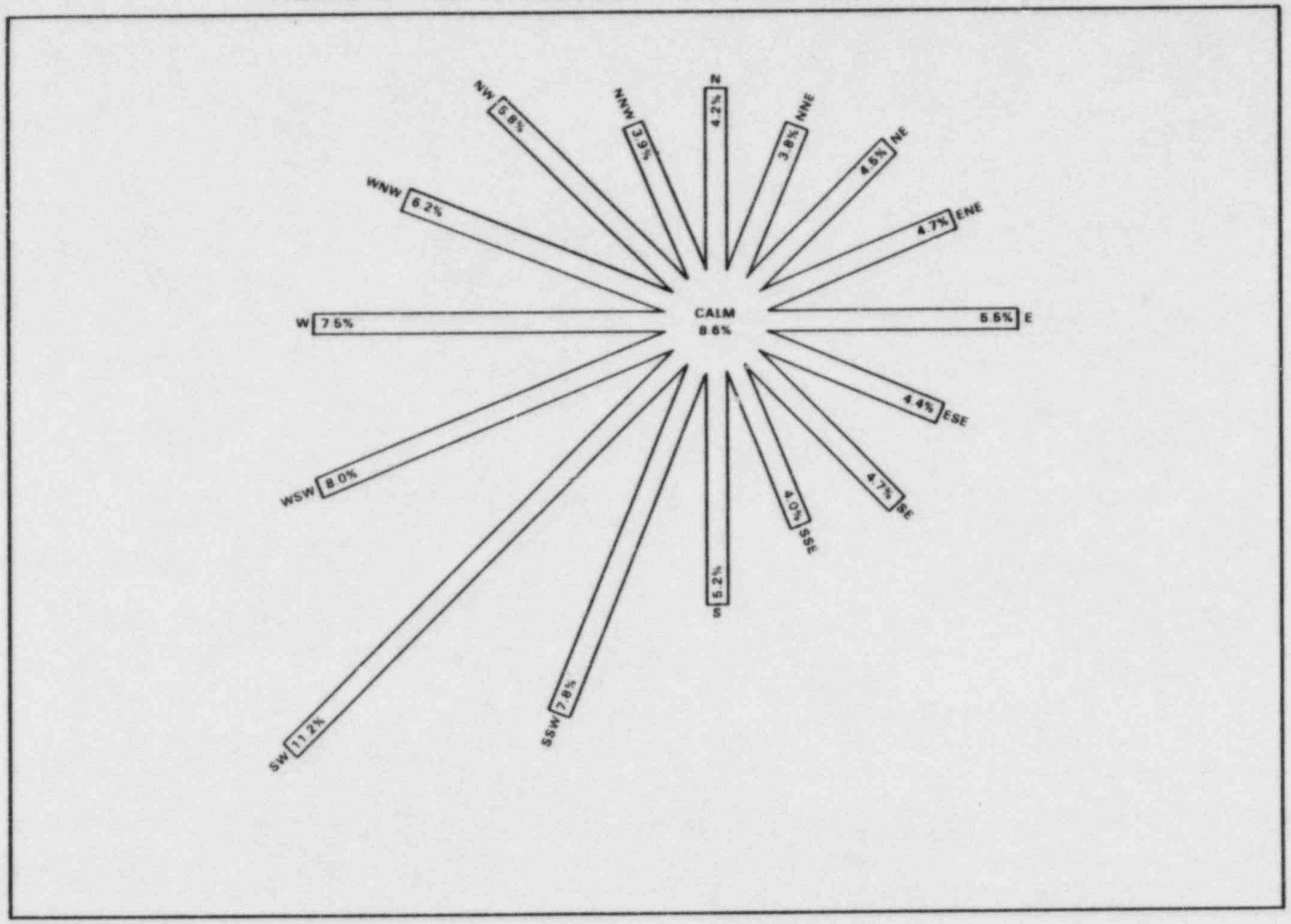


FIGURE 12. 1980 POPULATION