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ENVIRONMENTAL STUDIES GROUP
ANNUAL REPORT FOR 1978

Edited by

Douglas C. Hunt and John D. Hurley

Rockwell International

Energy Systems Group

Rocky Flats Plant

P.O. Box 464

Golden, Colorado 80401

U. S. DEPARTMENT OF ENERGY
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**ENVIRONMENTAL STUDIES GROUP
ANNUAL REPORT FOR 1978**

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SUBJECT DESCRIPTORS

Land Use
Monitoring Techniques
Radioecology
Radionuclides
Transuranics
Tritium

**ROCKWELL INTERNATIONAL
ENERGY SYSTEMS GROUP
ROCKY FLATS PLANT
P.O. BOX 464
GOLDEN, COLORADO 80401**

Prepared under Contract DE-AC04-76DPO3533
for the
Albuquerque Operations Office
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ENVIRONMENTAL STUDIES GROUP

ANNUAL REPORT FOR 1978

Abstract. This report summarizes Environmental Studies Group activities during 1978. Group projects include radioecological studies of aquatic and terrestrial systems, land management activities, foodstuff monitoring, dust transport studies including fugitive dust measurements and modeling, and several support programs involving evaluation of the Plant's ambient air samplers and airborne tritium monitoring techniques. Some salient results from the several project reports include (1) determination of an appropriate model for mechanically generated fugitive dust dispersion, (2) a radionuclide inventory of Smart Ditch Pond (Pond D-1), (3) a coefficient of community determination for two terrestrial sample plots on the Plant site buffer zone, (4) a natality and mortality rate determination for fawns in the Plant deer herd (including one positive coyote-kill determination), (5) inlet loss and filter paper collection efficiencies for the Plant ambient air samplers, and (6) differential tritium sampling measurements of the vapor in Building 771 stack effluent.

INTRODUCTION AND OBJECTIVES

The purpose of this report is to summarize the progress of Environmental Studies Group research activities during CY 1978, to provide a current status of these activities, and where appropriate, to supply anticipated future directions of these and other potential Group programs.

The overall objective of the Environmental Studies Group is to provide scientific research data of high quality for use in assisting the Environmental Sciences Department (of which the Studies Group is a part) in its mission of evaluating and controlling the impact of the Rocky Flats Plant on the Plant's surroundings. To accomplish this, a few salient projects from the great variety possible have been selected and are being actively pursued by the Studies Group. These projects involve efforts in the general areas of radioecology and land use but also include assistance to the Environmental Sciences

Department in the area of pilot program establishment and evaluation of current monitoring efforts. More specifically, this report details progress and results in the following areas:

1. Fugitive dust transport and emission rates as a function of meteorological conditions, the nature of the mechanical disturbance, and the degree of dust suppression involved.
2. Aquatic radiological results in which ecosystem compartmentalization of Pu-238, -239, -240, and Am-241 is described.
3. Land management practices in the Plant buffer zone including a description of the Plant Land Management Plan and of the administrative system to control buffer zone usage. The Plant program of remote sensing data acquisition is also included in the category of land management.
4. Primarily nonradiological assessments of ecosystem differences on terrestrial study plots having different levels of transuranic soil activity.
5. Demographic results concerning Plant deer population, also fawn mortality rates.
6. Progress toward development of a pilot program for monitoring foodstuff in the vicinity of the Plant site.
7. Results of a program to measure the inlet efficiency of the Plant's ambient air samplers and the collection efficiency of the air sampler Microsorban filter media.
8. Results of a program to measure the differential amounts of tritium, in the elemental and oxide forms, in Plant effluents.
9. Details of a project to estimate the mean and the variation of the level of transuranics in spillway sediments from Great Western Reservoir.

DUST TRANSPORT AND RESUSPENSION

This major program is concerned with release and transport mechanisms of dust particles from the Rocky Flats Plant. Some of the processes that cause the release of dust are (1) soil erosion by wind, (2) evaporation of sprays from cooling towers, leading to particulate residues, (3) release of ash particles from fuel combustion, and (4) emission of fugitive dust from unpaved roads and construction. For this report period, the work

reported is concerned only with fugitive dust from construction of the Woman Creek Surface Water Control Project. However, the groundwork has been laid for a major study on wind erosion of soil particles at Rocky Flats. An experimental plan was written by D. C. Hunt and J. Hayden for this work, and it is now being reviewed. Basic experimental equipment for the study has been acquired and tested.

FUGITIVE DUST MEASUREMENTS AND MODELING

Gerhard Langer

Introduction

This study is directed at the extent of fugitive dust generated by the Rocky Flats Surface Water Control Project. This project started in September 1978 and is scheduled for completion by the end of 1980. The project involves the construction of three dams and two interceptor canals to confine all rain and snow runoff from the Plant to dams at Woman and Walnut Creeks. The project also is designed to cover the worst possible drainage case (Gumbel, 1941) that may be encountered in a 100-year period. Impounded water will be monitored for contaminants to determine if any treatment is necessary before the water is released.

The primary purpose of this fugitive dust transport program is to evaluate the effectiveness of dust abatement procedures followed during topsoil removal at Woman Creek. These procedures will be used to a lesser extent during the main construction phase. During topsoil removal, the aim was to minimize the release into the atmosphere of dust particles that could carry small amounts of transuranic activity. A second objective is to quantify the dust emission and to incorporate the results into a model of fugitive dust emission for the Rocky Flats site. This model will facilitate evaluation of future soil moving activities and surface

disturbances by heavy construction vehicles. A third objective is to compare the model calculations with dust emission predictions for the main construction phase, as given in the Fugitive Dust Permit Application prepared for the project in accordance with requirements of the State of Colorado. Another objective is a good understanding of such predictive models. Such an understanding is important to place any projections of resuspension of radioactive material from gross dust dispersion data into proper perspective. This report is limited to the 1978 soil removal phase of the Surface Water Control Project.

Summary

The primary mission of the Environmental Sciences efforts in connection with the Woman Creek project was to evaluate the effectiveness of dust abatement procedures during the topsoil removal phase. This experience was incorporated into a preliminary fugitive dust model for the Rocky Flats site—a model that may be used to evaluate future construction projects. During the soil removal phase, the major concern was the release of radioactivity above normal levels. Long-lived alpha counts taken during the construction activity showed no such increases in activity during construction.

The concern is not with dust emission from wind-blown soil erosion but with the strong mechanical forces of earth movers. These latter forces are much more disruptive than wind forces. Chepil (1956) has shown that there is no dust generated by wind erosion at the soil moisture levels maintained in this construction work.

A representative finding from this study is that the amount of dust released during a typical operational day causes an increase in total dust loading above the background or upwind loading (see following text). The increase about 100 m downwind of the site is $75 \mu\text{g}/\text{m}^3$ as measured by a standard high-volume (Hi-Vol) sampler. This sampler is assumed to cut off at a $30\text{-}\mu\text{m}$ -diameter particle size because of sampler bias. After a determination of particle-size distribution of the collected dust containing particles up to $60 \mu\text{m}$ in diameter, a correction was made for the sampling loss. As a result, total loading above background is estimated at $209 \mu\text{g}/\text{m}^3$. True dust loadings are needed to study details of local deposition and resuspension of soil contaminants. Background or upwind loading from the standard Hi-Vol measurement was $66 \mu\text{g}/\text{m}^3$. This is typical of the area and is below most of the measured Jefferson County values. The respirable mass fraction of the construction dust was found to be about 1%, assuming a particle density of $2.5 \text{ g}/\text{cm}^3$.

The total amount of dust emission associated with the measured dust loading was estimated by applying a special highway traffic model. This model realistically simulates the effects of construction traffic on dust plume dispersion. A total representative source strength value (9.4 kg of dust) for this model had to be derived specifically for each of the several types of construction vehicles, i.e., scrapers, bulldozers, and pickups. For the scraper (which generates about 98% of the dust) an agricultural emission formula was applied that has an adjustment for soil moisture. The model was used to compute dust loading, at the downwind sampling site, resulting from the excavation and removal of 2893 metric tons of soil. Results closely matched the observed value; consequently, the total emission of 9.4 kg of dust for this particular day, as derived from the above source values, is considered realistic.

If the EPA emission factor (EPA, 1977) of 0.020 kg of fugitive dust per metric ton of excavated soil is applied instead, the expected uncontrolled emission is 56.8 kg of dust. This is about six times the observed emission and implies that dust abatement efforts in effect during construction activities were 85% effective. This added dust suppression efficiency is due to the practice of watering the soil both before ripping and afterwards to allow for deeper moisture penetration. The main construction phase of this project does not have as stringent dust abatement requirements. Using the relaxed abatement procedures, preliminary tests at the Walnut Creek gauge site showed that dust emissions during soil removal with a front loader still were consistent with the assumption of greater than 50% dust control effectiveness for general construction work.

Field Operations at the Woman Creek Soil Removal Site

The layout of the interceptor canal and dam is shown in Figure 1, which is an aerial photograph taken on October 5, 1978. This date was near the end of the topsoil removal phase. Figure 1 outlines the dam and canal and includes contours showing the soil plutonium concentration to a 5-cm depth. The former barrel storage area called the "pad" is shown in the upper right of the photo and is the source region of the plutonium contamination due to leakage from the barrels. Removal of topsoil over the entire construction site was the first step in site preparation. This operation was supervised directly by Rocky Flats personnel because it involved the removal of soil containing some transuranic activity. The soil with the highest activity, i.e., closest to the pad (see Figure 1), was removed to a depth of 15 cm and placed into a "waste storage" area to be covered with grass. This waste soil involved only the soil in the interceptor canal area. The topsoil removed from the dam site was placed into nearby storage piles and stabilized with Coherex.* The depth of removal was 38 cm along the base of the C2 dam and to 23 cm south of the dam. These different areas are shown in

*Coherex is a dust-retardant emulsion of petroleum resins that is water soluble and is manufactured by the Colorado Bituminous Company under a license from Witco Chemical Company, Golden Bear Division, Bakersfield, California.

FIGURE 1. Construction Site Showing Proposed Water Control System and Sampler Locations. Isopleths show concentrations, in dpm/g, of plutonium in soil to a depth of 5 cm.

Figure 1. The scraping depths were selected to allow for sufficient dilution of the contamination so that this soil could be used for topsoil revegetation of the site. Topsoil removal is also necessary to make sure that all vegetative matter is removed, thus allowing solid footing for the dam and embankments.

Scraping was done with two International Harvester Pay Scrapers, Model 442, weighing 30.8 metric tons when empty. Soil was loosened to the desired depth stated above with an IH Model TD 25 Ser. C bulldozer with two rippers. This machine weighed 42.6 metric tons. In addition, a smaller bulldozer with one ripper was used. The rippers also aided soil penetration by water. The bulldozer moved some of the burden into windrows to simplify pickup by the scrapers in area where the scrapers could not operate efficiently.

Other vehicular traffic in the area included pickup trucks and the watering truck. The watering truck operated a day or so prior to any scraping operations.

Dust abatement was especially important to reduce the transport of radioactivity. For permit calculations, an optimistic 100% dust suppression was assumed for preliminary topsoil removal. The volume of soil moved here was only 5% of the total amount estimated for the entire project; no dust emission factors are available for surface soil removal.

The following dust abatement control procedures were applied to minimize airborne dust dispersion during stripping of the topsoil:

1. All access roads to the site were stabilized with Coherex because dust from the south access road has exhibited elevated activity levels during sampling just behind the rear tire of a pickup truck. (Michels and Hofsheier, 1973).
2. Before an area was scraped, it was treated with water from sprinklers, then ripped and watered again by truck in this case, if deep scraping was to follow. Watering was often to the point where it precluded operation of earth moving equipment; nearly 30% moisture by weight was involved, which is above the measured 25% saturation level of Rocky Flats

soil (Michels, 1973). For reasonable dust control and good compacting, 15% had been stipulated in the Fugitive Dust Permit as suggested by the Colorado Department of Health and from practical experience by area contractors. The wetting procedure also caused typical vehicle speeds on the unpaved roads to be reduced to a few miles per hour, with an associated dust emission reduction (Cowherd and Hendricks, 1978).

3. If the wind speed exceeded a steady 16 km/hr or reached gusts of 24 km/hr, construction was to be suspended. The wind was measured with a portable anemometer 1.8 m above ground near the construction site. For a continuous record of wind speed and direction, a mechanical weather station by Meteorological Research, Inc. was used. The sensors were 2.4 m above the ground at Location 1 (see Figure 1) for the duration of the soil removal phase.
4. If the airborne, total, long-lived alpha activity exceeded 0.05 pCi/m^3 on any field sampler, construction was to be stopped and abatement procedures improved.

Field Measurements

Dust emission from a given site was measured with two high-volume air samplers ($1.22 \text{ m}^3/\text{min}$) of the type shown in Figure 2. These samplers were located at appropriate locations selected from those indicated in Figure 1. The locations were within 50 m or less of the construction sites. The sampler is a portable version of the USEPA Standard High Volume (Hi-Vol) Sampler described in the Federal Register (USFR, 1971). One Hi-Vol sampler was placed in a location anticipated to be downwind of the construction activity and the other at the corresponding upwind location. Once those locations were chosen for a particular day, they were not changed. These dust-loading determination samplers ran from 0800 hr to 1500 hr (8:00 a.m. to 3:00 p.m.), hence sampling about 530 m^3 of air daily. Similarly, Hi-Vol samplers were run in parallel to the dust-loading samplers to determine total long-lived airborne alpha activity; the only difference being that at Location 4, the alpha sampler was operated for 24 hr.

FIGURE 2. Portable Hi-Vol Sampler Used at Rocky Flats to Obtain Total Dust Loadings and Alpha Activity

Both sampling systems employed Microsorban filters made by Delbag-Luftfilter GMBH (1 Berlin 31, W. Germany). The filters are conditioned in a CaCl_2 desiccator for 24 hr to reach constant mass before being weighed and installed in the Hi-Vol samplers. After use, the filters are again conditioned for 24 hr and weighed. Some loaded filters did not reach constant mass in this period and were desiccated longer. For total dust-loading determination, compensation must be considered for the loss of fibers during the handling of these fragile filters. This loss was determined by taking several

filters to the field, mounting and removing them without exposure to air flow. For the amount of dust collected on this project, the fiber handling loss was less than 10% of the lightest loading; consequently, no adjustment was made. Small pieces of filter also were removed later from each filter for microscope particle size analysis with the Rocky Flats Quantimet image analyzer. For this purpose, the filter pieces were mounted in 1.71 index immersion oil matching the fiber refractive index. Measurements of soil moisture content were obtained by using a portable Nuclear Chicago

TABLE 1. Summary of Total Cubic Yards Moved During Topsoil Removal

Date (1978)	Location	Stripping Depth (in.)	Cubic Yards	No. of Trips ^a	Remarks
9/5	S. end dam	9	3440	172	31% soil moisture
9/6	S. end dam	9	5670	283	31% soil moisture
9/11	S. end dam	9	2920	146	15-60% soil moisture in wet areas, high winds
9/12	S. end dam	15	8330	417	Watered, low wind
9/13	S. end dam	15	8330	417	Same as above
9/18	Center dam	15	1850	93	Watered
9/19	Center and N. end dam	15	2080	104	Watered
9/20	W. end dam in canal	6	1440	72	Rain, snow, calm, no watering, dirt to waste area
9/21	N. E. end dam	15	2230	112	Sunny, calm, soil moist
9/26	E. end canal	6	1200	60	Watered, dirt to waste area
9/29	Center canal	6	800	44	Soil moisture o.k., equip. breakdown, dirt to waste area
10/2	W. end canal	6	900	45	Dirt to waste area, one scraper
10/3	Canal	6	1110	56	Dirt to waste area, one scraper
10/4	Canal	6	1110	56	Dirt to waste area, one scraper
10/5	S. & W. of waste area in canal	6	940	47	Dirt to waste area, one scraper, dusty atmosphere
			42,400 ^b	2,120	

a. Assuming 20 cubic yards per load.

b. Estimate was 44,600.

neutron scattering probe (Moisture Density Meter Model 5901), which measures average moisture to a soil depth of about 10 cm.

Data From Field Measurements

During the Woman Creek soil removal effort (between September 5 and October 5, 1978), a total of 32,400 m³ (42,400 cubic yards) of topsoil was removed.* Details concerning the soil removal appear in Table 1. A total of 2100 trips by the scrapers were involved at an estimated 7 minutes

per trip. The bulldozer covered about one-quarter the distance of the scrapers.

Soil moisture content after watering was determined with the neutron scattering probe for the first three operating days. After that, conditions were judged by visual observation and previous experience. For the first three days, the moisture content was adjusted to be near 30%. In wet areas it reached 60% and in dry areas it was as low as 15%. This indicates that the soil usually was near saturation during scraping. Over 600,000 gal of water were applied on some days. Halfway through the operation (on September 20, 1978), it snowed and rained. After this period, watering was much curtailed.

*Fugitive dust permit calculations estimated 44,600 cubic yards.

TABLE 2. Meteorological Conditions and Dust Loadings

Date (1978)	Time	Atmospheric Stability			Wind Data		Dust Loading ^a		Remarks
		Stable	Unstable	Neutral	Avg mph	Prevalent Direction ^b	Location ^c	$\mu\text{g}/\text{m}^3$	
9/5	0700-1000 1000-1500	x	x		3.9	97, 280	5, 6	<u>56</u> , 74 ^d	—
9/6	0700-1000 1000-1500	x	x		5.0	117	5, 6	<u>74</u> , 289	Blown dust reported
9/11	0700-0800 0800-1500	x		x	19.1	166	5, 6	182, <u>43</u>	Frontal passage, dust, windy
9/12	0700-0800 0800-1500	x	x		7.0	46	5, 6	----	Blown dust at times. Dust loading combined for 9/12 and 9/13
9/13	0700-0900 0900-1500	x	x		5.3	95	5, 6	<u>57</u> , 130	—
9/18	0700-0900 0900-1300 1300-1500	x	x	x	12.1	13, 300	3, 4	88, 56	Frontal passage, windy
9/19	0700-1000 1000-1500	x	x		8.6	122	3, 4	141, <u>66</u>	—
9/20	0700-1500			x	3.4	125	3, 4	36, <u>53</u>	Snow, rain, low clouds.
9/21	-----	—	—	—	—	—	—	—	—
9/26	0700-0900 0900-1500	x	x		5.9	52	2, 3	<u>28</u> , 162	—
9/29	0700-1500		x		5.8	50	2, 3	<u>46</u> , 88	Upslope conditions.
10/2	0700-1500		x		—	—	—	—	Wind instr. inoperative
10/3	0700-1500		x		—	—	—	—	Wind instr. inoperative
10/4	0700-1500			x	—	—	—	—	Wind instr. inoperative
10/5	0700-1000 1000-1500	x	x		—	—	—	—	Wind instr. inoperative, Wind instr. inoperative
10/10	0700-0800	x			—	—	2	14 ^e	Wind instr. inoperative, background dust sample, no construction

a. Samples all taken approximately between 0800-1500.

b. Numbers represent degrees of the compass.

c. Refer to Figure 1 for sampler location sites.

d. Underlined dust loading values mean upwind concentration or background value. If neither value is underlined, the wind direction was too variable or the plume tended to miss the samplers.

e. True value is nearer 20 when compensating for filter fiber losses due to handling.

Little visible dust was raised by the scraper blades during scraping. If visible dust was generated by the elevator mechanism of the scraper, operations were redirected to another area; meanwhile, the water truck was called to wet the former area more. On occasions, the bulldozer fan caused some resuspension.

Atmospheric stability criteria (Table 2) were determined for all operating days with the assistance of Loren Crow, a consulting meteorologist. On four days, the Rocky Flats meteorological tower provided the data, but for the five other days on which filter samples were obtained, reference had to be made to the daily weather maps and data from

TABLE 3. Total Long-Lived Alpha Activity for Air Samples at Woman Creek Construction Site

Date (1978)	Sampler Location (pCi/m ³)					
	1	2	3	4 ^a	5	6
9/01	0.005 ^b	—	—	—	< 0.002	< 0.002
9/05 ^c	0.003	—	—	—	< 0.002 ^e	< 0.002 ^f
9/06 ^c	0.005	—	—	—	< 0.002 ^e	< 0.002 ^f
9/07	< 0.002 ^d	—	—	—	0.004	< 0.002
9/08	< 0.002	—	—	—	< 0.002	< 0.002
9/11 ^c	< 0.002	—	—	—	< 0.002 ^f	< 0.002 ^e
9/12 ^c	< 0.002	—	—	—	< 0.002 ^e	0.006 ^f
9/13 ^c	0.007	—	—	—	0.005 ^e	< 0.002 ^f
9/14	< 0.002	—	—	—	0.006	< 0.002
9/15	< 0.002	—	< 0.002	< 0.002		
9/18 ^c	< 0.002	—	0.006 ^e	< 0.002 ^e		
9/19 ^c	0.006	0.000	< 0.002 ^f	0.014 ^e		
9/20 ^c	< 0.002	0.009	< 0.002	—		
9/21	< 0.002	< 0.002	< 0.002	0.004		
9/22	< 0.002	< 0.002	< 0.002	< 0.002		
9/25	< 0.002	0.004	< 0.002	0.036		
9/26	0.002	< 0.002 ^e	0.008 ^f	< 0.002		
9/27	< 0.002	< 0.002	< 0.002	< 0.002		
9/28	< 0.002	0.009	< 0.002	0.005		
9/29 ^c	< 0.002	< 0.002 ^e	< 0.002	< 0.002		
10/02 ^c	< 0.002	< 0.002	< 0.002	0.002		
10/03 ^c	< 0.002	< 0.002	< 0.002	< 0.002		
10/04 ^c	< 0.002	< 0.002	< 0.002			
10/05 ^c	< 0.002	0.005	< 0.002	< 0.002		
10/09	0.007	< 0.002	0.004	< 0.002		

a. 24-hour sample, other 0800 to 1600.

b. Samples over 0.01 pCi/m³ were run for 3 days to separate short- and long-lived activity.

c. Days during which soil was moved.

d. Values of < 0.002 indicate counts were below the minimum detectable limit of 0.002 as stated in the Rocky Flats Plant 1977 Environmental Report.

e. Upwind sampler.

f. Downwind sampler.

Denver Stapleton Airport radiosondes. Average wind speeds and directions are given in Table 2 along with the total dust loadings measured at the sampling site. The long-lived alpha counts are presented in Table 3 for the locations indicated in Figure 1. Figure 3 shows soil-removal sites in relation to the overall Woman Creek construction site. The dates of soil removal also are indicated.

Data Analysis

One object of this analysis was to determine the total amount of dust released utilizing the field measurements. This determination will permit validation of a pertinent dust emission model for the type of construction work being considered here. The basic strategy to accomplish this is to

FIGURE 3. Overall Outline of Soil Removal Areas

use upwind and downwind dust loadings as a measure of the total dust release. It was not economically feasible to completely profile the dust cloud issuing from the site in terms of dust concentrations. Therefore, atmospheric diffusion theory has to be applied to calculate the extent of the dust plume at the point of downwind sampling. One can then extend the local dust loading value at the downwind sampler to the whole dust plume volume. Data from the construction of a small dike, under the relaxed dust abatement conditions for the main phase dam construction, were analyzed for dust emission. This was done to anticipate possible emission problems.

Another important part of the data analysis is to study particle size data. The above calculations are limited to dust particles below $30\ \mu\text{m}$ because of sampler bias. The application of dispersion models that include deposition losses of larger particles are too complex. However, because of interest in the fate of soil contaminants, data analysis included

calculations to determine the absolute amount of dust emitted. The large particulates settle quickly but may be resuspended and eventually travel some distance. Information on the respirable fraction in the emitted dust also was of interest. The size data study also included a comparison of size distribution of the upwind and downwind aerosols as they reflect upon local dust transport or mixing.

Finally, long-lived alpha activity data were examined to discern any trends of increased airborne activity due to the construction.

Summary of Pertinent Meteorological Data and Dust Loadings for Case Study

As a first step, wind direction data, as a function of sampler location, were studied to establish if air flowing over a construction site was intercepted by the downwind sampler. It could happen that both samplers were exposed to construction dust or both

FIGURE 4. Earth Moving Operation for September 19, 1978 at Woman Creek C2 Dam Site

missed it. It was found that the samplers were not always in the optimum location, as wind conditions tended to be variable and calm at times; however, optimum siting was impossible unless more samplers were used or the available samplers could be activated only for a desired wind direction sector.

