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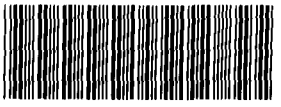

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# ANNUAL ENVIRONMENTAL MONITORING REPORT
# U S ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
## Rocky Flats Plant

**January through December 1976**


Environmental Analysis and Control
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SUBJECT DESCRIPTORS

Air
Americium
Beryllium
Dose Assessment
Effluents
Plutonium
Soil
Standards
Tritium
Uranium
Water
Weather Summary



ROCKWELL INTERNATIONAL
ATOMICS INTERNATIONAL DIVISION
ROCKY FLATS PLANT
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# U S ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
## Rocky Flats Plant

**January through December 1976**

*Daryl D Hornbacher*

## INTRODUCTION

The Rocky Flats Plant is a Government-owned and contractor-operated facility It is part of a nationwide research, development, and production complex that is administratively controlled by the Albuquerque Operations Office of the U S Energy Research and Development Administration (ERDA) The prime operating contractor is Rockwell International, Atomics International Division Construction of the facility began in 1951, it became operational in 1952

The Rocky Flats Plant is located in northern Jefferson County, Colorado, almost equidistant from the cities of Boulder, Golden, and Arvada The facility is approximately 26 kilometers (16 miles) northwest of downtown Denver, at 105° 11′ 30″ west longitude and 30° 53′ 30″ north latitude (see Figure 1*) The site consists of approximately 2,650 hectares (6,500 acres) of federally-owned land As shown in Figure 2, major Plant structures are located within a security-fenced area of 155 hectares (385 acres)

The Plant is a key ERDA facility for producing components for nuclear weapons, thus most of the work is directly related to national defense The Plant is involved in fabricating components from plutonium, uranium, beryllium, and stainless steel Production activities include numerous metal working, fabrication, and assembly shops, chemical recovery and purification processes, and associated quality control functions Research and Development programs include chemistry, physics, materials technology, ecology, nuclear safety, mechanical engineering, health physics, and environmental control

As part of ERDA's energy research programs, a Small Wind Energy Conversion Systems (SWECS) test facility is being constructed by Rockwell in the northwest corner of the Rocky Flats Plant site This test facility will be a key national research center in the development of wind energy devices

The more than 100 structures that now constitute the Plant represent about 2 1 million square feet of floor space Of this, the major fabrication (manufacturing), chemical processing, and waste treatment facilities account for about 1 4 million square feet (this includes about 331,000 square feet for a new plutonium recovery and waste treatment complex now under construction) The major laboratory and research buildings account for about 154,000 square feet The remaining floor space is divided among administrative, utility, security, warehousing, storage, and construction contractor facilities

All of the Plant's heating requirements are met by in-plant steam boilers that normally use natural gas but also are capable of using fuel oil During Calendar Year 1976, approximately 568 million cubic feet of natural gas and approximately 813 thousand gallons of fuel oil were used to meet the Plant's heating requirements Raw water is obtained from the Denver Water Board and is drawn from

*Figures appear at the end of this report

the Ralston Reservoir and the South Boulder Diversion Canal The Rocky Flats Plant used approximately 116 million gallons of water during 1976

The natural environment of the Plant site and vicinity is influenced primarily by two things (1) the Front Range of the Rocky Mountains, which is immediately west of the site, and (2) the site elevation, which is approximately 1,829 meters (6,000 feet) above sea level The surficial geology of Rocky Flats consists of a thin layer of gravelly topsoil underlain by a 6- to 15-meter-thick layer (20- to 49-feet) of coarser, clayey gravel This, in turn, is underlain by an impermeable bedrock structure upon which most of the building foundations are supported Area hydrology is influenced by the topsoil, which consists of gravelly and highly permeable alluvium Little water is retained in the soil, and vegetation in the area is sparse Assorted low-growing prairie grasses, prickly pear, and spanish bayonet cactus constitute the main ground cover Cottonwood trees grow adjacent to watercourses The piedmont of the Front Range of the Rocky Mountains rises 8 kilometers (5 miles) west of the site, and crests at the continental divide 32 kilometers (20 miles) beyond These topographic features, in combination with atmospheric processes and solar radiation, produce a harsh, semiarid climate that is reflected in the natural ecology of the site

All process wastewater is analyzed and, if required, radioactive and nonradioactive contaminants are removed prior to the wastewater being stored in evaporation and retention ponds located on the Plant site Stationary wastewater is treated by an on-site tertiary treatment facility As shown in Figure 3, surface water runoff from the Plant is from west to east Runoff is carried from the Plant boundaries by three major drainage basins that are tributary to Walnut Creek on the north and to Woman Creek on the south The south fork of Walnut Creek is the main effluent watercourse from the Plant The confluence of the north and south forks of Walnut Creek is 1 1 kilometers (0 7 mile) west of the Plant's eastern boundary Great Western Reservoir, a major water supply for the City of Broomfield, is about 1 6 kilometers (1 mile) east of this confluence Woman Creek flows east from Rocky Flats into Standley Lake, a water supply for the City of Westminster and for portions of the cities of Northglenn and Thornton The north fork of Walnut Creek, south fork of Walnut Creek, and Woman Creek watercourses are designated A, B, and C respectively

Personnel in the Environmental Sciences Department of Rockwell International at Rocky Flats conduct an ongoing environmental monitoring and sampling program The program is designed to provide assurance that the many safeguards in use are working properly Also, the program provides assurance that discharges of materials are as low as practicable and within the limits set by appropriate regulatory agencies

The environs are monitored and sampled for radioactivity and for chemical and biological pollutants Air, water, and soil are sampled not only on the Plant site but also in the surrounding region Several Federal, State, and local governmental agencies conduct additional, independent, environmental surveys on and off the Plant site The Colorado Department of Health samples air, soil, and water around the Rocky Flats site as part of its statewide surveillance program The Jefferson County Health Department performs monthly sewage-plant effluent sampling and analysis and has one continuous particulate air sampler on-site that is operated by the Colorado Department of Health The New York ERDA Health and Safety Laboratory conducts particulate air sampling in the vicinity of the Rocky Flats Plant and periodically performs soil sampling and analysis Additional monitoring or sampling is performed by the U S Environmental Protection Agency (EPA)

The information contained in this report is a compilation of data provided monthly to the Rocky Flats Area Office of ERDA, the Division of Occupational and Radiological Health of the Colorado Department of Health, the Regional Office of the EPA, the health departments of Boulder and Jefferson Counties, and to interested city officials in communities near the Plant

## SUMMARY

During 1976, the Rocky Flats Plant conducted an environmental monitoring program that included the sampling and analysis of air, water, and soil on and off the plant site Also, measurements of environmental penetrating-radiation dose were made using thermoluminescent dosimeters (TLD's)

Particulate samples were collected from air samplers that operated continuously at distances of 3 to 6 kilometers (2 to 4 miles) and in 12 communities that range from approximately 19 kilometers (12 miles) to 26 kilometers (16 miles) from the Plant Analysis of these samples for plutonium indicated that airborne plutonium in communities surrounding the Plant was within the range attributed to fallout from nuclear weapons testing The average plutonium concentration within 3 to 6 kilometers and in community ambient air was less than 0 08 percent of the applicable ERDA-established Radioactivity Concentration Guide (RCG)

Plutonium, uranium, americium, and tritium concentrations were monitored in South Walnut Creek (Pond B-4 monitoring station, see Figure 3), which contains effluents from Rocky Flats' sanitary waste treatment plant Similar monitoring was conducted at Ponds A-3 and C-1 monitoring stations in the other two watercourses that provide surface drainage from the Plant site All effluents were determined to be less than 0 13 percent of the applicable RCG

During 1976, all sanitary wastes were processed through a tertiary treatment system before being discharged from the Plant All Plant discharges were monitored for compliance with the Plant's NPDES* discharge permit No violations of the monthly discharge limitations occurred, however, the daily limitation for biochemical oxygen demand was exceeded on three occasions These exceptions were not believed to have been of any health or environmental consequence Overall, the monitoring of chemical or biological constituents indicated that the tertiary treatment plant provided effective treatment of the sanitary effluent

*National Pollutant Discharge Elimination System—an EPA permit identifying permissible discharge levels of various non-radioactive effluents

The plutonium, uranium, americium, and tritium radioactivity concentrations were measured in Great Western Reservoir and in Standley Lake during 1976 and were found to be less than 0 10 percent of the applicable RCG values Plutonium, uranium, and americium radioactivity concentrations, as measured in the drinking water from nine communities in the area, averaged less than 0 03 percent of the applicable RCG values

Soil samples are collected annually from locations at distances of 1 6 kilometers (1 mile), 3 2 kilometers (2 miles), and 8 0 kilometers (5 miles) from the Plant site at intervals of 18 degrees of arc Analysis of 56 soil samples collected during 1976 indicated little change in the plutonium concentration in soil The majority of above-background values were found in the eastern sector of the sampling grid system These elevated readings were east of an area in which the soil is known to contain some plutonium

An assessment was made of the Plant's contribution during 1976 to public radiation dose Results indicated that the maximum individual dose at the Plant perimeter was approximately 0 11 millirem per year, and the maximum individual dose at an occupied location was 0 04 millirem in Broomfield, Colorado The total population dose for this city was 0 55 man-rem These values represent 0 023, 0 008, and 0 022 percent respectively of the appropriate ERDA individual and population dose guides Total dose to the population living within 80 kilometers (50 miles) was calculated to be 11 1 man-rem In comparison, background radiation exposure in adjacent areas around the Plant was found to be approximately 117 millirem per year The background radiation, caused by terrestrial and cosmic sources, was measured using TLD's. This background radiation exposure results in an annual dose of 237,000 man-rem to the population living within 80 kilometers of the Plant

## SITE METEOROLOGY AND CLIMATOLOGY

A 61-meter (200-foot) meteorological tower and a digital data acquisition system were installed at Rocky Flats in March 1975 This system includes sensors for measuring wind speed, wind direction,

ambient temperature, solar radiation, dew point, barometric pressure, and precipitation Ambient temperature sensors are located at the 6-meter (20-foot), 30-meter (100-foot), and 61-meter (200-foot) levels on the tower Wind-speed and wind-direction sensors are located at the 6-meter and 61-meter levels

The wind-speed and wind-direction sensors are automatically sampled at 2-second intervals and averaged at 10-minute intervals Each 10 minutes, average wind speed, average wind direction, peak gust velocity, total precipitation, instantaneous dew point, and instantaneous barometric pressure are recorded

A summary of temperature, precipitation, and wind data is given in Table I (tables follow at the end of text, beginning on Page 13) Wind roses for the 6-meter and 61-meter level during 1976 are shown in Figures 4 and 5 respectively More detailed weather data is available in the Rocky Flats Plant Annual Weather Summary – 1976 [1]

## MONITORING, DATA COLLECTION, ANALYSIS, AND EVALUATION

### Applicable Guides and Standards

The U S Energy Research and Development Administration published what is called Radioactivity Concentration Guides (RCG) [2] These guides govern permissible concentrations of radionuclides in air ($RCG_a$) and water ($RCG_w$) accessible for intake by occupationally exposed individuals, incidentally exposed individuals, and the population at large The guides are based on recommendations published by the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurement (NCRP) Numerical values of these guides are cited in appropriate tables presented elsewhere in this report In all cases, these values are as restrictive or more restrictive than those limits set by the Nuclear Regulatory Commission in regulating nuclear facilities in private industry

All radionuclides in Plant effluents and environmental samples are assumed to be soluble for purposes of comparison with appropriate concentration guides This assumption serves as an additional safeguard since the RCG for soluble radionuclides are generally more restrictive than those for insoluble radioactive materials

The Rocky Flats administrative guide value for concentrations of plutonium in airborne effluents is $20 \times 10^{-15}$ microcuries per milliliter ($\mu$Ci/ml) This value is ERDA's ambient-air, soluble plutonium concentration guide for the population at large The Rocky Flats administrative guide value for uranium isotopes in airborne effluents is $3 \times 10^{-12}$ $\mu$Ci/ml The ERDA soluble plutonium concentration guide value in waterborne effluents for a suitable sample of the general population is $1667 \times 10^{-9}$ $\mu$Ci/ml The comparable ERDA guide for americium-241 in water is $1330 \times 10^{-9}$ $\mu$Ci/ml The EPA's discharge limitation for beryllium (a nonradioactive material) is 10 grams per stationary source in a 24-hour period [3]

The Rocky Flats Plant NPDES permit, issued in 1974 by the EPA, established effluent concentration limitations for total nitrogen, phosphate, 5-day biochemical oxygen demand, fluoride, dissolved oxygen, residual chlorine, total suspended solids, fecal coliform bacteria, total chromium, oil and grease, and pH in the sewage treatment plant discharge [4] It also established limitations for nitrate and pH in the discharge from Holding Pond A-3 in Walnut Creek Numerical values of the effluent concentration limitations are cited in Tables 4 and 12

### Background Radioactivity

Although the guide values for radioactivity relate to concentrations above background, the measurements given in this report include contributions from fallout and from radioactive materials found in air, soil, and water on the eastern slope of the Colorado Rockies Typical regional background values for radioactive materials in environmental media are listed with references in Table 2

Environmental background penetrating-radiation is measured using TLD's at 45 locations on and around the Rocky Flats Plant site These measurements are made over a period of approximately three months TLD's are placed at 17 locations within the inner area shown in Figure 2 Measurements are also made at 16 locations at 3 to 6 kilometers (2 to 4 miles) from the Plant and in 12 communities located within about 32 kilometers (20 miles) of Rocky Flats

At each location, two TLD's are placed at a height of 1 8 to 2 4 meters (6 to 8 feet) above ground level Each TLD consists of a sealed glass bulb enclosing two extruded ribbons of $CaF_2$ Mn that sandwich a central metal heater strip The TLD's are enclosed in a case equipped with an energy compensating shield

The 1976 TLD environmental measurements are given in Table 3 The arithmetic means for the TLD values, as measured on-site, in the environs, and in the communities, were 113, 106, and 117 millirem per year respectively These values are statistically indistinguishable and are considered to be typical background values derived from terrestrial and cosmic radiation at or near Rocky Flats

## Analytical Procedures

Analysis for plutonium, uranium, and americium is conducted in the following manner Prior to any separation of elements from the sample matrix, a known quantity of non-indigenous radioactive tracer is added to each sample These tracers are used to determine counting efficiency and chemical recovery The tracers used for plutonium, uranium, and americium are plutonium-236, uranium-236, and curium-244, respectively

Separation of the radioisotopes from the environmental and effluent matrices is performed by ion exchange techniques The purified radioisotopes are electrodeposited onto stainless steel disks and radiometrically determined by alpha pulse height spectrometry [5]

## Detection Limits

Table 4 shows nominal values for the Minimum Detectable Concentrations (MDC) of materials in various media The values shown are for typical sample volumes as used in the Rocky Flats monitoring program For any individual sample, the MDC may be greater or smaller, depending on the size of the sample collected and analyzed Table 4 also lists the various nonradioactive standards and radioactivity concentration guides applicable to airborne and waterborne effluent releases from the Rocky Flats Plant

## Data Reduction

Throughout the data presented, samples with concentrations below the MDC were considered to have the MDC value for averaging purposes When one or more MDC values are included in a set of values, the computed mean value of that set is indicated by a less-than sign (<). The average concentrations ($C_{avg}$) are represented by pairs of numbers (of the form a ±b%) that define the 95% confidence interval for $C_{avg}$. This interval is centered at the arithmetic mean of the observed concentrations ($\bar{c}$). The probability (P) that $C_{avg}$ lies within the stated interval is 95%, or

$$P\left[\left(\bar{c} - t_{0.975}\sqrt{\frac{\sum_{i=1}^{n} c_i^2 - n\bar{c}^2}{n(n-1)}}\right) < C_{avg} < \left(\bar{c} + t_{0.975}\sqrt{\frac{\sum_{i=1}^{n} c_i^2 - n\bar{c}^2}{n(n-1)}}\right)\right] = 0.95$$

Where,

$\bar{c}$ = the arithmetic mean of observed concentrations It is volume weighted whenever the volume is measured

$t_{0\ 975}$ = value taken from a standard t-test table

n = number of samples

$c_1$ = an individual, observed concentration

**Quality Control**

An analytical quality control program is conducted in the Rocky Flats Health and Environmental Laboratory The primary goals of the program are to improve and document the capability of environmental measurements During 1976, the activities of the analytical quality control program were threefold