WITHIN 80 km OF THE WEST JEFFERSON SITE

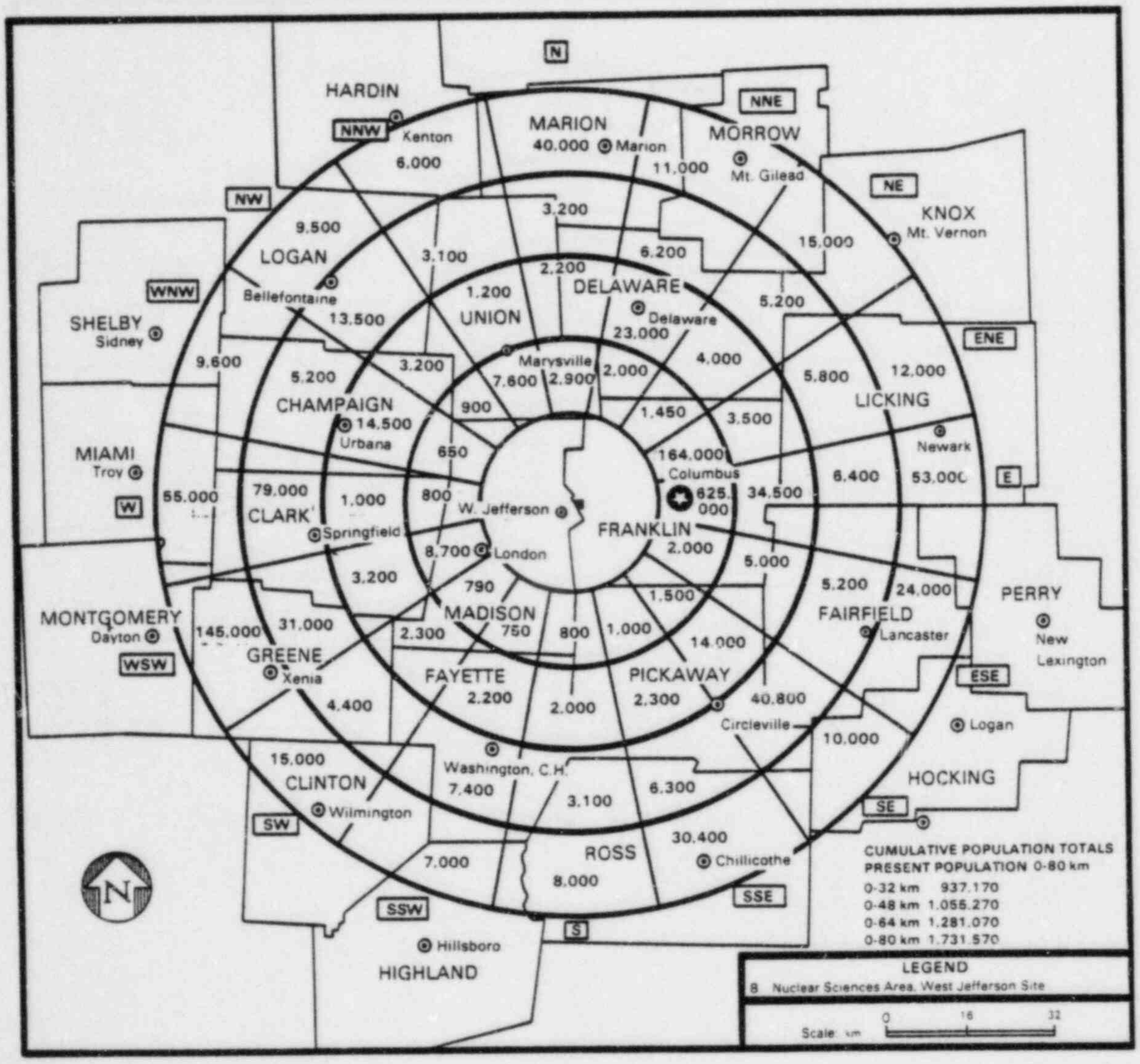
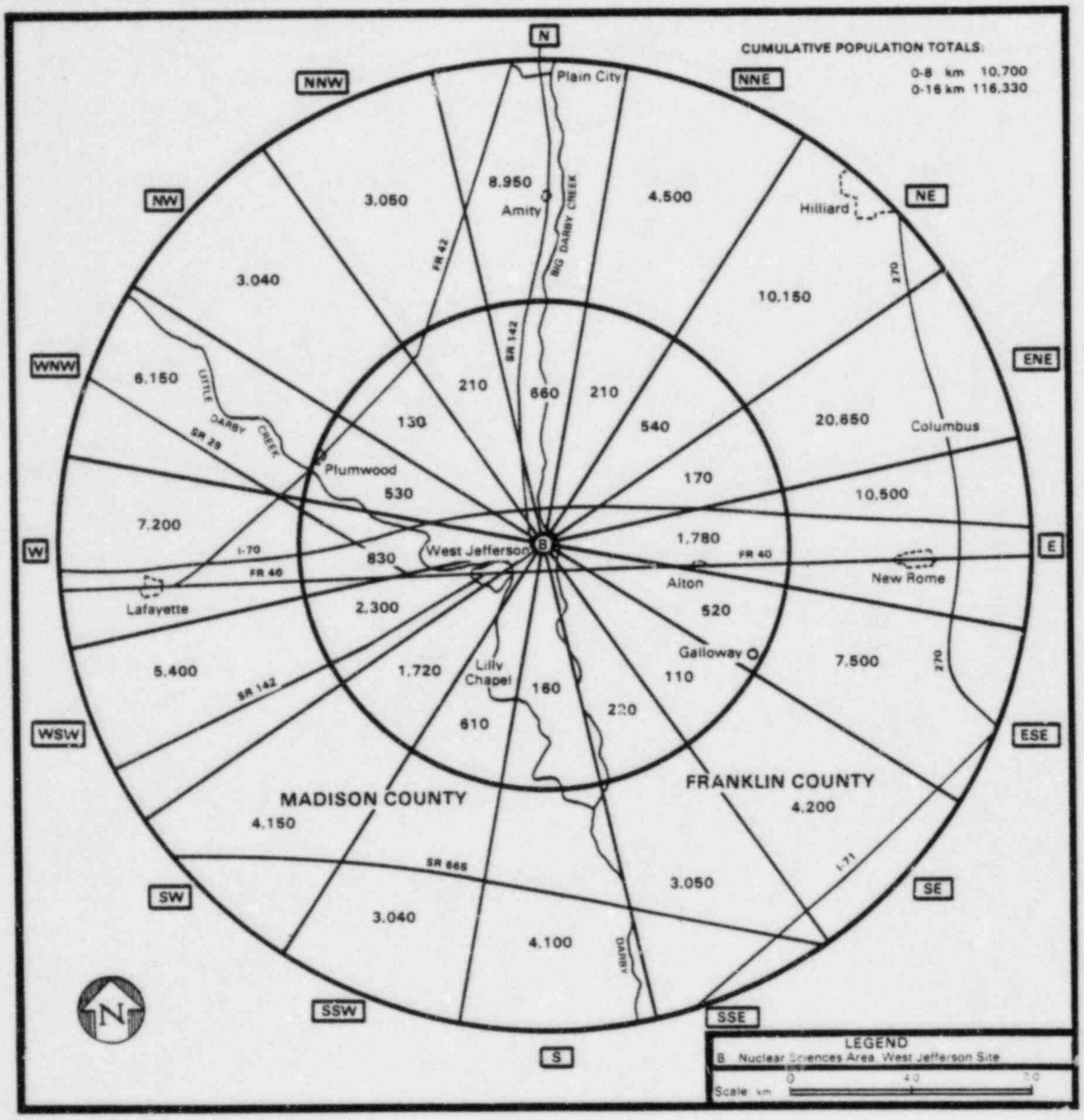