September 19 was chosen as a suitable day to illustrate data analysis procedures for modeling of the emission rate, for the effectiveness of the dust abatement techniques, and for dust transport. The remaining days will be analyzed in detail at a later

date. Figure 4 is a detailed layout of the construction area for September 19, showing the areas scraped and the stockpile locations. Samplers were at Locations 3 and 4. Wind conditions are indicated with an arrow giving the prevalent wind direction (122°). The range of wind variability was 60° to 180°. Within this range, the wind direction was from 105° to 135° during 72% of the sampling period. The mean wind speed was 3.8 m/s with a maximum of 5.5 m/s and a minimum of 1.1 m/s. The extreme values given here were sustained a few minutes. Meteorological conditions were stable

from 0700 to 1000 hours and unstable from 1000 to 1500 hours. The downwind sampler measured dust loading of $141 \mu\text{g}/\text{m}^3$; the upwind sampler measured $66 \mu\text{g}/\text{m}^3$. The upwind loading is not out of line for background values in this area. Rocky Flats had yearly mean values ranging from 50 to $60 \mu\text{g}/\text{m}^3$ over a 7-year period (1970 to 1976) based on 24-hour samples every fourth day (CDH, 1977). On a 24-hour basis, however, much larger variations are encountered as a result of winds giving high loadings and precipitation reducing the loadings (Crow, 1975). During windy periods at Rocky Flats, the loading can reach well over $100 \mu\text{g}/\text{m}^3$ (Crow, 1975) or be as low as $20 \mu\text{g}/\text{m}^3$ measured with a Hi-Vol sampler (see Table 2, October 10). The dust loading attainment standard set by the State and by EPA is $45 \mu\text{g}/\text{m}^3$. This is unattainable in an arid climate; a request has been made to change this level (Crow, 1975), and EPA has promulgated new standards for the Southwest.

Source Strength Estimate From Available Emission Factors

The following calculations are a refined estimate of the expected dust release compared to the general estimate in the Fugitive Dust Permit. Only the work done so far, which covers the surface soil removal, will be considered. No specific estimate was made for soil removal in the permit; i.e., it was assumed no dust would be released. The following work is an attempt to quantify released dust.

First, the amount of dust emitted by earth movers will be calculated. The two scrapers moved in an oval track pattern, scraping for approximately 92 m, then proceeding to the stockpile, dumping and compacting for 152 m, and then returning to scrape. A trip was estimated at 396 m (a total of 42 km for the day) at 7 minutes per trip, and at an average speed of 3.4 km/hr. The bulldozer covered 8.9 km but did not create dust. With four pickup trips per hour through the site, another 9.2 km of traffic at 16 km/hr were added. Note that all of the estimates used to determine the mileage are based on a 7.5-hr working day.

Applying the equation from Cowherd and Hendricks (1978) for emission of road dust* from unpaved roads by vehicles with tires, a source strength of 0.068 kg dust per vehicle kilometer was derived from the pickups. With watering to a content of 15%, the dust emission is estimated to be cut by 50% (EPA, 1977) or to 0.034 kg per vehicle kilometer for a total daily output of 0.19 kg. The emission factor formulas are adjusted for a 30- μm particle size cutoff to allow for the fact that the standard Hi-Vol sampler nominally is not supposed to aspirate particles over that size (Cowherd et al., 1974). However, the portable Hi-Vol used in this work allows the larger particles to enter (see discussion of particle size data).

Regarding dust generation from the scraper, the above source strength model is based on tests with vehicles traveling mostly above 48 km/hr (Cowherd and Hendricks, 1978; Cowherd et al., 1974). A linear relationship with speed for the emission factor applies at best in the 30 to 80 km/hr range; below that range, the emission varies with the square of the speed (Cowherd et al., 1974). This gives a low emission factor for the 3.4 km/hr speed of the scrapers as far as the tire dust output is concerned. This agrees with visual observations; hence, the remaining dust source is assumed to be the scraping itself. Fugitive Dust Permit calculations assumed the tires generated most of the dust, but the calculations used a high vehicle speed of 24 km/hr. A literature review was made to estimate dust output from the actual earth-moving operation of the scraper. It was found that probably the best available model applicable to this case is that of agricultural tilling (Cowherd et al., 1974). Detailed data have been derived for it, and procedures are available to adjust the emission for soil moisture content, soil type, and vehicle speed. The last item is in the range used by scrapers while scraping and dumping. Using the daily mileage estimate of 42 km and a scraper width of 8 ft, an equivalent acreage of 10.2 hectares tilled is obtained. With a silt content of 6% and a soil index of 100, the emission factor can then be calculated. The soil index is a factor that takes into account soil moisture content versus dust emission. It is a reversed square relation. For the Denver region,

*Associated dust particles less than 30 μm in diameter.

the index is given as 43 (Cowherd et al., 1974), but the soil moisture content was deliberately increased to 15% or better, making it more typical of the eastern United States. This was done so that a representative value of 100 from that region was used. The result is an emission factor of 4.9 kg/h (hectare) or a total of 9.2 kg for the day plus the pickup contribution, giving a grand total of 9.4 kg. This amount of released dust can now be related to the amount of dust measured by the sampler 168 m downwind from the center of the construction area. That measurement was a Hi-Vol value of $75 \mu\text{g}/\text{m}^3$ above the background value of $66 \mu\text{g}/\text{m}^3$. Pertinent dust loadings for September 19 are given in Table 2, and are shown in Figure 4 as well.

Dispersion Calculations

Several approaches to computing source plume dimensions or dust dispersion were attempted. Loren Crow (1979) suggested a simple intuitive formula for estimating the dust concentration a short distance (~ 100 m) from a construction site. It is simply assumed that the plume issuing from the site is 20-m high at the site boundary, and that the plume dimensions do not change significantly by the time a sampler ~ 100 m from the boundary is reached. Wind conditions are assumed to be steady, and the turbulence created by construction vehicles mixes the dust uniformly in the plume. Thus, being dealt with is a plume 20-m high and 152-m long that passed the sampler. Assuming that the plume intersected the sampler for the whole period, the expected concentration at the filter would be $29 \mu\text{g}/\text{m}^3$ above background or about 40% of what was observed using the above value of 9.2 kg of dust released. This is a rough calculation, but it should be better, by an order of magnitude, than any estimate. This type of procedure also was used by Cowherd et al. (1974) for aggregate storage pile emission.

A more sophisticated approach is the use of Gaussian dispersion models (Turner, 1969). Implicit in these models are the areal extent of the plume in terms of source strength, meteorological stability, and sampler location. These models usually deal with point, area, or line sources. None of these are truly applicable to the present case of moving sources. Closest to the present situation are high-

way traffic diffusion models that take into account vehicle turbulence, angle of crosswind, intermittency of source, and so on. A model by Chok (1978) will be used at Rocky Flats.

Agreement with the Gaussian model was forced empirically for a multilane highway on the basis of the field experiments (Chok, 1978); i.e., the parameters in the following equation were adjusted to achieve the best fit. This model will be applied now by considering the construction site as a section of multilane highway. The model is stated mathematically in the following form:

$$C(x,z) = \frac{Q}{\sqrt{2\pi} U \sigma_z} \left\{ \exp \left[\frac{1}{2} \left(\frac{z + h_0}{\sigma_z} \right)^2 \right] + \exp \left[\frac{1}{2} \left(\frac{z - h_0}{\sigma_z} \right)^2 \right] \right\}$$

where $C(x,z)$ is the concentration in grams per cubic meter at point (x,z) relative to the line source at x equals 0; Q is the emission rate per unit length, $\text{g s}^{-1} \text{ m}^{-1}$; U is the wind component at right angles to the road, m/s; σ_z is the vertical dispersion parameter, in meters (Chok, 1978); and h_0 is the plume center height in meters at a distance of x meters from the road. If U is over 1 m/s, h_0 is equal to the source height. The source strength, Q , here is the total emission over the 183-m linear source dimension normal to the line along which the samplers are located. The wind was 30° from this line so that the component of U directed toward the sampler is 3.3 m/s.

The model allows for advection of pollutants by the vehicle wake and exhaust heat. For the study being reported, vehicle speed is unrealistically low for a highway; however, this is compensated for by the sheer size of the vehicle generating mechanical turbulence that plays a major role in dispersing the pollutants in this highway model (Chok, 1978) plus the engine heat advecting the dust. Using a 1-m source and sampler height, the model predicts a dust loading of $70 \mu\text{g}/\text{m}^3$ at the sampler when compared to the observed value of $74 \mu\text{g}/\text{m}^3$. The close agreement is obviously fortuitous, but the highway model at this time appears to be superior to others in realism and should be applied to the remaining cases to confirm its validity. The agreement may also be cautiously interpreted as

confirming the effectiveness of dust suppression by watering.

Anticipated Dust Emission

During the Main Phase of Dam Construction

Dust emissions will not be controlled as rigidly during the main phase of the surface water control project. Principally, the watering procedure will not be as thorough so that shallower penetration will result, thereby allowing higher vehicle speeds with a resulting increase in dust emission. However, the total amount released must still be within the amount prescribed by calculations in the Fugitive Dust Permit. In the permit, a total release of 15.9 metric tons of particulates below $30\ \mu\text{m}$ was estimated from all sources: excavation, embankment, erosion, and traffic. This included a 50% watering allowance or reduction from the uncontrolled construction.

It was desirable to have verification that the proposed abatement procedures will meet the permit requirements, and if possible, exceed the goals considerably. Such an opportunity presented itself in October through November 1978 during construction of the Walnut Creek gauging station near Indiana Street. This involved soil removal, stockpiling, and construction of a small dike and flume. Dust abatement procedures were the same as specified for the major dam work; i.e., watering to reduce onsite dust emission by vehicles and earth moving machinery. Incidental to this, water was also applied to allow for proper compacting of the soil when constructing such things as embankments. One Hi-Vol sampler was used on the creek bank just south of the site. This was a standard EPA unit with automatic flow control and provisions for a Sierra Impactor. The impactor was used to provide rapid information on particle size. Background samples were taken by the same Hi-Vol sampler during no-construction periods. Wind conditions were monitored intermittently, as to speed, with a portable anemometer; direction was judged visually. The only earth-moving machine was a Fiat Allis 15-ton, 3-yd³ front loader.

In evaluating data from these measurements, the Sierra Impactor data proved to be of little value.

Most of the impacted particles bounced off and continued to do so on subsequent stages until trapped on the backup filter. This was microscopically verified by examining the backup filter, which should have contained only particles below $1\ \mu\text{m}$ but had particles up to $60\ \mu\text{m}$ and held 80% to 90% of the total mass. Therefore, the impactor samples were treated as total dust loading collections only. This experience indicated that further testing of the impactor is required before field use.

The background samples gave the following results. For the period November 1-6, 1978, a loading of $42\ \mu\text{g}/\text{m}^3$ was found during a time that included westerly winds up to 40 mph and no precipitation. Daytime samples only for October 30 and 31 gave $40\ \mu\text{g}/\text{m}^3$. For October 19, a construction period with rain the day before, the soil moisture was 7 to 16% at the surface, but despite this, an apparently large loading of $537\ \mu\text{g}/\text{m}^3$ was found with winds blowing at 4.8 to 16 km/hr toward the sampler. This loading is almost twice the highest found for the topsoil removal phase (see Table 2). However, the pay-loader was at times as close as 4 m and as far away as 100 m from the Hi-Vol sampler. When close to the sampler, the pay-loader dumped soil to raise a dike, and pulled a sheep-foot roller to compact the soil at intervals. The soil was obtained from a stockpile about 100 m away, which could not be watered with the truck dispenser. The truck dispenser sprinkled only the dumped material. It seemed that most of the dust was raised during the gradual release of soil over the area being built up. It is estimated that 68 metric tons of soil were moved.

Emission factors for soil stockpile work are not available, but reference can be made to handling data for sand and gravel storage piles (Cowherd et al., 1974). During working hours, dust loadings over $300\ \mu\text{g}/\text{m}^3$ are observed downwind of the stockpile areas, with no dust abatement procedures in use. Using Cowherd's emission factor of 0.21 kilogram per metric ton (for aggregate stockpile handling) for our operation, a release of 14.3 kg is estimated for handling 68 metric tons; the emission for just excavating the same amount of material would be 1.4 kg (EPA, 1977). The aggregate stockpiling factor includes loading, unloading, wind erosion, and traffic dust emission.

It is instructive to calculate the actual emission, using observed total dust loading data, to compare against the estimate just mentioned. Following the stockpile handling procedure of Cowherd et al. (1974), it is assumed that all dust emissions pass through an imaginary plane with dimensions of the length and average height of the stockpile [200 ft by 10 ft (60 m by 3 m)] at a velocity of 10 km/hr. The total volume of air passing the sampler during the 3 hours of operation can be estimated. This gives $5.4 \times 10^6 \text{ m}^3$ at a dust loading of $537 \mu\text{g}/\text{m}^3$ (less upwind dust loading). The latter is estimated at $37 \mu\text{g}/\text{m}^3$, which results in a 2.6 kg release. This is about $\frac{1}{6}$ of the estimate of 14.3 kg. However, Cowherd's procedure is based on the sampler being next to the stockpile. In the present case, the sampler was about 60 m away, resulting in some dilution. Furthermore, dust abatement procedures were in effect; that is, the construction traffic area was subject to watering, and the previous day's rain had wetted the stockpile surface. Cowherd's emission factors were for dry conditions. It is thus clear that stockpile work can be a source of considerable emission unless good dust abatement procedures are followed.

Discussion of the Effect of Particle Size Factors

No attempt was made in the model calculations to correct for settling of large particles. The dust emission calculations were made in accordance with EPA procedures that exclude particles over $30 \mu\text{m}$. The exclusion is based on the expectation that these particles will not reach the filter medium because of the sampler intake design. Also, EPA emission factors are all derived with Hi-Vol samplers. So, relatively speaking, all of the procedures used are compatible, but true dust loadings at Rocky Flats should be much higher because the large particles are missing. Generally speaking, particles over $30 \mu\text{m}$ are not of interest because they do not travel far. It is useful to verify the actual cutoff range of Hi-Vol samplers from microscopic measurements of the collected particles. But of principal concern is a knowledge of the absolute dust loading. This loading is a measure of the total amount of dust that has become airborne even though much is deposited nearby. Yet it is subject to subsequent resuspension. In case of contaminants in the soil,

this may be an important pathway of translocation over the years. Absolute dust loadings can be rather substantial; in agricultural operations, a concentration of $67,000 \mu\text{g}/\text{m}^3$ near a tractor has been reported (Milham et al., 1975).

Results of the microscopic studies are shown in Figures 5 and 6. It is reasonable to expect particles up to $100\text{-}\mu\text{m}$ equivalent aerodynamic diameter to be airborne several hundred meters from the site. As seen in Figure 5, particles over $50 \mu\text{m}$, but of unknown density, are present. Proportionally, however, there must be many more than shown. Above $10 \mu\text{m}$, the standard Hi-Vol sampler begins to exhibit a drop in sampling efficiency (Wedding and Carney, 1978). One can proceed to correct for losses related to particle size, to arrive at a true mass concentration value using data by Wedding and Carney (1978). As an aid in making this correction, Figure 6 gives particle size distributions from the filters for the upwind and downwind locations for September 6 and 26, respectively. These size distributions involve the highest and lowest loadings observed during construction, but are typical, as regards particle size, of all other dust samples listed in Table 2. The shapes of the distribution curves are about the same, even though it would be expected that the background air would contain fewer large particles because they settle out more rapidly. This question will be discussed in more detail later in this section.

To correct the total dust loading for larger particles that were not collected, data of Wedding and Carney (1978) are used. For $15\text{-}\mu\text{m}$ particles, the Hi-Vol sampler is 30% or 55% efficient, respectively, when the sampler side or corner is pointing into the wind. For $50\text{-}\mu\text{m}$ particles, the efficiency drops, respectively, to 10% and 40%. This is for a density of $0.89 \text{ g}/\text{cm}^3$ when dealing with mineral particles of a density of about $2.5 \text{ g}/\text{cm}^3$. This increases particle losses even further. These losses can be estimated by converting the geometric diameter (D) of a particle to its equivalent aerodynamic diameter (D_{ae}) using the relation $D_{ae} \text{ equals } D\sqrt{P}$, where P is the particle density (Raabe, 1976). D_{ae} is then used to determine sampling efficiency from the curves generated by Wedding and Carney (1978). The above diameter is valid providing the particles are in Stokes flow regime, and the drag coefficient for

FIGURE 5. Photomicrographs of the Particles Presented in the Size Distributions of Figure 6

both sizes is the same (Raabe, 1976). The adjusted diameters were used to derive a corrected particle size distribution and to adjust the loading figures.

Figure 6 gives the adjusted size curve by count, leading to a count median diameter of 2.3 μ m for the dust particles—about double the original size of 1.3 μ m.

FIGURE 6. Particle Size Distribution Data for Typical Upwind and Downwind Samples at Woman Creek. The particle size was determined with a quantimet image analyzer.

To make the dust loading correction, it is necessary to estimate the volume of a set of representative particles of both distributions. This was done by taking 100 representative particles and totaling their volumes. The ratio of these volumes was 2.8; i.e., 2.8 times as much material would have been on the filters if the sample intake had operated isokinetically. This correction involves a diameter cubed relationship and therefore is sensitive to small errors in measurement. The mean volume diameters for the new and old distribution are respectively, 10.4 and 7.4 μm . The question may arise why the log normal relationships were not used to relate count and volume median diameters,

since the calculations would be much simpler (Irani, 1963). As noted on Figure 6, the standard deviation for the size distribution is about 2.9, and the log normal fit is not too close. The combination of these two facts results in a large overestimate of the volume median diameter.

Making use of the 2.8 factor just mentioned, the actual dust loadings were estimated to be 185 and 394 $\mu\text{g}/\text{m}^3$ for the upwind and downwind sampler, respectively. This gives a net dust addition above background of 209 $\mu\text{g}/\text{m}^3$ versus the original figure of 74 $\mu\text{g}/\text{m}^3$ from the Hi-Vol samplers. For true dust generation, transport, deposition, and

resuspension calculations downwind of the samplers, the adjusted values are necessary. It is of interest to determine, using actual size data, what fraction by mass is respirable; i.e., below $7\text{-}\mu\text{m}$ aerodynamic diameter, or below $4.4\text{-}\mu\text{m}$ geometric diameter for Plant-site dust assuming a particle density of 2.5 g/cm^3 . Examining Figure 6 gives a respirable fraction of about 1%; i.e., the mass of dust below $7\text{ }\mu\text{m}$. For airborne dust at Rocky Flats in the absence of construction, the respirable fraction has been reported as 4% (Kolnsberg, 1976).

Another question raised by the size distribution data was alluded to earlier; that is, it was expected that the size distribution of the upwind, background aerosol would peak at a smaller size than the downwind, construction-dust aerosol. This was not true for the data in Figure 6 and for eight other sample sets of upwind/downwind samples. One obvious explanation is that the upwind sampler was seldom exposed to true background air because of the backwash of construction aerosols. This phenomenon is due to dust from site operations eddying or recirculating back into the upwind sampler region.

As a general rule, an upwind sampler in steady wind should be located upwind at least 1/10th of the so-called maximum downwind distance (Kolnsberg 1976). The maximum downwind distance is the furthest distance a sampler can be, that can still detect the pollutant, and that is known to be in

the pollutant cloud. In the situation at Rocky Flats, a minimum distance of 80 m from the construction site is indicated for the upwind sampler. The calculations take into account atmospheric stability, wind speed, sampler sensitivity, and sampling rate, but not topography. This minimum distance was not maintained with the sampler being almost next to the construction area; however, even at 100 m, the situation would not have changed. With the usual low-speed easterly wind and convective conditions, it was not possible for a steady flow regime to establish itself up the Woman Creek gully. The particle size data confirm this conclusion of a local mixing regime.

Long-Lived Alpha Activity Data

As pointed out earlier, the total long-lived alpha activity is a potential tracer of dust emission if the construction dust has more alpha activity than the background dust (presumably from plutonium). This assumes that the activity is distributed rather evenly throughout the topsoil. When studying the data in Table 3, there is no particular trend as to enhanced activity when comparing upwind and downwind samples (indicated in Table 3). Since many samples are below minimum detectable amounts, it is also difficult to discern trends. Basically, what is being seen is the natural or normal radioactivity for airborne dust in this area.

AQUATIC RADIOECOLOGY

PLUTONIUM/AMERICIUM INVENTORY OF THE SMART DITCH POND ECOSYSTEM

John D. Hurley and Terrol F. Winsor

Introduction

In 1975, the federal government acquired an additional 1,878 hectares (4,640 acres) of land surrounding the original 1,020-hectare (2,520 acre) Plant site. Several ecological and environmental studies have been performed on the original Plant

site land* resulting in a compilation of data that aids in evaluating the environmental impact of Rocky Flats on the surrounding community. However, little is known about the ecological state

* (Johnson, June 1974; Weber et al., July 31, 1974; Little, 1976; Clark, 1977; and Whicker, 1977b.)

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FIGURE 7. An Overview of the Rocky Flats Plant in Spring, 1975. Pond D-1 is located in the upper half of Section X.

of the 1975 purchase (henceforth referred to as the buffer zone).

The purpose of this research project was to obtain ecological and transuranic radioecological information on a Buffer Zone Aquatic System [Smart Ditch Pond (D-1)] and on a defined nonaquatic area surrounding the pond. Pond D-1 (Figure 7) is

located 2.7 km (1.7 mi) southeast and downwind of the Plant center. The information presented in this study provides a transuranic inventory of five compartments of the ecosystem (sediment, water, fish, soil, and vegetation). The study also provides insight into the relative ecological mobility of americium-241, an isotope not previously studied extensively in Plant ponds or streams.

FIGURE 8. Overview of Pond D-1 and the Pond Study Area. This photograph was taken in July 1977 when the pond was near its high water level.

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General Area Description

Historical photographs of the Rocky Flats area show the pond to have been in existence at least 40 years. It is believed to have once been a stock pond. Pierce (1977) characterizes Pond D-1 (Figure 8) and its environs as follows: "Pond D-1, located at 39° 52' 30" N, 105° 10' 30" W on the United States Geographical Survey (USGS) Louisville quadrangle, is a holding impoundment at the base of a small hill. Most of the drainage area of the pond lies within the Rocky Flats property. Prairie grasses *Poaceae*, family Graminae,

and thistle *Cirsium* spp., dominate the rolling hills of the area and extend to the water's edge. Major eroded areas seemed absent from the drainage. An earthen dam, approximately 20 meters wide, was constructed to form the pond with a maximum depth of four meters and surface area of 1.8 hectares when full."

The water depth of Pond D-1 is typically quite variable, having changed by as much as six feet during the sampling periods. The pond receives its water supply from Rocky Flats Lake, located west of Pond D-1, via Smart Ditch and from surface

FIGURE 9. Pond D-1 Study Area

runoff (Figure 7). Smart Ditch is the major contributor to the D-1 water supply; however, the release of water to D-1 pond is controlled by the owners of the water rights to Rocky Flats Lake.

Materials and Methods

Establishing a Study Area

The study area consists of the pond proper and an extended area that surrounds the pond and measures 30 m out from the high-water mark (Figure 9). A rectangular perimeter 180 m by 220 m was established as a reference frame, with the top of the dam being the southeastern boundary (see Figure 9). Wooden stakes were placed along

the perimeter at 25-m and 10-m intervals. Each of the 10-m stakes along the dam boundary and the boundary opposite the dam were numerically labeled (1 through 18). The stakes marking the boundaries perpendicular to the dam were alphabetically labeled (A through Z). Three-quarter-inch nylon ropes were extended across the pond at right angles to the perimeter markings on all sides of the pond. The intersection of the ropes attached to the perimeter stakes conveniently marked all potential sampling locations for soil, vegetation, water, and sediment. Each potential sampling site was assigned a number (1 through 422). The grid was divided into four quadrants (see Figure 9). Ten samples were taken from each quadrant for soil, vegetation, and sediment. To ensure representative sampling of the total study area and to minimize

FIGURE 10. Colorado Department of Health Soil Sampling Device

bias in sampling locations, all sampling sites were chosen from a random numbers table. Each sampling location chosen was then staked and assigned its respective grid designation; e.g., sample number 53 has a grid designation of H-2.