1 Development, updating, and issuance of procedures

2 Intra-laboratory quality control

3 Inter-laboratory quality control

Intra-laboratory quality control is achieved through routine analysis of "blind" standard samples prepared and issued by the Rocky Flats Chemical Standards Laboratory, using traceable standards Numerical analysis of analytical results from these "blind" samples and subsequent assessment of laboratory performance is conducted by the Chemical Standards Laboratory on a monthly basis The measurement statistics of all measurement control programs are based on a six-month moving average Data for the final six months of 1976 are shown in Table 5

The Rocky Flats Health and Environmental Laboratory also participates in the Inter-Laboratory Cross Check Program conducted by the EPA's Environmental Measurements Support Laboratory in Las Vegas, Nevada The EPA routinely submits environmental samples containing precisely known amounts of one or more radionuclides to the Rocky Flats Health and Environmental Laboratory and other participating laboratories for analysis The resulting analyses are returned to the EPA for performance evaluation relative to other participating laboratories Computer reports and laboratory performance charts periodically furnished by the EPA indicate that the Rocky Flats Health and Environmental Laboratory performance is satisfactory

**Airborne Effluent Monitoring**

Particulates in effluent air from production and research facilities at Rocky Flats are continuously sampled The filterable particulate samples are isokinetically collected downstream from the final stage of High Efficiency Particulate Air (HEPA) filters Exhaust air ducts from plutonium facilities have a minimum of two particulate sampling points These ducts also have an alpha-energy selective, automatically alarmed system Three times during each work week, particulate samples are collected from exhaust ducts and stacks in buildings that could contain plutonium, uranium, or beryllium Gelman Type AE® glass fiber filters are used in this sample collection system The particulate samples are radiometrically analyzed for total long-lived alpha (TLL$\alpha$) emitters Beryllium particulates are determined by the flame atomic absorption spectrophotometry technique [6] Effluent samples from buildings containing plutonium are composited weekly for specific radiochemical analysis for plutonium The effluent air is monitored continuously for tritium by using a water bubbler impinger

Table 6 shows the quantity of radioisotopes and beryllium released to the atmosphere from Plant facilities during 1976 During this time period, over 7100 individual analyses were performed The total amount of plutonium released to the atmosphere was less than 3 724 microcuries Total long-lived alpha emissions from uranium and research buildings were less than 27 671 microcuries In addition, less than 1 159 curies of tritium and less than 3 705 grams of beryllium were released to the atmosphere

Sulfur dioxide ($SO_2$) emissions from fixed sources are regulated by the State of Colorado Each emission source is limited to a maximum concentration of 500 parts per million (ppm) or a total of five tons per day The Rocky Flats central steam facility is normally fired by natural gas, with residual oil (No 6 fuel oil) or diesel fuel for standby operation being available as backup fuel

The emission of $SO_2$ from Rocky Flats is controlled by the use of low sulfur fuels The purchasing specification for residual oils requires that the sulfur content shall not exceed one percent Routine fuel analysis during 1976 showed that these residual oils contained a sulfur content ranging from 0 5 to 0 7 percent

Past emphasis in airborne effluent monitoring has been on sampling for radioactive particulates, tritium, and beryllium In the future, however, airborne effluent monitoring will be conducted for carbon tetrachloride, total hydrocarbons, mass emission rates for particulates, oxides of nitrogen, and sulfur dioxide Instrumentation to provide in-stack, real-time analysis and read-out of these effluents has been purchased and is being installed in selected exhaust ventilation systems This equipment will provide the required data to determine compliance with stack emission standards that have been promulgated by the Environmental Protection Agency and the Colorado Air Pollution Control Division

**Ambient Air Monitoring**

High-volume ambient air samplers are located on the Rocky Flats Plant site, off-site at a distance of approximately 3 to 6 kilometers (2 to 4 miles) from the Plant center, and in several surrounding communities The air samplers are of a Rocky Flats design incorporating a commercially available Rotron Cyclonair blower, Model CHE-3 This blower is mounted in an aluminum box and is equipped with inlet and exhaust mufflers Also included are a flowmeter operated by an annular probe and a resettable, elapsed-time indicator The high volume samplers operate continuously, drawing a volume of air of approximately 19 liters per second (40 cubic feet per minute) through a 20- X 25-centimeter (8- X 10-inch) Delbag Microsorban® filter

Airborne particulates in ambient air are sampled continuously at 24 locations within and on the perimeter of the Rocky Flats exclusion area as shown in Figure 6 The sample filters are collected weekly and composited by location The particulate samples are analyzed biweekly for plutonium, total long-lived beta-emitting radionuclides, and beryllium Table 7 shows the volume-weighted average concentrations of plutonium radioactivity in airborne particulates during 1976 The highest percentages of the $RCG_a$ were at Samplers S-5, S-6, S-7, and S-8 and S-9 Air Sampler S-5, located at the perimeter security fence, is east of the solar evaporation ponds A pond cleanup operation was conducted from August through October 1976 Air Sampler S-6, located at the perimeter security fence, is directly east of a sludge drying bed This sludge contains some residual plutonium Air Samplers S-7, S-8, and S-9 are located directly east of an area in which the soil is known to contain plutonium Soil removal operations in this area were undertaken during 1976 These locations experienced the greatest concentrations of airborne plutonium activity Approximately 10 of the 24 locations had an average plutonium concentration approaching background The average concentration of plutonium in ambient air at all on-site stations during 1976 was less than $0\ 192 \times 10^{-15}$ ±28% $\mu$Ci/ml This concentration was less than 0 32% of the $RCG_a$ for soluble plutonium in ambient air accessible to incidentally exposed individuals

Periodic increases in radioactive fallout occur in the United States following atmospheric nuclear weapon testing conducted by the Republic of China To assess the local effect of these tests, beta radioactivity monitoring is conducted at the Rocky Flats Plant The volume-weighted average concentrations of long-lived beta-emitting radionuclides measured during 1976 are shown in Table 8 At Sampling Stations S-1 through S-24, the beta radioactivity was $0\ 1371 \times 10^{-12}$ ±17% $\mu$Ci/ml This concentration was 0 14% of the $RCG_a$ for total long-lived beta radioactivity in ambient air accessible to incidentally exposed individuals One Chinese atmospheric nuclear weapons test was conducted in October and a second test in November, which resulted in higher beta radioactivity during these two months.

Samples of airborne particulates are collected on filters by high-volume air samplers at 14 locations surrounding the Rocky Flats Plant These samplers are located between 3 to 6 kilometers (2 to 4 miles) from the Plant center (Figure 7) The samplers

are numbered S-31 through S-44 Samples from each location are collected weekly, composited by location, and analyzed biweekly for plutonium Table 9 shows the volume-weighted average concentrations of plutonium radioactivity in airborne particulates at Stations S-31 through S-44 during 1976 The average concentration of plutonium in ambient air at these locations during 1976 was less than $0\ 015 \times 10^{-15} \pm 15\%\ \mu Ci/ml$ This concentration was less than 0 08% of the soluble plutonium $RCG_a$ for the general population

Samples of airborne particulates also were collected by high-volume air samplers at 12 locations in or near communities in the vicinity of the Rocky Flats Plant These locations, as shown in Figure 7, include Boulder, Broomfield, Denver, Golden, Jeffco Airport, Lafayette, Leyden, Marshall, Superior, Wagner, Walnut Creek, and Westminster Sample filters are collected weekly, composited by location, and analyzed biweekly for plutonium radioactivity and for total long-lived beta radioactivity

Table 10 shows the volume-weighted average concentrations of plutonium in airborne particulates at the community stations during 1976 The average concentration of plutonium in ambient air at the community stations was less than $0\ 013 \times 10^{-15} \pm 10\%\ \mu Ci/ml$ This concentration was less than 0 07% of the soluble plutonium $RCG_a$ for the general population

The volume-weighted average concentrations of long-lived beta radioactivity during 1976 are given in Table 11 Community beta samples were not analyzed during November and December 1976 The average concentration of long-lived beta emitters in the communities during 1976 was $0\ 035 \times 10^{-12} \pm 6\%\ \mu Ci/ml$ This concentration was 0 12% of the applicable $RCG_a$ for the general population

### Waterborne Effluent Monitoring

During 1976, wastewater discharged from the Rocky Flats Plant consisted of cooling-tower blowdown, stream condensate, and sanitary waste These liquid wastes were subjected to tertiary treatment before discharge from the Plant Solids resulting from this operation were decomposed in an anaerobic digestor After drying, the contents of the digestor were packaged in 55-gallon drums and shipped in compliance with applicable regulations to an ERDA waste-storage facility in Idaho

After treatment, the liquid effluents are discharged through the B-series holding ponds to South Walnut Creek (see Figure 3) Holding Ponds B-1, B-3, and B-4 provide additional natural treatment of water discharged from the sanitary waste treatment facility prior to that water's release off-site Ponds B-1 and B-3 are equipped to impound water so that analysis can be performed prior to release and to prevent accidental liquid releases Pond B-2 is isolated from the stream and is used to impound process wastewater The process wastewater is then pumped to Pond A-2 on North Walnut Creek for storage and evaporation

Average concentrations of chemical and biological constituents of routine liquid effluent samples collected during 1976 are shown in Table 12 This table is divided into sections that list the appropriate Colorado Department of Health standards and the EPA-NPDES permit limitations in effect during 1976 Daily NPDES effluent concentrations for biochemical oxygen demand were exceeded at the sewage treatment plant outfall on three occasions The daily maximum limitation for this parameter is 25 mg/l The first two violations occurred in March when daily values of 49 and 26 mg/l were recorded The third violation occurred in September when a daily maximum of 49 mg/l occurred Investigations conducted during these three days did not indicate any abnormal conditions All monthly NPDES limitations were in compliance during 1976 Overall, the tertiary treatment system operated successfully

North Walnut Creek receives natural runoff from the north side of the Plant site Holding Pond A-3 on North Walnut Creek is used to impound surface water runoff for analysis prior to that water being released Ponds A-1 and A-2 are isolated from the stream and are used to store process wastewater One holding pond, C-1, is located on Woman Creek and can be used to impound accidental releases of liquid No impoundment of effluent waters on any of the three watercourses was necessary during 1976 When planned releases are made from

Holding Pond A-3, the water is sampled continuously These samples are analyzed for plutonium, uranium, americium, and tritium Water is sampled continuously and collected daily from the outfalls of Ponds B-4 and C-1 (Figure 3) These daily samples are composited into weekly samples for analysis of plutonium, uranium, and americium

Concentrations of plutonium, uranium, and americium in water samples at the outfalls of Ponds A-3, B-4, and C-1 are shown in Table 13 The annual average concentrations of plutonium in the outfalls of these ponds during 1976 were

A-3 = 0 457 X $10^{-9}$ ±72% $\mu$Ci/ml (0 03% of the $RCG_W$)

B-4 = 2 161 X $10^{-9}$ ±26% $\mu$Ci/ml (0 13% of the $RCG_W$)

C-1 = 0 275 X $10^{-9}$ ±58% $\mu$Ci/ml (0 02% of the $RCG_W$)

All uranium and americium concentrations in these ponds were less than 0 08% of the applicable $RCG_W$

Walnut Creek is sampled continuously at Indiana Street, which is downstream from the confluence of the stream tributaries and approximately at the Plant's east boundary These samples are composited weekly and analyzed for plutonium, uranium, and americium Results of the analyses are shown in Table 14 The 1976 average concentrations, respectively, for plutonium, uranium, and americium at the Indiana Street location were as follows

0 529 X $10^{-9}$ ±20% $\mu$Ci/ml (0 03% of the $RCG_W$)

3 754 X $10^{-9}$ ±17% $\mu$Ci/ml (0 04% of the $RCG_W$)

0 197 X $10^{-9}$ ±25% $\mu$Ci/ml (0 01% of the $RCG_W$)

During 1976, the outfalls of Ponds B-4, C-1, and Walnut Creek at Indiana Street were sampled and analyzed weekly for tritium Pond A-3 was sampled and analyzed during each scheduled discharge Water samples collected weekly at Great Western Reservoir and Standley Lake also were analyzed The average concentrations for tritium in these water samples are summarized in Table 15 The tritium concentrations at all of the above locations were less than 0 11% of the applicable $RCG_W$

**Groundwater Monitoring**

The Rocky Flats Plant routinely samples 35 hydrologic test holes at approximately five-month intervals This test is conducted to determine if there is any movement of chemical or radioactive materials of possible Plant origin into water-bearing strata underlying the site

Five of the test holes are approximately 46 meters (150 feet) deep or deeper These test holes provide information concerning water movement in bedrock formations The remaining test holes range from 1 to 15 meters (4 to 50 feet) deep and are generally located near three on-site solar evaporation ponds and various other holding ponds Locations of the 35 test holes are shown in Figure 8

During May and October of 1976, test holes containing water were sampled and analyzed for plutonium, uranium, americium, and tritium Table 16 gives the depths of the test holes and the concentrations of radioactive material found in water samples collected during 1976

Tritium has appeared in test holes near the solar evaporation ponds and near Pond B-4 This indicates some seepage of water from these ponds into the surrounding soil Historically, samples from these test holes have not indicated any movement of plutonium into the groundwater of the Plant site

**Regional Water Monitoring**

Water samples are collected weekly from Great Western Reservoir, which is a water supply for the City of Broomfield, and from Standley Lake, which supplies the City of Westminster and portions of the Thornton-Northglenn area Tap or finished water from Boulder, Broomfield, and Westminster is collected weekly Quarterly tap water samples also are collected from the surrounding communities

of Arvada, Denver, Golden, Lafayette, Louisville, and Thornton These samples are analyzed specifically for plutonium, uranium, and americium The resulting data for 1976 are summarized in Table 17

During 1976, the plutonium concentration in reservoir samples averaged less than 0 061 X $10^{-9}$ ±38% μCi/ml Community tap water samples averaged less than 0 053 X $10^{-9}$ ±46% μCi/ml These concentrations were less than 0 004% of the soluble plutonium $RCG_W$ for the general population

In September 1976, single water samples were collected from 29 additional regional lakes, reservoirs, and streams Samples were collected to a distance of 32 kilometers (20 miles) from the Plant and were analyzed specifically for plutonium, uranium, and americium The resulting data, presented in Table 18, show that the average plutonium concentration in those samples was <0 226 X $10^{-9}$ ±159% μCi/ml That concentration was less than 0 01% of the soluble plutonium $RCG_W$ for the general population

### Soil Sampling and Analyses

Approximately 60 soil samples are collected annually in the Plant environs and analyzed for plutonium Samples are collected at radial intervals of 18 degrees and distances of 1 6, 3 2, and 8 kilometers (1, 2, and 5 miles) from the Plant The geometry of all soil samples is controlled by driving a 10- X 10-centimeter (4- X 4-inch) cutting tool 5 centimeters (2 inches) into undisturbed soil The soil sample contained within the tool cavity is then removed for analysis [7]

Sample preparation and analysis is conducted by a Rocky Flats Health and Environmental Laboratory Procedure [8] This procedure is adapted from a Nuclear Regulatory Commission guide [9] The entire sample is oven-dried, weighed, sieved through a 10-mesh sieve to remove coarser rubble, and homogenized A 10-gram aliquot of the homogenized soil is then used for the plutonium analysis Chemical recovery is determined by adding plutonium-236 as a tracer, and the analytical results are reported in units of disintegrations per minute per gram of dry soil fines To account for the coarse material removed by sieving, the laboratory results are multiplied by the ratio of grams fines to grams in the total sample These values, in units of disintegrations per minute per gram of dry soil, are then converted to picocuries per gram of dry soil

The 1976 soil data are displayed on a map in Figure 9 The soil sampling results ranged from less than 0 01 to 5 95 pCi/g, with the higher values being predominately located east and south of the Plant site There are no Federal standards for plutonium in soil

During the 1975 soil sampling and analysis program, a sample cross-contamination problem occurred and only 11 sample results were reported Evaluation and reanalysis of the remaining 1975 samples have been completed The 1975 soil data are shown in Figure 10

## ASSESSMENT OF PLANT CONTRIBUTION TO PUBLIC RADIATION DOSE

The Rocky Flats Plant has always strived to minimize all radioactive and nonradioactive effluents discharged from the Plant site to concentrations substantially less than the allowable limits Plant effluents containing traces of plutonium, uranium, americium, and tritium could contribute to the radiation exposure of the general population

