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INFORMAL REPORT

Ecological Investigation of Radioactive Materials in Waste Discharge Areas at Los Alamos

for the Period July 1, 1972 through March 31, 1973

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

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This work supported by the U. S. Atomic Energy Commission's Division of Biomedical and Environmental Research

ECOLOGICAL INVESTIGATION OF RADIOACTIVE MATERIALS IN WASTE DISCHARGE AREAS AT LOS ALAMOS FOR PERIOD JULY 1, 1972 THROUGH MARCH 31, 1973

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T. E. Hakonson, J. W. Nyhan, L. J. Johnson, and K. V. Bostick

ABSTRACT

This report describes the ecological research program at the Los Alamos Scientific Laboratory and, in addition, summarizes the progress which has been made on current project activities between July 1, 1972, and March 31, 1973.

Information is presented on an environmental inventory of the Los Alamos area, a radionuclide inventory in three liquid waste disposal areas, studies to determine the applicability of the honeybee as an indicator of environmental radiocontamination and a resurvey of the Trinity area to determine the bioavailability of the plutonium from the world's first nuclear detonation.

I. INTRODUCTION

The overlying objective of the investigation is to develop the necessary biological and ecological input data to provide a basis for assessing the environmental impact of research and development programs at the Los Alamos Scientific Laboratory (LASL) and to establish a predictive capability on the behavior and significance of various radionuclides which are released to the LASL environs. The information gained in this study will not only be valuable to the Laboratory from an operational standpoint, but it will also have application to nuclear-oriented industry. Research areas identified as being important to the success of this inventigation include a determination of

1. the quantities of radionuclides released through time,
2. the physical and chemical forms of the radionuclides present in the environment,
3. the plant and animal resources in the LASL environs as a whole, but especially in the pathway of discharged effluents,
4. data on the physical and chemical characteristics of the soils,
5. the radionuclide content of the plants, animals, and soils as a function of season,
6. the seasonal meteorological conditions in the area, including ambient air and alluvial soil temperatures and precipitation,
7. the radioecological concentration processes in abiotic and biotic compartments including rates of incorporation and loss,
8. the physical and biological processes influencing resuspension and redistribution of contaminant radionuclides and the relative importance of each, and

9. the biological effects anticipated from a given level of environmental contamination and corresponding total radiation doses and dose rates to critical tissues.

This report summarizes project activities and information gathered between July 1, 1972, and March 31, 1973. Most of the effort during this period has been spent in

1. compiling an environmental inventory of the Los Alamos area,

2. studying the in situ kinetics of various radionuclides in honeybee colonies,

3. conducting a radionuclide inventory in the soils and biota of liquid waste disposal areas, and

4. resurveying the radionuclide content of the soils and biota at Trinity, the site of the world's first nuclear detonation.

The following quote from the July-December 1972 environmental monitoring report[1] describes the history and function of the Laboratory. "The Laboratory and the Los Alamos Community are located in north-central New Mexico (Fig. 1) on the Pajarito Plateau, situated west of the Rio Grande on the eastern slopes of the Jemez Mountains. This location was orginally chosen for the atomic weapons laboratory during World War II because of its relative isolation. Thus the area surrounding Los Alamos, including all of Los Alamos County and large portions of Sandoval and Santa Fe Counties, is largely undeveloped except for those areas occupied by the Laboratory facilities and the associated communities. Large tracts of land in the Jemez Mountains to the north, west, and south of the Laboratory site are held by the Forest Service" (Fig. 2). "Agriculture is limited to home gardens with some grazing of beef cattle. In the river valleys to the east, agriculture is restricted to relatively small plots supported by irrigation. Primary crops are chili peppers, beans, and tree fruits. Milk is not produced in commercial quantities in the immediate vicinity of Los Alamos. More detailed descriptions of the geology, climatology, and economy of the area are given in the appendixes of the January-June 1971 environmental monitoring report."[2]

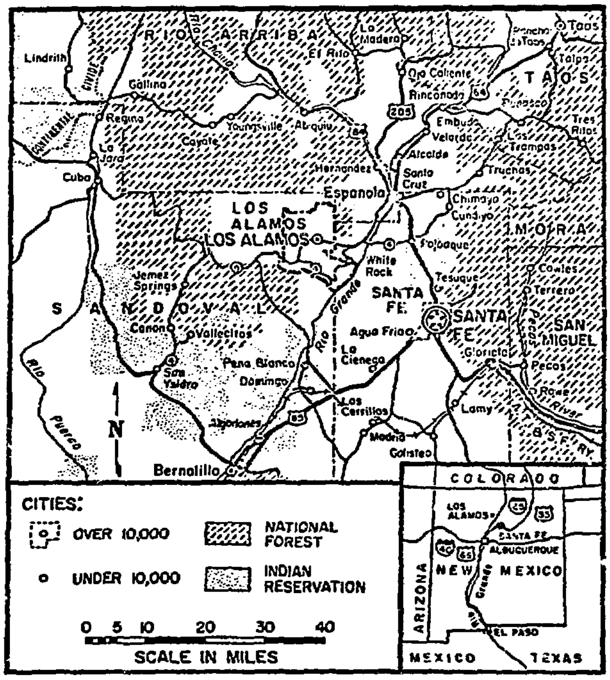

Fig. 1. North-central New Mexico.

"The Laboratory site covers about 28,000 acres in and adjacent to Los Alamos County. The principle mission of the Laboratory is, as it has been since its inception in 1943, the design and development of weapons for the nation's nuclear arsenal. This program is supported by extensive research programs in nuclear physics, hydrodynamics, conventional explosives, chemistry, metallurgy, radiochemistry, and biology. In addition to this program, considerable effort is directed toward the peaceful uses of nuclear energy including medium-energy physics (Los Alamos Meson Physics Facility), space nuclear propulsion, controlled thermonuclear fusion (Sherwood Program), nuclear safeguards, biomedical research, and space physics. These activities are located in 29 active Technical Areas (TA) widely spread over the AEC-controlled lands."

II. ENVIRONMENTAL INVENTORY

A. Background

The overall objective of this inventory is to qualitatively and quantitatively describe the physical, chemical, and biological characteristics of the LASL environs. The approach taken in initiating the inventory was to gather and summarize the existing data on the abiotic and biotic resources of this area. In addition, specific field investigations were undertaken to supplement the available information. It was recognized that the inventory must contain sufficient detail in the contaminated areas to maximize the interpretation and manipulation of the radionuclide data (e.g., in the systems analysis and dose commitment calculations). On the other hand, qualitative or semi-quantitative data which were used in characterizing the total LASL environs will provide a general basis for assessing the environmental impact of future Laboratory activities.

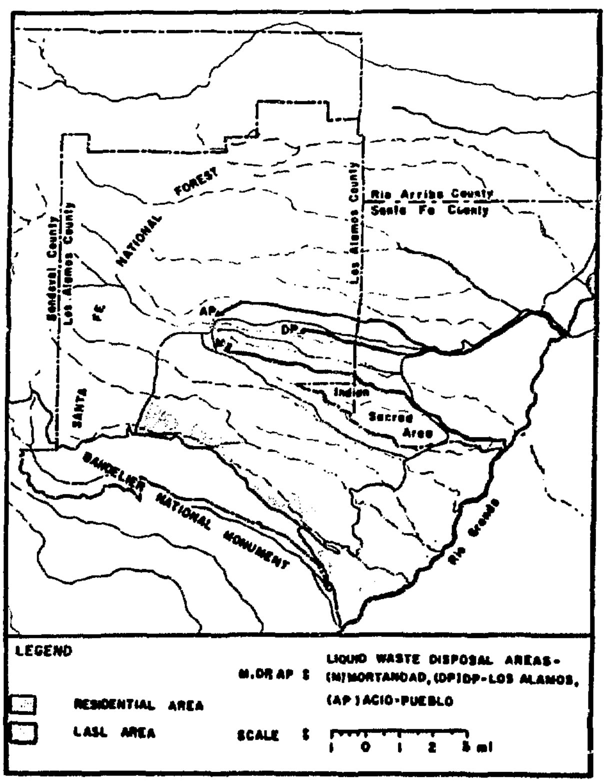

Fig. 2. Ecological investigations study area at Los Alamos.

The boundaries of the environmental inventory area were established somewhat arbitrarily and include all of Los Alamos County and all of Santa Fe County west of the Rio Grande River (Fig. 2). The Laboratory's environmental surveillance network provided data[1] which indicated that these boundaries were likely well outside the areas of radioecological significance.

Current research efforts on this inventory include

1. a qualitative description of the local soils,

2. a listing of the biota that are permanent or part-time residents of the areas,

3. a library of reference specimens, and

4. a semi-quantitative estimate of the type and density of vegetative cover.

B. Methods

A qualitative description of the local soils was synthesized from soil surveys of Los Alamos, Sandoval, and Santa Fe Counties[3,4] and from information compiled by the Soil Survey Staff of the Soil Conservation Service (SCS).[5] The soil survey data for Sandoval and Santa Fe Counties was validated by SCS field reconnaissance, but the soil map of Los Alamos County was prepared only on the basis of interpretation of topographic and geologic maps since no soils field observations have been made by SCS in this county.

A listing of some of the plants and animals which are found in Los Alamos County was compiled from information gathered by the New Mexico Environmental Improvement Agency,[6] the New Mexico Department of Game and Fish,[7] the U.S. National Park Service,[8] the U.S. Forest Service,[9] the Santa Fe section of the Audubon Society,[10] by Hubbard[11] in a text on the birds of

New Mexico, and by Martin and Castetter[12] in a checklist of the plants of New Mexico. Specific field observations in the present investigation supplemented the available data.

An indication of the degree of residency (e.g., permanent, migratory, etc.) of each faunal species was attempted by utilizing data summarized by Hubbard[11] for the avian species and by using field observations in the case of the remaining animals.

A field study was initiated during the summer of 1972 to gather plant specimens for a reference herbarium. Typical representatives of the various species were dried in a plant press and were mounted on a 8 1/2 x 11 in. sheet of bristol board along with a tag bearing information pertinent to the mounted specimen (Fig. 3). Taxonomic identifications of these specimens were made by personnel of the University of New Mexico Herbarium.

The description of the faunal and floral resources of the LASL environs presented in this report is by no means all inclusive. The floral listing lacks many of the forb species present in the area and the faunal listing is incomplete or devoid of amphibian, arthropod, annelid, and protozoan species, not because they are unimportant in the LASL environs, but because there is a lack of information on them.

Fig. 3. Preparation of the reference herbarium at the Los Alamos Scientific Laboratory.

Black and white and color infrared aerial photographs of the Los Alamos area are being utilized in a low resolution technique for estimating the types of vegetative ground cover.[13] Vegetative types identified from the photographs are confirmed by field reconnaissance. The acreage in each distinct vegetative type is calculated from a final type map with a planimeter and an estimate of the relative density of each species is made from data collected during the field reconnaissance.

C. Results and Discussion

1. General. Los Alamos is located in northern New Mexico on the Pajarito Plateau which occupies the eastern flank of the Jemez Mountains. The plateau, which is a shelf about 10 to 15 miles wide and 45 miles long and at an elevation of about 6500 to 7500 ft in those areas directly controlled by the Laboratory, has been deeply eroded by runoff with the result that the area consists of a series of mesas separated by canyons, many of which are several hundred feet deep (Fig. 4).

A 5000 ft elevational gradient within a 15 mile distance in the east-west direction of Los Alamos County along with corresponding chemical and physical changes in the abiotic environs results in a biotic composition which is characteristic of three life zones. Species which are typical of the Upper Sonoran life zone are found at elevations of about 5500 to 6300 ft at the eastern edge of the county, whereas from 6300 to 8000 ft the biotic composition is characteristic of the Transition life zone. Species typical of the Canadian zone are present from the 8000 to 10,500 ft elevations.

The distribution of vegetation community types within the survey area is primarily dependent upon elevation, slope

Fig. 4. A south-east view across the parajito Plateau in the vicinity of the LASL showing the general topography including the Rio Grande Gorge in the background.

exposure, and upon existing soil types. Vegetation at the eastern edge of the plateau is similar to that found in a continental, semi-arid region with pinons and junipers along with rabbitbrush and other species characteristic of the pinon-juniper climax (Fig. 5). The central portions of the area are forested with ponderosa pine and fir (Fig. 6) which grades into spruce, fir and groves of aspen at higher elevations. Wildlife is plentiful, particularly in the restricted areas of government ownership, and includes numerous faunal species.

The area has a semi-arid, continental mountain climate. the average annual precipitation is slightly more than 18 in. in the city of Los Alamos, with 75% of it falling during the months of May through October. There are no permanent, natural streams flowing through the Laboratory area, although Frijoles Creek flows through Bandelier National Monument located on the southern border of the Laboratory site and the Rio Grande flows through White Rock Canyon on the eastern border (see Fig. 2). There are, however, intermittent streams flowing in the canyons during the rainy season, and surface water exists in certain of the canyons for a short distance below the discharge points for industrial or sanitary wastes.

2. Soils. Understanding the many different kinds of soil in and around the LASL waste disposal areas would be hopeless if the occurrence of each kind of soil was random. Fortunately there is generally a repeated pattern of soils that is directly related to features of a landscape and the soil-forming factors of climate, vegetation, time, topography, and parent material. The soil series involved in this repeated pattern may or may not resemble one another, but they are classified as members of the soil association. The three principal soil association areas in the LASL area are an unnamed soil association area consisting of mountain soils forming in igneous materials, the Apache-Silver-Rockland area, and the Majada-Calabasas-Apache area.

Although the mountain soils forming in igneous materials have not been studied in detail, classified, and correlated, there is a limited amount of information available on unnamed soils A and B. These soils are developing in volcanic materials and occur in the Transition and Canadian life zones in this area, where the dominant vegetation

Fig. 5. Vegetation in the lower Transition Zone (6500 ft elevation at Los Alamos includes Pinon Pine(Pinus edulis), Juniper (Juniperus spp.), and Rabbitbrush (Chrysothamnus parryihowardi).

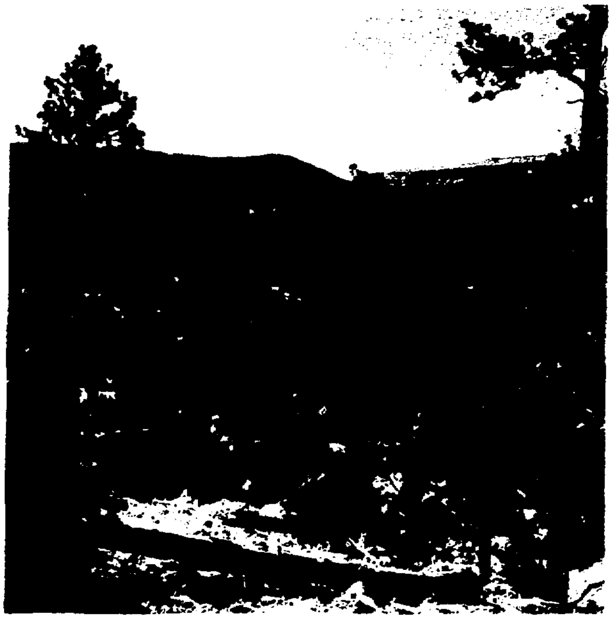

Fig. 6. Vegetation in the upper Transition Zone (8000 ft elevation) at Los Alamos showing the Ponderosa Pine (Pinus ponderosa) and Douglas Fir (Psuedotsuga taxifolia) overstory.

is pine and fir trees. Unnamed soil A occurs on gently-sloping to moderately-steep landscapes (5-15% slope) such as mesa tops, whereas unnamed soil B is found on ridge tops and on steep mountainside slopes (15-75% slope) adjacent to the radioactive waste discharge areas. Unnamed soil A has a dark brown noncalcareous sandy loam surface soil (0-7 in.), followed by a slightly acidic sandy clay loam layer at 7-10 in., and a sandy loam C horizon (18-30 in.). This soil was classified as an alfisol (Table I), indicating the presence of an argillic epipedon - an illuvial horizon in which silicate clays have accumulated to a significant extent. Unnamed soil B is classified as a mollisol, indicating the presence of a thick, dark surface layer (epipedon) which is dominantly saturated with bivalent cations (i.e., calcium ions), and contains at least 0.58% organic carbon, a narrow C:N ratio (13:1 to 17:1), and moderate to strong structure. Soil B is a shallower (10-20 in. soil depth) coarser textured soil than soil A and is composed of a dark grayish-brown sandy loam subsoil and surface soil. Both of these soils have moderate to rapid permeability.

The soils of the Apache-Silver-Rockland and the Majada-Calabasas-Apache associations occur primarily in the Upper Sonoran life zone in this area and are forming in materials of volcanic or basic igneous origin. The Apache-Silver-Rockland association is characterized by rocky, shallow soils. The Apache stony loam is found on gently-sloping to moderately-steep landscapes (0-10% slope) adjacent to drainageways and on the fronts of basalt flows. The Apache soils are typically shallow (10-20 in.), calcareous brown-colored soils with approximately 30% of the top 9 in. of the soil profile and 15% of the remainder of the profile consisting of basalt fragments greater than 3 in. in diameter. This factor, along with the overall coarse-textured nature of the 0-9 and 9-16 in. horizons (sandy loam over a loam soil), accounts for the moderate to rapid permeability of these soils. In contrast with the Apache mollisols, the Silver loam may have a soil depth of 59 in. and is a brown, noncalcareous soil which occupies nearly level areas (0-5% slope) on broad swales and depressions. The profile may be subdivided into four horizons on the basis of particle size distribution: 0-3 in. (loam), 3-14 in. (clay), 14-45 in. (silty clay loam), and 45-59 in. (loam). Thus, although the loamy horizons are moderately permeable to water, the clay and silty clay loam horizons exhibit very slow and slow permeability. Rockland, a miscellaneous land type, occurs on steep to very steep (5-50% slope) fronts of lava flows and sides of basalt-capped mesas adjacent to the channel alluvium of the liquid waste disposal areas. Although the Silver, Apache, and Rockland soils occupy approximately 10, 60, and 20% of this association in Sandoval and Los Alamos Counties, there are also small areas of Calabasas, Majada, and Prieta soils.

TABLE I

PEDOLOGIC CLASSIFICATION OF MAJOR SOIL TYPES
OF THE LASL AREA

Order	Soil Type	Subgroup	Family
Mollisol	Majada stony fine sandy loam	Aridic Argiustoll	Loamy-skeletal, mixed, mesic
Mollisol	Apache stony fine sandy loam	Aridic Lithic Haplustoll	Loamy, mixed, mesic
Mollisol	Unnamed Soil B	Lithic Haploborall	Coarse-loamy, mixed
Aridisol	Calabasas loam	Ustollic Camborthid	Fine-silty, mixed, mesic
Aridisol	Silver loam	Ustollic Haplargid	Fine, mixed, mesic
Alfisol	Unnamed Soil A	Typic Eutroboralf	Fine-loamy, mixed

The parent materials and dominant vegetation of the Majada-Calabasas-Apache association are similar to those of the Apache Silver-Rockland area. The Calabasas loam is found on the relatively gently-sloping swales and plains (1-5% slope) around the hills (20-50% slope) occupied by the Majada stony fine sandy loam. In contrast to the Majada mollisols, the Calabasas soils are classified as aridisols, implicating these soils as being lighter-colored, lower in organic carbon and thinner than the mollisols. The Calabasas loam is similar to the Majada soils in having a non-calcareous surface soil and ranging to a calcareous subsoil. However, the Calabasas soils exhibit a soil depth of 49-59 in. and their slow subsoil permeability is attributed to the clay loam horizon present at the 21-32 in. soil depth. The Majada stony fine sandy loam is found on rougher terrain than the Apache soils, and the surface soil is not calcareous. However, this soil contains only a few cobble and stones in the top 7 in. of soil (20% of the soil consists of particles with a diameter greater than (3 in.) whereas 40-70% of the deeper horizons (7-39 in.) are composed of particles in this coarse fraction. In spite of the cobby nature of the Majada profile, the presence of a sandy clay horizon at the 14-19 in. soil depth is responsible for the slow permeability of the subsoil. Although small areas of the Apache and Silver soils also occur in this soil association area, the remainder of the area contains soils forming from pumice such as the Los Alamos sandy loam on relatively level areas (0-10) slope) or the Guaje gravelly sandy loam on steeper topographic areas (10-30% slope). The Los Alamos sandy loam and the Guaje gravelly sandy loam exhibit depths to underlying pumice of 20-49 in. and 8-20 in. respectively. These soils have a light brown sandy loam surface layer and a brown clay loam subsoil. This horizon grades through a very light brown gravelly sandy clay loam to a layer that is composed of 80-90% pumice.