Sampling Protocol Quality Control and Preparation

Vegetation

Vegetation samples were collected from June 1, 1977 through June 30, 1977 at each selected sampling site. Figure 9 shows these sites with respect to the sampling area. Only standing vegetation was collected. Samples were collected by clipping the plant stem as close to the ground as possible. Root stem samples were not taken because of the difficulty of retrieving the entire root system, separating soil from the plant roots, and determining what is on the root as opposed to what has been taken up by the root system. Following each cutting, the sampling shears were rinsed with

methanol and dried with paper towels. All samples were collected within a one-meter radius of the sampling site designation. Vegetation samples were stored in sealed plastic bags that were placed in a freezer. Prior to analysis, each sample was dried overnight in a temperature-controlled drying oven and ground with a Wiley mill (Arthur H. Thomas Co.; Philadelphia, PA) for homogeneity.

Soil

Figure 9 shows the soil sampling sites with respect to the study area. Samples amounting to approximately 500 g of surface soil were taken at a depth of 0.32 cm using the Colorado Department of Health Soil Sampling Template (Figure 10). Following the collection of each sample, all equipment was rinsed with methanol and dried with paper towels. Soil samples were collected and stored in plastic bags. Prior to analysis, each sample was dried overnight in a temperature-controlled oven, sieved through a No. 10 mesh (2 mm) U. S. Standard

Sieve Series ASTM (American Society of Testing Material) Specification (a Tyler No. 9 series equivalent) screen, and ballmilled for 4 hours for homogeneity.

Water

Surface-water grab samples were collected in duplicate from four locations designated as grid locations O-9, J-12, H-9, O-11 on Figure 9. All water samples were divided into two one-liter aliquots. One liter of each sample was filtered through 0.45-mm Millipore filter paper. The seston was air dried. The filtered water, seston, and unfiltered waters were submitted for laboratory analysis without further treatment.

Sediment

Figure 9 shows the 40 sediment sampling locations for the pond. Ten core samples were taken from each quadrant with a Wildco K.B. (T.M.) Core Sampler* (Figure 11). The sediment samples were collected in individual plastic core liners, which were then capped and stored in a freezer. Prior to analysis, the core samples were horizontally sectioned into 5-cm segments. Composites of the top 5 cm, middle 5 cm, and bottom 5 cm were dried in temperature-controlled oven, sieved through a No. 10 mesh screen, and ballmilled for 4 hours.

Fish

Fish samples were collected with a No. 10 mesh seining net. Approximately 300 fish were collected and frozen. Prior to analysis, the fish were homogenized in a Waring blender. The homogenized slurry was divided into 3 aliquots, which were submitted for radiochemical analysis.

Quality Control

One hundred twenty-seven field samples with the following breakdown were submitted for radiochemical analysis:

40 Vegetation samples

40 Soil samples

40 Sediment samples

4 Water samples

3 Fish samples

127 total

Standard samples containing plutonium-239 and americium-241 were prepared by the Rocky Flats Standards Laboratory for 10% of the individual sample types. In situations where the total number of samples for a given compartment were less than 10, two pair of standard samples were prepared for the high and the low anticipated activity range. Standard samples of soil, vegetation, sediment, and fish were prepared at 2 and 20 disintegrations per minute per gram (d/m/g). Standard water samples were prepared at 2 and 20 disintegrations per minute per liter (d/m/l). These activity levels were based on the highest and lowest anticipated plutonium-239 and americium-241 values. Field and standard samples were submitted to the analytical laboratory for batching prior to analysis.

Limnology

Figure 12 indicates the sampling stations where limnological data were collected for Pond D-1. The parameters investigated include the following:

Temperature

Table 4 lists water temperatures ranging from 18.3 °C on the surface to 12.4 °C at a depth of ~ 3.0 m in the spring (Pierce, 1977).

Transparency

Transparency readings were taken for Pond D-1 at 12:30 p.m. on May 23, 1977 and again at 12:30 p.m. on July 26, 1977. Pierce (1977) reports a 20-cm Secchi disc was used to obtain comparative transparency readings of 0.4 m on both sampling dates. The Secchi transparency test corresponds to the distance below the pond surface to which

*Wildco Wildlife Supply, 301 Cass Street, Saginaw, Michigan, 48602.

FIGURE 11. Wildco K.B. (T.M.) Core Sampler. The illustration at right shows how sediment samples are collected.

approximately 5% of the incident light penetrates. This is approximately the compensation point, which is the depth where oxygen produced by photosynthesis begins to equal respiratory consumption by plants (Pierce, 1977).

Dissolved Oxygen

Table 5 shows dissolved oxygen readings obtained at various depths on May 23, 1977. All areas sampled had more than four milligrams per liter,

FIGURE 12. Pond D-1 Showing Pond Depth, Inlet, Outlet, and Sampling Stations

which is the minimum standard level, set by the Environmental Protection Agency, at which most fish species can exist (Carlson, 1977).

Conductivity

Tables 6 and 7 give conductivity data reported during spring and summer sampling, respectively. Conductivity is a measure of the total ionic strength

of a water sample. The conductivity of Pond D-1 ranged from 1600 $\mu\text{mho}/\text{cm}$ to 1950 $\mu\text{mho}/\text{cm}$. The average was 1650 μmho in the spring and 1900 μmho in the summer (Pierce, 1977).

Hardness

Tables 6 and 7 also display water hardness data for the spring and summer sampling. Hardness ranged

TABLE 4. Pond D-1 Temperature Range*

	Depth (meters)	Temperature (°C)
Station One**	0.0	16.0
	0.5	14.0
	1.0	13.5
	1.5	13.0
	2.0	12.6
	2.5	12.5
	3.0	12.4
	3.2 (bottom)	12.5
Station Two**	0.0	18.3
	0.6	17.8
	1.2 (bottom)	17.5

*Temperatures taken May 23, 1977
from 12:30 p.m. to 12:50 p.m.

**Station location shown in Figure 12.

TABLE 5. Pond D-1 Dissolved Oxygen Data*

	Depth (meters)	Dissolved Oxygen (mg/l or ppm)
Station One**	0.0 (surface)	8
	1.6	6
	3.2 (bottom)	4
Station Two**	0.0 (surface)	8

*12:40 p.m. to 12:55 p.m., May 23, 1977.

**See Figure 12.

TABLE 6. Pond D-1 Spring Chemistry^a

Depth	Conductivity (μmho/cm)	Hardness (mg/l as CaCO ₃)	Alkalinity (ppm)	pH	TDS ^c (mg/l)
Station 1 ^b					
0.0 m	1600	208	164	7.2	602
1.6 m	1600	208	164	7.2	612
3.2 m	1650	208	164	7.0	618
Inlet	1750	214	166	7.1	620

a. 12:40 p.m. to 1:00 p.m., May 23, 1977.

b. See Figure 12.

c. Total Dissolved Solids.

TABLE 7. Pond D-1 Summer Chemistry^a

Depth	Conductivity (μmho/cm)	Hardness (mg/l as CaCO ₃)	Alkalinity (ppm)	pH	TDS ^c (mg/l)
Station 1 ^b					
0.0 m	1850	184	176	8.1	638
1.6 m	1900	186	174	7.7	694
3.2 m	1950	200	196	7.2	648
Outlet	1900	290	302	7.3	654

a. 1:00 p.m. to 2:00 p.m., July 26, 1977.

b. See Figure 12.

c. Total Dissolved Solids.

TABLE 8. Biota Gathered From Pond D-1
(Biota samples obtained May 23-24 and July 26, 1977)

Phytoplankton	
Diatoms —	Synedia spp. Scoliopluera spp. Frustalia rhamboides
Algae —	Schithothrix tiuctoria
Mactophytes	
	Typha angustifolia Salix nuttallii
Zooplankton	
Rotifers —	Keratella spp.
Cladocerans —	Daphnia longispina Bosmina longirostris
Copepods —	Cyclops varicans Macrocyclops ater Paracyclops fimbriatus Eucyclops prasinus Ergasilus spp.
Invertebrates	
Benthic forms	Tendipes spp.
Pelagic forms	Oronectes immunis Graphocorixa spp.
Parasitic forms	Triannulata montana
Vertebrates	
Fish —	Pimephales promelas
Turtles —	Chrysemys pictabelli

from 184 mg/l as CaCO_3 to 290 mg/l as CaCO_3 , with an average, excluding the unusually high outlet reading, of 209.5 mg/l (s.d. 3*) as CaCO_3 in the spring and 190.0 mg/l (s.d. 8.7) as CaCO_3 in the summer (Pierce, 1977).

Alkalinity

Total alkalinity is a measure of carbonate and bicarbonate alkalinity and is influenced by water

*s.d. — standard deviation.

level, effluent, and affluent (Kurtz, 1965). Tables 6 and 7 indicate total alkalinity of Pond D-1 during the spring and summer sampling. Methyl orange alkalinity for Pond D-1 ranged from 164 to 302 ppm and averaged, excluding the outlet reading, 164.5 (s.d. 1) in the spring and 182.0 (s.d. 12.2) in the summer (Pierce, 1977). These values fall within the standard range of 150 to 250 ppm for most small ponds (Mackerith, 1963).

pH

The measure of pH was relatively stable throughout the pond, as indicated in Tables 6 and 7. Pierce (1977) reported pH values on the surface of 7.2 and 8.1, indicating uniform mixing.

Total Dissolved Solids

Tables 6 and 7 report total dissolved solids data ranging from 602 mg/l to 694 mg/l, averaging 613 mg/l (s.d. 8.1) in the spring and 658.5 mg/l (s.d. 24.6) in the summer (Pierce, 1977).

Biological Data

Table 8 lists the aquatic organisms found in Pond D-1. A description of the organisms by class is as follows:

Phytoplankton

Diatoms were numerous in samples collected in the spring and summer. Most of the diatoms consisted of Synedia spp., Scoliopluera spp., and Frustalia rhamboides (Pierce, 1977). Although not in great abundance, a filamentous alga identified as Schithothrix tiuctoria appeared in both samples.

Macrophytes

Pierce (1977) reports no true benthic macrophytes were found in Pond D-1. The cattails, Typha angustifolia and Salix nuttallii were the dominant

semiaquatic shore species found. The absence of submerged macrophytes is probably due to pond level fluctuations drying up the littoral zone.

Zooplankton*

Live specimens of rotifers were absent from pond samples; however, a significant number of rotifer cuticles of the genus Keratella spp. was found. Two species of cladocerans were noted in the spring sample but not in the summer sample. Daphnia longispina (O.F.M.), a cladoceran very common to waters of this region (Pennak, 1953), were more abundant than Bosmina longirostris (O.F.M.). Ehippia, the resistant eggs of most species, were found free-floating and in brood pouches of the organisms. Copepods were much more abundant than rotifers or cladocerans because of the high amount of suspended soil particles and turbidity, which influences planktonic production (Prosznaka, 1962). Cyclopoids copepods were present in the sample. The most abundant Cyclopoids copepods was Eucyclops prasinus (Fisher). Cyclops varicans (Sars) was the most abundant species, followed by Macrocyclus ater (Herrick) and Paracyclus fimbriatus (Fisher). A single species of Ergasilus spp., similar to Cyclops in body shape but parasitic, was noted on the gills of fish.

Invertebrates

The apparent lack of benthic invertebrates in the pond was probably caused by the lack of aquatic macrophytes and to the large amount of inorganic silt, which can create low oxygen levels—a limiting factor to most organisms (Jonasson, 1969). Diatom frustules, Frustalia rhomboides, and exoskeletons of copepoda species were present in sediment, along with a chironomid, Tendipes spp. A few hemipterans, the waterboatman or Graphocorixa spp., were found in the littoral zone. Freshwater crayfish, Oronectes immunis (Hagan), were found in great abundance, the majority of which were yearlings. A large number of crayfish burrows, each serving a single organism (Pennak, 1953), were noted along the

shoreline. These burrows gave an indication of the large number present. A parasitic oligochaete, Triannulata montana, was found on the gills, in the gill chambers, and on the general body surface of all crayfish.

Vertebrates

The only species of fish evident in the pond was the fathead minnow, Pimephales promelas, the majority of which were one-year-olds entering their second season. A sample of 100 fish yielded an average length of 5.13 ± 0.77 cm and an average weight of 0.497 ± 0.054 g; lengths ranged from 3.7 cm to 6.8 cm. According to Flickinger (1971), these fish are small for an optimum brood population; 6.35 cm is the optimum size for brood fish. The fish in Pond D-1 may be stunted by an overlarge population, which is dependent upon heredity, water temperature, pond elevation, and biotic environmental factors.

The trapnet yielded four western painted turtles, all Chrysemys pictabelli (Grey).

In essence, Pond D-1 is a slightly eutrophic, hard-water, alkaline pond with relatively stable conditions. Water temperatures in the pond are typical of most warmwater ponds in this region. Oxygen levels of 4 ppm at the bottom and 8 ppm at the surface are sufficient to support the biota. Pennate diatoms are the predominant life form of the plankton community, indicating an abundance of primary nutrients. In the spring, zooplankton were dominated by Cyclops varicans, a good source of food for the abundant fish population, which is fathead minnows exclusively. Large numbers of crayfish that prey on fish eggs (Flickinger, 1971) probably help keep the fish population in check.

Results

Radiochemical Analyses of Sediment, Water, and Fish

Sediment

Table 9 presents data on plutonium-239, -238, and americium-241 concentrations in Pond D-1 sediments. Concentrations in dpm/g ranged from 0.074 to 0.785

*Information on zooplankton and vertebrates was abstracted from Pierce (1977).

TABLE 9. Results of Radiochemical Analyses of Sediment Samples

Quadrant ^a	Profile Segment (cm)	Plutonium-239			Plutonium-238			Americium-241		
		dpm/g	$\bar{X}$	s.d. ^b	dpm/g	$\bar{X}$	s.d. ^b	dpm/g	$\bar{X}$	s.d. ^b
1	0-5	0.417			0.057			0.33		
	20-25	0.72	0.404	0.323	0.047	0.046	0.011	0.18	0.192	0.132
	36-41	0.074			0.034			0.065		
2	0-5	0.537			0.041			0.185		
	20-25	0.785	0.634	0.131	0.045	0.049	0.010	0.115	0.153	0.035
	36-41	0.579			0.06			0.16		
3	0-5	0.261			0.034			0.065		
	20-25	0.737	0.360	0.338	0.053	0.047	0.012	0.135	0.078	0.051
	36-41	0.083			0.054			0.035		
4	0-5	0.734			0.058			0.1		
	20-25	0.708	0.508	0.369	0.066	0.070	0.017	0.11	0.102	0.007
	36-41	0.082			0.087			0.095		

a. Refer to Figure 9.

b. s.d. — standard deviation.

TABLE 10. Randomized Complete Block Analysis of Variance of Plutonium-239 in Sediment at Rocky Flats Pond D-1

Source of Variation	Degrees of Freedom	Mean Square	F-Ratio
Mean	1	2.7237	
Blocks (quadrants)	3	0.0445	
Treatments (sediment depths)	2	0.2844	9.6653*
Experimental Error	6	0.0294	
Total	12		

*Significant at $P < 0.025$

Results of Tukey's Q-procedure:

0-5 cm	20-25 cm	35-41 cm
$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_3$
0.0487 dpm/g	0.738 dpm/g	0.205 dpm/g

The means that are significantly different at $P < 0.05$ are underlined.

for plutonium-239, 0.034 to 0.087 for plutonium-238, and 0.035 to 0.33 for americium-241. The primary interest was in the vertical distribution of radioisotopes because the deposition of these materials may vary with time.

Analysis of variance techniques were applied via the randomized complete block design (Ostle, 1963)

with designation of the four quadrants as blocks and the three depth intervals as treatments. The finding is that plutonium-239 distribution varies significantly with depth (Table 10). Application of Tukey's Q procedure (Snedcor and Cochran, 1967) reveals that the plutonium-239 concentration was higher in the 20-to-25-cm segment (0.738 dpm/g) than the 36-to-41-cm segment (0.205 dpm/g).

FIGURE 13. Gamma Analysis for Cesium-137 in Pond D-1 Sediment

The 0-to-5-cm portion was not significantly different than either the 20-to-25 cm or 36-to-41 cm. Analysis of variance does not show significant differences with depth for plutonium-238 and americium-241 concentrations. Statistical rules do not allow comparisons between quadrants, but inspection of mean squares for blocks and experimental error indicates there was no statistically significant block effect.

Cesium-137 in pond sediment was counted by gamma analysis to determine whether such data might reflect deposition history. The cesium-137 is treated as an index rather than an absolute quantitative result. Data were variable from quadrant to quadrant to each depth (Figure 13). No wide deflections were visible until the deepest sediment was reached, at which point the levels were lowest. Data from plutonium-239 and cesium-137 sediment profiles are insufficient to hypothesize a deposition history in Pond D-1.

Water

Data for surface water grab samples appear in Table 11. These data are incomplete in that filtered and

unfiltered water can be compared only from two quadrants. Pooled t-tests (Dunn, 1967) indicate that filtration was effective in removing plutonium-239 but not plutonium-238 and americium-241 from the water. Americium-241 values in filtered water are reported as 0.0, but variability precluded statistical difference from unfiltered water. The small sample sizes of these data require cautious interpretation, but filtration effectiveness for plutonium-239 implies that most of the radionuclide is associated with suspended matter. Filtered material was not analyzed during this survey, as previously explained, but such an analysis would provide a better estimate of fractions of dissolved and undissolved radionuclides.

Fish

Data on radionuclide levels in fish (Table 12) are presented without statistical comparison because they were aliquots of a single sample. All radionuclide concentrations in sampled fish were less than 0.1 dpm/g. Mean concentrations of plutonium-239, -238, and americium-241 did not differ by more than a factor of 3.

TABLE 11. Results of Radiochemical Analyses of Water Samples

Treatment	Quadrant ^a	Plutonium-239			Plutonium-238			Americium-241		
		dpm/l	$\bar{X}$	s.d. ^b	dpm/l	$\bar{X}$	s.d. ^b	dpm/l	$\bar{X}$	s.d. ^b
Unfiltered	1	2.520			0.320			2.571		
	2	1.181	2.313	1.345	0.240	0.291	0.060	0.628	2.267	1.940
	3	4.129			0.351			5.279		
	4	1.421			0.251			2.109		
Filtered	1	0.089	0.122	0.046	0.480	0.435	0.064	0	0	0
	3	0.155			0.389			0		

a. Refer to Figure 9.

b. s.d. — standard deviation.

TABLE 12. Results of Radiochemical Analyses of Fish Samples

Plutonium-239			Plutonium-238			Americium-241		
dpm/g	$\bar{X}$	s.d.*	dpm/g	$\bar{X}$	s.d.*	dpm/g	$\bar{X}$	s.d.*
0.042			0.026			0.028		
0.032	0.031	0.012	0.022	0.033	0.016	0	0.0113	0.015
0.018			0.052			0.006		

NOTE — Fish were not localized as to quadrant.

*s.d. — standard deviation.

Ratios

Ratios of radionuclide concentrations among samples of the same type (sediment, fish, filtered and unfiltered water) are given in Table 13. Within individual sediment samples, ratios generally indicate that plutonium-239 concentrations were highest, followed by americium-241, then by plutonium-238. In the cases of the 36-to-41-cm segment from Quadrants 1, 3, and 4, both americium-241 and plutonium-238 values were closer to respective plutonium-239 values than in all other comparisons. Also, in those three instances, plutonium-239 concentrations were an order of magnitude lower than plutonium-239 concentrations from any other sample (Table 9). This was reflected previously by analysis of variance showing plutonium-239 to be lowest at the 36-to-41-cm depth. It is beyond the scope of this report to

examine possible reasons for the relationship, but it is mentioned here that several possibilities exist. Plutonium-239 may be less mobile than americium-241 and plutonium-238 in sediment or it may be an artifact of analytical error of americium-241 and plutonium-238 as detection limits are approached.

Comparisons of ratios between filtered and unfiltered water reflect the earlier comment that filtration effectively removed plutonium-239 from water.

In the case of fish, plutonium-238 and americium-241 are higher in relation to plutonium-239 than expected, if compared to most sediment sample ratios; however, the absolute values of plutonium-239 concentrations in fish (Table 12) closely approach those lowest values found in sediment (Table 9) mentioned previously. Again, we cannot substantiate reasons.

TABLE 13. Ratios of Three Radionuclides in Sediment, Water, and Fish

Quadrant	Profile Segment (cm)	Sediment			Unfiltered Water			Filtered Water			Fish ^a		
		²³⁹ Pu	²³⁸ Pu	²⁴¹ Am	²³⁹ Pu	²³⁸ Pu	²⁴¹ Am	²³⁹ Pu	²³⁸ Pu	²⁴¹ Am	²³⁹ Pu	²³⁸ Pu	²⁴¹ Am
1	0-5	1	0.14	0.79	1	0.13	1.02	1	5.39	(b)	1	0.62	0.67
	20-25	1	0.07	0.25							1	0.69	—
	36-41	1	0.46	0.99							1	2.90	0.33
2	0-5	1	0.08	0.34	1	0.20	0.53						
	20-25	1	0.06	0.15									
	36-41	1	0.10	0.28									
3	0-5	1	0.13	0.25	1	0.09	1.28	1	2.51	—			
	20-25	1	0.07	0.18									
	36-41	1	0.65	0.42									
4	0-5	1	0.08	0.14	1	0.18	1.48						
	20-25	1	0.09	0.16									
	36-41	1	1.06	1.16									

a. Fish were not localized as to quadrant.

b. Indicates no ratio given because one value was 0.

TABLE 14. Ratios of Radionuclide Concentrations Between Sample Types^a

	²³⁹ Pu	²³⁸ Pu	²⁴¹ Am
Sediment (0-5 cm)	1	1	1
Unfiltered Water	0.0047 ^b	0.0061	0.0156
Filtered Water	0.0003	0.0092	(c)
Fish	0.0637	0.6947	0.0665

a. Comparisons based on means of sample groups.

b. Calculation made with water concentration as dpm/ml and fish and sediment as dpm/g.

c. Indicates no ratio given because one value was 0.

Table 14 presents ratios of radionuclide concentrations between sample types. In all comparisons, radionuclide concentrations are highest in sediment. Fish are intermediate between sediment and water. The 0-to-5-cm sediment depth was selected as the basis of comparison because it provides the exchange interface with water and fish. Water also might be employed as the basis of comparison.

Radiochemical Analyses—Soil, Vegetation

Soil

Radionuclides in soil from the four quadrants are expressed as individual sample concentrations, means, and standard deviations (Figure 14).

Plutonium-239 concentrations ranged from an average of 0.48 dpm/g in Quadrant 3 to 2.43 dpm/g in Quadrant 2. Mean concentrations of plutonium-238 and americium-241 were relatively uniform from quadrant to quadrant. Inspection of raw data and histograms (Figures 15-17) prompted tests to determine whether the data fit normal or log normal distributions. Data were segregated by quadrants. Homogeneity of variance between quadrants was also tested.

Table 15 indicates that by W tests (Hahn and Shapiro, 1967), in all cases except one (Quadrant 4, plutonium-238, log normal), no significant fit could be made to either normal or log normal distributions. Oste's (1963) test for homogeneity of variance resulted in the conclusion that there were no differences in precision among quadrants for any of the three radionuclides.

FIGURE 14. Concentration of Plutonium-239, -238, and Americium-241 in Pond D-1 Soil Samples

FIGURE 15. Plutonium-239 Concentration in Pond D-1 Soils

FIGURE 16. Plutonium-238 Concentration in Pond D-1 Soils

FIGURE 17. Americium-241 Concentration in Pond D-1 Soils.

TABLE 15. Results of W Tests for Normal and Log Normal Distribution of Radionuclide Concentrations in Soil Samples From Sides of Pond D-1

Quadrant*	Plutonium-239		Plutonium-238		Americium-241	
	Normal	Log Normal	Normal	Log Normal	Normal	Log Normal
1	0.159	0.288	0.045	0.719	0.316	0.858
2	0.102	0.026	0.618	0.827	0.062	0.082
3	< 0.0001	0.039	0.004	0.072	0.641	0.035
4	0.348	0.002	0.305	0.971	0.154	0.066

*Refer to Figure 9.

Nonparametric methods were selected for comparison of quadrant radionuclide concentrations. The Kruskal-Wallis rank sum test operates on the null hypothesis that the treatment populations do not differ in location (Mosteller and Rourke, 1973). This test allows elimination of the assumption that the populations are normally distributed. The test does assume constant dispersion, acceptable in this

case because of the results of Bartlett's homogeneity of variance test.