Plutonium in the vicinity of Rocky Flats can be attributed to either Plant operations or to fallout from nuclear testing Uranium occurs naturally and, in many areas in the state, is present in much higher concentrations than found in the Plant vicinity Tritium also occurs naturally, however, some tritium in the local environment has resulted from Plant operations

Potential radiation doses to the public resulting from Plant effluents were calculated using environmental exposure measurements made at the ERDA property boundaries and in each of the surrounding communities Inhalation and water consumption were found to be the principal pathways of

exposure Consumption of foodstuffs and fish, in addition to swimming, were found to be insignificant For example, most of the food consumed locally is produced at considerable distances from the Plant, and the transfer of plutonium to man is on the order of $10^{-5}$ or less [10]

Several assumptions were made in calculating the potential dose from the measured exposures Each of the radionuclides was considered to be in a chemical form that would result in maximum human uptake The radionuclides were assumed to be soluble for those organs that will take up only soluble radionuclides and to be completely insoluble for organs that take up the insoluble form Additionally, the average radiation exposure measured in the surrounding communities was assumed to be constant to a distance of 80 kilometers

The measured radioactivity exposures used for the dose calculations are listed in Table 19 Background radioactivity (as listed in Table 2) was subtracted before the dose assessments were made Dose assessments were made at the specific site-boundary location where maximum exposure rates were obtained Doses to individuals and population groups were calculated where the highest radioactivity concentrations were measured A dose estimate for total population within 80 kilometers (50 miles) also was made

The dose estimates from radionuclides originating in effluents released from the Rocky Flats Plant were obtained using models and data presented in publications of the International Commission on Radiological Protection[10, 11] and in other literature [12-14]

The general equation used in assessing the dose resulting from continuous inhalation or ingestion of a radionuclide was

$$D = \frac{C_i \epsilon f_i I_i (1 - e^{-\lambda_e t})}{m}$$

where

D = Dose in rems

$C_i$ = average nuclide concentration in $\mu$Ci/ml (as measured)

$\epsilon$ = effective absorbed energy per disintegration, including a quality factor for dose equivalent, MeV-rem/dis-rad (Ref 10)

$f_i$ = fraction of nuclide reaching organ of interest (Ref 10, 11)

$I_i$ = average air or water intake rate in ml/day (Ref 10)

$\lambda_e$ = effective elimination or clearance rate in $day^{-1}$ (Ref 10, 11)

t = exposure time in days

m = organ mass in grams (Ref 10)

Insertion of the numerical constants and conversion of units yield the following equation

$$D = \frac{(3.7 \times 10^4)(1.6 \times 10^{-6})(3.15 \times 10^7)(1 - e^{-\lambda_e t}) I_i f_i \epsilon C_i}{100 \lambda_e m}$$

where

$3.7 \times 10^4$ = dis/sec-$\mu$Ci

$1.6 \times 10^{-6}$ = ergs/MeV

$3.15 \times 10^7$ = sec/yr

100 = erg/g-rad

Air and water are considered to be the only significant modes of radionuclide intake Evaluating the equation for the various radionuclides in air or water and for each specific organ results in the dose conversion factor shown in Table 20

A Maximum Site-Boundary Dose Rate

During 1976, the point of maximum potential exposure to an individual on the site boundary was located east of the Plant at air sampler location S-37 If an individual were to continuously occupy this location, using the water from Walnut Creek, the dose in excess of that due to regional background concentration would be 0 11 millirem per year This dose represents less than 0 023% of the ERDA radiation protection standard for an individual in the population For purposes of comparison, the annual dose due to terrestrial and cosmic background sources was 128 millirem at this unoccupied location

B Maximum Individual and Population Dose

The maximum individual dose that may be attributed to Plant operations was found to

occur in the community of Broomfield, which is about 11 kilometers (6 8 miles) east of the Rocky Flats Plant The principal dose contribution was tritium in the water supply, which was in excess of regional background concentrations

The annual dose to a Broomfield resident was 0 04 millirem Multiplying this dose by the population in Broomfield results in a total dose commitment of 0 55 man-rem These doses represent 0 008 and 0 022% of the individual and population radiation protection standards, respectively This dose commitment to the Broomfield population compares to an annual dose from terrestrial and cosmic background radiation sources of 1,595 man-rem

C 80-Kilometer Man-Rem Dose

Environmental monitoring in the environs of the Rocky Flats Plant extends to a radial distance of about 26 kilometer (16 miles) To assess the individual and total dose to those populations within 80 kilometers (50 miles) of the Plant, it was assumed those doses would be comparable to radionuclide concentrations, in excess of background, as measured in the surrounding communities The population residing within 80 kilometers of the Plant was assumed to be approximately 1 809 million people distributed as shown in Figure 11 From these data, it is estimated that the total dose within 80 kilometers of the Plant is 11 1 man-rem This dose is 0 004% of the ERDA radiation protection standard for the general public and compares to a dose of 237,096 man-rem from terrestrial and cosmic background sources

## REFERENCES


1 J M West Rocky Flats Plant Annual Weather Summary–1976 Rockwell International, Rocky Flats Plant, Golden, Colorado February 1977

2 Standards for Radiation Protection AEC Manual, Chapter 0524 U S Atomic Energy Commission, Washington, D C 1968

3 National Emission Standards for Hazardous Air Pollutants 40-CFR Part 61 Subpart C U S Environmental Protection Agency, Washington, D C April 6, 1973

4 U S Environmental Protection Agency NPDES Permit No CO-0001333 National Pollutant Discharge Elimination System Washington, D C September 6, 1974

5 Health and Environmental Laboratory Procedures, H&EL-1, -4, -10, -14, -19 Rockwell International, Rocky Flats Plant, Golden, Colorado

6 D L Bokowski "Rapid Determination of Beryllium by a Direct-Reading Atomic Absorption Spectrometer " American Industrial Hygiene Association 29 471-481 1968

7 Environmental Analysis and Control Soil Sampling Procedure Procedure EAC-S-4 Rockwell International Rocky Flats Plant, Golden, Colorado

8 Health and Environmental Laboratory Procedure, H&EL-21 Rockwell International, Rocky Flats Plant, Golden, Colorado

9 USAEC Regulatory Guide 4 5 "Measurements of Radionuclides in the Environment Sampling and Analysis of Plutonium in Soil " USAEC May 1974

10 Metabolism of Plutonium and Other Actinides ICRP Publication 19 Report of Committee II Pergamon Press, London 1972

11 Recommendations of the International Commission on Radiological Protection ICRP Publication 2 Report of Committee II on Permissible Dose for Internal Radiation Pergamon Press, London 1959

12 ICRP Task Group on Lung Dynamics, "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract " Health Physics 12 173 1966

13 D B Turner Workbook of Atmospheric Dispersion Estimates U S Environmental Protection Agency, Research Triangle Park, North Carolina 1970

14 "Recommended Guide for the Prediction of the Dispersion of Airborne Effluents " ASME Guide Amer Soc of Mech Engr New York, New York 1968

# TABLES

## 1 through 20

TABLE 1 Summary of Temperature, Precipitation, and Wind Data

| Temperature (6 meters above ground) | 24-Year Period (1953-1976) Average | Record High | Record Low | 1976 |
|---|---|---|---|---|
| Annual Mean Temperature | | | | |
| °C | 9 8 | 11 4 | 7 4 | 9 6 |
| (°F) | ( 49 6 ) | ( 52 5 ) | ( 45 4 ) | ( 49 2 ) |
| Annual Maximum Temperature | | | | |
| °C | 35 1 | 38 9 | 32 0 | 32 0 |
| (°F) | ( 95 1 ) | ( 102 0 ) | ( 89 6 ) | ( 89 6 ) |
| Annual Minimum Temperature | | | | |
| °C | −22 1 | − 17 2 | −32 2 | −20 8 |
| (°F) | (− 7 8 ) | ( 1 0 ) | (−26 0 ) | (− 5 5 ) |
| Annual Precipitation | | | | |
| cm | 38 7 | 63 2 | 19 7 | 34 3 |
| (in ) | ( 15 2 ) | ( 24 9 ) | ( 7 8 ) | ( 13 5 ) |
| **Wind (6 meters above ground)** | | | | |
| Annual Mean Wind Speed | | | | |
| m/sec | 3 68 | 4 20 | 3 08 | 3 84 |
| (mph) | ( 8 24) | ( 9 40) | ( 6 90) | ( 8 60) |
| Annual Peak Gust | | | | |
| m/sec | 41 3 | 47 | 33 | 39 |
| (mph) | ( 92 4 ) | ( 106 ) | ( 74 ) | ( 87 ) |
| **Wind (61 meters above ground)** | | | | |
| Annual Mean Wind Speed | | | | |
| m/sec | 61-meter-level wind data measurement began in 1975 | | | 4 67 |
| (mph) | | | | ( 10 44) |
| Annual Peak Gust | | | | |
| m/sec | | | | 44 |
| (mph) | | | | ( 99 ) |

TABLE 2 Regional Background Radioactivity Concentrations

| Radionuclide | Air ($\times 10^{-15}$ µCi/ml) | Soil (pCi/g) | Water ($\times 10^{-9}$ µCi/ml) |
|---|---|---|---|
| Uranium-234, -235, -238 | 0 1382 ± 4 1%[a] | 5 680 ± 61 1%[b] | 0 274 ± 12 4%[a] |
| Plutonium-238 | 0 0055 ±16 4%[a] | 0 012 ±116 7%[c] | 0 003 ±100 0%[a] |
| Plutonium-239, -240 | 0 0165 ±10 3%[a] | 0 014 ± 29 0%[d] | 0 012 ± 66 7%[a] |
| Americium-241 | 0 0114 ±51 4%[c] | <0 039[c] | 0 046 ±289%[e] |
| Tritium ($^3$H) | 2000 ±50%[e] | No Value | 600 ± 33 3%[a] |

a. Report No 4 U S Environmental Protection Agency, Office of Radiation Programs, Montgomery, Alabama April 1976
b Program 25 U S Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada August 1973
c C W Thomas Personal Communication Battelle Pacific Northwest Laboratory, Richland, Washington. May 30, 1974
d P W Krey *Health Physics* 30 200-214 (1976)
e Rocky Flats Health and Environmental Laboratory 1976

TABLE 3 Summary of Environmental Thermoluminescent Dosimeter Measurements

| Location | Number of Measurements | Annual Dose (millirem) | | | |
|---|---|---|---|---|---|
| | | Arithmetic | | Geometric | |
| | | Mean | Standard Deviation | Mean | Standard Deviation |
| On-Site | 134 | 113 | 18 | 113 | 1 |
| Environs[a] | 124 | 106 | 11 | 108 | 1 |
| Communities | 78 | 117 | 4 | 113 | 1 |

a 3 to 6 kilometers (2 to 4 miles) from the Plant

TABLE 4 Radioactivity and Nonradioactivity Detection Limits and Applicable Standards

| Parameter | Approximate Detection Limit (per sample) | Approximate Sample Volume | Approximate Minimum Detection Limit | Applicable Guides and Standards | Reference |
|---|---|---|---|---|---|
| **Stack Samples** | | | | | |
| Plutonium | $2.0 \times 10^{-7}$ µCi | 1,140.0 m³ | $0.0002 \times 10^{-12}$ µCi/ml | < $0.06 \times 10^{-12}$ µCi/ml | RF Guide |
| Total Long-Lived Alpha | $2.9 \times 10^{-7}$ µCi | 163.0 m³ | $0.002 \times 10^{-12}$ µCi/ml | < $0.02 \times 10^{-12}$ µCi/ml | RF Guide |
| Tritium | $7.5 \times 10^{-4}$ µCi | 9.0 m³ | $83.3 \times 10^{-12}$ µCi/ml | < $2.0 \times 10^{-7}$ µCi/ml | RF Guide |
| Beryllium | $4.2 \times 10^{-5}$ µg | 1,140.0 m³ | $4.0 \times 10^{-8}$ µg/m³ | < 10.0 g/day | 40 CFR 61 |
| **Ambient Air Samples** | | | | | |
| Plutonium | $2.0 \times 10^{-7}$ µCi | 20,000.0 m³* | $0.00001 \times 10^{-12}$ µCi/ml | < $0.02 \times 10^{-12}$ µCi/ml | ERDAMC 0524 |
| Total Long-Lived Beta | $2.0 \times 10^{-5}$ µCi | 20,000.0 m³* | $0.001 \times 10^{-12}$ µCi/ml | < $33.3 \times 10^{-12}$ µCi/ml | ERDAMC 0524 |
| Tritium | $1.5 \times 10^{-5}$ µCi | 10.0 m³ | $1.5 \times 10^{-12}$ µCi/ml | <66,667.0 $\times 10^{-12}$ µCi/ml | ERDAMC 0524 |
| Beryllium | $6.0 \times 10^{-5}$ µg | 20,000.0 m³* | $3.0 \times 10^{-9}$ µg/m³ | < $1.0 \times 10^{-2}$ µg/m³ | 40 CFR 61 |
| **Effluent Water Samples, Radioactive** | | | | | |
| Plutonium | $2.0 \times 10^{-7}$ µCi | 1.0 liter | $0.2 \times 10^{-9}$ µCi/ml | < 1,667.0 $\times 10^{-9}$ µCi/ml | ERDAMC 0524 |
| Uranium | $2.0 \times 10^{-7}$ µCi | 1.0 liter | $0.2 \times 10^{-9}$ µCi/ml | <10,000.0 $\times 10^{-9}$ µCi/ml | ERDAMC 0524 |
| Americium | $0.2 \times 10^{-6}$ µCi | 1.0 liter | $0.2 \times 10^{-9}$ µCi/ml | < 1,330.0 $\times 10^{-9}$ µCi/ml | ERDAMC 0524 |
| Tritium | $2.5 \times 10^{-6}$ µCi | 0.005 liter | $0.5 \times 10^{-6}$ µCi/ml | < 1,000.0 $\times 10^{-6}$ µCi/ml | ERDAMC 0524 |
| Total Long-Lived Alpha | $1.3 \times 10^{-7}$ µCi | 25.0 ml | $5.2 \times 10^{-9}$ µCi/ml | < $40.0 \times 10^{-9}$ µCi/ml | RF Guide |
| **Soil Samples, Radioactive** | | | | | |
| Plutonium | $2.0 \times 10^{-7}$ µCi | 500.0 cm³ | $0.4 \times 10^{-9}$ µCi/cm³ | Not Applicable | Not Applicable |
| **Effluent Water Samples, Nonradioactive** | | | | | |
| pH | | Not Applicable | 0 – 14 | 6.0 – 9.0 | NPDES Permit |
| Total Nitrogen | | 10 ml | 0.2 mg/l | <=20 mg/l | NPDES Permit |
| Phosphorus as P | | 50 ml | 0.2 mg/l | <= 8 mg/l | NPDES Permit |
| Fluoride | | 20 ml | 0.2 mg/l | <= 1.7 mg/l | NPDES Permit |
| Biochemical Oxygen Demand, 5-Day | | 10 ml | 1.0 mg/l | <=25 mg/l | NPDES Permit |
| Dissolved Oxygen | | 300 ml | 1.0 mg/l | => 2 mg/l | NPDES Permit |
| Total Suspended Solids | | 100 ml | 2.0 mg/l | <=25 mg/l | NPDES Permit |
| Total Chromium | | 5 ml | 0.05 mg/l | <= 0.1 mg/l | NPDES Permit |
| Residual Chlorine | | 10 ml | <0.1 mg/l | <= 0.1 mg/l | NPDES Permit |
| Oil and Grease | | 500 ml | 0.1 mg/l | <=10 mg/l | NPDES Permit |
| Fecal Coliforms | | 10-100 ml | 0 | 400 organisms/100 ml (7-Day)<br>200 organisms/100 ml (30-Day) | NPDES Permit |

*2-Week Composite

Legend

µCi = microcuries
µg = micrograms
m³ = cubic meters
ml = milliliters
mg/l = milligrams per liter
g = grams
cm³ = cubic centimeters

RF = Rocky Flats
40 CFR 61 = Code of Federal Regulations [National Emission Standards for Hazardous Air Pollutants (USEPA)]
ERDAMC = ERDA Manual Chapter
NPDES = National Pollutant Discharge Elimination System