3. Biota. Since the Laboratory is located in the eastern half of Los Alamos County, most of the plant collection efforts and the field observations on wildlife have been confined to the Transition and Upper Sonoran life zones. A listing of some of the biota which can be found in Los Alamos County (and in the western portion of Santa Fe County) for at least a part of the year appears in Table A-1.

The flora listed includes 139 species of 37 different families. The listing also includes 37 species of 14 mammalian families, 13 species of cold-blooded animals from 6 families, and 187 species of 44 avian families. All of the cold-blooded and mammalian species are permanent residents even though some species may move seasonally within the county (e.g., mule deer and elk). On the other hand, Hubbard[11] lists only 37 of the 187 species of birds as being permanent residents of the county with an additional 46 species that use the area as a breeding area during the summer. Approximately 30 of the listed animal or avian representatives are game species which are legally hunted in New Mexico. Nine of the listed faunal species are considered rare or endangered in New Mexico.[7]

The herbarium which was prepared this past summer presently contains examples of all of the plant species listed in Table A-I. The collections which will be made during the summer of 1973 should complete the reference library for vegetation. A typical representative of each rodent species that was collected during the last six months was prepared as a study skin. This collection contains examples of most of the rodent species listed in Table A-I and additions are made to the collection as new species are caught.

A mosaic of the LASL environs has been prepared from black and white aerial photographs to serve as documentation of the existing composition of the tree and shrub species. In addition, vegetative types are in the process of being delineated on the mosaic by drawing boundaries around areas that appear to have a similar vegetative composition. A type designation is tentatively assigned to each area by examining the color infrared photographs which show a distinct contrast between the dominant and sub-dominant plant species. Each bounded area on the mosaic will be visited during the summer of 1973 in order to correlate the photos to the existing vegetation and to estimate the relative density of the species comprising the type.

III. RADIONUCLIDE STUDIES

A. Background

There are three specific projects which have been initiated under the radionuclide studies program thus far

1. a monthly summary of information on the use histories of the three liquid waste disposal areas including accumulative radionuclide inputs,

2. studies on the eco-distribution and kinetics of radionuclides in biotic and abiotic components of the liquid waste disposal areas,

3. a 27 year post-shot resurvey of the radionuclide content of the soils and biota in the fallout pathway of the world's first nuclear detonation at the Trinity Site.

B. History of the Laboratory's Liquid Waste Treatment and Disposal Procedures

Although the main function of the Laboratory has been in the field of weapons development, numerous other projects, mostly connected with nuclear energy, have been and are under way at the Laboratory. One experimental reactor program, the Sherwood Project, involves a characterization of the nuclear fusion process and is currently a major activity. Medium-energy physics research work of the Atomic Energy Commission will be centered at the new Clinton P. Anderson Meson Physics Facility (CAMPF). International research at this multimillion dollar installation is expected to start in 1973.

An 8-MW, light-water, moderated reactor and a 25-kW homogeneous reactor are operated to provide neutron sources for experiments conducted by the research groups at LASL.

The plutonium research program at the Laboratory has always been a major effort primarily directed toward the use of ^{239}Pu in weapon fabrication and as a reactor fuel element. Currently a major emphasis is being placed on the study of ^{238}Pu for power sources in space or for implantation in humans.

As may be expected, the nuclear programs have, and are, generating quantities of radioactive wastes, some fraction of which have been discharged to the environs. In addition, there are discharges of certain nonradioactive wastes, including those characteristic of high explosives work, as well as sanitary wastes. Airborne wastes are generally treated and the efficiency of air cleaning processes are constantly being improved to minimize discharges. It is estimated that about 1.5 Ci of plutonium have been discharged in airborne effluents from the plutonium facilities over the past 25 years with the majority of this material in the period before 1962. As a result, detectable quantities of plutonium are present in the soils in the environs near these facilities[1]. Some tritium is discharged to the atmosphere on a sporadic basis as essentially instantaneous point-source releases.

Radioactive wastes disposed to the ground at Los Alamos consist of solids, liquids, and sludges. The types and quantities of wastes have changed with time at some areas, and the techniques of disposal have evolved from crude uncontrolled dumping to controlled burial or discharge. In early disposal practices contaminated solid wastes were sometimes dumped into scrap piles near the laboratories, and both solid and liquid wastes were dumped outside buildings or down sink drains during emergencies. Liquid wastes were at first discharged untreated into canyons, into underground storage tanks, or into pits filled with gravel. Several old, marked burial grounds exist on site and in most cases are in fenced controlled areas.

Since about 1950, solid wastes consisting of laboratory or experimental equipment, ranging from glassware and gloves to entire buildings, have been buried in designated radioactive solid waste disposal pits. The operational site is currently on a mesa at the eastern edge of the Laboratory area. Lower level materials, contaminated mostly with traces of plutonium or fission products, are buried in cardboard boxes. Higher-level transuranic element wastes are buried in a 20-year retrievable form. Special attention is paid to very high-level sludge wastes by burial in metal-lined holes sealed with concrete. Tritium residues have, in the past, been buried in low-level waste burial sites. More recently the tritium wastes have been encased in asphalt prior to burial to minimize the migration of the nuclide. Several other old, marked burial grounds exist at LASL from earlier operations.

Nearly all of the liquid wastes generated by the Laboratory since its beginning in 1943 were collected by industrial waste lines, treated (since 1951) and released into one of three canyons. The effluent originating from the liquid waste treatment plants in Technical Areas (TA 21, 45, and 50 (see Fig. 2) eventually soaked into the alluvial soils in DP-Los Alamos (DP) Canyon (TA-21), Acid-Pueblo (AP) Canyon (TA-45) and Effluent-Mortandad (Mortandad) Canyon (TA-50).

Liquid wastes were handled differently in Technical Areas 45 and 21 before the establishment of the treatment plants in these two areas in 1951 and 1952, respectively. From 1943 to 1951 untreated liquid wastes, which originated in various chemical and metallurgical facilities at the Laboratory were discharged directly into the AP Canyon system. The amounts of radioactivity released during this period were not measured. Liquid wastes at TA-21 were discharged to two major systems of seepage beds, which were constructed as filters, i.e. they were filled with stones and gravel at the bottom and with layers of small gravel, soil, and tuff above. While these seepage beds were in operation, hundreds of soil and water samples were collected around and beneath these pits. The results of these observations indicated that plutonium had not been translocated into the adjacent DP Canyon.

In 1948 a joint effort was started by the Atomic Energy Commission, the U.S. Public Health Service, and LASL to determine the best method of treatment for radioactive liquid wastes. These bench scale experiments were evaluated and indicated that conventional water treatment plant methods would have to be elaborated upon for the management of radioactive wastes. Thus, the treatment plant was designed to provide flocculation-sedimentation and filtration of radioactive wastes.

The basic design of the TA-45 and TA-21 waste treatment plants, which started operations in 1951 and 1952, respectively, were quite similar. Liquid wastes received by these treatment plants first passed through a weir, where water flow and pH measurements were made, and samples were taken for influent radionuclide determinations. As the raw wastes passed into the flash mixer, sodium carbonate and calcium hydroxide were added if the influent was acidic and the wastes then entered the influent holding tanks. The raw waste was then pumped to the flocculators where calcium hydroxide, sodium carbonate, ferric sulfate, and a non-ionic, polyacrylamide-type coagulant aid were added to concentrate alpha activity in a ferric hydroxide floc at a relatively high pH. The coarse floc was then collected in large sedimentation tanks, removed to separate storage for decantation of excess liquid, and then further concentrated by vacuum filtration. The resulting filter cake was buried in drums in a contaminated burial ground. The sedimentation tank effluent now contained relatively low levels of alpha activity in a fine floc, which was then removed as the wastes passed through three sand or anthrafilt filters and into the effluent holding tanks. Starting in 1971 at TA-21 and TA-50, carbon dioxide was injected into the settling tank effluent in order to convert carbonates, which clog up the anthrafilt filter, to bicarbonates. The alkaline (pH 11 or greater) treated waste, which now contained about 1% of the plutonium received by the plant, was then discharged either to AP Canyon from TA-45 or to DP Canyon from TA-21. After the new TA-50 treatment plant was started in 1964, the TA-45 plant was dismantled and a small portion of the AP Canyon walls and alluvium near the effluent outfall was removed in the ensuing decontamination procedures. The original plant at TA-21 (Building 35) was replaced by a new plant (Building 257) in 1967, which used the same holding tanks for treated wastes.

The TA-50 plant, which took over the old TA-45 plant's waste treatment responsibilities in 1963, is slightly different than the TA-21 plant. The effluent from the anthrafilt filters at TA-50 is diverted through ion exchange columns to remove beta emitters (e.g. ^{90}Sr) from the liquid wastes. The TA-50 plant has not handled as many batch waste disposals (high fluoride potassium hydroxide wastes, acidic raffinate wastes, and alcoholic wastes) as have the TA-21 plants. In addition, the TA-50 plant does not receive the large amounts of intermediate-level americium wastes treated by the TA-21 plants and, thus, does not have routine procedures and equipment for incorporating americium wastes in a cement-vermiculite mortar.

The three canyons used as liquid waste disposal areas have received contaminated wastes for varying lengths of time. Acid-Pueblo Canyon was used for a period of 20 years during 1944-1964 but has not been used for at least 9 years. The DP Canyon area is one which has been used for about 20 years and still receives discharges from TA-21. It is expected, however, that use of this canyon for disposal of plutonium wastes will be eliminated within the next few years when a new Plutonium Research Facility is expected to become operative. Mortandad Canyon has been used for about 10 years as the disposal area for wastes from the TA-50 plant. This plant processes industrial wastes from the major portion of the Laboratory. It is presently planned that the industrial waste from the new Plutonium Research Facility will be handled by TA-50.

Thus a noteworthy opportunity exists for studying the ecological behavior of plutonium in disposal areas that are in three different time stages of useage

1. an area that has not received plutonium waste water for 9 years,

2. an area that has long been used as a disposal area for plutonium waste, but within 5 years will no longer be used,

3. an area that will be in continuous use, and further, one that will receive a marked increase in plutonium throughout a fixed date.

It is evident from data which are presented later and from discussions with the few personnel[14, 15] who were here when Laboratory operations began, that ^{3}H, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{241}Am, $^{89-90}Sr$, and ^{235}U were discharged into some or all of the liquid waste disposal areas. Unfortunately, the lack of comprehensive records on the radionuclide content of treated effluent (with the exception of plutonium) was not maintained until just recently. Therefore, it was impossible to estimate the quantities of these radionuclides which were released to the canyon areas. However, sufficient data were available to crudely estimate plutonium input to the canyons by utilizing gross alpha activity measurements which were made on the treated effluent. The assumption was made that all the alpha activity in the effluent was due to ^{239}Pu so that the estimated input to the canyons was in terms of ^{239}Pu "equivalents". In reality the "Pu" in liquid effluents released to DP and Mortandad Canyons after 1959 consisted of a mixture of ^{238}Pu and ^{239}Pu. Specific analyses for ^{238}Pu and ^{239}Pu in liquid effluents within the last two years indicate that about 80% of the Pu in DP Canyon effluents is ^{239}Pu while 80% of the Pu in Mortandad Canyon effluents is ^{238}Pu.

Records on the amounts of ^{239}Pu in the untreated effluent from TA-1 were not maintained during the 1944-1950 period and consequently, estimates of additions of this radionuclide into AP Canyon were necessarily without a quantitative basis. A crude estimate was made by assuming that the amount of ^{239}Pu in the effluent increased linearly through the 1944-1950 time period. The first year that complete records were available on the Pu content of liquid effluents was 1952, and during this year pretreatment liquid effluents designated for disposal in AP Canyon contained 45 mCi Pu. A linear extrapolation from 45 mCi Pu released in 1952 back to 0 released in 1943 (a year prior to plutonium processing) followed by numerical integration resulted in an estimated plutonium input of about 143 mCi into AP Canyon (Table II).

During the 13.5 year period when the TA-45 plant was operational (1951-1964), an additional 24 mCi Pu was released into AP Canyon which brings the total estimated Pu additions to this canyon to 170 mCi.

The TA-21 facility which became operational in 1952 has released an estimated 32 mCi Pu to DP Canyon through 1972. As mentioned previously, the possibility exists that prior to 1952, additional Pu (and other radionuclides) seeped into DP Canyon from disposal pits located on the adjacent mesa. However, there is no way of assessing the quantities (if any) involved.

The TA-50 waste treatment facility became operational in 1964 and as of 1972 has released an estimated 42 mCi Pu to Mortandad Canyon. As mentioned, the input of Pu to this canyon is expected to increase after the new Pultonium Research Facility becomes operational.

TABLE II

SUMMARY OF PLUTONIUM ADDITIONS TO THE LIQUID WASTE DISPOSAL AREAS FROM 1943 THROUGH 1972

	TA-45[a]		TA-21		TA-50	
Year	Kiloliters Effluent	mCi Pu in Effluent	Kiloliters Effluent	mCi Pu in Effluent	Kiloliters Effluent	mCi Pu in Effluent
1943-50		143.				
1951	16435	0.4				
1952	30037	0.3	11030	0.1		
1953	29407	0.9	15023	1.6		
1954	40870	2.0	12248	0.5		
1955	39446	2.2	10956	1.1		
1956	40326	1.1	14388	0.8		
1957	43676	0.9	17839	1.0		
1958	39270	0.9	10064	0.5		
1959	43982	1.2	9450	0.9		
1960	41072	2.2	8684	1.7		
1961	52852	5.7	9419	5.0		
1962	64150	3.9	11128	3.2		
1963	30887	5.1	12154	2.5	27292	1.5
1964	850	0.04	5754	1.1	51529	2.0
1965			9418	1.0	50632	3.5
1966			10182	0.8	53120	1.7
1967			9289	3.4	59678	4.2
1968			5381	1.6	60286	2.6
1969			6870	1.6	54480	6.8
1970			10889	1.5	54797	5.1
1971			9908	0.7	46201	6.0
1972			8989	1.1	59374	8.1
TOTALS	513260	170.	219063	31.7	517389	41.5

[a] TA-45, TA-21, and TA-50 released liquid effluent into Acid-Pueblo, DP-Los Alamos and Mortandad Canyons, respectively.

C. Description of the Canyon Areas

The elevational profiles of Mortandad, DP, and AP Canyons from the effluent outfall areas to the Rio Grande River are depicted in Figure 7 along with information on the relative density of some of the major biota. In general the physical features of the respective canyons are very similar. Near the outfalls, the stream channels are narrow, rocky, and contain relatively thin layers of sediment (from 1-6 in). The channels all rapidly drop in elevation within the first 1 1/2 mile below the outfalls where they enter fairly broad portions of the canyon (about 1/4 mile across). Thereafter AP and DP Canyons decrease gradually in elevation to a distance of about 3 miles post-outfall where they first join and then again precipitously drop before entering the flood plain on the west bank of the Rio Grande River. Mortandad Canyon, on the other hand, decreases gradually in elevation from 1 1/2 mile post outfall down to the rim of the Rio Grande escarpment before it rapidly drops to the Rio Grande River.

A permanent flow of surface water does not exist in the upper portions of AP and DP Canyons. Water samples in AP Canyon were obtained (as part of the honeybee study) about 0.1 mile post-outfall from a small permanent pool which apparently was derived from surface runoff. A permanent source of surface water (derived from a sanitary sewage plant) enters the AP Canyon system about 0.4 mile post-outfall and disappears into the alluvium about 6 mile post-outfall. The DP Canyon area near the waste outfall from TA-21 does not contain a natural supply of surface water. Liquid effluent emerging from the outfall pipe on the rim of DP Canyon rapidly soaks into the hillside and enters the stream channel in the bottom of the canyon as ground water. This water saturates the alluvium but does not cover it and the remainder of DP Canyon (i.e. from about 0.2 mile post-outfall and below) is usually without surface water all the way to the Rio Grande River.

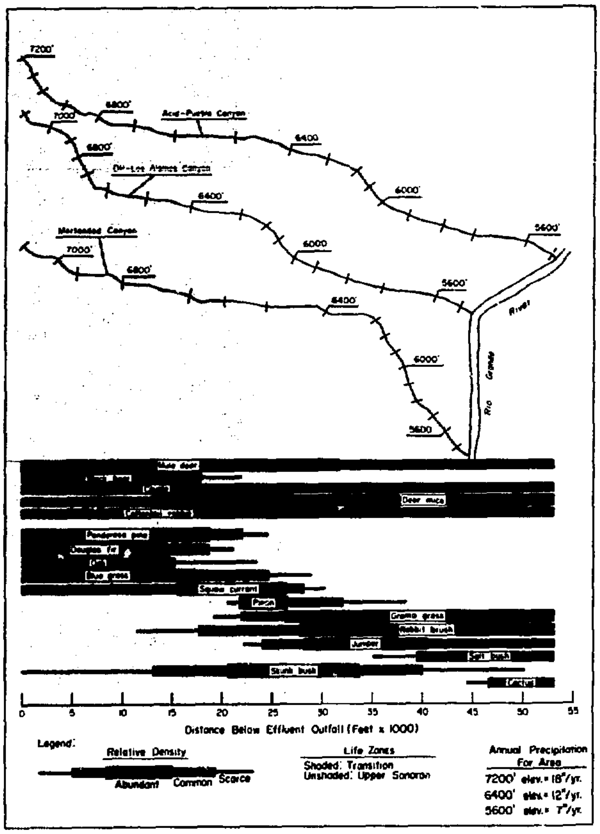

Fig. 7. Elevational profiles fo the liquid waste disposal areas including information on the relative density of the major biota.

Mortandad Canyon is the only one of the three canyons that has appreciable surface water near the outfall. Waste water from a steam plant above the outfall from TA-50 results in a small but continuous stream. This water, plus that derived from TA-50, seeps into the alluvium about 0.3 mile post-outfall and the canyon remains dry for the remainder of its length.

There are large quantities of water flowing in all three canyons following a heavy rain and it is also apparent that sediment is transported downstream during these times.

D. Radionuclide Analysis Methods

1. General. A standard procedure was established for the analysis of five radionuclides in various sample materials. The techniques now being used for ^{3}H and ^{137}Cs analyses were adapted and optimized from existing analytical procedures now used by Group H-8. Techniques for ^{238}Pu, ^{239}Pu, and ^{241}Am analysis[17] were adapted from procedures described in Harley,[18] Chu,[19] "Radioassay Procedures for Environmental Samples,"[20] DeBertoli,[21] Magno, Kauffman and Shleien,[22] and Talvitie.[23] Efforts are underway to optimize the analysis techniques for plutonium and americium in various kinds of sample matrix (e.g., soils, bone, plant and animal tissue).