Results of the Kruskal-Wallis test (Table 16) indicate significant differences of location between quadrants for plutonium-238 and plutonium-239. Because of the non-normality of the distributions, a parametric test to determine which quadrant or quadrants are

TABLE 16. Kruskal-Wallis Test for Identically Distributed Populations Utilizing Rank Sums of Soil Radionuclide Concentrations From Pond D-1

Quadrant	Plutonium-239		Plutonium-238		Americium-241	
	Rank Sum	H ^a	Rank Sum	H	Rank Sum	H
1	216		193		231.5	
2	256		257.5		177	
		14.98 ^b		7.946 ^c		2.21
3	85		125		178	
4	261		244.5		233.5	

- a. The Kruskal-Wallis statistic H is approximately distributed as a chi-square random variable with (C - 1) degrees of freedom. Here, C - 1 = 3 as there are C = 4 quadrants.
- b. Conclusion: At $p < 0.01$, the four quadrants do not all have identical means.
- c. Conclusion: At $p < 0.05$, the four quadrants do not all have identical means.

different from the others is not valid, and no such test is available for the Kruskal-Wallis nonparametric test.

Inspection of Table 16 indicates that rank sums for plutonium-239 and plutonium-238 are lower in Quadrant 3 than in other quadrants. It seems reasonable, therefore, that plutonium-239 and plutonium-238 are different in Quadrant 3 than in at least one of the other quadrants.

Vegetation

Figure 18 depicts individual sample values, means, and standard deviations for radionuclide concentrations in vegetation of the four quadrants. It is readily observed by comparison of Figures 14 and 18 that plutonium-239 exists in substantially lower concentration in vegetation than in soil. This relationship holds to a lesser degree for americium-241, but plutonium-238 values are similar between vegetation and soil. Statistical analyses of quadrant differences for vegetation, and vegetation-versus-soil are not presented because vegetation data are not yet complete. It is not readily apparent, from the data, whether differences exist between quadrants.

The survey did not include attempts to separate surface from systemic radionuclide deposits in

vegetation. At these low levels of total contamination, such attempts would be problematic in light of the large statistical error.

Ratios

Within individual soil samples, the predominant trend is plutonium-239 > americium-241 > plutonium-238 except for soil from Quadrant 3 (Table 17). Soil from Quadrant 3 and vegetation samples from every quadrant show results greatly at variance with the trend just described. In these latter cases, americium-241 and plutonium-238 usually exceed plutonium-239.

The clear trend in sampled media—pond or pondside, organic or inorganic—is that when sample analyses show the lowest plutonium-239 values, corresponding plutonium-238 and americium-241 values are not diminished in proportion. As stated in an earlier section, we are not yet prepared to select the most probable reason for these relationships.

Inventories

Total radionuclide quantities in sampled media are expressed here in preliminary form (Table 18).

FIGURE 18. Concentration of Plutonium-239, -238, and Americium-241 in Pond D-1

This is done to provide a view of the relative importance of various compartments as radionuclide reservoirs. This inventory may be altered slightly when remaining vegetation samples have been analyzed, and after total masses of pond sediment and vegetation have been more carefully estimated. Estimates presented herein were obtained from the measured means of radioisotope concentrations. Mass estimates are based on a pond area of 1.1 hectare (obtained from maps and aerial photographs), fish biomass of 10,000 g dry weight (not measured, estimated for computation), a vegetation mass density of 300 g/m² dry weight ($\bar{X}$ of 4 samples weighted by data from Little, 1976), and a soil and sediment density of 1.2 g/cm³ (Krey, 1970). It is

noted also that soil and vegetation values are given as dpm/m².

In the pond body (sediment, water, fish), over 98% of the plutonium-239 was found in sediment, which contained an estimated 1.16 mCi. Plutonium-238 and americium-241 also approached mCi amounts in sediment. It was previously stated that pond volume varies, a condition that would alter these fractions and complicate matters by exposing sediment to wind erosion. Sampled biological media never accounted for more than 6.87% of any radionuclide inventory [see plutonium-238 in pondside vegetation (Table 18)].

TABLE 17. Ratios of Three Radionuclides Within Soil and Vegetation

Quadrant		Soil			Vegetation		
		²³⁹ Pu ^a	²³⁸ Pu	²⁴¹ Am	²³⁹ Pu ^a	²³⁸ Pu	²⁴¹ Am
1	n	10	10	10	7 ^b	7	7
	$\bar{X}$	1	0.060	0.331	1	1.756	1.191
	s.d. ^c	—	0.051	0.204	—	1.457	1.047
2	n	10	10	10	10	10	10
	$\bar{X}$	1	0.096	0.338	1	2.388	2.123
	s.d.	—	0.086	0.336	—	1.200	3.692
3	n	10	10	10	8	8	8
	$\bar{X}$	1	0.454	3.288	1	4.023	3.583
	s.d.	—	0.463	3.962	—	2.771	3.064
4	n	10	10	10	6	6	6
	$\bar{X}$	1	0.056	0.292	1	4.072	1.549
	s.d.	—	0.065	0.393	—	2.488	1.368

a. Data normalized to all plutonium-239 values set at 1.

b. Two plutonium-239 values reported as 0 were not included in the calculations.

c. Standard deviations reflect only the variance of the ratios as individual numbers. Propagated error is not accounted for.

TABLE 18. Inventory Estimates of Three Radionuclides at Pond D-1

Location	Compartment	Plutonium-239		Plutonium-238		Americium-241	
		Inventory (dpm)	Fraction of Total	Inventory (dpm)	Fraction of Total	Inventory (dpm)	Fraction of Total
Pond	Sediment, 0-5 cm	3.21×10^8	0.1229	3.14×10^7	0.1079	1.12×10^8	0.1501
	Sediment, 20-25 cm	4.86×10^8	0.1861	3.48×10^7	0.1196	8.91×10^7	0.1194
	Sediment, 36-41 cm	1.35×10^8	0.0517	3.88×10^7	0.1333	5.86×10^7	0.0785
	Sediment, total estimated (0-41 cm)*	2.84×10^9	0.9889	2.85×10^8	0.9862	7.24×10^8	0.9521
	Unfiltered water	3.18×10^7	0.0111	4.0×10^6	0.0138	3.64×10^7	0.0479
	Fish	3.1×10^2	1.08×10^{-7}	3.3×10^2	1.14×10^{-6}	1.13×10^2	1.49×10^{-7}
	<u>Total</u>	2.8718×10^9		2.89×10^8		7.604×10^8	
Pondside	Soil, 0-0.32 cm	6.79×10^3 **	0.9985	2.93×10^4 **	0.9313	1.42×10^3 **	0.9921
	Vegetation	9.96	0.0015	2.16×10^1	0.0687	1.13×10^1	0.0079
	<u>Total</u>	6799.96		314.6		1431.3	

*Core segment results were extrapolated to estimate entire 0- to 41-cm inventory.

**dpm/m².

Discussion

The data indicate that concentrations of plutonium-239 exceed background levels in many cases, especially in soil [background $\approx 1.7 \text{ Ci/km}^2$ (Krey, 1976)], and sediment [background $\approx 8 \text{ nCi/m}^2$ (Hardy et al., 1978)]. It also has been shown that radionuclide concentrations vary from place to place in soil (plutonium-239, -238) and with depth in sediment (plutonium-239). The numbers for soil and vegetation indicate substantial dilution at Pond D-1 downwind from the source, as compared to values reported from a plot adjacent to the southeast security fence (Little, 1976). Decreasing levels of the radionuclides should continue with increasing distance to the southeast, but concentrations above background in soil have been reported for some distance beyond Rocky Flats boundaries (Krey, 1976).

Little (1976) reported that mean plutonium concentrations in the top 3 cm of soil at the plot just mentioned were 1910 dpm/g. He also reported vegetation from that plot to average 63.4 dpm/g. Numbers for soil and vegetation reported herein are consistent with other data (Little, 1976; Krey, 1976) indicating the steepness of the downwind dispersion curve.

Indications that plutonium-239 and -238 concentrations in Quadrant 3 soil were lower than in at least one other quadrant should not be surprising. This conclusion is based on the knowledge that much of this quadrant has been tilled and planted with wheatgrasses since 1969, the year during which the greater share of plutonium-239 dispersion is believed to have occurred. Not all of the soil samples from Quadrant 3 were collected from recently tilled ground. The remainder, however, was taken downwind and in close proximity to the tilled area. It is possible that soil from the tilled ground was eroded by frequent high winds, characteristic of Rocky Flats, and deposited upon the remainder of Quadrant 3. Thus, it is conceivable that the shallow (0.32 cm) soil samples reflected only such eroded soil. Subjectively, the planted wheatgrasses are showing vigorous growth, indicating future improvement of soil stability in this area.

Vegetation data are incomplete, but it is obvious that no clear patterns of radionuclide distribution are discerned. Prior studies (Little, 1976; Arthur, 1977) have indicated that most of the vegetation component of these radionuclides can be expected to exist as debris on plant surfaces rather than being systemically entrained.

Our data show a peak of plutonium-239 at the 20- to 30-cm sediment depth. This is equivalent to the depth of the peak reported for Standley Lake during 1976 (Hardy et al., 1978). The sediment distribution in Standley Lake was shown by a 50-cm profile analyzed at 2-cm intervals, and that peak was believed to represent the 1969 period of "maximum aerosol concentration of total long-lived alpha activity at the Rocky Flats site." Our sediment profile analyses were not as finely fractionated as that just mentioned, thus, we cannot say whether our data represent a true peak at Pond D-1. However, our data are not inconsistent with such an interpretation.

Concentration data from water and fish are difficult to interpret. Much of the difficulty stems from the additional questions raised by calculated ratios. Plutonium-239 values in water and fish were very low compared to the amount in sediment. However, there were comparatively high concentrations of plutonium-238 and americium-241 in these sample media. This suggests greater mobility for the last two radionuclides than for plutonium-239, even though these concentration ratios are considered tentative. Also, there is uncertainty regarding the measurement accuracy of low-level concentrations of plutonium-238 and americium-241. Others have encountered similar difficulties with concentration ratios of plutonium and/or americium (Little, 1976; Miller and Stannard, 1976).

Calculated inventories are a reasonable approximation of reality at Pond D-1 in revealing that most of the three radioisotopes remain in soil and sediment. This information verifies the pattern of data on radionuclide distribution at Rocky Flats in terrestrial (Little, 1976) and aquatic (Johnson et al., 1974) environments, but at concentration levels lower by one or more orders of magnitude. In the latter sense, the present data is unique and valuable.

LAND MANAGEMENT

LAND MANAGEMENT PLAN

Margaret F. Hickey

The Rocky Flats Land Management Plan was developed in 1977 as a tool for implementing the Land Management Policy (RFPM PLBL 2-001). The Policy and Plan provide for environmental and physical control of all open space land on the Plant site such that adverse environmental impacts are minimized.

The Plan supplies data on land characteristics, identifies areas of unique consideration, and establishes the formal specific criteria necessary to guide and control both short-term and long-range future development at the Plant site. This plan includes allocation of usage areas for various compatible activities in the open space areas, recognizing multiple land use as a viable option.

Key physical and biological parameters are documented through the use of a series of maps to provide the necessary in-depth analysis of available land resources. These maps include:

- Aerial photograph
- Topography
- Geology
- Landslide susceptibility hydrology
- Soil
- Plutonium-in-soil isopleths
- Vegetation
- Range site condition
- Wildlife

Past and current land-use practices are identified. This aids in future decisions regarding land use and in the coordination of projects in related areas and with related functions.

Primary use of the land is and will be in direct and indirect support of the Rocky Flats facility. This includes consideration of such use categories (to be defined) as operations/research, transuranic research, and general research. Also, grazing, recreation, and wildlife habitat improvement are land-use classes that are considered. Each land-use class is evaluated in terms of the previously identified site limitations, and requirements for each activity class are also specified.

The Plant site is subdivided into sectors of approximately 320 acres each, and a land sector analysis has been performed by describing the areas in terms of the land-use factors. These factors include radioactivity levels, sector accessibility, utilities and services available at the sector, existing fencing, sector topography, vegetative quality, and wildlife refuge.

Finally, Land Use Analysis maps are presented that categorize uses for each sector as "compatible," "incompatible," or "optimal." "Compatible" defines which uses are possible within a sector. "Incompatible" defines those areas that are not to be considered for a particular use because the use factor requirements cannot be met. "Optimal" defines the portions of each sector that conform best with the projected long-term site-zoning plan for that use and should therefore receive first consideration. This procedure enables potential users to employ the Plan and identify possible conflicts in use.

The use categories that have been identified are as follows:

Operations/Research

Definition: Any use requiring structures or excavation of soil for operations, research and development (R&D), or for any other purpose.

Where expansion of the primary facility or industrial-type development is necessary, areas have been designated such that any physically disruptive activities are confined to areas on the high rocky mesa, which are extremely difficult to improve for wildlife habitat, or to other land of lower utility such as previously disturbed zones or corridors. All future programs such as road developments and installation of utilities and fencing must be coordinated to minimize construction impacts. Long-term effects such as wind erosion and weed infestation, that such disturbances have led to in the past, should be mitigated by immediate revegetation of all affected areas.

Transuranic Research

Definition: Any use, especially research related, requiring the presence of measurable amounts of transuranic activity.

Certain areas have been retained for their utility in future research and monitoring of plutonium in the environment and any potential short- or long-range impacts. Ongoing programs being conducted by onsite and offsite researchers should be encouraged to gain a better understanding of the effects of transuranics in the natural environment. Coordination of these individual programs will be provided through the Land Management Council via the Land Use Request Forms, a procedure required prior to any nonroutine use of the buffer zone.

General Research

Definition: Any use not requiring structures, excavation, or disturbance of the land, especially for research purposes.

For conducting long-term environmental and ecological research and monitoring, segments of each main vegetation community are recommended for permanent protection from systematic disturbances. This is recommended so that recovery, succession, or changes in composition or structure of vegetative cover can be encouraged and observed. The Rocky Flats area provides a unique opportunity to onsite researchers and the education community

in general, since it can remain a relatively undisturbed island surrounded by industrial, urban, and rural development.

Grazing

It is not recommended at this time that any land should be considered for grazing; however, if general vegetative recovery is achieved, the potential for grazing does exist.

Recreation

Some area could be made available for recreational purposes. Any proposal for recreational development should not be for limited, special interest groups and should have multiple use possibilities with no adverse environmental impacts. Strict procedures will be adhered to with regard to access control and safety considerations for recreation and other uses.

Wildlife Habitat Improvement

Definition: Actions taken to enhance the natural ecological state of the land, especially for the use of wildlife such as deer, waterfowl, and fish.

The Rocky Flats land area contains a fragile mixed prairie and short grass community. Rocky Flats is situated in a climatic and topographic transition zone and receives moderate precipitation. It is desirable to improve the richness and diversity of habitats over the entire area. This is specifically recommended where such programs may be supported by the availability of water in the natural drainages. This action will facilitate the preservation of a substantial deer herd and diversify the habitats of other wildlife species.

An annual program for shelter belt plantings should be established. This would have a three-fold goal of providing wildlife shelter, aesthetic pleasure, and reducing soil drift to offsite locales. Weed control must continue to be pursued by a careful, timely spot program of aerial spraying, but must be

administered to minimize damage to desirable vegetation species. Also, biological weed controls such as thistle weevils on nodding thistle should be encouraged, and expanded, if they prove compar-

able to herbicides in effectiveness. Problem areas due to past disturbances should be revegetated to reduce further soil erosion and weed control problems.

LAND MANAGEMENT POLICY AND ITS IMPLEMENTATION

Douglas C. Hunt

A general policy for Land Management at Rocky Flats has been developed and appears as Policies PLBL-2-001 and OM 7-329. (Rockwell, no date.) These policies are as follows:

Land Management

Rockwell is responsible for management of all lands on the Rocky Flats Plant site. The responsibility includes land utilization planning plus environmental and physical control of the land and its natural resources. All major activities conducted on Rocky Flats Plant site lands require approval by the Plant Executive Committee (OM 7-329*) based upon recommendations of the Land Management Council (OM 7-329). For shorter-term, low-impact projects, Land Management Council approval is sufficient.

The following responsibilities are associated with implementation of this policy.

1. The Land Management Council will review research projects, Schedule 189 proposals, or other nonroutine activities on Plant lands to ensure that environmental integrity will be maintained. Information on such projects, proposals, or activities is to be submitted to the Land Management Council, on a Land Use Request (LUR) Form (Form RF-46427). The Land Management Council has the responsibility to review LURs and make recommendations or request further information regarding proposals within a 5-working-day period and refer the LURs to the Executive Committee as appropriate. The Land Management Council provides Plant Protection personnel with the authorized Access Master List, which includes names and dates involved with access to the buffer zone. This list is updated periodically.
2. Environmental Sciences personnel are responsible for auditing the activities being conducted on all Plant lands to ensure that these activities are performed as specified to the Land Management Council.
3. Facilities Engineering refers to the Land Management Council, all Engineering Job Orders that involve open space areas. Facilities Engineering personnel also have the responsibility of referring all Title I, II, and Design Criteria for construction and excavation to the Land Management Council for review and recommendation.
4. Plant Protection personnel
 - a. maintain a Buffer Zone Access Log recording name, area visited, time and date
 - b. prevent access by unauthorized personnel.
 - c. enforce the restriction of vehicles to approved roads.
5. All employees must protect the environment from abuse caused by their own actions and report inadvertent abuses or emergency exceptions to the Shift Superintendent.
6. Abuses are reported by the Shift Superintendent to the Environmental Sciences Manager by means of the Shift Superintendent's daily report.

*OM - Organization Manual.

Executive Committee

The Executive Committee is appointed by, and is responsible to, the General Manager. The Committee assists in administering the development, maintenance, and evaluation of proposed plans and activities that will affect or be impacted by long-range objectives at the Plant or will be included in the Rocky Flats Operation Plan.

Land Management Council

The Land Management Council is a working task group reporting to the Executive Committee through the Director of Health, Safety and Environment. The Council reviews and takes action on proposals for access to and use of open spaces. Membership on the Land Management Council is by appointment of the Director of Health, Safety and Environment. The key element in the administration of the land management policy is the LUR form. Any person or organization, either internal or external to the Rocky Flats Plant, who desires some specific use of any open space land on the Plant site must file an LUR with the Plant Land Use Coordinator. This LUR must be approved by either the Land Management Council (LMC) or the Executive Committee. Short-term uses with little or no environmental impact may be approved by the chairman of the LMC. Longer-term projects with the potential for high impact require review and approval by the membership of the LMC. Proposals that involve excavation or any permanent commitments of land or research must be approved by the Executive Committee subsequent to LMC review. The administrative flow of LUR's is given in Table 19.

Implementation of an approved LUR, especially one from offsite users, with significant potential long-term impact on the land and associated resources, typically requires leasing arrangements and other use agreements that often are not detailed on the LUR. Hence, an approved LUR in these cases is usually an agreement in principle and not a final authority to proceed immediately with a given project. To date, the following high-impact LUR's have been considered:

LUR Description	Status
Request from an Arvada model airplane club to use Plant land as a flying strip.	Approved; land lease arrangements pending.
Request to install a television transmitting antennae and satellite receiver.	Reviewed by LMC with recommendations transmitted to Executive Committee. Council members recommended rejection of request.
Request from a clay pit owner to cut a road from the clay pit to intersect with a Plant access road.	Reviewed by LMC with a recommendation for rejection transmitted to the Executive Committee.
Request from an area resident for grazing privileges.	Request denied by Executive Committee.
Request from an onsite user for road construction from a Plant access road to an outlying test site.	Reviewed by LMC with recommendations transmitted to Executive Committee. Council members recommended request approval.
Several medium-impact proposals have been reviewed or are pending review by the LMC. These include requests to (1) permit field trips by area students, (2) install a reverse osmosis pilot plant project at a Plant pond, (3) allow grazing privileges for animals owned by Plant employees, (4) allow Plant employee garden plots, (5) permit off-road training exercises in Security and Safeguards Department personnel carriers, (6) collect quantities of soil for test purposes, (7) install a mobile office outside the Plant	

TABLE 19. Land Use Request Form Administrative Flow

security fence, (8) relocate an outside storage area, (9) stockpile rocks, (10) collect marked deer from the onsite deer herd, and (11) upgrade the Security and Safeguards Department firing range. All of these proposals except numbers 3 and 4 were approved.

A number of other low-impact requests were reviewed and acted upon. These involve either environmental or ecological research projects where limited amounts of sampling occurs or persons who require short-time access for purpose such as nonroutine monitoring, surveying, or inspections.

REMOTE SENSING PROGRAM

Terrol F. Winsor

Introduction

Rockwell and DOE have a commitment to care for the Rocky Flats Plant site, including all Plant site

lands. This commitment is stated (Rockwell, no date), as Item PLBL-2-001 in the Facility Land Management Plan, and elsewhere. One phase of meeting this commitment is the continuing assess-

ment of past and present land management practices on Plant lands. A second phase is the evaluation of the effect of Plant operation, particularly of radionuclide releases, on the ecological status of Plant lands. With regard to the latter phase, several test areas have been established.

Meeting these two objectives necessitates a yearly record via remote sensing techniques of the Plant site and adjacent lands. These remote sensing pictures, combined with a limited amount of ground-truth field work will permit

1. Evaluation of changes in biomass distribution through time for the entire Plant.
2. Definition of present biomass and vegetative communities in the test areas.
3. An evaluation of weed spray practices, particularly in the Walnut Creek and Woman Creek drainages, and soil sterilization.
4. Evaluation of the effectiveness of revegetation efforts in several Plant site areas.
5. Evaluation of the impact on vegetative and soil stability of diverse Plant operations such as vehicular traffic and construction activities.

Program for 1978

During 1978, a remote sensing program was initiated via techniques of aerial photography. The photography was organized under Contract 92658-D by Dr. Jan Cipra, Department of Agronomy, Colorado State University, Fort Collins.

The scope of work was to provide high-quality color and color infrared photographs and transparencies of the Plant site prior to the end of the 1978 growing season. Included were 1:2500 photography of a pond and three terrestrial study plots. The studies performed on these four areas are described in later sections concerning aquatic radioecological studies and terrestrial radioecological studies, respectively. Photography of the entire Plant site was conducted at scales of 1:10,000 and 1:5000. All photographs, negatives, and transparencies that

were obtained are the property of the Department of Energy; however, it is anticipated that copies may be supplied to qualified requestors.

Methods and Materials

Color and color infrared photography was conducted over the Rocky Flats Plant on October 5, 1978. The flying was done by R and D Aerographics, Inc., of Loveland, Colorado. Photography was conducted between 10:00 a.m. and 2:00 p.m. The camera was a Wilde-Herrbrugg RC-10 mounted in a Cessna twin aircraft. This camera has a six-inch focal length. The color film used was Kodak aerial color negative film, Number 2445. The color infrared film used was Kodak infrared film, Number 2443.

Photographs were collected at three altitudes, resulting in three scales of photography. Photographs at a scale of approximately 1:5000 and 1:10,000 were collected over the entire Plant site. These scales were obtained by flying at 2500 ft and 5000 ft above the ground, respectively. A third flight at 1250 ft above the ground gave 1:2500 scale photos of the four designated test areas. All flights were done in both color and color infrared with 60% frontlap to facilitate stereoscopic analysis, and about 10% sidelap, for the 1:5000 and 1:10,000 scale photos. The higher altitude flights were flown in an east-west direction; the lowest altitude flights were flown generally east-west, with one site being flown north-south. The processed film was examined by Dr. Cipra and prints were then made. Processing and printing of all film was done at Precision Photo Lab in Dayton, Ohio. Final receipt of all negatives and prints was on December 21, 1978.

Results

Figures 19-23 are black and white reproductions of representative color negatives produced in this study. Similar reproductions appear elsewhere in this report. These reproductions illustrate, at the three

FIGURE 19. Aerial Photograph of Woman Creek Dam Area (scale 1:5000)

FIGURE 20. Aerial Photograph of Test Plot 1 (scale 1:2500)

FIGURE 21. Aerial Photograph of Test Plot 2 (scale 1:2500)

FIGURE 22. Aerial Photograph of Test Plot 3 (scale 1:2500)

FIGURE 23. Aerial Photograph of Pond D-1 (scale 1:2500)

scales of photography, the good resolution and overall high quality of the photographs.

Figure 19 is a 1:5000 scale photograph that includes C-1 pond, Woman Creek dam construction area, terrestrial test plot 1, and the eastern portion of the security zone. Some of the above-mentioned areas are shown at a 1:2500 scale in Figure 20. Terrestrial test plot 1 is located by the white corner markers

seen most easily in Figure 20. Terrestrial test plots 2 and 3, and Pond D-1 appear at 1:2500 scale (Figures 21-23).