FIGURE 13. 1980 POPULATION WITHIN 16 km OF THE WEST JEFFERSON SITE



APPENDIX

APPENDIX

ADDITIVE LEVELS DUE TO RADIONUCLIDE MIXTURE

The "Requirements for Radiation Protection" (DOE Order 5480.1, Chapter XI) states that a radionuclide may be considered as not present in a mixture if the ratio of its concentration to its RCG is not greater than one-tenth. Furthermore, the sum of all such excluded ratios cannot exceed one-fourth the sum of the ratios of the concentrations of radionuclides to their respective RCG's are listed below. The ratios are presented for maximum levels at the release point in both air and water.

West Jefferson Site

Radionuclide	Radionuclide Concentration / RCG Air
Plutonium-239	2.83×10^{-2}
Cobalt-60	9.36×10^{-7}
Actinium-228	1.75×10^{-6}
Lead-212	6.27×10^{-7}
Cesium-137	2.84×10^{-6}
Strontium-90	4.38×10^{-9}
Cerium-144	1.43×10^{-5}
Antimony-125	1.60×10^{-6}
Uranium-235	1.87×10^{-4}
Krypton-85	4.23×10^{-2}
Niobium-95	2.78×10^{-8}
Sum	7.08×10^{-2}

West Jefferson Site

Radionuclide	Radionuclide Concentration RCG Water
Uranium-235	1.57×10^{-4}
Lead-212	2.25×10^{-4}
Radium-228	1.43×10^{-2}
Radium-226	7.67×10^{-3}
Strontium-90	5.30×10^{-3}
Iodine-129	9.17×10^{-2}
Plutonium-238	1.00×10^{-5}
Plutonium-239	6.00×10^{-6}
Cesium-137	1.70×10^{-4}
Actinium-228	7.78×10^{-5}
Sum	1.20×10^{-1}

The data indicate that, according to the criteria of DOE Order 5480.1, Chapter XI, the sum of the above ratios does not exceed one-fourth; therefore, these nuclides are not considered as part of the mixture.

APPLICABLE STANDARDS

Radioactive Standards

In conformance with Federal Radiation Council (FRC) guidelines and DOE Order 5480.1 Chapter XI, "Standards for Radiation Protection," site boundary concentrations are compared with RCG's established for uncontrolled areas.

Uncontrolled Area (Site Boundary)

Air	Concentration, µCi/ml
Plutonium-239	6×10^{-14}
Krypton-85	3×10^{-7}
Cobalt-60	3×10^{-10}
Cesium-137	5×10^{-10}

Uncontrolled Area (Site Boundary)

Air	Concentration, Ci/ml
Actinium-228	6×10^{-10}
Lead-212	6×10^{-10}
Cerium-144	2×10^{-10}
Strontium-90	3×10^{-11}
Uranium-235	4×10^{-12}
Antimony-125	9×10^{-9}
Niobium-95	3×10^{-9}
Water	
Iodine-129	6×10^{-8}
Radium-226	3×10^{-8}
Radium-228	3×10^{-8}
Plutonium-238	5×10^{-6}
Plutonium-239	5×10^{-6}
Strontium-90	3×10^{-7}
Lead-212	2×10^{-5}
Cesium-137	2×10^{-5}
Actinium-228	9×10^{-5}
Uranium-235	3×10^{-5}

Mixture

DOE Order 5480.1, Chapter XI, "Requirements for Radiation Protection," provides for the calculation of guide values in any case where there is a mixture of radionuclides in air or water. The ratio between the concentration of each radionuclide present in the mixture and its repective RCG must first be determined. The sum of these ratios for all radionuclides in the mixture should not exceed unity. A radionuclide may be considered as not present in the mixture unless the ratio of the concentration of the radionuclide to its RCG is greater than one-tenth, provided that the sum of such excluded ratios does not exceed one-fourth.

Grass and Food Crops

There are no guidelines established for radionuclides in grass and food crops.

Soil and Sediment

There are no guidelines established for radionuclides in soil and sediment. The Environmental Protection Agency's radiation protection requirements for exposures to transuranium elements in the environment necessitates doses to the critical fraction of the unrestricted population be less than 1 mRad/yr to the pulmonary lung and 3 mRad/yr to the bone.

Fish

There are no guidelines established for radionuclides in fish.

Nonradioactive Standards (Water)

Concentrations of nonradioactive species in water are subject to the restrictions of the (NPDES) Permit as were determined by the Ohio EPA following a study of the Scioto River Basin.

External Radiation - General Public

The permissible level of radiation in an uncontrolled area is that which will cause any individual to receive a dose, to the whole body, not exceeding 0.5 rem in any period of one calendar year.

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