2. Tritium. Unbound water was collected from soils, vegetation, and animal tissue by a heat distillation and/or a vacuum distillation procedure. A 4 ml-aliquot of the water was added to 14 ml of a commercially prepared scintillator and the solution was analyzed for tritium by beta measurement in a liquid scintillation counter. The two types of distillation procedures were compared by collecting water from a particular sample by both techniques. Similar tritium concentrations were obtained by both methods provided that low temperatures were used in the heat distillation procedure. A temperature of about 37° C was used in the present study and higher temperatures, especially near

100° C, were strictly avoided since volatile organics were visibly observed in the condensed water sample.

The minimum sensitivity of our system for tritium was calculated from the following formula:

$$\text{MS (95\% confidence)} = \frac{2 \cdot \sqrt{\frac{R_B}{t_B}}}{E \cdot PC \cdot Alq}$$

where

MS = minimum sensitivity in units of pCi/ml for a 4 ml sample and a 100-min count

R_B = count rate of background = 26 cpm

t_B = time background counted = 100 min

E = efficiency of beta detection (cpm/dpm) = .31

PC = pico curie conversion = 2.22 dpm/pCi

Alq = sample aliquot size = 4 ml

The minimum sensitivity under the conditions given was 0.37 pCi ^{3}H/ml or about 1.5 pCi ^{3}H.

3. Cesium-137. Vegetation and animal tissues (muscle or carcass) were oven-dried at 100° C for 24 h and then were muffled at 450° C until a white ash was obtained. Ashed biotic samples as well as evaporated water and seston (suspended particulates in water) samples were dissolved in 50 ml of 7.2 N HNO_3 in a 600-ml Pyrex beaker and were counted on a 3 x 3-in. NaI scintillation detector. Non-ashed sediment samples were counted on a NaI detector in a 600-ml beaker and the height of the contained volume was recorded to the nearest millimeter. Standards containing known quantities of ^{137}Cs were prepared in the proper geometry to compare with sample materials.

Some samples contained measurable ^{134}Cs and ^{40}K and the channel ratios method was used to correct the ^{137}Cs photopeak area for ^{134}Cs and ^{40}K contributions.

The minimum ^{137}Cs sensitivity of the gamma detection system, after a 60-min count, for various sample types was

Sediment (100-gram sample) = 0.043 pCi/g
Vegetation (200-gram sample) = 0.021 pCi/g
Deer Muscle (500-gram sample) = 0.009 pCi/g
Mouse Carcass (15-gram sample) = 0.21 pCi/g
Honeybees (150-gram sample) = 0.029 pCi/g

4. Plutonium-238, Plutonium-239, Americium-241. All sample materials to which tracer quantities of ^{242}Pu and ^{243}Am were added, were subjected to a hydrofluoric-nitric acid leach, an ion exchange separation, electrodeposition, and alpha-ray spectroscopy to quantify the plutonium and americium content. The total sample was carried through the plutonium and americium chemistry to eliminate any errors associated with aliquoting a complex matrix such as sediment. The minimum detectable amount of ^{238}Pu, ^{239}Pu, and ^{241}Am, based solely on counting statistics was 0.03 pCi/sample. Split samples were submitted for analysis to determine the repeatability of the analytical procedures for any given sample matrix.

E. Applicability of the Honeybee as an Indicator of Environmental Radiocontamination

1. Background. One aspect of the radioecological studies at Los Alamos deals with the identification of plant and animal species which can be used as biological "indicators" of radionuclide contamination in the natural environment. Honeybees (*Apis mellifera*) are potentially useful as "indicator" organisms because they are known to incorporate certain radionuclides within their bodies;[24,25] require a source of water for drinking and other purposes;[26] forage over a large vegetated area and come into contact with plants which are eaten by other organisms; are colonizing insects and therefore are easily sampled; and produce a food (honey) which is consumed by humans.

2. Methods. The experiment was begun on June 29, 1972, when hives of bees were placed near the outfalls of three liquid waste disposal facilities (e.g., in Mortandad, DP and AP Canyons) at the Laboratory (see Fig. 12), where the insects had access to effluent water and vegetation which were potentially contaminated with various radionuclides. Seven hives were kept at a location remote to the study areas to serve as a source of uncontaminated background samples and to serve as replacement bees for future experiments.

Worker bees, which forage out from the hive as food and water gatherers, and hive bees, which are immature workers that minister to the larval bees within the hive, were collected periodically over a 170-day time interval with a battery powered automotive vacuum sweeper (Fig. 8). Some drones (males) were present in both the hive and worker bee samples. Initially, 20-50 gram samples of each bee type were collected; however, the quantity was increased to 150 grams to enhance the detection limits for ^{137}Cs. Freshly produced honey, which reflected recent food-gathering activities, along with the wax comb was sampled from within the hive. Effluent water (500 ml) was obtained from the stream channels in Mortandad, DP, and AP Canyons at the point closest to the hive and each water sample was filtered (Whatman 40) to remove the suspended particulate material (seston). The hives were positioned within 50 meters of the respective liquid waste streams and this water was the only immediate supply. Samples were prepared for ^{3}H, ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am analysis.

Fig. 8. Method used for collecting honeybees.

3. Results and Discussion.

a. Plutonium and Americium. The ^{238}Pu, ^{239}Pu, and ^{241}Am data for bees, effluent water, and the filtered portion of the water over the first 90 days of the experiment are presented in Tables A-II, A-III, and A-IV. A plot of the available data on the radionuclide content of the bees and the effluent water as a function of time indicated that there was little relationship between the plutonium content of the bees and the effluent water at corresponding sampling times. However, the data did indicate that the ratio of $^{238}Pu/^{239}Pu$ in the bees in DP and Mortandad Canyons were similar to the ratio of these isotopes in the effluent treated at the TA-21 and TA-50 facilities. Recall, for example, that TA-21 (which releases effluents to DP Canyon) now processes about 80% ^{239}Pu and 20% ^{238}Pu whereas the opposite is true for the TA-50 plant which releases liquid wastes to Mortandad Canyon. The ^{239}Pu content of the DP Canyon bees, in general, contained more ^{239}Pu than ^{238}Pu whereas in Mortandad Canyon, the bees contained more ^{238}Pu than ^{239}Pu. The significance of this finding (if indeed there is one) is not clear at this time, and awaits further investigation.

The ^{239}Pu content of water from the small seepage pool in AP Canyon, the liquid waste disposal area which has been unused for about nine years, was about a factor of 10 and 100 higher than the ^{239}Pu content of Mortandad and DP Canyon effluent water, respectively. Apparently, some fraction of the ^{239}Pu, which was released to AP Canyon from 1944-1964, is still soluble under the conditions that exist in the canyon.

The relative amount of Pu associated with the seston fraction of each water sample varied from a few percent to about 50% of the total. Therefore, the conclusion was that either a significant portion of the Pu in the water sample (at least 50%) was soluble or that the Pu was associated with colloidal material which the Whatman filters did not remove.

A final assessment of the plutonium and americium data for the bees will require the complete set of data. However, it was apparent that the concentrations of these radionuclides in bees were both low and comparable to values for other biotic materials here at Los Alamos[27] and at other locations in the United States.[28,29]

The analysis for plutonium and americium in honey samples was delayed due to the extreme difficulty encountered in ashing these samples.

b. Cesium-137. Concentrations of ^{137}Cs in all bee and honey samples throughout the 170 day observation period were not significantly different from zero ($\alpha = 0.05$) even though levels of this nuclide in DP and Mortandad Canyon water averaged about 50 pCi/liter and 1000 pCi/liter, respectively (see Tables A-II and A-III). Specific data on radiocesium metabolism in honeybees are not available. However, data for other insect species[30,31,32,33] show that ^{137}Cs, which is generally a soluble radionuclide, is readily incorporated into insect tissue just as it is in other faunal species. Therefore, it seems likely that the lack of measurable quantities of ^{137}Cs in the honeybees in the present study indicated that the bees were not ingesting the ^{137}Cs contaminated effluent water.

c. Tritium. A graphic summary of the tritium data over the first 120 days of the experiment for worker bees, honey, and effluent water from the canyons appears in Figures 9, 10, and 11. The tritium concentrations in hive bees, which closely followed the data for honey, were not included in the graphic summary.

The levels of tritium (pCi/ml of unbound water) in bees and honey from all of the canyons increased dramatically above the 1 pCi ^{3}H/ml which was measured in pre-experiment samples on June 29, 1972. For example, concentrations of tritium in worker bees from Mortandad, DP, and Acid Canyons increased to a maximum of 9600 pCi/ml in 75 days, 250 pCi/ml in 9 days, and 560 pCi/ml in 25 days, respectively. A general decrease in the tritium content of worker bees was noted for the remainder of the 170-day period. The overall behavior of tritium in hive bees and honey bees (i.e. dynamics and content) was very similar to the data for worker bees. It is interesting to note that the source of the tritium in the honey apparently was the hive bees which in turn were supplied with ^{3}H by the worker bees.

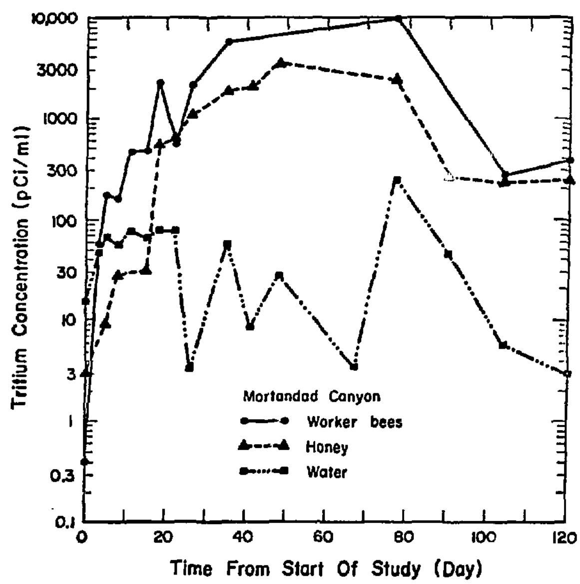

Fig. 9. Tritium concentrations in bees, honey and effluent water in Mortandad Canyon as a function of time following experiment initiation on June 29, 1972.

The data indicate that the transfer of tritium from worker bees to the hive bees to the honey was apparently very rapid. Studies[24,34,35] using ^{14}C, ^{198}Au, and ^{32}P labeled sugars have shown that the exchange of nourishment between all bees in the hive was rapid as evidence by the uniform radionuclide content of all bees in as little as one day.

The general decrease in the tritium content of bees (and honey) following the initial peak was probably associated with climatic changes. Maximum and minimum daily air temperatures in the vicinity of the hives decreased about 30 days after initiation of the experiment or on August 1, 1972, and minimum daily temperatures of 55°F were consistently measured about 60 days after experiment initiation. Studies by Farrar[35] indicated that bees perform little useful work at temperatures below 57°F. The incidence of precipitation was another climatic factor which was changing during the period of decreasing tritium levels in bees and honey and may have had a cooling and/or diluting effect. The rainy season at Los Alamos occurs in late July and August (20-60 days post-experiment initiation) and several heavy rains were recorded during this period in 1972.

Nearly all available evidence on tritium in the natural environment indicates that this radionuclide is not physiologically concentrated in biological systems.[36,37] Since bees require water for drinking and other purposes[26] it was presumed that they would drink the radionuclide contaminated effluent water and eventually come into equilibrium with it. This was either not the case or the effluent water was providing an insignificant amount of tritium to the bees because the tritium concentrations in Mortandad and AP Canhon bees were as much as a factor of 100 and 450, respectively, above the levels of the nuclide in the effluent water (Figs. 9 and 11). In contrast, the DP Canyon bees throughout the study period exhibited tritium concentrations which were about one-half of those in the effluent water.

A possible source of the unexpectedly high concentrations of tritium in Mortandad and AP Canyon samples could have been the pits which have been used for burial of high level tritium wastes (and other radionuclides as well). Such a pit is located within 300 meters of the Mortandad Canyon hive and during the summer this burial

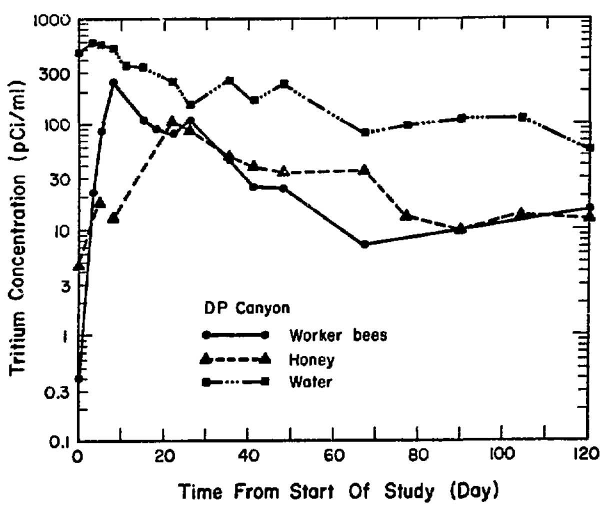

Fig. 10. Tritium concentrations in bees, honey and effluent water from DP-Los Alamos Canyon as a function of time following experiment initiation on June 29, 1972.

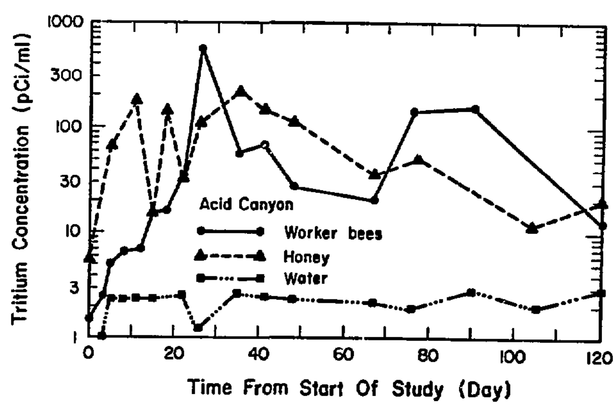

Fig. 11. Tritium concentrations in bees, honey and surface water in Acid Canyon as function of time follow-experiment initiation on June 29, 1972.

ground is covered with annual and biennial forbs including white sweet clover (Melilotus albus), a favorite nectar producing plant for honey bees.

A series of bee, honey, and water samples were taken at four different locations in the Espanola Valley at distances of 15-22 miles east and northeast of Los Alamos, to determine the levels of tritium in off-site bee colonies. In addition, a tritium analysis was also performed on one commercially available honey sample, bottled 190 miles north of Los Alamos in Saguache, Colorado. The results of these analyses which are presented in Table III show that tritium levels in all the samples ran from about 5-7 pCi/ml with the exception of one honey sample which measured about 11 pCi/ml.

The tritium content of the bees located in the effluent canyons on about the same date (October 25, 1972) was nearly 3 to 30 times higher than the Espanola Valley samples.

4. Conclusions. The use of the honey bee as an indicator of environmental plutonium and americium contamination cannot be assessed with the available data. It does seem likely, however, that the bees were not using the contaminated effluents as was anticipated (based on the ^{137}Cs and ^{3}H data). Honey bees are apparently very sensitive indicators of tritium in the environment at least during the summer months. The tritium content of vegetation, rodents, deer, coyotes, and two species of birds from the three canyon areas appears to be in equilibrium with the tritium content of the effluent water. However, levels of tritium in bees from two canyon areas were orders of magnitude higher than the effluent water. It was concluded that the wide ranging foraging habits of the bee make it an integrator and accumulator of tritium over a wide area. The bees, through the production of honey, also serve as a vector in the transport of tritium to man.

C. Radionuclide Content of Soils and Biota in Liquid Waste Disposal Areas

1. Background. This study was designed to provide data on the ecological behavior and significance of various radionuclides (especially plutonium) which are released to the environment in Laboratory-generated liquid waste effluents.

Specific short-range objectives of this study include the determination of

a. the ^{3}H, ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am content of sediment, vegetation, and fauna as a function of distance above and below the effluent outfalls in Mortandad, DP, and AP Canyons;

b. the vertical distribution of ^{137}Cs, plutonium, and americium in these stream bed sediments; and

c. the key species involved in the biological redistribution of the effluent associated radionuclides.

2. Methods. A permanent sampling network was established in all three canyons during the summer of 1972 (Fig. 12). Sampling stations which were permanently marked with aluminum stakes, were established at points 100 and 200 m above the waste discharge outfalls to serve as a source of "background" samples and also at 0, 20, 40, 80, 160, 320, 640, 1280, 2460, 5120, and 10,240 m below the outfalls. Considerably more sampling emphasis was placed on the areas immediately below the outfall since radionuclide concentration gradients were expected to be most dynamic in this region. A general review of the literature on the radioecology of ^{137}Cs, plutonium, and americium indicated that the sediments in the respective canyons would likely be the major reservoir of these radionuclides; therefore, considerable time was spent in evaluating sediment and soils-sampling techniques. Since the soils in the canyons are generally very sandy (and not rocky), it was decided that a core sampling device, which was designed to collect

TABLE III

THE TRITIUM CONTENT OF BEES, HONEY, AND SURFACE WATER FROM OFF-SITE LOCATIONS IN NEW MEXICO

Location	Collection Date	Bees (pCi/ml)	Honey (pCi/ml)	Surface Water (pCi/ml)	Air Miles From Los Alamos
Pojoaque, NM	10/26/72	8.0(0.51)[a]	7.0(0.51)	6.5(0.50)	15
Chimayo, NM	10/26/72	6.0(0.50)	6.1(0.50)	5.8(0.50)	22
La Mesilla, NM	10/26/72	6.6(0.50)	11.0(0.52)	6.3(0.50)	15
Hernandez, NM	10/26/72	6.1(0.50)	5.7(0.50)	6.1(0.50)	17
Saguache, CO	Unknown	---	5.5(0.49)	---	190

[a] The number in parenthesis indicates one standard deviation of the reported concentration and is based only on counting statistics.

a maximum of about 300 grams of sediment, would best suit the existing conditions. Such a sampling device would provide radionuclide concentration data in units of area and/or mass (e.g. pCi/cm^2 or pCi/g).

The concentrations of the various radionuclides were expected to vary by orders of magnitude down the length of the canyons, therefore, a disposable sampling device was required to prevent cross contamination of samples resulting from the repetitive use of just one sampler. A short section of 2.4-cm diameter plastic pipe, which was chosen as the coring device, was sharpened on one end and was gently driven into the sediment to a maximum depth of about 30 cm with a hammer. Each station was sampled at the center and two lateral positions in the stream channel for a total of three cores per station (Fig. 13). The coring device, which was rotated as it was being driven into the ground, compacted the contained 30 cm core about 2-3 cm. The depth of the core sample taken, in many cases, was less than 30 cm especially in the upper portions of the canyons where the sediments were shallow.

Individual sediment samples were sealed in a plastic bag to prevent cross contamination and they were frozen until the radionuclide analyses could be initiated. The frozen core sample from the center of the stream channel at each station was sectioned into a 0-2.5 cm layer, a 2.5-7.5 cm layer, a 7.5-12.5 cm layer and the remainder (i.e., below 12.5 cm) to provide data on the vertical distribution of ^{137}Cs, plutonium, and americium.