Application of the remote sensing photographs to meet the stated objectives will commence during Calendar Year 1979 and will involve the combined efforts of Rockwell International personnel and Dr. Cipra.

TERRESTRIAL RADIOECOLOGY

MONITORING AND MODELING PROGRAM

Terrol F. Winsor

Introduction

Purpose

Certain areas on the Rocky Flats Plant site contain radionuclides, mostly plutonium and americium, of industrial origin. To evaluate the environmental impact of Rocky Flats, it is desirable to describe the statics and dynamics of the distribution of these radionuclides in onsite biotic communities. It is equally desirable to know where the radionuclides localize and whether they present ecological or environmental hazards. Numerous projects in the Rocky Flats environs have provided useful data on environmental levels and behavior of plutonium (Arthur, 1977; Hiatt, 1977; Little, 1976; Whicker, 1977a). These data describe where plutonium is geographically and ecologically localized, and provide some reasonable suppositions as to predominant modes of transport. New questions have been raised by the data, and it is recognized that the influence of time on flow and effects of these radioactive materials requires investigation.

The Terrestrial Monitoring and Modeling Program involves the implementation of a long-term program intended primarily to study the influence of time (as previously mentioned) on the terrestrial ecosystem compartmentalization of transuranics. A schematic identifying the compartments, the transfer paths, and the relative importance of the transfer paths appears as Figure 24. The program

will include sampling of several of these compartments on three established plots (Figure 25). Sampling of the two plots (Numbers 2 and 3) farthest from the security fence, over a period of years, will enable a determination to be made as to whether quantities of plutonium and americium at those plots increase as a result of dispersal from areas of higher concentration closer to the security fence. Plot 1 (see Figure 25) contains more plutonium in soil than the other plots and other areas between the security fence and Rocky Flats Plant boundaries. Also, most existing data have been derived from Plot 1 (Little, 1976). Plot 2 is downwind of Plot 1. Plot 3 may be considered the control plot or plot of lowest plutonium and americium levels.

Supportive Studies

In support of the radioecological efforts, a supplemental data collection, the purpose of which is to obtain a baseline ecological description of the test plots, must be pursued. This work includes investigations of the static and dynamic aspects of plant and animal populations. It is necessary to determine rates and processes of structural and functional changes in plant communities. Any such changes may affect alterations in radionuclide transport. If plant communities become different, so does the nature of resident animal populations. Hence, the amount of radionuclides exported by

FIGURE 24. Compartments and Transfer Paths of Hypothetical Plutonium Model

animals and the numbers and species at risk may change. Some earlier information exists on plant ecology at Rocky Flats (Clark, 1977; Weber et al., 1974), but the possibility of eventual community modification necessitates further work.

Each plot can be considered a grassland community existing in a disturbed state. During 1978, a study began of structural similarity between the plant communities of the sites. This report presents current results of quantitative botanic technique, including information gathered prior to 1978 by others (Whicker, 1973).

Methods and Materials

The three terrestrial study plots are shown in aerial views at 1:2500 scale (Figure 20-22). Each plot

has an area of 10,000 m² (1 ha) and is located within the corner markers seen in the photographs. The description and analysis of the Plot 1 vegetation were done prior to 1978 (Whicker, 1973). Most work accomplished during 1978 was done on Plot 3; the techniques employed were modifications of those used on Plot 1. The data collection procedure involved establishment of a 100-m line running east to west through the center of Plot 3 and subdivided into 10 segments, each 10 m long. Ten transects, each 100 m long, were laid out perpendicular to the original line at a randomly determined point within each of the 10-m sections. The original line bisected each perpendicular line. Each perpendicular line was subdivided into ten 10-m sections, and a point was located within each of the sections as determined by a random

FIGURE 25. Location of Three Test Plots at Rocky Flats

number. The resulting 100 points represented locations for data collection. Botanical frequency values were obtained by noting the presence or absence of a plant species with a 20-cm by 50-cm metal quadrat frame placed at each of the 100 sampling points, and dividing the numbers of occurrences by 100.

Plants were identified from Weber (1972) and Harrington (1964). Estimates of species and litter coverage and percent bare soil and rock were also obtained from quadrat frame sampling. The estimated mass of standing crop was obtained by

clipping all standing vegetation on a 0.5-m² frame centered on 5 of the 100 quadrats that were sampled for frequency. Mass estimation of litter was obtained by collecting all of the litter at the same five locations. The vegetation samples were oven dried at 70 °C prior to being weighed.

Vegetation data obtained on Plot 3 were submitted to a frequency analysis to provide a basic description and to allow comparison with data collected earlier from Plot 1 (Whicker, 1973). Some data also were gathered from Plot 2 during 1978, but the amounts obtained were insufficient for analysis.

FIGURE 26. Species-Area Curve for Plot 3

Results

The adequacy of the sample size obtained for locating species is shown by the "species-area curve" (Daubenmire, 1968). From this curve (Figure 26), it is seen that 26 of 31 species found on Plot 3 were observed in the first 31 of 100 quadrats sampled. The asymptotic nature of this curve implies that a larger effort would not identify many more species and that undiscovered species are not important constituents, in terms of frequency. The only species seen in the field, which were not observed in the quadrats, were Erigeron strigosus (Daisy Fleabane), Carduus nutans (Nodding thistle),

Kochia iranica (Burning-bush), and Yucca glauca (Spanish Bayonet), all judged to be scarce.

Frequency-of-occurrence data collected from Plot 3 and from previously published data on Plot 1 (Whicker, 1973) are presented in Table 20. A coefficient of community (cc) was calculated from these data according to the following formula:

$$cc = \frac{2c}{a+b} \times 100$$

where c is the summed frequency of common species, a is the summed frequency of species unique

to Plot 1, and b is the summed frequency of species unique to Plot 3. Thus

$$a = \sum_{i=1}^n a_i, \quad b = \sum_{i=1}^n b_i, \quad c = \sum_{i=1}^n c_i$$

where $c_i = a_i$ if $a_i \leq b_i$

or $c_i = b_i$ if $a_i > b_i^*$

The data in Table 20 yield a cc of 47.8 percent.

A simpler coefficient of community is concerned only with the presence of species in the two plots and ignores frequency (Mueller-Dombois and Ellenberg, 1974). By this method,

$$cc = \frac{c}{a + b + c} \times 100$$

where a = number of species unique to Plot 1
b = number of species unique to Plot 2
c = number of common species

The data in Table 20 yield a cc of 42.9 percent.

These numbers are indices and are not absolute measures of similarity between two plant communities. No unique standard exists that dictate the coefficient of community value needed before two communities should be considered similar. However, from the experience of many investigators, based on presence only, coefficient of community values from 25 to 50 percent have been proposed as indicating that two communities are part of the same association; i.e., they have "similar floristic composition" (Mueller-Dombois and Ellenberg, 1974). The importance of these measures will become apparent only from interplot and intraplot comparisons over several years. These temporal comparisons may indicate whether succession occurs or disturbance influences floristic characteristics.

*Mueller-Dombois and Ellenberg, 1974.

Analysis of vegetation data pertinent to a more rigorous description of Plot 3 is presented in Table 21. Absolute values of frequency and coverage of species are summed and employed for calculation of relative frequency and relative coverage; i.e., the combined totals are set as 100 percent and frequency and coverage of individual species are taken as percents of the total. Relative frequency and relative coverage of a species are then summed to provide an importance value (Mueller-Dombois and Ellenberg, 1974).

The results show that Agropyron smithii (Western Wheatgrass) assumed greatest importance by a wide margin over other species at the site. This species is a perennial sod-forming grass commonly found on slopes throughout Rocky Flats (Weber et al., 1974). Six other species had importance greater than 10 (an arbitrary separation point); four of these are grasses. Two of the seven species with importance values greater than 10 are annuals common to disturbed ground: Bromus tectorum (Cheatgrass), and Chenopodium leptophyllum (Narrow-leaved Goose-foot). Some of the disturbance is doubtless attributable to burrowing activity of pocket gophers in the soft friable soil. Mounds and burrows were obvious on Plot 3.

Comparisons of frequency and coverage should be done carefully. For example, Chenopodium leptophyllum had a high frequency of 0.44, but the sparse, scattered distribution and small plant size accounted for a small coverage value of 0.0237. On the other hand, Agropyron smithii is a sod-forming grass that was frequent (0.87) with high coverage (0.2963), reflecting its larger size and denser growth. These values indicated that Agropyron smithii is the dominant plant species on Plot 3. However, as the indication of a dominant species often incorporates additional traits (e.g., basal area, volume productivity) beyond those measured here (Daubenmire, 1968; Krebs, 1972), this is not regarded as a final conclusion. Lastly, it is reasonable to conclude that grasses, as a family, form the most important group at this plant community.

Average dry weights of standing vegetation and litter on Plot 3 were measured as 223 g/m² and 195 g/m², respectively (Table 22). These data compare

TABLE 20. Frequency of Occurrence Data for Plants in Plots 1 and 3

Plant	Plot 1, a_i	Plot 3, b_i	Common, c_i
<u>Agropyron smithii</u>	0.810	0.87	0.810
<u>Allium textile</u>	0	0.01	0
<u>Ambrosia spp.</u>	0.124	0.01	0.01
<u>Andropogon gerardii</u>	0.064	0.01	0.01
<u>Aristida longiseta</u>	0.032	0.01	0.01
<u>Artemisia frigida</u>	0.020	0.10	0.020
<u>Artemisia ludoviciana</u>	0.028	0.04	0.028
<u>Aster spp.</u>	0.048	0.01	0.01
<u>Astragalus spp.</u>	0.024	0.03	0.024
<u>Bouteloua cartipendula</u>	0	0.11	0
<u>Bouteloua gracilis</u>	0.196	0.33	0.196
<u>Bromus spp.</u>	0.840	0.44	0.40
<u>Buchloe lachryloides</u>	0.004	0.48	0.004
<u>Carex spp.</u>	0.164	0	0
<u>Chenopodium leptophyllum</u>	0.004	0.44	0.004
<u>Cirsium spp.</u>	0.064	0	0
<u>Descurainia sophia</u>	0	0.02	0
<u>Echinocereus viridiflorus</u>	0.056	0.15	0.056
<u>Gaura coccinea</u>	0.028	0	0
<u>Grindelia squarrosa</u>	0.008	0.07	0.008
<u>Gutierrezia sarothrae</u>	0.008	0	0
<u>Helianthus spp.</u>	0.036	0.35	0.036
<u>Heterothea villosa</u>	0.004	0	0
<u>Hordeum jubatum</u>	0.004	0	0
<u>Hypericum perforatum</u>	0.004	0	0
<u>Koeleria gracilis</u>	0	0.01	0
<u>Lactuca scariola</u>	0.252	0.03	0.03
<u>Lappula redowskii</u>	0	0.01	0
<u>Lepidium densiflorum</u>	0.008	0	0
<u>Lesquerella spp.</u>	0.060	0	0
<u>Leucocrinum montanum</u>	0.004	0	0
<u>Linum lewisii</u>	0.024	0	0
<u>Lomatium orientale</u>	0	0.10	0
<u>Lupinus argenteus</u>	0	0.13	0
<u>Mirabilis linearis</u>	0.024	0	0
<u>Opuntia spp.</u>	0.056	0.08	0.056
<u>Orobancha fasciculata</u>	0	0.01	0
<u>Pediocactus simpsonii</u>	0	0.01	0
<u>Poa compressa</u>	0	0.02	0
<u>Psoralea tenuiflora</u>	0.088	0	0
<u>Salsola Kali</u>	0.016	0	0
<u>Senecio spartioides</u>	0.004	0	0
<u>Sitanion hystrix</u>	0.012	0.03	0.012
<u>Sparganium angustifolium</u>	0.156	0	0
<u>Stephanomeria pauciflora</u>	0.004	0	0
<u>Stipa spp.</u>	0.084	0.14	0.084
<u>Thelesperma megapotamicum</u>	0.004	0	0
<u>Tradescantia occidentalis</u>	0.020	0.01	0.01
<u>Tragopogon spp.</u>	0.232	0.01	0.01
	$a = 3.618$	$b = 4.03$	$c = 1.828$

TABLE 21. Vegetation Data for Species in Plot 3

Rank	Species	Frequency	Relative Frequency (%)	Cover	Relative Cover (%)	Importance Value*
1	<u>Agropyron smithii</u>	0.87	21.60	0.2963	41.11	62.71
2	<u>Buchloe dactyloides</u>	0.48	11.91	0.0731	10.14	22.05
3	<u>Helianthus spp.</u>	0.35	8.68	0.0581	8.06	16.74
4	<u>Bromus tectorum</u>	0.40	9.93	0.0463	6.42	16.35
5	<u>Chenopodium leptophyllum</u>	0.44	10.92	0.0237	3.29	14.21
6	<u>Boutelona gracilis</u>	0.33	8.19	0.0411	5.70	13.89
7	<u>Stipa spp.</u>	0.14	3.47	0.0555	7.70	11.17
8	<u>Lupinus argenteus</u>	0.13	3.23	0.0174	2.41	5.64
9	<u>Boutelona curtipendula</u>	0.11	2.73	0.0156	2.16	4.89
10	<u>Artemisia frigida</u>	0.10	2.48	0.0163	2.26	4.74
11	<u>Echinocereus viridiflorus</u>	0.15	3.72	0.0060	0.83	4.55
12	<u>Opuntia spp.</u>	0.08	1.99	0.008	1.11	3.10
13	<u>Lomatium orientale</u>	0.10	2.48	0.0043	0.60	3.08
14	<u>Grindelia squarrosa</u>	0.07	1.74	0.009	1.25	2.99
15	<u>Poa compressa</u>	0.02	0.50	0.012	1.67	2.17
16	<u>Actemisia ludoriciana</u>	0.04	0.99	0.0043	0.60	1.59
17	<u>Sitanion hystrix</u>	0.03	0.74	0.0056	0.78	1.52
18	<u>Andropogon gerardii</u>	0.01	0.25	0.006	0.83	1.47
19	<u>Tragopogon spp.</u>	0.01	0.25	0.008	1.11	1.36
20	<u>Astragalus spp.</u>	0.03	0.74	0.0027	0.37	1.11
21	<u>Lactuca serriola</u>	0.03	0.74	0.0005	0.07	0.81
22	<u>Aristida longiseta</u>	0.01	0.25	0.004	0.56	0.81
23	<u>Descurainia sophia</u>	0.02	0.50	0.0012	0.17	0.67
24	<u>Lapulla redowskii</u>	0.01	0.25	0.002	0.28	0.53
25	<u>Allium textile</u>	0.01	0.25	0.001	0.14	0.39
26	<u>Orobranche fasciculata</u>	0.01	0.25	0.0007	0.10	0.35
27	<u>Pediocactus simpsonii</u>	0.01	0.25	0.0007	0.10	0.35
28	<u>Ambrosia spp.</u>	0.01	0.25	0.0005	0.07	0.32
29	<u>Aster porteri</u>	0.01	0.25	0.0005	0.07	0.32
30	<u>Tradescantia occidentalis</u>	0.01	0.25	0.0002	0.03	0.28
31	<u>Koeleria gracilis</u>	0.01	0.25	0.0001	0.014	0.264
	Σ	4.03		0.7207		
	litter	1.0		0.6545		
	exposed soil	0.81		0.1384		
	rock	0.07		0.0044		

*Total of relative frequency and relative coverage.

with August estimates of approximately 230 g/m² standing vegetation and 220 g/m² litter on Plot 1, as reported by Little (1976). The values for Plot 3 represent only 5 samples; therefore, they are presented without drawing conclusions of overall reliability. An important point is to recognize

that these estimates will vary with seasonal and yearly growth conditions.

Discussion

Data presented herein provide a useful first description of two plant communities. Comparisons

TABLE 22. Dry Weight of Vegetation From Plot 3

Sample Number	Standing Vegetation (g/m ²)	Litter (g/m ²)
1	268	162
2	296	188
3	140	164
4	187	220
5	226	242
$\bar{x}$	223	195
Standard Deviation	62.3	35.1

between Plots 1 and 3 indicate an expression of similarity without specification of absolute degree. The two plant communities can be said to be similar in floristic composition; i.e., both communities have many species in common, with some of the species being frequent on both plots. A similar vegetative pattern was seen in the widespread distribution of Agropyron smithii, Bromus spp. (primarily B. tectorum), and Boyateloua gracilis on both sites. However, opposing patterns were shown by comparisons of frequencies of species that were much more widespread on one plot than another. Overall, both sites can be considered disturbed communities dominated by grasses. Bromus tectorum is a weedy annual grass abundant nearly everywhere at Rocky Flats. It frequently is considered a clear indicator of land disturbance, and once established, may prevent return of native dominants (Daubenmire, 1968). No coverage data are yet available from Plot 1; therefore, cheatgrass abundance on the plot is unknown.

Other comparisons between Plots 1 and 3 are subjective, but it is visually obvious that Plot 1 contains much more surface rock and gravel than Plot 3. From this information, it is impossible to predict the relative future status of the two plant communities. Clark (1977) found that the variables of nonvegetated area, moisture, and grazing (disturbance) were significantly related to vegetation distribution at Rocky Flats. Also, Rocky Flats vegetation appears no more stable than in 1914 (Clark, 1977). No grazing has occurred on Plots 1 and 3 for over 25 years but the severe climatic environment (frequent high winds, low

annual average precipitation, and poor soil) (especially Plot 1) may preclude natural stabilization of the two communities.

The seven most important plant species, in terms of frequency and coverage at Plot 3, are obviously well adapted to local conditions (Weber et al., 1974). Four of those species are native perennial grasses desirable for soil stability, especially two sod-formers -- Agropyron smithii and Buchloe dactyloides.

Approximately 14 percent of the soil surface was not vegetated nor covered by litter. Combined forces of pocket gopher activity and erosion by wind may be major factors preventing complete coverage. Future data collections should indicate the trend in the amount of barren ground at the study plots.

Visual inspection of Plot 3 reveals that vegetation is not uniformly distributed—an expected feature of many natural environments (Daubenmire, 1968). Data were not sufficient for mapping of distribution, but future efforts should allow rough map construction of each plot.

Awareness of limitations of current data cautions that much more information is necessary before the study plots are adequately described. Data from Plot 1 were collected 6 years prior to that from Plot 3 and at an earlier time of year, did not include coverage, and were taken by different methods. Future studies of the three plots must be much more extensive in terms of sampling quality and sample type. Consideration will be given to factors of soil, moisture, temperature, season, and disturbance so that the plots may be compared with greatest confidence.

It is impossible to pick identical vegetation stands so that effects of one environmental factor may be unambiguously determined; however, Plots 1 and 3 maintain sufficient similarity so that, with sufficient description, they should serve as comparators of plutonium and americium mobility.

POPULATION DYNAMICS, BEHAVIOR, AND FAWN MORTALITY IN MULE DEER AT ROCKY FLATS

Susan D. Teigen

Introduction

Mule deer (*Odocoileus hemionus*) fawns in Colorado have, in recent years, suffered high mortality rates of over 50 percent in the first year. In June 1976, an estimated 60 fawns were born at Rocky Flats. By the end of the summer, only 17 fawns were accounted for (Hiatt, 1977). Aerial counts taken by the Colorado Division of Wildlife (CDW) in Game Management Unit No. 29 (which lies immediately west of and includes Rocky Flats) gave fawn-to-doe ratios of 0.76:1 and 0.73:1 in February 1975, and January 1976, respectively. According to CDW, the annual fawn-to-doe ratios observed in late December through early February across Colorado range from 0.4:1 to 0.8:1. However, Schoonveld (1978) estimated that natality averaged as usual—one fawn per yearling doe and two fawns per older doe. Zwank (1976) implies that this trend toward higher fawn mortality (up to 50 percent) is characteristic throughout Colorado. A Colorado State representative at the Fifth Western States Mule Deer Workshop described mule deer productivity trends in the state: "There are no fawn production figures on a statewide basis, but on one area there were 31 fawns per 100 does in 1974 compared to 1965 when there were 60-to-70 fawns per 100 does." Observed ratios of yearling does to adult does at Rocky Flats were 4 yearlings to 40 adults in 1975-1976 and 7 yearlings to 39 adults in 1976-1977 (Hiatt, 1977). Reasons for the fawn mortality are many, but they are not quantitatively separated. Optimal deer management requires knowledge of the reasons for, and the long-term effects of this phenomenon.

The study reported here was conducted at the Rocky Flats Plant for Rockwell International, which operates the Plant for the Department of Energy. The study was designed to provide information helpful in the management of local deer. Rocky Flats is a particularly good study area in that there is a large population of deer, the majority of which are not migratory. The maximum population during the summer of 1976 was estimated

to be 130 deer; during the summer of 1977, the estimate was 121 deer (Hiatt, 1977). It was further estimated that up to 30 deer may have emigrated during the spring seasons, and 20-to-30 deer may have immigrated during the fall seasons. Migration was lower during the summer months. This study was undertaken during the summer months when the deer population was large and stable.

Optimal deer management also requires knowledge of the population dynamics, fawning season, and social behavior of the Rocky Flats deer. Such information was limited to studies done by the Colorado State University Department of Radiology and Radiation Biology between June 1975 and July 1977 (Arthur, 1977; Hiatt, 1977). These studies were done to measure plutonium intake and dispersal by the Rocky Flats deer. Plutonium intake was estimated by the study of the seasonal food habits and amount of soil ingestion by the deer. Population dynamics, habitat utilization, movements, and plutonium concentrations in selected tissues of mule deer were studied to evaluate dispersal of plutonium by the deer.

Hiatt's (1977) study gives maximum deer population estimates for eight seasons from the fall of 1975 to the summer of 1977, with increasing populations during the summer seasons. The increased population was attributed to the addition of newborn fawns. Half or more of these fawns disappeared from the population by the end of the summer seasons, probably due mostly to mortality. Nutritional deficiencies, poor cover, lack of water, predation, diseases and parasites, weather, and accidents are mentioned as possible causes of death (Zwank, 1976). However, the major cause of death was undetermined.

The information discussed in this paper will add to the known data about the Rocky Flats deer. It is the first study that investigates the possible reasons for fawn mortality suggested by Zwank (1976).

FIGURE 27. Rocky Flats Plant and Buffer Zone

Study Area

The study area was the 6,166-acre (25 km²) zone between the Rocky Flats Plant perimeter fence and the central industrial operating area. This area has limited use and access and serves to separate the Plant from surrounding private land. Rocky Flats is located 16 mi (26 km) northwest of downtown Denver, between Boulder and Golden. Figure 27 shows the Plant boundaries, study area boundaries, and the bordering roads. The Plant's location in relation to surrounding populated areas is shown in Figure 28.

The topography consists mainly of a series of valleys and plateaus cut by the several streams

shown in Figure 27. The primary vegetation is disturbed grassland (Weber et al., 1974).

Within the buffer zone, the study covered two major areas of superior cover vegetation. In these areas, deer concentrations were highest. The first of these areas was the Woman Creek area, shown as Area 1 in Figure 27. It runs generally east-west, and is located south of the Plant. Deer were most concentrated in and near the riparian vegetation cover. Area 2, located in the northwest corner of the buffer zone, was the second major area. The cover there was more dense, consisting of thick scrub in steep ravines. Three other areas used infrequently for observation were the Church Ditch, Walnut Creek, and Smart Ditch drainages

FIGURE 28. Rocky Flats in Relation to the Nearby Populated Areas

(see Figure 27). Deer concentrations were lower in these areas and cover was more sparse.

For analysis, the data are divided into that taken from north and south sections of the Plant. The boundaries for this division were the east and west access roads and the boundaries of the Plant itself. The north section, then, included the Rock Creek, Walnut Creek, and Upper Church Ditch areas; the south section included the Woman Creek and Smart Ditch areas.

Methods

Observations were made 4 to 5 times weekly between 0500 and 0900 MDT. This continued for seven weeks, June 13 through July 31, 1978. Observations made in August and September would have increased the data and would have improved the population and mortality estimates somewhat.

Natality estimates probably would have remained the same since the fawning period was over by late summer.

A variable spotting scope (15 X 60) on a tripod was used for observations at proximity greater than 100 meters. Movement of the observer prevented observation of uninhibited behavior of the deer with the spotting scope from distances less than 100 meters. At such close proximity, observations were made from inside a car with the use of 7 X 35 binoculars.