TABLE 5 Health and Environmental Laboratory Measurement Control Data
(July through December)

| Element | Matrix | Average Standard Value | Relative Error[a] (%) | Bias[b] (%) | Total Control Analyses |
|---|---|---|---|---|---|
| Americium | Effluent Filters (Gelman AE®) | 2 70 d/m | 15 9 | 12 5 | 240 |
| Beryllium | Effluent Filters (Gelman AE®) | 0 99 μg | 55 1 | 41 6 | 240 |
| Beryllium | Room Air Filters (Whatman®) | 63 8 μg | 9 4 | −10 0 | 240 |
| Uranium | Effluent Filters (Gelman AE®) | 18 2 d/m | 13 3 | − 0 9 | 60 |
| Plutonium | Effluent Filters (Gelman AE®) | 16 6 d/m | 9 2 | 5 2 | 240 |
| Americium | Surface Water | 0 13 d/m/l | 79 2 | 18 5 | 48 |
| Plutonium | Surface Water | 0 6 d/m/l | 22 2 | 21 5 | 48 |
| Uranium | Surface Water | 16 1 d/m/l | 66 1 | 8 1 | 48 |
| Tritium | Surface Water | 1 46 X $10^5$ pCi/l | 7 0 | − 1 0 | 60 |
| Strontium | Surface Water | 19 7 pCi/l | 24 9 | − 5 3 | 60 |
| Americium | Ambient Air Filter (Microsorban-98®) | 5 1 d/m | 14 5 | 9 4 | 48 |
| Plutonium | Ambient Air Filter (Microsorban-98®) | 33 0 d/m | 8 6 | 9 2 | 48 |
| Uranium | Ambient Air Filter (Microsorban-98®) | 48 3 d/m | 16 9 | −28 6 | 48 |
| Plutonium | Soil | 0 47 d/m/g | 3 4 | 6 0 | 15 |

a. The ratio of the standard deviation of the six-month differences to the average standard value in percent, i.e observed value minus standard value, divided by average standard value, times 100 equals the ratio as expressed in percent

b The six month average bias in percent A minus sign indicates a negative bias, i e , the value obtained were low No sign indicates a positive bias, i e , the values obtained were high

Legend

d/m = disintegrations per minute
μg = micrograms
d/m/l = disintegrations per minute per liter
pCi/l = picocuries per liter
d/m/g = disintegrations per minute per gram

TABLE 6 Effluent Releases to the Atmosphere

| Sample Period | Plutonium Number of Samples | Plutonium $C_{max}$[a] ($\times 10^{-12}$ µCi/ml) | Plutonium Total[a] (µCi) | Uranium Number of Samples | Uranium $C_{max}$[b] ($\times 10^{-12}$ µCi/ml) | Uranium Total[b] (µCi) |
|---|---|---|---|---|---|---|
| January | 100 | 0 005 | <0 195 | 168 | 0 248 | < 3 129 |
| February | 91 | 0 026 | <0 721 | 143 | 0 023 | < 1 839 |
| March | 129 | 0 020 | <0 283 | 155 | 0 165 | < 2 792 |
| April | 103 | 0 003 | <0 230 | 141 | 0 278 | < 2 788 |
| May | 104 | 0 004 | <0 326 | 144 | 0 726 | < 2 356 |
| June | 130 | 0 003 | <0 345 | 156 | 0 029 | < 3 397 |
| July | 104 | 0 002 | <0 180 | 140 | 0 020 | < 2 065 |
| August | 130 | 0 004 | <0 345 | 156 | 0 026 | < 1 914 |
| September | 104 | 0 002 | <0 286 | 155 | 0 048 | < 2 267 |
| October | 104 | 0 002 | <0 129 | 155 | 0 010 | < 1 629 |
| November | 130 | 0 010 | <0 340 | 144 | 0 014 | < 1 666 |
| December | 78 | 0 002 | <0 344 | 144 | 0 028 | < 1 829 |
| Summary | 1307 | 0 026 | <3 724 | 1801 | 0 726 | <27 671 |

| Sample Period | Tritium Number of Samples | Tritium $C_{max}$ ($\times 10^{-12}$ µCi/ml) | Tritium Total (Ci) | Beryllium Number of Samples | Beryllium $C_{max}$ (µg/m³)[c] | Beryllium Total (g) |
|---|---|---|---|---|---|---|
| January | 160 | 1700 | <0 084 | 171 | 0 003 | <0 443 |
| February | 144 | 1380 | <0 068 | 173 | 0 002 | <0 245 |
| March | 153 | 2030 | <0 104 | 191 | 0 004 | <0 179 |
| April | 154 | 2270 | <0 103 | 163 | 0 003 | <0 179 |
| May | 169 | 2430 | <0 088 | 168 | 0 007 | <0 284 |
| June | 161 | 1880 | <0 076 | 192 | 0 003 | <0 342 |
| July | 158 | 1500 | <0 074 | 166 | 0 005 | <0 243 |
| August | 168 | 1740 | <0 092 | 172 | 0 009 | <0 300 |
| September | 164 | 2380 | <0 133 | 183 | 0 009 | <0 220 |
| October | 164 | 4270 | <0 143 | 174 | 0 009 | <0 204 |
| November | 165 | 2420 | <0 115 | 173 | 0 006 | <0 385 |
| December | 158 | 1490 | <0 079 | 141 | 0 015 | <0 681 |
| Summary | 1918 | 4270 | <1 159 | 2067 | 0 015 | <3 705 |

a Radiochemically determined as plutonium

b Radiometrically determined as nonspecific total long-lived alpha activity

c The beryllium emission limitation is 10 grams per day under the provisions of 40CFR61 and Colorado Air Pollution Control Division Regulation No 8

TABLE 7 Plutonium Radioactivity in Rocky Flats Ambient Air

| Station | Number of Samples | Less Than Detectable | Volume (× 1,000 m³) | Concentration[a] (× $10^{-15}$ μCi/ml) | | | Percent of $RCG_a$[c] |
|---|---|---|---|---|---|---|---|
| | | | | $C_{min}$ | $C_{max}$ | $C_{avg}$[b] | |
| S-1 | 21 | 0 | 353 | 0 012 | 0 023 | 0 017 ±75% | 0 02 |
| S-2 | 27 | 0 | 475 | 0 013 | 0 035 | 0 021 ±66% | 0 04 |
| S-3 | 21 | 0 | 360 | 0 011 | 0 065 | 0 025 ±76% | 0 04 |
| S-4 | 27 | 0 | 538 | 0 015 | 0 209 | 0 047 ±60% | 0 08 |
| S-5 | 28 | 0 | 525 | 0 027 | 3 921 | 0 578 ±62% | 0 96 |
| S-6 | 25 | 0 | 534 | 0 050 | 2 723 | 0 485 ±58% | 0 81 |
| S-7 | 37 | 0 | 526 | 0 175 | 1 277 | 0 544 ±65% | 0 91 |
| S-8 | 36 | 0 | 480 | 0 080 | 1 324 | 0 531 ±64% | 0 89 |
| S-9 | 34 | 0 | 463 | 0 272 | 3 508 | 1 352 ±62% | 2 25 |
| S-10 | 27 | 0 | 491 | 0 010 | 0 057 | 0 025 ±65% | 0 04 |
| S-11 | 26 | 0 | 504 | 0 007 | 0 091 | 0 019 ±67% | 0 03 |
| S-12 | 25 | 0 | 492 | 0 012 | 0 115 | 0 039 ±63% | 0 07 |
| S-13 | 27 | 0 | 505 | 0 008 | 0 127 | 0 032 ±61% | 0 05 |
| S-14 | 26 | 0 | 510 | 0 006 | 0 045 | 0 017 ±67% | 0 03 |
| S-15 | 26 | 0 | 413 | 0 011 | 0 044 | 0 020 ±67% | 0 03 |
| S-16 | 23 | 0 | 422 | 0 008 | 0 075 | 0 029 ±66% | 0 05 |
| S-17 | 27 | 0 | 525 | 0 009 | 0 331 | 0 057 ±60% | 0 09 |
| S-18 | 37 | 0 | 486 | 0 014 | 0 115 | 0 037 ±64% | 0 06 |
| S-19 | 26 | 0 | 534 | 0 016 | 0 174 | 0 077 ±63% | 0 13 |
| S-20 | 26 | 0 | 451 | 0 019 | 2 551 | 0 383 ±54% | 0 64 |
| S-21 | 27 | 0 | 494 | 0 013 | 0 294 | 0 062 ±60% | 0 10 |
| S-22 | 26 | 0 | 513 | 0 008 | 0 046 | 0 019 ±63% | 0 03 |
| S-23 | 27 | 0 | 494 | 0 010 | 0 227 | 0 038 ±60% | 0 06 |
| S-24 | 25 | 0 | 484 | 0 007 | 0 556 | 0 063 ±65% | 0 11 |
| Summary | 657 | 0 | 11,572 | 0 006 | 3 921 | | |
| Volume-Weighted Average | | | | | | 0 192 ±28% | 0 32 |

a. Monthly composite station concentrations
b Volume-weighted average
c The Radioactivity Concentration Guide ($RCG_a$) for soluble plutonium in ambient air accessible to incidentally exposed individuals is $60 \times 10^{-15}$ microcuries per milliliter

TABLE 8 Total Long-Lived Beta Radioactivity in Rocky Flats Ambient Air

| Station | Number of Samples | Less Than Detectable | Volume (× 1,000 $m^3$) | Concentration[a] (× $10^{-12}$ μCi/ml) | Percent of $RCG_a$[b] |
|---|---|---|---|---|---|
| S-1 | 21 | 0 | 363 | 0 0402 | 0 04 |
| S-2 | 27 | 0 | 435 | 0 1441 | 0 14 |
| S-3 | 21 | 0 | 411 | 0 0970 | 0 09 |
| S-4 | 27 | 0 | 542 | 0 1211 | 0 12 |
| S-5 | 28 | 0 | 505 | 0 1456 | 0 15 |
| S-6 | 25 | 0 | 535 | 0 1235 | 0 12 |
| S-7 | 37 | 0 | 506 | 0 1453 | 0 15 |
| S-8 | 36 | 0 | 461 | 0 1565 | 0 16 |
| S-9 | 34 | 0 | 461 | 0 1604 | 0 16 |
| S-10 | 27 | 0 | 480 | 0 1537 | 0 15 |
| S-11 | 26 | 0 | 484 | 0 1548 | 0 15 |
| S-12 | 25 | 0 | 492 | 0 1130 | 0 11 |
| S-13 | 27 | 0 | 484 | 0 1386 | 0 14 |
| S-14 | 26 | 0 | 489 | 0 1760 | 0 18 |
| S-15 | 26 | 0 | 415 | 0 1411 | 0 14 |
| S-16 | 23 | 0 | 462 | 0 1114 | 0 11 |
| S-17 | 27 | 0 | 495 | 0 1320 | 0 13 |
| S-18 | 37 | 0 | 467 | 0 1767 | 0 18 |
| S-19 | 26 | 0 | 512 | 0 1385 | 0 14 |
| S-20 | 26 | 0 | 434 | 0 1430 | 0 14 |
| S-21 | 27 | 0 | 475 | 0 1390 | 0 14 |
| S-22 | 26 | 0 | 534 | 0 1425 | 0 14 |
| S-23 | 27 | 0 | 475 | 0 1448 | 0 14 |
| S-24 | 25 | 0 | 486 | 0 1276 | 0 13 |
| Summary | 657 | 0 | 11,403 | | |
| Volume-Weighted Average | | | | 0 1371 ±17% | 0 14 |

a Monthly station composite volume-weighted averages

b The Radioactivity Concentration Guide ($RCG_a$) for total long-lived beta activity in ambient air accessible to incidentally exposed individuals is 100 × $10^{-12}$ microcuries per milliliter

TABLE 9 Plutonium Radioactivity in Ambient Air [3 to 6 kilometers (2 to 4 miles) from Rocky Flats]

| Station | Number of Samples | Less Than Detectable | Volume (× 1,000 m³) | Concentration (× $10^{-15}$ μCi/ml) | | | Percent of $RCG_a$[b] |
|---|---|---|---|---|---|---|---|
| | | | | $C_{min}$ | $C_{max}$ | $C_{avg}$[a] | |
| S-31 | 25 | 1 | 415 | <0 003 | 0 018 | <0 012 ±91% | <0 06 |
| S-32 | 27 | 0 | 561 | 0 004 | 0 112 | 0 026 ±78% | 0 13 |
| S-33 | 25 | 0 | 544 | 0 003 | 0 031 | 0 012 ±92% | 0 06 |
| S-34 | 26 | 0 | 531 | 0 005 | 0 028 | 0 012 ±90% | 0 06 |
| S-35 | 27 | 0 | 548 | 0 004 | 0 037 | 0 013 ±86% | 0 07 |
| S-36 | 26 | 0 | 480 | 0 004 | 0 051 | 0 017 ±85% | 0 09 |
| S-37 | 27 | 0 | 561 | 0 007 | 0 055 | 0 024 ±89% | 0 12 |
| S-38 | 27 | 0 | 565 | 0 004 | 0 036 | 0 015 ±86% | 0 08 |
| S-39 | 27 | 0 | 509 | 0 005 | 0 025 | 0 013 ±90% | 0 07 |
| S-40 | 26 | 0 | 465 | 0 004 | 0 034 | 0 014 ±87% | 0 07 |
| S-41 | 27 | 0 | 508 | 0 004 | 0 027 | 0 012 ±89% | 0 06 |
| S-42 | 27 | 0 | 451 | 0 004 | 0 028 | 0 013 ±89% | 0 07 |
| S-43 | 24 | 0 | 403 | 0 005 | 0 021 | 0 014 ±93% | 0 07 |
| S-44 | 26 | 1 | 517 | <0 002 | 0 037 | <0 013 ±90% | <0 07 |
| Summary | 367 | 2 | 7,058 | <0 002 | 0 112 | | |
| Volume-Weighted Average | | | | | | <0 015 ±15% | <0 08 |

a Volume-weighted average

b The Radioactivity Concentration Guide ($RCG_a$) for soluble plutonium in ambient air accessible to the population at large is 20 × $10^{-15}$ microcuries per milliliter

TABLE 10 Plutonium Radioactivity in Community Ambient Air

| Community | Station | Number of Samples | Less Than Detectable | Volume (× 1,000 m³) | Concentration (× $10^{-15}$ μCi/ml) | | | Percent $RCG_a$[b] |
|---|---|---|---|---|---|---|---|---|
| | | | | | $C_{min}$ | $C_{max}$ | $C_{avg}$[a] | |
| Boulder | S-54 | 28 | 0 | 524 | 0 004 | 0 026 | 0 012 ±218% | 0 06 |
| Broomfield | S-56 | 27 | 0 | 495 | 0 004 | 0 022 | 0 012 ±210% | 0 06 |
| Denver | S-61 | 25 | 0 | 402 | 0 009 | 0 073 | 0 021 ±236% | 0 11 |
| Golden | S-62 | 28 | 1 | 518 | <0 003 | 0 016 | <0 010 ±217% | <0 05 |
| Jeffco Airport | S-52 | 28 | 0 | 341 | 0 004 | 0 019 | 0 012 ±229% | 0 06 |
| Lafayette | S-55 | 25 | 0 | 396 | 0 005 | 0 031 | 0 015 ±221% | 0 08 |
| Leyden | S-59 | 21 | 0 | 346 | 0 005 | 0 029 | 0 016 ±213% | 0 08 |
| Marshall | S-51 | 28 | 0 | 469 | 0 005 | 0 022 | 0 012 ±207% | 0 06 |
| Superior | S-53 | 26 | 0 | 474 | 0 003 | 0 029 | 0 013 ±196% | 0 07 |
| Wagner | S-58 | 28 | 0 | 502 | 0 006 | 0 020 | 0 012 ±219% | 0 06 |
| Walnut Creek | S-57 | 25 | 0 | 465 | 0 006 | 0 017 | 0 011 ±208% | 0 06 |
| Westminster | S-60 | 28 | 0 | 488 | 0 004 | 0 018 | 0 010 ±216% | 0 05 |
| Summary | | 317 | 1 | 5,420 | <0 003 | 0 073 | | |
| Volume-Weighted Average | | | | | | | <0 013 ± 10% | <0 07 |

a. Volume-weighted average

b The Radioactivity Concentration Guide ($RCG_a$) for soluble plutonium in ambient air accessible to the population at large is 20 × $10^{-15}$ microcuries per milliliter