A pH measurement was performed on each sediment core including the two lateral samples and the individual sections from the center sample. The pH measurement technique, which employed a 2:1 (w/w)

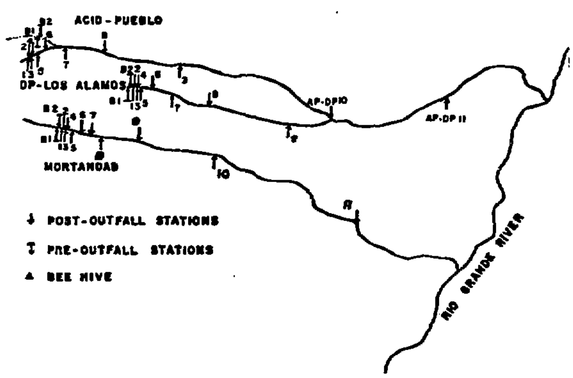

Fig. 12. Sampling locations for biotic and abiotic materials in the liquid waste disposal areas.

Fig. 13. Sediment sampling technique in the canyon stream channels. Note character of stream channel and vegetation in this view of upper Mortandad Canyon.

distilled water: sediment suspension and a glass electrode pH meter, followed procedures described by Peech.[38]

A sample of the most abundant grass, forb, shrub, and tree species present at each sampling station was collected to determine the key plant receptors of contaminant radionuclides. Only those plants which were directly rooted in the stream channel or that were likely to be inundated during high runoff periods were collected. The samples consisted of the complete above-ground portions of the grasses and forbs and the terminal leaves and stems of the shrub and tree species. No attempt was made to remove dust particles from the exterior of the plant surfaces.

Since it was not practical from a time and analytical standpoint to sample small mammals at each station, collections were made only in the two "background" areas above the respective outfall locations, and at distances of 0, 2560, and 10,240 m below the outfalls. Snap traps were positioned on a 6 x 8 grid network at each station (Fig. 14) with two traps at each grid point for a total of 96 traps per station. Eight grid points were established at 5-meter intervals along the stream channel and six points (three to a side) were established perpendicular to the stream channel at 10-meter intervals. Peanut butter was used as bait and each station was trapped for three nights (i.e., 288 trap-nights) without pre-baiting treatment. The grid point for each small mammal specimen was recorded to provide radionuclide data as a function of distance away from the stream channel (e.g., 0 m, 10 m, and 20 m). Each specimen was weighed, measured, and examined according to procedures outlined by Packard[39] to provide data on the physical and breeding characteristics of each species.

Authorized collections of mule deer, ravens, and Stellars' jays were made in each of the three canyons, including "background" locations which in the case of the

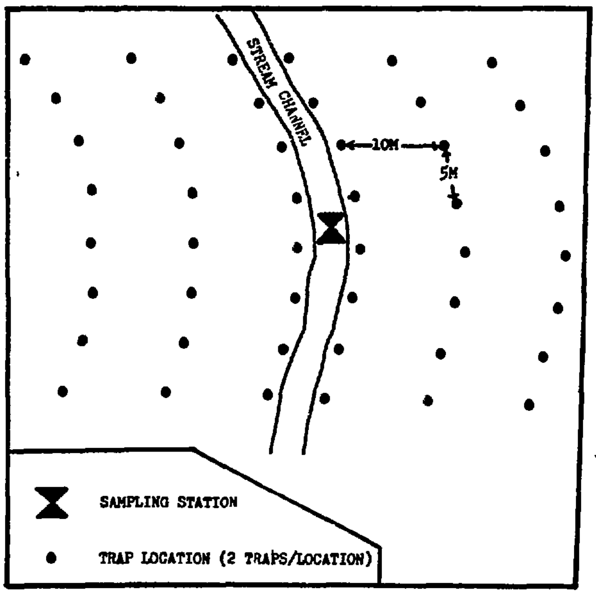

Fig. 14. Small mammal snap-trap grid network utilized at each sampling station.

birds was about 20 miles removed from the contaminated canyons. The deer collections were made during the summer of 1972, before migratory deer had moved into the area from the nearby mountains. Several animals, including some deer, skunks, coyotes, and porcupine, were obtained as road-killed specimens.

All faunal species were dissected into four portions, where possible, including the lung, liver, hide, and the eviscerated and skinned carcass. A greater variety of samples was taken from the larger animals and included the lungs, liver, kidneys, pulmonary lymph nodes, thyroids, skeletal muscle, and bone (thorasic vertebrae and femur). Tritium and ^{137}Cs analyses were performed on the carcass or muscle samples only.

The gastro-intestinal tract and brain was saved from most small mammal and bird specimens for eventual food-habits analysis and mercury determination.

3. Results and Discussion. A listing of the types and numbers of samples which were collected in the canyon study is presented in Table IV. The radionuclide analyses which have been completed are indicated in parentheses. It is obvious that the ^{3}H and ^{137}Cs analyses are nearing completion on all samples but are rather incomplete for plutonium and americium. The summaries

TABLE IV

ECOLOGICAL SAMPLE INVENTORY AND THE STATUS OF RADIONUCLIDE ANALYSIS.[a]

Sample Type	^{3}H	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am
Sediment	----	230(156)	230(9)	230(0)	230(0)
Vegetation	196(196)	196(194)	196(12)	196(12)	196(0)
Rodents	117(98)	117(98)	468(18)	468(18)	468(17)
Mule Deer	8(8)	12(12)	80(11)	80(11)	80(6)
Coyote	5(1)	5(1)	50(3)	50(3)	50(0)
Raven	6(6)	6(6)	36(11)	36(11)	36(0)
Stellers Jay	6(6)	6(6)	36(0)	36(0)	36(0)
Skunk	1(1)	1(1)	10(3)	10(3)	10(0)

[a]The values outside the parentheses indicate the number of samples collected while the values in parentheses indicate the number of completed radionuclide analyses.

for specific radionuclides in the various types of samples are presented in Tables V through XII. The collection locations referred to in the tables are identified on Figure 12.

The ^{3}H and ^{137}Cs data are emphasized in this report because the eco-distribution of these nuclides in the canyons will undoubtedly provide information which will be valuable in interpreting the plutonium and americium data.

The plutonium and americium content of some vegetation, rodents, and other fauna from the three canyons is summarized in Table V.

The ^{238}Pu and ^{239}Pu concentrations in vegetation ranged from minimums of about 0.3 fCi/g (wet) in samples taken in the lower reaches of the canyons to a maximum of 4800 fCi ^{238}Pu/g and 350 fCi ^{239}Pu/g in vegetation (Poa) near the effluent outfall in Mortandad Canyon. The maximum ^{238}Pu and ^{239}Pu concentrations measured in rodent tissues thus far were 7794 fCi/g (lung) and 6115 fCi/g (hide) but, in general, concentrations of plutonium in rodents were below 1000 fCi/g (i.e. 1 pCi/g). The plutonium and americium content of some tissues from mule deer, ravens, a skunk, and a coyote was, in most cases, below the sensitivity of the analytical techniques.

The data are too incomplete for rigorous interpretation at this time. There does appear to be, however, elevated plutonium and americium levels in biota near the effluent outfalls. In addition, the $^{238}Pu/^{239}Pu$ ratio in the biota apparently reflects the $^{238}Pu/^{239}Pu$ ratio in the effluent streams from the waste treatment facilities. Recall that this was also the case for the honey bees.

The tritium concentrations in vegetation, rodents, and other animals from the canyon areas along with corresponding background samples are shown in Tables VI, VII, and VIII.

TABLE V

THE Pu AND Am CONTENT OF SOME FAUNA AND FLORA FROM LIQUID WASTE DISPOSAL AREAS AT LOS ALAMOS

Sample Description	Collection Location	^{238}Pu (fCi/g wet)[a]	^{239}Pu (fCi/g wet)[a]	^{241}Am (fCi/g wet)[a]
VEGETATION				
Juniperus monosperma	MB-1[b]	<1.0	<1.0	
Poa sp.	MB-1	5.5 (0.35)[c]	1.2 (0.13)	
Poa sp.	MB-2	8.0 (0.8)		
Salix bebbiana	MB-2	<1.6	<1.9	
Psuedotsuga taxifolia	M-1	130 (10)	80 (8.0)	
Salix bebbiana	M-1	19 (1.7)	6.7 (0.65)	
Poa spp.	M-2	4800 (400)	350 (30)	
Quercus gambelii	M-2	30 (5.0)	4.0 (1.0)	
Quercus gambelii	M-3	57 (2.1)	95 (3.2)	
Physocarpus monogynus	M-3	29 (0.90)	7.5 (0.40)	
Pinus flexilis	M-4	50 (3.0)	6.0 (0.7)	
Poa spp.	M-4	2089 (86)	210 (10)	
Prunus virginiana	M-5	10 (1.0)	9.0 (1.0)	
Psuedotsuga taxifolia	M-6	22 (1.5)	16 (1.0)	
Acer negundo	M-8	2.3 (0.3)	0.4 (0.2)	
Quercus gambelii	M-8	1.8 (0.5)	4.0 (0.7)	
Quercus gambelii	M-9	4.4 (0.3)	2.3 (0.2)	
Acer negundo	M-9	1.3 (0.2)	1.0 (0.2)	
Bouteloua gracilis	M-10	17 (0.3)	3.0 (0.2)	
Gutierrezia sarothrae	M-10	ND[d]	ND	
Ribes cereum	M-10	2.9 (0.4)	2.7 (0.4)	
Rhus trilobata	M-11	1.4 (0.4)	2.2 (0.5)	
Ribes cereum	M-11	<29	<29	
Rhus trilobata	DP-8	1.3 (0.8)	5.0 (1.3)	
Quercus gambelii	DP-8	<0.6	2.0 (0.5)	
Pinus edulis	DP-9	0.17 (0.06)	1.2 (0.09)	
Poa spp.	DP-9	14 (1.1)	120 (5.0)	
Populus angustifolia	DP-9	1.1 (0.3)	5.4 (0.7)	
Juniperus sp.	DP-9	0.50 (0.10)	2.4 (0.20)	
Fallugia paradoxa	DP-9	54 (4.4)	19 (1.8)	
Rhus trilobata	DP-9	6.6 (1.0)	4.4 (0.8)	
Rhus trilobata	AP-8	1.5 (0.14)	4.4 (0.28)	
Verbascum thapsus	AP-8	1.1 (0.40)	1.6 (0.40)	
Pinus ponderosa	AP-8	ND	ND	
Rosa sp.	AP-8	0.70 (0.30)	2.8 (0.30)	
Poa fendleriana	AP-8	<1.7	96 (18)	
Verbascum thapsus	AP-9	0.50 (0.20)	1.6 (0.30)	
Poa spp.	AP/DP-10	8.1 (0.90)	200 (7.2)	
Fallugia paradoxa	AP/DP-10	<1.2	2.4 (0.90)	
Ribes cerum	AP/DP-11	<0.70	1.0 (0.50)	
Chrysothamnus parryhowardi	AP/DP-11	0.30 (0.10)	8.9 (0.50)	
Poa spp.	AP/DP-11	ND	ND	
RODENTS				
Petr[f] - Liver		<36	<36	<51
Lungs	A-Disposal[e]	<85	<85	-
Hide		46 (9.0)	26 (9.0)	17 (6.0)
Reme[f] - Lungs		<310	<310	<520
Hide	DP-Sewage[e]	<30	<30	<40
Pema[f] - Carcass	M-1	88 (4.1)	16 (1.8)	
Liver		<17	<17	30 (10)
Lungs		<63	<63	290 (80)
Hide		910 (70)	110 (20)	100 (20)
Pema - Whole Carcass	M-1	130	36	230

TABLE V continued

Sample	Description	Collection Location	(fCi/g wet)[a] ^{238}Pu	^{239}Pu	^{241}Am
Pema	- Whole Carcass	M-1	13	4.7	29
Sihi[f]	- Whole Carcass	M-1	8.3	2.2	13
Petr	- Liver	M-1	45 (15)	21 (10)	
	Lungs		1119(169)	407 (102)	
	Hide		594	57 (15)	
Petr	- Liver	M-1	22 (6.3)	4.2 (2.1)	
	Lungs		24 (54)	60 (60)	
	Hide		610 (70)	116 (25)	
Petr	- Liver	M-1	28 (10)	4.2 (3.1)	
	Lungs		148 (111)	74 (74)	
	Hide		1307(126)	189 (28)	
Pema	- Liver	M-9	19 (13)	7.4 (8.9)	
	Lung		5467(1367)	501 (364)	
Petr	- Liver	M-9	15 (6.1)	3.5 (4.3)	
	Lungs		67 (135)	27 (47)	
	Hide		24 (4.5)	3.1 (1.4)	
Petr	- Liver	M-9	0.30(3.9)	ND	
	Lungs		19 (23)	ND	
	Hide		18 (4.3)	4.7 (1.8)	
	Carcass		3.4 (0.95)	1.8 (0.57)	
Pema	- Liver	M-9	7.9 (4.5)	3.4 (2.3)	
	Lungs		410 (117)	111 (65)	
	Hide		26 (22)	4.3 (8.7)	
Petr	- Liver	M-11	87 (104)	121 (52)	
	Lungs		942	4172(673)	
	Hide		6.8 (5.2)	10 (6.2)	
Pema	- Liver	M-11	11 (19)	13 (9.7)	
	Lungs		7794(1798)	ND	
	Hide		13 (31)	8.7 (13)	
Petr	- Liver	M-11	20 (11)	2.5 (3.8)	
	Lungs		487 (133)	58 (58)	
	Hide		38 (22)	ND	
Petr	- Liver	M-11	ND	4.1 (7.1)	
	Lungs		15 (19)	ND	
	Hide		180 (108)	6115(1439)	
	Carcass		0.30(0.77)	0.77(0.48)	
Petr	- Liver	M-11	1.4 (2.7)	0.69(2.1)	
	Lungs		23 (29)	6.4 (16)	
	Hide		7.7 (7.7)	12 (7.2)	
	Carcass		1.5 (0.65)	ND	
Pema	- Whole Carcass	DP-1	310	1650	460

MULE DEER

Sample	Description	Collection Location	^{238}Pu	^{239}Pu
D-1	Hide	Parajito Canyon[e]	0.30(0.10)	<0.3
	Muscle		0.10(0.50)	<0.04
	Kidney		0.40(0.10)	<0.02
	Thyroid		17 (7.0)	<13
	Lymph node		<11	<11
	Thorasic Vertebrae		<0.6	<0.3
D-2	Thyroid	Mortandad Canyon	<4.3	<7.2
	Thorasic Vertebrae		0.28(0.09)	0.38 (0.10)
D-3	Kidney	DP Canyon	8.6 (0.80)	0.80 (0.20)
	Thyroid		<14	<10
	Liver		0.60(0.11)	0.12 (0.05)
	Lungs		0.07(0.01)	0.14 (0.02)
D-6	Kidney	R-Site[e]	0.16	0.28 (0.09)
	Thyroid		6.6 (3.6)	0.30 (1.6)
	Muscle		0.06(0.01)	0.09 (0.02)
D-7	Kidney	R-Site[e]	0.27(0.10)	<0.15
	Thyroid		8.3 (2.4)	2.4 (1.1)

TABLE V continued

	Sample Description	Collection Location	^{238}Pu		(fCi/g wet)[a] ^{239}Pu		^{241}Am
			RAVENS				
RA-1	Muscle	Mortandad Canyon	<0.3		<0.3		
	Feathers		<5.9		<0.48		
	Liver		<1.9		<1.9		
	Thorasic Vertebrae		5.1	(1.2)	4.5	(1.1)	
	Femur		<2.7		4.9	(1.5)	
RA-2	Muscle	Mortandad Canyon	<0.3		<0.3		
	Feathers		<7.0		31	(4.0)	
	Liver		<4.2		<5.5		
	Lungs		<6.8		<6.8		
	Femur		<4.1		<4.1		
	Thorasic Vertebrae		<11		<8.4		
			SKUNK				
SK-1	Muscle	Mortandad Canyon	<0.2		<0.2		
	Kidney		<4.0		<3.0		
	Thyroid		<280		<180		
			COYOTE				
C-1	Muscle	Parajito Road[e]	<0.04		<0.04		
	Kidney		<1.5		327	(29)	
	Thyroid		<26		<26		

[a] fCi = femtocuries = 10^{-15} curies.

[b] See Figure 12 for sampling station positions in the respective canyons. The letters M, DP and AP correspond to Mortandad, DP-Los Alamos, and Acid-Pueblo Canyons, respectively.

[c] ( ) = 1 standard deviation.

[d] Not Detectable

[e] Locations are all outside of liquid waste disposal areas.

[f] Petr = *Peromyscus truei*
Pema = *P. maniculatus*
Reme = *Reithrodontomys megalotis*
Sihi = *Sigmodon hispidus*

TABLE VI

TRITIUM IN RODENTS FROM LIQUID WASTE DISPOSAL AREAS AT LOS ALAMOS

Station[a]	Distance from Channel (meters)	Petr[b] (pCi/ml unbound water)	Pema	Reme
		Mortandad Canyon		
MB-1 & MB-2	10		5.0 (0.68)	
	20	4.7 (0.87)[c]		
M-1	0	23 (1.1)	19 (0.47)	
			38 (1.3)	
	10	28 (1.5)	18 (0.46)	
	20	15 (1.3)	18 (0.81)	
M-9	0		26 (1.3)	
	10	20 (0.79)		
		24 (1.3)	49 (2.7)	
		35 (1.2)		
		16 (1.1)		
	20	16 (0.79)		
M-11	0	12 (1.3)		
		18 (0.82)	20 (2.4)	13 (1.9)
		15 (1.3)		
		13 (1.2)		
	10	16 (1.4)	1.0 (0.62)	3.6 (1.3)
	20	10 (4.9)	5.1 (0.62)	4.5 (1.3)
			4.6 (1.3)	
		DP CANYON		
DPB-1 & DPB-2	10			1.7 (1.2)
	20	19 (1.7)		
		19 (2.4)		
		68 (11)		
		15 (1.3)		
		13 (0.75)		
DP-1	0	20 (0.82)	802 (2.1)	16 (1.4)
		32 (1.2)		25 (2.4)
				25 (1.1)
				21 (1.0)
	10	20 (2.4)		92 (1.8)
		19 (0.99)		19 (1.4)
		12 (1.3)		27 (2.4)
	20	13 (0.93)	35 (1.2)	27 (1.5)
				27 (1.5)
				43 (2.6)
DP-9	0			5.8 (1.3)
				7.7 (2.3)
	20	9.7 (0.66)		
		11 (2.0)		
		3.6 (0.67)		
		ACID CANYON		
APB-1 & APB-2	20	5.3 (0.41)		
		3.1 (0.46)		
		4.6 (1.3)		
		1.9 (0.67)		
AP-1	10	1.4 (0.74)		
		2.2 (0.66)		
	20	0.90 (0.66)		
AP-9	0			0.96 (1.3)
				4.7 (2.3)
				ND[d]
				7.0 (2.3)
	10			1.6 (0.66)
				1.7 (2.3)
				3.2 (0.86)
				2.9 (1.3)
	20	1.2 (0.44)		1.9 (0.66)
				ND
				0.75 (0.66)
				4.1 (2.3)
				0.42 (2.3)
AP/DP-11	0	5.3 (0.62)		
		4.5 (0.68)		
		3.2 (0.46)		
		4.1 (0.62)		
		0.47 (1.3)		
		1.9 (0.86)		
	20	3.4 (0.67)	2.2 (0.60)	1.0 (0.85)
		2.7 (0.86)	6.9 (2.3)	
		2.2 (1.3)		

[a] Station numbers are identified in Figure 12. The letters M, DP, and AP correspond to Mortandad, DP-Los Alamos and Acid-Pueblo Canyons respectively.