The following data were recorded for each observation: date, time of day, weather, location, number in each group, sex, behavior, identifying features, and number and estimated age of any fawns. The behavior that was noted included time spent grazing, walking, or resting. The does' behavior when searching for fawns, and in the presence of other

does, bucks, fawns, or coyotes also was noted. In addition, the number, estimated size and age, and behavior of fawns were recorded.

Identifying features of individual deer were recorded to help the observer recognize an individual upon successive sightings. These features included collars, eartags, and natural features. Blue vinyl collars with black numbers and aluminum eartags were placed on 24 deer during the winter of 1975 by personnel of the Colorado State University Department of Radiology and Radiation Biology. The following winter, eight additional deer were marked.

Of the 22 females and 10 males marked in this way, 3 females and 5 males are known to have died between January 1976 and March 1977. Three additional females died during the spring of 1978. Causes of death were as follows: four roadkills, five by predation, and two collected by the Colorado State University Department of Radiology and Radiation Biology.

During this study, 10 of the remaining 16 collared does were sighted. Several of the collars had badly faded numbers, but identification was made using the location of the eartags or natural markings. No collared bucks were sighted. Uncollared does and those with illegible collars were identified by natural markings such as notches or holes in their ears, or colored markings on the fur.

Once identification was assured, individual does were observed successively, and fawns were accounted for in association with their mothers. The disappearance of a fawn was assumed when the doe was observed on at least three successive sightings without the associated fawn. In this way, mortality estimates could be made. In the event of atypical behavior of a doe, the absence of fawns seen previously, or other factors such as the presence of a coyote, a thorough search of the area would be made for a dead fawn.

Fawns and does within camera range were photographed for illustration and for possible help in identification. A 35 mm reflex camera with a 50 mm lens was used.

Physical Data

Sightings

Each deer seen during any day was counted as one sighting, whether it appeared alone or in a group. No animal was counted more than once in any day. Sightings were totaled for June, July, and for the entire study period. Table 23 lists these sightings. Total sightings for the study period of does, bucks, and fawns were 529. Each member of a set of twins was counted as one sighting. In June, observations were made on 16 days for a total of 54.4 hours. Observations in July were made on 15 days totaling 43.5 hours. Mean sightings per day of does, bucks, and fawns also are listed in Table 23. Mean sightings per day of all fawns (single and twin) were much higher in July than in June. Maximum numbers of sightings in one day and the date they were observed for each of the two sections are shown in Table 24.

Population

Population estimates were calculated from daily sightings data. Maximum and minimum estimates were made to determine the range of the population estimates. A major assumption behind these estimates was that there was no movement of deer between the south and north sections of the buffer zone. No evidence of such movement was seen; any animal that was identified on more than one occasion was seen in the same section at initial and subsequent sightings. Trapping records of the collared deer, and the observations reported here, indicate that four does with readable numbers on their collars have remained in the section in which they were trapped. The other collared does had unreadable collars so the trapping records could not be checked.

The maximum total population was estimated by summing the number of total daily sightings and subtracting the number of repetitive sightings, when these could be identified.

Deer that had not previously been identified were classified as to sex, collared or uncollared, section seen in, and identifying features. These classifications were made to determine minimum estimates

TABLE 23. Total Sightings (T) and Mean Sightings Per Day (M)

	Does		Bucks		Single Fawns		Sets of Twin Fawns		Identifiable Does		Identifiable Bucks	
	T	M	T	M	T	M	T	M	T	M	T	M
June	180	11.3	48	3.0	7	0.4	3.5	0.2	32	2.0	0	0
July	170	11.3	19	1.3	17	1.1	40.5	2.7	33	2.2	6	0.4
June and July	350	11.3	67	2.1	24	0.8	44.0	1.4	65	2.1	6	0.2

TABLE 24. Maximum Total Sightings in One Day

	North Section		South Section	
	No.	Day	No.	Day
Doe	28	July 7	20	June 8
Buck	15	June 16	8	June 15
Single Fawn	3	July 4	3	July 21
Sets of Twin Fawns	7	July 11	3	July 10

TABLE 25. Minimum and Maximum Population Estimates

	Minimum Population Estimate			Maximum Population Estimate		
	North	South	Total	North	South	Total
Doe	30	22	52	143	210	353
Buck	20	3	23	33	29	62
Fawn	20	13	33	63	27	90
Totals	70	38	108	239	266	505

of "new" deer sighted each day. A deer was classified as "new" if it met one of the following criteria:

1. An individual had distinctive identifying features such that the observer was certain that it had not been seen before.
2. More individuals of a given description were seen in one section in one day than had been seen in any previous day. For example, six sightings of uncollared does in the north section, where the previous daily maximum number of sightings of uncollared does was four, should indicate two "new" sightings. An animal was counted only if it had not been seen previously that day. This was determined by its original location and the direction of its movements.

The minimum population estimate was then the sum of the daily "new" sightings of does, bucks, single fawns, and twin fawns in each section. Table 25 lists the minimum and maximum estimated populations for each section. Total estimated minimum and maximum populations are the sum

of estimates for the north and the south sections. Fawn population estimates count each member of a set of twins as one. Because of difficulty in positively identifying individuals, the maximum population estimates are high; the minimum population estimates are more realistic.

Natality

The total minimum fawn population and the number of associated does were used to determine the fawn-to-doe ratio. Nine single fawns and 12 sets of twin fawns constituted the 33 fawns in the minimum fawn population estimate. This indicated that there were 21 does, resulting in a fawn-to-doe ratio of 1.57:1 for does associated with fawns.

The observed natality period was calculated using estimated birth dates for 29 of the estimated minimum fawn population of 33. For each of the 29 fawns, the earliest and latest possible birth dates were estimated at its first sighting. In assigning birth dates, factors such as size, agility, coordination, and amount of movement of each fawn were considered (Alldredge, June 1978). No birth date

FIGURE 29. Natality Period

estimation was made for two sets of twins because the animals were moving rapidly and a useful estimate could not be made.

The midpoint of the earliest birth date estimate for each fawn was used to determine the natality period. The histograms in Figure 29 illustrate the total number of fawns, number of single fawns, and number of sets of twins born during each of the one week intervals. The intervals began June 9, the earliest estimated birth date.

Peak fawning periods occurred during June 9-15, and June 30-July 6 for all fawns. Single fawn natality was highest June 9-15, while twin fawn natality occurred 2-to-3 weeks later, June 30-July 6.

No comparison could be made between number of young and age of doe. Only in ideal situations could a yearling be identified as a yearling by such means as size comparison with an older doe.

Fawn Mortality

Repeated observations of an identifiable doe with young were necessary to determine the disappearance of fawns. Twelve identifiable does with young were each sighted at least 3 times. The 18 young included 6 single fawns and 6 sets of twins. The number of sightings of each doe during the study period ranged from 3 to 10. The mean number of sightings was 5.6 and the total was 67.

On June 20, the observation of a deer chasing a coyote led to a search of the area for a dead fawn. The dead fawn was found and it was estimated that it had been dead only a few hours. The body was still warm. The circumstances that led to its discovery and the results of the autopsy performed will be discussed more fully later. There were no other positively confirmed deaths during the study period; however, four additional fawns were assumed to have died during the study period. This assumption was based on the observation of two collared does with twins, which were later observed three and five times respectively without their fawns. In one case, twins were seen one day, and only one fawn was seen the next. The area was searched thoroughly, but the second fawn was not found. The following day, the doe was seen alone for the first of three times. All mortality was estimated to have occurred between June 15 and June 27.

Minimum and maximum estimates of length of life were derived from the estimated birth and death dates. It was estimated that the single fawn lived 7 to 9 days, while the two sets of twins lived 4 to 12 days and 2 to 4 days, respectively.

By use of the 18 fawns of identifiable does, the maximum mortality rate from this analysis was then 5 out of 18 or 28 percent for the study period of 7 weeks. The minimum mortality was calculated as 15 percent, by use of the 5 known and assumed deaths and the 33 minimum known fawns.

Social Behavior

The following descriptions are based on observations made during the study period. During the natality period, activities of does followed a particular general pattern that differed from the rest of the year (Hiatt, 1977). Doe-coyote interactions also were of particular interest.

Natality Period Activity

During the natality period, doe behavior changes distinctly. The does separate individually from groups to fawn. Early in the fawning season, then, a lone doe is a good indicator of the presence of a

fawn. Each doe usually occupies the same area from day to day, making repeated sightings easier. The doe stays in this area with her young for the first few weeks after the fawn is born (Alldredge, August 1978).

As the fawns got older, the does again began associating in larger groups. At least nine times, several does were seen intermingling among the several fawns. Eleven times, does with no young were also seen with such groups. On four occasions, bucks were seen in the groups, although the does usually drove the bucks away.

Daily Activities

Morning activity of does after sunrise consisted of grazing, resting, nursing, and moving to cover. The majority of time was spent grazing, interrupted by short (10 to 15 minutes) periods of rest. Fawns began grazing at approximately one week of age. For this reason, the does spent little time nursing their young. A fawn was never seen to nurse for more than 5 minutes.

Movement patterns differed for the two sections of the Plant. In the south section, almost all movement occurred as the doe grazed, while moving slowly along Woman Creek. In the north section, however, the does grazed for several hours in meadow areas near the south branch of Rock Creek, then ran further north with their fawns to scrub cover.

In the south section, the doe spent one to several hours grazing with her young. By approximately 0900, she left her fawns and moved to cover for the day. Young fawns 0 to 2 weeks of age were often left in tall grass, which provided adequate protection from the sun and served as camouflage. Figure 30 shows a newborn fawn as it was left by its mother. Figure 31 shows the same fawn from 0.5 meter away. This fawn remained still while the photographs were taken, although it had previously been seen walking. Older fawns moved around more after the does had left them. They, too, sought shelter from the sun, but relied less on camouflage. Figure 32 shows the resting place of an approximately 1- to 2-week-old fawn. This fawn ran to cover when disturbed by the observer.

FIGURE 30. A Newborn Fawn

23601-16

FIGURE 31. Closeup View of Newborn Fawn Shown in Figure 30

23601-2

Parturition and Post-Parturition Behavior

On one occasion, a doe was sighted with what was believed to be a newborn fawn. At 0600 on June 14, an uncollared doe was observed standing over a fawn. The doe's tail was exceptionally stiff and bristly, which indicated she had just given birth. The fawn was tiny and very dark brown, apparently still wet from birth.

The doe watched the observers for approximately one-half hour, when she began to wash herself and the fawn. Next, she and the fawn began walking north toward Woman Creek. They walked slowly, with the fawn frequently stumbling and falling. After 10 minutes of walking they lay down to rest for 5 to 10 minutes. They then got up and continued moving north, until they disappeared into a ravine.

The area of the birth was searched for any evidence of afterbirth, but none was found. The observers then followed the pair, startling the doe away. The fawn was found in the grassy area, as shown in Figures 30 and 31.

A detailed description of parturition behavior in tame does was made by Halford and Alldredge (1974).

Deer-Coyote Interactions

Twenty coyote sightings were made in 12 instances during the study period. In 6 of these instances, does were present and aware of the coyotes. Twice, does merely observed the coyote movements. In one case, one doe was within 10 meters of a coyote. Neither displayed nervous or antagonistic behavior. In the second case, five does associated with three

FIGURE 32. One- to Two-Week-Old Fawn at Rest

23601-11

sets of twins were grazing in a small area. Two young coyotes moved past them. The entire group stood, alert, until the coyotes moved out of sight.

In each of the remaining four instances, does chased coyotes that moved into their areas, usually for only 100 to 200 meters.

In one instance, the observation of a doe chasing a coyote led to the discovery of the dead fawn discussed earlier. Two does were first sighted at 0535 on June 20, while chasing a coyote. They chased it 100 to 200 meters, then returned to their original position.

The two does then moved nervously in circles, walking slowly, not grazing. They next concentrated on an area of sedge, searching it thoroughly. The observer saw one doe calling here, although no noise was heard. The does obviously were aware of the observers presence, within 150 meters of them, but did not move away as does usually did. They circled the area for over 1.5 hours and then moved a short distance away.

The fawn was found laying on its right side in the area of sedge. One of the does watched the observer carry the fawn away, but made no move toward the observer.

FIGURE 33. Carcass Showing Internal Injuries of Fawn Killed by a Coyote

23680-3A

Autopsy Results

The dead fawn found on June 20 was examined externally and was then frozen. The autopsy was performed on July 14. The fawn weighed 6.2 kg and measured 65 cm from nose to rump.

Upon external examination, four small (1 cm or less diameter) cuts were discovered on the head and small abrasion was discovered on the right front leg. There had been bleeding from the mouth and nose. There were no other signs of external damage.

The animal was skinned, revealing several internal injuries. There were numerous cuts on the hind legs, midsection, front legs, neck, and head. Figure 33 shows the cuts on the legs, body, and neck. Three cuts through the rib cage resulted in bruises on the liver and lungs. There were no other signs of internal damage.

Based on the nature and locations of the cuts, and the fact that a coyote was seen in the area of the dead fawn, it was concluded that the fawn was killed by a coyote. Hemorrhages on the injured organs indicated that the coyote attacked while the fawn was alive. The cuts on the rear legs possibly indicate that the coyote caught the fawn as it was running. Damage to the external jugular vein may have been the immediate cause of death.

Summary and Conclusions

The objective of this research was to provide information about population dynamics, fawning season, infant mortality, and social behavior of deer at Rocky Flats that would be useful in deer management.

During a two-month study in the summer of 1978, a minimum estimated population of 108 deer

occupied the areas studied within the buffer zone. This number included 52 does, 23 bucks, and 33 fawns. The 75 adults and yearlings estimate compares well with Hiatt's (1977) summer population estimate of 65 to 70 adult and yearling deer. The observation of 33 fawns reported here was, however, far below Hiatt's estimate of 50 to 60 fawns, which included augmentation based on the assumption that does without fawns had hidden fawns that could not be observed.

The data reported here, combined with Hiatt's data on adult and yearling deer, seem to indicate that the Rocky Flats deer population has remained stable for the past three years. There is no evidence of a decline in population due to high infant mortality or due to starvation caused by overpopulation.

Maximum population estimates made in this study were quite high and are believed to be unreliable. Better methods of identification of individuals would moderate these estimates and make the estimates more useful. In this study, photographs did not prove useful for identification, but with telescopic lenses, this method might prove valuable. Deer had unique face marking that could be repeatably identified from a high-quality photograph.

The highest number of births of single fawns occurred during the interval June 9-15; the most twin fawns were born later, during the interval June 30-July 6. These data indicate a trend toward later natality periods of twins. Further research is needed to confirm the reality of this trend.

A maximum mortality rate of 28 percent was estimated for the 6-week period between June 15

and July 31. No fawn mortality was observed before June 15 or after July 31. Should this maximum rate continue for the following 6-week period, fawn mortality would be over 50 percent, as measured by Hiatt (1977).

The minimum estimate of 15 percent would indicate lower than expected fawn mortality for the season. More identifiable deer would improve this estimate.

The maximum mortality rate was thought to be more accurate, since it was based on only identifiable does and fawns. It was based on a small number of observations, however, and thus was not totally reliable.

In one case, the known cause of death was predation by a coyote. In the remaining four cases, cause of death was undetermined. Possible causes of death include nutritional deficiencies, poor cover, lack of water, predation, diseases and parasites, effects of weather or accidents, as noted by Zwank (1976). Although predation by coyotes cannot be assumed as the cause of death in the undetermined cases, it must be considered as a possibility. The 12 instances of coyote sightings and the behavior of does in the presence of coyotes indicate that there is substantial pressure exerted by coyotes on the deer population.

Social behavior of the Rocky Flats deer followed a predictable pattern similar to that described by Hiatt (1977), Arthur (1977), and Alldredge (August 1978). Doe-coyote interactions are of particular interest, especially in relation to fawn mortality, and may merit further research.

FOODSTUFF MONITORING

PILOT PROGRAM FOR FOODSTUFF MONITORING

Cathrine A. Kellner

The area surrounding the Rocky Flats site is primarily agricultural or undeveloped, with the nearest population center being 3.3 miles south of the Plant. A major fraction of the land within a 5-mile radius of the Plant is used as grazing for

cattle or as cropland. A survey in the spring of 1978 indicated the presence of 19 beef cattle producers, 1 milk producer, and 17 vegetable/fruit producers in this area. This does not include many of the "backyard farmers" in the recently built

housing developments. Because of the numerous producers in this area, a foodstuff monitoring program for the area was proposed. Of special interest are those farmers who are located downwind of the Plant and whose water source is Standley Lake, private wells, or one of the creeks that crosses the Plant Site.

ERDA Manual Chapter 0513 (ERDA, June 1977) recommends the monitoring of all potential pathways for the flow of radionuclides through the environment. One such pathway may lead to the accumulation of radionuclides in foodstuffs via atmospheric disposition, groundwater flow, and crop irrigation. At present, research is being conducted to determine if a routine sampling program for the area surrounding the Plant site is necessary. Information is being gathered on previous studies done in the Rocky Flats area—also at other nuclear facilities with regards to radionuclide concentration in foodstuffs for analysis and comparison.

As an additional part of this research project, calculations are being done to determine possible concentrations of radionuclides in vegetables and various animal products. These calculations are

being made using the food code (Baker, 1977) generated by Battelle Pacific Northwest Laboratory. This code estimates radionuclide concentrations in vegetation via deposition on the plant and uptake through the roots, and in animal products through feed and water consumption. The code considers variables such as animal consumption rates, growing periods, and the rate of atmospheric deposition or irrigation. The calculations also are being done for other facilities already possessing routine foodstuff monitoring programs. Comparison of concentrations predicted by the code with those actually measured will indicate the relation reliability of the calculations in predicting concentrations in the Rocky Flats area.

Should these calculations indicate routine foodstuff monitoring is necessary, a sampling program will be implemented. Several possible sampling programs have been devised based on environmental and agricultural considerations, and one will be used that best meets the monitoring needs of the Plant. The probable sampling region would be the area within a 5-mile radius of the Plant center. The most likely sampling media will be milk, beef, and garden vegetables coming from the sample area.

SUPPORT PROJECTS

HIGH VOLUME SAMPLER EVALUATION

John D. Hurley

The material in this section is abstracted by J. D. Hurley from *Determination of Sampling Effectiveness of Rocky Flats High Volume Sampler and Filtration Efficiency of Microsorban-98 Fiber Filter*, a project report prepared for Rockwell International by Professor J. B. Wedding and Mr. T. C. Carney of the Colorado State University Civil Engineering Department.

In June 1978, Dr. J. B. Wedding and Mr. T. C. Carney of the Civil Engineering Department, Engineering Research Center, Colorado State University, completed a study of the inlet effectiveness of the

Rocky Flats High Volume Sampler and the collection efficiency of the filter paper used on the sampler. Results of that study were compared with previously completed tests on a Standard High Volume Sampler (Wedding et al., 1977) for a variety of simulated field conditions. Figure 34 is a schematic representation of both the Standard High Volume Sampler and the Rocky Flats High Volume Sampler.

Test results on the Rocky Flats sampler were obtained from measurements conducted in the Environmental Wind Tunnel Facility at Colorado State University. The measurements were made

FIGURE 34. Standard High Volume Air Sampler and Rockwell International Design High Volume Air Sampler With Approach Flow Orientation Angle (α)

using aerosolized oleic acid droplets $\rho = 0.89 \text{ g/cm}^3$ tagged with uranine dye. The experimental arrangement is shown in Figure 35. The inlet effectiveness of the Rocky Flats High Volume Sampler was determined as a function of particle size (1- μm to 34- μm diameter), wind speed (1.52 to 12.19 m/sec), and sampler orientation to the mean flow (0° , 45° , 180°), where inlet effectiveness on the collection is defined as "the ratio of the aerosol collected substrates of the sampler to that collected by an isokinetic sampling system" (Wedding and Carney, 1978). Figures 36 through 38 are graphs of the percent sampling effectiveness as a function of the previously mentioned parameters. The results show the Rocky Flats sampler (with an inlet flow rate of 880 l/min) has an inlet effectiveness that is a weak function of sampler

orientation for 1- μm to 10- μm particles, with a larger effect seen for 20- μm to 34- μm particles. A significant effect of flow velocity on inlet efficiency was seen up to 5 m/sec where a further velocity increase indicated only a slight decrease in effectiveness. At the zero degree orientation and 6 to 12 m/sec approach flow speeds, the effectiveness ranged from 75 percent at 10 μm to 15 percent at 34 μm .

Figure 39 is a comparison of the sampling effectiveness of the Rocky Flats High Volume Sampler and the Standard High Volume Sampler at a flow velocity of approximately 5 m/sec, particle size ranges of 1 μm to 34 μm , and sampler orientations of 0° , 45° , and 180° . From the figure, the two principal conclusions are (1) for particles less than approximately 12 μm in diameter, orientation and

FIGURE 35. Colorado State University Environmental Wind Tunnel
Experimental Configuration for Injection and Sampling of Particle Cloud

FIGURE 36. Sampling Effectiveness of the Rockwell International High Volume Sampler Versus Particle Diameter for an Orientation Angle (α) of 0°

FIGURE 37. Sampling Effectiveness of the Rockwell International High Volume Sampler Versus Particle Size Diameter for an Orientation Angle (α) of 45°

FIGURE 38. Sampling Effectiveness of the Rockwell International High Volume Sampler Versus Particle Diameter for an Orientation Angle (α) of 180°

FIGURE 40. Experimental System for Measuring Filter Efficiency

sampler type have no influence on inlet effectiveness and (2) for particles greater than $12\text{ }\mu\text{m}$, the Rocky Flats High Volume Sampler, at all orientations, has an inlet effectiveness that falls between the sampler effectiveness of the Standard sampler at 0° orientation and 45° orientation.

In an independent series of measurements, Microsorban-98 filters, the medium used by the Rocky Flats High Volume Samplers were tested for filtration efficiency. Hence, the efficiency is defined as the ratio of numbers of particles retained by the filter after passage of a known volume of

gas, to the original number of particles in the same volume of gas before passage through the filter. The filtration efficiency tests were made using a salt (NaCl) crystal aerosol having a particle size range of $0.01\text{ }\mu\text{m}$ to $1\text{ }\mu\text{m}$ in diameter. Pressure drops across the filter, from 20 to 24 inches of water (3.74 to 4.49 cm Hg), were used, which gave rise to filter-face velocities corresponding to sampler flow rates of 600, 800, and 1,000 l/min . Figure 40 shows the experimental systems used for measuring filter efficiency. Microsorban-98 was found to be greater than 99.8 percent efficient over the range of particle sizes and pressure drops tested.

DETERMINING TOTAL TRITIUM CONTENT OF ROCKY FLATS STACK EMISSIONS

John D. Hurley

Introduction

Tritium in the atmosphere exists in three chemical forms: oxide (HTO), elemental (HT or T_2) and organic (CT_4). Of these, the oxide poses the greatest health hazard because of its high potential

uptake by man. The Standards for Radiation Protection reflect the difference in health hazards between the oxide and elemental forms (ERDA, 1977). The limit for exposure to a member of the general population in an uncontrolled area is 66,000 pCi/SCM (standard cubic meter) for HTO

FIGURE 41. Rocky Flats—Design Greenburg-Smith Impinger

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but 13,300,000 pCi/SCM for T_2 or HT. Although elemental tritium is not as hazardous, it is of concern because it contributes to the total atmospheric dose to the general population and because it may be converted to the oxide by environmental reactions (Milham and Boni, 1976).

Scope

Tritium oxide has been monitored routinely in selected effluent and room air points at Rocky Flats since 1973 via the Rocky Flats - design Greenburg-Smith Impinger (RFGSI). (See Figure 41.) The RFGSI, capable of monitoring HTO

only, gives no indication of the total tritium content, in particular HT, found in stack emissions. The Environmental Studies group at Rocky Flats began an investigation of alternative methods for sampling total tritium (HTO plus HT) in stack emissions. A review of available sampling systems (discussed in the following section) led to the selection of a modification (Figure 42) of the Östlund-design differential tritium sampler (Östlund, 1970).