TABLE 11 Total Long-Lived Beta Radioactivity in Community Ambient Air

| Location | Number of Samples[a] | Less Than Detectable | Volume (× 1,000 $m^3$) | Concentration (× $10^{-12}$ μCi/ml) | Percent of $RCG_a$[b] |
|---|---|---|---|---|---|
| Boulder | 20 | 0 | 421 | 0 0319 | 0 09 |
| Broomfield | 20 | 0 | 403 | 0 0314 | 0 09 |
| Denver | 20 | 0 | 320 | 0 0368 | 0 12 |
| Golden | 20 | 0 | 415 | 0 0332 | 0 09 |
| Jeffco Airport | 12 | 0 | 223 | 0 0388 | 0 12 |
| Lafayette | 20 | 0 | 349 | 0 0353 | 0 12 |
| Leyden | 20 | 0 | 326 | 0 0333 | 0 09 |
| Marshall | 20 | 0 | 359 | 0 0470 | 0 15 |
| Superior | 20 | 0 | 370 | 0 0408 | 0 12 |
| Wagner | 20 | 0 | 395 | 0 0379 | 0 12 |
| Walnut Creek | 20 | 0 | 402 | 0 0307 | 0 09 |
| Westminster | 20 | 0 | 377 | 0 0323 | 0 09 |
| Summary | 232 | 0 | 4,360 | | |
| Volume-Weighted Average | | | | 0 0355 ±6% | 0 12 |

a No samples analyzed during November and December 1976

b The Radioactivity Concentration Guide ($RCG_a$) for total long-lived beta activity in ambient air accessible to the population at large is 33 3 × $10^{-12}$ microcuries per milliliter

TABLE 12 Average Concentrations of Chemical and Biological Constituents of Sewage Treatment Plant Effluent

| Parameter | Annual Average Concentration | Average Quantity | NPDES Monthly Limitations | Agency[a] | Annual[b] Percent of Limitation |
|---|---|---|---|---|---|
| Discharge Point 001 [c] | | | | | |
| pH | 7 3 | NA[d] | 6 0 to 9 0 | USEPA | In Range |
| Fecal Coliform Count | 0 1/100 ml | NA | <200/100 ml | USEPA | In Range |
| Dissolved Oxygen | 7 0 mg/l | NA | > 4 mg/l | USEPA | In Range |
| Residual Chlorine[e] | < 0 1 mg/l | NA | < 0 1 mg/l | USEPA | In Range |
| Suspended Solids | < 2 2 mg/l | <1 4 kg/day | <15 mg/l | USEPA | <15 |
| Biochemical Oxygen Demand, 5-Day | < 4 0 mg/l | <2 6 kg/day | <10 mg/l | USEPA | <40 |
| Phosphorus as P | 1 0 mg/l | NA | < 8 mg/l | USEPA | 12 |
| Nitrate as N | 5 9 mg/l | 3 7 kg/day | <10 mg/l | USEPA | 59 |
| Total Nitrogen | <10 9 mg/l | <7 9 kg/day | <20 mg/l | USEPA | <54 |
| Fluoride | < 0 4 mg/l | NA | < 1 7 mg/l | USEPA | 24 |
| Total Chromium | < 0.05 mg/l | NA | < 0 05 mg/l | USEPA | In Range |
| Oil and Grease | < 0 2 mg/l | NA | <10 mg/l | USEPA | < 2 |
| Turbidity | 1 0 JTU[f] | NA | <30 JTU | CDH | In Range |
| Color | 19 4 Units | NA | <30 Units | CDH | In Range |
| Discharge Point 002 [c] | | | | | |
| pH | 8 0 | NA | 6 0 to 9 0 | USEPA | In Range |
| Nitrate as N | < 3 4 mg/l | NA | 10 mg/l | USEPA | <34 |
| Discharge Point 003 [c] | | | | | |
| Nitrate as N | 0 4 mg/l | NA | NA | USEPA | NA |
| Total Dissolved Solids | 152 6 mg/l | NA | NA | USEPA | NA |
| pH | 8 4 mg/l | NA | NA | USEPA | NA |
| Chemical Oxygen Demand | 10 6 mg/l | NA | NA | USEPA | NA |

a CDH – Colorado Department of Health, Water Quality Control Commission, Denver, Colorado USEPA – U S Environmental Protection Agency, Washington, DC (Region Office VIII, Denver, Colorado)

b Annual average concentrations are indicators of overall performance All monthly limitations were in compliance

c The USEPA-NPDES discharge permit defines Discharge Points 001, 002, and 003 as the Sewage Treatment Plant, Pond A-3, and Pond C-1, respectively

d NA – Not applicable

e As measured at the outfall of Pond B-4

f JTU – Jackson Turbidity Unit

TABLE 13 Plutonium, Uranium, and Americium Radioactivity in Rocky Flats Ponds

| Location | Plutonium Concentration ($\times 10^{-9}$ µCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$ | Percent of $RCG_w$[c] | Uranium Concentration[a] ($\times 10^{-9}$ µCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$ | Percent of $RCG_w$[d] |
|---|---|---|---|---|---|---|---|---|---|---|
| Pond A-3 | 28 | 0 033 | 3 734 | 0 457 ±72% | 0 03 | 20 | 1 856 | 15 622 | 8 216 ±36% | 0 08 |
| Pond B-4 | 51 | 0 080 | 10 944 | 2 161 ±26%[b] | 0 13 | 38 | 1 578 | 4.505 | 1 656 ± 2%[b] | 0 02 |
| Pond C-1 | 51 | 0 013 | 3 379 | <0 275 ±58% | <0 02 | 38 | 0 473 | 2 801 | 1 191 ±22% | 0 01 |

| Location | Americium Concentration ($\times 10^{-9}$ µCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$ | Percent of $RCG_w$[e] |
|---|---|---|---|---|---|
| Pond A-3 | 28 | 0 009 | 0 612 | <0 142 ±47% | <0 01 |
| Pond B-4 | 51 | 0 014 | 3 244 | 0 618 ±26%[b] | 0 05 |
| Pond C-1 | 51 | 0 003 | 1 012 | <0 103 ±57% | <0 01 |

a. Uranium analyses through September
b Volume-weighted average
c The Radioactivity Concentration Guide ($RCG_w$) for soluble plutonium in water is 1,667 X $10^{-9}$ microcuries per milliliter
d The $RCG_w$ for soluble uranium is 10,000 X $10^{-9}$ microcuries per milliliter
e The $RCG_w$ for soluble americium is 1,330 X $10^{-9}$ microcuries per milliliter

TABLE 14 Plutonium, Uranium, and Americium Radioactivity in Walnut Creek

| Location | Plutonium Concentration ($\times 10^{-9}$ µCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[b] | Percent of $RCG_w$[c] | Uranium Concentration[a] ($\times 10^{-9}$ µCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[b] | Percent of $RCG_w$[d] |
|---|---|---|---|---|---|---|---|---|---|---|
| Walnut Creek at Indiana Street | 51 | 0 105 | 1 603 | 0 529 ±20% | 0 03 | 38 | 1 523 | 7 087 | 3 754 ±17% | 0 04 |

| Location | Americium Concentration ($\times 10^{-9}$ µCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[b] | Percent of $RCG_w$[e] |
|---|---|---|---|---|---|
| Walnut Creek at Indiana Street | 51 | 0 007 | 0 742 | 0 197 ±25% | 0 01 |

a Uranium analyses through September
b Sample-weighted average
c The Radioactivity Concentration Guide ($RCG_w$) for soluble plutonium in water is 1,667 X $10^{-9}$ microcuries per milliliter
d The $RCG_w$ for soluble uranium is 10,000 X $10^{-9}$ microcuries per milliliter
e The $RCG_w$ for soluble americium is 1,330 X $10^{-9}$ microcuries per milliliter

TABLE 15 Tritium Radioactivity in Water Samples

| Location | Tritium Concentrations ($\times 10^{-9}$ µCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[a] | Percent of $RCG_w$ |
|---|---|---|---|---|---|
| Pond A-3 | 33 | <500 | 1877 | < 804 ±14% | <0 08 |
| Pond B-4 | 58 | <500 | 2207 | < 887 ±11% | <0 09 |
| Pond C-1 | 58 | <500 | 1893 | < 660 ±11% | <0 07 |
| Walnut Creek at Indiana Street | 58 | <500 | 2160 | <1098 ±10% | <0 11 |
| Great Western Reservoir | 51 | <500 | 1872 | < 953 ± 9% | <0 10 |
| Standley Lake | 51 | <500 | 1314 | < 647 ±10% | <0 06 |

a Sample-weighted average
b The Radioactivity Concentration Guide ($RCG_w$) for tritium in water released to uncontrolled areas is 1,000,000 X $10^{-9}$ microcuries per milliliter

TABLE 16 Plutonium, Uranium, Americium, and Tritium Radioactivity in Groundwater

| Location Number | Depth (feet) | Plutonium Concentration ($\times 10^{-9}$ µCi/ml) | | Uranium Concentration ($\times 10^{-9}$ µCi/ml) | | Americium Concentration ($\times 10^{-9}$ µCi/ml) | | Tritium Concentration ($\times 10^{-9}$ µCi/ml) | |
|---|---|---|---|---|---|---|---|---|---|
| | | May | October | May | October | May | October | May | October |
| 1-60 | 23 | <MDA[a] | 0 041 | 20 509 | NR[b] | 0 095 | 0 054 | NR | 969 |
| 2-60 | 30 | <MDA | 0 014 | 16 568 | NR | 0 049 | 0 009 | NR | 2987 |
| 3-60 | 30 | 0 054 | 0 041 | 25 473 | NR | 0 041 | 0 045 | NR | 4322 |
| 4-60 | 30 | 0 077 | 0 090 | 16 878 | NR | 0 086 | 0 077 | NR | 1911 |
| 5-60 | 30 | Dry | 0 041 | Dry | NR | Dry | 0 032 | Dry | 2915 |
| 6-60 | 30 | 0 032 | 0 032 | 2 568 | NR | 0 014 | 0 032 | NR | 4318 |
| 1-66 | 148 | 0 009 | 0 041 | 0 351 | NR | 0 023 | 0 049 | NR | L[c] |
| 2-66 | 146 | 0 014 | 0 014 | 0 284 | NR | 0 027 | 0 027 | NR | 1493 |
| 3-66 | 153 | 0 068 | 0 027 | 1 059 | NR | 0 054 | 0 023 | NR | 821 |
| 1-71 | 30 | 0 050 | 0 018 | 0 392 | NR | <MDA | 0 054 | NR | 903 |
| 2-71 | 30 | 0 099 | 0 027 | 0 387 | NR | 0 059 | 0 041 | NR | 962 |
| 3-71 | 25 | 0 014 | 0 045 | 1 523 | NR | 0 018 | 0 018 | NR | 1270 |
| 4-71 | 22 | <MDA | 0 018 | 0 396 | NR | 0 027 | 0 014 | NR | 937 |
| 5-71 | 28 | Dry | 0 032 | Dry | NR | Dry | 0 009 | Dry | 1177 |
| 6-71 | 30 | 0 009 | 0 014 | 32 640 | NR | 0 027 | 0 063 | NR | 2993 |
| 1-74 | 24 | 0 018 | 0 045 | 5 284 | NR | 0 004 | 0 041 | NR | 879 |
| 2-74 | 10 | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 3-74 | 24 | Dry | 0 149 | Dry | NR | Dry | 0 054 | Dry | 875 |
| 4-74 | 6 | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 5-74 | 18 | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 6-74 | 7 | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 7-74 | 50 | 0 023 | 0 050 | 5 482 | 3 558 | 0 018 | L | NR | 838 |
| 8-74 | 40 | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 9-74 | 19 | 0 095 | 0 014 | 77 203 | NR | 0 041 | 0 014 | NR | 859 |
| 10-74 | 10 | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 11-74 | 20 | 0 027 | 0 054 | 1 167 | NR | 0 014 | 0 009 | NR | 886 |
| 12-74 | 4 | Dry | Dry | Dry | Dry | Dry | Dry | Dry | Dry |
| 13-74 | 19 | 0 014 | 0 068 | 6 086 | NR | 0 099 | 0 004 | NR | 894 |
| 14-74 | 4 | Dry | 0 045 | Dry | NR | Dry | 0 032 | Dry | Dry |
| 15-74 | 19 | 0 027 | 0 018 | 27 959 | NR | 0 014 | 0 005 | NR | 874 |
| 16-74 | 4 | Dry | 0 270 | Dry | NR | Dry | 0 032 | Dry | 879 |
| 17-74 | 16 | 0 036 | 0 009 | 10 631 | NR | 0 112 | <MDA | NR | 1664 |
| 18-74 | 7 | 0 014 | 0 014 | 41 518 | NR | 0 009 | LR[d] | NR | 930 |
| 21-74 | 265 | 0 018 | NS[e] | 1 694 | NS | 0 018 | NS | NR | NS |
| 22-74 | 315 | 0 027 | 0 045 | 3 667 | NR | 0 023 | 0 014 | NR | 860 |

a. <MDA – less than Minimum Detectable Activity
b NR – sampled but not analyzed
c L – Lost during analysis.
d LR – Low Recovery
e NS – Not Sampled.

TABLE 17 Plutonium, Uranium, and Americium Radioactivity in Public Water Supplies

| Reservoirs | Plutonium Concentration (× $10^{-9}$ μCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[a] | Percent of $RCG_w$[b] | Uranium Concentration (× $10^{-9}$ μCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[a] | Percent of $RCG_w$[c] |
|---|---|---|---|---|---|---|---|---|---|---|
| Great Western | 51 | <0 008 | 0 505 | <0 061 ± 38% | <0 004 | 33 | 0 647 | 6 326 | 0 877 ± 50% | 0 009 |
| Standley Lake | 46 | <0 002 | 0 689 | <0 045 ± 87% | <0 003 | 28 | 1 447 | 5 557 | 1 849 ± 38% | 0 020 |
| Summary | 97 | <0 002 | 0 689 | – | – | 61 | 0 647 | 6 326 | – | – |
| Finished Water | | | | | | | | | | |
| Arvada | 4 | <0 002 | 0 034 | <0 018 ±143% | <0 001 | 3 | 1 476 | 2 302 | 1 976 ± 61% | 0 020 |
| Boulder | 50 | <0 002 | 0 532 | <0 033 ± 67% | <0 002 | 31 | <0 016 | 3 153 | <0 190 ±116% | <0 002 |
| Broomfield | 49 | <0 002 | 1 128 | <0 095 ± 75% | <0 006 | 31 | 0 410 | 1 677 | 0 548 ± 38% | 0 005 |
| Denver | 4 | <0 004 | 0 023 | <0 013 ± 96% | <0 001 | 3 | 2 226 | 2 568 | 2 372 ± 18% | 0 020 |
| Golden | 4 | <0 008 | 0 014 | <0 011 ± 35% | <0 001 | 3 | 1 306 | 2.992 | 2 173 ± 97% | 0 020 |
| Lafayette | 4 | <0 004 | 0 079 | <0 036 ±142% | <0 002 | 3 | 0 385 | 0 462 | 0 424 ± 21% | 0 004 |
| Louisville | 4 | <0 005 | 0 018 | <0 011 ± 74% | <0 001 | 3 | 0 251 | 0 497 | 0 374 ± 82% | 0 004 |
| Thornton | 4 | <0 011 | 0 065 | <0 036 ±114% | <0 002 | 3 | 2 354 | 4 059 | 3 231 ± 66% | 0 030 |
| Westminster | 51 | <0 003 | 1 104 | <0 047 ± 95% | <0 003 | 34 | 0 619 | 6 728 | 1 078 ± 49% | 0 010 |
| Summary | 174 | <0 002 | 1 128 | – | – | 114 | <0 016 | 6 728 | – | – |
| Sample-Weighted Average | | – | – | <0 053 ± 46% | <0 003 | | – | – | <1 136 ± 14% | <0 010 |

| Reservoirs | Americium Concentration (× $10^{-9}$ μCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[a] | Percent of $RCG_w$[d] |
|---|---|---|---|---|---|
| Great Western | 51 | <0 002 | 0 176 | <0 025 ± 32% | <0 002 |
| Standley Lake | 47 | <0 001 | 0 830 | <0 051 ± 78% | <0 004 |
| Summary | 98 | <0 001 | 0 830 | – | – |
| Finished Water | | | | | |
| Arvada | 4 | <0 001 | 0 152 | <0 061 ±177% | <0 005 |
| Boulder | 50 | <0 002 | 0 342 | <0 033 ± 61% | <0 002 |
| Broomfield | 49 | <0 001 | 0 476 | <0 052 ± 52% | <0 004 |
| Denver | 4 | <0 006 | 0 066 | <0 024 ±187% | <0 002 |
| Golden | 4 | <0 004 | 0 033 | <0 017 ±133% | <0 001 |
| Lafayette | 4 | <0 002 | 0 249 | <0 104 ±161% | <0 008 |
| Louisville | 4 | <0 001 | 0 024 | <0 012 ±121% | <0 001 |
| Thornton | 4 | <0 002 | 0 062 | <0 037 ±127% | <0 003 |
| Westminster | 51 | <0 002 | 0 662 | <0 051 ± 68% | <0 004 |
| Summary | 174 | <0 001 | 0 662 | – | – |
| Sample-Weighted Average | | – | – | <0 044 ± 32% | <0 003 |

a. Sample-weighted average

b The Radioactivity Concentration Guide ($RCG_w$) for soluble plutonium in water is 1,667 × $10^{-9}$ microcuries per milliliter

c The $RCG_w$ for soluble uranium is 10,000 × $10^{-9}$ microcuries per milliliter

d. The $RCG_w$ for soluble americium is 1,330 × $10^{-9}$ microcuries per milliliter