[b] Petr = *Peromyscus truei*
Pema = *P. maniculatus*
Reme = *Reithrodontomys megalotis*

[c] ( ) = 1 standard deviation

[d] ND = Not detectable

TABLE VII

TRITIUM IN VEGETATION FROM THE LIQUID WASTE DISPOSAL AREAS AT LOS ALAMOS

(pCi/ml unbound water)

Species	B-1	B-2	1	2	3	4	5	6	7	8	9	10	11
							Station Number[a]						
MORTANDAD													
Artemisia tridentata													5.0(0.80)[b]
Acer negundo									60 (1.6)	32 (1.3)	16 (1.0)		
Moss			13 (0.50)	10 (0.40)	8.0 (1.1)	15 (0.40)	19 (1.1)	22 (1.1)	40 (0.73)	33 (6.6)		5.0 (0.77)	6.0(0.81)
Lichens	7.9 (0.84)	9.4 (11)	30 (0.70)		22 (11)	38 (5.6)		25 (3.0)					
Ribes sp.												5.5 (0.79)	4.0(0.75)
Juniperus spp.	7.0 (0.82)	7.0(0.82)									11 (0.92)	8.0 (1.9)	7.0(0.82)
Quercus gambelii		[illegible] (0.88)	31 (0.61)	28 (0.57)	28 (1.2)	22 (1.1)		27 (1.2)	48 (1.5)	36 (1.3)	13 (0.95)		
Prunus virginiana							26 (1.2)	17 (1.0)					
Typha latifolia	9.0 (0.33)	7.0 (0.32)											
Pinus ponderosa	5.0 (0.78)	8.0 (0.32)		16 (0.41)	13 (0.94)						15 (0.98)		
Verbascum thapsus						18 (1.0)							
Berberis fendleri			22 (0.49)		11 (0.90)	14 (0.98)				25 (1.2)			
Salix spp.	7.0 (0.82)	9.0 (0.87)	32 (0.63)	16 (1.0)									
Pinus flexilis						16 (1.0)							
Physocarpus monogynus				21 (0.48)	10 (0.90)		18 (2.1)		47 (1.5)				
Psuedotsuga taxifolia			18 (0.44)	13 (0.37)	13 (0.94)			16 (1.0)	46 (1.5)	15 (0.99)			
Poa spp.	8.0 (0.85)	7.0 (0.83)	28 (0.57)	14 ((1.7)	15 (0.99)	15 (1.2)	22 (0.49)	24 (1.2)	43 (1.4)	24 (1.1)	11 (0.90)	11 (1.2)	6.0(0.80)
Rhus trilobata												5.0(0.78)	5.0(0.78)
Chrysothamnus parryihowardi												7.0(0.82)	7.0(0.83)
Algae			1.7 (0.30)	2.3 (0.30)	1.8(0.30)								
DP - LOS ALAMOS													
Moss	5.6 (0.40)	7.2 (0.40)		20 (1.4)			11 (0.40)		6.2 (0.40)		5.0 (0.77)	5.0 (0.77)	
Pinus edulis												5.0 (0.78)	
Quercus gambelii	10 (0.90)	10 (0.34)	41 (1.4)	103(2.1)		176(2.6)			37 (0.69)		6.0 (1.0)		
Juniperus spp.	8.0 (0.84)	9.0 (0.87)			51 (1.5)	38(1.4)	42 (1.4)	8.0 (0.85)	32 (0.62)			7.0 (0.83)	
Kochia scoparia			25 (1.2)	18 (1.0)	15 (0.50)	10(0.89)							
Poa spp.	8.5 (0.33)	8.0 (0.32)					14 (0.79)	44 (0.79)	26 (0.54)		7.0 (0.81)		
Populus angustifolia							46 (1.5)					5.0 (0.78)	

Rhus trilobata												6.0 (0.80)	
Fallugia paradoxa												8.0 (0.84)	
Bromus spp.			17 (1.0)	29 (1.2)								5.0 (0.78)	
Verbascum thapsus								12 (0.93)					
Salix spp.									45 (0.80)				
Pinus ponderosa		8.0 (0.32)				22 (1.1)	18 (1.0)				4.0 (0.76)	8.0 (0.84)	
Muhlenbergia pulcherrima					29 (1.2)	21 (0.70)							
Berberis fendleri									30 (0.60)				
Lichens			20 (10)										
ACID - PUEBLO													
Rhus trilobata										ND[c]		4.0 (0.75)	
Verbascum thapsis										5.0 (0.77)	4.0 (0.75)		
Pinus ponderosa										3.0 (0.72)	7.0 (0.82)		
Psuedotsuga taxifolia										5.0 (0.78)			
Poa pratensis	3.0 (0.72)	3.0 (0.73)	6.0 (0.41)	7.0 (0.82)	5.0 (0.77)	4.5 (0.76)	3.0 (0.73)		3.0 (0.74)	3.0 (0.96)	2.0 (0.70)	5.0 (0.78)	3.0 (0.73)
Salix spp.		3.0 (0.73)											
Berberis fendleri	4.0 (0.30)			5.0 (0.77)		5.0 (0.76)							
Rosa spp.										3.0 (0.82)			
Pinus edulis												5.0 (0.78)	
Melilotus spp.				4.0 (0.76)									
Fallugia paradoxa												3.5 (0.74)	5.0 (0.77)
Quercus gambelii	2.5 (0.30)	3.1 (0.30)				4.0 (0.75)	8.0 (0.85)	3.0 (0.73)	4.0 (0.75)	4.0 (0.75)			
Physocarpus monogynus			4.0 (0.75)						4.0 (0.74)				
Artemisia tridentata											4.0 (0.75)		
Prunus virginiana							4.0 (0.30)						
Moss			5.1 (0.40)		2.6 (0.30)			11 (0.40)	3.7 (0.40)	2.3 (1.7)			
Juniperus spp.										3.0 (0.73)	4.0 ([illegible].74)	2.0 (1.4)	5.0 (0.77)
Ribes sp.													2.0 (0.71)
Chrysothamnus parryihowardi				8.4 (0.40)								4.0 (0.75)	2.0 (0.70)
Lichens							6.7 (0.40)						

[a] Station numbers are depicted in Figure 12.

[b] ( ) = 1 standard deviation

[c] ND = not detectable

TABLE VIII

TRITIUM CONCENTRATION IN VARIOUS ANIMALS COLLECTED IN "BACKGROUND" AND LIQUID WASTE DISPOSAL AREAS

Species	Ident.	Collection Location	pCi ^3H/ml
Mule deer	1	Parajito Canyon[a]	4.8 (0.43)[b]
	2	Mortandad Canyon	10. (0.49)
	3	DP Canyon	21. (0.55)
	4	R-Site[a]	3.4 (0.35)
	5	Acid Canyon	4.4 (0.36)
	6	R-Site[a]	3.8 (0.75)
	7	R-Site[a]	2.8 (0.72)
	8	Parajito Road[a]	11. (0.43)
Coyote	1	Parajito Road[a]	11 (0.50)
Raven	1	Mortandad Canyon	3.7 (0.46)
	2	Mortandad Canyon	6.1 (0.47)
	3	DP Canyon	2.7 (0.34)
	4	DP Canyon	3.8 (0.35)
	5	Espanola, NM[a]	0.68 (0.33)
	6	Espanola, NM[a]	0.35 (0.33)
Stellars Jay	1	Mortandad Canyon	6.8 (0.38)
	2	Mortandad Canyon	6.6 (0.38)
	3	DP Canyon	6.6 (0.38)
	4	Acid Canyon	2.3 (0.34)
	5	Chapadera Canyon[a]	1.5 (0.34)
	6	Chapadera Canyon[a]	1.7 (0.34)
Skunk	1	Mortandad Canyon	9.9 (0.49)

[a] collected outside liquid waste disposal areas
[b] ( ) = 1 standard deviation

Inspection of the data in the tables indicates that the tritium which is present in luquid waste effluents is being dispersed into the biotic components of Mortandad and DP Canyons, a finding which is not surprising in light of present knowledge on this nuclide.[36,40] On the other-hand, the tritium concentrations in Acid Canyon samples were uniformly low both above and below the site of the effluent outfall which may indicate that tritium was not released into this canyon in very large amounts or that any tritium which was released into the canyon was flushed out over the intervening 9 years since the TA-45 waste treatment facility was dismantled.

The up-stream or pre-outfall vegetation in Mortanded and DP Canyons contained about 5-10 pCi ^3H/ml but below the outfall contained as much as 48 pCi ^3H/ml and 176 pCi ^3H/ml, respectively. A similar pattern was evident for rodents where tritium levels increased from 5 and 15 pCi/ml to a maximum of 49 and 802 pCi/ml in Mortandad and DP Canyon samples, respectively. Mule deer, ravens, and Stellars jays which were collected from the canyon areas contained from 2 to 5 times higher tritium concentrations than pre-outfall samples. Recall that background bird samples were obtained about 20 miles north of the Los Alamos area.

The tritium content of the effluent water as a function of distance above and below the outfall areas in each canyon was not measured in this study because similar measurements are part of the Laboratory's environmental surveillance program.[1] The point to be made is that the maximum concentrations of tritium which were observed in the present study in biota corresponds in location (i.e. distance below effluent outfall) to the maximum tritium levels which were observed in surface and ground water in the respective canyons. In no case was the tritium level in the biota higher than the effluent water.

Cesium-137

The summary of ^{137}Cs concentrations in sediments, vegetation, rodents, and other animal species appear in Tables IX, X, XI, and XII.

It was readily apparent from the data that the alluvial sediment in each canyon was the major reservoir for this nuclide. The data also indicated that virtually all of the ^{137}Cs inventory in sediment, vegetation, and rodents from Mortandad and DP Canyons was deposited within 2560 m of the respective outfalls.

The maximum ^{137}Cs levels in sediments (3361 pCi/g dry), vegetation (40 pCi/g wet), and rodents (7 pCi/g wet) in Mortandad Canyon was observed near the point where the effluent water disappears into the alluvium. In Mortandad Canyon this point occurs about 500 m below the outfall. Maximum ^{137}Cs levels in DP Canyon sediments (820 pCi/g dry), vegetation (159 pCi/g wet) and rodents (209 pCi/g wet) were also measured near the point where surface water disappears underground (i.e. near the outfall).

The ^{137}Cs content of Acid Canyon samples as a function of distance below the effluent outfall did not change dramatically.

TABLE IX

^{137}CS IN ALLUVIAL SOILS FROM LIQUID WASTE DISPOSAL AREAS AT LOS ALAMOS

(pCi/g dry weight)

Station No.	0-2.5 cm[a]	2.5-7.5 cm	7.5-12.5 cm	Remainder
		MORTANDAD		
B-1[b]	1.7 (0.25)[c]	1.4 (0.38)	0.17 (0.24)	
B-2	ND[d]	1.6 (0.22)	14 (1.8)	0.26 (0.09)
1	3105 (22)			
2	1086 (6.7)	184 (6.5)	22 (0.87)	
3	719 (11)	1353 (14)	1068 (3.4)	
4	922 (6.8)	1376 (8.7)	768 (7.4)	22 (0.59)
5	207 (2.0)	1232 (13)		291 (2.8)
6	3361 (20)	643 (8.8)	1235 (8.6)	1961 (9.6)
7	298 (10)	367 (2.3)	413 (5.5)	469 (7.8)
8	129 (2.4)	180 (6.4)	109 (2.6)	68 (0.28)
9	67 (2.3)	154 (2.5)	88 (2.2)	18 (0.46)
10	1.3 (0.36)	ND	ND	0.14 (0.06)
11	ND	ND	ND	ND
		DP-LOS ALAMOS		
B-1	ND	0.02 (0.13)	0.16 (0.22)	ND
B-2	ND	ND		ND
1	820 (8.0)	567 (4.7)	100 (2.3)	52 (1.3)
2	442 (8.0)	560 (3.8)	214 (4.6)	254 (2.7)
3	28 (0.81)	2.3 (0.12)	3.2 (0.13)	2.9 (0.09)
4	747 (6.6)	158 (3.1)	23 (0.15)	5.2 (0.18)
5	15 (0.65)	21 (0.84)	19 (0.77)	45 (0.78)
6	11 (0.47)	13 (0.22)	10 (0.23)	20 (0.61)
7	42 (0.41)	91 (2.3)	59 (0.20)	42 (0.83)
8	12 (0.36)	14 (0.48)	18 (0.23)	15 (0.17)
9	1.1 (0.35)	1.7 (0.20)	3.2 (0.29)	2.8 (0.17)
		ACID-PUEBLO		
B-1	ND	ND	0.59 (0.04)	0.76 (0.12)
B-2	ND	ND		
1	ND	0.05 (0.03)		
2	3.9 (0.30)			
3	0.38 (0.16)	1.4 (0.14)	ND	11 (1.5)
4	ND	5.4 (0.25)	29 (0.83)	20 (0.27)
5	0.31 (0.27)	0.51 (0.12)	1.7 (0.15)	1.2 (0.07)
6	ND	1.0 (0.26)	1.8 (0.12)	0.92 (0.16)
7	0.29 (0.41)	0.85 (0.12)	ND	0.72 (0.22)
8	ND			ND
9	ND	ND	ND	ND
10	ND	ND	ND	0.24 (0.04)
11	3.9 (0.35)	ND	0.03 (0.20)	0.26 (0.05)

[a] Soil cores were cut into 4 sections. The remainder section was comprised of soil from the 12.5 cm depth to a maximum of 30 cm

[b] Sample numbers are depicted in Figure 12

[c] ( ) = 1 standard deviation

[d] ND = not detectable

There were residual pockets of ^{137}Cs contamination in Acid Canyon sediments as evidenced by the ^{137}Cs content of the core sections at station numbers three and four. However, it apoears that the ^{137}Cs which was released into Acid Canyon has either been flushed out of the canyon or it has been diluted considerably with uncontaminated sediments.

There is some evidence which suggests that ^{137}Cs is moving down the channel during periods of high runoff. For example, elevated ^{137}Cs concentrations in Mortandad sediments were measured about 1 mile below the point where a permanent flow of surface water exists. In addition, elevated ^{137}Cs levels in DP Canyon sediment were measured nearly 2 miles below the point where the effluent disappears into the alluvium. The runoff from heavy summer rains carries a tremendous particulate load and could carry the radionuclide contaminated sediments downstream.

A combination of factors including the mixing action of runoff waters and the sandy nature of the sediments may account for the fact that the vertical distribution of ^{137}Cs extended well below the five inch depth. The remainder section (i.e. 12.5-30 cm) of the core samples contained as much as 30% (Mortandad), 45% (DP), and 85% (AP) of the total ^{137}Cs activity.

The ^{137}Cs content of mule deer from Mortandad and DP Canyons was also elevated above "background" samples. Deer numbers 2 and 3 from Mortandad and DP Canyons had ^{137}Cs concentrations in muscle of 1.1 pCi/g (wet) and 1.8 pCi/g while deer from background locations measured only 0.02 (No. 1), 0.71 (No. 4), 0.05 (No. 6), 0.02 (No. 7), and 0.05 (No. 8) pCi/g. The ^{137}Cs content of the AP Canyon deer was also low (0.03 pCi ^{137}Cs/g). The mobile nature of the mule deer is certainly recognized and this fact must be considered in relation to background and contaminated canyon samples. However, deer numbers 2, 3, 5, 6, and 7 were shot in areas where they were repeatedly

TABLE X

^{137}Cs IN VEGETATION FROM THE LIQUID WASTE DISPOSAL AREAS AT LOS ALAMOS

(pCi/g wet weight)

Species	Station Number[a] B-1	B-2	1	2	3	4	5	6	7	8	9	10	11
MORTANDAD													
Artemisia tridentata													0.12(0.04)
Berberis fendleri			1.1 (0.11)[b]		0.17(0.04)	0.79(0.11)				0.91(0.06)			
Acer negundo									0.38(0.04)	0.20(0.01)	0.20(0.04)		
Chrysothamnus parryihowardi												0.04(0.01)	0.10(0.05)
Moss[c]			12 (0.76)	14 (0.62)	42 (0.49)	110 (2.4)	9.1 (1.7)	166 (5.2)	93 (3.7)	339 (2.6)		6.1 (0.72)	1.2 (0.37)
Lichens[c]	8.0 (0.48)	34 (3.5)	58 (1.9)		115 (3.0)	166 (9.1)		23 (0.81)					
Juniperus spp.		0.03(0.02)									0.11(0.01)		0.002(0.02)
Quercus gambelii			1.1(0.004)	5.7 (0.09)	1.9 (0.06)	3.7 (0.07)		0.24(0.05)	0.46(0.06)	0.25(0.04)	0.06(0.04)		
Prunus virginiana							0.54(0.07)						
Ribes sp.												0.16(0.03)	0.15(0.03)
Poa spp.	0.06(0.04)	0.70(0.15)	28 (0.18)	54 (0.38)	16 (0.17)	5.8 (0.12)	40 (0.40)	33 (0.25)	3.6 (0.11)				
Typha latifolia	0.10(0.03)	0.03(0.01)											
Pinus ponderosa	0.07(0.02)	0.06(0.01)		0.47(0.02)	0.33(0.03)						ND[d]		
Verbascum thapsus						9.3(0.12)							
Salix spp.	0.09(0.11)	0.05(0.01)	9.6 (0.06)	32 (0.17)									
Pinus flexilis						0.08(0.05)							
Physocarpus monogynus				4.3 (0.10)	0.15(0.03)		1.0(0.05)		13 (0.11)				
Psuedotsuga taxifolia			1.1 (0.02)	0.38(0.03)	0.10(0.02)			0.44(0.04)	0.21(0.02)				
Rhus trilobata												0.09(0.03)	0.19(0.03)
Bouteloua gracilis												0.52(0.09)	
Gutierrezia sarothrae												0.22(0.05)	
Algae[c]			2043(122)	1548(54)	1077(53)								
DP - LOS ALAMOS													
Pinus edulis											0.11(0.02)		
Berberis fendleri									0.49(0.11)				
Kochia scoparia			160(0.40)	86 (0.33)	1.6(0.11)	9.0 (0.10)							
Moss[c]	3.6(0.55)	1.0(0.18)					50 (1.1)		25 (0.69)		12 (0.79)	26 (0.99)	
Populus angustifolia							0.48(0.03)				0.12(0.02)		
Juniperus spp.	0.08(0.02)	0.07(0.02)	0.66(0.03)		0.13(0.02)	0.34(0.03)	0.19(0.02)	0.08(0.04)	0.14(0.03)		0.33(0.03)	0.07(0.02)	
Quercus gambelii	0.21(0.02)	0.13(0.05)		1.3(0.45)		0.99(0.23)			0.11(0.02)		0.19(0.03)		

Fallugia paradoxa											0.13(0.04)		
Poa spp.	ND	0.06(0.17)					0.53(0.09)	1.1 (0.06)	2.2(0.07)				
Muhlenbergia pulcherrima					0.19(0.09)	0.10(0.06)							
Pinus ponderosa		0.09(0.01)					0.05(0.01)			0.24(0.03)	0.22(0.01)		
Verbascum thapsus								0.13(0.01)					
Salix spp.									0.67(0.01)				
Lichens[c]			1700(32)										
Rhus trilobata										0.36(0.04)	0.10(0.03)		
						ACID - PUEBLO							
Artemisia tridentata											0.05(0.05)		
Berberis fendleri			0.10(0.04)	0.24(0.21)		0.19(0.05)							
Prunus virginiana							0.23(0.05)						
Chrysothamnus parryihowardi												0.08(0.02)	0.10(0.02)
Moss[c]			12 (0.25)		3.7 (0.55)			6.4(0.83)	2.1(0.67)	3.5(0.24)			
Rosa spp.										0.20(0.06)			
Juniperus spp.										ND	0.07(0.02)	0.12(0.03)	0.18(0.04)
Quercus gambelii	ND	0.04(0.04)				0.36(0.06)	0.29(0.02)	ND	0.32(0.05)	0.06(0.02)			
Fallugia paradoxa												0.07(0.03)	0.17(0.03)
Ribes spp.													0.07(0.02)
Poa spp.	ND	0.07(0.04)		0.12(0.19)	0.10(0.05)	0.10(0.04)	0.06(0.03)		0.06(0.06)	0.11(0.02)	0.03(0.03)	0.31(0.10)	0.24(0.12)
Pinus edulis												0.12(0.01)	
Pinus ponderosa										0.12(0.02)	0.06(0.01)		
Verbascum thapsus										0.06(0.02)	0.05(0.01)		
Salix spp.		0.06(0.01)											
Melilotus spp.				0.45(0.07)									
Physocarpus monogynus			0.25(0.07)						0.47(0.05)				
Pseudotsuga taxifolia										0.24(0.01)			
Rhus trilobata										0.19(0.03)		0.16(0.03)	
Lichens[c]				8.3(0.5)			ND						

[a] Station numbers are depicted in Figure 12

[b] ( ) = 1 standard deviation

[c] pCi/g dry weight

[d] ND = not detectable

observed during the summer of 1972. The ^{137}Cs data for birds were variable (Table VII) and did not conclusively show that birds from the radionuclide contaminated canyon areas contained higher concentrations of this nuclide.