Alternative Sampling Systems

During the past several years, considerable research has been conducted on methods of sampling

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FIGURE 42. Tritium Sampler Used for Collecting HTO and HT Samplers

tritium release from nuclear production facilities (Rogers and Michalek, no date). The major interest has been directed toward methods of sampling airstreams and distinguishing between the two most prevalent forms of tritium, HTO and HT. Sheehan, Curtis, and Carter (1975) have developed a differential tritium sampler that is a modification of the Greenburg-Smith Impinger. This sampler uses two series of three ethylene glycol bubblers, which are

separated by a heated palladium catalyst. The first series of bubblers collects the fraction of tritium in an airstream that exists as an oxide. The remaining tritium fraction is exposed to the heated palladium catalyst, where the elemental tritium is oxidized to tritium oxide. The second series of bubblers collects the oxidized elemental tritium as HTO. These samples are analyzed by liquid scintillation counting.

FIGURE 43. Operation of the Östlund-Design Tritium Sampler

Milham and Boni (1976) have developed a tritium sampler that also differentiates between the elemental and oxide forms of tritium. The sampler design is based on an original design by Östlund (1970) used for HTO and HT collection. The Östlund design tritium sampler (Figure 43) operates as follows: A 1500-ℓ air sample is drawn through the sampler. Tritium-free hydrogen is added near the inlet to increase the recovery efficiency and yield a volume of water that is convenient for counting. The airstream is first drawn through a type 4A molecular sieve* for removal of HTO initially in the airstream. The airstream (minus the

initial HTO) then passes through a 1.8% palladium-impregnated type 4A molecular sieve. The palladium is the catalyst that oxidizes the elemental tritium to the oxide form. The impregnated molecular sieve then adsorbs the oxidized elemental tritium.

The exposed sieves are heated in a furnace at 480 °C. Water leaves the sieves and is collected in a cold trap at -40 °C. The last traces of water are then flushed from the sieves by passing vapor from 3 ml of tritium-free water through the sieve. Stack samples undergo a 1:1000 dilution prior to scintillation counting.

Two counting systems of different sensitivity are used. Most samples are counted by liquid scintillation. Four milliliters of sample are added to 21 ml of dioxane-based liquid scintillator solution and counted for 20 min. The sensitivity of liquid scintillation counting is 1 pCi/m³ of air. The second system is gas proportional counting. Aqueous sample volumes of 2 to 3 ml are decomposed by passage over hot magnesium turnings. The resultant hydrogen is purified by passage through a palladium thimble. The purified hydrogen then is placed in an evacuated proportional counter with propane and additional hydrogen if needed. Counting time is typically 1000 min; the sensitivity is 0.01 pCi/m³ of air.

Site Selection, Sampler Installation and Methods

The ventilation systems main exhaust for Building 771 (71 main) was chosen as the sampling site because air from the various operations in Building 771, after being processed and filtered, is released to the atmosphere through this stack. Another reason for selecting the 71 main exhaust was that the Environmental Analysis and Control Department routinely monitors HTO emissions from this stack. Sampling at this location allowed for simultaneous sampling of the same airstream by both samplers.

A tritium sampler of the Östlund design was installed at 71 main to sample exhaust for HTO and HT. The 92-day sampling period began January 27, 1978 and ended April 28, 1978. Twenty-four-hour air

*Materials Systems Division, 270 Park Avenue, New York, New York 10017.

samples were collected and automatically changed at midnight. Routine glove-box handling of plutonium oxide material bearing tritium was carried out periodically during the study. Routine operations included dissolution of weapon components, the recovery of plutonium for subsequent fabrication, and the processing of a variety of components. In addition, 71 main received exhaust input from an incinerator that handles the burning of tritium-exposed combustibles on an irregular schedule.

Results

Daily analytical data from the Östlund-type sampler for the 92-day sampling period is presented in Table 26. Plots of the HTO and HT data as a function of time are shown in Figures 44 and 45. The HTO data collected by the Östlund sampler and the RFGSI, compared in Table 27, are presented as weekly averages.

Discussion

Stack emissions for the period January 27 through March 12 averaged 5.95 ± 4 pCi/SCM HTO and 6.26 ± 3 pCi/SCM HT. Normal background for stack emissions at Rocky Flats, measured as total tritium, is 10 pCi/SCM. Values above normal background were reported after March 12 to the end of the sampling period. These values are attributed to the processing of tritium-containing plutonium oxide materials received from other installations. The special materials received from these installations contained tritium ranging from 0.002 to 0.05 millicuries of tritium per kilogram of plutonium compared to the maximum permitted at Rocky Flats of 10 mCi/kg.

On several occasions, March 13 through March 15 and on April 19, tritium-containing plutonium oxide materials were processed. Stack emission for the period of March 12 through March 15 averaged 208.20 ± 3.4 pCi/SCM HTO and 40.20 ± 10 pCi/SCM HT. Stack emissions sampled on April 19 showed values of 573 ± 6.00 pCi/SCM HTO and 10 ± 2 pCi/SCM HT. During the processing of this special material, the incinerator also

was in operation, thus contributing to the average values reported March 13-15 and on April 19. The incinerator and special material handling operations are summarized in Table 28. Reported HTO and HT results show values significantly above background during these dates.

The average daily concentrations of stack tritium during non-operating days* was 11.73 ± 22 pCi/SCM HTO and 6.03 ± 3 pCi/SCM HT. The average ratio of HTO to HT during this time was 1.95, giving an average HTO percentage of 66.05. Average stack concentrations of tritium for the 25 active operating days was 653.76 ± 7.00 pCi/SCM HTO and 54.88 ± 1.56 pCi/SCM HT. The average percent of HTO for this period was 92.25, implying an average ratio of HTO to HT of 11.89. Note that the HTO stack concentrations, even during active operations, are well below the 66,000 pCi/SCM limit for general population members in an uncontrolled area.

In general, a relationship is observed between periods of stack emissions well above normal background and periods of incineration of combustible waste. Also, during active operation, the HTO-to-HT ratio always increased significantly. This is expected as there is greater likelihood of HTO as opposed to HT adsorbing onto the combustible waste burned in the incinerator.

Concentrations of HTO and HT given off by the processing of special materials alone could not be measured with this experimental design prior to the airstream passing through a scrubber. Because of the caustic environment of the glove-box atmosphere, it was impossible to sample the glove-box effluent airstream without damaging the sampler. There was also no period in which special materials were processed without the simultaneous operation of the incinerator. Hence, the airstream was passed through a scrubber and was combined with exhaust from the incinerator prior to being sampled. There is also the possibility of HT being converted to HTO as the airstream passes through the scrubber.

*Saturdays, Sundays, and weekdays when there was no dissolution or incineration of waste.

TABLE 26. Tritium Oxide and Elemental Tritium Data for the 92-Day Sampling Period

Date	HTO (pCi/SCM)*	HT (pCi/SCM)*	Percent HTO	Ratio HTO/HT	Date	HTO (pCi/SCM)*	HT (pCi/SCM)*	Percent HTO	Ratio HTO/HT
Jan 27	22 ± 5	6 ± 3	79	3.66	Mar 14	228 ± 4	78 ± 2	75	2.92
28	8 ± 2	3 ± 1	73	2.66	15	311 ± 3	88 ± 2	78	3.53
29	7 ± 2	4 ± 1	64	1.75	16	125 ± 3	14 ± 2	90	8.93
30	5 ± 1	10 ± 1	33	0.50	17	238 ± 4	10 ± 2	96	23.8
31	9 ± 1	15 ± 1	38	0.60	18	19 ± 1	5 ± 2	79	3.80
Feb 1	10 ± 1	12 ± 1	46	0.83	19	11 ± 2	9 ± 2	55	1.22
2	13 ± 1	6 ± 1	68	2.17	20	126 ± 2	12 ± 1	91	10.50
3	3 ± 1	5 ± 1	38	0.60	**21	78 ± 2	8 ± 1	91	9.75
4	8 ± 1	8 ± 1	50	1.00	22	21 ± 2	5 ± 4	81	4.20
5	7 ± 1	7 ± 1	50	1.00	23	10 ± 2	8 ± 1	56	1.25
6	12 ± 2	9 ± 1	57	1.33	24	5 ± 1	4 ± 1	56	1.25
7	13 ± 1	8 ± 1	62	1.63	25	1 ± 1	9 ± 1	10	0.11
8	9 ± 1	13 ± 1	41	0.69	26	3 ± 1	2 ± 1	60	1.50
9	12 ± 2	10 ± 1	55	1.20	**27	1086 ± 5	27 ± 1	98	40.22
10	6 ± 1	4 ± 1	60	1.50	**28	505 ± 4	8 ± 1	98	63.13
11	8 ± 1	6 ± 1	57	1.33	**29	529 ± 4	9 ± 1	98	58.78
12	5 ± 1	5 ± 1	50	1.00	**30	549 ± 5	9 ± 1	98	61.00
13	6 ± 1	4 ± 1	60	1.50	**31	2878 ± 9	62 ± 1	98	46.42
14	5 ± 1	8 ± 1	39	0.63	Apr 1	54 ± 2	4 ± 1	93	13.50
15	6 ± 1	8 ± 1	43	0.75	2	15 ± 1	14 ± 1	52	1.07
16	4 ± 1	9 ± 1	31	0.44	**3	44 ± 2	6 ± 1	88	7.33
17	5 ± 1	4 ± 1	56	1.25	**4	785 ± 5	16 ± 1	98	49.06
18	4 ± 1	4 ± 1	50	1.00	**5	420 ± 3	26 ± 1	94	16.15
19	4 ± 1	3 ± 1	57	1.33	**6	135 ± 3	20 ± 2	87	6.75
20	5 ± 1	5 ± 1	50	1.00	**7	2143 ± 7	809 ± 4	73	2.65
21	3 ± 1	3 ± 1	50	1.00	8	126 ± 3	2 ± 1	98	63
22	3 ± 1	2 ± 1	60	1.50	9	22 ± 2	2 ± 1	92	11
23	7 ± 1	5 ± 1	58	1.40	10	294 ± 3	6 ± 1	98	49
24	1 ± 1	2 ± 1	33	0.50	11	61 ± 1	9 ± 2	87	6.78
25	2 ± 1	1 ± 1	67	2.00	12	670 ± 6	13 ± 2	98	51.54
26	2 ± 1	4 ± 1	33	0.50	13	2193 ± 10	46 ± 2	98	47.67
27	4 ± 1	5 ± 1	44	0.80	**14	938 ± 1	12 ± 2	99	78.17
28	6 ± 1	6 ± 1	50	1.00	15	33 ± 1	6 ± 2	85	5.5
Mar 1	6 ± 1	8 ± 1	43	0.75	16	15 ± 3	6 ± 1	71	2.5
2	5 ± 1	11 ± 2	31	0.45	**17	604 ± 5	39 ± 2	94	15.49
3	3 ± 1	6 ± 1	33	0.50	**18	774 ± 5	27 ± 2	97	28.66
4	3 ± 1	2 ± 1	60	1.50	**19	573 ± 6	10 ± 2	98	57.30
5	5 ± 2	4 ± 1	56	1.25	**20	44 ± 2	9 ± 2	83	4.89
6	0 ± 1	1 ± 1	0	0.00	21	13 ± 2	5 ± 1	72	2.60
7	5 ± 2	5 ± 1	50	1.00	22	3 ± 1	7 ± 2	30	0.43
8	3 ± 2	4 ± 1	43	0.75	23	5 ± 2	7 ± 2	42	0.71
9	4 ± 2	2 ± 1	66	2.00	24	8 ± 2	7 ± 2	53	1.14
10	3 ± 1	5 ± 1	38	0.60	25	7 ± 2	5 ± 2	58	1.40
11	3 ± 1	5 ± 1	38	0.60	26	9 ± 2	7 ± 2	56	1.29
12	4 ± 2	5 ± 1	44	0.8	27	7 ± 2	4 ± 2	64	1.75
**13	139 ± 3	11 ± 2	93	12.64	28	5 ± 2	21 ± 1	29	0.42

*Picocuries per standard cubic meter.

**Indicates periods when material having measurable tritium activity was being processed.

FIGURE 44. Plot of HTO Data Collected From January 27, 1978 Through April 28, 1978. Plots are drawn with several vertical scales to illustrate variation in peak activity.

FIGURE 45. Plot of HT Data Collected From January 27, 1978 Through April 28, 1978. Plots are drawn with several vertical scales to illustrate variation in peak activity.

TABLE 27. HTO Levels From the Östlund Modified Sampler and the Greenburg-Smith Impinger (RFGSI)
(Weekly averages of HTO in pCi/SCM*)

Date 1978	Östlund	RFGSI
Jan 31 - Feb 7	8.86	< 10
Feb 7 - 14	8.43	< 10
14 - 21	4.71	< 10
21 - 28	3.14	< 10
28 - Mar 7	4.00	< 10
Mar 7 - 14	23.00	< 20
14 - 21	151.14	< 10
21 - 28	171.00	140
28 - Apr 4	653.86	350
Apr 4 - 11	560.71	270
11 - 18	644.86	260
18 - 25	202.86	40
Total	2436.57	< 1140.00
$\bar{X}$	203.048	< 95.00
Standard Deviation	262.250	126.81

*Picocuries per standard cubic meter.

TABLE 28. Incinerator and Special Material Handling Operations

Date	Drums Processed	Average Stack Emission per Day (pCi/m ³)		Operation
		HTO	HT	
March 13 - 17	36	208.2 ± 3.4	40.2 ± 10	Incinerator and special materials
March 21	12	78.0 ± 2	8 ± 1	Incinerator
March 27 - 31	45	1109.4 ± 5.4	28 ± 1	Incinerator
April 3 - 7	52	705.4 ± 4	175.4 ± 1.8	Incinerator
April 10 - 14	68	831.2 ± 4.2	17.2 ± 1.8	Incinerator
April 17 - 20	43	498.75 ± 4.5	21.25 ± 4	Incinerator and special materials

Summary and Conclusions

From January 27, 1978 to April 28, 1978, a sampler, based on the Östlund technique of oxidizing gaseous tritium (HT) to tritium vapor (HTO), measured HT and HTO in the effluent from the Building 771 main plenum. This effluent was measured simultaneously by a Greenburg-Smith bubble impinger, which routinely monitors the Building 771 main

effluent. Both samplers were located downstream of the main plenum, four-stage HEPA filter bank and were situated such that they measured the same effluent, namely that from all of Building 771.

Results of the Östlund sampler measurements are given on a day-by-day basis in Table 26, together

with the HTO percent and the ratio of HTO to HT. The operating periods, during which waste having low levels of associated HTO activity was processed, are indicated by asterisks. During non-operating periods, the data indicated an HTO to HT ratio of 1.95 ± 0.47 , and during operating periods, a ratio of 11.89 ± 0.37 . The Östlund sampler had a lower limit of detection of 1 pCi/m^3 for tritium as either HT or HTO when samples were analyzed by liquid scintillation and 0.01 pCi/m^3 when a gas proportional counting method was used.

The Greenburg-Smith impinger was changed weekly and hence gave weekly average HTO values. These weekly averages, together with the corresponding weekly average HTO numbers from the Östlund sampler, and the ratio of the HTO values seen by the impinger to those seen by the Östlund sampler, appear in Table 27. A typical minimum rank test indicates the HTO values seen by the Östlund

sampler are significantly higher than those obtained from the impinger. The average ratio of the HTO values is 0.48 ± 0.27 . These differences in the impinger and Östlund sampler data may stem from collection efficiency differences in the two samplers.

In conclusion, this study indicates (1) if the type of gaseous tritium releases seen here are typical, it is probably not essential to monitor for HT in addition to HTO because the permissible HT limit is 200 times the HTO limit and, also, because during periods of highest measured total tritium content, the effluent consists mostly of HTO; (2) airborne tritium levels in the stack emissions, as expected, correlate well with periods of handling of tritium-containing materials; and (3) the impinger sampler indicates lower HTO levels than the Östlund device, suggesting that further investigation into the reasons for this apparent collection efficiency difference may be desirable.

SEDIMENT SAMPLING PLAN FOR GREAT WESTERN RESERVOIR SPILLWAY

John D. Hurley

Introduction and Summary

In response to a request from the Rocky Flats Area Office, Department of Energy, a sediment sampling program is herein presented for sediment that has accumulated at the entrance to the Great Western Reservoir spillway. The sampling effort consists of taking a predetermined number of sediment samples from the spillway and analyzing these samples for plutonium-239 and americium-241 to determine activity levels and their variation. Numerical data from this sampling program will be analyzed, interpreted, reviewed, approved, and then presented to the Rocky Flats Area Office.

The project will be done in two phases. In the first phase, a predetermined number of samples, approximately 5 cm deep and 25 cm deep, will be taken and used to determine activity levels and their

variation in the sediment. If, based on this information, a determination is made to remove the spillway material, a trench will be dug in the deepest part of the sediment, and a series of horizontal core samples, approximately 15-cm long, will be taken from different depths in the trench wall. This second phase of sampling (referred to as vertical profile samples in the outlined plan that follows) will have as its objective (1) a determination of the historical record of plutonium deposition in the spillway area, (2) a more precise estimation of transuranic inventory in the spillway sediment, and (3) obtaining data that can assist the modeling of transuranic distributions for this mode of deposition.

The project will make use of the procedures specified for soil sampling and analysis in Appendix I where they apply. Any exception to the procedures will be noted.

FIGURE 46. Sampling Sites and Sediment Removal Depths at Great Western Reservoir Spillway

Plan

1. Area Definition

The City of Broomfield Public Works Department has provided a sketch of the spillway (Figure 46) indicating three lines of benchmarks. Eighteen benchmarks were established. Each benchmark also designates the depth of soil to be removed in that area. The depths vary from nine feet near the stop logs to less than three feet near the southeast end of the sediment. The area to be sampled is approximately 3700 square feet.

2. Sampling Site Selection

Fourteen sampling sites have been chosen within the 3700 square foot sampling area. The sites are designated on Figure 46 as AO+00, BO+00 through BI+00, CO+00 through CI+00, DO+50, and DO+75. Each of these locations has been staked and labeled

accordingly. Specific sample locations associated with each site are selected according to the criteria in Section 2.2.2 of the soil sampling procedure (included as Appendix I to this section of this report). Particular attention is paid to picking undisturbed, moderately vegetated* areas that are not heavily eroded. If the selected sampling site appears to have been disturbed (e.g., footprints or movement of soil by small mammals), an alternate sampling site will be chosen and reference made to the original sampling site. In the event an undisturbed area cannot be found within a 2-m distance, the general sample is to be taken twice from the same location, discarding the first 5-cm sample and retaining the 5-cm sample taken from a depth of approximately 5 to 10 cm. Note, however, that because the transuranic distribution is expected

*The excess vegetation has been burned off the sampling area using a hand-held torch. This should facilitate sampling by providing easier access to the sampling sites.

to be relatively homogeneous throughout the sediment, these considerations should not have an important effect on the sampling results.

3. Sample Type and Number

General purpose samples (10 cm by 10 cm by 5 cm deep) and core samples from approximately a 31-cm (1 ft) depth will be collected at each sampling site. Also, one vertical profile sample will be collected when (and if) the sediment is removed from the spillway. The location of the deepest sediment deposition (sampling site AO+00 near the spillway stop logs) has been chosen as the site to do this vertical profile. The actual number of samples will be

Surface Sampling	14
Subsurface Core Sampling	14
Vertical Profile Sampling	10
Total	38

This number of samples statistically should give a mean activity level (independent of area or volume to be sampled) with no more than a ± 30 percent uncertainty at the 95 percent confidence level. This will be true providing the sample values are distributed normally and the variance determined by Battelle Northwest (Thomas and Robertson, 1979) in sampling Great Western sediments is representative of the radioactivity to be measured in this program.

4. Sample Identification

General purpose and subsurface core samples will be labeled according to the respective sampling location and the sample type (general or core). The 10 vertical profile samples will be labeled individually according to depth of collection and the sampling location. All samples will be labeled with the collection date.

5. Sample Collection Quality Control

Personnel involved in the collecting and analysis of these sediment sample should meet the qualifications outlined in the Quality Control Section (Section 6.5) of the Appendix I Soil Sampling Procedure. All personnel are directly responsible to the project manager.

6. Sampling Methods

As described in Section 2.2 of Appendix I, sampling of the spillway will consist of three separate techniques:

- a. **General Purpose Sampling:** Here, the object is to obtain a sample consisting of 2500 cm³ of soil. The procedure to be followed is given in Section 2.2.3 of Appendix I. The radius of the sampling circle is to be one meter. Special emphasis will be placed on the cross contamination control procedure given in Section 2.2.3.5 of the Appendix.
- b. **Shallow Core Sampling:** The procedure to be used for this project is a slight modification of the procedure specified in Section 5.0 of the Appendix. The area being sampled does not have a well-established surface root zone; therefore it is not necessary to take a separate sod cut before the core sample is obtained. The volume to be sampled totals about 750 cm³.
- c. **Vertical Profile Sampling:** Again, special attention will be paid to the recommended cross contamination control procedures. The general procedures to be followed here are given in Section 5.0 of the Appendix. Ten samples (at approximately 25 cm intervals) will be collected with an 8.3-cm diameter (3.5 in.) auger, each sample having a horizontal core length of approximately 15 cm (6 in.). The procedure for coring will be the same as for subsurface core sampling, which was mentioned in the previous section.

7. Field Information

Throughout this sampling program, accurate field notes will be recorded. The notes (cf. Section 2.2.4 of the Appendix) will include

- a. Date
- b. Time
- c. Weather conditions
- d. Description of each sampling site, including moisture conditions, vegetation, slope and exposure, general soil type, and any special conditions
- e. Sampling site identification
- f. Sampling method employed
- g. Name and signature of sample collector
- h. Photographs of the sampling area

8. Sample Pretreatment and Analysis*

All samples will be analyzed for plutonium-239 by Rocky Flats Plant Health and Environmental Laboratory Procedure H&EL-15 (Rev. June 29, 1978), for americium-241 by Health and Environmental Laboratory Procedure H&EL-29 (Rev. July 21, 1977), and for americium-241 by gamma analysis in the Health and Environmental Laboratory, Building 123, as described below. The samples will be pretreated per procedures in Section 3.0 of the Appendix except that (cf. Section 3.7) a 500-ml aliquot (not 100 ml) will be supplied to the laboratory for gamma analysis. The larger sample is required to achieve the americium-241 minimum detectable activity level specified below. This aliquot will be placed in a Marinelli bottle for gamma counting. Following gamma analysis, a 100-g aliquot is labeled and returned to the Health and Environmental Central Receiving Laboratory for preparation prior to wet chemical analysis. The anticipated MDA for americium-241 gamma analysis is 0.1 ± 0.025 pCi/g at a 95 percent confidence level. For

americium-241 and plutonium-239, -240, the expected MDA is 0.01 ± 0.01 picocurie per sample at the 95 confidence level.

9. Quality Control

Thirty-eight samples will be collected from the spillway. In compliance with the Quality Control section of the Appendix (Section 6.4), blank and standard samples will be submitted to the Central Receiving Laboratory along with the field samples. A total of 46 samples with the following breakdown will be submitted:

spillway samples	38
blank samples	4
standard samples	4
Total	46

Personnel from the Central Receiving Laboratory will be responsible for batching submitted samples according to the Quality Control program (with the exception that the consensus standards will not be required). Arrangements will be made with the Standards Laboratory to collect and prepare the standards and blanks. The standards will be prepared with plutonium-239 (a high of ~ 5.9 pCi/g and a low of ~ 0.24 pCi/g) and americium-241 (a high of ~ 1.8 pCi/g and a low of ~ 0.1 pCi/g). These activity levels are based on the highest and lowest plutonium-239 and americium-241 values anticipated. To achieve an overall reliability of 40 percent on the measurements, relative to the anticipated statistical uncertainty defined in Section 6.10 (Appendix I) of 30 percent (at the 95 percent confidence), an accuracy of ± 25 percent at the 2σ level on control sample analysis is required. The laboratory will persist in analysis until this level of accuracy is achieved, as indicated by the standard samples.

10. Data Analysis

Data obtained from americium and plutonium analysis of the general and shallow core samples will be analyzed statistically to give an activity value and an uncertainty for both data sets. If the two numbers are statistically identical at

*Note that because of the expected low activity levels (less than 5 pCi plutonium activity), the samples will be brought directly to the Health and Environmental Laboratory.

the 95 percent confidence level, both sets will be combined to give a composite activity value and an associated uncertainty. Vertical profile activity results will be similarly incorporated into data presented in the final (Phase II) project report.