TABLE 18 Plutonium, Uranium, and Americium Radioactivity in Regional Lakes, Reservoirs, and Streams

| Distance from Rocky Flats Plant | Plutonium Concentration ($\times 10^{-9}$ μCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[a] | Percent of $RCG_w$[b] | Uranium Concentration ($\times 10^{-9}$ μCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[a] | Percent of $RCG_w$[c] |
|---|---|---|---|---|---|---|---|---|---|---|
| Less than 5 miles | 12 | <0 009 | 2 014 | <0 226 ±159% | <0 010 | 0 | NA[d] | NA | NA | NA |
| Greater than 5 miles | 17 | <0 005 | 0 189 | <0 040 ± 56% | <0 002 | 14 | 0 644 | 128 960 | 12 383 ±157% | 0 120 |

| Distance from Rocky Flats Plant | Americium Concentration ($\times 10^{-9}$ μCi/ml) Number of Samples | $C_{min}$ | $C_{max}$ | $C_{avg}$[a] | Percent of $RCG_w$[e] |
|---|---|---|---|---|---|
| Less than 5 miles | 11 | <0 014 | 0 400 | <0 129 ± 61% | <0 010 |
| Greater than 5 miles | 5 | <0 009 | 0 540 | <0 156 ±175% | <0 010 |

a Sample-weighted average
b The Radioactivity Concentration Guide ($RCG_w$) for soluble plutonium in water is 1,667 × $10^{-9}$ microcuries per milliliter
c The $RCG_w$ for soluble uranium is 10,000 × $10^{-9}$ microcuries per milliliter
d NA means no analysis was performed
e The $RCG_w$ for soluble americium is 1,330 × $10^{-9}$ microcuries per milliliter

TABLE 19 Radioactivity Concentrations Used for 1976 Dose Calculations

| Location | Parameter | Average Concentration[a] (μCi/ml) |
|---|---|---|
| **Fence Line** | | |
| Air Sampler S-37 | Plutonium in Air | 0 037 × $10^{-15}$ ± 93% |
| Walnut Creek at Indiana Street | Plutonium in Water | 0 529 × $10^{-9}$ ± 23% |
| Walnut Creek at Indiana Street | Uranium in Water | 3 754 × $10^{-9}$ ± 13% |
| Walnut Creek at Indiana Street | Americium in Water | 0 197 × $10^{-9}$ ± 30% |
| Walnut Creek at Indiana Street | Tritium in Water | <1 100 × $10^{-6}$ ± 5% |
| **Community** | | |
| Broomfield Ambient Air | Plutonium in Air | 0 012 × $10^{-15}$ ±210% |
| Broomfield Finished Water | Plutonium in Water | <0 095 × $10^{-9}$ ± 26% |
| Broomfield Finished Water | Uranium in Water | 0 548 × $10^{-9}$ ± 35% |
| Broomfield Finished Water | Americium in Water | <0 052 × $10^{-9}$ ± 31% |
| Great Western Reservoir | Tritium in Water | 0 953 × $10^{-6}$ ± 14% |
| **80 Kilometer** | | |
| Community Average | Plutonium in Air | <0 013 × $10^{-15}$ ± 10% |
| Community Average | Plutonium in Water | <0 053 × $10^{-9}$ ± 49% |
| Community Average | Uranium in Water | 1 136 × $10^{-9}$ ± 18% |
| Community Average | Americium in Water | <0 044 × $10^{-9}$ ± 25% |

a. Background values from Table 2 were subtracted from each number before it was used for the dose calculations.

TABLE 20 Factors for Conversion from Concentration to Dose (rem-ml/μCi)

| Organ | Air Factor[a] Plutonium | Water Factors[a] Plutonium | Uranium | Americium | Tritium |
|---|---|---|---|---|---|
| Total Body | 2.57 × $10^{10}$ | 3 40 × $10^{2}$ | 3 58 × $10^{2}$ | 1 21 × $10^{3}$ | 1 01 × $10^{2}$ |
| Bone | 1 05 × $10^{12}$ | 1 38 × $10^{4}$ | 3 66 × $10^{3}$ | 1 49 × $10^{4}$ | NA[b] |
| Liver | 1 61 × $10^{11}$ | 2 00 × $10^{3}$ | NA | 1 69 × $10^{4}$ | NA |
| Kidney | 1 20 × $10^{11}$ | 1 58 × $10^{3}$ | 1 50 × $10^{3}$ | 8 49 × $10^{3}$ | NA |
| Pulmonary Region | 2 38 × $10^{12}$ | NA | NA | NA | NA |

a. Concentrations expressed in μCi/ml multiplied by these conversion factors give the dose, in rems, during 1976
b NA means not applicable