The pH measurements of core samples collected in Mortandad, DP, and AP Canyons are summarized in Figures 15 and 16. Since no significant differences in soil pH were found with either depth (2.5 cm core increments to bedrock) or horizontal location at each sampling position, the average soil pH values of all samples taken at the same station are presented in the figures. The samples taken 200 and 100 m above the outfall were plotted at distances of 1 and 20 m in these figures.

The figures show a dramatic change in soil pH as a function of distance above and below the outfall areas in the two canyons currently receiving radioactive wastes: Mortandad and DP Canyons. The soil pH values in Mortandad and DP Canyons increase from about 6.6 and 7.6 at the pre-outfall stations to post-outfall maximum values of 9.0 and 9.2, respectively.

One explanation for these large pH changes is that various components of the alluvial soils have reacted with the relatively high levels of effluent sodium added during neutralization or flocculation of wastes in the treatment plants. Soil alkalinization has occurred to a large extent in some canyon stations and has resulted in soils with an undue accumulation of exchangeable sodium and sodium carbonate and with a pH greater than about 8.3. The high pH of these soils is due to the hydrolysis of sodium carbonate and sodium-soil complexes:

$$Na_2Co_3 + 2H_2O \rightleftharpoons 2NaOH + H_2CO_3$$

$$\text{Na-soil} + H_2O \rightleftharpoons \text{H-soil} + NaOH$$

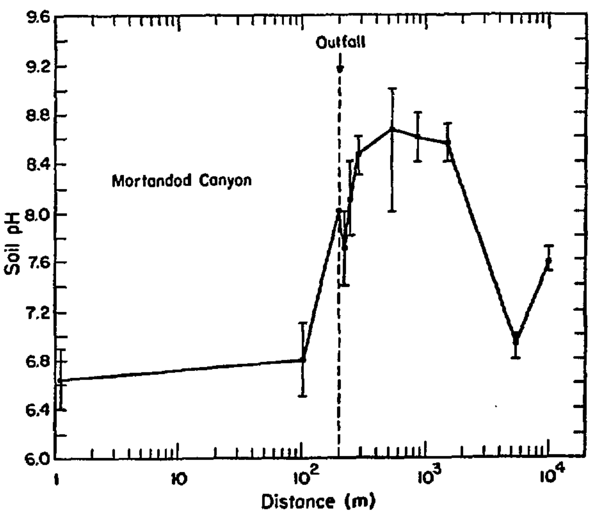

Fig. 15. Relationship of soil pH to distance from the radioactive waste outfall in Mortandad Canyon (1 meter distance represents location of samples taken 200 m before outfall).

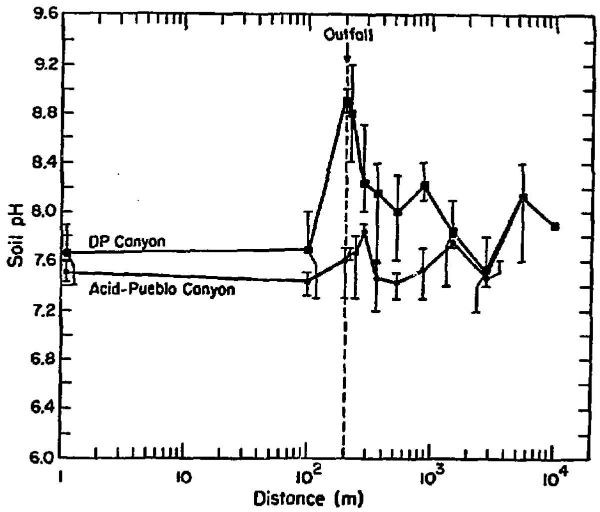

Fig. 16. Relationship of soil pH from the radioactive waste outfall in DP and Acid-Pueblo Canyons (1 meter distance represents location of samples taken 200 m before outfall).

TABLE XI

THE ^{137}Cs CONTENT OF RODENTS FROM LIQUID WASTE DISPOSAL AREAS AT LOS ALAMOS

Station	Distance From Channel (Meters)	Petr[a] (pCi/g wet carcass)	Pema (pCi/g wet carcass)	Reme (pCi/g wet carcass)
		MORTANDAD CANYON		
MB-1 & MB-2[b]	10		0.60 (0.43)	
	20	0.71 (0.44)[c]		
M-1	0	1.2 (0.49)	<0.21	
			2.3 (0.55)	
			<0.21	
	10	<0.21		
	20	0.05 (0.09)	<0.21	
M-9	0		2.2 (0.68)	
	10	0.16 (0.17)	<0.21	
		<0.21		
		0.87 (0.77)		
		0.08 (0.41)		
	20	0.47 (0.48)		
M-11	0	0.22 (0.43)	7.0 (0.18)	1.7 (0.81)
		0.85 (0.48)		
		<0.21		
		<0.21		
	10	<0.21	<0.21	0.69 (0.74)
	20	<0.21	0.82 (0.46)	<0.21
			<0.21	
		DP CANYON		
DPB-1 & DPB-2	10			1.7 (1.2)
	20	<0.21		
		1.5 (0.32)		
		0.97 (0.38)		
		0.85 (0.35)		
		0.31 (0.45)		
		6.5 (0.41)		
DP-1	0	96 (1.0)	209. (0.54)	<0.21
		84 (1.4)		131 (1.7)
				113 (0.73)
				0.23 (0.86)
	10	62 (0.92)		1.4 (0.62)
		< 0.21		116 (1.9)
		94 (1.5)		148 (2.2)
				133 (1.9)
				25 (1.4)
	20	< 0.21	0.42 (0.68)	1.2 (0.30)
		59 (1.3)		1.9 (0.39)
				0.85 (0.92)
DP-9	0			<0.21
				<0.21
	20	<0.21		
		0.81 (0.47)		
		<0.21		
		ACID CANYON		
APB-1 & APB-2	20	< .21		
		.45 (.35)		
		< .21		
		< .21		
AP-1	10	.34 (.51)		
		.02 (.41)		
	20	.22 (.34)		
AP-9	0			0.54 (1.0)
				<0.21
				4.5 (0.97)
				0.08 (1.0)
	10			3.3 (0.96)
				1.1 (0.97)
				<0.21
				<0.21
				<0.21
	20	0.23 (0.47)	<0.21	<0.21
		<0.21		<0.21
				<0.21
				1.8 (0.95)
				0.47 (0.95)
AP-DP-11	0	<0.21		
		0.52 (0.42)		
		0.23 (0.51)		
		<0.21		
		1.8 (0.39)		
		<0.21		
		0.05 (0.36)		
		0.95 (0.49)		
	20	0.19 (0.41)	0.34 (0.18)	1.7 (0.46)
		0.95 (0.28)	<0.21	
		2.0 (0.34)		

[a] Petr = Peromyscus truei
Pema = P. maniculatus
Reme = Reithrodontomys megalotis

[b] Station numbers are depicted in Figure 12.

[c] ( ) = 1 standard deviation.

Maximum ^{137}Cs concentrations were found in very alkaline soils in Mortandad and DP Canyons. This observation, along with literature citations inferring that soil pH is important in determining the solubility of other radionuclides, suggests that the role of soil pH in determining the availability of ^{137}Cs, plutonium, and americium will be a fruitful subject area to be investigated in 1973.

Over 95% of the small mammal species caught in snaptraps were either Peromyscus maniculatus, Peromyscus truei, or Reithrodontyms megalotus. Approximately two-fifths of the catch was P. truei, an additional two-fifths was R. megalotus and the remaining fifth was P. maniculatus. The average weight of male and female P. maniculatus without regard to collection location and age was 18.3 grams (n=12) and 19.1 grams (n=8) respectively. Corresponding data for P. truei and R. megalotus were 22.1 grams (n=25), 22.3 grams (n=31); and 10.2 grams (n=22), 12.4 grams (n=17), respectively. The sex ratio (males:females) based on the numbers of samples indicated by the weight data above was 1.5, 0.8, and 1.3 for P. maniculatus, P. truei, and R. megalotus, respectively.

Most of the small mammal specimens were in a nonbreeding condition at the time of collection. However, uterine scars were observable in nine _P. truei_ and two _P. maniculatus_, and litter sizes for these samples varied from 5-16 and 7-9 respectively.

Conclusions

The available data indicate that there is a definite accumulation of ^{3}H and ^{137}Cs in the biota below the liquid waste outfalls in Mortandad and DP Canyons but not in Acid Canyon. The extent of the ^{3}H and ^{137}Cs contamination in Mortandad and DP Canyons is confined primarily to the area within about 2500 meters of the waste outfalls. The plutonium content of a limited number of samples indicate that elevated levels may be present in samples near the outfalls.

IV. A 27-YEAR POST-SHOT SURVEY OF THE SOILS AND BIOTA AT TRINITY SITE

A. Background

Samples of soils and biota from the fallout pathway of the Trinity shot near Alamagordo, New Mexico in 1945 provided evidence for the bioaccumulation of radionuclides (particularly Pu) produced by this weapon.[41]

The radioecological group at LASL decided to resurvey the Trinity area to determine the concentrations of radionuclides in soils, vegetation and assorted animal life. Such a resurvey will provide data on the biological availability of weapons produced radionuclides which have "aged" in a natural environment for over 27 years.

B. Methods and Results

A sampling transect which duplicated Larsons work[41] was initiated at ground zero and continued in a NE direction (along the fallout pathway) at five mile increments out to a distance of 35 miles (Fig. 17) and each location was marked on a U. S. Geological Survey map of the area. Soil and biota collection were described earlier.

The kinds and numbers of samples which were collected are described in Table XIII. Preliminary data indicate that the samples contain several radionuclides including ^{137}Cs, ^{60}Co, ^{90}Sr-^{90}Y, ^{133}Ba, $^{152-155}Eu$, $^{238-239}Pu$, and ^{241}Am.

TABLE XII

THE ^{137}Cs CONTENT OF VARIOUS ANIMALS COLLECTED FROM BACKGROUND AND LIQUID WASTE DISPOSAL AREAS

Species	Ident.	Collection Location	pCi $^{137}Cs/g$[c]
Mule Deer	1	Parajito Canyon[a]	0.02 (0.007)[b]
	2	Mortandad Canyon	1.1 (0.004)
	3	DP Canyon	1.8 (0.01)
	4	R-Site[a]	0.71 (0.02)
	5	Acid Canyon	0.03 (0.008)
	6	R-Site[a]	0.05 (0.004)
	7	R-Site[a]	0.02 (0.002)
	8	Parajito Road[a]	0.05 (0.008)
Coyote	1	Parajito Road[a]	0.28 (0.02)
Raven	1	Mortandad Canyon	0.13 (0.08)
	2	Mortandad Canyon	<0.029
	3	DP Canyon	0.015 (0.034)
	4	DP Canyon	<0.029
	5	Espanola, NM[a]	0.033 (0.062)
	6	Espanola, NM[a]	<0.029
Stellars Jay	1	Mortandad Canyon	<0.029
	2	Mortandad Canyon	0.098 (0.30)
	3	DP Canyon	0.26 (0.34)
	4	Acid Canyon	<0.029
	5	Chapadera Canyon[a]	<0.029
	6	Chapadera Canyon[a]	<0.029
Skunk	1	Mortandad Canyon	0.01 (0.04)

[a] Samples were obtained outside the liquid waste disposal areas.

[b] ( ) = 1 standard deviation.

[c] pCi/g wet muscle

TABLE XIII

TYPES OF SAMPLES COLLECTED ON THE RADIONUCLIDE RESURVEY TRANSECT AT TRINITY[a]

	Miles NE of Ground Zero							
Type of Sample	0	+5	+10	+15	+20	+25	+30	+35
Soil	6	1	1	1	1	1	1	1
Vegetation[b]	5	1	1	1	1	1	1	1
Rodents	4	5	3	1	4	5	1	0
Turtles	1	0	1	0	0	0	0	0
Ground dwelling Insects	30	0	0	0	0	0	0	0
Jackrabbits[c]								
Rattlesnake[c]								

[a] Number collected are indicated in table.

[b] A forb, grass and shrub species was collected at each station.

[c] Both rabbits were road-kills at eight miles west of ground zero. The rattlesnake was collected 15 miles west of ground zero.

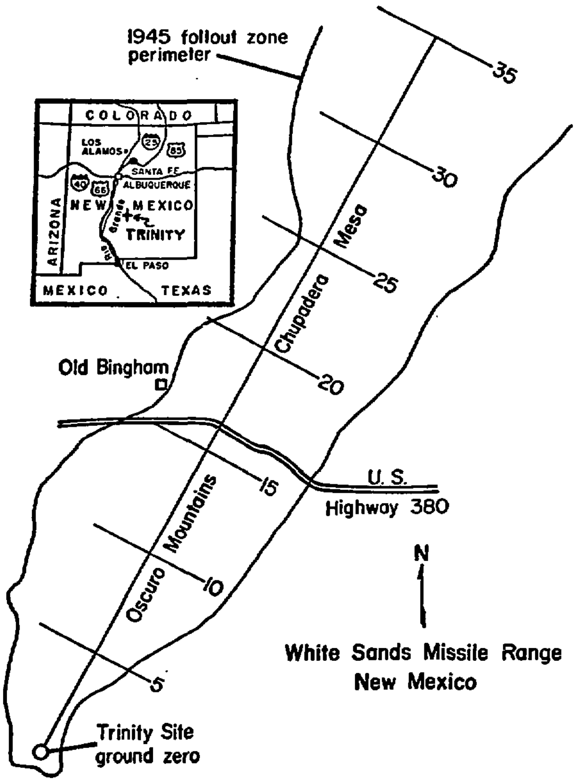

Fig. 17. Sampling transect utilized for the radioecological resurvey of Trinity.

V. SUMMARY

A listing of the fauna and flora occurring in the Los Alamos study area presently includes 139 plant species and 237 animal species. The 50 mammalian and poikilothermic species listed are all permanent residents of the area. However, only 37 of the 187 avian species are permanent residents and an additional 46 avian species use the area for breeding during the summer. An estimate of the type and density of vegetative cover in the study area has been initiated using black and white and color infrared aerial photographs. Three principal soil association areas have been identified at Los Alamos.

A summary of the use histories of the liquid waste disposal areas including accumulative plutonium additions was completed. Mortandad (M), DP-Los Alamos (DP), and Acid-Pueblo (AP) Canyons have each received about 42 mCi, 32 mCi, and 170 mCi Pu.

The radionuclide data for honey bees indicate that this insect may be an effective monitor for tritium contamination in the environment. The source of tritium to the honey bees, which achieved body concentrations of about 10 nCi ^{3}H/ml of unbound body water during the summer of 1972, is not known, it is suspected that nectar-producing vegetation in solid waste burial areas may be a possible source.

Permanent sampling transects were established in the liquid waste disposal areas to determine the eco-distribution of ^{3}H, ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am Tritium appears to be uniformly distributed in the effluent water and biota at corresponding sampling locations, whereas most of the ^{137}Cs is associated with the stream channel alluvium. There has been some redistribution of ^{137}Cs from the effluent water and/or sediments to the plants and animals. In general, the ^{3}H (exclusive of ground water) and ^{137}Cs present in the liquid waste disposal areas is confined to within one mile of the waste outfalls, although there is some evidence that ^{137}Cs-contaminated sediment may be carried downstream during high runoff periods. There is also evidence that effluent-associated plutonium may be present in (or on) some of the biota. The pH of stream channel alluvium increased by as much as 2 pH units from pre-outfall to post-outfall locations in some of the liquid disposal areas. The role that pH has in mediating plutonium redistribution is currently under investigation.

Data are also presented on the physical and breeding characteristics of 110 rodents from the study area.

An investigation of radionuclides in the soils and biota at Trinity, the site of the world's first nuclear detonation, is also described.

ACKNOWLEDGMENTS

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PUBLICATIONS

Three papers relating to the radioecological studies at the Laboratory have been submitted for presentation and publication in 1973

a. T. E. Hakonson, L. J. Johnson, and W. D. Purtymun, "The Application of the Honey Bee as an Indicator of Environmental Radiocontamination," submitted to the 18th Annual Health Physics Society Meeting, June 17-21, 1973 in Miami, Florida (accepted on February 21, 1973).

b. T. E. Hakonson, L. J. Johnson, and W. D. Purtymun, "The Eco-Distribution of Plutonium in Liquid Waste Disposal Areas at Los Alamos," submitted to the Third International Congress of the International Radiation Protection Association, September 9-14, 1973 in Washington, D.C. (accepted on March 23, 1973).

c. L. J. Johnson and T. E. Hakonson, "Distribution of Environmental Plutonium in the Trinity Site Ecosystem After 27 Years," submitted to the Third International Congress of the International Radiation Protection Association, September 9-14, 1973 in Washington, D.C. (accepted on March 23, 1973).

Two additional manuscripts were prepared in Laboratory report form

d. T. E. Hakonson, J. W. Nyhan, L. J. Johnson, and K. V. Bostick, "Ecological Investigation of Radioactive Materials in Waste Discharge Areas at Los Alamos," Los Alamos Scientific Laboratory (in preparation).

e. T. E. Hakonson, J. W. Nyhan, and K. V. Bostick, "An Ecological Inventory of the Los Alamos Environs," Los Alamos Scientific Laboratory Report (in preparation).

Six papers relating to the Division of Biomedical and Environmental Research funded research (Contract No. AT(11-1)-1156), and National Science Foundation funded research (Grant No. GB-31862X) at Colorado State University, were also prepared

f. T. E. Hakonson and F. W. Whicker, "Cesium Kinetics in a Montane Lake Ecosystem," (manuscript being reviewed by co-author).

g. T. E. Hakonson, A. F. Gallegos, and F. W. Whicker, "The Use of ^{133}Cs Kinetics Data for Predicting Food Consumption Rate in Rainbow Trout," (manuscript being reviewed by co-authors).

h. J. W. Nyhan and K. G. Doxtader, 1973, "Determination of Radiocarbon in Soil Amended with Carbon-14 Labeled Plant Materials by a Commercial Dumas Apparatus," Soil Sci. Soc. Am. Proc. 37.