REFERENCES

- Allredge, A. W., Department of Radiology and Radiation Biology, Colorado State University, Fort Collins, Colorado, Private communication, June 12, 1978.
- Allredge, A. W., Department of Radiology and Radiation Biology, Colorado State University, Fort Collins, Colorado, Private communication, August 4, 1978.
- Arthur, W. J., III, *Plutonium Intake by Mule Deer at Rocky Flats, Colorado*, M.S. thesis, Colorado State University, Fort Collins, Colorado, 1977.
- Baker, D. A., *User Guide for Computer Program Food*, BNWL-2209, Battelle Pacific Northwest Laboratory, Richland, Washington, February 1977.
- Carlson, C. A., *Fish Ecology*, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado, 1977.
- CDH, *Report to State of Colorado by Air Pollution Control Commission*, Colorado Department of Health, 1977.
- Chepil, W. S., "Influence of Moisture and Erodibility of Soil by Wind," *Soil Science Proceedings*, Vol 20, pp 288-292, (1956).
- Chok, D. P., "A Simple Line-Source Model for Dispersion Near Roadways," *Atmos. Env.*, Vol 12, pp 823-829, (1978).
- Clark, S. J. V.; *The Vegetation of Rocky Flats Colorado*; Department of Environmental, Population, and Organismic Biology; University of Colorado Institute of Arctic and Alpine Research; Boulder, Colorado; 1977.
- Cowherd, C., Axetell, K., Guenther, D. M., and Jutze, G. A., *Development of Emission Factors for Fugitive Dust Sources*, Report PB238 262, Midwest Research Institute, pp 46-67, (1974).
- Cowherd, C. and Hendricks, R. V., *Development of Fugitive Dust Emission Factors for Industrial Sources*, Paper 78-55.4, 71st Annual Meeting of Air Pollution Control Association, Houston, Texas, 1978.
- Crow, L. W., Consulting meteorologist, Denver, Private communication, 1979.
- Crow, L. W., Consulting meteorologist, Denver, Private communication, 1975.
- Daubenmire, R., *Plant Communities*, Harper and Row, Publishers, New York, 1968.
- Dunn, O. J., *Basic Statistics: A Primer for Biomedical Sciences*, pp 69-90, John Wiley and Sons, Inc., New York, London, Sydney, 1967.
- EPA, *Compilation of Air Pollution Emission Factors*, Report EPA AB42, Heavy Construction Section, EPA Office of Air Quality Plans and Controls, 1977.
- ERDA, "Effluent and Environmental Monitoring Reporting," *ERDA Manual*, Chapter 0513, June 17, 1977.
- ERDA, "Standards for Radiation Protection," *ERDA Manual*, Chapter 0524, Annex A, March 30, 1977.
- Flickinger, S. A., *Pond Culture of Bait Fishes*, Bulletin 478 A, Public Cooperative Extension Service, Colorado State University, Fort Collins, Colorado, 1971.
- Gumbel, E. J., "The Return Period of Flood Flows," *Ann. Math. Stat.*, Vol 12, pp 163-190, (1941).
- Hahn, G. J. and Shapiro, S. S., *Statistical Models in Engineering*, John Wiley and Sons, Inc., New York, 1967.
- Halford, D. K. and Allredge, A. W., "Behavior Associated With Parturition in Captive Rocky Mountain Mule Deer," *Journal of Wildlife Management*, Vol 56, No. 2, pp 520-522, (1974).
- Hardy, E. P., Livingston, H. D., Burke, J. C., and Volchok, H. L., "Time Pattern of Off-Site Plutonium Contamination From Rocky Flats Plant by Lake Sediment Analyses," USDOE Environmental

- Quarterly Report, EML-342, Department of Energy, Environmental Monitoring Laboratory, New York, 1978.
- Harrington, H. D., *Manual of the Plants of Colorado*, The Swallow Press, Inc., Chicago, 1964.
- Hiatt, G. S., *Plutonium Dispersal by Mule Deer at Rocky Flats, Colorado*, M.S. thesis, Colorado State University, Fort Collins, Colorado, 1977.
- Irani, R. R., *Particle Size Measurement, Interpretation, and Application*, John Wiley and Sons, Inc., New York, 1963.
- Johnson, J. E., Svalberg, S., Paine, D., *The Study of Plutonium in Aquatic Systems of the Rocky Flats Environs*, Department of Animal Sciences and the Department of Radiology and Radiation Biology, Colorado State University, Fort Collins, Colorado, June 1974.
- Jonasson, P. M., "Bottom Fauna and Eutrophication" in *Eutrophication Causes, Consequences, Correctives*, International Symposium on Eutrophication, National Academy of Sciences, Washington, D.C., pp 274-305, (1969).
- Kolnsberg, H. J., *Technical Manual for Measurement of Fugitive Emissions: Upwind/Downwind Sampling Method for Industrial Emission*, EPA-600/2-76-089a, Res. Corp. of New England, 1976.
- Krebs, C. J., *Ecology*, Harper and Row, Publishers, New York, 1972.
- Krey, P. W. and Hardy, E. P., *Plutonium in Soil Around the Rocky Flats Plant*, HASL-235, Department of Energy, Health and Safety Laboratory, New York, 1970.
- Krey, P. W., "Remote Plutonium Contamination and Total Inventories From Rocky Flats," *Health Physics*, Vol 30, pp 209-214, (1976).
- Kurtz, J. I., *Comparative Limnology of Small Bodies of Water Near Fort Collins, Colorado*, M.S. thesis, Colorado State University, Fort Collins, Colorado, 1965.
- Little, C. A., *Plutonium in a Grassland Ecosystem*, PhD thesis, Department of Radiology and Radiation Biology, Colorado State University, Fort Collins, Colorado, 1976.
- Mackerith, F. J., *Some Methods of Water Analysis for Limnologists*, Fresh Water Biological Association, No. 21, (1963).
- Michels, D. E. and Hofsheier, F., Dow Chemical U.S.A., Rocky Flats Division, Private communication, 1973.
- Michels, D. E., Dow Chemical U.S.A., Rocky Flats Division, Private communication, 1973.
- Milham, R. C., Schubert, J. F., Watts, J. R., Boni, A. L., and Corey, J. C., "Measured Plutonium Resuspension and Resulting Dose From Agricultural Operations on an Old Field at the Savannah River Plant in the SE USA," *Pro. Transuranium Nuclides in the Environment*, Inter. Atomic Energy Agency, IAEA-SM-299/83, pp 409-421, (1975).
- Milham, R. C. and Boni, A. L., *Detection and Measurement of Tritium Forms Released From a Nuclear Protection Complex*, Report DP-MS-76-38, Savannah River Laboratory, Environmental Laboratory, Aiken, South Carolina, 1976.
- Miller, M. W. and Stannard, J. N., *Environmental Toxicity of Aquatic Radionuclides: Models and Mechanisms*, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1976.
- Mosteller, F. and Rourke, R. E. K., *Study Statistics*, Addison-Wesley Publishing Company, Reading, Massachusetts, 1973.
- Mueller-Dombois, D. and Ellenberg, H., *Aims and Methods of Vegetation Ecology*, John Wiley and Sons, New York, 1974.
- Ostle, B., *Statistics in Research*, The Iowa State University Press, Ames, Iowa, 1963.
- Östlund, H. G., *A Rapid Field Sampling System for Tritium in Atmosphere Hydrogen*, USAEC Report TID-25345, (1970).

- Pennak, R. W., *Freshwater Invertebrates of the United States*, Ronald Press Company, New York, 1953.
- Pierce, J. D., *The Limnology of Pond D-1, Rocky Flats, Golden, Colorado*, Colorado State University, Fort Collins, Colorado, 1977.
- Prosznaka, M., "The Annual Cycle in Occurrence of Cladocera and Copepoda in Smaller Water Bodies." *Pol. Arch Hydrobiol*, Vol 10, pp 379-422, (1962).
- Raabe, O. G., "Aerosol Aerodynamic Size Conventions for Inertial Sampler Calibration," *APCA J.*, Vol 26, pp 856-860, (1976).
- Rogers, W. M. and Michalek R., *Tritium Removal*, Engelhard Minerals and Chemicals Corporation, Engelhard Industries Division, Systems Department, 205 Grant Ave., Newark, New Jersey, (no date).
- Rockwell International, Rocky Flats Energy Systems Group Policies Manual, no date.
- Schoonveld, G. G., Colorado Division of Wildlife, Private communication, August 1, 1978.
- Sheehan, W. E., Curtis, M. L., and Carter, D. C., *Development of a Low Cost Versatile Method for Measurement of HTO and HT in Air*, MLM-2205, Mound Laboratory, Monsanto Research Corporation, Miamisburg, Ohio, 1975.
- Snedecor, G. W. and Cochran, W. G., *Statistical Methods*, The Iowa State University Press, Ames, Iowa, 1967.
- Thomas C. W. and Robertson, D. E., *Radionuclide Concentrations in Waterways Near the Rocky Flats Installation*, Draft Report, Battelle Pacific Northwest Laboratory, Richland, Washington, April 7, 1978.
- Thomas, C. W. and D. E. Robertson., *Radionuclide Concentrations in Reservoirs, Streams, and Domestic Water Supplies Near the Rocky Flats Installation*, Report PNL-2919, Battelle Pacific Northwest Laboratory, Richland, Washington, January 1979.
- Turner, D. B., "Workbook of Atmospheric Dispersion Estimates," Public Health Service Publication 999-AP-26, Dept. of HEW, 1969.
- USFR, *U. S. Federal Register*, Vol 36, No. 84, p 8186, (1971).
- Weber, W. A., *Rocky Mountain Flora*, Colorado Associated University Press, Boulder, Colorado, 1972.
- Weber, W. A., Kunkel, G., and Shultz, L., *A Botanical Inventory of the Rocky Flats AEC Site (Final Report)*, University of Colorado, Boulder, Colorado, July 31, 1974.
- Wedding, J. B., McFarland, A. R., and Cermak, J. E., "Large Particle Collection Characteristics of Ambient Aerosol Samples," *Env. Sci. and Technol*, Vol 11, pp 387-389, (1977).
- Wedding, J. B., and Carney, T. C., *Determination of Sampling Effectiveness of Rocky Flats Hi-Volume Sampler and Filtration Efficiency of Microsorban-98 Fiber Filter*, Final Report, Engr. Res. Cntr., Colorado State University, Fort Collins, Colorado, 1978.
- Whicker, F. W., *Radioecology of Some Natural Organisms and Systems in Colorado*, Eleventh Technical Progress Report, COO-1156-63, Department of Radiology and Radiation Biology, Colorado State University, Fort Collins, Colorado, 1973.
- Whicker, F. W., *Radioecology of Natural Systems - Fifth Annual Progress Report*, COO-1156-89, Department of Radiology and Radiation Biology, Colorado State University, Fort Collins, Colorado, 1977a.
- Whicker, F. W., *Radioecology of Natural Systems, Three-Year Summary Report 1974-1977*, COO-1156-90. Department of Radiology and Radiation Biology, Colorado State University, Fort Collins, Colorado, 1977b.
- Zwank, P. J., "Mule Deer Productivity--Past and Present," Pages 79-86 in *Mule Deer Decline in the West, A Symposium*, G. W. Workman and J. B. Low, Eds., Utah State University, Logan, Utah, 1976.

APPENDIX I ROCKY FLATS PLANT

ENVIRONMENTAL ANALYSIS AND CONTROL SAMPLING PROCEDURE

SOIL SAMPLING EAC-S-4

This sampling procedure is conducted to collect soil samples in a uniform manner that is representative of the area selected. Undisturbed, open-area vegetations are chosen. The sample sites are elevated with respect to the surrounding area and are isolated from trees and buildings.

This procedure will be reviewed and updated during the last quarter of each calendar year or any time procedural changes occur.

1. Safety Precautions

- 1.1 Safety precautions include wearing approved safety shoes, safety glasses, and protective gloves. These precautions are necessary to prevent eye and hand injuries that could occur from flying objects and the use of typical hand tools such as hammers and chisels. It would also be advisable to wear boots, particularly during the warm weather when rattlesnakes are a potential hazard.

2. Inventory Sampling

2.1 Equipment

- 2.1.1 Soil sampling jig (10 X 10 X 5 cm)
- 2.1.2 Spare sampling jig parts
- 2.1.3 Scoop, stainless steel
- 2.1.4 Brushes, wire and paint
- 2.1.5 Paper towels
- 2.1.6 Paint cans, 1 gallon, new
- 2.1.7 Hammer
- 2.1.8 Miscellaneous cold chisels
- 2.1.9 Pointed cement trowel

- 2.1.10 Marking pens, grease type or felt tip
- 2.1.11 Metric rule
- 2.1.12 Wood block (10 X 10 X 30 cm)
- 2.1.13 Site selection plan
- 2.1.14 Log book

2.2 Procedure

2.2.1 General

- 2.2.1.1 The purpose of sampling is to determine the amount of accumulated plutonium that has been deposited on the ground. This is accomplished by collecting a sample volume of 2500 cm³ of soil in situ. The jig outlines a 10-cm square area and is driven 5 cm into the soil to cut three sides of the sample. At the fourth side, soil is removed from outside the jig perimeter. The scoop is used to finish-cut both the fourth side of the sample and the bottom surface. Five samples should be collected at each location and then composited.
- 2.2.1.2 In rocky areas, good sample geometry (shape) cannot be achieved with the jig. In those cases, the jig and the metric rule should be used to gauge the desired sample size. Rocks and soil are pried or chiseled out of place for collection.

2.2.2 Selection of Sample Site

- 2.2.2.1 A site-selection plan should be used to specify the general site location. The plan must provide adequate information for the sample collection crew to locate each specific site. The sites should be permanently marked so that the same area can be resampled. Permission to collect samples and mark the site should be obtained from each landowner. The sample-collection crew should be accompanied by supervision to ensure that specified procedures are followed.
- 2.2.2.2 The following site selection criteria should be considered:
 - (a) undisturbed location for the time interval of interest
 - (b) near the center of a large, flat, open area
 - (c) not subject to excessive runoff during heavy rain
 - (d) light to moderate vegetation and permeable soil
 - (e) not in area of mechanical disturbance

2.2.2.3 If a sample site is not available that meets the above criteria, the independent judgment of the crew supervisor should be used to meet the basic objectives as closely as possible.

2.2.2.4 All selected sites should be located on a map.

2.2.3 Collection Procedure

Five soil samples should be collected at each site and composited for analysis. Samples should be collected at a center point and a measured distance (such as five meters) north, south, east, and west of the center point.

2.2.3.1 Place the sampling jig on the ground, Using the wood block and hammer, drive the jig into the soil to a depth of 5 cm.

2.2.3.2 With minimal disturbance to the soil inside the jig, use a scoop, trowel, or chisel to remove the soil from around the open side of the sample jig. Soil should be removed to a depth that will allow easy removal of the sample.

2.2.3.3 Discard the soil removed from outside the jig.

2.2.3.4 Remove the soil sample from the interior of the jig with a scoop or trowel and place the sample in the paint can. Repeat this procedure at each of the five locations and place the samples in the same can to yield one composite sample.

2.2.3.5 Clean the sample tools with the brushes and paper towels prior to moving to another sample site. **THIS MUST BE DONE TO PREVENT CROSS-CONTAMINATION OF SAMPLES.**

2.2.3.6 Label the sample container with the following information:

- (a) sample site identification
- (b) collection date
- (c) name of sample collector

2.2.4 Record of Field Information

The sample collection log book should contain the following information:

- (a) sample number
- (b) sample location
- (c) date of collection

- (d) name of collector
- (e) weather conditions
- (f) soil type
- (g) vegetation
- (h) degree of slope and direction
- (i) soil moisture
- (j) any special conditions

3. Preparation for Analysis

- 3.1 Estimate the sample volume using a calibrated container.
- 3.2 Transfer the entire sample into a new disposable aluminum pan, which will be discarded after use.
- 3.3 Dry the sample in an oven at 110 °C for at least 12 hours.
- 3.4 Separate the sample into two fractions using a 10 mesh sieve.
 - 3.4.1 Use a pestle to break up any clumps of soil, but do not break up rocks.
 - 3.4.2 Weigh both fractions and record.
 - 3.4.3 Use the combined weight of the two fractions and the estimated volume to calculate the apparent density.
- 3.5 Transfer the fraction that did not pass through the 10 mesh sieve into a plastic bag and seal.
- 3.6 Transfer the fraction that passed through the 10 mesh sieve back into the original field can.
 - 3.6.1 Place 10 one-inch grinding balls in the sample can, secure the lid on the can, and rotate on a ball mill at 120 rpm for at least 4 hours.
- 3.7 Transfer a 100-g aliquot of the homogeneous fine powder to a 0.47-l (16 oz) plastic bottle. Mark the bottle with the sample number.
- 3.8 The remainder of the sample and the steel grinding balls should be retained in the field can until all analyses are complete.
- 3.9 Submit the aliquot of soil to the laboratory for analysis, as specified in Section 6.4.

4. Resuspendible Material Sampling

4.1 General

There is no standard measure of the availability of a contaminant for resuspension. In trying to collect surface samples, it is very difficult to

take into account the variations in ground contour, the presence of obstructions such as rocks, and to reproduce any particular sample. In its proposed guidance, the EPA recommends that where soil samples are taken to evaluate the inhalation pathway, samples should be taken to a depth of 1 cm, and radioactivity measurements should be made on all soil particles less than 2 mm in size.

4.2 Equipment

The equipment required for surface samples is the same as described in Section 2.1, with the following exceptions:

4.2.1 Soil sampling jig (10 × 10 × 1 cm)

4.2.2 Paint cans, 1 quart, new

4.3 Procedure

4.3.1 General

4.3.1.1 The purpose of sampling is to obtain a sample consisting of 500 cm³ of resuspendible surface soil. The jig outlines a 100-cm² area and is driven 1 cm into the soil.

4.3.2 Collection Procedure

The collection procedure is basically the same as that described in Section 2.2.3.

5. Special Sample Collection

5.1 At times, it may be necessary to employ other collection techniques if the purpose for sampling is different from those described earlier. In those cases, the purpose should be specified and the deviations to the standard techniques should be described in detail. Two additional techniques will be specified here—coring and profiling procedures.

5.2 Equipment

The equipment for subsurface coring is the same as described in Section 2.1, with the following exception:

5.2.1 Orchard auger, standard type with an 8.3-cm-diameter barrel, and a 150-cm-long T-handle instead of the jig.

5.3 Procedure for Coring

5.3.1 Place the auger carefully on the ground with the handle in a vertical position.

5.3.2 Cautiously rotate the auger handle to prevent caving of the walls of the hole. A slight downward pressure with slow turning will guide the auger.

- 5.3.3 When the auger cylinder is about 3/4 full, remove the auger slowly and either tap out or use a spatula to scrape out the soil core.
- 5.3.4 Repeat the procedure until the desired depth is reached.
- 5.3.5 Place the sample in a new paint can and seal the lid.
- 5.3.6 Fill each hole to the top with excess soil to prevent an accident.
- 5.4 Procedure for Profiling
 - 5.4.1 Using suitable equipment, such as a motorized backhoe, dig a trench to a suitable depth (usually 60 to 120 cm).
 - 5.4.2 All loose soil must be removed from the trench.
 - 5.4.3 Individual sample may be taken from the walls of the trench with various tools. These would include the auger described in Section 5.2.1 or the scoop, trowel, and chisels described in Section 2.1.
 - 5.4.4 Using the appropriate tool, collect samples starting at the bottom of the trench. This is necessary to prevent cross-contamination of samples from material falling downwards. It is assumed that contamination will decrease with depth.
 - 5.4.5 Sample-depth intervals will vary with each project depending upon such variables as total depth, soil composition and structure, and resources such as funds, available for multisample analysis.

6. Quality Control

6.1 Blank Standards

- 6.1.1 Blank soil shall be collected.
 - (a) Blank soil shall be collected at a depth of not less than 30 cm.
 - (b) Blank soil shall be collected at a site not less than 1 mi to the west of the Rocky Flats Plant.
 - (c) Standard collection procedures shall be used.
 - (d) Blank soil shall be indistinguishable from most of the sample soils.
- 6.1.2 A portion of the blank soil collected shall be reserved for the preparation of known standards.
- 6.1.3 Blank soil standards shall be handled, shipped, and analyzed in a manner identical with that of samples.

6.2 Consensus Standards

- 6.2.1 Consensus standards shall be collected.

- 6.2.2 A minimum of 25 kg of material shall be required for a consensus standard.
- 6.2.3 Consensus standards shall be collected in the same area as the samples, using normal sampling procedures.
- 6.3 Prepared Standards
 - 6.3.1 Blank matrix material shall be submitted to the Chemical Standards Laboratory.
 - 6.3.2 Personnel in the Chemical Standards Laboratory will add known concentration of plutonium, americium, and other radionuclides, as necessary, to the blank matrixes.
- 6.4 Sample Submission
 - 6.4.1 All materials shall be submitted to the central receiving laboratory.
 - 6.4.2 Receiving laboratory personnel shall make up batches consisting of 5 percent blanks, 5 percent consensus standards, 5 percent laboratory quality control standards, 5 percent prepared standards, and 80 percent samples.
 - 6.4.3 The Receiving laboratory shall mask all materials in such a manner that analytical laboratory personnel cannot distinguish between standards, blanks, and samples.
 - 6.4.4 Twenty percent of the samples, to be chosen randomly, shall be split and sent offsite for analysis, or used for replicate analysis onsite.
- 6.5 Personnel Qualifications and Responsibilities
 - 6.5.1 The responsibility for supplying trained, qualified personnel for sampling teams shall belong to the laboratory foreman or the manager of the H&E Laboratory.
 - 6.5.2 All members of the sampling team shall have a minimum of four hours training or experience in the soil collection technique to be used.
 - 6.5.3 All persons with the authority to certify shall have had no less than two hours of training in the duties and responsibilities of certification.
 - 6.5.4 It shall be the responsibility of the laboratory foreman or the manager of the H&E Laboratory to certify that any additional training or retraining necessary has taken place.
 - 6.5.5 All personnel shall be fully informed of the specific nature of the tasks for which they are responsible.
 - 6.5.6 The project manager shall have the responsibility of making clear to the sampling team and the laboratory staff the specific requirements of the project prior to startup.

6.6 Access to the Sample Area

- 6.6.1 Written permission from land owners shall be obtained by the project manager prior to soil collection of any kind on private land. A copy of this permission shall be kept as a part of the permanent record.
- 6.6.2 Access to the sampling site shall be limited to permit minimum disturbance to the environment and maximum protection of the integrity of the material collected.

6.7 Sample Handling and Shipping

- 6.7.1 It shall be the responsibility of the supervisor of the sampling team to protect all materials collected in such a manner as to avoid their alteration in any manner.

6.8 Procedural Changes

- 6.8.1 No modification shall be made in sampling or handling procedure unless prior written consent is given by the manager of Environmental Sciences.
- 6.8.2 The laboratory shall have written analytical procedures and shall adhere to them. No modification shall be made in analytical procedure unless prior written approval is given by both the manager of the H&E Laboratory and the project manager.

6.9 Nonconformance Reporting

- 6.9.1 It shall be the responsibility of the sampling team to report to the project manager any problem, unplanned event, or nonconformance with normal sampling procedure.
- 6.9.2 The analytical laboratory shall have a written quality control plan and shall adhere to it. The laboratory shall report any problem, failure, or nonconformance on its part, to the manager of the H&E Laboratory.

6.10 Acceptability Limits

- 6.10.1 Minimum reasonable acceptability limits for data accuracy and precision must be determined in advance. These limits will vary depending on need, detectability limits, and the amount of time available.
- 6.10.2 Prior to project startup, verification shall be made that all equipment and methods to be used can meet the necessary precision and accuracy requirements.

- 6.10.3 The analytical laboratory shall submit necessary written statistical verification that precision and accuracy requirements were met during analysis.

6.11 Custody of Samples and Records

- 6.11.1 There shall be an organized procedure for maintaining a chain of custody of samples and records.
- 6.11.2 Project data that assures the traceability and integrity of the information shall be identified, recorded, collected, and reported in a systematic manner.
- 6.11.3 Samples shall be identified and entered in a log book as they are collected. The sample collection log book shall contain
- (a) sample number
 - (b) sample location
 - (c) date of collection
 - (d) name and signature of sample collector
 - (e) weather and conditions
 - (f) general soil type
 - (g) vegetation
 - (h) direction degree of slope
 - (i) soil moisture
 - (j) method of sample collection
 - (k) special conditions
- 6.11.4 Sample receipt, handling, and analysis shall be certified by the analytical laboratory.

6.12 Weather Restrictions

- 6.12.1 No sample shall be collected when wind velocity exceeds 15 mph.
- 6.12.2 No sample shall be collected during rain or snow.

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