# ILLUSTRATIONS

**Figures 1 through 11**

FIGURE 1 Location of the Rocky Flats Plant and Surrounding Communities

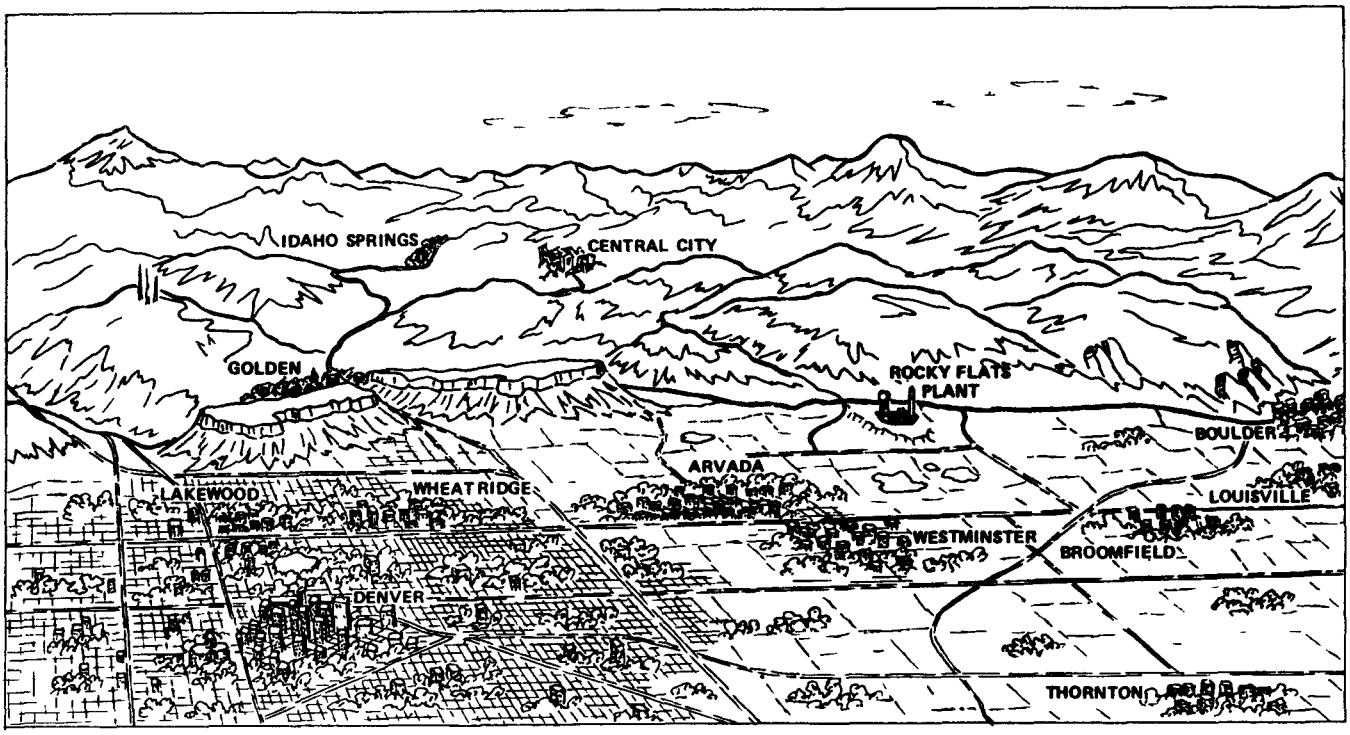


FIGURE 2 Location of the Rocky Flats Plant Boundaries

15299

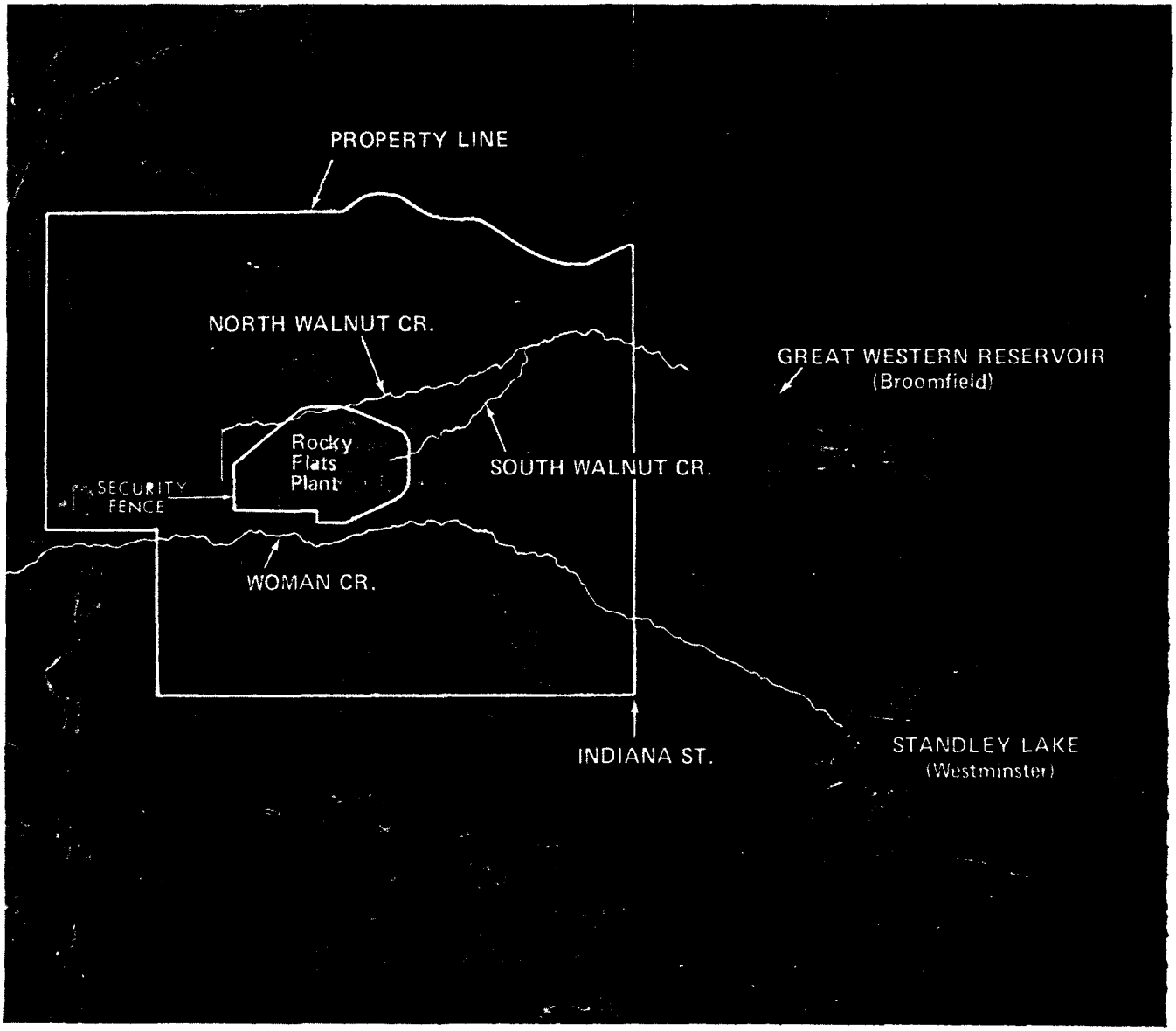


FIGURE 3 Liquid Effluent Watercourses

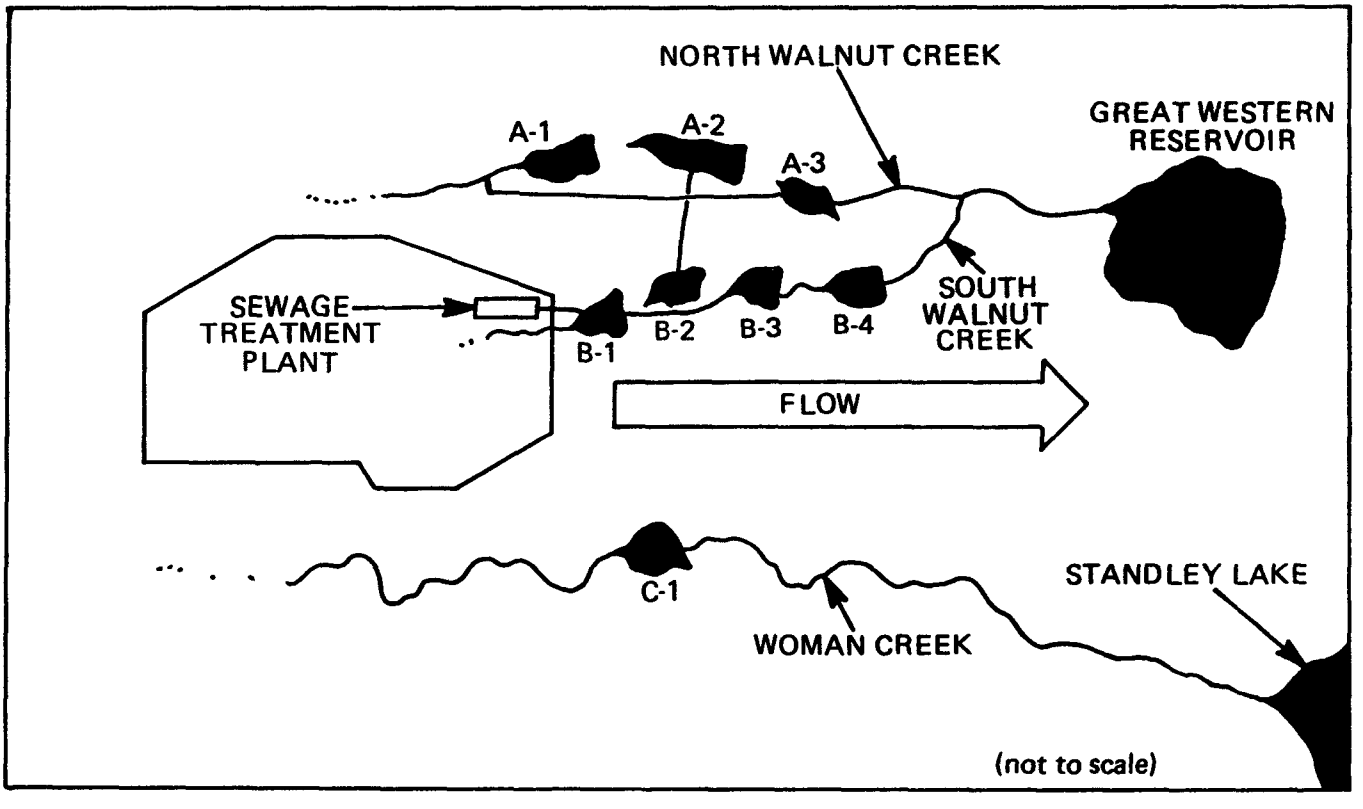
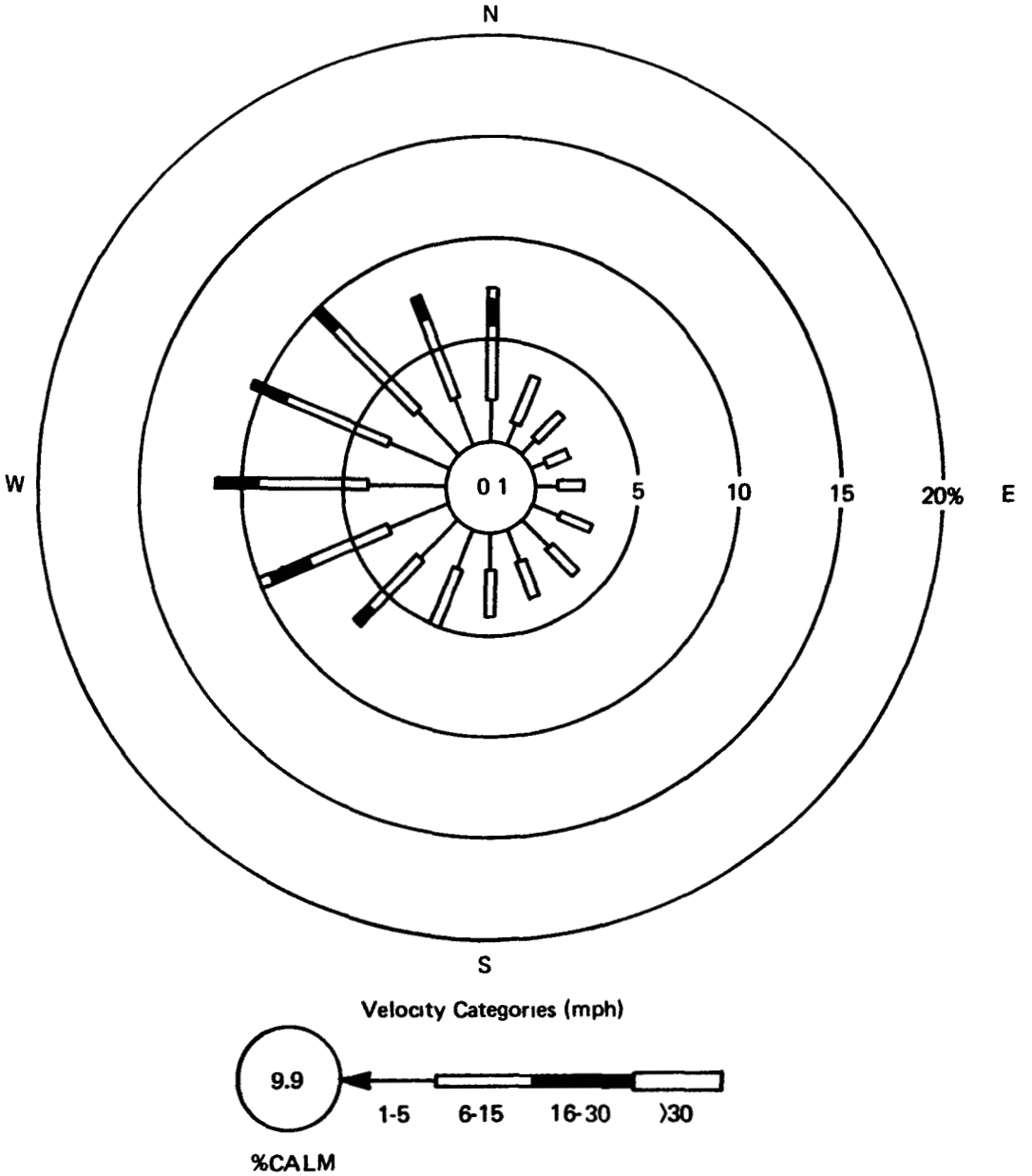
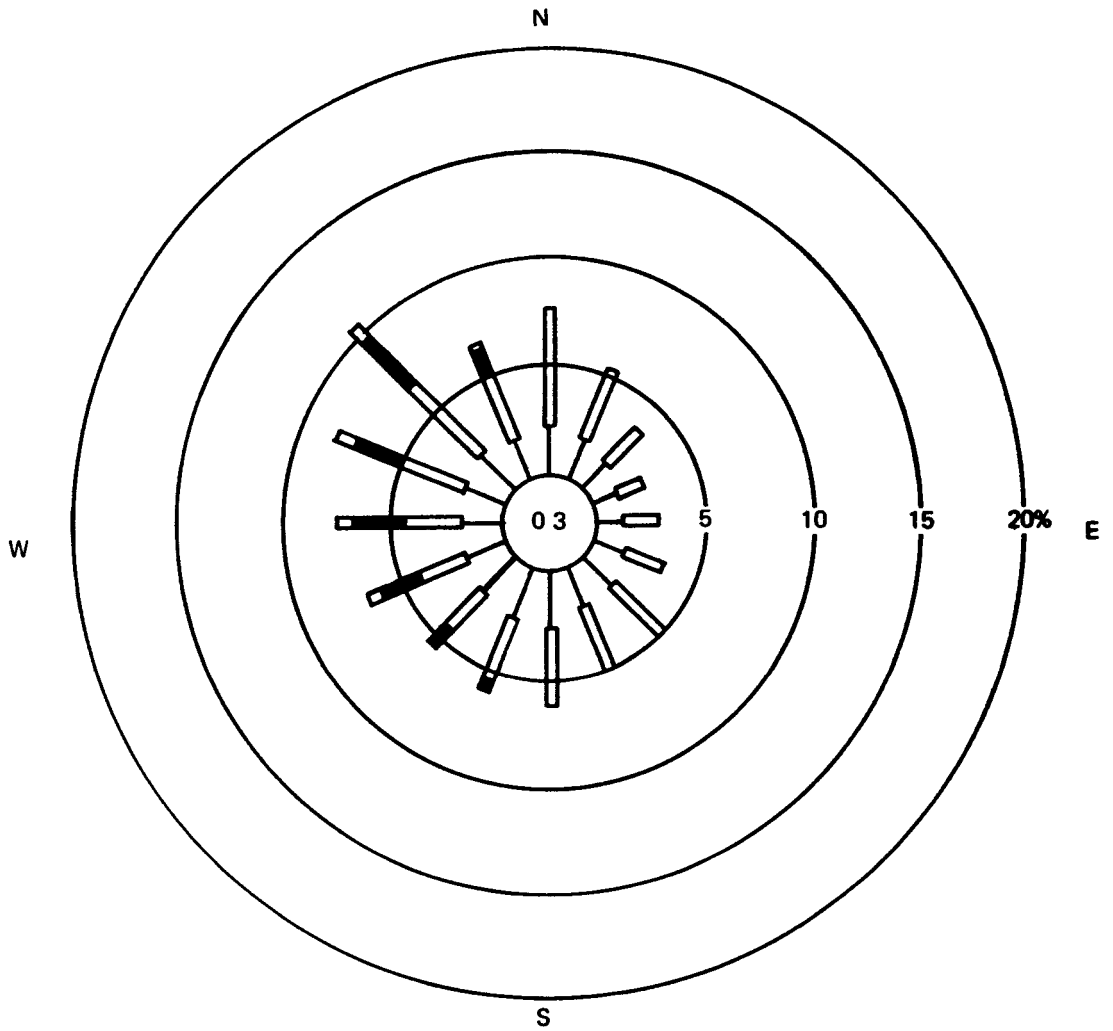


FIGURE 4 1976 Wind Rose at the 6-Meter (20-Foot) Level




Percent Frequency of Winds from 16 Directions

FIGURE 5 1976 Wind Rose at the 61-Meter (200-Foot) Level




Percent Frequency of Winds from 16 Directions

FIGURE 6 Location of On-Site Ambient Air Samplers

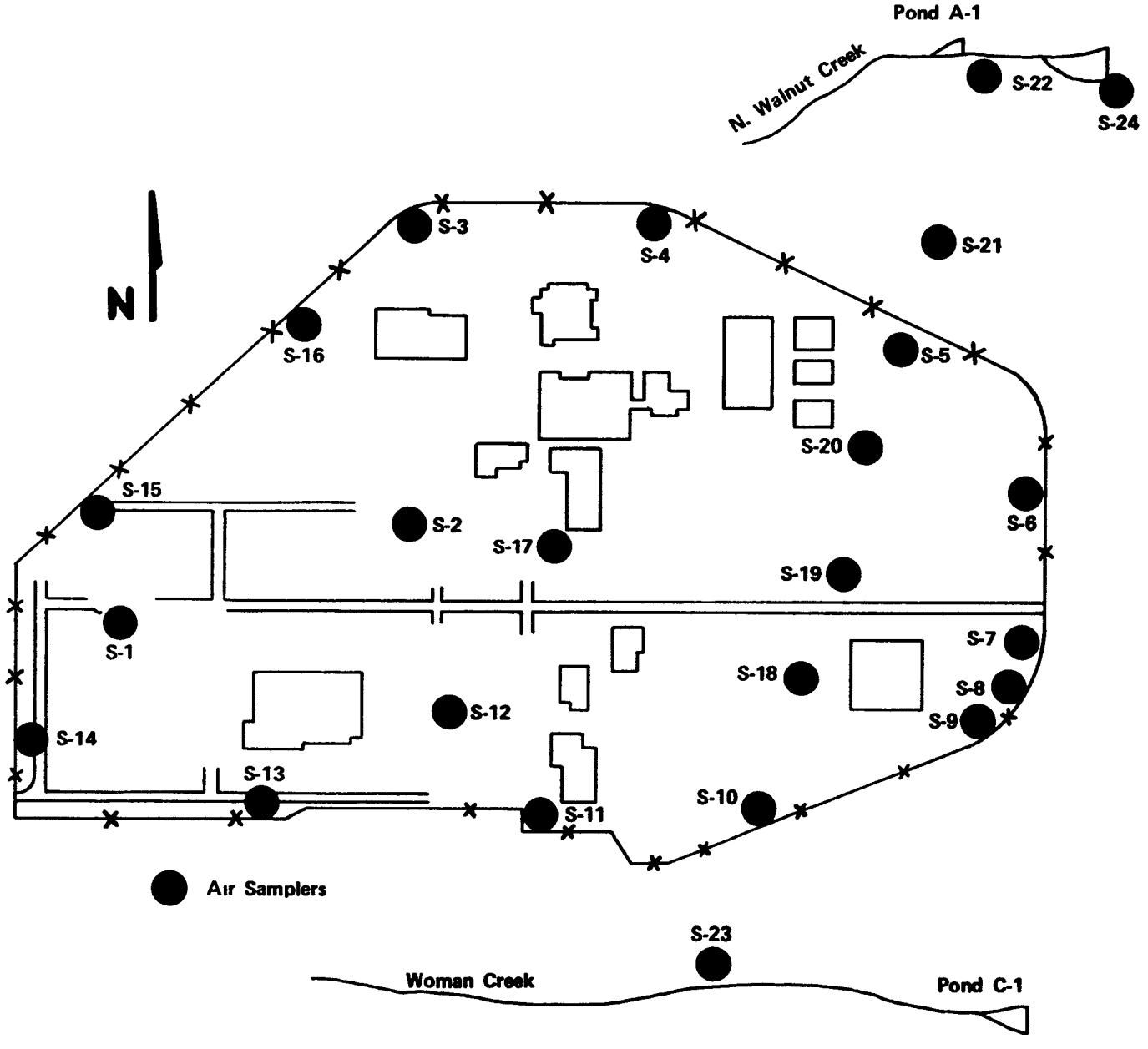
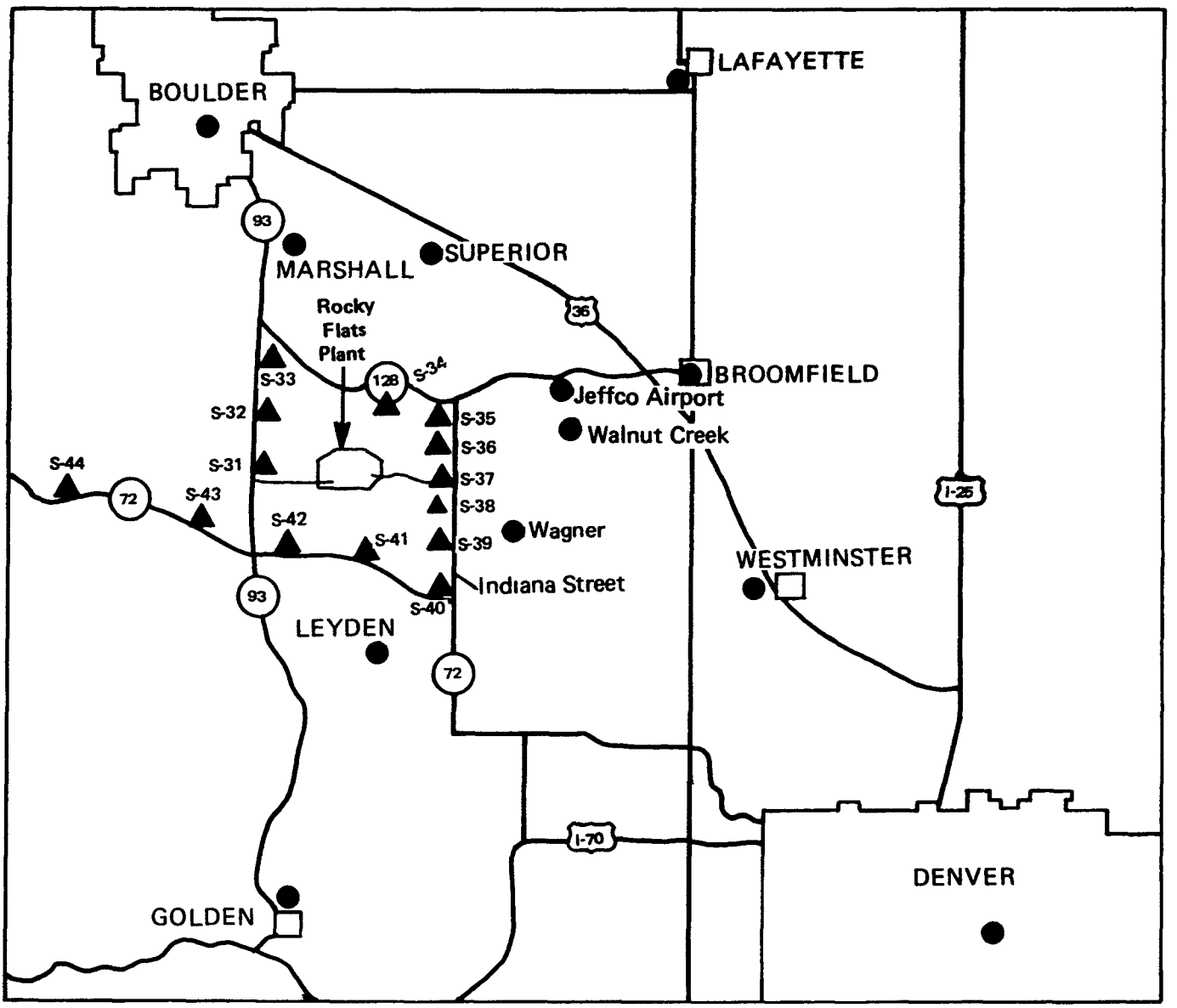