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ORAL PRESENTATIONS

l. T. E. Hakonson, "The Kinetics of ^{133}Cs in a Montane Lake Ecosystem," presented to the Los Alamos Chapter of the Health Physics Society of July 17, 1972 at Los Alamos, New Mexico.

m. T. E. Hakonson and L. J. Johnson, "The Bioavailability of Transuranium and Fission Prodect Contaminants of Liquid Waste Effluents at Los Alamos," presented at the Fall meeting of the Rio Grande Chapter of the Health Physics Society on November 3, 1972 at Albuquerque, New Mexico.

APPENDIX

TABLE A-I

A LISTING OF SOME OF THE BIOTA OCCURRING IN THE LOS ALAMOS AREA

Common Name	Scientific Name	Family
Colorado Pinon	Pinus edulis	Pinaceae
Limber Pine	Pinus flexilis	Pinaceae
White Fir	Abies concolor	Pinaceae
Douglas Fir	Psuedotsuga taxifolia	Pinaceae
Ponderosa Pine	Pinus ponderosa	Pinaceae
Rocky Mountain Juniper	Juniperus scopulorum	Cupressaceae
One-seed Juniper	Juniperus monosperma	Cupressaceae
Engelmann Spruce	Picea engelmanni	Pinaceae
Bebb Willow	Salix bebbiana	Salicaceae
Pacific Willow	Salix lasiandra	Salicaceae
Narrow-leaf Cottonwood	Populus augustifolia	Salicaceae
Quaking Aspen	Populus tremuloides	Salicaceae
Thin-leaf Alder	Alnus tenufolia	Betulaceae
New Mexican Locust	Robina neomexicana	Papilionoideae
Box-elder	Acer negundo	Aceraceae
Rocky Mountain Maple	Acer glabrum	Aceraceae
Choke Cherry	Prunus virginiana	Rosaceae
Wax Currant	Ribes cereum	Saxifragaceae
Cliff Bush	Jamesia americana	Saxifragaceae
Wild Gooseberry	Ribes Sp.	Saxifragaceae
Four-winged Salt Bush	Atriplex canescens	Chenopodiaceae
Buck-brush	Ceanothus fendleri	Rhamnaceae
Mountain Mahogany	Cercocarpus montanus	Rosaceae
Antelope Bitterbrush	Purshia tridentata	Rosaceae
Wild Rose	Rosa neomexicana	Rosaceae
Wild Rose	Rosa arizonica	Rosaceae
Apache Plume	Fallugia paradoxa	Rosaceae
Wild Raspberry	Rubus strigosus	Rosaceae
Wild Strawberry	Fragaria ovalis	Rosaceae
Service Berry	Amelanchier Sp.	Rosaceae
Big Sage	Artemisia tridentata	Compositae
Silvery Sagebrush	Artemisia cana	Compositae
Rabbitbrush	Chrysothamnus parrihowardi	Compositae
Barberry	Berberis fendleri	Berberidaceae
Skunk-bush	Rhus trilobata	Anacardiaceae
Poison Ivy	Rhus radicans	Anacardiaceae
Osier Dogwood	Cornus stolonifera	Cornaceae
Gambel Oak	Quercus gambelii	Fagaceae
Kinnikinnick	Arctostaphylos uva-ursi	Ericaceae
Muhly	Muhlenbergia pulcherrima	Graminae
Russian Wheatgrass	Agropyron desertorum	Graminae
Galleta	Hilaria jamesii	Graminae
Little Bluestem	Andropogon scoparius	Graminae
Six Weeks Three-awn	Aristida adscensionis	Graminae
Fringed Brome	Bromus ciliatus	Graminae
Witchgrass	Panicum capillare	Graminae
Knotroot Bristlegrass	Setaria geniculata	Graminae
Squirreltail	Sitanion hystrix	Graminae
Kentucky Bluegrass	Poa pratensis	Graminae
Kentucky Bluegrass	Poa pattersonii	Graminae
Sideoats Grama	Bouteloua curtipendula	Graminae
Blue Grama	Bouteloua gracilis	Graminae
Prairie Three-awn	Aristida oligantha	Graminae
Wheat Grass	Agropyron latiglume	Graminae
Weeping Brome	Bromus frondosus	Graminae
	Schedonnardus paniculatus	Graminae
New Mexican Porcupine Grass	Stipa neomexicana	Graminae
Kentucky Bluegrass	Poa fendleriana	Graminae
Japanese Brome	Bromus japonicus	Graminae
Tall Dropseed	Sporobolus asper	Graminae
Downy Chess	Bromus tectorum	Graminae
Spike Fescue	Hesperochloa kingii	Graminae
Mountain Brome	Bromus carinatus	Graminae
Canadian Wild Rye	Elymus canadensis	Graminae

TABLE A-I (Continued)

Common Name	Scientific Name	Family
Slender Wheat Grass	*Agropyron trachycaulum*	Graminae
Aster	*Aster glaucodes*	Compositae
Fetid Marigold	*Dyssodia papposa*	Compositae
Blazing Star/ Gay Feather	*Liatris punctata*	Compositae
Sunflower	*Helianthus annuus*	Compositae
Prickly Sow-thistle	*Sonchus asper*	Compositae
Bitterweed	*Hymenoxys argentea*	Compositae
Horseweed	*Conyza canadensis*	Compositae
Snakeweed	*Gutierrezia sarothrae*	Compositae
Wooton Groundsel	*Senecio wootonii*	Compositae
Groundsel	*Senecio neomexicanus*	Compositae
Bitterweed	*Hymenoxys brandegei*	Compositae
	Towsendia sericea	Compositae
Blanketflower	*Gaillardia pulchella*	Compositae
Aster	*Aster hirtifolius*	Compositae
Flea Bane	*Erigeron nudiflorus*	Compositae
Spreading Fleabane	*Erigeron divergens*	Compositae
Threadleaf Groundsel	*Senecio longilobus*	Compositae
Crownbeard	*Verbesina encelioides*	Compositae
Woolly Paperflower	*Psilostrophe tagetina*	Compositae
Wheeler Thistle	*Circium wheeleri*	Compositae
Aster	*Aster pauciflorus*	Compositae
Yellow Ragweed	*Bahia dissecta*	Compositae
Hairy Golden Aster	*Chrysopsis villosa*	Compositae
Gum Weed	*Grindelia aphanactis*	Compositae
Groundsel	*Senecio multicapitatus*	Compositae
Milkvetch	*Astragalus insularis*	Leguminosae
Low Hop Clover	*Trifolium procumbens*	Leguminosae
Silvery Lupine	*Lupinus argenteus*	Leguminosae
Alfalfa	*Medicago sativa*	Leguminosae
	Astragalus amphioxys	Leguminosae
Vetch	*Vicia producta*	Leguminosae
Vetch	*Vicia americana*	Leguminosae
White Sweet Clover	*Melilotus albus*	Leguminosae
Indian Sweet Clover	*Melilotus officinalis*	Leguminosae
Red Clover	*Trifolium pratense*	Leguminosae
Big Golden Pea	*Thermopsis pinetorum*	Leguminosae
Prairie Clover	*Petalostemum compactus*	Leguminosae
Yucca	*Yucca Spp*	Liliaceae
Wild Onion	*Allium cernuum*	Liliaceae
Virginia Creeper	*Parthenocissus inserta*	Vitaceae
Pincushion Cactus	*Corypmanthia vivi para*	Cactaceae
Prickly Pear	*Opuntia phaeacantha*	Cactaceae
Stick Weed	*Lappula redowskii*	Boraginaceae
Hidden Flower	*Cryptantha jamesii*	Boraginaceae
Puccoon	*Lithospermum incisum*	Boraginaceae
Paintbrush	*Castilleja integra*	Scrophulariaceae
Miner's Candle	*Verbascum thapsus*	Scrophulariaceae
Beardtongue	*Penstemon jamesii*	Scrophulariaceae
Beardtongue	*Penstemon lentus*	Scrophulariaceae
Paintbrush	*Castilleja linariaefolia*	Scrophulariaceae
Fennel	*Foeniculum vulgare*	Umbelliferae
Summer Cypress	*Kochia scoparia*	Chenopodiaceae
Evening Primrose	*Oenothera hookeri*	Onagraceae
Evening Primrose	*Oenothera coronopifolia*	Onagraceae
Evening Primrose	*Oenothera primiveris*	Onagraceae
New Mexican Olive	*Forestiera neomexicana*	Oleaceae
Pasque Flower	*Pulsatilla ludoviciana*	Ranunculaceae
Globe Mallow	*Sphaeralcea incana*	Malvaceae
Fendler Globe Mallow	*Sphaeralcea fendleri*	Malvaceae
Red Globe Mallow	*Sphaeralcea coccinea*	Malvaceae
Wall Flower	*Erysimum sp.*	Cruciferae
Tumble Mustard	*Sisymbrium altissimum*	Cruciferae
	Hesperidanthus linearifolius	Cruciferae
Richardson Geranium	*Geranium richardsonii*	Geraniaceae

TABLE A-I (Continued)

Common Name	Scientific Name	Family
	Gilia calcarea	Polemoniaceae
	Gilia longiflora	Polemoniaceae
	Gilia texana	Polemoniaceae
Field Bindweed	Convolvulus arvensis	Convolvulaceae
Four O'Clock	Mirabilis linearis	Nyctaginaceae
Blazing Star	Mentzelia rushbyi	Loasaceae
	Eriogonum pauciflorum	Polygonaceae
	MAMMALS	
Rocky Mountain Mule Deer (p)[a]	Odocoileus hemionus	Cervidae
Rocky Mountain Elk (p)	Cervus canadensis	Cervidae
Porcupine (p)	Erethizon dorsatum	Erethizontidae
Tassel-eared Squirrel (p)	Sciurus aberti	Sciuridae
Rock Squirrel (p)	Citellus variegatus	Sciuridae
Spotted Ground Squirrel (p)	Citellus spilosoma	Sciuridae
Cliff Chipmunk (p)	Eutamias dorsalis	Sciuridae
Colorado Chipmunk (p)	Eutamias quadrivittatus	Sciuridae
Least Chipmunk (p)	Eutamias minimus	Sciuridae
Mountain Cottontail (p)	Sylvilagus nuttalli	Leporidae
Black-Tailed Jack Rabbit (p)	Lepus californicus	Leporidae
Golden Mantled Ground Squirrel (p)	Citellus lateralis	Sciuridae
White Footed Mouse (p)	Peromyscus leucopus	Cricetidae
Deer Mouse (p)	Peromyscus maniculatus	Cricetidae
Pinon Mouse (p)	Peromyscus truei	Cricetidae
Mexican Woodrat (p)	Neotoma mexicana	Cricetidae
Western Harvest Mouse (p)	Reithrodontomys megalotis	Cricetidae
Gappers Red-Backed Vole (p)	Clethrionomys gapperi	Cricetidae
Montane Vole (p)	Microtus montanus	Cricetidae
Long-tailed Vole (p)	Microtus longicaudus	Cricetidae
House Mouse (p)	Mus musculus	Muridae
Ord's Kangaroo Rat (p)	Dipodomys ordii	Heteromyidae

Common Name	Scientific Name	Family
Red Squirrel (p)	Tamiasciurus hudsonicus	Sciuridae
Northern Pocket Gopher (p)	Thomomys talpoides	Geomyidae
Vagrant Shrew (p)	Sorex vagrans	Soricidae
Ermine/Short-tail weasel (p)	Mustela erminea	Mustelidae
Silky Pocket Mouse (p)	Perognathus flavus	Heteromyidae
Raccoon (p)	Procyon lotor	Procyonidae
American Badger (p)	Taxidea taxus	Mustelidae
Pine Marten (?)	Martes americiana	Mustelidae
Black-footed Ferret (?)	Mustela nigripes	Mustelidae
Striped Skunk (p)	Mephites mephites	Mustelidae
Spotted Skunk (p)	Spilogale putorius	Mustelidae
Grey Fox (p)	Urocyon cinereoargenteus	Canidae
Red Fox (p)	Vulpes fulva	Canida
Coyote (p)	Canis latrans	Canidae
Black Bear (p)	Ursus americanus	Ursidae
Bob Cat (p)	Lynx rufus	Felidae
Mountain Lion (p)	Felis concolor	Felidae
	COLD BLOODED ANIMALS	
Whiptail (p)	Cnemidophorus spp.	Teiidae
Horned Lizard (p)	Phrynosoma spp.	Iquanidae
Collared Lizard (p)	Crotaphytus collaris	Iquanidae
Desert Spiny (p)	Sceloporus magister	Iquanidae
Bull Snake (p)	Pituophis melanoleucas	Colubridae
Common Garter Snake (p)	Thamnophis sirtalis	Colubridae
Western Garter Snake (p)	Thamnophis elegans	Colubridae
Common King Snake (p)	Lampropeltis getulus	Colubridae
Prairie Rattlesnake (p)	Crotalus viridis viridis	Viperidae
Carp (p)	Cyprinus carpio	Cyprinidae
Chub (p)	Hybopsis sp.	Cyprinidae
White sucker (p)	Catostomus commersoni	Catostomidae
Carp-sucker (p)	Carpoides sp.	Catostomidae

TABLE A-I (Continued)

Common Name	Scientific Name	Family	Common Name	Scientific Name	Family
	BIRDS				
Common Loon (m)	Gavia immer	Gaviidae	Gambel Quail (p)	Lophortyx gambelii	Phasianidae
Eared Grebe (m)	Podiceps caspicus	Podicipedidae	Wild Turkey (p)	Meleagris gallopavo	Meleagrididae
Pied-Billed Grebe (m)	Podilymbus podiceps	Podicipedidae	Sandhill Crane (m)	Grus canadensis	Gruidae
Snowy Egret (m)	Leucophoyx thula	Ardeidae	Virginia Rail (m)	Rallus limicola	Rallidae
Canada Goose (m)	Branta canadensis	Anatidae	Sora (m)	Porzana carolina	Rallidae
Mallard (b)	Anas platyrhynchos	Anatidae	Killdeer (m)	Charadrius vociferus	Charadriidae
Gadwall (m)	Anas strepera	Anatidae	Common Snipe (m)	Capella gallinago	Scolopacidae
Pintail (m)	Anas acuta	Anatidae	Spotted Sandpiper (m)	Actitis macularia	Scolopacidae
Green-Winged Teal (m)	Anas carolinensis	Anatidae	Willet (m)	Catoptrophorus semipalmatus	Scolopacidae
Cinnamon Teal (m)	Anas cyanoptera	Anatidae	American Avoct (m)	Recurvirostra americana	Recurvirostridae
American Widgeon (m)	Mareca americana	Anatidae	Wilson Phalarope (m)	Steganopus tricolor	Recurvirostridae
Shoveler (m)	Spatula clypeata	Anatidae	Ring Billed Gull (m)	Larus delawarensis	Laridae
Ring Necked Duck (m)	Aythya collaris	Anatidae	Franklin Gull (m)	Larus pipixcan	Laridae
Lesser Scaup (m)	Aythya affinis	Anatidae	Band Tailed Pigeon (b)	Columba fasciata	Columbidae
Bufflehead (m)	Bucephala albeola	Anatidae	Mourning Dove (m)	Zenaidura macroura	Columbidae
Ruddy Duck (m)	Oxyura jamaicensis	Anatidae	Yellow Billed Cuckoo (m)	Coccyzus americanus	Cuculidae
Turkey (b) Vulture	Cathartes aura	Cathartidae	Roadrunner (w)	Geococcyx californianus	Cuculidae
Goshawk (p)	Accipiter gentilis	Accipitridae	Screech Owl (b)	Otus asio	Tytonidae
Sharp-Shinned Hawk (p)	Accipiter striatus	Accipitridae	Flammulated Owl (b)	Otus flammeolus	Tytonidae
Cooper Hawk (b)	Accipiter cooperii	Accipitridae	Great Horned Owl (b)	Bubo virginianus	Tytonidae
Red Tailed Hawk (p)	Buteo jamaicensis	Accipitridae	Pygmy Owl (p)	Glaucidium gnoma	Tytonidae
Zone Tailed Hawk (b)	Buteo albonotatus	Accipitridae	Spotted Owl (b)	Strix occidentalis	Tytonidae
Ferruginous Hawk (w)	Buteo regalis	Accipitridae	Saw-Whet Owl (w)	Aegolius acadicus	Tytonidae
Golden Eagle (b)	Aquila chrysaetos	Accipitridae	Poor-will (b)	Phalaenoptilus nuttallii	Caprimulgidae
Marsh Hawk (w)	Circus cyaneus	Accipitridae	Common Nighthawk (b)	Chordeiles minor	Caprimulgidae
Osprey (m)	Pandion haliaetus	Pandiionidae	White Throated Swift (b)	Aeronautes saxatalis	Apodidae
Prairie Falcon (b)	Falco mexicanus	Falconidae	Black-Chinned Hummingbird (b)	Archilochus alexandri	Trochilidae
Peregrine Falcon (p)	Falco peregrinus	Falconidae	Broad-Tailed Hummingbird (b)	Selasphorus platycercus	Trochilidae
Pigeon Hawk or Merlin (w)	Falco columbarius	Falconidae	Rufous Hummingbird (b)	Selasphorus rufus	Trochilidae
Sparrow Hawk (p)	Falco sparverius	Falconidae	Calliope Hummingbird (b)	Stellula calliope	Trochilidae
Blue Grouse (p)	Dendragapus obscurus	Tetraonidae	Yellow Shafted Flicker (w)	Colaptes auratus	Picidae
Scaled Quail (p)	Callipepla squamata	Phasianidae			

TABLE A-I (Continued)