FIGURE 7 Location of Off-Site Ambient Air Samplers




Legend

▲ Air Samplers, 3 to 6 kilometers (2 to 4 miles) distance

● Community Air Samplers

FIGURE 8 Location of Hydrologic Test Holes

△ – hydrologic test hole locations

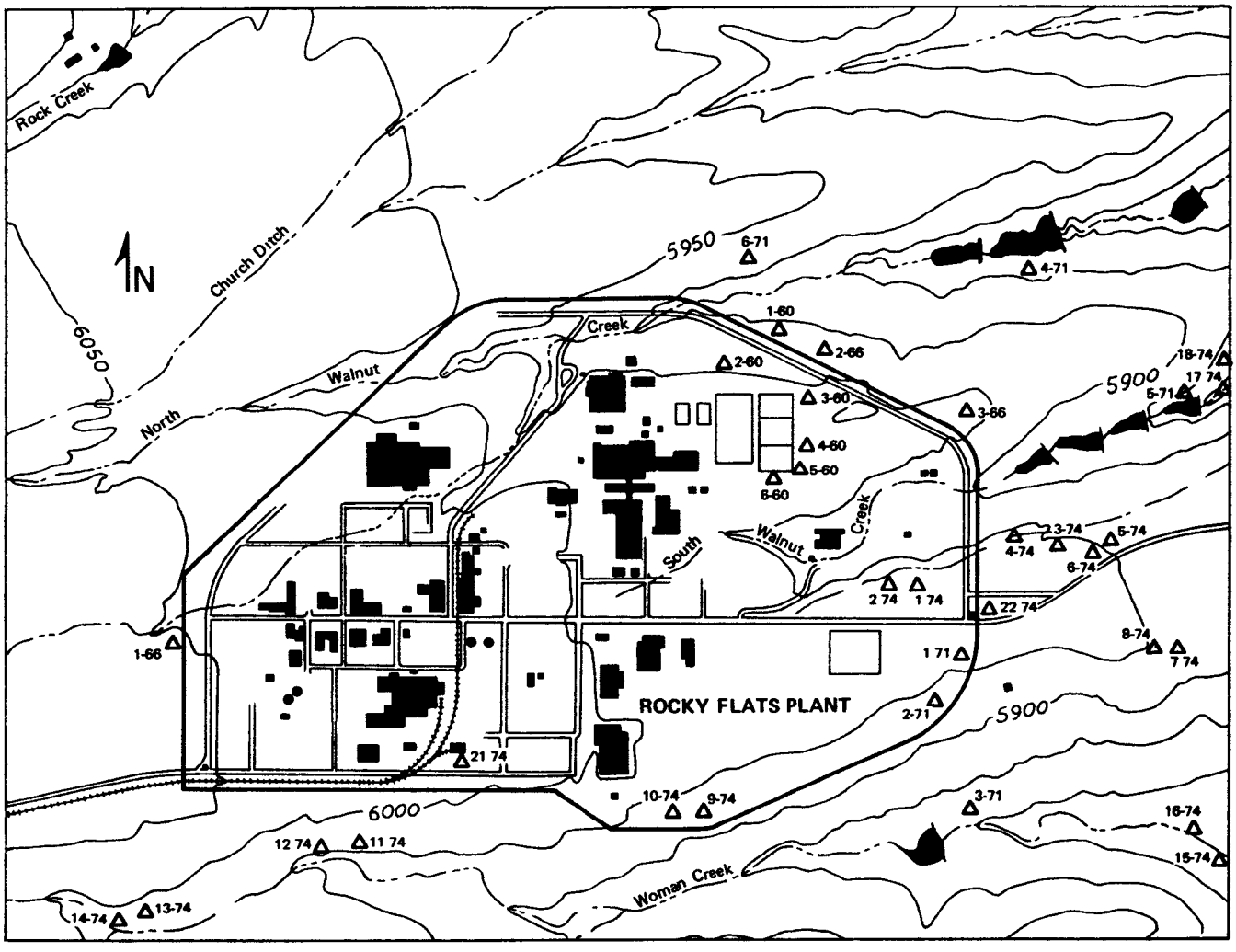


FIGURE 9 Plutonium Concentrations in Soil – 1976 (Values are in picocuries per gram of total sample)

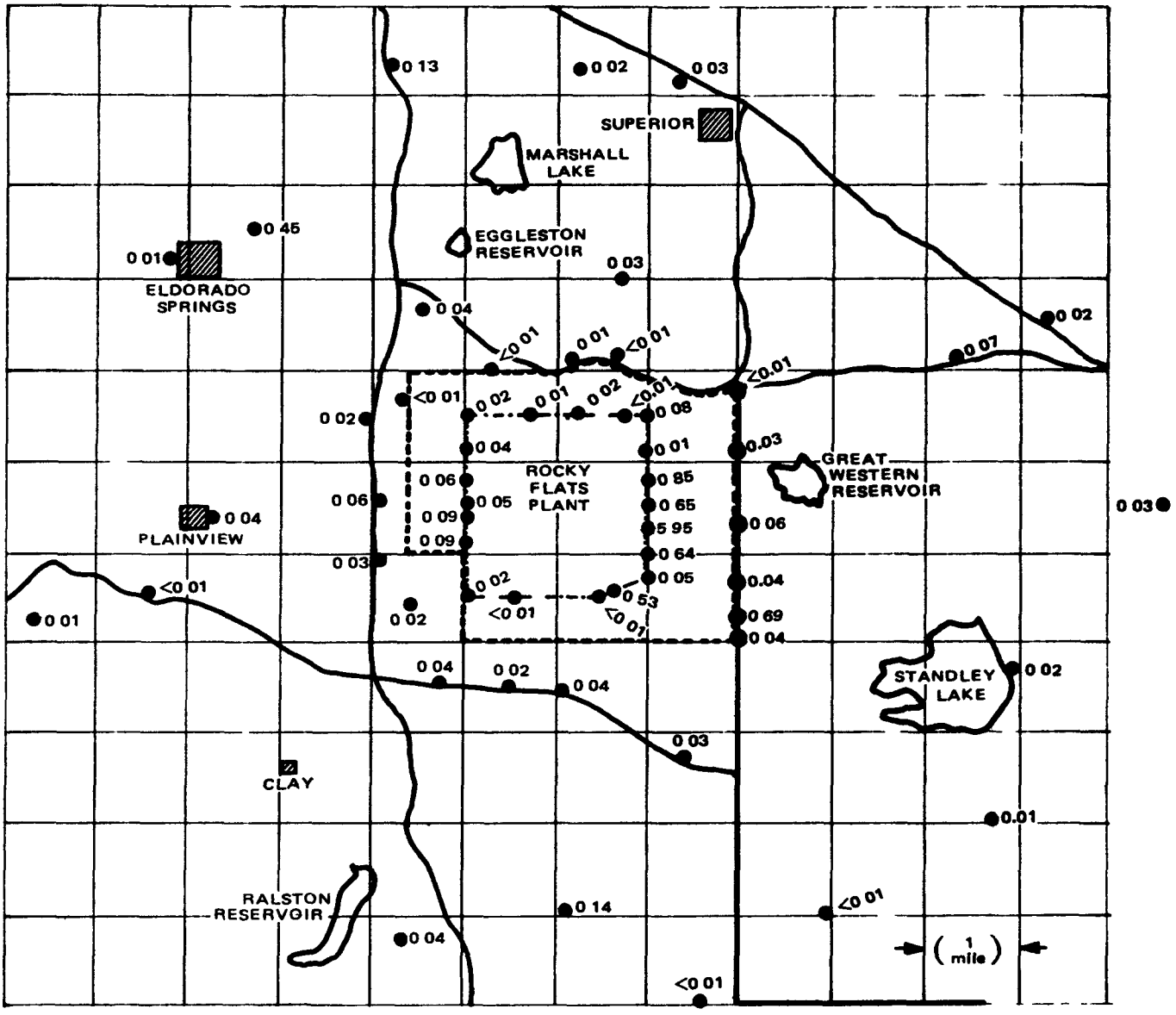
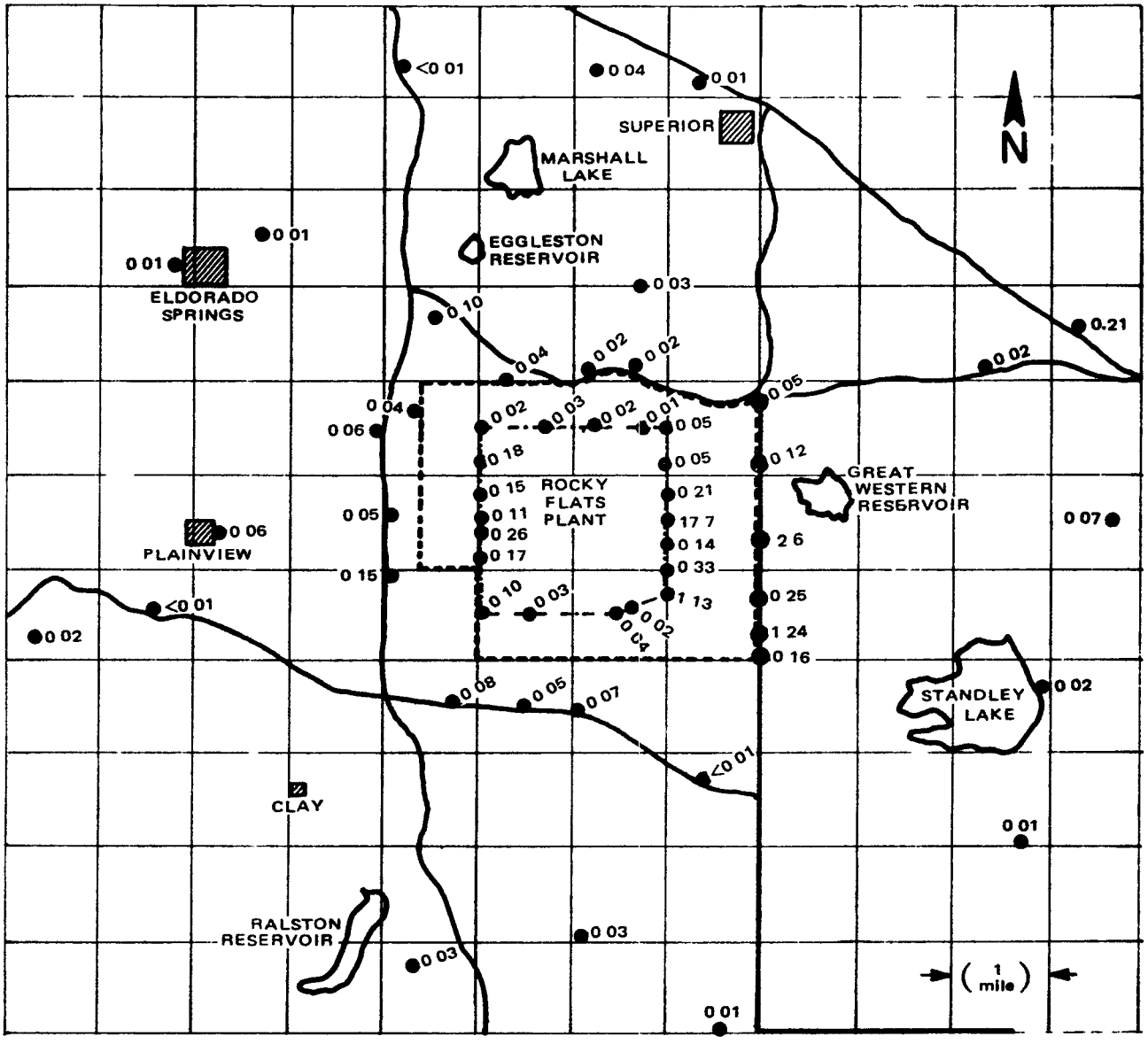
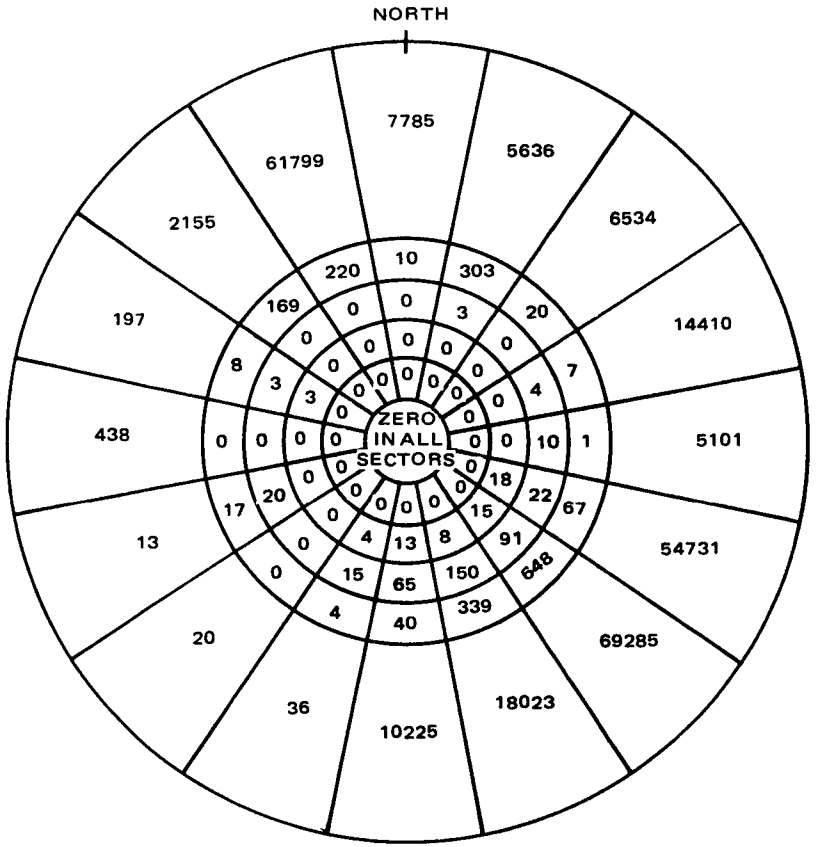
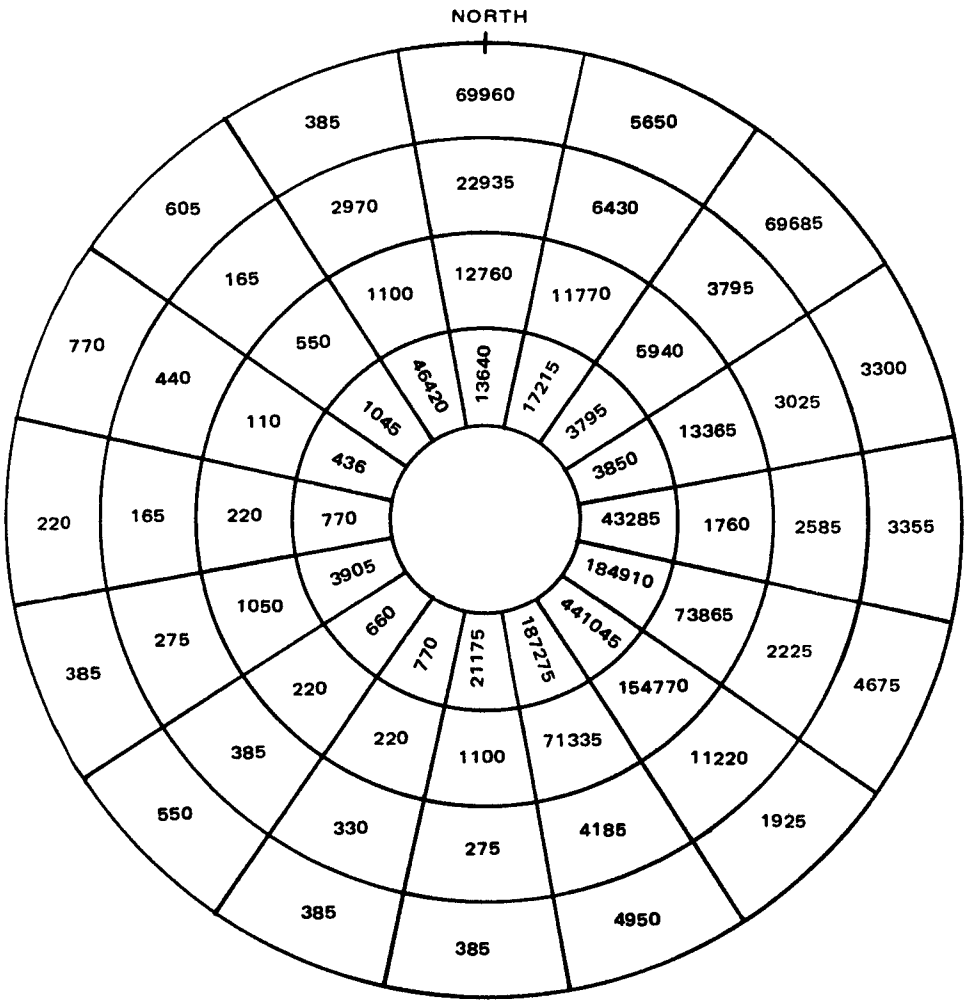


FIGURE 10 Plutonium Concentration in Soil – 1975 (Values are in picocuries per gram of total sample )






0-16 Kilometers (0-10 miles) from Rocky Flats




16-80 Kilometers (10-50 miles) from Rocky Flats

NOTE These population estimates were taken from the 1970 Census and from Community Growth Estimates for 1975 with an additional arbitrary growth of 10% for 1976

FIGURE 11 Demographic Estimates – 1976