Common Name	Scientific Name	Family
Red Shafted Flicker (b)	Colaptes cafer	Picidae
Red-Headed Woodpecker (b)	Melanerpes erythrocephalus	Picidae
Acorn Woodpecker (p)	Melanerpes formicivorus	Picidae
Lewis Woodpecker (m)	Asyndesmus lewis	Picidae
Yellow Bellied Sapsucker (p)	Sphyropicus varius	Picidae
Williamson Sapsucker (b)	Sphyrapicus thyroideus	Picidae
Hairy Woodpecker (p)	Dendrocopos villosus	Picidae
Downy Woodpecker (p)	Dendrocopos pubescens	Picidae
Ladder-Backed Woodpecker (b)	Dendrocopos scalaris	Picidae
Cassin Kingbird (b)	Tyrannus vociferans	Tyrannidae
Ash-Throated Flycatcher (b)	Myiarchus cinerascens	Tyrannidae
Say Phoebe (b)	Sayornis saya	Tyrannidae
Traill Flycatcher (m)	Empidonax traillii	Tyrannidae
Hammond Flycatcher (b)	Empidonax hammondii	Tyrannidae
Dusky Flycatcher (b)	Empidonax oberholseri	Tyrannidae
Western Flycatcher (b)	Empidonax difficilis	Tyrannidae
Western Wood Pewee (b)	Contopus sordidulus	Tyrannidae
Olive-Sided Flycatcher (m)	Nuttallornis borealis	Tyrannidae
Horned Lark (w)	Eremophila alpestris	Tyrannidae
Violet-Green Swallow (b)	Tachycineta thalassina	Hirundinidae
Tree Swallow (m)	Iridoprocne bicolor	Hirundinidae
Blue Jay (w)	Cyanocitta cristata	Corvidae
Stelle Jay (b)	Cyanocitta stelleri	Corvidae
Scrub Jay (p)	Aphelocoma coerulescens	Corvidae
Common Raven (p)	Corvus corax	Corvidae
Common Crow (b)	Corvus brachyrhynchos	Corvidae
Pinyon Jay (w)	Gymnorhinus cyanocephalus	Corvidae
Clark Nutcracker (p)	Nucifraga columbiana	Corvidae
Black-Capped Chickadee (m)	Parus atricapillus	Paridae
Mountain Chickadee (p)	Parus gambeli	Paridae
Plain Titmouse (p)	Parus inornatus	Paridae
Common Bushtit (m)	Psaltriparus minimus	Pardae
White-Breasted Nuthatch (p)	Sitta carolinensis	Sitlidae
Red-Breasted Nuthatch (w)	Sitta canadensis	Sitlidae
Pygmy Nuthatch (p)	Sitta pygmaea	Sitlidae
Brown Creeper (m)	Certhia familiaris	Certhiidae
Dipper (m)	Cinclus mexicanus	Cinclidae
House Wren (m)	Troglodytes aedon	Troglotytidae
Canyon Wren (m)	Catherpes mexicanus	Troglotytidae
Rock Wren (p)	Salpinctes obsoletus	Troglotytidae
Catbird (m)	Dumetella carolinensis	Mimidae
Brown Thrasher (w)	Toxostoma rufum	Mimidae
Sage Thrasher (w)	Oreoscoptes montanus	Mimidae
Robin (p)	Turdus migratorius	Turdidae
Wood Thrush (m)	Hylocichla mustelina	Turdidae
Hermit Thrush (b)	Hylocichla guttata	Turdidae
Swainson Thrush (m)	Hylocichla ustulata	Turdidae
Western Bluebird (p)	Sialia mexicana	Turdidae
Mountain Bluebird (p)	Sialia currucoides	Turdidae
Townsend Solitaire	Myadestes townsendi	Turdidae
Blue-Gray Gnatcatcher (b)	Polioptila caerulea	Sylviidae
Golden-Crowned Kinglet (w)	Regulus satrapa	Sylviidae
Ruby-Crowned Kinglet (w)	Regulus calendula	Sylviidae
Water Pipit (m)	Anthus spinoletta	Motacillidae
Bohemian Waxwing (w)	Bombycilla garrulus	Bombycillidae
Cedar Waxwing (w)	Bombycilla cedrorum	Bombycillidae
Northern Shrike (w)	Lanius excubitor	Laniidae
Starling (p)	Sturnus vulgaris	Sturnidae
Solitary Vireo (b)	Vireo solitarius	Vireonidae
Red-Eyed Vireo (m)	Vireo olivaceus	Vireonidae
Warbling Vireo (m)	Vireo gilvus	Vireonidae
Orange-crowned Warbler (m)	Vermivora celata	Parulidae
Nashville Warbler (m)	Vermivora ruficapilla	Parulidae
Virginia Warbler (b)	Vermivora virginiae	Parulidae
Yellow Warbler (m)	Dendroica petechia	Parulidae

TABLE A-I (Continued)

Common Name	Scientific Name	Family
Black-Throated Blue Warbler (m)	Dendroica caerulescens	Parulidae
Myrtle Warbler (m)	Dendroica coronata	Parulidae
Audubon Warbler (p)	Dendroica autoboni	Parulidae
Black-Throated Gray Warbler (b)	Dendroica nigrescens	Parulidae
Townsend Warbler (m)	Dendroica townsendi	Parulidae
Black-Throated Green Warbler (m)	Dendroica virens	Parulidae
Grace Warbler (b)	Dendroica graciae	Parulidae
Chestnut-sided Warbler (m)	Dendroica pensylvanica	Parulidae
Northern Waterthrush (m)	Seiurus noveboracensis	Parulidae
Macgillivray Warbler (m)	Oporornis tolmiei	Parulidae
Yellow-Breasted Chat (m)	Icteria virens	Parulidae
Wilson Warbler (m)	Wilsonia pusilla	Parulidae
American Redstart (m)	Setophaga ruticilla	Parulidae
Western Meadowlark (m)	Sturnella neglecta	Icteridae
Yellow-Headed Blackbird (m)	Xanthocephalus xanthocephalus	Icteridae
Red-Winged Blackbird (m)	Agelaius phoeniceus	Icteridae
Bullock Oriole (b)	Icterus bullockii	Icteridae
Rusty Blackbird (m)	Euphagus carolinus	Icteridae
Brewer Blackbird (b)	Euphagus cyanocephalus	Icteridae
Brown-Headed Cowbird (b)	Molothrus ater	Icteridae
Western Tanager (b)	Piranga ludoviciana	Thraupidae
Scarlet Tanager (m)	Piranga olivacea	Thraupidae
Hepatic Tanager (b)	Piranga flava	Thraupidae
Rose-Breasted Grosbeak (m)	Pheucticus ludovicianus	Fringillidae
Black-Headed Grosbeak (b)	Pheucticus melanocephalus	Fringillidae
Inidgo Bunting (m)	Passerina cyanea	Fringillidae
Lazuli Bunting (b)	Passerina amoena	Fringillidae
Dickcissel (m)	Spiza americana	Fringillidae
Evening Grosbeak (p)	Hesperiphona vespertina	Fringillidae
Cassin Finch (w)	Carpodacus cassinii	Fringillidae
House Finch (p)	Carpodacus mexicanus	Fringillidae
Pine Grosbeak (m)	Pinicola enucleator	Fringillidae
Pine Siskin (p)	Spinus pinus	Fringillidae
American Goldfinch (p)	Spinus tristis	Fringillidae
Lesser Goldfinch (b)	Spinus psaltria	Fringillidae
Red Crossbill (p)	Loxia curvirostra	Fringillidae
Green-Tailed Towhee (p)	Chlorura chlorura	Fringillidae
Rufous-Sided Towhee (p)	Pipilo erythrophthalmus	Fringillidae
Brown Towhee (p)	Pipilo fucus	Fringillidae
Lark Bunting (m)	Calamospiza melanocorys	Fringillidae
Vesper Sparrow (m)	Pooecetes gramineus	Fringillidae
Lark Sparrow (b)	Chondestes grammacus	Fringillidae
Sage Sparrow (m)	Amphispiza bellii	Fringillidae
White-Winged Junco (w)	Junco aikeni	Fringillidae
Slate-Colored Junco (w)	Junco hyemalis	Fringillidae
Oregon Junco (w)	Junco oreganus	Fringillidae
Gray-Headed Junco (p)	Junco caniceps	Fringillidae
Tree Sparrow (m)	Spizella arborea	Fringillidae
Chipping Sparrow (b)	Spizella passerina	Fringillidae
Clay-Colored Sparrow (m)	Spizella pallida	Fringillidae
Brewer Sparrow (m)	Spizella breweri	Fringillidae
Field Sparrow (w)	Spizella pusilla	Fringillidae
Harris Sparrow (w)	Zonotrichia querula	Fringillidae
White-Crowned Sparrow (m)	Zonotrichia leucophrys	Fringillidae
Golden-Crowned Sparrow (m)	Zonotrichia atricapilla	Fringillidae
White-Throated Sparrow (m)	Zonotrichia albicollis	Fringillidae
Fox Sparrow (w)	Passerella iliaca	Fringillidae
Lincoln Sparrow (m)	Melospiza lincolnii	Fringillidae
Swamp Sparrow (w)	Melospiza georgiana	Fringillidae

[a] Letter in parenthesis indicates the type of residency the species exhibits in the Los Alamos area. For example:

(m) = migratory through Los Alamos Co
(p) = permanent resident of Los Alamos Co
(b) = breeds or summers in Los Alamos Co
(w) = winters in Los Alamos Co
(?) = status unknown

TABLE A-II

SOME RADIONUCLIDE CONCENTRATIONS IN HONEYBEES, EFFLUENT WATER AND SESTON AS A FUNCTION OF TIME IN MORTANDAD CANYON

Days after Movement of Hive into Canyon	Work Bees (fCi/g wt)[b]			Effluent Water (fCi/ml)			
	^{238}Pu	^{239}Pu	^{241}Am	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am
0	13 (1.0)[c]	2.1 (0.69)	5.6(1.4)	830 (20)	6.0(0.34)	0.62(0.08)	
3				1510 (20)	22 (1.0)	1.4 (0.12)	
5	15 (2.4)	<2.4		1410 (20)	23 (1.0)	1.1 (0.12)	
8	2.5(1.1)	1.8 (0.72)	<7.0	520 (10)	42 (2.0)	2.8 (0.20)	
12	<18.	<8.9		370 (20)			
15	<1.0	<1.0	2.0(0.78)	640 (20)			
18	9.5 (0.82)	1.4 (0.41)	<1.0	2870 (30)	66 (2.0)	3.0 (0.14)	<0.10
22	3.8 (0.56)	2.1 (0.37)		1700 (20)	58 (1.8)	2.0 (0.10)	<0.80
26	3.0 (0.32)	1.6 (0.27)	<3.0	140 (10)	6.6(0.26)	0.36(0.04)	<0.10
35	9.8 (0.93)	2.8 (0.70)	3.0(0.70)	184 (13)	23 (1.0)	1.4 (0.14)	
41	14. (2.4)	12 (2.1)		1130 (20)	27 (1.2)	1.0 (0.10)	
48	24 (0.60)	<4.0		390 (10)	21 (1.0)	1.7 (0.14)	
55							
67	35 (1.2)	5.0 (3.6)		70 (9.0)			
77	7.1 (0.51)	1.0 (0.18)		240 (9.0)			
90	<0.9	<0.9		850 (10)	17 (1.0)	1.8 (0.16)	
105				150 (8.0)	20 (1.2)	0.68(0.10)	
120							
170							

Days after Movement of Hive into Canyon	Hive Bees (fCi/g wet)			Seston (fCi/ml of water filtered)		
	^{238}Pu	^{239}Pu	^{241}Am	^{137}Cs	^{238}Pu	^{239}Pu
0	2.2 (0.39)	0.98(0.39)	16 (5.9)	20 (11)	3.8(0.14)	0.54(0.04)
3				0.30(11)	3.9(0.20)	0.34(0.06)
5	10 (7.0)	2.2 (0.40)	<0.7	13 (11)	1.9(0.10)	0.14(0.03)
8	5.7 (1.1)	1.9 (0.76)	5.7(1.7)	8.0(0.0)	7.7(0.38)	0.58(0.08)
12	<1.0	2.1 (0.58)			7.6(0.40)	0.64(0.10)
15	2.7 (0.78)	12. (1.6)	<2.0	23 (8.0)	60 (3.0)	2.3 (0.20)
18	15 (0.97)	2.1 (0.35)	<2.0	29 (11)	16 (0.80)	0.40(0.06)
22	1.4 (0.28)	1.5 (0.28)	1.7(0.69)	ND[d]	26 (1.2)	0.92(0.10)
26	<0.9	1.4 (0.35)	3.2(1.1)	22 (11)	1.2(0.06)	0.17(0.03)
35	11 (0.75)	4.2 (0.45)	3.6(0.45)	ND	6.1(0.34)	0.48(0.06)
41	5.6 (0.51)	160 (5.1)	17 (2.6)	38 (8.0)	24 (1.2)	1.4 (0.14)
48	30 (2.9)	4.3 (0.87)		85 (9.0)	24 (1.0)	0.92(0.10)
55						
67				36 (11)		
77				ND	40 (1.4)	4.0 (0.18)
90	3.8 (0.50)	1.2 (0.33)		20 (10)	2.8(0.60)	0.22(0.08)
105				7.0(6.0)	8.0(0.32)	0.24(0.04)
120				20 (9.0)	1.6(0.10)	0.20(0.04)
170						

[a] Experiment was initiated on June 29, 1972.

[b] fCi = femtocuries = 10^{-15} curies.

[c] Value in parenthesis is 1 standard deviation of the reported concentration and is based only on counting statistics.

[d] Not detectable

TABLE A-III

SOME RADIONUCLIDE CONCENTRATIONS IN HONEYBEES, EFFLUENT WATER AND SESTON AS A FUNCTION OF TIME IN DP-LOS ALAMOS CANYON

Days after Movement of Hive into Canyon[a]	Work Bees (fCi/g wet)[b]			Effluent Water (fCi/ml)			
	^{238}Pu	^{239}Pu	^{241}Am	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am
0				79 (9.0)	0.18(0.04)	<0.06	
3	<2.0	<2.0	2.5 (1.2)	79 (9.0)	<0.06	0.05(0.02)	
5	1.2(0.59)	2.4(0.59)	2.6 (0.59)	99 (10)	0.10(0.03)	0.17(0.03)	
8	<1.0	2.6(0.65)	<3.0	59 (9.0)	<0.06	0.10(0.03)	
12	<2.0	13 (2.3)	7.5 (2.3)	44 (9.0)	0.10(0.04)	0.01(0.04)	<0.1
15	<3.0	<3.0	<5.0	58 (9.0)	<0.06	0.17(0.03)	
18	<0.60	3.8(0.42)		56 (12)	0.48(0.04)	0.15(0.03)	
22	<1.0	13 (1.6)	1.9 (0.62)	48 (9.0)	<0.06	0.14(0.04)	<0.1
26	<2.0	12 (1.6)	11 (1.9)	22 (8.0)	<0.06	0.14(0.04)	<0.1
35	<0.90	4.2(0.60)	1.2 (0.60)	117 (12)	<0.06	0.13(0.03)	
41	<0.80	2.0(0.47)		50 (8.0)	<0.06	0.10(0.03)	
48	<6.0	<5.0		80 (9.0)	<0.06	0.62(0.03)	
55							
67	0.36(0.93)	1.2(0.12)		80 (9.0)	<0.10	0.32(0.10)	
77				80 (9.0)	0.18(0.04)	0.96(0.08)	
90	<0.41	1.2(0.22)		50 (6.0)	<0.06	0.08(0.03)	
105				40 (6.0)	0.21(0.03)	0.14(0.03)	
120				50 (8.0)	0.20(0.03)	0.25(0.04)	
170							
	Hive Bees (fCi/g wet)			**Seston (fCi/ml of water filtered)**			
0	0.98(0.39)	<.004	2.4(0.98)	30 (11)	0.09(0.03)	0.09(0.03)	
3				ND[d]	<0.06	<0.06	
5	2.0 (0.31)	4.0(0.46)	1.7(0.46)	ND	<0.06	<0.06	
8	<0.9	6.2(0.91)	<20	0.20(11)	<0.06	0.10(0.03)	
12	<2.0	4.8(0.80)	4.0(1.2)	ND	<0.06	0.12(0.03)	
15	<1.0	14 (1.4)	<6.0	72 (9.0)	0.10(0.03)	0.31(0.04)	
18	<0.80	9.0(0.83)		11 (11)	0.11(0.03)	<0.06	
22	1.8(0.92)	12 (1.6)	<5.0	9.0(11)	0.25(0.04)	0.06(0.03)	
26	1.7(0.73)	110 (11)	42 (0.42)	1.0(10)	0.10(0.03)	<0.06	
35	1.1(0.31)	6.8(0.63)	4.9(0.63)	25 (11)	<0.06	0.15(0.03)	
41	0.71(0.28)	5.4(0.57)	2.0(0.57)	11 (8.0)	<0.06	0.06(0.03)	
48				12 (8.0)	<0.06	<0.06	
55							
67	0.33(0.06)	1.7(0.11)		49 (11)	0.10(0.03)	0.78(0.06)	
77	0.88(0.49)	<0.20		8.0(11)	0.26(0.06)	0.20(0.04)	
90	1.1 (0.31)	0.70(0.27)		20 (9.0)	<0.08	0.12(0.04)	
105				21 (9.0)	0.18(0.04)	0.12(0.03)	
120				20 (3.0)			
170							

[a] Experiment was initiated on June 29, 1972.

[b] fCi = femtocuries = 10^{-15} curies.

[c] Value in parenthesis is 1 standard deviation of the reported concentration and is based only on counting statistics.

[d] Not detectable.

TABLE A-IV

SOME RADIONUCLIDE CONCENTRATIONS IN HONEYBEES, EFFLUENT WATER AND SESTON AS A FUNCTION OF TIME IN ACID-PUEBLO CANYON

Days after Movement of Hive into Canyon[a]	Work Bees (fCi/g wet)[b]			Effluent water (fCi/ml)			
	^{238}Pu	^{239}Pu	^{241}Am	^{137}Cs	^{238}Pu	^{239}Pu	^{241}Am
0	<0.80	0.86(0.33)	<0.6				
3	8.6(1.1)[c]	2.1 (0.71)	2.9(1.1)	12 (11)	<0.06	2.3(0.10)	
5	<1.5	2.0 (0.71)		9.0(11)	0.18(0.06)	32 (1.6)	
8	<0.7	0.96(0.48)	<2.0	6.0(11)			
12	8.2 (2.4)	<4.0	11 (4.7)	ND[d]	0.4 (0.04)	70 (2.0)	2.2(0.2)
15	<1.6	<1.6		21 (8.0)			
18	1.6 (0.48)	1.6 (0.48)	0.73(0.36)	17 (11)			
22	<0.7	0.85(0.34)	<1.0	9.0(11)			
26	<1.0	<1.0	<2.0	5.0(11)			
35	2.8 (0.56)	2.6 (0.37)	3.2 (0.93)	21 (11)	0.2 (0.04)	25 (1.0)	
41	7.1 (1.6)	7.8 (1.6)	<1.0	40 (10)	<0.1	22 (1.4)	
48	1.3 (0.36)	1.0 (0.33)		30 (10)	<0.08	9.6(0.4)	
55							
67	<0.30	<0.30		20 (6.0)	0.26(0.08)	13 (0.8)	
77	0.50(0.14)	<0.14		3.0(6.0)	<0.08	11 (0.6)	
90	0.89(0.39)	3.1 (0.64)		20 (7.0)	<0.10	1.1(0.12)	
105				ND	<0.10	0.46(0.06)	
120				5.0(6.0)	0.38(0.08)	56 (3.2)	
	Hive Bees (fCi/g wet)			**Seston (fCi/ml of water filtered)**			
0	<0.4	<0.4					
3				2.0 (11)	<0.1	7.1(0.36)	
5	0.59(0.17)	0.50(0.16)	<1.0	16 (8.0)	<0.06	1.4(0.08)	
8	1.5 (0.42)	1.3 (0.42)	2.7(0.84)	8.0 (11)	0.26(0.06)	26 (1.2)	
12	10 (1.8)	6.5 (1.2)	5.3(1.8)	22 (8.0)	0.16(0.06)	40 (1.8)	
15	<1.0	<1.0	5.0(1.3)	12 (11)	<0.08	6.8(0.4)	
18	0.39(0.18)	1.9 (0.21)	0.94(0.42)	ND	1.4 (0.16)	11 (0.6)	
22	<0.6	2.2 (0.40)	1.2(0.40)		0.18(0.04)	20 (0.8)	
26	<0.9	<0.9	<2.0	ND	0.16(0.04)	11 (0.6)	
35	2.3 (0.49)	2.4 (0.49)	1.8(0.61)	7.0(11)	0.08(0.03)	0.46(0.18)	
41	2.2 (0.51)	2.4 (0.51)	3.6(1.0)	ND	0.16(0.04)	9.4(0.4)	
48				17 (8.0)	<0.06	2.3(0.16)	
55							
67				15 (11)	0.18(0.06)	11 (0.6)	
77				7.0(11)	0.14(0.04)	9.4(0.4)	
90	<2.0	<0.9		ND	<0.08	0.36(0.06)	
105				ND	<0.1	1.2(0.14)	
120				9.0(6.0)	<0.1	3.7(0.20)	
170							

[a] Experiment was initiated on June 29, 1972.

[b] fCi = femtocuries = 10^{-15} curies.

[c] Value in parenthesis is 1 standard deviation of the reported concentration and is based only on counting statistics.

[d] Not detectable.

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